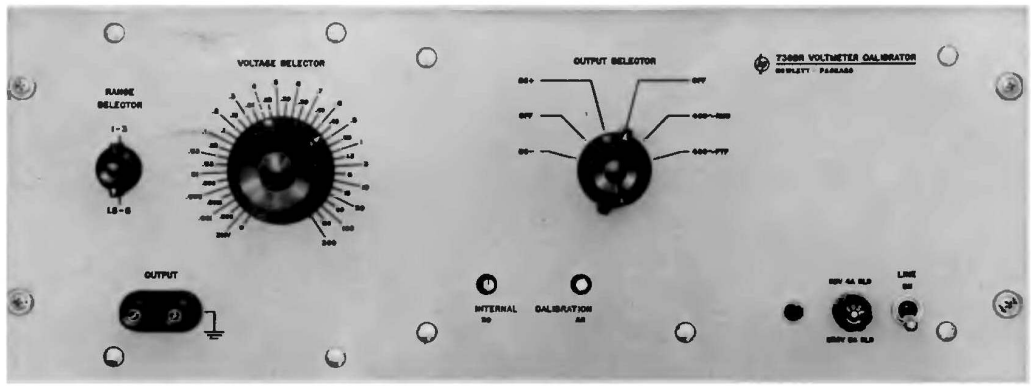
OPERATING AND SERVICE MANUAL

VOLTMETER CALIBRATOR
738BR



HEWLETT hp PACKARD

OPERATING AND SERVICE MANUAL

HP PART NO. 00738-90002

MODEL 738BR
VOLTMETER CALIBRATOR

SERIALS PREFIXED: 446-, 503-, 963-

P. O. Box 301, Loveland, Colorado, 80537 U. S. A.

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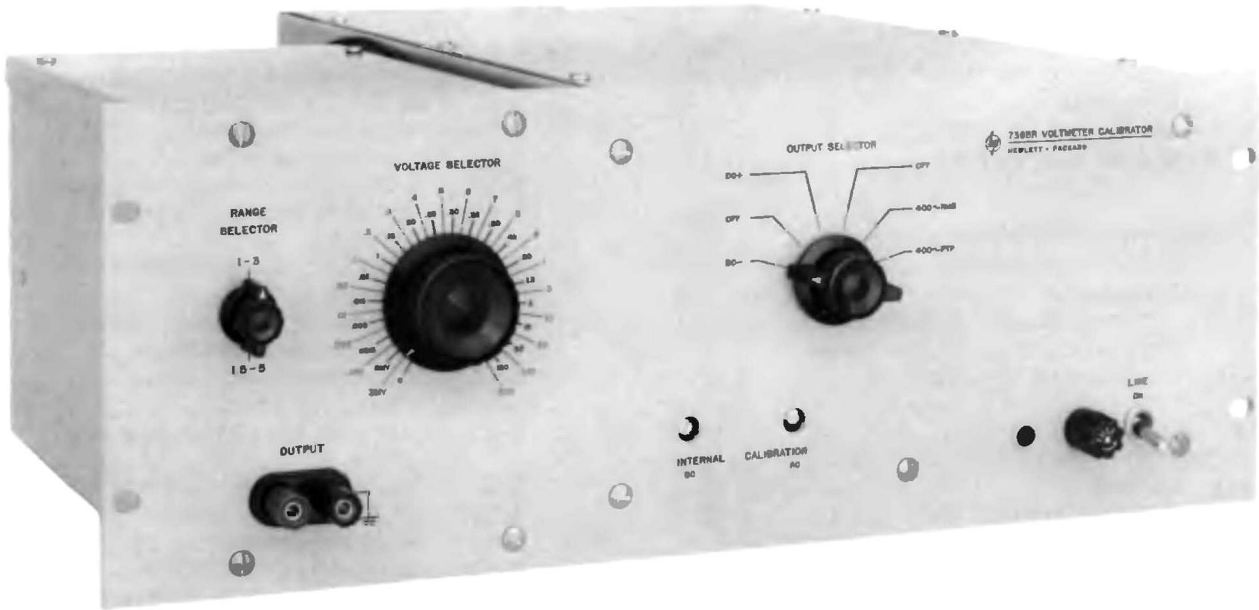


Figure 1-1. Model 738BR Voltage Calibrator

Table 1-1. Specifications

VOLTAGE RANGE: 300 μv to 300 v, dc or ac (rms and peak-to-peak, 400 cps). LEVELS: Calibration voltage 300 μv to 300 v in steps of 1, 3, 1.5, and 5. Tracking voltages 0.1 to 1.0 volts in 0.1 volt steps and 0.05 to 0.5 volts in 0.05 volt steps. ACCURACY: 300 v working voltage into attenuator, accurate within 0.1% dc and 0.2% ac after a 30-minute warm-up. LONG-TERM STABILITY: Less than 0.1% dc drift per week, less than 0.2% ac drift per week.	ATTENUATOR ACCURACY: Within ±0.1% or ±2.5 μv, whichever is larger, open circuit. POWER SUPPLY: 115/230 volts ±10%, 50-60 cycles, 350 watts. DIMENSIONS: Rack Mount: 19 inches (482, 6 mm) wide, 6-31/32 inches (177, 0 mm) high, 15-1/16 inches (382, 6 mm) deep. WEIGHT: Rack Mount: Net 38 lbs. (17 kg). Shipping approximately 53 lbs. (24 kg)

SECTION I
GENERAL INFORMATION

1-1. INTRODUCTION.

1-2. The hp Model 738BR 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 millivolts up to 300 volts, in precision steps. Accuracy of the output attenuator is within ±0.1% or ±2.5 μvolts, whichever is greater. The attenuator section is in a separate compartment. It is designed to operate into an open circuit, but it is within specifications when operated into a load as small as 10 megohms. The only operating adjustments required are adjustment of ac and dc source voltages and bi-yearly standardization.

1-3. The hp Model 738BR Voltmeter Calibrator has been designed to calibrate voltmeters which have ranges of 300, 100 and successive submultiples of 10 and voltmeters which have ranges of 150, 50 and submultiples of 10.

1-4. The hp Voltmeter Calibrator consists of two separate interconnected units mounted on one standard 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 Hz, 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.

1-5. The Attenuator section for the 738BR consists of a precision voltage divider, located on two etched circuit boards, and a dual switch located on the front panel. The electronic portion of the 738BR is identical to that of the 738AR, serial prefixed 441- and above.

1-6. The calibrating voltages run from 300 microvolts to 300 volts in two ranges of 20 precise steps each. Tracking voltages are for the 1 volt range in steps of 0.1 volt, and 0.5 volt range in steps of 0.05 volts.

1-7. No standardizing voltmeter is included with the Model 738BR. The amplitude of the 738BR output voltage cannot be adjusted accurately against a conventional voltmeter since the 0.1% accuracy of the 738BR is better than the accuracy of most meters. See the performance check procedure in Section V for proper test equipment used in checking the accuracy of the 738BR.

1-8. 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 four screws, two knobs, and one BNC connector. The circuitry of the generator section is easily accessible from below the chassis.

1-9. INSTRUMENT IDENTIFICATION.

1-10. Hewlett-Packard uses a two-section eight-digit serial number (000-00000). If the first three digits of the serial number on your instrument do not agree with those on the title page of this manual, change sheets supplied with the manual will define differences between your instrument and the Model 738BR described in this manual.

1-11. SPECIAL INSTRUMENTS.

1-12. Any ac output frequency from 400 Hz to 1000 Hz is available on special order.

SECTION III
OPERATING INSTRUCTIONS

3-1. GENERAL.

3-2. The ℗ Model 738B Voltmeter Calibrator Panel controls are shown in Figure 3-1 and the Operating Instructions are given in Figure 3-2.

3-3. A fan in the cabinet assures adequate ventilation provided 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 5-3 for cleaning instructions.

WARNING

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

3-4. EXTERNAL LOAD.

3-5. This instrument is designed to operate into an open circuit. Loads down to 10 megohms may be used without degrading the specifications of the instrument. See Table 3-1 for load and voltage variations. If less than a 1 megohm load is desired, a series resistor may be used to increase the resistance of the load to 1 megohm. For example, if a meter with a 100 K ohm input impedance is to be connected to the output of the 738BR, then a resistor of at least .9 megohms should be placed in series with the meter to be calibrated (Table 3-1).

3-6. PREVENTING ERRORS FROM GROUND CURRENTS.

3-7. Ground currents between the instrument being calibrated and the Model 738BR 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.

3-8. Most instruments that operate from a power line develop spurious voltages between their chassis and ground. The 738BR 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 738BR may be insulated from ground so that it cannot provide the ground-return path. This insulation from power ground may be accomplished by placing an insulating adapter (3 female pins to 2 male pins) between the power source outlet and the power input connector for the 738BR. The ℗ Part Number for this adapter connector is 1251-0048. The instrument under test must be connected to power ground. (See Figure 3-3.)

3-9. CHECKING FOR PRESENCE OF UNWANTED GROUND CURRENTS.

3-10. PREFERRED METHOD.

a. Connect the OUTPUT of the 738BR to the meter to be calibrated. (Connect as in Figure 3-3.)

b. Connect the 738BR OUTPUT to an -hp- Model 130C oscilloscope (200 μv/cm sensitivity) or equivalent.

c. Place the 738BR in the 1 millivolt position (0.001) at 400 cps RMS.

d. Adjust the Oscilloscope as follows:

VERTICAL.	.2 mv
HORIZONTAL	internal sweep X10
SWEEP.	2 ms

e. If a 60 cycle modulation appears on the 400 cycle signal, ground currents are present.

f. Eliminate these currents before calibrating the instrument under test.

1) Check for low resistance to power ground on instrument under test.

2) Check for proper isolation from power ground on 738BR.

3-11. ALTERNATE METHOD (to be used if oscilloscope is not available).

a. Place the 738BR in the 1 mv range.

b. Connect the 738BR to the voltmeter to be calibrated. Note the reading on the voltmeter.

c. Reverse the two prong power input connector in the 3 prong to 2 prong adapter. Note reading again. If there is an appreciable difference, ground currents are present.

3-12. STABILITY.

3-13. Allow at least 30 minutes of warm-up time before using the 738BR Calibrator.

3-14. The 738BR has been accurately set at the factory. If performance checks are made on the instrument, use test equipment listed in Section V or its equivalent.

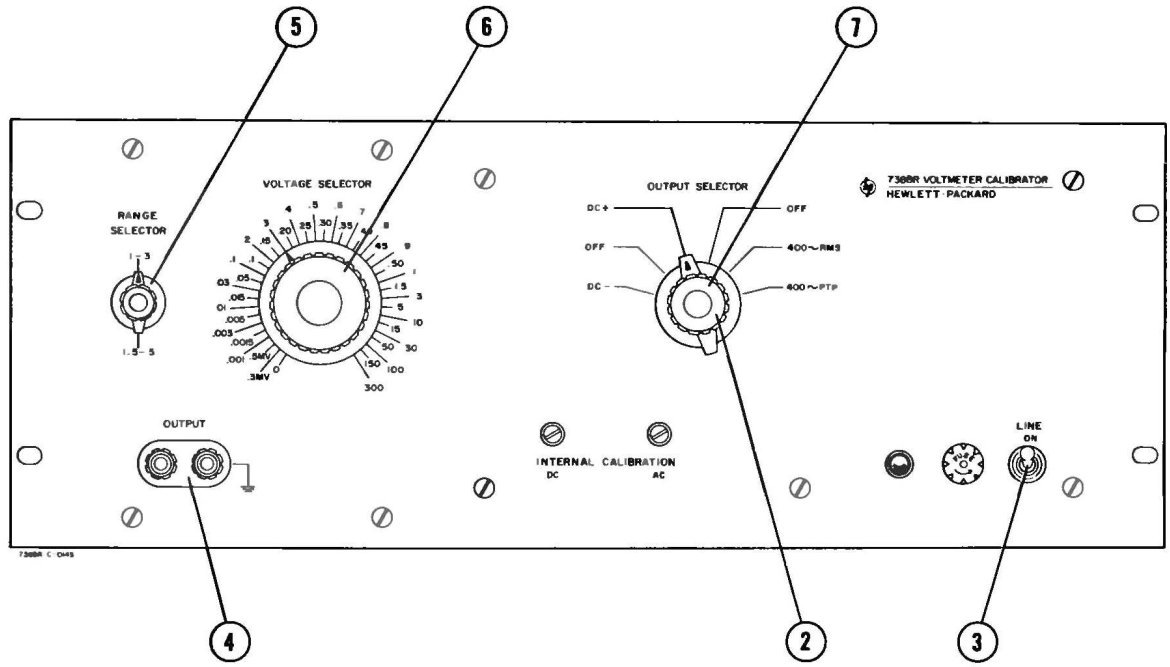
3-15. Accuracy of the 738BR is determined by:

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

b. The accuracy of the output attenuator.

c. The amplitude stability vs time.

d. The value of the external load resistance. (Attenuator performance check is advised once every six months.)



1. Ensure instrument has been calibrated in accordance with Table 5-2.
2. Rotate OUTPUT SELECTOR switch to the OFF position.
3. Turn LINE ON switch to the ON position; panel light glows. Allow instrument to warm up for at least one half hour.
4. Connect instrument to be calibrated to OUTPUT terminals (observe polarity).
5. Select proper range for instrument to be calibrated.
6. Rotate VOLTAGE SELECTOR switch to proper position for full-scale reading.
7. Rotate OUTPUT SELECTOR to the type of voltage for the instrument to be calibrated.

CAUTION

ROTATE OUTPUT SELECTOR TO THE OFF POSITION BEFORE REMOVING OUTPUT CABLE.

Figure 3-2. Operation

Table 3-1. Loading Errors for 738BR Attenuator

SELECTED OUTPUT VOLTAGE	APPARENT SOURCE RESISTANCE	OPEN/INFINITY CIRCUIT VOLTAGE	10 MEG LOAD % ERROR	3 MEG LOAD % ERROR	2 MEG LOAD % ERROR	1 MEG LOAD % ERROR
300	0.3 Ω	300.000	.0	.0	.0	.0
150	4500.075	150.000	-0.045	-0.150	-0.229	-0.445
100	4000.033	100.000	-0.040	-0.134	-0.200	-0.399
50	2500.008	50.000	-0.024	-0.084	-0.126	-0.250
30	1620.003	30.000	-0.017	-0.053	-0.080	-0.163
15	855.000	15.000	-0.008	-0.029	-0.043	-0.086
10	580.000	10.000	-0.006	-0.019	-0.020	-0.058
5	295.000	5.000	-0.003	-0.010	-0.015	-0.029
3	178.200	3.000	-0.002	-0.006	-0.009	-0.018
1.5	490.537	1.5000	-0.005	-0.016	-0.025	-0.049
1.0	418.016	1.0000	-0.004	-0.014	-0.022	-0.042
.9	392.593	.9000	-0.004	-0.013	-0.020	-0.039
.8	363.530	.8000	-0.004	-0.011	-0.018	-0.036
.7	330.828	.7000	-0.003	-0.011	-0.017	-0.033
.6	294.486	.6000	-0.003	-0.010	-0.015	-0.029
.5	254.504	.5000	-0.003	-0.008	-0.013	-0.025
.45	233.409	.4500	-0.003	-0.008	-0.013	-0.028
.4	210.883	.4000	-0.002	-0.007	-0.011	-0.021
.35	188.978	.3500	-0.002	-0.006	-0.010	-0.019
.3	163.621	.3000	-0.002	-0.005	-0.008	-0.016
.25	364.245	.2500	-0.003	-0.012	-0.018	-0.040
.2	466.661	.2000	-0.005	-0.016	-0.023	-0.047
.15	487.997	.15000	-0.005	-0.017	-0.024	-0.049
.1	416.665	.10000	-0.004	-0.014	-0.022	-0.042
.05	254.166	.05000	-0.003	-0.008	-0.013	-0.025
.03	163.500	.03000	-0.002	-0.005	-0.008	-0.016
.015	82.074	.01500	-0.001	-0.003	-0.004	-0.009
.01	56.881	.01000	-0.001	-0.002	-0.003	-0.006
.005	31.720	.00500	-0.000	-0.001	-0.002	-0.003
.003	20.455	.00300	-0.000	-0.001	-0.001	-0.002
.0015	57.195	.00150	-0.001	-0.002	-0.003	-0.006
.001	48.679	.00100	-0.001	-0.002	-0.002	-0.005
.0005	29.670	.00050	-0.000	-0.001	-0.001	-0.003
.0003	19.081	.00030	-0.000	-0.001	-0.001	-0.002

CAUTION

In no case use a load numerically less than 1,000 ohms per volt.

NOTE

The % figures in this table are rounded off to the third decimal place, the nearest 10 PPM.

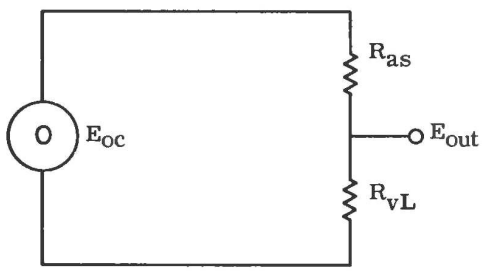
The accuracy of this table is in addition to the guaranteed accuracy of the attenuator which is ±0.10%.

Table 3-1. Loading Errors for 738BR Attenuator (Cont'd)

The last four columns in this table are illustrations of percent error for loads of 1, 2, 3 and 10 megohms. However, the effect of any load on the output of the 738BR may be determined by use of Equation (1) and the first 3 columns of this table.

The procedure for finding load errors other than those in this table is as follows: The operator first determines the load presented to the 738BR for the output voltage selected and then enters the table at that value of voltage in column 1. The apparent source resistance of the 738BR is obtained from column 2, and the open circuit voltage from column 3. With these values, equation (1) may be used to determine the actual output voltage, from which the percent error can be calculated, if desired.

$$E_{out} = \frac{R_{vL} \times E_{oc}}{R_{vL} + R_{as}} \qquad (1)$$



where:

R_{as} = apparent source resistance of 738BR.

R_{vL} = resistance of voltmeter as a "load".

E_{oc} = open circuit voltage.

E_{out} = actual output voltage under voltmeter load.

NOTE

The load (voltmeter) and the apparent source resistance (738BR) may be considered as a simple voltage divider supplied by a zero resistance source of the open circuit voltage for that particular output voltage selected.

Example: What is the output voltage at 30 volts position when calibrating a voltmeter with a 1 megohm input resistance?

$$E_{out} = \frac{10^6 \times 30.000}{10^6 + 1620.003} = 29.951$$

$$E_{out\ error} = \frac{(30.000 - 29.951)}{30} \times 100 = -.163$$

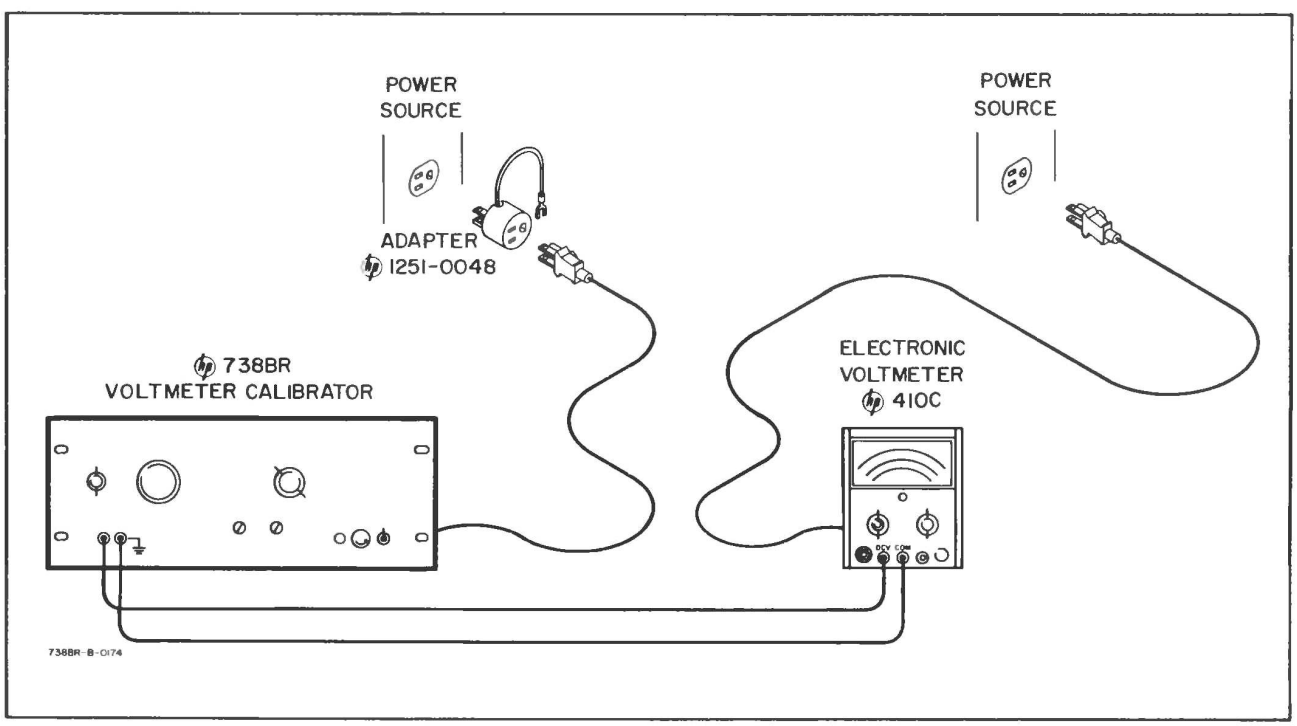


Figure 3-3. Connection for Eliminating Ground Current

SECTION IV
THEORY OF OPERATION

4-1. INTRODUCTION.

4-2. The -hp- Model 738BR Voltmeter Calibrator consists of a precision DC and AC Generator section and a precision attenuator section. Each is enclosed in its own compartment. Figure 4-1 shows the block diagram of the major circuit sections. The overall operation of the generator section is explained first.

4-3. GENERATOR SECTION.

4-4. The regulated dc power supply provides both 300 volts working standard and dc power for most of the circuits in the ac generator section. The ac generator is composed of a Wien bridge RC feedback oscillator and level control tube. It is followed by a three-section amplifier with a positive peak detector which operates an AGC circuit providing the stability for the 300 volt RMS output voltage. The 300 peak-to-peak voltage is obtained through an adjustable voltage divider setup. The OUTPUT SELECTOR switch selects the desired type of voltage and connects it to the attenuator section of the 738BR.

4-5. DC GENERATOR SECTION.

4-6. The dc power supply consists of a power transformer T1; a full-wave rectifier tube V14; filter network R50, R51, C26ABC and C27ABC; and an electronic voltage regulator. Two outputs, approximately +440 volts unregulated and the regulated +300 volts are used in the instrument.

4-7. The electronic regulator consists of a series regulator tube V13, which acts as a variable resistor, a regulator reference gas tube V10, and a two-stage differential amplifier V11 and V12.

4-8. The voltage regulating process is as follows: If the 300 volt output tends to change, a portion of this change is coupled to differential amplifier V11. This amplifier compares the change against the reference level 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 volt level tends to decrease, the current through V13 will increase and will instantly counteract the tendency of the output voltage to decrease. A differential 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.

4-9. The operation of the differential 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° out of phase. The plates of V11 are direct-coupled to the grids of V12A and B which is another differential 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.

4-10. The amplitude of the +300 volt dc regulated output is adjusted by potentiometer R63 (designated DC on the front panel). The common side of this voltage, designated ⏚ on the schematic (Figure 5-2), is floating so that the two outputs may be reversed in the -DC position of the OUTPUT SELECTOR switch.

4-11. AC GENERATOR SECTIONS.

4-12. The ac voltage generator consists of a conventional rc oscillator followed by a level control tube, a filter, a preamplifier, 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 - Hz 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.

4-13. The output of the level control tube is applied to a two-stage voltage preamplifier V4, then to the two-stage voltage amplifier and phase inverter V5. The cathode and plate of the second half of V5 is ac coupled to the push-pull power amplifier V6 and V7. The output of the power amplifier, coupled through T3, 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 peak detecting diodes CR2 and CR3 followed by amplifier V9 and rectifier CR1. CR2 and CR3 are biased by an exact dc voltage. Any portion of the ac wave that is above this voltage is passed by the diodes to amplifier V9 and is then rectified by CR1 to produce AGC bias for Level Control Tube V3. C32, AGC Sine Neutralizer, is adjusted for a minimum ripple at pin 6 of V9 to create a pure dc bias for the Level Control Tube, V3. The gain of the preamplifier 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 peak detecting diodes bias. If the output level tends to rise, the diodes pass 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.

4-14. To produce rms voltages, the cathode of CR2 is returned through series resistors R71, R67, R68, and R69 to +300 volts. To produce peak-to-peak voltages, the cathode return resistors R71, R67, R68, and R69 are made into a voltage divider by returning potentiometer R67 to ground through R66 and S2A. The wiper arm of R67 taps off a potential from the voltage divider which is connected to the cathode of CR2 through R71. 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.

4-15. THE OUTPUT SELECTOR SWITCH.

4-16. In the +DC position, the OUTPUT SELECTOR switch S2 connects the regulated +300 volts to the end of the attenuator marked "input" and the common floating connection to chassis ground. In the -DC position, the two connections are reversed. The floating common is connected to the input and +300 volts is connected to chassis ground. In the 400 Hz RMS and 400 Hz peak-to-peak positions, the ac output is connected to the attenuator. The amplitudes of these voltages are controlled as explained in Paragraph 4-13.

4-17. ATTENUATOR SECTION.

4-18. The Attenuator section of the 738BR consists of a precision voltage divider located on two etched circuit boards, and two switches located on the front panel. The 738BR Attenuator provides for voltages necessary to calibrate the -hp- Models 403B and 410C Voltmeters and other high impedance voltmeters and oscilloscopes.

4-19. The RANGE SELECTOR switch is a two-position switch which is mechanically connected to the rotary VOLTAGE SELECTOR switch. When the RANGE SELECTOR switch is changed from one position to the other, it moves the rotary switch one position (either forward or backward). Rotating the VOLTAGE SELECTOR switch moves the rotary switch two positions. Therefore, when the RANGE SELECTOR switch is in the 1-3 position, the long red marks are the positions of the VOLTAGE SELECTOR switch. When the RANGE SELECTOR switch is in the 1.5-5 position, the short black marks are the positions of the VOLTAGE SELECTOR switch.

4-20. The tracking voltages are obtained from the appropriate attenuator taps. The one volt range provides for 10 tracking points in 0.1 volt steps. The 0.5 volt range provides for 10 tracking points in 0.05 volt steps.

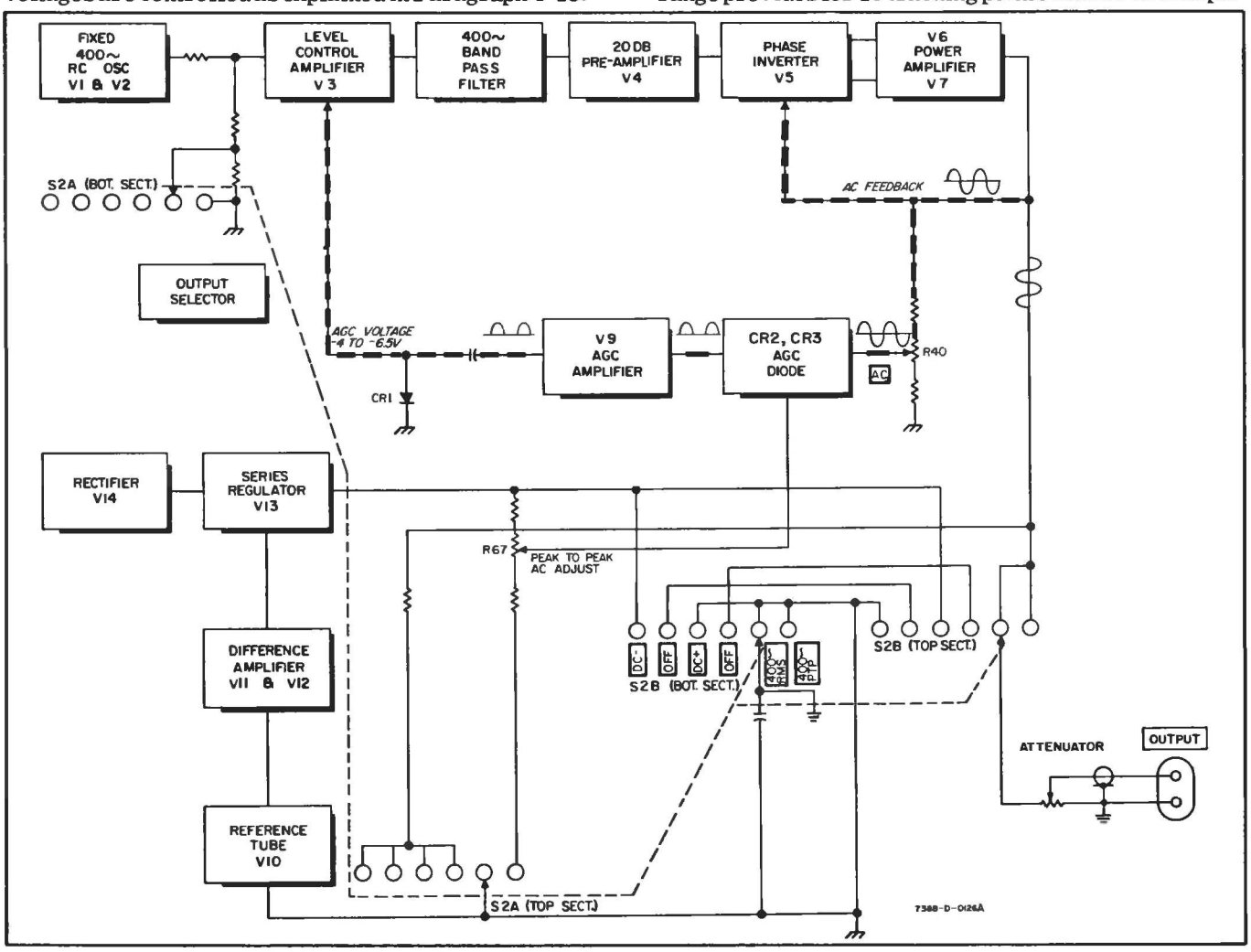
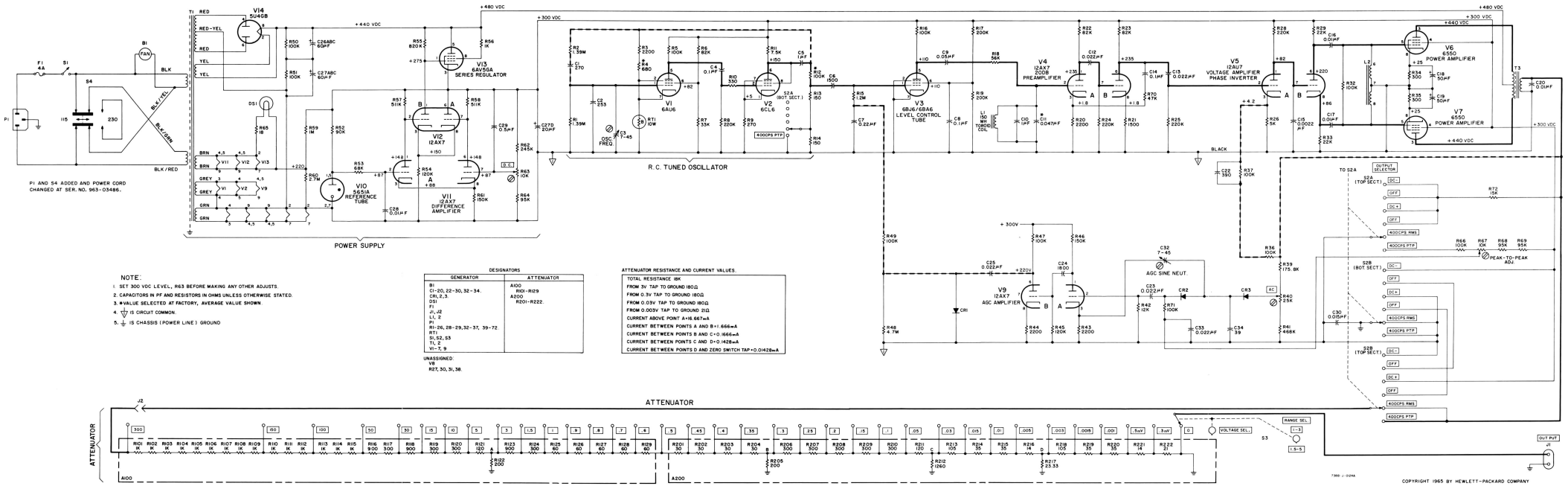


Figure 4-1. Model 738BR Block Diagram

Table 5-1. Test Equipment Required

INSTRUMENT TYPE	REQUIRED CHARACTERISTICS	USE	RECOMMENDED MODEL
AC-DC Differential Voltmeter	Accuracy: ±0.06% at 400 Hz (ac) Voltage Range: 100 and 1000 volts end scale Resolution: 0.005% end scale Input Impedance: 1 megohm (ac); 10^9 ohms (dc)	Voltage Calibration Checks and Adjustments	-hp- Model 741B
DC Differential Voltmeter	Accuracy: ±0.005% Voltage Range: 300 μv to 300 volts Resolution: 6 digits, all ranges Input Impedance: >10 megohms	Attenuator Accuracy Check	-hp- Model 740B
Distortion Analyzer	Resolution: At least 0.2% Frequency: 400 Hz Distortion Accuracy: ±3% Input Impedance: 1 megohm	Distortion Check	-hp- Model 331A
AC Voltmeter	Range: 0-300 VRMS Accuracy: ±2% f. s. Input Impedance: 10 megohms	AGC Amplifier Neutralization; Troubleshooting	-hp- Model 400D
DC Voltmeter-Ohmmeter	DC Voltage Range: ±500 VDC Voltmeter Accuracy: ±1% f. s. Input Resistance: >10 megohms Ohmmeter Range: 1 ohm-100 megohms Ohmmeter Accuracy: ±5% of reading	Troubleshooting	-hp- Model 412A
Oscilloscope	Vertical Bandwidth: DC - 400 cps Sensitivity: 1 mv/cm Input Impedance: 1 megohm	Hum Adjustment; Troubleshooting	-hp- Model 130C
Electronic Counter	Frequency: 400 Hz Accuracy: ±0.1%	Oscillator Frequency Adjustment	-hp- Model 5211A
NEMA Adaptor	3-prong to 2-prong line cord adaptor	Isolating ground currents	-hp- Part No. 1251-0048
Variable Line Voltage Transformer	Voltage Range: 103.5-126.5 VRMS Power: 350 watts	Line Regulation Check	Superior Type UC1M
Wheatstone Bridge	Accuracy: ±.05% Range: 14-1000 ohms	Troubleshooting	Leeds and Northrup Model 4735
Resistor	Resistance: 10 megohms Tolerance: ±5% Wattage: 1/2 watt	Load Impedance Check	-hp- Part No. 0686-1065



NOTE:

1. SET 300 VDC LEVEL, R63 BEFORE MAKING ANY OTHER ADJUSTS.
2. CAPACITORS IN PF AND RESISTORS IN OHMS UNLESS OTHERWISE STATED.
3. ★VALUE SELECTED AT FACTORY, AVERAGE VALUE SHOWN.
4. ⏚ IS CIRCUIT COMMON.
5. ⏚ IS CHASSIS (POWER LINE) GROUND

DESIGNATORS

GENERATOR	ATTENUATOR
B1 C1-20, 22-30, 32-34. CR1, 2, 3. DS1 F1 J1, J2 L1, 2 P1 R1-26, 28-29, 32-37, 39-72. RT1 S1, S2, S3 T1, 2 V1-7, 9	A100 R101-R129 A200 R201-R222.

UNASSIGNED:
V8
R27, 30, 31, 38.

ATTENUATOR RESISTANCE AND CURRENT VALUES.

TOTAL RESISTANCE 18K
FROM 3V TAP TO GROUND 180Ω
FROM 0.3V TAP TO GROUND 180Ω
FROM 0.03V TAP TO GROUND 180Ω
FROM 0.003V TAP TO GROUND 21Ω
CURRENT ABOVE POINT A=16.667mA
CURRENT BETWEEN POINTS A AND B=1.666mA
CURRENT BETWEEN POINTS B AND C=0.1666mA
CURRENT BETWEEN POINTS C AND D=0.1428mA
CURRENT BETWEEN POINTS D AND ZERO SWITCH TAP=0.01428mA

Figure 5-2. Model 738BR Schematic

01771-2

5-9/5-10