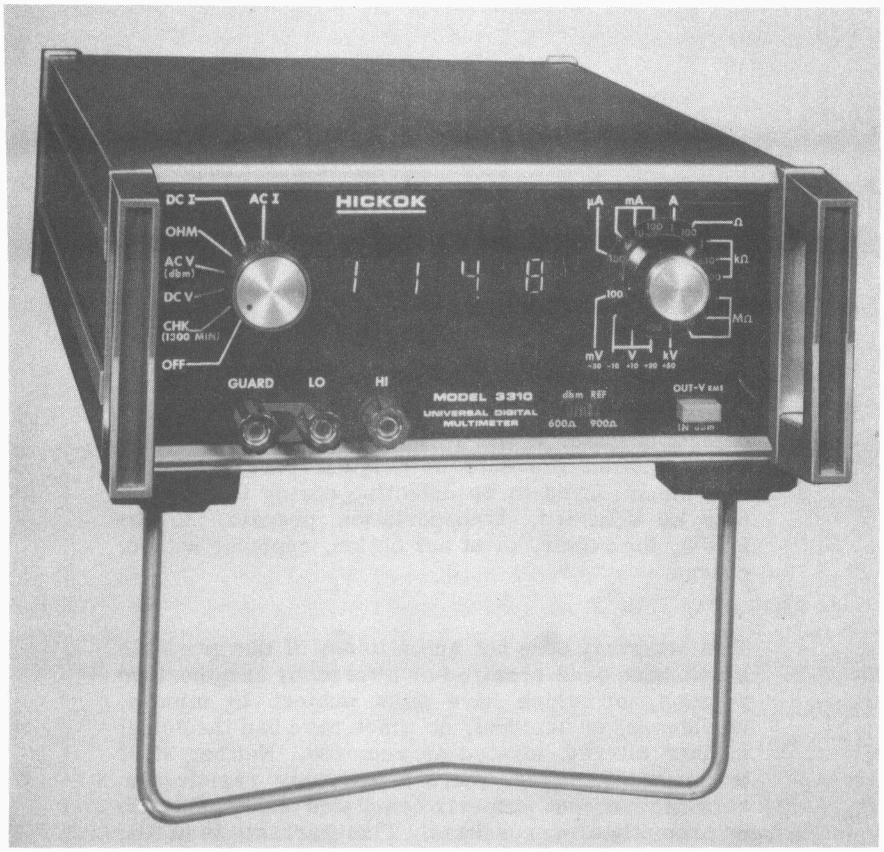

MODEL 3310
DIGITAL MULTIMETER

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2490-635

MODEL 3310 DIGITAL MULTIMETER

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SECTION I
GENERAL INFORMATION

The Model 3310 Universal Digital Multimeter has 32 ranges covering ac volts and ac current, dc volts and dc current, resistance, and direct reading true rms dBm at 1mW/600 Ω or 1 mW/900Ω reference. The multimeter may be operated from a 115 or 230 volt * ac line or from an internal rechargeable battery pack (The rechargeable nickel cadmium battery pack is optional). The batteries permit measurement with complete isolation from power line interference (infinite common mode rejection). Battery life is 20 hours on all functions except ac volts, ac current and dBm where life is minimum of 8 hours. The battery operated version may be operated from the ac power line while the batteries are being recharged. Charging circuits are internal to the multimeter.

The bright fluorescent digital display consists of seven-segment numerical indicators which provide a maximum display of 1999. The display features include non-blinking buffered readout, automatic polarity indicator, automatically positioned decimal point and blinking overrange indication. The reading rate is twice per second. The blinking over range indication occurs when the reading exceeds 1999.

*See Schematic diagram for 230 Volt connections.

Operator convenience and safety have been stressed in the design of the Model 3310. The equipment case consists of box-in-box construction with outer case connected to third wire ground. The input terminals and internal circuitry may be elevated 1500 volts from line ground without damage to the instrument. A color coded front panel is provided for ease in selection of the 32 ranges. High input impedance, guarded circuitry and true rms conversion minimize erroneous measurements. The direct reading dBm ranges provide conversion free dBm (1 mW/600 Ω or 1 mW/900 Ω) measurements over a 110 dB range.

Rugged construction, wide temperature operating range, exceptional overload specifications, and operator convenience make the Model 3310 ideal for laboratory, production line or field applications.

SECTION II
SPECIFICATIONS

FUNCTIONS

AC (true rms) and DC Volts

AC (true rms) and DC Current

Resistance

dBm

RANGES

AC (true rms) and DC Volts

Range	Reading	Resolution
100 mV	000.0 to 199.9 mV	100 microvolts
1 V	0.000 to 1.999 V	1 millivolt
10 V	00.00 to 19.99 V	10 millivolts
100 V	000.0 to 199.9 V	100 millivolts
1 kV*	0.000 to 1.500 kV	1 volt

*Product of volts and frequency $\leq 10^7$, 1000 volts rms max. input

AC (true rms) and DC Current

Range	Reading	Resolution	Insertion Resistance
100 μA	000.0 to 199.9 μA	100 nanoamperes	1 K Ω
1 mA	0.000 to 1.999 mA	1 microampere	100 Ω
10 mA	00.00 to 19.99 mA	10 microampere	10 Ω
100 mA	100.0 to 199.9 mA	100 microamperes	1 Ω
1 A	0.000 to 1.999 A	1 milliampere	0.1 Ω

dBm

Range	Reading	Resolution
-30 dBm	-45 to -20	0.1 dBm
-10 dBm	-25 to -0	0.1 dBm
+ 10 dBm	+ 0 to + 25	0.1 dBm
+ 30 dBm	+ 20 to +45	0.1 dBm
+ 50 dBm	+ 40 to +65	0.1 dBm

Front Panel Reference Selection of 1mW/600 Ω or 1 mW/900 Ω

ACCURACY

Function	Range	Accuracy at 20° C to 30° C	Temperature Coefficient 0-19° C 31-50° C
DC AMPS	All	±0.2% of reading, ±1% of range	200ppm/C°
AC AMPS	All		
20 Hz to 50 Hz and 20 KHz to 50 KHz *		± 1.0% of reading, ± 0.1% of range	200 ppm/C°
50 Hz to 20 kHz		±0.5% of reading, ±0.1% of range	200 ppm/C°
* Readings ≦ Full Scale			
OHMS			
	100 Ω thru 100K Readings ≦ 110% of Full Scale 1M thru 100M Readings ≦ 200% of Full Scale	± 0.3% of Range, ± 1 digit	200 ppm/C°
	100 Ω thru 100K Readings ≧ 110% of Full Scale and ≦ 200% of Full Scale	±1.25% of Reading ± 1 digit	200 ppm/C°

Except 100 Meg
±.6% of Range ± 1 Di

INPUT ISOLATION FROM GROUND

Infinite when operated on batteries.

1500 volts peak when line operated or with batteries charging.

INPUT IMPEDANCE AT PROBE TIP

dc: 11 megohms/5pF.

ac: Approx. 1000 MΩ /75 pF.

COMMON MODE REJECTION (with 1K ohm source unbalance)

Battery operation: Infinite

Line operation or on recharge: 120 dB at 60 Hz, 90 dB at 1 kHz.

NORMAL MODE REJECTION

50 dB at 40 Hz

60 dB at 50 Hz

70 dB at 120 Hz

DISPLAY

7-segment numerical indicators

non-blinking (buffered)

Maximum display of 1999

Automatically positioned decimal point

Automatic polarity indicator

Out-of-range indication

Sample rate: two per second

OPERATING POWER REQUIREMENTS

115 or 230 volts ac ± 10% *

50 to 400 Hz

5 Watts

DIMENSIONS

3-1/2 in. high x 8-3/8 in. wide x 13 in. deep.

WEIGHT

9-3/4 lbs. (without batteries)

* See Schematic Wiring Diagram for 230 volt connections

SECTION III
OPERATING INSTRUCTIONS

GENERAL

The Model 3310 multimeter is designed to operate from a 115 or 230 volt*, 50-400 Hz ac power source. The Model 3310 can be supplied with internal battery operation as an option. With batteries the operation is identifical to line operation except that the unit may be operated completely isolated from the line. Operation time on fully charged batteries is 20 hours on all functions except AC V AC I and dBm where it is a minimum of 8 hours.

A supply check position (CHK) is incorporated in the Model 3310 to monitor the state of the batteries. To perform this operation, set the function switch to CHK and the range switch to any volts position; the readout will then display a number proportional to the charge state of the batteries. If the number is greater than 1000 the multimeter may be operated. If the number is less than 1000 the batteries must be recharged (Refer to Fig. 1 for approximate hours of operation remaining verses CHK reading).

*See Schematic diagram for 230V connections.

The Model 3310 with battery option may be operated while plugged into an ac power source. When operated in this mode the unit receives power from the batteries while the batteries are being charged from the ac power source. The charging circuit supplies approximately 30% more power than necessary to operate the unit such that the batteries may be charged during operation. A sub-panel lamp above the display indicates when the battery is charging.

CAUTION

Whenever the Model 3310 is operated on ac power, the LO input must not be elevated more than 1500 volts ac peak plus dc as referenced to the ac power source ground.

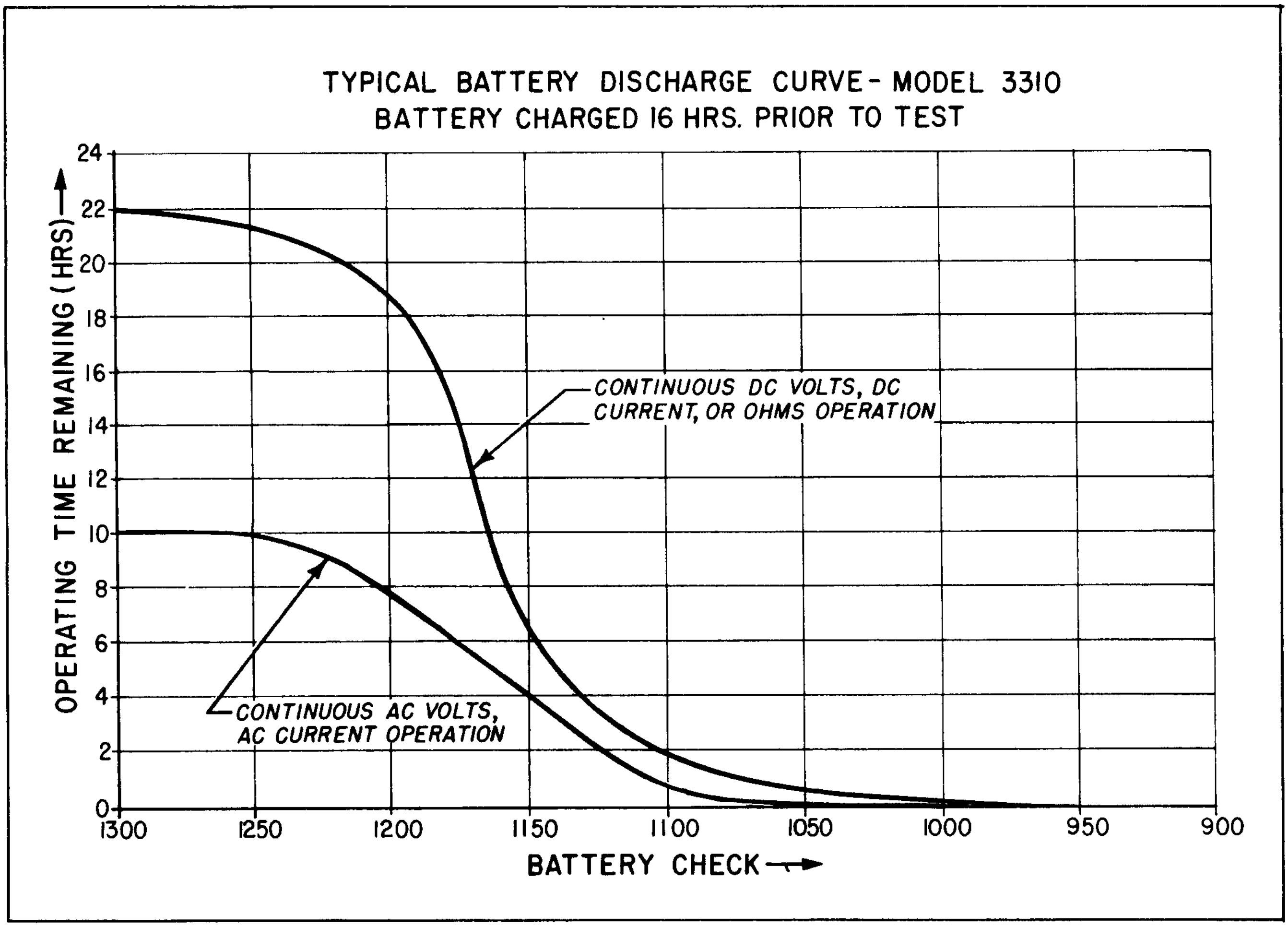


Figure 1. Typical Battery Discharge Curve, Model 3310

The following paragraphs describe the operation of the multimeter.

To turn the instrument on set the function switch, at the left of the control panel, to any position except OFF. This will activate the display showing that the multimeter is energized and ready for use. It is recommended that approximately five minutes warm up be allowed for the stabilization of the circuitry.

FRONT PANEL

The front panel is color coded for ease of operation. Each function has a characteristic color and the ranges for that function have the same color. AC and DC Volts functions are red and the range switch has five red ranges from 100mV through 1kV. OHMS function is green and the range switch has 7 green ranges from 100 Ω through 100 M Ω. AC I and DC I functions are yellow and the range switch has 5 yellow ranges from 100 μA through 1A. dBm function is blue and the range switch has 5 ranges from - 45 dBm to + 65 dBm. A front panel pushbutton switch energizes the dBm function.

Battery operated units have indicator lamps to indicate when the batteries are being charged. The state of the batteries may be checked in the CHK position of the function switch.

MEASUREMENTS

Six types of measurements can be made with the Model 3310. They are: ac true rms volts, dc volts, ac true rms current, dc current, dBm and ohms. Each type of measurement is selected by setting the function switch to the proper position and the range switch to the desired range.

The function switch selects the type of measurement to be made. The range switch sets the full scale value of the measurement. Each position on the range switch is labeled in the units to be measured and the full scale value of that range. As an example, there are three positions labeled "V". The unit is volts, the three positions are 1 volt, 10 volts, and 100 volts full scale. The decimal point is automatically positioned in the display. In all functions, if an unknown quantity is to be measured the range switch should be set to the highest range and then switched to lower ranges as required for a three or four digit reading.

DC VOLTS

DC voltage measurements are made by setting the function switch to DC V and the range switch to the desired voltage range. The LO input terminal is then connected to the point in the circuit under test that is nearest ground and the HI input is connected to the voltage to be measured relative to that point. The LO input should never be elevated more than 1500V above ac power line third wire ground.

The Series 3300 incorporates circuitry which enables it to withstand overloads up to 1000 volts on the 100 mV range and 1500 volts on all other ranges.

CAUTION

No dc voltage measurement above 1500 volts may be made without the use of a high voltage probe. Probes are available that extend the Series 3300 to either 15kV or 30kV.

AC VOLTS

AC voltages are measured by setting the function switch to AC V and the range switch to the desired range. When switching to the AC V function allow several seconds for the ac/dc converter to stabalize before making the measurement. The HI and LO inputs are used in the same fashion as in dc volts. AC functions are overload protected as specified in Section II.

CAUTION

The absolute maximum input voltage permitted between the HI and LO inputs is 1000 volts rms. Also, the input voltage times frequency product must not exceed 10^7.

OHMS

Resistance is measured by setting the function switch to OHMS and the range switch to the desired range. In all ohms ranges the HI jack is positive and in all megohms ranges the LO jack is positive. Maximum open circuit voltage is 2.5 volts on all ranges. When the multimeter is set up for ohmmeter use, the display will blank when not measuring a resistance or when the resistance is greater than 1999 on the range selected. The ohmmeter section is protected for high voltage application as specified in Section II.

A unique feature of the Series 3300 ohms ranges is that semiconductors may be forward biased and thereby checked for proper P-N junction behavior.

The voltage across the unknown resistor in ohms and k ohms varies from zero volts at zero readings to approximately 24mV at full scale readings. This voltage being the results of a voltage divide formed by an internal precision resistor and the unknown external resistor. The multimeter measures the voltage across the unknown resistor and is calibrated to read in resistance. An input voltage greater than 48mV (2Xf.s.) will cause the multimeter to overrange.

In megohms the voltage across the unknown resistor varies from zero volts at zero reading to approximately 2.4 volts at full scale (2.4V-0.024V). As discussed under functional operation, the megohm ranges are inverted such that the multimeter actually measures the voltage across the internal precision resistor (proportional to 1/Rx) and converts this to indicate the value of the unknown resistor directly.

Therefore, measurements on the 100 ohms through the 100 k ohms range produce 48mV or less across the unknown resistor for an in range reading and measurements on the 1 megohm through 100 megohm range produce 2.4V or less across the unknown resistor for an in range reading.

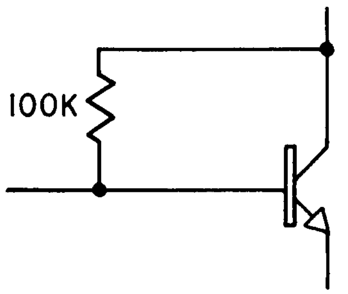


Figure 2. Transistor Circuit Ohmmeter Measurements

The 100k resistor shown above will measure 100k ohms on the 100k Ω range no matter which polarity is used since 24mV will not forward bias the base - collector of the NPN transistor. However, on the 1M Ω range the multimeter will read 0.100 megohm when the base-collector is reverse biased (HI is negative, LO is positive) and approximately 0.003 megohm when the transistor is forward biased. The forward bias of a silicon P-N junction, 0.600 volts, is equivalent to approximately 3% of range on all megohm ranges.

Note that if a diode or transistor alone is being checked on the megohm ranges the reading obtained will be overrange (open circuit), when the junction is reverse biased and 3% of full scale (003) when the junction is forward biased. Reverse leakages at 2.4 volts may be measured if below 200 megohms.

DC CURRENT

DC current is measured by setting the function switch to DC I and the range switch to desired current range. Insertion loss is as specified in Section II. The current shunts are designed to withstand a 10 times full scale overload.

AC CURRENT

AC current measurement is similar to dc current except that the function switch is set to AC I. When switching to AC I allow several seconds for the ac/dc converter to stabilize before making the measurement. Overload is the same as for dc current.

CAUTION

Overloads in excess of 10 times full scale may permanently damage the precision current shunts.

Elevated voltage and current measurements may be made in both battery and ac line operation. However, the total voltage between the LO input and third wire ac power line ground must not exceed 1500 volts ac peak plus dc. Breakdown between internal circuitry and the power supply transformer primary and between internal circuitry and outer case necessitate this limitation. Extreme caution is always necessary when high voltages are present.

GUARD (BENCH MODELS ONLY)

The multimeter is box-in-box construction with all circuitry housed in the inner box which provides exceptional isolation. The inner box is connected to the front panel GUARD terminal. Proper connection of the guard terminal. and thereby the guarded circuitry, reduces errors due to common mode signals. The GUARD terminal is normally strapped to the LO input terminal but may also be connected to a guard voltage within the circuit under test.

General Guarding Rules

1. Connect the GUARD such that it is at the same level as the LO input terminal.
2. Never exceed the GUARD to LO breakdown rating of 250 volts peak ac plus dc.
3. Never leave GUARD unconnected.
4. Guarding is generally only desirable for low level measurement.
5. If common mode signals are a definite problem and complete isolation is desirable, use a battery operated multimeter.

dBm (decibel referred to one milliwatt)

Direct reading dBm measurements are made by simply depressing the dBm/V RMS switch when the function switch is in the AC V position. References of 1 mW/600 Ω or 1 mW/900 Ω may be selected by a front panel slide switch. Overload protection and frequency response of the dBm function is the same as for AC Volts as shown in Section II.

The dBm function has internal out-of-range sensing such that an improper reading can not be taken. The dBm range covered by each position of the range switch is shown in Table 1. A dBm reading outside the range indicated will cause the multimeter to blank with only the sign and decimal on. If the sign is "+", the reading is higher than the range selected and the range switch should be set to the next highest range. If the sign is "-", the reading is lower than the range selected and the range switch should be switched to the next lowest range.

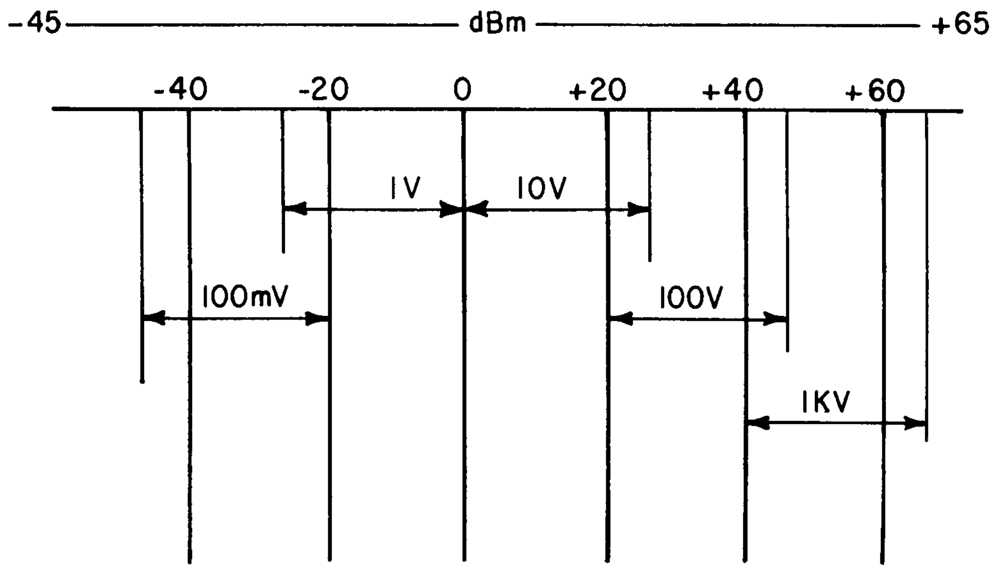


Table 1. dBm Range

SECTION IV
MINIMIZING EXTERNAL SOURCES OF ERROR

The multimeter is an exceptionally accurate and stable instrument. Operator convenience and measurement simplicity have been stressed throughout. Unique circuit design, special compensation techniques, and stable components have eliminated the necessity for front panel zero or calibration controls. If inaccuracies are encountered, the measurement setup external to the unit should be carefully checked.

The multimeter will measure dc volts and current, ac volts and current, and ohms to a high degree of accuracy. Attention to the details outlined in the following paragraphs will minimize external sources of error and help the operator to achieve maximum accuracy.

LOADING ERRORS - AC

The ac input impedance of the multimeter is designed to be as high as is practically possible. However, when voltage measurements are required to the full accuracy of the instrument the internal impedance of the voltage source should be considered.

AC INTERFERENCE ON DC MEASUREMENTS

It is often necessary, or convenient, to measure dc voltages in the presence of large ac voltages. This is most often the case when measurements are taken on equipment which is in normal operation; for example, measuring the collector voltage of a large signal pulse amplifier stage, or grid bias shifts in class B amplifiers. Further, unshielded high impedance circuits are subject to pickup of large voltages from nearby electrostatic fields, such as the 60 Hz line, fluorescent lights, etc. For these reasons the multimeter is designed to accept large ac voltages across its input terminals and still give an accurate indication of the dc component.

This ability to discriminate between ac and dc signals is an outstanding feature of this instrument. It is accomplished by two means: first, the input voltage is filtered by a conventional R-C network; then, the integrator amplifier, with a ramp peak of 10 volts and an integration time of 100 milliseconds, eliminates the remaining fluctuations.

The multimeter is specified to have, for example, a 60 dB rejection of 60 Hz interference. This means that the apparent reading error (which may be either plus or minus) will be 1/1000 (one thousandth) of the impressed ac value. To illustrate, if we add one volt rms of 60 Hz ac to one-half volt dc, we will have an extra error of 0.001 volt. Consequently, our readings could shift by ± 2 digits. So, as a result of adding one volt 60 Hz ac, we have added 0.001 volt of uncertainty to our final reading - a very small error. However, it is preferable to keep the ac voltages within the limits allowed for ± 1 digit of error.

DIELECTRIC ABSORPTION

Dielectric absorption is associated with insulating materials and is inherent in their chemical structure. This multimeter has been carefully designed to reduce this effect within itself, but it may occur in the external circuitry. After a capacitor has been charged and then shorted out, a small percentage of the original voltage will reappear across it after a time, thus requiring a second discharge. The capacitor may persist for several hours in generating these small voltages. Thus, care should be taken when a high voltage measurement is followed by a very low voltage measurement in a circuit with questionable dielectric absorption.

LOADING ERRORS - DC

Whenever voltage measurements are required to the full accuracy of the multimeter, the internal impedance of the voltage source should be considered. The input impedance of the multimeter was designed to be as high as possible, but if the internal impedance of the voltage source exceeds 5k ohms it must be taken into account. The input impedance of the multimeter is 11 megohms ± 0.1%. Consequently, an 11k ohms source impedance will cause the unit to read 0.1% low; a 110k source impedance will cause a 1% drop in reading. Corrections for loading can be made when the source impedance is known by applying the following formula:

$$\text{True voltage} = \text{multimeter reading} + \text{multimeter reading} \times \left(\frac{\text{source impedance in ohms}}{11 \times 10^6}\right)$$

By using the formula, loading errors can be kept below 0.1% for source impedances as high as 10^7 ohms.

ENVIRONMENT

A number of possible sources of error are introduced by severe environments. The multimeter is designed to eliminate as many of these as possible. Both temperature and humidity factors have been taken into account. The unit's specified accuracy will be retained over a temperature range of 20°C to 30°C. Humidity effects have been reduced by extremely careful treatment of insulating surfaces. If errors are encountered which can only be attributed to environmental changes, these will most likely be found in the external measurement setup.

Corrosive atmospheres, particularly when the humidity is high, can cause large leakage currents. The multimeter is totally enclosed and should not be opened or otherwise exposed to industrial atmospheres. The test setup as well should be kept as clean as possible. In the event of difficulties, clean, dry Freon TF mixed with Dow-Corning Silicone Oil DC 200 in a ratio of 50:1 should be used to carefully clean contaminated binding posts, switches or other leakage paths.

OHMS MEASUREMENTS

AC rejection on the ohms ranges is the same as is specified for the other ranges: a 60 Hz signal in excess of 60 dB will cause a fluctuation in the reading (input sensitivity is 25mV/1000 counts). The maximum sensitivity of the ohmmeter circuit is 0.1 ohms per digit on the 100 ohm range. As in any low range ohmmeter, contact resistance can become a significant portion of the total resistance being measured and must be considered. Careful attention to circuit connections can minimize these errors. High impedance measurements, in the megohms region, are subject to pickup of large voltages from nearby electrostatic fields. Careful attention to lead length, component placement and shielding will minimize pickup on high resistance measurements. External leakage paths through insulation material associated with the resistance under measurement can also cause error. In effect, these leakage paths form resistance paths in parallel with the true resistance, thus reducing the value. All of these are external effects and should be taken into account whenever there is doubt in the reading.

AC Distortion

The Model 3310 utilizes a computing type TRUE RMS converter. Therefore, the harmonic distortion present in a particular wave form will not affect the accuracy of the instrument. However, it should be kept in mind that the allowable crest factor is 4:1 at full scale. The allowable crest factor at any point on scale is

$$\text{Allowable C.F.} = \frac{4000}{\text{Reading}}$$

with peak input not exceeding four times full scale.

Note that the upper frequency limit of the system is 50kHz and harmonics above 50 kHz will be attenuated, and affect accuracy accordingly.

SECTION V
THEORY OF OPERATION

The multimeter utilizes a triple segment sequence time ratio integration technique that converts a dc input voltage to a number of pulses. The number of pulses is directly related to the dc input voltage and is internally counted and displayed. The cycle time is approximately one half second. At the beginning of each cycle an internally generated reset pulse resets the counters to zero and the system again samples the input dc voltage. The actual input sample time is approximately 100 milliseconds and the remaining 400 milliseconds is used for comparison and self-zeroing.

All functions on the multimeter use this dc to count conversion. In ac volts, alternating current, direct current, and ohms, the quantity being measured is converted to a dc voltage. This dc voltage is then measured and displayed.

The analog-to-digital conversion is accomplished through the use of a basic principal of electricity.

In figure 2, the expression for the voltage across the capacitor for time after the switch is closed is:

$$Vab = \frac{1}{C} \int_{o}^{t} idt \qquad (1)$$

It is obvious from the circuit that the capacitor will charge to the battery voltage at a rate determined by R and C. Equation (1) is the integral form for the charge voltage as a function of time (assuming no charge on the capacitor prior to switch closure). The current, i, in equation (1) is a time varying current and the solution of the equation yields the well-known exponential charge curve for the voltage across C.

However, if i is made constant by use of a constant current generator, large R, or other means, then the solution of equation (1) is a linear ramp voltage dependent only on time.

$$Vab = \frac{1}{C} \int_{o}^{t} idt$$

$$Vab = \frac{1}{C} \int_{o}^{t} Idt$$

$$Vab = \frac{I}{C} (t) \qquad (2)$$

Equation (2) illustrates the fact that the voltage across C, when I is constant, is a ramp voltage whose slope is dependent on I and whose magnitude varies with time. Therefore, since time is the only variable, the ramp voltage is linear, i.e., not exponential, if C is a perfect capacitor.

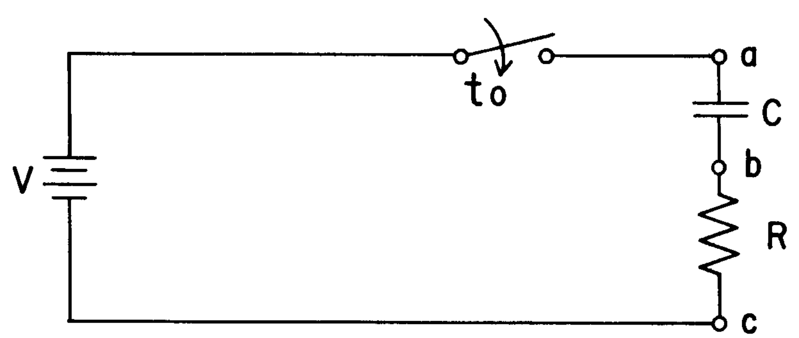


Figure 3. Basic RC Network

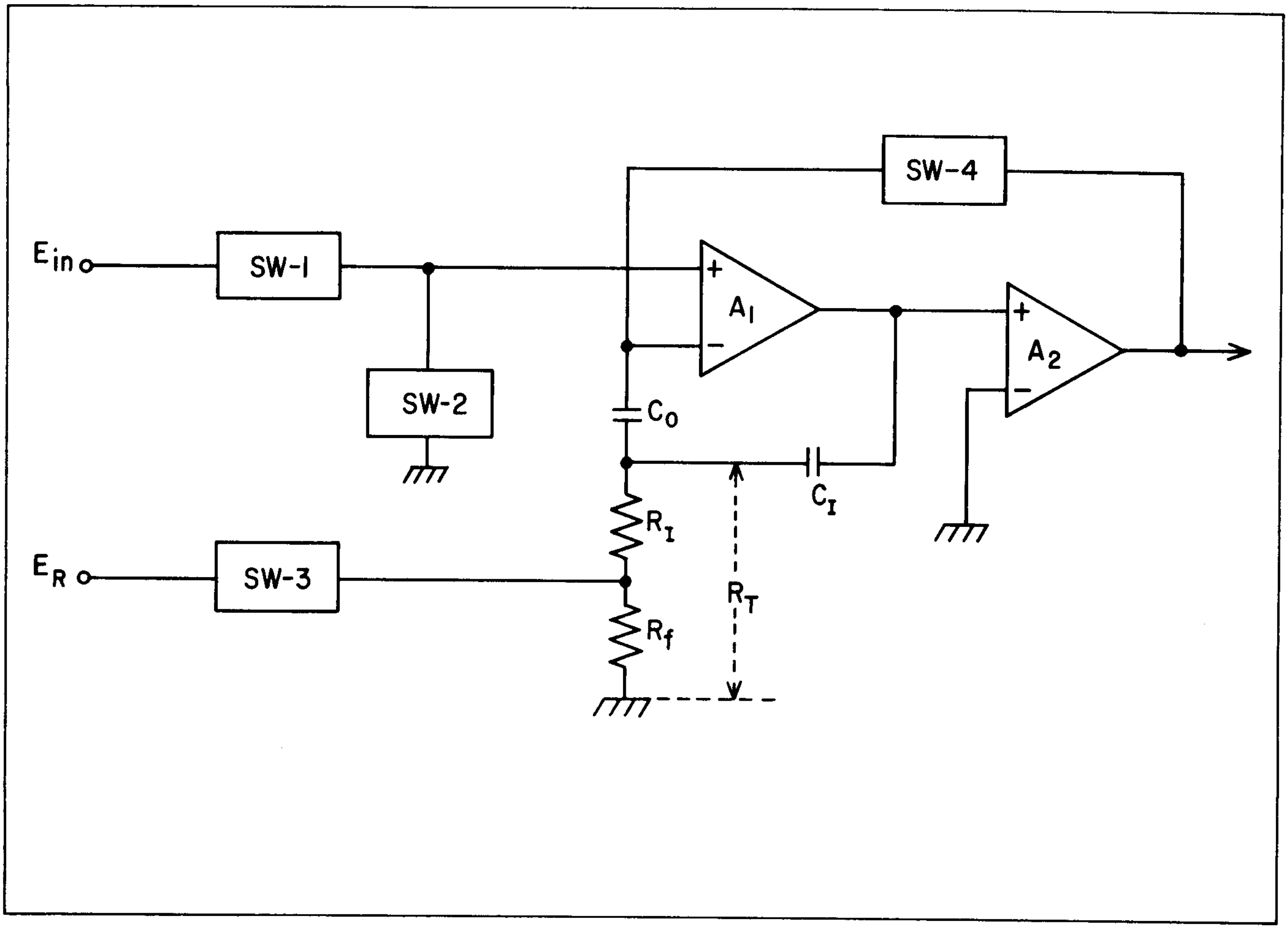


Figure 4. Simplified Block Diagram, Time Ratio Integration System

It is also important to note that the voltage across the resistor in figure 2 is equal to the source voltage minus the voltage across the capacitor.

At the time the switch is closed, $t = 0^+$, equation (1) yields zero voltage across the capacitor, as one would expect since the voltage across the capacitor cannot change instantaneously. Therefore, the full source voltage appears across terminals b and c or across R. Of significance is the fact that if R is infinite then $I = 0$ for all time then equation (1) is zero for all time, i.e., if R is infinitely large, then the capacitor drops no voltage and the voltage applied appears at the output or across terminals b and c.

These two theories comprise the basis for a unique, automatic zeroing, analog-to-digital converter used in this multimeter.

The simplified block diagram shown in figure 4 is the basic time ratio integration system. Amplifier A_1 is a high gain, high input impedance differential amplifier. Components C_I, R_I and R_f are the integration network. Capacitor C_O is the self-zeroing storage capacitor. Amplifier A_2 is a zero crossing detector.

The output of amplifier A_1 is always equal to the difference between the inverting input and non-inverting input times the gain as shown in equation (3).

$$E \text{ out } A_1 = (E_{in} - E_f) A \qquad (3)$$

Therefore, the output of A_1 is a large voltage if E_{in} and E_f are not equal. A_1 has a gain of approximately 10,000 so that a very small difference at the two inputs will drive the amplifier into saturation. This means that in order to balance the amplifier E_f must equal E_{in} for all practical purposes.

The conversion sequence begins with a condition in which SW-1 is open, removing E_{in} from the amplifier; SW-2 is closed, grounding the non-inverting input of the amplifier; SW-3 is open, removing the reference voltage; SW-4 is closed, setting the system into self-zero mode.

The output of amplifier A_2 is positive when its input is positive, negative when its input is negative and zero when its input is zero (neglecting offset). With SW-4 closed, the output of A_2 is connected to the inverting input of A_1 and capacitor C_O. This comprises a closed loop from the output to the input of the over-all system. Feedback from A_2 to A_1 stabilizes the over-all system in a condition where necessary offset voltage is self-generated and stored in capacitor C_O. In self-zero mode, if offsets in the amplifiers tend to drive the output of A_2 positive or negative, a voltage will be developed at the inverting input of A1 of such magnitude as to compensate for the amplifiers offset. This voltage is stored in C_O and remains constant during the conversion sequence due to the high input impedance of A_1. After each conversion sequence SW-4 is again closed, up-dating the offset voltage for each cycle.

The system is now stabilized in a self-zero condition. The input sampling is accomplished by opening SW-2, SW-4 and closing SW-1, applying E_{in} to the non-inverting input of A_1. A_1 sees a step input from zero volts to E_{in}. At this time the inverting input is zero, so amplifier A_1 will tend to saturate positive. However, the step input to A_1 produces a step output and since the charge on C_I cannot change instantaneously this step appears at the top of R_I and at the inverting input through C_O. Therefore, instead of saturating, A_1 output steps from zero volts to a magnitude equal to E_{in} which balances the two inputs. (Note that C_O acts as a short circuit to voltages at R_I since A_1 input impedance is very high.) This condition would exist only momentarily since the inverting input is always equal to the voltage across R_I and R_f.

$$E_f = I(R_I + R_f)$$

$$R_I + R_f = R_T$$

$$E_f = IR_T \qquad (4)$$

In order to keep the input to A_1 balanced, a constant current as required in equation (4) must flow through R_T. This constant current is supplied by A_1 charging C_I at a constant rate. As discussed, a constant current through C_I necessitates a linear ramp voltage across C_I: therefore, the output of A_1 steps from zero to E_{in} and then ramps positive (if E_{in} is positive) linearly.

This closed loop feedback system is stable as long as $E_{in} = E_f$ or when the current through C_I is constant as required by equation (4).

The output of A_1 is the voltage across R_I, R_f and C_I.

$$V\,out = \frac{I}{C_I}(t) + E_f$$

Since $E_{in} = E_f$ and from equation (4) $I = \frac{E_f}{R_T}$

$$V\,out = \frac{\frac{E_{in}}{R_T}}{C_I}(t) + E_{in}$$

or

$$V\,out = \frac{E_{in}}{R_T C_I}(t) + E_{in} \qquad (5)$$

Equation (5) is the expression for the voltage at the output of A_1 as a function of time, where the input voltage is E_{in}. This voltage steps, then increases linearly if E_{in} remains constant.

A similar condition exists if the non-inverting input of A_1 is set to zero (SW-1 open, SW-2 closed) and a positive voltage is applied through SW-3. This condition places a voltage E_R at the bottom of R_I. The non-inverting input of A_1 has stepped from E_{in} to zero so the output steps negative by E_{in} volts to again balance the two inputs. However, in order to maintain this balance condition there must exist a current through R_T to offset the reference voltage E_R. The magnitude of this current was expressed in equation (4).

Therefore, when E_{in} is removed and the reference is applied, the output of A_1 steps negative then ramps negative to produce a net sum of zero volts across R_T and therefore balanced inputs again at A_1.

The expression for the output of A_1 during this negative portion of the ramp is:

$$V\,out = -\frac{E_R}{R_T C_I}(t) - E_{in} \qquad (6)$$

If the switches shown in figure 3 are sequenced in specific order, the output of A_1 may be made to ramp positive for a period of time while E_{in} is applied and negative for a period of time while E_R is applied. A ramp similar to that shown in figure 4 would be produced for the sequence shown in table 2.

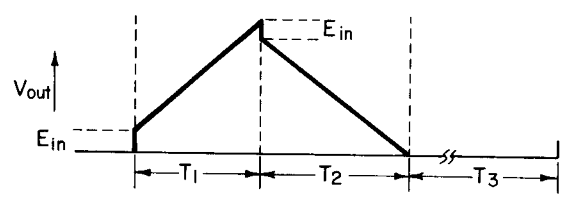


Figure 5. Integrator Output

Time	SW-1	SW-2	SW-3	SW-4
T_1	ON	OFF	OFF	OFF
T_2	OFF	ON	ON	OFF
T_3	OFF	ON	OFF	ON

Table 2. Switching Sequence

The equations for the up ramp and down ramp are (5) and (6). These equations are for all time but, in order to compare the unknown input voltage to a known reference voltage, the time it takes to charge C_I is compared to the time it takes to discharge C_I.

In figure 5 and table 2, if time T_1 is set to a specific value and time T_2 measured, then E_{in} is to T_1 as E_R is to T_2, or:

$$\frac{E_{in}}{E_R} = K \frac{T_1}{T_2} \qquad (7)$$

In this multimeter an oscillator is gated ON when E_{in} is applied to A_1 and allowed to run for 1000 cycles. At this point E_{in} is removed and E_R is applied and the oscillator continues to run during time T_2, for N_x cycles, until the output of A_1 again reaches zero volts (starting point). Therefore, from equation (7) E_{in} is related to E_R by the ratio of two series of pulses.

Since the increase in voltage out of A_1 during T_1 is equal to the decrease in voltage out during T_2 (returned to same voltage level) equations (5) and (6) must be equal for time T_1 and T_2, i.e., the sum of equation (5) and (6) over the two time periods must equal zero.

$$T_1 = \frac{1000}{f} \qquad (8)$$

$$T_2 = \frac{N_x}{f} \qquad (9)$$

f = oscillator frequency

N_x = number cycles during time T_2

Substituting equation (8) and (9) into equations (5) and (6) and summing the two equal to zero.

$$\frac{E_{in}}{R_T C_I}\left(\frac{1000}{f}\right) + E_{in} = \frac{E_R}{R_T C_I}\left(\frac{N_x}{f}\right) + E_{in}$$

Simplifying:

$$\frac{E_{in}}{R_T C_I f} 1000 = \frac{E_R}{R_T C_I f}\left(N_x\right)$$

and:

$$N_x = \frac{E_{in}}{E_R}\left(1000\right) \qquad (10)$$

Therefore, the number of pulses during the application of the reference voltage is proportional to the input voltage and the reference voltage.

If N_x is displayed on some type of readout device and the constant, $\frac{1000}{E_R}$, is adjusted to make N_x directly proportional to E_{in}, the system would then be a single-range voltmeter.

The accuracy of the analog-to-digital conversion is dependent only on the reference voltage. The frequency of the oscillator, amplifier gain, integrating capacitor and resistor do not appear in equation (10) and do not affect the accuracy of the system as long as they are within reason.

Most significant is the fact that the over-all system is automatically zeroed prior to each cycle and is able to maintain exceptional stability during the cycle. Zero drift and the subsequent offset in readings have been eliminated.

SECTION VI
CIRCUIT DESCRIPTION

The circuitry discussed in Theory of Operation plus the circuitry necessary to count and display N_x and thereby indicate the magnitude of the units being measured is shown schematically in figure 16 and block diagram form in figure 6.

The basic system has a full scale input sensitivity of 90.909 mV and is linear up to 100% overrange. All ranges are divided down to this level as a particular full scale input range is selected.

Range Switch S2

The range switch sets the full scale input value on all functions. This switch selects the appropriate dividers or range resistors to produce 90.909 mV input to the integrator for a full scale reading.

Function Switch S1

The function switch selects the particular unit to be measured. These units are dc volts and current, ac volts and current, and ohms. The function switch has provisions for checking battery voltage and de-energizing the unit.

Filter

The integrator input filter consists of an RC network which, when combined with the integrator, provides high ac noise rejection. The rejection is specified in Section II.

SW-1 and SW-2

SW-1 and SW-2 are the input switches consisting of junction FET's Q2 and Q4 and are controlled by bipolar inverters. When SW-1 is on and SW-2 is off, the input voltage is applied to the integrator. When SW-1 is off and SW-2 is on, the integrator is returned to ground.

SW-3a and SW-3b

The SW-3a and SW-3b are reference switches and are controlled by a flip-flop which is set according to input polarity. These switches are junction FETs Q18 and Q19.

Flip-flop

This is a controlled R-S flip-flop. The inputs are driven by Apply-1 and the polarity sensing circuitry. The flip-flop also has provisions for inhibit and output gating.

Reference Voltages

The negative reference voltage is generated by a temperature compensated zener, CR13, and constant current supply. This combination produces a reference voltage that is highly stable with very little or no effects from temperature or supply voltage. The plus reference is derived from this stable negative reference through use of a unity-gain inverting amplifier consisting of Q43 and Q44. Q43 is a matched differential pair to minimize temperature effects and the amplifier is compensated for variation in supply voltage.

The reference zener is only switched on when it is applied to the integrator to minimize power consumption.

Amplifier A_1

A_1 is the integrating amplifier described in Theory of Operation, Section V. This amplifier consists of a FET input differential stage, Q6 and Q11, which provides the necessary high input impedance, a bipolar differential stage, Q7 and Q10, and a bipolar inverting amplifier, Q9. The amplifier gain is high (approximately 10,000) to reduce the total conversion error to less than 0.1%. The input FET stage is operated at approximately 0.5mA per section supplied from a constant current source, Q8, with common mode feedback.

Amplifier A_2

A_2 is a high gain differential amplifier that serves as a zero crossing detector or comparator. Its function is to indicate when the integrator output ramp crosses zero volts or the voltage from which it started. The amplifier consists of two bipolar diffential stages, Q15 and Q17, Q14 and Q16. The high gain of A_2 makes it sensitive to ramps produced by inputs down to 50 u V; consequently, the system is able to make accurate measurements with 100 u V resolution. The output of A_2 ultimately controls the oscillator from which the display (N_x) is obtained.

Inverter 1 and Inverter 2

Inverter 1 and Inverter 2 sense the output of A_2. This output is positive for positive inputs and negative for negative inputs. The oscillator (in MOS-IC) is controlled by the YN input. The oscillator is ON when this input is low and OFF when this input is high. Therefore, Inverters 1 and 2, Q22 and Q26, sense the polarity and control the oscillator through YN. Inverter 1 senses positive polarity and is gated such that it may not control YN when the polarity is negative. Inverter 2 senses negative polarity and sets the flip-flop for negative polarity. Inverter 2 controls the oscillator through YN via SW-5.

SW-5

SW-5 consists of bipolar transistors Q28 and Q29. SW-5 is discussed under Megohms Operation, Section VII. It allows Inverter 2 to control the oscillator only when MOS-IC Apply-2 output is low.

Reset Generator

The reset pulse is generated by a multivibrator with a high on-off ratio. The reset pulse is approximately 50 u s wide and occurs every 0.5 seconds. Transistors Q38 and Q39 form the multivibrator; R85 and C18 determine the rate; R84 and C19 determine the pulse width.

SW-7

SW-7 controls the Polarity Sign. Transistor Q36 monitors the state of the flip-flop. When the flip-flop is set for positive polarity, (apply a positive reference) Test Point J goes to 0 volts turning Q36 on. Q36, in turn, turns Q34 on, lighting the "+" sign, and applies -13.0V to the base of Q33 extinquishing the "-" sign. When Q36 is off, "-" polarity, Q34 is off and Q33 has +11.5V applied to its base lighting the "-" sign.

Regulators

Transistors Q50, 51, 52, 53 and associated circuitry form a -13.5V regulator. The positive regulator, controlled by Q48 and Q49, is referenced to the negative regulator and adjusted for + 11.5V.

Battery Charging Circuit (Battery Operated Units)

The charging circuit is designed to recharge the + 14.4 volt, -14.4 volt and 1.25 volt nickel-cadmium batteries. The circuit consists of a transformer, half wave rectifier and filter with current limiting resistors.

Charging time for completely discharged batteries is approximately 16 hours. The multimeter may be operated during recharge, in which case the charging circuit is charging the batteries at 30% of capacity.

MOS-IC

The MOS-Integrated Circuit Z2 is designed specifically for this equipment. It contains an oscillator, three-stage counter, count storage latches, seven-segment decoder driver, and additional gating circuits to control the sequence of events in the multimeter. The output waveforms are shown in figures 9 and 10. The sequence is discussed in the Functional Operation, Section VII.

The MOS-IC is a 40-pin dual in-line package. It is compact and consumes very little power, enabling the multimeter to operate for long periods of time before battery recharge is necessary.

True RMS AC to DC Converter

The ac to dc converter consists of an ac amplifier and a true rms ac to dc conversion system. The ac amplifier consists of a triple cascode FET follower coupled with an operational amplifier. Transistor Q42 serves as a current source with negative dc feedback to stabalize the dc operating point of the amplifier. The input FET, Q40, is bootstrapped via Q41 and C30, which feeds back signal of the same phase and amplitude as the input signal. This unique configuration provides maximum input resistance and minimum input capacitance, thus allowing use of a pure capacitive input divider. Frequency response is specified from 20Hz to 50kHz with a constant input impedance of approximately 1000 megohms shunted by 75 pf. However, the upper frequency limit of the amplifier is approximately 200 kHz and the actual limiting factor is the true rms converter. Resistor R230 and R101 determine the closed loop gain which is approximately 25.

Components C27, R88, R89, and R94 provide input overload protection of 1000V rms on all ranges.

The true rms converter converts the amplified input ac signal to a dc voltage equivalent to the rms value of the input.

$$E_{out}(dc) = \sqrt{\frac{1}{T}\int \left[E_{in}(t)\right]^2 dt}$$

The indicated operations of squaring, averaging, and square-rooting are performed electronically within the true rms converter. The averaging operation is actually a one-pole low-pass filter such that a true "running" average is obtained.

Computing type true rms converters offer fast accurate conversion from ac to dc with no thermal time lag and with small compact circuits.

The true rms converter output is fed into the dc section of the 3310 where it is converted to a reading which is is proportional to the rms value of the input signal.

dBm

The conversion of ac volts to dBm is accomplished by coupling the dc output of the true rms converter into a log converter and then converting this log voltage to a displayed reading via the dc section of the multimeter.

The log converter consists of op-amps Z200, Z201, and differential transistor Q202. The logarithmic gain of the converter is derived from the inherent exponential characteristic of a transistor junction, i.e., the base-emitter voltage is proportional to the log of the collector current. As shown in the schematic diagram, Q202-1 is within the feedback loop of Z200. Z200 and associated circuitry is an inverting amplifier which forces the collector current of Q202-1 to be equal to the input

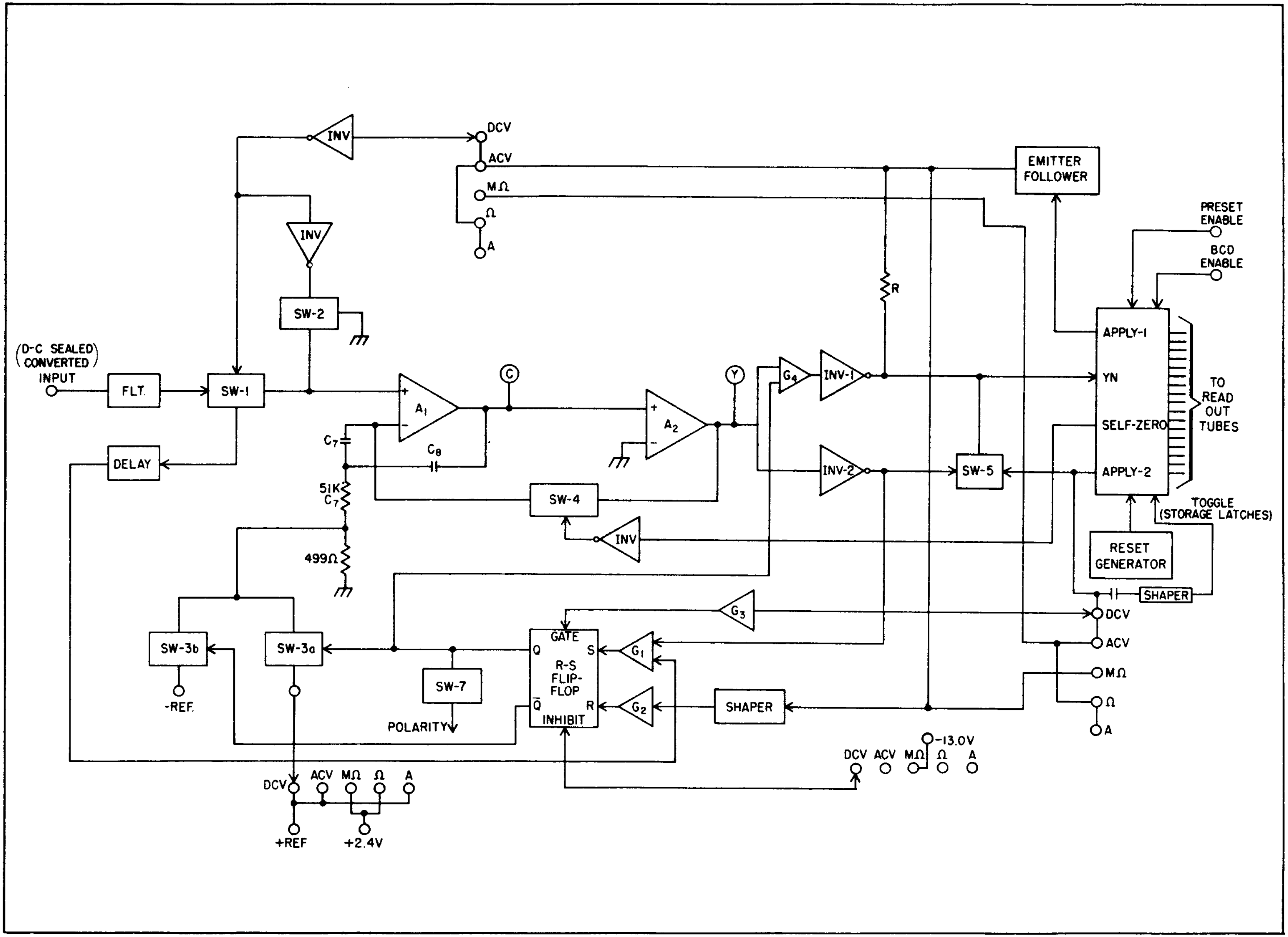


Figure 6. Complete Block Diagram

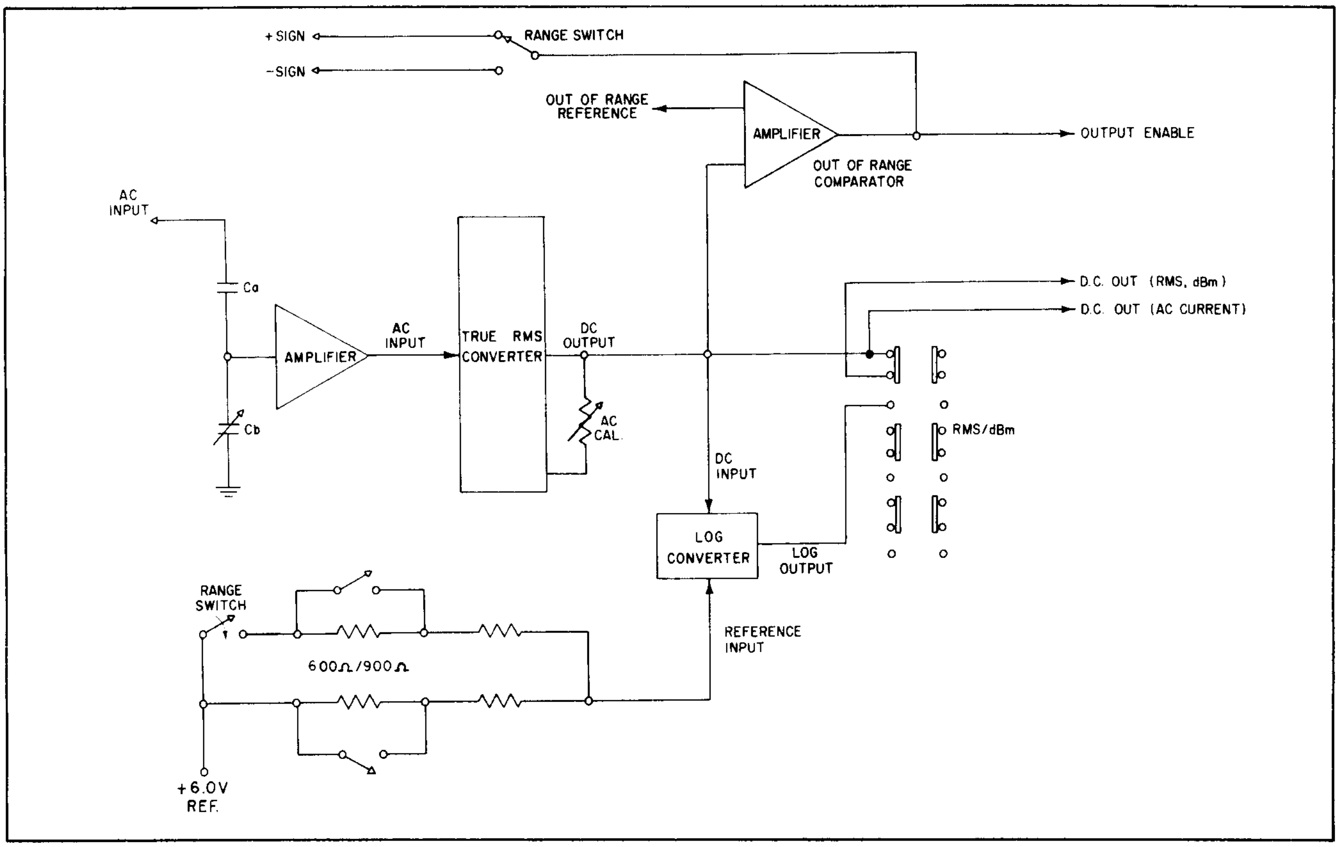


Figure 6A. True RMS/dBm Block Diagram

voltage divided by the input resistance (R209). Therefore, the base-emitter voltage of Q202-1 must be proportional to the log of the input voltage. Also, amplifier Z201 determines the collector current in Q202-2. This current must remain constant on any given range and dbM reference in order to balance inverter amplifier Z201. Therefore the collector current and base-emitter voltage of Q202-2 can not change and the voltage at the junction of the two emitters can not change. To balance the overall system the output of Z201 must then change proportional to the required Vbe of Q202-1. Divider R215 and RT200 set the log gain at approximately 1 volt per decade. The output is taken from the output of Z201 and through restive divider R204, R205, and R206 is calibrated to display 20.0 for the equivalent of 20 dBm input.

The input ac divider and true rms conversion system scale the input voltage such that the log converter works over a constant 25 db range, i.e., with 1mW/600 Ω reference, ± 20 dBm voltage into log converter is approximately equal to 1.936 volts and the voltage out is approximately equal to 1.0 volts; + 40 dBm voltage into log converter is also equal to 1.936 volts and the voltage out is again 1.0 volts (+20 dBm on 10V range, + 40 dBm on 100 V range). To obtain the + 40 dBm reading the display is preset to a reading of 20.0 at the end of Apply 1. If the voltage out of the log converter is 0 volts (equivalent to 0 dBm on 10V range or +20 dBm on 100V range) then the display is +20.0 dBm. Similiarly, on the 1kV range the display is preset to read + 40.0 with 0 volts into the dc to count system. If the input voltage on the 10V, 100V, and 1kV range is less than 0 dBm, +20 dBm, and + 40 dBm respectively, then the input to the log converter is less than 0 dBm reference and the output will be a negative voltage. This negative voltage turns on the "-" sign in the dc conversion system and via switch deck S2F, R200, and CR201, turns Q35 on, blanking the display thus indicating an out-of-range input. Out-of-range high, is sensed by op-amp. Z202 which then blanks the display while displaying a "+" sign.

In -dBm functions (100mV and 1V range), the displayed reading must decrease (toward 0 dBm) as the input voltage increases (toward 0 dBm). On the 100mV and 1V ranges the reference current is set to ten times (+20 dB) that of the 10V, 100V, and 1kV range by S2F rear and R117, 118, 119, and 120. The output of the log converter is then a negative voltage proportional to the log of the input and the magnitude of this voltage decreases as the ac input to the multimeter approaches 0 dBm. Therefore, the system now displays -dBm from -45 dBm to -0 dBm on the 100V and 1V ranges. The out-of-range sensing circuits are reversed such that the display is blanked if the log converter output is positive and if the input voltage goes below -45 dBm on the 100mV range or -25 dBm on the 1V range.

SECTION VII
FUNCTIONAL OPERATION

The multimeter is basically a dc voltmeter with a full scale sensitivity of 100 mV at the input terminals. Series and shunt resistors are switched in or out of the circuit to accomplish range changes and an ac/dc converter is switched in to permit ac measurements. Otherwise, the basic operation of the instrument is identical on all ranges and functions except megohms. The operation of the megohms measuring circuitry is described later in this section.

Table 3 lists the state of various switching functions during the three segments of the measurement sequence. These three segments are self-zero, count to 1000 or ramp by E_{in}, and count

$$N_x = \frac{E_{in}}{E_R} (1000) \text{ or ramp by ER.}$$

POSITIVE DC VOLTS

Referring to the complete block diagram, figure 5, integrator output waveform, figure 4, and the sequential event chart, table 3, consider the system to be in the self-zero mode. At this time, SW-4 is closed, connecting the output of A_2 to the inverting input of A_1. This forms a closed loop self-zeroing system in which amplifier offsets are automatically adjusted by placing the necessary offset voltage on C7.

Apply - 1 and Apply - 2 are off at a level of + 10V setting:

SW-1 off	-removing E_{in}
SW-2 on	-grounding the integrator input
SW-3a, b off	-removing E_R
SW-4 on	-self-zeroing

1. The next event is the generation of the reset pulse. The reset is self-generating and does not depend on other events. When the MOS-IC receives a reset pulse the following occurs:

a. MOS counters reset to 000.

b. Apply -1 turns ON (-13V).

(1) YN turns on (0V)

(2) SW-1 on; SW-2, SW-4 off

E_{in} is positive and is applied to the input of A_1 via SW-1. The output of A_1 begins ramping positive with a slope determined by E_{in}. The oscillator is running, being turned on by YN, and the MOS counters are counting the oscillator cycles. YN is held on by Apply -1 such that with zero volts in and consequently no ramp, the integrator remains on for 1000 counts.

2. The counter reaches a count of 1000 at which time an internal overspill pulse generates the following events:

a. Apply -1 turns off (+11V).

(1) SW-1 off.

(2) SW-2 on.

(3) Flip-flop automatically set to positive polarity via gate G2.

b. Apply -2 turns on (-13V).

(1) Flip-flop output gated to SW-3a and SW-3b.

(a) SW-3a on.

(b) Gate G4 and Inverter -1 on.

$+E_R$ is applied to the integrator. The output steps negative by the magnitude of E_{in} and then ramps negative with a slope determined by $+ E_R$. YN is held on by Inverter -2, allowing the oscillator to run.

3. When the Integrator output ramp crosses the zero reference, the output of A_2 turns off (0V)

OPERATING MODE	INTE-GRATOR INPUT	APPLY -1	APPLY -2	SELF-ZERO	SW-1	SW-2	FLIP-FLOP		INTEGRATOR		COM-PARATOR OUTPUT	SW-5	YN		NOTES
							SW-3a	SW-3b	SLOPE	POLARITY					
SELF-ZERO	GND.	OFF	OFF	ON	OFF	ON	OFF	OFF	0	0	0±.4V	OFF	OFF	POSITIVE INPUT	
RESET															
COUNT TO 1000	$+E_{in}$	ON	OFF	OFF	ON	OFF	OFF	OFF	+	+	+	OFF	ON		RAMP + $B_y + E_{in}$
MOS-SWITCH															
COUNT TO N_x	GND.	OFF	ON	OFF	OFF	ON	ON	OFF	-	+	+	ON	ON		RAMP - $B_y - E_r$
ZERO-CROSS															
	SELF ZERO AND COUNT TRANSFERRED TO DISPLAY														
	SELF-ZERO													NEGATIVE INPUT	
RESET															
COUNT TO 1000	$-E_{in}$	ON	OFF	OFF	ON	OFF	OFF	OFF	-	-	-	OFF	ON		RAMP - $B_y - E_{in}$
MOS-SWITCH															
COUNT TO N_x	GND.	OFF	ON	OFF	OFF	ON	OFF	ON	+	-	-	ON	ON		RAMP + $B_y - E_r$
ZERO-CROSS															
	SELF-ZERO AND COUNT TRANSFERRED TO DISPLAY														
	SELF-ZERO												OFF (+11V)	MEGOHMS OPERATION	
RESET															
COUNT TO 1000	GND.	ON	OFF	OFF	OFF	ON	ON	OFF	-	-	-	OFF	ON		RAMP - $B_y + E_r = \frac{R_f}{R_f + R_{cal}}(2.4V)$
MOS-SWITCH															
COUNT TO N_x	$+E_{in}$	OFF	ON	OFF	ON	OFF	OFF	OFF	+	-	-	ON	ON		RAMP + $B_y + E_{in} = \frac{R_b}{R_b + R_x}$ (2.4V)
ZERO-CROSS															
	SELF-ZERO AND COUNT TRANSFERRED TO DISPLAY														

NOTE: AC Volts, AC + DC Current and Ohms Operations Identical to Positive Input.

Table 3. Sequential Event Chart

and Inverter -1 turns YN off (+ 11V). The following events take place when YN turns off:

a. Oscillator stops (inhibited by YN).

b. Apply -2 turns off (+ 11V).

(1) Flip-flop outputs off.

(a) SW-3a and SW-3b off.

c. Self-zero turns on.

(1) SW-4 on.

d. Count (N_x) transferred to display.

The counters now display the number of cycles that occurred during the ramp down or Nx as defined in equation (10), Section V. The system is returned to the self-zero mode and remains in that state until the next reset pulse occurs.

The count to 1000, time (T_1), is approximately 100 rms. The time for Nx pulses (T_2) is 100 ms for full scale and 200 ms for twice full scale.

The display will remain unchanged if the count (N_x) is the same as the previous count. Latches in the MOS-IC store the displayed reading until a new reading has been taken.

NEGATIVE DC VOLTS

The operation for negative dc volts is very similar to positive dc volts. The three segments of the sequence remain identical. However, YN is controlled by Inverter -2 rather than Inverter -1; the flip-flop is set to apply a negative reference and indicate negative polarity on the display.

When E_{in} is applied to the amplifier via SW-1, the output steps negative by a magnitude of E_{in} and then ramps negative. At the end of T_1, 1000 counts, Apply -1 turns off and Apply-2 turns on. Apply-1 turns SW-1 off, SW-2 on and sets the flip-flop to positive polarity. The delay network connected to SW-1 opens gate G1 for several microseconds at the end of T_1, thus allowing Inverter-2 to switch the flip-flop to negative polarity. Since the ramp is negative, the output of A_2 will be negative and Inverter -2 will be on, setting the flip-flop to apply a negative reference. The negative reference then causes the output of A_1 to ramp positive toward zero volts.

At zero crossing, end of T_2, YN is turned off via A_2, Inverter-2 and SW-5, thus stopping the oscillator and the number N_x is displayed.

OHMS OPERATION

In order to measure resistance, the multimeter applies a constant current to the resistor to be measured (R_x) and then measures the dc voltage dropped across the resistor.

As shown in the Simplified Switching Diagram, figure 5, 2.4 volts is applied to the HI Input through resistor R_b. Resistor R_b is 100 times the full scale resistance value to reduce non-linearity in the current generator. This, coupled with the reference calibration, reduces the ohmmeter error to less than 0.3% of full scale.

The block diagram for ohms operation is shown in figure 8. System operation and switching are the same as described for +dc volts.

When an unknown resistor is placed across the Input, a voltage is developed at the input of the system as determined by R_b, R_x, and the + 2.4V supply. This voltage will be:

$$E_{in} = \frac{R_x}{R_x + R_b} (2.4) \qquad (11)$$

This voltage, when applied to the integrator through SW-1, will produce a positive ramp as described in + dc volts operation.

From Theory of Operation, the digital display obtained from this input will be:

$$N_x = \frac{E_{in}}{E_R} (1000) \qquad (10)$$

However, E_{in} is now expressed by equation (11) and E_R is determined by the voltage division of R_{cal} and R_f.

Therefore:

$$E_R = \frac{R_f}{R_f + R_c} (2.4) \qquad (12)$$

Substituting equation (11) and (12) into equation (10):

$$N_x = \frac{\frac{R_x}{R_x + R_b}(2.4)}{\frac{R_f}{R_f + R_c}(2.4)} (1000)$$

Simplifying:

$$N_x = \left(\frac{R_x}{R_x + R_b}\right)\left(\frac{R_f + R_c}{R_f}\right)(1000) \qquad (13)$$

The term $\frac{R_f + R_c}{R_f}$ is a constant and is adjusted in calibration to be approximately equal to 100. Therefore:

$$N_x = \frac{R_x}{R_x + R_b} (100,000) \qquad (14)$$

N_x is proportional to the resistive divider formed by R_x and R_b. If R_b is large in respect to R_x then N_x is directly proportional to R_x. At full scale

$$\frac{R_x}{R_x + R_b} = \frac{1}{1 + 100} = \frac{1}{101}.$$

It should be noted that the ohmmeter supply voltage (+2.4V) has no effect on the ohmmeter accuracy since it is used for both input divide supply and reference supply.

MEGOHMS OPERATION

The multimeter has been designed to make resistance measurements up to 199.9 megohms. This is accomplished by measuring $\frac{1}{R}$ and displaying the reciprocal of that measurement.

The block diagram for megohms operation is shown in figure 9.

Significant differences between the Megohms and Ohms circuitry are:

1. The input resistive divide consisting of R_x and R_b is inverted.

2. The reference voltage is applied to the integrator during T_1. The R-S flip-flop is set to apply a positive reference by locking it in a positive state.

As shown in the simplified switching diagram, figure 7, + 2.4 volts is applied to the LO input terminal. Rb is connected between the HI input terminal and ground.

When an unknown resistor is placed across the HI and LO terminals, a voltage is developed at the input or at SW-1. This voltage will be:

$$E_{in} = \frac{R_b}{R_x + R_b} (2.4V) \qquad (15)$$

This voltage is not applied to the integrator until Apply-2 occurs (Time T_2). When the reset occurs, Apply-1, via gate G3 and the flip-flop, applies a positive reference voltage to the integrator. This voltage produces a negative going ramp for the time period T_1 or 1000 counts.

At the end of 1000 counts Apply-1 turns off and Apply-2 turns on. This removes the reference voltage and applies the input voltage, producing a ramp with positive slope so the output of A1 begins ramping back toward zero volts.

When the ramp crosses zero volts, A_2 switches to zero and Inverter-2, via SW-5, switches YN off, stopping the oscillator. SW-5 is then turned off as Apply-2 turns off and the system switches to self-zero mode and displays the number of cycles that occurred during time T_2.

The output voltage change of A_1 during T_1 (ramp down by + E_R) will be:

$$V_{out} = \frac{E_R}{R_T C_I}\left(\frac{1000}{f}\right) \qquad (16)$$

Where:

$$E_R = \frac{R_f}{R_f + R_c} (2.4V) \qquad (17)$$

Therefore:

$$V_{out} = \frac{\frac{R_f}{R_f + R_c}}{R_T C_I}\left(\frac{1000}{f}\right)(2.4V) \qquad (18)$$

The output voltage change of A_1 during T_2 (ramp up by + E_{in}) will be:

$$V_{out} = + \frac{E_{in}}{R_T C_I}\left(\frac{N_x}{f}\right) + E_{in} \qquad (19)$$

where E_{in} is expressed in equation (15).

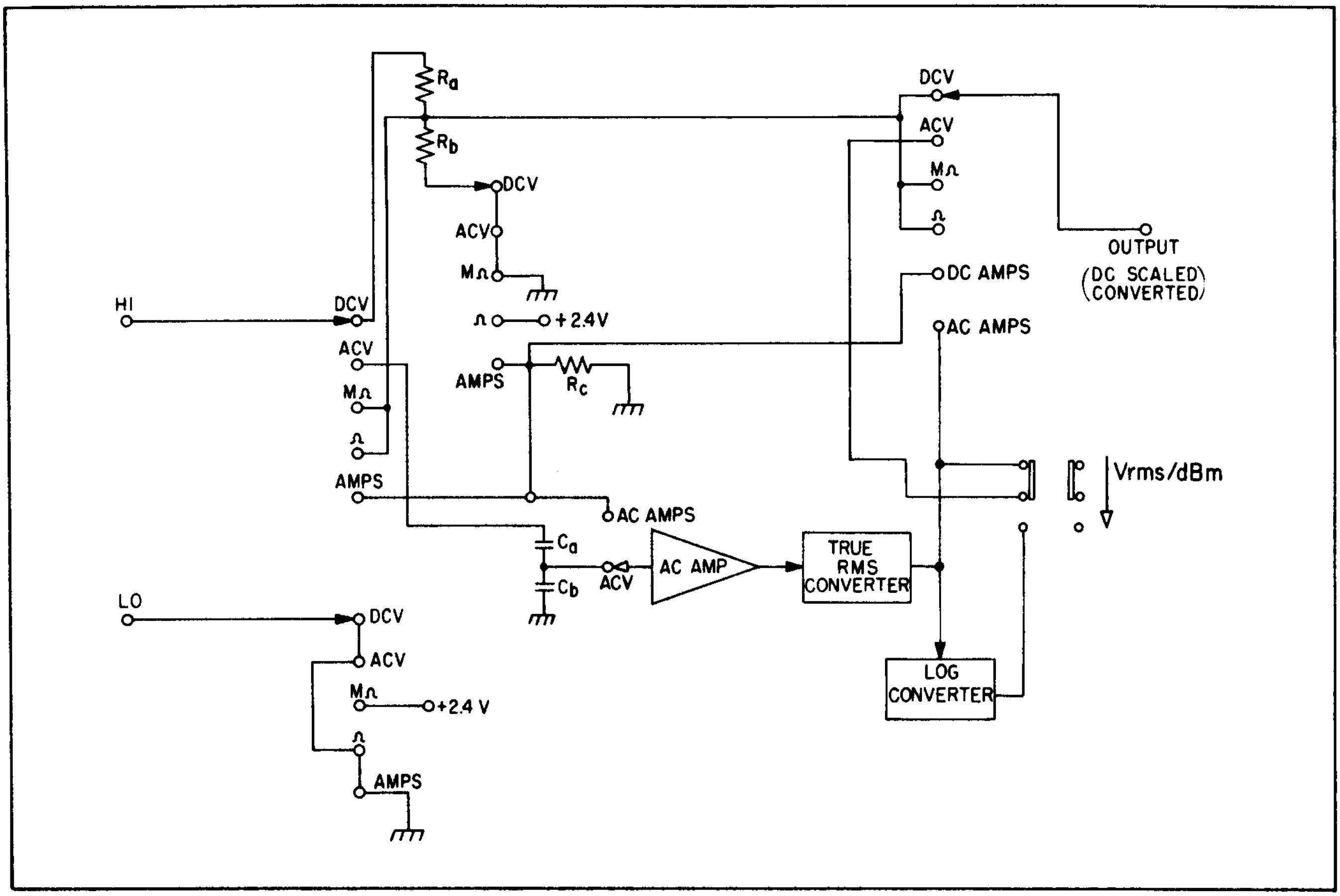


Figure 7. Simplified Switching Diagram

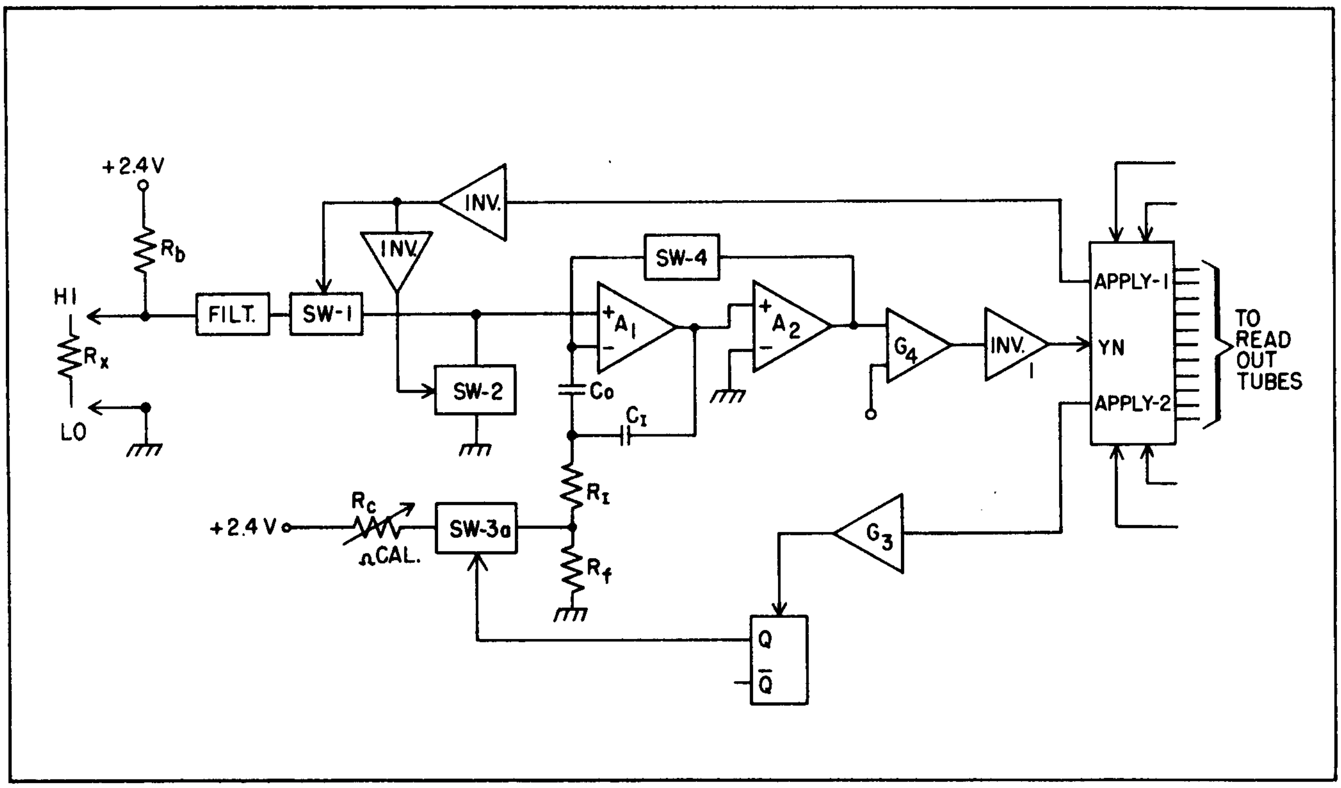


Figure 8. Ohms Block Diagram

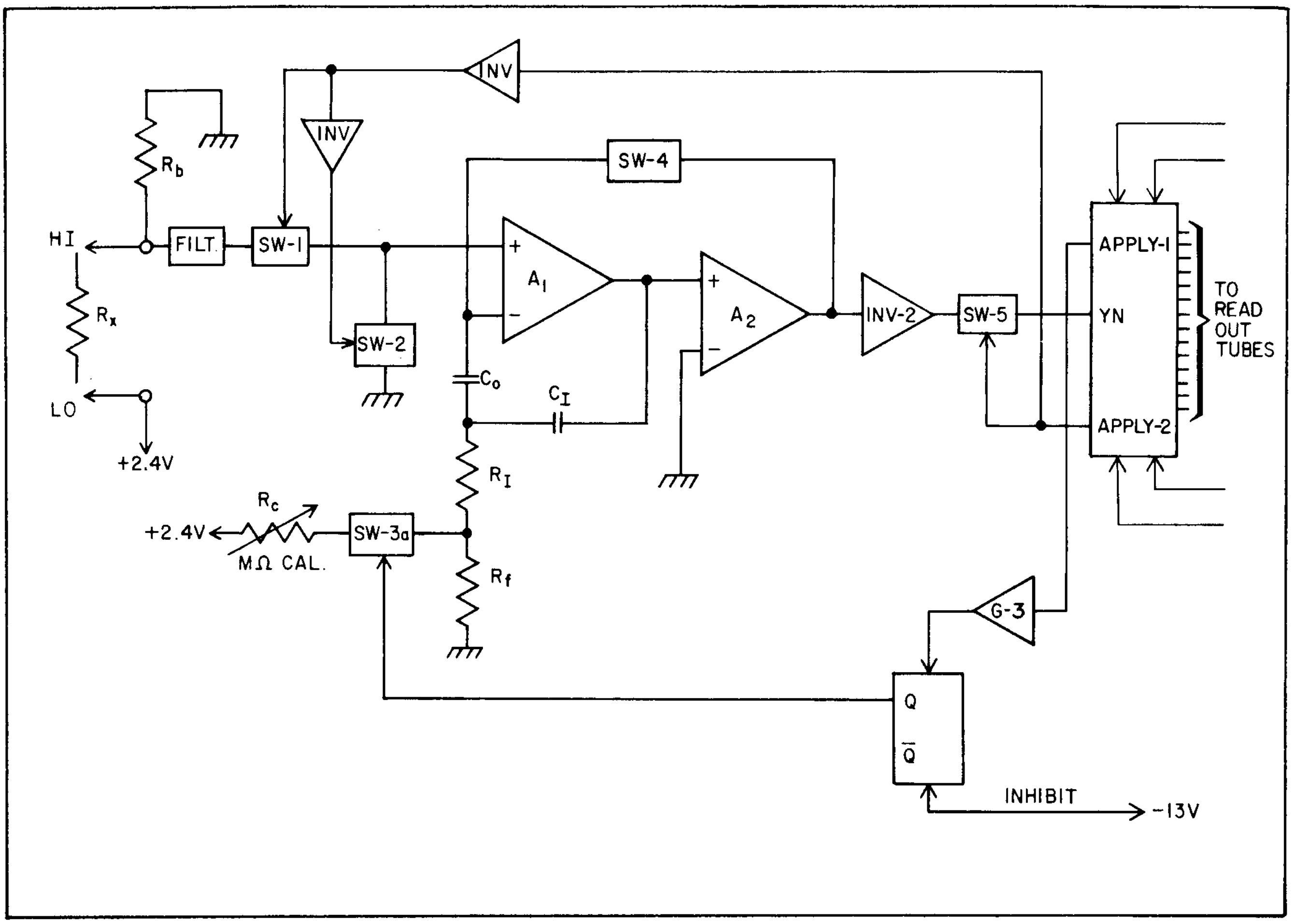


Figure 9. Megohms Block Diagram

Equating equation (18) and (19):

$$\left(\frac{R_f}{R_f R_C}\right)\left(\frac{1}{R_T C_I f}\right)\left(1000\right)\left(2.4\right) =$$

$$\left(\frac{R_b}{R_x+R_b}\right)\left(\frac{1}{R_T C_I f}\right)\left(N_x\right)\left(2.4\right) + \left(\frac{R_b}{R_x+R_b}\right)\left(2.4\right)$$

Therefore:

$$N_x = \left(\frac{R_f}{R_f R_c}\right)\left(\frac{R_x+R_b}{R_b}\right) 1000 - R_T C_I f \qquad (20)$$

The term $\frac{R_f}{R_f+R_c}$ is a constant and is adjusted in calibration to be 1/100.

Equation (20) is of the same form as the equation for the ohms reading with the exception of the term $-R_T C_I f$. For the megohms ranges R_T is adjusted such that this term is equal to 10 and exactly compensates for the non-linearity in the input resistive divide. Therefore, the megohms ranges are linear and may be used up to twice full scale.

Significantly, if R_x is zero ohms, i.e., HI and LO connected together, then $\frac{R_x + R_b}{R_b}$ is equal to one and N_x is equal to zero. Functionally, E_R is applied to the integrator for 1000 counts, E_{in} is then switched to the integrator (E_{in} is now equal to the ohmmeter supply voltage, +2.4V); in order to balance the inputs to the integrator the output steps positive by the amount of E_{in}, or 2.4V. From equation (18), if $R_T C_I f$ is equal to 10 then V_{out} at T_1 is equal to -2.4V and the application of E_{in} drives the integrator output back to zero, shutting off A_2 and ultimately YN to display a reading of 000.

AC VOLTS AND CURRENT OPERATION

In ac volts and current the ac/dc converter is used to convert the input signal to a dc voltage. This dc voltage is then displayed as any other dc voltage, except that the polarity indicator is turned off. The converter output is positive and is calibrated such that the + dc reference can be used.

The HI input terminal is connected to a calibrated capacitive divider which is switched for full scale ranges of 100 mV to 1 kV.

AC current is measured by monitoring the voltage across the shunt resistors and converting this ac signal to a dc voltage via the 100 mV AC VOLTS range.

DC CURRENT OPERATION

In dc current measurements, shunt resistors are switched across the input terminals. The voltage dropped across these shunts is monitored and displayed identical to the dc voltage reading. Polarity is automatically indicated as discussed under SW-7.

Since the basic analog conversion is designed to display 100.0 mV for 90.909 mV input, a fixed resistor, R122, is switched across R49 in all positions except DC AMPS. This changes the system from 90.909 mV to 100.0 mV sensitivity. This increases the resistor R_f in dc current mode, to produce an exact 100.0 mV reference supply.

dBm OPERATION

In dBm the output of the true rms ac to dc converter is fed into a log converter which effectively performs the function.

$$E_{out}\ (dc) = K\ Log_{10}\ \frac{E_{in}(dc)}{E_{ref}\ (dc)}$$

Since the dc input to the log converter is the equivalent of the rms value of the input to the multimeter, then the display is in dBm relative to the reference selected. Refer to Theory of Operation for details of the log conversion system.

The dBm/V rms switch supplies power to the log converter, sets the decimal XX.X position, turns on the multimeter references, and energizes the polarity indicators. Many of these functions are interlocked with the Function switch such that the dBm/V rms switch does not interfere with the operation of the multimeter in functions other than ac volts.

The 100's decade of the multimeter is preset to a 2 on the 100 mV range (-20 to -45 dBm) and on the 100V range (+20 to +45 dBm). On the 1kV range (+40 to 65 dBm) it is preset to a 4. This is accomplished by pulling the present enable (Pin 40 MOS-IC) to zero volts while holding the BCD input to the + 11.5V supply (at the end of Apply 1). Transistor Q200 and Q201 and associated circuitry perform this function with deck S2FF selecting either BCD 2 or BCD 4 inputs.

The dBm REF. switch selects either 1mW/600 Ω or 1mW/900 Ω reference for the log converter. The resistors associated with this switch along with the +6.0 V reference supply, set the 0dBm reference current into the log converter.

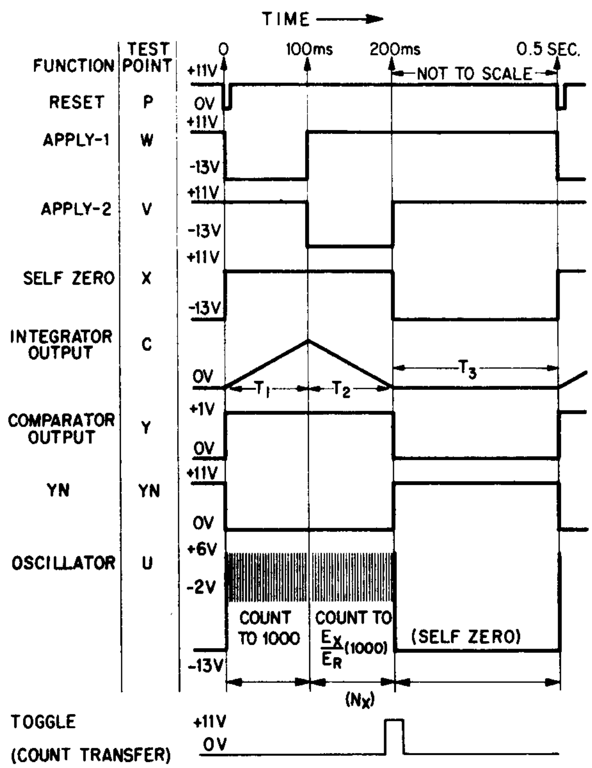
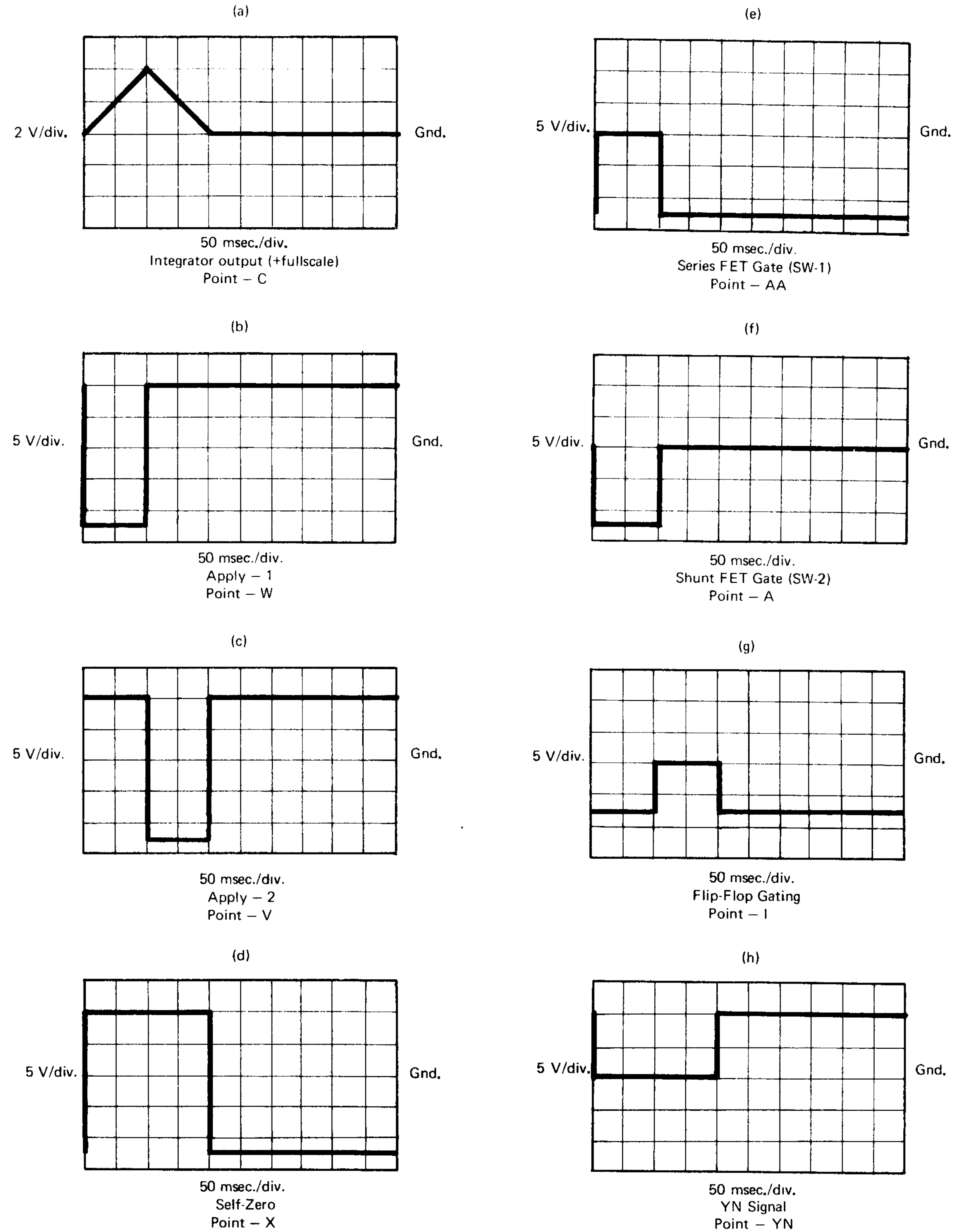


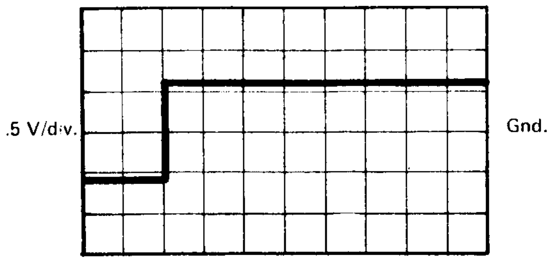
Figure 10. Waveforms - dc to Frequency System



NOTE: Waveforms taken with 10:1 scope probe. Ext. trigger to Point–W – Negative Trig. Slope – +100 MV input on 100 MV D.C. range unless otherwise specified.

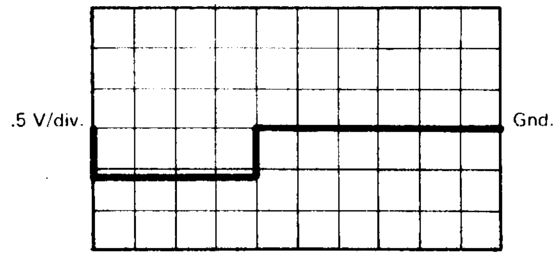
Figure 11. System Waveforms (Sheet 1 of 3)

(i)



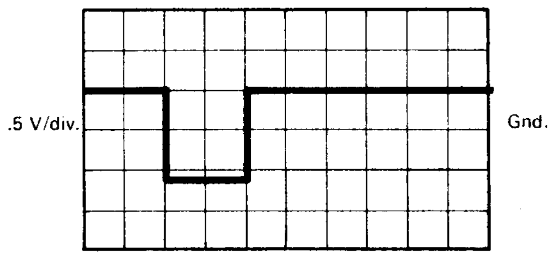
50 msec./div.
Base Q-1 (SW-1 Series FET Drive Switch)
Point – B

(m)



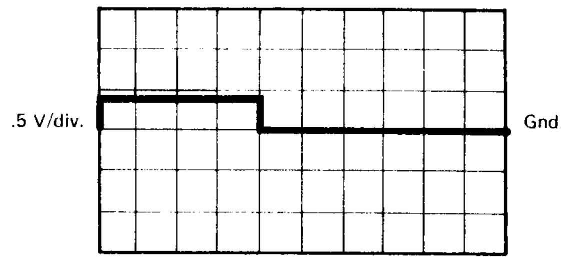
50 msec./div.
100 MV D.C. Range -100 MV Input
Point – Y

(j)



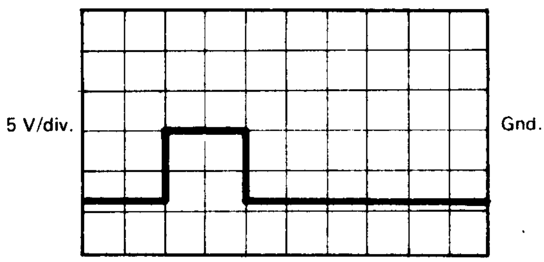
50 msec./div.
Base Q-44 (Flip-Flop Gating – Drive Signal)
Point – BB

(n)



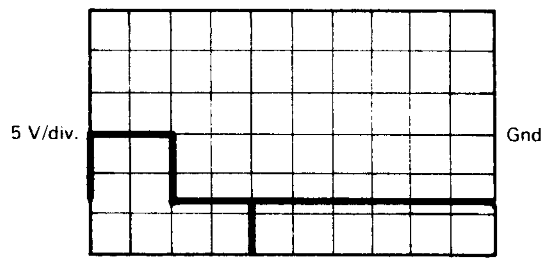
50 msec/div.
100 MV D.C. Range +100 MV Input
Point – Y

(k)



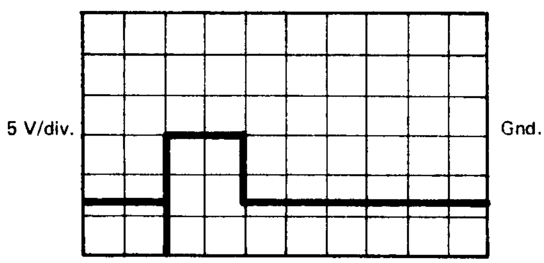
50 msec./div.
100 MV D.C. Range +100 MV Input
Point – J

(o)



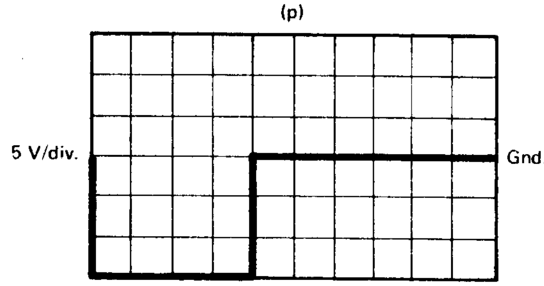
50 msec./div.
1 MΩ Range 1 MΩ Input
Point – J

(l)



50 msec./div.
100 MV D.C. Range -100 MV Input
Point – JJ

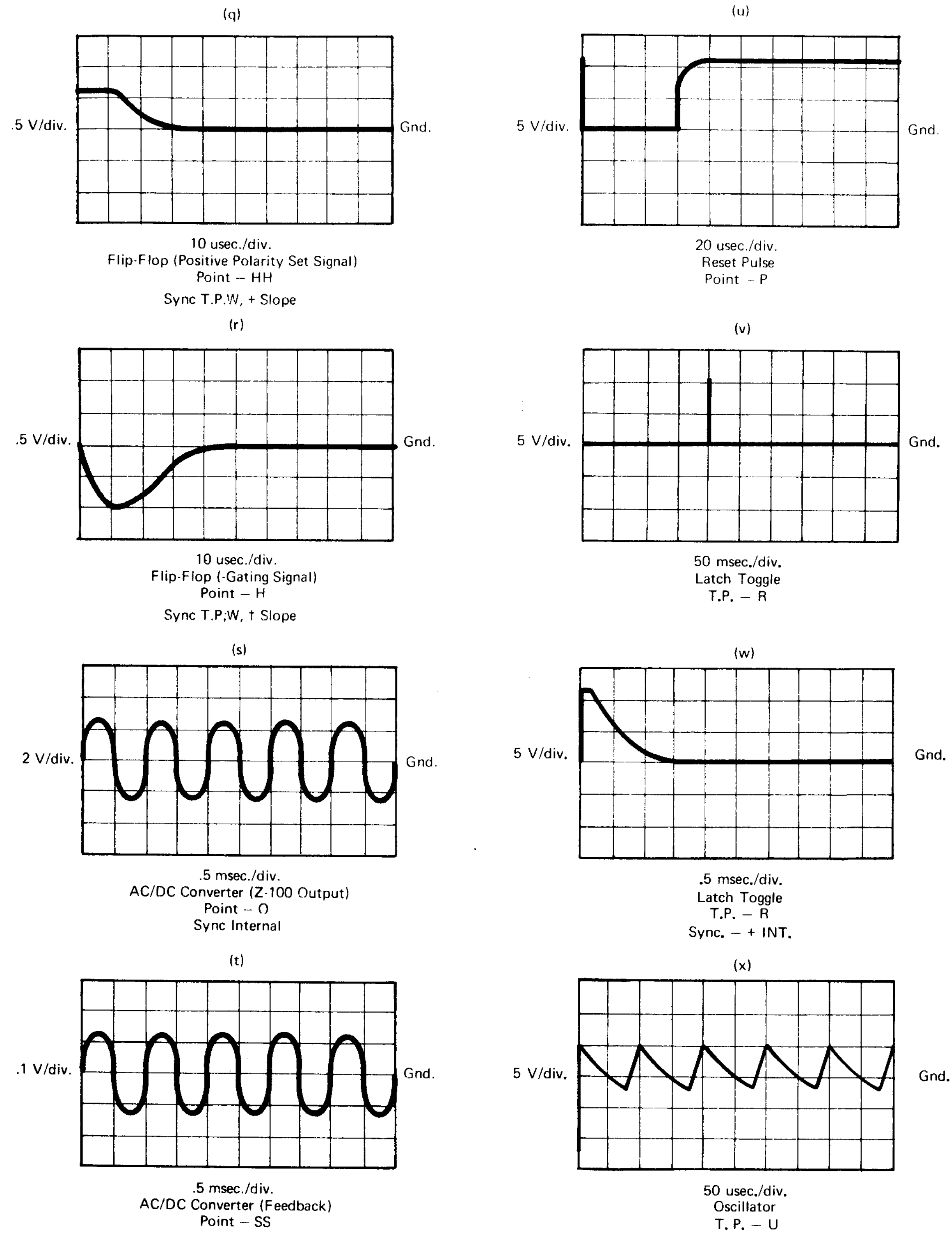
(p)



50 msec./div.
Self-Zero FET Gate
Point – D

NOTE: Waveforms taken with 10:1 scope probe. Ext. trigger to Point–W – Negative Trig. Slope – +100 MV input on 100MV D.C. range unless otherwise specified.

Figure 11. System Waveforms (Sheet 2 of 3)



NOTE: Waveforms taken with 10:1 scope probe. Ext. trigger to Point–W – Negative Trig. Slope – +100 MV input on 100 MV D.C. range unless otherwise specified.

Figure 11. System Waveforms (Sheet 3 of 3)

SECTION VIII
TROUBLESHOOTING

It is recommended that sections of this manual dealing with theory of operation and functional operation be thoroughly understood before attempting to initiate corrective action.

In every instance a complete evaluation of the multimeter's performance should be made from the front panel and, if possible, the probable malfunctioning circuit isolated prior to disassembly of the unit.

RECOMMENDED EQUIPMENT

1. DC Standard and Differential Voltmeter (Hewlett-Packard Model 740B).
2. Hickok Model 5002 Oscilloscope with two 10:1 Probes (Hickok Style 100-155).
3. DC Microvoltmeter and AC Voltmeter (Hickok Models DP110 and DP130 with Model 3202 Digital Main Frame).
4. Sine Wave Oscillator (Krohn-Hite Model 4200).

TROUBLESHOOTING

The circuitry is divided into the following sections:

1. MOS-IC outputs and display
2. Integrator
3. Comparator
4. Input and Self-Zero Switching
5. Reference Switching
6. Output circuitry and oscillator control (Yn)
7. Function and Range switching
8. Voltage Regulators
9. Reset Circuitry and Latch Toggle
10. Reference Supply
11. Power Supply
12. AC/DC Converter and Associated Circuitry

1. MOS-IC Outputs and Display

a. The Seven Segment tubes are driven directly from the MOS-IC. The filaments of each tube is elevated to the -13.0 volt supply and the MOS-IC internal drivers are connected to the + 11.5 volt supply (Subs +) such that when the segment driver is "on" there is 24.5 volts across the tube. If all other sections are operating properly the drivers may be checked by observing the segments of each tube.

b. If there is no count displayed, refer to paragraph 9 of this section for reset pulse and latch toggle problems. It should be noted at this point that the MOS-IC contains latches such that the information obtained during each read cycle is stored until updated by a high signal ($> +8.0$ V) at the latch toggle input (Pin 18). If Pin 18 is held high, the output of the latches follows the input and each count pulse is transferred directly to the display tubes.

c. The count pulses are generated by an oscillator on the MOS-IC chip. The oscillator is controlled by the Yn signal (Paragraph 6) and is on during Apply 1 and Apply 2. To check the oscillator:

(1) Connect the trigger input of the scope to test point WW, using a 10:1 probe.

(2) Set trigger to "external", mode to "AC-HF", slope to "-".

(3) Set Time/Div. to 50 μ Sec, Volts/Div. to 0.5V.

(4) Connect the vertical input to test point U, using a 10:1 probe. The waveform should be as shown in Fig. 10.

d. The positive and negative supplies for the MOS-IC enter on Pin 1 and Pin 38. If these are not correct refer to Paragraph 8 for Voltage Regulators.

e. Apply + 100 mV dc to the input on the 100 mV range or full-scale on any dc range. Observe the following test points.

Test Point	Test Value	Corrective Action
(W)	Fig. 11b	See Paragraph 9 of this section then check MOS-IC and R69
(WW)	Same as W-0.6V	Check Q32, R68
(V)	Fig. 11c	See Paragraph 2 of this section
(X)	Fig. 11d	Check MOS-IC, R40, R41

Also, with zero input, Apply 2 is on (-13 volts) for less than 50 u s. (Apply -2 is the time for which a DC reference voltage is being applied to the integrator to bring the ramp to zero level, and with zero input the ramp should be zero volts.) If the ramp is not zero, R22 should be readjusted per calibration procedure, or input FET's checked for leakage.

f. Out-3 (pin 29) is the full-scale output which turns the "1" bars of the first tube on (numbering from left to right). If the "1" does not light when the input exceeds 1000 volt (equivalent to 100 mV input on the 100 mV range), check the connection to the tube and IC socket pin connection. If that does not solve the problem, make sure that Yn is on (ground potential) for more than twice the time Apply -1 is on (refer to fig. 11h for wave form). If Yn checks correctly and the "1" bar does not light, the MOS package or tube should be changed.

To obtain polarity signs S1BF5 is tied to +11V on DC volts and DC amps via the range switch. Check Q33, Q36, Q34 and associated circuitry.

g. The output drivers from the MOS-IC package to the seven-segment tubes can be damaged only by the following:

(1) A short across the output connection of the MOS-IC package.

(2) The outputs might be working but the connections to the tube sockets are not making contact. (During the display cycle, and for a lighted bar, the output from the MOS-IC package is + 11 V.)

(3) The outputs might have internal leakage such that the bar does not turn off completely. Replace MOS-IC.

2. Integrator Check

a. With the function switch set to DC V and the range switch set to 100 mV, short the HI and LO input terminals.

b. Set the scope as follows:

(1) Connect trigger input to test point WW, using a 10:1 probe.

(2) Set TIME/DIV to 50 ms, VOLTS/DIV to 0.1 V.

(3) Set scope on EXT. trigger, model to AC-LF, slope to "-".

(4) Connect vertical input to test point C, using a 10:1 probe. Observe no ramp and DC level is 0. ± 0.5 V.

c. If the above DC level is not as stated, check the following test values at the indicated points:

Test Point	Test Value	Corrective Action
+ 11.5 V supply (E)	+ 11.5 ± 0.2V	See Paragraph 8
-13.0 V supply (EE)	-13.0 to -13.5 V	See Paragraph 8
(DD)	+ 7.5 ± 1.0	Check Q10 and Q7
(CC)	-6.0 ± 1.0	Check Q8
(C)	0 ± 0.5 V	Check Q9 and then Q6 and Q11

If the above values are correct, remove the input short and apply + 100 mV. With the scope set up as in Paragraphs 2b(1), 2b(2) and 2b(3) except set VOLTS/DIV to 0.2V, observe a ramp at point C as shown in figure 11a.

If the ramp is not correct, refer to Paragraphs 4 and 5 of this section for FET switching problems.

3. Comparator Check

a. With the same setup as in Paragraph 2a, check the following test values at the indicated points:

Test Point	Test Value	Corrective Action
(FF)	+ 9.0 ± 1.0	Check Q14 and Q16 and associated resistors
(F)	+ 9.5 ± 1.0	Check Q14 and Q16
(G)	-1.0 to -1.4V	Check Q15, Q17, CR2, CR3, and associated resistors

b. With a + 100 mV applied to the input oscilloscope (setup as in paragraphs 2b(1) and 2b(2), and 2b(3), observe a wave form at test point Y as shown in figure 11n.

If the wave form is not correct, refer to Paragraphs 4 and 5 for FET switching problems.

4. Input and Self-zero Switching

a. With the scope set up as in paragraphs 2b(1), 2b(2), and 2b(3), check the test values at the indicated test points as follows:

Test Point	Test Value	Corrective Action
(A)	Figure 11f	Check Q4 and Q5
(AA)	Figure 11e	Check Q1 and Q2
(B)	Figure 11i	Check Q1 and CR1
(D)	Figure 11p	Check Q12 and Q13

5. Reference FET Switching and Flip-Flop (Megohms Operation)

The flip-flop drives the two reference FETs Q18 and Q19 for the application of + ER and -ER voltages to the integrator. There are three controlling signals going in the flip-flop, plus a gate from the output of the comparator which senses the polarity of the input.

If it is determined that a problem exists in this area, check the following test points:

For Positive Inputs		Corrective Action
(JJ)	-13.0V	Check Q20 and Q21

For Netative Inputs		Corrective Action
(J)	-13.0V	Check Q24 and Q25

The flip-flop outputs are at test points JJ and J. These test points may be checked as follows:

Test Point	Waveform/DC Level	Corrective Action
Set-up + 100 mV input,	on 100 mV dc range	
(JJ)	-13.0V	Q20, Q21
(J)	Figure 11k	Q24, Q25
Set-up -100 mV input,	on 100 mV dc range	
(JJ)	Figure 11 1	Q20, Q21
(J)	-13.0V	Q24, Q25, Q26, Q30

If the flip-flop is working properly, the switching FETs, Q18 and Q19, may be checked by monitoring the voltage at the drain and source. This voltage is the reference voltage which is present only during Apply-2 (except in megohms operation). The source voltage should be +90.9 mV during Apply-2 for positive inputs (Q19 on) and -90.9 mV during Apply-2 for negative inputs (Q18 on). The operation of the reference FET's and flip-flop is identical on all functions except megohms. In megohms the flip-flop is held in the positive polarity state by connecting point JJ to -13.0V via the range switch deck 2A rear. This allows only the positive reference FET, Q19, to be turned on when the output of the flip-flop is gated on via Q44. Apply-1 and Apply-2 are interchanged at points K and BB. The waveform at BB is shown in figure 10j for all functions except megohms. In megohms test point BB will be similar to figure 10i. This signal is generated by Apply-1 and applies the reference to the integrator during Apply-1 which generates a negative ramp at point C.

Test Point	Test Value	Corrective Action
(HH)	Figure 11q	Check Q20, R22 and C12
(H)	Figure 11r	Check Q30, R119 and C42
(I)	Figure 11g	Check Q44 and associated circuitry

For test point I, the time for which the voltage is around ground depends on the dc voltage being applied (with 10 kHz oscillator frequency, 100 mV input on 100 mV range, test point I is at ground for 100 ms).

6. Output Circuitry and YN

YN is the controlling input for the MOS package. When YN is around ground the count starts; YN is on. When YN is + 11 volts the count stops; YN is off. Any time YN is below ground more than -0.7V, replace CR4.

With a negative dc input voltage on the dc volts range the YN drive conditions are:

Q29 off during Apply-2; Q26 and Q28 will turn on when the comparator output is negative. Q22 and Q23 are off.

If the above does not prove to be true, check and correct as needed, so that the YN operation is exactly as above. See also Section V.

7. Function and Range Switching

Check connections carefully. Check for any switch deck that may have been damaged due to excessive current and voltages. If switches are damaged, factory repair is recommended. Check component mountings and lead dress for possible shorts.

8. DC Voltage Regulators

The unregulated dc input voltage may be as follows:

a. Battery operated units only

+ 16.7 to + 13.0 V

-16.7 to -13.0 V

b. Line operated units only

+ 16.0 to + 22.0 V

-16.0 to -22.0 V

The unregulated voltages are switched, by the function switch, to the inputs of the positive and negative regulators. The negative regulator is adjustable by R151 and consists of a low current amplifier and reference element. Q53, 52, and 50 serve as the comparator and amplifier and Q51 the Series Pass element. CR15 is the reference Zener and should be 6.2 V ± 5% when the output of the regulator is sufficient for Zener breakdown.

The positive regulator is referenced to the negative regulated voltage and consists of amplifier transistor Q49 and series pass transistor Q48.

R151 should be adjusted to obtain + 11.5V output on the positive supply at test point E.

9. Reset and Latch Toggle

a. The reset pulse circuitry is located on the reference board. The wave form is shown in Figure 11 u. If problems exist in this area, check Q38, Q39, and associated circuitry. Note that the reset pulse initiates the count sequence within the MOS-IC.

b. The latch toggle is generated by capacitively coupling Apply 2 into Q-37 which in turn drives Pin 18 of the MOS-IC. The multimeter may operate properly but not display the readings obtained if this circuitry malfunctions. Figures 11V and 11W show wave forms of the latch toggle signal obtained at test point R.

10. Reference Supply

The negative reference is generated by a highly stable temperature compensated Zener CR13. To conserve power the Zener is turned on only when it is applied to the integrator. Transistor Q46 is turned on by Apply 2 which energizes the constant current generator, Q45. The positive reference is generated by a unity gain inverting amplifier consisting of Q43 and Q44.

The reference supplies may be checked by moving the input to R130 (Apply 2) and connecting this point to the + 11.5 V supply through a 100 k resistor thereby turning on both references at all times.

Test Point	Test Value	Corrective Action
Base of Q45	-0.7 V	Check CR11 and Q46
(S)	-6.3 V ± 5%	Check Q46, CR13, and Q45
(T)	+ 6.0 V ± 5%	Check Q43, Q44 (Adjust with R127)

If Q46 does not turn on when connected to R130, check signal at base. Note that this signal is Apply 2 and the length of time Q46 is on depends on the length of Apply 2 or the reading obtained (full scale reading ≈ 100 m Sec).

11. Power Supply

a. Battery operated

The batteries are charged by rectifying the ac voltage obtained from a stepdown transformer. The + 14.4 and -14.4 batteries are placed in series for charging. DSI serves as a charging indicator and series current limiter. The 1.2V filament battery is charged from a separate rectifier and transformer winding.

b. Line operation

Line operated units utilize full wave rectifiers and filters in place of the batteries. This raw voltage is then switched into the regulators via the function switch. The + 2.4 volt supply (used for ohmmeter) is derived from the + 11.5 volt regulated supply by emitter follower Q301. Note that the power supply is energized when plugged into an ac outlet but not switched to the multimeter unless the function switch is in some position other than OFF.

12. AC/DC Converter

The time constants in the ac/dc converter will hold the amplifier (A_1) in a saturated condition for several seconds after turn-on; however, if the input is shorted to ground and test point O is not at ground (± 1 V), check the following test points and correct where needed:

Test Point	Test Value	Corrective Action
(M)	+ 11.5V	Connections, switching
(MM)	-13.0 V	Connections, switching
(O)	0.0 + 1 V dc	Readjust R90 and check Q42
(LL)	+ 7.5 V	Check R92, 93
(SS)	Same as input	Z1, CR5, CR6, C35

If the R90 adjustment is not sufficient to bring point O to zero volts (allow time for stabilization) check Q42, Q41, and Q40. If replacement is necessary, use factory selected parts only.

12.1 RMS Converter

If the test point checks in paragraph 12 prove satisfactory, proceed as follows: With the function switch test set at AC V and the range switch set at 100mV, apply an input voltage of 100 mV rms at 2.5 kHz. Observe the signal at test point 0, it should be approximately 2.5 V rms with the same wave form as the input voltage. Test point 13, on the rms board, should show the same amplitude as test point O at 2.5 kHz and slightly less at much lower frequencies (less than 100 Hz). When the above conditions exist, a reading of approximately 2.5 V dc should be obtained at test point 10, on the rms board. If test point 10 does not measure 2.5V dc check the gain switching circuitry associated with switch deck S2-A.

12.2 Log Converter (dBm)

In the dBm function the output of the rms converter is switched to the log converter input. Set the function switch at AC V, the range switch to 10 V and press the dBm/V rms switch "IN". Apply 7.746 V rms at 2.5 kHz to the input posts and check the following test points.

Test Point	Test Value	Corrective Action
(7)	+ 11.0 V	Check CR203 and switching circuitry of S200
(8)	-13.0 V	Check switching circuitry of S200
(10)	1.95 V ac	Check rms converter (See Paragraph 12.1)
(3)	< 10 mV dc	Check Z200, Z201, and Q202.
(1)	< 5 mV dc	Check Z200, Z201, and Q202.
(4)	≈ + 1.0 V	Check Z200, Z201, and Q202

NOTE

Refer to theory of operation for detailed operational description.

SECTION IX
CALIBRATION

CLEANING PROCEDURE

If the unit to be calibrated has been serviced, it should be cleaned prior to calibration. Brush the circuit board clean of any rosin deposits, using clean "Printed Circuit Cleaner" manufactured by the John B. Moore Company. Dip the boards and switches into a tank of clean Freon TF or Genesolv D for a period of 20 seconds. Remove from this tank and dip immediately into a tank of Freon TF or Genesolv D with two parts of Dow Corning DC200 silicon oil added.

RECOMMENDED CALIBRATION EQUIPMENT

Hewlett-Packard 740B dc Standard and Differrential Voltmeter.

Hickok DP110 Microvoltmeter with Hickok Model 3202 Digital Main Frame.

Hickok DP130 ac Voltmeter calibrated for 100% overrange, with Hickok Model 3202 Main Frame.

Krohn-Hite Model 4200 Sine Wave Oscillator.

General Radio Model 1433H Resistor Standard Box, 1 Ohm to 11 Megohms, 0.02%.

DC Current Generator, capable of supplying 0.1 mA to 1A ± 0.02%.

Hickok Model 5000 or Model 5002 Oscilloscope.

CALIBRATION PROCEDURE

With the recommended calibration equipment, the multimeter inputs should be monitored to the given accuracy (unless the equipment being used is guaranteed to be within that accuracy). Ambient temperature should be 23°C ± 1°C.

NOTE

This procedure must be followed in sequential order. Do not attempt to calibrate any section until all previous sections have been calibrated or verified.

1. Voltage Regulator

Turn the multimeter on and make the following measurements using the DP110 Voltmeter.

a. Measure voltage between test point E and ground. A reading of + 11.5 V ± 0.1 V should be obtained. If necessary adjust R151 for proper reading.

b. Measure voltage between test point EE and ground. A reading between -13.0V and -13.5V should be obtained.

2. Zero and Ohms adjust

a. Set function switch to OHMS, range switch to 100 K Ω range.

b. Connect multimeter to decade resistor box set to 1.00 KΩ.

c. Adjust R22 for a reading of 01.0 ± 00.0.

d. Set decade resistor to 1.06 K Ω and check display for 01.1. Readjust R22 if necessary.

e. Set decade resistor to 0.94 K Ω and check display for 00.9. Readjust R22 if necessary.

f. Repeat c, d and e to verify the setting of R22; readjust if necessary.

3. Ohms

a. Set function switch to OHMS and range switch to 10 k Ω range.

b. Connect multimeter to decade resistor set to 10.00 KΩ.

c. Adjust R108 for a display of 9.98 ± 0.00. (Note: full scale on ohms must be adjusted to 998 to center non-linearity of divider.)

d. Set range switch at 10 M Ω and apply 10 megohms to input. Adjust R102 for a display of 10.00 ± 0.03.

e. Apply 10 k ohms to input. Adjust R79 for a display of 0.01 ± 0.00.

f. Short HI to LO and check for zero ± 1 digit on all ranges and functions.

g. Set range switch at 1 M Ω and apply 1 megohm to input. Adjust R233 (on Log Board) for a display of 1.000 ± 0.000.

4. DC Volts

a. Set function switch to DC V, range switch to 100 mV range.

b. Apply + 190.0 mV and adjust R127 to display + 190.0 ± 00.1.

c. Set range switch to 1V range and apply + 1.9000V. Adjust R2 to display 1.900 ± 0.001.

d. Repeat b and c as these adjustments are interacting.

e. Set range switch to 100 mV range and apply -190.00 mV. Adjust R124 to display -190.0 ± 00.1.

f. Check 10V, 100V and 1KV range to insure accuracy.

5. AC Volts

a. Set function switch to AC V, range switch to 100 mV.

b. Connect HI terminal to LO with 10:1 scope probe connected to test point O, adjust R90 for a dc level of 0 ± 1V. (Allow time for stabilization.) Check display and adjust R253 for a reading of 00.0 ± 00.0.

c. Calibrate individual ranges by the following table:

Range	Input Voltage 2.5 Khz	Adjust
100mV	190.0mV	R234
1V	1.900V	R235
10V	19.00V	R236
100V	190.0V	R237
1KV	1.000KV	R238

d. Check all ranges for proper accuracy (refer to Section II) at 20 Hz, 50 Hz, 20 kHz and 50 kHz. Maximum input frequency on 1KV range is 10 kHz.

6. Current

There is no current calibration. However, all ranges should be checked to insure that shunts are in tolerance.

7. dBm

a. With multimeter off, remove Q202 and P.C. Board connector #2 (input to R209 and R223). Connect P.C. Board terminal #2 to ground.

b. Connect ≈ 50 k Ω resistor from pin 6 Z200 to pin 2 Z200.

c. Set range switch to 10 V range, FUNCTION to AC V. Set dBm/ V RMS switch "IN" and monitor the voltage at Pin 6 of Z200 with the DP110 Voltmeter. Adjust R213 (offset adjust) for < 1 mV. Turn multimeter off and replace Q202 and P.C. Board connector #2.

d. Set FUNCTION switch to AC V, dBm/V RMS switch "IN", range and reference switches as indicated in the following table. Perform, in sequence, the operations listed as follows:

Step	Range	dBm REF.	Input Voltage (2.5kHz)	Equivalent dBm	Calibration Adjustment	Check or Adjust for
1	10V	600 Ω	0.7746 V	00.0	R229	<1mV at test point 2
2	10V	600 Ω	7.746 V	+20.0	R205	Display of + 20.0
3	10V	600 Ω	15.000V	+25.7	R224	Display of + 25.7
4	Repeat 1, 2, 3 until specified readings are obtained in all steps (± 0.1 dBm)					
5	10V	900 Ω	9.487V	+20.0	none	Check display + 20.0
6	100V	900 Ω	12.00V	+22.0	none	Check display + 22.0
7	1kV	900 Ω	948.7 V	+60.0	none	Check display +60.0
8	1V	900 Ω	0.9487V	00.0	R218	<1mV at test point 2
9	1B	900 Ω	94.87mV	-20.0	none	Check display -20.0
10	1V	600 Ω	77.46mV	-20.0	R220	<1mV at test point 2
11	1V	600 Ω	60.00mV	-22.2	none	Check display -22.2
12	100mV	600 Ω	60.00mV	-22.2	none	Check display -22.2

SECTION X

PARTS LIST

MODEL 3310 MULTIMETER

When ordering parts be sure to give the reference designation, description, and the Hickok part number as listed in the following table. Also include the model and serial number of the equipment. There is a minimum billing charge of $5.00 for all parts orders.

NOTES

1. Items marked with one asterisk "*" beside the reference designation are used in multimeters equipped for power line operation only.
2. Items marked with two asterisks "**" are used in multimeters supplied with optional rechargeable battery packs.

REF. DESIG.	DESCRIPTION	HICKOK PART NO.
BT1**	BATTERY ASSEMBLY: + 14.40, 0, -14.4 volts	2210-45
BT2 **	BATTERY: nk. cadmium, 1.25 volts	2210-46
C1	CAPACITOR, FIXED, DIPPED MICA: 22 pf, 5%, 500 volts	3096-509
C2	CAPACITOR, FIXED, POLYCARBONATE: 0.01 uf, 10%, 630 volts	3092-601
C3	CAPACITOR, FIXED, POLYCARBONATE: 0.10 uf, 10%, 400 volts	3092-413
C4	CAPACITOR, FIXED, CERAMIC: 220 pf, 20%, 500 volts	3111-518
C5	CAPACITOR, FIXED, DIPPED MICA: 270 pf, 5%, 500 volts	3096-535
C6	CAPACITOR, FIXED, DIPPED MICA: 390 pf, 5%, 500 volts	3096-539
C7	CAPACITOR, FIXED, POLYESTER FILM: 2.2 uf, 20%, 100 volts	3103-81
C8	CAPACITOR, FIXED, POLYCARBONATE: 0.047 uf, 10%, 400 volts	3092-409
C9	CAPACITOR, FIXED, DIPPED MICA: 100 pf, 5%, 500 volts	3096-525
C10	CAPACITOR, FIXED, CERAMIC: 1000 pf, +50%, -20%, 500 volts	3111-522
C11	CAPACITOR, FIXED, DIPPED MICA: 150 pf, 5%, 500 volts	3096-529
C12	CAPACITOR, FIXED, POLYESTER FILM: 0.22 uf, 20%, 100 volts	3103-80
C13	Same as C12	
C14	Same as C4	
C15	Same as C5	
C16	Same as C9	
C17	Same as C11	
C18	CAPACITOR, FIXED, POLYESTER FILM: 0.1 uf, 20%, 100 volts	3103-78
C19	CAPACITOR, FIXED, CERAMIC: 2200 pf, +50%, -20%, 500 volts	3111-524
C20	CAPACITOR, FIXED, POLYSTYRENE: 150 pf, 5%, 630 volts	3103-99
C21, C22	CAPACITOR, FIXED, POLYSTYRENE: 160 pf, 5%, 630 volts	3103-100
C23	CAPACITOR, FIXED, POLYSTYRENE: 430 pf, 5%, 160 volts	3103-102
C24	CAPACITOR, FIXED, POLYSTYRENE: 4700 pf, 5%, 30 volts	3103-101
C25	CAPACITOR, FIXED, POLYSTYRENE: 0.047 uf, 5%, 30 volts	3103-98
C26	CAPACITOR, FIXED, POLYSTYRENE: 0.47 uf, 5%, 30 volts	3103-97
C27	Same as C10	
C28	Same as C12	
C29	Same as C18	
C30, C31	Same as C18	
C32	Same as C9	
C33	CAPACITOR, FIXED, COMPOSITION: 3.9 pf, 10%, 500 volts	3116-20
	** Battery Operated Only	

REF. DESIG.	DESCRIPTION	HICKOK PART NO.
C34	Same as C18	
C35	CAPACITOR, FIXED, METALLIZED, POLYESTER FILM: 2.2 uf, 10%, 63 volts	3103-103
C36	Not used	
C37	Same as C1	
C38	Same as C19	
C39	Same as C11	
C40	Same as C9	
C41	CAPACITOR, FIXED, POLYCARBONATE: 0.022 uf, 10%, 400 volts	3092-405
C42 **	CAPACITOR, FIXED, ELECTROLYTIC: 100 uf, +40%, -20%, 70 volts	3085-393
C43, 44	CAPACITOR, FIXED, DIPPED MICA: 300 pf, 5%, 500 volts	3096-536
C200 thru C202	Same as C43	
C301, C302*	CAPACITOR, FIXED, ELECTROLYTIC: 500 uf, 25 volts	3085-423
C303 thru C305*	CAPACITOR, FIXED, METALLIZED POLYESTER FILM: 0.1 uf, 10%, 200 volts	3092-213
CR1 thru CR4	SEMICONDUCTOR DEVICE, DIODE: 1N914	3870-175
CR5, CR6	Not used	
CR7 thru CR11	Same as CR1	
CR12	SEMICONDUCTOR DEVICE, ZENER DIODE: 1N5731B	3870-302
CR13	SEMICONDUCTOR DEVICE, DIODE: 1N823A	3870-225
CR14	Same as CR1	
CR15	Same as CR12	
CR16	SEMICONDUCTOR DEVICE, DIODE: 1N2069	3870-62
CR17**	Same as CR16	
CR18 thru CR21	Same as CR1	
CR201 thru CR204	Same as CR1	
CR301 thru CR304*	SEMICONDUCTOR DEVICE, DIODE: SI-1	3870-304
DS1**	LAMP: 28 volt, 40 ma, with blue lens and 6" leads	12270-116
F1	FUSE: 1/4 amp, pigtail, 250 volt, SLO-BLO	6900-76
J1	CONNECTOR: 7 pin	3475-202
Q1	TRANSISTOR: 2N5139 PNP silicon	20861-181
Q2	TRANSISTOR: FET N-Channel, selected	20861-301
Q3, Q4	TRANSISTOR: silicon planar field effect N-Channel	20861-252
Q5	TRANSISTOR: 2N5133 NPN	20861-210
Q6	TRANSISTOR: FET N-Channel, selected	20861-253
Q7, Q8	Same as Q5	
Q9	TRANSISTOR: 2N4248 PNP	20861-268
Q10	Same as Q5	
Q11	Same as Q6	
Q12	TRANSISTOR: 2N3566 NPN silicon	20861-122
Q13	Same as Q3	
Q14	Same as Q9	
Q15	Same as Q5	
Q16	Same as Q9	
Q17	Same as Q5	
Q18, Q19	Same as Q3	
Q20 thru Q25	Same as Q5	
Q26	Same as Q1	
Q27 thru Q30	Same as Q5	
Q31	Not used	
	*Line Operated Only **Battery Operated Only	

REF. DESIG.	DESCRIPTION	HICKOK PART NO.
Q32	Same as Q12	
Q33	Same as Q5	
Q34	Same as Q9	
Q35 thru Q37	Same as Q5	
Q38	Same as Q1	
Q39	TRANSISTOR: D16P3 NPN	20861-267
Q40	TRANSISTOR: FET N-Channel, selected	20861-254
Q41, Q42	TRANSISTOR: FET N-Channel, selected	20861-255
Q43	TRANSISTOR: differential pair NPN silicon	20861-117
Q44	Same as Q1	
Q45	Same as Q5	
Q46, Q47	Same as Q1	
Q48	Same as Q39	
Q49	Same as Q5	
Q50	Same as Q1	
Q51	TRANSISTOR: 2N6013 PNP	20861-309
Q52	Same as Q5	
Q53	Same as Q1	
Q200	Same as Q5	
Q201	Same as Q1	
Q202	TRANSISTOR: QD102-78E	20861-308
Q301*	Same as Q5	
R1	RESISTOR, FIXED, METAL FILM: 8.87 megohms, 1%, 2 watt	18575-614
R2	RESISTOR, VARIABLE: composition, 300 K ohms, 20%, linear taper	16925-721
R3	RESISTOR, FIXED, METAL FILM: 900 K ohms, 0.05%, 1/2 watt	18526-134
R4	RESISTOR, FIXED, METAL FILM: 90 K ohms, 0.05%, 1/2 watt	18526-135
R5	RESISTOR, FIXED, METAL FILM: 9 K ohms, 0.05%, 1/2 watt	18526-136
R6	RESISTOR, FIXED, METAL FILM: 1 K ohms, 0.05%, 1/2 watt	18526-137
R7	RESISTOR, FIXED: calibration, value determined in production	
R8	RESISTOR, FIXED, WIRE WOUND: 0.1000 ohms, + 1%, -0%, 3 watt	18575-615
R9	RESISTOR, FIXED: calibration, value determined in production	
R10	RESISTOR, FIXED, WIRE WOUND: 1.000 ohm, + 1%, -0%, 3 watt	18575-616
R11	RESISTOR, FIXED, WIRE WOUND: 10 ohms, 0.1%, 1 watt	18550-236
R12	RESISTOR, FIXED, METAL FILM: 100 ohms, 0.1%, 1/2 watt	18526-133
R13	RESISTOR, FIXED, METAL FILM: 1 megohm, 0.25%, 1/2 watt	18526-138
R14	RESISTOR, FIXED, COMPOSITION: 20 megohms, 5%, 1/4 watt	18456-201
R15	RESISTOR, FIXED, COMPOSITION: 8.2 megohms, 5%, 1/4 watt	18455-821
R16	RESISTOR, FIXED, DEPOSITED CARBON: 270 K ohms, 5%, 1/4 watt	18470-274
R17	RESISTOR, FIXED, DEPOSITED CARBON: 3 K ohms, 5%, 1/4 watt	18470-302
R18	RESISTOR, FIXED, METAL FILM: 11.5 K ohms, 1%, 1/4 watt	18555-81
R19	RESISTOR, FIXED, METAL FILM: 1.13 megohms, 1%, 1/4 watt	18555-164
R20	RESISTOR, FIXED, DEPOSITED CARBON: 620 K ohms, 5%, 1/4 watt	18470-624
R21	RESISTOR, FIXED, DEPOSITED CARBON: 10 K ohms, 5%, 1/4 watt	18470-103
R22	RESISTOR, VARIABLE: composition, 3 K ohms, 20%, linear taper	16925-700
R23	RESISTOR, FIXED, DEPOSITED CARBON: 150 K ohms, 5%, 1/4 watt	18470-154
R24	Same as R16	
R25	RESISTOR, FIXED, DEPOSITED CARBON: 18 K ohms, 5%, 1/4 watt	18470-183
R26	RESISTOR, FIXED, DEPOSITED CARBON: 39 K ohms, 5%, 1/4 watt	18470-393
R27	Same as R21	
R28	RESISTOR, FIXED, DEPOSITED CARBON: 8.2 K ohms, 5%, 1/4 watt	18470-822
R29	RESISTOR, FIXED, DEPOSITED CARBON: 6.8 K ohms, 5%, 1/4 watt	18470-682
R30	RESISTOR, FIXED, DEPOSITED CARBON: 91 K ohms, 5%, 1/4 watt	18470-913
R31	RESISTOR, FIXED, DEPOSITED CARBON: 47 K ohms, 5%, 1/4 watt	18470-473
R32	RESISTOR, FIXED, DEPOSITED CARBON: 27 K ohms, 5%, 1/4 watt	18470-273
R33	Same as R28	
R34	RESISTOR, FIXED, DEPOSITED CARBON: 51 K ohms, 5%, 1/4 watt	18470-513
R35	RESISTOR, FIXED, DEPOSITED CARBON: 220 K ohms, 5%, 1/4 watt	18470-224
R36	Same as R21	
R37	Same as R26	

*Line Operated Only

REF. DESIG.	DESCRIPTION	HICKOK PART NO.
R38	RESISTOR, FIXED, DEPOSITED CARBON: 4.7 K ohms, 5%, 1/4 watt	18470-472
R39	RESISTOR, FIXED, DEPOSITED CARBON: 1 megohm, 5%, 1/4 watt	18470-105
R40	RESISTOR, FIXED, DEPOSITED CARBON: 3.9 K ohms, 5%, 1/4 watt	18470-392
R41	RESISTOR, FIXED, DEPOSITED CARBON: 62 K ohms, 5%, 1/4 watt	18470-623
R42, R43	Same as R21	
R44	Same as R26	
R45	Same as R17	
R46	Same as R21	
R47	Same as R29	
R48	RESISTOR, FIXED, DEPOSITED CARBON: 24 K ohms, 5%, 1/4 watt	18470-243
R49	RESISTOR, FIXED, METAL FILM: 549 ohms, 0.5%, 1/4 watt	18555-146
R50, R51	RESISTOR, FIXED, DEPOSITED CARBON: 22 K ohms, 5%, 1/4 watt	18470-223
R52	Same as R21	
R53	Same as R35	
R54	Same as R21	
R55	RESISTOR, FIXED, DEPOSITED CARBON: 360 K ohms, 5%, 1/4 watt	18470-364
R56	Same as R35	
R57	RESISTOR, FIXED, DEPOSITED CARBON: 100 K ohms, 5%, 1/4 watt	18470-104
R58	RESISTOR, FIXED, DEPOSITED CARBON: 470 K ohms, 5%, 1/4 watt	18470-474
R59	Same as R31	
R60	Same as R21	
R61	Same as R50	
R62	RESISTOR, FIXED, DEPOSITED CARBON: 33 K ohms, 5%, 1/4 watt	18470-333
R63	Same as R57	
R64	Same as R21	
R65	Same as R35	
R66	Same as R62	
R67	Same as R50	
R68	Same as R32	
R69	RESISTOR, FIXED, DEPOSITED CARBON: 56 K ohms, 5%, 1/4 watt	18470-563
R70	RESISTOR, FIXED, DEPOSITED CARBON: 4.3 K ohms, 5%, 1/4 watt	18470-432
R71	Same as R69	
R72	RESISTOR, FIXED, DEPOSITED CARBON: 20 K ohms, 5%, 1/4 watt	18470-203
R73	Same as R39	
R74	Same as R57	
R75	Same as R16	
R76	RESISTOR, FIXED, DEPOSITED CARBON: 330 K ohms, 5%, 1/4 watt	18470-334
R77	Same as R57	
R78	RESISTOR, FIXED, DEPOSITED CARBON: 3.3 K ohms, 5%, 1/4 watt	18470-332
R79	RESISTOR, VARIABLE: composition, 1 megohm, 20%, linear taper	16925-755
R80	Same as R50	
R81	RESISTOR, FIXED, DEPOSITED CARBON: 510 K ohms, 5%, 1/4 watt	18470-514
R82	Same as R57	
R83	RESISTOR, FIXED, COMPOSITION: 3 megohms, 5%, 1/4 watt	18455-301
R84	RESISTOR, FIXED, DEPOSITED CARBON: 2 K ohms, 5%, 1/4 watt	18470-202
R85	RESISTOR, FIXED, COMPOSITION: 6.8 megohms, 5%, 1/4 watt	18455-681
R86	Same as R40	
R87	Same as R35	
R88	Same as R57	
R89	RESISTOR, FIXED, COMPOSITION: 100 megohms, 10%, 1/2 watt	18417-102
R90	Same as R22	
R91	RESISTOR, FIXED, DEPOSITED CARBON: 560 ohms, 5%, 1/4 watt	18470-561
R92, R93	RESISTOR, FIXED, COMPOSITION: 10 megohms, 5%, 1/4 watt	18456-101
R94, R95	Same as R89	
R96	Same as R92	
R97	RESISTOR, FIXED, DEPOSITED CARBON: 1.5 K ohms, 5%, 1/4 watt	18470-152
R98	Same as R26	
R99	RESISTOR, FIXED, DEPOSITED CARBON: 12 K ohms, 5%, 1/4 watt	18470-123
R100	Not used	
R101	RESISTOR, FIXED, METAL FILM: 453 ohms, 1%, 1/4 watt	18554-79

REF. DESIG.	DESCRIPTION	HICKOK PART NO.
R102	RESISTOR, VARIABLE: composition, 2.5 megohms, 20%, linear taper	16925-748
R103	RESISTOR, FIXED, COMPOSITION: 2.2 megohms, 10%, 1/4 watt	18455-222
R104 thru R107	Not used	
R108	Same as R22	
R109	RESISTOR, FIXED, METAL FILM: 48.7 K ohms, 0.5%, 1/4 watt	18555-147
R110 thru R119	Not used	
R120, R121	Same as R35	
R122	RESISTOR, FIXED, METAL FILM: 5.47 K ohms, 0.5%, 1/4 watt	18555-162
R123	RESISTOR, FIXED, METAL FILM: 32.3 K ohms, 0.5%, 1/4 watt	18555-149
R124	Same as R22	
R125	RESISTOR, FIXED: calibration value determined in production	
R126	RESISTOR, FIXED, METAL FILM: 5.36 K ohms, 1%, 1/4 watt	18554-109
R127	RESISTOR, VARIABLE: composition, 300 ohms, 10%, linear taper	16925-709
R128	RESISTOR, FIXED: calibration, value determined in production	
R129, R130	Same as R21	
R131	RESISTOR, FIXED, DEPOSITED CARBON: 6.2 K ohms, 5%, 1/4 watt	18470-622
R132	RESISTOR, FIXED, DEPOSITED CARBON: 75 K ohms, 5%, 1/4 watt	18470-753
R133	Same as R62	
R134	RESISTOR, FIXED, DEPOSITED CARBON: 560 K ohms, 5%, 1/4 watt	18470-564
R135	RESISTOR, FIXED, DEPOSITED CARBON: 2.7 K ohms, 5%, 1/4 watt	18470-272
R136	RESISTOR, FIXED, DEPOSITED CARBON: 1200 ohms, 5%, 1/4 watt	18470-122
R137, R138	Same as R50	
R139, R140	Same as R35	
R141	Same as R57	
R142	Same as R55	
R143	RESISTOR, FIXED, DEPOSITED CARBON: 2.2 K ohms, 5%, 1/4 watt	18470-222
R144	Same as R57	
R145	RESISTOR, FIXED, METAL FILM: 100 K ohms, 1%, 1/4 watt	18555-37
R146	RESISTOR, FIXED, METAL FILM: 124 K ohms, 1%, 1/4 watt	18555-89
R147	Same as R99	
R148	Same as R50	
R149	Same as R41	
R150	RESISTOR, FIXED, DEPOSITED CARBON: 68 K ohms, 5%, 1/4 watt	18470-683
R151	RESISTOR, VARIABLE: composition, 25 K ohms, 20%, linear taper	16925-753
R152	Same as R69	
R153	Same as R81	
R154	Same as R55	
R155	RESISTOR, FIXED, METAL FILM: 1 K ohms, 0.1%, 1/2 watt	18526-141
R156 thru R159	Not used	
R160 **	RESISTOR, FIXED, WIRE WOUND: 1.9 ohms, 5%, 7 watt	18575-571
R161 **	RESISTOR, FIXED, COMPOSITION: 620 ohms, 5%, 1 watt	18421-621
R200	Same as R76	
R201	Same as R50	
R202	Same as R21	
R203	Same as R35	
R204	RESISTOR, FIXED, METAL FILM: 1.0 K ohms, 1%, 1/4 watt	18555-103
R205	RESISTOR, VARIABLE: composition, 5 K ohms, 20%, linear taper	16925-761
R206	RESISTOR, FIXED, METAL FILM: 52.5 K ohms, 1%, 1/4 watt	18555-161
R207	Same as R35	
R208	RESISTOR, FIXED, DEPOSITED CARBON: 51 ohms, 5%, 1/4 watt	18470-510
R209	RESISTOR, FIXED, METAL FILM: 6.19 K ohms, 1%, 1/4 watt	18555-160
R210	Same as R131	
R211	RESISTOR, FIXED, COMPOSITION: 5.1 megohms, 5%, 1/4 watt	18455-511
R212	Same as R92	
R213	Same as R2	
R214	Same as R84	
R215	RESISTOR, FIXED, METAL FILM: 15.8 K ohms, 1%, 1/4 watt	18555-159

**Battery Operated Only

REF. DESIG.	DESCRIPTION	HICKOK PART NO.
R216	Same as R41	
R217	RESISTOR, FIXED, METAL FILM: 17.1 K ohms, 1%, 1/4 watt	18555-158
R218	RESISTOR, VARIABLE: composition, 1 K ohms, 20%, linear taper	16925-754
R219	RESISTOR, FIXED, METAL FILM: 3.74 K ohms, 1%, 1/4 watt	18555-155
R220	RESISTOR, VARIABLE: composition, 500 ohms, 20%, linear taper	16925-762
R221	RESISTOR, FIXED, METAL FILM: 158 K ohms, 1%, 1/4 watt	18555-156
R222	RESISTOR, FIXED, METAL FILM: 35.4 K ohms, 1%, 1/4 watt	18555-154
R223	Same as R39	
R224	Same as R102	
R225	Same as R99	
R226	RESISTOR, FIXED, DEPOSITED CARBON: 36 K ohms, 5%, 1/4 watt	18470-363
R227	RESISTOR, FIXED, DEPOSITED CARBON: 750 ohms, 5%, 1/4 watt	18470-751
R228	Same as R35	
R229	RESISTOR, VARIABLE: composition, 50 K ohms, 20%, linear taper	16925-763
R230	RESISTOR, FIXED, METAL FILM: 10.3 K ohms, 1%, 1/4 watt	18555-157
R231	Not used	
R232	RESISTOR, FIXED, WIRE WOUND: 9.9 K ohms, 1%, 5 watt	18575-619
R233	Same as R127	
R234 thru R238	RESISTOR, FIXED, DEPOSITED CARBON: 7.5 K ohms, 5%, 1/4 watt	18470-752
R239	Same as R23	
R240 thru R249	Not used	
R250	RESISTOR, FIXED, METAL FILM: 26.5 K ohms, 1%, 1/4 watt	18555-153
R251	Same as R204	
R252	Same as R92	
R253	Same as R2	
R254 thru R258	RESISTOR, VARIABLE: composition, 10 K ohms, 20%, linear taper	16925-704
R301, R302*	RESISTOR, FIXED, COMPOSITION: 100 ohms, 10%, 1/2 watt	18411-102
R303 *	RESISTOR, FIXED, DEPOSITED CARBON: 1 K ohms, 5%, 1/4 watt	18470-102
R304 *	Same as R28	
R305 *	Same as R17	
R306 *	Same as R28	
RT200	RESISTOR: thermistor, 1 K ohms, 1%	18682-68
S1	SWITCH: rotary, function	19912-677
S2	SWITCH: rotary, range	19912-678
S200	SWITCH: push button, 8 pole push-push, with red button	19910-229
S201	SWITCH: slide, dpdt	19911-128
T1 **	TRANSFORMER	20800-387
T301 *	TRANSFORMER	20800-398
V1	TUBE: Alpha numeric display type Y-4105	20875-286
V2 thru V4	TUBE: Alpha numeric display type Y-4075	20875-287
W1	CORD: 8 ft., type SVT, 41/34 stranding, size 0.300 x 0.110, with molded plug on one end and molded receptacle on other end, grey	3675-51
Z1	INTEGRATED CIRCUIT: operational amplifier	9800-42
Z2	INTEGRATED CIRCUIT: dual in-line package	9800-55
Z200	INTEGRATED CIRCUIT: LM201A	9800-56
Z201, Z202	INTEGRATED CIRCUIT: LM741CN	9800-57
Z203	INTEGRATED CIRCUIT: true RMS converter	9800-54

*Line Operated Only
**Battery Operated Only

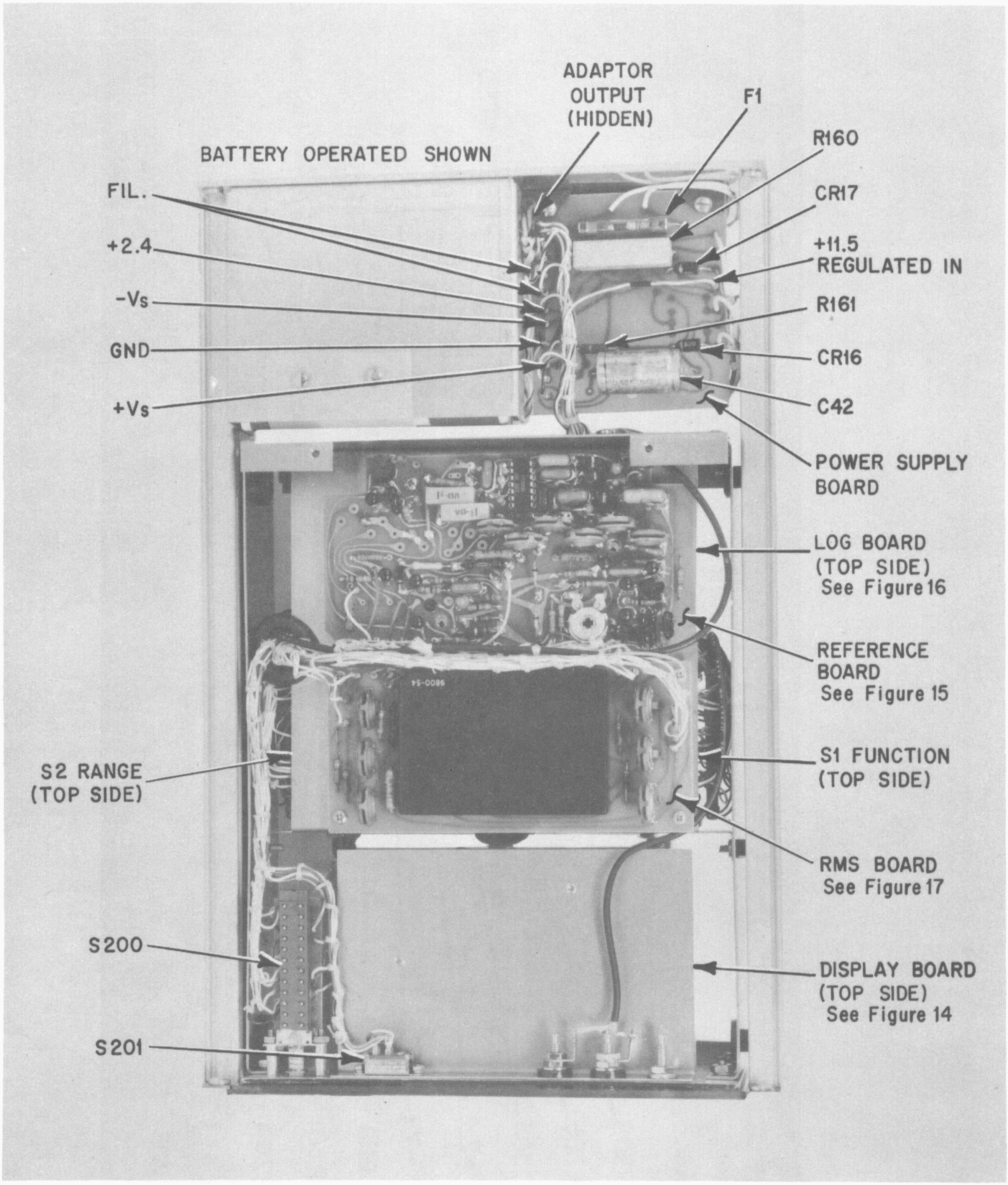


Figure 12. Model 3310, Chassis Layout, Bottom View

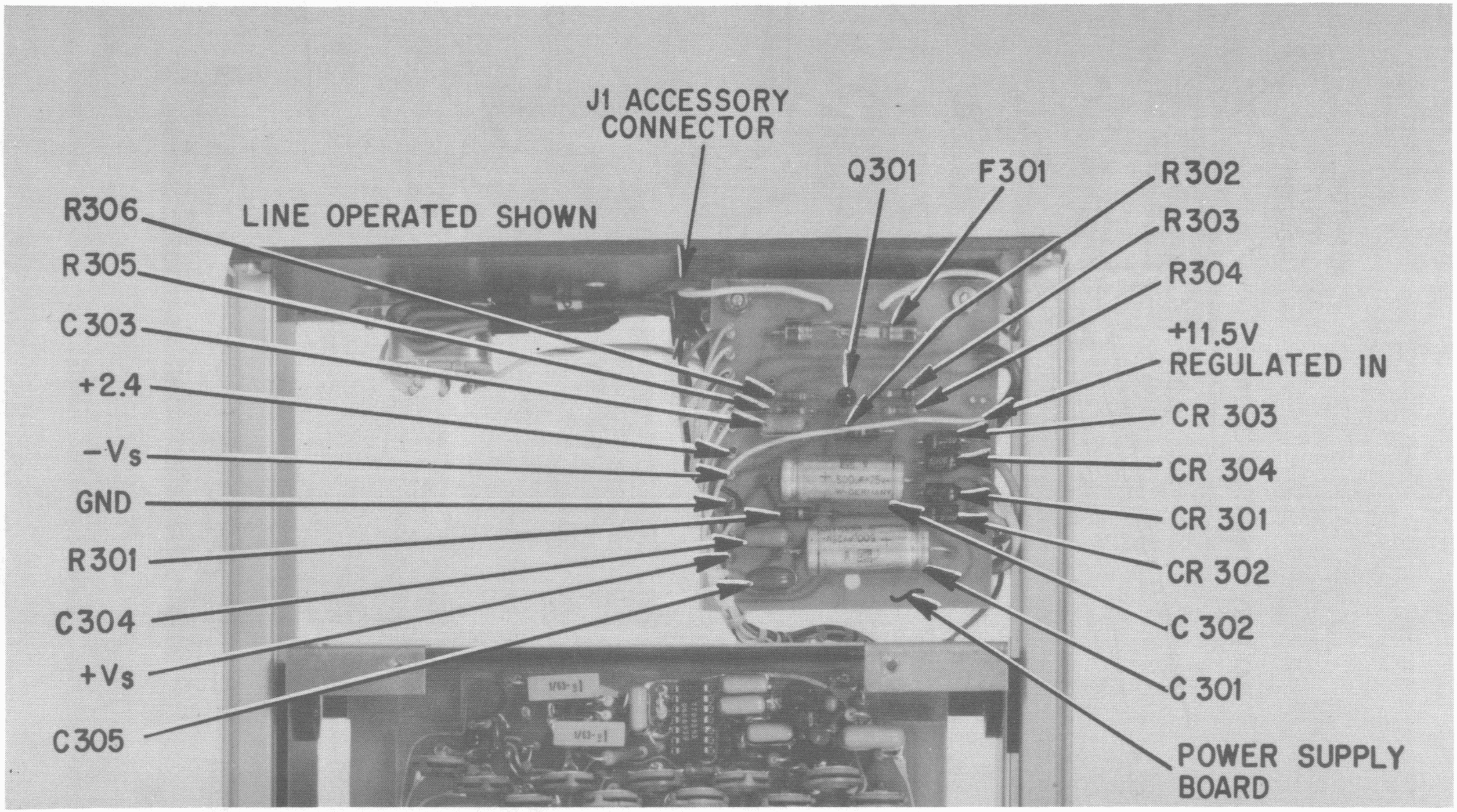


Figure 13. Model 3310, Layout, Line Operated Power Supply

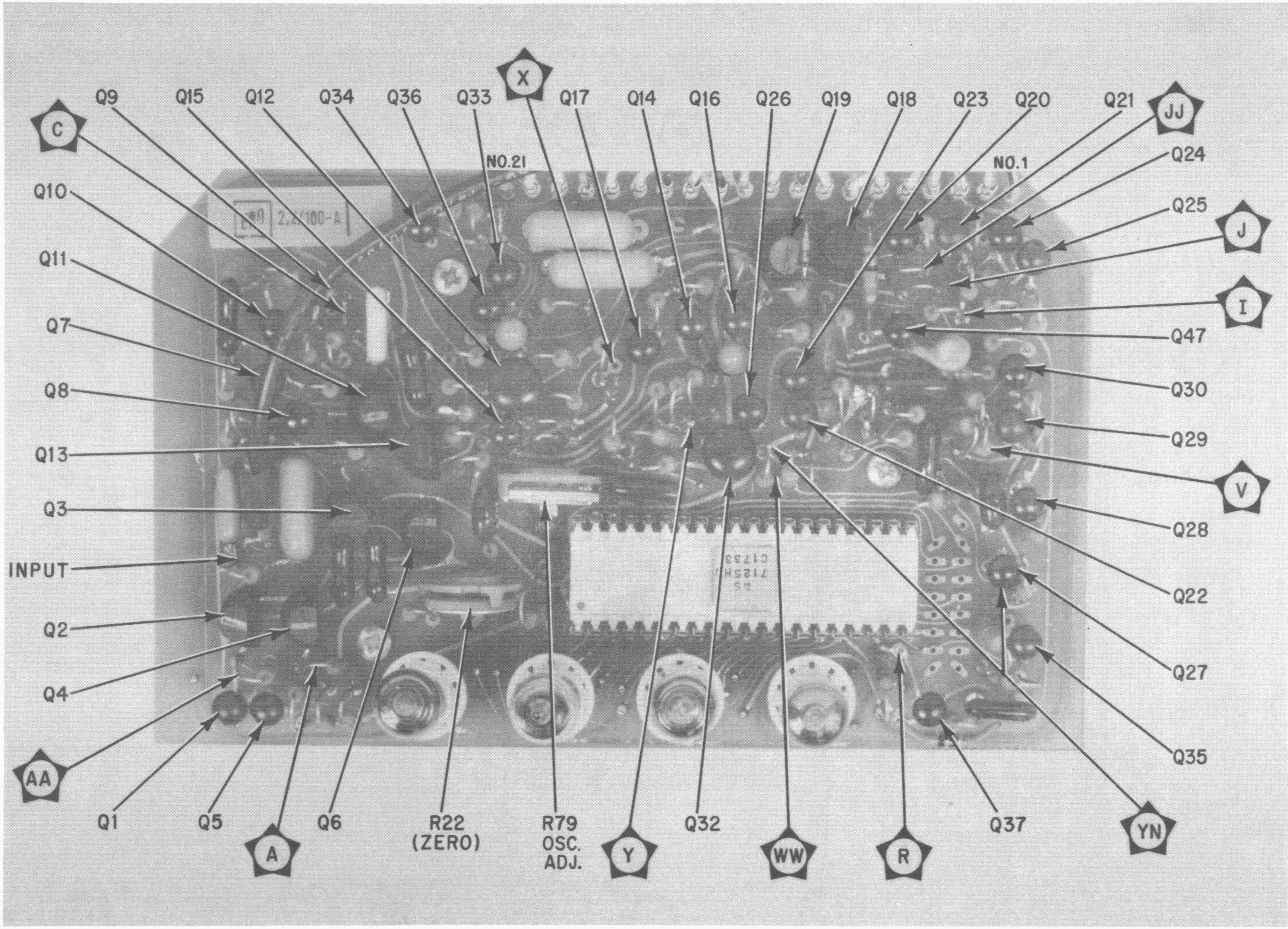


Figure 14. Model 3310, Display Board, Parts Locations

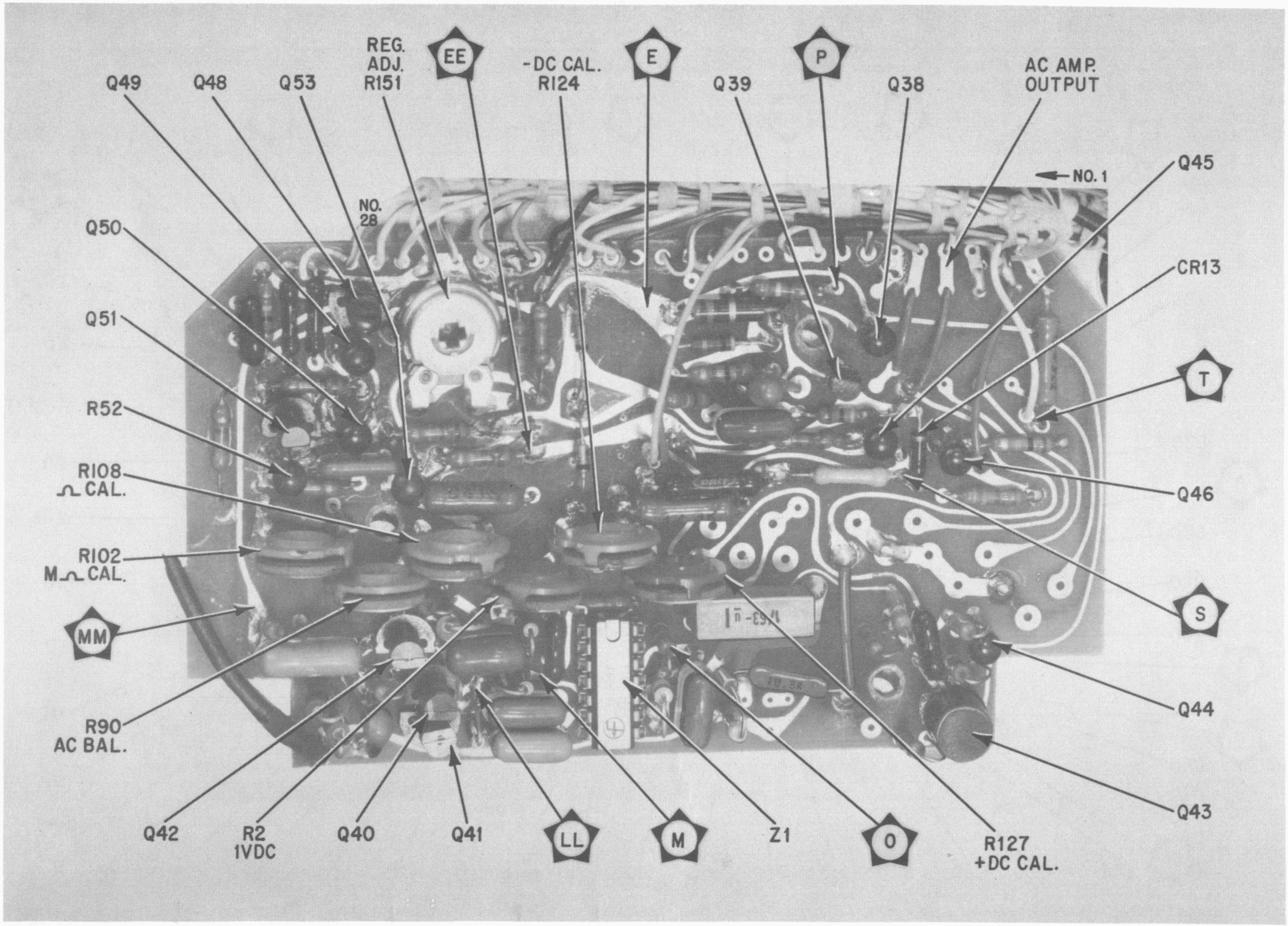


Figure 15. Model 3310, Reference Board, Parts Locations

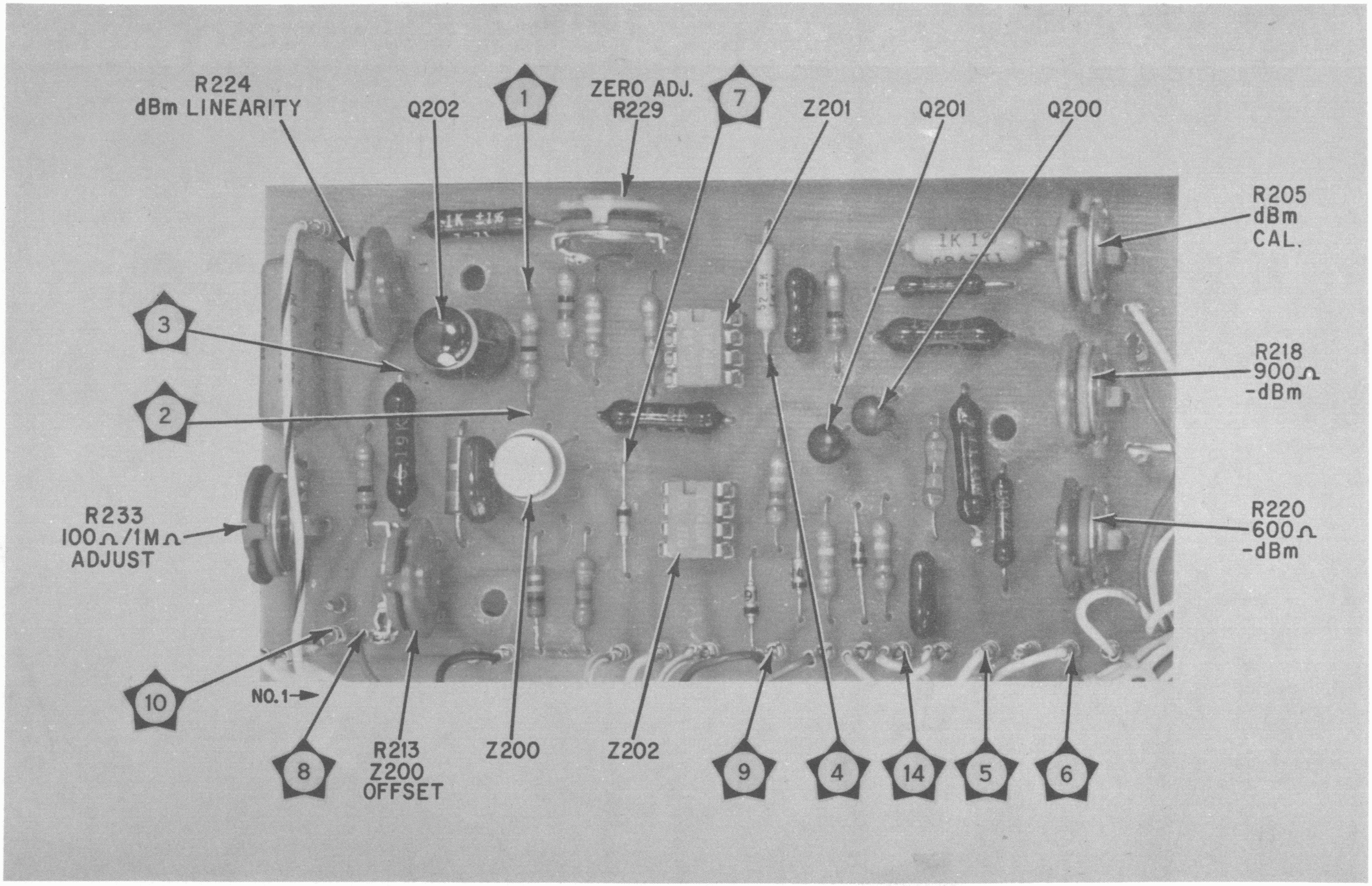


Figure 16. Model 3310, Log Board, Parts Locations

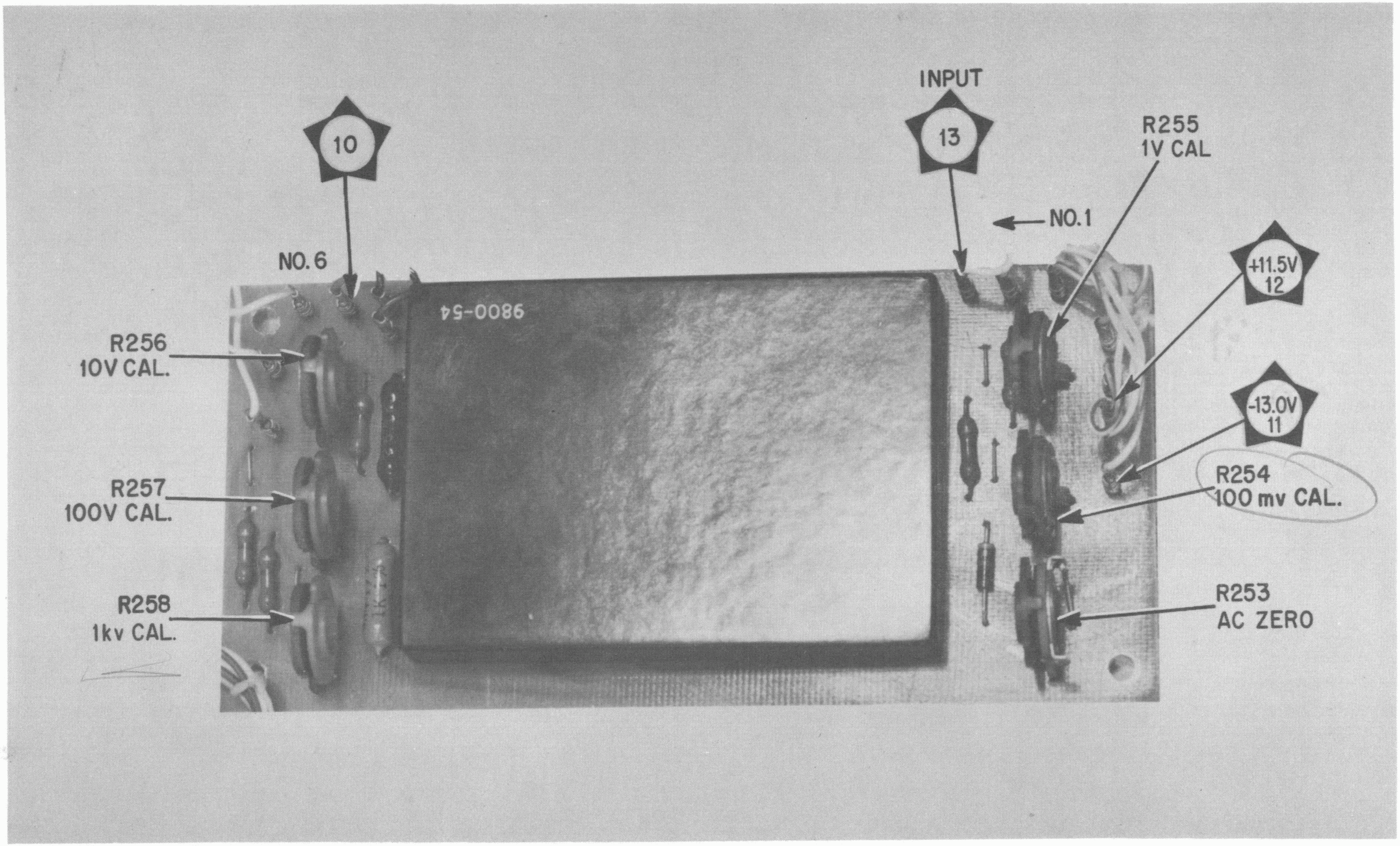
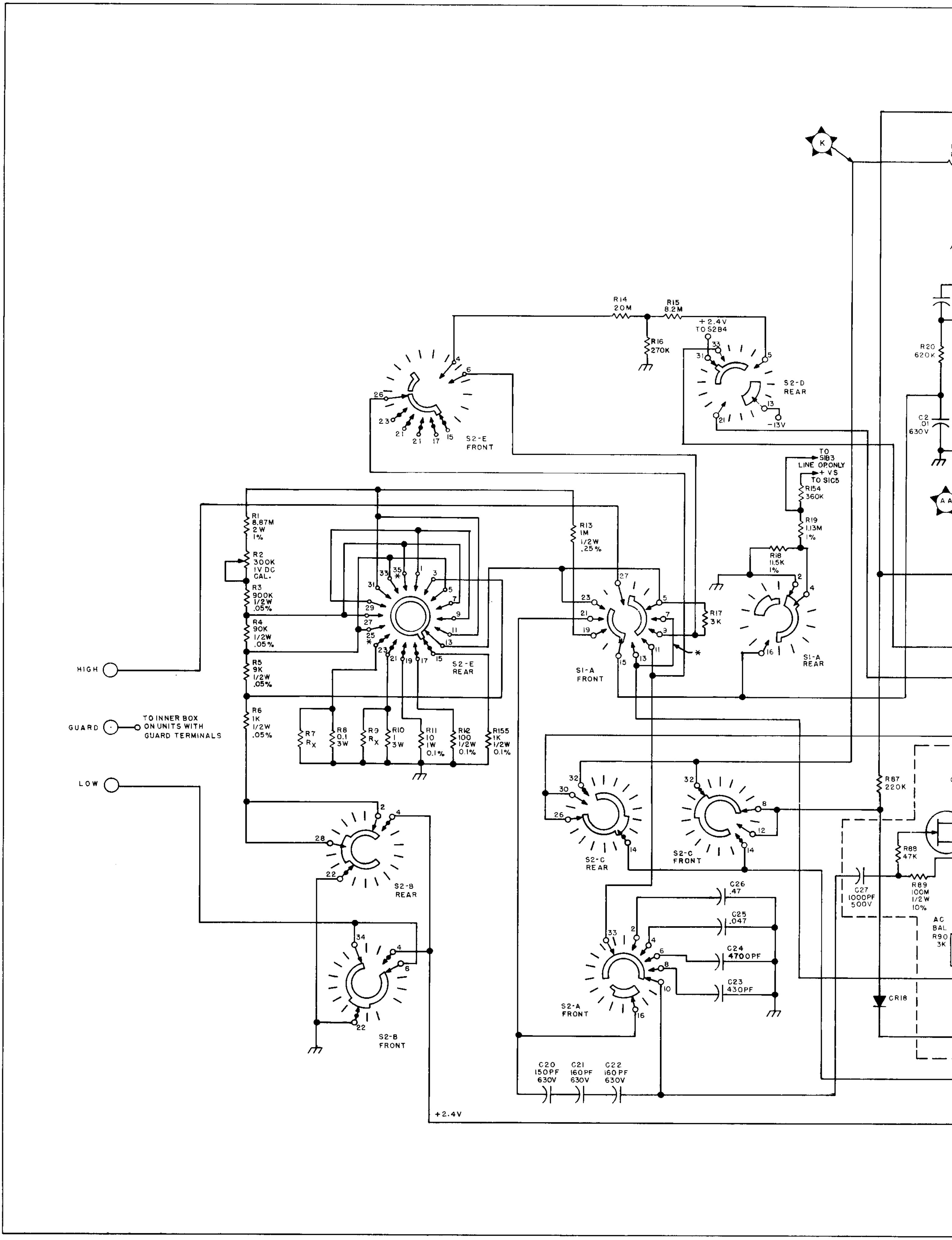
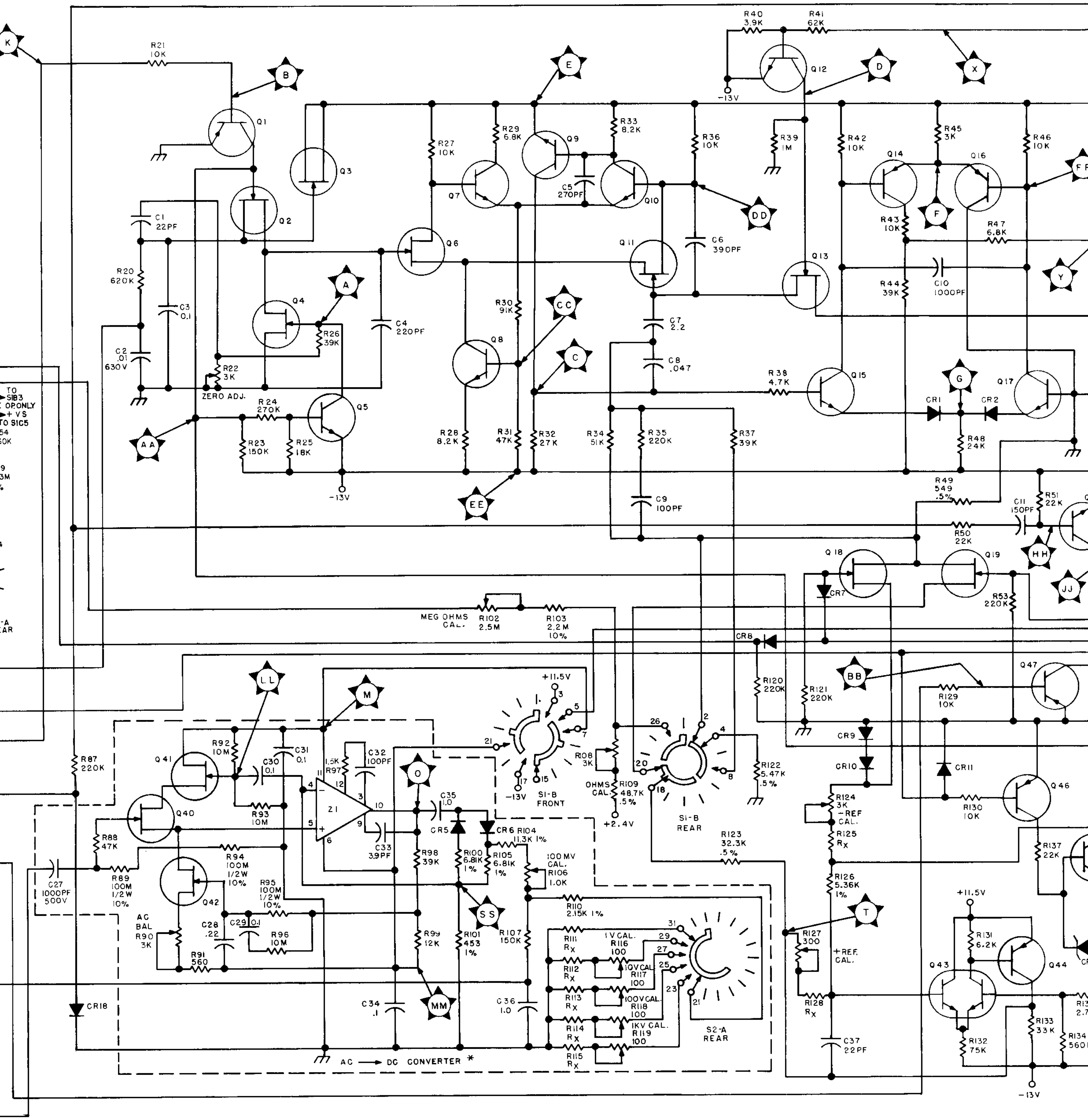


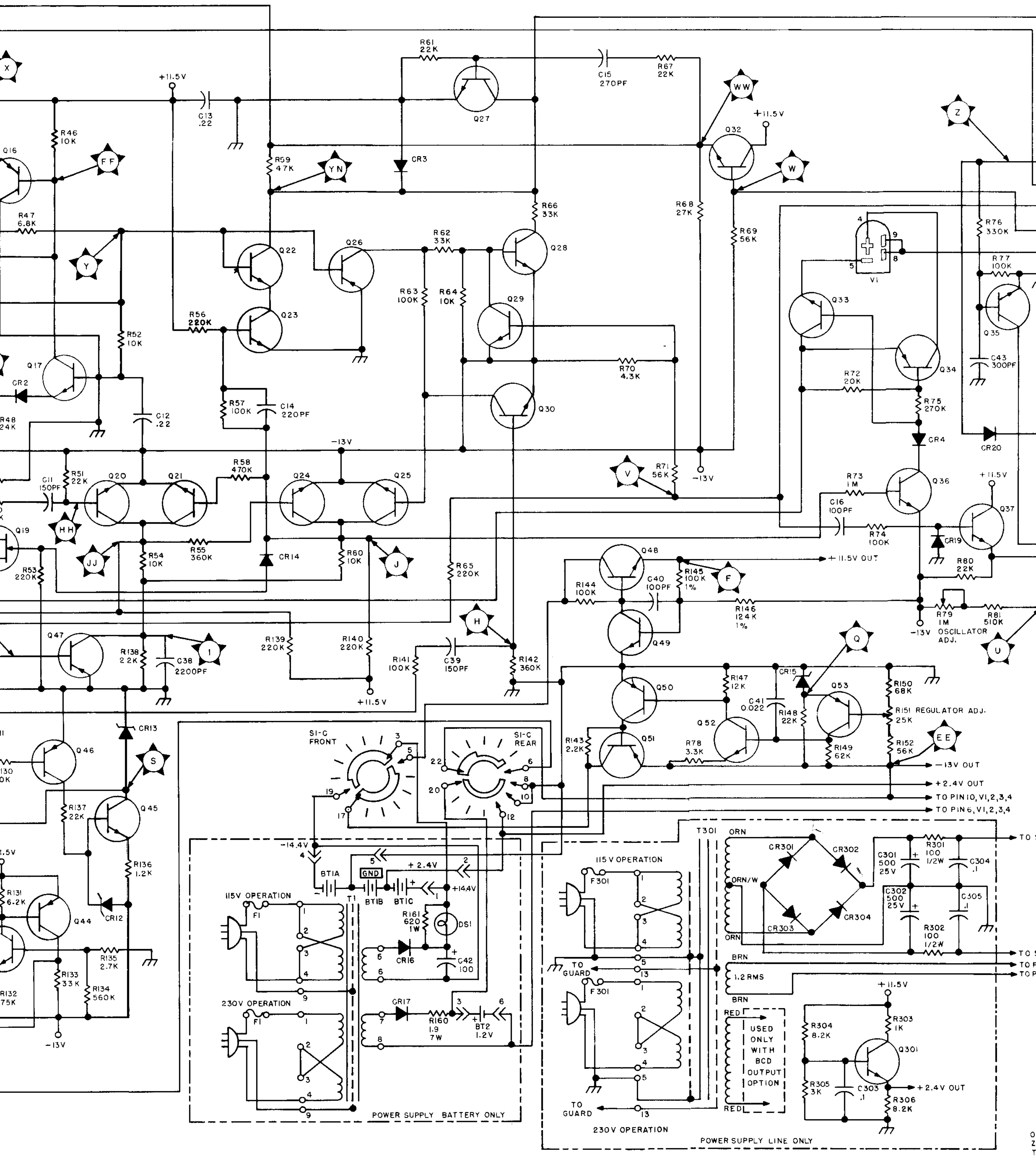
Figure 17. Model 3310, Rms Board, Parts Locations



HIGH
GUARD
TO INNER BOX ON UNITS WITH GUARD TERMINALS
LOW
R1 8.87M 2W 1%
R2 300K 1V DC CAL.
R3 900K 1/2W .05%
R4 90K 1/2W .05%
R5 9K 1/2W .05%
R6 1K 1/2W .05%
R7 Rx
R8 0.1 3W
R9 Rx
R10 1 3W
R11 10 1W 0.1%
R12 100 1/2W 0.1%
R155 1K 1/2W 0.1%
R13 1M 1/2W .25%
R14 20M
R15 8.2M
R16 270K
+2.4V TO S2B4
-13V
S2-D REAR
S2-E FRONT
S2-E REAR
S1-A FRONT
S1-A REAR
R17 3K
R18 11.5K 1%
R19 1.13M 1%
R154 360K
TO S1B3 LINE OP. ONLY
+VS TO S1C5
R20 620K
C2 .01 630V
R87 220K
R88 47K
R89 100M 1/2W 10%
C27 1000PF 500V
AC BAL R90 3K
CR18
S2-B REAR
S2-B FRONT
S2-C REAR
S2-C FRONT
S2-A FRONT
C26 .47
C25 .047
C24 4700PF
C23 430PF
C20 150PF 630V
C21 160PF 630V
C22 160PF 630V
+2.4V
K
AA

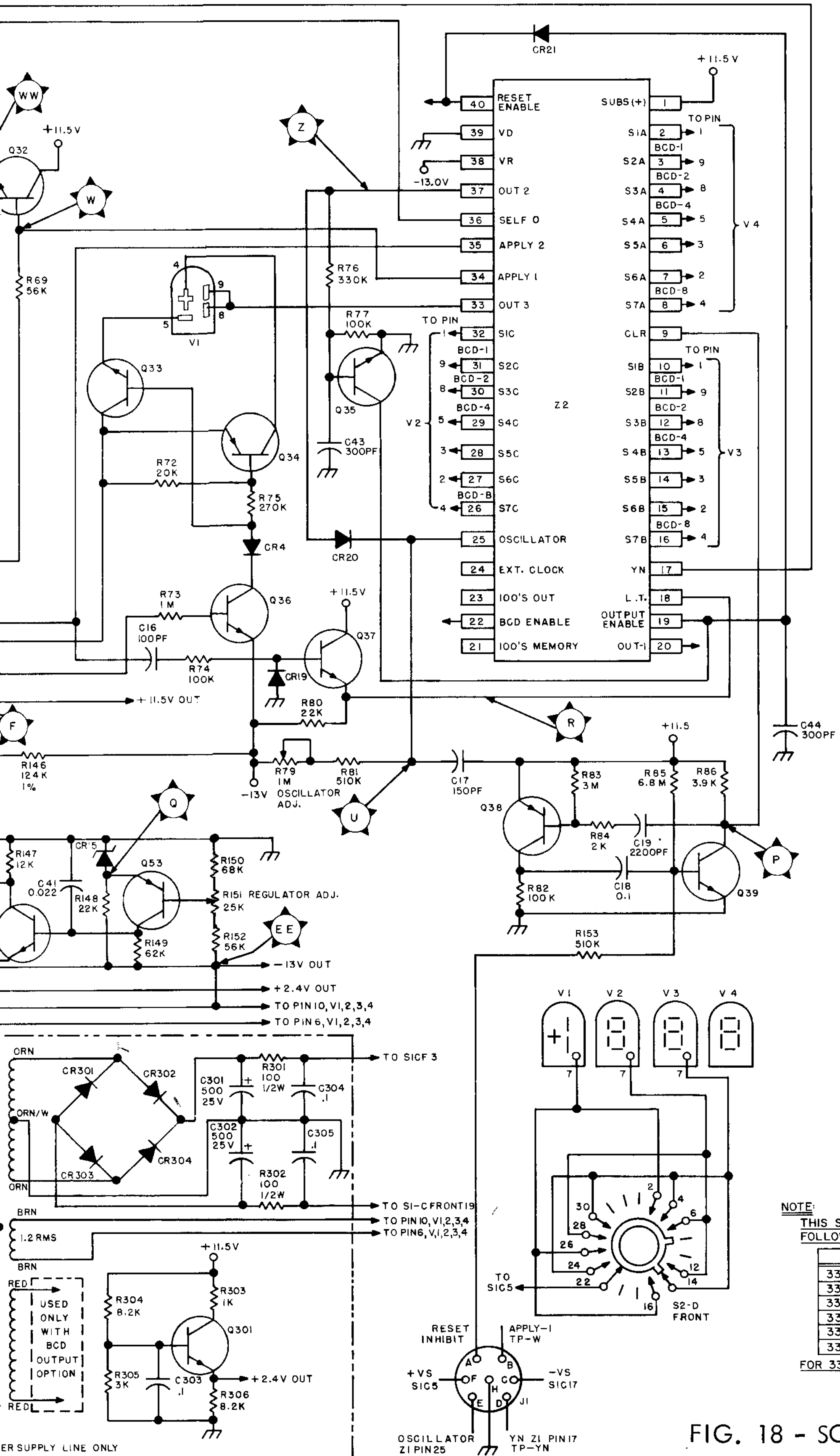


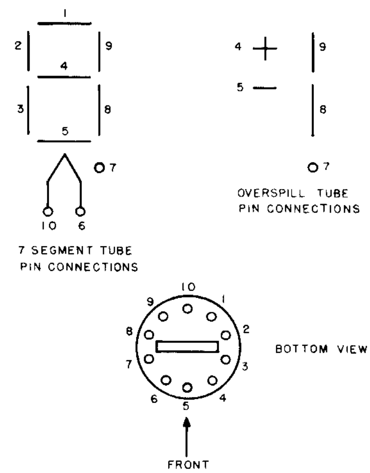
R21 10K
R40 3.9K
R41 62K
-13V
Q1
Q2
Q3
Q4
Q5
Q6
Q7
Q8
Q9
Q10
Q11
Q12
Q13
Q14
Q15
Q16
Q17
Q18
Q19
R27 10K
R29 6.8K
R33 8.2K
R36 10K
R39 1M
R42 10K
R45 3K
R46 10K
C1 22PF
C5 270PF
C6 390PF
R43 10K
R47 6.8K
R20 620K
C3 0.1
C4 220PF
R30 91K
R44 39K
C10 1000PF
C2 .01 630V
R26 39K
R22 3K
ZERO ADJ.
C7 2.2
C8 .047
R38 4.7K
CR1
CR2
R24 270K
R23 150K
R25 18K
R28 8.2K
R31 47K
R32 27K
R34 51K
R35 220K
R37 39K
R48 24K
C9 100PF
R49 549 .5%
R50 22K
C11 150PF
R51 22K
R53 220K
MEG OHMS CAL.
R102 2.5M
R103 2.2M 10%
CR7
CR8
R120 220K
R121 220K
Q47
R129 10K
CR9
CR10
CR11
R130 10K
Q46
R87 220K
R92 10M
C30 0.1
C31 0.1
C32 100PF
1.5K R97
+11.5V
Q41
Q40
R93 10M
Z1
C35 1.0
CR5
CR6
R104 11.3K 1%
C33 3.9PF
R88 47K
R94 100M 1/2W 10%
R98 39K
R100 6.81K 1%
R105 6.81K 1%
100 MV CAL. R106 1.0K
R108 3K
OHMS CAL. R109 48.7K .5%
+2.4V
S1-B FRONT
S1-B REAR
R122 5.47K .5%
R123 32.3K .5%
R124 3K -REF CAL.
R125 Rx
R126 5.36K 1%
R137 22K
C27 1000PF 500V
R89 100M 1/2W 10%
Q42
R95 100M 1/2W 10%
AC BAL R90 3K
C28 .22
C29 0.1
R96 10M
R91 560
R110 2.15K 1%
R99 12K
R101 453 1%
R107 150K
R111 Rx
1V CAL. R116 100
R112 Rx
10V CAL R117 100
R113 Rx
100V CAL. R118 100
R114 Rx
1KV CAL. R119 100
R115 Rx
S2-A REAR
R127 300
+REF. CAL.
R128 Rx
+11.5V
R131 6.2K
Q43
Q44
R133 33K
R132 75K
R134 560
C37 22PF
CR18
C34 .1
C36 1.0
AC → DC CONVERTER *
-13V
TO S1B3 OP ONLY +VS TO S1C5



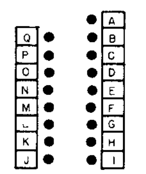
+11.5V
C13 .22
R46 10K
Q16
R47 6.8K
R52 10K
Q17
CR2
R48 24K
C12 .22
R51 22K
C11 150PF
Q19
Q20
Q21
R53 220K
R54 10K
R55 360K
R56 220K
R57 100K
C14 220PF
R58 470K
R59 47K
CR14
Q22
Q23
Q24
Q25
Q26
R60 10K
-13V
R61 22K
Q27
CR3
C15 270PF
R67 22K
R62 33K
R63 100K
R64 10K
Q28
Q29
Q30
R65 220K
R66 33K
R68 27K
R69 56K
R70 4.3K
R71 56K
Q32
+11.5V
V1
Q33
Q34
Q35
Q36
Q37
R72 20K
R73 1M
R74 100K
R75 270K
CR4
C16 100PF
CR19
R76 330K
R77 100K
C43 300PF
CR20
R79 1M OSCILLATOR ADJ.
R80 22K
R81 510K
Q47
R138 2.2K
C38 2200PF
R139 220K
R140 220K
R141 100K
C39 150PF
R142 360K
Q48
Q49
Q50
Q51
Q52
Q53
R143 2.2K
R144 100K
C40 100PF
R145 100K 1%
R146 124K 1%
R147 12K
C41 0.022
R148 22K
CR15
R149 62K
R150 68K
R151 REGULATOR ADJ. 25K
R152 56K
R78 3.3K
+11.5V OUT
-13V OUT
+2.4V OUT
TO PIN 10, V1, 2, 3, 4
TO PIN 6, V1, 2, 3, 4
S1-C FRONT
S1-C REAR
Q44
Q45
Q46
CR12
CR13
R130
R131 6.2K
R132 75K
R133 33K
R134 560K
R135 2.7K
R136 1.2K
R137 22K
-13V
-14.4V
BT1A
GND
BT1B
BT1C
+2.4V
+14.4V
T1
R161 620 1W
DS1
CR16
C42 100
CR17
R160 1.9 7W
BT2 1.2V
115V OPERATION
230V OPERATION
F1
POWER SUPPLY BATTERY ONLY
T301
ORN
ORN/W
BRN
1.2 RMS
RED
USED ONLY WITH BCD OUTPUT OPTION
F301
TO GUARD
CR301
CR302
CR303
CR304
C301 500 25V
C302 500 25V
R301 100 1/2W
R302 100 1/2W
C304 .1
C305 .1
+11.5V
R303 1K
R304 8.2K
R305 3K
C303 .1
R306 8.2K
Q301
+2.4V OUT
POWER SUPPLY LINE ONLY
X
FF
YN
Y
WW
W
Z
V
HH
JJ
J
H
F
I
Q
U
EE
S

ALTERATION	DRAWING NUMBER
	900-269W





	MOS-IC	FUNCTION
A	PIN 22	BCD ENABLE
B	PIN 40	PRESET ENABLE
C	PIN 26	100'S DECADE BCD 8
D	PIN 29	100'S DECADE BCD 4
E	PIN 12	10'S DECADE BCD 2
F	PIN 5	I'S DECADE BCD 4
G	PIN 3	I'S DECADE BCD I
H	PIN 8	I'S DECADE BCD 8
I	PIN 16	10'S DECADE BCD 8
J	PIN 4	I'S DECADE BCD 2
K	PIN 19	OUTPUT ENABLE
L	PIN 20	OUT I (1000)
M	PIN 13	10'S DECADE BCD 4
N	PIN 11	10'S DECADE BCD I
O	PIN 30	100'S DECADE BCD 2
P	PIN 31	100'S DECADE BCD I
Q	PIN 33	OUT 3 (2000)



DISPLAY BOARD MOS-IC OUTPUT PADS VIEWED FROM TOP OF BOARD

SYMBOLS	
LAST USED	NOT USED
R161	Q31
CR21	R156
Q53	R157
C44	R158
	R159

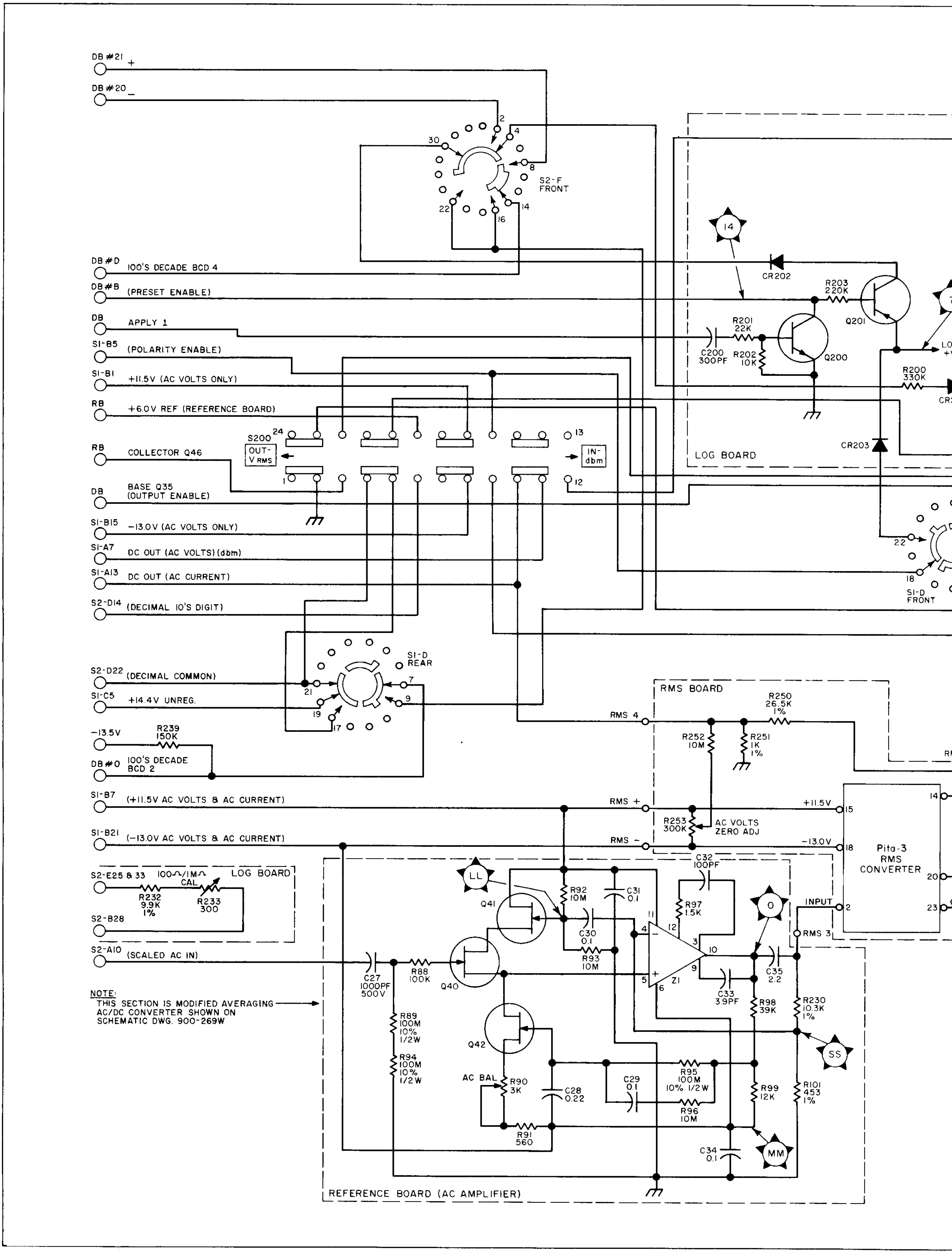
NOTES:
UNLESS OTHERWISE SPECIFIED, ALL RESISTORS ARE 1/4 WATT, 5% VALUE IN OHMS.
K=1,000 OHMS
M=1,000,000 OHMS
CAPACITANCES ARE IN MICROFARADS
+ = CONNECTIONS
+ = NO CONNECTIONS
*=DENOTES PORTIONS THAT ARE CHANGED IN MODEL 3310

NOTE:
THIS SCHEMATIC TO BE USED WITH THE FOLLOWING UNITS, WHERE APPLICABLE.

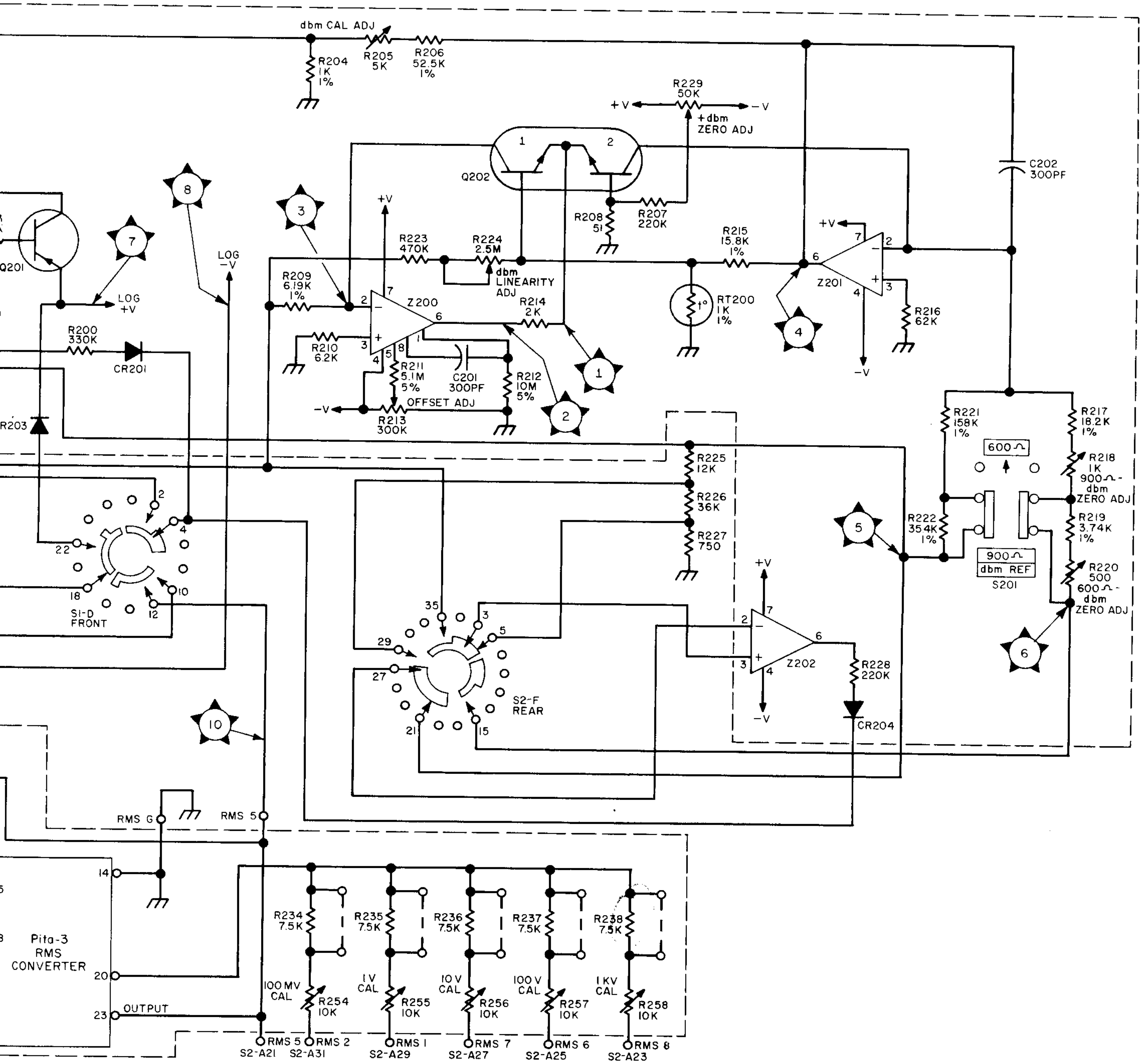
MODEL NO.	STYLE NO.
3300A	900-267
3301 BAT. OPER.	900-268
3301 LINE OPER.	900-269
3310 LINE OPER.	900-271
3310 BAT. OPER.	900-272
3310 ITE 5356	900-274

FOR 3310 SERIES ALSO SEE SCHEMATIC #900-271W.

FIG. 18 - SCHEMATIC WIRING DIAGRAM
Model 3310 Multimeter


DB #21 +
DB #20 _
S2-F FRONT
DB #D 100'S DECADE BCD 4
DB #B (PRESET ENABLE)
DB APPLY 1
SI-B5 (POLARITY ENABLE)
SI-BI +11.5V (AC VOLTS ONLY)
RB +6.0V REF (REFERENCE BOARD)
S200
OUT-V RMS
IN-dbm
RB COLLECTOR Q46
DB BASE Q35 (OUTPUT ENABLE)
SI-B15 −13.0V (AC VOLTS ONLY)
SI-A7 DC OUT (AC VOLTS)(dbm)
SI-A13 DC OUT (AC CURRENT)
S2-D14 (DECIMAL 10'S DIGIT)
SI-D REAR
S2-D22 (DECIMAL COMMON)
SI-C5 +14.4V UNREG.
−13.5V
R239 150K
DB #0 100'S DECADE BCD 2
SI-B7 (+11.5V AC VOLTS & AC CURRENT)
SI-B21 (−13.0V AC VOLTS & AC CURRENT)
S2-E25 & 33
100Ω/1MΩ CAL
LOG BOARD
R232 9.9K 1%
R233 300
S2-B28
S2-A10 (SCALED AC IN)
NOTE: THIS SECTION IS MODIFIED AVERAGING AC/DC CONVERTER SHOWN ON SCHEMATIC DWG. 900-269W
14
CR202
R203 220K
Q201
R201 22K
C200 300PF
R202 10K
Q200
R200 330K
CR203
LOG BOARD
SI-D FRONT
RMS BOARD
RMS 4
R250 26.5K 1%
R252 10M
R251 1K 1%
RMS +
RMS −
R253 300K
AC VOLTS ZERO ADJ
+11.5V
−13.0V
Pita-3 RMS CONVERTER
INPUT
RMS 3
LL
Q41
R92 10M
C31 0.1
C32 100PF
R97 1.5K
C30 0.1
R93 10M
Z1
O
C35 2.2
C33 3.9PF
C27 1000PF 500V
R88 100K
Q40
R89 100M 10% 1/2W
R94 100M 10% 1/2W
Q42
AC BAL
R90 3K
C28 0.22
R91 560
C29 0.1
R95 100M 10% 1/2W
R96 10M
R98 39K
R99 12K
R230 10.3K 1%
R101 453 1%
SS
C34 0.1
MM
REFERENCE BOARD (AC AMPLIFIER)

ALTERATION	DRAWING NUM
	900-271



NOTES:

UNLESS OTHERWISE SPECIFIED, ALL RESISTORS ARE 1/4 WATT, 5%, VALUE IN OHMS.
K=1,000 OHMS
M=1,000,000 OHMS
CAPACITANCES ARE IN MICROFARADS
✦=CONNECTION
+=NO CONNECTION

ABBREVIATIONS-
RB=REFERENCE BOARD
DB=DISPLAY BOARD
S1=FUNCTION SWITCH
S2=RANGE SWITCH

NOTE:
THIS SCHEMATIC TO BE USED WITH SCHEMATIC DWG #900-269W, WHERE APPLICABLE.

FIG. 19 - SCHEMATIC WIRING DIAGRAM
Model 3310 Multimeter