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OPERATION AND SERVICING MANUAL  
FOR

MODEL 650A  
TEST OSCILLATOR

650A-1  
SERVICE MANUAL

RETURN TO  
E. E. INSTRUCTION MANUAL FILE

This is a combined Operation and Service Manual for all -hp- 650A Test Oscillators. This manual contains complete operation and servicing instructions for the 650A and may be used in place of the Instruction and Operation Manual originally supplied with each instrument.

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HEWLETT-PACKARD COMPANY

275 PAGE MILL ROAD. PALO ALTO, CALIFORNIA, U.S.A.

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SPECIFICATIONS  
FOR  
MODEL 650A TEST OSCILLATOR

FREQUENCY RATING

FREQUENCY RANGE: 10 cps to 10 MC

FREQUENCY DIAL CALIBRATION: 1 to 10

RANGES:

X10 $\mu$	10 to 100 cps
X100 $\mu$	100 to 1000 cps
X1KC	1 to 10 KC
X10KC	10 to 100 KC
X100KC	100 to 1000 KC
X1M	1 to 10 MC

FREQUENCY RESPONSE:  $\pm 1$  db from 10 cps to 10 MC at rated output.

FREQUENCY STABILITY:  $\pm 2\%$  from 10 cps to 100 KC and  $\pm 3\%$  from 100 KC to 10 MC. Includes calibration error, warm-up drift, and line voltage variations.

POWER OUTPUT RATING

POWER OUTPUT: 15 milliwatts into a 600 ohm resistive load.  
3 volt output signal  
600 ohm source impedance.  
6 ohm source impedance is available with the voltage divider (65A-16D Output Cable).

DISTORTION: Less than 1% from 20 cps to 100 KC and approximately 5% from 100 KC to 10 MC.

HUM LEVEL: Less than .5% of the maximum attenuated signal level.

OUTPUT MONITOR

A vacuum tube voltmeter monitors the level at the input to the attenuator in volts and db when the instrument is properly terminated.  
Zero db - 1 mw in 600 ohms.  
Accuracy is  $\pm 5\%$  of full scale reading.  
Meter scales: 0-1 volt; 0-3 volt; -12 to +2 dbm.

OUTPUT ATTENUATOR

The output level is attenuated 50 db in 10 db steps. The attenuator when used with the AMPLITUDE control provides a continuously variable output voltage from +12 dbm to -50 dbm that is from 3 volts to 3 millivolts.

Low level sources down to 30 microvolts may be provided by using the 65A-16D Output Cable (voltage divider).

ATTENUATOR ACCURACY:  $\pm 1$  db when the instrument is working into 600 ohms resistive load.

POWER SUPPLY RATING

VOLTAGE: 115 or 230 volts  $\pm 10\%$

FREQUENCY: 50 to 1000 cps

ACCESSORIES FURNISHED

65A-16D Output Cable (voltage divider)

LENGTH OVERALL: 26"

CONNECTORS: Front (marked 600 $\Omega$ )  
In - Banana plugs spaced 3/4"  
Out - Universal binding posts spaced 3/4"  
Rear (marked 6 $\Omega$ )  
Out - Universal binding posts spaced 3/4"

OVERALL DIMENSIONS

CABINET MODEL: 20-1/2" wide x 12-1/2" high x 14-1/4" deep

RELAY RACK MODEL: 19" wide x 10-1/2" high. Depth behind panel 13".

PANEL SIZE: 19" wide x 10-1/2" high.

WEIGHT

CABINET MODEL: 45 lbs. net.

RACK MODEL: 38 lbs. net.

# general description

## 1-1 GENERAL

The Hewlett-Packard Model 650A Test Oscillator is a wide range precision resistance tuned oscillator covering from 10 cps to 10 MC. It has a highly stable output signal level that is adjustable from 30 microvolts to 3 volts into 600 ohms. Frequency response is essentially flat ( $\pm 1$  db) throughout the complete extended range.

The output impedance is normally 600 ohms. Where a low source impedance is desired, 6 ohms is provided by the Voltage Divider Cable supplied with the instrument.

The Model 650A Test Oscillator output voltage is constantly monitored by a vacuum tube voltmeter at the input to the output attenuator system. This VTVM has two voltmeter scales plus a dbm scale (0 dbm = 1 milliwatt in 600 ohms). The attenuator control, in conjunction with the AMPLITUDE control, will produce a monitored signal of any desired level when the instrument is resistive loaded with 600 ohms.

The flexibility and simplicity of the 650A Test Oscillator find a wide variety of uses in audio, video, rf, and alignment applications as well as laboratory wide band measurements. This instrument was designed for such applications as fast and accurate testing of filter trans-

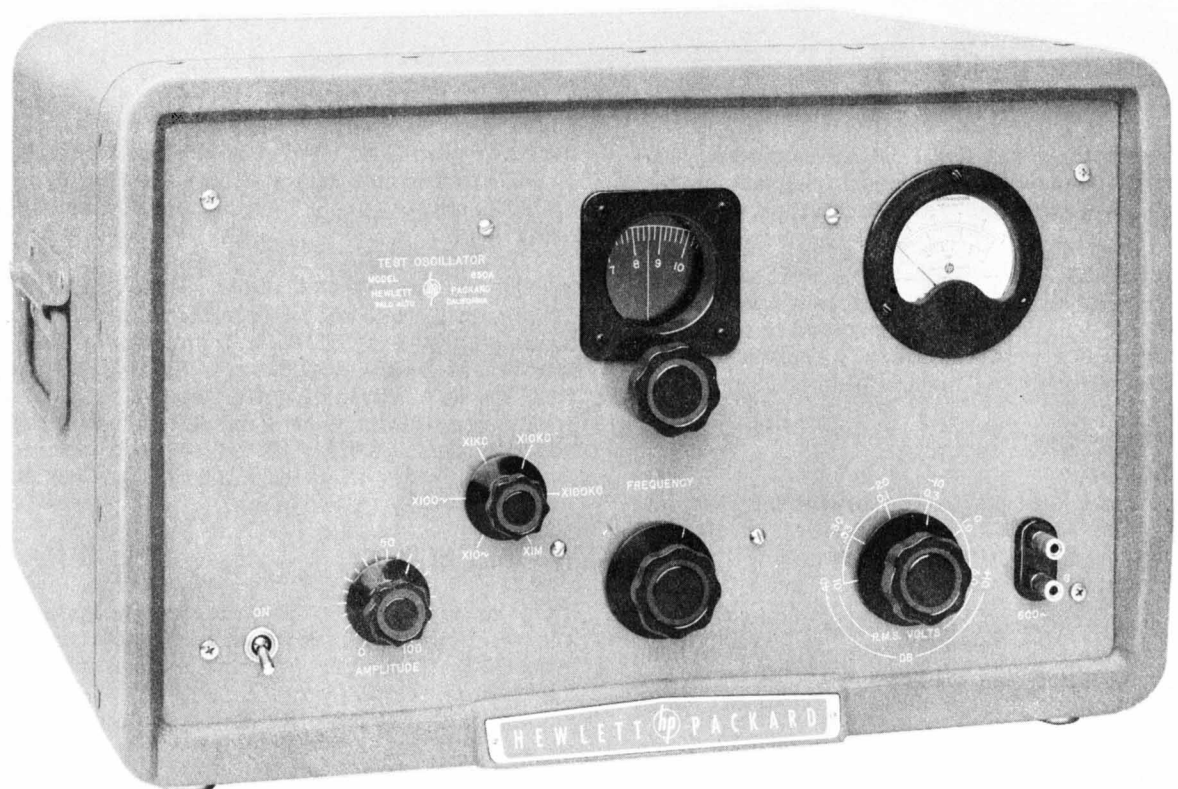


Figure 1-1 -hp- Model 650A Test Oscillator

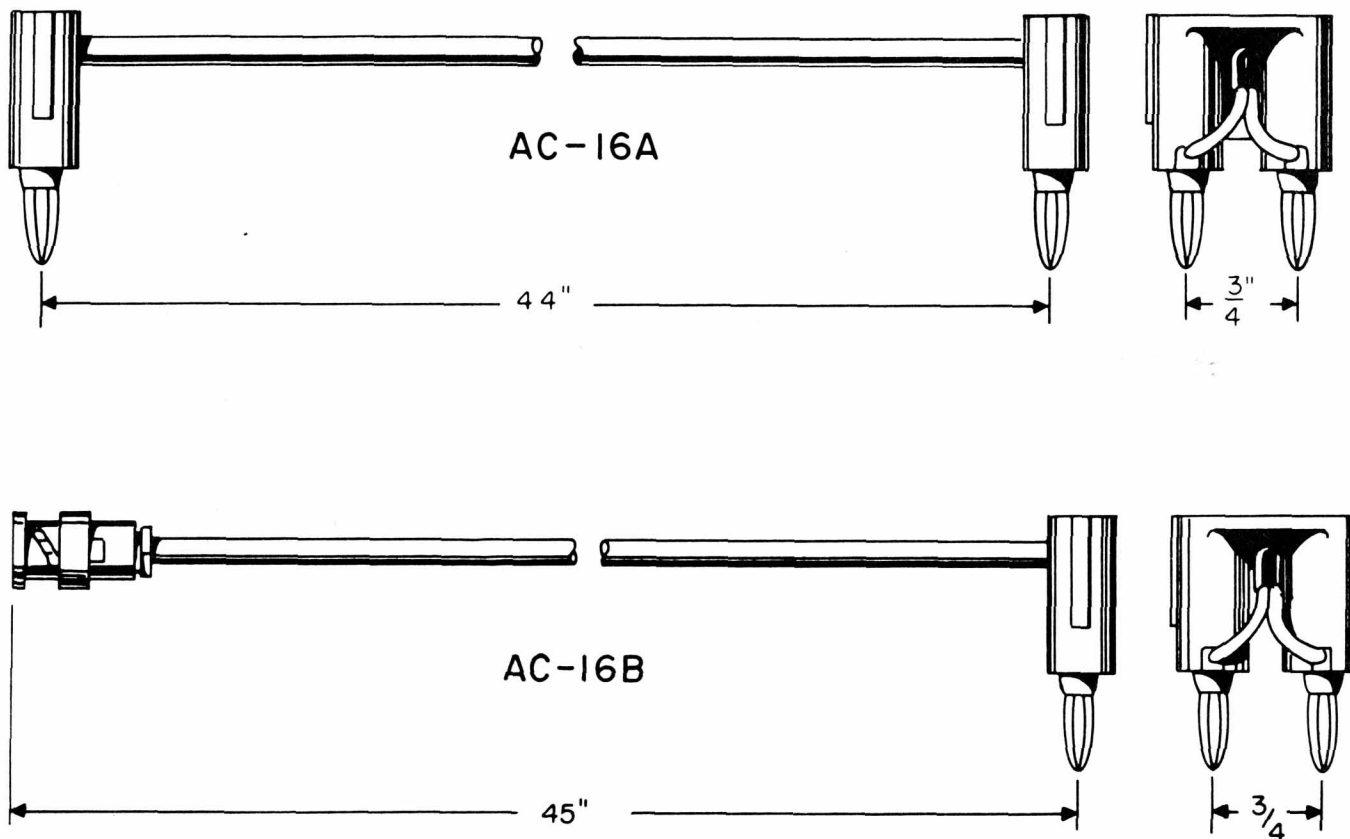


Figure 1-2. Accessory Cable Assemblies

mission characteristics, tuned circuit response, complete receiver alignment, telephone or telegraph carrier equipment, plus video and audio amplifiers.

The Model 650A Test Oscillator is well suited as a signal source for af and rf bridge measurements. The wide range of test frequencies necessary for repair and testing of electronic frequency counters is also available from the 650A Test Oscillator.

## 1-2 ACCESSORIES

The Model 650A Test Oscillator is supplied complete with a 65A-16D Output Divider Cable. The following accessories may be purchased separately:

a. -hp- Model AC-16A Cable Assembly. Equipped with two dual banana plugs having  $\frac{3}{4}$  inch centers. Made from 50 ohm coaxial cable type RG-58/U. (See Figure 1-2.)

b. -hp- Model AC-16B Cable Assembly. Same as AC-16A except one dual banana plug is replaced by a UG-88/U type BNC male connector. (See figure 1-2.)

c. -hp- Model AC-44 Cabinet. This cabinet was designed for use with Hewlett-Packard instruments having 10-1/2 in. x 19 in. front panels such as the Model 650 Test Oscillator. Cabinets are equipped with sturdy carrying handles and an easily detached back cover. Finish is grey wrinkle to match -hp- grey baked enamel panel color. Overall dimensions are 20-3/4 in. wide, 12 in. high, and 14 in. deep. Weight is approximately 15 pounds.

## 1-3 INSPECTION

This instrument has been thoroughly tested and inspected prior to shipment and is ready for use when received. Carefully examine for possible shipping damage before and after unpacking. If any shipping damage is found, refer to "Claim for Damage in Shipment".

# operating instructions

## 2-1 CONTROLS AND TERMINALS

### ON

This toggle switch controls the power transformer primary circuit. When switch is ON, the calibrated FREQUENCY dial is also illuminated.

### FREQUENCY RANGE SWITCH

This six-position rotary switch has markings of X10 $\sim$ , X100 $\sim$ , X1KC, X10KC, X100KC, and X1M. The position of this switch indicates the multiplication factor which must be applied to the reading of the FREQUENCY dial to determine output frequency.

### FREQUENCY

Oscillator frequency on any band is determined by rotating the two control knobs under the tuning dial. The upper knob provides coarse tuning while the lower knob provides a 6 to 1 mechanical vernier for fine tuning.

### TUNING DIAL

The tuning dial is accurately calibrated from .9 through 10. The dial reading multiplied by the Frequency Range Switch setting is the instrument output frequency.

### R.M.S. VOLTS/DB.

This rotary switch is the output attenuator control which provides signal levels from -40 dbm to +10 dbm in 10 db steps. This switch also indicates voltage across a 600 ohm load connected to output terminals when instrument output is adjusted for a full scale voltmeter indication.

Attenuator constants and switching are shown in a separate schematic detail on schematic diagram for Power Supply Section. Note that this control becomes a "straight-through" connection when rotated full clockwise and the attenuator is effectively switched out of the circuit.

### AMPLITUDE

This control permits adjustment of input level to the output amplifier and thereby controls instrument output level. Any desired output signal level between the 10 db steps of the R.M.S. VOLTS/DB selector switch can be obtained.

### OUTPUT METER

This meter continuously monitors the signal level when operating into a 600 ohm resistive load. It indicates as a full scale deflection the value of the R.M.S.

VOLTS/DB selector switch setting. The meter is indicated as M1 on the schematic diagram and together with V16 and associated components, constitutes the VTVM monitor section.

### 600 $\Omega$

The output terminals are universal binding posts on 3/4 in. centers. The output signal is developed between these two terminals with the one marked "G" grounded to the instrument chassis.

### FUSE

The fuseholder, located on rear of chassis, contains a 2 ampere "slo-blo" fuse for 115 volt operation. If instrument power transformer primary connections have been changed for 230 volt operation, a 1 ampere "slo-blo" fuse must be used.

### POWER CABLE

The three conductor power cable supplied with this instrument is terminated in a polarized three prong male connector recommended by the National Electrical Manufacturers' Association. The third contact is an offset round pin added to a standard two-blade ac plug which grounds the instrument chassis when used with the appropriate receptacle. To use this NEMA plug in a standard two contact outlet an adapter will be required. The ground connection emerges from the adapter as a short lead which should be connected to ground for the protection of operating personnel.

### NOTE

This Model 650A Test Oscillator is shipped from the factory with the power transformer dual primary windings connected in parallel for 115 volt operation. If operation from a 230 volt source is desired, primary windings must be reconnected in series as shown in the detail on the schematic diagram. A simultaneous fuse change will also be required.

## 2-2 OPERATION

The operation procedure for the -hp- Model 650A Test Oscillator is as follows:

- a. Connect instrument to power source of 115 volts, 50-1000 cps unless modified for 230 volt operation.



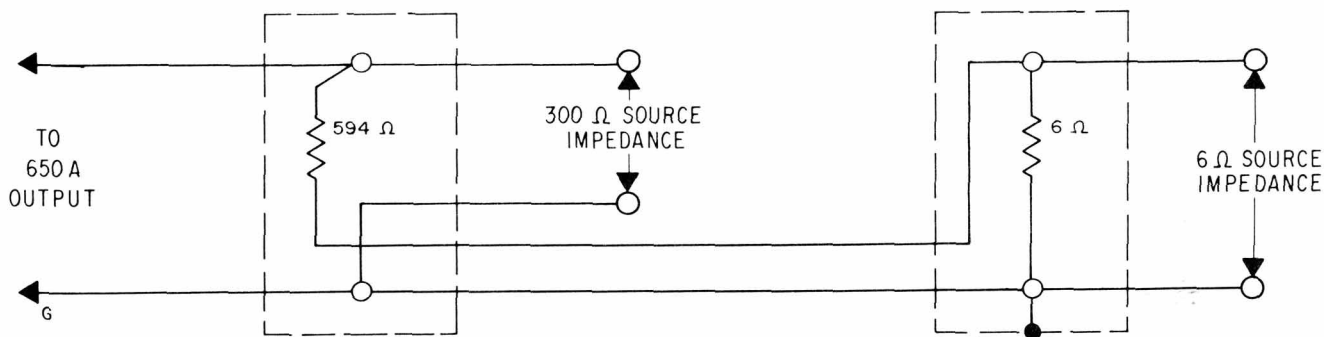


Figure 2-1. Schematic Diagram of Output Divider Cable

- b. Turn instrument on and, for best results, allow a minimum warm-up time of 15 minutes.
- c. Select desired output frequency by adjusting the Range Switch and FREQUENCY controls.
- d. Connect load to output terminals and adjust for desired output level by setting attenuator switch and AMPLITUDE controls.

Refer to the following paragraphs for specific instructions on setting to a frequency, loading, and use of the output monitor.

### 2-2A SETTING TO FREQUENCY

The frequency of a test signal from the 650A is controlled by the FREQUENCY dial setting and the setting of the Frequency Range Switch.

The FREQUENCY dial is calibrated from .9 through 10. This dial reading multiplied by the setting of the Frequency Range Switch will give the frequency of the output signal.

### 2-2B LOADING AND USE OF INTERNAL VOLTMETER

The internal vacuum tube voltmeter (VTVM) measures the input voltage to an output attenuator system. This output attenuator is the "R.M.S. VOLTS/DB" switch next to the "600Ω" output terminals in the lower right corner of the front panel. The VTVM has two voltage scales calibrated 0 to 1.0 and 0 to 3 plus a db scale calibrated -12 to +2 dbm (0 dbm = 1 milliwatt into 600 ohms). When using the db scales, the relative output signal level is determined in db by algebraically adding the db setting of the attenuator switch to the db reading of the VTVM.

#### NOTE

Calibration of the VTVM section is based upon a 600 ohm resistive load being connected to the instrument output terminals. The output divider cable supplied with instrument contains a load of this value. Loads of other values are then connected to either set of terminals on the output divider cable.

When using the voltage scales, the attenuator setting determines the scale to use and also indicates voltage at output terminals when a full scale voltmeter indication is obtained with a 600 ohm load. If VTVM indication is less than full scale, terminal voltage can be determined from the meter indication with the decimal point relocated to agree with the full scale value. This voltage, as indicated by the VTVM reading and the attenuator setting, will be referred to as the "indicated" voltage in the discussions that follow.

### 2-2C SPECIAL CONSIDERATION WITH +10/3.0 ATTENUATOR SETTING

When the "R.M.S. VOLTS/DB" switch is rotated full clockwise (+10/3.0 position), a "straight-through" connection is made in the attenuator to effectively disconnect it from the output system. The actual output voltage will be the same as the indicated voltage as read on the 0 to 3 volt scale. Any value load can be connected to the output terminals and the VTVM will indicate actual output voltage.

### 2-2D CONNECTING A 600 OHM LOAD

A resistive load of 600 ohms may be connected directly to the instrument output terminals. Under these conditions, the indicated voltage will be the voltage at the output terminals.

At higher frequencies, test leads must be short and the shunting capacitance low. At frequencies above approximately 2 MC, if the external shunt capacitance is high, use of the "6Ω VOLTAGE X.01" terminals of the Output Divider Cable is recommended.

### 2-2E OUTPUT DIVIDER CABLE

The Output Divider Cable contains two resistors connected in series to provide a load of 600 ohms as shown in Figure 2-1. The first resistor (594 ohms) is mounted in the connector for the instrument output terminals. The second resistor (6 ohms) is mounted at the output end of the cable. These two resistor values provide a 100 to 1 (-40 db) division ratio and a source impedance of 6 ohms at the output end of the cable.

a. "600  $\Omega$  LOAD" Terminals.

The terminals marked "600  $\Omega$  LOAD" at the input end of the output cable are in parallel with the instrument "600  $\Omega$ " output terminals. With attenuator in +10/3.0 position, output voltage at "600  $\Omega$  LOAD" terminals will be the same as the indicated voltage.

Internal impedance is 300 ohms with output divider cable connected. The voltage available at the "600  $\Omega$  LOAD" terminals will depend upon the value of the applied resistive load.

The actual voltage ( $E_a$ ) available at the "600  $\Omega$  LOAD" terminals with a resistive load ( $R$  in ohms) can be calculated from the indicated voltage ( $E_i$ ) as follows:

$$E_a = E_i \times \frac{R}{R + 300}$$

b. "6  $\Omega$  VOLTAGE X.01" Terminals.

These output terminals are recommended whenever the load has high distributed capacity or a low value. Loads from 6 ohms and up may be connected here.

The actual voltage available from these terminals is 1/100 of the indicated voltage provided the load resistance is very high with respect to 6 ohms.

The actual voltage ( $E_a$ ) available at the "6  $\Omega$  VOLTAGE X.01" terminals with a resistive load ( $R$  in ohms) can be calculated from the indicated voltage ( $E_i$ ) as follows:

$$E_a = E_i \times \frac{1}{100} \times \frac{R}{R + 6}$$

If the load resistance is 6 ohms, the actual voltage will be 1/200 of the indicated voltage.

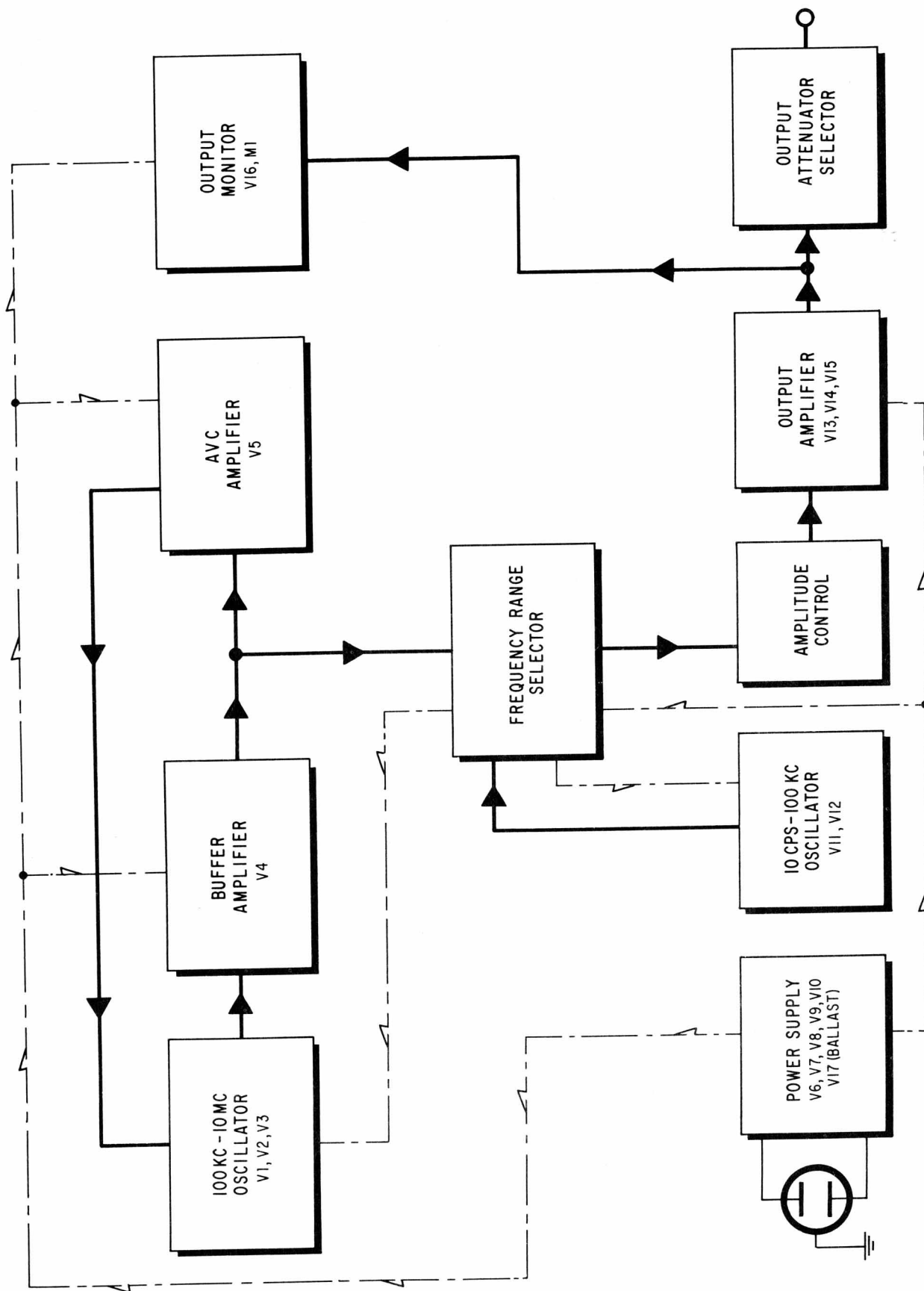


Figure 3-1. Block Diagram of -hp- Model 650A Test Oscillator

# circuit description and instrument modernization

## 3-1 INTRODUCTION

The -hp- Model 650 Test Oscillator circuitry can be divided into several basic circuits as shown in Figure 3-1, block diagram. A discussion of these basic circuits as well as a complete procedure for modernization of any -hp- Model 650A will be found in the following paragraphs:

Paragraph	Basic Circuit
3-2	Oscillators
3-3	Buffer Amplifier
3-4	AVC Amplifier
3-5	Output Amplifier
3-6	Output Monitor
3-7	Output Attenuator
3-8	Power Supply
3-9	Instrument Modernization Procedure

## 3-2 OSCILLATORS

Two oscillators are used to cover the frequency range from 10 cps to 10 MC. The low frequency oscillator covers from 10 cps to 100 KC in four ranges while the high frequency oscillator covers from 100 KC to 10 MC in two ranges.

Each oscillator section is separate and complete. The Frequency Range Switch allows only one oscillator to function at a time by automatically switching B+ to the desired oscillator section. It is recommended that if the instrument is to be on for long periods of time when not in actual use, that the Frequency Range Switch be left in one of the four lower ranges so that the high frequency oscillator will not be operating.

### 3-2A LOW FREQUENCY OSCILLATOR

The low frequency oscillator is used to cover frequencies from 10 cps to 100 KC and consists of tubes V11 and V12. These two tubes are connected as a two-stage amplifier in which a positive feedback loop in conjunction with an r-c network controls the frequency of oscillation.

The tubes must be operated over the linear portion of their characteristics in order to provide a sine wave output. A negative feedback loop is necessary for this purpose. The 10 watt incandescent lamp (R80) has a positive temperature coefficient and is part of the negative feedback loop. This lamp regulates the amount

of negative feedback in accordance with the amplitude of oscillation to maintain a constant output level with minimum distortion over the low frequency oscillator range.

The oscillator is adjusted for optimum performance by adjustment of resistor R46 in the negative feedback loop. Resistor R53 is used to set the low frequency oscillator input signal level to the AMPLITUDE control equal to the signal level from the high frequency oscillator. The procedure for adjustment of these controls will be found in the MAINTENANCE section of this manual.

## 3-2B REFERENCES

Bauer, B. "Design Notes on the Resistance Capacity Oscillator Circuit", Hewlett-Packard Journal, November - December, 1949.

Terman, F. E. Radio Engineers Handbook, McGraw Hill Book Co., Inc., New York, 1943. Pages 504-506.

Edson, W. A. Vacuum Tube Oscillators, John Wiley & Sons, Inc., New York, 1953. Pages 138-142.

## 3-2C HIGH FREQUENCY OSCILLATOR

The high frequency oscillator section uses three type 6AK5 (6AK5) tubes in cascade. These tubes should be as nearly alike as possible with transconductance values as recommended in the MAINTENANCE section of this manual. Normally, 6AK5 tube transconductance is satisfactory and does not need measuring. Type 6AK5 tubes vary widely and should be selected.

The high frequency oscillator consists of V1, V2, and V3 in an r-c phase shift oscillator. A simplified schematic diagram of this circuit is given in Figure 3-2

The phase shift network on the 1 to 10 MC range consists basically of plate load resistors R3, R4, and R6 plus C1A, C1B, and C1C sections of the tuning capacitor that shunt the grid circuits. The resistor and capacitor values produce a phase shift of 60 degrees at the frequency of oscillation. This shift is in addition to the 180 degree shift taking place from the grid to the plate of each tube which produces a total shift of 240 degrees for each tube. Three networks of this nature provide a 720 degree phase shift between the output of the third oscillator tube and the grid of the first oscillator tube. This condition makes the

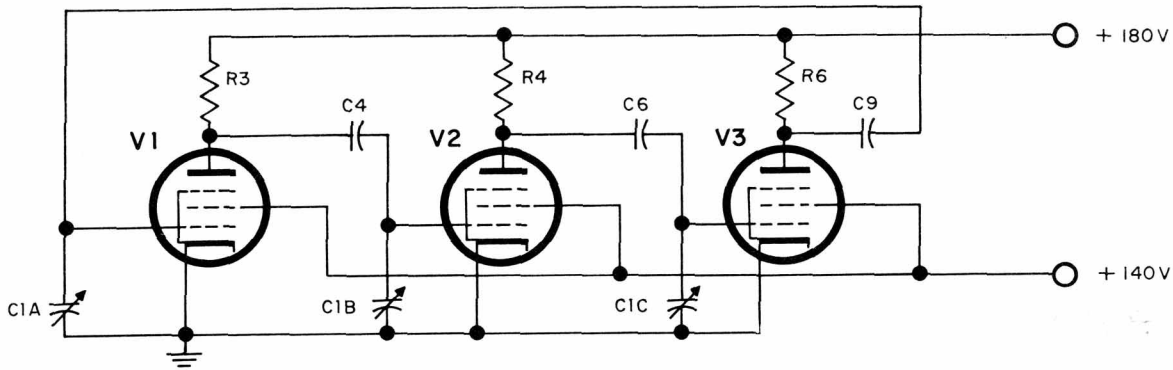


Figure 3-2. Simplified Schematic Diagram of High Frequency Oscillator Section

feedback signal in phase with the grid signal on V1 and oscillation occurs. Locating the phase shift networks between the oscillator tubes rather than in cascade permits the tube capacitance to be employed as part of the phase shift network.

On the 100 KC to 1 MC range an additional series resistance, not shown in the simplified diagram, is switched into the coupling circuits between the tubes which causes the phase shift to take place at one-tenth the frequency of the highest range.

These additional resistors, as well as the plate load resistors, are precision composition type which are factory matched and selected. Occasionally, small low value resistors are placed in the circuit to compensate for slight tolerances of the precision resistors.

Calibration adjustments are provided for the high frequency end of both ranges of the high frequency oscillator. The trimmer capacitors on the three sections of tuning capacitor C1 are adjusted at 10 MC. Ceramic capacitor C3 in the grid circuit of V1 is adjusted at 1 MC with the Frequency Range Switch in the "X100KC" position.

### 3-3 BUFFER AMPLIFIER

The signal from the high frequency oscillator tubes is fed into the buffer amplifier stage V4 which isolates

the high frequency oscillator from the amplitude control circuit and the AVC Amplifier stage V5.

A type 6AK5 pentode tube was used for V4 in many instruments. A type 5654 was used later and is recommended for replacement of V4 in all instruments.

In early instruments, plate and screen of V4 were tied together and the tube functioned as a triode. In later instruments, the circuitry was changed with the tube connected as a pentode. Modernization notes for making the necessary triode to pentode circuit modifications will be found in paragraph 3-9 of this manual.

### 3-4 AVC AMPLIFIER

The AVC Amplifier shown in the simplified schematic of Figure 3-3 is driven by buffer stage V4.

The output signal from V5 is rectified by germanium diode CR3 and is then used as grid bias for V1, V2, and V3. This maintains a constant output from the oscillator as well as the buffer stage V4 which is inside the AVC control loop.

The high frequency oscillator output level and frequency response can be controlled by adjustment of components in the AVC amplifier stage. For example, if the output of the high frequency oscillator increases

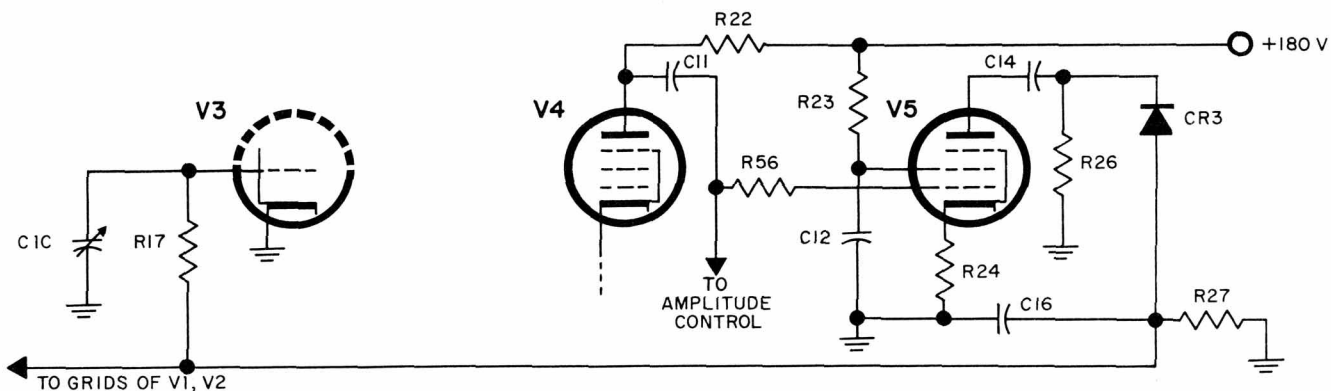


Figure 3-3. Simplified Diagram of High Frequency Oscillator AVC Control System

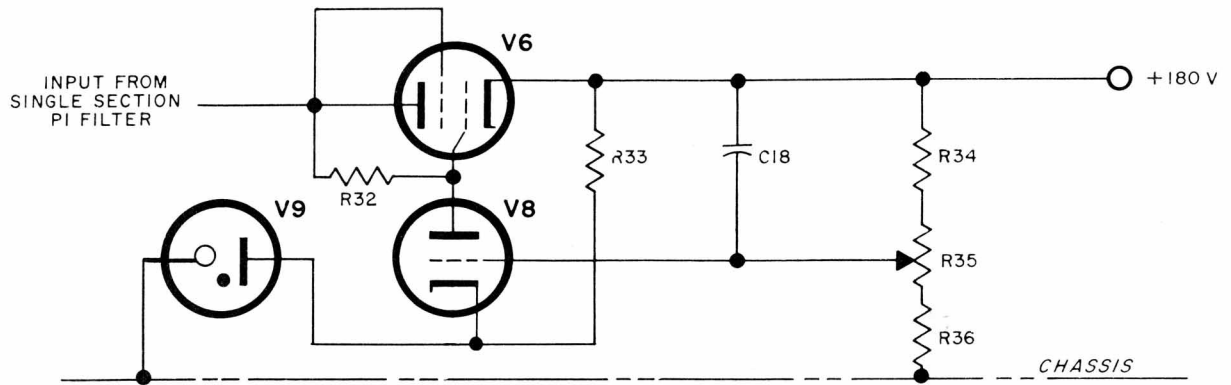


Figure 3-4. Simplified Schematic for Power Supply Regulator

toward the higher frequencies it is possible to adjust the frequency response of the AVC amplifier for increased gain at higher frequencies. This results in a higher AVC voltage being developed and the output from the oscillator will be reduced.

### 3-5 OUTPUT AMPLIFIER

The signal from the AMPLITUDE control is fed to the input of a three stage amplifier consisting of V13, V14 and V15. Type 6AK5 pentode tubes were used for V13, and V14 in many instruments. A type 5654 tube was used later and is recommended for replacement purposes in all instruments.

The output amplifier circuit is designed so that V13 and V14 operate as triodes at low frequencies and as pentodes at high frequencies. This is accomplished by careful selection of screen grid bypass capacitor values. The capacitor values selected provide more than adequate bypass action at higher frequencies but not at lower frequencies.

At low frequencies the degeneration in the screen grid circuit couples the screen to the plate load causing the tubes to operate as triodes. At high frequencies the screen grids are effectively bypassed and the tubes operate as pentodes with a resultant increase in gain. In addition, part of the plate load is bypassed to ground at high frequencies which results in a reduction of the tube load at these frequencies. This effect compensates for the increase in gain from the pentode operation. The two effects neutralize each other and the result is a flat gain characteristic over an extremely wide range.

The amplifier response and distortion characteristics are further improved by use of a negative feedback loop in the form of a common cathode circuit for V13 and V15. A single adjustment (C38) is provided for adjusting amplifier frequency response at 10 MC.

### 3-6 OUTPUT MONITOR

The Output Monitor section consists of a single stage voltage amplifier followed by a full wave average reading type voltmeter using germanium crystal diodes as

rectifiers. The indicating meter has a basic zero to one milliamper movement.

The voltage amplifier V16 obtains an input signal from the last stage of the Output Amplifier before the signal enters the output attenuator system. Hence, instrument loading is important when using the readings obtained on the output monitor meter to determine actual output voltage. The use of the output voltmeter is fully explained in paragraph 2-2 under the heading of LOADING AND USE OF INTERNAL VOLTMETER.

Variable capacitor C42 can be set to adjust the voltmeter frequency response at 10 MC. Resistor R77 is an additional calibration adjustment which is set at 1000 cps before adjusting capacitor C42 at 10 MC.

### 3-7 OUTPUT ATTENUATOR

The Output Attenuator is a five section "T" structure designed to have 50 db of attenuation in five steps of 10 db each when operated into a resistive load of 600 ohms. The attenuator is frequency compensated for maximum accuracy over the instrument frequency range.

Use of the output attenuator is fully explained in paragraph 2-2 under the heading of LOADING AND USE OF INTERNAL VOLTMETER.

### 3-8 POWER SUPPLY

All stages of the Model 650A Test Oscillator are supplied with regulated B+ from the internal power supply. In addition, heater voltage for tubes V1, V2, V3, V4, and V16 is regulated by an Amperite type 12-4 ballast tube.

The power transformer has a dual primary winding that may be connected for operation from 115 or 230 volts. The power line frequency may be from 50 to 1000 cps. Power requirements are approximately 165 watts.

A 5U4G full wave rectifier (V10) is followed by a capacitor input L-C filter network. The output of this pi filter goes to the regulator which is shown in simplified form in Figure 3-4. Series regulator tubes V6 and V7 are in parallel and both do not need to be shown in this diagram.

The cathode of the regulator control tube V8 is maintained at a constant potential by resistor R33 and regulator tube V9. Series regulator tubes V6 and V7 act as variable resistors whose resistance is controlled by the grid bias applied to them by control tube V8.

If the regulated B+ voltage at the cathode of V6 were to increase, the grid voltage of V8 would be increased a proportional amount. Tube V8 would then draw more plate current and the voltage drop across R32 would increase. This would result in a more negative grid voltage for V6 whose plate resistance would then increase. The increased resistance of V6 would cause a greater drop across V6 and the output voltage would drop to compensate for the original increase.

If the regulated B+ voltage tends to decrease, the reverse of the above action occurs. In either case, the voltage at the cathodes of the series regulator tubes is maintained at a constant level.

Ripple in the output voltage is coupled to the grid of V8 by capacitor C18. Variations in the dc voltage are coupled to the grid of V8 through the voltage divider consisting of R34, R35, and R36. The bias for V8, and consequently the regulated dc output voltage, is determined by the setting of R35.

The heater supply for High Frequency Oscillator tubes V1, V2, V3, Buffer Amplifier V4, and Voltmeter Amplifier tube V16 is regulated by means of a ballast tube.

The ballast tube has a high positive temperature coefficient. If the voltage applied to the heater circuit were to increase, current through the circuit and ballast tube V17 would also increase. This increased current would cause V17 resistance to increase which would cause the regulated voltage applied to the tubes to decrease and compensate for the initial increase. The reverse action would take place if the voltage applied to the heater circuit were to decrease.

The current through the ballast tube, and thereby the voltage applied to the tubes, can be set by adjusting control R42.

DO NOT remove any of tubes V1, V2, V3, V4, or V16 while the instrument is turned on. The current regulating properties of the ballast tube will apply a higher than normal voltage to the heaters of the remaining tubes operating from this regulated supply. A burned out tube may result.

### **3-9 PROCEDURE FOR COMPLETE MODERNIZATION OF ANY INSTRUMENT**

Modernization of an instrument should be undertaken only when a general overhaul is necessary and instruments are available for completing the TEST PROCEDURE given in this manual.

#### **NOTE**

An instrument must be completely tested following modernization as the circuit changes affect output voltmeter calibration, frequency response, oscillator output, or frequency calibration.

The modernization notes that follow do not necessarily give specific adjustments required after completing a single circuit change or modernization since the complete TEST PROCEDURE must be performed after completing the modernization.

The modernization procedures that follow are given in the approximate order that the changes were introduced in production.

Modernize any instrument by starting with the changes given under the serial number group into which the instrument falls. Complete all changes in the group as well as those in any subsequent groups.

#### **NOTE**

All circuit references apply to the schematic diagrams given in Figures 4-9 and 4-10 unless otherwise noted. The schematic diagrams given in Figures 4-7 and 4-8 will facilitate location of components not in instruments with Serial Numbers 1350 and above.

The modernizing instructions that follow are repetitious in several places. This is necessary to insure complete modernization of any instrument and to simplify the procedure for older instruments. Knowing this will eliminate any confusion that might arise when repetition is encountered.

The parts required for modernization of a particular instrument will vary depending upon instrument age. The parts list following the instructions contains all components required to modernize an instrument with Serial No. 529 or below and having a type number other than 4749.

### **3-9A SERIAL NO. 529 AND BELOW**

Instruments with serial numbers below 530 varied little from one another. Minor circuit changes were incorporated during manufacture to simplify production, calibration, and testing without changing performance specifications.

Incorporate the following changes in all instruments. Instruments having a type designation of 4749 had these changes incorporated during manufacture.

Instruments with Serial No. 530 and above do not have type numbers.

- a. Add resistors R84 and R85 (680 ohms,  $\pm 10\%$ , 1 watt, composition) to the screen grid circuits of series regulator tubes V6 and V7.
- b. Change regulator tube V9 from an OC3 (VR105) to a type OA3 (VR75). These two tubes have the same base connections and it is only necessary to change the values of R33, R34, and R36 as described in the next three steps.
- c. Change R33 from 6800 ohms to 10,000 ohms,  $\pm 10\%$ , 2 watt, composition.
- d. Change R34 from 120,000 ohms to 220,000 ohms,  $\pm 10\%$ , 1 watt, composition.

- e. Change R36 from 220,000 ohms to 120,000 ohms,  $\pm 10\%$ , 1 watt, composition.
- f. Rewire tube socket for low frequency oscillator tube V12 by referring to schematic diagrams of Figures 4-8 and 4-10. Replace type 6V6 tube with a type 6AG7 tube. Resistors R49 and R50 must then be changed and resistor R86 added as described in the next three steps.
- g. Change R49 from 560,000 ohms to 220,000 ohms,  $\pm 10\%$ , 1 watt, composition.
- h. Change R50 from 330 ohms to 220 ohms,  $\pm 10\%$ , 1 watt, composition.
- i. Add resistor R86 (270 ohms,  $\pm 10\%$ , 1 watt, composition) to the control grid circuit of V12 (6AG7).
- j. Add capacitor C48 (0.01  $\mu\text{f}$ ,  $\pm 10\%$ , 300 vdcw, mica) in screen circuit for V1, V2, and V3 in any instrument not having this capacitor.

### 3-9B SERIAL NO. 530 THROUGH 589

This group of instruments do not have a type number and were the first to incorporate a power transformer with a dual primary winding. Other than this, they are the same as type 4749 instruments with Serial No. 529 and below.

The -hp- Stock No. 910-37 power transformer was replaced by Stock No. 910-59 which has a dual primary winding that may be connected for operation from 115 or 230 volts. All other transformer ratings remained the same.

#### NOTE

Instrument modernization does not require changing transformers. Use the 910-59 transformer for all replacements.

- a. Change lamp for R80 from -hp- Stock No. 211-4 (115 volts, 3 watts) to -hp- Stock No. 211-29 (250 volts, 10 watts).
- b. Change resistor R47 from 2700 ohms to -hp- Stock No. 26-3000 resistor of 3000 ohms,  $\pm 5\%$ , 1 watt, wirewound (IRC type BW). Instructions for changing R46 from a fixed resistor to a wirewound potentiometer will be found with the modifications for instruments with Serial Numbers 3350 to 3399. Refer to this procedure for new R47 mounting location.

### 3-9C SERIAL NO. 590 THROUGH 1349

This group of instruments had the circuit changes described for instruments with Serial Numbers 530 through 589 incorporated during manufacture. Check the instrument to be modernized to be sure.

- a. Add resistor R87 (100 ohms,  $\pm 10\%$ , 1 watt, composition, -hp- Stock No. 24-100) in series with the 500 ohm potentiometer R77.

- b. Remove and discard trimmer capacitor C15, resistor R28 (82 ohms), and coil L2 from AVC Amplifier V5 plate circuit. Refer to Figure 4-8 for the location of these components.

- c. Replace resistor R29 (120 or 68 ohms) with L8 an 8.6 uh choke available under -hp- Stock No. 65A-60D. Temporarily connect resistor R90 (33 to 82 ohms,  $\pm 10\%$ , 1 watt, composition) in parallel with L8. Refer to Figure 4-8 for location of R29 in plate circuit of V5. Choke L8 and resistor R90 appear in Figure 4-10.

### 3-9D SERIAL NO. 1350 THROUGH 1649

The modifications that follow change the operating conditions for V4 Buffer Amplifier from a triode to a pentode connection. This change provides a sharp reduction of FM and distortion in high frequency oscillator output.

- a. Check wiring of AVC Amplifier V5 plate circuit. Chokes L1 and L8 along with resistors R25 and R90 as shown in Figure 4-10 are the only components that should remain. Other components such as C15, R28, R29, or L2, shown in Figure 4-8, should be removed. Change R25 if necessary to make it a 1 watt composition resistor with a value of 680 ohms.
- b. Replace resistor R20 in cathode circuit of Buffer Amplifier V4 with a wire jumper. This grounds one end of resistors R19 and R21 as shown in Figure 4-10. Refer to Figure 4-8 for R20 location.
- c. Replace R22 (2700 ohms) in plate circuit of V4 with a composition resistor of 5600 ohms,  $\pm 10\%$ , 1 watt. One end of this resistor must connect to V4 pin 5 while the other end connects to the +180 volt supply.
- d. Connect resistor R88 (22,000 ohms,  $\pm 10\%$ , 1 watt, composition) between V4 pin 6 and the +180 volt supply at the same point to which R22 is connected.
- e. Remove the wire jumper connecting V4 pins 5 and 6. Check to be sure that the lead from capacitor C11 connects to pin 5 and not to pin 6.
- f. Connect capacitor C49 (0.01  $\mu\text{f}$ ,  $\pm 10\%$ , 300 vdcw, -hp- Stock No. 14-23) between V4 pin 6 and pin 2 or 7.

### 3-9E SERIAL NO. 1650 THROUGH 1899

This group of instruments had the circuit changes described for instruments with Serial Numbers 1350 through 1649. Check instrument to be modernized and make any necessary changes.

Capacitor C47 (10  $\mu\text{f}$ ) in parallel with C38 in V15 Output Amplifier plate circuit will not be found in all instruments. When adjusting high frequency response of Output Amplifier, if trimmer C38 does not have enough capacity, add C47 using a 5 or 10  $\mu\text{f}$  capacitor.



a. Add resistors R89 and R91 (6800 ohms,  $\pm 10\%$ , 2 watts, composition) in series with B+ to V1, V2, and V3 oscillator tube plate circuits as shown in Figure 4-10. See Figure 4-6 for mounting position of these resistors. It may be necessary to install an insulated tie lug for mounting these resistors. Drill out rivet supporting resistor board near V2 socket to obtain mounting hole for this tie lug.

b. Screen dropping resistor R18 for these same three tubes must remain connected to the +180 volt supply as shown in Figure 4-6. In some instruments, it will be necessary to move R18 from a mounting location near V1 tube socket.

c. Connect tubular electrolytic capacitor C50 (10  $\mu\text{f}$ ,  $\pm 50\%$ , 450 vdcw, -hp- Stock No. 18-10) between ground and common junction of R3, R4, R6, R89, and R91 in plate circuits of V1, V2, and V3. Mount capacitor C50 on top side of resistor board as in Figure 4-5.

### 3-9F SERIAL NO. 1900 THROUGH 2499

This group of instruments had the changes given for instruments with Serial Numbers 1650 through 1899 incorporated during manufacture. A 20  $\mu\text{f}$  capacitor was used for C50 and must be replaced with the 10  $\mu\text{f}$ ,  $\pm 50\%$ , 450 vdcw unit.

a. Complete step 1 given for instruments with Serial Numbers 1350 through 1649.

b. Check connections for capacitor C49 which must be connected between screen grid pin 6 and cathode pin 7 of V4 Buffer Amplifier. If capacitor is connected between screen grid pin 6 and chassis, disconnect at chassis and reconnect to V4 cathode pin 7.

c. Add mica capacitor C51 (5  $\mu\text{f}$ ,  $\pm 20\%$ , 500 vdcw, -hp- Stock No. 14-5) between plate pin 5 and chassis of V13 in Output Amplifier stage.

d. If R37 is a 12 ohm, 1/2 watt resistor mounted on turret base for V15, change to a 12 ohm,  $\pm 10\%$ , 2 watt resistor. Mount new 2 watt resistor between negative terminal of C22 and chassis as shown in Figure 4-6.

### 3-9G SERIAL NO. 2500 THROUGH 2899

a. Type 6L6G, 6Y6G, 6L6GA, or 6L6GB tubes have been used for tubes V6 and V7 at various times during production of this instrument. If an instrument has type 6L6G or 6Y6G tubes, replace with type 6L6GA or preferably type 6L6GB tubes.

b. Tubes used for V1, V2, V3, V4, V5, V13, V14, and V16 should all be type 5654. Replace any type 6AK5 tubes with preferred type 5654 tubes. Refer to tube replacement section of this manual.

c. A type 5U4GA/B rectifier tube is recommended for V10 rectifier. If a 5U4G tube is in instrument, replace with preferred type 5U4GA/B.

### 3-9H SERIAL NO. 2900 THROUGH 2999

This group of instruments is the same as the previous group except the new preferred tube types were incorporated during manufacture.

a. Change R74 in cathode circuit of V16 Voltmeter from 1500 to 820 ohms,  $\pm 10\%$ , 1/2 watt, composition. This value may be adjusted during TEST PROCEDURE to flatten voltmeter frequency response.

b. Replace crystal diodes CR1, CR2, and CR3 with frequency selected diodes available under -hp- Stock No. 212-G11E. The cathode end of the diode is shown in the schematic of Figure 4-10 as a straight line or bar.

### 3-9I SERIAL NO. 3000 THROUGH 3249

a. Check the value of resistor R78 which should be 1000 ohms,  $\pm 10\%$ , 1/2 watt, composition. Any other resistor value should be changed to 1000 ohms.

b. Resistor R87 in series with R77 in meter circuit should be 100 ohms,  $\pm 10\%$ , 1 watt, composition. Any other resistor value should be changed to 100 ohms.

### 3-9J SERIAL NO. 3250 THROUGH 3349

a. Change R89 from 3300 ohms to 6800 ohms,  $\pm 10\%$ , 2 watts, composition.

b. Add resistor R91 (6800 ohms,  $\pm 10\%$ , 2 watts, composition) in parallel with R89 which has the same value and rating. See Figure 4-6.

c. Capacitor C50 must have a value of 10  $\mu\text{f}$ . The 20  $\mu\text{f}$  capacitor used in some instruments must be changed to 10  $\mu\text{f}$ .

### 3-9K SERIAL NO. 3350 THROUGH 3399

a. Mount potentiometer R46 (1000 ohms, wirewound, -hp- Stock No. 210-5) in a hole drilled in chassis halfway between and on a line through the centers of V11 and V12 tube sockets. See Figures 4-5 and 4-6. Position control with center lug toward base of socket for lamp R80. Disconnect lead (usually yellow) from R80 socket at lug on resistor board "B" near socket for tube V9. See Figure 4-6. Cut this lead to approximately 1-1/4 in. and reconnect to center terminal of R46 control.

b. Move resistor R47 (3000 ohms,  $\pm 5\%$ , 1 watt, wirewound, -hp- Stock No. 26-3000) from resistor board to a location between negative terminal of C28 and closest terminal of R46 control. See figure 4-6.

c. Completely remove wire (usually yellow) connecting negative terminal on C28 to lug on resistor board near socket for V9 tube.

d. Best instrument performance is obtained when a composition type control (-hp- Stock No. 210-25) is used for R55 Amplitude control. If a wirewound control is found, replace using the 210-25 unit.

### 3-9L SERIAL NO. 3400 THROUGH 3449

These instruments do not require modification as their circuitry is that given in schematic diagrams of Figures 4-9 and 4-10

#### CAUTION

A modernized instrument must be adjusted and calibrated by completing the "test procedure" given in the maintenance section of this manual.

A completely modernized instrument will have the basic circuitry, component values, and tube line up given in Figures 4-9 and 4-10. Frequency determining components in both oscillator circuits will vary in that values will differ and not all components shown

in schematics will be in an instrument. No attempt should be made to make these two oscillators in an instrument agree exactly with Figure 4-10.

The only changes recommended for the circuits of tubes V1, V2, V3, V11, and V12 are specifically covered in the modernizing instructions.

### 3-9M TABLE OF PARTS FOR MODERNIZATION

One each of the parts listed in Table 3-1 will be required for complete modernization of an instrument with Serial No. 529 or below and a type number other than 4749. A rough check can be made by comparing instrument components against those in Table 3-1. If all parts listed can be located in an instrument and have the values indicated, modernization should be complete.

TABLE 3-1. PARTS FOR MODERNIZATION

Circuit Reference	Description	-hp- Stock No.
C48, C49	Capacitor, 0.01 $\mu$ f, $\pm 10\%$ , 300 vdcw, mica	14-23
C50	Capacitor, 10 $\mu$ f, $\pm 50\%$ , 450 vdcw, electrolytic	18-10
C51	Capacitor, 5 $\mu$ f, $\pm 20\%$ , 500 vdcw, mica	14-5
CR1, CR2, CR3	Diode, germanium, selected	212-G11E
L8	Choke, rf, 8.6 $\mu$ f, wound on resistor form	65A60D
R22	Resistor, 5600 ohms, $\pm 10\%$ , 1 watt, comp.	24-5600
R25	Resistor, 680 ohms, $\pm 10\%$ , 1 watt, comp.	24-680
R33	Resistor, 10,000 ohms, $\pm 10\%$ , 2 watts, comp.	25-10K
R34	Resistor, 220,000 ohms, $\pm 10\%$ , 1 watt, comp.	24-220K
R36	Resistor, 120,000 ohms, $\pm 10\%$ , 1 watt, comp.	24-120K
R37	Resistor, 12 ohms, $\pm 10\%$ , 2 watts, comp.	25-12
R46	Potentiometer, 1000 ohms, $\pm 10\%$ , wire wound	210-5
R47	Resistor, 3000 ohms, $\pm 5\%$ , 1 watt, wire wound	26-3000
R49	Resistor, 220,000 ohms, $\pm 10\%$ , 1 watt, comp.	24-220K
R50	Resistor, 220 ohms, $\pm 10\%$ , 1 watt, comp.	24-220
R55	Potentiometer, 500 ohms, $\pm 10\%$ , comp.	210-25
R74	Resistor, 820 ohms, $\pm 10\%$ , 1/2 watt, comp.	23-820
R78	Resistor, 1000 ohms, $\pm 10\%$ , 1/2 watt, comp.	23-1000
R80	Lamp, incandescent, 250 volts, 10 watts, S6	211-29
R84, R85	Resistor, 680 ohms, $\pm 10\%$ , 1 watt, comp.	24-680
R86	Resistor, 270 ohms, $\pm 10\%$ , 1 watt, comp.	24-270
R87	Resistor, 100 ohms, $\pm 10\%$ , 1 watt, comp.	24-100
R88	Resistor, 22,000 ohms, $\pm 10\%$ , 1 watt, comp.	24-22K
R89, R91	Resistor, 6800 ohms, $\pm 10\%$ , 2 watts, comp.	25-6800
R90	Resistor, 33 ohms, $\pm 10\%$ , 1 watt, comp.	24-33
V1, V2, V3, V4 V5, V13, V14, V16	Tube, electron, type 5654	212-5654
V6, V7	Tube, electron, type 6L6GB	212-6L6GB
V9	Tube, electron, type 0A3	212-0A3
V10	Tube, electron, type 5U4GA/B	212-5U4GA/B
V12	Tube, electron, type 6AG7	212-6AG7

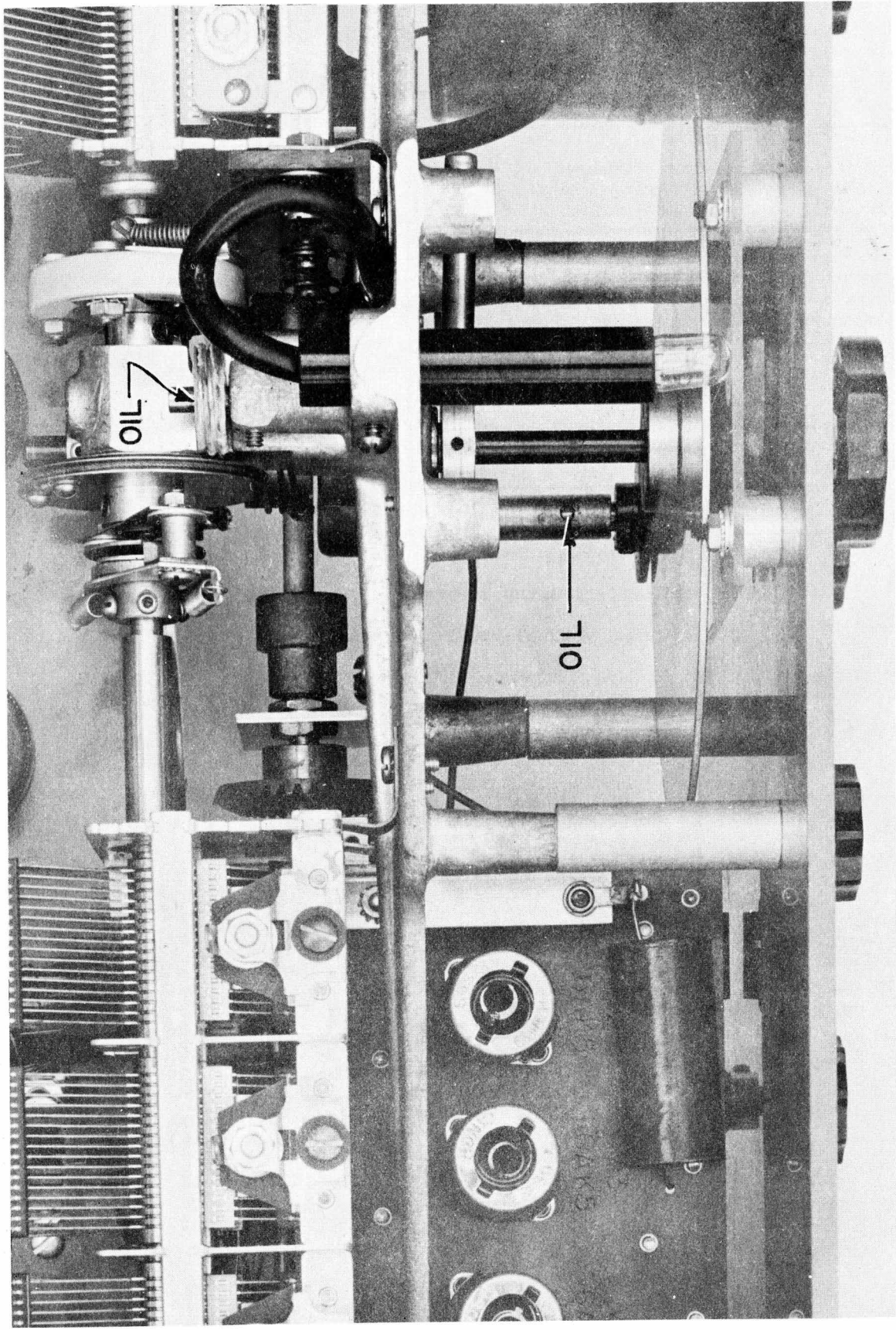


Figure 4-1. Lubrication Points for Tuning Capacitor Drive Mechanism

**4-1 CABINET REMOVAL**

The two piece cabinet can be easily and quickly removed as follows:

- a. Remove rear cabinet cover after unscrewing four sheet metal screws holding cover.
- b. Place instrument with front control panel up.
- c. Loosen two 3-16 in. Allen screws located on bottom of cabinet adjacent to front feet.
- d. Lift cabinet from instrument.

**CAUTION**

Do not change settings of trimmer capacitors mounted on or near tuning capacitor gangs. These trimmers affect both calibration and frequency response. Adjust these capacitors only when proper test equipment is available and according to instructions contained in this manual.

**4-2 LUBRICATION OF TUNING CAPACITOR DRIVE MECHANISM**

The tuning capacitor drive mechanism requires monthly lubrication if instrument is in constant use. Remove dirt or dust with a moderate air stream and place one drop of lubricant at two points as shown in Figure 4-1. Recommended lubricant is "Lubriplate #3" (Fiske Bros. Refining Co., Newark, N.J.) or equivalent.

**4-3 DRIVE SYSTEM FOR OSCILLATOR TUNING CAPACITORS**

The two oscillator tuning capacitors effectively have a common shaft since their shafts are mechanically connected by a short supported shaft and two flexible couplings. SET SCREWS IN COUPLINGS MUST NOT BE LOOSENED. If shafts of tuning capacitors are allowed to rotate with respect to each other, frequency dial calibration will be lost. It may be necessary to return instrument for factory recalibration.

The front panel FREQUENCY controls are coupled to the oscillator tuning capacitor shafts by means of a wire cable arrangement. This cable drive system

has a designed life expectancy greater than the electrical portion of instrument and will normally require no maintenance.

If cable drive system damage does occur, cable replacement can be accomplished by following directions in -hp- Service Notes No. M14 in the rear pages of this manual.

**4-4 TUBE REPLACEMENT**

Tubes in an -hp- Model 650A Test Oscillator can be replaced without special considerations with certain exceptions. Table 4-1 gives recommended tube replacements and tube functions. Instructions for selecting tubes, when required, along with any adjustments or test necessary after replacing a certain tube are given in the following paragraphs.

**CAUTION**

Power to instrument must be turned off prior to removing any of tubes V1, V2, V3, V4, or V16. This precaution will prevent ballast tube current regulator action from burning out heaters of remaining tubes.

**4-4A REPLACEMENT OF V1, V2, V3, V4, OR V5**

Only type 5654 tubes are recommended for replacement of these five tubes. If 6AK5 tubes are used, after replacing V1, V2, V3, or V4 it will be necessary to adjust R42 to set ac heater voltage. Transconductance of tubes V1, V2, and V3 should be nearly equal and above 5000 micromhos with a preferred value between 5400 and 5600 micromhos. Although not critical, improved performance will be obtained from low microphonic tubes.

Transconductance of replacement for V4 should be above 5000 micromhos.

Transconductance of replacement for V5 should not be more than 4000 micromhos. A tube with high transconductance for V5 may cause low output from the high frequency oscillator.

After replacement of all or any one of these five tubes, frequency response and calibration of the high frequency oscillator should be checked. It will also be

TABLE 4-1. TUBE COMPLEMENT AND FUNCTION CHART

CIRCUIT REFERENCE	ORIGINAL TUBE TYPE	RECOMMENDED REPLACEMENT	TUBE FUNCTION
V1			
V2	6AK5		High Frequency Oscillator.
V3	OR	5654	
V4	5654		Buffer Amplifier.
V5			AVC Amplifier.
V6	6L6G, 6Y6G		
V7	6L6GA or GB	6L6GB	Power Supply Series Regulator.
V8	6SQ7	6SQ7	Power Supply Regulator Control.
V9	OC3 OR OA3	OA3	Power Supply Voltage Reference. Modernize instruments with Serial No. 529 and below.
V10	5U4G, 5U4GA OR 5U4GB	5U4GB	Power Supply Full Wave Rectifier.
V11	6SJ7	6SJ7	Low Frequency Oscillator.
V12	6V6 OR 6AG7	6AG7	Low Frequency Oscillator. Modernize instruments with Serial No. 529 and below.
V13	6AK5 OR	5654	Output Amplifier First Stage.
V14	5654		Output Amplifier Second Stage
V15	6AG7	6AG7	Output Amplifier Final Stage.
V16	6AK5 OR 5654	5654	Output Voltmeter Voltage Amplifier.
V17	12-4	12-4	Heater Circuit Current Regulator.

necessary to check output level, distortion, and frequency modulation of this oscillator and balance oscillator output levels by adjusting R53.

**NOTE**

This discussion of  $G_m$  selection applies only to 6AK5 tubes. When the recommended 5654 tube is used, no  $G_m$  selection is needed.

**4-4B REPLACEMENT OF V6, V7, V8, V9, OR V10**

Any tube with standard RETMA characteristics may be used. It will be necessary to check and set power supply regulated output voltage to 180 volts. It is also advisable to check for hum in output of instrument and test line voltage response.

**4-4C REPLACEMENT OF V11 OR V12**

Any tube with standard RETMA characteristics may be used. Tubes selected for low microphonics and low heater to cathode leakage are preferred. Replacement tubes may introduce minor distortion or slightly change frequency dial calibration near 100 KC.

After tube replacement, set low frequency oscillator amplitude at 1000 cps by adjusting R46. Adjust control R46 to set voltage at junction of R47, R54, and C28. Check distortion at this same point when tuned to 100 cps. Check hum level in instrument output and adjust R53 to balance output levels of both oscillators.

**4-4D REPLACEMENT OF V13 OR V14**

It is recommended that only type 5654 tubes with a transconductance in the approximate range from 4200 to 4800 micromhos be used for replacement.

Check instrument frequency response, hum, distortion, and output level following tube replacement.

#### **4-4E REPLACEMENT OF V15**

A tube with standard RETMA characteristics can be used. Check instrument frequency response. Adjust capacitor C38 to set the 1 to 10 MC response.

Instrument hum, distortion, and output level should also be checked.

#### **4-4F REPLACEMENT OF V16**

Use only type 5654 tubes for replacement. A tube with relatively high transconductance (5000 micromhos or better) is recommended. Adjustment of meter calibrating shunt R77 will probably be necessary. Capacitor C42 is adjusted to flatten voltmeter frequency response in the 1 to 10 MC range.

#### **CAUTION**

Do not operate instrument with this tube removed. Turn instrument off before removing tube V16 to prevent possible meter damage.

#### **4-4G REPLACEMENT OF V17**

After replacing ballast tube, adjust control R42 to set heater voltage for V1, V2, V3, V4, and V16.

#### **4-4H REPLACEMENT OF LAMP R80**

Lamp R80 in the low frequency oscillator operates at a low power level resulting in long life with replacement seldom necessary.

After replacing a lamp, measure ac voltage at junction of R47, C28, and R54 with instrument tuned to 1000 cps. This oscillator voltage should be between 18 and 22 volts with approximately 19 volts being optimum in most instruments.

Large deviations from this voltage should be corrected by successive trials of new lamps. Small deviations can be corrected by adjusting control R46. A potentiometer can easily be installed for R46 in all instruments with Serial No. 3399 or below as detailed under modernization.

After adjusting oscillator level, balance output levels of two oscillators and check distortion of low frequency oscillator. If instrument seems to be unstable when switching between low frequency oscillator ranges, adjust R46 for a slightly higher oscillator level and repeat test.

Some lamps are highly microphonic and are not usable even though they perform satisfactorily in every other way.

#### **4-5 MISCELLANEOUS TESTS AND ADJUSTMENTS**

The following independent tests and adjustments can be made at any time. If an instrument is undergoing a complete test procedure, these tests and adjustments are performed in the sequence given in the

complete test procedure. Use output cable supplied with instrument for a 600 ohm resistive load.

#### **4-5A SETTING V1, V2, V3, V4, AND V16 HEATER VOLTAGE**

Set line voltage to 115 volts. Adjust control R42 to obtain 6.3 volts ac at pin 2 of V17 ballast tube. This voltage should not change by more than  $\pm 0.3$  volts when line voltage varies  $\pm 10\%$ .

#### **4-5B SETTING REGULATED POWER SUPPLY**

Connect a dc voltmeter between ground and cathode pin 8 of series regulator tube V6 or V7. Set dc output voltage to 180 volts by adjusting control R35 with line voltage set to 115 volts.

Check regulator line voltage response by varying line voltage  $\pm 10\%$  from 115 volts. The regulated dc output should not vary more than 2 volts.

#### **4-5C BALANCING OSCILLATOR OUTPUT LEVELS**

Load instrument with 600 ohms and adjust for a 100 KC output signal on the "X100KC" position. Adjust AMPLITUDE control R55 for a convenient reference point on the output meter.

Switch to 100 KC on the "X10KC" range and adjust R53 for the same output meter reference reading. Control R53 is mounted on the tuner drive casting on the underside of the chassis. See Figure 4-6.

#### **4-5D CHECK OUTPUT HUM LEVEL**

Place a resistive load of 600 ohms and an external ac voltmeter across output terminals. Switch to the "X10KC" range, unscrew lamp R80, and rotate AMP-LITUDE control full counterclockwise. Hum voltage should not exceed 0.015 volts (0.5% of 3.0 volt rated output).

#### **4-5E OUTPUT METER SENSITIVITY ADJUSTMENT**

Turn panel AMPLITUDE control full counterclockwise. Set the 650A output meter mechanical adjustment to zero. Connect an external ac voltmeter of known accuracy at 1000 cps and a resistor of 600 ohms across instrument output terminals.

Set AMPLITUDE control for a 3 volt reference reading on external voltmeter with output attenuator set to 3.0 volts and instrument tuned to 1000 cps. Adjust control R77 for a 3 volt reading on internal voltmeter. Check at 2 volts and at 1 volt.

#### **4-5F ATTENUATOR CHECK**

The output attenuator can be checked against a standard 600 ohm attenuator and reference ac voltmeter or with only a vacuum tube ac voltmeter such as -hp-Models 400C, 400D, or 400H.

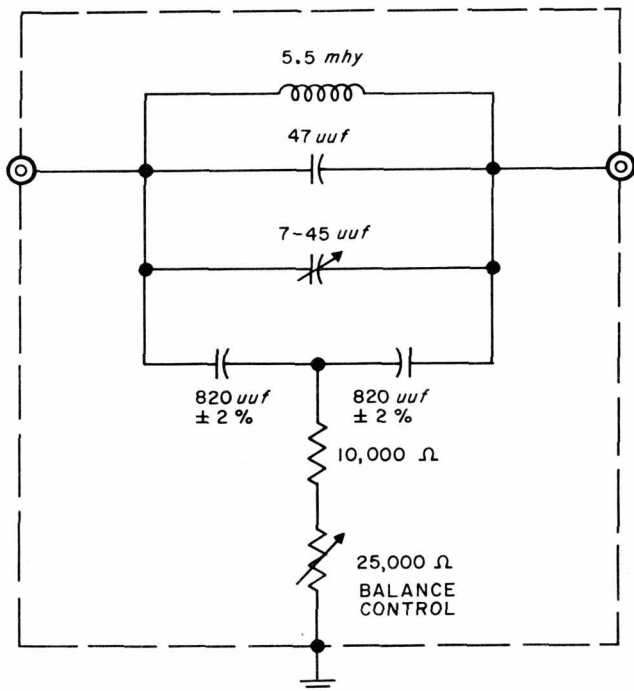


Figure 4-2. 100 KC Filter

When using only a vacuum tube voltmeter, connect a resistive load of 600 ohms across output terminals. Check at 1 KC and at 2 MC if a 400C is used and also at 4 MC if a 400D or 400H voltmeter is used.

#### 4-5G CHECK FOR 60 CPS BEAT

Tune to approximately 55 cps and adjust AMPLITUDE control for an approximate indication of 0.9 full scale on output meter. Slowly tune up through 60 cps and note amount of greatest meter swing. The total maximum swing should not exceed 4% of the full scale value. See paragraph 4-7, Trouble Shooting.

#### 4-5H INSTRUMENT RESPONSE TO LINE VOLTAGE CHANGES

Set output voltage at 10 cps to a reference level on 650A output meter. Vary line voltage from 105 to 125 volts. The output meter indication should not change more than 2% of full scale. If out of specifications, repeat check using an external voltmeter to determine if poor response is caused by the amplifier or the output meter circuit.

#### 4-5I OUTPUT IMPEDANCE

Set output attenuator to the 3 volt or +10 db range and tune instrument to approximately 1000 cps. Adjust AMPLITUDE control to obtain a full scale (3 volt) output meter indication with no load connected to output terminals. The meter indication should drop to half scale (1.5 volts) when a 600 ohm resistive load is connected to the output terminals.

#### 4-5J MAXIMUM OUTPUT VOLTAGE

Maximum output voltage to a 600 ohm resistive load should be at least 3 volts at all frequencies.

If output is low, increase high frequency oscillator output and balance oscillator output levels. See high frequency oscillator adjustment procedure given in test procedure section.

#### 4-6 COMPLETE TEST PROCEDURE

The procedure that follows is suitable for all -hp- Model 650A Test Oscillators. Modernization, particularly those instruments with serial numbers below 2500, is recommended prior to undertaking this Complete Test Procedure.

The following test equipment will be required:

- a. An ac vacuum tube voltmeter with known frequency response from 10 cps to 10 MC. -hp- Models 410A and 410B are suitable for this purpose.
  - b. A distortion analyzer such as -hp- Model 330B.
  - c. A means of constant line voltage control from 100 to 130 volts.
  - d. A dc voltmeter for setting 180 volt output from regulated supply.
  - e. Frequency determining equipment covering 10 cps to 10 MC range. An oscilloscope and frequency standard such as -hp- Model 100A, B, C, or D would be suitable for frequencies up to 100 KC. A crystal calibrator could then be used over the 100 KC to 10 MC range. A single electronic frequency counter such as -hp- Model 524A or 524B could also be used to determine frequency over the 10 cps to 10 MC range in place of the above equipment.
  - f. An oscilloscope such as -hp- Model 130A or 150A.
  - g. Elimination filter for 100 KC as shown in Figure 4-2. Any coil and capacitor combination can be used that will resonate at 100 KC. If a different inductor is used, the value of the balance control and series resistor will have to be changed. The inductor shown in Figure 4-2 can be obtained under -hp- Stock No. 48-3.
- Refer to Figures 4-9 and 4-10 for circuit references unless otherwise designated. All ac or dc voltages are measured between the indicated point and chassis ground.

#### NOTE

The "R.M.S. VOLTS/DB" output attenuator switch must always be in the "+10 - 3.0" position unless otherwise instructed.

A complete test requires completion of all of the following tests in the order given. In some cases where only partial testing is required, some steps can be

eliminated. A complete test is not always required after repair of an individual section in the 650A. If, for example, only the output amplifier has been repaired, those steps pertaining to adjustment and calibration of the two oscillators should be omitted.

#### **4-6A HEATER AND REGULATED POWER SUPPLY VOLTAGES**

Adjust heater voltage and output of regulated power supply as instructed in paragraph 4-5.

#### **4-6B PRELIMINARY LOW FREQUENCY RESPONSE ADJUSTMENT**

a. Place a 600 ohm resistive load across output terminals, set FREQUENCY dial to "1", switch to the "X1KC" range, and adjust AMPLITUDE control to any convenient reference level on an external vacuum tube voltmeter connected across output terminals. This external ac VTVM must have known frequency response characteristics and must be accurately calibrated.

b. Turn FREQUENCY dial to "10" without disturbing any other control settings. The reading obtained on the external meter should be the same as the reference reading established in step a. The output frequency should be 10 KC as indicated by range switch and FREQUENCY dial positions. Adjust trimmer capacitors C23 and C24 simultaneously to obtain a 10 KC output signal having an amplitude equal to the reference level of step a.

If both frequency and amplitude requirements cannot be obtained, adjust to secure the correct amplitude at a frequency as near to 10 KC as possible. Final frequency calibration will be completed in a later step.

c. Repeat steps a and b.

#### **4-6C LOW FREQUENCY OSCILLATOR OUTPUT VOLTAGE**

Measure ac voltage at junction of R47, R54, and C28 with 650A tuned to 1000 cps. This oscillator voltage should be between 18 to 22 volts with approximately 19 volts being optimum in most instruments.

Large deviations from this voltage can be corrected by installing a new lamp for R80. Small deviations can be corrected by adjusting control R46. A potentiometer can easily be installed for R46 in all instruments with Serial No. 3399 or below as detailed in paragraph 3-9, Modernization Procedure.

If recovery time (indicated by low frequency flutter in output signal amplitude) is excessively long when switching ranges, slightly increase low frequency oscillator output by adjusting R46. If trouble persists, replace oscillator tubes V11 and/or V12.

#### **4-6D LOW FREQUENCY OSCILLATOR DISTORTION**

Low frequency oscillator distortion measured at junction of R47, R54, and C28 with instrument tuned to

1000 cps will normally be from 0.3% to 0.5%. This exact figure is not critical as long as the distortion measured at the instrument output terminals does not exceed 1.0%.

Correct for excessive low frequency oscillator distortion by lowering the oscillator voltage or by replacing tubes V11 and/or V12.

#### **4-6E LOW FREQUENCY OUTPUT DISTORTION**

Measure distortion at 30, 1000, and 15,000 cps with distortion analyzer and a 600 ohm resistive load connected to output terminals. Distortion can be measured at 100 KC by means of an elimination filter as instructed under High Frequency Distortion.

Distortion in instrument output signal when tuned at any point between 10 cps and 100 KC should not exceed 1.0%.

#### **4-6F CALIBRATION OF LOW FREQUENCY OSCILLATOR**

Suggested setups for low frequency oscillator calibration and response checks are given in Figure 4-3.

Any high impedance ac voltmeter capable of accurate voltage measurements from 10 cps to 100 KC can be used.

a. Connect a 600 ohm resistive load and frequency measuring equipment to 650A output terminals. See Figure 4-3.

b. Switch to the "X1KC" range and set FREQUENCY dial to "10" which provides an output signal of 10 KC.

c. Adjust frequency calibration at this dial point by adjusting trimmer capacitors C23 and C24. The output amplitude may be disregarded at this time.

d. Set FREQUENCY dial to "5" and measure output frequency which should be 5 KC. If frequency is off, remove knob directly under dial window and loosen but do not remove four exposed Allen screws that secure dial to hub.

e. Set 650A for a 5 KC output signal. Slip frequency dial on hub to obtain a dial reading of "5" and re-tighten Allen screws.

f. Repeat steps b, c, d, and e.

g. Check dial calibration with dial set to "1" and other points between "1" and "10". If output frequency is not 1 KC with dial setting of "1", it may be necessary to change value of 1/2 watt padding resistors in series with R9 and/or R12. (See CAUTION that follows.) If calibration error is not more than 2%, change either resistor value. If error is more than 2%, change both values an equal amount as an unbalanced condition will cause the oscillator to operate at a different level than the other ranges. Increasing resistor values will decrease oscillator frequency with any given tuning capacitor setting.



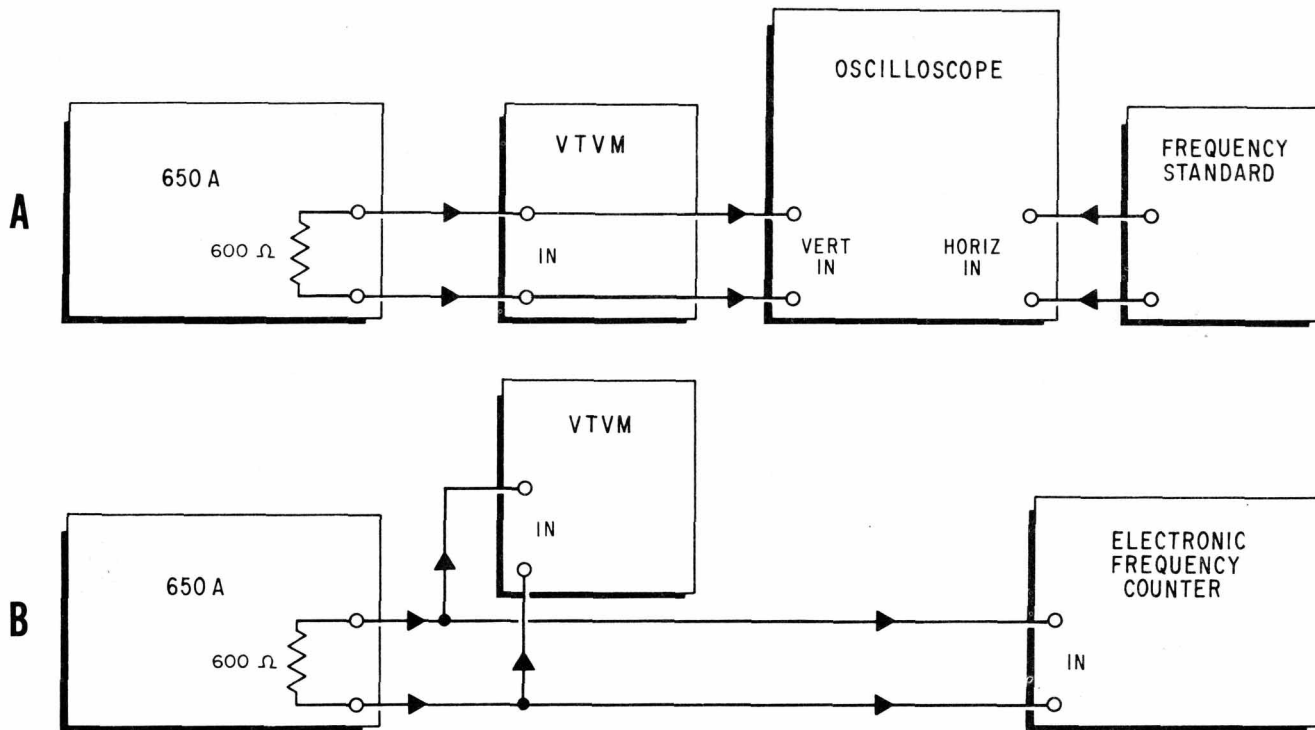


Figure 4-3. Calibration and Response Check for Low Frequency Oscillator  
(Figure B is suitable over entire 650A frequency range.)

### CAUTION

Before changing any 1/2 watt padding resistors, check the other low frequency oscillator ranges (X10~, X100~, and X10KC) for a possible constant error on all ranges. If error is constant, changing padding resistors for the X1K range would not be advisable.

- h. Repeat step b then turn frequency dial to "8" and measure output frequency.
- i. If output frequency is lower than 8 KC, bend end rotor plates outward on all sections of low frequency oscillator tuning capacitor. Bend only those segments of the rotor plates that are just meshing. If output frequency is high, bend rotor plates inward. Rotor and stator plates must not touch. Try to bend plates equally on all sections of the tuning gang.
- j. Repeat step i at frequency dial settings of "5", "3", "2", "1.3", and "1". Adjust plate segments without changing those that have already been adjusted. Bring calibration to within approximately 1%.
- k. Check frequency calibration of remaining low frequency oscillator ranges. These ranges should be within 1% calibration specifications. If they are not, change padding resistors for range that is off frequency as described in step g.
- l. Calibration at 100 KC with range switch on "X10KC" and FREQUENCY dial at "10" can be adjusted by changing value of capacitor C25 in cathode circuit of V11 low frequency oscillator tube.

### 4-6G LOW FREQUENCY OSCILLATOR RESPONSE

- a. Connect voltmeter and frequency measuring equipment as shown in Figure 4-3.
- b. Repeat Preliminary Low Frequency Response Adjustment.
- c. Check frequency response on three remaining low frequency oscillator ranges. Specifications require a response that is flat within  $\pm 1$  db from 10 cps to 100 KC with a 1 KC zero db reference. Adjacent ranges should be within 1/2 db of each other.
- d. Repeat Low Frequency Output Distortion measurement.

### 4-6H HIGH FREQUENCY OSCILLATOR AMPLITUDE ADJUSTMENT

- a. Measure ac voltage on plate pin 5 of V4 buffer amplifier stage. With range switch at "X100KC" and FREQUENCY dial at "1" (100 KC output signal) this voltage should be 1.1 volt,  $\pm 0.1$  volt. Instruments with Serial No. 1649 or below should be modernized.
- b. High frequency oscillator voltage is adjusted by changing tubes V1, V2, V3, and/or V5. To raise oscillator voltage, install tubes with a higher transconductance for V1, V2, and V3 oscillator stages and/or a tube with lower transconductance for V5 AVC amplifier tube.
- c. If oscillator voltage is too high, install a tube with higher transconductance for V5 AVC amplifier.

d. Plate load resistor R25 for V5 AVC amplifier can also be adjusted to obtain correct oscillator voltage. Increasing R25 will reduce oscillator voltage while decreasing R25 will increase this voltage. Use type 5654 tubes for replacement of V1, V2, V3, and V5.

### CAUTION

Turn off instrument when changing tubes V1, V2, V3, or V4. This is necessary to prevent possible burn out of remaining tube heaters.

e. Pull out tube V5 while instrument is operating. If AVC stage is functioning properly, high frequency oscillator voltage will go up.

### 4-6I OUTPUT METER FREQUENCY RESPONSE ADJUSTMENT

a. Connect a resistive load of 600 ohms across output terminals along with a high impedance ac meter of known accuracy up to 10 MC.

b. Adjust for a 1 MC output signal by switching to "X1M" range and setting FREQUENCY dial to "1".

c. Adjust AMPLITUDE control for a reference reading on both internal and external voltmeters and then turn FREQUENCY dial to "10".

d. Adjust capacitor C42 in V16 cathode circuit to obtain same reference reading established in step c. If C42 has insufficient capacity, add a small fixed capacitor in parallel with C42.

### 4-6J HIGH FREQUENCY OSCILLATOR RESPONSE ADJUSTMENT

When checking high frequency oscillator response, a purely resistive load must be connected directly across output terminals. Use of 65A-16D Output Divider Cable supplied with instrument is recommended.

A patch cord or voltmeter with high input capacity will completely disrupt these measurements.

a. Connect a resistive load of 600 ohms across output terminals.

b. Set range switch to "X1M" and adjust FREQUENCY dial to "1" to provide a 1 MC output signal.

c. Adjust AMPLITUDE control to establish a reference level on the internal voltmeter.

d. Turn FREQUENCY dial to "10" for a 10 MC output frequency.

e. Adjust capacitor C38 in V15 amplifier plate circuit to obtain the same reference level established in step d. It may be necessary to add or delete C47 (10  $\mu$ f, NPO, ceramic) in parallel with C38.

f. Check response curve between "1" and "10" on the "X1M" range. A "hump" or "sag" in the response curve can be corrected by changing value of resistor

R90 in plate circuit of V5. Trying a different tube for V5 is also recommended. A "hump" is corrected by increasing R90, a "sag" by decreasing.

g. Repeat steps a through f after changing R90 value. It may be necessary to repeat this process several times before a corrected response is obtained that is flat within approximately 1/2 db.

h. If R90 or V5 were changed in step f, check, and if necessary, adjust high frequency oscillator amplitude. Interaction resulting from adjusting R25 for oscillator amplitude and R90 for frequency response may necessitate repeated adjustments.

i. Switch to "X100KC" and check response over entire range. This range will normally be within specifications. In some cases, when response is not correct, replacement of V5 and repetition of steps a through h will be necessary.

j. Overall frequency response of instrument from 10 cps to 10 MC should be flat within  $\pm 1$  db. Zero db reference point is at 1000 cps on the "X1KC" range.

### 4-6K HIGH FREQUENCY DISTORTION MEASUREMENT

a. Connect a resistive load of 600 ohms across output terminals.

b. Adjust for a 100 KC output signal by switching to the "X100 KC" range and setting FREQUENCY dial to "1".

c. Adjust AMPLITUDE control to set output level to 3 volts as read by 650A output meter.

d. Connect 100 KC filter shown in Figure 4-2 across output terminals and an external ac meter across filter output terminals. The meter used must be capable of accurately measuring frequencies that are harmonics of 100 KC. See block diagram given in Figure 4-4.

e. Adjust balance control in filter and tune 650A to produce a minimum reading on external VTVM. The external meter reading should be 0.15 volt or less if instrument is within specifications of not more than 5% distortion at 100 KC.

f. Distortion can be checked at higher frequencies if the necessary elimination filters are available.

g. If distortion is excessive, interchange oscillator tubes V1, V2, and V3 or change buffer amplifier tube V4.

h. If an -hp- Model 410A or 410B was used as the external meter during High Frequency Oscillator Response Adjustment, it will be necessary to go back and repeat this adjustment if the distortion was found to be excessively high in steps e and/or f above.

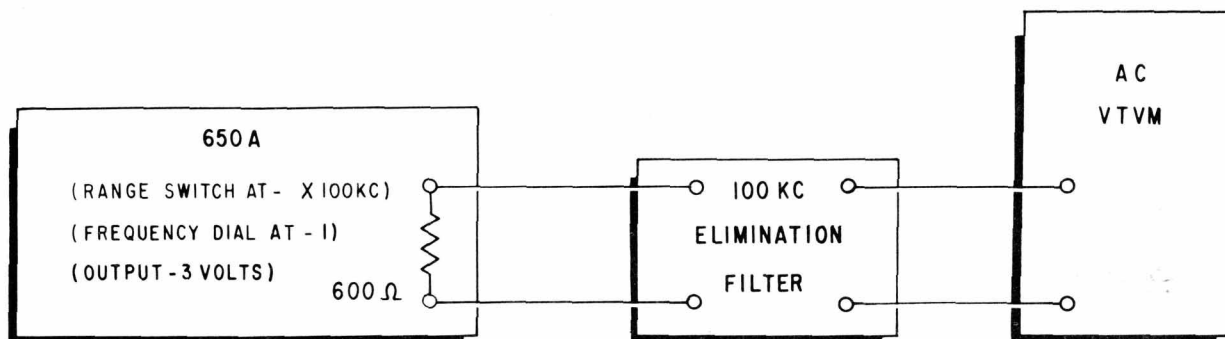


Figure 4-4. Equipment for High Frequency Distortion Measurement

#### 4-6L CHECK FM AT 10 MC

- a. Tune instrument to approximately 10 MC and connect a 10 MC crystal calibrator to output terminals. Set 650A output attenuator to the "0.3 R.M.S. VOLTS" position.
- b. Monitor resultant beat note with a set of headphones. Zero beat should be indicated by a distinct null. A warbling beat note or lack of a distinct null would indicate FM in the output signal. This problem usually occurs only in older instruments in need of modernization.
- c. Return output attenuator to "3.0 R.M.S. VOLTS" position.

#### 4-6M CALIBRATION OF HIGH FREQUENCY OSCILLATOR

- a. Connect frequency measuring equipment to 650A output terminals. See figure 4-3A.
- b. Turn FREQUENCY dial to "10" and switch to the "X1M" range.
- c. Set output frequency to 10 MC by adjusting the three trimmer capacitors on top of left-hand tuning capacitor when viewing instrument from front. Any one or all three capacitors may be adjusted. However, adjustment of all three an equal amount is recommended.
- d. Check calibration at 5 MC. Correct by loosening Allen set screws holding left-hand tuning capacitor shaft coupling and rotating capacitor shaft with respect to drive mechanism to obtain an output frequency of 5 MC with a dial reading of "5". Retighten set screws.

#### NOTE

Do not disturb relationship of right-hand, four section, turning gang and main frequency dial.

- e. Repeat step c.
- f. Recheck 10 MC calibration as in step c.

- g. Slight tracking errors can be corrected by bending plates of the three section tuning capacitor for the high frequency oscillator. The technique for bending capacitor plates has already been discussed under Calibration of Low Frequency Oscillator.

#### 4-6N CALIBRATION OF X100KC RANGE

- a. Turn range switch to "X100KC" and set FREQUENCY dial to "10" which should provide an output frequency of 1 MC.
- b. Connect frequency determining equipment to output terminals. See Figure 4-3B.
- c. If measured output frequency is not 1 MC, adjust capacitor C3 (20-50  $\mu\mu\text{f}$ , ceramic) to obtain this frequency. This capacitor is mounted on the bottom side of mounting board for V1, V2, and V3.
- d. Adjust calibration at bottom (100 KC) of same range, if necessary, by changing padding resistors which are in series with R1, R2, and R5. These resistors are located on the range switch mounted below mounting board for tubes V1, V2, and V3. Any one or all three resistor values can be changed. However, an equal change for all three is recommended.
- e. If it was necessary to change padding resistors in step d, repeat adjustment of capacitor C3 as in step c.

#### 4-6P OTHER ADJUSTMENTS

- a. Balance oscillator output levels. See paragraph 4-5.
- b. Check overall frequency response of 650A output meter. Response should be within  $\pm 1$  db over instrument frequency range of 10 cps to 10 MC. Zero db reference at 1000 cps on "X1KC" range.
- c. Check output hum level. Refer to paragraph 4-5 for procedure.
- d. Adjust output meter sensitivity and check output attenuator as instructed in paragraph 4-5.

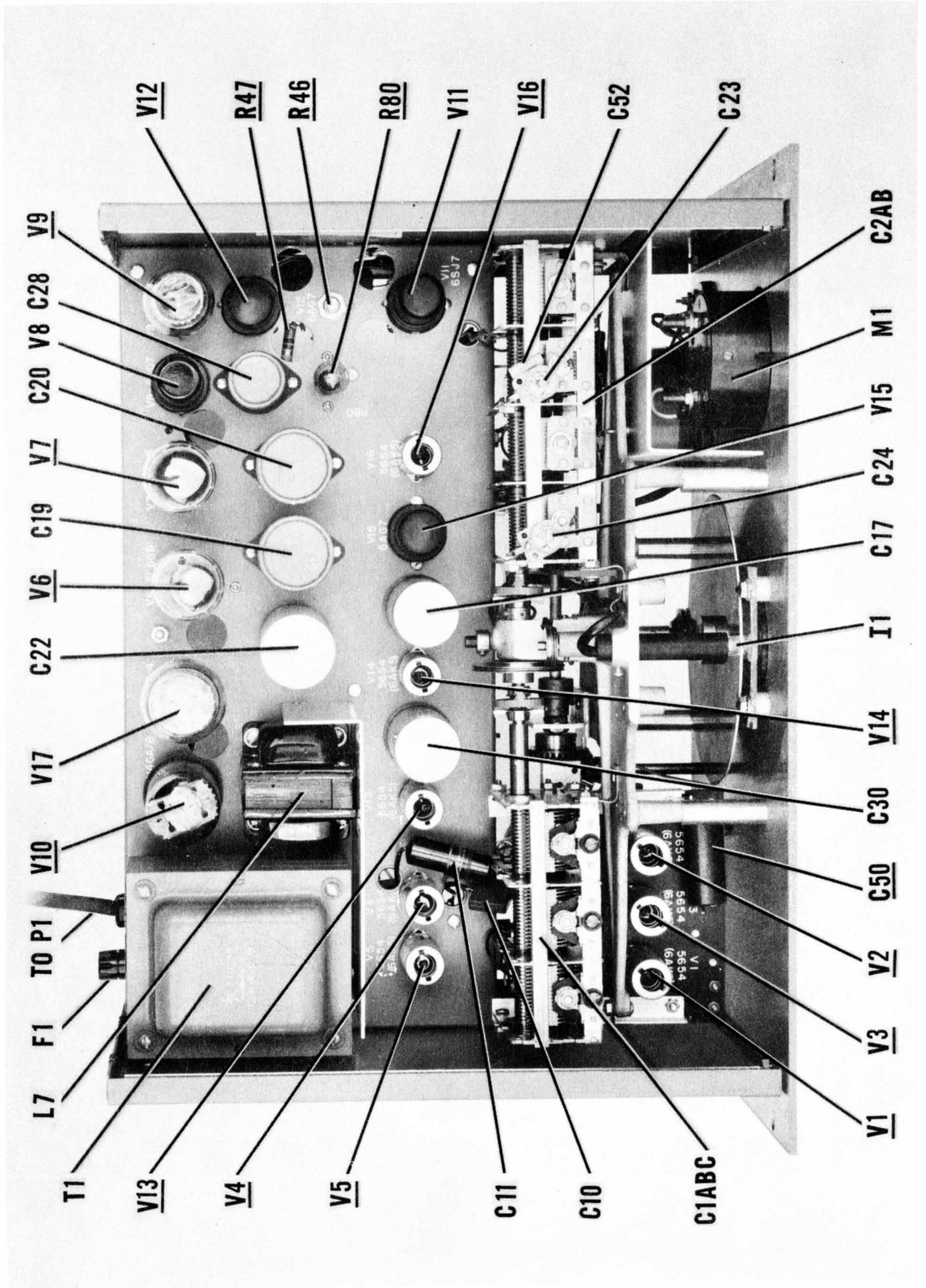


Figure 4-5. Model 650A Typical Top Chassis View

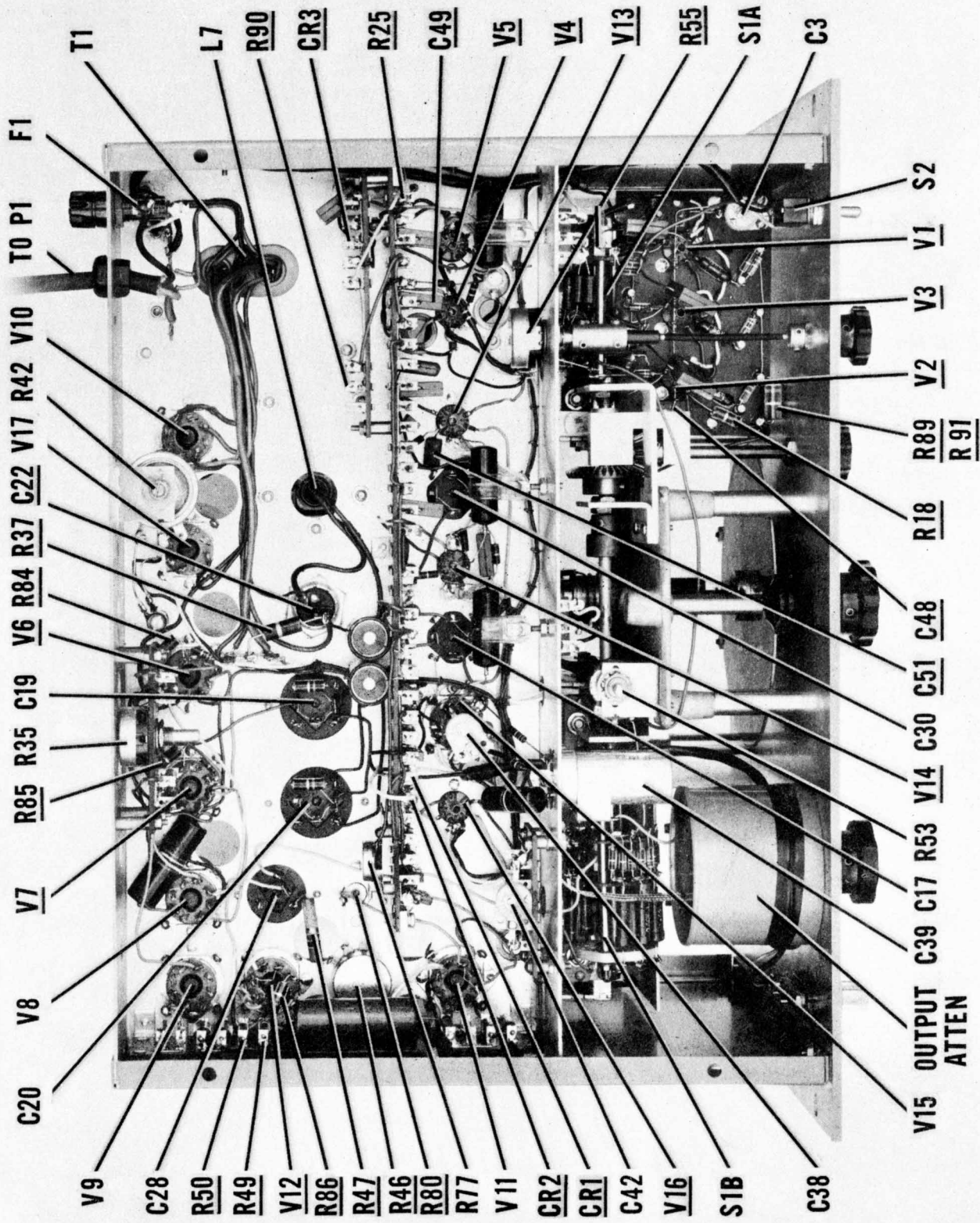


Figure 4-6. Model 650A Typical Bottom Chassis View  
 (Components underlined have changed as described in modernization procedure.)

- e. Check for a 60 cps beat. See paragraph 4-5.
- f. **Make** a final recheck of frequency calibration on all six ranges. Make any adjustments found to be necessary.
- g. Check instrument response to line voltage change. See paragraph 4-5.
- h. Check output impedance and maximum output voltage. See paragraph 4-5.

#### 4-7 TROUBLE SHOOTING

Notes given in Table 4-2 are based on -hp- experience. The more common troubles, their symptoms, and remedy are given.

It is beyond the scope of this manual to include all possible or obscure and rare troubles. If an instru-

ment develops trouble symptoms not covered by this chart, repair analysis will be simplified if the Circuit Description given in this manual is used to obtain a complete understanding of the instrument circuitry. In case of persistent trouble, contact your -hp- Sales Engineering Representative or the -hp- Factory Service Department directly.

All circuit references refer to Figures 4-9 and 4-10 unless otherwise noted. Signal, ac, or dc voltages when mentioned here, are measured between the indicated points and the chassis unless specified otherwise.

Tubes with standard RETMA characteristics can be used for tube replacements as explained in paragraph 4-4. In a great number of cases, instrument trouble can be traced to a defective tube. Avoid transposing tubes of the same type in their respective sockets as this may disturb instrument adjustment.

TABLE 4-2. TROUBLE SHOOTING

SYMPTOM	CAUSE AND/OR REMEDY
Dead on all ranges.	Blown line fuse Tube V13, V14, or V15 defective. Rectifier V10 defective. No. B+ voltage.
No B+ voltage or Low B+ voltage.	Rectifier V10 defective. Tubes V6 and/or V7 defective. Tube V8 shorted. Choke L7 open. Resistor R37 open. Defective filter capacitor. R34 open.
High B+ voltage. Cannot be adjusted by R35 control.	Tubes V6 or V7 shorted. Tubes V8 or V9 defective. Resistor R36 open.
Instrument blows line fuses.	Shorted rectifier V10. Shorted filter capacitor. Choke L7 shorted to chassis. Defective power transformer. Shorted heater wiring.
Power supply will not regulate with varying line voltage.	Defective tube in regulated power supply.

TABLE 4-2. TROUBLE SHOOTING (Cont)

SYMPTOM	CAUSE AND/OR REMEDY
	<p>Excessive power supply load due to failure elsewhere in instrument.</p> <p>Regulated output voltage set too high.</p> <p>Low dc input to regulator circuit.</p>
120 ~ hum in instrument output.	<p>Voltage regulator in power supply is not regulating.</p> <p>Defective filter capacitors.</p> <p>Capacitor C18 defective.</p>
60 ~ hum in instrument output.	<p>Heater-cathode leakage in any oscillator or amplifier tube.</p> <p>Capacitor C18 defective.</p> <p>Heater-cathode leakage in V6, V7, or V8.</p>
Beat frequency at 60 ~.	<p>Instrument bottom plate or top cover missing.</p> <p>Line frequency coupling to low frequency oscillator. Check dress of heater and dial light leads. Move leads away from tuning gangs and range switches.</p> <p>Heater-cathode leakage in V11, V12, V13, V14, and/or V15.</p>
Motorboating or parasitic oscillation.	<p>Regulator tube V9 defective.</p> <p>Tubes V12 or V15 defective.</p> <p>Regulated power supply not regulating.</p> <p>Control R55 is wirewound. Replace as per modification notes.</p>
Intermittent or noisy output particularly during frequency adjustment.	<p>Tuning gangs are dirty or intermittently shorting.</p>
Fuzzy output pattern.	<p>Heater-cathode leakage in V1, V2, V3, V11, or V12 will cause FM in output. Instruments with Serial No. 1649 and below should be modernized.</p> <p>Heater lead too close to range switch.</p>
Distortion and/or low output on all ranges.	<p>B+ voltage not correct.</p> <p>Coils L3, L4, or L5 open.</p> <p>Tubes V13, V14, and/or V15 defective.</p> <p>Defective coupling capacitor in output amplifier stages.</p>
Dead on two high ranges with no output meter indication on any range.	<p>No regulated heater voltage for V1, V2, V3, V4, and V16 tubes.</p> <p>Ballast tube V17 defective or open power transformer winding.</p>
Output meter reads low and cannot be corrected by R77 adjustment	<p>Tube V16 defective.</p>
Output meter has poor frequency response.	<p>Diodes CR1 or CR2 defective.</p>

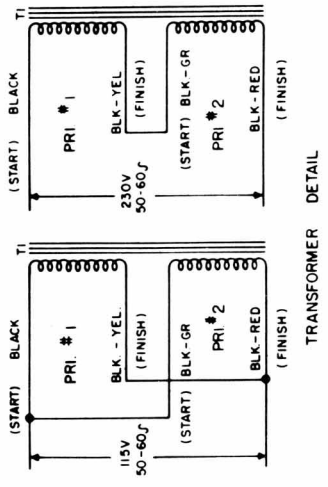
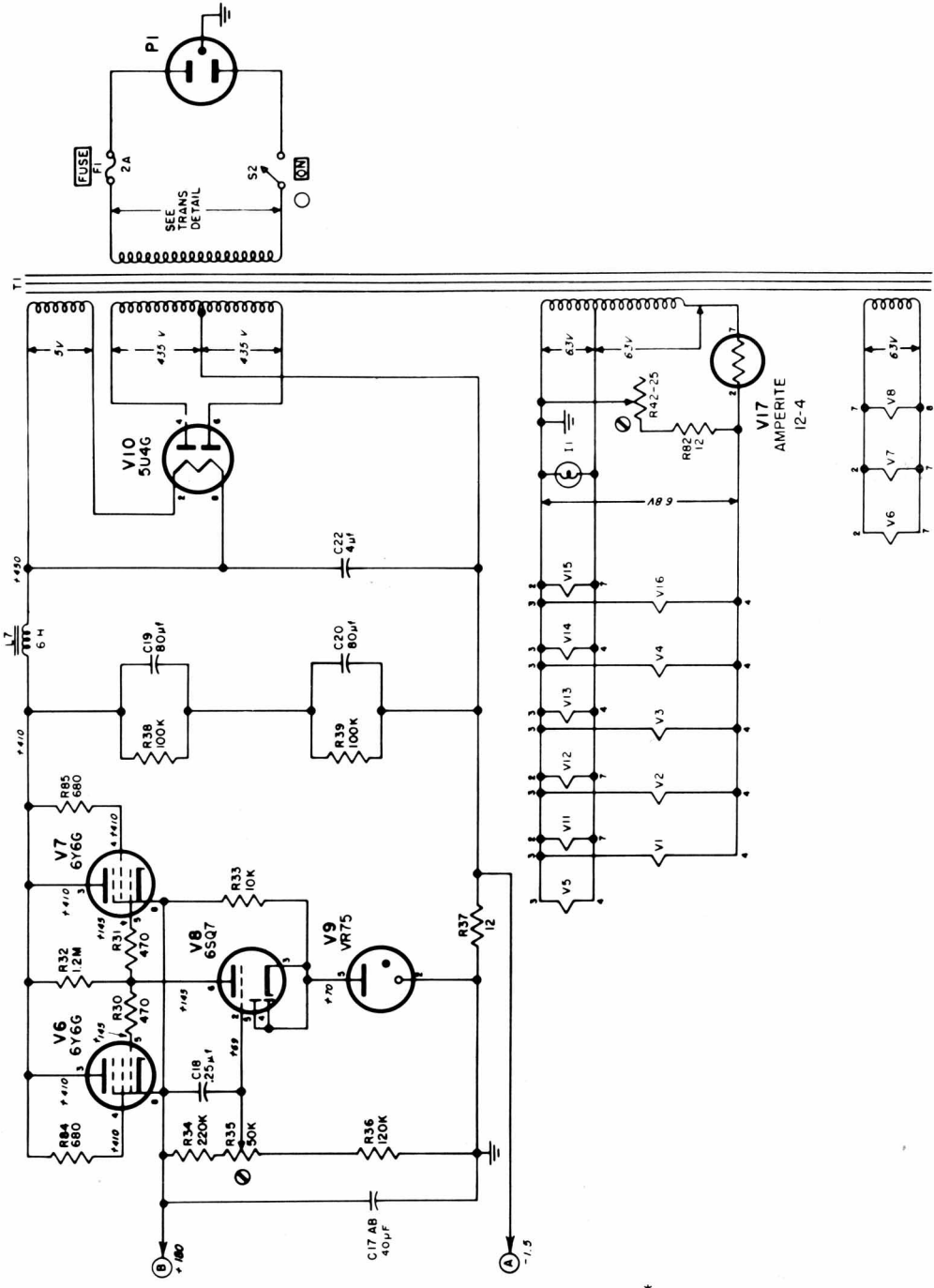
TABLE 4-2. TROUBLE SHOOTING (Cont)

SYMPTOM	CAUSE AND /OR REMEDY
Output meter reads low and cannot be corrected by R77 adjustment.(Cont.)	Modernize by adding resistor R87 if not already in instrument.
Output meter has poor frequency response. (Cont.)	Defective meter movement. Capacitor C40 defective.
Residual output meter indication	C43 or C44 capacitor defective. Tube V16 defective. Control R55 defective. Hum in output amplifier stages.
Microphonic.	Power supply series regulator tubes V6 and V7 defective. Dirt in tuning capacitor (s). Microphonic oscillator tube. Poor ground connection somewhere in instrument. Lamp R80 defective.
Low frequency oscillator level cannot be set by R46 control.	Lamp R80 defective. Tube V11 or V12 defective. It may be necessary to correct frequency response by adjusting C23 and C24 capacitors. Add potentiometer for R46 as per modification notes.
Lamp R80 flashing.	Capacitors C2A, C23, and/or C52 shorted.
Low frequency oscillator distortion.	Tube V11 and/or V12 defective. Low frequency oscillator output voltage set too high. Defective coupling capacitor. Tube V5 gassy.
Output level on four lower ranges cannot be set to match two high frequency ranges by control R53.	High frequency oscillator output level too high or too low. Control R46 in low frequency oscillator is maladjusted. Tube V5 defective.
Poor frequency response at 10 cps.	Capacitor C28 and/or C39 defective. Capacitor C30 defective. Coupling capacitors C33 and/or C37 defective. Tubes V13, V14, V15, and/or V16 defective.
No high frequency oscillator output.	Shorted tuning gang or trimmers. Tubes V1, V2, V3, and/or V4 defective. Defective range switch.



TABLE 4-2. TROUBLE SHOOTING (Cont)

SYMPTOM	CAUSE AND/OR REMEDY
No high frequency oscillator output. (Cont.)	Capacitors C10, C48, and/or C50 defective. Ballast tube V17 defective.
Low high frequency oscillator output.	Tube V5 defective. Low heater voltage. Resistor R25 defective. Tubes V1, V2, V3, and/or V4 weak.
High frequency oscillator output too high.	Tube V5 defective. Diode CR3 defective. Capacitor C14 defective. Capacitors C12, C13, or C16 shorted. Coil L1 or resistor R25 open.
Distortion and FM in high frequency oscillator.	V1, V2, V3, and/or V4 defective. Instruments with Serial No. 1649 and below should be modernized.
Poor high frequency response.	V1, V2, V3, V4, and/or V5 defective. Diode CR3 defective. Tubes V13, V14, and/or V15 defective. Coil L8 open. Coils L3, L4, and/or L5 defective. Modernize instruments with Serial No. 1649 or below.
Peaks and dips in 1 to 10 MC response.	Change control R55 from a wirewound to a composition potentiometer.
High frequency oscillator will not calibrate properly.	V1, V2, and/or V3 defective. C4, C6, and/or C9 defective.
No output on "X100KC" range only.	V1, V2, and/or V3 weak. Defective range switch. Capacitor C3 shorted. R89 or R91 defective.
Output frequency changes on two high ranges when R55 is adjusted.	Tube V4 defective.



**NOTES**

- CONDITIONS OF DC VOLTAGE MEASUREMENT:
1. LINE VOLTAGE AT 115/230 VOLTS, 50/60 ~
  2. RANGE SW. AT X1M \*
  3. ALL OTHER CONTROLS AT MAXIMUM COUNTERCLOCKWISE POSITION \*
  4. VOLTAGES MEASURED BETWEEN INDICATED POINTS AND CHASSIS WITH VOLTMETER OF 122 MEGOHMS INPUT RESISTANCE.
- ALL CAPACITANCE IN  $\mu\text{F}$  UNLESS OTHERWISE NOTED.  
 K = 1000 OHMS  
 M = 1 MEGOHM  
 \* = ADJUSTED AT FACTORY. AVERAGE VALUE SHOWN.

- ↓ = CHASSIS
  - = PANEL CONTROL
  - ⊗ = SCREWDRIVER ADJUSTMENT
- FOR TUBES V11, V12 VOLTAGES SET CONTROLS AS FOLLOWS:
- \* 2. RANGE SW. AT 10 KC
  - \* 3. ALL OTHER CONTROLS AT MAXIMUM COUNTER CLOCKWISE POSITION.

Figure 4-7. Schematic Diagram of Model 650A Power Supply Section, Serial No. 2749 and Below

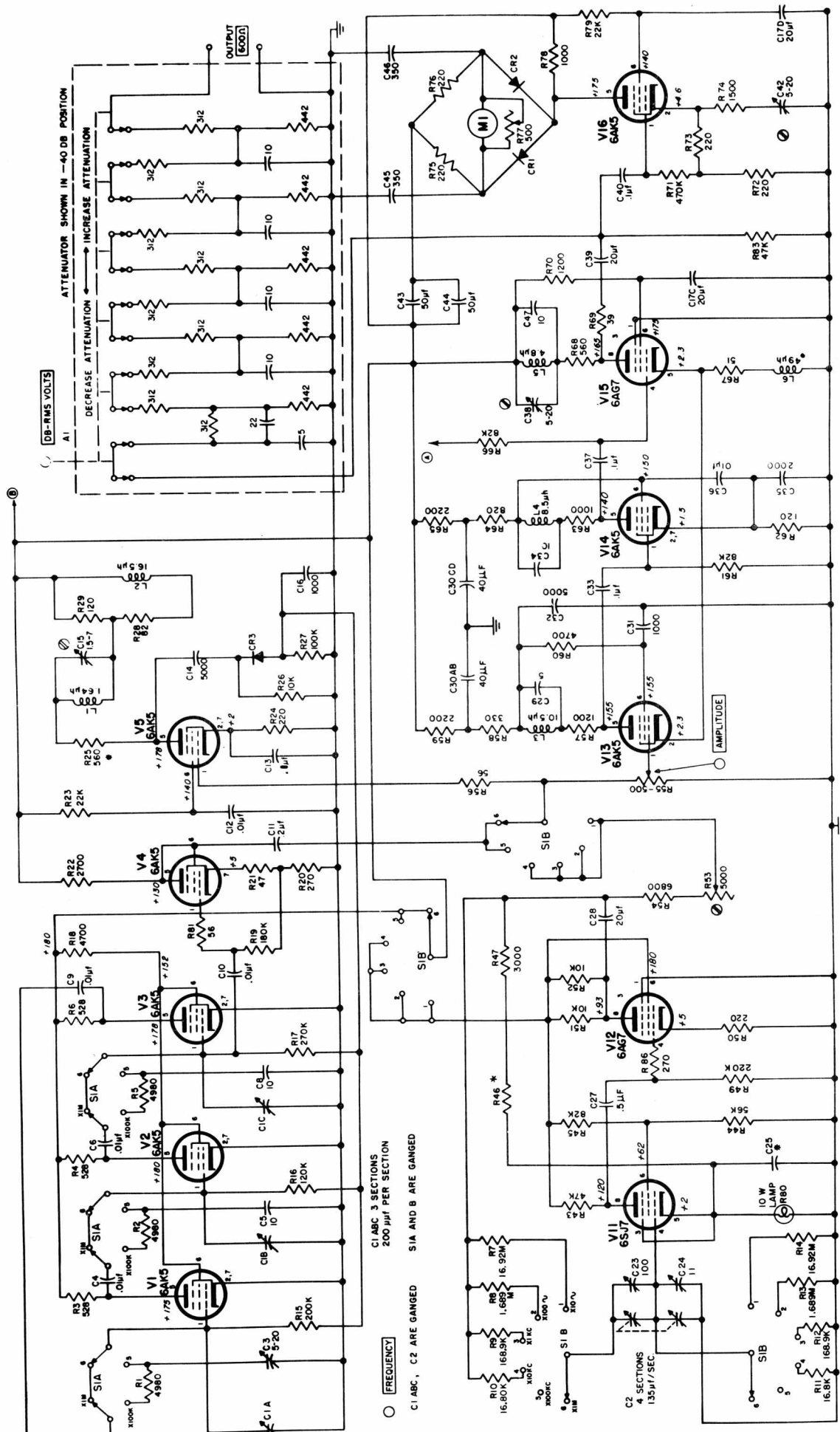
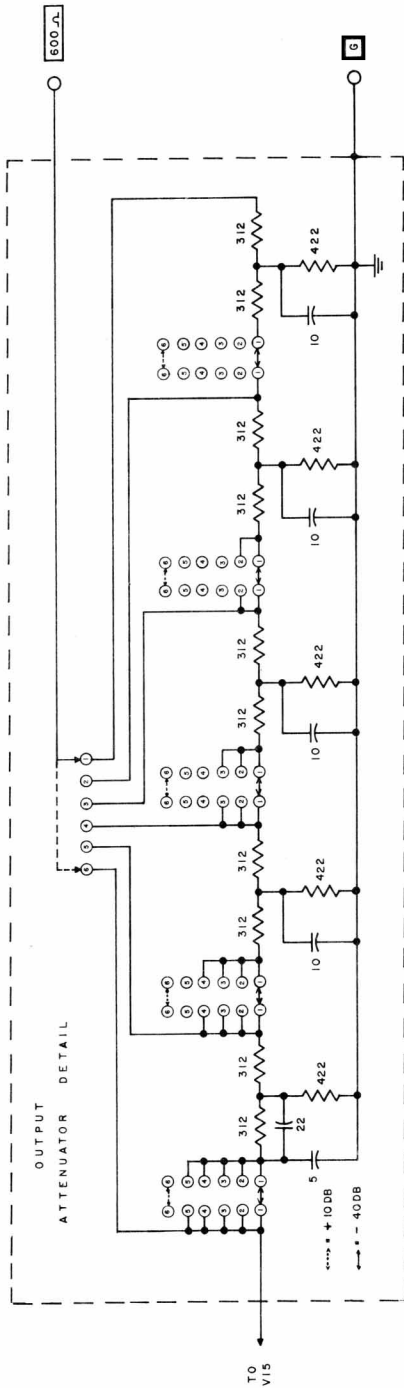
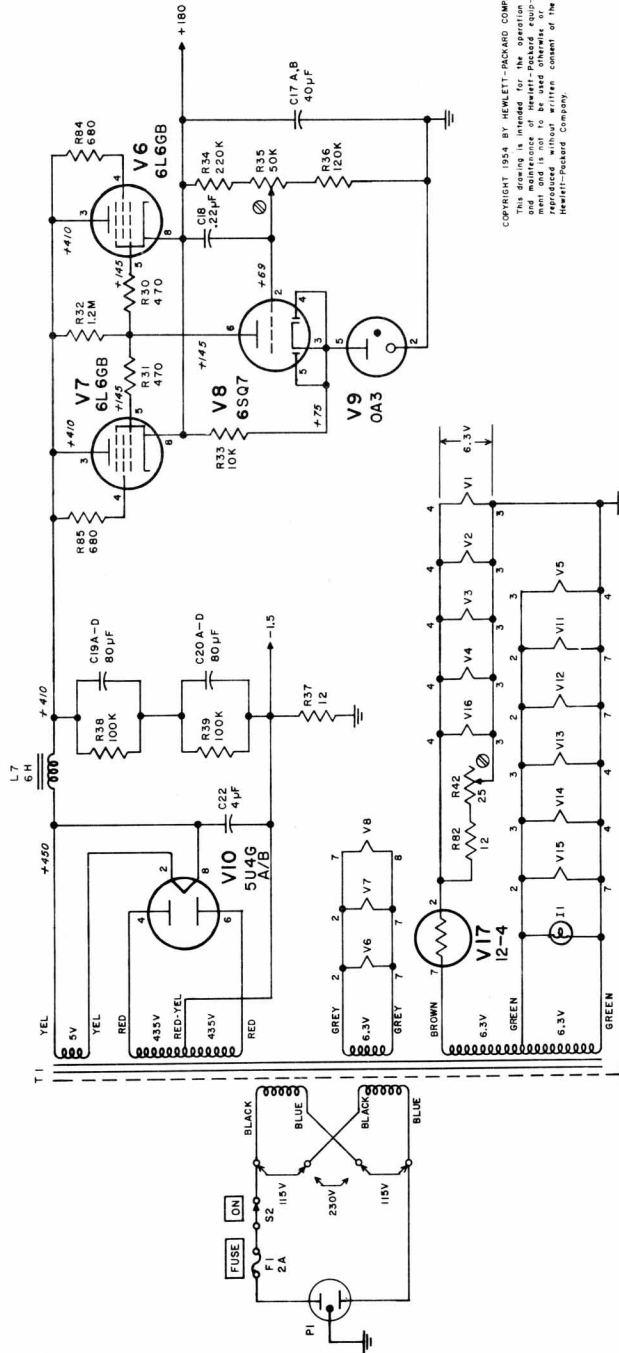


Figure 4-8. Schematic Diagram of Model 650A Oscillator Section, Serial No. 1349 and Below



- DB VOLTS RMS
- 1 -40 .01
  - 2 -30 .03
  - 3 -20 .01
  - 4 -10 .03
  - 5 0 .10
  - 6 +10 .30



NOTES:

CONDITIONS OF DC VOLTAGE MEASUREMENT

1. LINE VOLTAGE AT 12/250 VOLTS 50/1000 COUNTER AND OUTPUT ATTENUATOR MAXIMUM
2. SET RANGE SWITCH AT X1M
3. SET RANGE SWITCH AT X1M
4. (+10) FOR VOLTAGES INDICATED IN THIS MANNER
5. ALL VOLTAGES MEASURED BETWEEN INDICATED POINTS AND CHASSIS WITH A VOLTMETER HAVING 152 MEGOHM INPUT RESISTANCE

CONDITIONS OF AC VOLTAGE MEASUREMENT

- 1,2. SAME AS DC CONDITIONS
3. VOLTAGES MEASURED BETWEEN INDICATED POINTS WITH A 1000 OHMS/VOLT OR BETTER AC METER ALL VOLTAGES RMS

ALL CAPACITANCE IN  $\mu\text{F}$ , RESISTANCE IN OHMS UNLESS OTHERWISE NOTED

1 K = 1000 OHMS 1 M = 1 MEGOHM

\* ADJUSTED AT FACTORY FOR OPTIMUM PERFORMANCE AVERAGE VALUE SHOWN

○ PANEL CONTROL

● SCREWDRIVER ADJ

⊞ CHASSIS

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Figure 4-9. Schematic Diagram of Model 650A Power Supply Section, Serial No. 2750 and Above



OPERATION AND SERVICING MANUAL

FOR

MODEL 650A

TEST OSCILLATOR

PRODUCTION CHANGES

Serial 3700 and above:

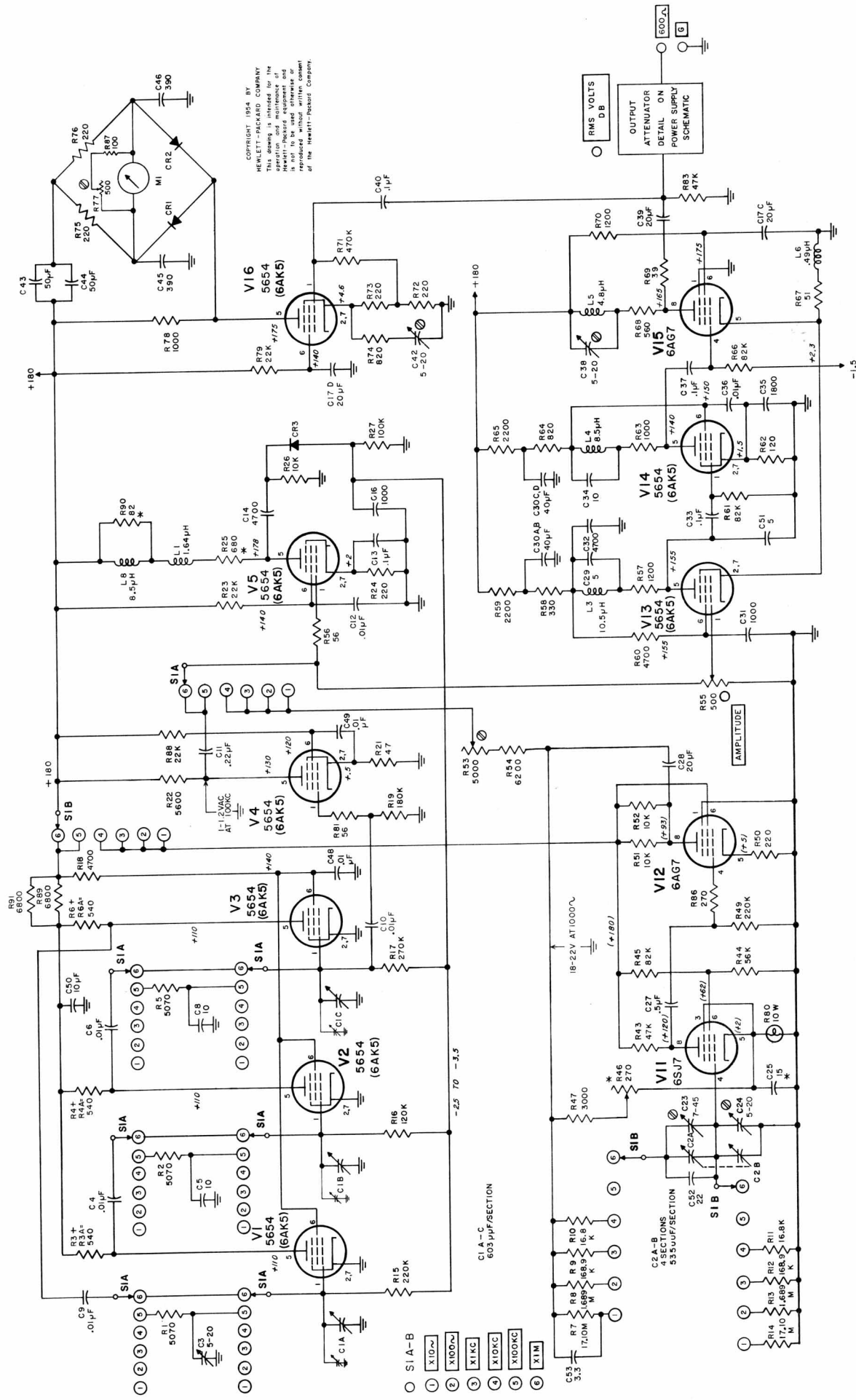
Change C25 to mica, 15  $\mu\mu\text{f}$ ,  $\pm 10\%$ , 500 vdcw, to -hp- stock No. 14-15, Mfr., V, Type Q.

Change R54 to composition, 6200 ohms,  $\pm 5\%$ , 1 W, to -hp- Stock No. 24-6200-5, Mfr., B, GB 6225.

Serial 3750 and above:

Change C53 from 2.2  $\mu\mu\text{f}$  to capacitor, fixed, titanium dioxide dielectric, 3.3  $\mu\mu\text{f}$ ,  $\pm 10\%$ , -hp- Stock No. 15-78, Mfr., DD, GA-5.

See schematic on reverse side.



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**MODEL 650A**  
 OSCILLATOR SECTION  
 SERIAL 3750 & ABOVE

- SIA-B
- ① X10~
- ② X100~
- ③ X1K
- ④ X10K
- ⑤ X100K
- ⑥ X1M

C1A-C  
 603 pF/SECTION

-25 TO -3.5

18-22V AT 1000~

C2A-B  
 5 SEC/SECTION

C2A-B  
 53.5 pF/SECTION

SIB

C2B

C2C

C2D

C2E

C2F

C2G

C2H

C2I

C2J

C2K

C2L

C2M

C2N

C2O

C2P

C2Q

C2R

# table of replaceable parts

## 5-1 GENERAL

Any changes in the Table of Replaceable Parts will be listed on a Production Change sheet at the front of this manual.

The following parts list may be used to determine replacement parts for all -hp- Model 650A Test Oscillators. To determine the required replacement part, refer to the schematic diagrams given in Figures 4-9 or 4-10. Use the circuit reference obtained from the schematic diagram to identify correct component in the Table of Replaceable Parts.

To assure receiving the correct replacement part, be sure to include instrument Model and Serial Numbers as well as the -hp- Stock Number and Description of the desired part. Failure to include this information may result in delay due to a wrong part being received

or additional correspondence being required before proper part identification is possible.

The Model 650A Test Oscillator has been manufactured over a span of several years with no major change in specifications or in basic circuitry. The components used, however, have changed. Different tube types and other miscellaneous components of higher quality have been incorporated whenever they become available. The components given in this parts list are those used in the latest instruments.

Some older instruments must be modernized before these new parts can be used. Refer to paragraphs 3-9 and 4-4.

It is necessary in some instances to substitute parts in this instrument. These substitutions do not impair instrument performance. Either the substitute part or the part specified in the Replaceable Parts Table can be used for replacement purposes.

Circuit Ref.	Description	-hp- Stock No.	Mfr. * & Mfrs. Designation
C1 ABC	Capacitor: variable, 603 $\mu\text{mf}$ per section	12-22	HP
C2 AB	Capacitor: variable, air, 535 $\mu\text{mf}$ per section	12-7	HP
C3	Capacitor: variable, ceramic, 5-20 $\mu\text{mf}$	12-20	L TS2A-N300
C4	Capacitor: fixed, mica, .01 $\mu\text{f}$ , $\pm 10\%$ , 300 vdcw	14-23	V Type W
C5	Capacitor: fixed, mica, 10 $\mu\text{mf}$ , $\pm 10\%$ , 500 vdcw (Part of range switch assembly (65A-19WH))	15-30	V Type OXM
C6	Capacitor: fixed, mica, .01 $\mu\text{f}$ , $\pm 10\%$ , 300 vdcw	14-23	V Type W
C7	This circuit reference not assigned.		
C8	Capacitor: fixed, mica, 10 $\mu\text{mf}$ , $\pm 10\%$ , 500 vdcw (Part of range switch assembly (65A-19WH))	15-30	V OXM
C9	Capacitor: fixed, mica, .01 $\mu\text{f}$ , $\pm 10\%$ , 300 vdcw	14-23	V Type W

\*See "List of Manufacturers Code Letters For Replaceable Parts Table".



Circuit Ref.	Description	-hp- Stock No.	Mfr. * & Mfrs. Designation
C10	Capacitor: fixed, mica, .01 $\mu$ f, $\pm$ 10%, 300 vdcw	14-23	V Type W
C11	Capacitor: fixed, paper, .22 $\mu$ f, $\pm$ 10%, 400 vdcw	16-48	CC 67P22494
C12	Capacitor: fixed, mica, .01 $\mu$ f, $\pm$ 10%, 300 vdcw	14-23	V Type W
C13	Capacitor: fixed, paper, .1 $\mu$ f, $\pm$ 10%, 400 vdcw	16-35	CC 67P10494
C14	Capacitor: fixed, mica, 4700 $\mu$ $\mu$ f, $\pm$ 10%, 500 vdcw	14-44	Z C-1247
C15	This circuit reference not assigned.		
C16	Capacitor: fixed, mica, 1000 $\mu$ $\mu$ f, $\pm$ 10%, 500 vdcw	14-11	V Type W
C17A, B, C, D	Capacitor: fixed, electrolytic, 20-20-20-20 $\mu$ f, 450 vdcw	18-42	X EP444
C18	Capacitor: fixed, paper, .22 $\mu$ f, $\pm$ 10%, 400 vdcw	16-48	CC 67P22494
C19A	Capacitor: fixed, electrolytic, 20-20-20-20 $\mu$ f, 450 vdcw	18-42	X EP444
C20A-D	Capacitor: fixed, electrolytic, 20-20-20-20 $\mu$ f, 450 vdcw	18-42	X EP444
C21	This circuit reference not assigned.		
C22	Capacitor: fixed, paper, 4 $\mu$ f, $\pm$ 10%, 600 vdcw	17-10	Z Type 4106-4
C23	Capacitor: variable, ceramic, 7 - 45 $\mu$ $\mu$ f, 500 vdcw	13-1	L TS2A
C24	Capacitor: variable, ceramic, 5 - 20 $\mu$ $\mu$ f, 500 vdcw	13-20	L TS2A-N300
C25	Capacitor: fixed, mica, 39 $\mu$ $\mu$ f, $\pm$ 10%, 500 vdcw (Electrical value adjusted at factory.)	14-48	V Type OXM
C26	This circuit reference not assigned.		
C27	Capacitor: fixed, paper, .5 $\mu$ f, $\pm$ 10%, 400 vdcw	16-58	Z 300405
C28	Capacitor: fixed, electrolytic, 20 $\mu$ f, 450 vdcw	18-20	X FP-144
C29	Capacitor: fixed, mica, 5 $\mu$ $\mu$ f, $\pm$ 20%, 500 vdcw	14-5	V Type OXM
C30 AB, CD	Capacitor: fixed, electrolytic, 20-20-20-20 $\mu$ f, 450 vdcw	18-42	X EP444
C31	Capacitor: fixed, mica, 1000 $\mu$ $\mu$ f, $\pm$ 10%, 500 vdcw	14-11	V Type W

\*See "List of Manufacturers Code Letters For Replaceable Parts Table".

Circuit Ref.	Description	-hp- Stock No.	Mfr. * & Mfrs. Designation
C32	Capacitor: fixed, mica, 4700 $\mu\mu\text{f}$ , $\pm 10\%$ , 500 vdcw	14-44	Z C-1247
C33	Capacitor: fixed, paper, .1 $\mu\text{f}$ , $\pm 10\%$ , 400 vdcw	16-35	CC 67P10494
C34	Capacitor: fixed, mica, 10 $\mu\mu\text{f}$ , $\pm 10\%$ , 500 vdcw	14-10	V Type OXM
C35	Capacitor: fixed, mica, 1800 $\mu\mu\text{f}$ , $\pm 10\%$ , 500 vdcw	14-47	V Type OXM
C36	Capacitor: fixed, mica, .01 $\mu\text{f}$ , $\pm 10\%$ , 300 vdcw	14-23	V Type W
C37	Capacitor: fixed, paper, .1 $\mu\text{f}$ , $\pm 10\%$ , 400 vdcw	16-35	CC 67P10494
C38	Capacitor: variable, ceramic, 5-20 $\mu\mu\text{f}$ , 500 vdcw	13-20	L #TS2A-N300
C39	Capacitor: fixed, electrolytic, 20 $\mu\text{f}$ , 450 vdcw	18-20	X FP-144
C40	Capacitor: fixed, paper, .1 $\mu\text{f}$ , $\pm 10\%$ , 400 vdcw	16-35	CC 67P10494
C41	This circuit reference not assigned.		
C42	Capacitor: variable, ceramic, 5-20 $\mu\mu\text{f}$ , 500 vdcw	13-20	L #TS2A-N300
C43	Capacitor: fixed, electrolytic, 50 $\mu\text{f}$ , $+200\% - 10\%$ , 50 vdcw	18-50	X TC-39
C44	Capacitor: fixed, electrolytic, 50 $\mu\text{f}$ , 50 vdcw	18-50	X TC-39
C45	Capacitor: fixed, mica, 390 $\mu\mu\text{f}$ , $\pm 10\%$ , 500 vdcw	14-65	V #RCM20B391K
C46	Capacitor: fixed, mica, 390 $\mu\mu\text{f}$ , $\pm 10\%$ , 500 vdcw	14-65	V #RCM20B391K
C47	Capacitor: fixed, tubular, ceramic, NPO, 10 $\mu\mu\text{f}$ , $\pm 0.5 \mu\mu\text{f}$ , 500 vdcw	15-30	K CI-1
C48	Capacitor: fixed, paper, .01 $\mu\text{f}$ , $\pm 10\%$ , 600 vdcw	16-11	CC #73P10396
C49	Capacitor: fixed, mica, .01 $\mu\text{f}$ , $\pm 10\%$ , 300 vdcw	14-23	V Type W
C50	Capacitor: fixed, electrolytic, 10 $\mu\text{f}$ , $\pm 50\%$ , 450 vdcw	18-10	X TC 72
C51	Capacitor: fixed, mica, 5 $\mu\mu\text{f}$ , $\pm 20\%$ , 500 vdcw	14-5	V Type OXM
C52	Capacitor: fixed, ceramic, 22 $\mu\mu\text{f}$ , $\pm 5\%$ , 500 vdcw	15-2	A Type CI-2

\*See "List of Manufacturers Code Letters For Replaceable Parts Table".

Circuit Ref.	Description	-hp- Stock No.	Mfr. * & Mfrs. Designation
C53	Capacitor: fixed, titanium dioxide, dielectric, 2.2 $\mu\mu\text{f}$ , $\pm 10\%$ , 500 vdcw	15-52	DD GA-4
R1-R14	Part of Range Switch Assembly	--	HP
R15	Resistor: fixed, composition, 220,000 ohms, $\pm 10\%$ , 1/2 W, taper	23-220K	B EB 2241
R16	Resistor: fixed, composition, 120,000 ohms, $\pm 10\%$ , 1/2 W, taper	23-120K	B EB 1241
R17	Resistor: fixed, composition, 270,000 ohms, $\pm 10\%$ , 1/2 W, taper	23-270K	B EB 2741
R18	Resistor: fixed, composition, 4,700 ohms, $\pm 10\%$ , 1 W	24-4700	B GB 4721
R19	Resistor: fixed, composition, 180,000 ohms, $\pm 10\%$ , 1/2 W	23-180K	B EB 1841
R20	This circuit reference not assigned.		
R21	Resistor: fixed, composition, 47 ohms, $\pm 10\%$ , 1/2 W	23-47	B EB 4701
R22	Resistor: fixed, composition, 5,600 ohms, $\pm 10\%$ , 1 W	24-5600	B GB 5621
R23	Resistor: fixed, composition, 22,000 ohms, $\pm 10\%$ , 1/2 W	23-22K	B EB 2231
R24	Resistor: fixed, composition, 220 ohms, $\pm 10\%$ , 1/2 W	23-220	B EB 2211
R25	Resistor: fixed, composition, 680 ohms, $\pm 10\%$ , 1 W (Electrical value adjusted at factory.)	24-680	B GB 6821
R26	Resistor: fixed, composition, 10,000 ohms, $\pm 10\%$ , 1/2 W	23-10K	B EB 1031
R27	Resistor: fixed, composition, 100,000 ohms, $\pm 10\%$ , 1/2 W	23-100K	B EB 1041
R28	This circuit reference not assigned.		
R29	This circuit reference not assigned.		
R30	Resistor: fixed, composition, 470 ohms, $\pm 10\%$ , 1/2 W	23-470	B EB 4711
R31	Resistor: fixed, composition, 470 ohms, $\pm 10\%$ , 1/2 W	23-470	B EB 4711
R32	Resistor: fixed, composition, 102 megohms, $\pm 10\%$ , 1 W	24-1.2M	B GB 1251
R33	Resistor: fixed, composition, 10,000 ohms, $\pm 10\%$ , 2 W	25-10K	B HB 1031
R34	Resistor: fixed, composition, 220,000 ohms, $\pm 10\%$ , 1 W	24-220K	B GB 2241

\*See "List of Manufacturers Code Letters For Replaceable Parts Table".

Circuit Ref.	Description	-hp- Stock No.	Mfr. * & Mfrs. Designation
R35	Resistor: variable, composition, 50,000 ohms, $\pm 20\%$ , 1/4 W	210-18	HP
R36	Resistor: fixed, composition, 120,000 ohms, $\pm 10\%$ , 1 W	24-120K	B GB 1241
R37	Resistor: fixed, composition, 12 ohms $\pm 10\%$ , 2 W	25-12	B HB 1201
R38	Resistor: fixed, composition, 100,000 ohms, $\pm 10\%$ , 1 W	24-100K	B GB 1041
R39	Resistor: fixed, composition, 100,000 ohms, $\pm 10\%$ , 1 W	24-100K	B GB 1041
R40	This circuit reference not assigned.		
R41	This circuit reference not assigned.		
R42	Resistor: variable, wirewound, 25 ohms, 3 W	65A-15A	HP
R43	Resistor: fixed, composition, 47,000 ohms, $\pm 10\%$ , 1 W	24-47K	B GB 4731
R44	Resistor: fixed, composition, 56,000 ohms, $\pm 10\%$ , 1 W	24-56K	B GB 5631
R45	Resistor: fixed, composition, 82,000 ohms, $\pm 10\%$ , 1 W	24-82K	B GB 8231
R46	Resistor: adjustable, wirewound, 1000 ohms, $\pm 10\%$ , 1 W	210-5	BO  Type 252
R47	Resistor: adjustable, wirewound, 3000 ohms, $\pm 5\%$ , 1 W	26-3000	R Type BW
R48	This circuit reference not assigned.		
R49	Resistor: fixed, composition, 220,000 ohms, $\pm 10\%$ , 1 W	24-220K	B GB 2241
R50	Resistor: fixed, composition, 220 ohms, $\pm 10\%$ , 1 W	24-220	B GB 2211
R51	Resistor: fixed, composition, 10,000 ohms, $\pm 10\%$ , 2 W	25-10K	B HB 1031
R52	Resistor: fixed, composition, 10,000 ohms, $\pm 10\%$ , 2 W	25-10K	B HB 1031
R53	Resistor: variable, composition, 5,000 ohms, 1 screw-driver slot shaft	210-15	HP
R54	Resistor: fixed, composition, 6,800 ohms, $\pm 10\%$ , 1 W	24-6800	B GB 6821
R55	Resistor: variable, composition, 500 ohms, $\pm 10\%$ , linear taper	210-25	HP
R56	Resistor: fixed, composition, 56 ohms, $\pm 10\%$ , 1/2 W	23-56	B EB 5601

\*See "List of Manufacturers Code Letters For Replaceable Parts Table".

Circuit Ref.	Description	-hp- Stock No.	Mfr. * & Mfrs. Designation
R57	Resistor: fixed, composition, 1,200 ohms, $\pm 10\%$ , 1/2 W	23-1200	B EB 1221
R58	Resistor: fixed, composition, 330 ohms, $\pm 10\%$ , 1/2 W	23-330	B EB 3311
R59	Resistor: fixed, composition, 2,200 ohms, $\pm 10\%$ , 1 W	24-2200	B GB 2221
R60	Resistor: fixed, composition, 4,700 ohms, $\pm 10\%$ , 1/2 W	23-4700	B EB 4721
R61	Resistor: fixed, composition, 82,000 ohms, $\pm 10\%$ , 1/2 W	23-82K	B EB 8231
R62	Resistor: fixed, composition, 120 ohms, $\pm 10\%$ , 1/2 W	23-120	B EB 1211
R63	Resistor: fixed, composition, 1,000 ohms, $\pm 10\%$ , 1/2 W	23-1K	B EB 1021
R64	Resistor: fixed, composition, 820 ohms, $\pm 10\%$ , 1/2 W	23-820	B EB 8211
R65	Resistor: fixed, composition, 2200 ohms, $\pm 10\%$ , 1 W	24-2200	B GB 2221
R66	Resistor: fixed, composition, 82,000 ohms, $\pm 10\%$ , 1/2 W	23-82K	B EB 8231
R67	Resistor: fixed, composition, 51 ohms, $\pm 10\%$ , 1 W	24-51	B GB 5101
R68	Resistor: fixed, composition, 560 ohms, $\pm 10\%$ , 1 W	24-560	B GB 5611
R69	Resistor: fixed, composition, 39 ohms, $\pm 10\%$ , 1/2 W	23-39	B EB 3901
R70	Resistor: fixed, composition, 1,200 ohms, $\pm 10\%$ , 1 W	24-1200	B GB 1221
R71	Resistor: fixed, composition, 470,000 ohms, $\pm 10\%$ , 1/2 W	23-470K	B GB 4741
R72	Resistor: fixed, composition, 220 ohms, $\pm 10\%$ , 1/2 W	23-220	B EB 2211
R73	Resistor: fixed, composition, 220 ohms, $\pm 10\%$ , 1/2 W	23-220	B EB 2211
R74	Resistor: fixed, composition, 820 ohms, $\pm 10\%$ , 1/2 W	23-820	B EB 8211
R75	Resistor: fixed, composition, 220 ohms, $\pm 10\%$ , 1/2 W	23-220	B EB 2211
R76	Resistor: fixed, composition, 220 ohms, $\pm 10\%$ , 1/2 W	23-220	B EB 2211
R77	Resistor: variable, wirewound, 500 ohms, linear, screw-driver slot shaft	210-29	HP

\*See "List of Manufacturers Code Letters For Replaceable Parts Table".

Circuit Ref.	Description	-hp- Stock No.	Mfr. * & Mfrs. Designation
R78	Resistor: fixed, composition, 1.000 ohms, $\pm 10\%$ , 1/2 W	23-1000	B EB 1021
R79	Resistor: fixed, composition, 22.000 ohms, $\pm 10\%$ , 1/2 W	23-22K	B EB 2231
R80	Lamp: incandescent, 10 W, 250 V S6	211-29	O 10S6/10 250V
R81	Resistor: fixed, composition, 56 ohms, $\pm 10\%$ , 1/2 W	23-56	B EB 5601
R82	Resistor: fixed, wirewound, 12 ohms, $\pm 10\%$ , 10 W	26-14	S Type 1-3/4E
R83	Resistor: fixed, composition, 47.000 ohms, $\pm 10\%$ , 1/2 W	23-47K	B EB 4731
R84	Resistor: fixed, composition, 680 ohms, $\pm 10\%$ , 1 W	24-680	B GB 6811
R85	Resistor: fixed, composition, 680 ohms, $\pm 10\%$ , 1 W	24-680	B GB 6811
R86	Resistor: fixed, composition, 270 ohms, $\pm 10\%$ , 1 W	24-270	B GB 2711
R87	Resistor: fixed, composition, 100 ohms, $\pm 10\%$ , 1 W	24-100	B GB 1011
R88	Resistor: fixed, composition, 22.000 ohms, $\pm 10\%$ , 1 W	24-22K	B GB 2231
R89	Resistor: fixed, composition, 6800 ohms, $\pm 10\%$ , 2 W	25-6800	B HB 6821
R90	Resistor: fixed, composition, 33 ohms, $\pm 10\%$ , 1 W (Electrical value adjusted at factory.)	24-33	B GB 3301
R91	Resistor: fixed, composition 6800 ohms, $\pm 10\%$ , 2 W	25-6800	B HB 6821
S1A, C5, C8, R1, R2, R5	Range Switch Assembly	65A-19WH	HP
S1B R7-14	Range Switch Assembly	65A-19WL	HP
S2	Toggle Switch: SPST	310-11	HP
T1	Power Transformer	910-59	HP

\*See "List of Manufacturers Code Letters For Replaceable Parts Table".

Circuit Ref.	Description	-hp- Stock No.	Mfr. * & Mfrs. Designation
	Tube Shield: 1-3/8 in. high (for V1, 2, 3, 4, 5, 13, 14, 16)	122-12	H 8660
	Cable: Output Divider	65A-16D	HP
	Binding Post	312-3	HP
CR1	Crystal Diode: 1N116 frequency selected	212-G11E	HP
CR2	Crystal Diode: 1N116 frequency selected	212-G11E	HP
CR3	Crystal Diode	212-G11E	HP
F1	Fuse: 2A, 3AG Type, withstands 200% overload for 25 seconds (for 115 V operation)	211-16	E MDL2
F1	Fuse: 1A, 3AG Type, withstands 200% overload for 25 seconds (for 230 V operation)	211-18	E MDL2
	Fuseholder	312-8	T #1342001
	Knob: 1-5/8 in. diameter	37-12	HP
	Knob: 1-1/2 in. diameter	37-11	HP
	Knob: 2 in. diameter	37-13	HP
	Pilot Lamp and Cable Assembly	65A-33	HP
I1	Lamp: Pilot, 6-8V, 0.15A, part of Pilot Lamp and Cable Assembly	211-47	O Mazda #47
	Lampholder: (R80)	145-15	KK #659-1
M1	Meter: 0-1 ma dc	65A-81	HP
	Output Attenuator: consists of 50 db attenuator in 10 db steps; 600 ohms input and output impedance	65A-34	HP
P1	Power Cable	812-56	HP
L1	RF Choke: 1.64 microhenries; wound on resistor form	65A-60A	HP
L3	RF Choke: 10.5 microhenries; wound on resistor form	65A-60C	HP
L4	RF Choke: 8.5 microhenries; wound on resistor form	65A-60D	HP
L5	RF Choke: 4.8 microhenries; wound on resistor form	65A-60E	HP
L6	RF Choke: 0.49 microhenries; wound on resistor form	65A-60F	HP
L7	Choke: Power supply, 6 henries	911-4	HP
L8	RF Choke: 8.5 microhenries; wound on resistor form	65A-60D	HP
V1	Tube: 5654	212-5654	HP
V2	Tube: 5654	212-5654	HP
V3	Tube: 5654	212-5654	HP

\*See "List of Manufacturers Code Letters For Replaceable Parts Table".

Circuit Ref.	Description	-hp- Stock No.	Mfr. * & Mfrs. Designation
V4	Tube: 5654	212-5654	HP
V5	Tube: 5654	212-5654	HP
V6	Tube: 6L6GB	212-6L6GB	ZZ
V7	Tube: 6L6GB	212-6L6GB	ZZ
V8	Tube: 6SQ7	212-6SQ7	ZZ
V9	Tube: 0A3	212-0A3	ZZ
V10	Tube: 5U4GA/B	212-5U4GA/B	ZZ
V11	Tube: 6SJ7	212-6SJ7	ZZ
V12	Tube: 6AG7	212-6AG7	ZZ
V13	Tube: 5654	212-G73C	HP (selected)
V14	Tube: 5654	212-G73C	HP (selected)
V15	Tube: 6AG7	212-6AG7	ZZ
V16	Tube: 5654	212-G73A	HP (selected)
V17	Ballast Tube: 12-4	211-25	Amperite #12-4

\*See "List of Manufacturers Code Letters For Replaceable Parts Table".



LIST OF CODE LETTERS USED IN TABLE OF REPLACEABLE PARTS  
TO DESIGNATE THE MANUFACTURERS

<u>Code Letter</u>	<u>Manufacturer</u>	<u>Address</u>
A	Aerovox Corporation	New Bedford, Mass.
B	Allen-Bradley Company	Milwaukee 4, Wis.
C	Amperite Company	New York, N. Y.
D	Arrow, Hart & Hegeman	Hartford, Conn.
E	Bussman Manufacturing Company	St. Louis, Mo.
F	Carborundum Company	Niagara Falls, N. Y.
G	Centralab	Milwaukee 1, Wis.
H	Cinch-Jones Mfg. Company	Chicago 24, Ill.
HP	Hewlett-Packard Company	Palo Alto, Calif.
I	Clarostat Mfg. Company	Dover, N. H.
J	Cornell Dubilier Elec. Company	South Plainfield, N. J.
K	Hi-Q Division of Aerovox	Olean, N. Y.
L	Erie Resistor Corporation	Erie 6, Penn.
M	Fed. Telephone & Radio Corporation	Clifton, N. J.
N	General Electric Company	Schenectady 5, N. Y.
O	General Electric Supply Corporation	San Francisco, Calif.
P	Girard-Hopkins	Oakland, Calif.
Q	Industrial Products Company	Danbury, Conn.
R	International Resistance Company	Philadelphia 8, Penn.
S	Lectrohm Incorporated	Chicago 20, Ill.
T	Littlefuse Incorporated	Des Plaines, Ill.
U	Maguire Industries Incorporated	Greenwich, Conn.
V	Micamold Radio Corporation	Brooklyn 37, N. Y.
W	Oak Manufacturing Company	Chicago 10, Ill.
X	P. R. Mallory Co., Incorporated	Indianapolis, Ind.
Y	Radio Corporation of America	Harrison, N. J.
Z	Sangamo Electric Company	Marion, Ill.
AA	Sarkes Tarzian	Bloomington, Ind.
BB	Signal Indicator Company	Brooklyn 37, N. Y.
CC	Sprague Electric Company	North Adams, Mass.
DD	Stackpole Carbon Company	St. Marys, Penn.
EE	Sylvania Electric Products Company	Warren, Penn.
FF	Western Electric Company	New York 5, N. Y.
GG	Wilkor Products, Incorporated	Cleveland, Ohio
HH	Amphenol	Chicago 50, Ill.
II	Dial Light Co. of America	Brooklyn 37, N. Y.
JJ	Leecraft Manufacturing Company	New York, N. Y.
KK	Switchcraft, Incorporated	Chicago 22, Ill.
LL	Gremar Manufacturing Company	Lynn, Mass.
MM	Carad Corporation	Redwood City, Calif.
NN	Electra Manufacturing Company	Kansas City, Mo.
OO	Acro Manufacturing Company	Columbus 16, Ohio
PP	Alliance Manufacturing Company	Alliance, Ohio
QQ	Arco Electronics, Incorporated	New York 13, N. Y.
RR	Astron Corporation	East Newark, N. J.
SS	Axel Brothers Incorporated	Long Island City, N. Y.
TT	Belden Manufacturing Company	Chicago 44, Ill.
UU	Bird Electronics Corporation	Cleveland 14, Ohio
VV	Barber Colman Company	Rockford, Ill.
WW	Bud Radio Incorporated	Cleveland 3, Ohio
XX	Allen D. Cardwell Mfg. Company	Plainville, Conn.
YY	Cinema Engineering Company	Burbank, Calif.
ZZ	Any brand tube meeting RETMA characteristics.	
AB	Corning Glass Works	Corning, N. Y.
AC	Dale Products, Incorporated	Columbus, Neb.
AD	The Drake Mfg. Company	Chicago 22, Ill.
AE	Elco Corporation	Philadelphia 24, Penn.
AF	Hugh H. Eby Company	Philadelphia 44, Penn.
AG	Thomas A. Edison, Incorporated	West Orange, N.J.
AH	Fansteel Metallurgical Corporation	North Chicago, Ill.

<u>Code Letter</u>	<u>Manufacturer</u>	<u>Address</u>
AI	General Ceramics & Steatite Corp.	Keasbey, N. J.
AJ	The Gudeman Company	Sunnyvale, Calif.
AK	Hammerlund Mfg. Co., Inc.	New York 1, N. Y.
AL	Industrial Condenser Corporation	Chicago 18, Ill.
AM	Insuline Corporation of America	Manchester, N. H.
AN	Jennings Radio Mfg. Corporation	San Jose, Calif.
AO	E. F. Johnson Company	Waseca, Minn.
AP	Lenz Electric Mfg. Company	Chicago 47, Ill.
AQ	Micro-Switch	Freeport, Ill.
AR	Mechanical Industries Prod. Co.	Acron 8, Ohio
AS	Model Eng. & Mfg., Incorporated	Huntington, Ind.
AT	The Muter Company	Chicago 5, Ill.
AU	Ohmite Mfg. Company	Skokie, Ill.
AV	Resistance Products Company	Harrisburg, Penn.
AW	Radio Condenser Company	Camden 3, N. J.
AX	Shallcross Manufacturing Company	Collingdale, Penn.
AY	Solar Manufacturing Company	Los Angeles 58, Calif.
AZ	Sealectro Corporation	New Rochelle, N. Y.
BA	Spencer Thermostat	Attleboro, Mass.
BC	Stevens Manufacturing Company	Mansfield, Ohio
BD	Torrington Manufacturing Company	Van Nuys, Calif.
BE	Vector Electronic Company	Los Angeles 65, Calif.
BF	Weston Electrical Inst. Corporation	Newark 5, N. J.
BG	Advance Electric & Relay Co.	Burbank, Calif.
BH	E. I. DuPont	Los Angeles 58, Calif.
BI	Electronics Tube Corporation	Philadelphia 18, Penn.
BJ	Aircraft Radio Corporation	Boontan, N. J.
BK	Allied Control Co., Incorporated	New York 21, N. Y.
BL	Augat Brothers, Incorporated	Attleboro, Mass.
BM	Carter Radio Division	Chicago, Ill.
BN	CBD Hytron Radio & Electric	Danvers, Mass.
BO	Chicago Telephone Supply	Elkhart, Ind.
BP	Henry L. Crowley Co., Incorporated	West Orange, N. J.
BQ	Curtiss-Wright Corporation	Carlstadt, N. J.
BR	Allen B. DuMont Labs	Clifton, N. J.
BS	Exsel Transformer Company	Oakland, Calif.
BT	General Radio Company	Cambridge 39, Mass.
BU	Hughes Aircraft Company	Culver City, Calif.
BV	International Rectifier Corporation	El Segundo, Calif.
BW	James Knight Company	Sandwich, Ill.
BX	Mueller Electric Company	Cleveland, Ohio
BY	Precision Thermometer & Inst. Co.	Philadelphia 30, Penn.
BZ	Radio Essentials Incorporated	Mt. Vernon, N. Y.
CA	Raytheon Manufacturing Company	Newton, Mass.
CB	Tung-Sol Lamp Works, Incorporated	Newark 4, N. J.
CD	Varian Associates	Palo Alto, Calif.
CE	Victory Engineering Corporation	Union, N. J.
CF	Weckesser Company	Chicago 30, Ill.
CG	Wilco Corporation	Indianapolis, Ind.
CH	Winchester Electric Incorporated	Santa Monica, Calif.
CI	Malco Tool	Los Angeles 42, Calif.
CJ	Oxford Electric Corporation	Chicago 15, Ill.
CK	Camlo Fastner Corporation	Paramus, N. J.
CL	George K. Garrett	Philadelphia 34, Penn.
CM	Union Switch	Swissvale, Penn.
CN	Radio Receptor	New York 11, N. Y.
CO	Automatic & Precision Mfg. Co.	Yonkers, N. Y.
CP	Bassick Company	Bridgeport 2, Conn.
CQ	Birnbach Radio Company	New York 13, N. Y.
CR	Fischer Specialties	Cincinnati 6, Ohio
CS	Telefunken (The American Elite Co)	New York, N. Y.



# SERVICE NOTES

HEWLETT-PACKARD COMPANY • 275 PAGE MILL ROAD • PALO ALTO, CALIFORNIA, U. S. A.  
CABLE "HEWPACK" TELEPHONE DAVENPORT 5-4451

## DRIVE CABLE REPLACEMENT IN HEWLETT-PACKARD INSTRUMENTS: M14

AUDIO OSCILLATORS . . . . .	MODELS 200H, 200I, 200T, AND 201B
AUDIO SIGNAL GENERATOR . . . . .	MODEL 206A
DISTORTION ANALYZER . . . . .	MODELS 330B, 330C, AND 330D
TEST OSCILLATOR . . . . .	MODEL 650A

Two drive cables, one 11 in. and the other 15 in. (length before end loops are formed) will be required to replace the drive cables in the above instruments. These two drive cables are available from Hewlett-Packard.

**CABLE REPLACEMENT PROCEDURE.** (Refer to Figure M14-1.)

1. Remove old dial cable and screws at A, B, C, and D. Loosen SET SCREW in SPRING LOADING COLLAR on rear of DRIVE SHAFT.

2. Insert free end of 11 in. cable through hole A of DRIVE PULLEY and form loop in end of cable as directed in Figure M14-2.

3. Set instrument tuning dial to high frequency limit and rotate tuning capacitors so plates are open full. Fasten cable at A and thread as shown in Figure M14-1 with other end fastened by screw at B on LARGE DRUM.

4. Repeat steps 2 and 3 using the 15 in. cable. Start at C and finish at D on the SMALL DRUM.

5. Revolve SPRING LOADING COLLAR counterclockwise (viewed as shown in Figure M14-1) until slack is removed from drive cables. Rotate an additional half turn counterclockwise to tighten SPRING and tighten SET SCREW.

6. Position cable on LARGE DRUM so that first turn from DRIVE PULLEY goes around LARGE DRUM in a plane perpendicular to the axis of the drum and tangent to the outside of the DRIVE PULLEY. Cable between IDLER PULLEY and SMALL DRUM should be positioned so that it does not rub in notch in the vertical center post.

7. Rotate tuning dial from one stop to the other for approximately 100 complete cycles to work out any stretch and allow cables to position themselves on the drums. Rotors of tuning capacitor sections should not be at the limit of their travel at either end of tuning range.

8. Check dial calibration. If a constant error appears, loosen set screw in DRIVE PULLEY and rotate pulley slightly as required to correct this error. If complete recalibration is required, refer to the Instruction Manual or contact the factory for instructions.

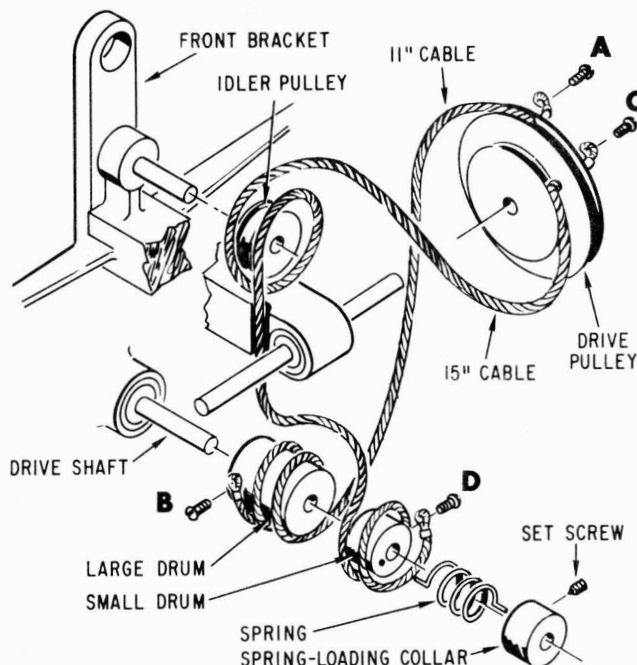


Figure M14-1. Exploded Rear View of Drive Cabling

### INSTALLATION OF CLAMPING EYELETS ON ENDS OF NEW PLASTIC COATED CABLE

A new type plastic coated braided wire with a stainless steel core is now supplied for replacement purposes.

This new cable is more durable and not so apt to become frayed and broken. A different fastening technique must be used for the end loops since the heat of a soldering iron would damage the plastic coating. The plastic coating slides on itself and a knot will not hold a loop tied in the end of the cable.

Special clamps in the form of small eyelets are supplied with the replacement cables for the instruments listed.

The replacement cables are supplied from the factory with a loop formed in one end. The other end is not looped since it is necessary to thread this end through a hole in the pulley before the loop is formed. (See A of Figure M14-2.)

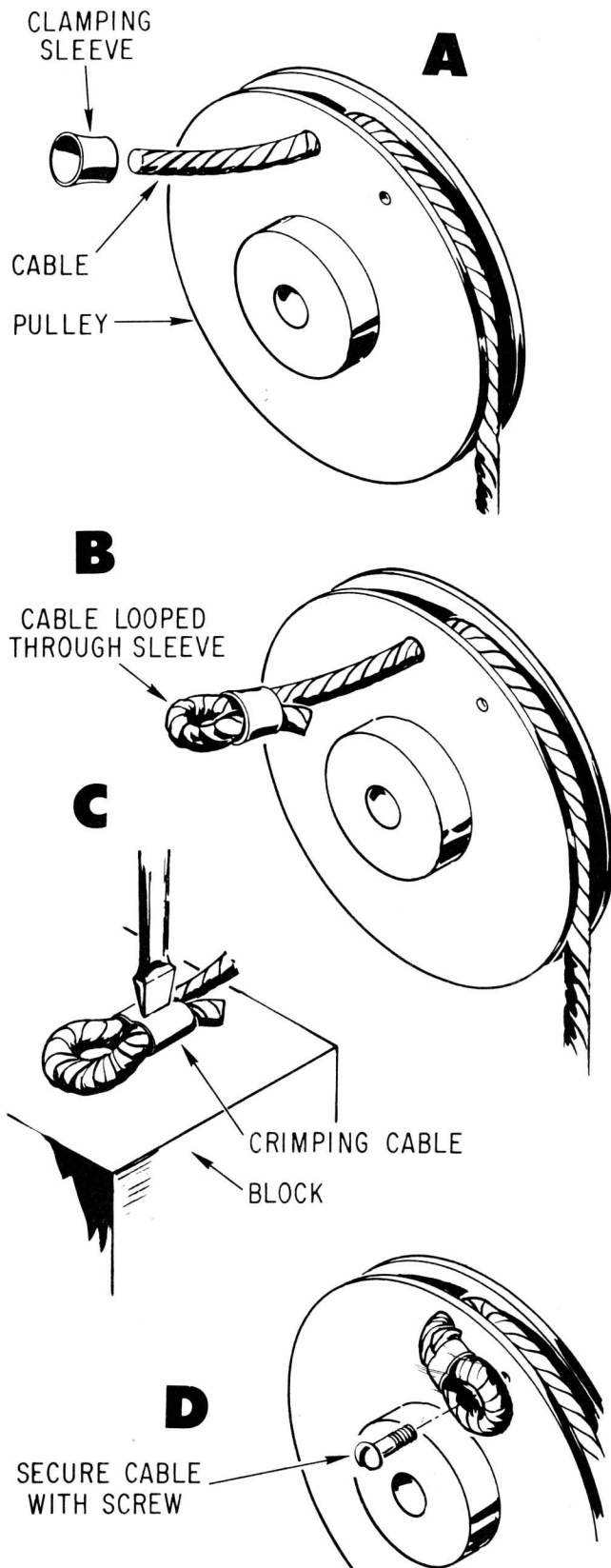


Figure M14-2. Installation of Eyelets on Plastic Coated Cable

After passing open end of cable through hole in pulley, form a loop on the end of the cable the same size as the factory made loop on the opposite end of the cable. Slide eyelet over loop and tap with a plastic headed hammer until eyelet is flat. Size of loop and length of end protruding from eyelet should be the same as the other end of the cable.

Crimp center of eyelet as shown in C of Figure M14-2 with a screwdriver and a hammer.

Cable is now ready to be attached to the pulley using the small screw previously removed. (Refer to D of Figure M14-2.)

#### FORMING LOOPS IN CABLES WITHOUT PLASTIC OUTER COATING

If cable to be used does not have plastic outer coating, form loop around the mounting screw. Fold cable back upon itself approximately 3/8 inch from the end and solder. The clamping eyelets used for the plastic coated cable will not hold on uncoated cables.

## 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 and serial number when referring to this instrument for any reason.

## WARRANTY

Hewlett-Packard Company warrants each instrument manufactured by them to be free from defects in material and workmanship. Our liability under this warranty is limited to servicing or adjusting any instrument returned to the factory for that purpose and to replace any defective parts thereof. Klystron tubes as well as other electron tubes, fuses and batteries are specifically excluded from any liability. This warranty is effective for one year after delivery to the original purchaser when the instrument is returned, transportation charges prepaid by the original purchaser, and when upon our examination it is disclosed to our satisfaction to be defective. If the fault has been caused by misuse or abnormal conditions of operation, repairs will be billed at cost. In this case, an estimate will be submitted before the work is started.

If any fault develops, the following steps should be taken:

1. Notify us, giving full details of the difficulty, and include the model number and serial number. On receipt of this information, we will give you service data or shipping instructions.
2. On receipt of shipping instructions, forward the instrument prepaid, to the factory or to the authorized repair station indicated on the instructions. If requested, an estimate of the charges will be made before the work begins provided the instrument is not covered by the warranty.

## SHIPPING

All shipments of Hewlett-Packard instruments should be made via Truck or Railway Express. The instruments should be packed in a strong exterior container and surrounded by two or three inches of excelsior or similar shock-absorbing material.

**DO NOT HESITATE TO CALL ON US**

**HEWLETT-PACKARD COMPANY**

*Laboratory Instruments for Speed and Accuracy*

275 PAGE MILL ROAD

PALO ALTO, CALIF. U.S.A.

CABLE



"HEWPACK"