OPERATING AND SERVICE MANUAL

TEST OSCILLATOR

MODEL 654A

HEWLETT PACKARD

HP 654A

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CERTIFICATION

The Hewlett-Packard Company certifies that this instrument was thoroughly tested and inspected and found to meet its published specifications when it was shipped from the factory. The Hewlett-Packard Company further certifies that its calibration measurements are traceable to the U.S. National Bureau of Standards to the extent allowed by the Bureau's calibration facility.

WARRANTY AND ASSISTANCE

All Hewlett-Packard products are warranted against defects in materials and workmanship. This warranty applies for one year from the date of delivery, or, in the case of certain major components listed in the operating manual, for the specified period. We will repair or replace products which prove to be defective during the warranty period provided they are returned to Hewlett-Packard. No other warranty is expressed or implied. We are not liable for consequential damages.

Service contracts or customer assistance agreements are available for Hewlett-Packard products that require maintenance and repair on-site.

For any assistance, contact your nearest Hewlett-Packard Sales and Service Office. Addresses are provided at the back of this manual.

OPERATING AND SERVICE MANUAL

-hp- Part No. 00654-90002

MODEL 654A
TEST OSCILLATOR

Serials Prefixed: 0951A-

Appendix C, Manual Backdating Changes, adapts manual to Serial No. 0951A00755 and below.

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SECTION I
GENERAL INFORMATION

1-1. DESCRIPTION.

1-2. The Hewlett-Packard Model 654A Test Oscillator is an ideal general purpose signal source whenever a flat balanced or unbalanced test signal is required. Balanced outputs of 135 ohms, 150 ohms and 600 ohms have many uses in the communications industry. Automatic leveling, together with the expanded meter, make the 654A ideally suited to voltmeter calibration or to test frequency response of components during manufacture. The instrument is shown in Figure 1-1 and the specifications are listed in Table 1-1.

General information relating to the instrument is listed in Table 1-2. The information in Table 1-2 should not be considered specifications.

1-3. The Model 654A is a stable, low distortion sine-wave signal source with a flat frequency response of +/-0.5% over the frequency range of 10 Hz to 10 MHz. The attenuators allow the signal to be adjusted in 1 dB and 10 dB steps from +10 dBm to -89 dBm, and the front panel AMPLITUDE control allows a continuous adjustment in level of +/-1 dB from the settings shown on the OUTPUT LEVEL attenuators. The flat frequency response is achieved by automatic leveling circuits within the 654A.

1-4. Five output impedances are available, selected by a front panel push-button control: these are 50 and 75 ohms unbalanced and 135, 150 and 600 ohms balanced. Balance is greater than 50 dB up to 1 MHz and greater than 40 dB up to 5 MHz.

1-5. The meter scale is expanded to indicate 0 dBm at center scale, with a total range of +/-1 dBm. The metering circuit monitors the signal level before the attenuators so that the meter indication is independent of the attenuator settings; the meter indicates the signal level set by the front panel AMPLITUDE control. The output signal level into the load is the algebraic sum of the meter indication and the OUTPUT LEVEL attenuator settings.

1-6. An additional feature is the COUNTER OUTPUT rear panel BNC connector. This allows the Model 654A frequency to be continuously monitored by an electronic counter without interrupting measurements or affecting terminal balance.

1-7. SUPPLIED ACCESSORIES.

Rack mount kit: -hp- Part No. 5060-0775.

1-8. RECOMMENDED ACCESSORIES.

-hp- 11048C	50 ohm Feedthrough Termination
-hp- 11094A	75 ohm Feedthrough Termination
-hp- 11095A	600 ohm Feedthrough Termination
-hp- 11143A	Balanced BNC to Alligator clip cable

1-9. INSTRUMENT AND MANUAL IDENTIFICATION.

1-10. Hewlett-Packard uses a two-section serial number. The first section (prefix) identifies a series of instruments. The last section (suffix) identifies a particular instrument within the series. If a letter is included with the serial number, it identifies the country in which the instrument was manufactured. If the serial prefix of your instrument differs from the one on the title page of this manual, a change sheet will be supplied to make this manual compatible with newer instruments or the backdating information in Appendix C will adapt this manual to earlier instruments. All correspondence with Hewlett-Packard should include the complete serial number.

Figure 1-1. Model 654A Test Oscillator

Table 1-1. Specifications

Frequency range: 10 Hz to 10 MHz in 6 bands.	**Amplitude control:** greater than 2 dB.
Frequency accuracy: 100 Hz (on X100 RANGE) to 5 MHz: +/-2% 10 Hz to 100 Hz: +/-3% 5 MHz to 10 MHz: +/-4%	**Amplitude accuracy:** +/-1% for 90 days (at 1 kHz, +10 dBm level with meter centered).
	Meter tracking: +/-0.05 dB.
Level flatness(+10 dBm and 0 dBm): +/-0.5% referenced to level at 1 kHz from 10 Hz to 10 MHz for unbalanced outputs, 10 Hz to 5 MHz for 135 ohm and 150 ohm outputs, and 10 Hz to 1 MHz for 600 ohm output.	**Balance** (on balanced impedances) when measured by the procedure given in Paragraph 5-28: greater than 50 dB for frequencies from 10 Hz to 1 MHz, greater than 40 dB to 5 MHz.
Attenuator Range: 99 dB in 10 dB and 1 dB steps. Accuracy: +/-1.5% (0.15 dB) except +/-10% (1 dB) at output levels below 60 dBm at frequencies greater than 300 kHz.	**Distortion (THD)** 10 Hz to 1 MHz: greater than 40 dB below fundamental. 1 MHz to 10 MHz: greater than 34 dB below fundamental.
	Hum and noise: greater than 70 dB down at full output.

Table 1-2. General Information

Output impedance: 50 ohm unbalanced, 75 ohm unbalanced, 135 ohm balanced, 150 ohm balanced and 600 ohm balanced.	**Output connectors:** BNC. Maximum voltage which can be applied to the output: less than +/-3 V peak.
Output level: +11 dBm to -90 dBm, 10 dB and 1 dB steps with adjustable +/-1 dB meter range; calibrated for each impedance.	**Counter output:** greater than 0.1 V rms into 50 ohm, BNC connector.
	Operating temperature: 0°C to +55°C (32°F to 130°F).
Meter resolution: 0.02 dB.	**Power:** 115 V or 230 V +/-10%, 48 Hz to 440 Hz, 30 W nominal, 35 W max.

SECTION II
INSTALLATION

2-1. INSPECTION.

2-2. This instrument was carefully inspected both mechanically and electrically before shipment. It should be physically free of mars or scratches and in perfect electrical order upon receipt. To confirm this, the instrument should be inspected for physical damage in transit. Also, check for supplied accessories, and test the electrical performance of the instrument using the procedure outlined in Section V of this manual. If there is damage or deficiency, see the warranty on Page ii of this manual.

2-3. POWER REQUIREMENTS.

2-4. This instrument will operate from either 115 or 230 Vac, 48 Hz to 440 Hz. The instrument can easily be converted from 115 volt to 230 volt operation by changing the position of the slide switch located on the rear panel, so that the designation appearing on the switch matches the nominal voltage of the power source.

2-5. GROUNDING REQUIREMENTS.

2-6. To protect operating personnel, the National Electrical Manufacturers' Association (NEMA) recommends that the instrument panel and cabinet be grounded. All Hewlett-Packard instruments are equipped with a three-conductor power cord which, when plugged into an appropriate receptacle, grounds the instrument. The offset pin on the power cord three-prong connector is the ground wire.

2-7. To preserve the protection feature when operating the instrument from a two-contact outlet, use a three-prong to two-prong adapter and connect the green pigtail on the adapter to ground.

2-8. INSTALLATION.

2-9. This instrument is fully transistorized; therefore no special cooling is required. However, the instrument should not be operated where the ambient temperature is outside the limits specified in Table 1-2.

2-10. RACK/BENCH INSTALLATION.

2-11. This instrument is initially shipped as a bench-type instrument (unless ordered specifically as a rack-type) with plastic feet and tilt stand in place. Conversion to a rack-mounted instrument can be accomplished by using the rack-mounting kit and instructions furnished with your instrument.

2-12. REPACKAGING FOR SHIPMENT.

2-13. The following is a general guide for repackaging for shipment. If you have any question, contact your local -hp- Sales and Service Office. (See Appendix at the back of this manual for office location.)

NOTE

If the instrument is to be shipped to Hewlett-Packard for service or repair, attach a tag to the instrument identifying the owner and indicating the service or repair to be accomplished; include the model number and full serial number of the instrument. In any correspondence, identify the instrument by model number and serial number.

a. Place instrument in original container if available. If original container is not available, a suitable one can be purchased from your nearest -hp- Sales and Service Office.

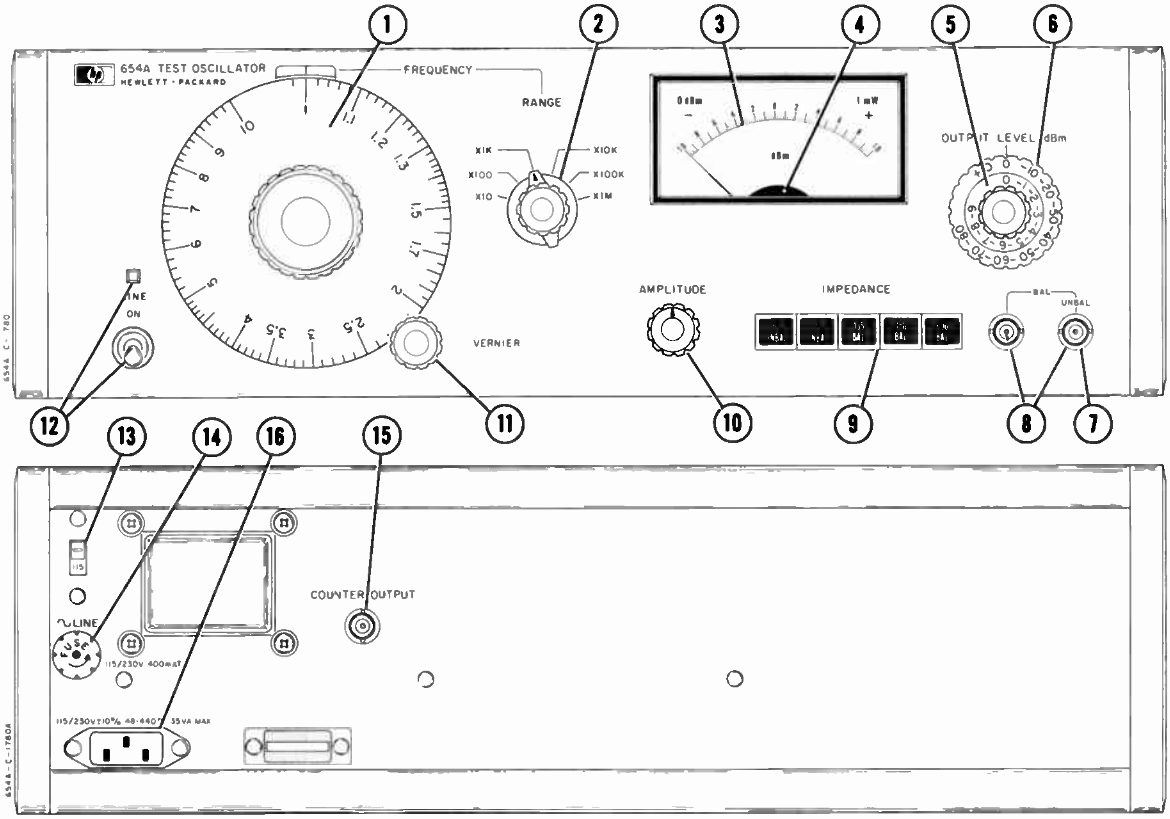
If original container is not used,

b. Wrap instrument in heavy paper or plastic before placing in an inner container.

c. Use plenty of packing material around all sides of instrument and protect panel faces with cardboard strips.

d. Place instrument and inner container in a heavy carton or wooden box and seal with strong tape or metal bands.

e. Mark shipping container with "DELICATE INSTRUMENT," "FRAGILE" etc.



(1) FREQUENCY dial (C1A/B/C): Varies test frequency continuously within each frequency range. Dial reading multiplied by range setting gives the output frequency in Hz of the 654A.

(2) FREQUENCY RANGE switch (S2): Selects one of six frequency multipliers from X10 to X1M.

(3) Output Meter (M1): Monitors amplitude of 654A output prior to OUTPUT LEVEL attenuators. Algebraic sum of meter indication and OUTPUT LEVEL attenuator setting gives output power into rated load.

(4) Mechanical Zero Adjust: Allows meter to be mechanically zeroed, when instrument is off.

(5) OUTPUT LEVEL (S4): Attenuates 654A output signal in nine steps of 1 dBm each.

(6) OUTPUT LEVEL (S4): Attenuates 654A output signal in nine steps of 10 dBm each.

(7) UNBAL output (J4): BNC connector provides an unbalanced output signal, at impedances of 50 ohms and 75 ohms.

(8) BAL output (J3 and J4): BNC connectors provide a balanced output signal at impedances of 135 ohms, 150 ohms and 600 ohms.

(9) IMPEDANCE switch (A4S1): Selects required output impedance of instrument; pushbuttons are interlocked so that when one is pressed the others spring out.

(10) AMPLITUDE control (R3): Allows adjustment of +/-1 dBm of output signal amplitude.

(11) FREQUENCY VERNIER: Provides a fine frequency adjustment for FREQUENCY dial.

(12) LINE ON switch (S1) and Pilot Lamp (DS1): Switch applies primary power to instrument; pilot lamp glows to indicate application of primary power.

(13) 115 V or 230 V Slide Switch (S3): Sets instrument to operate from a primary power source of either 115 Vac or 230 Vac, 48 Hz to 440 Hz.

(14) FUSE (F1): 0.4 amp slow blow fuse protects instrument from overloads.

(15) COUNTER OUTPUT (J2): BNC connector provides signal output of greater than 0.1 V rms into a 50 ohm load, at same frequency as front panel outputs.

(16) Primary Power Connector (J1): Connects primary power to instrument.

Figure 3-1. Location of Controls, Indicators and Connectors

SECTION III
OPERATING INSTRUCTIONS

3-1. INTRODUCTION.

3-2. This section contains instructions and information necessary for the operation of the 654A Test Oscillator. Included in this section are identification of controls, indicators and connectors, turn-on procedure, meter mechanical zero adjustment and operating instructions.

3-3. CONTROLS, INDICATORS, AND CONNECTORS.

3-4. All operating controls, indicators and connectors of the 654A are identified and described in Figure 3-1.

3-5. TURN-ON PROCEDURE.

3-6. OUTPUT METER MECHANICAL ZERO ADJUSTMENT.

3-7. The Model 654A output meter is properly mechanically zero-set when the meter pointer rests over the -1 dBm mark. Zero-set the output meter to obtain maximum accuracy and mechanical stability in the following manner. With LINE switch turned off, insert pointed object (such as tip of ball point pen) into recess on adjustment wheel, and rotate wheel until meter pointer rests exactly over -1 dBm mark.

3-8. PRIMARY POWER APPLICATION.

a. Before applying primary power to instrument, set 115 or 230 volt slide switch (S3) to position which indicates primary voltage to be used.

b. Connect primary power to connector J1. Switch LINE switch (S1) to ON position; pilot lamp (DS1) will glow.

3-9. OPERATING INSTRUCTIONS.

a. Zero-set meter (Paragraph 3-7) and turn instrument on (Paragraph 3-8).

b. Set the FREQUENCY RANGE switch and FREQUENCY dial (with VERNIER) to the desired frequency. (Dial reading multiplied by range setting gives the frequency in Hz.)

c. Connect a frequency counter to the rear panel COUNTER OUTPUT, if desired.

d. Select the required output impedance by pressing the appropriate IMPEDANCE pushbutton.

e. Adjust the OUTPUT LEVEL attenuators and the AMPLITUDE control for the desired signal output level. The algebraic sum of the meter indication and the attenuator setting gives the power level, in dBm, into a load equal to the impedance selected by the IMPEDANCE pushbutton. In Table 3-1, the 0 dBm and +10 dBm levels are converted to voltage for each impedance.

CAUTION

SWITCH THE 10 DBM STEP ATTENUATOR DOWN BEFORE CONNECTING TO SENSITIVE EQUIPMENT, SUCH AS THERMAL CONVERTERS, SO AS TO PREVENT DAMAGE FROM OVERLOADING.

Table 3-1. dBm/Voltage Conversion Chart

0 dBm = 1 m watt into rated load.		
Impedance	0 dBm	+10 dBm
50 ohm	0.224 V rms	0.707 V rms
75 ohm	0.274 V rms	0.866 V rms
135 ohm	0.367 V rms	1.162 V rms
150 ohm	0.387 V rms	1.225 V rms
600 ohm	0.775 V rms	2.449 V rms

f. Connect the load to the output connectors. Use the UNBAL connector for 50 ohm and 75 ohm loads and both connectors (BAL) for 135 ohm, 150 ohm and 600 ohm loads.

3-10. OPERATING CHECK.

3-11. Before making measurements using the 654A, perform the following front panel checks to ensure that your instrument is operating correctly.

a. Turn AMPLITUDE control until white arrow on knob is pointing up; meter should indicate approximately 0 dBm.

b. Turn AMPLITUDE control extreme counterclockwise; meter should indicate -1 dBm or less.

c. Turn AMPLITUDE control extreme clockwise; meter should indicate +1 dBm or greater.

SECTION IV
THEORY OF OPERATION

4-1. GENERAL DESCRIPTION.

4-2. The Model 654A Test Oscillator (see Block Diagram, Figure 7-1) contains a Wien Bridge Frequency Adjustable Oscillator (10 Hz to 10 MHz) followed by a Buffer Amplifier and a Balanced Amplifier with a single ended input and balanced output. The output of the Balanced Amplifier is a leveled, sinusoidal signal; this signal passes through Balanced Attenuators and a Balance and Unbalance Impedance Switch (output impedance switching network) to the front panel output connectors.

4-3. An Average Responding Detector monitors the output from the Balanced Amplifier to provide two dc currents (proportional to the signal level); one current flows to the meter circuits and the other to the Amplitude Control Integrator. Automatic leveling of the 654A signal is achieved by means of the Amplitude Control Integrator which compares the current from the Average Detector with the current from an Amplitude Current Reference to regulate the current through the lamp of a photosensitive control device (A2DSV1). The lamp controls the impedance of a resistive divider at the input of the Buffer Amplifier so as to maintain a constant output level from the Balanced Amplifier. The output level attenuators provide attenuation in 10 dB and 1 dB steps at the output connectors and a front panel AMPLITUDE control gives 2 dB of continuous output level adjustment by varying the current from the Amplitude Current Reference.

4-4. The current from the Average Detector which flows to the meter circuits is divided into two parts: a fixed amount of current (approximately 1.25 ma) flows into the Meter Offset Current Reference and the remainder flows to the meter. In this way the meter is offset so that it indicates only over the range of -1 dBm to +1 dBm. The current flowing into the Meter Offset Current Reference is held constant by the Meter Differential Amplifier which clamps the input of the current reference to a virtual ground.

4-5. A Counter Emitter Follower provides isolation between the oscillator circuit and the rear panel COUNTER OUTPUT. Regulated Power Supplies provide the +31 V and -26 V required to operate the 654A.

4-6. CIRCUIT DESCRIPTION.

4-7. OSCILLATOR CIRCUIT (Schematic No. 1, Figure 7-2)

4-8. The frequency adjustable Oscillator drives the Buffer Amplifier with a stable sine wave at a frequency determined by the setting of the FREQUENCY RANGE switch and the FREQUENCY dial. The circuit is a Wien Bridge Oscillator which has a standard, frequency selective, RC leg and a resistance leg modified by the addition of a variable impedance (A2CR1 and A2CR2). A2Q26 and A2Q1 through A2Q6 comprises the amplifier section and A2Q7 is a peak detector which provides negative feedback to the bridge for leveling. Two types of feedback are used; positive feedback from the frequency selective network drives the base of A2Q3 through the source follower A2Q1, and negative feedback from the resistive side of the bridge drives the base of A2Q2. A2Q2 and A2Q3 form a differential amplifier. Only at the selected frequency does the positive feedback overcome the negative feedback to sustain oscillations.

4-9. The six frequency ranges are selected by means of the RC networks mounted on the FREQUENCY RANGE switch (S2); continuous adjustment of the frequency on each range is accomplished by rotating the FREQUENCY dial, which controls the setting of the tuner capacitors C1A, C1B and C1C. The signal from the amplifier output (from A2Q5 and A2Q6) is developed across the RC network of the bridge; at the selected frequency, where $X_c = R$ (Figure 4-1), the positive feedback to the base of A2Q3 has the correct phase and sufficient amplitude to sustain oscillations. The high input impedance of the field effect transistor (A2Q1) prevents the amplifier from loading the frequency determining leg of the bridge; the feedback provided by A2Q26 prevents any changes in the parameters of A2Q1 from affecting the frequency response of the amplifier. The difference between the positive and negative

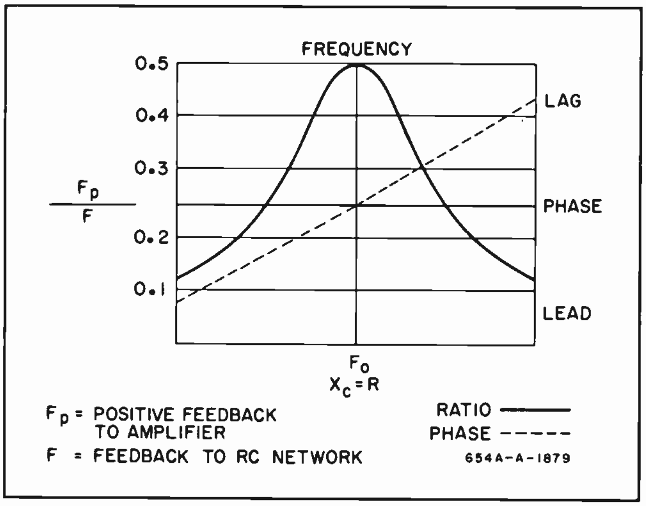


Figure 4-1. RC Network Characteristics

feedback signals is amplified by the differential amplifier (A2Q2 and A2Q3) and applied, through emitter follower A2Q4, to the complementary symmetry pair A2Q5 and A2Q6. The very low output impedance of the complementary pair acts as a constant voltage source for the Buffer Amplifier and also allows feedback to be applied to the bridge without loading the output of the oscillator. A2Q5 and A2Q6 are forward biased through A2CR7 and A2CR8 so as to conduct slightly when no signal is applied; this eliminates crossover distortion of the output signal.

4-10. A2Q7 acts as a peak detector. Part of the oscillator signal is superimposed on a negative bias at the base of A2Q7; A2Q7 conducts only when the positive peaks of the signal overcome the negative bias. The negative dc output of A2Q7 is filtered by A2C2, A2C3 and A2C4 and used to bias the diodes A2CR1 and A2CR2 so as to vary the impedance of the negative feedback side of the bridge to control the amplitude of oscillations. A2R8 is switched into the circuit on the X100 through X1M ranges and A2C5 on the X10 through X1K ranges for extra filtering. A2CR3 limits any reverse voltage transients across the polarized capacitors A2C3, A2C4 and A2C5. A2R9* is selected to draw current from the bridge so as to balance the current through A2CR1 and A2CR2 and improve distortion in the output signal.

4-11. BUFFER AMPLIFIER. (Schematic 1)

4-12. The Buffer Amplifier (A2Q8 through A2Q10) provides isolation between the oscillator and the Balanced Amplifier and is also used as the point at which the 654A signal is leveled. A2Q8 and A2Q9 form a differential amplifier whose output, from the collector of A2Q9, is amplified by A2Q10 and fed to the Balanced Amplifier. Part of the signal output from A2Q10 is applied as negative feedback through A2R39 to the base of A2Q8 to stabilize the amplifier gain over its 10 Hz to 10 MHz frequency range. The signal from the oscillator is divided down at the input to the Buffer Amplifier by a resistive divider consisting of A2R33 and the resistive element of the photosensitive resistor (A2DSV1). The resistance of the resistive element is determined by the current through the lamp, which is controlled by the Automatic Leveling Circuits (Paragraph 4-19 and following). The signal level at the input of the Buffer Amplifier varies with changes in the resistance of the photosensitive resistor to control the level of the 654A output signal.

4-13. COUNTER EMITTER FOLLOWER. (Schematic 1)

4-14. The Counter Emitter Follower (A3Q1) serves as isolation between the Oscillator circuit, and the rear panel COUNTER OUTPUT (J2). The output frequency is the same as the Variable Test Oscillator frequency. Signal amplitude at the COUNTER OUTPUT is approximately 0.1V rms into a 50 ohm load.

4-15. BALANCED AMPLIFIER. (Schematic 2, Figure 7-3)

4-16. The single-ended sinusoidal output from the Buffer Amplifier is amplified and converted into a balanced signal in the Balanced Amplifier. The Amplifier consists of three cascaded differential amplifiers (A2Q11 through A2Q16) and two complementary symmetry pairs (A2Q18, A2Q19 and A2Q20, A2Q21). The balanced output signal from the complementary symmetry pairs is developed across summing resistors A2R74 and A2R75 and then applied through A2R76 and C9, and through A2R77 and C10 to the attenuators (S4). The input sinusoidal signal at the base of A2Q11 is converted into two signals of equal amplitude, but 180° out of phase, taken from the collectors of A2Q11 and A2Q12. The two signals then follow parallel paths, while maintaining the 180° phase relationship, through the Balanced Amplifier. One signal path is through A2Q11, A2Q13 and A2Q15 to the complementary symmetry pair A2Q18 and A2Q19; the other signal path is through A2Q12, A2Q14 and A2Q16 to complementary symmetry pair A2Q20 and A2Q21. The complementary pairs are biased through diodes A2CR15, A2CR16 and A2CR17, A2CR18 so that the transistors conduct slightly when no signal is applied; this eliminates crossover distortion of the signal at the output of the Balanced Amplifier.

4-17. The gain of the Balanced Amplifier is stabilized by means of negative feedback. A2R51 couples the output signal from the top of A2R74 back to the base of A2Q11 and A2R53 couples the opposite signal from the bottom end of A2R75 back to the base of A2Q12. Note that the application of feedback together with the high gain of the Amplifier and the very low signal source impedance (from the Buffer Amplifier) causes the Balanced Amplifier to function as an operational amplifier with differential input and output; as a result, the overall gain of the Balanced Amplifier is determined by the ratio of A2R51 to A2R44 and A2R53 to A2R54. Capacitors A2C15 and A2C18 improve the high frequency response of the feedback paths.

4-18. To maintain proper balance of the output signal, the junction of summing resistors A2R74 and A2R75 is held at virtual ground by means of negative feedback to the third differential amplifier (A2Q15, A2Q16). The differential pair A2Q22 and A2Q23 compares the voltage at the junction of A2R74 and A2R75 with ground (the base of A2Q23 is connected directly to ground). Any signal unbalance or common mode signal across the two resistors moves their junction away from ground; this voltage at the junction is amplified by A2Q22 and A2Q23 and applied to the base of A2Q17 to change its collector current. A2Q17 is the source of current for A2Q15 and A2Q16 so that the change in current through them will be such as to restore the balance between the two sinusoidal signals and return the junction of A2R74 and A2R75 back to ground. A2C32 is adjusted for equal signal voltage across A2R74 and A2R75. A2R47, A2C16, A2C23, A2C26, A2C27, A2C28 and A2C29 all serve as frequency shaping elements to improve the frequency response and to insure stability of the Balanced Amplifier over its frequency range of 10 Hz to 10 MHz.

4-19. AMPLITUDE CONTROL AND AUTOMATIC LEVELING CONTROL.

4-20. The amplitude of the balanced sine wave signal from the Balanced Amplifier is independent of the Attenuator settings but can be varied over a 2 dB range by the front panel AMPLITUDE control (Schematic 2). The Automatic Leveling Circuit (ALC) consists of the Average Detector, the Amplitude Control Integrator, and the Amplitude Current Reference (varied by the AMPLITUDE control). The Average Detector monitors the output of the Balanced Amplifier and produces a dc current proportional to the amplitude of the Balanced Amplifier signal. The Amplitude Control Integrator compares this dc current with a current of opposite polarity from the Amplitude Current Reference; any difference in magnitude between the current from the Average Detector and the reference current is used to apply negative feedback to the photosensitive resistor at the input of the Buffer Amplifier until the output of the Balanced Amplifier is at the level where the two currents are equal. The output of the Balanced Amplifier is at the required level when the current from the Average Detector is equal to the reference current.

4-21. AVERAGE DETECTOR. (Schematic 2)

4-22. The detector monitors the output of the Balanced Amplifier. A2Q24 and A2Q25 form a high gain amplifier which is a current source for the detector (A2CR21 and A2CR22). A2CR21 supplies the metering circuits with a positive dc current and A2CR22 supplies the ALC circuits with a negative dc current. These currents are equal in amplitude to each other and proportional to the amplitude of the Balanced Amplifier output signal. A2Q24 and A2Q25 (together with the components connected to the base of A2Q25) form essentially one transistor with high gain, high output impedance and very low output capacitance; these factors together with the 'bootstrap' capacitor A2C42 account for the amplifier's effectiveness as a current source over a wide frequency and temperature range. A2C43 (Freq. Response) is adjusted for flat frequency response of the detector circuit.

4-23. AMPLITUDE CURRENT REFERENCE. (Schematic 2)

4-24. Zener Diode A1CR8 maintains a constant voltage across R3 (front-panel AMPLITUDE control) and A2R91 in series, the Amplitude Control Integrator maintains essentially 0 Vdc at the output of the current reference (at the base of A3Q6): thus, for any given setting of R3, there is a fixed voltage drop across A3R19 and A3R20 and a fixed amount of current flows from the Amplitude Current Reference. When the setting of the AMPLITUDE control (R3) is changed, the voltage drop across A3R19 and A3R20 is changed; this sets a new fixed value of current flowing towards the base of A3Q6.

4-25. AMPLITUDE CONTROL INTEGRATOR. (Schematic 2)

4-26. The circuit consists of A3Q6 through A3Q9 and associated circuitry, including the lamp of the photosensitive resistor A2DSV1 (Schematic 1). A3Q6 and A3Q7 form a differential amplifier; any change in output from the collector of A3Q7 is amplified by A3Q8 and applied to the base of A3Q9 to change the current through the lamp of the photosensitive resistor (A2DSV1). Changes in lamp current change the impedance of the voltage divider at the input of the Buffer Amplifier (Paragraph 4-12), thus changing the sine wave signal level through the Buffer Amplifier and the Balanced Amplifier. The dc current from the Average Detector is compared, at the base of A3Q6, with the current from the Amplitude Current Reference. In the differential pair (A3Q6, A3Q7) the base of A3Q7 is connected directly to ground; therefore, as long as the base of A3Q6 is held at 0 Vdc, there will be no change in output from the collector of A3Q7. The amplitude of the positive current flowing from the Amplitude Current Reference is fixed; the amplitude of the negative current flowing from the Average Detector depends on the level of signal at the output of the Balanced Amplifier. These currents are summed at the base of A3Q6. The difference current flows into the base of A3Q6. The amplitude of the base current is set by the AMPLITUDE CAL. adjustment and the AMPLITUDE control. As long as this current level is not changed by a variation in the Average Detector output, there will be no change in current through the lamp of the photosensitive resistor; thus the ac signal level at the output of the Balanced Amplifier will be constant. In this condition, the ALC loop is in the "quiescent" state and the output of the 654A is at the required level.

4-27. Suppose that the output level of the Balanced Amplifier now changes for some reason (e. g. the frequency of the Wien Bridge Oscillator is changed); then the Amplitude Control Integrator will act to return the signal back to its original level in the following manner:

a. The negative current from the Average Detector (A2CR22) will change proportionally with the change in ac signal level. This current flowing into the summing node at the base of A3Q6 diminishes the positive current amplitude thus decreasing the base current to A3Q6. This, in turn, begins to shut off the transistor.

b. The output of the Amplitude Control Integrator changes in response to the new input so as to change the ac signal level into the Buffer Amplifier. This will be in such a direction as to return the Balanced Amplifier ac output back to the level where the negative dc current from the Average Detector is again equal to its quiescent value. In this way the 654A output signal is maintained at a constant level.

4-28. To manually control the 654A output level over the 2 dBm range, the AMPLITUDE control setting is changed; this changes the current from the Amplitude Current Reference thus changing the base current to A3Q6. The Amplitude Control Integrator now acts as before to change the Balanced Amplfier ac output level until the current differential at the base of A3Q6 is equal to its quiscent value. The ALC circuit contains an integrator for fast response without overshoot and without sacrificing the ability to reject ripple superimposed on the current from the Average Detector. S2C14 is switched in parallel with A3C10 on the X10 RANGE for required response of the Amplitude Control Integrator at low frequencies.

4-29. METER CIRCUITS. (Schematic 2)

4-30. The meter circuits consist of the Meter Differential Amplifier, the Meter Offset Current Reference and the Meter. As explained in Paragraph 4-22, the Average Detector (A2CR21 and A2CR22) monitors the Balanced Amplifier output and produces two dc currents, equal in amplitude but opposite in polarity, proportional to the Balanced Amplifier output. The positive output of the Average Detector (from A2CR21) flows to the meter circuits. A fixed part of this current flows into the Meter Offset Current Reference and the remainder flows through the Meter and its shunt resistors A3R17 and A3R18. The Meter (M1) is calibrated to indicate center scale when the 654A output into rated load (the attenuators set at 0 dBm) is 0 dBm. The total range of the meter scale is +/-1 dBm so that when the Meter indicates -1 dBm, no current is flowing through the Meter and all of the current from the Average Detector is flowing through the Meter Offset Current Reference circuit.

4-31. The action of the Meter Offset Current Reference and the Meter Differential Amplifier is very similar to the action of the Amplitude Current Reference and the Amplitude Control Integrator (described in Paragraphs 4-22 through 4-25). Apart from a few minor differences the circuits are identical.

4-32. The Meter Offset Current Reference consists of A3R6, A3R7, A3R8, A3R9 and A3CR2. A3CR2 is a special temperature compensated Zener diode which maintains a constant voltage across A3R7 and A3R8 in series. Thus, the current flowing into the circuit is determined essentially by the voltage across A3R9. This current must always be a fixed amount so as to offset the Meter scale correctly; therefore, the voltage across A3R9 must always be fixed; this is achieved by means of the Meter Differential Amplifier. The Meter Differential Amplifier consists of A3Q2 through A3Q5. A3Q2 and A3Q3 form a differential pair; since the base of A3Q3 is connected directly to ground, the base of A3Q2 will be held at a virtual ground. Any difference between the two bases causes an output change from the collector of A3Q3 which is amplified by A3Q4 and applied to A3Q5 so as to return the base of A3Q2 back to virtual ground. One side of A3R9 is connected to the base of A3Q2, which is clamped to a virtual ground; the other side of A3R9 is connected to a constant voltage point (set by A3R7); thus the voltage across A3R9 is held constant as required, and the Meter Offset Current Reference always takes a fixed amount of the current from the Average Detector to offset the Meter. A3C5 serves to improve the frequency stability of the Meter Differential Amplifier. A3C6 is connected across the Meter to damp the meter movement, and A3C7 is switched in parallel with A3C6 on the X10 RANGE so as to further improve damping of the Meter at very low frequencies.

4-33. ATTENUATORS. (Schematic 3)

4-34. The balanced sine wave signal, developed across A2R74 and A2R75 in the Balanced Amplifier, is fed through A2R76 and C9, and through A2R77 and C10 to the Attenuators (S4). The attenuator assembly (S4) consists of four attenuators; a 1 dB step and a 10 dB step attenuator connected in series for each of the two halves of the balanced signal. Each attenuator consists of four resistive networks which are switched in various combinations to give the required attenuation. The front panel controls consist of two concentric rotary knobs labelled OUTPUT LEVEL dBm; the outer control, marked in 10 dB steps, controls both of the 10 dB step attenuators simultaneously; the inner control, marked in 1 dB steps, controls both of the 1 dB step attenuators simultaneously.

4-35. IMPEDANCE SELECTOR. (Schematic 3)

4-36. The front panel IMPEDANCE switch (A4S1) selects the required output impedance of the 654A. The impedance networks and the switching connections are shown on schematic 3; the switch connections are shown with the 50 ohm UNBAL button pushed. In the BAL mode, both front panel output connectors, J3 and J4, are used; in the UNBAL mode, only J4 is used.

4-37. REGULATED POWER SUPPLIES. (Schematic 4)

4-38. The regulated power supplies provide all voltages required by the 654A circuits. The power supplies consist of a (nominally) + 31 volt series regulated supply and a (nominally) - 26 volt series regulated supply. The - 26 volt supply is referenced to the + 31 volt supply.

4-39. The + 31 volt regulated supply is of the conventional series regulator type. Q1 and A1Q1 are connected in the Darlington Configuration to increase loop gain of the circuit, thus improving voltage regulation. A1R14 allows the voltage to be adjusted to + 31 volts (± 0.5); it also affects the - 26 volt supply (making the plus supply more positive, makes the negative supply more negative).

4-40. The - 26 volt regulated supply operates in a manner similar to the + 31 volt supply. A1Q5 is a current limiter which conducts only when the load current exceeds the set value. Conduction of A1Q5 causes the series regulator Q2 to reduce the output voltage until the load causing the excessive current is removed. Diodes A1CR6 and A1CR7 protect the control transistor A1Q4 from short circuits between the two supplies and short circuits at the output of the - 26 volt supply.

SECTION V
MAINTENANCE

5-1. INTROOUCTION.

5-2. This section contains maintenance and service information for the -hp- Model 654A Test Oscillator. Included are performance checks and adjustment and calibration procedures.

5-3. Table 5-1 lists the equipment required to properly maintain the Model 654A. If the recommended model is not available, any instrument that has specifications equal to, or better than, the required specifications may be used.

5-4. PERFORMANCE CHECKS.

5-5. The performance checks are in-cabinet tests (except where noted) to compare the performance of the Model 654A with the specifications given in Table 1-1. These checks may be used for incoming inspection, periodic maintenance and for performance checks after a repair. The Performance Check Test card at the end of Section V may be cut out and used as a permanent record of the instrument's performance during incoming inspection. It is recommended that performance checks and, if necessary, calibration be performed every 90 days.

5-6. FREQUENCY CHECKS.

5-7. FREQUENCY RANGE CHECK.

a. Connect an electronic counter to the 654A rear panel COUNTER OUTPUT.

b. Set the 654A controls as follows:

FREQUENCY RANGE X10
FREQUENCY dial .... Extreme clockwise

c. The counter should indicate a period average of 100ms or greater, verifying a frequency of 10Hz, or less, at the lower end of the frequency range.

d. Set the FREQUENCY RANGE switch to X1M and FREQUENCY dial to its extreme counter-clockwise postiton. The counter should indicate a frequency of 10MHz, or greater, verifying a frequency of at least 10MHz at the upper end of the frequency range.

e. Perform the Frequency Adjustments (Paragraphs 5-47 through 5-57) if the tolerances are not met.

5-8. FREQUENCY ACCURACY CHECK.

a. Connect an electronic counter to the 654A rear panel COUNTER OUTPUT.

b. Set the 654A controls as follows:

FREQUENCY RANGE X10
FREQUENCY dial 1

c. Verify frequency accuracy using the settings and tolerances given in Table 5-2. Use the period average setting on the counter for frequencies below 1kHz and use the frequency setting for frequencies above 1kHz.

d. Perform the frequency adjustments (Paragraphs 5-47 through 5-57) if the tolerances are not met.

5-9. AMPLITUDE ACCURACY CHECKS.
(See also Table 3-1, Page 3-1).

5-10. 50 UNBAL AMPLITUDE ACCURACY.

a. Connect the equipment as shown in Figure 5-1. Use the 50 ohm Feedthrough termination which should be connected directly to the 654A output connector.

b. Set the 654A controls as follows:

FREQUENCY dial 1
FREQUENCY RANGE X1K
OUTPUT LEVEL dBm .... +10,0
IMPEDANCE .... 50 UNBAL
AMPLITUDE .... Adjust for 0dBm on 654A meter.

c. The ac differential voltmeter indication should be between .7000V rms and .7142V rms verifying an absolute level of +10dBm, +/-1%.

d. If the tolerances are not met perform the Meter Tracking and Amplitude Control Adjustments of Paragraphs 5-58 through 5-60.

5-11. 75 UNBAL AMPLITUDE ACCURACY.

a. Perform the procedure of Paragraph 5-10 except: in step a. Use the 75 ohm feedthrough termination;

Table 5-1. Required Test Equipment

INSTRUMENT TYPE	REQUIRED CHARACTERISTICS	RECOMMENDED MODEL
Electronic Counter	Frequency: 10.00Hz to 10.00MHz. Period: 1.000ms to 100.0ms.	-hp- Model 5245L Electronic Counter.
AC Differential Voltmeter	Range: .9999V rms and 9.999V rms full scale. Accuracy: at least .1% of reading at 1kHz.	-hp- Model 741B AC-DC Differential Voltmeter/ DC Standard.
Wave Analyzer	Frequency Range: 1MHz to 22MHz. Must be compatible with Tracking Oscillator. (Note: the H05-312A is required only for distortion checks, otherwise a standard -hp- 312A can be used.)	-hp- Model H05-312A Wave Analyzer.
Tracking Oscillator	Must be capable of expanding wave analyzer meter indication to resolve 0.05dB.	-hp- Model 313A Tracking Oscillator.
Distortion Analyzer	Distortion Sensitivity: greater than 46dB. Frequency range: 10Hz to 600kHz.	-hp- Model 333A Distortion Analyzer.
Amplifier	Gain: 40dB. Frequency range: 1kHz to 10MHz.	-hp- Model 461A General Purpose Amplifier.
AC Voltmeter	Frequency range: 10Hz to 10MHz. Voltage range: 1.00mV rms to 1.00V rms (dB scales referenced to 1mW into 600 ohms).	-hp- Model 400E AC Voltmeter.
DC Null Voltmeter	Range: 10uV to 10mV. Accuracy: +/-2% of full scale.	-hp- Model 419A DC Null Voltmeter.
DC Voltmeter	Range: 0.1V to 100V. Input Impedance: 10 megohms.	-hp- Model 427A Multi-Function Meter.
Oscilloscope	Sensitivity: 5mV/cm. Bandwidth: dc to 50MHz.	-hp- Model 180A Oscilloscope with 1801A and 1820A plug-ins.
Feedthrough Terminating Resistance	Resistance: (a) 50 ohms +/-.25% (b) 75 ohms +/-.25%	Feed-Thru (a) -hp- Model 11048C (b) -hp- Model 11094C
Attenuators	Frequency range: 10Hz to 10MHz (with known accuracy at 10kHz, 300kHz and 10MHz). Attenuation range: (a) 9dB in 1dB steps. (b) 90dB in 10dB steps.	VHF Attenuators (a) -hp- Model 355C (b) -hp- Model 355D
Thermal Converters	Frequency range: 10Hz to 10MHz. Input: at least +10dBm into rated input impedance. Input impedance: (a) 50 ohms, unbalanced. (b) 75 ohms, unbalanced. (c) 135 ohms, balanced. (d) 150 ohms, balanced. (e) 600 ohms, balanced.	Thermal Converters (a) -hp- Model 11050A (b) -hp- Model H01-11050A (c) -hp- Model H11-11050A (d) -hp- Model H12-11050A (e) -hp- Model H10-11050A
BNC to Binding Post Adapter		-hp- Model 10110A (2 required)
Resistors.	1/8 W, metal film. (a) 75 ohms, .25% (two required). (b) 135 ohms, .1% (four required). (c) 300 ohms, .1% (two required).	-hp- Part No: 0698-6262 0698-7364 0698-6295

Note: The following items are not commercially available but can be easily constructed; refer to the figures listed for schematics and parts lists.

DC Reference Supply	Figure 5-4
75 ohm to 50 ohm Impedance Converter	Figure 5-7
Balance Box	Figure 5-9
10MHz Low-Pass Filter	Figure 5-12

Note: The following are useful optional items.

1). Jumper cable, 8 in., -hp- Part No. 10502-6001 (2 required, see Paragraph 5-30a)
2). Toriod Coil form, -hp- Part No. 9170-0995 (See Paragraph 5-24)
3). Sine-Wave Signal Generator: may be required for troubleshooting (Refer to Paragraphs 5-79 and 5-83.)

Table 5-2. Frequency Accuracy Check

FREQUENCY DIAL	RANGE	ACCURACY	COUNTER INDICATION
			Counter set to Period Average
1	X10	± 3%	100ms ± 3ms
2.5	X10	± 3%	40ms ± 1.2ms
5	X10	± 3%	20.0ms ± 0.6ms
8	X10	± 3%	12.5ms ± .375ms
10	X10	± 3%	10.0ms ± 0.3ms
1	X100	± 2%	10.0ms ± 0.2ms
2.5	X100	± 2%	4.00ms ± .08ms
5	X100	± 2%	2.00ms ± 0.04ms
8	X100	± 2%	1.25ms ± .025ms
10	X100	± 2%	1.00ms ± 0.02ms
			Counter set to Frequency
1	X1K	± 2%	1,000Hz ± 20Hz
2.5	X1K	± 2%	2500Hz ± 50Hz
5	X1K	± 2%	5,000Hz ± 100Hz
8	X1K	± 2%	8,000Hz ± 160Hz
10	X1K	± 2%	10,000Hz ± 200Hz
1	X10K	± 2%	10.0kHz ± 0.2kHz
2.5	X10K	± 2%	25kHz ± .5kHz
5	X10K	± 2%	50.0kHz ± 1.0kHz
8	X10K	± 2%	80kHz ± 1.6kHz
10	X10K	± 2%	100kHz ± 2kHz
1	X100K	± 2%	100kHz ± 2kHz
2.5	X100K	± 2%	250kHz ± 5kHz
5	X100K	± 2%	500kHz ± 10kHz
8	X100K	± 2%	800kHz ± 16kHz
10	X100K	± 2%	1,000kHz ± 20kHz
1	X1M	± 2%	1,000kHz ± 20kHz
2.5	X1M	± 2%	2,500kHz ± 50kHz
5	X1M	± 2%	5,000kHz ± 100kHz
8	X1M	± 4%	8,000kHz ± 320kHz
10	X1M	± 4%	10,000kHz ± 400kHz

in step b. Set IMPEDANCE to 75 UNBAL;
in step c. The ac differential voltmeter indication should be between .8573V rms and .8747V rms.

b. If the tolerances are not met, first assure that the 50 ohm output is correct (Paragraph 5-10) then troubleshoot the instrument. The trouble will most probably be in either the 50 ohm or 75 ohm impedance networks on the A4 board.

5-12. 135 BAL AMPLITUDE ACCURACY.

a. Connect the equipment (shown in Figure 5-2), in the following manner:
   1) Connect a 67.5 ohm resistor (use two 135 ohm resistors in parallel, R1 and R2) across two BNC to Binding Post Adapters as shown in Figure 5-2.

   2) Connect the adapters to the two output terminals of the 654A.

   3) Connect the ac differential voltmeter across the resistor which is connected to the 654A UNBAL terminal. Be sure to connect the ground lead of the voltmeter probe to the grounded side of the resistor.

b. Set the 654A controls as in Paragraph 5-10b except set IMPEDANCE to 135 BAL.

c. Record the ac differential voltmeter indication.

d. Disconnect the voltmeter from the one resistor and record the voltage across the other resistor (connect the ground lead as before).

e. Add the two voltages recorded in steps c and d. The total voltage should fall between 1.150V rms and 1.174V rms, verifying an absolute level of +10dBm, +/-1%.

f. If the tolerances are not met troubleshoot the instrument; the most likely problem would be the 135 ohm impedance network on the A4 board.

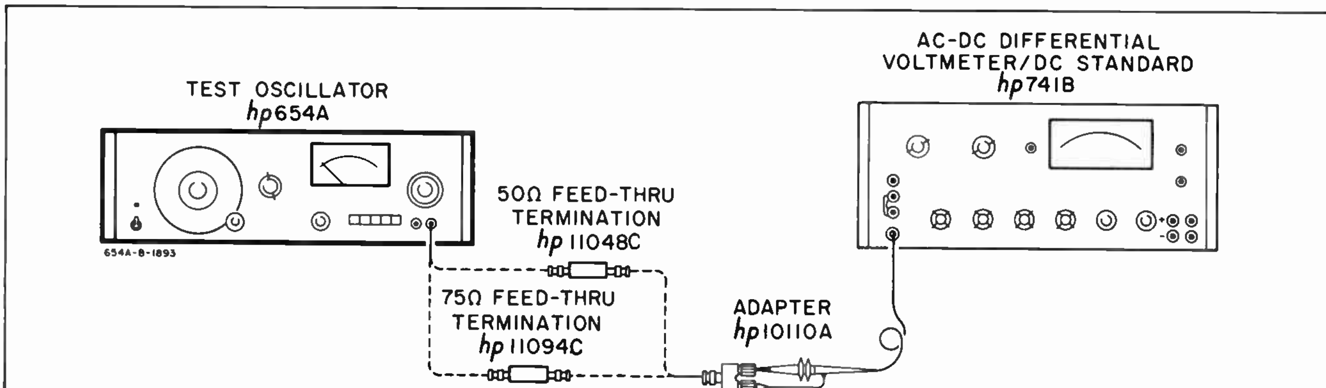


Figure 5-1. Amplitude Accuracy Checks - UNBAL

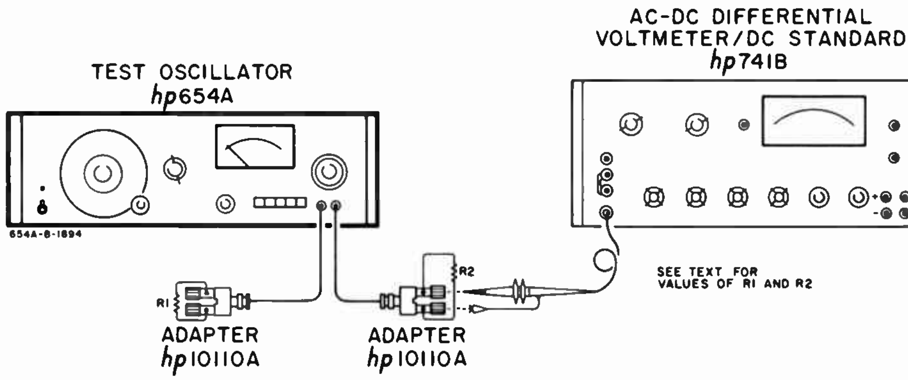


Figure 5-2. Amplitude Accuracy Checks - BAL

5-13. 150 BAL AMPLITUDE ACCURACY.

a. Connect the equipment as in Paragraph 5-12a except use 75 ohm resistors in place of the 67.5 ohms.

b. Set the 654A controls as in Paragraph 5-10b except set IMPEDANCE to 150 BAL.

c. Perform steps c and d of Paragraph 5-12.

d. Add the two voltages; the total voltage should fall between 1.213V rms and 1.237V rms verifying an absolute level of +10dBm, +/-1%.

e. If the tolerances are not met troubleshoot the instrument; the most likely problem would be the 150 ohm impedance network on the A4 Board.

5-14. 600 BAL AMPLITUDE ACCURACY.

a. Connect the equipment as in Paragraph 5-12a except use 300 ohm resistors in place of the 67.5 ohms.

b. Set the 654A controls as in Paragraph 5-10b except set IMPEDANCE to 600 BAL.

c. Perform steps c and d of Paragraph 5-12.

d. Add the two voltages; the total voltage should fall between 2.424V rms and 2.474V rms verifying an absolute accuracy of +10dBm +/-1%.

e. If the tolerances are not met troubleshoot the instrument; the most likely problem would be the 600 ohm impedance network on the A4 Board.

5-15. LEVEL FLATNESS CHECKS.

5-16. 50 UNBAL FLATNESS CHECK.

a. Set the 654A controls as follows:

FREQUENCY dial 1
FREQUENCY RANGE X1K
OUTPUT LEVEL dBm . . . . +10,0
IMPEDANCE . . . . 50 UNBAL
AMPLITUDE . . . . Adjust for 0dBm on 654A meter.

b. Connect the equipment shown in Figure 5-3; use the 50 ohm thermal converter (Table 5-3) which should be connected directly to the 654A UNBAL output connector. (The parts required to build the Reference Supply are shown in Figure 5-4).

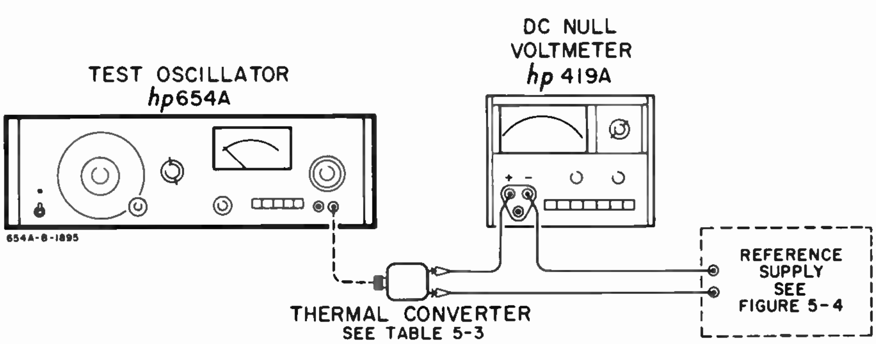


Figure 5-3. Level Flatness Checks

Table 5-3. Thermal Converters for Level Flatness Checks.
(See Paragraph 5-16 for explanation)

INPUT IMPEDANCE	-hp- Part No.	Input Level	Output Voltage (dc)	+/-0.5% deviation
50 UNBAL	11050A	+10dBm 0dBm	mV mV	+/- uV +/- uV
75 UNBAL	H01-11050A	+10dBm 0dBm	mV mV	+/- uV +/- uV
135 BAL	H11-11050A	+10dBm 0dBm	mV mV	+/- uV +/- uV
150 BAL	H12-11050A	+10dBm 0dBm	mV mV	+/- uV +/- uV
600 BAL	H10-11050A	+10dBm 0dBm	mV mV	+/- uV +/- uV

c. Set the reference supply for minimum output voltage and record, in Table 5-3, the thermal converter output voltage indicated on the dc null voltmeter.

d. Using the formula given below, calculate the voltage deviation which represents a change of +/-0.5%; record this in the last column of Table 5-3.

$$+/- \Delta E = \frac{2E\,(\%\ \text{change})}{100}$$

ΔE = maximum allowable deviation from E
E = thermal converter output voltage
% change = (+/-) 0.5%

Example: If E = 7mV

$$\text{Then } +/- \Delta E = \frac{2 \times 7 \times 10^{-3} \times (+/-)0.5}{10^2} = +/- 70\text{uV}.$$

NOTE

The factor 2 is included in the formula as the thermal converter is a square law device.

e. Adjust the reference supply for null indication on the dc null meter.

f. Sweep the 654A slowly over the frequency range of 10Hz to 10MHz; the dc null meter indication should not vary more than +/-ΔE (calculated in step d of this Paragraph) from null. This verifies a level flatness, referenced to 1kHz, of +/-0.5% at an output level of +10dBm.

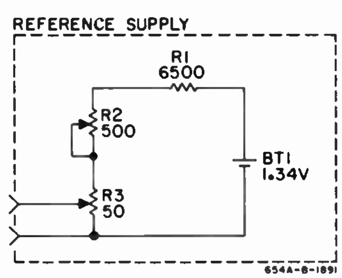
g. Reset the 654A frequency to 1kHz and the 10dBm step attenuator to 0 position and repeat steps c through f of this paragraph to verify a flatness of +/-0.5% at an output level of 0dBm.

h. If the tolerances are not met, first check the 75 UNBAL flatness (Paragraph 5-17) before performing the calibration of Paragraph 5-67.

5-17. 75 UNBAL FLATNESS CHECK.

a. Perform the procedure of Paragraph 5-16 steps a through g with the following changes:
in step a. Set IMPEDANCE to 75 UNBAL;
in step b. Use the 75 ohm thermal converter (Table 5-3).

b. If the tolerances are not met, perform the calibration of Paragraph 5-66.



Parts list:

R1: R fxd met flm 6500 ohms +/-1%
-hp- 0811-0392
R2: R var 500 ohms +/-5%
-hp- 2100-0324
R3: R var 50 ohms +/-5%
-hp- 2100-1481
BT1: 1.34V Mallory RM-42R

Figure 5-4. Reference Supply

5-18. 135 BAL FLATNESS CHECK.

a. Perform the procedure of Paragraph 5-16 steps a through g with the following changes:
In step a. Set IMPEDANCE to 135 BAL;
In step b. Use the 135 ohm thermal converter (Table 5-3) which should be connected directly to both output connectors of the 654A;
In step f. Sweep the 654A over the frequency range of 10Hz to 5MHz.

b. If the tolerances are not met, first assure that the 75 UNBAL flatness is within tolerance before troubleshooting the 654A.

5-19. 150 BAL FLATNESS CHECK.

a. Perform the procedure of Paragraph 5-16 steps a through g with the following changes:
In step a. Set IMPEDANCE to 150 BAL;
In step b. Use the 150 ohm thermal converter (Table 5-3) which should be connected directly to both output connectors of the 654A;
In step f. Sweep the 654A over the frequency range of 10Hz to 5MHz.

b. If the tolerances are not met, first assure that the 75 UNBAL flatness is within tolerance before troubleshooting the 654A.

5-20. 600 BAL FLATNESS CHECK.

a. Perform the procedure of Paragraph 5-16 steps a through g with the following changes:
In step a. Set IMPEDANCE to 600 BAL;
In step b. Use the 600 ohm thermal converter (Table 5-3) which should be connected directly to both output connectors of the 654A.
In step f. Sweep the 654A over the frequency range of 10Hz to 1MHz.

b. If the tolerances are not met, first assure that the 75 UNBAL flatness is within tolerance before troubleshooting the 654A.

5-21. METER TRACKING ACCURACY CHECK.

a. Connect the equipment as shown in Figure 5-5. Use an attenuator with known accuracy at 10kHz, and 10MHz.

b. Set the 654A controls as follows:

FREQUENCY RANGE X1K
FREQUENCY dial 10
OUTPUT LEVEL dBm . . . . +10,0
IMPEDANCE . . . . .50 UNBAL
AMPLITUDE . . . . .Adjust for 0dBm on 654A meter

c. On the rear panels of the instruments, connect the 312A Wave Analyzer RECORDER OUTPUT to the 313A Tracking Oscillator RECORDER INPUT. Set the tracking oscillator METER MODE switch to EXPAND 312A.

d. Set the external attenuator to -1dB position.

e. Adjust the wave analyzer to the same frequency as the 654A and for a meter indication of between -7dB and +3dB.

f. Adjust the tracking oscillator SCALE OFFSET control for a 0dB reference indication on the oscillator meter.

g. Set the external attenuator for 0dB attenuation.

h. Adjust the 654A AMPLITUDE control to return the tracking oscillator meter indication to 0dB reference; 654A meter should indicate -1dBm, +/-0.05dBm.

i. Set the external attenuator to -2dB position.

j. Adjust the 654A AMPLITUDE control to return the tracking oscillator meter indication to 0dB reference; 654A meter should indicate +1dBm, +/-0.05dBm.

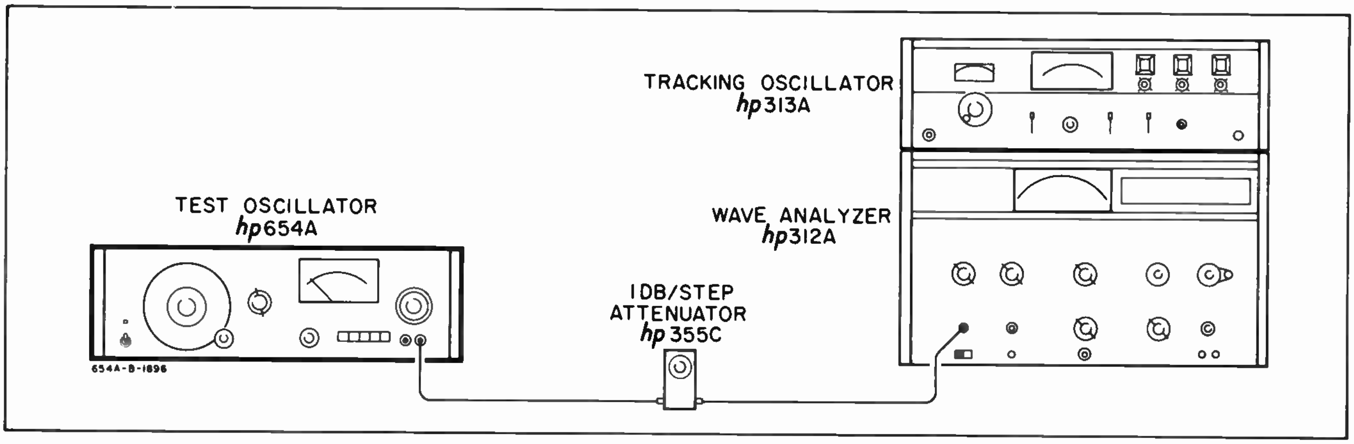


Figure 5-5. Meter Tracking Accuracy Check

k. Adjust the 654A to 10MHz and reset the AMPLITUDE control for 0dBm indication on the 654A meter.

l. Repeat steps d through j of this paragraph to check tracking at 10MHz.

m. These checks verify meter tracking accuracy of +/-0.05dB; perform the adjustments of Paragraphs 5-58 through 5-60 if the limits are not met.

5-22. ATTENUATOR ACCURACY CHECKS.

5-23. MEASUREMENT PROBLEMS.

5-24. The test setup (shown in Figure 5-6) for these checks is critical. Ground loops, noise, interference from other instruments, etc., can give measurement errors of up to greater than 1dB. Placement of the test instruments relative to each other may affect measurement accuracy; it is not possible to give an exact position for each instrument as this may also vary with the location of the test setup. To reduce ground loops between instruments a large coil can be placed in series with the interconnecting cables between two of the instruments. The coil can be easily constructed as follows:

1) Wrap about twenty turns of 50 ohm coaxial cable around any large diameter, ferrite, circular core (a 3in. o.d. X 1-3/4in. i.d. core, -hp- Part No. 9170-0995 is suitable) and tape the turns in place.

2) Cut the leads from the coil to a convenient length and attach BNC connectors (male) to both ends of the coax.

The effect of this coil is to present a high impedance to 60Hz signal between grounds without appreciably attenuating the required signal on the center conductor of the coax. The exact location of the coil in the test setup will depend on which instruments have a ground loop problem; this can be determined by trial and error.

5-25. If the 654A attenuators do not appear to be within the limits given in the following checks, carefully check the test setup before troubleshooting the attenuators; the placement of the shield around the 654A attenuators is extremely critical and, if disturbed, can adversely affect the high frequency response of the attenuators (see Paragraph 5-97).

5-26. 10dB-STEP ATTENUATOR CHECK.

NOTE

See Paragraphs 5-24 and 5-25 before making this check.

a. Connect the equipment shown in Figure 5-6. (Figure 5-7 shows the parts required to build the 75 ohm to 50 ohm impedance converter). Use the 10dB/step external attenuator (with known accuracy at 300kHz and 10MHz), do not connect the 1dB/step attenuator at this time.

b. On the rear panels of the instruments connect the 312A Wave Analyzer RECORDER OUTPUT to the 313A Tracking Oscillator RECORDER INPUT. Set the tracking oscillator METER MODE switch to EXPAND 312A.

c. Set the 654A controls as follows:

FREQUENCY dial 3
FREQUENCY RANGE X100K
OUTPUT LEVEL dBm .... +10,0
IMPEDANCE .... 150 BAL
AMPLITUDE .... Adjust for 0dBm on 654A meter.

d. Set the external attenuator to -90dB position and the external amplifier gain to +40dB.

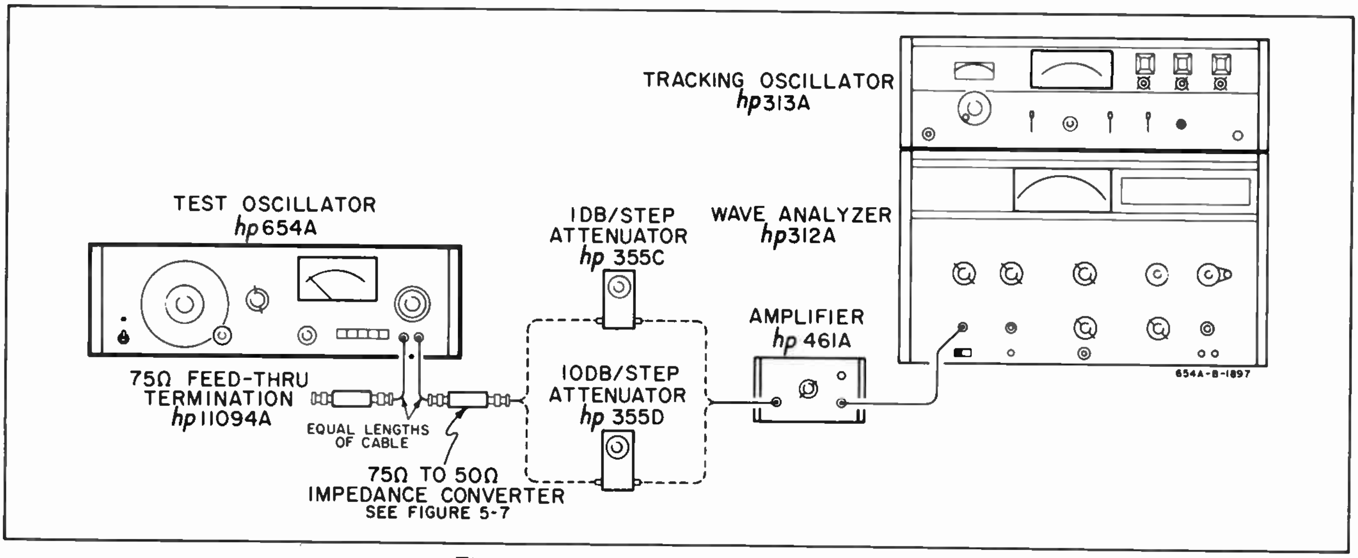


Figure 5-6. Attenuator Accuracy Checks

e. Adjust the wave analyzer to the same frequency as the 654A and for a meter indication of between -7dB and +3dB.

f. Adjust the tracking oscillator SCALE OFFSET control for a meter indication of 0dB reference level.

g. Check the 654A 10dB attenuator at each position by decreasing attenuation on the external attenuator as attenuation is increased on the 654A attenuator; at each position the tracking oscillator meter indication should be 0dB, +/-0.15dB.

h. Check the 654A 10dB attenuator at 10MHz using the following procedure.
1) Set the 654A to 10MHz.

2) Repeat steps d, e and f of this paragraph.

3) Repeat step g of this paragraph for the +10 through -60dB position of the 654A attenuator.

4) Repeat step g for the -70 and -80 positions of the 654A attenuators except that the tracking oscillator meter indication for these two positions should be 0dB, +/-1dB.

NOTE

This procedure, so far, has checked only one side of the attenuator, the following step describes how to check the other side.

i. Check the other side of the 654A 10dB attenuator at 300kHz and 10MHz by interchanging the two cables connected to the 654A output connectors (i.e. as viewed in Figure 5-6, the cable terminated in 75 ohms is moved with the termination to the right-hand connector and the cable connected to the 75 ohm to 50 ohm impedance converter is moved with the converter to the left-hand connector); then repeat steps c through h of this paragraph.

5-27. 1dB-STEP ATTENUATOR CHECK.

NOTE

See Paragraphs 5-24 and 5-25 before making this check.

a. Connect the equipment shown in Figure 5-6 except use the 1dB/step external attenuator and do not use an external amplifier.

b. Perform steps b and c of Paragraph 5-26.

c. Set the external attenuator to the -9dB position.

d. Perform steps e and f of Paragraph 5-26.

e. Check the 654A 1dB step attenuator at each position by decreasing attenuation on the external attenuator as attenuation is increased on the 654A attenuator; at each position the tracking oscillator meter indication should be 0dB, +/-0.15dB.

f. Repeat the check with the 654A and wave analyzer set to 10MHz to verify the attenuator accuracy at high frequency.

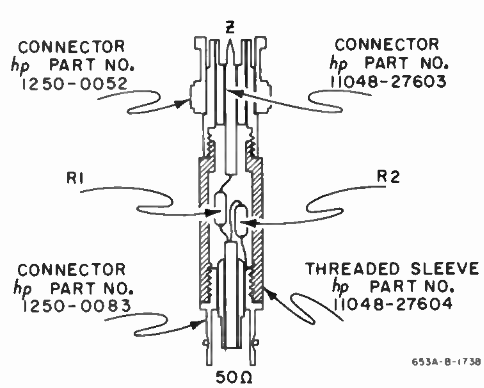
NOTE

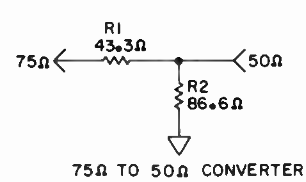
This procedure, so far, has checked only one side of the attenuator, the following step describes how to check the remaining half.

g. Check the other side of the 654A 1dB step attenuator at 300kHz and 10MHz by interchanging the cables (as described in Paragraph 5-26, step i) and repeating steps b through f of this paragraph (5-27).

5-28. BALANCE CHECKS.

5-29. If the tolerances given in the following procedures





Z	75Ω‡
R1	43.2Ω ±1% 1/8W hp PART NO. 0757-0392
R2	86.6Ω ±1% 1/8W hp PART NO. 0698-4398

Figure 5-7. Impedance Converter

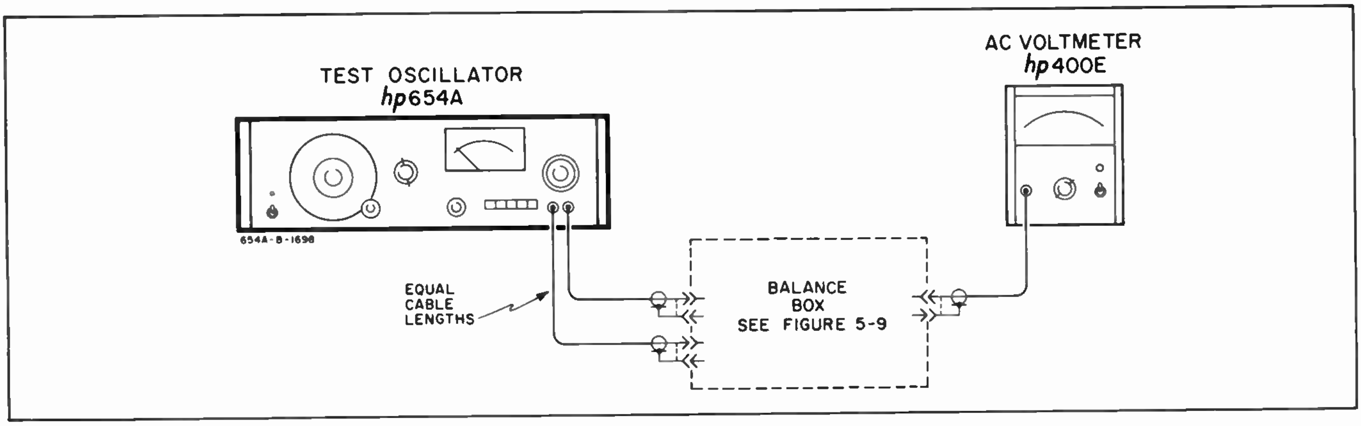


Figure 5-8. Balance Checks

(Paragraphs 5-30 through 5-34) are not met, perform the Balance Adjustments (Paragraph 5-62 through 5-64).

5-30. 135 BAL CHECK.

a. Connect the equipment, as shown in Figure 5-8, using the 135 ohm Balance Box: (the parts required to build the Balance Box are shown in Figure 5-9) the cables from the 654A should be as short as possible and of equal length (jumper cables, -hp- 10502-6001, which are made from 8 in. lengths of coaxial cable, are suitable for this application).

b. Set the 654A controls as follows:

FREQUENCY dial	1
FREQUENCY RANGE	X10
OUTPUT LEVEL dBm	+10,0
IMPEDANCE	135 BAL
AMPLITUDE	Adjust for 0dBm on 654A meter.

c. Sweep the 654A slowly over the frequency range of 10Hz to 1MHz; the ac voltmeter indication should remain below 3.68mV rms, verifying balance of greater than 50dB from 10Hz to 1MHz.

d. Sweep the 654A slowly over the frequency range of 1MHz to 5MHz; the ac voltmeter indication should remain below 11.6mV rms, verifying balance of greater than 40dB from 1MHz to 5MHz.

5-31. 150 BAL CHECK.

5-32. Repeat the procedure of Paragraph 5-30 with the following changes:

in step a. use the 150 ohm Balance Box (See Figure 5-9);
in step b. set IMPEDANCE to 150 BAL;
in step c. ac voltmeter indication should be below 3.87mV rms;
in step d. ac voltmeter indication should be below 12.25mV rms.

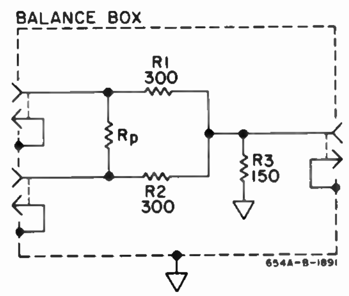
5-33. 600 BAL CHECK.

5-34. Repeat the procedure of Paragraph 5-30 with the following changes:

in step a. Use the 600 ohm Balance Box (See Figure 5-9);
in step b. Set IMPEDANCE to 600 BAL;
in step c. ac voltmeter indication should be below 7.75mV rms;
in step d. ac voltmeter indication should be below 24.5mV rms.

5-35. DISTORTION CHECK.

a. Connect a distortion analyzer to the 654A 50 ohm output as shown in Figure 5-10.



Parts List: (All resistors 1/8 watt metal film.)

R1, R2	300 ohms +/-.1%	-hp- 0698-6295
R3	150 ohms +/-1%	-hp- 0757-0284

Rp:

Input Impedance	Rp, +/-1%
135 ohms	174 ohms, -hp- 0698-4417
150 ohms	200 ohms, -hp- 0757-0407
600 ohms	open

Figure 5-9. Balance Box

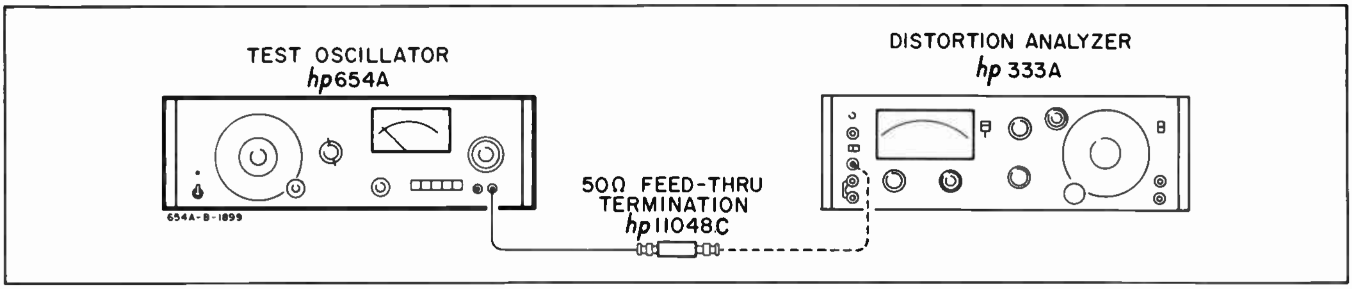


Figure 5-10. Distortion Check

b. Set the 654A controls as follows:

FREQUENCY dial 1
FREQUENCY RANGE X10
OUTPUT LEVEL dBm . . . . +10,0
IMPEDANCE .50 UNBAL
AMPLITUDE . . . . Adjust for +1dBm on 654A meter.

c. Verify distortion of greater than 40dB below the fundamental frequency by checking the distortion at the following frequency settings of the 654A:
1) FREQUENCY dial at 1, 2, 5, 8 and 10 for each FREQUENCY RANGE switch setting, X10, X100, X1K, and X10K.

2) FREQUENCY dial at 1, 2 and 5 for X100K setting of FREQUENCY RANGE switch.

d. Disconnect the 654A from the distortion analyzer and connect the 654A to the wave analyzer (remove 50 ohm feedthru termination).

e. Set the 654A FREQUENCY RANGE switch to X1M and the FREQUENCY dial to 1.

f. Tune the wave analyzer to 1MHz and note the level (in dB) of the 654A fundamental frequency as indicated on the wave analyzer meter.

g. Tune the wave analyzer to the second and third harmonics of the 654A frequency and record the difference (in dB) between the level of each harmonic and the level of the fundamental. Calculate the total harmonic distortion (calculation below) which should be at least 40dB below the fundamental frequency level.

NOTE

If both harmonics are more than 43dB below the fundamental, the total harmonic distortion will be more than 40dB down and it will not be necessary to make the following calculation.

1) Ascertain the difference between the two harmonic levels (in dB).

2) Using the chart below (Figure 5-12), determine the dB to be added to the largest harmonic level.

3) Add this amount to the largest harmonic level. This total should be ⩾ 40 dB below the level in step f.

Example:
If two harmonics with levels of -42dB and -48dB are measured, the difference is -48 -(-42) = -6. Observing the chart this corresponds to an added level of 1.0dB. Adding this to the largest harmonic level (-42dB) gives -42 +1.0 = -41dB.

h. Set the 654A frequency to 5MHz; tune the wave analyzer to 5MHz and repeat steps f and g to measure the total harmonic distortion at 5MHz, which should be greater than 34dB below the fundamental.

i. Set the 654A frequency to 10MHz; tune the wave analyzer to 10MHz and record the level indicated (in dB) on the wave analyzer meter.

j. Tune the wave analyzer to 20MHz and measure the distortion which should be at least 34dB below the level recorded in step i.

k. Perform the adjustment of Paragraph 5-51 if the tolerances are not met.

5-36. HUM AND NOISE CHECK.

a. Connect the equipment shown in Figure 5-11. Figure 5-13 shows the parts required to build the 10MHz Low-Pass Filter.

b. Set the 654A controls as follows:

FREQUENCY dial . . . . .Extreme Clockwise
FREQUENCY RANGE X1K
OUTPUT LEVEL dBm . . . . +10,0
IMPEDANCE .50 UNBAL

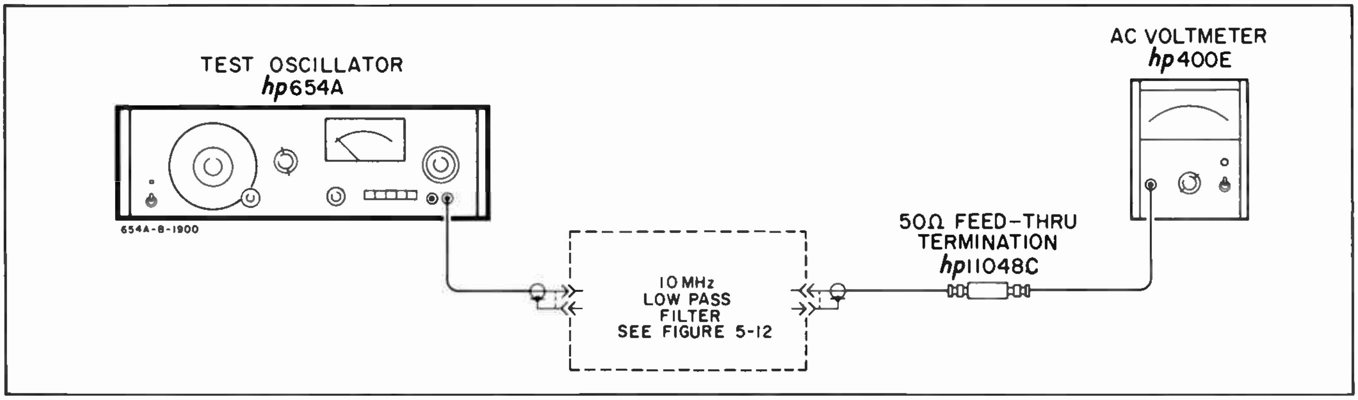


Figure 5-11. Hum and Noise Check

c. Adjust the 654A AMPLITUDE control for an ac voltmeter indication of 0dB on the 0dB range.

CAUTION

IN THE FOLLOWING STEP THE 654A TUNER CAPACITOR IS SHORTED TO GROUND. CARE SHOULD BE TAKEN NOT TO TOUCH OR DAMAGE THE PLATES OF THE TUNER CAPACITOR OTHERWISE THE INSTRUMENT WILL HAVE TO BE RECALIBRATED.

CAUTION

DO NOT MOVE THE TWO WIRES BETWEEN TUNER AND RANGE SWITCH (95 AND 8); THEIR POSITION WILL EFFECT FREQUENCY. ALL WIRES ON OR AROUND THE FREQUENCY RANGE SWITCH CAN EFFECT FREQUENCY RESPONSE.

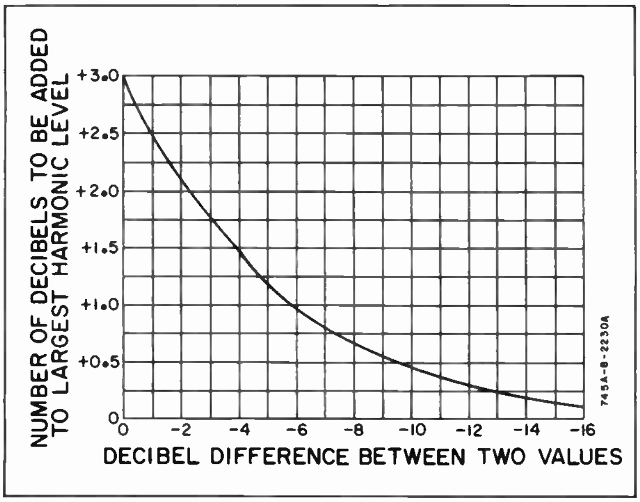
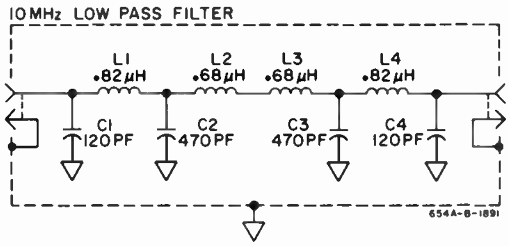


Figure 5-12. Logarithmic Addition of Harmonic Components

d. Remove the 654A top cover: insert a screwdriver between the tuner capacitor (point X on Figure 5-14) and chassis ground. The residual hum and noise indicated on the ac voltmeter should be greater than 70dB below the 0dB reference.



C1,C4,	Cap fxd: 120pF +/-5%	-hp- 0160-2205
C2,C3,	Cap fxd: 470pF +/-5%	-hp- 0140-0149
L1,L4,	Ind fxd: 0.82uH +/-10%	-hp- 9100-1614
L2,L3,	Ind fxd: 0.68uH +/-15%	-hp- 9140-0024

Figure 5-13. 10MHz Low Pass Filter

e. If the tolerance is not met ensure that a good ground connection was made in step d before troubleshooting the instrument.

5-37. COUNTER OUTPUT CHECK.

a. Set the 654A controls as follows:

FREQUENCY dial 1
FREQUENCY RANGE X10

b. Connect an ac voltmeter to the 654A rear panel COUNTER OUTPUT; terminate the the cable to the ac voltmeter with a 50 ohm feedthrough termination.

c. Sweep the FREQUENCY dial slowly from 1 to 10 for all positions of the FREQUENCY RANGE switch.

d. The ac voltmeter indication should be 0.1V rms or greater, verifying an output of at least 0.1V rms into 50 ohms.

e. If the limits are not met troubleshoot the instrument.

5-38. ADJUSTMENT PROCEDURE.

5-39. The following is a complete calibration procedure for the Model 654A Test Oscillator. These adjustments should be performed only if it has been determined by the Performance Checks that the 654A is not meeting its specifications. Figure 5-14 shows the location of all internal adjustments.

5-40. CALIBRATION PROCEDURE.

5-41. To remove the top or bottom cover, remove the two retaining screws, slide the cover about 1/2 inch to the rear and lift off. To remove the side covers, remove the two retaining screws and lift off. To replace the covers, reverse the procedure.

CAUTION

THE 654A CONTAINS HIGH IMPEDANCE, HIGH FREQUENCY CIRCUITS. CONTAMINATION OF THE SWITCHES, CIRCUIT BOARDS OR TUNING CAPACITOR WILL CAUSE HIGH IMPEDANCE LEAKAGE PATHS AND SUBSEQUENT DETERIORATION OF THE PERFORMANCE OF THE INSTRUMENT. AVOID TOUCHING ANY OF THESE CIRCUITS WITH THE BARE FINGERS, AS SKIN OILS ARE EXTREMELY CONTAMINATING. IF HANDLING IS NECESSARY, WEAR CLEAN COTTON OR RUBBER GLOVES. DO NOT USE A PENCIL TO TRACE CIRCUITS IN THE INSTRUMENT. GRAPHITE PENCIL LEAD IS AN EXTREMELY GOOD CONDUCTOR AND AN ACCIDENTALLY INTRODUCED PATH OF THIS TYPE IS SOMETIMES DIFFICULT TO LOCATE. TO AVOID SURFACE CONTAMINATION OF A PRINTED CIRCUIT OR SWITCH, CLEAN WITH A WEAK SOLUTION OF WARM WATER AND MILD DETERGENT AFTER REPAIR. RINSE THOROUGHLY WITH CLEAN WATER AND ALLOW IT TO DRY COMPLETELY BEFORE OPERATING. DO NOT APPLY ANY COMMERCIAL MOISTURE SEALING SPRAY TO THE BOARDS; APPLICATION OF THESE AGENTS MAY CAUSE LEAKAGE PATHS.

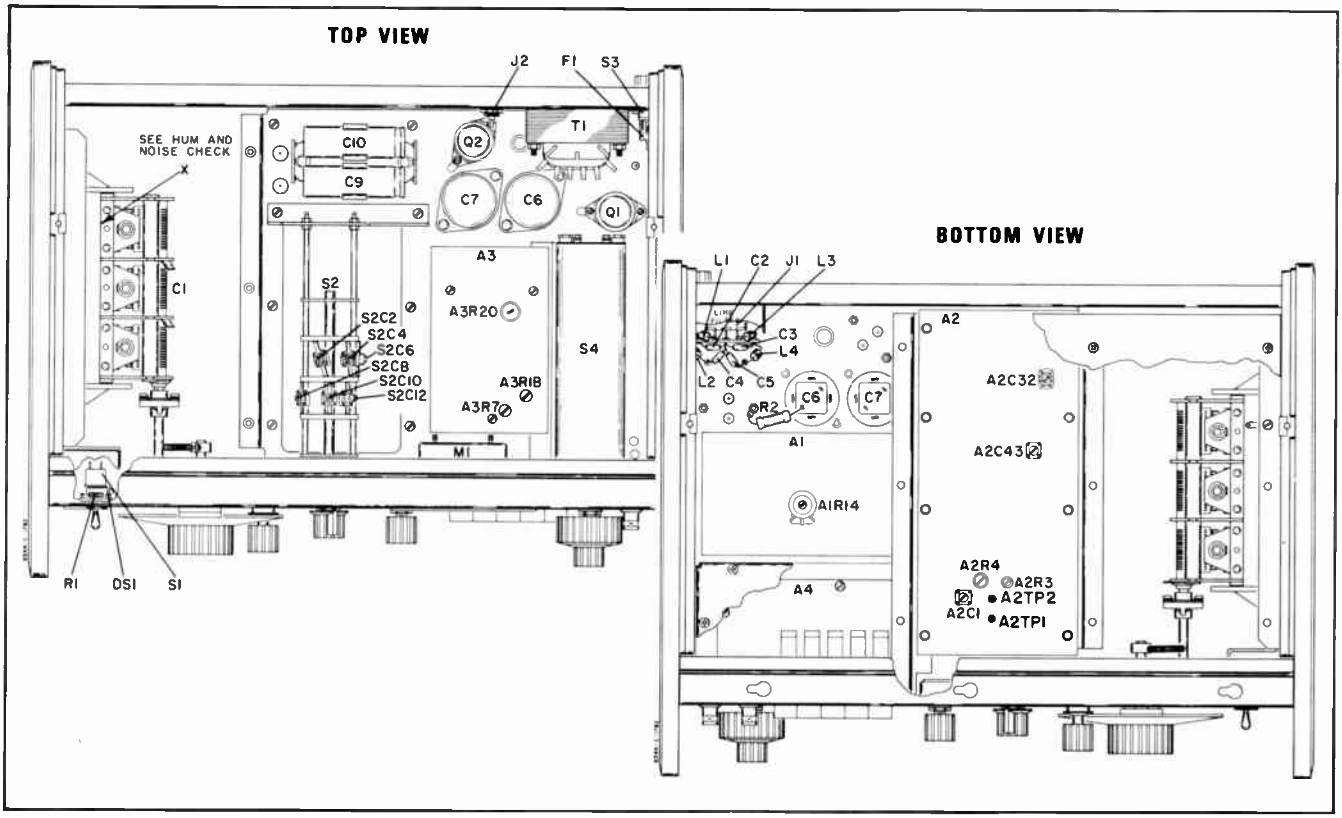


Figure 5-14. Location of Internal Adjustments

5-42. TURN-ON.

5-43. Connect the 654A to a variable power line supply (set for 115V or 230V as appropriate).

5-44. Zero set the meter (Paragraph 3-7), turn the instrument on (Paragraph 3-8), and allow 30 minutes warm-up time.

5-45. POWER SUPPLY VOLTAGE ADJUSTMENTS.

a. Connect a dc voltmeter to the power supply positive output (A1 Pin 12).

b. Adjust A1R14 (+30V Adjust) for 31, +/-0.2V.

c. Connect the dc voltmeter to the power supply negative output (A1 Pin 13). The voltage should be -26, +/-0.5V; if not, change the value of A1R15* to obtain the required voltage (increasing the value of A1R15* makes the power supply voltage less negative, and vice-versa).

d. For power supply troubleshooting, refer to Paragraph 5-78.

5-46. POWER SUPPLY REGULATION AND RIPPLE CHECK.

a. Connect the dc voltmeter to the power supply negative output (A1 Pin 13); switch the FREQUENCY RANGE switch to X100 and note the voltmeter indication.

b. Vary the power line voltage from 103.5V to 126.5V (207V to 253V for a 230V power line); the dc voltmeter indication should remain within +/-0.5V of the reading noted in step a.

c. Adjust the line voltage to 103.5V (207V for a 230V power line) and disconnect the dc voltmeter.

d. Connect an oscilloscope to the power supply positive output (A1 Pin 12) and short out the tuner capacitor (C1) by clipping a lead from the solder lug (green/white lead) on the tuner frame to the chassis. The oscilloscope ripple indication should be less than 15mV peak-to-peak.

CAUTION

DO NOT MOVE THE TWO WIRES BETWEEN TUNER AND RANGE SWITCH; THEIR POSITION WILL AFFECT FREQ. CAL.

e. Connect the oscilloscope to the power supply negative output (A1 Pin 13); the ripple indication should be less than 15mV peak-to-peak.

f. Disconnect the clip lead from the tuner.

5-47. FREQUENCY CALIBRATION PROCEDURES.

CAUTION

DO NOT MOVE THE TWO WIRES BETWEEN TUNER AND RANGE SWITCH AFTER CALIBRATION IS STARTED; THEIR POSITION WILL AFFECT FREQ. CAL.

5-48. The frequency calibration set-up is shown in Figure 5-14 (do not make the set-up at this time); the frequency should be continuously monitored at the rear panel COUNTER OUTPUT. Table 5-2 lists the accuracy required at each check frequency; adjustments for each range are listed in Table 5-4. Components located on the FREQUENCY RANGE switch (S2) are identified on the switch drawing of Figure 7-2.

Table 5-4. Frequency Adjustments

Increasing value of these components decreases frequency and changes A2TP2 voltage as shown. Adjust variable capacitors clockwise to increase capacitance, counter-clockwise to decrease capacitance.

FREQUENCY RANGE	FREQUENCY Dial = 1		FREQUENCY Dial = 10	
	Increases A2TP2 Voltage	Decreases A2TP2 Voltage	Increases A2TP2 Voltage	Decreases A2TP2 Voltage
X10	S2R2*	S2R10*	---	---
X100	---	---	S2C17*	---
X1K	---	---	S2C8, S2C9*, S2C13*, S2C16*	S2C2, S2C3*
X10K	---	---	S2C1*, S2C18*	---
X100K	---	---	S2C10, S2C11*	S2C4, S2C5*
X1M	S2R8*	S2R16*	A2C1, S2C12, S2C15*	S2C6, S2C7*

5-49. During calibration, the instrument bottom cover is removed; the top cover is removed to make adjustments and replaced while making frequency measurements (not necessary to replace retaining screws), all internal shields must be in place and held firmly by retaining screws. If desired Figure 5-17 gives a scaled drawing of top and bottom alignment access covers with cut-outs that will allow adjustments while the covers are in place. The dimensions are given in inches.

5-50. FEEDBACK LEVEL ADJUSTMENT.

a. Connect the equipment shown in Figure 5-15.

b. Set the 654A controls as follows:

FREQUENCY dial . . . . extreme clockwise
FREQUENCY RANGE X1K
OUTPUT LEVEL dBm . . . . +10,0
AMPLITUDE . . . . extreme counter-clockwise
IMPEDANCE . . . . 50 UNBAL

NOTE

Adjust A2C1, S2C2, and S2C8, if necessary, to start oscillations.

c. Adjust A2R3 (Feedback Level Adj.) for an indication on the dc voltmeter of -350mV, +/-10mV.

d. For oscillator troubleshooting, refer to Paragraph 5-81.

5-51. DISTORTION ADJUSTMENT.

a. Connect the 654A to the distortion analyzer as shown in Figure 5-10. Set the 654A controls for a frequency of 1 X 100.

b. Adjust A2R4 (Distortion Adj.) for minimum distortion, which should be at least -46dB. If the tolerance cannot be met, change the value of A2R9*

c. Check distortion at other dial and range settings.

NOTE

You can adjust A1R4 at other frequency to get them into specification providing that you still are in specification at 1 X 100.

d. Disconnect the distortion analyzer.

5-52. Frequency Dial and 1 K Range Adjustment.

a. Preliminary mechanical adjustments (perform only if necessary).

1) To prevent gear backlash problems during alignment, make sure that there is no movement between MP1 and MP2. See Figure 6-1. (They must be pressed tightly together.) Also MP3, 4, and MP5 spring gear assembly must be under tension.

2) Check to make sure that the stop MP6 prevents the tuning capacitor from being completely closed. MP6 should hold the capacitor at least 1/16 inch open. Adjust if necessary.

3) With the dial set to maximum clockwise position, slip the dial face such that the first mark left of 1 is 1/16 inch to the right of the fixed indicator. To slip dial, remove Frequency dial knob and loosen 4 dial retaining screws. After slipping dial, retighten the screws.

b. Connect equipment as shown in Figure 5-15 and set the 654A controls as in Paragraph 5-50b. Record output frequency.

c. Record frequency at dial settings 1, 2, 5, 8 and 10. If some readings are high and some are low, proceed to step e. If all readings are high or all

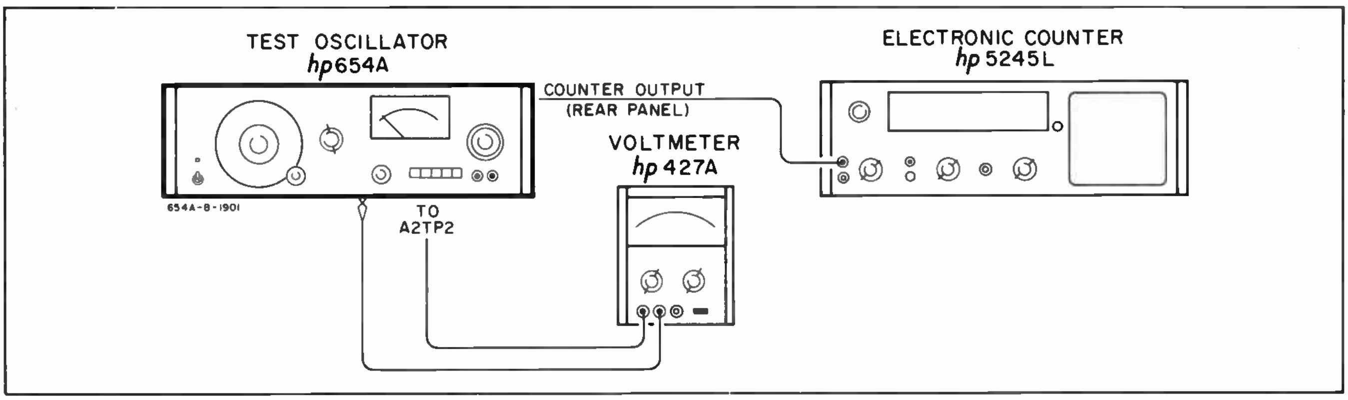


Figure 5-15. Frequency Calibration Test Setup

MANUAL CHANGES

MODEL 654A

TEST OSCILLATOR

-hp- Part Number 00654-90002

▌ New or Revised Item

ERRATA:

Page 6-6, Table 6-1, Chassis Mounted Components and Assemblies. Add Part No. 5061-0735 TUNER ASSEMBLY (consists of C1A, C1B, C1C and MP14). Add "Part of 5061-0735" to C1A, B, C and MP14.

ADDENDA:

CHANGE 1 FOR SERIAL NUMBERS 0951A01701 AND ABOVE.

Pages 6-3 and 6-4, Table 6-1, and Page 7-7/7-8, Schematic No. 2.
Add A2CR25, 1902-0222 Diode Breakdown 14 V.
Delete A2R70.
Add A2CR26, 1902-0554 Diode Breakdown 10 V.
Delete A2R73.
Change R61 and R62 to factory selected parts, 40.2 Ω 0698-3262.

CHANGE 2 FOR SERIAL NUMBERS 0951A02261 AND ABOVE.

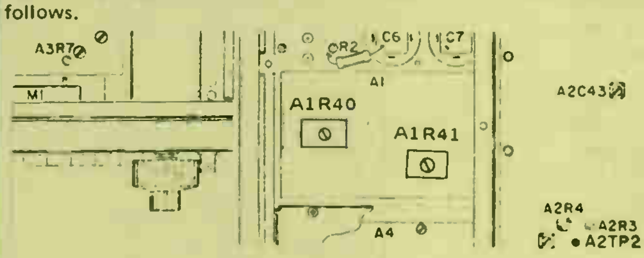
Page 4-4, Paragraphs 4-38 through 4-40. Replace with the following:

4-38. The regulated power supply provides all voltages required by the test oscillator circuits. The power supply consists of a + 31 V series regulated supply and a - 26 V series regulated supply. Each supply is referenced to a 6.2 V zener diode, CR16 and CR20 respectively.

4-39. The + 31 V and - 26 V series regulated supplies each contain an IC which compares a portion of the output (pin 2) with the reference voltage, 6.2 V. For a + 31 V or - 26 V output, R40 and R41 are adjusted to provide 6.2 V at pin 2 of the IC. When the output voltage changes due to loading, the voltage at pin 2 of the IC changes and the IC drives Q1, A1Q2 and A1Q3 to correct the output voltage.

4-40. Both supplies have a current limiting capability. When the output current of either supply exceeds 330 mA, the current limiting transistor (Q4 for the positive and Q7 for the negative supply) begins to conduct and drives the regulating circuit. The output voltage is then reduced until the load causing excessive current is removed.

Page 5-12, Figure 14. Replace the location of A1 adjustment as follows.



Page 5-13, Paragraph 5-45. Replace Steps b and c with the following:

b. Adjust A1R40 (+ 30 V adjust) for 31, ± 0.2 V.

c. Connect the dc voltmeter to the power supply negative output (A1 pin 13). Adjust A1R41 (- 25 V ADJUST) for 26 V ± 0.5 V.

Page 5-20. Delete the last sentence in (9)b and all of Step c. Refer to Paragraph 5-78 when troublshooting the power supply.

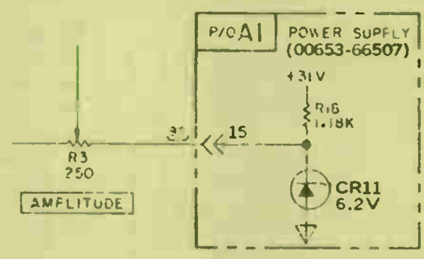
Page 5-22, Paragraph 5-78. In the NOTE, change the capacitor numbers to "C14" and "C15" and the rating to "400 V".

Page 6-2, Table 6-1. Replaceable Parts. Replace the A1 assembly parts list (-hp- Part No. 00654-66501) with the A1 assembly (-hp- Part No. 00653-66507) listed on Page 2 of this Change Sheet.

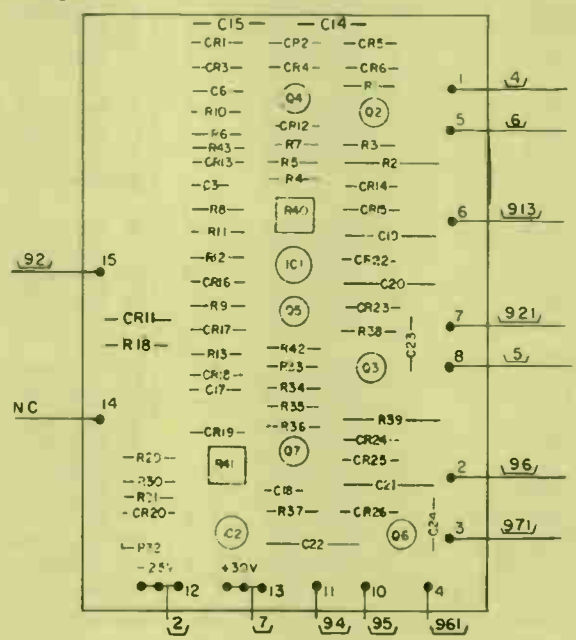
Page 6-6, Table 6-1. Under "Chassis Mounted Components" change the part numbers and descriptions of the following:

Q1, 1854-0063, TSTR:Si NPN, 2N3055
Q2, 1853-0305, TSTR:Si PNP, 2N5875

Page 7-7/7-8. Replace A1 circuit diagram with the following:



Page 7-11, Figure 7-5. Replace A1 Component Locator with the following:

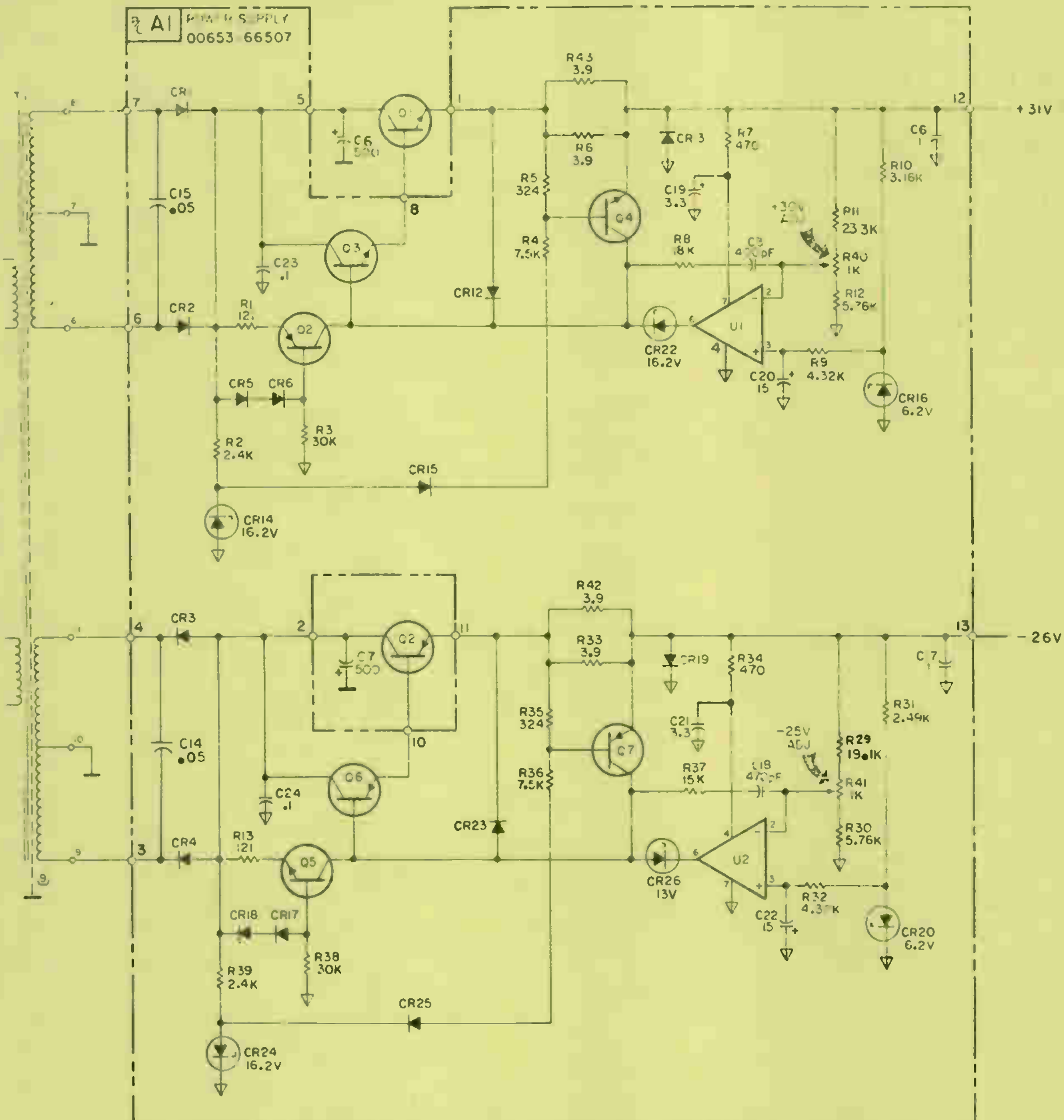


00653 - 66507

Table 6-1. Replaceable Parts (Cont'd)

REFERENCE DESIGNATOR	-hp- PART NO.	TQ	DESCRIPTION	MFR.	MFR. PART NO.
A1	00653-66507		PC BOARD: POWER SUPPLY	28480	00653-66507
A1C3	0140-0177		C: fxd 400 pF ± 1% 300 vdcw	72136	DM15F401F0300WV1CR
A1C6	0180-0230		C: fxd 1 μF ± 20% 50 vdcw	56289	150D105X0050A2
A1C14, 15	0150-0052		C: fxd A1 elect .05 μF +75% - 10% 400 vdcw	28480	0150-0052
A1C17	0180-0230		C: fxd 1 μF ± 20% 50 vdcw	56289	150D105X0050A2
A1C18	0140-0149		C: fxd 470 pF ± 5% 300 vdcw	72136	DM15F471J0300WV1CR
A1C19	0180-0161		C: fxd 3.3 μF ± 20% 35 vdcw	56289	150D335X003582
A1C20	0180-1746		C: fxd 15 μF ± 10% 20 vdcw	56289	150D156X902082
A1C21	0180-0161		C: fxd 3.3 μF ± 20% 35 vdcw	56289	150D335X003582
A1C23, A1C24	0150-0084		C: fxd .1 μF +80%, - 20% 100 vdcw	28480	0150-0084
A1CR1 thru A1CR4	1901-0158		Diode: Si	04713	SR1258-3 obd
A1CR5, CR6	1901-0040		Diode: Si 50 mA 30 V	28480	1901-0040
A11CR11	1902-0777		Diode: TC REF	04713	1N825
A1CR12, CR13	1901-0040		Diode: Si 50 mA 30 V	28480	1901-0040
A1CR14	1902-0184		Diode: bkdn 16.2 V	28480	1902-0184
A1CR15	1901-0040		Diode: Si 50 mA 30 V	28480	1901-0040
A1CR16	1902-0777		Diode: TC REF	04713	1N825
A1CR17–A1CR19	1901-0040		Diode: Si 50 mA 30 V	28480	1901-0040
A1CR20	1902-0777		Diode: TC REF	04713	1N825
A1CR22	1902-0184		Diode: Bkdn 16.2 V	28480	1902-0184
A1CR23	1901-0040		Diode: Si 50 mA 30 V	28480	1901-0050
A1CR24	1902-0184		Diode: Bkdn 16.2 V	28480	1902-0184
A1CR25	1901-0040		Diode: Si 50 mA 30 V	28480	1901-0040
A1CR26	1902-3190		Diode: Bkdn 13 V	04713	SZ10939-215
A1Q1			Not assigned		
A1Q2	1853-0037	3	Tstr: NPN	28480	1853-0037
A1Q3 thru Q5	1854-0474	3	Tstr: Si PNP	28480	1854-0474
A1Q6, Q7	1853-0037		Tstr: Si PNP	28480	1853-0037
A1R1	0757-0403	2	R: fxd comp 121 Ω ± 1% 1/8W	24546	C4-1/8-To-121-R-F
A1R3	0683-3035	2	R: fxd comp 30K ± 5% 1/4W	01121	CB3035
A1R4	0757-0440	2	R: fxd comp 7.5K ± 1% 1/8W	24546	C4-1/8-To-7501-F
A1R5	0698-4450	2	R: fxd comp 324 Ω ± 1% 1/8 W	24546	C4-1/8-To-324R-F
A1R6	0683-0395	4	R: fxd comp 3.9 Ω ± 5% 1/4W	01121	CB0395
A1R7	0683-4715	2	R: fxd comp 470 Ω ± 5% 1/4W	01121	CB4715
A1R8	0683-1835	1	R: fxd comp 18K ± 5% 1/4W	01121	CB1835
A1R9	0757-0436	2	R: fxd comp 4.32K ± 1% 1/8W	24546	C4-1/8-To-4321-F
A1R10	0757-0279	1	R: fxd comp 3.16K ± 1% 1/8W	24546	C4-1/8-To-3161-F
A1R11	0757-0451	2	R: fxd comp 24.3 kΩ ± 1% 1/8W	24546	C4-1/8-To-2432-F
A1R12	0698-4445	2	R: fxd 5.76K ± 1% 1/8W	16299	C4-1/8-To-5761-F
A1R13	0757-0403		R: fxd comp 121 Ω ± 1% 1/8W	24546	C4-1/8-To-121R-F
A1R18	0698-4888		R: fxd 1180 Ω ± 1% 1/8W	24546	NA6
A1R19, 20			Not Used in Model 654A		
A1R29	0698-4484	1	R: fxd comp 19.1K ± 1% 1/8W	24546	C4-1/8-To-1912-F
A1R30	0698-4445		R: fxd 5.76K ± 1% 1/8W	16299	C4-1/8-To-5761-F
A1R31	0698-4435	1	R: fxd comp 2.49K ± 1% 1/8W	16299	C4-1/8-To-2491-F
A1R32	0757-0436		R: fxd comp 4.32 K ± 1% 1/8W	24546	C4-1/8-To-4321-F
A1R33	0683-0395		R: fxd comp 3.9 Ω ± 5% 1/4W	01121	CB0395
A1R34	0683-4715		R: fxd comp 470 Ω ± 5% 1/4W	01121	CB4715
A1R35	0698-4450		R: fxd comp 324 Ω ± 1% 1/8W	24546	C4-1/8-To-324R-F
A1R36	0757-0440		R: fxd comp 7.5K ± 1% 1/8W	24546	C4-1/8-To-7501-F
A1R37	0683-1535		R: fxd comp 15 kΩ ± 5% 1/4W	01121	CB1535
A1R38	0683-3035		R: fxd comp 30K ± 5% 1/4W	01121	CB3035
A1R39	0761-0024		R: fxd comp 2.4K ± 5% 1 W	24546	FP32-1-Too-2401-J
A1R40, R41	2100-3211	2	R: var 1K ± 10%	28480	2100-3211
A1R42, R43	0683-0395		R: fxd comp 3.9 Ω ± 5% 1/4W	01121	CB0395
A1U1, U2	1826-0043	2	IC: OP AMP	27014	LM307H
	1200-0437	2	Socket: IC	17117	7009-265-5

Page 7-11, Figure 7-5. Replace A1 Circuit Diagram with the following:



readings are low, proceed to step d. If all the readings are within tolerances, proceed to step f.

d. Check readings at 1, 5 and 10 on the dial. If readings are close to proper value, proceed to step e. If they are not, perform the following:

1) Place dial to clockwise position.

2) Remove the frequency dial knob and loosen the four dial retaining screws.

3) Slip the dial to read 1 with a counter indication of 1 kHz (Frequency Range 1 K).

4) Tighten the retaining screws and replace the knob.

e. Set the FREQUENCY dial to 10. Adjust S2C2 and S2C8 alternately until the counter indicates a frequency of 10 kHz and A2TP2 voltage is - 370 ± 10 mV. Then recheck at 1 on the dial. Work back and forth between 1 and 10 on the dial until both are near or within the allowed limits. Recheck step c.

1) If S2C2 does not have sufficient range, change the value of S2C3* (refer to Table 5-5). If S2C8 does not have sufficient range, change S2C9*.

2) If A2TP2 should not remain - 370 mV ± 20 mV over the entire dial range, change value of S2C16* or S2C13* to bring frequency and A2TP2 voltage within limits.

f. Check all frequencies on the X1K range according to Table 5-2. The voltage at 1 and 10 on the dial should read the same ± 10 mV. If voltage is not within limits, proceed to step e(2).

NOTE

Steps d, e and f interact with each other.

5-53. X100, X1K and X10K RANGE TRACKING.

a. Connect the equipment as shown in Figure 5-15. Set the 654A controls as in Paragraph 5-50b.

b. Check frequency tracking of the FREQUENCY dial using the settings and tolerances given in Table 5-2 for the X100, X1K and X10K ranges. Also monitor A2TP2 voltage which should remain within - 0.3 to - 0.4 V over the entiry range. If necessary, pad S2C17* for X100 RANGE and S2C1* and S2C18* for X10K RANGE for correct frequency and A2TP2 voltage when the dial is set to 10.

5-54. X10 RANGE ADJUSTMENTS.

a. Connect the equipment as shown in Figure 5-15.

b. Set the 654A FREQUENCY RANGE switch to X10 and FREQUENCY dial to 1, other controls as in Paragraph 5-50b. The counter (set to read period average) should indicate 100 ± 3 msec (10 ± 0.3 Hz) and A2TP2 voltage should be - 370 ± 40 mV; if either frequency or A2TP2 voltage is not within tolerance, change the value of S2R2* and S2R10* simultaneously (see Table 5-4) until the tolerances are met.

c. Check frequency tracking using the settings and tolerances given in Table 5-2 for the X10 range. Monitor A2TP2 voltage which should remain at - 370 ± 40 mV over the entire range. If necessary, to make dial track, repeat step b but set the frequency towards the upper or lower tolerance.

5-55. X1M RANGE ADJUSTMENTS.

a. Connect the equipment as shown in Figure 5-15.

b. Set the 654A FREQUENCY RANGE switch to X1M and the FREQUENCY dial to 10, other controls as in Paragraph 5-50b.

NOTE

Adjust A2C1, S2C6 and S2C12, if necessary, to start oscillation.

c. Adjust S2C6 and S2C12 (see Table 5-4) for a counter indication between 10.1 and 10.2 MHz (1 to 2% high) and A2TP2 voltage between - 0.38 V and - 0.40 V.

d. Set the FREQUENCY dial to 5; counter should indicate 5,000 +/-65kHz. If not, perform the following.

1) Note whether the counter indication is higher or lower than 5,000kHz.

2) Set the FREQUENCY dial to 10; if the frequency of step 1) was high, adjust A2C1 to increase the counter indication slightly; if the frequency of step 1) was low, adjust A2C1 to slightly lower the counter indication.

NOTE

While making this adjustment to A2C1, the oscillator may stop oscillating; however, the adjustment to be made in step 3) will start oscillations again.

3) Readjust S2C6 and S2C12 as in step 5-55c.

4) Repeat step 5-55d as often as necessary until tolerances are met at both 5 and 10 settings of the FREQUENCY dial. If S2C6 does not have sufficient range, change the value of S2C7* in accordance with Table 5-4; similarly, for S2C12 change S2C15*.

e. Set the 654A FREQUENCY dial to 1; the counter should indicate 1000 ± 20 kHz and A2TP2 voltage should be between - 0.3 V to - 0.4 V; if frequency or A2TP2 voltage is not within tolerance, pad range resistors S2R8* and S2R16* simultaneously in accordance with Table 5-4.

NOTE

It may be necessary to set the frequency high at 10 on dial in order for the dial to track.

f. Set the dial to 10 and repeat steps c and d if necessary.

g. Check frequency tracking of the dial at the settings given in Table 5-2 for the X1M range; if any of these are not within tolerance, repeat steps c through g of this paragraph. A2TP2 voltage should be within - 0.25 to - 0.42 volts over the entire range.

5-56. X100K RANGE ADJUSTMENTS.

a. Connect the equipment as shown in Figure 5-15. Set the 654A controls as in Paragraph 5-50b except set FREQUENCY RANGE to X100K and FREQUENCY dial to 1.

b. Note the A2TP2 voltage which should be between - 0.3 V to - 0.4 V; set the FREQUENCY dial to 10 and adjust S2C4 and S2C10 for a counter indication of 1 MHz ± 20 kHz and an A2TP2 voltage as noted above. If S2C4 does not have sufficient range, change the value of S2C5* in accordance with Table 5-4; similarly, for S2C10, change the value of S2C11*.

c. Check the FREQUENCY dial tracking using the settings and tolerances given in Table 5-2 for the X100K range. If not in tolerance, repeat step b but set the frequency (with dial at 10) towards the lower or upper limit of the tolerance given in Table 5-2 so that the dial will track as required.

5-57. OUTPUT WAVEFORM CHECK.

a. Connect the 654A 50 ohm output to the oscilloscope; terminate the cable from the 654A with a 50 ohm feedthru.

b. Set the 654A controls as follows:

AMPLITUDE . . . . extreme counter-clockwise
OUTPUT LEVEL dBm . . . . extreme clockwise
IMPEDANCE . . . . 50 UNBAL

c. Check the 654A output waveform for spurious oscillations or visible distortion; check all frequencies by sweeping the FREQUENCY dial across the whole range at each FREQUENCY RANGE setting. If distortion or spurious oscillations occur, eliminate by changing the value of A2C8*.

NOTE

If A2C8* is changed it may be necessary to recalibrate the X1M and X100K ranges.

5-58. METER TRACKING AND AMPLITUDE CONTROL ADJUSTMENTS.

5-59. METER RANGE ADJUSTMENT.

a. Set the 654A controls as follows:

FREQUENCY dial 1
FREQUENCY RANGE X1K
OUTPUT LEVEL dBm . . . . +10,0
IMPEDANCE . . . . 50 UNBAL

b. Adjust A3R18 (Meter Cal) to its extreme clockwise position.

c. Adjust A3R7 (Meter Offset Cal) so that the AMPLITUDE control has sufficient range to exceed the maximum meter deflection at both ends of the meter scale.

d. Adjust the 654A AMPLITUDE control for a meter indication of -1dBm.

e. Connect the equipment shown in Figure 5-16 and set the external attenuator for 0dB attenuation.

f. Adjust the reference supply for null indication on the dc null voltmeter (which should be set to either the 30uV or 100uV range).

g. Set the external attenuator to -2dB position and adjust the 654A AMPLITUDE control to return the dc null voltmeter indication to null.

h. Adjust A3R18 (Meter Cal) until the 654A meter indicates +1dBm.

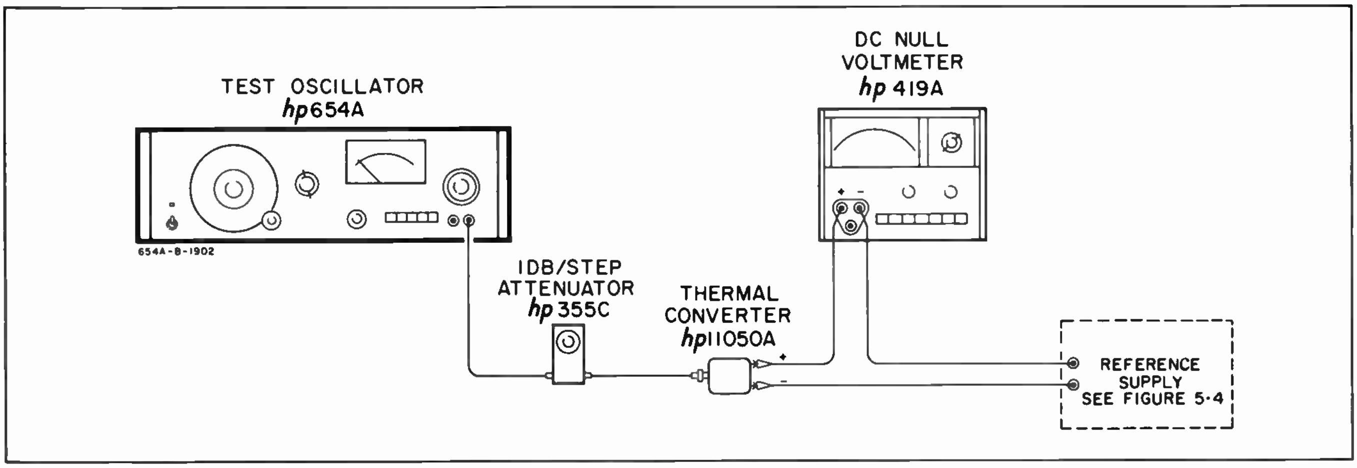


Figure 5-16. Meter Tracking Adjustment

i. Check the 654A meter tracking as follows:

1) Set the external attenuator to -1dB position and adjust the 654A **AMPLITUDE** control for null indication on the dc null voltmeter; the 654A meter should indicate 0 +/-0.05dBm.

2) Set the external attenuator to 0 dB position and adjust the 654A **AMPLITUDE** control for null indication on the dc null voltmeter; the 654A meter should indicate - 1 ± 0.01 dBm.

3) If the tolerances in steps 1) and 2) are not met then readjust A3R7 (Meter Offset Cal) as in step c and repeat steps d through i of this paragraph.

j. The meter tracking adjustment is completed by performing Paragraph 5-60.

k. For troubleshooting information refer to Paragraph 5-94.

5-60. AMPLITUDE CONTROL AND METER CALIBRATION.

NOTE

Perform adjustments of Paragraph 5-59 before making the following adjustments.

a. Connect the equipment shown in Figure 5-1 using the 50 ohm termination.

b. Set the 654A controls as follows:

FREQUENCY dial	1
FREQUENCY RANGE	X1K
OUTPUT LEVEL dBm	+ 10.0
IMPEDANCE	50 UNBAL

c. Adjust the 654A **AMPLITUDE** control for an indication on the ac differential voltmeter of .7071V rms (+10dBm); adjust A3R7 (Meter Offset Cal) for a 654A meter indication of 0dBm.

d. Set the 654A **AMPLITUDE** control to the extreme clockwise position and adjust A3R20 (Amplitude Cal) for an ac differential voltmeter indication of 0.80V rms (approximately +11.05dBm).

e. For troubleshooting information refer to Paragraph 5-95.

5-61. AMPLITUDE ACCURACY CALIBRATION.

a. Perform the Amplitude Accuracy checks of Paragraphs 5-9 through 5-14 but do not make any adjustments except as outlined below. If the +/-1% limits are met for all impedances do not perform the remaining steps of this Paragraph.

b. If the +/-1% limits are not met for any impedance:

1) Verify that the impedance networks on the Impedance Selector board (A4) have the correct impedance and if necessary replace any faulty resistors. The impedance can be checked by measuring the open circuit voltage (for each impedance) which should be twice the terminated voltage; alternatively set the attenuator to -80dB position and measure the output impedance with an ohmmeter.

2) Perform procedure of Paragraph 5-60 except, in step c (of 5-60) adjust the 654A **AMPLITUDE** control for an ac differential voltmeter indication slightly higher or lower than 0.707V rms (see example below) so as to correct any error noted in step a of this Paragraph (5-61): the offset from 0.707V rms should be as small as possible, but in any case, must remain within the limits of 0.700 to 0.714V rms.

EXAMPLE: Suppose that, in step a of this paragraph, the amplitude is found to be too high for one of the impedances; then set the 654A AMPLITUDE control for an ac voltmeter indication below 0.707V rms, and vice versa.

c. Repeat the steps of this paragraph as necessary to ensure that the level is correct for all impedances.

5-62. BALANCE ADJUSTMENTS.

5-63. 135 BAL.

a. Perform steps a and b of the Balance Check of Paragraph 5-30.

b. Set the 654A frequency to 10MHz and adjust A2C32 (High Freq. Balance) for optimum balance (lowest indication on the ac voltmeter.)

c. Set the 654A frequency to 5MHz; the ac voltmeter indication should be below 11.6mV rms indicating a balance of greater than 40dB. If it is not then select a value for A2C21* or A2C36* (but not both) to give the required balance at 5MHz. (Typically, balance of at least 46dB, 5.8mV rms, can be achieved).

NOTE

There is no way of predetermining which side of the balanced amplifier is unbalanced or what value of capacitance is required; A2C21* or A2C36* must be selected by trial and error. Select the lowest value of capacitance possible.

d. Perform steps c and d of Paragraph 5-30 (135 BAL CHECK) to ensure that limits are met at all frequencies of the 654A.

5-64. 150 AND 600 BAL CHECK.

a. Perform the checks of Paragraphs 5-31 through 5-34 to ensure that balance is within specifications for the 150 ohm and 600 ohm impedances.

b. If it is not, repeat the procedure of Paragraph 5-63 but slightly degrade the balance for the 135 ohm impedance (be careful to remain within the requirements of 40dB from 1MHz to 5MHz and 50dB from 10Hz to 1MHz) then repeat step a of this paragraph (5-64) until balance specifications are met for all three impedances.

NOTE

This situation is not likely to arise; however, if it does, then it is recommended that careful notes be made during the procedure as there is no way, other than by trial and error, of determining if the 135 ohm balance is being degraded in a direction which will improve the balance for the other impedances, or if it is being degraded in a direction which will worsen the balance for the other impedances.

5-65. LEVEL FLATNESS ADJUSTMENTS.

5-66. 75 UNBAL FLATNESS.

a. Perform steps a through e of Paragraph 5-16 (50 UNBAL FLATNESS CHECK) with the following exceptions:
in step a. Set IMPEDANCE to 75 UNBAL;
in step b. Use the 75 ohm thermal converter (see Table 5-3).

b. Set the 654A frequency to 10MHz and adjust A2C43 (Frequency Response) for null indication, +/-ΔE (calculated in step a of Paragraph 5-16) on the dc null voltmeter.

c. Sweep the 654A frequency slowly down to 1MHz; the null voltmeter indication should remain within +/-ΔE of null over the whole frequency range.

NOTE

It may be necessary to slightly offset the adjustment of A2C43 at 10MHz so that the flatness is within tolerance across the X1M range.

d. Set the 654A frequency to 10Hz; if the dc null voltmeter indication is not within +/-ΔE of null change the value of A2C40*. (Increase the value of A2C40* if the 654A level is too low at 10Hz, and vice-versa.)

e. Sweep the 654A FREQUENCY dial slowly from 1 to 10 for all settings of the FREQUENCY RANGE switch to ensure that the 75 ohm output is flat over the entire frequency range of the instrument.

5-67. 50 UNBAL FLATNESS.

NOTE

The adjustments of Paragraph 5-66 should be completed before making these adjustments.

a. Perform steps a through e of Paragraph 5-16.

b. Set the 654A frequency to 10MHz; the dc null voltmeter indication should be within +/-ΔE of null. If it is not change the value of A4C1* to bring the 654A level within tolerance (decrease A4C1* to increase the output level and vice-versa).

c. Sweep the 654A frequency slowly down to 1MHz and observe the dc null voltmeter indication which should remain within +/-ΔE of null. If it does not repeat step b of this paragraph but select a value for A4C1* which allows the flatness to be met across the 1MHz to 10MHz frequency range.

d. Check the 654A flatness over the 10Hz to 1MHz ranges as before.

5-68. **135, 150 and 600 BAL FLATNESS.**

5-69. Check the flatness for the balanced impedances by performing Paragraphs 5-18, 5-19 and 5-20. There are no adjustments to be made for these ranges.

5-70. TROUBLESHOOTING THE 654A.

5-71. This section contains information and procedures designed to aid in the process of isolating malfunctions. Troubleshooting should be undertaken only after it has been determined that the malfunction cannot be corrected by performing the adjustment and calibration procedures.

5-72. When a malfunction occurs first ensure that the trouble is not caused by conditions external to the instrument; then make the front panel checks described in Paragraph 5-74 before proceeding to the Troubleshooting Tree.

5-73. The Troubleshooting Tree (Figure 5-18) illustrates a systematic method of locating a faulty circuit. Additional checks (including visual) and measurements will be required to isolate the faulty component.

5-74. FRONT PANEL CHECKS.

a. Check that the LINE ON lamp is lit; if it is not, check the setting of the 115/230V slide switch, check the fuse (F1) and if necessary check the primary circuit of the power transformer (T1 on schematic No. 4, Figure 7-5).

b. In this procedure the 654A will be swept across its frequency range while the following points are monitored:

A. the COUNTER OUTPUT
B. the 654A meter indication
C. the front panel output connectors.

By applying the observation made to Table 5-5 it should be possible to localize any problems to a particular area in the instrument (refer also to the Block Diagram, Figure 7-1).

1) Set the 654A controls as follows:

AMPLITUDE . . . . fully clockwise
OUTPUT LEVEL dBm . . . . +10,0
IMPEDANCE . . . . 50 UNBAL

2) Connect an oscilloscope or ac voltmeter, through a 50 ohm feedthrough termination, to the 654A rear panel COUNTER OUTPUT.

3) Connect an oscilloscope or ac voltmeter, through a 50 ohm feedthrough termination, to the front panel UNBAL output connection.

4) Sweep the 654A FREQUENCY dial slowly from 1 to 10 (for all positions of the FREQUENCY RANGE switch) while observing the three monitoring points A, B and C.

5) Select from the left hand column of Table 5-5 the ABC combination which corresponds with the observations made in step 4). The center column of Table 5-5 gives the most likely trouble area for each combination and the right hand column indicates the next step to make in troubleshooting.

5-75. TROUBLESHOOTING TREE.

5-76. To use the tree start at (1), read step (1) of Paragraph 5-77 and make the required check; the next step then depends upon whether the first check was a PASS or FAIL. Several of the FAIL branches split into sub-branches, take the sub-branch which best fits the observations made. At each step of the tree it is important to read the appropriate step of Paragraph 5-77 as the tree itself does not give sufficiently detailed information, in most cases, for the check to be made. Refer also to the Block Diagram and Schematics of Section VII when using the troubleshooting tree. If you complete the tree and still have failed to localize the problem area then refer to Paragraph 5-78 for additional information.

5-77. This paragraph provides information for each step of the troubleshooting tree.

NOTE

Make the Front panel checks, described in Paragraph 5-74, if you have not already done so.

(1) Check with an oscilloscope at A2 Pin 4: there should be a sine wave of between 5.5V and 7V p-p. Sweep the FREQUENCY dial from 1 to 10 for all positions of the range switch. If the signal appears, even momentarily, then the problem is probably frequency calibration.

(2) Check the dc voltage at the output of the Buffer Amplifier (junction of A2CR24 and A2R44), this should be 0 +/-.1V dc.

(3) Check the dc power supply voltages on the A2 board:
+31 +/-.5V dc at A2 Pin 1.
-26 +/-.5V dc at A2 Pin 2.

(4) Check the ac voltage at the output of the Buffer Amplifier (junction of A2CR24 and A2R44) with an oscilloscope; this should be a sine wave of 3V +/-1V peak-to-peak. Notice that for the FAIL situation there are three possible branches (NO SIGNAL, LESS SIGNAL, GREATER SIGNAL). Take the appropriate branch to the next check point.

NOTE

If the output from the Buffer Amplifier is not correct then the problem is probably in the ALC loop; following the tree should be the fastest way of localizing the problem. If after completing the tree you still have not localized the problem, then refer to Paragraph 5-79 which gives a method for opening the ALC loop.

(5) A procedure for checking the oscillator circuit is given in Paragraph 5-81.

(6) FAIL if either (or both) supply is not present.

(7) Check the dc voltage on the lamp (A2DSV1) at A2 Pin 5. With a larger than normal signal level in the Buffer Amplifier the voltage at A2 Pin 5 should be low, from 0 to +5V dc.

(8) Check the dc voltage on the lamp (A2DSV1) at A2 Pin 5, normally this is +4 to +6V dc. If the voltage is less, then the lamp voltage is trying to increase the Buffer Amplifier signal level and the problem is in the Buffer Amplifier. If the voltage is greater, the lamp is causing the low signal in the Buffer Amplifier. The lamp is probably open if the voltage is higher than +15V dc.

(9) a. If only the - 26 V supply is inoperative proceed to branch (11).

b. Check if the external circuits are loading the power supply by lifting A1 Pin 12 and A1R18 (Schematic No. 2). If the supply operates the trouble is in the external circuits. If the supply does not operate proceed to step c of this Paragraph.

c. The - 26 V supply is referenced to the + 31 V. To check if the - 26 V supply is loading the + 31 V supply first lift A1 pin 13; if the supplies now operate the trouble is in the external circuits; if the supplies still do not operate, lift A1R15*, A1R6 and A1R7 to isolate the - 26 V supply from the + 31 V supply. If the + 31 V supply now operates the trouble is in the - 26 V supply (proceed to branch (11)); if the + 31 V does not operate troubleshoot the + 31 V supply.

(10) Check T1 and the line filter components; also check A2CR1 thru A1CR4, A1C9 and A1C10.

(11) a. Troubleshoot the - 26 V supply if you have arrived here from branch (9)c.

b. Lift A1 Pin 13 to isolate the -26V supply from external circuits. If the supply now operates the trouble is in the external circuits; if the - 26 V supply does not operate troubleshoot.

(12) Check the dc voltages at the Balanced Amplifier output which should be 0 +/-.1V dc at the top of A2R74 and the bottom of A2R75 ('top' and 'bottom' are as viewed on Schematic No. 2).

(13) Check for open lamp or resistor in the photo-resistor A2DSV1.

(14) Troubleshoot the Amplitude Control Integrator (A3Q6 through A3Q9) including the Amplitude Current Reference and the lamp of the photo-resistor (A2DSV1).

(15) Troubleshoot the Buffer Amplifier (A2Q8 thru A2Q10) also include the resistor of the photo-resistor, A2DSV1.

(16) Check the ac signal level at the Balanced Amplifier output with an oscilloscope. The signal should be a sine-wave of 4 +/- .5V peak-to-peak at the top of A2R74 and at the bottom of A2R75, the two signals should be 180% out of phase with each other. Note that in the FAIL condition there are two possible paths.

(17) Check the ac signal with an oscilloscope between the attenuators (S4) and C9 and C10, the signal at both points should be 3 +/- 1V peak-to-peak. If signal is not present, check C9, C10, A2R76 and A2R77.

(18) Check the input signal to the Impedance networks A4 Pin 1 and A4 Pin 2, this should be 3 +/- 1V peak-to-peak when the attenuators are set at +10dBm. If the signal is not present, try all positions of the attenuators and the impedance switch.

Table 5-5. Front Panel Troubleshooting (See Paragraph 5-74)

MONITOR † POINT INDICATIONS	MOST LIKELY TROUBLE AREAS	ACTION REQUIRED
$\bar{A}\ \bar{B}\ \bar{C}$	Oscillator circuit or Power Supplies	Go to (1) on troubleshooting tree.
$\bar{A}\ \bar{B}\ C$	Multiple troubles 1) Counter Emitter Follower 2) Meter circuits Average Detector	1) Troubleshoot 2) Go to (19) on troubleshooting tree.
$\bar{A}\ B\ \bar{C}$	Multiple troubles 1) Counter Emitter Follower 2) Attenuators (S4) and/or Impedance switch (A4)	1) Troubleshoot 2) Check all positions of attenuators and impedance switch.
$\bar{A}\ B\ C$	Counter Emitter Follower	Troubleshoot.
$A\ \bar{B}\ \bar{C}$	ALC Loop - consisting of Buffer and Balanced Amplifiers, Average Detector and ALC circuits	Go to (2) on troubleshooting tree.
$A\ \bar{B}\ C$	Metering circuits (and Average Detector)	Go to (19) on troubleshooting tree.
$A\ B\ \bar{C}$	Attenuators (S4) and/or Impedance Switch (A4)	Check all positions of attenuator and impedance switch.
OTHER TROUBLES		
Incorrect flatness or level	ALC Loop - consisting of Buffer and Balanced Amplifiers, Average Detector and ALC circuits	Go to (2) on troubleshooting tree.
No output only at certain frequencies	Oscillator calibration	Calibrate
Incorrect frequency	Oscillator calibration	Calibrate

†COUNTER OUTPUT	A = 0.1V rms into 50 ohms;	$\bar{A}$ = intermittent or no signal
654A meter indication	B = +1dBm or greater;	$\bar{B}$ = less than +1dBm
Front panel output connectors	C = approximately 0.8V rms into 50 ohms;	$\bar{C}$ = intermittent or no signal

(19) Check the dc voltage at the collector of A2Q25 which should be from +6 to +8 volts.

(20) Troubleshoot the Balanced Amplifier, A2Q11 through A2Q23 and associated components. If in step (12) the dc voltages were incorrect and were equal and opposite then the problem is probably in the differential amplifiers A2Q11 through A2Q16. If the dc voltages are incorrect but of the same polarity then the problem is probably in the feedback amplifier A2Q22, A2Q23 and A2Q17.

(21) If the output signal is not present on A4 Pin 3 and (in the BAL modes of the IMPEDANCE switch) A4 Pin 4 then check the resistive networks on the A4 board. If it is present, check the cables to the output connectors J3 and J4.

(22) Ensure that the problem is not in the cables before attempting to troubleshoot the attenuators.

(23) Check with an oscilloscope, the ac signal from the detector amplifier at the collector of A2Q25. This should be a flattened sine-wave (see schematic 2) of about .8V peak-to-peak. Note that there are two possible paths for the FAIL mode.

(24) Check the dc voltages at the outputs of the detector (A2 Pin 6 and A2 Pin 7), these should be 0 +/-.05V dc.

(25) Troubleshoot the Meter Differential Amplifier (A3Q2 through A3Q5), the Meter (M1) and the Meter Offset Current Reference.

(26) Check the detector diodes (A2CR21, A2CR22) and capacitors A2C40*, A2C41 and A2C44.

(27) Check the Detector Amplifier A2Q24, A2Q25 and associated components.

5-78. TROUBLESHOOTING THE POWER SUPPLY.

NOTE

To protect the output capacitors C9 and C10 (rated 3 V), pull connectors off of pins 15 and 16 of the A2 board. Ensure that the dc voltages on pins 15 and 16 are near zero (<500 mV) before reconnecting the wires to C9 and C10. Available test points for for power supply voltage:

+ 31 V at A1 pin 12, A2 pin 1, A3 pin 5;
- 26 V at A1 pin 13, A2 pin 2, A3 pin 4

WARNING

TURN OFF POWER BEFORE CONNECTING OR DISCONNECTING POWER SUPPLY LEADS.

5-79. Disconnect the power supply from the A2 and A3 boards. The pins are given in the preceding note. If the power supply voltages are still incorrect and cannot be adjusted, troubleshoot the power supply.

a. After the power supply has proper voltages, turn off power and reconnect the power supply leads to A3, one at a time while monitoring the - 26 V. If the negative voltage loads down, then troubleshoot that specific board.

b. Last, connect the power supply to the A2 board while monitoring the - 26 V. If - 26 V loads down, turn off the power and lift one end of A2R20 and A2R25. If the - 26 V supply is satisfactory, troubleshoot the Oscillator. If the negative voltage is still loaded, troubleshoot the Buffer Amplifier, Balance Amplifier and Average Detector.

5-80. PROCEDURE.

a. Lift one side of A2R33 to isolate the Wien Bridge Oscillator from the circuit.

b. Lift the side of A2R38 which is connected to A2DSV1.

c. Connect the signal generator with a large (at least 10 microfarad) non-polar capacitor in series to A2R38. The capacitor blocks any dc present on the signal generator output.

NOTE

If a large non-polar capacitor is not available, use two polarized capacitors in series, with their + ends connected together.

d. Set the signal generator frequency to 1kHz and the output level to about .25V rms (monitor with an ac voltmeter).

e. Signal trace the ALC loop. Signal levels, and voltages should correspond with those shown on the schematics.

5-81. TROUBLESHOOTING THE OSCILLATOR CIRCUIT.

NOTE

This procedure assumes that the front panel checks (Table 5-6) have been made and that the Troubleshooting Tree has been followed (together with the information in Paragraph 5-77) to branch (5)

a. If the signal at the junction of A2R22 and A2R23 is twice the normal amplitude then the Peak Detector is not operating. In particular check A2Q7 and A2C11.

b. If A2C12 is close to the A2Q1 FET the oscillator could break into spurious oscillations above 100 kHz.

c. If there is no signal at A2 Pin 4 isolate the Peak Detector by lifting one side of A2C11 and the emitter of A2Q7. If the oscillator comes on, check the Peak Detector components. If there is no apparent fault in the Peak Detector it is possible that A2R3 may be out of adjustment. To check this reconnect the peak detector, and perform the adjustment outlined in Paragraph 5-50.

d. If the oscillator still cannot be made to operate perform the procedure of the following paragraphs.

5-82. In the following procedure the oscillator circuit is driven by an external signal generator and the Wien Bridge is disabled. This allows the circuit to be checked out using the normal troubleshooting techniques for an amplifier.

5-83. The recommended signal generator is a 652A or 651B (which has 50 ohms output impedance and a frequency range of 10Hz to 10MHz). If this is not available any oscillator with low output impedance and capable of driving up to 3V rms open circuit will suffice. In most cases it will not be essential to use the generator at frequencies over 1kHz.

a. Turn off the power to the 654A.

b. Disconnect the Buffer Amplifier and Counter Emitter-Follower by lifting the negative side of A2C12.

c. Disconnect the Peak Detector by lifting one side of A2C11 and the emitter lead of A2Q7.

d. Disable the RC tuning network of the Wien Bridge by disconnecting A2 Pins 8, 10 and 11.

e. Connect the signal generator through a large capacitor (as described in Paragraph 5-80c and the note) to A2 Pin 10. Connect the ground side of the generator to A2 Pin 8.

f. Turn the 654A power on. Set the signal generator frequency to 1kHz and the output to approximately 1V rms (monitor with an ac voltmeter on A2 Pin 10). Monitor the output signal with an oscilloscope on A2C12.

1) The amplifier has a voltage gain of approximately 2, therefore the output should be a sine wave of between 5 and 6V peak-to-peak.

2) If the signal does not appear at the output then troubleshoot the amplifier (A2Q1 through A2Q6 and associated circuitry) using normal troubleshooting techniques for an amplifier. A2Q5 and A2Q6 should be replaced as a pair if either has to be replaced.

3) When the amplifier is operating correctly check the frequency response, which should remain essentially flat between 10Hz and 10MHz, by sweeping the signal generator over that range while maintaining a constant input voltage on the green lead.

4) Reconnect A2C11 and A2Q7 to ensure that the Peak Detector does not disable the amplifier (if it does troubleshoot the Peak Detector). If the signal is still present at A2 Pin 5 then the probable cause of trouble in the oscillator circuit is the FREQUENCY RANGE switch or associated components.

5-84. TROUBLESHOOTING THE BUFFER AMPLIFIER.

NOTE

AC output will be erroneous if the control voltage to DSV1 is the wrong value. This should be approximately 5 to 7 V dc.

5-85. The ac gain of the Buffer Amplifier should be 0.6 or less than 1. The dc voltage at A2R44 should be 0 V ± 150 mV and the ac voltage should be between 3 and 4 V p-p.

5-86. TROUBLESHOOTING THE BALANCED AMPLIFIER.

5-87. The balanced amplifier should have an ac gain of approximately two. The dc voltage at both sides of A2C32 should be near zero (± 300 mV) with one side positive and the other negative. The ac waveforms at each side of A2C32 should be equal in amplitude but 180° out of phase. The amplitude should be 6 to 7 V p-p.

a. If the ac voltages are near equal and the dc voltages are of opposite polarity but not near zero and the amplitude control has little effect, then the trouble is probably in the feedback loop A2Q17, Q22 or Q23. This circuit holds A2C32 near zero.

b. If the balanced amplifier output is clipped or distorted, replace A2Q17 with approximately 500 Ω resistor between emitter and collector, using pc board holes. If the balanced amplifier's output becomes a good sine wave, this indicates the Q17, Q22, Q23 loop is faulty. If not, the balanced amplifier differential pairs (Q11 thru Q21) are at fault.

c. If A2C32 ac voltages are not approximately equal, the fault is probably in the differential pairs Q11 thru Q21.

d. If the instrument will not pass its balance specifications check to see that A2R74 and R75 are the same value.

5-88. TROUBLE ISOLATION IN THE REMAINDER OF THE LEVELING LOOP.

5-89. The following check will determine if the trouble is in the Average Detector.

a. The input of A2C40 should be 4 to 5.5 V dc and the ac signal should be 0.8 V p-p to 1.0 V p-p.

b. AC waveshape should have the same wave shape as shown on Schematic No. 2. If you have a flatness problem, check the wave shape for symmetry and see if output capacitor C9 or C10 are leaking.

5-90. The following checks will determine if the trouble is in the Control Integrator or in the Meter Differential Amplifier.

NOTE

Disconnecting the outputs of A2CR21 and CR22 will cause the voltage readings to be incorrect.

a. If A2CR21 is not zero ± 20 mV, the trouble is in the Meter Differential Amplifier.

b. If A2CR22 is not zero ± 20 mV, the trouble is in the Control Integrator.

5-91. TROUBLESHOOTING THE AMPLITUDE CONTROL INTEGRATOR.

5-92. The Amplitude Control Integrator consists of A3Q6 thru A3Q9. The output is + 5 V to + 7 V dc. The output feeds back into the Photocell Module of the Buffer Amplifier. Check the resistance of the filament in the lamp. It should be approximately 40 Ω. The photocell should have approximately 1 kΩ to 2 kΩ resistance when a + 5 V to + 7 V dc is applied to the filament.

5-93. TROUBLESHOOTING THE ALC LOOP.

5-94. If the trouble is known to be in the ALC loop (Buffer and Balanced Amplifier and the Automatic Leveling Circuits) and cannot be isolated to a unit by the preceding paragraphs, then this method can be used to break open the loop. The Buffer Amplifier is then driven by an external signal generator (0.25 V rms at 1 kHz into 2.5 kΩ) and it can be checked as any amplifier.

a. Lift one side of A2R33 to isolate the Wien Bridge Oscillator from the circuit.

b. Lift the side of A2R38 which is connected to A2DSV1.

c. Connect the signal generator with a large (at least 10 μF) non-polar capacitor in series to A2R38. The capacitor blocks any dc present on the signal generator output.

NOTE

If a large non-polar capacitor is not available, use two polarized capacitors in series, with their + ends connected together.

d. Set the signal generator frequency to 1 kHz and the output level to about .25 V rms (monitor with an ac voltmeter).

e. Signal trace the ALC loop. Signal levels, and voltages should correspond with those shown on the schematics.

5-95. TROUBLESHOOTING THE METER DIFFERENTIAL AMPLIFIER.

5-96. The Meter Differential Amplifier is used for the meter in all functions. Use voltages on the schematic for locating the trouble. If the base of A3Q2 is not zero, the trouble could be in the offset current reference circuit.

5-97. TROUBLESHOOTING THE ATTENUATORS.

5-98. If either side of the attenuator is shorted to ground, remove the cover and make a physical check. The signal path is probably touching the metal case or cover. The contacts of the switches should be kept clean and lubricated (refer to CAUTION on Page 5-13 and Service Note M45B). For proper lubricant, use Electrolube 2A or Electrical Contact Lubricant, -hp- Part No. 6040-0300.

NOTE

In order for the attenuator to make specifications and ensure proper grounding, all mechanical connections must be *very* tight.

5-99. SERVICING ETCHED CIRCUIT BOARDS.

5-100. The Model 654A contains four plated-through, double-sided, etched circuit boards. When working on these boards, observe the following rules to prevent damage to the circuit board or components:

a. Use a low-heat (25 to 50 watts) soldering iron with a small tip.

b. To remove a component, clip a heat sink (long nose pliers, commercial heat sink tweezers, etc.) on the component lead as close to the component as possible. Place the soldering iron directly on the component lead, and pull up on the lead. If a component is obviously damaged or faulty, clip the leads close to the component, and remove the leads from the board.

CAUTION

EXCESSIVE OR PROLONGED HEAT CAN LIFT THE CIRCUIT FOIL FROM THE BOARD OR CAUSE DAMAGE TO COMPONENTS.

c. Clean the component lead holes by heating the solder in the hole, quickly removing the soldering iron, and inserting a pointed, non-metallic object such as a toothpick.

d. To mount a new component, shape the leads and insert them in the holes. Clip a heat sink on the component, heat with the soldering iron, and add solder as necessary to obtain a good electrical connection.

5-101. SERVICING ROTARY SWITCHES.

5-102. The Model 654A contains two rotary type switches: FREQUENCY RANGE and the ATTENUATOR. When working on these switches, observe the following rules:

a. Use a low heat (25 to 50 watts) soldering iron with a small tip.

b. When replacing components, attempt to dress them as nearly to their original alignment as possible.

c. Clean excessive flux from the connection and adjoining area.

d. After cleaning the switch, apply a light coat of lubriplate to the switch detent balls. DO NOT apply lubricant to switch contacts or allow lubricant to contaminate components.

e. To eliminate excessive contact wear and oxidation, the contacts may be lubricated with Electrolube 2G, -hp- Part No. 5060-6086. Only a very small amount of lubricant is necessary. Note: Electrolube 2G will change to a reddish brown color with time; however, the lubricating properties are not affected. A more detailed description on how to apply Electrolube 2G is available at no cost from your local Sales and Service Office. Ask for Service Note M45B.

5-103. SERVICING TUNER ASSEMBLY.

5-104. When replacing the tuning capacitor, C1, make certain that the tuner coupler and the frequency dial shaft are aligned to prevent binding of the FREQUENCY Dial or VERNIER control. If necessary, remove the frequency dial knob, frequency dial, and loosen the tuner drive assembly (casting and spur gears) retaining screws; then align tuner coupler and frequency dial shaft. Tighten retaining screws after tuner coupler and dial shaft are aligned.

NOTE

For correct alignment, refer to Frequency Dial Calibration, Paragraph 5-52.

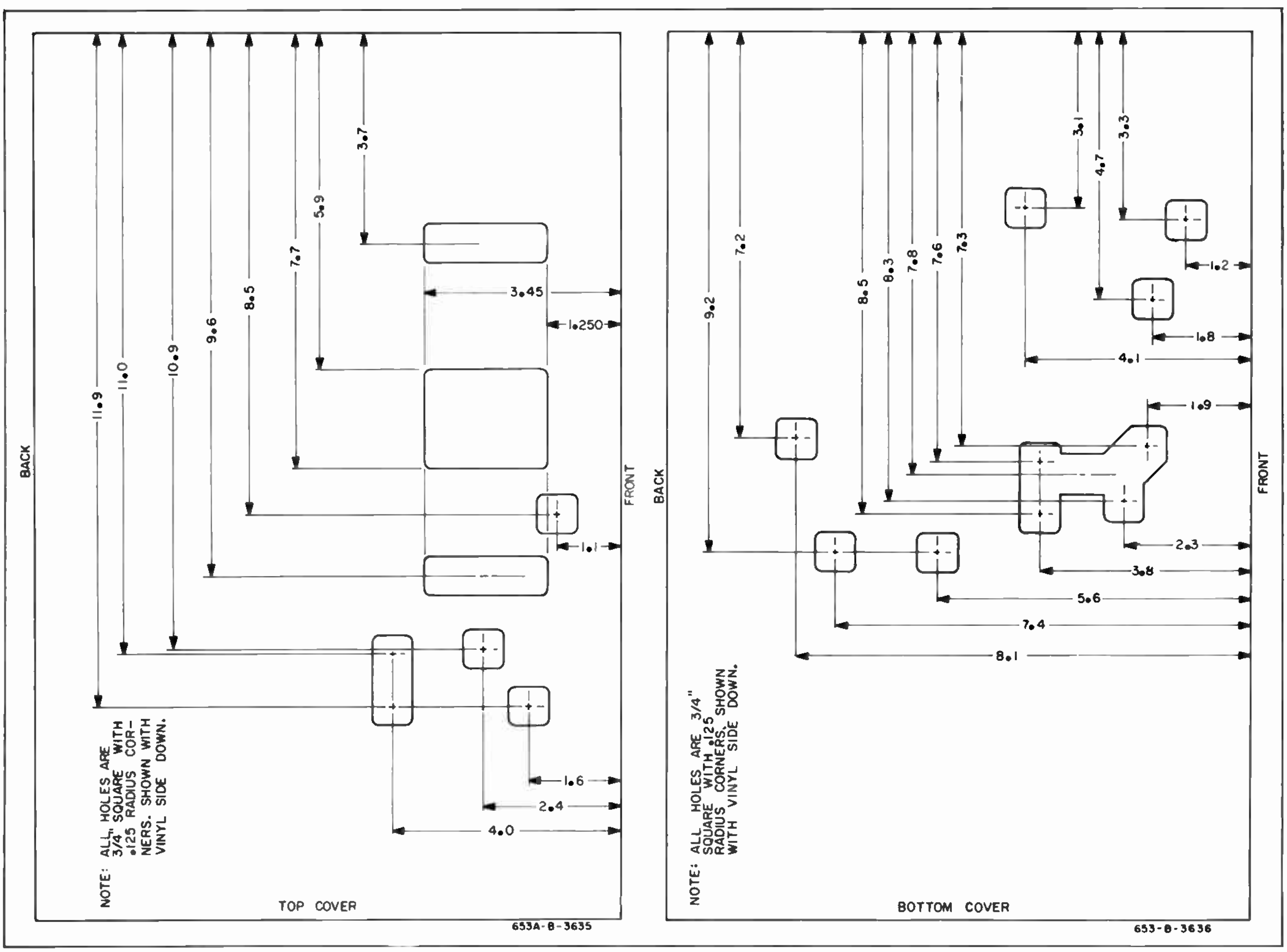
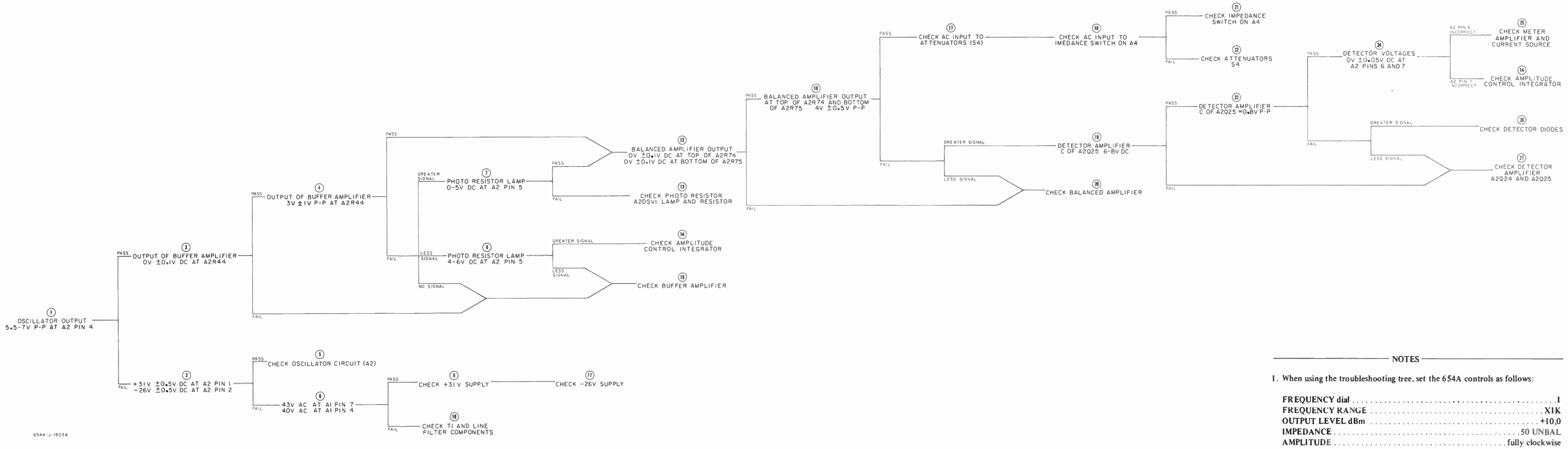


Figure 5-17. Alignement Access Covers for Models 651B, 2A, 3A, 4A



NOTES

1. When using the troubleshooting tree, set the 654A controls as follows:

FREQUENCY dial	1
FREQUENCY RANGE	X1K
OUTPUT LEVEL dBm	+10.0
IMPEDANCE	50 UNBAL
AMPLITUDE	fully clockwise

2. Refer to Paragraph 5-77 at each step of the tree.

3. It is important to perform the front panel checks of Paragraph 5-74 before using this troubleshooting tree.

Figure 5-18. Troubleshooting Tree.

PERFORMANCE CHECK TEST CARD

Hewlett-Packard Model 654A
Test Oscillator
Serial No. ____________

Tests Performed By ____________
Date ____________

DESCRIPTION	CHECK		
1. FREQUENCY RANGE (Paragraph 5-7)	10 Hz or less ____		10 MHz or greater ____
2. FREQUENCY ACCURACY (Paragraph 5-8)	10 Hz to 100 Hz (X10 RANGE)	+/-3%	____
	100 Hz to 5 MHz	+/-2%	____
	5 MHz to 10 MHz	+/-4%	____
3. AMPLITUDE ACCURACY (Paragraphs 5-9 through 5-14)	+10 dBm, +/-1% at 1 KHz		
	50 UNBAL		____
	75 UNBAL		____
	135 BAL		____
	150 BAL		____
	600 BAL		____
4. LEVEL FLATNESS (Paragraphs 5-15 through 5-20)	+/-0.5% (referenced to 1 KHz level) 10 Hz to 10 MHz		
	50 UNBAL		
	+10 dBm		____
	0 dBm		____
	75 UNBAL		
	+10 dBm		____
	0 dBm		____
	+/-0.5% (referenced to 1 KHz level) 10 Hz to 5 MHz		
	135 BAL		
	+10 dBm		____
	0 dBm		____
	150 BAL		
	+10 dBm		____
	0 dBm		____
	+/-0.5% (referenced to 1 KHz level) 10 Hz to 1 MHz		
	600 BAL		
	+10 dBm		____
	0 dBm		____
5. METER TRACKING ACCURACY (Paragraph 5-21)	+/-0.05 dB		____

PERFORMANCE CHECK TEST CARD (CONT'D)

6. ATTENUATOR ACCURACY (Paragraphs 5-22 through 5-27)		1st HALF	2nd HALF
	10 dB/STEP		
	300 KHz		
	+/-0.15 dB, all positions	____	____
	10 MHz		
	+/-0.15 dB, +10 through -60 dB	____	____
	+/-1 dB, -70 and -80 dB	____	____
	1 dB/STEP		
	300 KHz		
	+/-0.15 dB, all positions	____	____
	10 MHz		
	+/-0.15 dB all positions	____	____
7. BALANCE (Paragraphs 5-28 through 5-34)	Greater than 50 dB 10 Hz to 1 MHz		
	135 BAL		____
	150 BAL		____
	600 BAL		____
	Greater than 40 dB 1 MHz to 5 MHz		
	135 BAL		____
	150 BAL		____
	600 BAL		____
8. DISTORTION (Paragraph 5-35)	Greater than 40 dB below fundamental		
	10 Hz to 1 MHz		____
	Greater than 34 dB below fundamental		
	1 MHz to 10 MHz		____
9. HUM AND NOISE (Paragraph 5-36)	Greater than 70 dB below full output (+11 dBm)		____
10. COUNTER OUTPUT (Paragraph 5-37)	Greater than 0.1V rms into 50 ohms, 10 Hz to 10 MHz		____

SECTION VI
REPLACEABLE PARTS

6-1. INTRODUCTION.

6-2. This section contains information for ordering replacement parts. Table 6-1 lists parts in alphameric order of their reference designators and indicates the description, -hp- part number of each part, together with any applicable notes, and provides the following:

a. Total quantity used in the instrument (TQ column). The total quantity of a part is given the first time the part number appears.

b. Description of the part. (See list of abbreviations below.)

c. Typical manufacturer of the part in a five-digit code. (See Appendix A for list of manufacturers.)

d. Manufacturer's part number.

6-3. Figures 6-1 and 6-2 illustrate the replaceable mechanical parts used in the 654A. Miscellaneous parts are listed at the end of Table 6-1.

6-4. ORDERING INFORMATION.

6-5. To obtain replacement parts, address order or inquiry to your local Hewlett-Packard Field Office. (See Appendix B for list of office locations.) Identify parts by their Hewlett-Packard part numbers.

6-6. NON-LISTED PARTS.

6-7. To obtain a part that is not listed, include:

a. Instrument model number.

b. Instrument serial number.

c. Description of the part.

d. Function and location of the part.

ABBREVIATIONS

Ag .... silver
Al .... aluminum
A .... ampere(s)
Au .... gold

C .... capacitor
cer .... ceramic
coef .... coefficient
com .... common
comp .... composition
conn .... connection

dep .... deposited
DPDT .... double-pole double-throw
DPST .... double-pole single-throw

elect .... electrolytic
encap .... encapsulated

F .... farad(s)
FET .... field effect transistor
fxd .... fixed

GaAs .... gallium arsenide
GHz .... gigahertz = 10^{+9} hertz
gd .... guard(ed)
Ge .... germanium
gnd .... ground(ed)

H .... henry(ies)
Hg .... mercury

Hz .... hertz (cycle(s) per second)

ID .... inside diameter
impg .... impregnated
incd .... incandescent
ins .... insulation(ed)

kΩ .... kilohm(s) = 10^{+3} ohms
kHz .... kilohertz = 10^{+3} hertz

L .... inductor
lin .... linear taper
log .... logarithmic taper

mA .... milliampere(s) = 10^{-3} amperes
MHz .... megahertz = 10^{+6} hertz
MΩ .... megohm(s) - 10^{+6} ohms
met flm .... metal film
mfr .... manufacturer
ms .... millisecond
mtg .... mounting
mV .... millivolt(s) = 10^{-3} volts
μF .... microfarad(s)
μs .... microsecond(s)
μV .... microvolt(s) = 10^{-6} volts
my .... Mylar®

nA .... nanoampere(s) = 10^{-9} amperes
NC .... normally closed
Ne .... neon
NO .... normally open

NPO .... negative positive zero (zero temperature coefficient)
ns .... nanosecond(s) = 10^{-9} seconds
nsr .... not separately replaceable

Ω .... ohm(s)
obd .... order by description
OD .... outside diameter

p .... peak
pA .... picoampere(s)
pc .... printed circuit
pF .... picofarad(s) 10^{-12} farads
piv .... peak inverse voltage
p/o .... part of
pos .... position(s)
poly .... polystyrene
pot .... potentiometer
p-p .... peak-to-peak
ppm .... parts per million
prec .... precision (temperature coeffient, long term stability and/or tolerance)

R .... resistor
Rh .... rhodium
rms .... root-mean-square
rot .... rotary

Se .... selenium
sect .... section(s)
Si .... silicon

sl .... slide
SPDT .... single-pole double-throw
SPST .... single-pole single-throw

Ta .... tantalum
TC .... temperature coefficient
TiO_2 .... titanium dioxide
tog .... toggle
tol .... tolerance
trim .... trimmer
TSTR .... transistor

V .... volt(s)
vacw .... alternating current working voltage
var .... variable
vdcw .... direct current working voltage

W .... watt(s)
w/ .... with
wiv .... working inverse voltage
w/o .... without
ww .... wirewound

* .... optimum value selected at factory, average value shown (part may be omitted)
** .... no standard type number assigned selected or special type

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DECIMAL MULTIPLIERS

Prefix	Symbols	Multiplier	Prefix	Symbols	Multiplier
tera	T	10^{12}	centi	c	10^{-2}
giga	G	10^{9}	milli	m	10^{-3}
mega	M or Meg	10^{6}	micro	μ	10^{-6}
kilo	K or k	10^{3}	nano	n	10^{-9}
hecto	h	10^{2}	pico	p	10^{-12}
deka	da	10	femto	f	10^{-15}
deci	d	10^{-1}	atto	a	10^{-18}

STO-B-2734

DESIGNATORS

A .... assembly
B .... motor
BT .... battery
C .... capacitor
CR .... diode
DL .... delay line
DS .... lamp
E .... misc electronic part
F .... fuse

FL .... filter
HR .... heater
IC .... integrated circuit
J .... jack
K .... relay
L .... inductor
M .... meter
MP .... mechanical part
P .... plug

Q .... transistor
QCR .... transistor-diode
R .... resistor
RT .... thermistor
S .... switch
T .... transformer
TB .... terminal board
TC .... thermocouple
TP .... test point

TS .... terminal strip
U .... microcircuit
V .... vacuum tube, neon bulb, photocell, etc.
W .... cable
X .... socket
XDS .... lampholder
XF .... fuseholder
Y .... crystal
Z .... network

Table 6-1. Replaceable Parts

REFERENCE DESIGNATOR	-hp- PART NO.		TQ	DESCRIPTION	MFR.	MFR. PART NO.
A1	00654-66501		1	PC board: power supply	-hp-	
C1,C2	0180-0149		4	C: fxd Al elect 65 uF +100% -10% 60 vdcw	56289	D36978-DSM
C3,C4	0150-0069		2	C: fxd cer 0.001 uF +100% -20% 500 vdcw	72982	801-010X5G0102Z
C5,C6	0180-0045		2	C: fxd Al 20 uF +75% -10% 25 vdcw	56289	30D206G025CB2-DSM
C7,C8	0180-0149			C: fxd Al elect 65 uF +100% -10% 60 vdcw	56289	(type 30D)036978-DSM
C9,C10	0150-0052		2	C: fxd cer 0.05 uF +/-20% 400 vdcw	56289	33C17A-CDH
CR1 thru CR4	1901-0158		4	Diode: Si 200 piv	04713	SR13583
CR5	1902-0049		1	Diode: breakdown 6.19V +/-5% 400 mW	04713	SZ10939-122
CR6,CR7	1901-0025		14	Diode: Si 100 mA at +1V 100 piv 12 pF	07933	RD1526
CR8	1902-0777		2	Diode: zener 1N825 6.2V +/-5% 400 mW	12954	obd
CR9	1901-0025			Diode: Si 100 mA at +1V 100 piv 12 pF	07933	RD1526
Q1	1853-0037		2	TSTR: Si PNP 2N4036	04713	SS2109
Q2	1853-0036		8	TSTR: Si PNP 2N3906	04713	SPS-3612
Q3	1853-0037			TSTR: Si PNP 2N4036	04713	SS2109
Q4,Q5	1853-0036			TSTR: Si PNP 2N3906	04713	SPS-3612
R1 thru R4	0683-3925		4	R: fxd comp 3900 ohms +/-5% 1/4 W	01121	CB3925
R5	0686-7525		1	R: fxd comp 7500 ohms +/-5% 1/2 W	01121	EB7525
R6	0687-1531		1	R: fxd comp 15 kilohms +/-10% 1/2 W	01121	EB1531
R7	0683-4335		1	R: fxd comp 43 kilohms +/-5% 1/4 W	01121	CB4335
R8	0687-3921		1	R: fxd comp 3900 ohms +/-10% 1/2 W	01121	EB3921
R9	0683-8215		1	R: fxd comp 820 ohms +/-5% 1/4 W	01121	CB8215
R10,R11	0689-0915		2	R: fxd carbon comp 9.1 ohms +/-5% 1 W	01121	GB-91G5
R12	0757-0273		1	R: fxd met flm 3010 ohms +/-1% 1/8 W	91637	MF-1/10-32 obd
R13	0698-4020		1	R: fxd met flm 9.53 kilohms +/-1% 1/8 W	91637	MF-1/10-32 obd
R14	2100-0090		1	R: var comp lin 2000 ohms +/-30% 0.15 W	71450	UPM-70RE(hp) obd
R15*	0683-2715		1	R: fxd comp 270 ohms +/-5% 1/4 W	01121	CB2715
R16	0757-1013		1	R: fxd met flm 6000 ohms +/-1% 1/2 W	75042	CEC T-D obd
R17	0757-0039		1	R: fxd met flm 5030 ohms +/-1% 1/2 W	91637	MFF 1/2 T-1 obd
R18	0698-4888		1	R: fxd met flm 1180 ohms +/-1% 1/2 W	91637	MFF 1/2 T-1 obd
A2	00654-66502		1	PC board: main, oscillator and output	-hp-	
C1	0121-0421		2	C: var 2-10 pF	000LC	5640/10/PC
C2	0150-0084		8	C: fxd cer 0.1 uF +80% -20% 100 vdcw	72982	8131-100-651-104Z
C3	0180-1792		1	C: fxd Al 2900 uF +75% -10% 3 vdcw	56289	39D298G003GJ4-DSB
C4	0180-0228		1	C: fxd Ta 22 uF +/-10% 15 vdcw	56289	150D226X9015B2-DYS
C5	0180-0063		2	C: fxd Al 500 uF +75% -10% 3 vdcw	56289	30D507G003DF2-DSM
C6,C7				Not assigned		
C8*	0140-0202		1	C: fxd mica 15 pF +/-5%	72136	RDM15C150J5C
C9,C10	0150-0084			C: fxd cer 0.1 uF +80% -20% 100 vdcw	72982	8131-100-651-104Z
C11,C12	0180-0039		2	C: fxd Al 100 uF +75% -10% 12 vdcw	56289	30D107G012CC2-DSM
C13	0180-0101		1	C: fxd Ta 1.8 uF +/-10% 35 vdcw	56289	150D185X9035B2-DYS
C14				Not assigned		
C15	0150-0022		2	C: fxd TiO_2 3.3 pF +/-10% 500 vdcw	78488	Type GA obd
C16	0160-2206		1	C: fxd mica 160 pF +/-5%	72136	RDM15F161J3C
C17	0150-0093		12	C: fxd cer 0.01 uF +80% -20% 100 vdcw	91418	TA obd
C18	0150-0022			C: fxd TiO_2 3.3 pF +/-10% 500 vdcw	78488	Type GA obd
C19	0150-0093			C: fxd cer 0.01 uF +80% -20% 100 vdcw	91418	TA obd
C20	0150-0084			C: fxd cer 0.1 uF +80% -20% 100 vdcw	72982	8131-100-651-104Z
C21*	0150-0046		2	C: fxd TiO_2 0.68 pF +/-5% 500 vdcw	78488	Type GA obd
C22	0160-2197		1	C: fxd mica 10 pF +/-5%	72136	RDM15C100J3C
C23	0140-0145		1	C: fxd mica 22pF +/-5%	72136	RDM15C220J5C
C24	0160-2204		2	C: fxd mica 100 pF +/-5%	72136	RDM15F101J3C
C25	0150-0084			C: fxd cer 0.1 uF +80% -20% 100 vdcw	72982	8131-100-651-104Z
C26 thru C29	0160-2605		4	C: fxd cer 0.02 uF +80% -20% 25 vdcw	72982	5835Y5U203Z
C30,C31	0150-0093			C: fxd cer 0.01 uF +80% -20% 100 vdcw	91418	TA obd
C32	0121-0162		1	C: var 1.2-3.5 pF	74970	189-351-5
C33 thru C35	0150-0093			C: fxd cer 0.01 uF +80% -20% 100 vdcw	91418	TA obd
C36*	0150-0046			C: fxd TiO_2 0.68 pF +/-5% 500 vdcw	78488	Type GA obd
C37				Not assigned		
C38	0160-3431		1	C: fxd cer 6.8 pF +/-5% 500 vdcw	72982	301-000-S3B0689D
C39				Not assigned		
C40*	0180-2176		1	C: fxd Ta 180 uF +/-20% 10 vdcw	56289	109D187X0010F2-DYP
C41	0180-0137		2	C: fxd Ta 100 uF +/-20% 10 vdcw	37942	TAS107M010P1F
C42	0180-2276		1	C: fxd Ta 270 uF +/-20% 15 vdcw	56289	109D277X0015T2
C43	0121-0421			C: var 2-10 pF	000LC	5640/10/PC
C44	0180-0137			C: fxd Ta 100 uF +/-20% 10 vdcw	37942	TAS107M010P1F
C45,C46	0150-0084			C: fxd cer 0.1 uF +80% -20% 100 vdcw	72982	8131-100-651-104Z

Table 6-1. Replaceable Parts (Cont'd)

REFERENCE DESIGNATOR	-hp- PART NO.		TQ	DESCRIPTION	MFR.	MFR. PART NO.
A2 (Cont'd)						
CR1,CR2	1910-0016		2	Diode: Ge 60 wiv 1 ms	93332	D2361
CR3	1901-0025			Diode: Si 100 mA at +1V 100 piv 12 pF	07933	RD1526
CR4	1902-3182		2	Diode: breakdown 12.1V +/-5% 400 mW	04713	SZ10939-206
CR5	1902-0045		2	Diode: breakdown 7.32V +/-2% 400 mW	04713	SZ10939-144
CR6	1902-3237		2	Diode: breakdown 20V +/-5% 400 mW	04713	SZ10939-269
CR7 thru CR11	1901-0025			Diode: Si 100 mA at +1V 100 piv 12 pF	07933	RD1526
CR12	1902-0057		3	Diode: breakdown 6.49V +/-5% 400 mW	04713	SZ10939-128
CR13	1902-3259		1	Diode: breakdown 24.3V +/-5% 400 mW	04713	SZ10939-293
CR14	1902-0025		1	Diode: breakdown 10V +/-5% 400 mW	04713	SZ10930-182
CR15 thru CR18	1901-0025			Diode: Si 100 mA at +1V 100 piv 12 pF	07933	RD1526
CR19	1902-0766		1	Diode: breakdown 18.2V +/-5% 400 mW	04713	SZ10939-257
CR20	1902-0045			Diode: breakdown 7.32V +/-2% 400 mW	04713	SZ10939-144
CR21,CR22	1901-0347		3	Diode: Si hot carrier 20 mA 1.5 pF 8 vdcw	-hp-	
CR23	1902-0041		1	Diode: breakdown 5.11V +/-5% 400 mW	04713	SZ10939-98
CR24	1902-3182			Diode: breakdown 12.1V +/-5% 400 mW	04713	SZ10939-206
DSV1	1990-0082		1	Lamp: photocell module	03911	CLM5012
L1 thru L3	9170-0016		4	Bead: ferrite	02114	56-590-65A1/3B
Q1	1855-0081		1	TSTR: FET N-channel type A 2N5245	01295	obd
Q2	1854-0215		10	TSTR: Si NPN 2N3904	04713	SPS3611
Q3	1853-0036			TSTR: Si PNP 2N3906	04713	SPS3612
Q4	1854-0233		2	TSTR: Si NPN 2N3866	02735	obd
Q5	1854-0053		3	TSTR: Si NPN 2N2218	04713	2N2218
Q6	1853-0012		3	TSTR: Si PNP 2N2904A	04713	2N2904A
Q7 thru Q9	1854-0215			TSTR: Si NPN 2N3904	04713	SPS3611
Q10	1853-0036			TSTR: Si PNP 2N3906	04713	SPS3612
Q11,Q12	1854-0092		2	TSTR: Si NPN 2N3563	04713	MPS3563
Q13,Q14	1853-0034		2	TSTR: Si PNP	04713	SM3197
Q15,Q16	1854-0215			TSTR: Si NPN 2N3904	04713	SPS3611
Q17	1854-0233			TSTR: Si NPN 2N3866	02735	obd
Q18	1854-0053			TSTR: Si NPN 2N2218	04713	2N2218
Q19	1853-0012			TSTR: Si PNP 2N2904A	04713	2N2904A
Q20	1854-0053			TSTR: Si NPN 2N2218	04713	2N2218
Q21	1853-0012			TSTR: Si PNP 2N2904A	04713	2N2904A
Q22,Q23	1853-0015			TSTR: Si PNP 2N3640	04713	MPS3460-5
Q24	1854-0215			TSTR: Si NPN 2N3904	04713	SPS3611
Q25	1854-0296		1	TSTR: Si NPN	04713	MPS6543
Q26	1853-0036			TSTR: Si PNP 2N3906	04713	SPS3612
R1	0757-0430		1	R: fxd met flm 2210 ohms +/-1% 1/8 W	91637	MF-1/10-32 obd
R2 *	0698-4430		1	R: fxd met flm 1910 ohms +/-1% 1/8 W	91637	MF-1/10-32 obd
R3	2100-1984		2	R: var 100 ohm +/-10% 1/2 W	73138	62PR100
R4	2100-2604		1	R: var 50 ohms +/-10% 1/2 W	01121	Type SV5001
R5	0757-0401		6	R: fxd met flm 100 ohms +/-1% 1/8 W	91637	MF-1/10-32 obd
R6,R7	0683-0275		4	R: fxd comp 2.7 ohms +/-5% 1/4 W	01121	CB27C5
R8	0683-1035		1	R: fxd comp 10 kilohms +/-5% 1/4 W	01121	CB1035
R9*	0698-3158		1	R: fxd met flm 23.7 kilohms +/-1% 1/8 W	91637	MF-1/10-32 obd
R10	0757-0280		7	R: fxd met flm 1000 ohms +/-1% 1/8 W	91637	MF-1/10-32 obd
R11	0698-3279		3	R: fxd met flm 4.99 kilohms +/- 1% 1/8 W	91637	MF-1/10-32 obd
R12	0698-3558		3	R: fxd met flm 4020 ohms +/-1% 1/8 W	91637	MF-1/10-32 obd
R13	0757-0449		1	R: fxd met flm 20 kilohms +/-1% 1/8 W	91637	MF-1/10-32 obd
R14	0698-4453		1	R: fxd met flm 402 ohms +/-1% 1/8 W	35009	CEA obd
R15	0757-0283		6	R: fxd met flm 2000 ohms +/-1% 1/8 W	14674	C4 obd
R16				Not assigned		
R17	0757-0384		3	R: fxd met flm 20 ohms +/-1% 1/8 W	91637	MF-1/10-32 obd
R18	0683-9105		1	R: fxd comp 91 ohms +/-5% 1/4 W	01121	CB9105
R19	0698-3639		1	R: fxd met oxide 1200 ohms +/-5% 2 W	14674	C42S
R20	0683-1005		2	R: fxd comp 10 ohms +/-5% 1/4 W	01121	CB1005
R21	0683-3005		1	R: fxd comp 30 ohms +/-5% 1/4 W	01121	CB3005
R22,R23	0757-0346		6	R: fxd met flm 10 ohms +/-1% 1/8 W	91637	MF-1/10-32 obd
R24	0683-0275			R: fxd comp 2.7 ohms +/-5% 1/4 W	01121	CB27G5
R25	0683-1005			R: fxd comp 10 ohms +/-5% 1/4 W	01121	CB1005
R26	0757-0280			R: fxd met flm 1000 ohms +/-1% 1/8 W	91637	MF-1/10-32 obd

Table 6-1. Replaceable Parts (Cont'd)

REFERENCE DESIGNATOR	-hp- PART NO.		TQ	DESCRIPTION	MFR.	MFR. PART NO.
A2 (Cont'd)						
R27	0683-4705		1	R: fxd comp 47 ohms +/-5% 1/4 W	01121	CB4705
R28	0757-0444		1	R: fxd met flm 12.1 kilohms +/-1% 1/8 W	91637	MF-1/10-32 obd
R29				Not assigned		
R30	0757-0401			R: fxd met flm 100 ohms +/-1% 1/8 W	91637	MF-1/10-32 obd
R31	0683-5115		1	R: fxd comp 510 ohms +/-5% 1/4 W	01121	CB5115
R32				Not assigned		
R33	0698-4428		2	R: fxd met flm 1690 ohms +/-1% 1/8 W	91637	MF-1/10-32 obd
R34	0698-3558			R: fxd met flm 4020 ohms +/-1% 1/8 W	91637	MF-1/10-32 obd
R35,R36	0757-0401			R: fxd met flm 100 ohms +/-1% 1/8 W	91637	MF-1/10-32 obd
R37	0757-0290		2	R: fxd met flm 6190 ohms +/-1% 1/8 W	91637	MF-1/10-32 obd
R38	0698-4123		4	R: fxd met flm 499 ohms +/-1% 1/8 W	91637	MF-10-32 obd
R39	0757-0283			R: fxd met flm 2000 ohms +/-1% 1/8 W	14674	C4 obd
R40	0757-0277		2	R: fxd met flm 49.9 ohms +/-1% 1/8 W	91637	MF-1/10-32 obd
R41,R42				Not assigned		
R43	0757-0826		1	R: fxd met flm 2430 ohms +/-1% 1/2 W	75042	CEC T-0 obd
R44	0698-4123			R: fxd met flm 499 ohms +/-1% 1/8 W	91637	MF-1/10-32 obd
R45	0757-0280			R: fxd met flm 1000 ohms +/-1% 1/8 W	91637	MF-1/10-32 obd
R46,R47	0757-0407		4	R: fxd met flm 200 ohms +/-1% 1/8 W	91637	MF-1/10-32 obd
R48	0698-3558		1	R: fxd met flm 4020 ohms +/-1% 1/8 W	28480	0698-3558 obd
R49	0757-0280			R: fxd met flm 1000 ohms +/-1% 1/8 W	91637	MF-1/10-32 obd
R50	0757-0407			R: fxd met flm 200 ohms +/-1% 1/8 W	91637	MF-1/10-32 obd
R51	0757-0283			R: fxd met flm 2000 ohms +/-1% 1/8 W	14674	C4 obd
R52				Not assigned		
R53	0757-0283			R: fxd met flm 2000 ohms +/-1% 1/8 W	14674	C4 obd
R54	0698-4123			R: fxd met flm 499 ohms +/-1% 1/8 W	91637	MF-1/10-32 obd
R55	0757-0403		2	R: fxd met flm 121 ohms +/-1% 1/8 W	91637	MF-1/10-32 obd
R56	0757-0283			R: fxd met flm 2000 ohms +/-1% 1/8 W	14674	C4 obd
R57	0757-0434		1	R: fxd met flm 3650 ohms +/-1% 1/8 W	35009	CEA obd
R58	0757-0403			R: fxd met flm 121 ohms +/-1% 1/8 W	91637	MF-1/10-32 obd
R59	0757-0283			R: fxd met flm 2000 ohms +/-1% 1/8 W	14674	C4 obd
R60	0757-0828		2	R: fxd met flm 3010 ohms +/-1% 1/2 W	91637	MFF 1/2 T-1 obd
R61,R62	0757-0384			R: fxd met flm 20 ohms +/-1% 1/8 W	91637	MF-1/10-32 obd
R63	0757-0410		3	R: fxd met flm 301 ohms +/-1% 1/8 W	91637	MF-1/10-32 obd
R64	0698-4864		1	R: fxd met flm 499 ohms +/-1% 1/2 W	91637	MFF 1/2 T-1 obd
R65	0757-0407			R: fxd met flm 200 ohms +/-1% 1/8 W	91637	MF-1/10-32 obd
R66	0757-0828			R: fxd met flm 3010 ohms +/-1% 1/2 W	91637	MFF 1/2 T-1 obd
R67	0757-0410			R: fxd met flm 301 ohms +/-1% 1/8 W	91637	MF-1/10-32 obd
R68,R69	0757-0346			R: fxd met flm 10 ohms +/-1% 1/8 W	91637	MF-1/10-32 obd
R70	0686-2015		2	R: fxd comp 200 ohms +/-5% 1/2 W	01121	EB2015
R71,R72	0757-0346			R: fxd met flm 10 ohms +/-1% 1/8 W	91637	MF-1/10-32 obd
R73	0686-2015			R: fxd comp 200 ohms +/-5% 1/2 W	01121	EB2015
R74,R75	0698-6362		2	R: fxd met flm 1000 ohms +/-0.1% 1/8 W	91637	MF-1/10-32 obd
R76,R77	0698-6800		2	R: fxd met flm 62 ohms +/-0.1% 1/8 W	91637	MF-1/10-32 obd
R78	0698-3208		1	R: fxd met flm 4990 ohms +/-1% 1/4 W	91637	MF-1/8-44 obd
R79	0698-3558			R: fxd met flm 4020 ohms +/-1% 1/8 W	91637	MF-1/10-32 obd
R80				Not assigned		
R81	0698-4123			R: fxd met flm 499 ohms +/-1% 1/8 W	91637	MF-1/10-32 obd
R82	0698-4428			R: fxd met flm 1690 ohmd +/-1% 1/8 W	91637	MF-1/10-32 obd
R83	0757-0401			R: fxd met flm 100 ohms +/-1% 1/8 W	91637	MF-1/10-32 obd
R84	0757-0290			R: fxd met flm 6190 ohms +/-1% 1/8 W	91637	MF-1/10-32 obd
R85	0757-0401			R: fxd met flm 100 ohms +/-1% 1/8 W	91637	MF-1/10-32 obd
R86	0698-4423		1	R: fxd met flm 1370 ohms +/-1% 1/8 W	35009	CEA obd
R87	0757-0420		1	R: fxd met flm 750 ohms +/-1% 1/8 W	91637	MF-1/10-32 obd
R88	0757-0084		1	R: fxd met flm 2100 ohms +/-1% 1/2 W	91637	MFF 1/2 T-J obd
R89	0757-0427		2	R: fxd met flm 1500 ohms +/-1% 1/8 W	91637	MF-1/10-32 obd
R90	0683-0275			R: fxd comp 2.7 ohms +/-5% 1/4 W	01121	CB27G5
R91	0757-0280			R: fxd met flm 1000 ohms +/-1% 1/8 W	91637	MF-1/10-32 obd
	0340-0060		2	Insulator: feed thru	98291	FT-E-15
A3	**00654-66503**		1	**PC board: meter leveling**	-hp-	
C1	0150-0093			C: fxd cer 0.01 uF +80% -20% 100 vdcw	91418	TA obd
C2	0180-1942		1	C: fxd Al 150 uF +75% -10% 15 vdcw	56289	30D157G015DD2-DSM
C3	0150-0084			C: fxd cer 0.1 uF +80% -20% 100 vdcw	72982	8131-100-651-104Z
C4	0150-0093			C: fxd cer 0.01 uF +80% -20% 100 vdcw	91418	TA obd

Table 6-1. Replaceable Parts (Cont'd)

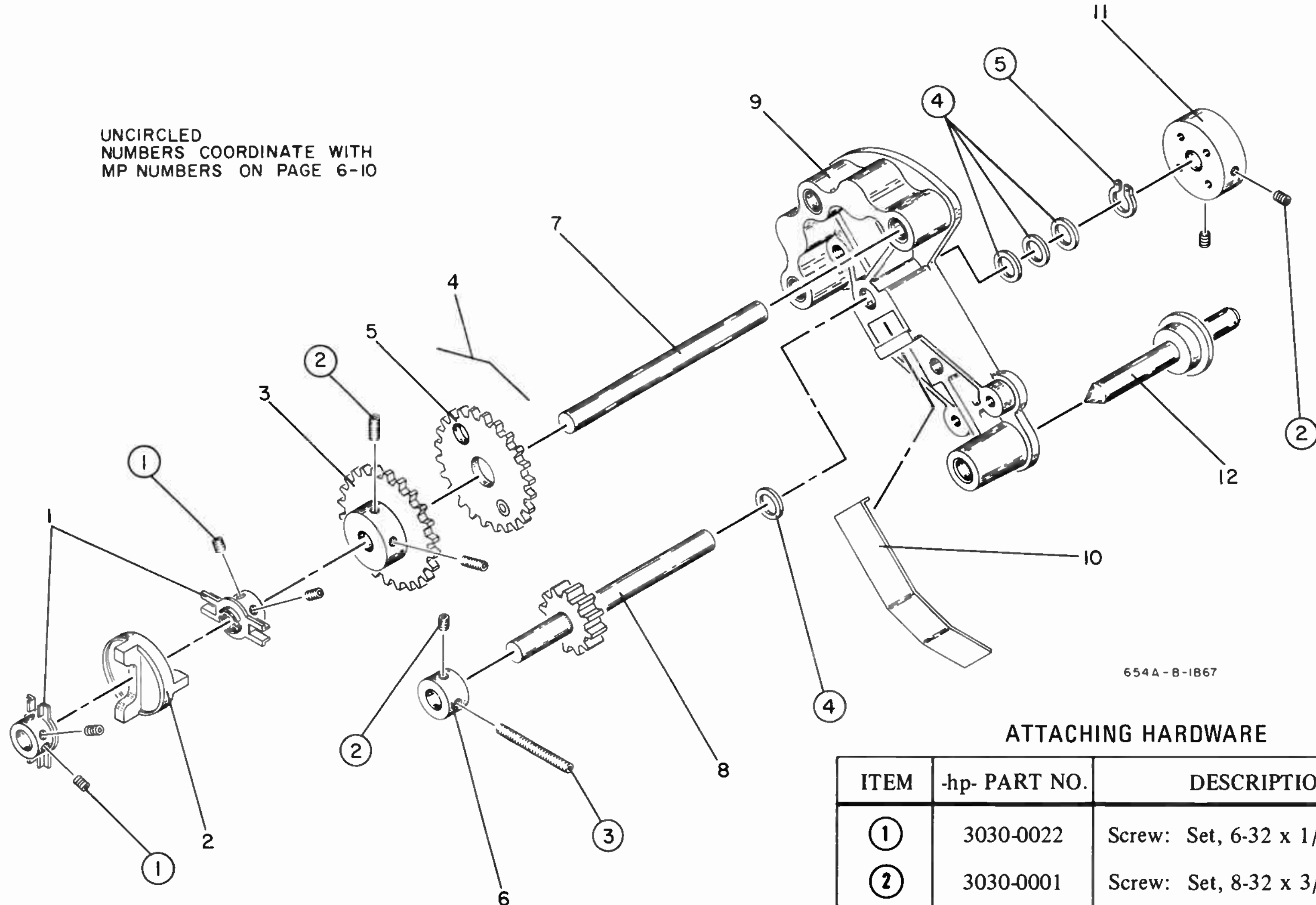
REFERENCE DESIGNATOR	-hp- PART NO.		TQ	DESCRIPTION	MFR.	MFR. PART NO.
A3 (Cont'd)						
C5	0140-0200		1	C: fxd mica 390 pF +/-5%	72136	RDM15F391J3C
C6	0180-0033		1	C: fxd Al 50 uF +100% -10% 6 vdcw	56289	30D506G006CB2-DSM
C7	0180-0063			C: fxd Al 500 uF +75% -10% 3 vdcw	56289	30D507G003DF2-DSM
C8	0150-0093			C: fxd cer 0.01 uF +80% -20% 100 vdcw	91418	TA obd
C9	0160-2204			C: fxd mica 100 pF +/-5% 300 vdcw	72136	RDM15F101J3C
C10	0180-1719		1	C: fxd Ta 22 uF +/-10% 25 vdcw	56289	109D226X9025C2
C11,C12	0150-0093			C: fxd cer 0.01 uF +80% -20% 100 vdcw	91418	TA obd
CR1	1902-3237			Diode: breakdown 20V +/-5% 400 mW	04713	SZ10939-269
CR2	1902-0777			Diode: zener 6.2V +/-5% 1N825 400 mW	12954	obd
CR3	1902-0057			Diode: breakdown 6.49V +/-5% 400 mW	04713	SZ10939-128
CR4	1901-0347			Diode: Si hot carrier 8 vdcw 20 mA 1.5 pF	-hp-	
CR5	1901-0025			Diode: Si 100 mA at +1V 100 piv 12 pF	07933	RD1526
CR6	1902-0057			Diode: breakdown 6.49V +/-5% 400 mW	04713	SZ10939-128
Q1 thru Q3	1854-0215			TSTR: Si NPN 2N3904	04713	SPS3611
Q4	1853-0036			TSTR: Si PNP 2N3906	04713	SPS3612
Q5 thru Q7	1854-0215			TSTR: Si NPN 2N3904	04713	SPS3611
Q8	1853-0036			TSTR: Si PNP 2N3906	04713	SPS3612
Q9	1854-0039		1	TSTR: Si NPN 2N3053	04713	2N3053
R1	0698-3279		2	R: fxd met flm 4990 ohms +/-1% 1/8 W	91637	MF-1/10-32 obd
R2	0757-0427			R: fxd met flm 1.5 kilohms +/-1% 1/8 W	91637	MF-1/10-32 obd
R3	0757-0743		1	R: fxd met flm 3320 ohms +/-1% 1/4 W	91637	MF-1/8-44 obd
R4	0757-0410			R: fxd met flm 301 ohms +/-1% 1/8 W	91637	MF-1/10-32 obd
R5	0757-0277			R: fxd met flm 49.9 ohms +/-1% 1/8 W	91637	MF-1/10-32 obd
R6	0698-3406		1	R: fxd met flm 1.33 kilohms +/-1% 1/2 W	91637	MFF-1/2-T-1 obd
R7	2100-1984			R: var 100 ohms +/-10% 1/2 W	73138	62PR100
R8	0757-0280			R: fxd met flm 1000 ohms +/-1% 1/8 W	91637	MF-1/10-32 obd
R9	0698-6799		1	R: fxd met flm 4530 ohms +/-1% 1/8 W	91637	MF-1/10-32 obd
R10	0757-0271		2	R: fxd met flm 124 kilohms +/-1% 1/8 W	35009	CEA obd
R11	0698-4504		2	R: fxd met flm 69.8 kilohms +/-1% 1/8 W	35009	CEA obd
R12,R13				Not assigned		
R14	0757-0442			R: fxd met flm 10.0 kilohms +/-1% 1/8 W	91637	MF-1/10-32 obd
R15	0698-4486		2	R: fxd met flm 24.9 kilohms +/-1% 1/8 W	91637	MF-1/10-32 obd
R16	0757-0442			R: fxd met flm 10.0 kilohms +/-1% 1/8 W	91637	MF-1/10-32 obd
R17	0698-3279			R: fxd met flm 4.99 kilohms +/-1% 1/8 W	91637	MF-1/10-32 obd
R18	2100-2030		1	R: var 20 kilohms +/-20% 1/2 W	73138	62PR20K
R19	0698-6801		1	R: fxd met flm 3480 ohms +/-1% 1/8 W	91637	MF-1/10-32 obd
R20	2100-1772		1	R: var 500 ohms +/-10% 1/2 W	75042	Type 500 obd
R21	0757-0271			R: fxd met flm 124 kilohms +/-1% 1/8 W	35009	CEA obd
R22	0698-4504			R: fxd met flm 69.8 kilohms +/-1% 1/8 W	35009	CEA obd
R23	0683-1825		1	R: fxd comp 1.8 kilohms +/-5% 1/4 W	01121	CB1825
R24	0698-4486			R: fxd met flm 24.9 kilohms +/-1% 1/8 W	91637	MF-1/10-32 obd
R25	0812-0049		1	R: fxd w.w. 500 ohms +/-5% 2W	91637	CW2B-3
A4	**00654-66504**		1	**PC board: impedance**	-hp-	
C1*	0160-0196		1	C: fxd mica 24 pF +/-5%	72136	RDM15C240J3S
R1	0757-0276		2	R: fxd met flm 61.9 ohms +/-1% 1/8 W	19701	MF4C obd
R2	0698-7160		1	R: fxd met flm 113.65 ohms +/-0.1% 1/8 W	91637	MF-1/10-32 obd
R3	0698-7166		1	R: fxd met flm 27.276 ohms +/-0.1% 1/8 W	91637	MF-1/10-32 obd
R4	0757-0276			R: fxd met flm 61.9 ohms +/-1% 1/8 W	19701	MF4C obd
R5	0698-7161		1	R: fxd met flm 139.19 ohms +/-0.1% 1/8 W	91637	MF-1/10-32 obd
R6	0698-7171			R: fxd met flm 1.73 ohms +/-1% 1/4 W	75042	TF07 obd
R7	0698-7168		1	R: fxd met flm 31.283 ohms +/-0.1% 1/8 W	91637	MF-1/10-32 obd
R8	0698-7165		2	R: fxd met flm 21.105 ohms +/-0.1% 1/8 W	91637	MFF 1/8 T-2 obd
R9	0698-7167		2	R: fxd met flm 29.261 ohms +/-0.1% 1/8 W	91637	MF-1/10-32 obd
R10,R11	0698-7170		2	R: fxd met flm 70.832 ohms +/-0.1% 1/8 W	91637	MF-1/10-32 obd
R12	0698-7165			R: fxd met flm 21.105 ohms +/-0.1% 1/8 W	91637	MFF-1/8-T-2 obd
R13	0698-7167			R: fxd met flm 29.261 ohms +/-0.1% 1/8 W	91637	MF-1/10-32 obd
R14	0698-7164		2	R: fxd met flm 17.273 ohms +/-0.25% 1/8 W	01295	MC55D
R15	0698-7169		2	R: fxd met flm 36.550 ohms +/-0.1% 1/8 W	91637	MF-1/10-32 obd
R16,R17	0698-7159		2	R: fxd met flm 74.663 ohms +/-0.1% 1/8 W	91637	MF-1/10-32 obd
R18	0698-7164			R: fxd met flm 17.273 ohms +/-0.25% 1/8 W	01295	MC55D

Table 6-1. Replaceable Parts (Cont'd)

REFERENCE DESIGNATOR	-hp- PART NO.		TQ	DESCRIPTION	MFR.	MFR. PART NO.
A4 (Cont'd)						
R19	0698-7169			R: fxd met flm 36.550 ohms +/-0.1% 1/8 W	91637	MF-1/10-32 obd
R20	0698-7162		2	R: fxd met flm 239.86 ohms +/-0.1% 1/8 W	91637	MF-1/10-32 obd
R21,R22	0698-7163		2	R: fxd met flm 2008.1 ohms +/-0.1% 1/8 W	91637	MF-1/10-32 obd
R23	0698-7162			R: fxd met flm 239.86 ohms +/-0.1% 1/8 W	91637	MF-1/10-32 obd
S1	3101-0837		1	Switch: pushbutton	71590	Series PB15
				CHASSIS MOUNTED COMPONENTS AND ASSEMBLIES		
C1A,B,C	0121-0018		3	C: var 14.75 pF to 617.75 pF	-hp-	
C2 thru C5	0160-3333		4	C: fxd cer 5000 pF +/-20% 3000 vdcw	-hp-	
C6,C7	0180-0047		2	C: fxd Al 500 uF 75 vdcw	56289	D32443 DFP
C8				Not assigned		
C9,C10	0180-2117		2	C: fxd Al 4000 uF +75% -10% 3 vdcw	56289	(39D)D46446-DSB
DS1	2140-0015		1	Neon: NE-2H	24455	Bulb T-2
	5040-0234		1	Pilot light: jewel	-hp-	
	5040-0235		1	Pilot light: base	-hp-	
F1	2110-0340		1	Fuse: 0.4 amp S.B. 250 V	71400	MDL 4/10
J1	1251-2357		1	Receptacle: power 3 pin	82389	EAC-301
J2 thru J4	1250-0083		3	Jack: BNC	000LB	28JR-130-1
L1, L3				Not assigned		
L2, L4	9140-0029		2	Coil: 100 uH 2.6 ohms	99848	3100-15-101
M1	1120-0945		1	m: meter	55026	07760
	1460-0256		4	Spring: compression	83909	obd
Q1, Q2	1850-0098		2	TSTR: Ge PNP* 300 kHz 250 mA	-hp-	
R1	0684-3331		1	R: fxd comp 33 kilohms +/-10% 1/4 W	01121	CB3331
R2	0766-0029		1	R: fxd met oxide 10 ohms +/-2% 3 W	14674	FP-3 obd
R3	2100-0079		1	R: var 250 ohms +/-10% 2.25 W	01121	Type J obd
S1	3101-0036		1	Switch: power	88140	8928D61
S2	**00653-61901**		1	**Switch assembly: range**	-hp-	
C1*	0150-0011		3	C: fxd TiO_2 1.5 pF +/-20% 500 vdcw	78488	Type GA obd
C2	0121-0420		6	C: var 2-10 pF Teflon dielectric	000LC	5640/10
C3*	0140-0146		2	C: fxd mica 82 pF +/-5%	72136	RDM15D820J3S
C4	0120-0420			C: var 2-10 pF	000LC	5640/10
C5*	0140-0146			C: fxd mica 82 pF +/-5%	72136	RDM15E820J3S
C6	0121-0420			C: var 2-10 pF	000LC	5640/10
C7*	0160-2322		2	C: fxd mica 18 pF +/-5%	72136	RDM15C180J1S
C8	0121-0420			C: var 2-10 pF	000LC	5640/10
C9*	0160-0763		2	C: fxd mica 5 pF +/-10%	72136	RDM15C050K5S
C10	0121-0420			C: var 2-10 pF	000LC	5640/10
C11*	0160-0763			C: fxd mica 5 pF +/-10%	72136	RDM15C050K5S
C12	0121-0420			C: var 2-10 pF	000LC	5640/10
C13*	0150-0011			C: fxd TiO_2 1.5 pF +/-20% 500 vdcw	78488	Type GA obd
C14	0180-0294		1	C: fxd Ta 390 uF +/-20% 10 vdcw	56289	109D397X0010T2DYP
C15*	0160-2322			C: fxd mica 18 pF +/-5%	72136	RDM15C180J1S
C16*	0150-0029		2	C: fxd TiO_2 1 pF +/-10% 500 vdcw	78488	Type GA obd
C17*	0150-0011			C: fxd TiO_2 1.5 pF +/-20% 500 vdcw	78488	Type GA obd
C18*	0150-0029			C: fxd TiO_2 1pF +/-10% 500 vdcw	78488	Type GA obd
R1	0698-6711		1	R: fxd met flm 12 megohms +/-1% 1/2 W	00327	M12 obd
R2*	0686-1545		1	R: fxd comp 150 kilohms +/-5% 1/2 W	01121	EB1545
R3	0698-6702		1	R: fxd met flm 1.24 megohms +/-0.25% 1/2 W	91637	MFF 1/2 T-0 obd
R4	0698-6722		1	R: fxd met flm 124 kilohms +/-0.1% 1/8 W	91637	MF-1/10-32 obd
R5	0698-6707		1	R: fxd met flm 12.4 kilohms +/-0.25% 1/8 W	91637	MF-1/10-32 obd
R6	0698-6706		1	R: fxd met flm 1.24 kilohms +/-0.25% 1/8 W	91637	MF-1/10-32 obd
R7	0698-4408		1	R: fxd met flm 124 ohms +/-1% 1/8 W	91637	MF-1/10-32 obd
R8				Not assigned		
R9	0698-6713		1	R: fxd met flm 24.3 megohms +/-1% 1/2 W	00327	M12 obd
R10*	0686-1855		1	R: fxd comp 1.8 megohms +/-5% 1/2 W	01121	EB1855

Table 6-1. Replaceable Parts (Cont'd)

REFERENCE DESIGNATOR	-hp- PART NO.		TQ	DESCRIPTION	MFR.	MFR. PART NO.
S2 (Cont'd)						
R11	0698-6857		1	R: fxd met flm 2.61 megohms +/-0.25% 1/2 W	00327	M12D obd
R12	0698-6821		1	R: fxd met flm 261 kilohms +/-0.25% 1/8 W	91637	MF-1/10-32 obd
R13	0698-6822		1	R: fxd met flm 26.1 kilohms +/-0.25% 1/8 W	91637	MF-1/10-32 obd
R14	0698-6823		1	R: fxd met flm 2.61 kilohms +/-0.25% 1/8 W	91637	MF-1/10-32 obd
R15	0757-0409		1	R: fxd met flm 274 ohms +/-1% 1/8 W	91637	MF-1/10-32 obd
R16				Not assigned		
R17	0575-0280			R: fxd met flm 1000 ohms +/-1% 1/8 W	91637	MF-1/10-32 obd
	00653-01202		1	Bracket: switch	-hp-	
S3	3101-1234		1	Switch: slide 115/230V	82389	11A-1242A
S4	**00654-63401**		**1**	**Assembly: attenuator**	-hp-	
R1	0698-6812		8	R: fxd met flm 362.6 ohms +/-0.25% 1/8 W	91637	MF-1/10-32 obd
R2	0698-6813		4	R: fxd met flm 21.84 ohms +/-0.25% 1/8 W	35009	CEA obd
R3,R4	0698-6812			R: fxd met flm 362.6 ohms +/-0.25% 1/8 W	91637	MF-1/10-32 obd
R5	0698-6813			R: fxd met flm 21.84 ohms +/-0.25% 1/8 W	35009	CEA obd
R6	0698-6812			R: fxd met flm 362.6 ohms +/-0.25% 1/8 W	91637	MF-1/10-32 obd
R7	0698-6804		4	R: fxd met flm 540.9 ohms +/-0.25% 1/8 W	91637	MF-1/10-32 obd
R8	0698-6803		2	R: fxd met flm 14.40 ohms +/-0.25% 1/8 W	91637	MF-1/10-32 obd
R9	0698-6804			R: fxd met flm 540.9 ohms +/-0.25% 1/8 W	91637	MF-1/10-32 obd
R10	0698-6805		4	R: fxd met flm 1078 ohms +/-0.25% 1/8 W	91637	MF-1/10-32 obd
R11	0698-6827		2	R: fxd met flm 7.154 ohms +/-0.5% 1/8 W	00327	M11D obd
R12	0698-6805			R: fxd met flm 1078 ohms +/-0.25% 1/8 W	91637	MF-1/10-32 obd
R13	0698-6810		8	R: fxd met flm 66.05 ohms +/-0.25% 1/8 W	91637	MF-1/10-32 obd
R14	0698-6811		4	R: fxd met flm 979.3 ohms +/-0.25% 1/8 W	91637	MF-1/10-32 obd
R15,R16	0698-6810			R: fxd met flm 66.05 ohms +/-0.25% 1/8 W	91637	MF-1/10-32 obd
R17	0698-6811			R: fxd met flm 979.3 ohms +/-0.25% 1/8 W	91637	MF-1/10-32 obd
R18	0698-6810			R: fxd met flm 66.05 ohms +/-0.25% 1/8 W	91637	MF-1/10-32 obd
R19	0698-6808		4	R: fxd met flm 75.78 ohms +/-0.25% 1/8 W	91637	MF-1/10-32 obd
R20	0698-6809		2	R: fxd met flm 306.9 ohms +/-0.25% 1/8 W	91637	MF-1/10-32 obd
R21	0698-6808			R: fxd met flm 75.78 ohms +/-0.25% 1/8 W	91637	MF-1/10-32 obd
R22	0698-6806		4	R: fxd met flm 119.3 ohms +/-0.25% 1/8 W	91637	MF-1/10-32 obd
R23	0698-6807		2	R: fxd met flm 88.23 ohms +/-0.25% 1/8 W	91637	MF-1/10-32 obd
R24	0698-6806			R: fxd met flm 119.3 ohms +/-0.25% 1/8 W	91637	MF-1/10-32 obd
R25	0698-6812			R: fxd met flm 362.6 ohms +/-0.25% 1/8 W	91637	MF-1/10-32 obd
R26	0698-6813			R: fxd met flm 21.84 ohms +/-0.25% 1/8 W	35009	CEA obd
R27,R28	0698-6812			R: fxd met flm 362.6 ohms +/-0.25% 1/8 W	91637	MF-1/10-32 obd
R29	0698-6813			R: fxd met flm 21.84 ohms +/-0.25% 1/8 W	35009	CEA obd
R30	0698-6812			R: fxd met flm 362.6 ohms +/-0.25% 1/8 W	91637	MF-1/10-32 obd
R31	0698-6804			R: fxd met flm 540.9 ohms +/-0.25% 1/8 W	91637	MF-1/10-32 obd
R32	0698-6803			R: fxd met flm 14.40 ohms +/-0.25% 1/8 W	91637	MF-1/10-32 obd
R33	0698-6804			R: fxd met flm 540.9 ohms +/-0.25% 1/8 W	91637	MF-1/10-32 obd
R34	0698-6805			R: fxd met flm 1078 ohms +/-0.25% 1/8 W	91637	MF-1/10-32 obd
R35	0698-6827			R: fxd met flm 7.154 ohms +/-0.5% 1/8 W	00327	M11D obd
R36	0698-6805			R: fxd met flm 1078 ohms +/-0.25% 1/8 W	91637	MF-1/10-32 obd
R37	0698-6810			R: fxd met flm 66.05 ohms +/-0.25% 1/8 W	91637	MF-1/10-32 obd
R38	0698-6811			R: fxd met flm 979.3 ohms +/-0.25% 1/8 W	91637	MF-1/10-32 obd
R39,R40	0698-6810			R: fxd met flm 66.05 ohms +/-0.25% 1/8 W	91637	MF-1/10-32 obd
R41	0698-6811			R: fxd met flm 979.3 ohms +/-0.25% 1/8 W	91637	MF-1/10-32 obd
R42	0698-6810			R: fxd met flm 66.05 ohms +/-0.25% 1/8 W	91637	MF-1/10-32 obd
R43	0698-6808			R: fxd met flm 75.78 ohms +/-0.25% 1/8 W	91637	MF-1/10-32 obd
R44	0698-6809			R: fxd met flm 306.9 ohms +/-0.25% 1/8 W	91637	MF-1/10-32 obd
R45	0698-6808			R: fxd met flm 75.78 ohms +/-0.25% 1/8 W	91637	MF-1/10-32 obd
R46	0698-6806			R: fxd met flm 119.3 ohms +/-0.25% 1/8 W	91637	MF-1/10-32 obd
R47	0698-6807			R: fxd met flm 88.23 ohms +/-0.25% 1/8 W	91637	MF-1/10-32 obd
R48	0698-6806			R: fxd met flm 119.3 ohms +/-0.25% 1/8 W	91637	MF-1/10-32 obd
T1	9100-3239		1	Transformer	-hp-	
W1	8120-1348		1	Cord: power	70903	KH-4147



ATTACHING HARDWARE

ITEM	-hp- PART NO.	DESCRIPTION
(1)	3030-0022	Screw: Set, 6-32 x 1/8 in. long
(2)	3030-0001	Screw: Set, 8-32 x 3/16 in. long
(3)	3030-0004	Screw: Set, 8-32 x 1 in. long
(4)	3050-0180	Washer: .270 ID x .375 OD
(5)	0510-0054	Ring Retaining: .25 OD SHAFT

Figure 6-1. Frequency Tuning Mechanism

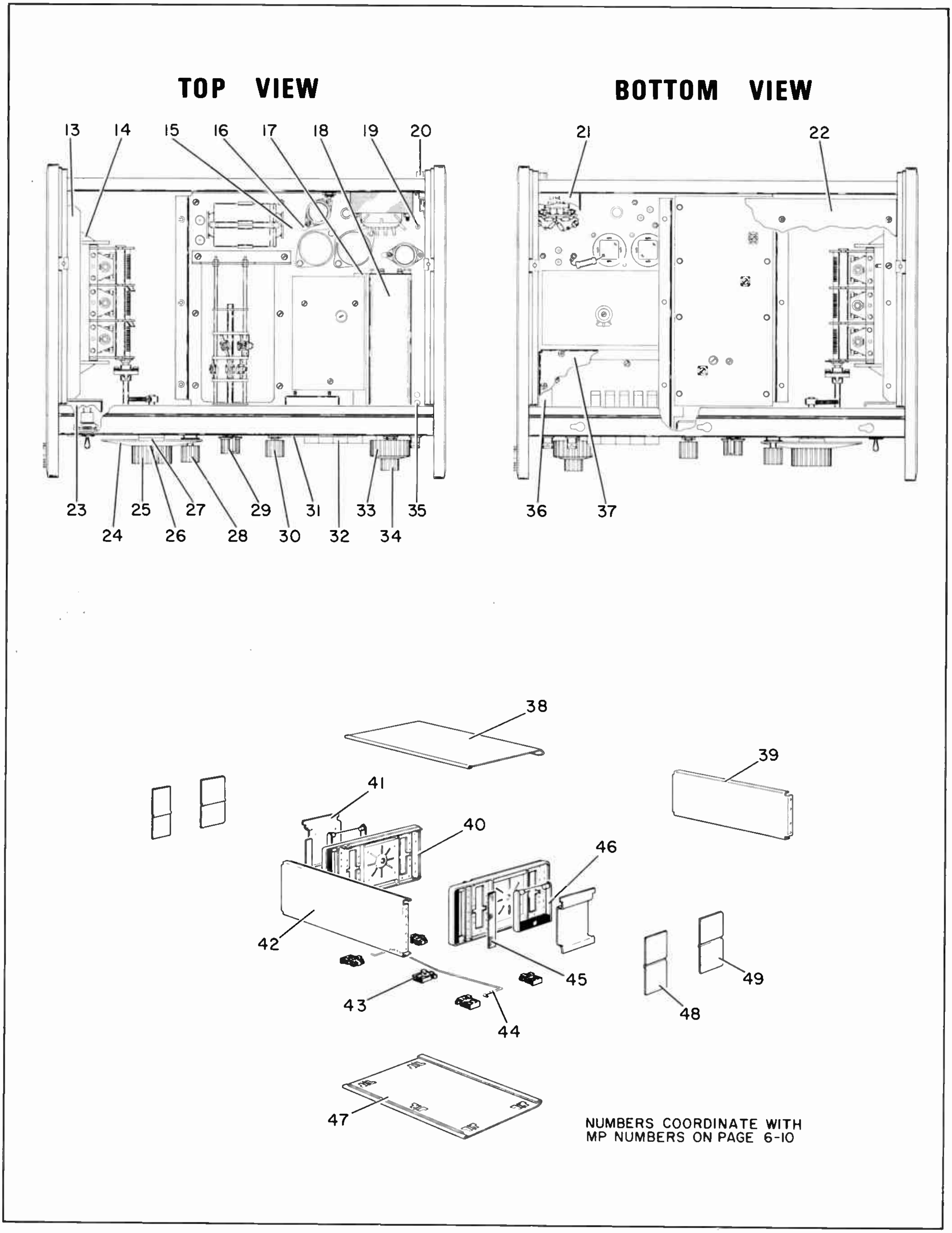


Figure 6-2. Chassis Mechanical Parts

Table 6-1. Replaceable Parts (Cont'd)

REFERENCE DESIGNATOR	-hp- PART NO.		TQ	DESCRIPTION	MFR.	MFR. PART NO.
				MECHANICAL PARTS		
MP1	1500-0253		2	Yoke-Flex: coupler	76489	39006
MP2	5040-0004		1	Coupler: insulator, flex	-hp-	
MP3	5060-0021		1	Gear: ass'y	-hp-	
MP4	1460-0114		1	Wireform	91260	obd
MP5	5060-0020		1	Gear: ass'y	-hp-	
MP6	5020-0233		1	Collar	-hp-	
MP7	5020-0348		1	Shaft	-hp-	
MP8	5020-0641		1	Gear: spur ass'y shaft	-hp-	
MP9	5020-0639		1	Casting: Cap drive ass'y	-hp-	
MP10	5000-0637		1	Spring: thrust	-hp-	
MP11	5020-0630		1	Dial: hub	-hp-	
MP12	5040-0607		1	Disc: vernier drive	-hp-	
MP13	00653-00102		1	Deck: capacitor	-hp-	
MP14	5040-0631		2	Mount: capacitor, bracket	-hp-	
MP15	00653-00101		1	Deck: main	-hp-	
MP16	1200-0043		2	Insulator: TSTR	76530	293011
MP17	00653-01205		1	Bracket: attenuator mount	-hp-	
MP18	00653-05502		1	Shield: attenuator	-hp-	
MP19	0360-1507		2	Insulator: feedthrough	12284	4242-1-0119
MP20	1400-0084		1	Holder: fuse	75915	342014
MP21	00651-05503		1	Shield: filter	-hp-	
MP22	00653-04101		1	Cover: plate	-hp-	
MP23	00651-05501		1	Shield: power	-hp-	
MP24	00651-04001		1	Dial	-hp-	
MP25	0370-0160		1	Knob: dial	-hp-	
MP26	61B-40D-4		1	Plate: freq. dial	-hp-	
MP27	5040-5158		1	Indicator: dial	-hp-	
MP28	0370-0025		1	Knob-Freq: vernier	-hp-	
MP29	0370-0112		1	Knob-Bar: black	-hp-	
MP30	0370-0026		1	Knob: amp	-hp-	
MP31	4040-0297		1	Bezel: meter	-hp-	
MP32	0370-0440		5	Knob: pushbutton	-hp-	
MP33	00653-47401		1	Knob: attenuator outer	-hp-	
MP34	00653-67401		1	Knob: attenuator, inner	-hp-	
MP35	1250-0901		2	Connector: RF	74163	1104/D
MP36	00654-05501		1	Shield: output	-hp-	
MP37	00653-05501		1	Shield: S. W.	-hp-	
MP38	5060-8587		1	Cover ass'y: top	-hp-	
	2370-0013		8	Attaching hardware: screw, machine	83385	obd
	0150-0075		8	Attaching hardware: nut, sheet metal	-hp-	
MP39	00653-00204		1	Panel: rear	-hp-	
MP40	5060-0731		2	Frame ass'y	-hp-	
MP41	5060-8737		2	Retainer: 5H handle ass'y	-hp-	
MP42	00654-00202		1	Panel: front	-hp-	
MP43	5060-0767		5	Foot ass'y: FM	-hp-	
MP44	1490-0030		1	Stand: tilt	91260	obd
MP45	5000-0051		2	Trim: fluted Al plate	-hp-	
MP46	5060-0222		2	Handle ass'y: 5H side	-hp-	
MP47	5060-8711		1	Cover ass'y: bottom	-hp-	
	2370-0013			Attaching hardware: screw, machine	83385	obd
	0150-0075			Attaching hardware: nut, sheet metal	-hp-	
MP48	5000-8599		2	Cover: side front	-hp-	
	2370-0016		4	Attaching hardware: screw, machine	80120	obd
MP49	5000-8597		2	Cover: side rear	-hp-	
	2370-0016			Attaching hardware: screw, machine	80120	obd
MP50	00653-01206		1	Bracket: attenuator	-hp-	

Table 6-1. Replaceable Parts (Cont'd)

REFERENCE DESIGNATOR	-hp- PART NO.		TQ	DESCRIPTION	MFR.	MFR. PART NO.
				MISCELLANEOUS		
	00653-61602		2	Cable: attenuator input	-hp-	
	00653-61601		2	Cable: attenuator output	-hp-	
	00651-61604		1	Cable: power	-hp-	
	5060-8740		1	Kit: rack mount, 5H	-hp-	
	5000-7133		1	Label: pushbutton 50 ohms	-hp-	
	5000-7126		1	Label: pushbutton 75 ohms	-hp-	
	5000-7134		1	Label: pushbutton 135 ohms	-hp-	
	5000-7135		1	Label: pushbutton 150 ohms	-hp-	
	5000-7136		1	Label: pushbutton 600 ohms	-hp-	
	00654-90001		1	Manual: operating and service	-hp-	
	1205-0033		8	Heat sink semiconductor for A2Q4-Q6, A2Q18-Q21 and A3Q9	05820	207-CB
	5040-0234		1	Holder: lamp		
	5040-0235		1	Base: lampholder		

SECTION VII
CIRCUIT DIAGRAMS

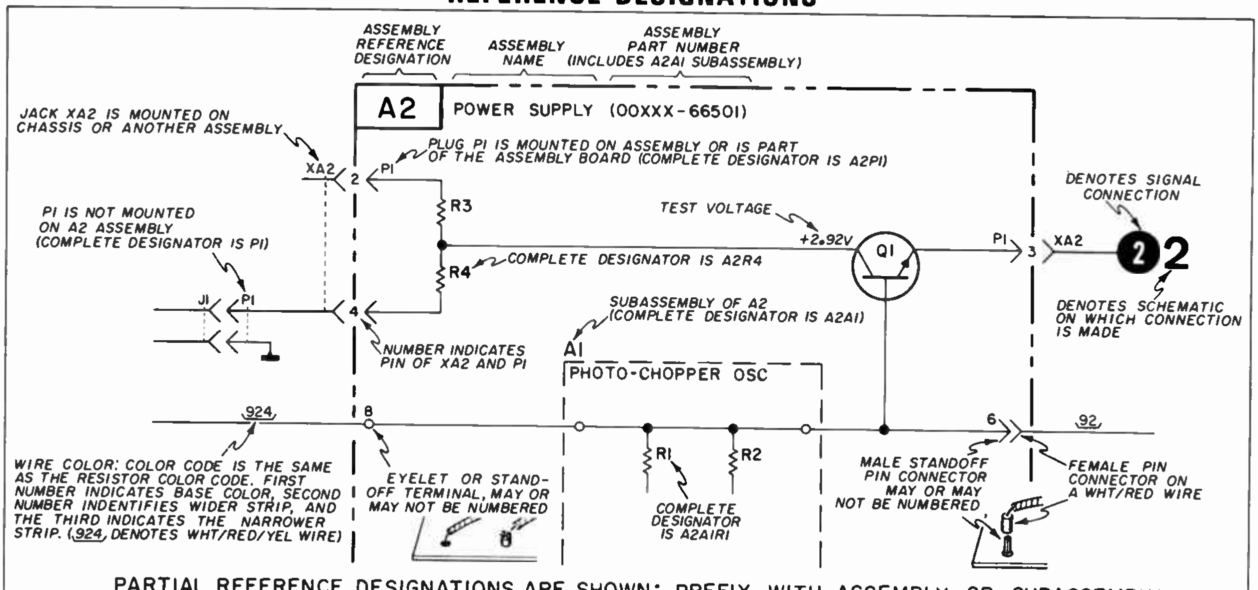
7-1. INTRODUCTION.

7-2. This section contains circuit diagrams to aid in the operation and maintenance of the Model 654A. Figure 7-1 is a functional circuit diagram which shows the overall relationship between the basic circuits of the instrument. Figures 7-2 through 7-5 contain the detailed schematic diagrams as well as component location drawings of each printed circuit board and the rotary switches.

7-3. General schematic notes, which apply to all the schematic diagrams, are listed on Page 7-2.

7-4. An explanation of terms and symbols used on the schematic diagrams is given below.

REFERENCE DESIGNATIONS



PARTIAL REFERENCE DESIGNATIONS ARE SHOWN: PREFIX WITH ASSEMBLY OR SUBASSEMBLY DESIGNATION(S) OR BOTH FOR COMPLETE DESIGNATION

SCHEMATIC NOTES

1. PARTIAL REFERENCE DESIGNATIONS ARE SHOWN, PREFIX WITH ASSEMBLY OR SUBASSEMBLY DESIGNATION(S) OR BOTH FOR COMPLETE DESIGNATION.

2. COMPONENT VALUES ARE SHOWN AS FOLLOWS UNLESS OTHERWISE NOTED.

   RESISTANCE IN OHMS

   CAPACITANCE IN MICROFARADS

   INDUCTANCE IN MICROHENRYS

3. DENOTES ASSEMBLY.

4. DENOTES MAIN SIGNAL PATH.

5. DENOTES DC FEEDBACK PATH.

6. DENOTES AC FEEDBACK PATH.

7. DENOTES FRONT PANEL MARKING.

8. DENOTES REAR PANEL MARKING.

9. DENOTES SCREWDRIVER ADJUST.

10. DENOTES FRONT PANEL CONTROL.

11. DENOTES POWER LINE GROUND.

12. DENOTES FRAME GROUND.

13. DENOTES ASSEMBLY GROUND.

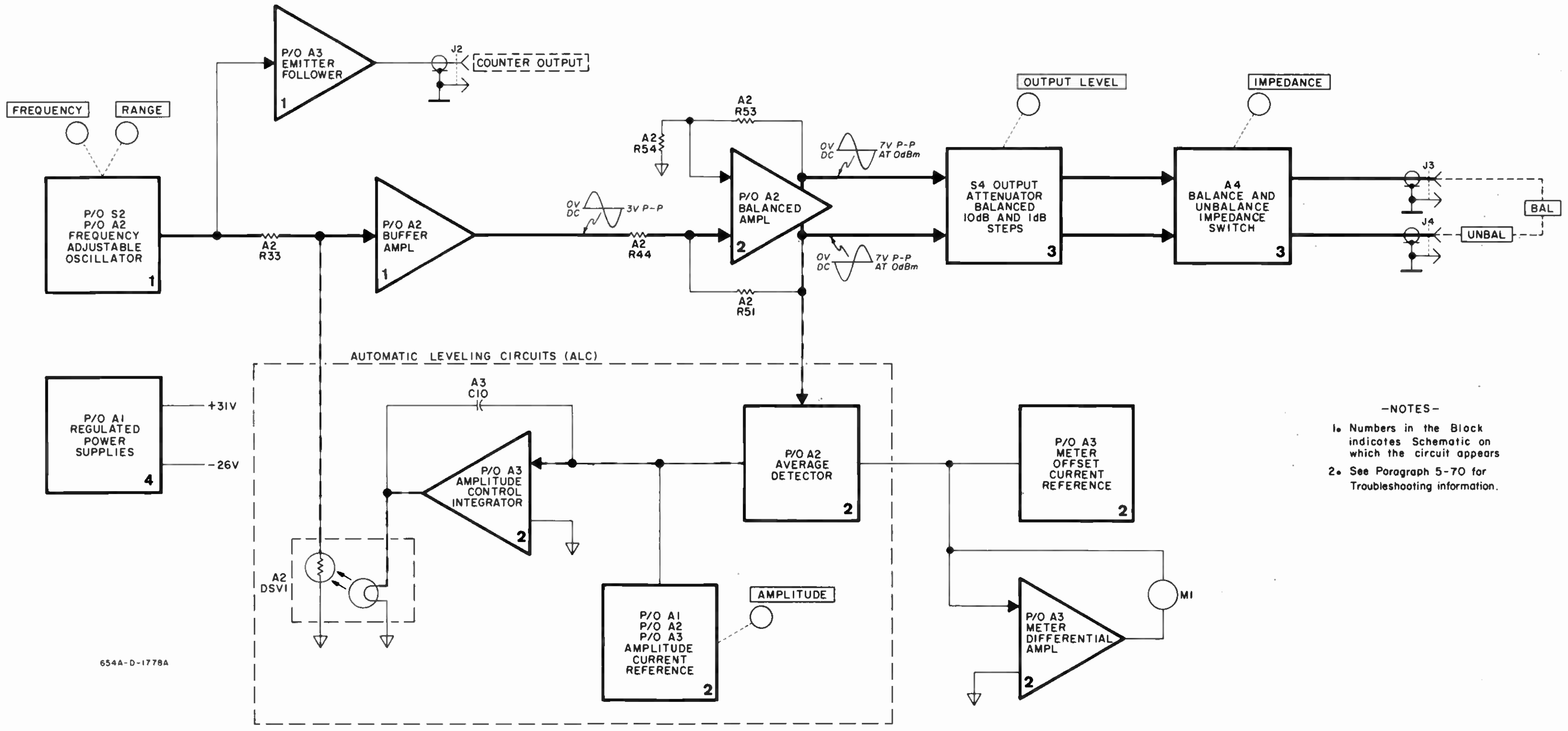
14. * AVERAGE VALUE SHOWN, OPTIMUM VALUE SELECTED AT FACTORY. COMPONENT MAY OR MAY NOT BE PRESENT.

15. DENOTES GROUND CONNECTION MADE WITH ASSEMBLY MOUNTING SCREWS IN PLACE.

16. 2 DENOTES SIGNAL CONNECTION.

17. 2 DENOTES SCHEMATIC ON WHICH SIGNAL CONNECTION IS MADE.

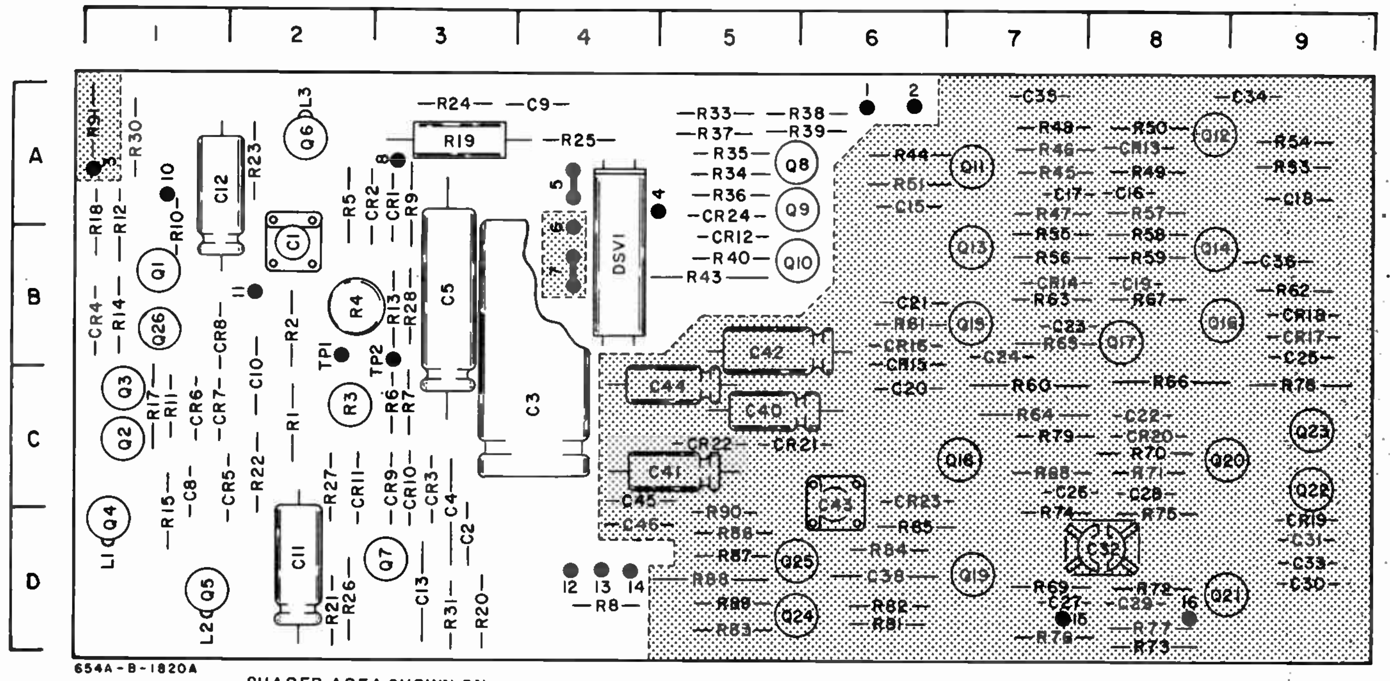
18. DENOTES COMPONENTS NOT MOUNTED ON ASSEMBLY.



-NOTES-

1. Numbers in the Block indicates Schematic on which the circuit appears
2. See Paragraph 5-70 for Troubleshooting information.

Figure 7-1. Block Diagram.



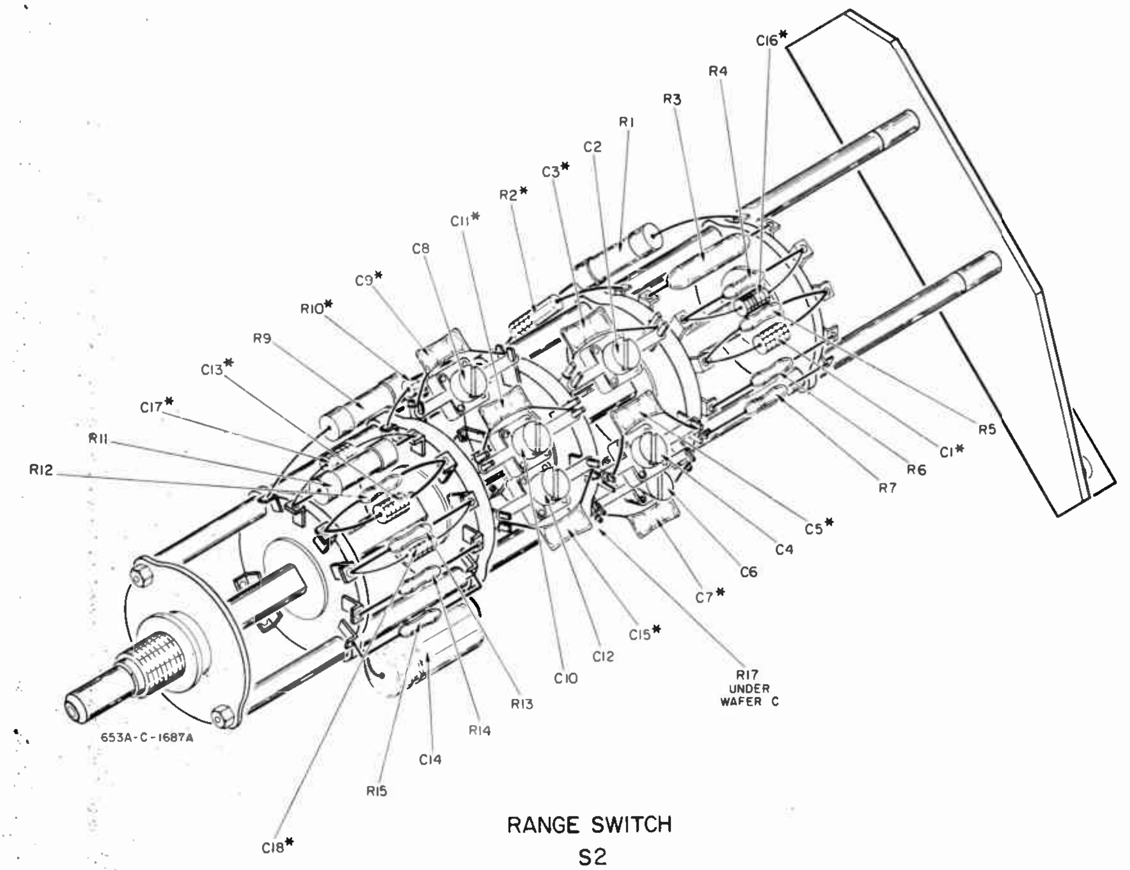
SHADED AREA SHOWN ON SCHEMATIC NO. 2

A2
hp Part No. 00654-66502
Rev. A

A2 ASSEMBLY
COMPONENT LOCATIONS

	Q	C	CR		C		R	C		R		R		R
11	A7			26	C7	41		C5	56	B7	71	C8	86	D5
12	A8			27	D7	42		B5	57	A8	72	D8	87	D5
13	B7		A8	28	C8	43		C6	58	B8	73	D8	88	D5
14	B8		B7	29	D8	44	A6	C5	59	B8	74	D7	89	D5
15	B7	A6	B6	30	D9	45	A7	C4	60	C7	75	D8	90	D5
16	B8	A8	B6	31	D9	46	A7	D4	61	B6	76	D7	91	A1
17	B8	A7	B9	32	D8	47	A7		62	B9	77	D8		
18	C7	A9	B9	33	D9	48	A7		63	B7	78	C9		
19	D7	B8	D9	34	A8	49	A8		64	C7	79	C7		
20	C8	C6	C8	35	A7	50	A8		65	B7	80	---		
21	D8	B6	C5	36	B9	51	A6		66	C8	81	D6		
22	C9	C8	C5	37	---	52	---		67	B8	82	D6		
23	C9	B7	C6	38	D6	53	A9		68	C7	83	D5		
24	D5	B7		39	---	54	A9		69	D7	84	D6		
25	D5	B9		40	C5	55	B7		70	C8	85	D6		

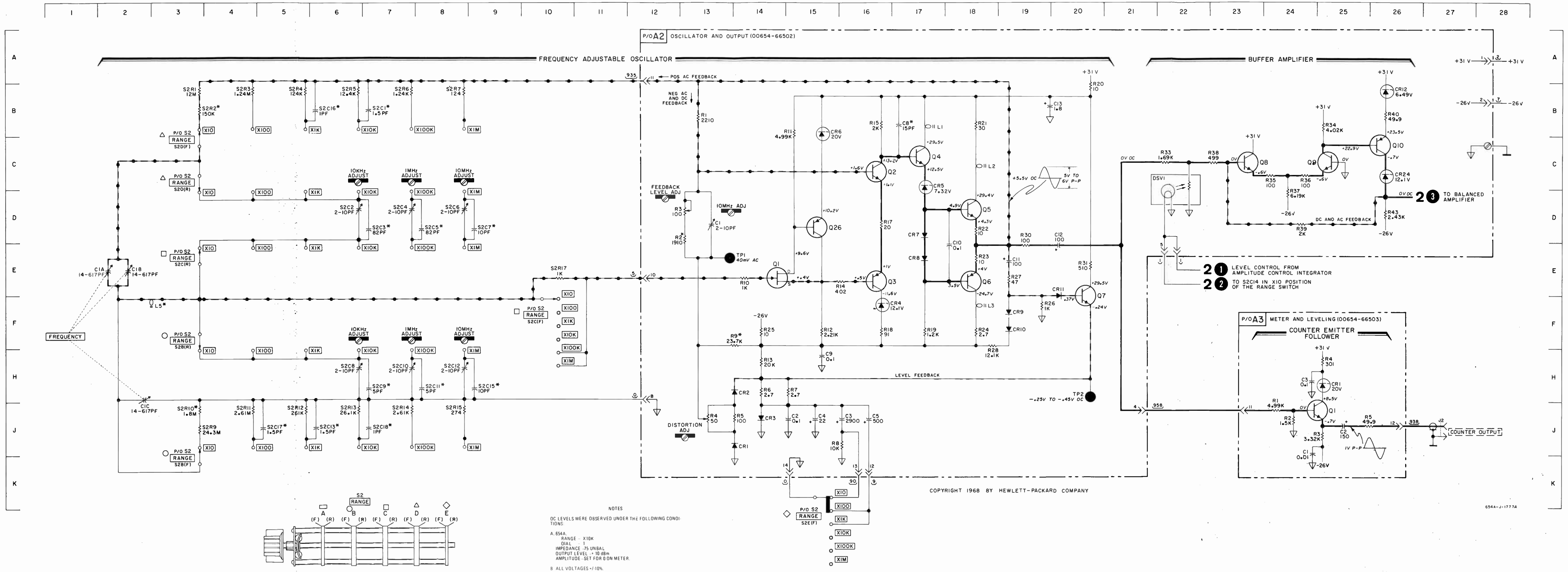
P/O Figure 7-2. Oscillator and Buffer Amplifier



RANGE SWITCH
S2
hp Part No. 00653-61901

A2 SCHEMATIC COMPONENT LOCATIONS

	R	Q	C	CR	L	OSV		R	Q	CR		R
1	B13	E14	D13	J14	B17	C22	16	---			31	E20
2	D13	C16	J15	H14	C18		17	D16			32	---
3	D13	E16	J16	J14	F18		18	F16			33	C22
4	J13	C17	J15	F16			19	F17			34	B25
5	J14	D18	J16	C17			20	B20			35	C24
6	H14	E18	---	C15			21	B18			36	C24
7	H15	E20	---	D17			22	D18			37	D24
8	J16	C23	B17	E17			23	E18			38	C23
9	F13	C25	H15	F19			24	F18		C26	39	D24
10	E14	C26	E18	F19			25	F14			40	B26
11	D15		E19	E20			26	F19	D15		41	---
12	F15		E20	B26			27	E19			42	---
13	H14		B19				28	F18			43	D26
14	E15		---				29	---			44	
15	B16						30	E19			45	



NOTES

DC LEVELS WERE OBSERVED UNDER THE FOLLOWING CONDITIONS:

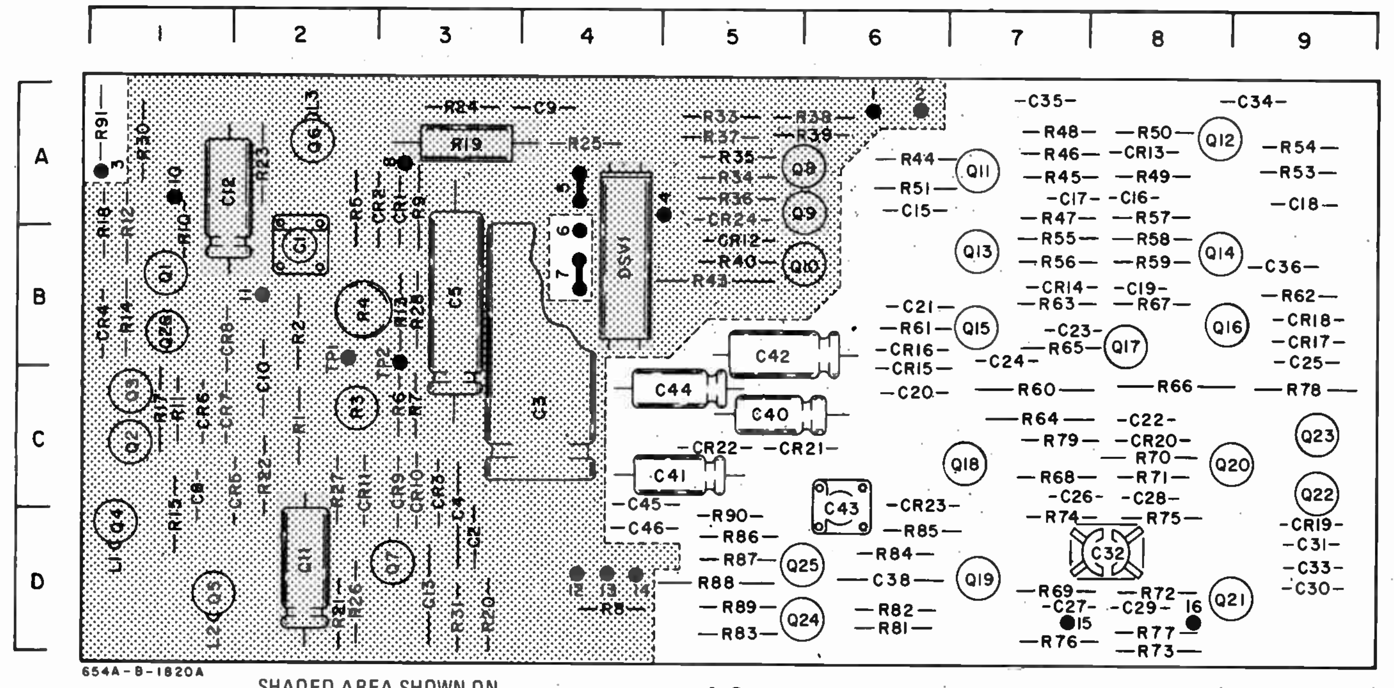
A. 654A.
RANGE – X10K
DIAL – 1
IMPEDANCE –75 UNBAL
OUTPUT LEVEL –+ 10 dBm
AMPLITUDE – SET FOR 0 ON METER.

B. ALL VOLTAGES +/-10%.

C. VOLTAGES WERE TAKEN WITH AN -HP- MODEL 3440A DIGITAL VOLTMETER HAVING A 3443A PLUG-IN. HOWEVER, ANY DC VOLTMETER WITH APPROXIMATELY 10 MEGOHMS INPUT IMPEDANCE WILL YIELD ABOUT THE SAME RESULTS.

1

P/O Figure 7-2. Oscillator and Buffer Amplifier S2, A2, A3.



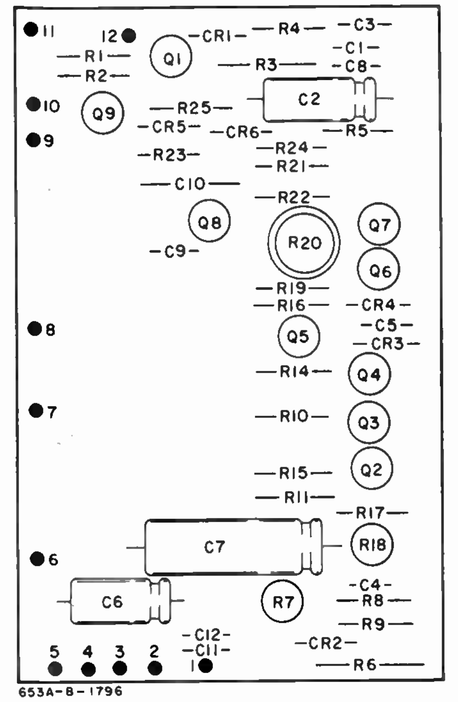
SHADED AREA SHOWN ON SCHEMATIC NO. 1

A2
hp Part No. 00654-66502
Rev. A

A2 ASSEMBLY COMPONENT LOCATIONS

	R	Q	C	CR	L	OSV		R	Q	CR		R
1	C2	B1	B2	A3	D1	B4	16	---			31	D3
2	B2	C1	D3	A3	D1		17	C1			32	---
3	C2	C1	C4	C3	A2		18	B1			33	A5
4	B2	D1	C3	B1			19	A3			34	A5
5	A2	D1	B3	C2			20	D3			35	A5
6	C3	A2	---	C1			21	D2			36	A5
7	C3	D3	---	C2			22	C2			37	A5
8	D4	A5	C1	B2			23	A2			38	A6
9	A3	A5	A4	C3			24	A3		A5	39	A6
10	B1	B5	C2	C3			25	A4			40	B5
11	C1		D2	C2			26	D2	B1		41	---
12	B1		A2	B5			27	C2			42	---
13	B3		D3				28	B3			43	B5
14	B1		---				29	---				
15	D1						30	A1				

P/O Figure 7-3. Balanced Amplifier, Meter and Leveling



A3
hp Part No. 00654-66503

NOTES

DC LEVELS WERE OBSERVED UNDER THE FOLLOWING CONDITIONS:

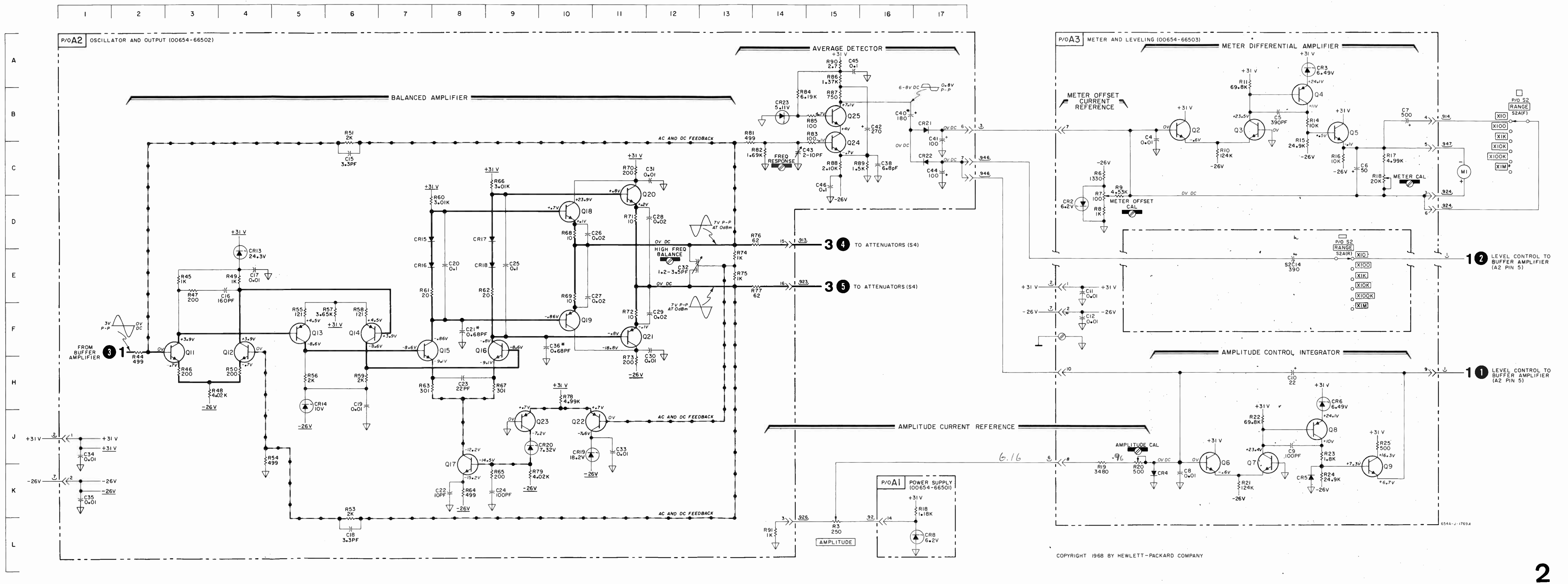
A. 654A.
RANGE – X10K
DIAL – 1
IMPEDANCE –75 UNBAL
OUTPUT LEVEL –+ 10 dBm
AMPLITUDE–SET FOR 0 ON METER.

B. ALL VOLTAGES +/-10%.

C. VOLTAGES WERE TAKEN WITH AN -HP- MODEL 3440A DIGITAL VOLTMETER HAVING A 3443A PLUG-IN. HOWEVER, ANY DC VOLTMETER WITH APPROXIMATELY 10 MEGOHMS INPUT IMPEDANCE WILL YIELD ABOUT THE SAME RESULTS.

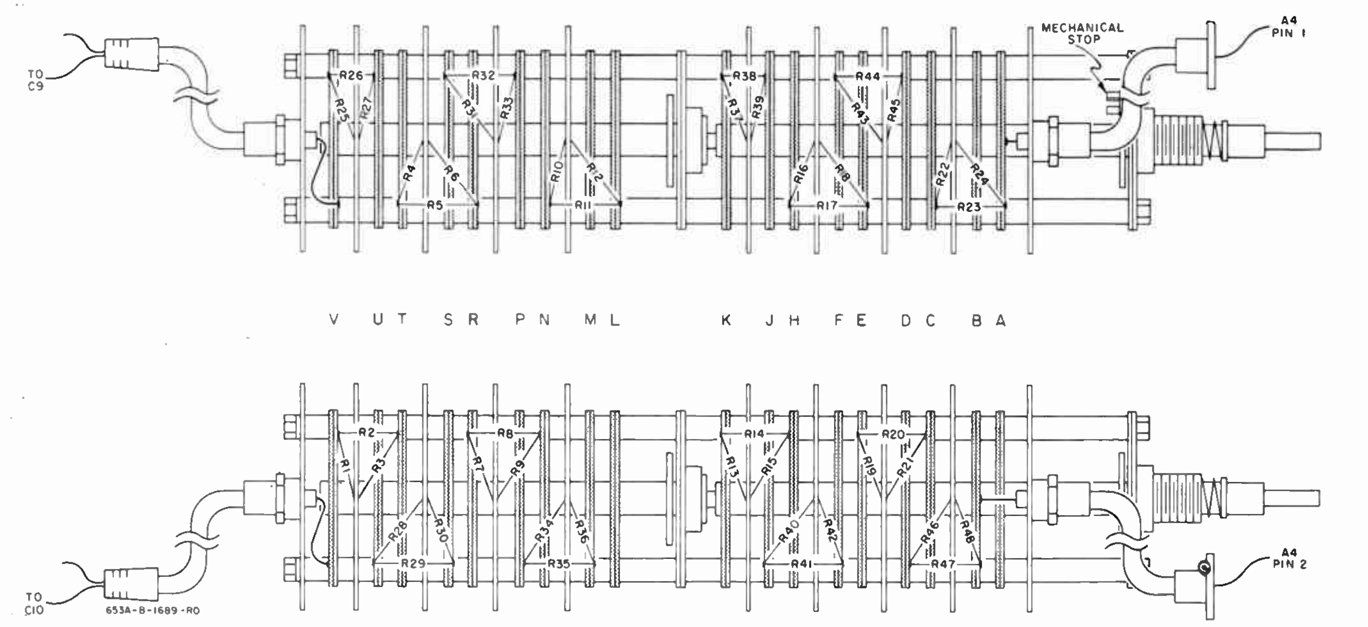
A2 SCHEMATIC COMPONENT LOCATIONS

	Q	C	CR		C		R	C		R		R		R
11	F3			26	D10	41		B17	56	H5	71	D11	86	A15
12	F4			27	E10	42		B16	57	F6	72	F11	87	B15
13	F5		E4	28	D12	43		C14	58	F6	73	H11	88	C15
14	F6		H5	29	F12	44	F2	C17	59	H6	74	E13	89	C16
15	F7	C6	D7	30	F12	45	E3	A15	60	D7	75	E13	90	A15
16	F9	E4	E7	31	C12	46	H3	C15	61	E7	76	D14	91	L14
17	K8	E4	D9	32	E12	47	E3		62	E9	77	E14		
18	D10	L6	E9	33	J11	48	H3		63	H7	78	H10		
19	F10	H6	J10	34	J1	49	E4		64	K8	79	K9		
20	C11	E8	J9	35	K1	50	H4		65	K9	80	- - -		
21	F11	F8	B17	36	F10	51	C6		66	C9	81	C13		
22	J10	K8	C17	37	- - -	52	- - -		67	H9	82	C14		
23	J9	H8	B14	38	C16	53	L6		68	D10	83	C15		
24	C15	K9		39	- - -	54	J4		69	E10	84	B14		
25	B15	E9		40	B16	55	F5		70	C11	85	B15		

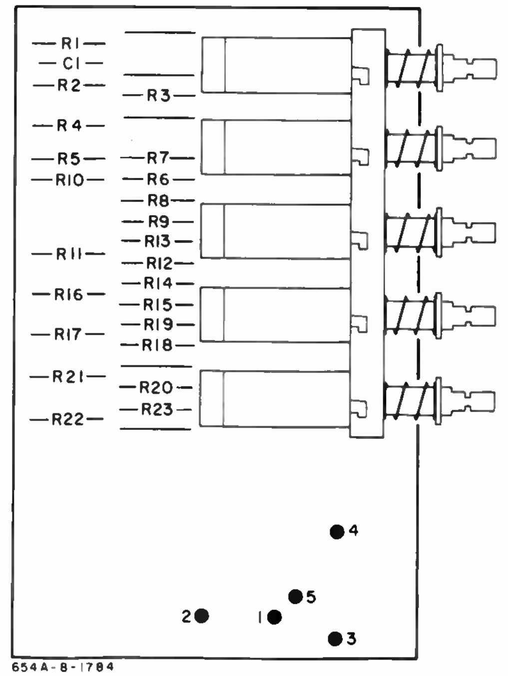


2

P/O Figure 7-3. Balanced Amplifier, Meter and Leveling A1, A2, A3.



ATTENUATOR
S4
hp Part No. 00654-63401



A4
hp Part No. 00654-66504

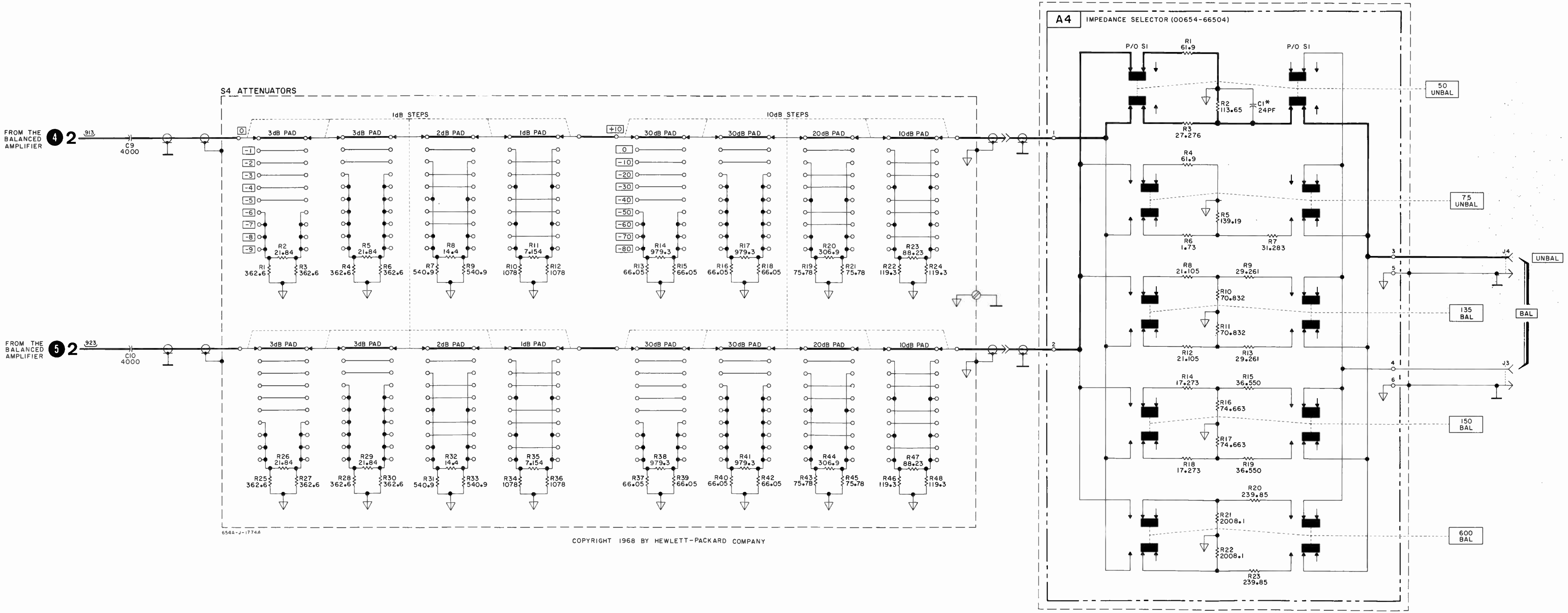
NOTES

DC LEVELS WERE OBSERVED UNDER THE FOLLOWING CONDITIONS:

A. 654A.
   RANGE – X10K
   DIAL – 1
   IMPEDANCE –75 UNBAL
   OUTPUT LEVEL –+ 10 dBm
   AMPLITUDE–SET FOR 0 ON METER.

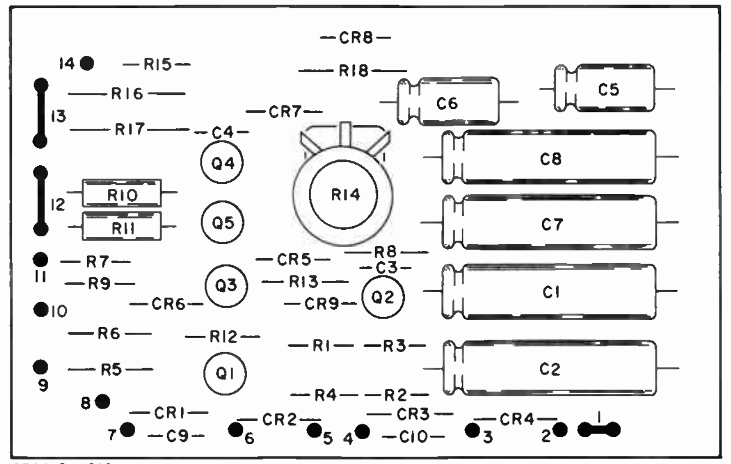
B. ALL VOLTAGES +/-10%.

C. VOLTAGES WERE TAKEN WITH AN -hp- MODEL 3440A DIGITAL VOLTMETER HAVING A 3443A PLUG-IN. HOWEVER, ANY DC VOLTMETER WITH APPROXIMATELY 10 MEGOHMS INPUT IMPEDANCE WILL YIELD ABOUT THE SAME RESULTS.



3

Figure 7-4. Attenuators and Impedance Selector S4, A4.



654A-B-1819

A1
hp Part No. 00654-66501

NOTES

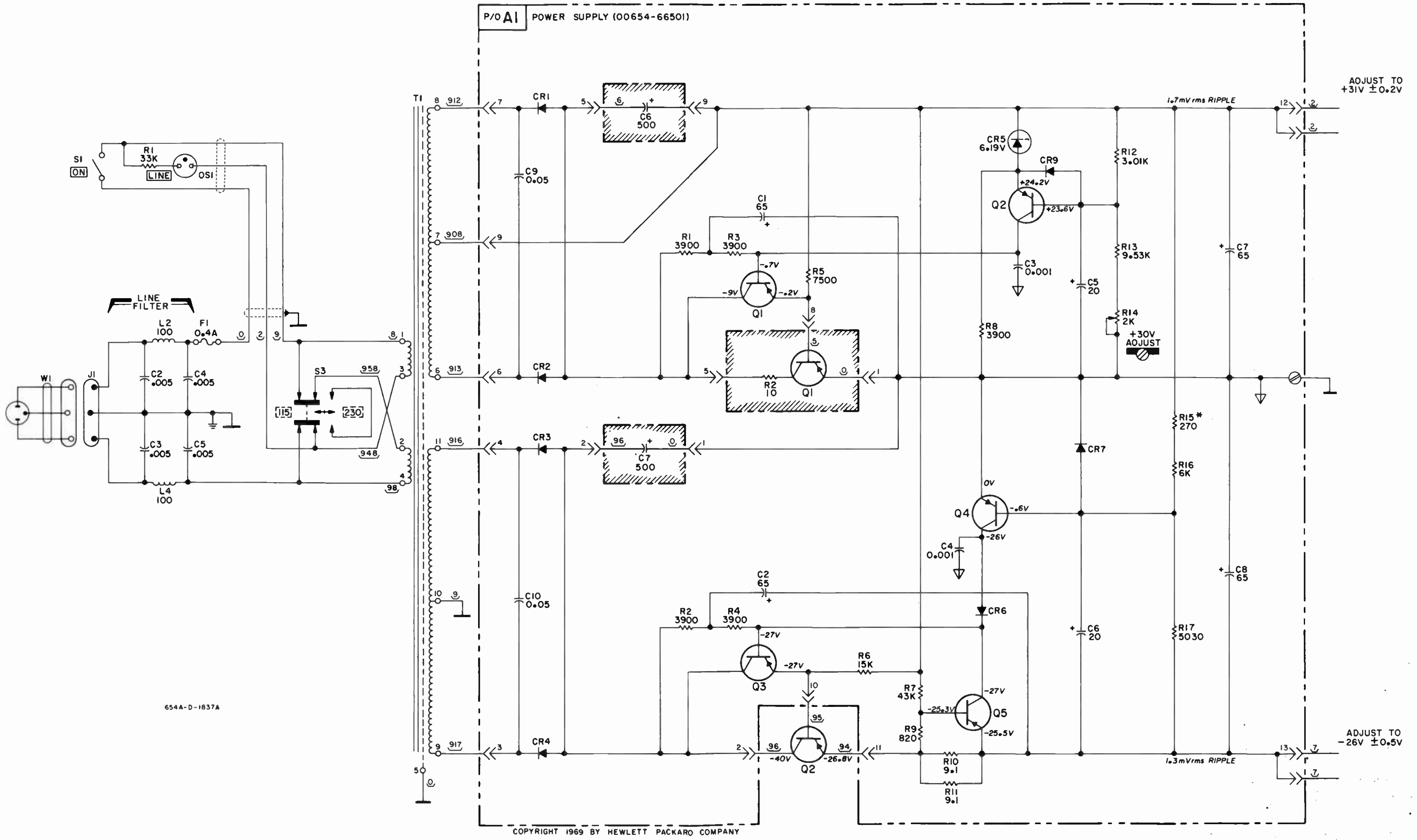
DC LEVELS WERE OBSERVED UNDER THE FOLLOWING CONDITIONS:

A. 654A.
RANGE – X10K
DIAL – 1
IMPEDANCE –75 UNBAL
OUTPUT LEVEL –+ 10 dBm
AMPLITUDE–SET FOR 0 ON METER.

B. ALL VOLTAGES +/-10%.

C. VOLTAGES WERE TAKEN WITH AN ·HP· MODEL 3440A DIGITAL VOLTMETER HAVING A 3443A PLUG-IN. HOWEVER, ANY DC VOLTMETER WITH APPROXIMATELY 10 MEGOHMS INPUT IMPEDANCE WILL YIELD ABOUT THE SAME RESULTS.

654A-D-1837A



4

Figure 7-5. Power Supplies, A1.

CODE LIST OF MANUFACTURERS

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
00000	U. S. A Common	Any supplier of U.S.
00136	McCoy Electronics	Mount Holly Springs, Pa.
00213	Sage Electronics Corp.	Rochester, N.Y.
00287	Cemco, Inc.	Danielson, Conn.
00334	Humidial	Colton, Calif.
00348	Mictron, Co., Inc.	Valley Stream, N.Y.
00373	Garlock Inc.	Cherry Hill, N.J.
00656	Aerovox Corp.	New Bedford, Mass.
00779	Amp. Inc.	Harrisburg, Pa.
00781	Aircraft Radio Corp.	Boonton, N.J.
00809	Croven, Ltd.	Whitby, Ontario, Canada
00815	Northern Engineering Laboratories, Inc.	Burlington, Wis.
00853	Sangamo Electric Co., Pickens Div.	Pickens, S.C.
00866	Goe Engineering Co.	City of Industry, Cal.
00891	Carl E. Holmes Corp.	Los Angeles, Cal.
00929	Microlab Inc.	Livingston, N.J.
01002	General Electric Co., Capacitor Dept.	Hudson Falls, N.Y.
01009	Alden Products Co.	Brockton, Mass.
01121	Allen Bradley Co.	Milwaukee, Wis.
01255	Litton Industries, Inc.	Beverly Hills, Cal.
01281	TRW Semiconductors, Inc.	Lawndale, Cal.
01295	Texas Instruments, Inc., Transistor Products Div.	Dallas, Texas
01349	The Alliance Mfg. Co	Alliance, Ohio
01538	Small Parts Inc.	Los Angeles, Cal.
01589	Pacific Relays, Inc.	Van Nuys, Cal.
01670	Gudebrod Bros. Silk Co.	New York, N.Y.
01930	Amerock Corp.	Rockford, Ill.
01960	Pulse Engineering Co	Santa Clara, Cal.
02114	Ferroxcube Corp. of America	Saugerties, N.Y.
02116	Wheelock Signals, Inc.	Long Branch, N.J.
02286	Cole Rubber and Plastics Inc	Sunnyvale, Cal.
02660	Amphenol-Borg Electronics Corp.	Broadview, Ill.
02735	Radio Corp. of America, Semiconductor and Materials Division	Somerville, N.J.
02771	Vocaline Co. of America, Inc.	Old Saybrook, Conn.
02777	Hopkins EngineeringCo.	San Fernando, Cal.
02875	Hudson Tool & Die	Newark, N.J.
03296	Nylon Molding Corp.	Springfield, N.J.
03508	G. E. Semiconductor Prod. Dept.	Syracuse, N.Y.
03705	Apex Machine & Tool Co.	Dayton, Ohio
03797	Eldema Corp.	Compton, Calif.
03818	Parker Seal Co.	Los Angeles, Cal.
03877	Transitron Electric Corp.	Wakefield, Mass.
03888	Pyrofilm Resistor Co., Inc.	Cedar Knolls, N.J.
03954	Singer Co., Diehl Div., Finderne Plant	Sumerville, N.J.
04009	Arrow, Hart and Hegeman Elect. Co.	Hartford, Conn.
04013	Taruus Corp.	Lambertville, N.J.
04062	Areo Electronic Inc.	Great Neck, N.Y.
04217	Essex Wire	Los Angeles, Cal.
04222	Hi-Q Division of Aerovox	Myrtle Beach, S.C.
04354	Precision Paper Tube Co.	Wheeling, Ill.
04404	Palo Alto Division of Hewlett-Packard Co.	Palo Alto, Cal.
04651	Sylvania Electric Products, Microwave Device Div.	Mountain View, Cal.
04673	Dakota Engr. Inc.	Culver City, Cal.
04713	Motorola Inc. Semiconductor Prod. Div.	Phoenix, Arizona
04732	Filtron Co., Inc. Western Div.	Culver City, Cal.
04773	Automatic Electric Co.	Northlake, Ill.
04796	Sequoia Wire Co.	Redwood City, Cal.
04811	Precision Coil Spring Co.	El Monte, Cal.
04870	P. M. Motor Company	Westchester, Ill.
04919	Component Mfg. Service Co.	W. Bridgewater, Mass.
05006	Twentieth Century Plastics, Inc.	Los Angeles, Cal.
05277	Westinghouse Electric Corp. Semiconductor Dept.	Youngwood, Pa.
05347	Ultronix, Inc.	San Mateo, Cal.
05397	Union Carbine Corp., Elect. Div.	New York, N.Y.
05574	Viking Ind. Inc.	Canoga Park, Cal.
05593	Icore Electro-Plastics Inc.	Sunnyvale, Cal.
05616	Cosmo Plastic (c/o Electrical Spec. Co.)	Cleveland, Ohio
05624	Barber Colman Co.	Rockford, Ill.
05728	Tiffen Optical Co.	Roslyn Heights, Long Island, N.Y.
05729	Metro-Tel Corp.	Westbury, N.Y.
05783	Stewart Engineering Co.	Santa Cruz, Cal.
05820	Wakefield Engineering Inc.	Wakefield, Mass.
06004	Bassick Co., Div. of Stewart Warner Corp.	Bridgeport, Conn.
06090	Raychem Corp.	Redwood City, Cal.
06175	Bausch and Lomb Optical Co.	Rochester, N.Y.
06402	E. T. A. Products Co. of America	Chicago, Ill.
06540	Amatom Electronic Hardware Co., Inc.	New Rochelle, N.Y.
06555	Beede Electrical Instrument Co., Inc.	Penacook, N.H.
06666	General Devices Co., Inc.	Indianapolis, Ind.
06751	Components Inc., Ariz. Div.	Phoenix, Arizona
06812	Torrington Mfg. Co., West Div.	Van Nuys, Cal.
06980	Varian Assoc. Etmac Div.	San Carlos, Cal.
07088	Kelvin Electric Co.	Van Nuys, Cal.
07126	Digitran Co.	Pasadena, Cal.
07137	Transistor Electronics Corp.	Minneapolis, Minn.
07138	Westinghouse Electric Corp., Electronic Tube Div.	Elmira, N.Y.
07149	Filmohm Corp.	New York, N.Y.
07233	Cinch-Graphik Co.	City of Industry, Cal.
07256	Silicon Transistor Corp.	Carle Place, N.Y.
07261	Avnet Corp.	Culver City, Cal.
07263	Fairchild Camera & Inst. Corp., Semiconductor Div.	Mountain View, Cal.
07322	Minnesota Rubber Co.	Minneapolis, Minn.
07387	Birtcher Corp, The	Monterey Park, Cal.
07397	Sylvania Elect. Prod. Inc., Mt. View Operations	Mountain View, Cal.
07700	Technical Wire Products Inc.	Cranford, N.J.
07829	Bodine Elect. Co.	Chicago, Ill.
07910	Continental Device Corp.	Hawthorne, Cal.
07933	Raytheon Mfg. Co., Semiconductor Div.	Mountain View, Cal.
07980	Hewlett-Packard Co., New Jersey Division	Rockaway, N.J.
08145	U. S. Engineering Co.	Los Angeles, Cal.
08289	Blinn, Delbert Co.	Pomona, Cal.
08358	Burgess Battery Co.	Niagara Falls, Ontario, Canada
08524	Deutsch Fastener Corp.	Los Angeles, Cal.
08664	Bristol Co., The	Waterbury, Conn.
08717	Sloan Company	Sun Valley, Cal.
08718	ITT Cannon Electric Inc., Phoenix Div.	Phoenix, Arizona
08727	National Radio Lab. Inc.	Paramus, N.J.
08792	CBS Electronics Semiconductor Operations, Div. of CBS Inc	Lowell, Mass.
08806	General Electric Co., Miniature Lamp Dept.	Cleveland, Ohio
08984	Mel-Rain	Indianapolis, Ind.
09026	Babcock Relays Div.	Costa Mesa, Cal.
09097	Electronic Enclosures Inc.	Los Angeles, Calif.
09134	Texas Capacitor Co.	Houston, Texas
09145	Tech. Ind. Inc. Atohm Elect.	Burbank, Cal.
09250	Electro Assemblies, Inc.	Chicago, Ill.
09353	C & K Components Inc.	Newton, Mass.
09569	Mallory Battery Co. of Canada, Ltd.	Toronto, Ontario, Canada
09795	Pennsylvania Florocarbon	Clifton Heights, Penn.
09922	Burndy Corp.	Norwalk, Conn.
10214	General Transistor Western Corp.	Los Angeles, Cal.
10411	Ti-Tal, Inc.	Berkeley, Cal.
10646	Carborundum Co.	Niagara Falls, N.Y.
11236	CTS of Berne, Inc.	Berne, Ind.
11237	Chicago Telephone of California, Inc.	So. Pasadena, Cal.
11242	Bay State Electronics Corp.	Waltham, Mass.
11312	Teledyne Inc., Microwave Div.	Palo Alto, Cal.
11314	National Seal	Downey, Cal.
11453	Precision Connector Corp.	Jamaica, N.Y.
11534	Duncan Electronics Inc.	Costa Mesa, Cal.
11711	General Instrument Corp., Semiconductor Division Products Group	Newark, N.J.
11717	Imperial Electronic, Inc.	Buena Park, Cal.
11870	Melabs, Inc.	Palo Alto, Cal.
12136	Philadelphia Handle Co.	Camden, N.J.
12361	Grove Mfg. Co., Inc.	Shady Grove, Pa.
12574	Gulton Ind. Inc., Data System Div.	Albuquerque, N.M.
12697	Clarostat Mfg. Co.	Dover, N.H.
12728	Elmar Filter Corp	W. Haven, Conn.
12859	Nippon Electric Co., Ltd.	Tokyo, Japan
12881	Metex Electronics Corp.	Clark, N.J.
12930	Delta Semiconductor Inc.	Newport Beach, Cal.
12954	Dickson Electronics Corp.	Scottsdale, Arizona
13019	Airco Supply Co., Inc.	Witchita, Kansas
13061	Wilco Products	Detroit, Mich.
13103	Thermolloy	Dallas, Texas
13327	Solitron Devices Inc.	Tappan, N.Y.
13396	Telefunken (GmbH)	Hanover, Germany
13835	Midland-Wright Div. of Pacific Industries, Inc.	Kansas City, Kansas
14099	Sem-Tech	Newbury Park, Cal.
14193	Calif. Resistor Corp	Santa Monica, Cal.
14298	American Components, Inc.	Conshohocken, Pa.
14433	ITT Semiconductor, a Div. of Int. Telephone and Telegraph Corporation	West Palm Beach, Fla.
14493	Hewlett-Packard Company	Loveland, Colo.
14655	Cornell Dublier Electric Corp	Newark, N.J.
14674	Corning Glass Works	Corning, N.Y.
14752	Electro Cube Inc.	San Gabriel, Cal.
14960	Williams Mfg. Co.	San Jose, Cal.
15106	The Sphere Co., Inc.	Little Falls, N.J.
15203	Webster Electronics Co.	New York, N.Y.
15287	Scionics Corp.	Northridge, Cal.
15291	Adjustable Bushing Co.	N. Hollywood, Cal.
15558	Micron Electronics	Garden City, Long Island, N.Y.
15566	Amprobe Inst. Corp.	Lynbrook, N.Y.
15631	Cabletronics	Costa Mesa, Cal.
15772	Twentieth Century Coil Spring Co.	Santa Clara, Cal.
15801	Fenwal Elect. Inc.	Framingham, Mass.
15818	Amelco Inc	Mountain View, Cal.
16037	Spruce Pine Mica Co.	Spruce Pine, N.C.
16179	Omni-Spectra Inc.	Detroit, Ill.
16352	Computer Diode Corp.	Lodi, N.J.
16554	Electroid Co.	Union, N.J.
16585	Boots Aircraft Nut Corp.	Pasadena, Cal.
16688	Ideal Prec. Meter Co., Inc., De Jur Meter Div.	Brooklyn, N.Y.
16758	Delco Radio Div. of G. M. Corp.	Kokomo, Ind.
17109	Thermonetics Inc.	Canoga Park, Cal.
17474	Tranex Company	Mountain View, Cal.
17675	Hamlin Metal Products Corp.	Akron, Ohio
17745	Angstrohm Prec. Inc.	No. Hollywood, Cal
17856	Siliconix Inc.	Sunnyvale, Cal.
17870	McGraw-Edison Co.	Manchester, N.H.
18042	Power Design Pacific Inc.	Palo Alto, Cal.
18083	Clevite Corp. Semiconductor Div.	Palo Alto, Cal.
18324	Signetics Corp.	Sunnyvale, Cal.
18476	Ty-Car Mfg. Co., Inc.	Holliston, Mass.
18486	TRW Elect. Comp. Div.	Des Plaines, Ill.
18565	Chomerics	Plainville, Mass.
18583	Curtis Instrument, Inc.	Mt. Kisco, N.Y.
18612	Vishay Instruments Inc.	Malvern, Pa.
18873	E.I. DuPont and Co., Inc.	Wilmington, Del.
18911	Durant Mfg. Co.	Milwaukee, Wis.
19315	The Bendix Corp., Navigation & Control Div.	Teterboro, N.J.
19500	Thomas A. Edison Industries, Div. of McGraw-Edison	West Orange, N.J.
19589	Concoa	Baldwin Park, Cal.

00015-49
Revised: May, 1970

From: Handbook Supplements
H4-1 Dated January 1970

CODE LIST OF MANUFACTURERS (Continued)

Code No.	Manufacturer	Address
19644	LRC Electronics	Horseheads, N.Y.
19701	Electra Mfg. Co.	Independence, Kansas
20183	General Atronics Corp.	Philadelphia, Pa.
21226	Executone, Inc.	Long Island City, N.Y.
21355	Fafnir Bearing Co., The	New Britian, Conn.
21520	Fansteel Metallurgical Corp.	N. Chicago, Ill.
23020	General Reed Co.	Metuchen, N.J.
23042	Texscan Corp.	Indianapolis, Ind.
23783	British Radio Electronics Ltd.	Washington, D.C.
24455	G.E. Lamp Division, Nela Park,	Cleveland, Ohio
24655	General Radio Co.	West Concord, Mass.
24681	Memcor Inc., Comp. Div.	Huntington, Ind.
26365	Gries Reproducer Corp.	New Rochelle, N.Y.
26462	Grobert File Co. of America, Inc.	Carlstadt, N.J.
26851	Compac/Hollister Co.	Hollister, Cal.
26992	Hamilton Watch Co.	Lancaster, Pa.
28480	Hewlett-Packard Co.	Palo Alto, Cal.
28520	Heyman Mfg. Co.	Kenilworth, N.J.
30817	Instrument Specialties Co., Inc.	Little Falls, N.J.
33173	G.E. Receiving Tube Dept.	Owensboro, Ky.
35434	Lectrohm Inc.	Chicago, Ill.
36196	Stanwyck Coil Products, Ltd.	Hawkesbury, Ontario, Canada
36287	Cunningham, W.H. & Hill, Ltd.	Toronto, Ontario, Canada
37942	P.R. Mallory & Co., Inc.	Indianapolis, Ind.
39543	Mechanical Industries Prod. Co.	Akron, Ohio
40920	Miniature Precision Bearings, Inc.	Keene, N.H.
40931	Honeywell Inc.	Minneapolis, Minn.
42190	Muter Co.	Chicago, Ill.
43990	C.A. Norgren Co.	Englewood, Colo.
44655	Ohmite Mfg. Co.	Skokie, Ill.
46384	Penn Eng. & Mfg. Corp.	Doylestown, Pa.
47904	Polaroid Corp.	Cambridge, Mass.
48620	Precision Thermometer & Inst. Co.	Southampton, Pa.
49956	Microwave & Power Tube Div.	Waltham, Mass.
52090	Rowan Controller Co.	Westminster, Md.
52983	HP Co., Med. Elec. Div.	Waltham, Mass.
54294	Shallcross Mfg. Co.	Selma, N.C.
55026	Simpson Electric Co.	Chicago, Ill.
55933	Sonotone Corp.	Elmsford, N.Y.
55938	Raytheon Co. Commercial Apparatus & System Div.	So. Norwalk, Conn.
56137	Spaulding Fibre Co., Inc.	Tonawanda, N.Y.
56289	Sprague Electric Co.	North Adams, Mass.
58474	Superior Elect. Co.	Bristol, Conn.
59446	Telex Corp.	Tulsa, Okla.
59730	Thomas & Betts Co.	Elizabeth, N.J.
60741	Triplett Electrical Inst. Co.	Bluffton, Ohio
61775	Union Switch and Signal Div. of Westinghouse Air Brake Co.	Pittsburgh, Pa.
62119	Universal Electric Co.	Owosso, Mich.
63743	Ward-Leonard Electric Co.	Mt. Vernon, N.Y.
64959	Western Electric Co., Inc.	New York, N.Y.
65092	Weston Inst. Inc. Weston-Newark	Newark, N.J.
66295	Wittek Mfg. Co.	Chicago, Ill.
66346	Minnesota Mining & Mfg. Co. Revere Mincom Div.	St. Paul, Minn.
70276	Allen Mfg. Co.	Hartford, Conn.
70309	Allied Control	New York, N.Y.
70318	Allmetal Screw Product Co., Inc.	Garden City, N.Y.
70417	Amplex, Div. of Chrysler Corp.	Detroit, Mich.
70485	Atlantic India Rubber Works, Inc.	Chicago, Ill.
70563	Amperite Co., Inc.	Union City, N.J.
70674	ADC Products Inc.	Minneapolis, Minn.
70903	Belden Mfg. Co.	Chicago, Ill.
70998	Bird Electric Corp.	Cleveland, Ohio
71002	Birnbach Radio Co.	New York, N.Y.
71034	Bliley Electric Co., Inc.	Erie, Pa.
71041	Boston Gear Works Div. of Murray Co. of Texas	Quincey, Mass.
71218	Bud Radio, Inc.	Willoughby, Ohio
71279	Cambridge Thermionics Corp.	Cambridge, Mass.
71286	Camloc Fastener Corp.	Paramus, N.J.
71313	Cardwell Condenser Corp.	Lindenhurst, L.I., N.Y.
71400	Bussmann Mfg. Div. of McGraw-Edison Co.	St. Louis, Mo.
71436	Chicago Condenser Corp.	Chicago, Ill.
71447	Calif. Spring Co., Inc.	Pico-Rivera, Cal.
71450	CTS Corp.	Elkhart, Ind.
71468	ITT Cannon Electric Inc.	Los Angeles, Cal.
71471	Cinema, Div. Aerovox Corp.	Burbank, Cal.
71482	C.P. Clare & Co.	Chicago, Ill.
71590	Centralab Div. of Globe Union Inc.	Milwaukee, Wis.
71616	Commercial Plastics Co.	Chicago, Ill.
71700	Cornish Wire Co., The	New York, N.Y.
71707	Coto Coil Co., Inc.	Providence, R.I.
71744	Chicago Miniature Lamp Works	Chicago, Ill.
71785	Cinch Mfg. Co., Howard B. Jones Div.	Chicago, Ill.
71984	Dow Corning Corp.	Midland, Mich.
72136	Electro Motive Mfg. Co., Inc.	Willimantic, Conn.
72619	Dialight Corp.	Brooklyn, N.Y.
72656	Indiana General Corp., Electronics Div.	Keasby, N.J.
72699	General Instrument Corp., Cap Division	Newark, N.J.
72765	Drake Mfg. Co.	Harwood Heights, Ill.
72825	Hugh H. Eby Inc.	Philadelphia, Pa.
72928	Gudeman Co.	Chicago, Ill.
72962	Elastic Stop Nut Corp.	Union, N.J.
72964	Robert M. Hadley Co.	Los Angeles, Cal.
72982	Erie Technological Products, Inc.	Erie, Pa.
73061	Hansen Mfg. Co., Inc.	Princeton, Ind.
73076	H.M. Harper Co.	Chicago, Ill.
73138	Helipot Div. of Beckman Inst., Inc.	Fullerton, Cal.
73293	Hughes Products Division of Hughes Aircraft Co.	Newport Beach, Cal.
73445	Amperex Elect. Co.	Hicksville, L.I., N.Y.
73506	Bradley Semiconductor Corp.	New Haven, Conn.
73559	Carling Electric, Inc.	Hartford, Conn.
73586	Circle F Mfg. Co.	Trenton, N.J.
73682	George K. Garrett Co., Div. MSL Industries, Inc.	Philadelphia, Pa.
73734	Federal Screw Products, Inc.	Chicago, Ill.
73743	Fischer Special Mfg. Co.	Cincinnati, Ohio
73793	General Industries Co., The	Elyria, Ohio
73846	Goshen Stamping & Tool Co.	Goshen, Ind.
73899	JFD Electronics Corp.	Brooklyn, N.Y.
73905	Jennings Radio Mfg. Corp.	San Jose, Cal.
73957	Groove-Pin Corp.	Ridgefield, N.J.
74276	Signalite Inc.	Neptune, N.J.
74455	J.H. Winns, and Sons	Winchester, Mass.
74861	Industrial Condenser Corp.	Chicago, Ill.
74868	R.F. Products Division of Amphenol-Borg Electronic Corp.	Danbury, Conn.
74970	E.F. Johnson Co.	Waseca, Minn.
75042	International Resistance Co.	Philadelphia, Pa.
75263	Keystone Carbon Co., Inc.	St. Marys, Pa.
75378	CTS Knights, Inc.	Sandwich, Ill.
75382	Kulka Electric Corp.	Mt. Vernon, N.Y.
75818	Lenz Electric Mfg. Co.	Chicago, Ill.
75915	Littlefuse, Inc.	Des Plaines, Ill.
76005	Lord Mfg. Co.	Erie, Pa.
76210	C.W. Marwedel	San Francisco, Cal.
76433	General Instrument Corp., Micamold Division	Newark, N.J.
76487	James Millen Mfg. Co., Inc.	Malden, Mass.
76493	J.W. Miller Co.	Los Angeles, Cal.
76530	Cinch-Monadnock, Div. of United Carr Fastener Corp.	San Leandro, Cal.
76545	Mueller Electric Co.	Cleveland, Ohio
76703	National Union	Newark, N.J.
76854	Oak Manufacturing Co.	Crystal Lake, Ill.
77068	The Bendix Corp., Electrodynamics Div.	N. Hollywood, Cal.
77075	Pacific Metals Co.	San Francisco, Cal.
77221	Phaostran Instrument and Electronic Co.	So. Pasadena, Cal.
77252	Philadelphia Steel and Wire Corp.	Philadelphia, Pa.
77342	American Machine & Foundry Co. Potter & Brumfield Div.	Princeton, Ind.
77630	TRW Electronic Components Div.	Camden, N.J.
77638	General Instrument Corp., Rectifier Division	Brooklyn, N.Y.
77764	Resistance Products Co.	Harrisburg, Pa.
77969	Rubbercraft Corp. of Calif.	Torrance, Cal.
78189	Shakeproof Division of Illinois Tool Works	Elgin, Ill.
78277	Sigma	So. Braintree, Mass.
78283	Signal Indicator Corp.	New York, N.Y.
78290	Struthers-Dunn Inc.	Pitman, N.J.
78452	Thompson-Bremer & Co.	Chicago, Ill
78471	Tilley Mfg. Co.	San Francisco, Cal
78488	Stackpole Carbon Co.	St. Marys, Pa.
78493	Standard Thomson Corp.	Waltham, Mass.
78553	Tinnerman Products, Inc.	Cleveland, Ohio
78790	Transformer Engineers	San Gabriel, Cal.
78947	Ucinite Co.	Newtonville, Mass.
79136	Waldes Kohinoor Inc.	Long Island City, N.Y.
79142	Veeder Root, Inc.	Hartford, Conn.
79251	Wenco Mfg. Co.	Chicago, Ill.
79727	Continental-Wirt Electronics Corp.	Philadelphia, Pa.
79963	Zierick Mfg. Corp.	New Rochelle, N.Y.
80031	Mepco Division of Sessions Clock Co.	Morristown, N.J.
80033	Prestole Corp.	Toledo, Ohio
80120	Schnitzer Alloy Products Co.	Elizabeth, N.J.
80131	Electronic Industries Association. Standard tube or semi-conductor device, any manufacturer.	
80207	Unimax Switch, Div. Maxon Electronics Corp.	Wallingford, Conn.
80223	United Transformer Corp.	New York, N.Y.
80248	Oxford Electric Corp.	Chicago, Ill.
80294	Bourns Inc.	Riverside, Cal.
80411	Arco Div. of Robertshaw Controls Co.	Columbus, Ohio
80486	All Star Products Inc.	Defiance, Ohio
80509	Avery Label Co.	Monrovia, Cal.
80583	Hammarlund Co., Inc.	Mars Hill, N.C.
80640	Stevens, Arnold, Co., Inc.	Boston, Mass.
80813	Dimco Gray Co.	Dayton, Ohio
81030	International Inst. Inc.	Orange, Conn.
81073	Grayhill Co.	LaGrange, Ill.
81095	Triad Transformer Corp.	Venice, Cal.
81312	Winchester Elec. Div. Litton Ind., Inc.	Oakville, Conn.
81349	Military Specification	
81483	International Rectifier Corp.	El Segundo, Cal.
81541	Airpax Electronics, Inc.	Cambridge, Maryland
81860	Barry Controls, Div. Barry Wright Corp.	Watertown, Mass.
82042	Carter Precision Electric Co.	Skokie, Ill.
82047	Sperti Faraday Inc., Copper Hewitt Electric Div.	Hoboken, N.J.
82116	Electric Regulator Corp.	Norwalk, Conn.
82142	Jeffers Electronics Division of Speer Carbon Co.	Du Bois, Pa.
82170	Fairchild Camera & Inst. Corp., Space & Defense Systems Div.	Paramus, N.J.
82209	Magurie Industries, Inc.	Greenwich, Conn.
82219	Sylvania Electric Prod., Inc. Electronic Tube Division	Emporium, Pa.
82376	Astron Corp.	East Newark, Harrison, N.J.
82389	Switchcraft, Inc.	Chicago, Ill.
82647	Metals & Controls Inc., Spencer Products	Attleboro, Mass.
82768	Phillips-Advance Control Co.	Joliet, Ill.
82866	Research Products Corp.	Madison, Wis.
82877	Rolton Mfg. Co., Inc.	Woodstock, N.Y.
82893	Vector Electronic Co.	Glendale, Cal.
83058	Carr Fastener Co.	Cambridge, Mass.
83086	New Hampshire Ball Bearing, Inc.	Peterborough, N.H.
83125	General Instrument Corp., Capacitor Div.	Darlington, S.C.
83148	ITT Wire and Cable Div.	Los Angeles, Cal.
83186	Victory Eng. Corp.	Springfield, N.J.
83298	Bendix Corp., Red Bank Div.	Red Bank, N.J.
83315	Hubbell Corp.	Mundelein, Ill.
83324	Rosan Inc.	Newport Beach, Cal.
83330	Smith, Herman H., Inc.	Brooklyn, N.Y.
83332	Tech Labs	Palisades Park, N.J.
83385	Central Screw Co.	Chicago, Ill.
83501	Gavitt Wire and Cable Co., Div. of Amerace Corp.	Brookfield, Mass.
83594	Burroughs Corp., Electronic Tube Div.	Plainfield, N.J.
83740	Union Carbide Corp., Consumer Prod. Div.	New York, N.Y.
83777	Model Eng. and Mfg., Inc.	Huntington, Ind.
83821	Loyd Scruggs Co.	Festus, Mo.
83942	Aeronautical Inst. & Radio Co.	Lodi, N.J.
84171	Arco Electronics Inc.	Great Neck, N.Y.
84396	A.J. Glesener Co., Inc.	San Francisco, Cal.
84411	TRW Capacitor Div.	Ogallala, Neb.

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Code No.	Manufacturer	Address
94870	Sarkes Tarzian, Inc.	Bloomington, Ind.
85454	Boonton Molding Company	Boonton, N.J.
85471	A.B. Boyd Co.	San Francisco, Cal.
85474	R.M. Bracamonte & Co.	San Francisco, Cal.
85660	Koiled Kords, Inc.	Hamden, Conn.
85911	Seamless Rubber Co.	Chicago, Ill.
86174	Fafnir Bearing Co.	Los Angeles, Calif.
86197	Clifton Precision Products Co., Inc.	Clifton Heights, Pa.
86579	Precision Rubber Products Corp.	Dayton, Ohio
86684	Radio Corp. of America, Electronic Comp. & Devices Division	Harrison, N.J.
86928	Seastrom Mfg. Co.	Glendale, Cal.
87034	Marco Industries	Anaheim, Cal.
87216	Philco Corporation (Lansdale Division)	Lansdale, Pa.
87473	Western Fibrous Glass Products Co.	San Francisco, Cal.
87664	Van Waters & Rogers Inc.	San Francisco, Cal.
87930	Tower Mfg. Corp.	Providence, R.I.
88140	Cutler-Hammer, Inc.	Lincoln, Ill.
88220	Gould-National Batteries, Inc.	St. Paul, Minn.
88698	General Mills, Inc.	Buffalo, N.Y.
89231	Graybar Electric Co.	Oakland, Cal.
89473	G.E. Distributing Corp.	Schenectady, N.Y.
89479	Security Co.	Detroit, Mich.
89665	United Transformer Co.	Chicago, Ill.
90030	United Shoe Machinery Corp.	Beverly, Mass.
90179	U.S. Rubber Co., Consumer Ind. & Plastics Prod. Div.	Passaic, N.J.
90365	Belleville Speciality Tool Mfg., Inc.	Belleville, Ill.
90763	United Carr Fastener Corp.	Chicago, Ill.
90970	Bearing Engineering Co.	San Francisco, Cal.
91146	ITT Cannon Elect. Inc., Salem Div.	Salem, Mass.
91260	Connor Spring Mfg. Co.	San Francisco, Cal.
91345	Miller Dial & Nameplate Co.	El Monte, Cal.
91418	Radio Materials Co.	Chicago, Ill.
91506	Augat Inc.	Attleboro, Mass.
91637	Dale Electronics, Inc.	Columbus, Nebr.
91662	Elco Corp.	Willow Grove, Pa.
91673	Epiphone Inc.	New York, N.Y.
91737	Gremar Mfg. Co., Inc.	Wakefield, Mass.
91827	K F Development Co.	Redwood City, Cal.
91886	Malco Mfg., Inc.	Chicago, Ill.
91929	Honeywell Inc., Micro Switch Division	Freeport, Ill.
91961	Nahm-Bros. Spring Co.	Oakland, Cal.
92180	Tru-Connector Corp.	Peabody, Mass.
92367	Elgeet Optical Co., Inc.	Rochester, N.Y.
92607	Tensolite Insulated Wire Co., Inc.	Tarrytown, N.Y.
92702	IMC Magnetics Corp.	Westbury, L.I., N.Y.
92966	Hudson Lamp Co.	Kearney, N.J.
93332	Sylvania Electric Prod. Inc., Semiconductor Div.	Woburn, Mass.
93369	Robbins & Myers Inc.	Pallisades Park, N.J.
93410	Stemco Controls, Div. of Essex Wire Corp.	Mansfield, Ohio
93632	Waters Mfg. Co.	Culver City, Cal.
93929	G.V. Controls	Livingston, N.J.
94137	General Cable Corp.	Bayonne, N.J.
94144	Raytheon Co., Comp. Div., Ind. Comp. Operations	Quincy, Mass.
94148	Scientific Electronics Products, Inc.	Loveland, Colo.
94154	Wagner Elect. Corp., Tung-Sol Div.	Newark, N.J.
94197	Curtiss-Wright Corp., Electronics Div.	East Patterson, N.J.
94222	South Chester Corp.	Chester, Pa.
94330	Wire Cloth Products, Inc.	Bellwood, Ill.
94375	Automatic Metal Products Co.	Brooklyn, N.Y.
94682	Worcester Pressed Aluminum Corp.	Worcester, Mass.
94696	Magnecraft Electric Co.	Chicago, Ill.
95023	George A. Philbrick Researchers, Inc.	Boston, Mass.
95146	Alco Elect. Mfg. Co.	Lawrence, Mass.
95236	Allies Products Corp.	Diania, Fla.
95238	Continental Connector Corp.	Woodside, N.Y.
95263	Leecraft Mfg. Co., Inc.	Long Island, N.Y.
95265	National Coil Co.	Sheridan, Wyo.
95275	Vitramon, Inc.	Bridgeport, Conn.
95348	Gordos Corp.	Bloomfield, N.J.
95354	Methode Mfg. Co.	Rolling Meadows, Ill.
95566	Arnold Engineering Co.	Marengo, Ill.
95712	Dage Electric Co., Inc.	Franklin, Ind.
95984	Siemon Mfg. Co.	Wayne, Ill.
95987	Weckesser Co.	Chicago, Ill.
96067	Microwave Assoc., West. Inc.	Sunnyvale, Cal.
96095	Hi-Q Div. of Aerovox Corp.	Olean, N.Y.
96256	Thordarson-Meissner Inc.	Mt. Carmel, Ill.
96296	Solar Mfg. Co.	Los Angeles, Cal.
96396	Microswitch, Div. of Minn.-Honeywell	Freeport, Ill.
96330	Carlton Screw Co.	Chicago, Ill.
96341	Microwave Associates, Inc.	Burlington, Mass.
96501	Excel Transformer Co.	Oakland, Cal.
96508	Xcelite, Inc.	Orchard Park, N.Y.
96733	San Fernando Elec. Mfg. Co.	San Fernando, Cal.
96881	Thomson Ind. Inc.	Long Island, N.Y.
97464	Industrial Retaining Ring Co.	Irvington, N.J.
97539	Automatic & Precision Mfg.	Englewood, N.J.
97979	Reon Resistor Corp.	Yonkers, N.Y.
97983	Litton System Inc., Adler-Westrex Commun. Div.	New Rochelle, N.Y.
98141	R-Tronics, Inc.	Jamaica, N.Y.
98159	Rubber Teck, Inc.	Gardena, Cal.
98220	Hewlett-Packard Co., Medical Elec. Div.	Pasadena, Cal.
98278	Microdot, Inc.	So. Pasadena, Cal.
98291	Sealectro Corp.	Mamaroneck, N.Y.
98376	Zero Mfg. Co.	Burbank, Cal.
98410	Etc Inc.	Cleveland, Ohio
98731	General Mills Inc., Electronics Div.	Minneapolis, Minn.
98734	Paeco Division of Hewlett-Packard Co.	Palo Alto, Cal.
98821	North Hills Electronics, Inc.	Glen Cove, N.Y.
98978	International Electronic Research Corp.	Burbank, Cal.
99109	Columbia Technical Corp.	New York, N.Y.
99313	Varian Associates	Palo Alto, Cal.
99378	Atlee Corp.	Winchester, Mass.
99515	Marshall Ind., Capacitor Div.	Monrovia, Cal.
99707	Control Switch Division, Controls Co. of America	El Segundo, Cal.
99800	Delevan Electronics Corp.	East Aurora, N.Y.
99848	Wilco Corporation	Indianapolis, Ind.
99928	Branson Corp.	Whippany, N.J.
99934	Rembrandt, Inc.	Boston, Mass.
99942	Hoffman Electronics Corp., Semiconductor Division	El Monte, Cal.
99957	Technology-Instrument Corp. of California	Newbury Park, Cal.

The following HP Vendors have no number assigned in the latest supplement to the Federal Supply Code for Manufacturers Handbook.

Code No.	Manufacturer	Address
0000F	Malco Tool and Die	Los Angeles, Calif.
0000Z	Willow Leather Products Corp.	Newark, N.J.
000AB	ETA	England
000BB	Precision Instrument Comp. Co.	Van Nuys, Cal.
000CS	Hewlett-Packard Co., Colorado Springs Div.	Colorado Springs, Colorado
000MM	Rubber Eng. & Development	Hayward, Cal.
000NN	A "N" D Mfg. Co.	San Jose, Cal.
000QQ	Cooltron	Oakland, Cal.
000WW	California Eastern Lab	Burlington, Cal.
000YY	S.K. Smith Co.	Los Angeles, Cal.

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ELECTRONIC

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Tel: (602) 244-1361
TWX 910-951-1330

5737 East Broadway
Tucson 85711
Tel (602) 298-2313
TWX 910-952-1162

(Effective Dec 15, 1973)
2424 East Aragon Rd
Tucson 85706
Tel (602) 889-4661

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1430 East Orangethorpe Ave
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Tel (714) 870-1000
TWX 910-592-1288

3939 Lankershim Boulevard
North Hollywood 91604
Tel (213) 877-1282
TWX 910-499-2170

6305 Arizona Place
Los Angeles 90045
Tel (213) 649-2511
TWX 910-328-6148

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Tel (415) 327-6500
TWX 910-373 1280

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P.O Box 23333
San Diego 92123
Tel. (714) 279 3200
TWX 910-335-2000

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Tel (303) 771-3455
TWX 910-935 0705

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12 Lunar Drive
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TWX 710-465-2029

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2806 W. Oakland Park Blvd
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TWX 510-955-4099

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6177 Lake Ellenor Dr
Orlando, 32809
Tel (305) 859-2900
TWX 810-850-0113

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450 Interstate North
Atlanta 30328
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TWX 810 766-4890

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Honolulu 96814
Tel (808) 955 4455

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Skokie 60076
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TWX 910 223-3613

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3839 Meadows Drive
Indianapolis 46205
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TWX 810-341-3263

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TWX 810-955-5524

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Baltimore 21207
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TWX 710-862-9157

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2 Choke Cherry Road
Rockville 20850
Tel (301) 948-6370
TWX 710-828-9684

MASSACHUSETTS
32 Hartwell Ave
Lexington 02173
Tel (617 861-8960
TWX 710-326 6904

MICHIGAN
23855 Research Drive
Farmington 48024
Tel (313) 476-6400
TWX 810-242-2900

MINNESOTA
2459 University Avenue
St. Paul 55114
Tel (612) 645-9461
TWX 910-563-3734

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11131 Colorado Ave
Kansas City 64137
Tel: (816) 763-8000
TWX 910-771-2087

148 Weldon Parkway
Maryland Heights 63043
Tel (314) 567-1455
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TWX 710-892-4945

W 120 Century Rd.
Paramus 07652
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TWX 710-990-4951

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P.O. Box 8366
Station C
6501 Lomas Boulevard N.E
Albuquerque 87108
Tel (505) 265-3713
TWX 910-989-1665

156 Wyatt Drive
Las Cruces 88001
Tel (505) 526-2485
TWX 910-983-0550

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6 Automation Lane
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Tel (518) 458-1550
TWX 710-441-8270

1219 Campville Road
Endicott 13760
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TWX 510 252-0890

New York City
Manhattan, Bronx
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Brooklyn, Queens, Richmond
Contact Woodbury, NY Office
Tel: (516) 921-0300

82 Washington Street
Poughkeepsie 12601
Tel (914) 454-7330
TWX 510-248-0012

39 Saginaw Drive
Rochester 14623
Tel (716) 473-9500
TWX 510-253-5981

5858 East Molloy Road
Syracuse 13211
Tel: (315) 454 2486
TWX 710 541-0482

1 Crossways Park West
Woodbury 11797
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TWX 510-221-2168

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P O. Box 5188
1923 North Main Street
High Point 27262
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TWX 510-926-1516

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25575 Center Ridge Road
Cleveland 44145
Tel (216) 835-0300
TWX 810-427-9129

330 Progress Rd
Dayton 45449
Tel (513) 859-8202
TWX 810-459-1925

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Columbus 43229
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OKLAHOMA
P O. Box 32008
Oklahoma City 73132
Tel (405) 721-0200
TWX 910-830-6862

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17890 SW Boones Ferry Road
Tualatin 97062
Tel (503) 620-3350
TWX 910-467-8714

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2500 Moss Side Boulevard
Monroeville 15146
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TWX 710-797-3650

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King of Prussia 19406
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TWX 510-660-2670

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MANUAL BACKDATING CHANGES

Model 654A

TEST OSCILLATOR

Serials Prefixed: 0951A-

This manual backdating sheet makes this manual applicable to earlier instruments. Instrument-component values that differ from those in the manual, yet are not listed in the backdating sheet, should be replaced using the part number given in the manual.

Instrument Serial Prefix	Make Manual Changes	Instrument Serial Prefix	Make Manual Changes
907-00200 and below	1		
951-00340 and below	1, 2		
0951A00755 and below	1, 2, 3		

CHANGE NO. 1
Table 6-1: Change A2R11 to R: fxd, 10 kΩ ± 1%, 1/8 W, -hp- Part No. 0757-0442.

Change A2R12 to R: fxd, 4.02 kΩ ± 1%, 1/8 W, -hp- Part No. 0698-3558.

Figure 7-2: Change the value of A2R11 to 10 kΩ and the value of A2R12 to 4.02 kΩ.

CHANGE NO. 2
Table 6-1: Change the -hp- Part No. of J1 to 1251-0148
Change the -hp- Part No. of W1 to 8120-0078.
Change the -hp- Part No. of Panel: rear to 00653-00202 (Mechanical Parts).
Change the -hp- Part No. of MP17 to 00653-01204.
Delete MP50, Bracket: Attenuator -hp- Part No. 00653-01206.

CHANGE NO. 3
Change the -hp- Part No. of T1 to 9100-0294.

HEWLETT PACKARD