INSTRUCTIONS

GEK- 34012 C
Insert Booklet GEK-7386

STATIC GROUND DISTANCE RELAY

TYPE SLCG12B

GENERAL ELECTRIC

CONTENTS

STATIC GROUND DISTANCE RELAY

TYPE SLCG12B

DESCRIPTION

The Type SLCG12B relay is a static lens-type ground distance relay designed to provide high-speed detection of ground faults in combination with the SLD43A phase comparison relay, SLYL11B phase relay, and SLA17C auxiliary logic and tripping relay in a single-pole tripping scheme. These instructions supplement the basic SLCG instructions, GEK-7386, which are included in this book. The addition of the two forms completes the total instructions for the Type SLCG12B relay.

The Type SLCG12B relay includes three ground lens tripping units identified as $LTG_{\phi C}$, $LTG_{\phi B}$, and $LTG_{\phi A}$, which are connected to operate as faulted-phase selectors for ground faults in the single-pole tripping scheme. These are distance-measuring functions having offset lens characteristics. The relay also has a high-set ground overcurrent unit G4 which is employed with the ground lens (LTG) units to provide direct tripping of the faulted phase; a time-delay trip function (TU/G) which is initiated by operation of any one of the LTG units, plus FDL in the SLD43A relay, which provides time delay backup tripping; and various logic functions which are necessary to provide single-pole tripping in combination with the SLD43A relay.

The Type SLCG relay is packaged in two separate cases. One case, three rack units (1 3/4 inches equals one rack unit), houses the network unit which contains the magnetic circuits and tap adjustments for setting the reach of the LTG functions. A potentiometer is provided to set the overcurrent function pickup level. Figure 1 illustrates the outline and mounting dimensions for this unit, Figure 2 shows the location of adjustments, Figure 3 indicates the location of components, and internal connections of the network unit appear in Figure 4. The remaining case, two rack units, houses the logic unit which contains the printed circuit cards and isolation transformers for the SLCG functions. The outline and mounting dimensions are shown in Figure 5. The printed circuit cards plug in from the access in the front of the unit into sockets. The letter addresses (D, E, and F) appear on the guide in front of each socket, on the location of components diagram, Figure 6, and on the logic unit internal diagram, Figure 7. The test points (TP2, TP3, etc.) shown in Figure 7 are connected to instrument jacks on the test cards in positions S and T (with TP1 at the top). Also included in the logic unit are push buttons $LTG_{\phi C}$, $LTG_{\phi B}$, and $LTG_{\phi A}$ which can be used to simulate operation of the LTG functions.

The Type SLCG12B relay must be used with a Type SSA dc power supply which provides a regulated +17 volt dc output with bias levels of 0.6 volts and 15.6 volts. The outputs of the SLCG12B are logic voltages for the SLD43A and SLA17C relays. Signal connections between the SLCG12B network and logic units, between the SLCG12B logic unit and SSA power supply, and SLD43A and SLA17C relays are made by plug-in, multiconductor shielded cables. The incoming current and potential connections are made by a ten-conductor cable which plugs into the TLA Test and Connection Receptacle, illustrated in Figure 8. The receptacle allows disconnection from CT's and PT's by removal of the connection plug and AC testing with the standard Type XLA relay test plug.

For a complete description of the overall scheme in which this relay is employed, refer to the overall logic diagram and the associated memorandum that covers the specific components involved in the scheme.

RANGES

The following ranges of adjustment are incorporated in the Type SLCG12B relay:

LTG FUNCTION (offset lens)

Reach in tripping direction; 2-20; 6-60 ohms at 85 degrees (phase-neutral ohms)

G4 FUNCTION (non-directional overcurrent)

Range of Adjustment; 2-20 amperes
10-80 amperes

TU/G TIMER: 0.1 - 2.0 seconds

Note that subsequent to this writing additional ranges may have been made available; check nameplate on relay for confirmation of ranges.

RATINGS

THERMAL

The Type SLCG12B relay is designed for use in an environment where the ambient air does not exceed 55°C.

ELECTRICAL

The current circuits of the Type SLCG12B relay are rated at 5 amperes, 50 hertz, for continuous duty, with a one-second rating of 250 amperes.

The potential polarizing circuit and the restraint circuit are both rated 70 volts, 50 hertz, line-to-neutral continuous.

BURDENS

The maximum current burden at 5 amperes 50 hertz imposed on one CT for a single-phase-to-ground fault condition is approximately 6 volt-amperes.

The maximum potential burdens approximately are tabulated below.

CIRCUIT	VOLTS	FREQUENCY	V.-A
Polarizing	70	50 Hz.	10
Restraint	70	50 Hz.	2

The Type SLCG12B relay presents a burden of approximately 250 milliamperes to the equipment power supply.

APPLICATION

The Type SLCG12B relay is normally applied in conjunction with the SLD43A relay in a phase-comparison relaying scheme with single-pole switching. It includes three LTG ground lens units, one per phase, which are used as the faulted-phase selectors in the single-pole tripping scheme.

The tap block (network) unit includes zero sequence current compensation circuits and the necessary auxiliary current transformer is provided with the relay. It is recommended that the zero sequence current compensation feature always be used with this relay. With compensation the relay responds essentially to the positive sequence impedance between relay and fault. This permits a shorter reach setting on the lens function which is an advantage on a single-pole application since there is then less exposure to operation of more than one phase LTG function on a single-phase-to-ground fault.

Since the Type SLCG12B relay uses phase-to-neutral voltage, the magnitude of fault resistance which can be accommodated during a phase-to-ground fault will be as indicated by the plot of the steady-state relay characteristic on an R-X diagram. This fact must be recognized when considering any application since fault resistance on ground faults can be significant.

In considering the performance of a phase distance relay on a phase-to-phase fault, the resistance which must be accommodated on the R-X plot is arc resistance, which can be estimated with reasonable accuracy. During ground faults on the other hand, the fault resistance includes not only an arc resistance but also the resistance introduced by the fault current path through the structure and tower footing to ground. The magnitude of this ground fault resistance will be influenced by many factors such as the type of structure, i.e. wood pole or steel tower, the presence of a shield wire, procedures followed to reduce tower footing resistance, and local soil conditions. The total fault resistance during phase-to-ground faults consequently tends to be much higher than the arc resistance magnitude for phase faults, and furthermore, because of the nature of the factors involved, cannot be determined with as much accuracy.

It is recommended that the application of the Type SLCG12B relay be limited to lines with shield wires, since their presence tends to reduce the effects of tower footing resistance during a ground fault, and preferably be limited to lines with steel towers where structure resistance and individual tower footing resistance tend to be lower. In any case the effect of maximum predicted ground fault resistance on relay performance should be checked on an R-X plot of the steady-state relay characteristic. It is essential that a nearby internal fault and a remote internal fault be checked to insure that the maximum expected fault resistance does not result in a net impedance which falls outside the relay lens characteristic. From the preceding discussion it should be apparent that the Type SLCG12B relay is more generally applicable on longer lines where the fault resistance tends to be a smaller percentage of the relay ohmic reach setting.

In considering the application of the Type SLCG12B lens units, there are two principal concerns:

(a) The lens function must operate for any single-phase-to-ground fault on the protected line with margin, including the effects of the ground fault resistance.

(b) During a single-phase-to-ground fault on the protected line, only the LTG function associated with the faulted phase should operate.

In addition, it is of course necessary that the margin mentioned in (a) be sufficient to insure fast operation of the associated scheme on an internal fault. And further, since the LTG functions respond to positive sequence impedance, a check should be made that with the setting required to satisfy (a) above, the function will not operate during maximum expected load flow over the protected line.

As a general recommendation, it is suggested that the forward reach of the lens function be set for twice the positive sequence impedance of the protected line at the line angle and that the reverse reach be set equal to the line impedance. Since the principal concern is that the LTG function operate for any Ø-G fault on the protected line with margin, it is recommended next that the resulting lens characteristic and apparent impedances (See Appendix II) for internal faults at the relay location and at the remote end of the line be plotted on an R-X diagram. A suggested method for plotting the lens characteristic is described in Appendix III. A typical plot based on these proposed settings is shown in Figure 9.

Since the main concern in setting the LTG functions is that they detect any internal Ø-G fault, if the plot using the suggested settings indicates more than 25 percent margin over the apparent impedance, the forward and reverse reach should be reduced. That is, these reach settings should be no greater than necessary to provide 25 percent margin for internal faults at the relay location and at the remote end of the line.

The setting of the compensating transformer taps is determined by the equation:

$$K' = \frac{X_0' - X_1'}{3X_1'} \times 100$$

The value of K' thus determined will be in percent. Note that K' can only be set in 10 percent steps; it should be set on the next higher available tap. For example, if the equation indicates a 55 percent setting, the 60 percent tap should be used. This tap would be obtained by connecting the CT residual circuit in series with the 10 and 70 percent taps and feeding the compensating circuit from the 0 and 100 percent points (see external connections of the tap block unit in Figure 10).

A detailed discussion of the overall scheme in which the SLCG12B is normally applied is included in the instruction book for the associated SLA17C relay.

OPERATING PRINCIPLES AND CHARACTERISTICS

A. GENERAL INTRODUCTION

TRANSACTOR THEORY

All distance type characteristics (Mho, Offset Mho, Lens) are obtained by measuring the phase angle between two voltages. These voltages are derived from the system voltage and the system current supplied to the relay. Inside the relay, the system current is transformed into a voltage by a transactor. A transactor is an air gap transformer which produces a secondary voltage proportional to the primary current. This voltage leads the current by an angle Ø which is determined by the amount of secondary resistance placed across the transactor. If the secondary resistance is decreased, then both the magnitude of the secondary voltage and Ø will decrease. The vector ratio of the secondary voltage to the primary current is the transfer impedance of the transactor. This impedance is labeled Z and it determines the base reach of a mho characteristic.

POLARIZATION

The offset lens function (LTG) in the Type SLCG12B relay employs phase-to-neutral polarization. Since the lens characteristic is offset, memory action is not necessary to insure reliable operation on close-in zero voltage faults. As noted in the section on APPLICATION, the function will accommodate only as much ground fault resistance as indicated by a plot of its fixed characteristic on an R-X diagram. This is true for either steady-state or transient conditions.

B. LTG CHARACTERISTIC

Distance type characteristics are generally plotted on an R-X diagram; but since these characteristics are determined by the angle between two voltage phasors, it is desirable to plot the characteristics on a voltage diagram in order to describe how they are derived. The voltage diagram is obtained from the impedance diagram by multiplying every point of the R-X diagram by the current supplied to the relay. Since the fault current will change as the system voltages and fault location change, the voltage diagram will contract or expand for different fault currents. However, the voltage phasors will have the same relative phase positions and magnitudes that the impedance vectors have on a R-X diagram. Because of this, any characteristic plotted on the R-X diagram will have the same shape when it is plotted on a voltage diagram.

The LTG characteristic for the Type SLCG12B relay is shown in Figure 9. The principle used to derive the electrical characteristics is illustrated in Figure 11. The axes are "IR" and "IX". This LTG characteristic is readily derived from the ground-mho unit simply by changing the pickup setting of its associated timer.

The line YZ is defined as the major axis of the characteristic and it corresponds to the maximum reach of the mho unit. If it is assumed that the percent restraint tap is set at 100, then the major axis is determined by $(\overline{IZ_1} + \overline{IZ_2})$. At the balance point the voltage phasors $(\overline{IZ_2} + \overline{V})$ and $(\overline{IZ_1} - \overline{V})$ form an inscribed triangle with the major axis. The angle C is the angle opposite the major axis and because it will be the same for any $(\overline{IZ_2} + \overline{V})$ terminating on the characteristic, it is used to define the characteristic. If C is greater than 90 degrees, the characteristic resembles a lens. It should be recognized that C is the supplement of the angle B; and therefore, it is directly related to the coincidence of the voltage phasors. If the timer setting is greater than 5.0 milliseconds, more coincidence is required at the balance point such that the phase angle between $\overline{V}$ and $(\overline{IZ_1} - \overline{V})$ will be less than 90 degrees. Hence, the angle C will be larger than 90 degrees and a lens characteristic is formed.

C. LTG MEASUREMENT PRINCIPLE

The overreaching ground lens functions (LTG) are used to provide the necessary tripping characteristics for pilot relaying schemes. In such applications, it is not necessary that the function has a limited transient overreach. Although the LTG functions may or may not be applied with zero sequence current compensation, in this single-pole scheme compensation is recommended. The overreaching ground mho functions must be set with a reach at least large enough to detect a single phase to ground fault anywhere in the protected line section, with margin, under all system conditions.

If the $\overline{IZ}$ and voltage tap values are used directly to make a reach setting of the ground lens unit, this measurement is accurate only for the special case where the zero-sequence impedance to the fault is equal to the positive-sequence impedance to the fault, and where there is no mutual coupling from parallel lines. Instructions are given in Appendices II and III for choosing tap settings when these two factors are taken into consideration.

Appendix II discusses the application of the LTG functions with zero sequence current compensation. This compensation for the zero-sequence impedance of the protected line section makes the ground lens function better suited for use on longer transmission lines since it is possible to reduce the reach settings and still provide adequate line coverage. The smaller ohmic reach setting reduces the possibility of the ground lens function interfering with the load carrying ability of the line.

The ground lens characteristic is produced with a block-block measuring scheme, in which both input quantities, $\overline{V}$ and $\overline{IZ}$, are converted to blocks of voltage, and the duration of their coincidence (having same polarity) is measured. This is illustrated in Figure 12. Blocks which are 90^o apart are coincident for 7 milliseconds. Blocks which are less than 120^o apart are coincident for more than 7 milliseconds. The maximum operating time, shown at the bottom of Figure 10, is 21 milliseconds (3/4 cycle) and minimum operating time is 7 milliseconds (1/4 cycle).

D. G4 OVERCURRENT FUNCTION

The G4 is a non-directional instantaneous overcurrent function used for direct tripping. It provides high speed direct tripping for close in heavy current faults. The G4 function must be set to operate at 125% or more of the maximum external single phase to ground fault current. Since this unit is non-directional, the heaviest fault current condition must be considered whether it is at the remote bus location or on the bus immediately behind the relay.

CONSTRUCTION

NETWORK UNIT

The network unit (see Figures 1 and 2) contains the tap blocks for making reach settings on the ground LTG functions. It also includes rheostats for adjusting the maximum reach angle of the LTG functions, and a potentiometer for adjusting the operating level of the G4 overcurrent unit. These adjustments are located on the front mounting plate of the network unit behind the hinged front panel.

There are three sets of reach-setting tap blocks, one set each for phase A, phase B, and phase C. Each set includes voltage ($\overline{V}$) taps on the upper two blocks and current ($\overline{IZ}$) taps on the lower block. The 10% voltage taps are on the upper tap block and settings are made by connecting a jumper from the fixed tap to the desired 10% tap. The 1% voltage taps are on the middle tap block and adjustment is made by connecting a jumper from the fixed tap to the desired 1% tap. Current ($\overline{IZ}$) tap settings are made by means of a tap screw in the lower block. Incoming currents and voltages are supplied to the network unit through screw terminal blocks (GA and GB) at the rear of the unit. Output voltage signals appear at two 10-point sockets at the rear of the unit for interconnection with the card or logic unit via shielded cable.

LOGIC UNIT

The Type SLCG12B relay logic unit contains one row of printed circuit cards. Mounted behind the cards are the isolating transformers (TA, TB, etc.), resistors, and diode boards. Push buttons on the front panel provide means of simulating $LTG_{\emptyset A}$, $LTG_{\emptyset B}$, $LTG_{\emptyset C}$, or G4 operation.

TESTING

The Type SLCG12B relay will be supplied from the factory either mounted and wired in a static relay equipment, or as separate unmounted units. All units of a given terminal of protection have been calibrated together at the factory and will have the same summary number on the unit nameplates.

The user adjustments required prior to putting the Type SLCG12B relay into service include the following:

1) Basic reach ($\overline{IZ}$) taps for LTG and LTG*.
2) LTG and LTG* reach by voltage tap setting.
3) Overcurrent function (G4) - OPERATING LEVEL.
4) LTG timer (TU/G) if used.

CAUTION:

IT IS A DESIGN CHARACTERISTIC OF MOST ELECTRONIC INSTRUMENTS THAT ONE OF THE SIGNAL INPUT TERMINALS IS CONNECTED TO THE INSTRUMENT CHASSIS. SINCE THE TYPE SLCG12B RELAY REFERENCE VOLTAGE, WHICH NORMALLY WILL BE CONNECTED TO THE GROUND INPUT OF THE INSTRUMENT, IS NEAR THE (+) OR (-) OF THE STATION BATTERY VOLTAGE LEVEL, THE INSTRUMENT CHASSIS MUST BE INSULATED FROM STATION GROUND. IF THE INSTRUMENT POWER CORD CONTAINS A THIRD LEAD, THAT LEAD MUST NOT BE CONNECTED TO STATION GROUND.

IF THE TYPE SLCG12B RELAY IS INSTALLED IN AN EQUIPMENT AND CONNECTED TO AN SLA TRIPPING RELAY, BE SURE TO DISCONNECT THE SLA OUTPUTS FROM THE SYSTEM BY REMOVING THE SLA CONNECTION PLUGS BEFORE PERFORMING ANY TESTS ON THE TYPE SLCG12B RELAY.

GENERAL TESTING INSTRUCTIONS

1. INPUTS

The AC test inputs can be supplied by way of a standard Type XLA relay test plug at the TGA and TGB receptacles on the associated test panel if the Type SLCG12B relay is being tested in a complete equipment, or directly to the unit terminals if the relay is being tested separately. The cables must be connected between the Tap Block and Logic Units, and the Logic Unit must be connected to any PS socket on the associated SSA DC power supply. To obtain an accurate check on the relay calibration, the AC test source should provide a good sine wave. The use of a series reactor to limit the test current, instead of just a load box, should minimize the effects of harmonics and distortion in the test source.

2. OUTPUT SIGNALS

The Type SLCG12B relay logic unit has test cards in the S and T positions. These test cards have 10 pin jacks mounted on the outer edge of the cards and numbered 1 to 10 from top to bottom on the S card and 11 to 20 on the T card. These are the test points shown as TP1 to TP20 on the Type SLCG12B relay logic diagram.

Output signals are measured with respect to the reference bus, TP1. Outputs are continuous signals of approximately +10 to +15 volts for the ON condition, and 0 volts for the OFF condition. This output can be monitored with an oscilloscope, a portable high impedance DC voltmeter, or with the test panel voltmeter if available. When the test panel voltmeter is available, the voltmeter negative terminal will normally be connected to the reference bus, and placing the relay test lead in the proper test point pin jack will connect the meter for testing.

DETAILED TESTING INSTRUCTIONS
REQUIRED ADJUSTMENTS

1. REACH TAP SETTINGS

It will be necessary to set the base reach taps ($\overline{IZ}$) and the restraint voltage taps ($\overline{V}$) to obtain desired LTG unit reach as determined for the specific application, with due consideration of minimum and maximum permissible reach settings as discussed in Appendices II and III respectively. The arrangement of the reach-setting tap blocks is described in the section on CONSTRUCTION. Make tap settings for each phase as described in that section, moving only the knurled screws and associated jumpers to obtain the desired base reach. The $\overline{IZ}$ tap blocks for each phase have two base reach settings, 2 and 6 ohms, in the forward direction, and two additional base reach settings, 1 and 3 ohms, in the reverse direction. The tap values represent line-to-neutral positive-phase-sequence ohms. When selecting the base reach tap, use the next lower tap below the desired reach setting, and then set the $\overline{V}$ taps (10% and 1%) to obtain the desired reach.

The sensitivity of the LTG function is measured by the relation between the relay fault current and the reduction of the ohmic reach of these functions as the current decreases. The sensitivity is defined as the minimum relay current required for the minimum ohm tap selected that will cause the LTG reach to pull back to no less than 90% of the nominal or set reach. Relay current is defined as the phase current or the phase current plus the zero sequence compensation current when it is used. For the LTG function these approximate current requirements are as follows:

	RELAY TAP	RELAY CURRENT
LTG	2 ohms	1.5 amperes
LTG	6 ohms	0.50 ampere
LTG*	1 ohm	3.0 amperes
LTG*	3 ohms	1.0 ampere

2. LTG TEST

The ground mho offset lens LTG can be checked by means of the test circuit in Figure 13, after the functions have been set for the deisred forward and reverse reach as described in the section on CONSTRUCTION. Set the input current at a level commensurate with the reach setting of the function. Make input connections for the phase to be checked as shown in Table I.

TABLE I

	CONNECT TERMINAL TO POINTS IDENTIFIED BY LETTERS IN FIGURE 13					
	A	B	C	D	E	F
ØA	GA4	GB4	GB7	GB8	GA9	GA10
ØB	GA3	GB3	GB7	GB8	GA7	GA8
ØC	GA2	GB2	GB7	GB8	GA5	GA6

Measure outputs at test points shown in Table II. NOTE: Points C and D must be jumpered together, in order to test without compensation.

TABLE II

	LTG OUTPUT
ØA	TP8
ØB	TP6
ØC	TP4

Adjust the phase shifter for the desired test angle, and gradually reduce the A-C test voltage with the test autotransformer until an output appears at the indicated test point. Half-cycle output may occur right at the balance point, since the LTG measurements are made on both polaritites of input and there may be slight differences in the sensitivities. If there is a difference between the first half-cycle of pickup and full pickup, it should be less than 2 percent. The level at which the initial half-cycle output occurs should be considered as the operating point of the function.

Since the "lens-shaped" LTG characteristics come to a point at the angle of maximum reach (both forward and reverse), it is suggested that the operating point be checked at 2 degree intervals for 10 degrees either side of the maximum reach angle (85 degrees forward, 265 degrees reverse, current lags voltage). Pickup checks at 20 degree intervals over the remainder of the characteristic should be satisfactory. It is suggested that the results be plotted on polar graph paper.

If the test reactor scheme (Figure 14) is used, points can be taken only in the first and third quadrants, and since only 4 points can be taken in each quadrant (0^{o}, 30^{o}, 60^{o} and approximately 85^{o}) the results are not as accurate as the phase-shifter scheme of Figure 13. The test reactor scheme should not be used in checking lens functions, except as a last resort when other test equipment is not available.

3. G4 OPERATING LEVEL

The operating level of the G4 overcurrent function can be checked by supplying a variable test current to studs GB9 and GB10, using a test-reactor as part of the current-limiting impedance. Output is observed at TP3 in the logic unit. Gradually increase current to check operate level; gradually reduce current to check reset level. Output is +10 to +15 volts when unit operates. To adjust operate level, use OVERCURRENT potentiometer on tap block front panel, turning it CLOCKWISE to increase operating level.

4. TIME DELAY TRIP (TU/G)

The TU/G timer (T9 card, pos. P) is energized by the operation of any one of the ground LTG functions and FDL in the associated SLD43A. When used in conjunction with the SLA17C, the TU/G function will provide time-delay trip of all breaker poles independent of a phase comparison operation. It has been set at the factory for a one-second delay but can be readjusted for a time setting within its 0.1 to 2 second range.

To check or readjust the time setting using an oscillograph with calibrated horizontal sweep and external trigger control, connect TP12 to trigger the sweep, TP19 to the vertical input, and TP1 (REF) to scope ground. Set sweep at 0.5 secs/cm with positive slope triggering. Connect a jumper from TP2 to + at TP20, and provide a second jumper which can be connected from TP20 to TP4. When the jumper is connected to TP4 the "D" card should operate triggering the sweep and energizing the TU/G card (pos. P). The trace should step from 0 to 13-16 volts in one second ± 5% as set at the factory.

The time setting of TU/G can be adjusted by means of the adjusting screw on the potentiometer mounted on the T9 card. Turn the screw clockwise to increase the time.

An electronic counter with digital readout may also be used for greater accuracy, using TP12 to start the time and TP19 to stop it.

5. OVERALL TEST

In its normal application the SLCG12B is applied with the SLD43A, SLYL11B, and SLA17C relays. An overall check of the logic necessarily involves the logic circuits of these associated relays. Such a test is described in the SLA17C instructions.

MAINTENANCE

PERIODIC TESTS

For periodic tests it is recommended that the LTG function reach be spot checked using the procedure outlined in item 2 under DETAILED TESTING INSTRUCTIONS and also that the operating point of G4 be checked as described under item 3. Overall tests, using the push buttons, are described in the SLA17C instruction book.

TROUBLE SHOOTING

In any trouble shooting of equipment, it should first be established which unit is functioning incorrectly. The overall logic diagram supplied with each equipment contains the combined Logic (internal connection diagrams) of the Type SLCG12B, Type SLA17C and other associated relays, and the various test points in each unit. By signal tracing using this overall logic diagram and the various test points it should be possible to quickly isolate the trouble.

A Test Adapter Card is supplied with each static relay equipment to supplement the pre-wired test points on the test card. This adapter can be plugged into any card position, and then the logic card for that address can in turn be plugged into the adapter. The unit test card can then be plugged into the second socket in the adapter, giving access to all ten connection points by instrument jacks while the logic card is operating in the circuit. The connections to each pin on the adapter logic card socket are individually removable to allow circuit wiring changes to the logic card during trouble shooting.

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

The following information covers items which have been covered during factory tests and adjustments, and which normally do not require readjustment by the user. This information is supplied for use in trouble shooting or in checking overall performance of the Type SLCG12B relay.

1. LTG MAGNITUDE ADJUSTMENT

The three potentiometers, located on the front panel of the tap block unit, control the magnitude of the polarizing voltage. These potentiometers are factory-adjusted to produce a maximum reach angle of 85° and normally should not require field adjustment.

2. T13 (7/11) TIME DELAY CARDS

These cards should have a 7.0 millisecond delay on operate time and an 11 millisecond reset time. The 7.0 millisecond time is important in making the 120° measurement and affects the shape of the lens characteristic: times longer than 7.0 milliseconds tend to further narrow the characteristic and times shorter than 7.0 milliseconds tend to widen the characteristic. The 11 millisecond reset time is provided to overlap the next half-cycle measurement and produce a continuous output.

To check the 7/11 time delay cards, connect the test circuit given under "LTG Tests" item 2 under DETAILED TESTING INSTRUCTIONS, using the test reactor (for an angle near 90°). Reduce the applied voltage until the fault condition applied to the relay is within the relay characteristic. Connect TP2 to TP20 to operate the AND function on T13 card, and connect T13 card inputs and outputs to oscilloscope as shown in Figure 15.

Typical waveshape of the input to the 7/11 card is shown in the upper trace of Figure 15. This input should consist of blocks just slightly longer than 7.0 milliseconds (adjust applied test voltage to get this condition). These blocks occur every half-cycle, and the gap between blocks is less than 7 milliseconds. In order to check the T13 card time delay, it is necessary to reduce the 7/11 card reset time so that the output at TP12 appears as shown on the center trace of Figure 15. This can be done by turning the outer pot on the 7/11 card COUNTERCLOCKWISE. The 7 millisecond operate time can be checked using the calibrated horizontal sweep of the oscilloscope. Turn the inner pot on the 7/11 card CLOCKWISE to increase time delay. After the operate time has been checked and adjusted, the reset time can be extended (turn outer pot, CLOCKWISE) just enough to obtain continuous output as shown in the lower trace of Figure 15. Check the 7/11 cards for each phase, one at a time.

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 repair 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 semi-conductor components. The repaired area should be re-covered with a suitable high dielectric plastic coating to prevent possible breakdowns across the printed busses due to moisture and dust. The complete wiring diagrams and component values for the various cards are shown in GEK-7364.

Spare parts supplied from the factory with each equipment include extra Tap Block Unit jumpers, tap plugs, polarizing keys for card sockets, unit mounting hardware, and a test lead to interconnect the test panel voltmeter to the unit test points.

APPENDIX I

DEFINITION OF SYMBOLS

In the following appendices, and throughout other portions of this instruction book, the symbols used for voltages, currents, impedances, etc., are consistent. Note that all of the parameters listed below are secondary quantities based on the CT and PT ratios on the protected line terminal. Note also that some of the parameters defined below may not be involved in discussions which follow in Appendices II & III.

Voltage

E_a = Phase A-to-neutral voltage.

E_b = Phase B-to-neutral voltage.

E_c = Phase C-to-neutral voltage.

$E_{ab} = (E_a - E_b)$

$E_{bc} = (E_b - E_c)$

$E_{ca} = (E_c - E_a)$

E_0 = Zero sequence phase-to-neutral voltage.

E_1 = Positive sequence phase-to-neutral voltage.

E_2 = Negative sequence phase-to-neutral voltage.

Note that when one of these symbols is primed, such as E_a', it then represents the voltage at the location of the relay under consideration.

Current

I_a = Total phase A current in the fault.

I_b = Total phase B current in the fault.

I_c = Total phase C current in the fault.

I_0 = Total zero sequence current in the fault.

I_1 = Total positive sequence current in the fault.

I_2 = Total negative sequence current in the fault.

Note that when one of the above symbols is primed, such as I_a', or I_2', it then represents only that portion of the current that flows in the relays under consideration.

I'_{RES} = CT residual current at relay location (= $3I_0'$)

I_0'' = Zero sequence current flowing in a line that is parallel to the protected line, taken as positive when the current flow in the parallel line is in the same direction as the current flowing in the protected line. Although this current flows in the parallel line, the secondary value is based on the CT ratio at the protected line terminal under consideration.

Distribution Constants

C = Positive sequence distribution constant. Assumed equal to the negative sequence distribution constant.

$$C = \frac{I_1'}{I_1} = \frac{I'_2}{I_2}$$

C_0 = Zero sequence distribution constant.

$$C_0 = \frac{I'_0}{I_0}$$

D. Impedances

Z_o = System zero sequence phase-to-neutral impedance as viewed from the fault.

Z_1 = System positive sequence phase-to-neutral impedance as viewed from the fault.

Z_2 = System negative sequence phase-to-neutral impedance as viewed from the fault. Assume equal to Z_1.

Z_o' = Zero sequence phase-to-neutral impedance of the protected line from the relay to the remote terminal.

Z_1' = Positive sequence phase-to-neutral impedance of the protected line from the relay to the remote terminal.

Z_2' = Negative sequence phase-to-neutral impedance of the protected line from the relay to the remote terminal. Assume equal to Z_1'.

Z_{om} = Total zero sequence mutual impedance between the protected line and a parallel circuit over the entire length of the protected line.

Miscellaneous

T = Relay tap setting in percent.

α,A,B,θ,$\emptyset$ = Angles in degrees as defined where used.

S_1,S_2,S_3 = Ratio of distance as defined where used.

* Reverse Direction

APPENDIX II

APPARENT IMPEDANCE SEEN BY THE GROUND LENS FUNCTION

The lens functions in the Type SLCG12B relay include means for zero sequence current compensation. It is recommended that this compensation feature always be used since this will permit a shorter relay reach setting. Zero sequence compensation of the LTG function is accomplished by adding a portion of the residual current of the protected line section to the normal phase current. That is $K'(3I_0')$, or $K'I'_{RES}$, is added to I_a'. The result is to eliminate the zero sequence impedance of the line (Z_0') from the apparent impedance seen by the relay, assuming that the compensation is complete.

For a phase A to ground fault at the remote end of the protected line, the apparent impedance Z_A seen by the ground lens function with complete compensation is given by the following equation:

$$Z_A = Z_1' + \frac{I_0'' Z_{0m}}{I_a' + 3K'I_0'} + \frac{I_a R_a}{I_a' + 3K'I_0'} \qquad \text{(II-1)}$$

The second term of this equation represents the error impedance introduced by the mutual-effect of a parallel line if one is present. This error term may add or subtract, the I_0'' term being considered positive when the current flow in the parallel line is in the same direction as the current flow in the protected line. When these currents are opposite the I_0'' is considered negative.

The K' term in equation II-1 is determined by the following relation:

$$K' = \frac{X_0' - X_1'}{3X_1'} \times 100 \qquad \text{(II-2)}$$

The third term of equation II-1 is the impedance introduced by the ground fault resistance R_a. Note that R_a includes not only arc resistance, but also resistance in the current path through the structure tower footing and ground.

APPENDIX III

PLOTTING LTG CHARACTERISTIC

The best way to check that the LTG settings will be satisfactory is by means of a graphical analysis on an R-X diagram with all values plotted in terms of secondary impedance. Such a plot is shown in Figure 16 on which the LTG lens characteristic for terminal A of line A-B are shown.

First note the method of constructing the lens characteristic. The angle of maximum reach will be along the line Y-Z, passing through the origin A. Since this is a 120° lens, draw lines as shown 30° on either side of Y and Z. These will intersect at U and V. Now center a compass at U and draw a circle through Y, V and Z. Then center the compass at V and draw another circle through Y, U and Z. The two circles will intersect to form the lens characteristic with the common chord Y-Z defining the angle of maximum reach.

The impedance of line A-B should next be plotted. We see that the lens characteristic will see a fault anywhere on the line, including an allowance for arc resistance, with ample margin.

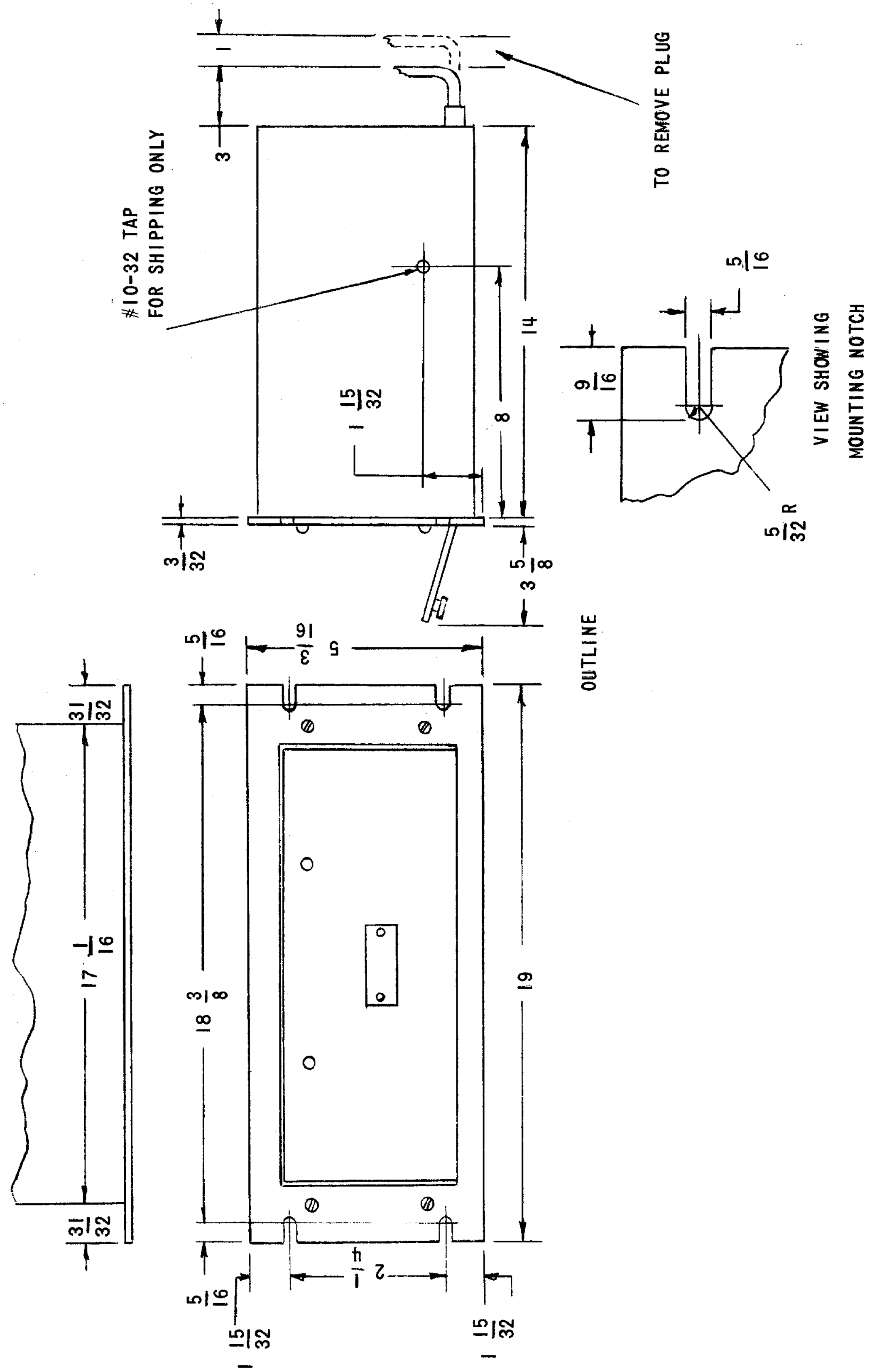


FIG. 1 (0165A7754-5) Outline And Mounting Dimensions For Network Unit (3 Rack Unit)

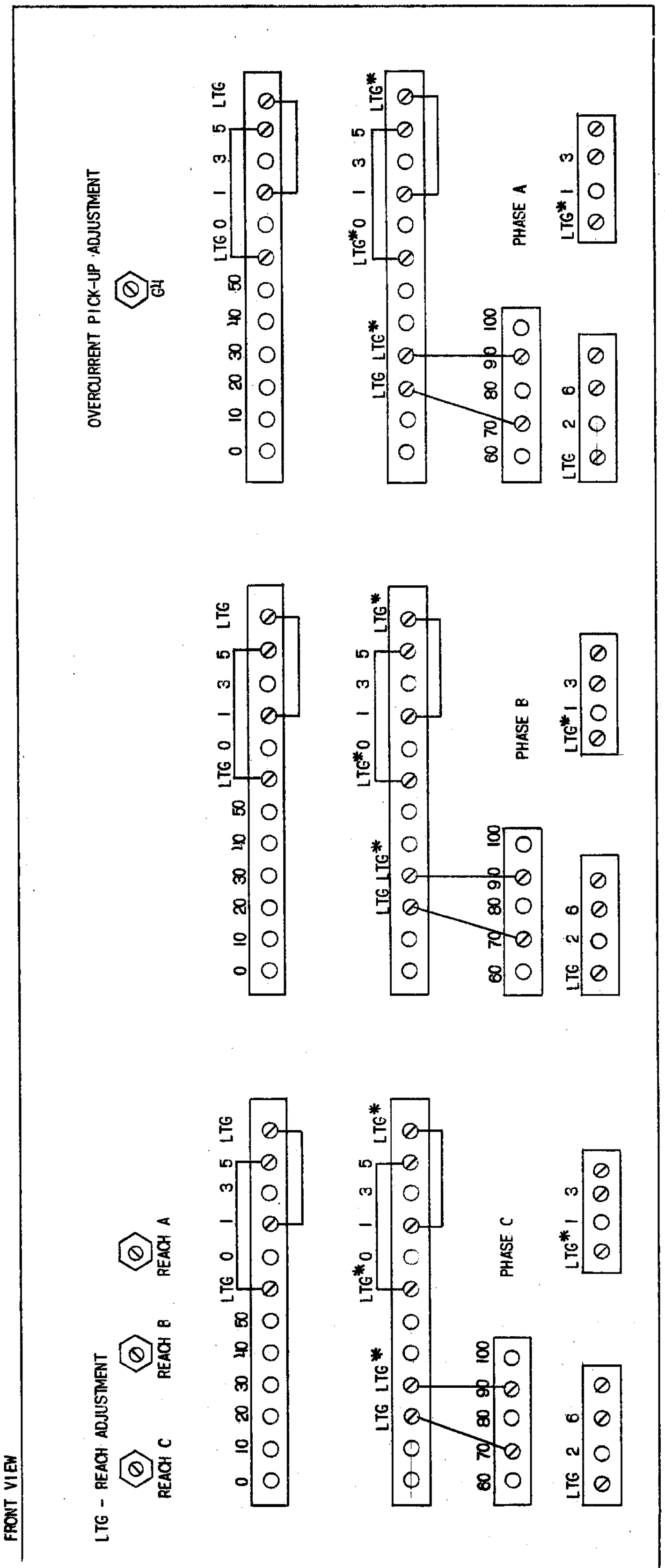
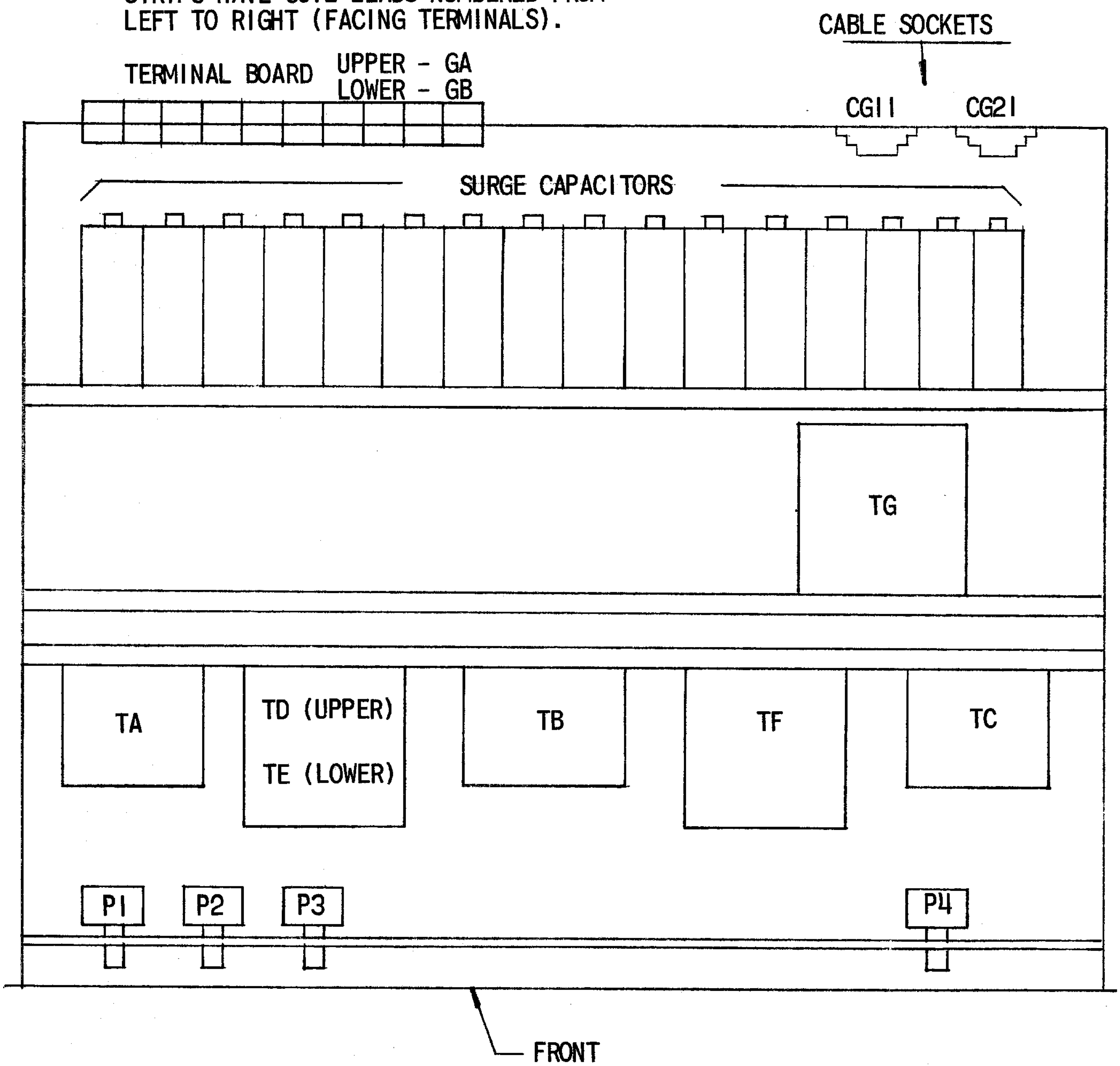


FIG. 2 (165B2603-1) Type SLCG12B Network Unit Location Of Adjustments

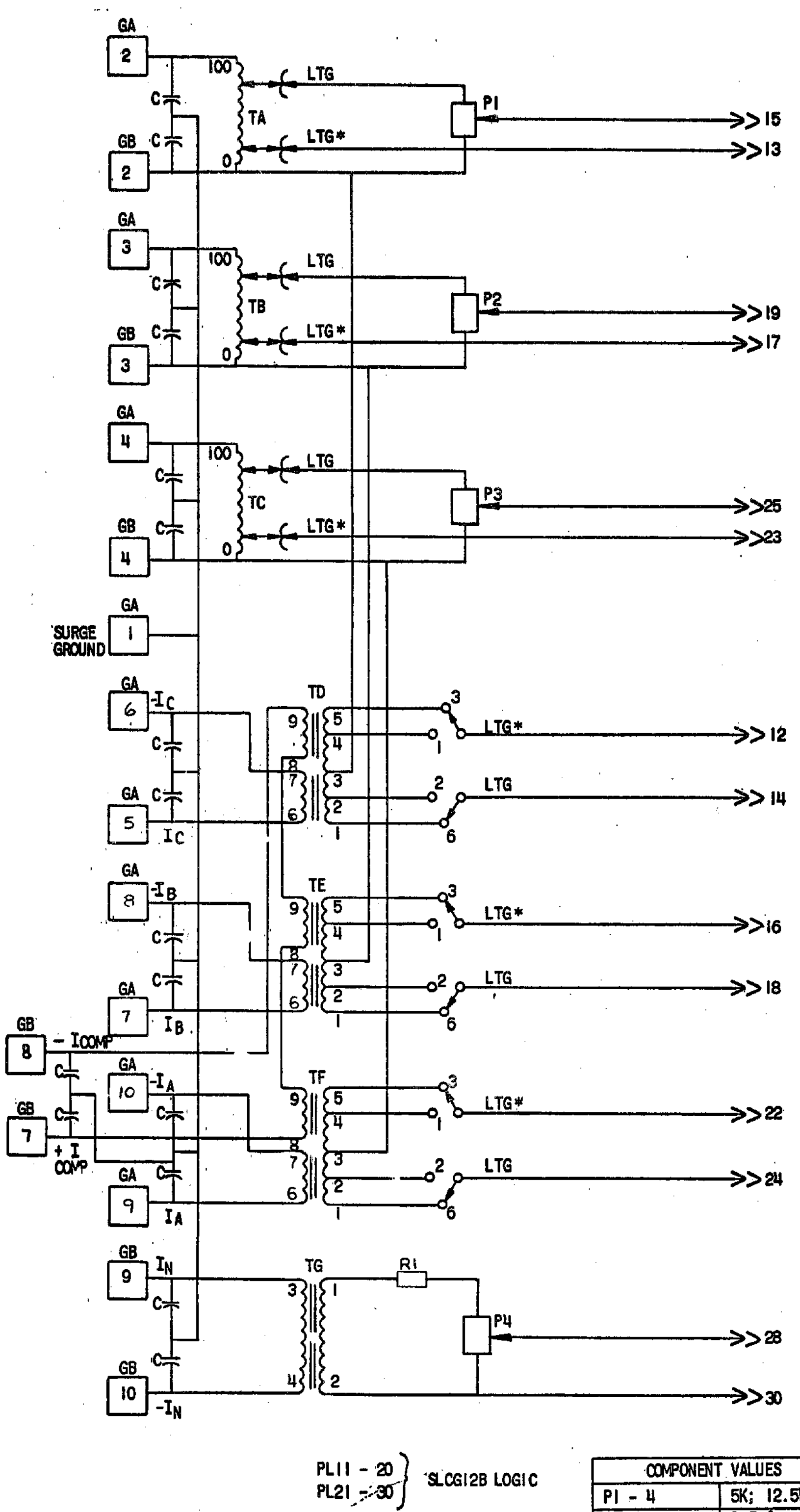
NOTE: EACH MTG. PLATE MAY BE REMOVED AS SEPARATE SUB-ASSEMBLY, WITHOUT DISCONNECTING LEADS BY REMOVING FOUR MTG. SCREWS. TRANSFORMER WITH TERMINAL STRIPS HAVE COIL LEADS NUMBERED FROM LEFT TO RIGHT (FACING TERMINALS).



TOP VIEW

TOP COVER REMOVED. REFER TO INTERNAL CONNECTIONS 0165B2558.

FIG. 3 (0246A2191-0) Type SLCG12B Network Unit Location Of Components



COMPONENT VALUES	
P1 - 4	5K; 12.5W
C	0.5uf
R1	2.5K, 10W

FIG. 4 (0165B2558-6) Internal Connection Diagram For Type SLCG12B Relay (Network)

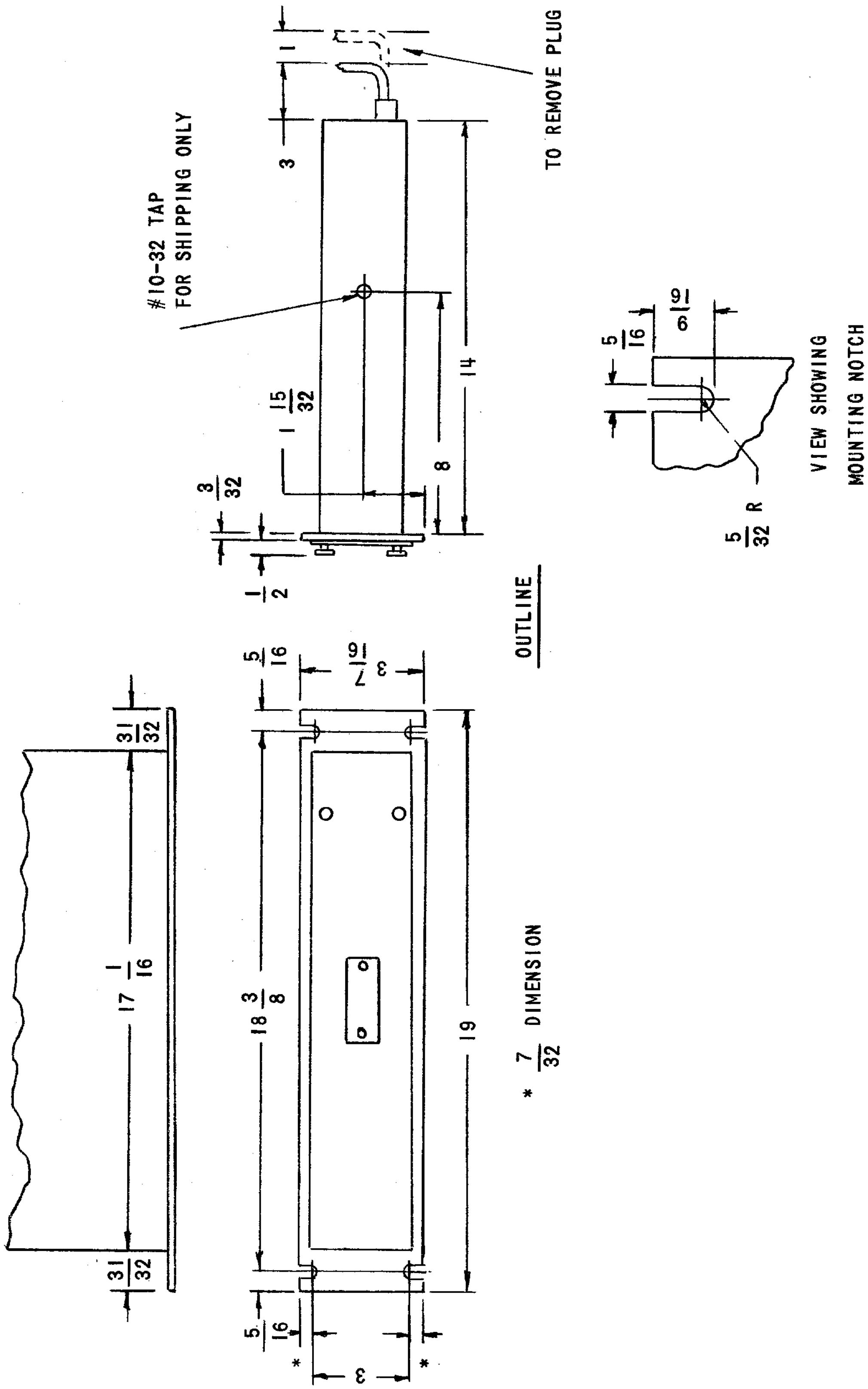


FIG. 5 (0165A7660-6) Outline And Mounting Dimensions For Logic Unit (2 Rack Unit)

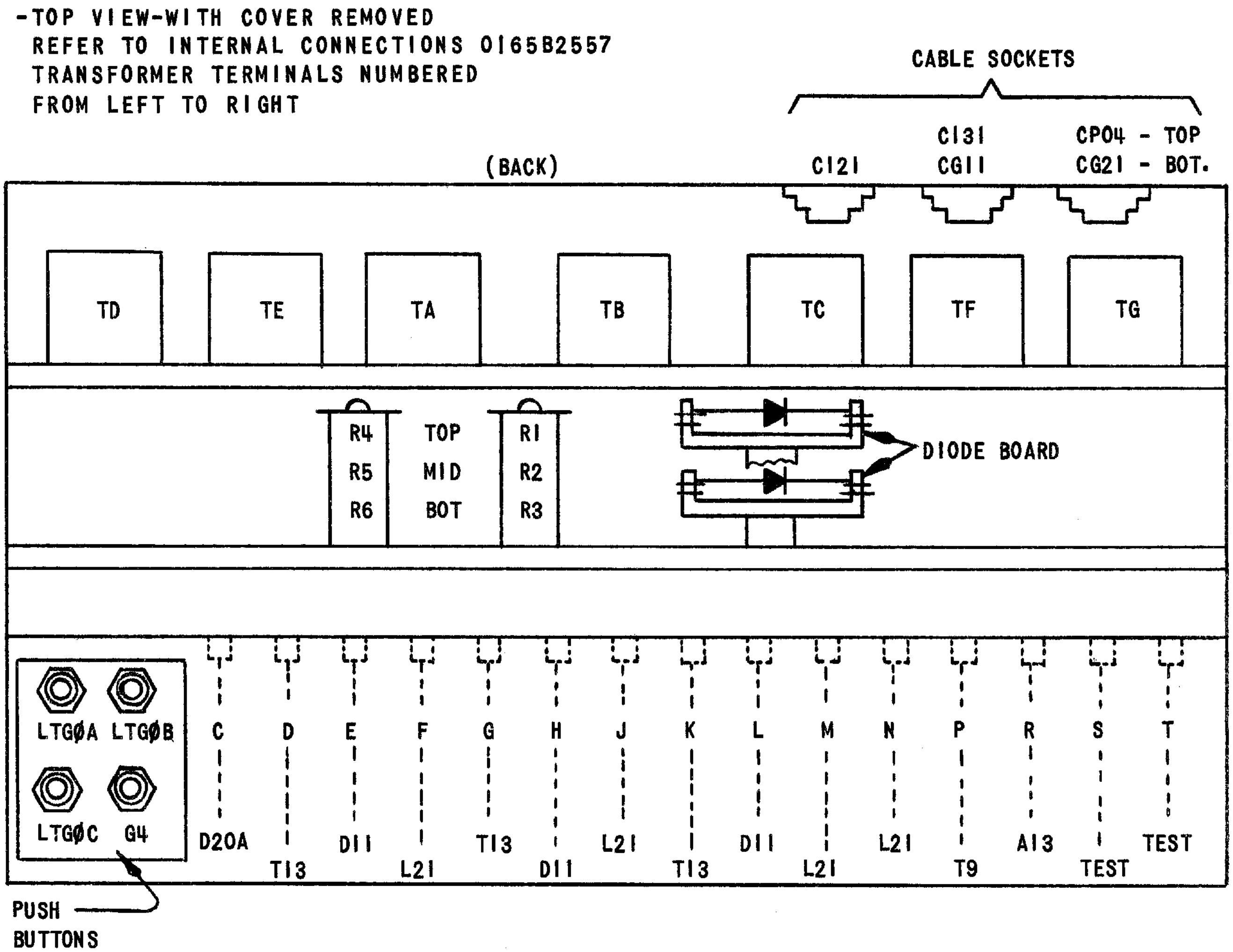
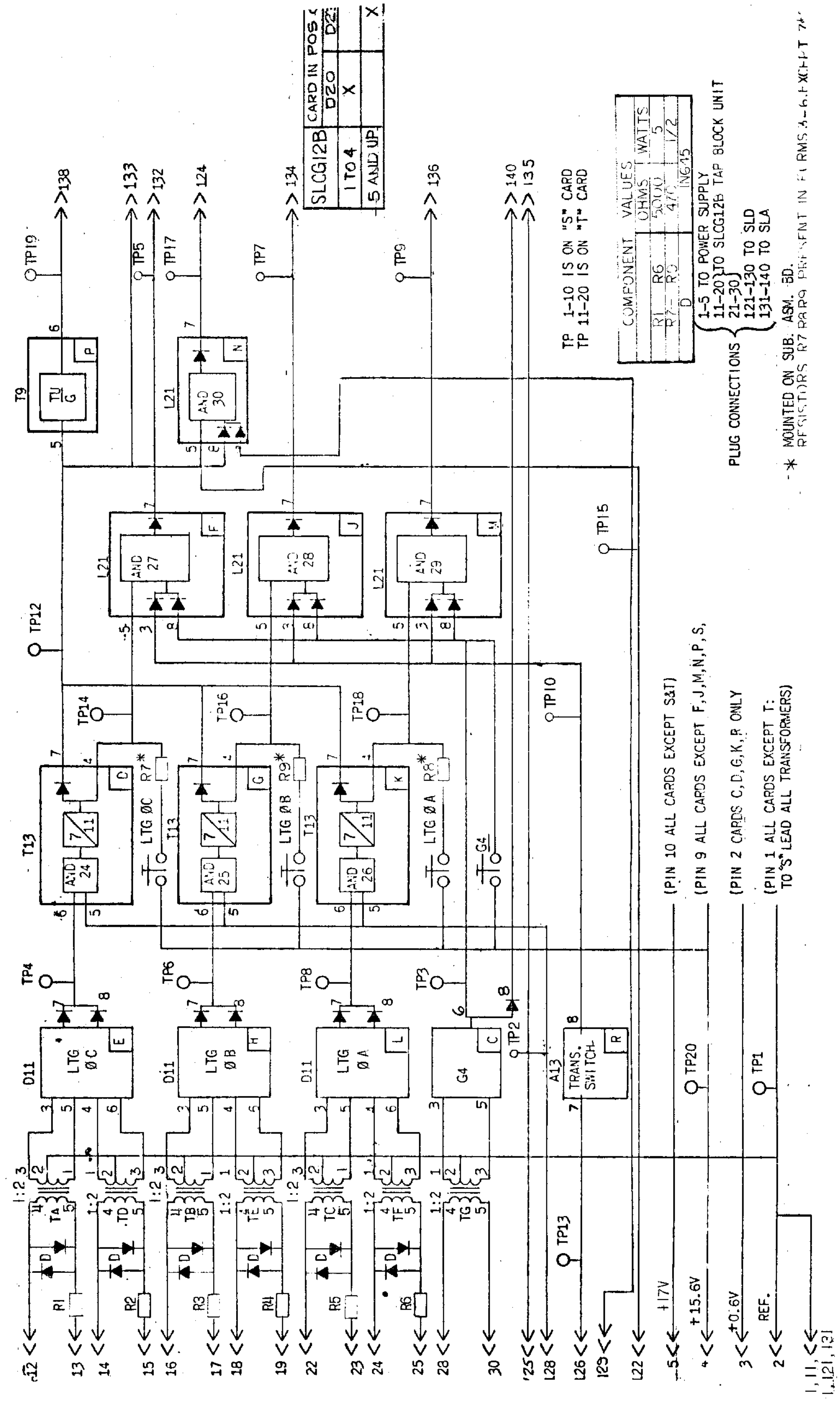


FIG. 6 (0246A2166-0) Type SLCG12B Logic Unit Location Of Components



IG. 7 (0165B2557-4) Internal Connection Diagram For Type SLCG12B Relay (Logic)

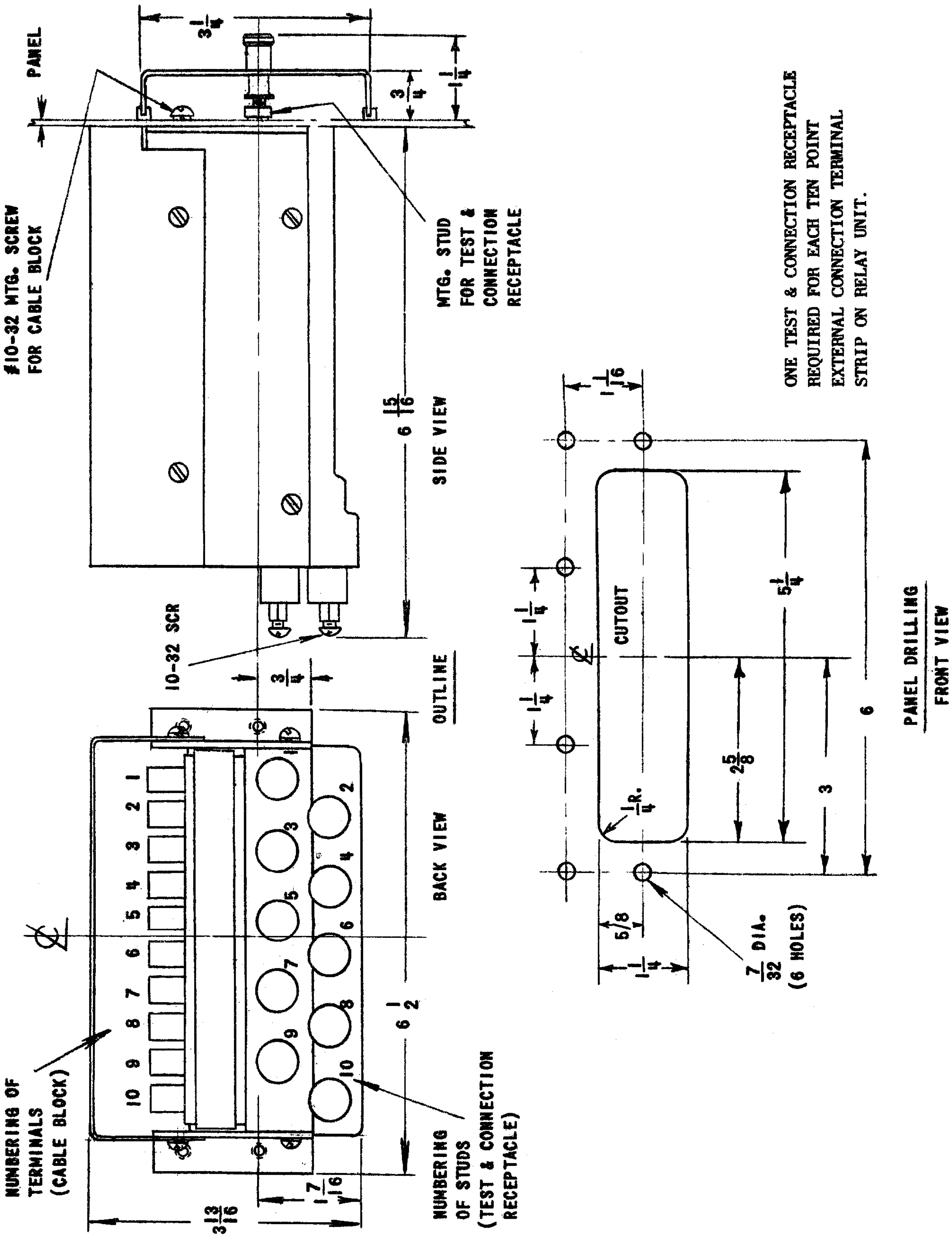


FIG. 8 (0178A5813-1) Outline And Panel Drilling For Test And Connection Receptacle (Static Relays)

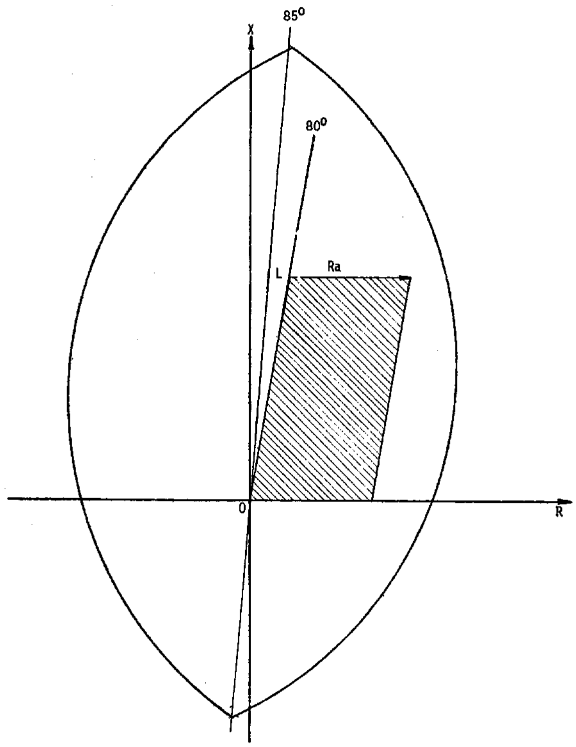


FIG. 9 (0246A2599-0) Plot Of LTG Characteristic Functions For Type SLCG12B Relay

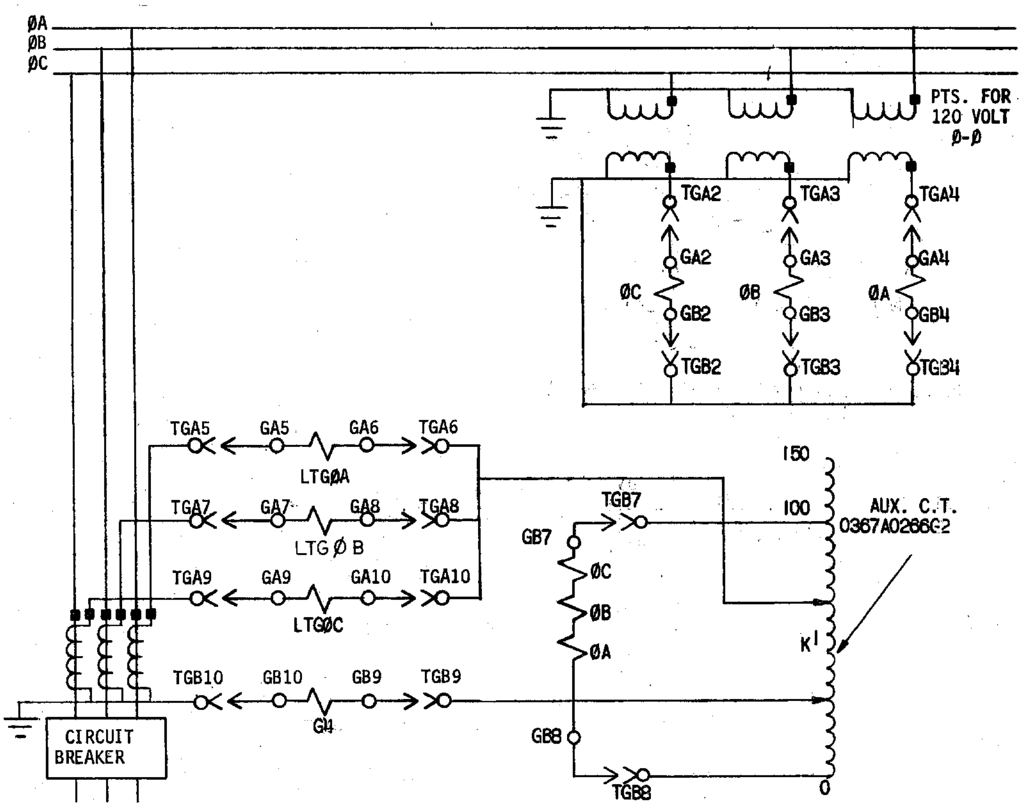


FIG. 10 (0246A2291-1) External Connections Type SLCG12B Relay

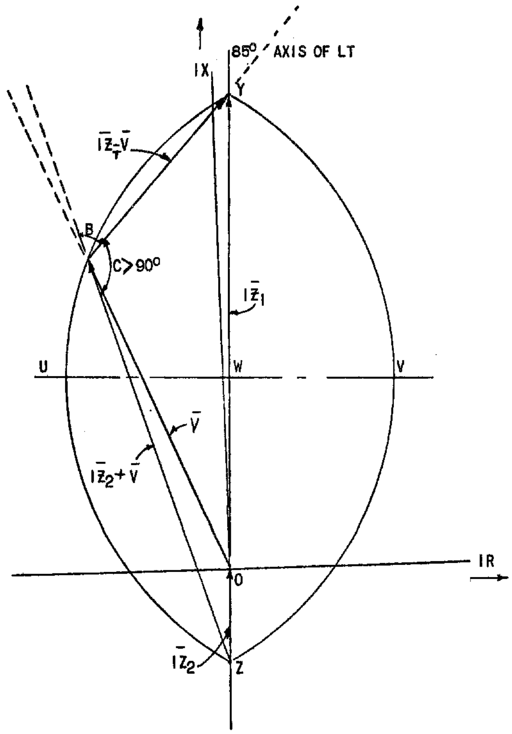


FIG. 11 (0227A7021-0) Graphical Representation Of The LTG Function

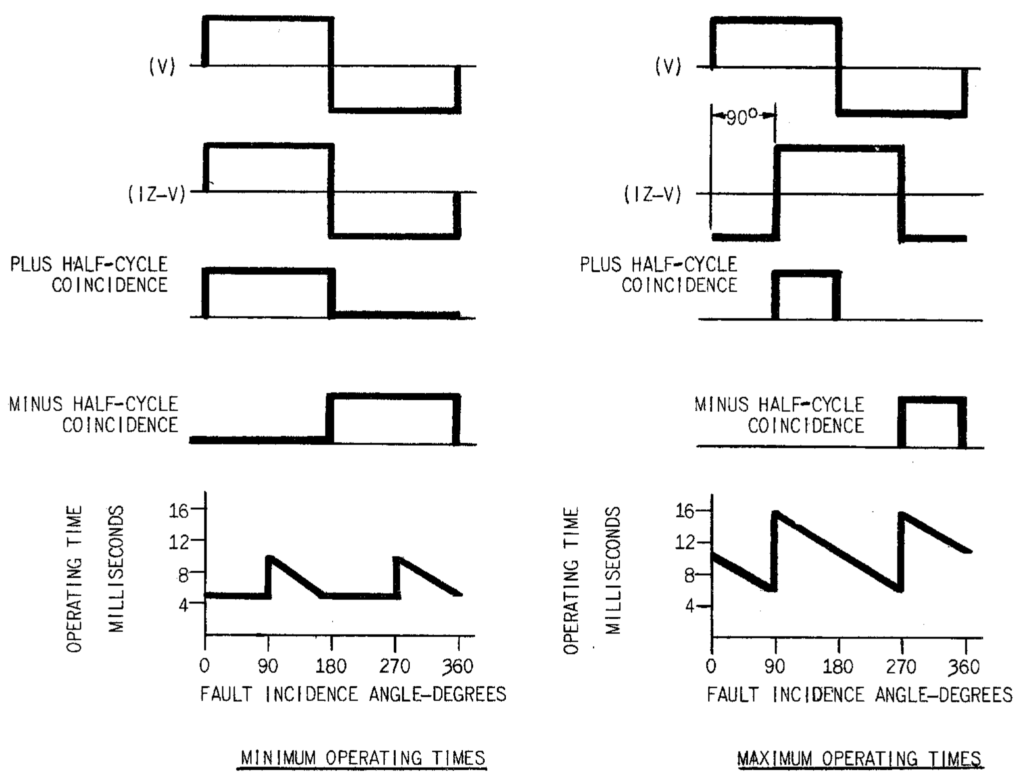


FIG. 12 (0203A8514-0) MT Measurement Principle And Operating Time Characteristics Type SLCG12B (50 hertz) Relay

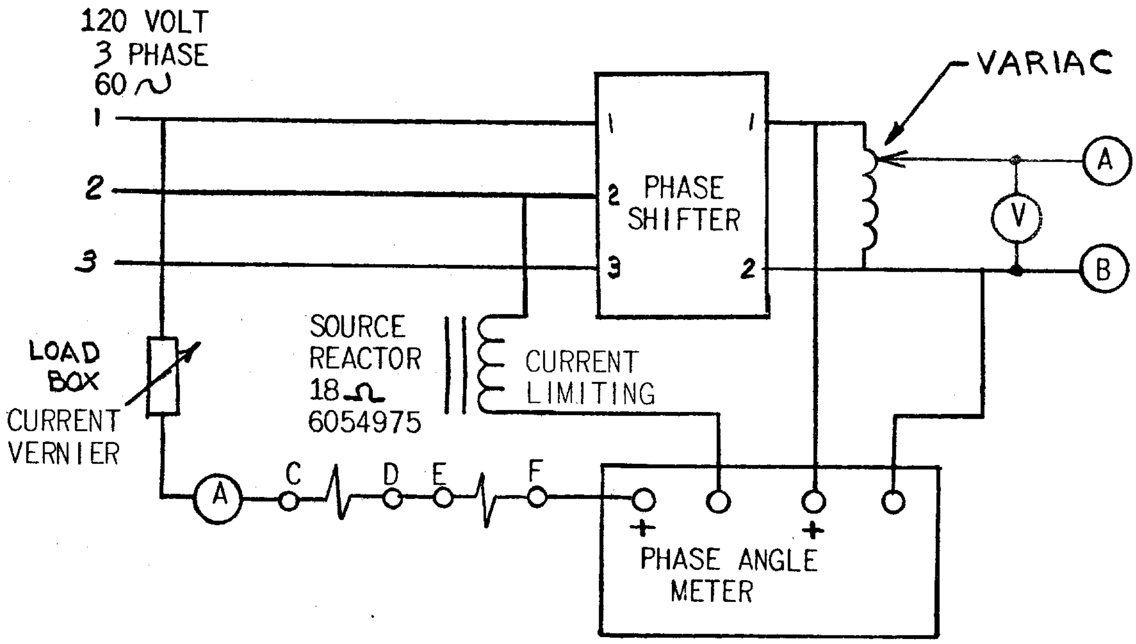


FIG. 13 (0178A7029-3) Phase Shifter Test Circuit

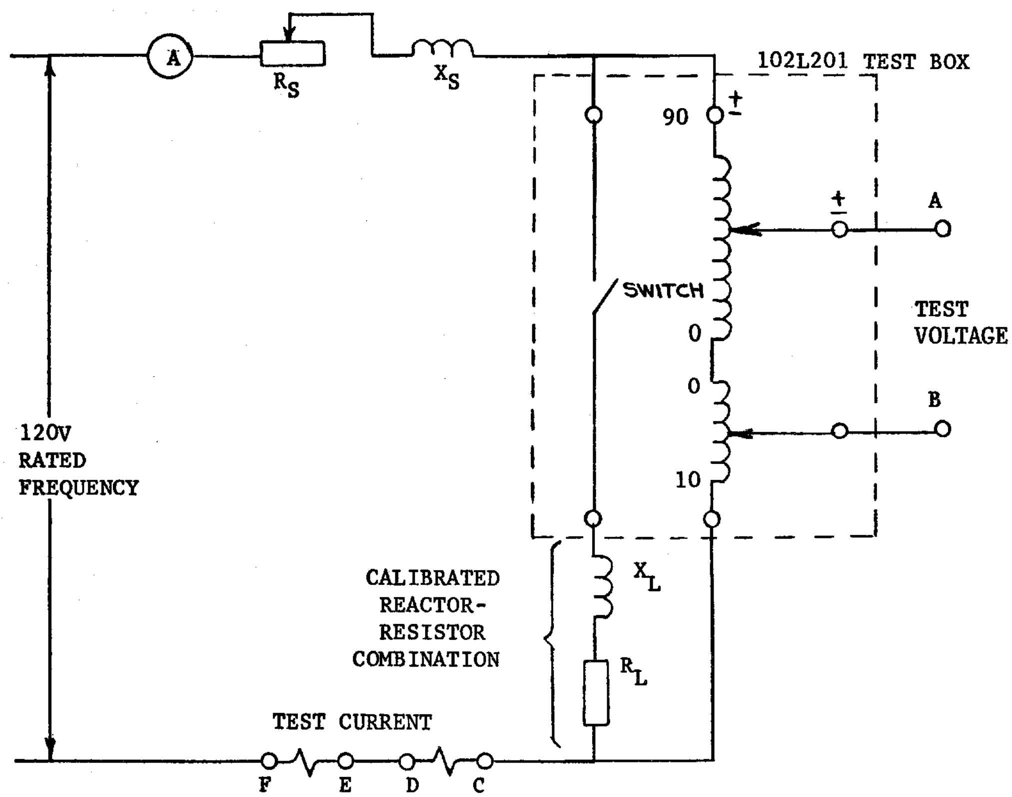
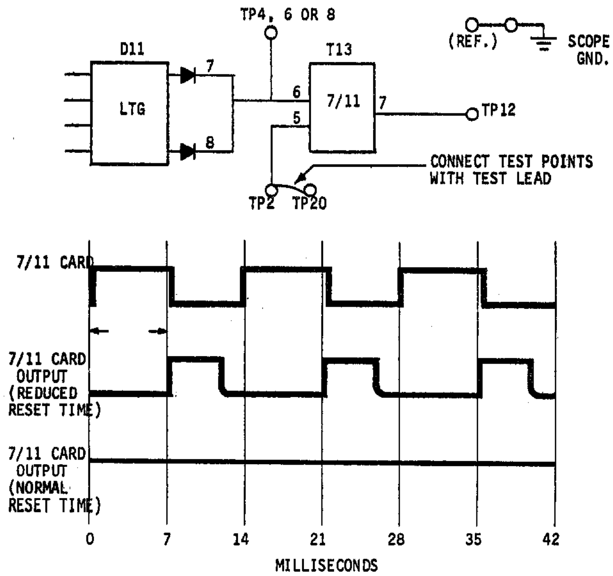


FIG. 14 (0178A7028-3) Test Circuit For Characteristic Check Using Test Box Test Reactor And Test Resistor Method



TEST CONNECTIONS AND CONDITIONS

PHASE	TO TEST 5/11 CARD	CHANNEL A OSC.	CHANNEL B OSC.
C	D	TP4	TP12
B	G	TP6	TP12
A	K	TP8	TP12

FIG. 15 (0246A3750-0) Test Conditions For 7/11 Timers In Ground MHO Units Of Type SLCG12B (50 Hertz) Relay

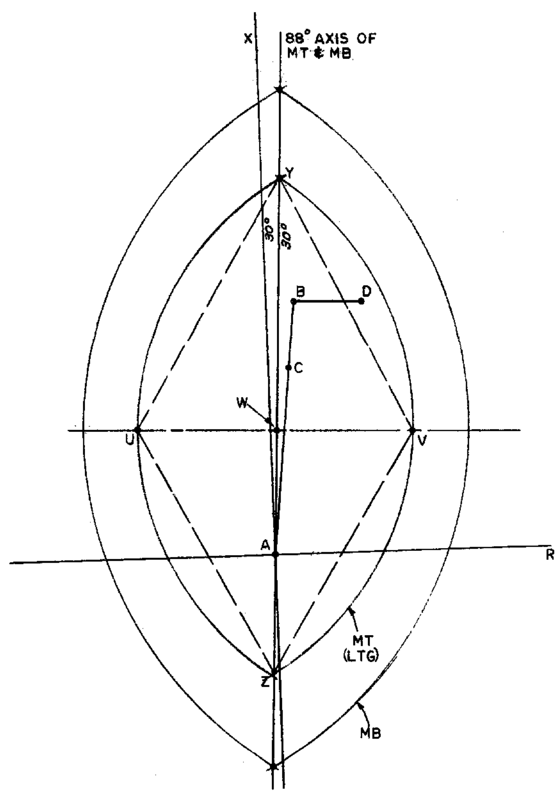


FIG. 16 (0246A2419-0) Graphical Determination Of Lens Characteristic

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