INSTRUCTIONS

INSTRUCTIONS

GEI-98313

TYPE SLCG11A RELAY

POWER SYSTEMS MANAGEMENT DEPARTMENT

GENERAL ELECTRIC

# TYPE SLCG11A RELAY

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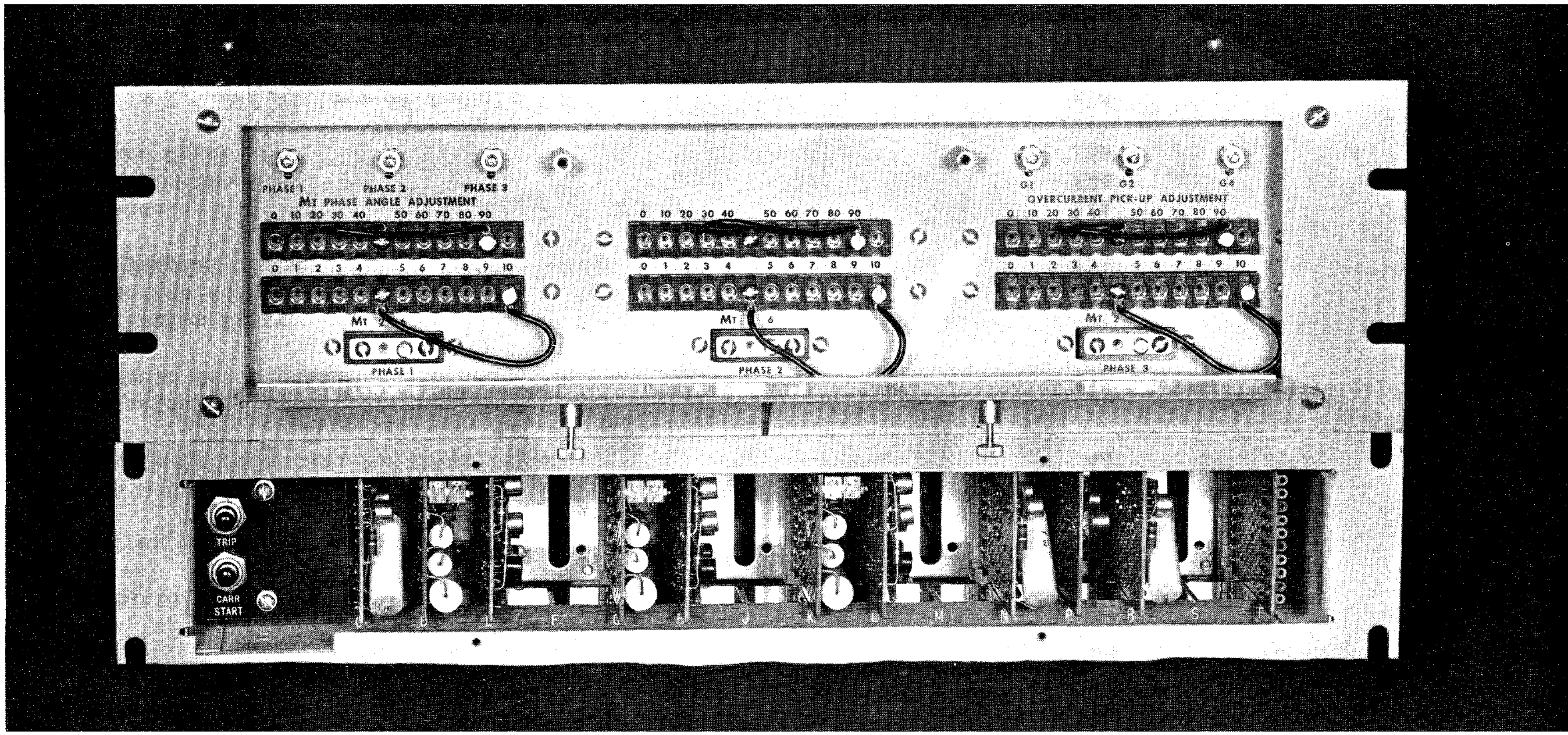



SLCG11A Relay Fig.1

# TYPE SLCG11A RELAY

## DESCRIPTION

The Type SLCG11A relay is a transistorized ground distance relay intended for use in a transmission line directional comparison protective scheme employing a communication channel, such as carrier current. It has three ground-mho tripping units, one for each phase, and uses an overcurrent measurement of residual current to start the pilot channel blocking signal. A second, higher-set overcurrent measurement supervises tripping, and a third high-set overcurrent measurement provides direct tripping without directional comparison.

The SLCG11A is packaged in two separate units, as shown in Fig. 1, (1) a tap block unit, containing tap blocks and other adjustments for setting the reach and the overcurrent operating levels, and (2) a logic unit containing printed circuit cards, isolating transformers, and push-buttons for simulating relay output. Each of these physical units is in a metal enclosure designed for mounting on 19 inch racks. The tap block unit is 3 rack units high and the logic unit is 2 rack units high (one rack unit is 1 3/4").

These two units contain the necessary components for detecting ground faults on any phase of a three-phase power system. Only one SLCG11A relay is required per relaying terminal.

The SLCG11A requires a 17 volt d-c power source, with bias voltages, which can be obtained from a Type SSA11A power supply. The output of the SLCG11A consists of low voltage signals which feed into a Type SLA12A "pilot control and trip" unit.



## RATINGS

The SLCG11A relay is designed for use in an environment where the air temperature outside the relay case does not exceed 55°C.

The current circuits of the SLCG11A relay are rated at 5 amperes, 60 cycles, for continuous duty, and have a one-second rating of 260 amperes. The potential polarizing circuits (line-to-line) are rated 120 volts, 60 cycles, and the restraint circuits (line-to-neutral) are rated 70 volts, 60 cycles.

The range of adjustment of the function in the SLCG11A relay are listed below:

MT: 2 to 60 ohms at 60° maximum reach angle, with base ohm taps of 2 and 6 ohms.
G1: 0.4 to 4 amperes
G2: 0.5 to 8 amperes
G4: 10 to 80 amperes

## APPLICATION

The SLCG relay provides directional discrimination for ground faults on transmission lines where a pilot channel is used to provide directional comparison relaying. This relay, operating in conjunction with the pilot channel and with similar relays at the other ends of the protected line section, provides high speed relaying for all single-phase-to-ground faults within the protected line section.

The SLCG relay uses three single-phase ground distance (mho) units for the tripping function, and uses a non-directional overcurrent unit, operating from CT residual current, to start the pilot channel blocking signal. Other non-directional overcurrent units supervise tripping and provide a high-level direct trip function.

The directional mho units (MT) are not accurate distance measuring units, in that they are not compensated for differences between zero sequence and positive sequence impedance, nor for the effect of mutual impedance. They should be set to overreach the remote terminal (s) with adequate margin. Instructions for setting these units to insure adequate reach are given in the section CHOICE AND CALCULATION OF SETTINGS.

The sensitivity and range of adjustment of the units are described under RATINGS. Typical external connections are shown in Fig. 2.

## OPERATING PRINCIPLES AND CHARACTERISTICS

The SLCG relay uses overcurrent units for starting a blocking signal and single-phase MT (mho) units for stopping the blocking signal and providing the local trip signal in a directional comparison scheme involving a pilot channel.

The overcurrent units measure current transformer neutral, or residual current. There are three level detectors (G1, G2, and G4) and each is supplied by a separate transactor. A transactor is an air-gap reactor with a secondary winding and is used to convert a current signal in the primary winding to a voltage signal in the secondary winding.

The MT (mho) characteristic is obtained by combining the transactor signal (IZ) with a signal proportional to line-to-neutral voltage, and measuring the phase angle between this "IZ-V" voltage and a polarizing voltage. The polarizing voltage in the SLCG is a median voltage (the voltage from one phase to the midpoint of the opposite two phases) and is in phase with line-to-neutral voltage under normal conditions.



The MT function has a directional characteristic with the mho circle passing through the origin on an R-X diagram. The measurement principle is shown graphically in Fig. 3. Comparison is between the polarizing voltage V and the operating quantity $IZ_1-V$. The angle (B) between these two quantities is greater than 90° for faults external to the relay characteristic, and is less than 90° for faults within the relay characteristic. For faults which cause V to terminate on the relay characteristic, the angle B is equal to 90°. This is true for any angular location of V, because V, $IZ_1$, and $IZ_1-V$ form a right triangle for any point on the relay characteristic.

If the IZ and voltage tap values are used directly, to make a reach setting of the MT 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 Appendix II for choosing tap settings when these two factors are taken into consideration.

The maximum reach angle for the MT characteristic is 60°, measured between phase current and the median polarizing voltage, with current lagging voltage by 60°. The use of median polarizing voltage provides the relay with polarizing voltage in phase with line-to-neutral voltage for single-phase and three-phase faults, and with only a small phase-angle error (not more than 30°) and corresponding shift of the characteristic for other types of faults. The use of median voltage, rather than line-to-neutral, for polarizing assures adequate polarizing voltage for single phase-to-ground faults where the fault voltage is near zero.

The $M_T$ characteristic is produced with a block-block measuring scheme in which both input quantities, V and IZ-V, are converted to blocks of voltage, and the duration of their coincidence (having same polarity) is measured. This is illustrated in Fig. 4. Blocks which are 90° apart are coincident for 4.15 milliseconds. Blocks which are less than 90° apart are coincident for more than 4.15 milliseconds. Thus, the M cards contain circuits to detect coincidence of the two input blocks, and are followed by a 4.15 millisecond time measurement (4/9 card). Maximum operating time, shown at the bottom of Fig. 4, is 12 milliseconds (3/4 cycle) and minimum operating time is 4 milliseconds (1/4 cycle).

## CHOICE AND CALCULATION OF SETTINGS

The information below applies to two-terminal lines. See Appendix IV for information on 3-terminal applications.

### OVERCURRENT FUNCTION

The following is given as a general guide for the setting of the three overcurrent units:

G1 Unit: Preferred operating level setting is the minimum rated value, or 0.4 ampere. Do not set higher than 80% of the G2 unit at the remote end of the line.

G2 Unit: Set operating level no higher than 67% of the minimum single-phase-to-ground fault current in the relay calculated with the remote breaker closed. Lower settings are desirable for increased speed of operation. However, the G2 operating level should not be set lower than 125% of the G1 operating level at the remote end of the line.



G4 Unit: The operating level of this unit should be set above the maximum ground fault current which can flow at the local terminal for an external fault beyond the remote terminal. This unit by-passes the directional comparison circuits ($M_T$ and receiver blocking signal) and trips directly.

### DISTANCE ($M_T$) FUNCTION

The ground mho unit must be set with a reach great enough to permit tripping for faults at the far end of the line. The apparent impedance of a transmission line as seen by the $M_T$ unit for a single phase-to-ground fault will usually be greater than the positive sequence line-to-neutral impedance from the relay to the fault because of the difference between zero-sequence and positive-sequence impedance, and because of zero-sequence mutual inductance with parallel lines. Instructions are given in Appendix II for calculating the minimum permissible reach setting (maximum permissible tap setting) to insure adequate reach.

At some relay locations, depending on system impedances and the positive and zero-sequence distribution factors (C and $C_O$), fault current flowing in the unfaulted phase conductors can produce an apparent impedance that is within the reach of the ground mho unit on this phase. This is true for external as well as internal faults. To avoid tripping falsely for this condition, the ground mho reach must not be set large enough to see this apparent impedance. Instructions are given in Appendix III for determining the maximum permissible reach setting (minimum permissible tap setting) to avoid this.

The SLCG relay has two "base reach" tap settings, 2 ohms and 6 ohms. Use the 2 ohm tap for settings between 2 and 6 ohms, and the 6 ohm tap for settings above 6 ohms.

## SAMPLE CALCULATION FOR GROUND MHO SETTINGS

In order to illustrate the calculations required, assume the portion of a transmission system shown in Fig. 5.

Consider the protected line to be line #1 having the following characteristics:

$Z_1'$ = $24.0\underline{/79^\circ}$ primary ohms

$Z_0'$ = $72.0\underline{/75^\circ}$ primary ohms

$Z_{om}$ = $14.4\underline{/75^\circ}$ primary ohms

CT Ratio = 600/5

PT Ratio = 1200/1

$Z_1'$ = $2.4\underline{/79^\circ}$ secondary ohms

$Z_0'$ = $7.2\underline{/75^\circ}$ secondary ohms

$Z_{om}$ = $1.4\underline{/75^\circ}$ secondary ohms

### Terminal A

Consider first the minimum reach setting of the ground mho unit, using instructions given in Appendix II. Assume that a system study has produced the following quantities for the relays at Terminal A with the fault at $F_3$:

$C_o$ = 0.17

$C$ = 0.20

$I_a'$ = 13.7 secondary amperes based on 600/5 CT's



$I_o''$ = -0.88 secondary amperes based on the protected line CT ratio of 600/5. Note the negative sign because $I_o''$ flows in the opposite direction in line #2 from that in which $I_o'$ flows in line #1.

Substituting these values into equation II-c of Appendix II, and recalling the values of:

$Z_{om}$ = 1.4 secondary ohms

$Z_1'$ = 2.4 secondary ohms

$Z_o'$ = 7.2 secondary ohms

$K$ = 200 for the 2 ohm base reach tap

We obtain for T a maximum permissible setting of 41 percent. This corresponds to a reach setting, at the maximum reach angle, of 2/0.41 = 4.9 ohms.

(The 2 ohm base reach tap was chosen to illustrate the absolute minimum permissible reach setting. Note that if the 6 ohm tap had been chosen, the answer for T would have been 122 percent, which is greater than the maximum available setting of 100%. This would have indicated that there was no limitation on the maximum voltage tap when the 6 ohm base reach tap is used.)

Now consider the minimum permissible tap setting (maximum permissible reach setting) for the relay at A, following instructions given in Appendix III. Consider first a single phase-to-ground fault at $F_1$ in Fig. 5. For this fault, assume that a system study yields the following system constants:

$C = 0.73$

$C_o = 0.89$

$Z_1 = 0.875\underline{/82^o}$ secondary ohms

$Z_o = 1.05\ \underline{/78^o}$ secondary ohms

From equations III-a and III-b of Appendix III, we get, for a fault at $F_1$:

| QUANTITY | EQUATION III-a | EQUATION III-b |
|---|---|---|
| $Z_1$ | $0.875\underline{/82^o}$ | $0.875\underline{/82^o}$ |
| $Z_o$ | $1.05\ \underline{/78^o}$ | $1.05\ \underline{/78^o}$ |
| $Z_o/Z_1$ | 1.2 | 1.2 |
| $C_o$ | 0.89 | 0.89 |
| $C$ | 0.73 | 0.73 |
| $K_s$* | 192 | 192 |
| $\alpha$ | 12 degrees | 12 degrees |
| $\theta$ | 82 degrees | 82 degrees |
| T | 6.1% | -19.6% |

* Assume base reach tap setting of 6 ohms. If 2 ohm base reach tap setting is used, $K_s$ will be 1/3 this value. (See Fig. A-2, Appendix.)

The 6% value for equation III-a represents a relay reach of 6/.06 or 100 ohms, which is greater than the reated 60 ohm maximum reach of the relay, and therefore does not limit the maximum reach setting. The negative value for T in equation III-b means that there is no limit to the maximum reach setting for that condition, other than the 60 ohm rated maximum.

(The 6 ohm base reach tap was assumed in this case to illustrate the absolute maximum permissible reach setting. Note that if the



2 ohm tap had been assumed, the values for T above would be 2% and -6.5%, or 1/3 of the values above.)

In order to evaluate the minimum permissible tap setting for equation III-c, the same values for $C_o$, C, and $Z_o$ above are used again, and the zero-sequence impedance angle, 78°, is used for θ. Since the 6 ohm base reach tap setting is being considered, the value for K = 600.

$$T = \frac{600\ (0.74-0.89)}{3\ \ 2\ (1.05)} \cos (78-60)$$

$$T = -28.6 \text{ percent}$$

In this case, since T is negative, this equation presents no limitation on the setting of the ground mho unit tap. In general, after the values of T have been calculated from equation III-a, III-b, and III-c, the largest positive value (in this case, 6%) should be selected. This value should be multiplied by a safety factor of 1.1 (6 X 1.1 = 7.7 or 8). The resulting tap is the minimum safe tap setting to apply to the ground mho units. In this case the 8% tap would produce a reach greater than the maximum rated reach of 60 ohms, and therefore does not represent a real limitation.

To summarize, then, the only limitation developed above is the max. value of 41% for T if the 2 ohm base reach tap is used. This means the station A relay reach, at 60°, may be safely set at any value between 4.9 and 60 ohms as far as fault conditions are concerned.

## Terminal B

Now consider the relays a Terminal B. Assume that a board study provides the following quantities for the relay a "B" and a fault at $F_2$.

$C = 0.27$

$C_o = 0.11$

$I_a' =$ 15.4 secondary amperes based on 600/5 CT's

$\theta = 79^\circ$

$I_o'' =$ 1.55 secondary amperes based on the protected line CT ratio of 600/5.

Substituting these values into equation II-c of Appendix II and recalling the values of:

$Z_{om} =$ 1.4 secondary ohms

$Z_1' =$ 2.4 secondary ohms

$Z_o' =$ 7.2 secondary ohms

$K =$ 200 for the 2 ohm base reach tap

we obtain for T a maximum permissible tap setting of 45 percent. This corresponds to a minimum reach setting, at the maximum reach angle of 2/0.45 = 4.45 ohms.

Consider now the maximum permissible reach setting for relays at B, using instructions from Appendix III. Assume that a system study yields the following system constants for a single phase-to-ground fault at $F_4$:

$C = 0.80$

$C_o = 0.83$

$Z_1 = 0.72\underline{/82^\circ}$ secondary ohms

$Z_o = 1.33\underline{/78^\circ}$ secondary ohms



From the equations III-a, III-b, and III-c of Appendix III, using the values of K and $K_g$ for the assumed base reach tap settings of 6 ohms, we obtain:

Equation III-a - T = 0.75 percent

Equation III-b - T = -6.2 percent

Equation III-c - T = -4.3 percent

The only positive value (0.75) in the three answers above is too small to impose any restriction on the maximum reach setting of the ground mho unit. Therefore the reach may be set for any value up to 60 ohms (or T down to 10%) the maximum rated reach.

To summarize, then, for station B the only limitation is the 45% maximum setting for T if the 2 ohm base reach tap is used. This means the relay reach, at 60°, may be set at any value between 4.45 and 60 ohms, as far as correct operation during faults is concerned.

## CONSTRUCTION

The components of the SLCG relay are mounted in two separate containers, (1) the tap block unit, and (2) the logic unit. Interconnections between these units are made by multiconductor shielded cable, as shown in Fig. 6.

### TAP BLOCK UNIT

The tap block unit (see Fig. 1) contains the tap blocks for making reach settings of the mho tripping ($M_T$) function. It also contains rheostats and potentiometers for adjusting the maximum reach angle of the $M_T$ function and for setting the operating level of the overcurrent functions, G1, G2, and G4. (G3 is not used in this equipment.)

Incoming currents and voltages are supplied to the tap block unit through two screw terminal blocks (GA and GB) at the rear of the unit. Output voltage signals appear at two 10-point sockets for interconnection with the card or logic unit.

There are three groups of reach-setting tap blocks on the front panel of the tap block unit, one group for each phase. Each group contains voltage (V) taps on the upper tap blocks and current (IZ) tap blocks below.

Tap settings are made by connecting jumpers from fixed taps (round-head screws), to adjustable taps (knurled-head screws). In the voltage tap block arrangement, the upper block provides a choice of 10% steps, and the lower block provides a choice of 1% steps. The total percent voltage tap setting is the sum of these two tap block settings. This arrangement provides an adjustment range from 10% to 100% in 1% steps.

The current (IZ) taps provide a choice of 2 or 6 ohms base reach. These numbers are equal to the reach of the relay, along the maximum reach angle, when the 100% voltage taps are used.

The left-hand rheostats on the tap plate are loading resistors on the secondaries of transactors, and control the maximum reach angle of the mho characteristics. Turning these rheostats CW increases the angle.

The right-hand potentiometers control the operate level of the G1, G2, and G4 overcurrent functions.



LOGIC UNIT

The logic unit contains a row of printed circuit cards mounted behind the front cover. There is also a small panel containing two push-buttons for simulating a G1 (or CARRIER START) output and a TRIP output. Mounted behind the printed circuit cards are isolating transformers, resistors, and a diode board.

Printed circuit cards are identified by a code number, such as D11, L4, and T13, where D means discriminator, L means logic, and T means time delay. The identification and location of individual cards is shown in Fig. 7. Individual cards and sockets are keyed to prevent inserting cards in the wrong sockets.

This logic unit has a test card in the far right-hand position (position T). Test points are numbered 1 to 10 from top to bottom on this card, and are identified on the logic diagram by TP numbers. The upper pin jack on the test card, TP1, is connected to the reference bus of the transistor circuits, and TP10 is connected to the +15.6 volt bus. The remaining test points are connected to selected points within the logic circuits and may be used to trace outputs and to make settings on time delay cards.

Circuit Description

Internal connections for the tap block unit are shown in Fig. 8. Input current and voltage terminals are identified at the left of the drawing, where numbers within squares represent GA and GB terminal block numbers. Output signals are represented by the double-arrow connector symbol and corresponding socket pin number at the right of the drawing.

The a-c voltage supply to the tapped transformers TA, TB, and TC consists of three phase-to-neutral voltages (66 volts each). The neutral point for each phase is connected to a separate stud, so that each phase-to-neutral voltage can be isolated from the other phases when testing. The three neutral points $V_{N(1)}$, $V_{N(2)}$, and $V_{N(3)}$ will normally be connected together externally. To obtain the polarizing voltage for $M_T$, resistance voltage-dividers are connected across the phase voltages $V_{1-2}$, $V_{2-3}$, and $V_{3-1}$. These midpoints on the line-to-line voltages are used with the opposite phase voltage to provide median voltage polarizing.

Phase currents are supplied to separate transactors, and the transactor secondary voltages are connected to tapped autotransformers for the same phase to produce the (IZ-V) signal. Residual, or neutral, current is supplied to the three transactors which supply the overcurrent level detectors G1, G2, and G4.

Internal connections for the logic unit are shown in Fig. 9, which is also a logic diagram for this unit. A legend of symbols used on this and other logic diagrams is shown in Fig. 10. All inputs to the logic unit are from the tap block unit, and all outputs are connected to a Type SLA "pilot control and trip" unit.

A schematic representation of the a-c circuits for phase 1 of the SLCG11A is shown in



circuit that are in the tap block unit with the parts that are in the logic unit to give a better understanding of the input signals to the logic unit cards. Phases 2 and 3 have similar connections, except for pin numbers at the sockets.

The D11 card which produces the $M_T$ characteristic for phase 1 is supplied with a median polarizing voltage that is obtained from $V_1$ and the midpoint between $V_2$ and $V_3$. This voltage is passed directly through an isolating transformer and appears at pins 4 and 6 of the D11 card. The other input to the D11 card is (IZ-V) with the IZ coming from the transactor secondary and the V from the tapped autotransformer. This voltage is limited by diode clippers in the logic unit, stepped up through an isolating transformer, and applied to pins 5 and 3 of the D11 card.

Transactor outputs for the level detectors are supplied to the cards through isolating transformers in the logic unit.

Referring now to Fig. 9, the SLCG11A logic diagram, the D11 cards have two outputs, one for each polarity. These are paralleled and supplied to the T13 card which contains the 4/9 measurement necessary to produce the mho characteristic. This T13 card also includes an AND function to provide G1 supervision of the $M_T$ output. $M_T$ output appears at TP2 and at cable pin #125.

G1 output is available at TP8, and G2 output at TP5. G2 plus $M_T$, or the TRIP output, is available at TP9 and at cable pins #122 and #124. The high-set level detector G4, has its output available at TP3 and cable pin #126.

Push-buttons apply +15.6 volt signals to TP8 for the CARRIER START (or G1) function, and to TP2 and TP5 for the TRIP function. These push-buttons can be used to check interconnections between the SLCG and the SLA relay.

## INSTALLATION TESTS

### NECESSARY ADJUSTMENTS

The following adjustments should be made by the user, in accordance with the instructions given below, before putting the relays into service:

(1) reach IZ taps: (2 ohms or 6 ohms)
(2) $M_T$ reach by voltage tap setting
(3) overcurrent operating levels

Connect all interconnecting cables from tap block to logic unit, and from logic unit to power supply, before beginning tests.

### GENERAL TESTING INSTRUCTIONS

1. Input Circuits

The SLCG11A tap block unit has two 10-point terminal blocks mounted on the rear of the unit and identified as the GA and GB terminal blocks (see Fig. 6). Where the drawout case test and connection receptacles are used, these are connected to the GA and GB terminal blocks by 10-conductor cables, and input currents and voltages can be supplied through the standard Type XLA test plug. Where other test facilities are used, input currents and voltages should be applied to test points which connect to the same GA and GB terminal points as those shown on the test circuit diagrams.

2. Output Signals

The SLCG11A logic unit has a test card in the T position. This test card has 10 pin jacks mounted on the outer edge of the card



and numbered 1 to 10 from top to bottom. The location of these points in the logic circuits is shown on the SLCG11A logic diagram, Fig. 9.

Output signals are measured with respect to the reference bus, or TP1. Outputs are continuous signals of approximately +10 to +15 volts for the ON condition, and 0 to +2 volts for the OFF condition. This output can be monitored with an oscilloscope, a portable high impedance 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.

Where time delay cards (such as T13) are to be adjusted or checked, an oscilloscope which can display two traces simultaneously and which has a calibrated horizontal sweep should be 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 SLCG reference voltage, which normally will be connected to the ground input of the instrument, is near 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. However, if the input to the oscilloscope is a differential amplifier and neither incoming voltage signal lead is tied directly to the instrument ground, it is not necessary to observe the above precautions.

## DETAILED TESTING INSTRUCTIONS - REQUIRED ADJUSTMENT

### 1. Reach Tap Settings

The arrangement of the reach setting tap blocks is described under the section on CONSTRUCTION, and the choice of tap settings is discussed under the sections on APPLICATION and CHOICE AND CALCULATION OF SETTINGS. Make tap settings in accordance with these instructions, moving only the knurled head screws (and associated jumpers) to get the desired relay reach setting.

### 2. Testing Mho ($M_T$) Characteristic

The reach of the $M_T$ characteristic may be checked over a portion of its range by using the single phase test circuit of Fig. 12. This circuit uses the test box (102L201), test reactor (6054975) and test resistor (6158546) described in GEI-44236. Combinations of resistor and reactor taps may be chosen to provide 30° and 60° angles between the current and voltage supplied to the relay, and the reactor alone provides a check at an angle near 90°.

The $M_T$ function measures distance to the fault location accurately only for the special case where the zero-sequence impedance is equal to the positive sequence impedance and there is no mutual coupling to adjacent lines. This test indicates the line-to-neutral ohms the relay would measure under these conditions. This reach is equal to the base ohm reach (IZ tap value) when the 100% voltage tap is used, and the fault impedance angle is 60°.



The $M_T$ reach may be checked at the 60° maximum reach angle, using a reactor-resistor combination ($R_L$ and $X_L$) to give 60° between the voltage at A-B and the current at C-D. Although the polarizing voltage is normally a median voltage (for example, $V_1$ to midpoint of $V_{2-3}$, for the phase 1 characteristic), this test circuit uses the A-B voltage as both the polarizing and the restraint voltage. This method is accurate for checking the $M_T$ behavior on single-phase-to-ground faults.

Choose a resistor-reactor combination to give a test impedance that is greater than the reach being checked. For example, if the $M_T$ reach setting is 8 ohms, use the resistor-reactor combination that gives approximately 13.5 ohms at 60°.

If the test box selector switch is reduced from 100% until a steady state relay output is observed, the selector switch setting indicates relay reach at this angle expressed as a percent of the test impedance. For example, if the test impedance is 13.5 ohms and the test box selector switch setting is 50%, the relay reach is 0.50 times 13.5 or 6.75 ohms. This reach measurement should be within ±5% of that calculated from tap values.

The $M_T$ reach also may be checked at two other angles. The reactor may be used alone ($R_L = 0$) to obtain an angle of approximately 86°, and an $R_L$ - $X_L$ combination may be chosen to make a check at 30°. The reach at 30° should be between 80% and 90% of the reach at 60°, and the reach with $X_L$ alone should be between 85% and 95% of the reach at 60°.

The source impedance ($X_S$ and $R_S$) may be adjusted so that the tests at the three angles are made at the same current level. This source impedance should be predominantly inductive, with the resistance portion used only to make a fine adjustment of current level.

3. Overcurrent Operating Level

The operating level of the overcurrent functions G1, G2, and G3 can be checked by supplying a variable test current to studs GB5 and GB6, using a test reactor as part of the current limiting impedance. Outputs are observed at the following test points in the logic (or card) unit:

G1 - TP8

G2 - TP5

G4 - TP3

Gradually increase current to check operating level; gradually decrease current to check reset level. Output is +10 to +15 volts when operation occurs. To adjust operate level, use OVERCURRENT potentiometer on tap block front panel, turning it CLOCKWISE to increase operating level. Reset level should be above 90% of operate level.

## ADDITIONAL ADJUSTMENTS AND TESTS

The following information covers items whick have been covered in factory test. The following information is supplied for use in trouble-shooting or in checking overall performance of the SLCG functions.



1. Mho Phase Angle Adjustment

These three rheostats, located on the front panel of the tap block unit, control the angle between the transactor output voltage and input current. This angle is factory adjusted for 60°, which produces a 60° maximum reach angle of the $M_T$ characteristic.

This adjustment can be checked by using the test circuit described under "Testing Mho Characteristic" and observing the reach measured at the 30°, 60°, and 86° test angles. The reach at 30° should be 87% of the 60° reach, and at 86° should be 90% of the 60° reach. If the measured results indicate that a shift of the mho characteristic is required, this can be accomplished by turning the mho phase angle rheostat for the phase being checked.

2. T13 (4/9) Time Delay Cards

These cards should have a 4.15 millisecond delay on operate time and a 9 millisecond delay on reset time. The 4.15 millisecond time is important in making the 90° measurement and affects the shape of the mho characteristic: times longer than 4.15 milliseconds tend to narrow the characteristic and times shorter than 4.15 milliseconds tend to widen the characteristic. The 9 millisecond reset time is provided to overlap the next half-cycle measurement and to produce a continuous output.

To check the 4/9 time delay cards, connect the test circuit used for "Testing Mho Characteristic" using either the test reactor alone (for a fault angle near 90°) or a reactor-resistor combination which gives a 30° angle. Reduce the applied voltage by changing selector switches on the test box until the fault condition applied to the relay is within the relay characteristic. Connect TP8 to operate the AND function on the T13 card, and connect T13 card inputs and outputs to oscilloscope as shown in Fig. 13.

Typical waveshape of the input to the 4/9 card is shown in the upper trace of Fig. 13. This input should consist of blocks just slightly longer than 4.15 milliseconds (adjust applied test voltage to get this condition). These blocks occur every half-cycle, and the gaps between blocks are less than 4 milliseconds. In order to check the T13 card time delay, it is necessary to reduce the 4/9 card reset time so that the output at TP2 appears as shown on the center trace of Fig. 13. This can be done by turning the outer pot on the 4/9 card CCW. The 4.15 millisecond operate time can be checked by using the calibrated horizontal sweep of the oscilloscope. Turn the inner pot on the 4/9 card CLOCKWISE to increase time delay. After the operate time has been checked and adjusted, the reset time can be extended (turn outer pot CW) just enough to obtain continuous output as shown in the lower trace of Fig. 13. Check the 4/9 cards for each phase, one at a time.

## MAINTENANCE

### PERIODIC TESTS

**NOTE:** For any periodic testing of the SLCG relay, the trip coil circuit of the circuit breaker should be opened by removing one of the connection plugs in the SLA test and connection receptacle, or by opening other test switches provided for this purpose.



Removing the connection plug at the GA or GB test and connection receptacle does not open the trip circuit.

Reach of the $M_T$ units and operating level of the overcurrent units may be checked at periodic intervals using the instructions under INSTALLATION TESTS. Cable connections between the SLCG and SLA relays may be checked by using push-buttons in the SLCG to produce CARRIER START and TRIP output signals. Proper operation can be checked by observing carrier output, or by checking carrier start, carrier stop, and trip test points in the SLA relay.

### TROUBLE-SHOOTING

Test points are provided at selected points in the SLCG logic unit and may be used to trace outputs if trouble-shooting is necessary. The use of a card adapter will make all the pins on any one card available for testing.

All output voltages at the test points are measured with respect to the reference bus, TP1, and in the OFF condition are less than +2 volts. When an output appears at any test point, the voltage at that point switches to an ON signal (+10 to +15 volts).

The test points in the SLCG are identified below:

| TEST POINT | FUNCTION |
|---|---|
| 1 | REFERENCE (0 Volts) |
| 2 | $M_T$ Output |
| 3 | G4 Output |
| 4 | T13 Card Input, Phase 1 |
| 5 | G2 Output |
| 6 | T13 Card Input, Phase 2 |
| 7 | T13 Card Input, Phase 3 |
| 8 | G1 Card Output |
| 9 | Trip Output ($M_T$ AND G2) |
| 10 | +15.6 VOLT BUS |

The physical location of components (transactors, transformers, ect.) in the tap block unit is shown in Fig. 14. The location of components behind the printed circuit card area in the logic unit is shown in Fig. 15. The letters on these drawings refer to components on internal connection diagrams, Figs. 8 and 9.

## SPARE CARDS

The number of spare cards to carry in stock would depend on the total number of static relays, using similar cards, at the same location or serviced by the same test group. For each type of card (different code designation) a suggested minimum number of spare cards would be:

1 spare for 1 to 25 cards
2 spares for 26 to 75 cards
3 spares for 76 to 150 cards

The following table lists the quantity of each type of printed circuit card used in the SLCG relays and the part numbers to be used in ordering spare cards. These numbers are stamped on the individual cards.

| CODE | PART NUMBER | QUANTITY |
|---|---|---|
| D11 | 0116B6773G1 | 3 |
| D13 | 0116B6775G1 | 3 |
| L4 | 0116B4949G1 | 1 |
| T13 | 0127B8149G1 | 3 |

## CARD DRAWINGS

Details of the circuits of the printed circuit cards are shown in Fig. 16.



## OUTLINE DRAWINGS

Outline drawings are shown in the following Figs.:

Fig. 17 - Tap Block Unit
Fig. 18 - Logic Unit
Fig. 19 - Test & Connection Receptacle

## APPENDIX I

### DEFINITIONS 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.

#### A - Voltage

$E_a$ = Phase A-to-neutral voltage.

$E_b$ = Phase B-to-neutral voltage.

$E_c$ = Phase C-to-neutral voltage.

$E_{am}$ = (Phase A to midpoint of $E_{bc}$) voltage.

$E_{bm}$ = (Phase B to midpoint of $E_{ca}$) voltage.

$E_{cm}$ = (Phase C to midpoint of $E_{ab}$) voltage.

$E_o$ = 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.

#### B - Currents

$I_a$ = 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.

$I_o$ = 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.

$I_o''$ = 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. While this current flows in the parallel line, the secondary value is based on the CT ratio at the protected line terminal under consideration.

C - Distribution Constants

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

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

$C_o$ = Zero sequence distribution constant.

$$C_o = \frac{I_o'}{I_o}$$

D - Impedance

$Z_o$ = 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. Equals $Z_1'$.

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

All of the above are secondary ohms, where:

$$\text{Secondary Ohms} = \text{Primary Ohms} \times \frac{\text{CT Ratio}}{\text{PT Ratio}}$$

and $Z_{om}$ is calculated using the CT ratio for the protected line.

Miscellaneous

$T$ = Relay tap setting in percent.

$\propto, B, \theta, \& \emptyset$ = Angles in degrees as defined where used.

$K_s$ = Constant depending on the ratio of $Z_o/Z_1$.

$K$ = Design constant of ground mho unit:
= 200 for 2 ohm Base Reach Tap Setting,
= 600 for 6 ohm Base Reach Tap Setting.

## APPENDIX II
## MINIMUM PERMISSIBLE REACH SETTING FOR GROUND MHO UNIT

The phase A ground mho unit has a characteristic that is defined by equation II-a below. For the phase B and phase C units, similar equations apply except that different potentials and currents are applied.

$$TE_a'E_{am}' \cos B = KI_a'E_{am}' \cos(60-\phi) \qquad \text{II-a}$$

where:

- $T$ = Tap setting in percent.
- $K$ = Design constant of Ground Mho Unit:
  = 200 for 2 ohm Base Reach Tap Setting,
  = 600 for 6 ohm Base Reach Tap Setting.
- $E_a'$ = Phase A-to-neutral voltage applied to the relay.
- $E_{am}'$ = Median polarizing voltage (phase A to midpoint of $E_{bc}$ voltage) applied to the relay.
- $I_a'$ = Phase A current in the relay.
- $B$ = Angle between $E_a'$ and $E_{am}'$.
- $\phi$ = Angle by which $I_a'$ lags the voltage $E_{am}'$.

For faults involving ground, these units will operate to produce an output when the right-hand side of equation II-a is larger in magnitude than the left-hand side. For single phase-to-ground faults on a line where the zero sequence impedance ($Z_o'$) is equal to the positive sequence impedance ($Z_1'$) and there is no mutual impedance to parallel



circuits, the reach of the ground mho units in secondary phase-to-neutral positive-sequence ohms, for any line impedance angle ($\theta$), is given by:

$$Z = \frac{K}{T} \cos(60-\theta)$$

Conversely, the tap setting in percent required to reach a given secondary ohms at a given angle is:

$$T = \frac{K}{Z} \cos(60-\theta)$$

For the usual condition where $Z_o'$ and $Z_1'$ are not equal and/or mutual impedance exists, the reach of the ground mho unit is modified. The apparent impedance presented to the ground mho unit on the faulted phase for a fault at the far end of the line becomes:

$$Z_1' + \frac{(Z_o' - Z_1')\,C_o}{2C + C_o} + \frac{Z_{om}I_o''}{I_a'} \qquad \text{II-b}$$

where:

- $Z_1'$ = Positive sequence impedance of the protected line.
- $Z_o'$ = Zero sequence impedance of the protected line.
- $Z_{om}$ = Total zero sequence mutual impedance between protected line and parallel line.
- $I_o''$ = Zero sequence current in the parallel line. Taken as positive when the current flow in the parallel line is in the same direction as the current in the protected line.

$I_a'$ = Phase A current in the relay.

$C$ = Positive sequence distribution constant $I_1'/I_1$.

$C_o$ = Zero sequence distribution constant $I_o'/I_o$.

To insure that the ground mho unit on the faulted phase picks up for a fault at the remote bus, the maximum percent tap setting permissible is:

$$T = \frac{K \cos (60^\circ - \theta)}{1.25 \left[ Z_1' + \frac{(Z_o' - Z_1')\, C_o}{2C + C_o} + \frac{Z_{om} I_o''}{I_a'} \right]} \qquad \text{II-c}$$

If the solution to equation II-c yields a tap value (T) greater than 100 percent, this implies that even the shortest reach setting possible (100 percent tap) will suffice.

The factor 1.25 introduced in equation II-c is a safety factor. In order to extend the reach of the ground mho unit beyond the far bus, lower tap settings will be required.

If there is no zero sequence mutual impedance, the last term in the denominator of equation II-c becomes zero. If there is mutual impedance existing between the protected line and several other circuits, this last term becomes:

$$\frac{1}{I_a'} \left( \Sigma\ Z_{om} I_o'' \right)$$

Note that in this summation, the direction of the zero sequ[illegible] current flow ($I_o''$) in each



of the parallel circuits must be considered.

All voltages, currents and impedances in the above equations are in terms of secondary quantities based on the CT and PT ratios of the protected line. This applies to $I_o''$ as well as $I_a'$.

## APPENDIX III
## MAXIMUM PERMISSIBLE REACH SETTING FOR GROUND MHO UNIT

The ground mho unit on the faulted phase or phases will provide correct directional action. If the distribution constants for positive sequence currents (C) and for zero-sequence currents ($C_o$) were equal there would be no fault current flowing in the conductors of the unfaulted phases. However, where there is a difference between C and $C_o$, fault current does flow in the unfaulted conductors, and the current may flow in either direction, depending on which of the distribution constants is larger. Furthermore, for a single or double phase to ground fault very near the relay location, fault current in the unfaulted conductor (s) flows in the same direction for an external fault ($F_2$) as it does for an internal fault ($F_1$).

Because of this system characteristic, each application should be checked to insure that the apparent impedances seen by the relays on the unfaulted phase (s) do not fall within the relay characteristic. In the usual case, the line-to-neutral voltage on the unfaulted phase (s) is near normal and the fault current is relatively small, so that the apparent impedance is higher than normal reach settings.

Although false tripping on external faults is the chief concern, fault location ($F_1$ or $F_2$ in Fig. A1) does not affect relay operation on the unfaulted phase (s) and the following equations are derived using distribution constants for internal faults.

The application limits should be checked for both single and double phase to ground faults as described below:

(a) Single Phase to Ground Faults

In order to avoid false tripping on external single phase to ground faults, it is necessary to limit the reach setting of the ground mho units by keeping the voltage tap settings, T, above the larger of the two T values given below:

$$T = \frac{K_s\ (C-C_o)}{Z_1} \text{ Cos } (\alpha - \theta - 30) \qquad \text{III-a}$$

$$T = \frac{K_s\ (C-C_o)}{Z_1} \text{ Cos } (150 - \alpha - \theta) \qquad \text{III-b}$$

(Equation III-a is for the ground mho unit in the phase lagging the faulted phase, and equation III-b is for the ground mho unit in the phase leading the faulted phase.)

T = Minimum permissible tap setting in percent.

C = Positive sequence distribution constant, $I_1'/I_1$, for a fault at $F_1$.

$C_o$ = Zero sequence distribution constant, $I_o'/I_o$, for a fault at $F_1$.





$Z_1$ = System positive sequence impedance as viewed from the fault.

$\theta$ = The angle of the system positive sequence impedance $Z_1$.

$K_s$ = Constant depending on the ratio of $Z_o/Z_1$. See curves on Fig. A-2.

$\alpha$ = Angle depending on the ratio of $Z_o/Z_1$. See curves on Fig. A-2.

(b) Double Phase to Ground Faults

In order to avoid false tripping on external double phase to ground faults, it is necessary to limit the reach of the ground mho units by keeping the voltage restraint tap setting, T, above the value given below:

$$T = \frac{K\ (C-C_o)}{3\ Z_o} \text{ Cos } (\theta - 60) \qquad \text{III-c}$$

where:

K = design constant of ground mho unit:
= 200 for 2 ohm Base Reach Tap Setting,
= 600 for 6 ohm Base Reach Tap Setting.

All other terms are as derived above, except that $\theta$ is the zero sequence impedance angle. Note that C and $C_o$ have identically the same values as they have in equations III-a and III-b and are the distribution constants for an internal fault at $F_1$.

After the values of T have been calculated for equations III-a, III-b, and III-c above, the largest of the three values should be selected and then some margin such as 10% T (not 10 percentage points) should be added to this setting. This value of tap setting T is then the minimum permissible tap setting (maximum reach setting) for the ground mho units at the terminal under consideration. If either (or all) of the values of T calculated from the three equations is negative, this signifies that the particular equation (or equations) offers no limitation on the minimum permissible tap setting.

All voltages, currents, and impedances in the above equations are in terms of secondary quantities based on the CT and PT ratios of the protected line.

The effects of arc resistance have not been included in these calculations.

## APPENDIX IV
## THREE-TERMINAL APPLICATIONS

The ideal performance of a line relaying system for either a 2-terminal or a 3-terminal line may be defined in very broad and simple terms, as follows:

INTERNAL -- Trip all terminals simultaneously for an internal fault at any location with any expected distribution of current contributions.

EXTERNAL -- Trip no terminal for an external fault at any location with any expected distribution of current contributions.



It is the choice of settings for the G1, G2 and $M_T$ functions which needs to be analyzed in detail in order to insure that both of these requirements will be met.

(NOTE: It may be impossible to meet the first requirement, of obtaining response of all terminals for every fault, if there are external ties between source and fault terminals, or if one of the terminals lacks a ground-current source; and in such cases some special provision must be made in order to provide simultaneous tripping. It is even possible to have ground fault current flowing out of one terminal, through an external tie, to an internal fault near another terminal; and in such a case, special provision must be made in order to permit the tripping of the other two terminals.)

### OVERCURRENT FUNCTIONS

The G1 and G2 units are not affected by the system voltage or the zero sequence voltage, and their designs are coordinated in such a way that time coordination (on external faults) is assured if current coordination is obtained by means of the settings. Therefore the two items listed above can be met as follows:

INTERNAL -- The tripping ground fault detector G2 at any terminal A must be set at not more than 80% of the current that it receives for a ground fault at the bus of either of the other two terminals B or C, with the third terminal C or B either closed or opened. A similar requirement applies for B with respect to C and A, or for C with respect to A and B. In the relaying of a 3-terminal line, (Fig. A-3a), this requirement is complicated by the possible presence of infeed from B with A and B closed and a fault at C, since the added zero-sequence-voltage drop in the common branch from J to C, due to the contribution from B, decreases the contribution from A.

EXTERNAL- Before detailing the requirements for the performance of the blocking level detector (G1) on an external ground fault it would be well to explain first that on a 3-terminal line, an external fault may involve two source terminals and one fault terminal, as is normally expected or it may involve one source terminal and two fault terminals because of the existence of an external tie between two terminals with the fault occurring on that external tie.

If there is no external tie from one terminal to either of the other two, a fault external to that terminal cannot cause current to flow out of either of the other two. Therefore, for those conditions, G1 at that terminal needs only to be set to pick up at 80% or less, of the other two terminals, as in the case of a 2-terminal line.



With an external tie between any two terminals, the location of the fault on that external tie may be such as to divide the contribution from the source terminal equally between the two fault terminals, with a source contribution still in excess of the pick-up of the tripping fault detector G2 at the source terminal; and for this reason it is common practice to set the blocking fault detectors G1 at each of these fault terminals having such an external tie, for a pick up 40% as great as the pick-up of the lower-set G2 at either of the other two terminals of the 3-terminal line.

If this results in specifying an unavailable or undesirably low setting, and if a fault study shows that there is a section $D_B$-$D_C$ (called here a "dead zone") of the external tie $B_C$ of Fig. A-3b, where the contribution from A through the 3-terminal line is too low to operate G2 at its source terminal A, then a G1 pick-up at B or C, greater than 40% of G2 pick-up, may still provide the normal 20% margin of the effective blocking level below the tripping level. This may possibly be done by choosing the pick-up for G1 on the basis of a fault at the near end of the "dead zone" D of the external tie, at such a value as will maintain its normal 2-terminal margin.

## DISTANCE FUNCTIONS

In order to provide simultaneous tripping of all three terminals, it is necessary to use reach settings of the mho units ($M_T$) large enough to insure that all three terminals will respond, with margin, for an INTERNAL fault at any terminal with all three closed, regardless of the possible outage of some adjacent external line connecting two terminals either directly or indirectly, or outage of some external source forming part of the system near a given terminal.

The calculation of the apparent impedances resulting from infeed of the junction J (Fig. A3-c), requires knowledge of the maximum current contributions from other terminals, and, therefore, requires a fault study that takes into account possible outages of lines or generation or both, external to the protected line. With this data at hand, the apparent impedances for terminal A can be calculated from the relations:

$$Z_{AC} = Z_{AJ} + Z_{JC} (I_{AJ} + I_{BJ})/I_{AJ}$$

and:

$$Z_{AB} = Z_{AJ} + Z_{JB} (I_{AJ} + I_{CJ})/I_{AJ}$$

The impedance values $Z_{AJ}$, $Z_{BJ}$, and $Z_{CJ}$ should be the apparent impedance value derived in Appendix II (Equation II-b) measured from each terminal to the junction and taking into account the zero sequence impedance ($Z_o$), the mutual impedance ($Z_{OM}$) and the distribution constants (C and $C_o$).

Similar relations, except with the subscripts interchanged, apply for the two apparent impedances seen by the relays at B for faults at C or A, and by the relays at C for faults at A or B. These



six results can all be tabulated, like those in Table A-1, which were calculated for a specific case where one of the line terminals include a power transformer.

TABLE A-1

| RELAY LOCATION | APPARENT OHMS FOR FAULT AT: A | B | C |
|---|---|---|---|
| A | 0 | 1.96 | <u>4.46</u> |
| B | <u>4.82</u> | 1.70 | 4.50 |
| C | <u>6.56</u> | 1.34 | 0 |

In each horizontal row, representing conditions seen by a given relaying terminal, the <u>higher</u> of the two values for faults at the other two terminals is underlined. This is the value on which the forward reach setting $Z_F$ should be based, and the $M_T$ reach suggested for 3-terminal lines is 1.25 X the apparent impedance.

$$Z_F = 1.25\ Z_{APP}.$$

Since the line angle θ will probably exceed the maximum reach angle (60°) of $M_T$ by an appreciable amount, this difference should be taken into account by the following expression to determine the voltage tap setting which fixes the diameter:

$$T = \frac{100\ K}{Z_F} \cos(\theta - 60)$$

Where:

K = 200 for 2 ohms Base Reach Tap
<u>or</u> 600 for 6 ohms Base Reach Tap

## A9A

The maximum permissible reach setting for the ground mho unit is determined by conditions at a given relay location for an external fault at that end of the line. The presence of a third terminal does not affect this consideration, other than the fact that it may change the total system impedance and the distribution constants. The maximum permissible reach setting should be determined in accordance with instructions given in Appendix III.

## A9B

CODE A

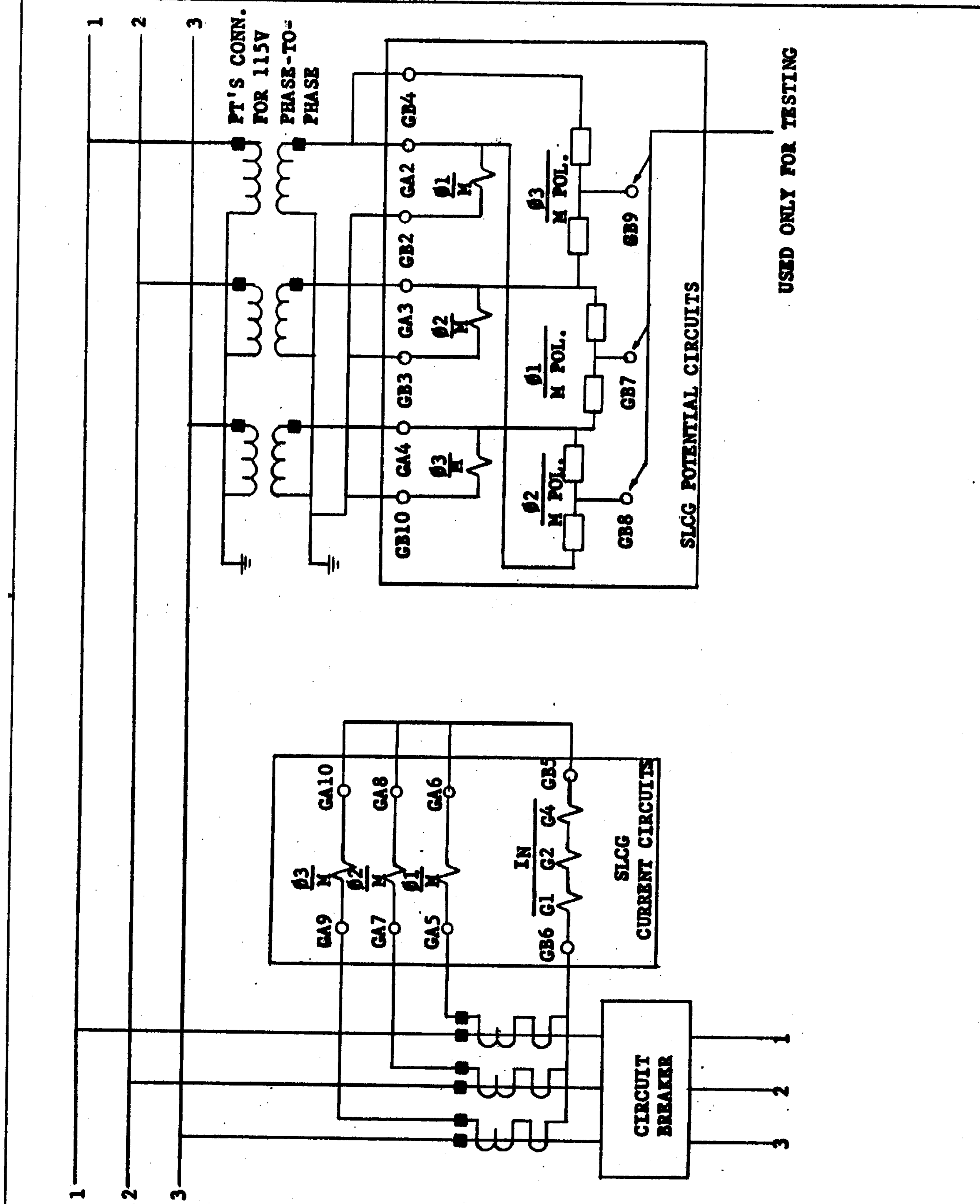
GENERAL ELECTRIC

0178A7178

CONT ON SHEET | SH NO.

| REV NO. | TITLE |
|---|---|
| 0178A7178 | AC ELEMENTARY DIAGRAM TYPE SLCG11A RELAY |
| CONT ON SHEET SH NO. | FIRST MADE FOR GEI-98313 |

FIG. 2




REVISIONS

PRINTS TO

| MADE BY | APPROVALS | | |
|---|---|---|---|
| R.F Create July 9, 1964 | Cam | L.V. SWITCHGEAR — DIV OR DEPT. | 0178A7178 |
| ISSUED July 20, 1964 | | PHILADELPHIA — LOCATION | CONT ON SHEET SH NO. |

LOST A

GENERAL ELECTRIC

0178A7024

CONT ON SHEET SH NO.

REV NO.

0178A7024

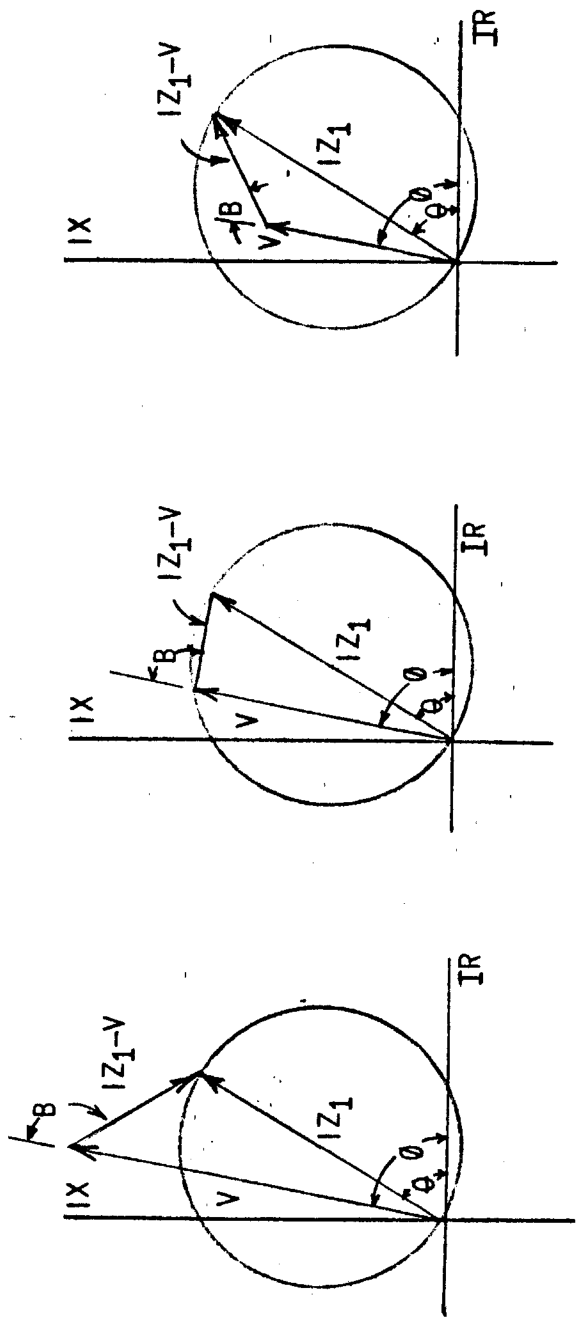
CONT ON SHEET SH NO.

TITLE MHO CHARACTERISTIC BY PHASE-ANGLE MEASUREMENT

FIRST MADE FOR GEI-98309

FIG. 3

REVISIONS




(c) INTERNAL FAULT $B < 90^o$

(b) BALANCE POINT $B = 90^o$

(a) EXTERNAL FAULT $B > 90^o$

PRINTS TO

MADE BY A. Fedrue March 5, 1964

ISSUED March 13, 1964

APPROVALS Cam

SWITCHGEAR DIV OR DEPT.

PHILADELPHIA LOCATION

0178A7024

CONT ON SHEET SH NO.

A

GENERAL ELECTRIC

0178A7021

CONT ON SHEET SH NO.

REV NO.

0178A7021

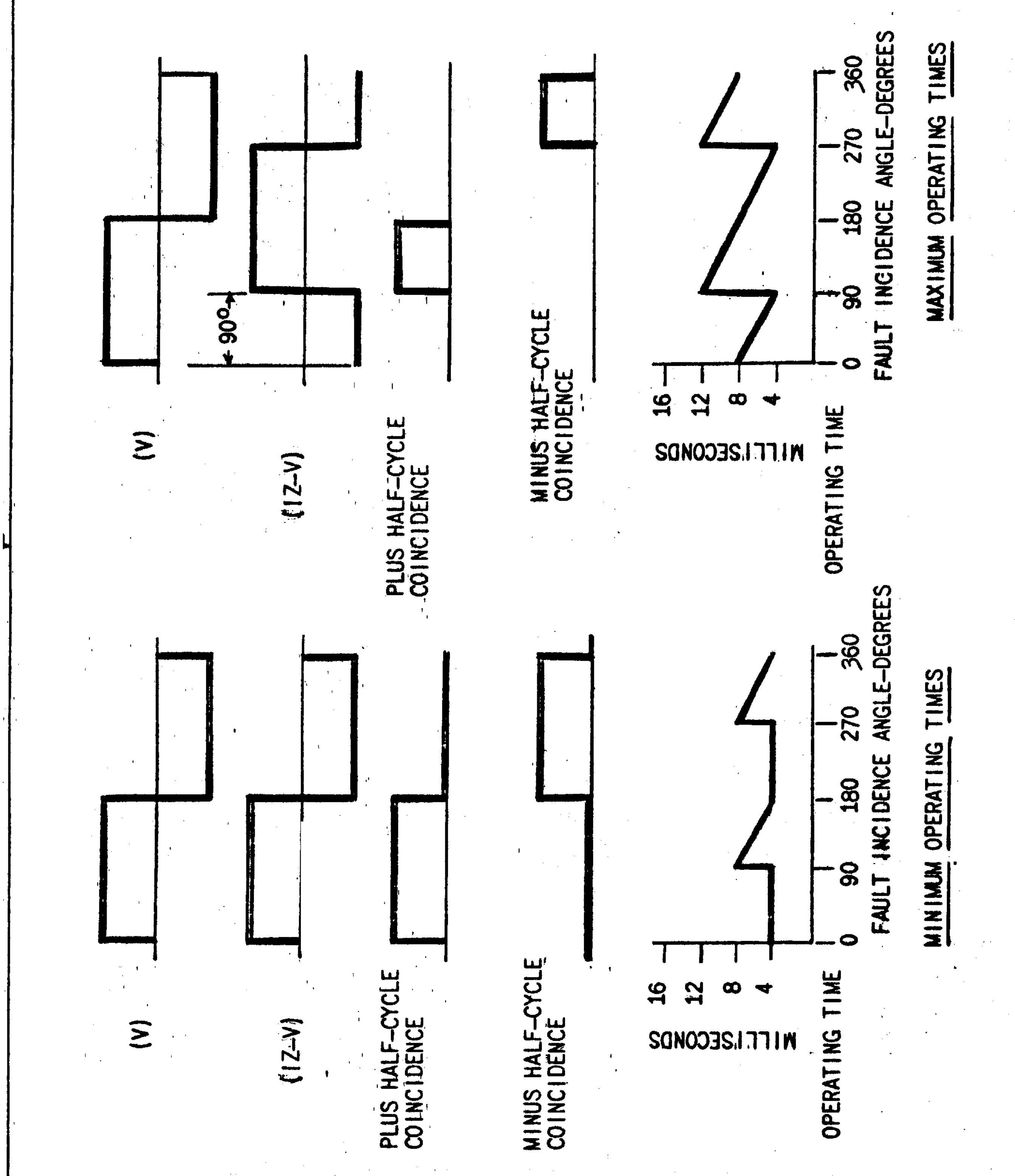
CONT ON SHEET SH NO.

TITLE $M_T$ MEASUREMENT PRINCIPLES & OPERATING TIME CHARACTERISTICS

FIRST MADE FOR GEI-98309

FIG. 4

REVISIONS




PRINTS TO

| | | | |
|---|---|---|---|
| MADE BY A. Frederick March 5, 1964 | APPROVALS | SWITCHGEAR — DIV OR DEPT. | 0178A7021 |
| ISSUED March 13, 1964 | Cam | PHILADELPHIA — LOCATION | CONT ON SHEET SH NO. |

H

**GENERAL ELECTRIC**

0 1 6 5 A 7 6 2 2

CONT ON SHEET SH NO.

REV NO.

0 1 6 5 A 7 6 2 2

CONT ON SHEET SH NO.

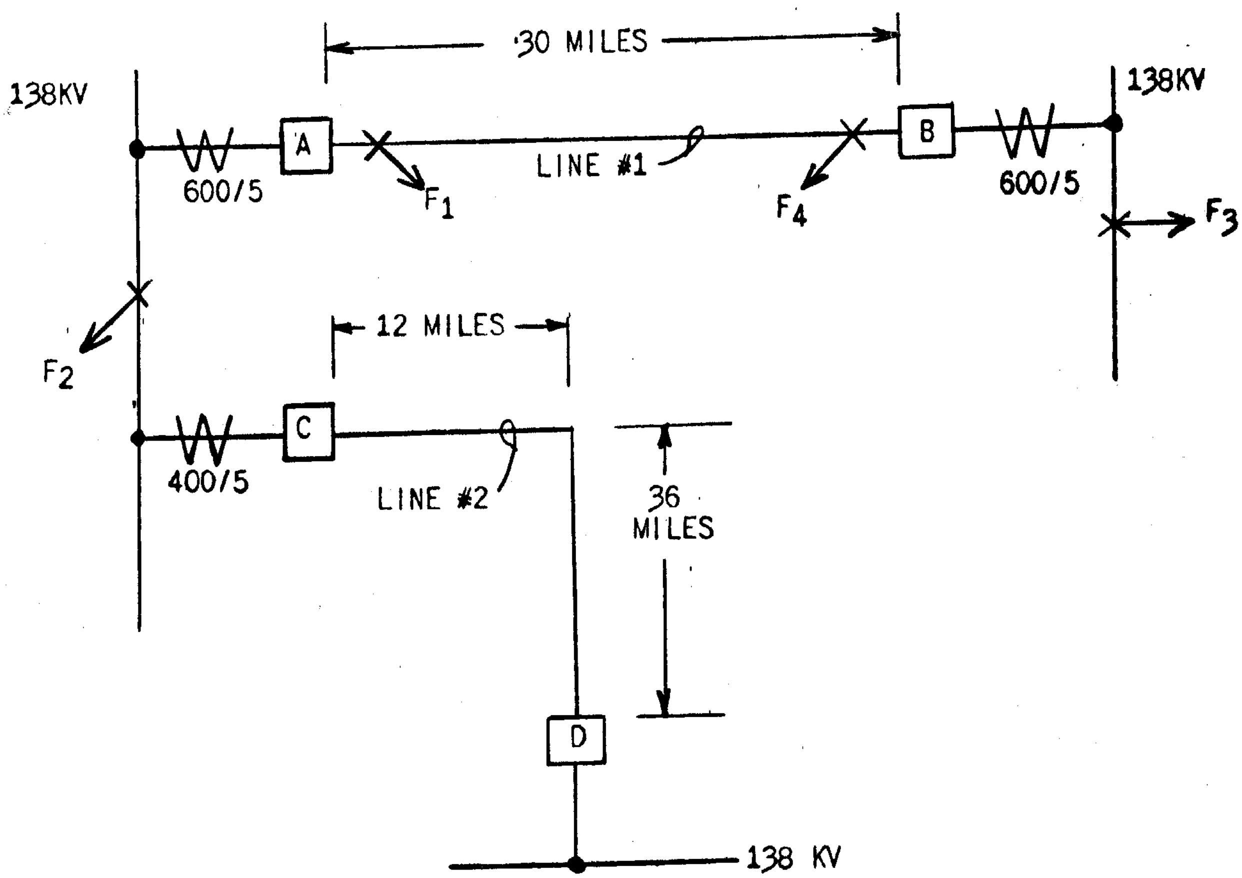
TITLE

TYPICAL TRANSMISSION SYSTEM

FIRST MADE FOR GCX17G

FIG. 5

REVISIONS




PRINTS TO

MADE BY A. Freund April 2, 1963

ISSUED May 7, 1963

APPROVALS WPA

L.V. SWITCHGEAR DIV OR DEPT

PHILADELPHIA LOCATION

0 1 6 5 A 7 6 2 2

CONT ON SHEET SH NO.

CODE A

GENERAL ELECTRIC

0178A7187

CONT ON SHEET | SH NO.

REV NO.

0178A7187

CONT ON SHEET | SH NO.

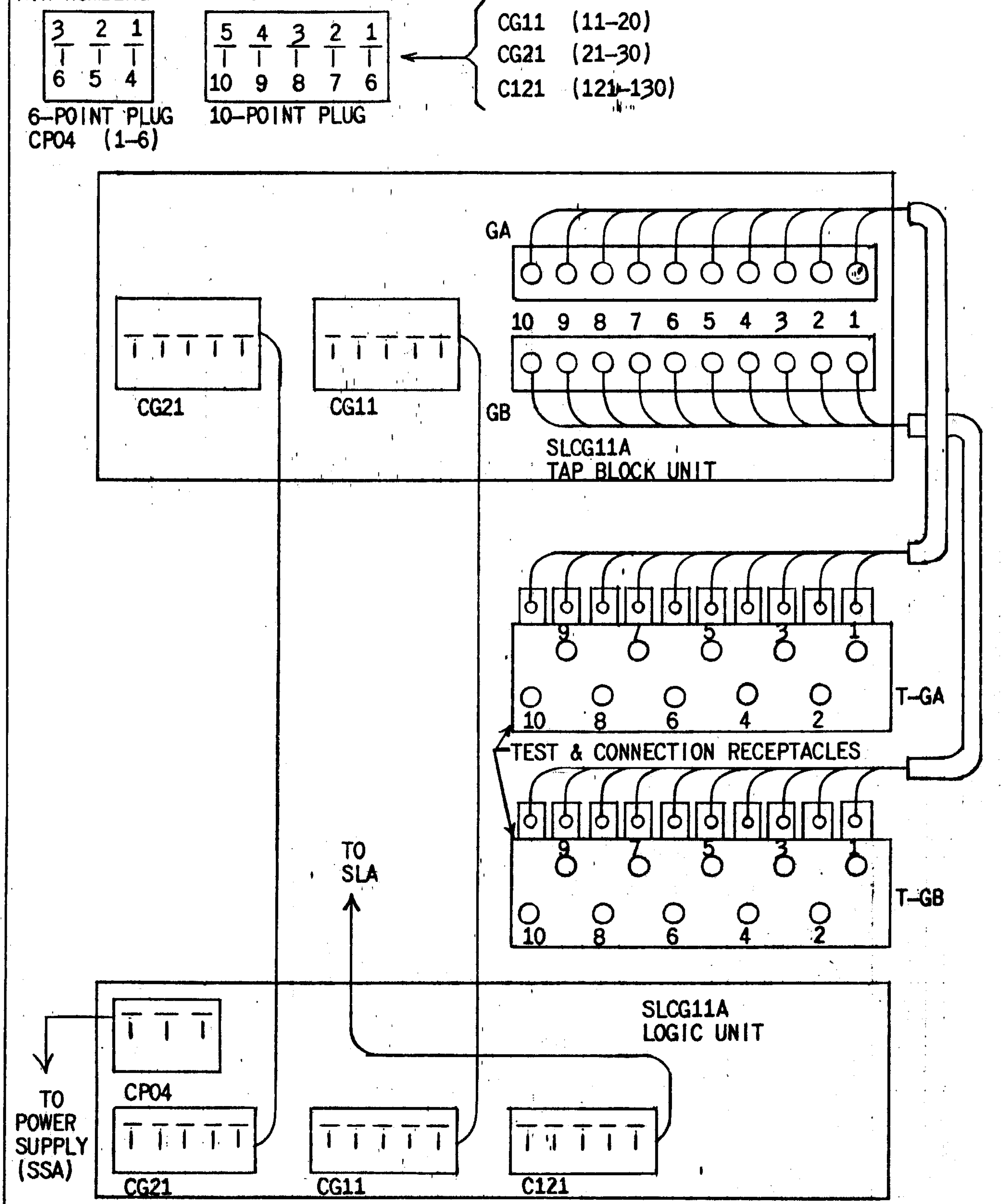
TITLE
TYPE SLCG11A REAR VIEW
INTERCONNECTIONS

FIRST MADE FOR GEI-98313

FIG. 6

REVISIONS

PIN NUMBERS - CABLE SOCKETS




REAR VIEW

PRINTS TO

MADE BY Robert Ceato Aug 11, 1964

ISSUED August 13, 1964

APPROVALS Cam

SWITCHGEAR — DIV OR DEPT.

PHILADELPHIA — LOCATION

0178A7187

CONT ON SHEET | SH NO.

CODE A

GENERAL ELECTRIC

0 1 7 8 A 7 1 8 6
CONT ON SHEET SH NO.

REV NO.

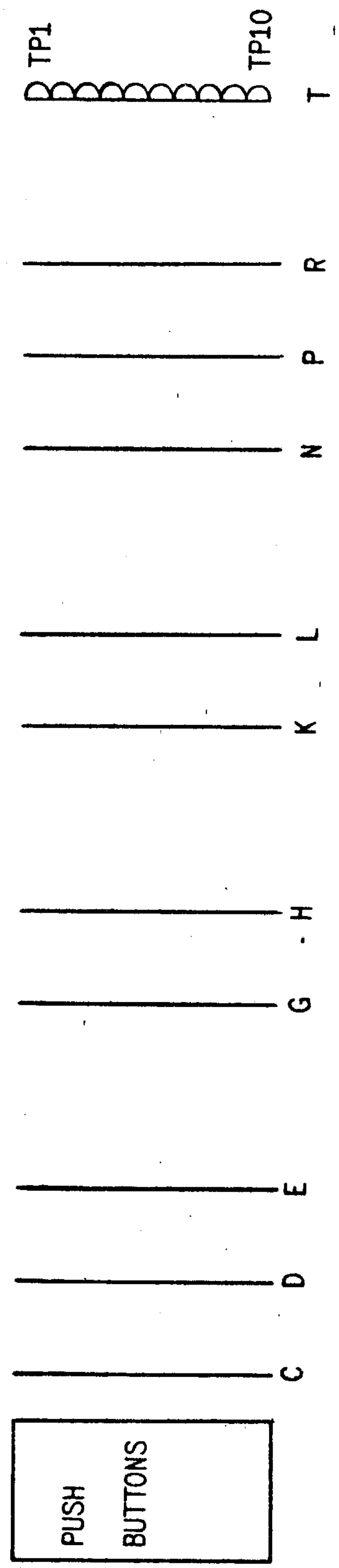
0 1 7 8 A 7 1 8 6
CONT ON SHEET SH NO.

TITLE CARD LOCATION-TYPE SLCG11A RELAY

FIRST MADE FOR GEI-98313

FIG. 7

REVISIONS




| POSITION | CODE | CARD | PART NUMBER |
|---|---|---|---|
| C | D13 | OVERCURRENT | 0116B6775G1 |
| D | T13 | 4/9 | 0127B8149G1 |
| E | D11 | MHO | 0116B6773G1 |
| G | T13 | 4/9 | 0127B8149G1 |
| H | D11 | MHO | 0116B6773G1 |
| K | T13 | 4/9 | 0127B8149G1 |
| L | D11 | MHO | 0116B6773G1 |
| N | D13 | OVERCURRENT | 0116B6775G1 |
| P | L4 | 3 INPUT AND | 0116B4939G1 |
| R | D13 | OVERCURRENT | 0116B6775G1 |
| T | TEST | TEST | 0116B6672G1 |

PRINTS TO

MADE BY Rita P. Crate Aug. 10, 1964

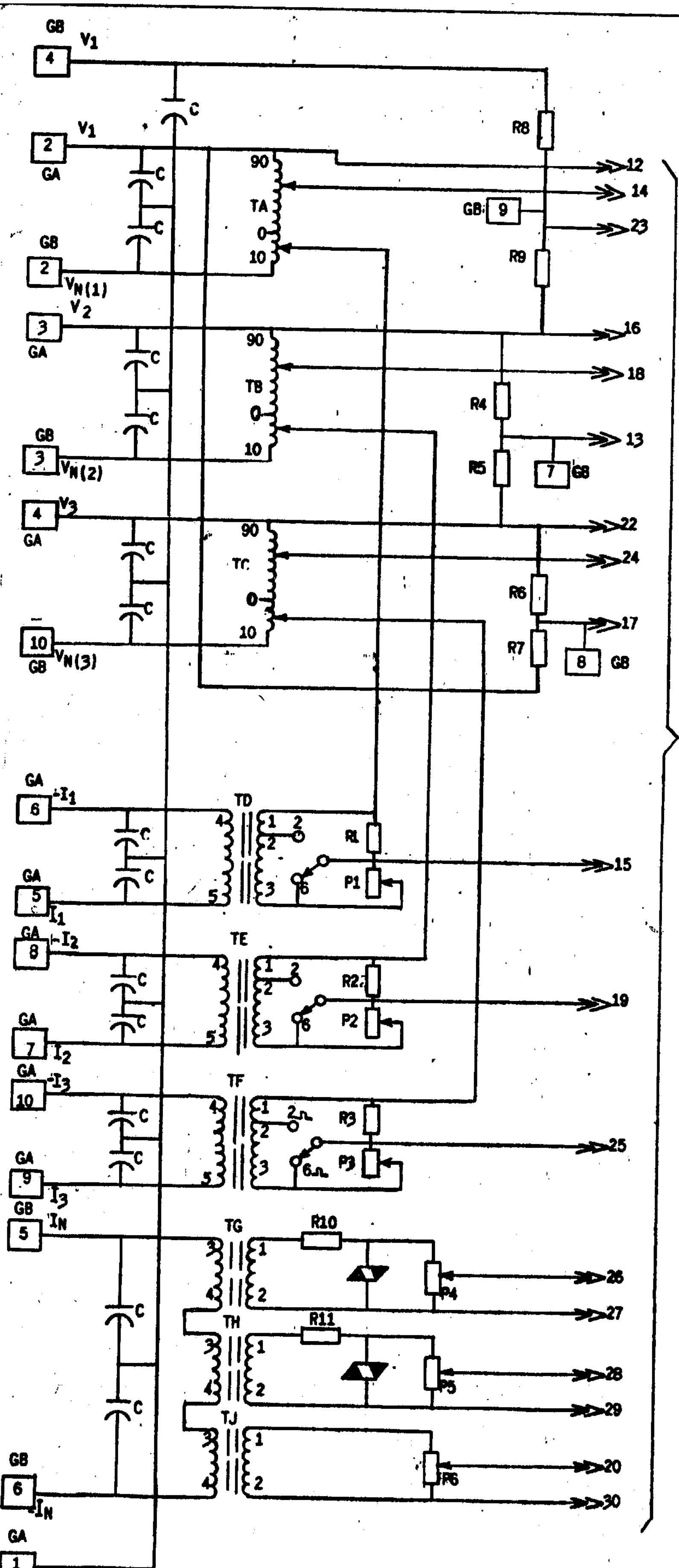
ISSUED August 13, 1964

APPROVALS Cam

SWITCHGEAR — DIV OR DEPT.

PHILADELPHIA — LOCATION

0 1 7 8 A 7 1 8 6
CONT ON SHEET SH NO.




| COMPONENT VALUES | | |
|---|---|---|
| | OHMS | WATTS |
| R1, R2, R3 | 500 | 10 |
| R4, R5, R6, R7, R8, R9 | 2K | 5 |
| R10, R11 | 400 | 10 |
| P1, P2, P3 | 250 | 12.5 |
| P4, P5, P6 | 5K | 12.5 |
| C = 0.5 MUF | | |

NOTE: TRANSACTOR LEADS MARKED "S" ARE CONNECTED TO PIN NO. 1, ALL PLUG SOCKETS

GENERAL ELECTRIC

TITLE INTERNAL CONNECTIONS-TYPE SLCG11A,B,C,D RELAY TAP BLOCK UNIT

FIRST MADE FOR REQ.

S.O. FIG 8

CODE A

DRAWING NO. 0116B6845

SWITCHGEAR DIV. PHILADELPHIA

REVISIONS

APPROVALS

PRINTS TO

0116B6846

CODE A

GENERAL ELECTRIC

REV. NO. 1-2-3-4-5-6-7-

0116B6846

CONT ON SHEET / SH NO.

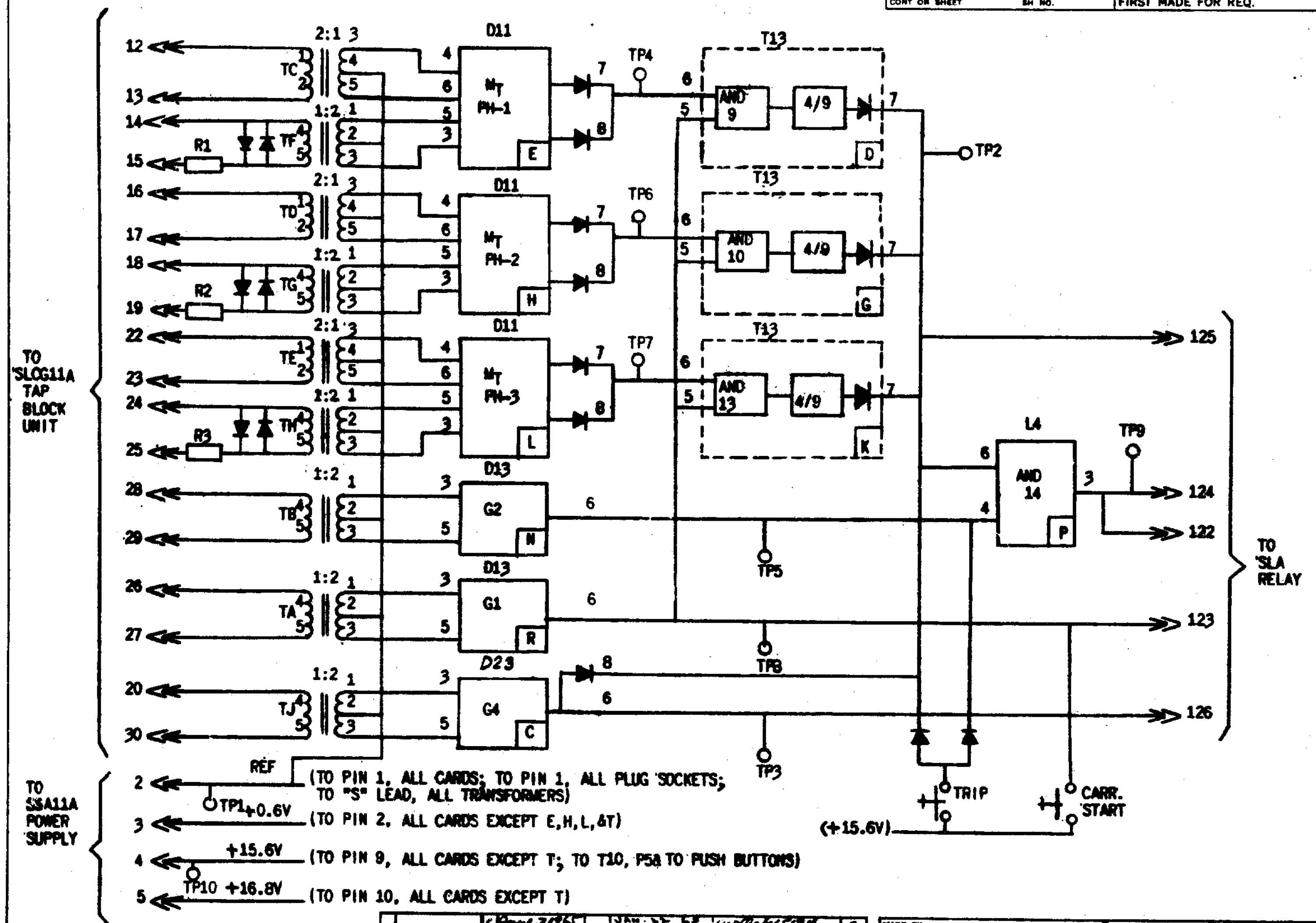
TITLE INTERNAL CONNECTIONS–TYPE 'SLCG11A LOGIC UNIT

FIRST MADE FOR REQ. S.O. Fig. 9

0116B6846

CONT ON SHEET / SH NO.

| COMPONENT VALUES | | |
|---|---|---|
| | OHMS | WATTS |
| R1, R2, R3 | 5,000 | 5 |




| 7 | 12-2-66 | 6 | June 2-1965 | 4 | RECirc To | 2 |
|---|---|---|---|---|---|---|
| | | 5 | | 3 | | 1 |

REVISIONS

MADE BY: April 16, 1964

ISSUED: April 23, 1964

APPROVALS: RLP

SWITCHGEAR DIV.

PHILADELPHIA WORKS

0116B6846

CONT ON SHEET / SH NO.

PRINTS TO

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FF-6001-P (7-63) PRINTED IN U.S.A.

CODE -1

GENERAL ELECTRIC

0178A7026

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REV NO. -2-

0178A7026

CONT ON SHEET SH NO.

TITLE

LEGEND FOR SYMBOLS USED ON STATIC RELAY LOGIC DIAGRAMS

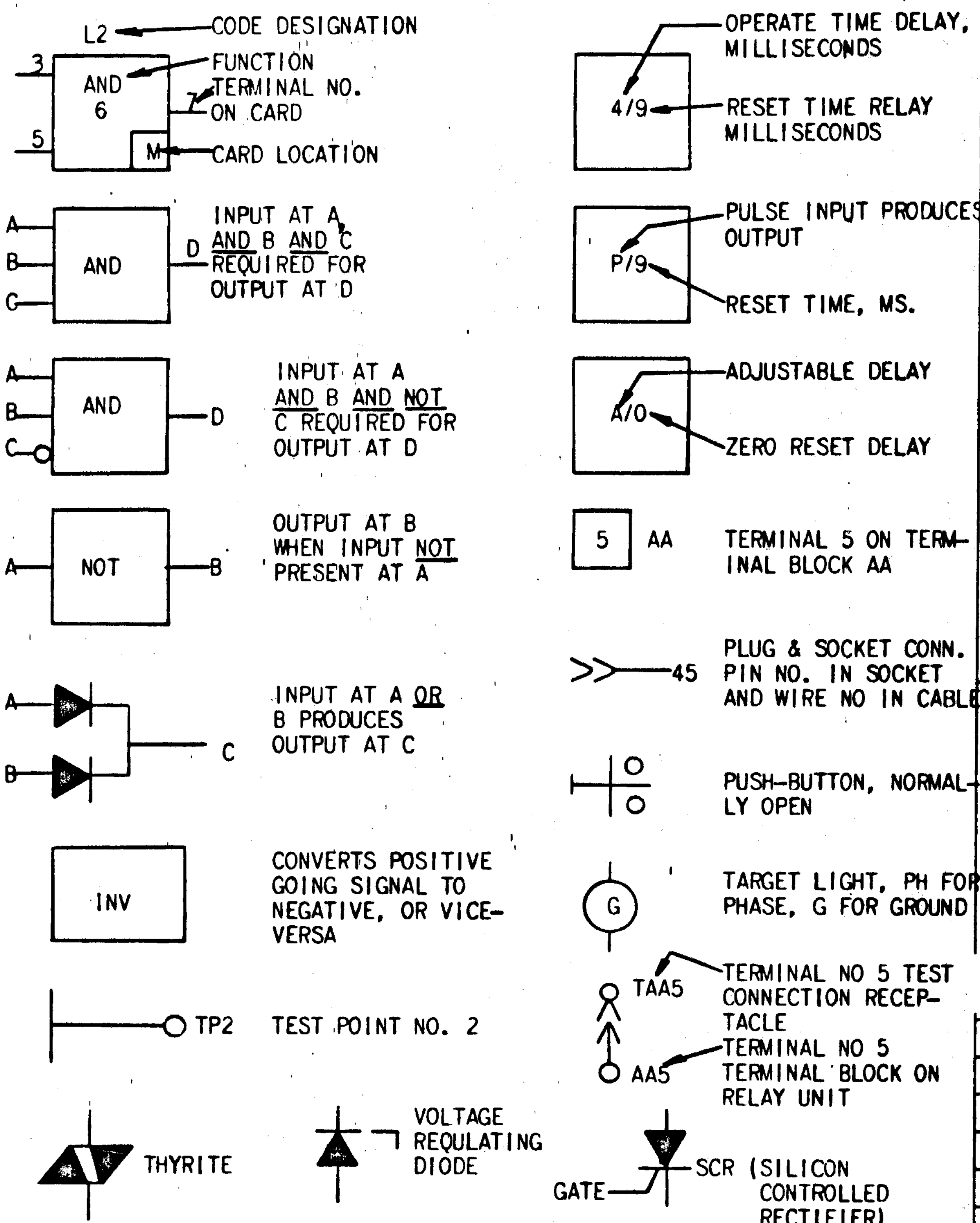
FIRST MADE FOR

FIG. 10

REVISIONS

2

7-6-66 R.O. RETRACED




PRINTS TO

MADE BY A. FREDRICK 3-10-64

ISSUED MARCH 13, 1964

APPROVALS cam

SWGR. DIV OR DEPT.

PHILA. LOCATION

0178A7026

CONT ON SHEET SH NO.

FF-803-WA (4-65) REV.

CODE A

GENERAL ELECTRIC

0178A7185

CONT ON SHEET SH NO.

REV. NO. 1-2-3-4

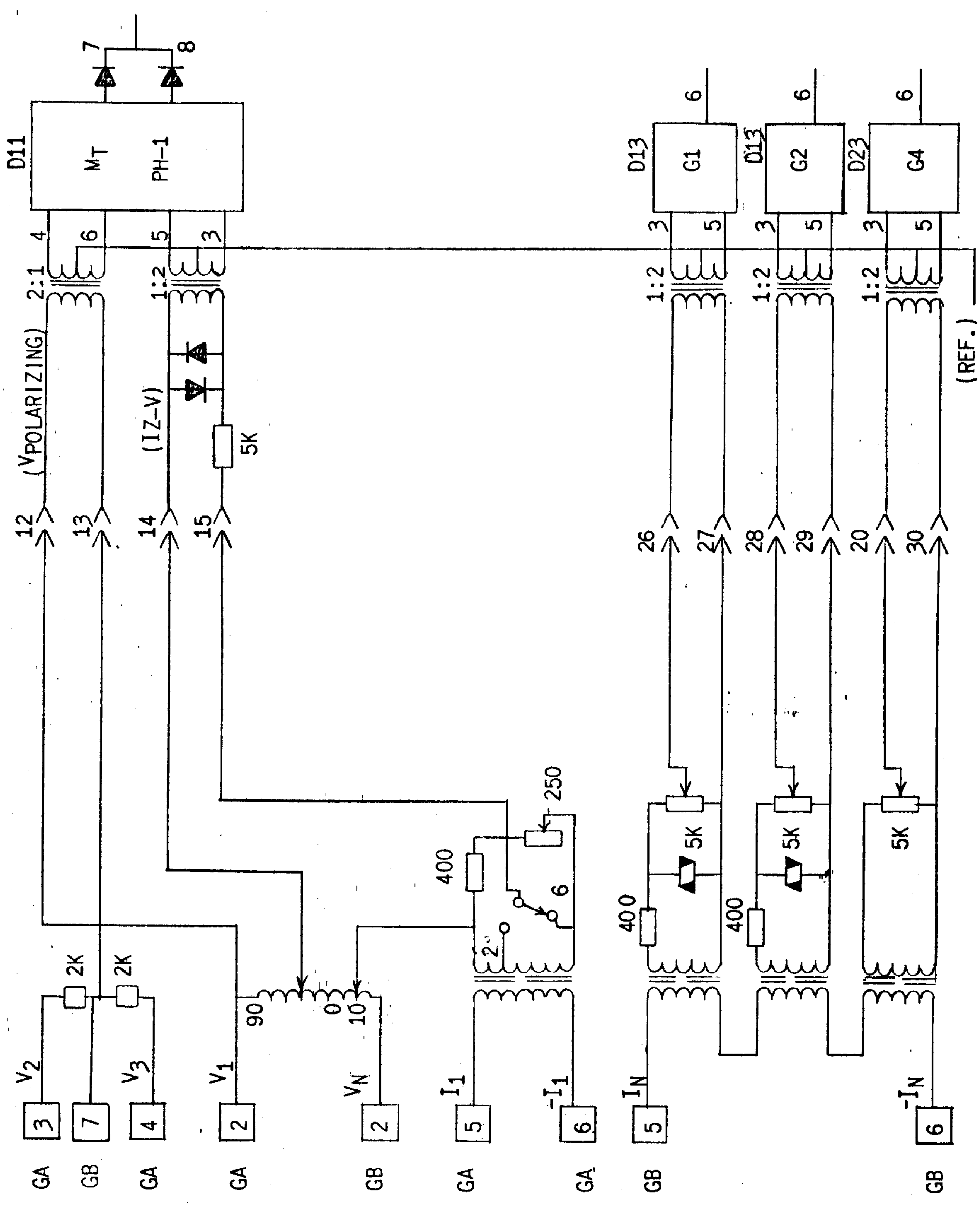
0178A7185

CONT ON SHEET SH NO.

TITLE TYPE SLCG RELAY
SCHEMATIC A-C CIRCUITS FOR PHASE 1

FIRST MADE FOR GEI-98313

FIG. 11




REVISIONS

| | |
|---|---|
| 4 | 5-3-67 RF Creato |
| 3 | RF Creato |
| 2 | June 8 1965 RF Creato |
| 1 | RO |

PRINTS TO

MADE BY R. F. Creato July 21, 1964

ISSUED August 13, 1964

APPROVALS

SWITCHGEAR DIV OR DEPT.

PHILADELPHIA LOCATION

0178A7185

CONT ON SHEET SH NO.

GENERAL ELECTRIC

0 1 7 8 A 7 1 8 4
CONT ON SHEET SH NO.

REV NO.

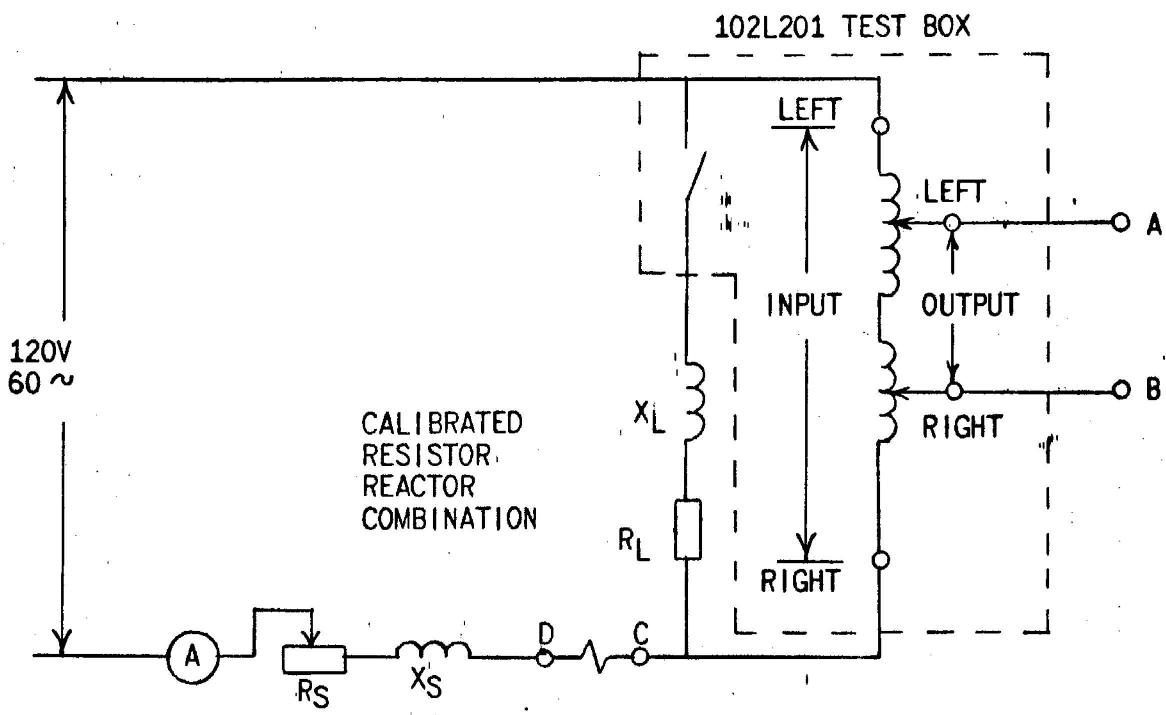
0 1 7 8 A 7 1 8 4
CONT ON SHEET SH NO.

TITLE
TEST CIRCUIT FOR $M_T$ CHARACTERISTIC,
TYPE SLCG & SLYG RELAYS

FIRST MADE FOR GEI 98313

FIG. 12

REVISIONS




TEST CONNECTIONS

| PHASE | A | B | C | D | OUTPUT |
|---|---|---|---|---|---|
| 1 | GA2, GB4 | GB2, GB7 | GA5 | GA6 | TP2 |
| 2 | GA3 | GB3, GB8 | GA7 | GA8 | TF2 |
| 3 | GA4 | GB10, GB9 | GA9 | GA10 | TP2 |

PRINTS TO

MADE BY R.F. Arcato July 17, 1964
ISSUED August 13, 1964

APPROVALS
cam

SWITCHGEAR
DIV OR DEPT.
PHILADELPHIA
LOCATION

0 1 7 8 A 7 1 8 4
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CODE IDENT NO.

CODE A

GENERAL ELECTRIC

0178A7179

CONT ON SHEET SH NO.

REV NO.-1-

0178A7179

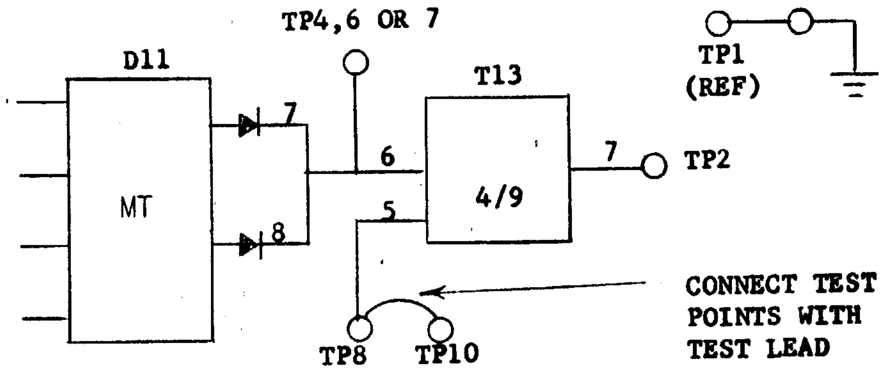
CONT ON SHEET SH NO.

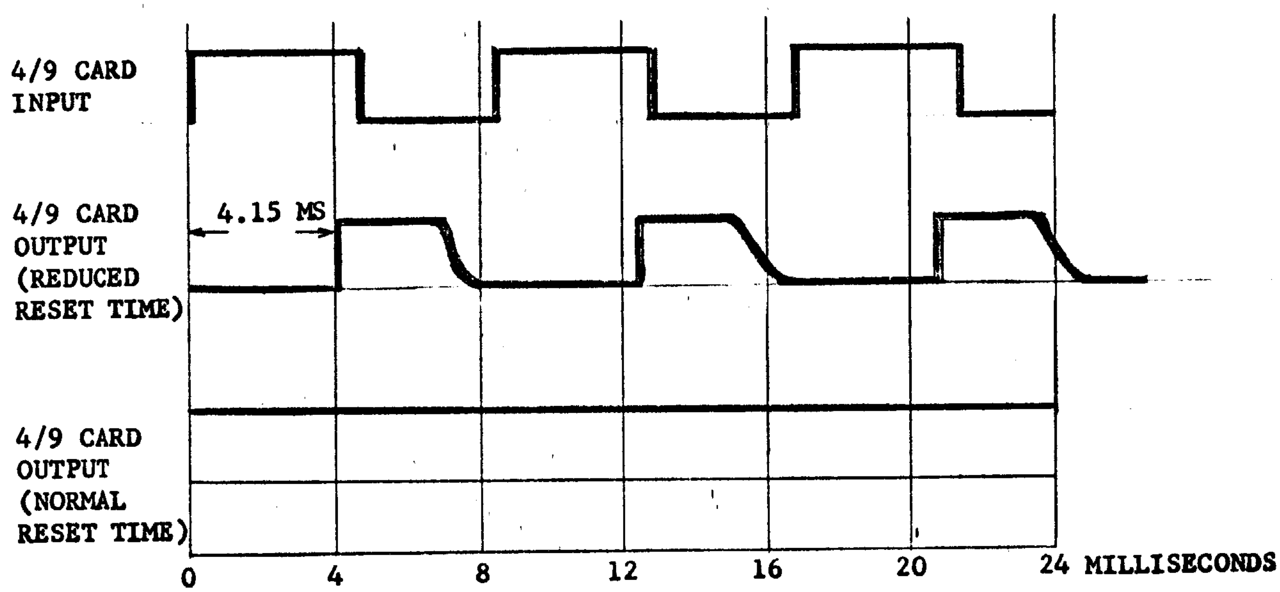
TITLE TEST CONDITIONS FOR 4/9 TIMERS IN GROUND MHO UNITS OF SLCG11A

FIRST MADE FOR GEI-98313 (SLCG)

FIG. 13

REVISIONS




Made B 1-11-66 R.F. Corte

1

TEST CONNECTIONS & CONDITIONS

| PHASES | TO TEST 4/9 CARD | CHANNEL A OSC. | CHANNEL B OSC. |
|---|---|---|---|
| 1 | D | TP4 | TP2 |
| 2 | G | TP6 | TP2 |
| 3 | K | TP7 | TP2 |

PRINTS TO

MADE BY R.F. Corte July 13, 1964

ISSUED July 20, 1964

APPROVALS CAm

SWITCHGEAR DIV OR DEPT.

PHILADELPHIA LOCATION

0178A7179

CONT ON SHEET SH NO.

CODE A

GENERAL ELECTRIC

0178A7180

CONT ON SHEET | SH NO.

REV NO.

0178A7180

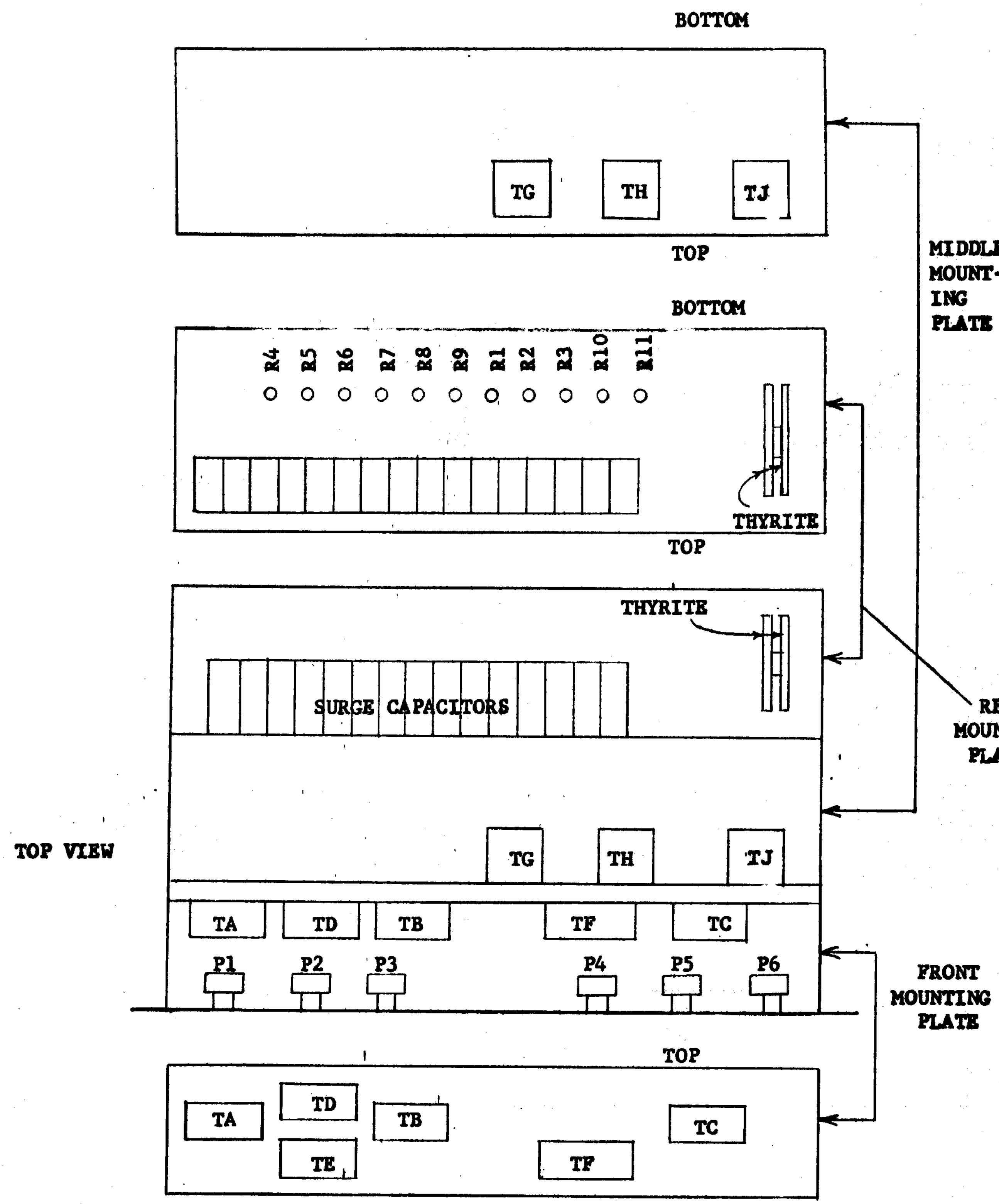
CONT ON SHEET | SH NO.

TITLE LOCATION OF COMPONENTS
TAP BLOCK UNIT - SLCG11A RELAY

FIRST MADE FOR GEI-98313

FIG. 14

REVISIONS




PRINTS TO

MADE BY R.E. Creato July 14, 1964

ISSUED July 20, 1964

APPROVALS Cam

SWITCHGEAR — DIV OR DEPT.

PHILADELPHIA — LOCATION

0178A7180

CONT ON SHEET | SH NO.

FF-803-(W)A (9-63)

CODE A

GENERAL ELECTRIC

0178A7181

CONT ON SHEET SH NO.

REV NO.

0178A7181

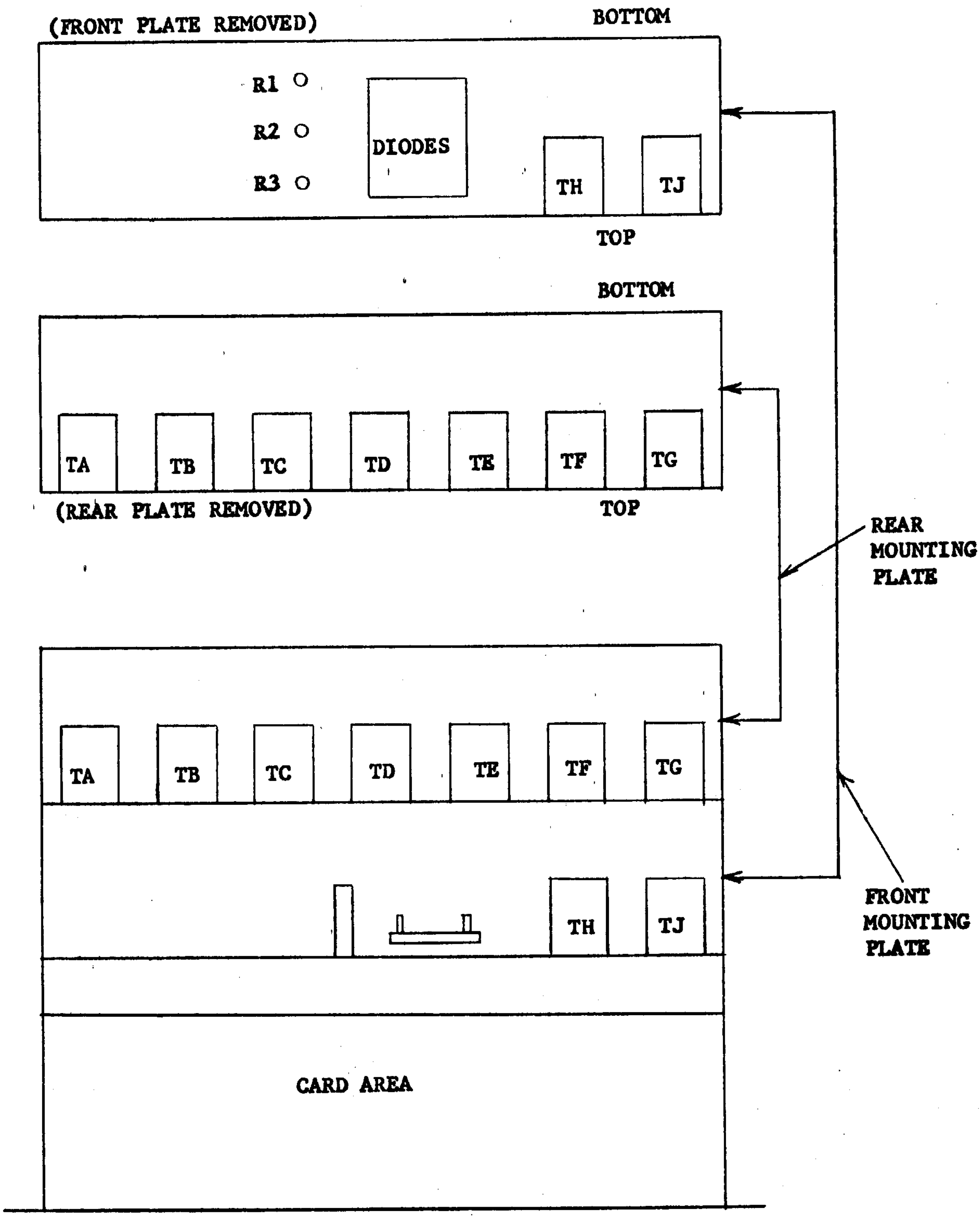
CONT ON SHEET SH NO.

TITLE LOCATION OF COMPONENTS - LOGIC UNIT TYPE SLCG11A RELAY

FIRST MADE FOR GEI-98313

FIG. 15

REVISIONS




PRINTS TO

| MADE BY | APPROVALS | | | |
|---|---|---|---|---|
| R. F. Preato July 14, 1964 | Cam | SWITCHGEAR | DIV OR DEPT. | 0178A7181 |
| ISSUED July 20, 1964 | | PHILADELPHIA | LOCATION | CONT ON SHEET SH NO. |

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**GENERAL ELECTRIC**

0148A3917AH

CONT ON SHEET SH NO.

REV NO. C148A3917AH

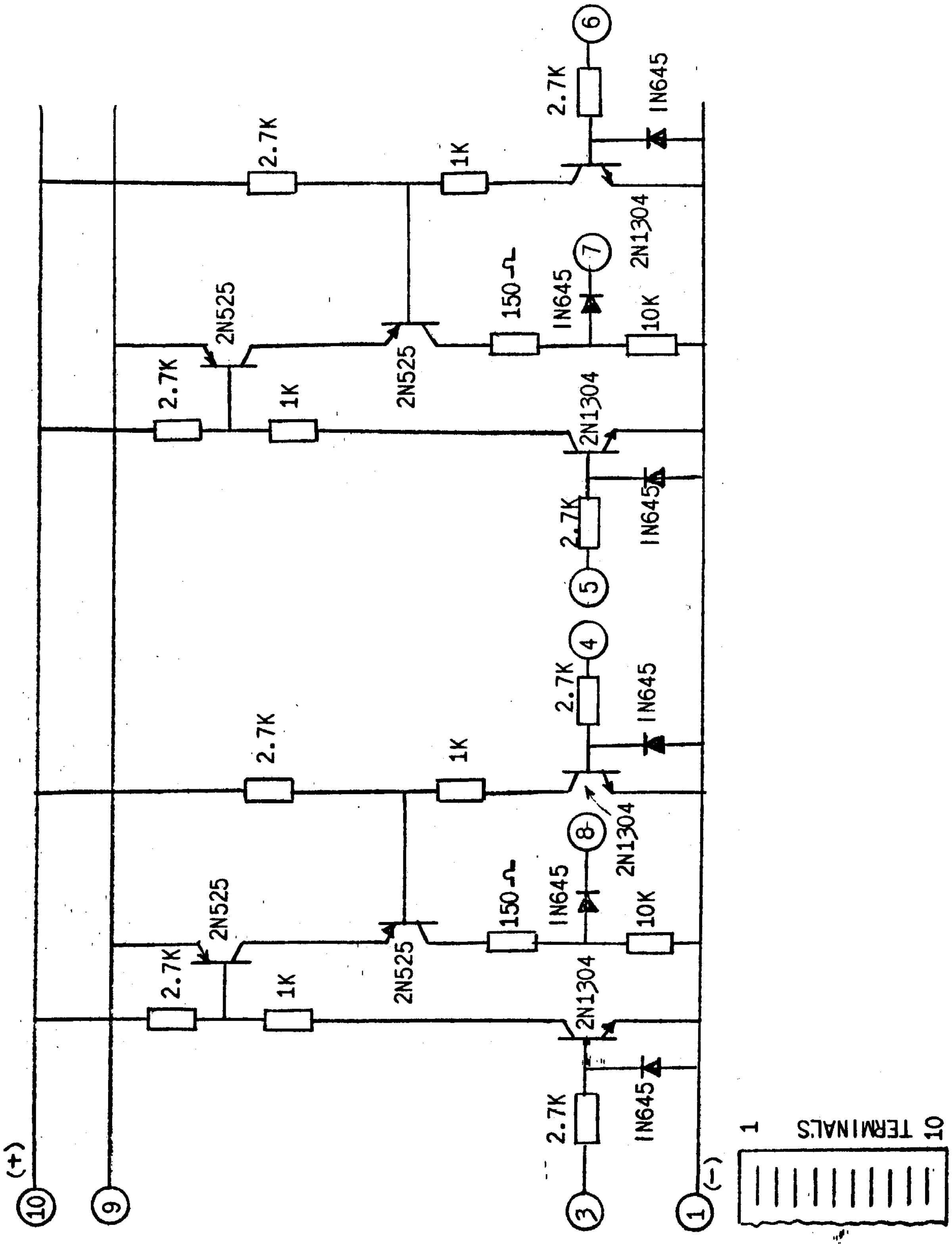
CONT ON SHEET SH NO.

TITLE MHO UNIT - 2 POLARITIES- "BLOCK-BLOCK"

FIRST MADE FOR

FIG. 16A D11

REVISIONS




PC CARD 0116B6773 G1

PRINTS TO

MADE BY [illegible] Feb. 7, 1964

ISSUED February 14, 1964

APPROVALS

SWITCHGEAR DIV OR DEPT.

PHILADELPHIA LOCATION

0148A3917AH

CONT ON SHEET SH NO.

CODE A

GENERAL ELECTRIC

0148A3902AJ

CONT ON SHEET SH NO.

REV NO. -2-

C148A3902AJ

CONT ON SHEET SH NO.

TITLE

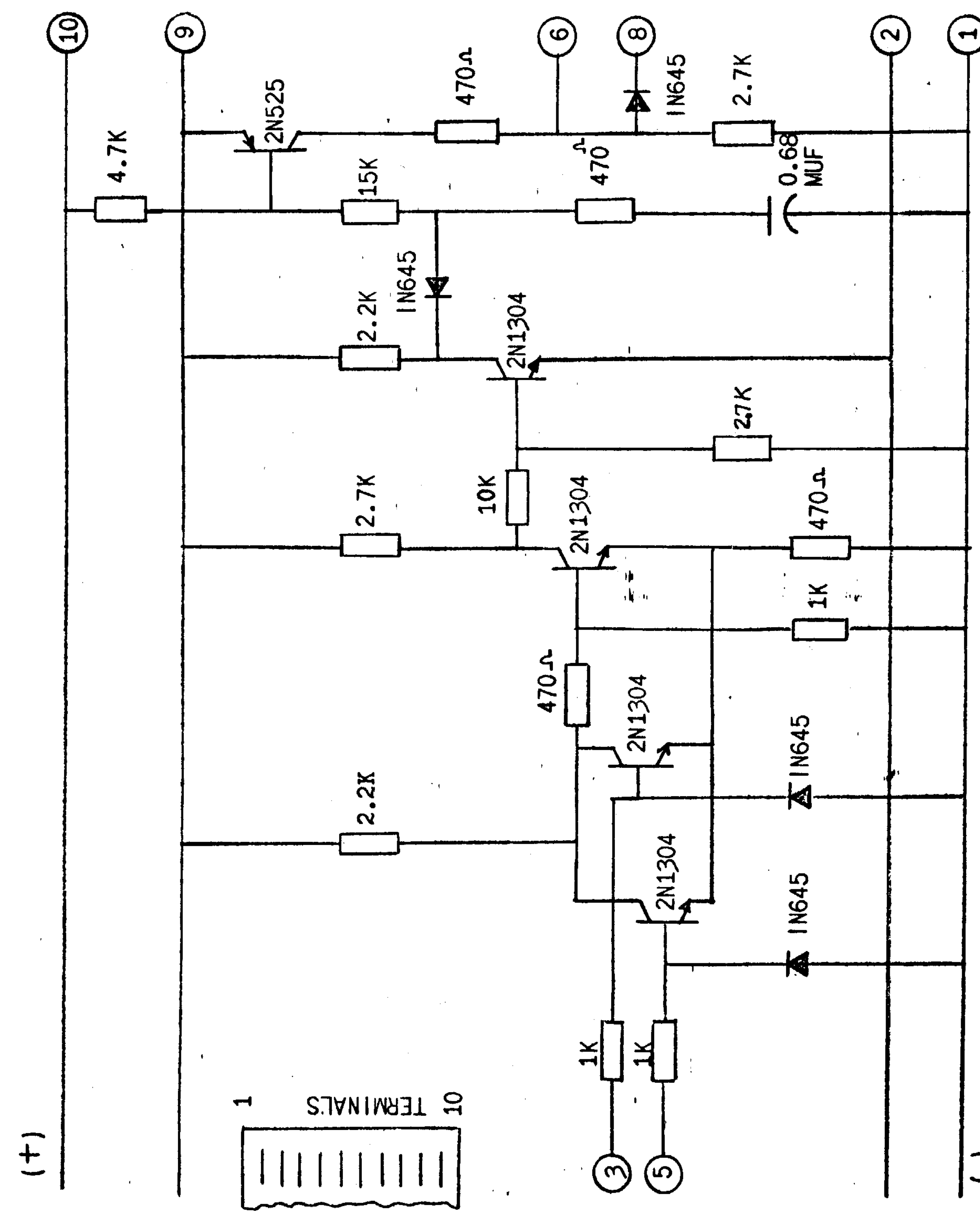
# D-13 OVERCURRENT LEVEL DETECTOR

FIRST MADE FOR

FIG. 16 B

D13

REVISIONS




PC CARD 0116B6775 G1

PRINTS TO

MADE BY A. Fiedrich Feb 2, 1968

ISSUED February 17, 19..

APPROVALS Cam

SWITCHGEAR DIV OR DEPT.

PHILADELPHIA LOCATION

0148A3902AJ

CONT ON SHEET SH NO.

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CODE IDENT NO.

CODE A | GENERAL ELECTRIC | 0148A3901AN
CONT ON SHEET SH NO.

REV NO. 1-

0148A3901AN

CONT ON SHEET SH NO.

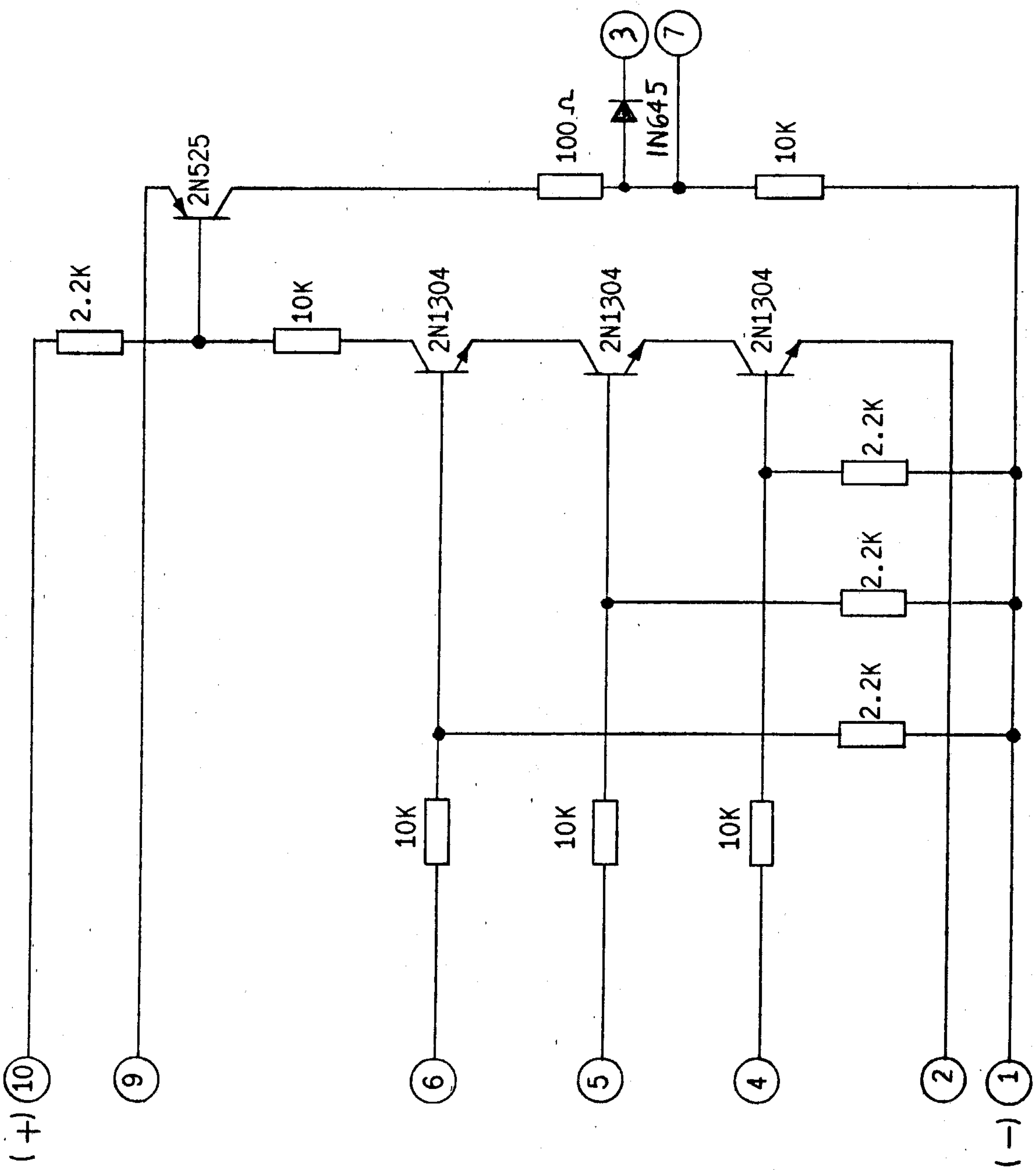
TITLE 3 AND

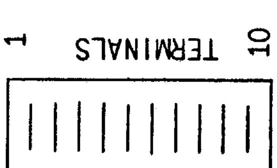
FIRST MADE FOR SLZ

FIG. 16C L4

REVISIONS

1 JAN 23 64




PC CARD 0116B4939 G1

PRINTS TO

| MADE BY | APPROVALS | L.V. SWITCHGEAR | DIV OR DEPT. | 0148A3901AN |
|---|---|---|---|---|
| C Bechtold FEB.5,1962 | | PHILADELPHIA | LOCATION | CONT ON SHEET SH NO. |
| ISSUED June 6, 1963 | | | | |

GENERAL ELECTRIC

0148A3906AJ

CONT ON SHEET SH NO.

REV NO. 2-2-74

0148A3906AJ

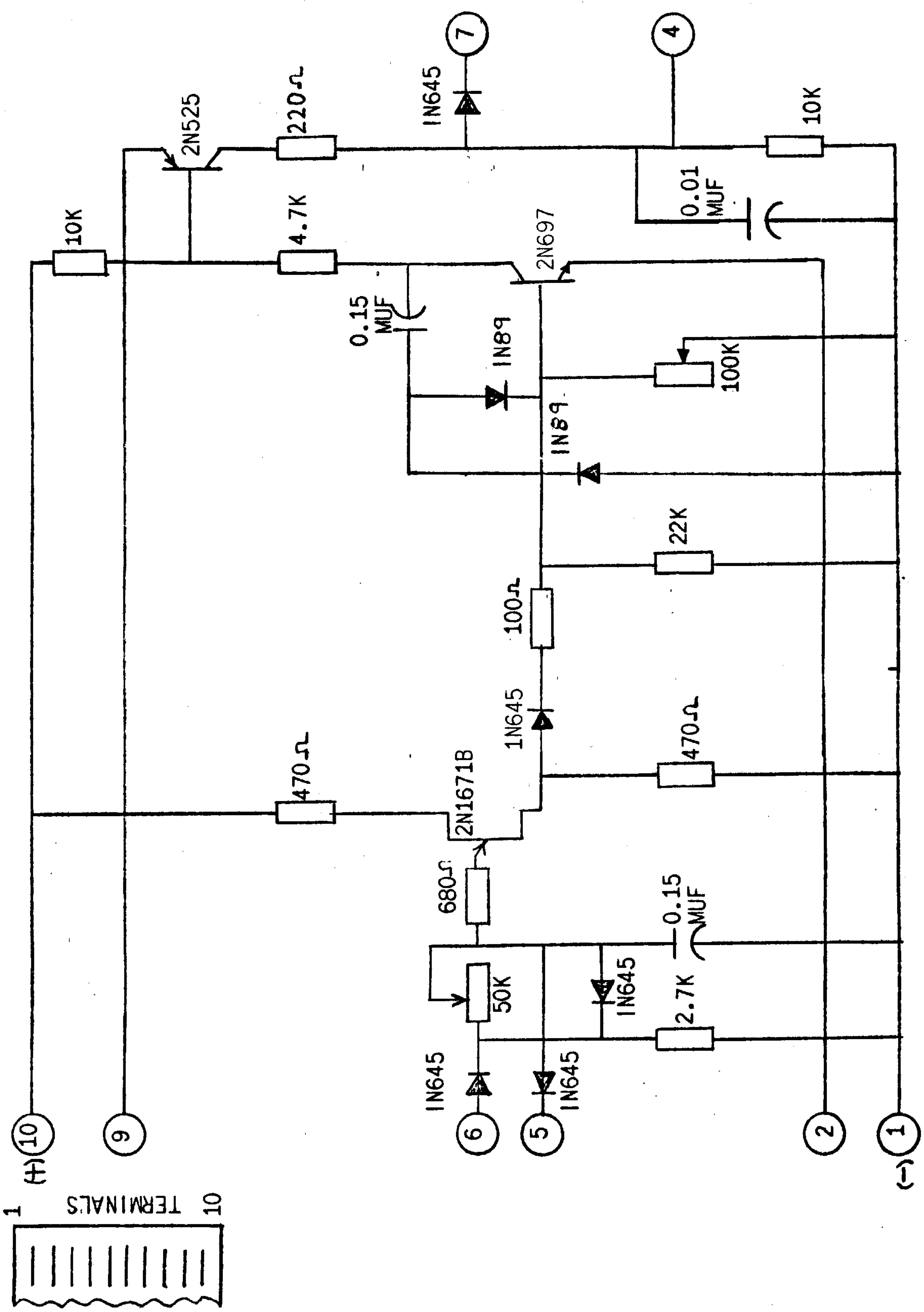
CONT ON SHEET SH NO.

TITLE 4/9

FIRST MADE FOR SLX & SLXG

FIG. 16D T13

REVISIONS




PC CARD 0127B8149 G1

PRINTS TO

MADE BY A. Fredrick June 5, 1964

ISSUED

APPROVALS ACR

SWITCHGEAR DIV OR DEPT.

PHILADELPHIA LOCATION

0148A3906AJ

CONT ON SHEET SH NO.

CODE D

GENERAL ELECTRIC

0165A7754

CONT ON SHEET SH NO.

REV NO. 4

0165A7754

CONT ON SHEET SH NO.

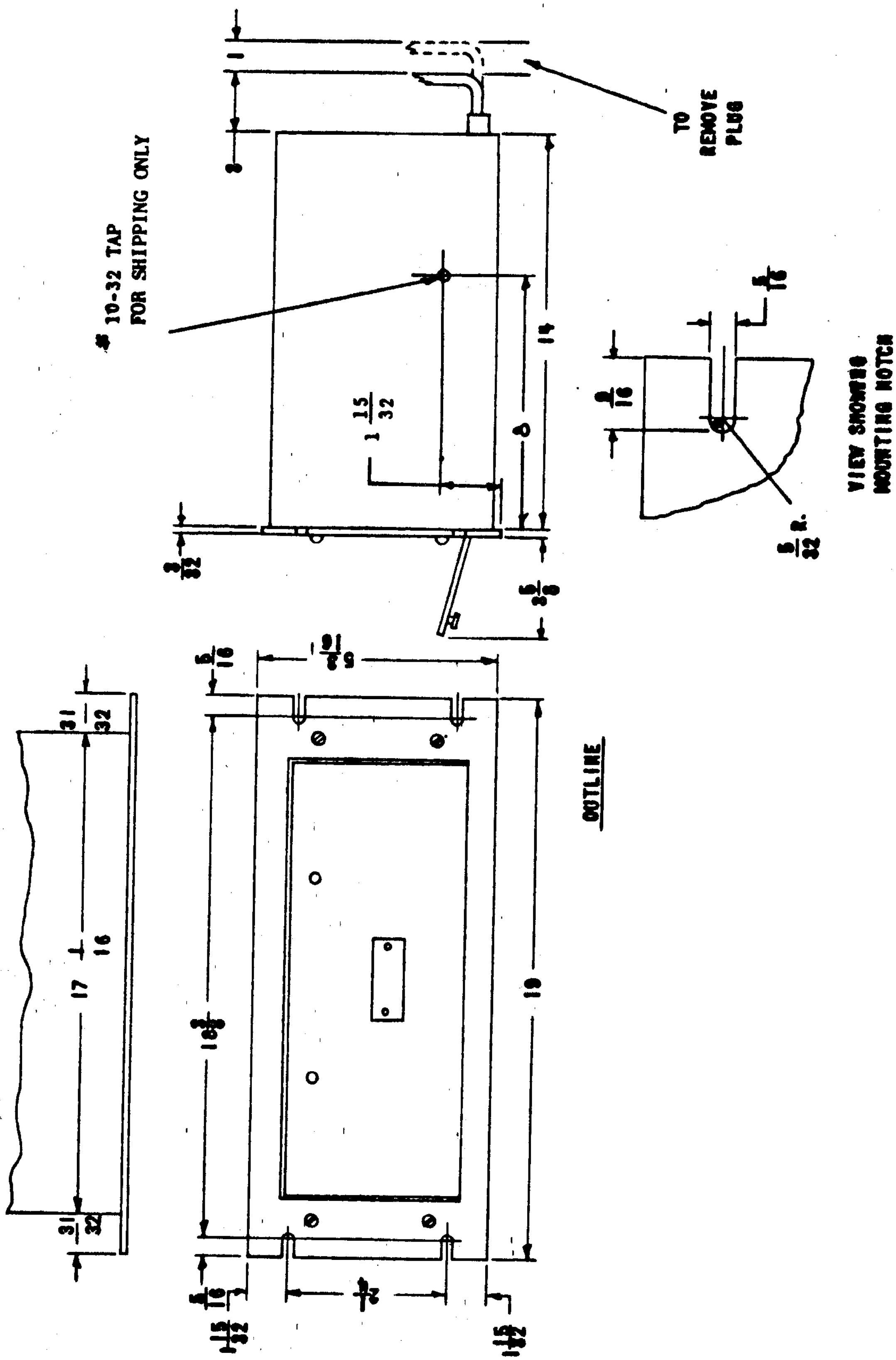
TITLE

OUTLINE & MOUNTING DIMENSIONS

FIRST MADE FOR 9 RACK UNIT (TAP BLOCK)

FIG. 17

REVISIONS




PRINTS TO

MADE BY R Bechtold DEC. 10, 1963

ISSUED DEC. 19 1963

APPROVALS

L.V. SWITCHGEAR DIV OR DEPT.

PHILADELPHIA LOCATION

0165A7754

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FF-803-WA (1-63)

CODE D

GENERAL ELECTRIC

0165A7660

CONT ON SHEET SH NO.

REV NO. ~~1-2-3-4~~-5-

0165A7660

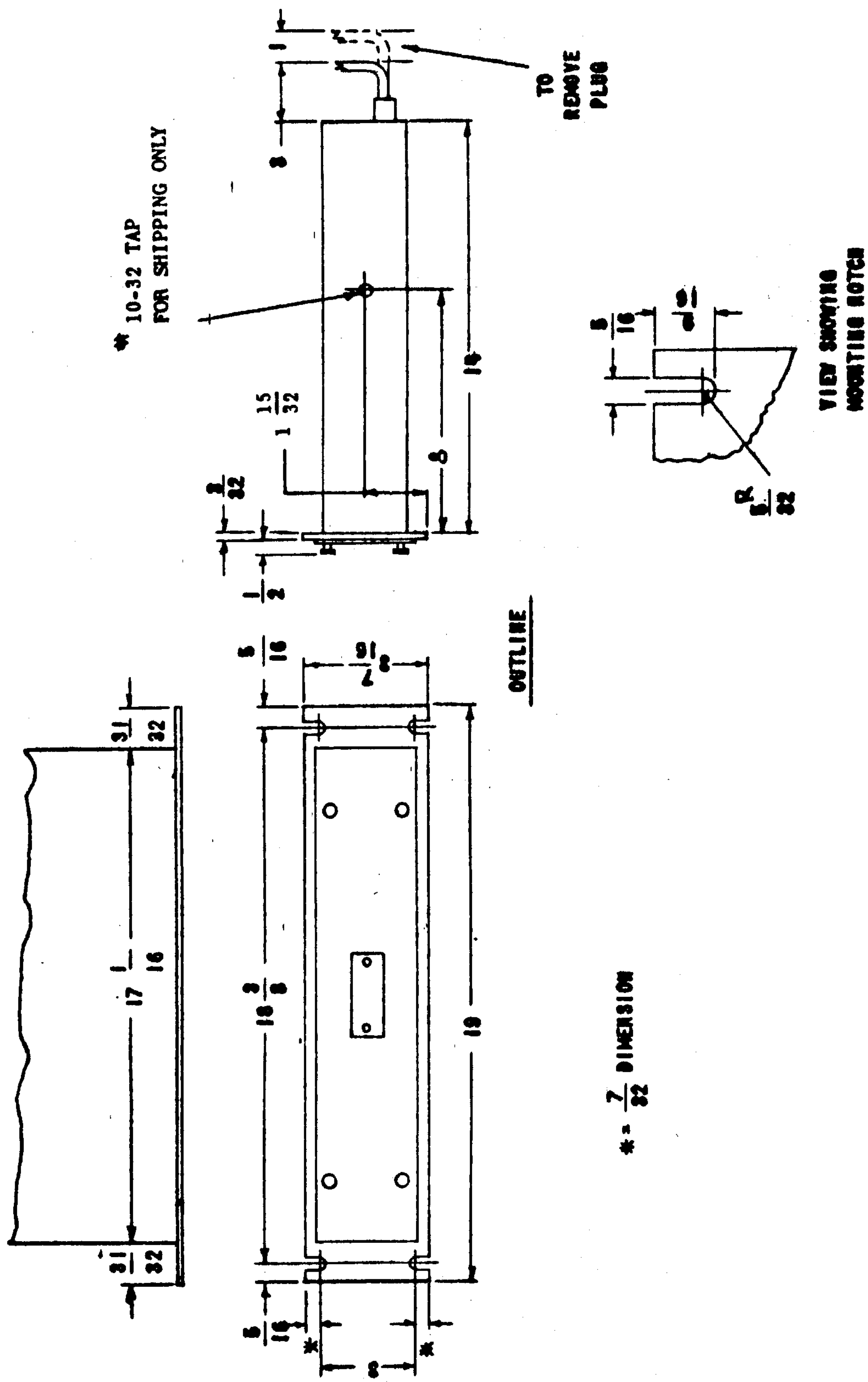
CONT ON SHEET SH NO.

TITLE
OUTLINE & MOUNTING DIMENSIONS

FIRST MADE FOR 2 RACK UNIT (LOGIC & TAP BLOCK)

FIG. 18

REVISIONS




PRINTS TO

MADE BY R. Bechtold JUNE 27, 1963

ISSUED July 12, 1963

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L.V. SWITCHGEAR DIV OR DEPT.

PHILADELPHIA LOCATION

0165A7660

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CONT A

GENERAL ELECTRIC

0 1 7 8 A 5 8 1 3

CONT ON SHEET SH NO.

REV NO. -1

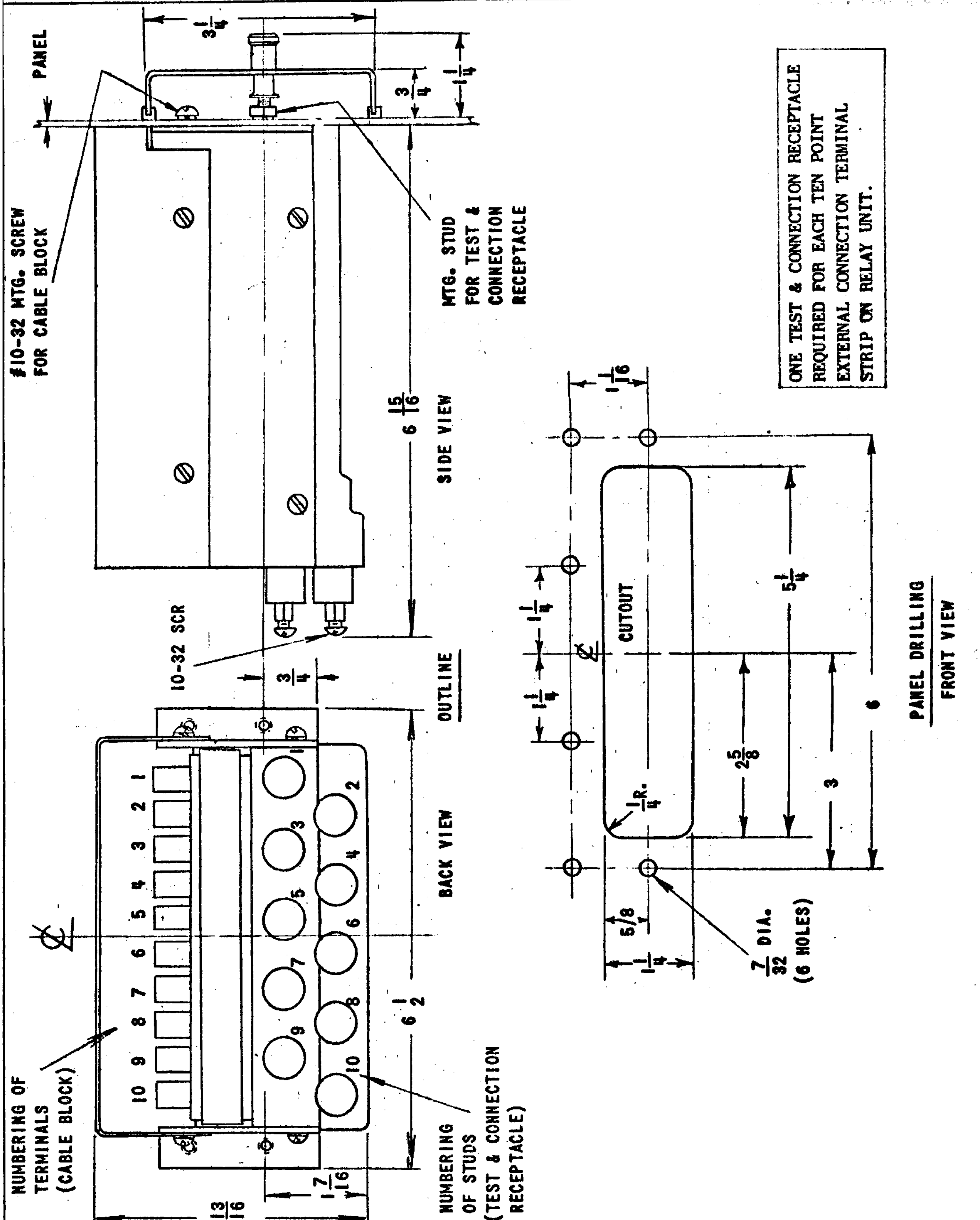
0 1 7 8 A 5 8 1 3

CONT ON SHEET SH NO.

TITLE
OUTLINE & PANEL DRILLING
FOR TEST & CONNECTION RECEPTACLE
FIRST MADE FOR STATIC RELAYS

FIG. 19

REVISIONS




PRINTS TO

MADE BY J. Connor Feb. 7, 1964

ISSUED February 24, 1964

APPROVALS

SWITCHGEAR DIV OR DEPT.

PHILADELPHIA LOCATION

0 1 7 8 A 5 8 1 3

CONT ON SHEET SH NO.

LSP-R

H GENERAL ELECTRIC

0165A7623

CONT ON SHEET SH NO.

REV NO. Q -1-

0165A7623

CONT ON SHEET SH NO.

TITLE
TYPICAL TRANSMISSION LINE
WITH GROUND FAULT

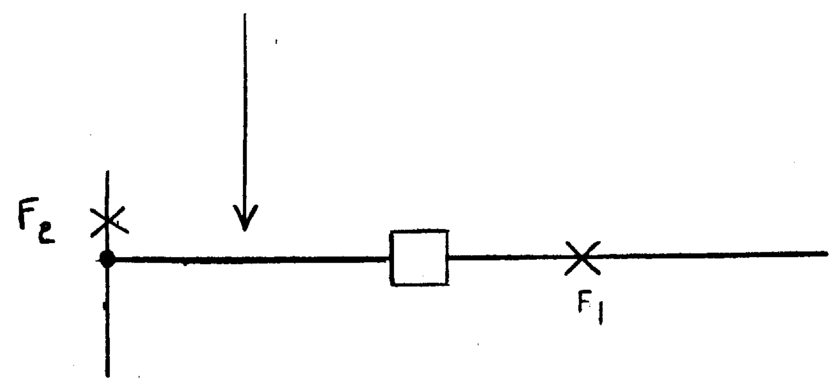
FIRST MADE FOR GCX17G

FIG A1

REVISIONS

MAR 20 64
1

RELAY LOCATION

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| | | | |
|---|---|---|---|
| MADE BY G. Frederick April 2, 1963 | APPROVALS WPA | L.V. SWITCHGEAR DIV OR DEPT | 0165A7623 |
| ISSUED May 7, 1963 | | PHILADELPHIA LOCATION | CONT ON SHEET SH NO. |

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178A71 2

TITLE: VALUATION OF "Ks" AND "∝" A
FUNCTION OF $Zo/Z_i$
F.M.F. GEI-98313 (SLCG)

**CODE H**

GENERAL ELEC C
DRAWN BY R.F. Crate July 15, 1964 Cam
ISSUED July 20, 1964

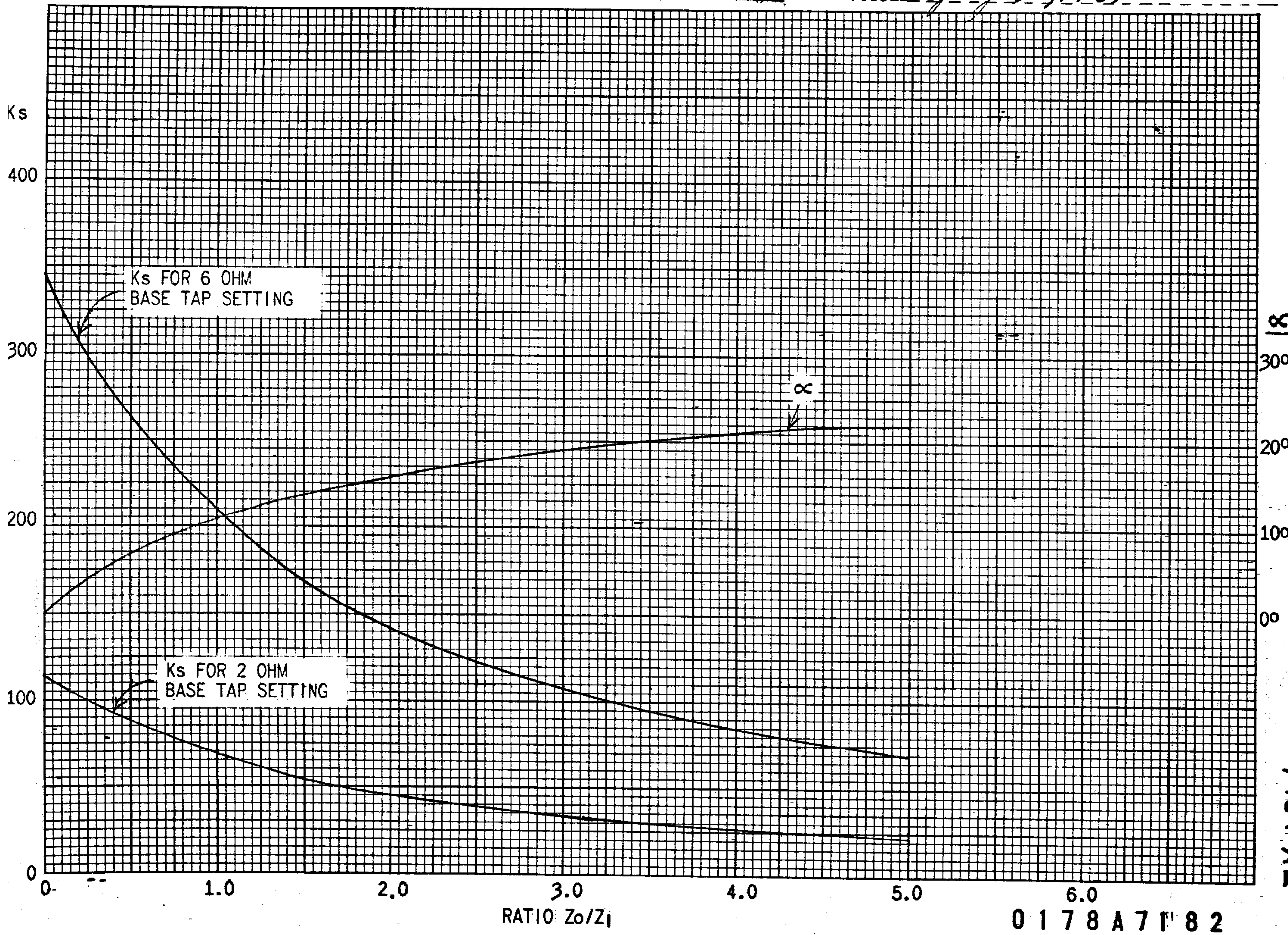


FIG. A2

0178A71182

CODE A

GENERAL ELECTRIC

0178A7183

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REV NO.

0178A7183

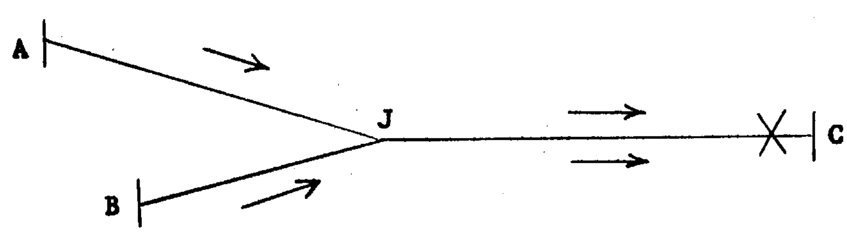
CONT ON SHEET SH NO.

TITLE 3-TERMINAL APPLICATIONS

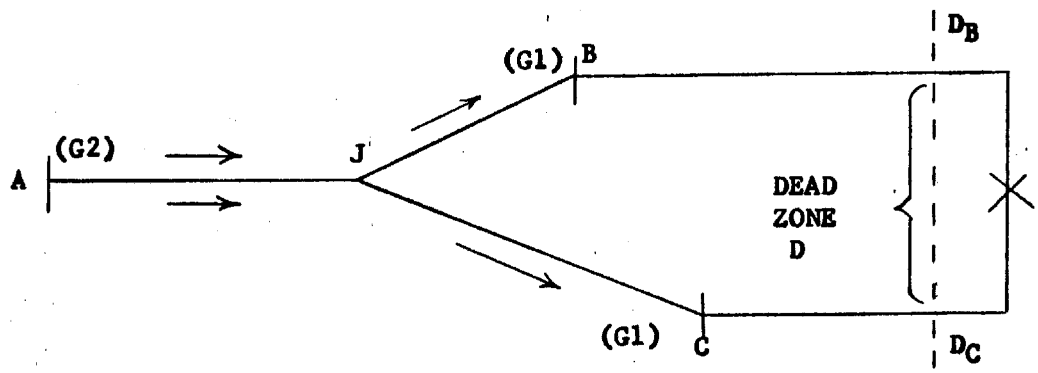
FIRST MADE FOR GEI-98313 (SLCG11A)

FIG. A3

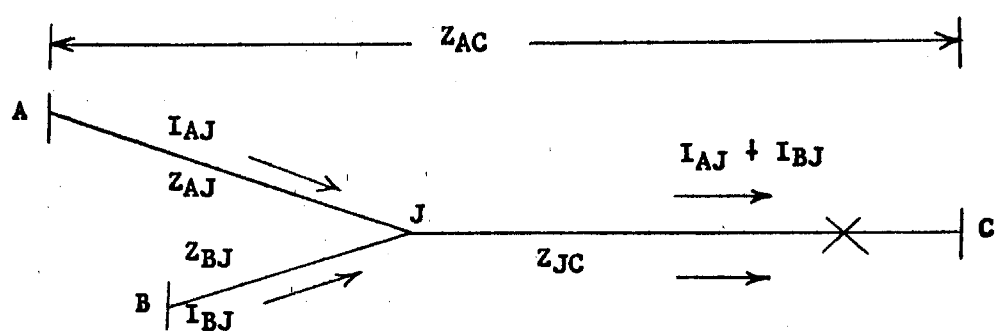
REVISIONS




A- INTERNAL FAULT, 3-TERMINAL LINE




B- EXTERNAL FAULT, 3-TERMINAL LINE




C- INTERNAL FAULT WITH INFEED, 3-TERMINAL LINE

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|---|---|---|---|
| S. F. [illegible] July 15, 1964 | Cam | SWITCHGEAR — DIV OR DEPT. | 0178A7183 |
| ISSUED July 20, 1964 | | PHILADELPHIA — LOCATION | CONT ON SHEET SH NO. |

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