HEWLETT-PACKARD COMPANY / OPERATING AND SERVICE MANUAL

738AR

VOLTMETER CALIBRATOR

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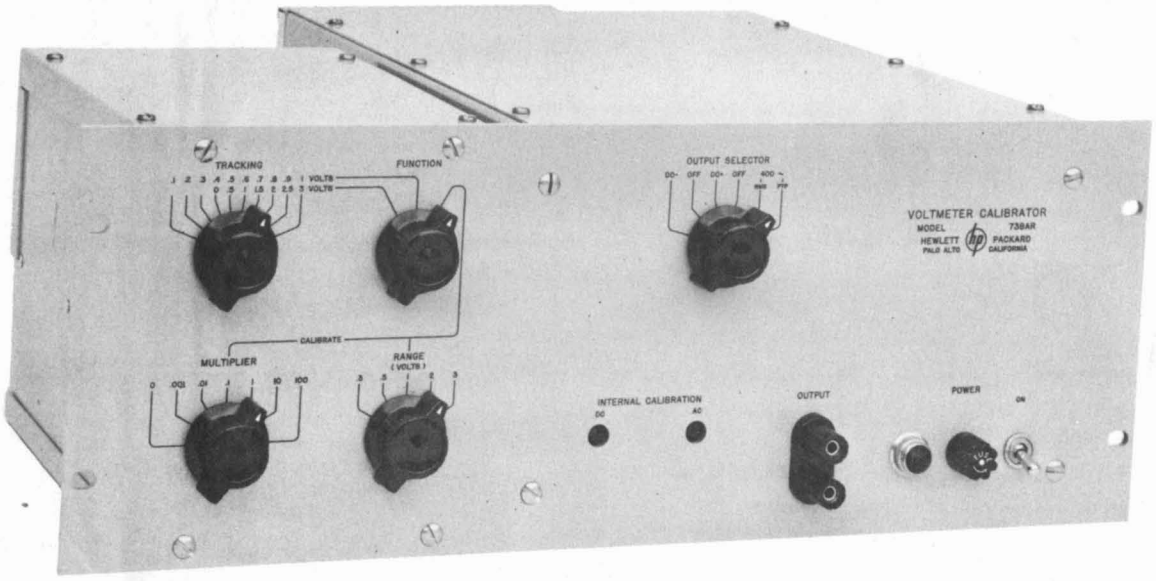
OPERATING AND SERVICING MANUAL

MODEL 738A/AR
VOLTMETER CALIBRATOR
SERIALS PREFIXED: 001 -



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SPECIFICATIONS

VOLTAGE RANGE:	300 microvolts to 300 volts
LEVELS:	Calibration voltage 300 microvolts to 300 volts in steps of .3, .5, 1, 2 and 3 volts with multipliers of .001, .01, .1, 1, 10 and 100. Tracking voltage .1 to 1 volt in .1 volt steps; and 0 to 3 volts in .5 volt steps.
WORKING VOLTAGE ACCURACY:	300 volts working voltage into attenuator, accurate within 0.1% dc and 0.25% ac after one-half hour warmup.
LONG-TERM STABILITY:	Less than 0.1% dc drift per week; less than 0.25% ac drift per week.
OUTPUT VOLTAGE FUNCTION*:	DC positive to ground, dc negative to ground, ac 400 cycle rms value or ac 400 cycle peak-to-peak value.
HUM AND DISTORTION:	Less than 0.2% total
ATTENUATOR ACCURACY:	Within ± 0.1%, or ± 5 microvolts, whichever is larger
LOAD IMPEDANCE:	Designed to work into a 3 megohm input impedance. When working into 10 megohms impedance, the voltage from 20 to 200 volts will be approximately 0.15% high.
POWER SUPPLY:	115/230 volts ±10%, 50-60 cycles, approximately 350 watts
DIMENSIONS:	Rack Mount: 19 inches wide, 7 inches high, 15 inches deep
WEIGHT:	Rack Mount: Net 38 lbs. Shipping approximately 75 lbs

* Any output frequency from 400 to 1000 cps available on special order.

CONTENTS

SECTION I
GENERAL DESCRIPTION

1-1 INTRODUCTION

The Hewlett-Packard Model 738A Voltmeter Calibrator is a compact, completely self-contained, precision generator for calibrating high-impedance electronic voltmeters, oscilloscopes, etc. Special design assures accurate and reliable calibrating voltages from 0.3 millivolt up to 300 volts, in precision steps. Accuracy of output attenuator is within ±0.1% or ±5 μvolt, whichever is greater, when loaded by a meter with an input impedance of 3 megohms. No operating adjustments are required, other than weekly standardization.

The hp Voltmeter Calibrator consists of two separate inter-connected units mounted on one small rack panel. The voltage generator section includes a regulated power supply which produces the 300 volts dc working standard, a conventional low distortion rc oscillator with AGC, and a stabilized amplifier which generates the 400 cycle 300 volt rms working standard. The 300 volt peak-to-peak voltage is derived from the 300 volt rms voltage through a resistive network. The type of voltage required is selected by a simple output selector and fed to the attenuator section.

The attenuator section consists of control switches and a series of voltage dividers constructed with 0.1% wirewound, non-inductive, ceramic-core resistors. The attenuator accepts the desired 300 volt working standard and will deliver calibrating voltages or tracking voltages.

Calibrating voltages run from 300 microvolts to 300 volts in 25 precise steps in a .3, .5, 1, 2, 3 sequence. Two tracking ranges are available: either 0.1 volt to 1 volt in 1/10 volt steps or 0 to 3 volts in 1/2 volt steps.

No standardizing voltmeter is included with the Model 738A. The amplitude of the 738A output voltage cannot be adjusted accurately against a conventional voltmeter since the 0.1% stability of the 738A is higher than the accuracy of most meters. Only special high-resolution meters that can be read to an accuracy of at least 0.1%, or other standards laboratory methods, should be used for standardizing the 738A when maximum accuracy is desired. If maximum accuracy is not important a less accurate voltmeter may be used, in which case the accuracy of the 738A will depend upon the accuracy of the meter used.

The Model 738A is designed for mounting in a standard 19-inch relay rack. A fan in the cabinet assures adequate ventilation.

Physically, the instrument is built in two separately housed sections mounted on the front panel, an attenuator section and a generator section. The attenuator section is easily removed for service or replacement by removing a few screws, knobs, and two BNC connectors. The circuitry of the generator section is easily accessible from below the chassis.

1-2 POWER CABLE

The three-conductor power cable for the 738A is terminated in a polarized, three-contact connector recommended by the National Electrical Manufacturers' Association for protection of operating personnel. The third contact is an offset round pin, added to a standard two-blade connector which grounds the instrument chassis when used with a suitable receptacle. To use this connector in a standard, two-contact receptacle, or to disconnect the third (ground) lead in the cable, an adapter is available. Refer to Section II before ground connectors are made.

1-3 OPERATION ON 230 VOLTS

This instrument is normally supplied for 115 volt operation, unless specifically ordered for 230 volt operation. The power transformer has a dual primary that may be easily connected for either 115 or 230 volt operation. The schematic diagram illustrates both methods of connection. Always replace the power line fuse with the rating specified in Section V, Table of Replaceable Parts, for the particular line voltage you are using.

TABLE 2-1. INTERNAL RESISTANCE AND MINIMUM LOAD FOR 1% ACCURACY

Output Voltage	Internal Resistance of Generator in Ohms	Approximate Load Resistance which Produces 1% Decrease in Output Voltage
300	0*	#
200	4000	400K
100	4000	400K
50	2600	260K
30	1600	160K
20	1150	115K
10	580	58K
5	295	29K
3	180	18K
2	480	48K
1	420	42K
.5	260	26K
.3	170	17K
.2	480	48K
.1	420	42K
.05	260	26K
.03	170	17K
.02	125	12.5K
.01	66	6.6K
.005	35	3.5K
.003	21.5	2.1K
.002	57	5.7K
.001	50	5.0K
.0005	31	3.0K
.0003	21	2.0K

* Within the limits of the regulators.

The minimum load should be greater than 16,000 ohms to prevent overload of the power supplies. With a 16,000 ohm load there will be no change in accuracy.

SECTION II
OPERATING INSTRUCTIONS

2-1 INSTALLATION

No special instructions are required for installing the Model 738A Voltmeter Calibrator. It can be used either in a rack or on a test bench. A fan in the cabinet assures adequate ventilation in either mounting, providing the air filter is kept clean and the ventilating holes in the right side are not blocked. Adequate air flow through the filter must be maintained. Inspect the air filter weekly. Damage to the instrument can occur if the filter becomes clogged and air flow is restricted. See paragraph 4-3, Cleaning the Air Filter.

CAUTION

THE OUTPUT OF THIS INSTRUMENT MAY CONTAIN VOLTAGES WHICH ARE DANGEROUS. When connecting or disconnecting the output of this instrument, switch the OUTPUT SELECTOR to OFF first.

2-2 EXTERNAL LOAD

CAUTION

THIS INSTRUMENT IS DESIGNED TO OPERATE INTO A 3 MEGOHM LOAD. THE MINIMUM SAFE LOAD IS 1,000 OHMS PER VOLT. IF A SHORT OR LOW RESISTANCE IS CONNECTED TO THE OUTPUT TERMINALS PERMANENT DAMAGE WILL RESULT. Note that any calibrating meter must also have this resistance.

The Model 738A is designed to produce calibrating voltages that are accurate to within ± 0.1% or ± 5μv, whichever is greater, with an external load of 3 megohms. If the meter being checked has a higher input resistance, such as 11 megohms, the output voltages between 20 and 200 volts will be as much as 0.15% high. For highest accuracy when calibrating an 11 megohm instrument, the OUTPUT terminals should be shunted with 4.12 megohms. The lower voltage ranges will not change with load resistances above 3 megohms.

The following equation may be used to determine the value of shunt resistance necessary to obtain maximum accuracy when calibrating high impedance devices:

$$R_x = \frac{3 R_m}{R_m - 3}$$

where, R_x = Shunt resistance in megohms

R_m = Input resistance of instrument under test (in megohms).

With some sacrifice in accuracy the 738A may be used to calibrate instruments having an input resistance less than 3 megohms. Under no conditions should the load on the OUTPUT terminals be less than 1,000 ohms per volt. Table 2-1 indicates both the internal resistance of the calibrator for each output voltage and the minimum external load for a 1% decrease in the indicated voltage.

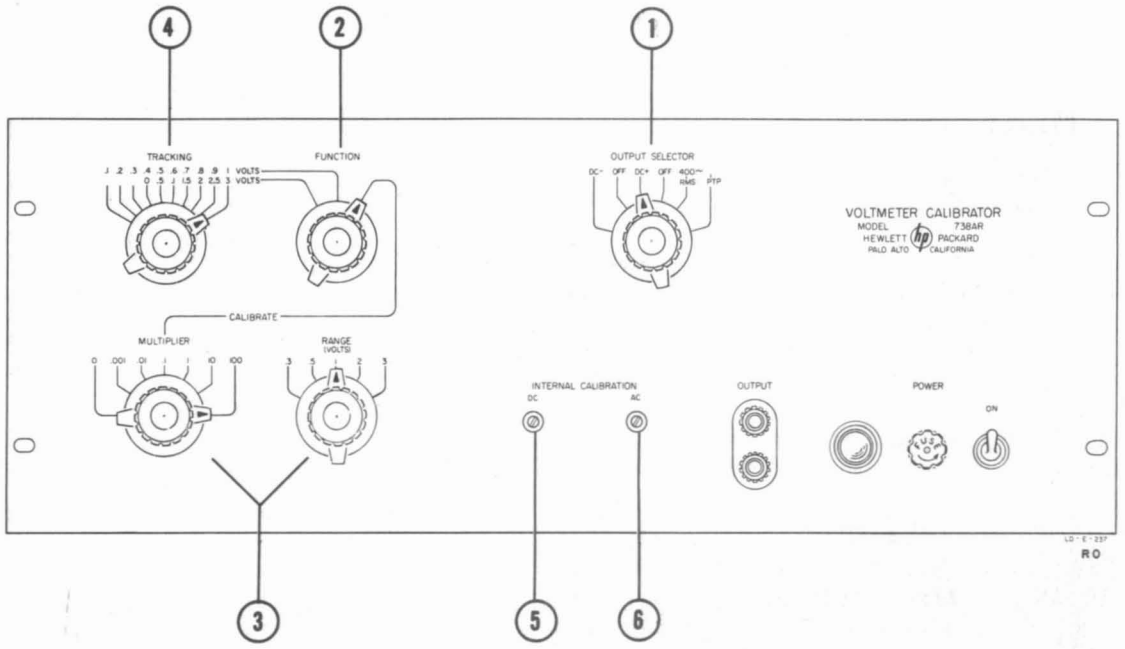
2-3 PREVENTING ERRORS FROM GROUND CURRENTS

A. INTRODUCTION

Ground currents between the instrument being calibrated and the Model 738A must be minimized to realize the rated accuracy of the Calibrator. A 10 microvolt signal, developed by ground currents between the two instruments, will introduce a 1% error on the 1 millivolt range and a 3.3% error on the 0.3 millivolt range. When using the lower voltage ranges you must minimize ground currents in the signal leads.

All instruments that operate from a power line develop spurious voltages between their chassis

OPERATING CONTROLS



1. Select the output voltage required by the meter to be calibrated.

2. Select for use desired - To calibrate, or to check meter scale tracking. For tracking, select range corresponding to meter scale under test.

3. Set for full-scale reading.

4. Switch through the entire range to observe accuracy at each meter calibration point.

5. Calibrate 300 vdc output.

6. Calibrate 300 vac output.

Figure 2-1

and ground. The 738A is designed to minimize the development of such signals on its own chassis. To minimize the effects of these currents further, the instrument being calibrated should be grounded with its own low-resistance ground, or the 738A may be insulated from ground so that it cannot provide the ground-return path. See Figure 2-2 and the next paragraph.

B. GROUNDING ARRANGEMENTS

Grounding arrangements most often encountered, together with comment on their relative merits, are shown in Figure 2-2. The grounding arrangement found most reliable provides a low-resistance connection to the power-line ground for the instrument being calibrated and insulates the 738A chassis from ground. So that the 738A may be easily disconnected from the power-line ground, an adapter is available in which the ground connection on the NEMA power plug is an external pigtail lead and may be connected or disconnected as desired.

C. CHECKING FOR PRESENCE OF UNWANTED CURRENT--To check for effects from ground currents:

1) Connect the 738A to the voltmeter to be calibrated. Set the 738A for 1 millivolt output. Note reading on voltmeter.

2) Remove or add ground connections as the case may be and again note voltmeter reading. The reading with and without ground connections should remain constant. If the reading does not remain constant, use the grounding arrangement which results in the lowest reading. Find the source of the ground current and provide it with a low-resistance connection to the power-line ground.

2-4 STABILITY AND WARMUP

Check and, if necessary, calibrate the Model 738A Calibrator upon receipt. Allow at least 30 minute warmup before checking the calibration.

The 738A has been accurately set at the factory and should remain accurate to within ± 0.1% for over a week without readjustment. To obtain best accuracy after this period see paragraph 2-6, Calibrating the 738A.

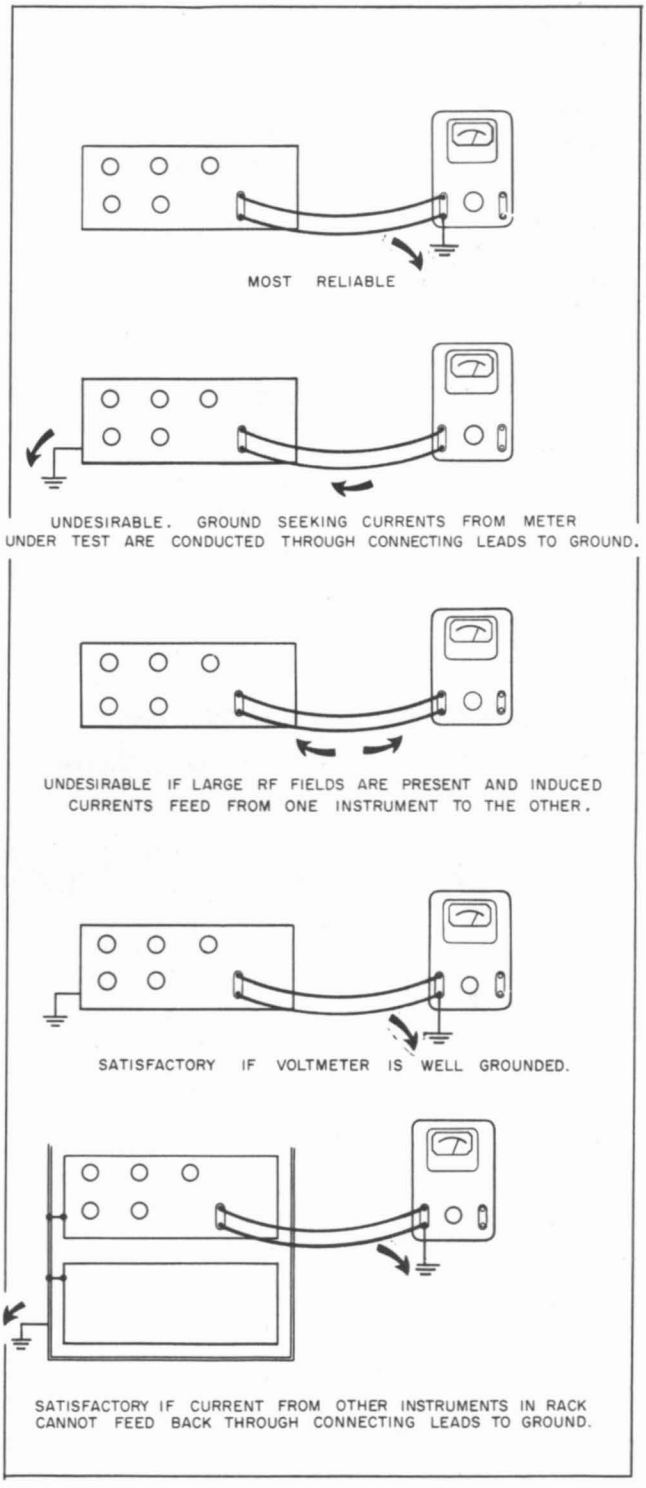


Figure 2-2. Desirable and undesirable arrangements for grounding instrument chassis when using the Voltmeter Calibration Generator

The accuracy of the 738A is determined by:

1) The precision with which it is calibrated (the accuracy of the calibrating meter).

2) The accuracy of the output attenuators (0.1%).

3) The amplitude stability vs time.

4) The value of the external load resistance.

The 738A reaches its maximum stability of 0.1% per week after about 30 minutes warmup time. After this warmup, the normal drift of the dc output voltage is about 0.1% per week. Any drift exceeding this amount indicates subnormal operation. If the 738A has been calibrated within a week, adequate accuracy for most average uses (1%) is reached after only 2 minutes warmup. Repeated turning on and off does not noticeably affect the accuracy of the output voltage.

2-5 OPERATING INSTRUCTIONS

To use the 738A to calibrate an oscilloscope or voltmeter, proceed as follows:

1) Turn on the 738A and allow to warm up for 3 to 30 minutes, depending on accuracy required.

2) Set the FUNCTION switch to CALIBRATE, and MULTIPLIER to 0.

3) Connect the voltmeter input to the 738A output by two plain wires or a shielded cable with the shield connected to the bottom OUTPUT binding post. Observe precautions discussed in paragraphs 2-3 and 2-5.

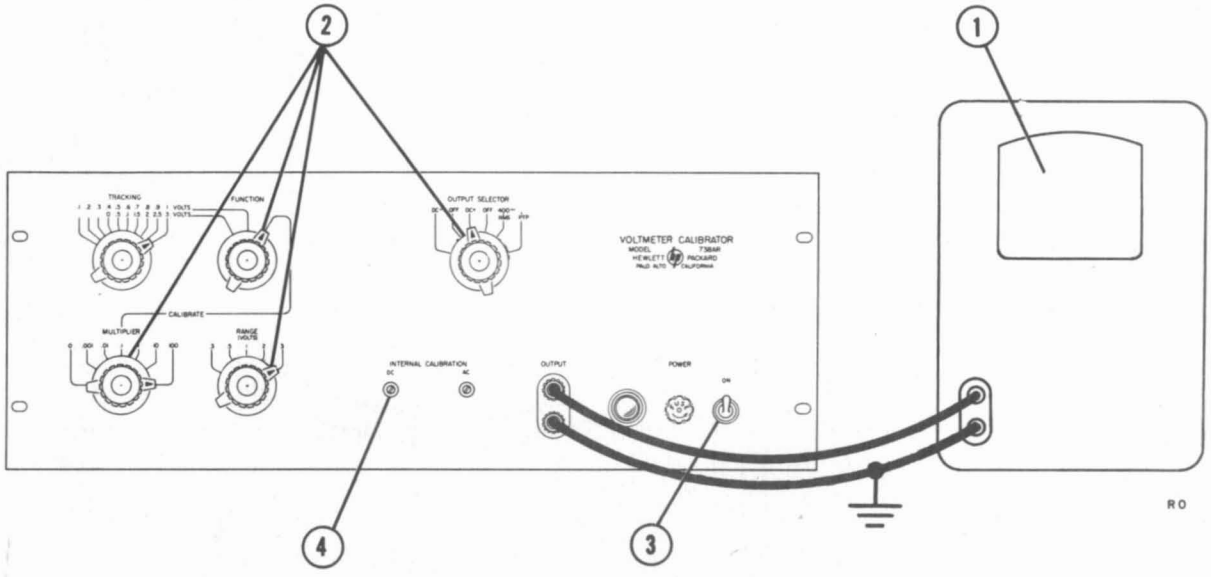
4) Set the MULTIPLIER and RANGE selectors for the desired voltage.

2-6 CALIBRATING THE 738A

There are three output-voltage calibrating adjustments: the 300-volt dc output adjustment, the 300-volt rms ac output adjustment, both on the front panel; and the 300-volt peak-to-peak ac adjustment on the left side of the electronics chassis just to the rear of the attenuator section. The dc voltage must be set correctly first, the rms ac voltage second, and the peak-to-peak ac voltage last. It is important that the 300-volt dc output be set accurately before any other adjustments are attempted. Make all three calibration adjustments in one procedure, as shown in the following Figures:

Figure 2-3. Calibration I
Figure 2-4. Calibration II
Figure 2-5. Calibration III

CALIBRATION I



1. Connect a 300-volt meter of calibration standard quality, having an accuracy of 0.1% or better and appropriate resolution, to the OUTPUT terminals of the 738A as shown.

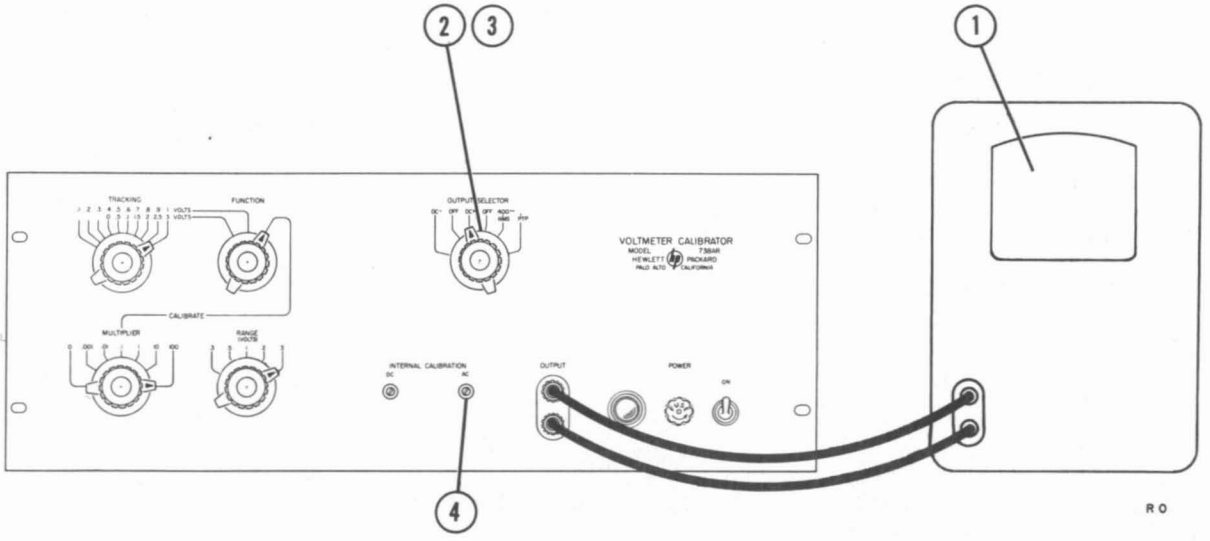
2. Set the controls on the 738A as shown.

3. Turn on 738A and allow to warm up for 30 minutes.

4. If necessary, adjust potentiometer R63, accessible through the panel hole marked DC, to obtain exactly 300 volts. Disconnect the standard meter.

Figure 2-3

CALIBRATION II

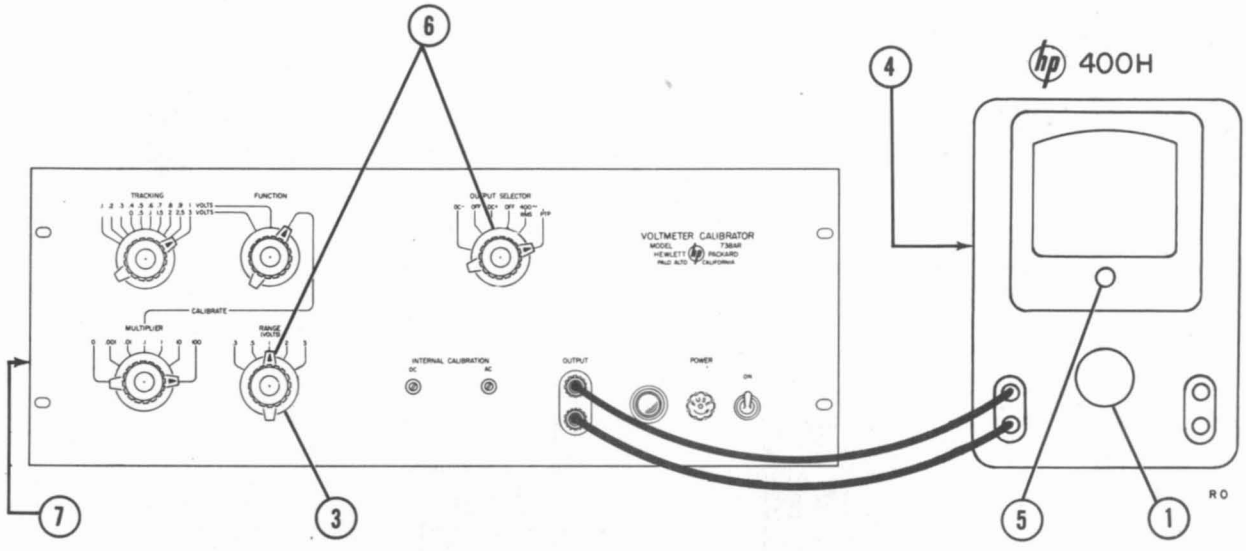


This procedure assumes that the procedure shown in the preceding illustration, CALIBRATION I, has been performed.

1. With OUTPUT SELECTOR on OFF, connect either an electrostatic or thermocouple type 300-volt ac-dc meter of calibration standard accuracy to the OUTPUT terminals of the 738A as shown.
2. Switch the OUTPUT SELECTOR between DC- and DC+ and note the midpoint between the readings.
3. Set the OUTPUT SELECTOR to 400 ∿ RMS.
4. If necessary, adjust potentiometer R40, accessible through the front panel hole marked AC, to obtain the midpoint reading noted in step 2.

Figure 2-4

CALIBRATION III



This procedure assumes that the procedure shown in the preceding illustrations, CALIBRATION I and CALIBRATION II, has been performed.

1. Switch hp Model 400H to the 100-volt range.

2. Connect the 738A to the 400H as shown, with the 738A OUTPUT SELECTOR set to OFF.

3. Set controls as follows:
   RANGE switch to 1
   MULTIPLIER switch to 100
   OUTPUT SELECTOR to 400 ∿ RMS
   FUNCTION switch to CALIBRATE

4. On the 400H adjust .001V-400CPS control until the meter reads exactly 100. This control is mounted on a bracket near the front panel on the left side of the chassis, as viewed from the front.

5. While 100 volts remain across the 400H, turn the mechanical meter zero until the meter pointer indicates exactly 94 volts.

6. Set the 738A OUTPUT SELECTOR to 400 ∿ PTP and the RANGE switch to 3.

7. The 400H should now read 100 exactly. If necessary adjust R67 (on left side of Voltmeter Calibrator chassis just to the rear of the attenuator section).

8. Repeat step 5, but turn the mechanical meter zero-set until the meter indicates 100 to recalibrate the 400H.

Figure 2-5

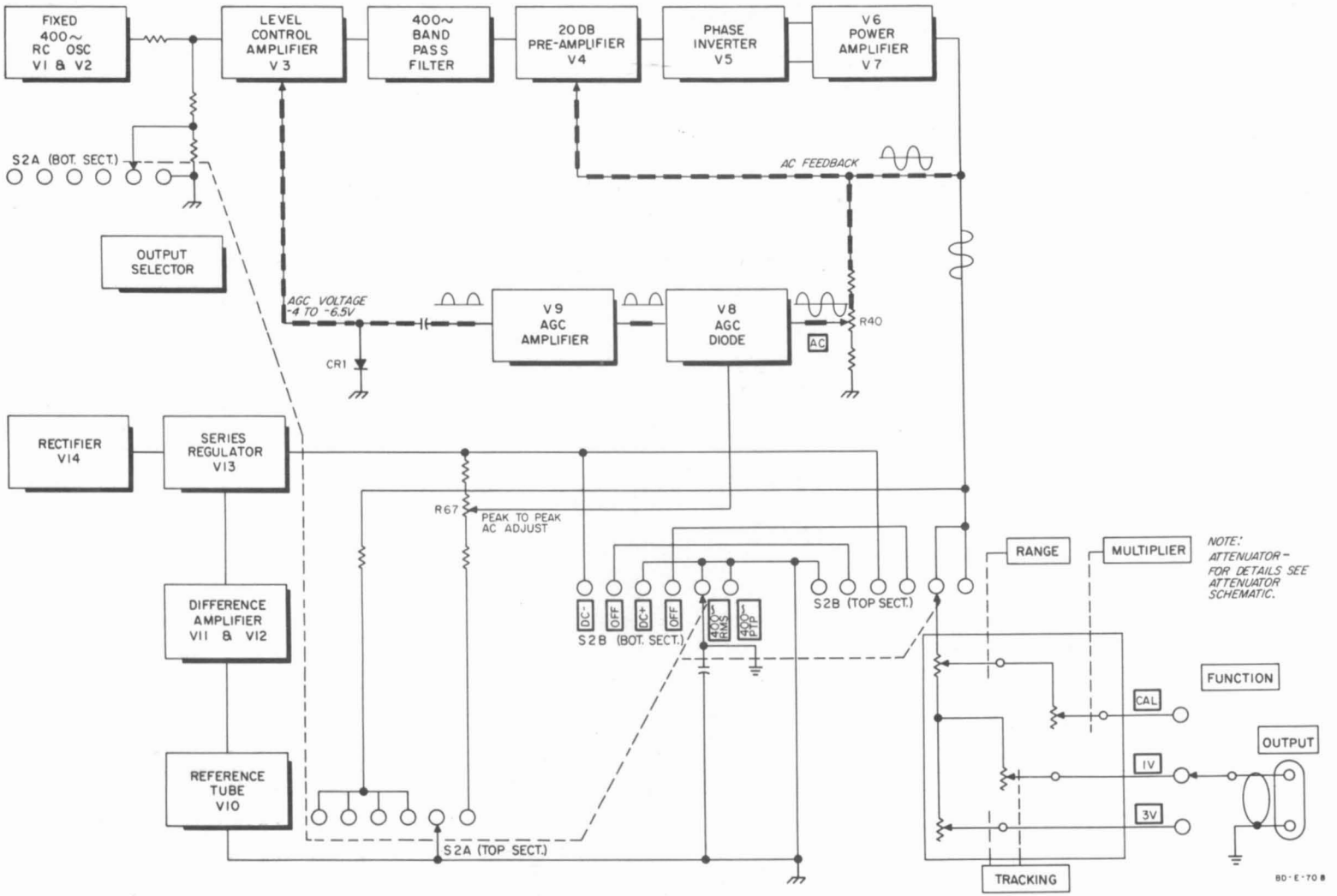


Figure 3-1. Block Diagram Model 738A

SECTION III
THEORY OF OPERATION

3-1 INTRODUCTION

The Model 738A Voltmeter Calibrator consists of the major circuit sections shown in the block diagram in Figure 3-1. The overall operation of the generator is explained first, then certain important circuits are explained in greater detail.

The regulated dc power supply provides both the 300 volt working standard and dc power to most of the circuits in the ac generator. The accuracy of the 300 volts dc primarily determines the accuracy of all calibrating voltages. Stability is determined almost entirely by the gaseous voltage reference tube which supplies a reference voltage for the dc supply. The 300 vdc is adjustable by a screwdriver-adjusted potentiometer R63, marked DC, accessible through the front panel.

For dc meter calibration, the output of the 300 volt supply is connected through the OUTPUT SELECTOR switch S2, to the attenuator and through the FUNCTION switch S102, to the OUTPUT terminals. The internal impedance of the dc generator ahead of the output attenuator is nearly 0 ohm up to the point of overload. Negative and positive dc voltages are obtained by reversing the output leads of the floating dc power supply. The supply is grounded only after the switching so that either the positive or negative lead can be grounded as required.

For ac voltmeter calibration, the OUTPUT SELECTOR switch connects the output from the ac generator to the attenuator. The internal impedance of the ac voltage generator up to the point of overload is also nearly 0 ohm. The generation of rms and peak-to-peak voltages is determined by switching within the ac generator and is described later.

3-2 DC GENERATOR SECTION

The dc power supply consists of a power transformer and rectifier which supply voltages for an electronic regulator consisting of a series regulator tube which acts as a variable resistor, a reference tube providing a stable voltage against which the 300 volts is continuously compared, and a two-stage difference amplifier applying an amplified difference voltage to the series regulator tube. The voltage regulating process is as follows: If the 300 volt output tends to change, a portion of this change is coupled to difference amplifier V11 and V12. This amplifier compares the change against the output of the Voltage Reference tube V10, amplifies and inverts the difference voltage and applies it to the grid of Series Regulator Tube V13. If the 300 volts level tends to decrease, the current through V13 will increase and will instantly counteract the tendency of the output voltage to decrease.

A difference type of amplifier is used to amplify the degenerative feedback because it is relatively insensitive to changes in tube characteristics and supply voltages (heater voltages and cathode emission in particular). The operation of the difference amplifier is as follows:

Tube V11, the input stage, compares a sample of the dc output with the constant voltage from Voltage Reference Tube V10. The comparison is accomplished by applying a portion of the +300 vdc to the grid of V11A which is normally equal to the output of Voltage Reference Tube V10. Assume the voltage applied to the grid of V11A tends to go positive, the current in V11A will increase, and due to the large common cathode resistor, the current in V11B will decrease. The plate voltages of V11A and B will have changed by equal amounts and will be 180^{o} out of phase. The plates of V11 are direct-coupled to the grids of V12A&B which is another difference

amplifier whose operation is similar to the one just described. The control voltage of the desired polarity for Series Regulator V13 is obtained from the plate of V12B.

3-3 AC GENERATOR SECTION

The ac voltage generator consists of a conventional rc oscillator followed by a level control tube, a filter, a pre-amplifier, an output amplifier and an automatic gain control (AGC) circuit. The oscillator generates a highly stable, low-distortion signal whose frequency is adjusted to the exact resonant frequency of the 400-cycle filter which follows. The signal from the oscillator is applied to Level Control Tube V3. The output from V3 is kept constant by application of AGC bias to its variable-mu control grid. The output of the level Control Tube is filtered to remove harmonics introduced by the variable-mu grid characteristic. The signal is then amplified and fed through the feedback stabilized output amplifier, V5, V6 and V7.

The signal from the output amplifier is connected both to the function selector for further application to the output attenuator, and to the automatic gain control circuit. The automatic gain control circuit consists of Reference Clipping Diode, V8, followed by amplifier V9 and rectifier CR1. The Reference Clipping Diode is biased by an exact dc voltage. Any portion of the ac wave that is above this voltage is passed by the diode to amplifier V9 and is then rectified by CR1 to produce AGC bias for Level Control Tube V3. The gain of the pre-amplifier and output amplifier is such that the ac output level would always tend to rise were it not held down by the AGC bias applied to the grid of V3. Consequently, any tendency for the ac output level to decrease (due to loading, etc) would be corrected automatically, as amplifier V9 is always trying to maintain the level established by the Reference Clipping Diode bias. If the output level tends to rise, the diode passes more of the ac which, when rectified, develops more bias. The increase in bias reduces the gain of the amplifier and holds the output constant. The second diode automatically divides the current between the two diodes so that the bias on the signal diode is constant with varying signal levels.

To produce rms voltages, the cathode of V8 is returned through series resistors R67, R68 and R69 to +300 volts. To produce peak-to-peak voltages the cathode return resistors R67, R68 and R69 are made into a voltage divider by returning potentiometer R67 to ground through R66 and S2A. At the same time OUTPUT SELECTOR switch S2 also reduces the level of the 400∿ input to V3. Thus the desired reduction in output voltage is obtained with a small increase in AGC bias. This arrangement avoids the increase in distortion which would result with the greater grid bias.

3-4 OUTPUT ATTENUATOR

The OUTPUT SELECTOR connects either the dc or ac output to the attenuator The FUNCTION switch selects the output voltage either from the MULTIPLIER (S103) and RANGE (S104) switches, or from the 1 or 3 volt positions of the TRACKING (S101) switch.

The attenuator consists of five voltage dividers, each divider is returned to ground, each subsequent divider is connected to the lowest tap on the previous divider, each divider produces voltages that are 1/10 the voltage from the divider before it. The MULTIPLIER switch selects the output voltage from one of these dividers. The RANGE switch selects the output from one of the five taps on the voltage divider selected by the MULTIPLIER switch.

The tracking voltages are obtained from the appropriate attenuator taps. One position provides 0.1 volt divisions from 0 to 1 volt, the other provides 0.5 volt divisions from 0 to 3 volts. The attenuators are simple, uncompensated series and parallel combination of precision wirewound resistors that are very stable.

SECTION IV
MAINTENANCE

4-1 INTRODUCTION

This section contains instructions for tube replacement and for adjusting, calibrating, and trouble shooting the Model 738A Voltmeter Calibrator. To facilitate service, location illustrations are included at the end of the section. A trouble shooting procedure gives a quick systematic method of localizing a fault to a small circuit area through the use of test points. These test points are shown on the schematic diagram. Damaged attenuator assemblies should be removed and returned to the Hewlett-Packard Company for repair.

4-2 TUBE REPLACEMENT

The 738A does not require specially selected tubes. Tubes V8 and V10 are the only tubes whose characteristics directly affect the accuracy of the output voltages. Tube V10 affects all voltages in the generator; V8 affects only the accuracy of the ac output voltages and can be replaced without affecting the dc voltages. Replacement of a tube within the rc oscillator may cause a minor change in frequency. After tube replacement, the oscillator frequency should be checked and, if necessary, adjusted to the center frequency of the filter at the input to preamplifier V4. The other tubes can be replaced without adjustment. The accuracy of the output voltages should be checked after any servicing.

4-3 CLEANING THE AIR FILTER

This instrument contains a fan-air filter combination for cooling. The filter must be kept clean for the fan to be effective. Clean the filter as soon as it appears dirty. It is located at the rear of the instrument cabinet and may be removed simply by pulling it out of its holder. To clean the filter element, wash in warm water and detergent; then recoat with special oil available for this purpose A suitable coating oil is R-P Filter Coat #3, made by Research Products Corp. This oil is available at hardware stores and other stores carrying heating and air-conditioning supplies.

4-4 ADJUSTING THE FREQUENCY OF THE AC OUTPUT

It is important that the frequency of the oscillator output be the same as the resonant frequency of the filter in order to obtain proper operation. The function of the high-Q 400 cycle filter (L1, C10) which follows Level Control Tube V3 is to remove distortion introduced by V3. For maximum output and maximum signal-to-noise ratio, the frequency of the rc oscillator output must be the same as the resonant frequency of the filter. The oscillator frequency is adjusted by capacitor C3, located in the bottom compartment. A simple and satisfactory way to set the oscillator output frequency to the resonant frequency of the filter is to adjust C3 for maximum dc voltage at test point D, as measured by a dc vacuum-tube voltmeter, such as the hp Model 410B.

In the more exact tuning procedure given below, the oscillator is tuned so that the filter is resistive and therefore there is no phase shift between the input and output signals. The following procedure requires an oscilloscope, such as the hp Model 150A with a Model 152 Dual Channel Amplifier. Proceed as follows:

1) Remove the metal dust cover from the 738A, turn on, and allow a five-minute warmup.

2) Connect one vertical input to test point B, the other vertical input to test point E. Synchronize the oscilloscope externally from test point F. Oscilloscope connections are made at these points to avoid shifting the resonant frequency of either the oscillator or filter.

3) Adjust the vertical position control to superimpose the horizontal centerlines of the two traces. Adjust the vertical sensitivity to equalize the amplitude of the two traces.

4) If necessary, adjust C3 to superimpose the traces, i.e. to reduce the phase difference between the two signals to zero. The oscillator frequency is now at the peak of the resonance curve of the filter, and best stability and greatest output are achieved.

4-5 TESTING AND TROUBLE SHOOTING THE CALIBRATION GENERATOR

To test or trouble shoot the 738A Voltmeter Calibrator, first determine if it is operating satisfactorily by measuring its output voltages at the OUTPUT terminals. To locate a failure, measure the key voltages at the test points shown on the schematic diagram. When a measured voltage is correct, assume the circuit to be operating properly, and proceed to the next step.

A. DC CHECKS

1) Connect the 738A through a variable transformer to a power source, turn on and allow to warm up.

2) Set the OUTPUT SELECTOR to DC+, all other switches to maximum clockwise positions.

3) With an electronic voltmeter, having a resolution of at least ±0.1% at 300 vdc, measure the voltage at the OUTPUT terminals. Vary the line voltage from 103 to 127 volts. The voltage should remain constant. If it varies over all or part of the range, check V14 for low output; check V13, V12 and V11, then check for excessive loading of the regulator. Check ripple voltage on the 300 volt bus. The ripple level should be approximately 0.8 millivolts peak-to-peak. If the ripple is too high, check V11, V12 and C29.

4) Switch the OUTPUT SELECTOR to the 400 ∿ RMS position and check the line voltage regulation as in the preceding paragraph. Disconnect the voltmeters.

5) If the dc output of the attenuator is measured with a low impedance voltmeter on any but the 300 volts (straight through) range, the attenuator may be damaged. If too much current is drawn the precision resistors may be overheated and lose their accuracy. In addition this instrument is designed to work into an impedance of 3 megohms and will not read accurately with other impedance meters (see paragraph 2-2).

To prevent damage to the attenuator, use a voltmeter which has at least 1000 ohms/volt impedance or a differential-type voltmeter to measure all voltages except the 300 volts. If the impedance of the meter is different from 3 megohms be sure to apply the correction as given in paragraph 2-2.

Switch the MULTIPLIER and RANGE selectors through their positions to determine if all the calibrated output voltages are correct. If the 300 volts dc is correct, but any one of the lower voltages is incorrect, the attenuator section is defective.

6) Switch the FUNCTION switch to the TRACKING positions to determine if all of the calibrated output voltages are correct. If the 300 volts dc is correct, but any one of the lower voltages is incorrect, the attenuator section is defective.

The above steps should indicate if operation is satisfactory and, if not, which section contains a circuit failure.

B. AC CHECKS

1) Set the OUTPUT to 400∿ RMS.

2) With a precision voltmeter measure the signal voltage at test point F. If it is too high or too low, adjust to obtain the correct voltage. If it is too low and cannot be adjusted up, check V6 and V7, then other tubes in the amplifier. If the voltage is too high and cannot be adjusted down, check V6, V7, V8 and the voltage-divider circuit which determines the bias for V8.

3) With a high impedance ac electronic voltmeter, such as the ℌ Model 400D/H/L measure the 400 cycle voltage at point C in the oscillator circuit. The voltage at point C should be between 20 and 25 volts. If it is excessively high and cannot be reduced, replace lamp RT1. If it is excessively low and cannot be raised, check RT1, V1 and V2. It may also be desirable to check the distortion at check point C which should be at least 60 db down (0.1%). If necessary, select tubes to reduce distortion.

5) With a dc electronic voltmeter, such as the Model 410B Vacuum Tube Voltmeter, measure the bias voltage at test point D: it should be between -4 and -6.5 volts. If too low, the gain on one of the amplifier tubes V3, V4, V5, V6 and/or V7 is low.

6) Measure the distortion at the output terminals, test point F. If good tubes are used for V4, V5, V6 and V7 and if the output tubes are balanced, the distortion in the output should be reduced to below about 0.15%. The distortion must be kept low since it will affect the AGC voltage and cause a drift in the ac level.

When measuring distortion, monitor the output of the 330B with an oscilloscope. If the distortion contains appreciable 60∿ hum the toroid coil may need balancing. However, when doing this be sure you are not just introducing hum to buck out hum in the unit. To determine if the unit has hum, short out the leads of the toroid coil L1 with the shortest piece of wire possible. Note if the output contains 60∿ hum on the screen of the oscilloscope. If there is hum in the unit remove it by replacing tubes etc. Then remove ths short across the toroid. Now place the short from the ground side of the toroid to junction of C9 and R18. The ground side of the toroid is the lead that goes to the black wire. Make this short with the shortest piece of wire possible. This will remove all hum ahead of the toroid coil. Now rotate the toroid for minimum hum pickup. To rotate the coil loosen the nut, rotate for minimum hum, and tighten while still observing the hum. The hum should be down to about 0.03%. Remove the short. If the hum comes up, replace V3. If the cover of the toroid must be removed be sure to retain the washer between the cover and the coil. There must be an air gap between the cover and the case of this coil for proper operation.

4-6 METHODS OF CALIBRATION

Accuracy of this instrument will depend upon the accuracy of the standard used for calibration and the frequency of calibration. Standards laboratory methods involving standard cells, precision potentiometers, and precision voltage dividers may be used. The method described involves the use of only one extra piece of equipment --a precision voltmeter. The accuracy of the standardization will depend upon the accuracy of this meter. If maximum accuracy of the 738A is not necessary a less accurate meter may be used.

There are three output voltage calibrating adjustments: the 300-volt dc output adjustment, the 300-volts rms ac output adjustment, both on the front panel; and the 300-volt peak-to-peak ac adjustment on the instrument chassis. The dc voltage must be set first, the rms ac voltage second and the peak-to-peak ac voltage last. It is important that the 300-volt dc output be set accurately before any other adjustments are attempted.

Make all three calibration adjustments in one procedure as described in paragraph 2-6, Calibrating the 738A, and Figures 2-3, 2-4, and 2-5.

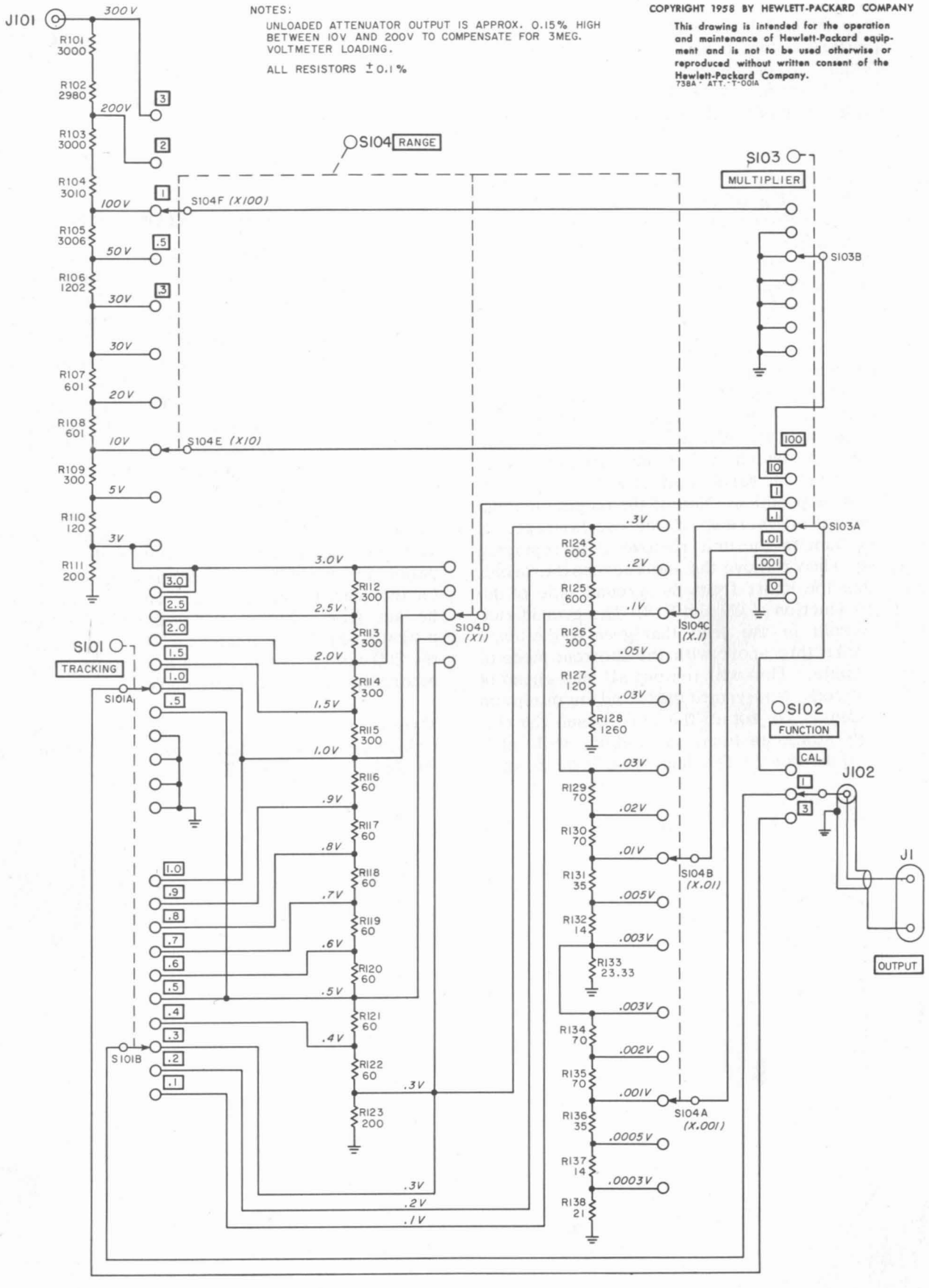
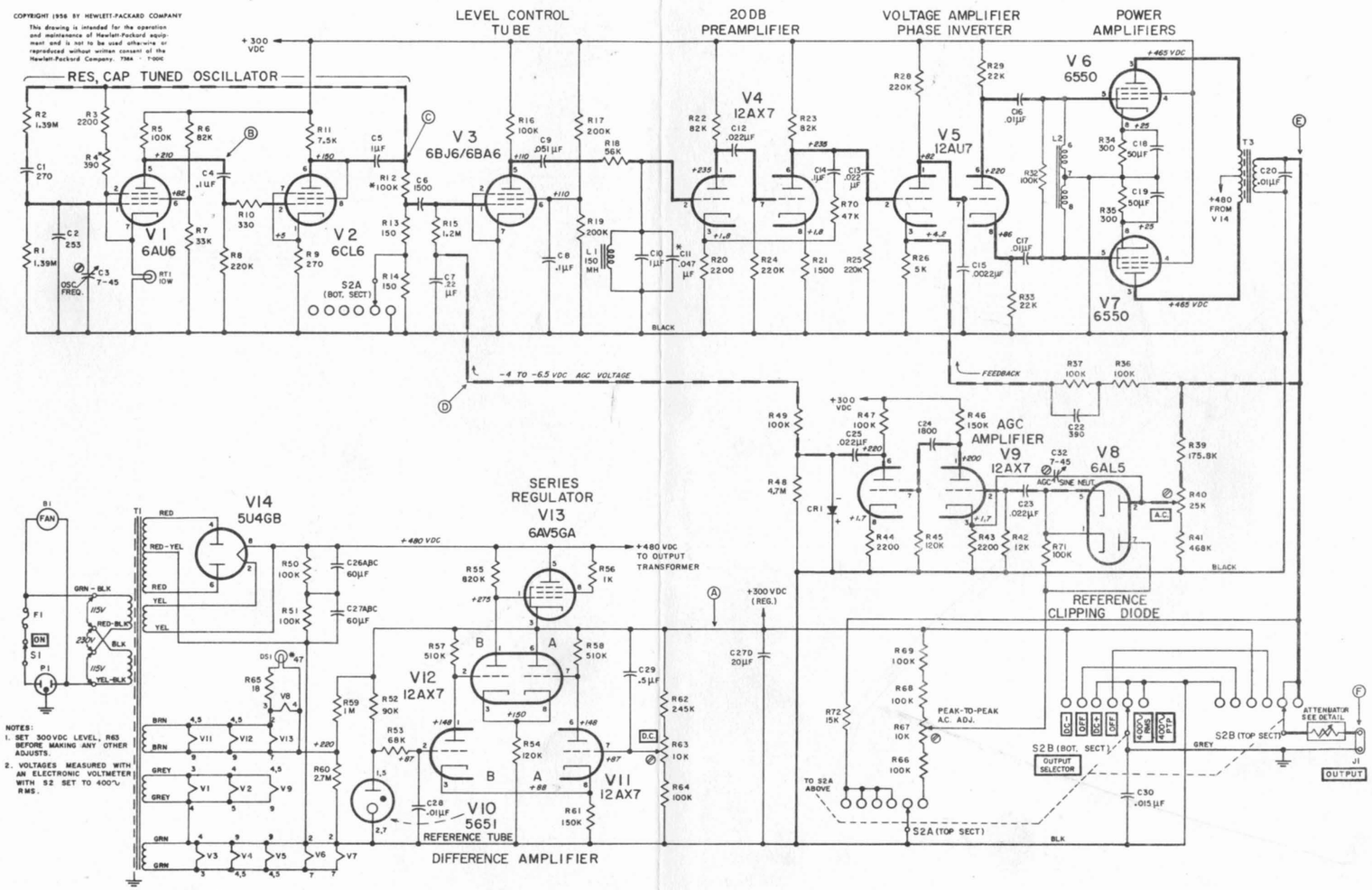


Figure 4-1. Attenuator



NOTES:
1. SET 300 VDC LEVEL, R63 BEFORE MAKING ANY OTHER ADJUSTS.
2. VOLTAGES MEASURED WITH AN ELECTRONIC VOLTMETER WITH S2 SET TO 400 V RMS.

SECTION V
REPLACEABLE PARTS

5-1 INTRODUCTION

This section contains information for ordering replacement parts for the Model 738A Voltmeter Calibrator.

Table 5-1 lists replaceable parts in alpha-numerical order of their reference designators. Detailed information on a part used more than once in the instrument is listed opposite the first reference designator applying to the part. Other reference designators applying to the same part refer to the initial designator. Miscellaneous parts are included at the end of the list. Detailed information includes the following:

1) Reference designator.

2) Full description of the part.

3) Manufacturer of the part in a five-digit code; see list of manufacturers in appendix.

4) Hewlett-Packard stock number.

5) Total quantity used in the instrument (TQ col).

6) Recommended spare quantity for complete maintenance during one year of isolated service (RS col).

5-2 ORDERING INFORMATION

To order a replacement part, address order or inquiry either to your authorized Hewlett-Packard sales representative or to

CUSTOMER SERVICE
Hewlett-Packard Company
395 Page Mill Road
Palo Alto, California

or, in Western Europe, to

Hewlett-Packard S. A.
Rue du Vieux Billard No. 1
Geneva, Switzerland

Specify the following information for each part:

1) Model and complete serial number of instrument.

2) Hewlett-Packard stock number.

3) Circuit reference designator.

4) Description.

To order a part not listed in table 5-1, give a complete description of the part and include its function and location.

Table 5-1. Replaceable Parts

Ckt Ref	Description	Mfr	Stock No.	TQ	RS		
B1	Motor: fan	28480	3140-0010	1	1		
C1	Capacitor: fixed, mica, 270 pf ±10%, 500 vdcw	00853	0140-0015	1	1		
C2	Capacitor: fixed, mica, 253 pf ±2%, 300 vdcw	76433	0140-0108	1	1		
C3	Capacitor: variable, ceramic, 7-45 pf, 500 vdcw	72982	0130-0001	2	1		
C4	Capacitor: fixed, mylar, .1 μf ±20%, 600 vdcw	09134	0170-0022	2	1		
C5	Capacitor: fixed, paper, 1 μf ±10%, 600 vdcw	24466	0160-0079	2	1		
C6	Capacitor: fixed, paper, 1500 pf ±10%, 600 vdcw	56289	0160-0012	1	1		

Table 5-1. Replaceable Parts (Cont'd)

Ckt Ref	Description	Mfr *	hp Stock No.	TQ*	RS*		
C7	Capacitor: fixed, mylar, .22 μf ±10%, 200 vdcw	56289	0170-0038	1	1		
C8	Capacitor: fixed, mylar, .1 μf ±5%, 200 vdcw	84411	0170-0019	2	1		
C9	Capacitor: fixed, paper, .051 μf ±5%, 600 vdcw	56289	0160-0021	1	1		
C10	Same as C5						
C11	Same as C8						
C12, 13	Capacitor: fixed, mylar, .022 μf ±10%, 400 vdcw	84411	0170-0005	4	1		
C14	Same as C4						
C15	Capacitor: fixed, paper, .0022 μf ±10%, 600 vdcw	56289	0160-0007	1	1		
C16, 17	Capacitor: fixed, paper, .01 μf ±10%, 600 vdcw	56289	0160-0002	3	1		
C18, 19	Capacitor: fixed, electrolytic, 50 μf -10% + 200%, 50 vdcw	37942	0180-0029	2	1		
C20	Capacitor: fixed, paper, .01 μf ±10%, 1600 vdcw	00656	0160-0023	1	1		
C21	Not assigned						
C22	Capacitor: fixed, mica, 390 pf ±2%, 500 vdcw	76433	0140-0114	1	1		
C23	Same as C12						
C24	Capacitor: fixed, mylar, .0018 μf ±2%, 600 vdcw	09134	0170-0035	1	1		
C25	Same as C12						
C26, 27	Capacitor: fixed, electrolytic, 4 sect. 20 μf/sect., 450 vdcw	56289	0180-0025	2	1		
C28	Same as C16						
C29	Capacitor: fixed, paper, .5 μf ±10%, 400 vdcw	14655	0160-0024	1	1		

* See introduction to this section

Table 5-1. Replaceable Parts (Cont'd)

Ckt Ref	Description	Mfr *	℗ Stock No.	TQ*	RS*		
C30	Capacitor: fixed, paper, .015 μf ±10%, 600 vdcw	56289	0160-0065	1	1		
C31	Not assigned						
C32	Same as C3						
CR1	Diode, silicon: 3ES2	81483	1901-0005	1	1		
DS1	Lamp, incandescent: 6-8V, .15 amp, #47	24455	2140-0009	1	1		
F1	Fuse, cartridge: 4 amp, slow blow, 125V for 115V operation	71400	2110-0014	1	10		
	2 amp, slow blow, 125V for 230V operation	71400	2110-0006				
J1	Binding Post Assembly:						
	Insulator	28480	AC-54A	2	1		
	Binding Post (black)	28480	G-10C	1	1		
	Binding Post (red)	28480	G-10D	1	1		
J2 thru J100	Not assigned						
J101	Connector, female BNC Jack, panel mounting	91737	1250-0074	1	1		
J102	Connector, female, BNC Jack	91737	1250-0075	1	1		
L1	Coil: toroid, assembly	28480	738A-60A	1	1		
L2	Coil: type A-11	89665	9120-0050	1	1		
P1	Cable: power	83148	8120-0015	1	1		
R1,2	Resistor: fixed, deposited carbon, 1.39 megohms ±1%, 1 W	19701	0730-0109	2	1		
R3	Resistor: fixed, composition, 2200 ohms ±10%, 2 W	01121	0693-2221	1	1		
R4	Resistor: fixed, composition, 390 ohms ±10%, 1 W Optimum value selected at factory Average value shown	01121	0690-3911	1	1		

* See introduction to this section

Table 5-1. Replaceable Parts (Cont'd)

Ckt Ref	Description	Mfr *	℗ Stock No.	TQ*	RS*		
R5	Resistor: fixed, composition, 100,000 ohms ±10%, 1 W	01121	0690-1041	5	2		
R6	Resistor: fixed, composition, 82,000 ohms ±10%, 1 W	01121	0690-8231	1	1		
R7	Resistor: fixed, composition, 33,000 ohms ±10%, 1 W	01121	0690-3331	1	1		
R8	Resistor: fixed, composition, 220,000 ohms ±10%, 1/2 W	01121	0687-2241	3	1		
R9	Resistor: fixed, metal film, 270 ohms ±10%, 4 W	07115	0771-0001	1	1		
R10	Resistor: fixed, composition, 330 ohms ±10%, 1/2 W	01121	0687-3311	1	1		
R11	Resistor: fixed, wirewound, 7500 ohms ±10%, 10 W	91637	0816-0007	1	1		
R12	Same as R5 Optimum value selected at factory Average value shown						
R13, 14	Resistor: fixed, composition, 150 ohms ±10%, 1/2 W	01121	0687-1511	2	1		
R15	Resistor: fixed, composition, 1.2 megohms ±10%, 1/2 W	01121	0687-1251	1	1		
R16	Same as R5						
R17	Resistor: fixed, composition, 200,000 ohms ±5%, 1/2 W	01121	0686-2045	2	1		
R18	Resistor: fixed, composition, 56,000 ohms ±10%, 1/2 W	01121	0687-5631	1	1		
R19	Same as R17						
R20	Resistor: fixed, composition, 2200 ohms ±10%, 1/2 W	01121	0687-2221	3	1		
R21	Resistor: fixed, composition, 1500 ohms ±10%, 1/2 W	01121	0687-1521	1	1		
R22,23	Resistor: fixed, composition, 82,000 ohms ±10%, 1/2 W	01121	0687-8231	2	1		

* See introduction to this section

Table 5-1. Replaceable Parts (Cont'd)

Ckt Ref	Description	Mfr *	Stock No.	TQ*	RS*		
R24,25	Same as R8						
R26	Resistor: fixed, wirewound, 5000 ohms ±1%, 5 W	91637	0811-0006	1	1		
R27	Not assigned						
R28	Resistor: fixed, composition, 220,000 ohms ±10%, 1 W	01121	0690-2241	1	1		
R29	Resistor: fixed, composition, 22,000 ohms ±5%, 2 W	01121	0692-2235	2	1		
R30,31	Not assigned						
R32	Same as R5						
R33	Same as R29						
R34,35	Resistor: fixed, wirewound, 300 ohms ±5%, 10 W	35434	0815-0007	2	1		
R36,37	Resistor: fixed, deposited carbon, 100,000 ohms ±1%, 2 W	19701	0730-0069	2	1		
R38	Not assigned						
R39	Resistor: fixed, wirewound, 175,800 ohms ±1%, 1 W	91827	0811-0039	1	1		
R40	Resistor: variable, wirewound, 25,000 ohms ±10%, 4 W	79727	2100-0247	1	1		
R41	Resistor: fixed, wirewound, 468,000 ohms ±1%, 1/2 W	91827	0811-0013	1	1		
R42	Resistor: fixed, composition, 12,000 ohms ±5%, 1/2 W	01121	0686-1235	1	1		
R43,44	Same as R20						
R45	Resistor: fixed, composition, 120,000 ohms ±10%, 1/2 W	01121	0687-1241	1	1		
R46	Resistor: fixed, composition, 150,000 ohms ±10%, 1/2 W	01121	0687-1541	1	1		
R47	Resistor: fixed, composition, 100,000 ohms ±10%, 1/2 W	01121	0687-1041	3	1		

* See introduction to this section

Table 5-1. Replaceable Parts (Cont'd)

Ckt Ref	Description	Mfr *	℗ Stock No.	TQ*	RS*		
R48	Resistor: fixed, composition, 4.7 megohms ±10%, 1/2 W	01121	0687-4751	1	1		
R49	Same as R47						
R50,51	Same as R5						
R52	Resistor: fixed, deposited carbon, 90,000 ohms ±1%, 1 W	19701	0730-0064	1	1		
R53	Resistor: fixed, composition, 68,000 ohms ±10%, 1 W	01121	0690-6831	1	1		
R54	Resistor: fixed, composition, 120,000 ohms ±10%, 1 W	01121	0690-1241	1	1		
R55	Resistor: fixed, composition, 820,000 ohms ±10%, 1 W	01121	0690-8241	1	1		
R56	Resistor: fixed, composition, 1000 ohms ±10%, 1 W	01121	0690-1021	1	1		
R57,58	Resistor: fixed, composition, 510,000 ohms ±10%, 1 W	01121	0689-5145	2	1		
R59	Resistor: fixed, composition, 1 megohm ±10%, 1/2 W	01121	0687-1051	1	1		
R60	Resistor: fixed, composition, 2.7 megohms ±10%, 1/2 W	01121	0687-2751	1	1		
R61	Resistor: fixed, composition, 150,000 ohms ±10%, 1 W	01121	0690-1541	1	1		
R62	Resistor: fixed, wirewound, 245,000 ohms ±1%, 1 W	91827	0811-0037	1	1		
R63	Resistor: variable, wirewound, 10,000 ohms ±20%, 2 W	79727	2100-0246	1	1		
R64	Resistor: fixed, wirewound, 100,000 ohms ±1%, 1 W	71471	0811-0019	4	1		
R65	Resistor: fixed, composition, 18 ohms ±10%, 1 W	01121	0690-1801	1	1		
R66	Same as R64						
R67	Resistor: variable, wirewound, 10,000 ohms	71590	2100-0053	1	1		

* See introduction to this section

Table 5-1. Replaceable Parts (Cont'd)

Ckt Ref	Description	Mfr *	ⓗ Stock No.	TQ*	RS*		
R68,69	Same as R64						
R70	Resistor: fixed, composition, 47,000 ohms ±10%, 1 W	01121	0690-4731	1	1		
R71	Same as R47						
R72	Resistor: fixed, wirewound, 15,000 ohms ±10%, 20 W	94310	0819-0008	1	1		
R73 thru R100	Not assigned						
R101	Resistor: fixed, wirewound, 3000 ohms ±.1%, 2 W	71471	0811-0022	2	1		
R102	Resistor: fixed, wirewound, 2980 ohms ±.1%, 2 W	71471	0811-0023	1	1		
R103	Same as R101						
R104	Resistor: fixed, wirewound, 3010 ohms ±.1%, 2 W	71471	0811-0020	1	1		
R105	Resistor: fixed, wirewound, 3006 ohms ±.1%, 2 W	71471	0811-0021	1	1		
R106	Resistor: fixed, wirewound, 1202 ohms ±.1%, 1-1/4 W	71471	0811-0024	1	1		
R107, R108	Resistor: fixed, wirewound, 601 ohms ±.1%, 1 W	71471	0811-0026	1	1		
R109	Resistor: fixed, wirewound, 300 ohms ±.1%, 1/4 W	71471	0811-0029	6	2		
R110	Resistor: fixed, wirewound, 120 ohms ±.1%, 1/4 W	71471	0811-0031	2	1		
R111	Resistor: fixed, wirewound, 200 ohms ±.1%, 1/4 W	71471	0811-0030	2	1		
R112 thru R115	Same as R109						
R116 thru R122	Resistor: fixed, wirewound, 60 ohms ±.1%, 1/4 W	71471	0811-0032	7	2		

* See introduction to this section

Table 5-1. Replaceable Parts (Cont'd)

Ckt Ref	Description	Mfr *	Stock No.	TQ*	RS*		
R123	Same as R111						
R124,125	Resistor: fixed, wirewound, 600 ohms ±.1%, 1/4 W	71471	0811-0028	2	1		
R126	Same as R109						
R127	Same as R110						
R128	Resistor: fixed, wirewound, 1260 ohms ±.1%, 1/4 W	71471	0811-0027	1	1		
R129,130	Resistor: fixed, wirewound, 70 ohms ±.1%, 1/4 W	71471	0811-0025	3	1		
R131	Resistor: fixed, wirewound, 35 ohms ±.1%, 1/4 W	71471	0811-0033	2	1		
R132	Resistor: fixed, wirewound, 14 ohms ±.1%, 1/4 W	71471	0811-0036	2	1		
R133	Resistor: fixed, wirewound, 23.33 ohms ±.1%, 1/4 W	71471	0811-0034	1	1		
R134,135	Same as R129						
R136	Same as R131						
R137	Same as R132						
R138	Resistor: fixed, wirewound, 21 ohms ±.1%, 1/4 W	71471	0811-0035	1	1		
RT1	Lamp, incandescent: 250V, 10 W	24455	2140-0007	1	1		
S1	Switch, toggle: SPST, OFF-ON	04009	3101-0001	1	1		
S2	Switch assembly: (OUTPUT SELECTOR)	28480	738A-19A	1	1		
S3 thru S100	Not assigned						
S101	Switch, rotary: 2 sect., 10 pos.	71471	3100-0205	1	1		
S102	Switch, rotary: 2 sect., 3 pos.	71471	3100-0206	1	1		
	Switch Assembly: FUNCTION	28480	738A-19A	1	1		

* See introduction to this section

Table 5-1. Replaceable Parts (Cont'd)

Ckt Ref	Description	Mfr *	Stock No.	TQ*	RS*		
S103	Switch, rotary: 2 sect., 7 pos.	71471	3100-0203				
	Switch Assembly: MULTIPLIER	28480	738A-19C	1	1		
S104	Switch, rotary: 3 sect., 5 pos.	71471	3100-0204				
	Switch Assembly: RANGE	28480	738A-19B	1	1		
T1	Transformer, power	28480	9100-0082	1	1		
T2	Not assigned						
T3	Transformer, output	28480	9120-0030	1	1		
V1	Tube, electron: 6AU6	80131	1923-0021	1	1		
V2	Tube, electron: 6CL6	80131	1923-0030	1	1		
V3	Tube, electron: 6BA6	80131	1923-0025	1	1		
V4	Tube, electron: 12AX7	80131	1932-0030	4	4		
V5	Tube, electron: 12AU7	80131	1932-0029	1	1		
V6, 7	Tube, electron: 6550	80131	1923-0009	1	1		
V8	Tube, electron: 6AL5	80131	1930-0013	1	1		
V9	Same as V4						
V10	Tube, electron: 5651	80131	1940-0001	1	1		
V11, 12	Same as V4						
V13	Tube, electron: 5U4GB	80131	1930-0008	1	1		
V14	Tube, electron: 6AV5GA	80131	1923-0023	1	1		
	MISCELLANEOUS						
	Attenuator, assembly: includes J101,J102, R101 thru R138, S101 thru S104 (Due to the extreme precision of the parts used in this assembly, it is recommended that the complete attenuator assembly be sent to the factory for repair and calibration.)	28480	738A-34A	1	1		
	Blade, fan	06812	3160-0014	1	1		
	Filter, air	82866	3150-0005	1	1		
	Holder, fuse	75915	1400-0084	1	1		
	Knob	28480	G-74N	5	1		
	Lampholder, candelabra	95263	1450-0013	1	1		
	Oil, soluble: for air filter; 1-pint can with spray dispenser	82866	3150-0002	1	0		

* See introduction to this section

APPENDIX
CODE LIST OF MANUFACTURERS (Sheet 1 of 2)

The following code numbers are from the Federal Supply Code for Manufacturers Cataloging Handbooks H4-1 (Name to Code) and H4-2 (Code to Name) and their latest supplements. The date of revision and the date of the supplements used appear at the bottom of each page. Alphabetical codes have been arbitrarily assigned to suppliers not appearing in the H4 handbooks.

CODE NO.	MANUFACTURER	ADDRESS
00334	Humidial Co.	Colton, Calif.
00335	Westrex Corp.	New York, N.Y.
00373	Garlock Packing Co., Electronic Products Div.	Camden, N.J.
00656	Aerovox Corp.	New Bedford, Mass.
00779	Amp, Inc.	Harrisburg, Pa.
00781	Aircraft Radio Corp.	Boonton, N.J.
00853	Sangamo Electric Co., Cap. Div.	Marion, Ill.
00866	Goe Engineering Co.	Los Angeles, Calif.
00891	Carl E. Holmes Corp.	Los Angeles, Calif.
01121	Allen Bradley Co.	Milwaukee, Wis.
01255	Litton Industries, Inc.	Baverly Hills, Calif.
01281	Pacific Semiconductors, Inc.	Culver City, Calif.
01295	Texas Instruments, Inc. Semiconductor Components Div.	Dallas, Texas
01349	The Alliance Mfg. Co.	Alliance, Ohio
01561	Chassi-Trak Corp.	Indianapolis, Ind.
01930	Amerock Corp.	Rockford, Ill.
01961	Pulse Engineering Co.	Santa Clara, Calif.
02114	Ferroxcube Corp. of America	Saugerties, N.Y.
02286	Cole Mfg. Co.	Palo Alto, Calif.
02660	Amphenol Electronics Corp.	Chicago, Ill.
02735	Radio Corp. of America Semiconductor and Materials Div.	Somerville, N.J.
02771	Vocaline Co. of America, Inc.	Old Saybrook, Conn.
02777	Hopkins Engineering Co.	San Fernando, Calif.
03508	G.E. Semiconductor Products Dept.	Syracuse, N.Y.
03705	Apex Machine & Tool Co.	Dayton, Ohio
03797	Eldema Corp.	El Monte, Calif.
03877	Transitron Electronic Corp.	Wakefield, Mass.
03888	Pyrofilm Resistor Co.	Morristown, N.J.
03954	Air Marine Motors, Inc.	Los Angeles, Calif.
04009	Arrow, Hart and Hegeman Elect. Co.	Hartford, Conn.
04062	Elmenco Products Co.	New York, N.Y.
04222	Hi-Q Division of Aerovox	Myrtle Beach, S.C.
04298	Elgin National Watch Co., Electronics Division	Burbank, Calif.
04404	Dymec Division of Hewlett-Packard Co.	Palo Alto, Calif.
04651	Special Tube Operations of Sylvania Electronic Systems	Mountain View, Calif.
04713	Motorola, Inc., Semiconductor Prod. Div.	Phoenix, Arizona
04732	Filtron Co., Inc. Western Division	Culver City, Calif.
04773	Automatic Electric Co.	Northlake, Ill.
05006	Twentieth Century Plastics, Inc.	Los Angeles, Calif.
05277	Westinghouse Electric Corp., Semi-Conductor Dept.	Youngwood, Pa.
05593	Illumitronic Engineering Co.	Sunnyvale, Calif.
05624	Barber Colman Co.	Rockford, Ill.
05729	Metropolitan Telecommunications Corp., Metro Cap. Div.	Brooklyn, N.Y.
05783	Stewart Engineering Co.	Soquel, Calif.
06004	The Bassick Co.	Bridgeport, Conn.
06555	Beede Electrical Instrument Co., Inc.	Penacook, N.H.
06812	Torrington Mfg. Co., West Div.	Van Nuys, Calif.
07115	Corning Glass Works Electronic Components Dept.	Bradford, Pa.
07126	Digitran Co.	Pasadena, Calif.
07137	Transistor Electronics Corp.	Minneapolis, Minn.
07138	Westinghouse Electric Corp. Electronic Tube Div.	Elmira, N.Y.
07261	Avnet Corp.	Los Angeles, Calif.
07263	Fairchild Semiconductor Corp.	Mountain View, Calif.
07910	Continental Device Corp.	Hawthorne, Calif.
07933	Rheem Semiconductor Corp.	Mountain View, Calif.
07980	Boonton Radio Corp.	Boonton, N.J.
08145	U.S. Engineering Co.	Los Angeles, Calif.
08358	Burgess Battery Co.	Niagara Falls, Ontario, Canada
08717	Sloan Company	Burbank, Calif.
08718	Cannon Electric Co. Phoenix Div.	Phoenix, Ariz.
08792	CBS Electronics Semiconductor Operations, Div. of C.B.S. Inc.	Lowell, Mass.
09026	Babcock Relays, Inc.	Costa Mesa, Calif.
09134	Texas Capacitor Co.	Houston, Texas
09250	Electro Assemblies, Inc.	Chicago, Ill.
09569	Mallory Battery Co. of Canada, Ltd.	Toronto, Ontario, Canada
10411	Ti-Tal, Inc.	Berkeley, Calif.
10646	Carborundum Co.	Niagara Falls, N.Y.
11236	CTS of Berne, Inc.	Berne, Ind.
11237	Chicago Telephone of California, Inc.	So. Pasadena, Calif.
11312	Microwave Electronics Corp.	Palo Alto, Calif.
11870	Melabs, Inc.	Palo Alto, Calif.
12697	Clarostat Mfg. Co.	Dover, N.H.
14655	Cornell Dubilier Elec. Corp.	So. Plainfield, N.J.
15909	The Daven Co.	Livingston, N.J.
16758	Delco Radio Div. of G. M. Corp.	Kokomo, Ind.
18873	E. I. DuPont and Co., Inc.	Wilmington, Del.
19315	Eclipse Pioneer, Div. of Bendix Aviation Corp.	Teterboro, N.J.
19500	Thomas A. Edison Industries, Div. of McGraw-Edison Co.	West Orange, N.J.
19701	Electra Manufacturing Co.	Kansas City, Mo.
20183	Electronic Tube Corp.	Philadelphia, Pa.
21520	Fansteel Metallurgical Corp.	No. Chicago, Ill.
21335	The Fafnir Bearing Co.	New Britain, Conn.
21964	Fed. Telephone and Radio Corp.	Clifton, N.J.
24446	General Electric Co.	Schenectady, N.Y.
24455	G.E., Lamp Division	Nela Park, Cleveland, Ohio
24655	General Radio Co.	West Concord, Mass.
26462	Grobet File Co. of America, Inc.	Carlstadt, N.J.
26992	Hamilton Watch Co.	Lancaster, Pa.
28480	Hewlett-Packard Co.	Palo Alto, Calif.
33173	G.E. Receiving Tube Dept.	Owensboro, Ky.
35434	Lectrohm Inc.	Chicago, Ill.
37942	P. R. Mallory & Co., Inc.	Indianapolis, Ind.
39543	Mechanical Industries Prod. Co.	Akron, Ohio
40920	Miniature Precision Bearings, Inc.	Keene, N.H.
42190	Muter Co.	Chicago, Ill.
43990	C. A. Norgren Co.	Englewood, Colo.
44655	Ohmite Mfg. Co.	Skokie, Ill.
47904	Polaroid Corp.	Cambridge, Mass.
48620	Precision Thermometer and Inst. Co.	Philadelphia, Pa.
49956	Raytheon Mfg. Co.	Waltham, Mass.
54294	Shallcross Mfg. Co.	Selma, N.C.
55026	Simpson Electric Co.	Chicago, Ill.
55933	Sonotone Corp.	Elmsford, N.Y.
55938	Sorenson & Co., Inc.	So. Norwalk, Conn.
56137	Spaulding Fibre Co., Inc.	Tonawanda, N.Y.
56289	Sprague Electric Co.	North Adams, Mass.
59446	Telex, Inc.	St. Paul, Minn.
61775	Union Switch and Signal, Div. of Westinghouse Air Brake Co.	Pittsburgh, Pa.
62119	Universal Electric Co.	Owosso, Mich.
64959	Western Electric Co., Inc.	New York, N.Y.
65092	Weston Inst. Div. of Daystrom, Inc.	Newark, N.J.
66346	Wollensak Optical Co.	Rochester, N.Y.
70276	Allen Mfg. Co.	Hartford, Conn.
70309	Allied Control Co., Inc.	New York, N.Y.
70485	Atlantic India Rubber Works, Inc.	Chicago, Ill.
70563	Amperite Co., Inc.	New York, N.Y.
70903	Belden Mfg. Co.	Chicago, Ill.
70998	Bird Electronic Corp.	Cleveland, Ohio
71002	Birnbach Radio Co.	New York, N.Y.
71041	Boston Gear Works Div. of Murray Co. of Texas	Quincy, Mass.
71218	Bud Radio Inc.	Cleveland, Ohio
71286	Camloc Fastener Corp.	Paramus, N.J.
71313	Allen D. Cardwell Electronic Prod. Corp.	Plainville, Conn.
71400	Bussmann Fuse Div. of McGraw-Edison Co.	St. Louis, Mo.
71450	CTS Corp.	Elkhart, Ind.
71468	Cannon Electric Co.	Los Angeles, Calif.
71471	Cinema Engineering Co.	Burbank, Calif.
71482	C. P. Clare & Co.	Chicago, Ill.
71590	Centralab Div. of Globe Union Inc.	Milwaukee, Wis.
71700	The Cornish Wire Co.	New York, N.Y.
71744	Chicago Miniature Lamp Works	Chicago, Ill.
71753	A. O. Smith Corp., Crowley Div.	West Orange, N.J.
71785	Cinch Mfg. Corp.	Chicago, Ill.
71984	Dow Corning Corp.	Midland, Mich.
72136	Electro Motive Mfg. Co., Inc.	Willimantic, Conn.
72354	John E. Fast & Co.	Chicago, Ill.
72619	Dialight Corp.	Brooklyn, N.Y.
72656	General Ceramics Corp.	Keasbey, N.J.
72758	Girard-Hopkins	Oakland, Calif.
72765	Drake Mfg. Co.	Chicago, Ill.
72825	Hugh H. Eby Inc.	Philadelphia, Pa.
72928	Gudeman Co.	Chicago, Ill.
72982	Erie Resistor Corp.	Erie, Pa.
73061	Hansen Mfg. Co., Inc.	Princeton, Ind.
73138	Helipot Div. of Beckman Instruments, Inc.	Fullerton, Calif.
73293	Hughes Products Div. of Hughes Aircraft Co.	Newport Beach, Calif.
73445	Amperex Electronic Co., Div. of North American Phillips Co., Inc.	Hicksville, N.Y.
73506	Bradley Semiconductor Corp.	New Haven, Conn.
73559	Carling Electric, Inc.	Hartford, Conn.
73682	George K. Garrett Co., Inc.	Philadelphia, Pa.
73743	Fischer Special Mfg. Co.	Cincinnati, Ohio
73793	The General Industries Co.	Elyria, Ohio

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APPENDIX
CODE LIST OF MANUFACTURERS (Sheet 2 of 2)

CODE NO.	MANUFACTURER	ADDRESS
73905	Jennings Radio Mfg. Co.	San Jose, Calif.
74455	J. H. Winns, and Sons	Winchester, Mass.
74861	Industrial Condenser Corp.	Chicago, Ill.
74868	Industrial Products Co.	Danbury, Conn.
74970	E. F. Johnson Co.	Waseca, Minn.
75042	International Resistance Co.	Philadelphia, Pa.
75173	Jones, Howard B., Division of Circh Mfg. Corp.	Chicago, Ill.
75378	James Knights Co.	Sandwich, Ill.
75382	Kulka Electric Mfg. Co., Inc.	Mt. Vernon, N.Y.
75818	Lenz Electric Mfg. Co.	Chicago, Ill.
75915	Littelfuse Inc.	Des Plaines, Ill.
76005	Lord Mfg. Co.	Erie, Pa.
76210	C. W. Marwedel	San Francisco, Calif.
76433	Micamold Electronic Mfg. Corp.	Brooklyn, N.Y.
76487	James Millen Mfg. Co., Inc.	Malden, Mass.
76530	Monadnock Mills	San Leandro, Calif.
76545	Mueller Electric Co.	Cleveland, Ohio
76854	Oak Manufacturing Co.	Chicago, Ill.
77068	Bendix Corp., Bendix Pacific Div.	No. Hollywood, Calif.
77221	Phaostron Instrument and Electronic Co.	South Pasadena, Calif.
77342	Potter and Brumfield, Inc.	Princeton, Ind.
77630	Radio Condenser Co.	Camden, N.J.
77634	Radio Essentials Inc.	Mt. Vernon, N.Y.
77638	Radio Receptor Co., Inc.	Brooklyn, N.Y.
77764	Resistance Products Co.	Harrisburg, Pa.
78283	Signal Indicator Corp.	New York, N.Y.
78471	Tilley Mfg. Co.	San Francisco, Calif.
78488	Stackpole Carbon Co.	St. Marys, Pa.
78553	Tinnerman Products, Inc.	Cleveland, Ohio
78790	Transformer Engineers	Pasadena, Calif.
78947	Ucinite Co.	Newtonville, Mass.
79142	Veeder Root, Inc.	Hartford, Conn.
79251	Wenco Mfg. Co.	Chicago, Ill.
79727	Continental-Wirt Electronics Corp.	Philadelphia, Pa.
79963	Zierick Mfg. Corp.	New Rochelle, N.Y.
80031	Mepco Division of Sessions Clock Co.	Morristown, N.J.
80130	Times Facsimile Corp.	New York, N.Y.
80131	Electronic Industries Association Any brand tube meeting EIA standards	Washington, D.C.
80207	Unimax Switch, Div. of W. L. Maxson Corp.	Wallingford, Conn.
80248	Oxford Electric Corp.	Chicago, Ill.
80411	Acro Manufacturing Co.	Columbus, Ohio
80486	All Star Products Inc.	Defiance, Ohio
80583	Hammerlund Co., Inc.	New York, N.Y.
80640	Stevens, Arnold, Co., Inc.	Boston, Mass.
81030	International Instruments, Inc.	New Haven, Conn.
81415	Wilkor Products, Inc.	Cleveland, Ohio
81453	Raytheon Mfg. Co., Industrial Tube Division	Quincy, Mass.
81483	International Rectifier Corp.	El Segundo, Calif.
81860	Barry Controls, Inc.	Watertown, Mass.
82042	Carter Parts Co.	Skokie, Ill.
82142	Jeffers Electronics Division of Speer Carbon Co.	Du Bois, Pa.
82170	Allen B. DuMont Labs., Inc.	Clifton, N.J.
82209	Maguire Industries, Inc.	Greenwich, Conn.
82219	Sylvania Electric Prod. Inc., Electronic Tube Div.	Emporium, Pa.
82376	Astron Co.	East Newark, N.J.
82389	Switchcraft, Inc.	Chicago, Ill.
82647	Texas Instruments, Inc., Metals and Controls Div., Spencer Products	Attleboro, Mass.
82866	Research Products Corp.	Madison, Wis.
82877	Rotron Manufacturing Co., Inc.	Woodstock, N.Y.
82893	Vector Electronic Co.	Glendale, Calif.
83148	Electro Cords Co.	Los Angeles, Calif.
83186	Victory Engineering Corp.	Union, N.J.
83298	Bendix Corp., Red Bank Div.	Red Bank, N.J.
83501	Gavitt Wire and Cable Co., Div. of Amerace Corp.	Brookfield, Mass.
83594	Burroughs Corp., Electronic Tube Div.	Plainfield, N.J.
83777	Model Eng. and Mfg., Inc.	Huntington, Ind.
83821	Loyd Scruggs Co.	Festus, Mo.
84171	Arco Electronics, Inc.	New York, N.Y.
84396	A. J. Glesener Co., Inc.	San Francisco, Calif.
84411	Good All Electric Mfg. Co.	Ogallala, Neb.
84970	Sarkes Tarzian, Inc.	Bloomington, Ind.
85454	Boonton Molding Company	Boonton, N.J.
85474	R. M. Bracamonte & Co.	San Francisco, Calif.
85660	Koiled Kords, Inc.	New Haven, Conn.
85911	Seamless Rubber Co.	Chicago, Ill.
86684	Radio Corp. of America, RCA Electron Tube Div.	Harrison, N.J.
87473	Western Fibrous Glass Products Co.	San Francisco, Calif.
88140	Cutler-Hammer, Inc.	Lincoln, Ill.
89473	General Electric Distributing Corp.	Schenectady, N.Y.
89636	Carter Parts Div. of Economy Baler Co.	Chicago, Ill.
89665	United Transformer Co.	Chicago, Ill.
90179	U.S. Rubber Co., Mechanical Goods Div.	Passaic, N.J.
90970	Bearing Engineering Co.	San Francisco, Calif.
91418	Radio Materials Co.	Chicago, Ill.
91506	Augat Brothers, Inc.	Attleboro, Mass.
91637	Dale Products, Inc.	Columbus, Neb.
91662	Elco Corp.	Philadelphia, Pa.
91737	Gremar Mfg. Co., Inc.	Wakefield, Mass.
91827	K F Development Co.	Redwood City, Calif.
91929	Micro-Switch Div. of Minneapolis Honeywell Regulator Co.	Freeport, Ill.
92196	Universal Metal Products, Inc.	Bassett Puente, Calif.
93332	Sylvania Electric Prod. Inc., Semiconductor Div.	Woburn, Mass.
93369	Robbins and Myers, Inc.	New York, N.Y.
93410	Stevens Mfg. Co., Inc.	Mansfield, Ohio
93983	Insuline-Van Norman Ind., Inc. Electronic Division	Manchester, N.H.
94144	Raytheon Mfg. Co., Receiving Tube Div.	Quincy, Mass.
94145	Raytheon Mfg. Co., Semiconductor Div.	Newton, Mass.
94148	Scientific Radio Products, Inc	Loveland, Colo.
94154	Tung-Sol Electric, Inc.	Newark, N.J.
94197	Curtiss-Wright Corp., Electronics Div.	Carlstadt, N.J.
94310	Tru Ohm Prod. Div. of Model Engineering and Mfg. Co.	Chicago, Ill.
94682	Worcester Pressed Aluminum Corp.	Worcester, Mass.
95236	Allies Products Corp.	Miami, Fla.
95238	Continental Connector Corp.	Woodside, N.Y.
95263	Leecraft Mfg. Co., Inc.	New York, N.Y.
95264	Lerco Electronics, Inc.	Burbank, Calif.
95265	National Coil Co.	Sheridan, Wyo.
95275	Vitramon, Inc.	Bridgeport, Conn.
95354	Methode Mfg. Co.	Chicago, Ill.
95987	Weckesser Co.	Chicago, Ill.
96067	Huggins Laboratories	Sunnyvale, Calif.
96095	Hi-Q Division of Aerovox	Olean, N.Y.
96296	Solar Manufacturing Co.	Los Angeles, Calif.
96330	Carlton Screw Co.	Chicago, Ill.
96341	Microwave Associates, Inc.	Burlington, Mass.
96493	J. W. Miller Co.	Los Angeles, Calif.
96501	Excel Transformer Co.	Oakland, Calif.
97539	Automatic and Precision Mfg. Co.	Yonkers, N.Y.
97966	CBS Electronics, Div. of C.B.S., Inc.	Danvers, Mass.
98141	Axel Brothers Inc.	Jamaica, N.Y.
98220	Francis L. Mosley	Pasadena, Calif.
98278	Microdot, Inc.	So. Pasadena, Calif.
98291	Sealectro Corp.	New Rochelle, N.Y.
98405	Carad Corp.	Redwood City, Calif.
98734	Palo Alto Engineering Co., Inc.	Palo Alto, Calif.
98925	Clevite Transistor Prod. Div. of Clevite Corp.	Waltham, Mass.
98978	International Electronic Research Corp.	Burbank, Calif.
99109	Columbia Technical Corp.	New York, N.Y.
99313	Varian Associates	Palo Alto, Calif.
99515	Marshall Industries, Electron Products Division	Pasadena, Calif.
99707	Control Switch Division, Controls Co. of America	El Segundo, Calif.
99800	Delevan Electronics Corp.	East Aurora, N.Y.
99821	North Hills Electric Co.	Great Neck, L.I., N.Y.
99848	Wilco Corporation	Indianapolis, Ind.
99934	Renbrandt, Inc.	Boston, Mass.
99942	Hoffman Semiconductor Div. of Hoffman Electronics Corp.	Evanston, Ill.
99957	Technology Instruments Corp. of Calif.	No. Hollywood, Calif.

THE FOLLOWING H-P VENDORS HAVE NO NUMBER ASSIGNED IN THE LATEST SUPPLEMENT TO THE FEDERAL SUPPLY CODE FOR MANUFACTURERS HANDBOOK.

0000C	Connor Spring Mfg. Co.	San Francisco, Calif.
0000F	Malco Tool and Die	Los Angeles, Calif.
0000H	Philco Corp. (Lansdale Division)	Lansdale, Pa.
0000I	Telefunken (c/o American Elite)	New York, N.Y.
0000L	Winchester Electronics, Inc.	Santa Monica, Calif.
0000M	Western Coil Div. of Automatic Ind., Inc.	Redwood City, Calif.
0000N	Nahm-Bros. Spring Co.	San Leandro, Calif.
0000P	Ty-Car Mfg. Co., Inc.	Holliston, Mass.
0000T	Texas Instruments, Inc. Metals and Controls Div.	Versailles, Ky.
0000U	Tower Mfg. Corp.	Providence, R.I.
0000V	Imperial Electronics, Inc.	Buena Park, Calif.
0000W	Webster Electronics Co. Inc.	New York, N.Y.
0000X	Spruce Pine Mica Co.	Spruce Pine, N.C.
0000Y	Midland Mfg. Co. Inc.	Kansas City, Kans.
0000Z	Willow Leather Products Corp.	Newark, N.J.
000AA	British Radio Electronics Ltd.	Washington, D.C.
000BB	Precision Instrument Components Co.	Van Nuys, Calif.
000CC	Computer Diode Corp.	Lodi, N.J.
000DD	General Transistor	Los Angeles, Calif.

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WARRANTY

All our products are warranted against defects in materials and workmanship for one year from the date of shipment. Our obligation is limited to repairing or replacing products (except tubes) which prove to be defective during the warranty period. We are not liable for consequential damages.

For assistance of any kind, including help with instruments under warranty, contact your authorized hp Sales Representative for instructions. Give full details of the difficulty and include the instrument model and serial numbers. Service data or shipping instructions will be promptly sent to you. There will be no charge for repair of instruments under warranty, *except transportation charges*. Estimates of charges for non-warranty or other service work will always be supplied, if requested, before work begins.

CLAIM FOR DAMAGE IN SHIPMENT

Your instrument should be inspected and tested as soon as it is received. The instrument is insured for safe delivery. If the instrument is damaged in any way or fails to operate properly, file a claim with the carrier or, if insured separately, with the insurance company.

SHIPPING

On receipt of shipping instructions, forward the instrument prepaid to the destination indicated. You may use the original shipping carton or any strong container. Wrap the instrument in heavy paper or a plastic bag and surround it with three or four inches of shock-absorbing material to cushion it firmly and prevent movement inside the container.

GENERAL

Your authorized hp Sales Representative is ready to assist you in any situation, and you are always welcome to get directly in touch with Hewlett-Packard service departments:

CUSTOMER SERVICE

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395 Page Mill Road
Palo Alto, California, U.S.A.
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Direct Dial Area Code 415
TWX No. PAL AL 117-U
Cable: "HEWPACK"

OR (In Western Europe)

Hewlett-Packard S.A.
Rue du Vieux Billard No. 1
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Cable: "HEWPACKSA"