INSTRUCTIONS

GEK-45471A

SUPERSEDES GEK-45471

STATIC PHASE OFFSET MHO DISTANCE RELAY

TYPE SLY53B

GENERAL ELECTRIC

CONTENTS

OFFSET MHO DISTANCE RELAY

SLY53B

DESCRIPTION

The type SLY53B relay is a three-phase static mho distance relay with provision for offsetting the mho characteristic. One type SLY53B relay will detect all multi-phase faults that fall within its reach setting. The type SLY53B relay is packaged in a two-rack unit case, the outline and mounting dimensions of which are shown in Figure 8. Component locations are shown in Figure 7.

The SLY53B relay is not intended to be used by itself, but rather as a part of a complement of equipment that forms a protective relaying scheme. For example, in addition to the SLY53B, a typical directional comparison pilot-relaying scheme may be composed of a type SLC overcurrent relay, a type SLY phase tripping relay, a type SLYG ground relay, a type SLA logic relay, a type SLAT output relay and a type SSA power supply. Figure 12 illustrates typical external connections to the SLY53B relay when it is used in a directional comparison blocking scheme.

The type SLY53B relay outputs are d-c logic signals that are fed into a type SLA logic relay, the circuitry of which depends on the overall protection scheme. The static circuits of the SLY53B require $\pm$15V d-c which is obtained from a type SSA power supply. The internal connections for the SLY53B relay are shown in Figure 6.

The type SLY53B relay includes tap blocks for setting the reach in the blocking and offset directions. These reach settings are commonly referred to as MB* (blocking) and MB (offset).

For a complete description of the overall scheme in which this relay is employed, refer to the overall logic diagram and its associated logic description that is supplied with each complete terminal of equipment.

APPLICATION

The type SLY53B static distance relay with its offset mho characteristic is applied primarily to provide the carrier starting (i.e. blocking) function in directional comparison pilot-relaying schemes. However, it may also provide non-directional delayed backup protection via a suitable timing function in the associated SLA logic. The relay will provide protection against all multi-phase faults that fall within its reach setting.

The SLY53B relay is not intended for use by itself, but rather is meant to be used as part of a complement of equipment to complete a protective relaying scheme. The additional relays and other equipment required to complete a specific scheme are dependent on the nature of the scheme and are described in the logic description that accompanies the overall logic diagram for that particular scheme. Figure 12 illustrates typical external connections to the SLY53B relay when it is used in a directional comparison blocking scheme.

In a directional comparison blocking scheme, the blocking (carrier starting) functions at a given terminal must be able to detect all external faults in back of that terminal that are within the reach of the tripping (MT) functions at the remote terminal(s) of the protected line. Any effects of arc resistance that may be present must also be included. If this were not so, carrier would not be started for certain external faults, a blocking signal would not be sent, and the remote MT functions would initiate a false trip. This is illustrated in Figure 13 where the characteristics of the blocking function (MB) at station B and the tripping function (MT) at station A have been plotted on an R-X diagram. It will be noted that for any external fault along or near the angle of the protected line for which the MT function will operate at A, the MB function at B will also operate. However, for a fault just beyond terminal B with sufficient arc resistance to plot in the shaded area, the MT function at A is apt to operate while the MB function at B will not. For this condition a false trip could result. An increase in either the MB offset reach setting or its reach setting in the blocking direction, or both, would eliminate this source of trouble.

These instructions do not purport to cover all details or variations in equipment nor to provide for every possible contingency to be met in connection with installation, operation or maintenance. Should further information be desired or should particular problems arise which are not covered sufficiently for the purchaser's purposes, the matter should be referred to the General Electric Company.

To the extent required the products described herein meet applicable ANSI, IEEE and NEMA standards; but no such assurance is given with respect to local codes and ordinances because they vary greatly.

With reference to the above, 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 MB will suffice.

The reach settings for the SLY53B will depend to some degree on the specific application. Thus, for any given equipment, the description of the scheme that accompanies the logic diagram should be consulted for specific recommendations concerning the settings. However, as a general rule the following guide lines should be followed:

1. The reach setting in the blocking direction (MB*) should be based on whichever of the following two criteria results in the larger setting.
   a) The ohmic reach setting in the blocking direction should be at least as great as the ohmic reach setting of the MT function at the remote end of the line.
   b) The ohmic reach setting in the blocking direction should be at least twice as great as the remote MT function reach beyond the end of the line. That is, referring to Figure 13, the distance $\overline{BC}$ should be at least twice the distance $\overline{BD}$.

2. The offset, which is the reach in the tripping direction (MB), will be a fixed percentage, determined by tap setting (PR), of the reach in the blocking direction. This feature is described in detail in a later section on OPERATING PRINCIPLES AND CHARACTERISTICS. The combination of reach in the blocking direction (MB)* and the per unit offset multiplier (PR) should produce a reach in the tripping direction (MB) of at least 25 percent of the ohmic reach of the line.

3. Where required, the settings should be such that the shaded area on Figure 4 would be eliminated.

In order to actually make the settings discussed above, it is necessary to select basic tap settings and percent restraint settings. In general, the sensitivity of the MB function increases as the base reach is raised. Therefore, it is recommended that the highest base reach setting that will accommodate the desired reach setting should be used. In selecting the base reach setting for the reach in the blocking direction, it is necessary that the tap selected be at least equal to and preferably greater than the base reach setting used in the MT function at the remote end of the line. This must be done even if it means setting a larger circle diameter than initially contemplated. If this procedure is followed, the MB function in this relay will automatically coordinate with the MT function at the remote end of the line.

On three terminal lines, the same general considerations apply. The blocking function must detect all faults outside the protected area that can be detected by the MT tripping functions at the remote terminals. The application is more complex and the effects of infeed must be considered in setting the MT functions. Consequently, the settings of the blocking functions will be affected accordingly. Infeed affects tha apparent impedance seen by the MT functions and the fault can appear to be further away impedance-wise than it actually is. Increase in the infeed leads to an increase in the apparent impedance and consequently to an increase in the required reach settings of the MT functions. With infeed removed, the MT functions will reach considerably farther beyond the remote terminals. This must be considered in setting the blocking functions if they are not to be outreached by the tripping functions during zero infeed conditions.

There is a certain amount of flexibility in the recommended settings. In general, the larger the setting of the MB function relative to the remote MT function, the more secure will be the application. However, the gain diminishes rapidly beyond the recommendations given above. In any case, the MB function should not be set so big that maximum load and/or minor system swings will cause it to produce an output.

RATINGS

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

The current circuits of this relay are rated for 5 amperes, 60 hertz for continuous duty and have a one-second rating of 300 amperes. The potential circuits are rated for 120 volts, 60 hertz.

The relay requires a ±15 volt d-c power source which may be obtained from type SSA50 and up power supplies.

RANGES

The SLY53B has an adjustable reach of 0.1 to 30 ohms in the blocking direction with a selectable offset in the tripping direction of 0.0, 0.1, 0.2, 0.3 or 0.4 per unit of the reach in the blocking direction. Current input connections of 1 and 3 ohms exist in the current circuit and 10 to 100 percent (in 1 percent increments) restraint taps in the voltage circuit. In addition to the basic ohmic taps, the relay has a selectable base reach multiplier of 1.0, 0.5, 0.2 or 0.1. The unit has an angle of maximum reach which can be adjusted for 60 or 75 degrees in the tripping direction (240 or 255 degrees in the blocking direction).

BURDEN

The maximum potential burden per phase pair, measured at 120 volts is:

0.30 volt-ampere
0.24 watt
0.18 var

The maximum current burden per phase, measured at 5 amperes is:

$Z = 0.017\angle 40^{o}$ ohm
$R = 0.013$ ohm
$X = 0.011$ ohm

The maximum burden that the logic circuits present to the power supply is:

0.210 ampere to the +15 VDC supply
0.090 ampere to the -15 VDC supply

OPERATING PRINCIPLES AND CHARACTERISTICS

GENERAL

The offset mho characteristic of the relay is illustrated in Figure 1. This MB characteristic is a circle that does not pass through the origin of the IR-IX diagram. All measurements are made on a phase-to-phase basis (V_{a-b} is compared with I_a-I_b) in order to obtain the same relay reach for a phase-to-phase, a double phase-to-ground or a three-phase fault.

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 phase angle between the appropriate combinations to obtain the desired characteristic.

Currents are converted into IZ signals by means of transactors (TE, TG and TJ); that is, air gap reactors with secondary windings. The transactors in this equipment are tapped on the primary to obtain the current input connection (1 and 3 ohm).

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

The offset mho characteristic of Figure 1 is obtained by comparing the phase angle between the quantities (IZ-TV) and (IZ*+TV) where V is the phase-to-phase voltage at the relay, I is the phase-to-phase current, Z is the relay base reach in the tripping direction, Z* is the relay base reach in the blocking direction and T is the voltage restraint tap. For a circular characteristic, relay operation occurs when the angle B between (IZ-TV) and (IZ*+TV) is less than or equal to 90 degrees.

RELAY REACH

The base reach of the relay in the blocking direction (Z*) is determined by the current input connection (TB) and the base reach multiplier tap (BRM). The base reach in the blocking direction is equal to the product of the basic ohmic tap and the base reach multiplier tap, i.e.

$$Z^* = TB \cdot BRM \qquad \text{(Eq 1)}$$

As an example, assume that the relay is set on the 3-ohm current input connection with a base reach multiplier tap setting of 0.5. The base reach of the relay (Z*) will be (0.5)(3) or 1.5 ohms.

The base reach of the relay in the tripping direction (Z) is determined by the base reach in the blocking direction (Z*) and the per unit offset reach tap (PR). The base reach in the tripping direction is the product of the base reach in the blocking direction and the per unit offset reach, i.e.:

$$Z = Z^{*} \cdot PR = TB \cdot BRM \cdot PR \qquad \text{(Eq 2)}$$

As an example, assume the relay is set on the 3 ohm tap, with a base reach multiplier of 0.5 and a per unit offset of 0.2. The base reach in the tripping direction will be (3) (0.5) (0.2) or 0.3 ohms.

The reach of the MB function in the blocking direction at 255 degrees is given by the expression:

$$Z^{*}_{255} = \frac{Z^{*}}{T} \times 100 \qquad \text{(Eq 3)}$$

or

$$Z^{*}_{255} = \frac{T_B \cdot BRM}{T} \times 100 \qquad \text{(Eq 4)}$$

where:
- Z^{*}_{255} is the relay reach in the blocking direction at 255 degrees
- Z^{*} is the relay base reach in the blocking direction
- T is the voltage restraint tap in percent
- T_B is the current input connection
- BRM is the base reach multiplier.

The reach of the MB function in the tripping direction at 75 degrees is given by the relationship:

$$Z_{75} = \frac{Z}{T} \times 100 \qquad \text{(Eq 5)}$$

$$Z_{75} = \frac{T_B \cdot BRM \cdot PR}{T} \times 100 \qquad \text{(Eq 6)}$$

where:
- Z_{75} is the relay reach in the tripping direction at 75 degrees
- Z is the relay base reach in the tripping direction
- PR is the per unit offset
- TB, BRM, and T as defined above.

If the 100 percent voltage restraint tap is used, the reach of the relay at 75 degrees and 255 degrees is equal to the relay base reach in the tripping and blocking directions respectively. If a voltage tap other than 100 percent is chosen, the relay reach is increased in inverse proportion to the voltage restraint tap as demonstrated by equations 3 through 6. For example, if the 50 percent voltage restraint tap is used, relay operation still occurs for the same voltage on the secondary of the tapped autotransformer (TA, TB or TC); however, because the line voltage applied to the relay is twice this amount, the resultant relay reach is twice the base reach.

PHASE ANGLE MEASUREMENT

The operating quantities (IZ-TV) and (IZ^{*}+TV) are fed into a filter card (F156). This card filters out extraneous frequencies from the input quantities and produces square wave outputs. The phase relationship between these square waves is the same as that between the input quantities (IZ-TV) and (IZ*+TV). The coincidence of these square waves (coincidence is defined as having the same polarity) is determined by a coincidence logic circuit (C104). The output of the coincidence logic circuit is a pulse whose width is equal to the coincidence of the two square waves and thereby has a direct relationship to the phase angle between the square waves. Refer to Figure 2. The last function in the phase angle measurement circuit is a timer (T121) which measures the duration of the pulse produced by the coincidence logic. If the timer is set to pickup on a pulse of 4.17 milliseconds (90 degrees) a circular characteristic is generated. If the timer setting is less than 4.17 milliseconds, an expanded circle is generated. Refer to Figure 3. In this case, the angle between (IZ-TV) and (IZ*-TV) (Figure 1) is greater than 90 degrees.

SHAPE OF THE MB CHARACTERISTIC

If the angle of maximum reach of the relay is set for 75 degrees in the tripping direction (255 degrees in the blocking direction), the MB characteristic is symmetric about the angle of maximum reach for all timer settings. In order to plot the characteristic, convert the characteristic timer pickup setting from milliseconds to degrees using the following relationship:

$$C = 21.6\,P \qquad \text{(Eq 7)}$$

where: C is the characteristic timer pickup setting in degrees

P is the characteristic timer pickup setting in milliseconds

Construct two diameters, one on each side of the angle of maximum reach. Refer to Figure 4. The angle between these diameters and the angle of maximum reach is given by:

$$D = 90 - C \qquad \text{(Eq 8)}$$

where D is the angle between D_1 and D_2 and the angle of maximum reach

C is the characteristic timer pickup setting in degrees

Construct the perpendicular bisector of the maximum reach (Z plus Z*). The points at which this bisector intersects the diameters D_1 and D_2 are the centers of the two circular lobes of the MB characteristic. Use a compass to construct two circular arcs, centered at these intersections, which pass through the two ends of the maximum reach. Refer to Figure 4.

If the relay is set for a maximum reach angle of 60 degrees, the MB characteristic will be asymmetrical for timer settings other than 4.16 milliseconds (90 degrees). Refer to Figure 5. The reach of the characteristic at 75 degrees and 255 degrees remains constant when the angle of maximum reach or the timer setting is changed. The reach at these points is a function of the base reach and voltage restraint tap only.

To construct the characteristic, draw the reach of the relay at 75 degrees and 255 degrees. Draw the angle of maximum reach at 60 degrees. Calculate C and D from equations 7 and 8 respectively. Draw two diameters (D_1 and D_2) D degrees on either side of the 60-degree angle of maximum reach. Construct the perpendicular bisector of the relay reach at 75 degrees and 255 degrees. The intersection of this line with diameters D_1 and D_2 are the centers of the two circular lobes of the MB characteristic. Use a compass to construct two circular arcs, centered at these intersections, which pass through the two ends of the reach at 75 degrees. Refer to Figure 5.

CIRCUIT DESCRIPTION

The internal connections of the SLY53B relay are shown in Figure 6. The voltage inputs are on the upper left of the diagram. The current inputs are on the lower left. The YH and YG designations refer to twelve point terminal blocks located on the rear of the unit. The component and card locations are shown on the diagram of Figure 7.

The phase-to-phase input voltages are passed through transformers (TA, TB, TC) with one percent taps on the secondary. This voltage is then fed to the processing card in location D and into the operating circuit of one of the three filtering cards. The voltage is inverted on the processing card and then fed to the polarizing circuit of the filter card.

The input phase currents are passed through transactors (TE, TG, TJ). The three resulting voltages are then fed to the processing card in location E. This card develops three phase-to-phase IZ quantities, the Z of which can be changed by means of the Base Reach Multiplier (BRM) selector located on the card. The Base Reach Multiplier selector sets the Z of all three IZ quantities with one adjustment. The outputs of the card are fed to the operating circuit of the appropriate filter card where it is added to the phase-to-phase voltage signal to form the (IZ*+TV) quantity. The output is also fed to the processing card in location F. The Per Unit Offset Reach (PR) selector is located on this card. The output of this card is then fed to the polarizing circuit of the appropriate filter card where it is used to form the (IZ-TV) quantity.

The filter cards are used to filter the a-c signals and to produce square waves whose phase relationship is the same as between the quantities (IZ-TV) and (IZ*+TV). These two square waves are then fed into the coincidence logic circuit (L,M,N). The coincidence logic produces a +15 VDC output whenever the two input signals have the same polarity. The pulse width of the card output is proportional to the phase angle between (IZ-TV) and (IZ*+TV). The width of the pulse is measured by the timing circuit on the timer card

(P,R,S). The timer card produces an output whenever the fault falls within the MB characteristic. The circuitry for all three phase pairs is the same.

CHOICE AND CALCULATION OF SETTINGS

The following settings must be made in the SLY53B relay:

1. Reach in blocking direction (MB*)
   a) Current input connection (T_B - 1 ohm or 3 ohm)
   b) Base reach multiplier (BRM)
   c) Percent restraint tap setting (10-100)
2. Reach in tripping direction (offset, MB)
   a) Per unit offset reach tap (PR)
3. Angle of maximum reach
   a) 240 or 255 degrees in blocking direction
   b) 60 or 75 degrees in tripping direction (offset).

To illustrate the determination of the required settings assume that the line to be protected is a two-terminal line having the following characteristics:

$$Z_L = 21\angle 85^o \text{ primary ohms}$$

CT ratio = 2000/5

PT ratio = 3000/1

In terms of secondary ohms:

$$Z_L\ (\text{sec}) = Z_L\ (\text{pri}) \times \frac{\text{CT Ratio}}{\text{PT Ratio}}$$

$$= 21\angle 85^o \times \frac{400}{3000}$$

$$= 2.8\angle 85^o$$

Assume that the MT function at the remote end of the line is set for 4.5 secondary ohms at an angle of 75 degrees. Based on the considerations given in the section on APPLICATION, assume further that it is desired to set the MB reach in the blocking direction (MB*) for $5.2\angle 75^o$ ohms, and the offset in the tripping direction (MB) for approximately $0.75\angle 75^o$ ohms.

Since the angle of the protected line is 85 degrees, relay angle of maximum reach should be at the higher value, 75 degrees (i.e. 255 degrees). This is the normal factory setting.

The base reach in the blocking direction (Z^*) will be the product of the base reach multiplier (BRM) and base impedance (T_B) determined by the current input connection:

$$Z^* = T_B \times \text{BRM}$$

The base reach Z^* should be the highest attainable value that is less than the required reach of the MB unit in the blocking direction, in this case $5.2\angle 75^o$ ohms. Therefore, T_B should be on the input connection that results in the 3 ohm base ohms, and the base reach multiplier should be on the one tap.

The required reach of the relay, $5.2\angle 75^o$ ohms, is now obtained by the percent restraint tap setting T:

$$Z^*_{255} = \frac{Z^*}{T} \times 100$$

$$= \frac{T_B \times \text{BRM}}{T} \times 100$$

or
$$T = \frac{T_B \times BRM}{Z^*_{255}} \times 100$$

$$= \frac{3 \times 1}{5.2} \times 100 = 58 \text{ percent}$$

It will be noted that in many cases it will be possible to obtain a base reach (Z^*) less than the required reach setting (Z^*_{255}) by using either of the two current input connections (1 or 3 ohms). It is recommended, however, that the 3 ohm base ohms connection be used whenever possible.

Now that the base reach and percent restraint taps have been determined in the example, the per unit offset tap (PR) must next be calculated. This is determined from equation 6:

$$Z_{75} = \frac{T_B \times BRM \times PR}{T} \times 100$$

It was previously assumed that an offset (Z_{75}) of $0.75\angle 75^\circ$ was required. Therefore:

$$0.75 = \frac{3 \times 1 \times PR}{58} \times 100$$

$$PR = \frac{.75(58)}{3(1)(100)} = 0.145$$

It is suggested that the 0.2 PR tap be used, which will result in an offset in the tripping direction of approximately one ohm.

CONSTRUCTION

The Type SLY53B 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 Figure 8. 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 phase-to-phase mho blocking characteristics. The relay has a hinged front cover and a removable top cover.

The current input setting is accomplished by the connection of the input currents to the YG terminal board on the rear of the relay. The connection points for the one and three ohm taps are shown in the table on the internal connection diagram of Figure 6.

The voltage restraint tap blocks are located on the front of the unit at the left hand side. Refer to the component location diagram of Figure 7. The voltage restraint tap settings are made by jumpers with taper tip pins on the end. Two special tools are supplied for these pins in the accessory kit accompanying each equipment. One is an insertion tool and the other is an extraction tool. In order to achieve a proper connection and not to damage 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.

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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 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.

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, and 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 D-C 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 +15VDC. Output signals are measured with respect to the relay reference (TP1). Logic signals are approximately +15VDC for the ON or LOGIC ONE condition, and between 0 and +1VDC 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 whould 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 CHOICE AND CALCULATION OF SETTINGS. The adjustments should be made in the order shown.

1. Base reach setting (Z, Z^*)
   a) Current input tap selection (T_B)
   b) Base reach multiplier selection (BRM)
   c) Per unit offset reach selection (PR)
2. Voltage restraint tap setting (T)
3. Angle of maximum reach setting

4. Characteristic timer setting
5. Reach vernier adjustment
6. MB characteristic plot

DETAILED TESTING INSTRUCTIONS

RELAY BASE REACH

The current input tap (TB) is determined by the terminals to which the relay input currents are connected to the relay. The correct input terminals for the one and three ohm current input taps are given in Table I.

TABLE I

	IA		IB		IC	
BASE OHMS	IN	OUT	IN	OUT	IN	OUT
1 OHM	YH8	YG4	YH9	YG6	YH10	YG8
3 OHM	YH8	YG3	YH9	YG5	YH10	YG7

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 pair 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.

TABLE II

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

The per unit offset reach 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 pair is set to the proper value of per unit offset reach multiplier. The per unit offset reach for each jumper position on the card is shown in Table III.

TABLE III

JUMPER POSITION	PER UNIT OFFSET REACH (PR)
A	0.0
B	0.1
C	0.2
D	0.3
E	0.4

The relay base reach in the reverse direction (Z*) is given by equation 1. The relay base reach in the forward direction (Z) is given by equation 2.

VOLTAGE RESTRAINT TAP SETTING

The voltage restraint tap setting (T) is accomplished on the tap blocks located on the front of the relay. A separate tap block is 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. The reach of the relay at 255 degrees is given by equation 3 or 4. The reach of the relay at 75 degrees is given by equation 5 or 6.

ANGLE OF MAXIMUM REACH SETTING

The angle of maximum reach of the relay is set by adjusting the position of plug X on the cards in locations H, J and K. There are two positions for the jumper plug, one for a 75 degree angle of maximum reach and one for a 60 degree angle. The setting must be made on each of the three filter cards. The angle of maximum reach for each position is shown in Table IV.

TABLE IV

PLUG X SHORTING ARRANGEMENT	ANGLE OF MAXIMUM REACH
2 to 3 and 4 to 5	75°
1 to 2 and 3 to 4	60°

CHARACTERISTIC TIMER SETTING

The pickup setting of the characteristic timer affects the shape of the MB characteristic. Increasing the pickup time tends to narrow 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 and provides a time delay before resetting after the input signal is removed. The inputs of the timers are +15V pulses whose width is proportional to the phase angle between (IZ-TV) and (IZ*+TV). One pulse occurs every half cycle. The outputs of the timers are d-c logic signals. The timer settings are discussed in the section CHOICE AND CALCULATIONS 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 d-c input, T2 is the pulse width which will cause the timer to pickup 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 d-c pickup (T1) and the dropout (T3) of the MBG characteristic timer may be set using the test circuit of Figure 10. 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 Figure 10 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 dropout (step to less than 1VDC) 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

TIMER UNDER TEST	REMOVE CARD
P	L
R	M
S	N

OVERALL CHECK OF THE MB CHARACTERISTIC

An overall check of the MB characteristic can be made by applying current and voltage to the relay and plotting the MB characteristic on an R-X (ohms) or IR-IX (voltage) diagram. This plot may be compared with a theoretical characteristic plotted following the directions given in the section SHAPE OF THE MB CHARACTERISTIC.

* The MB characteristic may be checked using the test circuit of Figure 11. The connections for testing each of the three phase pairs are listed in Table VI for one ohm tap and Table VII for three ohm tap.

*Indicates Revision

** TABLE VI

FIGURE 11 CONNECTION POINTS, 1 OHM CURRENT TAP

	A	B	C	D	E	F	OUTPUT
PHASE 1-2	YH2	YH3	YH8	YG4	YG6	YH9	TP4
PHASE 2-3	YH4	YH5	YH9	YG6	YG8	YH10	TP6
PHASE 3-1	YH6	YH7	YH10	YG8	YG4	YH8	TP8

** TABLE VII

FIGURE 11 CONNECTION POINTS, 3 OHM CURRENT TAP

	A	B	C	D	E	F	OUTPUT
PHASE 1-2	YH2	YH3	YH8	YG3	YG5	YH9	TP4
PHASE 2-3	YH4	YH5	YH9	YG5	YG7	YH10	TP6
PHASE 3-1	YH6	YH7	YH10	YG7	YG3	YH8	TP8

The following procedure should be used for each of the three phase pairs.

** a) Use the test circuit of Figure 11 and the appropriate connections from Table VI or VII.

b) Set the input current for 5 amperes (rms). Set the input voltage for 120 volts (rms).

c) Set the phase shifter for the angle of interest.

d) Lower the input voltage until the output (TP4, TP6 or TP8) steps to +12 - +15VDC.

e) Record the voltage and angle.

By varying the phase angle, the operating point voltage may be determined for the whole characteristic and plotted on polar paper.

The operating voltage at 75 degrees is given by the expression:

$$V = \frac{2IZ}{T} \times 100 \qquad \text{(Eq 9)}$$

where:

I is the 5 ampere test current

Z is the base reach in the tripping direction as given by equation 2

T is the voltage restraint tap setting in percent

V is the pickup voltage at 75 degrees.

The reach at 75 degrees should be within five percent of the calculated value. The pickup voltage at 75 degrees may be adjusted by P52 on the appropriate filter card. Turning P52 clockwise increases the voltage needed to pick up the MB function.

The operating voltage at 255 degrees is given by the expression:

** $$V = \frac{2IZ^*}{T} \times 100 \qquad \text{(Eq 10)}$$

where:

I is the 5 ampere test current

Z^* is the base reach in the blocking direction as given by equation 1

T is the voltage restraint tap setting in percent

V is the pickup voltage at 255 degrees.

The reach at 255 degrees should be within five percent of the calculated value.

The pickup voltage at 255 degrees may be adjusted by P10 on the appropriate filter card. Turning P10 lockwise increases the voltage needed to pick up the MB function.

**Indicates Revision

Each filter card contains two factory adjusted and sealed potentiometers: P27 and P61. These potentiometers are used in setting the filter circuits used on the cards and should not be adjusted by the user.

PERIODIC CHECKS AND ROUTINE MAINTENANCE

PERIODIC CHECKS

The MB functions included in the relay may be checked at periodic intervals using the procedures described in the DETAILED TESTING INSTRUCTIONS section. Cable connections between the relay and the associated Type SLA relay can be checked by observing the relay outputs at points in the SLA relay.

TROUBLE SHOOTING

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 busses, 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 busses 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, Figure 7.

TERMS

IZ - voltage output of transactor proportional to input current

TB - basic ohmic tap (in ohms)

T - voltage restraint tap (in percent)

Z - base reach in tripping direction

Z* - base reach in blocking direction

BRM - base reach multiplier (P.U.)

PR - per unit offset (P.U.)

B - angle between (IZ-V) and (IZ*+V)

MB - mho blocking function

C - characteristic timer pickup setting in degrees

P - characteristic timer pickup setting in milliseconds

D1,D2 - diameter of MB lobs

D - angle between D1 and D2 and angle of maximum reach

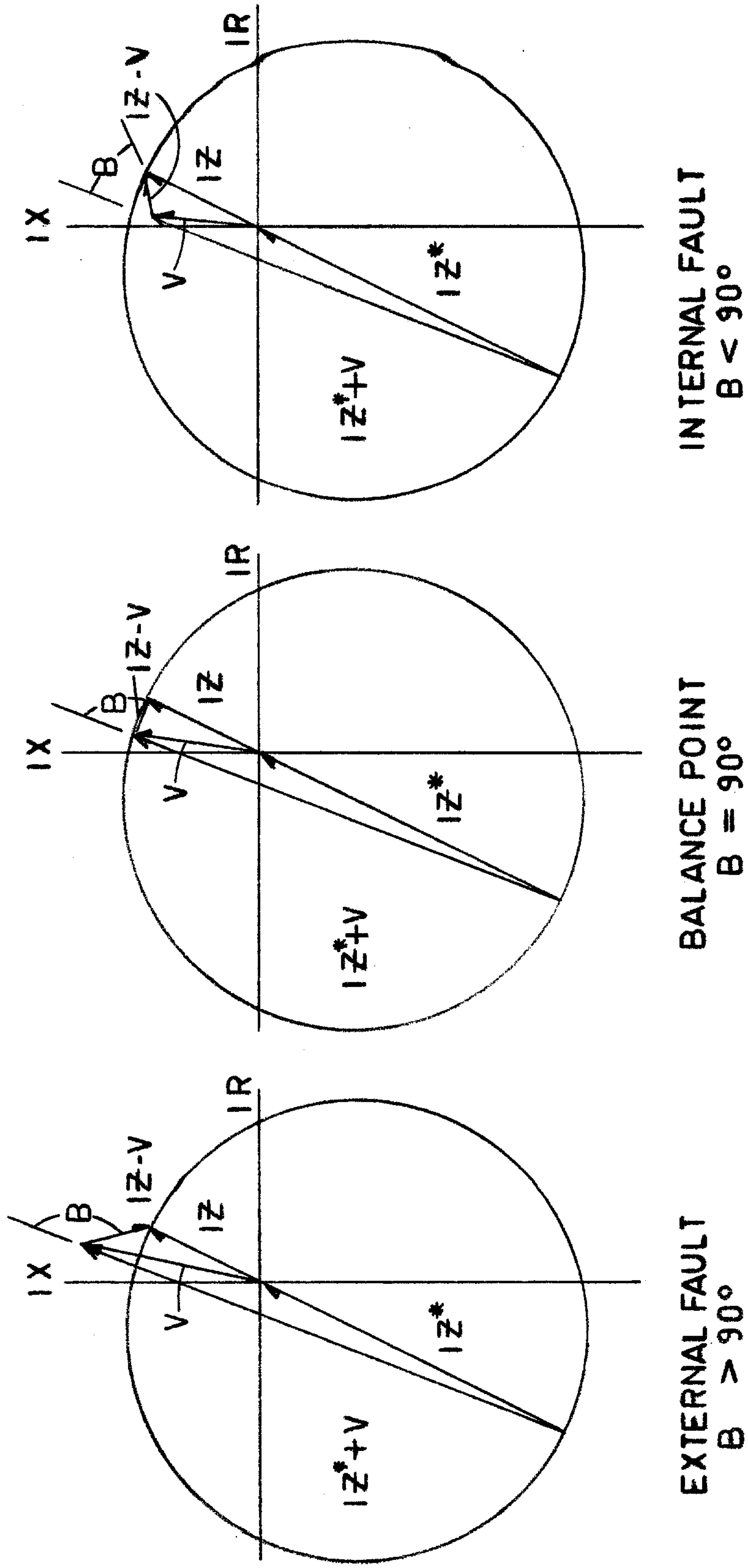
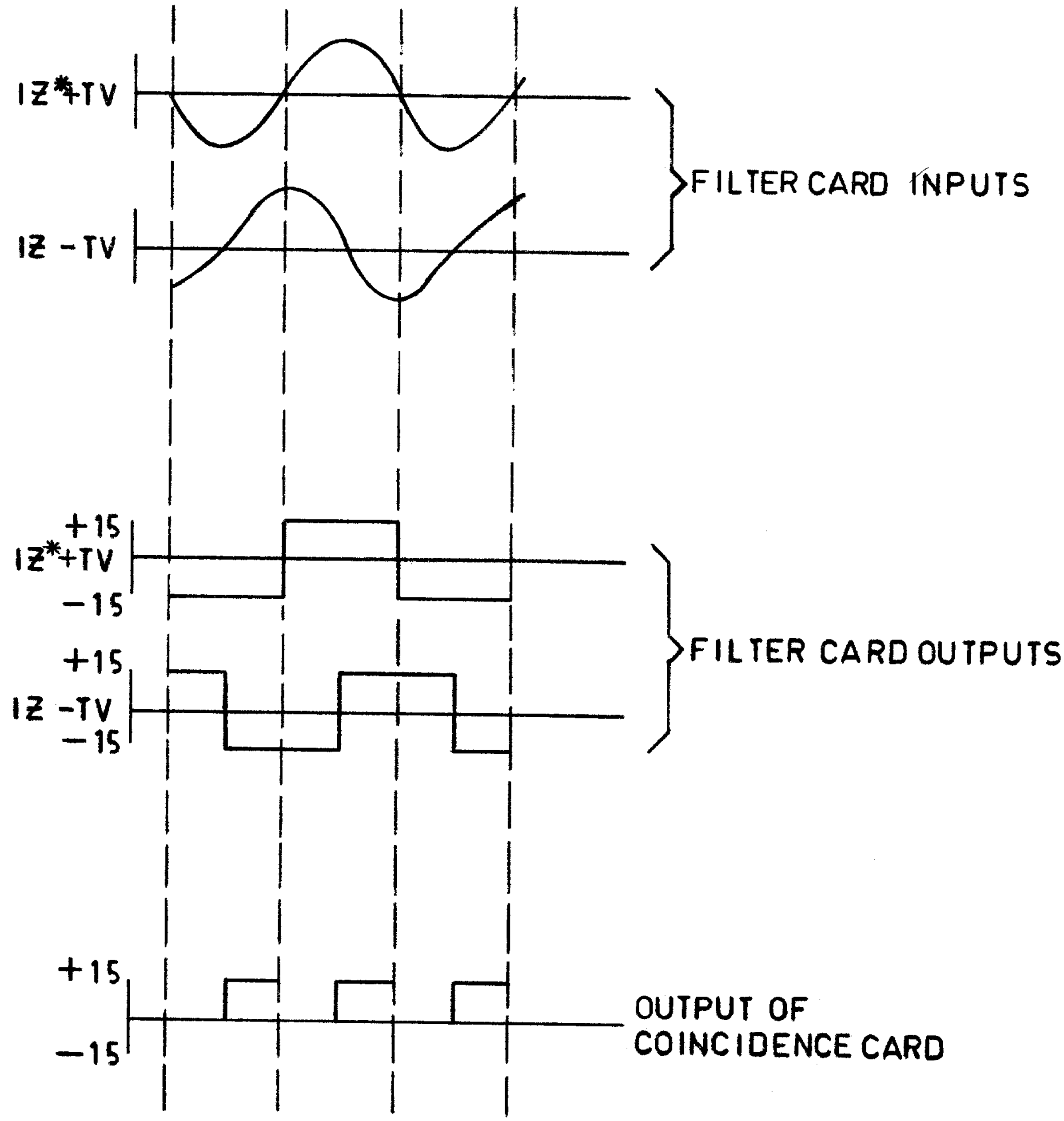


Fig. 1 (0269A3109-0) OFFSET MHO CHARACTERISTIC BY PHASE ANGLE MEASUREMENT



NOTE: THESE WAVEFORMS ARE SHOWN IN SIMPLIFIED FORM. NORMALLY THE FILTER CARD OUTPUTS ARE PHASE SHIFTED WITH RESPECT TO THE INPUT.

Fig. 2 (0269A3110-0) OPERATING QUANTITY WAVEFORMS

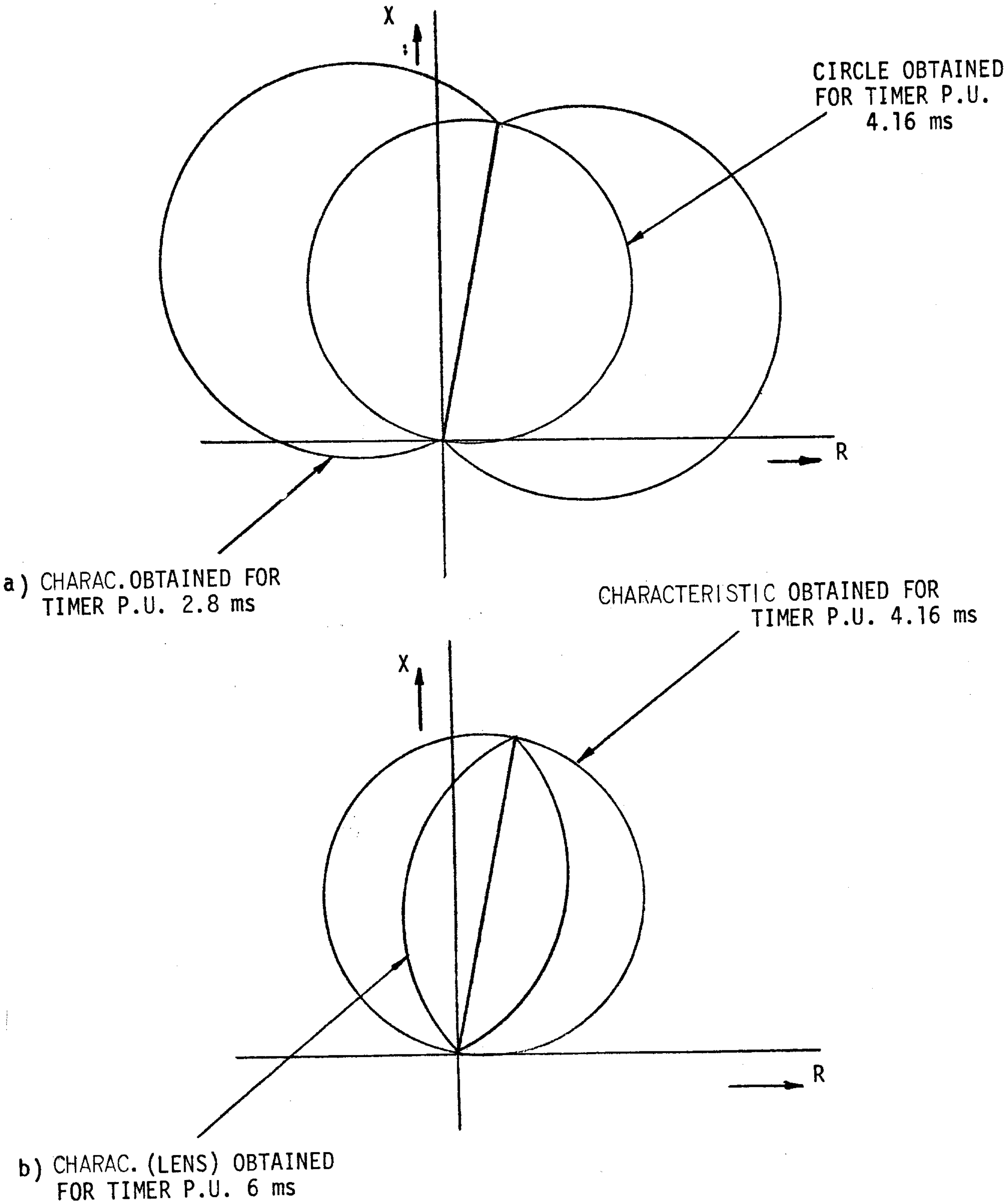
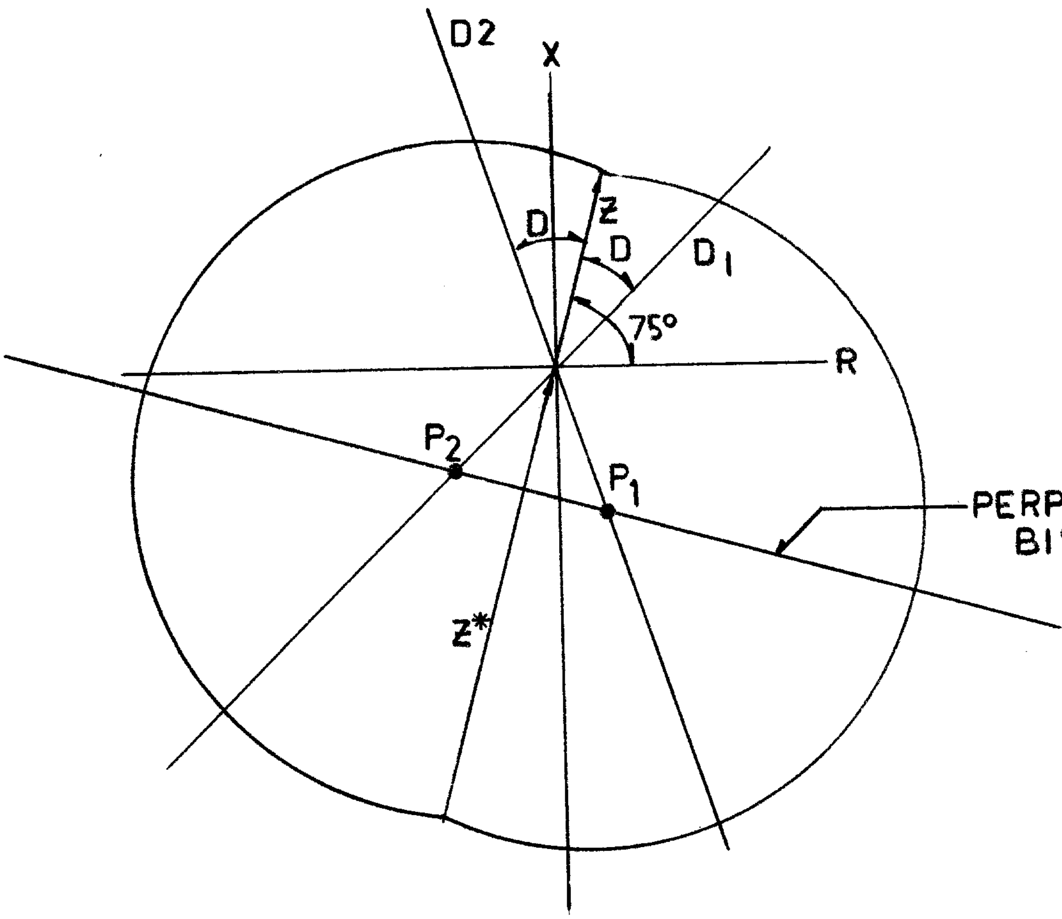
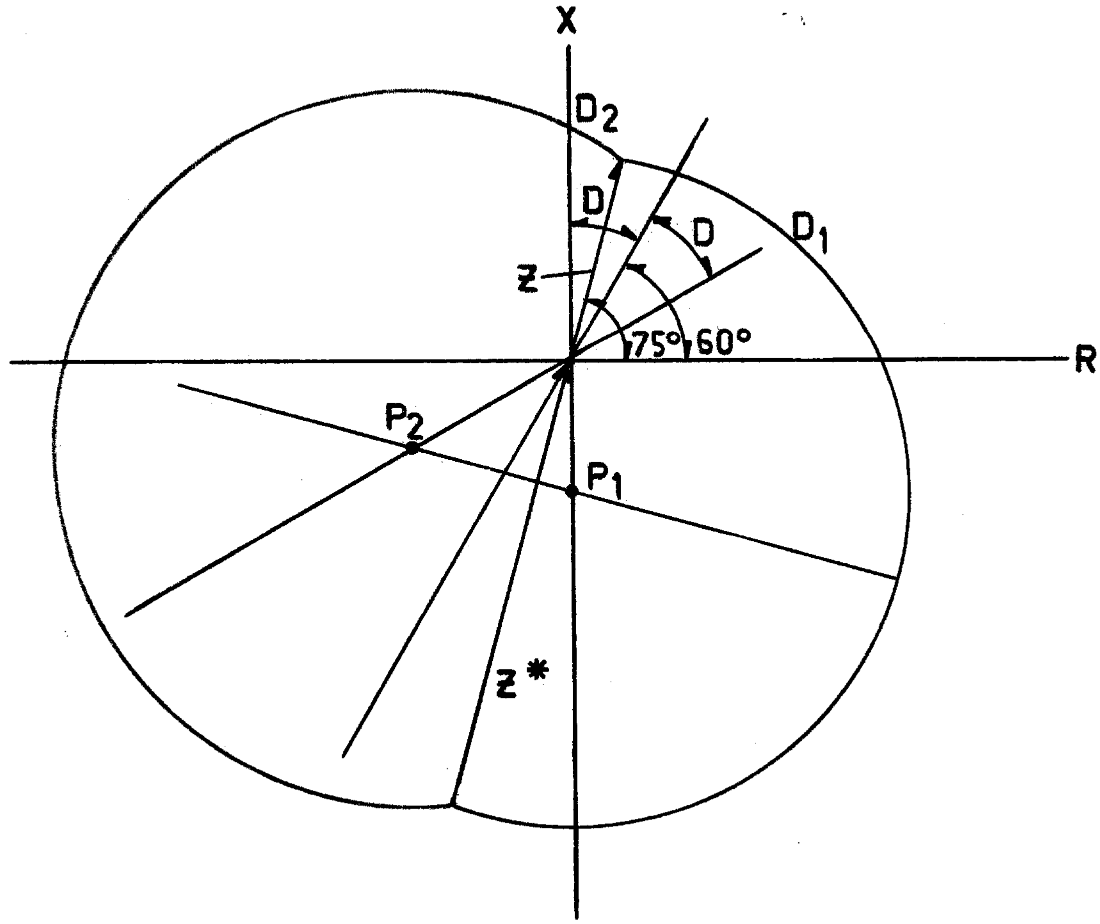


Fig. 3 (0226A7034-0) MHO CHARACTERISTIC VARIATIONS WITH PICKUP TIME SETTING



P = 2.78 MS
C = 21.6 X 2.78 = 60°
D = 90-60 = 30°
P_1, P_2 : CENTER OF CIRCULAR ARCS

Fig. 4 (0269A3111-0) PLOTTING THE MB CHARACTERISTIC AT 75° ANGLE OF MAXIMUM REACH



P 2.78 MS
C 21.6 X 2.78 = 60°
D 90-60 = 30
P_1 P_2 CENTER OF CIRCULAR ARC

Fig. 5 (0269A3112-0) PLOTTING THE MB CHARACTERISTIC AT 60° ANGLE OF MAXIMUM REACH

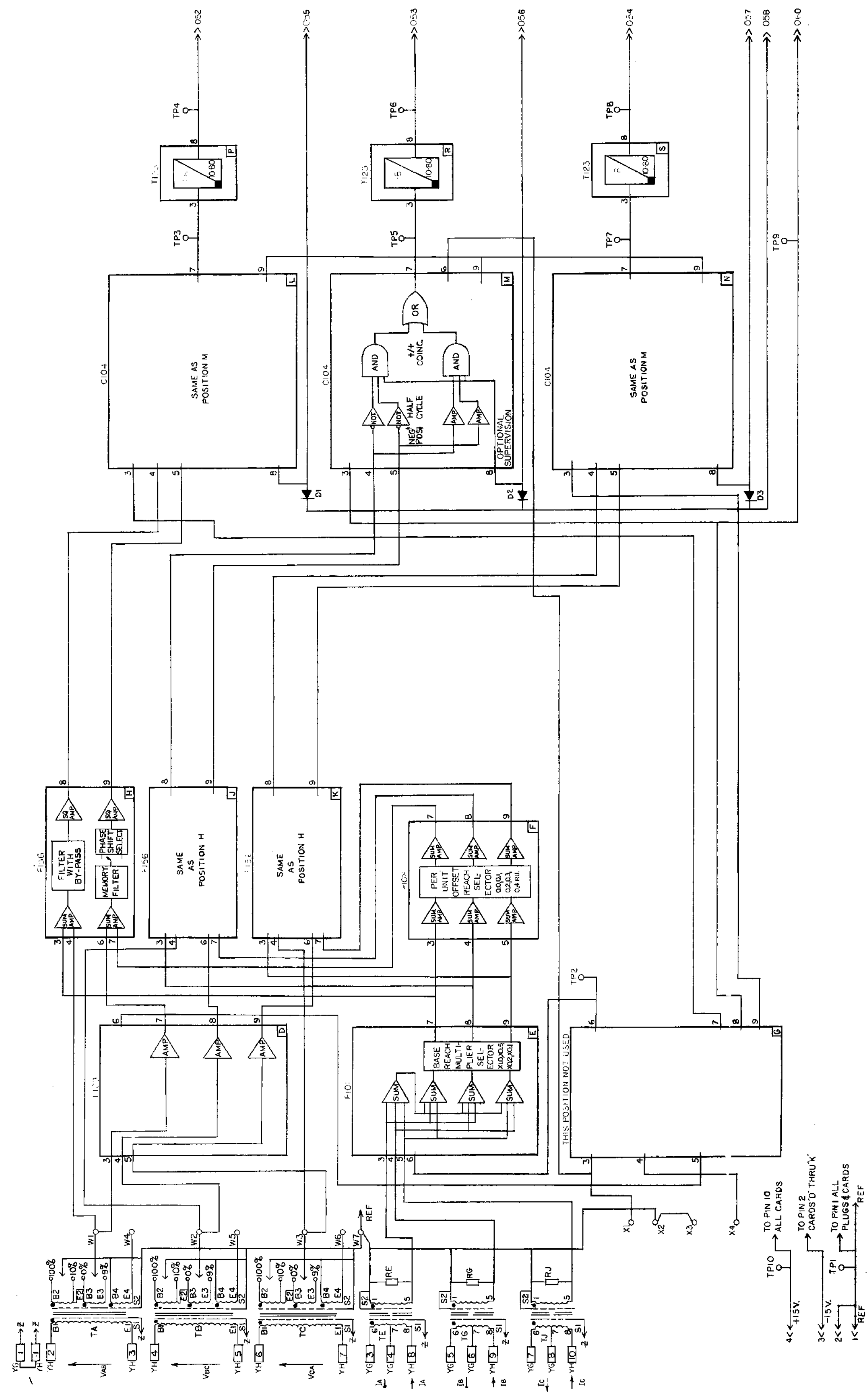


Fig. 6 (0136D1466-1) INTERNAL CONNECTIONS FOR THE SLY53B RELAY

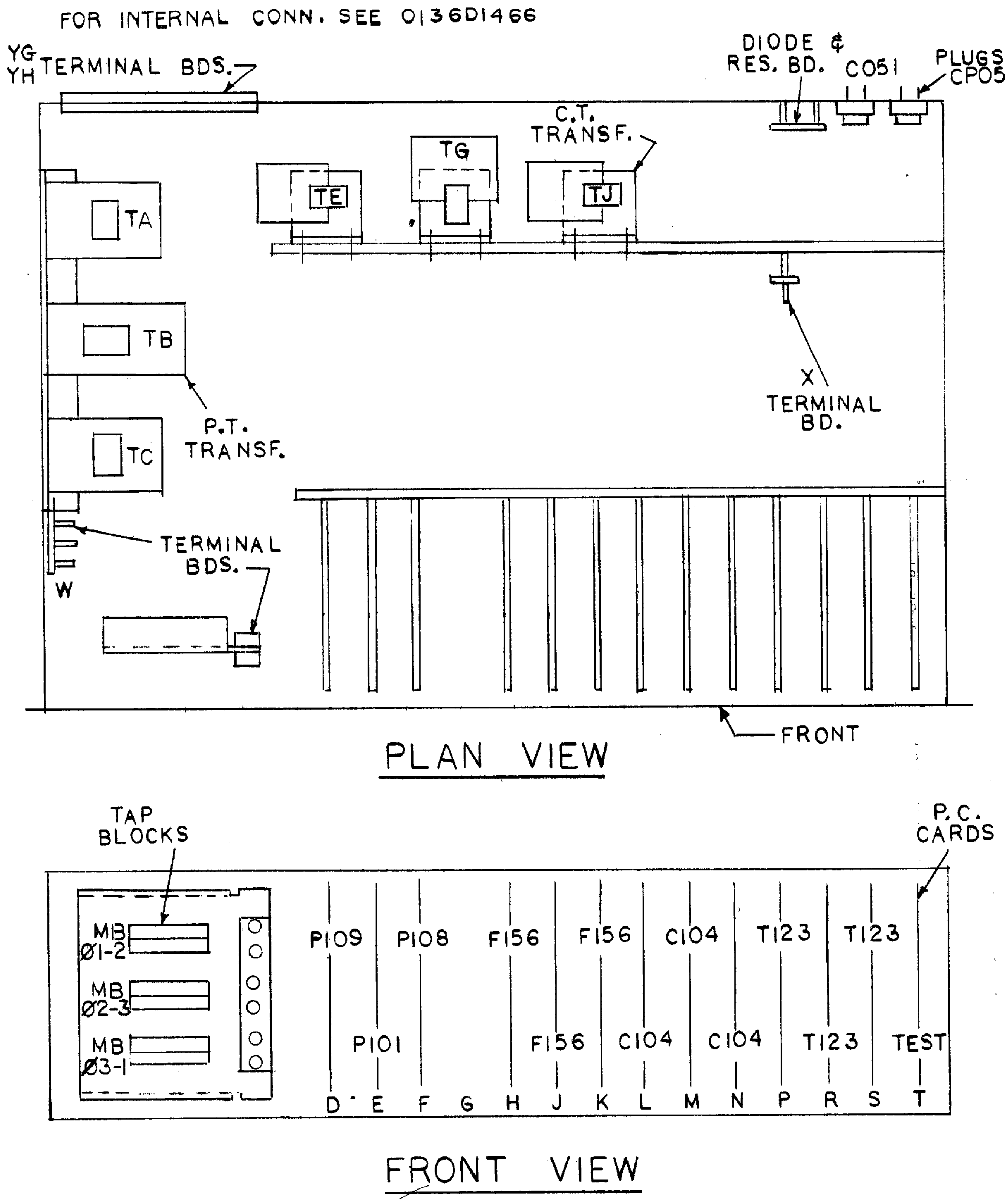


Fig. 7 (0257A8742-0) COMPONENT AND CARD LOCATION DIAGRAM FOR THE SLY53B

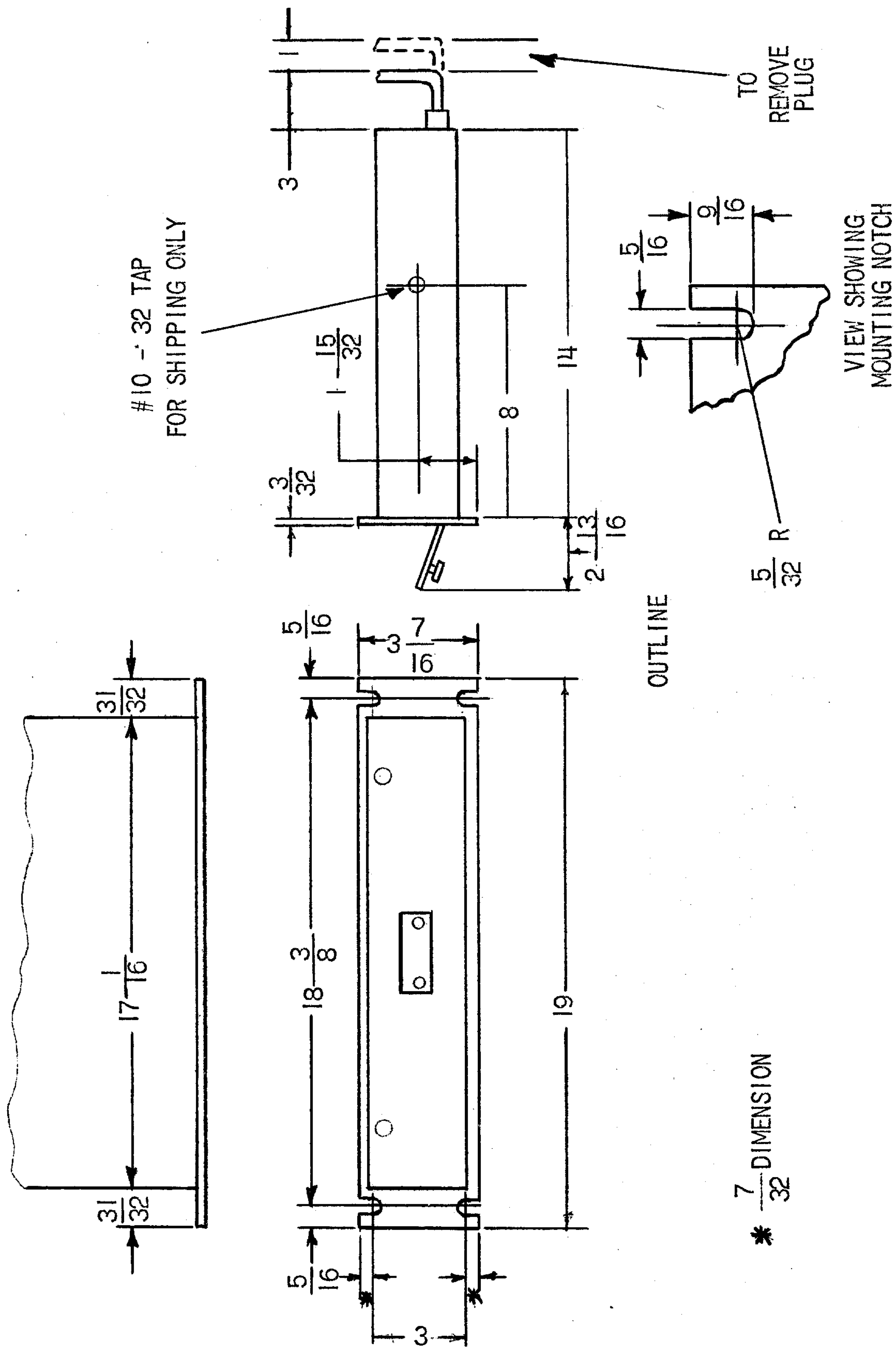


Fig. 8 (0227A2036-0) OUTLINE AND MOUNTING DIMENSIONS FOR THE SLY53B RELAY

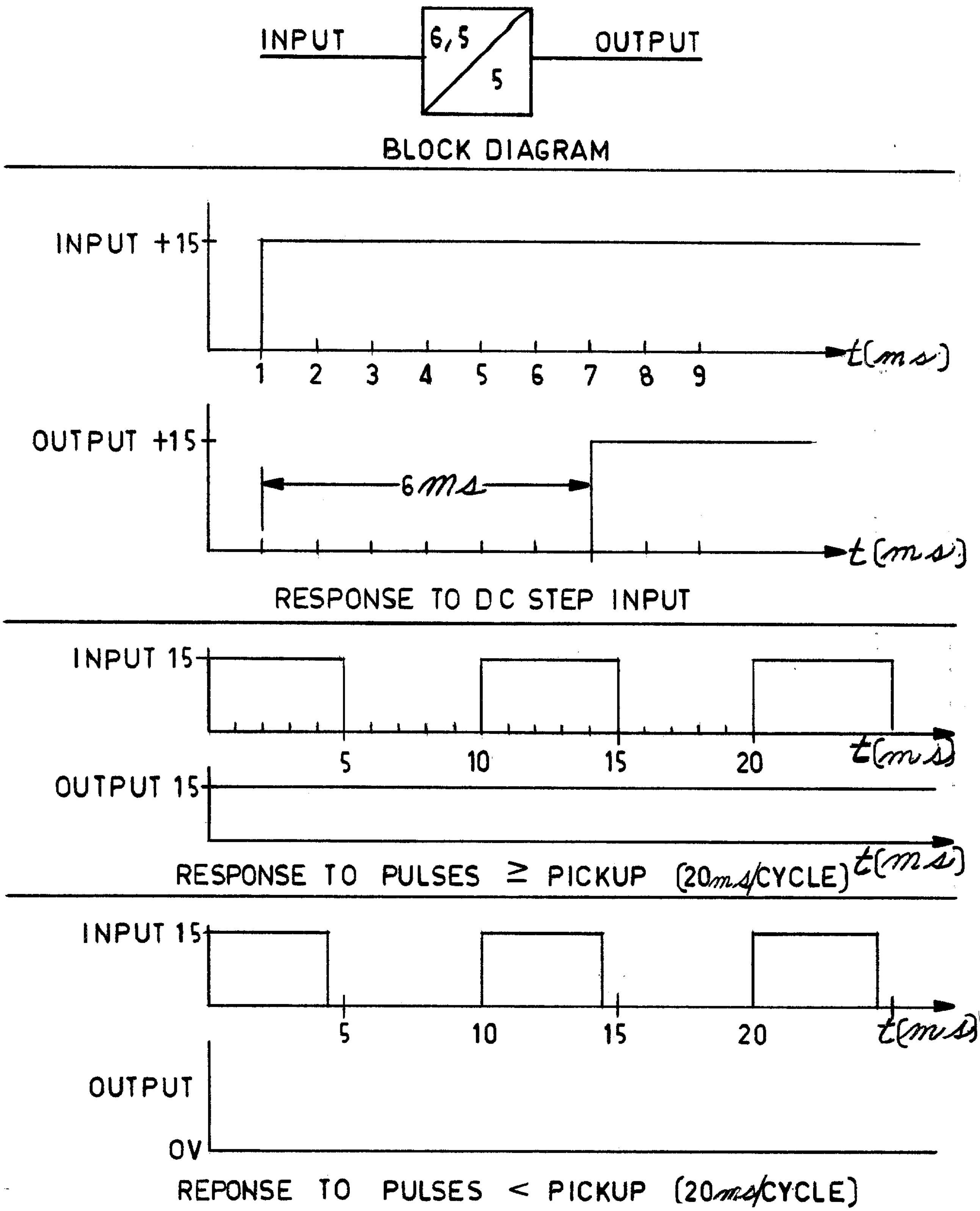
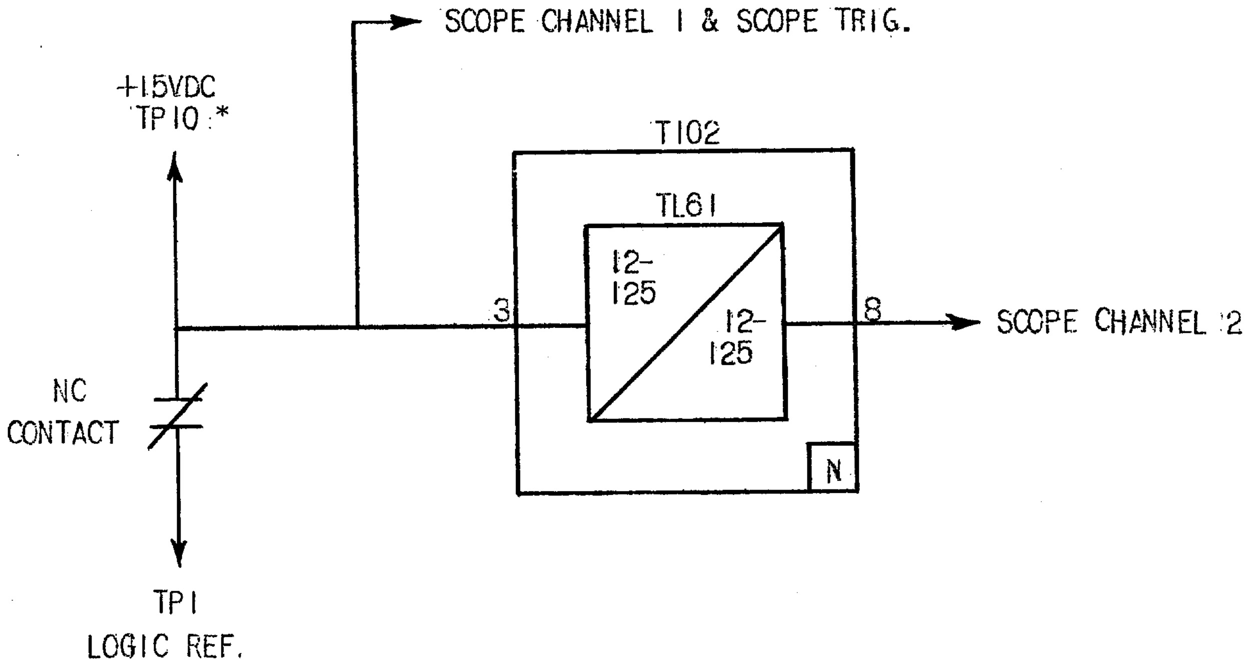


Fig. 9 (0257A9624-0) INTEGRATING TIMER PICKUP WAVEFORMS



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

Fig. 10 (0246A7987-0) LOGIC TIMER TEST CIRCUIT

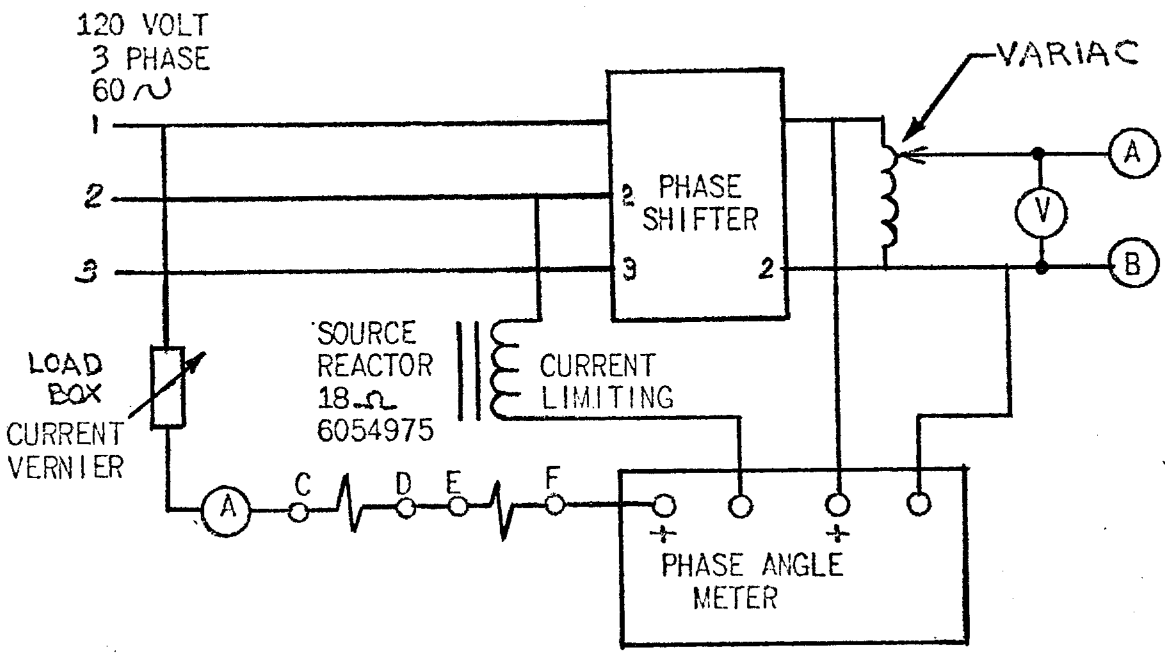


Fig. 11 (0178A7029-3) SLY53B CHARACTERISTIC TEST CIRCUIT

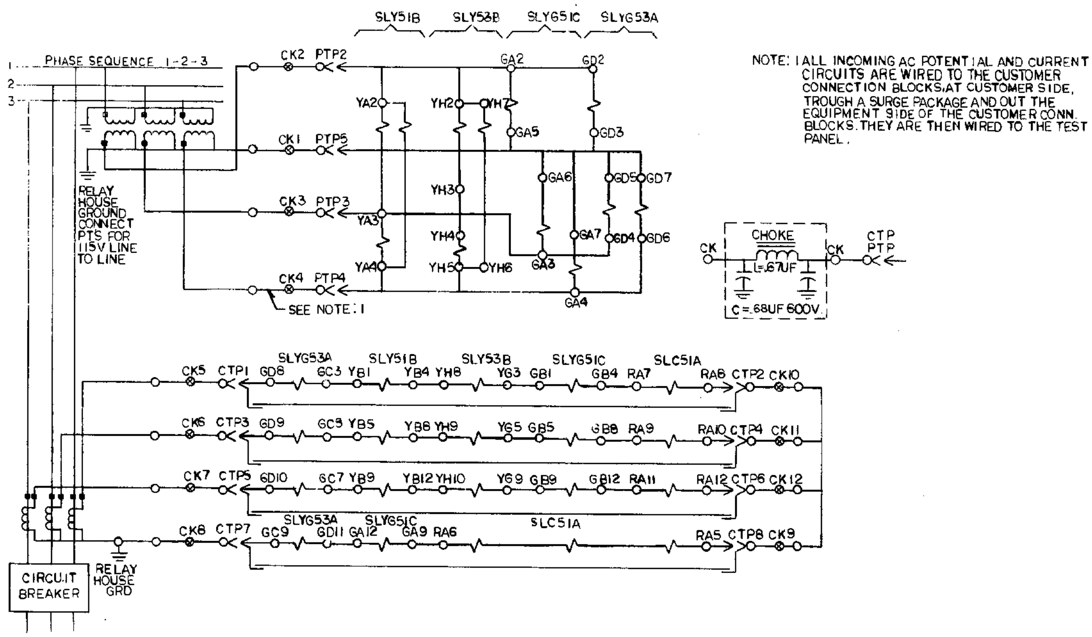
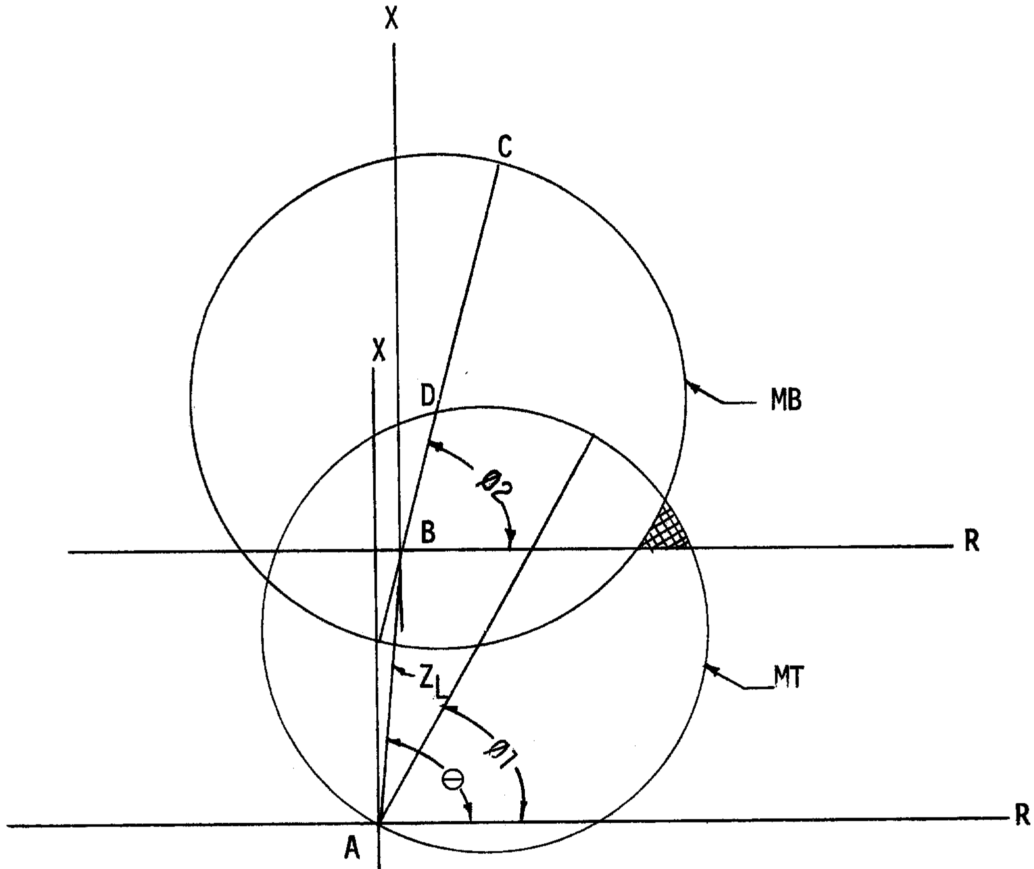


Fig. 12 (0188B9706-0) TYPICAL AC EXTERNAL CONNECTIONS FOR THE SLY53B



MT = 150% of Z_L
Ø1 = ANGLE OF MAX. REACH OF MT = 60°

MB = 30% OF Z_L
MB* = 150% of Z_L
Ø2 = ANGLE OF MAX. REACH OF MB = 75°

θ = ANGLE OF Z_L = 85°

Fig. 13 (0246A6818-0) RX DIAGRAM SHOWING RELATIONSHIP OF MT AND MB IN DIRECTIONAL COMPARISON SCHEME

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