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650A

TEST OSCILLATOR

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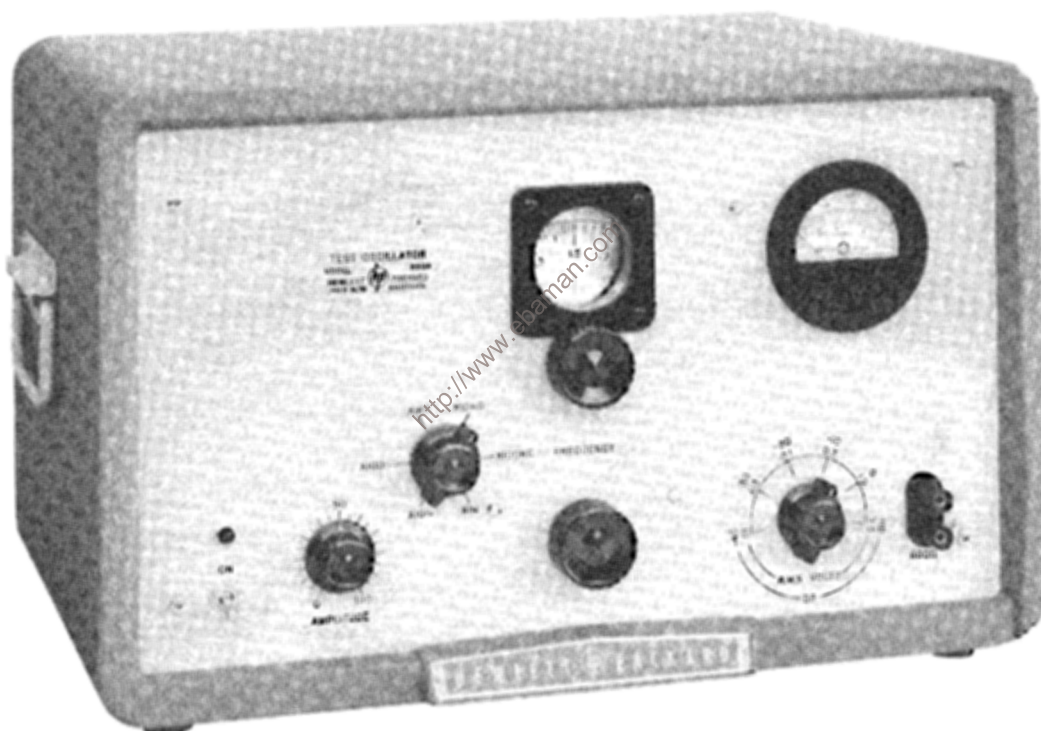
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OPERATING AND SERVICING MANUAL



MODEL 650A TEST OSCILLATOR

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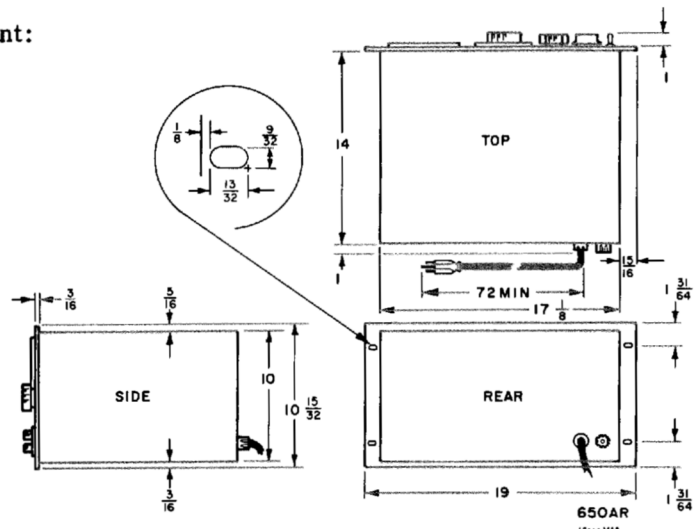
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SPECIFICATIONS

Frequency Range:	10 cps to 10 mc. Six decade bands.
Calibration Accuracy:	$\pm 2\%$, 10 cps to 100 kc; $\pm 3\%$, 100 kc to 10 mc including warm-up and $\pm 10\%$ line voltage variation.
Output:	15 milliwatts or 3 volts rms into 600 ohm resistive load 6 volts rms open circuit.
Output Attenuator:	0 to 50 db in 10 db steps. Accuracy ± 1 db, into resistive load of 600 ohms.
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.
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 Impedance:	600 ohms; 300 ohms or 6 ohms when using 65A-16D Output Divider Cable.
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.
Accessory Furnished:	Ⓢ 65A-16D Output Divider Cable (voltage divider).
Accessories Available:	Ⓢ AC-16A Cable, two dual banana plugs. Ⓢ AC-16B Cable, dual banana plug to BNC.
Dimensions:	Cabinet Mount: 20-3/4 in. wide, 12-3/4 in. high, 15 in. deep.
	Rack Mount:



Weight:	Cabinet Mount: Net 46 lbs, shipping 55 lbs.
	Rack Mount: Net 37 lbs, shipping 52 lbs.

TABLE OF CONTENTS

Section	Page	Section	Page
I GENERAL DESCRIPTION	I-1	4-6 Complete Test Procedure	IV-4
I-1 General	I-1	1) Heater and Regulated Power Supply Voltages	IV-5
I-2 Accessories	I-1	2) Preliminary Low Frequency Response Adjustment	IV-5
I-3 Inspection	I-1	3) Low Frequency Oscillator Output Voltage	IV-5
II OPERATING INSTRUCTIONS	II-1	4) Low Frequency Oscillator Distortion	IV-5
2-1 Controls and Terminals	II-1	5) Low Frequency Output Distortion	IV-6
2-2 Operation	II-2	6) Calibration of Low Frequency Oscillator	IV-6
III CIRCUIT DESCRIPTION	III-1	7) Low Frequency Oscillator Response	IV-7
3-1 Introduction	III-1	8) Output Meter Frequency Response Adjustment	IV-7
3-2 Oscillators	III-1	9) High Frequency Response Adjustment	IV-7
3-3 Buffer Amplifier	III-2	10) High Frequency Distortion Measurement	IV-8
3-4 AVC Amplifier	III-2	11) Check FM at 10 mc	IV-8
3-5 Output Amplifier	III-3	12) Calibration of High Frequency Oscillator	IV-8
3-6 Output Monitor	III-3	13) Calibration of X100KC Range	IV-9
3-7 Output Attenuator	III-3	14) Other Adjustments	IV-9
3-8 Power Supply	III-3	4-7 Trouble Shooting	IV-9
IV MAINTENANCE	IV-1	4-8 Drive Cable Replacement Procedure	IV-14
4-1 Cabinet Removal	IV-1	V REPLACEABLE PARTS	V-1
4-2 Lubrication of Tuning Capacitor Drive Mechanism	IV-1	5-1 Introduction	V-1
4-3 Drive System for Oscillator Tuning Capacitor	IV-1	5-2 Ordering Information	V-1
4-4 Tube Replacement	IV-1		
4-5 Miscellaneous Test and Adjustments	IV-3		

LIST OF ILLUSTRATIONS

Number	Title	Page	Number	Title	Page
2-1.	Schematic Diagram of Output Divider Cable	II-3	4-3.	Calibration and Response Check for Low Frequency Oscillator	IV-6
3-1.	Block Diagram Model 650A	III-0	4-4.	Equipment for High Frequency Distortion Measurement	IV-8
3-2.	Simplified Diagram of High Frequency Oscillator Section	III-2	4-5.	Model 650A Top View	IV-10
3-3.	Simplified Diagram of High Frequency Oscillator AVC System	III-2	4-6.	Model 650A Bottom View	IV-11
3-4.	Simplified Diagram for Power Supply Regulator	III-3	4-7.	Installation of Eyelets on Plastic Coated Cable	IV-14
4-1.	Lubrication Points for Tuning Capacitor Drive Mechanism	IV-2	4-8.	Exploded Rear View of Drive Cabling	IV-15
4-2.	100 kc Filter	IV-5	4-9.	Servicing Etched Circuit Boards	IV-16
			4-10.	Power Supply Section (Schematic)	IV-17
			4-11.	Oscillator Section (Schematic)	IV-18

LIST OF TABLES

4-1.	Tube Complement and Function Chart	IV-3
4-2.	Trouble Shooting	IV-12
5-1.	Replaceable Parts	V-1

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 Ω , X100 Ω , 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 slow-blow fuse for 115 volt operation. If instrument power transformer primary connections have been changed for 230 volt operation, a 1 ampere slow-blow 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 Model 650A Test Oscillator is as follows:

- Connect instrument to power source of 115 volt, 50-1000 cps unless modified for 230 volt operation.
- Turn instrument on and, for best results, allow a minimum warm-up time of 15 minutes.
- Select desired output frequency by adjusting the Range Switch and FREQUENCY controls.
- 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.

- "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 LOAD" 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.

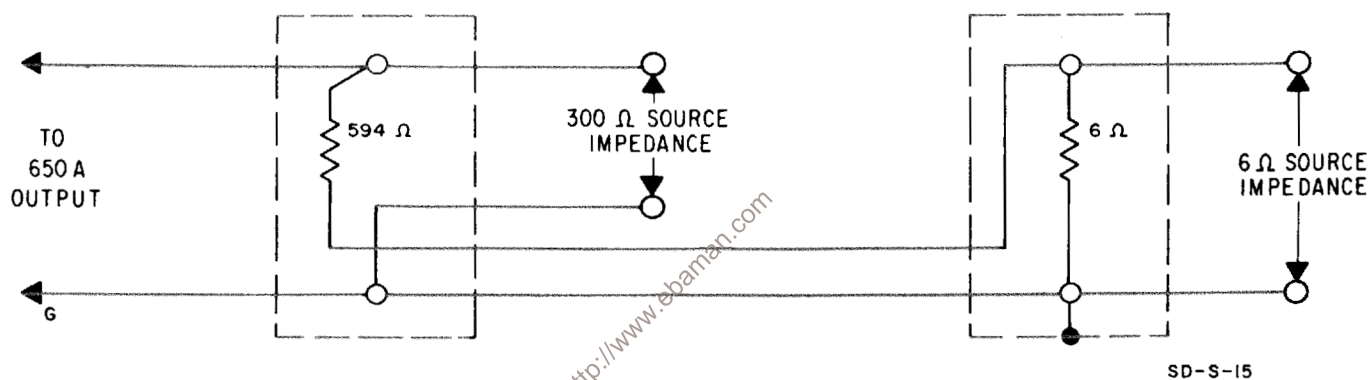
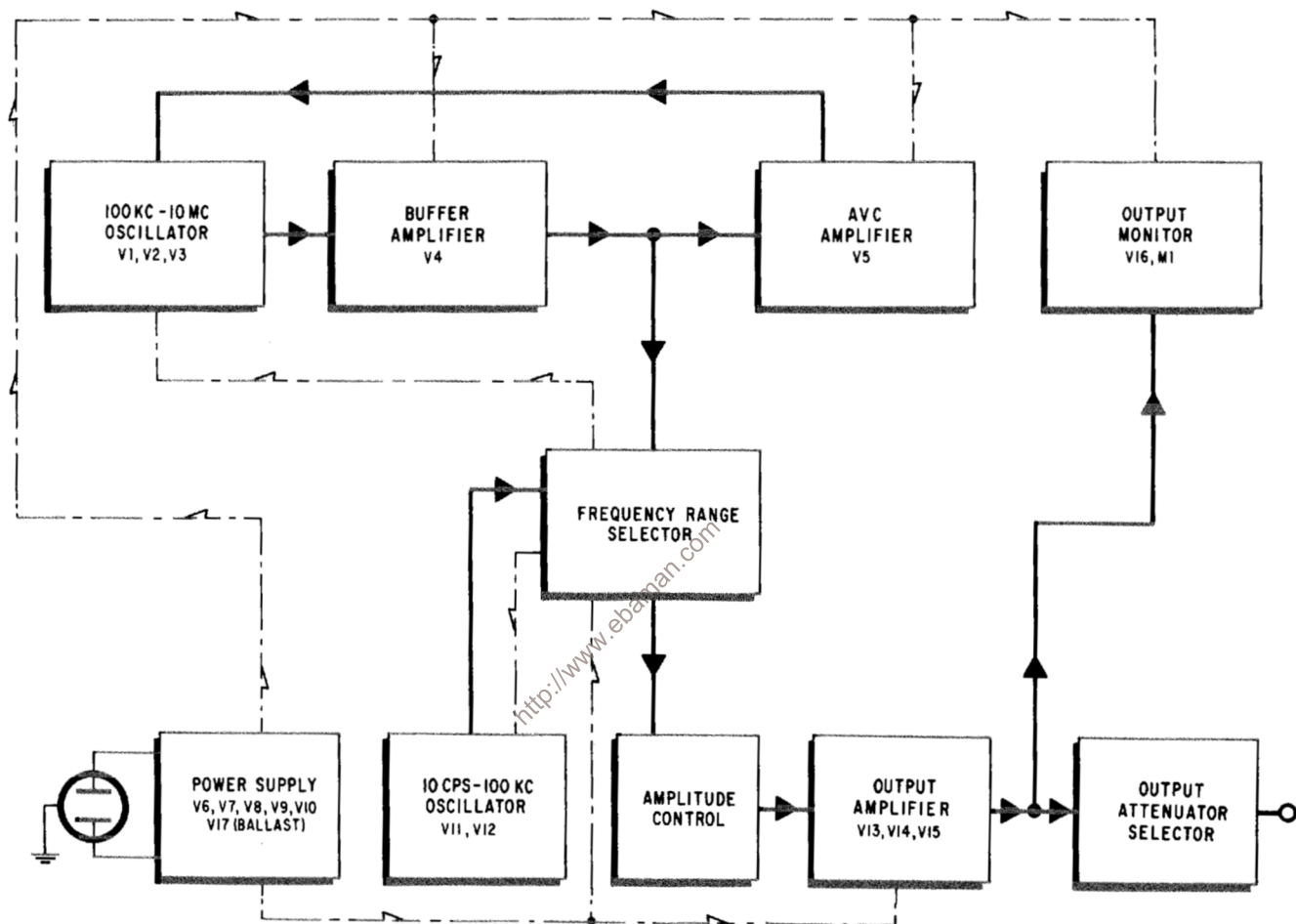


Figure 2-1. Schematic Diagram of Output Divider Cable

SD-S-15



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

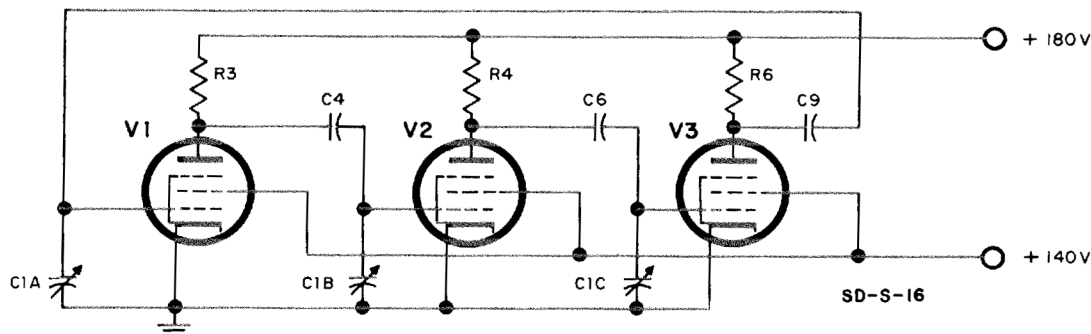


Figure 3-2. Simplified Diagram of High Frequency Oscillator Section

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.

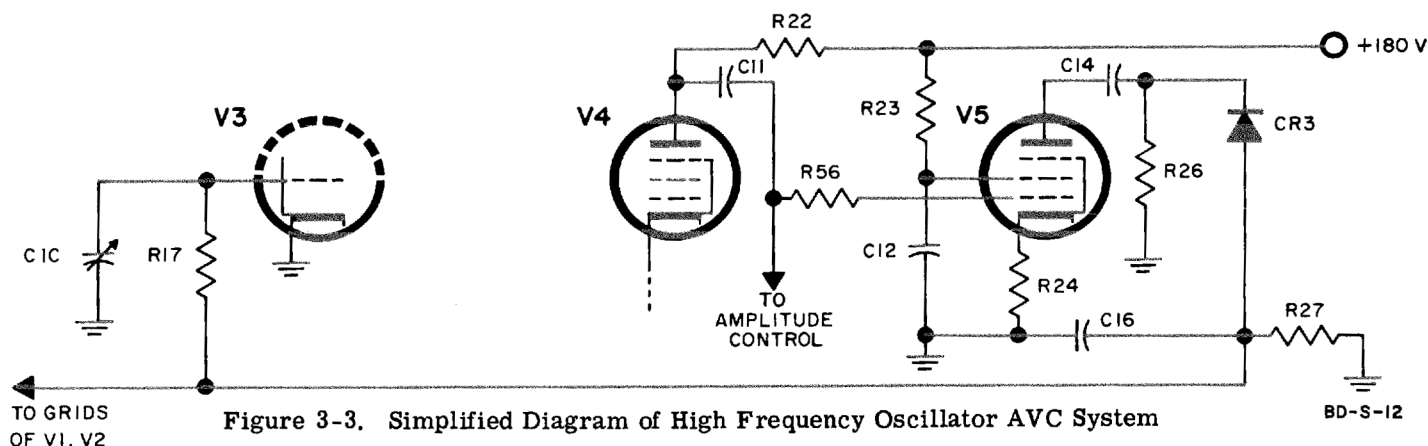


Figure 3-3. Simplified Diagram of High Frequency Oscillator AVC System

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 voltage from the AMPLITUDE control (R55) is amplified by a three stage feedback amplifier (V13, V14, and V15).

The output amplifier is stabilized with a negative feedback loop in the form of common cathode circuit for V13 and V15. In addition, the transconductance (G_m) of V13 and V14 is stabilized by local dc degenerative feedback. Thus, the amplifier has uniform gain and low distortion over the frequency range from 10 cps to 10 mc.

An adjustment (C38) is provided for adjusting the 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 5U4GA/B 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.

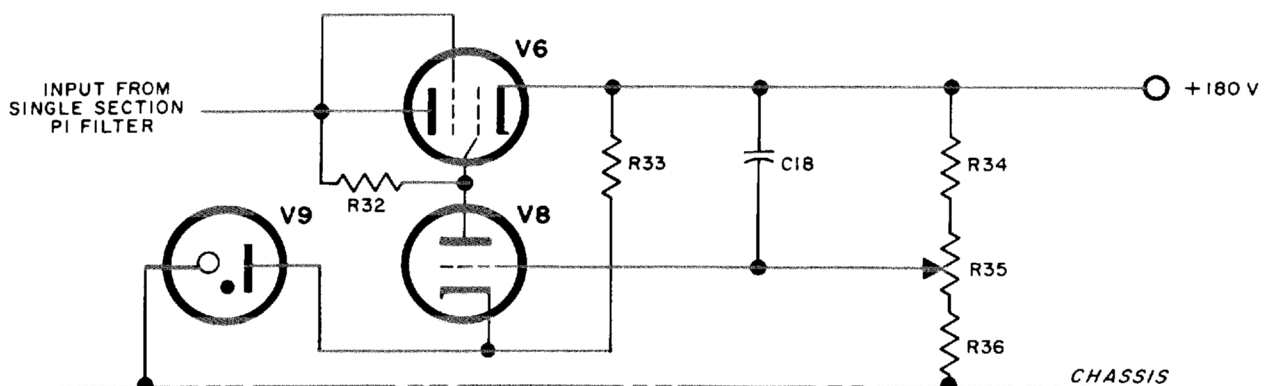


Figure 3-4. Simplified Diagram for Power Supply Regulator

SD-S-13

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 EIA 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 EIA 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.

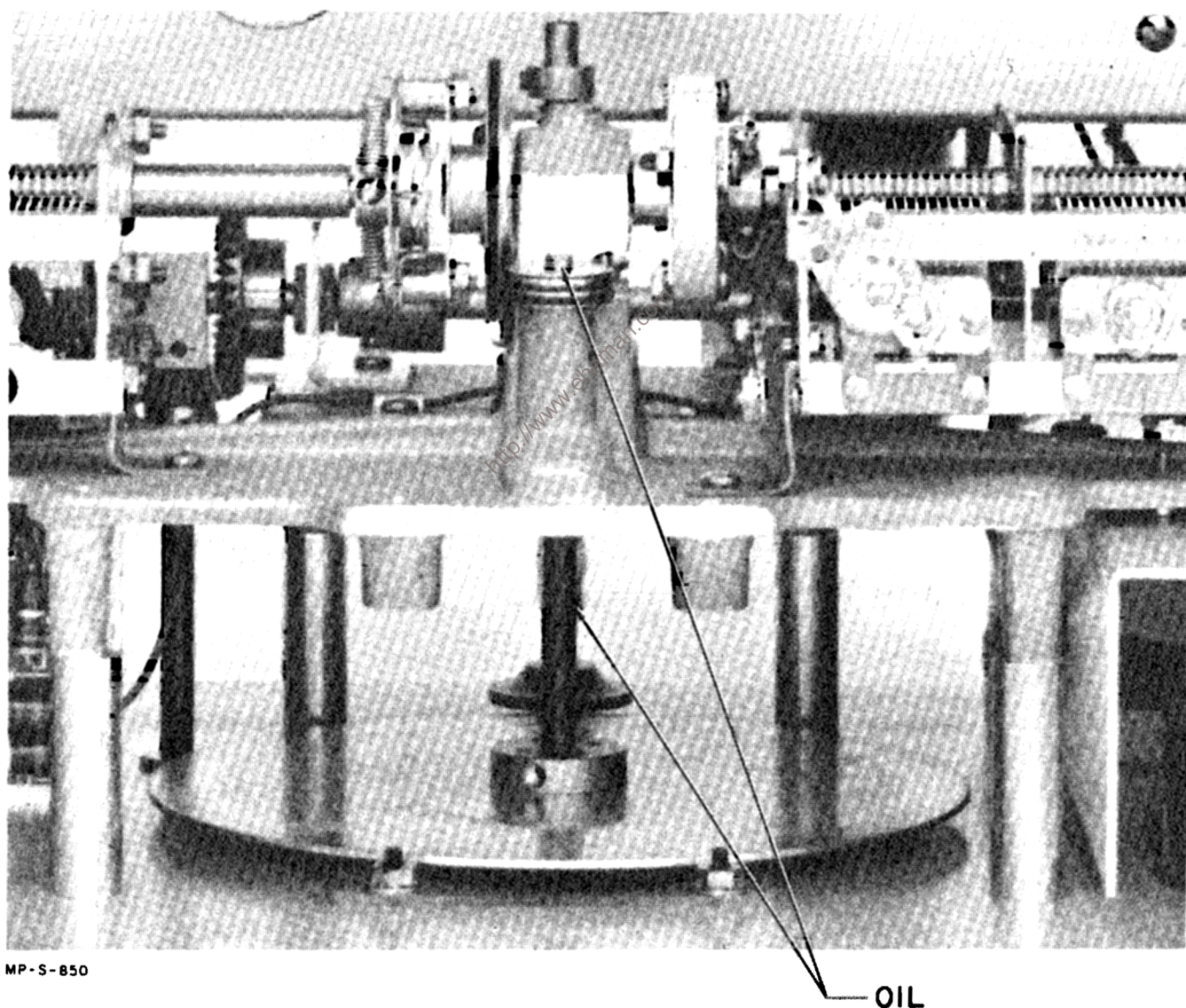


Figure 4-1. Lubrication Points for Tuning Capacitor Drive Mechanism

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	6EW6	Output Ampl. First Stage
V14	6EW6	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 Φ 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. Φ Models 410A and 410B are suitable for this purpose.
- b. A distortion analyzer such as Φ 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 Φ Model 100 Series 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 Φ Model 524 Series 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 Φ Model 150A or 160B.

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  Stock No. 48-3.

Refer to Figures 4-10 and 4-11 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.

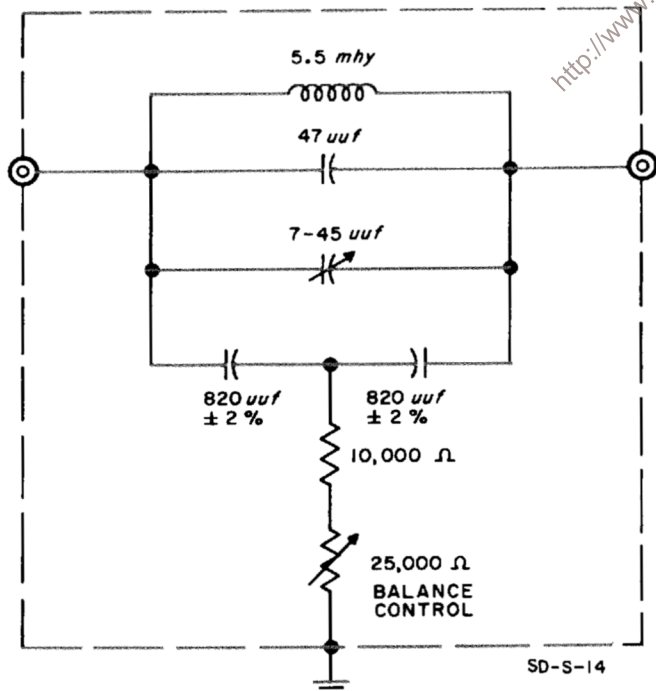


Figure 4-2. 100 kc Filter

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

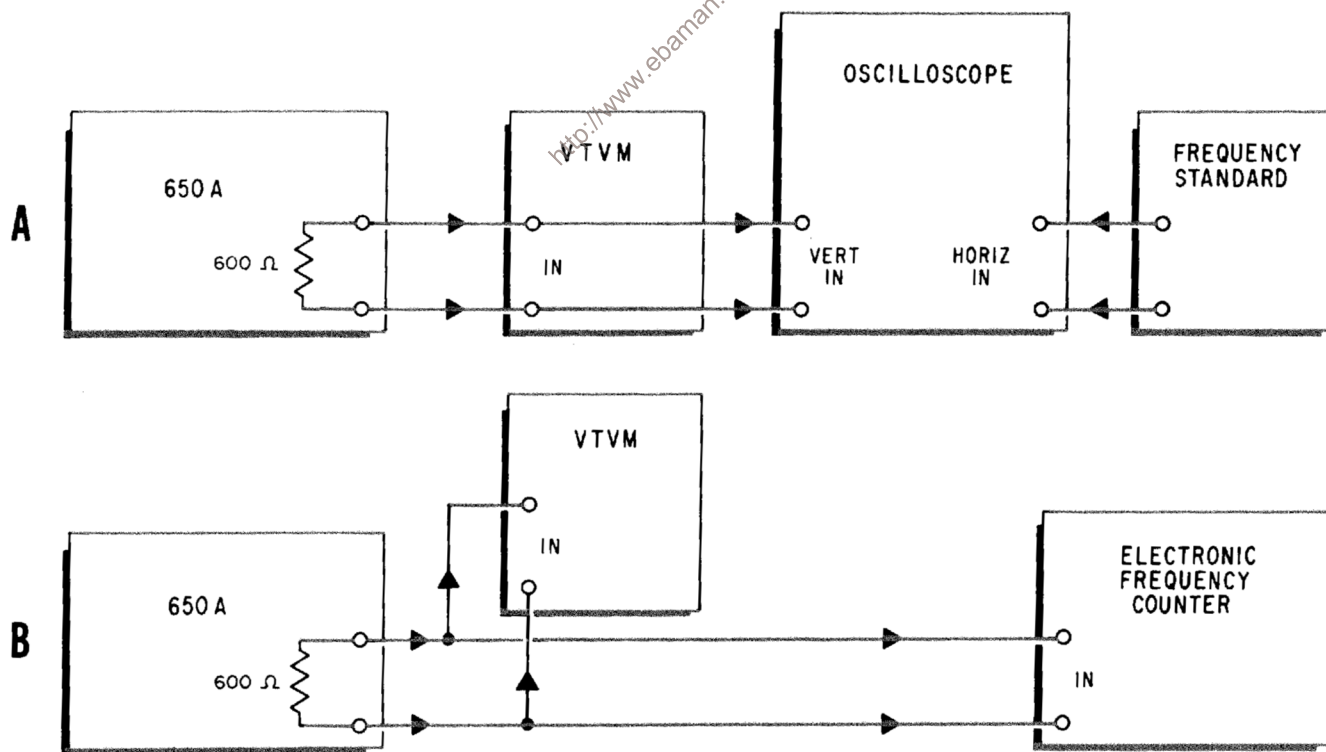


Figure 4-3. Calibration and Response Check for Low Frequency Oscillator
(Figure B is suitable over entire 650A frequency range.)

8D-S-28

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) 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.

9) HIGH FREQUENCY RESPONSE ADJUSTMENT

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

B. Turn H.F. Amplitude Adjust control (R25) maximum counterclockwise. Adjust C38 for minimum capacitance.

C. Set frequency range switch (S1) to "X1M" and frequency dial on "10" to provide a 10 mc output signal.


D. Adjust AMPLITUDE control (R55) to obtain 0 dbm indication on the internal voltmeter.

E. Set frequency dial on ".9" and adjust R25 to obtain 0 dbm indication on the internal voltmeter.

F. Set frequency dial on "10" and adjust C38 to obtain 0 dbm indication on the internal voltmeter.

G. Check overall frequency response of instrument from 10 cps to 10 mc. If necessary, repeat steps A through F (above). If the response is greater than ± 1 db (zero db reference point is at 1000 cps on the "X1KC" range) after completion of above adjustment, change the value of R90 in the plate circuit of V5 and repeat the procedure described above.

10) 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  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.

11) 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.

12) 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.

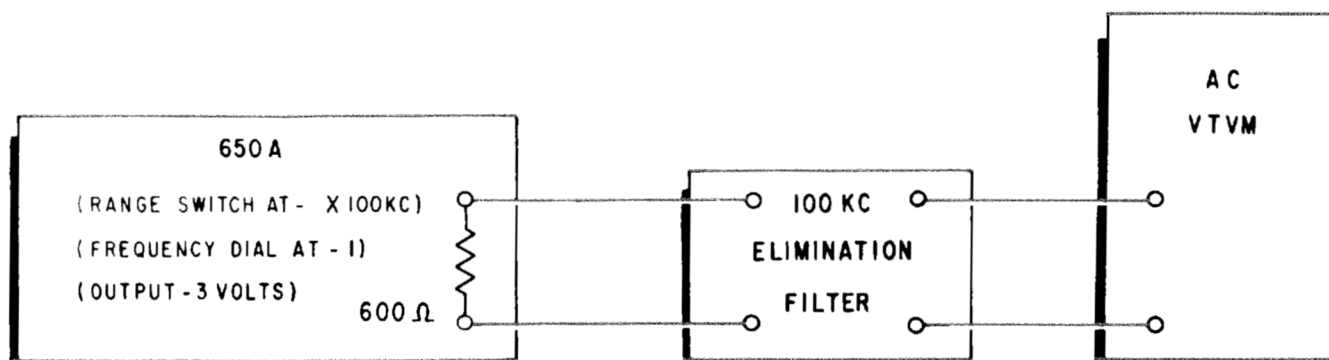


Figure 4-4. Equipment for High Frequency Distortion Measurement

BD-S-29

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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 (see step 6).

13) 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 pf, 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.

14) 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.

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

E. Check for a 60 pcs 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 Hewlett-Packard 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 table, 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 Hewlett-Packard sales office or the Hewlett-Packard Customer Service department directly.

All circuit references refer to Figures 4-10 and 4-11 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 EIA 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.

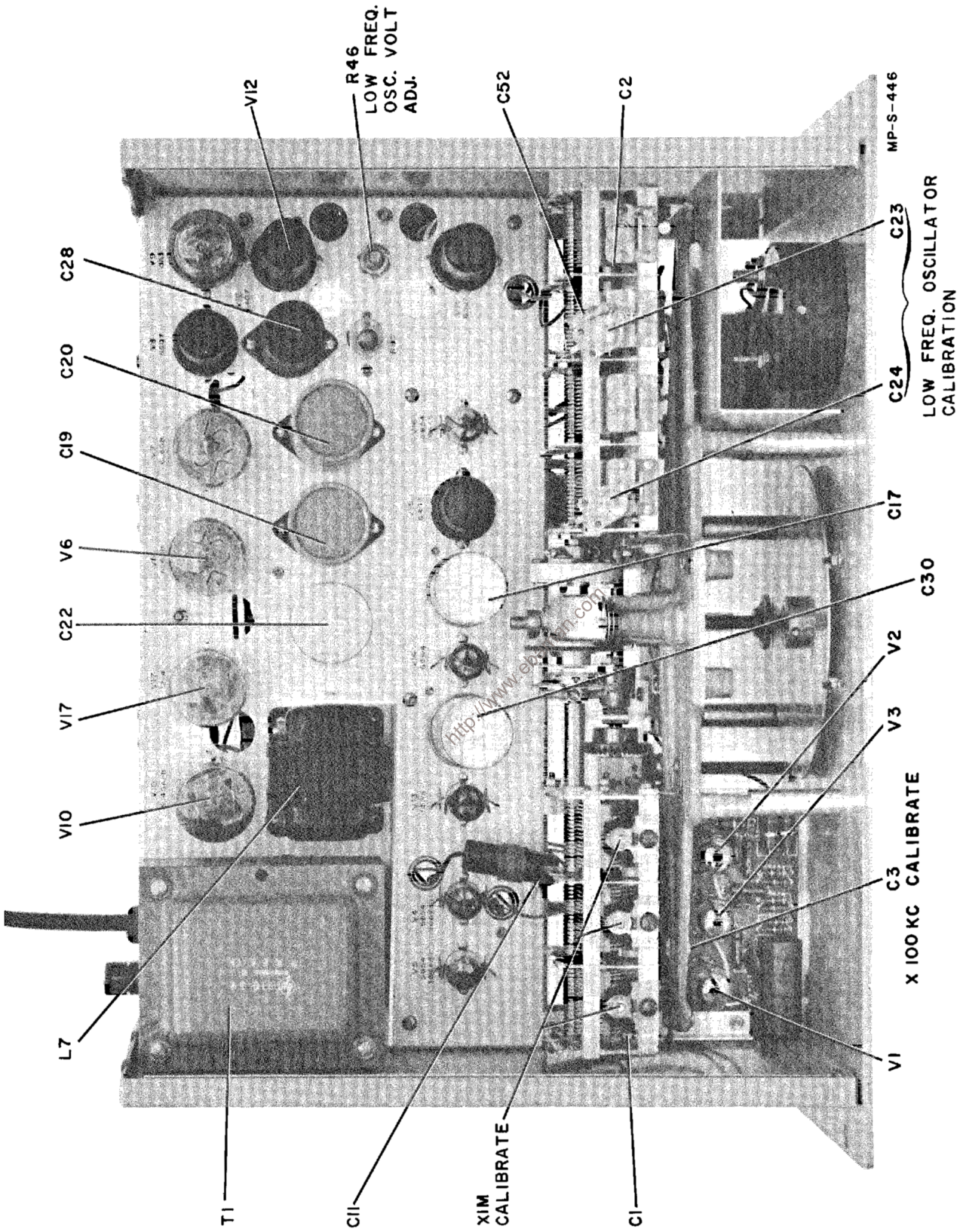


Figure 4-5. Model 650A Top View

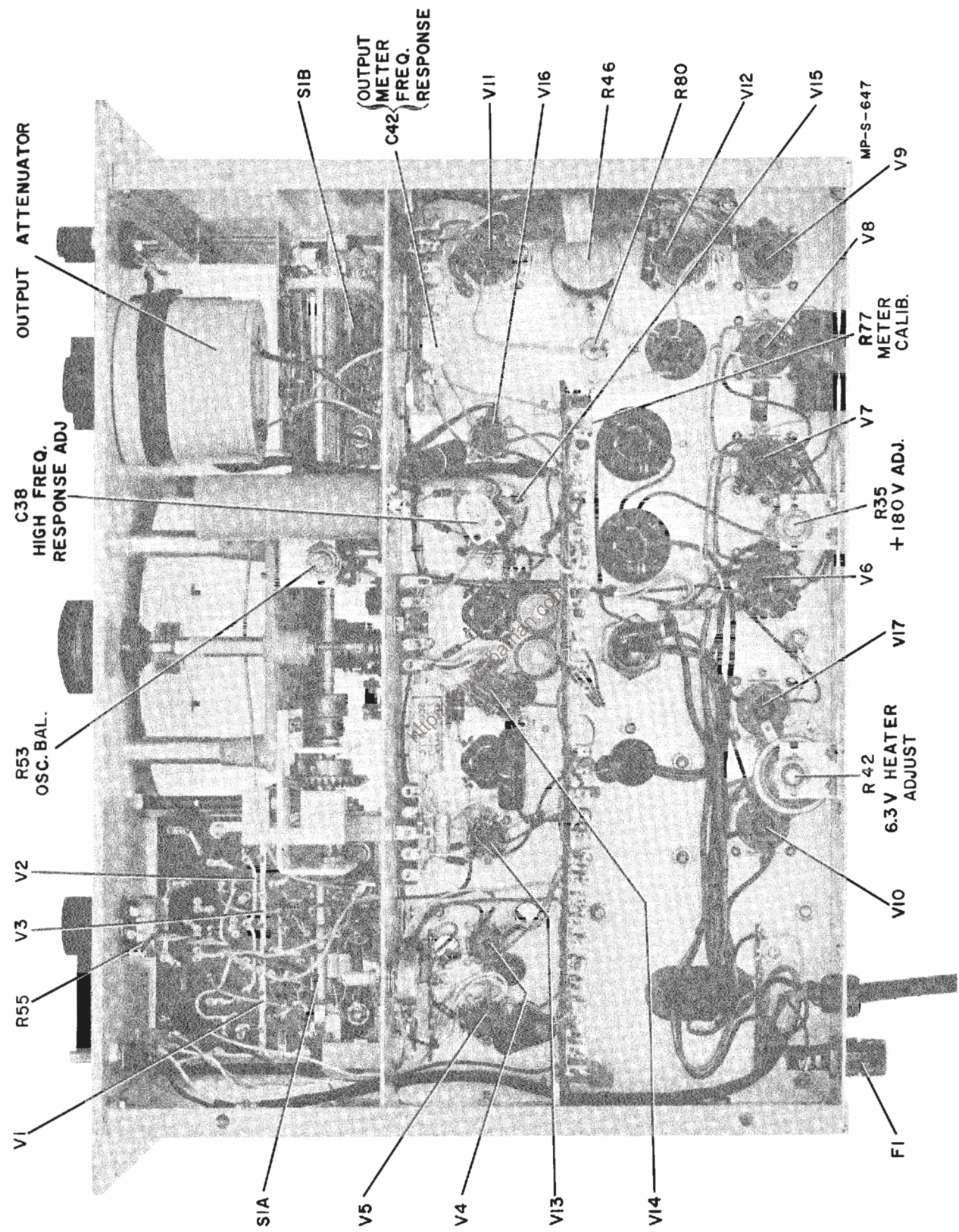


Figure 4-6. Model 650A Bottom View

TABLE 4-2. TROUBLE SHOOTING (Sheet 1 of 2)

Symptom	Cause and/or Remedy	Symptom	Cause and/or Remedy
Dead on all ranges.	Blown line fuse. Tube V13, V14, or V15 defective. Rectifier V10 defective. No B+ voltage.	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.
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.	Motorboating or parasitic oscillation.	Regulator tube V9 defective. Tubes V12 or V15 defective. Regulated power supply not regulating. Control R55 is wirewound.
High B+ voltage. Cannot be adjusted by R35 control.	Tubes V6 or V7 shorted. Tubes V8 or V9 defective. Resistor R36 open.	Intermittent or noisy output particularly during frequency adjustment.	Tuning gangs are dirty or intermittently shorting.
Instrument blows line fuses.	Shorted rectifier V10. Shorted filter capacitor. Choke L7 shorted to chassis. Defective power transformer. Shorted heater wiring.	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.
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.	Distortion and/or low output on all ranges.	B+ voltage not correct. Coil L5 open. Tubes V13, V14, and/or V15 defective. Defective coupling capacitor in output amplifier stages.
120 ν hum in instrument output.	Voltage regulator in power supply not regulating. Defective filter capacitors. Capacitor C18 defective.	Dead on two high ranges with no output meter indication on any range.	No regulated heater voltage for V1, V2, V3, V5, and V16 tubes. Ballast tube V17 defective or open power transformer winding.
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.	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.

TABLE 4-2. TROUBLE SHOOTING (Sheet 2 of 2)

Symptom	Cause and/or Remedy	Symptom	Cause and/or Remedy
Residual output meter indication.	C43 or C44 capacitor defective. Tube V16 defective. Control R55 defective. Hum in output amplifier stages.	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.
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.	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 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.	Low high frequency oscillator output.	Tube V5 defective. Low heater voltage. Resistor R25 defective. Tubes V1, V2, V3, and/or V4 weak.
Lamp R80 flashing.	Capacitors C2A, C23, and/or C52 shorted.	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.
Low frequency oscillator distortion	Tube V11 and/or V12 defective. Low frequency oscillator output voltage set too high. Defective coupling capacitor. Tube V5 gassy.	Distortion and fm in high frequency oscillator.	V1, V2, V3 and/or V4 defective.
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 high frequency response.	V1, V2, V3, V4, and/or V5 defective. Diode CR3 defective. Tubes V13, V14, and/or V15 defective. Coil 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.

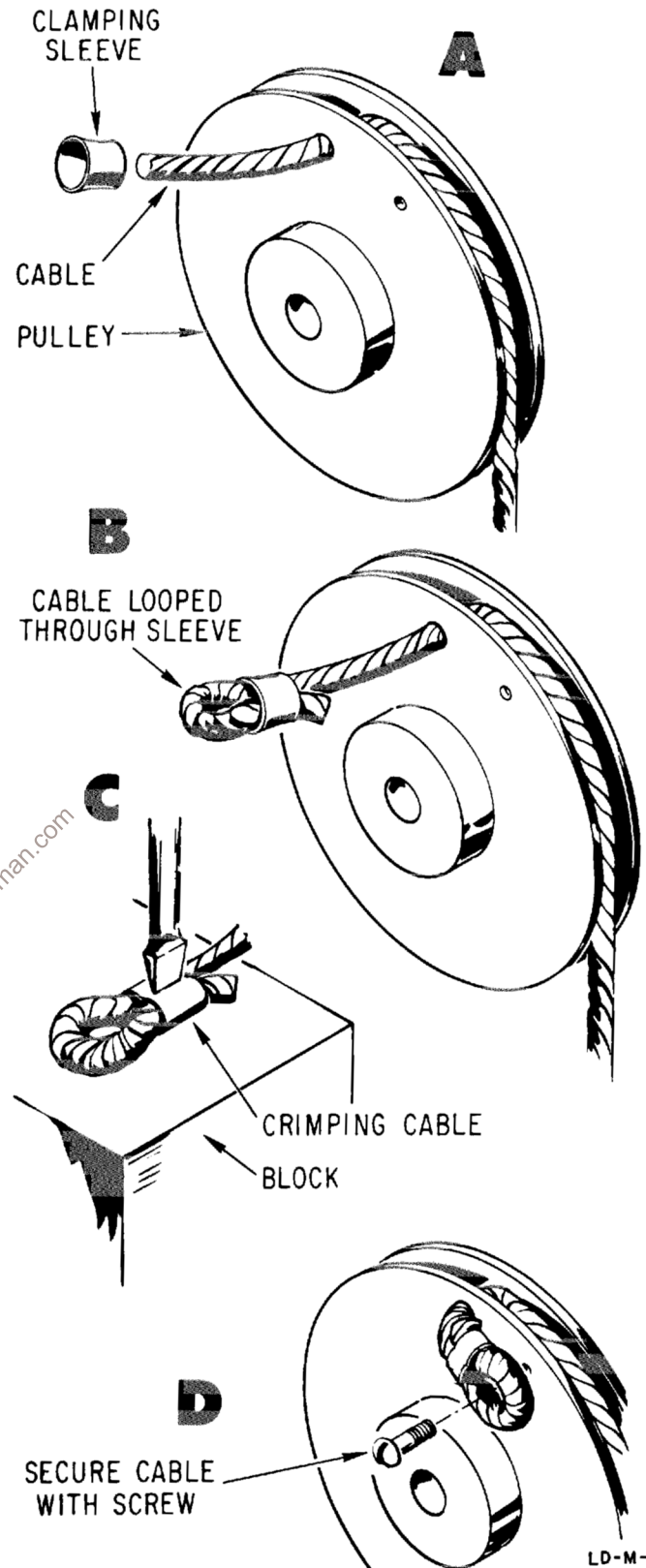


Figure 4-7. Installation of Eyelets on Plastic Coated Cable

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.)

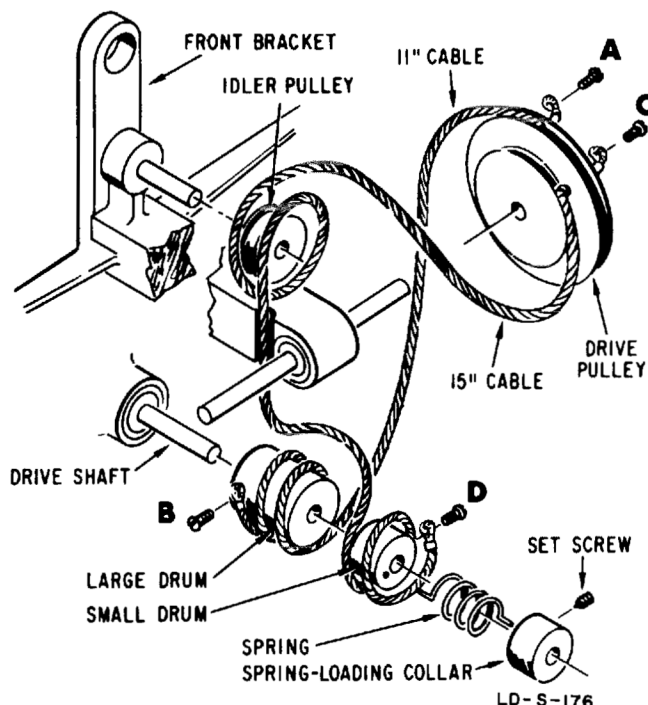


Figure 4-8. Exploded Rear View of Drive Cabling

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.

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

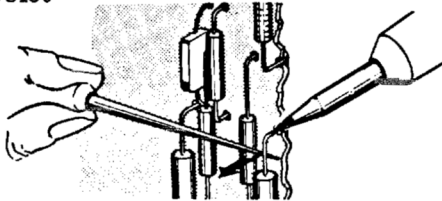
Use only high quality rosin core solder when repairing etched circuit boards. NEVER USE PASTE FLUX. After soldering, clean off any excess flux and coat the repaired area with a high quality electrical varnish or lacquer.

When replacing components with multiple mounting pins such as tube sockets, electrolytic capacitors, and potentiometers, it will be necessary to lift each pin slightly, working around the components several times until it is free.

WARNING: If the specific instructions outlined in the steps below regarding etched circuit boards without eyelets are not followed, extensive damage to the etched circuit board will result.

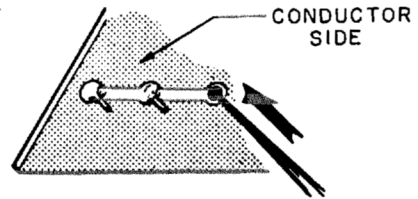
1. Apply heat sparingly to lead of component to be replaced. If lead of component passes through an eyelet

in the circuit board, apply heat on component side of board. If lead of component does not pass through an eyelet, apply heat to conductor side of board.

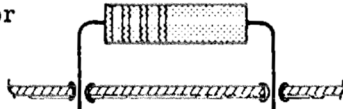


2. Reheat solder in vacant eyelet and quickly insert a small awl to clean inside of hole.

If hole does not have an eyelet, insert awl or a #57 drill from conductor side of board.

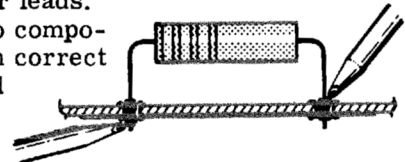


3. Bend clean tinned lead on new part and carefully insert through eyelets or holes in board.



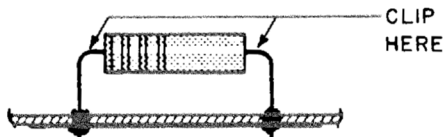
4. Hold part against board (avoid overheating) and solder leads.

Apply heat to component leads on correct side of board as explained in step 1.

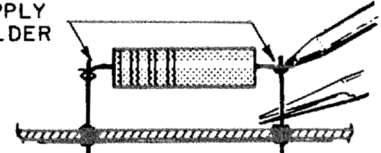


In the event that either the circuit board has been damaged or the conventional method is impractical, use method shown below. This is especially applicable for circuit boards without eyelets.

1. Clip lead as shown below.



2. Bend protruding leads upward. Bend lead of new component around protruding lead. Apply solder using a pair of long nose pliers as a heat sink.



This procedure is used in the field only as an alternate means of repair. It is not used within the factory.

Figure 4-9. Servicing Etched Circuit Boards

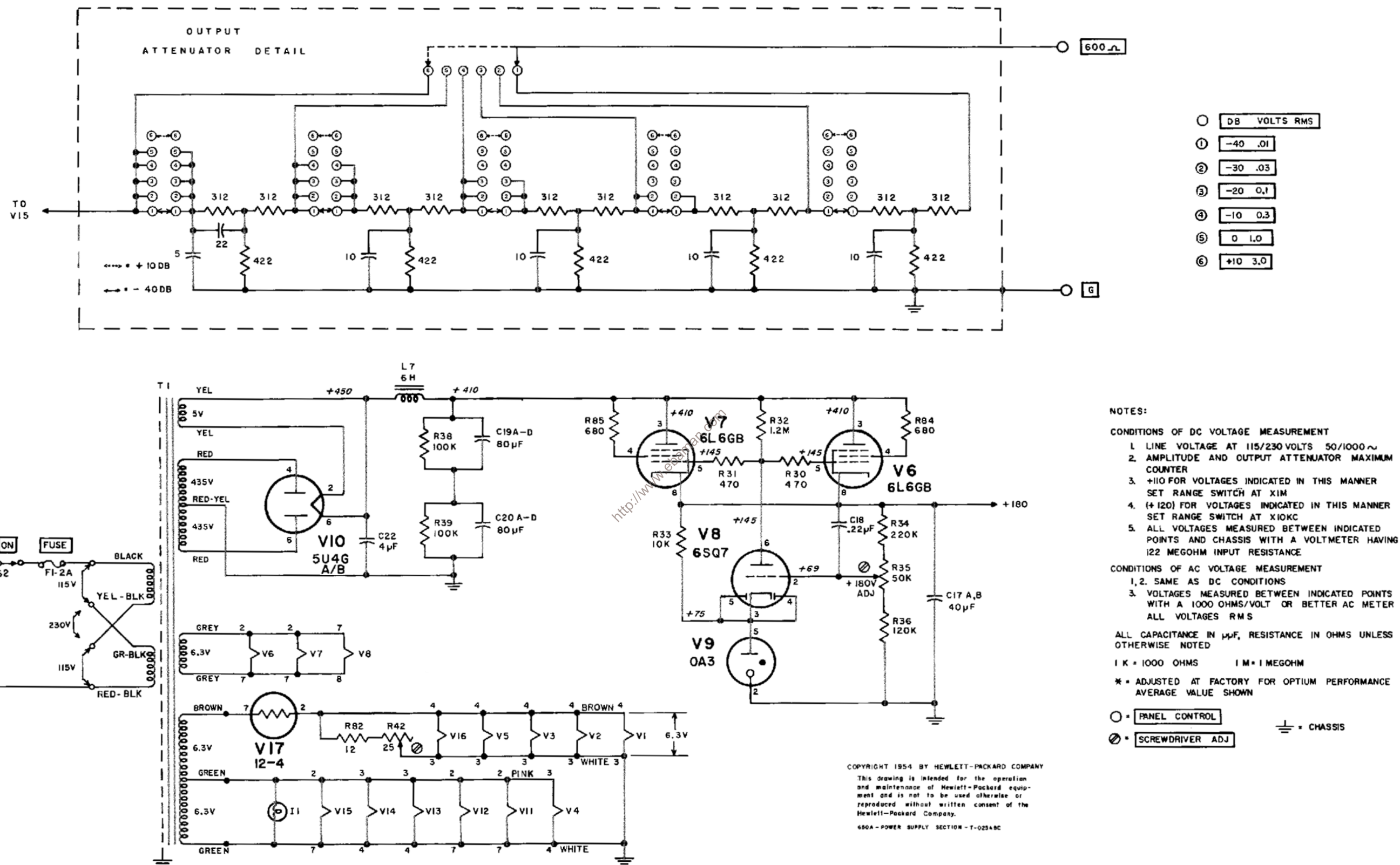


Figure 4-10. Power Supply Section

SECTION V

REPLACEABLE PARTS

5-1 INTRODUCTION

This section contains information for ordering replacement parts for the Model 650A Test Oscillator.

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

- a. Reference designator.
- b. Full description of the part.
- c. Manufacturer of the part in a five-digit code; see list of manufacturers in appendix.
- d. Hewlett-Packard stock number.
- e. Total quantity used in the instrument (TQ col).
- f. Recommended spare quantity for complete maintenance during one year of isolated service (RS col).

5-2 ORDERING INFORMATION

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

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

or, in Western Europe, to

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

Specify the following information for each part:

- a. Model and serial number of instrument.
- b. Hewlett-Packard stock number.
- c. Circuit reference designator.
- d. Description.

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

Table 5-1. Replaceable Parts (Sheet 1 of 11)

Ckt Ref	Description	Mfr	Ⓜ Stock No.	TQ	RS		
C1ABC	Capacitor: variable, air, 603 pf max: 3 section	76854	0121-0015	1	1		
C2AB	Capacitor: variable, air, 12.4 pf-535 pf/sect. 4 sections	76854	0121-0004	1	1		
C3	Capacitor: variable, trimmer, ceramic, 5-25 pf, 500 vdcw	72982	0130-0012	1	1		
C4	Capacitor: fixed, mica, 0.01 μ f, $\pm 10\%$, 300 vdcw	72136	0140-0171	3	1		
C5	Capacitor: fixed, ceramic, 10 pf ± 0.5 pf, 500 vdcw	96095	0150-0009	2	1		

Table 5-1. Replaceable Parts (Sheet 2 of 11)

Ckt Ref	Description	Mfr *	Ⓢ Stock No.	TQ*	RS*		
C6	Same as C4						
C7	Not assigned						
C8	Same as C5						
C9	Same as C4						
C10	Capacitor: fixed, ceramic, 0.01 μ f \pm 20%, 1000 vdcw	56289	0150-0012	4	1		
C11	Capacitor: fixed, paper, 0.22 μ f \pm 10%, 400 vdcw	56289	0160-0018	2	1		
C12	Same as C10						
C13	Capacitor: fixed, paper, 0.1 μ f \pm 10%, 400 vdcw	56289	0160-0013	3	1		
C14	Capacitor: fixed, mica, 4700 pf \pm 10%, 500 vdcw	76433	0140-0017	1	1		
C15	Not assigned						
C16	Capacitor: fixed, ceramic, 2000 pf \pm 20%, 1000 vdcw	91418	0150-0023	1	1		
C17	Capacitor: fixed, electrolytic, 4 sections, 20 μ f/sect., 450 vdcw	37942	0180-0025	4	1		
C18	Same as C11						
C19,20	Same as C17						
C21	Not assigned						
C22	Capacitor: fixed, paper, 4 μ f \pm 10%, 600 vdcw	00853	0160-0077	1	1		
C23	Capacitor: variable ceramic, 7-45 pf, 500 vdcw	72982	0130-0001	3	1		
C24	Capacitor: variable ceramic, 5-20 pf, 500 vdcw	72982	0130-0006	2	1		
C25	Same as C23						
C26	Not assigned						
C27	Capacitor: fixed, paper, 0.5 μ f \pm 10%, 400 vdcw	14655	0160-0024	1	1		

* See introduction to this section

Table 5-1. Replaceable Parts (Sheet 3 of 11)

Ckt Ref	Description	Mfr *	Ⓢ Stock No.	TQ*	RS*		
C28	Capacitor: fixed, electrolytic, 20 μ f, 450 vdcw	00656	0180-0011	1	1		
C29, 30	Not assigned						
C31	Same as C17						
C32	Capacitor: fixed, mica, 820 pf $\pm 5\%$, 500 vdcw	00853	0140-0091	1	1		
C33	Capacitor: fixed, mylar, 1 μ f $\pm 5\%$, 200 vdcw	84411	0170-0018	1	1		
C34	Not assigned						
C35	Capacitor: fixed, electrolytic, 35 μ f, -10%, +100%, 6 vdcw	56289	0180-0064	1	1		
C36	Same as C13						
C37	Capacitor: fixed, ceramic, 0.05 μ f $\pm 20\%$, 400 vdcw	19701	0150-0052	2	1		
C38	Same as C23						
C39	Capacitor: fixed, electrolytic, 80 μ f, -10%, +100%, 300 vdcw	37942	0180-0044	1	1		
C40	Same as C13						
C41	Not assigned						
C42	Same as C24						
C43, 44	Capacitor: fixed, electrolytic, 50 μ f, -10% +200%, 50 vdcw	37942	0180-0029	2	1		
C45, 46	Capacitor: fixed, mica, 390 pf $\pm 10\%$, 500 vdcw	76433	0140-0030	2	1		
C47	Not assigned						
C48, 49	Same as C10						
C50	Capacitor: fixed, electrolytic, 10 μ f $\pm 50\%$, 450 vdcw	37942	0180-0005	1	1		
C51	Not assigned						
C52	Capacitor: fixed, ceramic, 22 pf $\pm 5\%$, 500 vdcw	96095	0150-0001	1	1		

* See introduction to this section

Table 5-1. Replaceable Parts (Sheet 4 of 11)

Ckt Ref	Description	Mfr *	Ⓟ Stock No.	TQ*	RS*		
C53	Capacitor: fixed, titanium dioxide, 3.3 pf $\pm 10\%$, 500 vdcw	78488	0150-0022	1	1		
C54	Capacitor: fixed, electrolytic, 10 μ f, 10 vdcw	56289	0180-0032	1	1		
C55	Capacitor: fixed, paper, 0.033 μ f $\pm 10\%$, 600 vdcw	56289	0160-0004	1	1		
C56	Capacitor: fixed, mica, 22 pf $\pm 5\%$, 500 vdcw	76433	0140-0034	1	1		
C57	Same as C37						
CR1, 2,3	Diode, germanium	73293	1910-0011	3	3		
F1	Fuse, cartridge: 2 amps, slow-blow, for 115V operation	71400	2110-0006	1	10		
	Fuse, cartridge: 1 amp, slow-blow, for 230V operation	71400	2110-0007				
I1	Lamp, incandescent: 6-8V, 2 pin base, GE #12	24455	2140-0012	1	1		
L1	Coil, R.F.: 6.8 μ h	99848	9140-0026	1	1		
L2 thru L4	Not assigned						
L5	Coil, R.F.: 4.7 μ h, $\pm 10\%$	99848	9140-0025	1	1		
L6	Coil, R.F.: .2 μ h	28480	65A-60H	1	1		
L7	Reactor, filter: power supply, 6h	28480	9110-0002	1	1		
L8	Coil, R.F.: 8 μ h	28480	65A-60G	1	1		
M1	Meter	55026	1120-0014	1	1		
P1	Cable, power	70903	8120-0015	1	1		
R1,2	Resistor: fixed, deposited carbon, 4860 ohms, $\pm 1\%$, 1/2 W	19701	0727-0135	3	1		
R3,4	Resistor: fixed, deposited carbon, 495 ohms $\pm 1\%$, 1/2 W	19701	0727-0076	3	1		

* See introduction to this section

Table 5-1. Replaceable Parts (Sheet 5 of 11)

Ckt Ref	Description	Mfr *	Ⓢ Stock No.	TQ*	RS*		
R5	Same as R1						
R6	Same as R3						
R7	Resistor: fixed, deposited carbon, 16.71 megohms, $\pm 1\%$, 1 W	19701	0730-0147	2	1		
R8	Resistor: fixed, deposited carbon, 1.63 megohms, $\pm 1\%$, 1 W	19701	0730-0110	2	1		
R9	Resistor: fixed, deposited carbon, 160,000 ohms, $\pm 1\%$, 1 W	19701	0730-0075	2	1		
R10, 11	Resistor: fixed, deposited carbon, 15,800 ohms, $\pm 1\%$, 1 W	19701	0730-0036	2	1		
R12	Same as R9						
R13	Same as R8						
R14	Same as R7						
R15	Resistor: fixed, composition, 220,000 ohms, $\pm 10\%$, 1/2 W	01121	0687-2241	1	1		
R16	Resistor: fixed, composition, 120,000 ohms, $\pm 10\%$, 1/2 W	01121	0687-1241	1	1		
R17	Resistor: fixed, composition, 270,000 ohms, $\pm 10\%$, 1/2 W	01121	0687-2741	2	1		
R18	Resistor: fixed, composition, 4700 ohms, $\pm 10\%$, 1 W	01121	0690-4721	2	1		
R19	Resistor: fixed, composition, 180,000 ohms, $\pm 10\%$, 1/2 W	01121	0687-1841	1	1		
R20	Not assigned						
R21	Resistor: fixed, composition, 47 ohms, $\pm 10\%$, 1/2 W	01121	0687-4701	5	2		
R22	Resistor: fixed, composition, 5600 ohms, $\pm 10\%$, 1 W	01121	0690-5621	2	1		
R23	Resistor: fixed, composition, 22,000 ohms, $\pm 10\%$, 1/2 W	01121	0687-2231	2	1		
R24	Resistor: fixed, composition, 220 ohms, $\pm 10\%$, 1/2 W	01121	0687-2211	3	1		

* See introduction to this section

Table 5-1. Replaceable Parts (Sheet 6 of 11)

Ckt Ref	Description	Mfr *	Ⓢ Stock No.	TQ*	RS*		
R25	Resistor: variable, composition, linear taper, 1000 ohms	71590	2100-0036	1	1		
R26	Resistor: fixed, composition, 10,000 ohms, $\pm 10\%$, 1/2 W	01121	0687-1031	1	1		
R27	Resistor: fixed, composition, 100,000 ohms, $\pm 10\%$, 1 W	01121	0690-1041	3	1		
R28, 29	Not assigned						
R30, 31	Resistor: fixed, composition, 470 ohms, $\pm 10\%$, 1/2 W	01121	0687-4711	2	1		
R32	Resistor: fixed, composition, 1.2 megohms, $\pm 10\%$, 1 W	01121	0690-1251	1	1		
R33	Resistor: fixed, composition, 10,000 ohms, $\pm 10\%$, 2 W	01121	0693-1031	2	1		
R34	Resistor: fixed, composition, 220,000 ohms, $\pm 10\%$, 1 W	01121	0690-2241	2	1		
R35	Resistor: variable, composition, linear taper, 50,000 ohms, $\pm 20\%$, 1/2 W	71590	2100-0013	1	1		
R36	Resistor: fixed, composition, 120,000 ohms, $\pm 10\%$, 1 W	01121	0690-1241	1	1		
R37	Not assigned						
R38, 39	Same as R27						
R40, 41	Not assigned						
R42	Resistor: variable, wirewound, 25 ohms, $\pm 10\%$, 3 W	71590	2100-0035	1	1		
R43	Resistor: fixed, composition, 47,000 ohms, $\pm 10\%$, 1 W	01121	0690-4731	2	1		
R44	Resistor: fixed, composition, 56,000 ohms, $\pm 10\%$, 1 W	01121	0690-5631	1	1		
R45	Resistor: fixed, composition, 82,000 ohms, $\pm 10\%$, 1 W	01121	0690-8231	1	1		
R46	Resistor: variable, wirewound, 5000 ohms	01121	2100-0006	1	1		

* See introduction to this section

Table 5-1. Replaceable Parts (Sheet 7 of 11)

Ckt Ref	Description	Mfr *	Ⓢ Stock No.	TQ *	RS *		
R47, 48	Not assigned						
R49	Same as R34						
R50	Resistor: fixed, composition, 150 ohms $\pm 10\%$, 1 W Optimum value selected at factory. Average value shown.	01121	0690-1511	1	1		
R51A	Resistor: fixed, wirewound, 3000 ohms $\pm 10\%$, 10 W	35434	0816-0002	1	1		
R51B	Resistor: fixed, composition, 820 ohms $\pm 10\%$, 2 W	01121	0693-8211	1	1		
R52	Not assigned						
R53	Resistor: variable, composition, linear taper, 10,000 ohms $\pm 30\%$, 1/3 W	11237	2100-0167	1	1		
R54	Resistor: fixed, composition, 7500 ohms $\pm 5\%$, 1 W	01121	0689-7525	1	1		
R55	Resistor: variable, composition, linear taper, 500 ohms, $\pm 10\%$	12697	2100-0019	1	1		
R56	Resistor: fixed, composition, 56 ohms $\pm 10\%$, 1/2 W	01121	0687-5601	2	1		
R57	Not assigned						
R58	Resistor: fixed, composition, 330 ohms $\pm 10\%$, 1/2 W	01121	0687-3311	2	1		
R59	Same as R33						
R60	Resistor: fixed, composition, 18,000 ohms $\pm 10\%$, 1 W	01121	0690-1831	2	1		
R61	Resistor: fixed, composition, 82,000 ohms $\pm 10\%$, 1/2 W	01121	0687-8231	2	1		
R62	Same as R58						
R63	Not assigned						
R64	Same as R18						
R65	Same as R22						

* See introduction to this section

Table 5-1. Replaceable Parts (Sheet 8 of 11)

Ckt Ref	Description	Mfr *	Ⓢ Stock No.	TQ *	RS *		
R66	Same as R17						
R67	Resistor: fixed, composition, 51 ohms $\pm 5\%$, 1 W	01121	0689-5105	1	1		
R68	Resistor: fixed, composition, 910 ohms, $\pm 5\%$, 1 W	01121	0689-9115	1	1		
R69, 70	Resistor: fixed, composition, 39 ohms $\pm 10\%$, 1/2 W	01121	0687-3901	2	1		
R71	Resistor: fixed, composition, 470,000 ohms $\pm 10\%$, 1/2 W	01121	0687-4741	3	1		
R72, 73	Same as R24						
R74	Resistor: fixed, composition, 820 ohms $\pm 10\%$, 1/2 W	01121	0687-8211	1	1		
R75, 76	Resistor: fixed, composition, 220 ohms $\pm 10\%$, 1 W	01121	0690-2211	2	1		
R77	Resistor: variable, wirewound, linear taper, 500 ohms $\pm 20\%$, 1 W	11236	2100-0022	1	1		
R78	Resistor: fixed, composition, 1000 ohms $\pm 10\%$, 1/2 W	01121	0687-1021	1	1		
R79	Same as R23						
R80	Lamp, incandescent: 250V, 10 W	24455	2140-0007	1	1		
R81	Same as R56						
R82	Resistor: fixed, wirewound, 12 ohms $\pm 10\%$, 10 W	35434	0816-0010	1	1		
R83	Same as R43						
R84, 85	Resistor: fixed, composition, 680 ohms $\pm 10\%$, 1 W	01121	0690-6811	3	1		
R86	Resistor: fixed, composition, 270 ohms $\pm 10\%$, 1 W	01121	0690-2711	1	1		
R87	Same as R21						
R88	Resistor: fixed, composition, 22,000 ohms $\pm 10\%$, 1 W	01121	0690-2231	1	1		
R89	Resistor: fixed, composition, 6800 ohms $\pm 10\%$, 2 W	01121	0693-6821	2	1		

* See introduction to this section

Table 5-1. Replaceable Parts (Sheet 9 of 11)

Ckt Ref	Description	Mfr *	Ⓟ Stock No.	TQ*	RS*		
R90	Resistor: fixed, composition, 82 ohms $\pm 10\%$, 1/2 W Optimum value selected at factory Average value shown	01121	0687-8201	1	1		
R91	Same as R89						
R92	Resistor: fixed, composition, 2.2M $\pm 10\%$, 1/2 W	01121	0687-2251	1	1		
R93	Same as R61						
R94	Same as R21						
R95	Resistor: fixed, composition, 150 ohms $\pm 10\%$, 1/2 W	01121	0687-1511	1	1		
R96, 97	Same as R71						
R98	Resistor: fixed, composition, 3.3 megohms $\pm 10\%$, 1/2 W	01121	0687-3351	1	1		
R99	Same as R21						
R100	Same as R60						
R101	Same as R21						
R102	Same as R84						
R103	Resistor: fixed, composition, 1500 ohms $\pm 5\%$, 1 W	01121	0689-1525	1	1		
S1A	Range Switch Assembly (high frequency)	28480	65A-19WH	1	1		
S1B	Range Switch Assembly (high frequency)	28480	65A-19WL	1	1		
S2	Switch, toggle: SPST	04009	3101-0001	1	1		
T1	Transformer, power	28480	9100-0012	1	1		
V1, 2, 3, 4, 5	Tube, electron: 5654	80131	1923-0001	6	6		
V6, 7	Tube, electron: 6L6GB	80131	1923-0035	2	2		
V8	Tube, electron: 6SQ7	80131	1939-0005	1	1		
V9	Tube, electron: OA3	80131	1940-0006	1	1		

* See introduction to this section

Table 5-1. Replaceable Parts (Sheet 10 of 11)

Ckt Ref	Description	Mfr *	Ⓢ Stock No.	TQ*	RS*		
V10	Tube, electron: 5U4GA/B	80131	1930-0008	1	1		
V11	Tube, electron: 6SJ7	80131	1923-0037	1	1		
V12	Tube, electron: 6AG7	80131	1923-0016	2	2		
V13, 14	Tube, electron: 6EW6	80131	1923-0043	2	2		
V15	Same as V12						
V16	Same as V1						
V17	Tube, ballast: glass, octal base, #12-4	70563	0852-0001	1	1		
	<u>MISCELLANEOUS</u>						
	Attenuator Assembly (output) complete	28480	65A-34	1	1		
	Bearing Ball	28480	1410-0024	1	0		
	Binding Post Assembly: black	28480	AC-10C	1	1		
	Binding Post Assembly: red	28480	AC-10D	1	1		
	Cable Assembly: output	28480	65A-16D	1	0		
	Conversion Kit: (for field conversion of cabinet mount to rack mount)	28480	35F-95A	1	0		
	Cable, mechanical: for dial drive assembly	28480	G-18A	1	1		
	Disc, vernier drive	28480	G-14H	1	0		
	Eschutcheon, dial window	28480	G-99E	1	0		
	Holder, fuse	75915	1400-0084	1	1		
	Holder, lamp: (for R80)	72765	1450-0013	1	0		
	Insulator, binding post	28480	AC-54A	1	0		
	Jewel, pilot light	72765	1450-0020	1	0		
	Knob: AMPLITUDE	28480	G-74K	1	0		
	Knob: FREQUENCY, RMS VOLTS	28480	G-74N	2	0		
	Knob: tuning dial	28480	G-74R	2	0		
	Lampholder, for I1	72765	1450-0022	1	0		

* See introduction to this section

Table 5-1. Replaceable Parts (Sheet 11 of 11)

Ckt Ref	Description	Mfr *	Ⓢ Stock No.	TQ*	RS*
	Resistor: 6 ohms, for output cable assembly	28480	65A-95A	1	1
	Spring, compression	28480	1460-0063	1	1
	Window, dial	28480	202A-40B	1	0

* See introduction to this section

APPENDIX

CODE LIST OF MANUFACTURERS (Sheet 1 of 2)

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

CODE NO.	MANUFACTURER	ADDRESS	CODE NO.	MANUFACTURER	ADDRESS	CODE NO.	MANUFACTURER	ADDRESS
00334	Humidial Co.	Colton, Calif.	08792	CBS Electronics Semiconductor Operations, Div. of C.B.S. Inc.	Lowell, Mass.	70276	Allen Mfg. Co.	Hartford, Conn.
00335	Westrex Corp.	New York, N.Y.	09134	Texas Capacitor Co.	Houston, Texas	70309	Allied Control Co., Inc.	New York, N.Y.
00373	Garlock Packing Co., Electronic Products Div.	Camden, N.J.	09250	Electro Assemblies, Inc.	Chicago, Ill.	70485	Atlantic India Rubber Works, Inc.	Chicago, Ill.
00656	Aerovox Corp.	New Bedford, Mass.	09569	Mallory Battery Co. of Canada, Ltd.	Toronto, Ontario, Canada	70563	Amperite Co., Inc.	New York, N.Y.
00779	Amp, Inc.	Harrisburg, Pa.	10411	Ti-Tal, Inc.	Berkeley, Calif.	70903	Belden Mfg. Co.	Chicago, Ill.
00781	Aircraft Radio Corp.	Boonton, N.J.	10646	Carborundum Co.	Niagara Falls, N.Y.	70998	Bird Electronic Corp.	Cleveland, Ohio
00853	Sangamo Electric Co., Cap. Div.	Marion, Ill.	11236	CTS of Berne, Inc.	Berne, Ind.	71002	Birnbach Radio Co.	New York, N.Y.
00866	Goe Engineering Co.	Los Angeles, Calif.	11237	Chicago Telephone of California, Inc.	So. Pasadena, Calif.	71218	Bud Radio Inc.	Cleveland, Ohio
00891	Carl E. Holmes Corp.	Los Angeles, Calif.	11264	Dymec, Inc.	Palo Alto, Calif.	71286	Camloc Fastener Corp.	Paramus, N.J.
01121	Allen Bradley Co.	Milwaukee, Wis.	12697	Clarostat Mfg. Co.	Dover, N.H.	71313	Allen D. Cardwell Electronic Prod. Corp.	Plainville, Conn.
01255	Litton Industries, Inc.	Beverly Hills, Calif.	14655	Cornell Dubilier Elec. Corp.	So. Plainfield, N.J.	71400	Bussmann Fuse Div. of McGraw-Edison Co.	St. Louis, Mo.
01281	Pacific Semiconductors, Inc.	Culver City, Calif.	15909	The Daven Co.	Livingston, N.J.	71450	Chicago Telephone Supply Co.	Elkhart, Ind.
01295	Texas Instruments, Inc. Semiconductor Components Div.	Dallas, Texas	16758	Delco Radio Div. of G. M. Corp.	Kokomo, Ind.	71468	Cannon Electric Co.	Los Angeles, Calif.
01349	The Alliance Mfg. Co.	Alliance, Ohio	18873	E. I. DuPont and Co., Inc.	Wilmington, Del.	71471	Cinema Engineering Co.	Burbank, Calif.
01561	Chassi-Trak Corp.	Indianapolis, Ind.	19315	Eclipse Pioneer, Div. of Bendix Aviation Corp.	Teterboro, N.J.	71482	C. P. Clare & Co.	Chicago, Ill.
01961	Pulse Engineering Co.	Santa Clara, Calif.	19500	Thomas A. Edison Industries, Div. of McGraw-Edison Co.	West Orange, N.J.	71590	Centralab Div. of Globe Union Inc.	Milwaukee, Wis.
02114	Ferroxcube Corp. of America	Saugerties, N.Y.	19701	Electra Manufacturing Co.	Kansas City, Mo.	71700	The Cornish Wire Co.	New York, N.Y.
02286	Cole Mfg. Co.	Palo Alto, Calif.	20183	Electronic Tube Corp.	Philadelphia, Pa.	71744	Chicago Miniature Lamp Works	Chicago, Ill.
02660	Amphenol Electronics Corp.	Chicago, Ill.	21520	Fansteel Metallurgical Corp.	No. Chicago, Ill.	71753	A. O. Smith Corp., Crowley Div.	West Orange, N.J.
02735	Radio Corp. of America Semiconductor and Materials Div.	Somerville, N.J.	21335	The Fafnir Bearing Co.	New Britain, Conn.	71785	Cinch Mfg. Corp.	Chicago, Ill.
02777	Hopkins Engineering Co.	San Fernando, Calif.	21964	Fed. Telephone and Radio Corp.	Clifton, N.J.	71984	Dow Corning Corp.	Midland, Mich.
03508	G.E. Semiconductor Products Dept.	Syracuse, N.Y.	24446	General Electric Co. G. E. Lamp Division	Schenectady, N.Y.	72136	Electro Motive Mfg. Co., Inc.	Willimantic, Conn.
03705	Apex Machine & Tool Co.	Dayton, Ohio	24455	General Electric Co. Nela Park, Cleveland, Ohio		72354	John E. Fast & Co.	Chicago, Ill.
03797	Eldema Corp.	El Monte, Calif.	24655	General Radio Co.	West Concord, Mass.	72619	Dialight Corp.	Brooklyn, N.Y.
03877	Transitron Electronic Corp.	Wakefield, Mass.	26462	Grobel File Co. of America, Inc.	Carlstadt, N.J.	72656	General Ceramics Corp.	Keasbey, N.J.
03954	Air Marine Motors, Inc.	Los Angeles, Calif.	26992	Hamilton Watch Co.	Lancaster, Pa.	72758	Girard-Hopkins	Oakland, Calif.
04009	Arrow, Hart and Hegeman Elect. Co.	Hartford, Conn.	28480	Hewlett-Packard Co.	Palo Alto, Calif.	72765	Drake Mfg. Co.	Chicago, Ill.
04062	Elmenco Products Co.	New York, N.Y.	33173	G. E. Receiving Tube Dept.	Owensboro, Ky.	72825	Hugh H. Eby Inc.	Philadelphia, Pa.
04222	Hi-Q Division of Aerovox	Myrtle Beach, S.C.	35434	Lectrohm Inc.	Chicago, Ill.	72928	Gudeman Co.	Chicago, Ill.
04651	Special Tube Operations of Sylvania Electronic Systems	Mountain View, Calif.	37942	P. R. Mallory & Co., Inc.	Indianapolis, Ind.	72982	Erie Resistor Corp.	Erie, Pa.
04713	Motorola, Inc., Semiconductor Prod. Div.	Phoenix, Arizona	39543	Mechanical Industries Prod. Co.	Akron, Ohio	73061	Hansen Mfg. Co., Inc.	Princeton, Ind.
04732	Filtron Co., Inc. Western Division	Culver City, Calif.	40920	Miniature Precision Bearings, Inc.	Keene, N.H.	73138	Helipot Div. of Beckman Instruments, Inc.	Fullerton, Calif.
04777	Automatic Electric Sales Corp.	Northlake, Ill.	42190	Muter Co.	Chicago, Ill.	73293	Hughes Products Div. of Hughes Aircraft Co.	Newport Beach, Calif.
05006	Twentieth Century Plastics, Inc.	Los Angeles, Calif.	43990	C. A. Norgren Co.	Englewood, Colo.	73445	Amperex Electronic Co., Div. of North American Phillips Co., Inc.	Hicksville, N.Y.
05277	Westinghouse Electric Corp., Semi-Conductor Dept.	Youngwood, Pa.	44655	Ohmite Mfg. Co.	Skokie, Ill.	73506	Bradley Semiconductor Corp.	New Haven, Conn.
05624	Barber Colman Co.	Rockford, Ill.	47904	Polaroid Corp.	Cambridge, Mass.	73559	Carling Electric, Inc.	Hartford, Conn.
05783	Stewart Engineering Co.	Soquel, Calif.	48620	Precision Thermometer and Inst. Co.	Philadelphia, Pa.	73682	George K. Garrett Co., Inc.	Philadelphia, Pa.
06004	The Bassick Co.	Bridgeport, Conn.	49956	Raytheon Mfg. Co.	Waltham, Mass.	73743	Fischer Special Mfg. Co.	Cincinnati, Ohio
06812	Torrington Mfg. Co., West Div.	Van Nuys, Calif.	54294	Shallcross Mfg. Co.	Selma, N.C.	73793	The General Industries Co.	Elyria, Ohio
07115	Corning Glass Works Electronic Components Dept.	Bradford, Pa.	55026	Simpson Electric Co.	Chicago, Ill.	73905	Jennings Radio Mfg. Co.	San Jose, Calif.
07137	Transistor Electronics Corp.	Minneapolis, Minn.	55933	Sonotone Corp.	Elmsford, N.Y.	74455	J. H. Winns, and Sons	Winchester, Mass.
07261	Avnet Corp.	Los Angeles, Calif.	55938	Sorenson & Co., Inc.	So. Norwalk, Conn.	74861	Industrial Condenser Corp.	Chicago, Ill.
07263	Fairchild Semiconductor Corp.	Mountain View, Calif.	56137	Spaulding Fibre Co., Inc.	Tonawanda, N.Y.	74868	Industrial Products Co.	Danbury, Conn.
07933	Rheem Semiconductor Corp.	Mountain View, Calif.	56289	Sprague Electric Co.	North Adams, Mass.	74970	E. F. Johnson Co.	Waseca, Minn.
07980	Boonton Radio Corp.	Boonton, N.J.	59446	Telex, Inc.	St. Paul, Minn.	75042	International Resistance Co.	Philadelphia, Pa.
08358	Burgess Battery Co.	Niagara Falls, Ontario, Canada	61775	Union Switch and Signal, Div. of Westinghouse Air Brake Co.	Pittsburgh, Pa.	75173	Jones, Howard B., Division of Cinch Mfg. Corp.	Chicago, Ill.
08718	Cannon Electric Co. Phoenix Div.	Phoenix, Ariz.	62119	Universal Electric Co.	Owosso, Mich.	75378	James Knights Co.	Sandwich, Ill.
			64959	Western Electric Co., Inc.	New York, N.Y.	75382	Kulka Electric Mfg. Co., Inc.	Mt. Vernon, N.Y.
			65092	Weston Inst. Div. of Daystrom, Inc.	Newark, N.J.	75818	Lenz Electric Mfg. Co.	Chicago, Ill.
			66346	Wollensak Optical Co.	Rochester, N.Y.	75915	Littelfuse Inc.	Des Plaines, Ill.
			70119	Advance Electric and Relay Co.	Burbank, Calif.	76005	Lord Mfg. Co.	Erie, Pa.
						76210	C. W. Marwedel	San Francisco, Calif.
						76433	Micamold Electronic Mfg. Corp.	Brooklyn, N.Y.

APPENDIX

CODE LIST OF MANUFACTURERS (Sheet 2 of 2)

CODE NO.	MANUFACTURER	ADDRESS	CODE NO.	MANUFACTURER	ADDRESS	CODE NO.	MANUFACTURER	ADDRESS
76487	James Millen Mfg. Co., Inc.	Malden, Mass.	83777	Model Eng. and Mfg., Inc.	Huntington, Ind.	97539	Automatic and Precision Mfg. Co.	Yonkers, N.Y.
76530	Monadnock Mills	San Leandro, Calif.	83821	Loyd Scruggs Co.	Festus, Mo.	97966	CBS Electronics, Div. of C.B.S., Inc.	Danvers, Mass.
76545	Mueller Electric Co.	Cleveland, Ohio	84171	Arco Electronics, Inc.	New York, N.Y.	98141	Axel Brothers Inc.	Jamaica, N.Y.
76854	Oak Manufacturing Co.	Chicago, Ill.	84396	A. J. Giesener Co., Inc.	San Francisco, Calif.	98220	Francis L. Mosley	Pasadena, Calif.
77068	Bendix Corp., Bendix Pacific Div.	No. Hollywood, Calif.	84411	Good All Electric Mfg. Co.	Ogallala, Neb.	98278	Microdot, Inc.	So. Pasadena, Calif.
77221	Phaestron Instrument and Electronic Co.	South Pasadena, Calif.	84970	Sarkes Tarzian, Inc.	Bloomington, Ind.	98291	Sealectro Corp.	New Rochelle, N.Y.
77342	Potter and Brumfield, Inc.	Princeton, Ind.	85474	R. M. Bracamonte & Co.	San Francisco, Calif.	98405	Carad Corp.	Redwood City, Calif.
77630	Radio Condenser Co.	Camden, N.J.	85660	Koiled Kords, Inc.	New Haven, Conn.	98734	Palo Alto Engineering Co., Inc.	Palo Alto, Calif.
77634	Radio Essentials Inc.	Mt. Vernon, N.Y.	85911	Seamless Rubber Co.	Chicago, Ill.	98925	Clevite Transistor Prod. Div. of Clevite Corp.	Waltham, Mass.
77638	Radio Receptor Co., Inc.	Brooklyn, N.Y.	86684	Radio Corp. of America, RCA Electron Tube Div.	Harrison, N.J.	98978	International Electronic Research Corp.	Burbank, Calif.
77764	Resistance Products Co.	Harrisburg, Pa.	88140	Cutler-Hammer, Inc.	Lincoln, Ill.	99109	Columbia Technical Corp.	New York, N.Y.
78283	Signal Indicator Corp.	New York, N.Y.	89473	General Electric Distributing Corp.	Schenectady, N.Y.	99313	Varian Associates	Palo Alto, Calif.
78471	Tilley Mfg. Co.	San Francisco, Calif.	90179	U.S. Rubber Co., Mechanical Goods Div.	Passaic, N.J.	99515	Marshall Industries, Electron Products Division	Pasadena, Calif.
78488	Stackpole Carbon Co.	St. Marys, Pa.	90970	Bearing Engineering Co.	San Francisco, Calif.	99800	Delevan Electronics Corp.	East Aurora, N.Y.
78790	Transformer Engineers	Pasadena, Calif.	91418	Radio Materials Co.	Chicago, Ill.	99821	North Hills Electric Co.	Great Neck, L.I., N.Y.
78947	Ucinite Co.	Newtonville, Mass.	91506	Augat Brothers, Inc.	Attleboro, Mass.	99848	Wilco Corporation	Indianapolis, Ind.
79142	Veeder Root, Inc.	Hartford, Conn.	91637	Dale Products, Inc.	Columbus, Neb.	99934	Renbrandt, Inc.	Boston, Mass.
79251	Wenco Mfg. Co.	Chicago, Ill.	91662	Elco Corp.	Philadelphia, Pa.	99942	Hoffman Semiconductor Div. of Hoffman Electronics, Corp.	Evanston, Ill.
79963	Zierick Mfg. Corp.	New Rochelle, N.Y.	91737	Gremar Mfg. Co., Inc.	Wakefield, Mass.	99957	Technology Instruments Corp. of Calif.	No. Hollywood, Calif.
80130	Times Facsimile Corp.	New York, N.Y.	91827	K F Development Co.	Redwood City, Calif.			
80131	Electronic Industries Association Any brand tube meeting EIA standards	Washington, D.C.	91929	Micro-Switch Div. of Minneapolis Honeywell Regulator Co.	Freeport, Ill.			
80248	Oxford Electric Corp.	Chicago, Ill.	92196	Universal Metal Products, Inc.	Bassett Puente, Calif.			
80411	Acro Manufacturing Co.	Columbus, Ohio	93332	Sylvania Electric Prod. Inc., Semiconductor Div.	Woburn, Mass.	0000C	Connor Spring Mfg. Co.	San Francisco, Calif.
80486	All Star Products Inc.	Defiance, Ohio	93369	Robbins and Myers, Inc.	New York, N.Y.	0000D	Connex Corp.	Oakland, Calif.
80583	Hammerlund Co., Inc.	New York, N.Y.	93410	Stevens Mfg. Co., Inc.	Mansfield, Ohio	0000E	Fisher Switches, Inc.	San Francisco, Calif.
80640	Stevens, Arnold, Co., Inc.	Boston, Mass.	93983	Insuline-Van Norman Inc., Electronic Division	Manchester, N.H.	0000F	Malco Tool and Die	Los Angeles, Calif.
81030	International Instruments, Inc.	New Haven, Conn.	94144	Raytheon Mfg. Co., Receiving Tube Div.	Quincy, Mass.	0000G	Microwave Engineering Co.	Palo Alto, Calif.
81415	Wilkor Products, Inc.	Cleveland, Ohio	94145	Raytheon Mfg. Co., Semi-conductor Div.	Newton, Mass.	0000H	Philco Corp. (Lansdale Division)	Lansdale, Pa.
81453	Raytheon Mfg. Co., Industrial Tube Division	Quincy, Mass.	94148	Scientific Radio Products, Inc.	Loveland, Colo.	0000I	Telefunken (c/o American Elite)	New York, N.Y.
81483	International Rectifier Corp.	El Segundo, Calif.	94154	Tung-Sol Electric, Inc.	Newark, N.J.	0000L	Winchester Electronics, Inc.	Santa Monica, Calif.
81860	Barry Controls, Inc.	Watertown, Mass.	94197	Curtiss-Wright Corp., Electronics Div.	Carlstadt, N.J.	0000M	Western Coil Div. of Automatic Ind., Inc.	Redwood City, Calif.
82042	Carter Parts Co.	Skokie, Ill.	94310	Tru Ohm Prod. Div. of Model Engineering and Mfg. Co.	Chicago, Ill.	0000N	Nahm-Bros. Spring Co.	San Leandro, Calif.
82142	Jeffers Electronics Division of Speer Carbon Co.	Du Bois, Pa.	95236	Allies Products Corp.	Miami, Fla.	0000P	Ty-Car Mfg. Co., Inc.	Holliston, Mass.
82170	Allen B. DuMont Labs., Inc.	Clifton, N.J.	95238	Continental Connector Corp.	Woodside, N.Y.	0000R	Metro Cap. Div., Metropolitan Telecommunications Corp.	Brooklyn, N.Y.
82209	Maguire Industries, Inc.	Greenwich, Conn.	95263	Leecraft Mfg. Co., Inc.	New York, N.Y.	0000S	Moulton Electronics	San Carlos, Calif.
82219	Sylvania Electric Prod. Inc., Electronic Tube Div.	Emporium, Pa.	95265	National Coil Co.	Sheridan, Wyo.	0000T	Texas Instruments, Inc.	
82376	Astron Co.	East Newark, N.J.	95987	Weckesser Co.	Chicago, Ill.		Metals and Controls Div.	Versailles, Ky.
82389	Switchcraft, Inc.	Chicago, Ill.	96067	Huggins Laboratories	Sunnyvale, Calif.			
82647	Texas Instruments, Inc., Metals and Controls Div., Spencer Products	Attleboro, Mass.	96095	Hi-Q Division of Aerovox	Olean, N.Y.			
82866	Research Products Corp.	Madison, Wis.	96296	Solar Manufacturing Co.	Los Angeles, Calif.			
82893	Vector Electronic Co.	Glendale, Calif.	96330	Carlton Screw Co.	Chicago, Ill.			
83148	Electro Cords Co.	Los Angeles, Calif.	96341	Microwave Associates, Inc.	Burlington, Mass.			
83186	Victory Engineering Corp.	Union, N.J.	96501	Excel Transformer Co.	Oakland, Calif.			
83298	Bendix Corp., Red Bank Div.	Red Bank, N.J.						
83594	Burroughs Corp., Electronic Tube Div.	Plainfield, N.J.						

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


From: F.S.C. Handbook Supplements
H4-1 Dated Oct. 1960
H4-2 Dated Oct. 1960

00015-9
Revised: 8 May 1961



WARRANTY

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

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


CLAIM FOR DAMAGE IN SHIPMENT

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

SHIPPING

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

GENERAL

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

CUSTOMER SERVICE

Hewlett-Packard Company
395 Page Mill Road
Palo Alto, California, U.S.A.
Telephone: DAVenport 6-1755
Direct Dial Area Code 415
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Cable: "HEWPACK"

OR (In Western Europe)

Hewlett-Packard S.A.
Rue du Vieux Billard No. 1
Geneva, Switzerland
Telephone: (022) 26. 43. 36
Cable: "HEWPACKSA"



MANUAL BACKDATING CHANGES

MODEL 650A

TEST OSCILLATOR

Manual Serial Prefixed: 233

Manual Printed: 10/64

To adapt this manual to instruments with other serial prefixes check for errata below, and make changes shown in tables.

NOTE

This backdating manual change sheet (green sheet) is similar to the updating (yellow sheet) and makes this manual applicable to the earlier instrument. Instrument-component values that differ from those in the manual, yet are not listed in the backdating sheet, should be replaced using the stock number given in the manual.

Instrument Serial Prefix	Make Manual Changes	Instrument Serial Prefix	Make Manual Changes
203-	1	Serials 3399 to 3350	1 thru 5
150-	1, 2	Serials 3349 to 3250	1 thru 6
025-	1, 2, 3	Serials 3249 to 3000	1 thru 7
Serials 5647 to 3400	1 thru 4	Serials 2999 to 2900	1 thru 8

CHANGE #1

Table of Replaceable Parts,

C25: description to read "Same as C23"
 C42: description to read "Same as C24"

CHANGE #2

Table of Replaceable Parts and Schematic Figure 4-11,

R63: Delete from parts list; remove from schematic at Pin 1 of V16 and junction of R71 and C40. Replace with wire connection.

CHANGE #3

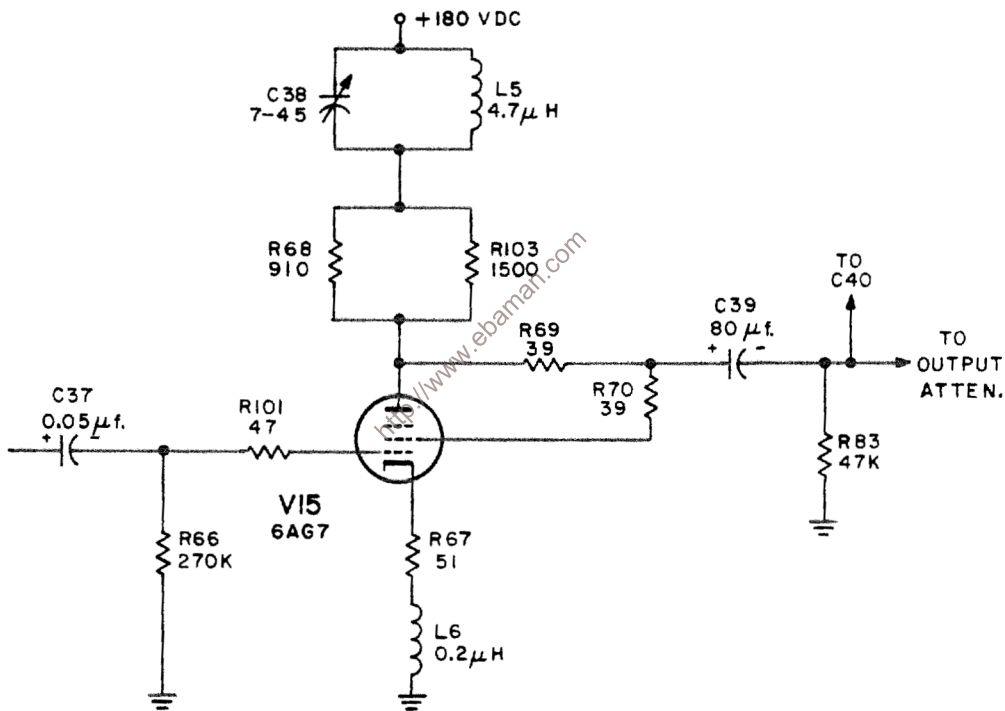
Table of Replaceable Parts,

R68: change to "Resistor, fixed, composition, 910 ohms $\pm 5\%$, 1 W;
 $\frac{hp}{p}$ Stock No. 0689-9115; Mfr. No. 01121"
 R103: change to "Resistor, fixed, composition, 1500 ohms $\pm 5\%$, 1 W;
 $\frac{hp}{p}$ Stock No. 0689-1525; Mfr. No. 01121"
 R69.
 R70: change to "Resistor, fixed, composition, 39 ohms $\pm 10\%$, 1/2 W;
 $\frac{hp}{p}$ Stock No. 0687-3901; Mfr. No. 01121"

Instrument Serial Prefix	Make Manual Changes	Instrument Serial Prefix	Make Manual Changes
Serials 2899 to 2500	1 thru 9	Serials 1349 to 590	1 thru 13
Serials 2499 to 1900	1 thru 10	Serials 589 to 530	1 thru 14
Serials 1899 to 1650	1 thru 11	Serials 529 and below	1 thru 15
Serials 1649 to 1350	1 thru 12		

L9: delete
R83: change description to read "Same as R43"

Change Schematic Figure 4-11 as shown below:



CHANGE 4

These instruments do not require modification as their circuitry is that given in schematic diagrams of Figure 4-10 and the following figure 2. There will be some physical variations between instruments in this serial group.

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 2 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 2.

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

CHANGE 5

- 1) Mount potentiometer R46 (1000 ohms, wirewound, h-p 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. 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. Cut the lead to approximately 1-1/4 in. and reconnect to center terminal of R46 control.
- 2) Move resistor R47 (3000 ohms $\pm 5\%$, 1 watt, wirewound, h-p Stock No. 26-3000) from resistor board to a location between negative terminal of C28 and closest terminal of R46 control.
- 3) Completely remove wire (usually yellow) connecting negative terminal on C28 to lug on resistor board near socket for V9 tube.
- 4) Best instrument performance is obtained when a composition type control (h-p Stock No. 2100-0019 is used for R55 Amplitude control. If a wirewound control is found, replace using the 2100-0019.

CHANGE 6

- 1) Change R89 from 3300 ohms to 6800 ohms $\pm 10\%$, 2 watts, composition.
- 2) Add resistor R91 (6800 ohms $\pm 10\%$, 2 watts, composition) in parallel with R89 which has the same value and rating. See Figure 6.
- 3) Capacitor C50 must have a value of 10 μ f. The 20 μ f capacitor used in some instruments must be changed to 10 μ f.

CHANGE 7

- 1) 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.
- 2) 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.

CHANGE 8

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

- 1) 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.
- 2) Replace crystal diodes CR1, CR2 and CR3 with frequency selected diodes available under h-p Stock No. 212-G11A. The cathode end of the diode is shown in the schematic of Figure 2 as a straight line or bar.

CHANGE 9

- 1) Type 6L6G, 6Y6G, 6L6GA or 6L6GB tubes have been used for tubes V6 and V7 at various times during production of this instrument. If and instrument has type 6L6GA or 6Y6G tubes, replace with type 6L6GA or preferably type 6L6GB tubes. Refer to power supply schematic for Serials 2749 and below.
- 2) 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.
- 3) A type 5U4GA/B rectifier tube is recommended for V10 rectifier. If a 5U4G tube is in instrument, replace with preferred type 5U4GA/B.

CHANGE 10

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

- 1) Complete step 1 given for instruments with Serial Numbers 1350 through 1649.
- 2) 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 as chassis and reconnect to V4 cathode pin 7.
- 3) Add mica capacitor C51 (5 μ f $\pm 20\%$, 500 vdcw, h-p Stock No. 14-5) between plate pin 5 and chassis of V13 in Output Amplifier stage.
- 4) 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.

CHANGE 11

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 $\mu\mu\text{f}$) 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 $\mu\mu\text{f}$ capacitor.

- 1) 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 2. 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.
- 2) Screen dropping resistor R18 for these same three tubes must remain connected to the +180 volt supply. In some instruments, it will be necessary to move R18 from a mounting location near V1 tube socket.
- 3) Connect tubular electrolytic capacitor C50 (10 μf $\pm 50\%$, 450 vdcw, h-p Stock No. 0180-0005) 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.

CHANGE 12

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.

- 1) Check wiring of AVC Amplifier V5 plate circuit. Chokes L1 and L8 along with resistors R25 and R90 as shown in Figure 2 are the only components that should remain. Other components such as C15, R28, R29 or L2, shown in Figure 3, should be removed. Change R25 if necessary to make it a 1 watt composition resistor with a value of 680 ohms.
- 2) Replace resistor R20 in cathode circuit of Buffer Amplifier V4 with a wire jumper. This grounds one end of resistors R19 and 21 as shown in Figure 2. Refer to Figure 3 for R20 location.
- 3) 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.
- 4) 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.
- 5) 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.
- 6) Connect capacitor C49 (0.01 μf $\pm 10\%$, 300 vdcw, h-p Stock No. 14-23) between V4 pin 6 and pin 2 or 7.

CHANGE 13

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 sure and refer to the oscillator schematic following for serials 1349 and below.

- 1) Add resistor R87 (100 ohms $\pm 10\%$, 1 watt, composition, h-p Stock No. 24-100) in series with 500 ohms potentiometer R77.
- 2) Remove and discard trimmer capacitor C15, resistor R28 (82 ohms), and coil L2 and AVC Amplifier V5 plate circuit.
- 3) Replace resistor R29 (120 or 68 ohms) with L8 and 8.6 μ h choke available under h-p Stock No. 65A-60D. Temporarily connect resistor R90 (33 to 82 ohms $\pm 10\%$, 1 watt, composition) in parallel with L8. Refer to Figure 3.

CHANGE 14

This group of instruments does not have a type number and was 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 h-p 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.

- 1) Change lamp for R80 from h-p Stock No. 211-4 (115 volts, 3 watts) to h-p Stock No. 211-29 (250 volts, 10 watts).
- 2) Change resistor R47 from 2700 ohms to h-p 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.

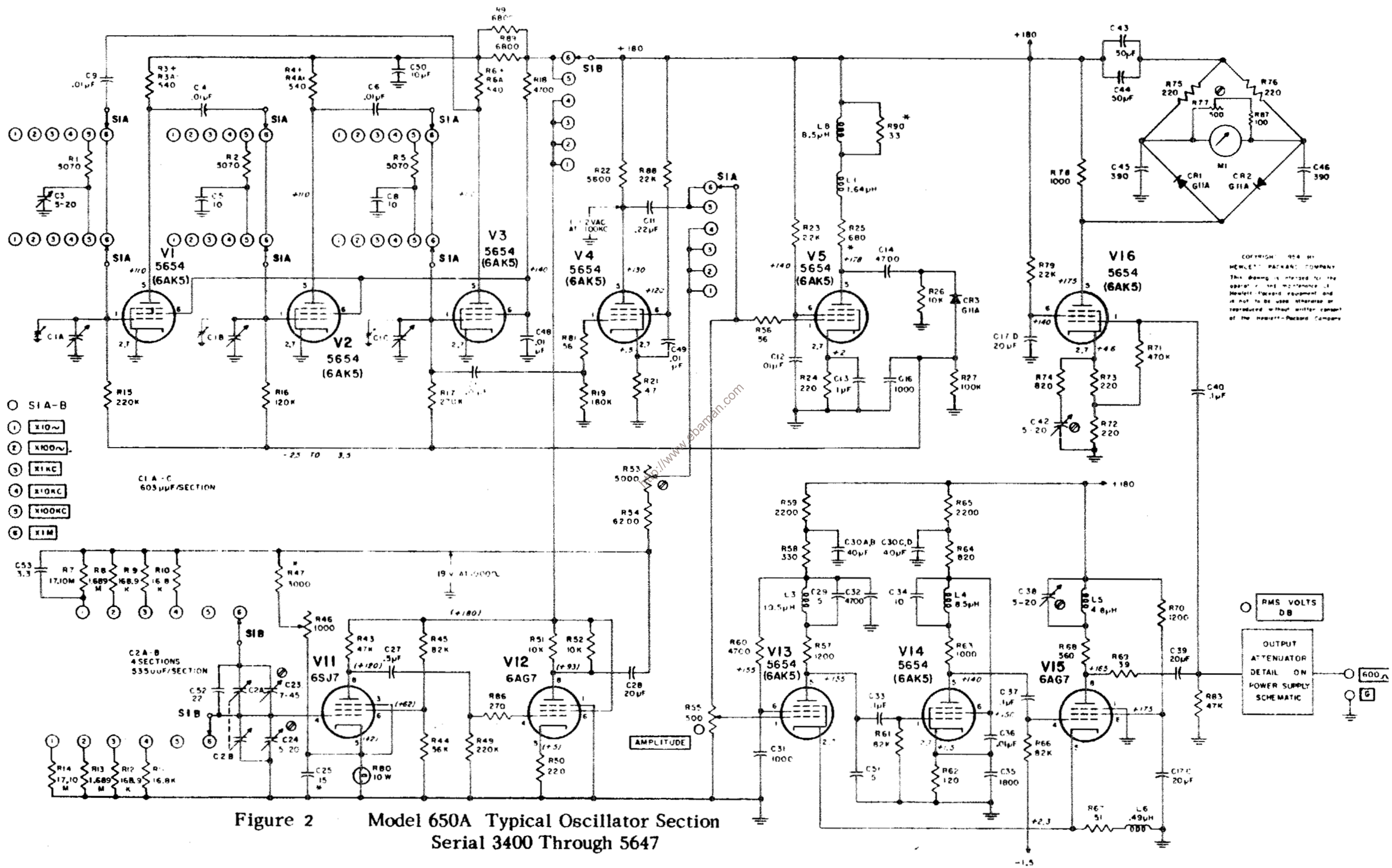
CHANGE 15

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.

- 1) Add resistors R84 and R85 (680 ohms $\pm 10\%$, 1 watt, composition) to the screen grid circuits of series regulator tubes V6 and V7.
- 2) 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.
- 3) Change R33 from 6800 ohms to 10,000 ohms $\pm 10\%$, 2 watt, composition.
- 4) Change R34 from 120,000 ohms to 220,000 ohms $\pm 10\%$, 1 watt, composition.
- 5) Change R36 from 220,000 ohms to 120,000 ohms $\pm 10\%$, 1 watt, composition.
- 6) Rewire tube socket for low frequency oscillator tube V12 by referring to schematic diagrams of Figures 2 and 3. 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.
- 7) Change R49 from 560,000 ohms to 220,000 ohms $\pm 10\%$, 1 watt, composition.
- 8) Change R50 from 330 ohms to 220 ohms $\pm 10\%$, 1 watt, composition.
- 9) Add resistor R86 (270 ohms $\pm 10\%$, 1 watt, composition) to the control grid circuit of V12(6AG7).
- 10) Add capacitor C48 (0.01 μ f, $\pm 10\%$, 300 vdcw, mica) in screen circuit for V1, V2 and V3 in any instrument not having this capacitor.



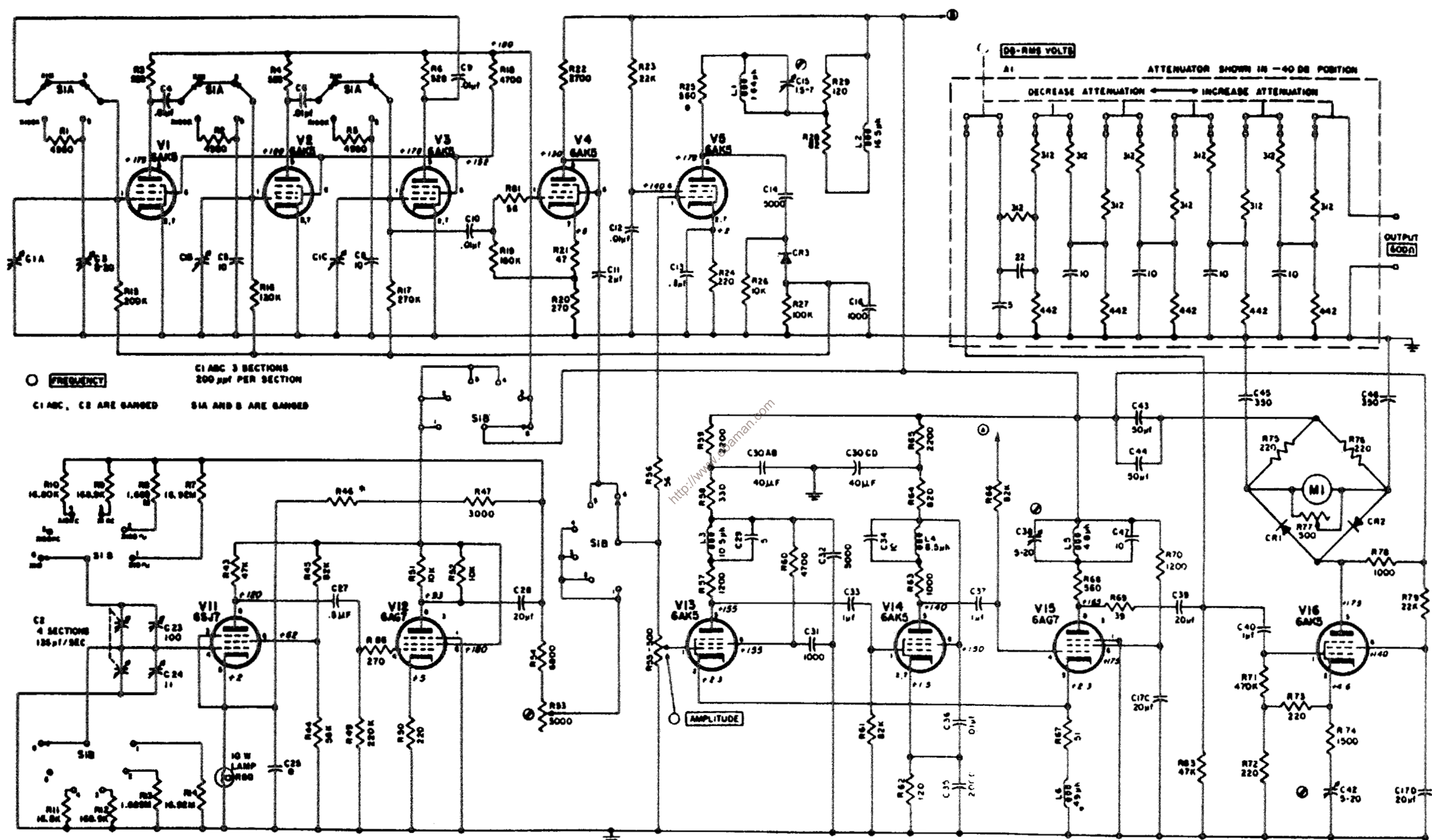
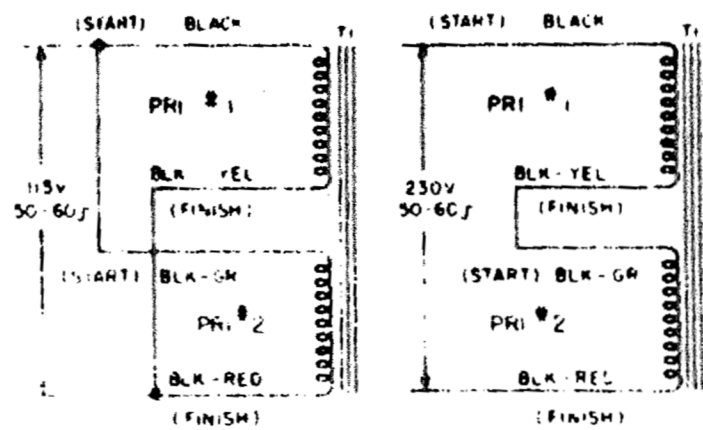


Figure 3 Schematic Diagram of Model 650A Oscillator Section, Serial No. 1349 and Below



TRANSFORMER DETAIL

NOTES

CONDITIONS OF DC VOLTAGE MEASUREMENT

1. LINE VOLTAGE AT 115 VOLTS, 50-60 Hz.
2. RANGE SW. AT 10M.
3. ALL OTHER CONTROLS AT MAXIMUM COUNTERCLOCKWISE POSITION.
4. VOLTAGES MEASURED BETWEEN INDICATED POINTS AND CHASSIS WITH VOLTMETER OF 22 MEGOHMS INPUT RESISTANCE.

ALL CAPACITANCE IN μF UNLESS OTHERWISE NOTED

K = 1000 OHMS

M = MEGOHM

♦ ADJUSTED AT FACTORY - AVERAGE VALUE SHOWN

• CHASSIS

○ PANEL CONTROL

⊗ SCREWDRIVER ADJUSTMENT

1. SET RANGE SW. TO 10M. SET CONTROLS AS FOLLOWS:

2. SET RANGE SW. TO 10M.

3. SET ALL OTHER CONTROLS AT MAXIMUM COUNTERCLOCKWISE POSITION.

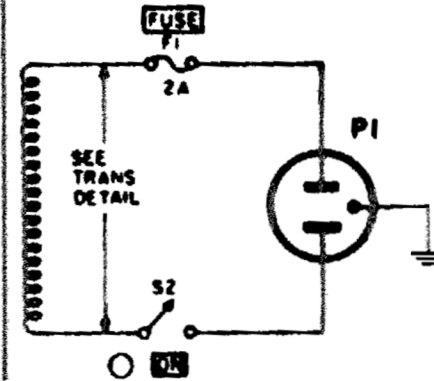
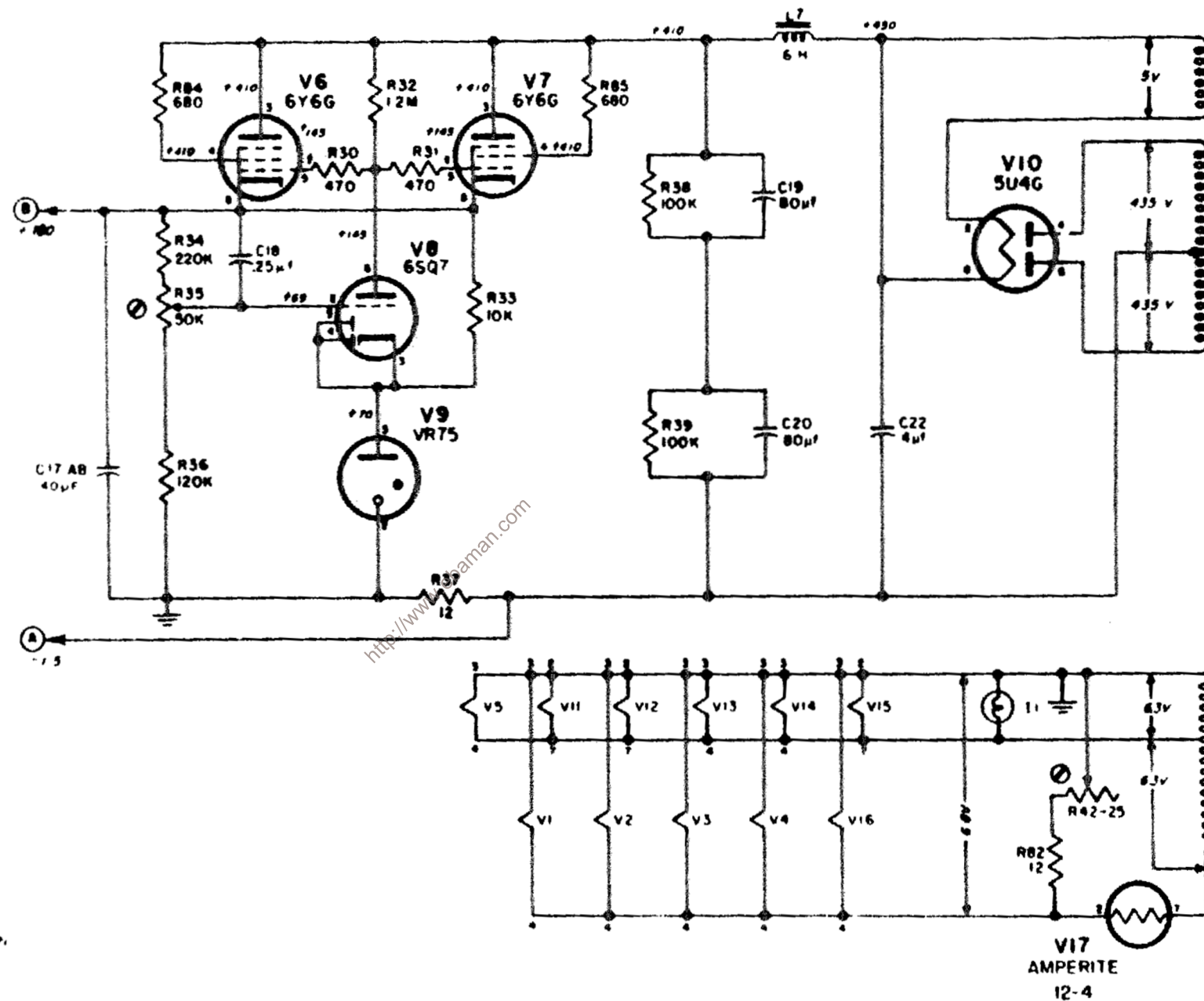
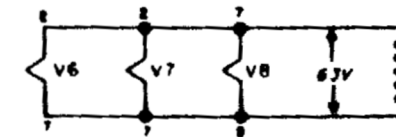


Figure 4 Schematic Diagram of Model 650A Power Supply Section, Serial No. 2749 and Below



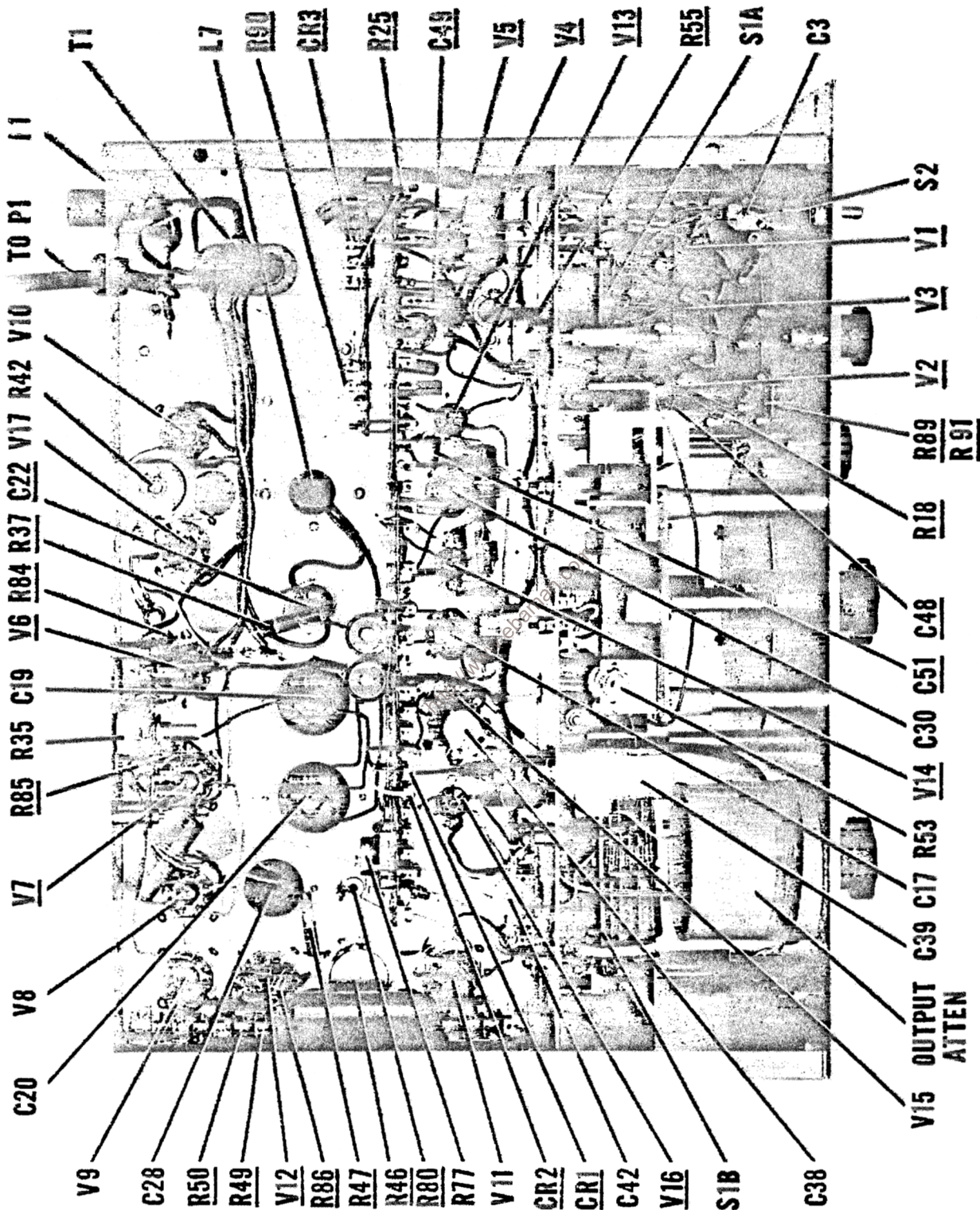


Figure 5 Model 650A Typical Bottom Chassis View
(Components underlined have been changed as described in modernization procedure.)

MANUAL CHANGES

MODEL 650A

TEST OSCILLATOR

Manual Serial Prefixed 025-
Manual Printed: 6/61


To adapt this manual to instruments with other serial prefixes check for errata below, and make changes shown in tables.


Instrument Serial Prefix	Make Manual Changes	Instrument Serial Prefix	Make Manual Changes
150-	1		
203-	1, 2		
233	1, 2, 3		


CHANGE #1


Table of Replaceable Parts,

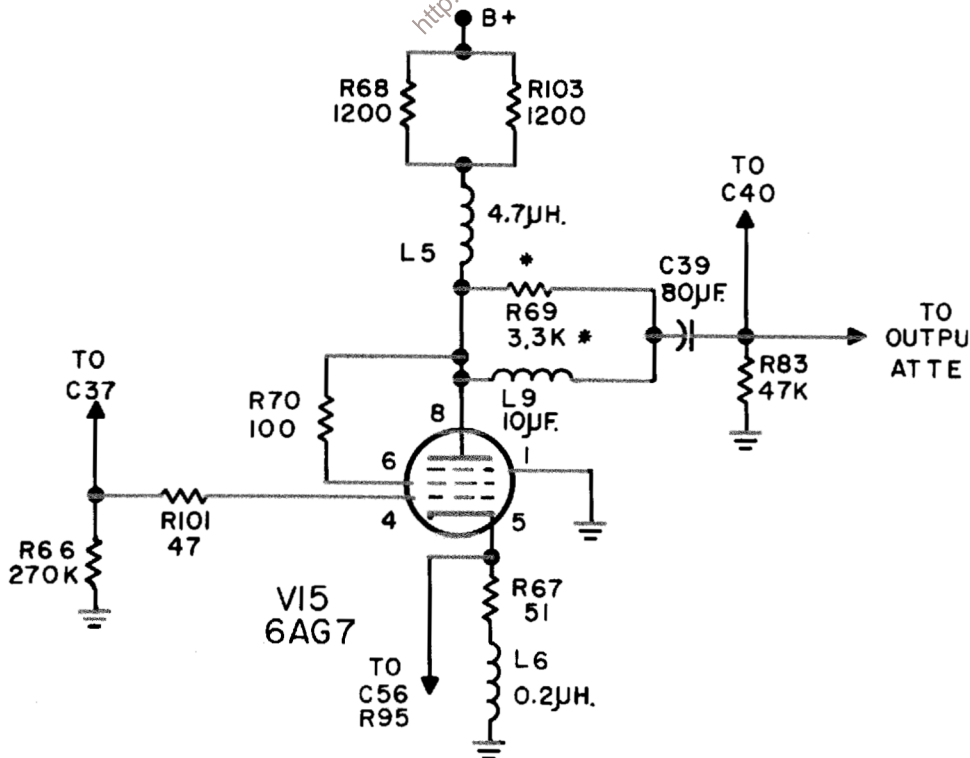
C38: Delete


R68, R103: Change to resistor, fixed, composition, 1.2K ohms $\pm 5\%$, 1W;
 Stock No. 0689-1221; Mfr. 01121

R69: Change to resistor, fixed, composition, 3.3K ohms $\pm 10\%$, 1/2W;
 Stock No. 0687-3321; Mfr. 01121. Optimum value selected at factory; average value shown

R70: Change to resistor, fixed, composition, 100 ohms $\pm 10\%$, 1/2W;
 Stock No. 0687-1011; Mfr. 01121

L9: Add inductor, RF:  Stock No. 9140-0032; Mfr. 99848



R83: Change to resistor, fixed, composition, 47K ohms $\pm 10\%$, 1/2W;
 Stock No. 0687-4731; Mfr. 01121

Instrument Serial Prefix	Make Manual Changes	Instrument Serial Prefix	Make Manual Changes
150-	1		
203-	1, 2		
233	1, 2, 3		

CHANGE #2

R63: Add resistor, fixed, composition, 56 ohms $\pm 10\%$, 1/2W;
 Ⓟ Stock No. 0687-5601; Mfr. 01121, connected between pin 1
 of V16 and the junction of R71 and C40

CHANGE #3

C25 Was Same as C23

Now Capacitor: Trimmer, Ceramic, 8-50 pf, 500 vdcw, Mfr. 72982,
 Ⓟ Stock No. 0130-0008. TQ-1, RS-1.

C42 Was Same as C24

Now Capacitor: Rotary 1-Section, Ceramic, 5-25 pf, 500 vdcw,
 Mfr. 72982, Ⓟ Stock No. 0130-0012, TQ-1, RS-1.

R77 Was Resistor: Variable, Wirewound, linear taper, 500 ohms $\pm 20\%$, 1W
 Now Resistor: Variable, Wirewound, linear taper, 500 ohms $\pm 20\%$, 1W,
 Mfr. 11237, Ⓟ Stock No. 2100-0151, TQ-1, RS-1

ERRATA

Table of Replaceable Parts,

R80: Change description to read, "Lamp, incandescent: 250 v, 10W
 (coded: GE8A/S6 12v)

Change schematic (Figure 4-11) and Table of Replaceable Parts as follows:

R1 + R1A: 5070 ohms

R2 + R2A: 5070 ohms

R5 + R5A: 5070 ohms

These are factory selected resistors.