

# TM 9-6625-2469-15

DEPARTMENT OF THE ARMY TECHNICAL MANUAL

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OPERATOR'S, ORGANIZATIONAL, DIRECT SUPPORT,

GENERAL SUPPORT AND DEPOT MAINTENANCE

MANUAL [INCLUDING REPAIR PARTS]

**POWER METER** [HEWLETT-PACKARD MODEL 432A]

[ 4 9 3 1 - 4 3 6 - 4 8 8 3 ]

**THERMISTOR MOUNT**

[HEWLETT-PACKARD MODEL 478A]

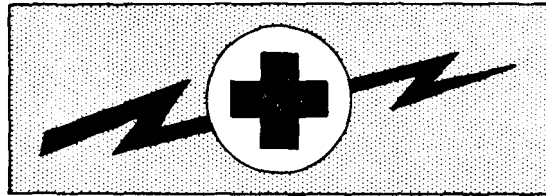
[6625-866-1955]

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HEADQUARTERS, DEPARTMENT OF THE ARMY

DECEMBER 1969



WE 20780

**WARNING**  
**HIGH VOLTAGE**

is used in the operation of this equipment.

**DEATH ON CONTACT**

may result if personnel fail to observe safety precautions.

Learn the areas containing high voltage  
in each piece of equipment.

Be careful not to contact high-voltage or 115-volt ac input connections  
when installing or operating this equipment.

Before working inside the equipment, turn power off and ground points of  
high potential before touching them.

# **POWER METER 432A**

## **SERIAL PREFIX: 914-**

This manual applies directly to HP Model 432A Power Meters having serial prefix number 914.

## **SERIAL PREFIXES NOT LISTED**

For serial prefixes above 914, a "Manual Changes" sheet is included with this manual. For HP Model 432A with serial prefix below 914 refer to Appendix A.

(This manual contains copyright material.)

TM 9-6625-2469-15

TECHNICAL MANUAL )  
)  
No. 9-6625-2469-15)

HEADQUARTERS  
DEPARTMENT OF THE ARMY  
Washington, D.C. 22 December 1969

POWER METER (HEWLETT-PACKARD MODEL 432A)

(4931-436-4883)

THERMISTOR Mount (HEWLETT-PACKARD MODEL 478A)

(6625-866-1955)

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## THERMISTOR MOUNT 478A

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Figure 1-1. HP Model 432A POWER METER

## SECTION I

### GENERAL INFORMATION

#### 1-1. DESCRIPTION.

1-2. The Hewlett-Packard Model 432A Power Meter, with HPtemperature -compensated thermistor mounts, measures RF power from 10 microwatt (-20 dBm) to 10 milliwatts (+10dBm) full scale with 1% of full scale accuracy from 10 MHz to 40 GHz. With a selector switch, the instrument normalizes the power meter reading to compensate for the Calibration Factor of a thermistor mount used for a given measurement. For portable operation, Option 01 instruments have a rechargeable nickel-cadmium battery. See Table 1-1 for complete specifications.

1-3. The Model 432A has provision for dc substitution measurements and for power meter calibration. An output is provided for recorders or digital voltmeter readout.

1-4. Accessories, Two accessories are supplied with the Model 432A Power Meter: a 7.5-foot (2290 mm) detachable power cable and a 5-foot (1520 mm) cable that connects the thermistor mount to the meter. Thermistor mounts are available but not supplied with the power meter (refer to Table 1-2). Table 1-1 lists those accessories supplied and also those available.

#### 1-5. INSTRUMENT IDENTIFICATION.

1-6. Hewlett-Packard instruments are identified by an 8-digit serial number. The first three digits are the Serial Prefix. To properly match a manual with the instrument to which it applies, the prefix on the instrument must be the same as the prefix at the front of the manual. If the numbers are different, information is supplied either on yellow Manual Change Supplements, or in an Appendix in the Manual. If the change information is missing, contact your HP Sales Office (Sales Offices are listed at the back of the Manual).

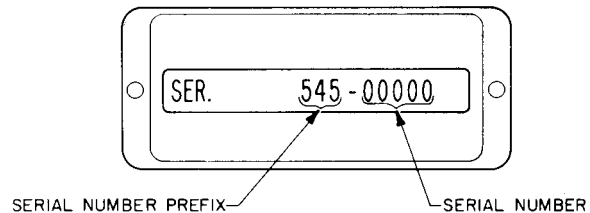


Figure 1-2. Instrument Identification

Table 1-1. Specifications

|                                                                                                                                                                          |                                                                                                                                                                       |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Instrument Type: Automatic, self -balancing power meterforuse with temperature -compensated thermistor mount.                                                            | Zero Carryover: Less than +0.5% of full scale when zeroed on most sensitive range.                                                                                    |
| Power Range: 7 ranges with full-scale readings of 10, 30, 100, and 300 $\mu$ W, 1, 3 and 10 mW; also calibrated in dBm from -20 dBm to +10 dBm full scale in 5-dB steps. | Fine Zero: Automatic, operated by toggle switch.                                                                                                                      |
| Accuracy: $\pm 1\%$ of full scale on all ranges (+0°C, to +55°C).                                                                                                        | Recorder Output: 1.000 volt into open circuit corresponds to full-scale meter deflection (1.0 on O, -1 scale) +0.5%; 1000-ohm output impedance, BNC connector.        |
| Calibration Factor Control: 13-position switch normalizes meter reading to account for thermistor mount Calibration Factor.<br>Range: 100% to 88% in 1% steps.           | RFI: Meets all conditions specified in MIL-I-6181D.                                                                                                                   |
| Thermistor Mount: External temperature -compensated thermistor mounts required for operation (see Table 1-2).                                                            | Power: 115 or 230 Vac $\pm 10\%$ , 50 to 400 Hz, 2-1/2 watts. Optional rechargeable battery provides up to 20 hours continuous operation. Automatic battery recharge. |
| Meter: Taut -band suspension, individually computer-calibrated, mirror-backed scales. Mini -watt scale more than 4-1/4 inches (108 mm) long.                             | Weight: Net 6-1/2lb(3kg), shipping 9-1/4lb(4.2kg).                                                                                                                    |
|                                                                                                                                                                          | Weight with Optional Battery Pack: Net 9-1/4 lb (4.2 kg), shipping 12 lb (5.5 kg).                                                                                    |

Table 1-1. Specifications (Cont.)

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p><b>Dimensions:</b></p> <p><b>NOTE</b><br/> DIMENSIONS IN INCHES AND (MILLIMETERS)<br/> (A) FOR TOTAL LENGTH INCLUDING KNOBS<br/> ADD 1/8 IN. (25 MM)<br/> (B) FOR HEIGHT INCLUDING FEET<br/> ADD 7/16 IN. (11 MM)</p> <p><b>Accessories Furnished:</b> 5-ft (1,42 m) cable for HP temperature compensated thermistor mounts; 7-1/2 ft (2,29 m) power cable, NEMA plug.</p> <p><b>Accessories Available:</b></p> <p>00415-606 Rechargeable Battery Pack for field installation.</p> <p>5060-0797 Rack Adapter Frame (holds three instruments the size of the 432A).</p> <p>8477A Power Meter Calibrator.</p> <p>11076A Carrying Case.</p> | <p><b>Combining Cases:</b></p> <p>1051A, 11-1 4 in. (286 mm) deep.<br/> 1052A, 16-3 8 in. (416 mm) deep.</p> <p>The combining cases accept the 1 3-module HP instruments for bench use or rack mounting. See 1051A data sheet for details.</p> <p><b>Options:</b></p> <p>01: Rechargeable battery installed, provides up to 24 hours continuous operation.</p> <p>02: Rear thermistor mount input connector wired in parallel with front panel input connector.</p> <p>03: Input connector placed on rear panel instead of front.</p> <p><b>Note</b></p> <p>Thermistor mount cable impedance is part of the 432A input bridge circuit. For cables over 20 feet long the bridge is matched to specific cable options, so the various cables should not be interchanged.</p> <p>09: 10-foot (3,05 m) cable for 100-ohm or 200-ohm mount.</p> <p>10: 20-foot (6,10 m) cable for 100-ohm or 200-ohm mount.</p> <p>11: 50-foot (15,24 m) cable for 100-ohm or 200-ohm mount.</p> <p>12: 100-foot (30,48 m) cable for 100-ohm or 200-ohm mount.</p> <p>13: 200-foot (60,96 m) cable for 100-ohm or 200-ohm mount.</p> |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

Table 1-2. Thermistor Mounts for the 432A

| HP Model                                   | Frequency Range (GHz) | Operating Resistance (Ohms) |
|--------------------------------------------|-----------------------|-----------------------------|
| <b>COAXIAL MOUNTS:</b>                     |                       |                             |
| 478A (Type N Connector)                    | 0.01-10               | 200                         |
| 8478B (Type N Connector)                   | 0.01-18               | 200                         |
| 8478B-Option 11 (APC-7 Connector)          | 0.01-18               | 200                         |
| <b>WAVEGUIDE MOUNTS:</b>                   |                       |                             |
| S486A                                      | 2.6-3.95              | 100                         |
| G486A                                      | 3.95-5.85             | 100                         |
| J486A                                      | 5.3-8.2               | 100                         |
| H486A                                      | 7.05-10               | 100                         |
| X486A                                      | 8.2-12.4              | 100                         |
| M486A                                      | 10-15                 | 100                         |
| P486A                                      | 12.4-18               | 100                         |
| K486A                                      | 18-26.5               | 200                         |
| R486A                                      | 26.5-40               | 200                         |
| <b>WAVEGUIDE MOUNT ACCESSORIES:</b>        |                       |                             |
| 11515A: Circular Flange Adapter for K486A. |                       |                             |
| 11516A: Circular Flange Adapter for R486A. |                       |                             |

## SECTION II

### INSTALLATION

#### 2-1. INITIAL INSPECTION.

#### 2-2. MECHANICAL CHECK.

2-3. If damage to the shipping carton is evident, ask that the carrier's agent be present when the instrument is unpacked. Inspect the instrument for mechanical damage. Also check the cushioning material for signs of severe stress.

#### 2-4. PERFORMANCE CHECKS.

2-5. The electrical performance of the Model 432A should be verified upon receipt. Performance checks suitable for incoming inspection are given in Section V, Maintenance.

#### 2-6. DAMAGE CLAIMS.

2-7. If the instrument is mechanically damaged in transit, notify the carrier and the nearest Hewlett-Packard field office immediately. A list of field offices is at the back of this manual. Retain the shipping carton and padding material for the carrier's inspection. The field office will arrange for replacement or repair of your instrument without waiting for claim settlements against the carrier.

2-8. Before shipment this instrument was inspected and found free of mechanical and electrical defects. If there is any deficiency, or if electrical performance is not within specifications, notify your nearest Hewlett-Packard Sales and Service Office.

#### 2-9. THREE-CONDUCTOR POWER CABLE.

2-10. 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 cable which, when plugged into an appropriate receptacle, grounds the instrument. The offset pin on the power cable three-prong connector is the ground wire.

2-11. To preserve the protection feature when operating the instrument from a two-connector outlet, use a three-prong to two-prong adapter and connect the green pigtail on the adapter to ground.

#### 2-12. PRIMARY POWER REQUIREMENTS.

2-13. The Model 432A operates from 115 or 230 volts ac line voltage. Line frequency may vary from 50 to 400 Hz. A slide switch on the rear panel is moved to the correct position for the line voltage available. Before operating the equipment, ensure that the fuse installed in the instrument corresponds to the value marked on the panel for the line voltage available (1/8 amp slow-blow).

#### 2-14. INTERNAL BATTERY OPERATION.

2-15. Model 432A Option 01 instruments contain an internal battery and a battery charging assembly. By connecting the 432A to an ac source, the battery may be charged overnight. The battery can be maintained in the charging state indefinitely without damage. It will assume its full capacity, 1.25 ampere-hours, and will not charge in excess of that. This enables the instrument to operate for approximately 20 hours continuously without recharging.

#### 2-16. BATTERY INSTALLATION.

a. Set power switch to off and remove power plug from rear panel,

b. Remove top and bottom, and side instrument covers.

c. The battery is installed with the terminals toward the right hand side of the instrument when faced from the front. The two terminals on the battery fit into spaces provided on the circuit board.

d. Using the retaining nuts, fasten the battery firmly in place. Be careful not to short the battery terminals at any time as this may cause battery cell damage.

e. Install Assembly A7, battery charging board, in the space provided for it just ahead of the battery.

f. Reinstall instrument covers and adjust circuit. Instrument is now ready for operation.

#### 2-17. BATTERY STORAGE.

2-18. Store the battery at or below room temperature. Extended storage at high temperature will reduce the cell charge, but will not damage the battery if the storage temperature is below 140° F. Install the battery in the instrument and recharge before using Model 432A in battery operation.

#### 2-19. RACK MOUNTING.

2-20. Model 432A is narrower than full-rack width. It is what is termed a sub-modular unit. When used alone, the instrument can be bench mounted. When used in combination with other sub-modular units it may be bench or rack mounted. The HP 1051A and 1052A Combining Cases and Rack Adapter Frames are designed specifically for this purpose.

#### 2-21. COMBINING CASE.

2-22. A model 1051A Combining Case is shown in Figure 2-1. This case is full rack width and accepts varying combinations of submodular instruments. The case, purchased separately, is provided with a rack mounting kit. The combining case will hold three

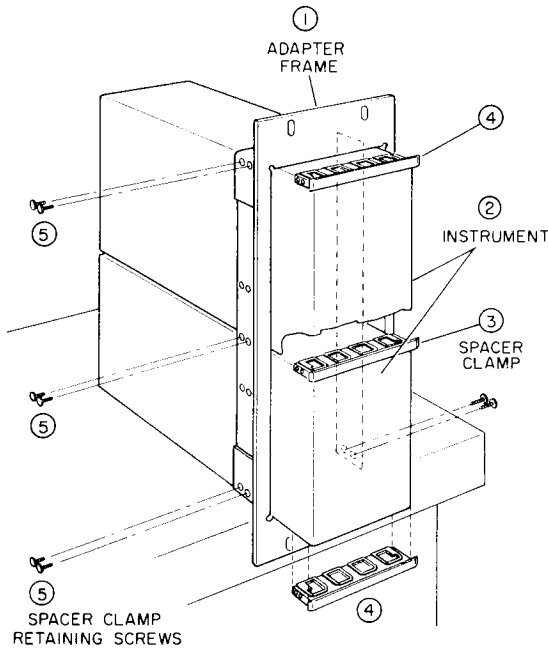


Figure 2-1. Sub -module Installation in Rack Adapter Frame

instruments the same size as the Model 432A. When instruments are installed in the combining case, they may be installed or removed individually.

## 2-23. ADAPTER FRAMES.

2-24. The 5060-0797 Adapter Frame is shown in Figure 2-2. The frame will accept a variety of submod - ular units in a manner suitable for rack mounting. Submodular units, in combination with any necessary spacers are assembled within the frame. A submod - ular unit cannot be removed individually.

## 2-25. REPACKING FOR SHIPMENT.

2-26. When returning an instrument to Hewlett-Packard use the original packing material. If the orig - inal foam type packing material is not available, contact an authorized HP Sales Office for assistance. If this is not possible, first protect the instrument sur - faces by wrapping in heavy kraft paper or with sheets of cardboard flat against the instrument. Protect the instrument on all s i d e s using approximately 4" of packing material and pack in a durable container. Mark the container clearly for proper handling and insure adequately before shipping.

2-27. When an instrument is returned to HP for serv - ice or repair, attach atagtothe instrument specifying the owner and desired action. All correspondence should identify the instrument by model number and full eight -digit serial number.

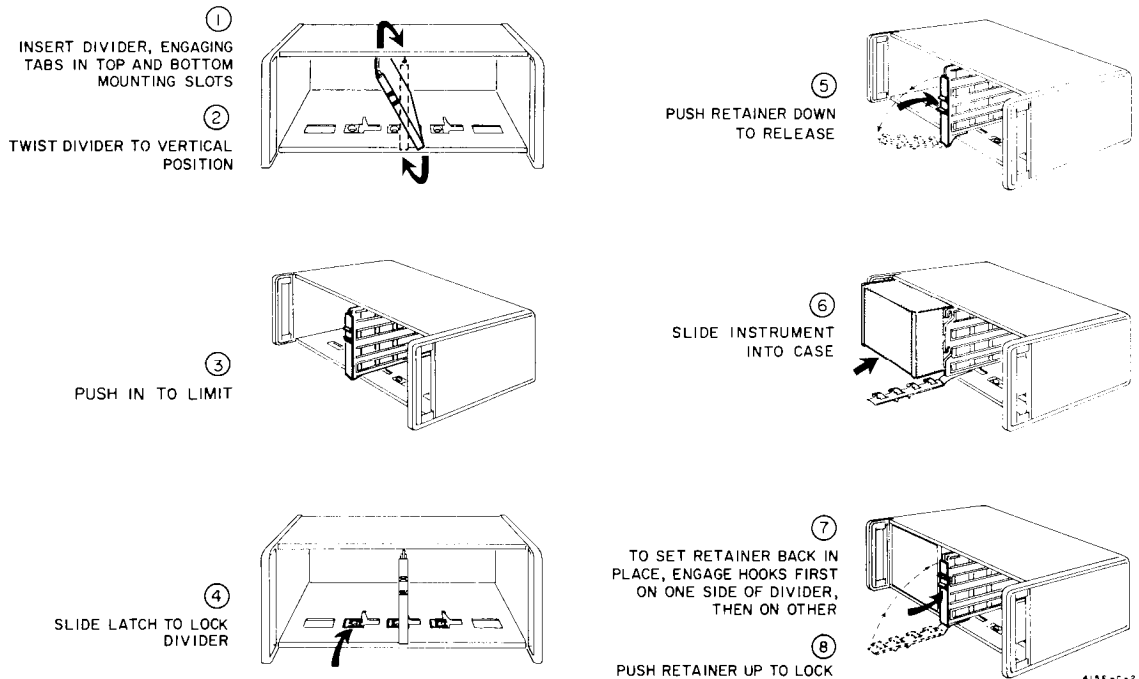


Figure 2-2. HP Model 1051A Combining Case Instrument Installation

## SECTION III

## OPERATING INFORMATION

**3-1. INTRODUCTION.**

3-2. The Model 432A Power Meter operates with HP temperature-compensated thermistor mounts such as the 8478B and 478A Coaxial, and 486A Waveguide series. The frequency range of the 432A with these mounts in 50-ohm coaxial systems is 10 MHz to 18 GHz; in waveguide systems it is 2.6 GHz to 40 GHz. Full-scale power ranges are 10 microwatts to 10 milliwatts (-20 dBm to +10 dBm). Extended measurements may be made to 1 microwatt (-30 dBm). The total measurement capacity of the instrument is divided into seven ranges, selected by a front-panel RANGE switch.

3-3. This section describes general operating procedures and error analysis in microwave power measurement. Application Note 64, available on request from Hewlett-Packard, is a detailed analysis of microwave power measurement problems and techniques.

**3-4. CONTROLS, CONNECTORS, AND INDICATORS.**

3-5. The front and rear panel controls, connectors, and indicators are explained in Figure 3-2. The descriptions are keyed to the corresponding items which are indicated on the figure.

3-6. The COARSE ZERO and FINE ZERO controls zero the meter. Zero carry-over from the most sensitive range to the other six ranges is within  $\pm 0.5\%$ . When the RANGE switch is set to COARSE ZERO, the meter indicates thermistor bridge unbalance, and the front panel COARSE ZERO adjust is for initial bridge balance. For best results, FINE ZERO the 432A on the particular meter range in use.

3-7. The CALIBRATION FACTOR switch provides discrete amounts of compensation for measurement uncertainties related to SWR and thermistor mount efficiency. The Calibration Factor value permits direct meter reading of the RF power delivered to an impedance equal to the characteristic impedance ( $Z_0$ ) of the transmission line between the thermistor mount and the RF source. Calibration Factor values are marked on the label of each 8478B, 478A, or 486A Thermistor Mount. For further details, see Paragraph 3-23.

3-8. The MOUNT RESISTANCE switch on the front panel compensates for three types of thermistor mounts. Model 486A waveguide mounts can be used by setting the MOUNT RESISTANCE switch to 100 $\Omega$  or 200 $\Omega$ , depending on the thermistor mount used (refer to Table 1-2). The 200 $\Omega$  position is used with Models 478A and 8478B Thermistor Mounts.

3-9. The rear-panel BNC connector labeled RE-CORDER provides an output voltage linearly proportional to the meter current; 1 volt into an open cir-

cuit equals full-scale meter deflection. This voltage is developed across a 1K resistor; therefore, when a recorder with a 1K input impedance is connected to the RE-CORDER output, approximately .5 volts will equal full scale deflection. This loading of the RE-CORDER output has no effect on the accuracy of the 432A panel meter.

3-10. A digital voltmeter can be connected to the rear-panel RE-CORDER output for more resolution of power meter readings. When a voltmeter with input impedance greater than 1 megohm is connected to the RE-CORDER output, 1 volt equals full scale deflection.

3-11. The 432A has two calibration jacks (V<sub>RF</sub> and v<sub>comp</sub>) on the rear panel that can be used for precision power measurements. Instrument error can be reduced from  $\pm 1\%$  ( $\pm 0.2\%$  of reading  $+5\mu\text{W}$ ) of reading, depending on the care taken in measurement, and on the accuracy of auxiliary equipment. For further information, see Paragraph 3-27.

**3-12. BATTERY OPERATION,**

3-13. The Model 432A Option 01 operates from battery and conventional 115- or 230-volt line power. A rechargeable Nickel-Cadmium battery is factory-installed in Option 01 instruments. The same battery can be ordered and later installed in the basic instrument, thereby modifying the power meter to the Option 01 configuration. The battery installation kit (including battery charging circuit) may be ordered from the nearest HP Sales Office.

3-14. It is recommended that the Model 432A be battery-operated for up to 8 hours, and then allowed to recharge 8 hours, or overnight. Continuous battery operation is possible for up to about 24 hours, but then the battery must be recharged for about 24 hours.

3-15. The 432A automatically operates on its internal batteries whenever the ac line power is disconnected and the POWER switch is ON. When the battery terminal voltage decreases far enough to force the power supply voltage regulator out of regulation, then the meter stops working and the meter indicator points to the red RECHG BAT. To recharge the battery, simply connect the 432A to ac line power, and turn it ON.

3-16. Battery Storage. Storage of the battery at or below room temperature is best. Extended storage at temperatures above room temperature will reduce cell charge, but will not damage the battery; however, the battery should not be stored where the temperature exceeds 60°C (+140°F).

### 3-17. MICROWAVE POWER MEASUREMENT ACCURACY.

3-18. A number of factors affect the overall accuracy of power measurement. The major sources of error are mismatch error, RF losses, and instrumentation error.

3-19. Mismatch Error. In a practical measurement situation, both the source and thermistor mount have SWR, and the source is seldom matched to the thermistor mount unless a tuner is used. The amount of mismatch loss in any measurement depends on the total SWR present. The impedance that the source sees is determined by the actual thermistor mount impedance, the electrical length of the line, and the characteristic impedance of the line,  $Z_0$ .

3-20. In general, neither the source nor the thermistor mount has  $Z_0$  impedance, and the actual impedances are known only as reflection coefficients, mismatch losses, or SWR. The power delivered to the thermistor mount - and hence the mismatch loss - can only be described as being somewhere between two limits. The uncertainty of power measurement due to mismatch loss increases with SWR. Limits of mismatch loss are generally determined by means of a chart such as the Mismatch Loss Limits charts in Application Note 64. The total mismatch loss uncertainty in power measurement is determined by algebraically adding the thermistor mount losses to the uncertainty caused by source and thermistor mount mismatch.

3-21. RF Losses. RF losses account for the power entering the thermistor mount but not dissipated in the detection thermistor element. Such losses may be in the walls of a waveguide mount, the center conductor of a coaxial mount, capacitor dielectric, poor connections within the mount, or due to radiation.

3-22. Instrumentation Error. The degree of inability of the instrument to measure the substitution power supplied to the thermistor mount is called power meter accuracy or instrumentation error. Instrumentation error of the Model 432A is  $\pm 1\%$  of full scale,  $0^\circ\text{C}$  to  $+55^\circ\text{C}$ .

### 3-23. CALIBRATION FACTOR AND EFFECTIVE EFFICIENCY.

3-24. Calibration factor and effective efficiency are correction factors for improving power measurement accuracy. Both factors are marked on every HP thermistor mount. Calibration factor compensates for thermistor mount VSWR and RF losses whenever the thermistor mount is connected to an RF source without a tuner. Effective efficiency compensates for thermistor mount RF losses when a tuner is used in the measurement system.

3-25. When the 432A CALIBRATION FACTOR selector is set to the appropriate factor indicated on the thermistor mount, the power indicated by the meter is the power that would be delivered by the source to

a load impedance equal to  $Z_0$ . More accurately, the relationship between indicated power and the power available to a  $Z_0$  load is given by the following equation:

$$P_o = \frac{P_{\text{indicated}} (1 \pm \rho_s \rho_m)^2}{\text{Calibration Factor}}$$

where

$P_o$  = power available to a  $Z_0$  load

$\rho_s$  = source reflection coefficient

$\rho_m$  = thermistor mount reflection coefficient

$$\rho = \frac{\text{SWR} - 1}{\text{SWR} + 1}$$

Calibration factor does not compensate for source VSWR, or for multiple reflections between the source and the thermistor mount.

3-26. To minimize mismatch between the source and the thermistor mount without a tuner, insert a low SWR precision attenuator in the transmission line between the thermistor mount and the source. Since the mount impedance (and corresponding SWR) deviates significantly only at the high and low ends of a microwave band, it is generally unnecessary to use a tuner. A tuner or other effective means of reducing mismatch error is recommended when the source SWR is high or when more accuracy is required. For further details, there is a complete discussion of microwave power measurement with emphasis on modern techniques, accuracy considerations and sources of error available in Application Note 64.

### 3-27. PRECISION POWER MEASUREMENT.

#### 3-28. GENERAL.

3-29. Using precision instruments and careful procedures, measurement error can be reduced to  $\pm 0.2\%$  of reading  $+0.5 \mu\text{W}$ . The technique involves: 1) zeroing the bridge circuits and measuring the bridge amplifier output voltage difference with a digital voltmeter, then 2) connecting RF power to the thermistor mount and then measuring the bridge amplifier output voltage difference again, and 3) calculating the power from the two measurements. Figure 3-1 shows the instrument setup for dc substitution measurement. Use an HP Model 3440A DVM, with a 3443A Plug-in Unit or a digital voltmeter with equivalent accuracy,

#### 3-30. MEASUREMENT PROCEDURE.

a. Connect the DVM to the 432A rear panel Vcomp and VRF outputs. Be sure that the digital voltmeter input is isolated from chassis ground,

b. Turn off, or disconnect the RF power from the thermistor mount.

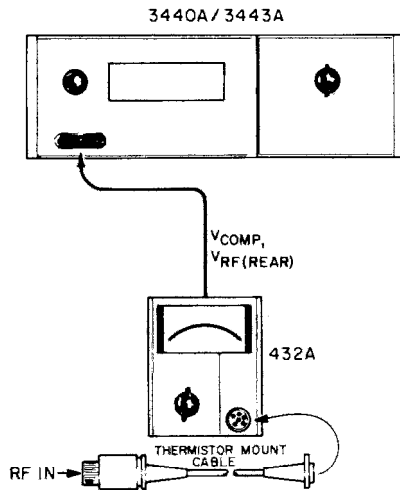


Figure 3-1. Precision Power Measurements

c. Zero the 432A with the COARSE ZERO controls.

d. Depress the FINE ZERO toggle, and measure the differential voltage ( $V_0$ ) between  $V_{comp}$  and  $V_{RF}$ .

$$V_0 = V_{COMP} - V_{RF}$$

e. Release the FINE ZERO toggle, and turn on, or reconnect the RF power to the thermistor mount.

f. Measure again the differential voltage ( $V_1$ ) between  $V_{RF}$  and  $V_{COMP}$ .

$$V_1 = V_{COMP} - V_{RF}$$

g. Measure  $V_{COMP}$  to ground.

h. Calculate incident RF power from the equation

$$P_{RF} = \frac{\frac{1}{4R} 2 V_{COMP} (V_1 - V_0) + V_0^2 - V_1^2}{\text{EFFECTIVE EFFICIENCY}}$$

where

$R$  is the thermistor mount resistance.

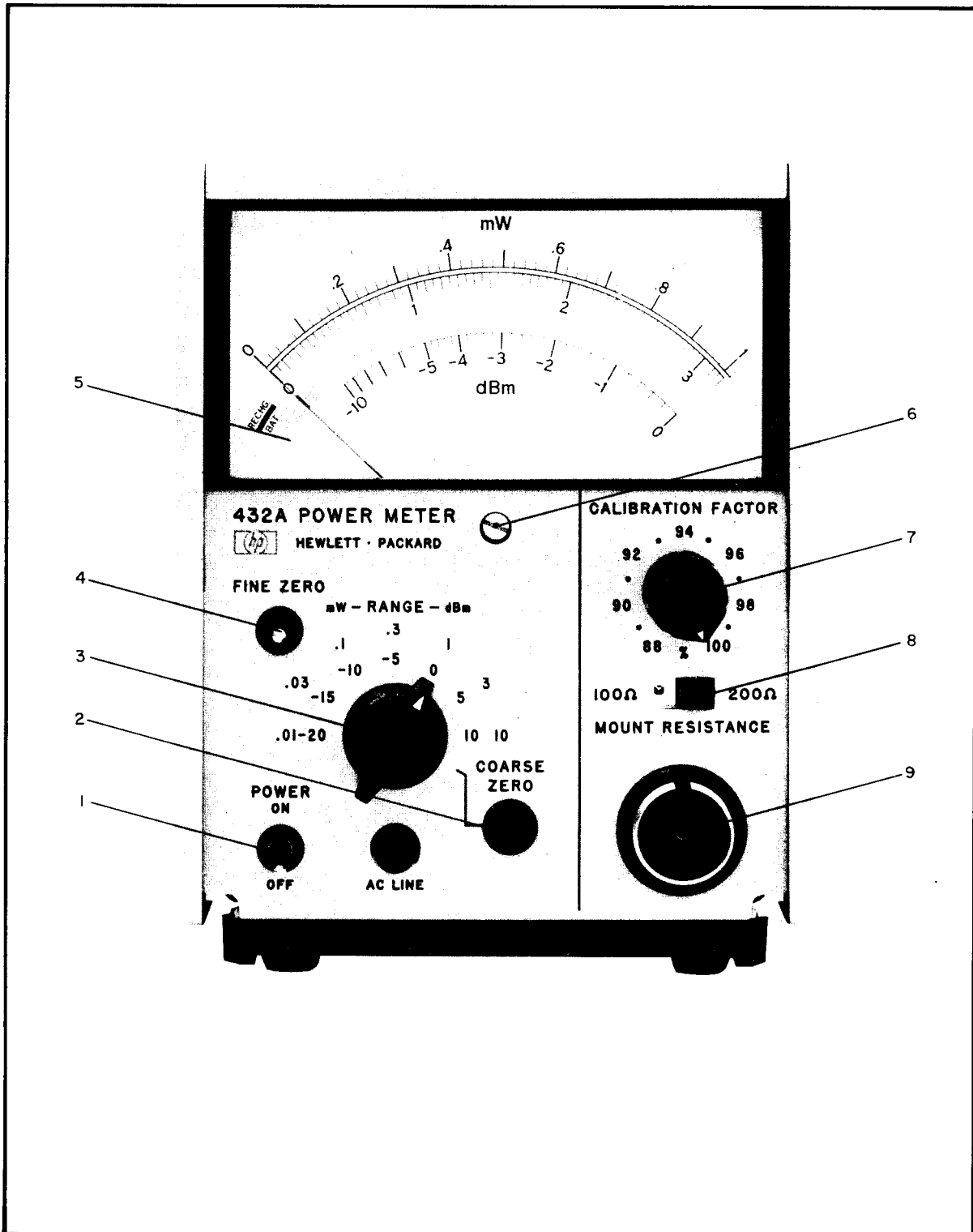


Figure 3-2. Front Panel Controls, Connectors and Indicators (Sheet 1 of 2)

1. **POWER.** Instrument power ON/OFF switch; connects either ac line voltage or internal battery (Option 01 only) to internal voltage regulator circuits. When ac power is on, optional battery charging circuit operates.
2. **COARSE ZERO.** Meter zero adjustment; set the RANGE selector to COARSE ZERO, turn OFF the RF power, and adjust to zero the meter.
3. **RANGE.** Power measurement range selector; selects ranges from 0.01 to 10 milliwatts (-20 to +10dBm). COARSE ZERO setting is used to zero meter with no power applied to thermistor mount.
4. **FINE ZERO.** Electronic zero that balances the compensation bridge with zero RF input. To zero meter during operation, close the switch momentarily. Be sure that RF power is not applied to the thermistor mount when the FINE ZERO switch is depressed.
5. **Meter.** Indicates power input to thermistor mount in milliwatts and dBm. To use the dBm scale, note the value in dBm of the range in use, and subtract from it the reading on the meter dBm scale.
6. **Mechanical Meter Zero.** Sets meter suspension so that meter indicates zero. To adjust the zero:
  - a. Turn POWER switch off.
  - b. Turn the adjustment screw clockwise until the indicator falls below zero and comes back up to zero again.
  - c. Turn the adjustment very slightly counter-clockwise to free up the mechanism from the adjusting peg.
7. **CALIBRATION FACTOR.** Amplifier gain compensation selector. Set to correspond to the calibration factor printed on the thermistor mount body. See Paragraph 3-23 for more information.
8. **MOUNT RESISTANCE.** Selects resistance equal to that of mount in use to balance bridges. Table 1-2 lists Hewlett-Packard thermistor mounts and resistances. Set with meter power OFF, when mount is initially connected to the meter.
9. **Thermistor Mount Cable Connector.** Input connector for 5-1/2 foot cable that connects to the 478A, 8478B, or 486A Thermistor Mounts.

Figure 3-2. Front Panel Controls, Connectors and Indicators (Sheet 2 of 2)

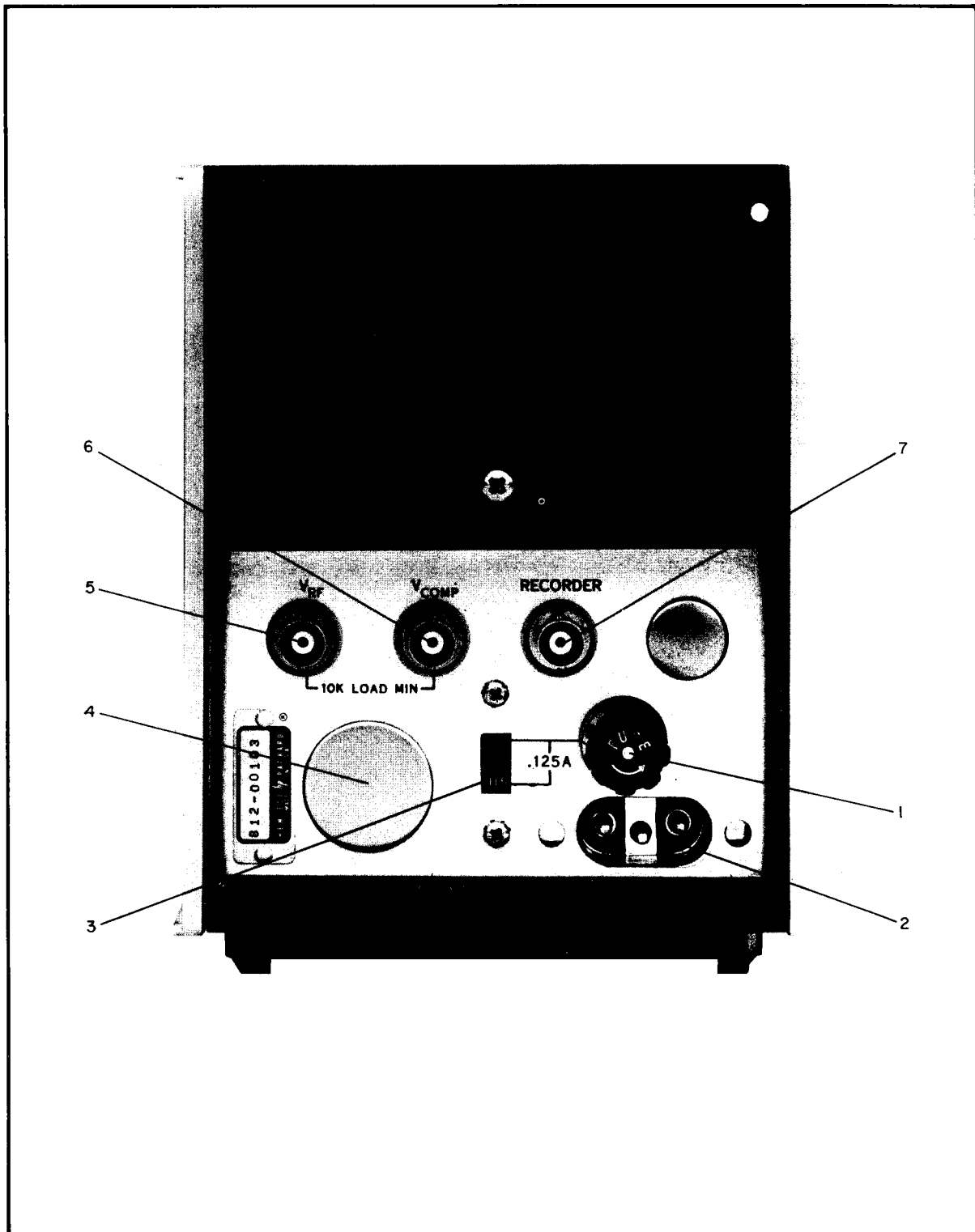


Figure 3-3. Rear Panel Controls and Connectors (Sheet 1 of 2)

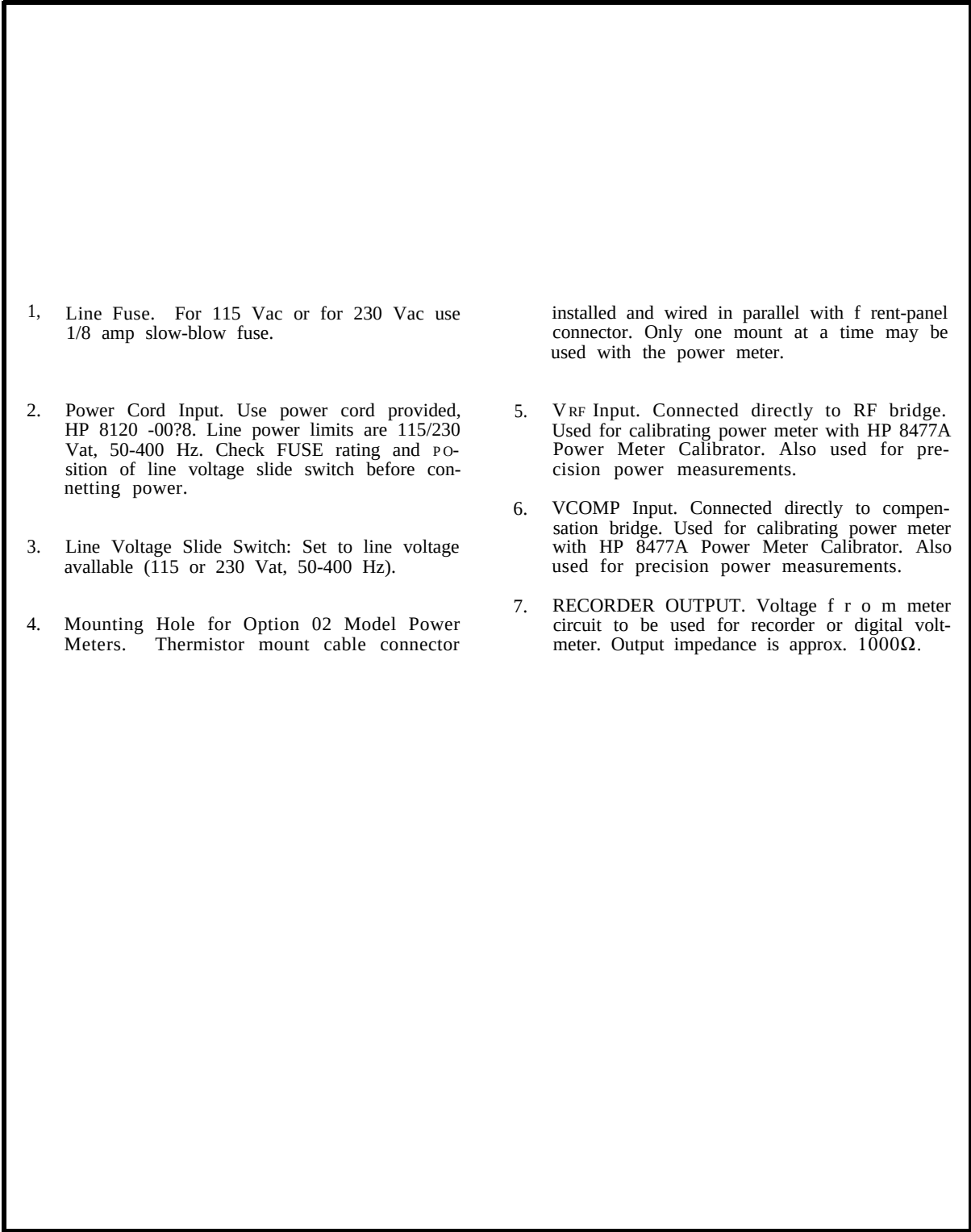
- 
1. Line Fuse. For 115 Vac or for 230 Vac use 1/8 amp slow-blow fuse. installed and wired in parallel with front-panel connector. Only one mount at a time may be used with the power meter.
  2. Power Cord Input. Use power cord provided, HP 8120 -0078. Line power limits are 115/230 Vat, 50-400 Hz. Check FUSE rating and position of line voltage slide switch before connecting power.
  3. Line Voltage Slide Switch: Set to line voltage available (115 or 230 Vat, 50-400 Hz).
  4. Mounting Hole for Option 02 Model Power Meters. Thermistor mount cable connector
  5. V<sub>RF</sub> Input. Connected directly to RF bridge. Used for calibrating power meter with HP 8477A Power Meter Calibrator. Also used for precision power measurements.
  6. VCOMP Input. Connected directly to compensation bridge. Used for calibrating power meter with HP 8477A Power Meter Calibrator. Also used for precision power measurements.
  7. RECORDER OUTPUT. Voltage from meter circuit to be used for recorder or digital voltmeter. Output impedance is approx. 1000Ω.

Figure 3-3. Rear Panel Controls and Connectors (Sheet 2 of 2)

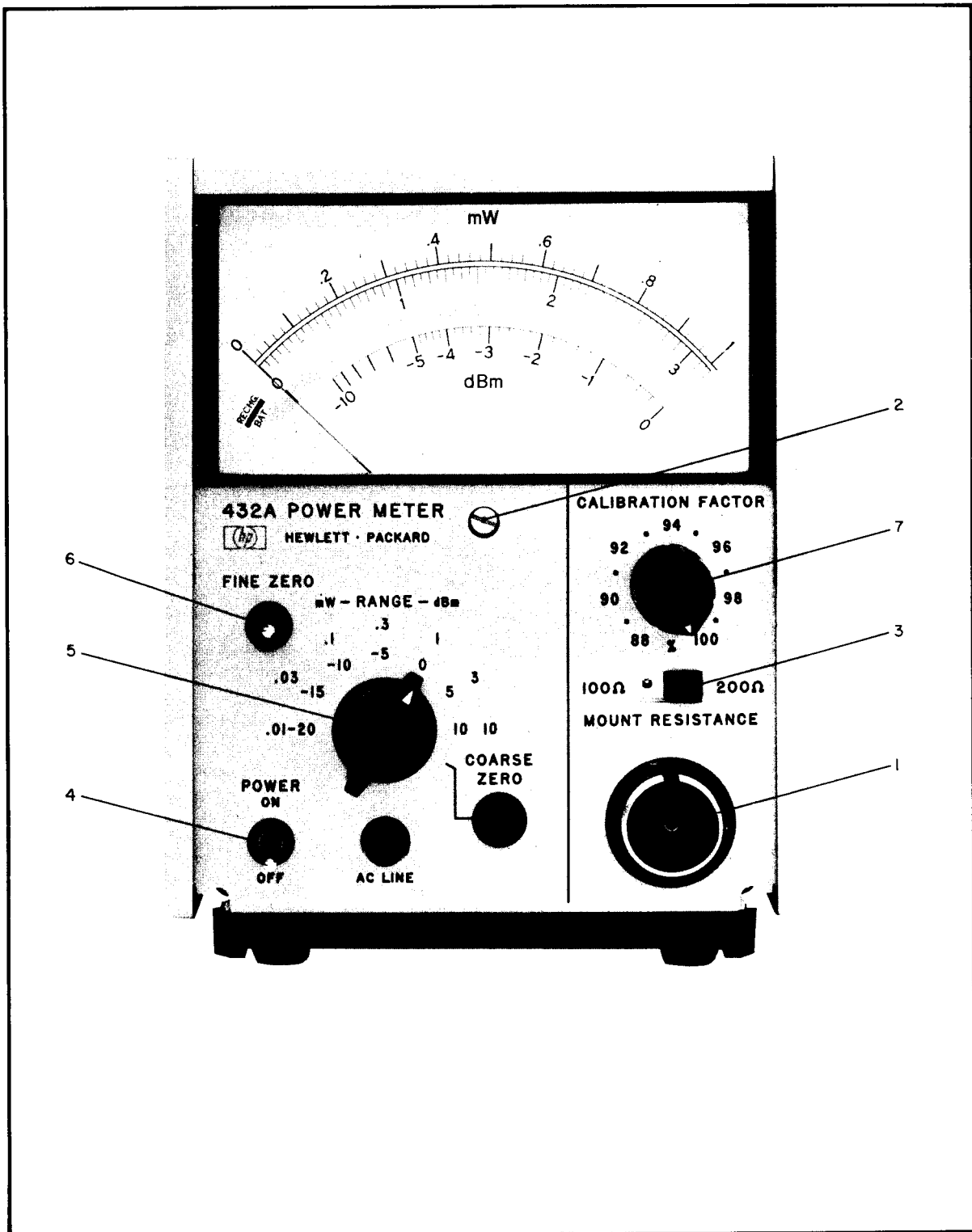


Figure 3-4. Turn On and Zeroing Procedure (Sheet 1 of 2)

1. Connect the thermistor mount and cable to THERMISTOR MOUNT connector. Refer to Table 1-2 for recommended thermistor mounts and their frequency ranges.
  2. Meter Mechanical Zero:
    - a. With the instrument turned off, rotate the meter adjustment screw clockwise until the pointer approaches the zero mark from the left.
    - b. Continue the clockwise rotation until the pointer coincides with the zero mark. If the pointer overshoots, continue rotating the adjustment screw clockwise until the pointer once again approaches the zero mark from the left.
    - c. Rotate the adjustment screw about three degrees counterclockwise to disengage screw adjustment from the meter suspension.
  3. Set the MOUNT RES switch to correspond to the operating resistance of thermistor mount used.
  4. Turn the 432A POWER switch ON. For battery operation, the AC LINE indicator does not turn on.
  5. Set the RANGE selector to COARSE ZERO and then zero the meter with the COARSE ZERO screwdriver adjustment.
- Note
- The power meter should be zeroed with the RF power source turned off, or the mount disconnected from the source.
6. Set the range selector to the 0.01 mW range; then depress the FINE ZERO switch until the meter indicates zero.
- Note
- Range-to-range zero carryover is less than  $\pm 0.5\%$  if the meter zero has been adjusted (step 2 above), and the instrument has been properly zero-set on the sensitive range. For maximum accuracy, zero-set the power meter on the range to be used.
7. Set CALIB FACTOR switch to correspond to Calibration Factor imprinted on HP thermistor mount label.
  8. Apply RF power to the thermistor mount. Power is indicated on the meter directly in mW or dBm.

Figure 3-4. Turn On and Zeroing Procedure

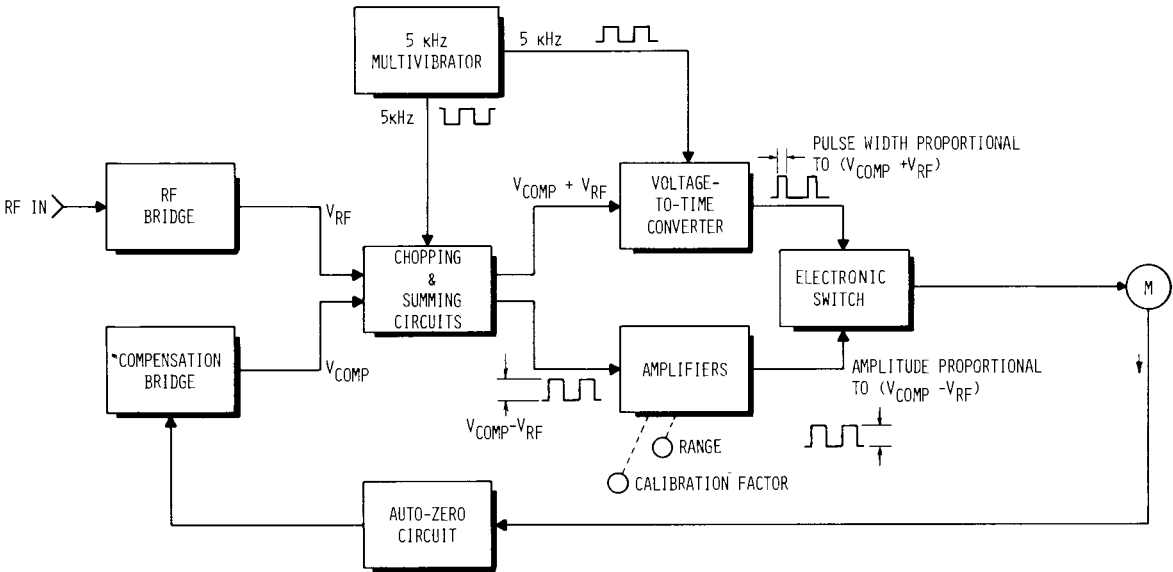


Figure 4-1. Simplified 432A Block Diagram

## SECTION IV

### PRINCIPLES OF OPERATION

#### 4-1. SIMPLIFIED DESCRIPTION

4-2. The HP 432A Power Meter consists of two major sections: the bridge and meter logic assemblies. The instrument also contains an auto zero circuit which provides for automatic zeroing on any range. A simplified Mock diagram of the HP 432A is shown in Figure 4-1.

4-3. The bridge section contains circuits which form two self-balancing bridge circuits when a suitable thermistor mount is connected to the 432A. Each bridge is automatically brought to balance by the action of a high gain dc amplifier feeding power to the top of the bridge. The voltage at the top of the RF bridge  $V_{RF}$  is responsive to both input RF power and ambient temperature changes. The voltage at the top of the compensation bridge,  $V_{COMP}$  is responsive only to ambient temperature changes. Knowing  $V_{RF}$  and  $V_{COMP}$ , the RF power can be calculated.

4-4. The meter logic section processes  $V_{RF}$  and  $V_{COMP}$  to produce a meter current proportional to RF power. The sum  $(V_{RF} + V_{COMP})$  controls the width of 5 kHz pulses. The difference  $(V_{COMP} - V_{RF})$  is chopped, amplified and fed to an electronic switch actuated by the controlled width pulses. Therefore, the meter current is pulses of variable height and width with the meter indicating the average current. (This process produces a meter current proportional to  $(V_{RF} + V_{COMP})(V_{RF} - V_{COMP})$ ). Paragraph 4-10 explains why this is necessary.

#### 4-5. FUNCTIONAL BLOCK DIAGRAM

4-6. A functional block of the 432A power meter is shown in Figure 4-2. The instrument comprises two major assemblies: bridge assembly A1 and meter logic assembly A2. Auto zero circuit A1, which provides for automatic zeroing of the instrument, is included as part of logic assembly A1.

4-7. The thermistor bridges are biased with direct current from the bridge amplifiers. Each bridge amplifier supplies enough heating current to bring the thermistor resistance to 100 or 200 ohms, depending upon the setting of the MOUNT RESISTANCE switch on the 432A. If one of the thermistor bridges is unbalanced due to incorrect thermistor resistance, an error voltage occurs and is amplified by the bridge amplifier. The error voltage is applied to the top of the bridge and changes the power dissipation of the negative temperature coefficient thermistor. The change of power dissipation causes the resistance to the thermistor to change in the direction required to balance the bridge. Application of RF power to the RF bridge heats the thermistor and lowers its resistance. The bridge circuit responds by reducing the dc voltage applied to the top of the bridge thus maintaining bridge balance.

4-8. If ambient temperature causes changes in the thermistor resistance, the bridge circuits respond by applying an error voltage to the bridges to maintain bridge balance. The voltage at the top of the RF bridge is dependent upon both ambient temperature and the RF input. The voltage at the top of the compensation bridge is dependent upon the ambient temperature only. The power meter reading is brought to zero with no applied RF power by making  $V_{COMP}$  equal to  $V_{RF}$  so  $(V_{COMP} - V_{RF})$  equals zero. Since ambient temperature causes both thermistors to respond similarly, there will be no net difference between the amplifier output voltages. Therefore, any difference in output voltages from the bridges is now due to RF power absorbed by the thermistor mount.

4-9. The RF bridge voltage,  $V_{RF}$ , and the compensation bridge voltage,  $V_{COMP}$ , contain the "RF power" information. To provide a meter reading proportional to RF power the dc voltages ( $V_{RF}$ ,  $V_{COMP}$ ) must be further processed by the meter logic circuits.

4-10. The required processing is derived as follows: P. is absorbed power needed by the RF thermistor to bring its resistance to R ohms (100 or 200 ohms). P. consists of two components: RF power from the signal source to be measured and dc power supplied by the 432A. The self balancing action of the bridge circuit automatically adjusts the dc power so that the total power in the thermistor is  $P_0$ . This dc power is related to the voltage  $V_{RF}$  at the top of the bridge by  $(V_{RF}/2)^2/R$ . Thus

$$\begin{aligned} P_0 &= \text{RF power} + \text{DC power} \\ &= \text{RF power} + \frac{V_{RF}^2}{4R} \end{aligned}$$

4-11. RF power can be redetermined by measuring  $V_{RF}$  with and without applied RF power and then doing some arithmetic. But this power measuring scheme is neither convenient nor temperature compensated (since P. changes with temperature). The 432A introduces another thermistor bridge circuit exposed to the same ambient temperature but not RF power. This circuit includes adjustments (COARSE and FINE ZERO) so that the dc voltage  $V_{COMP}$  at the top of its bridge can be set equal to  $V_{RF}$ . Assuming matched RF and compensation thermistors,  $V_{RF_0}$  (with no RF power) and  $V_{COMP}$  remain equal with ambient temperature fluctuation. They differ only when the RF power to be measured is applied to the RF thermistor. Thus, we have

$$\begin{aligned} V_{COMP} &= V_{RF_0} \quad \text{when RF power} = 0 \\ \text{and} \quad P_0 &= 0 + \frac{V_{COMP}^2}{4R} \end{aligned}$$

Combining equations, we have

$$\frac{V_{\text{COMP}}^2}{4R} = \text{RF power} + \frac{V_{\text{RF}}^2}{4R}$$

$$\begin{aligned} \text{or} \quad \text{RF power} &= \frac{V_{\text{COMP}}^2 - V_{\text{RF}}^2}{4R} \\ &= \frac{1}{4R} (V_{\text{COMP}} + V_{\text{RF}})(V_{\text{COMP}} - V_{\text{RF}}) \end{aligned}$$

4-12. Thus an RF power measurement reduces to setting  $V_{\text{COMP}} = V_{\text{RF}_0}$  (with zero RF power) initially,

measuring  $V_{\text{COMP}}$  and  $V_{\text{RF}}$ , and computing with the above formula. The 432A carries out the computation by forming the indicated sum and difference, performing the multiplication and displaying the result on a meter.

4-13. The meter logic circuits change the two dc voltages to two pulse signals which contain all the RF power information. One of the signals will be a square wave whose amplitude is proportional to  $V_{\text{COMP}} - V_{\text{RF}}$ . The other signal will have a pulse width proportional to  $V_{\text{COMP}} + V_{\text{RF}}$ .

4-14. The  $V_{\text{COMP}} - V_{\text{RF}}$  signal is obtained by taking the dc voltage outputs from the A1 assembly and applying them to a chopper circuit. This chopper circuit is driven by a 5-kHz multivibrator. The output of the chopper is a square wave signal whose amplitude is proportional to  $V_{\text{COMP}} - V_{\text{RF}}$ . The output of the chopper is coupled to the range amplifier and then to the calibration factor amplifier. The amplification that the signal receives in these two amplifiers depends upon the setting of the RANGE switch and the CALIBRATION FACTOR switch. The output of the calibration factor amplifier is  $V$ . This current is fed to the electronic switch. A square wave current with amplitude proportional to  $(V_{\text{COMP}} - V_{\text{RF}})$ .

4-15. The  $V_{\text{COMP}} + V_{\text{RF}}$  signal is obtained by taking the two dc voltages from A1 assembly through a summing circuit and feeding this voltage to a voltage-to-time converter. The voltage-to-time converter is driven by a 5-kHz multivibrator. The output of the voltage-to-time converter is a signal whose pulse width is proportional to the sum of  $V_{\text{COMP}} + V_{\text{RF}}$ . This signal controls the electronic switch. From the  $V_{\text{COMP}} - V_{\text{RF}}$  and  $V_{\text{COMP}} + V_{\text{RF}}$  inputs, the electronic switch provides a 5-kHz pulse train whose amplitude is proportional to  $V_{\text{COMP}} - V_{\text{RF}}$  and whose pulse width is proportional to  $V_{\text{COMP}} + V_{\text{RF}}$ . The pulse width is always 90 msec or less.

4-16. The bias circuit switch and filter provides a zero current reference for the meter circuit. This is accomplished by controlling the dc bias to the first stage of the calibration factor amplifier. This circuit, in effect, restores the dc component to the square wave which has been amplified by ac coupled amplifiers.

4-17. The meter is 0-1 mA, full-scale meter that has a capacitor across its terminals. The capacitor integrates the output pulses from the current switch so the current into the meter is proportional to the time average of the input pulses. That is, the input current to the meter is proportional to the product of

$$(V_{\text{COMP}} + V_{\text{RF}})(V_{\text{COMP}} - V_{\text{RF}}) = (V_{\text{COMP}})^2 - (V_{\text{RF}})^2.$$

4-18. The output from the meter is further filtered so the voltage at the rear panel RECORDER output is suitable for use with either a digital voltmeter or X-Y recorder. The RECORDER output voltage is returned to the compensation bridge through the automatic zero circuit when the FINE ZERO switch is depressed. The automatic zero circuit holds a correction voltage at the input of the compensation bridge amplifier, so when the RF is zero, the meter indication will also be zero.

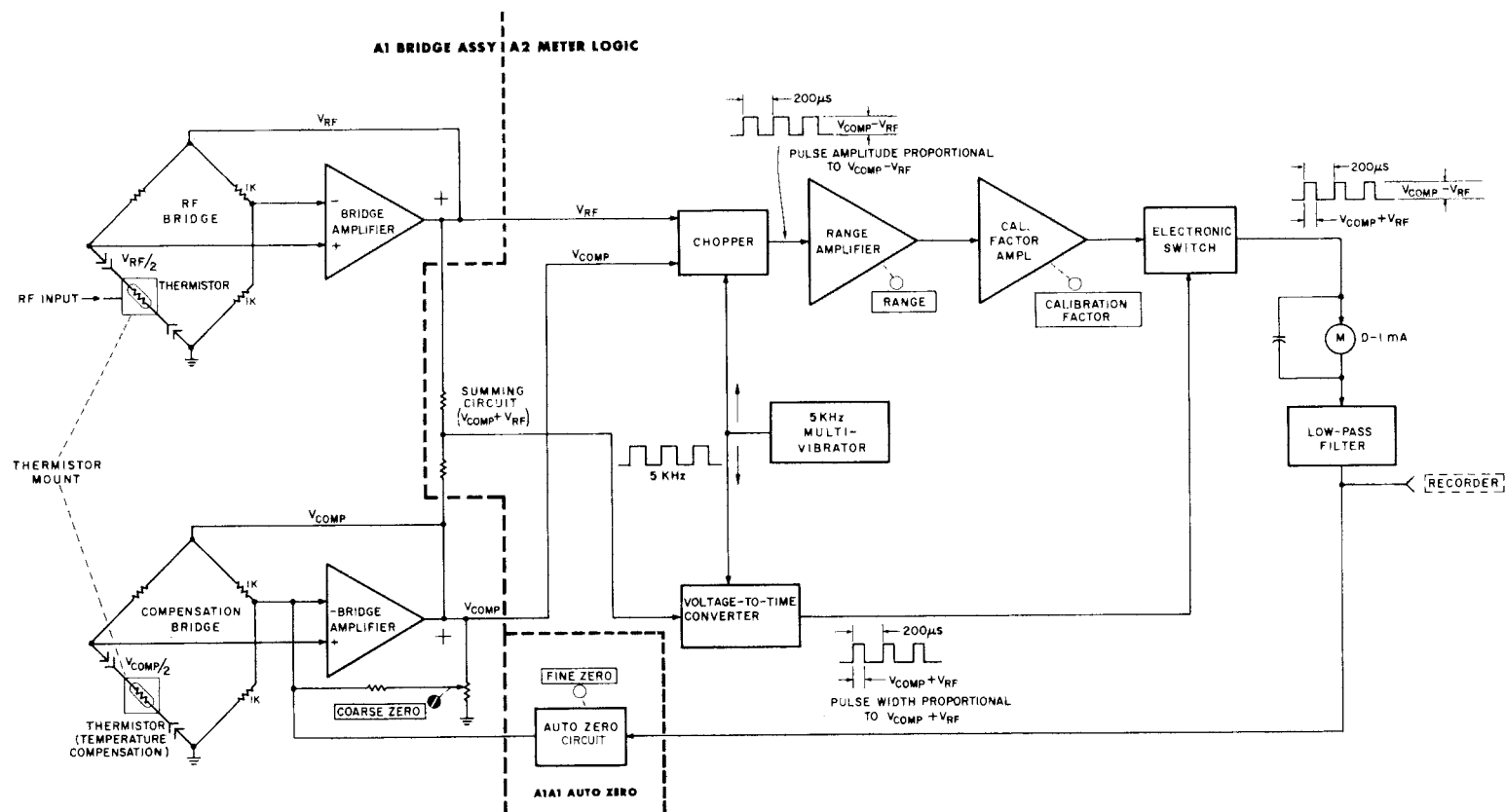


Figure 4-2. Model 432A Block Diagram

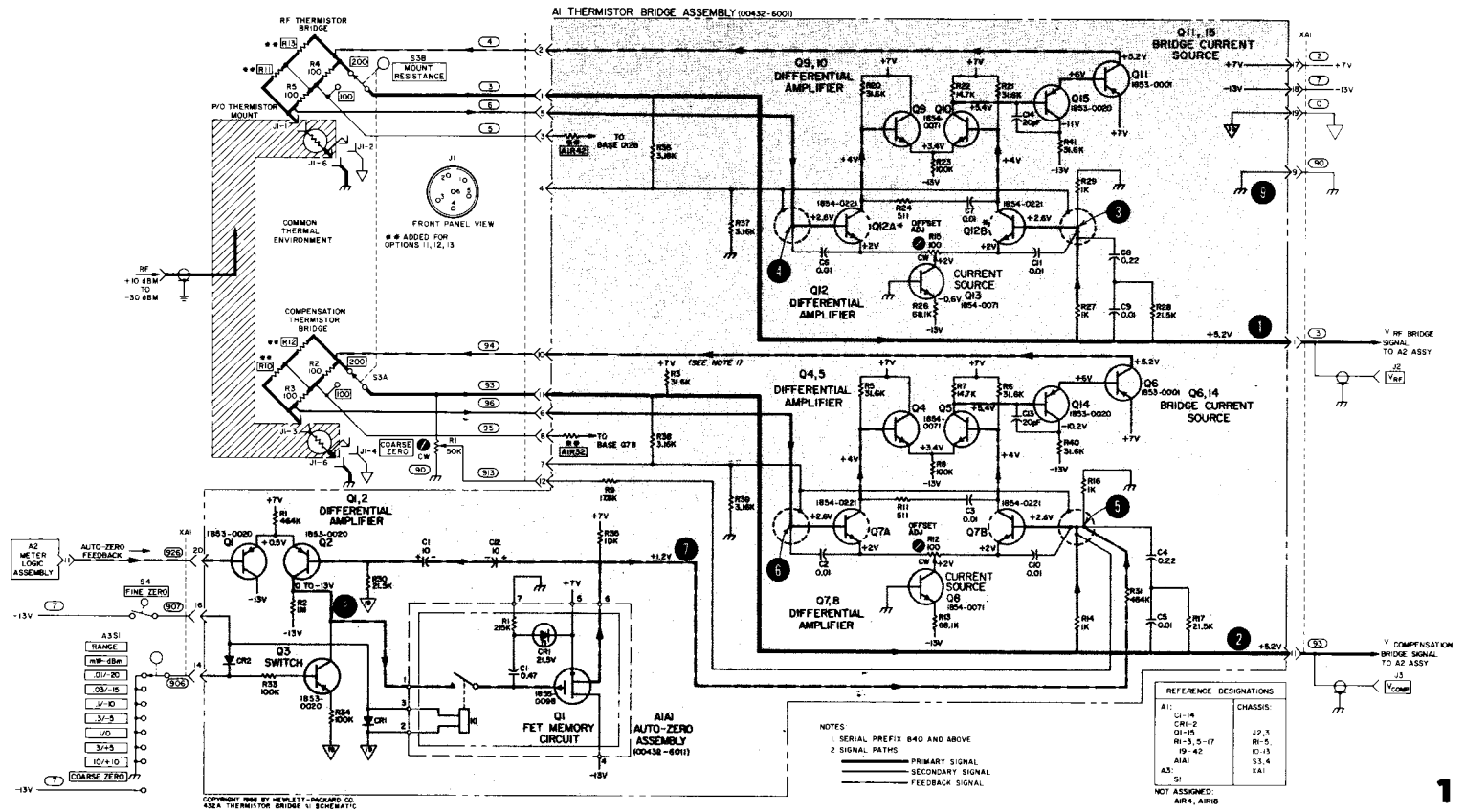


Figure 4-3. Model 432A RF Bridge Talking Schematic (Sheet 1 of 2)



**4-5**

4-6

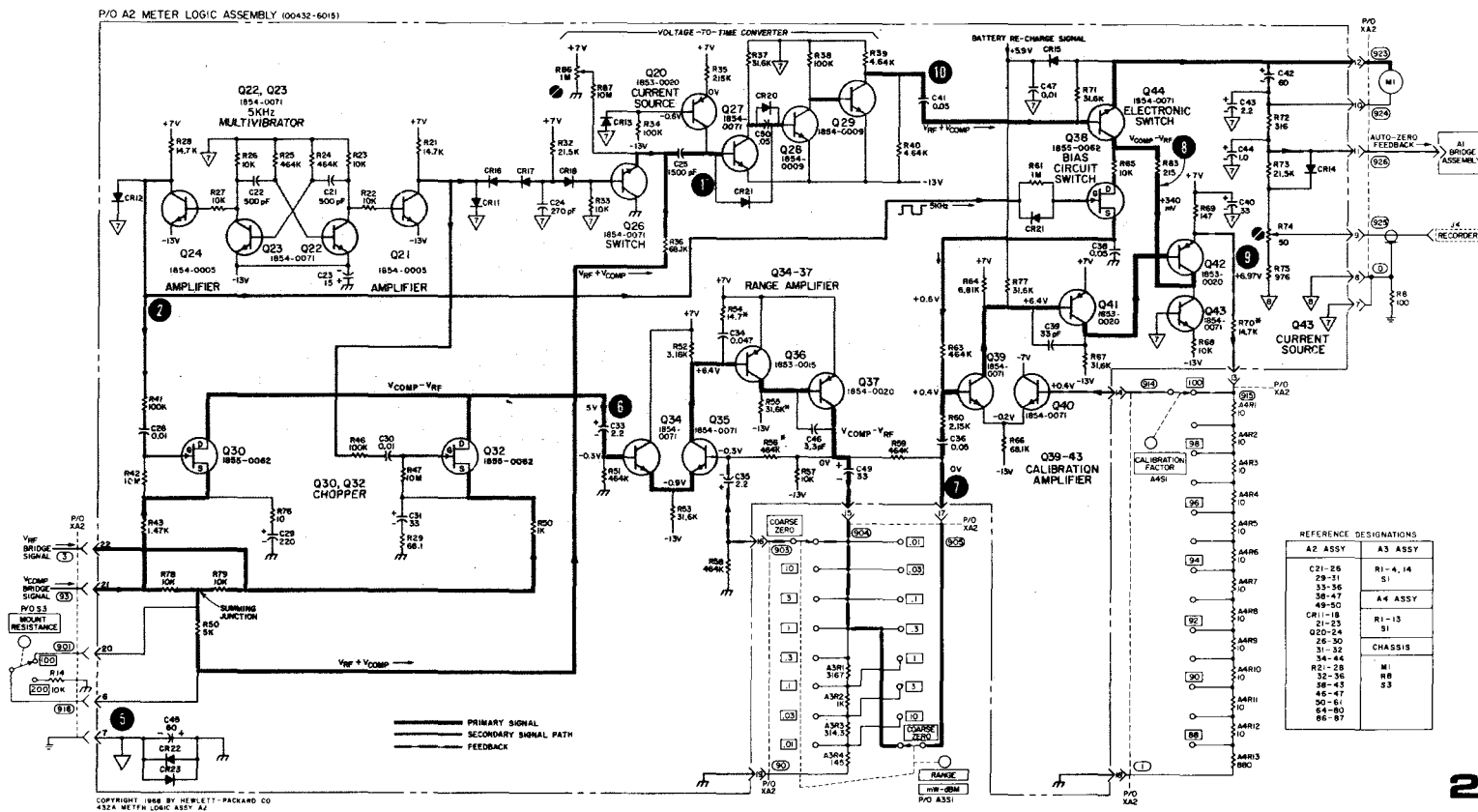


Figure 4-4. Model 432A Meter Logic Talking Schematic (Sheet 1 of 2)

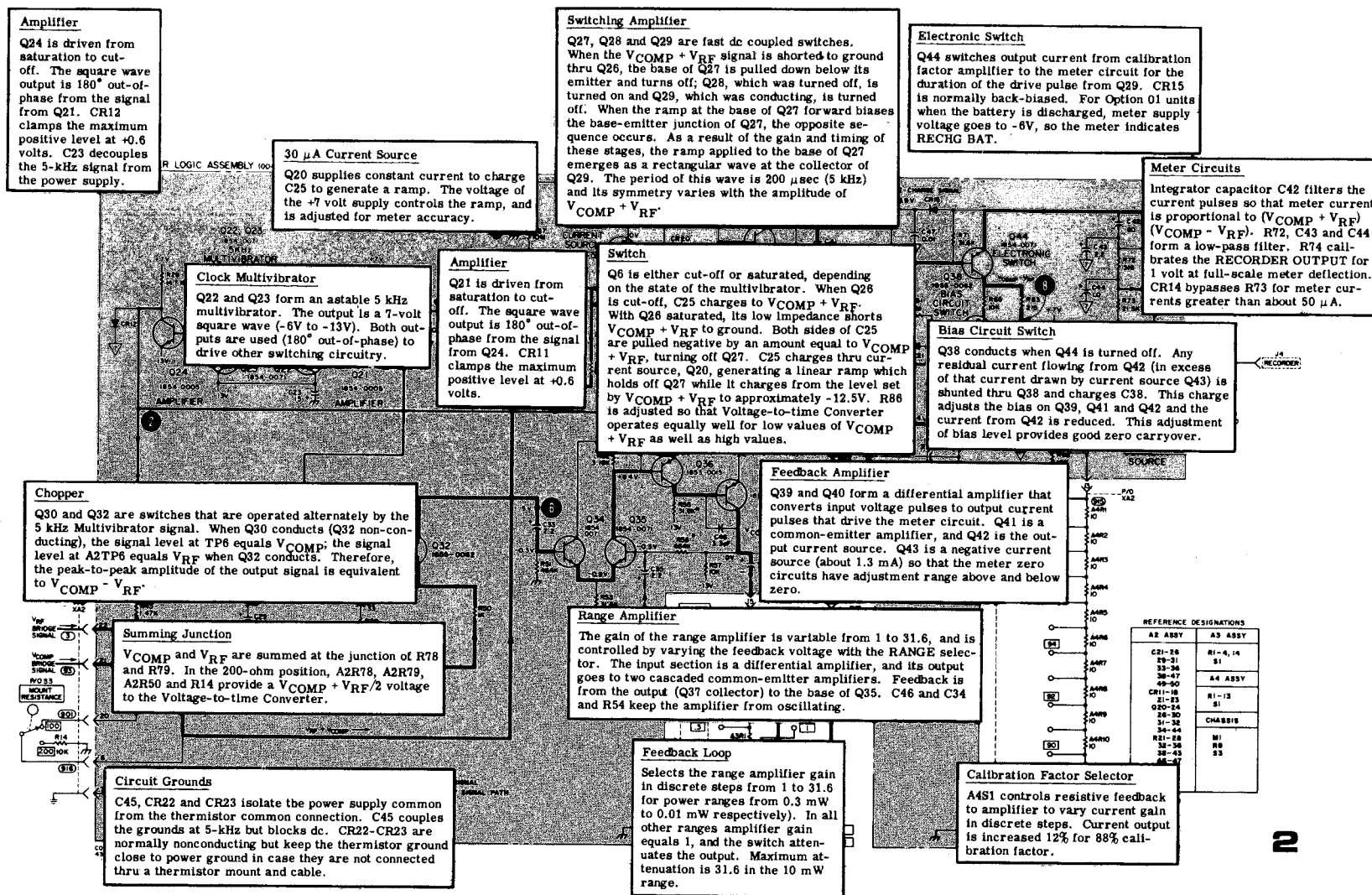
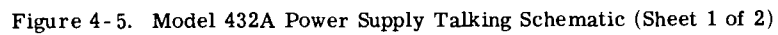


Figure 4-4. Model 432A Meter Logic Talking Schematic (Sheet 2 of 2)





4-9

Table 5-1. Recommended Test Equipment

| Instrument Type                | Critical Specifications                                                                                              | Recommended Model                             |
|--------------------------------|----------------------------------------------------------------------------------------------------------------------|-----------------------------------------------|
| Power Meter Calibrator         | Range: 0.1 to 10 mW<br>Accuracy: .1 to 10 mW ranges: 0.2%<br>.01 and .03 mW ranges: 0.5%                             | HP 8477A                                      |
| DC Digital Voltmeter           | Range: 0.5 to 50 volts dc<br>Accuracy: $\pm 0.05\%$<br>Input Impedance: 10 megohms, floating<br>Resolution: 4 digits | HP 3440A with 3443A<br>Plug-in Unit           |
| Storage Oscilloscope           | Variable Persistence Display<br>Bandwidth: dc to 5 MHz<br>Input Impedance: 1 megohm<br>Sensitivity: 5 mV/division    | HP 141A with 1405A<br>and 1420A Plug-in Units |
| Vertical Plug-in               | Bandwidth: 400 kHz<br>Input Impedance: 1 megohm<br>Sensitivity: 1 mV/division                                        | HP 1401A                                      |
| Cable Assembly<br>(2 required) | RG 58C/U coaxial cable with 2 each BNC<br>male connectors                                                            | HP 10503A                                     |
| Test Lead                      | Insulated cable terminated with dual<br>banana plug and test clips                                                   | HP 11001A                                     |
| Cable Assembly                 | Shielded cable with one each BNC and dual<br>banana plug connectors                                                  | HP 11000A                                     |
| Thermistor Mount               | Operating Resistance: 100 ohm or 200 ohms                                                                            | HP 478, 8478                                  |
| Filter Network                 |                                                                                                                      | See Figure 5-2                                |
| Oscilloscope Probes (2)        | Division Ratio: 10:1 $\pm 2\%$<br>Bandwidth: dc to 30 MHz<br>Rise Time: 5 nsec                                       | HP 10001A                                     |
| Differential Voltmeter         | Accuracy: $\pm 0.005\%$ of reading<br>$+0.0004\%$ of range $\pm 1 \mu V$                                             | HP 740B                                       |
| Resistor (2)                   | 10K 1%, 1/8 watt                                                                                                     | 0757-0442                                     |

## SECTION V MAINTENANCE

### 5-1. INTRODUCTION.

5-2. This section provides information for performance testing, adjusting, troubleshooting and repairing the 432A Power Meter. Performance tests allow the instrument to be checked for conformance to specifications. If performance is not within specifications, adjust or troubleshoot the instrument.

### 5-3. CONTENT.

#### 5-4. PERFORMANCE TESTS .

5-5. The procedures test power meter performance for incoming inspection, periodic evaluation, calibration and troubleshooting. Specifications in Table 1-1 are the performance standards. If the power meter fails to meet any of the performance test specifications, refer to the troubleshooting diagrams.

#### 5-6. ADJUSTMENTS

5-7. Procedures describe the adjustments necessary to calibrate the power meter. Adjust the power meter only when it is determined that the meter is out of adjustment, and not malfunctioning due to a circuit failure.

5-8. To avoid errors due to possible ground loop currents, isolate the power meter from ground used for other auxiliary equipment. A power plug adapter that removes the ground connection at the line outlet can be used to isolate the power meter.

5-9. Several circuit components are factory-selected to meet specific circuit requirements. The factory selected parts are indicated on the schematic diagrams.

#### 5-10. TEST EQUIPMENT.

5-11. Instruments and accessories required for adjusting and testing the power meter are listed and briefly described in Table 5-1. Instruments used to maintain the instrument must meet or exceed the specifications given.

#### 5-12. SERVICE INFORMATION.

5-13. Service information in the form of troubleshooting, waveforms, schematics, and component locations are given in Section VII. Also, an overall system block diagram is included which contains keyed numbers corresponding to the test points.

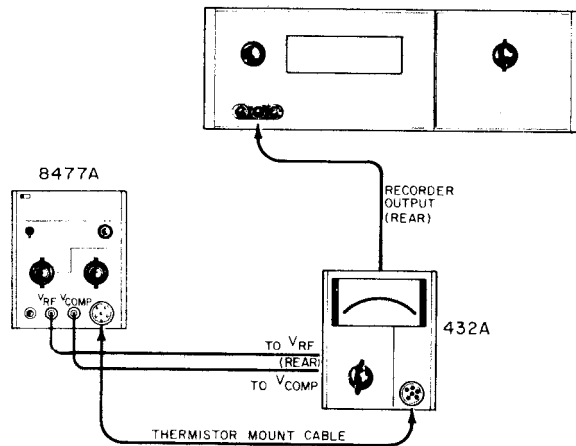


Figure 5-1. Check and Adjustment Test Set-up

### 5-14. 432A PERFORMANCE TESTS WITH 8477A CALIBRATOR

#### 5-15. INITIAL SET-UP.

a. Connect the 8477A outputs to the 432A inputs as shown in Figure 5-1. Use appropriate test equipment as listed in Table 5-1.

b. If necessary, mechanically zero the meter movement as follows:

- (1) With instrument turned off, rotate meter adjustment screw clockwise until pointer approaches zero mark from the left.
- (2) Continue rotating clockwise until pointer coincides with zero mark. If pointer overshoots, continue rotating adjustment screw clockwise until pointer once again approaches zero mark from the left.
- (3) Rotate adjustment screw about three degrees counterclockwise to disengage screw adjustment from meter suspension.

#### 5-16. METER ACCURACY TEST.

a. Set the 8477A Calibrator controls as follows:

|                     |        |
|---------------------|--------|
| POWER . . . . .     | 0.01mW |
| FUNCTION . . . . .  | 200Ω   |
| ZERO/TEST . . . . . | ZERO   |

b. Set the 432A controls as follows:

|                              |        |
|------------------------------|--------|
| MOUNT RESISTANCE.. . . .     | 200Ω   |
| RANGE . . . . .              | 0.01mW |
| POWER . . . . .              | ON     |
| CALIBRATION FACTOR . . . . . | 100%   |

c. Adjust 8477A ZERO knob for 0 volts  $\pm 2$  mV indication on the DVM.

d. Set the 8477A controls as follows:

POWER ..... 0.01mW  
ZERO/TEST ..... TEST

e. The digital voltmeter should indicate 1000  $\pm 10$  millivolts.

f. The 432A meter should indicate full scale  $\pm 1/2$  division.

g. Repeat steps d through f for each of the other ranges. Set the power meter range selector to the position indicated in Column 1 of Table 5-2, and set the 8477A meter reading selector to the corresponding position indicated in Column 2 of Table 5-2. In each case, the meter indications should correspond to those shown in Table 5-2, Columns 3 and 4.

Table 5-2. Meter Accuracy Test

| 432A Range (mW) | 8477A Range (mW) | Digital Voltmeter Indication (millivolts $\pm 10$ mV) | 432A Meter Indication (Full scale $\pm 1/2$ Div.) |
|-----------------|------------------|-------------------------------------------------------|---------------------------------------------------|
| .01             | .01              | 1000                                                  | 1                                                 |
| .03             | .03              | 948.8                                                 | 3                                                 |
| .1              | .1               | 1000                                                  | 1                                                 |
| .3              | .3               | 948.8                                                 | 3                                                 |
| 1               | 1                | 1000                                                  | 1                                                 |
| 3               | 3                | 948.8                                                 | 3                                                 |
| 10              | 10               | 1000                                                  | 1                                                 |

#### 5-17. CALIBRATION FACTOR TEST.

a. Set 432A controls as follows:

RANGE ..... 0.1 mW  
CAL FACTOR ..... .88%  
MOUNT RESISTANCE ..... 2000

b. Set 8477A controls as follows:

FUNCTION ..... 200 $\Omega$   
ZERO/TEST Switch ..... TEST  
POWER ..... 0.1mW

c. Set 8477A ZERO control so that the digital voltmeter reads 1000  $\pm 2$  mV.

d. Set the calibration factor selector to 89%.

e. The digital voltmeter should indicate 989  $\pm 10$  millivolts.

f. Repeat steps d and e for each position of the CALIBRATION FACTOR selector. In each case, the digital voltmeter should indicate the voltage shown in the second column of Table 5-3 for the CALIBRATION FACTOR shown in the first column.

Table 5-3. Calibration Factor Test

| Calibration Factor Selector Setting (%) | Digital Voltmeter Indication (mV) |
|-----------------------------------------|-----------------------------------|
| 88                                      | 1000 $\pm 2$                      |
| 89                                      | 989 $\pm 10$                      |
| 90                                      | 978 $\pm 10$                      |
| 91                                      | 967 $\pm 10$                      |
| 92                                      | 957 $\pm 10$                      |
| 93                                      | 946 $\pm 10$                      |
| 94                                      | 935 $\pm 10$                      |
| 95                                      | 926 $\pm 10$                      |
| 96                                      | 916 $\pm 10$                      |
| 97                                      | 907 $\pm 10$                      |
| 98                                      | 897 $\pm 10$                      |
| 99                                      | 889 $\pm 10$                      |
| 100                                     | 880 $\pm 10$                      |

#### 5-18. METER LINEARITY CHECK.

a. Set the 8477A POWER (MW) selector to 1 mW, and FUNCTION to 200 $\Omega$ , ZERO/TEST switch to TEST.

b. Set the 432A RANGE selector to 3 mW, MOUNT RESISTANCE to 200 $\Omega$ .

c. The 432A meter should indicate 1 mW  $\pm 1/2$  division.

d. Set the 8477A POWER (MW) selector to 2 mW.

e. The 432A meter should indicate 2 mW  $\pm 1/2$  division.

f. Set the 8477A POWER (MW) selector to 3 mW.

g. The 432A meter should indicate 3 mW  $\pm 1/2$  division.

#### 5-19. ZERO CARRYOVER TEST.

a. Disconnect the 432A from the 8477A.

b. Turn the 432A power OFF, and connect the thermistor mount cable to a thermistor mount.

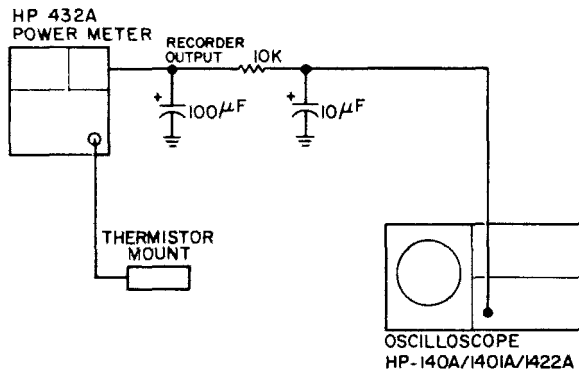


Figure 5-2. Zero Carryover Test Setup

c. Set the 432A Power Meter MOUNT RESISTANCE selector to the resistance shown on the thermistor mount.

d. Turn ON the 432A power.

e. Connect 141A through filtering network to rear of 432A as shown in Figure 5-2. Set 141A controls as follows:

INPUT ..... DC  
Sensitivity ..... 1 mV/cm  
SWEEP ICE ..... 2 sec/cm  
TRIGGER LEVEL ..... max clockwise (free run)

f. Zero the 432A as follows:

- 1) Set the RANGE selector maximum cw to COARSE ZERO.
- 2) Set the COARSE ZERO screwdriver adjust so that the meter indicates zero.
- 3) Set 432 ARANGE switch to .01 mW. Depress the FINE ZERO switch. The meter indication should to to zero without overshoot.

g. Rotate the RANGE switch clockwise, one step at a time, while the oscilloscope is sweeping. On each 432 A range, the scope trace should be within .01mW divisions ( $\pm 5$  mV) from where it was on the .01 mW range.

#### 5-20. FINE ZERO RANGE CHECK.

a. Set the 432A RANGE selector to 0.3 mW. Leave the thermistor mount connected to the cable, and the MOUNT RESISTANCE selector set to correspond to the resistance of the mount used.

b. Depress the FINE ZERO switch.

c. Slowly turn the COARSE ZERO screwdriver adjustment counterclockwise until the meter will no longer zero. The FINE zero circuit is at one end of its range.

d. Release FINE ZERO.

e. Set the COARSE ZERO screwdriver adjustment so that the meter indicates full scale on the 0-3 scale (0.3 mW range).

f. Depress FINE ZERO switch (the fine zero circuit is at the other end of its range). Meter should indicate below 2 on the 0-3 scale. Record the indication.

g. Release FINE ZERO.

h. Rotate RANGE switch to COARSE ZERO position. The fine zero circuit is now in the center of its range. The meter reading should be (1.5 + reading of +1/2 of reading in step f,  $\pm 0.1$  on the 0-3 scale.

#### 5-21. 432A CALIBRATION WITHOUT 8477A CALIBRATOR

5-22. The 432A Power Meter can be calibrated without an 8477A Calibrator using a method similar to the precision power method outlined in Paragraph 3-27.

5-23. A major difference between the two measurements is that external power need not be applied when calibrating the instrument. Normally, in a stable environment, the VCOMP output voltage remains constant, not being affected by external RF power; only the VRF output varies during power measurement. Since the power that the meter indicates is proportional to VCOMP and VRF, we can cause the meter to indicate a power also by holding VRF constant and varying VCOMP. This is easily done on the 432A by turning the COARSE ZERO control. Two calibration procedures are given below.

#### 5-24. CALIBRATION PROCEDURE 1.

a. Connect thermistor mount to power meter; let instrument warm up for at least 10 minutes.

b. Select range which instrument is to be calibrated on. Note: ranges below 0.3 mW require a precise differential voltmeter capable of resolving 1  $\mu$ V. The HP 740B DC Standard/A Voltmeter, which has an accuracy of  $\pm(0.005\%$  of reading  $\pm 0.0004\%$  of range  $\pm 1\mu$ V) is recommended. A digital voltmeter is adequate for the 1.0 mW and higher ranges.

c. Connect Differential Voltmeter (or DVM differentially) between the VCOMP and VRF output jacks on the rear panel. See Figure 3-3 for location of VRF and VCOMP outputs.

d. While pressing the FINE ZERO switch, measure and record V0. (V. is the difference of the bridge voltages with no power applied.)

e. Turn COARSE ZERO control (on front panel) clockwise to a convenient power, e.g., 9 on the zero to 10 scale or 2 on the 0 to 3 scale.

f. Differentially measure and record V1. V1 is the difference voltage between VCOMP and VRF with power applied.

g. Measure and record VCOMP. Note that the VCOMP jack is isolated from chassis ground; measure from the center conductor of the BNC to the outer conductor.

**Note.** Calibration will be performed in the AN/TSM-55V5 Maintenance Calibration Equipment Shelter.



INSTRUMENT SERIAL NO. \_\_\_\_\_

DATE \_\_\_\_\_

**TABLE 5-4. PERFORMANCE TEST CARD**

Data in this test card corresponds to Performance Tests in Paragraphs 5-16 through 5-20.

TABLE 5-4. PERFORMANCE TEST CARD

| Para. Ref. | Test                                                     | Measurement Unit | Min.  | Actual | Max.  |
|------------|----------------------------------------------------------|------------------|-------|--------|-------|
| 5-16       | <u>METER ACCURACY</u>                                    |                  |       |        |       |
| e          | 0.01 mW applied; measure RECORDER OUT voltage            | mVdc             | 990   | _____  | 1010  |
| f          | Meter indicates full-scale (0-1 scale)                   | divisions        | -1/2  | _____  | + 1/2 |
|            | <u>Repeat on remaining 432A power ranges:</u>            |                  |       |        |       |
| e          | Power applied: 0.03 mW                                   | mVdc             | 938.8 | _____  | 958.8 |
| f          | Meter indication (0-3 scale)                             | divisions        | -1/2  | _____  | + 1/2 |
| e          | Power applied: 0.1 mW                                    | mVdc             | 990   | _____  | 1010  |
| f          | Meter indication (0-1 scale)                             | divisions        | -1/2  | _____  | +1/2  |
| e          | Power applied: 0.3 mW                                    | mVdc             | 938.8 | _____  | 958.8 |
| f          | Meter indication (0-3 scale)                             | divisions        | -1/2  | _____  | +1/2  |
| e          | Power applied: 1 mW                                      | mVdc             | 990   | _____  | 1010  |
| f          | Meter indication (0-1 scale)                             | divisions        | -1/2  | _____  | + 1/2 |
| e          | Power applied: 3 mW                                      | mVdc             | 938.8 | _____  | 958.8 |
| f          | Meter indication (0-3 scale)                             | divisions        | -1/2  | _____  | +1/2  |
| e          | Power applied: 10 mW                                     | mVdc             | 990   | _____  | 1010  |
| f          | Meter indication (0-1 scale)                             | divisions        | -1/2  | _____  | + 1/2 |
| 5-17       | <u>CALIBRATION FACTOR</u>                                |                  |       |        |       |
| i          | <u>Calibration Factor (%)</u> <u>DVM Reading (mVdc )</u> |                  |       |        |       |
|            | 88                                      1000             | mVdc             | 990   | _____  | 1010  |
|            | 89                                      989              | mVdc             | 979   | _____  | 999   |
|            | 90                                      978              | mVdc             | 968   | _____  | 988   |
|            | 91                                      967              | mVdc             | 957   | _____  | 977   |
|            | 92                                      957              | mVdc             | 947   | _____  | 967   |
|            | 93                                      946              | mVdc             | 936   | _____  | 956   |
|            | 94                                      935              | mVdc             | 925   | _____  | 945   |
|            | 95                                      926              | mVdc             | 916   | _____  | 936   |
|            | 96                                      916              | mVdc             | 906   | _____  | 926   |
|            | 97                                      907              | mVdc             | 897   | _____  | 917   |
|            | 98                                      897              | mVdc             | 887   | _____  | 907   |
|            | 99                                      889              | mVdc             | 879   | _____  | 899   |
|            | 100                                     880              | mVdc             | 870   | _____  | 890   |

TABLE 5-4. PERFORMANCE TEST CARD

| Para.<br>Ref. | Test                                                       | Measurement<br>Unit | Min. | Actual | Max. |
|---------------|------------------------------------------------------------|---------------------|------|--------|------|
| 5-18          | <u>METER LINEARITY</u>                                     |                     |      |        |      |
| c             | 1 mW applied, 3 mW scale: meter indicates 1 mW             | divisions           | -1/2 | _____  | +1/2 |
| e             | 2 mW applied, 3 mW scale: meter indicates 2 mW             | divisions           | -1/2 | _____  | +1/2 |
| g             | 3 mW applied, 3 mW scale: meter indicates 3 mW             | divisions           | -1/2 | _____  | +1/2 |
| 5-19          | <u>ZERO CARRY-OVER</u>                                     |                     |      |        |      |
| d             | Zero carry-over:                                           |                     |      |        |      |
|               | <u>Range (mW)</u> <u>Scope Indication</u>                  |                     |      |        |      |
|               | .01                      0 ±5 mVdc                         | mVdc                | -5   | _____  | +5   |
|               | .03                      0 ±5 mVdc                         | mVdc                | -5   | _____  | +5   |
|               | .1                        0 ±5 mVdc                        | mVdc                | -5   | _____  | +5   |
|               | .3                        0 ±5 mVdc                        | mVdc                | -5   | _____  | +5   |
|               | 1                         0 ±5 mVdc                        | mVdc                | -5   | _____  | +5   |
|               | 3                         0 ±5 mVdc                        | mVdc                | -5   | _____  | +5   |
|               | 10                        0 ±5 mVdc                        | mVdc                | -5   | _____  | +5   |
| 5-20          | <u>FINE ZERO RANGE</u>                                     |                     |      |        |      |
| f             | Meter indication on 1-3 scale:                             | divisions           | 1.75 | _____  | 2.0  |
| g             | Meter indication on 1-3 scale: 1.5+ 1/2 reading of step f. | divisions           |      | _____  | 1.5  |

h. Calculate the power using the following formula?\*

$$P = \frac{1}{4R} \left[ 2V_{\text{COMP}} (V_1 - V_0) - V_1^2 \right] \quad (1)$$

where R is the resistance of the thermistor mount and should be identical to the setting of the MOUNT RESISTANCE switch.

i. If calculated power is different from the value that was set with the COARSE ZERO control, adjust A2R6 so that the meter reads calculated power. If the range of A2R6 is insufficient to set new power, it will be necessary to change the value of A2R70.

j. Set COARSE ZERO so that meter reads one on the 0 to 1 scale. Set A2R72 for 1.000 V ± 10 mV at the RECORDER output jack on the rear panel.

5-25. There is a simpler form of the equation that was used to calculate power in step h above. This form ignores  $V_0$ , the small voltage difference between the two bridges with no power applied. However,  $V_0$  becomes negligible on the higher ranges, that is, 1 mV and above, and can be ignored with little decrease in accuracy. The simpler form is as follows:

$$P = \frac{1}{4R} (V_C - V_{\text{RF}}) (V_C + V_{\text{RF}}) \quad (2)$$

#### 5-26. CALIBRATION PROCEDURE 2.

a. Connect thermistor mount to power meter; let instrument warm up for at least 10 minutes.

b. Select 1, 3, or 10 mW range.

c. Turn the COARSE ZERO control clockwise to indicate some convenient on-scale reading.

d. Measure  $V_{\text{COMP}}$  and record. Note that  $V_{\text{COMP}}$  jack is isolated from chassis ground; measure from the center conductor of the BNC to the outer conductor.

e. Measure  $V_{\text{RF}}$  and record. Follow measurement procedure in step d.

f. Measure and record  $V_{\text{COMP}} - V_{\text{RF}}$ . This term must be measured differentially, that is, one side of the DVM connected to  $V_{\text{COMP}}$  and the other side connected to  $V_{\text{RF}}$ . In this way the full resolution of the DVM can be used.

g. Substituting the measured values into the above formula, calculate the power,

h. If calculated power is different from the power set with the COARSE ZERO control, adjust A2R6 so that meter indicates that power. If the range of A2R6 is not great enough to set new power level, the value of A2R70 will have to be changed.

i. Adjust COARSE ZERO so that meter reads 1 on the 0 to 1 scale. Set A2R72 for 1.000 V ± 10 mV at the RECORDER output jack on the rear panel.

\*This formula is accurate for on-scale readings; however, with no power applied (i. e.,  $V_1 = V_0$ ) it does not solve to  $P = 0$  because of a deleted term  $+ V_0$ . This term can be neglected for any on-scale reading.

#### 5-27. COVER REMOVAL AND REPLACEMENT.

5-28. The side covers can be removed and replaced independently of the top and bottom covers. Each side cover is held in place by four screws retained by nuts which are fastened to the side frames.

#### 5-29. TOP COVER REMOVAL.

a. At the rear of the instrument, remove the screw that retains the cover.

b. Grasp the cover from the rear, and slide it back 1/2 inch. Then tilt forward edge of the cover upward and lift the cover from the instrument.

#### 5-30. TOP COVER REPLACEMENT.

a. Rest the cover flat on the cast guides projecting inward near the top of each side frame.

b. Slide the cover forward, allowing its forward edge to enter the groove in the front panel.

c. Replace the cover retaining screw.

#### 5-31. BOTTOM COVER REMOVAL.

a. Remove the retaining screw at the rear of the cover.

b. Swing the tilt stand out to free the cover

c. Slide the cover rearward far enough to free the forward edge.

d. Tilt the forward edge of the cover upward and lift the cover from the instrument.

#### 5-32. BOTTOM COVER REPLACEMENT.

a. Set the tilt stand out of the way of the cover

b. Rest the bottom cover flat on the cast guides projecting inward near the bottom of each side frame.

c. Slide the cover forward on the guides so that the formed portion at the rear of the cover slides over the two short projections at the rear corner of each side frame.

d. Replace the retaining screw.

#### 5-33. ADJUSTMENT PROCEDURES.

#### 5-34. INITIAL SETUP.

a. Remove the power meter side panels.

b. Connect the equipment as shown in Figure 5-1. Refer to Table 5-1 for equipment specifications.

#### 5-35. MECHANICAL METER ADJUSTMENT.

a. When the meter is properly zero-set, the pointer rests over the zero mark on the meter scale when the instrument is:

- (1) at normal operating temperature
- (2) in its normal operating position
- (3) turned off

b. Set the pointer as follows to obtain best accuracy and mechanical stability:

- (1) Turn instrument off.
- (2) Rotate the meter mechanical adjustment screw clockwise until the meter pointer is to the left of zero and moving up the scale toward zero. Stop when the pointer is exactly over the zero mark. If the pointer overshoots, repeat step 2.
- (3) When the pointer is exactly on zero, rotate the adjustment screw approximately 3 degrees counterclockwise. This frees the adjustment screw from the meter suspension. If the pointer moves during this step, repeat steps 2 and 3.

#### 5-36. BRIDGE AMPLIFIER TESTS

a. Connect equipment as shown in Figure 5-3.

b. Compensation Bridge.

1. Connect 3440A/3443A between A1TP5 and A1TP6 (using 10K isolation resistors).

2. Make the following settings:

432A  
RANGE .....10mW  
MOUNT RESISTANCE .....200Ω  
8477A  
FUNCTION ..... SET

3. Adjust A1R12 (OFFSET ADJUST) for 0.0 ±0.1 mV dc reading on the digital voltmeter.
4. Change 8477A FUNCTION to CHECK. The digital VM reading should not exceed ±0.4 mVdc.

c. RF BRIDGE

1. Connect DVM between A1TP3 and A1TP4 using 10 kΩ isolation resistors in series with the leads.
3. Set 8477A FUNCTION to SET. Adjust A1R15 (OFFSET ADJUST) for DVM reading of 0.0 ± 0.1 mVdc.

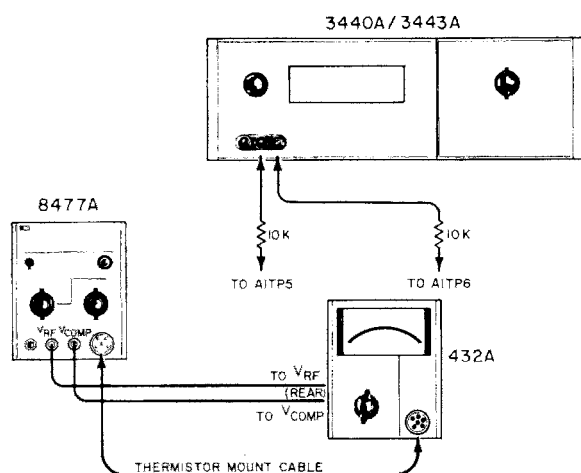


Figure 5-3. Bridge Amplifier Test

4. Change 8477A FUNCTION to CHECK. The reading should not exceed ±0.4 mVdc.

Note: Failure of the instrument to meet the specification of steps (4) of b and c above indicates insufficient bridge gain. Refer to Table 7-3 or 7-4 in the troubleshooting section.

#### 5-37. METER AND RECORDER OUTPUT CALIBRATION

a. Connect the DVM to the 432A RECORDER output.

b. Set 8477A controls as follows:

FUNCTION .....200Ω  
ZERO/TEST ..... ZERO  
POWER .....1mw

c. Set 432A controls as follows:

MOUNT RES .....200Ω  
RANGE .....1mW  
CAL FACTOR ..... 100%

d. Adjust ZERO control on 8477A for DVM indication of 0.000 ±0.001V.

e. ZERO/TEST on 8477A to TEST

f. Adjust A2R6 in 432A for 432A meter reading of 1.0 mW ±0.1 mW.

g. Adjust A2R74 in 432A for DVM reading of 1.0V ±0.001V

h. Change the following settings:

432A RANGE to 10 mW  
8477A POWER (mW) to 10 mW and ZERO/TEST to ZERO.

Note: When switching 432A to 10 mW or switching from 10 mW to any other range, the meter will react slowly for a short period. This is due to time constants in the instrument and is normal.

i. Zero instrument as in step d and c.

j. Adjust A2R86 for DVM reading of 1.00 ±0.00 IV.

k. Return 432A RANGE and 8477A POWER switches to 1 mW and zero as before.

1. Adjust A2R6 for DVM reading of 1.000 ±0.00 1V.

m. Perform the adjustments of steps h through 1 again until 432A reads 1 ±0.010V (at recorder output) on both 1 mW and 10 mW ranges.

n. Turn to the beginning of this section; verify that the instrument meets its specifications by completing the PERFORMANCE TESTS.

#### 5-38. BATTERY CHARGER ADJUSTMENT (OPTION 01 ONLY)

a. Remove the power meter top panel.

b. Connect 432A to ac line power and turn ON.

- c. Set A7R8 fully clockwise for maximum battery charge rate.
- d. With the digital voltmeter, measure the voltage between A7TP1 and A7TP2.
- e. Adjust A7R8 for digital voltmeter reading of 0.2 to 0.4 volts (20 to 40 mA through R3).
- f. Disconnect the test equipment and power and replace the power meter top and side panels.

#### 5-39. BATTERY REMOVAL

- a. Remove the top cover.
- b. Remove the two Phillips screws on the top rear of the battery cover.
- c. Lift off the battery cover.
- d. Loosen the nuts on the battery binding posts.
- e. Lift out the battery.

#### 5-40. ISOLATING TROUBLE IN TRANSISTOR CIRCUITS.

5-41. General. The following information should help determine if a transistor works. There are tests for both in-circuit and out-of-circuit transistors, which help to determine if a particular trouble is due to a faulty transistor or some other component. See Figure 5-2.

5-42. hi-circuit Testing. Intransistor Circuit testing the most important consideration is the transistor base-emitter junction. Like the control grid of a vacuum tube, this is the control point in the transistor.

5-43. To check a transistor, first see if the emitter-base diode is forward-biased by measuring the voltage difference between emitter and base. When using an electronic voltmeter, do not measure directly between emitter and base; there may be sufficient loop current between the voltmeter lead to damage the transistor. Instead, measure each voltage separately with respect to a voltage common point (e.g., chassis).

5-44. If the transistor base-emitter junction is forward-biased, the transistor conducts. If the diode is heavily forward-biased, the transistor saturates. However, if the base-emitter diode is reverse-biased, the transistor is cut off (open). The voltage drop across a forward-biased emitter-base junction varies with transistor collector current. A germanium transistor has a typical base-emitter voltage of 0.2-0.3 volt with 1-10 mA collector current, and 0.4-0.5 volt with 10-100 mA collector current. In contrast, base-emitter voltage for silicon transistors is about twice that for germanium types; about 0.5-0.6 volt for low collector current, and about 0.8-0.9 for high collector current.

5-45. If the emitter base-junction is forward-biased, check for amplifier action by short-circuiting base to emitter while observing collector voltage. The transistor should stop conduction (cut off), which should shift the collector voltage close to the supply voltage. Any difference is due to current leadage through the transistor. In general, the smaller the current, the better the transistor. If collector voltage does not change, the transistor has either an emitter-collector short circuit or emitter-base open circuit.

#### 5-46. OUT-OF-CIRCUIT TESTING,

5-47. The two common causes of transistor failure are internal short - and open-circuits. Remove the transistor from the circuit and use an ohmmeter to measure internal resistance. See Table 5-5 for measurement data.

Table 5-5. Out-of-Circuit Transistor Resistance Measurements

| Transistor Type                                                                                  |              | Connect Ohmmeter |                  | Measure Resistance (ohms)   |
|--------------------------------------------------------------------------------------------------|--------------|------------------|------------------|-----------------------------|
|                                                                                                  |              | Positive Lead to | Negative Lead to |                             |
| PNP Germanium                                                                                    | Small Signal | emitter          | base *           | 200-500                     |
|                                                                                                  |              | emitter          | collector        | 10K - 100K                  |
|                                                                                                  | Power        | emitter          | base*            | 30 - 50                     |
|                                                                                                  |              | emitter          | collector        | several hundred             |
| NPN Silicon                                                                                      | Small Signal | base             | emitter          | 1K - 3K                     |
|                                                                                                  |              | collector        | emitter          | very high (might read open) |
|                                                                                                  | Power        | base             | emitter          | 200 -1000                   |
|                                                                                                  |              | collector        | emitter          | high, often greater than 1M |
| * To test for transistor action, add collector -base short. Measured resistance should decrease. |              |                  |                  |                             |

| DEVICE         | SYMBOL | CUT OFF | CONDUCTING |
|----------------|--------|---------|------------|
| NPN TRANSISTOR |        |         |            |
| PNP TRANSISTOR |        |         |            |

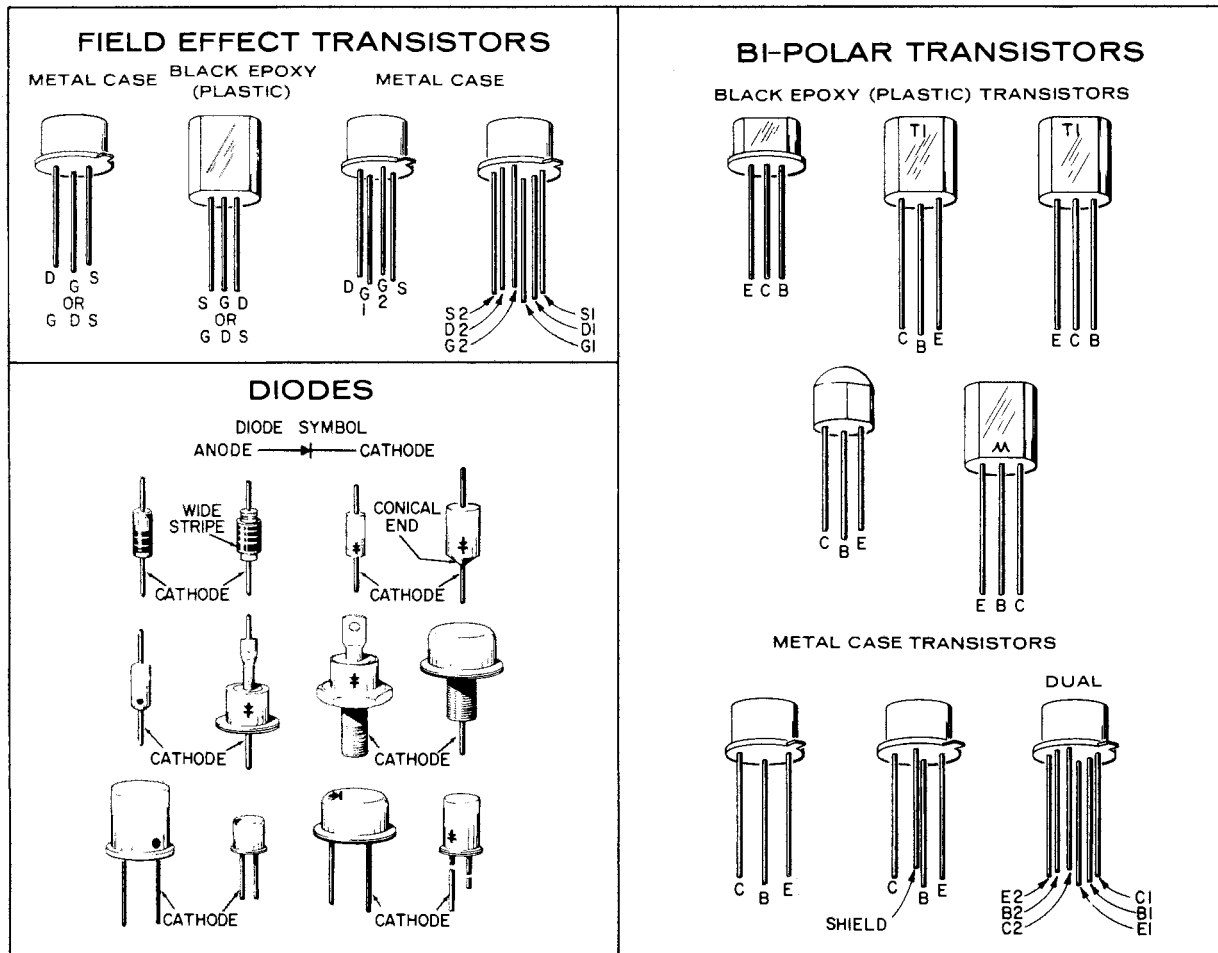


Figure 5-4. Transistor Biasing and Operating Characteristics

Table 5-6. Etched Circuit Soldering Equipment

| Item                                    | Use                                                                                     | Specification                                                                            | Item Recommended                                                                                                       |
|-----------------------------------------|-----------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------|
| Soldering Tool                          | Soldering, unsoldering                                                                  | Wattage rating: 37.5<br>Tip temp: 750-800°F<br>Tip size: 1/8" OD                         | Ungar #776 handle with<br>Ungar #1237                                                                                  |
| Soldering Tip,<br>General Purpose       | Soldering, unsoldering                                                                  | Shape: chisel<br>Size: 1/8"                                                              | Ungar #PL113                                                                                                           |
| De-soldering Aid                        | Unsoldering multiconnection<br>components                                               | Suction device to remove<br>molten solder from connection                                | Soldapult by the Edsyn<br>Company, Arleta, Calif.                                                                      |
| Resin (flux)<br>Solvent                 | Remove excess flux from<br>soldered area before appli-<br>cation of protective coating. | Must not dissolve etched cir-<br>cuit base board material or<br>conductor bonding agent. | Freon, Acetone, Lacquer<br>Thinner, Isopropyl Alco-<br>hol (100% dry)                                                  |
| Solder                                  | Component replacement,<br>circuit board repair, wiring                                  | Resin (flux) core, high tin con-<br>tent (60/40 tin/lead), 18 gauge<br>(SWG) preferred   |                                                                                                                        |
| Protective<br>Coating                   | Contamination, corrosion<br>protection after soldering                                  | Good electrical insulation,<br>corrosion-prevention<br>properties                        | Krylon #1302*, Humiseal<br>Protective Coating, Type<br>1B12 by Columbia Tech-<br>nical Corp., Woodside 77,<br>New York |
| *Krylon, Inc., Norristown, Pennsylvania |                                                                                         |                                                                                          |                                                                                                                        |

Table 5-7. Safe Ohmmeter Range for Transistor Resistance Measurements

| Ohmmeter           | Safe Range(s)                                         | Open Circuit Voltage                      | Short Circuit Current                                               | Lead                         |          |
|--------------------|-------------------------------------------------------|-------------------------------------------|---------------------------------------------------------------------|------------------------------|----------|
|                    |                                                       |                                           |                                                                     | Color                        | Polarity |
| HP 412A<br>HP 427A | R x 1 k<br>R x 10 k<br>R x 100 k<br>R x 1M<br>R x 10M | 1.0 V<br>1.0 V<br>1.0 V<br>1.0 V<br>1.0 V | 1 mA<br>100 $\mu$ A<br>10 $\mu$ A<br>1 $\mu$ A<br>0.1 $\mu$ A       | Red<br>Black                 | +<br>-   |
| HP 410C            | R x 1 k<br>R x 10 k<br>R x 100 k<br>R x 1M<br>R x 10M | 1.3 V<br>1.3 V<br>1.3 V<br>1.3 V<br>1.3 V | 0.57 mA<br>57 $\mu$ A<br>5.7 $\mu$ A<br>0.5 $\mu$ A<br>0.05 $\mu$ A | Red<br>Black                 | +<br>-   |
| HP 410B            | R x 100<br>R x 1 k<br>R x 10 k<br>R x 100 k<br>R x 1M | 1.1 V<br>1.1 V<br>1.1 V<br>1.1 V<br>1.1 V | 1.1 mA<br>110 $\mu$ A<br>11 $\mu$ A<br>1.1 $\mu$ A<br>0.11 $\mu$ A  | Black<br>Red                 | +<br>-   |
| Simpson 260        | R x 100                                               | 1.5 V                                     | 1 mA                                                                | Red<br>Black                 | +<br>-   |
| Simpson 269        | R x 1 k                                               | 1.5 V                                     | 0.82 mA                                                             | Black<br>Red                 | +<br>-   |
| Triplet 630        | R x 100<br>R x 1 k                                    | 1.5 V<br>1.5 V                            | 3.25 mA<br>325 $\mu$ A                                              | Varies with<br>Serial Number |          |
| Triplet 310        | R x 10<br>R x 100                                     | 1.5 V<br>1.5 V                            | 750 $\mu$ A<br>75 $\mu$ A                                           |                              |          |

**5-48. COMPONENT REPLACEMENT IN  
ETCHED CIRCUITS.**

5-49. General. Etched circuit boards are sensitive to heat and to scratches with sharp objects. This is because the conductors are plated on to the circuit boards and the plating extends through the component mounting holes. Whenever possible, avoid unnecessary component substitution; it can damage the circuit board and adjacent components. See Table 5-6 for recommended tools and materials.

**5-50. AXIAL-LEAD COMPONENTS .**

5-51. Resistors, tubular capacitors and other axial-lead components can be replaced without unsoldering. Cut the component leads near the body of the defective component, remove the component and straighten the leads left in the board. Wrap leads of the replacement component one turn around the original leads, solder the connection, and clip off the excess lead.

**5-52. OTHER COMPONENTS.**

5-53. Replace other components as follows:

a. Remove defective component from circuit board. Use a low-power soldering iron because excessive heat may lift a conductor or damage the board.

b. Remove solder from mounting holes with a suction device or a wooden toothpick. DO NOT USE A SHARP METAL OBJECT SUCH AS AN AWL OR TWIST DRILL. SHARP OBJECTS MAY DAMAGE THE PLATED-THROUGH CONDUCTOR.

c. Shape the leads of the replacement component to match the mounting-hole spacing.

d. Insert the component leads in the mounting holes and position it as the original was. DO NOT FORCE LEADS OF REPLACEMENT COMPONENT INTO MOUNTING HOLES. A sharp edge on the lead may damage the plated -through conductor.

e. Solder the component in place and remove excess flux from the soldered areas. Apply a protective coating to prevent contamination and corrosion. See Table 5-6 for recommendations.

**CAUTION**

Most ohmmeters can supply enough current or voltage to damage a transistor. Before using an ohmmeter to measure transistor forward or reverse resistance, check its open -circuit voltage and short -circuit current output ON THE RANGE TO BE USED. Open-circuit voltage must not exceed 1.5volts and short-circuit current must be less than 3 mA.



## SECTION VI

### REPLACEABLE PARTS

#### 6-1. INTRODUCTION.

6-2. This section contains information for ordering replacement parts. Table 6-1 lists parts in alpha-numerical order of their reference designators and indicates the description and HP stock number of each part, together with any applicable notes. Miscellaneous parts are listed at the end of Table 6-1, Table 6-2 lists parts in alpha-numerical order of their HP stock number and provides the following information on each part:

- a. Description.
- b. Manufacturer of the part in a five-digit code; see list of manufacturers in Table 6-3.
- c. Manufacturer's part number.
- d. Total quantity used (TQ column).

#### 6-3. ORDERING INFORMATION.

6-4. To obtain replacement parts for Power Meter 432A, refer to Appendix

D, table D-1, Repair Parts List.

6-5. 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.

#### REFERENCE DESIGNATORS

|    |                           |    |                      |    |                   |    |                                            |
|----|---------------------------|----|----------------------|----|-------------------|----|--------------------------------------------|
| A  | = assembly                | F  | = fuse               | MP | = mechanical part | V  | = vacuum, tube, neon bulb, photocell, etc. |
| B  | = motor                   | FL | = filter             | P  | = plug            | VR | = voltage regulator                        |
| BT | = battery                 | IC | = integrated circuit | Q  | = transistor      | W  | = cable                                    |
| C  | = capacitor               | J  | = jack               | R  | = resistor        | X  | = socket                                   |
| CP | = coupler                 | K  | = relay              | RT | = thermistor      | Y  | = crystal                                  |
| CR | = diode                   | L  | = inductor           | S  | = switch          | Z  | = tuned cavity, network                    |
| DL | = delay line              | LS | = loud speaker       | T  | = transformer     |    |                                            |
| DS | = device signaling (lamp) | M  | = meter              | TB | = terminal board  |    |                                            |
| E  | = misc electronic part    | MK | = microphone         | TP | = test point      |    |                                            |

#### ABBREVIATIONS

|       |                               |         |                            |        |                                                         |         |                            |
|-------|-------------------------------|---------|----------------------------|--------|---------------------------------------------------------|---------|----------------------------|
| A     | = amperes                     | H       | = henries                  | N/O    | = normally open                                         | RMO     | = rack mount only          |
| AFC   | = automatic frequency control | HDW     | = hardware                 | NPO    | = negative positive zero (zero temperature coefficient) | RMS     | = root-mean square         |
| AMPL  | = amplifier                   | HEX     | = hexagonal                |        |                                                         | RWV     | = reverse working voltage  |
| BFO   | = beat frequency oscillator   | HG      | = mercury                  | NPN    | = negative-positive-negative                            | S-B     | = slow-blow                |
| BE CU | = beryllium copper            | HR      | = hour(s)                  | NRFR   | = not recommended for field replacement                 | SCR     | = screw                    |
| BH    | = binder head                 | HZ      | = hertz                    | NSR    | = not separately replaceable                            | SE      | = selenium                 |
| BP    | = bandpass                    | IF      | = intermediate freq        |        |                                                         | SECT    | = section(s)               |
| BRS   | = brass                       | IMPG    | = impregnated              |        |                                                         | SEMICON | = semiconductor            |
| BWO   | = backward wave oscillator    | INCD    | = incandescent             |        |                                                         | SI      | = silicon                  |
| CCW   | = counter-clockwise           | INCL    | = include(s)               | OBD    | = order by description                                  | SIL     | = silver                   |
| CER   | = ceramic                     | INS     | = insulation(ed)           | OH     | = oval head                                             | SL      | = slide                    |
| CMO   | = cabinet mount only          | INT     | = internal                 | OX     | = oxide                                                 | SPG     | = spring                   |
| COEF  | = coefficient                 | K       | = kilo = 1000              | P      | = peak                                                  | SPL     | = special                  |
| COM   | = common                      | LH      | = left hand                | PC     | = printed circuit                                       | SST     | = stainless steel          |
| COMP  | = composition                 | LIN     | = linear taper             | PF     | = picofarads = 10 <sup>-12</sup>                        | SR      | = split ring               |
| COMPL | = complete                    | LK WASH | = lock washer              | PH BRZ | = phosphor bronze                                       | STL     | = steel                    |
| CONN  | = connector                   | LOG     | = logarithmic taper        | PHL    | = Phillips                                              | TA      | = tantalum                 |
| CP    | = cadmium plate               | LPF     | = low pass filter          | PIV    | = peak inverse voltage                                  | TD      | = time delay               |
| CRT   | = cathode-ray tube            | M       | = milli = 10 <sup>-3</sup> | PNP    | = positive-negative-positive                            | TGL     | = toggle                   |
| CW    | = clockwise                   | MEG     | = meg = 10 <sup>6</sup>    | P/O    | = part of                                               | THD     | = thread                   |
| DEPC  | = deposited carbon            | MET FLM | = metal film               | POLY   | = polystyrene                                           | TI      | = titanium                 |
| DR    | = drive                       | MET OX  | = metallic oxide           | PORC   | = porcelain                                             | TOL     | = tolerance                |
| ELECT | = electrolytic                | MFR     | = manufacturer             | POS    | = position(s)                                           | TRIM    | = trimmer                  |
| ENCAP | = encapsulated                | MHZ     | = mega hertz               | POT    | = potentiometer                                         | TWT     | = traveling wave tube      |
| EXT   | = external                    | MINAT   | = miniature                | PP     | = peak-to-peak                                          | U       | = micro = 10 <sup>-6</sup> |
| F     | = farads                      | MOM     | = momentary                | PT     | = point                                                 | VAR     | = variable                 |
| FH    | = flat head                   | MTG     | = mounting                 | PWV    | = peak working voltage                                  | VDCW    | = dc working volts         |
| FIL H | = fillister head              | MY      | = "mylar"                  | RECT   | = rectifier                                             | W/W     | = with watts               |
| FXD   | = fixed                       | N       | = nano (10 <sup>-9</sup> ) | RF     | = radio frequency                                       | WIV     | = working inverse voltage  |
| G     | = giga (10 <sup>9</sup> )     | N/C     | = normally closed          | RH     | = round head or right hand                              | WW      | = wirewound                |
| GE    | = germanium                   | NE      | = neon                     |        |                                                         | W/O     | = without                  |
| GL    | = glass                       | NI PL   | = nickel plate             |        |                                                         |         |                            |
| GRD   | = ground(ed)                  |         |                            |        |                                                         |         |                            |

Table 6-1. Reference Designation Index

| Reference Designation | Part No.   | Description #                                        | Note |
|-----------------------|------------|------------------------------------------------------|------|
| A1                    | 00432-6001 | BOARD AS SY:BRIDGE                                   |      |
|                       | 00432-2001 | BOARD: BLANK PC                                      |      |
| A1C1                  | 0180-0374  | C:FXD ELECT 10 UF 10% 20VDCW                         |      |
| A1C2                  | 0160-2930  | C:FXD CER 0.01 UF +80-20% 100VDCW                    |      |
| A1C3                  | 0160-2930  | C:FXD CER 0.01 UF +80-20% 100VDCW                    |      |
| A1C4                  | 0160-0380  | C:FXD MY 0.22 UF 10% 200VDCW                         |      |
| A1C5                  | 0160-2930  | C:FXD CER 0.01 UF +80-20% 100VDCW                    |      |
| A1C6                  | 0160-2930  | C:FXD CER 0.01 UF +80-20% 100VDCW                    |      |
| A1C7                  | 0160-2930  | C:FXD CER 0.01 UF +80-20% 100VDCW                    |      |
| A1C8                  | 0160-0380  | C:FXD MY 0.22 UF 10% 200VDCW                         |      |
| A1C9                  | 0160-2930  | C:FXD CER 0.01 UF +80-20% 100VDCW                    |      |
| A1C10                 | 0160-2930  | C:FXD CER 0.01 UF +80-20% 100VDCW                    |      |
| A1C11                 | 0160-2930  | C:FXD CER 0.01 UF +80-20% 100VDCW                    |      |
| A1C12                 | 0180-0374  | C:FXD ELECT 10 UF 10% 20VDCW                         |      |
| A1C13                 | 0160-2264  | C:FXD CER 20 PF 5% 500VDCW                           |      |
| A1C14                 | 0160-2264  | C:FXD CER 20 PF 5% 500VDCW                           |      |
| A1CR1                 | 1901-0040  | DIODE:SILICON 30MA 30WV                              |      |
| A1CR2                 | 1901-0040  | DIODE:SILICON 30MA 30WV                              |      |
| A1Q1                  | 1853-0020  | TRANSISTOR:SILICON PNP                               |      |
| A1Q2                  | 1853-0020  | TRANSISTOR:SILICON PNP                               |      |
| A1Q3                  | 1853-0020  | TRANSISTOR:SILICON PNP                               |      |
| A1Q4                  | 1854-0071  | TRANSISTOR:SILICON NPN                               |      |
| A1Q5                  | 1854-0071  | TRANSISTOR:SILICON NPN                               |      |
| A1Q6                  | 1853-0001  | TRANSISTOR:PNP SILICON 30V 900MW                     |      |
| A1Q7                  | 1854-0221  | TRANSISTOR DUAL:SILICON NPN<br>FACTORY SELECTED PART |      |
| A1Q8                  | 1854-0071  | TRANSISTOR:SILICON NPN                               |      |
| A1Q9                  | 1854-0071  | TRANSISTOR:SILICON NPN                               |      |
| A1Q10                 | 1854-0071  | TRANSISTOR:SILICON NPN                               |      |
| A1Q11                 | 1853-0001  | TRANSISTOR:PNP SILICON 30V 900MW                     |      |
| A1Q12                 | 1854-0221  | TRANSISTOR DUAL:SILICON NPN<br>FACTORY SELECTED PART |      |
| A1Q13                 | 1854-0071  | TRANSISTOR:SILICON NPN                               |      |
| A1Q14                 | 1853-0020  | TRANSISTOR: SILICON PNP                              |      |
| A1Q15                 | 1853-0020  | TRANSISTOR:SILICON PNP                               |      |
| A1R1                  | 0698-3260  | R:FXD MET FLM 464K OHM 1% 1/8W                       |      |
| A1R2                  | 0686-1055  | R:FXD COMP 1 MEGOHM 5% 1/2W                          |      |
| A1R3                  | 0698-3160  | R:FXD MET FLM 31.6K OHM 1% 1/8W                      |      |
| A1R4                  |            | NOT ASSIGNED                                         |      |
| A1R5                  | 0698-3160  | R:FXD MET FLM 31.6K OHM 1% 1/8W                      |      |
| A1R6                  | 0698-3160  | R:FXD MET FLM 31.6K OHM 1% 1/8W                      |      |

# See introduction to this section for ordering information

Table 6-1. Reference Designation Index (Cont'd)

| Reference Designation | Part No.   | Description #                   | Note |
|-----------------------|------------|---------------------------------|------|
| A1R7                  | 0698-3156  | R:FXD MET FLM 14.7K OHM 1% 1/8W |      |
| A1R8                  | 0757-0465  | R:FXD MET FLM 100K OHM 1% 1/8W  |      |
| A1R9                  | 0698-3136  | R:FXD MET FLM 17.8K OHM 1% 1/8W |      |
| A1R10                 | 0698-3441  | R:FXD MET FLM 215 OHM 1% 1/8W   |      |
| A1R11                 | 0757-0416  | R:FXD MET FLM 511 OHM 1% 1/8W   |      |
| A1R12                 | 2100-1770  | R:VAR WW 100 OHM 10% LIN 1/2W   |      |
| A1R13                 | 0757-0461  | R:FXD MET FLM 68.1K OHM 1% 1/8W |      |
| A1R14                 | 0811-2284  | R:FXD WW 1K OHM 0.1% 1/40W      |      |
| A1R15                 | 2100-1770  | R:VAR WW 100 OHM 10% LIN 1/2W   |      |
| A1R16                 | 0811-2284  | R:FXD WW 1K OHM 0.1% 1/40W      |      |
| A1R17                 | 0757-0199  | R:FXD MET FLM 21.5K OHM 1% 1/8W |      |
| A1R18                 |            | NOT ASSIGNED                    |      |
| A1R19                 | 0698-3441  | R:FXD MET FLM 215 OHM 1% 1/8W   |      |
| A1R20                 | 0698-3160  | R:FXD MET FLM 31.6K OHM 1% 1/8W |      |
| A1R21                 | 0698-3160  | R:FXD MET FLM 31.6K OHM 1% 1/8W |      |
| A1R22                 | 0698-3156  | R:FXD MET FLM 14.7K OHM 1% 1/8W |      |
| A1R23                 | 0757-0465  | R:FXD MET FLM 100K OHM 1% 1/8W  |      |
| A1R24                 | 0757-0416  | R:FXD MET FLM 511 OHM 1% 1/8W   |      |
| A1R25                 |            | NOT ASSIGNED                    |      |
| A1R26                 | 0757-0461  | R:FXD MET FLM 68.1K OHM 1% 1/8W |      |
| A1R27                 | 0811-2284  | R:FXD WW 1K OHM 0.1% 1/40W      |      |
| A1R28                 | 0757-0199  | R:FXD MET FLM 21.5K OHM 1% 1/8W |      |
| A1R29                 | 0811-2284  | R:FXD WW 1K OHM 0.1% 1/40W      |      |
| A1R30                 | 0757-0199  | R:FXD MET FLM 21.5K OHM 1% 1/8W |      |
| A1R31                 | 0698-3260  | R:FXD MET FLM 464K OHM 1% 1/8W  |      |
| A1R32                 |            | NOT ASSIGNED                    |      |
| A1R33                 | 0757-0465  | R:FXD MET FLM 100K OHM 1% 1/8W  |      |
| A1R34                 | 0757-0465  | R:FXD MET FLM 100K OHM 1% 1/8W  |      |
| A1R35                 | 0757-0442  | R:FXD MET FLM 10.0K OHM 1% 1/8W |      |
| A1R36                 | 0757-0279  | R:FXD MET FLM 3.16K OHM 1% 1/8W |      |
| A1R37                 | 0757-0279  | R:FXD MET FLM 3.16K OHM 1% 1/8W |      |
| A1R38                 | 0757-0279  | R:FXD MET FLM 3.16K OHM 1% 1/8W |      |
| A1R39                 | 0757-0279  | R:FXD MET FLM 3.16K OHM 1% 1/8W |      |
| A1R40                 | 0698-3160  | R:FXD MET FLM 31.6K OHM 1% 1/8W |      |
| A1R41                 | 0698-3160  | R:FXD MET FLM 31.6K OHM 1% 1/8W |      |
| A1R42                 |            | NOT ASSIGNED                    |      |
| A1R43                 | 0757-0442  | R:FXD MET FLM 10.0K OHM 1% 1/8W |      |
| A1                    | 0360-0124  | TERMINAL:SOLDER LUG             |      |
| A1A1                  | 00432-6011 | ASSY:AUTO ZERO                  |      |

# See introduction to this section for ordering information

Table 6-1. Reference Designation Index (Cont'd)

| Reference Designation | Part No.   | Description #                     | Note |
|-----------------------|------------|-----------------------------------|------|
| A2                    | 00432-6015 | BOARD ASSY: LOGIC                 |      |
|                       | 00432-2015 | BOARD: BLANK PC                   |      |
| A2C1                  | 0180-1819  | C:FXD ELECT 100 UF +75-10% 50VDCW |      |
| A2C2                  | 0180-0229  | C:FXD ELECT 33 UF 10% 10VDCW      |      |
| A2C3                  | 0160-2917  | C:FXD CER 0.05 UF +80-20% 100VDCW |      |
| A2C4                  |            | NOT ASSIGNED                      |      |
| A2C5                  | 0160-2917  | C:FXD CER 0.05 UF +80-20% 100VDCW |      |
| A2C6-                 |            | NOT ASSIGNED                      |      |
| A2C20                 |            | NOT ASSIGNED                      |      |
| A2C21                 | 0140-0234  | C:FXD MICA 500 PF 1%              |      |
| A2C22                 | 0140-0234  | C:FXD MICA 500 PF 1%              |      |
| A2C23                 | 0180-1746  | C:FXD ELECT 15 UF 10% 20VDCW      |      |
| A2C24                 |            | NOT ASSIGNED                      |      |
| A2C25                 | 0160-0978  | C:FXD MICA 1500 PF 1% 500VDCW     |      |
| A2C26                 | 0160-2930  | C:FXD CER 0.01 UF +80-20% 100VDCW |      |
| A2C27                 |            | NOT ASSIGNED                      |      |
| A2C28                 |            | NOT ASSIGNED                      |      |
| A2C29                 | 0180-2178  | C:FXD ELECT 220 UF 20% 8VDCW      |      |
| A2C30                 | 0160-2930  | C:FXD CER 0.01 UF +80-20% 100VDCW |      |
| A2C31                 | 0180-1940  | C:FXD ELECT 33 UF 10% 15VDCW      |      |
| A2C32                 |            | NOT ASSIGNED                      |      |
| A2C33                 | 0180-0197  | C:FXD ELECT 2.2 UF 10% 20VDCW     |      |
| A2C34                 | 0160-2672  | C:FXD MY 0.047 UF 5% 80VDCW       |      |
| A2C35                 | 0180-0197  | C:FXD ELECT 2.2 UF 10% 20VDCW     |      |
| A2C36                 | 0160-2917  | C:FXD CER 0.05 UF +80-20% 100VDCW |      |
| A2C37                 |            | NOT ASSIGNED                      |      |
| A2C38                 | 0160-2917  | C:FXD CER 0.05 UF +80-20% 100VDCW |      |
| A2C39                 | 0160-2150  | C:FXD MICA 33 PF 5%               |      |
| A2C40                 | 0180-0229  | C:FXD ELECT 33 UF 10% 10VDCW      |      |
| A2C41                 | 0160-2917  | C:FXD CER 0.05 UF +80-20% 100VDCW |      |
| A2C42                 | 0180-0106  | C:FXD ELECT 60 UF 20% 6VDCW       |      |
| A2C43                 | 0180-0197  | C:FXD ELECT 2.2 UF 10% 20VDCW     |      |
| A2C44                 | 0180-0291  | C:FXD ELECT 1.0 UF 10% 35VDCW     |      |
| A2C45                 | 0180-0106  | C:FXD ELECT 60 UF 20% 6VDCW       |      |
| A2C46                 | 0150-0059  | C:FXD CER 3.3-0.25 PF 500VDCW     |      |
| A2C47                 | 0160-2930  | C:FXD CER 0.01 UF +80-20% 100VDCW |      |
| A2C48                 | 0140-0192  | C:FXD MICA 68 PF 5%               |      |
| A2C49                 | 0180-0229  | C:FXD ELECT 33 UF 10% 10VDCW      |      |
| A2C50                 | 0160-2917  | C:FXD CER 0.05 UF +80-20% 100VDCW |      |
| A2CR1                 | 1901-0026  | DIODE: SILICON 0.75A 200 PIV      |      |
| A2CR2                 | 1901-0026  | DIODE: SILICON 0.75A 200 PIV      |      |
| A2CR3                 | 1901-0026  | DIODE: SILICON 0.75A 200 PIV      |      |
| A2CR4                 | 1901-0026  | DIODE: SILICON 0.75A 200 PIV      |      |
| A2CR5                 |            | NOT ASSIGNED                      |      |

# See introduction to this section for ordering information

Table 6-1. Reference Designation Index (Cont'd)

| Reference Designation | Part No.  | Description #                    | Note |
|-----------------------|-----------|----------------------------------|------|
| A2CR6                 | 1902-0033 | DIODE BREAKDOWN:6.2V             |      |
| A2CR7                 | 1901-0040 | DIODE:SILICON 30MA 30WV          |      |
| A2CR8                 | 1901-0026 | DIODE:SILICON 0.75A 200 PIV      |      |
| A2CR9                 |           | NOT ASSIGNED                     |      |
| A2CR10                |           | NOT ASSIGNED                     |      |
| A2CR11                | 1901-0040 | DIODE:SILICON 30MA 30WV          |      |
| A2CR12                | 1901-0040 | DIODE:SILICON 30MA 30WV          |      |
| A2CR13                | 1901-0040 | DIODE:SILICON 30MA 30WV          |      |
| A2CR14                | 1901-0040 | DIODE:SILICON 30MA 30WV          |      |
| A2CR15                | 1901-0040 | DIODE:SILICON 30MA 30WV          |      |
| A2CR16                | 1901-0040 | DIODE:SILICON 30MA 30WV          |      |
| A2CR17                | 1901-0040 | DIODE:SILICON 30MA 30WV          |      |
| A2CR18                | 1901-0040 | DIODE:SILICON 30MA 30WV          |      |
| A2CR19                | 1901-0040 | DIODE:SILICON 30MA 30WV          |      |
| A2CR20                | 1901-0040 | DIODE:SILICON 30MA 30WV          |      |
| A2CR21                | 1901-0040 | DIODE:SILICON 30MA 30WV          |      |
| A2CR22                | 1901-0040 | DIODE:SILICON 30MA 30WV          |      |
| A2CR23                | 1901-0040 | DIODE:SILICON 30MA 30WV          |      |
| A2Q1                  | 1854-0071 | TRANSISTOR:SILICON NPN           |      |
| A2Q2                  | 1854-0062 | TRANSISTOR:SILICON NPN 2N1701    |      |
| A2Q3                  | 1854-0071 | TRANSISTOR:SILICON NPN           |      |
| A2Q4                  | 1853-0012 | TRANSISTOR:PNP SILICON 2N2904A   |      |
| A2Q5                  | 1853-0020 | TRANSISTOR:SILICON PNP           |      |
| A2Q6                  | 1853-0020 | TRANSISTOR:SILICON PNP           |      |
| A2Q7                  | 1853-0020 | TRANSISTOR:SILICON PNP           |      |
| A2Q8                  | 1854-0071 | TRANSISTOR:SILICON NPN           |      |
| A2Q9                  | 1854-0003 | TRANSISTOR:NPN SILICON           |      |
| A2Q10                 | 1853-0001 | TRANSISTOR:PNP SILICON 30V 900MW |      |
| A2Q11                 | 1854-0071 | TRANSISTOR:SILICON NPN           |      |
| A2Q12-                |           | NOT ASSIGNED                     |      |
| A2Q19                 |           | NOT ASSIGNED                     |      |
| A2Q20                 | 1853-0020 | TRANSISTOR:SILICON PNP           |      |
| A2Q21                 | 1854-0005 | TRANSISTOR:SILICON NPN 2N708     |      |
| A2Q22                 | 1854-0071 | TRANSISTOR:SILICON NPN           |      |
| A2Q23                 | 1854-0071 | TRANSISTOR:SILICON NPN           |      |
| A2Q24                 | 1854-0005 | TRANSISTOR:SILICON NPN 2N708     |      |
| A2Q25                 |           | NOT ASSIGNED                     |      |
| A2Q26                 | 1854-0071 | TRANSISTOR:SILICON NPN           |      |
| A2Q27                 | 1854-0071 | TRANSISTOR:SILICON NPN           |      |
| A2Q28                 | 1854-0009 | TRANSISTOR:SILICON NPN 2N709     |      |
| A2Q29                 | 1854-0009 | TRANSISTOR:SILICON NPN 2N709     |      |
| A2Q30                 | 1855-0062 | TRANSISTOR: FIELD EFFECT 30V     |      |
| A2Q31                 |           | NOT ASSIGNED                     |      |
| A2Q32                 | 1855-0062 | TRANSISTOR:FIELD EFFECT 30V      |      |
| A2Q33                 |           | NOT ASSIGNED                     |      |
| A2Q34                 | 1854-0071 | TRANSISTOR:SILICON NPN           |      |
| A2Q35                 | 1854-0071 | TRANSISTOR:SILICON NPN           |      |
| A2Q36                 | 1853-0015 | TRANSISTOR: SILICON PNP 2N3640   |      |

# See introduction to this section for ordering information

Table 6-1. Reference Designation Index (Cont'd)

| Reference Designation | Part No.  | Description #                                           | Note |
|-----------------------|-----------|---------------------------------------------------------|------|
| A2Q37                 | 1853-0020 | TRANSISTOR: SILICON PNP                                 |      |
| A2Q38                 | 1855-0062 | TRANSISTOR: FIELD EFFECT 30V                            |      |
| A2Q39                 | 1854-0071 | TRANSISTOR: SILICON NPN                                 |      |
| A2Q40                 | 1854-0071 | TRANSISTOR: SILICON NPN                                 |      |
| A2Q41                 | 1853-0020 | TRANSISTOR: SILICON PNP                                 |      |
| A2Q42                 | 1853-0020 | TRANSISTOR: SILICON PNP                                 |      |
| A2Q43                 | 1854-0071 | TRANSISTOR: SILICON NPN                                 |      |
| A2Q44                 | 1854-0071 | TRANSISTOR: SILICON NPN                                 |      |
| A2R1                  | 0757-0279 | R: FXD MET FLM 3.16K OHM 1% 1/8W                        |      |
| A2R2                  | 0683-0685 | R: FXD COMP 6.8 OHM 5% 1/4W                             |      |
| A2R3                  | 0757-0835 | R: FXD MET FLM 6.81K OHM 1% 1/2W                        |      |
| A2R4                  |           | NUT ASSIGNED                                            |      |
| A2R5                  | 0698-3156 | R: FXD MET FLM 14.7K OHM 1% 1/8W                        |      |
| A2R6                  | 2100-1773 | R: VAR WW 1K OHM 10% LIN 1/2W                           |      |
| A2R7                  | 0757-0289 | R: FXD MET FLM 13.3K OHM 1% 1/8W                        |      |
| A2R8                  | 0757-0280 | R: FXD MET FLM 1K OHM 1% 1/8W                           |      |
| A2R9                  | 0698-3160 | R: FXD MET FLM 31.6K OHM 1% 1/8W                        |      |
| A2R10                 | 0698-3441 | R: FXD MET FLM 215 OHM 1% 1/8W<br>FACTORY SELECTED PART |      |
| A2R11                 | 0757-0465 | R: FXD MET FLM 100K OHM 1% 1/8W                         |      |
| A2R12                 | 0757-0442 | R: FXD MET FLM 10.0K OHM 1% 1/8W                        |      |
| A2R13                 | 0698-3136 | R: FXD MET FLM 17.8K OHM 1% 1/8W                        |      |
| A2R14                 |           | NUT ASSIGNED                                            |      |
| A2R15                 | 0757-0442 | R: FXD MET FLM 10.0K OHM 1% 1/8W                        |      |
| A2R16                 | 0757-0279 | R: FXD MET FLM 3.16K OHM 1% 1/8W                        |      |
| A2R17                 | 0757-0198 | R: FXD MET FLM 100 OHM 1% 1/2W                          |      |
| A2R18                 | 0698-3401 | R: FXD MET FLM 215 OHM 1% 1/2W                          |      |
| A2R19                 |           | NUT ASSIGNED                                            |      |
| A2R20                 |           | NUT ASSIGNED                                            |      |
| A2R21                 | 0698-3156 | R: FXD MET FLM 14.7K OHM 1% 1/8W                        |      |
| A2R22                 | 0757-0442 | R: FXD MET FLM 10.0K OHM 1% 1/8W                        |      |
| A2R23                 | 0757-0442 | R: FXD MET FLM 10.0K OHM 1% 1/8W                        |      |
| A2R24                 | 0698-3260 | R: FXD MET FLM 464K OHM 1% 1/8W                         |      |
| A2R25                 | 0698-3260 | R: FXD MET FLM 464K OHM 1% 1/8W                         |      |
| A2R26                 | 0757-0442 | R: FXD MET FLM 10.0K OHM 1% 1/8W                        |      |
| A2R27                 | 0757-0442 | R: FXD MET FLM 10.0K OHM 1% 1/8W                        |      |
| A2R28                 | 0698-3156 | R: FXD MET FLM 14.7K OHM 1% 1/8W                        |      |
| A2R29                 | 0757-0397 | R: FXD MET FLM 68.1 OHM 1% 1/8W                         |      |
| A2R30                 |           | NOT ASSIGNED                                            |      |
| A2R31                 |           | NUT ASSIGNED                                            |      |
| A2R32                 | 0757-0199 | R: FXD MET FLM 21.5K OHM 1% 1/8W                        |      |
| A2R33                 | 0757-0442 | R: FXD MET FLM 10.0K OHM 1% 1/8W                        |      |
| A2R34                 | 0757-0465 | R: FXD MET FLM 100K OHM 1% 1/8W                         |      |
| A2R35                 | 0698-3454 | R: FXD MET FLM 215K OHM 1% 1/8W                         |      |
| A2R36-                |           | NOT ASSIGNED                                            |      |
| A2R37                 |           | NOT ASSIGNED                                            |      |
| A2R38                 | 0757-0465 | R: FXD MET FLM 100K OHM 1% 1/8W                         |      |
| A2R39                 | 0698-3155 | R: FXD MET FLM 4.64K OHM 1% 1/8W                        |      |
| A2R40                 | 0698-3155 | R: FXD MET FLM 4.64K OHM 1% 1/8W                        |      |
| A2R41                 | 0757-0465 | R: FXD MET FLM 100K OHM 1% 1/8W                         |      |

# See introduction to this section for ordering information

Table 6-1. Reference Designation Index (Cont'd)

| Reference Designation | Part No.  | Description #                   | Note |
|-----------------------|-----------|---------------------------------|------|
| A2R42                 | 0683-1065 | R:FXD COMP 10M OHM 5% 1/4W      |      |
| A2R43                 | 0757-1094 | R:FXD MET FLM 1.47K OHM 1% 1/8W |      |
| A2R44-                |           | NOT ASSIGNED                    |      |
| A2R45                 |           | NOT ASSIGNED                    |      |
| A2R46                 | 0757-0465 | R:FXD MET FLM 100K OHM 1% 1/8W  |      |
| A2R47                 | 0683-1065 | R:FXD COMP 10M OHM 5% 1/4W      |      |
| A2R48-                |           | NOT ASSIGNED                    |      |
| A2R49                 |           | NOT ASSIGNED                    |      |
| A2R50                 | 0757-0280 | R:FXD MET FLM 1K OHM 1% 1/8W    |      |
| A2R51                 | 0698-3260 | R:FXD MET FLM 464K OHM 1% 1/8W  |      |
| A2R52                 | 0757-0279 | R:FXD MET FLM 3.16K OHM 1% 1/8W |      |
| A2R53                 | 0698-3160 | R:FXD MET FLM 31.6K OHM 1% 1/8W |      |
| A2R54                 | 0698-3428 | R:FXD MET FLM 14.7 OHM 1% 1/8W  |      |
|                       |           | FACTORY SELECTED PART           |      |
| A2R55                 | 0698-3160 | R:FXD MET FLM 31.6K OHM 1% 1/8W |      |
|                       |           | FACTORY SELECTED PART           |      |
| A2R56                 |           | NOT ASSIGNED                    |      |
| A2R57                 | 0757-0442 | R:FXD MET FLM 10.0K OHM 1% 1/8W |      |
| A2R58                 | 0698-3260 | R:FXD MET FLM 464K OHM 1% 1/8W  |      |
| A2R59                 | 0698-3260 | R:FXD MET FLM 464K OHM 1% 1/8W  |      |
| A2R60                 | 0698-0084 | R:FXD MET FLM 2.15K OHM 1% 1/8W |      |
| A2R61                 | 0683-1055 | R:FXD COMP 1 MEGOHM 5% 1/4W     |      |
| A2R62-                |           | NOT ASSIGNED                    |      |
| A2R63                 |           | NOT ASSIGNED                    |      |
| A2R64                 | 0757-0439 | R:FXD MET FLM 6.81K OHM 1% 1/8W |      |
| A2R65                 | 0757-0442 | R:FXD MET FLM 10.0K OHM 1% 1/8W |      |
| A2R66                 | 0757-0461 | R:FXD MET FLM 68.1K OHM 1% 1/8W |      |
| A2R67                 | 0698-3160 | R:FXD MET FLM 31.6K OHM 1% 1/8W |      |
| A2R68                 | 0757-0442 | R:FXD MET FLM 10.0K OHM 1% 1/8W |      |
| A2R69                 | 0698-3438 | R:FXD MET FLM 147 OHM 1% 1/8W   |      |
| A2R70                 |           | NOT ASSIGNED                    |      |
| A2R71                 | 0698-3160 | R:FXD MET FLM 31.6K OHM 1% 1/8W |      |
| A2R72                 | 0698-3444 | R:FXD MET FLM 316 OHM 1% 1/8W   |      |
| A2R73                 | 0757-0199 | R:FXD MET FLM 21.5K OHM 1% 1/8W |      |
| A2R74                 | 2100-1769 | R:VAR WW 50 OHM 10% LIN 1/2W    |      |
| A2R75                 | 0698-4466 | R:FXD MET FLM 976 OHM 1% 1/8W   |      |
| A2R76                 | 0757-0346 | R:FXD MET FLM 10 OHM 1% 1/8W    |      |
| A2R77                 | 0698-3160 | R:FXD MET FLM 31.6K OHM 1% 1/8W |      |
| A2R78                 | 0811-2277 | R:FXD WW 10K OHM 0.1% 1/40W     |      |
| A2R79                 | 0811-2277 | R:FXD WW 10K OHM 0.1% 1/40W     |      |
| A2R80                 | 0811-2537 | R:FXD WW 5K OHM 0.1% 1/4W       |      |
| A2R81-                |           | NOT ASSIGNED                    |      |
| A2R82                 |           | NOT ASSIGNED                    |      |
| A2R83                 | 0698-3441 | R:FXD MET FLM 215 OHM 1% 1/8W   |      |
| A2R84-                |           | NOT ASSIGNED                    |      |
| A2R86                 |           | NOT ASSIGNED                    |      |
| A2R87                 | 0683-1065 | R:FXD COMP 10M OHM 5% 1/4W      |      |
| A2                    | 0360-0124 | TERMINAL:SOLDER LUG             |      |
|                       | 0370-0077 | KNOB:5/8" SKIRTED BAR           |      |

# See introduction to this section for ordering information

Table 6-1. Reference Designation Index (Cont'd)

| Reference Designation | Part No.   | Description #                     | Note |
|-----------------------|------------|-----------------------------------|------|
| A3                    | 00432-6003 | SWITCH ASSY: RANGE                |      |
| A3R1                  | 0811-2536  | R:FXD WW 3167 OHM 0.1% 1/40W      |      |
| A3R2                  | 0811-2284  | R:FXD WW 1K OHM 0.1% 1/40W        |      |
| A3R3                  | 0811-2534  | R:FXD WW 314.3 OHM 0.1% 1/40W     |      |
| A3R4                  | 0811-2535  | R:FXD WW 145.0 OHM 0.1% 1/40W     |      |
| A3S1                  | 3100-2470  | SWITCH:ROTARY                     |      |
| A4                    | 00432-6004 | SWITCH ASSY: CALIBRATION FACTOR   |      |
| A4R1                  | 0757-0346  | R:FXD MET FLM 10 OHM 1% 1/8W      |      |
| A4R2                  | 0757-0346  | R:FXD MET FLM 10 OHM 1% 1/8W      |      |
| A4R3                  | 0757-0346  | R:FXD MET FLM 10 OHM 1% 1/8W      |      |
| A4R4                  | 0757-0346  | R:FXD MET FLM 10 OHM 1% 1/8W      |      |
| A4R5                  | 0757-0346  | R:FXD MET FLM 10 OHM 1% 1/8W      |      |
| A4R6                  | 0757-0346  | R:FXD MET FLM 10 OHM 1% 1/8W      |      |
| A4R7                  | 0757-0346  | R:FXD MET FLM 10 OHM 1% 1/8W      |      |
| A4R8                  | 0757-0346  | R:FXD MET FLM 10 OHM 1% 1/8W      |      |
| A4R9                  | 0757-0346  | R:FXD MET FLM 10 OHM 1% 1/8W      |      |
| A4R10                 | 0757-0346  | R:FXD MET FLM 10 OHM 1% 1/8W      |      |
| A4R11                 | 0757-0346  | R:FXD MET FLM 10 OHM 1% 1/8W      |      |
| A4R12                 | 0757-0346  | R:FXD MET FLM 10 OHM 1% 1/8W      |      |
| A4R13                 | 0698-6635  | R:FXD MET FLM 880 OHM 1% 1/8W     |      |
| A4S1                  | 3100-2469  | SWITCH:ROTARY                     |      |
|                       | 0370-0193  | KNOB:BLACK                        |      |
| A5                    |            | NOT ASSIGNED                      |      |
| A6                    |            | NOT ASSIGNED                      |      |
| A7                    | 00432-6007 | BOARD ASSY:BATTERY CHARGER        |      |
|                       | 00432-2007 | BOARD:BLANK PC                    |      |
| A7C1                  | 0160-2930  | C:FXD CER 0.01 UF +80-20% 100VDCW |      |
| A7CR1                 | 1901-0026  | DIODE:SILICON 0.75A 200 PIV       |      |
| A7CR2                 | 1902-0048  | DIODE BREAKDOWN:6.81V 5%          |      |
| A7Q1                  | 1854-0039  | TRANSISTOR:SILICON 2N3053         |      |
| A7Q2                  | 1853-0020  | TRANSISTOR:SILICON PNP            |      |
| A7Q3                  | 1854-0071  | TRANSISTOR:SILICON NPN            |      |
| A7Q4                  | 1854-0071  | TRANSISTOR:SILICON NPN            |      |
| A7R1                  | 0698-3635  | R:FXD MET OX 680 OHM 5% 2W        |      |
| A7R2                  | 0757-0280  | R:FXD MET FLM 1K OHM 1% 1/8W      |      |
| A7R3                  | 0757-0346  | R:FXD MET FLM 10 OHM 1% 1/8W      |      |
| A7R4                  | 0757-0439  | R:FXD MET FLM 6.81K OHM 1% 1/8W   |      |
| A7R5                  | 0757-0280  | R:FXD MET FLM 1K OHM 1% 1/8W      |      |
| A7R6                  | 0757-0199  | R:FXD MET FLM 21.5K OHM 1% 1/8W   |      |
| A7R7                  | 0757-0199  | R:FXD MET FLM 21.5K OHM 1% 1/8W   |      |
| A7R8                  | 2100-1775  | R:VAR WW 5K OHM 10% LIN 1/2W      |      |
| BT1                   | 1420-0062  | BATTERY:RECHARGEABLE 24V          |      |
| BT1                   | 00432-0008 | BRACKET:BATTERY UPPER             |      |
| BT1                   | 00432-0009 | BRACKET:BATTERY LOWER             |      |
| C1                    | 0160-3043  | C:FXD CER 2 X 0.005 UF 20% 250VAC |      |

# See introduction to this section for ordering information

Table 6-1. Reference Designation Index (Cont'd)

| Reference Designation | Part No.   | Description #                                     | Note |
|-----------------------|------------|---------------------------------------------------|------|
| DS1                   | 2140-0015  | LA MP:GLOW NEON NE- 2H                            |      |
| F1                    | 2110-0027  | FUSE:0.125A 250V                                  |      |
| J1                    | 1251-1280  | CONNECTOR:AUDIO 6 FEMALE CONTACTS                 |      |
| J2                    | 1250-0118  | CONNECTOR:BNC                                     |      |
| J2                    |            | V-RF                                              |      |
| J3                    | 1250-0118  | CONNECTOR:BNC                                     |      |
| J3                    |            | V-COMP                                            |      |
| J4                    | 1250-0118  | CONNECTOR:BNC                                     |      |
| J4                    |            | RECORDER OUT                                      |      |
| J5                    | 1251-0148  | CONNECTOR:POWER 3 PIN MALE                        |      |
| M1                    | 1120-1497  | METER                                             |      |
| R1                    | 2100-2849  | R:VAR WW 50K OHM 5% LIN 1-1/2W(SERIAL PREFIX 904) |      |
| R1                    | 2100-2659  | R:VAR WW 50K OHM 5% LIN 1-1/2W(SERIAL PREFIX 919) |      |
| R2                    | 0811-2538  | R:FXD WW 100 OHM 0.1% 1/10W                       |      |
| R3                    | 0811-2538  | R:FXD WW 100 OHM 0.1% 1/10W                       |      |
| R4                    | 0811-2538  | R:FXD WW 100 OHM 0.1% 1/10W                       |      |
| R5                    | 0811-2538  | R:FXD WW 100 OHM 0.1% 1/10W                       |      |
| R6                    | 0757-0198  | R:FXD MET FLM 100 OHM 1% 1/2W                     |      |
| R7                    | 0757-0198  | R:FXD MET FLM 100 OHM 1% 1/2W                     |      |
| R8                    | 0757-0198  | R:FXD MET FLM 100 OHM 1% 1/2W                     |      |
| R9                    | 0698-3160  | R:FXD MET FLM 31.6K OHM 1% 1/8W                   |      |
| R10-                  |            | NUT ASSIGNED                                      |      |
| R13                   |            | NOT ASSIGNED                                      |      |
| R14                   | 0811-2277  | R:FXD WW 10K OHM 0.1% 1/40W                       |      |
| S1                    | 3101-0957  | SWITCH:TOGGLE DPDT                                |      |
| S1                    |            | POWER                                             |      |
| S2                    | 3101-0033  | SWITCH:SLIDE DPDT 0.5A 125V AC/DC                 |      |
| S2                    |            | (115V/230V OPERATION)                             |      |
| S3                    | 3101-1180  | SWITCH:SLIDE 3PDT                                 |      |
| S3                    |            | MOUNT RESISTANCE                                  |      |
| S3                    | 7204-0004  | ALUMINUM:SHEET 0.063 THICK                        |      |
| S3                    | 0590-0041  | NUT:KNURLED 1-72 THREAD                           |      |
| S4                    | 3101-1357  | SWITCH:TOGGLE SPDT                                |      |
| S4                    |            | (FINE ZERO)                                       |      |
| T1                    | 9100-2504  | TRANSFORMER:28.4V SEC.                            |      |
| T1                    | 00432-0005 | BRACKET:TRANSFORMER                               |      |
| W1                    | 8120-1082  | CABLE ASSY:5 FT                                   |      |
| W2                    | 8120-0078  | CABLE ASSY:POWER CORD                             |      |
| XA1                   | 1251-0172  | CONNECTOR:PRINTED CIRCUIT 22-CONN                 |      |
| XA1                   |            | (PART OF 00432-0006 DECK LOWER)                   |      |
| XA2                   | 1251-0172  | CONNECTOR:PRINTED CIRCUIT 22-CONN                 |      |
| XDS1                  | 5040-0257  | LAMPHOLDER                                        |      |
| XDS1                  | 5040-0235  | BASE:LAMPHOLDER                                   |      |
| XF1                   | 1400-0084  | FUSEHOLDER: EXTRACTOR POST TYPE                   |      |

# See introduction to this section for ordering information

Table 6-1. Reference Designation Index (Cont'd)

| Reference Designation | Part No.   | Description #                  | Note |
|-----------------------|------------|--------------------------------|------|
|                       | 0403-0005  | BUMPER: BLACK RUBBER           |      |
|                       | 5020-0704  | METER TRIM: THIRD MOD.         |      |
|                       | 5040-0700  | HINGE                          |      |
|                       | 5040-0702  | INSULATOR: CONNECTOR           |      |
|                       | 5040-4528  | GUIDE: PC BOARD (GRAY PLASTIC) |      |
|                       | 00432-2003 | NUT: DRESS                     |      |
|                       | 00432-2004 | BUSHING: PANEL                 |      |
|                       | 00432-2005 | NUT: CONNECTOR                 |      |

# See introduction to this section for ordering information

Table 6-1. Reference Designation Index (Cont'd)

| Reference Designation | Part No.   | Description #  | Note |
|-----------------------|------------|----------------|------|
|                       |            |                |      |
| 1.                    | 5060-0703  | FRAME ASSEMBLY |      |
| 2.                    | 1490-0031  | STAND: TILT    |      |
| 3.                    | 5040-0700  | HINGE          |      |
| 4.                    | 5060-0727  | FOOT ASSEMBLY  |      |
| 5.                    | 5020-0700  | SPACER         |      |
| 6.                    | 5000-0703  | SIDE COVER     |      |
| 7.                    | 5060-0706  | COVER: TOP     |      |
| 8.                    | 5000-0711  | COVER: BOTTOM  |      |
| 9.                    | 00432-0002 | PANEL: REAR    |      |
| 10.                   | 00432-0001 | PANEL: FRONT   |      |

# See introduction to this section for ordering information

Table 6-2. Replaceable Parts

| Part No.  | Description #                     | Mfr.  | Mfr. Part No.      | TQ |
|-----------|-----------------------------------|-------|--------------------|----|
| 0140-0192 | C:FXD MICA 68 PF 5%               | 28480 | 0140-0192          | 1  |
| 0140-0234 | C:FXD MICA 500 PF 1%              | 28480 | 0140-0234          | 2  |
| 0150-0059 | C:FXD CER 3.3-0.25 PF 500VDCW     | 72982 | 301-000-C0J0-339C  | 1  |
| 0160-0380 | C:FXD MY 0.22 UF 10% 200VDCW      | 28480 | 0160-0380          | 2  |
| 0160-0978 | C:FXD MICA 1500 PF 1% 500VDCW     | 28480 | 0160-0978          | 1  |
| 0160-2150 | C:FXD MICA 33 PF 5%               | 28480 | 0160-2150          | 1  |
| 0160-2264 | C:FXD CER 20 PF 5% 500VDCW        | 72982 | 301-000-C0G0-200J  | 2  |
| 0160-2672 | C:FXD MY 0.047 UF 5% 80VDCW       | 28480 | 0160-2672          | 1  |
| 0160-2917 | C:FXD CER 0.05 UF +80-20% 100VDCW | 84411 | TYPE TA            | 6  |
| 0160-2930 | C:FXD CER 0.01 UF +80-20% 100VDCW | 91418 | TA                 | 12 |
| 0160-3043 | C:FXD CER 2 X 0.005 UF 20% 250VAC | 56289 | 29C147A-CDH        | 1  |
| 0180-0106 | C:FXD ELECT 60 UF 20% 6VDCW       | 28480 | 0180-0106          | 2  |
| 0180-0197 | C:FXD ELECT 2.2 UF 10% 20VDCW     | 28480 | 0180-0197          | 3  |
| 0180-0229 | C:FXD ELECT 33 UF 10% 10VDCW      | 28480 | 0180-0229          | 3  |
| 0180-0291 | C:FXD ELECT 1.0 UF 10% 35VDCW     | 28480 | 0180-0291          | 1  |
| 0180-0374 | C:FXD ELECT 10 UF 10% 20VDCW      | 28480 | 0180-0374          | 2  |
| 0180-1746 | C:FXD ELECT 15 UF 10% 20VDCW      | 28480 | 0180-1746          | 1  |
| 0180-1819 | C:FXD ELECT 100 UF +75-10% 50VDCW | 28480 | 0180-1819          | 1  |
| 0180-1940 | C:FXD ELECT 33 UF 10% 15VDCW      | 56289 | 109D336X9015C2-DYP | 1  |
| 0180-2178 | C:FXD ELECT 220 UF 20% 8VDCW      | 56289 | 109D227X0008F2-DYP | 1  |
| 0360-0124 | TERMINAL:SOLDER LUG               | 28480 | 0360-0124          | 17 |
| 0370-0077 | KNOB:5/8 SK BAR                   | 28480 | 0370-0077          | 1  |
| 0370-0193 | KNOB:BLACK                        | 28480 | 0370-0193          | 1  |
| 0403-0005 | BUMPER:BLACK RUBBER               | 70485 | #1059              | 1  |
| 0590-0041 | NUT:KNURLED 1-72 THREAD           | 28480 | 0590-0041          | 1  |
| 0683-0685 | R:FXD COMP 6.8 OHM 5% 1/4W        | 01121 | CB68G5             | 1  |
| 0683-1055 | R:FXD COMP 1 MEGOHM 5% 1/4W       | 01121 | CB 1055            | 1  |
| 0683-1065 | R:FXD COMP 10M OHM 5% 1/4W        | 01121 | CB 1065            | 3  |
| 0686-1055 | R:FXD COMP 1 MEGOHM 5% 1/2W       | 01121 | EB 1055            | 1  |
| 0698-0084 | R:FXD MET FLM 2.15K OHM 1% 1/8W   | 28480 | 0698-0084          | 1  |
| 0698-3136 | R:FXD MET FLM 17.8K OHM 1% 1/8W   | 28480 | 0698-3136          | 2  |
| 0698-3155 | R:FXD MET FLM 4.64K OHM 1% 1/8W   | 28480 | 0698-3155          | 2  |
| 0698-3156 | R:FXD MET FLM 14.7K OHM 1% 1/8W   | 28480 | 0698-3156          | 5  |
| 0698-3160 | R:FXD MET FLM 31.6K OHM 1% 1/8W   | 28480 | 0698-3160          | 14 |
| 0698-3260 | R:FXD MET FLM 464K OHM 1% 1/8W    | 28480 | 0698-3260          | 7  |
| 0698-3401 | R:FXD MET FLM 215 OHM 1% 1/2W     | 28480 | 0698-3401          | 1  |
| 0698-3428 | R:FXD MET FLM 14.7 OHM 1% 1/8W    | 28480 | 0698-3428          | 1  |
| 0698-3438 | R:FXD MET FLM 147 OHM 1% 1/8W     | 28480 | 0698-3438          | 1  |
| 0698-3441 | R:FXD MET FLM 215 OHM 1% 1/8W     | 28480 | 0698-3441          | 4  |
| 0698-3444 | R:FXD MET FLM 316 OHM 1% 1/8W     | 28480 | 0698-3444          | 1  |
| 0698-3454 | R:FXD MET FLM 215K OHM 1% 1/8W    | 28480 | 0698-3454          | 1  |
| 0698-3635 | R:FXD MET UX 680 OHM 5% 2W        | 28480 | 0698-3635          | 1  |
| 0698-4466 | R:FXD MET FLM 976 OHM 1% 1/8W     | 28480 | 0698-4466          | 1  |
| 0698-6635 | R:FXD MET FLM 880 OHM 1% 1/8W     | 28480 | 0698-6635          | 1  |
| 0757-0198 | R:FXD MET FLM 100 OHM 1% 1/2W     | 28480 | 0757-0198          | 4  |
| 0757-0199 | R:FXD MET FLM 21.5K OHM 1% 1/8W   | 28480 | 0757-0199          | 7  |
| 0757-0279 | R:FXD MET FLM 3.16K OHM 1% 1/8W   | 28480 | 0757-0279          | 7  |
| 0757-0280 | R:FXD MET FLM 1K OHM 1% 1/8W      | 28480 | 0757-0280          | 4  |
| 0757-0289 | R:FXD MET FLM 13.3K OHM 1% 1/8W   | 28480 | 0757-0289          | 1  |
| 0757-0346 | R:FXD MET FLM 10 OHM 1% 1/8W      | 28480 | 0757-0346          | 14 |
| 0757-0397 | R:FXD MET FLM 68.1 OHM 1% 1/8W    | 28480 | 0757-0397          | 1  |
| 0757-0416 | R:FXD MET FLM 511 OHM 1% 1/8W     | 28480 | 0757-0416          | 2  |
| 0757-0439 | R:FXD MET FLM 6.81K OHM 1% 1/8W   | 28480 | 0757-0439          | 2  |
| 0757-0442 | R:FXD MET FLM 10.0K OHM 1% 1/8W   | 28480 | 0757-0442          | 12 |

# See introduction to this section for ordering information

Table 6-2. Replaceable Parts (Cont'd)

| Part No.  | Description #                     |       | Mfr. Part No. | TQ |
|-----------|-----------------------------------|-------|---------------|----|
| 0757-0461 | R:FXD MET FLM 68.1K OHM 1% 1/8W   | 28480 | 0757-0461     | 3  |
| 0757-0465 | R:FXD MET FLM 100K OHM 1% 1/8W    | 28480 | 0757-0465     | 9  |
| 0757-0835 | R:FXD MET FLM 6.81K OHM 1% 1/2W   | 28480 | 0757-0835     | 1  |
| 0757-1094 | R:FXD MET FLM 1.47K OHM 1% 1/8W   | 28480 | 0757-1094     | 1  |
| 0811-2277 | R:FXD WW 10K OHM 0.1% 1/40W       | 28480 | 0811-2277     | 3  |
| 0811-2284 | R:FXD WW 1K OHM 0.1% 1/40W        | 28480 | 0811-2284     | 5  |
| 0811-2534 | R:FXD WW 314.3 OHM 0.1% 1/40W     | 28480 | 0811-2534     | 1  |
| 0811-2535 | R:FXD WW 145.0 OHM 0.1% 1/40W     | 28480 | 0811-2535     | 1  |
| 0811-2536 | R:FXD WW 3167 OHM 0.1% 1/40W      | 28480 | 0811-2536     | 1  |
| 0811-2537 | R:FXD WW 5K OHM 0.1% 1/4W         | 28480 | 0811-2537     | 1  |
| 0811-2538 | R:FXD WW 100 OHM 0.1% 1/10W       | 28480 | 0811-2538     | 4  |
| 1120-1497 | METER                             | 28480 | 1120-1497     | 1  |
| 1250-0118 | CONNECTOR:BNC                     | 28480 | 1250-0118     | 3  |
| 1251-0148 | CONNECTOR:POWER 3 PIN MALE        | 87930 | 1065-1        | 1  |
| 1251-0172 | CONNECTOR:PRINTED CIRCUIT 22-CONN | 28480 | 1251-0172     | 2  |
| 1251-1280 | CONNECTOR:AUDIO 6 FEMALE CONTACTS | 28480 | 1251-1280     | 1  |
| 1400-0084 | FUSEHOLDER:EXTRACTOR POST TYPE    | 79515 | 342014        | 1  |
| 1420-0062 | BATTERY:RECHARGEABLE 24V          | 28480 | 1420-0062     | 1  |
| 1490-0031 | STAND:TILT                        | 28480 | 1490-0031     | 1  |
| 1853-0001 | TRANSISTOR:PNP SILICON 30V 900MW  | 28480 | 1853-0001     | 3  |
| 1853-0012 | TRANSISTOR:PNP SILICON 2N2904A    | 04713 | 2N2904A       | 1  |
| 1853-0015 | TRANSISTOR:SILICON PNP 2N3640     | 28480 | 1853-0015     | 1  |
| 1853-0020 | TRANSISTOR:SILICON PNP            | 28480 | 1853-0020     | 13 |
| 1854-0003 | TRANSISTOR:NPN SILICON            | 28480 | 1854-0003     | 1  |
| 1854-0005 | TRANSISTOR:SILICON NPN 2N708      | 02735 | 2N708         | 2  |
| 1854-0009 | TRANSISTOR:SILICON NPN 2N709      | 07263 | 2N709         | 2  |
| 1854-0039 | TRANSISTOR:SILICON 2N3053         | 02735 | 2N3053        | 1  |
| 1854-0062 | TRANSISTOR:SILICON NPN 2N1701     | 02735 | 2N1701        | 1  |
| 1854-0071 | TRANSISTOR:SILICON NPN            | 28480 | 1854-0071     | 22 |
| 1854-0221 | TRANSISTOR DUAL:SILICON NPN       | 28480 | 1854-0221     | 2  |
| 1855-0062 | TRANSISTOR:FIELD EFFECT 30V       | 28480 | 1855-0062     | 2  |
| 1901-0026 | DIODE:SILICON 0.75A 200 PIV       | 28480 | 1901-0026     | 6  |
| 1901-0040 | DIODE:SILICON 30MA 30WV           | 28480 | 1901-0040     | 16 |
| 1902-0033 | DIODE BREAKDOWN:6.2V              | 04713 | 1N823         | 1  |
| 1902-0048 | DIODE BREAKDOWN:6.81V 5%          | 28480 | 1902-0048     | 1  |
| 2100-1769 | R:VAR WW 50 OHM 10% LIN 1/2W      | 28480 | 2100-1769     | 1  |
| 2100-1770 | R:VAR WW 100 OHM 10% LIN 1/2W     | 28480 | 2100-1770     | 2  |
| 2100-1773 | R:VAR WW 1K OHM 10% LIN 1/2W      | 28480 | 2100-1773     | 1  |
| 2100-1775 | R:VAR WW 5K OHM 10% LIN 1/2W      | 28480 | 2100-1775     | 1  |
| 2100-2659 | R:VAR WW 50K OHM 5% LIN 1-1/2W    | 28480 | 2100-2659     | 1  |
| 2100-2849 | R:VAR WW 50K OHM 5% LIN 1-1/2W    | 28480 | 2100-2849     | 1  |
| 2110-0027 | FUSE:0.125A 250V                  | 75915 | 312.125       | 1  |
| 2140-0015 | LAMP:GLOW NEON NE-2H.             | 24455 | NE 2H         | 1  |
| 3100-2469 | SWITCH:ROTARY                     | 28480 | 3100-2469     | 1  |
| 3100-2470 | SWITCH:ROTARY                     | 28480 | 3100-2470     | 1  |
| 3101-0033 | SWITCH:SLIDE DPDT 0.5A 125V AC/DC | 79727 | G326-0001     | 1  |
| 3101-0957 | SWITCH:TOGGLE DPDT                | 28480 | 3101-0957     | 1  |
| 3101-1180 | SWITCH:SLIDE 3PDT                 | 82389 | 11L-1020      | 1  |
| 3101-1357 | SWITCH:TOGGLE SPDT                | 09353 | 7109          | 1  |
| 5000-0703 | SIDE COVER                        | 28480 | 5000-0703     | 1  |
| 5000-0711 | COVER:BOTTOM                      | 28480 | 5000-0711     | 1  |
| 5020-0704 | METER TRIM:THIRD MOD.             | 28480 | 5020-0704     | 1  |
| 5040-0235 | BASE:LAMPHOLDER                   | 28480 | 5040-0235     | 1  |
| 5040-0257 | LAMPHOLDER                        | 28480 | 5040-0257     | 1  |
| 5040-0700 | HINGE                             | 28480 | 5040-0700     | 1  |

# See introduction to this section for ordering information

Table 6-2. Replaceable Parts (Cont'd)

| Part No.   | Description #                  | Mfr.  | Mfr. Part No. | TQ |
|------------|--------------------------------|-------|---------------|----|
| 5040-0702  | INSULATOR:CONNECTOR            | 28480 | 5040-0702     | 1  |
| 5040-4528  | GUIDE:PC BOARD( GRAY PLASTIC)  | 28480 | 5040-4528     | 1  |
| 5060-0703  | FRAME ASSY:6 X 11 SM           | 28480 | 5060-0703     | 1  |
| 5060-0706  | COVER:TOP                      | 28480 | 5060-0706     | 1  |
| 5060-0727  | FOOT ASSY                      | 28480 | 5060-0727     | 1  |
| 7204-0004  | ALUMINUM:SHEET 0.063 THICK     | 28480 | 7204-0004     | 1  |
| 8120-0078  | CABLE ASSY:POWER CORD          | 28480 | 8120-0078     | 1  |
| 8120-1082  | CABLE ASSY:5 FT                | 28480 | 8120-1082     | 1  |
| 9100-2504  | TRANSFORMER:28.4V SEC.         | 28480 | 9100-2504     | 1  |
| 00432-0001 | PANEL:FRONT                    | 28480 | 00432-0001    | 1  |
| 00432-0002 | PANEL:REAR                     | 28480 | 00432-0002    | 1  |
| 00432-0005 | BRACKET:TRANSFORMER            | 28480 | 00432-0005    | 1  |
| 00432-0006 | DECK:LOWER                     | 28480 | 00432-0006    | 1  |
| 00432-0007 | DECK:UPPER                     | 28480 | 00432-0007    | 1  |
| 00432-0008 | BRACKET:BATTERY UPPER          | 28480 | 00432-0008    | 1  |
| 00432-0009 | BRACKET:BATTERY LOWER          | 28480 | 00432-0009    | 1  |
| 00432-2001 | BOARD:BLANK PC                 | 28480 | 00432-2001    | 1  |
| 00432-2003 | NUT:DRESS                      | 28480 | 00432-2003    | 1  |
| 00432-2004 | BUSHING:PANEL                  | 28480 | 00432-2004    | 1  |
| 00432-2005 | NUT:CONNECTOR                  | 28480 | 00432-2005    | 1  |
| 00432-2007 | BOARD:BLANK PC                 | 28480 | 00432-2007    | 1  |
| 00432-2015 | BOARD:BLANK PC                 | 28480 | 00432-2015    | 1  |
| 00432-6001 | BOARD ASSY:BRIDGE              | 28480 | 00432-6001    | 1  |
| 00432-6003 | SWITCH ASSY:RANGE              | 28480 | 00432-6003    | 1  |
| 00432-6004 | SWITCH ASSY:CALIBRATION FACTOR | 28480 | 00432-6004    | 1  |
| 00432-6007 | BOARD ASSY:BATTERY CHARGER     | 28480 | 00432-6007    | 1  |
| 00432-6011 | ASSY:AUTO ZERO                 | 28480 | 00432-6011    | 1  |
| 00432-6015 | BOARD ASSY:LOGIC               | 28480 | 00432-6015    | 1  |

# See introduction to this section for ordering information

TABLE 6-3.  
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                  | Code No. | Manufacturer                                                  | Address                            | Code No. | Manufacturer                                                 | Address                         |
|----------|----------------------------------------------------------|--------------------------|----------|---------------------------------------------------------------|------------------------------------|----------|--------------------------------------------------------------|---------------------------------|
| 00000    | U. S. A. Common                                          | Any supplier of U. S.    | 05397    | Union Carbide Corp., Linde Div.                               | Kemet Dept.                        | 11242    | Bay State Electronics Corp.                                  | Waltham, Mass.                  |
| 00136    | McCoy Electronics                                        | Mount Holly Springs, Pa. |          |                                                               | Cleveland, Ohio                    | 11312    | Teledyne Inc. Microwave Div.                                 | Palo Alto, Calif.               |
| 00213    | Sage Electronics Corp                                    | Rochester, N. Y.         | 05593    | Ilumitronic Engineering Co                                    | Sunnyvale, Calif.                  | 11314    | National Seal                                                | Downey, Calif.                  |
| 00287    | Cemco Inc.                                               | Danielson, Conn.         | 05616    | Cosmo Plastic                                                 |                                    | 11534    | Duncan Electronics Inc.                                      | Costa Mesa, Calif.              |
| 00334    | Humidial                                                 | Colton, Calif.           |          | (C/o Electrical Spec. Co.)                                    | Cleveland, Ohio                    | 11711    | General Instrument Corp., Semiconductor                      |                                 |
| 00348    | Microtron Co., Inc.                                      | Valley Stream, N. Y.     | 05624    | Barber Colman Co                                              | Rockford, Ill.                     |          | Div., Products Group                                         | Newark, N. J.                   |
| 00373    | Garlock Inc.                                             | Cherry Hill, N. J.       | 05728    | Tiffen Optical Co                                             |                                    | 11717    | Imperial Electronic, Inc.                                    | Buena Park, Calif.              |
| 00656    | Aerovox Corp.                                            | New Bedford, Mass.       |          |                                                               | Roslyn Heights, Long Island, N. Y. | 11870    | Melabs, Inc.                                                 | Palo Alto, Calif.               |
| 00779    | Amp Inc.                                                 | Harrisburg, Pa.          | 05729    | Metro-Tel Corp                                                | Westbury, N. Y.                    | 12136    | Philadelphia Handle Co.                                      | Camden, N. J.                   |
| 00781    | Aircraft Radio Corp                                      | Boonton, N. J.           | 05783    | Stewart Engineering Co                                        | Santa Cruz, Calif.                 | 12361    | Grove Mfg. Co., Inc.                                         | Shady Grove, Pa.                |
| 00815    | Northern Engineering Laboratories, Inc.                  | Burlington, Wis.         | 05820    | Wakefield Engineering Inc                                     | Wakefield, Mass.                   | 12574    | Gulton Ind. Inc. Data System Div.                            | Albuquerque, N. M.              |
| 00853    | Sangamo Electric Co., Pickens Div.                       | Pickens, S. C.           | 06004    | Bassick Co., Div. of Stewart Warner Corp.                     | Bridgeport, Conn.                  |          |                                                              | Dover, N. H.                    |
| 00866    | Goe Engineering Co.                                      | City of Industry, Cal.   | 06090    | Raychem Corp                                                  | Redwood City, Calif.               | 12697    | Clarostat Mfg. Co.                                           | W. Haven, Conn.                 |
| 00891    | Carl E. Holmes Corp.                                     | Los Angeles, Calif.      | 06175    | Bausch and Lomb Optical Co                                    | Rochester, N. Y.                   | 12728    | Elmar Filter Corp.                                           | Tokyo, Japan                    |
| 00929    | Microfab Inc.                                            | Livingston, N. J.        | 06402    | E. T. A. Products Co of America                               | Chicago, Ill.                      | 12881    | Metex Electronics Corp.                                      | Clark, N. J.                    |
| 01002    | General Electric Co., Capacitor Dept.                    | Hudson Falls, N. Y.      | 06540    | Amatom Electronic Hardware Co., Inc.                          | New Rochelle, N. Y.                | 12930    | Delta Semiconductor Inc.                                     | Newport Beach, Calif.           |
| 01009    | Alden Products Co.                                       | Brockton, Mass.          | 06555    | Beede Electrical Instrument Co., Inc.                         | Penacook, N. H.                    | 12954    | Dickson Electronics Corp.                                    | Scottsdale, Arizona             |
| 01121    | Allen Bradley Co.                                        | Milwaukee, Wis.          | 06666    | General Devices Co Inc.                                       | Indianapolis, Ind.                 | 13103    | Thermolloy                                                   | Dallas, Texas                   |
| 01255    | Litton Industries S. Inc.                                | Beverly Hills, Calif.    | 06751    | Semcor Div. Components Inc.                                   | Phoenix, Ariz.                     | 13396    | Telefunken (GmbH)                                            | Hanover, Germany                |
| 01281    | TRW Semiconductors, Inc.                                 | Lawndale, Calif.         | 06812    | Torrington Mfg. Co., West Div.                                |                                    | 13835    | Midland-Wright Div. of Pacific Industries, Inc.              | Kansas City, Kansas             |
| 01295    | Texas Instruments, Inc.                                  |                          |          |                                                               | Van Nuys, Calif.                   | 14099    | Sem-Tech                                                     | Newbury Park, Calif.            |
|          | Transistor Products Div                                  | Dallas, Texas            | 06980    | Varian Assoc. Eimac Div.                                      | San Carlos, Calif.                 | 14193    | Calif. Resistor Corp.                                        | Santa Monica, Calif.            |
| 01349    | The Alliance Mfg. Co.                                    | Alliance, Ohio           | 07088    | Kelvin Electric Co.                                           | Van Nuys, Calif.                   | 14298    | American Components, Inc.                                    | Conshohocken, Pa.               |
| 01589    | Pacific Relays, Inc.                                     | Van Nuys, Calif.         | 07126    | Digatron Co.                                                  | Pasadena, Calif.                   | 14433    | ITT Semiconductor, A Div. of Int Telephone & Telegraph Corp. | West Palm Beach, Fla.           |
| 01930    | Amerock Corp.                                            | Rockford, Ill.           | 07137    | Transistor Electronics Corp.                                  | Minneapolis, Minn.                 | 14493    | Hewlett-Packard Company                                      | Loveland, Colo.                 |
| 01961    | Pulse Engineering Co.                                    | Santa Clara, Calif.      | 07138    | Westinghouse Electric Corp.                                   |                                    | 14655    | Cornell Dublier Electric Corp.                               | Newark, N. J.                   |
| 02114    | Ferroxcube Corp. of America                              | Saugerties, N. Y.        |          | Electronic Tube Div                                           | Elmira, N. Y.                      | 14674    | Corning Glass Works                                          | Corning, N. Y.                  |
| 02116    | Wheelock Signals, Inc.                                   | Long Branch, N. J.       | 07149    | Filmohm Corp                                                  | New York, N. Y.                    | 14752    | Electro-Cube Inc.                                            | San Gabriel, Calif.             |
| 02286    | Cole Rubber and Plastics Inc.                            | Sunnyvale, Calif.        | 07233    | Cinch Graphix Co                                              | City of Industry, Calif.           | 14960    | Williams Mfg. Co                                             | San Jose, Calif.                |
| 02660    | Amphenol-Borg Electronics Corp.                          | Chicago, Ill.            | 07261    | Avnet Corp                                                    | Culver City, Calif.                | 15203    | Webster Electronics Co.                                      | New York, N. Y.                 |
| 02735    | Radio Corp. of America, Semiconductor and Materials Div. | Somerville, N. J.        | 07263    | Fairchild Camera & Inst Corp                                  | Mountain View, Calif.              | 15287    | Scionics Corp.                                               | Northridge, Calif.              |
| 02771    | Vocaline Co of America, Inc.                             | Old Saybrook, Conn.      | 07322    | Minnesota Rubber Co                                           | Minneapolis, Minn.                 | 15291    | Adjustable Bushing Co.                                       | N. Hollywood, Calif.            |
| 02777    | Hopkins Engineering Co.                                  | San Fernando, Calif.     | 07387    | Birchler Corp The                                             | Monterey Park, Calif.              | 15558    | Micron Electronics                                           | Garden City, Long Island, N. Y. |
| 03508    | G. E. Semiconductor Prod. Dept.                          | Syracuse, N. Y.          | 07397    | Sylvania Elect Prod Inc.                                      | MT. View Operations                | 15566    | Amprobe Inst. Corp                                           | Lynbrook, N. Y.                 |
| 03705    | Apex Machine & Tool Co.                                  | Dayton, Ohio             |          |                                                               | Mountain View, Calif.              | 15631    | Cabletronics                                                 | Costa Mesa, Calif.              |
| 03797    | Eldema Corp                                              | Compton, Calif.          | 07700    | Technical Wire Products Inc.                                  | Cranford, N. J.                    | 15772    | Twentieth Century Coil Spring Co.                            | Santa Clara, Calif.             |
| 03877    | Transitron Electric Corp                                 | Wakefield, Mass.         | 07910    | Continental Device Corp                                       | Hawthorne, Calif.                  | 15801    | Fenwal Elect. Inc.                                           | Framingham, Mass.               |
| 03888    | Pyrofilm Resistor Co., Inc.                              | Cedar Knolls, N. J.      | 07933    | Raytheon Mfg. Co                                              |                                    | 15818    | Amelco Inc                                                   | Mt. View, Calif.                |
| 03954    | Singer Co., Diehl Div.                                   | Sumerville, N. J.        |          | Semiconductor Div.                                            | Mountain View, Calif.              | 16037    | Spruce Pine Mica Co                                          | Spruce Pine, N. C.              |
|          | Finderne Plant                                           |                          | 07980    | Hewlett-Packard Co., Boonton Radio Div.                       | Rockaway, N. J.                    | 16179    | Omni-Spectra Inc.                                            | Detroit, Ill.                   |
| 04009    | Arrow, Hart and Hegeman Elect Co.                        | Hartford, Conn.          | 08145    | U. S. Engineering Co                                          | Los Angeles, Calif.                | 16352    | Computer Diode Corp.                                         | Lodi, N. J.                     |
| 04013    | Taurus Corp.                                             | Lambertville, N. J.      | 08289    | Blinn, Delbert Co.                                            | Pomona, Calif.                     | 16688    | Ideal Prec. Meter Co. Inc.                                   | Brooklyn, N. Y.                 |
| 04062    | Arco Electronic Inc.                                     | Great Neck, N. Y.        | 08358    | Burgess Battery Co.                                           | Niagara Falls, Ontario, Canada     |          | De Jur Meter Div.                                            | Kokoma, Ind.                    |
| 04222    | Hi-Q Division of Aerovox                                 | Myrtle Beach, S. C.      | 08524    | Deutsch Fastener Corp.                                        | Los Angeles, Calif.                | 16758    | Delco Radio Div. of G. M. Corp.                              | Canoga Park, Calif.             |
| 04354    | Precision Paper Tube Co.                                 | Wheeling, Ill.           | 08664    | Bristol Co., The                                              | Waterbury, Conn.                   | 17109    | Thermometrics Inc                                            | Mountain View, Calif.           |
| 04404    | Dymec Division of Hewlett-Packard Co                     | Palo Alto, Calif.        | 08717    | Sloan Company                                                 | Sun Valley, Calif.                 | 17474    | Tranex Company                                               | Akron, Ohio                     |
| 04651    | Sylvania Electric Products, Microwave Device Div         | Mountain View, Calif.    | 08718    | ITT Cannon Electric Inc. Phoenix Div.                         | Phoenix, Arizona                   | 17745    | Angstrom Prec. Inc.                                          | No Holly wood, Calif.           |
| 04713    | Motorola, Inc Semiconductor Prod. Div.                   | Phoenix, Arizona         | 08792    | CBS Electronics Semiconductor Operations, Div. of C B S. Inc. |                                    | 17870    | McGraw-Edison Co.                                            | Manchester, N. H.               |
| 04732    | Filtron Co., Inc. Western Div.                           | Culver City, Calif.      |          |                                                               | Lowell, Mass.                      | 18042    | Power Design Pacific Inc                                     | Palo Alto, Calif.               |
| 04773    | Automatic Electric Co.                                   | Northlake, Ill.          | 08984    | Mel-Rain                                                      | Indianapolis, Ind.                 | 18083    | Clevite Corp. Semiconductor Div.                             | Palo Alto, Calif.               |
| 04796    | Sequoia Wire Co                                          | Redwood City, Calif.     | 09026    | Babcock Relays Div                                            | Costa Mesa, Calif.                 | 18324    | Signetics Corp.                                              | Sunnyvale, Calif.               |
| 04811    | Precision Coil Spring Co                                 | El Monte, Calif.         | 09134    | Texas Capacitor Co                                            | Houston, Texas                     | 18476    | Ty-Car Mfg Co., Inc                                          | Holliston, Mass.                |
| 04870    | P. M. Motor Company                                      | Westchester, Ill.        | 09145    | Tech Ind Inc Atohm Elect.                                     | Burbank, Calif.                    | 18486    | TRW Elect Comp Div.                                          | Des Plaines, Ill.               |
| 04919    | Component Mfg. Service Co.                               | W. Bridgewater, Mass.    | 09250    | Electro Assemblies, Inc.                                      | Chicago, Ill.                      | 18583    | Curtis Instrument, Inc.                                      | Mt. Kisco, N. Y.                |
| 05006    | Twentieth Century Plastics, Inc.                         | Los Angeles, Calif.      | 09569    | Mallory Battery Co. of Canada, Ltd.                           | Toronto, Ontario, Canada           | 18873    | E. I. DuPont and Co., Inc.                                   | Wilmington, Del.                |
| 05277    | Westinghouse Electric Corp. Semiconductor Dept           | Youngwood, Pa.           | 10214    | General Transistor Western Corp                               | Los Angeles, Calif.                | 18911    | Durant Mfg. Co.                                              | Milwaukee, Wis.                 |
| 05347    | Ultronic, Inc                                            | San Mateo, Calif.        | 10411    | Ti-Tal, Inc.                                                  | Berkeley, Calif.                   | 19315    | The Bendix Corp. Navigation & Control Div                    | Teterboro, N. J.                |
|          |                                                          |                          | 10646    | Carborundum Co                                                | Niagara Falls, N. Y.               | 19500    | Thomas A Edison Industries, Div. of McGraw-Edison Co.        | West Orange, N. J.              |
|          |                                                          |                          | 11236    | CTS of Berne, Inc                                             | Berne, Ind                         | 19589    | Concoa                                                       | Baldwin Park, Calif.            |
|          |                                                          |                          | 11237    | Chicago Telephone of California, Inc.                         | So. Pasadena, Calif.               | 19644    | LRC Electronics                                              | Horseheads, N. Y.               |
|          |                                                          |                          |          |                                                               |                                    | 19701    | Electra Mfg Co.                                              | Independence, Kansas            |

TABLE 6-3.  
CODE LIST OF MANUFACTURERS (Cont'd)

| Code No. | Manufacturer                                               | Address                     | Code No. | Manufacturer                                            | Address                 | Code No. | Manufacturer                                              | Address                       |
|----------|------------------------------------------------------------|-----------------------------|----------|---------------------------------------------------------|-------------------------|----------|-----------------------------------------------------------|-------------------------------|
| 20183    | General Atomics Corp.                                      | Philadelphia, Pa            | 71436    | Chicago Condenser Corp.                                 | Chicago, Ill            | 77252    | Philadelphia Steel and Wire Corp.                         | Philadelphia, Pa.             |
| 21226    | Executone, Inc.                                            | Long Island City, N. Y.     | 71447    | Cal if. Spring Co Inc                                   | Pico-Rivera, Calif.     |          |                                                           |                               |
| 21335    | Fafnir Bearing Co The                                      | New Britain, Conn           | 71450    | CTS Corp.                                               | Elkhart, Ind.           | 77342    | American Machine & Foundry Co Potter                      | Princeton, Ind                |
| 21520    | Fansteel Metallurgical Corp                                | N. Chicago, Ill             | 71468    | ITT Cannon Electric Inc.                                | Los Angeles, Calif.     |          |                                                           |                               |
| 23783    | British Radio Electronics Ltd                              | Washington, D C             | 71471    | Cinema, Div. Aerovox Corp.                              | Burbank, Calif.         | 77630    | TRW Electronic Components Div                             | Camden, N J                   |
| 24455    | G E Lamp Division                                          |                             | 71482    | C P Clare & Co                                          | Chicago, Ill.           | 77638    | General Instrument Corp Rectifier Div                     | Brooklyn, N Y                 |
|          |                                                            | Nela Park, Cleveland, Ohio  | 71590    | Centralab Div. of Globe Union Inc.                      |                         | 77764    | Resistance Products Co                                    | Harrisburg, Pa                |
| 24655    | General Radio Co                                           | West Concord, Mass          |          |                                                         |                         | 77969    | Rubbercraft Corp of Calif                                 | Torrance, Calif               |
| 24681    | Memco or Inc Comp. Div.                                    | Huntington, Ind.            | 71616    | Commercial Plastics Co.                                 | Chicago, Ill.           | 78189    | Shakeproof Division of Illinois Tool Works                | Elgin, Ill.                   |
| 26365    | Gries Reproducer Corp.                                     | New Rochelle, N. Y.         | 71700    | Cornish Wire Co The                                     | New York, N. Y.         |          |                                                           |                               |
| 26462    | Grobet File Co of America, Inc.                            |                             | 71707    | Coto Coil Co Inc                                        | Providence, R. I.       | 78283    | Signal Indicator Corp                                     | New York, N. Y.               |
|          |                                                            | Carlstadt, N. J.            | 71744    | Chicago Miniature Lamp Works                            | Chicago, Ill.           | 78290    | Stuthers-Dunn Inc                                         | Pitman, N. J.                 |
| 26992    | Hamilton Watch Co                                          | Lancaster, Pa.              | 71785    | Cinch Mfg. Co., Howard B. Jones Div                     | Chicago, Ill.           | 78452    | Thompson-Bremer & Co                                      | Chicago, Ill                  |
| 28480    | Hewlett Packard Co                                         | Palo Alto, Calif.           |          |                                                         |                         | 78471    | Triley Mfg Co                                             | San Francisco, Calif          |
| 28520    | Heyman Mfg Co.                                             | Kenilworth, N. J.           | 71984    | Dow Corning Corp.                                       | Midland, Mich.          | 78488    | Stackpole Carbon Co                                       | St Marys, Pa                  |
| 33173    | G E Receiving Tube Dept.                                   | Owensboro, Ky               | 72136    | Electro Motive Mfg Co Inc.                              | Williamstic, Conn.      | 78493    | Standard Thomson Corp                                     | Waltham, Mass.                |
| 35434    | Lectrohm Inc                                               | Chicago, Ill.               | 72519    | Diallight Corp.                                         | Brooklyn, N Y           | 78553    | Tinnerman Products, Inc                                   | Cleveland, Ohio               |
| 36196    | Stanwyck Coil Products Ltd                                 |                             | 72656    | Indiana General Corp., Electronics Div                  | Keasby, N. J.           | 78790    | Transformer Engineers                                     | San Gabriel, Calif.           |
|          |                                                            | Hawkesbury, Ontario, Canada |          |                                                         |                         | 78947    | Ucinite Co                                                | Newtownville, Mass            |
| 36287    | Cunningham, W. H. & Hill, Ltd.                             |                             | 72699    | General Instrument Corp., Cap. Div.                     | Newark, N. J.           | 79136    | Waldes Kohinoor Inc                                       | Long Island City, N. Y.       |
|          |                                                            | Toronto Ontario, Canada     | 72765    | Drake Mfg. Co.                                          | Harwood Heights, Ill.   | 79142    | Veeder Root, Inc                                          | Hartford, Conn                |
| 37942    | P. R. Mallory & Co Inc                                     | Indianapolis, Ind           | 72825    | Hugh H. Eby Inc.                                        | Philadelphia, Pa        | 79251    | Wenco Mfg Co                                              | Chicago, Ill                  |
| 39543    | Mechanical Industries Prod. Co                             | Akron, Ohio                 | 72928    | Gudeman Co.                                             | Chicago, Ill            | 79727    | Continental-Wirt Electronics Corp                         | Philadelphia, Pa.             |
| 40920    | Miniature Precision Bearings, Inc.                         | Keene, N. H.                | 72964    | Robert M. Hadley Co.                                    | Los Angeles, Calif      |          |                                                           |                               |
| 42190    | Muter Co                                                   | Chicago, Ill                | 72982    | Erie Technological Products, Inc                        | Erie, Pa                | 79963    | Zierick Mfg Corp                                          | New Rochelle, N. Y.           |
| 43990    | C. A. Norgren Co                                           | Englewood, Colo             | 73061    | Hansen Mfg. Co., Inc.                                   | Princeton, Ind.         | 80031    | Meeco Division of Sessions Clock Co                       | Morristown, N. J              |
| 44655    | Ohmite Mfg Co                                              | Skokie, Ill                 | 73076    | H. M. Harper Co                                         | Chicago, Ill.           |          |                                                           |                               |
| 46384    | Penn Eng & Mfg Corp.                                       | Doylestown, Pa.             | 73138    | Helipot Div of Beckman Inst., Inc                       | Fullerton, Calif        | 80120    | Schnitzer Alloy Products Co                               | Elizabeth, N. J               |
| 47904    | Polaroid Corp                                              | Cambridge, Mass             |          |                                                         |                         | 80131    | Electronic Industries Association, Any brand              | Washington, DC                |
| 48620    | Precision Thermometer & Inst Co.                           |                             | 73293    | Hughes Products Division of Hughes Aircraft Co.         | Newport Beach, Calif    | 80207    | Unimax Switch Div Maxon Electronics Corp                  | Wallingford, Conn             |
|          |                                                            | Southampton, Pa             |          |                                                         |                         |          |                                                           |                               |
| 49956    | Microwave & Power Tube Div                                 | Waltham, Mass.              | 73445    | Amperex Elect Co.                                       | Hicksville, L. I. N. Y. | 80223    | United Transformer Corp                                   | New York, N. Y.               |
| 52090    | Rowan Controller Co                                        | Westminster, Md.            | 73506    | Bradley Semiconductor Corp.                             | New Haven, Conn         | 80248    | Oxford Electric Corp                                      | Chicago, Ill                  |
| 52983    | Sanborn Company                                            | Waltham, Mass.              | 73559    | Carling Electric, Inc.                                  | Hartford, Conn          | 80294    | Bourne Inc                                                | Riverside, Calif              |
| 54294    | Shall cross Mfg Co                                         | Selma, N. C                 | 73586    | Circle F Mfg. Co.                                       | Trenton, N. J.          | 80411    | Acro Div of Robertshaw Controls Co                        | Columbus, Ohio                |
| 55026    | Simpson Electric Co                                        | Chicago, Ill                | 73682    | George K Garrett Co., Div. MSL Industries Inc.          | Philadelphia, Pa.       | 80486    | All Star Products Inc.                                    | Defiance, Ohio                |
| 55933    | Sonotone Corp                                              | Elmsford, N. Y.             |          |                                                         |                         | 80509    | Avery Label Co                                            | Monrovia, Calif               |
| 55938    | Raytheon Co Commercial Apparatus & Systems Div             | So Norwalk, Conn.           | 73734    | Federal Screw Products Inc.                             | Chicago, Ill            | 80583    | Hammarlund Co Inc                                         | New York, N. Y.               |
| 56137    | Spaulding Fibre Co Inc                                     | Tonawanda, N. Y.            | 73743    | Fischer Special Mfg. Co                                 | Cincinnati, Ohio        | 80640    | Stevens, Arnold, Co Inc                                   | Boston, Mass                  |
| 56289    | Sprague Electric Co                                        | North Adams, Mass.          | 73793    | General Industries Co The                               | Elyria, Ohio            | 81030    | International Instruments Inc                             | Orange, Conn.                 |
| 59446    | Telex Corp                                                 | Tulsa, Okla.                | 73846    | Goshen Stamping & Tool Co.                              | Goshen, Ind             | 81073    | Grayhill Co                                               | LaGrange, Ill                 |
| 59730    | Thomas & Betts Co                                          | Elizabeth, N. J.            | 73899    | JFD Electronics Corp.                                   | Brooklyn, N. Y.         | 81095    | Triad Transformer Corp                                    | Venice, Calif.                |
| 60741    | Triplett Electrical Inst. Co                               | Bluffton, Ohio              | 73905    | Jennings Radio Mfg Corp                                 | San Jose, Calif         | 81312    | Winchester Elec Div. Litton Ind Inc                       | Oakville, Conn.               |
| 61775    | Uni on Switch and Signal, Div of Westinghouse Air Brake Co |                             | 73957    | Groov-Pin Corp.                                         | Ridgefield, N. J.       |          |                                                           |                               |
|          |                                                            | Pittsburgh, Pa.             | 74276    | Signalite Inc                                           | Neptune, N. J           | 81349    | Military Specification                                    |                               |
| 62119    | Universal Electric Co                                      | Owosso, Mich.               | 74455    | J. H. Winns, and Sons                                   | Winchester, Mass        | 81483    | International Rectifier Corp                              | El Segundo, Calif.            |
| 63743    | Ward-Leonard Electric Co                                   | Mt Vernon, N. Y.            | 74861    | Industrial Condenser Corp                               | Chicago, Ill            | 81541    | Alpa x Electronics, Inc                                   | Cambridge, Maryland           |
| 64959    | Western Electric Co Inc                                    | New York, N. Y.             | 74868    | R F Products Division of Amphenol-Borg Electronics Corp | Danbury, Conn           | 81860    | Barry Controls Div. Barry Wright Corp                     | Watertown, Mass.              |
| 65092    | Western Inst. Inc Weston-Newark                            | Newark, N. J.               |          |                                                         |                         |          |                                                           |                               |
| 66295    | Witteck Mfg Co.                                            | Chicago, Ill                | 74970    | E. F. Johnson Co                                        | Waseca, Minn            | 82042    | Carter Precision Electric Co                              | Skokie, Ill.                  |
| 66346    | Minnesota Mining & Mfg Co. Revere Mincom Div.              |                             | 75042    | International Resistance Co                             | Philadelphia, Pa        | 82047    | Sperit Faraday Inc Copper Hewitt Electric Div             | Hoboken, N. J.                |
|          |                                                            | St Paul, Minn.              | 75378    | CTS Knights Inc.                                        | Sandwich, Ill           | 82142    | Jeffers Electronics Division of Speer Carbon Co           | Du Bois, Pa                   |
| 70276    | Allen Mfg Co                                               | Hartford, Conn.             | 75382    | Kulka Electric Corporation                              | Mt Vernon, N. Y.        | 82170    | Fairchild Camera & Inst. Corp. Space & Defense System Div | Paramus, N. J.                |
| 70309    | Allied Control                                             | New York, N. Y.             | 75818    | Lenz Electric Mfg Co.                                   | Chicago, Ill.           | 82209    | Maguire Industries, Inc                                   | Greenwich, Conn               |
| 70318    | Allmetal Screw Product Co Inc                              |                             | 75915    | Littlefuse, Inc                                         | Des Plaines, Ill        | 82219    | Sylvania Electric Prod Inc Electronic Tube Division       | Emporium, Pa                  |
|          |                                                            | Garden City, N. Y.          | 76005    | Lord Mfg Co.                                            | Erie, Pa                | 82376    | Astron Corp                                               | East Newark, Harri son, N. J. |
| 70485    | Atlantic India Rubber Works, Inc                           | Chicago, Ill.               | 76210    | C W Marwedel                                            | San Francisco, Calif    | 82389    | Switchcraft, Inc                                          | Chicago, Ill.                 |
| 70563    | Amperite Co Inc                                            | Union City, N. J.           | 76433    | General Instrument Corp., Micamold Division             | Newark, N. J.           | 82647    | Metals & Controls Inc. Spencer Products                   | Attleboro, Mass.              |
| 70674    | ADC Products Inc.                                          | Minneapolis, Minn.          |          |                                                         |                         |          |                                                           |                               |
| 70903    | Belden Mfg Co                                              | Chicago, Ill.               | 76487    | James Millen Mfg Co., Inc.                              | Malden, Mass.           | 82768    | Phillips-Advance Control Co                               | Joliet, Ill.                  |
| 70998    | Bird Electronic Corp                                       | Cleveland, Ohio             | 76493    | J. W. Miller Co.                                        | Los Angeles, Calif.     | 82866    | Research Products Corp.                                   | Madison, Wis.                 |
| 71002    | Birnback Radio Co.                                         | New York, N. Y.             | 76530    | Cinch Monadnock, Div. of United Carr Fastener Corp.     | San Leandro, Calif      | 82877    | Rotron Mfg Co Inc.                                        | Woodstock, N. Y.              |
| 71041    | Boston Gear Works Div of Murray Co. of Texas               | Quincy, Mass                |          |                                                         |                         | 82893    | Vector Electronic Co                                      | Glendale, Calif.              |
| 71218    | Bud Radio, Inc.                                            | Willoughby, Ohio            | 76545    | Mueller Electric Co                                     | Cleveland, Ohio         |          |                                                           |                               |
| 71286    | Camloc Fastener Corp                                       | Paramus, N. J.              | 76703    | National Union                                          | Newark, N. J.           |          |                                                           |                               |
| 71313    | Cardwell Condenser Corp.                                   |                             | 76854    | Oak Manufacturing Co.                                   | Crystal Lake, Ill       |          |                                                           |                               |
|          |                                                            | Lindenhurst L. I., N. Y.    | 77068    | The Bendix Corp Electroductronics Div.                  | N. Hollywood, Calif     |          |                                                           |                               |
| 71400    | Bussmann Mfg. Div. of McGraw-Edison Co                     | St. Louis, Mo.              |          |                                                         |                         |          |                                                           |                               |
|          |                                                            |                             | 77075    | Pacific Metals Co                                       | San Francisco, Calif    |          |                                                           |                               |
|          |                                                            |                             | 77221    | Phanotron Instrument and Electronic Co.                 | South Pasadena, Calif.  |          |                                                           |                               |

TABLE 6-3.  
CODE LIST OF MANUFACTURERS (Cont'd)

| Code No. | Manufacturer                                            | Address                                 | Code No. | Manufacturer                                    | Address                    | Code No. | Manufacturer                                     | Address                    |
|----------|---------------------------------------------------------|-----------------------------------------|----------|-------------------------------------------------|----------------------------|----------|--------------------------------------------------|----------------------------|
| 83056    | Carr Fastener Co.                                       | Cambridge, Mass.                        | 91418    | Radio Materials Co.                             | Chicago, Ill.              | 97464    | Industrial Retaining Ring Co                     | Irrington, N. J.           |
| 83086    | New Hampshire Ball Bearing, Inc.                        | Peterborough, N. H.                     | 91506    | Augat Inc.                                      | Attleboro, Mass.           | 97539    | Automatic & Precision Mfg.                       | Englewood, N. J.           |
| 83125    | General Instrument Corp. Capacitor Div.                 | Darlington, S. C.                       | 91637    | Dale Electronics, Inc.                          | Columbus, Nebr.            | 97979    | Reon Resistor Corp.                              | Yonkers, N. Y.             |
| 83142    | ITT Wire and Cable Div.                                 | Los Angeles, Calif.                     | 91662    | Elco Corp.                                      | Willow Grove, Pa.          | 97983    | Litton System Inc. Adler-Westrex Commun. Div.    | New Rochelle, N. Y.        |
| 83186    | Victory Eng. Corp.                                      | Springfield, N. J.                      | 91737    | Gremar Mfg. Co., Inc.                           | Wakefield, Mass.           | 98141    | R-Tronics, Inc.                                  | Jamaica, N. Y.             |
| 83298    | Bendix Corp. Red Bank Div.                              | Red Bank, N. J.                         | 91827    | KF Development Co.                              | Redwood City, Calif.       | 98159    | Rubber Teck, Inc.                                | Gardena, Calif.            |
| 83315    | Hubbell Corp.                                           | Mundelein, Ill.                         | 91886    | Malco Mfg. Co., Inc.                            | Chicago, Ill.              | 98220    | Hewlett-Packard Co., Moseley Div.                | Pasadena, Calif.           |
| 83330    | Smith, Herman H. Inc.                                   | Brooklyn, N. Y.                         | 91929    | Honeywell Inc. Micro Switch Div.                | Freeport, Ill.             | 98278    | Microdot, Inc.                                   | So. Pasadena, Calif.       |
| 83332    | Tech Labs                                               | Palisade's Park, N. J.                  | 91961    | Nahm Bros. Spring Co.                           | Oakland, Calif.            | 98291    | Sealectro Corp.                                  | Mamaroneck, N. Y.          |
| 83385    | Central Screw Co.                                       | Chicago, Ill.                           | 92180    | Tru-Connector Corp.                             | Peabody, Mass.             | 98376    | Zero Mfg. Co.                                    | Burbank, Calif.            |
| 83501    | Gavitt Wire and Cable Co.                               | Div. of Amerace Corp. Brookfield, Mass. | 92367    | Eigeel Optical Co. Inc.                         | Rochester, N. Y.           | 98731    | General Mills Inc., Electronics Div.             | Minneapolis, Minn.         |
|          | Burroughs Corp. Electronic Tube Div.                    | Plainfield, N. J.                       | 92607    | Tensolite Insulated Wire Co., Inc.              | Tarrytown, N. Y.           | 98734    | Paeco Div. of Hewlett-Packard Co.                | Palo Alto, Calif.          |
| 83740    | Union Carbide Corp. Consumer Prod. Div.                 | New York, N. Y.                         | 92702    | IMC Magnetics Corp.                             | Wesbury Long Island, N. Y. | 98821    | North Hills Electronics, Inc.                    | Glen Cove, N. Y.           |
| 83777    | Model Eng and Mfg., Inc.                                | Huntington, Ind.                        | 92966    | Hudson Lamp Co.                                 | Kearney, N. J.             | 98978    | International Electronic Research Corp.          | Burbank, Calif.            |
| 83821    | Loyd Scruggs Co.                                        | Festus, Mo.                             | 93332    | Sylvania Electric Prod. Inc. Semiconductor Div. | Woburn, Mass.              | 99109    | Columbia Technical Corp.                         | New York, N. Y.            |
| 83942    | Aeronautical Inst. & Radio Co.                          | Lodi, N. J.                             | 93369    | Robbins & Myers Inc.                            | Palisades Park, N. J.      | 99313    | Varian Associates                                | Palo Alto, Calif.          |
| 84171    | Arco Electronics Inc.                                   | Great Neck, N. Y.                       | 93410    | Stevens Mfg. Co. Inc.                           | Mansfield, Ohio            | 99378    | Allee Corp.                                      | Winchester, Mass.          |
| 84396    | A. J. Glesener Co., Inc.                                | San Francisco, Calif.                   | 93929    | G. V. Controls                                  | Livingston, N. J.          | 99515    | Marshall Ind., Capacitor Div.                    | Monrovia, Calif.           |
| 84411    | TRW Capacitor Div.                                      | Ogallala, Neb.                          | 94137    | General Cable Corp.                             | Bayonne, N. J.             | 99707    | Control Switch Division, Controls Co. of America | El Segundo, Calif.         |
| 84970    | Sarkes Tarzian, Inc.                                    | Bloomington, Ind.                       | 94144    | Raytheon Co. Comp. Div., Ind. Comp. Operations  | Quincy, Mass.              | 99800    | Delevan Electronics Corp.                        | East Aurora, N. Y.         |
| 85454    | Boonton Molding Company                                 | Boonton, N. J.                          | 94148    | Scientific Electronics Products, Inc.           | Loveland, Colo.            | 99848    | Wilco Corporation                                | Indianapolis, Ind.         |
| 85471    | A. B. Boyd Co.                                          | San Francisco, Calif.                   | 94154    | Wagner Elect. Corp. Tung-Sol Div.               | Newark, N. J.              | 99934    | Renbrandt, Inc.                                  | Boston, Mass.              |
| 85474    | R. M. Bracamonte & Co.                                  | San Francisco, Calif.                   | 94197    | Curtiss-Wright Corp. Electronics Div.           | East Paterson, N. J.       | 99942    | Hoffman Electronics Corp. Semiconductor Div.     | El Monte, Calif.           |
| 85660    | Koiled Kords, Inc.                                      | Hamden, Conn.                           | 94222    | South Chester Corp.                             | Chester, Pa.               | 99957    | Technology Instrument Corp of Calif.             | Newbury Park, Calif.       |
| 85911    | Seamless Rubber Co.                                     | Chicago, Ill.                           | 94330    | Wire Cloth Products, Inc.                       | Bellwood, Ill.             |          |                                                  |                            |
| 86197    | Clifton Precision Products Co., Inc.                    | Clifton Heights, Pa.                    | 94682    | Worcester Pressed Aluminum Corp.                | Worcester, Mass.           |          |                                                  |                            |
| 86579    | Precision Rubber Products Corp.                         | Dayton, Ohio                            | 94696    | Magnecraft Electric Co.                         | Chicago, Ill.              |          |                                                  |                            |
| 86684    | Radio Corp. of America, Electronic Comp. & Devices Div. | Harrison, N. J.                         | 95023    | George A Philbrick Researchers, Inc.            | Boston, Mass.              |          |                                                  |                            |
| 87034    | Marcol Industries                                       | Anaheim, Calif.                         | 95236    | Allies Products Corp.                           | Dania, Fla.                |          |                                                  |                            |
| 87216    | Philco Corporation (Lansdale Division)                  | Lansdale, Pa.                           | 95238    | Continental Connector Corp.                     | Woodside, N. Y.            |          |                                                  |                            |
| 87473    | Western Fibrous Glass Products Co.                      | San Francisco, Calif.                   | 95263    | Leecraft Mfg. Co. Inc.                          | Long Island, N. Y.         |          |                                                  |                            |
| 87664    | Van Waters & Rogers Inc.                                | San Francisco, Calif.                   | 95265    | National Coil Co.                               | Sheridan, Wyo.             |          |                                                  |                            |
| 87930    | Tower Mfg. Corp.                                        | Providence, R. I.                       | 95275    | Vitramon, Inc.                                  | Bridgeport, Conn.          | 0000F    | Malco Tool and Die                               | Los Angeles, Calif.        |
| 88140    | Cutler-Hammer, Inc.                                     | Lincoln, Ill.                           | 95348    | Gordos Corp.                                    | Bloomfield, N. J.          | 0000Z    | Willow Leather Products Corp.                    | Newark, N. J.              |
| 88220    | Gould-National Batteries, Inc.                          | St. Paul, Minn.                         | 95354    | Method Mfg. Co.                                 | Rolling Meadows, Ill.      |          |                                                  |                            |
| 88698    | General Mills, Inc.                                     | Buffalo, N. Y.                          | 95566    | Arnold Engineering Co.                          | Marengo, Ill.              |          |                                                  |                            |
| 89231    | Graybar Electric Co.                                    | Oakland, Calif.                         | 95712    | Dage Electric Co., Inc.                         | Franklin, Ind.             | 000AB    | ETA                                              | England                    |
| 89473    | G. E. Distributing Corp.                                | Schenectady, N. Y.                      | 95984    | Siemon Mfg. Co.                                 | Wayne, Ill.                | 000BB    | Precision Instrument Components Co.              | Van Nuys, Calif.           |
| 89665    | United Transformer Co.                                  | Chicago, Ill.                           | 95987    | Weckesser Co.                                   | Chicago, Ill.              | 000CS    | Hewlett-Packard Co. Colorado Springs             | Colorado Springs, Colorado |
| 90179    | US Rubber Co. Consumer Ind. & Plastics Prod. Div.       | Passaic, N. J.                          | 96067    | Huggins Laboratories                            | Sunnyvale, Calif.          | 000MM    | Rubber Eng. & Development                        | Hayward, Calif.            |
| 90970    | Bearing Engineering Co.                                 | San Francisco, Calif.                   | 96095    | Hi-Q Div. of Aerovox Corp.                      | Olean, N. Y.               | 000NN    | A "N" D Mfg. Co.                                 | San Jose, Calif.           |
| 91146    | ITT Cannon Elect. Inc., Salem Div.                      | Salem, Mass.                            | 96256    | Thordarson-Meissner Inc.                        | Mt. Carmel, Ill.           | 000QQ    | Coaltron                                         | Oakland, Calif.            |
| 91260    | Connor Spring Mfg. Co.                                  | San Francisco, Calif.                   | 96296    | Solar Manufacturing Co.                         | Los Angeles, Calif.        | 000WW    | California Eastern Lab.                          | Burlington, Calif.         |
| 91345    | Miller Dial & Nameplate Co.                             | El Monte, Calif.                        | 96330    | Carlton Screw Co.                               | Chicago, Ill.              | 000YY    | S. K. Smith Co.                                  | Los Angeles, Calif.        |
|          |                                                         |                                         | 96341    | Microwave Associates, Inc.                      | Burlington, Mass.          |          |                                                  |                            |
|          |                                                         |                                         | 96501    | Excel Transformer Co.                           | Oakland, Calif.            |          |                                                  |                            |

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

|       |                                      |                            |
|-------|--------------------------------------|----------------------------|
| 0000F | Malco Tool and Die                   | Los Angeles, Calif.        |
| 0000Z | Willow Leather Products Corp.        | Newark, N. J.              |
| 000AB | ETA                                  | England                    |
| 000BB | Precision Instrument Components Co.  | Van Nuys, Calif.           |
| 000CS | Hewlett-Packard Co. Colorado Springs | Colorado Springs, Colorado |
| 000MM | Rubber Eng. & Development            | Hayward, Calif.            |
| 000NN | A "N" D Mfg. Co.                     | San Jose, Calif.           |
| 000QQ | Coaltron                             | Oakland, Calif.            |
| 000WW | California Eastern Lab.              | Burlington, Calif.         |
| 000YY | S. K. Smith Co.                      | Los Angeles, Calif.        |



## SECTION VII

### TROUBLESHOOTING, SCHEMATICS, AND COMPONENT LOCATIONS

#### 7-1. INTRODUCTION.

7-2. This section contains troubleshooting instructions, schematics, and component locations for the power meter. Also included is an overall block diagram that indicates the location of test points in the instrument.

7-3. Reference designations shown within circuit card outlines are abbreviated. To find the part in the Parts List, use the full reference designation. For example, R6 on the A2 Meter Logic Assembly is listed as A2R6.

7-4. The Schematic Notes in Table 7-1 pertain to all the schematics. Additional notes on the schematics indicate test conditions, and special information for use when maintaining the instrument.

#### 7-5. TROUBLESHOOTING.

7-6. Table 7-2 is the Overall Troubleshooting chart for the power meter. Procedures for isolating circuit malfunctions to specific stages are based on the use of the HP 8477A Power Meter Calibrator and the calibration procedures in Section V. The information obtained when calibration is attempted is used to troubleshoot the instrument.

7-7. Table 7-2 contains references that direct the user to the detailed troubleshooting charts, Tables 7-3 through 7-11. The detailed charts refer the user to transistor stages. In a few instances, specific parts are called out as being possible causes of circuit malfunction, however, the troubleshooting charts are not intended to locate specific parts that have failed. They are intended to locate only malfunctioning stages.

#### 7-8. SCHEMATICS.

7-9. The schematics contain signal routing information, nominal voltage levels, and notes that assist in understanding the circuit. They are laid out to show electrical operation, and are not intended as wiring diagrams.

7-10. Component location photographs next to the schematic foldouts indicate the physical location of parts. Test points are also shown, and are marked on the schematic in the same manner as they are in the meter.

7-11. Factory selected parts are indicated by an asterisk. These are components that generally are installed to fulfill circuit operation requirements. They may be the nominal value, or they may be some value close to nominal. In any case, if the component fails, circuit operation should be verified after these components are replaced.

#### 7-12. AIAI AUTO ZERO ASSEMBLY.

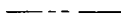
7-13. The Auto Zero circuit is encapsulated and must be replaced as a unit. A solder removing tool, such as the Soldapullit suction device listed in Section V, is required to remove solder around the leads. After solder is removed, the unit must be carefully removed from the circuit card in such a manner that the circuits on the card do not delaminate. After the Auto Zero assembly is replaced, perform the adjustment procedure given in Section V.

#### 7-14. TEST CONDITIONS.

7-15. For most tests of circuit operation when troubleshooting the instrument, the troubleshooting charts call out control settings. In special cases, notes on the schematics indicate control settings required to measure voltage levels in circuits. Generally, the following control settings should be selected, and changed only as the troubleshooting procedures indicate:

|                              |                                   |
|------------------------------|-----------------------------------|
| Raffle . . . . .             | .3 mW (-5 dBm)                    |
| MOUNT RESISTANCE . . . . .   | 200 (Mount installed)             |
| CALIBRATION FACTOR . . . . . | 100                               |
| COARSE ZERO . . . . .        | turn until meter is at full scale |

Table 7-1. Schematic Notes

|     |                                                                                     |                                                                                                                     |
|-----|-------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------|
| 1.  |                                                                                     | Resistance in ohms, capacitance in microfarads unless otherwise indicated.                                          |
| 2.  |    | Screwdriver adjustment                                                                                              |
|     |    | Front panel control                                                                                                 |
| 3.  |    | Front panel designation                                                                                             |
|     |    | Rear panel designation                                                                                              |
| 4.  |    | Printed circuit card border                                                                                         |
|     |    | Main signal path                                                                                                    |
|     |    | Secondary signal path                                                                                               |
|     |   | Secondary feedback path                                                                                             |
| 5.  |                                                                                     | P/O = part of                                                                                                       |
| 6.  |  | Wiper moves toward CW when control rotated clockwise                                                                |
| 7.  |  | Test point. Number in circle matches number on printed circuit card.                                                |
| 8.  |  | Breakdown diode                                                                                                     |
| 9.  |  | Tunnel diode                                                                                                        |
| 10. |  | Wire color code. Numerical color code same as resistor coding. For example, 947 denotes white, yellow, violet wire. |
| 11. |  | Indicates socket connections and pin numbers.                                                                       |



# THERMISTOR MOUNT 478A

HP Model 478A Thermistor Mount

## GENERAL INFORMATION

### 1. INTRODUCTION.

2. The HP Model 478A Coaxial Thermistor Mount is designed for use with HP Model 431 and 432 Power Meters to measure microwave power from  $1\mu\text{W}$  to 10 mW. Design of the mount minimizes adverse effects from environmental temperature changes during measurement. For increased measurement accuracy, Effective Efficiency and Calibration Factor are measured for each mount, and at selected frequencies across the operating range; the results are marked on the label of the instrument (see Paragraph 31). The Model 478A can be used over the 10-MHz to 10-GHz frequency range. Through-

out the range, the mount terminates the coaxial input in a 50-ohm impedance, and has a SWR of not more than 1.75 without external tuning.

3. Each mount contains two series pairs of thermistors, which are matched to cancel the effects of drift with ambient temperature change. Thermal stability is accomplished by mounting the leads of all four thermistors on a common thermal conductor to ensure a common thermal environment. This conductor is thermally insulated from the main body of the mount so the thermal noise or shocks applied externally to the mount, such as those from handling the mount manually, cannot significantly penetrate to disturb the thermistor. This thermal immunity enables the thermistors to be used in the

Table 1. Specifications

frequency Range: 478A: 10 MHz to 10 GHz

Mount Calibration: Calibration Factor and Effective Efficiency furnished at six frequencies between 10 MHz and 10 GHz.

Impedance: 50 ohms.

Maximum Reflection Coefficient:  
 10 to 25 MHz: 0.273 (1.75 SWR, 11.3 dB return loss).  
 25 MHz to 7 GHz: 0.13 (1.3 SWR, 17.7 dB return loss).  
 7 to 10 GHz: 0.2 (1.5 SWR, 14 dB return loss)

Operating Resistance: 200 ohms.

Power Range with Model 431 and 432A: 1  $\mu$ W to 10 mW.

Maximum Peak Power: 200W.

Maximum Average Power: 30 mW.

Maximum Energy per Pulse: 10 W  $\cdot$   $\mu$ s for a PRF  $\geq$  1 kHz; 5 W  $\cdot$   $\mu$ s for a PRF < 1 kHz.

Elements: Field-replaceable, thermally balanced thermistor assembly. Thermistor assembly field adjustable so that full "zero-set" capability can be restored in the event of inadvertent overload (mount calibration no longer valid).

RF Connector: Type -N male, compatible with female connectors whose dimensions conform to MIL-C-71 or MIL-C-39012. Brass connector.

Output Connector: Mates with 431 and 432 cables.

Weight: Net, 5 oz (140 g). Shipping, 1 lb (450 g).

Uncertainty of Calibration Factor and Effective Efficiency Data for 478A

| Sum Uncertainties (%) |             |                      | Probable Uncertainties (%) |                      |
|-----------------------|-------------|----------------------|----------------------------|----------------------|
| Freq. (GHz)           | Cal. Factor | Effective Efficiency | Cal. Factor                | Effective Efficiency |
| 1.0                   | 2.3         | 2.3                  | 1.1                        | 1.1                  |
| 3.0                   | 2.8         | 3.1                  | 1.6                        | 1.6                  |
| 5.0                   | 3.6         | 3.5                  | 2.1                        | 2.1                  |
| 7.0                   | 3.7         | 4.1                  | 2.1                        | 2.1                  |
| 8.2                   | 2.8         | 3.5                  | 1.3                        | 1.3                  |
| 9.8                   | 2.8         | 3.1                  | 1.3                        | 1.3                  |
| 12.4                  | 6.3         | 4.6                  | 2.1                        | 1.6                  |
| 15.0                  | 6.3         | 4.6                  | 2.1                        | 1.6                  |
| 18.0                  | 6.3         | 4.8                  | 2.1                        | 1.6                  |

\*Includes uncertainty of reference standard and transfer uncertainty. Directly traceable to NBS. In addition to the listed uncertainties, add the following for the indicated 431 ranges: 0.3% ; 0.1 mW,  $\pm$ 0.7% ; 0.03 mW,  $\pm$ 1.5% ; 0.01 mW. When using the 432 Power Meter no additional uncertainties are encountered.

measurement of microwave power down to the micro-watt region.

#### 4. INCOMING INSPECTION.

5. Inspect the Model 478A upon receipt for mechanical damage. Also check it electrically; if the mount was subjected to severe mechanical shock during shipment, the match between the thermistors may be affected. To check thermistor match, proceed as described in Paragraph 58.

6. If any damage is found, inform the carrier and your nearest HP Sales and Service Office immediately.

### OPERATION

#### 7. PRECAUTIONS.

#### 8. MECHANICAL SHOCK

9. DO NOT DROP OR SUBJECT TO SEVERE MECHANICAL SHOCK. SHOCK MAY DESTROY THE MATCH BETWEEN THERMISTORS AND INCREASE SUSCEPTIBILITY TO DRIFT.

#### 10. BIASING THERMISTORS.

#### CAUTION

Before connecting the Model 478A to the 431 or 432 Power Meters, set the MOUNT RES switch to 200-ohm position. CONNECTING A 200-OHM MOUNT TO A POWER METER SET FOR A 100-OHM MOUNT CAN RESULT IN THERMISTOR DAMAGE.

#### 11. MAXIMUM INPUT.

12. The Model 478A 431 and 478A 432 combinations respond to the average RF power applied. The maximum signal applied to the thermistor mount should not exceed the limitations for 1) average power, 2) pulse energy and 3) peak pulse power. Excessive input can permanently damage the Model 478A by altering the match between the RF and compensation thermistors (resulting in excessive drift or zero shift) or cause error in indicated power.

13. AVERAGE POWER. The 478A 431 and 478A 432 combinations can measure average power up to 10 mW. To measure power in excess of 10 mW, insert a calibrated directional coupler such as one of the HP Model 770 series or 790 series between the mount and the source. UNDER NO CIRCUMSTANCES APPLY MORE THAN 30 mW AVERAGE POWER TO THE MOUNT.

14. PULSE ENERGY AND PEAK POWER FOR 478A 432 COMBINATION. For pulses shorter than 250  $\mu$ s, energy per pulse must not exceed 10 W  $\cdot$   $\mu$ s and peak power should never exceed 200 watts. (For example, a 40 mW, 250  $\mu$ s pulse contains 10 W  $\cdot$   $\mu$ s of energy.) Pulses longer than 250  $\mu$ s are allowed to contain more energy but peak power must not exceed 40 mW. Figures 1 and 2 interpret these limits in graphical form. (For lack of space, the mount nameplate lists only a 5 W  $\cdot$   $\mu$ s

## Model 478A

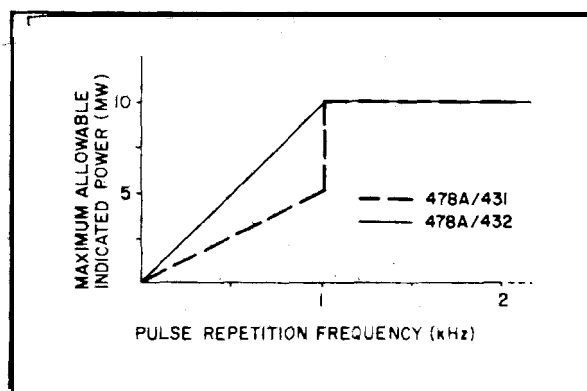


Figure 1. Maximum Power Meter Reading vs PRF for Pulses Shorter than 250  $\mu$ s

limit, a rating which applies to the 478A 431 combination.)

15. PULSE ENERGY AND PEAK POWER FOR 478A/431 COMBINATION. The limitations of this combination are basically the same as the 478A 432 with the exception that at pulse repetition rates less than 1 kHz, energy per pulse must not exceed 5 W-U's and peak power must not exceed 10 mW. These limits are also interpreted in Figures 1 and 2.

16. Square-wave modulation is a special case of pulse modulation, and maximum power-meter reading versus square -wave frequency is illustrated in Figure 3. This figure also holds for sine -wave modulation.

17. In the discussions above, the primary consideration is maximum power or energy. However, for modulation frequencies less than 100 Hz, the low repetition frequency itself causes errors in indicated power. These errors may be as large as two percent regardless of range or reading.

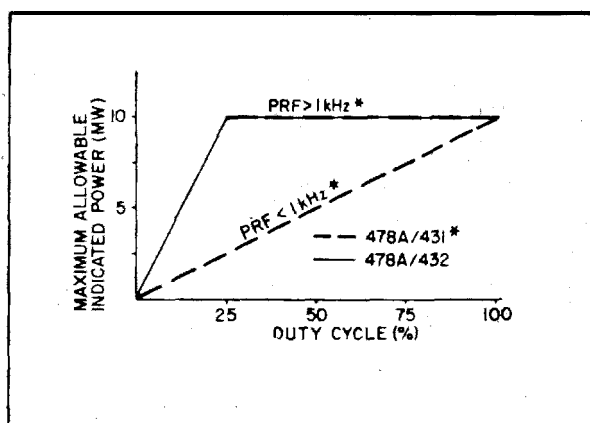


Figure 2. Maximum Power Meter Readings vs Duty Cycle for Pulses Longer than 250  $\mu$ s

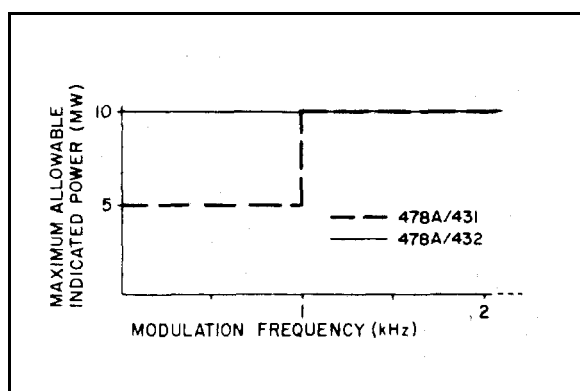


Figure 3. Maximum Power Meter Reading vs Square and Sine -Wave Frequency

18. When RF is switched by pulse-gating (coaxial solid state switches), consideration must be given to the RF energy contained in the switching pulse itself. This energy must be added to actual RF pulse power when estimating the RF power dissipated in the thermistor mount. PIN diode modulators of H P Model 8741A/8716A Modulators and 8614A/8616A Signal Generators, however, are not subject to this consideration because output filtering prevents transmission of modulating signals.

### 19. DRIFT PRECAUTION.

20. Thermistors are inherently temperature -sensitive devices. A cold thermistor mount connected to a warm piece of equipment, or vice versa, produces rapid drift. FOR MINIMUM DRIFT ON SENSITIVE RANGES, MAKE SURE THAT THE MOUNT AND THE EQUIPMENTCONNECTED TO IT ARE AT NEARLY THE SAME TEMPERATURE BEFORE MAKING A MEASUREMENT.

### 21. ZERO-SET.

22. It is necessary to electrically zero-set the Model 431/432 Power Meter before making a power measurement. To preserve the same zero reference throughout the measurement, maintain the same thermal environment when RF power is applied. Two recommended set-ups for 431 zero-set up are presented in Paragraphs 23 and 25. The recommended set-up for zero-set in the 432 is shown in Paragraph 30.

### 23. RF POWER TURNED OFF FOR ZERO-SET.

24. There is minimum zero drift when the zero is set with the RF system connected to the thermistor mount and the RF power switch off or greatly attenuated by the generator attenuator. The methods used to switch off RF output in HP signal generators are listed in Table 2. After allowing time for the mount to stabilize thoroughly, follow zero-set procedures in the 431 or 432 Power Meter manual and then turn on the RF source.

Table 2. Methods of Switching Off RF Output of Various HP Signal Generators

| HP Generator                                        | Frequency Range                                                                                    | Proedure to Switch Off RF Output                                                            |
|-----------------------------------------------------|----------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------|
| Model 606                                           | 50kHz to 65 MHz                                                                                    | Increase the generator output attenuation 30 or more dB                                     |
| Model 8614A 8616A<br>Model 614 616<br>Model 618 620 | 800 to 2400 MHz 1800 to 4500 MHz<br>800 to 2100 MHz 1800 to 4200 MHz<br>3.8 to 7.6 GHz 7 to 11 GHz | Release RF pushbutton<br>Set modulation selector to OFF<br>Set modulation selector to OFF   |
| Model 608<br>Model 682 687                          | 10 to 480 MHz 10 to 420 MHz<br>1 to 2 GHz 12.4 to 18.0 GHz                                         | Set MOD SELECTOR to PULSE, but do not apply modulation signal to modulation input terminal  |
| Model 612                                           | 450 to 1230 MHz                                                                                    | Set MODSELECTOR to PULSE 2, but do not apply modulation signal to modulation input terminal |
| Model 690, 8690 Series                              | 1 to 20 GHz                                                                                        | Set LINE to STANDBY                                                                         |

## 25. THERMISTOR MOUNT DISCONNECTED FOR ZERO-SET.

26. 478A 431. When it is inconvenient to turn off the RF power in the RF system, connect the Model 478A mount to the RF system and set RANGE on the Model 431 Power Meter for an approximate midscale reading. When the reading no longer drifts, disconnect the

### Note

In the proximity of a high RF field, shield the disconnected thermistor mount from possible stray RF pick-up during the zero-set.

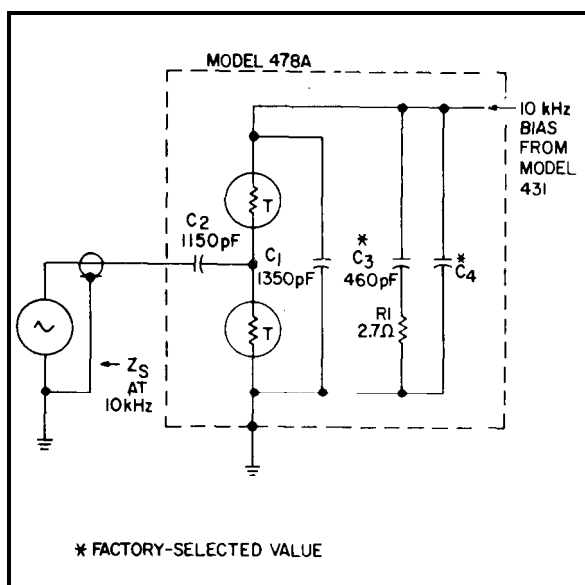


Figure 4. Source Impedance Shunting One RF Thermistor Mount

mount from the source, terminate the mount, if necessary, as described in Paragraph 27, and then zero-set the power meter. Immediately reconnect the mount to the RF source for the power measurement.

27. With the Model 478A mount connected to the RF system, the source impedance shunts one of the RF thermistors (see Figure 4); when the Model 478A mount is disconnected, the source impedance is removed. Unless source impedance is high, this variation in impedance affects the RF bridge 10-kHz feedback loop in the power meter, and the zero-level setting obtained with the source disconnected is no longer zero for the measurement. This error can be eliminated by terminating the mount in an impedance which approximately matches the generator impedance at 10 kHz; the termination should be connected while the mount is disconnected (see Paragraph 26) from the source. For example, if the impedance presented by the RF system to 10 kHz is low (1K ohm or less) terminate the thermistor mount in a 50-ohm resistor or a short. On the other hand, if the impedance of the RF system at 10 kHz is high (100 K ohms or more) leave the thermistor mount unterminated during zero-set.

28. Note that some 10-kHz bias signal is coupled into the RF transmission system by C2 (Figure 5). If the RF source output impedance at 10 kHz is 15K ohms or greater, 10-kHz bias voltage is typically 1.3 V RMS and could equal 1.5 V RMS. For an RF source output impedance of 50 ohms at 10 kHz, bias signal voltage is typically 5 mV RMS.

29. The presence of this 10-kHz bias signal may affect solid state RF sources and RF voltmeter measurements. To minimize or eliminate these effects, use an additional blocking capacitor at the Model 478A or a high-pass filter at the RF source output.

30. 478A 432. When it is inconvenient to turn the RF power off while using the 478A 432 combination simply remove the mount from the source, and using the COARSE and FINE ZERO, zero the 432.

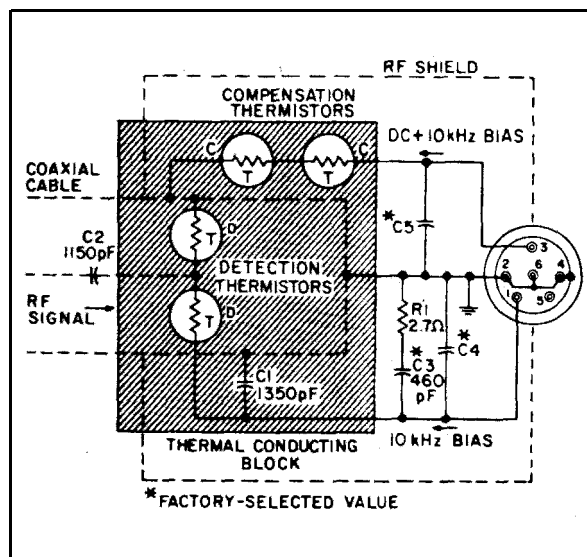


Figure 5. Schematic Diagram of a Model 478A Thermistor Mount when Connected to a 431 Power Meter

### 31. MOUNT CALIBRATION DATA.

32. The calibration points imprinted on the label of each 478A allow power measurements to be made with increased accuracy. Values of Calibration Factor and Effective Efficiency are given at six frequencies between 10 MHz and 10 GHz. The mounts are tested on a swept-frequency basis to assure accurate interpolation between calibration points. Calibration Factor and Effective Efficiency values are traceable to the National Bureau of Standards to the extent allowed by the Bureau's calibration facilities.

33. **CALIBRATION FACTOR.** Calibration Factor is the ratio of substituted audio or dc power in a thermistor mount to the microwave RF power incident upon the mount.

$$\text{Calibration Factor} = \frac{P_{dc} \text{ Substituted}}{P_{\text{wave}} \text{ Incident}}$$

34. Calibration Factor is a figure of merit assigned to a thermistor mount to correct for the following sources of error: 1) RF reflected by the mount due to mismatch, 2) RF loss caused by absorption within the mount but not in the detection thermistor elements, and 3) dc-to-microwave power substitution error. Calibration Factor is applied as a correction factor to all measurements made without a tuner. When these factors and thermoelectric effect (refer to Paragraph 39) are taken into consideration, the power indicated is the power that would be delivered by the RF source to the characteristic impedance of the transmission line. The total SWR in the transmission line determines a region of uncertainty about the measured power. This subject is discussed in Application Note 64, available from any Hewlett-Packard Sales and Service Office.

**NOTE.** Calibration will be performed in the AN/TSM-55V5 Maintenance Calibration Equipment Shelter.

35. **EFFECTIVE EFFICIENCY.** Effective Efficiency is the ratio of substituted, audio or dc power in a thermistor mount to the microwave RF power dissipated within the mount.

$$\text{Effective Efficiency} = \frac{P_{dc} \text{ Substituted}}{P_{\mu\text{wave}} \text{ Dissipated}}$$

36. Effective Efficiency corrects for power absorbed in parts of the mount other than the detection thermistor elements and dc-to-microwave power substitution error in the thermistor mount. Effective Efficiency is applied as a correction factor when a tuner is used to match the thermistor mount to the transmission line or RF source. In this case, all of the RF power incident upon the mount is absorbed in the mount. Since all power is absorbed in the mount, measurement uncertainty due to mount SWR is eliminated; however, losses in the tuner must be considered.

### 37. CALIBRATION DATA APPLICATION.

38. When the 478A is used with the Model 431 or 432 Power Meters, Calibration Factor or Effective Efficiency corrections can be made by setting a front panel switch. With the proper setting, the 431 or 432 compensates for the Calibration Factor or Effective Efficiency in the 478A. If the 478A is used with a power meter other than the 431 or 432, Calibration Factor or Effective Efficiency corrections can be made by dividing the measured power by the Calibration Factor or Effective Efficiency value respectively.

### 39. THERMOELECTRIC EFFECT.

40. Mount calibration uncertainties given in Table 1 include inaccuracies caused by thermoelectric effect error. Calibration Factor uncertainty of  $\pm 1.5\%$  and Effective Efficiency uncertainty of  $\pm 2.5\%$  can be maintained on the three lowest power ranges of the Model 431 series Power Meters by correcting for the measurement error introduced by thermoelectric effect. An error correction procedure is given in Paragraph 44.

41. A mild thermocouple exists at each point of contact where the connecting wires join to the thermistor elements. Each thermocouple creates a dc voltage. Thus, two thermocouple voltages of opposite relative polarity are formed, one at each junction to each thermistor element.

42. Ideally, each thermocouple voltage would be equal in magnitude so that they cancel with no resultant effect on the accuracy of power measurement. In practice however, each point of contact does not have identical thermocouple characteristics, and in addition, the temperatures at each junction may not be the same. These differences cause an incomplete cancellation of the thermoelectric voltages, resulting in a voltage that causes a thermoelectric effect error. The magnitude of the error is important when making dc substitution measurements on the 0.1 mW, 0.03 mW and 0.01 mW ranges with one of the Model 431 series Power Meters. On other ranges, the effect is negligible. Maximum error introduced by thermoelectric effect is about 0.3  $\mu\text{W}$  and is typically 0.1  $\mu\text{W}$  on the 0.01 mW range.

#### 43. THERMOELECTRIC EFFECT ERROR CORRECTION FOR 478A 431 COMBINATION.

44. Use the following technique to correct for thermoelectric effect error.

- a. Measure power.
- b. Connect a HP Model 8402 Power Meter Calibrator to the power meter DC CALIBRATION AND SUBSTITUTION connector.
- c. Zero and null power meter.
- d. By dc substitution (refer to procedure in 431 Manual), duplicate power measurement made in step a. Calculate and record substituted power as  $P_1$ .
- e. Reverse connection polarity between the calibrator and power meter.
- f. Re-zero and re-null power meter, if necessary.
- g. By dc substitution, duplicate lower measurement made in step a. Calculate and record substituted power as  $P_2$ .
- h. Calculate arithmetic mean of the two substitution powers  $P_1$  and  $P_2$ . This mean power includes a correction for thermoelectric effect error.

$$\text{Power} = \frac{P_1 + P_2}{2}.$$

#### 45. THERMOELECTRIC ERROR FOR 478A 432 COMBINATION.

46. The thermoelectric errors present in the 431 are minimized in the 432 since the thermoelectric voltage is negligible compared with the dc voltage used to bias the thermistor bridges.

### OPERATING PRINCIPLES

#### 47. CIRCUIT DESCRIPTION.

48. Two matched series thermistors are mounted on a common thermal conducting block, represented by the shaded rectangle in Figure 5. One pair, marked "D" for detection, is mounted between the end of a coaxial cable and cylindrical cavity. These thermistors are exposed to incoming RF power which heats them, lowering their resistance. The other pair, marked "C" for compensation and situated immediately outside the cavity, is completely shielded from RF. With the 478A attached to the 431 Power Meter, the detection thermistors are part of the metering circuit.

49. With the 478A attached to the 432 Power Meter the detection thermistors are part of the RF bridge and the compensation thermistors are part of the compensation bridge. Since the two pairs of thermistors show the same thermal environment, any change in temperature which affects the RF bridge simultaneously affects the metering bridge; this allows the power meter circuit to compensate for changes in temperature and thus minimize drift.

50. During 431 478A operation, sufficient amounts of dc and 10 kHz bias currents are supplied from the 431 Power Meter to heat the thermistors until their resistances are reduced to approximately  $200\Omega$  per series pair. Capacitor C1 offers high impedance to 10 kHz, but is practically a short to RF. This causes "D" to appear series connected to 10 kHz, but parallel connected to RF. In this manner, "D" appears to the audio bridge of the 431 Power Meter as a  $200\Omega$  resistance, but terminates the coaxial cable in  $50\Omega$ . Capacitor C2 blocks any dc and audio power that may be present in the incoming signal, and passes only RF power.

51. During 432 operation (see Figure 6) sufficient amounts of dc current are supplied from 432 Power Meter to heat the thermistors until their resistances are reduced to approximately  $200\Omega$  per series pair. Capacitor C1 is practically a short to RF. This causes "D" to appear series connected to the dc bridge, parallel connected to RF. In this manner, "D" appears to the dc bridge in the 432 Power Meter as a  $200\Omega$  resistance that terminates the coaxial cable into  $50\Omega$ . Capacitor C2 blocks any dc and audio power that may be present in the incoming signal and passes only RF power.

#### 52. 431 POWER METER DETECTION.

53. Under normal operation, the total power supplied to heat thermistor pair "D" (see Figure 5) consists of 1) RF signal, 2) 10 kHz bias, 3) heat from the environment. The total power supplied to heat thermistor pair "C" consists of: 1) dc bias, 2) an equal amount of 10 kHz bias, and 3) heat from the same environment. As "D" and "C" are matched thermally, the total amounts of heat applied to reduce their series resistance equally must be equal.

#### 54. 432 POWER DETECTION.

55. Under normal operation the total power applied to heat thermistor pair "D" (see Figure 6) consists of: 1) RF signal and 2) heat from the environment. The total power supplied to heat thermistor "C" consists of: 1) dc bias and 2) heat from the same environment. As "D" and "C" are matched thermally, the total amounts of heat applied to reduce their series resistance equally must be equal.

### MAINTENANCE

#### 56. MECHANICAL SHOCK.

57. The Model 478A is a precision instrument. Avoid dropping or other mechanical shocks. Such shocks can destroy the match between the thermistors.

#### 58. CHECK ON THERMISTOR MATCH.

59. Match between the thermistors may be checked by comparing the thermistor resistances under simulated operating conditions. Equipment required is indicated in Figure 6. Make connections to the connector at the rear of the thermistor mount; pins are shown in Figure 6. Note that the small battery in series with the HP Model 3440 Digital Voltmeter is connected in opposition

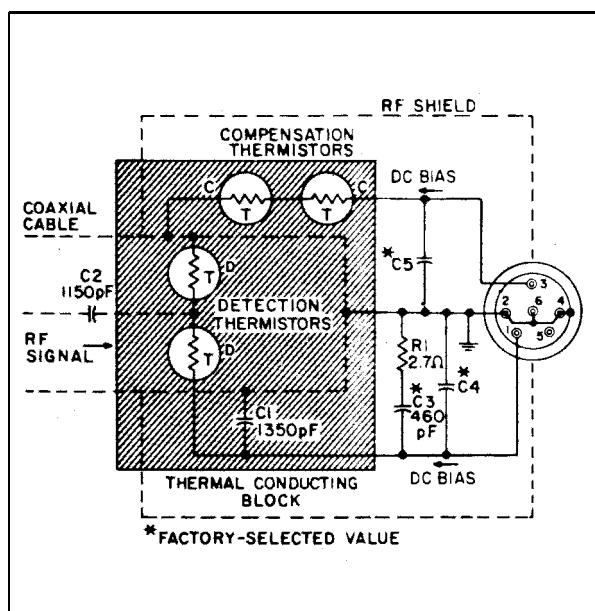


Figure 6. Schematic Diagram of a Model 478A Thermistor Mount when Connected to a 432 Power Meter

#### WARNING

Under no conditions should the mount be required to carry a current higher than 14 mA.

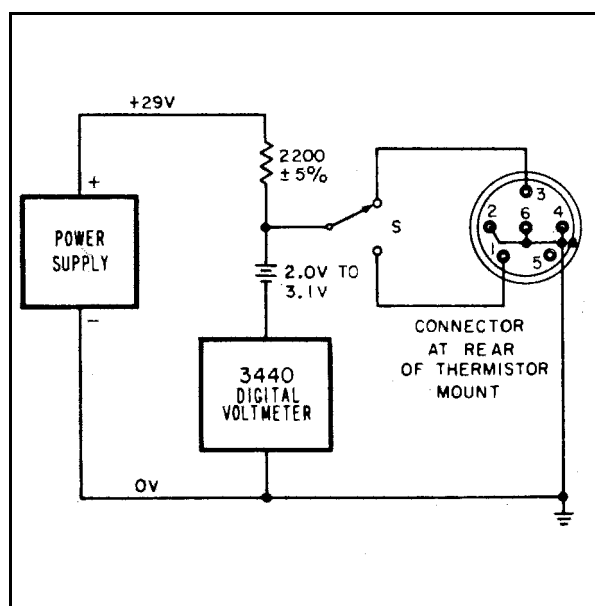


Figure 7. Check on Model 478A Thermistor Resistance Match

to the power supply. The value of this bucking voltage should be such that voltmeter resolution down to 0.001 volt is obtained. Take readings with switch S connected to pin 1 and then to pin 3. Thermistor match is satisfactory if the two readings do not differ by more than 0.030 volt. Nonoperating mounts with readings as high as 0.150 volt can probably be repaired as outlined in the succeeding paragraphs.

#### 60. REPAIR.

61. Exceeding the cw or pulse power limit of the Model 478A Thermistor Mount may result in damage such that the mount will no longer zero on the Model 431 or 432 Power Meter.

62. Before adjusting the mount in any way, make sure that the mount is the cause of the problem. An open or short indication, using the checks in Paragraphs 59 or 64, means that the mount is not repairable by the procedures outlined in the following paragraphs. However, the mount may be nonoperative but still repairable. Test for this by using the procedures in Paragraph 58, or by connecting the mount to a Model 431 or 432 Power Meter and a cable which is known to be good. A faulty cable will not have continuity through the respective connector pins or may have poor contact in the mount connector. Poor contact will show as an intermittency or a great deal of noise (visible on the 431 or 432 Meter) when the cable is gently flexed near the connector end.

#### Note

The following procedures are set down for the 431 478A combination. The same procedures can be used for the 432 except for the ZERO VERNIER control. These controls on the 431 are replaced by the COARSE ZERO and FINE ZERO control on the 432.

63. The major difference between the 478A 431 and 478A 432 combination is that the 478A 432 combination does not use 10 kHz as a biasing factor in the thermistor. All biasing factors in the 432 are from dc sources therefore, lowering the thermoelectric effect.

64. To troubleshoot a damaged mount, proceed as follows:

- a. Connect mount to Model 431.
- b. Set:
 

|           |       |         |
|-----------|-------|---------|
| MOUNT RES | ..... | 200 ohm |
| RANGE     | ..... | 10 mW   |
| POWER     | ..... | ON      |
- c. Rotate ZERO from one limit to the other.

65. If meter remains pegged upscale, the thermistor elements have been damaged. However, it may be possible to recompensate the thermistors per Paragraphs 68 and 69 and return the mount to operation; otherwise they must be replaced. In either case, the Effective Efficiency and Calibration Factor data on the nameplate are no longer valid (see Paragraph 77).

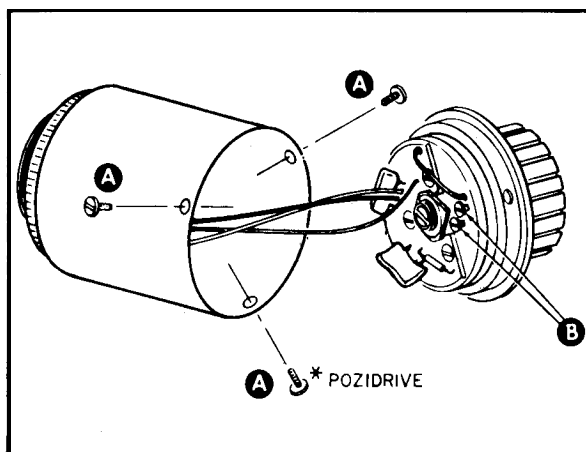


Figure 8. Thermistor Compensation

66. If meter remains pegged downscale, measure resistance between pins 1 and 2, and pins 3 and 4. The resistance should measure between 1000 and 5000 ohms. An open or shorted reading indicates the need for replacement of the thermistors.

67. If the resistance reading is satisfactory, it may be possible to recompensate the mount and return it to service. The drift with temperature changes will be higher because of the damage to the thermistors, but it will be possible to zero the meter and to make measurements. The Effective Efficiency and Calibration Factor indicated on the label will no longer be valid (see Paragraph 77). There are two adjusting screws inside the instrument which permit recompensation within limits. Most instruments with serials lower than 7663 do not have the adjusting screws at the time of manufacture, but are modified if the instrument was sent in for repair after March 1964.

68. Refer to Figure 8 and proceed as follows:

- a. Remove the three screws (A).
- b. Slide instrument out of its cover.
- c. Plug cover into Model 431.
- d. Set: MOUNT RES . . . . . 200 ohm  
POWER . . . . . ON

69. If meter is pegged downscale:

- a. Set RANGE to 10 mW.
- b. Set ZERO and VERNIER to mid-range.
- c. Turn screws (B) clockwise, 1 8 turn alternately.

#### CAUTION

If there is a sudden jump in meter indication when advancing either screw, back off 1 8 turn, and do not advance that screw further. Check resistance as in Paragraph 66. If either screw bottoms, do not apply force. Thermistor replacement (Paragraph 71) is indicated.

d. When meter pointer rises, trim to zero with each adjusting screw.

e. Replace cover and three screws (A). The instrument is now operative.

#### Note

Make sure the three screws in the body of the thermistor mount are tight when the mount is put together; this insures quiet operation.

70. If meter is pegged upscale:

- a. Set ZERO and VERNIER to mid-range.
- b. Set RANGE to highest position which will not peg the meter.
- c. Turn one of the screws (B) counterclockwise to obtain a meter reading half that observed in step b.

d. Turn the other screw (B) counterclockwise to zero the meter. If it is impossible to zero the meter, replace the thermistors (Paragraph 71).

e. Replace cover and three screws (A). The instrument is now operative.

#### 71. THERMISTOR ASSEMBLY REPLACEMENT PROCEDURE.

#### Note

After replacement of the thermistor assembly, the Effective Efficiency and Calibration Factor indicated on the label of the mount are no longer valid (see Paragraph 77).

72. The procedure consists of removing the damaged thermistor assembly, the printed circuit assembly and replacing them with pretested assemblies included in

Table 3. Parts Furnished in Thermistor Assembly Replacement Kit, HP 00478-600

| Qty                 | Description                                              | HP Stock No. |
|---------------------|----------------------------------------------------------|--------------|
| 1                   | Thermistor Assembly                                      | 478A-95A     |
| 1                   | Etched Circuit Board                                     | 478A-65A     |
| 1                   | Resistor, fixed composition, 2.7 ohms $\pm 10\%$<br>1/4W | 0684-0271    |
| 1 or 2              | Capacitors, fixed, dipped mica                           |              |
| * Factory Selected. |                                                          |              |

Thermistor Assembly Replacement Kit, HP Stock No. 00478-600.

73. The replacement assemblies are pretested at the factory. However, since the operation of the thermistor mount depends on proper installation of the assembly, it may be desirable to check the SWR and efficiency following replacement. The efficiency may be checked by comparing against a known mount. The SWR is checked at 9 GHz and 10 GHz. SWR should be approximately equal at 9 and 10 GHz, and should be 1.5 or less.

#### Note

In the field, replaceable thermistor assembly connection of the RF thermistors to the Type N center conductor is made by a bellows. If the bellows does not contact the center conductor, SWR will be about 2.0 at 10 GHz. The bellows may be lengthened slightly with a pair of tweezers.

74. The following special tools may be required for the completion of this procedure:

- a. One small screwdriver, 0.070 tip, suitable for removing a 00-90 x 1.8 screw.
- b. One pair of tweezers.

#### 75. REMOVAL PROCEDURE.

- a. Remove three 2-56 x 3.16 screws holding terminal shield (Figure 9). Move terminal shield aside.

#### CAUTION

Do not break wires connecting printed circuit assembly to receptacle connector.

- b. Loosen locknut and remove 5.16-32 setscrew from thermistor assembly.

- c. Disconnect the three wires between the printed circuit assembly and the receptacle connector from the printed circuit assembly.

- d. In early thermistor assemblies there is a 00-90 x 1.8 screw used to connect the RF Thermistors to the Type N center conductor. Remove this screw, if present, using small screwdriver and tweezers.

- e. Remove the three 2-56 x 5.8 inch screws holding printed circuit and thermistor assemblies to the RF connector assembly.

- f. Remove printed circuit and thermistor assemblies.

- g. Remove the three insulator bushings from thermistor assembly. This completes the removal of the damaged assembly.

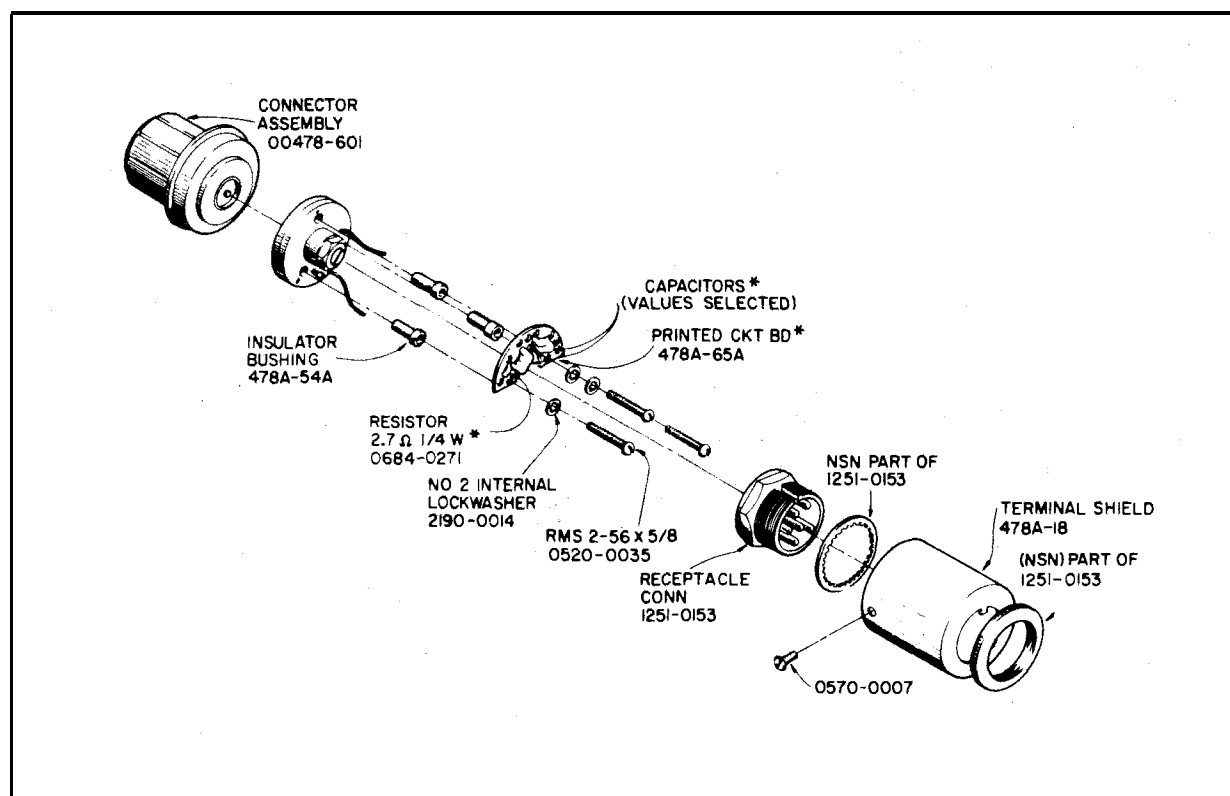


Figure 9. Model 478A Thermistor Mount Assembly

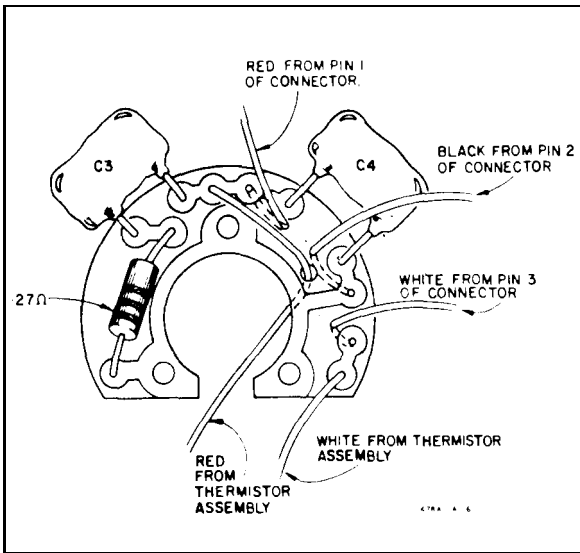


Figure 10. HP Model 478A Printed Circuit Assembly Wiring

#### 76. INSTALLATION PROCEDURE.

a. Referring to Figure 10, connect the three wires from receptacle connector to printed circuit assembly.

##### Note

For strain relief, the wires should go through the holes indicated and connect from the bottom of the printed circuit assembly.

b. Install the three insulator bushings in the thermistor assembly.

c. Pass the red wire from the thermistor assembly through the hole indicated in Figure 10. Do not connect to printed circuit assembly at this time.

d. Mount thermistor and printed circuit assemblies on RF connector assembly. Use three 2-56 x 5/8 inch screws and lockwashers. Screws must be tightened firmly to insure proper bellows contact with the Type N center conductor.

##### Note

Printed circuit assembly must be positioned so it does not cover compensating screws.

e. Connect red and white wires from thermistor assembly to printed circuit assembly.

f. Connect thermistor mount to a HP Model 431. Check for proper null and zero.

g. If desired, check SWR and efficiency. The Mount SWR has been adjusted at the factory to be about equal at 9 GHz and 10 GHz and less than 1.5. The adjustment is made with the 5/16-23 setscrew which is secured by a locknut. The setscrew should not be moved unless SWR is being recalibrated. Efficiency may be checked by comparing to a known good mount.

##### CAUTION

To prevent pulling wires out of terminal connector, secure terminal shield with one 2-56 x 3/16 inch screw while making checks.

h. When any testing or recalibration is completed, secure terminal shield with three 2-56 x 3/16 inch screws. This completes the Installation Procedure.

77. RECALIBRATION. If recalibration of the mount is desired, the instrument may be sent to the factory for repair and recalibration. Any Hewlett - Packard Sales and Service Office will arrange for such repair.

# MANUAL CHANGES

BACKDATING

MODEL 432A  
POWER METER

Manual Serial Prefixed: 812- Manual Printed: August 1968

MAKE ALL CO IN THIS MANUAL ACCORDING TO ERRATA BELOW, THEN CHECK THE FOLLOWING TABLE FOR YOUR INSTRUMENT SERIAL PREFIX (3 DIG OR SERIAL NUMBER (8 DIG AND MAKE ANY LISTED CHANGE(S) IN THE MANUAL.

. NEW ITEM.

| SERIAL PREFIX OR NUMBER | MAKE MANUAL CHANGES | SERIAL PREFIX OR NUMBER | MAKE MANUAL CHANGES |
|-------------------------|---------------------|-------------------------|---------------------|
| 812-00201 & above       | Change 1, 4         |                         |                     |
| 840                     | Change 1, 2, 4      |                         |                     |
| 843                     | Change 1, 2, 3, 4   |                         |                     |
|                         |                     |                         |                     |

## CHANGE 1

Change A2R61 and A2R62 to R: FXD 215K OHM 0698-3454

Change A2R36 to R: FXD 1M OHM 0683-1055

Change A2C24 to C: FXD 270 PF 0140-0210

Add A2C48 from A3Q38 base to ground. C: FXD 68 PF 0490-0192

## CHANGE 2

Add A1R3 between A1 pin 11 and +7 Vdc. R: FXD 3 1.6K 0698-3160

Delete A1R43.

## CHANGE 3

Add A2C49 between A2 pin 15 and junction of A2R59 and A2R57.

C: FXD 2.2  $\mu$ f 0180-0197Add A2R29 between  and the bottom of A2C31.R: FXD 68.1 $\Omega$  0757-0397

## CHANGE 4

Figure A1-1, A1-2, A1-3 and Table A1-1 and A1-2 apply to 432A Power Meters with serial prefix 843 and below.

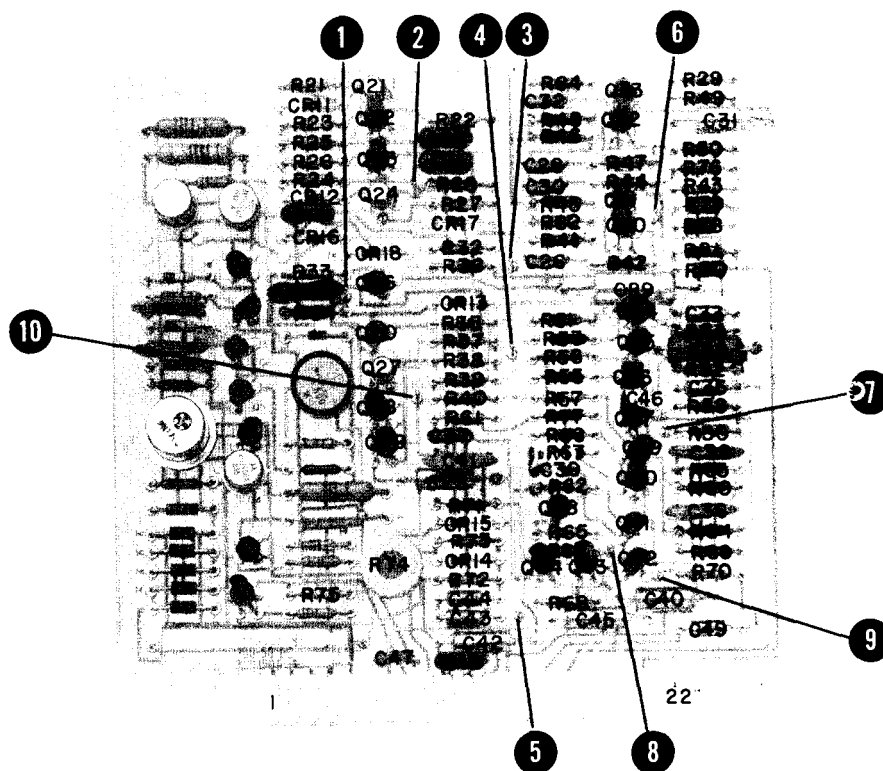


Figure A1-1. A2 Meter Logic Component Locations

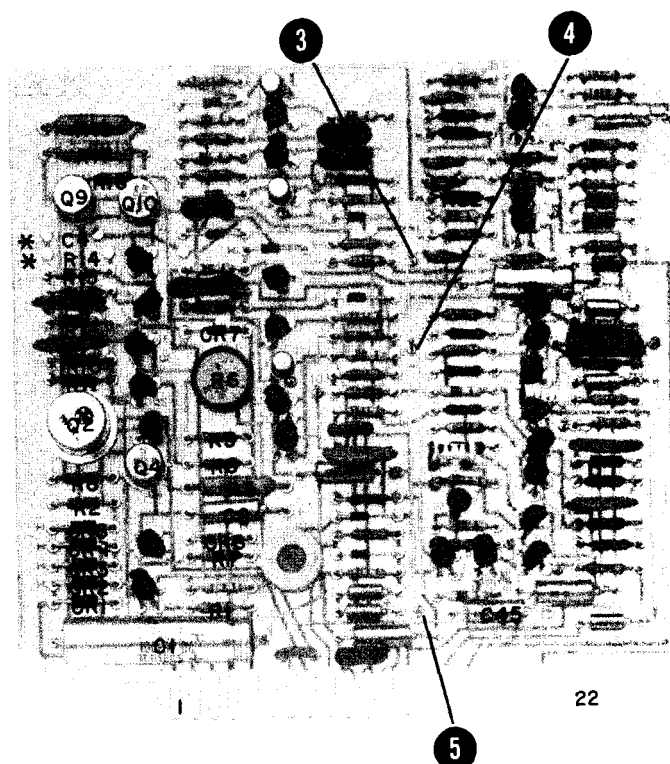


Figure A1-2. A2 Meter Logic Assembly, Power Supply Component Locations

Table A1-1. Reference Designation Index

| Reference Designation | Part No.   | Description #                                              | Note |
|-----------------------|------------|------------------------------------------------------------|------|
| A2                    | 00432-6002 | BOARD ASSY: LOGIC                                          |      |
|                       | 00432-2002 | BOARD: BLANK PC                                            |      |
| A2C1                  | 0180-1819  | C:FXD ELECT 100 UF +75-10% 50VDCW                          |      |
| A2C2                  | 0180-0229  | C:FXD ELECT 33 UF 10% 10VDCW                               |      |
| A2C3                  | 0160-2917  | C:FXD CER 0.05 UF +80-20% 100VDCW                          |      |
| A2C4                  | 0160-2917  | C:FXD CER 0.05 UF +80-20% 100VDCW<br>FACTORY SELECTED PART |      |
| A2C5                  | 0160-2917  | C:FXD CER 0.05 UF +80-20% 100VDCW                          |      |
| A2C6-                 |            | NOT ASSIGNED                                               |      |
| A2C20                 |            | NOT ASSIGNED                                               |      |
| A2C21                 | 0140-0234  | C:FXD MICA 500 PF 1%                                       |      |
| A2C22                 | 0140-0234  | C:FXD MICA 500 PF 1%                                       |      |
| A2C23                 | 0180-1746  | C:FXD ELECT 15 UF 10% 20VDCW                               |      |
| A2C24                 | 0140-0198  | C:FXD MICA 200 PF 5%                                       |      |
| A2C25                 | 0160-0978  | C:FXD MICA 1500 PF 1% 500VDCW                              |      |
| A2C26                 | 0160-2930  | C:FXD CER 0.01 UF +80-20% 100VDCW                          |      |
| A2C27                 |            | NOT ASSIGNED                                               |      |
| A2C28                 | 0160-2930  | C:FXD CER 0.01 UF +80-20% 100VDCW                          |      |
| A2C29                 | 0180-2178  | C:FXD ELECT 220 UF 20% 8VDCW                               |      |
| A2C30                 | 0160-2930  | C:FXD CER 0.01 UF +80-20% 100VDCW                          |      |
| A2C31                 | 0180-1940  | C:FXD ELECT 33 UF 10% 15VDCW                               |      |
| A2C32                 | 0160-2930  | C:FXD CER 0.01 UF +80-20% 100VDCW                          |      |
| A2C33                 | 0180-0197  | C:FXD ELECT 2.2 UF 10% 20VDCW                              |      |
| A2C34                 | 0160-2672  | C:FXD MY 0.047 UF 5% 80VDCW                                |      |
| A2C35                 | 0180-0197  | C:FXD ELECT 2.2 UF 10% 20VDCW                              |      |
| A2C36                 | 0160-2917  | C:FXD CER 0.05 UF +80-20% 100VDCW                          |      |
| A2C37                 | 0160-2143  | C:FXD CER 2000 PF +80-20% 1000VDCW                         |      |
| A2C38                 | 0160-2917  | C:FXD CER 0.05 UF +80-20% 100VDCW                          |      |
| A2C39                 | 0160-2265  | C:FXD CER 22 PF 5% 500VDCW                                 |      |
| A2C40                 | 0180-0229  | C:FXD ELECT 33 UF 10% 10VDCW                               |      |
| A2C41                 | 0160-2917  | C:FXD CER 0.05 UF +80-20% 100VDCW                          |      |
| A2C42                 | 0180-0106  | C:FXD ELECT 60 UF 20% 6VDCW                                |      |
| A2C43                 | 0180-0197  | C:FXD ELECT 2.2 UF 10% 20VDCW                              |      |
| A2C44                 | 0180-0291  | C:FXD ELECT 1.0 UF 10% 35VDCW                              |      |
| A2C45                 | 0180-0106  | C:FXD ELECT 60 UF 20% 6VDCW                                |      |
| A2C46                 | 0150-0059  | C:FXD CER 3.3-0.25 PF 500VDCW                              |      |
| A2C47                 | 0160-2930  | C:FXD CER 0.01 UF +80-20% 100VDCW                          |      |
| A2C48                 |            | NOT ASSIGNED                                               |      |
| A2C49                 | 0180-0197  | C:FXD ELECT 2.2 UF 10% 20VDCW                              |      |
| A2CR1                 | 1901-0026  | DIODE: SILICON 0.75A 200 PIV                               |      |
| A2CR2                 | 1901-0026  | DIODE: SILICON 0.75A 200 PIV                               |      |
| A2CR3                 | 1901-0026  | DIODE: SILICON 0.75A 200 PIV                               |      |
| A2CR4                 | 1901-0026  | DIODE: SILICON 0.75A 200 PIV                               |      |
| A2CR5                 |            | NOT ASSIGNED                                               |      |

# See introduction to section VI for ordering information

Table A1-1. Reference Designation Index (Cont'd)

| Reference Designation | Part No.  | Description #                    | Note |
|-----------------------|-----------|----------------------------------|------|
| A2CR6                 | 1902-0033 | DIODE BREAKDOWN:6.2V             |      |
| A2CR7                 | 1901-0040 | DIODE:SILICON 30MA 30WV          |      |
| A2CR8                 | 1901-0026 | DIODE:SILICON 0.75A 200 PIV      |      |
| A2CR9                 |           | NOT ASSIGNED                     |      |
| A2CR10                |           | NOT ASSIGNED                     |      |
| A2CR11                | 1901-0040 | DIODE:SILICON 30MA 30WV          |      |
| A2CR12                | 1901-0040 | DIODE:SILICON 30MA 30WV          |      |
| A2CR13                | 1901-0040 | DIODE:SILICON 30MA 30WV          |      |
| A2CR14                | 1901-0040 | DIODE:SILICON 30MA 30WV          |      |
| A2CR15                | 1901-0040 | DIODE:SILICON 30MA 30WV          |      |
| A2CR16                | 1901-0040 | DIODE:SILICON 30MA 30WV          |      |
| A2CR17                | 1901-0040 | DIODE:SILICON 30MA 30WV          |      |
| A2CR18                | 1901-0040 | DIODE:SILICON 30MA 30WV          |      |
| A2Q1                  | 1854-0071 | TRANSISTOR: SILICON NPN          |      |
| A2Q2                  | 1854-0062 | TRANSISTOR:SILICON NPN 2N1701    |      |
| A2Q3                  | 1854-0071 | TRANSISTOR:SILICON NPN           |      |
| A2Q4                  | 1853-0012 | TRANSISTOR:PNP SILICON 2N2904A   |      |
| A2Q5                  | 1853-0020 | TRANSISTOR: SILICON PNP          |      |
| A2Q6                  | 1853-0020 | TRANSISTOR:SILICON PNP           |      |
| A2Q7                  | 1853-0020 | TRANSISTOR:SILICON PNP           |      |
| A2Q8                  | 1854-0071 | TRANSISTOR:SILICON NPN           |      |
| A2Q9                  | 1854-0003 | TRANSISTOR:NPN SILICON           |      |
| A2Q10                 | 1853-0001 | TRANSISTOR:PNP SILICON 30V 900MW |      |
| A2Q11                 | 1854-0071 | TRANSISTOR:SILICON NPN           |      |
| A2Q12-                |           | NOT ASSIGNED                     |      |
| A2Q19                 |           | NOT ASSIGNED                     |      |
| A2Q20                 | 1853-0020 | TRANSISTOR: SILICON PNP          |      |
| A2Q21                 | 1854-0005 | TRANSISTOR:SILICON NPN 2N708     |      |
| A2Q22                 | 1854-0071 | TRANSISTOR:SILICON NPN           |      |
| A2Q23                 | 1854-0071 | TRANSISTOR: SILICON NPN          |      |
| A2Q24                 | 1854-0005 | TRANSISTOR: SILICON NPN 2N708    |      |
| A2Q25                 |           | NOT ASSIGNED                     |      |
| A2Q26                 | 1854-0071 | TRANSISTOR:SILICON NPN           |      |
| A2Q27                 | 1854-0005 | TRANSISTOR:SILICON NPN 2N708     |      |
| A2Q28                 | 1854-0071 | TRANSISTOR:SILICON NPN           |      |
| A2Q29                 | 1854-0071 | TRANSISTOR: SILICON NPN          |      |
| A2Q30                 | 1854-0071 | TRANSISTOR:SILICON NPN           |      |
| A2Q31                 | 1853-0020 | TRANSISTOR:SILICON PNP           |      |
| A2Q32                 | 1854-0071 | TRANSISTOR:SILICON NPN           |      |
| A2Q33                 | 1853-0020 | TRANSISTOR: SILICON PNP          |      |
| A2Q34                 | 1854-0071 | TRANSISTOR:SILICON NPN           |      |
| A2Q35                 | 1854-0071 | TRANSISTOR:SILICON NPN           |      |
| A2Q36                 | 1853-0015 | TRANSISTOR:SILICON PNP 2N3640    |      |
| A2Q37                 | 1853-0020 | TRANSISTOR:SILICON PNP           |      |
| A2Q38                 | 1854-0071 | TRANSISTOR:SILICON NPN           |      |
| A2Q39                 | 1854-0071 | TRANSISTOR:SILICON NPN           |      |
| A2Q40                 | 1854-0071 | TRANSISTOR:SILICON NPN           |      |

# See introduction to section VI for ordering information

Table A1-1. Reference Designation Index (Cont'd)

| Reference Designation | Part No.  | Description #                                          | Note |
|-----------------------|-----------|--------------------------------------------------------|------|
| A2Q41                 | 1853-0020 | TRANSISTOR: SILICON PNP                                |      |
| A2Q42                 | 1853-0020 | TRANSISTOR: SILICON PNP                                |      |
| A2Q43                 | 1854-0071 | TRANSISTOR: SILICON NPN                                |      |
| A2Q44                 | 1854-0071 | TRANSISTOR: SILICON NPN                                |      |
| A2R1                  | 0757-0279 | R:FXD MET FLM 3.16K OHM 1% 1/8W                        |      |
| A2R2                  | 0683-0685 | R:FXD COMP 6.8 OHM 5% 1/4W                             |      |
| A2R3                  | 0757-0835 | R:FXD MET FLM 6.81K OHM 1% 1/2W                        |      |
| A2R4                  |           | NUT ASSIGNED                                           |      |
| A2R5                  | 0698-3156 | R:FXD MET FLM 14.7K OHM 1% 1/8W                        |      |
| A2R6                  | 2100-1773 | R:VAR WW 1K OHM 10% LIN 1/2W                           |      |
| A2R7                  | 0757-0289 | R:FXD MET FLM 13.3K OHM 1% 1/8W                        |      |
| A2R8                  | 0757-0280 | R:FXD MET FLM 1K OHM 1% 1/8W                           |      |
| A2R9                  | 0698-3160 | R:FXD MET FLM 31.6K OHM 1% 1/8W                        |      |
| A2R10                 | 0698-3441 | R:FXD MET FLM 215 OHM 1% 1/8W<br>FACTORY SELECTED PART |      |
| A2R11                 | 0757-0465 | R:FXD MET FLM 100K OHM 1% 1/8W                         |      |
| A2R12                 | 0757-0442 | R:FXD MET FLM 10.0K OHM 1% 1/8W                        |      |
| A2R13                 | 0698-3136 | R:FXD MET FLM 17.8K OHM 1% 1/8W                        |      |
| A2R14                 | 0757-0346 | R:FXD MET FLM 10 OHM 1% 1/8W<br>FACTORY SELECTED PART  |      |
| A2R15                 | 0757-0442 | R:FXD MET FLM 10.0K OHM 1% 1/8W                        |      |
| A2R16                 | 0757-0279 | R:FXD MET FLM 3.16K OHM 1% 1/8W                        |      |
| A2R17                 | 0757-0198 | R:FXD MET FLM 100 OHM 1% 1/2W                          |      |
| A2R18                 | 0698-3401 | R:FXD MET FLM 215 OHM 1% 1/2W                          |      |
| A2R19                 |           | NUT ASSIGNED                                           |      |
| A2R20                 |           | NUT ASSIGNED                                           |      |
| A2R21                 | 0698-3156 | R:FXD MET FLM 14.7K OHM 1% 1/8W                        |      |
| A2R22                 | 0757-0442 | R:FXD MET FLM 10.0K OHM 1% 1/8W                        |      |
| A2R23                 | 0757-0442 | R:FXD MET FLM 10.0K OHM 1% 1/8W                        |      |
| A2R24                 | 0698-3260 | R:FXD MET FLM 464K OHM 1% 1/8W                         |      |
| A2R25                 | 0698-3260 | R:FXD MET FLM 464K OHM 1% 1/8W                         |      |
| A2R26                 | 0757-0442 | R:FXD MET FLM 10.0K OHM 1% 1/8W                        |      |
| A2R27                 | 0757-0442 | R:FXD MET FLM 10.0K OHM 1% 1/8W                        |      |
| A2R28                 | 0698-3156 | R:FXD MET FLM 14.7K OHM 1% 1/8W                        |      |
| A2R29-                |           | NUT ASSIGNED                                           |      |
| A2R31                 |           | NUT ASSIGNED                                           |      |
| A2R32                 | 0757-0199 | R:FXD MET FLM 21.5K OHM 1% 1/8W                        |      |
| A2R33                 | 0757-0442 | R:FXD MET FLM 10.0K OHM 1% 1/8W                        |      |
| A2R34                 | 0757-0465 | R:FXD MET FLM 100K OHM 1% 1/8W                         |      |
| A2R35                 | 0698-3454 | R:FXD MET FLM 215K OHM 1% 1/8W                         |      |
| A2R36                 | 0757-0461 | R:FXD MET FLM 68.1K OHM 1% 1/8W                        |      |
| A2R37                 | 0757-0470 | R:FXD MET FLM 162K OHM 1% 1/8W                         |      |
| A2R38                 | 0757-0442 | R:FXD MET FLM 10.0K OHM 1% 1/8W                        |      |
| A2R39                 | 0698-3155 | R:FXD MET FLM 4.64K OHM 1% 1/8W                        |      |
| A2R40                 | 0698-3155 | R:FXD MET FLM 4.64K OHM 1% 1/8W                        |      |
| A2R41                 | 0757-0465 | R:FXD MET FLM 100K OHM 1% 1/8W                         |      |
| A2R42                 | 0757-0461 | R:FXD MET FLM 68.1K OHM 1% 1/8W                        |      |
| A2R43                 | 0757-1094 | R:FXD MET FLM 1.47K OHM 1% 1/8W                        |      |
| A2R44                 | 0757-0461 | R:FXD MET FLM 68.1K OHM 1% 1/8W                        |      |
| A2R45                 | 0757-0465 | R:FXD MET FLM 100K OHM 1% 1/8W                         |      |

# See introduction to section VI for ordering information

Appendix 1

Table A1-1. Reference Designation Index (Cont'd)

| Reference Designation | Part No.  | Description #                                            | Note |
|-----------------------|-----------|----------------------------------------------------------|------|
| A2R46                 | 0757-0465 | R:FXD MET FLM 100K OHM 1% 1/8W                           |      |
| A2R47                 | 0757-0461 | R:FXD MET FLM 68.1K OHM 1% 1/8W                          |      |
| A2R48                 | 0757-0465 | R:FXD MET FLM 100K OHM 1% 1/8W                           |      |
| A2R49                 | 0757-0461 | R:FXD MET FLM 68.1K OHM 1% 1/8W                          |      |
| A2R50                 | 0757-0280 | R:FXD MET FLM 1K OHM 1% 1/8W                             |      |
| A2R51                 | 0698-3260 | R:FXD MET FLM 464K OHM 1% 1/8W                           |      |
| A2R52                 | 0757-0279 | R:FXD MET FLM 3.16K OHM 1% 1/8W                          |      |
| A2R53                 | 0698-3160 | R:FXD MET FLM 31.6K OHM 1% 1/8W                          |      |
| A2R54                 | 0698-3428 | R:FXD MET FLM 14.7 OHM 1% 1/8W<br>FACTORY SELECTED PART  |      |
| A2R55                 | 0698-3160 | R:FXD MET FLM 31.6K OHM 1% 1/8W<br>FACTORY SELECTED PART |      |
| A2R56                 | 0698-3260 | R:FXD MET FLM 464K OHM 1% 1/8W                           |      |
| A2R57                 | 0757-0442 | R:FXD MET FLM 10.0K OHM 1% 1/8W                          |      |
| A2R58                 | 0698-3260 | R:FXD MET FLM 464K OHM 1% 1/8W                           |      |
| A2R59                 | 0698-3260 | R:FXD MET FLM 464K OHM 1% 1/8W                           |      |
| A2R60                 | 0698-0084 | R:FXD MET FLM 2.15K OHM 1% 1/8W                          |      |
| A2R61                 | 0698-3260 | R:FXD MET FLM 464K OHM 1% 1/8W                           |      |
| A2R62                 | 0698-3260 | R:FXD MET FLM 464K OHM 1% 1/8W                           |      |
| A2R63                 | 0698-3260 | R:FXD MET FLM 464K OHM 1% 1/8W                           |      |
| A2R64                 | 0757-0439 | R:FXD MET FLM 6.81K OHM 1% 1/8W                          |      |
| A2R65                 | 0757-0442 | R:FXD MET FLM 10.0K OHM 1% 1/8W                          |      |
| A2R66                 | 0757-0461 | R:FXD MET FLM 68.1K OHM 1% 1/8W                          |      |
| A2R67                 | 0698-3160 | R:FXD MET FLM 31.6K OHM 1% 1/8W                          |      |
| A2R68                 | 0757-0442 | R:FXD MET FLM 10.0K OHM 1% 1/8W                          |      |
| A2R69                 | 0698-3438 | R:FXD MET FLM 147 OHM 1% 1/8W                            |      |
| A2R70                 | 0698-3156 | R:FXD MET FLM 14.7K OHM 1% 1/8W                          |      |
| A2R71                 | 0698-3160 | R:FXD MET FLM 31.6K OHM 1% 1/8W                          |      |
| A2R72                 | 0698-3444 | R:FXD MET FLM 316 OHM 1% 1/8W                            |      |
| A2R73                 | 0757-0199 | R:FXD MET FLM 21.5K OHM 1% 1/8W                          |      |
| A2R74                 | 2100-1769 | R:VAR WW 50 OHM 10% LIN 1/2W                             |      |
| A2R75                 | 0698-4466 | R:FXD MET FLM 976 OHM 1% 1/8W                            |      |
| A2R76                 | 0757-0346 | R:FXD MET FLM 10 OHM 1% 1/8W                             |      |
| A2R77                 | 0698-3160 | R:FXD MET FLM 31.6K OHM 1% 1/8W                          |      |
| A2R78                 | 0811-2277 | R:FXD WW 10K OHM 0.1% 1/40W                              |      |
| A2R79                 | 0811-2277 | R:FXD WW 10K OHM 0.1% 1/40W                              |      |
| A2R80                 | 0811-2537 | R:FXD WW 5K OHM 0.1% 1/4W                                |      |
| A2R81                 | 0757-0465 | R:FXD MET FLM 100K OHM 1% 1/8W<br>FACTORY SELECTED PART  |      |
| A2R82                 | 0757-0401 | R:FXD MET FLM 100 OHM 1% 1/8W                            |      |
| A2R83                 | 0698-3441 | R:FXD MET FLM 215 OHM 1% 1/8W                            |      |
| A2R84                 | 0757-0280 | R:FXD MET FLM 1K OHM 1% 1/8W                             |      |
| A2                    | 0360-0124 | TERMINAL:SOLDER LUG                                      |      |

# See introduction to section VI for ordering information

Table A1-2. Replaceable Parts

| Part No.  | Description #                      | Mfr.  | Mfr. Part No.      | TQ |
|-----------|------------------------------------|-------|--------------------|----|
| 0140-0198 | C:FXD MICA 200 PF 5%               | 28480 | 0140-0198          | 1  |
| 0140-0234 | C:FXD MICA 500 PF 1%               | 28480 | 0140-0234          | 2  |
| 0150-0059 | C:FXD CER 3.3-0.25 PF 500VDCW      | 72982 | 301-000-C0J0-339C  | 1  |
| 0160-0978 | C:FXD MICA 1500 PF 1% 500VDCW      | 28480 | 0160-0978          | 1  |
| 0160-2143 | C:FXD CER 2000 PF +80-20% 1000VDCW | 91418 | TYPE B             | 1  |
| 0160-2265 | C:FXD CER 22 PF 5% 500VDCW         | 72982 | 301-NP0-22PF       | 1  |
| 0160-2672 | C:FXD MY 0.047 UF 5% 80VDCW        | 28480 | 0160-2672          | 1  |
| 0160-2917 | C:FXD CER 0.05 UF +80-20% 100VDCW  | 84411 | TYPE TA            | 6  |
| 0160-2930 | C:FXD CER 0.01 UF +80-20% 100VDCW  | 91418 | TA                 | 5  |
| 0180-0106 | C:FXD ELECT 60 UF 20% 6VDCW        | 28480 | 0180-0106          | 2  |
| 0180-0197 | C:FXD ELECT 2.2 UF 10% 20VDCW      | 28480 | 0180-0197          | 4  |
| 0180-0229 | C:FXD ELECT 33 UF 10% 10VDCW       | 28480 | 0180-0229          | 2  |
| 0180-0291 | C:FXD ELECT 1.0 UF 10% 35VDCW      | 28480 | 0180-0291          | 1  |
| 0180-1746 | C:FXD ELECT 15 UF 10% 20VDCW       | 28480 | 0180-1746          | 1  |
| 0180-1819 | C:FXD ELECT 100 UF +75-10% 50VDCW  | 28480 | 0180-1819          | 1  |
| 0180-1940 | C:FXD ELECT 33 UF 10% 15VDCW       | 56289 | 109D336X9015C2-DYP | 1  |
| 0180-2178 | C:FXD ELECT 220 UF 20% 8VDCW       | 56289 | 109D227X0008F2-DYP | 1  |
| 0360-0124 | TERMINAL:SOLDER LUG                | 28480 | 0360-0124          | 10 |
| 0683-0685 | R:FXD COMP 6.8 OHM 5% 1/4W         | 01121 | CB68G5             | 1  |
| 0698-0084 | R:FXD MET FLM 2.15K OHM 1% 1/8W    | 28480 | 0698-0084          | 1  |
| 0698-3136 | R:FXD MET FLM 17.8K OHM 1% 1/8W    | 28480 | 0698-3136          | 1  |
| 0698-3155 | R:FXD MET FLM 4.64K OHM 1% 1/8W    | 28480 | 0698-3155          | 2  |
| 0698-3156 | R:FXD MET FLM 14.7K OHM 1% 1/8W    | 28480 | 0698-3156          | 4  |
| 0698-3160 | R:FXD MET FLM 31.6K OHM 1% 1/8W    | 28480 | 0698-3160          | 6  |
| 0698-3260 | R:FXD MET FLM 464K OHM 1% 1/8W     | 28480 | 0698-3260          | 9  |
| 0698-3401 | R:FXD MET FLM 215 OHM 1% 1/2W      | 28480 | 0698-3401          | 1  |
| 0698-3428 | R:FXD MET FLM 14.7 OHM 1% 1/8W     | 28480 | 0698-3428          | 1  |
| 0698-3438 | R:FXD MET FLM 147 OHM 1% 1/8W      | 28480 | 0698-3438          | 1  |
| 0698-3441 | R:FXD MET FLM 215 OHM 1% 1/8W      | 28480 | 0698-3441          | 2  |
| 0698-3444 | R:FXD MET FLM 316 OHM 1% 1/8W      | 28480 | 0698-3444          | 1  |
| 0698-3454 | R:FXD MET FLM 215K OHM 1% 1/8W     | 28480 | 0698-3454          | 1  |
| 0698-4466 | R:FXD MET FLM 976 OHM 1% 1/8W      | 28480 | 0698-4466          | 1  |
| 0757-0198 | R:FXD MET FLM 100 OHM 1% 1/2W      | 28480 | 0757-0198          | 1  |
| 0757-0199 | R:FXD MET FLM 21.5K OHM 1% 1/8W    | 28480 | 0757-0199          | 2  |
| 0757-0279 | R:FXD MET FLM 3.16K OHM 1% 1/8W    | 28480 | 0757-0279          | 3  |
| 0757-0280 | R:FXD MET FLM 1K OHM 1% 1/8W       | 28480 | 0757-0280          | 3  |
| 0757-0289 | R:FXD MET FLM 13.3K OHM 1% 1/8W    | 28480 | 0757-0289          | 1  |
| 0757-0346 | R:FXD MET FLM 10 OHM 1% 1/8W       | 28480 | 0757-0346          | 2  |
| 0757-0401 | R:FXD MET FLM 100 OHM 1% 1/8W      | 28480 | 0757-0401          | 1  |
| 0757-0439 | R:FXD MET FLM 6.81K OHM 1% 1/8W    | 28480 | 0757-0439          | 1  |
| 0757-0442 | R:FXD MET FLM 10.0K OHM 1% 1/8W    | 28480 | 0757-0442          | 11 |
| 0757-0461 | R:FXD MET FLM 68.1K OHM 1% 1/8W    | 28480 | 0757-0461          | 6  |
| 0757-0465 | R:FXD MET FLM 100K OHM 1% 1/8W     | 28480 | 0757-0465          | 7  |
| 0757-0470 | R:FXD MET FLM 162K OHM 1% 1/8W     | 28480 | 0757-0470          | 1  |
| 0757-0835 | R:FXD MET FLM 6.81K OHM 1% 1/2W    | 28480 | 0757-0835          | 1  |
| 0757-1094 | R:FXD MET FLM 1.47K OHM 1% 1/8W    | 28480 | 0757-1094          | 1  |
| 0811-2277 | R:FXD WW 10K OHM 0.1% 1/40W        | 28480 | 0811-2277          | 2  |
| 0811-2537 | R:FXD WW 5K OHM 0.1% 1/4W          | 28480 | 0811-2537          | 1  |
| 1853-0001 | TRANSISTOR:PNP SILICON 30V 900MW   | 28480 | 1853-0001          | 1  |
| 1853-0012 | TRANSISTOR:PNP SILICON 2N2904A     | 04713 | 2N2904A            | 1  |
| 1853-0015 | TRANSISTOR:SILICON PNP 2N3640      | 28480 | 1853-0015          | 1  |
| 1853-0020 | TRANSISTOR:SILICON PNP             | 28480 | 1853-0020          | 9  |
| 1854-0003 | TRANSISTOR:NPN SILICON             | 28480 | 1854-0003          | 1  |
| 1854-0005 | TRANSISTOR:SILICON NPN 2N708       | 02735 | 2N708              | 3  |

# See introduction to section VI for ordering information

Table A1-2. Replaceable Parts (Cont'd)

| Part No.  | Description #                  | Mfr.  | Mfr. Part No. | TQ |
|-----------|--------------------------------|-------|---------------|----|
| 854-C062  | TRANSISTOR: SILICON NPN 2N1701 | 02735 | 2N1701        | 1  |
| 854-0071  | TRANSISTOR: SILICON NPN        | 28480 | 1854-0071     | 18 |
| 901-C026  | DIODE: SILICON 0.75A 200 PIV   | 28480 | 1901-0026     | 5  |
| 901-0040  | DIODE: SILICON 30MA 30WV       | 28480 | 1901-0040     | 9  |
| 902-C033  | DIODE BREAKDOWN: 6.2V          | 04713 | 1N823         | 1  |
| 100-1769  | R: VAR WW 50 OHM 10% LIN 1/2W  | 28480 | 2100-1769     | 1  |
| 100-1773  | R: VAR WW 1K OHM 10% LIN 1/2W  | 28480 | 2100-1773     | 1  |
| 0432-2002 | BOARD: BLANK PC                | 28480 | 00432-2002    | 1  |
| 0432-6002 | BOARD ASSY: LOGIC              | 28480 | 00432-6002    | 1  |

# See introduction to section VI for ordering information

# MANUAL CHANGES

## MODEL 432A POWER METER

Manual Serial Prefixed: 914    Manual Printed: Feb 1969

MAKE ALL CORRECTIONS IN THIS MANUAL ACCORDING TO ERRATA BELOW, THEN CHECK THE FOLLOWING TABLE FOR YOUR INSTRUMENT SERIAL PREFIX (3 DIGITS) OR SERIAL NUMBER (8 DIGITS) AND MAKE ANY LISTED CHANGE(S) IN THE MANUAL

► NEW ITEM.

| SERIAL PREFIX OR NUMBER | MAKE MANUAL CHANGES | SERIAL PREFIX OR NUMBER | MAKE MANUAL CHANGES |
|-------------------------|---------------------|-------------------------|---------------------|
| ► 904, 919              | ERRATA              |                         |                     |
|                         |                     |                         |                     |
|                         |                     |                         |                     |
|                         |                     |                         |                     |

### ERRATA:

- Page 3-3, Paragraph h: Bracket the equation as follows:

$$P_{RF} = \frac{1}{4R} \left[ \frac{2V_{COMP} (V_1 - V_0) + V_0^2 - V_1^2}{\text{EFFECTIVE EFFICIENCY}} \right]$$

Page 3-7, Figure 3-3:

Delete the words "slow-blow" from number 1.

Change last sentence of number 7 to read "Output impedance is 1000Ω. "

Page 4-2, Paragraph 4-13:

Change " $V_{COMP} = V_{RF}$ " to " $V_{COMP} + V_{RF}$ "

Page 4-4, Figure 4-3, change the value of the following capacitors,

A1C13 at collector and base of A1Q15 to .01 μf.

A1C14 at collector and base of A1Q14 to .01 μf.

- Page 4-6, Figure 4-4:

Change the stock number of Q37 to 1853-0020,

Page 6-2, Table 6-1, change as follows:

Delete:

A1C13, 0160-2264 C : FXD CER 20 pF 5%, 500 VDCW

A1C14, 0160-2264 C : FXD CER 20 PF 5%, 500 VDCW

Add:

A1C13, 0160-2930 C: FXD CER .01 μf +80-20% 100 VDCW

A1C14, 0160-2930 C : FXD CER .01 μf + 80-20% 100 VDCW

Page 6-9, Table 6-1, change as follows:

R1 2100-2659 R: VAR WW 50K OHM 5% LIN 1-1/2 W (SERIAL PREFIX 904 and below)

- R1 2100-2849 R: VAR WW 50K OHM 5% LIN 1-1/2 W (SERIAL PREFIX 919 and above)

Page 6-12, Table 6-2, change as follows:

Delete: 0160-2264 C: FXD CER 20 pF 5%, 500 VDCW

Add: 2 to the TQ column for 0160-2930

Page 7-3, Figure 7-1, change as follows:

Delete test point 7 from voltage-to-time converter

Page 7-5, Figure 7-7, Assy A1, change as follows:

Delete: 5. 2V from test point 7 and 2.

ADD :     1. 2V for test point 7.  
          5. 2V for test point 2.

Page 7-11, Figure 7-9, change as follows:

Change the value of A1C13 and A1C14 to .01  $\mu$ f.

► Page 7-13/7-14, Figures 7-11 and 7-12.

Delete page 7-13/7-14, Figures 7-11 and 7-12,

Add new page 7-13/7-14, Figures 7-11 and 7-12 (an attached sheet)

APPENDIX B

BASIC ISSUE ITEMS LIST

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Basic issue items list will be published at a later date.



## APPENDIX C

### MAINTENANCE ALLOCATION CHART

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#### Section I. INTRODUCTION

##### C-1. General.

This Maintenance Allocation Chart designates overall responsibility for the performance of maintenance functions on the identified end item or component. The implementation of field maintenance tasks upon this end item or component will be consistent with the assigned maintenance operations.

##### C-2 . Maintenance Functions.

Maintenance functions will be limited to and defined as follows:

a. Insect To determine serviceability of an item by comparing its physical, mechanical and electrical characteristics with established standards.

b. Test. To verify serviceability and to detect electrical or mechanical failure by use of test equipment.

c. Service. To clean, to preserve, to charge and to add fuel, lubricants, cooling agents, and air, If it is desired that elements, such as painting and lubricating, be defined separately, they may be so listed.

d. Adjust. To rectify to the extent necessary to bring into proper operating range.

e. Align. To adjust specified variable elements of an item to bring to optimum performance.

f. Calibrate. To determine the corrections to be made in the readings of instruments or test equipment used in precise measurement, Consists of the comparison of two instruments, one of which is a certified standard of known accuracy, to detect and adjust any discrepancy in the accuracy of the instrument being compared with the certified standard.

g. Install. To set up for use in an operational environment such as an emplacement, site, or vehicle.

h. Replace. To replace unserviceable items with serviceable like items.

i. Repair. Those maintenance operations necessary to restore an item to serviceable condition through correction of material damage or a specific failure. Repair may be accomplished at each category of maintenance.

i. Overhaul. Normally, the highest degree of maintenance performed by the Army in order to minimize time work in process is consistent with quality and economy of operation. It consists of that maintenance necessary to restore an item to completely serviceable condition as prescribed by maintenance standards in technical publications for each item of equipment. Overhaul normally does not return an item to like new, zero mileage, or zero hour condition.

k. Rebuild. The highest degree of material maintenance. It consists of restoring equipment as nearly as possible to new condition in accordance with original manufacturing standards. Rebuild is performed only when required by operational considerations or other paramount factors and then only at the depot maintenance category. Rebuild reduces to zero the hours or miles the equipment, or component thereof, has been in use.

l. Symbols The uppercase letter placed in the appropriate column indicates the lowest level at which that particular maintenance function is to be performed.

### **C-3. Explanation of Columns.**

Listed below is an explanation of the columns shown in the maintenance allocation chart:

a. Column 1, Group Number. Column 1 lists group numbers, the purpose of which is to identify components, assemblies, subassemblies and modules with the next higher assembly.

b. Column 2, Functional Group. Column 2 lists the noun names of components, assemblies, subassemblies and modules on which maintenance is authorized.

c. Column 3, Maintenance Functions. Column 3 lists the lowest level at which that particular maintenance function is to be performed.

d. Column 4, Tools and Equipment. This column shall be used to specify, by code, those tools and test equipment required to perform the designated function.

e. Column 5, Remarks. Self-explanatory.





## APPENDIX D

### REPAIR PARTS LIST

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D-1. This appendix provides a list of repair parts for maintenance support of the equipment. The parts along with their descriptions are listed in table D-1 below.

D-2. Instructions for 'requisitioning parts not identified by Federal. Stock Numbers require the following information be furnished to the Supply officer:

a. Manufacturer's Federal Supply Code Number.

b. Manufacturer's identification number,

c. Manufacturer's nomenclature.

d. Any other information as listed on parts list that will aid in identification of the item being requisitioned.

D-3. If DD Form 1348 is used, fill in all blocks except 4, 5, 6 and Remarks field in accordance with AR 725-50. Complete Form as follows:

a. In Blocks 4, 5 and 6 list Manufacturer's Federal Supply Code Number followed by a colon and the Manufacturer's part number.

b. Complete Remarks Field as follows; Nomenclature of the repair part and any other identification to assist Supply Officer in procurement.

D-4. Report of errors, omissions and recommendations for improving this publication by the individual user is encouraged. Reports should be submitted on DA Form 2028 (Recommended Changes to DA Publications) and forwarded direct to Commanding Officer, Frankford Arsenal., ATTN: AMSWE-SMF-W3100, Philadelphia, Pa. 19137.

Table D-1. Repair Parts List for Power Meter 432A

| Part No.  | Description                           | Mfr.<br>Federal<br>Supply Code | Mfr. Part No.          | Total<br>Qty | FSN           |
|-----------|---------------------------------------|--------------------------------|------------------------|--------------|---------------|
| 0140-0198 | C:FXD MICA 200 PF<br>5%               | 28480                          | 0140-0198              | 1            |               |
| 0140-0234 | C:FXD MICA 500 PF 1%                  | 28480                          | 0140-0234              | 1            | 5910-494-5056 |
| 0150-0059 | C:FXD CER 3.3-0.25<br>PF 500VDCW      | 72982                          | 301-000-COJO-339C      | 1            |               |
| 0150-0380 | C:FXD MY 0.22 UF<br>10% 200VDCW       | 28480                          | 0150-0380              | 1            | 5910-586-5233 |
| 0150-0973 | C:FXD MICA 1500 PF<br>1% 500VDCW      | 28480                          | 0160-0978              | 1            |               |
| 0160-2143 | C:FXD CER 2000 PF<br>+80-20% 1000VDCW | 91418                          | Type B                 | 1            |               |
| 0160-2264 | C:FXD CER 20 PF 5%<br>500VDCW         | 72982                          | 301-000-30G0-200J      | 1            | 5910-318-8758 |
| 0160-2265 | C:FXD CER 22 PF 5%<br>500VDCW         | 72982                          | 301-NP0-22PF           | 1            |               |
| 0160-2672 | C:FXD MY 0.047 UF<br>5% 80VDCW        | 28480                          | 0160-2672              | 1            |               |
| 0160-2917 | C:FXD CER 0.35 UF<br>+80-20% 100VDCW  | 84411                          | Type TA                | 1            |               |
| 0160-2930 | C:FXD CER 0.01 UF<br>+80-20% 100VDCW  | 91418                          | TA                     | 2            | 5910-194-3010 |
| 0160-3043 | C:FXD CER 2 X 0.005<br>UF 20% 250VAC  | 56289                          | 29C147A-CDH            | 1            |               |
| 0180-0106 | C:FXD ELECT TA 60UF<br>20% 6VDCW      | 56289                          | 150D606X0006B2         | 1            | 5910-127-1668 |
| 0180-0197 | C:FXD ELECT 2.2 UF<br>10% 20VDCW      | 56289                          | 150D225X9020A2         | 1            |               |
| 0180-0229 | C:FXD ELECT 33 UF<br>10% 10VDCW       | 28480                          | 0180-0229              | 1            |               |
| 0180-0291 | C:FXD ELECT 1UF<br>10% 35VDCW         | 56289                          | 150D105X9035A2         | 1            | 5910-931-7055 |
| 0180-0374 | C:FXD ELECT 10 UF<br>10% 20VDCW       | 28480                          | 0180-0374              | 1            | 5910-931-7050 |
| 0180-1746 | C:FXD ELECT 15 UF<br>10% 20VDCW       | 56289                          | 150D156X9020B2         | 1            |               |
| 0180-1819 | C:FXD ELECT 100 UF<br>+75-10% 50VDCW  | 28480                          | 0180-1819              | 1            |               |
| 0180-1940 | C:FXD ELECT 33 UF<br>10% 15VDCW       | 56289                          | 109D336X9015C2-<br>DYP | 1            |               |
| 0180-2178 | C:FXD ELECT 220 UF<br>20% 3VDCW       | 56289                          | 109D227X0008F2-<br>DYP | 1            |               |
| 0360-0124 | TERMINAL:SOLDER LUG                   | 28480                          | 0360-0124              | 3            | 5940-993-9338 |

Table D-1. Repair Parts List for Power Meter 432A (Continued)

|           | Description                        | Mfr.<br>Federal<br>Supply Code | Mfr. Part No. | Total<br>Qty | FSN           |
|-----------|------------------------------------|--------------------------------|---------------|--------------|---------------|
| 0683-0685 | R:FXD COMP 6.8<br>OHM 5% 1/4W      | 01121                          | CB68G5        | 1            | 5905-461-8385 |
| 0686-1055 | R:FXD COMP 1 MEGOHM<br>5% 1/2W     | 01121                          | EB 1055       | 1            | 5905-577-9667 |
| 0698-0084 | R:FXD MET FLM 2.15K<br>OHM 1% 1/8W | 28480                          | 0698-0084     | 1            | 5905-974-6073 |
| 0698-3136 | R:FXD MET FLM 17.8K<br>OHM 1% 1/8W | 28480                          | 0698-3136     | 1            | 5905-891-4247 |
| 0698-3155 | R:FXD MET FLM 4.64K<br>OHM 1% 1/8W | 28480                          | 0698-3155     | 1            | 5905-976-3418 |
| 0698-3156 | R:FXD MET FLM 14.7K<br>OHM 1% 1/8W | 28480                          | 0698-3156     | 1            | 5905-974-6084 |
| 0698-3160 | R:FXD MET FLM 31.6K<br>OHM 1% 1/8W | 28480                          | 0698-3160     | 3            | 5905-974-6078 |
| 0698-3260 | R:FXD MET FLM 464K<br>OHM 1% 1/8W  | 28480                          | 0698-3260     | 2            | 5905-998-1809 |
| 0698-3401 | R:FXD MET FLM 215<br>OHM 1% 1/2W   | 28480                          | 0698-3401     | 1            |               |
| 0698-3428 | R:FXD MET FLM 14.7<br>OHM 1% 1/8W  | 28480                          | 0698-3428     | 1            | 5905-891-4238 |
| 0698-3438 | R:FXD MET FLM 147<br>OHM 1% 1/8W   | 28480                          | 0698-3438     | 1            | 5905-974-6080 |
| 0698-3441 | R:FXD MET FLM 215<br>OHM 1% 1/8W   | 28480                          | 0698-3441     | 1            | 5905-974-6076 |
| 0698-3444 | R:FXD MET FLM 316<br>OHM 1% 1/8W   | 28480                          | 0698-3444     | 1            | 5905-974-6074 |
| 0698-3454 | R:FXD MET FLM 215K<br>OHM 1% 1/8W  | 28480                          | 0698-3454     | 1            | 5905-974-6077 |
| 0698-3635 | R:FXD MET OX 680<br>OHM 5% 2W      | 28480                          | 0698-3635     | 1            |               |
| 0698-4466 | R:FXD MET FLM 976<br>OHM 1% 1/8W   | 28480                          | 0698-4466     | 1            |               |
| 0698-6635 | R:FXD MET FLM 880<br>OHM 1% 1/8W   | 28480                          | 0698-6635     | 1            |               |
| 0757-0198 | R:FXD MET FLM 100<br>OHM 1% 1/2W   | 28480                          | 0757-0198     | 1            | 5905-830-6188 |
| 0757-0199 | R:FXD MET FLM 21.5K<br>OHM 1% 1/8W | 28480                          | 0757-0199     | 1            | 5905-981-7513 |

Table D-1. Repair Parts List for Power Meter 432A (Continued)

| Part No.  |                                    | Federal Supply Code | Mfr. Part No. | Total Qty | FSN           |
|-----------|------------------------------------|---------------------|---------------|-----------|---------------|
| 0757-0279 | R:FXD MET FLM 3.15K<br>OHM 1% 1/8W | 28480               | 0757-0279     | 1         | 5905-221-8310 |
| 0757-0230 | R:FXD MET FLM 1K<br>OHM 1% 1/8W    | 28480               | 0757-0230     | 1         | 5905-853-8190 |
| 0757-0239 | R:FXD MET FLM 13.3K<br>OHM 1% 1/8W | 28480               | 0757-0239     | 1         | 5905-998-1908 |
| 0757-0346 | R:FXD MET FLM 10 OHM<br>1% 1/8W    | 28480               | 0757-0346     | 3         | 5905-998-1906 |
| 0757-0401 | R:FXD MET FLM 100<br>OHM 1% 1/8W   | 28480               | 0757-0401     | 1         |               |
| 0757-0416 | R:FXD MET FLM 511<br>OHM 1% 1/8W   | 28480               | 0757-0416     | 1         | 5905-998-1795 |
| 0757-0439 | R:FXD MET FLM 6.81K<br>OHM 1% 1/3W | 28480               | 0757-0439     | 1         |               |
| 0757-0442 | R:FXD MET FLM 10.0K<br>OHM 1% 1/8W | 28480               | 0757-0442     | 2         | 5905-998-1792 |
| 0757-0461 | R:FXD MET FLM 68.1K<br>OHM 1% 1/8W | 28480               | 0757-0461     | 1         | 5905-089-7577 |
| 0757-0465 | R:FXD MET FLM 100K<br>OHM 1% 1/8W  | 28480               | 0757-0465     | 2         | 5905-974-5725 |
| 0757-0470 | R:FXD MET FLM 152K<br>OHM 1% 1/8W  | 28480               | 0757-0470     | 1         |               |
| 0757-0835 | R:FXD MET FLM 6.81K<br>OHM 1% 1/2W | 28480               | 0757-0835     | 1         | 5905-980-3049 |
| 0757-1094 | R:FXD MET FLM 1.47K<br>OHM 1% 1/8W | 28480               | 0757-1094     | 1         | 5905-917-0580 |
| 0811-2277 | R:FXD WW 10K OHM<br>0.1% 1/40W     | 28480               | 0811-2277     | 1         |               |
| 0811-2284 | R:FXD WW 1K OHM<br>0.1% 1/40W      | 28480               | 0811-2284     | 1         | 5905-858-6516 |
| 0811-2534 | R:FXD WW 314.3 OHM<br>0.1% 1/40W   | 28480               | 0811-2534     | 1         |               |
| 0811-2535 | R:FXD WW 145.0 OHM<br>0.1% 1/40W   | 28480               | 0811-2535     | 1         |               |
| 0811-2536 | R:FXD WW 3167 OHM<br>0.1% 1/40W    | 28480               | 0811-2536     | 1         |               |
| 0811-2537 | R:FXD WW 5K OHM<br>0.1% 1/4W       | 28480               | 0811-2537     | 1         |               |
| 0811-2538 | R:FXD WW 100 OHM<br>0.1% 1/10W     | 28480               | 0811-2538     | 1         |               |
| 1120-1497 | METER                              | 28480               | 1120-1497     | 1         |               |
| 1420-0062 | BATTERY:RECHARGEABLE<br>24V        | 28480               | 1420-0062     | 1         |               |

Table D-1. Repair Parts List for Power Meter 432A (Continued)

| Part No.  | Description                             | Mfr.<br>Federal<br>Supply Code | Mfr. Part No. | Total<br>Qty | FSN              |
|-----------|-----------------------------------------|--------------------------------|---------------|--------------|------------------|
| 1853-0001 | TRANSISTOR: PNP<br>SILICON 30V<br>900MW | 28480                          | 1853-0001     | 2            | 5961-962-5213    |
| 1853-0012 | TRANSISTOR: PNP<br>SILICON<br>2N2904A   | 04713                          | 2N2904A       | 1            |                  |
| 1853-0015 | TRANSISTOR: SILICON<br>PNP 2N3640       | 28480                          | 1853-0015     | 1            | 5961-927-0845    |
| 1853-0020 | TRANSISTOR: SILICON<br>PNP              | 28480                          | 1853-0020     | 3            | 5961-904-2540    |
| 1854-0003 | TRANSISTOR: MPN<br>SILICON              | 28480                          | 1854-0003     | 1            | 5961-990-5369    |
| 1854-0005 | TRANSISTOR: SILICON<br>NPN 2N708        | 02735                          | 2N708         | 2            |                  |
| 1854-0039 | TRANSISTOR: SILICON<br>2N3053           | 02735                          | 2N3053        | 1            | 5961-985-9703    |
| 1854-0052 | TRANSISTOR: SILICON<br>NPN 2N1701       | 02735                          | 2N1701        | 1            | 5961-082-1617    |
| 1854-0071 | TRANSISTOR: SILICON<br>NPN              | 28480                          | 1854-0071     | 7            | 5961-928-3161    |
| 1854-0221 | TRANSISTOR DUAL:<br>SILICON NPN         | 28480                          | 1854-0221     | 1            | 5961-836-1887    |
| 1901-0026 | DIODE: SILICON 0.75<br>200 PIV          | 28480                          | 1901-0026     | 3            | 5961-060-8638    |
| 1901-0040 | DIODE: SILICON 30MA<br>30WV             | 28480                          | 1901-0040     | 3            | 5961-965-5917AX1 |
| 1902-0033 | DIODE BREAKDOWN:<br>6.2V                | 04713                          | 1N823         | 1            | 5961-103-7417    |
| 1902-0048 | DIODE BREAKDOWN:<br>6.81V 5%            | 28480                          | 1902-0048     | 1            | 5961-912-3099    |
| 2100-1769 | R: VAR WW 50 OHM<br>10% LIN 1/2W        | 28480                          | 2100-1769     | 1            | 5905-891-4230    |
| 2100-1770 | R: VAR WW 100 OHM<br>10% LIN 1/2W       | 28480                          | 2100-1770     | 1            | 5905-891-4229    |
| 2100-1773 | R: VAR WW 1K OHM<br>10% LIN 1/2W        | 28480                          | 2100-1773     | 1            | 5905-115-7158YA  |
| 2100-1775 | R: VAR WW 5K OHM<br>10% LIN 1/2W        | 28480                          | 2100-1775     | 1            | 5905-228-5990YA  |
| 2100-2659 | R: VAR WW 50K OHM<br>5% LIN 1-1/2W      | 28482                          | 2100-2659     | 1            |                  |
| 2110-0027 | FUSE: 0.125A 250V                       | 75915                          | 312.125       | 1            | 6240-402-0401    |
| 2140-0015 | LAMP: GLOW NEON<br>NE-2H                | 24455                          | NE 2H         | 1            |                  |

Table D-1. Repair Parts List for Power Meter 432A (Continued)

| Part No.  | Description                             |       |           |   |               |
|-----------|-----------------------------------------|-------|-----------|---|---------------|
| 3100-2469 | SWITCH:ROTARY,<br>CALIBRATION<br>FACTOR | 28480 | 3100-2469 | 1 |               |
| 3100-2470 | SWITCH:ROTARY,<br>RANGE                 | 28480 | 3100-2470 | 1 |               |
| 3101-0033 | SWITCH:SLIDE DPOT                       | 79727 | 6510 C    | 1 | 5930-228-5970 |
| 3101-0957 | SWITCH:TOGGLE DPOT                      | 28480 | 3101-0957 | 1 |               |
| 3101-1180 | SWITCH:SLIDE 3POT                       | 82389 | 11L-1920  | 1 |               |
| 3101-1357 | SWITCH:MOMENTARY,<br>FINE ZERO          | 28480 | 3101-1357 | 1 |               |
| 8120-0073 | CABLE ASSY:POWER<br>CORD                | 28480 | 8120-0073 | 1 |               |
| 8120-1082 | CABLE ASSY:5 FT,<br>THERMISTOR CABLE    | 28480 | 8120-1082 | 1 |               |

By Order of the Secretary of the Army:

Official:

W. C. WESTMORELAND,  
General, United States Army,  
Chief of Staff.

KENNETH G. WICKHAM,  
Major General, United States Army,  
The Adjutant General.

**DISTRIBUTION:**

To be distributed in accordance with DA Form 12-37 (qty rqr Block #201) Operator requirements for Gun, 20-MM XM163; DA Form 12-40 (qty rqr Block #168), Operator/Crew requirements for Gun, 20-MM XM167.



## TEST POINT MEASUREMENT CONDITIONS AND VOLTAGES

## Measurement Conditions

1. .3 mW
2. 200 ohm mount
3. 100% CAL FACTOR
4. COARSE ZERO turned to get full-scale deflection
5. Measurements made with respect to CHASSIS GROUND

## Test Point Voltages

| Test Point | Voltage       | Notes                                                    |
|------------|---------------|----------------------------------------------------------|
| A1TP1      | +5.2          |                                                          |
| A1TP2      | +5.2          |                                                          |
| A1TP3      | +2.7          |                                                          |
| A1TP4      | +2.7          |                                                          |
| A1TP5      | +2.7          |                                                          |
| A1TP6      | +2.7          |                                                          |
| A1TP7      | +1.2          | RANGE to COARSE ZERO, meter zeroed                       |
| A1TP8      | -6.5          | Varies from 0 to -13 V under normal operating conditions |
| A1TP9      | +4 mV         | Thermistor ground                                        |
| A2TP1      | Waveform      | Figure 7-3                                               |
| A2TP2      | Waveform      | Figure 7-3                                               |
| A2TP3      | +7 Nominal    |                                                          |
| A2TP4      | -13 Nominal   |                                                          |
| A2TP5      | 0 V           | Chassis Ground                                           |
| A2TP6      | Waveform      | Figure 7-3                                               |
| A2TP7      | Waveform      | Figure 7-3                                               |
| A2TP8      | Waveform      | Figure 7-3                                               |
| A2TP9      | Waveform      | Figure 7-3                                               |
| A2TP10     | Waveform      | Figure 7-3                                               |
| A7TP1      | +1 Variable   |                                                          |
| A7TP2      | +1.6 Variable |                                                          |

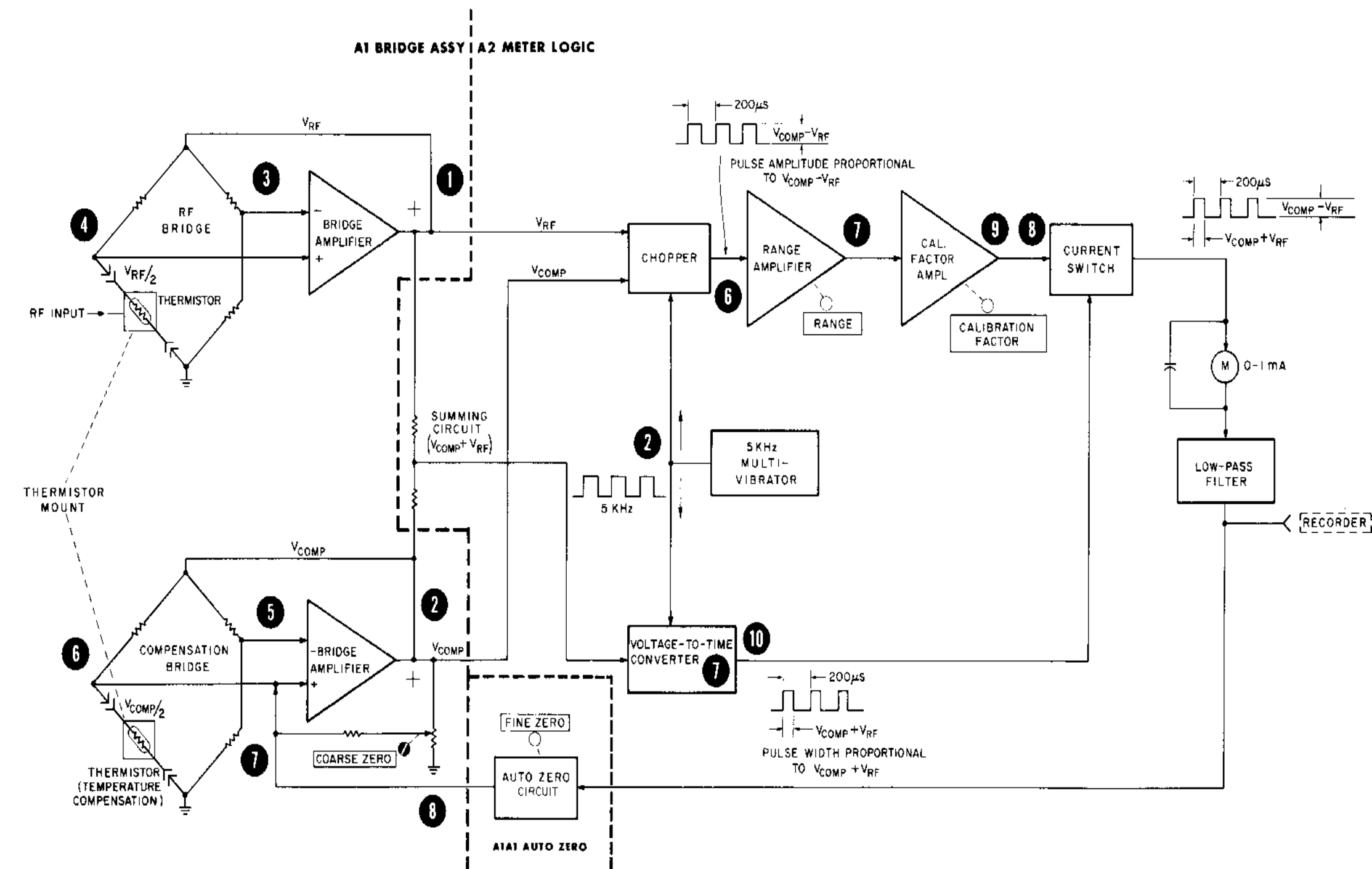


Figure 7-1. Servicing Block Diagram

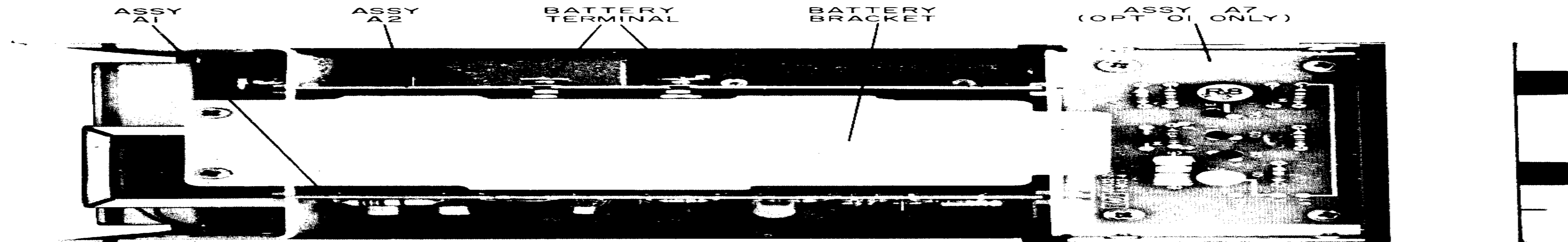


Figure 7-2. Model 432A Top Internal View

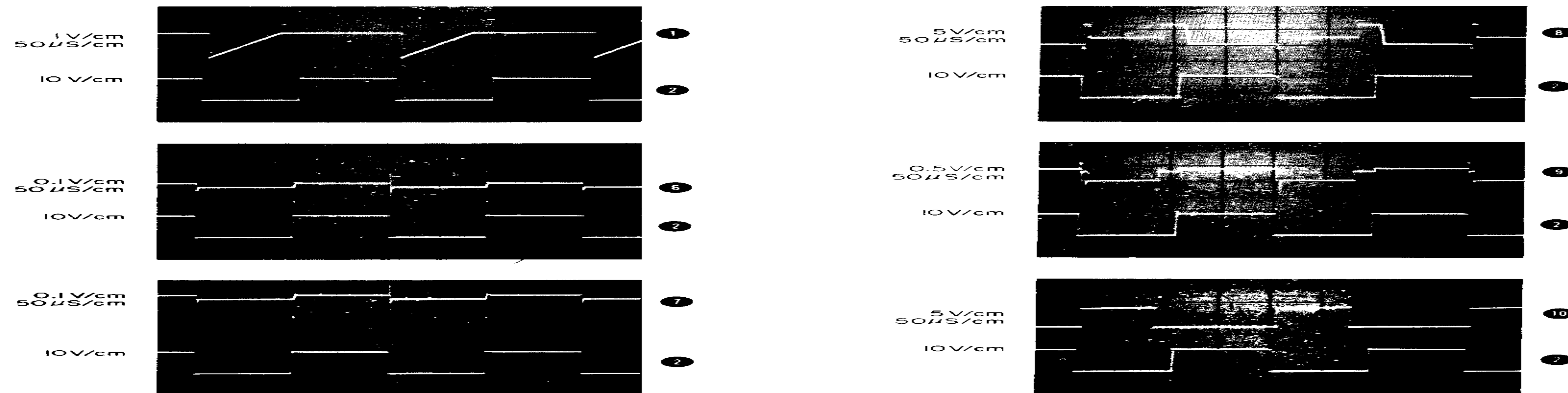
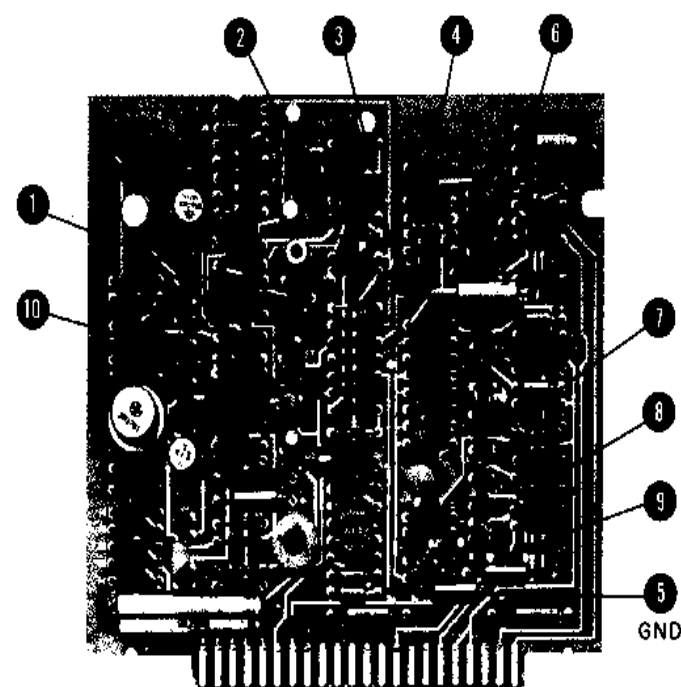
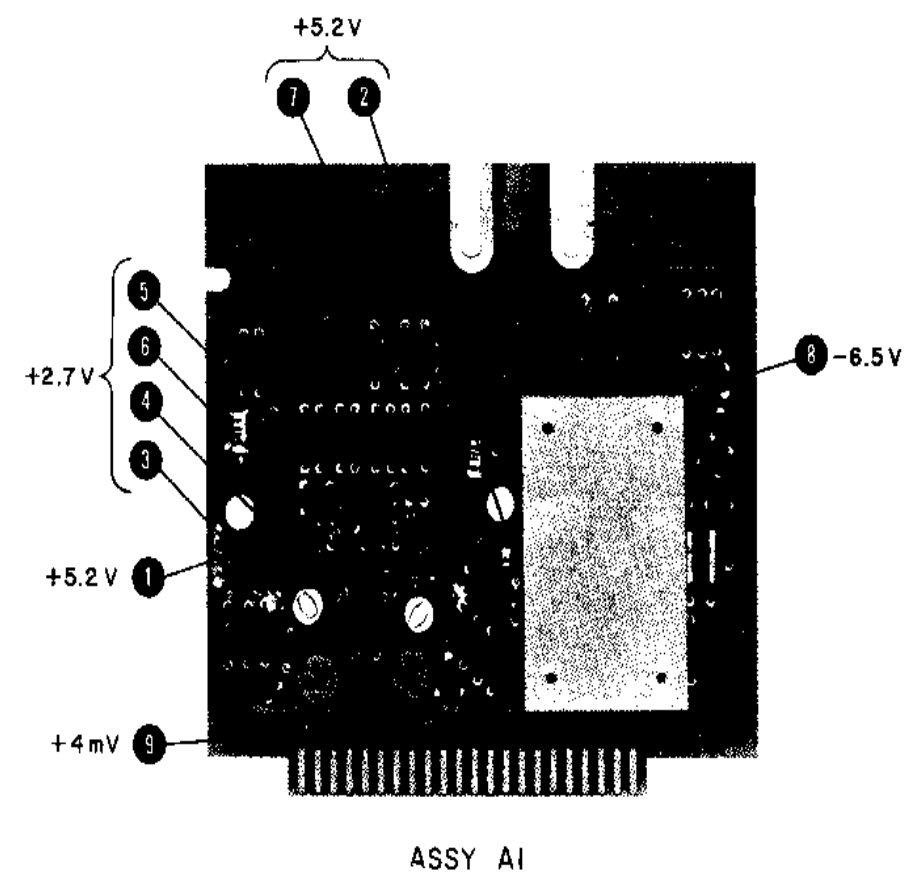
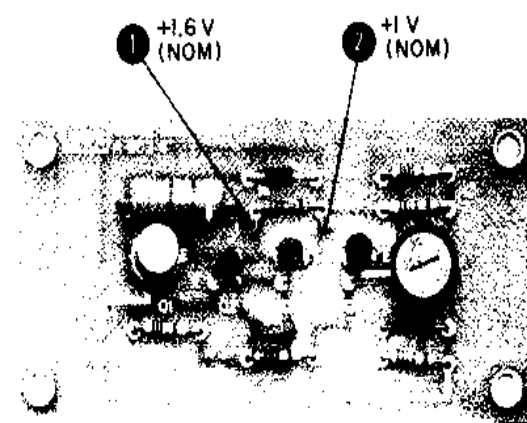


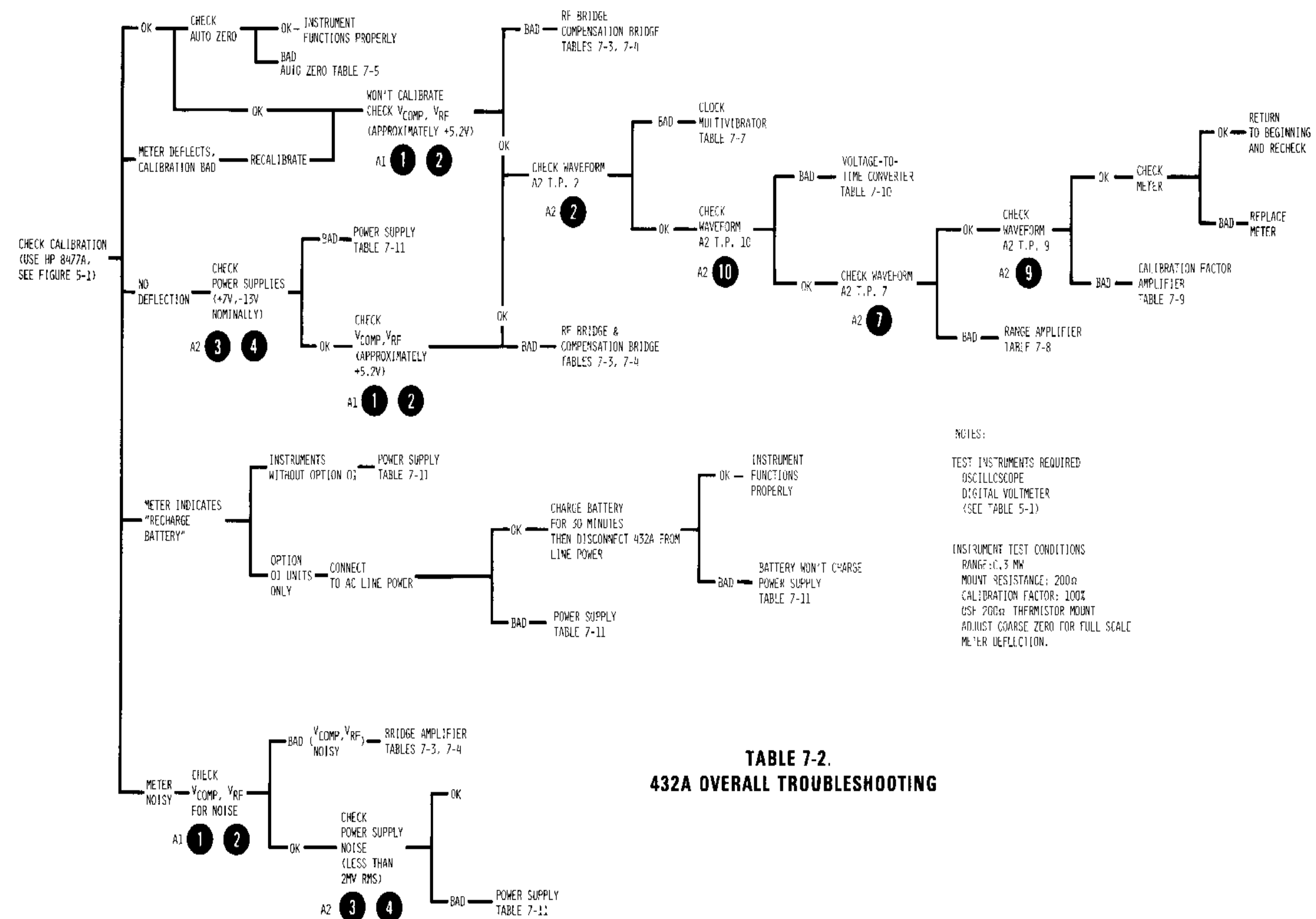
Figure 7-3. Model 432A Waveforms, A2 Meter Logic Assembly



ASSY A2



ASSY A7



**TABLE 7-2.**  
**432A OVERALL TROUBLESHOOTING**

NOTES:

TEST INSTRUMENTS REQUIRED

OSCILLOSCOPE

DIGITAL VOLTMETER

(SEE TABLE 5-1)

INSTRUMENT TEST CONDITIONS

RANGE: 0.3 MW

MOUNT RESISTANCE: 200 $\Omega$

CALIBRATION FACTOR: 100%

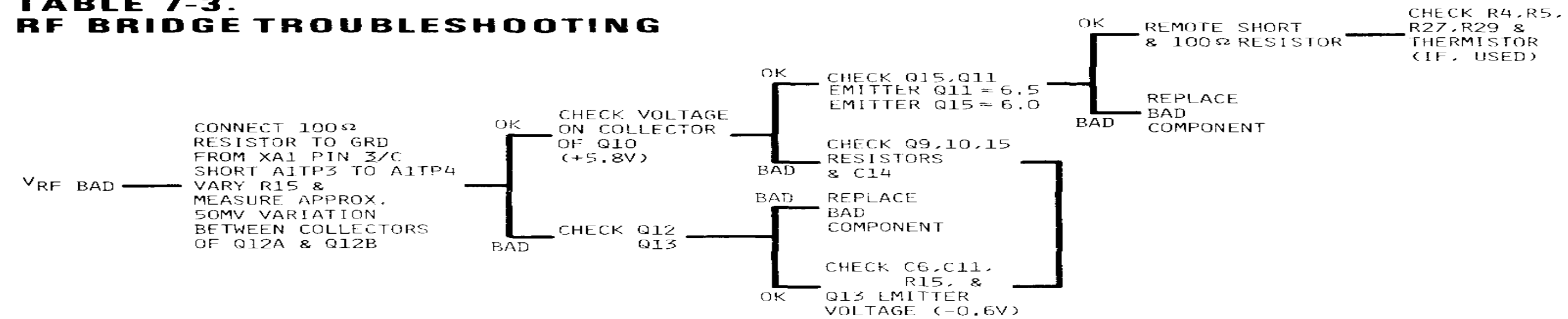
CW: 200 $\mu$ s THERMISTOR MOUNT

ADJUST COARSE ZERO FOR FULL SCALE  
MILIEY DEFLECTION.

Figure 7-4. Model 432A Test Point Locations

Table 7-2. Overall Troubleshooting

**TABLE 7-3.**  
**RF BRIDGE TROUBLESHOOTING**



NOTE: IF TROUBLESHOOTING RF BRIDGE FOR NOISE, CHECK Q12.

**TABLE 7-4.**  
**COMPENSATION BRIDGE P/O A1 TROUBLESHOOTING**

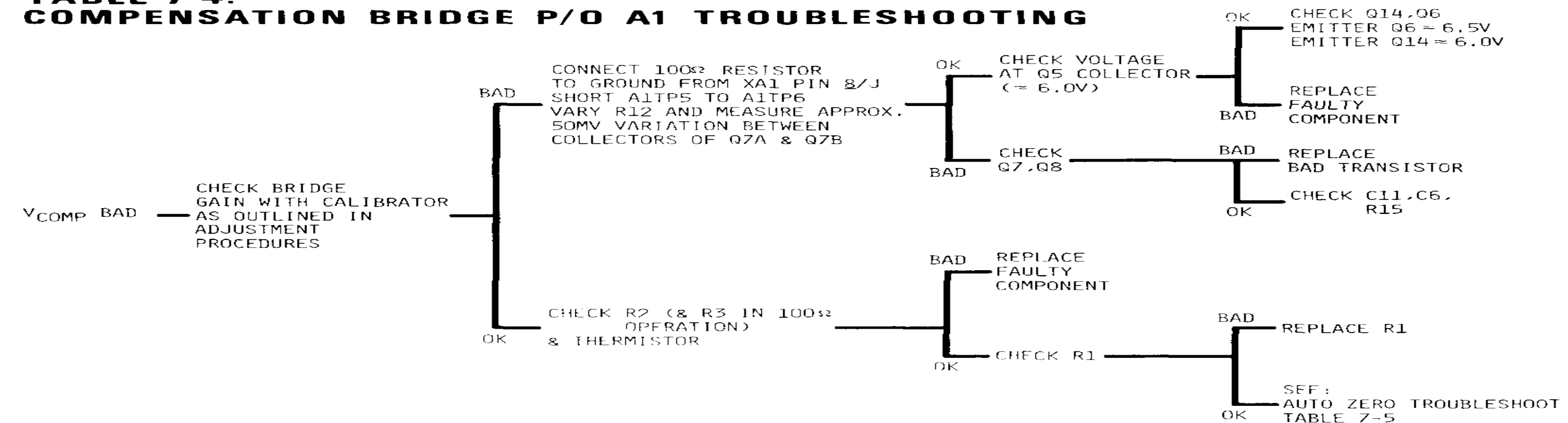


TABLE 7-5.  
AUTO ZERO CIRCUIT P/O A1 TROUBLESHOOTING

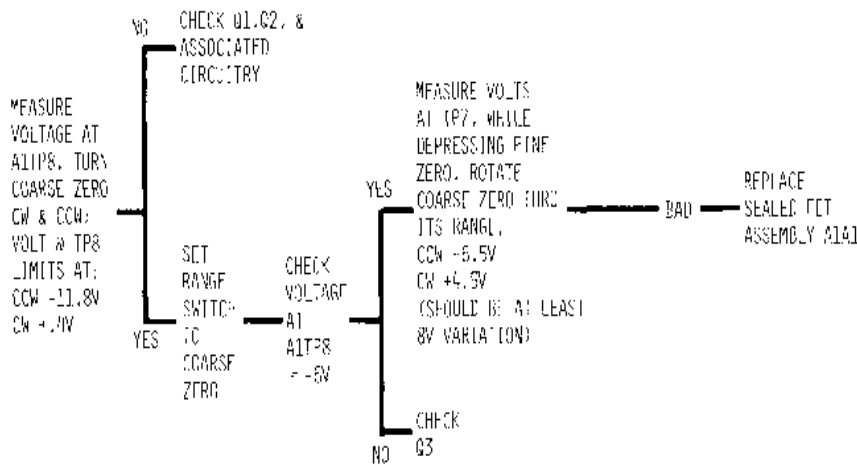
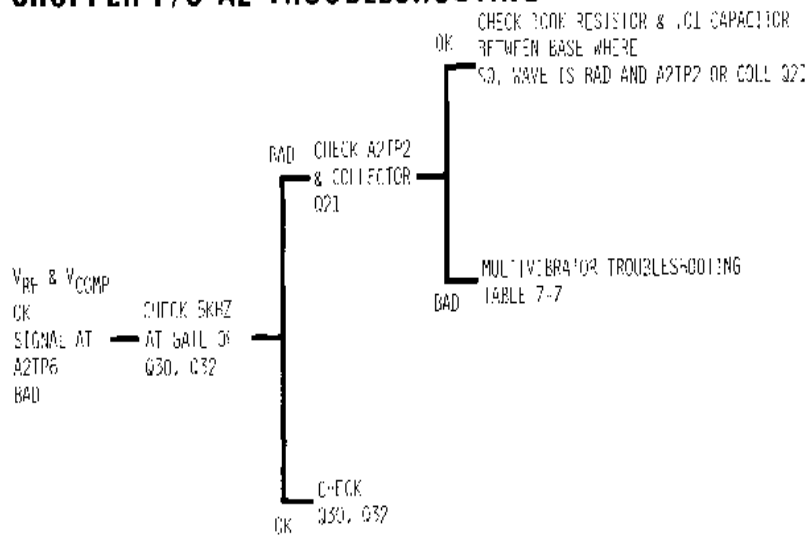


TABLE 7-6.  
CHOPPER P/O A2 TROUBLESHOOTING



SERVICE HINT: IF TROUBLESHOOTING CHOPPER FOR NOISE, LEFT END OF C25 & C31 AND SEE IF NOISE PERSISTS.

TABLE 7-7.  
MULTIVIBRATOR P/O A2 TROUBLESHOOTING

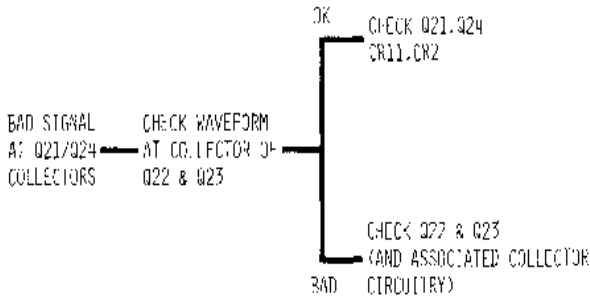


TABLE 7-9.  
CALIBRATION FACTOR AMPLIFIER P/O A2 TROUBLESHOOTING

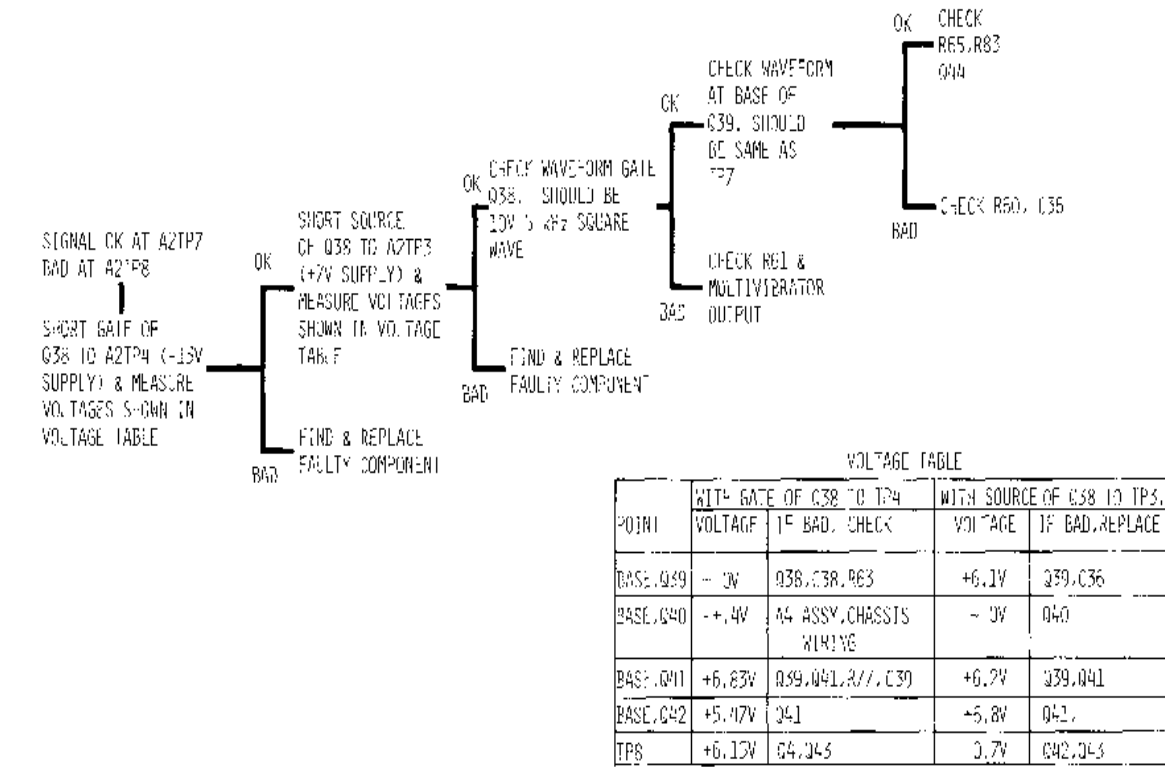


TABLE 7-8.  
RANGE AMPLIFIER TROUBLESHOOTING

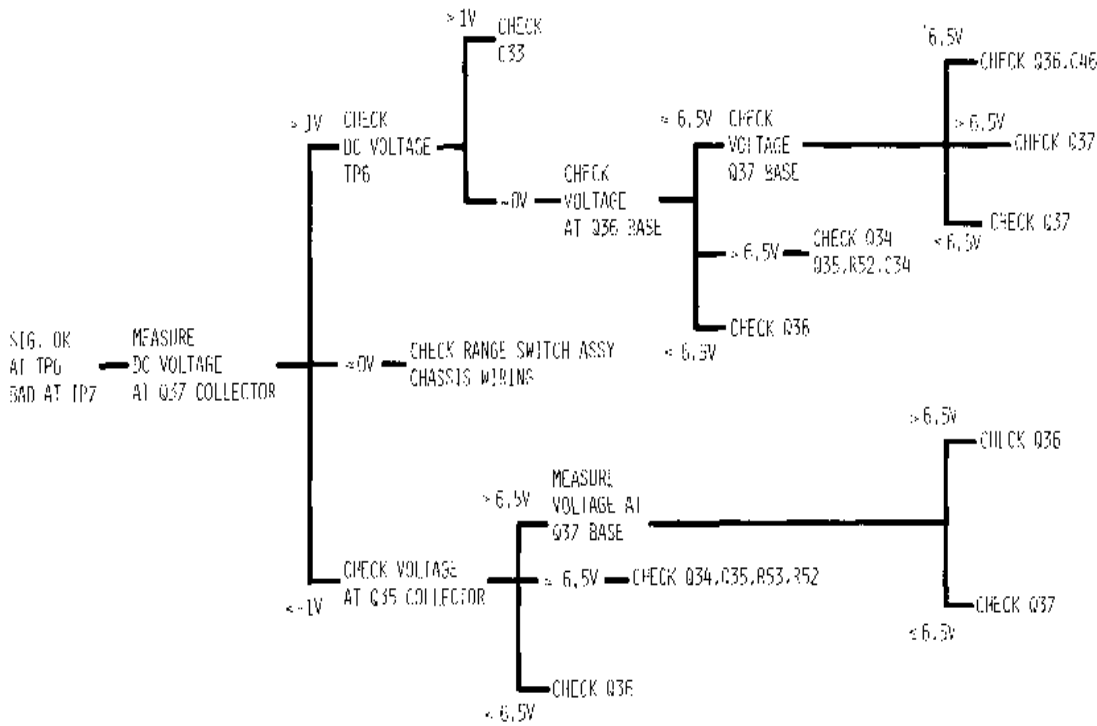
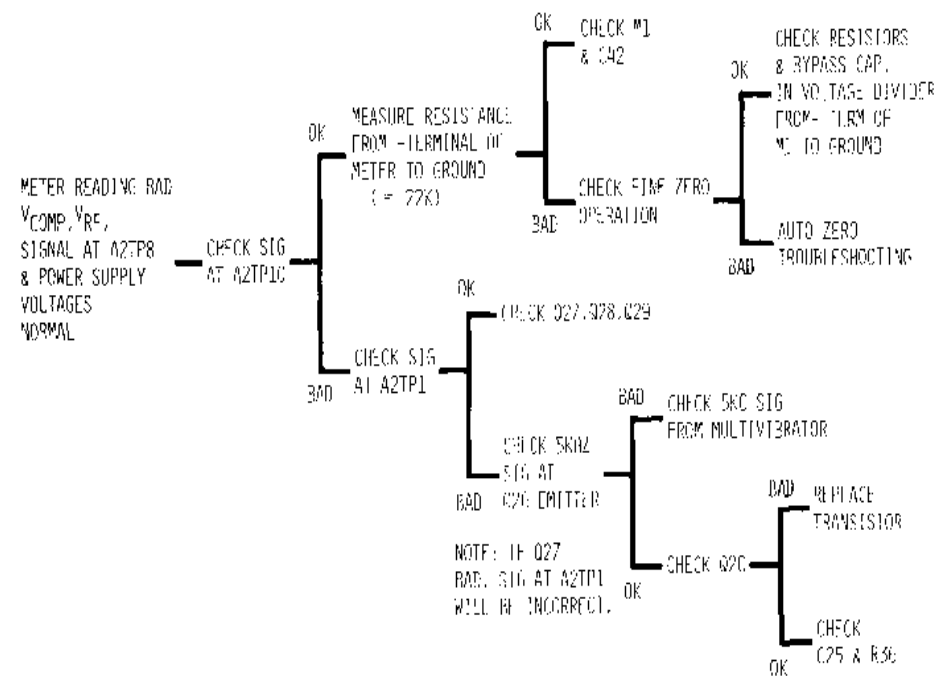
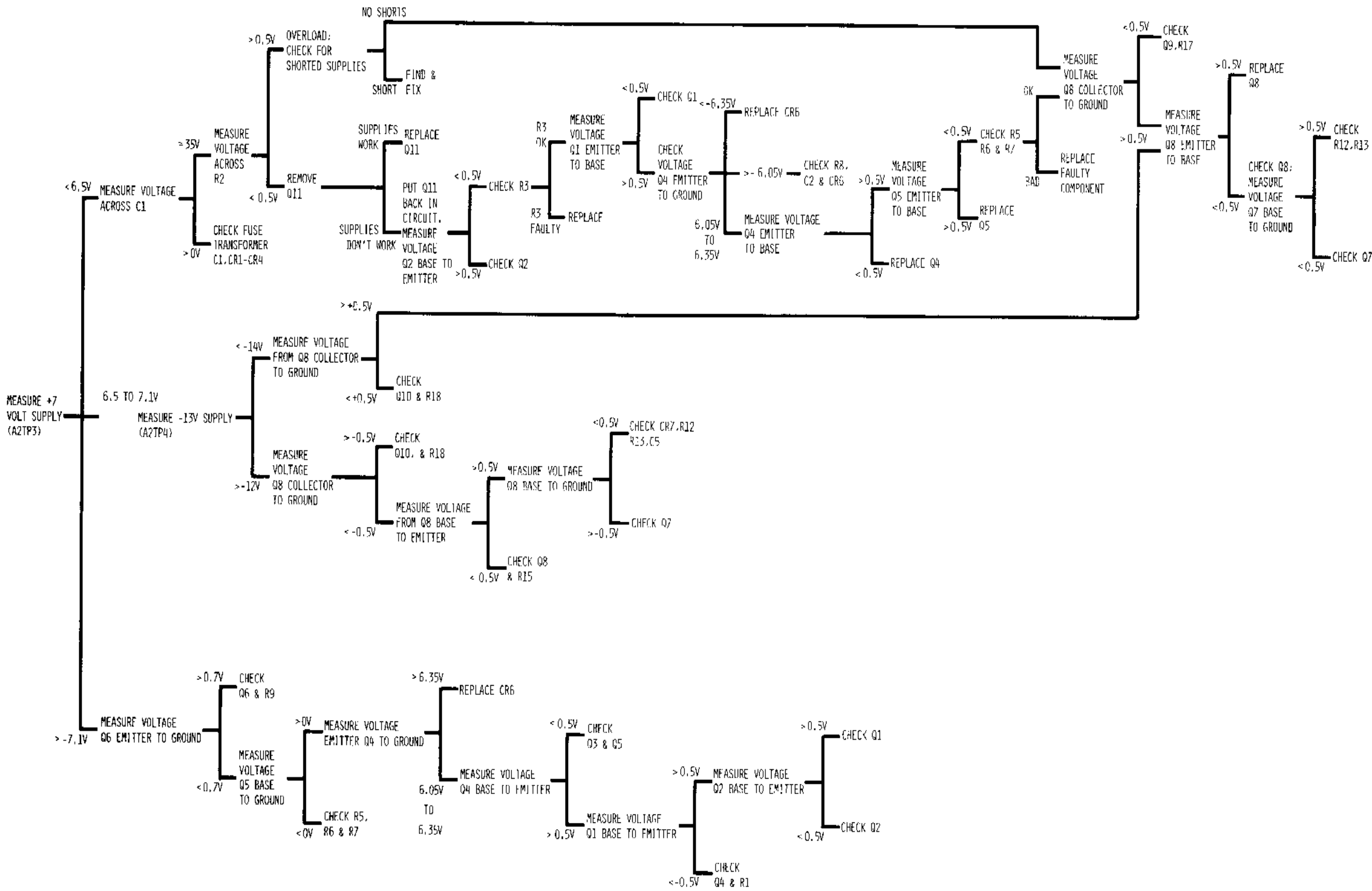


TABLE 7-10.  
VOLTAGE-TO-TIME CONVERTER & METER TROUBLESHOOTING



### TABLE 7-11. POWER SUPPLY TROUBLESHOOTING



### Table 7-11. Power Supply Troubleshooting

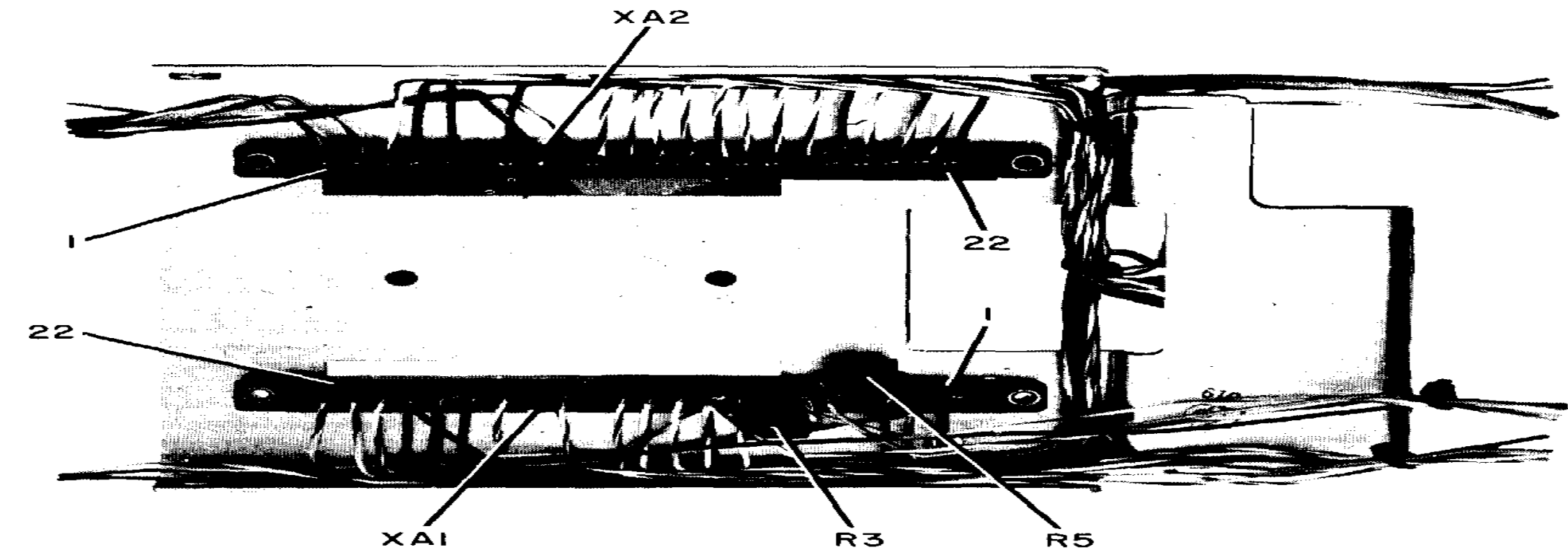


Figure 7-5. 432A Bottom View, Component Locations

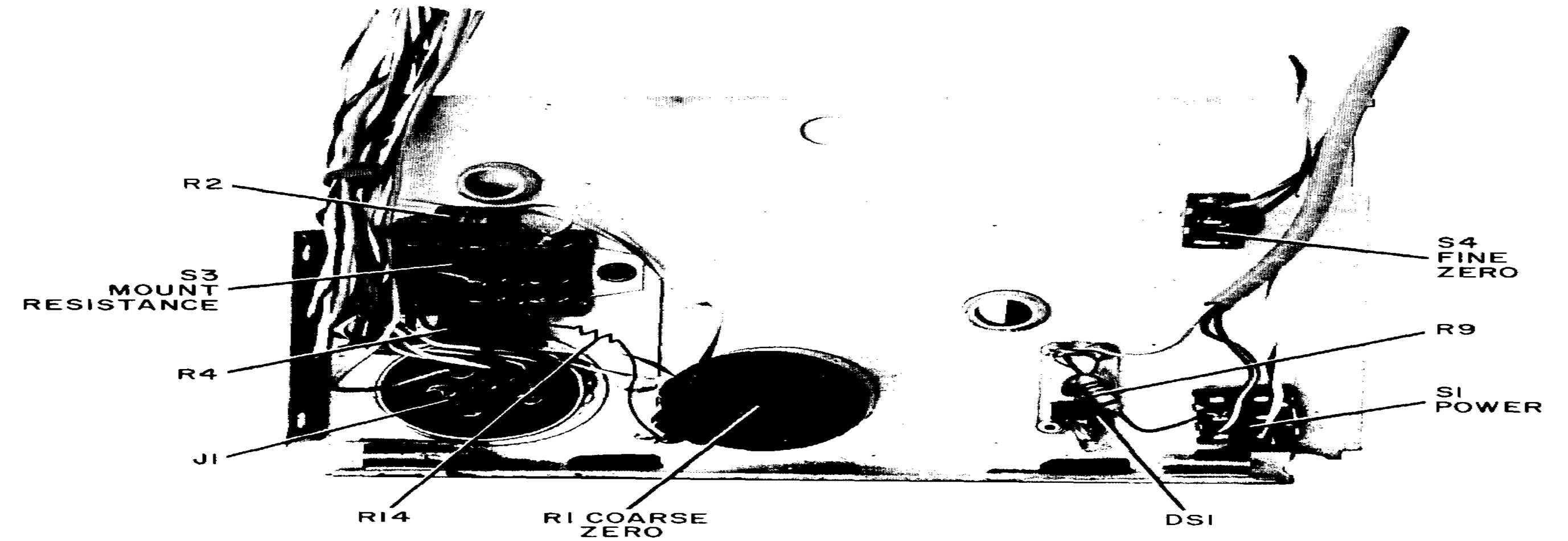


Figure 7-6. 432A Front Panel Interior

\*\* ADDED FOR LONG CABLE OPTIONS (11,12)

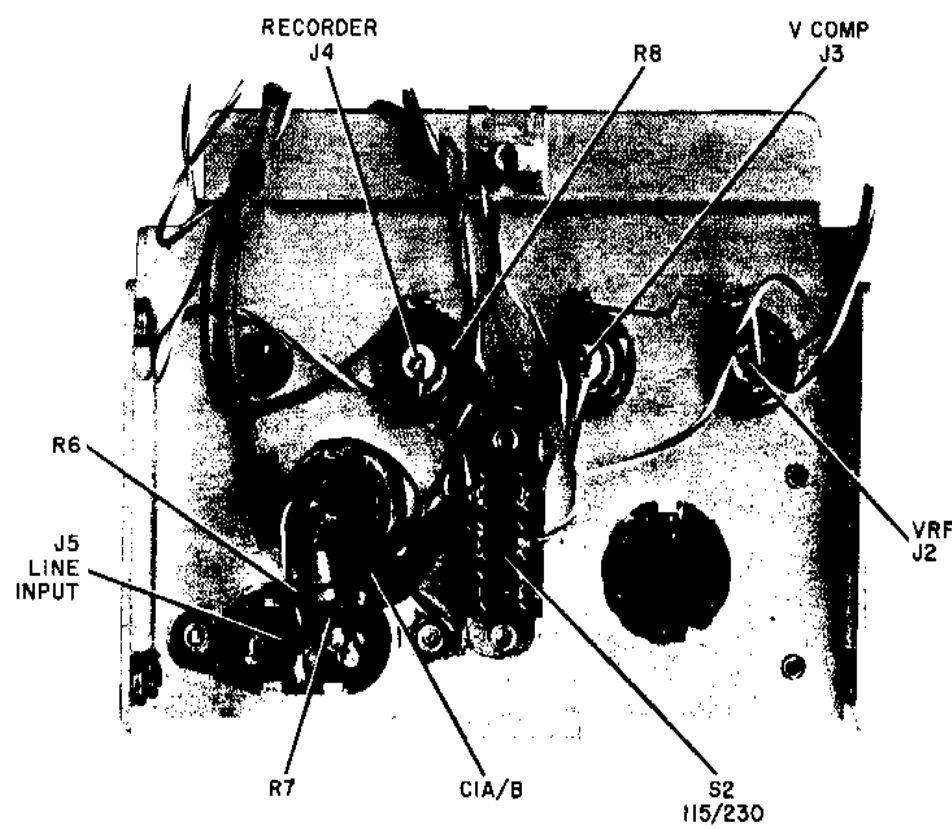
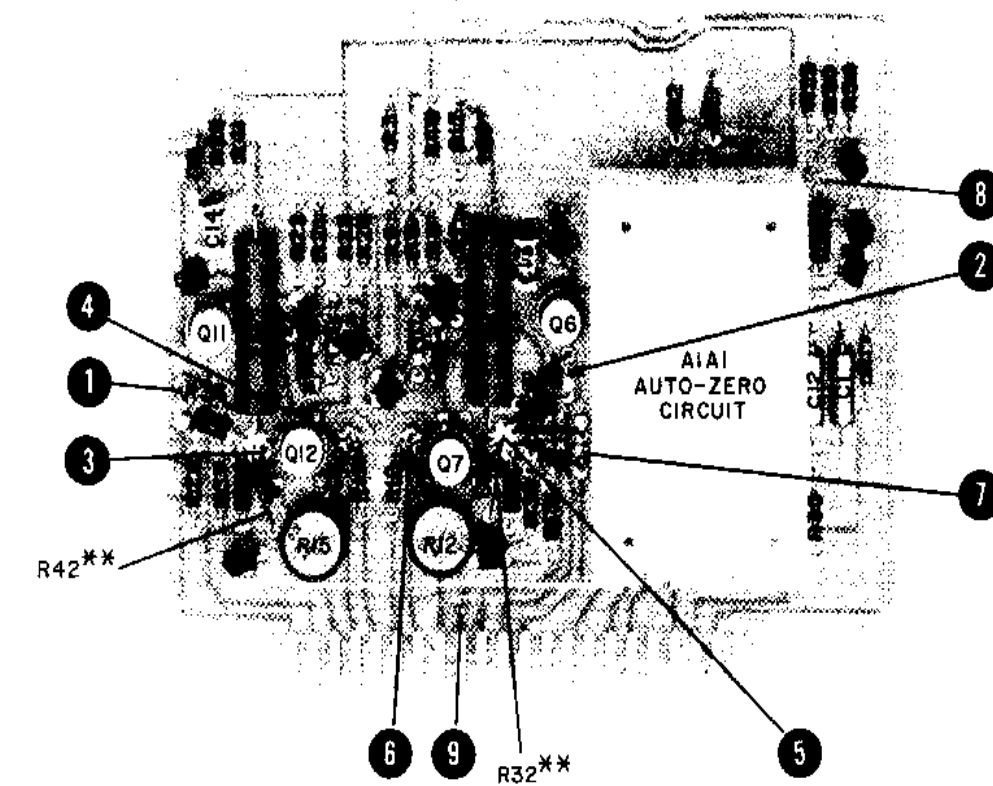


Figure 7-8. 432A Rear Panel Interior

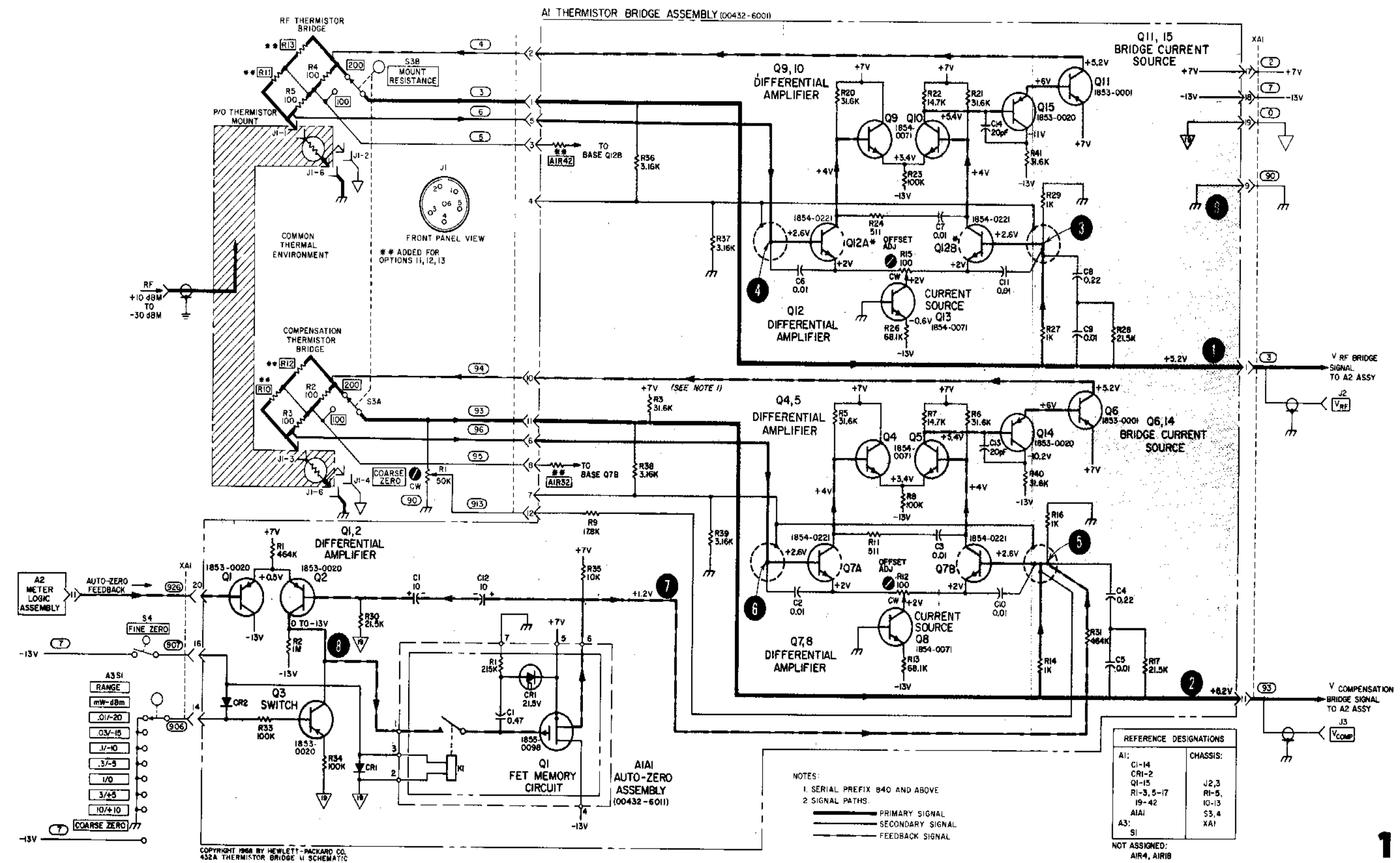


Figure 7-9. RF and Compensation Bridge Schematic

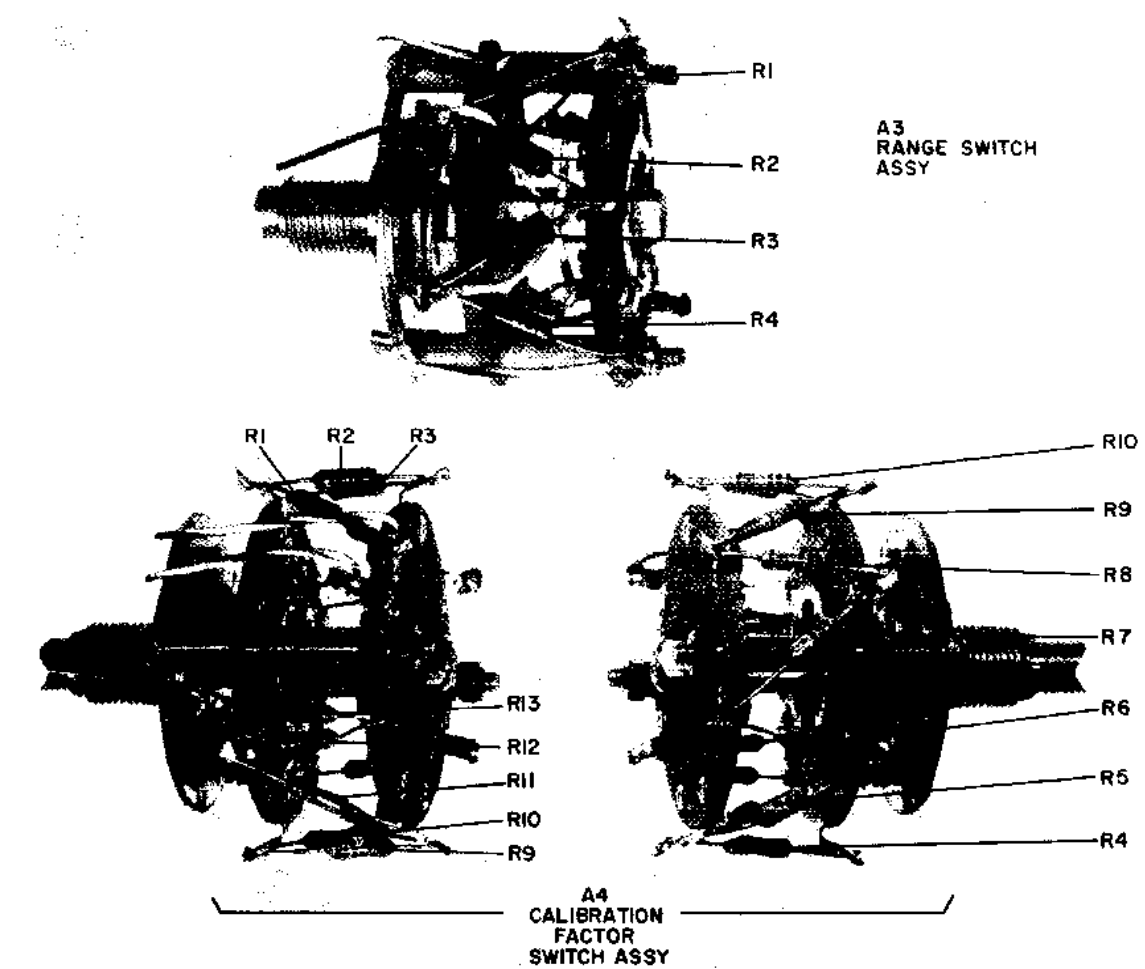


Figure 7-10. Model 432A Switches

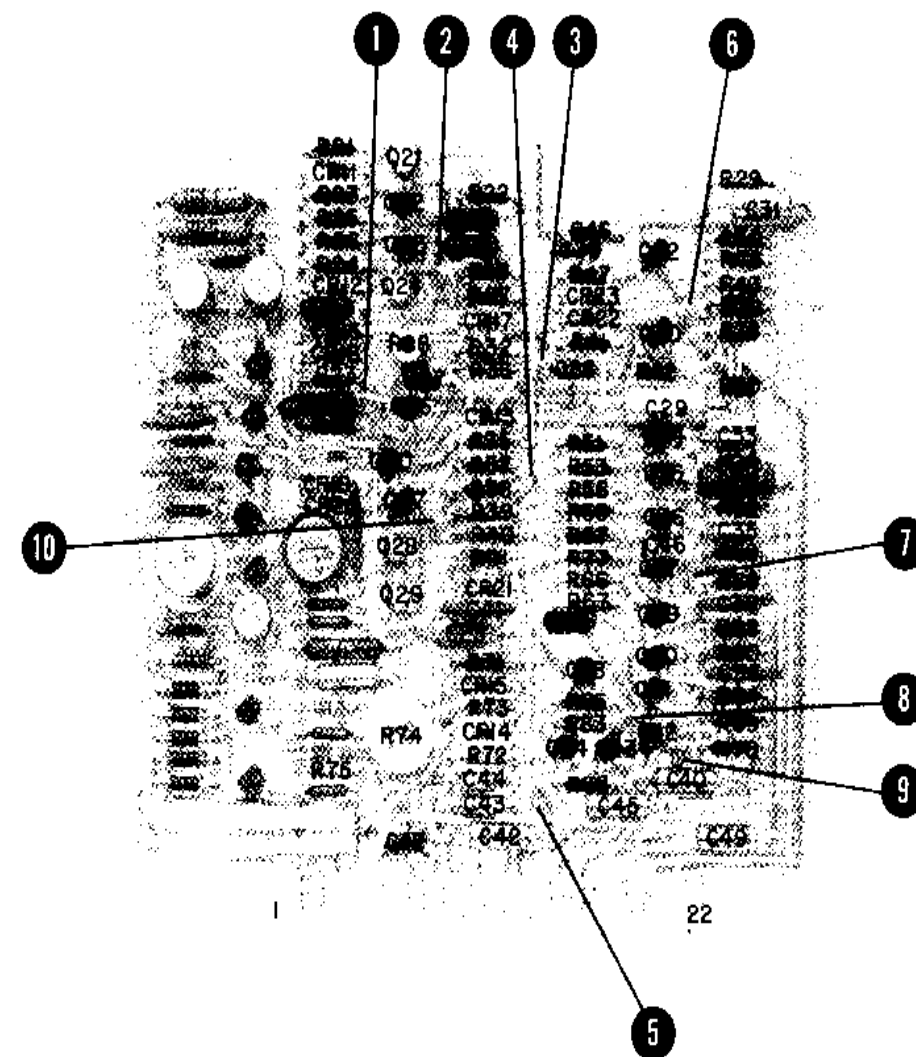


Figure 7-11. A2 Meter Logic Assembly Component Locations

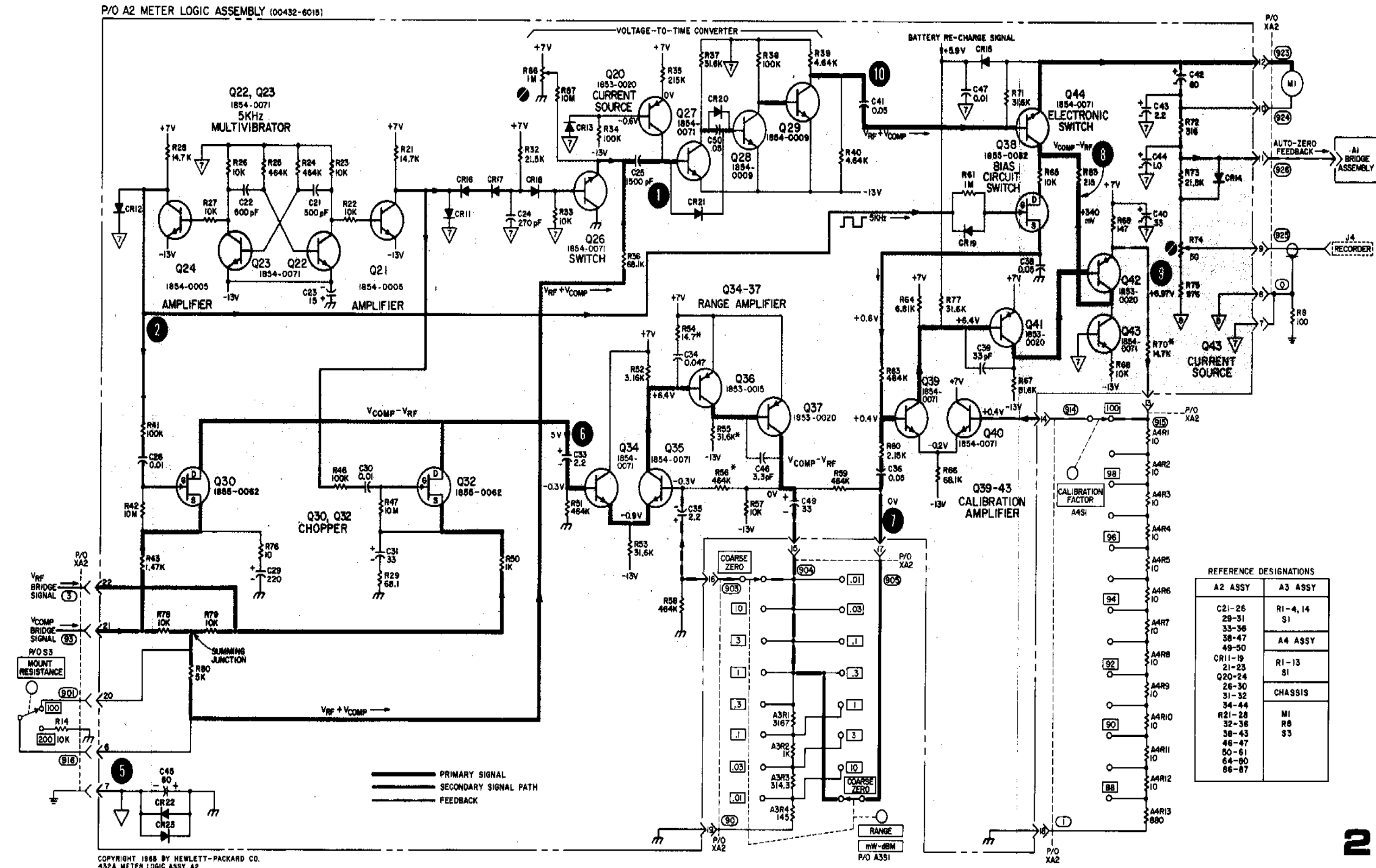


Figure 7-12. Meter Logic Schematic

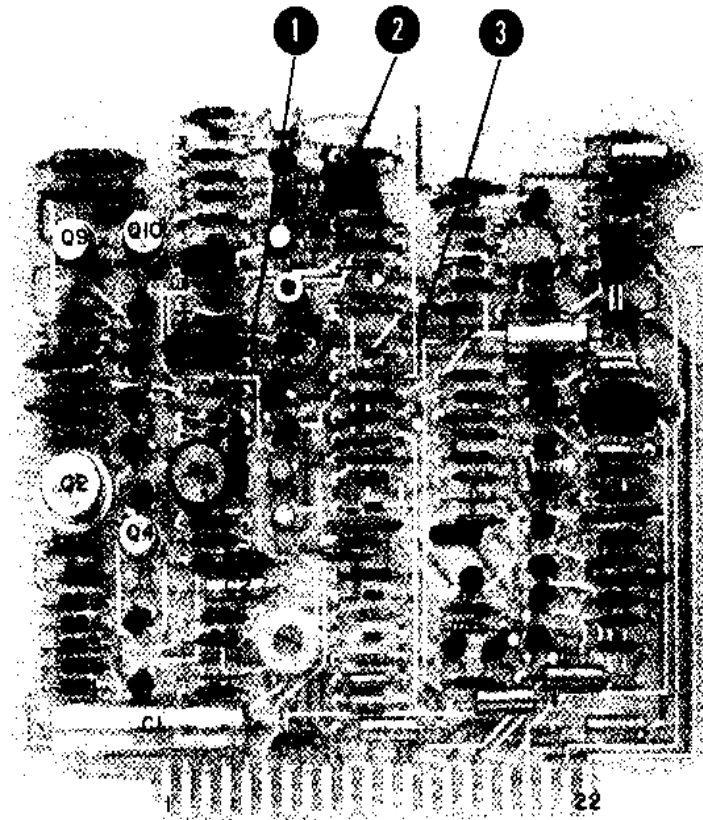


Figure 7-13. A2 Meter Logic Assembly, Power Supply Component Locations

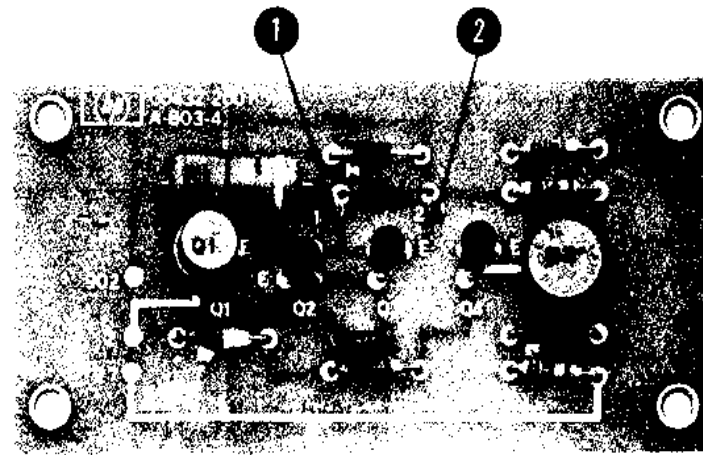
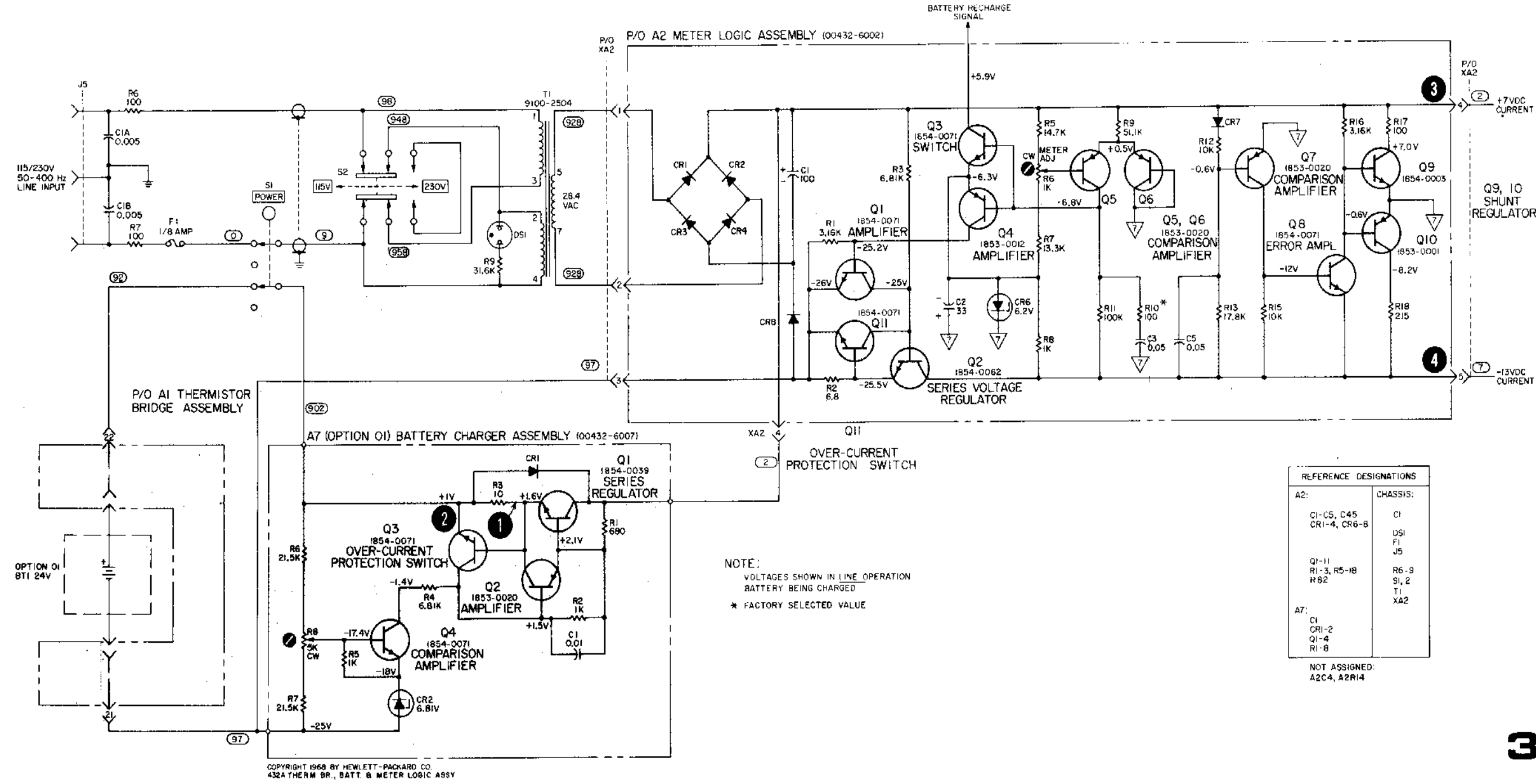


Figure 7-14. A7 Battery Charging Circuit (Option 01), Component Locations



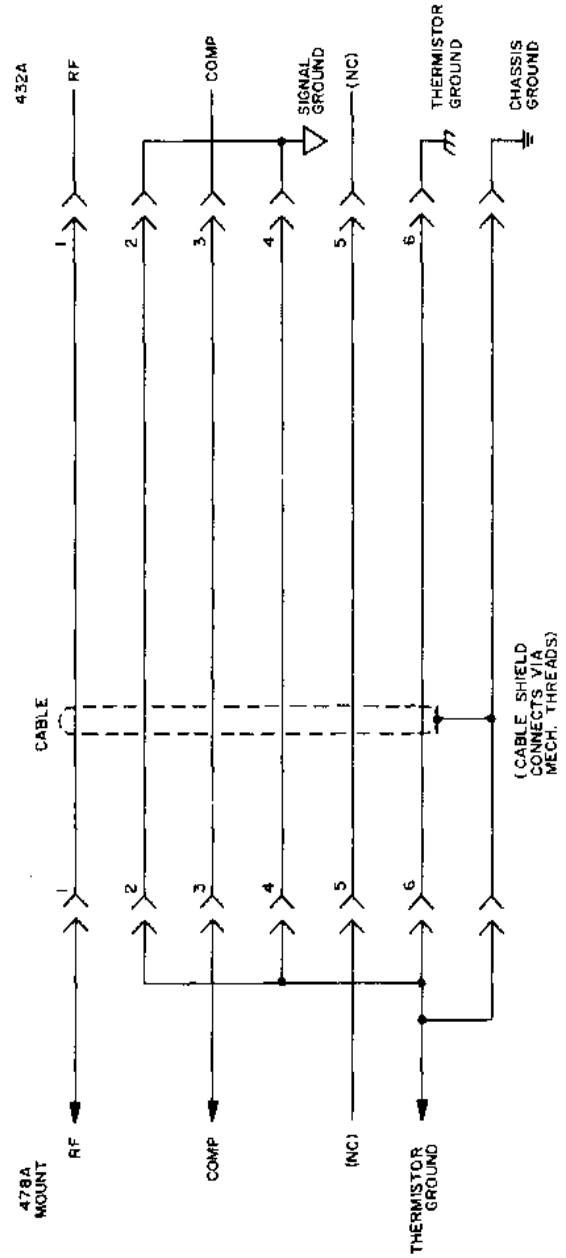


Figure 7-16. Thermistor Cable Wiring Diagram

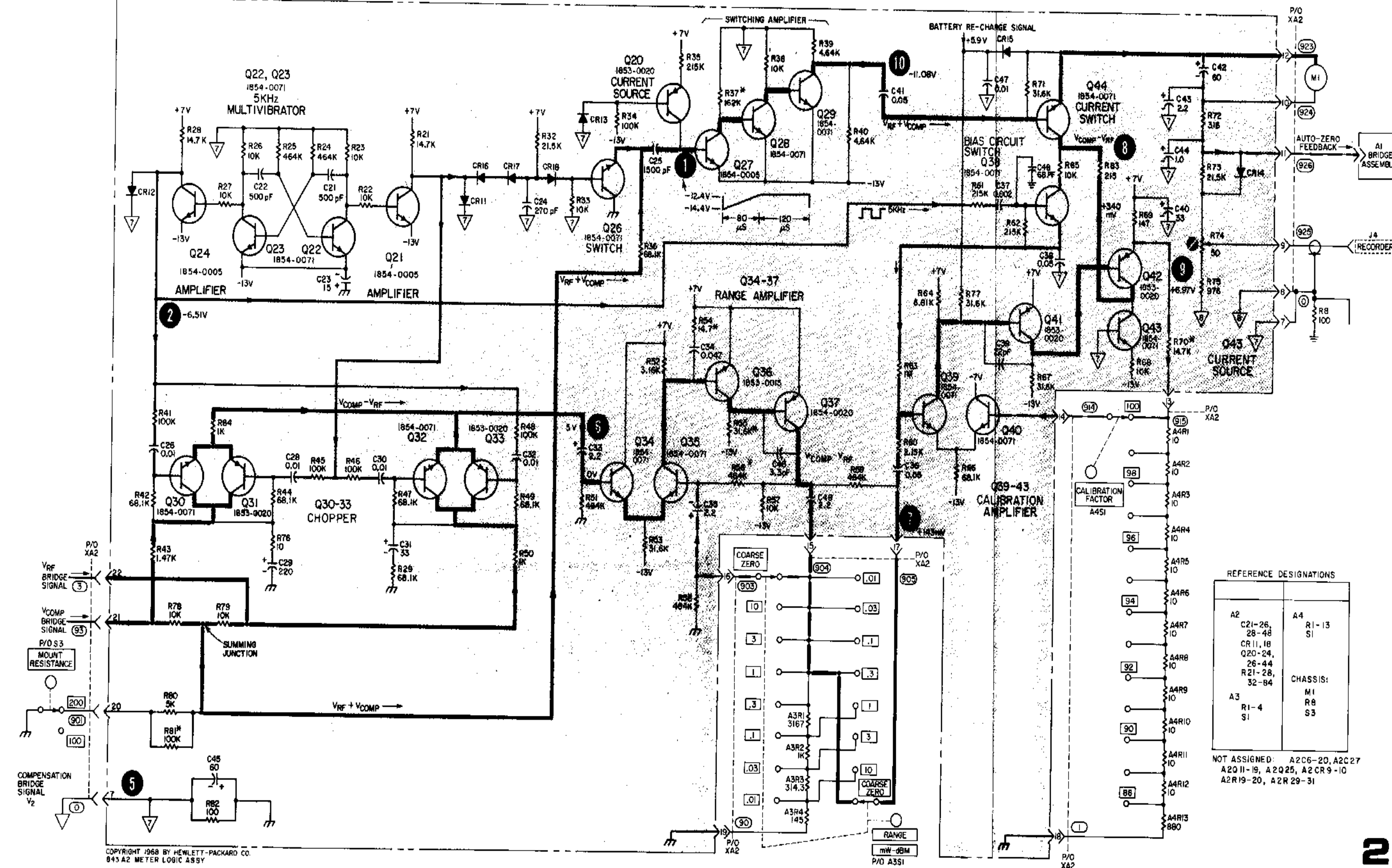


Figure A1-3. Meter Logic Schematic

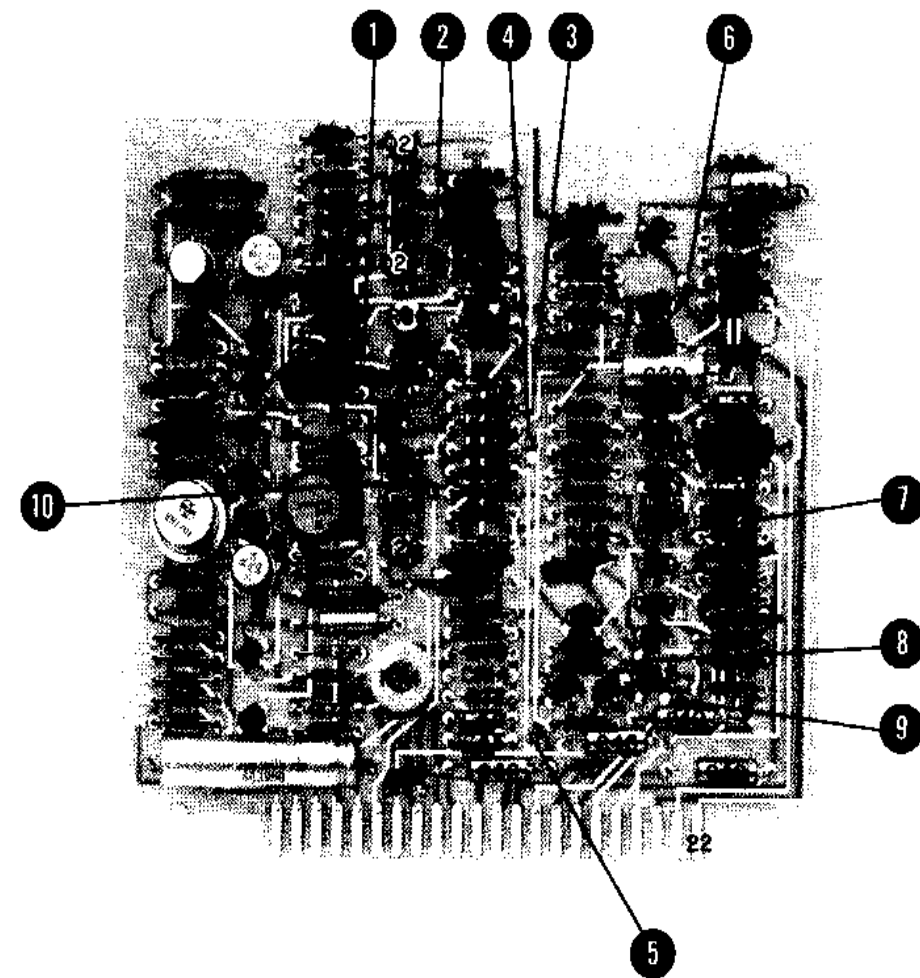


Figure 7-11. A2 Meter Logic Assembly Component Locations

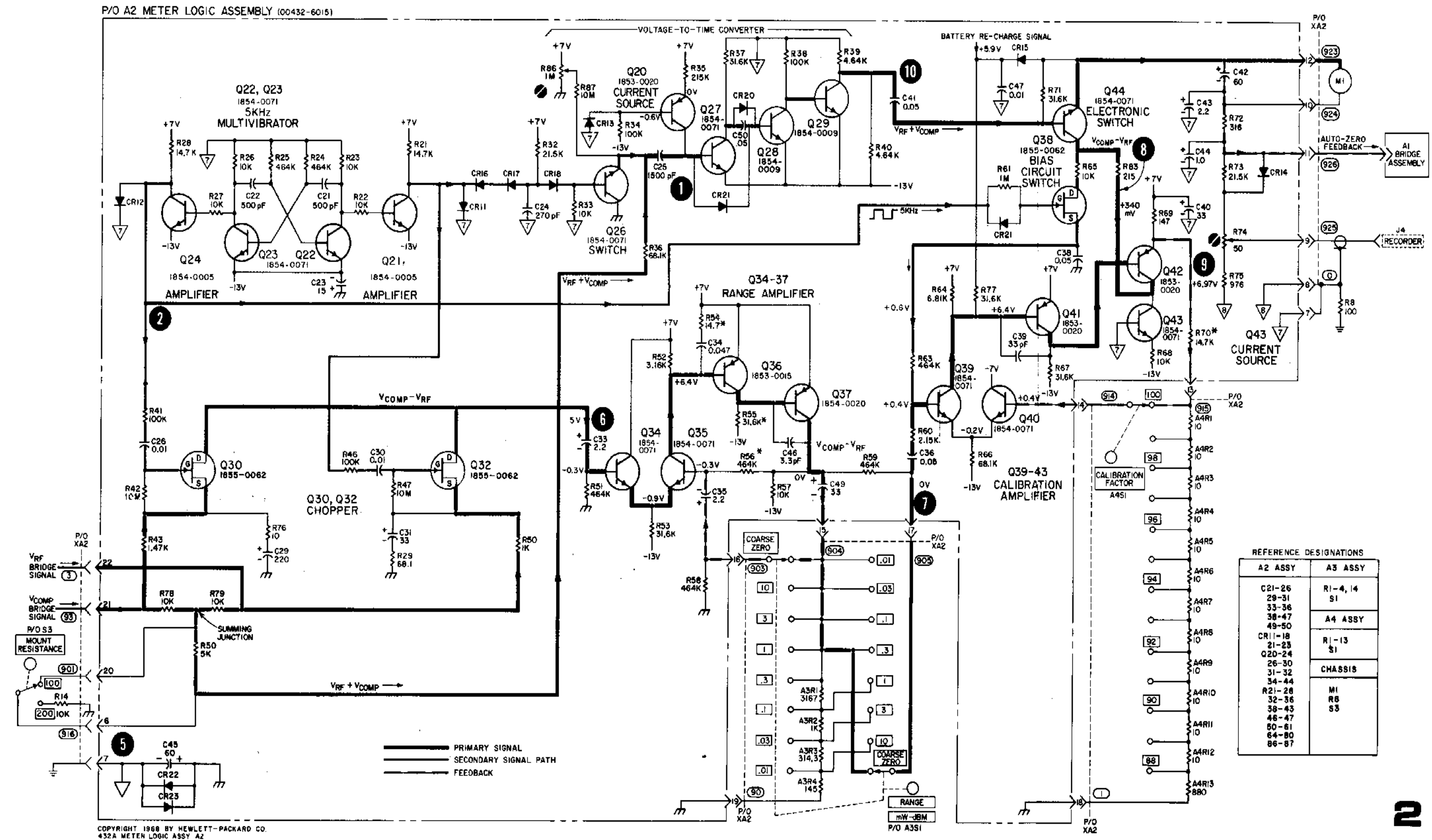


Figure 7-12. Meter Logic Schematic

