INSTRUCTIONS

GEK-49890A

STATIC GROUND MHO DISTANCE RELAY

TYPE SLYG61B

GENERAL ELECTRIC

CONTENTS

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DESCRIPTION

The SLYG61B relay is a first zone, three phase, static phase ground distance relay. It is a rack mounted unit, two rack units high. The unit requires other fault detecting relays, an SSA power supply, SLA logic unit(s), SLAT output unit(s), and a test panel to provide a complete scheme for protection of a transmission line.

APPLICATION

The SLYG61B relay is suitable for application in single pole tripping schemes, as well as three pole tripping schemes, for the protection of series compensated or uncompensated transmission lines.

The SLYG61B relay utilizes a three-input phase-angle comparator for the ground distance measurement. The three inputs for the phase A-to ground measurements are:

(a)	$(I_A - I_0) Z_{R1} + I_0 K_0 Z_{R0} - T\,V_{AN}$	Operating Quantity
(b)	$V_{AN1} - \left[(I_A - I_0) Z_{R1} + I_0 K_0 Z_{R0}\right] P$	#1 Polarizing Quantity
(c)	$T_0 K_0 I_0 Z_{R0}$	#2 Polarizing Quantity

where:

- I_A is the faulted phase current
- I_0 is the zero sequence component of current
- Z_{R1} is the phase (positive and negative) base reach impedance with a selectable impedance angle of 85 degrees or 75 degrees
- Z_{R0} is the zero sequence base reach impedance with a selectable impedance angle of 75 degrees or 65 degrees
- $T\,V_{AN}$ is the faulted phase line-to-neutral voltage, multiplied by the restraint tap, T
- V_{AN1} is the positive sequence component of the faulted phase voltage
- P is the offset reach multiplier and may be set for 0.0, 0.75, 1.5, 2.25, or 3.0
- T_0 is a design variable set equal to 0.4
- K_0 is a ratio tap to compensate for the magnitude ratio between the zero and positive sequence line impedance

The use of a three-input comparator provides advantages over previous designs in simplifying the application of a ground distance relay. The #1 and #2 polarizing signals will be approximately in phase in the faulted phase comparator and approximately 120 degrees or more out of phase in the unfaulted phases. Hence the traditional concern of the unfaulted phases operating for a fault behind the relay is not a problem with the SLYG61B.

The use of the positive sequence voltage for the #1 polarizing signal produces a "variable mho" characteristic which increases in size as the source impedance increases to accomodate increasing arc resistance.

The SLYG61B has an adjustable characteristic which is adjusted by means of the timer setting on the characteristic timer. For short lines a circular characteristic is recommended, but for longer lines, lines with unusually heavy load transfer, or three-terminal lines where very large reach settings are required, a lens shaped characteristic is recommended.

The SLYG61B has the capability of a forward offset of the tripping characteristic to permit a more circular characteristic (and therefore faster operation) on long, heavily loaded lines. The forward offset also enhances the steady state directional integrity of the tripping unit in those cases where there are series capacitors between the potential source of the relay and an external fault behind the relay.

The SLYG61B relay has the capability of reducing the sensitivity of the polarizing circuit. This feature improves the directional integrity and also allows a shorter characteristic timer pickup setting.

The SLYG61B relay can be used as a standard distance relay or as a hybrid overcurrent-distance relay. When the relay is used as a hybrid overcurrent-distance relay, operation is not permitted unless the magnitude of the IZ-V quantity is greater than a preset level.

RATINGS

This relay is designed for use in an environment where the air temperature outside the relay case is between minus 20°C and plus 65°C.

Forms of the SLYG61B are available for either 50 or 60 hertz applications.

Forms of this relay are available with current circuits rated for either five amperes or one ampere for continuous duty, with a one second rating of 300 or 60 amperes, respectively.

The potential circuits are rated for 69 volts.

The relay requires a plus or minus 15 volt DC power source which can be obtained from Type SSA power supplies.

Refer to the unit nameplate for the frequency and current ratings for a particular relay.

RANGES

The SLYG61B has an adjustable reach of 0.1 to 30 ohms for the five ampere rated relay or 0.5 to 150 ohms for the one ampere rated relay.

Current input connections to establish the basic ohmic tap of 1 and 3 ohms line-to-neutral (five ampere relay) or 5 and 15 ohms (one ampere relay) are available at the current input terminals. Restraint taps in the voltage circuit range between 10 and 100 percent in one percent increments. In addition to the current input taps, the relay has a selectable base reach multiplier of 1.0, 0.5, 0.2 or 0.1 per unit. The relay has a selectable offset in the tripping direction of 0.0, 0.75, 1.50, 2.25 or 3.00 per unit of the base reach.

The relay has a positive sequence base reach angle which can be adjusted for 85 or 75 degrees.

The relay has a zero sequence current compensation circuit with a K_0 (Z_0/Z_1) adjustment range of 1.0 to 10.9 per unit in 0.1 per unit steps. The zero sequence base reach angle can be adjusted for 75 or 65 degrees.

The polarizing voltage has an adjustable phase shift relative to the operating quantity of zero to twenty degrees lead.

BURDENS

The maximum potential burden per phase, measured at 60 volts RMS is:

60 Hertz Relay	50 Hertz Relay
0.35 Volt-ampere	0.45 Volt-ampere
0.28 Watt	0.34 Watt
0.20 Var	0.29 Var

The maximum phase current burden per phase is:

Five Ampere Relay			One Ampere Relay		
1 or 3 Ohm tap			1 or 15 Ohm tap		
Z:	0.024 $\underline{/7.0^{o}}$	Ohm	Z:	0.115 $\underline{/1.5^{o}}$	Ohm
R:	0.024	Ohm	R:	0.115	Ohm
X:	0.003	Ohm	X:	0.003	Ohm

The maximum zero sequence current burden is:

Five Ampere Relay 1 or 3 Ohm tap		One Ampere Relay 1 or 15 Ohm tap	
Z:	$0.024 \angle 7.0^{\circ}$ Ohm	Z:	$0.115 \angle 1.5^{\circ}$ Ohm
R:	0.024 Ohm	R:	0.115 Ohm
X:	0.003 Ohm	X:	0.003 Ohm

The maximum burdens that the logic circuits present to the power supply are:

0.240 ampere to the +15 VDC supply
0.120 ampere to the -15 VDC supply

SENSITIVITY

Sensitivity is defined as the steady state RMS voltage or current, measured at the relay terminals, required for a particular quantity to cause the relay to operate if all input quantities are in the optimal phase relationship. The nominal sensitivities for the signal quantities in the SLYG61B relay are as follows:

OPERATING CIRCUIT SENSITIVITY

To determine the current sensitivity, the ratio of I_0 to $I_\emptyset$ (phase current) must be known or assumed The current sensitivity can be determined from the relationship:

$$(I_\emptyset - I_0)\, Z_{R1} + I_0 K_0 Z_{R0} = \frac{0.16}{1-X}$$

where:

$$X = \frac{\text{Actual Relay Reach}}{\text{Nominal Relay Reach}}$$

For example, if $I_\emptyset = 3I_0$, $Z_{R1} = Z_{R0} = 3$ ohms, $K_0 = 3$ and $X = 0.9$, then:

$$2I_\emptyset + 3I_\emptyset = 1.6$$

$$I_\emptyset = 0.32 \text{ ampere}$$

#1 POLARIZING CIRCUIT SENSITIVITY (V_{AN1})

Sensitivity is adjustable between 5 and 35 percent of rated voltage; it is factory set at 5 percent.

#2 POLARIZING CIRCUIT SENSITIVITY ($T_0K_0I_0BOT_0$)

The current sensitivity can be determined from the relationship:

$$T_0K_0I_0BOT_0 = 0.05$$

OPERATING PRINCIPLES AND CHARACTERISTICS

GENERAL

The mho characteristic is obtained by converting relay currents into voltage signals (IZ), combining these IZ signals with signals proportional to the line voltage (V), and measuring the angle between the appropriate combinations to obtain the desired characteristic.

Currents are converted into IZ signals by means of transactors (TE, TG and TJ) which are air gap reactors with secondary windings. The transactors are tapped on the primary to provide the basic ohmic tap selection of one or three ohms (five ampere rating) and five or fifteen ohms (one ampere rating).

The Z of the IZ quantity is the transfer impedance of the transactor and is equal to V_{OUT}/I_{IN}. The transactor secondaries have loading resistors across them. These resistors provide the desired angle between V_{OUT} and I_{IN}. This angle determines the base reach angle of the relay.

The mho distance characteristic is obtained by comparing the phase angle between the quantities (IZ-TV) and (Vpol-IZP), where V is the phase-to-neutral voltage at the relay, V_{pol} is the positive sequence voltage at the relay which is used as the polarizing voltage, I is the phase current, Z is the relay base reach, P is a percentage of the relay base reach, and T is the voltage restraint tap. For a circular characteristic, relay operation occurs when the angle between (IZ-TV) and (Vpol-IZP) is less than or equal to 90 degrees.

RELAY REACH

The positive and negative sequence base reach of the relay (Z_{R1}) is determined by the basic ohmic tap (BOT) and the base reach multiplier tap (BRM). The base reach is equal to the product of the basic ohmic tap and the base reach multiplier tap.

$$Z_{R1} = (BOT) \times (BRM) \qquad \text{(Eq. 1)}$$

The reach of the MG1 function at the base reach angle is given by the expression:

$$Z_R = \frac{Z_{R1}}{T} \times 100 = \frac{BOT \times BRM}{T} \times 100 \qquad \text{(Eq. 2)}$$

To obtain the same distance measurement for all ratios of zero to positive sequence current, set:

$$K_0 = \frac{Z_{0L}}{Z_{1L}} \text{ and } Z_{R0} = Z_{R1} \qquad \text{(Eq. 3)}$$

where:

Z_R is the positive sequence reach at the base reach angle in line-to-neutral ohms

T is the voltage restraint tap in percent

K_0 is the zero sequence current compensation setting in per unit

BOT is the basic ohmic tap in line-to-neutral ohms

BRM is the base reach multiplier

Z_{R1} is the positive and negative sequence base reach of the relay in line-to-neutral ohms

Z_{R0} is the zero sequence base reach of the relay in line-to-neutral ohms

The reach of the relay is inversely proportional to the voltage restraint tap setting. The maximum reach of the relay (30 or 150 ohms depending upon the relay rating) is obtained with the suggested minimum restraint setting of ten percent.

CHARACTERISTIC OFFSET

The relay may be adjusted by means of a movable jumper block on one of the printed circuit cards to produce a characteristic with a forward (tripping direction) offset. When the relay is adjusted in this manner, a plot of its characteristic will be a circle that does not pass through the origin of the IR-IX diagram.

The amount of characteristic offset is equal to a percentage (P) of the relay base reach.

$$\text{Offset} = (Z_{R1})\ (P) \qquad \text{(Eq. 4)}$$

where: P = per unit offset factor.

The offset quantity $(I\phi - I_0)(Z_{R1})(P)$ is clamped to a maximum value of 0.25 times the rated phase to neutral voltage.

IZ-TV LEVEL DETECTOR SETTING

A low set level detector is incorporated in the mho operate circuitry for use in certain applications. The "D" option jumper on the F177 cards should be in the "2" position if the low set level detector is to be used. The level detector setting is made by adjusting the P20 potentiometer on the F177 cards in positions H, J and K. The level detector insures that the mho function will not produce an output until the IZ-TV operating quantity is greater than the set level.

If the "D" option jumper on the F177 cards is placed in position "1," the level detector is bypassed by a filter circuit, and operates as a standard mho distance function.

ANGLE OF MAXIMUM REACH

The relay base reach angle is adjustable by means of links on the rear of the unit. The positive sequence base reach angle can be set for either 85 or 75 degrees; the zero sequence base reach angle can be set for either 75 or 65 degrees.

The polarizing quantity used to develop the mho characteristic can be phase shifted relative to the operating quantity. The phase shift can be adjusted between zero and 20 degrees lead. The 20-degree setting results in a clockwise shift in the angle of maximum reach away from the base reach angle. The angle of maximum reach is equal to the base reach angle minus the polarizing phase shift. The 20-degree setting increases the reach at the relay angle of maximum reach by the factor 1/cos (20 degrees) which is equal to 1.064.

PHASE ANGLE MEASUREMENT

The quantities (IZ-TV) and (Vpol-IZP) are supplied to a summing amplifier-filter card. This card sums IZ and -TV and Vpol and -IZP then filters extraneous frequencies from those quantities. Each of the resulting signals is then amplified to produce two square-wave outputs. The square waves are applied to a coincidence logic circuit which establishes the coincidence of the same instantaneous polarity of the square waves. The output of the coincidence logic is a rectangular pulse with a duration which is proportional to the phase angle between (IZ-TV) and (Vpol-IZP). A square wave derived from the zero sequence quantity K_0I_0Z is also supplied to the coincidence logic card and supervises the coincidence measurement.

The coincidence logic output is applied to a timing circuit which produces an output whenever the pulse width exceeds a preset duration. If the timer is set for 90 degrees (4.17 milliseconds on a 60 hertz base, 5.0 milliseconds on a 50 hertz base) a circular R-X characteristic is obtained. If the timer is set for less than 90 degrees, an expanded circle (tomato shaped) characteristic is obtained. If the timer is set for more than 90 degrees, a contracted circle (lens shaped) characteristic is obtained.

ZERO SEQUENCE CURRENT COMPENSATION

Zero sequence current compensation is provided as an integral part of each relay. The compensating factor (K_0) must be set equal to the ratio of the zero impedance to the positive sequence impedance of the protected line (Z_0'/Z_1'). The selection of the value of the K_0 setting is discussed in the **CALCULATION AND CHOICE OF SETTINGS** section of this book.

CALCULATION AND CHOICE OF SETTINGS

The following discussion is limited to the use of the SLYG61B relay as a standard distance relay. The forward offset, IZ-V level detector, and the polarizing voltage phase shift and sensitivity are left at the factory settings. A discussion of these settings will be found in the logic description for the scheme in which the unit is used.

Assume that the line to be protected is approximately 70 miles long and has primary impedances as follows:

$$Z_1' = 42 \angle 83^\circ, \quad Z_0' = 130 \angle 78^\circ$$

Assume CT ratio is 1000/5 and PT ratio is 2000/1.

$$Z_1' \text{ sec} = 42 \left(\frac{1000}{5}\right)\left(\frac{1}{2000}\right) = 4.2 \underline{/83^{o}}$$

$$Z_0' \text{ sec} = 130 \left(\frac{1000}{5}\right)\left(\frac{1}{2000}\right) = 13 \underline{/78^{o}}$$

For short to medium length lines, that is, lines that are under 100 miles long, the SLYG61B relay is set as follows:

(a) The positive and negative sequence base reach angle is selected based on the positive sequence impedance angle of the line; for line angles above 80 degrees, select the 85-degree base reach angle tap. For line angles 80 degrees and below, select the 75-degree base reach angle tap. For the sample line, select the 85-degree tap.

(b) The zero sequence base reach angle tap is selected at 75 degrees if the zero sequence line impedance angle is above 70 degrees. Select the 65-degree tap if the line impedance angle is 70 degrees and below. For the sample line, select the 75-degree tap.

(c) A typical relay reach setting (Z_R) for the sample line would be 85 percent of the positive sequence line impedance (Z_{1L}). For the sample line the relay reach would be 0.85 (4.2) or 3.57 ohms.

The positive and negative sequence base reach tap (Z_{R1}) is typically selected to be as large as possible, but still less than the relay reach. This gives the maximum current sensitivity. The positive and negative sequence base reach tap (Z_{R1}) is the product of two factors: the base ohmic tap (BOT) and the base reach multiplier (BRM). The basic ohmic taps available are one ohm and three ohms; the base reach multiplier taps are 0.1, 0.2, 0.5 and 1.0. The available base reach settings are given in the following table:

Z_{R1}	BOT	BRM
0.1	1	0.1
0.2	1	0.2
0.3	3	0.1
0.5	1	0.5
0.6	3	0.2
1.0	1	1.0
1.5	3	0.5
3.0	3	1.0

For the sample line, the suggested base reach, Z_R, is three ohms. This results from a BOT of three ohms and BRM of 1.0.

(d) After Z_{R1} has been selected, T, the restraint tap setting, can be calculated in accordance with the formula:

$$Z_R = \frac{Z_{R1}}{T} \text{ or } T = \frac{Z_{R1}}{Z_R}$$

For the sample line $T = \frac{3}{3.57} \times 100 = 0.84$ or 84 percent

(e) Z_{R0}, the zero sequence base reach, multiplied by the K_0 multiplier, provides the "replica impedance" for the zero sequence impedance of the line. $Z_{R0} = (BOT_0)\ (BRM)$, where the BOT_0 taps have the same ohmic value as BOT, one ohm and three ohms. BRM for the zero sequence base reach tap is set by the same taps as the BRM for the positive sequence base reach. K_0 is adjustable from one to 10.9 in steps of 0.1. The desired zero sequence reach setting is 0.85 (Z_{0L}) or 0.85 (13) = 11.05 ohms for the sample line. Typically Z_{R0} has the same value as Z_{R1}, that is BOT_0 is selected equal to BOT, or three ohms; the BRM has already been established as 1.0. K_0 can be calculated as follows if $Z_{R0} = Z_{R1}$:

$$K_0 = \frac{Z_{0L}}{Z_{1L}} = \frac{130}{42} = 3.095 \qquad \text{Use } 3.1$$

The zero sequence reach setting is

$$\frac{K_0 Z_{R0}}{T} \times 100 = \frac{3.1\ (3)}{84} \times 100 = 11.07 \text{ ohms}$$

This is very close to the desired reach setting, and hence $K_0 = 3.1$ is appropriate.

(f) The polarizing phase shift is typically set at zero-degrees for normal applications involving lines less than 100 miles long.

(g) For lines less than 100 miles long, the characteristic timer setting is typically the factory setting, namely, 97 degrees, 90 degrees/110 degrees. For 60 hertz applications, this is approximately 4.5, 4.2/5 milliseconds, and for 50 hertz, 5.3, 5/6 milliseconds.

Longer lines, such as those over 100 miles and particularly those with heavy load transfer or series compensated lines, may require modification of the settings for optimum performance. Refer to the nearest General Electric Company Sales Office for suggested setting modifications.

CONSTRUCTION

The Type SLYG61B relay is packaged in a metal enclosure designed for mounting on a 19-inch rack. The relay is two rack units high (one rack unit is 1-3/4 inches). The outline and mounting dimensions are shown in Fig. 1. The relay contains the magnetics and tap blocks for setting the base reach and the percent restraint. It also contains the printed circuit cards for developing three mho ground characteristics. The relay has a hinged front cover and a removable top cover.

The setting of the basic ohmic tap is accomplished by the connection of the input currents to the GA terminal board on the rear of the relay. The connection points for the basic ohmic taps are shown in the table on the internal connection diagram of Fig. 2.

The voltage restraint tap blocks are located on the front of the unit at the left-hand side. Refer to the component location diagrams of Fig. 3. The voltage restraint tap settings are made by jumpers with taper tip pins on the end. In the accessory kit accompanying each equipment there are two special tools supplied for use with these pins. One is an insertion tool and the other is an extraction tool. In order to achieve a proper connection and to prevent damage to the pins, it is essential that these tools be used. Two tap blocks are used per phase: one is for the ten percent tap and one is for the one percent tap. The voltage restraint tap setting is the sum of the one and ten percent settings.

The relay also contains printed circuit cards which are located to the right of the tap blocks. The printed circuit cards are identified by a code number such as F177, C106, T133 or P102, where F designates filter, C designates coincidence, T designates time delay, and P designates processing. The printed circuit cards plug in from the front of the unit. The sockets are identified by letter designations or "addresses," (D, E, F, etc.) which appear on the guide strips in front of each socket, on the component location diagram, on the internal connection diagram and on the printed circuit card itself.

RECEIVING, HANDLING AND STORAGE

These relays will normally be supplied as a part of a static relay equipment, mounted in a rack or cabinet with other static relays and test equipment. Immediately upon receipt of a static relay equipment, it should be unpacked and examined for any damage sustained in transit. If damage resulting from rough handling is evident, file a damage claim at once with the transportation company and promptly notify the nearest General Electric Sales Office.

Reasonable care should be exercised in unpacking the equipment. If the equipment is not to be installed immediately, it should be stored indoors in a location that is free from moisture, dust, metallic chips, and severe atmospheric contaminants.

Just prior to final installation the shipping support bolt should be removed from each side of all relay units, to facilitate possible future unit removal for maintenance. These shipping support bolts are approximately eight inches back from the relay unit front panel. Static relay equipment, when supplied in swing rack cabinets, should be securely anchored to the floor or to the shipping pallet to prevent the equipment from tipping over when the swing rack is opened.

INSTALLATION TESTS

CAUTION

THE LOGIC SYSTEM SIDE OF THE DC POWER SUPPLY USED WITH MOD III STATIC RELAY EQUIPMENT IS ISOLATED FROM GROUND. IT IS A DESIGN CHARACTERISTIC OF MOST ELECTRONIC INSTRUMENTS THAT ONE OF THE SIGNAL INPUT TERMINALS IS CONNECTED TO THE INSTRUMENT CHASSIS. IF THE INSTRUMENT USED TO TEST THE RELAY EQUIPMENT IS ISOLATED FROM GROUND, ITS CHASSIS MAY HAVE A ELECTRICAL POTENTIAL WITH RESPECT TO GROUND. THE USE OF A CONNECTION TO THE EQUIPMENT, SUCH AS A TEST LEAD INADVERTENTLY DROPPING AGAINST THE RELAY CASE, MAY CAUSE DAMAGE TO THE LOGIC CIRCUITRY. IT IS A GOOD TEST PROCEDURE TO CONNECT THE REFERENCE LEAD OF A TEST INSTRUMENT TO RELAY REFERENCE BEFORE CONNECTING THE SIGNAL LEAD.

GENERAL

The test points (TP1, TP2, etc.) shown on the internal connection diagram are connected to the instrument test jacks on a test card in location T. TP1 is located at the top of the card and is connected to relay reference. TP10 is located at the bottom of the card and is connected to plus 15 volt DC. Output signals are measured with respect to the relay reference (TP1). Logic signals are approximately plus 15 volt DC for the ON or LOGIC ONE condition, and between zero and plus one volt DC for the OFF or LOGIC ZERO condition. Filter card outputs are square waves which shift from plus 15 volt DC to minus 15 volt DC.

Any of the input/output pins on the printed circuit boards can be monitored by using the test card adapter as described in the printed circuit card instruction book, GEK-34158. The logic signals can be monitored with an oscilloscope, a portable high-impedance voltmeter, or the voltmeter on the equipment test panel. When the test panel meter is supplied, it will normally be connected to relay reference. Placing the test lead to the proper test point will connect the meter for testing. When time-delay cards are to be adjusted or checked, an oscilloscope which can display two traces simultaneously and which has a calibrated horizontal sweep should be used.

The relay contains printed circuit cards with trimmer potentiometers mounted on them. Some of these potentiometers are factory set and sealed. These potentiometers should not be readjusted.

Before testing the relay, the trip outputs from the associated Type SLAT relay should be opened to prevent inadvertent tripping of the breakers.

Input currents and voltages may be supplied to the relay through Type XLA test plugs placed in the test receptables on the equipment test panel. Reference to the elementary diagram for the static relay equipment will provide information concerning equipment inputs. All units of a given terminal have been calibrated together at the factory and will have the same summary number on the unit nameplates. These units should be tested and used together.

NECESSARY ADJUSTMENTS

The following checks and adjustments should be made by the user in accordance with the procedures given under **DETAILED TESTING INSTRUCTIONS** before the relay is put into service. The necessary set points may be calculated following the procedures under **CALCULATION AND CHOICE OF SETTINGS.** The adjustments should be made in the order shown.

1. Base reach setting (BR)
   (a) Basic ohmic tap selection (BOT)
   (b) Base reach multiplier selection (BRM)
   (c) Per unit offset reach selection (P)
2. Voltage restraint tap setting (T)
3. Angle of maximum reach setting
   (a) Positive sequence base reach angle
   (b) Zero sequence base reach angle
   (c) Polarizing voltage phase shift
4. Polarizing sensitivity setting
5. Zero sequence current compensation setting (K_0)
6. Characteristic timer setting
7. Level detector setting
8. IZ-V cancellation magnitude selection
9. Overall check of the MG1 function

DETAILED TESTING INSTRUCTIONS

BASE REACH SETTING

The basic ohmic tap (BOT) is determined by the terminals to which the relay input currents are connected to the unit. The correct input terminals for the various taps are given in Table I.

TABLE I

CURRENT TAP	I_A		I_B		I_C		$(I_A+I_B+I_C)$	
	IN	OUT	IN	OUT	IN	OUT	IN	OUT
1 OR 5 OHM	GA4	GB8	GA6	GB9	GA8	GB10	GA10	GB11
3 OF 15 OHM	GA3	GB8	GA5	GB9	GA7	GB10	GA9	GB11

The base reach multiplier selector is located on the card in location E. The adjustment is accomplished by a four-position jumper block. In each position the gain of the IZ circuit for each phase is set to the proper value of base reach multiplier. The base reach multiplier for each jumper position on the card is shown in Table II. The relay base reach is given by Equation 1.

TABLE II

JUMPER POSITION	BASE REACH MULTIPLIER (BRM)
B	1.0
C	0.5
D	0.2
E	0.1

The per unit characteristic offset selector is located on the card in location F. The adjustment is accomplished by a five-position jumper block. In each position the gain of the IZ circuit for each phase is set to the proper value of the per unit offset reach multiplier. The per unit offset reach for each jumper position on the card is shown in Table III. The relay characteristic offset is given by Equation 4.

TABLE III

JUMPER POSITION	PER UNIT OFFSET REACH (P)
A	0.00
B	0.75
C	1.50
D	2.25
E	3.00

VOLTAGE RESTRAINT TAP SETTING

The voltage restraint tap setting (T) is accomplished on tap blocks located on the front of the relay. Two separate tap blocks are provided for each phase pair. The setting consists of a ten percent tap and a one percent tap. A restraint tap setting of 57 percent would consist of a ten percent setting of 50 and a one percent setting of 7. Only the special tools supplied with the relay should be used to change the tap setting.

ANGLE OF MAXIMUM REACH SETTING

The positive and zero sequence base reach angles are adjusted by means of links on the rear of the relay. The positive sequence base reach angle can be set for 75 or 85 degrees. The zero sequence base reach angle can be set for 65 or 75 degrees.

In order to set the polarizing voltage phase shift, it is necessary to adjust the P80 potentiometer on the filter cards in locations H, J and K. The setting must be made on each of the three cards.

The polarizing phase shift is adjusted by using the test circuit of Fig. 5 and appropriate connections of Table IV. Note that only voltage is applied to the relay for this test. The following procedure is recommended.

1. Start with the phase A connections of Table IV. Set the voltage restraint tap for 100 percent. Adjust the voltage for 30 volts RMS.

TABLE IV

PHASE	FIGURE 5 CONNECTIONS 1 OR 5 OHM TAP				
	A	B	C	D	E THROUGH H
A	GB2	GB4	GB6	**	NO CONNECTION
B	GB4	GB6	GB2	**	NO CONNECTION
C	GB6	GB2	GB4	**	NO CONNECTION

**Jumper GB3, GB5 and GB7 to point D.

2. Observe the output at pins 8 and 9 of the filter card in location H for phase A. The following phase angle measurements should be made using a dual-trace oscilloscope with a calibrated sweep sufficiently fast to provide an accurate measurement, and with both traces carefully zeroed on the center line.

3. (a) Zero Degree Polarizing Phase Shift

   The square waves at pins 8 and 9 of the filter card should be exactly 180 degrees out of phase, i.e., the zero crossings of each trace should coincide at the center line and the traces should have opposite slopes. The phase shift between pin 8 and pin 9 may be adjusted by potentiometer P80 on the filter card.

(b) Twenty Degree Polarizing Phase Shift

The square wave at pin 9 can be made to lead the square wave at pin 8 by up to 20 degrees. At 20 degrees the zero crossing of the square waves should occur 20 degrees apart (0.926 milliseconds on a 60 hertz base, 1.11 milliseconds on a 50 hertz base). The square wave at pin 9 will be toward the left-hand edge of the screen. The phase shift between pins 8 and 9 may be adjusted by potentiometer P80 on the filter card.

4. Repeat steps 1, 2 and 3 for phases B and C. Observe the outputs of the filter card associated with the phase under test. Use the appropriate connections from Table IV.

POLARIZING SENSITIVITY SETTING

The polarizing sensitivity is adjusted by means of the P90 potentiometer on the filter card (positions H, J and K). The following procedure is recommended:

1. Use the test circuit of Fig. 6, adjust the test voltage to the desired level.

2. Monitor the signal at pin 9 of the filter card (position H for phase A).

3. Adjust the P90 potentiometer on the filter card to the point that causes the wave form monitored at pin 9 to become a sine wave with magnitude of 7.5 volts RMS.

4. Repeat steps 2 and 3 for the other two filter cards (position J and K).

ZERO SEQUENCE CURRENT COMPENSATION SETTING

The zero sequence current compensation setting (K_0) is adjusted by means of two thumb-wheel switches mounted on the card in position G.

The upper switch (S10) selects the unit value and is adjustable from one to ten in integer steps. The lower switch (S11) selects the tenth's value and is adjustable from 0.0 to 0.9 in one-tenth increments. The zero sequence current compensation setting is the sum of the settings on the two switches. The setting may be read directly from the positions of the two switches.

CHARACTERISTIC TIMER SETTING

The pickup settings of the characteristic timer determines the shape of the MG1 characteristic as plotted on an R-X diagram. Increasing the pickup time narrows the characteristic; decreasing the pickup time widens the characteristic. The reset time delay (drop-out time) provides an overlap of the next half-cycle measurement. The inputs to the characteristic timers are chains of pulses (one per half-cycle) from the coincidence logic cards. The outputs of the timers are DC logic signals. Timer settings are discussed in the section **CALCULATION AND CHOICE OF SETTINGS.**

The timers used for the MG1 function are integrating characteristic timers. These timers are typically listed on the overall logic as T1, T2/T3, where T1 is the pickup time in milliseconds on a step DC input, T2 is the pulse width which will cause the timer to pick up with one pulse applied per half-cycle, and T3 is the drop-out delay. The operation of the integrating characteristic timers is discussed in the printed circuit card instruction book, GEK-34158.

The DC pickup (T1) and the dropout (T3) of the MG1 characteristic timer may be set using the test circuit of Fig. 4. Before testing the timer with this circuit, the card which normally supplies the input to the timer must be removed (refer to Table V). Opening the normally closed contact of Fig. 4 causes the output to step to plus 15 volts DC after the pickup delay of the timer. To increase the pickup delay, turn the upper potentiometer (P1) on the timer card clockwise. Closing the contact causes the timer output to drop out (step to less than one volt DC) after the reset delay setting of the card. To increase the reset delay, turn the second potentiometer (P2) clockwise. The pulse pickup mode of the timer may be observed while plotting the characteristic as described in OVERALL CHECK OF THE MG1 FUNCTION. The applied voltage and current, as well as the phase angle between them, can be adjusted to vary the pulse width of the timer input.

TABLE V

PHASE	TIMER UNDER TEST	REMOVE CARD
A	P	L
B	R	M
C	S	N

LEVEL DETECTOR SETTING

The IZ-TV level detector setting is made by means of the P20 on the filter cards (positions H, J and K). The following procedure should be used to make the setting.

1. Move the "D" option jumper block to Position 2 and remove the "C" option jumper block.

2. Determine the proper IZ-TV level as discussed in the section **CALCULATION AND CHOICE OF SETTINGS.**

3. Use the test connections of Fig. 5.

4. Set the applied voltage for the proper level (per calculations in 2 above).

5. Adjust P20 on the filter cards in Positions H, J and K to obtain blocks at pin 8 of the card, the longer of which is 4.2 milliseconds (5.0 milliseconds for 50 hertz). The width of the blocks should be measured at the 7.5 volt level of the square wave.

The "B" option jumper block on the filter card is the level detector range selector; changing the position of this block will extend the range of adjustment of the level detector. The upper position (1 and 3) is normally used for Zone 1 applications, and the lower position (2 and 4) is normally used for Zone 2 applications.

Moving the "D" option jumper block on the filter card to Position 2 removes the filtered component from the operate circuit of the filter card and makes it act as a level detector only. If it is not intended that the circuit act as a level detector only, move the "D" option jumper block to Position 1.

IZ-V CANCELLATION MAGNITUDE SELECTION

The "C" option jumper block on the filter card is used to select the desired magnitude of IZ-V cancellation. Check the logic description supplied with the equipment for the proper method of determining the required magnitude of IZ-V cancellation. The upper position (1 and 3) is used for 0.7 or 0.8 cancellation, and the lower position (2) is used for 0.4 cancellation.

SEVERE FAULT DETECTION OPTION

The severe fault detection circuit is an optional non-directional overcurrent/distance function. If this function is to be used, the "G" option jumper block on the filter card must be moved from position 2 to position 1.

OVERALL CHECK OF THE MG1 FUNCTION

The test circuit of Fig. 5 should be used to check the operation of the MG1 function. Use the connections of Table VI for the one or five-ohm basic ohmic tap or Table VII for the three or fifteen-ohm basic ohmic tap.

TABLE VI

PHASE	FIG. 5 CONNECTIONS - 1 or 5 OHM TAP								OUTPUT
	A	B	C	D	E	F	G	H	
A	GB2	GB4	GB6	**	GA4	GB8	GA10	GB11	TP5
B	GB4	GB6	GB2	**	GA6	GB9	GA10	GB11	TP7
C	GB6	GB2	GB4	**	GA8	GB10	GA10	GB11	TP9

**Jumper GB3, GB5 and GB7 to point D.

TABLE VII

PHASE	FIG. 5 CONNECTIONS - 3 or 15 OHM TAP								OUTPUT
	A	B	C	D	E	F	G	H	
A	GB2	GB4	GB6	**	GA3	GB8	GA9	GB11	TP5
B	GB4	GB6	GB2	**	GA5	GB9	GA9	GB11	TP7
C	GB6	GB2	GB4	**	GA7	GB10	GA9	GB11	TP9

**Jumper GB3, GB5 and GB7 to point D.

RELAY BASE REACH ANGLE AND REACH CHECK

The base reach angle is a function of the positive sequence base reach angle, the zero sequence base reach angle, and the zero sequence current compensation factor. The nominal base reach angle for this test configuration is given in Table VIII for various combinations of base reach angles and zero sequence current compensation settings (K_0). If a K_0 setting other than one in the table is used, the base reach angle can be found by interpolation.

TABLE VIII

K_0 TAP	POSITIVE SEQUENCE SETTING / ZERO SEQUENCE SETTING	85° / 75°	85° / 65°	75° / 75°	75° / 65°
1	Nominal base	81.7°	78.4°	75°	71.7°
3	reach angles are	79.0°	73.0°	75°	69.0°
5	for test circuit	77.8°	70.7°	75°	67.8°
7	of Fig. 5	77.2°	69.4°	75°	67.2°
9	($I_1 = I_0$)	76.8°	68.6°	75°	66.8°
10.9		76.5°	68.1°	75°	66.5°

The following procedure is recommended to check the base reach angle (A) and the relay reach setting.

1. Use the test circuit of Fig. 5, starting with the phase A connections from Table VI or VII.

   Set the test current for a current equal to or greater than that specified in Table IX. Currents greater than twice rated should not be continuously applied to the relay. Currents greater than four times rated should not be applied to the relay. Currents between two and four times rated should not be applied longer than five minutes with an off time of at least five minutes.

   Note that the minimum currents of Table IX are for $K_0 = 1$; for larger values of K_0, the minimum current for each base reach is lower. Refer to the **SENSITIVITY** section of this book for further information.

TABLE IX

BASE REACH OHMS	RECOMMENDED MINIMUM TEST CURRENT (AMP) FOR LESS THAN 3 PERCENT PULL BACK	
	FIVE AMPERE RELAY	ONE AMPERE RELAY
3.0	3.5	0.7
1.5	7.0	1.4
1.0	10	2.0
0.6	17	3.4
0.5	20	4.0
0.3	20**	4.0**
0.2	20**	4.0**
0.1	20**	4.0**

**Less than 10 percent pull back.

2. Adjust the phase angle for the nominal base reach angle as found from Table VIII.

3. Observe the output at pin 8 of the appropriate filter card (card location H for phase A, J for phase B or K for phase C).

4. Lower the voltage to the value given by the following expression:

$$V = \frac{2 + K_0}{3} + I \times BOT \times BRM \times \frac{100}{T} \qquad \text{(Eq. 5)}$$

where:

V is the pickup voltage at the base reach angle
BOT is the basic ohmic tap in ohms
BRM is the base reach multiplier
I is the test current
K_0 is the zero sequence current compensation setting
T is the voltage restraint tap setting in percent

5. As the voltage is lowered, observe the output of the MG1 function: TP5 for phase A, TP7 for B and TP9 for C. At the point where MG1 picks up, a slight adjustment of the phase angle and voltage should cause the square wave at pin 8 of the filter card to come out of saturation. A further adjustment will cause the signal at pin 8 to be reduced to a null voltage consisting of only third and fifth harmonics. The angle on the phase angle meter is the base reach angle and should be within two degrees of the nominal setting. The voltage should be within five percent of the value given by Equation 5.

6. A vernier adjustment on the reach is provided on the filter card (position H, J and K). Turning P10 on the appropriate filter card clockwise increases the voltage required to null the MG1 function, thereby increasing the relay reach.

7. If an offset characteristic is being used, it can be checked using the circuit shown in Fig. 5 and the connections shown on Table VI or VII.

   The voltage should be lowered to the value given by the following expression:

$$V_{OS} = 2 \times I_T \times BOT \times BRM \times P$$

where: P is per unit offset setting (percent of base reach setting)
V_{OS} is the offset (dropout) voltage at the base reach angle.

NOTE: Because the maximum value of the offset quantity, V_{OS}, is limited to 0.25 rated phase-to-phase voltage, the applied current must be in accordance with equation 6 when checking characteristic offset.

$$I_T \leq \frac{0.25 \times \text{nominal } \emptyset\text{-N voltage}}{BOT \times BRM \times \text{Offset Tap (PU)} \times 2} \qquad \text{(Eq. 6)}$$

where:

BOT is the basic ohmic tap
BRM is the base reach multiplier
I_T is the test current

A per unit offset tap must be picked such that the reach of the relay is greater (typically 2X) than the offset. For example, if a base reach tap of 1.5 ohms is used with a voltage restraint tap of 100 percent, then the relay reach, per equation 2, is

$$Z_R = Z_{R1} \times \frac{100}{T}$$

$$Z_R = 1.5 \times \frac{100}{100} = 1.5 \text{ ohms}$$

For Z_R to be greater than twice offset

$$P \leq \frac{2Z_R}{Z_{R1}}$$

or

$$P \leq Z \times \frac{100}{T}$$

For the example, P must be less than or equal to 2.

8. Lower the voltage as indicated in Step 5 to the point where the MG1 function picks up. Because this test takes place at low currents, there will be some pull-back of the MG1 pickup. Continue to lower the voltage

and observe that the MG1 function drops out at the point indicated by the expression given in Step 7. Note that when the test voltage is at the point indicated in Step 7, the signal at pin 9 of the filter card is reduced to a null voltage consisting of only third and fifth harmonics.

9. A vernier adjustment of the characteristic offset is provided by the P60 potentiometer on the filter card (Positions H, J and K).

10. Repeat Steps 1 through 9 for phases B and C, using the connections from Table VI or VII.

COMPLETE MG1 FUNCTION CHECK

The following procedure is recommended to provide an overall check of all the adjustments included in the MG1 function. It is only necessary to check the relay reach at two angles other than the base reach angle.

1. Use the test circuit of Fig. 5, and the phase A connections from Table VI or VII. Set the current for the desired test level (Table IX); monitor the output at TP5 for phase A, TP7 for phase B, or TP9 for phase C.

NOTE: The following equations apply with 0.0 characteristic offset.

2A. Pickup for angles less than or equal to the base reach angle:

(a) Adjust the phase shifter to obtain a phase angle 30 degrees less than the base reach angle.

(b) Lower the applied voltage and check for an MG1 output within five percent of the voltage given by the expression:

$$V_D = V_T \times \frac{\text{SIN } (D - A + B + 180 - C)}{\text{SIN } (B + 180 - C)} \qquad \text{(Eq. 7)}$$

where:

- A is the base reach angle found in Table VIII
- B is the polarizing voltage phase shift setting in degrees
- C is the characteristic timer setting in degrees. For 50 hertz relays, multiply the timer setting in milliseconds by 18 to obtain degrees; for 60 hertz relays, multiply by 21.6.
- D is the phase angle meter reading (voltage leading current)
- V_T is the pickup voltage at the base reach angle given by Equation 5

2B. Pickup for angles greater than the base reach angle:

(a) Adjust the phase shifter to obtain a phase angle 30 degrees greater than the base reach angle.

(b) Lower the applied voltage and check for an MG1 output within five percent of the voltage given by the expression:

$$V_D = V_T \times \frac{\text{SIN } (D - A + B + C)}{\text{SIN } (B + C)} \qquad \text{(Eq. 8)}$$

PERIODIC CHECKS AND ROUTINE MAINTENANCE

PERIODIC CHECKS

The MG1 functions included in the relay may be checked at periodic intervals using the procedures described under OVERALL CHECK OF THE MG1 FUNCTION. By checking the reach of each unit at the base reach angle and one angle either side of the base reach angle, all settings of the MG1 function may be verified.

TROUBLESHOOTING

In any troubleshooting of equipment, it should first be established which unit is functioning incorrectly. The overall logic diagram supplied with the equipment shows the combined logic of the complete equipment and the various test points in each unit. By signal tracing, using the overall logic diagram and the various test points, it should be possible to quickly isolate the trouble.

A test adapter card (0149C7259G-2) is supplied with each static relay equipment to supplement the prewired test points on the test cards. Use of the adapter card is described in the printed circuit card instruction book, GEK-34158.

A dual-trace oscilloscope is a valuable aid to detailed troubleshooting, since it can be used to determine phase shift, operate and reset times, as well as input and output levels. A portable dual-trace oscilloscope with a calibrated sweep and trigger facility is recommended.

SPARE PARTS

To minimize possible outage time, it is recommended that a complete maintenance program should include the stocking of at least one spare card of each type. It is possible to replace damaged or defective components on the printed circuit cards, but great care should be taken in soldering so as not to damage or bridge-over the printed circuit buses, or overheat the semiconductor components. The repaired area should be recovered with a suitable high-dielectric plastic coating to prevent possible breakdowns across the printed buses due to moisture and dust. The wiring diagrams for the cards in the relay are included in the card book, GEK-34158; the card types are shown on the component location diagram, Fig. 3.

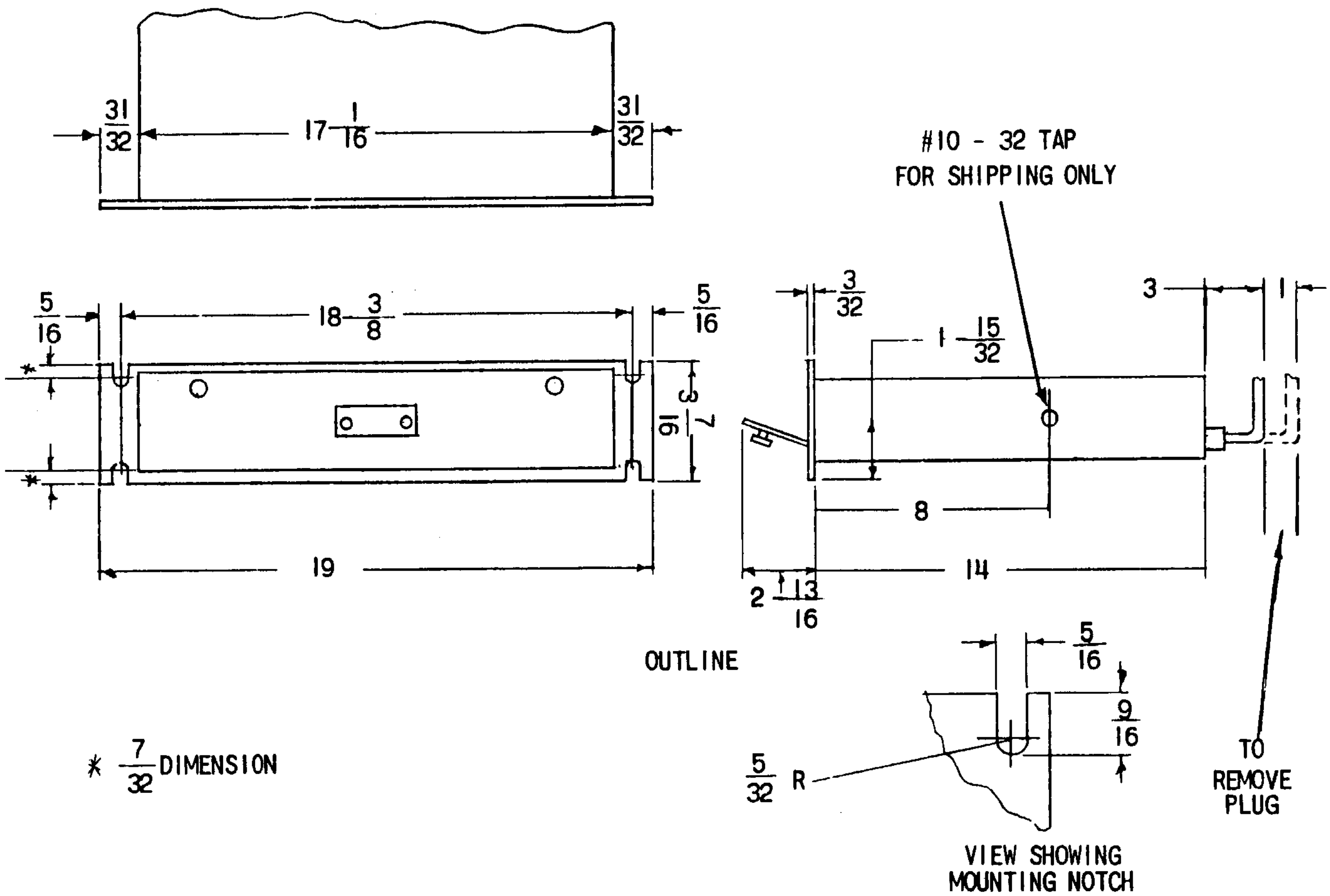


Fig. 1 (0227A2036-0) Outline and Mounting Dimensions for the SLYG61B Relay

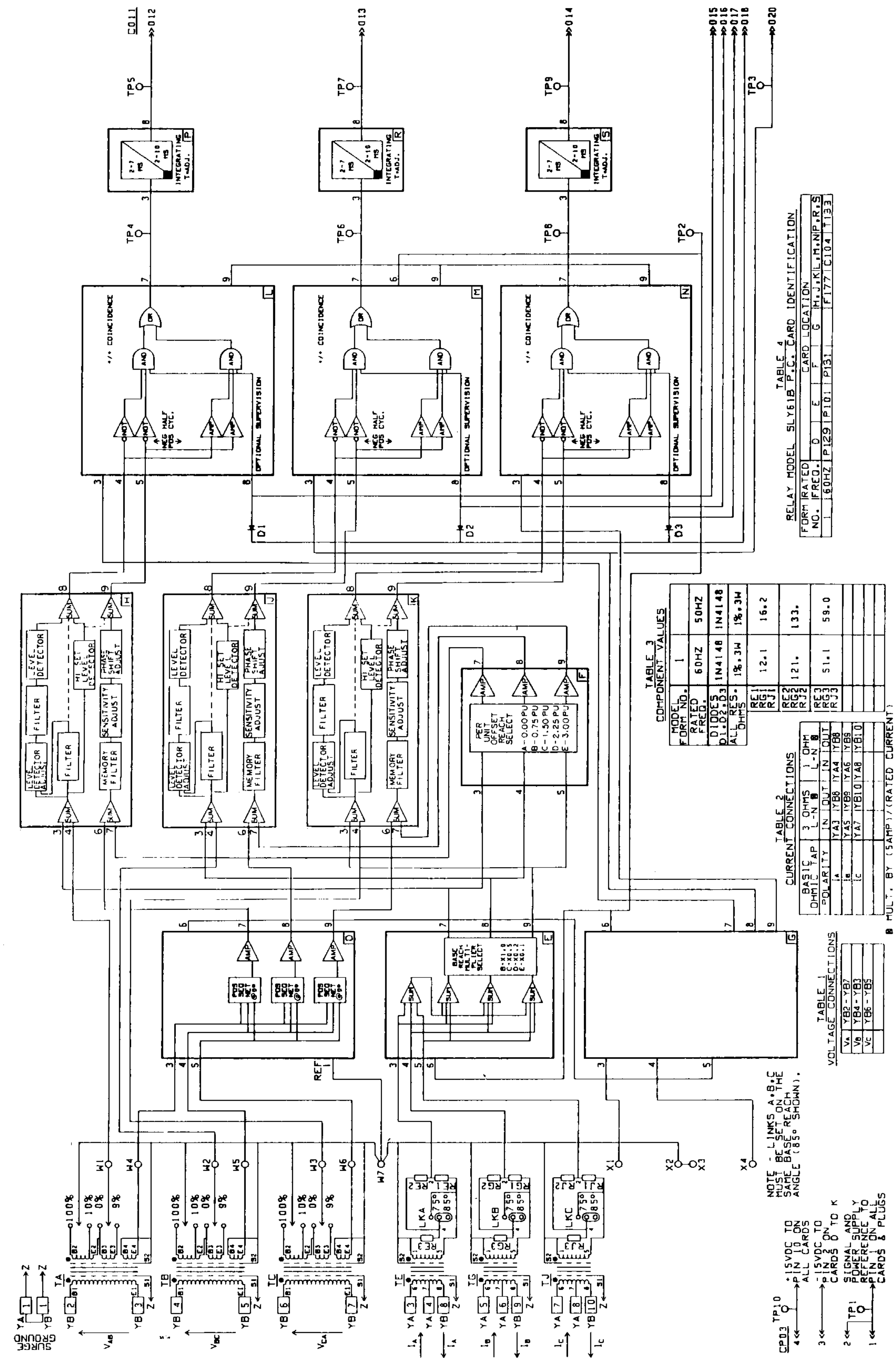


Fig. 2 (0136D5111-0) Internal Connection Diagram for the SLYG61B Relay

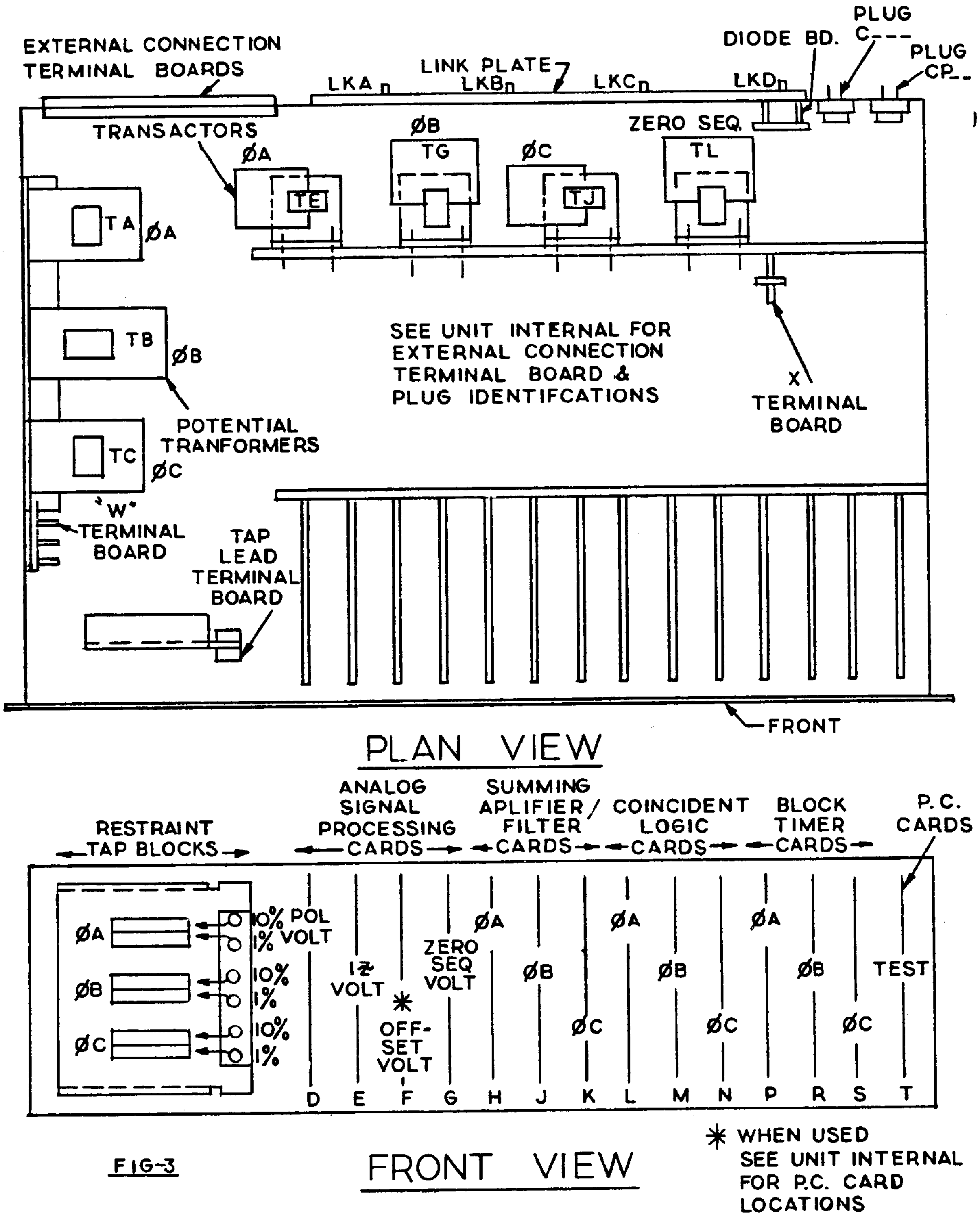
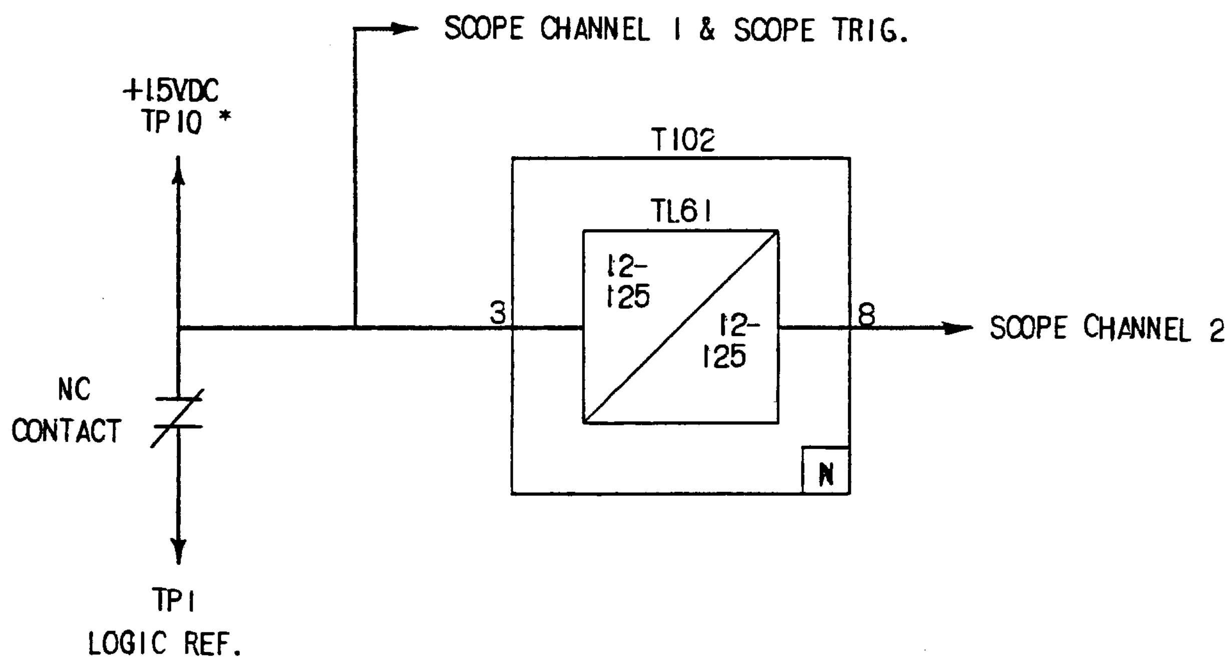
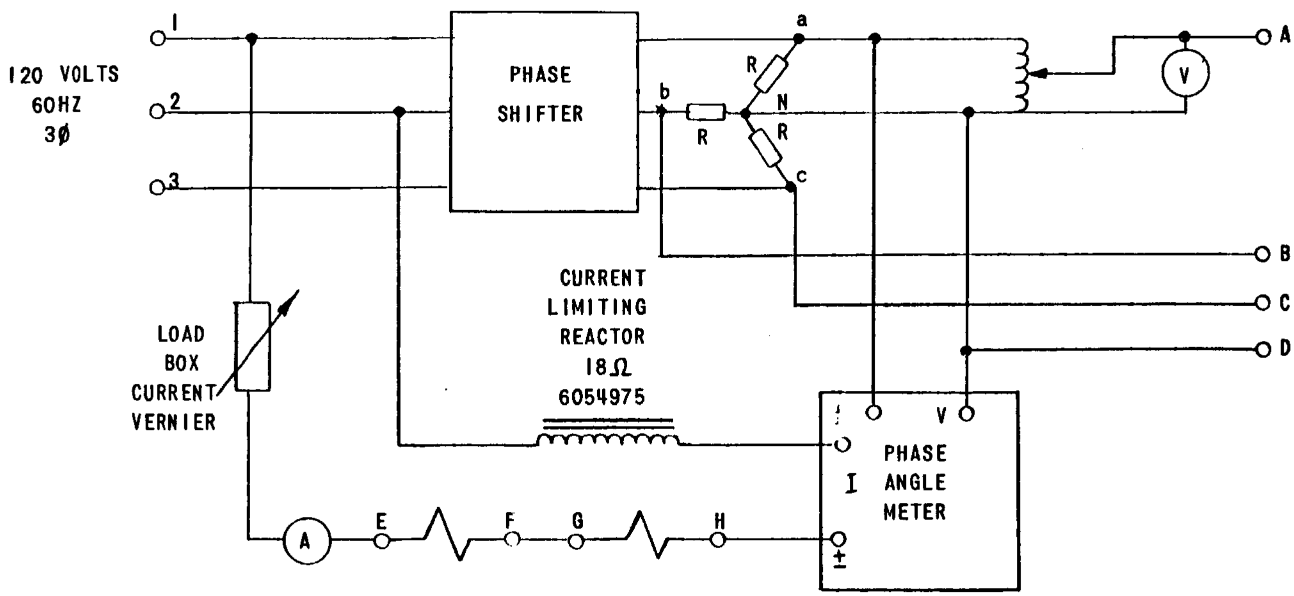


Fig. 3 (0269A3158-1) Component Location Diagram for the SLYG61B Relay



* THE 15VDC SIGNAL AT PIN 10 HAS A CURRENT LIMITING RESISTOR MOUNTED ON THE TEST CARD.

Fig. 4 (0246A7987-0) Timer Test Circuit



R = APPROX. 100 Ω (100W)
(ADJUST THE VALUE OF THE R's SO THAT $V_{A-N} =$
$V_{B-N} = V_{C-N}$)

Fig. 5 (0246A6530-2) MG1 Function Test Circuit

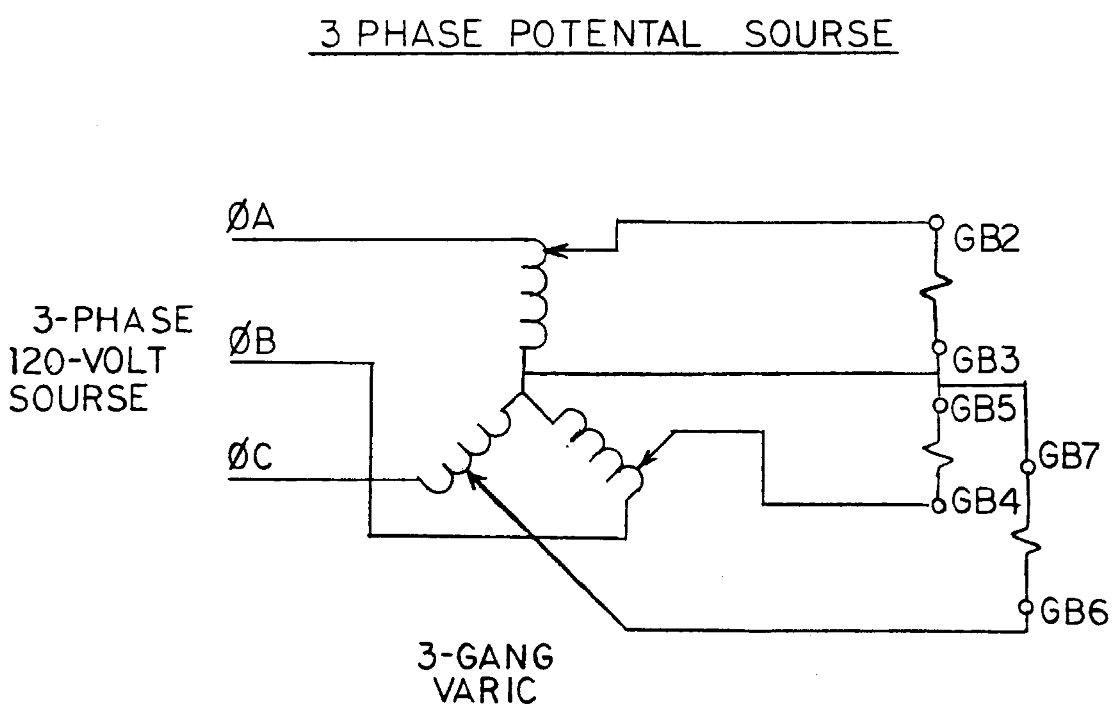


Fig. 6 (0285A6178-0) Test Circuit and Wave Form for Polarizing Sensitivity Setting

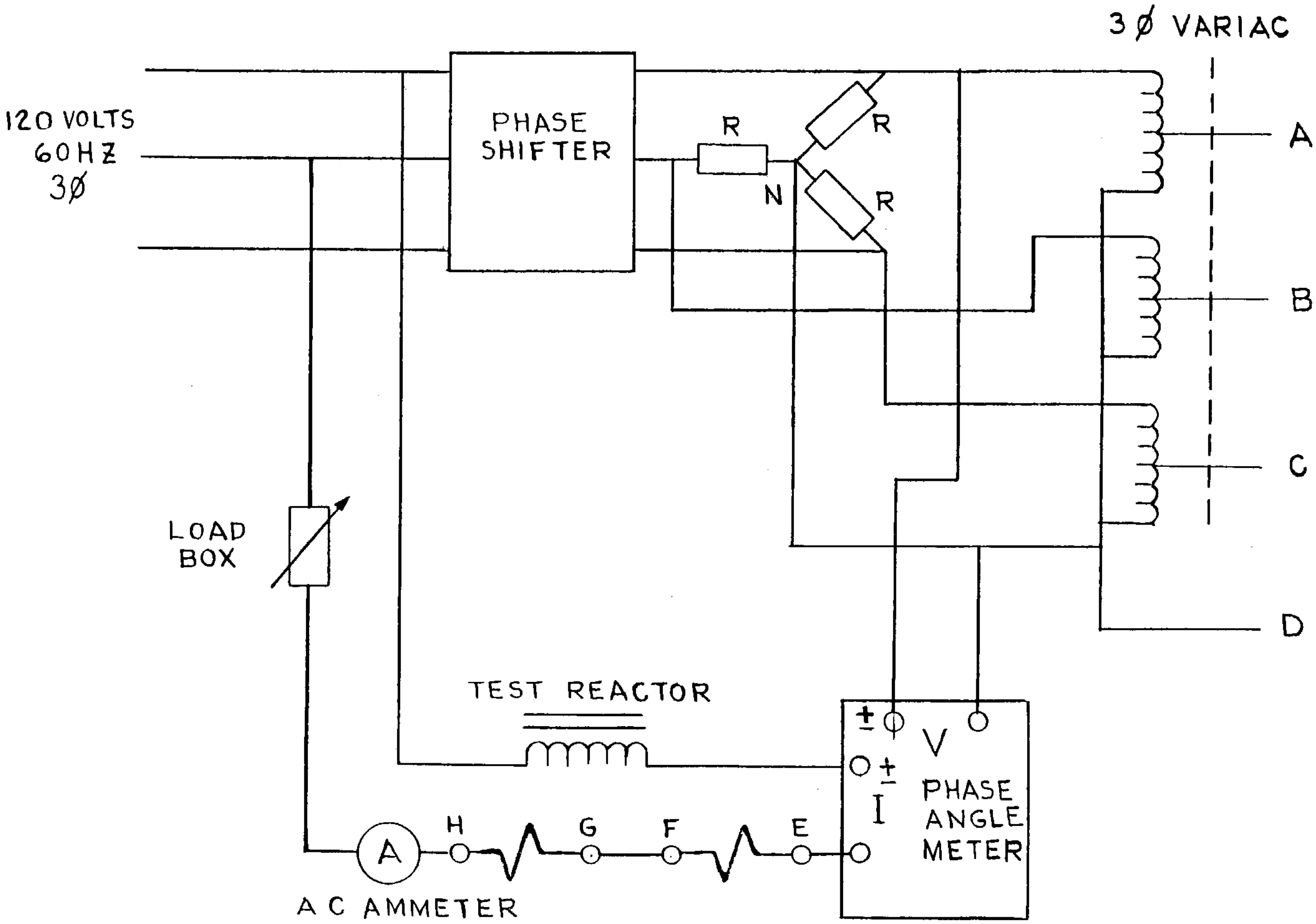


Fig. 7 (0273A9547-0) Test Circuit for Offset Characteristic Test

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