INSTRUCTIONS

GEK-49873

STATIC GROUND MHO DISTANCE BLOCKING RELAY

TYPE SLYG63A

GENERAL ELECTRIC

CONTENTS

ATTACH TO: GEK-49873

NO. 80-9

ERRATA SHEET

This sheet notes changes which should be made in the attached instruction book GEK-49873 for the SLYG63A relay.

On Page 12 substitute the following for the existing paragraph.

$T_0I_0Z_{R0}$ MAGNITUDE AND ANGLE

The magnitude of the $T_0I_0Z_{R0}$ quantity is adjusted by means of the T_0 plug on the G card. T_0 may be set for 0.0, 0.1, 0.2, 0.3 or 0.4. It is shipped from the factory in the 0.4 position. The angle of the $T_0I_0Z_{R0}$ quantity is not adjustable. Note: On the earlier versions of this relay, the angle was adjustable. On these relays the phase shift adjustment plug should be set to the position marked 60 on the board (this is a zero degree phase shift).

STATIC GROUND MHO DISTANCE BLOCKING RELAY
TYPE SLYG63A

DESCRIPTION

The SLYG63A is a three phase, static ground distance blocking relay with a forward offset. It is suitable for mounting in a standard 19 inch rack. The unit requires two rack units of space (one rack unit = 1.75 inches). A typical line protection scheme will include, in addition to the SLYG63A, other fault detecting relays; a type SSA power supply; a type SLA logic unit(s); a type SLAT logic and output unit(s); and a test panel. The internal connection diagram is shown in Fig. 1. The component location diagram is shown in Fig. 2.

The SLYG63A relay utilizes a three-input phase angle comparator, for the ground distance measurement. The three inputs for the Phase A-to-ground measurement are:

1. $(I_A - I_o)Z_{R1}+I_0K_0Z_{R0} - TV_{AN}$ — Operating Quantity (Eq 1)
2. $V_{BC}\angle 90^o + PR\left[(I_A-I_0)Z_{R1}+I_0K_0Z_{R0}\right]$ — #1 Polarizing (Eq 2)
3. $T_0K_0I_0Z_{R0} - V_0$ — #2 Polarizing (Eq 3)

where:

I_A is the faulted phase current

I_0 is the zero sequence component of the faulted phase current.

Z_{R1} is the positive sequence base reach impedance with a selectable impedance angle of 85 degrees or 75 degrees. The Z_{R1} value in phase-to-neutral ohms is determined by the phase basic ohmic tap setting (BOT), and the base reach multiplier setting (BRM); i.e., Z_{R1} = (BOT) (BRM).

Z_{R0} is the zero sequence base reach impedance, with selectable impedance reach angle of 75 or 65 degrees. The Z_{R0} value in phase-to-neutral ohms is determined by the zero sequence basic ohmic tap setting (BOT_0), and the base reach multiplier (BRM); i.e., Z_{R0} = (BOT_o)(BRM).

T_{VAN} is the faulted phase line-to-neutral voltage, multiplied by the restraint tap T.

$V_{BC}\angle 90^o$ is the phase-to-phase voltage in quadrature to the faulted phase voltage, shifted 90 degrees leading, so as to be in phase with the faulted phase prefault voltage.

V_0 is the zero sequence voltage at the relay location.

T_0 is a design variable that may be set equal to 0.0; 0.1; 0.2; 0.3; or 0.4.

K_0 is a ratio tap to compensate for magnitude ratio between the zero and positive sequence line impedance.

P is the offset measured in per-unit of forward reach; i.e., the term "forward" refers to the reach in the blocking direction.

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 SLYG63A.

APPLICATION

The type SLYG63A ground mho distance relay is used primarily to provide the carrier starting function (MBG) for ground faults in directional comparison relaying schemes. In this application it is used with its offset characteristics, since, when properly set, this will provide more reliable coordination with the ground mho tripping function at the remote end of the protected line. The relay may also be connected to provide non-directional delayed back-up protection via a suitable timing function.

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 sequence impedance to the positive sequence impedance of the protected line. When zero sequence current compensation is set properly ($K_0 = Z_0/Z_1$), the relay will measure the positive sequence impedance from the relay location to the fault. In general, the relay may be set with lower reach settings than would otherwise be possible had zero sequence current compensation not been used. The relay does not have provisions for compensating for zero sequence mutual coupling with parallel lines.

In a directional comparison blocking scheme the blocking function MBG at a given terminal must be able to detect all external ground faults in back of that terminal that are within the reach of the tripping (MTG) functions at the remote terminals of the protected line. Any effects of fault resistance that may be present must also be included. If this were not so, carrier might not be started for certain external faults, a blocking signal would not be sent, and the remote MTG functions would initiate a false trip.

The SLYG63A relay is generally applicable on any line strung on steel towers and having shield wires. The relay may be used on lines without shield wires, but in this case, the tower footing resistance may contribute significantly to the total fault resistance such as to cause the impedance to plot outside the characteristic of the relay. If the relay is used on lines strung on wooden structures, with or without shield wires, it is probable that the total fault resistance will be increased considerably thus increasing the likelihood that the impedance may plot outside the characteristic. Because the possibility exists that the impedance may plot outside the characteristic of the relay when it is used in lines without shield wires or strung on wooden towers, it is suggested that the effects of the total fault resistance be carefully studied if the relay is to be used in these applications.

It should be recognized that fault resistances that are relatively large as compared to the relay settings will generally occur on short lines where increased reach settings of both the tripping and blocking functions introduce no load limiting problems. On long lines, the arc resistance tends to be smaller relative to the relay settings so that any reasonable setting of MBG will suffice.

The use of the quadrature voltage for the #1 polarizing signal produces a "variable mho" characteristic, that is, a characteristic which increases in size as the source impedance increases to accommodate increasing fault resistance.

The SLYG63A 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 applied, a lens shaped characteristic is recommended.

On three terminal lines, the same general considerations apply, but the application is more complex and the effects of infeed must be considered in setting the mho functions.

RATINGS

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

Forms of the SLYG63A 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 and have a one second rating of 300 or 60 amperes respectively.

The potential circuits are rated for 69 volts, phase-to-neutral.

The relay requires a ± 15 VDC power source which may be obtained from a General Electric Company type SSA power supply.

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

RANGES

The SLYG63A relay has an adjustable reverse 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 one and three ohms line-to-neutral (five ampere relay) or five and fifteen 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 positive sequence base reach angle which can be adjusted for 85 or 75 degrees, and a zero sequence base reach angle that can be set for 75 or 65 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 or fifteen degrees lead.

BURDENS

The maximum potential burden per phase, measured at 69 volts rms is:

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

The maximum phase current burden per phase is:

5 Ampere Relay			1 Ampere Relay		
1 or 3 Ω Tap			1 or 15 Ω 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
Z:	0.003	Ohm	X:	0.003	Ohm

The maximum zero sequence current burden is:

5 Ampere Relay			1 Ampere Relay		
1 or 3 Ω Tap			1 or 15 Ω 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 SLYG63A relay are as follows:

OPERATING CIRCUIT SENSITIVITY

To determine the current sensitivity the ratio of I_0 to I_ϕ (phase current) must be known or assumed. The current sensitivity can then be determined from the relationship:

$$(I_\phi - I_0)\, Z_{R1} + I_0 K_0 Z_{R0} = \frac{0.14}{1-X} \qquad \text{(Eq. 4)}$$

where

$$X = \frac{\text{Actual Relay Reach}}{\text{Nominal Relay Reach}} \qquad \text{(Eq. 5)}$$

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

$$2I_\phi + 3I_\phi = 1.4$$

$$I_\phi = 0.28 \text{ amperes}$$

NUMBER ONE POLARIZING CIRCUIT SENSITIVITY $V_{BC}\angle 90^\circ{+}P\ \left[(I_A - I_0)Z_{R1} + I_0 K_0 Z_{R0}\right]$

Sensitivity is one percent of rated voltage.

NUMBER TWO POLARIZING CIRCUIT SENSITIVITY

The current sensitivity can be determined from the relationship:

$$T_0 K_0 I_0 Z_{R0} - V_0 = 0.05 \qquad \text{(Eq. 6)}$$

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 gapped 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 and offset characteristic is obtained by comparing the phase angle between the quantities (IZ-TV) and (V_q+P IZ). Where:

V is the phase-to-neutral voltage at the relay.

V_q+P IZ is the sum of quadrature voltage shifted 90 degrees, and offset voltage.

I is the phase current.

Z is the relay base reach.

T is the voltage restraint tap.

P is the offset measured in per-unit of forward reach.

For a circular characteristic, relay operation occurs when the angle between (IZ-TV) and (V_q+P IZ) is less than, or equal to 90 degrees.

RELAY REACH

The positive sequence base reach of the relay (Z_{R1}) is determined by the phase basic ohmic tap (BOT), and the base reach multiplier tap (BRM). The zero sequence base reach of the relay (Z_{R0}) is similarly determined by the $3I_0$ basic ohmic tap (BOT_0), and the base reach multiplier (BRM). Base reach is given by:

$$Z_{R1} = (BOT) \times (BRM) \qquad \text{(Eq. 7)}$$

$$Z_{R0} = (BOT_0) \times (BRM) \qquad \text{(Eq. 8)}$$

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

$$Z_R = \left(\frac{2Z_{R1} + K_0 Z_{R0}}{3}\right) \times \frac{I}{T} \times 100 \qquad \text{(Eq. 9)}$$

or

$$Z_R = \frac{(BOT) \times (BRM) \times 100}{T} \times \frac{2 + K_0(BOT_0/BOT)}{3} \qquad \text{(Eq. 10)}$$

The offset reach is established by the relay's reach (Z_R), and the per unit offset tap setting (P). It is given by:

$$Z_{ROS} = P \times Z_R \qquad \text{(Eq. 11)}$$

Z_{R1} is the positive 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.

Z_R is the 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. (Ratio of zero sequence to positive sequence line impedance).

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

BOT_0 is the $3I_0$ basic ohmic tap in line-to-neutral ohms.

BRM is the base reach multiplier.

Z_{ROS} is the offset reach of the relay, in line-to-neutral ohms.

P is the offset reach multiplier in per-unit of forward reach.

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 tap setting of ten percent.

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 set for either zero or fifteen degrees lead. The fifteen 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 fifteen degree setting increases the reach at the relay angle of maximum reach, in both the reverse and forward reach, by a factor of $1/(\cos 15^{\circ})$ which is 1.035.

PHASE ANGLE MEASUREMENT

The quantities IZ, -TV, V_q, and P·IZ are supplied to a summing amplifier-filter card. This card sums IZ, -TV, V_q, and P·IZ, while filtering extraneous frequencies from these quantities. Each of the resulting signals is then amplified to produce two square wave outputs. These 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 proportional to the phase angle between (IZ-TV) and (V_q+P·IZ). A square wave derived from the zero sequence quantity ($K_0 I_0 Z_{R0}$) is also supplied to the coincidence logic card, to improve the accuracy of the coincidence measurement. (Refer to the APPLICATION section).

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 sequence impedance to the positive sequence impedance of the protected line (Z_0'/Z_1'), where the prime indicates protected line impedance. The selection of the value of K_0 setting is discussed in the CALCULATION AND CHOICE OF SETTINGS section of this book.

CALCULATION AND CHOICE OF SETTINGS

The suggested settings for the MBG functions used in a particular application can be found in the logic description supplied with the scheme. The following is provided to tabulate the required settings, and to show how these settings can be calculated.

The following settings must be made:

1. Positive sequence base ohm tap, BOT; and zero sequence base ohm tap, BOT_0. Available taps are one ohm and three ohms for five-ampere rated relays, and five ohms or 15 ohms for one-ampere rated relays.
2. Base reach multiplier, BRM. Available multipliers are 0.1, 0.2, 0.5 and 1.0.
3. Restraint tap setting, T. T is adjustable in 1.0 percent steps over the suggested range of 10 to 100 percent.
4. Variable tap, T_0.
5. Offset reach tap, P. Available taps are 0, 0.1, 0.2, 0.3 and 0.4.

6. Zero sequence current compensation, K_0. Adjustable from one to 10.9 in 0.1 steps.

7. Angle of maximum reach: 85 degrees or 75 degrees for BOT; 75 degrees or 65 degrees for BOT_0. In selecting the maximum reach angle, the following is suggested:

   a. Set the positive sequence base ohm tap angle at 85 degrees if the positive sequence impedance angle of the line is greater than 80 degrees. For line angles less than 80 degrees, set the angle at 75 degrees.

   b. Set the zero sequence base ohm tap angle at 75 degrees if the zero sequence impedance angle of the line is greater than 70 degrees. For line angles less than 70 degrees, set the angle at 65 degrees.

In making the reach setting, it is first necessary to determine base reach settings Z_{R1} and Z_{R0}. These base reach settings can be calculated as follows:

$$Z_{R1} = (BOT) \quad (BRM)$$

$$Z_{R0} = (BOT_0) \ (BRM)$$

Most applications, unless specifically stated otherwise in the logic description, will require that $Z_{R1} = Z_{R0}$, therefore, BOT = BOT_0 since BRM is common to both settings. In making a particular setting, always select the maximum base reach that is less than the desired reach of the function. By doing this, maximum sensitivity will be obtained.

For purposes of demonstration, consider a 75 mile, 230 kV transmission line, and assume the following:

$$Z_1' = 52 \angle 86^0 \text{ ohms (primary)}$$

$$Z_0' = 130 \angle 74^0 \text{ ohms (primary)}$$

CT ratio = 1200/5 = 240

PT ratio = 230000/115 = 2000

Converting to secondary values:

$$Z_1' = (52) \frac{(240)}{(2000)} = 6.24 \text{ ohms (secondary)}$$

$$Z_0' = (130) \frac{(240)}{(2000)} = 15.6 \text{ ohms (secondary)}$$

The suggested MBG setting for a 75-mile line is a forward reach of 250 percent of the positive sequence line impedance (2.5 x Z_1). The term "forward" applies to the reach in the blocking direction, i.e., looking away from the protected line. An offset equal to 30 percent of the forward reach is also suggested.

The desired forward reach is obtained by calculating the desired reach, selecting a suitable base reach Z_{R1}, and then calculating the restraint tap T to get this reach as follows:

$$T = \frac{(Z_{R1})(100)}{Z}$$

where,

T = restraint tap setting in percent

Z_{R1} = base reach = (BOT) (BRM)

Z = desired forward reach (in blocking direction) in positive sequence secondary ohms.

For the assumed conditions and suggested setting,

$$Z = (2.5)(Z_1') = (2.5)(6.24) = 15.6 \text{ ohms}$$

The maximum base reach that is less than Z_R is three ohms; i.e., Z_{R1} = (BOT)(BRM) = (1)(3) = 3 ohms, then,

$$T = \frac{(3)(100)}{(15.6)} = 19.2 \text{ percent}$$

Use the 19 percent restraint tap.

Set the offset tap, P, at 0.3 which yields an offset of (0.3)(15.6) = 4.68 ohms.

Calculate the zero sequence current compensation factor, K_0

$$K_0 = \frac{Z_0'}{Z_1'} = \frac{15.6}{6.24} = 2.5$$

Set K_0 at 2.5.

The factor $T_0K_0Z_{R0}$ should be set less than the minimum zero sequence source impedance (Z_{S0}) behind the terminal where the relay is located; i.e., the zero sequence impedance seen looking away from the protected line. Select the maximum T_0 to meet this requirement. For this example, a T_0 tap setting of 0.4 yields $T_0K_0Z_{R0}$=(0.4)(2.5)(3)=3. If this is less than Z_{S0}, a T_0 tap setting of 0.4 is satisfactory. If it is not less than Z_{S0}, select a lower value of T_0; if necessary; T_0 can be set to zero.

CONSTRUCTION

The SLYG63A relay is packaged in a metal enclosure, designed for mounting in a standard 19 inch rack. The outline and mounting dimensions are shown in Fig. 3. 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 ground mho offset blocking 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 General Electric Company 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. 1.

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. 2. 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 F156, C106, T121 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

The SLYG63A relay 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 the static relay equipment should be unpacked and examined for any damage sustained in transit. If injury or 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. The same procedure applies when the relay alone is being shipped.

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.

CAUTION:

STATIC RELAY EQUIPMENT, WHEN SUPPLIED IN A SWING RACK CABINET, SHOULD BE SECURELY ANCHORED TO THE FLOOR, OR TO THE SHIPPING PALLET IN ORDER 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 AN 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 instrument test jacks on a test card in card 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 +15 VDC. Output signals are measured with respect to the relay reference (TP1). Logic signals are approximately +15 VDC for the ON or LOGIC ONE condition, and between zero and plus one VDC for the OFF or LOGIC ZERO condition. Filter card outputs are square waves which shift from +15V to -15V.

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 receptacles 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

   a) Basic ohmic tap selection (BOT)

   b) Base reach multiplier selection (BRM)

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. Zero sequence current compensation setting (K_0)
5. Offset reach select (P)
6. Characteristic timer setting
7. Overall check of the MBG function.

SUGGESTED REACH AND CHARACTERISTIC TIMER SETTINGS

	MTG				MBG				
		Pickup		Dropout		Pickup		Dropout	
Line Length-Miles	Reach % of Line	First Block Width (ms)	Contin. Block Width (ms)	(ms)	Reach % of Line	First Block Width (ms)	Contin. Block Width (ms)	(ms)	MBG Offset in Per Unit of Reach
0-50	200	5.5	4.2	5	300	3.8	3.7	30	0.3
50-100	175	5.5	4.2	5	250	3.8	3.7	30	0.3
100-150	150	6	4.8	5	200	4.0	3.9	30	0.3
150-200	135	6	5.5	5	150	4.2	4.1	30	0.3
200-250	125	6.5	5.8	5	125	4.2	4.1	30	0.3
250-300	125	6.5	5.8	5	125	4.5	4.4	30	0.3

DETAILED TESTING INSTRUCTIONS

$T_0 I_0 Z_{R0}$ MAGNITUDE AND ANGLE

The magnitude of the $I_0 Z_{R0}$ quantity is factory set at the maximum (T_0 = 0.4). This is accomplished by setting the T_0 plug on the G card to position 0.4. The angle of the $T_0 I_0 Z_{R0}$ quantity is factory set at zero degrees. This is accomplished by setting the phase shift plug on the G card to the 15 degree position. These settings should not be changed. For T_0=0 settings, the three phase test source can not be used, since no zero sequence voltage exists. For the test, set $T_0 \neq 0$ and run the test then set T_0=0.

BASE REACH SETTING

The basic ohmic taps (BOT_0) and (BOT) are 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

	BOT						BOT_0	
	I_A		I_B		I_C		$(I_A+I_B+I_C)$	
CURRENT TAP	IN	OUT	IN	OUT	IN	OUT	IN	OUT
1 OR 5 OHM	GF8	GE4	GF9	GE6	GF10	GE8	GF11	GE10
3 or 15 OHM	GF8	GE3	GF9	GE5	GF10	GE7	GF11	GE9

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 equations 7 and 8.

TABLE II

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

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 seven. 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 degrees or 85 degrees. The zero sequence base reach angle can be set for 65 degrees or 75 degrees.

In order to set the polarizing voltage phase shift, it is necessary to adjust the X option plug on the filter cards in card locations H, J and K. The setting must be made on each of the three cards. The polarizing voltage phase shift for each position is shown in Table III.

TABLE III

PLUG X SHORTING ARRANGEMENT	DEGREES OF LEADING PHASE SHIFT
2 to 3 and 4 to 5	0
1 to 2 and 3 to 4	15

The polarizing phase shift may be checked and, if necessary, adjusted by using the test circuit of Fig. 4 and the 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. Set the voltage restraint tap for 100 percent. Adjust the voltage for 30 V rms.

TABLE IV

PHASE	FIGURE 5 CONNECTIONS 1 OR 5 OHM TAP					OUTPUT
	A	B	C	D	E Through H	
A	GF2	GF4	GF6	**	NO CONNECTION	TP5
B	GF4	GF6	GF2	**	NO CONNECTION	TP7
C	GF6	GF2	GF4	**	NO CONNECTION	TP9

**Jumper GF3, 5 and 7 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. Refer to Fig. 5 for sample waveforms.

3A) 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 P71 on the filter card.

3B) Fifteen Degree Polarizing Phase Shift
The square wave at pin 9 is now shifted 15 degrees in the leading direction (toward the left-hand edge of the screen.) The zero crossings of the square waves should now occur 15 degrees apart (0.694 milliseconds on a 60 hertz base, 0.833 milliseconds on a 50 hertz base). Refer to Fig. 5. The phase shift between pins 8 and 9 may be adjusted by potentiometer P71 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.

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 tenths 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 setting of the characteristic timer affects the shape of the MBG 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 (dropout 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. The timer settings are discussed in the section CALCULATION AND CHOICE OF SETTINGS.

The timers used for the MBG 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 pickup time, in milliseconds, for a steady state square wave input. T3 is the dropout delay. In some applications of the SLYG63A relay, T2 will not be given, even though the timer used is still an integrating timer. In those cases, the steady state pickup time will automatically be set as the step pickup (T1) is set.

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 MBG characteristic timer may be set using the test circuit of Fig. 6. 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. 6 causes the output to step to +15VDC 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 to drop out (step to less than one VDC) 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 MBG CHARACTERISTIC. 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

OVERALL CHECK OF THE MBG FUNCTION

The test circuit of Fig. 7 should be used to check the operation of the MBG 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	FIGURE 5 CONNECTIONS 1 OR 5 OHM TAP								OUTPUT
	A	B	C	D	E	F	G	H	
A	GF2	GF4	GF6	**	GF8	GE4	GF11	GE10	TP5
B	GF4	GF6	GF2	**	GF9	GE6	GF11	GE10	TP7
C	GF6	GF2	GF4	**	GF10	GE8	GF11	GE10	TP9

**Jumper GF3, 5 and 7 to point D.

TABLE VII

PHASE	FIGURE 5 CONNECTIONS 3 OR 15 OHM TAP								OUTPUT
	A	B	C	D	E	F	G	H	
A	GF2	GF4	GF6	**	GF8	GE3	GF11	GE9	TP5
B	GF4	GF6	GF2	**	GF9	GE5	GF11	GE9	TP7
C	GF6	GF2	GF4	**	GF10	GE7	GF11	GE9	TP9

**Jumper GF3, 5 and 7 to point D.

BASE REACH ANGLE, REACH, AND OFFSET 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 angles for this test configuration are 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.

The offset reach in the forward direction depends on the reverse reach setting, and the offset selecting jumper plug on PC card position "F". For example, with the plug in the "A" position, the offset is zero ohms. With the plug in the "E" position, the offset is:

$$Z_{ROS} = 0.4 \times Z_R$$

TABLE VIII

K_0 TAP	POS. SEQ. SET	85°	85°	75°	75°
	ZERO SEQ. SET	75°	65°	75°	65°
1	Nominal base	$(81.7^\circ)261.7^\circ$	$(78.4^\circ)258.4^\circ$	$(75^\circ)255^\circ$	$(71.7^\circ)251.7^\circ$
3	reach angles are	$(79.0^\circ)259.0^\circ$	$(73.0^\circ)253.0^\circ$	$(75^\circ)255^\circ$	$(69.0^\circ)249.0^\circ$
5	for test	$(77.8^\circ)257.8^\circ$	$(70.7^\circ)250.7^\circ$	$(75^\circ)255^\circ$	$(67.8^\circ)247.8^\circ$
7	circuit of	$(77.2^\circ)257.2^\circ$	$(69.4^\circ)249.4^\circ$	$(75^\circ)255^\circ$	$(67.2^\circ)247.2^\circ$
9	Figure 6	$(76.8^\circ)256.8^\circ$	$(68.6^\circ)248.6^\circ$	$(75^\circ)255^\circ$	$(66.8^\circ)246.8^\circ$
10.9	$(I_1 = I_0)$	$(76.5^\circ)256.5^\circ$	$(68.1^\circ)248.1^\circ$	$(75^\circ)255^\circ$	$(66.5^\circ)246.5^\circ$

( ) indicates offset angle of maximum reach in the forward direction.

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

1) Use the test circuit of Fig. 7 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 currents for each base reach are 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% PULL BACK (K_0=1)	
	5 AMPERE RELAY	1 AMPERE RELAY
3.0	2	0.4
1.5	5	1.0
1.0	10	2.0
0.6	10	2.0
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 in the reverse direction as found from Table VIII.

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

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

$$V_{AR} = \left(\frac{2 + K_0}{3}\right) \times I \times BOT_0 \times BRM \times \frac{100}{T} \qquad \text{(Eq. 12)}$$

   where:

   V_{AR} is the pickup voltage at the base reach angle

   BOT_0 is the basic ohmic tap in ohms

   BRM is the base reach multiplier

   I is the test current (one or five amperes)

   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 MBG function: TP5 for phase A, TP7 for B and TP9 for C. At the point where MBG 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 only of third and fifth harmonics. The angle on the phase angle meter is the reverse reach angle and should be within two degrees of nominal. The voltage should be within five percent of the value given by Equation 12.

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

7) Adjust the angle to the forward (angle) found in Table VIII, offset angle of maximum reach.

8) Observe the output at pin 8 of the appropriate filter card (card location "H" for a phase, location "J" for B phase, and location "K" for C phase).

9) Lower the voltage to the per unit offset reach selected times the reverse voltage obtained from Equation 12.

$$V_{AOS} = (V_{AR}) \times (P) \qquad \text{(Eq. 13)}$$

10) As the voltage is lowered, observe the output of the MBG function: TP5 for phase A, TP7 for B and TP9 for C. At the point where MBG picks up, a slight adjustment of the phase angle and voltage should cause the square wave at pin 9 of the filter card to come out of saturation. A further adjustment will cause the signal at pin 9 to be reduced to a null voltage consisting only of third and fifth harmonics. The angle on the phase angle meter is the forward reach angle and should be within two degrees of nominal. The voltage should be within five per cent of the value given by Equation 13.

11) A vernier adjustment on the forward reach is provided on the filter card (position H, J and K). Turning P52 on the filter card clockwise increases the voltage required for the null, thereby increasing the relay reach.

12) Repeat Steps One through Six for the phases B and C using the appropriate connections from Table VI or VII.

COMPLETE MBG FUNCTION CHECK

The following table gives the per unit pickup voltage at four points on the MBG characteristic, based on an offset tap of 0.3, a polarizing voltage phase shift of zero degrees, and a characteristic timer setting as specified.

TABLE X

CHARACTERISTIC TIMER SETTING	PER UNIT PICKUP VOLTAGE AT AMR$\pm$30^o (REV)	PER UNIT PICKUP VOLTAGE AT AMR$\pm$30^o (FWD)
3.8 ms	1.00	0.35
4.0	0.96	0.33
4.2	0.93	0.32
4.5	0.87	0.30

Example - SLYG63A

Basic Ohmic Tap (BOT)	3Ω
Base Reach Multiplier (BRM)	0.5
Per Unit Offset (P)	0.3
Zero Sequence Compensation (K_0)	3.0
Polarizing Voltage Phase Shift (B)	0^o
Characteristic Timer Set (C)	4.2 ms (90^o)
Voltage Restraint Tap (T)	57%
Positive Sequence Base Reach Angle	85^o
Zero Sequence Base Reach Angle	75^o
Test Current (I)	5A

1. From Table VIII, the base reach angles for these settings are:

   Forward Reach (Tripping Direction) = 79°
   Reverse Reach (Blocking Direction) = 259° ($79^{\circ} + 180^{\circ}$)

2. The operating voltage in the reverse direction is given by

$$V_A = \left(\frac{2 + K_0}{3}\right) \times \text{BOT} \times \text{BRM} \times I \times \frac{100}{T}$$

   For these settings, $V_A = 22V$

3. From Table X, the reach at 229° and 289° is

   $0.93 \times V_A$ or 20.4V

   The reach at 49 degrees and 109 degrees is

   $0.32 \times V_A$ or 7.02V

4. To check the MBG characteristic, it is sufficient to check at six points, as mentioned above. However, the complete mho circle can be plotted, if so desired or settings differ from those covered above.

5. Use the test circuit of Fig. 7 and the phase A connections from Table VI or VII. Set the current for rated current (one or five amperes); monitor the output at the TP5 for A phase, TP7 for B phase or TP9 for C phase.

6. The operating point impedance for test angles between ($A-180^{\circ}$) and A, where A is the OFFSET reach angle from Table VIII, is calculated using Equation 14. The impedance for test angles between the OFFSET reach angle A and $A+180^{\circ}$ is calculated using Equation 15.

   For offsets other than 0.3, polarizing voltage phase shift other than zero degrees, or timer setting other than shown, the pickup voltage must be calculated by solving the following quadratic equations first.

$$(A-180) \leq D \leq A \qquad Z^2 - Z\left[\frac{Z_R(P\sin(A-D+C-B) + \sin(A-D-C+B))}{\sin(C-B)}\right] - PZ_R^{\,2} = 0 \qquad \text{(Eq. 14)}$$

$$A < D < (A+180) \qquad Z^2 - Z\left[\frac{Z_R(P\sin(A-D-C-B) + \sin(A-D+C+B))}{\sin(-C-B)}\right] - PZ_R^{\,2} = 0 \qquad \text{(Eq. 15)}$$

   where:
   Z = Impedance at the test angle
   A = Angle of maximum reach (Table VIII)
   B = Polarizing phase shift angle
   C = Characteristic timer setting in degrees
   D = Angle under test
   All other terms as previously defined.

7. Lower the applied voltage, and check for an MBG output within five percent of the voltage given by the expression:

$$V = (I_{TEST}) \times Z \qquad \text{(Eq. 16)}$$

   where: Z can be found from the above quadratic equations.

PERIODIC CHECKS AND ROUTINE MAINTENANCE

PERIODIC CHECKS

The MBG functions included in the relay may be checked at periodic intervals using the procedures described under OVERALL CHECK OF THE MBG 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 MBG functions may be verified.

TROUBLESHOOTING

In any troubleshooting 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 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 semi-conductor 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. 2.

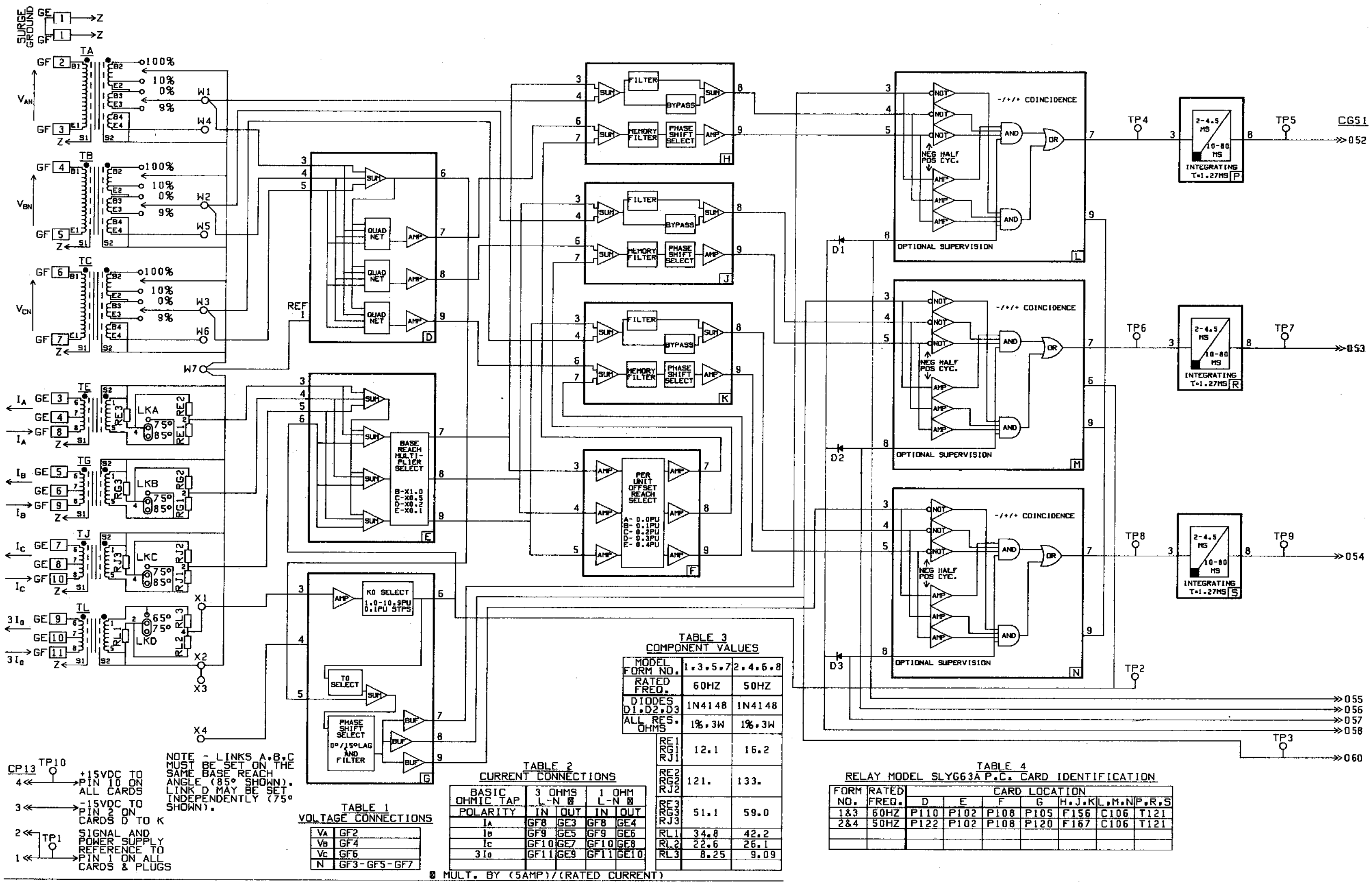


TABLE 1
VOLTAGE CONNECTIONS

V_A	GF2
V_B	GF4
V_C	GF6
N	GF3-GF5-GF7

TABLE 2
CURRENT CONNECTIONS

BASIC OHMIC TAP	3 OHMS L-N ⊠		1 OHM L-N ⊠	
POLARITY	IN	OUT	IN	OUT
I_A	GF8	GE3	GF8	GE4
I_B	GF9	GE5	GF9	GE6
I_C	GF10	GE7	GF10	GE8
$3I_0$	GF11	GE9	GF11	GE10

⊠ MULT. BY (5AMP)/(RATED CURRENT)

TABLE 3
COMPONENT VALUES

MODEL FORM NO.	1,3,5,7	2,4,6,8
RATED FREQ.	60HZ	50HZ
DIODES D1,D2,D3	1N4148	1N4148
ALL RES. OHMS	1%,3W	1%,3W
RE1 RG1 RJ1	12.1	16.2
RE2 RG2 RJ2	121.	133.
RE3 RG3 RJ3	51.1	59.0
RL1	34.8	42.2
RL2	22.6	26.1
RL3	8.25	9.09

TABLE 4
RELAY MODEL SLYG63A P.C. CARD IDENTIFICATION

FORM NO.	RATED FREQ.	CARD LOCATION						
		D	E	F	G	H,J,K	L,M,N	P,R,S
1&3	60HZ	P110	P102	P108	P105	F156	C106	T121
2&4	50HZ	P122	P102	P108	P120	F167	C106	T121

Fig. 1 (136D5031-0) Internal Connections for the SLYG63A Relay

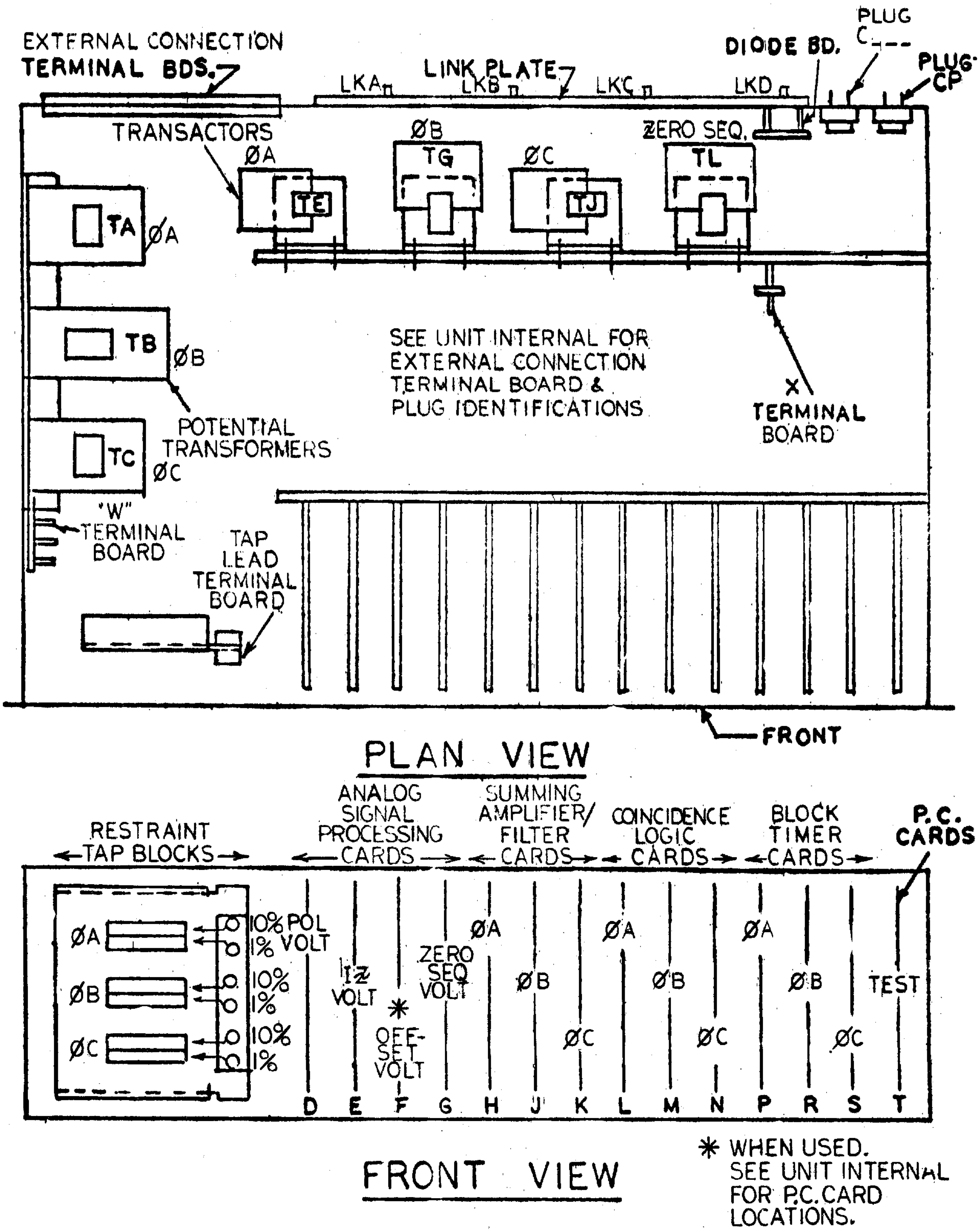


Fig. 2 (269A3158-0) Component Location Diagram

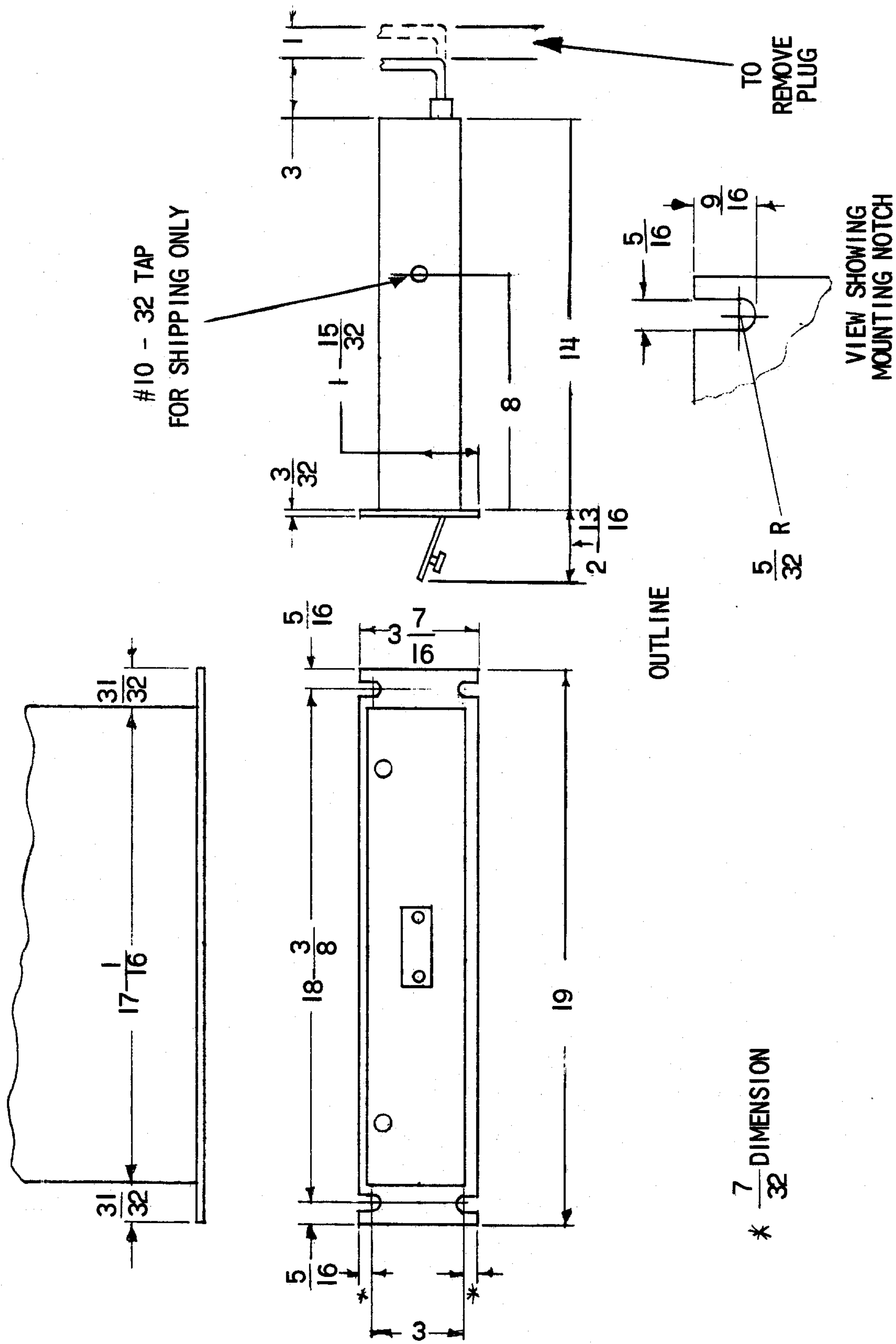
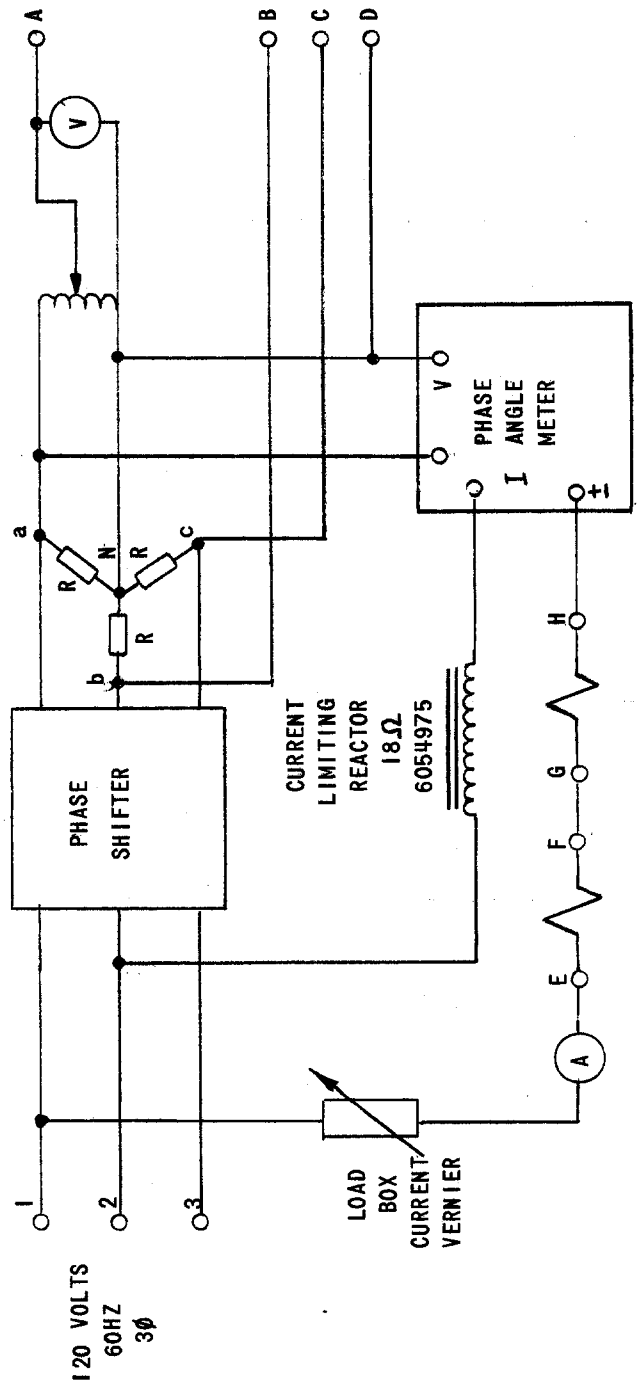
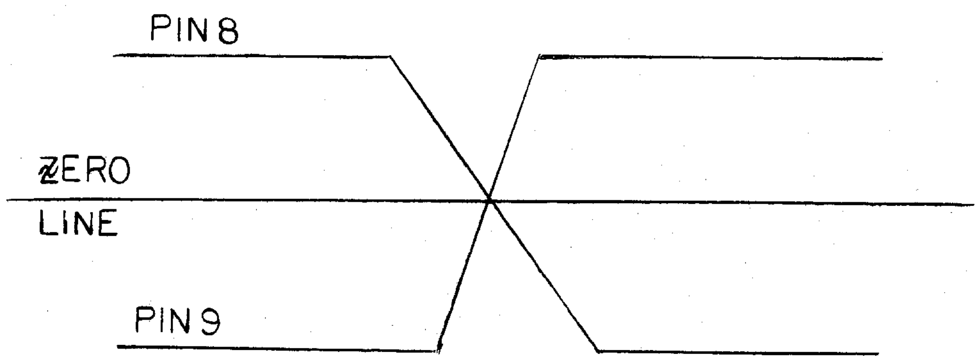


Fig. 3 (227A2036-0) Outline and Mounting Dimension for the SLYG63A

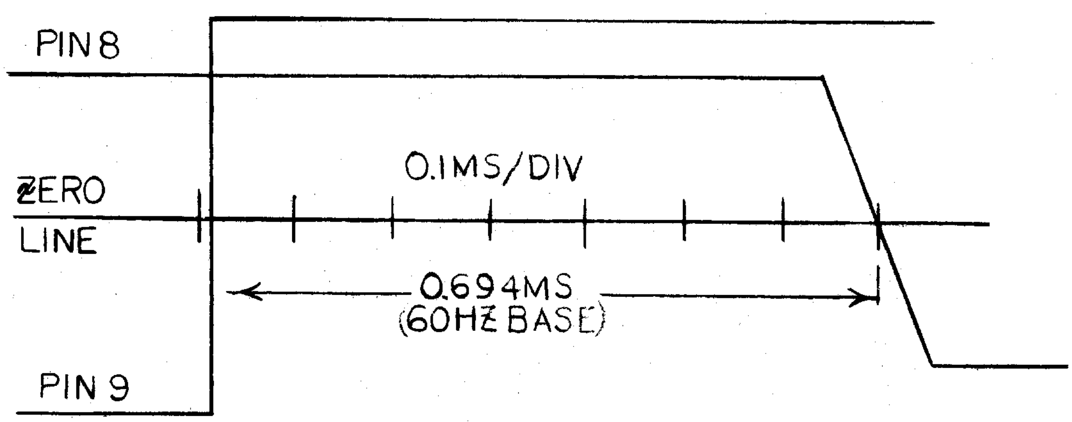


R = APPROX. 100 Ω (100W)
(ADJUST THE VALUE OF THE R's SO THAT V_{A-N} = V_{B-N} = V_{C-N})

Fig. 4 (246A6530-2) Polarizing Phase Shift Test Circuit

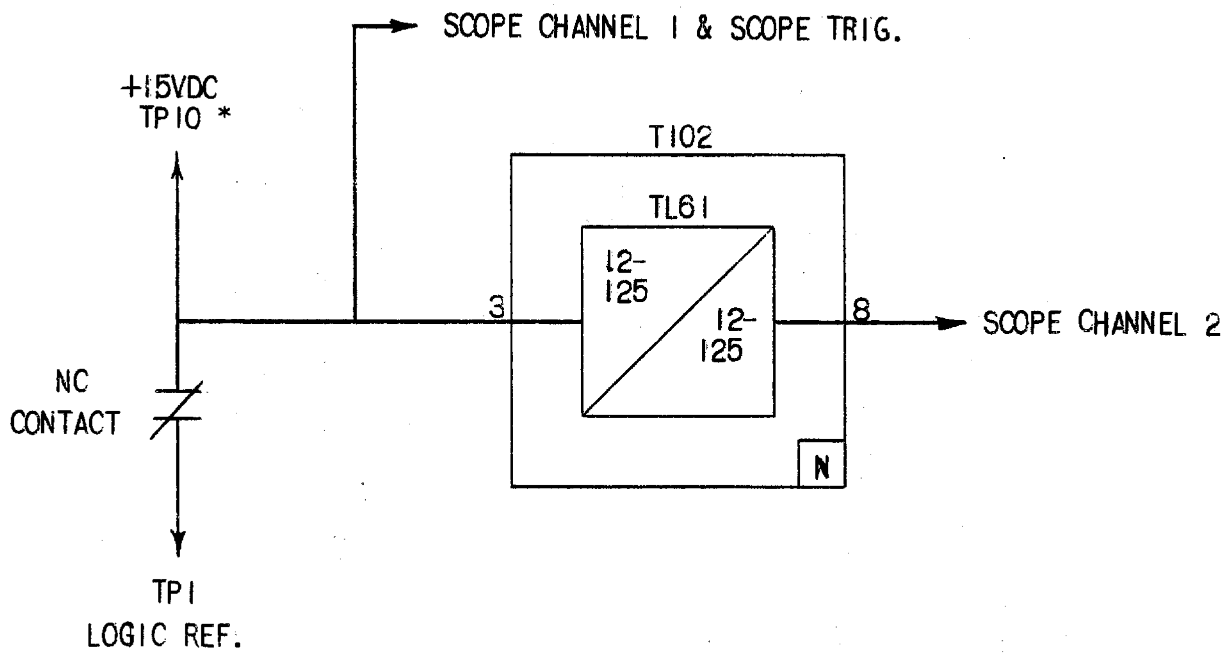


PROPERLY SET 0 DEGREE PHASE SHIFT



PROPERLY SET 15 DEGREE PHASE SHIFT

Fig. 5 (257A9696-0) Polarizing Circuit Phase Shift Waveforms



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

Fig. 6 (246A7987-0) Timer Test Circuit

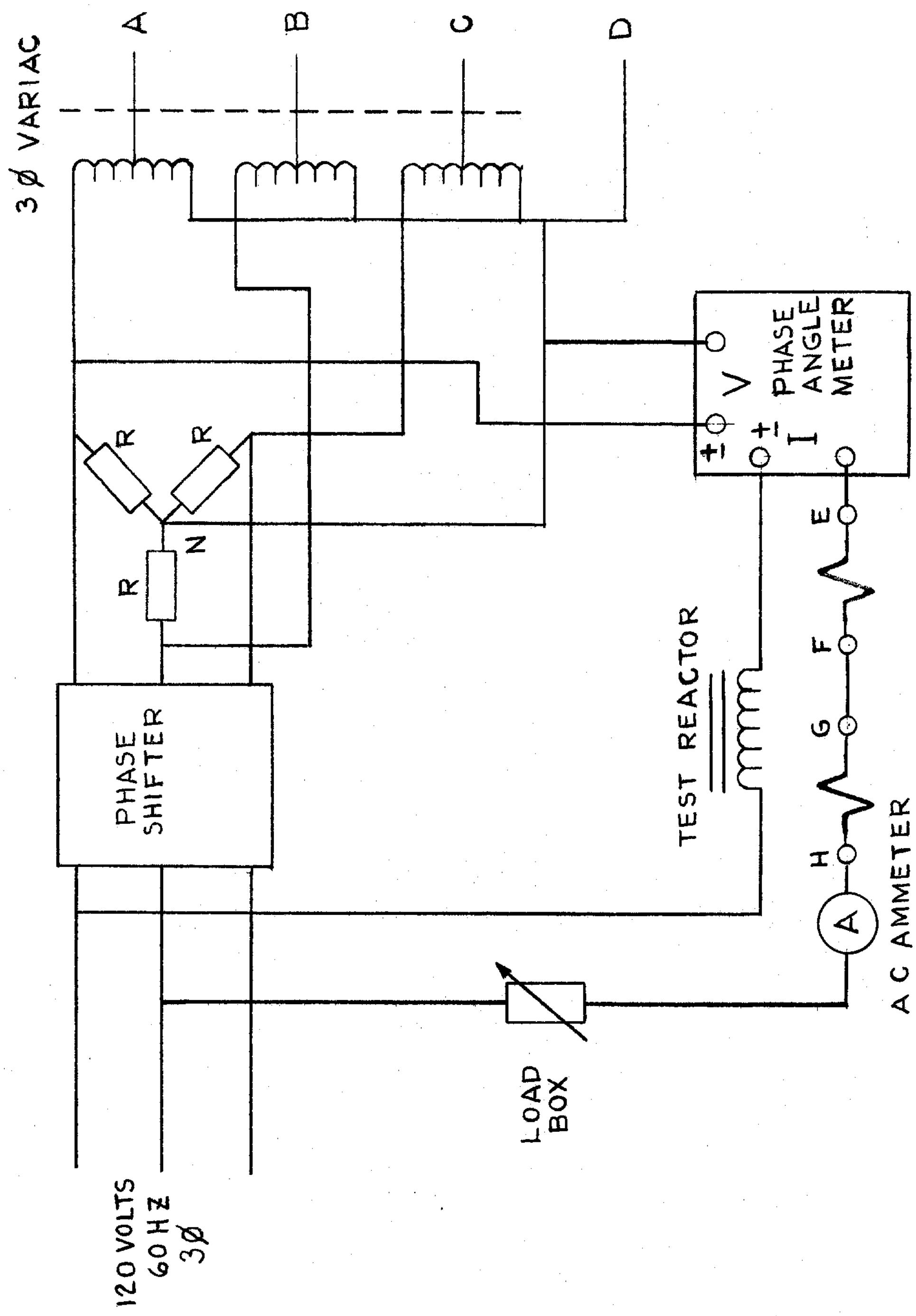


Fig. 7 (273A9547-0) Test Circuit for Offset MBG Characteristic Test

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