# SEL-121-3

## Distance Relay
## Fault Locator

## Instruction Manual

19930719

SCHWEITZER ENGINEERING LABORATORIES, INC.

⚠CAUTION

Equipment components are sensitive to electrostatic discharge (ESD). Undetectable permanent damage can result if you do not use proper ESD procedures. Ground yourself, your work surface, and this equipment before removing any cover from this equipment. If your facility is not equipped to work with these components, contact SEL about returning this device and related SEL equipment for service.

⚠ATTENTION

Les composants de cet équipement sont sensibles aux décharges électrostatiques (DES). Des dommages permanents non-décelables peuvent résulter de l'absence de précautions contre les DES. Raccordez-vous correctement à la terre, ainsi que la surface de travail et l'appareil avant d'en retirer un panneau. Si vous n'êtes pas équipés pour travailler avec ce type de composants, contacter SEL afin de retourner l'appareil pour un service en usine.

⚠WARNING

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

⚠AVERTISSEMENT

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

⚠WARNING

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

⚠AVERTISSEMENT

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

⚠DANGER

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

⚠DANGER

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

⚠DANGER

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

⚠DANGER

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



PM121-02

**Warning**

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

**ATTENTION!**

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

20001120

# Standard Product Warranty – Ten Years

## Definition of Terms

| | |
|---|---|
| Product: | All items manufactured by SEL that are sold to a customer. |
| New Product: | A product manufactured by SEL that is sold for the first time. |
| Customer: | An end-user of the product. |

## New Product Warranty

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

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

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

## Product Upgrade Policy

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

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

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## EQUIPMENT REPAIR AND WARRANTY

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

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

## LIMITATIONS

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

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

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

## SEL-121-3 TARGETING

The SEL-121-3 targets display the latest relay-element condition at the time of tripping. The targets indicate the closest-in zone which is picked up at the time of the trip, and the associated fault type.

The targets are cleared whenever the TARGET RESET button is pressed. They are also cleared after a new fault occurs, but before the new fault target data are presented, so that the targets show the most-recent fault or trip.

# SEL RELAY INSTRUCTION MANUAL ADDENDUM

## ACB PHASE ROTATION OPTION

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

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

# SEL-121 MANUAL ADDENDUM

## FIRMWARE IDENTIFICATION

A means of determining relay Firmware Identification (FID) data is now provided. The FID string is printed near the top of each long event report. The string format is as follows:

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

Where:

[PN] = Product Name (eg: SEL-121)

[RN] = Revision Number (eg: 100)

[VS] = Version Specifications (eg: 656mpacp21c)

[RD] = Release Date (eg: YYMMDD = 880331)

For the SEL-121 family of relays, the version specifications are interpreted as follows:

V[VS] = V[ABCDEFGHIJK]

| Option: | Specifier: | Specifier Meaning : | Option Description |
|---|---|---|---|
| A : | 5, 6 : | 50 Hz, 60 Hz : | Power System Frequency |
| B : | 1, 5 : | 1 amp, 5 amps : | Nominal Amps per Phase |
| C : | 1, 6 : | 120 volts, 67 volts: | Nominal Volts per Phase |
| D : | m, k : | miles, kilometers : | Fault Locator Distance Units |
| E : | p, n : | positive, negative : | Phase Sequence of Power System |
| F : | a, t : | all, trip only : | Zones Reported on Target LED's |
| G : | c, r : | cumulative, recent : | Target LED Update Logic |
| H : | p, z : | phase, zone : | Multi-TRIP Output Discrimination |
| I : | 2, a : | Z2 inst, all faults: | BLOCK TRIP Input Logic |
| J : | 1, 2 : | Z1 unbal. inst, all Z1/Z2 faults : | Reclose Initiation Logic |
| K : | c, u : | compensated, uncomp: | Ground Mho Residual Compensation |
| L : | c, e : | control, event : | BT, TT, DT, and DC Input Contact Logic |

## TARGET RESET BUTTON FUNCTIONS

The TARGET RESET button performs three functions, two of which are new. Pressing the TARGET RESET button on the front panel clears the TAR 0 (see TARGET command description) data and lights all target LED's for one second, as a lamp test. Furthermore, pressing the TARGET RESET button unlatches the TRIP output from the 52A input. This new feature is useful during relay testing, and it minimizes the risk of re-installing the relay with the TRIP output asserted.

## AUTOPORT

Autoport may now be set to 3 which causes automatic messages (i.e., short event reports, self-test status reports) to be sent to both ports 1 and 2. This is useful in conjunction with some SEL-DTA installations.

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# INTRODUCTION

## OVERVIEW

The SEL-121 DISTANCE RELAY/FAULT LOCATOR performs protective relaying, fault locating, and many other unique functions.

The features of the SEL-121 include:

- THREE-ZONE DISTANCE RELAYING WITH SINGLE-POLE TRIP OUTPUTS
- AUTOMATIC RECLOSING
- TRANSMISSION LINE FAULT LOCATING
- EVENT RECORDING
- AUTOMATIC SELF TESTING
- METERING
- TARGET INDICATORS FOR FAULTS AND TESTING
- TIME CODE INPUT
- COMMUNICATIONS PORT FOR LOCAL AND REMOTE ACCESS
- COMPACT SIZE

The protection features and economy of the SEL-121 make it the ideal relay to apply at most transmission voltages.

The economy of the SEL-121 is enhanced by its many unique features, some of which are listed above.

## GENERAL INFORMATION

This introduction gives the specifications for the SEL-121, and describes its theory of operation. Although you should be familiar with the specifications and theory of operation, you may wish to first complete the INITIAL CHECKOUT procedure, which follows this introduction.

The SEL-121 provides three zones of MHO-circle directional distance protection and accurately locates all fault types. It is a precision, low-burden system offering reliability through a simple hardware design and the use of VLSI components. Hardware simplicity is afforded by careful application of microprocessor technology and the use of efficient digital signal processing techniques. Reliability and availability are enhanced by extensive self-testing and communicating capabilities.

Communications functions provide remote and local examination of a wide range of data, including the voltages and currents presented to the instrument, the system settings, and a history of the most recent fault types and locations. System settings may be remotely entered and modified. Circuit breaker control via the communications channel is also provided. Settings and circuit breaker control are protected by a secure two-level password access scheme which is monitored for unauthorized access by an alarm contact output.

A fault locator is included which uses fault type, prefault and fault conditions to provide an accurate estimate of fault location, without the need for communications channels, special instrument transformers, or source impedances, even during conditions of substantial load flow and fault resistance.

A detailed event report is generated following every fault. It contains all information needed to quantitatively examine the prefault, fault, and postfault voltages and currents. Such parameters as fault current sensed by the relay, relay response time, and total fault clearing time are easily obtained. The event report includes the distance to the fault, the type of fault, and the state of all relay units during the event. The event is time-tagged by a self-contained clock. In addition to the automatic generation of this report in the event of faults, the report may be generated upon command, or by assertion of any of several control inputs to the instrument. This allows triggering the report from other equipment, such as oscillographic starting units or other relaying systems. The SEL-121 retains the twelve most-recent event reports. Any of these reports may be recalled by command.

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

Long-term accuracy and availability are designed into the instrument. Amplitude-dependent measurements are made with respect to an internal stable and precise voltage reference, which is monitored as a part of the self-checking process. Long-term phase stability is guaranteed, since all phase-shifting operations are performed by precise time delays controlled from a quartz crystal oscillator.

## SPECIFICATIONS

| | |
|---|---|
| Relay Functions | MHO characteristics for all fault types.<br>MHO units are sound-phase polarized.<br>Negative sequence directional supervision.<br>Three zones of distance protection.<br>Separate zone timers for phase and ground faults.<br>Instantaneous positive-sequence overcurrent unit.<br>Instantaneous positive-sequence overvoltage unit.<br>Instantaneous negative-sequence overcurrent unit.<br>Instantaneous negative-sequence overvoltage unit.<br>Ground switch detection.<br>Blown potential fuse detection.<br>Automatic phase-sequence checking of voltages and currents upon power-up. |

| | |
|---|---|
| | Single-pole tripping outputs.<br>Automatic reclosing for zone 1 faults and zone 2 faults (cleared by transfer tripping) except three-phase faults.<br>Settable phase overcurrent units supervise MHO elements. |
| Reach Setting | Zone 1: 0.125 to 32 ohms<br><br>Zone 2 and 3: One to 16 times zone 1, for zone 1 settings up to 8 ohms. One to four times zone 1, for zone 1 settings above 8 ohms. |
| Operating Time | 10 - 32 ms; 20 ms typical, including output relay delay. |
| Steady-state Error (distance relays) | Less than 3% of set reach. |
| Transient Overreach | Less than 5% of set reach. |
| Zero-Sequence Compensation | The zero-sequence compensation factor (k) has setting limits associated with its magnitude and angle. The calculation for the residual compensation factor is |

$$k = \frac{Z0 - Z1}{Z1}$$

where Z0 is the zero-sequence line impedance and Z1 is the positive-sequence line impedance. The limits for the k-factor magnitude are given in the following table, where Z1′ is the Zone 1 mho circle diameter in secondary ohms.

| Z1′ Range (ohms) | \|k\| Range |
|---|---|
| 0.125 - 0.5039 | $\frac{0.126}{Z1'} < \lvert k\rvert < \frac{1.6}{Z1'}$ |
| 0.5039 - 2.015 | $\frac{0.502}{Z1'} < \lvert k\rvert < \frac{6.4}{Z1'}$ |
| 2.015 - 32 | $0.251 < \lvert k\rvert < 3.2$ |

Where the diameter of the Zone 1 mho circle (Z1′) is given by:

$$Z1' = \frac{\text{Secondary Zone 1 Reach Setting}}{\text{Cos ( T. L. ANGLE - MTA )}}$$

The k-factor angle range limits are shown below (all angles units in degrees):

$$(47 - MTA) < \text{angle of } k < (100 - MTA)$$

**Fault Detector**

The 50FD pickup setting does not have fixed limits. This is because the sensitivity of the current channels is adjusted according to the Zone 1 secondary reach, permitting higher current resolution. The actual 50FD setting limits are given in the table below, where Z1′ is the Zone 1 mho circle diameter in secondary ohms.

| Z1′ Range (ohms) | 50FD Range |
|---|---|
| 0.125 - 0.5039 | $\frac{0.129}{Z1'} < \frac{50FD}{CTR} < \frac{263}{Z1'}$ |
| 0.5039 - 2.015 | $\frac{0.514}{Z1'} < \frac{50FD}{CTR} < \frac{1053}{Z1'}$ |
| 2.015 - 32 | $0.257A < \frac{50FD}{CTR} < 527A$ |

Where the diameter of the Zone 1 mho circle is given by:

$$Z1' = \frac{\text{Secondary Zone 1 Reach Setting}}{\text{Cos ( T. L. ANGLE - MTA )}}$$

**High-Set Positive-Sequence Overcurrent**

The 46PH setting does not have fixed limits (similar to 50FD). The setting limits are as follows:

| Z1′ Range (ohms) | 46PH Range |
|---|---|
| 0.125 - 0.5039 | $\frac{0.239}{Z1'} < \frac{40PH}{CTR} < \frac{78.2}{Z1'}$ |
| 0.5039 - 2.015 | $\frac{0.954}{Z1} < \frac{46PH}{CTR} < \frac{313}{Z1'}$ |
| 2.015 - 32 | $0.477A < \frac{46PH}{CTR} < 156A$ |

**Fault Location**

Algorithm compensates for prefault load flow and fault resistance for improved accuracy over a wide range of system conditions. Demonstrated accuracy is about one percent of line length. Fault location is reported in miles and secondary ohms.

**Fault Reporting**

A data record including time, fault type and location, relay settings, and units which operated is transmitted after each fault. Phasor information on currents and voltages indicates prefault, fault and postfault conditions. This report may also be generated upon command or triggered by a contact closure. The state of all contact inputs and outputs is also reported.

**Self-Testing**

Analog AC channels checked for offset errors. Stall timer monitors processor and five-volt supply. Power supply voltage level checking. Settings, RAM, ROM and A/D converter checking. These self tests are designed to detect virtually any hardware or firmware failure.

| | |
|---|---|
| | Failure of any test generates alarm message, and closes alarm contacts. Critical failures disable protection and control to prevent misoperation. |
| Signal Inputs | Three voltage channels (67 V L-N nominal)<br>Three current channels (5 A nominal; 390 A for 1 sec.)<br>Demodulated, isolated IRIG-B input for time synchronization. |
| Setting Means | Digital, via serial communications ports. Settings are entered in response to prompting messages. Constants of line are entered in primary ohms. Line length and CT, PT ratios are entered, and displayed quantities are scaled into primary units (e.g. miles, KV, A). Settings are retained in nonvolatile memory in two identical arrays. Self-tests compare these arrays. Should any difference ever be detected, alarm is generated, and relay and control functions are disabled to prevent misoperation. |
| System Outputs and Inputs | Seven relay outputs rated for breaker tripping.<br>Six optically-isolated contact inputs.<br>Two serial communications ports (RS-232-C) for use with CRT, printing terminal, printer, modem, computer, etc. Ports are EMI protected. Time code input. |
| Indicators | Eight LED indicators normally provide fault targeting. The display may be used for testing purposes upon command. |
| Power Supply | 48 Volt: 30 - 60 VDC; 12 watts<br>125 Volt: 85 - 200 VAC or VDC; 12 watts<br>250 VOLT: 85 - 200 VAC or 85 - 280 VDC; 12 watts |
| Surge Filtering | Power supply line filter.<br>All control inputs and outputs bypassed to ground.<br>Contact inputs filtered by RC networks.<br>Relay outputs protected by MOVs.<br>SWC tested to ANSI C37-90 specifications. |
| Dimensions (HWD) | 5-1/4" x 19" x 13". Mounts in standard 19" relay rack. |
| Unit Weight | 21 pounds |
| Shipping Weight With Two Manuals | 30 pounds |
| Operating Temp. | -10$^{o}$C to +55$^{o}$C |

## HARDWARE DESCRIPTION

The hardware is discussed in three sections: the microprocessor-based data acquisition subsystem, the interfacing components and the relay's mechanical features. The hardware design enhances ruggedness, reliability and serviceability. Please refer to the SEL-121 BLOCK DIAGRAM as you read this section.

## Data Acquisition Subsystem

The microprocessor-based data acquisition subsystem is the heart of the SEL-121 relay. Its main components include a 6809 microprocessor supported by 40 kilobytes of program memory (PROM), 16 kilobytes of static random access memory (RAM), 2 kilobytes of non-volatile electrically erasable memory (EEPROM), two 6850 serial communications ports, a 6840 programmable timer and three 6821 dual parallel ports. The parallel ports and timer control an analog-to-digital conversion section consisting of a 12-bit analog to digital converter (ADC), a programmable gain amplifier (PGA), an analog multiplexer (MUX), and sample and hold circuits (S/H). The sample and hold circuits are fed by eight low-pass filters. Each filter consists of a passive RC network to reduce RF interference, followed by an active two-pole lowpass filter. An analog summing circuit is employed to find residual current from the phase currents.

The relay uses an optimal four-samples-per-cycle sampling rate that limits the computational burden placed on the microprocessor. For this reason the hardware design can be kept simple.

Hardware dedicated specifically to self testing includes scaled power supply inputs to the MUX for checking power supply levels and a stall timer-deadman alarm relay setup (located on the interface board) that closes the relay contacts if the processor fails to reset the stall timer, or if the +5 supply is lost.

Reliability is further enhanced by limiting the number of interconnections in the SEL-121. This too stems from a simple hardware design.

All of the EPROMs are installed in sockets. In this way any future software improvements or modifications can be implemented by IC replacement.

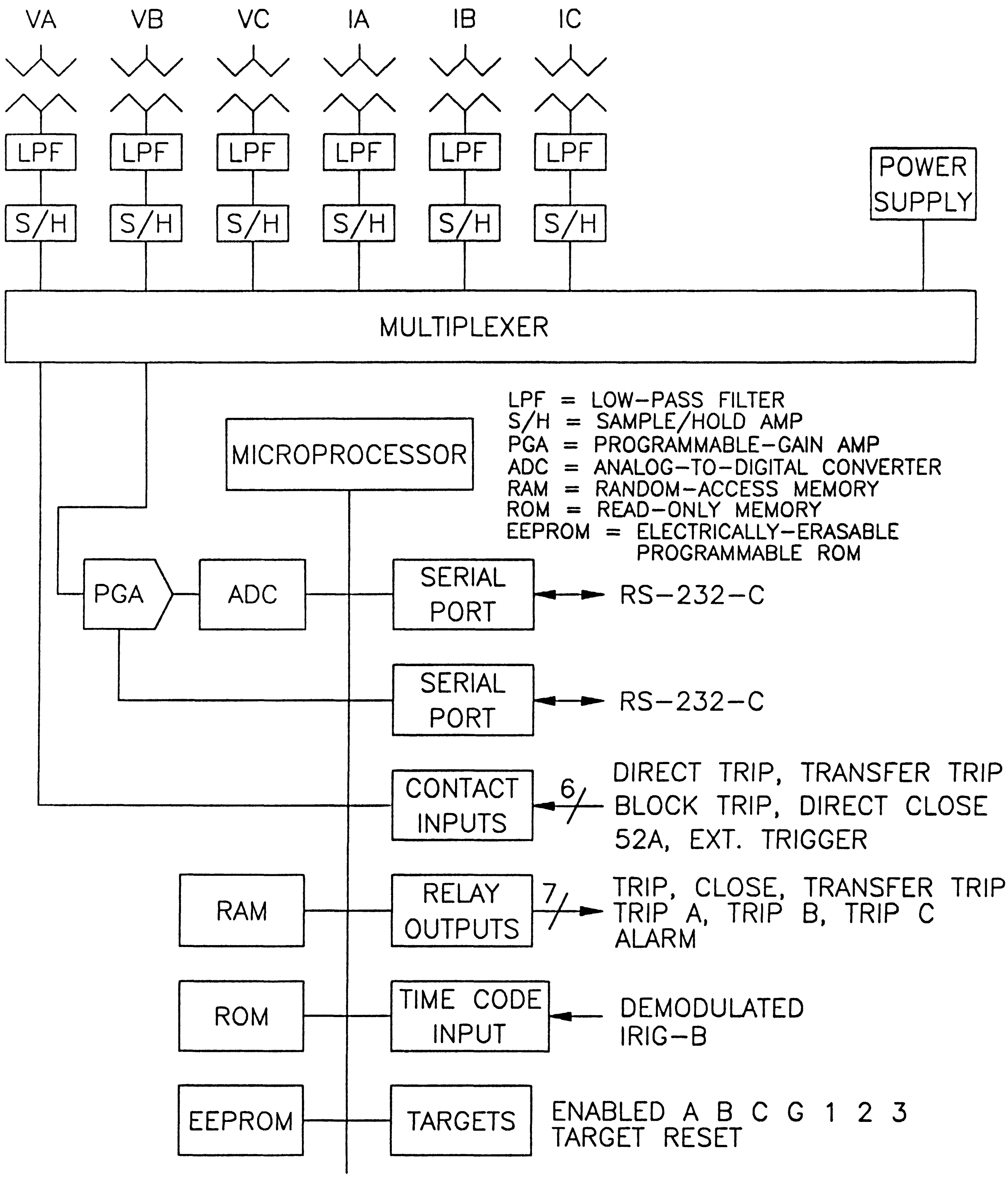
## Interfacing Components

Special attention was given to the problems of noise and surges, and how they might affect the SEL-121 in the substation environment. The results of this attention can be seen in the electrical and mechanical designs of all interface components.

Eight trip-circuit-rated relay output contacts from seven relays are provided. All relay outputs are bypassed to ground with 4700 pf capacitors and protected from contact flashover by MOV's. The relay coils (except the alarm relay) are driven by circuits designed to quicken their response.

Six optically-isolated control input circuits are included. Each input terminal is bypassed to ground with a 4700 pf capacitor. Additional protection is provided by a symmetrical RC network designed to limit both common mode and differential surges. The input circuits include a bridge rectifier, so polarity of the applied input voltage does not matter. Hysteresis provided in the optical isolators contributes more noise immunity. Finally, debouncing of inputs is accomplished in software, and provides additional security.

Three current and three potential transformers are utilized to scale the analog input quantities. The transformer primaries are fastened to the terminal blocks inside the case with number eight screws and ring lugs. The secondaries

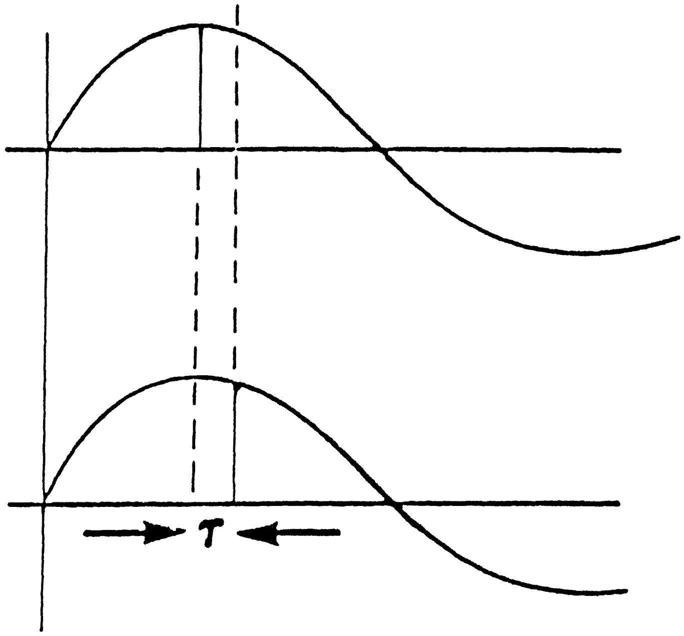



SEL-121 BLOCK DIAGRAM



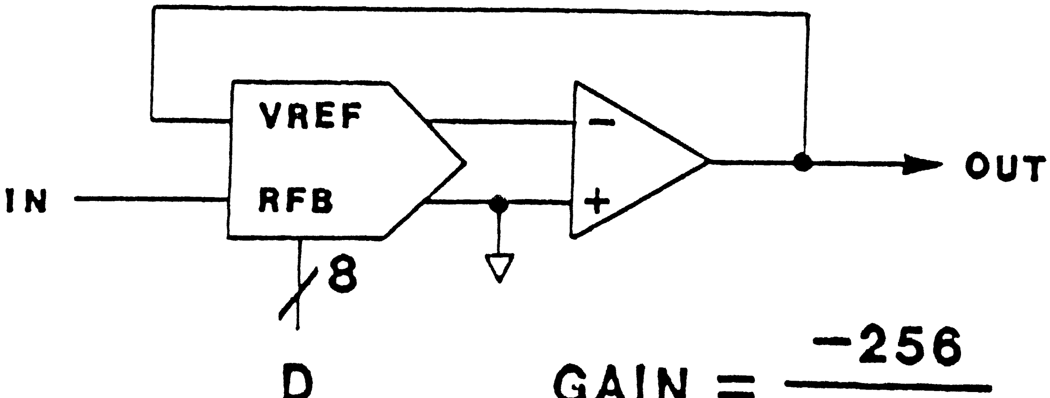
DWG. NO. A7-0259
DATE: 03-28-88
REV. 01-09-89

# STAGGERED SAMPLING CONTROLS PHASE SHIFTS




$$\theta = 360^{\circ} \cdot \frac{\tau}{T}$$

# CURRENT AND VOLTAGE GAINS ARE CONTROLLED BY A PROGRAMMABLE – GAIN AMPLIFIER




$$\text{GAIN} = \frac{-256}{D}$$

of the potential transformers terminate in resistive divider networks that include a MOV at their outputs. The current transformer secondaries are terminated across one ohm shunt resistors.

Internal power to the relay circuits is provided by a switching power supply. Additional protection from common mode and differential surges is afforded the switching supply inputs by two balun coil-capacitor networks, 4700 pf bypassing capacitors and a MOV.

Each RS-232 input and output line is protected by an RC network and MOV. They are then connected to current limited RS-232 drivers or input buffers.

The demodulated IRIG-B time code input is optically isolated and protected from surges by MOVs. The opto-coupler output is filtered by an RC network before passing through a decoding circuit on the interface board that connects to a parallel port.

### Mechanical Features

Almost all of the SEL-121 components are contained on a drawout assembly. This includes the main circuit board, the interface circuit board, and the switching power supply. The only components to remain in the box are the rear panel board, which has only passive components, and the transformer sub-chassis, which mounts the transformers and the transformer termination board.

## SIGNAL PROCESSING AND ALGORITHMS

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

### Digital Filters

The requirements for the digital filters include elimination of dc offsets introduced by the analog electronics, reduction of the decaying exponential offset present on the current data following a fault, and passing the power-system frequency information. The digital filters are simple, so that a minimum burden of computation is placed on the microprocessor.

A very simple and effective digital filter which has the properties of a double-differentiator smoother, and which requires only addition and subtraction of data samples is employed. Let the latest four samples of one channel of information be X1, X2, X3, and X4. Then the filter is defined by:

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

This filter has the desired property of eliminating dc offsets, as can be seen by setting all the samples to the same value and noting that the filter output is zero. It also eliminates ramps, as can be seen by setting the samples equal to, say, 1, 2, 3, 4, and again noting that the resulting output is zero.

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

## MHO Relay Algorithms

Six zone-three MHO relay algorithms execute every one-fourth cycle. These encompass all possible fault types. Based on the operation of these six units, and a residual overcurrent condition, the appropriate zone 1 and 2 MHO elements are run in the same quarter cycle. Thus, no operating time sacrifice is made for fault type determination.

Line-to-line voltages and the current difference between associated phases are processed for each three types of phase faults. Line-to-ground voltages and residual-compensated line currents are used for the three types of ground faults.

In each case, the MHO relay algorithm determines the difference between the selected voltage and the current times the relay impedance. This difference is compared in phase with the voltage. For impedances inside the circle, the angle between these quantities is acute. For impedances outside the circle, the angle is obtuse. If the impedance is on the circle, then the angle is 90 degrees. The phase comparison process is performed by computing the dot product of the difference voltage phasor and the voltage phasor. If the dot product is positive, then the impedance is inside the circle. If it is negative, then the impedance is outside the circle. If it is zero, then the impedance is on the relay boundary.

Multiplication of the currents by the relay impedance is accomplished by analog scaling using the PGA, and by the skewed sampling scheme described earlier. Thus the relay reach is controlled by PGA gain, and the relay angle is controlled by the phase shift introduced by the skew in sampling instants between the voltages and the currents.

## Sound-Phase (Cross) Polarization

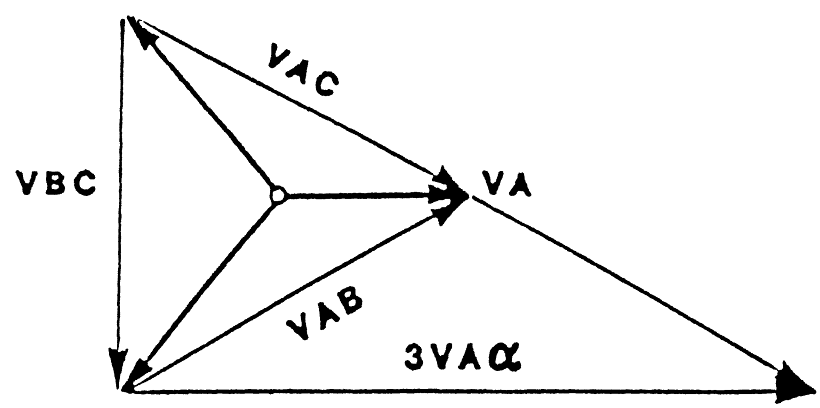
To ensure correct operation of the relay units for close-in faults, sound-phase polarization is implemented. For ground faults, the voltage used in the MHO algorithm consists of the sound-phase line-to-line voltage, advanced 90 degrees, plus the faulted-phase-to-neutral voltage. For L-L faults, the voltage is the uninvolved L-G voltage, advanced 90 degrees, plus the faulted line-to-line voltage. Consult the factory for other polarization options.

## Directional Relay

Under some conditions, distance relays can operate for faults in the reverse direction. For example, a close-in AG fault in the reverse direction could cause the BG and CG relay units to operate if they are set to very long reach. This possibility is eliminated in the SEL-121 by supervising the operation of

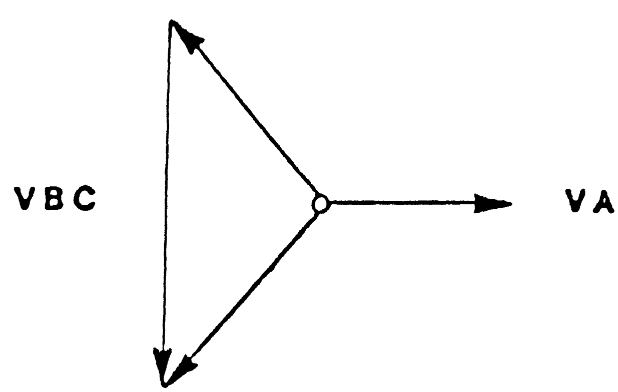
# POLARIZATION OF MHO ELEMENTS

## PHASE UNITS




VPOL = VBC − J·VA = − J·3VAα

## GROUND UNITS




VPOL = VA + J·VBC

the mho elements by a negative-sequence directional relay. The cross product of the negative-sequence voltage and current phasors is computed: if the result is negative, then the fault is in the forward direction; otherwise it is in the reverse direction. Supervision, when selected, is used for all unbalanced faults in all zones.

Negative-sequence overvoltage and overcurrent units supervise the negative-sequence directional relay: if the negative-sequence components are too small, then tripping for unbalanced faults is not affected by the negative-sequence directional relay state.

Fault Location

The system stores approximately four cycles of prefault data and seven cycles of fault and postfault data, which are processed using the Takagi algorithm. The algorithm is much less sensitive to fault resistance and load flow than a direct reactance computation, since it takes into account load flow conditions prior to the fault. No communications schemes are required for this fault locator algorithm.

The fault location is automatically computed after each fault occurs, and is included in the fault reports.

It is possible to use two-end algorithms for fault location, using the data available in the event reports from units located at both ends of the line. These schemes require additional data processing and communications, but do not depend on the zero-sequence parameters of the transmission line. Consult the factory for further details.

Reclosing

A single-shot recloser is included, which recloses for all unbalanced zone 1 faults, and those unbalanced faults in zone 2 which are cleared by transfer tripping.

Reclose initiation requires proper fault type, a closed circuit breaker (as indicated by the 52A input), and an expired reset interval timer which does not indicate lockout. The open interval is timed from the instant the fault is cleared, until the CLOSE output contact is asserted.

The reset-interval timer is started following any close action, whether caused by the SEL-121, or sensed by an open-to-close transition on the 52A input. Any close action provides escape from the lockout state, once the reset-interval timer expires. The reset interval may be set from 60 to 1800 cycles in 1/4 cycle steps.

The CLOSE output relay closes as described above. It opens once the 52A input indicates the power circuit breaker has closed.

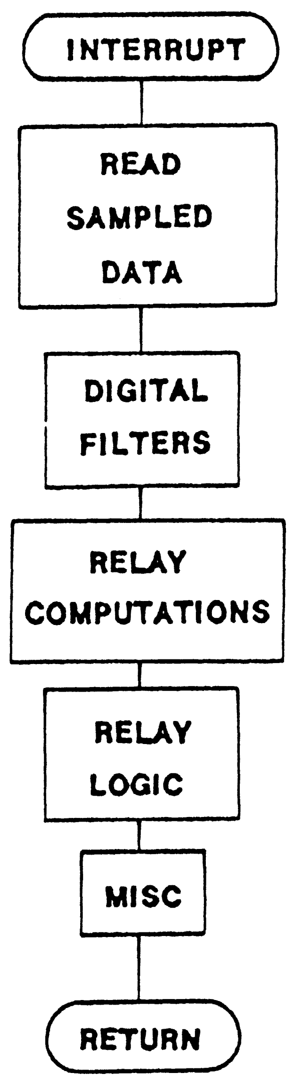
The open interval may be set from 1/4 to 240 cycles in 1/4 cycle steps. A setting of zero disables reclosing.

Relay Program Structure

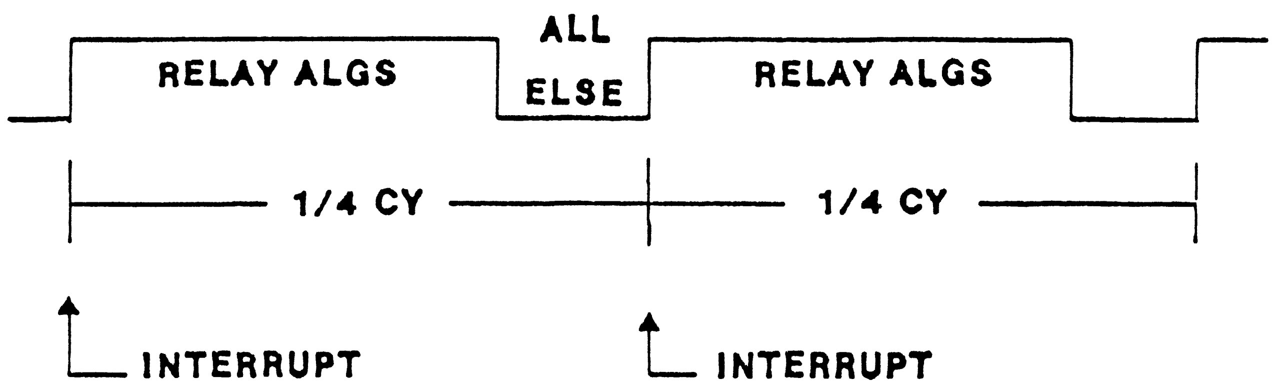
The sampling clock generates a microprocessor interrupt every one-fourth cycle. The interrupt starts the relay calculations for that quarter cycle. The microprocessor completes the calculations well before the next interrupt occurs, under all conditions.

The time remaining between the end of the relay calculations and the next interrupt is used by all other functions, including self testing, fault locating and event reporting. This structure guarantees that the relay functions have top priority.

RELAY PROGRAM STRUCTURE



# INTERRUPTS GUARANTEE RELAY FUNCTIONS RUN EVERY 1/4 CYCLE



# INITIAL CHECKOUT

The initial checkout of the SEL-121 is intended to familiarize you with the instrument, and to ensure that it is operational.

## EQUIPMENT REQUIRED

The equipment listed below is necessary for initial checkout of the SEL-121.

1. Computer terminal with RS-232C serial interface.
2. Interconnecting cable between terminal and SEL-121.
3. Source of control power.
4. Source of three-phase voltages and at least one current.

## CHECKOUT PROCEDURE

In the procedure below, you will use several of the SEL-121 commands. These commands are described in detail in the COMMANDS AND SERIAL COMMUNICATIONS section. The detail given below should allow you to complete the checkout without referring to the detailed descriptions, however.

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

2. Connect a computer terminal to Port 2 on the rear panel of the SEL-121. The terminal should be configured to 2400 baud, eight data bits, two stop bits and no parity. Be sure your terminal is compatibly configured. Additional details on the port configurations are given in the Functional Description section. Baud rate selection is described in the BAUD RATE SELECTION section of this manual, near its end.

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

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

```
SEL-121
=
```

should appear on the terminal, and the Alarm relay should pull in, holding its B contacts (terminals 27,28) open. (If the relay pulls in, but no message is received, then check the configuration of the terminal. If neither occurs, turn off the power and refer to the testing and troubleshooting guide section.)

The equal sign is a prompt which indicates that communications with the SEL-121 are at Access Level 0, the lowest of the three levels of access to the SEL-121. The only allowable command at this level is ACCESS, which gains access to Access Level 1, as described below.

5. Enter the command "ACCESS" and press the RETURN key. In response to the prompt, enter the password "OTTER" and press RETURN. The prompt => should appear, indicating communications at Access Level 1 are established.

6. The SEL-121 is shipped with demonstration settings which can be inspected using the SHOWSET command. Type "SHOWSET", and press RETURN to inspect these settings. The following should be obtained:

```
=>SHOWSET

Settings for:
Example 230 KV Line
R1  = 13.90   X1  = 79.96   R0  = 41.50   X0   = 248.57   LL  = 100.00
CTR = 200     PTR = 2000    MTA = 80.80   79OI = 30.00    79RS=  60.00
Z1% = 80.00   Z2% = 120.00  Z2DG= 60.00   Z2DL = 30.00
Z3% = 150.00  Z3DG= 90.00   Z3DL= 60.00   50FD = 100      46PH=  6000    TTI = 1
Z1E = Y       Z2E = Y       Z3E = Y       32QE = Y        GSE =  Y       BPFE= Y
```

A detailed explanation of these settings is given under the description of the SET command. Briefly, the first line shows: positive-and zero-sequence impedances of the transmission line (primary ohms), and the line length (miles) for which the impedances are given.

The second line shows: current and voltage transformer ratios, maximum torque angle, and reclosing open interval and reset delay.

The third line provides: zone 1 and 2 reaches as a percent of the line, and zone 2 time delays for ground and phase faults.

The fourth line presents: zone 3 reach and delays, pickup current for the fault detectors, pickup current for the positive-sequence overcurrent element, and the zone on which transfer tripping is initiated.

The bottom line shows the enables for each of the three zones, and the enables for the negative-sequence directional element, the ground-switch detection scheme and the blown-potential-fuse detection scheme.

7. Turn the power off, and connect a source of balanced three-phase voltages to the SEL-121 at terminals 29-32. These potentials should have a magnitude of about 67 volts line-to-neutral. Connect a current source to the phase A current terminals (1,7). Set the current source to two amperes, and in phase with Van.

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

9. The voltages and current can be measured with the METER command. Type "METER" and press RETURN. With applied voltages of 67 volts per phase, and with the potential transformer ratio setting of 2000, the displayed voltages should be 134 kV. With an applied current of two amperes, and a current transformer ratio setting of 200, the displayed current in phase A should be 400 amperes. The B and C phase currents should be near zero.

10. Test the digital relay/fault locator for the voltages and currents listed below. They were obtained assuming a source impedance of 0.2 times the total 100-mile line impedance, and single-end feed, for faults at the indicated locations and types. A BASIC program is included at the end of the manual, which you may find useful in computing of the test set settings.

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

The faults at 75 miles are within zone 1, since zone 1 reach is set to 80.0% of a 100-mile line. (See Z1% in the settings above.)

The zone-1 faults should cause the TRIP, TRIP A and the TRANSFER TRIP output relays to remain closed as long as the fault condition persists. If the fault lasts longer than zone 2 time, then the TRIP B and TRIP C contacts should also close.

The faults at 85 miles are beyond zone 1, but within the 120-mile setting of zone 2. (See Z2% in the settings.) The TRIP output relay and the single-pole output relays should close 60 cycles after the AG fault is detected, and 30 cycles after the BC fault is detected. These times correspond to the settings for Z2DG (zone 2 delay, ground) and for Z2DL (zone 2 delay, line). The transfer-trip initiate (TTI) output relay should not close for the zone-2 faults, since the logic parameter TTI is set to 1 (zone 1), as can be seen in the response to the SHOWSET command.

The faults at 125 miles are inside zone 3, and three-pole tripping should occur in the times shown for the zone delays Z3DG and Z3DL.

Faults generate a short event report. To see the full event report for the last fault, type "EVENT 1 L" and press RETURN. The report provides an eleven-cycle record of the currents, voltages, relay element states, and the states of all contact inputs and outputs. The twelve newest reports are saved.

The SEL-121 includes a check for loss of potential in one phase, such as might occur when a secondary-circuit potential fuse blows. To demonstrate the response of the instrument, be sure the currents are zero or balanced, and turn off one of the three phase potentials. The SEL-121 should respond by closing the ALARM relay.

Upon power-up, the SEL-121 checks for reverse-phase sequences in the voltages and currents. This feature is intended to prevent commissioning a relay if a wiring error exists. To demonstrate this, turn the SEL-121 control power off, and interchange two of the line-to-neutral potentials. Now, turn the control power back on. The instrument should respond by sending the following message:

REVERSE PHASE SEQUENCE - V

Restore the correct phase sequence, and note that the alarm contacts remain closed. To re-enable the SEL-121, either turn the control power off and back on, or execute the setting procedure (described later.)

This checkout procedure demonstrates only a few of the features of the SEL-121. Study the Functional Description, Command, and Event Report sections of this manual to obtain a complete understanding of the capabilities of the SEL-121.

# FUNCTIONAL DESCRIPTION

## INTRODUCTION

This section describes all SEL-121 inputs and outputs, relay elements, and the logic equations which relate the inputs, outputs and relay elements.

It also describes the self tests and their effects on system operation.

## INPUTS AND OUTPUTS

All connections to the SEL-121 are made on the rear panel. A rear-panel drawing is included at the back of this manual.

### Serial Interfaces

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

The port pin assignments and signal definitions are given below.

| PIN | NAME | DESCRIPTION |
|---|---|---|
| 2 | TXD | transmit data output |
| 3 | RTS | The SEL-121 asserts this line under normal conditions. When its received-data buffer is full, the line is unasserted, and asserts again once the buffer has sufficient room to receive more data. Connected devices should monitor RTS (usually with their CTS input) and stop transmitting characters whenever the line unasserts. If transmission of data continues, data may be lost. |
| 4 | RXD | receive data input |
| 5 | CTS | The SEL-121 monitors CTS, and transmits characters only if CTS is asserted. |
| 6 | + 5 volts | |
| 7 | +12 volts | |
| 8 | -12 volts | |
| 1,9 | GND | Ground for ground wires and shields |

## Input Power

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

## Contact Inputs

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

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

To assert an input, a nominal control voltage is applied to the appropriate terminal pair. The inputs draw 6 mA at nominal control voltage. Polarity is unimportant. The table below shows input parameters:

| Rated Control Voltage | Contact Input Range | Nominal Current |
|---|---|---|
| 48 VDC | 25 - 60 VDC | 6 mA |
| 125 VDC | 60 - 200 VDC | 6 mA |
| 250 VDC | 200 - 280 VDC | 6 mA |

## Relay Outputs

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

| | | |
|---|---|---|
| TRIP | (13,14)-A | (15,16)-A |
| CLOSE | (17,18)-A | |
| TRANSFER TRIP INITIATE | (19,20)-A | |
| TRIP A | (21,22)-A | |
| TRIP B | (23,24)-A | |
| TRIP C | (25,26)-A | |
| ALARM | (27,28)-B | |

All relay contacts are rated for circuit breaker tripping duty.

## Potential Inputs

The potential inputs are intended to be driven from a set of three line potential transformers connected with their primaries connected in a grounded-wye configuration, and their secondaries connected in four-wire wye. Inside the relay is a set of three input transformers connected in four-wire wye. Since the SEL-121 includes ground-relaying functions, it is necessary to connect the neutral input terminal to the star point of the PT secondaries. The nominal voltage rating is 115 volts line-to-line, or 67 volts line-to-neutral.

Terminal-number assignments for the potentials are:

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

Current Inputs

The rating of the input transformers in the relay is ten amperes continuous, and 390 amperes for one second.

Terminal-number assignments for the current circuits are:

| | |
|---|---|
| A-dot, A | (1,7) |
| B-dot, B | (2,8) |
| C-dot, C | (3,9) |

IRIG-B Input Description

The port labelled J201 / AUX INPUT is for the IRIG-B input. The pin definitions are:

| PIN | NAME | DESCRIPTION |
|---|---|---|
| 2 | IRIGIN HI | positive IRIGB input |
| 3 | IRIGIN LOW | negative IRIGB input |
| 6 | +5 * | |
| 7 | +12 * | |
| 8 | -12 * | |
| 1,5,9 | GND | ground |

(* Consult the factory before using these power supply outputs)

The actual IRIG-B input circuit is a 56 ohm resistor in series with a opto-coupler input diode. Driver circuits should be designed to put approximately 10 mA through the diode when "on".

The IRIG-B serial format consists of a one second long, 100 pulse code divided into fields. The SEL-121 decodes the second, minute, hour and day fields.

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

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

## DEFINITION OF LOGIC VARIABLES

The SEL-121 output relay states depend on the states of the following:

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

Since so many binary variables are involved, we define the functioning using boolean logic equations. The logic variables involved are defined below.

### Relay Elements

| | | |
|---|---|---|
| single-phase overcurrent relays | 50A 50B 50C | pickup = settable, for use as fault detector (0.5 A to 25 A sec.) |
| ground distance relays (zone 1) | 21A1 21B1 21C1 | |
| ground distance relays (zone 2) | 21A2 21B2 21C2 | |
| ground distance relays (zone 3) | 21A3 21B3 21C3 | |
| phase distance relays (zone 1) | 21AB1 21BC1 21CA1 | |
| phase distance relays (zone 2) | 21AB2 21BC2 21CA2 | |
| phase distance relays (zone 3) | 21AB3 21BC3 21CA3 | |
| negative sequence directional relay | 32Q | * |
| negative sequence overvoltage relay | 47Q | pickup = 0.75 V sec |
| negative sequence overcurrent relay | 46Q | pickup = 0.14 to 0.7 A sec** |
| high-set neg seq overvoltage relay | 47QH | pickup = 11 V sec |
| positive sequence overvoltage relay | 47P | pickup = 0.14 to 0.7 V sec** |
| high-set pos seq overcurrent relay | 46PH | pickup = settable |
| positive sequence overcurrent relay | 46P | pickup = 0.14 to 0.7 A sec** |

* This logic variable is also asserted when a three-phase fault is indicated by the operation of a zone 3 relay of each type.

**Depends on relay reach. For all reaches above 2 ohms secondary, the lower limit applies.

Contact Inputs

| | |
|---|---|
| circuit breaker monitor | 52A |
| direct trip | DT |
| block trip | BT |
| direct close | DC |
| transfer trip | TT |
| external trigger | EXT |

Logic Parameters Entered as Settings, and Zone Timers

| | |
|---|---|
| zone 1 enabled | Z1E |
| zone 2 enabled | Z2E |
| zone 3 enabled | Z3E |
| neg. seq. directional relay enabled | 32QE |
| transfer trip initiated on zone 1 | TTI1 |
| transfer trip initiated on zone 2 | TTI2 |
| transfer trip initiated on zone 3 | TTI3 |
| zone 2 ground fault timer timeout | Z2GT |
| zone 3 ground fault timer timeout | Z3GT |
| zone 2 phase fault timer timeout | Z2PT |
| zone 3 phase fault timer timeout | Z3PT |
| ground switch detection enabled | GSE |
| blown fuse detection enabled | BPFE |
| open interval timer expires | 79OI |
| reset interval timer expires | 79RS |

Logic Parameters Received as Commands via Communications Channel

| | |
|---|---|
| close command received | CC |
| trip command received | TC |

Relay Outputs

| | |
|---|---|
| circuit breaker trip - any phase | TRIP |
| circuit breaker trip - phase A | TRIP A |
| circuit breaker trip - phase B | TRIP B |
| circuit breaker trip - phase C | TRIP C |
| circuit breaker close | CLOSE |
| transfer trip initiate | TTI |
| system alarm | ALARM |

LOGIC EQUATIONS

Below, the logic equations interrelating the variables defined above are given. Equations in the first group relate the variables defined above to particular system conditions. The second group of equations, in turn, describes the operation of the output relays.

Logic Equations For Particular System Conditions

```
21G1 =  21A1*50A +  21B1*50B +  21C1*50C       any zone 1 ground unit picked up
21P1 = 21AB1*50A + 21BC1*50B + 21CA1*50C       any zone 1 phase unit picked up

21G2 =  21A2*50A +  21B2*50B +  21C2*50C       any zone 2 ground unit picked up
21P2 = 21AB2*50A + 21BC2*50B + 21CA2*50C       any zone 2 phase unit picked up

21G3 =  21A3*50A +  21B3*50B +  21C3*50C       any zone 3 ground unit picked up
21P3 = 21AB3*50A + 21BC3*50B + 21CA3*50C       any zone 3 phase unit picked up

GD   = [32Q+NOT(46Q*47Q)]+NOT(32QE)            direction forward
GS   = 46PH * NOT(47P) * GSE                   ground switches closed
BPF  = 47QH*NOT(46Q) * BPFE                    blown potential fuse detected

ABC  = 50A*50B*50C*(21A3*21B3*21C3
                 + 21AB3*21BC3*21CA3)          three-phase fault

RI   = TRIP * NOT[Z2FT + Z3FT + DT + GS
              + TC + ABC] * 52A * 79RS         (reclose initiate timer)
                                               (starts open interval)

Z1F  = [(21G1+21P1)*GD*46P*47P+GS]*NOT(BPF)    zone 1 fault

Z2F  = (21G2 + 21P2)*GD*46P*47P*NOT(BPF)       zone 2 fault
Z2FT = (21G2*Z2GT+21P2*Z2PT)*46P*47P*NOT(BPF)  zone 2 fault and timeout

Z3F  = (21G3 + 21P3)*GD*46P*47P*NOT(BPF)       zone 3 fault
Z3FT = (21G3*Z3GT+21P3*Z3PT)*46P*47P*NOT(BPF)  zone 3 fault and timeout
```

Output Equations

```
Close TRIP Contact = [(Z1F * Z1E               zone 1 fault (if enabled)

    + Z2FT*Z2E * NOT (BT)                      zone 2 fault timeout (if
                                               enabled), and BLOCK TRIP input
                                               not asserted

    + Z3FT*Z3E                                 zone 3 fault timeout (if
                                               enabled)

    + Z2F*TT) * NOT (BPF)                      zone 2 fault, and transf. trip
                                               rec'd, and BLOWN POTENTIAL FUSE
                                               not detected or enabled

    + DT                                       DIRECT TRIP input asserted

    + TC ]                                     trip command received on
                                               comm. link
```

| | | |
|---|---|---|
| Close TRIP A contact = | TRIP* | trip, if |
| | [NOT(21B2 + 21C2) | not BG or CG |
| | + ABC | or if three phase |
| | + Z2FT | or zone 2 times out |
| | + Z3FT] | or zone 3 times out |
| Close TRIP B contact = | TRIP * | |
| | [NOT(21C2 + 21A2) | not CG or AG |
| | + ABC | or if three phase |
| | + Z2FT | or zone 2 times out |
| | + Z3FT] | or zone 3 times out |
| Close TRIP C contact = | TRIP * | |
| | [NOT(21A2 + 21B2) | not AG or BG |
| | + ABC | or if three phase |
| | + Z2FT | or zone 2 times out |
| | + Z3FT] | or zone 3 times out |
| Open TRIP Contact = | NOT(52A) | Circuit breaker opens, and |
| | * NOT(Z1F+Z2FT*Z2E+Z2F*TT | no fault detected (provides seal-in) |
| | +Z3FT*Z3E+Z3F*TT) | |
| TRANSFER TRIP INITIATE = | [Z1F*TTI1 | initiate on zone 1 fault |
| | + Z2F*TTI2 | or, on zone 2 fault |
| | + Z3F*TTI3] | or, on zone 3 fault |
| CLOSE = | (DC | DIRECT CLOSE input asserted |
| | + 79OI | or automatic reclose |
| | + CC) | or close command asserted |
| | * NOT(52A) | unless 52A input asserted |

Close ALARM Contact = BPF

+ self-test failure of: RAM, ROM, ADC, POWER, SETTINGS

+ PHASE SEQUENCE ERROR ON POWER-UP

+ BLOWN POTENTIAL FUSE

+ STALL TIMER TIMEOUT

Pulse ALARM Contact Closed for one second =

offset self test failure

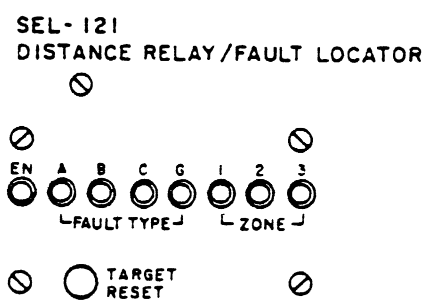
+ Access Level 1 password violation (third attempt)

+ any Access Level 2 attempt

The ALARM contact also closes for about four seconds during the setting process, when the internal settings are being computed. See SET command.

TARGETS

Below is a drawing of the SEL-121 front-panel targets.



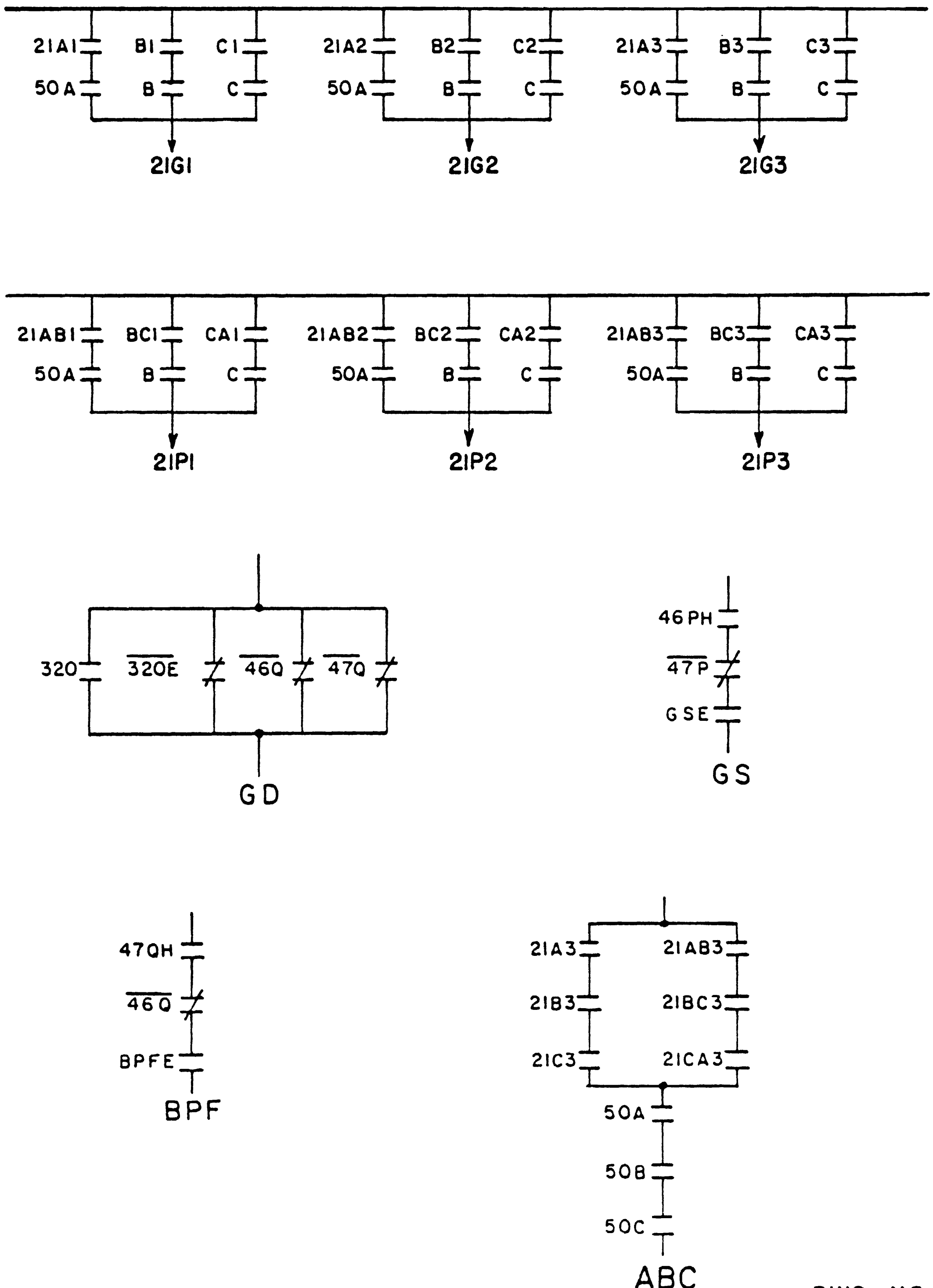

EN Indicators

Under normal operating conditions, this LED is on. Should the relay be out of service for any reason, it is dark.

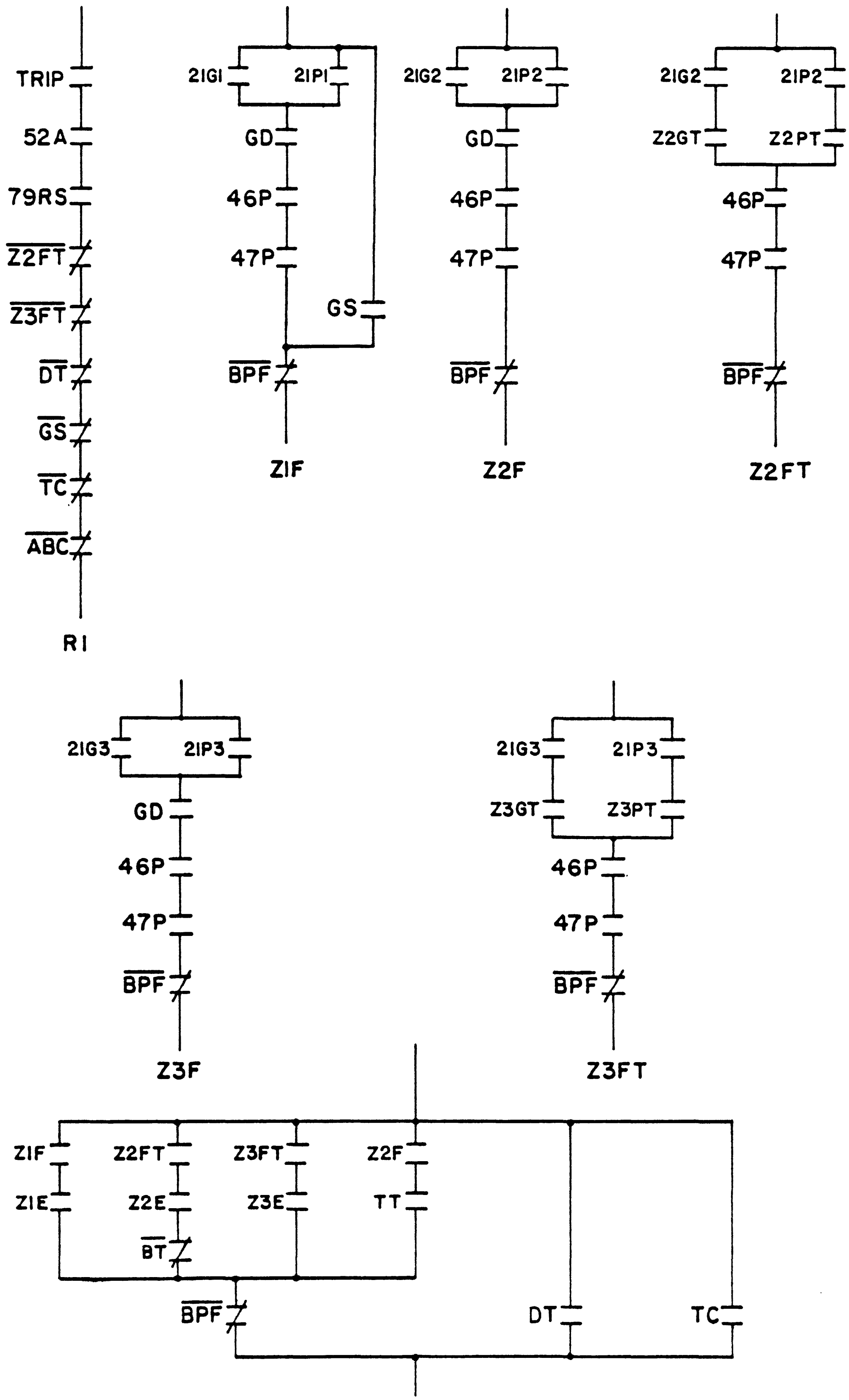
Fault Type Indicators

Four indicators indicate the fault type. For examples, a B-C fault turns on the "B" and "C" LEDs; an A-G fault illuminates the "A" and "G" LEDs. The indicators remain on until reset by pressing the target reset button.

Ladder Logic Representation
of SEL-121 Internal Logic

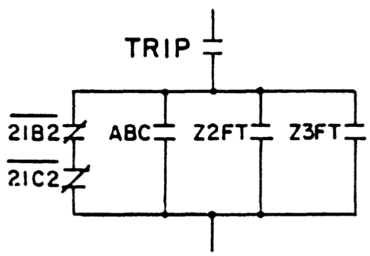



DWG. NO. A7 - 0262
DWG. 1 OF 4
DATE : 3 - 28 - 88

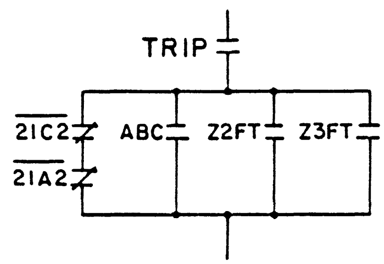



Close TRIP Contact

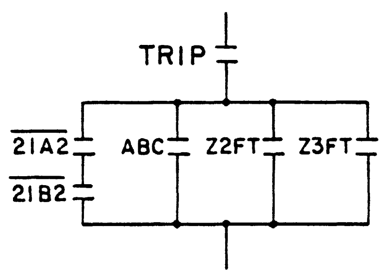
DWG. NO. A7 - 0262
DWG. 2 OF 4
DATE : 3 - 28 - 88




TRIP A



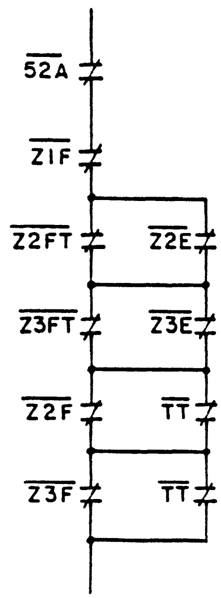

TRIP B



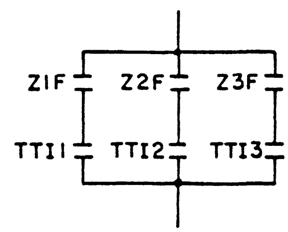

TRIP C



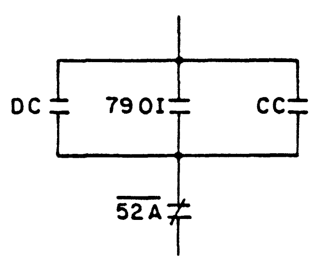
DWG. NO. A7 - 0262
DWG. 3 OF 4
DATE : 3 - 28 - 88



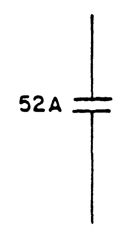

Open TRIP Contacts




TRANSFER TRIP INITIATE




Close CLOSE Contact




Open CLOSE Contact

### Zone Indicators

A zone 3 fault turns on LED "3".
A zone 2 fault turns on LEDs "2" and "3".
A zone 1 fault turns on LEDs "1" and "2" and "3".
They are all cleared by pressing the pushbutton.

## SELF TESTS

The SEL-121 runs a variety of self tests that ensures reliable operation. This section describes each test and what steps are taken if the test fails. Some tests have warning and failure states, while some, such as the A/D test, only have failure states. Any change in self test status results in the generation of a status report.

Failure of any test causes closure of the Alarm contacts. Failures that disable the control functions also place the output relay driver port in an input mode so that no A-contact outputs may be asserted. All self tests are run on power up before the relay is enabled, or prior to enabling the relay after using the setting procedure. Afterwards all self tests, except the phase sequence test, are run at least every few minutes.

### Offset

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

### Power Supply

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

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

The STATUS command response is transmitted for any failure or warning. A failure of the +5 volt supply causes all output relays to be deenergized and blocked from operation. A failure of the +/-15 volt supplies disables protective relay functions, but does not disable control functions. The ALARM relay remains closed for a power supply failure.

## Random-Access Memory

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

## Read-Only Memory

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

## Analog-to-Digital Converter

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

## Settings

Two images of the system settings are stored in nonvolatile memory. These are compared when the SEL-121 is initially set, and periodically thereafter. Should the images ever disagree, the setting test fails, and all protection and control functions are disabled. The STATUS message is transmitted to indicate the failed test. The ALARM relay remains closed for a setting failure.

## Phase-Sequence Check

When the SEL-121 is turned on, it checks the phase sequence of the voltages and currents. If the phase sequence check passes, then normal operation proceeds. If it fails, then the ALARM relay closes, and (assuming the automatic-port timeout is disabled) a message is transmitted, indicating the problem:

REVERSE PHASE SEQUENCE - V

or

REVERSE PHASE SEQUENCE - I

The phase sequence test compares the positive-sequence voltage or current to the negative-sequence voltage or current. If the negative-sequence voltage exceeds 150% of the positive-sequence voltage, plus a small bias, then the test fails; and, similarly for the current.

A failure of this test blocks further startup of the system. Once the phase-sequence error is corrected, the SEL-121 is restarted by either a control power off/on sequence, or by executing the SET command and entering settings.

This test is different from the other, in that it is designed to detect possible connection errors, as opposed to instrument malfunction. Because of this, its status is excluded from the STATUS command.

## SETTING PROCEDURE

Settings for the SEL-121 are entered using the SET command, via either of the serial interface ports. The settings are stored in non-volatile memory, so that they are retained when the power is off.

Refer to the command description for details.

## EVENT REPORT

The SEL-121 transmits an event report following any of these events:

- zone 1 fault
- zone 2 fault
- zone 3 fault
- direct trip
- external trigger
- block trip
- command (TRIGGER)
- transfer trip

Execution of the OPEN or CLOSE commands does not trigger an event.
Direct close, by asserting the DIRECT CLOSE input, does not trigger an event.
The event report contains voltages, currents, system settings, and other information. It is described in detail in a separate section.

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

## FAULT LOCATOR

The fault locator operates when any event containing a fault occurs. Its output is displayed as a part of the EVENT command response and the HISTORY command response.

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

instrument transformer ratio errors due to overburden by other devices
capacitive potential transformer capacitor value drift
transmission line parameter errors

The algorithm uses prefault and fault information to compensate for the errors introduced by fault resistance in the presence of load flow. It is triggered on the first occurrence of an event, and cannot trigger again until after the fault condition is cleared.

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

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

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

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

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

When series capacitor compensation is used, accurate performance is obtained for faults between the SEL-121 and the capacitors, and beyond the capacitors if the capacitor protective gaps flash. If the gaps do not flash, the measured impedance includes the line impedance and the capacitance impedance, and the errors can be substantial. This problem is aggravated by high-speed clearing and the excitation of eigenmodes or resonances of the line-capacitor system, which may not be much removed from 60 Hz. On the other hand, we have had success in cases where series capacitor gaps did not flash, by recomputing the fault location from the event-report data, using a voltage equal to the measured voltage minus the capacitor voltage drop. The latter is computed from the capacitance value and the measured current.

MHO UNITS

The mho circles are affected by these settings: maximum torque angle, set reach, and transmission line (positive sequence) angle and length. The circles pass through the impedance-plane origin, and the diameter passing through the origin is at an angle of MTA (maximum torque angle) with respect to the resistance axis. The chord passing through the origin at the positive sequence impedance (Z1) angle of the transmission line has a length equal to the set reach. Therefore the mho circle diameter is:

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

## COMMANDS AND SERIAL COMMUNICATIONS

### INTRODUCTION

The SEL-121 is set and operated via serial communications interfaces, which connect to a computer terminal and/or a modem, or the SEL Protective Relay Terminal Unit. Communication serves these purposes:

1. Setting of the relay/fault locator.

2. SEL-121 transmits messages in response to changes in system status, e.g. self-test warning.

3. SEL-121 transmits an event record following any zone 1, 2 or 3 fault for any of the following conditions:

   a) a fault
   b) assertion of the external trigger input
   c) assertion of the direct trip input
   d) assertion of the transfer trip input
   e) in response to the TRIGGER command

   (No event record is made for assertion of the CLOSE input, assertion of the 52A input or execution of the TRIP or CLOSE commands.)

4. SEL-121 responds to commands spanning all functions of the instrument, such as metering, setting the clock, and control operations.

Two levels of access (Access Levels 1 and 2) through the communications ports are protected against unauthorized access via passwords.

It is impossible to disable any relaying or control functions via communications, except by entering unintended or improper settings.

### SERIAL PORT CONNECTIONS AND CONFIGURATIONS

Two serial port connectors are located on the rear panel of the SEL-121. The connectors are marked "PORT 1" and "PORT 2". Both ports adhere to RS-232C data communications standards.

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

Port 2 is intended for local communications via a CRT, printing terminal, or other device. Cable diagrams for several devices are given elsewhere in the manual.

The baud rates of the ports are set by jumpers which are accessible by removing the top cover, near the front. Available rates are 300, 600, 1200, 2400, 4800 and 9600 baud.

The serial data format is

eight data bits
two stop bits
no parity bit

This format cannot be altered.

The port pin assignments and signal definitions are given below.

| PIN | NAME | DESCRIPTION |
|---|---|---|
| 2 | TXD | transmit data output |
| 3 | RTS | The SEL-121 asserts this line under normalconditions. When its received-data buffer is full, the line is unasserted, and asserts again once the buffer has sufficient room to receive more data. Connected devices should monitor RTS (usually with their CTS input) and stop transmitting characters whenever the line unasserts. If transmission of data continues, data may be lost. |
| 4 | RXD | receive data input |
| 5 | CTS | The SEL-121 monitors CTS, and transmits characters only if CTS is asserted. |
| 6 | + 5 volts | |
| 7 | +12 volts | |
| 8 | -12 volts | |
| 1,9 | GND | Ground for ground wires and shields |

## COMMUNICATIONS PROTOCOL

The communications protocol consists of hardware and software features. The hardware protocol consists of the control line functions described above. A software protocol designed for manual and automatic communications is provided, and described here.

1. All commands received by the SEL-121 must be of the form:

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

Thus a command transmitted to the SEL-121 should consist of the command name, followed by either a carriage return, or a carriage return and a line feed.

2. All messages transmitted by the SEL-121 are of the following format:

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

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

3. The SEL-121 indicates the volume of data in its received-data buffer by an XON/XOFF protocol.

XON (ASCII hex 11) is transmitted by the SEL-121 when the buffer drops below 1/4 full. The SEL-121 also asserts the RTS output.

XOFF (ASCII hex 13) is transmitted when the buffer fills above 3/4 full. The SEL-121 unasserts the RTS output, when the buffer is approximately 95% full. Automatic transmitting sources should monitor for the XOFF character so as not to overwrite the SEL-121 received-data buffer. Transmission should terminate at the end of the message being transmitted when XOFF is received, and may be resumed when the XON character is received.

4. An XON/XOFF procedure may be used to control data transmission by the SEL-121. When the SEL-121 receives XOFF while it is transmitting, it responds by pausing until an XON character is received. If no message is being transmitted when XOFF is received, the SEL-121 blocks transmission of any message that may be presented to its transmitting buffer. The message will be transmitted once XON is received.

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

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

| | | |
|---|---|---|
| XON: | control-Q | (hold down the control key, and press Q) |
| XOFF: | control-S | (hold down the control key, and press S) |
| CAN: | control-X | (hold down the control key, and press X) |

COMMAND CHARACTERISTICS

The SEL-121 responds to commands received by either of its serial communications interfaces. A two-level password system provides security against unauthorized access.

When the power is first turned on, the instrument is in Access Level 0, and honors only the ACCESS command. "Invalid command" is the response to any other entry.

Most commands are available from Access Level 1, which is entered using the ACCESS command and a password. The password is factory-set to OTTER, and may be changed via the PASSWORD command (Access Level 2).

Critical commands, such as for circuit breaker control and changing settings are available only from Access Level 2, which is entered from Access Level 1 using the 2ACCESS command and a different password. The Level 2 password is factory-set to TAIL, and may be changed via the PASSWORD command.

## Startup

When power is first applied, the instrument transmits the following message to the port designated as the "automatic" port:

```
SEL-121
=
```

You should also hear the ALARM relay pull in, opening its B contact.

The instruments are shipped with Port 2 designated as the automatic port; however, an Access Level 2 command (AUTO) exists for selecting either port for the transmission of automatic responses from the SEL-121.

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

```
=ACCESS <CR>
```

The response is:

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

Respond by entering the Level 1 password, e.g. OTTER, followed by a carriage return. The response is:

```
Level 1 access  -  Example 230 KV Line                  1/1/86     01:01:44
=>
```

The equals sign and greater-than sign form the Access Level 1 prompt. Now, any Level 1 command can be executed.

To enter Access Level 2, a similar procedure is used:

Enter the command 2ACCESS, and listen for the ALARM relay to drop out and pull in. This action pulses the ALARM relay contact closed for about one second, indicating that Level 2 Access is being attempted. Provide the proper password, e.g. TAIL, in response to the prompt for password. In response to the correct password, access to Level 2 is attained, as indicated by the following message and the Level 2 prompt:

```
Level 2 access  -  Example 230 KV Line                    1/1/86    01:01:50
=>>
```

Any Level 2 or Level 1 command can now be executed.

## Command Format

Commands consist of three or more characters; only the first three characters of any command need be entered.

Upper or lower case characters may be used without distinction.

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

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

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

## COMMAND DESCRIPTIONS

### Access Level 0 Command

### Access

Use ACCESS to gain access to the system from the Level 0 prompt (=). After typing ACCESS <CR>, a prompt for the Level 1 password appears. Enter the password, and press return.

Successful access is indicated by the typical response shown below:

```
=ACCESS <CR>
Password: @@@@@@@@
Level 1 access  -  Example 230 KV Line                    1/1/86    01:01:35
=>
```

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

If three unsuccessful access attempts are made in a row, the alarm contact is pulsed closed for one second. This feature can be used to alert operations personnel that possible unauthorized access is being attempted, if the alarm contact is connected to a monitoring system, such as SCADA.

## Access Level 1 Commands

### 2Access

Use 2ACCESS to gain access to Level 2 from Level 1. After typing 2ACCESS <CR>, a prompt for the Level 2 password appears. Enter the password in the same manner as for the ACCESS command, and press return.

Successful access is indicated by the typical response shown below:

```
=>2ACCESS
Password: @@@@@@@@
Level 2 access  -  Example 230 KV Line                        1/1/86     01:02:13
=>>
```

The =>> prompt signifies that Access Level 1 and 2 commands may now be used. The alarm contact is pulsed closed for one second for any Level 2 access attempt, successful or otherwise.

### Date [mm/dd/yy]

To read the date kept by the internal calendar/clock, type DATE <CR>.
To set the date, type DATE mm/dd/yy <CR>.

For example, to set the date to February 28, 1986, enter:

DATE 2/28/86 <CR>

When the power is first turned on, the date is 1/1/86.

### Event [N][L]

Event records may be reviewed via a summary or a complete report. To review a summary report of the Nth event, enter EVENT N <CR>. To review the complete report for the Nth event, enter EVENT N L <CR>. The parameter N is 1 for the most-recent event, through 12 for the oldest event stored in the SEL-121 memory.

For example, to inspect the newest report in full, enter EVENT 1 L <CR>.

To review a summary of the newest report, enter EVENT 1 <CR>. The summary provides the relay identifier string, date and time, type of event, and, for faults, the location, duration and current.

Recall (from the COMMUNICATIONS PROTOCOL description) that you can terminate any transmission from the SEL-121 using the CTL-X (cancel) sequence, you can pause using CTL-S, and you can continue using CTL-Q. These are useful in reviewing or terminating a long report.

When the event buffers are cleared by a control power interruption, all the event data are lost. Asking for an event from an empty buffer results in this message:

    Invalid event

## History

The date, time, type of event, and distance (if event is a fault) duration and current are shown for each of the twelve most recent events. An example of the display is shown below:

| DATE | TIME | TYPE | DIST | DUR | CURR |
|---|---|---|---|---|---|
| 10/31/86 | 09:03:01 | 3AG | 100.2 | 7.2 | 798 |
| 10/31/86 | 09:02:13 | 3AG | 74.9 | 7.0 | 1016 |
| 10/31/86 | 09:00:39 | 1AG | 25.3 | 7.2 | 2162 |
| 10/31/86 | 09:00:13 | 1BC | 25.5 | 7.2 | 3167 |

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

The TYPE column indicates "EXT" for externally-triggered events, such as caused by asserting the TRIP, TRANSFER TRIP, EXTERNAL TRIGGER, or BLOCK inputs, or by executing the TRIGGER command under no-fault conditions. For faults, the zone and fault type are given. For example, 1CG indicates a zone 1 phase C-to-ground fault.

## Irig

Executing the Irig command causes the relay to try to read the demodulated IRIG-B time code input at J201 on the rear panel, if present.

If the time code is successfully read, then the internal clock/calendar time and date are updated to the time code reading, and a message consisting of the relay ID string and the date and time is output.

If no time code signal is present or if the time code cannot be successfully decoded, the error message "ERROR in IRIGB data acq" is produced.

Note: It is normally unnecessary to synchronize using this command, as the relay performs it automatically every few minutes. The command is provided as a test and setup feature, to avoid waiting for automatic synchronization during test and installation.

## Meter [N]

The voltages, currents, and real and reactive power are displayed in primary quantities of amperes, kilovolts, megawatts and megavars. An example is shown on the following page.

```
Example 230 KV Line                          Date:  12/21/85   Time:  13:27:05

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

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

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

The optional command parameter N selects the number of times the meter data are displayed. For example, to see a series of eight meter readings, type METER 8.

## Quit

Executing the QUIT command returns control to Access Level 0 from either Access Level 1 or 2, and displays the date and time when QUIT is executed. Use this command when you are done communicating with the SEL-121, so that unauthorized access is avoided. (Note that control returns to Access Level 0 automatically after a settable interval of no activity. See the INTERVAL command (Access Level 2).

## Showset

Enter SHOWSET to inspect the settings of the SEL-121. The settings cannot be modified with this command. The settings are entered using the SET command, under Access Level 2.

An example of the output from executing SHOWSET is shown below.

```
Settings for:
Example 230 KV Line
R1  = 13.90    X1  = 79.96    R0  = 41.50    X0   = 248.57  LL   = 100.00
CTR = 200      PTR = 2000     MTA = 80.80    79OI = 30.00    79RS = 60.00
Z1% = 80.00    Z2% = 120.00   Z2DG= 60.00    Z2DL = 30.00
Z3% = 150.00   Z3DG= 90.00    Z3DL= 60.00    50FD = 100      46PH = 6000    TTI = 1
Z1E = Y        Z2E = Y        Z3E = Y        32QE = Y        GSE  = Y       BPFE= Y
```

A detailed explanation of these settings is given under the description of the SET command. Briefly, the first line shows: positive- and zero-sequence impedances of the transmission line (primary ohms), and the line length (miles) for which the impedances are given.

The second line shows: current and voltage transformer ratios, maximum torque angle, and reclosing open interval and reset delay.

The third line provides: zone 1 and 2 reaches as a percent of the line, and zone 2 time delays for ground and phase faults.

The fourth line presents: zone 3 reach and delays pickup current for the fault detectors, the pickup current for the positive-sequence overcurrent element, and the zone on which transfer tripping is initiated.

The bottom line shows the enables for each of the three zones, and the enables for the negative-sequence directional element, the ground-switch detection scheme and the blown-potential-fuse detection scheme.

## Status

The self test status of the SEL-121 is inspected using STATUS. The instrument also automatically executes the STATUS command whenever self test enters a warning or a failure state, causing the STATUS report to be transmitted out of the port(s) selected for automatic transmissions. (See AUTO command, Access Level 2.)

The format of the STATUS report is shown below.

```
SELF TEST STATUS   2/28/84   02:05:04
W=Warning F=Failure

      IM   IR   IA   IB   IC   VA   VB   VC
OS     7   14  -11   -1    5    8   -3   -6
PS      5.05      +15.54    -14.89
RAM   ROM    A/D      MOF     SET
OK    OK     OK       OK      OK
```

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

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

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

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

The A/D self test checks the A/D conversion time. If it exceeds a threshold, the test fails, and the protection functions are disabled. The MOF test is a check of the offset in the MUX-PGA-A/D circuit when a grounded input is selected. It has warning and failure thresholds the same as the offset tests. SET indicates the state of the self test which compares two copies of the settings stored in nonvolatile memory. Failure of this test disables relay and control functions.

## Time [hh:mm:ss]

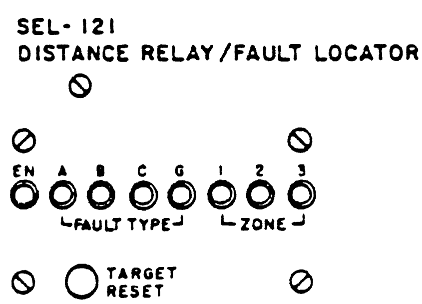
To read the internal clock, enter TIME <CR>. To set the clock, enter TIME followed by the desired setting. Separate the hours, minutes and seconds with colons, semicolons, spaces, commas or slashes. For examples, to set the clock to 23:30:00, enter: TIME 23 30 00 <CR> or TIME 23:30:00 <CR>, etc.

A quartz crystal oscillator provides the time base for the internal clock, and the SEL-121 time code input can be used to synchronize this clock to an external clock having a demodulated IRIG-B time code output.

## Targets [N]

This command selects the information to be displayed on the front-panel targets LEDs, and also communicates the state of the selected LEDs.

When the relay power is turned on, the LED display indicates the functions marked on the front panel. That is, the LEDs default to displaying fault information shown below.




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

| LED: | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | |
|---|---|---|---|---|---|---|---|---|---|
| N | | | | | | | | | |
| 0 | EN | A | B | C | G | 1 | 2 | 3 | Fault Targets |
| 1 | | | CA1 | BC1 | AB1 | C1 | B1 | A1 | Zone 1 MHO Flags |
| 2 | | | CA2 | BC2 | AB2 | C2 | B2 | A2 | Zone 2 MHO Flags |
| 3 | | | CA3 | BC3 | AB3 | C3 | B3 | A3 | Zone 3 MHO Flags |
| 4 | | 46P | 46PH | 47P | 46Q | 47Q | 47QH | 32Q | Auxiliary Relay Flags |
| 5 | | TRIP | CLOSE | TTI | A | B | C | ALARM | Output Relays |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 6 | | | ET | 52A | DC | BT | TT | DT | Inputs |
| 7 | Z3FT | Z3F | Z2FT | Z2F | Z1F | BPF | GS | GD | Intermediate Logic #1 |
| 8 | ABC | | 21L3 | 21G3 | 21L2 | 21G2 | 21L1 | 21G1 | Intermediate Logic #2 |

These selections are useful in testing, in checking contact states, and in remotely reading the targets.

Be sure to return the function of the targets to display the fault targets, so that field personnel do not misinterpret the displayed data. Do this by typing TAR 0.

## Trigger

Enter TRIGGER <CR> to generate an event record. The prompting message "Trigger event record (Y/N) ?" is transmitted. Respond with Y <CR> if you want to trigger an event record. A response of "Triggered" is transmitted. After a short delay, during which the computer is formatting the just-triggered record, a summary of the record is displayed.

The TRIGGER command is useful in inspecting the phasor voltages and currents at any time. For example, when the SEL-121 is first installed, execute the TRIGGER command, and draw the phasors (the EVENT REPORTING section explains how to do this), and check for the proper polarity and phase sequence of the inputs.

Entering N <CR> terminates the command without triggering an event record.

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

## Access Level 2 Commands

All commands are available from Access Level 2; however, the commands listed below are available ONLY from Access Level 2. Recall that any attempt, successful or otherwise, at entering Access Level 2 causes the alarm relay to pulse closed for one second.

## Auto [N]

The SEL-121 automatically transmits messages, such as STATUS and EVENT reports. The AUTO command selects port 1, port 2, or both ports, as the destination for the automatic transmissions. To designate serial port 2 as the "automatic port", enter AUTO 2 <CR>. The selection is stored in nonvolatile memory, and is retained when the control power is lost.

Entering AUTO <CR> shows the selected automatic port.

Automatic messages are transmitted out the selected port(s) as long as the control lines and protocol allow transmission, with no regard to the access level.

## Close

The CLOSE output relay can be closed by execution of the CLOSE command or by asserting the DIRECT CLOSE input, as long as the 52A input is not asserted. The CLOSE output relay then remains closed until the 52A input is asserted, (indicating that the circuit breaker is closed).

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

The CLOSE command aborts unless the remote open/close jumper (Jumper 2) is in place on the mainboard.

## Interval [N]

Each of the serial ports has a timeout interval, which, when expired, causes control to pass to Access Level 0. This is a safety procedure limiting the possibility of unauthorized personnel using an unattended terminal. The interval is measured from the last command entered.

The interval may be set from one to 30 minutes. Entering 0 disables automatic timeout. For example, suppose a timeout interval of 10 minutes is desired. Enter INTERVAL 10 <CR>. The response of the system is: "Time-out 10 minutes". Entering INTERVAL <CR> displays the timeout interval.

## Modem [N]

Port 1 is designed to connect to a modem, and software is provided to set a Hayes Smartmodem for automatic answer after a settable number of rings. The SEL-121 responds to MODEM with the programmed number of rings. Typing MODEM followed by a number of 1 to 255 sets the parameter specifying the number of rings to that number. The modem is initialized when the telephone is answered by the SEL-121. Thus if the modem has been turned off and back on between calls, it will answer on the first ring on the next call, and on the programmed number of rings thereafter, until the power to the modem is turned off again. The number of rings you select with the MODEM command is stored in nonvolatile memory, and is therefore retained when the control power is off.

Additional detail on the use of the Hayes Smartmodem with the SEL-121 is provided in the MODEM COMMUNICATIONS section of this manual.

## Open

The TRIP output relay closes in response to the OPEN command as long as the BLOCK TRIP input is not asserted. The TRIP relay remains closed until the 52A input is not asserted AND no fault is detected. Thus, the TRIP output relay seals in.

When the 52A contact is not asserted and the OPEN command is executed, the TRIP output relay pulses closed for about 1/2 second.

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

The OPEN command aborts unless the remote open/close jumper (Jumper 2) is in place on the main board.

## Password (1 or 2) [password]

To inspect the passwords, enter PASSWORD <CR>.

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

    PASSWORD 1 BIKE<CR>

The SEL-121 responds by setting the password, pulsing closed the alarm relay, and transmitting the response "Set".

AFTER ENTERING NEW PASSWORDS, EXECUTE "PASS" TO INSPECT THE NEW PASSWORDS. MAKE SURE THEY ARE WHAT YOU INTENDED. BE SURE TO WRITE DOWN THE PASSWORDS AFTER YOU CHANGE THEM. THERE IS NO COMMUNICATIONS PROCEDURE TO ACCESS THE SEL-121 WITHOUT THE PASSWORDS.

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

OTTER    otter    Ot3456    +TAIL+    !@#$%^    SEL-121    123456    12345.    12345    ab1CDE

Should the passwords be lost, or should you wish to operate the SEL-121 without password protection, install Jumper 1 on the main board. (NO password protection). Witn no password protection, you may gain access without knowing the passwords, and then execute the PASSWORD command to discover or change the "forgotten" passwords.

## Set

The setting procedure consists of answering prompting messages with new data, or by typing <CR>, indicating no change. Once all data are provided, the new settings are displayed, and a prompt is issued requesting your approval to enable the SEL-121 with the new settings. Error messages are included to indicate when the entered data result in out-of-range settings.

The following data are required to set the relay:

| | |
|---|---|
| R1, X1 | (pos. seq. primary impedance of line - ohms) |
| R0, X0 | (zero seq " " " " " ) |
| LL | Line length (miles) |
| | |
| CTR | CT ratio ( e.g. for 600/5, enter 120) |
| PTR | PT ratio ( e.g. 1200/1, enter 1200) |
| | |
| MTA | Maximum torque angle for MHO elements (47-90 degrees) |
| | |
| 79OI | Reclosing relay open interval (1/4 to 240 cycles; 0 disables reclosing) |
| 79RS | Reclosing relay next time (60 to 1800 cycles) |
| | |
| Z1% | Zone 1 reach (percent of line length: 1 to 200%) |
| Z2% | Zone 2 reach (percent of line length: 4 to 800%) |
| Z2DG | Zone 2 delay for ground faults (0-999 cycles in 1/4 cycle steps) |
| e.g., | enter 10.25 for a delay of 10 1/4 cycles. |
| Z2DP | Zone 2 delay for line-to-line faults (0-999 cycles in 1/4 cy steps) |
| | |
| Z3% | Zone 3 reach (percent of line length: 4 to 800%) |
| Z3DG | Zone 3 delay for ground faults (0-999 cycles in 1/4 cycle steps) |
| Z3DP | Zone 3 delay for line-to-line faults (0-999 cycles in 1/4 cy steps) |
| 50FD | Fault detector instantaneous overcurrent element pickup (primary amperes) |
| 46PH | Positive-sequence overcurrent threshold (primary amperes) |
| | |
| TTI | Should zone 1, 2 or 3 faults operate the transfer trip init. relay? (1, 2 or 3) |
| Z1E | Trip for zone 1 faults? (Y or N) |
| Z2E | Trip for zone 2 faults after time delay? (Y or N) |
| Z3E | Trip for zone 3 faults after time delay? (Y or N) |
| | |
| 32QE | Do you want negative sequence directional supervision of MHO units? (Y or N) |
| GSE | Should immediate tripping occur for closing into ground switches? (Y or N) |
| BPFE | Should tripping be blocked when a blown potential fuse is detected? (Y or N) |

REFER TO THE FUNCTIONAL DESCRIPTION AND BE SURE THE SETTINGS YOU CHOOSE RESULT IN RELAY PERFORMANCE APPROPRIATE TO YOUR APPLICATION. WE ARE NOT LIABLE FOR MISAPPLICATION DUE TO INCORRECT SETTING, INTERPRETATION OR APPLICATION.

Listed below are some points that may aid in applying the SEL-121.

1. Very close three-phase faults can be detected by a positive-sequence overcurrent condition occurring simultaneously with a sensitive positive-sequence undervoltage condition, when the setting option of ground-switch detection is enabled. This feature is designed to provide positive action for three-phase faults that may not provide enough voltage for directionality.

To enable this protection, answer the prompt "Ground Switch Det" with "Y".
To disable this protection, answer the prompt with "N".

2. The negative-sequence directional element can be set to supervise the MHO units. For long transmission lines, under some system conditions, it is possible (although unlikely) for a MHO unit to operate for a reverse-direction fault in the leading phase. The 32Q element is tangent to the MHO circle at the origin, i.e., it has the same maximum-torque angle as the MHO units. The 32Q element is bypassed whenever three-phase faults are detected in which case the relay assumes the fault is forward.

To supervise the MHO units with the 32Q, answer the "Neg Seq Dir Supervsn" prompt with "Y".

To disable this supervision, answer the prompt with "N".

3. Blocking of tripping for operation of the MHO units and the ground-switch detection condition is provided by logic designed to detect open potential circuits. This logic prevents false tripping for blown secondary-potential fuses, and is settable in response to the prompting question in the setting procedure. Note that the detection of a blown potential-circuit fuse does not block direct tripping via the DIRECT TRIP control input, or by the OPEN command. A blown potential fuse condition is declared when the negative-sequence voltage exceeds a high-set threshold, and when, simultaneously, the negative-sequence current is below a low-set threshold. The latter prevents fault conditions from appearing to be a blown potential fuse. When enabled, the blown potential fuse logic not only blocks tripping as described above, but also closes the ALARM output relay.

To block tripping when a blown potential fuse is detected by the above logic, answer the prompt "Blown Pot Fuse Det" with "Y".

To allow tripping even if a blown potential fuse is detected by the above logic, answer the prompt with "N".

4. The TRANSFER TRIP INITIATE output relay can be set to close in response to Zone 1, 2, or 3 faults. The output relay responds with no intentional delay after detection of the selected fault type.

If you want the TRANSFER TRIP INITIATE relay to close for Zone 1 faults, answer the prompt "Trans Trip Init Zone" with "1".

Answer the prompt with 2 or 3 if you want the TRANSFER TRIP INITIATE relay to close for Zone 2 or 3 faults.

5. Zone 1 instantaneous and Zone 2 and 3 time-step tripping can be individually enabled or disabled. Answer the prompting messages for Zones 1, 2 and 3 direct trip with "Y" or "N" as desired.

6. The zone 1, 2 and 3 reach values are the reaches of the mho units for a zero-resistance fault on the transmission line. The maximum torque angle (MTA) for the mho circles is independently set, and the diameter of the circle is expanded to keep the reach setting in the direction of the transmission line impedance constant as the maximum torque angle is separated from the transmission line angle. Thus the maximum torque angle setting does not affect the reach in the direction of the transmission line, and the mho circle diameter relates to thc set reach and the difference between the transmission line angle and the MTA by the expression below.

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

# EVENT REPORTING

## INTRODUCTION

The SEL-121 transmits a summary event report in response to several events, and saves a full event report in its memory. The summary report includes the identifier message entered at the beginning of the setting procedure, date, time, and type of event. If it is a fault, then the fault location in miles and secondary ohms, the fault duration, and a fault current measurement are also displayed.

The summary report is automatically transmitted out the designated AUTOMATIC port(s) (see AUTO command), regardless of access level, as long as the designated port(s) has(have) not timed out. If the automatic transmissions are to be monitored by a dedicated channel or to be printed on a dedicated printer, be sure to execute INT 0 at that port, so the port never times out. See the INTERVAL command (Access Level 2) for further details.

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

The full report is not automatically transmitted, owing to its length (about one page). Its transmission is requested by using the EVENT command, e.g., EVENT 1 L, where the L signifies you want the full (long) report.

The most-recent twelve events are stored in the SEL-121 volatile memory. These data are retained as long as the control power remains on. (This differs from the relay settings, which are retained in non-volatile memory. The settings are retained until changed by the SET command, regardless of control power cycling.) You may quickly review the stored events using the HISTORY command.

Event reporting is triggered by any of the following:

| | |
|---|---|
| Fault in any zone | Execution of TRIGGER command |
| Assertion of DIRECT TRIP Input | Assertion of TRANSFER TRIP Input |
| Assertion of BLOCK TRIP Input | Assertion of EXTERNAL TRIGGER Input |

Event reporting is NOT triggered by any of the following:

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

EXAMPLE EVENT REPORT

A full report is provided at the end of this section. The report was generated in response to a simulated fault on the Example 230 KV Line described in the INITIAL CHECKOUT section of this manual. An A-to-ground fault 50 miles away, was used. The test set settings were computed using the BASIC program in Appendix C, and assume a source impedance of 0.2 of the total line impedance. For this test, the SEL-121 currents and voltages were provided by a Doble F-3 Test System. A latching relay was used to simulate the circuit breaker action and to provide a contact whose state is sensed by the SEL-121 52A input. An auxiliary relay 'B' contact was wired across the test set current output, so that most of the current initially passed through the relay contact. To stage a fault, the auxiliary relay was energized, allowing all of the test set current to pass through the SEL-121 current input. Logic was included to deenergize the auxiliary relay once the fault was detected and the latching relay responded, thereby shunting most of the current around the SEL-121, as in the prefault case.

The computed and actual settings for the test set are given below.

| VA | VB | VC | IA | | |
|---|---|---|---|---|---|
| 47.9 | 71.3 | 71.2 | 6.9 | volts or amps | (computed) |
| 0 | -125 | 126 | -80 | degrees | (computed) |
| 48 | 71 | 71 | 6.9 | volts or amps | (actual) |
| 0 | -125 | 125 | -80 | degrees | (actual) |

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

| VA | VB | VC | IA | |
|---|---|---|---|---|
| 96 | 142 | 142 | 1380 | kilovolts or amperes |

These were obtained using the potential and current transformer ratios assumed in the Example 230 KV Line. Note that these ratios are displayed at the end of the report: PTR = 2000 CTR = 200.

The paragraphs following describe the response of the SEL-121 to this simulated fault, using information taken from the full event report.

## INTERPRETATION OF VOLTAGE AND CURRENT DATA

The voltage and current data provided in the event report are determined from the secondary quantities presented to the rear panel of the SEL-121, by the processing steps outlined below.

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

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

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

1, -1, -1, 1

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

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

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

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

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

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

The residual current data are rotated by the angle of the zero-sequence compensation factor. The notation /K*RES on the column heading indicates this rotation of the residual current.

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

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

| Currents | | | | Voltages | | | |
|---|---|---|---|---|---|---|---|
| /K*RES | A | B | C | A | B | C | |
| -491 | -516 | | | 81.0 | -130.7 | -6.6 | (use for Y-component) |
| 1274 | 1277 | 0 | 0 | 51.4 | 55.1 | -142.0 | (use for X-component) |

These were taken near the "middle" of the fault, as can be judged from the action of the AG MHO unit.

Convert these to polar form (magnitude and angle):

| Currents | | | | Voltages | | | |
|---|---|---|---|---|---|---|---|
| /K*RES | A | B | C | A | B | C | |
| 1365 | 1377 | 0 | 0 | 96 | 142 | 142 | (magnitudes) |
| -21 | -22 | -- | -- | 58 | -67 | -177 | (angle) |
| -79 | -80 | -- | -- | 0 | -125 | 125 | (angle - 58) |

In the third row, 58 degrees are subtracted from all angles of the second row, so as to assign the phase-A voltage phasor as the zero-degree reference. The magnitude and shifted angles can be compared to the settings of the test set given earlier. The angle errors are one degree or less, and the magnitude errors are less than one percent.

The residual current compensation factor is:

$$(Z_0 - Z_1) / (3Z_1) = K$$

Its angle, using the data for the Example 230 KV Transmission Line, is 0.6 degrees. The displayed angle for the residual current is the residual current angle plus the residual current compensation angle. Therefore, the measured angle of the residual current is: -79 + 0.6 = -79.6 degrees, for a 0.4 degree error, since all of the residual current is phase-A current.

The event report indicates a fault current of 1378 amperes primary, which agrees well with the 1380-ampere test set current referred to the primary.

The indicated fault location is 50.28 miles. The "actual" fault location is 50 miles.

The error is 50.28 - 50.00, or 0.28 mile, which is about 0.3 percent of the set reach.

## RELAY ELEMENT STATUS INDICATORS

The states of all relay elements are indicated in three groups of columns, headed MHO (Mho elements), +Seq (positive-sequence elements), and -Seq (negative-sequence elements).

In the example event report, note that the AG MHO units were the only MHO units to respond to the fault. The zone-2 and 3 units picked up first, followed one-quarter cycle later by the zone-1 unit. The negative-sequence directional unit (32) indicated a forward-direction fault as soon as the zone-2 unit operated, and tripping, as indicated by the TRIP (TP) output, was initiated as soon as the zone-1 MHO unit picked up. Since Transfer Tripping on zone 1 faults is selected (as indicated by TTI=1), closing of the TRANSFER TRIP INITIATE output relay was initiated. The TRIP A contact but not TRIP B or TRIP C contacts, closed since the fault meets the criteria for single pole tripping.

The 52A contact input monitored the latching relay (circuit breaker simulator) state. The 52A input indicated that the latching relay had changed to the "open" state about one cycle after tripping had been initiated.

The duration of the fault can be estimated from the total time the MHO units are picked up. Note that they were picked up for a total of 16 quarter-cycles, or four cycles. This value is reported near the bottom of the report as: Duration: 4.00.

## SAMPLE EVENT REPORT

```
Example 230 KV Line                               Date: 1/1/86      Time: 01:26:31.426

         Currents                    Voltages          MHO    +Seq   -Seq   Outs     Ins
          (amps)                       (kV)
                                                       ABCABC iIv    ivV3   TCTTTTA  DTBD5E
/K*RES     A       B      C     A        B       C     GGGBCA            2  PLTABCL  TTTC2T

   -13    -13      0      0   82.3   -129.4   -10.1    ...... ..*    .*..   .......  ....*.
    31     35      3      0   49.4     58.4  -141.6    ...... ..*    .*..   .......  ....*.
    13     13      0      3  -82.1    129.6     9.8    ...... ..*    .*..   .......  ....*.
   -31    -38      0      0  -49.6    -58.2   141.7    ...... ..*    .*..   .......  ....*.

   -13    -13      0      0   82.0   -129.6    -9.5    ...... ..*    .*..   .......  ....*.
    35     35      0      0   49.8     57.8  -141.7    ...... ..*    .*..   .......  ....*.
     9     13      0      0  -82.0   -129.7     9.2    ...... ..*    .*..   .......  ....*.
   -35    -31      3      0  -49.9    -57.5   141.6    ...... ..*    .*..   .......  ....*.

    -9    -13      0      0   81.9   -129.8     8.8    ...... ..*    .*..   .......  ....*.
    35     31     -3      0   50.0     57.3  -141.7    ...... ..*    .*..   .......  ....*.
     9     13      0      0  -81.8    129.8     8.4    ...... ..*    .*..   .......  ....*.
   -35    -31      3      3  -46.0    -52.6   142.1    ...... ..*    .*..   .......  ....*.

    13     13      0      0   83.2   -128.4    -8.0    ...... ..*    .*..   .......  ....*.
   252    252      0      0   40.2     45.8  -142.4    ...... *.*    **..   .......  ....*.
   111    113      0      0  -83.4    128.2     7.5    ...... *.*    **..   .......  ....*.
  -823   -827      0      0  -43.9    -48.9   142.3    2..... *.*    **.*   .......  ....*.

  -358   -371      0      0   81.8   -129.8    -7.2    1..... *.*    **.*   *.**...  ....*.
  1217   1224      0      0   50.0     54.9  -142.1    1..... *.*    **.*   *.**...  ....*.
   469    491      3      0  -81.2    130.5     7.0    1..... *.*    **.*   *.**...  ....*.
 -1265  -1268      0      0  -51.0    -55.6   142.0    1..... *.*    **.*   *.**...  ....*.

  -491   -516     -3      0   81.0   -130.7    -6.6    1..... *.*    **.*   *.**...  ......
  1274   1277      0      0   51.4     55.4  -142.0    1..... *.*    **.*   *.**...  ......
   500    516      3      0  -81.0    130.8     6.3    1..... *.*    **.*   *.**...  ......
 -1274  -1277      0      0  -51.5    -55.1   142.0    1..... *.*    **.*   *.**...  ......

  -496   -510      0      0   81.0   -130.8    -6.1    1..... *.*    **.*   *.**...  ......
  1279   1280      0      0   52.5     55.7  -141.7    1..... *.*    **.*   *.**...  ......
   487    507      0      0  -81.5    130.2     5.6    1..... *.*    **.*   *.**...  ......
 -1199  -1202      0      0  -53.1    -55.9   141.6    1..... *.*    **.*   *.**...  ......

  -288   -308      3      3   81.3   -130.4    -5.2    1..... *.*    **.*   *.**...  ......
   730    733      0      0   52.4     54.6  -141.8    2..... *.*    **.*   *..*...  ......
    58     69      0     -3  -80.5    131.2     5.1    2..... *.*    **.*   *..*...  ......
  -204   -211      0      0  -52.2    -54.0   142.0    ...... *.*    **..   .......  ......

   -22    -25      0      0   80.4   -131.4    -4.9    ...... *.*    **..   .......  ......
    49     53      0      3   52.4     53.9  -141.7    ...... ..*    .*..   .......  ......
    13     16      0      0  -80.4    131.3     4.5    ...... ..*    .*..   .......  ......
   -31    -35      0      0  -52.5    -53.4   141.7    ...... ..*    .*..   .......  ......

    -9    -16      0      0   80.3   -131.5    -4.2    ...... ..*    .*..   .......  ......
    27     35      0      0   52.5     53.0  -142.0    ...... ..*    .*..   .......  ......
     9     16      0      0  -80.0    131.7     4.0    ...... ..*    .*..   .......  ......
   -27    -35      0      0  -52.7    -52.8   142.1    ...... ..*    .*..   .......  ......

    -9    -13      0      0   79.8   -131.7    -3.7    ...... ..*    .*..   .......  ......
    27     31      0      0   53.0     52.6  -142.1    ...... ..*    .*..   .......  ......
     9     13      0      0  -79.8    131.8     3.4    ...... ..*    .*..   .......  ......
   -27    -31      3      0  -53.2    -52.4   142.0    ...... ..*    .*..   .......  ......

Event   : 1AG     Location   : 50.28  mi   4.08    ohms sec
Duration: 4.00    Flt Current: 1378

R1  = 13.90     X1   = 79.96     R0   = 41.50    X0   = 248.57    LL    = 100.00
CTR = 200       PTR  = 2000      MTA  = 80.80    79OI= 30.00      79RS  = 60.00
Z1% = 80.00     Z2%  = 120.00    Z2DG= 60.00     Z2DL= 30.00
Z3% = 150.00    Z3DG= 90.00      Z3DL= 60.00     50FD= 100        46PH  = 6000      TTI = 1
Z1E = Y         Z2E  = Y         Z3E  = Y        32QE= Y          GSE   = Y         BPFE= Y

=>
```

## EXPLANATION OF SEL-121 EVENT REPORT

```
Example 230 KV Line                          Date: 1/1/86     Time: 01:26:31.426

               Currents                   Voltages          MHO
+Seq -Seq Outs    Ins                       (amps)                       (kV)
                                                          ABCABC  iIv  ivV3 TCTTTTA DTBD5E
K*RES      A        B       C       A        B        C   GGGBCA          2 PLTABCL TTTC2T

 -823     -827      0       0     -48.9    -48.9   142.3  2.....  *.* **.* ........ ....*.
 -358     -371      0       0      81.8   -129.8    -7.2  1.....  *.* **.* *.**...  ....*.
 1217     1224      0       0      50.0     54.9  -142.1  1.....  *.* **.* *.**...  ....*.
  469      491      3       0     -81.2    130.5     7.0  1.....  *.* **.* *.**...  ....*.
-1265    -1268      0       0     -51.0    -55.6   142.0  1.....  *.* **.* *.**...  ....*.

Event   :1AG      Location   : 50.28  mi   4.08   ohms sec
Duration: 4.00    Flt Current: 1378

R1  = 13.90       X1  = 79.96     R0  = 41.50     X0   = 248.57    LL   = 100.00
CTR = 200         PTR = 2000      MTA = 80.80     79OI = 80.0      79RS = 60.00
Z1% = 80.00       Z2% = 120.00    Z2DG= 60.00     Z2DL = 30.00
Z3% = 150.00      Z3DG= 90.00     Z3DL= 60.00     50FD = 100       46PH = 6000      TTI = 1
Z1E = Y           Z2E = Y         Z3E = Y         32QE = Y         GSE  = Y         BPFE= Y
```

Currents and voltages are in primary amps and kV. Lines are 1/4 cycle apart. Time runs down page. Obtain RMS value and angle using one value as Y component, and the entry immediately underneath as X component. For example, from bottom rows,

IAY = 491 IAX = -1268 Therefore, IA = 1360 amperes RMS primary,

at an angle of ATAN(491/-1268) = -21 degrees, with respect to sampling clock.

Notation /K*RES indicates residual current, shifted by angle of residual current compensation factor (Z0-Z1)/Z1.

MHO columns show states of mho elements for AG, BG, CG, AB, BC, CA faults. Number indicates zone: 1 - zone 1; 2 - zone 2; 3 - zone 3.

+Seq columns show states of positive-sequence elements: i - sensitive overcurrent; I - high-set instantaneous; v - sensitive overvoltage.

-Seq columns show states of negative-sequence elements: i - sensitive overcurrent; v - sensitive overvoltage; V - overvoltage for open-phase detection; 32 - negative-sequence directional element.

Outs columns indicate states of output relays: TP - trip; CL - close; TT - transfer trip initiate; TA-trip A; TB-trip B; TC-trip C; AL - alarm.

Ins columns indicate states of contact inputs: 52 - 52A; DT - direct trip; TT - transfer trip; BT - block trip; DC - direct close; ET - external trigger.

| | |
|---|---|
| Duration: | Fault duration (cycles) is determined from mho elements. |
| Flt current: | Fault current (primary amperes) is taken near middle of fault. |
| R1,X1,R0,X0: | Primary series impedance settings for transmission line. |
| LL: | Line length corresponding to specified line impedances. |
| CTR, PTR: | Current and potential transformer ratios. |
| MTA: | Maximum torgue angle (degrees) for MHO circles. |
| 79OI,79RS: | Reclose open and reset intervals. |
| Z1%,Z2%,Z3%: | Reaches of MHO circles, as percent of line length (LL). |
| Z2DG,Z3DG: | Zone timers for ground faults. |
| Z3DL,Z3DL: | Zone timers for phase-to-phase faults. |
| 50FD: | Fault detector pickup. |
| 46PH: | High-set positive sequence overcurrent primary current setting. |
| TTI: | Transfer trip initiate output closes for zone 1, 2, or 3 faults. |
| Z1E,Z2E,Z3E: | Zones 1, 2, and 3 may be enabled or disabled. |
| 32QE: | Enable or disable negative-sequence directional supervision of MHOs. |
| GSE: | Block when closing in on ground switches is detected. |
| BPFE: | Block if a blown potential fuse is detected. |

=>

# INSTALLATION

## MOUNTING

The SEL-121 is intended for mounting by its front vertical flanges, in a 19-inch vertical relay rack. Four #10 screws should be used for this purpose. Front and rear panel drawings are included at the rear of this manual.

## FRAME GROUND CONNECTION

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

## POWER CONNECTIONS

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

## SECONDARY CIRCUITS

The SEL-121 presents a very low burden to the secondary current and potential circuits. Each current circuit is independent of the other two circuits. That is, there is no interconnection of current circuits inside the instrument.

The SEL-121 requires four-wire wye potentials, as it includes ground relaying functions. It is not possible to directly apply the SEL-121 to circuits where line-to-line potential transformers are used. Please consider the SEL-121D for such applications.

## CONTROL CIRCUITS

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

Control outputs are dry relay contacts rated for tripping duty. Each contact is protected by a metal-oxide varistor (GE V150LA20A or equal). These devices have an energy rating of 80 joules, a maximum clamping voltage of 395 volts, and a minimum varistor voltage (for 1 mA DC current) of 212 volts.

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

## COMMUNICATIONS CIRCUITS

Connections to the two RS-232-C serial communications ports are made via the two nine-pin connectors, labeled Port 1 and Port 2 on the rear panel. Pins 1, and 9 connect directly to frame (chassis) ground. THESE CONNECTIONS SHOULD NOT BE RELIED UPON FOR SAFETY GROUNDING, SINCE THEIR CURRENT-CARRYING CAPACITY IS LESS THAN CONTROL-POWER SHORT CIRCUIT CURRENT AND PROTECTION LEVELS.

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

Route the communications cables well away from the secondary and control circuits. In no case should the communications cables be bundled with secondary or control-circuit wiring. Coupling invites the induction of noise from the control or secondary wiring into the communications wiring. This noise could exceed the communications logic thresholds and introduce communications errors.

The IRIG-B clock cable should also be routed away from the control wiring and secondary circuits.

## JUMPER SELECTION

All jumpers are on the front edge of the main board. They are easily accessed by removing the top cover.

### RS-232 Jumpers

Jumper 6 provides for RS-232 baud rate selection. Baud rates available are 300, 600, 1200, 2400, 4800 and 9600. To select a baud rate for a particular port, place the jumper so it connects a pin labeled with the desired port to a pin labeled with the desired baud rate.

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

## Password Protection Jumpers

When Jumper 1 is in place the password protection is disabled. This feature is useful if passwords are not required, or if they are forgotten.

## Remote Trip/Close Enable Jumper

When Jumper 2 is in place remote trip/close commands may be executed. If Jumper 2 is removed attempts to use the OPEN or CLOSE commands result in an "Aborted" message.

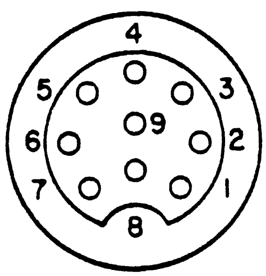
## RS-232 AND IRIG-B INSTALLATION

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

The current drive for a IRIG-B "one" is 10 to 20 mA.

What follows is a pin definition of the nine-pin port connectors and cabling information for the RS-232 ports. Several types of RS-232 cables are given. These and other cable configurations are available from SEL.

## Nine pin connector pin number convention




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

## RS-232 cables

| SEL-121 | | CRT | |
|---|---|---|---|
| GND | 1 | 7 | GND |
| TXD | 2 | 3 | RXD |
| RTS | 3 | 5 | CTS |
| RXD | 4 | 2 | TXD |
| CTS | 5 | 4 | RTS |
| GND | 9 | 1 | GND |
| | | 6 | DSR |
| | | 8 | DCD |
| | | 20 | DTR |

(SEL CABLE 123)

| SEL-121 | | | MODEM | |
|---|---|---|---|---|
| GND | 1 | —— | 7 | GND |
| TXD | 2 | —— | 2 | RXD |
| RTS | 3 | —— | 20 | DTR |
| RXD | 4 | —— | 3 | TXD |
| CTS | 5 | —— | 8 | CD |
| GND | 9 | —— | 1 | GND |

(SEL CABLE 422)

| SEL 121 | | | PRTU | |
|---|---|---|---|---|
| GND | 1 | —— | 1 | GND |
| TXD | 2 | —— | 4 | RXD |
| +12V | 5 | —— | 5 | CTS |
| RXD | 4 | —— | 2 | TXD |
| GND | 9 | —— | 9 | GND |
| CTS | 5 | —— | 7 | +12V |

(SEL CABLE 331A-338A)

## INITIAL CHECKOUT

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

A portable terminal or computer is a convenient tool for providing local communications with the SEL-121 during checkout in the field. Such a device should be connected to Port 2 for checkout, and Port 2 should be designated as the automatic port, using the AUTO 2 command, during checkout.

1. Apply control power, and verify that the startup message is received on the terminal. If it is not then set INTERVAL = 0, using the INTERVAL command, from Access Level 2. Using the ACCESS command and the SHOWSET command, check the settings. Set the clock.

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

3. Using the TRIGGER command, save an event record. Type the EVENT 1 L command, and examine the triggered event record. Referring to the top row of data as the "Y" components, and the next row as the "X" components, plot the three voltage phasors, and insure that they are 120 degrees a part, of reason-

able magnitudes, and rotating in the positive-sequence direction. The zero-sequence voltage Y and X components (times a factor of three) are obtained by adding the three Y components of voltage together and adding the three X components of voltage together. These sums should be near zero if balanced three-phase potentials are present.

4. Using the TARGETS command, check the state of all contact inputs and outputs. For example, if the connections to the circuit breaker 52A contact are made, and if the circuit breaker is closed, the TARGETS command should show an asterisk (*) under the 52A heading. (Type TARGET 6 <CR>).

5. Gain access to Access Level 2 using the 2ACCESS command and the appropriate password. Be sure that the ALARM relay contacts close and open when the 2ACCESS command is executed.

6. The tripping function should be tested three ways. First, be sure the circuit breaker can be tripped by the SEL-121 by executing the OPEN command. Second, the circuit breaker may be tripped by asserting the DIRECT TRIP input. The TRIP output relay opens in both of these cases after the 52A input is unasserted, indicating that the circuit breaker has indeed opened. This function of testing the 52A contact ensures that the output relay does not inadvertently open while trip coil current is flowing in response to a control operation. Third, the circuit breaker may be tripped by applying voltages and currents representing a fault condition. Here, the TRIP relay closes, regardless of the state of the 52A contact, and opens when the 52A input is unasserted AND fault conditions no longer exist. The single-pole trip outputs all follow the TRIP output for control actions.

7. The circuit breaker may be closed two ways, by executing the CLOSE command, or by assertion of the DIRECT CLOSE input. The CLOSE output relay closes for either of these conditions, as long as the 52A input is unasserted (indicating that the circuit breaker is indeed open). The CLOSE relay opens when the 52A input is asserted.

8. If the TRANSFER TRIP and BLOCK TRIP inputs are used, these should also be checked for proper operation.

9. Asserting the EXTERNAL TRIGGER input should trigger the recording of an event record.

10. Use the STATUS command to inspect the self-test status. You may wish to save the reading as part of an "as-left" record. When local checkout is complete, communications with the instrument via a remote interface (if used) should be tested. Be sure, in particular, that the automatic port is properly assigned, and that the desired timeout intervals are selected for each port. Also, be sure to record password settings.

# SERVICE AND CALIBRATION

## REMOVAL OF FRONT PANEL AND DRAWOUT ASSEMBLY

TO PREVENT SHOCK HAZARD, POWER TO THE RELAY MUST BE INTERRUPTED BEFORE REMOVING THE FRONT PANEL ASSEMBLY.

1. Disconnect external power source.

2. Remove the four outermost front panel screws.

3. Front panel may be hinged forward and left alone, or removed by disconnecting the display board ribbon cable and the power switch/fuse connector if installed.

4. Disconnect the analog input connector from the main board (P 104). It is the right-most connector.

5. Remove the two hex head screws from under the forward outside edges of the drawout assembly.

6. Remove drawout assembly by pulling on spacers located on bottom of tray with index fingers.

## CALIBRATION

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

1. Replacement of any analog components in the system, such as op amps, the A/D converter or the sample/hold amplifiers.

2. Replacement of the input transformers or their secondary burden resistors.

3. Out-of-tolerance analog indication of voltages or currents.

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

## EQUIPMENT REQUIRED

1. AC digital voltmeter.
2. Precision three-phase voltage and current source (Doble F3 or similar.)
3. Computer terminal.

## PROCEDURE

### Offset Adjustments

1. Be sure zero voltage and current inputs are present at the relay rear panel, and remove the top cover of the instrument.

2. Turn the system power on.

3. Execute the STATUS command to observe the offsets, as required, while adjusting potentiometers R135, 137-142 for indications of 5 mV or less. (Clockwise rotation results in positive offset). Potentiometers correspond to voltage and current channels as follows:

| | | |
|---|---|---|
| R135 | - | IR |
| R137 | - | IA |
| R138 | - | IB |
| R139 | - | IC |
| R140 | - | VA |
| R141 | - | VB |
| R142 | - | VC |

### Gain Adjustments

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

1. Connect a 50-volt 60 Hz source to the three voltage inputs, and a 10-ampere source to the phase current inputs. Turn on the system power.

2. Type METER 222 to cause the meter command and display to repeat 222 times. (You may jump out of any command by pressing the Control-X key sequence.)

3. Adjust R117-R122 for correct indication, taking into account your settings for the CT and PT ratios. Potentiometers correspond to voltage and current channels as follows:

R117 - IA
R118 - IB
R119 - IC
R120 - VA
R121 - VB
R122 - VC

4. Turn off the ac test source.

5. Replace the instrument cover.

# TROUBLESHOOTING GUIDE

## INSPECTION PROCEDURE

The inspection procedure given below should be followed before the system is disturbed in any way. After completing the inspection procedure, proceed to the troubleshooting table.

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

2. Check to see that the ON/OFF switch is on, but do NOT turn system off if it is on.

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

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

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

## TROUBLESHOOTING TABLE

### All Front Panel LED'S Dark

1. Power is off

2. Blown fuse

3. Input power not present

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

### System Does Not Respond to Commands

1. Communications device not connected to system.

2. SEL-121 or communications device at incorrect baud rate or other communication parameter incompatibility, including cabling error.

3. Internal ribbon cable connector loose or disconnected.

4. System is processing event record. (Wait several seconds.)

5. System is attempting to transmit information, but cannot due to handshake line conflict. (Check communications cabling.)

## Tripping Output Relay Remains Closed Following Fault

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

## No Prompting Message Issued to Terminal upon Power-Up

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

## System Does Not Respond to Faults

1. Relay improperly set.
2. Test set improperly set.
3. CT or PT input cable wiring error.
4. Analog input cable between transformer-termination and main board loose or defective.
5. Check built-in-test status with STATUS command.
6. Check input voltages and currents with METER command; and with TRIGGER and EVENT sequence.

Terminal Displays Meaningless Characters

1. Baud rate incorrectly set.

2. Check terminal configuration: see Commands and Serial Communications section of manual.

Self-Test Failure: +5 Volts

1. Power supply +5 volt output out of tolerance: see STATUS command.
2. A/D converter failure.

Self-Test Failure: +15 Volts

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

2. A/D converter failure.

Self-Test Failure: -15 Volts

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

2. A/D converter failure.

Self-Test Failure: Offset

1. Offset drift. (Adjust offsets)

2. A/D converter drift. (Calibrate A/D converter.)

3. Loose ribbon cable from transformers to main board.

Self-Test Failure: ROM Checksum

1. EPROM failure. (Replace EPROMS)

Self-Test Failure: RAM

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

Self-Test Failure: A/D Converter

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

Stall Relay Closed (Alarm)

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

## MODEM COMMUNICATIONS

The SEL-121 interfaces directly to a commercial-grade Hayes Compatible telephone modem for automatic-answer dial-up communications applications. A field installation consisting of a SEL-121 and a modem can be accessed by telephone, with another modem and a computer or terminal.

The modem connects to port 1 of the SEL-121 with a cable available from SEL. The modem normally is powered from 120 VAC; however, a DC powered modem is available which can be powered from the SEL-121. Please contact SEL for further details.

The SEL-121 responds to the control messages sent by the modem to the SEL-121. These are RING, CONNECT, NO CARRIER, ERROR and OK. The responses ensure that the modem is programmed to answer after the number of rings specified using the MODEM command.

In applying and using the SEL-121 and a modem in an automatic-answer scheme, keep the following points in mind:

1. Modem setting considerations:

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

    b. Modem must be set to auto answer.

    c. Modem must not echo commands sent to it.

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

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

2. Always use a finite timeout interval, so that if communications are disturbed, the SEL-121 has a chance to reconfigure the modem and to clear its communications buffers of data and control characters. An interval of five minutes is recommended. (See the INTERVAL setting.) When the port 1 timeout occurs the SEL-121 sends a command to the modem to hang up. This feature helps prevent accumulation of a large telephone toll when no activity is sensed by the SEL-121 for the timeout interval.

3. Be careful about the number of rings which is programmed as the MODEM setting. It can be set up to 30, but large numbers correspond to very long waits.

4. Some communications devices, such as the Radio Shack Model 100 briefcase computer, allow the use of an XON/XOFF communications protocol. We have found that, in general, the SEL-121 functions quite well with these. However, at times, the Model 100 and other devices leave the SEL-121 in the XOFF state upon hanging up. The problem here is that you must wait your timeout interval before the XOFF state is cancelled automatically by the SEL-121 since

in that state, the SEL-121 cannot respond to the modem as it has been told to be silent. If you call the SEL-121 and do not get a prompt, send an XON (control-Q).

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

6. When the modem answers the telephone, the SEL-121 forces it into its control state to ensure it is properly initialized. To do that, the SEL-121 sends the following string immediately after the connection is established:

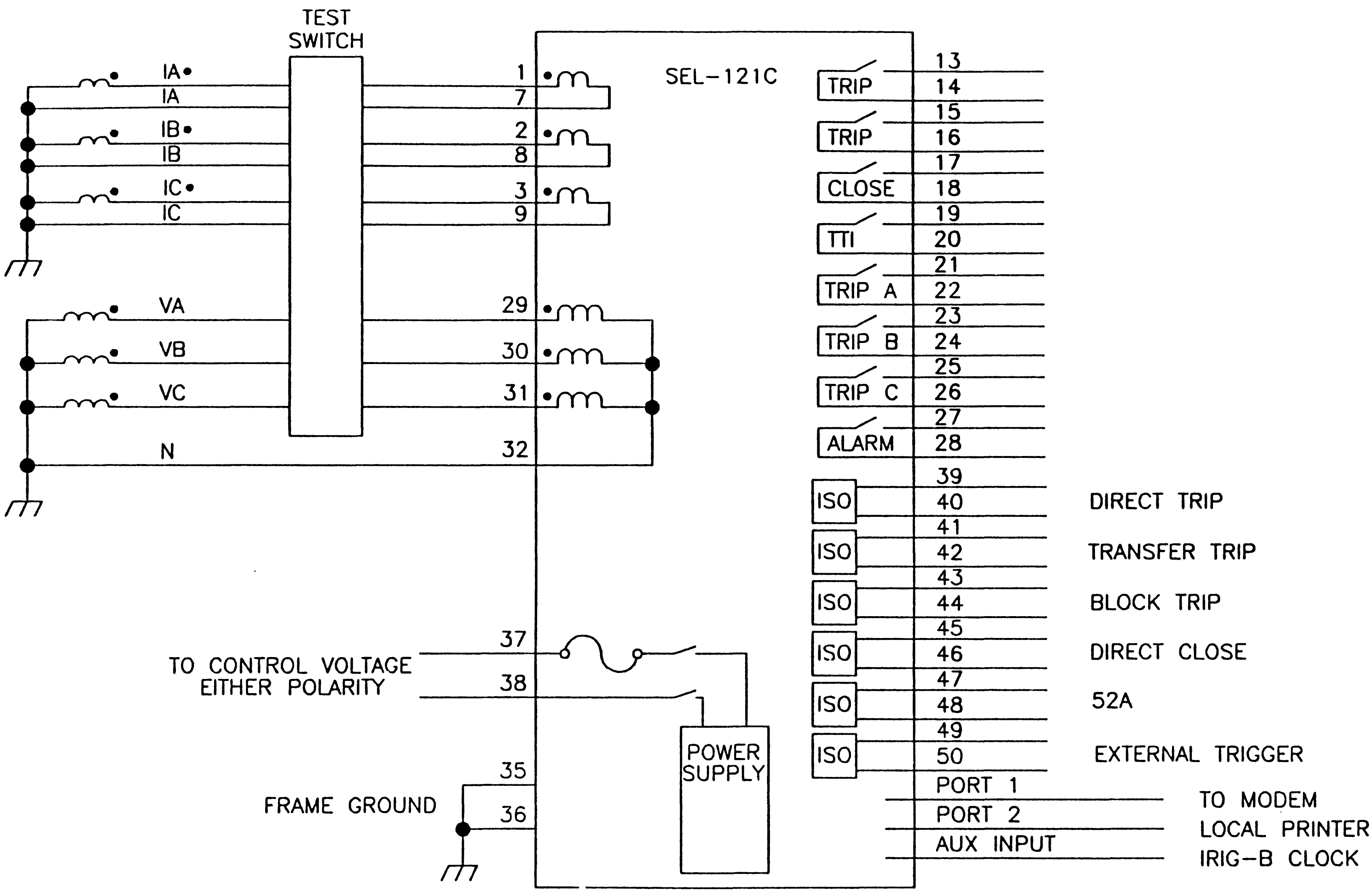
AT+++

Wait for the SEL-121 prompt before typing commands. If no prompt appears, send an XON or a RETURN.

7. If modem power is turned off and back on, many modems "forget" the number of rings to wait before answering. The SEL-121 programs the modem with the number of rings to wait before the modem should answer. Thus, the modem will answer the first call after its power is restored on the first ring. After that, it will answer on the number of rings you programmed with the MODEM command until the power to the modem is interrupted again. The SEL-121 retains the number of rings in its nonvolatile memory, so control power interruptions do not disturb that setting.

# APPENDIX A

# EXTERNAL CONNECTION DIAGRAM



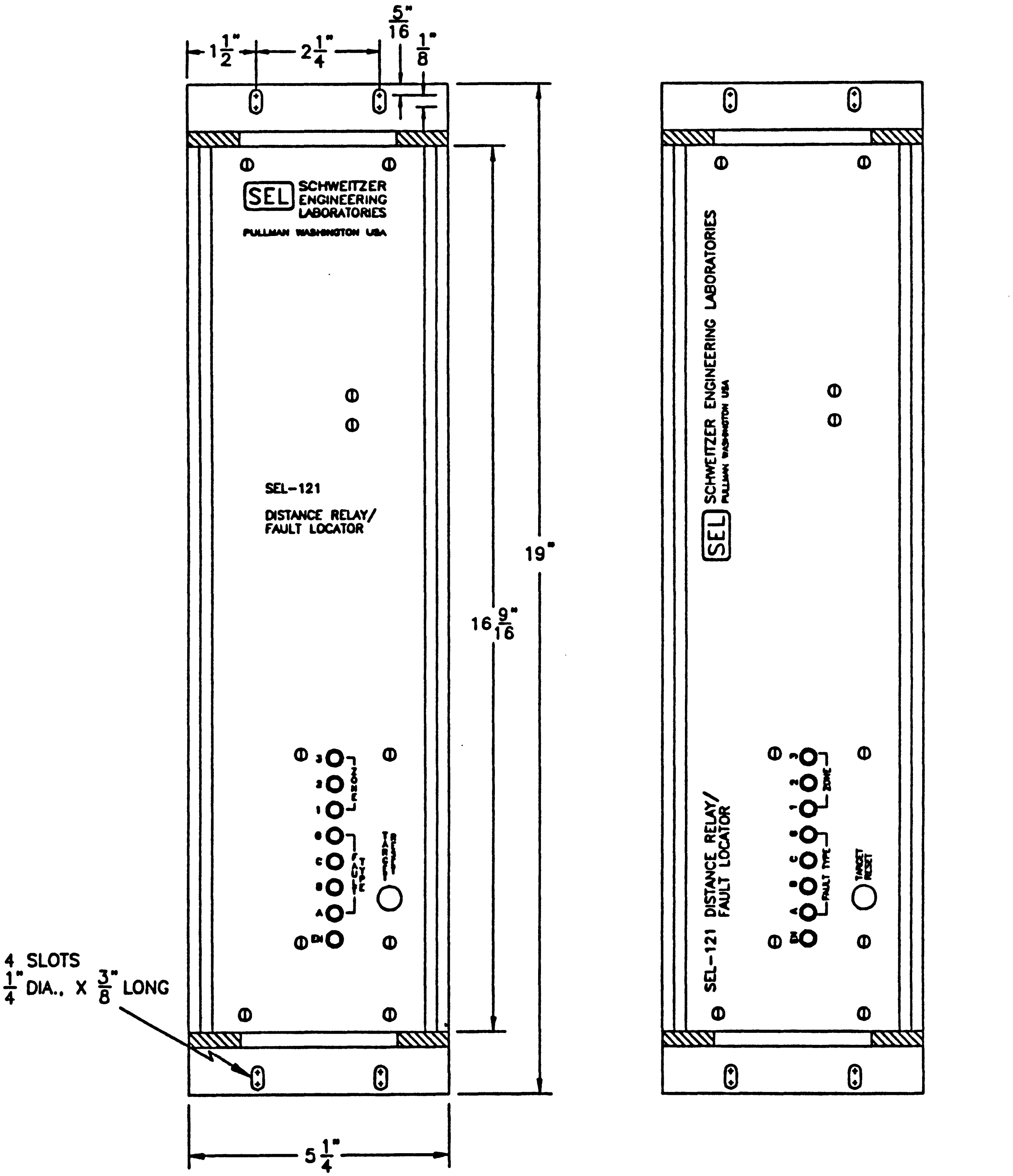

# SEL-121 EXTERNAL CONNECTION DIAGRAM



DWG. NO. A7-0260
DATE: 3-28-88
REV. 12-20-88

# APPENDIX B

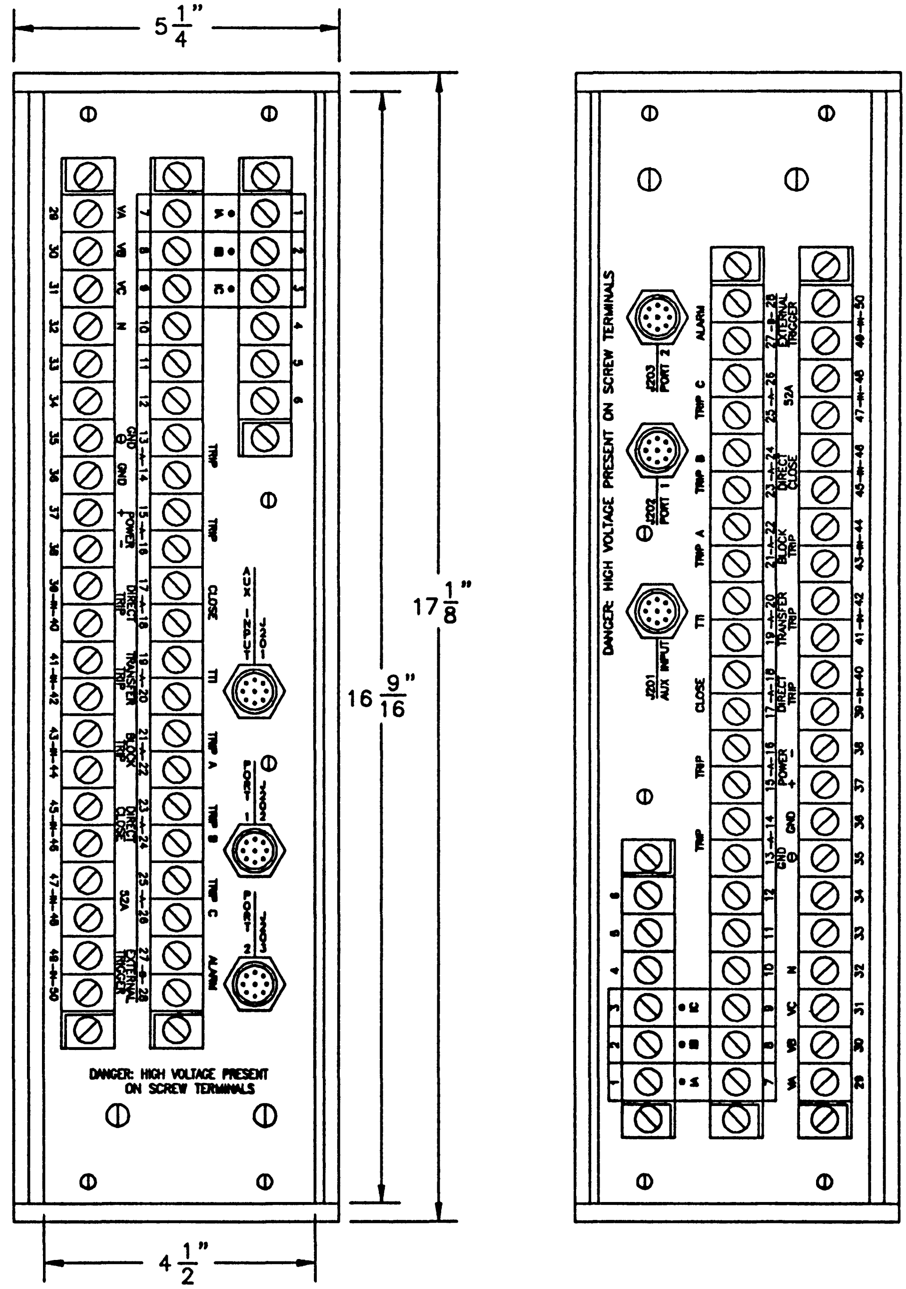
MECHANICAL DIMENSIONS
PANEL CUT OUT AND DRILL PLAN
PARTS LIST
COMMUNICATIONS AND CLOCK CONNECTIONS
MODULE INTERCONNECTION
PLACEMENT DIAGRAMS




# SEL-121 VERTICAL AND HORIZONTAL FRONT PANEL DRAWING



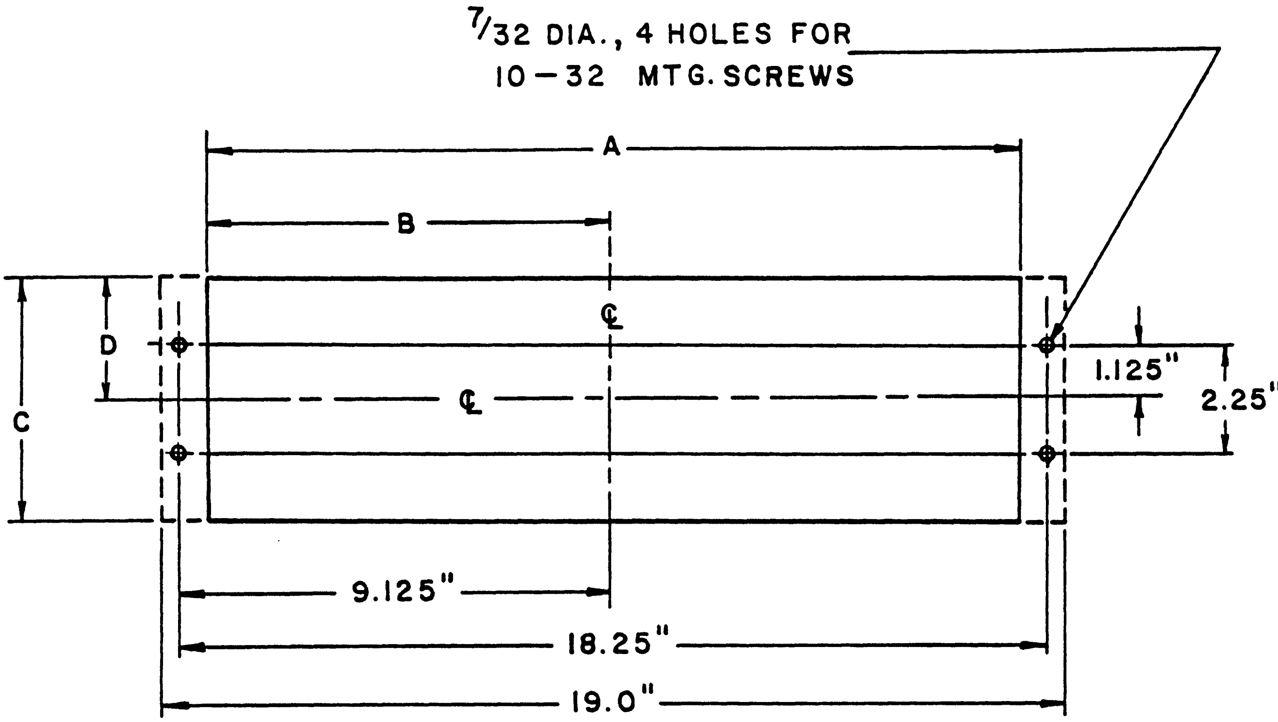
DWG. NO. A7-0443
DATE: 11-15-88
REV. 12-29-88




# SEL–121 VERTICAL AND HORIZONTAL REAR PANEL DRAWING



DWG. NO. A7–0477
DATE: 12–29–88




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

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

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

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

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

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

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

## SEL-121 BACKPLANE COMPONENT LIST DWG NO. C1-0101

| IDENTIFIER | DESCRIPTION | MFR | PART |
|---|---|---|---|
| ------- | CIRCUIT BOARD | SEL | X4-0101 |
| U201 | OPTO COUPLER | MOT | 4N35 |
| C202,204,206, 209,211, 214,216 | .1 UF MONOGLASS | CENTRALAB | C43C104ZNP |
| C207 | .01 UF/50V | | SR155E1032AA or C320C103K1R5CA |
| C210,212,213, 217 | .022 UF 50V | CENTRALAB | C43C223MNP |
| C218-247 | .0047 UF 3000 WVDC CERAMIC | SPRAGUE | 564CZ5UAA30ZEJ472M |
| D201 | 1 amp 1000 PRV | MOTOROLA | 1N4007 |
| R201 | 6.8K OHM 1/4W C.F. | | |
| R202 | 2.7M OHM 1/4W C.F. | | |
| R203 205-208, 210-213 | 56 OHM 1/4W C.F. | | |
| MOV201-203, 205-208, 210-213,222,223 | 18V VARISTOR | GE | V18ZA1 |
| MOV214-221, 224 | 150V VARISTOR (B240: 48/125V RELAYS) | GE<br>MAIDA | U150LA20<br>D65Z0V151RA20 |
| | 250V VARISTOR (B242: 220/250V RELAYS) | GE | V250LA40 |
| J201,202, 203 | CONNECTORS, 9-PIN FEMALE | CON-X-ALL | 4282-956 |
| P201 | 0.1" 17-PIN HEADER | MOLEX | 22-10-2171 |
| P202,203,204 | 0.2" 11-PIN HEADER | MOLEX | 10-16-1111 |
| P205 | 0.2" 8-PIN HEADER | MOLEX | 10-16-1081 |
| P206 | 0.2" 6-PIN HEADER | MOLEX | 10-16-1061 |

881219
B235- 48V
B230-125V
B231-220V
B232-250V

## SEL-121 INTERFACE BOARD COMPONENT LIST DWG NO: C1-0105

| IDENTIFIER | DESCRIPTION | MFR | PART |
|---|---|---|---|
| ------- | CIRCUIT BOARD | SEL | X4-0105 |
| U501,503 | QUAD LINE RECIEVER | | MC1489 |
| U502 | QUAD LINE DRIVER | | MC1488 |
| U504 | QUAD SCHMITT NAND | | 74LS132 |
| U505 | DUAL 4 BIT COUNTER | | 74LS393 |
| U506 | DUAL D F/F | | 74LS74 |
| U507 | TIMER | | 555 |
| U508 | +12 REGULATOR | | 7812 |
| U515 | -12 REGULATOR | | 7912 |
| U509-514 | OPTO COUPLER | HP | HCPL3700 |
| R502-507 | 1K 1/4W 5% RESISTOR | | RCR07G102JS |
| R508 | 100K 1/4W 5% RESISTOR, CARBON | | RC07GF104J |
| R509-520 | 3.6K 1/2W 5% RESISTOR, CARBON (B235: 48V LOGIC INPUT) | | RC20GF362J |
| | 10K 1W 5% RESISTOR, CARBON (B230: 125V LOGIC INPUT) | | RC32GF103J |
| | 27K 1W 5% RESISTOR, CARBON (B231: 220V LOGIC INPUT) | | RC32GF273J |
| | 30K 2.5W 5% RESISTOR, CARBON (B232: 250V LOGIC INPUT) | | RS-2C |
| R527 | 3.3K 1/4W 5% RESISTOR, CARBON | | RC07GF332J |
| C501 | .1 UF 600 VDC POLYESTER | SPRAGUE OR MALLORY | 6PS-P10 PXC-601 |
| C502-505 | .0047 UF 3000 VDC CERAMIC | SPRAGUE | 564CZ5UAA30ZEJ472M |
| C506,507,508 C516-521, 5001-5006 C542-557 | .1 UF 50V MONOGLASS | CENTRALAB | C43C104ZNP |
| C537 | 100 UF 20V | KEMET | T310D107M020AS |
| C522-533 | 500 PF ± 20% 3KV | CENTRALAB | DD30501 |
| C510-515,538, 539 | 47UF35V ± 10% | KEMET | T310D476K035AS |
| C535-536 | 15 UF 20V TANTALUM 10% | MALLORY | CSR13E156KM-2289 |
| Q501 | NPN TRANSISTOR | MOTOROLA | 2N2222A |
| Q502-508 | NPN DARLINGTON TRANS. | MOTOROLA | MM6427 (PLASTIC) |
| | | MOTOROLA | MPSA13 (METAL CAN) |
| D501-D508; 510-515;522 | DIODE | | 1N4007 |

SEL-121 INTERFACE BOARD COMPONENT LIST C1-0105

| | | | |
|---|---|---|---|
| D516-D521 | ZENER DIODE, 2.0V | MOTOROLA | 1N4679 or 1N4615 |
| D509 | JUMPER | | |
| B501 | ONLY USED ON 48V RELAYS | | |
| J501 | .1" RIGHT ANGLE, 17 CKT GOLD, PC BOARD CONNECTOR-FE | MOLEX | 22-16-2171 |
| J502,503,504 | .2" RIGHT ANGLE, 11 CKT TIN, PC BOARD CONNECTOR-FE | MOLEX | 10-10-1111 |
| J505 | .2" RIGHT ANGLE, 8 CKT | MOLEX | 10-16-1081 |
| J506 | .156 CONNECTOR TO POWER SUPPLY | " | 09-50-7181 |
| P501 | LOW PROFILE STRAIGHT, 20 PIN HEADER | ANSLEY | 609-2053 |
| P502 | LOW PROFILE STRAIGHT, 50 PIN HEADER | ANSLEY | 609-5053 |
| J507 | FEMALE SOCKET, 20 PIN W/STRAIN RELIEF | | 609-2001M |
| J508 | FEMALE SOCKET, 50 PIN | | 609-5001M |
| ____ | 20 PIN CABLE | | |
| ____ | 50 PIN CABLE | | |
| K501-507 | RELAY, 5 VOLT COIL | P & B<br>SCHRACK<br>FUJITSU | RK1IZ-4.5W<br>RP820-005<br>FBR621ND005 |

881218
B215-120V
5 AMP

## SEL-121 TRANSFORMER TERMINATION COMPONENT LIST DWG NO. B1-0102

| IDENTIFIER | DESCRIPTION | MFR | PART |
|---|---|---|---|
| | CIRCUIT BOARD | SEL | X4-0102 |
| J301 | 20-POS. 0.1"CONNECTOR | ANSLEY | 609-2001M |
| P301 | 20-POS. 0.1"SLIMLINE PCB HEADER | ANSLEY | 609-2053 |
| MOV305-307 | 18 VOLT MOV | GE | V18ZA1 |
| R305-307 | 10.0K 1/8W METAL FILM 1% | | |
| R313-315 | 2.49K 1/8W METAL FILM 1% | | |
| R317-320 | 1 OHM 2W METAL FILM 1% | DALE | RS-2B |

SEL-121 DISPLAY BOARD COMPONENT LIST DWG NO: C1-0103

| IDENTIFIER | DESCRIPTION | MFR | PART |
|---|---|---|---|
| ------- | CIRCUIT BOARD | SEL | X4-0103 |
| C401 | 0.1 UF 50V CERAMIC CAP | CENTRALAB | C43C104Z |
| D402-408 | RED LED | GI | MV5753 |
| P401 | RIGHT ANGLE PCB HEADER | ANSLEY | 609-2007 |
| Q401-408 | NPN TRANSISTOR | | 2N2222 |
| R401-408 | 330 OHM 1/4W 5% RESISTOR | MEPCO | 5043CX330R0J |
| R409,411-417 | 1K 1/4W 5% RESISTOR | DALE | RCR07G102JS |
| R410 | 3.3K 1/4W 5% RESISTOR | A-B | RC07GF332J |
| PB1 | PUSHBUTTON | ITT | D60201 |

## SEL-121 MAIN BOARD COMPONENT LIST DWG NO. D1-0100

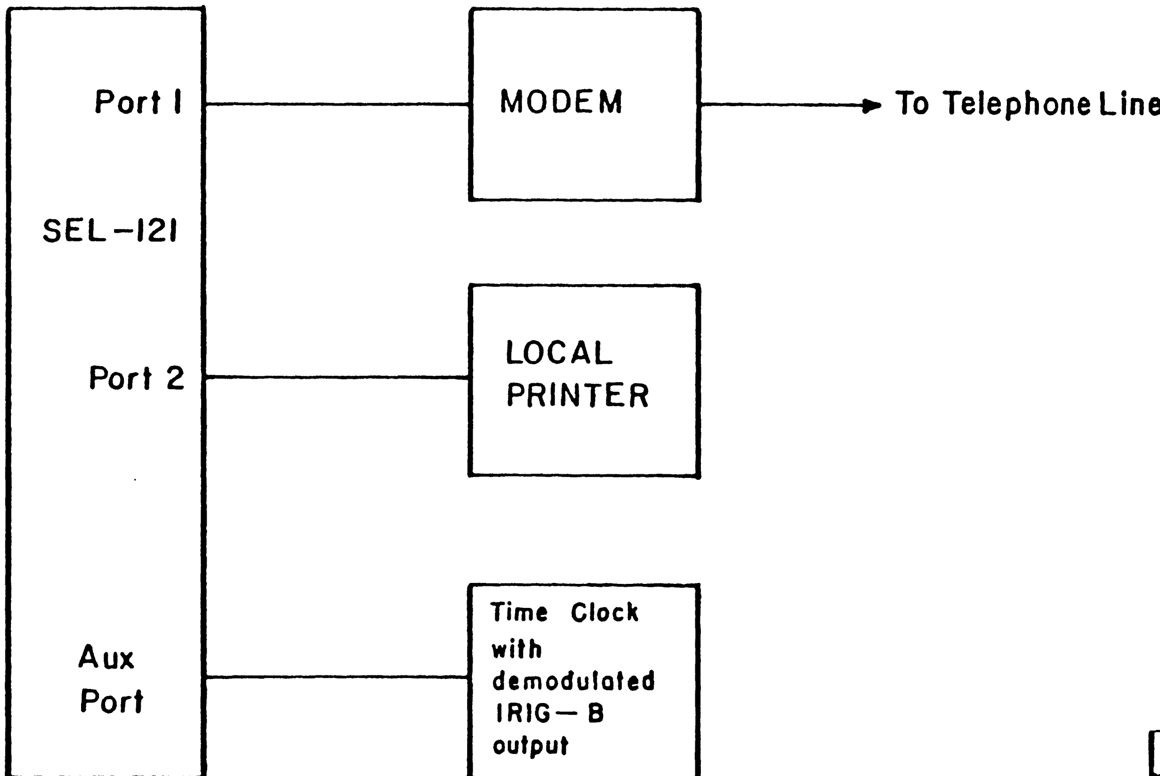
| IDENTIFIER | DESCRIPTION | MFR | PART |
|---|---|---|---|
| ----- | CIRCUIT BOARD | SEL | X4-0100 |
| U109-13 130,132,135 | 28 PIN SOCKETS | | |
| U115,138,139 | 24 PIN SOCKETS | | |
| U101,136,137, 140 | 40 PIN SOCKETS | | |
| U133 | 16 PIN SOCKET | | |
| U101 | 2 MHZ 8-BIT MICROPROCESSOR | MOTOROLA | MC68B09 |
| U136,137,140 | 2 MHZ PIA | " | MC68B21 |
| U130 | 2 MHZ PTM | " | MC68B40 |
| U138,139 | 2 MHZ ACIA | " | MC68B50 |
| U104 | QUAD NAND | MOTOROLA | 74LS00N or HD74S00P |
| U108 | QUAD AND | " | 74LS08 |
| U119 | TRIPLE THREE INPUT NOR | " | 74LS27 |
| U105 | QUAD OR | " | 74LS32 |
| U129 | BUS BUFFER | " | 74LS245 |
| U102,103 | 3 TO 8 DECODE | " | 74LS138 |
| U106 | 4-BIT U/D COUNTER | " | 74LS193 |
| U107 | CMOS 12BIT COUNTER | RCA | CD4040B or MC4040B or 74HC4040 |
| U109,110 | 16K EPROM | | 27128 |
| U111, | 8K EPROM | | 2764 |
| U112,113 | 8K CMOS RAM | | 6264 |
| U114 | NOT USED | | |
| U115 | 2K EEPROM | XICOR | X2816A |
| U117,118 | QUAD BIFET OPAMP | MOTOROLA | MC34004AP |
| U116,134 | DUAL BI-FET OPAMP | " | MC34002AP or LM353 or TL072 |
| U120;U122- U127 | TRACK AND HOLD | NATIONAL | LF398A or LF398N8 |
| U132 | 16 CHANNEL MUX | A. DEVICES | AD7506 |
| U133 | 10-BIT DAC | A. DEVICES | AD7533JN |
| U135 | 12-BIT A/D CONVERTER | A. DEVICES | AD574A |
| C149,151 | 15 UF 20V TANT CAP 10% | MALLORY | CSR13E156KM-2289 |
| C101,155, | 39 UF 10V TANT CAP 10% | MALLORY | CSR13C396KM-2259 |

SEL-121 MAIN BOARD COMPONENT LIST

| | | | |
|---|---|---|---|
| C160-199 | .1 UF MONO-GLASS | CENTRALAB | C43C104ZNP |
| C1000-1013 | | | |
| C142-144,146,148 | | | |
| C150,152,156 | | | |
| C104 | 18 pf | | CN15A180J |
| C106-111 | .01 UF 10% CERAMIC | KEMET | C320C103K1R5CA |
| C102 | 15 pf 10% MONO-KAP 50V | CENTRALAB | SR151A150KAA |
| C157 | 10 pf MONO-KAP | " | CN15A100J |
| C103 | 3.5-20 pf | JOHNSON | 274-0020-005 |
| C1027-1029 | 47 UF 35V 10% | KEMET | T310D476K035A5 or |
| | | | T322F476K035A5 |
| C115-120 | .033 UF 100V 1% | F-DYNE | PPA11-.033-100-3 |
| | | MEPCO | 703E1FJ333PF161AX |
| C124-129 | .01 UF 100V 1% | F-DYNE | PPA11-.01-100-3 |
| 132-134;139 | | MEPCO | 703E1FE103PF161AX |
| R101 | 22K 1/4W 10% RESISTOR | | RC07GF223 |
| R102,104,105, | 4.7K 1/4W 10% RESISTOR | | RC07GF472 |
| R140,141 | 10K 1/8W 1% RESISTOR | | RN55D1002F |
| R103 | 15K 1/4W 10% RESISTOR | | RC07GF153 |
| R111 | 2.43K 1/8W ± 1% RESISTOR | | RN55D2431F |
| R125;127-132 | 24.3K 1/8W ± 1% RESISTOR | | RN55D2432F |
| R112-114 | 10K 1/8W ± 1% RESISTOR | | RN55D1002F |
| 147,148 | | | |
| R115 | 3.32K 1/8W ± 1% RESISTOR | | RN55D3321F |
| R145,146 | 49.9 OHMS 1/8W ± 1% RESISTOR | BOURNS | 49R9FJ |
| R117-122 | 2K 10T POT | BOURNS | 3296Y-1-202 |
| R135;137-142 | 1K 10T POT | " | 3296Y-1-102 |
| RP101,115 | 6.8K 8-PIN CONFORMAL | AB | 708B682 |
| RP108 | 4.7K 8-PIN CONFORMAL | AB | 708B472 |
| RP102,103 | 120K 8-PIN ± 1% | AB | 108B124 |
| RP109,110 | | | |
| RP107,114 | 10K 8-PIN | AB | 708B103 |
| RP116 | 6.8K 8-PIN | AB | 708A682 |
| D101 | DIODE | | 1N4007 |
| Y101 | 8 MHZ CRYSTAL | CRYSTEK | CY-86 - 8.000 |
| J101 | 20-PIN FEMALE CONN. W/ SR | ANSLEY | 609-2001M |
| P101 | 20-PIN SLIMLINE SOLDER TERM. | ANSLEY | 609-2053 |

SEL-121 MAIN BOARD LIST

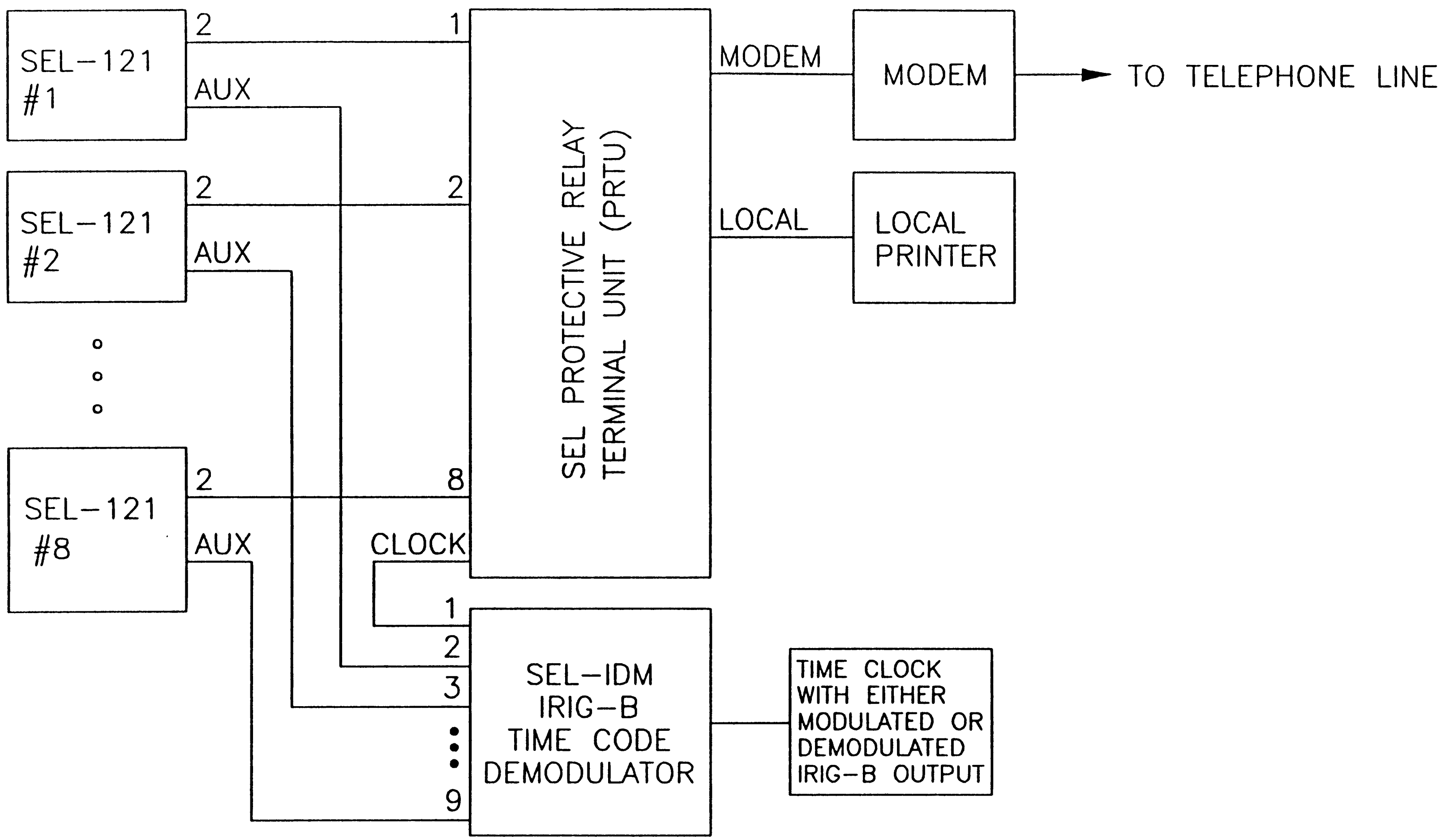
| | | |
|---|---|---|
| P102,104 | 20-PIN RIGHT ANGLE PCB HEADER ANSLEY | 609-2007 |
| P103 | 50-PIN RIGHT ANGLE PCB HEADER | 609-5007 |
| J101-P101 | CABLE, FLAT | |
| | SINGLEROW HEADER | 929647-01-36 |
| | CONNECTOR | 92995506-I |




SEL-121 Communications and Clock Connections
One Unit at One Location



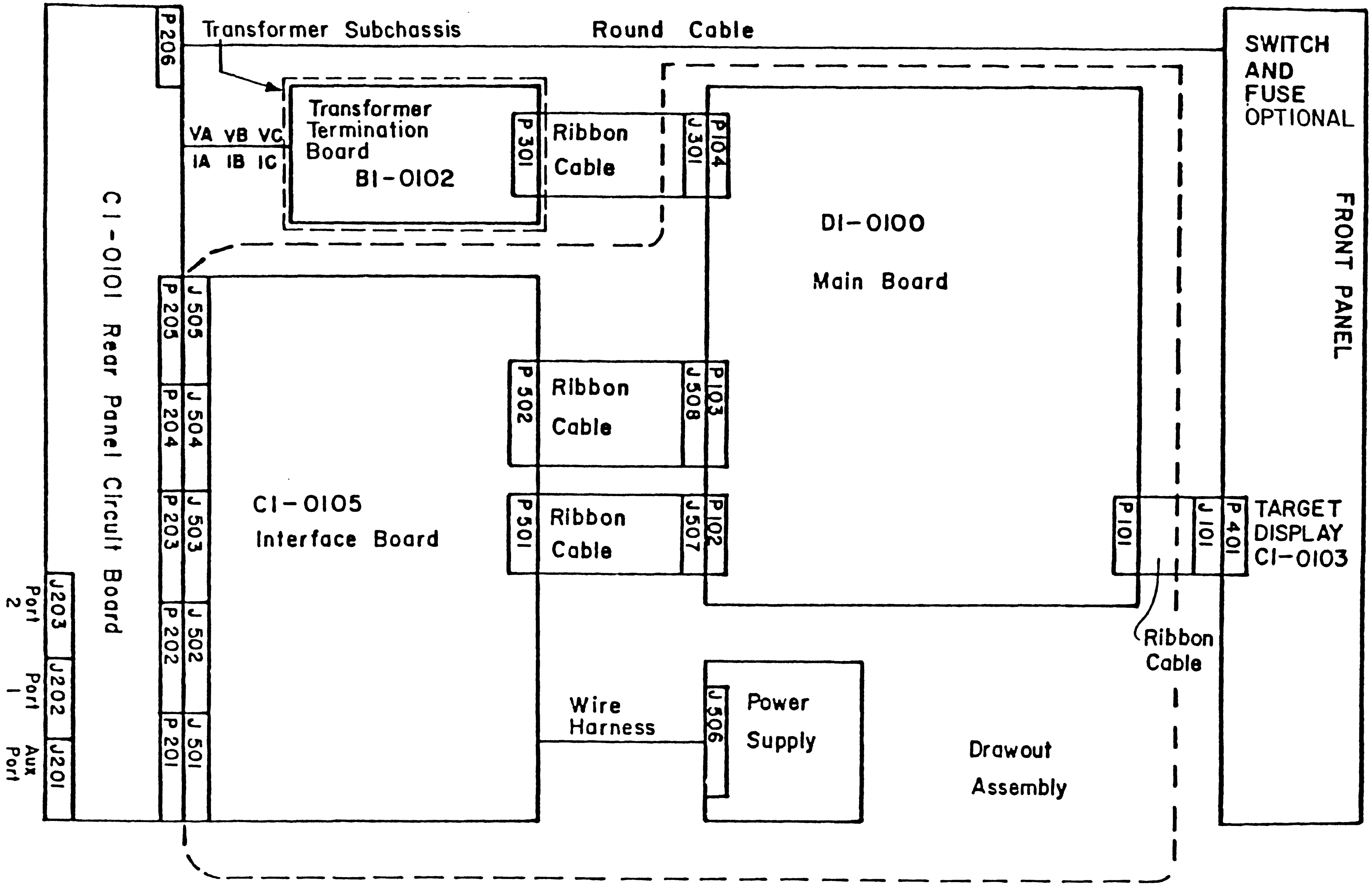
DWG. NO. A7-0258
DATE : 3-28-88




SEL-121 COMMUNICATIONS AND CLOCK CONNECTIONS
MULTIPLE UNITS AT ONE LOCATION



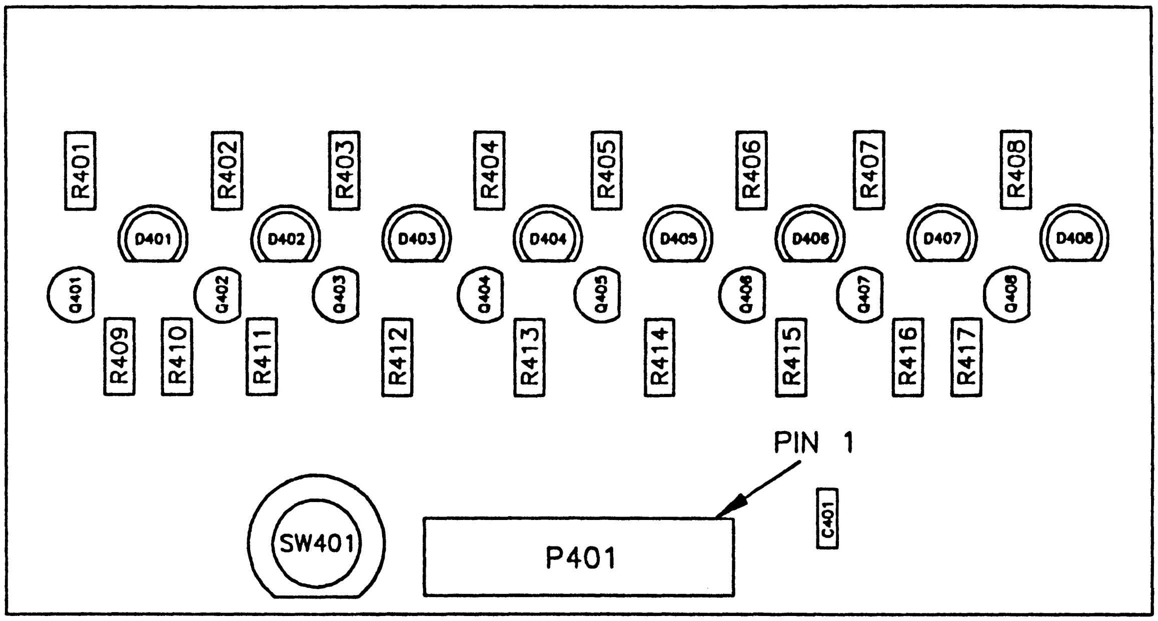
DWG. NO. A7-0261
DATE: 03-28-88
REV. 12-29-88



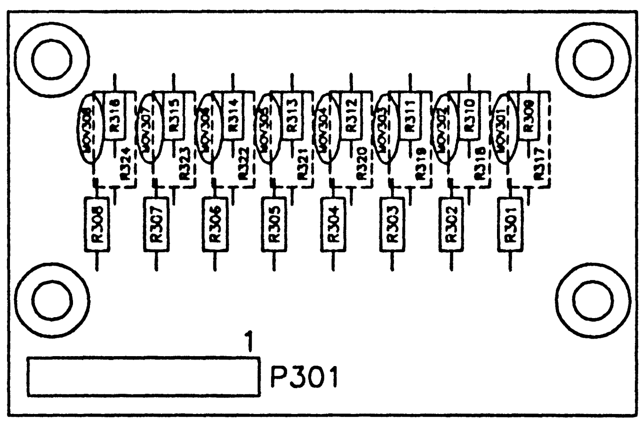

SEL-121 Module Interconnections



DWG. NO. A7-0227
DATE: 12-11-87




DPR-FP1




DPR-TT2

# PARTS PLACEMENT DRAWINGS
# DPR-FP1 FRONT PANEL BOARD
# AND
# DPR-TT2 TRANSFORMER TERMINATION BOARD



DWG. NO. A1-0200
DATE: 01-10-89

# APPENDIX C

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

SEL SCHWEITZER ENGINEERING LABORATORIES, INC.
2350 NE HOPKINS COURT • PULLMAN, WA 99163-5603 • TEL: (509) 332-1890

# PROGRAM TO COMPUTE TEST SET SETTINGS FOR TESTING DISTANCE RELAYS

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

It 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 a new impedance data (I), changing the distance from the source to the bus (B), specifying a new fault location (F), or quitting (Q).

TWX: 5106012265 (SCHWEITZER SEL) FACSIMILE: (509) 332-7990

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

# APPENDIX D

# TEST PROCEDURE

SEL-121 TEST PROCEDURE

Testing of the SEL-121 consists of performing the Initial Checkout, described near the beginning of the Instruction Manual, and following some additional steps described here.

## Initial Checkout

Please follow the steps listed in the Initial Checkout section of the Instruction Manual. The Initial Checkout procedure makes it easy to set up the relay for testing, and to ensure that it is generally functional.

## Setting Test

To ensure the SEL-121 accepts settings, perform the following steps:

1. Gain Level 2 Access. (See Access and 2Access commands.)

2. Type SET.

3. Change one setting. For example change zone 1 reach from 80 to 82 percent.

4. Complete the setting procedure. The ALARM contact should close for several seconds while the relay computes internal settings.

5. Use the SHOWSET command to inspect the settings, and ensure that yourchange was accepted.

6. Use the SET and SHOWSET commands again to restore and check the settings.

## METER test

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

1. Connect the voltage input terminals VA, VB and VC together, and apply about 50 VAC from those terminals to the neutral point.

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

3. Using the METER command, inspect the measured voltages, currents, and power. Voltages VA, VB and VC should equal the applied voltage times the potential transformer ratio setting. With the Example 230 KV Line settings, you should obtain:

VA = VB = VC = 50 * 2000 = 100 KV. (+/- 0.5 %)

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

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

IA = IB = IC = 5 * 200 = 1000 A.    (+/- 1 %)

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

The power reading should be:

VA*IA + VB*IB + VC*IC = 300 MW.

The reactive power reading should be less than 5 MW.

## MHO Relay Testing

The three-phase test described below is recommended. The status of any MHO element may be observed using the TARGETS command. For example, using TARGET 1 causes the target LEDs to follow the six MHO elements for zone 1. The total output of any zone may be observed using the TRANSFER TRIP output relay, and setting the TRANSFER TRIP output to follow the desired zone, via the SET command. A third way to isolate the zones for testing is to use the individual zone enables for zones 1, 2 and 3 near the end of the setting procedure.

The steps below apply to any of the three zones.

1. Connect a relay test set capable of providing four-wire voltages and at least one current to the SEL-121. To connect the set for testing a ground element, connect the current source to the corresponding current input. To connect the set for testing a phase element, connect the current source so that the current enters the dotted end of one phase and exits the dotted end of the other phase. (For example, for a BC test, inject the current into B-dot, connect the undotted B and C current terminals together, and connect C-dot to the current source return terminal.)

2. Determine the voltages and currents required for a fault on the boundary at the maximum-reach point of the relay. The easiest and most convenient way to do this is to use the short BASIC program given in Appendix C. Using zero source impedance further simplifies the test.

For example, using the Example 230 KV Line settings, we see the CT/PT ratio is 0.1, so the secondary-ohm line data to enter into the BASIC program are:

Z1 = 1.39 + j 7.996   ohms

Z0 = 4.15 + j 24.857  ohms

Enter 0 for ground fault resistance.

Enter zero source-to-bus impedance.

To test zone 1, which is set to 80 percent of the line, enter 0.8 for the per-unit distance from the bus to the fault. The program will compute the test set voltages and currents for AG and BC faults 0.8 pu or 80 miles away from the bus. Since the 80.8 degree MTA setting places the MHO circle diameter on the transmission line positive-sequence impedance characteristic, the computed voltages and currents test the MHO characteristic at its point of maximum reach along its maximum torque angle.

For the AG fault, the voltages and currents so obained are given below:

| VA | VB | VC | IA | |
|---|---|---|---|---|
| 67.0 | 67.0 | 67.0 | 6.1 | volts or amperes, secondary |
| 0 | -120 | +120 | -80 | degrees |

3. To obtain two other convenient test points, consider a square inscribed in the MHO circle with one diagonal being the diameter along the MTA. The two corners of that square on the other diagonal are reached by increasing the current by a factor of 1.414, at angles of +/- 45 degrees away from the angle obtained from the BASIC program.

For our example, the required current is 6.1 * 1.414 = 8.63 amperes, at angles of -80 + 45 = -35 degrees and -80 - 45 = -125 degrees.

4. Test the relay at the three current settings.

5. Demonstrate directionality for a zero-voltage fault by setting the faulted-phase voltage to zero, and ensuring the relay operates with the current in the forward direction, and restrains with the current reversed.

6. While testing for AG, BG, and CG faults, ensure the proper single-pole outputs operate.

Testing the Input Circuits

1. Use the TARGETS command to set the LEDs to follow the contact inputs, by typing TAR 6.

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

## Testing the Serial Ports

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

## Testing the IRIG-B Time Code Input

1. Connect a source of demodulated IRIG-B time code to the Auxiliary Port of the SEL-121, with a series resistor to monitor the current. Adjust the source to obtain an "ON" current of about 10 mA.

2. Execute the IRIG command, and ensure that the SEL-121 clock is set to the correct time, and that the indicated date is correct.

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

## Testing the Power Supply Voltages

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

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

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

4. The 15 and 12 volt supplies should be within 0.5 volt of their nominal values.

# SEL-121 DISTANCE RELAY/FAULT LOCATOR COMMAND SUMMARY

**Level 0**

| | |
|---|---|
| ACCESS | Answer password prompt (if password protection enabled) to access Level 1. ALARM relay pulses after three unsuccessful attempts. |

**Level 1**

| | |
|---|---|
| 2ACCESS | Answer password prompt (if password protection enabled) to access Level 2. This command always pulses the ALARM relay. |
| DATE | Show or set date. DAT 2/3/86 sets date to Feb. 3, 1986. The month and date settings are overridden when IRIG-B synchronization occurs. |
| EVENT | Show event record in long or short form. EVE 1 L shows the long form of most recent event. EVE 12 shows the short form of oldest event. |
| HISTORY | Show DATE, TIME, EVENT TYPE, FAULT LOCATION, DURATION, and CURRENT for the 12 most recent faults. |
| IRIG | Force immediate execution of time-code synchronization task. |
| METER | Show primary current, voltage, real, and reactive power. METER runs once. "METER N" runs N times. |
| QUIT | Return to Access Level 0. |
| SHOWSET | Show the relay settings. This command does not affect the settings. |
| STATUS | Show self-test status. |
| TARGETS | Show data and set target lights as follows:<br>TAR 0: Relay Targets TAR 1: Zone 1 MHO elements<br>TAR 2: Zone 2 MHO elements TAR 3: Zone 3 MHO elements<br>TAR 4: Aux elements TAR 5: Contact Outputs<br>TAR 6: Contact Inputs TAR 7: Internal logic 1<br>TAR 8: Internal Logic 2<br>Be sure to return to TAR 0 when done, so LEDs display fault targets. |
| TIME: | Show or set time. TIM 13/32/00 sets clock to 1:32:00 PM. This setting is overridden when IRIG-B synchronization occurs. |
| TRIGGER: | Trigger and save an event record (type of event is EXT). |

**Level 2**

| | |
|---|---|
| AUTO | Show or select port for destination of automatically-generated messages. AUT 1 selects PORT 1. AUT 2 selects PORT 2. AUT 3 selects PORTS 1 and 2. |
| CLOSE | Close circuit breaker, if allowed by jumper setting. |
| INTERVAL | Show or set command timeout interval. A separate timeout value is used for each port. Executing INT 0 from PORT 2 disables timeout of PORT 2. INT 4 from PORT 1 sets a four minute timeout for PORT 1. |
| MODEM | Show or set number of rings before modem at PORT 1 answers. |
| OPEN | Open circuit breaker, if allowed by jumper setting. |
| PASSWORD | Show or set passwords. ALARM relay pulses momentarily when new passwords are set.<br>PAS 1 OTTER sets Level 1 password to OTTER.<br>PAS 2 TAIL sets Level 2 password to TAIL. |
| SET | Initiate setting procedure. ALARM relay closes while new settings are being computed and event data buffers are cleared. |

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

---

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

SEL/7-90

## SAMPLE EVENT REPORT

```
Example 230 KV Line                        Date: 1/1/86      Time: 01:26:31.426

            Currents                 Voltages        MHO  +Seq  -Seq  Outs    Ins
             (amps)                   (kV)
                                                ABCABC iIv  ivV3  TCTTTTA DTBD5E        /K*RES      A
B       C     A      B       C   GGGBCA              2  PLTABCL TTTC2T

   -13    -13     0      0  82.3  -129.4  -10.1  ...... ..*  .*..  ....... ....*.
    31     35     3      0  49.4    58.4 -141.6  ...... ..*  .*..  ....... ....*.
    13     13     0      3 -82.1   129.6    9.8  ...... ..*  .*..  ....... ....*.
   -31    -38     0      0 -49.6   -58.2  141.7  ...... ..*  .*..  ....... ....*.

   -13    -13     0      0  82.0  -129.6   -9.5  ...... ..*  .*..  ....... ....*.
    35     35     0      0  49.8    57.8 -141.7  ...... ..*  .*..  ....... ....*.
     9     13     0      0 -82.0  -129.7    9.2  ...... ..*  .*..  ....... ....*.
   -35    -31     3      0 -49.9   -57.5  141.6  ...... ..*  .*..  ....... ....*.

    -9    -13     0      0  81.9  -129.8    8.8  ...... ..*  .*..  ....... ....*.
    35     31    -3      0  50.0    57.3 -141.7  ...... ..*  .*..  ....... ....*.
     9     13     0      0 -81.8   129.8    8.4  ...... ..*  .*..  ....... ....*.
   -35    -31     3      3 -46.0   -52.6  142.1  ...... ..*  .*..  ....... ....*.

    13     13     0      0  83.2  -128.4   -8.0  ...... ..*  .*..  ....... ....*.
   252    252     0      0  40.2    45.8 -142.4  ...... *.*  **..  ....... ....*.
   111    113     0      0 -83.4   128.2    7.5  ...... *.*  **..  ....... ....*.
  -823   -827     0      0 -43.9   -48.9  142.3  2..... *.*  **.*  ....... ....*.

  -358   -371     0      0  81.8  -129.8   -7.2  1..... *.*  **.*  *.**... ....*.
  1217   1224     0      0  50.0    54.9 -142.1  1..... *.*  **.*  *.**... ....*.
   469    491     3      0 -81.2   130.5    7.0  1..... *.*  **.*  *.**... ....*.
 -1265  -1268     0      0 -51.0   -55.6  142.0  1..... *.*  **.*  *.**... ....*.

  -491   -516    -3      0  81.0  -130.7   -6.6  1..... *.*  **.*  *.**... ......
  1274   1277     0      0  51.4    55.4 -142.0  1..... *.*  **.*  *.**... ......
   500    516     3      0 -81.0   130.8    6.3  1..... *.*  **.*  *.**... ......
 -1274  -1277     0      0 -51.5   -55.1  142.0  1..... *.*  **.*  *.**... ......

  -496   -510     0      0  81.0  -130.8   -6.1  1..... *.*  **.*  *.**... ......
  1279   1280     0      0  52.5    55.7 -141.7  1..... *.*  **.*  *.**... ......
   487    507     0      0 -81.5   130.2    5.6  1..... *.*  **.*  *.**... ......
 -1199  -1202     0      0 -53.1   -55.9  141.6  1..... *.*  **.*  *.**... ......

  -288   -308     3      3  81.3  -130.4   -5.2  1..... *.*  **.*  *.**... ......
   730    733     0      0  52.4    54.6 -141.8  2..... *.*  **.*  *.*.... ......
    58     69     0     -3 -80.5   131.2    5.1  2..... *.*  **.*  *.*.... ......
  -204   -211     0      0 -52.2   -54.0  142.0  ...... *.*  **..  ....... ......

   -22    -25     0      0  80.4  -131.4   -4.9  ...... *.*  **..  ....... ......
    49     53     0      3  52.4    53.9 -141.7  ...... ..*  .*..  ....... ......
    13     16     0      0 -80.4   131.3    4.5  ...... ..*  .*..  ....... ......
   -31    -35     0      0 -52.5   -53.4  141.7  ...... ..*  .*..  ....... ......

    -9    -16     0      0  80.3  -131.5   -4.2  ...... ..*  .*..  ....... ......
    27     35     0      0  52.5    53.0 -142.0  ...... ..*  .*..  ....... ......
     9     16     0      0 -80.0   131.7    4.0  ...... ..*  .*..  ....... ......
   -27    -35     0      0 -52.7   -52.8  142.1  ...... ..*  .*..  ....... ......

    -9    -13     0      0  79.8  -131.7   -3.7  ...... ..*  .*..  ....... ......
    27     31     0      0  53.0    52.6 -142.1  ...... ..*  .*..  ....... ......
     9     13     0      0 -79.8   131.8    3.4  ...... ..*  .*..  ....... ......
   -27    -31     3      0 -53.2   -52.4  142.0  ...... ..*  .*..  ....... ......

Event   : 1AG    Location   : 50.28  mi  4.08   ohms sec
Duration: 4.00   Flt Current: 1378

R1  = 13.90   X1  = 79.96   R0  = 41.50   X0  = 248.57   LL   = 100.00
CTR = 200     PTR = 2000    MTA = 80.80   79OI= 30.00    79RS = 60.00
Z1% = 80.00   Z2% = 120.00  Z2DG= 60.00   Z2DL= 30.00
Z3% = 150.00  Z3DG= 90.00   Z3DL= 60.00   50FD= 100      46PH = 6000   TTI = 1
Z1E = Y       Z2E = Y       Z3E = Y       32QE= Y        GSE  = Y      BPFE= Y
```

# SEL-121 DISTANCE RELAY/FAULT LOCATOR COMMAND SUMMARY

Level 0

| | |
|---|---|
| **ACCESS** | Answer password prompt (if password protection enabled) to access Level 1. ALARM relay pulses after three unsuccessful attempts. |

Level 1

| | |
|---|---|
| **2ACCESS** | Answer password prompt (if password protection enabled) to access Level 2. This command always pulses the ALARM relay. |
| **DATE** | Show or set date. DAT 2/3/86 sets date to Feb. 3, 1986. The month and date settings are overridden when IRIG-B synchronization occurs. |
| **EVENT** | Show event record in long or short form. EVE 1 L shows the long form of most recent event. EVE 12 shows the short form of oldest event. |
| **HISTORY** | Show DATE, TIME, EVENT TYPE, FAULT LOCATION, DURATION, and CURRENT for the 12 most recent faults. |
| **IRIG** | Force immediate execution of time-code synchronization task. |
| **METER** | Show primary current, voltage, real, and reactive power. METER runs once. "METER N" runs N times. |
| **QUIT** | Return to Access Level 0. |
| **SHOWSET** | Show the relay settings. This command does not affect the settings. |
| **STATUS** | Show self-test status. |
| **TARGETS** | Show data and set target lights as follows:<br>TAR 0: Relay Targets — TAR 1: Zone 1 MHO elements<br>TAR 2: Zone 2 MHO elements — TAR 3: Zone 3 MHO elements<br>TAR 4: Aux elements — TAR 5: Contact Outputs<br>TAR 6: Contact Inputs — TAR 7: Internal logic 1<br>TAR 8: Internal Logic 2<br>Be sure to return to TAR 0 when done, so LEDs display fault targets. |
| **TIME:** | Show or set time. TIM 13/32/00 sets clock to 1:32:00 PM. This setting is overridden when IRIG-B synchronization occurs. |
| **TRIGGER:** | Trigger and save an event record (type of event is EXT). |

Level 2

| | |
|---|---|
| **AUTO** | Show or select port for destination of automatically-generated messages. AUT 1 selects PORT 1. AUT 2 selects PORT 2. AUT 3 selects PORTS 1 and 2. |
| **CLOSE** | Close circuit breaker, if allowed by jumper setting. |
| **INTERVAL** | Show or set command timeout interval. A separate timeout value is used for each port. Executing INT 0 from PORT 2 disables timeout of PORT 2. INT 4 from PORT 1 sets a four minute timeout for PORT 1. |
| **MODEM** | Show or set number of rings before modem at PORT 1 answers. |
| **OPEN** | Open circuit breaker, if allowed by jumper setting. |
| **PASSWORD** | Show or set passwords. ALARM relay pulses momentarily when new passwords are set.<br>PAS 1 OTTER sets Level 1 password to OTTER.<br>PAS 2 TAIL sets Level 2 password to TAIL. |
| **SET** | Initiate setting procedure. ALARM relay closes while new settings are being computed and event data buffers are cleared. |

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

---

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

SEL/7-90

## SAMPLE EVENT REPORT

```
Example 230 KV Line                    Date: 1/1/86      Time: 01:26:31.426

         Currents               Voltages        MHO  +Seq  -Seq  Outs    Ins
          (amps)                 (kV)
                                           ABCABC iIv  ivV3  TCTTTTA DTBD5E       /K*RES      A
B     C     A      B      C    GGGBCA              2  PLTABCL TTTC2T

  -13   -13     0     0  82.3  -129.4  -10.1  ...... ..*. .*..  ....... ....*.
   31    35     3     0  49.4    58.4 -141.6  ...... ..*. .*..  ....... ....*.
   13    13     0     3 -82.1   129.6    9.8  ...... ..*. .*..  ....... ....*.
  -31   -38     0     0 -49.6   -58.2  141.7  ...... ..*. .*..  ....... ....*.

  -13   -13     0     0  82.0  -129.6   -9.5  ...... ..*. .*..  ....... ....*.
   35    35     0     0  49.8    57.8 -141.7  ...... ..*. .*..  ....... ....*.
    9    13     0     0 -82.0  -129.7    9.2  ...... ..*. .*..  ....... ....*.
  -35   -31     3     0 -49.9   -57.5  141.6  ...... ..*. .*..  ....... ....*.

   -9   -13     0     0  81.9  -129.8    8.8  ...... ..*. .*..  ....... ....*.
   35    31    -3     0  50.0    57.3 -141.7  ...... ..*. .*..  ....... ....*.
    9    13     0     0 -81.8   129.8    8.4  ...... ..*. .*..  ....... ....*.
  -35   -31     3     3 -46.0   -52.6  142.1  ...... ..*. .*..  ....... ....*.

   13    13     0     0  83.2  -128.4   -8.0  ...... ..*. .*..  ....... ....*.
  252   252     0     0  40.2    45.8 -142.4  ...... *.*. **..  ....... ....*.
  111   113     0     0 -83.4   128.2    7.5  ...... *.*. **..  ....... ....*.
 -823  -827     0     0 -43.9   -48.9  142.3  2..... *.*. **.*  ....... ....*.

 -358  -371     0     0  81.8  -129.8   -7.2  1..... *.*. **.*  *.**... ....*.
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  469   491     3     0 -81.2   130.5    7.0  1..... *.*. **.*  *.**... ....*.
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  730   733     0     0  52.4    54.6 -141.8  2..... *.*. **.*  *..*... ......
   58    69     0    -3 -80.5   131.2    5.1  2..... *.*. **.*  *..*... ......
 -204  -211     0     0 -52.2   -54.0  142.0  ...... *.*. **..  ....... ......

  -22   -25     0     0  80.4  -131.4   -4.9  ...... *.*. **..  ....... ......
   49    53     0     3  52.4    53.9 -141.7  ...... ..*. .*..  ....... ......
   13    16     0     0 -80.4   131.3    4.5  ...... ..*. .*..  ....... ......
  -31   -35     0     0 -52.5   -53.4  141.7  ...... ..*. .*..  ....... ......

   -9   -16     0     0  80.3  -131.5   -4.2  ...... ..*. .*..  ....... ......
   27    35     0     0  52.5    53.0 -142.0  ...... ..*. .*..  ....... ......
    9    16     0     0 -80.0   131.7    4.0  ...... ..*. .*..  ....... ......
  -27   -35     0     0 -52.7   -52.8  142.1  ...... ..*. .*..  ....... ......

   -9   -13     0     0  79.8  -131.7   -3.7  ...... ..*. .*..  ....... ......
   27    31     0     0  53.0    52.6 -142.1  ...... ..*. .*..  ....... ......
    9    13     0     0 -79.8   131.8    3.4  ...... ..*. .*..  ....... ......
  -27   -31     3     0 -53.2   -52.4  142.0  ...... ..*. .*..  ....... ......

Event   : 1AG     Location   : 50.28  mi  4.08   ohms sec
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Z3% = 150.00  Z3DG= 90.00   Z3DL= 60.00   50FD= 100      46PH = 6000    TTI = 1
Z1E = Y       Z2E = Y       Z3E = Y       32QE= Y        GSE  = Y       BPFE= Y
```