INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

TYPE SDGU 1-2-3-4-5-6-7
SOLID STATE GROUND DISTANCE RELAYS

CAUTION: It is recommended that the user of this equipment become acquainted with the information in these instructions before energizing the relay. Failure to do so may result in damage to the equipment.

Before putting the relay into service, operate the relay to check the electrical connections.

Printed circuit modules should not be removed or inserted while the relay is energized unless specific instructions elsewhere in this instruction leaflet state that such action is permissible. Failure to observe this precaution can result in an undesired tripping output, and can cause component damage.

These instructions cover the seven (7) basic types listed in table 1. This line of relays provides single-zone ground-distance protection. The relay reaches the preset amount for single-line-to-ground faults and as much as 10% less for double-line-to-ground faults for SDGU-1, SDGU-2 and SDGU-7 relays when set for S=1.

TABLE 1

Relay	Io Adjustable	ϕ - ϕ Desensitizer	Freq. Verifier	$V_0X\bar{I}_0$ Logic	Application	
					Io Fixed	
SDGU-1	–	X	X	–	X	Zone 1
SDGU-2	–	X	X	–		Zone 1
SDGU-3	–	–	–	–	X	Timed Trip
SDGU-4	–	–	–	–		Blocking Start
SDGU-5	–	–	X	–	–	Pilot Trip
SDGU-6	X	–	X	X	–	Pilot Trip
SDGU-7	X	X	X	X	–	Zone 1

The potential supply must be wye-grounded. The broken delta potential connection is provided inside the relay.

Relay outputs are 15 V d-c to 19V and up to 0.01 ampere d-c. An auxiliary unit such as an ARS tripping relay or an SRU output package is necessary to trip a breaker or operate other electromechanical devices.

The frequency-verifier circuit should be utilized for all high-speed trip applications to avoid undesired trips due to high-frequency transients. This circuit is not needed for timed trips (e.g., zone 2), but the SDGU-1, SDGU-2 or SDGU-7 may be used instead of the SDGU-3 in the interest of standarization.

Relays with an Io unit are used to prevent tripping due to potential circuit trouble; the SDGU-2 requires SIU current-detector supervision. Relay SDGU-6 and SDGU-7 are provided with a 0.4 to 2.0 Amp Adjustable Overcurrent Unit, so there is no need for SIU supervision.

The a-c potential failure logic ($V_0X\bar{I}_0$) logic produces a reliable, sustained output on loss of potential. The added logic responsive to "$V_0X\bar{I}_0$" provides a sustained output for loss of one or two phases and a momentary output on complete loss of potential. In cases where the potential failure logic is not desired, function can be eliminated by just un-plugging the $V_0X\bar{I}_0$ printed circuit board. This will not affect any other function available in the relay.

The phase-phase-to-ground desensitizer is used to eliminate a possible 15% overreach on two-line-to-ground faults. This circuit is needed for zone 1 applications where the relay reaches 85% towards the far bus.

A type IK auxiliary current transformer may be used to mutually compensate a zone 2 back-up relay. See Appendix I. Neither zone 1, nor the high-speed pilot trip distance relay should be compensated for mutual

SUPERSEDES I.L. 41-496.4A
Complete Revision

EFFECTIVE MARCH 1972

induction. The IK transformer is not required unless mutual compensation is to be used.

Use of a SDGU-type relay for overreaching pilot tripping for 3 terminal lines should be carefully considered to see if complete coverage can be achieved while retaining directional sense for near-by reversed faults. In most cases over compensation of the phase setting and undercompensation of the ground setting will be required. Directional over-current relay SRGU (zero-sequence polarized) or SRQU (negative-sequence polarized) may be a better choice.

Fundamentals of Distance Measurement on Ground Faults

The SDGU distance relay operates on both single and double line-to-ground faults. In either case, neglecting fault resistance, the faulted phase-to-ground voltage(s) at the relay consists of the line drop:

V_{LG} = Faulted phase-to-ground relay voltage

$$= K_1 I_1 n Z_{1L} + K_2 I_2 n Z_{1L} + K_0 I_0 n Z_{0L} + I_{0E}\, n Z_{0M} \quad (1)$$

Where K_1, K_2, K_0 are current distribution factors for the pos., neg., and zero sequence networks, respectively.

I_1, I_2, I_0 are the pos., neg., and zero sequence currents in the fault.

nZ_{1L}, nZ_{0L} are the pos. and zero sequence line impedances to the fault.

I_{0E} zero sequence mutual impedance.

See Fig. 10 for further definition of terms. For an A to ground fault eq. (1) would be written in terms of the phase A quantities.

$$V_{AG} = K_1 I_{A1} n Z_{1L} + K_2 I_{A2} n Z_{1L} + K_0 I_0 n Z_{0L} + I_{OE}\, n Z_{OM} \quad (2)$$

Eq. (2) also applies for an AB to ground fault; an additional expression applies for the phase B quantities for an AB to ground fault.

Hence, a distance ground relay made to respond to single phase-to-ground faults will also respond in the same way to double line-to-ground faults. This is true except for the effect of ground resistance, R_G. The different nature of these effects can be sensed from fig. 11. In Fig. 11 the ground current $3I_0$ flowing through R_G is essentially in phase with the total faulted phase current. This is so, since $I_{A1} = I_{A2} = I_0$. This is not true for a 2ϕ –G fault. The current $3I_0$ is out of phase with K_1K_{A1} and K_2I_{A2} (also out of phase with K_1I_{B1} and K_2I_{B2}). As a result, the drop across R_G produces an apparent reactance term to the distance relay, causing it to underreach on one phase and overreach on the other faulted phase. The SDGU-1 and -2 relays contain a desensitizer circuit to prevent overreach on 2ϕ –G faults, by reducing the reach of the relay.

$$V_{XN} = (V_{A1} + V_{A2}) - Z_C (K_1 I_{A1} + K_2 I_{A2}) \quad (3)$$

$$V_{YN} = (V_{B1} + V_{B2}) - Z_C (K_1 I_{B1} + K_2 I_{B2}) \quad (4)$$

$$V_{ZN} = (V_{C1} + V_{C2}) - Z_C (K_1 I_{C1} + K_2 I_{C2}) \quad (5)$$

These voltages are obtained by the use of compensators with an impedance Z_C, set to match the desired positive sequence line impedance reach. Only positive and negative sequence voltages appear in eq. (3) to (5). The zero sequence voltage is filtered out by not grounding the neutral of the set of Y-connected auxiliary transformers (T_{A2}, T_{B2} and T_{C2}) which are used to feed the restraint portion of the magnitude comparison circuit. These same connections render the zero sequence current flowing in the phase compensators ineffective. So the restraint voltages duplicate the delta voltage conditions at the fault when the fault is Z_C ohms from the relay (i.e., at the balance point). Zero sequence quantities are not required to duplicate the system voltage traingle at the balance point since zero sequence voltage cancels out of the line to line voltages.

The operating voltage is:

$$V_{W0} = V_0 - \frac{Z_{0L}}{Z_{1L}} \times Z_C \left(K_0 I_0 + I_{0E} \frac{Z_{0M}}{Z_{0L}}\right) \quad (6)$$

Here V_0 is the relay zero sequence voltage: it is compensated by using a compensator impedance $\frac{Z_{0L}}{Z_{1L}} Z_C$, representing the zero sequence line impedance to the desired balance point. For mutual coupled lines this compensator can be fed with not only the protected line current but also with a portion of the mutual current I_{0E}. The operating voltage V_{WO} duplicates the system zero sequence voltage for a fault at the balance point.

Since the faulted phase-to-ground voltage is zero at the fault (neglecting fault resistance), the operating and faulted phase restraint voltage will be equal for a balance point fault. This can be seen by manipulating the fault voltage expression, remembering that the relay compensated voltages are a replica of the fault-point voltages:

V_{LGF} = Faulted phase-to-ground voltage at fault

$$= V_{1F} + V_{2F} + V_{0F} = 0 \quad (7)$$

$$V_{1F} + V_{2F} = -V_{0F} \quad (8)$$

$$|V_{1F} + V_{2F}| = |V_{0F}| \quad (9)$$

Eq. (9) states that the magnitude of the sum of the pos. and neg. sequence voltage equals the magnitude of the zero sequence voltage at the fault. This holds regardless of how many phases are grounded. Eq. (9) is the keystone of the SDGU system.

The balance point condition is shown in Fig. 12 for an A-G fault.

The bus voltages (V_{A1} + V_{A2}) and V_0 are shown along with the compensator voltages, which modify the bus voltages to produce restraint voltage V_{XN} and operating voltage V_{WO}.

For this condition V_{YN} and V_{ZN} are also produced but these will be larger in magnitude since these are derived from the sound phases. Since these voltages exceed V_{ZN}, they are irrelevant.

In Fig. 12 for a fault beyond the balance point, V_{XN} exceeds V_{WO}; the reverse is true for the fault within the balance point. Note ,that for all these faults in the trip direction that the phase compensation acts to reduce the bus positive and negative sequence voltages; whereas, the zero sequence compensation is added to V_O. The reverse is true for a fault behind the relay. For this reason the SDGU is inherently directional.

One other aspect of Fig. 12 bears amplification. Note for the fault within the balance point that the phase compensation is almost enough to reverse V_{XN} polarity. It is possible for such a reversal to occur, and it is possible if very little zero sequence current flows for the phase compensation to overtake the operating voltage and restrain the relay. Thus, the relay may fail to see a close-in fault if the zero sequence current is quite small. Any time this extreme occurs the phase distance relay will operate. The phase-distance relay will clear the fault when:

$$Z_1 \geq \frac{V_0 / I_0}{K_1 + K_2 - pK_0}$$

where Z_1 is positive-sequence relay reach

V_0 = zero-sequence bus voltage for close-in fault

I_0 = total zero-sequence fault current for close-in fault

K_1, K_2, K_0 pos.-, neg.,- & zero-sequence current distribution factors for close-in fault.

p = ratio of zero-sequence to positive-sequence line impedance.

CONSTRUCTION & OPERATION

The type SDGU relay consists of four air-gap transformers; three autotransformers for reach adjustment; four phase-splitter transformers; one isolating transformer which couples the zero sequence network a-c output to the static frequency verifier circuit; one zero sequence current-to-voltage transformer, four phase-splitter and rectifier networks; a double line-to-ground fault desensitizer; one voltage regulating zener diode, and several printed circuit assemblies.

Printed circuit boards are plug-in types which may be removed for tests or examination and then reinserted. They may also be plugged into a card extender, style #849A534G01, to make the test points and components accessible for in-service checking.

Compensators (T_A, T_B, T_C, T_O)

The compensators which are designated T_A, T_B, T_C and T_O are 3-winding air-gap transformers. Each current winding has seven taps which terminate at the tap block. A voltage is induced in the secondary which is proportional to the primary tap and current magnitude. This proportionality is established by the cross-sectional area of the laminated steel core, the length of an air-gap which is located in the center of the coil, and the tightness of the laminations. All of these factors which influence the secondary voltage have been precisely set at the factory. The clamps which hold the lamination should not be disturbed by either tightening or loosening the clamp screws.

One secondary winding has a single tap which divides the winding into two sections. One section is connected subtractively in series with the relay terminal voltage. Thus a voltage which is proportional to the phase current is subtracted vectorially from the relay terminal voltage. The second section is connected to an adjustable loading resistor (R_1, R_2, R_3, R_4) and provides a means of adjusting the phase angle between primary current and the induced secondary voltage. The phase angle may be set for any value between 60° and 90° by adjusting this resistor. The factory setting is for a maximum sensitivity angle of 75° current lagging voltage.

A tertiary winding M has four taps which may be connected to directly modify the T setting by a value from −18 to +18 per cent in steps of 3 per cent. The sign of M is negative when the R lead is above the L lead. M is positive when L is in a tap location which is above the tap location of the R lead. The M setting is determined by the sum of per unit values between the R and L lead. The actual per unit values which appear on the tap plate between taps are 0, .03, .09, and .06.

Auto-Transformer (T_{A1}, T_{B1}, T_{C1})

The auto-transformers T_{A1}, T_{B1}, T_{C1} have three taps on their main winding S which are numbered 1, 2 and 3 on the tap block.

The three secondary windings of the auto-transformers are connected in a "broken delta", thus serving as a source of zero sequence voltage for the operating circuit. The primary to secondary turn ratio is 3:1, thus producing the proper zero sequence voltage magnitude as required by the theory of relay operation. Using S = 2 or S = 3 settings reduces zero sequence voltage in the same proportion as the line-to-neutral voltages.

The auto-transformer makes it possible to expand the basic range of T ohms by a multiplier of S.

Phase-Splitter Transformer (T_{A2}, T_{B2}, T_{C2}, T_{02})

The phase splitter transformer provides isolation between the a-c analog network and the magnitude comparer circuitry located on the printed circuit board, and couples the restraint and operating outputs to the phase splitter network. The tap connection on the secondary winding serves as part of the phase splitting circuit that converts a single-phase input into a three-phase output, thus minimizing the ripple of the rectified output.

Isolating Transformer (I_0)

The isolating transformer I_0 serves two purposes: first, it isolates the a-c circuit from the d-c circuit, and second, it produces a secondary voltage in the presence of zero sequence current.

Isolating Transformer (F_C)

The isolating transformer F_C serves two purposes: first, it isolates the a-c circuit from the d-c circuit and second, it steps up the clipped a-c signal to make the frequency check circuit sensitive to low level input signals.

Isolating Transformer (V_O)

The isolating transformer "V_O" serves two purposes: first, it isolates the a-c circuit from the d-c circuit and second, it produces a secondary voltage in the presence of any unbalanced condition across the open delta of the potential circuit.

Double Line-to-Ground Fault Desensitizer

The double line-to-ground fault desensitizer in Figs. 3 & 4 consist of the three networks. Each network consists of a minimum voltage network. In this network the proportion of each restraint voltage is blocked by the same proportion of two other restraint voltages. If any combination of the two restraining voltages become smaller than the third restraint voltage, transistors Q17 and Q18 are turned on to prevent Q1 transistor from turning on. When operating voltage becomes larger than the highest restraint the relay is allowed to trip. The desensitizer effect is limited to S = 1 setting only and is not effective on the S = 2 or S = 3 setting. If S = 2 or S = 3 setting is used for zone 1 the setting should be reduced to 75% of the protected line to avoid overreach on double-line-to-ground faults.

Magnitude Comparator Circuit

The magnitude comparator circuit consists of a minimum voltage network of the voltage balance type in which operating current is caused to flow through a current detector whenever one of the phase restraint voltages becomes smaller than the operating voltage.

Resistors (R9, R10, R11) provide a return path for the operating current.

The current detector consists of a special voltage reference circuit formed by R75, R34, R35, and

TH2 resistors. The use of this circuit secures a sharp turn on characteristic for the triggering network. The TP3 – potential derived from this reference circuit is providing base drive for Q5 transistor that is prevented from turning on as long as Q2 is turned on by TP1-potential. Whenever operating voltage V_{WO} exceeds one of the restraint voltages (V_{XN}, V_{YN}, V_{ZN}) transistor Q1 is turned on lowering the TP1 potential below TP3 - potential thus making it possible for Q5 to conduct, thus turning on Q6 and after time delay controlled by R76-C7- time constant producing an output.

Zero Sequence Current Detector (Fig. 14)

To prevent output of the magnitude comparator for a blown potential fuse or similar condition a zero sequence current detector supervises the operation of the output network by keeping the input to Q28 transistor at negative potential through the diode D106. This provides for the I_0XZ operation.

The detector employes tunnel diodes as a level detector. The tunnel diodes are biased through resistor R99 to the high voltage state so that enough voltage is maintained across the base-to-emitter junction of Q28 transistor to keep it conducting.

In the presence of the residual current, a current-derived voltage through transformer I_0 is rectified and appears across resistor R95, switching off TD1 and TD2 to allow the low voltage state, thus turning transistor Q28 off and raising its collector to the positive d-c voltage supply level blocking D109 action.

SDGU-6-7 relays are provided with a variable I_0 unit. This feature allows current settings for a 0.4 to 2.0 amp. range.

Blown Fuse Detector Circuit ($V_0 X \bar{I_0}$) (Fig.8)

Blown fuse detector (BFD) circuit in SDGU-6 and SDGU-7 relays provide an output in the presence of zero sequence voltage and the absence of an output from zero sequence current detector circuit (I_0). I_0- output will depend on the level of the current setting (0.4 - 2.0 amp). BFD circuit consists of two circuits: zero sequence voltage detector (V_0- transformer, Q25 transistor and associated diode and resistor network), and logic "AND" - circuit Q26, Q27 - transistor). Q27 transistor is turned "ON" to produce on output when Q-28 in I_0-circuit has not been turned "OFF" (No I_0-output) and Q26 is "ON" (V_0 - detector has operated).

Frequency Verification (Fig. 15)

During certain switching conditions, such as energization of a transmission line, residual currents and voltages may exist of higher frequencies than 60 hertz. The frequency verifier prevents relay operation for these conditions when the Q1 (magnitude comparator) is switched on for less than 5.0 ms. The frequency verification circuit is performed by means of a zero-crossing circuit. The zero crossing is detected by Q3 and Q4 transistors. The zero-crossing circuit will not prevent operation of relay in the presence of higher frequencies of small magnitude superimposed on a fundamental of 60 Hz. During the positive or negative half cycles of the operating voltage V_{WO}, Q3, or Q4 transistors are driven into saturation by the output of the F_C transformer. Transistor Q20 (Mag. Comp. Board) conducts until capacitors C8 or C10, respectively are fully charged. While either capacitor is charging through R66, transistor Q20 drives transistor Q19 (Mag. Comp. Board) to discharge timing capacitor C7, thus starting the timing cycle with close to zero charge on the capacitor. The function of the timing capacitor is to delay the operation of the relay for 5 milliseconds. The delay is obtained by delaying the firing time of Z1 zener diode. If a next zero crossing should occur within the preset delay time, C7 capacitor is discharged again and the timing cycle is repeated. In case of presence of predominant higher frequencies (over 100 Hz), zero crossing pulses will occur within the preset time delay, thus keeping the C7 capacitor from charging up to the Zener firing voltage.

The transient blocking is accomplished through the operation of Q7 (Mag-Comp.) transistor that is driven by a short pulse formed through R37 and C6 to clear C7 capacitor (Mag. Comp. Board) of any charge before initiating 5.0 ms delay. Any tripping signal coming off Q6 transistor of a duration of less than 5 ms will not produce a relay output.

Output Circuits

All relay outputs are standard buffered outputs as shown by Fig. 16. A positive signal to the first stage turns the transistor on. This will, then, drive the output transistor into saturation. An output of 20 ± 2 volts is then registered across the output terminals.

Printed Circuit Board Assembly

The SDGU-1 (Fig. 3) relay uses five printed circuit board (PCB) assemblies. The five basic PCB's are: one "magnitude comparator", one "rectifier," one "rectifier and I_0-fault detector," one "frequency verifier," and one "2ϕ-G" (Phase-to-phase desensitizer). The SDGU-2 (Fig. 4) relay uses total of five PCB boards – four of PCB are common with the SDGU-1 relay except for "rectifier and I_0-detector." This board does not include I_0 detector. PCB styles are identified on internal schematics.

The SDGU-3 (Fig. 5) relay uses three printed circuit boards (PCB). The three PCB's are: one "magnitude comparator," one "rectifier," one "rectifier and I_0-detector". These boards with exception of "rectifier-board" are different from the boards used SDGU-1 or SDGU-2 relays. The SDGU-4 (Fig. 6) relay uses a total of three printed circuit boards (PCB). Two of the PCB's are common with SDGU-3 relays, these are "magnitude comparator" and "rectifier" boards. The "rectifier and I_0-detector" board for SDGU-4 does not include I_0-detector. The SDGU-5 relay (Fig. 7) is similar to SDGU-2 except "2ϕ-G" board omitted.

The SDGU-6 (Fig. 8) relays use 5 PCB's. The five printed circuits are:one"magnitude comparator," one "rectifier," one "frequency verifier," and "V_0 x $\overline{I_0}$," one "Z x I_0." These boards with the exception of "V_0 +$\overline{I_0}$" and "Z_0 + I_0" are identical to those used by SDGU-1-2-3-4-5 relays.The SDGU-7 (Fig. 9) relay uses a total of 6 boards. Five of these are common with SDGU-6, plus a phase-to-phase desensitizer ("2ϕ-G"). The"3ϕ-G"board is identical to that one used by SDGU-1 relays.

Caution should be used when replacing printed circuit boards that have adjustable components (potentiometer), or components that are added during factory calibration.

These components should be adjusted as per "Calibration Procedure," when boards are replaced.

PCB assemblies shown in Figures 17 to 28 contain all the resistors, diodes, transistors, and thyristors necessary to perform the intended functions.

Components on each board are identified by a letter followed by a number so that every component has an exclusive identification. Resistors are identified by the letter R followed by a number. Similarly, diodes are identified by a D, and the cathode (the end out of which conventional current flows) is identified by a bar across the point of an arrow. Zener diodes are identified by Z, transistors by Q, thyristors by QS, capacitors by C, and test points by TP.

Component letter designations are listed as below:

Capacitor C	Tunnel Diode TD
Diode D	Thyristor QS
Resistor R	Transistor Q
Test Point TP	Zener Diode Z (or DZ)

CHARACTERISTICS

Distance Characteristics

Fig. 29 shows that the relay characteristic in the complex plane is $Z = nZ_{1L} + \frac{3R_G}{F}$ for single line-to-ground faults where $F = K_1 + K_2 = pK_0$. Where K_1, K_2,K_0 = positive, negative and zero sequence current distribution factors and p = ratio of zero sequence to positive sequence line impedance. Impedance nZ_{1L} is the positive-sequence line impedance from the relay to the fault. The apparent impedance Z must fall within the characteristic shown in Fig. 29 in order to operate.

R-X characteristic is a composite of three circles whose centers are A, B, and C in Fig. 29A. The circle whose center is A is produced from the comparison of faulted phase restraint and operating voltage for a single line-to-ground fault; whereas, the "B" and "C" circles result from sound-phase restraint comparison with operating voltage.

Note that part (A) of Fig. 29 applies for the case of a low source impedance vs. line impedance; parts (B) and (C) represent increasing amounts of source impedance, or conversely shorter line lengths. The solid-line characteristic is based on current distribution factors for a balance point fault with all breakers closed. As the fault moves toward the relay these distribution factors increase, with the relay approaching the dashed-line characteristic. In the case of Fig. 29C the dashed-line characteristic is not shown, as it essentially coincides with the solid-line characteristic. Regardless of system conditions, the relay reaches Z_C positive-sequence ohms for a fault at the compensator angle. The fact that the circle diameter expands with increasing source impedance is beneficial, since this provides increased fault resistance accommodation for the shorter line applications. By this we mean that if takes a greater $\frac{3R_G}{K_1 + K_2 + pK_0}$ component to yield a Z phasor which is outside the operate zone. In Fig. 29C only the faulted phase characteristic is shown, since the other two fall well out of the first quadrant.

One might conclude from Fig. 29 that the relay is not directional since its characteristic includes the origin. This conclusion would be erroneous, since the characteristic equations assume faults in the trip direction per Fig. 12 and do not apply for reversed faults. The relay is directional. In Fig. 29 the second and third quadrants are essentially theoretical since a "negative resistance" is only possible due to out-of-phase infeed. The fourth quadrant is pertinent for series capacitor applications. So we are normally only interested in the first quadrant.

General Characteristics

Impedance settings in ohms reach can be made in steps of 3 per cent. The maximum sensitivity angle, which is set for 75 degrees at the factory, may be set for any value from 60 degrees to 82 degrees. A change in the maximum sensitivity angle will produce a slight change in reach for any given setting of the relay. Referring to Fig. 30 note that the compensator secondary voltage output V, is largest when V leads the primary current, I, by 90°. This 90° relationship is approached, if the compensator loading resistor is open-circuited. The effect of the loading resistor, when connected, is to produce an internal drop in the compensator, which is out-of-phase with the induced voltage, IT_A, IT_B or IT_C. Thus the net voltage, V, is the phase-shifted to change the compensator maximum sensitivity angle. As a result of this phase shift the magnitude of V is reduced, as shown, in Fig. 30. The tap markings are based upon a 75° compensator angle setting. If the resistors R1, R2, R3, and R4 are adjusted for some other maximum sensitivity angle the nominal reach is different than that indicated by the taps. The reach Z_θ, varies with the maximum sensitivity angle, θ as follows:

$$Z_\theta = \frac{TS \sin\theta \ (1 + M)}{\sin 75^\circ}$$

TAP PLATE MARKING.

T_A, T_B, T_C (Pos. Seq.)

1.2 1.5 2.1 3.0 4.5 6.3 8.7 for 1.0-31 ohms range

.23 .307 .383 .537 .69 .92 1.23 for .2-4.35 ohms range

T_0 (Zero Seq.)

3.60 4.5 6.3 9.0 13.5 18.9 26.1 for 1.0-31 ohms range

0.69 0.92 1.15 1.61 2.07 2.76 3.69 for .2-4.35 ohms range

(S_A, S_B, S_C)		
1	2	3

± Values between taps	(M_A, M_B, M_C, M_O)		
	.03	.09	.06

TIME CURVES AND BURDEN DATA

Operating Time

The speed of operation is shown in Fig. 31. The curves indicate the time in milliseconds required for the relay to provide an output for tripping after the occurrence of a fault at any point on a line within the relay setting

Current Circuit Rating in Amperes

Continuous – 10 Amperes

1 Second – 240 Amperes

Burden

The potential burden at 69 volts varies from a maximum of 1.4 volt-amperes at S = 1 setting to a minimum of 0.42 volt-amperes based on 69 volts line-to-neutral per phase. Current burden varies from a maximum of 4.5 volt-amperes at 5 amperes for a maximum T-setting to a minimum of 0.60 volt-amperes for a minimum T-setting. This burden applies to each phase and residual current circuit. D.C. current burden is 0.7 amperes at all rated voltages.

CALCULATIONS & SELECTIONS OF SETTINGS

Relay reach is set on the tap plate. Maximum sensitivity angle, θ is set for 75° (current lagging voltage) in the factory. This adjustment need not be disturbed for line angles of 65° or higher. For line angles below 60°, set θ for a 60° maximum sensitivity angle, by adjusting R_1, R_2, R_3 and R_4. Set zone 1 reach to be 85% of the line, if S = 1 is used, but set for 75% if S = 2 or 3 is used.

Assume a desired balance point which is 85% of the total length of the line. The general formulas for setting the ohms reach of the relay are:

$$Z_1 = Z_{1L}\frac{0.85\ R_C}{R_V};\quad Z_0 = Z_{0L}\frac{0.85\ R_C}{R_V}$$

The terms used in these formulas and hereafter are defined as follows:

- R_C = Current Transformer Ratio
- R_V = Potential Transformer Ratio
- Z_O = Zero sequence ohmic reach. To be used for relay setting.
- Z_{OL} = Zero sequence ohms per phase of the total line section. Referred to primary.
- Z_1 = Positive sequence ohmic reach. To be used for relay setting.
- Z_{1L} = Positive sequence ohms per phase of the total line section. Referred to primary.
- $Z_{1,0}$ = TS (1 + M) = the tap plate setting.
- T = Compensator tap value
- S = Auto-transformer tap value
- θ = Maximum sensitivity angle setting of the relay.
- ± M = Compensator tertiary tap value. (This is a per unit value and is determined by the sum of the values between the "L" and the "R" leads. The sign is positive when "L" is above "R" and acts to raise the Z setting. The sign is negative when "R" is above "L" and acts to lower the "Z" setting).

The following procedure should be followed in order to obtain an optimum setting of the relay.

Zone 1 Setting (SDGU-1, SDGU-2, SDGU-7 Relays)

Establish the desired values of Z_1 and Z_0 as above (available from transmission line data), and follow one of the two procedures below.

Procedure 1 (Preferred)

This procedure avoids recalibration of the relay maximum sensitivity angle.

Step 1

Compute desired tap settings according to equation: $Z'_{1,0} = \frac{Z_{1,0}}{\cos(75-\theta)}$, (Eq.III)

where θ- is characteristic angle of the line. In case $\phi_1 = \phi = 60°$

$$\text{Then } Z'_1 = \frac{7}{\cos(75°-60°)} = \frac{7}{.965} = 7.25$$

$$\text{Then } Z'_0 = \frac{21}{\cos(75°-60°)} = \frac{21}{.965} = 21.75$$

If this procedure is followed calculation can be made allowing for $\phi_0 = \phi_1$

Step 2 (a)

From Table IV we find 7.25 value and 21.75 ohms value as the exact values.

Step 2 (b)

From Table IV – Read off

S = 1

T = 6.3

M = +.15

T_0 = 18.9

M_0 = +.15

Step 2 (c)

Recheck settings.

$Z_1 = Z'_1 \cos(75° - \phi) = 7.25 \times .965 = 7$ ohms

$Z_0 = Z'_0 \cos(75° - \phi) = 21.75 \times .965 = 21$ ohms

Procedure 2

1. If relay maximum sensitivity angle of 75° has been recalibrated to angle θ, determine the desired tap plate value Z' using the formula:

$$Z'_1 = Z_1\frac{\text{Sin } 75°}{\text{Sin } \theta°} \quad \text{and} \qquad \text{(Eq I)}$$

$$Z'_0 = Z_0\frac{\text{Sin } 75°}{\text{Sin } \theta°} \qquad \text{(Eq II)}$$

of course, when $\theta = 75°$, $Z'_1 = Z_1$ and $Z'_0 = Z_0$
If recalibrated, calibrate θ the same for Z_0 and Z_1

2. Now refer to Table II or IV giving preferred zone 1 settings for the SDGU relays. If the desired reach exceeds the relay range for S = 1, use S = 2 and Table III or V (set for 75% of line).

   a. Locate a table value for relay reach nearest to the desired Z' value (it will always be within 1.5% of the desired value.)

b. From this table read off the "S", "T" and "M" settings. The "M" column includes additional information for the "L" and "R" lead setting for the specified "M" value. If the desired settings cannot be found in this table proceed to Table III or V to find the desired setting. The relay reach must now be reduced from 85 to 75% to avoid overreach on two phase-to-ground faults on high fault resistance faults.

c. Recheck relay settings for Z_1 and Z_0 using equation:

$Z = TS\ (1 + M)$

For example, assume the desired reach, Z_1 is 7 ohms at 60° (step la) and Z_0 is 21 ohms at 60°.

Next step is (1b). If relay maximum sensitivity angle has been recalibrated to match the characteristic angle of the line (60°) that is different from factory setting of 75°, we find the corrected relay tap setting using equations I and II.

$Z'_1 = 7 \times 1.115 = 7.81$ ohms

$Z'_0 = 21 \times 1.115 = 23.41$ ohms,

Note, $\frac{\sin 75°}{\sin 60°} = 1.115$

(This computation is made when R_1, R_2, R_3 and R_4 settings are changed.)

Step (2a)

In Table IV we find 7.90 to be the nearest value to 7.81 ohms.

$100 \times \frac{7.90}{7.81} = 101.1\%$ or 1.2% from the desired value.

For the Z_0 selection find the nearest value to 23.41 ohms using the same S setting as above. 23.7 ohms is the nearest value.

$100 \times \frac{23.7}{23.41} = 101.2\%$ or 1.2% within the desired value.

Step (2b)

From Table IV read off:

S = 1

T = 8.7

M = -.09

T_0 = 26.1

M_0 = -.09

The "R" lead should be connected over "L" lead, with "L" lead connected to .03 - tap and "R" - lead to tap "09". (The sum of values between L and R is 0.09).

Step (2c)

Recheck Settings

$Z'_1 = T_S\ (1 \pm M) = 1. \times 8.7\ (.91) = 7.92$ and

$Z'_0 = 1 \times 26.1\ (.91) = 23.65$

$Z_1 = Z'_1 \frac{\text{Sin } 60°}{\text{Sin } 75°} = 7.92 \times .897 = 7.10$ ohms at 60° (From Eq. I)

$Z_0 = Z'_0 \frac{\text{Sin } 60°}{\text{Sin } 75°} = 23.65 \times .897$ v 21.2 ohms at 60° (From Eq. II)

For Pilot Trip or Zone 2, Zone 3, Settings

For Pilot Trip application use SDGU-5 or -6 type. For Zone 2 and Zone 3 (Timed Trip) use SDGU-3, or -4, relays. There is no need to make correction for maximum sensitivity angle, for either application. Do not recalibrate maximum sensitivity angle of the relay and use any of the tables from II to V, otherwise proceed as per Procedure 1 above. If SDGU-1-2 or-7 are used for Zone 2, Zone 3 or Carrier Settings, remove 2ϕ – G desensitizer board. Limit relay setting to maximum 150 percent setting of Zone 1 setting to prevent operation on fault behind the relay if the remote buss includes generation source with source impedance smaller than the 50 percent of zone 1 impedance.

NOTE: The S setting must be the same for both the positive and zero sequence reach.

SETTING THE RELAY

The SDGU relays require settings for the four compensators (T_A, T_B, T_C and T_0), the three auto-transformer primaries (S_A, S_B, and S_C) and the four compensator tertiaries (M_A, M_B, M_C and M_0). All of these settings are made with taps on the tap plate.

Compensator (T_A, T_B, T_C, T_0 and M_A, M_B, M_C, M_0)

Each set of compensator primary T_A, T_B, T_C, and T_0 taps terminates in inserts which are grouped on a socket and form approximately three-quarters of a circle around a center insert which is the common connection for all of the taps. Electrical connections between common insert and tap inserts are made with a link that is held in place with two connector screws, one in the common and one in the tap. A compensator tap setting is made by loosening the connector screw in the center. Before removing the screw make sure the current circuit is deenergized. Remove the connector screw in the tap end of the link, swing the link around until it is in position over the insert for the desired tap setting, replace the connector screw to bind the link to this insert, and retighten the connector screw in the center. Since the link and connector screws carry current, be sure that the screws are turned to bind snugly. Compensator secondary tap connections are made through two leads identified as L and R for each side of the vertical row of "M" tap inserts. The connectors are held in place on the proper tap by connector screws.

Values for which an "M" setting can be made are from -.18 to +.18 in steps of .03. The value of a setting is the sum of the numbers that are crossed when going from the R lead position to the L lead position. The sign of the "M" value is determined by which lead is in the higher position on the tap plate. The sign is positive (+) if the L lead is higher and negative (–) if the R lead is higher.

An "M" setting may be made in the following manner. Remove the connector screws so that the L and R leads are free. Refer to Table II through Table V to determine the desired "M" value. Neither lead connector should make electrical contact with more than one tap at a time.

Line Angle Adjustment

Maximum sensitivity angle is set for 75° (current lagging voltage) in the factory. This adjustment need not be disturbed for line angles of 60° or higher. For line angles below 60° set 60° maximum sensitivity angle by adjusting the compensator loading resistors R_1, R_2, R_3, R_4. Refer to repair calibration under "Maximum Torque Angle Adjustment," when a change in maximum sensitivity angle is desired. It is not necessary to change maximum sensitivity angle for Zone 2 or Zone 3 applications regardless of the value of the characteristic angle of the line. The change in maximum torque angle adjustment, if desired, can be avoided. In this case the reach of the relay is adjusted to compensate for difference in the maximum torque angle of the relay (75°) and the characteristic angle of the line ϕ according to the following equation:

$$Z_{1,0} = \frac{Z_{1,0}}{\cos(75-\phi)}$$

Here $Z_{1,0}$ – tap plate setting

Z_1 or Z_0 – desired ohmic reach

INSTALLATION

The relays should be mounted on switchboard panels or their equivalent in a location free from dirt, moisture, excessive vibration and heat. Mount the relays by means of the four slotted holes on the front of the case. Additional support should be provided toward the rear of the relay in addition to the front panel mounting. This will protect against warping of the front panel due to the extended weight within the relay case.

EXTERNAL CONNECTIONS

Fig. 33 shows the external connections for an SDGU-1 or SDGU-2, -3, -4 relay.

Current circuit connections are made to an eight section terminal block located at the rear. Potential circuits, both a-c and d-c as well as input and output logic signal circuits, are connected through a 24-terminal jack. Connections are made by a plug on the wiring harness. The plug is inserted between the two latching fingers which hook over the back of the plug to prevent an accidental loosening of the plug. The plug can be removed by spreading the two fingers apart enough to disengage the hooks from the back. The plug must be withdrawn while the fingers are spread apart.

Note that terminal number 1 is connected to the case within the relay and may be used for grounding the shields of connecting cables. The grounding connections will be broken when the plug is disconnected.

Permanent grounding of the case is accomplished by connecting a ground wire under a washer of a cover screw. These are self-tapped screws and provide excellent low resistance contact with the case.

TABLE II
.2–4.35 OHM RELAY RANGE
PREFERRED ZONE 1 OR PILOT TRIP SETTINGS

POSITIVE SEQUENCE (Z1) S = 1								ZERO SEQUENCE (Z0) S = 1								M		CONNECT		
T	.230	.307	.383	.537	.69	.92	1.23	T_0	.69	.921	1.15	1.61	2.07	2.76	3.69	+ M	– M	"L" LEAD TO TAP	"R" LEAD TO TAP	
	.272	.362	.452	.632	.815	1.09	1.45		.815	1.09	1.36	1.90	2.44	3.26	4.40	+.18		.06	0	"L" OVER "R"
	.264	.352	.441	.617	.794	1.06	1.41		.794	1.06	1.32	1.85	2.38	3.18	4.25	+.15		.06	.03	"L" OVER "R"
	.258	.344	.430	.601	.772	1.03	1.38		.772	1.03	1.29	1.80	2.32	3.10	4.15	+.12		.09	0	"L" OVER "R"
	.251	.335	.418	.585	.754	1.00	1.34		.754	1.00	1.25	1.76	2.26	3.00	4.04	+.09		.09	.03	"L" OVER "R"
	.244	.325	.405	.570	.732	.975	1.30		.732	.975	1.22	1.71	2.20	2.92	3.92	+.06		.06	.09	"L" OVER "R"
	.237	.316	.396	.555	.710	.950	1.27		.710	.950	1.18	1.66	2.13	2.84	3.80	+.03		.03	0	"L" OVER "R"
	.230	.307	.383	.537	.69	.920	1.23		.69	.921	1.15	1.61	2.07	2.76	3.69	0	0	0	0	
	.223	.298	.370	.520	.670	.892	1.19		.670	.892	1.12	1.56	2.00	2.68	3.58		–.03	0	.03	"R" OVER "L"
	.216	.288	.360	.505	.650	.865	1.15		.650	.865	1.08	1.52	1.95	2.60	3.46		–.06	.09	.06	"R" OVER "L"
	.209	.280	.348	.488	.627	.840	1.12		.627	.840	1.05	1.47	1.88	2.51	3.36		–.09	.03	.09	"R" OVER "L"
	.202	.270	.336	.472	.607	.810	1.08		.607	.810	1.01	1.42	1.82	2.43	3.25		–.12	0	.09	"R" OVER "L"
	.195	.260	.324	.456	.587	.782	1.05		.587	.782	.980	1.37	1.76	2.35	3.14		–.15	.03	.06	"R" OVER "L"
	.188	.252	.314	.440	.565	.755	1.01		.565	.755	.940	1.32	1.70	2.26	3.02		–.18	0	.06	"R" OVER "L"

TABLE III
.2–4.35 OHM RELAY RANGE
PREFERRED ZONE 2 & 3 OR PILOT TRIP SETTINGS

POSITIVE SEQUENCE SETTINGS (Z_1)										ZERO SEQUENCE SETTINGS (Z_0)										M		CONNECT		
S = 2								S = 3		S = 2								S = 3						
T	.230	.307	.383	.537	.69	.92	1.23	.92	1.23	T_0	.69	.921	1.15	1.61	2.07	2.76	3.69	2.76	3.69	+ M	– M	"L" Lead To Tap	"R" Lead To Tap	
	.544	.724	.905	1.26	1.63	2.17	2.90	3.26	4.40		1.63	2.17	2.72	3.80	4.90	6.50	8.70	9.80	13.1	+.18		.06	0	"L" OVER "R"
	.528	.704	.880	1.23	1.59	2.12	2.82	3.18	4.25		1.59	2.12	2.65	3.70	4.76	6.35	8.48	9.55	12.7	+.15		.06	.03	"L" OVER "R"
	.516	.688	.860	1.20	1.55	2.06	2.76	3.10	4.15		1.55	2.06	2.58	3.60	4.65	6.20	8.25	9.30	12.4	+.12		.09	0	"L" OVER "R"
	.502	.670	.835	1.17	1.51	2.00	2.68	3.00	4.04		1.51	2.00	2.50	3.50	4.52	6.00	8.05	9.05	12.1	+.09		.09	.03	"L" OVER "R"
	.488	.650	.810	1.13	1.46	1.95	2.60	2.92	3.92		1.46	1.95	2.44	3.41	4.40	5.85	7.80	8.80	11.8	+.06		.06	.09	"L" OVER "R"
	.474	.632	.790	1.10	1.42	1.90	2.53		3.80		1.42	1.90	2.37	3.32	4.26	5.70	7.60		11.4	+.03		.03	0	"L" OVER "R"
	.460	.614	.766	1.07	1.38	1.84	2.46		3.69		1.38	1.84	2.30	3.22	4.14	5.52	7.38		11.1	0	0	0	0	
	.446	.596	.740	1.04	1.34	1.78	2.40		3.58		1.34	1.78	2.24	3.12	4.02	5.35	7.15		10.7		–.03	0	.03	"R" OVER "L"
	.432	.576	.716	1.01	1.30	1.73	2.32		3.46		1.30	1.73	2.16	3.02	3.90	5.16	6.94		10.4		–.06	.09	.06	"R" OVER "L"
	.418	.560	.695	.975	1.25	1.67	2.24		3.36		1.25	1.67	2.09	2.94	3.78	5.00	6.70		10.1		–.09	.03	.09	"R" OVER "L"
	.404	.540	.674	.940	1.21	1.62	2.17				1.21	1.62	2.02	2.83	3.66	4.85	6.50		9.8		–.12	0	.09	"R" OVER "L"
	.390	.520	.650	.910	1.17	1.56	2.10				1.17	1.56	1.95	2.74	3.55	4.67	6.27		9.4		–.15	.03	.06	"R" OVER "L"
	.376	.504	.625	.880	1.13	1.50	2.08				1.13	1.50	1.79	2.64	3.40	4.50	6.05		9.1		–.18	0	.06	"R" OVER "L"

TABLE IV
1.1–31 OHMS RELAY RANGE
PREFERRED ZONE 1 OR PILOT TRIP SETTINGS

POSITIVE SEQUENCE (Z_1) S = 1								ZERO SEQUENCE (Z_0) S = 1								M		CONNECT		
T	1.2	1.5	2.1	3.0	4.5	6.3	8.7	T_0	3.6	4.5	6.3	9.0	13.5	18.9	26.1	+ M	– M	"L" Lead To Tap	"R" Lead To Tap	
	1.42	1.77	2.48	3.54	5.3	7.45	10.2		4.25	5.30	7.45	10.6	15.9	22.2	30.8	+.18		.06	0	"L" OVER "R"
	1.38	1.73	2.42	3.45	5.17	7.25	10.0		4.15	5.17	7.25	10.4	15.5	21.7	30.0	+.15		.06	.03	"L" OVER "R"
	1.34	1.68	2.36	3.36	5.04	7.05	9.75		4.05	5.04	7.05	10.1	15.1	21.2	29.3	+.12		.09	0	"L" OVER "R"
	1.31	1.64	2.29	3.27	4.90	6.89	9.50		3.94	4.90	6.89	9.81	14.7	20.6	28.4	+.09		.09	.03	"L" OVER "R"
	1.27	1.59	2.22	3.18	4.77	6.70	9.25		3.82	4.77	6.70	9.54	14.3	20.0	27.7	+.06		.06	.09	"L" OVER "R"
	1.24	1.55	2.16	3.09	4.64	6.50	8.95		3.71	4.64	6.50	9.27	13.9	19.5	26.9	+.03		.03	0	"L" OVER "R"
	1.20	1.5	2.10	3.00	4.50	6.30	8.70		3.6	4.50	6.30	9.0	13.5	18.9	26.1	0	0	0	0	
	1.16	1.45	2.04	2.91	4.36	6.10	8.45		3.50	4.36	6.10	8.73	13.1	18.3	25.2		–.03	0	.03	"R" OVER "L"
	1.13		1.97	2.82	4.23	5.90	8.15		3.38		5.90	8.46	12.7	17.7	24.5		–.06	.09	.06	"R" OVER "L"
	1.09		1.91	2.73	4.10	5.74	7.90		3.27		5.74	8.19	12.3	17.2	23.7		–.09	.03	.09	"R" OVER "L"
	1.06		1.85	2.64	3.96	5.55	7.65		3.16		5.55	7.92	11.9	16.6	23.0		–.12	0	.09	"R" OVER "L"
	1.02		1.77	2.55	3.82	5.35			3.06		5.35	7.65	11.5	16.0			–.15	.03	.06	"R" OVER "L"
	0.99				3.69				2.95				11.1				–.18	0	.06	"R" OVER "L"

TABLE V
1.1–31 OHMS RELAY RANGE
PREFERRED ZONE 2 & 3 OR PILOT TRIP SETTINGS

POSITIVE SEQUENCE SETTINGS (Z_1)										ZERO SEQUENCE SETTINGS (Z_1)										M M		CONNECT		
	S = 2							S = 3			S = 2							S = 3						
T	1.2	1.5	2.1	3.0	4.5	6.3	8.7	6.3	8.7	T_0	3.6	4.5	6.3	9.0	13.5	18.9	26.1	18.9	26.1	+ M	– M	"L" Lead To Tap	"R" Lead To Tap	
	2.84	3.54	4.96	7.08	10.62	14.9	20.5	22.3	30.8		8.50	10.6	14.9	21.2	31.8	44.5	61.5	66.6	92.5	+.18		.06	0	"L" OVER "R"
	2.76	3.46	4.84	6.90	10.35	14.5	20.0	21.6	30.0		8.30	10.34	14.5	20.7	31.0	43.5	60.0	65.1	90.0	+.15		.06	.03	
	2.68	3.36	4.72	6.72	10.08	14.1	19.5	21.2	29.3		8.10	10.08	14.1	20.2	30.2	42.4	58.5	63.6	87.5	+.12		.09	0	
	2.62	3.28	4.58	6.54	9.81	13.8	19.0		28.4		7.88	9.80	13.8	19.6	29.4	41.2	56.8		85.2	+.09		.09	.03	
	2.54	3.18	4.44	6.36	9.54	13.4	18.5		27.7		7.64	9.54	13.4	19.1	28.6	40.0	55.3		83.0	+.06		.06	.09	
	2.48	3.10	4.32	6.18	9.27	13.0	17.9		27.0		7.42	9.28	13.0	18.5	27.8	39.0	53.8		80.5	+.03		.03	0	
	2.4	3.0	4.20	6.0	9.0	12.6	17.4		26.1		7.20	9.0	12.6	18.0	27.0	37.8	52.2		78.3	0	0	0	0	
	2.32	2.90	4.08	5.82	8.73	12.2	16.9		25.2		7.00	8.72	12.2	17.5	26.2	36.6	50.5		75.8		–.03	0	.03	"R" OVER "L"
	2.26		3.95	5.64	8.46	11.8	16.3		24.5		6.76		11.8	16.9	25.4	35.4	49.0		73.5		–.06	.09	.06	
	2.18		3.82	5.46	8.19	11.5	15.8		23.7		6.54		11.5	16.4	24.6	34.4	47.5		71.0		–.09	.03	.09	
	2.12		3.70	5.28	7.92	11.1	15.3		23.0		6.32		11.1	15.8	23.8	33.2	45.8		68.8		–.12	0	.09	
	2.04		3.54	5.10	7.65	10.7			22.7		6.12		10.7	15.3	23.0	32.0					–.15	.03	.06	
	1.98				7.38						5.90				22.2						–.18	0	.06	

RECEIVING ACCEPTANCE

1. Give visual check to the relay to make sure there are no loose connections, broken resistors, or broken wires.
2. Perform electrical acceptance test that consists of an electrical test to make certain that the relay measures the balance point impedance accurately.
3. Unless otherwise specified, relay output refer to distance output (Relay Terminal #14) for SDGU-6 and -7 relays. Use relay Terminal #13 for SDGU-1-2-3-4-5 Relay.

Recommended Instruments for Testing

Westinghouse Type PC-161-S#291B749A33 or equivalent a-c- voltmeter.

Westinghouse Type PA-161-S#291B719A21 or equivalent a.c. ammeter.

Electrical Tests

Distance Unit

Check Zener power supply voltage across P.C.B. terminals 1 and 14 on "Mag. Comp Board". It should be between 16-23 volts.

The test for distance unit is accomplished by use of test connections shown in Fig. 34. Tripping is indicated by a voltmeter reading connected to the output terminals. At the balance point, the voltmeter reading may be as low as 1 volt or 2 volts d.c. indicating that the system is only tripping during a part of a cycle. This is normal balance point characteristic; however, an increase in current over 10 per cent should produce output of 15 to 21 volts d.c. A reading less than 12 volts indicates a defective tripping output. When checking current and voltage limits allow for additional instrumentation errors.

Note that in each case phase A- quantity is adjusted as fault quantities and are switched around by means of fault test switch. This is identical to one used for SKD or KDAR relay testing.

.2-4.35 Ohm Relay	1.0-31.0 Ohm Relay
all T = 1.23	all T = 8.7
T_0 = 3.69	T_0 = 26.1
all S = 1	all S = 1
all M = +.18	all M = +.18

For .2-4.35 Ohm Relay

A. Use connections for test No. 5 and set V_{AN} voltage = 20 volts. V_{BN} = V_{CN} = 70 volts. Set the phase shifter for 75° current lagging voltage.

B. The relay current required to make the trip should be between 8.0 - 8.6 amp.

C. Use connections for Test No. 6. The relay trip should be 8.0 - 8.6 amps.

D. Use connections for Test No. 7. The relay trip should be 8.0 - 8.6 amp.

For 1.0-31.0 Ohm Relay

A. Use connections for test No. 5 and set V_{AN} = V_{BN} = V_{CN} = 70 volts. Set phase shifter for 75° current lagging voltage. The relay trip current should be 3.95 - 4.20 amperes.

B. Use connections for Test No. 6. The relay trip current should be 3.95 - 4.20 amperes.

C. Use test connections for Test No. 7. The relay trip current should be 3.95 - 4.20 amperes.

If the electrical response is outside the limits a more complete series of tests outlined in the section titled "Calibration" may be performed to determine which component is faulty or out of calibration.

If it is desired to check relay response at some other settings at the same angle use following equation for the trip value of current.

$$I = \frac{3V_{LN}}{(2+p)\ Z_1}\text{, where } p = \frac{Z_0}{Z_1}$$

Z_0 = Zero sequence reach

Z_1 = Positive sequence reach
(in above cases p = 3)

Overcurrent Unit

A. SDGU-1 and SDGU-3

Check operation of the overcurrent unit by using test connection #5 of the Figure 34. Set V_{AN} = 0, $V_{BN} = V_{CN}$ = 70 volts. The .2-4.35 ohm relay should trip at .75 to .83 amps, and the 1-31.0 ohms relay should operate at .37 to .430 amps.

B. SDGU-6 and SDGU-7

SDGU-6 and SDGU-7 relays are provided with an adjustable overcurrent unit. Use test connection #5 of Fig. 34. Set V_{AN} = 0, $V_{BN} = V_{CN}$ = 70 volts. Set the overcurrent unit by adjusting the potentiometer in front of ZXI_0 circuit board. Trip current should be within 6% of preset current value. Reset current should be within 25% of actual trip current. Output should be monitored at relay terminal No. 13. Relay terminal 13 must show an output for the preceding test condition output.

$V_0 X\bar{I}_0$ Unit

Check operation of $V_0 X\bar{I}_0$ unit by using test connection #5 of Fig. 34. Adjust overcurrent unit for about 1 amp. and set V_{AN} = 20, $V_{BN} = V_{CN}$ = 70 volts. Apply about 1.5 amps and monitor relay terminal #15. No output should be present. Disconnect the current, output should go to 15 to 21 volts d.c.

Maximum Torque Angle Setting

Maximum torque angle check is optional. In general, this check is complicated for SDGU-1, SDGU-2 and SDGU-7 by the presence of transient blocking circuit, and the two phase-to-ground fault desensitizer circuit. The presence of transient blocking circuit requires that check for maximum torque angle should be made going from non-tripping to tripping condition at each end of the tripping range of the relay under test. Since the lab method of testing as used here presents artificial voltage conditions under certain voltage and phase angle conditions two-phase-to-ground desensitizer will distort phase angle response; hence, it is required to disable the 2ϕ–G circuit by removing the board marked "2ϕ–G" from SDGU-1, -2, -7 relays, and short out resistor R38 on "Mag. Comp. Board" to eliminate effect of transient blocking.

Phase A Check

Use connection #5. Relay tap settings should be the same as before. For all ranges set V_{AN} = 20 volts, V_{BN} - V_{CN} = 70 volts.

Set current for 1-31 ohm relay for 1.54 amp, and for .2-4.35 ohm relay for 11 amp. Set phase-shifter for 75° - current lagging V_{AN} - voltage. Turn phase-shifter toward 0° after relay has dropped out, reverse phase-shifter rotation and note the angle (ϕ_1) at which relay is fully tripped. Then rotate the phase shifter past the 75° until relay resets again until relay is fully tripped – Note the angle again (ϕ_2).

Maximum torque angle is equal then to:

$$\frac{\phi_1 + \phi_2}{2} = 75° \ (\pm 4°).$$

Any other T setting may be used, except use 130% current of the trip current at 75° angle.

Phase B Check

Use connection #6. Otherwise follow the same procedure as for phase A.

Phase C Check

Use connection #7. Otherwise follow the same procedure as for phase A.

When check is completed replace the 2ϕ–G board in its proper place.

Two Phase-to-Ground Desensitizer Check (SDGU-1 and SDGU-2)

Use connections #5, except no current connection is required for this test.

A-B Combination

Set V_{CN} = 70 volts. $V_{AN} = V_{BN}$ = 20 volts. Check DC voltage on magnitude comparator board between terminals "6" and "1" – with positive on "6" it should measure 11.5 - 13.5 volts.

Set V_{CN} = 75 volts. $V_{AN} = V_{BN}$ = 10 volts. The DC voltage should measure 16.0 - 19.0 volts.

B-C Combination

Same check as for AB except first set V_{AN} = 70 volts, $V_{BN} = V_{CN}$ = 20 volts and then V_{AN} = 75 volts, $V_{BN} = V_{CN}$ = 10 volts.

CA Combination

Same as for AB except first set V_{BN} = 70 volts, V_{CN} - V_{AN} = 20 volts and then V_{BN} = 75 volts, $V_{CN} = V_{AN}$ = 10 volts.

ROUTINE MAINTENANCE

The relays should be inspected periodically, at such time intervals as may be dictated by experience, to insure that the relays have retained their calibration and are in proper operating condition.

REPAIR CALIBRATION

Use the following procedure for calibrating the relay if the relay has been taken apart for repairs, or the adjustments disturbed.

Part A: Preliminary Settings

1. Make visual inspection to make sure there are no loose connections, broken resistors, or broken connections to the printed circuit boards.

2. Look over printed circuit boards for obvious damages to the components or to the conducting strips. Do no insert boards yet.

3. All potentiometers are locking type and should be unlocked before adjustment is made. Set R1-R2-R3-R4 potentiometers clockwise maximum. Set R5-R6-R7-R8 potentiometers counterclockwise maximum.

4. For SDGU-6 and -7 set I_0-dial for minimum pickup.

Part B: Voltage Circuit Test

1. Set relay for S = 1, M = +18 ("L" lead over "R" lead). "T" settings should be as follows:

Relay Range	T_A, T_B, T_C	To
.2 – 4.35	1.23	3.69
1.0 – 31.0	8.7	26.1

2. Set $V_{AN} = V_{BN} = V_{CN}$ 70 volts: Test connection #1, no current is used. Measure following a-c voltages from jack plug terminal #10 to

   a. S_A = 1 – tap 70 (± 1) volt.

   b. S_A = 2 – tap 140 (±1) volt.

   c. S_A = 3 – tap 210 (±3) volts on latest relays, 221 (±3) volts on earlier versions.

   d. R_A = lead 39.2 (± 0.3) volts.

3. Repeat the same measurements, except to S_B and S_C taps and R_B and R_C leads.

   Disconnect R_0 lead from its tap and measure voltage from R_0 lead to test point marked "O" located on the R.H. front plate between potentiometer R2 and R6. This voltage should measure below 0.7 volts.

4. Apply rated d-c voltage to the jack plug terminals "4" and "3" with positive on "4". D-C voltage of 20 volts (± 2.0) should be measured between terminals "14" and "1" on the printed circuit board connector, where the "magnitude comparator" board is located, terminal #14 should be positive.

5. Plug in all printed circuit boards.

Part C: Potentiometer Adjustments

1. R5, R6, R7, Adjustments

   Set $V_{AN} = V_{BN} = V_{CN}$ = 70 volts.

   NOTE: R5 controls voltage across R9
   R6 controls voltage across R10
   R7 controls voltage across R11

   Using oscilloscope observe voltage waveform across R9 resistor located on board marked "RECT." Adjust R5 so that two ripple peaks are equal and one always will be just a little higher at approximately 26-27 volt level. When finished, tighten R5 nut. Repeat the same procedure for R10 and R6, and for R11 and R7.

   NOTE: R10 and R11 are located on same board as R9.

2. R8 Adjustment

   Set V_{AN} = 0 volts; and, using oscilloscope observe voltage waveform across R12 resistor located on board marked "Freq. Ver." for SDGU-6 and /7, but on "Io + Rect." board for SDGU-1-2-3-4-5 relays. Adjust R8 so that two ripple valleys are equal and one slightly lower. Voltage peak should be at approximately 9.5 volt level. When finished, tighten retaining nut.

Part D: "M" Taps – Check

1. Open all "L" leads and "R" leads.

2. Use a Rectox-type voltmeter, 0-10 volt range. Use test connection #1. Pass 10 amperes of current. The voltages should read as follows on "M_A" taps:

	For Relay Range:	
Between	1-31 Ohms	.2-4.35 Ohms
"O" tap and ".03" tap	1.5 (± .2)	.425 #
"O" tap and ".09" tap	6.0 (± .6)	1.70 #
"O" tap and ".06" tap	9.0 (± 1.0)	2.55 #
# – Apply 20 amperes instead of 10, tolerance ± 0.06		

3. Repeat the above measurements for:

   a. "M_B" taps using connection #2.

   b. "M_C" taps using connection #3.

   c. "M_O" taps using connection #4.

Maximum Torque Angle Adjustment

1. Jumper test point "N" located on the front panel to the jack plug terminal #10.

2. R-1 Adjustment

   Use test connection #1.

   Set V_{AN} voltage and current 75° lagging as per table below.

RELAY RANGE	
1-31 Ohms	.2-4.35 Ohms
45 volts	20 volts
5.08 amp, 75° lagging V_{AN}	15.65 amp 75° lagging V_{AN}

Set V_{BN} = V_{CN} = 0 volts. Insert a-c voltmeter (0-3.0 volt range) between "RA" and "LA" leads. Adjust R1 potentiometer for a minimum (null) voltage reading (below 1 volt), vary current slightly, if necessary, to achieve "null." Rotate phase shifter ± 10° to make sure the "null" exists at 75° setting only. Lock the potentiometer.

For other angles than 75°, multiply current by $K = \frac{\text{Sin } 75°}{\text{Sin } \phi}$ where ϕ desired angle.

For 60°, K = 1.11.

3. R-2 Adjustment

   Use #2 test connection. Measure voltage between "R_B" and "L_B" leads. Adjust R2 for "null" reading following the same procedure as for R1. Voltage and current settings should be the same as for R1 adjustment.

4. R-3 Adjustment

   Use #3 test connection. Measure voltage between "R_C" and "L_C" leads. Adjust R3 for "null" reading following the same procedure as for R1. Voltage and current settings should be the same as for R1 adjustment.

5. R-4 Adjustment

   R-4 is always set for the same angle as R1. Use #4 test connection. Connect all L and R leads back except "L" to over "R" connection equivalent to M = + 18 except R_O lead. Remove jumper from terminal "10" and test point "N". Measure voltage between R_O lead and the lowest M_O tap marked "C". Adjust R4 for "null" reading using the same procedure as for R1 except use following voltage and current values:

   Set V_{AN} = O.

For Relay Range

1-31.0 Ohms	.2-4.35 Ohms
Set V_{BN} = V_{CN} = 70 volts	Set V_{BN} = V_{CN} = 45 volts.
I_A = 2.34 amps. 75° lagging V_{AN}	I_A = 9.9 amps. 75° lagging V_{AN}
(or 2.60 Amp. for 60° calibration)	(or 10.9 amp. for 60° calibration)

Overcurrent Detector (for SDGU-1 and SDGU-3)

1. Energize d-c circuit with rated d-c voltage.

2. Use test connections #5. Set V_{AN} = 0, V_{BN} = V_{CN} = 70 volts. Set current for 0.4 amperes for 1-31 ohm relays, and for 0.8 amperes for .2-4.35 ohm relays lagging voltage by 75°. This is the pickup current. An output of 20 ± 2 volts should be observed at relay terminal #13.

   Adjust R45 potentiometer located on the "RECT. and I_0" board at specified pickup current until continuous relay output of 18-22 volt-level is obtained (Relay terminal #13). The output drop-out should occur at:

.38 to .3 amp for 1-31 ohm relays

.76 to .6 amp. for .2-4.35 ohm relays

If no relay output is obtained, recheck output at collector of Q8 transistor on "RECT. and I_0" board.

Overcurrent Detector (for SDGU-6 and SDGU-7)

1. Energize d-c circuit with rated d-c voltage.
2. Use test connection #5, Fig. 34. Set V_{AN} = 0, V_{BN} = V_{CN} = 70 volts. Set current for 0.4 amperes lagging voltage by 75°. Set potentiometer (R97) mounted in front of ZXI_0 board) for .4 amps. Output should be observed at relay terminal 13. If there is no relay output check TP2 on "I_0 x Z" board. If TP2 has no output set R97 all way clockwise and readjust R99-potentiometer for output. Recheck calibration of the dial, readjust R99 if necessary.

   Pickup values should be within ±5 percent.

"Magnitude Comparator Circuit Adjustment"

R75 Adjustment

Energize relay with d-c only. Connect 10K resistor (± 5%) between TP1 (Mag. Comp. Board) and printed board terminal #1 (d-c negative). Use scope to monitor TP2 and adjust R75 until a positive output is obtained at TP2 (17-23 volts).

Frequency Verifier Adjustment (SDGU-1, SDGU-2, SDGU-5, SDGU-6, SDGU-7)

Use scope to observe wave shape at test point TP7 (Mag. Comp. Board). Use test connection #5 (Fig. 34). Set V_{AN} = 0, V_{BN} = V_{CN} = 70 volts. Set current for 2.5 amps lagging voltage by 75°. Adjust R76 until less than one (1) volt signal of approximately 5 ms duration is followed by a positive pulse (17-23 volts) of 3.0 to 3.3 ms duration.

V_0 - Detector

1. Extend $V_0 X\overline{I_0}$ board using card extender.
2. Energize d-c circuit with rated d-c voltage.
3. Connect d-c voltmeter or oscilloscope across terminals TP6 to terminal 1 of the PCB.
4. Using test connection #5, Set V_{AN} = 64 volts, V_{BN} = V_{CN} = 70 V. Do not apply any current, Voltage settings should be as close as possible.
5. Adjust R87 (circuit board) until an output of 20 ± 2 volts just appear at TP6.
6. Increase V_{AN} to 70 volts. Output should drop to zero for V_{AN} greater than 66 volts.
7. Open, suddenly, V_{AN} connection. Output should observed at TP6.
8. Disconnect all circuits.

$V_0 X\overline{I_0}$ Unit

Check operation of $V_0 X\overline{I_0}$ unit by using test connection #5 of Fig. 34. Set overcurrent unit for 1 amp. and set V_{BN} = V_{CN} = 70 volts. Apply about 1.5 amps. and monitor relay terminal #15. No output should be present. Disconnect the current, output should go to 15 to 21 volts d.c. Connect V_{AN} to the relay and set V_{AN} = 70 volts. There should be no dc output.

Impedance Check

Use voltmeter for monitoring the relay output, use first deflection as positive indication of meeting current limits. Then increase current slightly to see if full 18-22 volt output is obtained. There should be no drop in output to zero volts while current is increased. Relay output, unless specified, refer to distance output, that means output at relay terminal #14 (For SDGU-6 or -7 and #13 for other types). If currents are outside the limits for 2.5 volt-test outlined below, proceed as follows:

Set V_{AN} = V_{BN} = V_{CN} = 70 volts as close to each other as possible. Use test connection #5. No current is applied. Measure d-c voltage across R9, R10, R11 resistors ("Rect." board). Re-adjust potentiometers R5, R6, R7 (Front of panel – right-hand side), until the voltages across R9, R10, and R11 are as close to each other as possible. Those voltages should be in the 20-25 volt range. In most cases only slight adjustment of R5, R6, or R7 will be required. Then recheck pickup current again. If the pickup currents are close together but outside the specified limits, readjust R18 (Mag. Comp. Board) to move all pickup values up or down. Note that R5, R6, R7 are interacting. Hence, recheck all three (3) voltages after each separate adjustment. If difficulties in balancing at 2.5 volts persist, use 5 volts and double the limits. If it is desired to check relay response at some other setting, use the following equation for the trip value of current.

$$I = \frac{3V_{LN}}{(2 + p)\ Z_1},\ \text{where}\ p = \frac{Z_0}{Z_1}$$

(in this case p = 3)

Z_0 = Zero sequence reach

Z_1 = Positive sequence reach

1-31 Ohm Range (All relays) Check output at relay terminal #14 for SDGU-6 and -7. Use #13 for others.

Using previous relay tap settings, apply rated d-c voltage and proceed as follows:

Part A: 2.5 Volt Test

For SDGU-1 and -3 disable overcurrent unit by jumpering TP6 on "Rec. I_0" - Board to DC negative (Term #1).

1. Phase A

   Use test connection #5. Set V_{AN} = 2.5 volts, V_{BN} = V_{CN} = 70 volts.

   Adjust R18 (Mag. Comp. Board) for proper pick - up level. Pickup current should be (amps) 0.135-0.155, 75° lagging voltage.

2. Phase B

   Same as phase A except use test connection #6.

3. Phase C

   Same as phase A except use test connection #7. If limits above are not met, see note under "Impedance check." Remove the jumper.

Part B: 70-Volt Test

For SDGU-7 and -6 check output at relay terminal #13.

1. Use connections for test #5 and set V_{AN} = V_{BN} = V_{CN} = 70 volts. Set phase shifter for 75° current lagging voltage. The relay trip current should be 3.95-4.20 amperes.

2. Same as phase A except use connections for test #6.

3. Same as phase A except use connections for test #7.

Part C: S = 3 Test

Set S_A, S_B, S_C = 3. Set V_{BN} = V_{CN} = 70 volts. V_{AN} = 70 volts.

Phase A

Use test connection #5. Pickup current I_A should be (amp.) .190-.218 - 75° lagging voltage.

Phase B

Same as phase A except use test connection #6.

Phase C

Same as phase A except use test connection #7. Return all connections to S = 1.

Phase D: Two Phase-to-Ground Desensitizer Check

Use connection #5, except no current connection is required for this test.

A-B Combination

Set V_{CN} = 70 volts. V_{AN} = V_{BN} = 20 volts.

Check d-c voltage on magnitude comparator board between terminals "6" and "1" with positive on "6" – it should measure 11.0 - 14.5 volts.

Set V_{CN} = 75 volts. V_{AN} = V_{BN} = 10 volts. The d-c voltage should measure 16 - 19 volts.

B-C Combination

Same check as for A-B except first set V_{AN} = 70 volts. V_{BN} = V_{CN} = 20 volts and then V_{AN} = 75 volts. V_{BN} = V_{CN} = 10 volts.

C-A Combination

Same check as for A-B except first set V_{BN} = 70 volts. V_{CN} = V_{AN} = 20 volts and then V_{BN} = 75 volts. V_{CN} = V_{AN} = 10 volts.

.2-4.25 Ohm Relay (All Relays) Check relay output at relay terminal #14 for SDGU-6 and -7, use #13 terminal for other relays.

Using previous relay tap settings, apply rated d-c voltages and proceed as follows:

Part A: 2.5-Volt Test

For SDGU-1 and SDGU-3 disable overcurrent unit by jumpering TP6 on "Rec. & I_0" Board to DC negative (Term #1).

Phase A

Use test connection #5. Set V_{AN} = 2.5 volts. V_{BN} = V_{CN} = 70 volts. Pickup current should be 1.0 - 1.10 amp. 75° current voltage. Adjust R18 for proper pickup level.

Phase B

Same as phase A except use test connection #6.

Phase C

Same as phase A except use test connection #7.

If limits above are not met see special note under "IMPEDANCE CHECK." Remove jumper.

Part B: 20-Volt Test

For SDGU-6-7 relays check output now at relay terminal #13.

Phase A

Use test connection #5. Set V_{AN} = 20 volts. V_{BN} = V_{CN} = 70 volts. Set phase shifter for 75° current lagging voltage.

Pickup current I_A should be 8.05 - 8.55 amp, 75° lagging V_{AN} voltage.

Phase B

Same as phase A except use test connection #6.

Phase C

Same as phase A except use test connection #7.

Part C: S = 3 Test

Set $S_A = S_B = S_C = 3$. Set V_{AN} = 10 volts. V_{BN} = V_{CN} = 70 volts.

Phase A

Use test connection #5. Pickup current I_A should be 1.35 - 1.62, 75° lagging V_{AN} voltage.

Phase B

Same as phase A except use test connection #6.

Phase C

Same as phase A except use test connection #7.

Return all "S" connections to S = 1.

Part D: Two Phase-to-Ground Desensitizer Check

Use connection #5, except no current connections is required for this test.

A-B Combination

Set V_{CN} = 70 volts. V_{AN} = V_{BN} = 20 volts. Check d-c voltage on magnitude comparator board between terminals "6" and "1" with positive on "6" - it should measure 11.5 - 13.5 volts.

Set V_{CN} = 75 volts. V_{AN} = V_{BN} = 10 volts. The d-c voltage should measure 16.5 - 18.5 volts.

B-C Combination

Same check as for A-B except first set V_{AN} = 70 volts. V_{BN} = V_{CN} = 20 volts and then V_{AN} = 75 volts, V_{BN} = V_{CN} = 10 volts.

C-A Combination

Same check as for A-B except set V_{BN} = 70 volts. V_{CN} = V_{AN} = 20 volts and then V_{BN} = 75 volts. V_{CN} = V_{AN} = 10 volts.

APPENDIX I

MUTUAL IMPEDANCE EFFECT

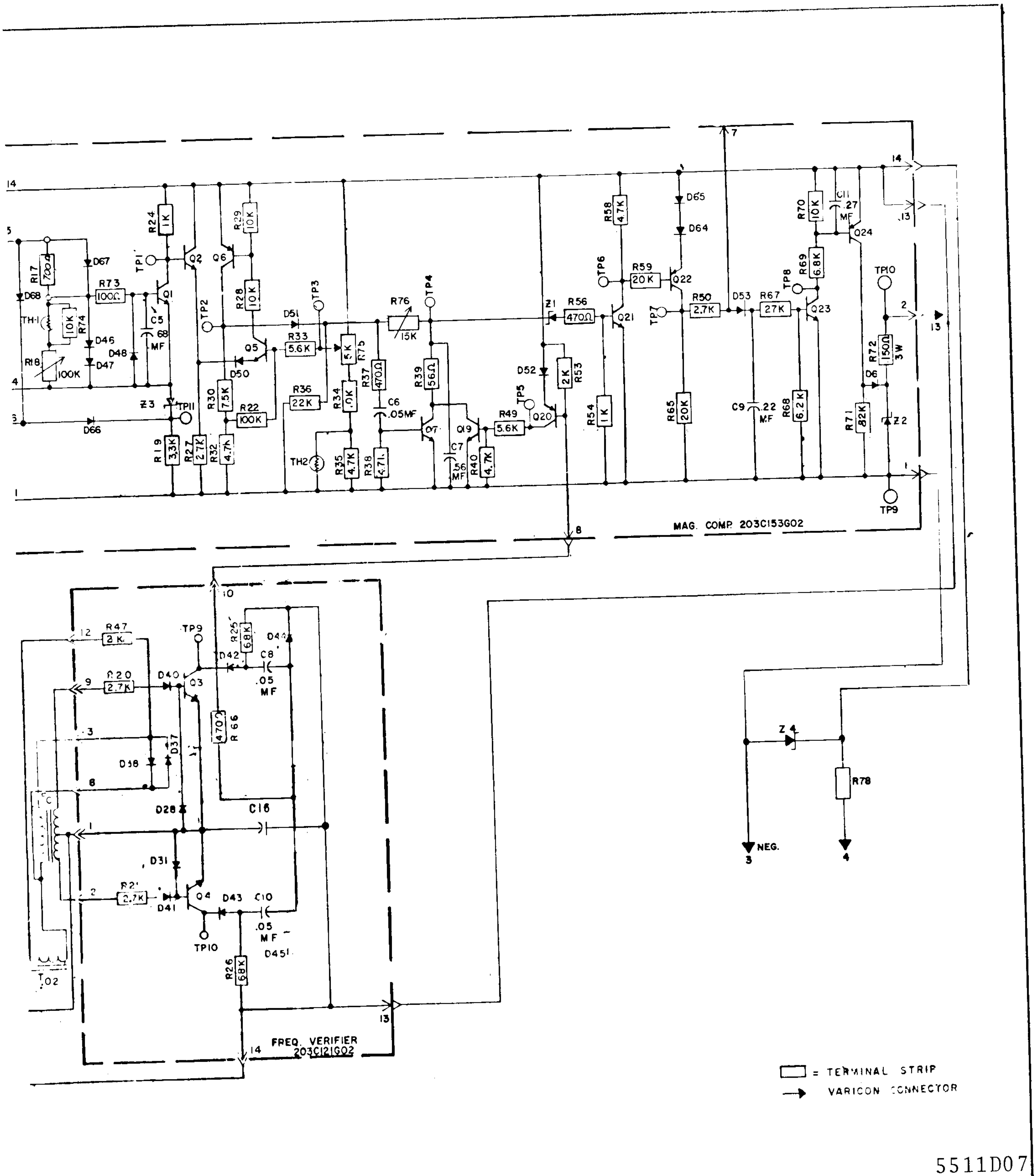
Where mutual compensation of zone 2 (timed trip) is desired, a type IK auxiliary current transformer (Fig. 35) may be used with a step-down current ratio of $\frac{Z_{OM}}{Z_{OL}} = C'$.

Here Z_{OM} is zero sequence mutual impedance, and Z_{OL} is the zero sequence self-impedance of line. Do not compensate a zone 1 or pilot-trip relay because of loss of directional sensing for a nearby fault on the mutually coupled line 4. By not compensating for Zone 1 - setting, the relay reach varies between 85 percent and 70 percent of the line impedance if relay is set for 85 percent of the line impedance.

The "parallel line" leads on the IK transformer are set for factor C' as defined above. These leads are set so that the difference between the taps is nearest to the desired C' – value.

The external terminals of the IK transformer numbered 3 and 4 are connected across the SDGU relay terminals 7 and 8 as shown in the external schematic, Figure 33. The external terminals 5 and 6 are connected in series with the residual CT circuit of the parallel line.

The IK transformer is set as follows: (a) Before the proper tap settings are made, the cover of the transformer should be completely open. Complete opening of the cover assures continuity in the residual current transformer circuits and isolates the IK transformer windings from the residual circuits. (b) The taps are set so that difference between the two



·rnal Schematic SDGU-2

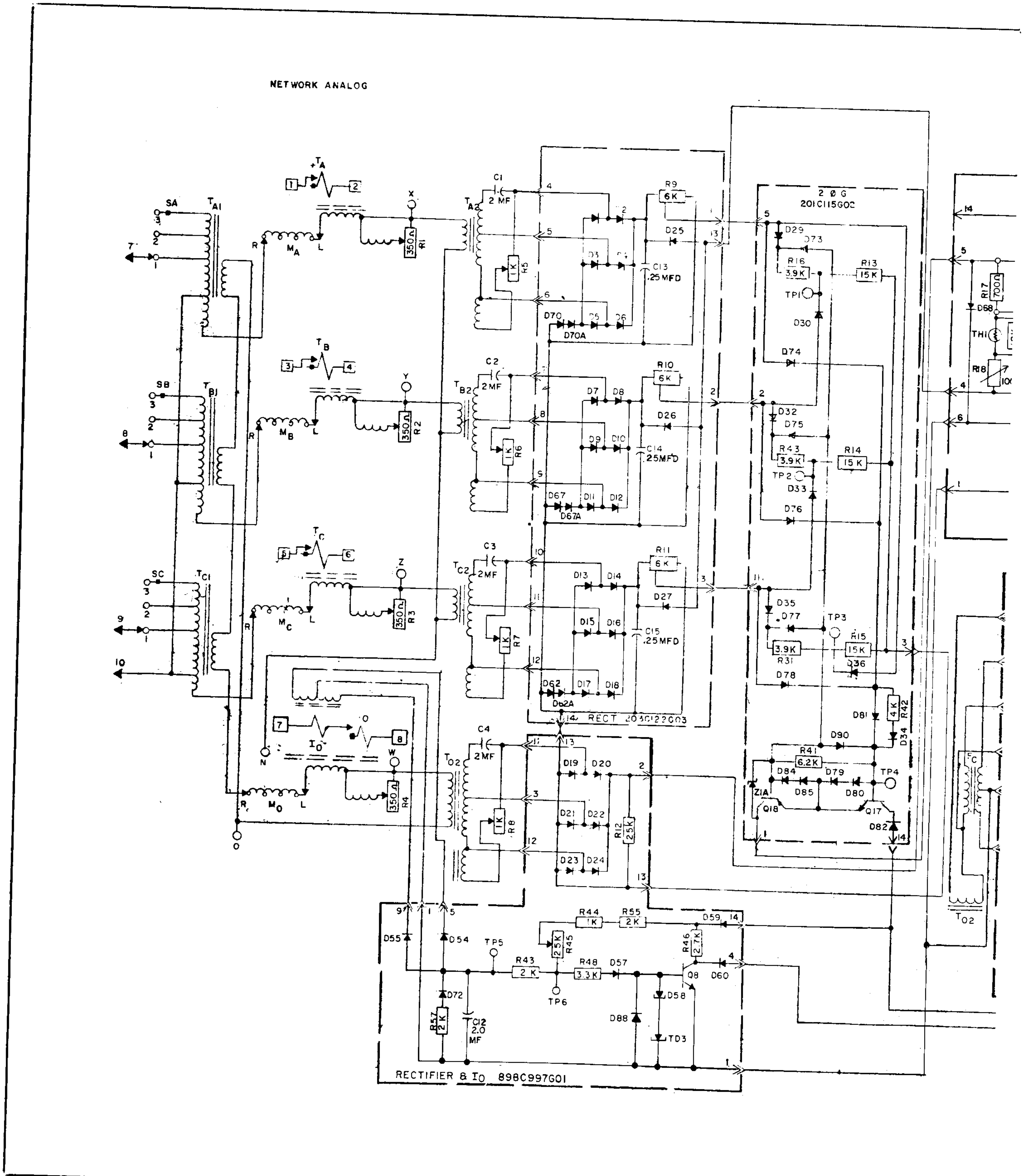
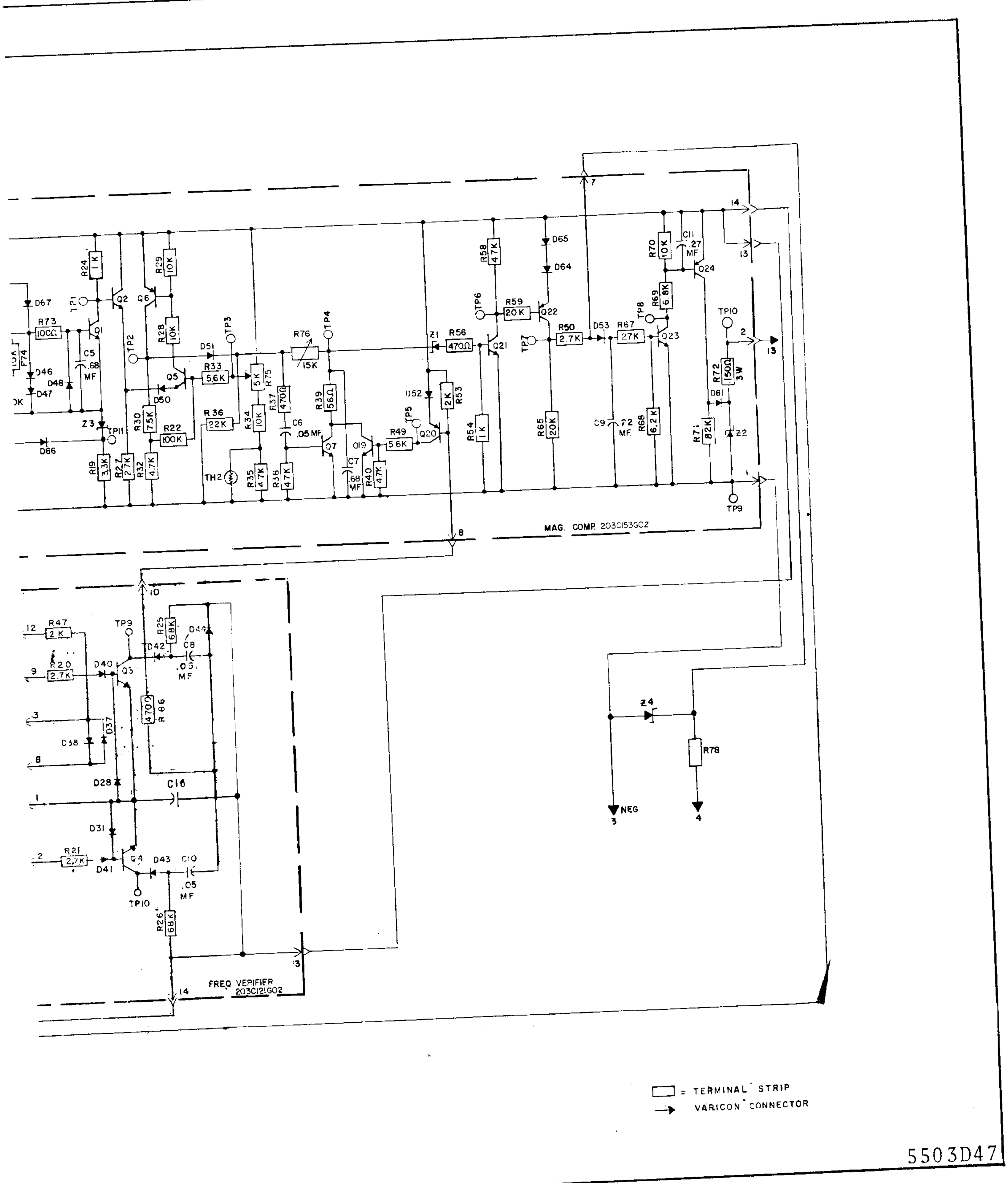


Fig. 3. Internal Sch


MAG. COMP. 203C153G02
FREQ VERIFIER 203C121G02
NEG
▭ = TERMINAL STRIP
→ VARICON CONNECTOR
5503D47

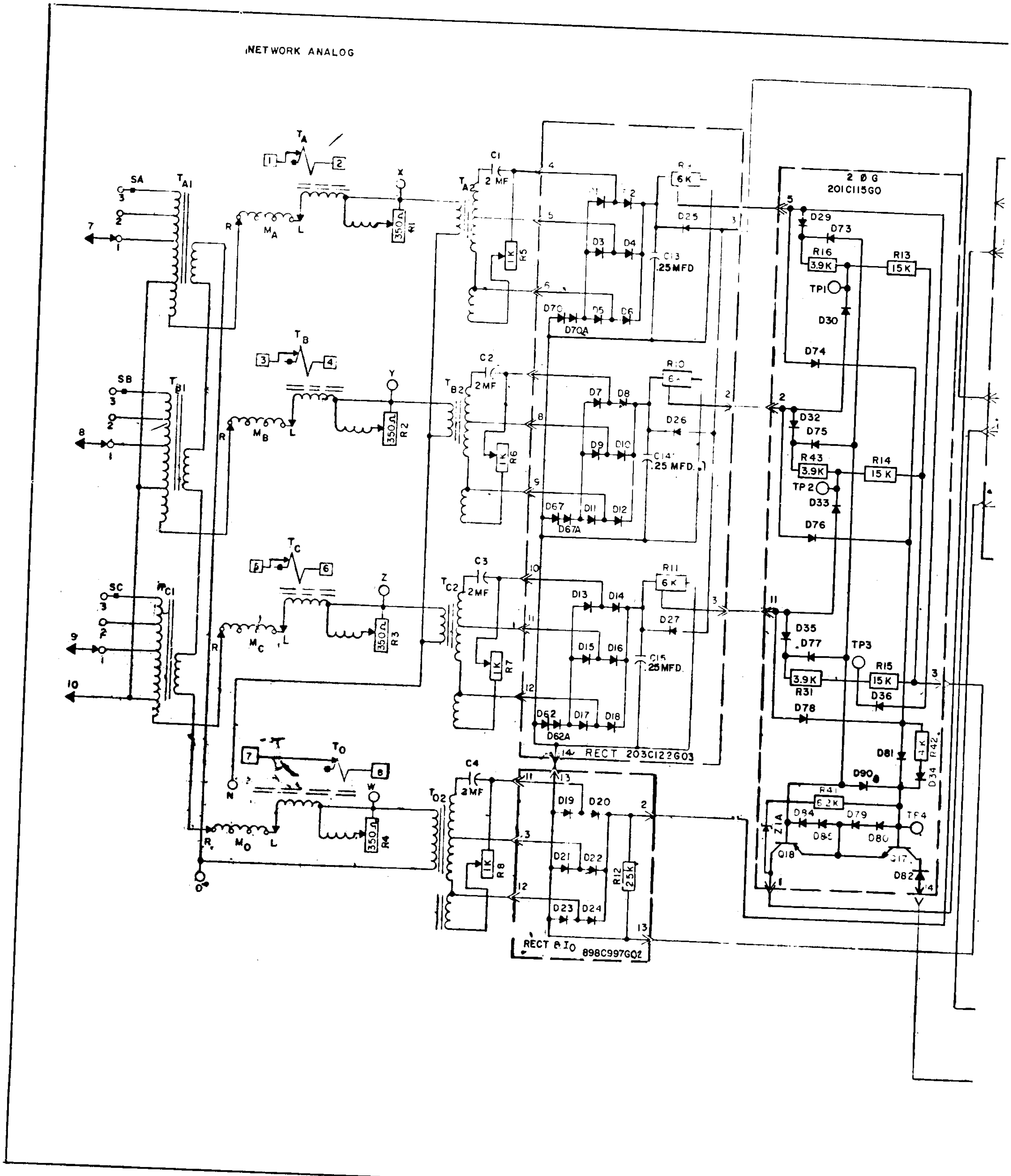
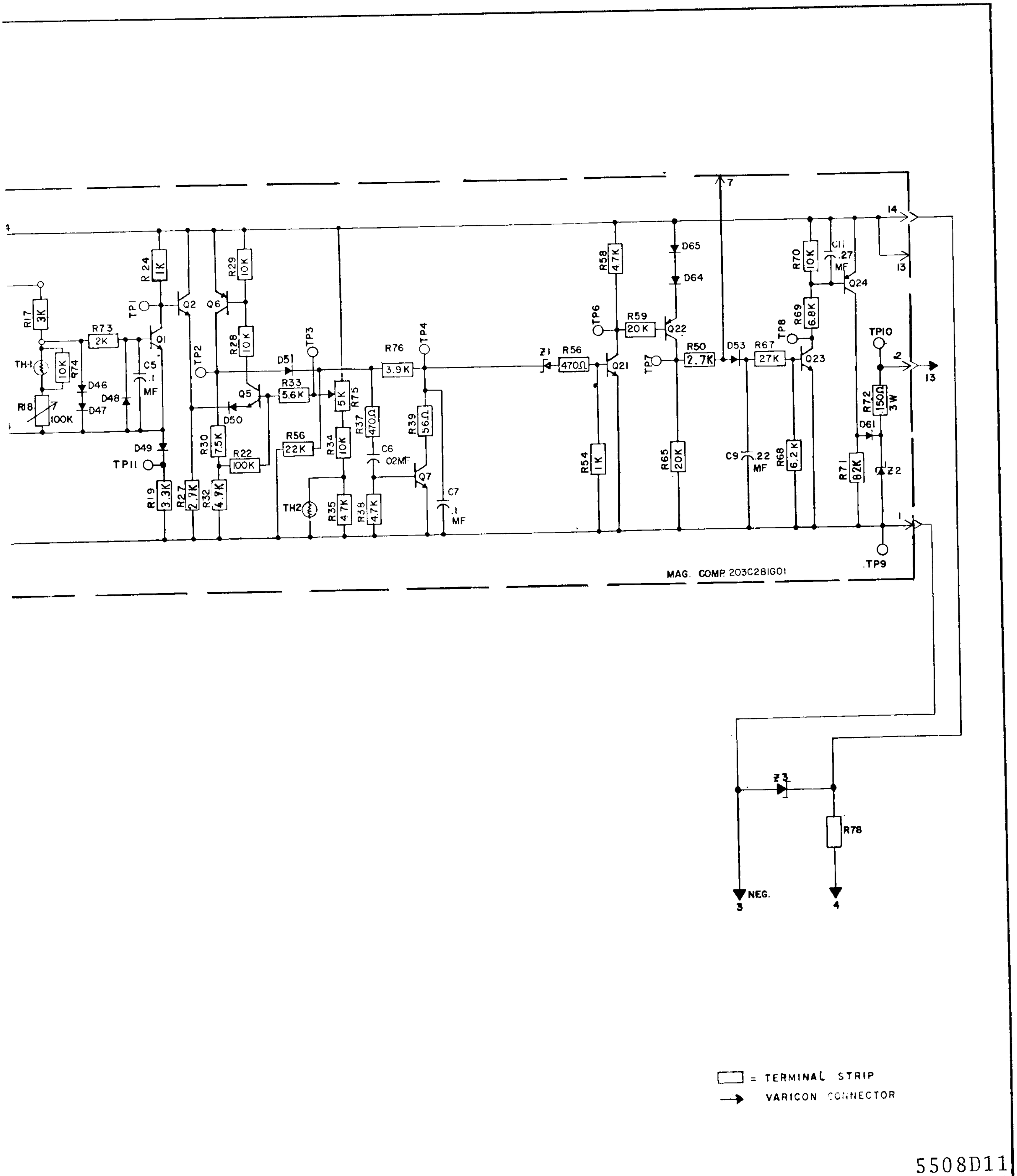

NETWORK ANALOG
SA
SB
SC
T_{A1}
T_{B1}
T_{C1}
T_A
T_B
T_C
T_O
M_A
M_B
M_C
M_O
T_{A2}
T_{B2}
T_{C2}
T_{O2}
C1 2 MF
C2 2MF
C3 2MF
C4 2MF
350Ω R1
350Ω R2
350Ω R3
350Ω R4
1K R5
1K R6
1K R7
1K R8
C13 .25MFD
C14 .25 MFD.
C15 .25MFD.
R12 25K
RECT 203C122G03
RECT $3I_0$ 898C997G02
2 ØG
201C115G0
R16 3.9K
R13 15K
R43 3.9K
R14 15K
R31 3.9K
R15 15K
R41 6.2K
R42 4K
TP1
TP2
TP3
TP4
Q18
Q17
Z1A

Fig. 4. Inte



l Schematic SDGU-4

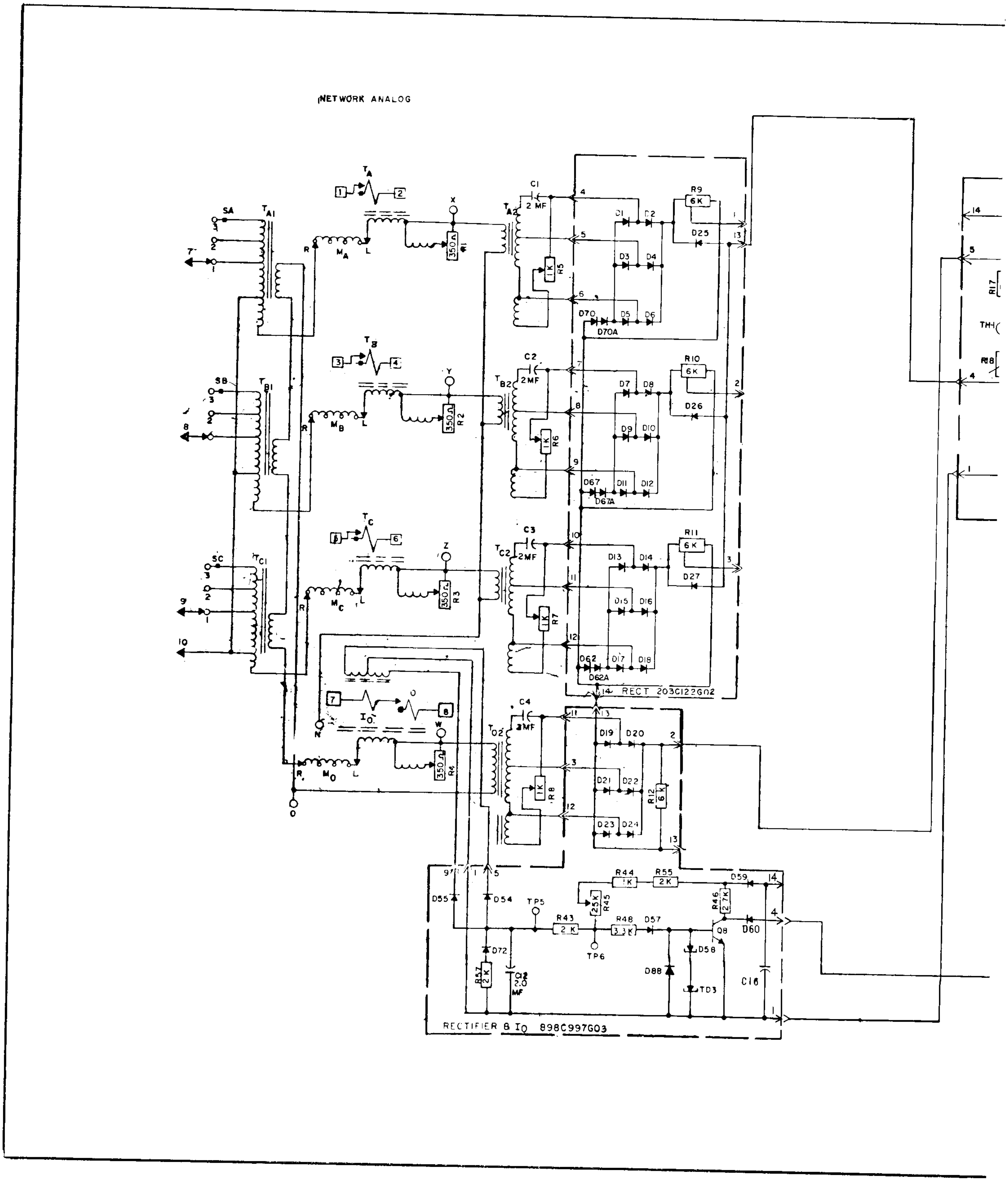
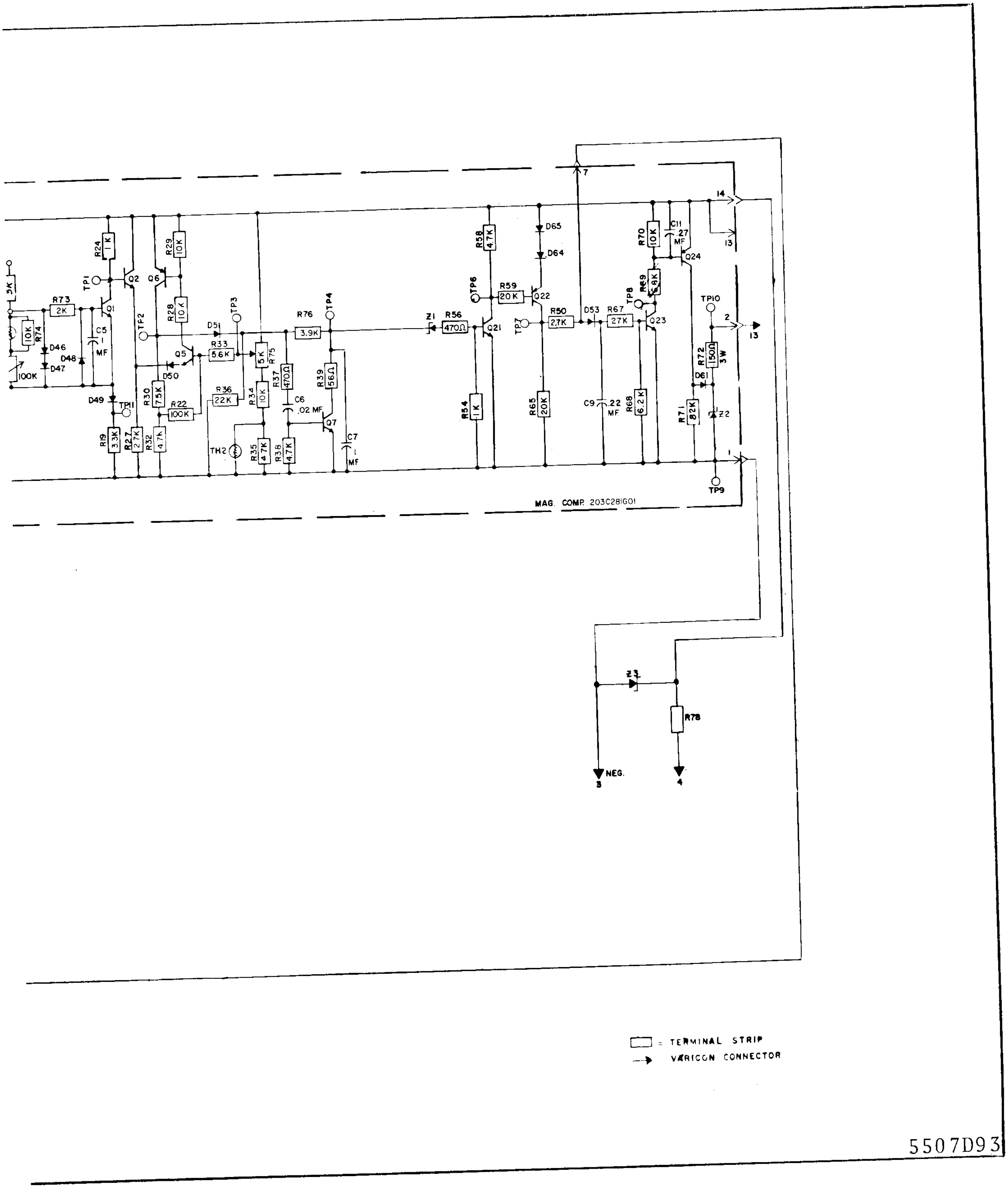


Fig. 5. Internal Sche


R24 1K
Q2
Q6
R29 10K
TP1
Q1
R73 2K
5K
10K
R74
100K
D46
D47
D48
C5 1 MF
TF2
R28 10K
D51
TP3
R33 5.6K
Q5
D50
5K R75
R37 470Ω
R76 3.9K
TP4
R39 56Ω
D49
TP11
R19 3.3K
R27 2.7K
R30 7.5K
R32 4.7K
R22 100K
R36 22K
R34 10K
C6 .02 MF
Q7
C7 1 MF
TH2
R35 4.7K
R38 4.7K
Z1
R56 470Ω
Q21
R58 4.7K
TP6
R59 20K
Q22
D65
D64
TP7
R50 2.7K
D53
R67 27K
TP8
R69 6.8K
Q23
R70 10K
C11 .27 MF
Q24
14
13
7
TP10
2
13
R72 150Ω 3W
D61
Z2
R54 1K
R65 20K
C9 .22 MF
R68 6.2K
R71 82K
1
TP9
MAG. COMP. 203C281G01
Z3
R78
NEG.
3
4
= TERMINAL STRIP
VARICON CONNECTOR
5507D93

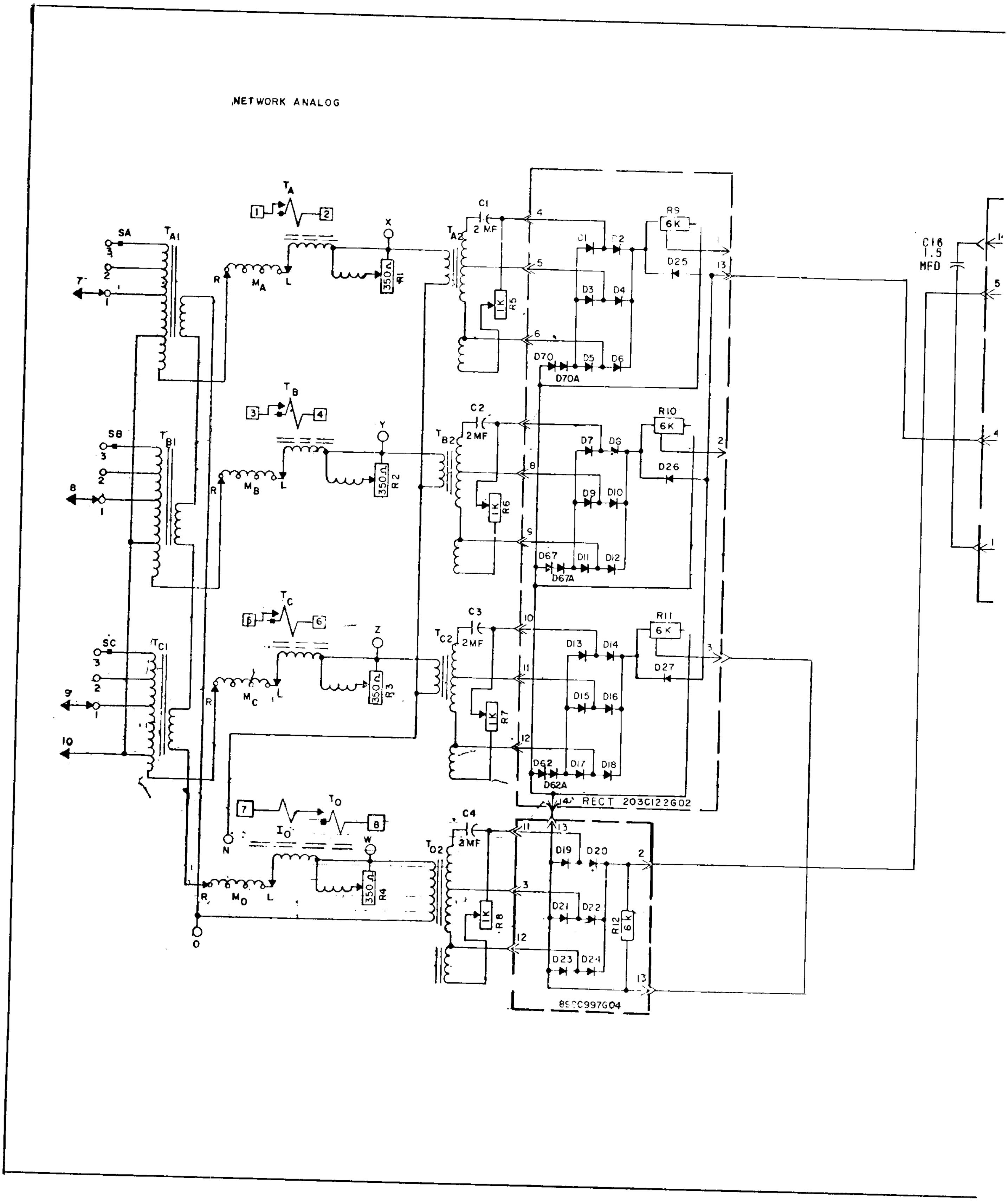
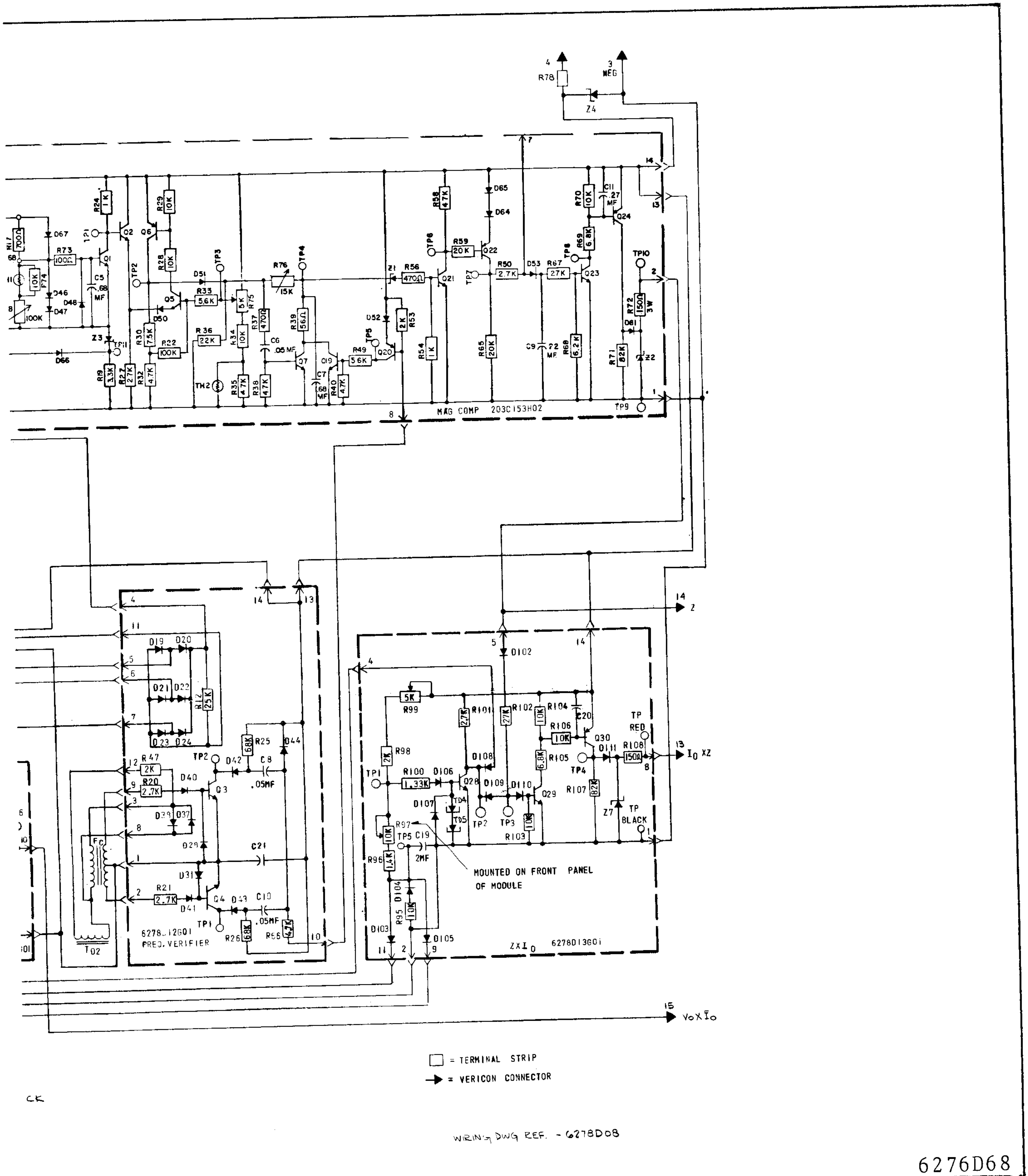


Fig. 6. Internc



| Schematic SDGU-6

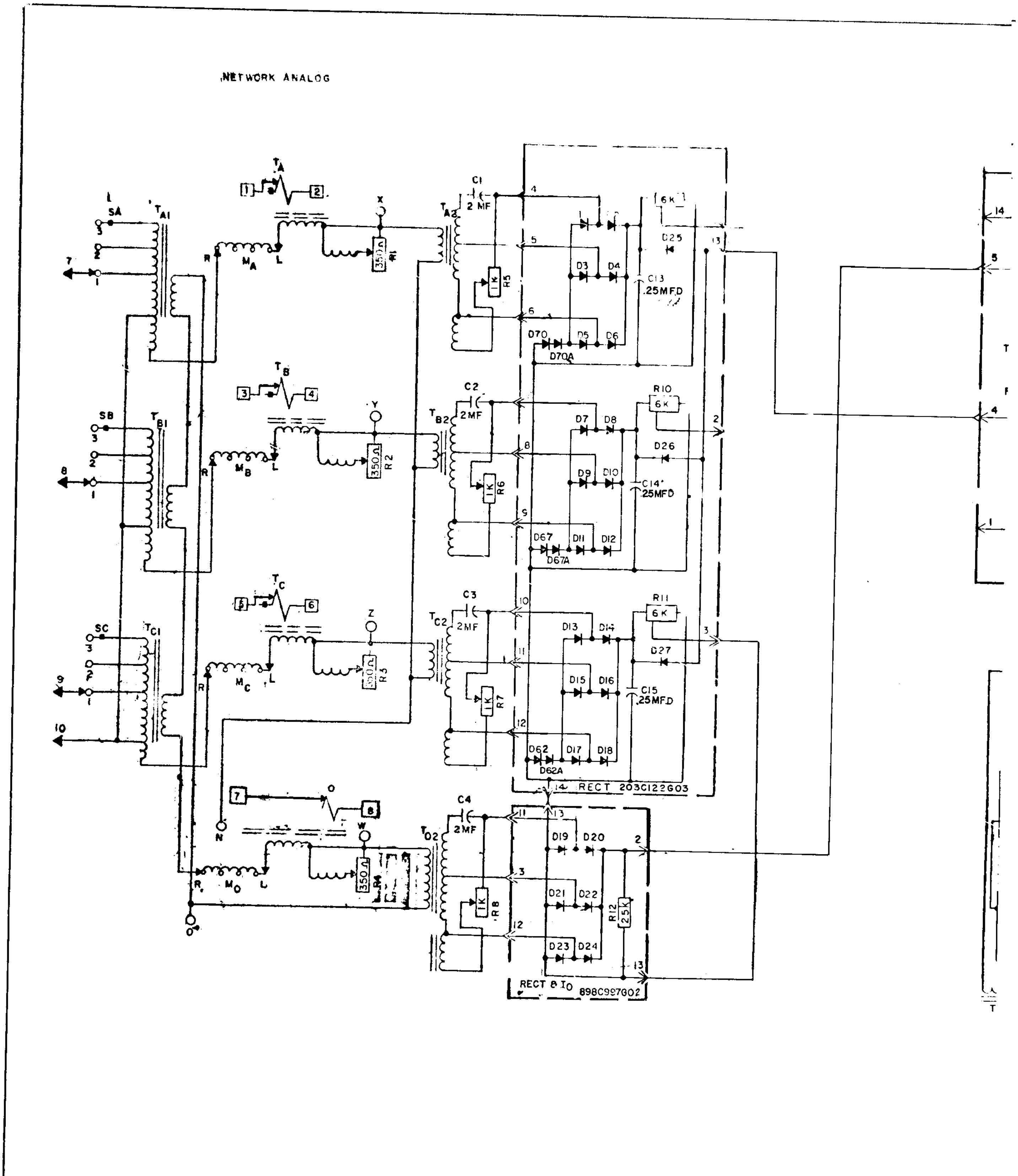
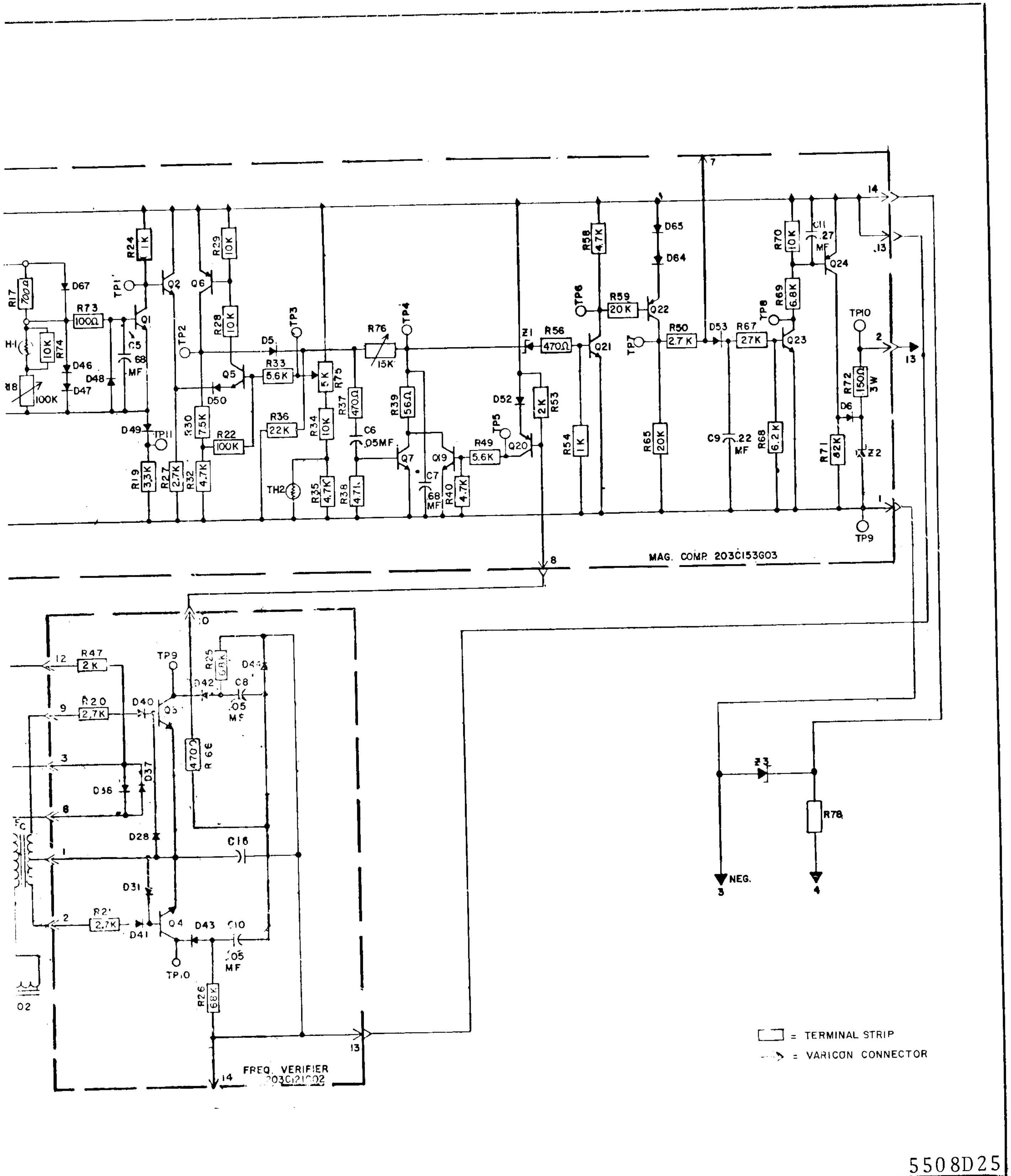


Fig. 7. Internal Sc



hematic SDGU-5

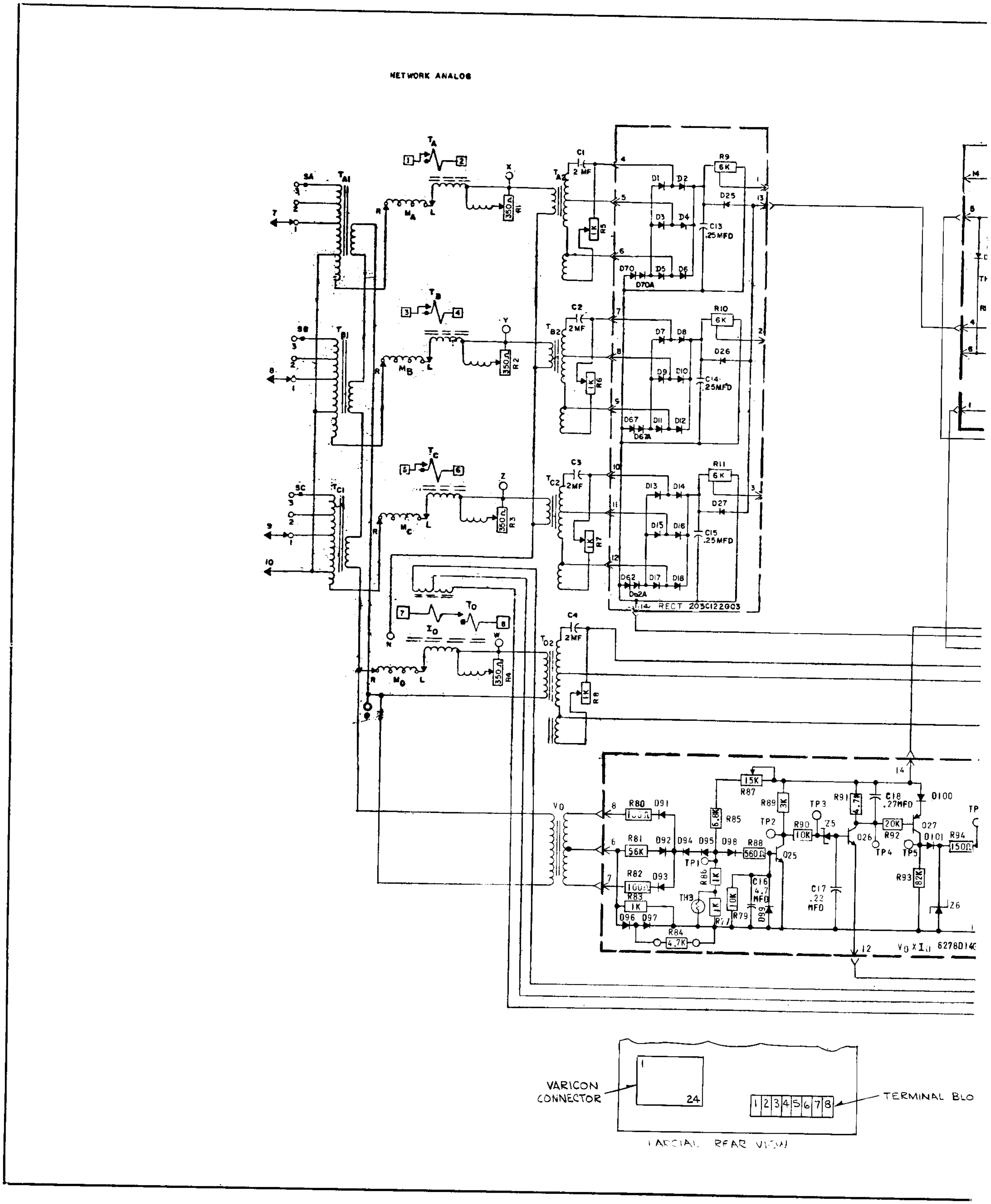


Fig. 8. Interna

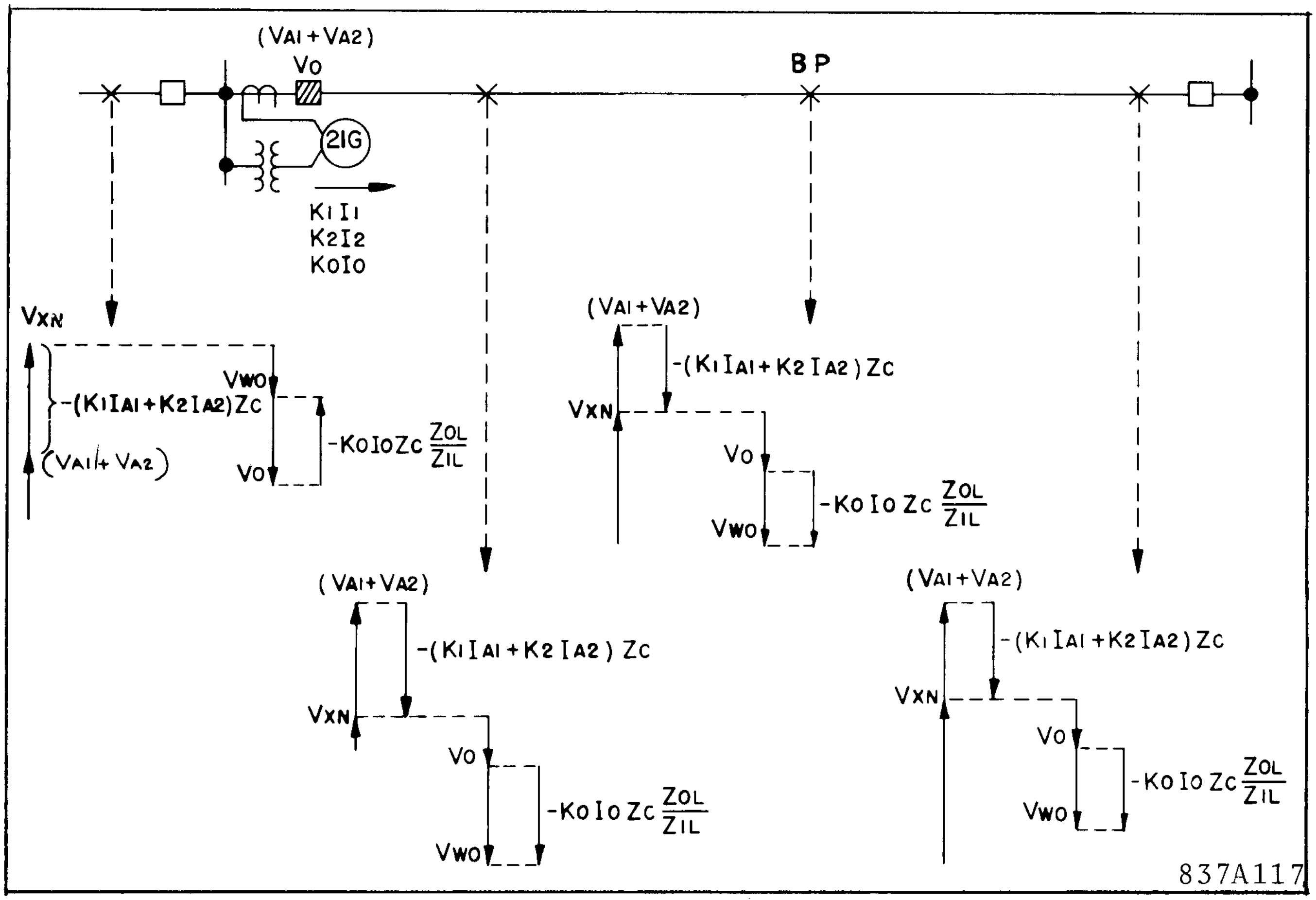


Fig. 12. Relay Voltages A-G Faults

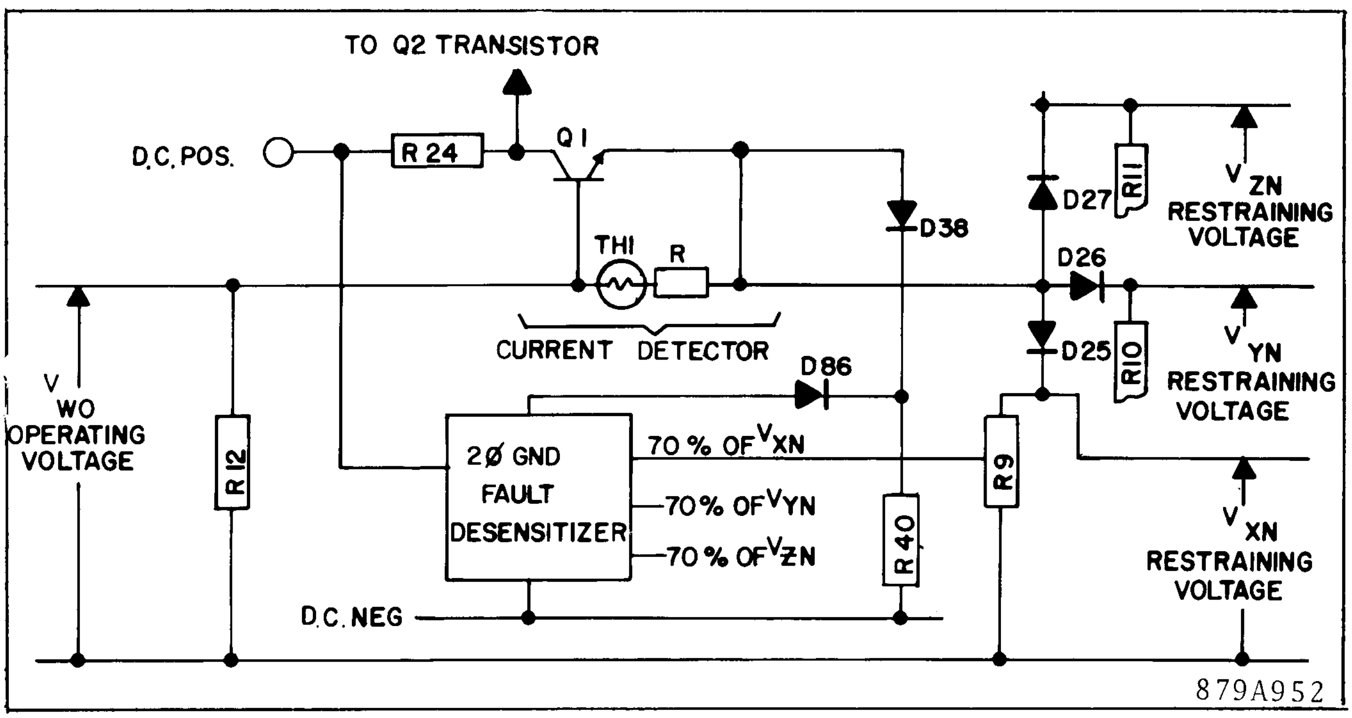


Fig. 13. Magnitude Comp. Ckt.

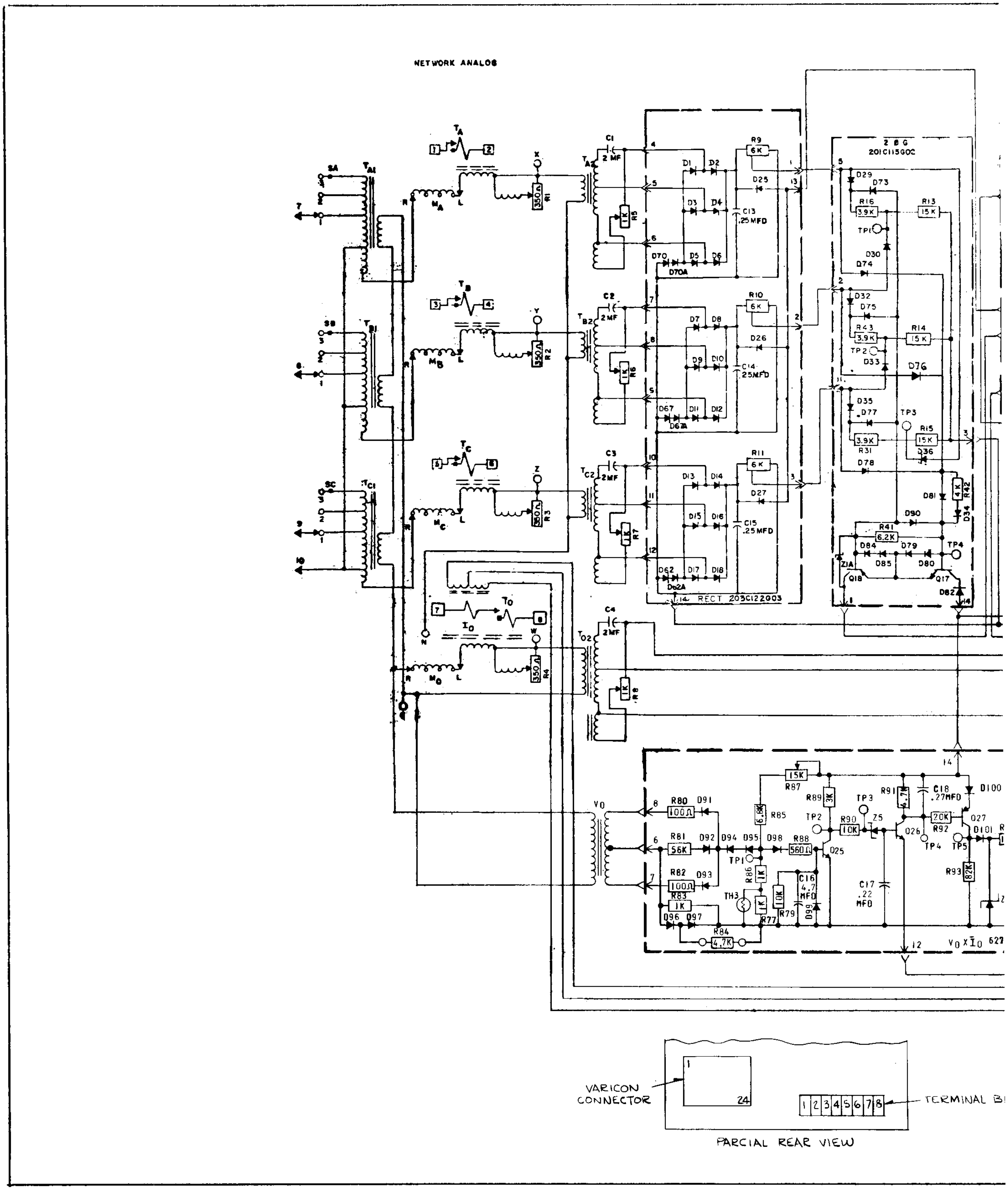
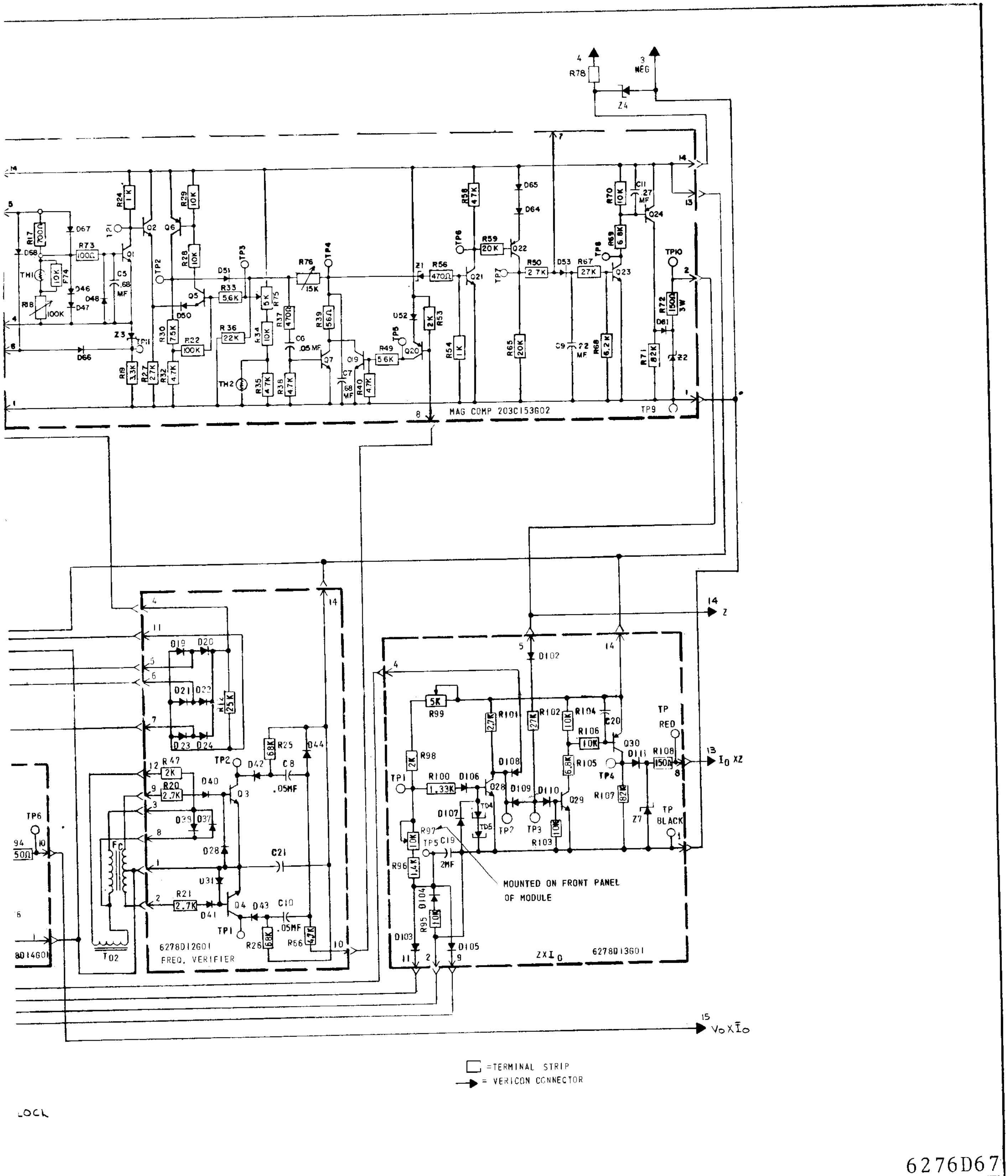


Fig. 9. Internal Sch



ematic SDGU-7

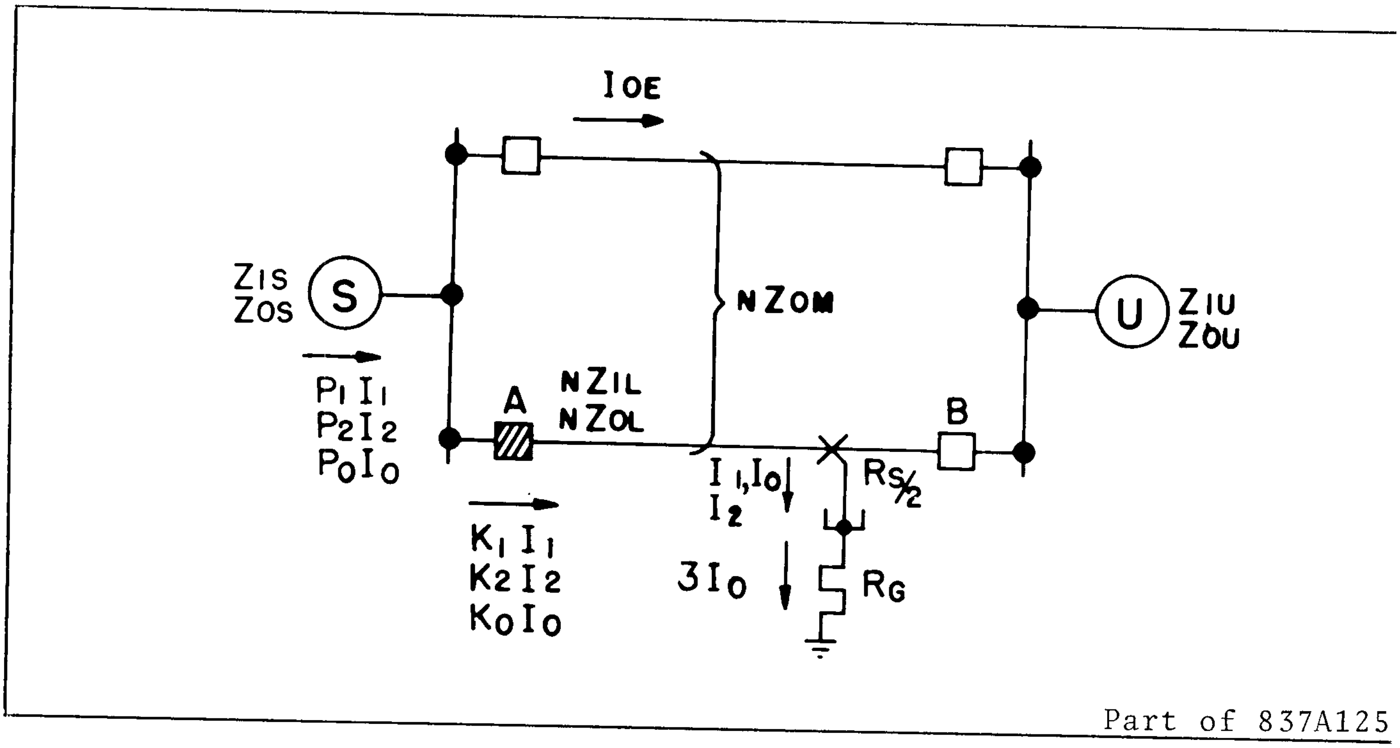


Fig. 10. Definition of Terms

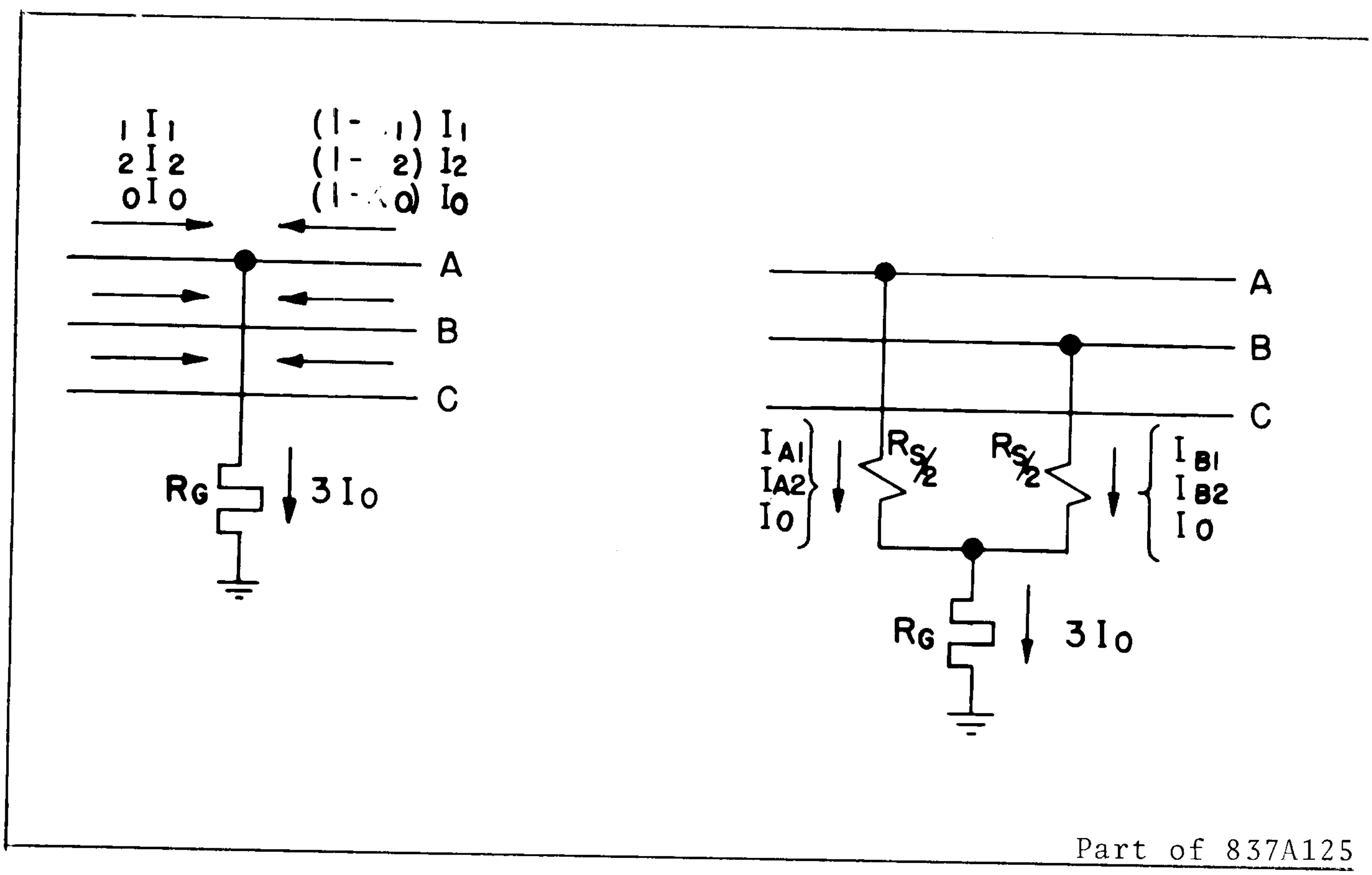


Fig. 11. Fault Resistance

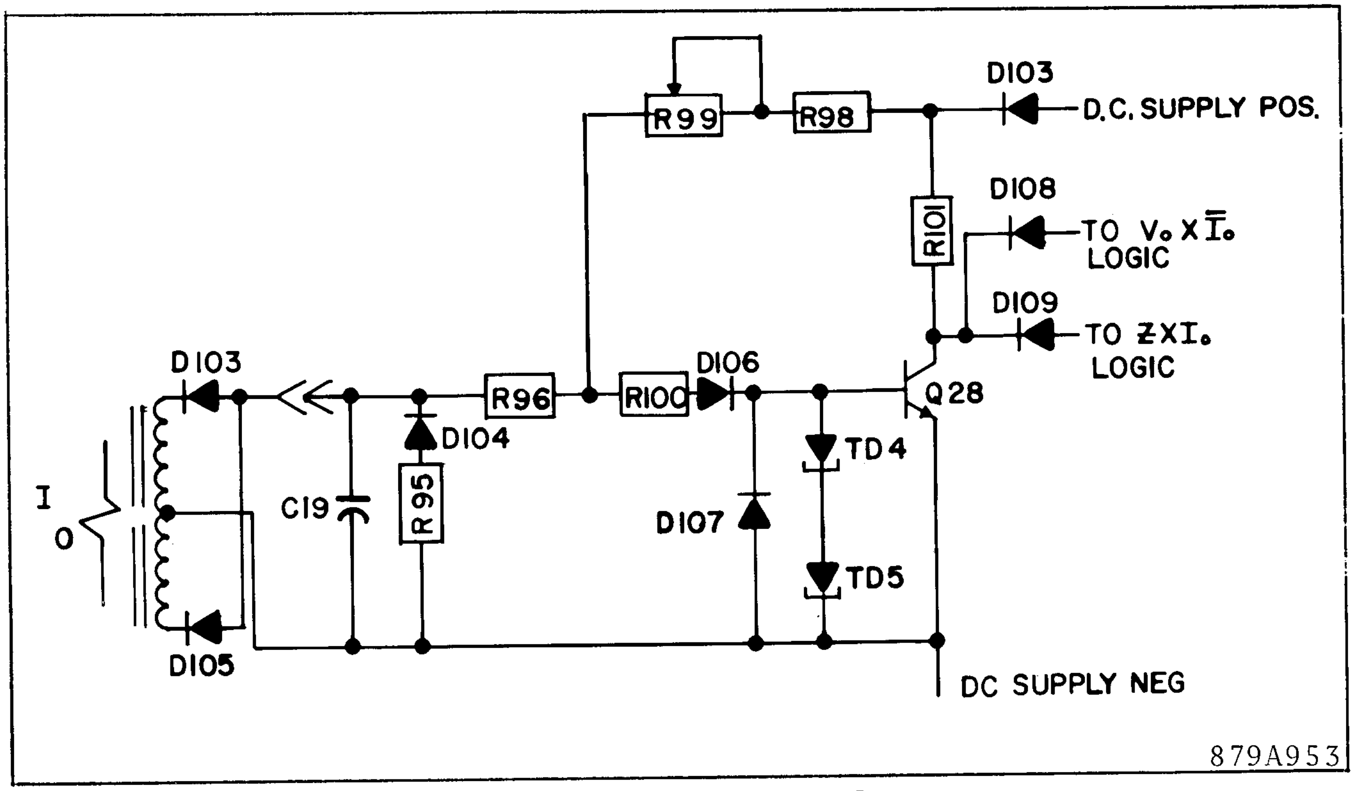


Fig. 14. Zero Sequence Current Detector

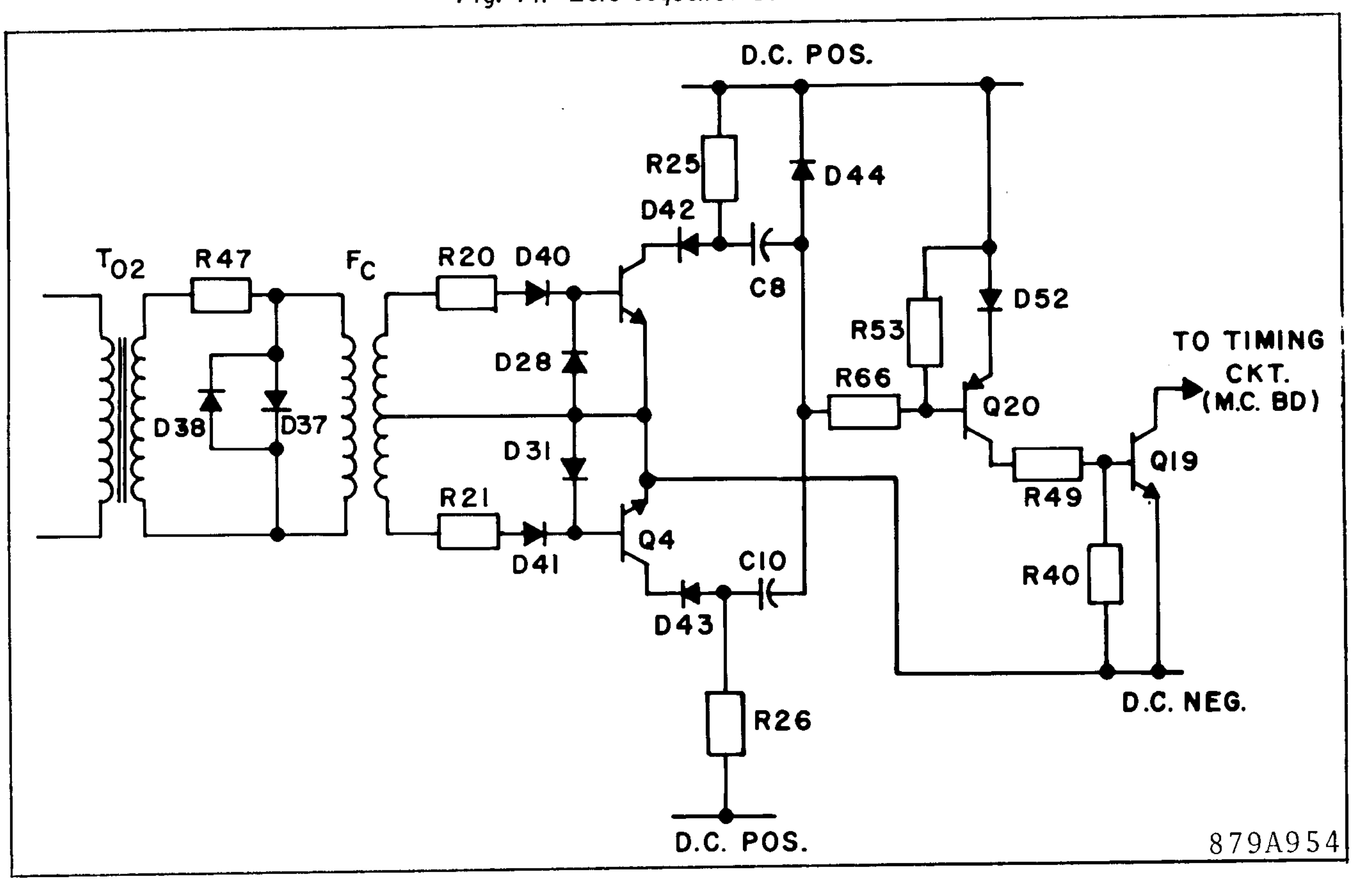


Fig. 15. Frequency Verifier Ckt.

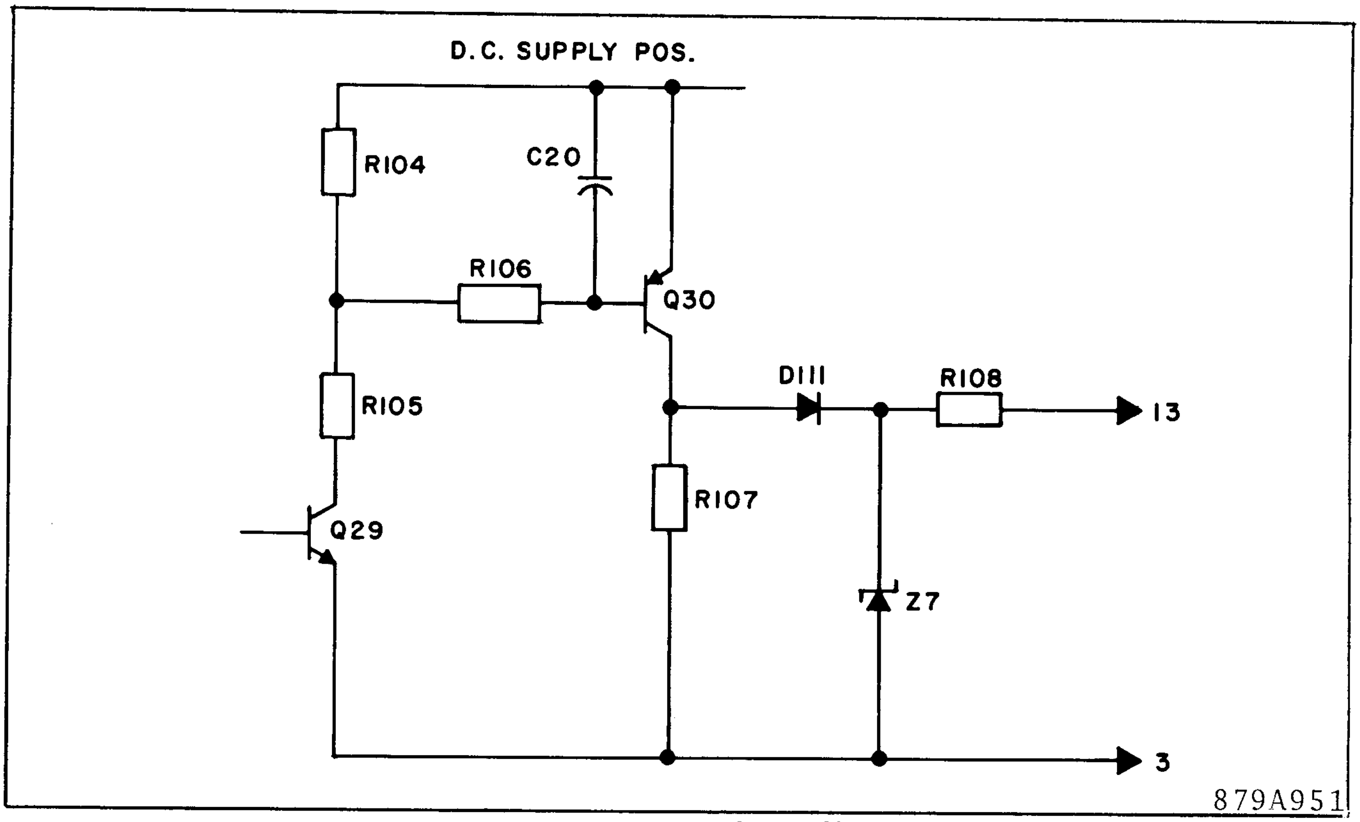


Fig. 16. Std. Output Ckt.

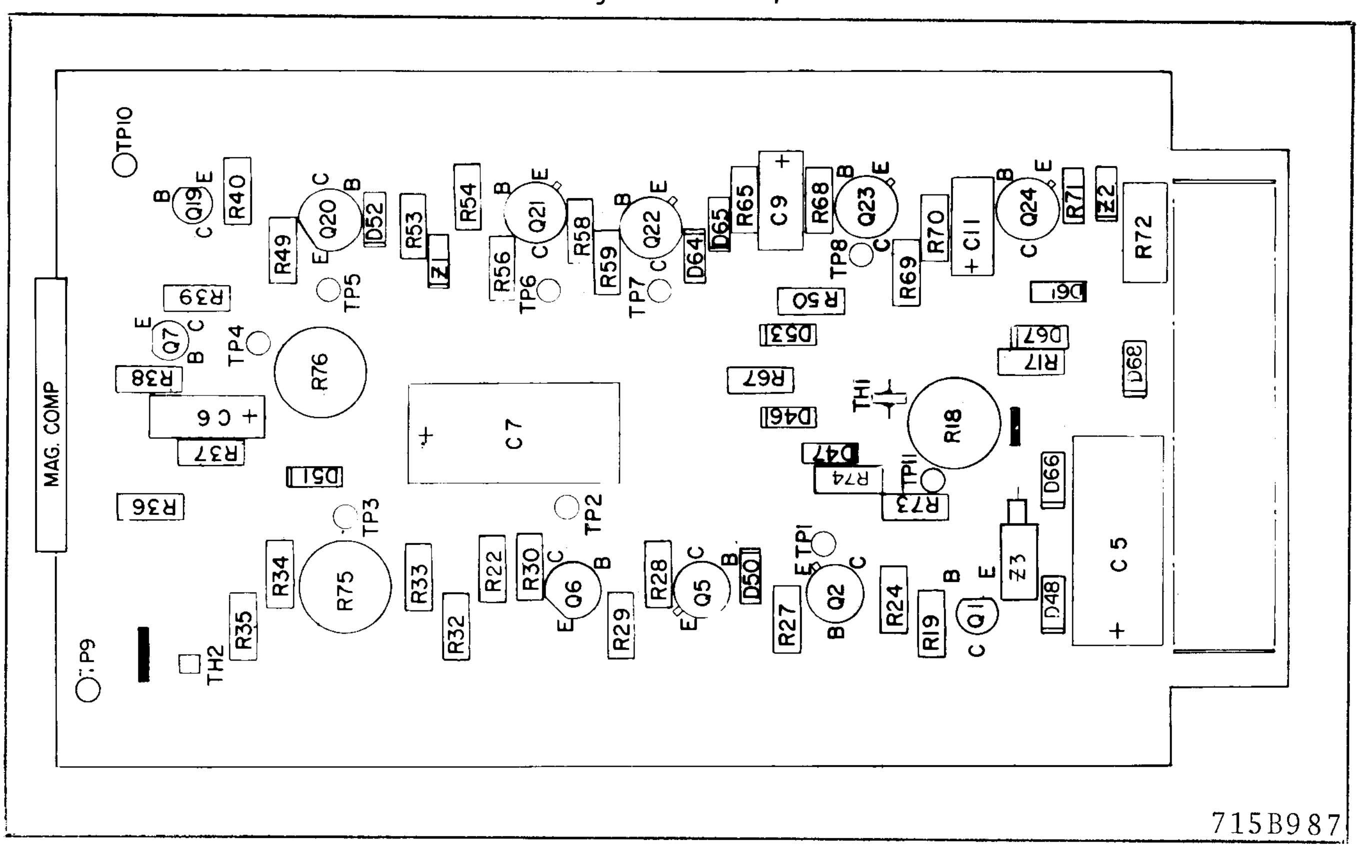


Fig. 17. Component Location SDGU-1,2,6,7 Mg. Comp. Bd.

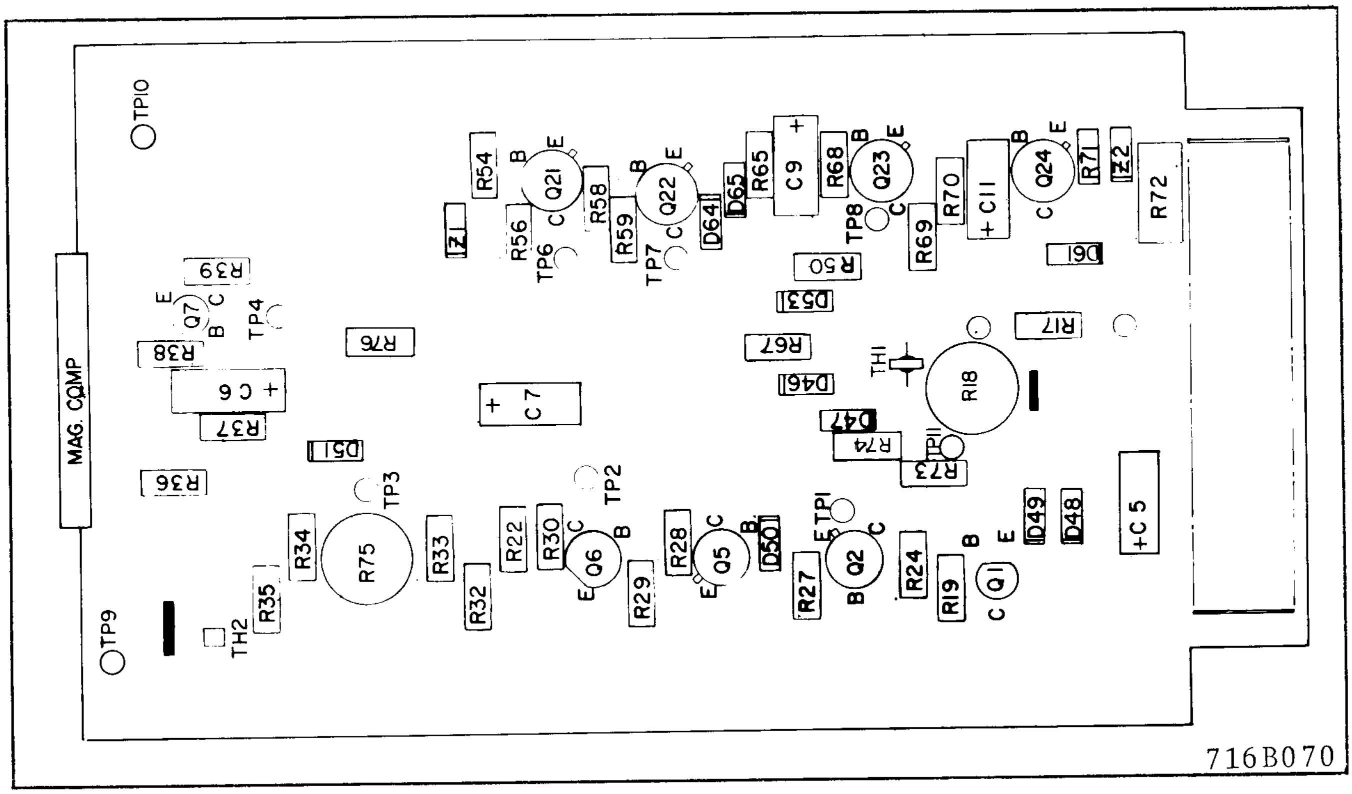


Fig. 18. Component Location SDGU-3 Mag. Comp. Bd.

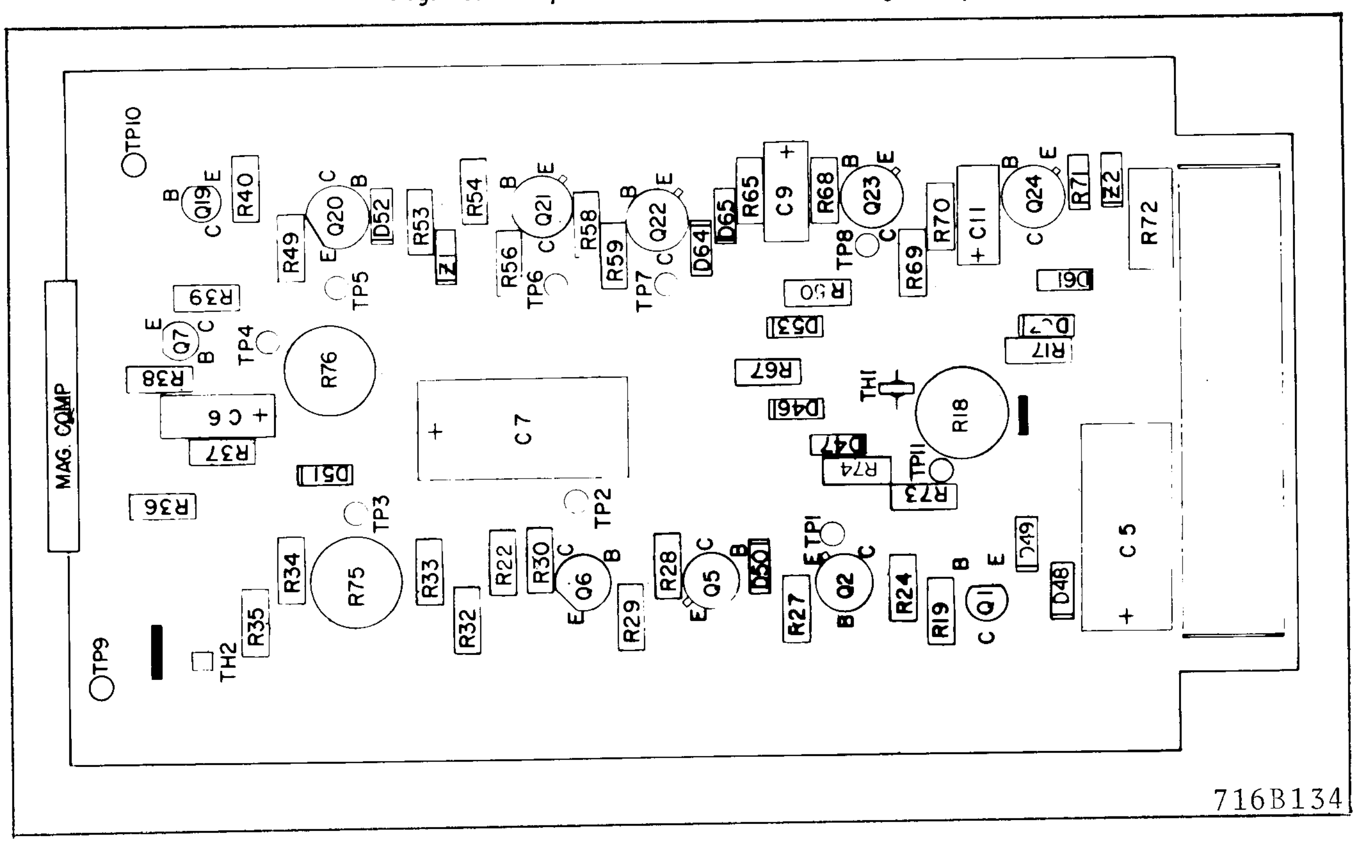


Fig. 19. Component Location SDGU-4 & 5 Mag. Comp. Bd.

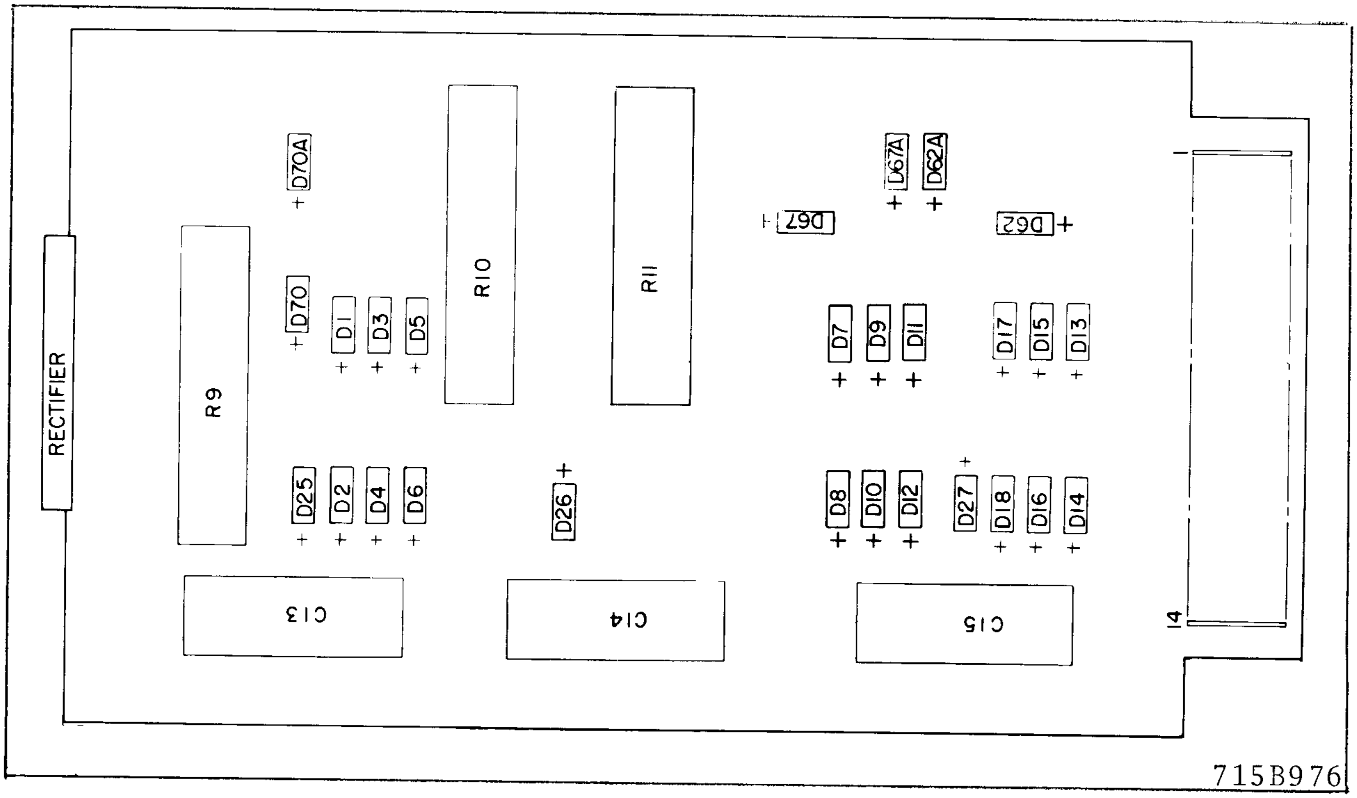


Fig. 20. Component Location SDGU-1-2-5-6-7 Rect. Board

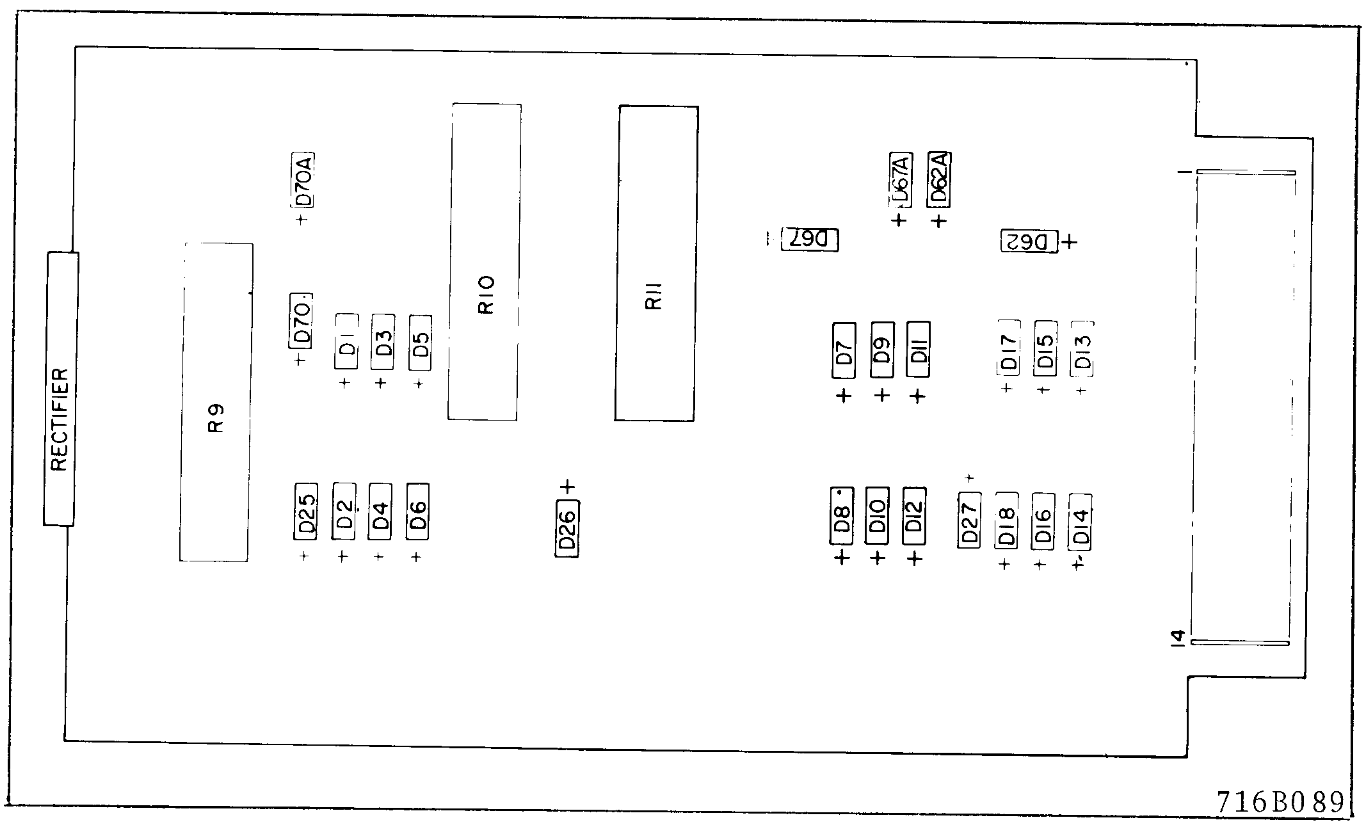


Fig. 21. Component Location SDGU-3-4 Rect. Bd.

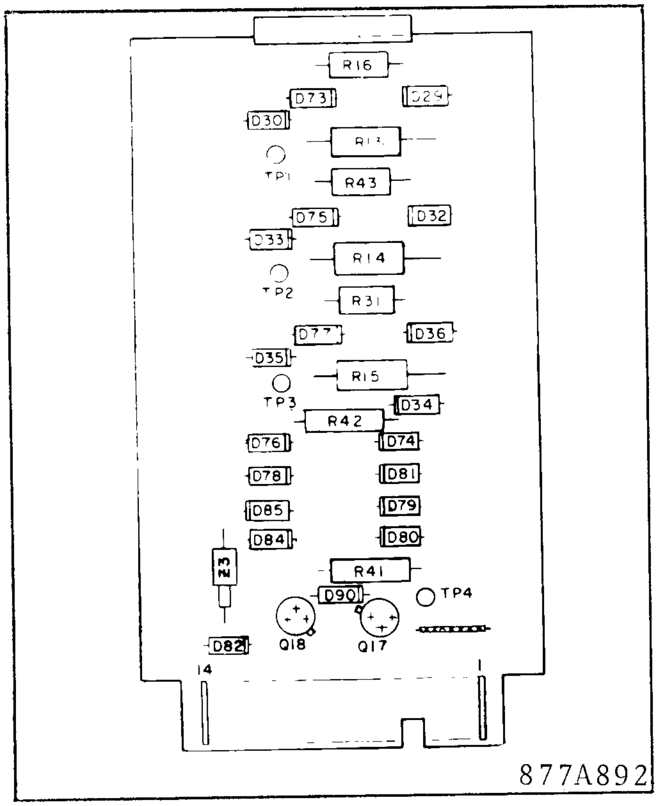


Fig. 22. Component Location 2 ϕ-G Board

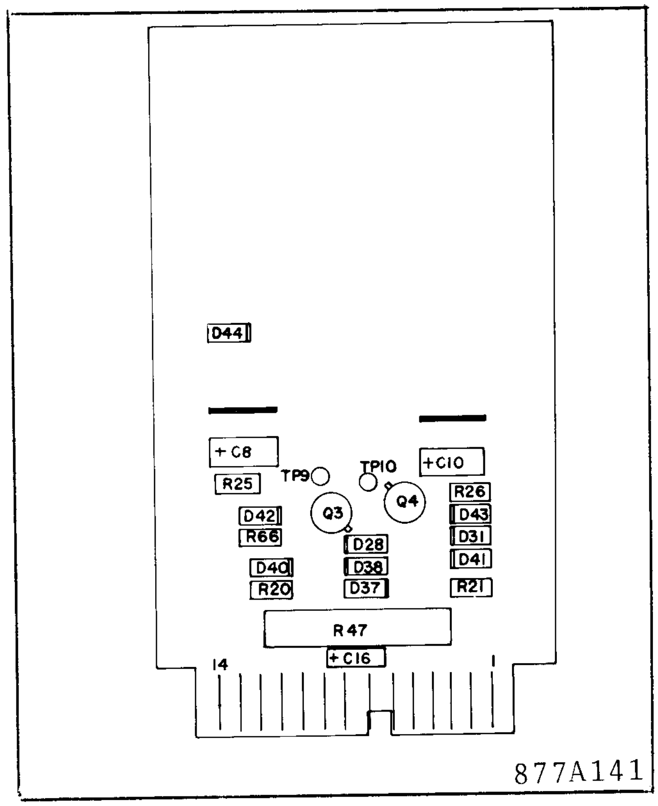


Fig. 23. Component Location SDGU-1-2-5 Frequency Verifier

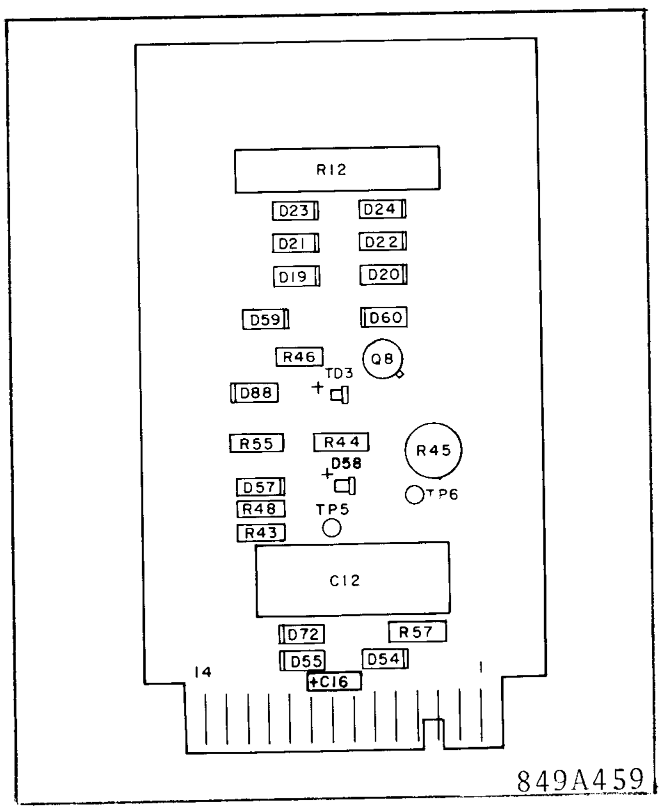


Fig. 24. SDGU-1-3 Rect. I_o Board

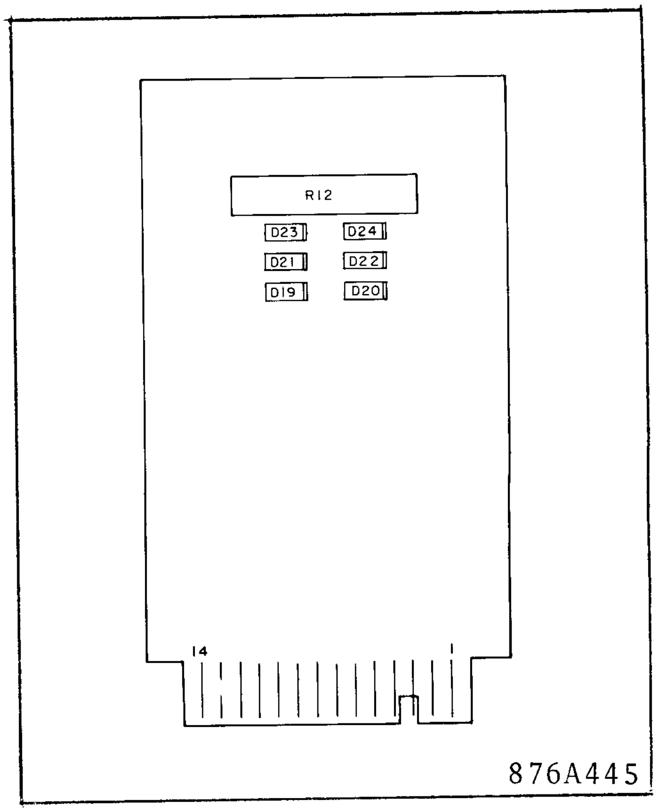


Fig. 25. Component Location SDGU-2-4-5 Rectifier I_o Board

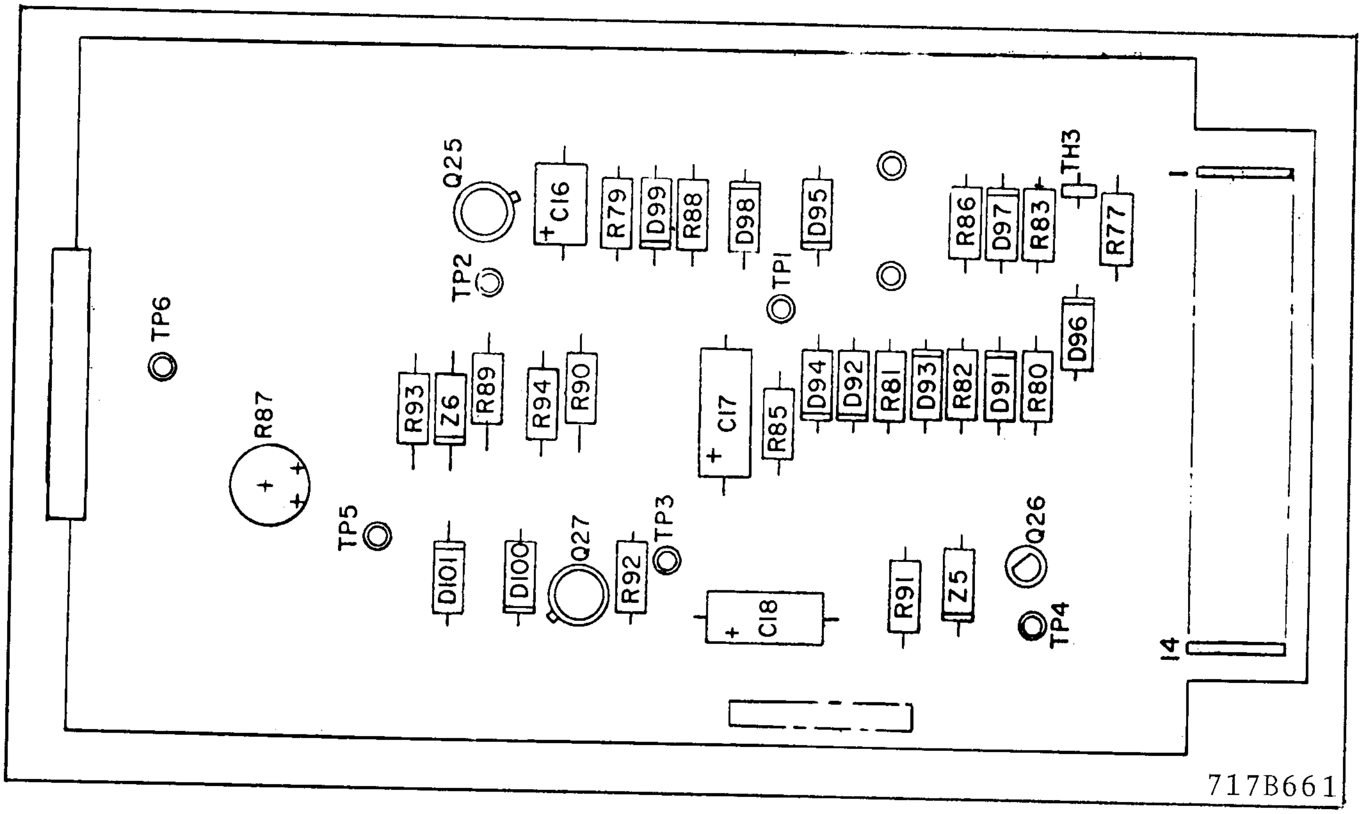


Fig. 26. Component Location SDGU-6-7 V_oXI_o Bd.

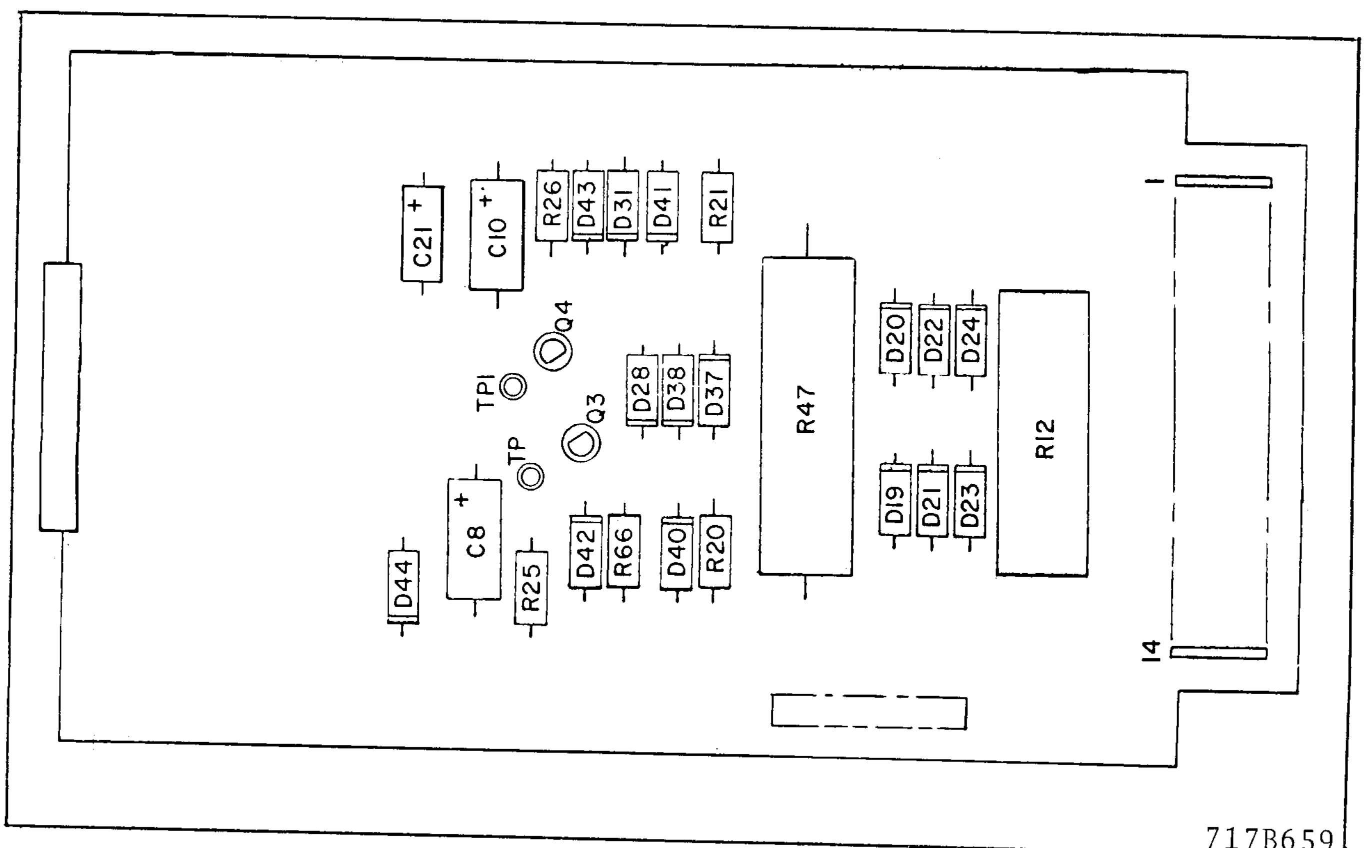


Fig. 27. Component Location SDGU-6-7 Freq. Ver. Bd.

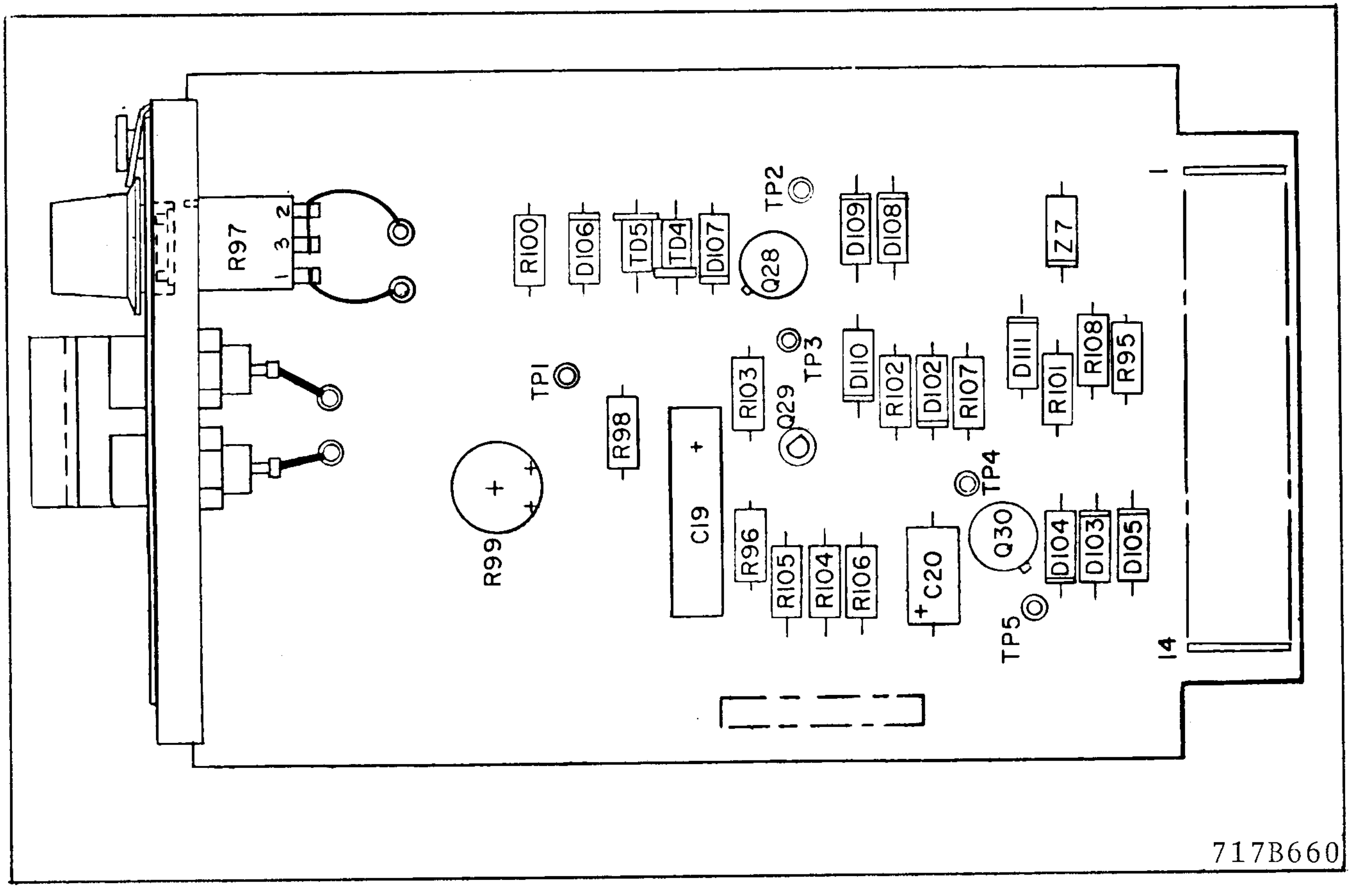
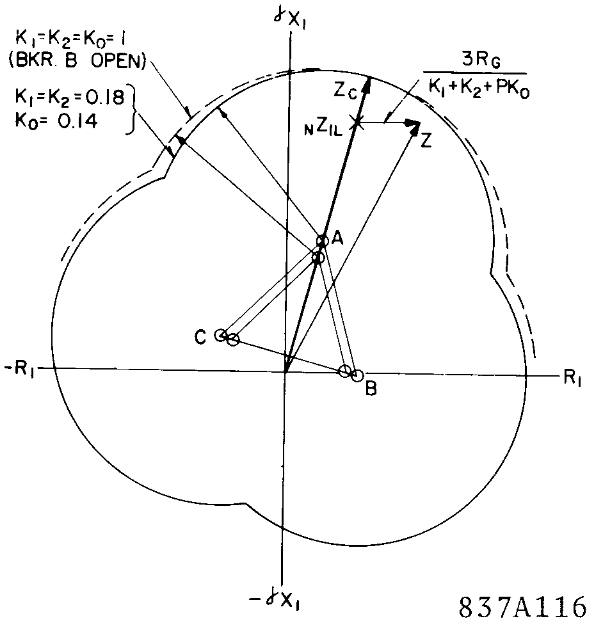
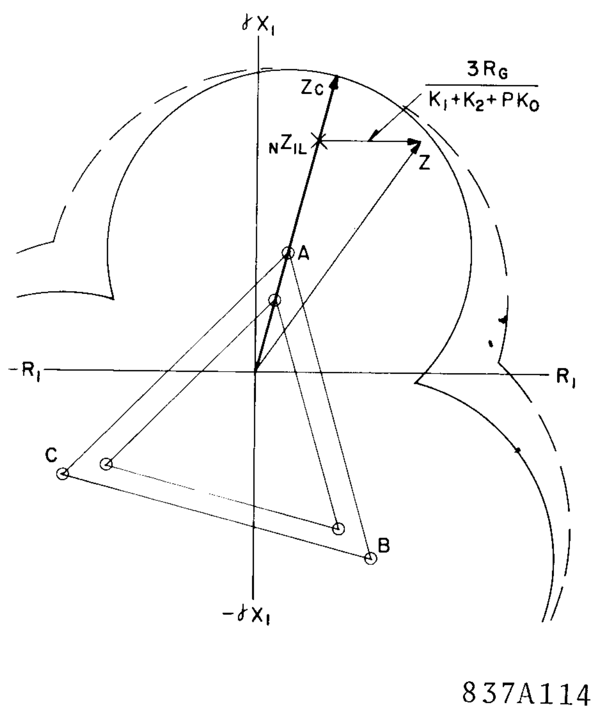


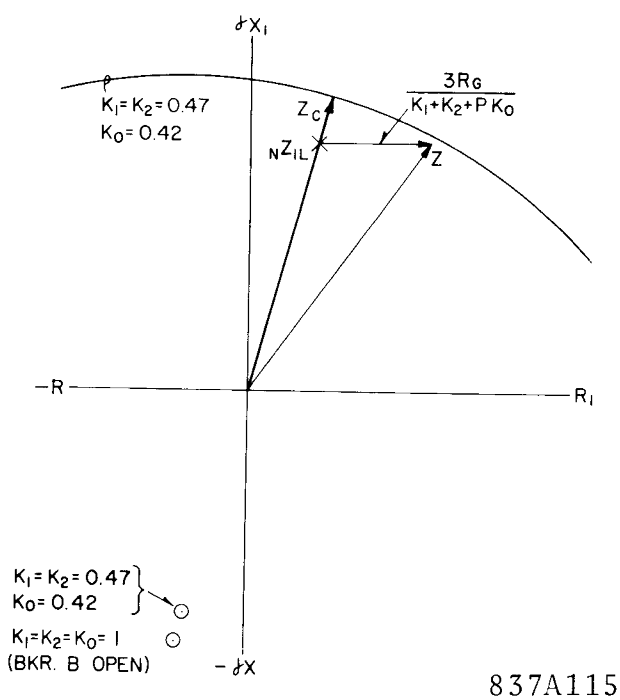
Fig. 28. Component Location SDGU-6-7 ZXI$_0$ Bd.



(A) Long Line



(B) Medium Length Line



(C) Short Line

Fig. 29. Impedance Circles

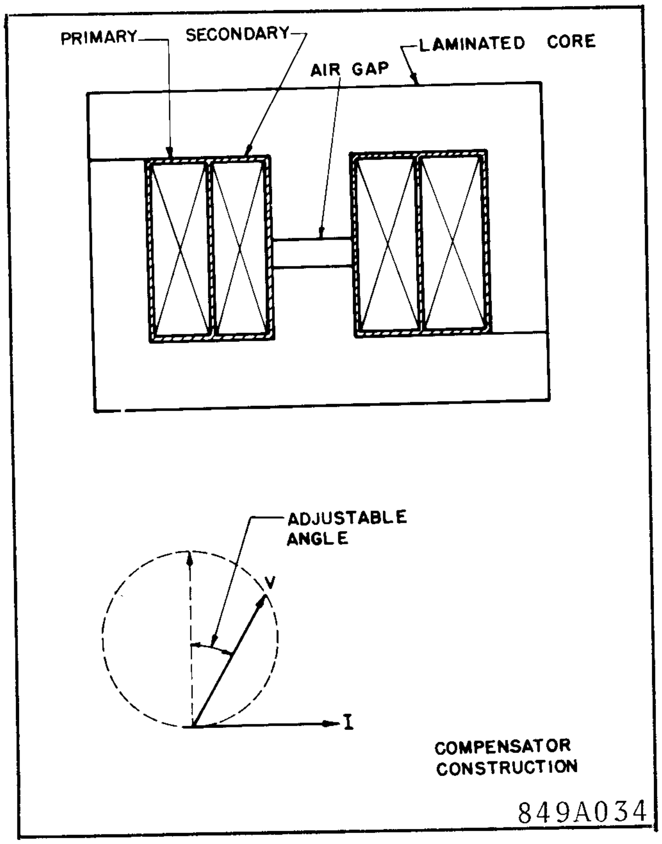


Fig. 30. Compensator Construction

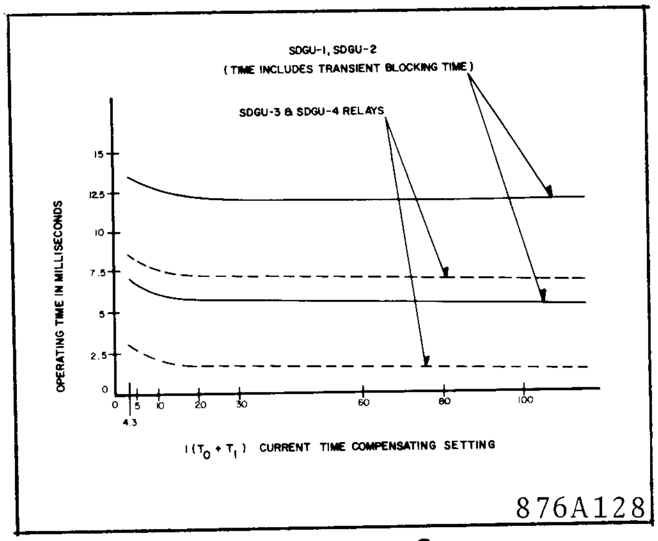


Fig. 31. Operating Curves

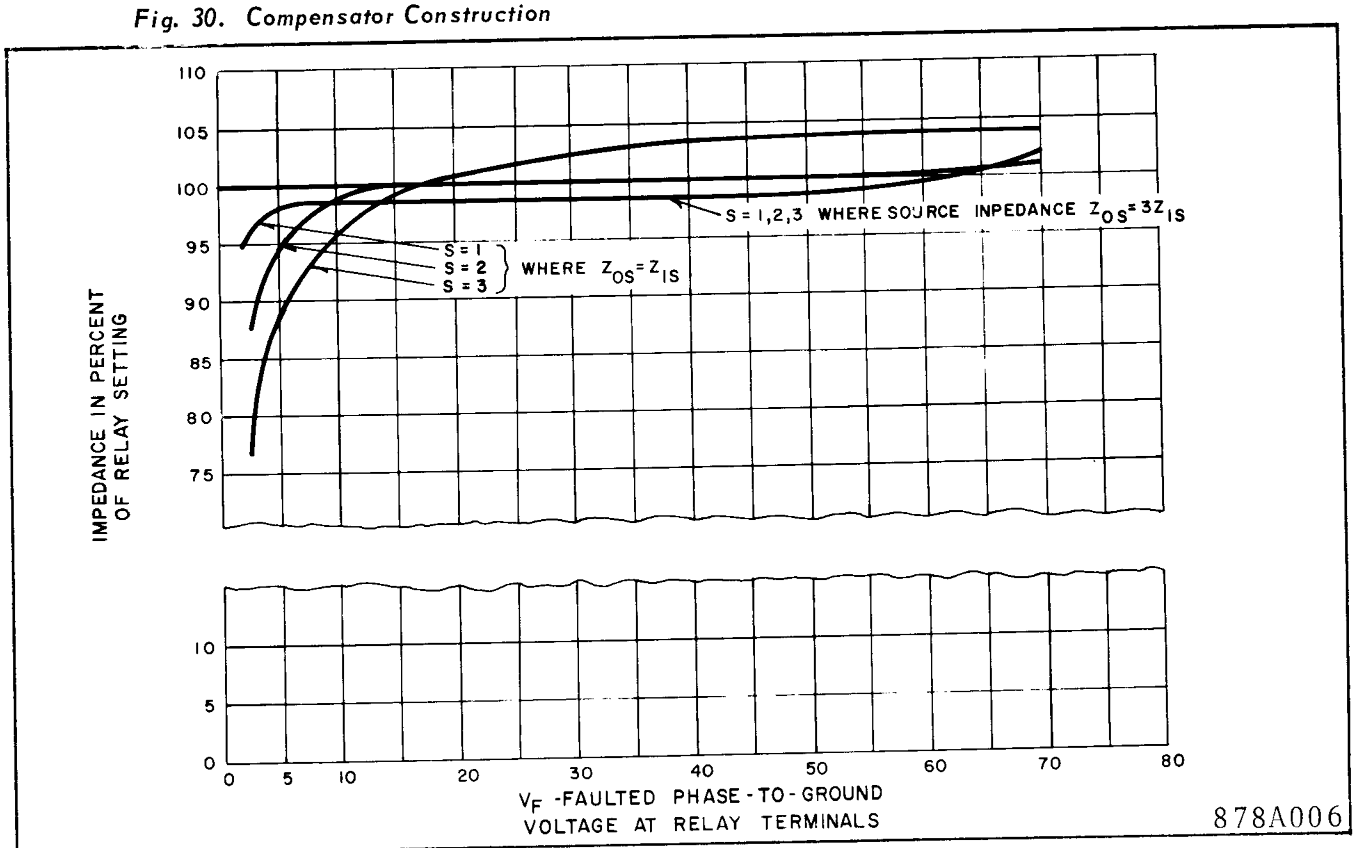


Fig. 32. Impedance Curves

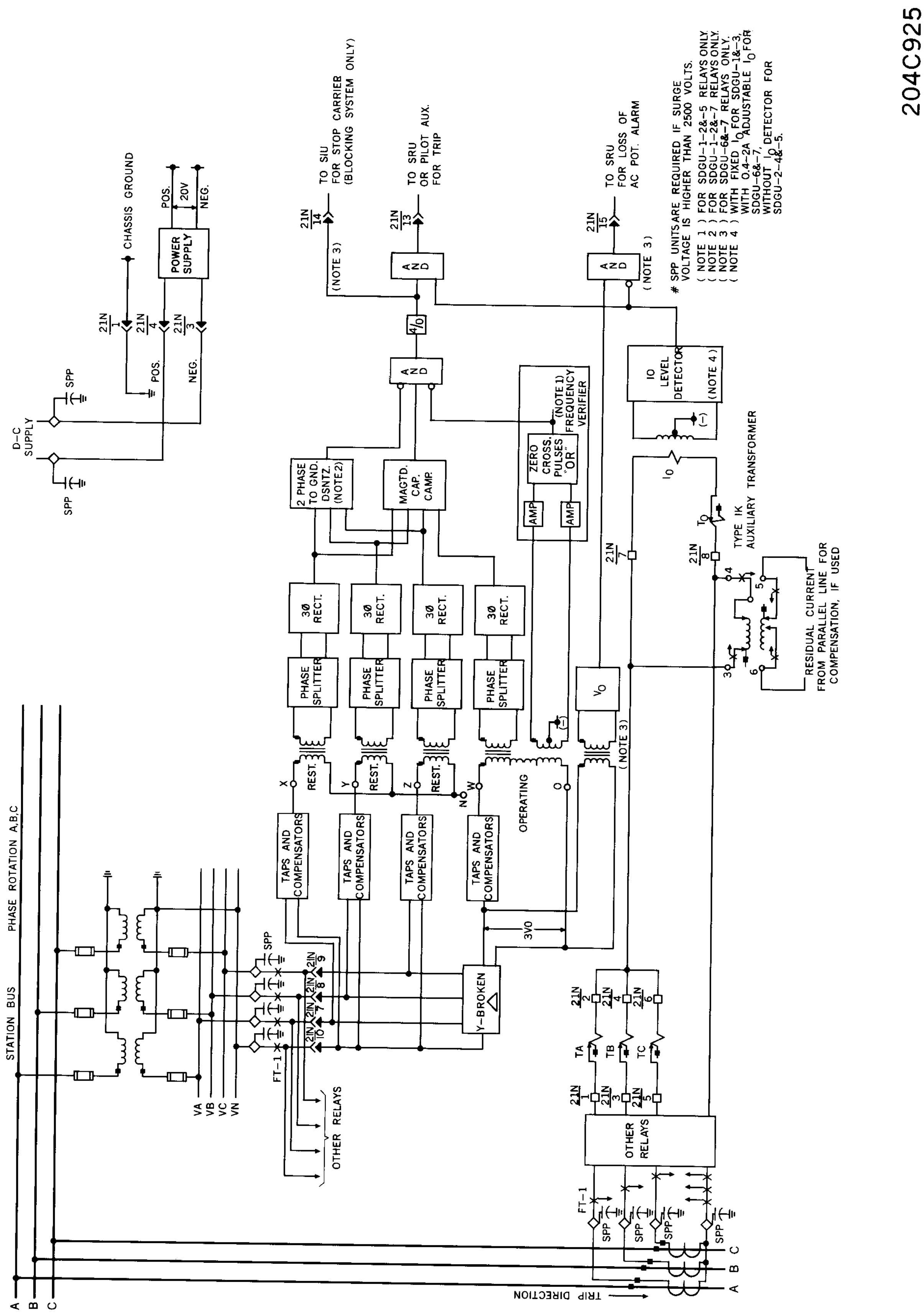
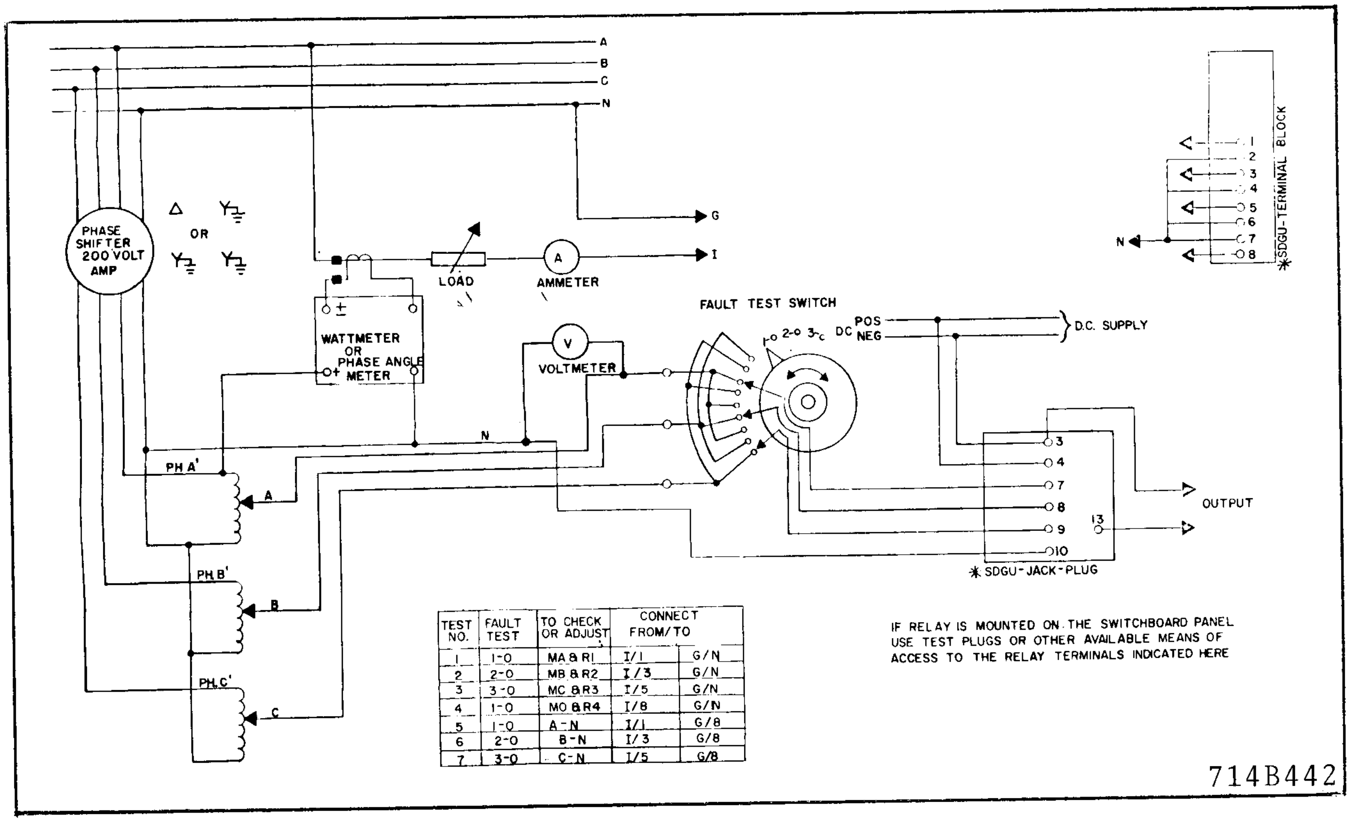


Fig. 33. External Schematic



TEST NO.	FAULT TEST	TO CHECK OR ADJUST	CONNECT FROM/TO	
1	1-0	MA & R1	I/1	G/N
2	2-0	MB & R2	I/3	G/N
3	3-0	MC & R3	I/5	G/N
4	1-0	MO & R4	I/8	G/N
5	1-0	A-N	I/1	G/8
6	2-0	B-N	I/3	G/8
7	3-0	C-N	I/5	G/8

Fig. 34. Test Connection

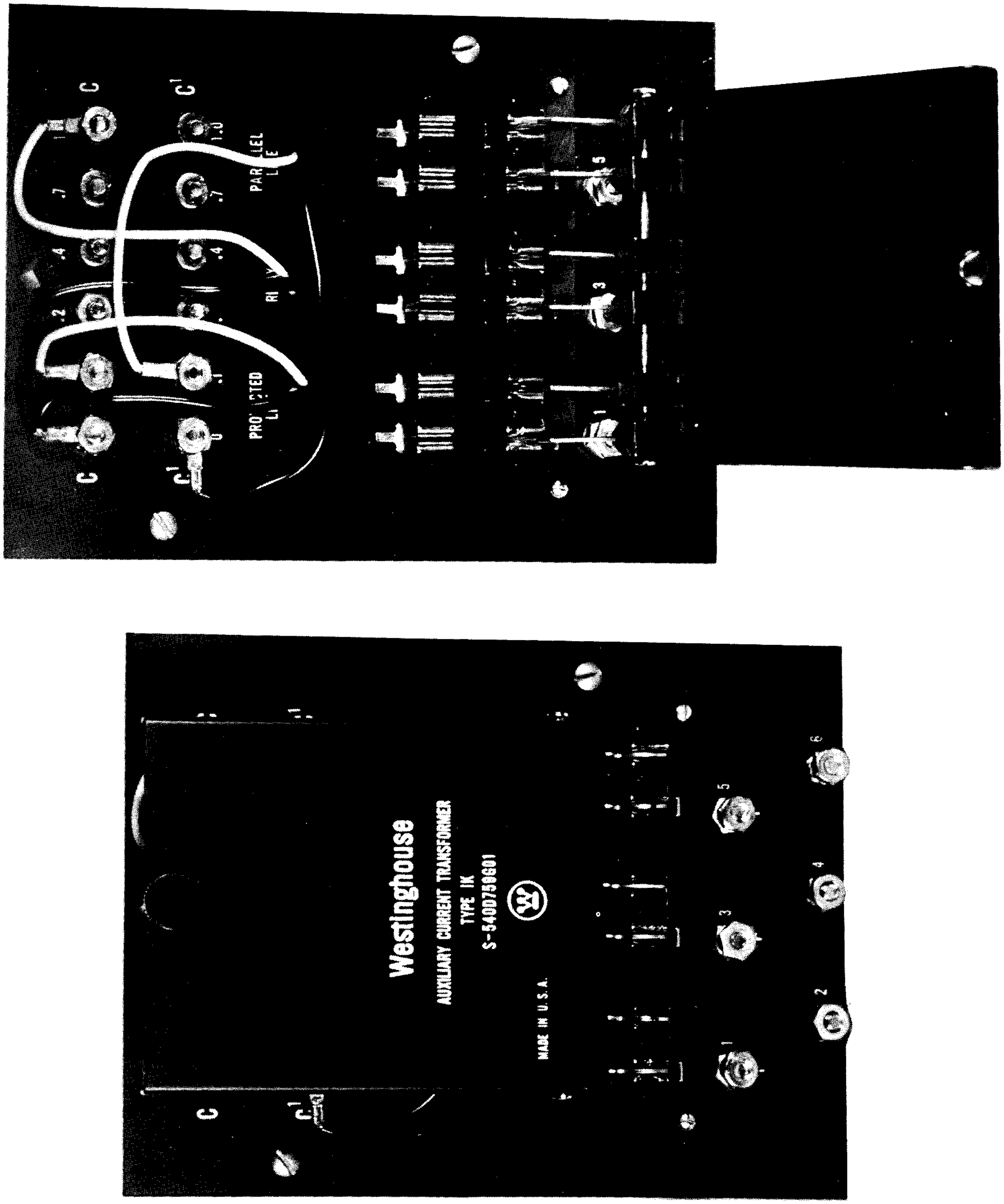
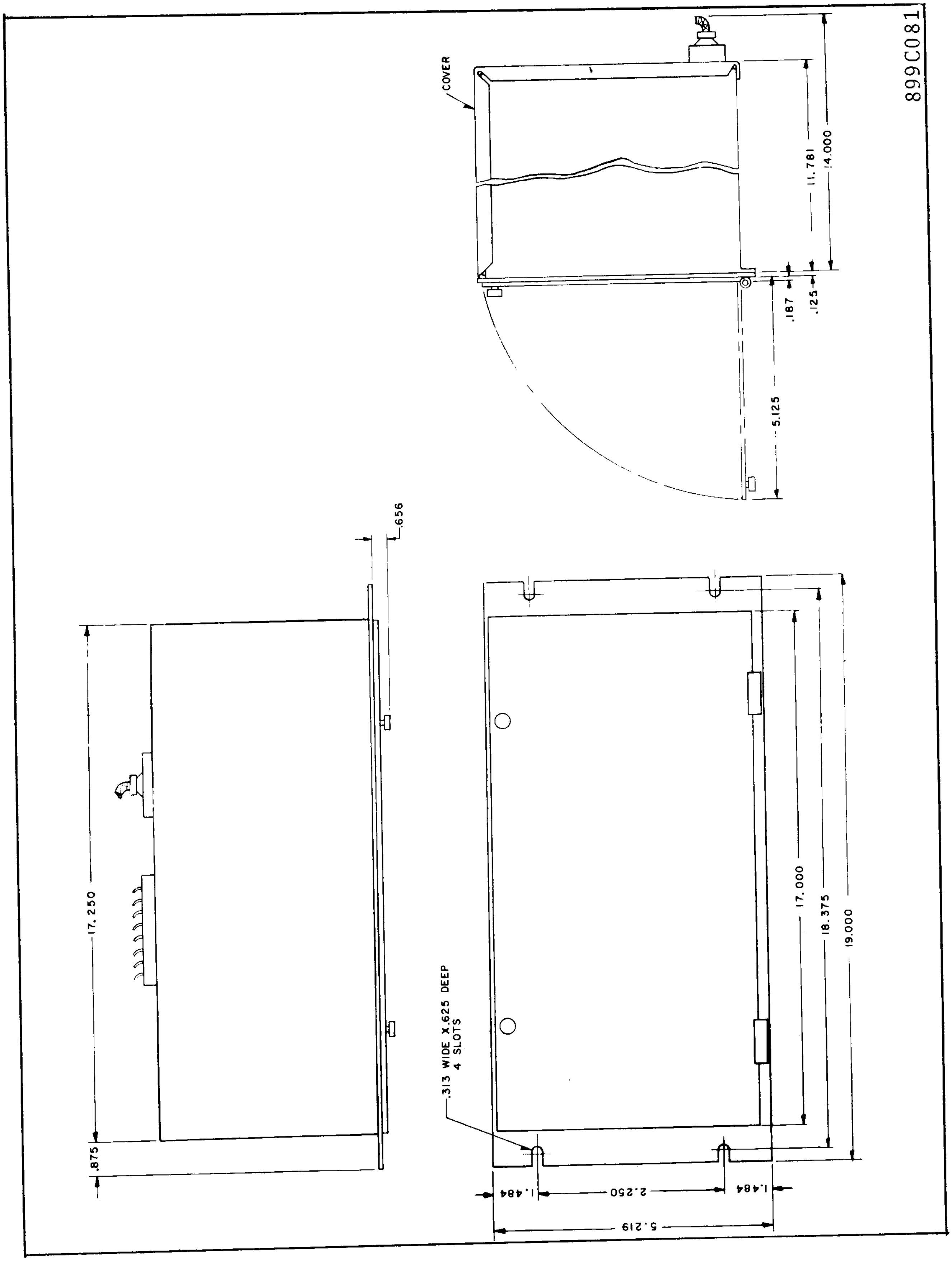


Fig. 35. Type IK Transformer


899C081
COVER
11.781
14.000
.187
.125
5.125
.656
17.250
.875
.313 WIDE X.625 DEEP
4 SLOTS
17.000
18.375
19.000
1.484
2.250
1.484
5.219

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