VACUUM TUBE VOLTMETER

HEWLETT-PACKARD MODEL 400D/H/L AND H02-400D

DESCRIPTION

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1. GENERAL

1.01 This section describes the Hewlett-Packard Model 400D, 400H, 400L, and H02-400D Vacuum Tube Voltmeters (Fig. 1), which are portable ac voltmeters useful for frequencies from 10 Hz to 4 MHz. They have 12 voltage ranges from a scale of 0 to 0.001 up to a scale of 0 to 300.

1.02 This section is reissued to include information on the 400H, 400L, and H02-400D, to make minor corrections, and to bring the section up to date. Arrows normally used to indicate changes have been omitted. This reissue affects Equipment Test Lists.

1.03 The information contained in this section is obtained from an instruction manual issued by the manufacturer and is reproduced herein with the permission of the Hewlett-Packard Company.

1.04 This section contains operating and servicing instructions and a parts breakdown for the 400D, 400H, 400L, and H02-400D Vacuum Tube Voltmeters (VTVMs). Where applicable, the

Fig. 1—Model 400H Vacuum Tube Voltmeter

instruments are repaired at locations designated by the Telephone Company.

1.05 The models are the same except for full-scale readings and panel meters. Table A presents a summary specification list for these voltmeters.

1.06 Information in this section applies directly to 400D and H02-400D with serial numbers prefixed 310- and higher, and 400H and 400L with serial numbers prefixed 313- and higher.

> *Note:* Models 400D and H02-400D are electrically identical. They differ only in that H02-400D has a detachable power cord. Therefore, where the 400D is discussed in this section, all data will pertain to both models unless the H02-400D is specifically mentioned.

1.07 Each model VTVM has three calibrated scales on the panel meter (Fig. 2). The 400D and 400H have two linear RMS VOLTS scales, 0 to 1 and 0 to 3, and one DECIBELS scale, −12 to +2. The meters used in the 400H and 400L are larger and include a mirror to eliminate the parallax in viewing and to facilitate use of higher scale calibration accuracy of these models. In the 400L, the RMS VOLTS scales are logarithmic in calibration, from .3 to 1 and from .8 to 3, and the DECIBELS scale is linear, from −10 to +2. In all models, the RMS VOLTS scales are calibrated to indicate the root-mean-square (RMS) value of an applied sine wave. Actual meter deflection is proportional to the average value of the applied signal, thereby minimizing additional meter deflection due to noise and harmonic distortion.

1.08 A voltmeter output signal is provided at the front panel OUTPUT terminals. This output is proportional to the meter reading and has a waveshape similar to the applied signal. This signal level is about 0.15 volt RMS for a full-scale meter reading regardless of the input signal level. The internal impedance at the OUTPUT terminal is 50 ohms over the full frequency range. High-impedance loads (above 100K) will not adversely affect the accuracy of the voltmeter. This output is valuable for increasing the sensitivity of bridges, etc, where distortion added to the waveform is not a factor. The maximum gain is 150 on the 0.001-volt range.

1.09 Models designated with a suffix -R are rack-mount configurations of the VTVMs and are identical in every other respect to their cabinet model counterparts.

1.10 Initial physical and electrical inspection of the VTVMs should be made. Signs of physical damage, such as scratched surfaces, broken knobs, etc, should be noted. Refer to Part 5 for electrical performance tests. These are good procedures for incoming quality-control inspection.

2. PHYSICAL DESCRIPTION

2.01 The voltmeters may be either cabinet-mounted or rack-mounted. The cabinet-mounted models are 7-1/2 inches wide, 11-1/2 inches high, and 12 inches deep and weigh approximately 18 pounds. The rack-mounted models are designed to mount in a standard 19-inch wide by 7-inch high relay rack space.

2.02 The external controls, terminals, and meter of the VTVM, as viewed from the front (Fig. 1), and their functions are described in the following paragraphs.

TABLE A

SPECIFICATIONS FOR 400D, –H, –L VTVM

DESCRIPTION	SPECIFICATION
Voltage Range	1.0 millivolt to 300 volts in 12 ranges
Decibel Range	–72 to +52 dB in 12 ranges: (see subtable below)
Frequency Range	10 Hz to 4 MHz
Input Impedance	10 megohms shunted by 20 pF on ranges from 1 volt to 300 volts; 35 pF on ranges from 0.001 volt to 0.3 volt.
Stability	Line voltage variations of ±10% do not reduce the specified accuracy and line voltage transients are not reflected in the meter reading. Electron tube deterioration to 75% of normal transconductance affects accuracy less than 0.5% from 20 Hz to 1 MHz.
Amplifier	OUTPUT terminals are provided so that the VTVM can be used to amplify small signals or to enable monitoring of waveforms under test with an oscilloscope. Output voltage is 0.15 volt RMS on all ranges for full RMS scale meter deflection. Output impedance is 50Ω, with a maximum gain of 150 on 0.001-volt range.
Accuracy	*Model 400D (or H02-400D)* 10 Hz to 20 Hz — ±10% of full scale 20 Hz to 1 MHz — ±2 % of full scale 1 MHz to 2 MHz — ±3 % of full scale 2 MHz to 4 MHz — ±10% of full scale

Decibel Range subtable:

SWITCH POSITION		VOLTAGE RANGE	DECIBEL RANGE
VOLTS	DB		
.001	–60	0 to 0.001	–72 to –58
.003	–50	0 to 0.003	–62 to –48
.01	–40	0 to 0.01	–52 to –38
.03	–30	0 to 0.03	–42 to –28
.1	–20	0 to 0.1	–32 to –18
.3	–10	0 to 0.3	–22 to –8
1	0	0 to 1	–12 to +2
3	+10	0 to 3	–2 to +12
10	+20	0 to 10	+8 to +22
30	+30	0 to 30	+18 to +32
100	+40	0 to 100	+28 to +42
300	+50	0 to 300	+38 to +52

TABLE A (Cont)

SPECIFICATIONS FOR 400D, –H, –L VTVM

DESCRIPTION	SPECIFICATION	
Accuracy (Cont)	*Model 400H*	
	10 Hz to 20 Hz	±10% of full scale
	20 Hz to 50 Hz	±2 % of full scale
	50 Hz to 500 kHz	±1 % of full scale
	500 kHz to 1 MHz	±2 % of full scale
	1 MHz to 2 MHz	±3 % of full scale
	2 MHz to 4 MHz	±10% of full scale
	Model 400L	
	10 Hz to 20 Hz	±5 % of reading
	20 Hz to 50 Hz	±2 % of full scale or ±3% of reading*
	50 Hz to 500 kHz	±1 % of full scale or ±2% of reading*
	500 kHz to 1 MHz	±2 % of full scale or ±3% of reading*
	1 MHz to 2 MHz	±3 % of full scale or ±4% of reading*
	2 MHz to 4 MHz	±5 % of reading
Power Requirement	Voltage: 115 or 230 volts ±10%	
	Frequency: 50 to 440 Hz	
	Wattage: 75 watts for Models 400D and H02-400D 100 watts for Models 400H and 400L	

* Whichever is more accurate.

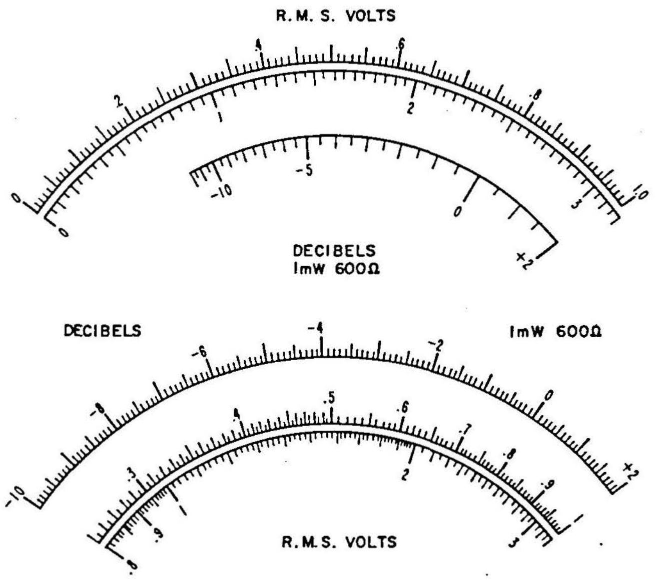


Fig. 2—Typical Meter Scales of the VTVMs

2.03 *ON:* This toggle switch controls the power transformer primary circuit. When the switch is in the ON position, the indicator light on the left side of the face plate will be illuminated.

2.04 *RANGE (DB-VOLTS):* This 12-position switch selects the full-scale deflection sensitivity for either dB or RMS voltage input.

2.05 *INPUT:* The INPUT terminals are special binding posts which accept either bare wire or banana plugs. The 3/4-inch spacing between the binding posts accepts standard dual-banana plugs. The INPUT terminals receive voltage to be measured or signals to be amplified.

2.06 *OUTPUT:* The OUTPUT terminals are physically similar to the INPUT terminals. When the VTVM is used to amplify small signals, the output of the last stage of the broadband amplifier may be connected to an oscilloscope or to other circuits (see 1.08).

2.07 *Meter:* The meter scales vary for the models of the VTVMs and are discussed thoroughly in 1.07. A zero adjusting screw is provided on the meters of the 400D and 400H only.

2.08 *Fuse:* The fuseholder, located on the rear of the chassis, contains a 1-ampere slow-blow fuse for 115-volt operation. If the VTVM is to be connected to a 230-volt source of power, it will be necessary to change the fuse to a 1/2-ampere slow-blow fuse. Use the fuse specified in Table F.

2.09 *Power Cable:* The 3-conductor power cable is attached to the rear of the chassis in all models except the H02-400D (which is removable). The other end of the cable is terminated in a polarized 3-prong male connector. The third contact is an offset round pin added to a standard 2-blade ac plug which grounds the VTVM chassis when used with the appropriate receptacle. To use this plug in a standard 2-contact outlet, an adapter is required. The ground connection emerges from the adapter as a short green lead for connection to a suitable ground. The ground lead should always be connected for the protection of operating personnel.

2.10 The VTVMs are equipped by the factory, with the power transformer dual primary windings connected in parallel for 115-volt operation. If operation from a 230-volt source is desired, primary windings must be reconnected in series (Fig. 3).

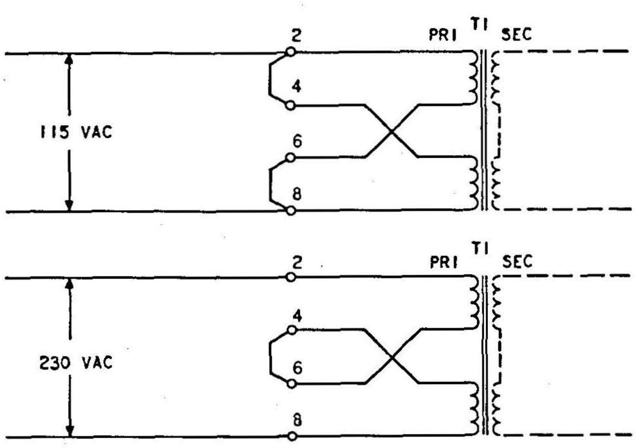


Fig. 3—Power Transformer Windings—115- or 230-Volt Operation

3. OPERATION

A. General Operating Instructions

3.01 *Meter Zero Characteristics:* When the 400D or 400H VTVM is turned off, the meter pointer should return to zero. If it does not, zero-set the meter as instructed in 5.04. The meter supplied with the 400L is not provided with a mechanical meter zero adjustment. When the voltmeter is turned on with the INPUT terminals shorted, the meter pointer may deflect upscale slightly. This deflection does not affect the accuracy of a reading.

> *Note:* When the voltmeter RANGE (DB-VOLTS) switch is set to the lowest ranges and the INPUT terminals are not terminated or shielded, noise pickup can be enough to produce up to full-scale meter deflection. This condition is normal and is caused by stray voltages in the vicinity of the instrument. For maximum accuracy on the 0.001-volt range, the voltage under measurement should be applied to the voltmeter through a shielded test lead.

3.02 *Meter Scales:* The two voltage scales on each of the VTVM models are related to each other by a factor of 1:10 (10 dB). In conjunction with the calibrated RANGE switch steps, this provides an intermediate range step spaced 10 dB between "power of ten" ranges, which are 20 dB apart. The relationship of the DECIBELS scale to the 0 to 1 RMS VOLTS scale is determined by making 0 dB on the DECIBELS scale equal to the voltage required to produce 1 milliwatt in 600 ohms (0.775 volt). Thus, the DECIBELS scale reads directly in dBm across a 600-ohm circuit. It can also be used to measure relative levels of any group of signals which have the same waveform across any constant circuit impedance. The RANGE switch changes voltmeter sensitivity in 10-dB steps accurate to within ±0.125 dB. The RANGE switch position indicates the value of a full-scale meter reading.

3.03 *Test Leads and Connections:* Test leads used to connect the VTVM to the equipment to be tested will depend upon the impedance and frequency of the signal source. The types of leads required are listed below.

(a) For connection to low-impedance signal sources, plain wire leads are sufficient if the frequency is sufficiently low.

(b) For connection to high-impedance signal sources or where noise pickup is a problem, low-capacity shielded wire must be used with a shielded dual-banana plug.

(c) If a probe is used, it should always be shielded to prevent pickup from the user's hand.

(d) When measurements are to be made of signals above a few hundred hertz, the capacity of the test leads must be kept to a minimum by using very short leads, preferably unshielded. An alligator clip should be used at the test end so that the connection can be made without adding the capacity of the user's hands.

3.04 Accessories connected to the VTVMs extend the range and application of the meters, such as increasing the voltage measurement range and input impedance, converting to current measurement, line matching, etc. Some of the accessories are:

(a) HP 1104A Line Matching Transformer which provides balanced 135- or 600-ohm input, 5 to 600 kHz.

(b) HP 1105A Bridging Transformer which allows voltage measurements on balanced lines, 20 Hz to 45 kHz.

(c) HP 11039A Capacitive Voltage Divider (Model 452A in older manuals) for measuring power-frequency voltages up to 25,000 volts. It has a division ratio of 1000:1 and an input capacity of 15 pF ± 1 pF.

(d) HP 11041A Capacitive Voltage Divider (Model 454A in older manuals) for measuring voltage up to 1,500 volts. It has a division ratio of 100:1 with an input impedance of 50 megohms shunted with a 2.75-pF capacitor.

(e) HP 456A Alternating Current Probe which allows current measurements without opening the measured circuit with a sensitivity of 1 mV/mA $\pm 2\%$ at 1 kHz. When the probe is clipped to a wire carrying 1 mA, 1 mV is produced at the amplifier output. Maximum input is 1 ampere RMS or 2 amperes peak. The output noise is less than 50 microvolts RMS.

(f) HP 11029A-11034A Shunt Resistors (Model 470A-470F in older manuals) for measuring currents as small as 1 microampere full scale. Measurement accuracy is $\pm 1\%$ to 100 kHz and $\pm 5\%$ to 4 MHz (470A is $\pm 5\%$ to 1 MHz). The maximum power dissipation is 1 watt.

Shunt values available are:

0.1 ohm 3 amperes

1.0 ohm 1 ampere

10 ohms 300 mA

100 ohms 100 mA

600 ohms 41 mA

1000 ohms 30 mA

Note: Western Electric Co resistors of the 145- or 106-type are available for use.

3.05 ***Maximum Input Voltage:*** The maximum voltage (the sum of the dc voltage and ac peak voltage) applied to the INPUT terminals of the VTVM ***must not exceed 600 volts.*** Higher voltages will break down the capacitors in the input system of the instrument.

3.06 If an applied voltage momentarily exceeds the selected full-scale voltmeter sensitivity, a few seconds may be required for circuit recovery. No damage to the VTVM will result.

3.07 ***Input Voltage Waveform:*** The voltmeter is calibrated to indicate the root-mean-square value of a sine wave. However, meter pointer deflection is proportional to the average value of whatever waveform is applied to the input. If the input signal waveform is not a sine wave, the reading will be in error by an amount dependent upon the amount and phase of the harmonics present as indicated in Table B. When harmonic distortion is less than about ten percent, the error which results is negligible.

3.08 Since the meter deflection is proportional to the average value of the input waveform, it is not adversely affected by moderate levels of

TABLE B

EFFECT OF HARMONICS ON VOLTAGE MEASUREMENTS

INPUT VOLTAGE CHARACTERISTICS	MEASURED VOLTAGE	TRUE RMS VALUE
Fundamental = 100%	100	100
Fundamental + 10% 2nd Harmonic	100	100.5
Fundamental + 20% 2nd Harmonic	100-102	102
Fundamental + 50% 2nd Harmonic	100-110	112
Fundamental + 10% 3rd Harmonic	96-104	100.5
Fundamental + 20% 3rd Harmonic	94-108	102
Fundamental + 50% 3rd Harmonic	90-116	112

Note: This table is universal in application since these errors are inherent in all average-responding type voltage-measuring instruments.

random noise. The effect that noise has on the accuracy of the meter reading depends upon the waveform of the noise and upon the signal-to-noise ratio. A square wave has the greatest effect, a sine wave has intermediate effect, and ***white*** noise has the least effect on the meter reading.

3.09 If the noise signal is a 50-percent duty cycle square wave and the signal-to-noise ratio is 10:1 (between peak voltages), the error will be about one percent of the meter reading. If the noise signal is ***white*** noise and the signal-to-noise ratio is 10:1, the error is negligible.

B. Low-Level Measurements and Ground Currents

3.10 When the VTVM is used to measure signal levels below a few millivolts, ground currents in the meter test leads can cause an error in meter reading. Such currents are created when two or more ground connections are made between the instruments of a test setup and/or between the instruments and the power line ground. Two ground connections complete a ground loop for the voltages which are generated across all instrument chassis by stray fields, particularly the fields of transformers. These ground currents can be minimized by disconnecting the ground lead in the power cord from either the VTVM or the signal source being measured and by making sure that in the test setup no other ground loop is formed that can cause a ground current to flow in the VTVM test leads. Although the resultant voltage developed across a test lead is in the order of microvolts, it is enough to cause noticeable errors in measurements of a few millivolts. The presence of ground currents can sometimes be determined by simply changing the grounds for the instruments in the setup and watching for a change in meter reading. If changing the ground system causes a change in meter reading, ground currents are present.

C. *Measurement of Voltages*

3.11 The meters of the 400D and 400H have two VOLTS scales: 0 to 1 and 0 to 3 (the 400L has scales of .3 to 1 and .8 to 3). When the RANGE switch is set to the following values, read the scales accordingly.

RANGE SWITCH POSITION	READ SCALE
.001, .01, .1, 1, 10, and 100	0 to 1 (.3 to 1)
.003, .03, .3, 3, 30, and 300	0 to 3 (.8 to 3)

3.12 The basic operational procedure for the VTVMs is as follows.

(1) Connect the VTVM to a power source of 115 volts, 50 through 440 Hz, unless modified for 230-volt operation.

(2) If the meter pointer on the 400D or 400H does not point exactly on the zero calibration mark on the meter scale while the VTVM is turned off, proceed to adjust the pointer as described in 5.04.

Note: The special meter in the 400L is adjusted with the VTVM turned on, since the meter pointer rests against the stop at the left end of the scale when the instrument is turned off. The mechanical zero is preset during manufacture of the meter movement.

(3) Operate the toggle switch on the front of the VTVM to the ON position and allow the instrument to warm up for a period of 5 minutes.

(4) Disconnect any external equipment from the OUTPUT terminals.

(5) Set the RANGE switch to the VOLTS range which will permit the voltage being measured to register at midscale or higher on the RMS VOLTS scale. If in doubt, select a higher VOLTS range.

(6) Connect the proper test leads (3.03) and accessories (3.04) as required to the INPUT terminals.

Caution: The lower (black) INPUT terminal and instrument case are connected to the power system ground when the instrument is used with a standard 3-terminal (grounding) receptacle. Connect only ground-potential circuits to this terminal. To prevent short-circuiting power lines, first connect only the upper (red) INPUT terminal to the power line to be measured, checking to see which side of the power line causes a reading on the meter. Leave this side connected to the VTVM and then connect the other side of the power line to the lower (black) INPUT terminal.

(7) Read the meter, using the appropriate RMS VOLTS scale in accordance with the RANGE switch position (see 3.11). Compute the voltage by multiplying the indicated reading by the RANGE switch position, and dividing this result by the meter full-scale value (either 1 or 3). For example, if the RANGE switch is on position .1 and the meter indicates .64 on the 1-volt RMS VOLTS scale, the voltage being measured is

$$\frac{.64 \times .1}{1} = .064 \text{ volt}$$

If the RANGE switch is on 30 and the meter indicates 1.6 on the 3-volt RMS VOLTS scale, the voltage being measured is

$$\frac{1.6 \times 30}{3} = 16 \text{ volts}$$

D. Measurement of Decibels

3.13 The DECIBELS meter scale is provided for measuring dBm directly across 600 ohms and for measuring the dB ratio for comparison purposes when each measurement is made across the same circuit impedance. To measure the signal level directly in dBm, proceed as follows.

(1) Proceed as described in 3.12, Steps (1) through (4).

(2) Set the RANGE switch to the DB range which will give an upscale reading of the signal to be measured. If in doubt, select a higher-level scale. In cases where a meter scale reading below −8 dB is obtained, it is best to switch to the next lower range on the instrument so that a reading will be obtained in the upper

portion of the scale where the highest accuracy may be obtained.

(3) Connect the signal to be measured to the INPUT terminals. See ***Caution*** in 3.12, Step (6).

(4) Note the meter indication on the DECIBELS scale (−12 to +2 dB). The signal level is the algebraic sum of the meter indication and the dB value indicated by the RANGE switch. For example, if the indication on the DECIBELS scale is +2 and the RANGE switch is in the +20 DB position, the level is +22 dBm.

+20 (RANGE switch position)

+ 2 (meter dB scale indication)

+22 (level in dB of signal being measured)

If the indication on the DECIBELS scale is +1.5 and the RANGE switch is in the −40 DB position, the level is −38.5 dBm.

−40 (RANGE switch position)

+ 1.5 (meter dB scale indication)

−38.5 (level in dB of signal being measured)

3.14 To measure dB across impedances other than 600 ohms, follow the above procedure and evaluate the results as follows.

Note: Since the measurement is made across other than 600 ohms, the level obtained in 3.13, Step (4) is in dB, but not in dBm.

(a) To obtain the difference in dB between measurements made across equal impedances, algebraically subtract the levels being compared.

(b) To obtain the reading of a single measurement in dBm, note the impedance across which the measurement is made and refer to 3.15.

(c) To obtain the difference in dBm between measurements made across different impedances, convert each measurement to dBm as described in 3.15. Algebraically subtract the dBm levels being compared.

E. Impedance and Other Correction Factors

3.15 As the VTVM DECIBELS scale is calibrated to indicate dBm for measurements made across 600-ohm circuits, a correction factor must be used when measurements are made across circuit impedances other than 600 ohms if absolute dBm levels are desired. The correction factor is not necessary in measuring relative dB (not dBm) levels across the same impedance, but it is required for comparison of dB levels measured across different impedances. The impedance correction graph in Fig. 4 gives the correction factor for conversion of the meter reading to dBm when the impedance of the circuit under test is known. To use the graph, read the conversion factor corresponding to the test circuit impedance and add it to the meter reading determined in Part D. Observe the algebraic sign of the correction factor in making algebraic addition. For example, if the measurement is made across 90 ohms, and the indication on the DECIBELS scale is +2, and the RANGE switch is at the +30 DB position, the level in dBm is

+ 2 (meter indication)

+30 (RANGE switch position)

+32 (sum)

+ 8 (correction factor from graph)

+40 dBm

If the same indication is obtained under the same RANGE switch setting and the circuit impedance is 60,000 ohms, the level in dBm is

+ 2 (meter indication)

+30 (RANGE switch position)

+32 (sum)

−20 (correction factor from graph)

+12 dBm

3.16 An additional correction will be necessary if the signal being measured is due to an input at two frequencies of equal magnitude, such as sometimes occurs with certain type N, O, and ON carrier system tests. This correction is due to the fact that the meter detector is of the averaging type rather than the square-law type. This correction is +0.5 dB and applies at either 600 ohms or 135 ohms.

F. Use Of Voltmeter Amplifier

3.17 The amplifier in the VTVM may be used for amplifying weak signals. With full-scale meter deflection, the open-circuit output of the amplifier is approximately 0.15 volt RMS regardless of the RANGE switch position. The impedance looking into the OUTPUT terminals approximates 50 ohms. The frequency response and calibration of the VTVM may be affected by the impedance of a load applied to the OUTPUT terminals. To check the effect of the applied load, observe the meter reading obtained with no load connected to the OUTPUT terminals and then note any change in reading when the external circuit is connected to the OUTPUT terminals. If the change is negligible, the measurement is not being affected appreciably by the load. Whenever the input signal is changed, ie, a different frequency or band of frequencies is applied, repeat the quick check described above.

3.18 Maximum gain from the amplifier is obtainable only on the lowest range (RANGE switch on .001) since the output level is the same for all bands. This is due to the 10-dB amplification loss per step inserted by the RANGE switch as it is turned clockwise. Amplification may also be obtained on the .003, .01, .03, and 1 RANGE switch positions.

3.19 When the voltmeter is used as an amplifier, select a range which gives the meter deflection near full scale. Off-scale signals more than twice the value of the position of the RANGE switch will cause severe distortion.

> ***Caution:*** ***The lower (black) signal OUTPUT terminal and instrument case are connected to the power system ground when the instrument is used with a standard 3-terminal (grounding) receptacle. Connect only ground potential circuits to the black OUTPUT terminal.***

4. CIRCUIT DESCRIPTION

A. General

4.01 The basic circuits of the VTVMs are shown in Fig. 5. These circuits consist of an input voltage divider circuit controlled by the RANGE switch, a cathode follower input tube, a precision step attenuator controlled by the RANGE switch, a broadband amplifier, an indicating meter, and a regulated power supply. A discussion of these circuits is provided in Parts B through E and applies directly to those VTVMs listed in 1.06.

B. Input Voltage Divider and Step Attenuator

4.02 The input voltage divider limits the signal level applied to the input cathode follower (V1) to less than 0.3 volt RMS, when voltages above this level are measured with the RANGE switch set at the 1-volt range or above. The divider consists of a resistive branch with one element made adjustable to obtain exact 1000:1 division at middle frequencies and a parallel capacitive branch with one element made adjustable to maintain exact 1000:1 division to beyond 4 MHz. The input impedance of the VTVM is established by this divider and is the same for all positions of the RANGE switch. On the six low-voltage positions of the RANGE switch, the input divider provides no attenuation of the input voltage (see Fig. 6 and 7).

4.03 The step attenuator in the cathode circuit of V1 reduces the voltage to be measured to a value of 1 millivolt or less for application to the voltmeter amplifier. Each step of the attenuator lowers the signal level by exactly 10 dB. The attenuator consists of six precision wirewound resistors which are selected for very high accuracy and carefully mounted on a 12-position rotary switch. The RANGE switch rotor has two contactors (Fig. 8 and 9). The first rotor finger contacts each resistor in turn while the input divider is in the nonattenuating position. The second rotor finger repeats these contacts while the input attenuator is in the attenuating position. On the 0.003-volt range, a fixed capacitor (C15) is automatically connected to provide flat frequency response beyond 4 MHz. On the 0.003- and 0.01-volt ranges, separate adjustable capacitors (C14 and C16) are automatically connected to the attenuator to permit setting the frequency response at 4 MHz. These capacitors are also connected to the attenuator on the 3- and 10-volt ranges. Fixed capacitor C106 (permanently connected) flattens the frequency response on the 0.03- and 30-volt ranges.

4.04 Cathode follower V1 provides a constant high input impedance to the input voltage divider

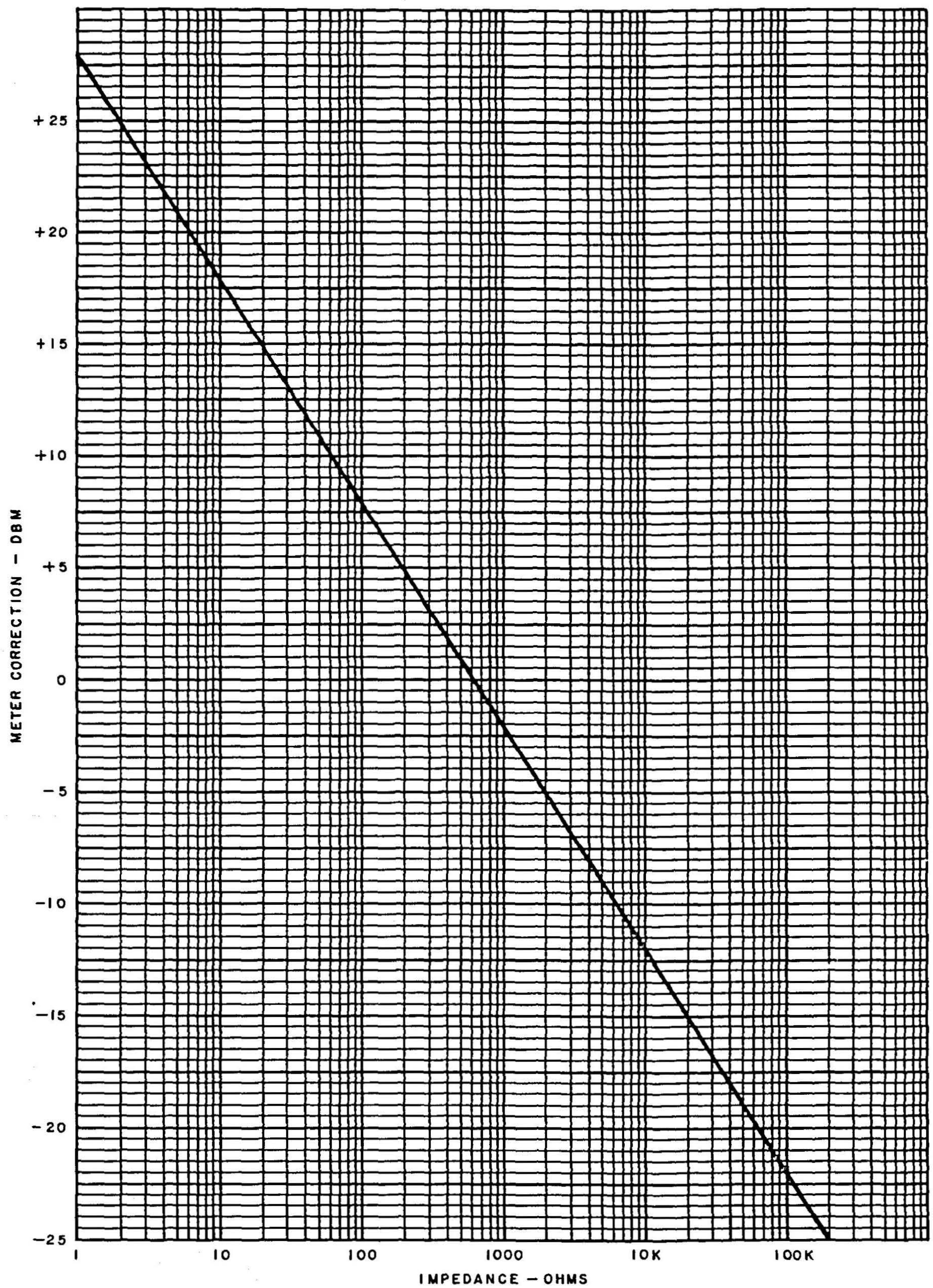
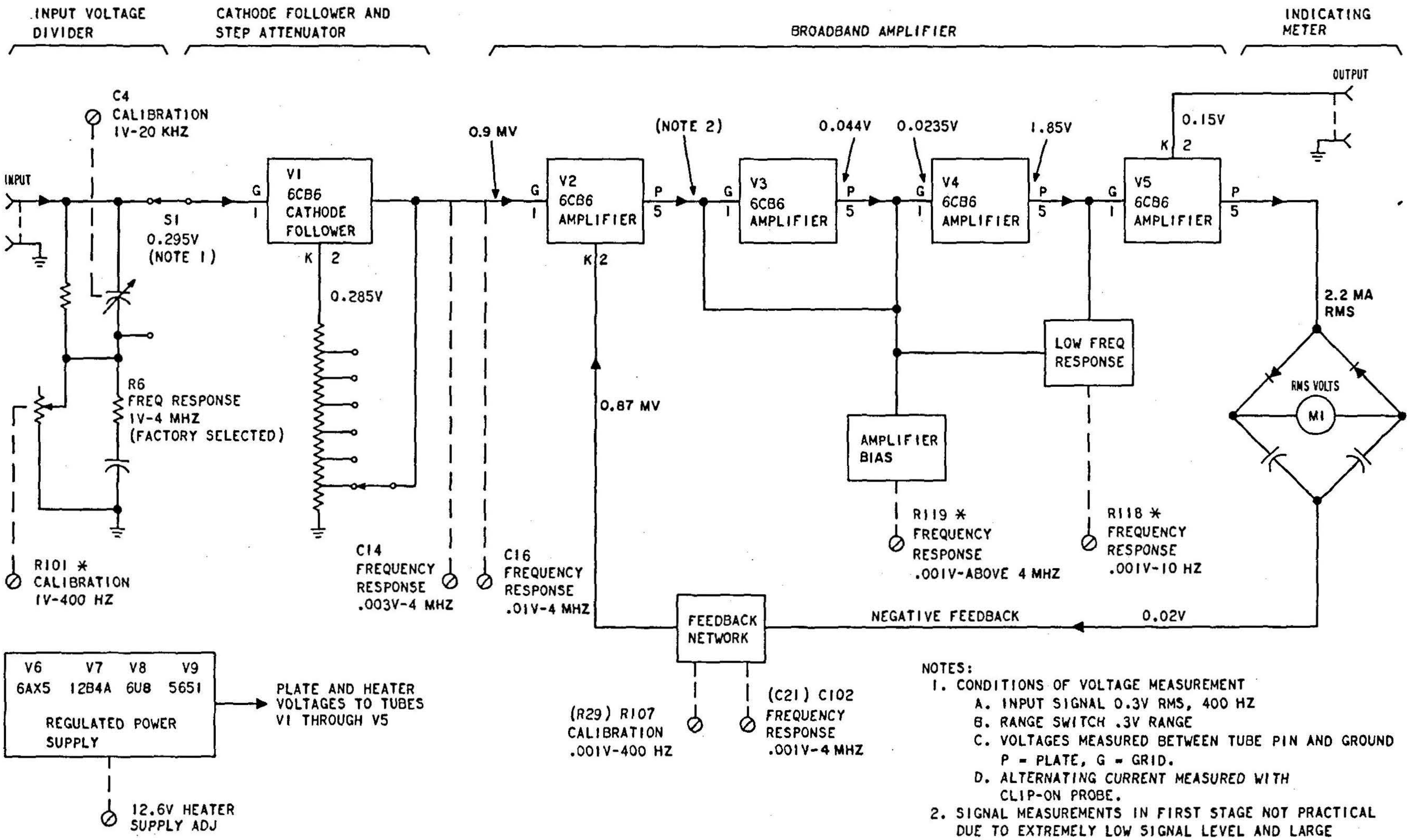


Fig. 4—Impedance Correction Graph

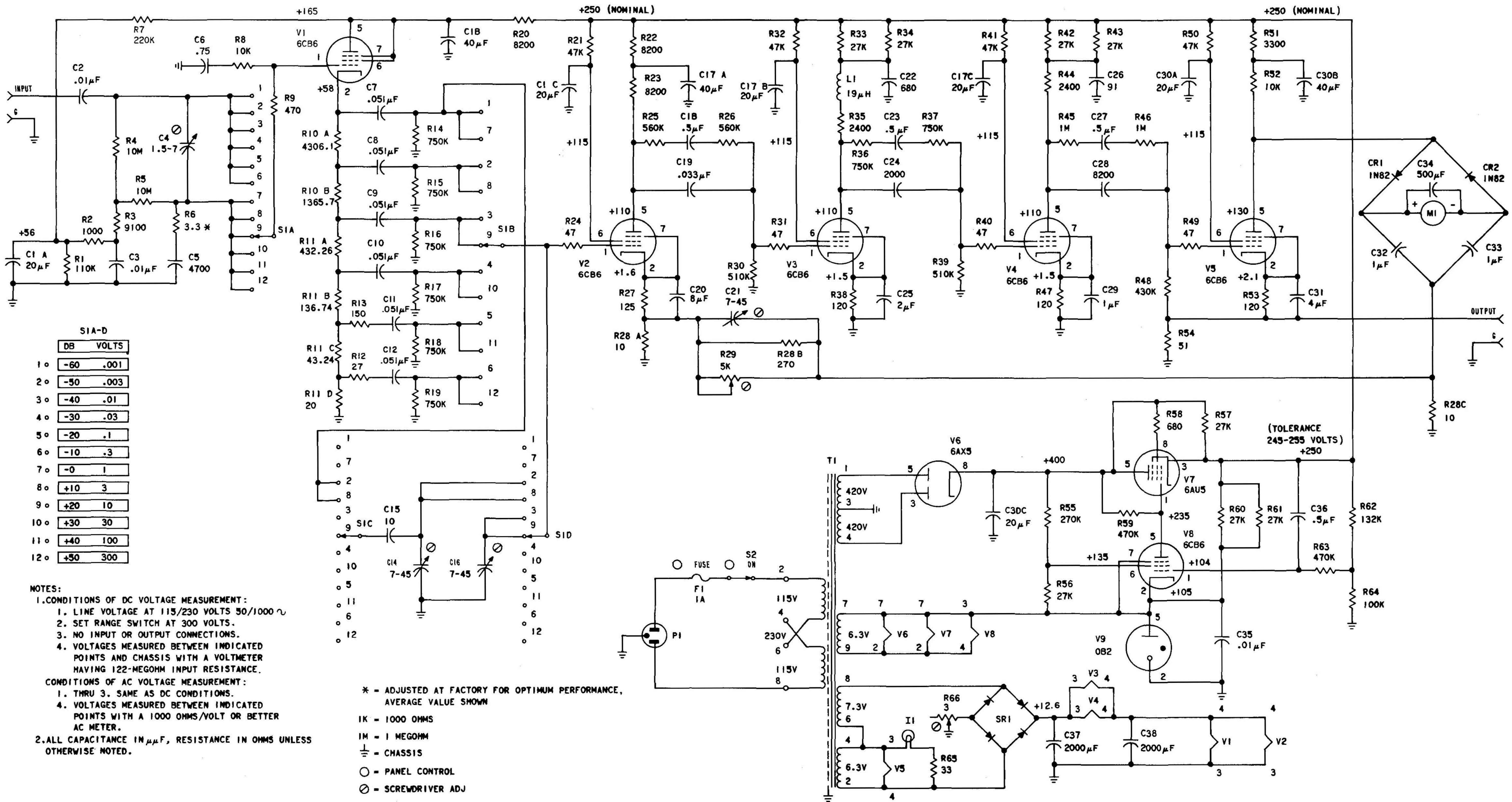


NOTES:

1. CONDITIONS OF VOLTAGE MEASUREMENT
   A. INPUT SIGNAL 0.3V RMS, 400 HZ
   B. RANGE SWITCH .3V RANGE
   C. VOLTAGES MEASURED BETWEEN TUBE PIN AND GROUND P = PLATE, G = GRID.
   D. ALTERNATING CURRENT MEASURED WITH CLIP-ON PROBE.
2. SIGNAL MEASUREMENTS IN FIRST STAGE NOT PRACTICAL DUE TO EXTREMELY LOW SIGNAL LEVEL AND LARGE DEGENERATION APPLIED TO V2.
3. WHEN MAKING MEASUREMENTS AT TUBE V5, AVOID SHORTING DIODES CR1 AND CR2 TO GROUND.
4. VARIABLE CONTROLS ARE INDICATED BY SCREWDRIVER-ADJUST SYMBOL.
5. COMPONENT NUMBERS IN ( ) PROVIDED IN MODELS NOT LISTED IN 1.06.

* COMPONENTS PROVIDED IN MODELS LISTED IN 1.06.

Fig. 5—Basic Circuits of the VTVMs



S1A-D

	DB	VOLTS
1	-60	.001
2	-50	.003
3	-40	.01
4	-30	.03
5	-20	.1
6	-10	.3
7	-0	1
8	+10	3
9	+20	10
10	+30	30
11	+40	100
12	+50	300

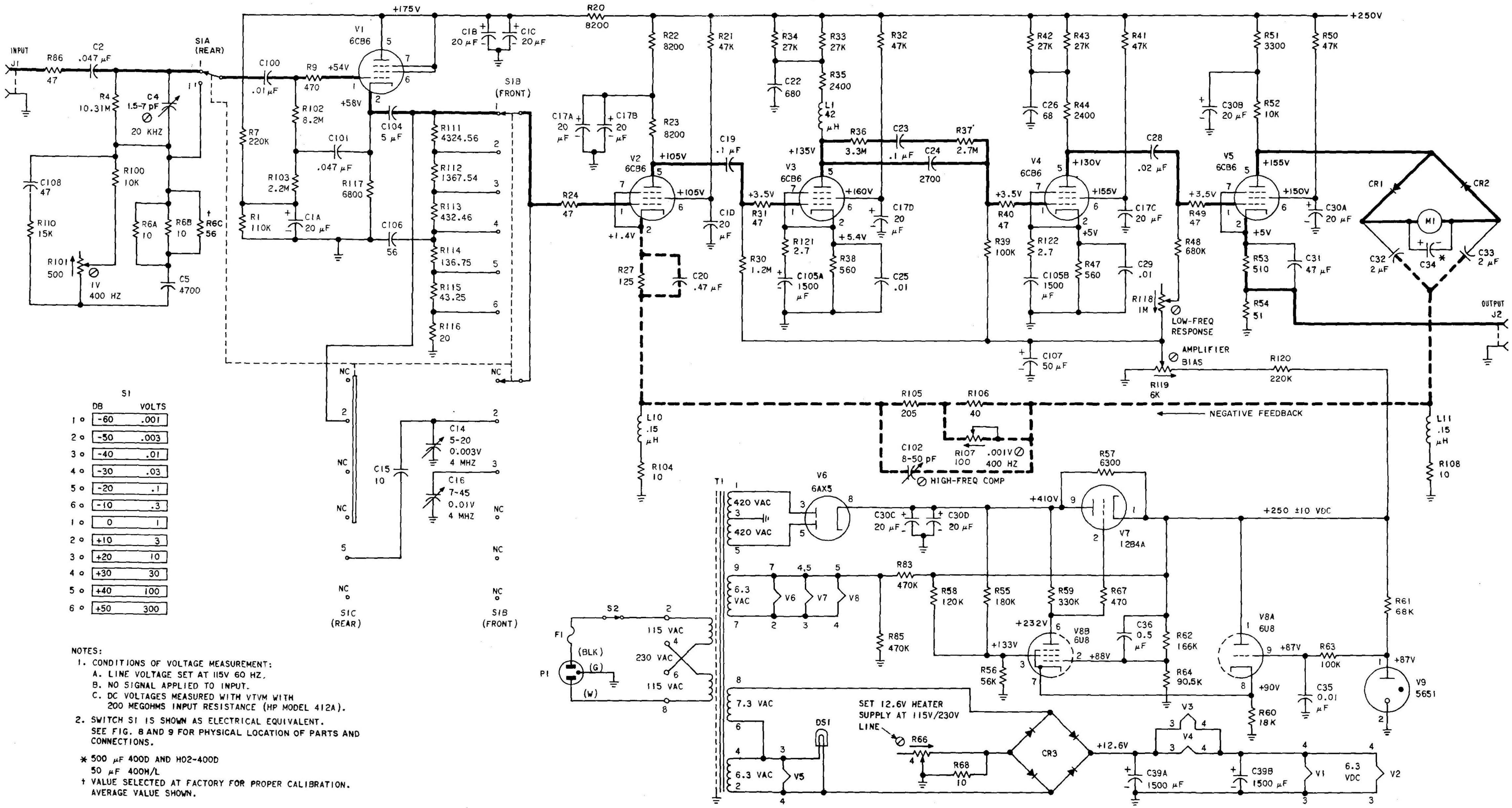
NOTES:

1. CONDITIONS OF DC VOLTAGE MEASUREMENT:
   1. LINE VOLTAGE AT 115/230 VOLTS 50/1000 ∿
   2. SET RANGE SWITCH AT 300 VOLTS.
   3. NO INPUT OR OUTPUT CONNECTIONS.
   4. VOLTAGES MEASURED BETWEEN INDICATED POINTS AND CHASSIS WITH A VOLTMETER HAVING 122-MEGOHM INPUT RESISTANCE.

   CONDITIONS OF AC VOLTAGE MEASUREMENT:
   1. THRU 3. SAME AS DC CONDITIONS.
   4. VOLTAGES MEASURED BETWEEN INDICATED POINTS WITH A 1000 OHMS/VOLT OR BETTER AC METER.
2. ALL CAPACITANCE IN $\mu\mu$F, RESISTANCE IN OHMS UNLESS OTHERWISE NOTED.

* = ADJUSTED AT FACTORY FOR OPTIMUM PERFORMANCE, AVERAGE VALUE SHOWN
IK = 1000 OHMS
IM = 1 MEGOHM
⏚ = CHASSIS
○ = PANEL CONTROL
⊘ = SCREWDRIVER ADJ

Fig. 6—Schematic Diagram—Models With Prefixed Serial Numbers Not Listed in 1.06



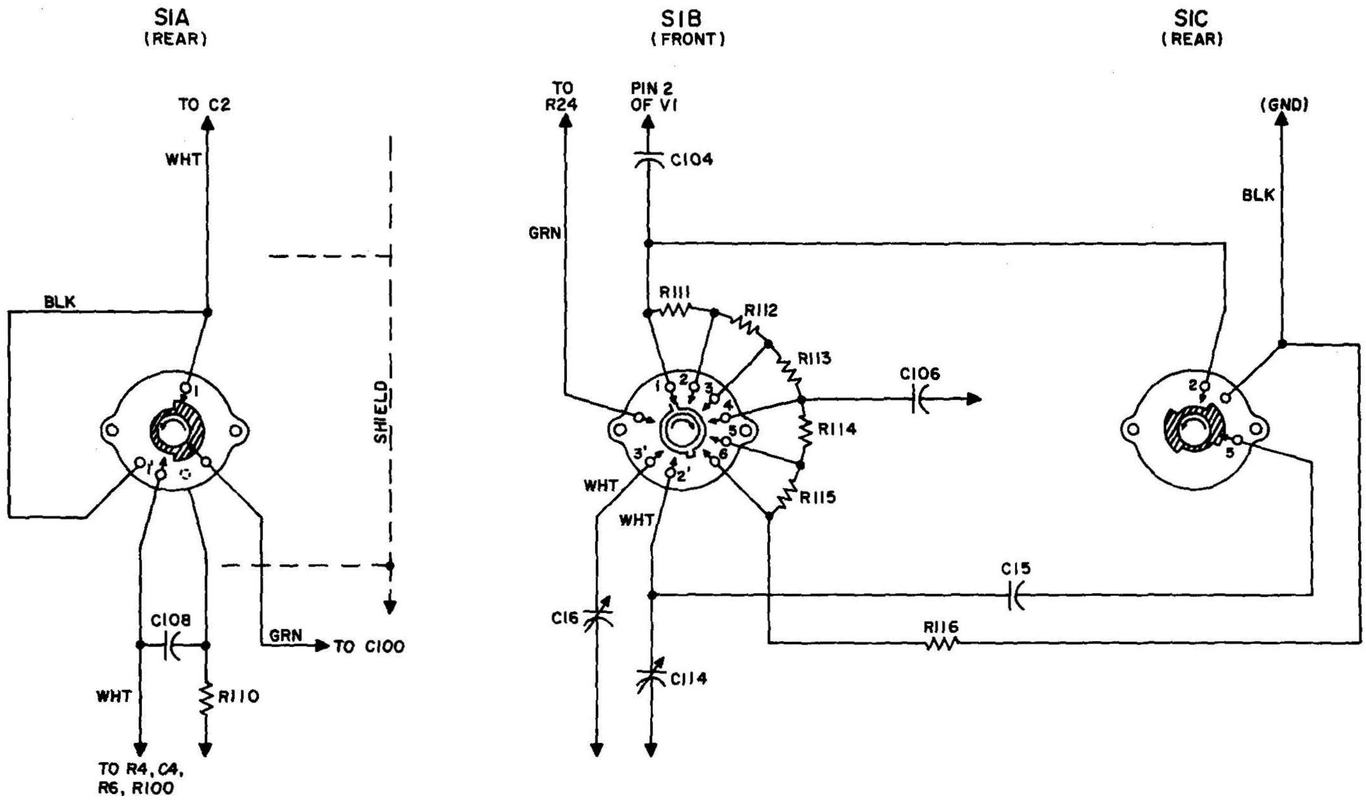
NOTES:

1. CONDITIONS OF VOLTAGE MEASUREMENT:
   A. LINE VOLTAGE SET AT 115V 60 HZ.
   B. NO SIGNAL APPLIED TO INPUT.
   C. DC VOLTAGES MEASURED WITH VTVM WITH 200 MEGOHMS INPUT RESISTANCE (HP MODEL 412A).
2. SWITCH S1 IS SHOWN AS ELECTRICAL EQUIVALENT. SEE FIG. 8 AND 9 FOR PHYSICAL LOCATION OF PARTS AND CONNECTIONS.

* 500 μF 400D AND H02-400D
  50 μF 400H/L

† VALUE SELECTED AT FACTORY FOR PROPER CALIBRATION. AVERAGE VALUE SHOWN.

Fig. 7—Schematic Diagram—Models Listed in 1.06



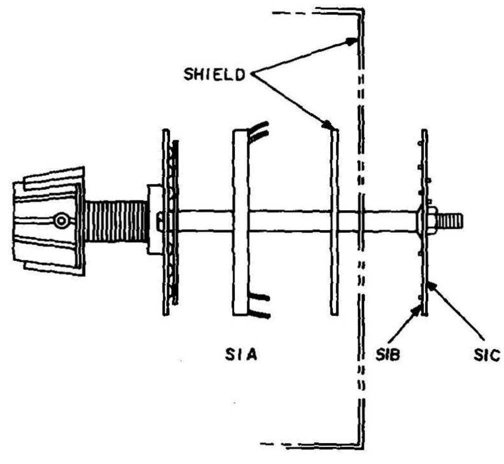


Fig. 8—Range Switch Diagram—Models Listed in 1.06

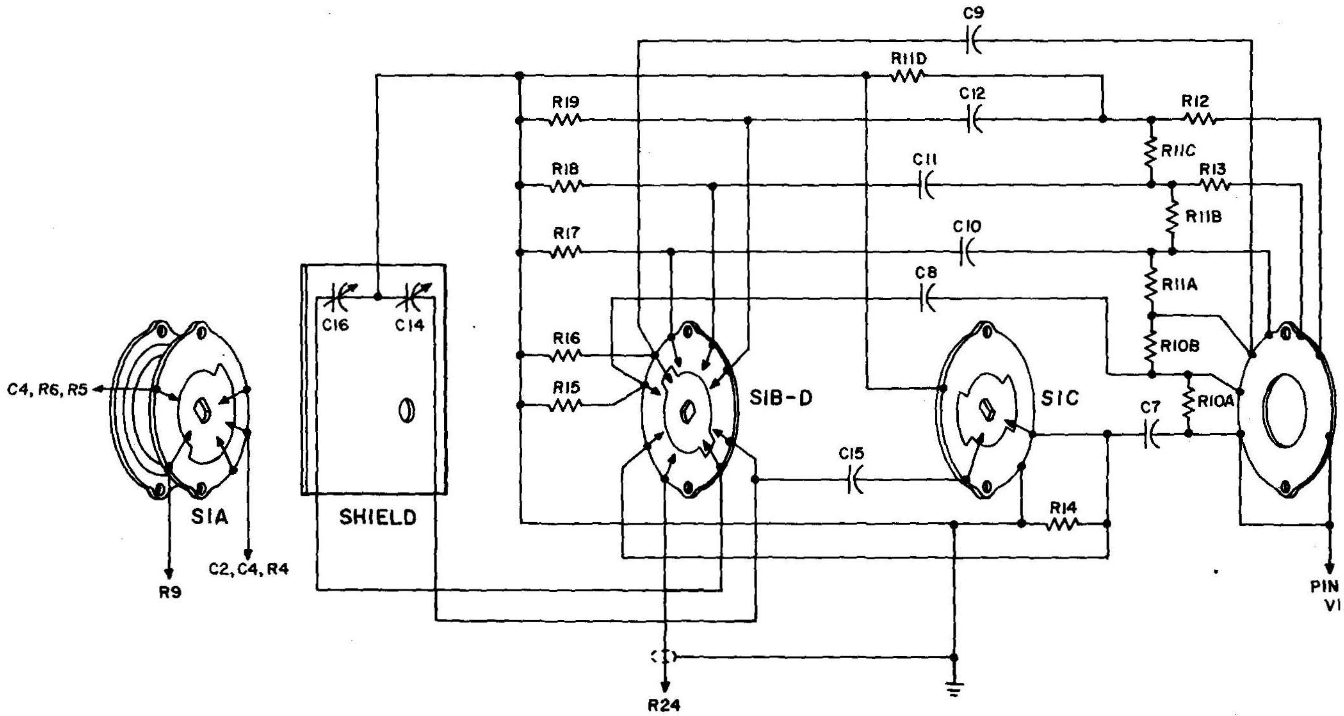


Fig. 9—Range Switch Diagram—Models Not Listed in 1.06

and INPUT terminals of the VTVM and provides a relatively low impedance in its cathode circuit to drive the step attenuator. The voltage gain factor across V1 is 0.95.

C. Broadband Voltmeter Amplifier

4.05 Amplification of the signal voltage is provided by a 4-stage stabilized amplifier consisting of tubes V2, V3, V4, and V5 and associated circuits. The amplifier provides between 55 and 60 dB of gain with about 55 dB of negative feedback at midfrequencies. The feedback signal is taken from the plate of V5 through the meter rectifiers and gain-adjusting circuit to the cathode of V2. Variable resistor R107 in the feedback network adjusts the negative feedback level to set the basic gain of the amplifier at midfrequencies. Adjustable capacitor C102 permits setting amplifier gain at 4 MHz. Variable resistor R118 in the coupling circuit between V4 and V5 permits adjusting the gain of the amplifier at 10 Hz by controlling the phase shift of low-frequency signals between these two stages (increasing phase shift decreases degeneration and increases gain).

4.06 Variable resistor R119 in the grid return path of V3, V4, and V5 adjusts the total transconductance of these tubes in order to restrict the maximum gain-bandwidth product of the amplifier. The gain-bandwidth product must be restricted to give a smooth frequency-response rolloff above 4 MHz and to prevent possible unstable operation at frequencies far above 4 MHz when tubes having unusually high transconductance are used. The plate voltage from V5 is rectified by the meter rectifiers and drives the feedback network. The cathode voltage of V5 is fed to the meter OUTPUT terminals for monitoring purposes. The current through V5, and thus the signal voltage at the cathode, is affected by the loading of the meter rectifiers. For signal levels causing third-scale or more meter deflection, this distortion consists of a very small irregularity near zero volts on the waveform as each diode begins conduction.

D. Indicating Meter Circuit

4.07 The meter rectifier circuit consists of two silicon diodes and two capacitors connected as a bridge with the indicating meter across the midpoints as shown in Fig. 10. The diodes provide full-wave rectification of the signal current for operating the meter. Electron flow through the meter is supplied in the following manner. During the positive-going half cycle of plate voltage on V5, rectifier CR1 conducts electrons from both C32 and C33 back to the B+ bus. The portion of electrons from C33 flows through the meter on the way to B+. At this point in the cycle, both C32 and C33 are charged to the potential of B+ less some small drop in R51 and R52 in the plate circuit of V5.

4.08 During the negative-going half cycle of the plate voltage of V5, rectifier CR2 conducts electrons back to both C32 and C33 from the plate of V5. That portion of electrons going back to C32 flows through the meter on the way (in the same direction that the electrons flowed in the first, positive half cycle). At this point in the cycle, both C32 and C33 are discharged. The pulsating current through the meter is smoothed by C34 to prevent meter pointer vibration when measuring low-frequency signals. The current is proportional to the arithmetic average value of the waveform amplitude of the signal. Meter calibration in RMS volts is based on the mathematical ratio between the average and RMS values of true sine-wave current.

4.09 In addition, the bridge serves as a segment of a voltage divider (in series with L11 and R108) connected across the output of the amplifier. The negative feedback voltage fed to the input of the amplifier is obtained across L11 and R108. The alternating charge and discharge of C32 and C33 produce at their junction with L11 an alternating current of the same phase and waveform as that

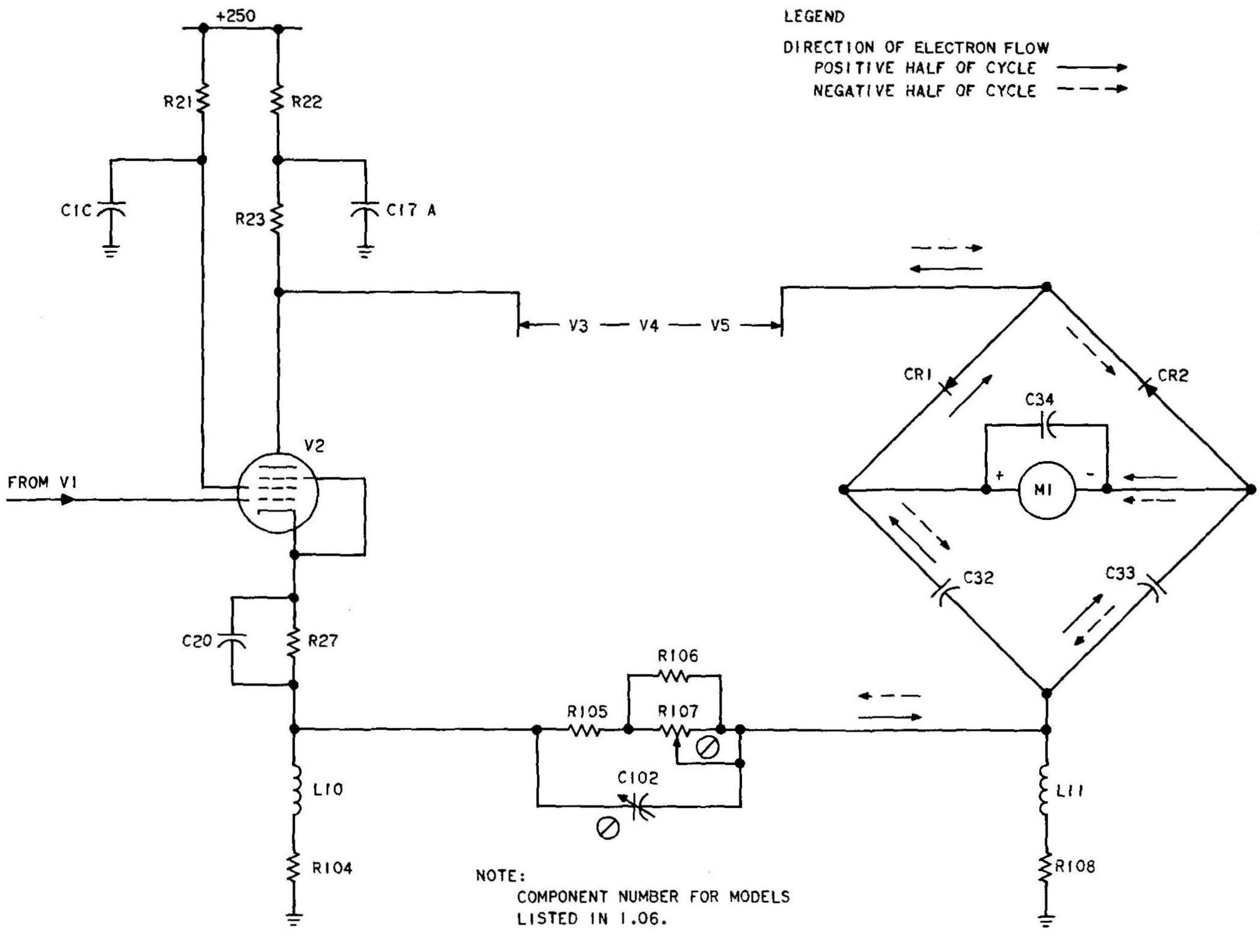


Fig. 10—Simplified Schematic of Meter Bridge Circuit

at the plate of V5. This phase is negative with respect to the input signal applied to the first stage of the amplifier (V2), and drives the negative feedback network.

E. Power Supply

4.10 The power supply consists of tubes V6, V7, V8, V9, and associated circuits. The power supply furnishes regulated +250 volts dc for the grid and plate bias circuits of V1 through V5, unregulated 12.6 volts dc for the heater supply of V1 through V4, and 6.3 volts ac for the heater supply of V1 through V8. The power supply is designed to operate from either a 115- or 230-volt ac power source of 50 to 1000 Hz. The primary winding of the power transformer is provided with taps that permit use of the winding in either parallel (115-volt) or series (230-volt), dependent upon the power source.

4.11 The output of rectifier V6 is applied to the voltage regulator circuit consisting of V7 through V9. V7 is the series regulator tube and V9 provides a fixed reference voltage drop. This reference voltage is compared with the output voltage in amplifier V8B. V8A is a cathode follower which couples the reference voltage from V9 to V8B without loading V9. The regulated output voltage is applied to the control grid of V8B and the reference voltage is simultaneously applied to its cathode. The difference between the control grid and cathode voltages controls the operating point of V8B and thus its plate voltage, which in turn supplies the grid voltage for regulator V7. Any change in the regulated output of V7 produces a correcting change in the grid bias of V7 through the action of V8B. This maintains an essentially constant output voltage despite changes in line voltage or load on the power supply. The gain of V8B is high enough to keep the output at the V7 cathode regulated to within ± 1.0 volt dc as the V7 plate voltage is varied $\pm 10\%$ with about 60 mA of load current. The response of the regulating circuits is fast enough to reduce ripple in the output voltage to less than 1 mV, supplementing the filtering action of C30. C36 couples the ripple component in the regulated output directly to V8B to avoid attenuation in R62. R57 shunts a small portion of the load current around V7 to prevent excessive V7 plate dissipation at high line voltages. R63 and C35 constitute a low-pass filter which prevents noise generated in V9 from reaching V8B.

4.12 The heater supply for the VTVM tubes is divided into two sections. One section supplies dc voltage for the tubes in the input cathode follower and the amplifier. The other section supplies ac voltage for the tubes in the power supply. The voltage required for the heaters of V1 through V4 is obtained from 6.3- and 7.3-volt secondary windings of the power transformer. These are series connected and rectified by full-wave rectifier CR3, reduced to 12.6 volts by R66 and R68 in parallel, and applied to the series-parallel connected heaters of V1 through V4. The series-parallel connection establishes 6.3 volts dc for each of the four heaters. The heater of V5 receives 6.3 volts ac from one of the windings which drives CR3. A separate 6.3-volt winding of the power transformer supplies the heaters of the power supply.

5. MAINTENANCE

5.01 This part includes (a) troubleshooting information to aid in locating the more common malfunctions of the VTVMs; (b) tests, adjustments, and calibrations to be performed subsequent to repair or replacement of the malfunctioning component or section; and (c) other maintenance information pertinent to the VTVMs.

5.02 Information relative to calibration and frequency-response adjustments is divided between the serial prefix number of the VTVM models. Earlier models do not have as many calibration adjustments as current models. The stability of the VTVMs is sufficient to insure a minimum of frequency-response adjustments; and therefore, if it is suspected that the VTVM is not operating properly, a check can be made using these procedures without removing the instrument from its case. If the checks prove unsatisfactory, the frequency-response adjustments may be performed if the equipment is available that will provide satisfactory results.

A. Apparatus

5.03 The equipment required to perform the procedures described in this section is listed in Table C. The test procedures and paragraph references are in the order of their appearance in the text and with a combination of the frequency-response and calibration procedures in the form of a table for simplification.

TABLE C

TEST PROCEDURE	APPARATUS
5.18 Tube Socket Measurements	Multimeter with 100-megohm input or greater, dc voltage range of 0 to 450, ac voltage range of 0 to 400, and ohmmeter range of 0 to 15 megohms.
5.20 High-Voltage Supply Tests	Line Voltage Transformer with range of 103 to 107 volts ac, rated at 100 watts. (CN-16/U or Ohmite VT2.) AC Voltmeter with 3-mV scale reading capability. DC Milliammeter with range of 0 to 100 mA. (Clip-on type should be used.)
5.21 Low-Voltage Supply Test	DC voltmeter with range of up to 15 volts.

TEST PROCEDURE	OSCILLATOR								MEASURING SET			
	4A TMS	21A TMS	HP 200CD	HP 650A	HP 652A	KS-19260, L1	KS-19353, L1	KS-19353, L4	4A TMS	21A TMS	40B TMS	HP 3400A RMS VM
5.24(a) Calibration	X	X	X	X	X	X	X	X	X	X	X	X
5.24(b) Calibration		X	X	X	X				X	X		X
5.25(a) Freq Response			X	X	X		X	X				X
5.25(b) Freq Response				X	X							X

Note: X denotes capability of producing desired results.

B. *Meter Zero Adjustment*

5.04 The meter is properly zero-set when its pointer rests over the zero calibration mark on the meter scale when the instrument is

(a) At normal operating temperature

(b) In its normal operating position

(c) Turned off.

Adjust the zero-set, if necessary, as follows:

(1) Allow the VTVM to operate for 20 minutes so that the meter movement will reach normal operating temperature.

(2) Turn the VTVM off and allow 1 minute for all capacitors to discharge.

(3) Rotate the mechanical zero-adjustment screw (400D and 400H only) clockwise until the meter pointer is to the left of zero and moving upscale towards zero.

(4) Continue to rotate the adjustment screw clockwise.

(5) ***Stop*** when the pointer is exactly on zero. If the pointer overshoots zero, repeat Steps (3), (4), and (5).

(6) When the pointer is exactly on zero, rotate the adjustment screw approximately 15

degrees ***counterclockwise.*** This is enough to free the zero-adjustment screw from the meter suspension. If the pointer moves during this step (a result of turning the adjustment too far counterclockwise), repeat the procedure of Steps (3) through (6).

C. Cabinet Removal

5.05 The VTVM may be removed from its cabinet in the following manner.

(1) Remove the two cabinet retaining screws at the rear of the instrument.

(2) Push the instrument chassis forward out of the cabinet. The bezel ring remains attached to the front panel.

(3) When replacing the cabinet, pull the power cable through the opening at the rear of the cabinet. Be sure that the power cable is not caught between chassis and cabinet. Replace the retaining screws.

D. Tube Replacement

5.06 In many cases, instrument malfunction can be corrected by replacing a weak or defective tube. Check tubes by substitution while following the VTVM calibration and frequency-response procedure in Part I. Results obtained through the use of a tube checker can be misleading. Before removing the tubes from the instrument, mark the original tubes so that they can be returned to the same socket if they are not defective. Replace only those tubes proven to be defective.

> ***Caution: Do not remove tubes from the VTVM when power is applied. To do so may damage the voltmeter.***

5.07 Table D lists each tube in the VTVM with its function and the check or adjustment required if the tube is replaced.

E. Replacement of Special Parts

5.08 ***Precision Resistors and Inductors:*** Several parts used in the VTVM have closer tolerances

TABLE D

ADJUSTMENTS REQUIRED WHEN TUBES ARE REPLACED

CIRCUIT REFERENCE	TYPE	FUNCTION	CHECK OR ADJUSTMENT
V1	6CB6*	Cathode Follower	Calibration and Frequency Response (5.24 and 5.25)
V2	6CB6	1st Amplifier	
V3	6CB6	2nd Amplifier	
V4	6CB6	3rd Amplifier	
V5	6CB6	4th Amplifier	
V6	6AX5	High-Voltage Rectifier	Test of Power Supply (5.20)
V7	12B4A	Series Regulator	
V8	6U8	Control Tube	
V9	5651	Reference Table (OB2)	

***V1 must be replaced by a 6CB6, aged and selected for low noise and microphonics.**

than those used in most test equipment. Resistors R104, R105, R108, and R111 through R116 are precision components. If these resistors require replacement, use the same value and type as the original. If different values are used or component positions are moved, the calibration of the VTVM may be inaccurate or the frequency response may be altered. The inductance of L10 and L11 affects the frequency response of the VTVM. Do not alter the shape or position of these coils. Install replacement components in the same positions as the original components occupied, as nearly as possible.

5.09 ***Electrolytic Capacitors:*** It should be noted that the electrolytic capacitors in this instrument are high-quality capacitors which have a useful life of from 5 to 10 years. These should not be replaced unless they are proven defective by accurate tests.

5.10 ***Diode Rectifiers:*** Special high-performance silicon diodes are used for CR1 and CR2. When replacing the silicon diodes, be careful in soldering. Heat can damage them. Place a heat sink on each diode lead close to the body of the diode. If CR1 or CR2 is replaced, the VTVM calibration and frequency response must be checked as described in 5.24 and 5.25.

5.11 ***Range Switch:*** Because of the critical construction and wiring of S1, it is not practical to attempt a major repair on the switch. When mechanical failure occurs in S1, replace the complete switch assembly. The following procedure is recommended.

(1) Remove the VTVM cabinet (see 5.05).

(2) Loosen the setscrews in the RANGE switch knob and remove the knob.

(3) Disconnect C104 from S1.

(4) Disconnect the white leads from C14 and C16. Mark or label each lead.

(5) Remove the two screws and one nut which retain the switch shield plate.

(6) Disconnect the white leads from the switch contacts. Mark or tag each lead to permit easy connection to the new switch.

(7) Disconnect the heavy dark green switch lead, the heavy light green switch lead, and the heavy black switch lead from the terminal strips. Mark or tag each lead.

Note: The input shield must be removed for access to the terminal board connection of the dark green lead.

(8) Remove the nut which holds the switch bushing to the front panel.

(9) Remove the RANGE switch assembly.

(10) The sequence for installing the replacement RANGE switch assembly is the reverse of the removal procedure.

(11) After replacement of S1, check the calibration and frequency response of the VTVM and make the necessary adjustments (see 5.24 and 5.25).

F. Servicing Etched Circuit Boards

5.12 Excessive heat or pressure can lift the copper strip from an etched circuit board. Damage can be avoided by using a low-power soldering iron (50 watts maximum) and by following these instructions. Copper that lifts off the board should be cemented in place with a quick-drying acetate-base cement having good electrical insulating properties.

5.13 A break in the copper should be repaired by soldering a short length of tinned copper wire across the break. Only high-quality rosin-core solder should be used when repairing etched circuit boards. ***Never use paste flux.*** After soldering, any excess flux should be cleaned off and the repaired area coated with a high-quality electrical varnish or lacquer.

5.14 When replacing components with multiple mounting pins, it is necessary to lift each pin slightly, working around the components several times until it is free.

5.15 The procedure below should be followed to replace a component on an etched circuit board.

> ***Caution: If the specific instructions outlined in the steps regarding etched circuit boards without eyelets are not followed, extensive damage to the etched circuit board will result.***

(a) ***Conventional Method:***

STEP	PROCEDURE
1	Apply heat sparingly to the lead of the component to be replaced (see Fig. 11A). If the lead of the component passes through an eyelet in the circuit board, apply heat on the component side of the board. If the lead of the component ***does not*** pass through an eyelet, apply heat to the conductor side of the board.
2	Reheat the solder in a vacant eyelet and quickly insert a small awl to clean the inside of the hole (Fig. 11B). If the hole ***does not*** have an eyelet, insert an awl or a No. 57 drill from the conductor side of the board.
3	Bend the clean, tinned lead on the new component and carefully insert it through the eyelets or holes in the board (Fig. 11C).
4	Hold the component against the board (avoid overheating) and solder the leads (Fig. 11D). Apply heat to the component leads on the correct side of the board as explained in Step 1.

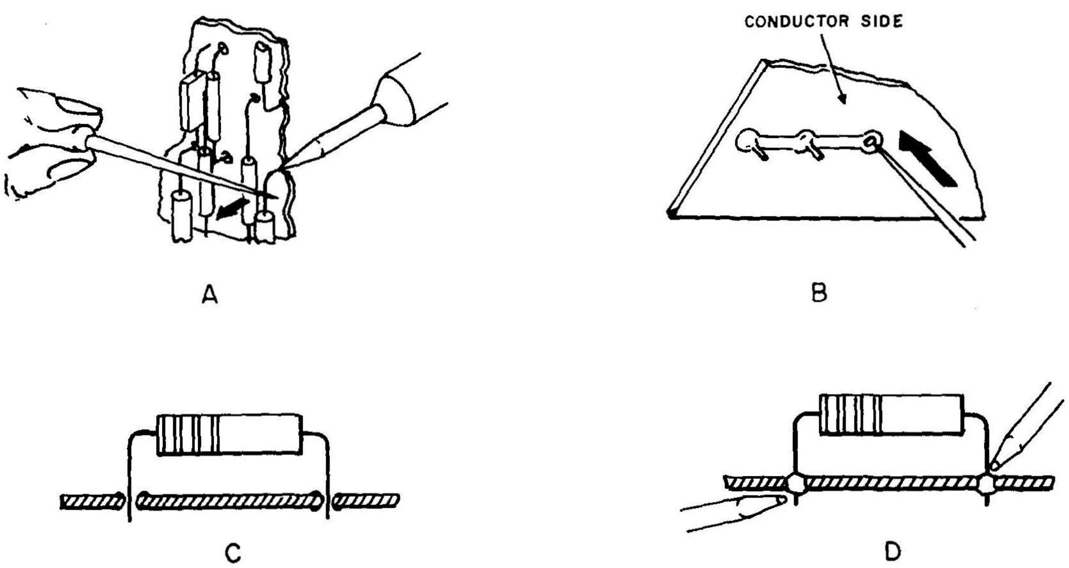


Fig. 11—Servicing Etched Circuit Boards—Conventional Method

(b) ***Alternate Method:***

STEP	PROCEDURE
	Note 1: In the event that either the circuit board has been damaged or the conventional method is impractical, this method should be used. This method is especially applicable to circuit boards without eyelets.
	Note 2: This procedure is used as an alternate means of repair only in the field; it is not used at the factory.
1	Clip the lead as shown in Fig. 12A.
2	Bend the protruding leads upward (see Fig. 12B). Bend the lead of the new component around the protruding lead.
3	Apply solder, using a pair of long-nose pliers as a heat sink.

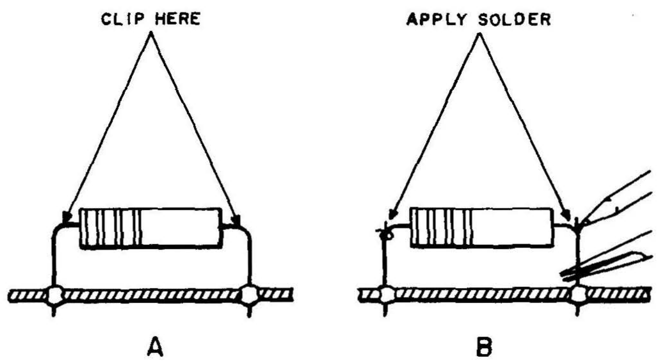


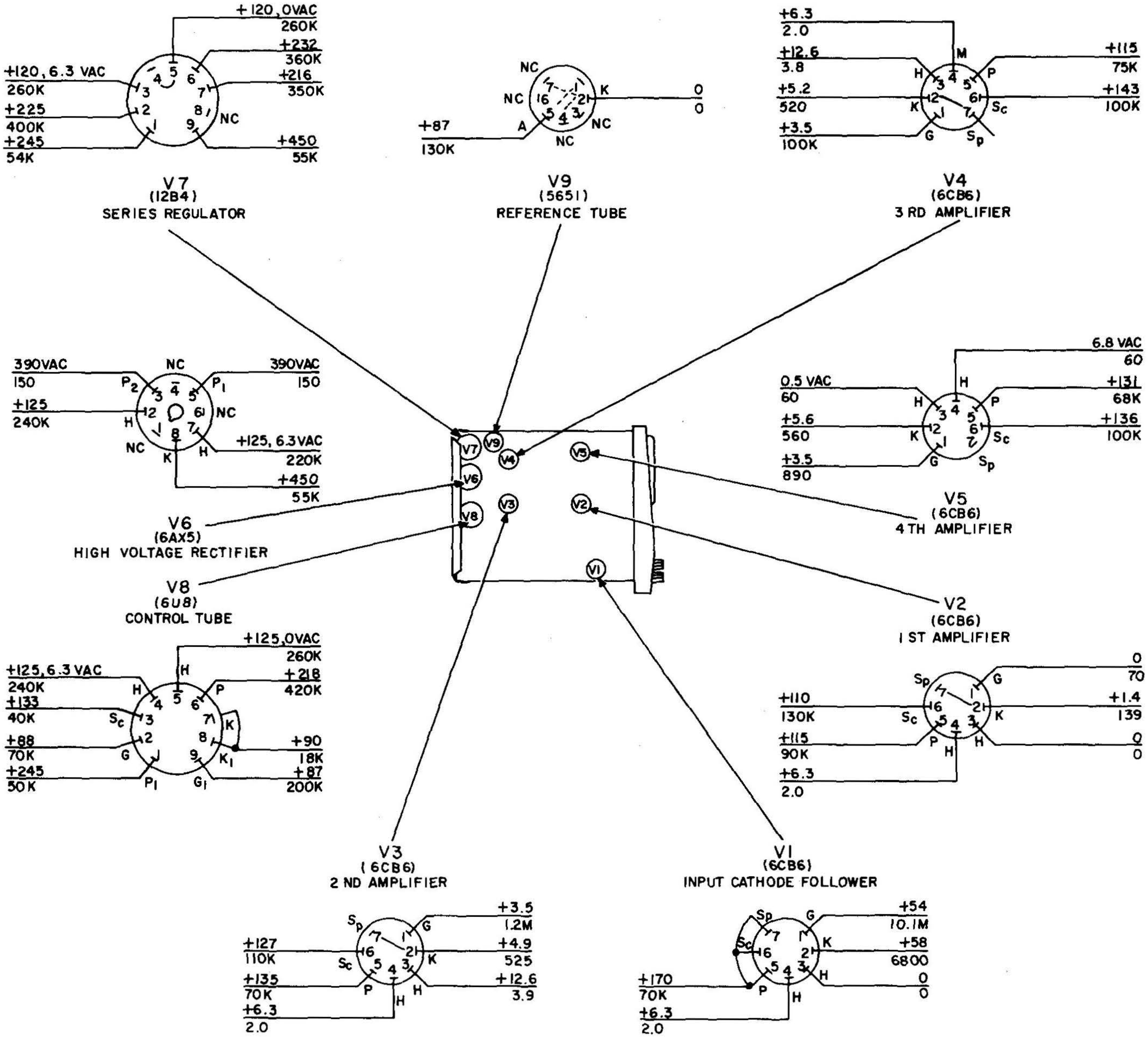
Fig. 12—Servicing Etched Circuit Boards—Alternate Method

G. Troubleshooting

5.16 Table E lists the more common symptoms of malfunction, their cause and remedy. In cases of persistent trouble, the Hewlett-Packard Sales and Service Office should be contacted.

5.17 The first step in troubleshooting is to learn the nature of the symptoms of the malfunction with as much detail as possible. Inspect the test setup being used. Be sure that the source of trouble is not external to the VTVM before attempting to check the VTVM. For example, if the instrument fails to indicate "on" with the power-indicating lamp, be sure that the power outlet is good. Also, if the instrument has warmed up and is ready for service but a reading cannot be obtained, check all connections and the condition of test leads used in the setup. Then proceed to analyze the possible trouble symptoms that are characteristic to the VTVM. If the malfunction appears to be in the VTVM, remove the cabinet as described in 5.05. Inspect the circuits of the VTVM, looking for signs of overheating, deterioration, and physical damage or tampering. The very first thing to do if the VTVM fails to turn on, is to check the fuse. If it is not blown, then proceed with the checks in Table E.

5.18 Use of the checks in Table E in conjunction with the tube socket voltage and resistance values shown in Fig. 13 should suffice for most malfunction-locating procedures. Application of a test signal to the input of the VTVM and the measurement of the test signal voltage while tracing it through each coupling network and each stage of amplification may be required as a procedure. Compare the readings with those shown in Fig. 5. In Fig. 5, a current value is indicated in the meter circuit. This value can be checked with the use of an alternating current probe, such as the HP Model 456A probe. This permits measurement of the current without breaking the leads in the meter circuit. If this or a similar probe is not available, avoid measurement of the current. An oscilloscope may be used for observing test signal waveshape and measuring amplitude, if desired.



NOTES:

1. CONDITIONS OF DC VOLTAGE MEASUREMENTS:
   A. BETWEEN INDICATED POINT AND GROUND.
   B. NO CONNECTION TO INPUT OR OUTPUT.
   C. LINE VOLTAGE: 115 VOLTS, 60 HERTZ.
   D. DB VOLTS SWITCH: 300V RANGE.
2. VOLTAGES MAY VARY UP TO TO ±10%.
3. CONDITIONS OF RESISTANCE MEASUREMENTS:
   A. BETWEEN INDICATED POINT AND GROUND WITH MULTIMETER.
   B. EXTERNAL CABLES DISCONNECTED.
   C. CIRCUIT CAPACITY MUST BE CHARGED BY OHMMETER BEFORE ACCURATE RESISTANCE READING CAN BE OBTAINED.
4. RESISTANCE MEASUREMENTS MAY VARY UP TO ±10%.

Fig. 13—Voltage and Resistance Diagram—Tube Sockets of Models Listed in 1.06

TABLE E

TROUBLESHOOTING PROCEDURES

TROUBLE AND PROBABLE CAUSE	REMEDY
1. Power indicator lamp does not light.	
a. Fuse F1 burned out.	a. Replace fuse F1. If replaced fuse blows, check items 2 and 3 below.
b. Power indicator lamp DS1 defective.	b. Replace power indicator lamp DS1.
c. Defective ac power cable.	c. Repair or replace power cable.
d. Power switch S2 defective.	d. Replace power switch S2.
e. Transformer T1 primary winding terminals incorrectly connected.	e. Check connections of transformer T1 primary winding; rewire if necessary.
2. Fuse F1 blows immediately when power switch S2 is operated to ON.	
a. Tube V6 shorted.	a. Replace rectifier tube V6.
b. Rectifier CR3 defective.	b. Replace heater rectifier CR3.
c. Short circuit in transformer T1 or in circuit wiring.	c. Remove all tubes, and check transformer windings. Replace transformer T1 if defective. Check for short circuit.
3. Fuse F1 blows after power switch S2 has been operated to ON and tube heaters have warmed up.	
a. Short in power supply circuit.	a. Check for short circuit at cathodes V6 and V7. Replace defective component.
4. Power indicator lamp lights; voltmeter does not indicate on all ranges.	
a. Power supply or voltage regulator circuits defective.	a. Check tubes V6, V9, V7, and V8 in turn. Check high-voltage winding of transformer T1. Replace defective component.
b. Rectifier CR3 or circuit component defective.	b. Check for 12.6 volts dc across output of rectifier CR3. Check resistors R66 and R68. If tubes V1 and V2 are not lighted, check capacitor C39. Replace defective component.
c. Diode CR1 or CR2 defective.	c. Replace diode (5.10).
5. Meter indication normal on low ranges (.001 to 3. volt). Meter sensitivity distorted on high ranges (1 to 300 volts).	
a. Compensated 1000: 1 divider defective.	a. Check C4 and R4. Replace defective component.

TABLE E (Cont)

TROUBLESHOOTING PROCEDURES

TROUBLE AND PROBABLE CAUSE	REMEDY
6. Meter indicates low on all ranges.	
a. Low amplifier gain.	a. Check B+ voltage (5.20). Check tubes V2 through V5 for low emission. If any tube is replaced, check and recalibrate the voltmeter (5.24, 5.25).
b. Diode CR1 or CR2 defective.	b. Replace diode (5.10).
7. Meter indication unstable or erratic.	
a. Power supply circuit defective.	a. Check heaters and B+ voltage (5.19). Replace defective component.
b. Amplifier tubes V1, V2, V3, V4, and V5 defective.	b. Check V1 through V5 for microphonics or noise. If tube is replaced, check and recalibrate the voltmeter (5.24, 5.25).
8. Meter indication normal on .001- and 1-volt ranges. Meter sensitivity distorted on all other ranges (.003, .01, .03, .1, .3, 3, 10, 30, 100, and 300 volts).	
a. Faulty RANGE switch S1.	a. Check switch contacts of S1. Replace RANGE switch S1 if defective (5.11).

H. Power Supply Tests

5.19 The stability of the VTVM depends directly upon the stability of the +250 volts dc from the power supply. When the supply is operating satisfactorily, the +250 volt output remains constant and the ripple level on it remains less than about 1 mV for line voltages between 103 and 127 volts. Weak tubes (V6, V7, and V8) are the usual cause of instability. An unstable regulator tube is indicated by excessive line-frequency ripple and varying output voltage as the line voltage is changed. Marginal operation is indicated if a trouble symptom appears only when a low or high line voltage is applied. To test the complete power supply, proceed as follows.

5.20 ***Test of High-Voltage Rectifier and Regulator Circuit:***

STEP	PROCEDURE	REMARKS
1	Connect the VTVM to an adjustable line transformer. Set the line voltage for 115 volts.	Use a transformer with a rating of at least 100 watts and a range of 103 to 127 volts.
2	Turn on the VTVM and allow a 5-minute warmup period.	

STEP	PROCEDURE	REMARKS
3	Measure dc voltage between pin 8 of V6 and chassis ground. ***Requirement:*** 400 to 420 volts dc.	Use a dc voltmeter with a sensitivity of 20,000 ohms per volt or better. If the requirement is not met, replace V6. If not met after replacing V6, make tube socket voltage and resistance measurements per Fig. 13.
4	Lower line voltage to 103 volts. Wait 2 minutes for heaters to stabilize.	
5	Repeat Step 3. ***Requirement:*** The voltage shall not drop below 360 volts dc.	If the voltage drops below the requirement, replace V6.
6	Readjust the line voltage to 115 volts. Wait 2 minutes for heaters to stabilize.	
7	Measure dc voltage between pin 1 of V7 and chassis ground. ***Requirement:*** 245 to 255 volts.	If the requirement is not met, replace V7. If not met after replacing V7, make tube socket voltage and resistance measurements per Fig. 13.
8	Raise line voltage to 127 volts. Wait 2 minutes for heaters to stabilize.	
9	Repeat Step 7. ***Requirement:*** The voltage should not change more than ± 1.0 volt.	If the requirement is not met, replace V7, V8, or V9, or all three if necessary.
10	Measure the ac ripple voltage between pin 1 of V7 and chassis ground while varying the line voltage between 103 and 127 volts. ***Requirement:*** The ripple voltage must be less than 3 mV for all line voltages.	Use an ac voltmeter that will measure in the 3-mV range. If the requirement is not met, replace V8, V7, V6, or V9. Replace in this order.
	Note: The following test is performed if it is suspected that a short circuit or partial short exists in the VTVM amplifier section and that the above tests are satisfactory. A clip-on type dc milliammeter should be used to make the test.	

STEP	PROCEDURE	REMARKS
11	Attach the probe to the lead from pin 1 of V7 and read the current. ***Requirement:*** The direct current shall be less than 60 mA.	Do not break the lead and insert a meter. Use a probe. If the current is in excess of the requirement, make a physical check of the VTVM amplifier circuit for shorted or damaged parts, make tube socket voltage and resistance measurements per Fig. 13, or replace tubes, one at a time, in the amplifier section.
	Note: If the output voltage is stable (Steps 3, 5, 7, and 9) but of an incorrect value, proceed as follows.	
12	Measure the resistance of R62 and R64. ***Requirement:*** R62 = 166K ohms R64 = 90.5K ohms.	The ratio of these two resistors determines the output voltage. If the value of one of these resistors is incorrect, replace it with a resistor which produces the correct output voltage.

5.21 ***Test of Low-Voltage Rectifier Circuit:***

STEP	PROCEDURE	REMARKS
1	With a line voltage of 115 volts, measure the dc voltage across C39A. ***Requirement:*** 12.6 volts.	If the requirement is not met, adjust R66 until the meter reads exactly 12.6 volts. If the requirement still cannot be met, (1) check the ac voltage across the power transformer windings supplying this circuit and (2) check CR3 and C39.

I. Calibration and Frequency-Response Adjustments

5.22 Calibration and frequency-response adjustments may be required when components in the input, attenuator, amplifier, or meter circuit are replaced. Equipment that is available in most offices limits the degree of accuracy desired to make these adjustments. However, the following procedures and the apparatus listed in 5.03 should produce results that are satisfactory for general use of the VTVMs. If a higher degree of accuracy is required, it will be necessary to use a source of signals similar to those provided by a voltmeter calibrator (with capability of producing a 1-mV signal over a wide range of frequencies) and other measurement standards.

5.23 Before performing the calibration and frequency-response procedures, the preliminary requirements are as follows.

(a) The equipment used in these procedures should be checked and, if required, adjusted accurately by the use of a 22A milliwatt reference meter, a 71B milliwatt reference generator, or a milliwatt outlet that has been verified to be accurate by the use of a 22A milliwatt reference meter.

(b) The power supply output should be checked and verified to be within the requirements specified in Part H.

(c) The lettered steps in the following procedures need not be performed unless equipment is available that can produce the desired results or if the frequency at which the VTVM is to be used does not warrant making them.

Note: ***Do not use an outlet from the office milliwatt supply unless*** it is ascertained that there is an isolating transformer (repeating coil) in the outlet itself, or that there are no other grounds, ac or dc, intentional or unintentional, on any other part of the milliwatt distributing system. Since the VTVM has one input terminal grounded, the output of the milliwatt outlet will be in error when the VTVM is connected to it if there is a ground on any other part of the system. For example, the calibrating circuit for the 1W amplifier-rectifier shown in SD-59433-01 provides such a ground.

5.24 ***Calibration:*** In addition to the replacement of any of the parts mentioned in 5.22, the VTVM should be calibrated from time to time although the meters have a high degree of accuracy and stability.

(a) Calibration of meters with prefixed serial numbers below those in 1.06 or which do not have resistors R101 and R107 is as follows.

STEP	PROCEDURE
1	Connect the VTVM to a source of power and operate the toggle switch to ON. Allow 15 minutes for warmup and stabilization.
2	Connect in parallel the input of a measuring set and the output of an oscillator to the INPUT terminals of the VTVM. Set the RANGE switch of the VTVM to .3.
3	Adjust the oscillator frequency to 1000 Hz and at a level that will produce a −10 dB reading on the measuring set.
4	Read the VTVM. ***Requirement:*** The meter should read between .745 and .805 on the 1-volt RMS VOLTS scale. (Use the 1-volt RMS VOLTS scale as the markings are easier to read.) If the requirement is not met, remove the VTVM from its cabinet (5.05) and adjust R29 until the meter reads ***exactly*** .775 on the 1-volt RMS VOLTS scale.
5	Set the RANGE switch of the VTVM to 1.
6	Adjust the oscillator frequency to 1000 Hz and at a level that will produce a 0.0-dBm reading on the measuring set.
7	Read the VTVM. ***Requirement:*** The meter should read between .745 and .805 on the 1-volt RMS VOLTS scale. If the requirement is not met, remove the VTVM from its cabinet (5.05) and adjust C4 until the meter reads ***exactly*** .775.

(b) Calibration of meters with prefixed serial numbers listed in 1.06 is as follows.

STEP	PROCEDURE
1	Connect the VTVM to a source of power and operate the toggle switch to ON. Allow 15 minutes for warmup and stabilization.
2	Connect in parallel the input of a measuring set and the output of an oscillator to the INPUT terminals of the VTVM. Set the RANGE switch of the VTVM to .01.
3	Adjust the oscillator frequency to 400 Hz and at a level that will produce a −40 dB reading on the measuring set.
4	Read the VTVM.
	Requirement: The meter should read between .745 and .805 on the 1-volt RMS VOLTS scale. If the requirement is not met, remove the VTVM from its cabinet (5.05) and adjust R107 until the meter reads ***exactly*** .775.
5	Set the RANGE switch of the VTVM to 1.
6	Adjust the oscillator frequency to 400 Hz and at a level that will produce a 0.0-dB reading on the measuring set.
7	Read the VTVM.
	Requirement: The meter should read between .745 and .805 on the 1-volt RMS VOLTS scale. If the requirement is not met, remove the VTVM from its cabinet (5.05) and adjust R101 until the meter reads ***exactly*** .775.
	Note: Step 4 checks and adjusts the gain of the VTVM amplifier at audio frequencies. Step 7 checks and adjusts the division ratio of the input voltage divider at audio frequencies.

5.25 ***Frequency Response:*** The accuracy of the calibration should be checked over the frequency range in which the VTVM is to be used. The measuring set used in the procedure is a reference meter for adjusting the output of the oscillator at the different frequencies. The impedance of the set is not a factor, but the set must be capable of reading the output of the oscillator at all frequencies and levels to assure accurate results. Observe the preliminary requirements in 5.23 and be sure that the meter meets the calibration requirements in 5.24 before making any frequency-response adjustments.

(a) Frequency-response adjustment of meters with prefixed serial numbers below those in 1.06 or which do not have C102, R118, and R119 is as follows.

STEP	PROCEDURE
1	Connect the VTVM to a source of power and operate the toggle switch to ON. Allow 15 minutes for warmup and stabilization.
2	Connect in parallel the input of a measuring set and the output of an oscillator to the INPUT terminals of the VTVM. Set the RANGE switch of the VTVM to .1.
3	Adjust the oscillator frequency to 10 kHz.
4	While reading the VTVM 1-volt RMS VOLTS scale, adjust the output level of the oscillator until the meter reads .9.
5	Read the level on the measuring set (approximately −18.6 dBm) and use this value as the reference level in the following steps. ***Note:*** Do not attempt to relate the .9 reading to the actual voltage as it is used only as a reference point on the meter for adjustment purposes. The RANGE switch settings are required to include the adjustable components in the procedure.
6	Change the frequency of the oscillator to 150 kHz. Set the output level to the reference level obtained in Step 5.
7	Read the VTVM. ***Requirement:*** The meter shall read between .81 and .99 on the 1-volt RMS VOLTS scale. If the requirement is not met, adjust C21 until the meter reads ***exactly*** .9.
8	Set the RANGE switch of the VTVM to .003.
9	Adjust the oscillator frequency to 10 kHz.
10	While reading the VTVM 1-volt RMS VOLTS scale, adjust the output level of the oscillator until the meter reads .9.
11	Read the level on the measuring set (approximately −48.6 dBm) and use this value as the reference level in the following steps.
12	Change the frequency of the oscillator to 150 kHz. Set the output level to the reference level obtained in Step 11.
13	Read the VTVM. ***Requirement:*** The meter shall read between .81 and .99 on the 1-volt RMS VOLTS scale. If the requirement is not met, adjust C14 until the meter reads ***exactly*** .9.

STEP	PROCEDURE
14	Set the RANGE switch of the VTVM to .01.
15	Adjust the oscillator frequency to 10 kHz.
16	While reading the VTVM 1-volt RMS VOLTS scale, adjust the output level of the oscillator until the meter reads .9.
17	Read the level on the measuring set (approximately −38.6 dBm) and use this value as the reference level in the following steps.
18	Change the frequency of the oscillator to 150 kHz. Set the output level to the reference level obtained in Step 17.
19	Read the VTVM.
	Requirement: The meter shall read between .81 and .99 on the 1-volt RMS VOLTS scale. If the requirement is not met, adjust C16 until the meter reads ***exactly*** .9.

(b) Frequency-response adjustment of meters with pefixed serial numbers listed in 1.06 is as follows.

STEP	PROCEDURE
1	Connect the VTVM to a source of power and operate the toggle switch to the ON position. Allow 15 minutes for warmup and stabilization.
2	Connect in parallel the input of a measuring set and the output of an oscillator to the INPUT terminals of the VTVM. Set the RANGE switch of the VTVM to .3.
3	Adjust the oscillator frequency to 400 Hz.
4	While reading the VTVM 1-volt RMS VOLTS scale, adjust the output level of the oscillator until the meter reads .9.
5	Read the level on the measuring set (approximately −8.6 dBm) and use this value as the reference level in the following steps.
	Note: Do not attempt to relate the .9 reading to the actual voltage as it is used only as a reference point on the meter for adjustment purposes. The RANGE switch settings are required to include the adjustable components in the procedure.
6	Change the frequency of the oscillator to 4 MHz. Set the output level to the reference level obtained in Step 5.

STEP	PROCEDURE
7	Read the VTVM. ***Requirement:*** The meter shall read between .81 and .99 on the 1-volt RMS VOLTS scale. If the requirement is not met, adjust C102 until the meter reads ***exactly*** .9.
8a	Change the frequency of the oscillator to 10 MHz. Set the output level to the reference level obtained in Step 5.
9a	Read the VTVM. ***Requirement:*** The meter shall read between 0 and .92 on the 1-volt RMS VOLTS scale. If the requirement is not met, adjust R119 until the meter reads in this range. ***Note:*** Adjustment of R119 will affect both low- and high-frequency response and it will be necessary to repeat the frequency-response tests. While adjusting the oscillator frequency from 4 to 10 MHz, attempt to keep the level constant. Observe that the frequency-response curve increases from 4 to approximately 6 MHz and then drops off from approximately 6 to 10 MHz.
10	Change the oscillator frequency to 20 Hz. Set the output level to the reference level obtained in Step 5.
11	Read the VTVM. ***Requirement:*** The meter shall read between .81 and .99 on the 1-volt RMS VOLTS scale. If the requirement is not met, adjust R118 until the meter reads ***exactly*** .9.
12b	Change the oscillator frequency to 10 Hz. Set the output level to the reference level obtained in Step 5.
13b	Read the VTVM. ***Requirement:*** The meter shall read between .81 and .99 on the 1-volt RMS VOLTS scale. If the requirement is not met, readjust R118 slightly until the meter reads ***exactly*** .9.
14	Set the RANGE switch to .003.
15	Adjust the frequency of the oscillator to 400 Hz.
16	While reading the VTVM 1-volt RMS VOLTS scale, adjust the output level of the oscillator until the meter reads .9.
17	Read the level on the measuring set (approximately −48.6 dB) and use this value as the reference level in the following steps.
18	Change the oscillator frequency to 4 MHz. Set the output level to the reference level obtained in Step 17.

STEP	PROCEDURE
19	Read the VTVM. ***Requirement:*** The meter shall read between .81 and .99 on the 1-volt RMS VOLTS scale. If the requirement is not met, adjust C14 until the meter reads ***exactly*** .9.
20	Set the RANGE switch of the VTVM to .01.
21	Adjust the oscillator frequency to 400 Hz.
22	While reading the VTVM 1-volt RMS VOLTS scale, adjust the output level of the oscillator until the meter reads .9.
23	Read the level on the measuring set (approximately −38.6 dBm) and use this value as the reference level in the following steps.
24	Change the oscillator frequency to 4 MHz. Set the output level to the reference level obtained in Step 23.
25	Read the VTVM. ***Requirement:*** The meter shall read between .81 and .99 on the 1-volt RMS VOLTS scale. If the requirement is not met, adjust C16 until the meter reads ***exactly*** 0.9.
26	Set the RANGE switch of the VTVM to 1.
27	While reading the VTVM 1-volt RMS VOLTS scale, adjust the output level of the oscillator until the meter reads .9. ***Note:*** It may be necessary to adjust C4 to obtain a .9 scale reading.
28	Read the level on the measuring set (approximately +1.4 dBm) and use this value as the reference level in the following steps.
29	Change the frequency of the oscillator to 4 MHz. Set the output level to the reference value obtained in Step 28.
30	Read the VTVM. ***Requirement:*** The meter shall read between .85 and .95 on the 1-volt RMS VOLTS scale. If the requirement is not met, it may be necessary to change the value of R6 by increasing the value of one of the resistors. Increasing the value of one of these resistors raises the meter reading at 4 MHz. The input shield must be in place on the chassis when making this reading.

6. ORDERING INFORMATION

A. General

6.01 Information for ordering replacement parts of models listed in 1.06 is contained in Table F. The parts are listed in alphanumerical order of their circuit references. Detailed information on a part used more than once in the VTVM is listed opposite the first circuit reference applying to the part. Other circuit references applying to the same part refer to the initial reference. Miscellaneous parts are listed at the end of the table. Detailed information includes the following:

(a) Circuit reference

(b) Full description of the part

(c) Manufacturer of the part in a 5-digit code (Table G)

(d) Hewlett-Packard stock number

(e) Total quantity used in the VTVM.

6.02 To assist in the locating of components of the VTVMs, Fig. 14 through 20 are provided. Any component not shown will necessarily have to be identified by using the schematic diagrams (Fig. 6 and 7).

B. Ordering Instructions

6.03 To order a replacement part, address the order or inquiry to the authorized Hewlett-Packard Sales and Service Office. Include the following information for each part:

(a) Model and serial number of the instrument

(b) Hewlett-Packard stock number

(c) Circuit reference

(d) Description.

6.04 To order a part not listed in Table F, a complete description of the part, its function, and location should be included.

6.05 The manufacturers listed in Table G supply components used in the manufacture of the VTVM. The code numbers are taken from the Federal Supply Code for Manufacturers Cataloging Handbooks H4-1 (name to code) and H4-2 (code to name)and their latest supplements.

TABLE F

PARTS LIST – MODELS LISTED IN 1.06

CIRCUIT REFERENCE	DESCRIPTION	MANUFACTURER CODE	HEWLETT-PACKARD STOCK NUMBER	TOTAL QUANTITY
C1 A-D	Capacitor: fixed, electrolytic, 4 sections 20 μF per section, 450 Vdcw	56289	0180-0025	3
C2	Capacitor: fixed, paper, 047 μF ±10%, 600 Vdcw	56289	0160-0005	1
C3	Not assigned			
C4	Capacitor: variable, ceramic, 1.5-7 pF, 500 Vdcw	72982	0130-0003	1
C5	Capacitor: fixed, mica, 4700 pF ±5%, 500 Vdcw	*	0140-0084	1
C6-13	Not assigned			
C14	Capacitor: variable, ceramic, 5-20 pF, 500 Vdcw	72982	0130-0006	1
C15	Capacitor: fixed, ceramic, 10 pF ±0.5 pF, 500 Vdcw	72982	0150-0009	1
C16	Capacitor: variable, ceramic, 7.45 pF, 500 Vdcw	72982	0130-0001	1
C17	Same as C1			
C18	Not assigned			
C19	Capacitor: fixed, paper, 0.1 μF ±10%, 400 Vdcw	56289	0160-0013	2
C20	Capacitor: fixed, paper, 0.47 μF ±10%, 100 Vdcw	56289	0170-0064	2
C21	Not assigned			
C22	Capacitor: fixed, mica, 680 pF ±10%, 500 Vdcw	*	0140-0007	1
C23	Same as C19			

*Manufacturer not significant. Use reliable source.

TABLE F (CONT)

PARTS LIST – MODELS LISTED IN 1.06

CIRCUIT REFERENCE	DESCRIPTION	MANUFACTURER CODE	HEWLETT-PACKARD STOCK NUMBER	TOTAL QUANTITY
C24	Capacitor: fixed, paper, 0.0027 μF ±10%, 600 Vdcw	56289	0160-0044	1
C25	Capacitor: fixed, ceramic, 0.01 μF ±20%, 1000 Vdcw	56289	0150-0012	3
C26	Capacitor: fixed, mica, 68 pF ±10%, 500 Vdcw	*	0140-0025	1
C27	Not assigned			
C28	Capacitor: fixed, plastic, 0.020 μF ±10%, 400 Vdcw	56289	0170-0063	1
C29	Same as C25			
C30	Same as C1			
C31	Same as C20			
C32, 33	Capacitor: fixed, paper, 2.0 μF ±20%, 400 Vdcw	84411	0170-0002	2
C34	Capacitor: fixed, electrolytic, 500 μF +100%, –10%, 3 Vdcw for 400D and H02-400D	56289	0180-0063	1
	Capacitor: fixed, electrolytic, 50 μF, 6 Vdcw for 400H and 400L	56289	0180-0033	1
C35	Same as C25			
C36	Capacitor: fixed, paper, 0.5 μF ±10%, 400 Vdcw	14655	0160-0024	1
C37, 38	Not assigned			
C39	Capacitor: fixed, electrolytic, 2 sections 1500 μF per section, 15 Vdcw	56289	0180-0028	2
C40-99	Not assigned			
C100	Capacitor: fixed, paper, 0.01 μF ±10%, 600 Vdcw	56289	0160-0002	1

*Manufacturer not significant. Use reliable source.

TABLE F (CONT)

PARTS LIST – MODELS LISTED IN 1.06

CIRCUIT REFERENCE	DESCRIPTION	MANUFACTURER CODE	HEWLETT-PACKARD STOCK NUMBER	TOTAL QUANTITY
C101	Capacitor: fixed, plastic, 0.047 μF ±10%, 200 Vdcw	56289	0170-0040	1
C102	Capacitor: variable, ceramic, 8 to 50 pF, 350 Vdcw	72982	0130-0002	1
C103	Not assigned			
C104	Capacitor: fixed, paper, 5.0 μF ±10%, 100 Vdcw	56289	0170-0057	1
C105	Same as C39			
†C106	Capacitor: fixed, mica, 56 pF ±10%, 500 Vdcw	*	0140-0014	1
C107	Capacitor: fixed, electrolytic, 50 μF, 6 Vdcw	56289	0180-0033	1
C108	Capacitor: fixed, mica, 47 pF ±10%, 500 Vdcw	*	0140-0039	1
CR1, 2	Diode: (Hughes Aircraft, Type HD-5004)	82577	1901-0347	2
CR3	Rectifier: metallic, Cooperative Industries, Type 61-6911	81482	1882-0005	1
DS1	Lamp: incandescent, 6 to 8-volt, 2-pin base (GE Type 12)	93519	2140-0012	1
F1	Fuse: cartridge, 250V, slow-blow (1 amp for 115-volt operation)	71400	2110-0007	1
	Fuse: cartridge, 250V, slow-blow (1/2 amp for 230-volt operation)	71400	2110-0008	1
L1	Coil: RF, 42 μH ±10% (Phenolic form)	99848	9140-0040	1
L2-9	Not assigned			
L10, 11	Coil: RF, 0.15 μH	28480	400D-60B	2

*Manufacturer not significant. Use reliable source.

†Average value selected at factory for calibration. Not the actual value required for replacement. Replace with the value that is currently in the VTVM.

TABLE F (CONT)

PARTS LIST – MODELS LISTED IN 1.06

CIRCUIT REFERENCE	DESCRIPTION	MANUFACTURER CODE	HEWLETT-PACKARD STOCK NUMBER	TOTAL QUANTITY
M1	Meter: Model 400D, replacement	28480	1120-0005	1
	Meter: Model 400H, replacement	28480	1120-0301	1
	Meter: Model 400L, replacement	28480	1120-0098	1
R1	Resistor: fixed, 110K ohms ±5%, 1 W	*	0689-1145	1
R2, 3	Not assigned			
R4	Resistor: fixed, film, 10.31M ohms ±1%, 1/2 W	19701	0698-4116	1
R5	Not assigned			
R6A, B	Resistor: fixed, 10 ohms ±10%, 1/2 W	*	0687-1001	2
‡R6C	Resistor: fixed, 56 ohms ±10% 1/2 W	*	0687-5601	1
R7	Resistor: fixed, 220K ohms ±10%, 1 W	*	0690-2241	2
R8	Not assigned			
R9	Resistor: fixed, 470 ohms ±10%, 1/2 W	*	0687-4711	2
R10-19	Not assigned			
R20	Resistor: fixed, 8.2K ohms ±10%, 2 W	*	0693-8221	2
R21	Resistor: fixed, 47K ohms ±10%, 1 W	*	0690-4731	4
R22	Same as R20			
R23	Resistor: fixed, film, 8.2K ohms ±5%, 1 W	14674	0761-0001	1
R24	Resistor: fixed, 47 ohms ±10%, 1/2 W	*	0687-4701	4
R25, 26	Not assigned			

Note: All resistors are composition unless otherwise stated.

***Manufacturer not significant. Use reliable source.**

‡Value selected at factory, optimum value shown. Replace with value in instrument.

TABLE F (CONT)

PARTS LIST – MODELS LISTED IN 1.06

CIRCUIT REFERENCE	DESCRIPTION	MANUFACTURER CODE	HEWLETT-PACKARD STOCK NUMBER	TOTAL QUANTITY
R27	Resistor: fixed, 125 ohms ±10%, 2 W	91637	0813-0009	1
R28, 29	Not assigned			
R30	Resistor: fixed, 1.2M ohms ±10%, 1/2 W	*	0687-1251	1
R31	Same as R24			
R32	Same as R21			
R33, 34	Resistor: fixed, 27K ohms ±10%, 2 W	*	0693-2731	4
R35	Resistor: fixed, 2.4K ohms ±5%, 1 W	*	0689-2425	2
R36	Resistor: fixed, 3.3M ohms ±10%, 1/2 W	*	0687-3351	1
R37	Resistor: fixed, 2.7M ohms ±10%, 1/2 W	*	0687-2751	1
R38	Resistor: fixed, 560 ohms ±10%, 1/2 W	*	0687-5611	2
R39	Resistor: fixed, 100K ohms ±10%, 1/2 W	*	0687-1041	1
R40	Same as R24			
R41	Same as R21			
R42, 43	Same as R33			
R44	Same as R35			
R45, 46	Not assigned			
R47	Same as R38			
R48	Resistor: fixed, 680K ohms ±10%, 1/2 W	*	0687-6841	1
R49	Same as R24			
R50	Same as R21			
R51	Resistor: fixed, 3.3K ohms ±10%, 1 W	*	0690-3321	1

Note: All resistors are composition unless otherwise stated.

*Manufacturer not significant. Use reliable source.

TABLE F (CONT)

PARTS LIST – MODELS LISTED IN 1.06

CIRCUIT REFERENCE	DESCRIPTION	MANUFACTURER CODE	HEWLETT-PACKARD STOCK NUMBER	TOTAL QUANTITY
R52	Resistor: fixed, 10K ohms ±10%, 2 W	*	0693-1031	1
R53	Resistor: fixed, 510 ohms ±5%, 1/2 W	*	0686-5115	1
R54	Resistor: fixed, 51 ohms ±5%, 1 W	*	0689-5105	1
R55	Resistor: fixed, 180K ohms ±10%, 2 W	*	0693-1841	1
R56	Resistor: fixed, 56K ohms ±10%, 1 W	*	0690-5631	1
R57	Resistor: fixed, wirewound, 6.3K ohms ±10%, 10 W	35434	0816-0017	1
R58	Resistor: fixed, 120K ohms ±10%, 1 W	*	0690-1241	1
R59	Resistor: fixed, 330K ohms ±10%, 1 W	*	0690-3341	1
R60	Resistor: fixed, 18K ohms ±10%, 1 W	*	0690-1831	1
R61	Resistor: fixed, 68K ohms ±10%, 1 W	*	0690-6831	1
R62	Resistor: fixed, film, 166K ohms ±1%, 1 W	19701	0730-0076	1
R63	Resistor: fixed, 100K ohms ±10%, 1/2 W	*	0687-1041	1
R64	Resistor: fixed, film, 90.5K ohms ±1%, 1 W	19701	0730-0065	1
R65	Not assigned			
R66	Resistor: variable, 4 ohms ±20%, 1 W	28480	2100-0077	1
R67	Same as R9			
R68	Resistor: fixed, 10 ohms ±10%, 1 W	*	0690-1001	1
R69-82	Not assigned			

Note: All resistors are composition unless otherwise stated.

***Manufacturer not significant. Use reliable source.**

TABLE F (CONT)

PARTS LIST – MODELS LISTED IN 1.06

CIRCUIT REFERENCE	DESCRIPTION	MANUFACTURER CODE	HEWLETT-PACKARD STOCK NUMBER	TOTAL QUANTITY
R83	Resistor: fixed, 470K ohms ±10%, 1/2 W	*	0687-4741	2
R84	Not assigned			
R85	Same as R83			
R86	Resistor: fixed, 47 ohms ±10%, 1/2 W	*	0687-4701	1
R87-99	Not assigned			
R100	Resistor: fixed, film, 10K ohms ±1%, 1/2 W	19701	0757-0839	1
R101	Resistor: variable, 500 ohms ±20%, 1/5 W	28480	2100-0151	1
R102	Resistor: fixed, 8.2M ohms ±10%, 1/2 W	*	0687-8251	1
R103	Resistor: fixed, 2.2M ohms ±10%, 1/2 W	*	0687-2251	1
R104	Resistor: fixed, wirewound, 10 ohms ±1/2%, 1/2 W	28480	400D-26F	2
R105	Resistor: fixed, wirewound, 205 ohms ±1/2%	28480	400D-26C	1
R106	Resistor: fixed, film, 40 ohms ±1%, 1/2 W	19701	0727-0018	1
R107	Resistor: variable, 100 ohms ±30%, 1/3 W	28480	2100-0108	1
R108	Same as R104			
R109	Not assigned			
R110	Resistor: fixed, 15K ohms ±10%, 1/2 W	*	0687-1531	1
R111-116	Resistor: assembly, matched set of 6 wirewound resistors, replaceable only as a set	28480	400D-26G	1
R117	Resistor: fixed, 6.8K ohms ±10%, 2 W	*	0693-6821	1
R118	Resistor: variable, 1M ohms ±30%, 0.2 W	28480	2100-0080	1

Note: All resistors are composition unless otherwise stated.

*Manufacturer not significant. Use reliable source.

TABLE F (CONT)

PARTS LIST – MODELS LISTED IN 1.06

CIRCUIT REFERENCE	DESCRIPTION	MANUFACTURER CODE	HEWLETT-PACKARD STOCK NUMBER	TOTAL QUANTITY
R119	Resistor: variable, 6K ohms ±20%, 0.3 W	28480	2100-0136	1
R120	Same as R7			
R121, 122	Resistor: fixed, 2.7 ohms ±10%, 1 W	*	0699-0005	2
S1	Switch: rotary, assembly, replace as unit	28480	400D-19A	1
S2	Switch: toggle, SPST (Arrow Type 80994-H)	04009	3101-0001	1
T1	Transformer: power, replacement	28480	9100-0050	1
V1-5	Tube: electron, 6CB6	*	5080-0621	5
V6	Tube: electron, 6AX5-GT	*	1930-0014	1
V7	Tube: electron, 12B4A	*	1921-0010	1
V8	Tube: electron, 6U8	*	1933-0004	1
V9	Tube: electron, 0B2 or 5651	*	1940-0001	1
	MISCELLANEOUS			
	Bezel: instrument mounting	28480	5020-0137	1
	Board: printed circuit, no components	28480	400D-65C-1	1
	Board: printed circuit, no components	†	400D-75F-1	1
		†	400D-75G-1	1
		†	400D-75G-2	1
	Cabinet	28480	400D-44B	1
	Cable: assembly, power, 400D, -H, -L (Belden, Type CS-9941/ PH151/7.5FT)	70903	8120-0050	1
	Cable: assembly, power, H02-400D	28480	H02-400D PWR CORD	1

Note: All resistors are composition unless otherwise stated.

*Manufacturer not significant. Use reliable source.

†Obtain number from board in VTVM.

TABLE F (CONT)

PARTS LIST – MODELS LISTED IN 1.06

REFERENCE	DESCRIPTION	MANUFACTURER CODE	HEWLETT-PACKARD STOCK NUMBER	TOTAL QUANTITY
	MISCELLANEOUS (Cont)			
	Connector: plug, electrical, H02-400D	*	1251-0037	1
	Fuseholder: (Littlefuse Type 342014)	75915	1400-0084	1
	Insulator: standoff	28480	0340-0089	2
	Insulator: standoff	28480	0340-0090	2
	Knob: RANGE switch	28480	0370-0035	1
	Lampholder: 2-pin base (Drake Type 2020-AE)	72765	1450-0022	1
	Lens: indicator light (Drake Type 14L-15)	72765	1450-0020	1
	Panel: front, 400D and H02-400D	28480	400D-2	1
	Panel: front, 400H and 400L	28480	400H-2A	1
	Panel: rear	28480	400D-1A	1
	Post: binding, red	28480	1510-0008	2
	Post: binding, black	28480	1510-0009	2
	Socket: electron tube (Elco Type 316PH-3702)	91662	1200-0009	6
	Socket: electron tube (Cinch Type 44F-16388)	71785	1200-0008	2
	Socket: electron tube (Cinch Type 51A-12272)	71785	1200-0020	1

*Manufacturer not significant. Use reliable source.

TABLE G

CODE LIST OF MANUFACTURERS

CODE NUMBER	MANUFACTURER	ADDRESS
04009	Arrow, Hart and Hegeman Electric Co	Hartford, Conn
14655	Cornell Dubilier Electric Co	S Plainfield, NJ
14674	Corning Glass Works	Corning, NY
19701	Electra/Midland Corp.	Kansas City, Mo
28480	Hewlett-Packard Co	Palo Alto, Calif
35434	Lectrohm, Inc	Chicago, Ill.
56289	Sprague Electric Co	North Adams, Mass.
70903	Belden Manufacturing Co	Chicago, Ill.
71400	Bussman Fuse, Division of McGraw-Edison Co	St Louis, Mo
71785	Cinch Manufacturing Corp.	Elk Grove Village, Ill.
72765	Drake Manufacturing Co	Harwood Heights, Ill.
72982	Erie Technological Products, Inc	Erie, Pa.
75915	Littlefuse, Inc	Des Plaines, Ill.
81482	Cooperative Industries, Inc	Chester, NJ
82577	Hughes Aircraft Co	Newport Beach, Calif
84411	T R W Capacitor Co	Ogallala, Neb
91637	Dale Electronics, Inc	Columbus, Neb
91662	Elco Corp.	Willow Grove, Pa.
93519	General Electric Co	Cleveland, Ohio
99848	Wilco Corp.	Indianapolis, Ind

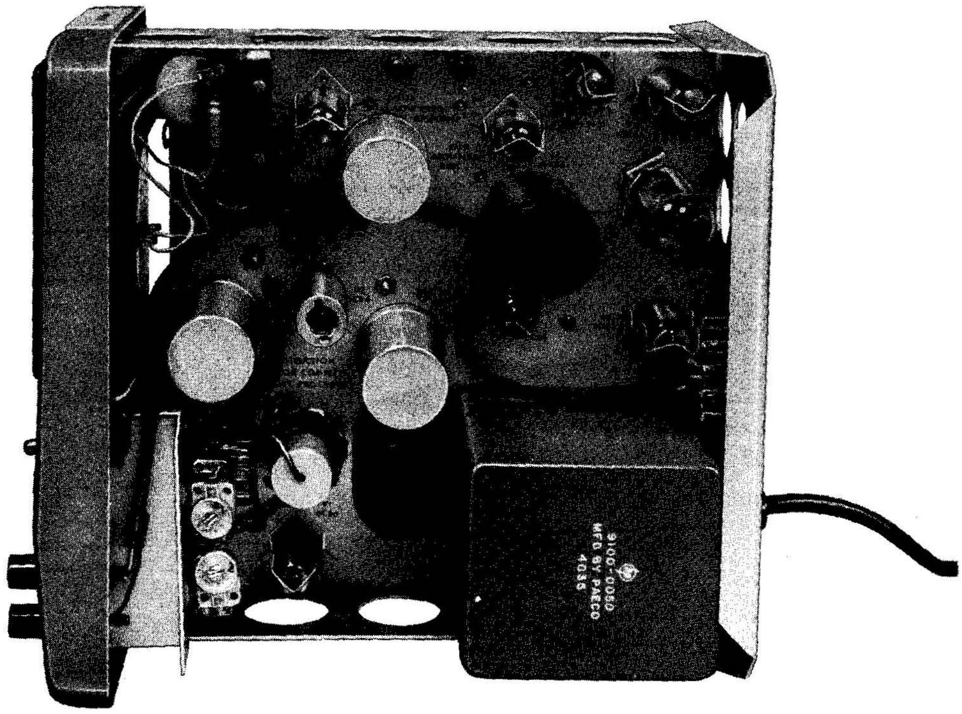


Fig. 14—Left Side View of VTVM Chassis—Models Listed in 1.06

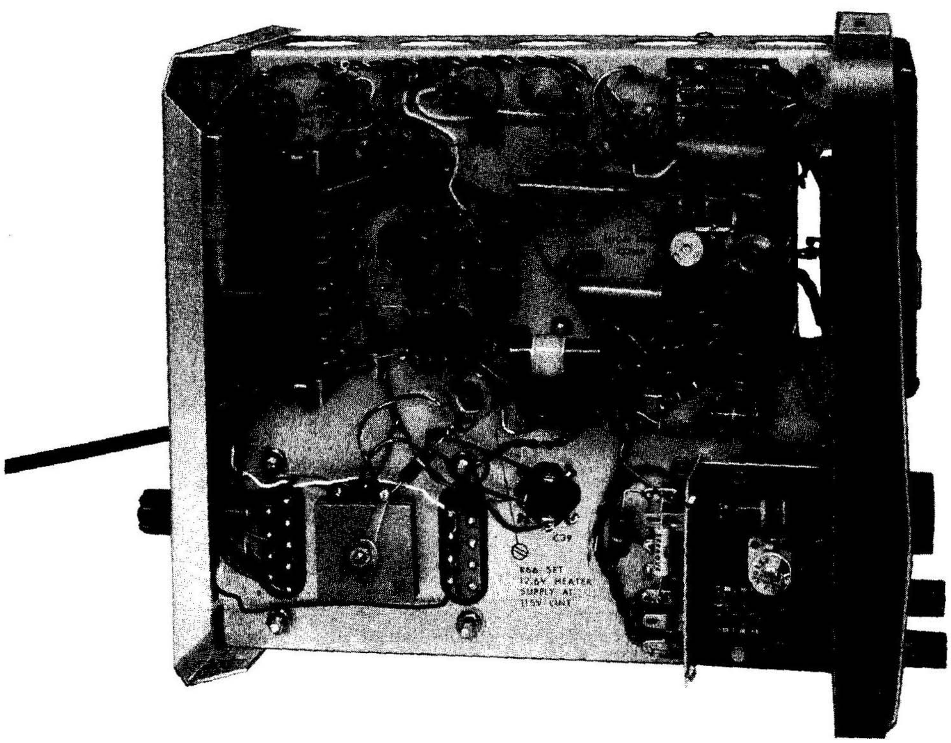


Fig. 15—Right Side View of VTVM Chassis—Models Listed in 1.06

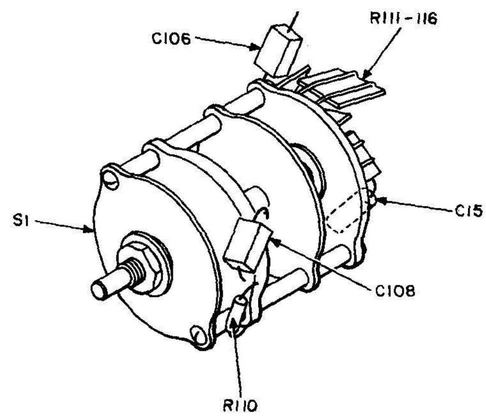


Fig. 16—Range Switch Assembly—Models Listed in 1.06

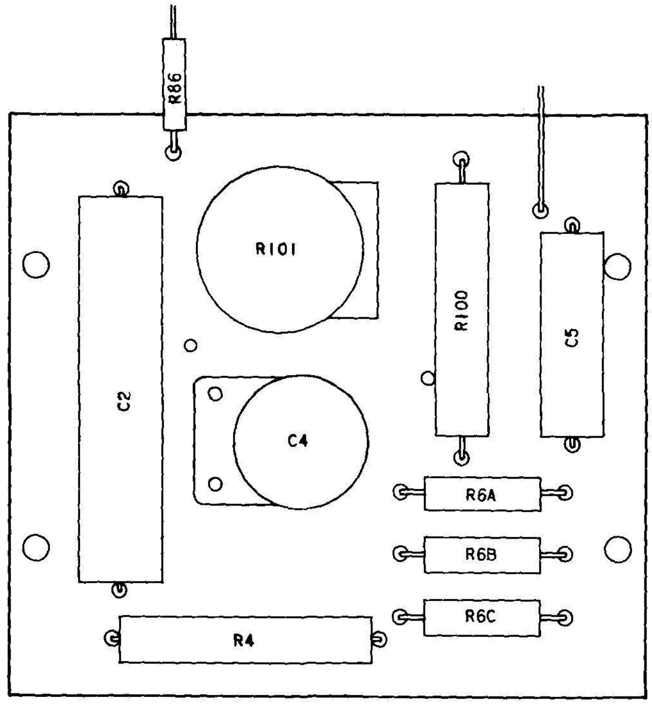


Fig. 17—Printed Circuit Board Assembly, Part No. 400D-65C—Models Listed in 1.06

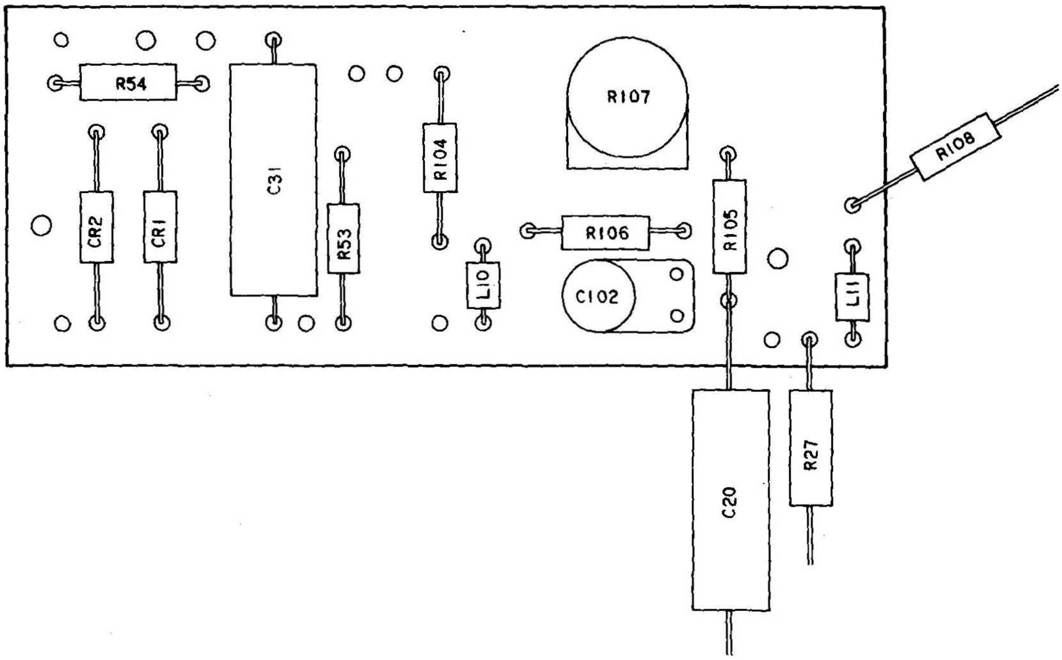


Fig. 18—Printed Circuit Board Assembly, Part No. 400D-75F—Models Listed in 1.06

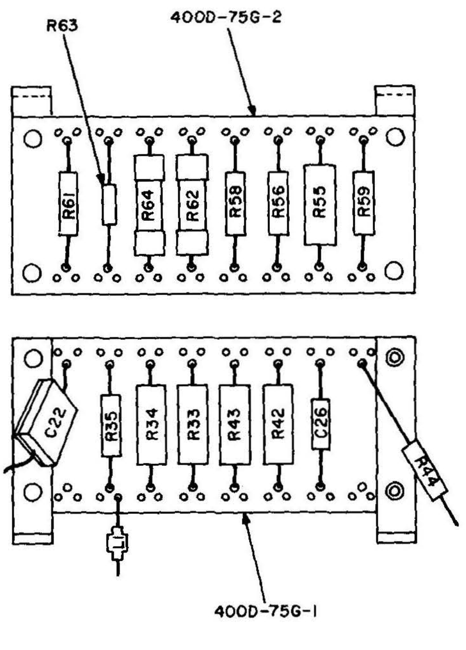


Fig. 19—Printed Circuit Board Assembly, Part No. 400D-75G—Models Listed in 1.06

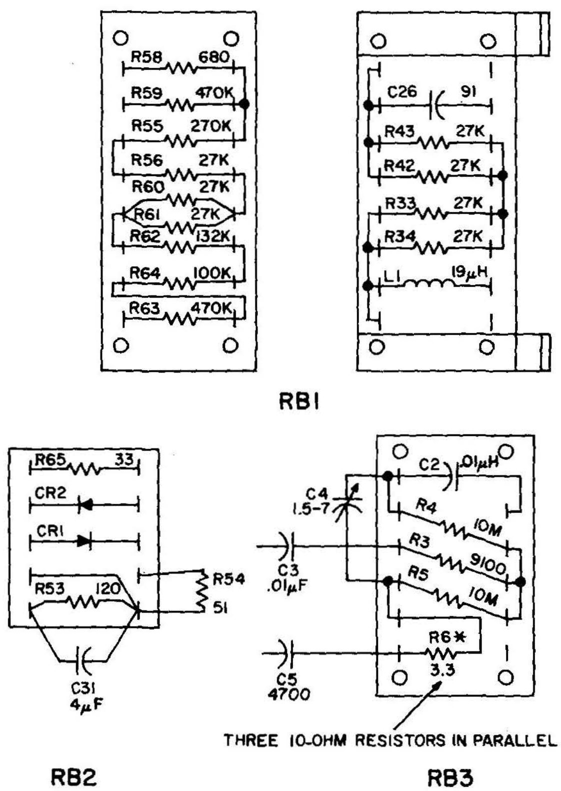


Fig. 20—Resistor Board Detail—Models Not Listed in