INSTALLATION • OPERATION • MAINTENANCE

# INSTRUCTIONS

# TYPE SKSU OUT-OF-STEP RELAY

## APPLICATION

The SKSU relay is a single phase compensator distance relay used with the three-phase element of an SKDU relay to sense an out-of-step condition on the power system.

Its functions, following detection of out-of-step are:

1. Block the development of a tripping output of the three-phase element of one or more SKDU relays.
2. Block high-speed reclosing, through an auxiliary device (ARS or SRU).
3. Temporarily block tripping of the Zone 1 SKDU three-phase element until the SKSU distance element resets. This forces a more favorable recovery voltage to appear across the circuit breaker contacts at the instant of interruption, substantially reducing the duty. This function is optional.

## CONSTRUCTION

The type SKSU relay consists of two air gap transformers (compensators) one auto-transformer, a phase shifting network, a memory circuit, and two isolating transformers which couple the a-c quantities into the static network, and the relay's case.

The static circuit contains either four or six printed-circuit boards. Four are required to provide the out-of-step-blocking logic. Two additional logic boards are required when an out-of-step-tripping function is desired. They 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.

A hinged and removable door provides access to all adjustments and printed-circuit boards. A 24-terminal jack provides external voltage connections, and a terminal block provides current connections.

### Compensators

The compensators which are designated $T_{LR}$ and $T_{SR}$ are three-winding air-gap transformers. There are two primary current windings, $T_{AL}$, $T_{BL}$ for long-reach and $T_{AS}$, $T_{BS}$ for short reach. Each current winding has seven taps which terminate at the tap block, Fig. 2. The T values for short-reach compensators are marked (0.87, 1.16, 1.45, 2.03, 2.9, 4.06, and 5.8), and for long reach (1.31, 1.74, 2.18, 3.05, 4.35, 6.1, and 8.7).

A voltage is induced in the secondary which is proportional to the primary tap value and the 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 proportionality have been precisely set at the factory. The clamps which hold the laminations should not be disturbed by either tightening or loosening the clamp screws.

The 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 the 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 and provides a means of adjusting the phase angle relation between the current and induced secondary voltage. The phase angle may be set any value between 60° to 80° by adjusting the resistor between its minimum and maximum value respectively or for 89° by open circuiting the resistor. The factory setting is for a maximum sensitivity angle of 75° ± 3° current lagging voltage.

### Auto-Transformer

The auto-transformer has three taps on its main winding, S, which are numbered 1, 2, and 3 on the tap block, Figure 2. A tertiary winding M has four taps which may be connected additively or sub-

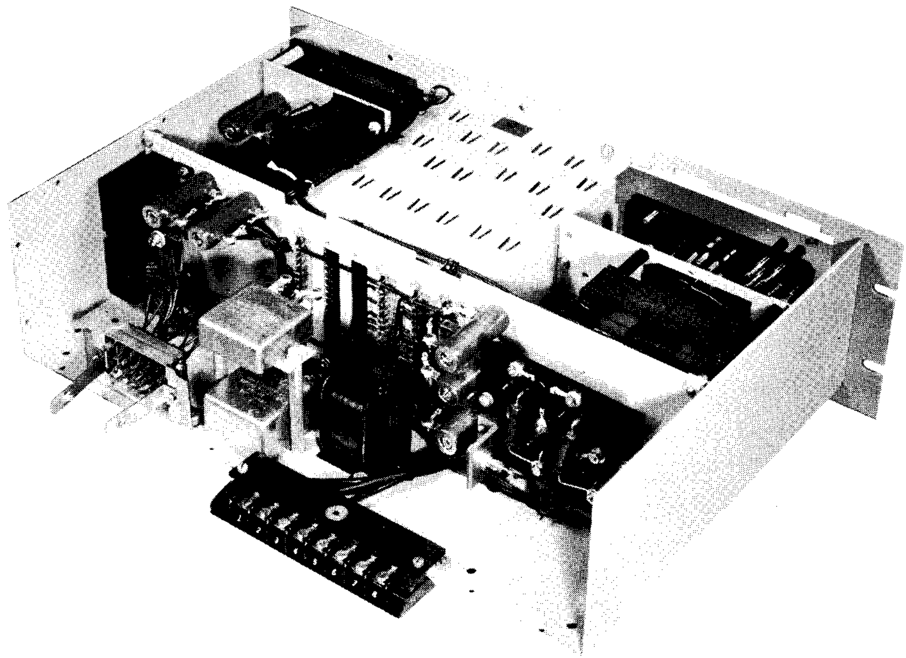


Fig. 1. Relay's Picture

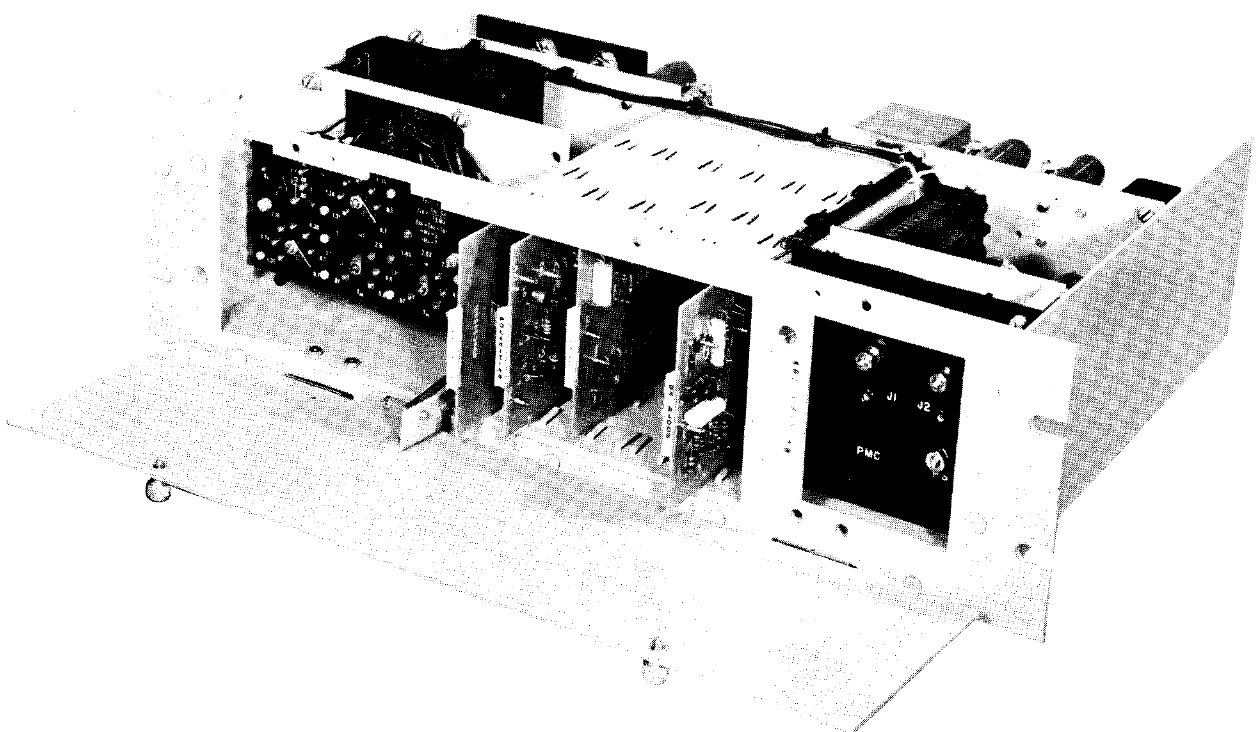



Fig. 2. Tap Plate (Picture)

tractively to inversely modify the S setting by any 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.

The auto-transformer makes it possible to expand the basic range of T ohms by a multiplier of $\frac{S}{1 \pm M}$. Therefore, any relay ohm "long-reach" setting can be made within ± 1.5 percent from the minimum value of a given range by combining the compensator taps $T_{LR}$ with the auto-transformer taps SA - MA.

## Phase Shifting Circuit

"Polarization" is the reference against which the "operate" signal is compared. Polarization for this relay is obtained by shifting the phase 1-2 voltage ahead 90°. The phase shifting circuit consists of a center tapped auto-transformer, XS, which supplies voltage to a series connected resistance and capacitor, RS plus PS and CS respectively (Figure 4). Voltage between the resistor-capacitor junction and the auto-transformer center tap leads the applied voltage by 90°.

## Memory Circuit

The memory circuit consists of a large inductive reactance, XL, a large capacitive reactance, C3C, and a resistor RC which are series connected and are tuned very closely to sixty Hertz. In the event of a close-in fault which drops the relay terminal voltages to zero, the energy trapped in memory circuit will delay relatively slowly, while oscillating at a sixty Hertz frequency. This will maintain a polarizing signal long enough for the relay to operate with an accurate reach and directional sense.

## Isolating Transformers

Transformers T1 and T2 serve two purposes. Firstly, they isolate the a-c circuits from the d-c circuit. Secondly, they amplify the clipped a-c signal by a factor of 1:8 to make the relay sensitive to low level input signals.

## Printed Circuit Board Assembly

The printed circuit boards shown in Fig. 3 contains all the resistors, diodes, transistors, and thyristors necessary to perform the functions of a polarized phase angle comparison unit. All the components are identified by a letter and two numbers. The letter indicates the component's name, the number in the left is the circuit board number, and the number in the right of the letter is the component's number.

In these circuit boards the resistors are identified by R, the diodes by D, transistors by Q, thyristors by QS, capacitors by C, the Zener diodes by Z, and test points by TP.

When facing the component side with terminals at the bottom, terminals are numbered from right to left starting at 1 and going through 14. These terminal numbers are shown within brackets on the internal schematic and will be referred to as Printed Circuit Terminals, PCT, in the trouble shooting section.

## Relay Case

The jack plug on the rear has 24 terminals numbered left to right and top to bottom. Thus terminal No. 1 is located in the upper left hand corner when viewed from the rear and terminal 24 is in the lower right hand corner. Terminal No. 1 is connected internally to the chassis ground and may be used for grounding the connecting cable shields.

There is also an 8-terminal strip used for current terminals which is located in the right hand side of rear when viewed from the back. The terminals are numbered from left to right.

The chassis case, cover, and front panel have electrical connections established by the use of shakeproof washers which cut through any paint or protective coating to make electrical contact with the base metal. The complete relay is then grounded to the switchboard or cabinet by an external wire connection which must be made by clamping the wire under a shakeproof washer which also serves to help hold the cover in place.

The door is hinged at the bottom and is secured at the top by two captive screws. It may be opened to 90 degrees where it is stopped by a slotted strap attached to the door and also to the frame of the case. To remove the door, release the strap by either unscrewing it or unhooking it from the door and then slide the door to the right to disengage the hinges

Printed-circuit boards are connected into the electrical circuits of the relay through 14-terminal connectors. The boards can be disengaged by a steady pull outward. Sometimes a simultaneous up-and-down motion (if there is clearance) will help free the mating connections. The boards are keyed so that they cannot be pushed home into the wrong connector although they may be replaced into the guides of the wrong position.

## OPERATION

The SKSU relay is basically a single phase relay operating from delta voltage and current.

Figure 4 illustrates the connections which apply voltage to the static phase angle comparison unit. Voltage $V_{AB}$ is either modified by the compensator output voltage $(I_A-I_B)\ Z_{LR}$ or $(I_A-I_B)\ Z_{SR}$ to produce a mho circle which includes the origin.

The long reach compensator is set to be a replica of the protected line section as seen by the secondary side and has the same relative current flowing through it as flows through the total line impedance. The short-reach compensator is connected in reverse direction to produce an off-set mho characteristic.

Referring to Fig. 5, consider a fault at location A which is beyond the long reach setting. For the sake of simplicity, assume both the line angle and and maximum sensitivity angle to be 90°. Compensator $Z_{LR}$ modifies the voltage $V_{AB}$ by adding the mutual impedance drop $(I_A-I_B)\ Z_{LR}$ which leaves the difference voltage $V_{XB}$ across the input of transformer $T_1$. The compensator $T_{SR}$ modifies the voltage $V_{AB}$ by adding $(I_B-I_A)\ Z_{SR}$ and then is phase shifted 90 degrees by means of the capacitor CS and the resulting voltage, $V_{YB}$, is applied across transformer T2. As shown, the voltage $V_{YB}$ leads the voltage $V_{XB}$ which is a restraint condition.

For the fault within the protected line section at point C, $V_{AB}$ becomes smaller than the permissible minimum computed by the long reach compensator. This results in $V_{XB}$ being flipped 180° so that the polarizing voltage $V_{YB}$ lags $V_{XB}$ and a trip signal appears at the output.

For the fault behind the relay such as point D, current through the relay has the opposite polarity from that for the fault at point A and C. If the fault impedance is within the tap setting of the short reach compensator, the voltage $V_{AB}$ will be modified with mutual impedance drop of $(I_B-I_A)$ which leaves a voltage $V_{YB}$. This voltage is phase shifted by 90 degrees and appears across the transformer T2 as $V_{YB}$. The compensator $Z_{LR}$ modifies the voltage $V_{AB}$ by adding the compensator voltage output $(I_A-I_B)\ Z_{LR}$ and leaves a sum of voltages $V_{AB} + (I_A-I_B)\ Z_{LR}$ across the transformer $T_1$. This results in $V_{YB}$ still lagging $V_{XB}$ which is a trip condition.

For a fault at location E, the voltage $V_{AB}$ is is greater than the short reach compensator drop and causes $V_{YB}$ to lead $V_{XB}$ which is a restraint condition.

### Phase Angle Comparison Unit

Referring to Figure 4, the phase angle comparison unit trips when current flows into the base of transistor 3Q3 through Zener diode 3Z2. Such tripping current must come from the 20V bus through either transistor 1Q2 or 1Q4 located in what might be be called the "operate" circuit. The operate circuit, driven by transformer T1, is continually trying to trip the unit by supply current through 1Q1 and 1Q3 on alternate half cycles. 1Q2 conducts when the polarity marked terminal of T1 is positive.

When 1Q2 conducts, a portion of the current goes through resistor 2R9. This current, $I_{R24}$, may take either of two paths to the negative bus. If 2QS1 is in a conducting state, $I_{R9}$ passes through it directly to the negative bus. If 2QS1 is in a blocking state, $I_{R9}$ passes through 2D16 and then through 3Z2 to transistor 3Q3 to cause tripping. Silicon controlled switch $Z_{QS1}$ is located in what might be called the "polarizing" circuit of the relay. This circuit is driven by transformer T2.

To prevent the operate circuit from tripping, the polarity marked terminals of T2 must go positive before the polarity terminals of T1 do. This caused 2Q1 to conduct current through 2R5, and 2D14 to drive the base of 2Q4. 2Q4 then conducts current from the 13V bus through 2R6 to gate 2QS1 into conduction. When 2QS1 conducts, it short circuits the current which might otherwise pass through 2D16 to cause tripping. Once 2QS1 begins to conduct, the gate loses control and it remains in the conducting state until the current is turned off by 1Q2. No tripping output can develop as long as the T2 voltage leads the T1 voltage.

The operating circuit switches for the next half cycle so that transistors 1Q3 and 1Q4 conduct in an attempt to cause tripping. In the polarizing circuit, 2Q2, 2Q5, and 2QS2 seek to prevent tripping by short circuiting the current which might otherwise pass through 2D1, 3Z2, and 3Q3.

Restraint Squelch: When the operate circuit transistor 1Q2 conducts, approximately 18V is applied through diode 2D15 to back bias 2D14 and prevent 2Q4 from turning on. Thus a trip signal, initiated because the T1 voltage is leading, cannot be improperly interrupted when the T2 voltage goes positive. A full half cycle tripping output is therefore produced by 1Q2. This back biasing connection is called the restraint squelch circuit.

## Restraint-Signal Detector

If a condition should develope so that no polarizing voltage appears at transformer T2, then no gating signal would be available to switch 2QS1 and short circuit the 1Q2 current. This, of course, could cause incorrect tripping. A restraint-signal detector circuit prevents this to happen.

When the transistors 2Q1 and 2Q2 are conducting for each half cycle, they short circuit the current coming through 2R3 from a 20 volts d-c bus. If the polarizing voltage goes to zero, both transistors 2Q1 and 2Q2 stop conducting and a voltage will develop to break the Zener diode 2Z2 and to turn the transistor 2Q3 on, and hence to drive the base of 2Q4 and 2Q5 to short circuit 2QS1 and 2QS2 and to prevent incorrect tripping.

The operating circuit, driven by T1, and the polarizing circuit, driven by T2 are duals having identical circuits which operate on alternate half cycles. The restraint squelch and the voltage detector both work into each of the duals in the same manner.

## Voltage Detector Circuit Board

When the SKDU is first energized with either a-c or d-c, there is no prior knowledge to inform the circuits as to which voltage is leading. A race exists between the operate and the polarizing circuits. Therefore, it is desirable to disable the tripping long enough for the circuits to properly relate to each other.

When the d-c is first turned on, a voltage appears across transistor 3Q2 which drives current through diodes 3D1 and 3D3 to keep thyristors 2QS1 and 3QS2 turned on. When 1Q2 and 1Q4 start conducting, they send current through 3D6 and 3D7 to charge capacitor 3C1 after which current flows into the base of 3Q2 to cause the voltage across 3Q2 to be short circuited.

The Zener diode 3Z1 monitors the d-c voltage level. If the d-c voltage drops too low for the logic to operate properly, it will cause 3Q1 to turn off, and thereby send a gate signal to the restraint thyristors. This will block tripping as long as the d-c voltage is at a level which would otherwise cause an incorrect operation.

## Output Circuit (Voltage Detector Circuit Board)

Consider a trip signal from the restraint thyristors which sends current through 3Z2, 3R8, and into the base of 3Q3. This will turn on 3Q3 to give an unsupervised output at terminal 10 of the voltage detector circuit board.

## Out-of-Step Detection

The out-of-step blocking logic receives three inputs, two of which are compared to the third on a time basis. Operation of this logic can be understood best when referring to the circle characteristics and moving electrical center illustrated in Figure 6.

Under out-of-step conditions, the apparent impedance measured by the relay anywhere near the electrical center starts at a high value, gradually decreases to a much lower value, and then gradually increase again to a higher value, and thus the system goes through a complete beat oscillation. On the other hand, if the disturbance is a fault, the impedance seen by the relay will suddenly drop to a much lower value, and then either retain this value or slightly increase due to the effects of fault resistance, until the fault is cleared.

The SKSU relay uses this distinction between a fault and an out-of-step condition. Under out-of-step conditions, the impedance unit will operate when the electrical center moves across the 68(Z) line into zoneA. This provides an input into L1 (AND) to fulfil the necessary conditions for an output into the (25–45)/0 timer L2. These necessary conditions are: An input form 68(Z) + an input from L3 (OR) (which exists under normal conditions) + no input from 21-2G. Any other condition will stop the output from L1.

If the zone A condition exists long enough for the timer setting to expire, L2 will give an output which influences up to four bits of logic, the output for trip blocking, L3, L4, and L5. First, the output amplifier is driven to provide a signal at varicon terminal 5 which is applied to auxiliary logic to block tripping. The timer also drives L3 to insure a continued output from L3 into L1 when the electrical center moves into zone B. Additionally, the timer drives L4 which receives also an input from 21–2 (3ϕ) when zones B, C, and D conditions exist. When L4 receives these two inputs it initiates an output signal at varicon terminal 6. This output is applied to auxiliary logic to block the reclosing of a breaker which may have been allowed to trip. The fourth bit of logic driven by the timer is L5 (AND) located in the "OS Tripping" circuit. This is an optional feature and will be discribed later.

If a fault occurs within the 21–2 (3ϕ) characteristic such as in zone B, the 21–2 (3ϕ) input causes an L3 output into L1 to stop and thereby block L1 so that the L2 timer can never start. Likewise a ground fault which produces a 21–2G input will also block L1 so L2 cannot start. All of the out-of-step detection logic and out-of-step trip-block logic which is L1 through L4 is contained on the O.S. BLOCK circuit baord.

## Out-Of-Step Tripping

The tripping of a breaker during a swing condition will impose an excessive voltage across the breaker contacts if the clectrical center is close to the breaker location within the "C" zone of Figure 6. Therefore, it is not necessary to wait until the electrical center has passed through zone F and the swing voltages are more nearly in phase before tripping the breaker.

Additional logic, L5 through L10, must be specified when desired that the SKSU relay initiate out-of-step tripping. This additional logic is contained on two printed circuit board assemblies, O.S. TRIP (1) and O.S. TRIP (2).

# OPERATION

Referring to Figure 6 when 68(Z) operates it will block L9 to prevent tripping until the electrical center moves out of the 68(Z) characteristic and into zone F. In the meantime L5 receives a signal from L2, as described previously for a swing condition, and is subsequently switched when the electrical center enters zone C causing a signal to be received from 21–1 (3ϕ). L5 switches L6 which switches L7 and is maintained by feedback from L7. L8 is a delayed dropout timer which is also switched on by L7 and continues to provide a signal to L9 for approximately 40 milliseconds after the L7 signal is removed. The circuit is now latched in by the feedback from L7 so that nothing happens when the 21–1 (3ϕ) signal is removed by the swing moving out of zone C and into zones D and E. At the same time L9 is still blocked by the 68(Z) signal.

When the electrical center moves into zone F, 68(Z) will reset and permit an output from L9 to start L10 which is a 0.0 to 1000 millisecond timer. (This timer should be set by the user to the time required for the electrical center to move sufficiently away from the relaying location so an excessive voltage will not be imposed across the breaker contacts when tripping occurs. The time adjustment is made by adjusting potentiometer R9 on the O.S. BLOCK circuit style no. 201C271G01). When the L10 time expires, a trip signal is supplied to the O.S. Trip circuit and simultaneously a reset signal is supplied to turn off L7. With L7 turned off, L8 will maintain an output and sustains the O.S. Trip output for approximately 40 milliseconds after which the entire circuit resets to normal standby conditions.

# CHARACTERISTICS

## Distance Characteristics

A characteristic circle is established by setting two points on the circle, diametrically opposite one another, by means of the long reach and short reach compensators – Fig. 7. As it is shown in Fig. 4, the short reach setting $Z_{SR}$ is negative in respect to the long reach $Z_{LR}$ to produce a circle which includes the origin.

When the out-of-step condition occurs, the fault moves and crosses the circle impedance of SKSU, the resulting output in conjunction with 21–2 and

21-2G output of the out-of-step blocking logic board to provide a signal to block tripping and reclosing for this condition.

### General Characteristics

Impedance settings in ohms for the long reach can be made in steps of 3 per cent for any range between (1.1 – 31.8) and for short reach in step of 30% for any range between (.87 – 5.8) ohms. The maximum sensitivity angle, which is set for 75° at the factory, may be set for any value for 60° to 80°. A change in maximum sensitivity angle will produce a slight change in reach for any given setting of the relay. 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 ($P_{2A}$ or $P_{2C}$) shown in Fig. 4 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 $IT_{AB}$ or $IT_{CB}$. Thus the net voltage, V, is phase-shifted to change the compensator maximum sensitivity angle. As a result of this phase shift, magnitude of V is reduced.

Tap markings, in Fig. 2, are based upon a 75° compensator angle setting. If the potentiometer $P_{2A}$ and $P_{2C}$ are adjusted for some other maximum sensitivity angle, the nominal reach is different than indicated by the taps. The reach, $Z\theta$, varies with the maximum sensitivity angle, $\theta$, as follows:

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

## TAP PLATE MARKINGS

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Long Reach | 1.31 | 1.74 | 2.18 | 3.05 | 4.35 | 6.1 | 8.7 |
| Short Reach | .87 | 1.16 | 1.45 | 2.03 | 2.9 | 4.06 | 5.8 |

| $S_A$ | | |
|---|---|---|
| 1 | 2 | 3 |

± Values Between Taps =

| $M_A$ | | |
|---|---|---|
| .03 | .09 | .06 |

## CURRENT CIRCUIT RATING IN AMPERES

| "T" Tap Setting | | Continuous | | | 1 Second |
|---|---|---|---|---|---|
| | | S=1 | S=2 | S=3 | 240 |
| 5.8 | 8.7 | 5.0 | 8.5 | 9.5 | 240 |
| 4.06 | 6.1 | 6.0 | 10.0 | 10.0 | 240 |
| 2.9 | 4.35 | 8.0 | 10.0 | 10.0 | 240 |
| 2.03 | 3.05 | 10.0 | 10.0 | 10.0 | 240 |
| 1.45 | 2.18 | 10.0 | 10.0 | 10.0 | 240 |
| 1.16 | 1.74 | 10.0 | 10.0 | 10.0 | 240 |
| .87 | 1.31 | 10.0 | 10.0 | 10.0 | 240 |

### Burden

The burden which the relays impose upon potential and current transformers in each phase is listed in Table 1 and 2. The potential burden and burden phase angle are based on 69.3 bolts line-to-neutral applied to the relay terminals.

### Output Circuits

| | |
|---|---|
| Open Circuit Voltage | 18V to 21V d-c |
| Rated Current | 10 Milliamperes |

## SETTING CALCULATIONS

Long Reach (1.1 to 31.8 ohms) 1.31, 1.74, 2.18, 3.05, 4.35, 6.1, 8.7

Short Reach (.87 to 5.8 ohms) .87, 1.16, 1.45, 2.03, 2.9, 4.06, 5.8

| $S_A$ | | |
|---|---|---|
| 1 | 2 | 3 |

Values between taps ±

| $M_A$ | | |
|---|---|---|
| .03 | .09 | .06 |

Maximum sensitivity angle, $\theta$, 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 65°, set $\theta$ for a 60° maximum sensitivity angle by adjusting P2A and P2C.

Calculations for setting the SKSU relay are straightforward and apply familiar principles. Assume a desired forward looking balance point which is 2 secondary ohms greater than the zone 2 distance relay setting. The general formula for setting the ohms reach of the relay is:

$$Z\theta = Zpri \frac{R_C}{R_V} \qquad \text{Eq. (1)}$$

The terms used in this formula and hereafter are defined as follows:

Eq. (2)

$Z_\theta$ = the ohmic reach of the relay in secondary ohms when the maximum sensitivity angle is set for $\theta$ degrees.

$Z_{LR} = \frac{T_{AL}S}{1 \pm M}$ = the tap plate setting for the forward reach. ($T_{BL}$ must be set equal to $T_{AL}$)

$Z_{SR}$ = Tas = Tbs = the tap plate setting for the reverse reach.

$T_{AL}$, $T_{BL}$, $T_{AS}$, $T_{BS}$ = compensator tap value

S = auto-transformer primary tap value

$\theta$ = Maximum sensitivity angle setting of the relay (factory setting of $\theta = 75°$)

$\pm M$ = auto-transformer secondary 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 lower the Z setting. The sign is negative when "R" is above "L" and acts to raise the Z setting.)

Zpri = ohms per phase of the total line section

$R_C$ = current transformer ratio

$R_V$ = potential transformer ratio

The following procedure should be followed in order to obtain an optimum setting for the long reach setting.

1. A. Establish the value of $Z_\theta$ as above.
   B. Determine the tap blate value, $Z_{LR}$, using the formula:

$$Z_{LR} = Z_\theta \frac{\text{Sin } 75°}{\text{Sin } \theta°}$$

when $\theta = 75°$, $Z = Z_\theta$

2. Now refer to Table III for the optimum tap settings.
   A. Locate a table value for relay reach nearest the desired value $Z_{LR}$. (It will always be within 1.5% of the desired value).
   B. Select from the Table "S", "T", and "N" settings. "M" column includes additional information for "L" and "R" lead settings for the specified "M" value.
   C. Recheck the selected "S", "T", and "M" settings to assure the correct value of Z by using equation (2).

$$Z_{LR} = \frac{T_{AL}S}{1 \pm M}$$

Step 1A

For example, assume the desired reach, $Z\theta$, for the long reach compensator is 7 ohms at 60°.

Step 1B

The line angle of 60° requires that the relay maximum sensitivity angle be changed from a factory setting of 75° to the new value of 60°. Using equation (3), we find the corrected value for the relay tap settings:

$$Z_{LR} = 7 \times \frac{\text{Sin } 75°}{\text{Sin } 60°} = 7.8 \text{ ohms}$$

Step 2A

Ir. Table III, we find nearest value to 7.8 ohms is 7.76. That is $100 \times \frac{7.76}{7.8} = 99.5$ percent of the desired reach.

Step 2B

From Table III, read off:

S = 1
T = 8.7
M = ±.12

and "L" lead should be connected over "R" lead, with the "L" lead connected to .09 tap and "R" lead to tap "O".

Step 2C

Recheck settings:

$$Z_{LR} = \frac{T_{AL}S}{1 + M} = \frac{(8.7)(1)}{1 + .12} = 7.76$$

From Eq. (2)

$$Z\angle\theta = Z_{LR}\angle 60\pm = 7.76 \times .896 = 6.95$$

Fron Eq. (3)

which is 99.2 per cent of the desired setting

**Short Reach Setting**

There is no auto-transformer for short reach reverse connected compensator, therefore $Z_\theta$ may be as much as 15% off the desired reach. Assume a desired reach of $Z_\theta = 2.3 \angle 60°$ ohms. $Z_{SR} = \frac{2.3 \times \sin 75°}{\sin 60°} = 2.56$ ohms, select $T_{AS} = T_{BS} = 2.9$.

$$Z_\theta = Z_{SR} \angle 60° = 2.9 \frac{\sin 60°}{\sin 75°} = 2.6$$

which is 113 per cent of the desired setting.

## SETTING THE RELAY

The SKSU relays require settings for the two compensators ($T_{SR}$ and $T_{LR}$), the one auto-transformer primary ($S_A$) and secondary ($M_A$ and $M_C$). All of these settings are made with taps on the tap plate.

### Compensators $T_{SR}$ and $T_{LR}$

Each set of compensator 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. 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 operating current, be sure that the screws are turned to bind snugly but not so tightly as to break the tap screw. There are four T taps, two for long reach and two for short reach and connected in such a way to use delta current.

### Auto-Transformer Primary ($S_A$)

Primary tap connections are made through a single lead for each transformer. The lead comes out of the tap plate through a small hole located just below or above the taps and is held in place on the tap by a connector screw (Figure 2).

An "S" setting is made by removing the connector screw, placing the connector in position over the insert of the desired setting, replacing and tightening the connector screw. The connector should never make electrical contact with more than one tap tap at a time.

### Auto-Transformer Secondary ($M_A$)

Secondary tap connections are made through two leads identified as L and R for each transformer. These leads come out of the tap plate each through a small hole, one on each side of the vertical row of "M" tap inserts. The lead 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 III 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° ± 3° (current lagging voltage) in the factory. This adjustment need not be disturbed for line angles of 65° or higher. For line angles below 65°, set for a 60° maximum sensitivity angle by adjusting the compensator loading resistors $P_{2A}$ and $P_{2C}$. Refer to Repair Calibration when a change in maximum sensitivity angle is desired.

## 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 relay 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 panel due to the extended weight within the relay case.

## EXTERNAL CONNECTIONS

Figure 8 shows the external connections for an SKSU relay.

# TABLE III

## SETTINGS FOR 1.1 – 31.8 OHM RANGE

| | "S" = 1 | | | | | | | "S" = 2 | | "S" = 3 | | "M" | | LEAD CONNECTIONS | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| T = | 1.31 | 1.74 | 2.18 | 3.05 | 4.35 | 6.1 | 7.8 | 6.1 | 8.7 | 6.1 | 8.7 | +M | -M | "L" LEAD | "R" LEAD | |
| | 1.11 | 1.47 | 1.85 | 2.58 | 3.68 | 5.16 | 7.37 | — | 14.71 | — | 22.1 | +.18 | | .06 | 0 | "L" OVER "R" |
| | 1.14 | 1.51 | 1.89 | 2.65 | 3.78 | 5.30 | 7.56 | — | 15.11 | — | 22.7 | +.15 | | .06 | .03 | "L" OVER "R" |
| | 1.17 | 1.55 | 1.95 | 2.72 | 3.88 | 5.45 | 7.76 | 10.9 | 15.5 | — | 23.3 | +.12 | | .09 | 0 | "L" OVER "R" |
| | 1.20 | 1.6 | 2.00 | 2.8 | 3.99 | 5.6 | 7.98 | 11.2 | 16 | — | 23.9 | +.09 | | .09 | .03 | "L" OVER "R" |
| | 1.23 | 1.64 | 2.06 | 2.87 | 4.10 | 5.75 | 8.20 | 11.5 | 16.4 | — | 24.6 | +.06 | | .06 | .09 | "L" OVER "R" |
| | 1.27 | 1.69 | 2.12 | 2.96 | 4.22 | 5.92 | 8.45 | 11.8 | 16.9 | — | 25.3 | +.03 | | .03 | 0 | "L" OVER "R" |
| | 1.31 | 1.74 | 2.18 | 3.05 | 4.35 | 6.1 | 8.7 | 12.2 | 17.4 | — | 26.1 | 0 | 0 | 0 | .03 | |
| | 1.35 | 1.79 | 2.25 | 3.14 | 4.49 | 6.29 | 8.96 | 12.6 | 17.9 | — | 26.9 | | -.03 | 0 | .03 | "R" OVER "L" |
| | 1.39 | | 2.32 | 3.24 | 4.62 | 6.49 | 9.25 | 13 | 18.5 | — | 27.8 | | -.06 | .09 | .06 | "R" OVER "L" |
| | 1.44 | — | 2.4 | 3.35 | 4.78 | 6.70 | 9.55 | 13.4 | 19.1 | — | 28.7 | | -.09 | .03 | .09 | "R" OVER "L" |
| | | — | 2.48 | 3.46 | 4.94 | 6.93 | 9.88 | 13.9 | 19.8 | — | 29.7 | | -.12 | 0 | .09 | "R" OVER "L" |
| | — | — | 2.56 | 3.59 | 5.11 | 7.17 | 10.2 | 14.3 | 20.5 | 2.15 | 31.4 | | -.15 | .03 | .06 | "R" OVER "L" |
| | — | — | — | — | — | — | 10.6 | — | 21.2 | — | 31.8 | | -.18 | 0 | .06 | "R" OVER "L" |

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 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 cable. The grounding connection will be broken when the plug is disconnected.

Note that terminal number 1 is connected to the case within the relay and may be used for grounding the shields of connecting cable. The grounding connection 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-tapping screws and provide excellent low resistance contact with the case.

## RECEIVING ACCEPTANCE

Acceptance tests consist of an electrical test to make certain that the relay measures the balance point impedance accurately.

### Recommended Instruments for Testing

Westinghouse Type PC-161, Style #291B749A33 or equivalent a-c voltmeter

Westinghouse Type PA-161, Style #291B719A21 or equivalent a-c ammeter

Testing can be accomplished by use of the test connections shown in Figure 9.

Tripping is indicated by a d-c voltmeter reading. At the balance point, the output may be as low as 1 volt or 2 volts indicating that the system is only partially tripping. This is a normal balance point characteristic. However, a 5 per cent increase in current should produce an output of 15 to 20 volts. A reading of less than 15 volts indicates a defective tripping output.

### Distance Unit – Electrical Test

1. Check the electrical response of the relay by using the test connection shown in Figure 9.
2. Set the long and short reach setting as follows:

   $T_{AL}$ and $T_{BL}$ - Set for the highset Tap value (8.7)

   $T_{AS}$ and $T_{BS}$ - Set for 2.03

   $S_A$ - Set on 1

   "R" for $M_A$ - Set on 0

   "L" for $M_A$ - Set on .06 (top position)
3. Long reach testing - Apply 30 volts a-c between terminal 7 and 8 and set the switch in the test circuit on the normal polarity.
4. Supply 105% of the current necessary to trip the relay at 75° (current lags voltage); swing the phase shifter to determine the two angles, $\theta 1$ and $\theta 2$, at which relay just trips. The maximum sensitivity angle $\theta$ is $\frac{\theta 1 + \theta 2}{2}$.

   This should be 75° ± 3°. The angle shifts from 75° at $70V_{LL}$ to approximately 70 at $5V_{LL}$. This is a normal response of the logic and is not detrimental to the relay protection.
5. The current required to make the relay trip should be within the limits given in Table 4. at an angle of 75° current lags.
6. Short reach compensator – Throw the switch in the test circuit to the "reverse polarity" and apply 30 volts between terminal 7 and 8.
7. Repeat parts 4 and 5 of the long reach compensator and check the current against Table 5. 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.

## ROUTINE MAINTENANCE

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

### Distance Units:

CAUTION: Before making hi-pot test, connect together varicon connector terminals 3, 4, 5, 6, 10, 11, 14, and 15 to avoid destroying components in the static network. These connections are not necessary for surge testing.

Since the relay uses the line to line voltage and delta current, the impedance measured by the relay would be $Z_R = \frac{V_{L-L}}{2I_L}$

## REPAIR CALIBRATION

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

1. Replace the operating circuit board with card extender style # 849A534G01 and disconnect. but do not remove, all other d-c boards. Apply rated d-c voltage between varicon terminals 3 and 4 with positive on terminal 4. Measure the d-c voltage on the card extender between 1 and 14 with 14 as positive. Voltage should be between 19V d-c and 21V d-c.
2. Remove the card extender and reconnect all boards. Apply rated Vd-c and check for outputs on the Output Terminals. There should be none.

| CIRCUIT BOARD | OUTPUT TERMINALS AND TEST POINTS | NORMAL TRIPPING OUTPUT |
|---|---|---|
| O.S. BLOCK BOARD | O.S.T.B.: TP10 and Varicon Term. 5 | 15 to 20 volts |
| | O.S.T.B.: TP11 and Varicon Term. 6 | |
| O.S. Trip Board | TP8 and Varicon Term. 14 | |

The following steps are straightforward testing and calibrating procedure, but if any misoperation is noticed during the testing of the relay, the "trouble shooting" section 25, 26, 27, and 28 could be helpful to locate the faulty component.

3. <u>Distance Unit Calibration</u>

   Check to see that the taps on front of the tap block are set as follows:

   $T_{AL}$ and $T_{BL}$ - Set on the highest tap value (8.7)
   $T_{AS}$ and $T_{BS}$ - Set on the lowest tap value
   $S_A$ - Set on 1
   "R" for $M_A$ - Disconnect
   "L" for $M_A$ - Set for .06 (top position)

4. <u>Maximum Sensitivity Angle adjustment Long Reach Compensator</u>

   (Standard setting is 75°)

   Connect the relay for a fault as indicated in the test circuit. Connect a high resistance voltmeter(2000 ohms/volts) between the "R" lead and the .03 tap position of $M_A$ and adjust voltage between terminal 7 and 8 for 30 volts.

5. Pass the current, called for in Table 4 for 30 volts, through terminal 1 out of 3 with the phase shifter set for the desired maximum sensitivity angle. Adjust potentiometer $P_{2A}$ for a null, or minimum reading, on the voltmeter.

6. Swing the phase shifter and adjust $P_{2A}$ slightly to obtain a minimum reading on the voltmeter when the phase angle reading is at the desired maximum sensitivity angle. This adjusts the long-reach compensator angle.

7. <u>Maximum Sensitivity Angle Check – Long Reach</u>

   Reconnect R and L lead, and use the 30 volt condition in Table 4. Supply 105% of the current necessary to trip at the calibrated angle of maximum sensitivity and swing the phase shifter to determine the two angles, $\theta_1$ and $\theta_2$ at which the unit just trips. The maximum sensitivity angle $\theta$ is $\frac{\theta_1 + \theta_2}{2}$.

   This value should be within + 3°. Adjust potentiometer PS to obtain the desired maximum sensitivity angle for this check.

8. <u>Maximum Sensitivity Setting Short-Reach Compensator</u>

   Set $T_{AL}$ and $T_{BL}$ on minimum value, $T_{AS}$ and $T_{BS}$ on maximum value. Open the $S_A$ tap by removing the tap screw. Connect the high resistance voltmeter in series with the varicon input terminal No. 7.

9. Reverse the current connections to terminal block terminals 1 and 4 and adjusting potentiometer $P_{2C}$.

10. Long Reach Impedance Curve Check

With the switch in the normal polarity, and the taps settings as follows, the former trip current should be within the limits listed for the given test voltage and angle in Table 4 below.

11. $T_{BL}$ and $T_{AL}$ - Set on 8.7
$T_{BS}$ and $T_{AS}$ - Set on 2.03
$S_A$ - Set on 1
"R" for $M_A$ - Set on 0
"L" for $M_A$ - Set on -06 (top position)

## TABLE IV

| VOLTS BETWEEN 7&8 | AMPS TO TRIP FOR $\theta = 75°$ 1.1 – 31.8 RANGE | |
|---|---|---|
| | IMIN | IMAX |
| 5.0 | .33 | .36 |
| 30.0 | 1.98 | 2.1 |
| 70.0 | 4.7 | 4.8 |

| VOLTS BETWEEN 7&8 | AMPS TO TRIP FOR $\theta = 60°$ 1.1 – 31.8 RANGE | |
|---|---|---|
| | IMIN | IMAX |
| 5 | .37 | .4 |
| 30 | 2.21 | 2.34 |
| 70 | 5.25 | 5.36 |

12. Circuit Boards Test

Connect a jumper between varicon connector terminals 7 and 8, jumper terminal 4 block block terminals 2 and 4 together, and pass 2 amperes into terminal block 3 terminal 1 and out of terminal 3. There should be an O.S.T.B. output of TP10 and varicon term. 5.

13. With the output at relay term. 5, supply 15 to 20 volts d-c pos. to varicon terminal 10 (neg. to term. 3). This should produce an O.S.R.B. output at varicon term. 6.

14. Supply 15 to 20 volts d-c pos. to varicon term. 11. Outputs at 5 and 6 should drop to zero.

15. With relay de-energized, apply rated V d-c, supply 15 to 20 volts d-c pos. to varicon term. 10 and then pass 2 amperes a-c into terminal block terminal 1 and out of terminal 3. There should be no output from either varicon terminals 5 or 6.

Repeat 6 above except supply 15 to 20 volts d.c pos. to varicon term. 11 instead of term. 10. There should be no output from either varicon terms. 5 or 6.

The out-of-step block logic has already been functionally tested. However, the timer range of R9 must be checked and set.

16. Space out the O.S. Block Circuit Board located in position 6 with card extender style 849A534G01. With rated V d-c on the relay and R9 fully counter clockwise, apply 15 to 20 volts d-c position to the circuit board terminal 6 and check the time for an output to appear at TP10. This should be 25 milliseconds or less.

17. Set R9 fully clockwise, apply 15 to 20 volts pos. d-c to P.C.B. terminal 6 and check time required for an output to appear at TP10. This should be 45 milliseconds or more.

18. Leave R9 set for 25 milliseconds and return the PC board back inside the relay.

## OUT-OF-STEP LOGIC

19. Space out the O.S. Trip (2) circuit board with the card extender and trip the O.S.T.B. unit with a 30 volt a-c fault condition. Apply 15 to 20 volts d-c pos. to varicon term. 15 for one second. Reset the O.S.T.B. unit by removing the a-c amperes and check for a 40 millisecond output at varicon terminal 14.

20. Set potentiometer R13 on the O.S. Trip (2) board fully counterclockwise and repeat step 19. The output at varicon 14 should appear within 1 millisecond after the a-c current is removed.

21. Set R13 fully clockwise and repeat step 19. The output should appear one second or more after the a-c current is removed.

22. Leave R13 set for 500 milliseconds. Relay test is complete.

## Trouble Shooting

23. For trouble shooting compensator when "amperes to trip" is out of limits: The compensator output can be checked by connecting the voltmeter between the "L" lead of $M_A$ and jack $J_1$ located just below $P_{2A}$. Pass 5 amperes through the compensator. The secondary voltage should be:

$V_S = 10.35\ T \sin\theta \pm 1.0\%$

where: $\theta$ = the desired maximum sensitivity angle

T = compensator tap setting

10.35 = a design constant = $\frac{10}{\sin 75°}$

1.0% = the allowable variation from nominal

| | | VS VOLTS FOR GIVEN "T" SETTINGS | |
|---|---|---|---|
| $\theta$ | Va | Ts = 5.8 | $T_1$ = 8.7 |
| 75° | 10T | (58) 57.4 to 58.6 | (87) 86.1 to 87.9 |
| 69° | 8.96T | (52) 51.5 to 52.5 | (78) 77.2 to 78.8 |

## Auto-Transformer Check

24. Set $S_A$ on tap number 3. Set the "R" lead of $M_A$ on O.O. Apply 90 (± 1) volts between varicon connector terminals 7 and 8. Measure the voltage from varicon connector terminal 8 to the #1 tap of $S_A$. It should be 30 (± 1) volts. From 8 to the #2 tap of $S_A$ should be (± 1) volts.

25. Set $S_A$ on 1 and apply a voltage $V_T$ (which is equal to 100 volts ± 1 volt a-c) between varison terminal 7 and 8. Measure the voltage drop from 8 to each of the $M_A$ taps. This voltage should be equal ± 1 volt to the sum of $V_T$ = (the sum of digits between "R" and the tap being measured).

Example: 99 = (103 + .09) x 100 = 111 volts ± 1 (R set on O.O, L set on .09). If the voltage readings are not within limits, then the transformer connections are wrong.

26. If the relay is within the above (25, 26, 27) calibration, and the relay does not still operate properly, there is either a defective board or a wrong wiring.

## RENEWAL PARTS

Repair work can be most satisfactorily done at the factory. However, interchangeable parts can be furnished to the customers who are equipped for doing repair work. When ordering parts, always give the complete nameplate data. The chassis outline is shown in Fig. 10.

# ELECTRICAL PARTS LIST

| ITEM | DESCRIPTION | WESTINGHOUSE STYLE NUMBER |
|---|---|---|
| | **CAPACITORS** | |
| $C_{2A}$ | 1.8 MFD | 14C9400H12 |
| $C_{1A}$ | 1.0 MFD | 1876999 |
| $C_{3A}$ | .45 MFD | 1723408 |
| $C_S$ | .45 MFD | 1723408 |
| | **ZENER DIODE** | |
| DZP | 1N2984B (20V 5%) | 762A631H01 |
| $Z_1$ to $Z_4$ | 1N2846A | 184A845H08 |
| $J_1$, $J_2$ | Test Jacks | |
| | **POTENTIOMETER** | |
| $P_{2A}$ & $P_{2C}$ | 1K | 836A635H03 |
| $P_S$ | 5K | 836A635H05 |
| | **RESISTOR** | |
| $R_S$ | 10K Adjustable | 185A925H05 |
| $R_C$ | 1.5K | 1267293 |
| $R_{AC}$, $R_A$, $R_{MA}$ | 1.8K | 1201004 |
| $R_{DC}$, $R_{3C}$ | 80 Ohms (25W) for 48V d-c | 1201005 |
| $R_{DC}$, $R_{3C}$ | 400 Ohms (25W) for 125V d-c | 1202587 |
| $R_1$ & $R_2$ | 500 Ohms | 763A129H03 |
| | **AUTO-TRANSFORMER** | |
| S & M | Printed Circuit Board | |
| | Operating Circuit Board | 899C345G01 |
| | Polarizing | 899C347G01 |
| | Voltage Detector | 201C308G01 |
| | O.S. Block C.B. | 201C271G01 |
| | O.S. Trip (1) C.B. | 201C270G01 |
| | O.S. Trip (2) C.B. Card Extender | 201C290G01 |
| $T_1$, $T_2$ | Coupling Transformer, Center Taped Secondary (Step up 1:8) | 292B563G05 |
| ($T_{AL}$ & $T_{BS}$) & ($T_{AS}$ & $T_{BS}$) | Compensator Assemblies | 671B471G01 |
| $X_L$ | Memory Circuit Reactor | 606B544G02 |
| $X_S$ | Center Taped Auto-Transformer for Phase Shift Circuit | 671B470G01 |

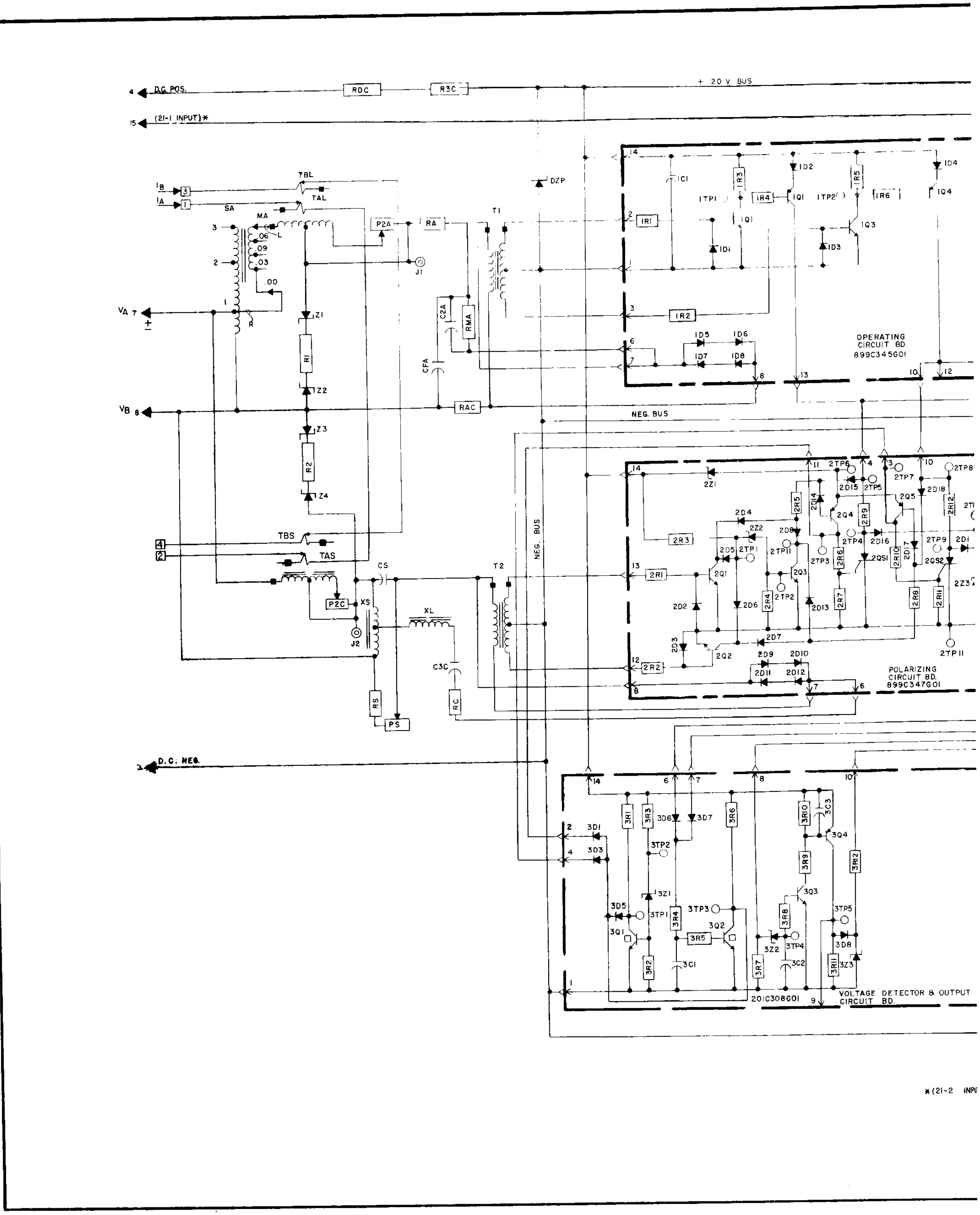
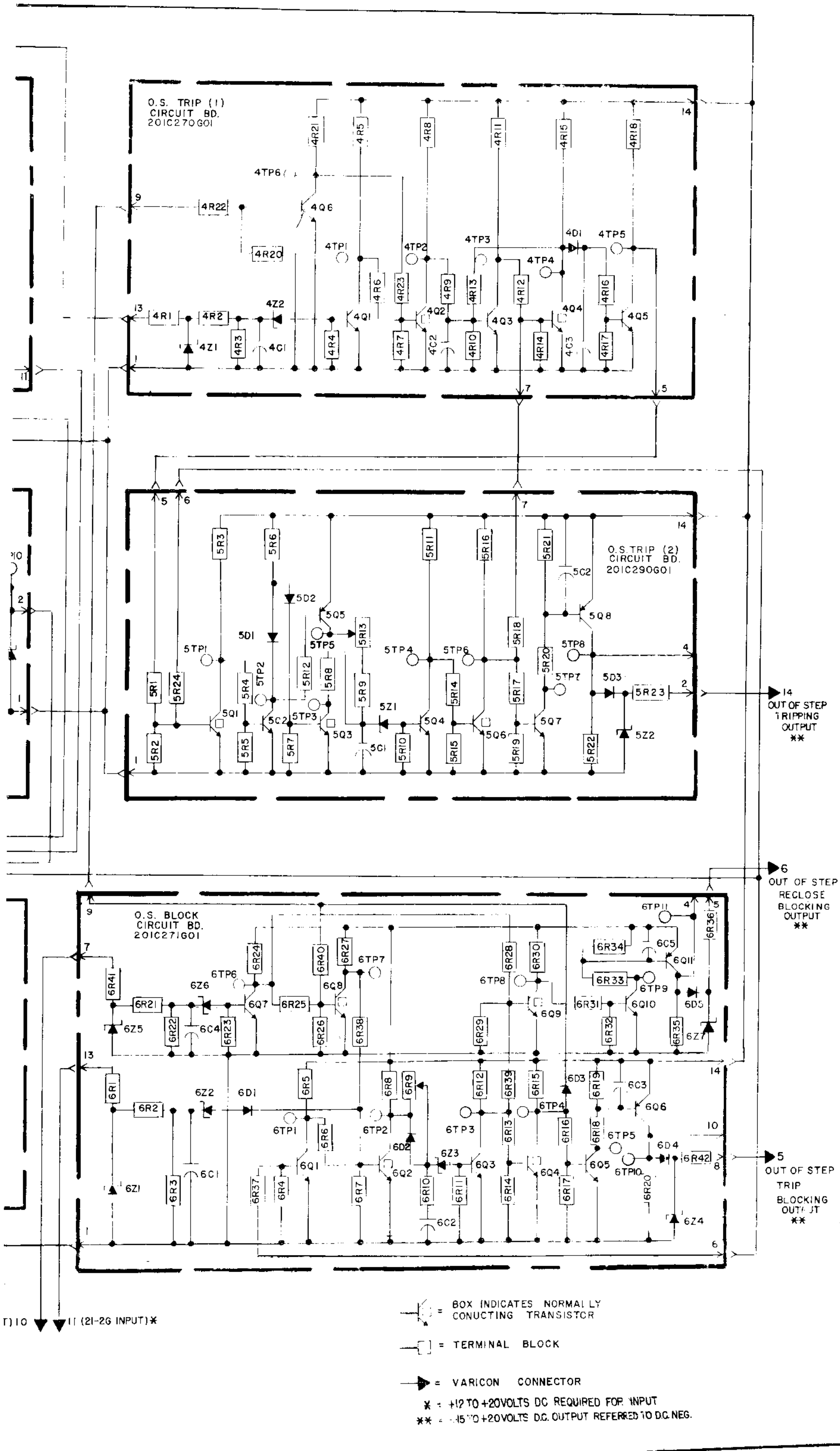



*Fig. 4 Detaile*




| RESISTOR | STYLE | REQ. | [illegible] |
|---|---|---|---|
| RA·RMA·RAC | 1201004 | 3 | 1.8K |
| RC | 1267293 | 1 | 1.5K |
| RDC·R3C (48V.D.C.) | 1201005 | 2 | 8[illegible] Ω |
| RS | 185A925H05 | 1 | 10 K |
| RDC R3C (125V.D.C.) | 1202587 | 2 | 400 Ω |
| R1·R2 | 763A129H03 | 2 | 500 Ω |
| 1R4·1R6·2R5·2R8 | 184A763H49 | 4 | 8.2[illegible] |
| 2R7·2R9·2R11·2R12·3R1 | 184A763H37 | 5 | 2.7K |
| 3R9· ·4R5·4R8·4R11· | 184A763H47 | 21 | 6.8K |
| 4R15·4R18·4R21·5R3·5R6 | " | | " |
| 5R11·5R16·5R21·6R5·6R12· | " | | " |
| 6R15·6R18·6R24·6R27· | " | | " |
| 6R30·6R33 | " | | " |
| 2R3 | 184A763H63 | 1 | 33 K |
| 2R6 2R10 · 6R28 | 629A531H42 | 3 | 2.7K |
| 1R3·1R5 | 184A763H99 | 2 | 1 MEG |
| 3R2·4R6·4R8·4R9·4R12· | 184A763H61 | 23 | 27K |
| 4R13·4R16·4R22· 5R24 | " | | " |
| 4R23·5R1·5R4·5R12·5R14 | " | | " |
| 5R17·5R20·6R6·6R13·6R16 | " | | " |
| 6R25·6R38·6R39·6R40 | " | | " |
| 3R3 | 184A763H57 | 1 | 18K |
| 3R10· ·4R4·4R7·4R10· | 184A763H51 | 24 | 10K |
| 4R14·4R17·4R20·5R2·5R5· | " | | " |
| 5R7·5R22·5R15·5R19· | " | | " |
| 6R4·6R7·6R11·6R14·6R17· | " | | " |
| 6R19·6R23·6R26·6R29· | " | | " |
| 6R32·6R34 | " | | " |
| 3R11 4R3·6R3·6R22· | 184A763H73 | 6 | 82K |
| 6R20· 6R35 | " | | " |
| 4R1·4R2·6R1·6R2·6R21· | 184A763H43 | 6 | 4.7K |
| 6R41 | " | | " |
| 3R4·1R1·1R2 | 184A763H75 | 1 | 100 K |
| 3R5 2R1·2R2 | 184A763H83 | 1 | 220K |
| 3R6 | 184A763H45 | 1 | 5.6K |
| 3R7·3R8· | 184A763H69 | 4 | 56 K |
| 3R12· ·5R23·6R42· | 762A679H01 | 3 | 150 Ω |
| 5R8·6R10 | 863A908H02 | 2 | 33 Ω |
| 5R9 | 18 A763H07 | 1 | 150 Ω |
| 6R8 | 629A531H58 | 1 | 12 K |
| 5R10 | 184A763H68 | 1 | 51K |
| DIODE | | | |
| 3D1 TO 3D8 4D1·5D1 TO 5D3· | 837A692H02 | 18 | 1N645A |
| 6D1 TO 6D5 | " | | " |
| 1D1 TO 1D8·3D1 TO 3D18 | 188A342H06 | 26 | CER69 |
| | | | |
| ZENER DIODE | | | |
| 2Z2·3Z1·2Z3 | 186A797H01 | 3 | 1N758 |
| 3Z2· | 186A797H12 | 1 | 1N752A |
| 3Z3· ·5Z2·6Z4·6Z7 | 862A288H01 | 4 | 1N3688A |
| 4Z1·6Z1·6Z5 | 185A212H06 | 3 | 1N3686B |
| 2Z1·4Z2·6Z2·6Z6 | 186A797H06 | 4 | 1N957B |
| 5Z1 6Z3 | 184A639H11 | 2 | 1N1315A |
| Z1 TO Z4 | 184A845H08 | 4 | 1N2846A |
| DZP | 762A631H01 | 1 | 1N2984B |
| CAPACITOR | | | |
| 1C1 | 187A508H10 | 1 | 18 MFD |
| 3C1 | 187A624H02 | 1 | .25MFD |
| 3C2 | 187A624H.0 | 1 | .015MFD |
| 3C3· ·6C3·6C5·5C2 | 837A241H03 | 4 | .27 MFD |
| 4C1·6C1·6C4 | 849A437H04 | 3 | .047MFD |
| 4C2 | 848A646H01 | 1 | .068 MFD |
| 5C1 | 184A661H10 | 1 | 6.8 MFD |
| 4C3 | 837A241H15 | 1 | 1 MFD |
| 6C2 | 837A241H20 | 1 | 1.8 MFD |
| CS·C3C | 1723408 | 2 | .45MFD |
| C2A | 14C9400H12 | 1 | 1.8 MFD |
| CFA | 1876999 | 1 | 1 MFD |
| | | | |
| TRANSISTOR | | | |
| 1Q1 1Q3·2Q1·2Q5 | 848A851H01 | 4 | 2N3991 |
| 2Q3 | 184A638H18 | 1 | 2N697 |
| 1Q2·1Q4·2Q4·2Q5 | 184A638H20 | 4 | 2N1132 |
| 3Q4·3Q6·5Q5·5Q8·6Q6·6Q11 | 849A441H01 | 6 | 2N3645 |
| 3Q1·3Q2·3Q3·3Q5·4Q1 TO | 848A851H02 | 25 | 2N3417 |
| 4Q6·5Q1 TO 5Q4·5Q6·5Q7· | " | | " |
| 6Q1 TO 6Q5·6Q7 TO 6Q10 | " | | " |
| | | | |
| TRANSFORMER | | | |
| T1·T2 | 292B563G05 | 2 | |
| | | | |
| SWITCH | | | |
| 3QS1·3QS2 | 185A517H05 | 2 | 2N884 |
| | | | |
| POTENTIOMETER | | | |
| 6R9 | 629A430H08 | 1 | 15 K |
| P2A·P2C | 836A635H03 | 2 | 1 K |
| PS | 836A635H05 | 1 | 5 K |
| 5R13 | 629A430H05 | 1 | 200K |

5317D94

d Internal Schematic

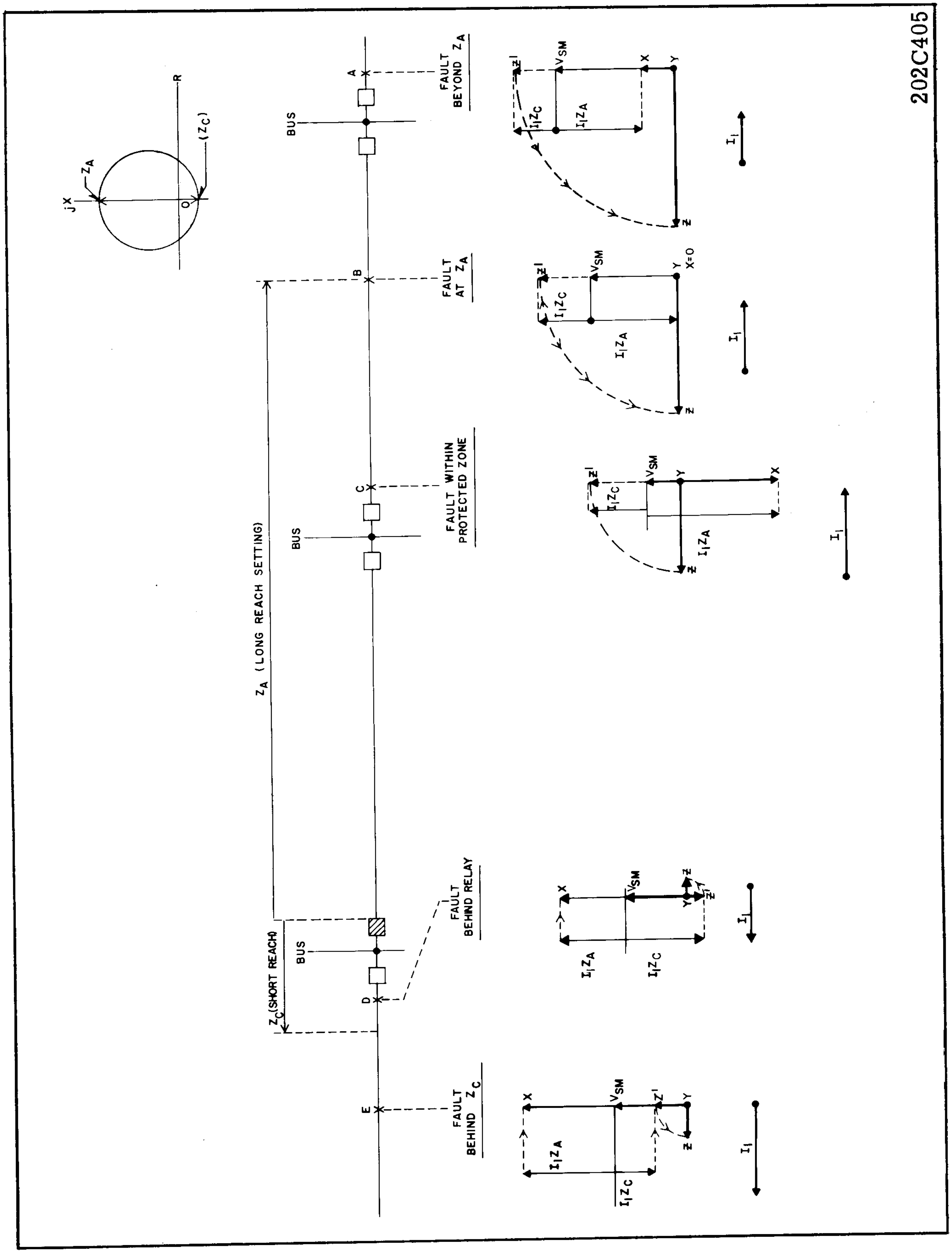



*Fig. 5 Voltage and Current Condition for SKSU*

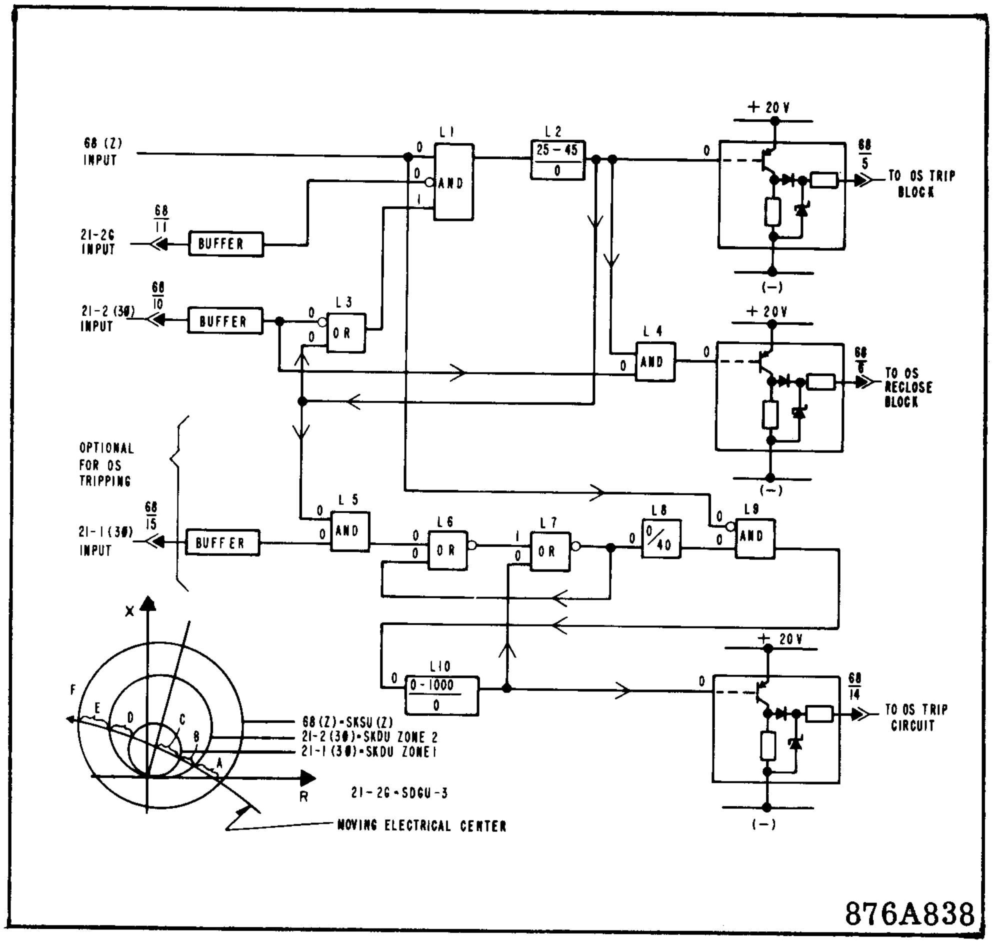



*Fig. 6 Out-of-Step Logic*

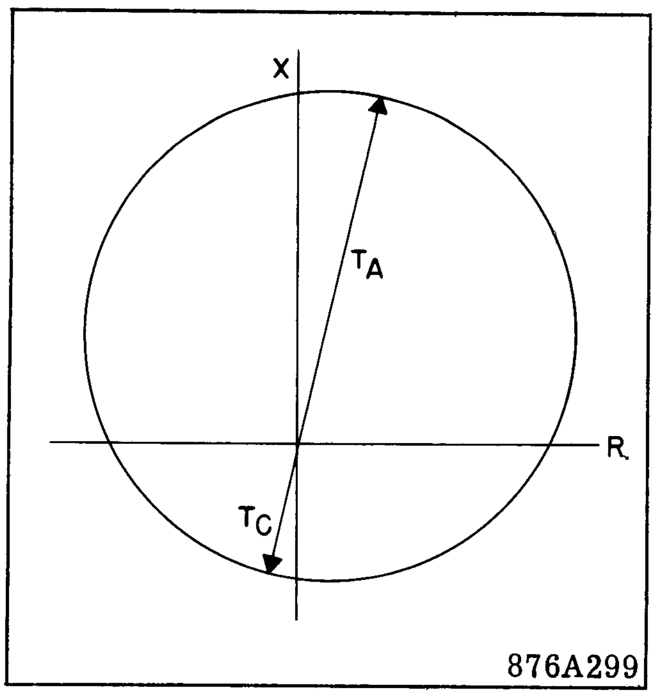
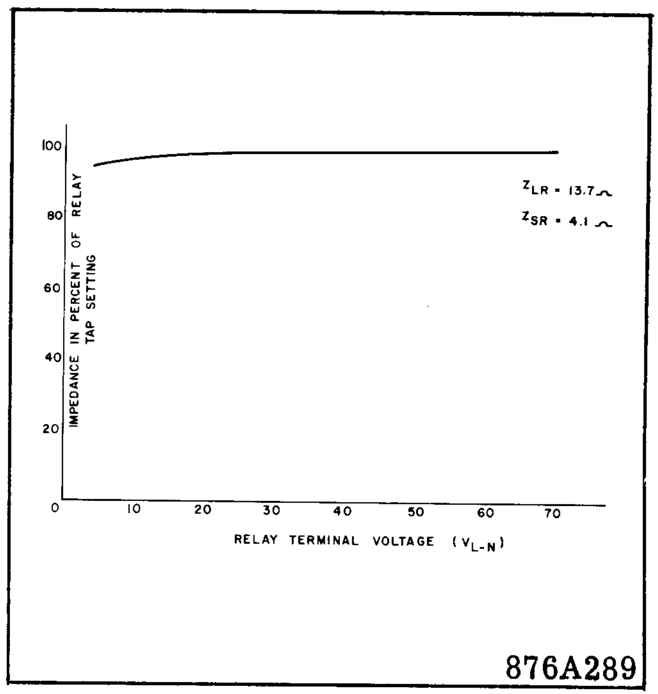



*Fig. 7 Circle Characteristic*




*Impedance Curve*

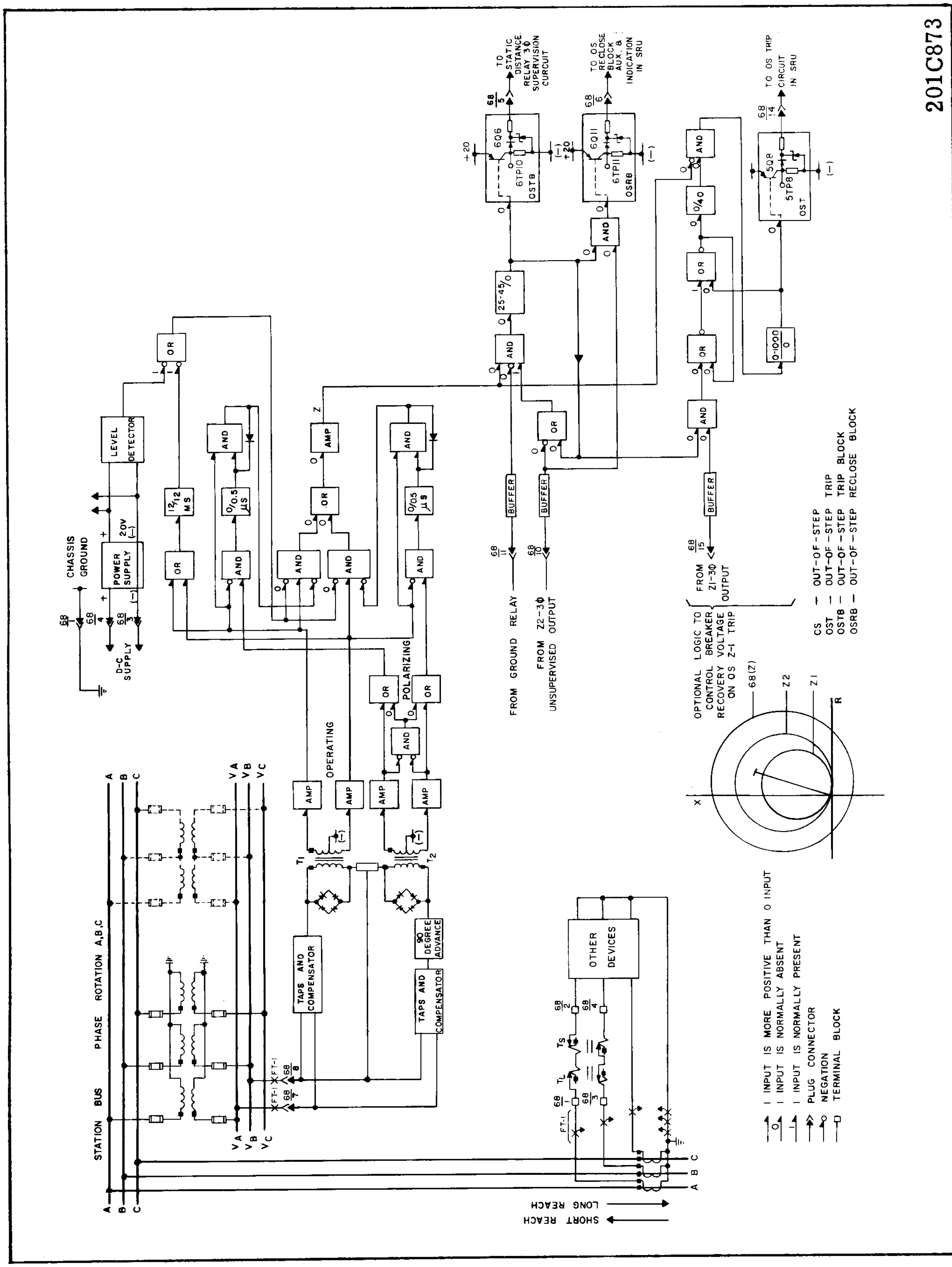



*Fig. 8 External Schematic*

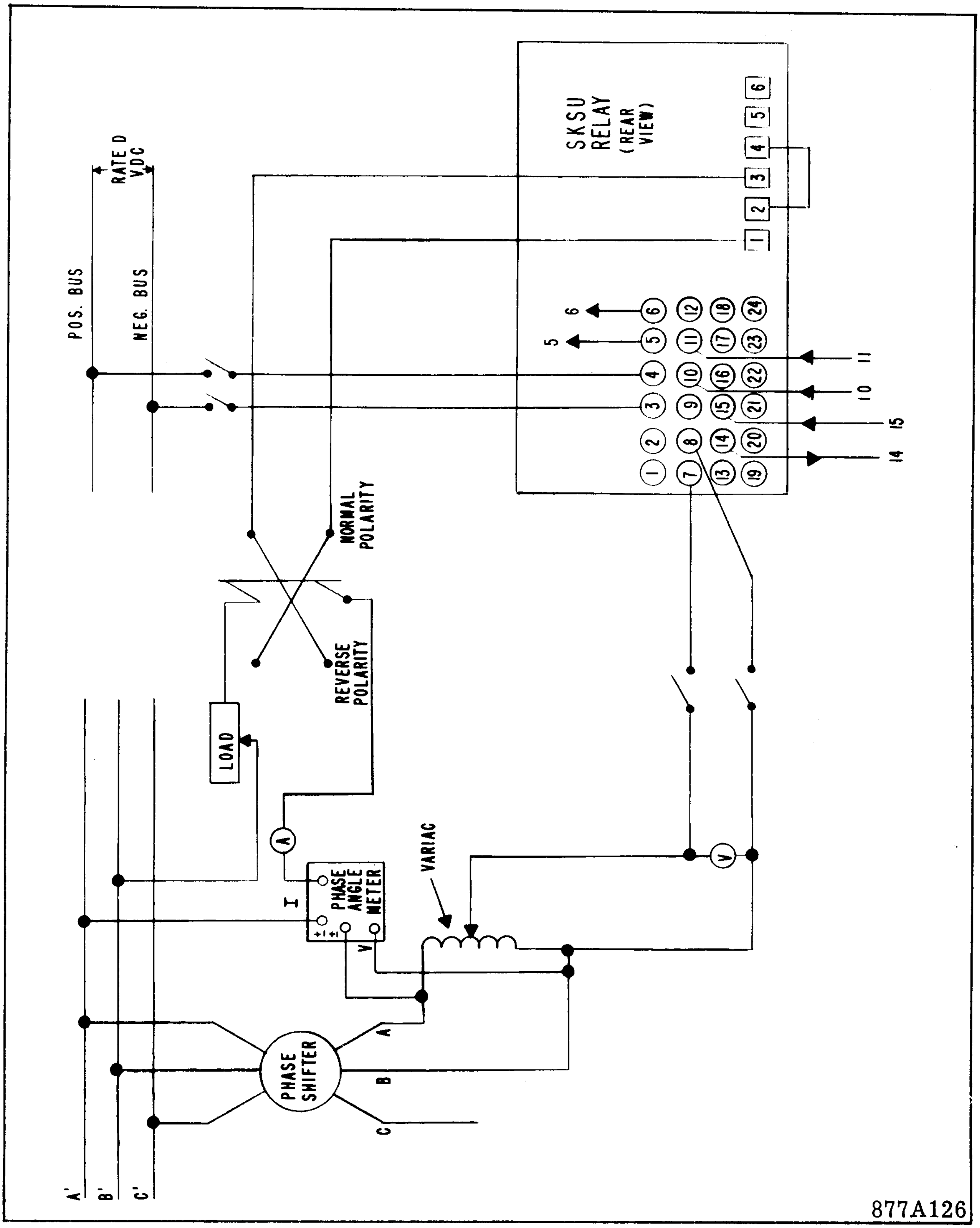



Fig. 9 Test Circuit

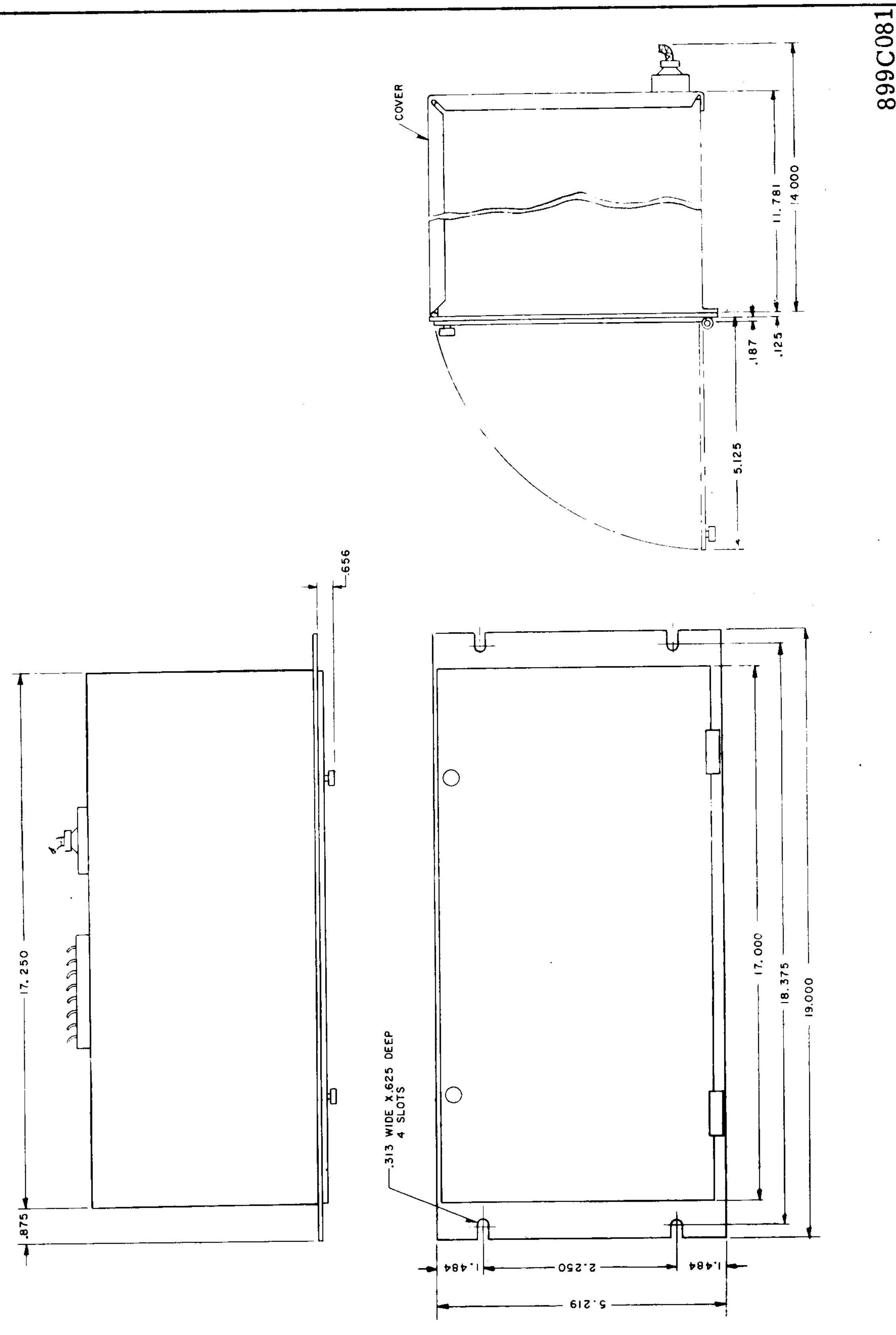



*Fig. 10 Chassis Outline*

**WESTINGHOUSE ELECTRIC CORPORATION**

**RELAY-INSTRUMENT DIVISION**

**NEWARK, N. J.**

Printed in U.S.A.

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# INSTRUCTIONS

# TYPE SKSU OUT-OF-STEP RELAY

## APPLICATION

The SKSU relay is a single phase compensator distance relay used with the three-phase element of an SKDU relay to sense an out-of-step condition on the power system.

Its functions, following detection of out-of-step are:

1. Block the development of a tripping output of the three-phase element of one or more SKDU relays.
2. Block high-speed reclosing, through an auxiliary device (ARS or SRU).
3. Temporarily block tripping of the Zone 1 SKDU three-phase element until the SKSU distance element resets. This forces a more favorable recovery voltage to appear across the circuit breaker contacts at the instant of interruption, substantially reducing the duty. This function is optional.

## CONSTRUCTION

The type SKSU relay consists of two air gap transformers (compensators) one auto-transformer, a phase shifting network, a memory circuit, and two isolating transformers which couple the a-c quantities into the static network, and the relay's case.

The static circuit contains either four or six printed-circuit boards. Four are required to provide the out-of-step-blocking logic. Two additional logic boards are required when an out-of-step-tripping function is desired. They 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.

A hinged and removable door provides access to all adjustments and printed-circuit boards. A 24-terminal jack provides external voltage connections, and a terminal block provides current connections.

### Compensators

The compensators which are designated $T_{LR}$ and $T_{SR}$ are three-winding air-gap transformers. There are two primary current windings, $T_{AL}$, $T_{BL}$ for long-reach and $T_{AS}$, $T_{BS}$ for short reach. Each current winding has seven taps which terminate at the tap block, Fig. 2. The T values for short-reach compensators are marked (0.87, 1.16, 1.45, 2.03, 2.9, 4.06, and 5.8), and for long reach (1.31, 1.74, 2.18, 3.05, 4.35, 6.1, and 8.7).

A voltage is induced in the secondary which is proportional to the primary tap value and the 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 proportionately have been precisely set at the factory. The clamps which hold the laminations should not be disturbed by either tightening or loosening the clamp screws.

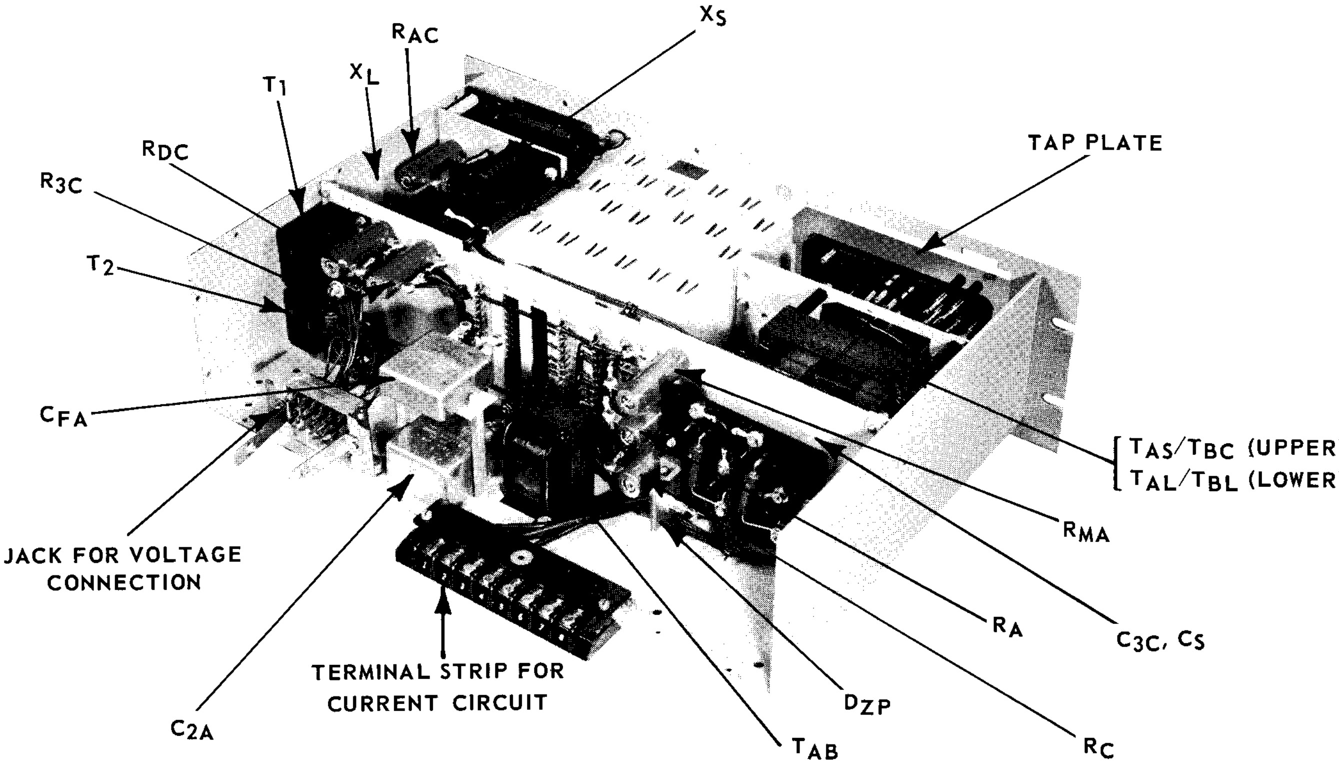
The secondary winding has a single tap which divides the winding into two sections. One section is connected subtractively in series with the relay terminal voltage. Thus the voltage which is proportional to the phase current is subtracted vectorially from the relay terminal voltage. The second section is connected to an adjustable loading resistor and provides a means of adjusting the phase angle relation between the current and induced secondary voltage. The phase angle may be set any value between 60° to 80° by adjusting the resistor between its minimum and maximum value respectively or for 89° by open circuiting the resistor. The factory setting is for a maximum sensitivity angle of 75° ± 3° current lagging voltage.

### Auto-Transformer

The auto-transformer has three taps on its main winding, S, which are numbered 1, 2, and 3 on the tap block, Figure 2. A tertiary winding M has four taps which may be connected additively or sub-

SUPERSEDES I.L. 41-492.2
*Denotes change from superseded issue.

EFFECTIVE JULY 1969




* *Fig. 1. Relay's Picture*

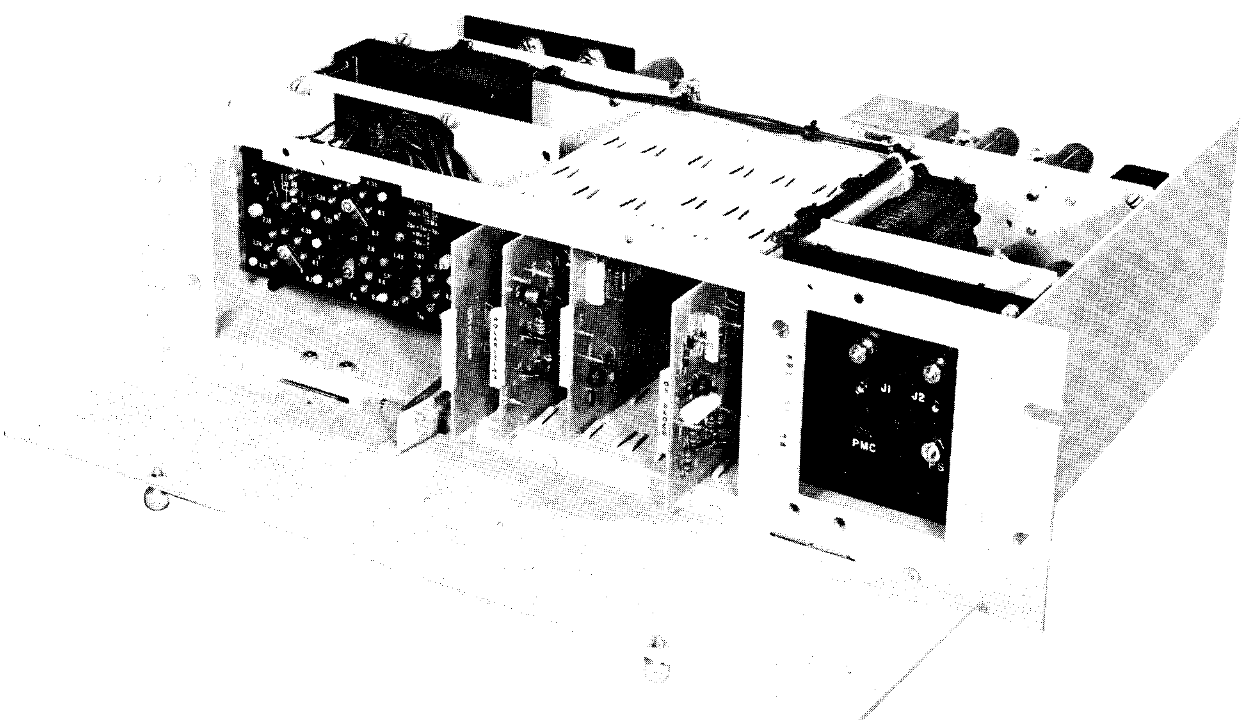



*Fig. 2. Tap Plate (Picture)*

tractively to inversely modify the S setting by any 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.

The auto-transformer makes it possible to expand the basic range of T ohms by a multiplier of $\frac{S}{1 \pm M}$. Therefore, any relay ohm "long-reach" setting can be made within ± 1.5 percent from the minimum value of a given range by combining the compensator taps $T_{LR}$ with the auto-transformer taps SA - MA.

## Phase Shifting Circuit

"Polarization" is the reference against which the "operate" signal is compared. Polarization for this relay is obtained by shifting the phase 1-2 voltage ahead 90°. The phase shifting circuit consists of a center tapped auto-transformer, XS, which supplies voltage to a series connected resistance and capacitor, RS plus PS and CS respectively (Figure 4). Voltage between the resistor-capacitor junction and the auto-transformer center tap leads the applied voltage by 90°.

## Memory Circuit

The memory circuit consists of a large inductive reactance, XL, a large capacitive reactance, C3C, and a resistor RC which are series connected and are tuned very closely to sixty Hertz. In the event of a close-in fault which drops the relay terminal voltages to zero, the energy trapped in memory circuit will delay relatively slowly, while oscillating at a sixty Hertz frequency. This will maintain a polarizing signal long enough for the relay to operate with an accurate reach and directional sense.

## Isolating Transformers

Transformers T1 and T2 serve two purposes. Firstly, they isolate the a-c circuits from the d-c circuit. Secondly, they amplify the clipped a-c signal by a factor of 1:8 to make the relay sensitive to low level input signals.

## Printed Circuit Board Assembly

The printed circuit boards shown in Fig. 3 contains all the resistors, diodes, transistors, and thyristors necessary to perform the functions of a polarized phase angle comparison unit. All the components are identified by a letter and two numbers. The letter indicates the component's name, the number in the left is the circuit board number, and the number in the right of the letter is the component's number.

In these circuit boards the resistors are identified by R, the diodes by D, transistors by Q, thyristors by QS, capacitors by C, the Zener diodes by Z, and test points by TP.

When facing the component side with terminals at the bottom, terminals are numbered from right to left starting at 1 and going through 14. These terminal numbers are shown within brackets on the internal schematic and will be referred to as Printed Circuit Terminals, PCT, in the trouble shooting section.

## Relay Case

The jack plug on the rear has 24 terminals numbered left to right and top to bottom. Thus terminal No. 1 is located in the upper left hand corner when viewed from the rear and terminal 24 is in the lower right hand corner. Terminal No. 1 is connected internally to the chassis ground and may be used for grounding the connecting cable shields.

There is also an 8-terminal strip used for current terminals which is located in the right hand side of rear when viewed from the back. The terminals are numbered from left to right.

The chassis case, cover, and front panel have electrical connections established by the use of shakeproof washers which cut through any paint or protective coating to make electrical contact with the base metal. The complete relay is then grounded to the switchboard or cabinet by an external wire connection which must be made by clamping the wire under a shakeproof washer which also serves to help hold the cover in place.

The door is hinged at the bottom and is secured at the top by two captive screws. It may be opened to 90 degrees where it is stopped by a slotted strap attached to the door and also to the frame of the case. To remove the door, release the strap by either unscrewing it or unhooking it from the door and then slide the door to the right to disengage the hinges

Printed-circuit boards are connected into the electrical circuits of the relay through 14-terminal connectors. The boards can be disengaged by a steady pull outward. Sometimes a simultaneous up-and-down motion (if there is clearance) will help free the mating connections. The boards are keyed so that they cannot be pushed home into the wrong connector although they may be replaced into the guides of the wrong position.

## OPERATION

The SKSU relay is basically a single phase relay operating from delta voltage and current.

Figure 4 illustrates the connections which apply voltage to the static phase angle comparison unit. Voltage $V_{AB}$ is either modified by the compensator output voltage $(I_A-I_B)\ Z_{LR}$ or $(I_A-I_B)\ Z_{SR}$ to produce a mho circle which includes the origin.

The long reach compensator is set to be a replica of the protected line section as seen by the secondary side and has the same relative current flowing through it as flows through the total line impedance. The short-reach compensator is connected in reverse direction to produce an off-set mho characteristic.

Referring to Fig. 5, consider a fault at location A which is beyond the long reach setting. For the sake of simplicity, assume both the line angle and and maximum sensitivity angle to be 90°. Compensator $Z_{LR}$ modifies the voltage $V_{AB}$ by adding the mutual impedance drop $(I_A-I_B)\ Z_{LR}$ which leaves the difference voltage $V_{XB}$ across the input of transformer $T_1$. The compensator $T_{SR}$ modifies the voltage $V_{AB}$ by adding $(I_B-I_A)\ Z_{SR}$ and then is phase shifted 90 degrees by means of the capacitor CS and the resulting voltage, $V_{YB}$, is applied across transformer T2. As shown, the voltage $V_{YB}$ leads the voltage $V_{XB}$ which is a restraint condition.

For the fault within the protected line section at point C, $V_{AB}$ becomes smaller than the permissible minimum computed by the short reach compensator

This results in $V_{XB}$ being flipped 180° so that the polarizing voltage $V_{YB}$ lags $V_{XB}$ and a trip signal appears at the output.

For the fault behind the relay such as point D, current through the relay has the opposite polarity from that for the fault at point A and C. If the fault impedance is within the tap setting of the short reach compensator, the voltage $V_{AB}$ will be modified with mutual impedance drop of $(I_B-I_A)$ which leaves a voltage $V_{YB}$. This voltage is phase shifted by 90 degrees and appears across the transformer T2 as $V_{YB}$. The compensator $Z_{LR}$ modifies the voltage $V_{AB}$ by adding the compensator voltage output $(I_A-I_B)\ Z_{LR}$ and leaves a sum of voltages $V_{AB} + (I_A-I_B)\ Z_{LR}$ across the transformer $T_1$. This results in $V_{YB}$ still lagging $V_{XB}$ which is a trip condition.

For a fault at location E, the voltage $V_{AB}$ is is greater than the short reach compensator drop and causes $V_{YB}$ to lead $V_{XB}$ which is a restraint condition.

### Phase Angle Comparison Unit

Referring to Figure 4, the phase angle comparison unit trips when current flows into the base of transistor 3Q3 through Zener diode 3Z2. Such tripping current must come from the 20V bus through either transistor 1Q2 or 1Q4 located in what might be be called the "operate" circuit. The operate circuit, driven by transformer T1, is continually trying to trip the unit by supply current through 1Q1 and 1Q3 on alternate half cycles. 1Q2 conducts when the polarity marked terminal of T1 is positive.

When 1Q2 conducts, a portion of the current
* goes through resistor 2R9. This current, $I_{R9}$, may take either of two paths to the negative bus. If 2QS1 is in a conducting state, $I_{R9}$ passes through it directly to the negative bus. If 2QS1 is in a blocking state, $I_{R9}$ passes through 2D16 and then through 3Z2 to transistor 3Q3 to cause tripping. Silicon con-
* trolled switch $2QS_1$ is located in what might be called the "polarizing" circuit of the relay. This circuit is driven by transformer T2.

To prevent the operate circuit from tripping, the polarity marked terminals of T2 must go positive before the polarity terminals of T1 do. This causes 2Q1 to conduct current through 2R[illegible] and 2D14 to drive the base of 2Q4. 2Q4 then conducts current from the 13V bus through 2R6 to gate 2QS1 into conduction. When 2QS1 conducts, it [illegible] the current which might otherwise pass through 2D16 to cause tripping. Once 2QS1 begins to conduct, the gate loses control and it remains in the conducting state until the current is turned off by 1Q2. No tripping output can develop as long as the T2 voltage leads the T1 voltage.

The operating circuit switches for the next half cycle so that transistors 1Q3 and 1Q4 conduct in an attempt to cause tripping. In the polarizing circuit, 2Q2, 2Q5, and 2QS2 seek to prevent tripping by short circuiting the current which might otherwise pass through 2D1, 3Z2, and 3Q3.

Restraint Squelch: When the operate circuit transistor 1Q2 conducts, approximately 18V is applied through diode 2D15 to back bias 2D14 and prevent 2Q4 from turning on. Thus a trip signal, initiated because the T1 voltage is leading, cannot be improperly interrupted when the T2 voltage goes positive. A full half cycle tripping output is therefore produced by 1Q2. This back biasing connection is called the restraint squelch circuit.

## Restraint-Signal Detector

If a condition should develope so that no polarizing voltage appears at transformer T2, then no gating signal would be available to switch 2QS1 and short circuit the 1Q2 current. This, of course, could cause incorrect tripping. A restraint-signal detector circuit prevents this to happen.

When the transistors 2Q1 and 2Q2 are conducting for each half cycle, they short circuit the current coming through 2R3 from a 20 volts d-c bus. If the polarizing voltage goes to zero, both transistors 2Q1 and 2Q2 stop conducting and a voltage will develop to break the Zener diode 2Z2 and to turn the transistor 2Q3 on, and hence to drive the base of 2Q4 and 2Q5 to short circuit 2QS1 and 2QS2 and to prevent incorrect tripping.

The operating circuit, driven by T1, and the polarizing circuit, driven by T2 are duals having identical circuits which operate on alternate half cycles. The restraint squelch and the voltage detector both work into each of the duals in the same manner.

## Voltage Detector Circuit Board

* When the SKSU is first energized with either a-c or d-c, there is no prior knowledge to inform the circuits as to which voltage is leading. A race exists between the operate and the polarizing circuits. Therefore, it is desirable to disable the tripping long enough for the circuits to properly relate to each other.

When the d-c is first turned on, a voltage appears across transistor 3Q2 which drives current through diodes 3D1 and 3D3 to keep thyristors 2QS1 and 3QS2 turned on. When 1Q2 and 1Q4 start conducting, they send current through 3D6 and 3D7 to charge capacitor 3C1 after which current flows into the base of 3Q2 to cause the voltage across 3Q2 to be short circuited.

The Zener diode 3Z1 monitors the d-c voltage level. If the d-c voltage drops too low for the logic to operate properly, it will cause 3Q1 to turn off, and thereby send a gate signal to the restraint thyristors. This will block tripping as long as the d-c voltage is at a level which would otherwise cause an incorrect operation.

## Output Circuit (Voltage Detector Circuit Board)

Consider a trip signal from the restraint thyristors which sends current through 3Z2, 3R8, and into the base of 3Q3. This will turn on 3Q3 to give an unsupervised output at terminal 10 of the voltage detector circuit board.

## Out-of-Step Detection

The out-of-step blocking logic receives three inputs, two of which are compared to the third on a time basis. Operation of this logic can be understood best when referring to the circle characteristics and moving electrical center illustrated in Figure 6.

Under out-of-step conditions, the apparent impedance measured by the relay anywhere near the electrical center starts at a high value, gradually decreases to a much lower value, and then gradually increase again to a higher value, and thus the system goes through a complete beat oscillation. On the other hand, if the disturbance is a fault, the impedance seen by the relay will suddenly drop to a much lower value, and then either retain this value or slightly increase due to the effects of fault resistance, until the fault is cleared.

The SKSU relay uses this distinction between a fault and an out-of-step condition. Under out-of-step conditions, the impedance unit will operate when the electrical center moves across the 68(Z) line into zoneA. This provides an input into L1 (AND) to fulfil the necessary conditions for an output into the (25–45)/0 timer L2. These necessary conditions are: An input form 68(Z) + an input from L3 (OR) (which exists under normal conditions) + no input from 21-2G. Any other condition will stop the output from L1.

If the zone A condition exists long enough for the timer setting to expire, L2 will give an output which influences up to four bits of logic, the output for trip blocking, L3, L4, and L5. First, the output amplifier is driven to provide a signal at varicon terminal 5 which is applied to auxiliary logic to block tripping. The timer also drives L3 to insure a continued output from L3 into L1 when the electrical center moves into zone B. Additionally, the timer drives L4 which receives also an input from 21–2 (3$\phi$) when zones B, C, and D conditions exist. When L4 receives these two inputs it initiates an output signal at varicon terminal 6. This output is applied to auxiliary logic to block the reclosing of a breaker which may have been allowed to trip. The fourth bit of logic driven by the timer is L5 (AND) located in the "OS Tripping" circuit. This is an optional feature and will be discribed later.

If a fault occurs within the 21–2 (3$\phi$) characteristic such as in zone B, the 21–2 (3$\phi$) input causes an L3 output into L1 to stop and thereby block L1 so that the L2 timer can never start. Likewise a ground fault which produces a 21–2G input will also block L1 so L2 cannot start. All of the out-of-step detection logic and out-of-step trip-block logic which is L1 through L4 is contained on the O.S. BLOCK circuit baord.

### Out-Of-Step Tripping

The tripping of a breaker during a swing condition will impose an excessive voltage across the breaker contacts if the electrical center is close to the breaker location within the "C" zone of Figure 6. Therefore, it is not necessary to wait until the electrical center has passed through zone F and the swing voltages are more nearly in phase before tripping the breaker.

Additional logic, L5 through L10, must be specified when desired that the SKSU relay initiate out-of-step tripping. This additional logic is contained on two printed circuit board assemblies, O.S. TRIP (1) and O.S. TRIP (2).

## OPERATION

Referring to Figure 6 when 68(Z) operates it will block L9 to prevent tripping until the electrical center moves out of the 68(Z) characteristic and into zone F. In the meantime L5 receives a signal from L2, as described previously for a swing condition, and is subsequently switched when the electrical center enters zone C causing a signal to be received from 21–1 (3$\phi$). L5 switches L6 which switches L7 and is maintained by feedback from L7. L8 is a delayed dropout timer which is also switched on by L7 and continues to provide a signal to L9 for approximately 40 milliseconds after the L7 signal is removed. The circuit is now latched in by the feedback from L7 so that nothing happens when the 21–1 (3$\phi$) signal is removed by the swing moving out of zone C and into zones D and E. At the same time L9 is still blocked by the 68(Z) signal.

When the electrical center moves into zone F, 68(Z) will reset and permit an output from L9 to start L10 which is a 0.0 to 1000 millisecond timer. (This timer should be set by the user to the time required for the electrical center to move sufficiently away from the relaying location so an excessive voltage will not be imposed across the breaker contacts when tripping occurs. The time adjustment is made by adjusting potentiometer R9 on the O.S. BLOCK circuit style no. 201C271G01). When the L10 time expires, a trip signal is supplied to the O.S. Trip circuit and simultaneously a reset signal is supplied to turn off L7. With L7 turned off, L8 will maintain an output and sustains the O.S. Trip output for approximately 40 milliseconds after which the entire circuit resets to normal standby conditions.

## CHARACTERISTICS

### Distance Characteristics

A characteristic circle is established by setting two points on the circle, diametrically opposite one another, by means of the long reach and short reach compensators – Fig. 7. As it is shown in Fig. 4, the short reach setting $Z_{SR}$ is negative in respect to the long reach $Z_{LR}$ to produce a circle which includes the origin.

When the out-of-step condition occurs, the fault moves and crosses the circle impedance of SKSU, the resulting output in conjunction with 21–2 and

21—2G output of the out-of-step blocking logic board to provide a signal to block tripping and reclosing for this condition.

**General Characteristics**

Impedance settings in ohms for the long reach can be made in steps of 3 per cent for any range between (1.1 – 31.8) and for short reach in step of 30% for any range between (.87 – 5.8) ohms. The maximum sensitivity angle, which is set for 75° at the factory, may be set for any value for 60° to 80°. A change in maximum sensitivity angle will produce a slight change in reach for any given setting of the relay. 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 ($P_{2A}$ or $P_{2C}$) shown in Fig. 4 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 $IT_{AB}$ or $IT_{CB}$. Thus the net voltage, V, is phase-shifted to change the compensator maximum sensitivity angle. As a result of this phase shift, magnitude of V is reduced.

Tap markings, in Fig. 2, are based upon a 75° compensator angle setting. If the potentiometer $P_{2A}$ and $P_{2C}$ are adjusted for some other maximum sensitivity angle, the nominal reach is different than indicated by the taps. The reach, $Z\theta$, varies with the maximum sensitivity angle, $\theta$, as follows:

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

## TAP PLATE MARKINGS

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Long Reach | 1.31 | 1.74 | 2.18 | 3.05 | 4.35 | 6.1 | 8.7 |
| Short Reach | .87 | 1.16 | 1.45 | 2.03 | 2.9 | 4.06 | 5.8 |

$$\frac{S_A}{1 \quad 2 \quad 3}$$

± Values Between Taps = $\dfrac{M_A}{.03 \quad .09 \quad .06}$

## CURRENT CIRCUIT RATING IN AMPERES

| "T" Tap Setting | | Continuous | | | 1 Second |
|---|---|---|---|---|---|
| | | S=1 | S=2 | S=3 | 240 |
| 5.8 | 8.7 | 5.0 | 8.5 | 9.5 | 240 |
| 4.06 | 6.1 | 6.0 | 10.0 | 10.0 | 240 |
| 2.9 | 4.35 | 8.0 | 10.0 | 10.0 | 240 |
| 2.03 | 3.05 | 10.0 | 10.0 | 10.0 | 240 |
| 1.45 | 2.18 | 10.0 | 10.0 | 10.0 | 240 |
| 1.16 | 1.74 | 10.0 | 10.0 | 10.0 | 240 |
| .87 | 1.31 | 10.0 | 10.0 | 10.0 | 240 |

**Burden**

The burden which the relays impose upon potential and current transformers in each phase is listed in Table 1 and 2. The potential burden and burden phase angle are based on 69.3 bolts line-to-neutral applied to the relay terminals.

**Output Circuits**

| | |
|---|---|
| Open Circuit Voltage | 18V to 21V d-c |
| Rated Current | 10 Milliamperes |

## SETTING CALCULATIONS

Long Reach (1.1 to 31.8 ohms) 1.31, 1.74, 2.18, 3.05, 4.35, 6.1, 8.7

Short Reach (.87 to 5.8 ohms) .87, 1.16, 1.45, 2.03, 2.9, 4.06, 5.8

$$\frac{S_A}{1 \quad 2 \quad 3}$$

Values between taps ± $\dfrac{M_A}{.03 \quad .09 \quad .06}$

Maximum sensitivity angle, $\theta$, 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 65°, set $\theta$ for a 60° maximum sensitivity angle by adjusting P2A and P2C.

Calculations for setting the SKSU relay are straightforward and apply familiar principles. Assume a desired forward looking balance point which is 2 secondary ohms greater than the zone 2 distance relay setting. The general formula for setting the ohms reach of the relay is:

$$Z\theta = Zpri \frac{R_C}{R_V} \qquad \text{Eq. (1)}$$

The terms used in this formula and hereafter are defined as follows:

Eq. (2)

$Z_\theta$ = the ohmic reach of the relay in secondary ohms when the maximum sensitivity angle is set for $\theta$ degrees.

$Z_{LR} = \frac{T_{AL}S}{1 \pm M}$ = the tap plate setting for the forward reach. ($T_{BL}$ must be set equal to $T_{AL}$)

$Z_{SR}$ = Tas = Tbs = the tap plate setting for the reverse reach.

$T_{AL}$, $T_{BL}$, $T_{AS}$, $T_{BS}$ = compensator tap value

S = auto-transformer primary tap value

$\theta$ = Maximum sensitivity angle setting of the relay (factory setting of $\theta = 75°$)

$\pm M$ = auto-transformer secondary 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 lower the Z setting. The sign is negative when "R" is above "L" and acts to raise the Z setting.)

Zpri = ohms per phase of the total line section

$R_C$ = current transformer ratio

$R_V$ = potential transformer ratio

The following procedure should be followed in order to obtain an optimum setting for the long reach setting.

1. A. Establish the value of $Z_\theta$ as above.
   B. Determine the tap blate value, $Z_{LR}$, using the formula:

$$Z_{LR} = Z_\theta \frac{\text{Sin } 75°}{\text{Sin } \theta°}$$

when $\theta = 75°$, $Z = Z_\theta$

2. Now refer to Table III for the optimum tap settings.
   A. Locate a table value for relay reach nearest the desired value $Z_{LR}$. (It will always be within 1.5% of the desired value).
   B. ✱ Select from the Table "S", "T", and "M" settings. "M" column includes additional information for "L" and "R" lead settings for the specified "M" value.
   C. Recheck the selected "S", "T", and "M" settings to assure the correct value of Z by using equation (2).

$$Z_{LR} = \frac{T_{AL}S}{1 \pm M}$$

Step 1A

For example, assume the desired reach, $Z\theta$, for the long reach compensator is 7 ohms at 60°.

Step 1B

The line angle of 60° requires that the relay maximum sensitivity angle be changed from a factory setting of 75° to the new value of 60°. Using equation (3), we find the corrected value for the relay tap settings:

$$Z_{LR} = 7 \times \frac{\text{Sin } 75°}{\text{Sin } 60°} = 7.8 \text{ ohms}$$

Step 2A

In Table III, we find nearest value to 7.8 ohms is 7.76. That is $100 \times \frac{7.76}{7.8} = 99.5$ percent of the desired reach.

Step 2B

From Table III, read off:

S = 1
T = 8.7
M = ±.12

and "L" lead should be connected over "R" lead, with the "L" lead connected to .09 tap and "R" lead to tap "O".

Step 2C

Recheck settings:

$$Z_{LR} = \frac{T_{AL}S}{1 + M} = \frac{(8.7)(1)}{1 + .12} = 7.76$$

From Eq. (2)

$Z\angle\theta = Z_{LR} \angle 60 \pm = 7.76 \times .896 = 6.95$

Fron Eq. (3)

which is 99.2 per cent of the desired setting

## Short Reach Setting

There is no auto-transformer for short reach reverse connected compensator, therefore $Z_\theta$ may be as much as 15% off the desired reach. Assume a desired reach of $Z_\theta = 2.3 \angle 60°$ ohms. $Z_{SR} = 2.3 \frac{\times \sin 75°}{\sin 60°} = 2.56$ ohms, select $T_{AS} = T_{BS} = 2.9$.

$$Z_\theta = Z_{SR} \angle 60° = 2.9 \frac{\sin 60°}{\sin 75°} = 2.6$$

which is 113 per cent of the desired setting.

## SETTING THE RELAY

The SKSU relays require settings for the two compensators ($T_{SR}$ and $T_{LR}$), the one auto-transformer primary ($S_A$) and secondary ($M_A$ and $M_C$). All of these settings are made with taps on the tap plate.

### Compensators $T_{SR}$ and $T_{LR}$

Each set of compensator 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. 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 operating current, be sure that the screws are turned to bind snugly but not so tightly as to break the tap screw. There are four T taps, two for long reach and two for short reach and connected in such a way to use delta current.

### Auto-Transformer Primary ($S_A$)

Primary tap connections are made through a single lead for each transformer. The lead comes out of the tap plate through a small hole located just below or above the taps and is held in place on the tap by a connector screw (Figure 2).

An "S" setting is made by removing the connector screw, placing the connector in position over the insert of the desired setting, replacing and tightening the connector screw. The connector should never make electrical contact with more than one tap
* at a time.

### Auto-Transformer Secondary ($M_A$)

Secondary tap connections are made through two leads identified as L and R for each transformer. These leads come out of the tap plate each through a small hole, one on each side of the vertical row of "M" tap inserts. The lead 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 III 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° ± 3° (current lagging voltage) in the factory. This adjustment need not be disturbed for line angles of 65° or higher. For line angles below 65°, set for a 60° maximum sensitivity angle by adjusting the compensator loading resistors $P_{2A}$ and $P_{2C}$. Refer to Repair Calibration when a change in maximum sensitivity angle is desired.

## 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 relay 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 panel due to the extended weight within the relay case.

## EXTERNAL CONNECTIONS

Figure 8 shows the external connections for an SKSU relay.

# TABLE III
## SETTINGS FOR 1.1 – 31.8 OHM RANGE

| | "S" = 1 | | | | | | | "S" = 2 | | "S" = 3 | | "M" | | LEAD CONNECTIONS | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| T = | 1.31 | 1.74 | 2.18 | 3.05 | 4.35 | 6.1 | 7.8 | 6.1 | 8.7 | 6.1 | 8.7 | +M | −M | "L" LEAD | "R" LEAD | |
| | 1.11 | 1.47 | 1.85 | 2.58 | 3.68 | 5.16 | 7.37 | — | 14.71 | — | 22.1 | +.18 | | .06 | 0 | "L" OVER "R" |
| | 1.14 | 1.51 | 1.89 | 2.65 | 3.78 | 5.30 | 7.56 | — | 15.11 | — | 22.7 | +.15 | | .06 | .03 | "L" OVER "R" |
| | 1.17 | 1.55 | 1.95 | 2.72 | 3.88 | 5.45 | 7.76 | 10.9 | 15.5 | — | 23.3 | +.12 | | .09 | 0 | "L" OVER "R" |
| | 1.20 | 1.6 | 2.00 | 2.8 | 3.99 | 5.6 | 7.98 | 11.2 | 16 | — | 23.9 | +.09 | | .09 | .03 | "L" OVER "R" |
| | 1.23 | 1.64 | 2.06 | 2.87 | 4.10 | 5.75 | 8.20 | 11.5 | 16.4 | — | 24.6 | +.06 | | .06 | .09 | "L" OVER "R" |
| | 1.27 | 1.69 | 2.12 | 2.96 | 4.22 | 5.92 | 8.45 | 11.8 | 16.9 | — | 25.3 | +.03 | | .03 | 0 | "L" OVER "R" |
| | 1.31 | 1.74 | 2.18 | 3.05 | 4.35 | 6.1 | 8.7 | 12.2 | 17.4 | — | 26.1 | 0 | 0 | 0 | .03 | |
| | 1.35 | 1.79 | 2.25 | 3.14 | 4.49 | 6.29 | 8.96 | 12.6 | 17.9 | — | 26.9 | | -.03 | 0 | .03 | "R" OVER "L" |
| | 1.39 | | 2.32 | 3.24 | 4.62 | 6.49 | 9.25 | 13 | 18.5 | — | 27.8 | | -.06 | .09 | .06 | "R" OVER "L" |
| | 1.44 | — | 2.4 | 3.35 | 4.78 | 6.70 | 9.55 | 13.4 | 19.1 | — | 28.7 | | -.09 | .03 | .09 | "R" OVER "L" |
| | | — | 2.48 | 3.46 | 4.94 | 6.93 | 9.88 | 13.9 | 19.8 | — | 29.7 | | -.12 | 0 | .09 | "R" OVER "L" |
| | — | — | 2.56 | 3.59 | 5.11 | 7.17 | 10.2 | 14.3 | 20.5 | 2.15 | 31.4 | | -.15 | .03 | .06 | "R" OVER "L" |
| | — | — | — | — | — | — | 10.6 | — | 21.2 | — | 31.8 | | -.18 | 0 | .06 | "R" OVER "L" |

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 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 cable. The grounding connection 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-tapping screws and provide excellent low resistance contact with the case.

## RECEIVING ACCEPTANCE

Acceptance tests consist of an electrical test to make certain that the relay measures the balance point impedance accurately.

### Recommended Instruments for Testing

Westinghouse Type PC-161, Style #291B749A33 or equivalent a-c voltmeter

Westinghouse Type PA-161, Style #291B719A21 or equivalent a-c ammeter

Testing can be accomplished by use of the test connections shown in Figure 9.

Tripping is indicated by a d-c voltmeter reading. At the balance point, the output may be as low as 1 volt or 2 volts indicating that the system is only partially tripping. This is a normal balance point characteristic. However, a 5 per cent increase in current should produce an output of 15 to 20 volts. A reading of less than 15 volts indicates a defective tripping output.

### Distance Unit – Electrical Test

1. Check the electrical response of the relay by using the test connection shown in Figure 9.
2. Set the long and short reach setting as follows:

   $T_{AL}$ and $T_{BL}$ - Set for the highset Tap value (8.7)

   $T_{AS}$ and $T_{BS}$ - Set for 2.03

   $S_A$ - Set on 1

   "R" for $M_A$ - Set on 0

   "L" for $M_A$ - Set on .06 (top position)
3. Long reach testing - Apply 30 volts a-c between terminal 7 and 8 and set the switch in the test circuit on the normal polarity.
4. Supply 105% of the current necessary to trip the relay at 75° (current lags voltage); swing the phase shifter to determine the two angles, $\theta 1$ and $\theta 2$, at which relay just trips. The maximum sensitivity angle $\theta$ is $\frac{\theta 1 + \theta 2}{2}$.

   This should be 75° ± 3°. The angle shifts from 75° at $70V_{LL}$ to approximately 70 at $5V_{LL}$. This is a normal response of the logic and is not detrimental to the relay protection.
5. The current required to make the relay trip should be within the limits given in Table 4. at an angle of 75° current lags.
6. Short reach compensator – Throw the switch in the test circuit to the "reverse polarity" and apply 30 volts between terminal 7 and 8.
7. Repeat parts 4 and 5 of the long reach compensator and check the current against Table 5. 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.

## ROUTINE MAINTENANCE

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

### Distance Units:

CAUTION: Before making hi-pot test, connect together varicon connector terminals 3, 4, 5, 6, 10, 11, 14, and 15 to avoid destroying components in the static network. These connections are not necessary for surge testing.

Since the relay uses the line to line voltage and delta current, the impedance measured by the relay would be $Z_R = \frac{V_{L-L}}{2I_L}$

## REPAIR CALIBRATION

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

1. Replace the operating circuit board with card extender style # 849A534G01 and disconnect. but do not remove, all other d-c boards. Apply rated d-c voltage between varicon terminals 3 and 4 with positive on terminal 4. Measure the d-c voltage on the card extender between 1 and 14 with 14 as positive. Voltage should be between 19V d-c and 21V d-c.
2. Remove the card extender and reconnect all boards. Apply rated Vd-c and check for outputs on the Output Terminals. There should be none.

| CIRCUIT BOARD | OUTPUT TERMINALS AND TEST POINTS | NORMAL TRIPPING OUTPUT |
|---|---|---|
| O.S. BLOCK BOARD | O.S.T.B.: TP10 and Varicon Term. 5 | 15 to 20 volts |
| | O.S.T.B.: TP11 and Varicon Term. 6 | |
| O.S. Trip Board | TP8 and Varicon Term. 14 | |

The following steps are straightforward testing and calibrating procedure, but if any misoperation is noticed during the testing of the relay, the "trouble shooting" section 25, 26, 27, and 28 could be helpful to locate the faulty component.

3. Distance Unit Calibration

Check to see that the taps on front of the tap block are set as follows:

$T_{AL}$ and $T_{BL}$ - Set on the highest tap value (8.7)
$T_{AS}$ and $T_{BS}$ - Set on the lowest tap value
$S_A$ - Set on 1
"R" for $M_A$ - Disconnect
"L" for $M_A$ - Set for .06 (top position)

4. Maximum Sensitivity Angle adjustment Long Reach Compensator

(Standard setting is 75°)

Connect the relay for a fault as indicated in the test circuit. Connect a high resistance voltmeter (2000 ohms/volts) between the "R" lead and the .03 tap position of $M_A$ and adjust voltage between terminal 7 and 8 for 30 volts.

5. Pass the current, called for in Table 4 for 30 volts, through terminal 1 out of 3 with the phase shifter set for the desired maximum sensitivity angle. Adjust potentiometer $P_{2A}$ for a null, or minimum reading, on the voltmeter.

6. Swing the phase shifter and adjust $P_{2A}$ slightly to obtain a minimum reading on the voltmeter when the phase angle reading is at the desired maximum sensitivity angle. This adjusts the long-reach compensator angle.

7. Maximum Sensitivity Angle Check — Long Reach

Reconnect R and L lead, and use the 30 volt condition in Table 4. Supply 105% of the current necessary to trip at the calibrated angle of maximum sensitivity and swing the phase shifter to determine the two angles, $\theta_1$ and $\theta_2$ at which the unit just trips. The maximum sensitivity angle $\theta$ is $\frac{\theta_1 + \theta_2}{2}$.

This value should be within + 3°. Adjust potentiometer PS to obtain the desired maximum sensitivity angle for this check.

8. Maximum Sensitivity Setting Short-Reach Compensator

Set $T_{AL}$ and $T_{BL}$ on minimum value, $T_{AS}$ and $T_{BS}$ on maximum value. Open the $S_A$ tap by removing the tap screw. Connect the high resistance voltmeter in series with the varicon input terminal No. 7.

9. Reverse the current connections to terminal block terminals 1 and 4 and adjusting potentiometer $P_{2C}$.

10. Long Reach Impedance Curve Check

With the switch in the normal polarity, and the taps settings as follows, the former trip current should be within the limits listed for the given test voltage and angle in Table 4 below.

11. $T_{BL}$ and $T_{AL}$ - Set on 8.7
$T_{BS}$ and $T_{AS}$ - Set on 2.03
$S_A$ - Set on 1
"R" for $M_A$ - Set on 0
"L" for $M_A$ - Set on -06 (top position)

## TABLE IV

| VOLTS BETWEEN 7&8 | AMPS TO TRIP FOR $\theta$= 75° 1.1 – 31.8 RANGE | |
|---|---|---|
| | IMIN | IMAX |
| 5.0 | .33 | .36 |
| 30.0 | 1.98 | 2.1 |
| 70.0 | 4.7 | 4.8 |

| VOLTS BETWEEN 7&8 | AMPS TO TRIP FOR $\theta$ = 60° 1.1 – 31.8 RANGE | |
|---|---|---|
| | IMIN | IMAX |
| 5 | .37 | .4 |
| 30 | 2.21 | 2.34 |
| 70 | 5.25 | 5.36 |

12. Circuit Boards Test

Connect a jumper between varicon connector terminals 7 and 8, jumper terminal 4 block block terminals 2 and 4 together, and pass 2 amperes into terminal block 3 terminal 1 and out of terminal 3. There should be an O.S.T.B. output of TP10 and varicon term. 5.

13. With the output at relay term. 5, supply 15 to 20 volts d-c pos. to varicon terminal 10 (neg. to term. 3). This should produce an O.S.R.B. output at varicon term. 6.

14. Supply 15 to 20 volts d-c pos. to varicon term. 11. Outputs at 5 and 6 should drop to zero.

15. With relay de-energized, apply rated V d-c, supply 15 to 20 volts d-c pos. to varicon term. 10 and then pass 2 amperes a-c into terminal block terminal 1 and out of terminal 3. There should be no output from either varicon terminals 5 or 6.

Repeat 6 above except supply 15 to 20 volts d.c pos. to varicon term. 11 instead of term. 10. There should be no output from either varicon terms. 5 or 6.

The out-of-step block logic has already been functionally tested. However, the timer range of R9 must be checked and set.

16. Space out the O.S. Block Circuit Board located in position 6 with card extender style 849A534G01. With rated V d-c on the relay and R9 fully counter clockwise, apply 15 to 20 volts d-c position to the circuit board terminal 6 and check the time for an output to appear at TP10. This should be 25 milliseconds or less.

17. Set R9 fully clockwise, apply 15 to 20 volts pos. d-c to P.C.B. terminal 6 and check time required for an output to appear at TP10. This should be 45 milliseconds or more.

18. Leave R9 set for 25 milliseconds and return the PC board back inside the relay.

## OUT-OF-STEP LOGIC

19. Space out the O.S. Trip (2) circuit board with the card extender and trip the O.S.T.B. unit with a 30 volt a-c fault condition. Apply 15 to 20 volts d-c pos. to varicon term. 15 for one second. Reset the O.S.T.B. unit by removing the a-c amperes and check for a 40 millisecond output at varicon terminal 14.

20. Set potentiometer R13 on the O.S. Trip (2) board fully counterclockwise and repeat step 19. The output at varicon 14 should appear within 1 millisecond after the a-c current is removed.

21. Set R13 fully clockwise and repeat step 19. The output should appear one second or more after the a-c current is removed.

22. Leave R13 set for 500 milliseconds. Relay test is complete.

## Trouble Shooting

23. For trouble shooting compensator when "amperes to trip" is out of limits: The compensator output can be checked by connecting the voltmeter between the "L" lead of $M_A$ and jack $J_1$ located just below $P_{2A}$. Pass 5 amperes through the compensator. The secondary voltage should be:

$V_S = 10.35\ T \sin\theta \pm 1.0\%$

where: $\theta$ = the desired maximum sensitivity angle

T = compensator tap setting

10.35 = a design constant = $\frac{10}{\sin 75°}$

1.0% = the allowable variation from nominal

| | | VS VOLTS FOR GIVEN "T" SETTINGS | |
|---|---|---|---|
| $\theta$ | Va | Ts = 5.8 | $T_1$ = 8.7 |
| 75° | 10T | (58) 57.4 to 58.6 | (87) 86.1 to 87.9 |
| 69° | 8.96T | (52) 51.5 to 52.5 | (78) 77.2 to 78.8 |

## Auto-Transformer Check

24. Set $S_A$ on tap number 3. Set the "R" lead of $M_A$ on O.O. Apply 90 (± 1) volts between varicon connector terminals 7 and 8. Measure the voltage from varicon connector terminal 8 to the #1 tap of $S_A$. It should be 30 (± 1) volts. From 8 to the #2 tap of $S_A$ should be (± 1) volts.

25. Set $S_A$ on 1 and apply a voltage $V_T$ (which is equal to 100 volts ± 1 volt a-c) between * varicon terminal 7 and 8. Measure the voltage drop from 8 to each of the $M_A$ taps. This voltage should be equal ± 1 volt to the sum of $V_T$ = (the sum of digits between "R" and the tap being measured).

Example: 99 = (103 + .09) x 100 = 111 volts ± 1 (R set on O.O, L set on .09). If the voltage readings are not within limits, then the transformer connections are wrong.

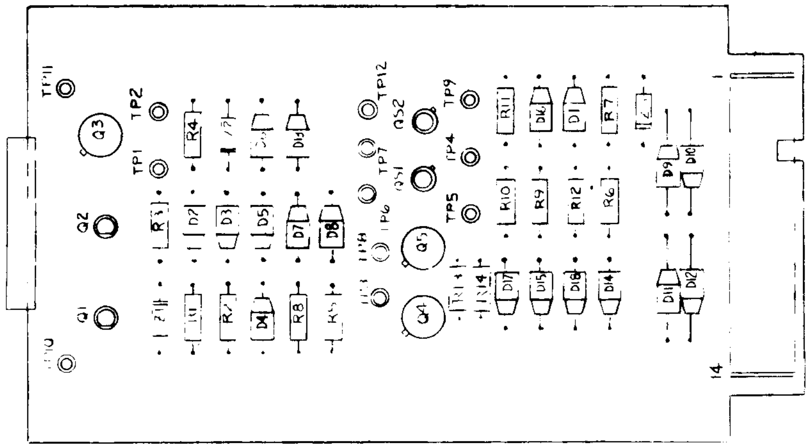
26. If the relay is within the above (25, 26, 27) calibration, and the relay does not still operate properly, there is either a defective board or a wrong wiring.

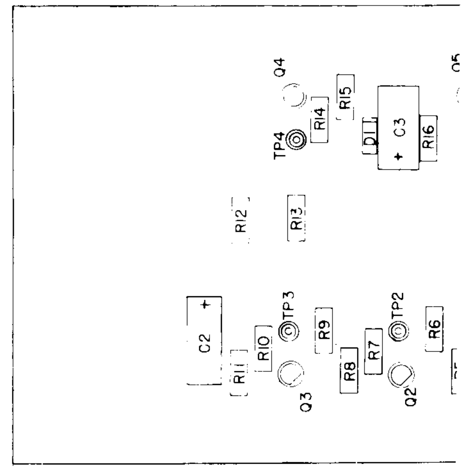
# RENEWAL PARTS

Repair work can be most satisfactorily done at the factory. However, interchangeable parts can be furnished to the customers who are equipped for doing repair work. When ordering parts, always give the complete nameplate data. The chassis outline is shown in Fig. 10.

# ELECTRICAL PARTS LIST

| ITEM | DESCRIPTION | WESTINGHOUSE STYLE NUMBER |
|---|---|---|
| | **CAPACITORS** | |
| $C_{2A}$ | 1.8 MFD | 14C9400H12 |
| * $C_{FA}$ | 1.0 MFD | 1876999 |
| $C_{3C}$ | .45 MFD | 1723408 |
| $C_S$ | .45 MFD | 1723408 |
| | **ZENER DIODE** | |
| DZP | 1N2984B (20V 5%) | 762A631H01 |
| $Z_1$ to $Z_4$ | 1N2846A | 184A845H08 |
| $J_1$, $J_2$ | Test Jacks | |
| | **POTENTIOMETER** | |
| $P_{2A}$ & $P_{2C}$ | 1K | 836A635H03 |
| $P_S$ | 5K | 836A635H05 |
| | **RESISTOR** | |
| $R_S$ | 10K Adjustable | 185A925H05 |
| $R_C$ | 1.5K | 1267293 |
| $R_{AC}$, $R_A$, $R_{MA}$ | 1.8K | 1201004 |
| $R_{DC}$, $R_{3C}$ | 80 Ohms (25W) for 48V d-c | 1201005 |
| $R_{DC}$, $R_{3C}$ | 400 Ohms (25W) for 125V d-c | 1202587 |
| $R_1$ & $R_2$ | 500 Ohms | 763A129H03 |
| | **AUTO-TRANSFORMER** | |
| S & M | Printed Circuit Board | |
| | Operating Circuit Board | 899C345G01 |
| | Polarizing | 899C347G01 |
| | Voltage Detector | 201C308G01 |
| | O.S. Block C.B. | 201C271G01 |
| | O.S. Trip (1) C.B. | 201C270G01 |
| | O.S. Trip (2) C.B. Card Extender | 201C290G01 |
| $T_1$, $T_2$ | Coupling Transformer, Center Taped Secondary (Step up 1:8) | 292B563G05 |
| ($T_{AL}$ & $T_{BS}$) & ($T_{AS}$ & $T_{BS}$) | Compensator Assemblies | 671B471G01 |
| $X_L$ | Memory Circuit Reactor | 606B544G02 |
| $X_S$ | Center Taped Auto-Transformer for Phase Shift Circuit | 671B470G01 |





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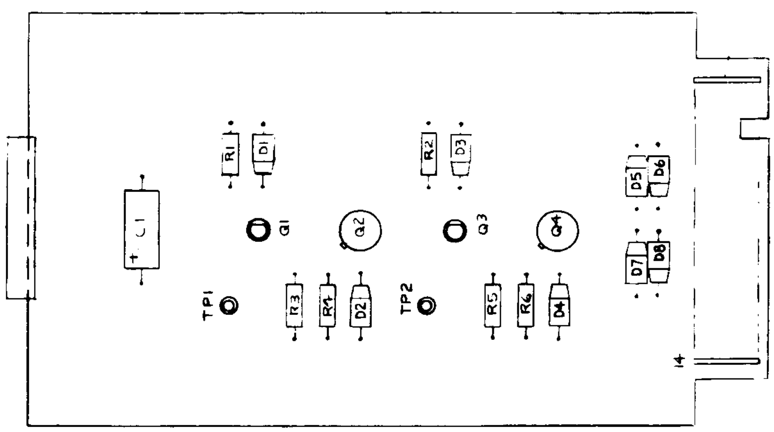

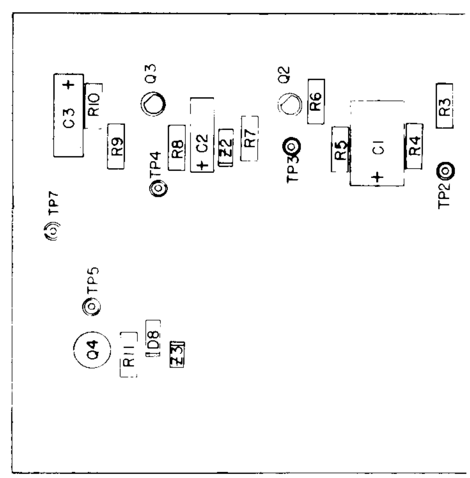

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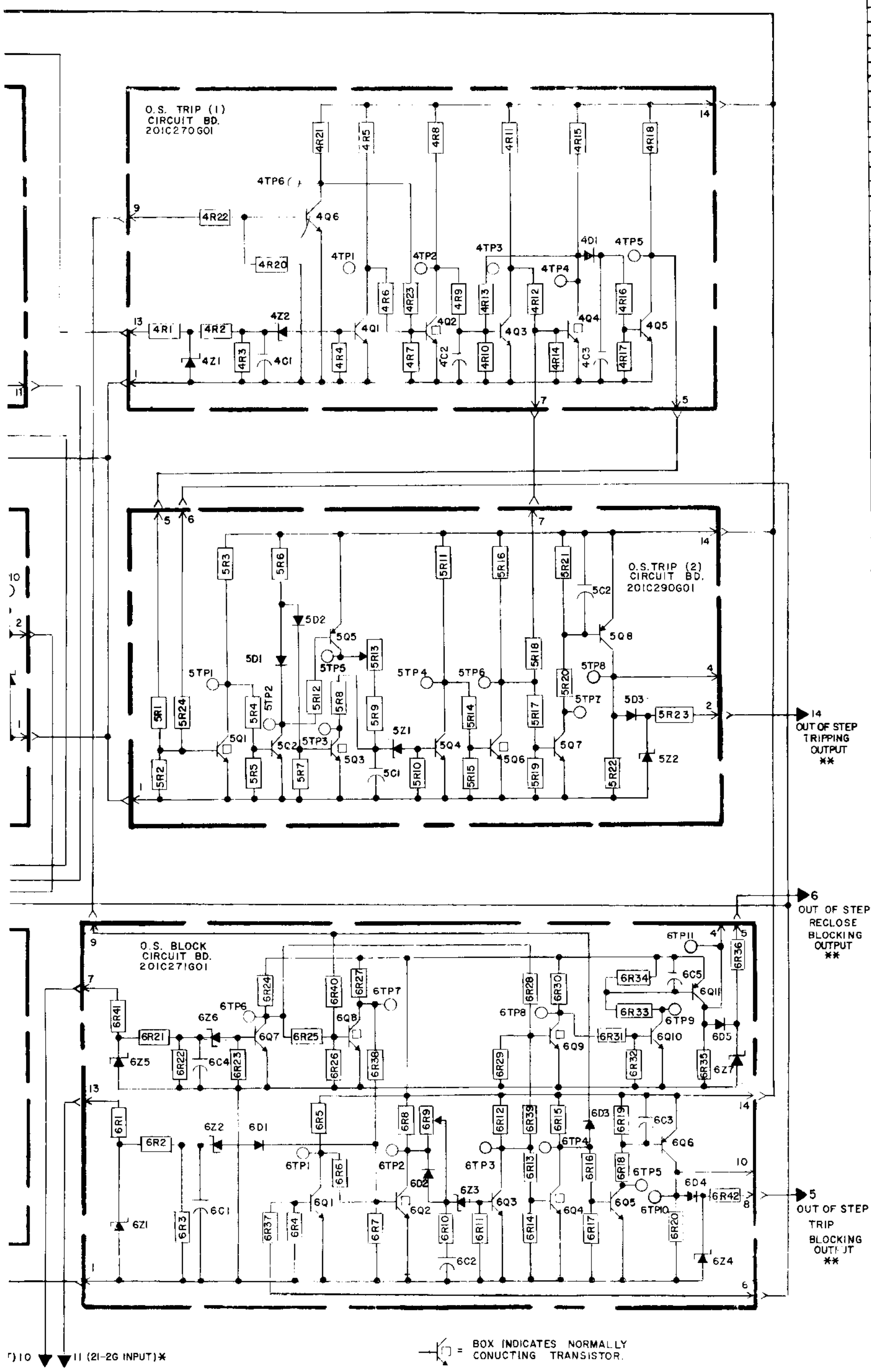



| RESISTOR | STYLE | REQ. | [illegible] |
|---|---|---|---|
| RA·RMA·RAC | 1201004 | 3 | 1.8K |
| RC | 1267293 | 1 | 1.5K |
| RDC·R3C (48V.D.C.) | 1201005 | 2 | 8[illegible] Ω |
| RS | 185A925H05 | 1 | 10 K |
| RDC R3C (125V.D.C.) | 1202587 | 2 | 400 Ω |
| R1·R2 | 763A129H03 | 2 | 500 Ω |
| 1R4·1R6·2R5·2R8 | 184A763H49 | 4 | 8.2K |
| 2R7·2R9·2R11·2R12·3R1 | 184A763H37 | 5 | 2.7K |
| 3R9· ·4R5·4R8·4R11· | 184A763H47 | 21 | 6.8K |
| 4R15·4R18·4R21·5R3·5R6 | " | | " |
| 5R11·5R16·5R21·6R5·6R12· | " | | " |
| 6R15·6R18·6R24·6R27· | " | | " |
| 6R30·6R33 | " | | " |
| 2R3 | 184A763H63 | 1 | 33 K |
| 2R6·2R10 6R28 | 629A531H42 | 3 | 2.7K |
| 1R3·1R5 | 184A763H99 | 2 | 1 MEG |
| 3R2·4R6·4R8·4R9·4R12· | 184A763H61 | 23 | 27K |
| 4R13·4R16·4R22· 5R24 | " | | " |
| 4R23·5R1·5R4·5R12·5R14 | " | | " |
| 5R17·5R20·6R6·6R13·6R16 | " | | " |
| 6R25·6R38·6R39·6R40 | " | | " |
| 3R3 | 184A763H57 | 1 | 18K |
| 3R10· ·4R4·4R7·4R10· | 184A763H51 | 24 | 10K |
| 4R14·4R17·4R20·5R2·5R5· | " | | " |
| 5R7·5R22·5R15·5R19· | " | | " |
| 6R4·6R7·6R11·6R14·6R17· | " | | " |
| 6R19·6R23·6R26·6R29· | " | | " |
| 6R32·6R34 | " | | " |
| 3R11· 4R3·6R3·6R22· | 184A763H73 | 6 | 82K |
| 6R20· 6R35 | " | | " |
| 4R1·4R2·6R1·6R2·6R21· | 184A763H43 | 6 | 4.7K |
| 6R41 | " | | " |
| 3R4·1R1·1R2 | 184A763H75 | 1 | 100 K |
| 3R5 2R1·2R2 | 184A763H83 | 1 | 220K |
| 3R6 | 184A763H45 | 1 | 5.6K |
| 3R7·3R8· | 184A763H69 | 4 | 56 K |
| 3R12· ·5R23·6R42· | 762A679H01 | 3 | 150 Ω |
| 5R8·6R10 | 863A908H02 | 2 | 33 Ω |
| 5R9 | 184A763H07 | 1 | 150 Ω |
| 6R8 | 629A531H58 | 1 | 12 K |
| 5R10 | 184A763H68 | 1 | 51K |
| DIODE | | | |
| 3D1 TO3D8 4D1·5D1 TO5D3· | 837A692H02 | 18 | 1N645A |
| 6D1 TO6D5 | " | | " |
| 1D1 TO1D8·3D1 TO3D18 | 188A342H06 | 26 | CER69 |
| | | | |
| ZENER DIODE | | | |
| 2Z2·3Z1·2Z3 | 186A797H01 | 3 | 1N758 |
| 3Z2· | 186A797H12 | 1 | 1N752A |
| 3Z3· ·5Z2·6Z4·6Z7 | 862A288H01 | 4 | 1N3688A |
| 4Z1·6Z1·6Z5 | 185A212H06 | 3 | 1N3686B |
| 2Z1·4Z2·6Z2·6Z6 | 186A797H06 | 4 | 1N957B |
| 5Z1·6Z3 | 184A639H11 | 2 | 1N1315A |
| Z1 TO Z4 | 184A845H08 | 4 | 1N2846A |
| DZP· | 762A631H01 | 1 | 1N2984B |
| CAPACITOR | | | |
| 1C1 | 187A508H10 | 1 | 18 MFD |
| 3C1 | 187A624H02 | 1 | .25MFD |
| 3C2· | 187A624H10 | 1 | .015MFD |
| 3C3· ·6C3·6C5·5C2 | 837A241H03 | 4 | .27 MFD |
| 4C1·6C1·6C4 | 849A437H04 | 3 | .047MFD |
| 4C2 | 848A646H01 | 1 | .068MFD |
| 5C1 | 184A661H10 | 1 | 6.8 MFD |
| 4C3 | 837A241H16 | 1 | 1MFD |
| 6C2 | 837A241H20 | 1 | 1.8 MFD |
| CS·C3C | 1723408 | 2 | .45MFD |
| C2A | 14C9400H12 | 1 | 1.8 MFD |
| CFA | 1876999 | 1 | 1 MFD |
| | | | |
| TRANSISTOR | | | |
| 1Q1 1Q3·2Q1·2Q5 | 848A851H01 | 4 | 2N3991 |
| 2Q3 | 184A638H18 | 1 | 2N697 |
| 1Q2·1Q4·2Q4·2Q5 | 184A638H20 | 4 | 2N1132 |
| 3Q4·3Q6·5Q5·5Q8·6Q6·6Q11 | 849A441H01 | 6 | 2N3645 |
| 3Q1·3Q2·3Q3·3Q5·4Q1 TO | 848A851H02 | 25 | 2N3417 |
| 4Q6·5Q1 TO5Q4·5Q6·5Q7· | " | | " |
| 6Q1 TO6Q5·6Q7 TO 6Q10 | " | | " |
| | | | |
| TRANSFORMER | | | |
| T1·T2 | 292B563G05 | 2 | |
| | | | |
| SWITCH | | | |
| 3QS1·3QS2 | 185A517H05 | 2 | 2N884 |
| | | | |
| POTENTIOMETER | | | |
| 6R9 | 629A430H08 | 1 | 15 K |
| P2A·P2C | 836A635H03 | 2 | 1 K |
| PS | 836A635H05 | 1 | 5 K |
| 5R13 | 629A430H05 | 1 | 200K |

BOX INDICATES NORMALLY CONDUCTING TRANSISTOR.

TERMINAL BLOCK

VARICON CONNECTOR

* = +12 TO +20VOLTS DC REQUIRED FOR INPUT

** = +15 TO +20VOLTS D.C. OUTPUT REFERRED TO D.C. NEG.

5317D94

*d Internal Schematic*

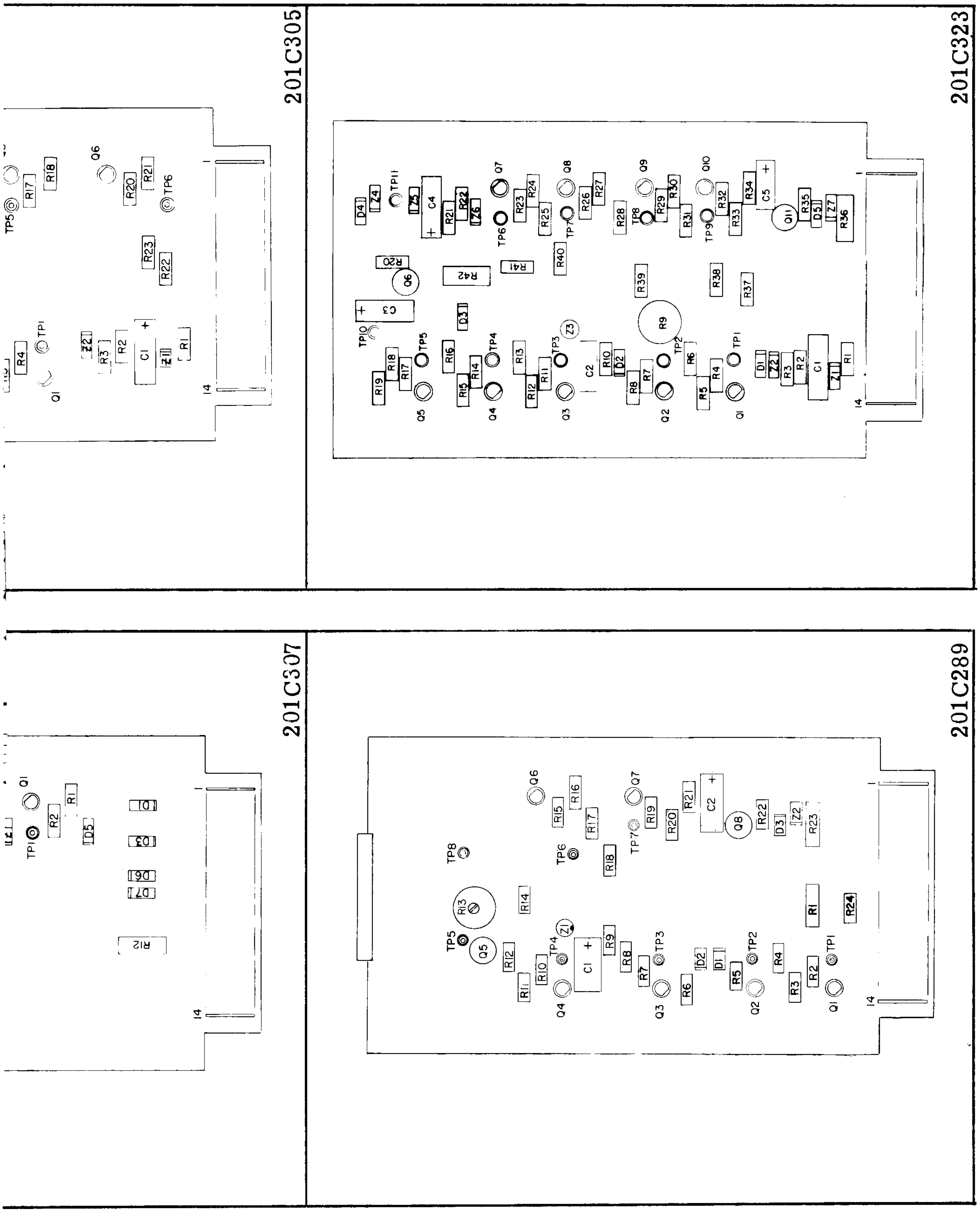



*Fig. 3 Printed Circuit Board*

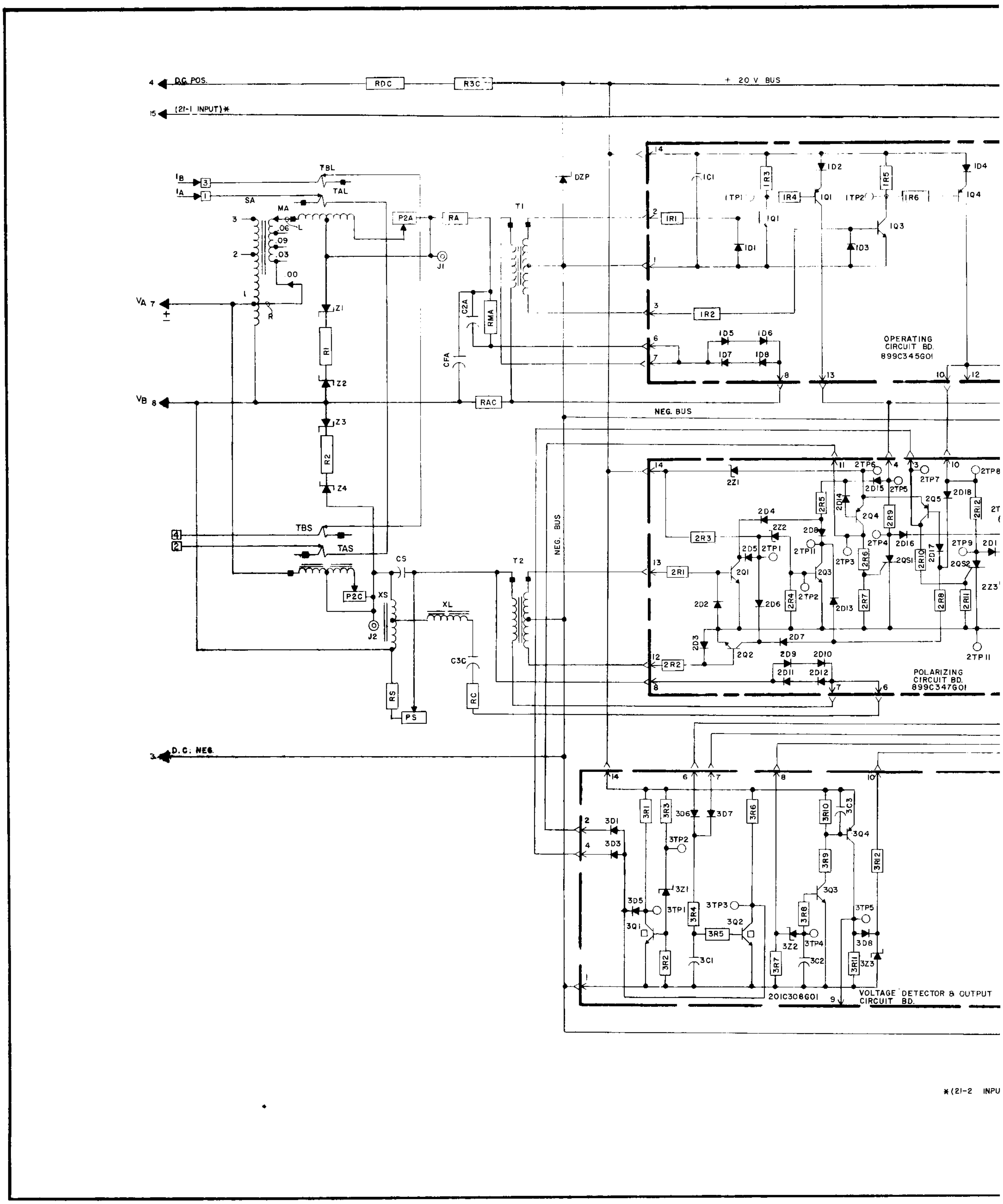



*Fig. 4 Detaile*

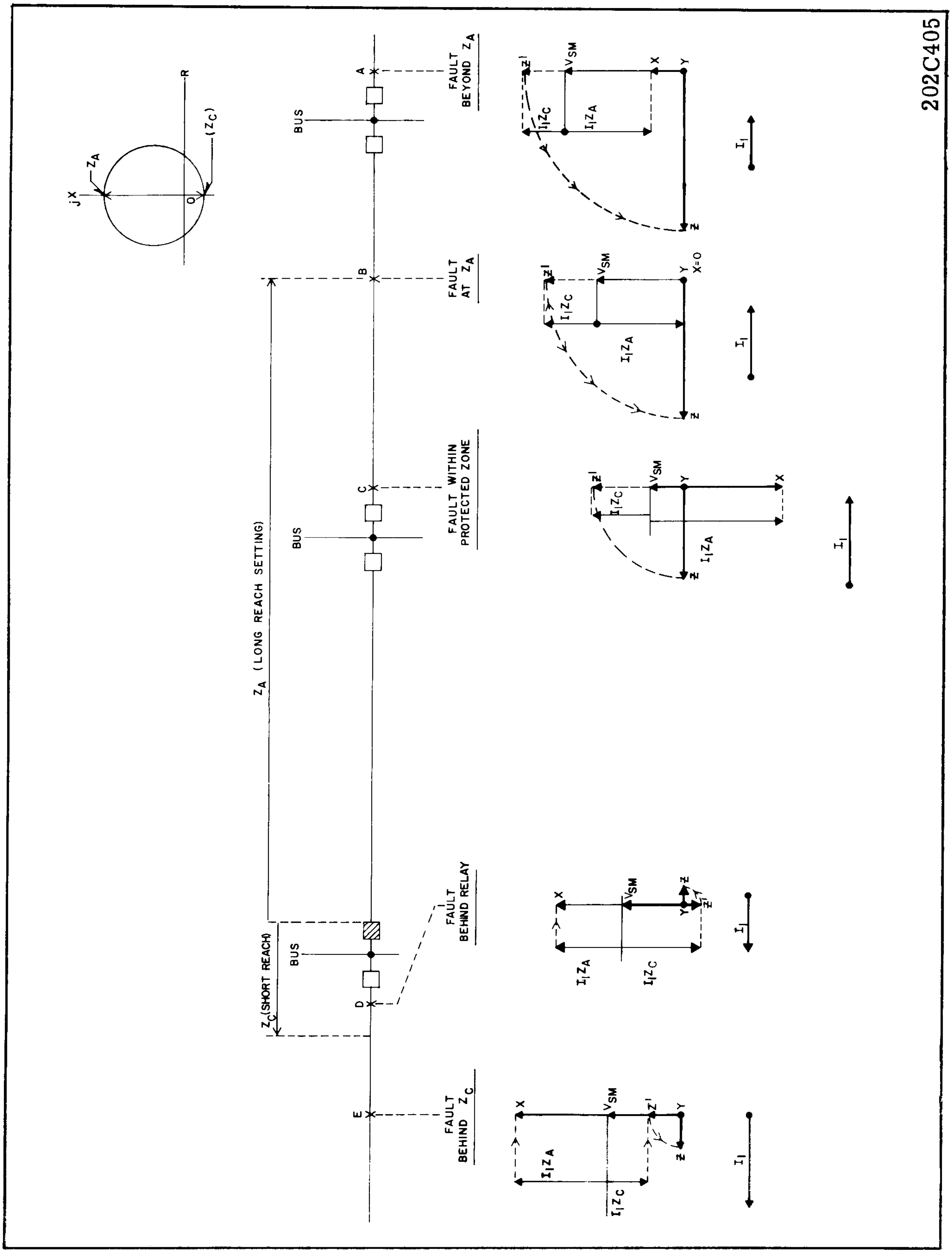



*Fig. 5 Voltage and Current Condition for SKSU*

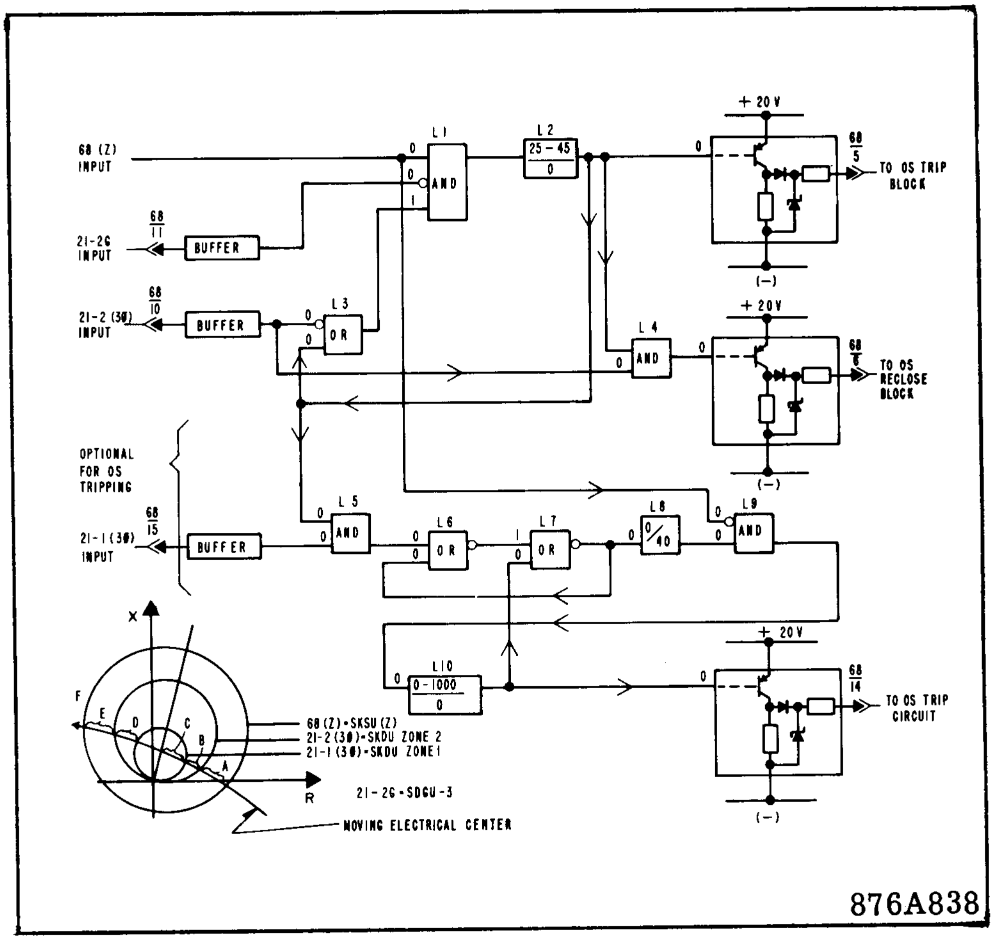



*Fig. 6 Out-of-Step Logic*

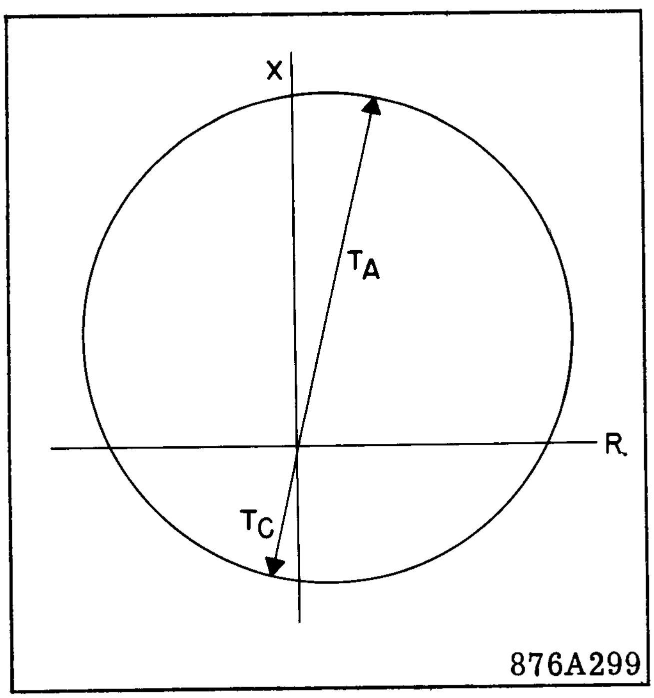
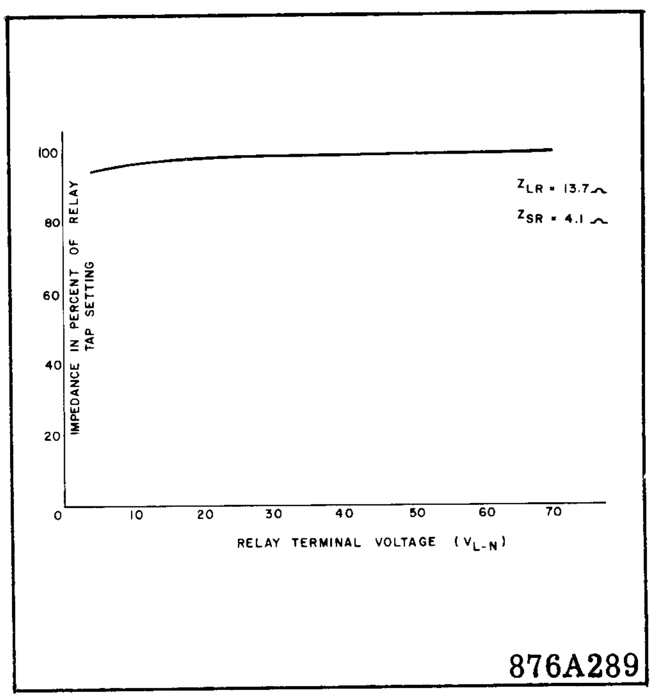



*Fig. 7 Circle Characteristic*




*Impedance Curve*

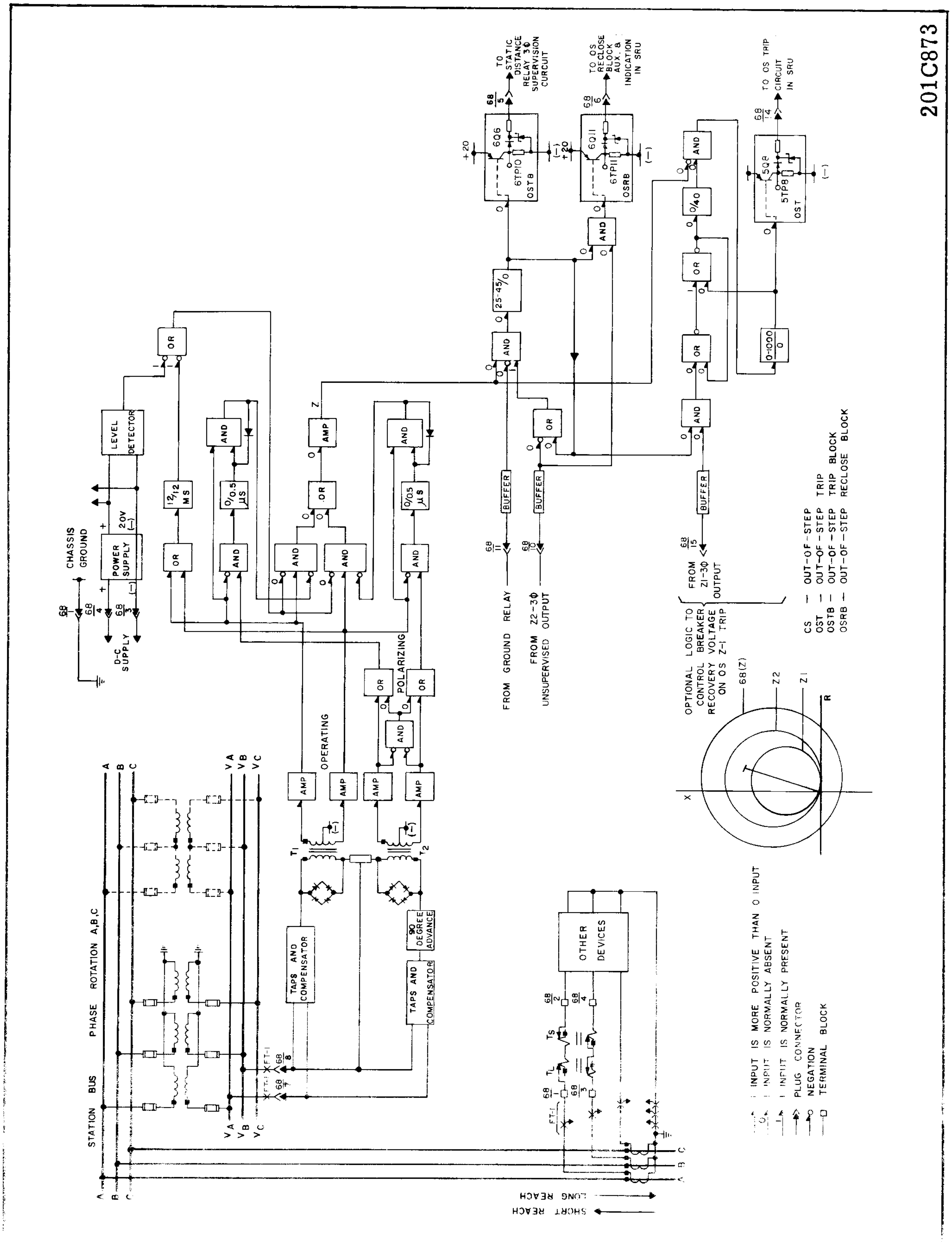



*Fig. 8 External Schematic*

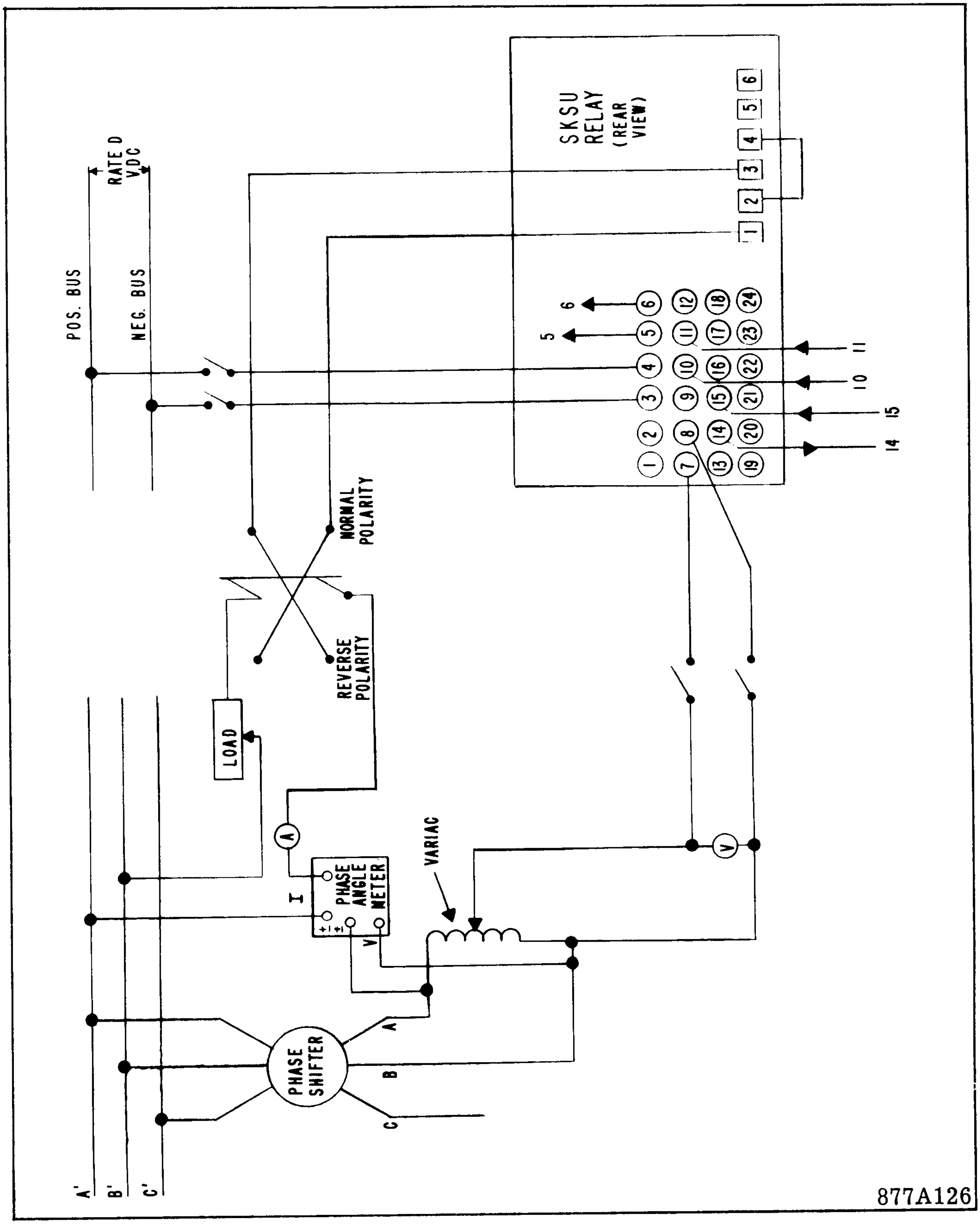



*Fig. 9 Test Circuit*

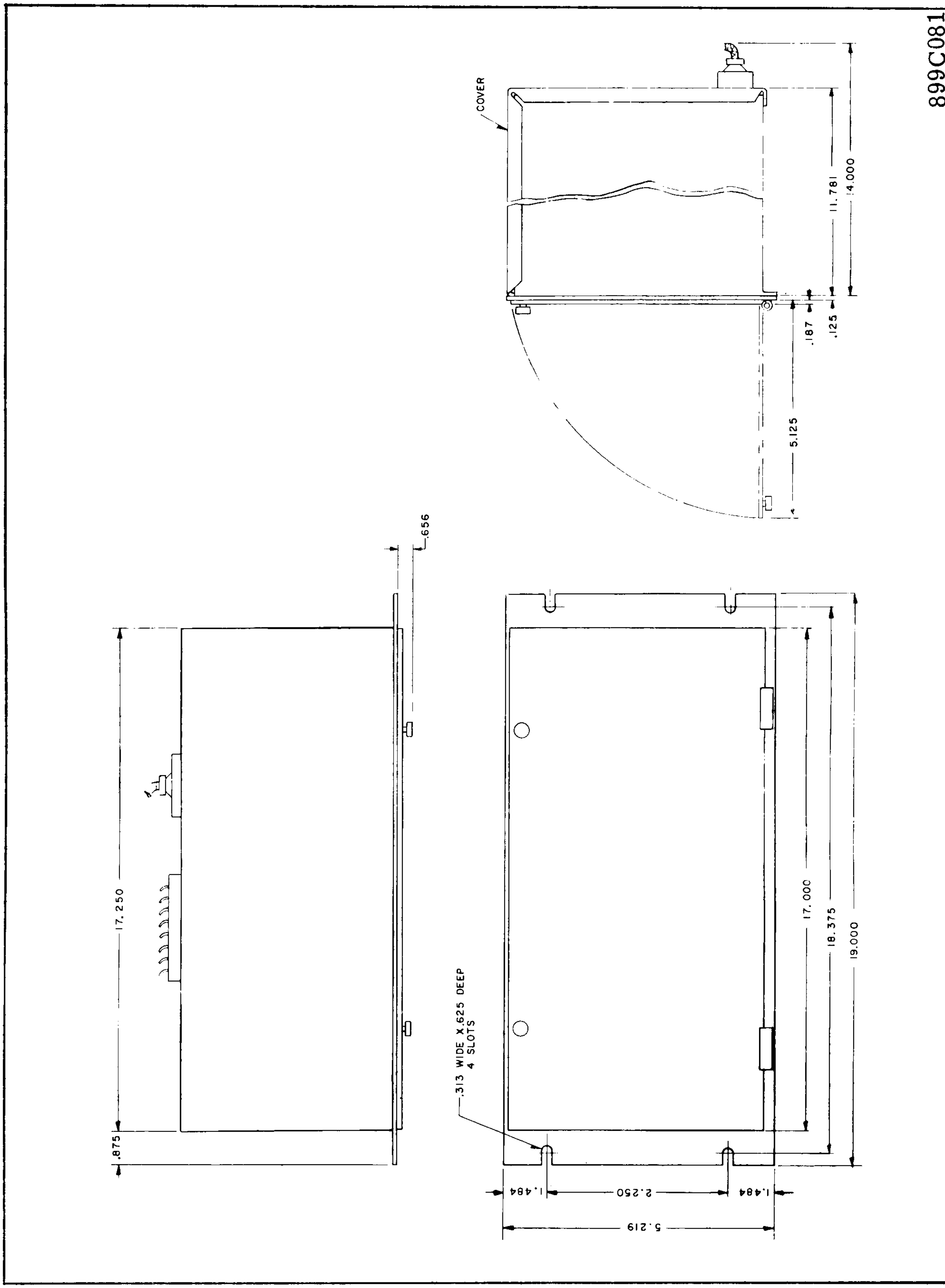



*Fig. 10 Chassis Outline*

**WESTINGHOUSE ELECTRIC CORPORATION**

**RELAY-INSTRUMENT DIVISION** **NEWARK, N. J.**

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