PHASE MONITOR
TYPE 112

Vitro ELECTRONICS
A DIVISION OF VITRO CORPORATION OF AMERICA
919 JESUP-BLAIR DRIVE • SILVER SPRING, MARYLAND

PRODUCERS OF NEMS • CLARKE EQUIPMENT

UNCLASSIFIED

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NEMS CLARKE
EQUIPMENT

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TYPE 112

• PRODUCED BY

Vitro ELECTRONICS

A DIVISION OF VITRO CORPORATION OF AMERICA MR. BIRCH

301 - JU 5 - 1000

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UNCLASSIFIED

Warranty for Equipment and Accessories

Vitro Electronics warrants each new equipment to be free of defects in material and workmanship, for a period of one (1) year after date of original shipment, except that tubes, fuses, transistors and diodes will be warranteed for a period of 90 days. Any instrument which is found within the one year period not to meet the foregoing standards, after examination by our factory, will be repaired or at the option of Vitro replaced without charge. This warranty does not apply to equipment which has been altered, improperly handled, or damaged in any way.

Changes in Specifications

The right is reserved to change the published specifications of equipment at any time, and to furnish merchandise in accordance with current specifications, without incurring any liability to modify equipment previously sold.

Returning Equipment to Factory

Factory service is available for repair and readjustment of this instrument; however, a description of the trouble, plus the model and serial numbers of the unit should be forwarded first, whereupon instructions for correcting the trouble or authorization for returning the equipment will be given. This applies to all units, whether under warranty or not.

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SECTION 1. GENERAL DESCRIPTION

1.1 Introduction.

The Model 112 Phase Monitor is designed to measure phase relationships and relative amplitudes of currents in a directional antenna system. Phase angle readings are presented on a panel meter having a linear scale indicating from 0 to 180 degrees. Relative values of tower currents are measured on a panel meter having a linear scale graduated from 0 to 110. Both phase and current are presented simultaneously as each tower is selected, with no adjustments required.

Provision is made for reading out phase and current on external instruments, such as a chart recorder, or - where increased resolution is required - on a digital voltmeter or extra-large panel meter. The linear dc voltage generated by the phase and current measuring circuits may also be fed to an existing remote control system for remote operation of the monitor. All switching in the monitor, including day-night transfer, is done with relays, to facilitate remote operation. The Model 113 Remote Meter Panel is available for remote extension of the monitor meters.

Space is provided for a maximum of nine inputs. Six input connectors and six sockets for the selector relays are provided normally. Input termination assemblies, selector relays, and the day-night relay are installed according to the requirements of the individual installation. Connections are also made at the factory for the reference tower or towers, and sampling line impedance required by the user. There are no frequency-determining components in the monitor.

Figure 1-1. Model 112 Phase Monitor.

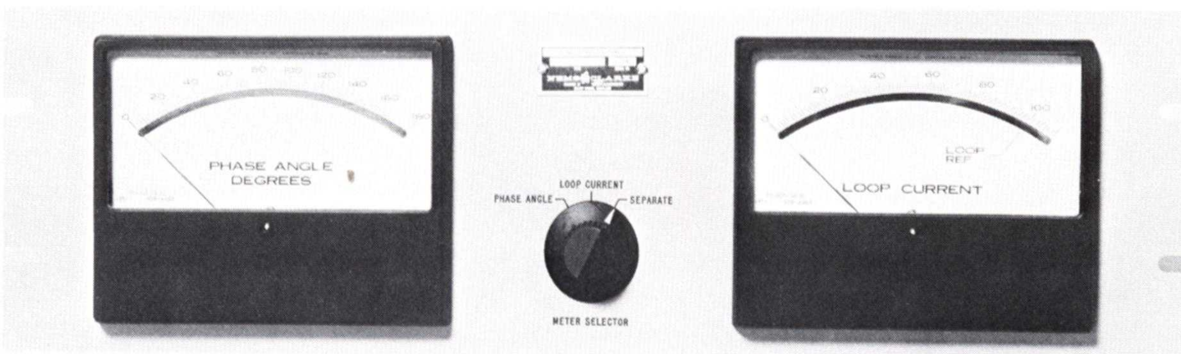


Figure 1-2. Model 113 Remote Meter Panel.

Table 1-1. Design Specifications

Frequency range:	540 to 1600 kc
Phase angle range:	0 to 180 degrees
Phase measurement accuracy:	±1.0 degree
Phase resolution:	0.5 degree
Current measurement accuracy:	±2.0%
Current resolution:	0.5%
Maximum inputs:	9
RF input impedance:	51 or 75 ohms
RF input voltage level:	1.5 to 20 volts rms
Minimum reference RF input level:	3.5 volts rms
DC output level, phase:	3.5 v for 180 degrees
DC output level, current:	3.0 v for 100%
Maximum remote circuit resistance:	11 K ohms
Relay voltage:	48 vdc
Circuitry:	Completely solid-state
Input power:	117 v ±10%, 50-60 cps, 11 watts May be strapped for 234 v
Dimensions:	19" wide x 7" high x 14" deep
Weight:	20 lbs.
Accessories:	Model 113 Remote Meter Panel

SECTION 2. INSTALLATION

2.1 General.

Upon receipt of the instrument, unpack carefully, remove the top and bottom covers, remove the shipping bracket holding down the plug-in modules, and inspect for damage in shipment. Replace the bottom cover only, since access is necessary to the top of the chassis for installation adjustments. Install in the rack as closely to eye level as possible, so that full advantage may be taken of the mirror scales on the panel meters.

The following items are included with the monitor:

1 instruction manual
1 line cord, VE 019709-01
1 adapter plug, #228
6 PL-259 coaxial plugs
1 P330CCE external connection plug

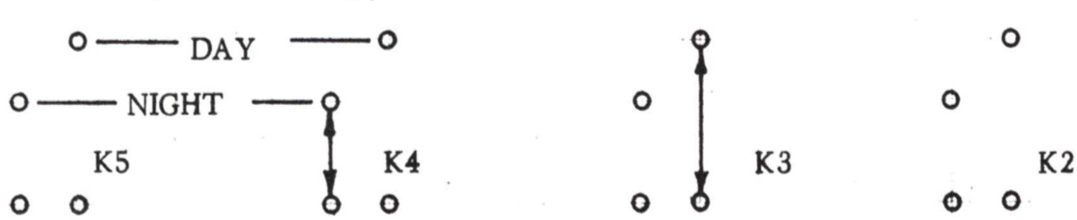
Check the label on the rear panel, to see that all the requirements of the installation have been complied with. This label shows factory connections that have been made for:

number of towers
sampling line impedance
reference tower number
day-night relay, if required

In the event that sampling line impedance was not known when the order was placed, it will be necessary to establish the correct impedance. The termination is normally 51 ohms. For 75 ohms, cut the jumper to R1, the outer most resistor on the input termination assembly. (Refer to the wiring diagram, fig. 7-4.)

Note that if the monitor is to be used with a single directional pattern system, either DA-1 or DA-N, it has been connected for operation in the "day" mode.

The jumper connecting the appropriate input to the reference channel, as shown in fig. 7-4, is wired between solder terminals on top of the base board, as illustrated below:



In this example, tower #3 is the reference tower for day time operation, and #4 is the night reference tower. For DA-1, DA-N and DA-D systems, one jumper is installed, in the day position.

2.2 Transmission Lines.

Connect the transmission lines to the UHF receptacles on the rear panel, in the order in which it is desired to read the towers. Termination resistance has been set at the factory to 75 or 51 ohms (or any other value, if specifically ordered). It is recommended that the sampling lines from each tower be of equal length, so that no error is introduced in the absolute value of phase indication due to different lengths of line.

With a DA-N system, it is important to measure the daytime voltage on the sampling line from the single tower in use, to determine if it exceeds the maximum specified value of 20 volts rms. If this voltage is too high, damage to the input termination resistors may result. To prevent this, a coaxial relay may be mounted directly at the appropriate input receptacle and connected so that it transfers the sampling line from the monitor to a dissipating resistance during daytime operation. The coil may be energized by the master phasor contactor, from either the 48 volt supply in the monitor or 117 volts ac.

2.3 External Connections.

Other external connections to be made are:

1. Connect the power to ac receptacle J10.

2. Connect external indicating devices, where used, as described in Section 2.6.

3. Connect remote control circuits, where used, as described in Section 2.7.

4. Connect the day-night relay to the master day-night relay for the transmitter and phasor, if automatic changeover of the monitor is desired. An external contact closure is required, to switch from day to night. Connect one of the contacts to J11-10, and the other to J11-25.

2.4 Adjustments.

Before turning on the power:

1. Adjust the pointer on each meter to exactly zero, with the zero set screw on the bezel.

2. Turn all input level controls completely counter-clockwise. These are the controls labeled R5 and R6 on each input termination assembly, and are located on the main chassis, toward the rear.

3. Open the subpanel door by pressing on its left edge, and turn both loop current dials to zero, or completely counter-clockwise.

Turn on the power switch, and after 15 minutes make the following adjustments:

1. Set the subpanel METER switch to INPUT LEVEL.

2. Set the MODE switch to DAY or NIGHT, depending on the pattern in use. (Single pattern stations will keep this switch in the DAY position.)

3. Select input #1 with the front panel TOWER SELECTOR switch.

4. Adjust R6 for day, or R5 for night, on the input termination assembly, so that the LOOP CURRENT meter reads in the INPUT LEVEL area on the scale. The input termination assembly for input #1 is on the extreme right, facing the front of the monitor.

5. Repeat step 4 for each input, and for each pattern. For single pattern operation, leave the unused controls in the CCW position.

6. Set the subpanel METER switch to the LOOP CURRENT position. Set the front panel TOWER SELECTOR switch to the reference tower position and adjust the DAY LOOP CURRENT or NIGHT LOOP CURRENT dials, depending on the pattern in use, so that the LOOP CURRENT meter indicates 100 on the scale. (Where the reference tower is not the highest level tower in the system, set it at a level that would allow simple computation such as at 50.)

7. Select any tower but the reference tower, set the METER switch on the subpanel to SYM REF CHAN and adjust the trimmer control associated with that position so that the LOOP CURRENT meter reads zero.

8. Repeat for the SYM SEL CHAN position.

9. Select the reference tower, and adjust the ZERO NULL capacitor for a null or minimum reading on the PHASE ANGLE meter.

10. Adjust the ZERO SET control for a reading of zero on the PHASE ANGLE meter.

11. Depress the 180° SET push-button switch, and adjust the control above it for a reading of 180° on the PHASE ANGLE meter.

12. Repeat steps 7 through 11. Note that the ZERO SET adjustment has an effect on the 180° reading, but not vice versa. Also, both symmetry adjustments have an effect on the zero reading.

The instrument is now ready to operate.

2.5 Calibration.

Since the loop current meter has what is described by the FCC as an "arbitrary scale" (one that does not read in the same units as the base current meters) it will be necessary to make a calibration curve showing the relationship between the loop current meter scale and the scale of each base current meter. This requirement, which applies when the loop current meter is used to remotely read the base currents, is outlined in paragraph 73.39 of the FCC Rules and Regulations.

2.6 External Indicating Devices.

In the event that increased resolution is required, it is possible to add an external measuring instrument such as an extra-large panel meter, a differential voltmeter, or a digital voltmeter to read both phase angle and loop current.

To install an additional panel meter, contact Vitro Electronics for additional information. To install a differential or digital voltmeter, proceed as follows:

1. Connection is made through the 30-pin remote plug, which plugs into J11. Connect to pin 15 for phase angle, and pin 20 for loop current. Pin 14 is the ground return. (To read both phase angle and loop current, an external transfer switch will be required, not supplied with this instrument.)

2. Follow the manufacturers instructions regarding warm-up time and calibration of the voltmeter.

3. With the phase monitor operating normally, switch the voltmeter to phase angle, select the reference tower and depress the 180° SET push-button. Adjust R2 on the rear panel so that the voltmeter indicates 1.800 volts.

4. Since the voltmeter provides better resolution than the phase angle meter on the monitor, it should now be used to make the zero setting. Adjust the ZERO SET control on the subpanel for a zero reading on the voltmeter.

5. Recheck the 180° reading, and adjust R2 again if necessary.

6. The voltmeter will now read out directly in degrees, with the decimal point displaced two places to the left. If desired, the decimal point lamps may be rewired to indicate correctly.

7. Switch the voltmeter to loop current, select the reference tower, set the DAY or NIGHT LOOP CURRENT dial to obtain a reading of 100 on the LOOP CURRENT METER, and adjust R6 on the rear panel so that the voltmeter indicates 1.000 volts. If a reference level other than 100 is used, set the voltmeter to the same value.

For a four-digit digital voltmeter, the resolution is 0.1 degree and 0.1 percent, plus or minus the inherent one count ambiguity in the last digit, or tenths place. The repeatability is the same, provided that the 0° and 180° points in the monitor, and the calibration of the meter, are maintained. Modulation will affect the resolution and repeatability rating of the loop current reading.

2.7 Remote Operation.

The FCC has adopted specific rules governing the reading of phase angle, loop current and base current in a directional antenna system, where operation by remote control is authorized. Vitro Electronics may be contacted for information and assistance on this subject.

For remote operation of the monitor, it is necessary to operate the tower selector relays from the transmitter unit of the remote control system. Also, selection must be made between the phase output and the loop current output, for each tower. Meter readings may be extended directly over telephone lines that provide a dc path except that there should be no series diodes in the lines the forward voltage drop of which would prevent the remote meters from indicating the minimum required values.

Before making interconnections, one of the two methods of operating the monitor must be selected.

1. If there are sufficient metering positions available, one group of positions may be assigned to phase and another group to current. (The group for phase may contain one less than the number of towers, if it is not desired to read the zero angle for the reference tower.) Each monitor selector relay may be energized by using the "raise" switch, for each position.

2. To conserve metering positions, both phase and current for any one tower may be read on one selector position, by using the "raise" switch to select phase and the "lower" switch to select current.

For method 1 above, a typical interconnection system is illustrated in fig. 7-1. A four tower system is shown, and the schematics for the monitor and remote control system are simplified.

The relays shown as the "auxiliary switching assembly" are required for use with remote control systems in which the "raise" and "lower" circuits switch any voltage other than 48 volts dc. In the Gates systems, those relays would be 6 vdc types, and it would not be necessary to operate the "raise" switch, since 6 volts is applied directly from the stepping switch. In other systems, the relays would be selected to match the voltage in use.

In systems where the raise-lower voltage is 48 vdc, such as those made by Rust and Shafer, the auxiliary assembly is eliminated. Make connections directly from the "raise" stepping switch to terminals 1, 2, 3, 4, etc., of J11, with the jumper as shown to operate each relay twice. At the + METER gang, connect the jumpered loop current terminals to J11-19, and the phase terminals to J11-13. Also, connect the raise-lower common voltage (-48 for Rust, +48 for Shafer) to J11-26.

For method 2 above, auxiliary relays will be required with all remote control systems. See fig. 1-2 for a typical interconnection. Relays are selected to match the raise-lower circuit voltage. For Gates systems, each pair of relays (K1-K2, K3-K4, etc.) will be replaced by an M5249 assembly, and the wiring modified accordingly.

Both fig. 7-1 and fig. 7-2 show connections for the Model 113 Remote Meter Panel. For method 1, selection between the two meters is done automatically by the stepping switch. For method 2, it is necessary to operate the METER SELECTOR switch manually, in conjunction with the raise-lower switch. It may be convenient, however, to modify the wiring of the remote panel to accomplish the meter transfer with the raise-lower switch, either directly or through a relay.

The final step in the installation is the calibration of the meters. Control R1 on the rear panel of the Phase Monitor is used to adjust the remote phase meter to agree with the phase meter on the Monitor. R5 calibrates the remote loop current meter. These adjustments are made after the remote control system has been calibrated.

2.8 Local Logger.

An automatic logger or chart recorder may be connected to the phase monitor. Circuitry must be provided for sequentially operating the monitor selector relays, and for selecting between phase and loop current if it is desired to log both. The dc outputs for phase and loop current may be taken off at J11-13 and J11-19, respectively, and calibrated with rear panel pots R1 and R5.

If these terminals are in use for another purpose, it will be necessary to add pots at positions R3 and R7 and connect these as shown on the wiring diagram. The controls are Bourns Type 273-1-103M.

2.9 Additional Outputs.

As mentioned above, additional output calibrating controls may be added on the rear panel at positions R3 and R7. Also, 3/8" diameter holes are provided at positions R4 and R8 for the installation of high-resolution multi-turn controls such as the Bourns 3500S-1. These controls will be wired in parallel with R1 or R5, and the arms connected to J11 as shown on the wiring diagram.

SECTION 3. OPERATION

3.1 Phase Measurement.

After the initial adjustments are made as outlined in Section 2.4, it is only necessary to rotate the TOWER SELECTOR switch to take phase angle and loop current readings.

The relationship of the selected tower phase angle to the reference tower can be determined by depressing the SENSE push button. If the phase angle reading decreases when the push button is depressed, the selected tower lags the reference tower by the indicated angle. If the reading increases, the selected tower leads the reference tower. For example, if the meter reads 160° and decreases when the push button is depressed, the selected tower lags the reference by 160°, (or it may be said to lead it by 200°). If the reading increases, the selected tower leads by 160°.

It is important to note that an error in the sense indication will result for leading angles close to 180°, and lagging angles close to zero, if the measured angle is closer to 180° or zero than one-half the amount of phase shift obtained from the sense circuit. For example, the average sensing phase angle shift is about four degrees at 1600 kc. (The shift is directly proportional to frequency.) For a measured leading phase angle of 178° at 1600 kc, the sense circuit will advance the phase angle to 182°, which will read as 178° on the meter. Thus, no shift will be evident. The sense circuit will advance a measured angle of 179° to 183°, which will read as 177° on the meter, and this decrease in the meter reading would erroneously indicate a lagging angle. The same analysis can be made for lagging angles near zero. To obtain a useful reading under these conditions, a delay line should be inserted at the input receptacle, in series with the sampling line.

The phase angle meter will indicate a random reading when there is no rf signal applied to the two channels.

3.2 Tuning the Array.

The phase angle indication is relatively unaffected by reasonable changes in input levels from the sampling loops. If the voltage level from either of the two towers being measured changes while tuning, the effect on phase angle is less than 0.5° for a 30% increase in level, and less than 1.0° for a 30% decrease in level, compared with the value at which the inputs were originally set. The change is less than 1.0° for an increase of 100%. To operate within a ±1.0° tolerance, the input level indication as read on the LOOP CURRENT meter should be maintained between 19 and 71.

3.3 Loop Current Measurement.

The purpose of the dial on the DAY LOOP CURRENT and NIGHT LOOP CURRENT controls is to provide a means of recording the setting that produces a reading of 100 on the LOOP CURRENT meter for the reference tower when the array has been properly tuned. This reading should be entered in the log at the time of final adjustment, and each time that it is necessary to change it due to retuning, or changing the associated diode (CR5 on the phase meter board). When the reference tower is set at 100, the ratios of the other towers may be read directly on the LOOP CURRENT meter scale. It is important to note that the error in the current ratio reading increases at the low end of the meter for two reasons: 1) The resolution of the meter is a larger percentage of the lower readings. For example, one-half of a scale division represents 5% of the reading at 10 on the scale, but only 0.5% of the reading at 100. 2) The metering circuit is less accurate for low RF input levels. An accuracy of 2% can be maintained for inputs down to 3 volts rms.

The dial will not normally be adjusted each time the meters are read, to compensate for the normal variations in the reference tower level. Instead, the absolute readings for each tower will be logged, and the ratios calculated from these readings. The settings may be locked with the levers provided for this purpose.

Modulation affects the loop current reading as a function of the amount of carrier shift in the transmitter. The shift may be upward or downward, depending on the modulating waveform. The transmitter should be adjusted to provide the lowest possible carrier shift. Readings should be taken in the absence of modulation whenever possible.

With no input signals applied, there is a small residual upward reading of the LOOP CURRENT meter. This is the result of a slight bias in the loop current circuit which improves linearity.

To protect the LOOP CURRENT DIODE from damage due to high voltage transients on the sampling lines, it is recommended that the TOWER SELECTOR switch be placed in the OFF position between meter reading periods. This is especially important during electrical storms.

3.4 Calibration.

The ZERO SET, 180° SET, SYMMETRY and mechanical zero set adjustments should be checked periodically. The frequency of adjustment can best be determined by the individual user.

SECTION 4. THEORY OF OPERATION

4.1 General.

Refer to the overall wiring diagram, fig. 7-4. Only two inputs are shown on this drawing for simplicity; all are wired identical to these.

Input signals are supplied to J1 and J2. Pots R5 and R6 adjust the levels to about 0.4 volt rms, for application to the phase metering circuitry. This voltage is measured by the LOOP CURRENT meter M2 with the METER switch S4 in the INPUT LEVEL position, at the point where the selected signal is applied to the input of the selected channel limiter amplifier, module A11. Thus the level for each tower may be set by energizing the associated input relay K1 through K9.

When an input relay is energized, the outputs of both R5 and R6 are applied to the day-night relay K10. The state of this relay determines which pot is connected to A11. At the same time, the full value of the sampling voltage, appearing at the top of the input termination network, is applied to the loop current diode, CR5 in the phase meter module A12, through pin D.

The outputs of R5 and R6 for the reference tower are permanently connected to the reference limiter, A13, through K10. This is done by means of jumpers between the appropriate R5 and R6 to a day bus and a night bus which run the length of the relay base board, terminating at K10.

K10 also switches either the DAY LOOP CURRENT control or the NIGHT LOOP CURRENT control into the loop current metering circuit.

When the monitor is used in a single directional pattern installation, the relay K10 is replaced with jumpers as described in note 5.

The dc output generated by the phase meter circuitry is applied to controls R1 and R2. R1 may be used to feed the metering line in a remote control system, or a local automatic logger. R2 calibrates a digital voltmeter, when used. The purpose of R30, R31, and R32 is to provide a vernier action for R2, setting its range to provide an output varying slightly above and below 1.8 volts, for a 180° phase reading.

R5 and R6 are available in the loop current circuit for the same purpose as R1 and R2. R2 provides adjustment of output voltage slightly above and below one volt for a 100% loop current reading.

4.2 Limiter Amplifier.

Refer to the schematic of the limiter and phase meter modules, fig. 7-3.

The limiter amplifier serves three purposes in this monitor: it removes amplitude modulation from the input RF signal; it provides a square wave to the phase meter circuit, improving its switching time and accuracy; and it provides a method of making the input signal symmetrical, which is necessary for the accuracy of the phase meter circuit.

Q1 and Q2 are biased at the same point by their respective base divider networks. With no signal, equal current flows in both transistors. As the applied signal goes positive, Q1 conducts more heavily, cutting off Q2.

As the input voltage goes negative, Q1 cuts off. The square waves produced at the collectors of Q1 and Q2, which are reversed in phase, are applied to another differential amplifier, Q3 and Q4. While the input signal to Q3 is going positive, the base of Q4 is going negative at the same rate, resulting in a very fast switching time.

R9 and R10 on the subpanel are adjusted to obtain a symmetrical square wave. The symmetry detector is composed of CR1A and CR1B, C7, C8, R15, and R16. Each half of the square wave produces current in the diodes in opposite directions, and when the currents are equal, there is zero current in the meter, connected to pin A. The LOOP CURRENT meter is used for this purpose.

Note that both limiters are identical.

4.3 Phase Meter.

The phase detector is made up of Q1, Q2 and Q3. These transistors are connected between the +12.5 and -12.5 volt supplies, and their bases are at dc ground potential. (The base of Q3 is also at ac ground potential.)

Since the bases are at dc ground, the emitters are held at a bias a few tenths of a volt below ground and cannot swing with the input signal, as is usual in the emitter follower connection. Thus, each input transistor cuts off as its input signal goes negative.

When both input transistors are cut off, the total circuit current, determined by R8, flows through Q3, causing it to saturate. During the remaining time, when either or both of the input signals are positive, Q3 is cut off. Thus, the voltage at the collector of Q3 is a square wave whose positive limit is approximately the break-down voltage of Zener diode CR1, and whose negative limit is slightly below ground potential. The width of the negative-going pulse is determined by the time during which both input signals are negative; which, in turn, is determined by the phase angle between them. For zero phase angle, the square wave at the collector of Q3 is symmetrical. As the phase angle approaches 180°, the negative-going pulse becomes narrower. At 180°, Q3 is cut off completely, and the voltage at its collector equals the Zener voltage. A dc meter connected to the collector of Q3 will read the average value of this signal. Capacitor C7 integrates this signal so that the average dc value is applied to the following circuit.

To simulate 180°, it is only necessary to cut off Q3. This is accomplished by applying a negative voltage through S6 to its base.

Since zero phase angle produces a finite voltage at the collector of Q3, it is not possible to read this voltage against ground, because the meter must read zero at this time. It is necessary to shift this voltage to ground potential, and this is accomplished by Zener diode CR3, emitter follower Q4 and constant current source Q5.

The voltage at Q3 is approximately +2.5 volts at zero degrees, and +6.0 volts at 180°.

The combination of 6.3 volt diode CR3, and the base-emitter bias of Q4, shifts these voltages downward by about 7.0 volts. By connecting a pot, R11, across this diode, the zero voltage point can be adjusted.

Q5 maintains a constant current in its collector circuit, practically independent of collector load, due to the fixed bias on its base provided by Zener diode CR2. This is necessary to maintain the voltage drop across CR3 constant. Since this diode has a finite impedance of about 20 ohms, its breakdown voltage would vary as the phase angle changed, if the current were not supplied from a constant current source.

PNP transistor Q6 is complimentary to Q4, and provides temperature compensation for it. Phase angle readout voltage is taken off at the emitter of Q6.

4.4 Loop Current.

The loop current circuitry is located on the phase meter board.

Diode CR5 rectifies the loop current RF signal, which is obtained directly from the sampling line input receptacle, through the input relays. The diode load resistor is either of the two loop current pots, selected by the day-night relay. Output of the pots connects to emitter follower stages Q7 and Q8, which are complimentary to provide temperature compensation. The low impedance output of Q8 feeds the parallel arrangement of output controls shown on the wiring diagram.

Adjustment of R36 provides a positive offset on the loop current meter of approximately 1 to 1 1/2 divisions. This offset is in the direction to oppose the forward drop in CR5, improving linearity.

4.5 Power Supply and Regulator.

Refer to the overall wiring diagram and to the dual regulator schematic.

Two secondaries on power transformer T1 supply power to the +12.5 and -12.5 volt regulators. The third secondary is connected to a half-wave rectifier and capacitor filter to produce the 48 volts required for operation of the relays. Both sides of the 48 volt supply are brought out to the remote receptacle, J11, to facilitate remote operation of the monitor relays.

The regulators for the +12.5 and -12.5 volt supplies are identical except for resistors R3 and R8. The 21 volt ac supply is rectified by bridge rectifier CR1 and filtered by chassis mounted capacitor C1, producing about 26.5 volts. Load current flows through series transistors Q1 and Q2, in a Darlington configuration. Changes in output voltage, caused by a change in either line voltage or load, are sensed by Q3 through divider R4, R11, and R5. Zener diode CR8 maintains the emitter of Q3 at a constant +6.2 volts. The output variations are amplified by Q3, and applied to the base of Q2 - Q1, changing the series resistance in the direction that opposes the original output shift. R11 sets the output voltage at exactly 12.5 volts.

Q4 is a high impedance collector load for Q3. In conjunction with R2, R3 and CR3 it provides short-circuit protection for the regulator. If the load current increases above about 200 ma, the voltage drop across R3 causes CR5 to conduct. Q4 then becomes nearly cut off, limiting the current into the collector of Q2-Q1 and increasing the resistance of the series transistor. An equilibrium point is reached when the load current is limited to 200 ma even if the load resistance is reduced to a short circuit. (Limiting current in the -12.5 volt supply is 150 ma.)

Temperature compensation is provided in several places. CR4 compensates for the temperature change of the base-emitter diode of Q4. CR8 is a temperature compensated Zener diode having a temperature coefficient of .005%/deg. C. CR6 and CR7 compensate for the temperature change of the base-emitter diode of Q3.

SECTION 5. MAINTENANCE

5.1 General.

Normally, the instrument should require no maintenance, except for checking the adjustments as described in Section 3.5. If trouble develops the monitor can best be repaired at the factory. However, if this is not practical, Vitro Electronics should be contacted for advice on making repairs. The procedure that follows may be helpful in some cases.

5.2 Troubleshooting.

Taking measurements on the monitor when it is operating normally can be helpful when trouble occurs. Specifically, measure the sampling loop voltage at the input connectors, by the use of a T-connector. Record these values along with a description of the meter used. These readings will be useful in locating trouble in the sampling loops or in any of the fittings or lines between the loops and the monitor. Also, record the value of the +12.5 and -12.5 volt supplies with one particular dc meter. These can be measured at pins 28 and 29 of remote connector J11 against ground.

Some routine checks which can be made if trouble occurs are as follows:

1. Check the fit of the module plug pins in their respective sockets.

2. Check the sampling voltages.

3. Check the +12.5 and -12.5 volt supplies.

4. Check the +48 volt relay supply at pin 25 of J11, measured against pin 26. (-48 v is not grounded.) This should measure about 60 volts with all relays de-energized.

5. Check screws which mount the input receptacles and the input termination assemblies, for tightness.

6. RF level out of the day and night pots, R5 and R6, should be about 0.4 volts rms, if set correctly on the INPUT LEVEL meter.

7. Square wave out of the limiters should be about 2.3 volts p-p, as measured on an oscilloscope with good high frequency response. (5 mc or better.) Symmetry can also be checked at this point, with the oscilloscope.

8. DC output level, as measured at terminal 3 of the output calibrating pots R1 and R5 on the rear panel should be +3.5 volts at 180° for the phase angle section, and +3.0 volts at 100% for the loop current section, both ±5%.

9. Operating dc voltages on the transistors are as follows, measured to chassis ground.

Regulator:

Transistor	Collector	Base	Emitter
Q1	23.0	13.1	12.5
Q2	23.0	13.7	13.1
Q3	13.7	6.9	6.3
Q4	13.7	20.0	20.6
Q5	10.5	0.6	0
Q6	10.5	1.2	0.6
Q7	1.2	-5.6	-6.2
Q8	1.2	6.8	7.4

Limiter: (no signal)

Q1	8.3	3.0	2.4
Q2	8.3	3.0	2.4
Q3	10.2	8.3	8.2
Q4	10.2	8.3	8.2

Phase meter:

Q1	5.8	0	
Q2	5.8	0	
Q3:			
0°	2.5	0	
180°	6.1	-2.1	
Q1, Q2, Q3:			
0°			-0.3
180°			-0.8
Q4:			
0°	7.1		1.8
180°	7.1		5.4
Q5:			
0°	-4.4	-6.8	-7.5
180°	-0.8	-6.8	-7.5
Q6:			
0°	-9.6	-0.7	0
180°	-10.5	2.9	3.5

Phase meter: (cont)

Transistor	Collector	Base	Emitter
Following taken at 100% loop current.			
Q7	7.8	2.9	2.3
Q8	-7.0	2.3	3.1

SECTION 6. PARTS LIST

6.1 General.

When ordering replacement parts, specify the equipment name and model number, and the reference designation number and description of each item ordered.

Table 6-1. Replaceable Parts, Main Chassis, 112 Phase Monitor

Reference Designation	Name and Description	Part Number Vitro	Part Number Vendor
C1, C2	CAPACITOR: 500 mfd, 50 v	90910202	Mallory WP-065
C3	CAPACITOR: 100 mfd, 150 v	90910203	Mallory FP-116A
C4	CAPACITOR, Variable: 5.5-100 mmf	90950253	Hammarlund APC-100
C5	CAPACITOR, Dura-Mica: 68 mfd, 5%, 500 v	90921198	Elmenco
CR1	DIODE	91600268	GE 1N1695
DS1	LAMP HOLDER with NE-2J	92500062	Dialco 137-8836H-33K-931
J1 thru J6	CONNECTOR, Recp:	91371130	Amphenol SO-239
mates with above	CONNECTOR, Plug	91370730	Amphenol 83-1SP
J10	CONNECTOR, Recp:	91371250	Hubbell 7486
J11	CONNECTOR, Recp:	91371345	Cinch S-330-EB
mates with above	CONNECTOR, Plug	91370505	Cinch P-330-CCE
K1 thru K10 (as required)	RELAY	93400094	Potter and Brumfield KHP17D11
M1	PHASE METER	103484-01	API

Table 6-1. Replaceable Parts, Main Chassis, 112 Phase Meter (Cont)

Reference Designation	Name and Description	Part Number Vitro	Part Number Vendor
M2	LOOP CURRENT METER	103488-01	API
R1, R2, R5, R6	RESISTOR, Variable: 10 K, 1/4 w	931790019	Bourns 273-1-103M
R9, R10, R11	RESISTOR, Variable: 200 ohm, 1/4 w	93160200	A. Bradley RK201UAB
R12	RESISTOR, Variable: 5 K, 1/4 w	93170018	Bourns 273-1-502M
R13, R14	RESISTOR, Variable: 10 K, 2 w	93170150	Bourns 3500S-2-103
R30	RESISTOR, Deposited Carbon: 4640 ohm, 1%, 1/4 w	93585290	IRC RN60B4641F
R31	RESISTOR, Deposited Carbon: 1100 ohm, 1%, 1/4 w	93585202	IRC RN60B1101F
R32	Same as R30		
R33	RESISTOR, Deposited Carbon: 6190 ohm, 1%, 1/4 w	93585305	IRC RN60B6191F
R34	Same as R31		
R35	RESISTOR, Deposited Carbon: 2800 ohm, 1%, 1/4 w	93585260	IRC RN60B2801F
R36	RESISTOR, Variable 100 ohm, 10%, IW	93170060	Bourns 2605-1-101M
R37	RESISTOR, Fixed Composition: 6.2 K, ±5%, 1/2 w	93550940	RC20GF622J MIL-R-11
S1	SWITCH, Rotary	94850140	Centralab PA2001
S2	SWITCH, Rotary	94850150	Centralab PA2003
S3	SWITCH, Toggle: SPST	94850430	H. H. Smith 510
S4	SWITCH, Rotary	103610	Centralab
S5	SWITCH, Push Button: 30-1	94850073	Gray Hill
S6	SWITCH, Push Button: 203-S	94850068	Switch Craft

Table 6-2. Replaceable Parts, Limiter Module, 112 Phase Monitor

Reference Designation	Name and Description	Part Number Vitro	Part Number Vendor
C1	CAPACITOR, Monolytic: 1.0 mfd, 25 v	90901910	Sprague 5C13
C2	CAPACITOR, Monolytic: .47 mfd, 20%, 25 v	90901906	Sprague 5C11
C3	CAPACITOR, Monolytic: .1 mfd, 25 v	90901805	Sprague 5C7
C4, C5	Same as C1		
C6	Same as C3		
C7, C8	CAPACITOR: .01 mfd, 50 v	90901758	Sprague 19C214
CR1	DIODE, Pair	91600012	Fairchild FA2009
L1	CHOKE, RF: 10,000 μh WEE DUCTOR	91150355	Nytronics
P1	CONNECTOR, Plug	91370798	Amphenol 133-015-03
Q1, Q2, Q3, Q4	TRANSISTOR: w 1/2 in leads	95350101	2N708
R1	RESISTOR, Fixed Composition: 240 ohm, 5%, 1/2 w	93550420	RC20GF241J MIL-R-11
R2	RESISTOR, Deposited Carbon: 2 K, 1%	93580014	IRC RN65B2001F
R3	RESISTOR, Deposited Carbon: 1 K, 1%	93580018	IRC RN65B1001F
R4	RESISTOR, Fixed Composition: 220 ohm, 5%, 1/2 w	93550400	RC20GF221J MIL-R-11
R5	RESISTOR, Fixed Composition: 390 ohm, 5%, 1/2 w	93550480	RC20GF391J MIL-R-11
R6	RESISTOR, Fixed Composition: 330 ohm, 5%, 1/2 w	93550450	RC20GF331J MIL-R-11
R7	Same as R4		
R8	Same as R2		
R9	Same as R3		

Table 6-2. Replaceable Parts, Limiter Module, 112 Phase Monitor (Cont)

Reference Designation	Name and Description	Part Number Vitro	Part Number Vendor
R10	RESISTOR, Fixed Composition: 180 ohm, 5%, 1/2 w	93550370	RC20GF181J MIL-R-11
R11	RESISTOR, Fixed Composition: 220 ohm, 5%, 1/2 w	93550400	RC20GF221J MIL-R-11
R12	RESISTOR, Fixed Composition: 750 ohm, 5%, 1/2 w	93550580	RC20GF751J MIL-R-11
R13	RESISTOR, Fixed Composition: 220 ohm, 5%, 1/2 w	93550400	RC20GF221J MIL-R-11
R14	RESISTOR, Fixed Composition: 43 ohm, 5%, 1/2 w	93550150	RC20GF430J MIL-R-11
R15, R16	RESISTOR, Deposited Carbon: 3.01 K, 1%	93580014	IRC RN65B3011F

Table 6-3. Replaceable Parts, Phase Meter Module, 112 Phase Monitor

Reference Designation	Name and Description	Part Number Vitro	Part Number Vendor
C1, C2, C3	CAPACITOR, Monolytic: .1 mfd, 25 v	90901805	Sprague 5C7
C4, C5	CAPACITOR, Monolytic: 1 mfd, 25 v	90901910	Sprague 5C13
C6, C7	Same as C1		
C8, C9	CAPACITOR: .01 mfd, 50 v	90901758	Sprague 19C214
C10	Same as C1		
CR1	DIODE	91600227	1N825
CR2	DIODE	91600204	1N708A
CR3	Same as CR1		
CR4	Not Used		
CR5	DIODE	91600090	1N38A
P1	CONNECTOR, Plug	91370798	133-015-03
Q1, Q2	TRANSISTOR	95350101	2N708
Q3	TRANSISTOR	95350102	2N709
Q4	TRANSISTOR	95350709	2N2218
Q5	Same as Q1		
Q6	TRANSISTOR	95354050	2N2904
Q7	Same as Q4		
Q8	TRANSISTOR	95350510	2N1991
R1	RESISTOR, Fixed Composition: 390 ohm, 5%, 1/2 w	93550480	RC20GF391 MIL-R-11
R2	RESISTOR, Fixed Composition: 100 ohm, 5%, 1/2 w	93550290	RC20GF101J MIL-R-11
R3	Same as R1		
R4	Same as R2		
R5	RESISTOR, Fixed Composition: 2 K, 5%, 1/2 w	93550730	RC20GF202J MIL-R-11
R6	RESISTOR, Fixed Composition: 10 K, 5%, 1/2 w	93551020	RC20GF103J MIL-R-11

Table 6-3. Replaceable Parts, Phase Meter Module, 112 Phase Monitor (Cont)

Reference Designation	Name and Description	Part Number Vitro	Part Number Vendor
R7	RESISTOR, Deposited Carbon: 619 ohm, 1%	93580016	IRC RN65B6190F
R8	RESISTOR, Deposited Carbon: 1 K, 1%	93580018	IRC RN65B1001F
R9	RESISTOR, Fixed Composition: 820 ohm, 5%, 1/2 w	93550590	RC20GF821J MIL-R-11
R10	RESISTOR, Fixed Composition: 390 ohm, 5%, 1/2 w	93550480	RC20GF391J MIL-R-11
R11	RESISTOR, Deposited Carbon: 357 ohm, 1%	93580012	IRC RN65B3570F
R12	RESISTOR, Deposited Carbon: 324 ohm, 1%	93586300	IRC RN65B3240F
R13	Same as R5		
R14	RESISTOR, Fixed Composition: 620 ohm, 5%, 1/2 w	93550550	RC20GF621J MIL-R-11
R15	Same as R9		
R16	RESISTOR, Fixed Composition: 330 ohm, 5%, 1/2 w	93550460	RC20GF331J MIL-R-11
R17	RESISTOR, Fixed Composition: 4.3 K, 5%, 1/2 w	93550860	RC20GF432J MIL-R-11
R18	Same as R6		
R19	RESISTOR, Fixed Composition: 1 K, 5%, 1/2 w	93550620	RC20GF102J MIL-R-11
R20	RESISTOR, Fixed Composition: 680 ohm, 5%, 1/2 w	93550560	RC20GF681J MIL-R-11

Table 6-4. Replaceable Parts, Regulator Module, 112 Phase Monitor

Reference Designation	Name and Description	Part Number Vitro	Part Number Vendor
C1, C2	CAPACITOR, Tantalum: 22 mfd, 35 v	90930138	Sprague
CR1, CR2	DIODE, Silicon Bridge	9160017	Mallory FW100
CR3	DIODE, Zener	91600206	Motorola 1N753A
CR4, CR5, CR6, CR7	DIODE	91600160	Hughes 1N457
CR8	DIODE, Zener	91600228	1N823
CR9	Same as CR3		
CR10, CR11	Same as CR4		
CR12	Same as CR8		
CR13, CR14	Same as CR4		
P1	CONNECTOR, Plug	91370798	Amphenol 133-015-03
Q1	TRANSISTOR	95350230	RCA 2N1483
Q2, Q3	TRANSISTOR	95350709	2N2218
Q4	TRANSISTOR	95350510	Sylvania 2N1991
Q5	Same as Q1		
Q6, Q7	Same as Q2		
Q8	Same as Q4		
R1	RESISTOR, Fixed Composition: 2.4 K, 5%, 1/2 w	93550770	RC20GF242J MIL-R-11
R2	RESISTOR, Fixed Composition: 1 K, 5%, 1/2 w	93550620	RC20GF102J MIL-R-11
R3	RESISTOR, Fixed Composition: 33 ohm, 5%, 2 w	93570045	RC42GF330J MIL-R-11
R4, R5	RESISTOR, Deposited Carbon: 1020 ohm, 1%	93586500	IRC RN65B1021F
R6	Same as R1		

Table 6-4. Replaceable Parts, Regulator Module, 112 Phase Monitor (Cont)

Reference Designation	Name and Description	Part Number Vitro	Part Number Vendor
R7	Same as R2		
R8	RESISTOR, Fixed Composition: 51 ohm, 5%, 2 w	93570070	RC42GF510J MIL-R-11
R9, R10	Same as R4		
R11, R12	RESISTOR, Variable: 500 ohm, 5%, 1/2 w	93170030	Bourns 3067P-1-501

Table 6-5. Replaceable Parts, Base Board, 112 Phase Monitor

Reference Designation	Name and Description	Part Number Vitro	Part Number Vendor
C6	CAPACITOR, Dura-Mica: 47 mmf, 5%, 500 v	90921192	Elmenco
C7	CAPACITOR: .01 mfd, 50 v	90901758	Sprague 19C214
C8, C9, C10, C11, C12, C13, C14, C15, C16, C17	CAPACITOR: .01 mfd, 500 v	90901760	Sprague 29C9B8
CR2	DIODE	91600098	1N64
R15	RESISTOR, Fixed Composition: 13 K, 5%, 1/2 w	93551070	RC20GF133J MIL-R-11
R16	RESISTOR, Fixed Composition: 100 K, 5%, 1/2 w	93551430	RC20GF104J MIL-R-11
R17	RESISTOR, Deposited Carbon: 475 ohm, 1%	93586400	IRC RN65B4750F
R18, R19	RESISTOR, Deposited Carbon: 33.2 K, 1%	93586700	IRC RN65B3322F
R20, R21, R22, R23, R24, R25, R26, R27, R28, R29	RESISTOR, Fixed Composition: 4.3 K, 5%, 1/4 w	93530640	RC07GF432J MIL-R-11
XA11, XA12, XA13, XA14	CONNECTOR, Socket	91370799	Amphenol 143-015-03
XK1 thru XK10	SOCKET, Relay	94450001	Potter & Brumfield 9KH2

Table 6-6. Replaceable Parts, Resistor Bracket Assembly, 112 Phase Monitor

Reference Designation	Name and Description	Part Number Vitro	Part Number Vendor
R1	RESISTOR: 158 ohm, 1% 2 w	93580248	IRC DCH
R2	RESISTOR: 33.2 ohm, 1%, 2 w	93580244	IRC DCH
R3, R4	RESISTOR, Deposited Carbon: 110 ohm, 1%, 2 w	93580246	IRC DCH
R5, R6	RESISTOR, Variable: 100 ohm, 10%, 1 w	93170060	Bourns 260S-1-101M

Table 6-7. Replaceable Parts, Remote Meter Panel, 113

Reference Designation	Name and Description	Part Number Vitro	Part Number Vendor
M1	METER PHASE ANGLE	103484-01	API
M2	METER LOOP CURRENT	103586-01	API
R1,R2	RESISTOR, Deposited Carbon: 21.5 K, ±1%	93586650	RN65B2152F
S1	SWITCH, Rotary	94850150	Centralab PA2003
TB1	TERMINAL BOARD BARRIER	95150150	Cinch 354-11-06-001

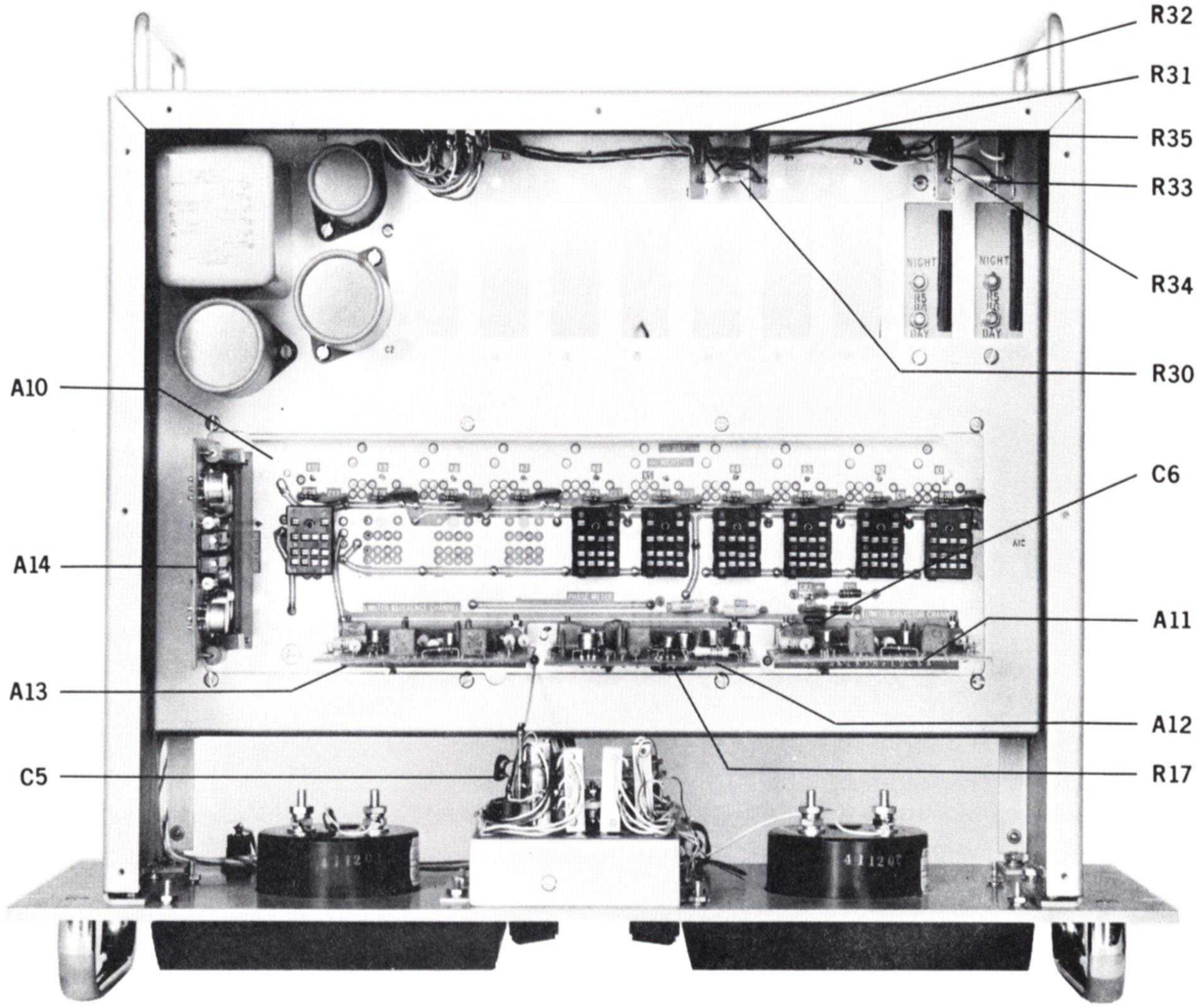


Figure 6-1. Chassis and Baseboard, Component Location.

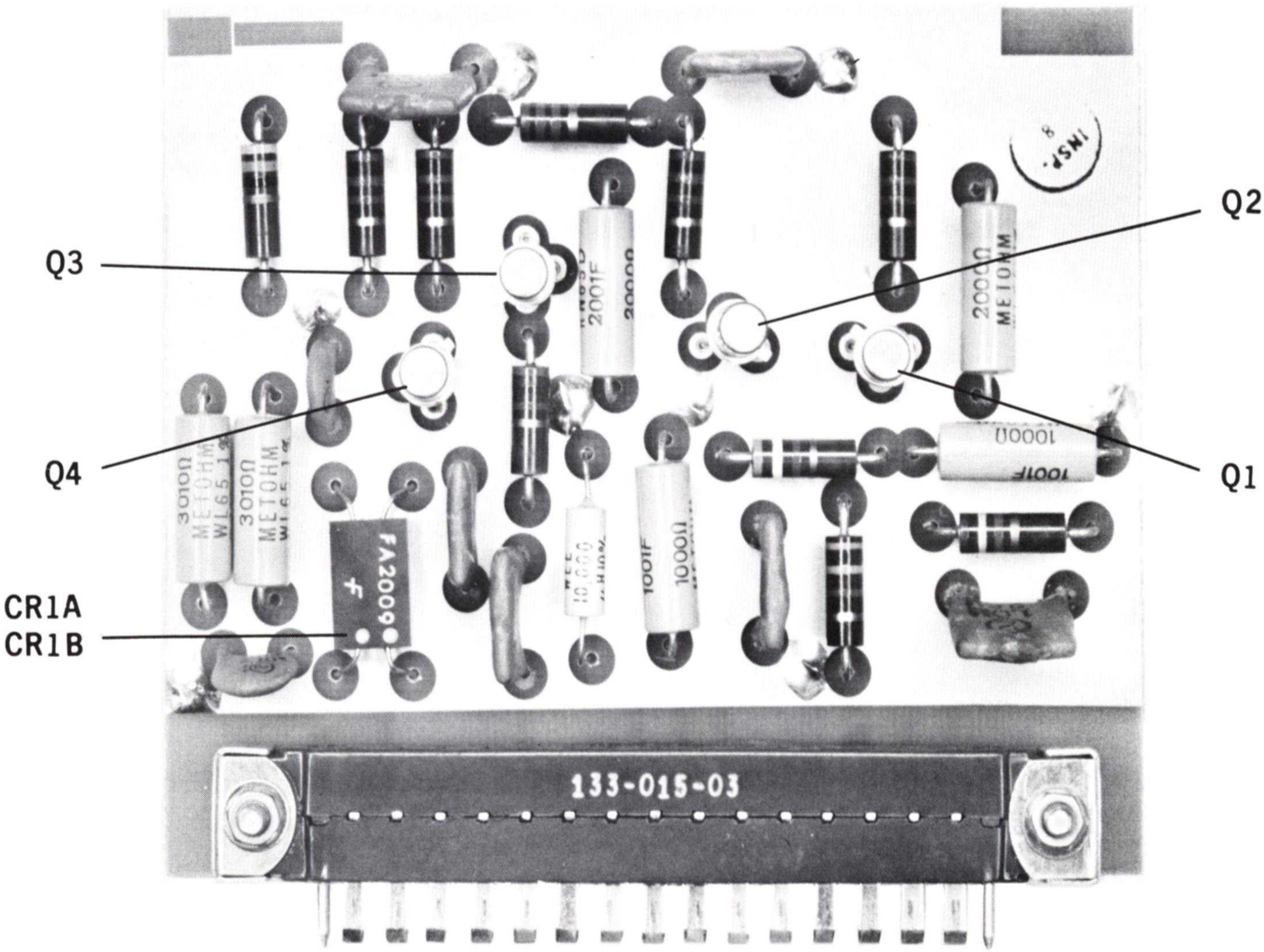


Figure 6-2. Limiter Module, Component Location.

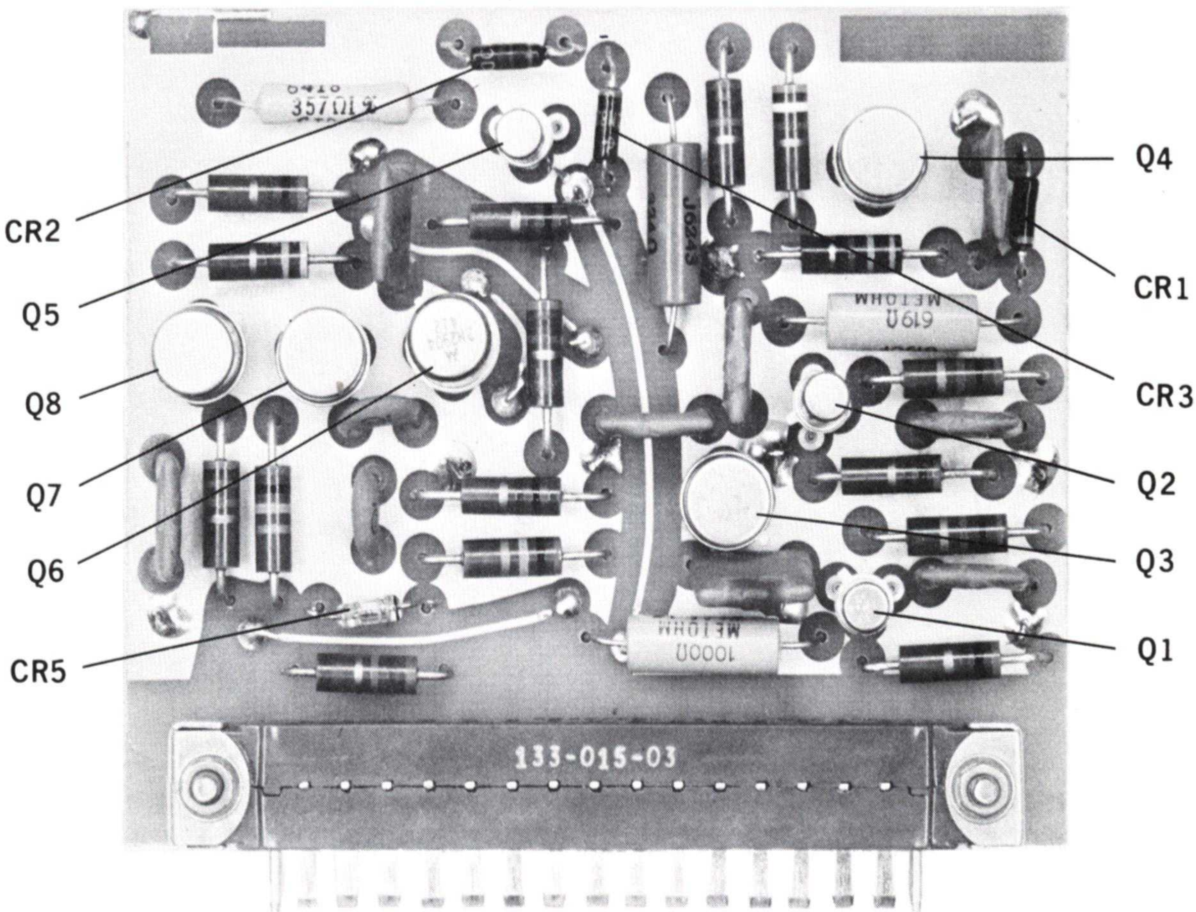


Figure 6-3. Phase Meter Module, Component Location.

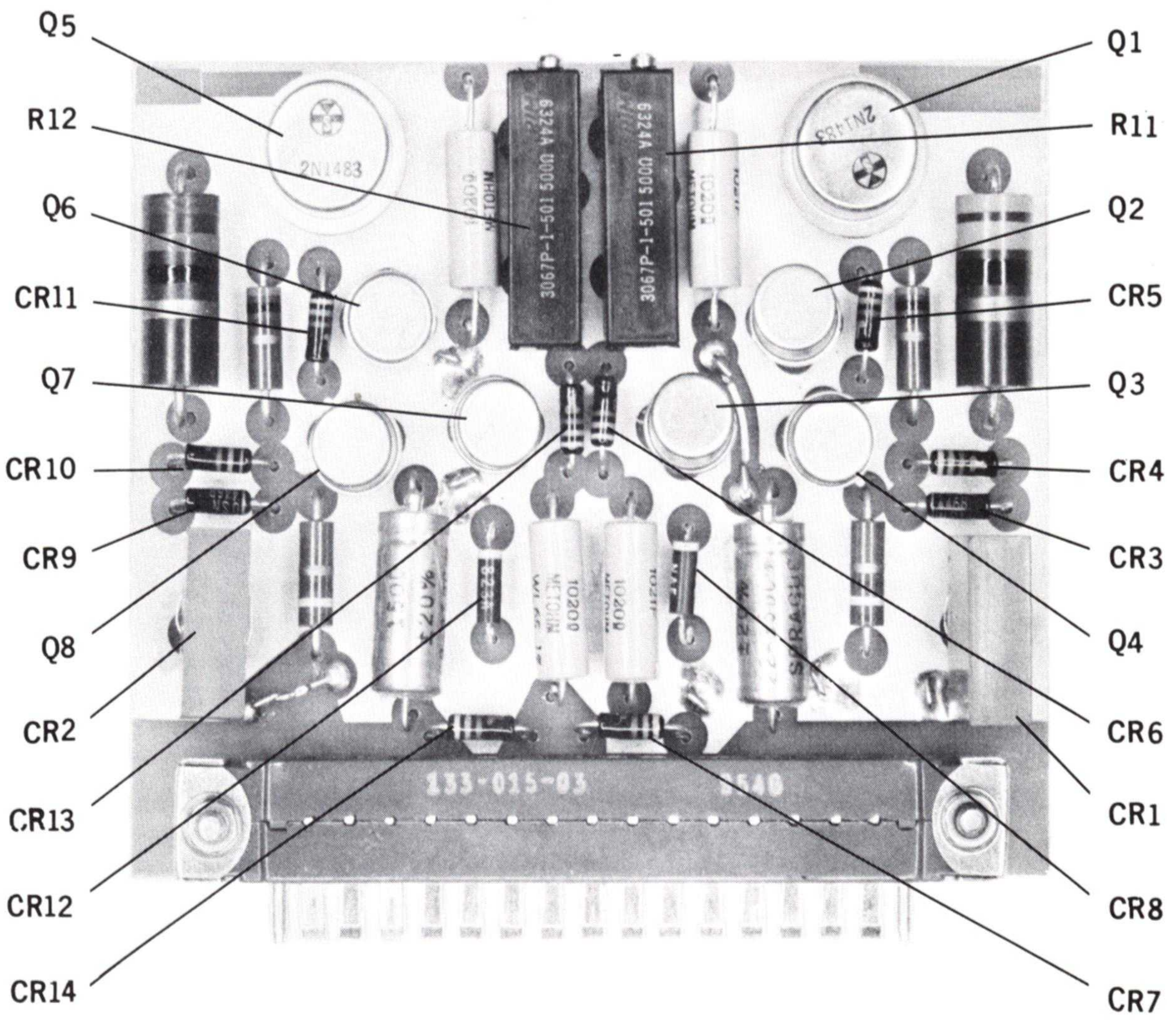


Figure 6-4. Regulator Module, Component Location.

SECTION 7. SCHEMATIC DIAGRAMS

7.1 General.

This section contains schematic diagrams for the 112 Phase Monitor.

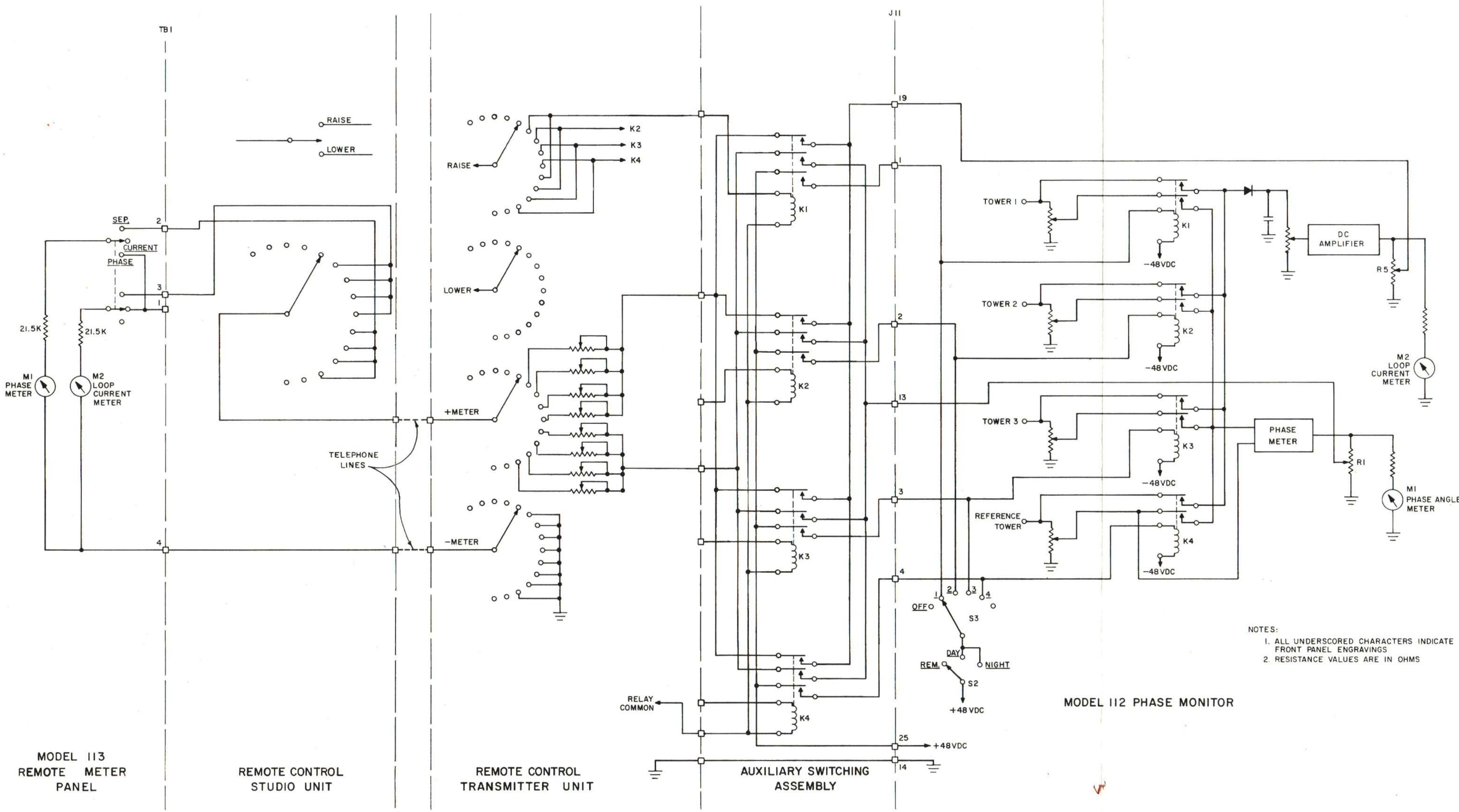


Figure 7-1. Typical Remote Phase Metering System, Separate Phase and Loop Current

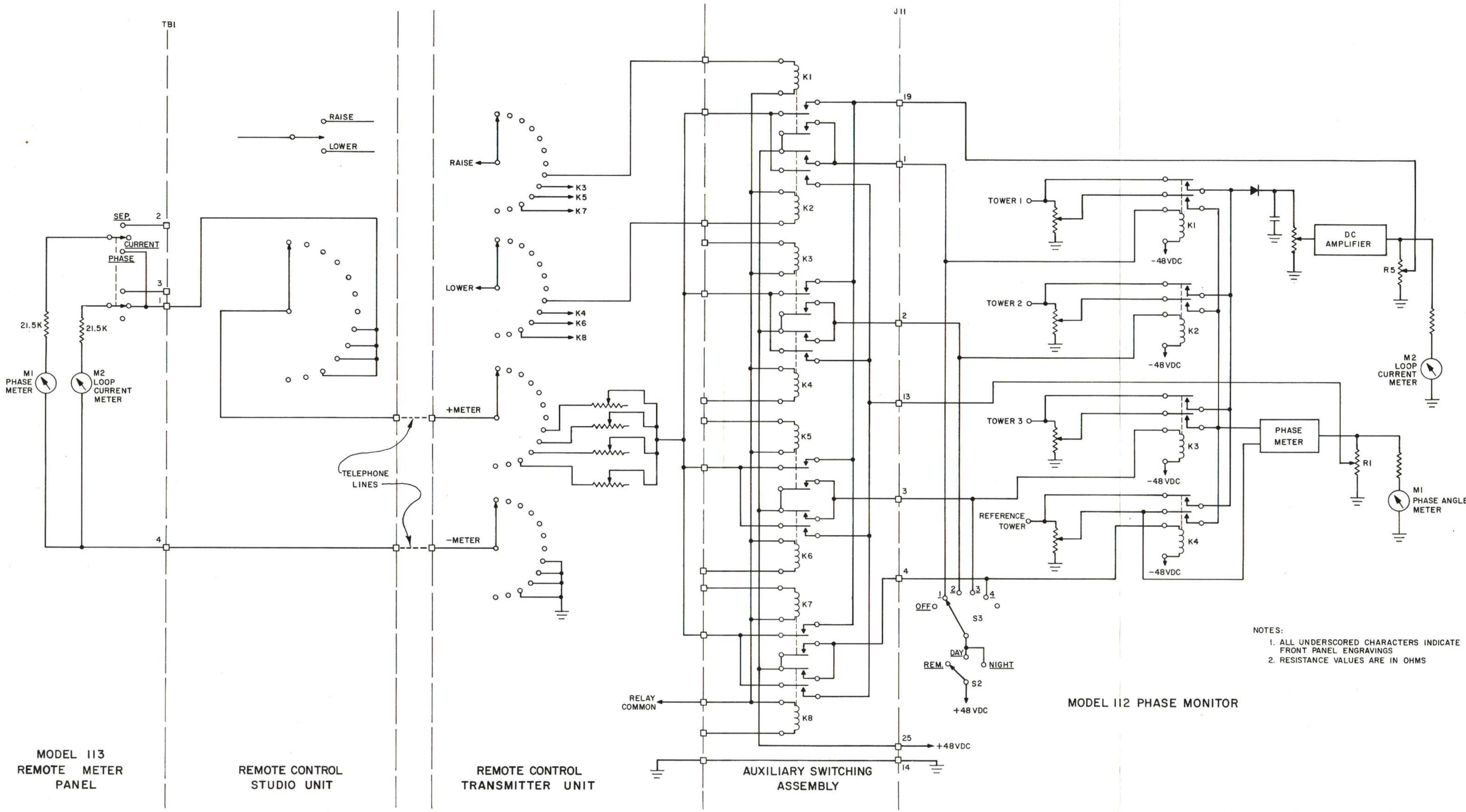
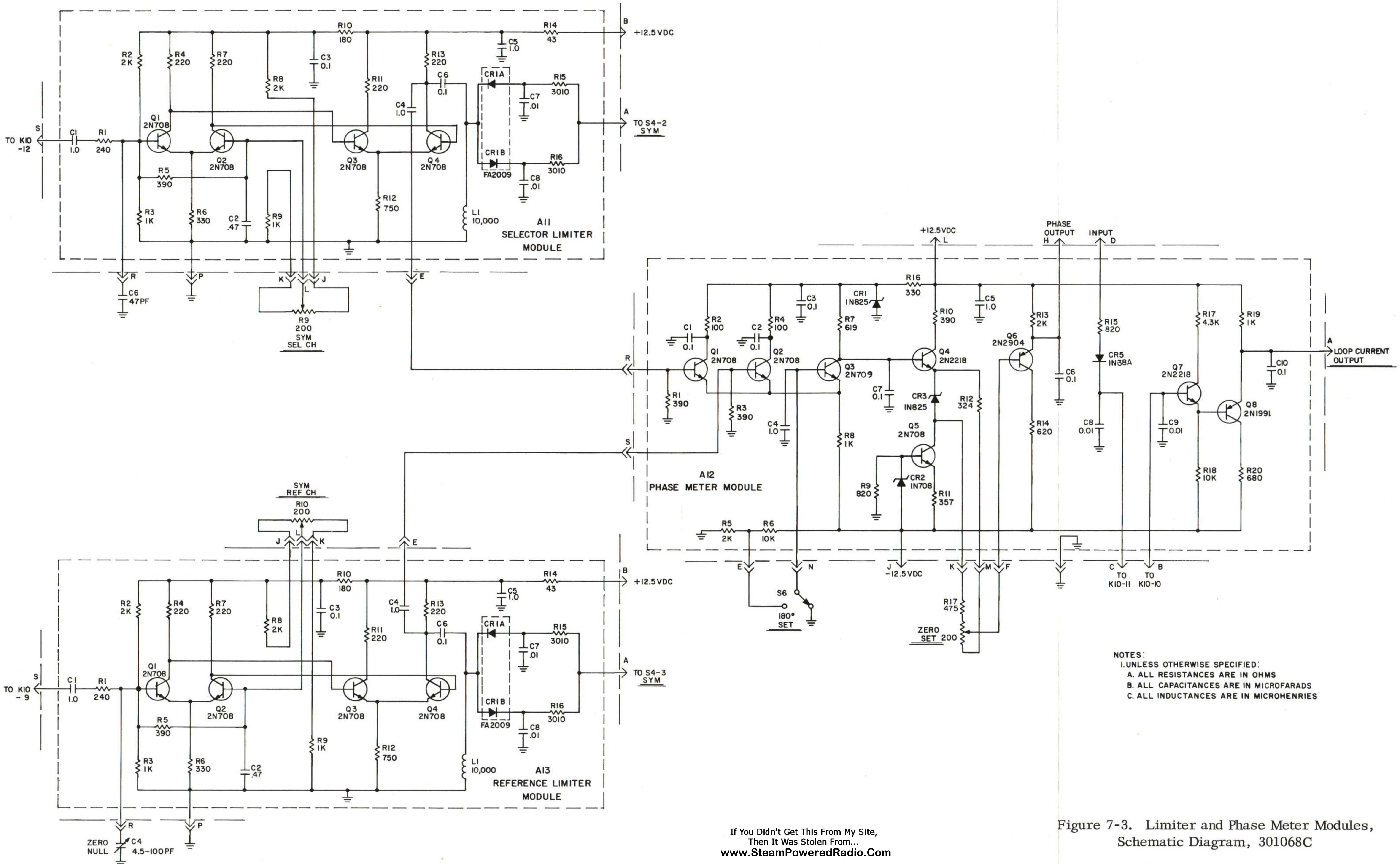
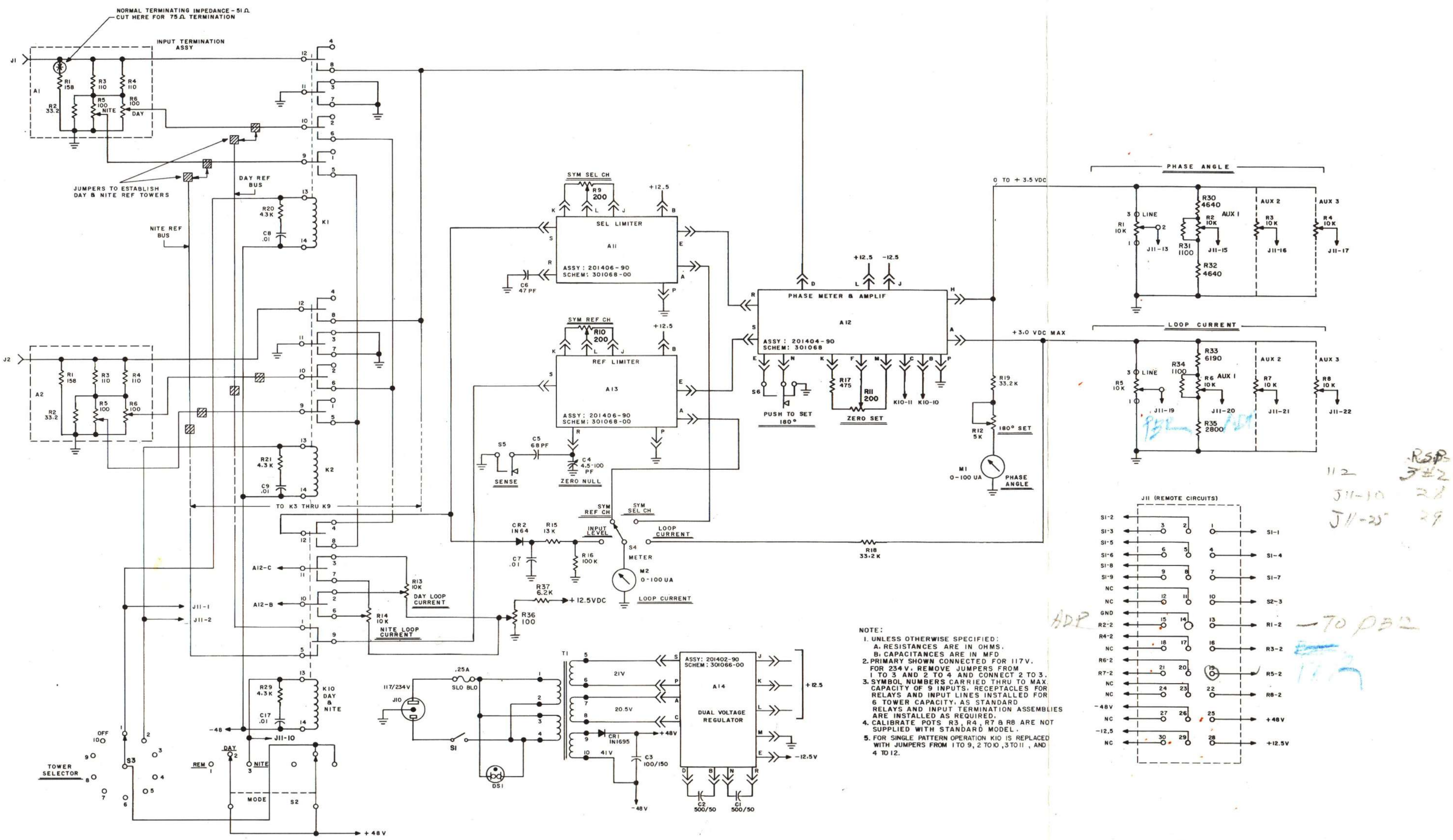


Figure 7-2. Typical Remote Phase Metering System, Combined Phase and Loop Current



NOTES:
1. UNLESS OTHERWISE SPECIFIED:
A. ALL RESISTANCES ARE IN OHMS
B. ALL CAPACITANCES ARE IN MICROFARADS
C. ALL INDUCTANCES ARE IN MICROHENRIES

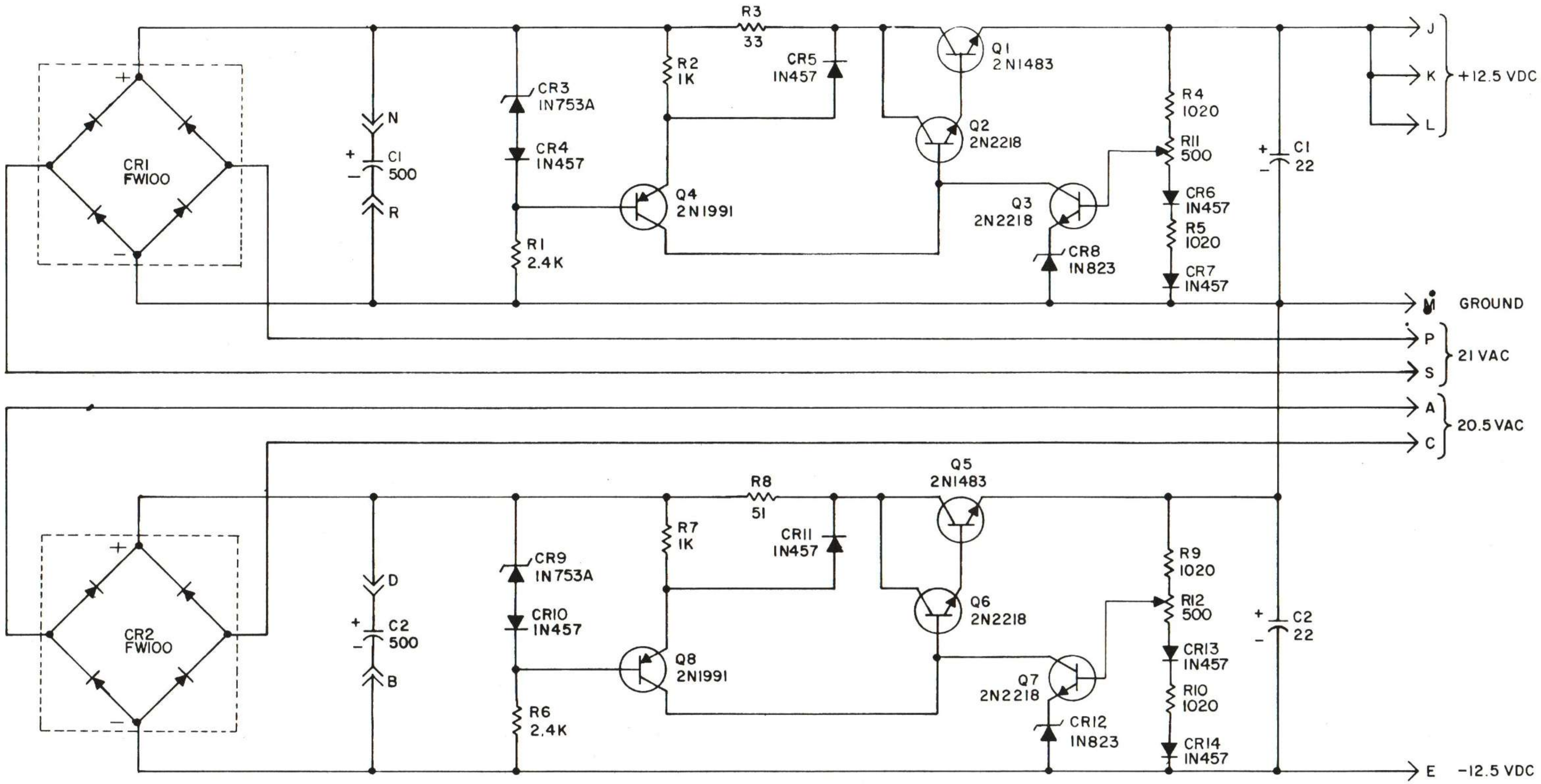
Figure 7-3. Limiter and Phase Meter Modules, Schematic Diagram, 301068C



NOTE:

1. UNLESS OTHERWISE SPECIFIED:
   A. RESISTANCES ARE IN OHMS.
   B. CAPACITANCES ARE IN MFD
2. PRIMARY SHOWN CONNECTED FOR 117V. FOR 234V, REMOVE JUMPERS FROM 1 TO 3 AND 2 TO 4 AND CONNECT 2 TO 3.
3. SYMBOL NUMBERS CARRIED THRU TO MAX. CAPACITY OF 9 INPUTS. RECEPTACLES FOR RELAYS AND INPUT LINES INSTALLED FOR 6 TOWER CAPACITY, AS STANDARD RELAYS AND INPUT TERMINATION ASSEMBLIES ARE INSTALLED AS REQUIRED.
4. CALIBRATE POTS R3, R4, R7 & R8 ARE NOT SUPPLIED WITH STANDARD MODEL.
5. FOR SINGLE PATTERN OPERATION K10 IS REPLACED WITH JUMPERS FROM 1 TO 9, 2 TO 10, 3 TO 11, AND 4 TO 12.

Figure 7-4. Wiring Diagram Model 112 Phase Monitor, 301072 C



NOTES:
1. UNLESS OTHERWISE SPECIFIED:
A. ALL RESISTANCES ARE IN OHMS
B. ALL CAPACITANCES ARE IN MICROFARADS

Figure 7-5. Model 112 Phase Monitor Dual Regulator, Schematic Diagram, 301066

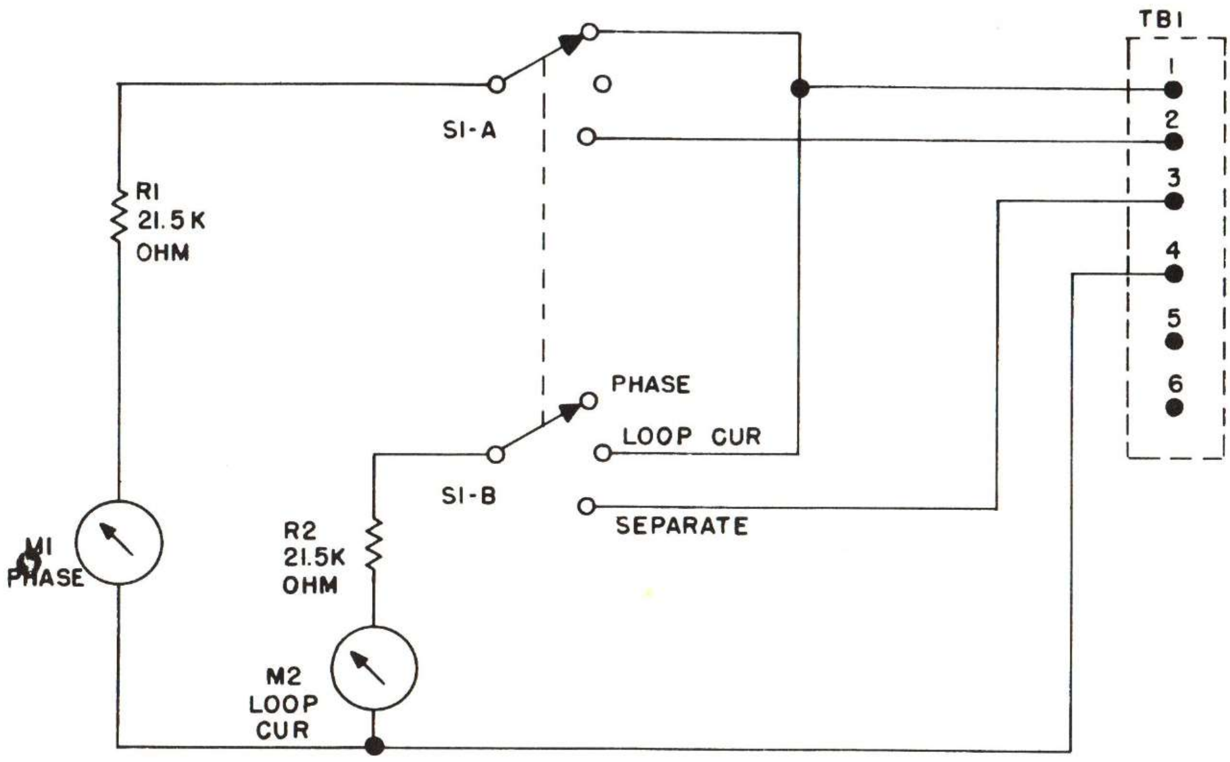


Figure 7-6. Type 113, Remote Meter Panel,
Schematic Diagram, 103588