

HEWLETT PACKARD

650A

TEST OSCILLATOR

OPERATING AND SERVICING MANUAL



OPERATING AND SERVICING MANUAL



MODEL 650A
TEST OSCILLATOR
SERIAL 6148 AND ABOVE



SPECIFICATIONS

FREQUENCY RANGE: 10 cps to 10 mc. Six bands.

FREQUENCY CALIBRATION:	1.0 to 10.	<u>Multiplying Factor</u>	<u>Frequency Range</u>
		x10 cps	10 to 100 cps
x100 cps	100 to 1,000 cps		
x1 kc	1,000 to 10,000 cps		
x10 kc	10 to 100 kc		
x100 kc	100 to 1,000 kc		
x1 mc	1 to 10 mc		

STABILITY: $\pm 2\%$, 10 cps to 100 kc; $\pm 3\%$, 100 kc to 10 mc including warmup, $\pm 10\%$ line voltage variations, and calibration error.

OUTPUT: 15 milliwatts or 3 volts into 600 ohm resistive load. Open circuit voltage is at least 6 volts. 600 ohm source impedance. Source impedance of 6 ohms available when 65A-16D voltage divider is used.

FREQUENCY RESPONSE: Within ± 1 db, 10 cps to 10 mc into 600 ohm resistive load.

DISTORTION: Less than 1% from 20 cps to 100 kc, less than 2% from 100 kc to 1 mc, approximately 5% at 10 mc.

OUTPUT MONITOR: Vacuum tube voltmeter monitors level at input to attenuator, in volts or dbm. (Zero dbm = 1 mw in 600 ohms.) Accuracy $\pm 5\%$ of full scale reading.


OUTPUT ATTENUATOR: 50 db in 10 db steps, providing continuously variable output voltage from +12 dbm to -50 dbm, 3 volts to 3 millivolts, (or down to 30 microvolts with voltage divider). Accuracy ± 1 db, into resistive load of 600 ohms.



HUM VOLTAGE: Less than 0.5% of output signal with meter at full scale.

POWER SUPPLY: 115/230 volts $\pm 10\%$, 50-1000 cps, 165 watts.

DIMENSIONS: Cabinet Mount: 20-3/4" wide, 12-3/4" high, 15" deep.
 Rack Mount: 19" wide, 10-1/2" high, 13-3/4" deep.

WEIGHT: Cabinet Mount: 46 lbs., shipping 66 lbs.
 Rack Mount: 37 lbs., shipping 60 lbs.

ACCESSORIES FURNISHED:  Model 65A-16D Output Cable (voltage divider).

ACCESSORIES AVAILABLE:  Model AC-16A Cable Assembly, two dual banana plugs.
 Model AC-16B Cable Assembly, dual banana plug to BNC.

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SECTION I

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 (± 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 transmission 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.  Model AC-16A 44 inch Cable Assembly. Equipped with two dual banana plugs having 3/4 inch centers. Made from 50 ohm coaxial cable type RG-58/U.
- b.  Model AC-16B 45 inch Cable Assembly. Same as AC-16A except one dual banana plug is replaced by a UG-88/U type BNC male connector.

1-3 INSPECTION

Carefully examine this instrument for possible shipping damage before and after unpacking. If any shipping damage is found, refer to "Claim for Damage in Shipment".

SECTION II

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 ν , X100 ν , 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.

When rotated full clockwise 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 Ω -

The output terminals are universal binding posts on 3/4 inch 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 volt, 50-1000 cps unless modified for 230 volt operation.
- 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.

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.

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 "600 Ω " 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 scale, 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 discussion that follows.

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.

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 "6 Ω VOLTAGE X.01" terminals of the Output Divider Cable is recommended.

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 Ω LOAD" Terminals -

The terminals marked "600 Ω LOAD" at the input end of the output cable are in parallel with the instrument "600 Ω " output terminals. With

attenuator in +10/3.0 position, output voltage at "600 Ω 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 Ω LCAD" terminals will depend upon the value of the applied resistive load.

The actual voltage (E_a) available at the "600 Ω 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 Ω 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 Ω 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.

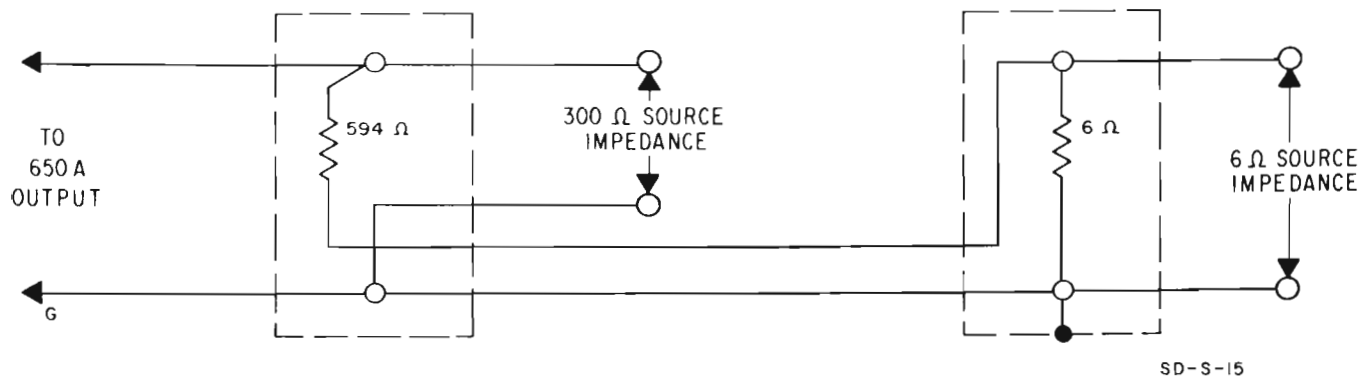
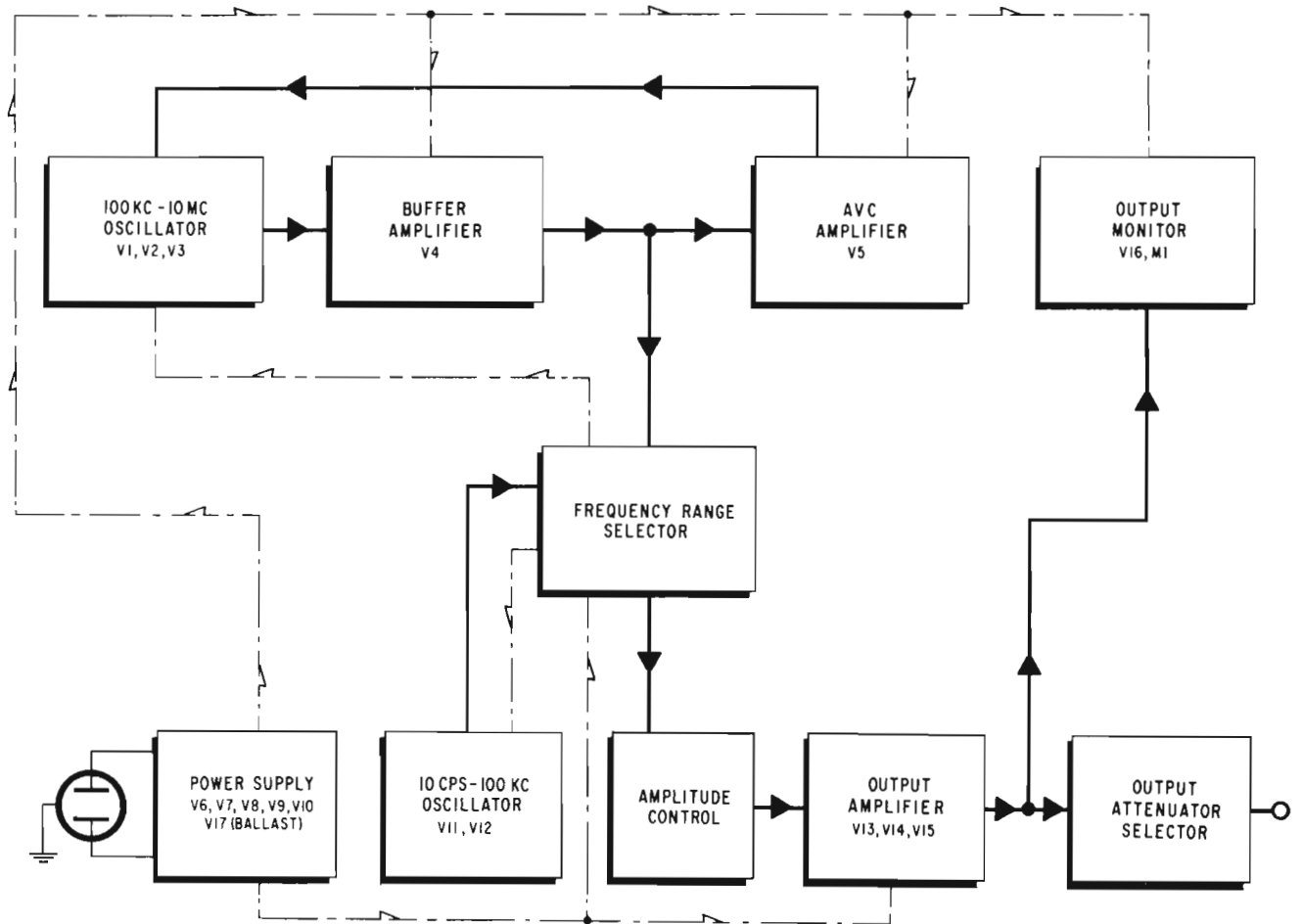


Figure 2-1. Schematic Diagram of Output Divider Cable



BD-S-27

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

SECTION III

CIRCUIT DESCRIPTION

3-1 INTRODUCTION

The Model 650A Test Oscillator circuitry can be divided into several basic circuits as shown in Figure 3-1. A discussion of these basic circuits will be found in the following paragraphs:

- 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

3-2 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.

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.

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., New York, 1943. Pages 504-506.

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

HIGH FREQUENCY OSCILLATOR

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

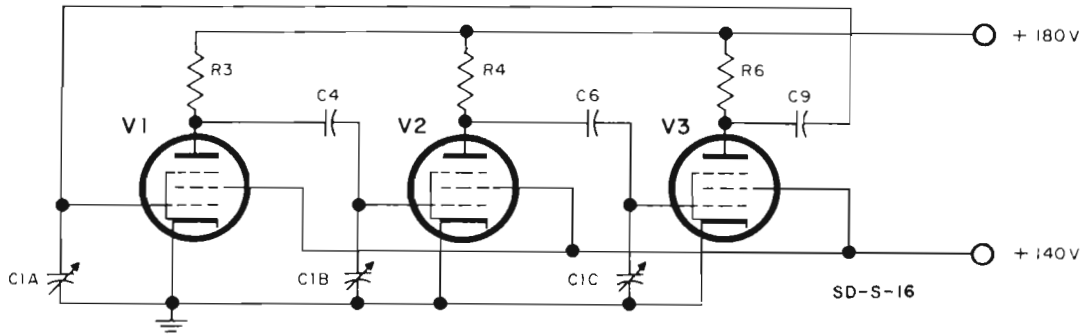


Figure 3-2. Simplified Schematic Diagram of High Frequency Oscillator Section

shift between the output of the third oscillator tube and the grid of the first oscillator tube. This condition makes the 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.

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 loop.

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.

The output amplifier circuit is designed so that V13 and V14 operate as triodes at low frequencies and

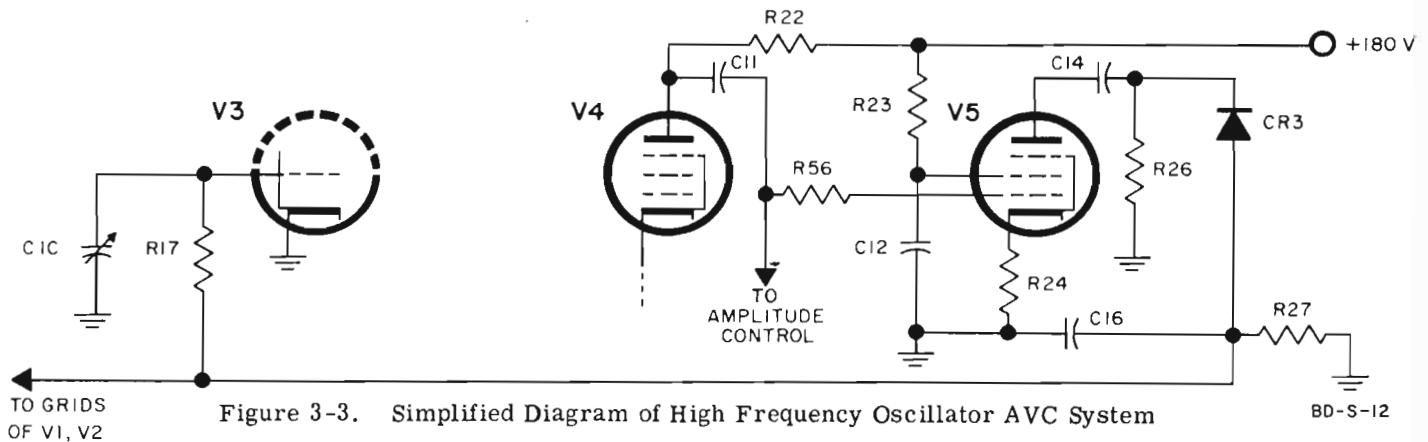


Figure 3-3. Simplified Diagram of High Frequency Oscillator AVC System

TO GRIDS
OF V1, V2

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 milliampere 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.

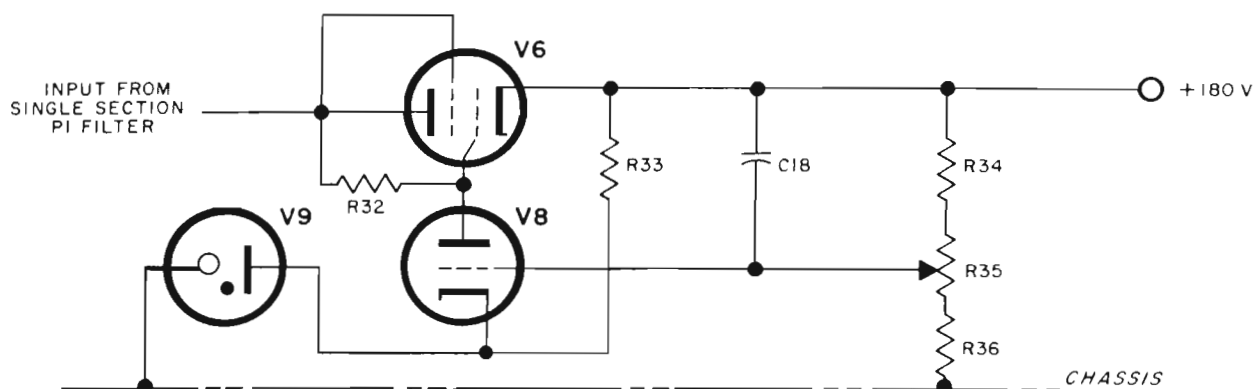


Figure 3-4. Simplified Schematic for Power Supply Regulator

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 increase 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.

SECTION IV MAINTENANCE

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 inch 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 CAPACITOR

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. SETSCREWS 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 paragraph 4-8.

4-4 TUBE REPLACEMENT

Tubes in an Φ 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 paragraph.

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.

a. REPLACEMENT OF V1, V2, V3, V4 OR V5

Only type 5654 tubes are recommended for replacement of these five tubes. Although not critical, improved performance will be obtained from low microphonic tubes.

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

b. 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.

c. REPLACEMENT OF V11 OR V12

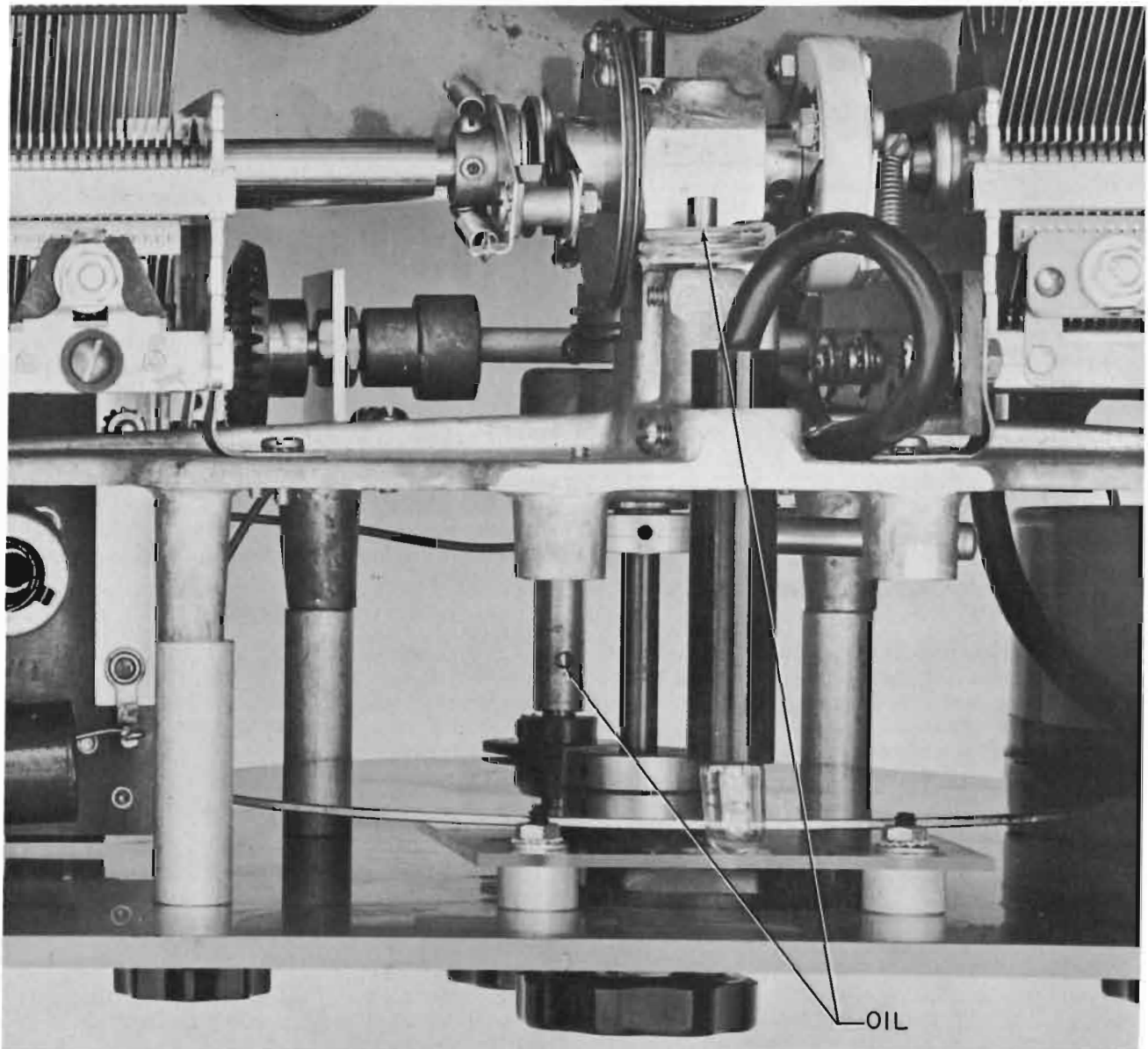
Any tube with standard RETMA characteristics may be used. Tubes selected for low microphonics

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.

d. REPLACEMENT OF V13 OR V14

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



MP-S-333

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

e. 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.

f. REPLACEMENT OF V16

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.

TABLE 4-1. TUBE COMPLEMENT AND FUNCTION CHART

Circuit Ref.	Tube Type	Tube Function
V1, 2, 3	5654	High Frequency Oscillator
V4	5654	Buffer Amplifier
V5	5654	AVC Amplifier
V6, 7	6L6GB	Power Supply Series Regulator
V8	6SQ7	Power Supply Regulator Control
V9	OA3	Power Supply Voltage Reference
V10	5U4GB	Power Supply Full Wave Rectifier
V11	6SJ7	Low Frequency Oscillator
V12	6AG7	Low Frequency Oscillator
V13	5654	Output Ampl. First Stage
V14	5654	Output Ampl. Second Stage
V15	6AG7	Output Ampl. Final Stage
V16	5654	Output Voltmeter Ampl.
V17	12-4	Heater Current Regulator

g. REPLACEMENT OF V17

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

h. 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.

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.

a. 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 ± 0.3 volts when line voltage varies $\pm 10\%$.

b. 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.

c. 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.

d. 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 AMPLITUDE control full counterclockwise. Hum voltage should not exceed 0.015 volts (0.5% of 3.0 volt rated output).

e. 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.

f. 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.

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.

g. 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.

h. 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.

i. 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 volts) 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.

j. 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 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 ^{typ} 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.

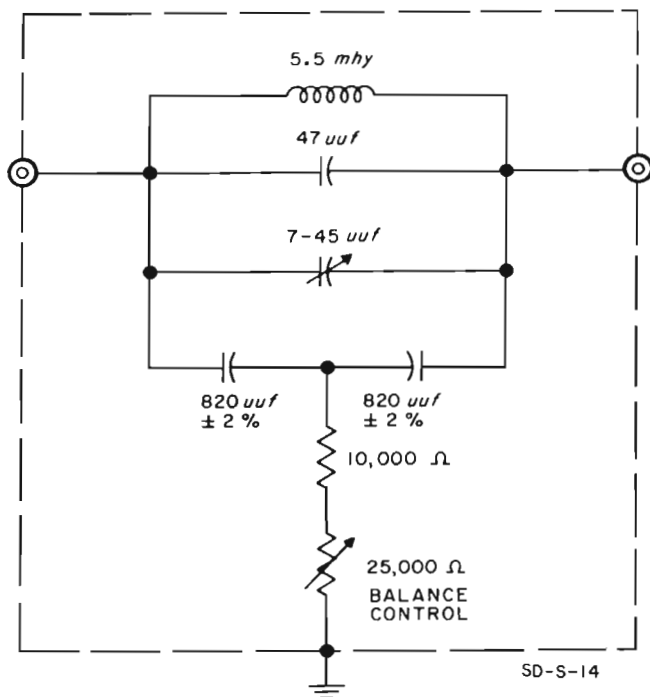


Figure 4-2. 100 kc Filter

1) HEATER AND REGULATED POWER SUPPLY VOLTAGES

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

2) 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.

3) 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 and 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.

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) 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.

5) 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%.

6) 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 measurement 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 retighten 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

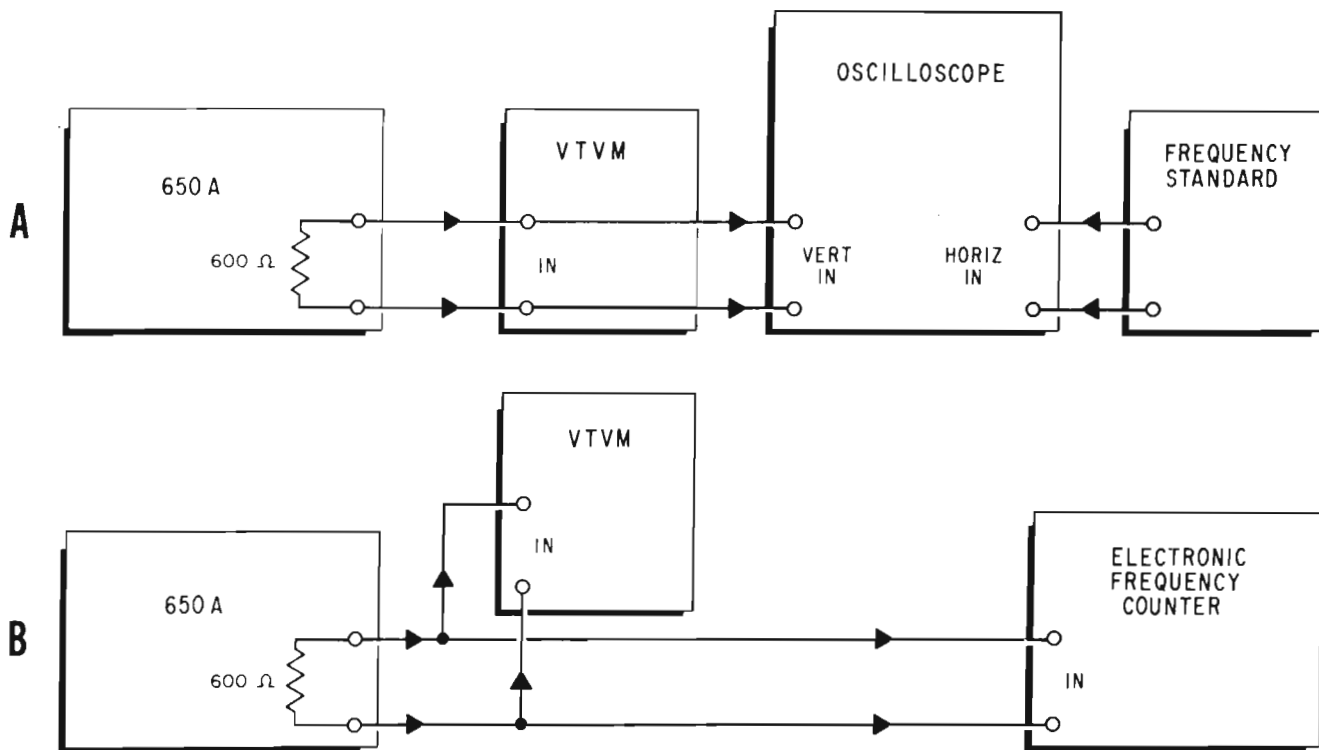


Figure 4-3. Calibration and Response Check for Low Frequency Oscillator (Figure B is suitable over entire 650A frequency range.)

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.

CAUTION

Before changing any 1/2 watt padding resistors, check the other low frequency oscillator ranges (X10 ν , X100 ν , 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 setting 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 set by adjusting capacitor C25 in the cathode circuit of V11, the low frequency oscillator tube.
- 7) 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 ± 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.
- 8) 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, ± 0.1 volt.
- B. This voltage may be set by adjusting R25. This varies the plate load of the AVC amplifier and thus the gain of the amplifier. Increasing R25 will reduce the oscillator voltage, while decreasing R25 will increase this voltage.
- C. Pull out tube V5 while instrument is operating. If AVC stage is functioning properly, high frequency oscillator voltage will go up.
- 9) 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 AMPLITUDE control to obtain same reference reading on external voltmeter established in step C.
- E. Adjust capacitor C42 in V16 cathode circuit to obtain same reference reading on internal voltmeter established in step C.
- 10) 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 μ 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 ± 1 db. Zero db reference point is at 1000 cps on the "X1KC" range.

11) 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 "X100KC" 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 Φ 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.

12) 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 "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.
- C. Return output attenuator to "3.0 R. M. S. VOLTS" position.

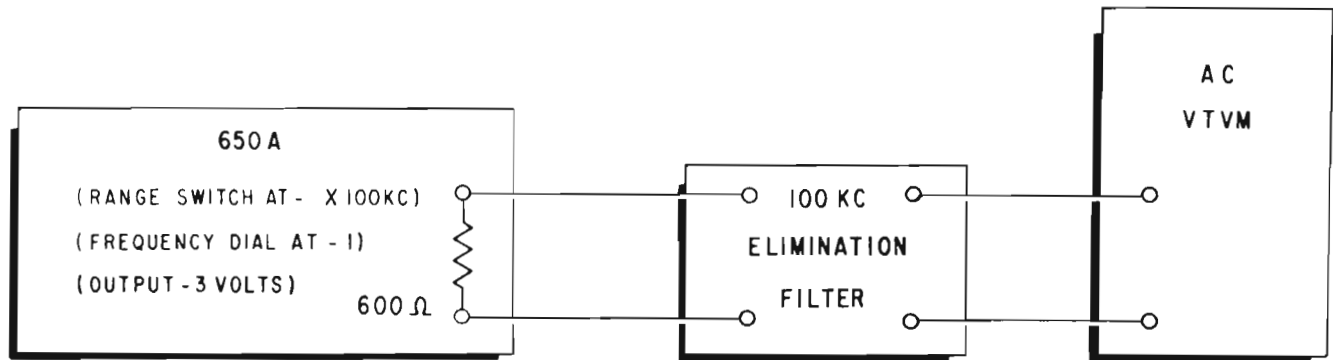


Figure 4-4. Equipment for High Frequency Distortion Measurement

BD-S-29

13) 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 setscrews 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 setscrews.

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.

14) 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 $\mu\mu$ 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.

15) OTHER ADJUSTMENTS

- A. Balance oscillator output levels. See paragraph 4-5.
- B. Check overall frequency response of 650A output meter. Response should be within ± 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.

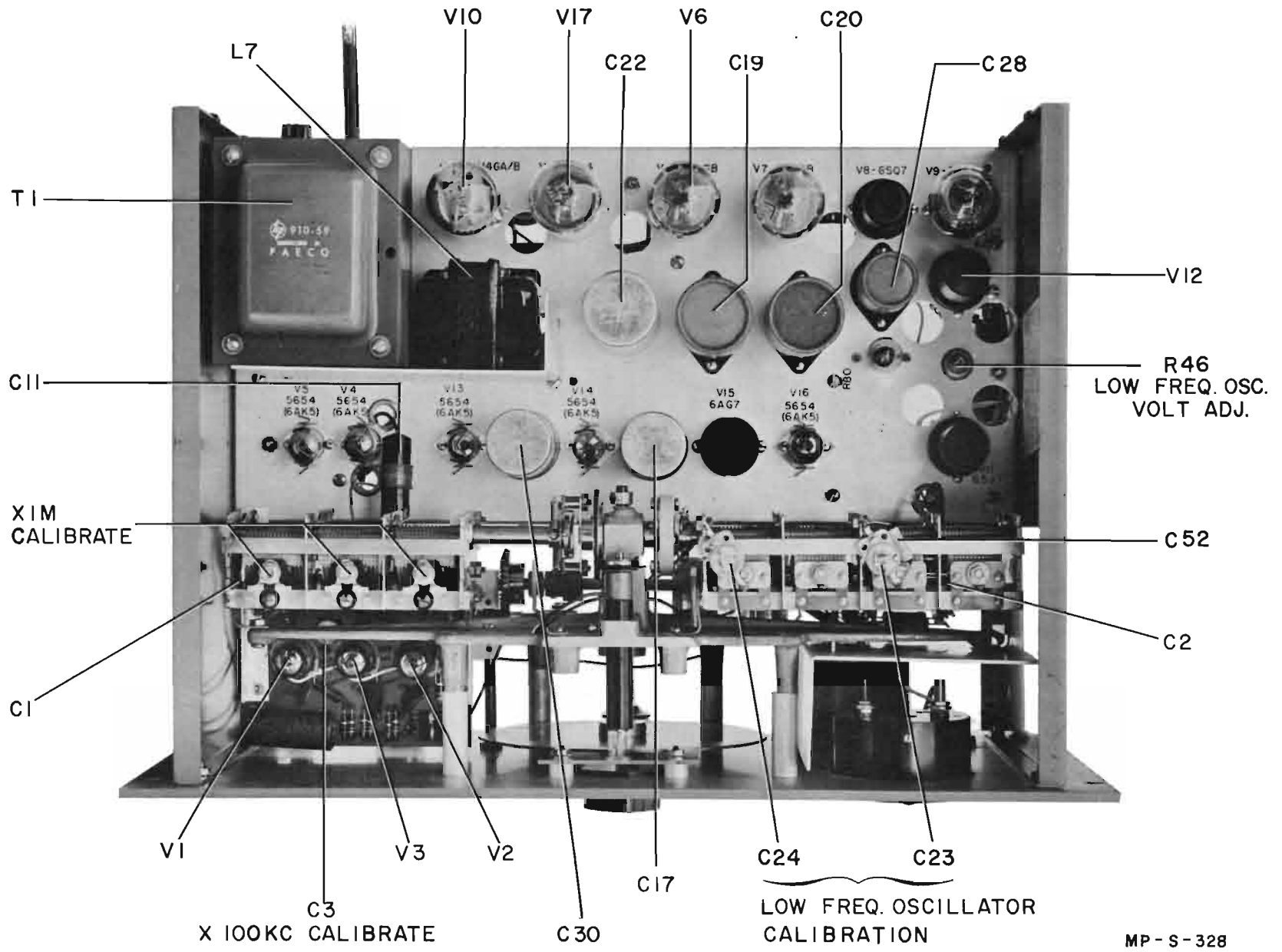


Figure 4-5. Model 650A Top View

MP - S - 328

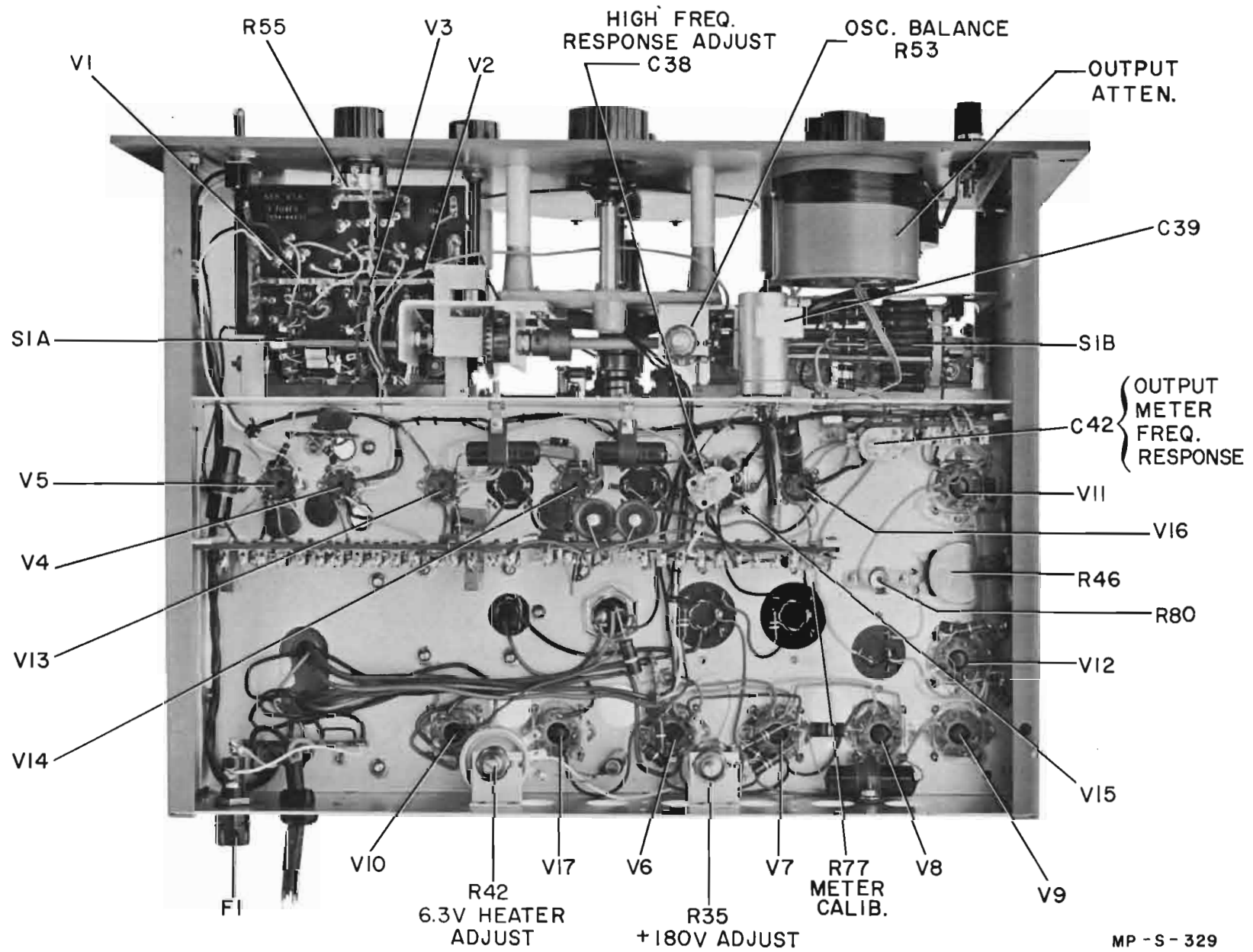


Figure 4-6. Model 650A Bottom View

MP - S - 329

- D. Adjust output meter sensitivity and check output attenuator as instructed in paragraph 4-5.
- 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 instrument 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 Figure 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 CHART

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. Excessive power supply load due to failure elsewhere in instrument. Regulated output voltage set too high. Low dc input to regulator circuit.

TABLE 4-2. TROUBLE SHOOTING CHART (CONT'D.)

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

TABLE 4-2. TROUBLE SHOOTING CHART (CONT'D.)

SYMPTOM	CAUSE AND/OR REMEDY
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
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 out of adjustment. Tube V5 defective.
Poor frequency response at 10 cps.	Capacitors C28, C30, and/or C39 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. 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.
Poor high frequency response.	V1, V2, V3, V4, and/or V5 defective. Diode CR3 defective. Tubes V13, V14, and/or V15 defective. Coils L3, L4, L5, and/or L8 defective.
High frequency oscillator will not calibrate properly.	V1, V2, and/or V3 - 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.

4-8 DRIVE CABLE REPLACEMENT PROCEDURE

Two drive cables, one 11 inches and the other 15 inches (length before end loops are formed) will be required to replace the drive cables. These two cables are available from Hewlett-Packard, under stock number 816-3-650A.

- a. Remove old dial cable and screws at A, B, C, and D (see Figure 4-8). Loosen setscrew in spring loading collar on rear of drive shaft.
- b. Insert free end of 11-inch cable through hole A of drive pulley and form loop in end of cable as directed in Figure 4-7.
- c. 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 4-8 with other end fastened by screw at B on large drum.
- d. Repeat steps b and c using the 15-inch cable. Start at C and finish at D on the small drum as shown in Figure 4-7.
- e. Revolve spring loading collar counterclockwise (viewed as shown in Figure 4-8) until slack is removed from drive cables. Rotate an additional half turn counterclockwise to tighten spring and tighten setscrew.
- f. 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.
- g. 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.
- h. Check dial calibration. If a constant error appears, loosen setscrew in drive pulley and rotate pulley slightly as required to correct this error.

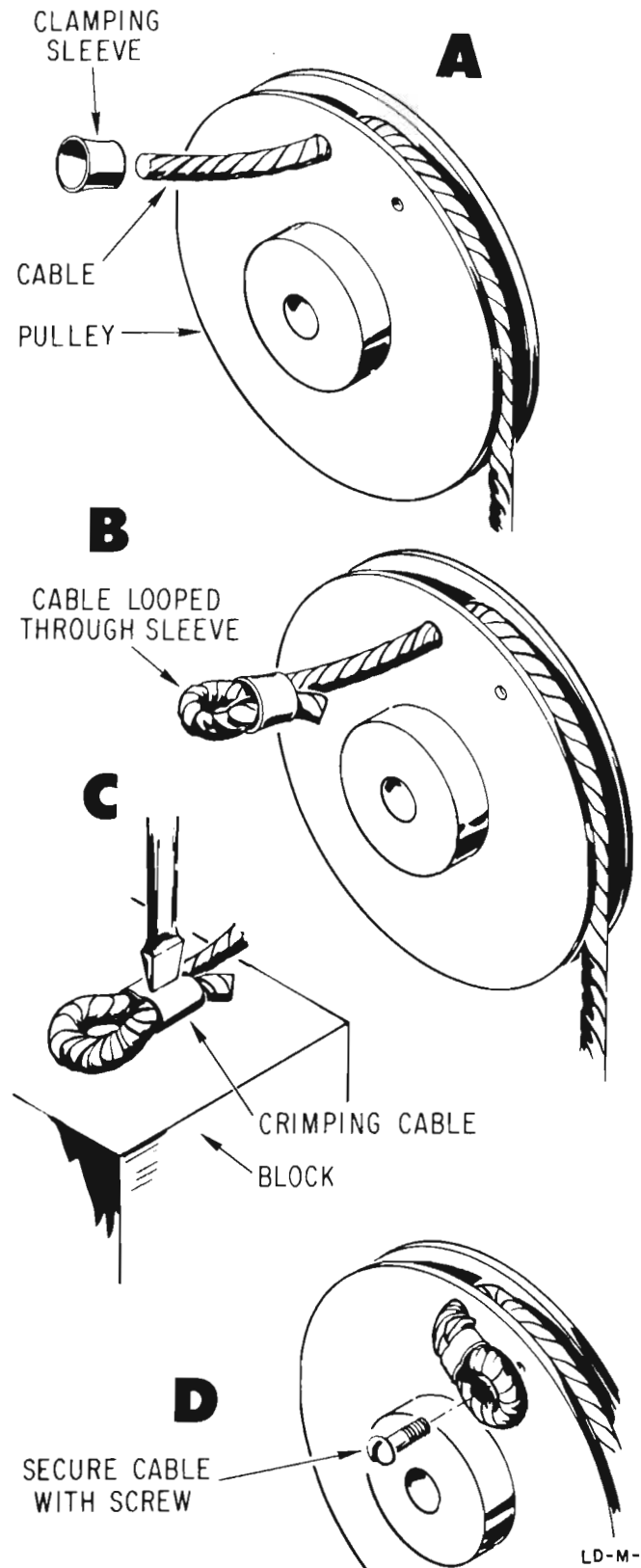


Figure 4-7. Installation of Eyelets on Plastic Coated Cable

INSTALLATION OF CLAMPING EYELETS ON ENDS OF PLASTIC COATED CABLE -

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 4-7.)

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 4-7 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 4-7.)

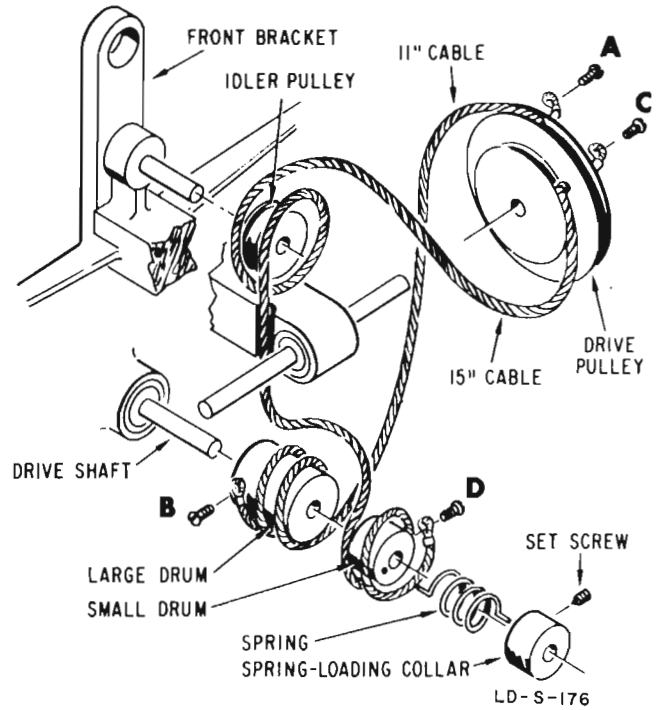


Figure 4-8. Exploded Rear View of Drive Cabling

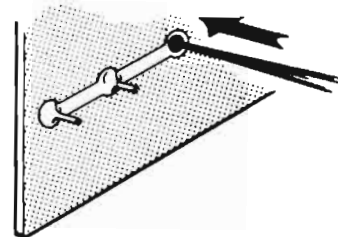
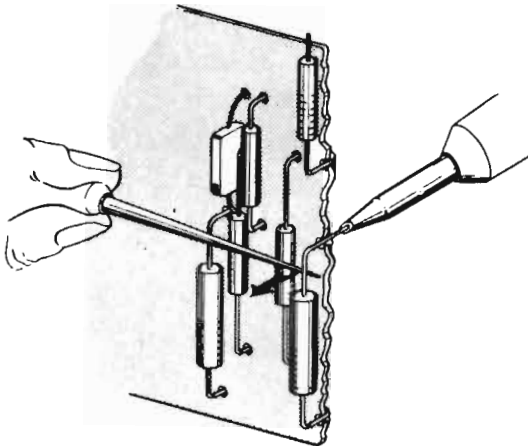
SERVICING ETCHED CIRCUIT BOARDS

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

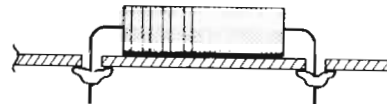
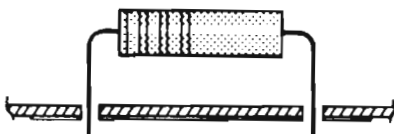
Use only high quality rosin core solder when repairing etched circuit boards. **NEVER USE PASTE FLUX.** After soldering, clean off any excess flux and coat the repaired area with a high quality electrical varnish or lacquer.

A break in the copper should be repaired by soldering a short length of tinned copper wire across the break.

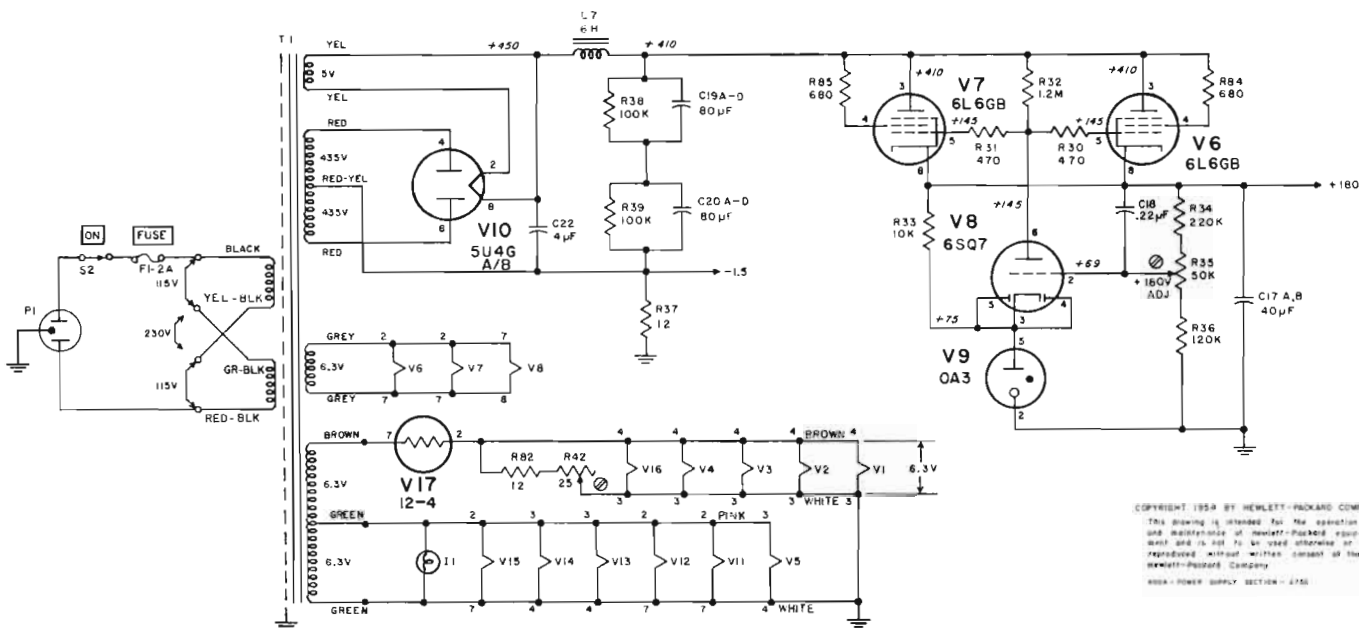
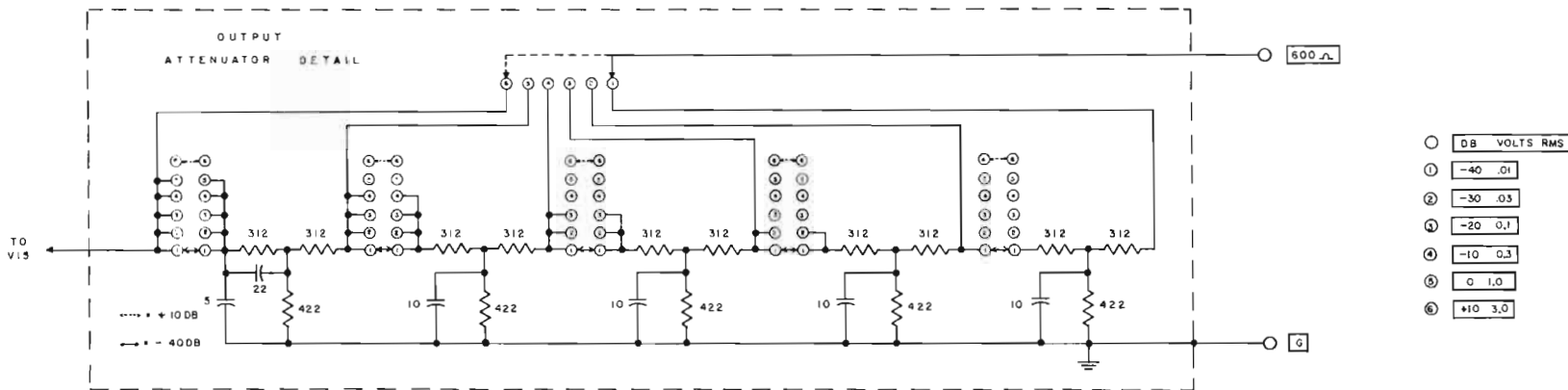
When replacing tube sockets it will be necessary to lift each pin slightly, working around the socket several times until it is free.



1. Apply heat sparingly to lead of part to be replaced. Remove part from card as iron heats the lead.
2. Using a small awl, carefully clean inside of hole left by old part.

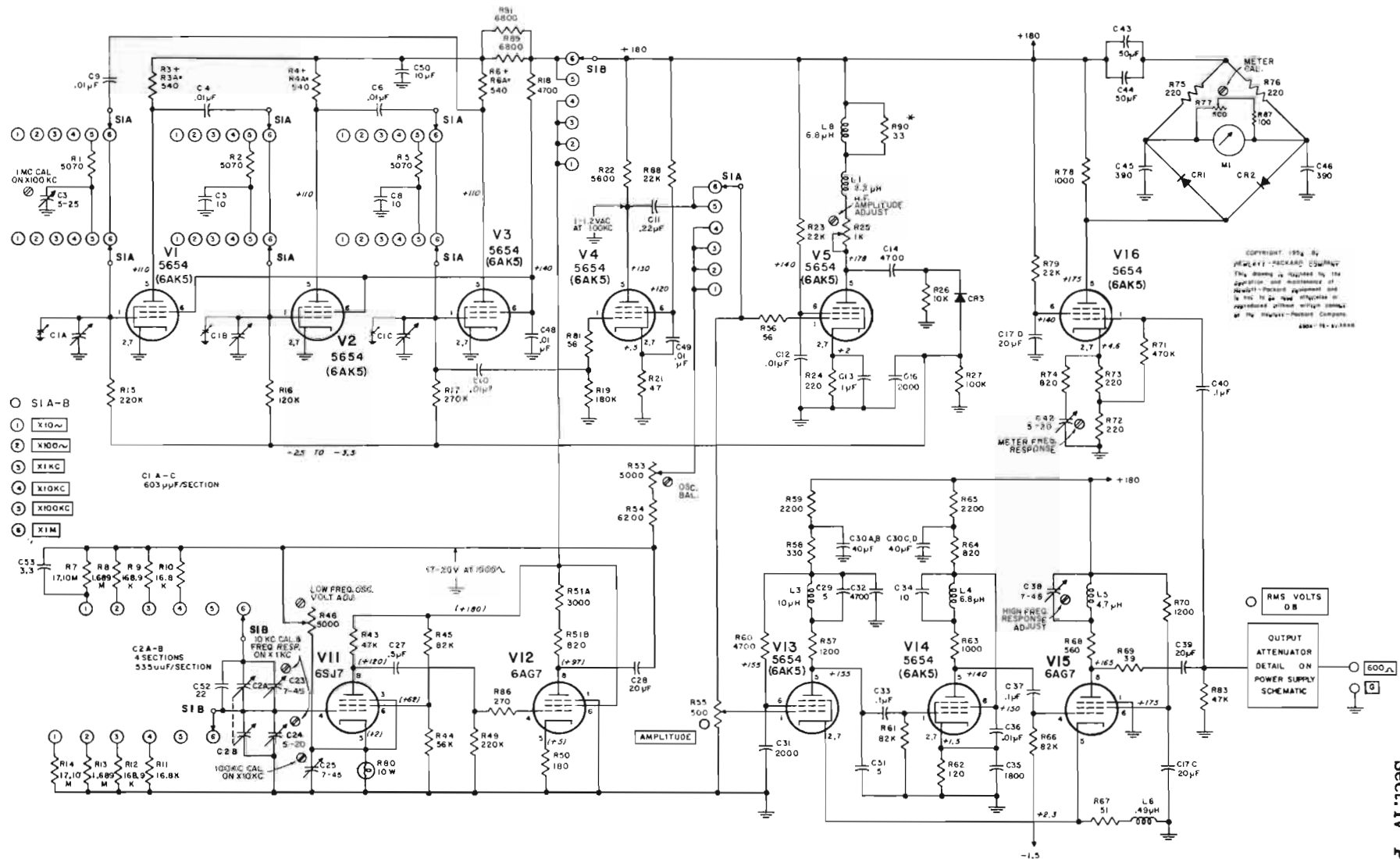


3. Bend clean tinned leads on new part and carefully insert through holes on board.
4. Hold part against board and solder leads. Avoid overheating the board.



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 8004-POWER SUPPLY SECTION - 1751

Figure 4-9. Power Supply Section



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 This drawing is subject to the
 application and acceptance of
 HAWORTH-PRESTON equipment and
 is not to be made without the
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 Company.
 4004-18-5-54-10


Figure 4-10. Oscillator Section

SECTION V TABLE OF REPLACEABLE PARTS

NOTE

Readily available standard-components have been used in this instrument, whenever possible. However, special components may be obtained from your local Hewlett-Packard representative or from the factory.

When ordering parts always include:

1.  Stock Number.
2. Complete description of part including circuit reference.
3. Model number and serial number of instrument.
4. If part is not listed give complete description, function, and location of part.

If there are any corrections for the Table of Replaceable Parts they will be listed on an Instruction Manual Change sheet at the front of this manual.

TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION, MFR. * & MFR. DESIGNATION	Ⓢ STOCK NO.	#			
C1ABC	Capacitor: variable, 3 sections, 603 μ f/sect. W*	12-22	1			
C2AB	Capacitor: variable, air, 4 sections, 12.4 μ f-535 μ f/sect. W*	12-7	1			
C3	Capacitor: variable, trimmer, ceramic, 5-25 μ f, 500 vdcw L*	13-28	1			
C4	Capacitor: fixed, ceramic, .01 μ f, tol. -0% +100%, 1000 vdcw CC*	15-43	8			
C5	Capacitor: fixed, ceramic, 10 μ f \pm 0.5 μ f, 500 vdcw K*	15-30	2			
C6	Same as C4					
C7	This circuit reference not assigned					
C8	Same as C5					
C9, 10	Same as C4					
C11	Capacitor: fixed, paper, .22 μ f, \pm 10%, 400 vdcw CC*	16-48	2			
C12	Same as C4					
C13	Capacitor: fixed, paper, 0.1 μ f, \pm 10%, 400 vdcw CC*	16-35	4			
C14	Capacitor: fixed, mica, 4700 μ f, \pm 10%, 500 vdcw V*	14-44	2			
C15	This circuit reference not assigned					
C16	Capacitor: fixed, ceramic, 2000 μ f, \pm 20%, 1000 vdcw Radio Materials Corp.	15-80	1			
C17	Capacitor: fixed, electrolytic, 4 sections, 20 μ f/sect., 450 vdcw X*	18-42HP	4			
C18	Same as C11					
C19, 20	Same as C17					

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

Total quantity used in the instrument.

TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION, MFR. * & MFR. DESIGNATION	Ⓢ STOCK NO.	#			
C21	This circuit reference not assigned					
C22	Capacitor: fixed, paper, 4 μ f, $\pm 10\%$, 600 vdcw	Z* 17-10	1			
C23	Capacitor: variable, ceramic, 7-45 μ f, 500 vdcw	L* 13-1	3			
C24	Capacitor: variable, ceramic, 5-20 μ f, 500 vdcw	L* 13-20	2			
C25	Same as C23	V* 14-15	1			
C26	This circuit reference not assigned					
C27	Capacitor: fixed, paper, 0.5 μ f, $\pm 10\%$, 400 vdcw	J* 16-58	1			
C28	Capacitor: fixed, electrolytic, 20 μ f, 450 vdcw	A* 18-20HP	2			
C29	Capacitor: fixed, mica, 5 μ f, $\pm 20\%$, 500 vdcw	Z* 14-5	2			
C30	Same as C17					
C31	Capacitor: fixed, mica, 1000 μ f, $\pm 10\%$, 500 vdcw	V* 14-11	1			
C32	Same as C14					
C33	Same as C13					
C34	Capacitor: fixed, mica, 10 μ f, $\pm 10\%$, 500 vdcw	V* 14-10	1			
C35	Capacitor: fixed, mica, 1800 μ f, $\pm 10\%$, 500 vdcw	Z* 14-47	1			
C36	Same as C4					
C37	Same as C13					
C38	Same as C23					

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

Total quantity used in the instrument.

TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION, MFR. * & MFR. DESIGNATION	Ⓟ STOCK NO.	#			
C39	Same as C28					
C40	Same as C13					
C41	This circuit reference not assigned					
C42	Same as C24					
C43, 44	Capacitor: fixed, electrolytic, 50 μ f, -10% +200%, 50 vdcw	X*	18-50	2		
C45, 46	Capacitor: fixed, mica, 390 μ f, \pm 10%, 500 vdcw	V*	14-65	2		
C47	This circuit reference not assigned					
C48, 49	Same as C4					
C50	Capacitor: fixed, electrolytic, 10 μ f, \pm 50%, 450 vdcw	X*	18-10	1		
C51	Same as C29					
C52	Capacitor: fixed, ceramic, 22 μ f, \pm 5%, 500 vdcw	K*	15-2	1		
C53	Capacitor: fixed, titanium dioxide, 3.3 μ f, \pm 10%, 500 vdcw	DD*	15-78	1		
CR1, 2, 3	Diode, germanium	BU*	212-G11A	3		
F1	Fuse, cartridge: 125V	E*	211-16	1		
I1	Lamp, incandescent: 6-8V, 2 pin base, #12	N*	211-78	1		

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

Total quantity used in the instrument.

TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION, MFR. * & MFR. DESIGNATION	Ⓢ STOCK NO.	#			
L1	Choke: 2.2 μ h	CG*	48-43	1		
L2	This circuit reference not assigned					
L3	Coil, R. F.: 10 μ h	CG*	48-54	1		
L4	Coil, R. F.: 6.8 μ h, $\pm 10\%$	CG*	48-41	2		
L5	Coil, R. F.: 4.7 μ h, $\pm 10\%$	CG*	48-40	1		
L6	Coil, R. F.: 0.49 μ h	HP*	65A-60F	1		
L7	Reactor, filter: power supply, 6h	HP*	911-4	1		
L8	Same as L4					
M1	Meter	Simpson	112-19	1		
P1	Cable, power	Elect. Cords Co.	812-56	1		
R1, 2	Resistor: fixed, deposited carbon, 4860 ohms, $\pm 1\%$, 1/2 W	NN*	33-4860	3		
R3, 4	Resistor: fixed, deposited carbon, 495 ohms, $\pm 1\%$, 1/2 W	NN*	33-495	3		
R5	Same as R1					
R6	Same as R3					
R7	Resistor: fixed, deposited carbon, 16.71 megohms, $\pm 1\%$, 1 W	NN*	31-16.71M	2		

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

Total quantity used in the instrument.

TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION, MFR. * & MFR. DESIGNATION	Ⓢ STOCK NO.	#			
R8	Resistor: fixed, deposited carbon, 1.63 megohms, $\pm 1\%$, 1 W NN*	31-1.63M	2			
R9	Resistor: fixed, deposited carbon, 160,000 ohms, $\pm 1\%$, 1 W NN*	31-160K	2			
R10, 11	Resistor: fixed, deposited carbon, 15,800 ohms, $\pm 1\%$, 1 W NN*	31-15.8K	2			
R12	Same as R9					
R13	Same as R8					
R14	Same as R7					
R15	Resistor: fixed, composition, 220,000 ohms, $\pm 10\%$, 1/2 W B*	23-220K	1			
R16	Resistor: fixed, composition, 120,000 ohms, $\pm 10\%$, 1/2 W B*	23-120K	1			
R17	Resistor: fixed, composition, 270,000 ohms, $\pm 10\%$, 1/2 W B*	23-270K	1			
R18	Resistor: fixed, composition. 4700 ohms, $\pm 10\%$, 1 W B*	24-4700	1			
R19	Resistor: fixed, composition, 180,000 ohms, $\pm 10\%$, 1/2 W B*	23-180K	1			
R20	This circuit reference not assigned					
R21	Resistor: fixed, composition, 47 ohms, $\pm 10\%$, 1/2 W B*	23-47	1			
R22	Resistor: fixed, composition, 5600 ohms, $\pm 10\%$, 1 W B*	24-5600	1			
R23	Resistor: fixed, composition, 22,000 ohms, $\pm 10\%$, 1/2 W B*	23-22K	2			
R24	Resistor: fixed, composition, 220 ohms, $\pm 10\%$, 1/2 W B*	23-220	3			
R25	Resistor: variable, composition, linear taper, 1000 ohms G*	210-51	1			

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

Total quantity used in the instrument.

TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION, MFR. * & MFR. DESIGNATION	Ⓢ STOCK NO.	#			
R26	Resistor: fixed, composition, 10,000 ohms, $\pm 10\%$, 1/2 W B*	23-10K	1			
R27	Resistor: fixed, composition, 100,000 ohms, $\pm 10\%$, 1 W B*	24-100K	3			
R28, 29	These circuit references not assigned					
R30, 31	Resistor: fixed, composition, 470 ohms, $\pm 10\%$, 1/2 W B*	23-470	2			
R32	Resistor: fixed, composition, 1.2 megohms, $\pm 10\%$, 1 W B*	24-1.2M	1			
R33	Resistor: fixed, composition, 10,000 ohms, $\pm 10\%$, 2 W B*	25-10K	1			
R34	Resistor: fixed, composition, 220,000 ohms, $\pm 10\%$, 1 W B*	24-220K	2			
R35	Resistor: fixed, composition, 50,000 ohms, $\pm 20\%$, 1/2 W I*	210-18	1			
R36	Resistor: fixed, composition, 120,000 ohms, $\pm 10\%$, 1 W B*	24-120K	1			
R37	Resistor: fixed, composition, 12 ohms, $\pm 10\%$, 2 W B*	25-12	1			
R38, 39	Same as R27					
R40, 41	These circuit references not assigned					
R42	Resistor: variable, wirewound, 25 ohms, $\pm 10\%$, 3 W Precision Parts Co.	210-46	1			
R43	Resistor: fixed, composition, 47,000 ohms, $\pm 10\%$, 1 W B*	24-47K	1			
R44	Resistor: fixed, composition, 56,000 ohms, $\pm 10\%$, 1 W B*	24-56K	1			
R45	Resistor: fixed, composition, 82,000 ohms, $\pm 10\%$, 1 W B*	24-82K	1			
R46	Resistor: variable, wirewound, 5000 ohms B*	210-7	1			

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

Total quantity used in the instrument.

TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION, MFR. * & MFR. DESIGNATION	Ⓢ STOCK NO.	#			
R47, 48	These circuit references not assigned					
R49	Same as R34					
R50	Resistor: fixed, composition, 180 ohms $\pm 10\%$, 1 W	B* 24-180	1			
R51A	Resistor: fixed, wirewound, 3000 ohms $\pm 10\%$, 10 W	S* 26-3	1			
R51B	Resistor: fixed, composition, 820 ohms $\pm 10\%$, 2 W	B* 25-820	1			
R52	This circuit reference not assigned					
R53	Resistor: variable, composition, linear taper, 5000 ohms,	G* 210-15	1			
R54	Resistor: fixed, composition, 6200 ohms, $\pm 5\%$, 1 W	B* 24-6200-5	1			
R55	Resistor: variable, composition, linear taper, 500 ohms, $\pm 10\%$	I* 210-25	1			
R56	Resistor: fixed, composition, 56 ohms, $\pm 10\%$, 1/2 W	B* 23-56	2			
R57	Resistor: fixed, composition, 1200 ohms, $\pm 10\%$, 1/2 W	B* 23-1200	1			
R58	Resistor: fixed, composition, 330 ohms, $\pm 10\%$, 1/2 W	B* 23-330	1			
R59	Resistor: fixed, composition, 2200 ohms, $\pm 10\%$, 1W	B* 24-2200	1			
R60	Resistor: fixed, composition, 4700 ohms, $\pm 10\%$, 1/2 W	B* 23-4700	1			
R61	Resistor: fixed, composition, 82,000 ohms, $\pm 10\%$, 1/2 W	B* 23-82K	2			
R62	Resistor: fixed, composition, 120 ohms, $\pm 10\%$, 1/2 W	B* 23-120	1			
R63	Resistor: fixed, composition, 1000 ohms, $\pm 10\%$, 1/2 W	B* 23-1000	2			
R64	Resistor: fixed, composition, 820 ohms, $\pm 10\%$, 1/2 W	B* 23-820	2			

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

Total quantity used in the instrument.

TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION, MFR. * & MFR. DESIGNATION	Ⓟ STOCK NO.	#			
R65	Resistor: fixed, composition, 2200 ohms, $\pm 10\%$, 2 W	B* 25-2200	1			
R66	Same as R61					
R67	Resistor: fixed, composition, 51 ohms, $\pm 5\%$, 1 W	B* 24-51-5	1			
R68	Resistor: fixed, composition, 560 ohms, $\pm 5\%$, 1 W	B* 24-560-5	1			
R69	Resistor: fixed, composition, 39 ohms, $\pm 10\%$, 1/2 W	B* 23-39	1			
R70	Resistor: fixed, composition, 1200 ohms, $\pm 10\%$, 1 W	B* 24-1200	1			
R71	Resistor: fixed, composition, 470,000 ohms, $\pm 10\%$, 1/2 W	B* 23-470K	1			
R72, 73	Same as R24					
R74	Same as R64					
R75, 76	Resistor: fixed, composition, 220 ohms $\pm 10\%$, 1 W	B* 24-220	2			
R77	Resistor: variable, wirewound, 500 ohms,	AT* 210-29	1			
R78	Same as R63					
R79	Same as R23					
R80	Lamp, incandescent: 250V, 10 W	N* 211-29	1			
R81	Same as R56					
R82	Resistor: fixed, wirewound, 12 ohms, $\pm 10\%$, 10 W	S* 26-14	1			
R83	Resistor: fixed, composition, 47,000 ohms, $\pm 10\%$, 1/2 W	B* 23-47K	1			

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

Total quantity used in the instrument.

TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION, MFR. * & MFR. DESIGNATION	Ⓢ STOCK NO.	#			
R84, 85	Resistor: fixed, composition, 680 ohms, $\pm 10\%$, 1 W B*	24-680	2			
R86	Resistor: fixed, composition, 270 ohms, $\pm 10\%$, 1 W B*	24-270	1			
R87	Resistor: fixed, composition, 100 ohms, $\pm 10\%$, 1 W B*	24-100	1			
R88	Resistor: fixed, composition, 22,000 ohms, $\pm 10\%$, 1 W B*	24-22K	1			
R89	Resistor: fixed, composition, 6800 ohms, $\pm 10\%$, 2 W B*	25-6800	2			
R90	Resistor: fixed, composition, 33 ohms, $\pm 10\%$, 1 W Electrical value adjusted at factory B*	24-33	1			
R91	Same as R89					
S1A	Range Switch Assembly (high frequency) HP*	65A-19WH	1			
S1B	Range Switch Assembly (low frequency) HP*	65A-19WL	1			
S2	Switch, toggle: SPST D*	310-11	1			
T1	Transformer, power Paeco	910-59	1			
V1,2,3,4,5	Tube, electron: 5654 ZZ*	212-5654	8			
V6, 7	Tube, electron: 6L6GB ZZ*	212-6L6GB	2			
V8	Tube, electron: 6SQ7 ZZ*	212-6SQ7	1			
V9	Tube, electron: OA3 ZZ*	212-OA3	1			
V10	Tube, electron: 5U4GA/B ZZ*	212-5U 4GA/B	1			

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

Total quantity used in the instrument.

TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION, MFR. * & MFR. DESIGNATION	STOCK NO.	#			
V11	Tube, electron: 6SJ7	ZZ* 212-6SJ7	1			
V12	Tube, electron: 6AG7	ZZ* 212-6AG7	2			
V13, 14	Same as V1					
V15	Same as V12					
V16	Same as V1					
V17	Tube, ballast: glass, octal base, #12-4	C* 211-25	1			
	<u>MISCELLANEOUS</u>					
	Attenuator Assembly (output) complete	HP* 65A-34	1			
	Binding Post Assembly: black	HP* AC-10C	1			
	Binding Post Assembly: red	HP* AC-10D	1			
	Cable Assembly: output	HP* 65A-16D	1			
	Conversion Kit: (for field conversion of cabinet mount to rack mount)	HP* 35F-95A	1			
	Cable, mechanical: for dial drive assembly	HP* 816-3-650A	1			
	Escutcheon, dial window	HP* G-99A	1			
	Holder, fuse	T* 140-16	1			
	Holder, lamp: (for R80)	AD* 145-15	1			
	Insulator, standoff	E. F. Johnson 34-58	1			
	Insulator, binding post	HP* AC-54A	1			
	Jewel, pilot light	AD* 145-23A	1			
	Knob: AMPLITUDE	HP* G-74K	1			
	Knob: FREQUENCY, RMS VOLTS	HP* G-74N	2			
	Knob: tuning dial	HP* G-74R	2			
	Lampholder, for I1	AD* 145-25	1			
	Resistor: 6 ohms, for output cable assembly	HP* 65A-95A	1			
	Window, dial	HP* M-64	1			

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

Total quantity used in the instrument.

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

CODE LETTER	MANUFACTURER	ADDRESS	CODE LETTER	MANUFACTURER	ADDRESS
A	Aerovox Corp.	New Bedford, Mass.	AK	Hammerlund Mfg. Co., Inc.	New York 1, N. Y.
B	Allen-Bradley Co.	Milwaukee 4, Wis.	AL	Industrial Condenser Corp.	Chicago 18, Ill.
C	Amperite Co.	New York, N. Y.	AM	Insuline Corp. of America	Manchester, N. H.
D	Arrow, Hart & Hegeman	Hartford, Conn.	AN	Jennings Radio Mfg. Corp.	San Jose, Calif.
E	Bussman Manufacturing Co.	St. Louis, Mo.	AO	E. F. Johnson Co.	Waseca, Minn.
F	Carborundum Co.	Niagara Falls, N. Y.	AP	Lenz Electric Mfg. Co.	Chicago 47, Ill.
G	Centralab	Milwaukee 1, Wis.	AQ	Micro-Switch	Freeport, Ill.
H	Cinch-Jones Mfg. Co.	Chicago 24, Ill.	AR	Mechanical Industries Prod. Co.	Akron 8, Ohio
HP	Hewlett-Packard Co.	Palo Alto, Calif.	AS	Model Eng. & Mfg., Inc.	Huntington, Ind.
I	Clarostat Mfg. Co.	Dover, N. H.	AT	The Muter Co.	Chicago 5, Ill.
J	Cornell Dubilier Elec. Co.	South Plainfield, N. J.	AU	Ohmite Mfg. Co.	Skokie, Ill.
K	Hi-Q Division of Aerovox	Olean, N. Y.	AV	Resistance Products Co.	Harrisburg, Pa.
L	Erie Resistor Corp.	Erie 6, Pa.	AW	Radio Condenser Co.	Camden 3, N. J.
M	Fed. Telephone & Radio Corp.	Clifton, N. J.	AX	Shallcross Manufacturing Co.	Collingdale, Pa.
N	General Electric Co.	Schenectady 5, N. Y.	AY	Solar Manufacturing Co.	Los Angeles 58, Calif.
O	General Electric Supply Corp.	San Francisco, Calif.	AZ	Sealectro Corp.	New Rochelle, N. Y.
P	Girard-Hopkins	Oakland, Calif.	BA	Spencer Thermostat	Attleboro, Mass.
Q	Industrial Products Co.	Danbury, Conn.	BC	Stevens Manufacturing Co.	Mansfield, Ohio
R	International Resistance Co.	Philadelphia 8, Pa.	BD	Torrington Manufacturing Co.	Van Nuys, Calif.
S	Lectrohm Inc.	Chicago 20, Ill.	BE	Vector Electronic Co.	Los Angeles 65, Calif.
T	Littlefuse Inc.	Des Plaines, Ill.	BF	Weston Electrical Inst. Corp.	Newark 5, N. J.
U	Maguire Industries Inc.	Greenwich, Conn.	BG	Advance Electric & Relay Co.	Burbank, Calif.
V	Micomold Radio Corp.	Brooklyn 37, N. Y.	BH	E. I. DuPont	San Francisco, Calif.
W	Oak Manufacturing Co.	Chicago 10, Ill.	BI	Electronics Tube Corp.	Philadelphia 18, Pa.
X	P. R. Mallory Co., Inc.	Indianapolis, Ind.	BJ	Aircraft Radio Corp.	Boonton, N. J.
Y	Radio Corp. of America	Harrison, N. J.	BK	Allied Control Co., Inc.	New York 21, N. Y.
Z	Sangamo Electric Co.	Marion, Ill.	BL	Augat Brothers, Inc.	Attleboro, Mass.
AA	Sarkes Tarzian	Bloomington, Ind.	BM	Carter Radio Division	Chicago, Ill.
BB	Signal Indicator Co.	Brooklyn 37, N. Y.	BN	CBS Hytron Radio & Electric	Danvers, Mass.
CC	Sprague Electric Co.	North Adams, Mass.	BO	Chicago Telephone Supply	Elkhart, Ind.
DD	Stackpole Carbon Co.	St. Marys, Pa.	BP	Henry L. Crowley Co., Inc.	West Orange, N. J.
EE	Sylvania Electric Products Co.	Warren, Pa.	BQ	Curtiss-Wright Corp.	Carlstadt, N. J.
FF	Western Electric Co.	New York 5, N. Y.	BR	Allen B. DuMont Labs	Clifton, N. J.
GG	Wilkor Products, Inc.	Cleveland, Ohio	BS	Excel Transformer Co.	Oakland, Calif.
HH	Amphenol	Chicago 50, Ill.	BT	General Radio Co.	Cambridge 39, Mass.
II	Dial Light Co. of America	Brooklyn 37, N. Y.	BU	Hughes Aircraft Co.	Culver City, Calif.
JJ	Leecraft Manufacturing Co.	New York, N. Y.	BV	International Rectifier Corp.	El Segundo, Calif.
KK	Switchcraft, Inc.	Chicago 22, Ill.	BW	James Knights Co.	Sandwich, Ill.
LL	Gremar Manufacturing Co.	Wakefield, Mass.	BX	Mueller Electric Co.	Cleveland, Ohio
MM	Carad Corp.	Redwood City, Calif.	BY	Precision Thermometer & Inst. Co.	Philadelphia 30, Pa.
NN	Electra Manufacturing Co.	Kansas City, Mo.	BZ	Radio Essentials Inc.	Mt. Vernon, N. Y.
OO	Acro Manufacturing Co.	Columbus 16, Ohio	CA	Raytheon Manufacturing Co.	Newton, Mass.
PP	Alliance Manufacturing Co.	Alliance, Ohio	CB	Tung-Sol Lamp Works, Inc.	Newark 4, N. J.
QQ	Arco Electronics, Inc.	New York 13, N. Y.	CD	Varian Associates	Palo Alto, Calif.
RR	Astron Corp.	East Newark, N. J.	CE	Victory Engineering Corp.	Union, N. J.
SS	Axel Brothers Inc.	Long Island City, N. Y.	CF	Weckesser Co.	Chicago 30, Ill.
TT	Belden Manufacturing Co.	Chicago 44, Ill.	CG	Wilco Corporation	Indianapolis, Ind.
UU	Bird Electronics Corp.	Cleveland 14, Ohio	CH	Winchester Electronics, Inc.	Santa Monica, Calif.
VV	Barber Colman Co.	Rockford, Ill.	CI	Malco Tool & Die	Los Angeles 42, Calif.
WW	Bud Radio Inc.	Cleveland 3, Ohio	CJ	Oxford Electric Corp.	Chicago 15, Ill.
XX	Allen D. Cardwell Mfg. Co.	Plainville, Conn.	CK	Camloc-Fastener Corp.	Paramus, N. J.
YY	Cinema Engineering Co.	Burbank, Calif.	CL	George K. Garrett	Philadelphia 34, Pa.
ZZ	Any brand tube meeting RETMA standards.		CM	Union Switch & Signal	Swissvale, Pa.
AB	Corning Glass Works	Corning, N. Y.	CN	Radio Receptor	New York 11, N. Y.
AC	Dale Products, Inc.	Columbus, Neb.	CO	Automatic & Precision Mfg. Co.	Yonkers, N. Y.
AD	The Drake Mfg. Co.	Chicago 22, Ill.	CP	Bassick Co.	Bridgeport 2, Conn.
AE	Elco Corp.	Philadelphia 24, Pa.	CQ	Birnbach Radio Co.	New York 13, N. Y.
AF	Hugh H. Eby Co.	Philadelphia 44, Pa.	CR	Fischer Specialties	Cincinnati 6, Ohio
AG	Thomas A. Edison, Inc.	West Orange, N. J.	CS	Telefunken (c/o MVM, Inc.)	New York, N. Y.
AH	Fansteel Metallurgical Corp.	North Chicago, Ill.	CT	Potter-Brumfield Co.	Princeton, Ind.
AI	General Ceramics & Steatite Corp.	Keasbey, N. J.	CU	Cannon Electric Co.	Los Angeles, Calif.
AJ	The Gudeman Co.	Sunnyvale, Calif.	CV	Dynac, Inc.	Palo Alto, Calif.
			CW	Good-All Electric Mfg. Co.	Ogallala, Nebr.

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

CABLE



PALO ALTO, CALIF. U.S.A.

"HEWPACK"



MANUAL CHANGES

MODEL 650A

TEST OSCILLATOR

Serial 7048 and above:

R50: Change to resistor, fixed, composition, 150 ohms $\pm 10\%$, 1 W; -hp- Stock No. 24-150, Mfr., B Optimum value selected at factory. Average value shown.

For instruments with Serials Prefixed: 007-, include the following changes in addition to those previously listed:

MISC.:

Escutcheon: -hp- Stock No. G-99E, Mfr., HP

Indicator, dial window: -hp- Stock No. 202A-40B, Mfr., HP

Disc, vernier drive: -hp- Stock No. G-14H, Mfr., HP

Bearing, ball: -hp- Stock No. 141-25, Mfr., HP

Spring, compression: -hp- Stock No. 146-74, Mfr., HP

3/15/60 - 650A

2/8/60 - 650A

1/12/60

