INSTRUCTIONS

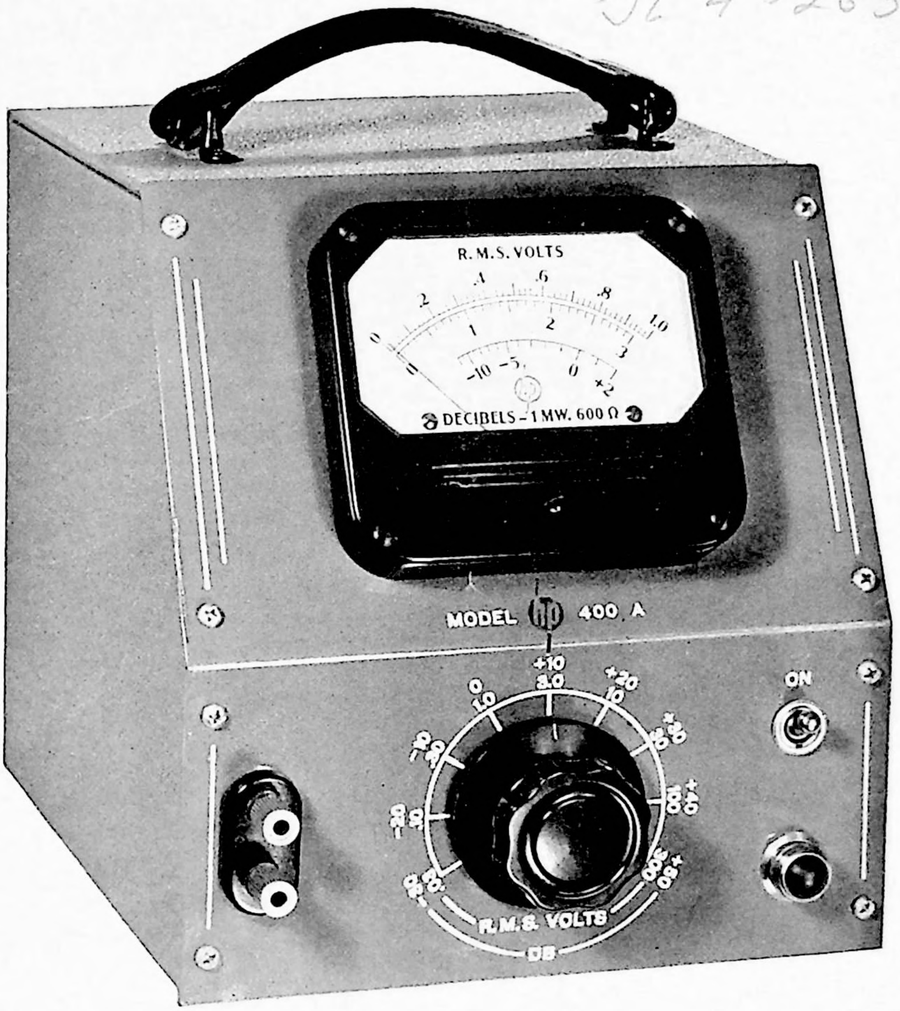
MODEL 400A
VACUUM TUBE VOLTMETER

HEWLETT-PACKARD COMPANY
Laboratory Instruments for Speed and Accuracy
395 PAGE MILL ROAD PALO ALTO, CALIF.

I often say that when you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely, in your thoughts, advanced to the stage of science, whatever the matter may be.

—Lord Kelvin, 1883.

Stolen From
C. M. Jorgensen
2304 Henley St
Glenview, Ill
GL 4-2637



Hewlett-Packard Model 400A Vacuum Tube Voltmeter is an extremely useful laboratory instrument designed for a-c voltage measurements especially in the communications and electronics fields. Its simplicity of operation, accuracy, small size, and wide frequency and voltage range make it unquestionably one of the outstanding test equipments available to the industry today.

—hp— MODEL 400A

VACUUM TUBE VOLTMETER

ELECTRICAL SPECIFICATIONS

VOLTAGE RANGES:	Nine (0.03, 0.1, 0.3, 1.0, 3.0, 10.0, 30.0, 100, and 300 volts).
FREQUENCY RANGE:	10 cps to 1 mc.
OVERALL ACCURACY:	Within ±3% from 10 cps to 100 kc and within ±5% to 1 mc.
VOLTMETER INDICATION:	Proportional to the average value of the rectified full wave.
VOLTMETER CALIBRATION:	Volts—rms value of a sine wave. Decibels—from a reference level of 1 milliwatt in 600 ohms.
SCALE:	Linear.
INPUT IMPEDANCE:	Input capacity—approximately 15 mmfd. Shunt resistance— 30-volt range and below: 1 megohm. 100-volt range: 3 megohms. 300-volt range: 2.4 megohms.
REGULATED POWER SUPPLY:	Line voltage variations from 105 to 125 volts cause less than ±3% variations in reading on all frequencies below 100 kc. and less than 5% on all frequencies between 100 kc. and 1 mc.
OVERVOLTAGE CAPACITY:	100 times normal will not damage meter.
POWER REQUIREMENTS:	115 volts, 50-60 cps, 40 watts.

MECHANICAL SPECIFICATIONS

DIMENSIONS:	9½″ high, 7½″ long, 10½″ deep.
WEIGHT:	15 pounds.
FINISH:	Panel—gray baked enamel. Chassis—gray wrinkle enamel.

OPERATING INSTRUCTIONS

Initial Adjustments

Before being shipped from the factory, this instrument has been rigidly tested and inspected and is ready for use when first received. After unpacking the unit, however, it is desirable to make an inspection for possible damage in transit. Directions will be found at the rear of this book regarding procedure to be followed if any damage is found.

Before turning the instrument on for the first time, make certain that the tubes are all secure in their sockets.

Operation

Snap on the power switch and allow the instrument to heat for five minutes or so after which it is ready for operation.

The range selector switch is the only control for the instrument and indicates the full-scale voltage value of each of the nine voltage ranges. When switching from range to range, a transient deflection of the meter pointer may be noticed. This deflection is normal, however, and will not affect the accuracy of the readings.

Although the instrument will withstand large overloads, it is desirable to set the range switch to one of the higher ranges before connecting to an unknown voltage.

It should be noted that the lower input terminal of the Model 400A is grounded and therefore should not be connected to any potential above ground unless precautions are taken to insulate the voltmeter.

Input Impedance

On all ranges except the 100- and 300-volt ranges, the input resistance of the Model 400A is one megohm. On the 100-volt range, the input resistance is 3 megohms, and on the 300-volt range the input resistance is 2.4 megohms. The input capacity is approximately 15 micromicrofarads in parallel with the input resistance.

Calibration

The Model 400A is calibrated to indicate the rms value of a sine wave, but the instrument responds to the average value of the rectified full wave applied. Because both the positive and negative portions of the applied wave thus influence the meter, "turn-over" effects are negligible and errors caused by the presence of harmonics in the applied voltage are minimized.

If harmonics are present in the applied voltage, the error in the indication of the Model 400A is dependent upon the magnitude and phase of the harmonics. Since the phase of the harmonics is seldom known (even though their magnitude be known), the following table will prove useful in determining the maximum error present in the indications.

In the first column of the table a wave is listed having harmonics given in terms of the fundamental. In the second column the actual rms value of the wave of column I is given, while the third column gives the reading which would be obtained with the Model 400A. The fourth column gives the indication which might be obtained with a peak-reading meter calibrated in terms of the rms value of a sine wave.

% Harmonic	Actual Rms Value	400A Indication	Peak Meter Indication
0	100	100	100
10% 2nd.	100.5	100	90 to 110
20% 2nd.	102	100-102	80 to 120
50% 2nd.	112	100-110	75 to 150
10% 3rd.	100.5	96 to 104	90 to 110
20% 3rd.	102	94 to 108	82 to 120
50% 3rd.	112	90 to 116	108 to 150

DB Calibration

In addition to its voltage calibration, the Model 400A is calibrated in decibels from the accepted standard of zero level at 1 milliwatt in 600 ohms. Therefore, the instrument can be used very conveniently as a gain-measuring device. Although true power levels are limited to a 600-ohm basis (unless calculated), the instrument will show voltage comparisons directly in terms of decibels regardless of the impedance of the device under test, as long as the readings are taken across the same impedance.

Overloads

Large overloads of 100 times the scale reading of the voltmeter will not damage the meter, owing to the limiting action of the amplifier. In general, however, overloads are undesirable and should be avoided.

Circuit Description

Referring to the schematic diagram opposite page 10, it may be seen that voltages applied to the input terminals are passed through a blocking capacitor to the grid of the 6J5 cathode-follower input stage. The cathode resistor is a tapped precision wire-wound resistor which serves as the voltmeter multiplier on all but the two highest ranges. On the latter two ranges a high-resistance frequency-compensated voltage divider is switched across the input terminals and ahead of the grid of the first tube.

The cathode follower feeds into a broad-band resistance-coupled amplifier using 6AC7 tubes. Negative feedback is used in this amplifier in order to obtain high stability and uniform response over a wide frequency range, and to make the amplifier more independent from variations in tube characteristics.

From the amplifier the voltage is passed to a full-wave rectifier using a 6H6 duo-diode tube. The indicating meter is connected from one plate to the opposite cathode of the tube and therefore is actuated by a portion of the plate current of the two diodes.

Direct current for the plate supply of the tubes in the instrument is obtained from a conventional full-wave rectifier feeding into a resistance-capacity filter. A voltage-regulating circuit across the output of the rectifier keeps the plate supply voltage constant over a wide range of line voltages.

Throughout the circuit large resistance-capacity filters are used to isolate the individual stages and to prevent any feedback from currents flowing through the common power supply impedance.

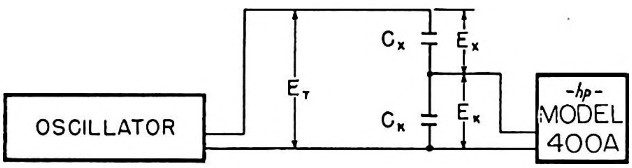
APPLICATIONS

A precision voltmeter is one of the most useful and most used equipments in the laboratory and production departments. In addition to the more common measurements in the audio, supersonic, and lower broadcast range, the -hp- Model 400A can be used in a number of special applications to measure capacitance, resistance, volume levels, etc. Some of these special applications are set out below for the convenience of the user.

Capacitance Measurements

The following method for measuring capacity is only one of many methods, but since most of the other methods require that the frequency used be known, the method below is offered.

Connect a known capacitor in series with the unknown capacitor across the output of an oscillator as shown in the diagram. Measure E_t and E_k. Obtain E_x by subtraction.



Then, if C_k = known capacitor,

$$E_x = E_t - E_k \qquad (1)$$

$$\text{and } C_x = (C_k + 15 \text{ mmf}) \frac{E_k}{E_x} \qquad (2)$$

In equation (2) above, the 15 micromicrofarads represent the input capacity of the Model 400A and may often be neglected because of its negligible effect on the measurement.

Resistance Measurement

Resistance can be measured in a manner similar to that for capacitance. Connect the resistors the same way as the capacitors. Measure E_t and E_k and calculate the unknown resistance as follows:

$$E_x = E_t - E_k \qquad (1)$$

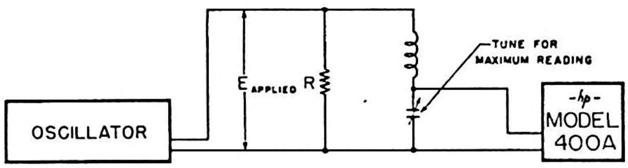
then

$$R_x = \frac{R_k \cdot R_{400A}}{R_k + R_{400A}} \cdot \frac{E_x}{E_k} \qquad (2)$$

R_{400A} in equation (2) represents the input resistance of the Model 400A (see page 3) and may often be neglected if the resistors being measured have low values.

Figure of Merit Measurements

Using the circuit shown below, the Q or figure of merit of a coil can be easily determined with an -hp- Model 400A for frequencies as high as one megacycle. Since the voltage across the inductance at resonance equals QE (where E is the output of the oscillator), it is necessary only to measure the output of the oscillator and the voltage across the inductance.



The voltage from the oscillator should be introduced across a low value of resistance (about 1/100 of the anticipated radio frequency resistance of the LC circuit to obtain errors of not more than 1%). For average measurements this resistor may be of the order of 0.1 ohm.

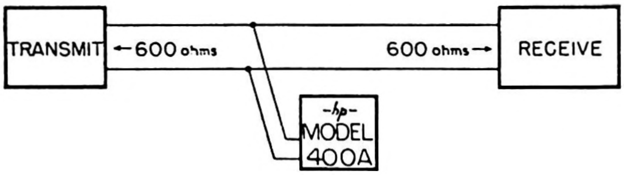
When the oscillator at hand is not designed to operate into impedances of 0.1 ohm, it is necessary to use some sort of a matching device. For instance, a transformer is often convenient to use with the -hp- Model 200C Oscillator. It is desirable to make C as large as convenient in order to minimize the ratio of the impedance of the circuit looking back from the Model 400A to the impedance of the Model 400A.

The voltage across the resistor is made some small even value—say 0.01 volt. Then the LC circuit is adjusted to resonance and the resultant voltage is measured. The Q of the circuit can then be calculated, for

$$Q = \frac{\text{Resonant voltage across condenser}}{\text{Voltage across resistor}}$$

VU Meter

The Model 400A can be used very easily as a VU meter because of its 600-ohm decibel calibration. When used in this manner, the decibel calibration becomes a *vu* calibration.



The instrument can be used on other than 600-ohm lines by adding to the voltmeter reading:

+10.78 *vu* for a 50-ohm line
+ 4.76 *vu* for a 200-ohm line
+ .78 *vu* for a 500-ohm line
—9.2 *vu* for a 5000-ohm line

Bridge Measurements

In bridge work the Model 400A will be found to be a sensitive, quick-acting null detector. However, it is recommended that the Model 400A be used only in bridges where one side of the detector can be at ground. In such bridges the Model 400A can be used as a null detector at frequencies up to four or five megacycles.

MAINTENANCE

General—Tubes

The Model 400A Vacuum Tube Voltmeter requires no maintenance other than occasional replacement of tubes and removal of any accumulated dust and dirt. The design of the circuit is such that changing tubes will have only a slight effect on the calibration of the instrument, especially at frequencies below 100 kc. Tubes which differ widely from the average type characteristics can, however, affect calibration at frequencies above 100 kc, and for this reason it is desirable that the calibration be checked if possible when 6AC7 and 6H6 tubes are replaced.

Calibration Check

Probably the most accurate method which can be used in the field to check the calibration of the Model 400A is a test using a cathode-ray oscilloscope and a freshly calibrated dynamometer type voltmeter.

After the new tube has heated in the Model 400A, apply a low-frequency (50-60 cps) voltage simultaneously to both the Model 400A and the dynamometer type voltmeters. Readings of the two instruments should agree closely. Try another tube if necessary.

Next, calibrate the cathode-ray tube of the oscilloscope by applying a low-frequency sinusoidal voltage simultaneously to the dynamometer voltmeter and to the vertical-deflecting electrodes of the c-r tube. No horizontal sweep voltage should be used. Directions for connecting to the deflecting electrodes of the tube are usually given by the manufacturer of the oscilloscope. By measuring the peak-to-peak deflection of the c-r tube trace with a graph screen and by noting the reading of the voltmeter, the deflection voltage of the c-r tube can be quickly determined. It is important that the voltage used to calibrate the c-r tube be essentially sinusoidal and free from harmonics.

Now connect the Model 400A in parallel with the vertical-deflecting plates of the c-r tube and apply sinusoidal voltages of frequencies up to one megacycle to the combination of the two instruments. The voltage shown by the Model 400A should agree closely with that indicated by the magnitude of deflection of the c-r tube trace. If such is not the case, try another new tube in the Model 400A and repeat the process.

The above procedure will give a reasonable check at all frequencies within the range of the Model 400A, although a check cannot be made of small voltages. Low voltage ranges can be checked by starting with a voltage within one of the ranges checked on the oscilloscope and working downward. For example, if the accuracy and frequency response of the 100-volt range of the Model 400A have been checked on the oscilloscope, apply a 25-volt wave to the Model 400A and note the reading on the 100-volt range. Then switch to the 30-volt range and note that the reading is correct. By extending this procedure, all ranges of the instrument can be checked.

Although the above methods will not give precision results, they will often prove helpful in determining whether or not old tubes have exceeded their service life or new tubes are satisfactory to use.

Now and then, when replacing 6AC7 tubes, a permanent deflection of the meter pointer will be observed with the input terminals shorted and when the new tube has heated. This condition is usually caused by cathode-heater leakage and the tube should be rejected in favor of another.

When replacing 6H6 and/or 6AC7 tubes, it is desirable to check the voltage response of the new tube if the voltmeter is being operated from an unregulated line voltage. This check can be made by applying a constant voltage to the input terminals and varying the line voltage ±10 volts from 115 volts. The voltmeter reading should not change by more than 3% at frequencies below 100 kc nor by more than 5% at frequencies below one megacycle. Try another tube if necessary.

A defective neon regulator lamp will sometimes cause the meter pointer to have a continuous reading well up on the scale with no input. This condition may or may not exist on all ranges. Replace the neon lamp (see parts list at back of book) and check d-c voltage at the cathode of the 6V6 tube with a high-impedance instrument. The cathode voltage should be approximately 215 volts. Try another neon lamp if necessary.

Beyond changing tubes and the neon lamp, it is not recommended that repair or recalibration of this instrument be attempted in the field, because of the elaborate equipment required. The Hewlett-Packard Company will recalibrate the instrument quickly and at a nominal charge. Use of this service will usually save a great deal of time.

LIST OF COMPONENT PARTS

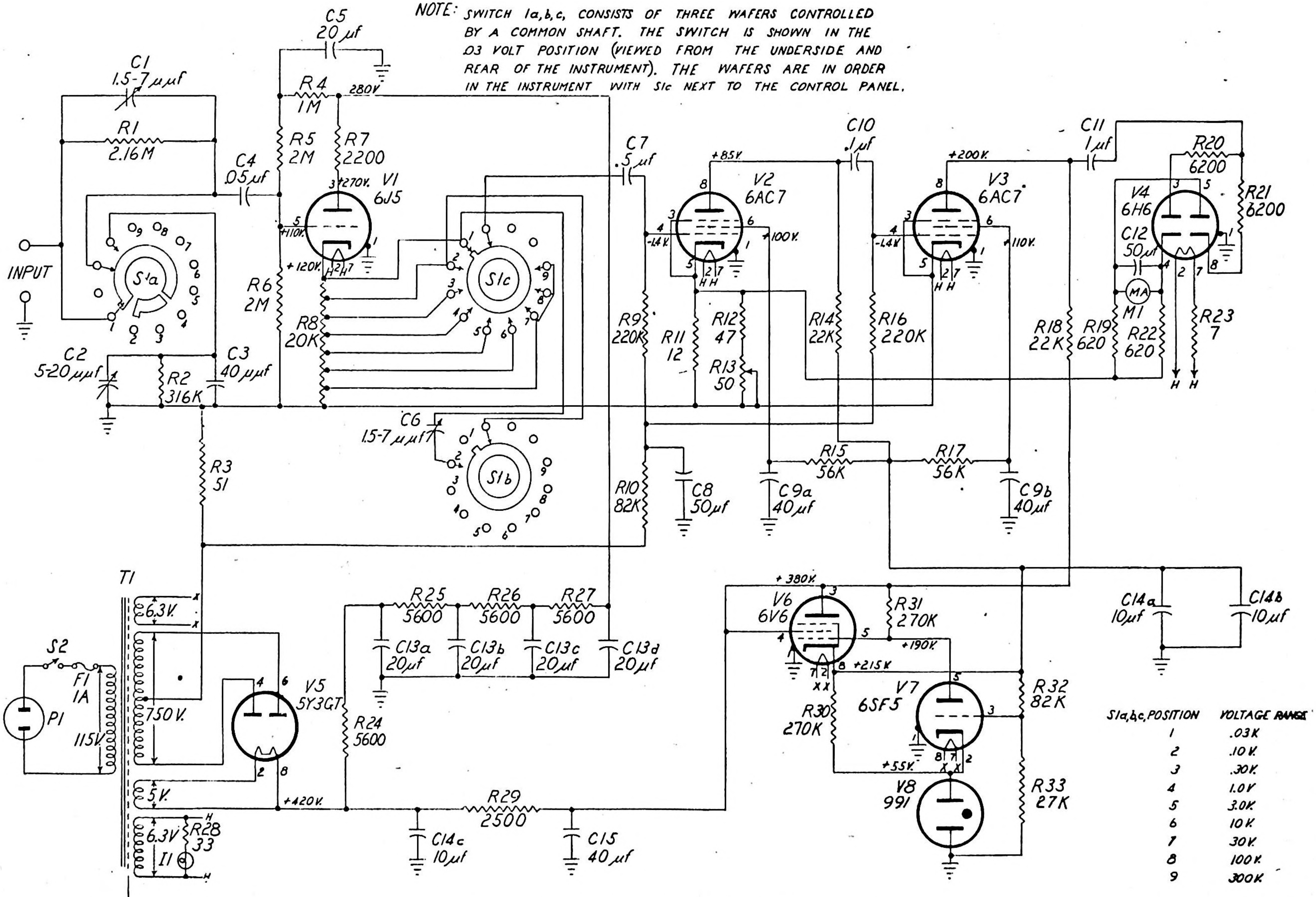
Symbol	Description	Function	HP Stock No.	Mfg. Code Ref.
C1	CAPACITOR: variable; ceramic; 1.5-7 micromicrofarad.	Frequency compensating capacitor	13-T-7	Erie: TS2A
C2	CAPACITOR: variable; ceramic; 5-20 micromicrofarad.	Frequency compensating capacitor	13-T-20	Erie: TS2A
C3	CAPACITOR: fixed; mica; 40 micromicrofarad; ±10%; 500 vdcw	Frequency compensating capacitor	14-40	Micamold: Type OXM
C4	CAPACITOR: fixed; paper; .05 microfarad, —10% +30%; 600 vdcw	Blocking capacitor	16-15	Aerovox: Type 684
C5	CAPACITOR: fixed; electrolytic; 20 microfarad, —10% +50%; 450 vdcw	Decoupling capacitor	18-20	Mallory: FPS-144
C6	CAPACITOR: Same as C1	Frequency compensating capacitor		
C7	CAPACITOR: fixed; paper; .5 microfarad, —10% +20%; 600 vdcw	Blocking capacitor	16-5	Aerovox: Type 684
C8	CAPACITOR: fixed; electrolytic; 50 microfarad, —10% +200%; 50 vdcw	Decoupling capacitor	18-50	Mallory: WB-39
C9a, b	CAPACITOR: fixed; electrolytic; two sections, each 40 microfarads; 450 vdcw	Decoupling capacitor	18-240	Mallory: FPD-238
C10	CAPACITOR: fixed; paper; .1 microfarad, —10% +20%; 600 vdcw	Blocking capacitor	16-1	Aerovox: Type 684
C11	CAPACITOR: fixed; paper; 1 microfarad, ±10%; 600 vdcw	Blocking capacitor	17-1	Girard-Hopkins: P2
C12	CAPACITOR: Same as C8	Bypass capacitor		
C13a, b, c, d	CAPACITOR: fixed; electrolytic; four sections, each 20 microfarads; 450 vdcw	Filter capacitor	18-420	Mallory: FPS-444
C14a, b	CAPACITOR: fixed; electrolytic; three sections, each 10 microfarads —10% +50%; 450 vdcw	Decoupling capacitor	18-310	Mallory: FPT-389
C15	CAPACITOR: fixed; electrolytic; 40 microfarads; 450 vdcw	Decoupling capacitor	18-40	Mallory: FPS-146
F1	FUSE: cartridge type; 3AG size; 1 ampere; 250 volts	A-c line fuse	211-1	Littelfuse: 1040
M1	METER, MILLIAMMETER: D-c; 0-1 ma; scale calibrated in volts and in decibels	Indicating meter	112-400	Weston: Model 801
R1	RESISTOR: fixed; composition; 2.16 megohms; ±2%; 1 watt	Voltage divider	29-2.16M	Continental Carbon: A-1
R2	RESISTOR: fixed; composition; 316,000 ohms; ±2%; 1 watt	Voltage divider	29-316K	Continental Carbon: A-1
R3	RESISTOR: fixed; composition; 51 ohms; ±5%; 1 watt	Grid bias resistor	24-5-51	Allen-Bradley: GB5105
R4	RESISTOR: fixed; composition; 1 megohm; ±10%; 1 watt	Decoupling resistor	24-1M	Allen-Bradley: GB-1051
R5	RESISTOR: fixed; composition; 2 megohms; ±.25%; 1 watt (measured to value by Hewlett-Packard Co.)	Voltage divider	4A-79	Continental Carbon: A-1
R6	RESISTOR: Same as R5	Voltage divider		
R7	RESISTOR: fixed; composition; 2200 ohms; ±10%; ½ watt	Plate resistor	23-2200	Allen-Bradley: EB-2221
R8	RESISTOR: fixed; wirewound; tapped; 20,000 ohms; ±.5%; (part of range switch assembly S1, HP Stock 4A19)	Voltage divider		

LIST OF COMPONENT PARTS (Continued)

Symbol	Description	Function	Stock No. HP	Mfg. Code Ref.
R9	RESISTOR: fixed; composition; 220,000 ohms; ±10%; ½ watt	Grid resistor	23-220K	Allen-Bradley: EB-2241
R10	RESISTOR: fixed; composition; 82,000 ohms, ±10%; 1 watt	Decoupling resistor	24-82K	Allen-Bradley: GB-8231
R11	RESISTOR: fixed; wirewound; nominally 12 ohms; adjusted to circuit at factory	Cathode resistor	4A-90	Hewlett-Packard: 4A-90
R12	RESISTOR: fixed; composition; 47 ohms; ±10%; ½ watt	Cathode resistor	23-47	Allen-Bradley: EB-4701
R13	POTENTIOMETER: wirewound; 50 ohms; 1 watt	Amplifier gain adjusting resistor	210-50W	Globe-Union: 21-010-067
R14	RESISTOR: fixed; composition; 22,000 ohms, ±10%; 2 watts	Plate resistor	25-22K	Allen-Bradley: HB2231
R15	RESISTOR: fixed; composition; 56,000 ohms, ±10%; 1 watt	Decoupling resistor	24-56K	Allen-Bradley: GB-5631
R16	RESISTOR: Same as R9	Grid resistor		
R17	RESISTOR: Same as R15	Decoupling resistor		
R18	RESISTOR: Same as R14	Plate resistor		
R19	RESISTOR: fixed; composition; 620 ohms, ±5%; ½ watt	Rectifier bridge resistor	23-5-620	Allen-Bradley: EB-6215
R20	RESISTOR: fixed; composition; 6200 ohms, ±5%; 1 watt	Rectifier bridge resistor	24-5-6200	Allen-Bradley: GB-6225
R21	RESISTOR: Same as R20	Rectifier bridge resistor		
R22	RESISTOR: Same as R19	Rectifier bridge resistor		
R23	RESISTOR: fixed; wirewound; 7 ohms, ±5%; 1 watt	Voltage dropping resistor	2G52	Hewlett-Packard: 2G52
R24	RESISTOR: fixed; composition; 5600 ohms, ±10%; 1 watt	Filter resistor	24-5600	Allen-Bradley: GB-5621
R25	RESISTOR: Same as R24	Filter resistor		
R26	RESISTOR: Same as R24	Filter resistor		
R27	RESISTOR: Same as R24	Filter resistor		
R28	RESISTOR: fixed; composition; 33 ohms, ±10%; 1 watt	Voltage dropping resistor	24-33	Allen-Bradley: GB-3301
R29	RESISTOR: fixed; wirewound; 2500 ohms; ±10%; 10 watts	Filter resistor	26-2500	Lectrohm: Type 1-¾ E
R30	RESISTOR: fixed; composition; 270,000 ohms, ±10%; 1 watt	Voltage dropping resistor	24-270K	Allen-Bradley: GB-2741
R31	RESISTOR: Same as R30	Plate resistor		
R32	RESISTOR: Same as R10	Voltage divider		
R33	RESISTOR: fixed; composition; 27,000 ohms, ±10%; 1 watt	Voltage divider	24-27K	Allen-Bradley: GB-2731
S1a, b, c	SWITCH, ASSEMBLY: rotary; 3 sections, 9 position switch; includes R5 and C9	Range selector switch	4A19	Hewlett-Packard: 4A19
S2	SWITCH: toggle; SPST; 3 amperes, 250 volts	A-c power switch	310-11	Arrow-Hart & Hegemann: 20994
T1	TRANSFORMER, POWER: pri-115 volts 50-60 cyc; Sec- 750 volts @40 ma CT; 5 volts @2 amps; 6.3 volts @2 amps; 6.3 volts @ 1 amp.	Power transformer	4A8	Hadley: 8160-A

LIST OF COMPONENT PARTS (Continued)

Symbol	Description	Function	HP Stock No.	Mfg. Code Ref.
V1	VACUUM TUBE: type 6J5	Input cathode follower	212-6J5	
V2	VACUUM TUBE: type 6AC7	Amplifier	212-6AC7	
V3	VACUUM TUBE: Same as V2	Amplifier		
V4	VACUUM TUBE: type 6H6 duo-diode	Full wave rectifier	212-6H6	
V5	VACUUM TUBE: type 5Y3GT/G full wave rectifier	Power rectifier	212-5Y3	
V6	VACUUM TUBE: type 6V6 beam power tetrode	Voltage regulator	212-6V6	
V7	VACUUM TUBE: type 6SF5 triode	Voltage regulator	212-6SF5	
V8	LAMP, GLOW: 105-125 V, ¼W; bulb-T4-½ clear;	Voltage regulator	211-N	General Electric: NE 16 T4½ ¼W
	LAMPHOLDER: double contact bayonet base	Socket for V8	38-N	Dial Light Co.: Cat. P-9606
	POST, BINDING: ferrule thumbscrew type;	Binding post	312-BP	Hewlett-Packard: 312-BP
	INSULATOR, FEEDTHRU: rectangular; molded black phenolic	Insulate binding posts	312-TI	General Radio: 274-Y
	KNOB: molded black phenolic	Range switch knob	37-2	Kurz-Kasch: S-311-642
	LAMPHOLDER, ASSEMBLY: Min bayonet base; ruby glass lens	Pilot lamp holder	312-P	Signal Indicator: 807BS
	LAMP: incandescent miniature bayonet base; 6-8 volts; .15 amps	Pilot lamp	211-47	General Electric: 47
	SOCKET, TUBE: std octal molded bakelite	Socket for V1 through V7	38-8	Cinch: 9950
	HANDLE	Carrying handle	312-LH	Specialty Leather Prod. Co.: Cat. 467



SCHEMATIC DIAGRAM FOR -hp- MODEL 400A VACUUM TUBE VOLTMETER

CLAIM FOR DAMAGE IN SHIPMENT

The instrument should be tested as soon as it is received. If it fails to operate properly, or is damaged in any way, a claim should be filed with the carrier. A full report of the damage should be obtained by the claim agent, and this report should be forwarded to us. We will then advise you of the disposition to be made of the equipment and arrange for repair or replacement. Include model number, type number and serial number when referring to this instrument for any reason.

WARRANTY

Our instruments are guaranteed to be free from defects in material and workmanship for one year from date of purchase. Our liability under this warranty is limited to repair and adjustment or replacement of defective parts (except tubes, fuses and batteries) of any instrument which shall within one year after making delivery to the original purchaser be returned to the factory for that purpose with transportation charges prepaid, and which upon our examination shall be found to be defective. This warranty covers service for the first year without charge except for transportation to the factory.

If, during subsequent service, any fault develops in the equipment, the following steps should be taken:

1. Notify us, giving full particulars of the difficulty, and include the serial and type numbers of the instrument in question. On receipt of this information, we will give you service information or shipping instructions.

2. On receipt of shipping instructions, forward the apparatus to us prepaid, and we will make repairs and adjustments immediately at the factory. The instrument will then be returned via express collect.

If the fault has been caused by misuse or abnormal conditions of operation as disclosed by our examination, repairs will be billed at cost. In this case, an estimate of the cost will be submitted before the work is started.

DO NOT HESITATE TO CALL ON US

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