TM 11-6625-1549-15

DEPARTMENT OF THE ARMY TECHNICAL MANUAL

OPERATOR'S, ORGANIZATIONAL, DIRECT SUPPORT, GENERAL SUPPORT, AND DEPOT MAINTENANCE MANUAL

TEST SET, RADIO FREQUENCY POWER AN/USM-260 (NSN 6625-00-917-3099)

This copy is a reprint which includes current pages from Change 1. The title was changed to read as shown above.

HEADQUARTERS, DEPARTMENT OF THE ARMY

APRIL 1967

WARNING

DANGEROUS VOLTAGES

EXIST IN THIS EQUIPMENT

Be careful when working on the power supplies and their circuits, or on the 115-volt ac line connections.

DON'T TAKE CHANCES!

TECHNICAL MANUAL
No. 11-6625-1549-15

HEADQUARTERS
DEPARTMENT OF THE ARMY
WASHINGTON, DC, *25 April 1967*

OPERATOR'S, ORGANIZATIONAL, DIRECT SUPPORT, GENERAL SUPPORT, AND DEPOT MAINTENANCE MANUAL

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This technical manual is an authentication of the manufacturer's commercial liternture and does not conform with the fomnat and content specified in AR 310-3, Military Publication. This technical manual does, however, contain available information that is essential to the operation and maintenance of the equipment.

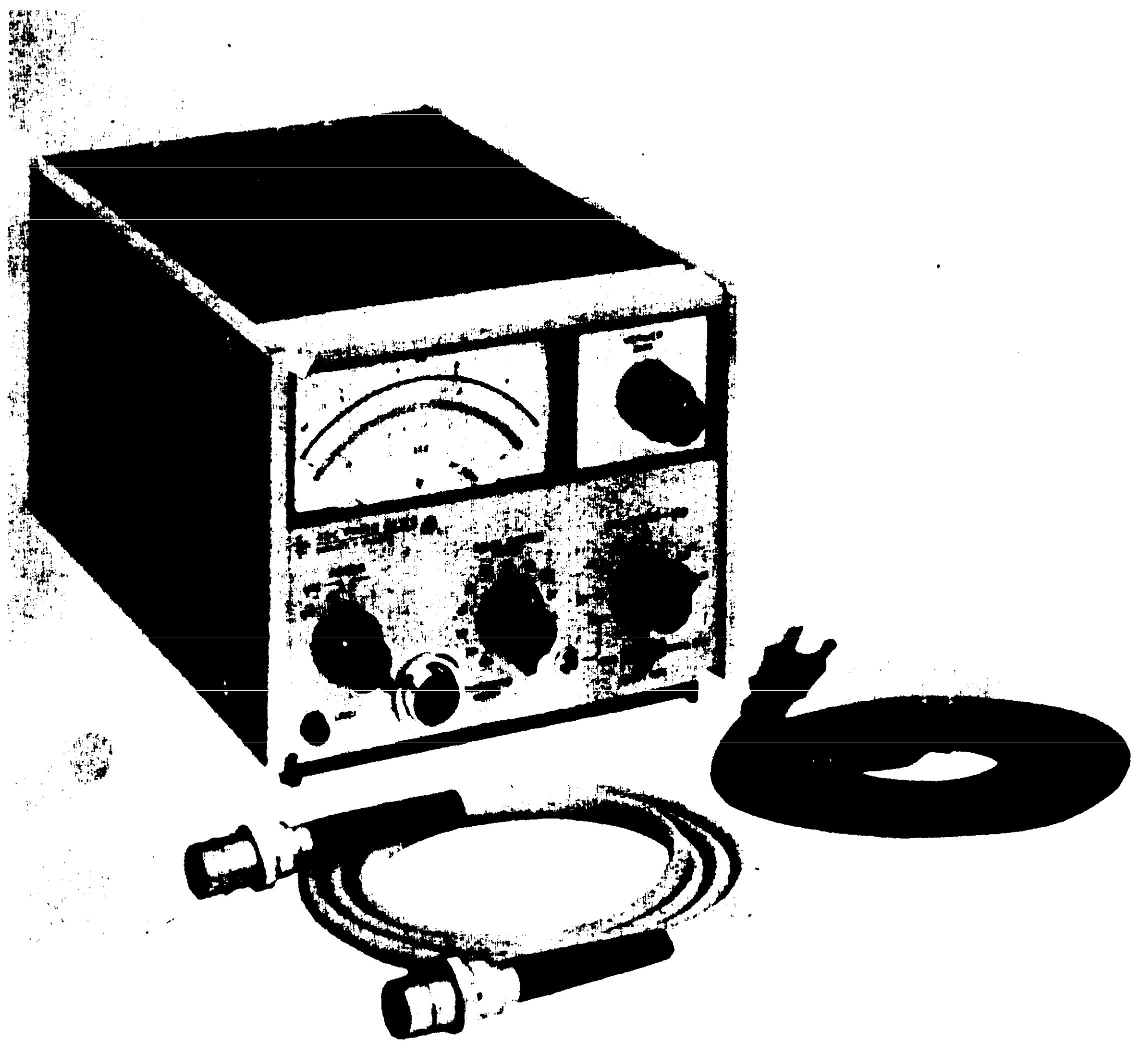


Figure 1-1. Model 43lC Power Meter

SECTION I
GENERAL INFORMATION

1-A.1. Scope

This manual includes installation and operation instructions and covers operator's, organizational, direct support (DS), general support (GS), and depot maintenance. It describes Test Set, Radio Frequency Power AN/USM-260, also referred to in this manual as Power Meter 431C, members prefixed 548. A basic issue items list for this equipment is not included as part of this manual.

1-A.2. Indexes of Publications

a. DA Pam 310-4. Refer to the latest issue of DA Pam 310-4 to determine whether there are new editions, changes, or additional publications pertaining to this equipment.

b. DA Pam 310-7. Refer to DA Pam 310-7 to determine whether there are modification work orders (MWO's) pertaining to this equipment.

1-A.3. Forms and Records

a. Reports of Maintenance and Unsatisfactory Equipment. Maintenance forms, records, and reports which are to be used by maintenance personnel at all maintenance levels are listed in and prescribed by TM 38-750.

b. Report of Packaging and Handling Deficiencies. Fill out and forward DD Form 6 (Packaging Improvement Report) as prescribed in AR 700-58/NAVSUPINST 4030.29/AFR 71-13/ MCO P4030.29A, and DSAR 4145.8.

c. Discrepancy in Shipment Report (DISREP) (SF 361). Fill out and forward Discrepancy in Shipment Report (DISREP) (SF 361) as prescribed in AR 55-3WNAVSUPINST 4610-33A/ AFR 75-18/MCO P4610.19B and DSAR 4500.15.

1-A.4. Reporting Equipment Improvement Recommendations (EIR)

EIR's will be prepared using DA Form 2407, Maintenance Request. Instructions for preparing EIR's are provided in TM 38-750, The Army Maintenance Management System. EIR's should be mailed direct to Commander, US Army Electronics Command, ATTN: DRSEL-MA-Q, Fort Monmouth, NJ 07703. A reply will be furnished direct to you.

1-A.5. Administrative Storage

Administrative storage of equipment issued to and used by Army activities shall be in accordance with TM 740-90-1.

1-A.6. Destruction of Army Electronics Materiel

Destruction of Army electronics materiel to prevent enemy use shall be in accordance with TM 750-2442

1-1. DESCRIPTION

1-2. The Hewlett-Packard Model 431C Power Meter, with hp temperature-compensated thermistor mounts, measures RF power from 10 microwatt (-20 dBm) to 10 milliwatts (+ 10 dBm) full scale in the 10-MHZ to 40-GHz frequency range. Direct reading accuracy of the instrument is ±1% of full scale. By selector switch, the instrument normalizes the power meter reading to compensate for the Calibration Factor of a thermistor mount used for a given measurement. A rechargeable nickel-cadmium battery is included with Option 01 instruments for portable operation. Complete specifications are presented in Table 1-1.

1-3. The Model 431C makes provision for using the DC substitution method of measuring RF power and to assure accuracy of the power meter calibration. Outputs are provided for a digital voltmeter readout, permanent recording of measurements, operation of alarm or control systems, or to allow the Power Meter to be used in a closed-loop leveling system.

1-4. INSTRUMENT IDENTIFICATION. The Model 43 lC carries an eight-digit serial number (000-00000) When the SERIALS PREFIXED number on the title page of the manual is the same as the first three digits of the instrument serial number, the manual applies directly to the instrument. For other serial numbers, see the change sheet enclosed with the manual.

1-5. ACCESSORIES. Two accessories are supplied with the Model 431C Power Meter: a 7.5-foot (2290 mm) detachable power cable and a 5-foot (1520 mm) cable that connects a thermistor mount to the instrument. Thermistor mounts are available (refer to Table 1-2) but not supplied with the power meter. A rechargeable battery with installation kit is also available. Supplied and available accessories are listed in Table 1-1.

Table 1-1. Specifications

Power Range: 7 ranges with full-scale readings of 10, 30, 100, and 300 μW, 1, 3, and 10 mW; also calibrated in dBm from -20 dBm to +10 dBm full scale in 5 dB steps.

Accuracy: ±1% of full scale from +20°C to +35°C, ±2.5% of full scale from 0°C to +55°C.

Calibration Factor Control: 13 position switch normalizes meter reading to account for thermistor mount Calibration Factor (or Effective Efficiency). Range: 100% to 88% in 1% steps.

Thermistor Mount: External temperature-compensated thermistor mounts required for operation (hp 478A and 486A series listed in Table 1-2).

Meter Movement: Taut-band suspension, individually calibrated mirror-backed scales. Milliwatt scale greater than 4.25 in.(108 mm) long.

Zero Carryover: Less than 0.5% of full scale when zeroed on most sensitive range.

Zero Balance: Continuous control about zero point. Range below zero is equivalent to at least 3% of full scale.

Voltmeter Output: With load impedance of 500 k ohms or more, voltmeter output is 1.000Vdc ±0.3% at full scale meter deflection. BNC female connector.

Recorder/Leveler Output: With load impedance of 600 ohms or more, output is approximately 1 volt dc at full scale meter deflection. BNC female connector.

DC Calibration Input: Binding posts for calibration of bridge with hp 8402B Calibrator or precise dc standards.

RFI: Meets all conditions specified in MIL-I-6181D.

Power: 115 or 230 volts ±10%, 50 to 400 Hz, 2.5 watts. Optional rechargeable battery provides up to 24 hours continuous operation.

Dimensions: 7-25/32 in. wide, 6-3/32 in. high, 11 in. deep from front of side rail (190 x 155 x 279 mm).

Weight: Net, 7 lb (3,2 kg), 9 lb (4,1 kg) with battery.

Furnished: 5-ft (1520 mm) cable for hp temperature compensated thermistor mounts; 7.5 ft (2290 mm) power cable, NEMA plug.

Available: 00415-606 Rechargeable Battery Pack for field installation.

5060-0797 Rack Adapter Frame, (holds two instruments the side of the 431C, e.g., 431C and 415E SWR Meter).

H01-8401A Leveler Amplifier.

8402B Power Meter Calibrator.

Combining Cases:
1051A, 11-1/4 in. (286 mm) deep.
1052A, 16-3/8 in. (416 mm) deep.

These Combining Cases accept the small hp module instrument for bench use or rack mounting.

Table 1-1. Specifications (Cont'd)

Options:

01. Rechargeable battery installed, provides up to 24 hours continuous operation.

02. Rear thermistor mount input connector wired in parallel with front panel input connector.

09. With 10-foot (3050 mm) cable for 100Ω or 200Ω mount.

10. With 20-foot (6100 mm) cable for 100Ω or 200Ω mount.

11. With 50-foot (15240 mm) cable for 100Ω mount.

12. With 100-foot (30480 mm) cable for 100Ω mount.

13. With 200-foot (60960 mm) cable for 100Ω mount.

21. With 50-foot (15240 mm) cable for 200Ω mount.

22. With 100-foot (30480 mm) cable for 200Ω mount.

23. With 200-foot (60960 mm) cable for 200Ω mount.

Table 1-2. Model 431C Thermistor Mounts

hp Type		Frequency Range	Operating Resistance in Ohms
Coaxial	Waveguide		
478A		10 MHz to 10 GHz	200
	S486A	2.6 to 3.95 GHz	100
	G486A	3.95 to 5.85 GHz	100
	J486A	5.3 to 8.2 GHz	100
	H486A	7.05 to 10.0 GHz	100
	X486A	8.2 to 12.4 GHz	100
	M486A	10.0 to 15.0 GHz	100
	P486A	12.4 to 18.0 GHz	100
	K486A	18.0 to 26.5 GHz	200
	R486A	26.5 to 40.0 GHz	200

SECTION II
INSTALLATION

2-1. INITIAL INSPECTION.

2-2. Before shipment this instrument was inspected and found free of mechanical or electrical defect. As soon as the instrument is unpacked, inspect for any damage that may have occurred in transit. Check for the supplied accessories. Electrical performance may be tested using the "performance test procedure outlined in Paragraph 5-5. If there is any damage or deficiency, refer to paragraph 1-A.3.

2-3. RACK MOUNTING.

2-4. The Model 431C is narrower than full-rack width. This 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 combining case and the adapter frame are specifically for this purpose.

2-5. COMBINING CASE. The Model 1051 A Combining Case is shown in Figures 2-1 and 2-2. This case is a full-rack width unit which accepts varying combinations of sub-modular instruments. The case itself is a full-module unit. It can be bench or rack mounted; a rack-mounting kit is supplied with the case.

2-6. ADAPTER FRAME. The 5060-0797 Adapter Frame is shown in Figure 2-3. The frame accepts a variety of sub-modular units in a manner suitable for rack mounting. Sub - modular units, in combination with any necessary spacers are assembled within the frame. The sub-modular units and the adapter frame, together forming a complete assembly, can then be

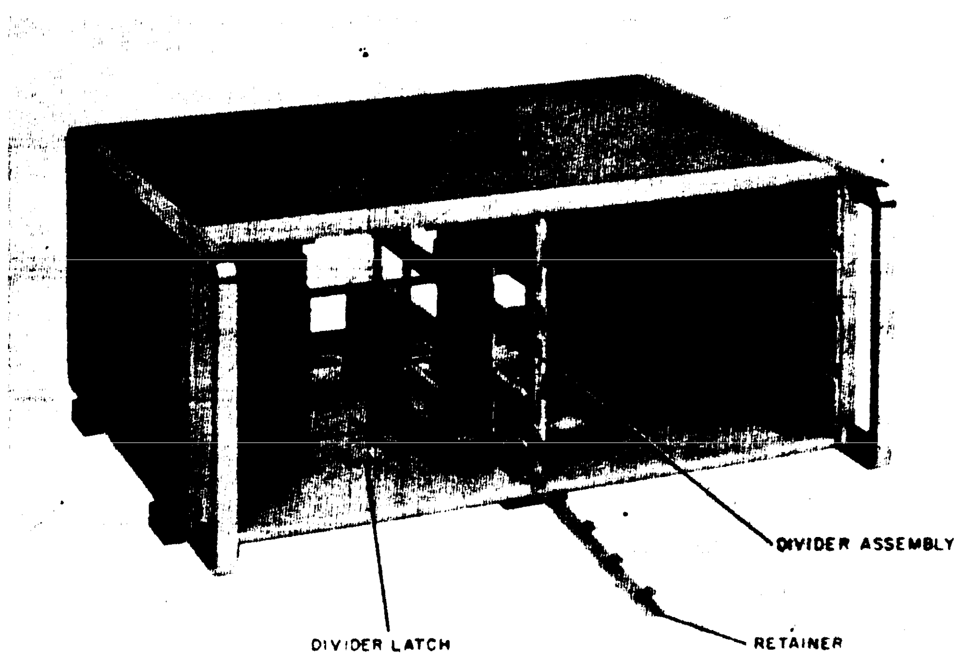


Figure 2-1. The Combining Case

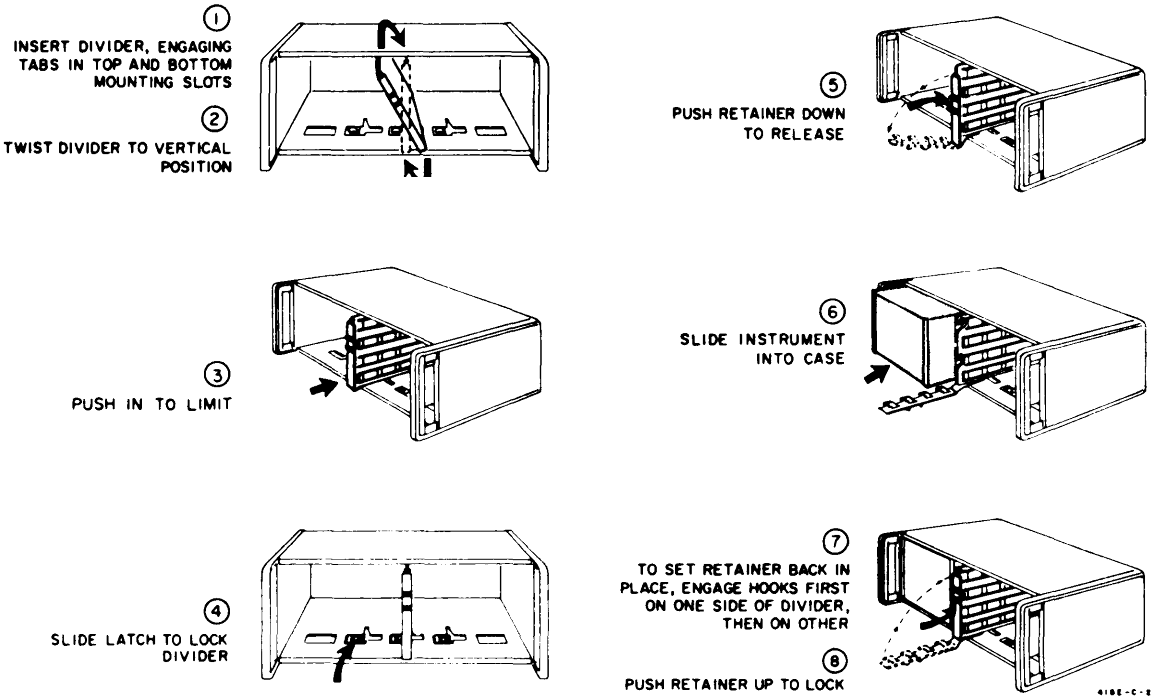


Figure 2-2. Steps to Place Instrument in Combining Case

mounted in a standard rack. The sub-modular units cannot be removed individually when the adapter frame is used. Instructions for assembly of the adapter frame and sub-modular units are given below. Refer to Figure 2-4.

a. Place the adapter frame on the edge of a bench, step 1.

b. Stack the sub-modular units in the frame, step 2.

c. Place the spacer clamps between the instruments, step 3.

d. Place the spacer clamps on the two end instruments. Push the combination into the frame, step 4.

e. Insert screws on either side of the frame, step 5. Tighten until the sub-modular units are tight in the frame.

2-7. PRIMARY POWER REQUIREMENTS.

2-8. The Model 431C can be operated from an AC or DC primary power source. The AC source can be either 115- or 230-volt, 50 to 400 Hz. The DC source is a 24-volt rechargeable battery. The rechargeable battery is supplied with Option 01 instruments.

CAUTION

For AC operation, set the rear-panel 115-230 volt switch to the proper position before connecting the p o w e r cord to the service outlet.

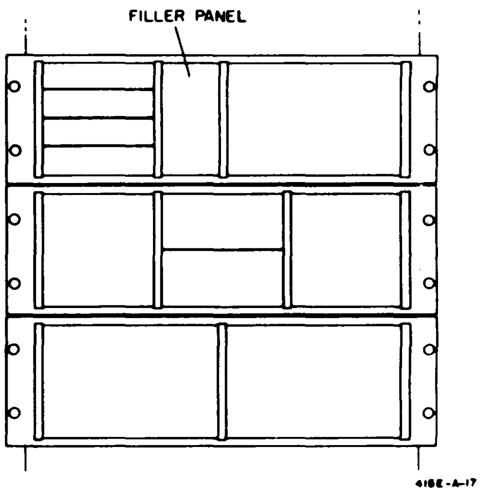


Figure 2-3. Adapter Frame Instrument Combinations

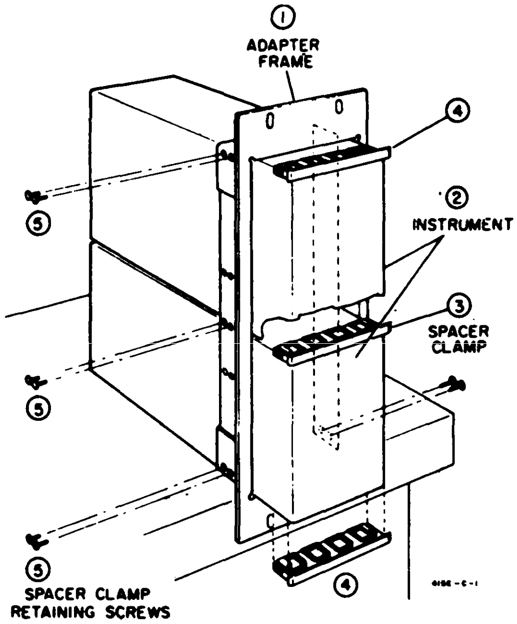
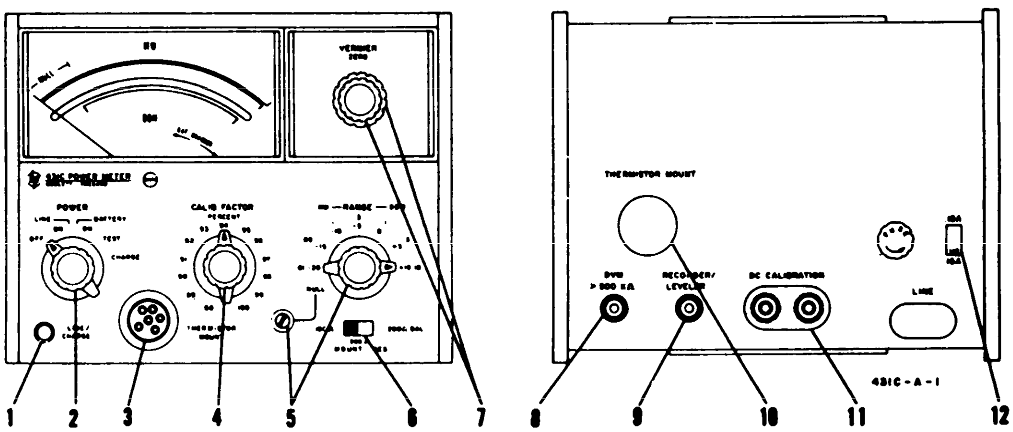


Figure 2-4. Two Half Modules in Rack Adapter

2-9. THREE-CONNECTOR POWER CABLE.

2-10. To protect operating personnel, the National Electrical Manufacturers' Association (NEMA) recommends that the instrument panel and cabinet be grounded. This instrument is 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. To preserve the protection feature when operating the instrument from a two-contact outlet, use a three-prong to two-prong adapter and connect the green pigtail on the adapter to ground.



1. **LINE/CHARGE.** Lamp lights when the POWER switch is in the LINE ON or BATTERY CHARGE position.

2. **POWER.** Determines connections to primary power sources and the battery charging circuit.

   LINE OFF: Instrument off.

   LINE ON: Instrument on. Trickle charge applied to battery.

   BATTERY ON: Instrument on, battery powered.

   BATTERY TEST: Meter indicates battery charge.

   BATTERY CHARGE: Instrument off. Trickle change applied to battery.

3. **THERMISTOR MOUNT.** Accepts the thermistor mount cable.

4. **CALIB FACTOR.** Switch compensates for the Calibration Factor of the thermistor mount. Calibration Factor values from 88% to 100% may be set in 1% steps.

5. **RANGE.** Sets power range; also includes a NULL position which, in conjunction with the adjacent null screwdriver adjustment, ensures that the metering bridge is reactively balanced.

6. **MOUNT RES.** A three position slide switch which sets the power meter to accommodate thermistor mounts of 100 ohm, 200 ohm and 200 ohm balanced operating resistances.

7. **ZERO and VERNIER.** Sets the meter pointer over the zero mark. The VERNIER control is a fine adjustment of the ZERO control setting.

8. **DVM >500 KΩ.** A BNC type jack providing an output voltage linearly proportional to the meter indication. A DC voltmeter with an input impedance greater than 500 k ohms is required to minimize introduction of measurement error (refer to Paragraph 3-49).

9. **RECORDER/LEVELER.** A BNC type jack providing a DC voltage of low source impedance for a recorder or leveler amplifier.

10. In Option 02 instruments a thermistor mount connector is wired in parallel with the front panel connector. Two mounts cannot be connected simultaneously.

11. **DC CALIBRATION.** This connector permits a DC input for power meter calibration and DC substitution method of power measurement.

12. **LINE VOLTAGE.** Selects 115- or 230-volt line operation.

Figure 3-1. Front and Rear Panel Controls, Connectors, and Indicators

SECTION III
OPERATION

3-1. INTRODUCTION.

3-2. This section presents the basic information required to operate the Model 431C Power Meter.

3-3. The Model 431C is an automatic self-balancing power-measuring instrument employing dual-bridge circuits. The power meter is designed to operate with hp temperature-compensated thermistor mounts such as the Model 478A Coaxial and Model 486A Waveguide series. Power may be measured with these mounts in 50-ohm coaxial systems from 10 MHz to 10 GHz, and in waveguide systems from 2.6 GHz to 40 GHz. Full-scale power ranges are 10 microwatts to 10 milliwatts and -20 dBm to +10 dBm. Extended measurements may be made to 1 microwatt and to -30 dBm. The total measurement capacity of the instrument is divided into seven ranges, selectable by a front panel RANGE switch.

3-4. ZERO and VERNIER zero-set controls zero the meter. Zero carry-over from the most sensitive range to the other six less sensitive ranges is accurate to ±0.5%. Greater accuracy can be obtained by setting the zero point on the particular range to be used. When the RANGE switch is in the NULL position, the meter indicates inherent metering bridge unbalance, and a front panel NULL screwdriver adjustment is provided for initial calibration.

3-5. The CALIB FACTOR switch allows the introduction of discrete amounts of compensation for measurement uncertainties related to SWR, and measurement errors caused by substitution error and thermistor mount efficiency. The appropriate selection of a Calibration Factor value permits direct meter reading of the RF power delivered to an impedance equal to the characteristic impedance (Z_O) of the transmission line connecting the thermistor mount to the RF source. Calibration Factor values are determined from the data marked on the label of each hp Model 478A or 486A thermistor mount.

3-6. The Model 431C has a DC CALIBRATION jack on the rear panel that can be used for DC substitution method of power measurement. DC substitution is an extension of the power measurement technique normally used. Through the use of DC substitution, instrument error can be reduced from a nominal value of ±1% to ±0.16% of reading, or less, depending on the care taken in procedure and accuracy of auxiliary equipment.

CAUTION

To avoid serere damage to the thermistor mount, be careful not to move the MOUNT RES switch while operating the RANGE switch.

3-7. The MOUNT RES switch on the front panel permits the use of three types of thermistor mounts with the 431C. Model 486A waveguide mounts can be used by setting the MOUNT RES switch to the 100 Ω or 200 Ω position, depending on the microwave band used (refer to Table 1-2). The 200 Ω position is used with Model 478A thermistor mounts and the 200 Ω BAL position is used with a balanced thermistor mount.

3-8. Two output BNC type jacks are provided on the rear panel of the instrument, labeled DVM and RECORDER/LEVELER. The DVM jack provides a voltage linearly proportional to the meter current; 1 volt equal to full scale meter deflection. A DVM connected to the 431C must have an input impedance greater than 500 k ohms on the range used. The RECORDER/LEVELER jack furnishes a DC voltage of low source impedance necessary for isolation between a recorder or leveler amplifier and the metering circuit of the power meter. The output voltage is proportional to the power measured and is offset ±40 mV or less from its nominal value, depending on the load impedance. This output voltage allows the Model 431C to be used in a number of additional applications (refer to Paragraph 3-53).

3-9. CONTROLS, CONNECTORS, AND INDICATORS.

3-10. The front and rear panel controls, connectors, and indicators are explained in Figure 3-1. The descriptions are keyed to the corresponding items which are indicated on the figure. Further information regarding the various settings and uses of the controls, connectors, and indicators is included in the applicable procedures of this section.

3-11. BATTERY OPERATION.

3-12. The Model 431C can be operated from a battery instead of a conventional 115- or 230-volt primary power source. 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 rechargeable battery installation kit may be ordered by hp stock number 00415-606.

3-13. OPTIMUM BATTERY USAGE. It is recommended that the Model 431C be operated by the battery for up to 8 hours, followed by 16 hours of recharge. If continuous battery operation is required for more than. 8 hours, the recharge time should be double the operating time. Continuous battery operation is possible for up to 24 hours but this must be followed by a prolonged recharge period.

3-14. INITIAL BATTERY USE. When the Model 431C is to be battery operated for the first time, perform the following steps:

a. Set the POWER switch to the BATTERY TEST position and note meter pointer indication. A meter pointer indication within the "BAT CHARGED" area indicates the internal battery is properly charged and ready. for use. A meter pointer indication to the left of the "BAT CHARGED" area means that the battery must be charged as described below. Actual battery voltage can be measured on the 0-3 mW scale. Battery voltage is equal to 10 times meter scale reading.

b. Connect the Model 431C to AC power source. Set POWER switch to BATTERY CHARGE and charge the battery until a meter pointer indication within the "BAT CHARGED" region can be obtained as in step a.

3-15. BATTERY STORAGE. Storage of the battery at or below room temperature is best. Extended storage at high temperatures, less than 60°C (140°F), will reduce the cell charge but will not damage the battery. Charge the battery after removal from storage and before using the Model 431C for battery operation.

3-16. OPERATING INSTRUCTIONS.

3-17. Figure 3-8, Turn-On and Nulling Procedure, and Figure 3-9, DC Substitution, present step-by-step instructions for operating the Model 431C. Steps are numbered to correspond with the appropriate control, connector, or indicator on the power meter and/or required auxiliary equipment.

3-18. MAJOR SOURCES OF ERROR IN MICROWAVE POWER MEASUREMENT.

3-19. A number of factors affect the overall accuracy of power measurement. Major sources of error are presented in the following paragraphs to show the cause and effect of each error. Particular corrections or special measurement techniques can be determined and applied to improve overall measurement accuracy. The following are the major sources of error to consider: 1) Mismatch error, 2) RF losses, 3) DC-to-microwave substitution error, 4) Thermoelectric effect error, and 5) Instrumentation error.

3-20. MISMATCH ERROR. The following discussion uses the terms conjugate power, Z_o available power, conjugate match and mismatch, and Z_o match and mismatch. These basic terms are defined as follows:

Conjugate power is the maximum available power. It is dependent on a conjugate match condition in which the impedance seen looking toward the thermistor mount is the complex conjugate of the impedance seen looking toward the RF source. A special case of this maximum power transfer is when both the RF source and the thermistor mount have the same impedance as the transmission line.

Z_o Available power is the power a source will deliver to a Z_o It is dependent on a Z match condition in which the impedance seen looking into a transmission line is equal to the characteristic impedance of the line.

3-21. In a practical measurement situation, both the source and thermistor mount have SWR, and the source is seldom matched to the thermistor mount without the use of a tuner. 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_o.

3-22. In general, neither the source nor the thermistor mount has Z_o impedance, and the actual impedances are known only as reflection coefficients, mismatch losses or SWR. These forms of information lack phase information data. As a result, 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

3-23. An example may explain how imperfect match affects the uncertainty of power measurement. A typical Z_o available power measurement situation can involve a source with an SWR of 1.7 ($\rho_s = 0.26$) and a thermistor mount with an SWR of 1.3 ($\rho_m = 0.13$). Figure 3-2 shows a plot of power levels and mismatch power uncertainties that result from source and thermistor mount mismatch. The source Z_o mismatch results in a power loss of -0.29 dB from the maximum power that would be delivered by the source to a conjugate match. The power level that results from this loss is the Z_o available power. The thermistor mount Z_o mismatch causes an additional power loss of -0.07 dB. However, on the thermistor mount Z_o mismatch loss is an uncertainty resulting from the unknown phase relationships between the impedances of the source and thermistor mount. This uncertainty is +0.30 dB to -0.28 dB.

3-24. The result of the total mismatch loss uncertainty on the Z_o available power level is determined by algebraically adding the thermistor mount loss to the uncertainty caused by source and thermistor mount Z_o mismatch SWR. Thus, the Z_o available power uncertainty is (-0.07 dB) + (+0.30 dB), and (-0.07 dB) + (-0.28 dB), equal to a range of +0.23 dB to -0.35 dB or +5.5% to -8.2%. The power delivered by the source to a Z_o load, with source and thermistor mount mismatch as in this example, would be somewhere between 0.23 dB (5.5%) below the maximum power and 0.35 dB (8.2%) above the minimum power actually entering the thermistor mount.

3-25. Power measurement uncertainty caused by mismatch loss is one source of error to consider when measuring Z_o available power without a tuner. A continuation of this example is given in Paragraphs 3-38 through 3-39 to discuss the basic principle of Calibration Factor correction to a measurement of Z_o available power.

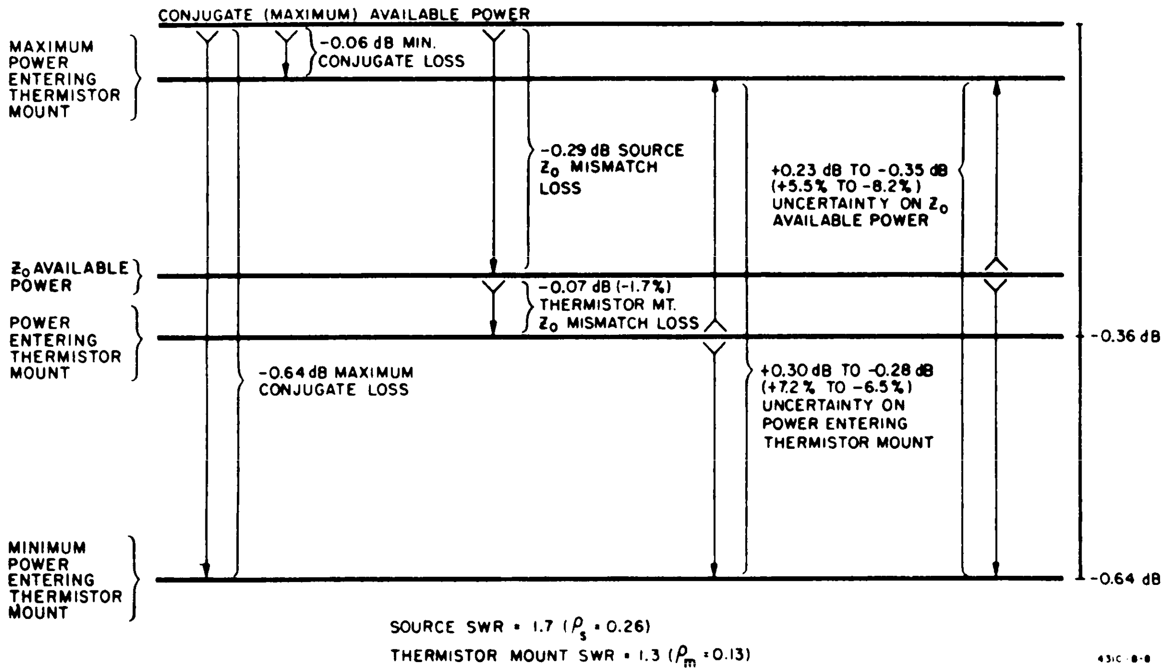


Figure 3-2. Mismatch Power Measurement Uncertainty

3-26. RF LOSSES AND DC-TO-MICROWAVE SUBSTITUTION ERROR. 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. DC-to-microwave substitution error is caused by the difference in heating effects of the substituted audio bias or DC power and the RF power in a thermistor. The difference results from the fact that the spatial distributions of voltage, current, and resistance within the thermistor element are not the same for audio, DC and RF power. RF losses and DC-to-microwave substitution error are generally combined for the simplicity of analysis.

3-27. THERMOELECTRIC EFFECT ERROR. 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

3-28. 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. On other ranges, the effect is negligible. For hp mounts maximum error introduced by thermoelectric effect is about 0.3 µW and is typically 0.1 µW on the .01 mW range.

3-29. THERMOELECTRIC EFFECT ERROR CORRECTION. Use the following technique to correct for thermoelectric effect error.

a. Measure power.

b. Connect an hp Model 8402 Power Meter Calibrator to the power meter DC CALIBRATION jack.

Note

If a balanced thermistor mount is being used, an 8402B Calibrator is required.

c. Zero and null power meter.

d. By DC Substitution (see Figure 3-9), 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 power 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.

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

3-30. INSTRUMENTATION ERROR. The degree of inability of the instrument to measure the true substitution audio bias or DC power supplied to the thermistor mount is called power meter accuracy or instrumentation error. Instrumentation error of the Model 431C is ±1% of full scale, +20°C to +35°C. Instrumentation error can be reduced to ±0.16% of reading, or less, by using DC substitution as described in Figure 3-9.

3-31. CALIBRATION FACTOR AND EFFECTIVE EFFICIENCY.

3-32. Calibration Factor and Effective Efficiency are two power ratios used as correction factors to improve overall accuracy of microwave power measurement. The ratios are used under different measurement conditions. .Calibration Factor is used when the thermistor mount is coupled to the RF source without a tuner. Calibration Factor corrects for both SWR and inefficiency of the thermistor mount. Effective Efficiency is used when a tuner matches the source to the thermistor mount. Effective Efficiency corrects only for the inefficiency of the thermistor mount.

3-33. Each thermistor mount has a particular impedance. This impedance, and hence the mount SWR, remain constant over the major portion of the mciro-wave band for which the mount is designed to operate. For hp thermistor mounts this constant SWR is low; thus the mismatch uncertainty is small. Since the mount impedance and corresponding SWR deviate significantly only at the high and low ends of a microwave band, it is generally unnecessary to use a tuner. However, a tuner or other effective means of reducing mismatch error is recommended when the source SWR is high or when high accuracy is required. To minimize mismatch between the source and the thermistor mount without the use of a tuner, a low SWR precision attenuator can be inserted in the transmission line to isolate the thermistor mount from the source. Since a tuner is not often used, Calibration Factor is a more practical term than Effective Efflciency.

3-34. CALIBRATION FACTOR. Calibration Factor is the ratio of substituted audio or DC power in the thermistor mount to the microwave RF power incident upon the mount.

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

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 thermistor element, and 3) DC-to-micro-wave substitution error.

3-35. The CALIB FACTOR switch on the front pane allows rapid power measurements to be made with improved accuracy. The switch is set to the Calibration Factor value, appropriate to the frequency of measurement, imprinted on the thermistor mount label. With the proper setting, the 431C compensates for the Calibration Factor of the thermistor mount.

3-36. Calibration Factor is applied as a correction factor to all measurements made without a t u n e r. Under this condition, the power indicated is the power that would be delivered by the source to a load impedance equal to Z_O. This measured power is called Z_O available power.

3-37. Calibration Factor correction ensures that a power measurement uncertainty range is centered on the Z_O available power level instead of on the power delivered to the thermistor mount impedance. Total measurement uncertainty limits f o r a given power measurement using Calibration Factor are the sum of the uncertainties contributed by: 1) Mismatch loss, 2) Calibration Factor uncertainty, and 3) Instrumentation error.

3-38. An example of power measurement uncertainty caused by source and thermistor mount mismatch is given in Paragraphs 3-23 through 3-25. Continuing the example will show the basic principle of Calibration Factor correction to a measurement of Z_O available power. Figure 3-3 shows the relationship and limits of e r r o r before correction. A source SWR of 1.7 and a thermistor mount SWR of 1.3 result in a Z_O available power uncertainty of +5.5% to -8.2%. Assuming a thermistor mount Calibration Factor of 94% (accuracy of ±2%), the Calibration Factor uncertainty is (-6%) + (±2%), or -4% to -8%. The 4S1C Power Meter has an instrumentation error of ±1% (may be reduced by DC substitution, Figure 3-9). The algebraic addition of Calibration Factor, instrumentation and Z_O available power uncertainties determines t h e limits of error before Calibration Factor correction. In this case, the limits are +2.5% to -17.2%.

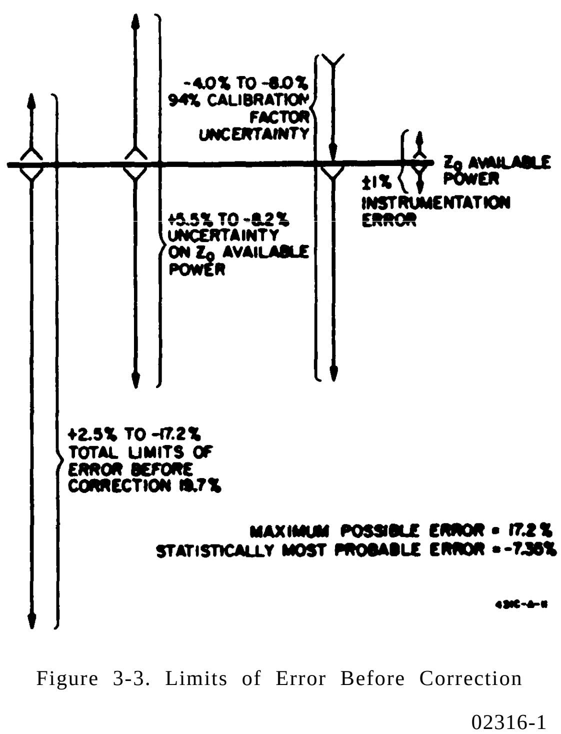


Figure 3-3. Limits of Error Before Correction

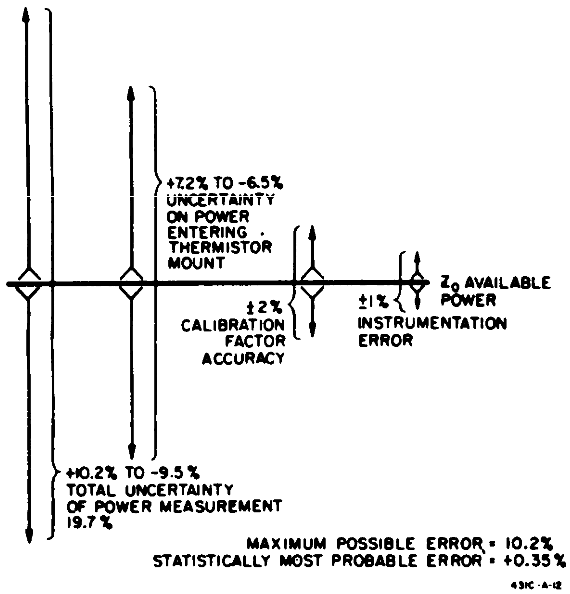


Figure 3-4. Total Uncertainty After Correction

Before correction, the maximum possible error is 17.2% and the statistically most probable error is -7.35%.

3-39. Figure 3-4 shows the total power measurement uncertainty after Calibration Factor correction. Note that the range of uncertainty, 19.7%, is the same as it was before correction. However, the measurement uncertainty range has shifted, and is now more symmetrical about the Z_0 available power level.* The total uncertainty after correction is the algebraic sum of the instrumentation error (±1%), the accuracy to which Calibration Factor is determined (±2%), and the uncertainty on the power actually entering the thermistor mount. After correction, the power measurement uncertainty on the Z_0 available power is +10.2% to -9.5%. The maximum possible error is 10.2% (was 17.2%) and the statistically most probably error is +0.35% (was -7.35%). This is a typical example showing how the use of Calibration Factor correction to a measurement of Z_0 available power not only reduces. the maximum possible error, but more importantly, the magnitude of the statistically most probable error is reduced to very near the Z_0 available power level.

1 The relationship between indicated power on the 431C and the Z_0 available power is given by the following equation:

$$P_0 = \frac{P\ \text{indicated}\ (1 \pm \rho_s \rho_m)^2}{\text{Calibration Factor}}$$

Where: P_0 = Z_0 available power

ρ_s = source reflection coefficient

ρ_m = thermistor mount reflection coefficient

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

3-40. EFFECTIVE EFFICIENCY. Effective Efficiency is the ratio of substituted audio or DC power in the thermistor mount to the microwave RF power dissipated within the mount.

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

This power ratio corrects for RF losses and DC-to-microwave substitution error in the thermistor mount. It is largely independent of the level of input RF power. When a tuner is used to present either a conjugate or Z_0 match to the microwave RF source, Effective Efficiency is to be applied as a correction factor to the power measurement because all of the power incident upon the mount is absorbed in the mount. The use of a tuner and application of Effective Efficiency is the most accurate method of measuring power since source and thermistor mount power reflections are eliminated, and thus, measurement uncertainty due to mismatch is eliminated. Tuner loss will generally be small. However, its effects on power measurement can be corrected for by dividing the indicated power by the tuner-loss ratio, power out/power in.

3-41. Effective Efficiency can be applied as a correction factor to both conjugate available and Z_0 available power measurements. The CALIB FACTOR switch is set to the Effective Efficiency value, appropriate to the frequency under test, imprinted on the thermistor mount label. The type of application of the tuner determines if the power measured is conjugate available or Z_0 available.

3-42. Conjugate available power is measured when the system consisting of the RF source, transmission line, tuner and thermistor mount is tuned for a maximum power level on the 431C. In this application, the system-mouht combination presents a conjugate match to the source. The power measured is the actual power that would be delivered by the source to a conjugate load.

3-43. Z_0 available power is measured when a tuner-thermistor mount combination is tuned for minimum reflection caused by mount mismatch at the frequency of interest. The tuner adjustment is made on a reflectometer or slotted line system, external to the measurement system used for power measurement. After the tuner adjustment, the tuner-thermistor mount combination is connected to the transmission line and RF source on which a power measurement is made.

3-44. HIGH ACCURACY Of POWER MEASUREMENT USING DC SUBSTITUTION.

3-45. The instrumentation source of error can be reduced by using DC substitution. With precision instruments used in a DC substitution set up, and careful procedure, instrument error can be reduced from ±1% of full scale to ±0.16% of readings or less. The technique involves: 1) applying the RF power to be meAsured to the thermistor mount and noting the power meter reading, 2) removing the RF power from the thermistor mount and substituting a DC current from an external DC power source to precisely duplicate the meter reading obtained in step 1, and 3) calculating the power from the substituted DC current and thermistor operating resistance.

3-46. EQUIPMENT USED FOR DC SUBSTITUTION. Figure 3-9 shows the instrument setup for a DC substitution measurement. The hp Model 8402B Calibrator conveniently provides DC power and appropriate switching to perform DC substitution measurement with the Model 431C. If the 431C is being used with, a balanced 200 ohm thermistor mount, the 8402B must be used. If the 431C is used with an unbalanced thermistor mount such as hp Model 478A Coaxial or 486A Wavegulae types, the 8402B may be replaced with an 8402A Power Meter Calibrator.

3-47. Although the DC substitution technique is the most accurate method of measuring RF power, there are sources of error that must be considered. The accuracy of DC substitution depends largely u p on: 1) how accurately substituted DC is known, 2) how precisely the power meter reading is duplicated, and 3) the actual operating resistance of the thermistor.

3-48. SUBSTITUTION FUNCTION MEASUREMENT ACCURACY. Voltmeter terminals are located on the rear panel of the 8402B Calibrator. These terminals provide a means to monitor the magnitude of calibrator output currents by presenting a DC voltage proportional to the substituted current. For the purpose of calculating a substituted power, this voltage carries a total uncertain y of ±0.12%. This uncertainty includes a ±0.06% uncertain y of the thermistor resistance function of the calibrator (steps 8 through 11 of Figure 3-9). However, the output impedance of this voltage is finite (100 ohms on 1.0 mW through 10 mW ranges; 1 kohms on lower ranges). This output Impedance requires the use of a differential or high impedance voltmeter in order to obtain an accurate measurement of the calibrator outpt. At null, a differential voltmeter does not draw current from the calibrator voltage output circuitry. For this reason, a differential voltmeter will not introduce measurement error due to loading. When using a voltmeter other than a differential type, correction must be made for the measurement error that is introduced by the voltmeter input impedance. For example, a digital voltmeter with an input impedance of 1 megohm will introduce a measurement error of 0.1% when used to measure calibrator output on ranges below, 1.0 mW. Substitution current measurement error corrections must be doubled since the power measured is proportiornl to the square of the substituted current. Twice the voltage uncertainty is the power uncertainty Introduced by t h e voltmeter. Therefore, the correction to be applied in the above example is 0.2%. Corrections should be added to voltmeter readings since voltmeter impedance loading causes voltage measurements to decrease.

3-49. POWER M E T E R DVM OUTPUT MEASUREMENT. A digital voltmeter can be connected to the 431C DVM jack to increase resolution of a power meter reading. This feature provides a convenience to the operator and allows an easy method of repeating a precise measurement readout value. Measurement error corrections for voltmeter impedance loading must be made when using a voltmeter to measure the voltage output of the 431C Power Meter. The DC voltage at the DVM jack on the rear panel is developed across a 1 k ohm resistor. Therefore, a voltage measurement made with a digital voltmeter having an input impedance of 500 k ohms will introduce an error of 0.2%. A digital voltmeter with an input impedance of 10 megohms will introduce a much smaller error of 0.01%. Correction percentages should be added to voltmeter readings.

3-50. D E T E C T IO N THERMISTOR RESISTANCE. Steps 8 through 11 of Figure 3-9 list a procedure to determine the operating resistance of the RF detection bridge at balance and thus measure the operating resistance of the detection thermistor element (R_d) during a power measurement. The actual operaing resistance of detection thermistors may deviate as much as ±0.5% from their nominal values. For this reason, the actual operating resistance should be checked. The t r u e operating resistance must be known in order to accurately calculate substituted DC power in a DC substitution measurement.

3-51. The hp Model 8402B Calibrator provides a convenient method of determining the detection thermistor operating resistance. The thermistor mount cable is connected between the 431C Power Meter THERMISTOR MOUNT and 8402B Calibrator RESISTANCE STANDARD connectors. By the THERMISTOR RESISTANCE switch the 8402B Calibrator substitutes precision resistance vaules in place of the thermistor elements normally in the 431C bridge circuits. The switched resistances provide a method of determining a oscillation/no-oscillation state of the 431C Power Meter.

3-52. With the 431C RANGE switch at NULL, a stable reading greater than zero indicates an audio-bias oscillation state. While changing the substituted resistances, the operator can determine when oscillations

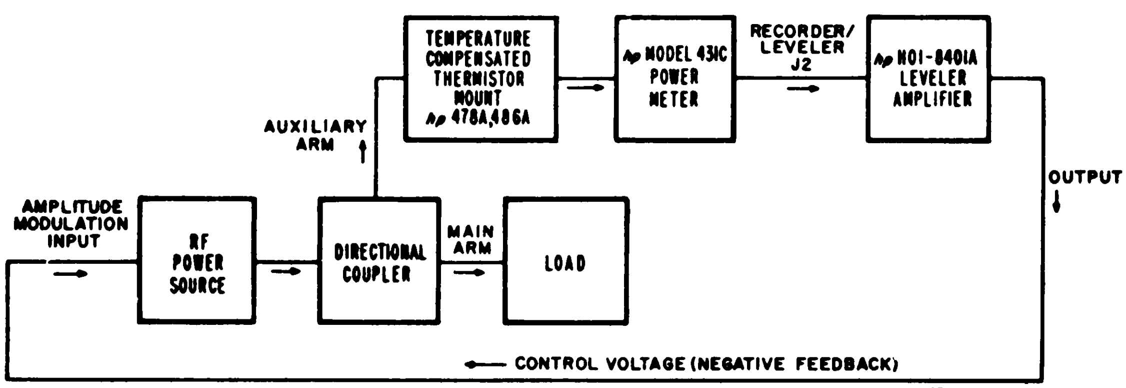


Figure 9-5. Output Power Leveling

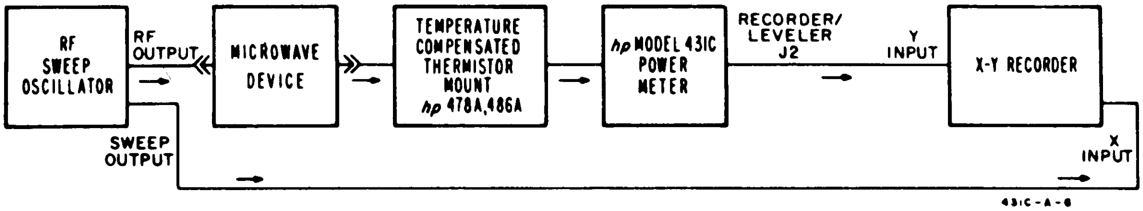


Figure 3-6. Insertion Loss or Gain Measurement

cease by noting a change of meter reading to zero. The operating resistance of the detection thermistor element is measured by reading the resistance deviation in percent directly from the switch setting that causes oscillations to cease.

3-53 ADDITIONAL APPLICATIONS.

3-54.

The RECORDER/LEVELER output allows the 431C to be used in systems of greater capability than would be possible with a meter indication alone. Important applications include: 1) permanent recording of measurement data 2) output power leveling, 3) insertion 1 o s s o r gain measurement and, 4) control system monitoring. These applications are discussed in the following paragraphs. Other applications include readout of the level of a microwave RF power source at a remote location, and using the ratio of two power meter DVM outputs to make precise measurements of small attenuations.

3-55. OUTPUT POWER LEVELING. A block diagram of an output power leveling system is shown in Figure 3-5. The power meter is used as an element in a control circuit that maintains a constant power level at a particular point in the system. The thermistor mount, connected to the auxiliary arm of a directional coupler, senses a portion of the power incident upon the directional coupler. The power meter RECORDER/ LEVELER output provides a DC voltage that is proportional to the power measured at the thermistor mount. This voltage can be directly applied to the power meter leveling input of one of the hp Model 690 Sweep Oscillators, or to the input of a leveler amplifier. At the leveler amplifier, the voltage is compared to an internal reference, the difference voltage amplified, and applied as negative feedback to the amplitude modulation input of the source. The feedback maintains a constant RF power level at the sampling point on the auxiliary arm of the directional coupler. This control will hold the forward power at the main arm of the coupler at a constant level.

3-56. INSERTION LOSS OR GAIN. Figure 3-6 shows a block diagram of a system to determine insertion loss or gain as a function of frequency. Initially, the device to be tested is not connected into the system and the thermistor mount is connected directly to the sweep oscillator output. Variations in power amplitude are measured by the power meter as the frequency range of interest is swept by the sweep oscillator. This is a reference measurement and is recorded by the X-Y recorder. The device to be tested is then inserted between the sweep oscillator and the thermistor mount. Power amplitude versus frequency is again measured and recorded. The difference between the s e c o n d reading and the reference, at any frequency, is the insertion loss or gain of the device at that frequency.

3-57. CONTROL SYSTEM MONITORING. The arrangement of a system to actuate alarm or control circults is shown in Figure 3-7. A relay circuit can be connected directly to the RECORDER/LEVELER output. This type of curcuit will provide a control system operated by full-scale magnitude power changes of the power meter. Small magnitude power change control can be achieved through the use of a comparison reference level and a differential amplifier. The differential amplifier output can be connected to the relay circuit to actuate the alarm or control circuits.

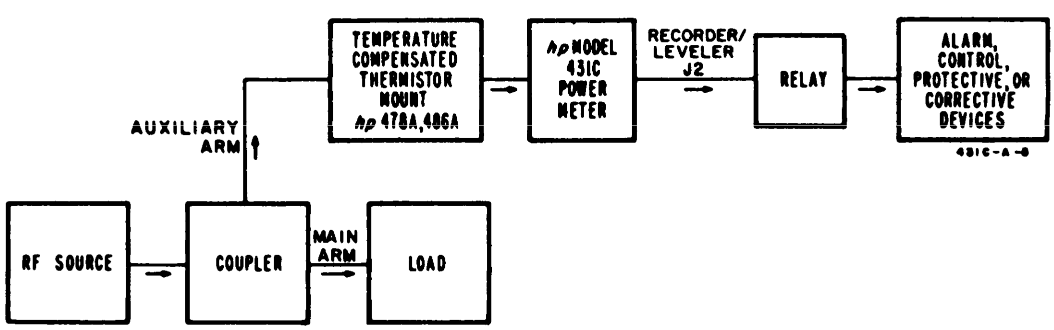
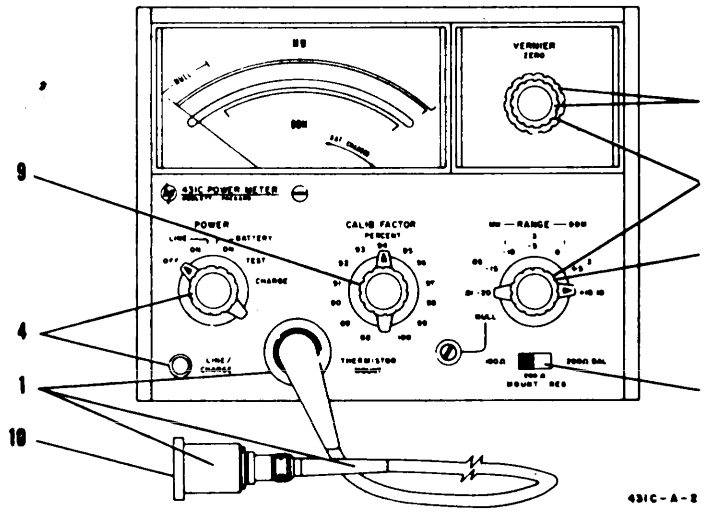


Figure 3-7. Control System Monitoring



1. Connect thermistor mount and cable to THERMISTOR MOUNT connector. Refer to Table 1-2 for recommended thermistor mounts and their frequency ranges.

Note

When using an hp Model 478A or other 200 ohm unbanalced coaxial thermistor mount, the power meter should be zeroed and nulled with the RF power source turned off and connected to the thermistor mount. If the RF power source cannot be turned off, the power meter must be zeroed and nulled while the RF input connection of the thermistor mount is terminated in the same 10 kHz impedance as that presented by the power source (short, open, or 50 ohm). These precautions are not necessary when waveguide mounts such as the hp Model 486A series or balanced 200 ohm coaxial mounts are used.

2. Set MOUNT RES switch to correspond to the operating resistance and type of thermistor mount used.

3. Set RANGE to .01 mW.

4. Set POWER to LINE ON. If instrument is to be battery operated, rotate POWER to BATTERY ON.

5. Adjust ZERO control for 25% to 75% of full scale on meter.

6. Rotate RANGE switch to NULL and adjust NULL screwdriver adjustment (adjacent to NULL on RANGE switch) for minimum reading.

7. Repeat steps 5 and 6 until NULL reading is within NULL region on the meter.

8. Set RANGE switch to the power range to be used and zero-set the meter with ZERO and VERNIER controls.

Note

Range-to-range zero carryover is less than 0.5% if the zero is set on the most sensitive range. For maximum accuracy, zero set the meter on the range to be used.

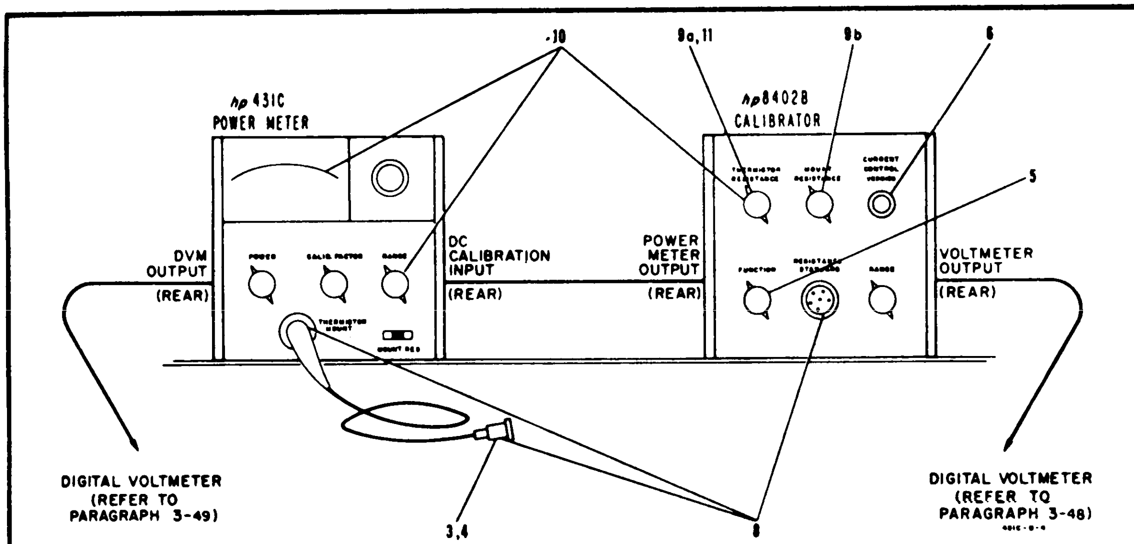
9. Set CALIB FACTOR switch to correspond with Calibration Factor imprinted on hp thermistor mount label.

10. Apply RF power at the thermistor mount. Power is indicated on the meter directly in mW or dBm.

CAUTION

To avoid severe damage to the thermistor mount, be careful not to move the MOUNT RES switch while operating the RANGE switch.

Figure 3-8. Turn On and Nulling Procedure



1. Connect the equipment shown above. DC substitution is discussed in Paragraphs 3-44 through 3-52.

2. Set the 431C Power Meter for normal operation using the procedure given in Figure 3-8.

3. Apply RF power to the thermistor mount; then note and record the reading of the power meter as indicated by the digital voltmeter. This recorded value is a reference to be precisely duplicated in the DC substitution measurement, step 6.

Note

If the .01, .1, 1, or 10 mW power meter ranges are used, the digital voltmeter reads directly. If the .03, .3, or 3 mW power meter ranges are used, the digital voltmeter reading must be multiplied by .0316, .316, or 3.16 respectively.

4. Turn off, or disconnect, the RF source.

5. Turn on 8402B Calibrator by setting the FUNCTION switch to CURRENT OFF; then apply a substitution current by setting FUNCTION switch to SUBSTITUTE.

6. Using 8402B Calibrator CURRENT CONTROL and VERNIER controls, adjust the substitution current until the reference reading of step 3 is precisely duplicated.

7. Note 8402B VOLTMETER output DVM reading. On .01, .03, .1 and .3 mW ranges, reading is substituted current (I_{DC}) in mA. On other ranges multiply reading by 10 to obtain I_{DC} in mA.

8. Disconnect thermistor mount from thermistor mount cable. Connect thermistor mount cable between 431C Power Meter THERMISTOR MOUNT and 8402B Calibrator RESISTANCE STANDARD connectors.

9. Set 8402B Calibrator controls as follows:
   a. THERMISTOR RESISTANCE . . . -.5%
   b. MOUNT RESISTANCE to correspond with resistance and type of thermistor mount used.

10. Set 431C Power Meter RANGE switch to NULL. Rotate THERMISTOR RESISTANCE switch on 8402B Calibrator clockwise until the 431C Power Meter changes from a zero reading to a stable reading greater than zero.

11. The operating resistance of the detection thermistor (R_d) is the nominal value indicated on the thermistor mount label plus or minus the correction indicated by the setting of the THERMISTOR RESISTANCE switch. The percentage correction is a value in-between the limits set by the two positions of the THERMISTOR RESISTANCE switch that correspond to the zero reading and the stable meter reading obtained in step 10. If desired, the average of these two values may be calculated and used as the correction value.

12. Calculate power in mW from the following expression:

$$\text{Power (mW)} = \frac{(I_{DC})^2 \, (R_d) \, (10^{-3})}{4}$$

Where: I_{DC} = Substitution current in mA (from step 7)
R_d = Operating resistance of the detection thermistor (from step 11)

Figure 3-9. DC Substitution

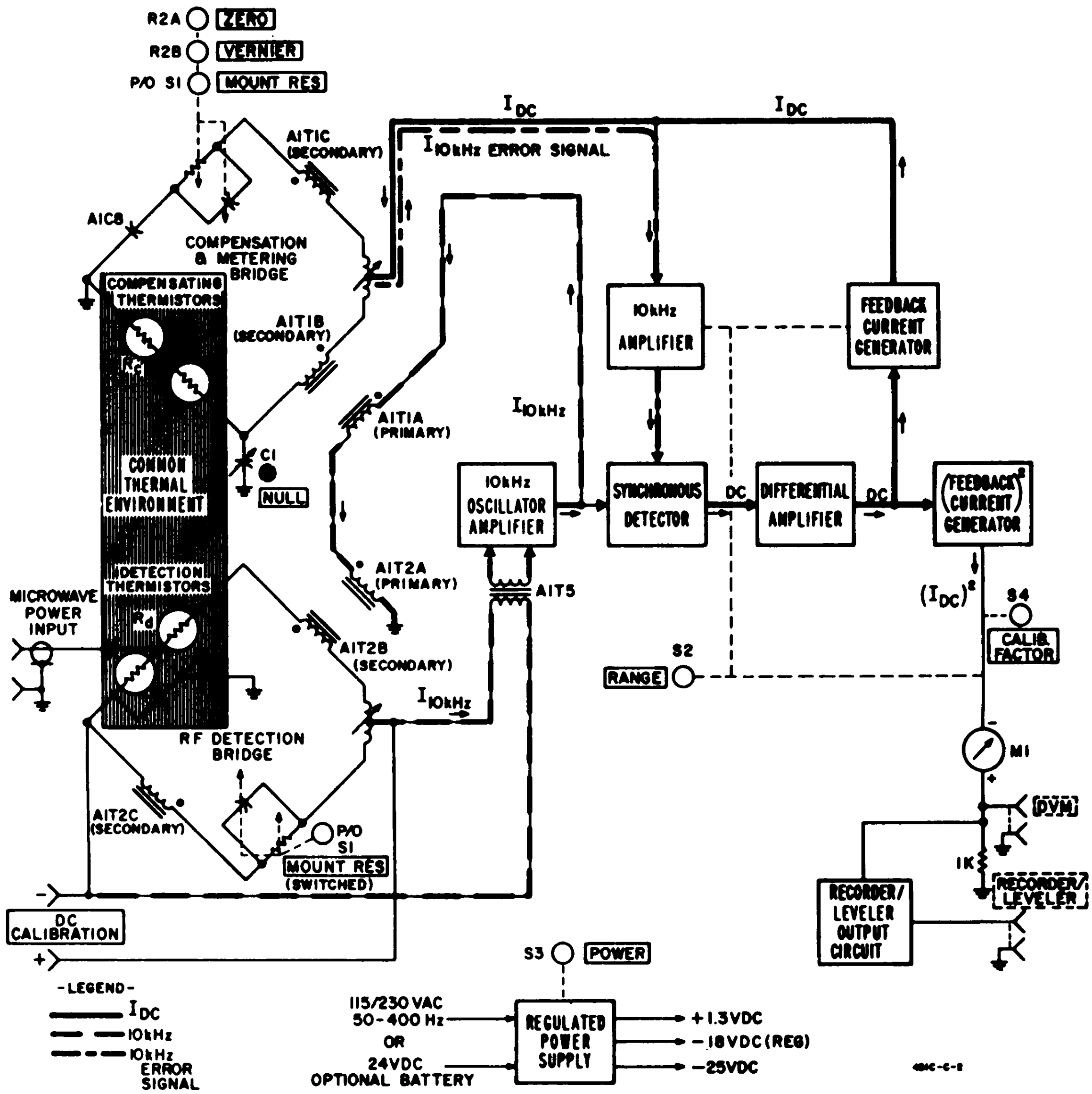


Figure 4-1. Block Diagram

SECTION IV
PRINCIPLES OF OPERATION

4-1. OVERALL DESCRIPTION.

4-2. Figure 4-1 is a block diagram which shows the Model 431C Power Meter with an associated thermistor mount. The thermistor mount contains two sets of termistor elements, R_c and R_d, which are mounted in an identical thermal environment with R_c isolated from applied microwave power. Thermistor elements R_d absorb the microwave power applied to the mount and initiate a power level data conversion to a correspending meter indication. Thermistor elements R_c provide compensation in the metering circuit to correct for ambient temperature changes at the therm istor mount.

4-3. The p o w e r meter circuitry incorporates two bridges which are made self-balancing by means of separate feedback loops. Regenerative (positive) feedback is used in the detection loop; degenerative feedback in the metering loop. Thermistor elements are used in one arm of each of the self-balancing bridges. In the detection loop, the 10 kHz oscillator-amplifier supplies enough 10 kHz power (I_{10} kHz) to bias thermistor element R_d to the operating resistance which balances the RF bridge. The same amount of 10 kHz power is also supplied to thermistor element R_c by the series-connected primaries of transformers A1T1 and A1T2.

4-4. When RF power is applied to thermistor element R_d, an amount of 10 kHz power equal to the RF power is removed from thermistor element R_d by the self-balancing action of the RF bridge. Since the primaries of A1T1 and A1T2 are series-connected, the same amount of 10 kHz power is also removed from thermistor element R_c, thus, the action which balances the RF bridge unbalances the metering bridge. The metering bridge 100 p automatically re-balances by substituting DC power for 10 kHz power. Since the 10 kHz power equaled the applied RF power, the substituted DC power is a 1 s o equal to the applied RF power. Instead of metering the feedback current directly, which would require the use of a nonlinear meter scale, an analog current is derived which is proportional to the square of the feedback. Since power is a square-law function of current, the analog current thus derived is proportional to RF power, making possible the use of a linear scale on the meter.

4-5. There is little drift of the power meter zero point when ambient temperature at the thermistor mount changes because of compensating thermistors. For example, if the ambient temperature at the mount increases, a decrease in electrical power to the thermistors is required to hold their operating resistances constant. The decrease, for both thermistors, Is made automatically by the detection loop w h i c h reduces 10 kHz power. The amount of DC power in the metering loop remains unchanged however, and since this DC power controls the meter action, the ambient temperature changes do not affect the meter indication. The compensation capability depends upon t h e match of thermistor temperature characteristics. When thermistor mounts are built, the thermiutors are selected to insure optimum match of thermal characteristics.

4-6. CIRCUIT DESCRIPTION.

4-7. RF DETECTION BRIDGE. A simplified schematic diagram of the RF detection bridge is shown in Figure 4-2. The RF detection bridge combines with a high gain 10 kHz tuned amplifier to form a 10 kHz oscillator-amplifier. The bridge and amplifier are connected in a closed loop (the detection loop) which provides positive feedback to the input of the amplifier. The feedback causes the amplifier and associated bridge circuitry to oscillate. The RF bridge includes thermistor elements, R_d, secondary windings of transformer A1T2, capacitance represented by C_a and C_b, and a fixed resistance bridge arm consisting of A1R10 and parallel resistances selected by the MOUNT RES switch.

4-8. When the power meter is off, thermistor R_d is at ambient temperature and its resistance is about 1500 ohms; the RF bridge is unbalanced. When the power meter is turned on, this unbalance of the RF bridge causes a large error signal to be applied to the 10 kHz oscillator-amplifier. Consequently, maximum 10 kHz bias voltage is applied to the RF bridge. As this 10 kHz voltage biases R_d to its operating resistance (100 or 200 ohms) the RF bridge approaches a state of balance and regenerative feedback diminishes until there is just sufficient 10 kHz bias power to hold R_d at operating resistance. This condition is equilibrium for detection loop.

4-6. With application of RF power, the resistance of thermistor R_d decreases causing the regenerative signal from the RF bridge to decrease. Accordingly, 10 kHz power diminishes, the thermistor returns to operating resistance and the detection loop regains equilibrium.

4-10. The MOUNT RES switch, S1, changes the resistance arm of the RF detection bridge so that the bridge will function with either a 100 ohm, 200 ohm, or 200 ohm balanced thermistor mount. The 200 Ω BAL position allows the power meter to be operated with balanced thermistor mounts. When the MOUNT RES switch is in this position two equal capacitors are connetted in series across t h e thermistors with their

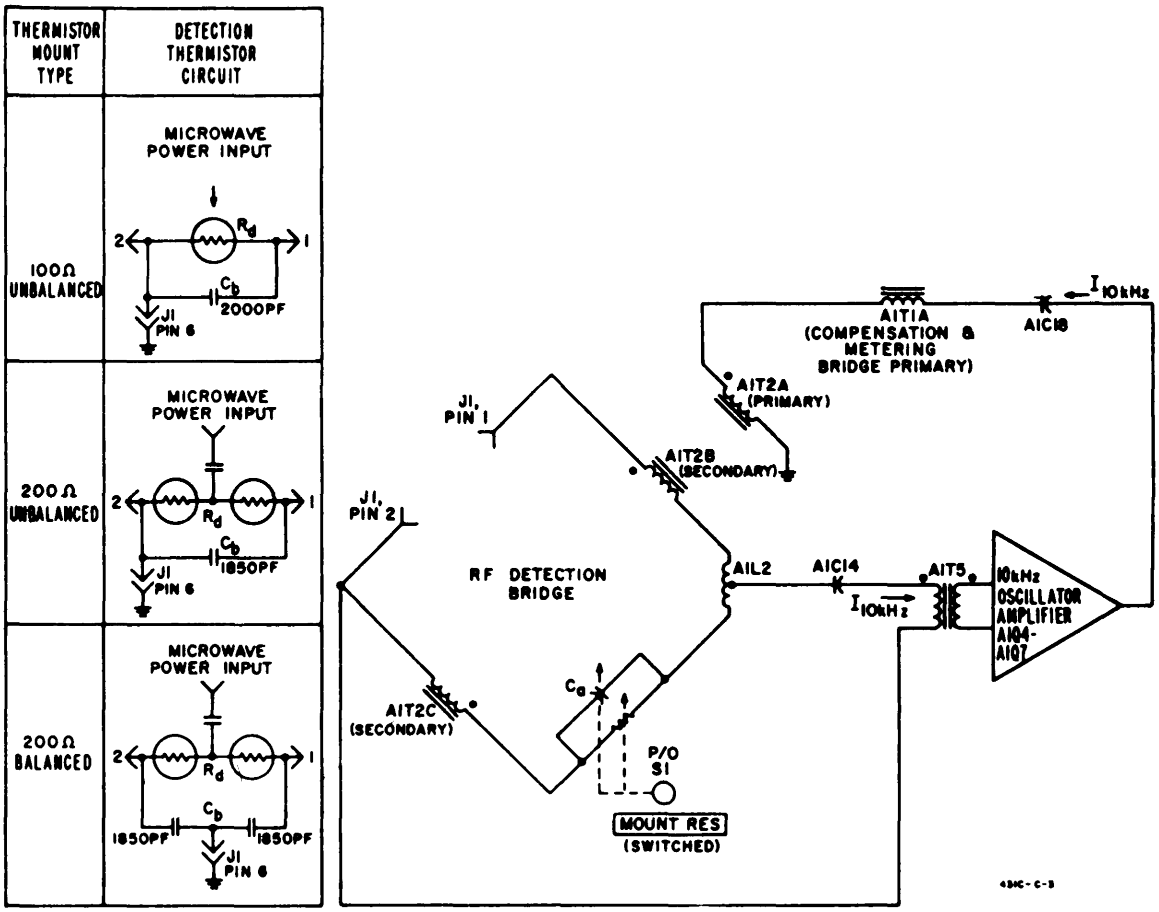


Figure 4-2. RF Detection Bridge

common point grounded. Identical capacitors are connected in a similar manner across A1R10 in the resistance arm of the RF detection bridge. All other grounds are removed from the bridge so that the entire bridge is floating with respect to DC ground. This circuit configuration provides a virtual 10 kHz ground at the RF input point to the balanced thermistor mount.

4-11. COMPENSATION AND METERING BRIDGE CIRCUIT.

4-12. A simplified schematic diagram of the compensation and metering bridge circuit is shown in Figure 4-3. Operation of the metering bridge circuit is similar to the RF detection bridge circuit. It uses the same principle of self-balancing through a closed loop (metering loop). The major difference is that DC rather than 10 kHz power is used to re-balance the loop. The resistive balance point is adjusted by the ZERO and VERNIER controls which constitute one arm of the bridge. The MOUNT RES switch which is mechanically linked to both the RF bridge and metering bridge, changes metering bridge reference resistance from 100 to 200 ohms. When the MOUNT RES switch is in the 200 Ω or 200 Ω BAL position some of the feedback current is shunted to ground through R1. This maintains the I^2R function constant when mount resistabce is changed from 100 or 200 ohms. The switch also adds the necessary reactance for each position.

4-13. The same 10 kHz power change produced In the RF bridge by RF power also affects the metering bridge through the series connection of A1T1 and A1T2 primaries. Although this change of 10 kHz power has equal effect on both the RF and metering bridge, it is initiated by the RF bridge circuit alone. The metering bridge cannot control 10 kHz bias power, but the 10 kHz bias power does affect the metering circuit. Once a change in the 10 kHz bias power has affected (unbalanced) the metering bridge, a separate, closed DC feedback loop (metering loop) re-establishes equilibrium in the metering circuit.

4-14. Variations in 10 kHz bias level, initiated in the RF bridge circuit, cause proportional unbalance of the metering bridge, and there is a change in the 10 kHz error signal ($I_{10\ kHz}$) applied to the 10 kHz tuned amplifiers in the metering loop. These error signal variations are amplified by three 10 kHz amplifiers, and rectified by the synchronous detector. From the synchronous detector the DC equivalent (I_{DC}) of the 10 kHz signal is returned to the metering bridge, and is monitored by the metering circuit to be indicated by the meter. This DC feedback to the metering bridge acts to return the bridge to its normal, near-balance condition.

4-15. The reactive components of the metering bridge are balanced with variable capacitor C1 and inductor A1L1. Null adjust, C1, is an operation adjustment and L1 is a maintenance adjustment. Null dust C1, is adjusted with the RANGE switch in the NULL position. The 10 kHz signal is taken at the synchronous detector, rectified by A1CR8, and read on the meter. The rectified signal contains both reactive and resistive voltage component of the bridge unbalance.

4-16. SYNCHRONOUS DETECTOR.

4-17. A simplified schematic of the synchronous detector is shown in Figure 4-4. The synchronous detector converts the 10 kHz error signal from the metering bridge to a varying DC signal. The detector is a bridge rectifier which as a rectifier in series with a linearizing resistance in each of its arms. Two

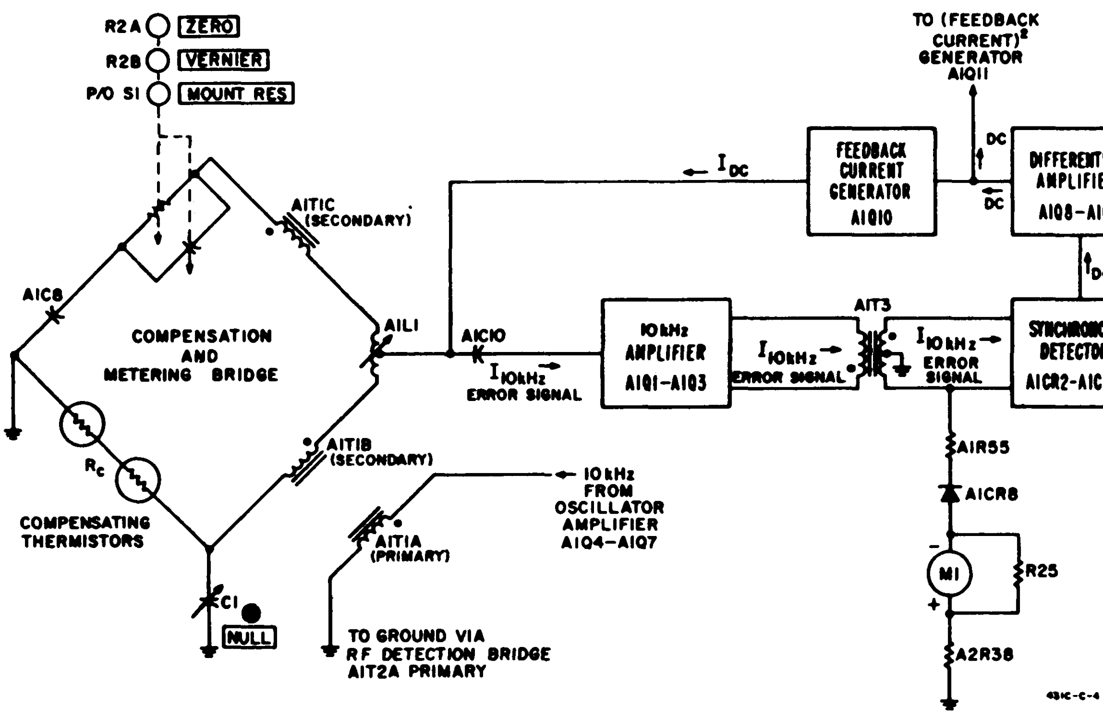


Figure 4-3. Compensation and Metering Bridge

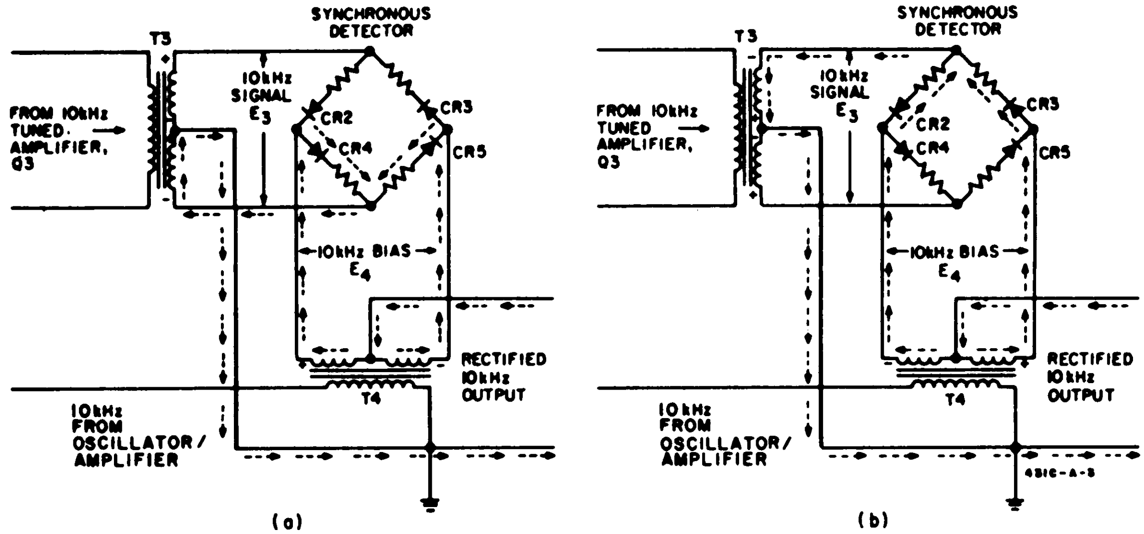


Figure 4-4. Synchronous Detector

10 kHs voltages, designated E3 and E4 in Figure 4-4, are applied to the bridge; 1) voltage E3, induced in the secondary of transformer A1T3, is proportional to the metering bridge error signal and is incoming from 10 kHz tuned amplifier Q3; 2) voltage E4, induced in the secondary of A1T4, is proportional to a voltage supplied by the 10 kHz oscillator-amplifier. Voltage E4 is much larger than voltage E3 and switches appropriate diodes in and out of the circuit to rectify voltage E3. Section (4 of Figure 4-4 shows the current path through diodes A1CR2 and A1CR3 for a negative-going signal. The rectified outpu is taken at the center taps of transformers A1T3 and A1T4.

4-18. The synchronous detector operates in the following manner. When the left side of A1T4 is positive with respect to the right side, as in Figure 4-4(a), diodes A1CR4 and A1CR5 conduct while diodes A1CR2 and A1CR3 are biased off. With the polarities reversed, as in Figure 4-4(b), the diodes A1CR4 and A1CR5 are biased off. The resultant output is a pulsating DC signal equivalent to the applied 10 kHz error signal. The pulsating DC signal is filtered and applied to differential amplifier A1Q8 and A1Q9.

4-19. The operation of the synchronous detector requires an in-phase relationship between E3 and E4. The amplitude of E4 must be greater than that of ES at all times.

4-20. FEEDBACK DIFFERENTIAL AMPLIFIER.

4-21. A simplified schematic diagram of the feedback differential amplifier is shown in Figure 4-5. The feedback circuit differential amplifier comprises A1Q8, A1Q9 and associated circuitry. Pulsating DC from the synchronous detector is filtered by A1C19, A1C20, and A1R35, amplified by A1Q8 and fed to both the feedbsck current-squared generator A1Q1l, and the feedback current generator A1Q10. Temperature compensation and low emitter circuit resistance for A1Q10 is provided by A1Q9. D i o d e A1CR7 protects A1Q10 and A1Q11 from excessive reverse bias when A1Q8 is not conducting.

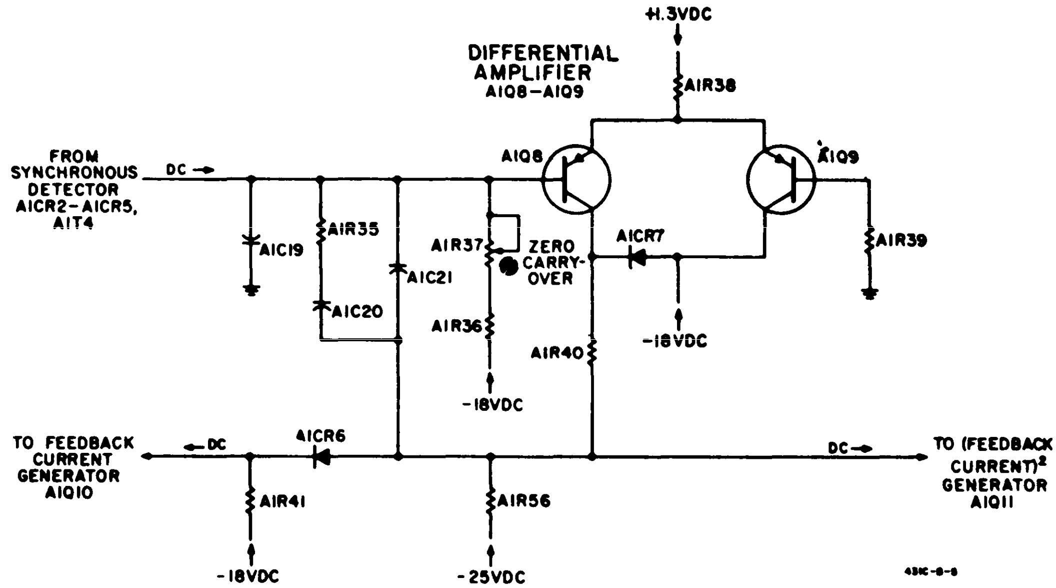


Figure 4-5. Feedback Differential Amplifier

4-22. FEEDBACK CURRENT GENERATOR.

4-23. A simplified schematic diagram of the feedback current generator is shown in Figure 4-6. The DC signal from the differential amplifier is applied to the feedback current generator A1Q10. A1Q10 serves two functions: 1) it completes the metering loop to the metering bridge, and 2) it operates in conjunction with the first 10 kHz amplifier, A1Q1, and the RANGE switch to change metering loop gain so that the meter will read full scale for each power range. Potentiometer adjustments are provided to accurately set the calibration on each range. Diode A1CR6 provides temperature compensation for A1Q10.

4-24. METER CIRCUIT.

4-25. A simplified schematic diagram of the meter circuit is shown in Figure 4-7. The meter circuit includes feedback current-squared generator A1Q11, a squaring circuit, the meter, RECORDER/LEVELER and DVM jacks, J2 and J4. The purpose of the meter circuit is to convert a linear volage function, proportional to applied power, to a square function so that power may be indicated on a linear meter scale. The linear voltage function is applied to the base of A1Q11 and is converted to a square law function by the squaring circuit in series with A1Q11 emitter.

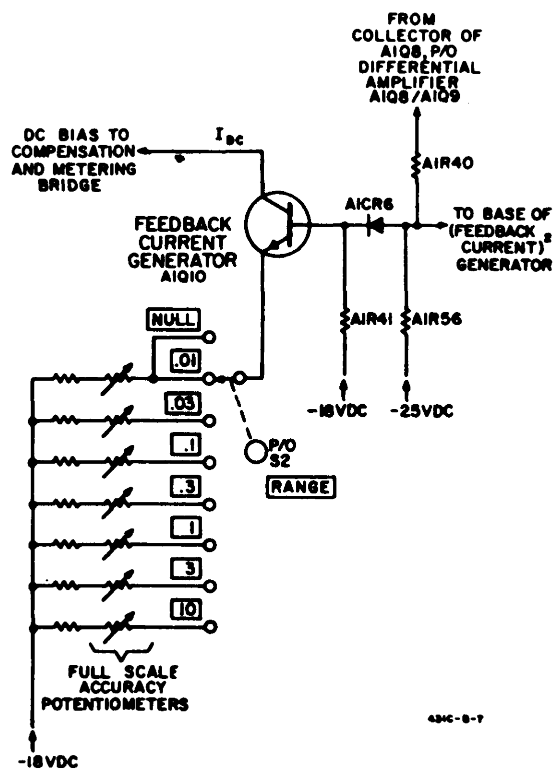


Figure 4-6. Feedback Current Generator

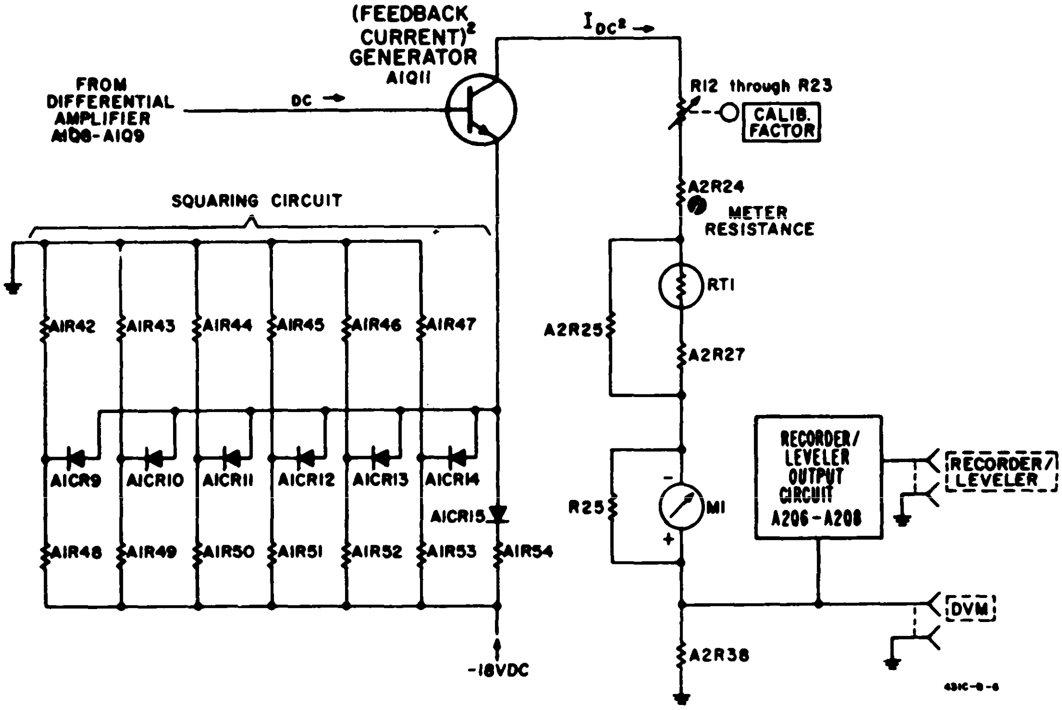


Figure 4-7. Meter Circuit

4-26. METERING CIRCUIT DIFFERENTIAL AMPLIFIER.

4-27. The metering circuit RECORDER/LEVELER output is a voltege of low source impedance necessary for isolation between l recorder or leveler amp1ifier and the metering circuit of the power meter. The isolation c i r c u i t comprises the differential amplifier A2Q6-A2Q7 and output transistor A2Q8. The voltage developed across A2R38 for the DVM output is referenced at the base of A2Q6 for comparison to the voltage at the RECORDER/LEVELER jack placed on the baes of A2Q7. Any difference voltage creates an error voltage that changes the base-emitter bias on A2Q8. A corresponding change in A2Q8 collector current occurs and the RECORDER/LEVELER voltage across A2R41 automatically adjusts to maintain the same magnitude as the DVM reference voltage.

4-28. SQUARING CIRCUIT. A simplified schematic diagram of the squaring circuit is shown in Figure 4-7. The squaring circuit includes diodes A1CR8-14, and resistors A1R42-54. Temperature compensation for the squaring circuit is provided by A1CR15.

4-28. The design of the squaring circuit is such that individual diodes are normally reverse-biased. The diodes are biased so that they conduct one after another at discrete values of emitter voltage. This causes the emitter resistance to be proportionately greater for

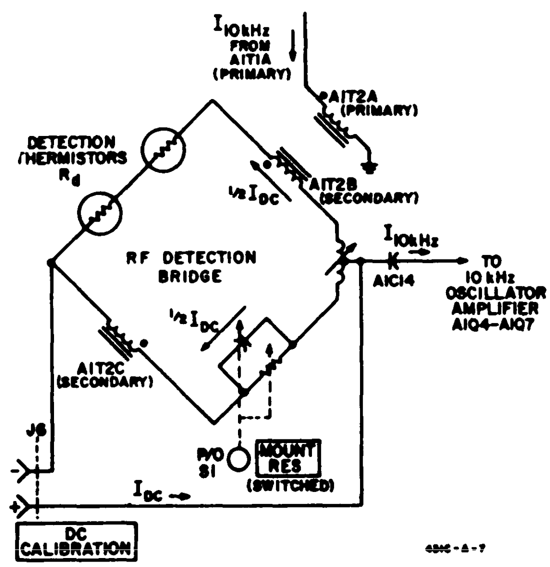


Figure 4-8. DC Calibration and Substitution

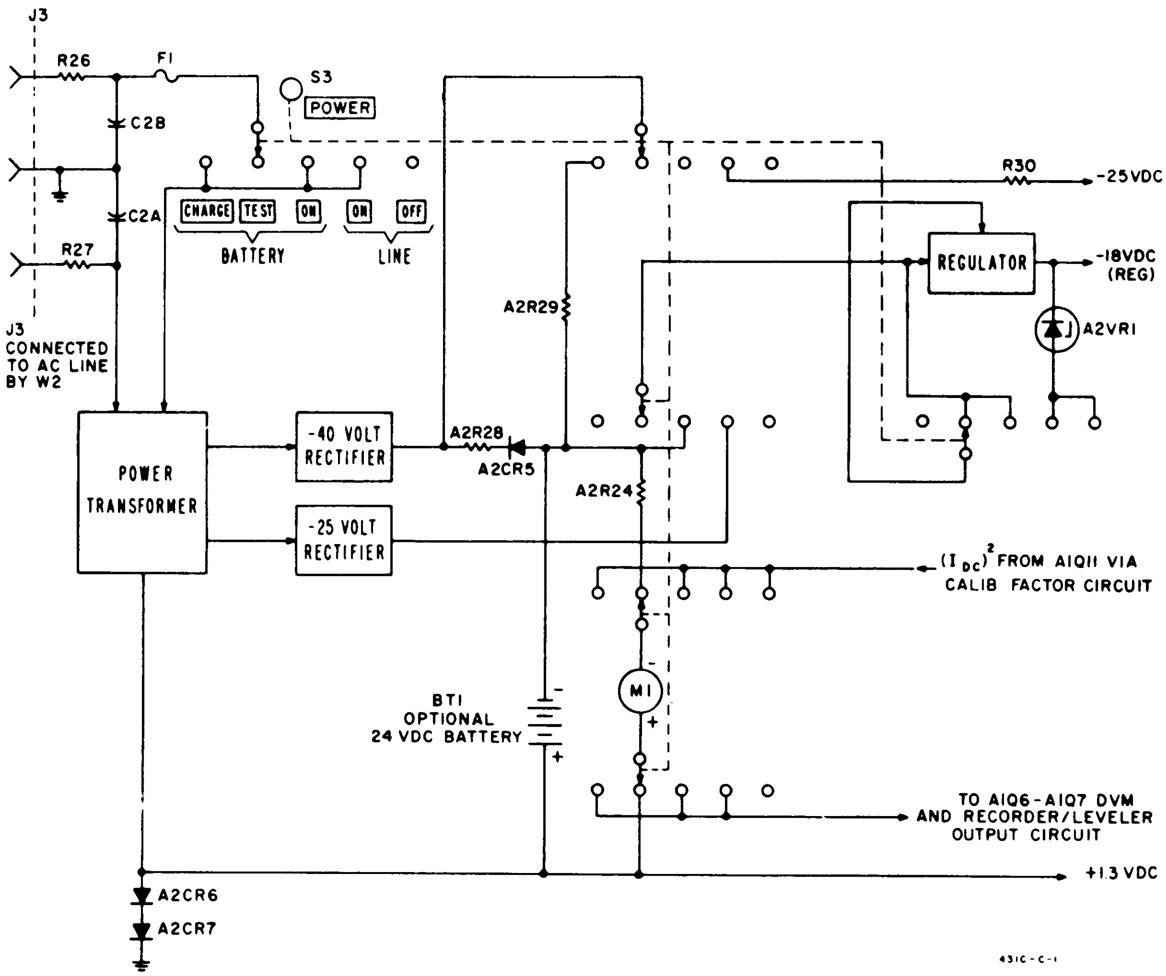


Figure 4-9. Power Switch Arrangement

larger currents. Thus, the collector current of A1Q11 is made to approximate a square law function, and the meter indicates power on a linear scale.

4-30. ZEROING. Perfect balance of the metering bridge would mean that no 10 kHz error signal would be applied to the 10 kHz amplifiers, there would be no DC feedback from A1Q10, and the metering loop would be open. With an open metering loop, zero reference could not be accurately established. In the Model 431C this occurrence is prevented by insuring a closed metering loop even when the ZERO control causes the meter pointer to deflect down-scale from zero. By the combined actions of A1R36 and A1R33, the zero setting of the meter pointer does not coincide with absolute balance of the metering bridge. A slight unbalance of the bridge is maintained by A1R36, while A1R33 provides a counter-action in the feedback current-squared generator, A1Q11, so that the meter can indicate zero even though the metering bridge is not perfectly balanced. Resistor A1R33 also sets the full scale accuracy of the meter.

4-31. DC SUBSTITUTION.

4-32. A simplified schematic diagram of the DC Substitution and Calibration circuit is shown in Figure 4-8. A block diagram of the auxiliary equipment required to perform DC substitution is presented in Figure 3-9 and discussed in Paragraphs 3-34 through 3-36. An accurately determined DC current, I_{DC}, is supplied to the DC CALIBRATION terminals on the rear panel and adjusted to allow the RF detection bridge to precisely duplicate the RF power measurement reading. Calculation of DC power from the substituted DC current gives an accurate measure of the unknown RF microwave power.

4-33. REGULATED POWER SUPPLY.

4-34. A simplified schematic diagram of the power supply is shown in Figure 4-9. The power supply operates from either a 115- or 230-volt, 50 to 400 Hz AC source or from an optional 24 volt, 30 mA rechargeable battery. Three voltages and two current outputs are provided by the power supply, Regulated voltages of -18, +1.3, and unregulated -25 VDC operate the power meter circuits. The current outputs are used for maintaining a trickle battery charge for recharging the battery.

4-35. The -18 VDC is regulated by a conventional series regulator, A2Q1 through A2Q5. The unregulated -25 VDC is developed across A2CR1 and A2CR4. The +1.3 VDC is taken across the series diodes, A2CR6 and A2CR7. The -18 VDC supply is adjusted by A2R36.

4-36. POWER SWITCH.

4-37. A simplified schematic diagram of the power switch arrangement is shown in Figure 4-9. The POWER switch has five positions: LINE OFF, LINE ON, BATTERY ON, BATTERY TEST, and BATTERY CHARGE. In the LINE ON position the instrument operates from the conventional line voltage. If a rechargeable battery has been installed, a trickle charge is supplied to the battery. In the BATTERY ON position, instrument operation is dependent on the battery. In the BATTERY CHARGE position, -25 volts is connected to the battery for recharging. In the BATTERY TEST position, battery voltage can be measured on the 0-3 mW scale. Battery voltage is 10 times meter scale reading. Proper charge of the battery is indicated by a reading within the BAT CHARGED region on the bottom of the meter face.

SECTION V
MAINTENANCE

5-1. INTRODUCTION.

5-2. This section provides instructions for performance testing, calibration adjustments, t r o u b 1 e-shooting and repairing the 431C power Meter. Front panel controlled performance tests allow the instrument to be checked for conformance to specifications. If performance is not within specifications, adjustment and troubleshooting instructions are provided.

5-3. Test equipment and accessories required to perform maintenance are listed in Table 5-1. Equipment other than the recommended models can be used provided their performance equals or exceeds the critical specifications.

5-4. MECHANICAL METER ADJUSTMENT. When the meter is properly zero-set, the winter rests over the zero mark on the meter scale when the instrument is: 1) at normal operating temperature, 2) in its normal operating position, and 3) turned off. Set the pointer as follows to obtain best accuracy and mechanical stability:

a. Turn instrument off.

b. Rotate the meter mechanical adjustment screw clockwise until the meter pointer is to the left of zero and moving up the scale towards zero. Stop when the pointer is exactly over the zero mark. If the pointer overshoots, repeat step b.

c. When the pointer is exactly on zero, rotate the adjustment screw approximately 15 degrees counter-clockwise. This frees the adjustment screw from the meter suspension. If the pointer moves during this step, repeat steps b and c.

Table 5-1. Recommended Test Equipment

Instrument Type	Critical Specifications	Recommended Model
Direct Current Power Source	Range: 0.01 to 10 mW Accuracy: ±0.1%	hp 8402B
Electronic Counter	Sensitivity: 4V rms Frequency: 10 kHz Accuracy: ±0.01% or better Resolution: Five digits	hp 5512A
DC Voltmeter	Range: 0.5 to 50 volts DC Accuracy: ±0.05% Input Impedance: 10 Megohms, floating Resolution: Three or more digits	hp 3440A with 3443A plug-in unit
Ohmmeter	Range: 1 ohm to 10 Megohms Accuracy: ±5%	hp 410B/C hp 412A hp 427A
AC Voltmeter	Range: 10 to 100 mV Accuracy: ±5% Input Impedance: 1 Megohm	hp 403A/B hp 427A
Oscilloscope	Bandwidth: 100 kHz Accuracy: ±5% Input Impedance: 1 Megohm Sensitivity: 1 mV/division	hp 140A with 1400A and 1402A plug-in units
Thermistor Mount	Refer to Table 1-2 for recommended thermistor mounts	hp 478A hp 486A Series
Decade Capacitor	Range: 0.0 to 0.01 uF Capacitance per step: 100 pF Accuracy: ±2%	General Radio 1419-B
Audio Oscillator	Frequency: 10 kHz Accuracy: ±2%	hp 200AB hp 200CD

5-5. PERFORMANCE TESTS.

5-6. PURPOSE. The procedures listed in Table 5-2 test power meter performance for incoming inspection, periodic evaluation, calibration and troubleshooting. The tests can be performed without access to the instrument interior. 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 adjustment procedure. If a circuit malfuction is suspected refer to the troubleshooting paragraphs.

5-7. ADJUSTMENTS.

5-8. GENERAL. The following procedures outline the adjustments necessary to calibrate the power meter. The actual adjustments should be made only when it is determined that the instrument is out of adjustment, and not malfunctioning due to a circuit failure.

5-9. 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.

5-10. Several circuit component parts of the power meter are selected at the factory to meet specific circult requirements. The factory selected parts are indicated by an asterisk on the schematic diagrams and in the replaceable parts list. Table 5-3 lists the circuit requirements for factory selected parts.

2-11. COVER REMOVAL AND REPLACEMEMT.

5-12. 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.

5-13. TOP COVER REMOVAL.

a. At the rear of the instrument, remove the two screws which retain the cover.

Table 5-2. Performance Tests

1. ACCURACY: ±1% of full scale from +20°C to +35°C.

Procedure

a. Connect equipment as shown in Figure 3-9.

b. Set 8402B Calibrator controls as follows:
FUNCTION . . . . CURRENT OFF
RANGE . . . . .01 mW
MOUNT RESISTANCE to correspond with resistance and type of thermistor mount used.

c. Set 431C Power Meter controls as follows:
CALIB FACTOR 100%
POWER . . . . ON
RANGE . . . . .01 mW
MOUNT RES to correspond with resistance and type of thermistor mount used.

d. Null and zero-set the power meter (refer to Turn-On and Nulling Procedure, Figure 3-8).

e. Set 8402B FUNCTION switch to CALIBRATE. Successively set RANGE (mW) switch on calibrator and RANGE switch on power meter to identical range values starting with the counterclockwise position of .01 mW. The power meter should read the power set on the calibrator within ±1% of full scale.

f. Set RANGE (mW) switch on calibrator and RANGE switch on power meter to 10 mW.

g. If necessary, adjust ZERO and VERNIER controls on power meter to obtain an exact 10 mW reading.

h. Successively set RANGE (mW) switch on calibrator to 8, 6, 4, and 2 mW positions while observing power meter reading. The power meter should read the power set on the calibrator within ±1% of full scale.

2. ZERO CARRYOVER: Less than +0.5% of full scale when zeroed on most sensitive range.

Procedure

a. Connect hp 3440A DC Voltmeter to DVM output jack on rear of 431C Power Meter (refer to Paragraph 3-49).

b. Set power meter controls as follows:
POWER . . . . ON
RANGE . . . . .01 mW
CALIB FACTOR 100%
MOUNT RES to correspond with resistance and type of thermistor mount used.

c. Adjust ZERO for 0.000 VDC reading on 10 volt range of DC voltmeter.

d. Rotate power meter RANGE switch clockwise through remaining ranges. Reading on DC voltmeter should remain within 0.000 ±.005 VDC on each range.

3. VOLTMETER OUTPUT: 1.000 VDC ±0.3% into 500 k ohm or greater load at full scale meter deflection.

Procedure

a. Perform steps a through d of ACCURACY performance test.

b. Set 8402B FUNCTION switch to CALIBRATE. Reading on DC voltmeter should be 0.997 to 1.003 VDC, and correspond with full scale meter reading of power meter.

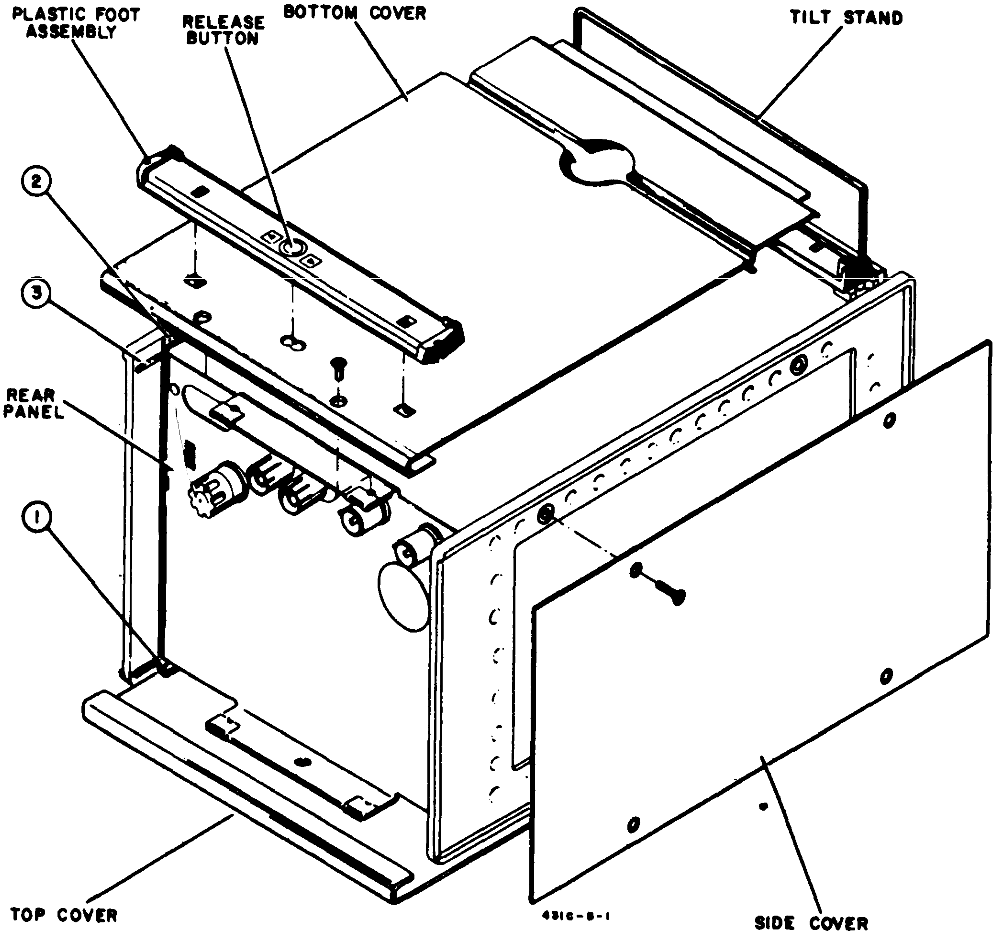


Figure 5-1. Cover Removal

b. Grasp the cover from the rear, slide it back 1/2 inch then tilt forward edge of thr cover upward end lift the cover from the instrutment.

5-14. TOP COVER REPLACEMENT.

a. Rest the cover flat on the cast guides pojecting inward near the top of l ech side frame (see ① ,Fig. ure 5-l).

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

c. Replace the two cover retaining screws.

5-15. BOTTOM COVER REMOVAL.

a. Set the tilt stand as shown in Figure 5-1.

b. Remove the two retaining screws at the rear of the cover.

c. Slide the cover rearward far enough to free its forward edge from the front foot assembly.

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

5-16. BOTTOM COVER REPLACEMENT.

l . Set the tilt stand as shown in Figure 5-1.

b. Rest the bottom cover flat on the cast guides projecting inward near the bottom of each side frame (see ② Figure 5-1).

c. Slide the cover fomerd 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 (see ③ Figure 5-1).

d. Replace the two retaining screws and the rear foot assembly.

Table 5-3. Circuit Requirements for Factory Selected Parts

Part Ref. Desig.	Circuit Requirements
R25	Full scale deflection of meter M1 when 1 mA of DC flows through the combination of the meter and R25.
A1R7	Balance of RF detection bridge when using a 100 ohm thermistor mount with no microwave power applied.
A1R9	Balance of RF detection bridge when using a 200 ohm thermistor mount with no microwave power applied.
A1C1	NULL capacitor, C1, set near midrange for null when using a 200 ohm thermistor mount. Refer to Paragraph 5-20.
A1C2	NULL capacitor, C1, set near midrange for null when using a 100 ohm thermistor mount. Refer to Paragraph 5-20.
A1C3	10 kHz oscillation of oscillator amplifier, A1Q4-Q7, when using a 100 ohm thermistor mount. Refer to Paragraph 5-22.
A1C22	Frequency of 10 kHz for A1T5/A1C15 tuned circuit combination. Refer to Paragraph 5-21.

5-17. POWER SUPPLY ADJUSTMENT.

Procedure

Note

An adjustment of the power supply voltage may require a readjustment of the full scale accuracy potentiometers (refer to Paragraph 5-18).

a. Connect a DC voltmeter between pin W, XA2 and ground,

b. Adjust A2R36 for -18.00 +0.02 VDC.

5-18. FULL SCALE ACCURACY Adjustments

Procedure.

a. Connect equipment as shown in Figure 3-9.

b. Set 8402B Calibrator controls as follows:

FUNCTION. . . . . CURRENT OFF
MOUNT RESISTANCE to correspond with resistance and type of thermistor mount used.

c. Set 431C Power Meter as follows:

POWER . . . . .ON
CALIB FACTOR 100%
MOUNT RES to correspond with resistance and type of thermistor mount used.

d. Null and zero-set the power meter (refer to Turn On and Nulling Procedure, Figure 3-8).

e. 200 OHM THERMISTOR MOUNT. Set calibrator and power meter controls and make corresponding adjustment as listed below.

Range (mW)	8402B Calibrator	431C Power Meter	
	Function	Adjust	Reading
.01	CURRENT OFF	ZERO	0.0
.01	CALIBRATE	A2R14	.01 mW
.03	CURRENT OFF	ZERO	0.0
.03	CALIBRATE	A2R13	.03 mW
.1	CURRENT OFF	ZERO	0.0
.1	CALIBRATE	A2R12	.1 mW
.3	CURRENT OFF	ZERO	0.0
.3	CALIBRATE	A2R11	.3 mW
1	CURRENT OFF	ZERO	0.0
1	CALIBRATE	A2R10	1.0 mW
3	CURRENT OFF	ZERO	0.0
3	CALIBRATE	A2R9	3.0 mW
10	CURRENT OFF	ZERO	0.0
10	CALIBRATE	A2R8	10.0 mW

f. 100 OHM THERMISTOR MOUNT. Set calibrator and power meter controls and make corresponding adjustments as listed below.

Range (mW)	8402B Calibrator	431C Power Meter	
	Function	Adjust	Reading
.01	CURRENT OFF	ZERO	0.0
.01	CALIBRATE	A2R1	.01 mW
.03	CURRENT OFF	ZERO	0.0
.03	CALIBRATE	A2R2	.03 mW
.1	CURRENT OFF	ZERO	0.0
.1	CALIBRATE	A2R3	.1 mW
.3	CURRENT OFF	ZERO	0.0
.3	CALIBRATE	A2R4	.3 mW
1	CURRENT OFF	ZERO	0.0
1	CALIBRATE	A2R5	1.0 mW
3	CURRENT OFF	ZERO	0.0
3	CALIBRATE	A2R6	3.0 mW
10	CURRENT OFF	ZERO	0.0
10	CALIBRATE	A2R7	10.0 mW

5-19. ZERO AND VERNIER CONTROL ADJUSTMENT.

Procedure

a. Perform steps a through c of ZERO CARRY-OVER performance test, Table 5-2.

b. Rotate 431C Power Meter RANGE switch clockwise through remaining ranges. Adjust A1R37 to hold DC voltmeter reading within 0.000 ±0.005 VDC on each range.

5-20. COARSE NULL ADJUSTMENT.

Procedure

100 OHM THERMISTOR MOUNT

a. Connect 100 ohm thermistor mount to power meter.

b. Connect oscilloscope or AC voltmeter from A1R55 to ground.

c. Set power meter controls as follows:

POWER . . . . .ON
RANGE . . . . .01 mW
CALIB FACTOR 100%
MOUNT RED . . . . 100 Ω

d. Adjust ZERO control for an on-scale meter reading.

e. Mechanically center NULL capacitor, C1.

f. Adjust A1L1 for a voltage null at A1R55. Fine adjust NULL capacitor C1 for less than 1.5 volts peak to peak.

g. Set power meter RANGE switch to NULL, and fine adjust NULL capacitor C1 for a zero power meter reading. C1 should remain near mechanical center of range ±10°.

h. Rotate power meter RANGE switch clockwise through remaining ranges. Voltage null at A1R55 should remain less than 1.5 volts peak to peak.

200 OHM THERMISTOR MOUNT

i. Connect 200 ohm thermistor mount to power meter.

j. Connect oscilloscope or AC voltmeter from A1R55 to ground.

k. Set power meter controls as follows:

POWER . . . . ON
RANGE . . . . .01 mW
CALIB FACTOR 100%
MOUNT RED . . . . 200 Ω

m. Adjust ZERO control for an on-scale meter reading.

n. Mechanically center NULL capacitor C1.

o. Select capacitor A1C1 (refer to Table 5-3) for a voltage null at A1R55. Fine adjust NULL capacitor C1 for less than 1.5 volts peak to peak.

p. Set power meter RANGE switch to NULL, and fine adjust NULL capacitor Cl for a zero power meter reading. C1 should remain near mechanical center of range ±45°.

Note

If a null cannot be obtained, do not select A1C1 for a value greater than 1000 pF. Increase A1C2 in 50pF steps, and repeat steps d through g until limits are met.

5-21. OSCILLATOR TANK CIRCUIT TUNING.

Procedure

a. Connect 100 or 200 ohm thermistor mount to power meter.

b. Set power meter MOUNT RES switch to correspond to resistance and type of thermistor mount used.

c. Disconnect negative side of capacitor A1C18 from power meter assembly board A1.

d. Connect 200CD Oscillator output and electronic counter input between negative lead of capacitor A1C18 and ground.

e. Connect oscilloscope probe between point of circuit from which A1C18 was disconnected and ground.

f. Set vertical sensitivity of oscilloscope to 0.2V/division.

g. Adjust 200CD Oscillator amplitude to obtain a sine wave display on the oscilloscope.

h. Using a decade capacitance, select a value for A1C22 that causes a peak display on the oscilloscope at a frequency of 10.00 ±0.02 kHz. Range of A1C22: 300 pF to 6000 pF.

i. Install selected value of A1C22 and reconnect negative lead of A1C18 to assembly board A1.

5-22. OSCILLATOR FREQUENCY ADJUSTMENT.

Procedure

a. Connect 100 or 200 ohm thermistor mount to power meter.

Note

Oscillator frequency will vary approximately ±0.1 kHz depending on thermistor mount terminating impedance. For the following adjustments, terminate the thermistor mount with a standard 50 ohm termination. Balanced and waveguide mounts do not require termination.

b. Set power meter controls as follows:

POWER . . . . ON
CALIB FACTOR 100%
MOUNT RES to correspond to resistance and type of thermistor mount used.

c. Connect an electronic counter between the positive side of capacitor A1C18 and ground.

d. Perform the following adjustment that corresponds to the resistance and type of thermistor mount connected to power meter.

(1) 100 OHM THERMISTOR MOUNT. Use a decade capacitance to select a value for A1C3 (1000 pF maximum) that causes an oscillation frequency of 10.00 ±0.05 kHz. Install selected value of A1C3.

(2) 200 OHM THERMISTOR MOUNT. Adjust A1L2 for an oscillation frequency of 10.00 ±0.01 kHz.

5-23. TROUBLESHOOTING.

5-24. Check the fuse to ensure that it is not open. Make a thorough visual inspection for burned out or loose components, loose connections, contaminated switch contacts or any condition that may suggest a source of trouble.

5-25. The first step in troubleshooting the 431C is to isolate the trouble to either the thermistor mount and thermistor-mount cable combination or the power meter. The operating note furnished with hp thermistor mounts gives a procedure to check the thermistor mount. This procedure will indicate any deficient performance of the mount. An ohmmeter continuity check call be used to determine if the thermistor mount cable or cable connectors are defective.

5-26. TROUBLE ISOLATION. Circuits in the 431C can be divided into five basic functional unite as follows: 1) RF detection bridge and 10 kHz oscil1ator-amplifier (A1Q4-A1Q7), 2) compensation and metering bridge, 10 kHz amplifier (A1Q1 -A1Q3) and synchronous detector, 3) differential amplifier (AlQ8-A1Q9) and feedback current generator (A1Q10), 4) feedback current-squared generator (A1Q11) and metering circuits, and 5) power supply.

5-27. The procedure in Table 5-4 allows front panel controls and indications to be used to isolate failures to particular basic functional circuits. The procedure is limited by the extensive use of feedback loops and interdependence of circuit operation.

5-28. The following assumptions are made throughout the front panel trouble isolation procedure: 1) the thermistor mount and thermistor-mount cable combination is working properly, 2) transformers in the detection

Table 5-4. Front Panel Trouble Isolation

Step	Instructions	Indication	Action or Trouble Circuit
1.	a. Connect thermistor mount b. Set RANGE to .01 mW c. Set POWER to ON d. Adjust ZERO for zero meter reading, if possible e. Rotate RANGE from .01 through 10 mW	No meter reading	Proceed with step 2
		Meter reads below low scale limit or meter reads above high scale limit	Proceed with step 3
2.	a. Set RANGE to 10 mW b. Apply RF power to thermistor mount c. Decrease RANGE from 10 mW until reading is obtained	No meter reading	Proceed with step 3
		Any meter reading	a. Perform ACCURACY performance test, Figure 5-2. Particular range inaccuracy: check first for improper range resistance selected by RANGE switch (A1S2). All range inaccuracy: 10 kHz amplifier (A1Q1-A1Q3) and feedback current generator (A1Q10) combination or power supply. b. Proceed with step 3.
3.	a. Remove RF power from thermistor mount b. Set RANGE to NULL c. Adjust NULL screwdriver adjustment	Meter reading that changes with NULL adjustment	Proceed with step 4
		Meter reading that does not change with NULL adjustment	Compensation and metering bridge, 10 kHz amplifier (A1Q1-A1Q3) and synchronous detector combination
		No meter reading	RF detection bridge, and 10 kHz oscillator-amplifier (A1Q4-A1Q7) combination
			Power supply
4.	a. Set RANGE to .01 mW b. Adjust ZERO for zero meter reading c. Rotate RANGE from .01 through 10 mW	Zero	Feedback current-squared generator (A1Q11) and metering circuits
		No zero	Differential amplifier (A1Q8-A1Q9) and feedback current generator (A1Q10) combination
		Zero does not carry-over within specifications	Differential amplifier (A1Q8-A1Q9) and feedback current-squared generator (A1Q11) combination

bridge, metering bridge and synchronous detector have not failed, and 3) only one basic functional circuit has failed.

5-29. Front panel trouble isolation is intended only to suuggest the most probable functional circuit failure and to give a general direction in which to look before starting a detailed troubleshooting procedure.

5-30. It is Important that the procedures listed in Table 5-4 be performed in the order listed. Each step forms the basis on which the indications of a subsequent step are analyzed.

5-31. DETAILED TROUBLESHOOTING. To assist detailed troubleshooting, normal-operation waveforms are given in Figures 7-3 and 7-8. Locations of test points and components are given in Figures 7-2, 7-4, and 7-6. In addition, normal-operation voltages relative to chassis ground are provided on the schematic diagrams for the collector, base and emitter of every transistor in the instrument. Waveforms and voltage measurements were made with a thermistor mount connected, and the instrument nulled, according to instructions given in Figure 3-8. The first detailed troubleshooting checks should be performed in the following order: 1) check for power supply output voltages of +1.3, -18, and -25 VDC, 2) check at test point 6 to ensure that the 10 kHz oscillator - amplifier, A1Q4-Al Q?, has the proper output waveform, 3) check at test point 2 for correct output of the 10 kHz amplifier, A1Q1 - A1Q3. For signal tracing through the amplifier stages, capacitor A1C10 can be disconnected from A1L1 and used as a means to inject a 10 kHz test signal to the input of the first 10 kHz amplifier, A1Q1.

5-32. COMPONENT TROUBLE ISOLATION. The following procedures and data are given to aid in determining whether a transistor is operational. Tests are given for both in-circuit and out-of-circuit transistors and should be useful in determining whether a particular functional circuit trouble is due to a faulty transistor or an associated component.

5-33. IN-CIRCUIT TESTING. The common causes of transistor failures are internal short - and open - circuits, In transistor circuit testing the most important consideration is the transistor base-emitter junction, Like the control grid of a vacuum tube, this is the operational control point in the transistor. This junction is essentially a solid-state diode. For the transistor to conduct, the diode must conduct; that is, the diode must be forward biased. As with simple diodes, the forward bias polarity is determined by the materials forming the junction. Use the transistor symbol on the schematic diagram to determine the bias polarity required to forward-bias the base-emitter junction. The A part of Figure 5-2 shows transistor symbols with terminals labeled. The emitter arrow points toward the type N material. The other two columns of the illustration compare the biasing required to cause conduction and cut - off in transistors and vacuum tubes. If the transistor base-emitter diode (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 (no conduction). The voltage drop across a forward-biased emitter-base diode varies with transistor collector current. For example, a germanium transistor has l typical forward bias, base - emitter voltage of 0.2 -0.3 volts when collector current is 1 - 10 mA and 0.4 -0.5 volts when collector current is 10 - 100 mA. In contrast, forward-bias voltage for silicon transistors is about twice that for germanium types: about 0.5 - 0.6 volts when collector current is low, and about 0.8 - 0.9 volts when collector current is high.

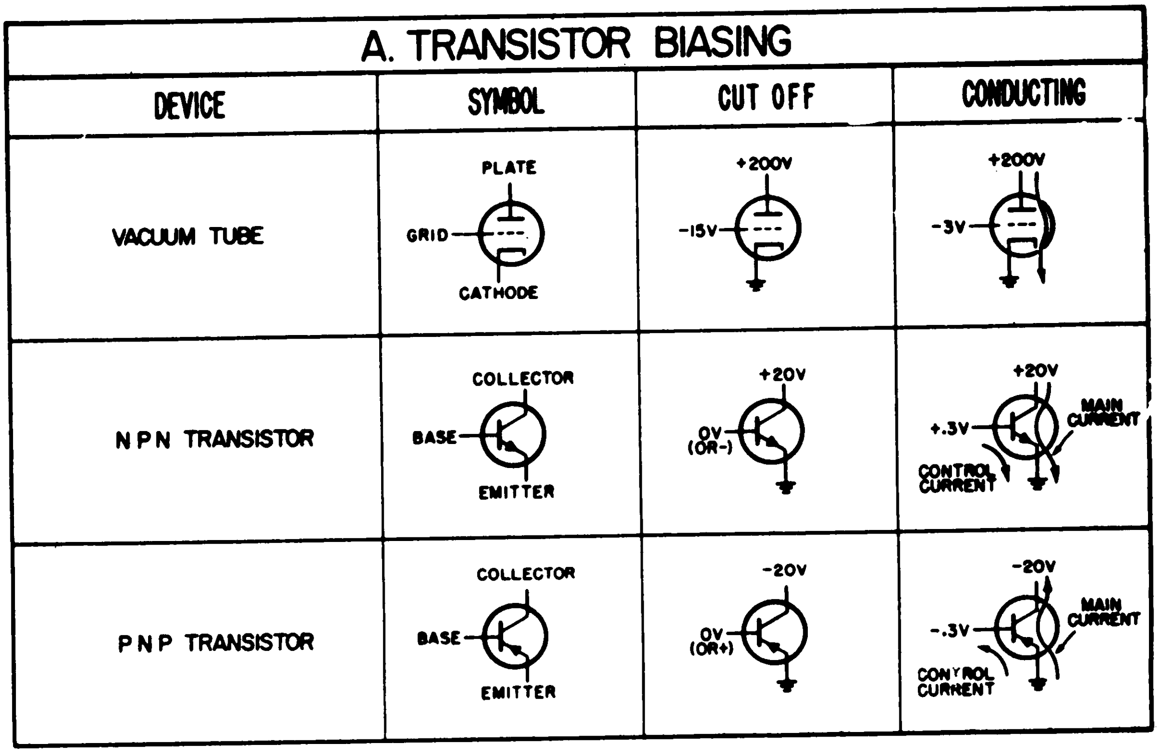
5-34. Figure 5-2, part B, shows simplified versions of the three basic transistor circuits and gives the operating characteristics of each. When examining a transistor stage, first determine if the emitter-base diode is biased for conduction (forward - biased) by measuring the voltage difference between emitter and base. When using an electronic voltmeter, do not measure directly between emitter and base since there may be sufficient loop current between the voltmeter 1 e ad l to damage the transistor. Instead, measure each voltage separately with respect to a voltage common point (e. g., chassis). If the emitter-base diode is forward biased, check for amplifier action by shorting base to emitter while observing collector voltage. The short circuit eliminates base-emitter bias and should cause the transistor to stop conducting (cutoff). Collector voltage should then shift to near the supply voltage. Any difference is due to leakage current through the transistor and, in general, the smaller this 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.

5-35. OUT-OF-CIRCUIT TESTING. Remove the transistor from the circuit and use an ohmmeter to measure internal resistance. Refer to Table 5-5 for measurement data.

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

Transistor Type		Connect Ohmmeter Pos. lead to	Connect Ohmmeter Neg. lead to	Measure Resistance (ohms)
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	1 k - 3 k
		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.



B. AMPLIFIER CHARACTERISTICS

CHARACTERISTIC	COMMON BASE	COMMON EMITTER	COMMON COLLECTOR
INPUT Z	30-50 Ω	500-1500 Ω	20-500K Ω
OUTPUT Z	300-500K Ω	30-50K Ω	50-1000 Ω
VOLTAGE GAIN	500-1500	300-1000	< 1
CURRENT GAIN	< 1	25-50	25-50
POWER GAIN	20-30 db	25-40 db	10-20 db

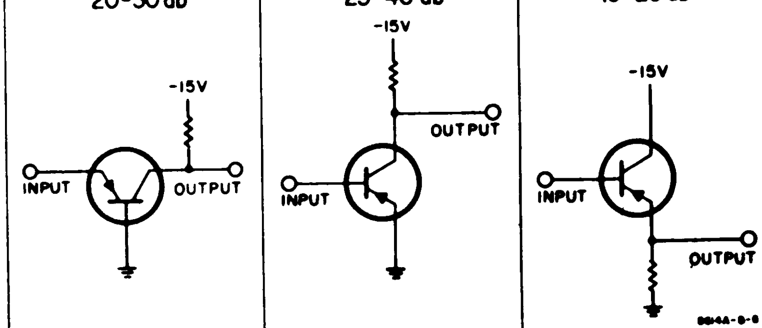


Figure 5-2. Transistor Biasing and Operating Characteristics

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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 1.5 volts and short-circuit current must be less than 3 mA.

Table 5-6. Safe Ohmmeter Range for Transistor Resistance Measurements

Ohmmeter	Safe Range(s)	Open Ckt Voltage	Short Ckt Current	Lead	
				Color	Polarity
hp 412A hp 427A	R x 1 k R x 10 k R x 100 k R x 1M R x 10M	1.0V 1.0V 1.0V 1.0V 1.0V	1 mA 100 μA 10 μA 1 μA 0.1 μA	Red Blk	+ -
hp 410C	R x 1 k R x 10 k R x 100 k R x 1M R x 10M	1.3V 1.3V 1.3V 1.3V 1.3V	0.57 mA 57 μA 5.7 μA 0.5 μA 0.05 μA	Red Blk	+ -
hp 410B	R x 100 R x 1 k R x 10 k R x 100 k R x 1M	1.1V 1.1V 1.1V 1.1V 1.1V	1.1 mA 110 μA 11 μA 1.1 μA 0.11 μA	Blk Red	+ -
Simpson 260	R x 100	1.5V	1 mA	Red Blk	+ -
Simpson 269	R x 1 k	1.5V	0.82 mA	Blk Red	+ -
Triplett 630	R x 100 R x 1 k	1.5V 1.5V	3.25 mA 325 μA	Varies with Serial Number	
Triplett 310	R x 10 R x 100	1.5V 1.5V	750 μA 75 μA		

SECTION VII
SCHEMATIC DIAGRAMS

7-1. INTRODUCTION.

7-2. Schematic presentations in this manual show electrical circuit operation and are not intended to serve as wiring diagrams. Figure 7-1 lists notes which apply to the schematic diagrams.

7-3. Some switch and circuit board assemblies are shown in part on different pages. To find a specific instrument component, refer to the "REFERENCE DESIGNATIONS" box which appears on each schematic diagram. Reference designations within assemblies are abbreviated. The full designation includes the assembly on which the component is mounted, and the individual component designation. For example, Resistor R1 mounted on Assembly A1 has the complete reference designation of A1R1 , Certain parts are not included on assemblies, and are classified as chassis parts. Chassis parts are assigned only the reference designation shown on the schematic diagram.

7-4. This section also contains information on component and test point locations within the instrument. Figure 7-4 shows the Power Meter Assembly, A1, and Figure 7-6 shows the Power Supply Assembly, A2. Figure 7-2 shows switch component locations.

7-5, Figures 7-3 and 7-8 illustrate normal-operation waveforms obtained at test points 1 through 6. Normal-operation voltages are given on the schematic diagrams, adjacent to the point of measurement. All voltages and waveforms were taken with the instrument zeroed and nulled and a 200 ohm thermistor mount connected in accordance with Figure 3-8, Turn-On and Nulling Procedure. Full scale voltage measurements were made by setting the meter to full scale deflection with the ZERO control.

7-6. An asterisk indicates a factory selected part; the component value shown is the typical or most commonly selected value. Circuit requirements that determine the values of factory selected parts are listed in Table 5-3.

7-7. Component procurement information and specific component descriptions are included in Section VI. Refer to page 6-1 for information on how to order parts.

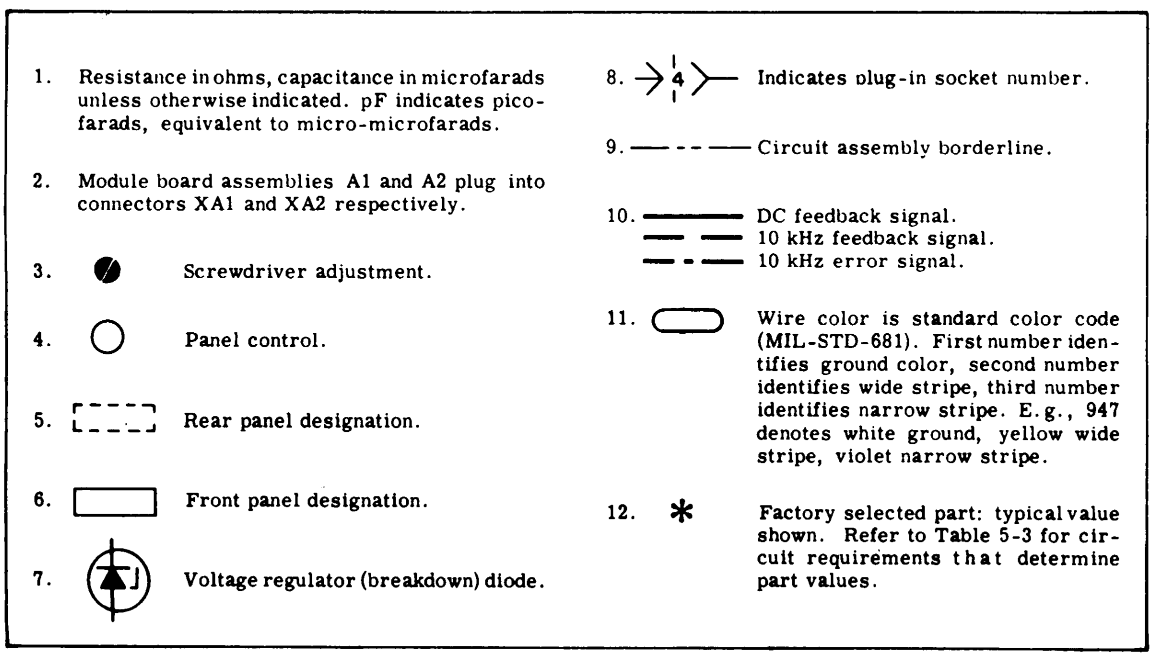

Figure 7-1. Schematic Diagram Notes

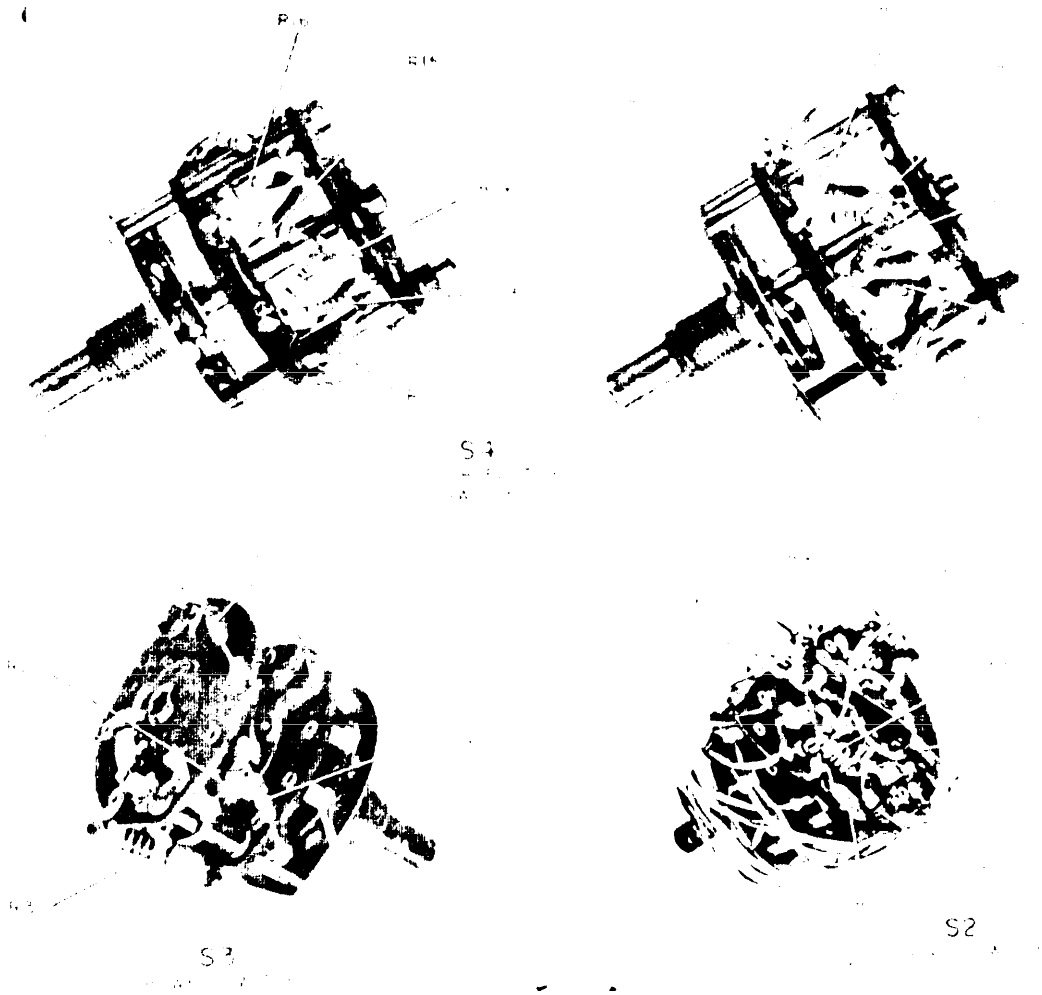

Figure 7-2. Switch Component Locations

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SECTION VIII
AUXILIARY EQUIPMENT

8-1. GENERAL

8-2. Auxiliary equipment extends the operation of the basic equipment, is not part of the basic equipment, and is not required for normal operation.

8-3. OPTION 01

8-4. The 431c Option 01 instrument consists of a standard Model 431C Power Meter with a rechargeable battery installed. A list of Option 01 component parts is given in Table 6-1. Instruction for installation of the battery is given in the following paragraph.

8.5. OPTION 01 INSTALLATION PROCEDURE.

a. Set POWER switch to LINE OFF and remove power plug from power meter.

b. Remove top and bottom instrument covers.

c. Refer to Figure 8-1 which shows the battery cover disassembled from the battery. Install the battery and battery cover from the bottom of the instrument into the top chassis. Note that the battery is installed so that the two battery terminals are toward the top and front of the instrument.

d. Secure the battery in place with four retaining nuts.

CAUTION

Be careful not to short the battery terminals; battery cell damage may result.

e. Solder a red wire (No. 22 gauge, stranded) between the positive battery terminal and circuit board connector XA2, pin Z.

f. Solder a black wire (No. 22 gauge, stranded) between the negative battery terminal and circuit board connector XA2, pin 1.

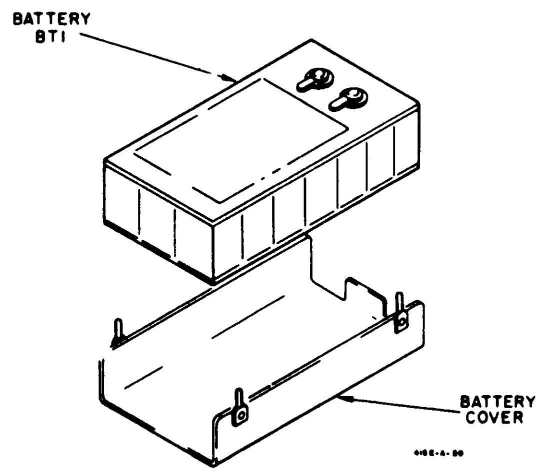

Figure 8-1. Battery and Battery Cover Assembly

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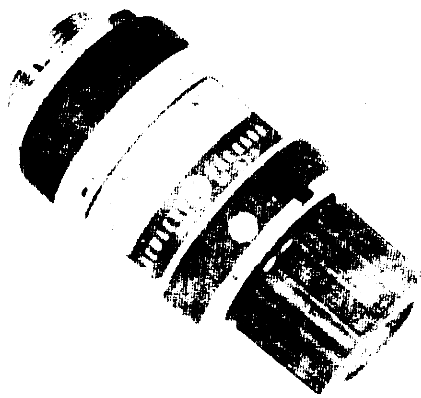

Figure 8-2. Model 478A Thermistor Mount

8-6. THERMISTOR MOUNT MODEL 478A

8-7. GENERAL INFORMATION

8-8. INTRODUCTION.

8-9. The Model 478A Coaxial Thermistor Mount is designed for use with Model 431 Power Meters to measure microwave power from 1 µw 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 8-41). The Model 478A can be used over the 10-Mc to 10-Gc frequency range. Throughout the range, the mount terminates the coaxial input in a 50-ohm impedance, and has an SWR of not more than 1.6 without external tuning.

8-10. Each mount contains two series pairs of thermistors, which are matched for cancellation of 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 that thermal noise or shocks applied externally to the mount, such as those from handling the mount manually, cannot significantly penetrate to disturb the thermistors. This thermal immunity enables the thermistors to be used in the measurement of microwave power down to the microwatt region.

Table 8-l. Specifications, Model 478A Thermistor Mount

Frequency Range:	10 Mc to 10 Gc
SWR: 10 to 25 Mc:	1.6, max
25 Mc to 7 Gc:	1.3, max
7 to 10 Gc:	1.5, max
Power Range:	1µw to 10 mw
Max Energy per pulse:	10 w-µs, PRF > 1kc 5 w-µs, PRF < 1kc
Elements:	Four permanently installed thermistors
Operating Resistance:	200 ohms ±1%
Efficiency Data:	Effective Efficiency and Calibration Factor furnished at six frequencies between 10 Mc and 10 Gc. Maximum uncertainty of data, ±(1% + uncertainty of reference standard*).
RF Connector:	Type N, male
Bridge Connector:	Mates with cable supplied with the Model 431 type Power Meters.
Dimensions:	2-13/16 in. long (72 mm), 1-3/8 in. (35 mm) maximum diameter.
Net Weight:	5 oz (140 grams)

* Directly traceable to the National Bureau of Standards at those frequencies at which the Bureau offers calibration service.

8-11. INCOMING INSPECTION.

8-12. 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 8-54.

8-13. If there is any damage or deficiency, refer to paragraph 1-A.3.

8-14. OPERATION

8-15. PRECAUTIONS.

8-16. MECHANICAL SHOCK.

8-17. DO NOT DROP OR SUJECT TO SEVERE MECHANICAL SHOCK. SHOCK MAY DESTROY THE MATCH BETWEEN THERMISTORS AND INCREASE SUSCEPTIBILITY TO DRIFT.

8-18. BIASING THERMISTORS.

CAUTION: Before connecting the Model 478A to Model 431 Power Meters, set 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.

8-19. **MAXIMUM INPUT.**

8-20. The Model 478A/431 combination responds 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.

8-21. AVERAGE POWER. The 478A/431 combination 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 Model 770 series (774D through 777D) between the mount and the source. UNDER NO CIRCUMSTANCES APPLY MORE THAN 30 MW AVERAGE TO THE MOUNT.

8-22. PULSE ENERGY AND PEAK POWER. In measuring pulse power, there is a limit on the energy per pulse which may be applied to the mount. For a pulse repetition frequency (PRF) less than 1 kc, energy per pulse can be up to 5 watt-µsec; for a PRF 1 kc and above, up to 10 watt-µsec (for lack of space, only the lower limit is shown on the mount name plate). However, this energy limit applies only to pulses shorter than 250 µsec. In Figure 8-3, the pulse energy limit is translated into a maximum power-meter reading for any PRF. For pulses in this category, allowable peak power is inversely proportional to pulse width but should never exceed 200 watts.

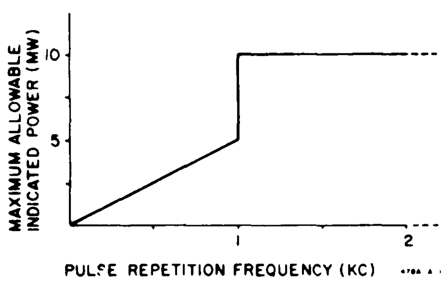

Figure 8-3. Maximum Power Meter Reading vs PRF for Pulses Shorter than 250 µsec

8-23. For pulses longer than 250 psec, the peak limitation can be expressed in terms of PRF: 10 mw for a PRF below 1 kc, 40 mw for a PRF 1 kc or above, provided 30 mw average is not exceeded. In Figure 8-4, the peak power limit is translated into power-meter reading versus duty cycle.

8-24. Square -wave modulation is a special case of pulse modulation, and maximum power-meter reading versus square-wave frequency is illustrated in Figure 8-5. This figure also holds for sine-wave modulation.

8-25. In the discussions above, the primary consideration is maximum power or energy. However, for modulation frequencies less than 100 cps, the low

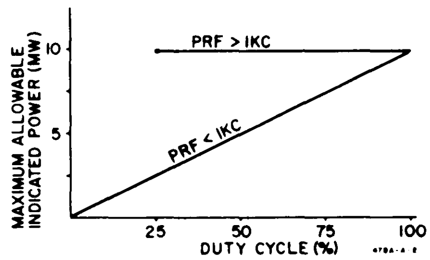

Figure 8-4. Maximum Power Meter Reading vs Duty Cycle for Pulses Longer than 250 µsec

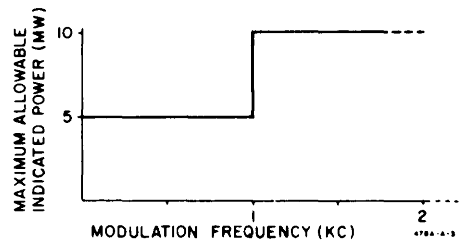

Figure 8-5. Maximum Power Meter Reading vs Square and Sine-Wave Frequency

repetition frequency itself causes errors in indicated power. These errors may be as large as 2% regardless of range or reading.

8-26. When RF is switched by pulse-gating (coaxial solid state switches), consideration must be given to RF energy contained in the switching pulse itself. And this energy must be added to actual RF pulse power when estimating the RF power dissipated in the thermister count. PIN diode modulators of Model 8714A 8716A Modulators and 8614A/8616A Signal Generators, however, are not subject to this consideration because output filtering prevents transmission of modulating signals.

8-27 T. DRIFT PRECAUTION:

8-28. 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 EQUIPMENT CONNECTED TO IT ARE AT NEARLY THE SAME TEMPERATURE BEFORE MAKING A MEASUREMENT.

8-29. RESPONSE TO DC (POLARIZATION EFFECT).

8-30. When a DC current is applied to a thermistor, the power apparently dissipated (as indicated by the power meter when the thermistor is part of a power-measuring bridge) will be slightly different from the power found by calculating I^2R, and the magnitude of this small difference between apparent and actual power will change with a reversal of current-flow through the thermistor. This behavior of the thermistor is called the polarization effect. Maximum error introduced by polarization effect is about 0.3µw, and typically this error will be only 0.1 µw. Except on the three lowest ranges of the Model 431A/B, therefore, polarization error is insignificant. To determine the polarization-effect correction factor for any given thermistor, apply a known low-level DC power, such as 10 µw, to the Model 431A/B DC Calibration & Substitution terminals, and take a reading (P_{DCa}); reverse connection between power source and Model 431A/B to get a reverse in current flow, and again take a reading (P_{DCb}). Assuming that, under measurement conditions, current-flow will have the direction it had when reading P_{DCa} was made, subtract P_{DCa} from P_{DCb} and divide the difference by two; this is the polarization-effect correction factor. Step-by-step instructions for determining and applying this correction factor are given in the manual for the ⊕ Model 8402A Power Meter Calibrator.

8-31. ZERO-SET.

8-32. It is necessary to electrically zero-set the Model 431A/B 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 setups for zero-set are presented below:

8-33. RF POWER TURNED OFF FOR ZERO-SET.

8-34. There is minimum zero drift when the zero is set with the RF system connected to the thermistor mount and the RF power switched off or greatly attenuated by the generator attenuator. After allowing time for the mount to stabilize thermally, follow the steps for zero-set described in the Model 431 Power Meter manual, and then turn on the RF source.

8-35. The several methods used in the ⊕ signal generators to switch off the RF output are listed in Table 8-2.

8-36. THERMISTOR MOUNT DISCONNECTED FOR ZERO-SET.

8-37. 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 reaing. When the reading no longer drifts, disconnect the mount from the source, immediately terminate the mount, if necessary, as described in Paragraph 8-38 and then immediately zero-set the power meter. Immediately reconnect the mount to the RF source for the power measurement.

8-38. With the Model 478A mount connected to the RF system, the source impedance shunts one of the RF thermistors (see Figure 8-6); 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-kc 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 kc; the termination should be connected while the mount is disconnected (see Paragraph 8-37) from the source. For example, if the impedance presented by the RF system to 10 kc 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 kc is high (100K ohms or more) leave the thermistor mount unterminated during zero-set.

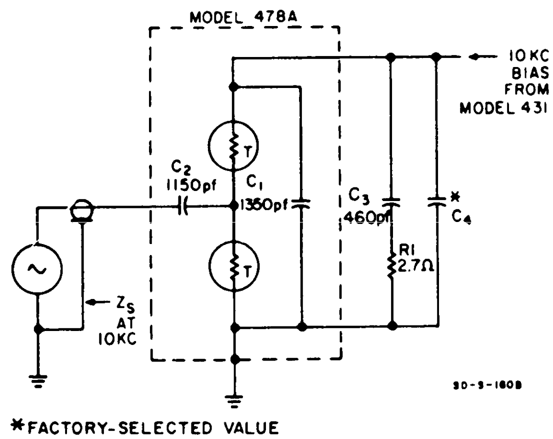

Figure 8-6. Source Impedance Shunting One RF Thermistor

Table 8-2. Methods of Switching Off RF Output of Various Signal Generators.

⊕ Generator	Frequency Range	Procedure to Switch Off RF Output
Model 606A	50 kc to 65 Mc	Increase the generator output attenuation 30 or more db
Model 8614A/8616A Model 614A/616B Model 618B/620A	800 to 2400 Mc/1800 to 4500 Mc 800 to 2100 Mc/1800 to 4200 Mc 3.8 to 7.6 Gc/7 to 11 Gc	Release RF pushbutton Set modulation selector to OFF Set modulation selector to OFF
Model 608C/D Model 682C/687C	10 to 480 Mc/10 to 420 Mc 1 to 2 Gc/12.4 to 18.0 Gc	Set MOD SELECTOR to PULSE, but do not apply modulation signal to modulation input terminal
Model 612A	450 to 1230 Mc	Set MOD SELECTOR to PULSE 2, but do not apply modulation signal to modulation input terminal

Note

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

8-39. Note that some 10-kc bias signal is coupled into the RF transmission system by C2 (Figure 8-7). If the RF source output impedance at 10 kc is 15K ohms or greater, 10-kc bias voltage is typically 1.3v RMS and could equal 1.5v RMS. For an RF source output impedance of 50 ohms at 10 kc, bias signal voltage is typically 5 mv RMS.

8-40. The presence of this 10-kc 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

8-41. <u>CALIBRATION DATA.</u>

8-42. The calibration points stamped on the label of each 478A permit increased accuracy in measurement results. Both Calibration Factor and Effective Efficiency are shown at specific frequencies, and the mounts are tested on a swept- frequency basis to assure the interpolation between points is valid. Effective Efficiency and Calibration Factor values are traceable to the National Bureau of Standards to the extent allowed by the Bureau's calibration facilities.

8-43. EFFECTIVE EFFICIENCY. Effective Efficiency is the ratio of DC substituted power in the mount to absorbed RF power. This is a measure of the power which is absorbed in parts of the mount other than the thermistor, and errors due to imperfect substitution of DC for RF power. Effective Efficiency is used as a correction factor when a tuner is included in the circuit to match the mount to the line. Divide the measured power by the Effective Efficiency factor to obtain corrected power.

8-44. CALIBRATION FACTOR. Calibration Factor is the ratio of DC substituted power to power incident on the mount. This factor therefore includes the effect of mismatch loss. If the source has low SWR and no tuner is used, divide the measured power by the Calibration Factor to obtain corrected power. If the source SWR is not low, there is a region of ambiguity in the result obtained.

8-45. OPERATING PRINCIPLES

3-46 <u>CIRCUIT DESCRIPTION.</u>

3-47 Two matched series thermistor pairs are mounted on a common thermal conducting block, represented by the shaded rectangle in Figure 8-7. One pair, marked D for detection, is mounted between the end of a coaxial cable and a cylindrical cavity. These thermistors are exposed to incoming RF power which heats them, lowering their resistances. The other pair, marked C for compensation and situated immediately outside the cavity, is completely shielded from RF. With the Model 478A attached to a Model 431 Power Meter, the detection thermistors are part of the RF bridge and the compensation thermistors are part of the metering bridge. Since the two pairs of thermistors share the same thermal environment, any change in temperature which affects the RF bridge simultaneously affects the metering bridge, thereby allowing the power meter circuit to compensate for changes in temperature, and thus to minimize drift.

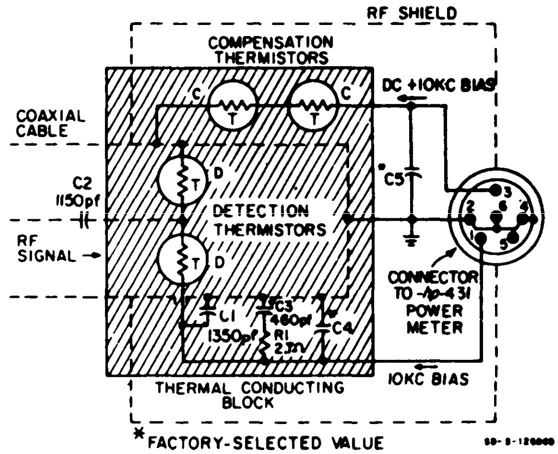

Figure 8-7. Schematic Diagram Model 478A Thermistor Mount

8-48. During operation, sufficient amounts of DC and 10-kc bias currents are supplied from the Model 431 Power Meter to heat the thermistors until their resistances are reduced to approximately 200 ohms per series pair. Capacitor C1 offers high impedance to 10 kc, but is practically a short to RF. This causes D to appear series-connected to 10 kc, but parallel-connected to RF. In this manner, D appears to the audio bridge of the Model 431 Power Meter as a 200-ohm resistance, but terminates the coaxial cable in 50 ohms. Capacitor C2 blocks any DC and audio power that might be present in the incoming signal, and passes only RF power.

8-49. <u>POWER DETECTION.</u>

8-50. Under normal operation, the total power supplied to heat thermistor pair D (see Figure 8-7) consists of: 1) RF signal, 2) lo-kc bias, and 3) heat from the environment. The total power supplied to heat thermistor pair C consists of: 1) DC bias, 2) an equal amount of lo-kc 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 resistances equally must be equal. Restating the foregoing algebraically: under normal operation

$$P_{\text{total to } D} = P_{\text{total to } C}$$

$$P_{\text{total to } D} = P_{\text{RF to } D} + P_{\text{10 kc to } D} + P_{\text{env heat to } D}$$

and

$$P_{\text{total to } C} = P_{\text{DC to } C} + P_{\text{10 kc to } C} + P_{\text{env heat to } C}$$

Since the thermistors are mounted on the same thermal block,

$$P_{\text{env heat to D}} = P_{\text{env heat to C}}$$

and since

$$P_{\text{10 kc to D}} \text{ is made } = P_{\text{10 kc to C}}$$

this leaves

$$P_{\text{RF to D}} = P_{\text{DC to C}}$$

$P_{\text{DC to C}}$ is monitored by the Model 431 Power Meter.

8-51. MAINTENANCE

8-52. MECHANICAL SHOCK.

8-53. The Model 478A is a precision instrument. Avoid dropping or other mechanical shocks. Such shocks can destroy the match between the thermistors.

8-54. CHECK ON THERMISTOR MATCH.

8-55. Match between the thermistors may be checked by comparing the thermistor resistances under simulated operating conditions. Equipment required is indicated in Figure 8-8. Make connections to the connector at the rear of the thermistor mount; pins are shown in Figure 8-8. Note that the small battery in series with the Ⓗ Model 405 Digital Voltmeter is connected in opposition 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 .030 volt. Non-operating mounts with readings as high as' 0.150 volt can probably be repaired as outlined in the succeeding paragraphs.

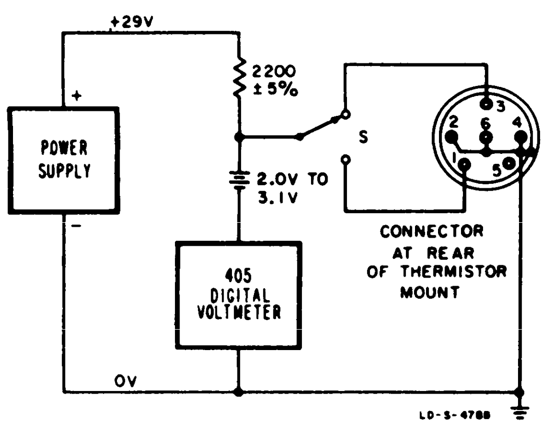

Figure 8-8. Check on Model 478A Thermistor Resistance Match

8-56. REPAIR.

8-57. Exceeding the CW or pulse power limits of the Model 478A Thermistor Mount may result in damage so that the mount will no longer zero on the Model 431 Power Meter.

8-58. 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 Paragraph 8-55 or 8-61, means that the mount is not repairable by the procedure outlined in the following paragraphs. However, the mount may be non-operative, but still repairable. Test for this by using the procedure in Paragraph 8-55, or by connecting the mount to a Model 431 and cable which are known to be good. A faulty cable will not have continuity through the respective connector pins, or may have poor contact at the mount connector. Poor contact will show up as intermittence or a great deal of noise (visible on the 431 meter) when the cable is gently flexed near the connector end.

8-59. To troubleshoot a damaged mount, proceed as follows:

a. Connect mount to Model 431.

b. Set: MOUNT RES . . . 200 ohm
RANGE . . . . . .10 MW
POWER . . . . AC

c. Rotate coarse ZERO from one limit to the other.

8-6o. If meter remains pegged upscale, the thermistor elements have been damaged. However, it may be possible to recompensate the thermistors per Paragraphs 8-63 and 8-65 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.

8-61. 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.

WARNING

Under no conditions should the mount be required to carry a current htgher than 10 ma.

8-62. 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. 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.

8-63. Refer to Figure 8-9, 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 . . . . AC

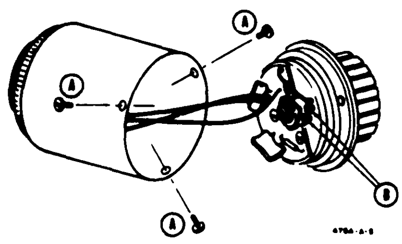

Figure 8-9, Thermistor Compensation

8-64. If meter is pegged downscale:

a. Set RANGE to 10 MW.

b. Set coarse 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 8-61. If either screw bottoms, do not apply force. Thermistor replacement (Paragraph 8-66) 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.

8-65. If meter is pegged upscale:

a. Set coarse 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 8-66).

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

8-66. 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.

8-67. The procedure consists of removing the damaged thermistor assembly, the printed circuit assembly, and replacing them with pretested assemblies included in Thermistor Assembly Replacement Kit, Stock No. 00478-600.

8-68. 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 VSWR and efficiency following replacement. The efficiency may be checked by comparing against a known mount. The VSWR is checked at 9 Gc and 10 Gc. VSWR should be approximately equal at 9 Gc and 10 Gc 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, VSWR will be about 2.0 at 10 Cc. The bellows may be lengthened slightly with a pair of tweezers.

8-69. The following special tools may be required [or the completion of this procedure:

a. One small screwdriver, .070 tip, suitable for removing a 00-90 x 1/8 screw.

b. One pair of tweezers.

Table 8-3. Parts Furnished in Thermistor Assembly Replacement Kit, 00478-600

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

8-70. REMOVAL PROCEDURE

a. Remove three 2-56 x 3/16 screws holding Terminal Shield (Figure 8-11). Move Terminal Shield aside.

CAUTION

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

b. Loosen locknut and remove 5/16-32 set screw 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.

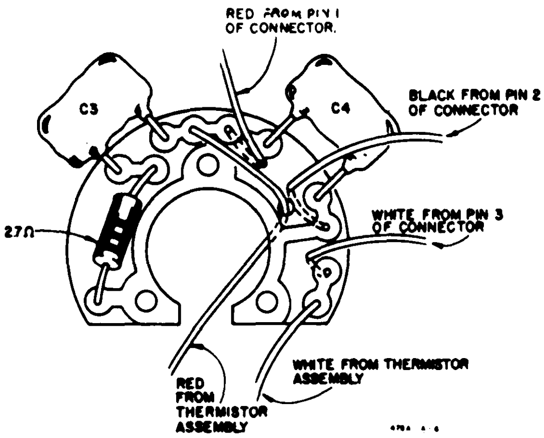

Figure 8-10, Model 478A Printed Circuit Assy Wiring

8-71. INSTALLATION PROCEDURE

a. Referring to Figure 8-10, 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 8-10. 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 tires from Thermistor Assembly to printed circuit assembly.

f. Connect Thermistor Mount to an ⓗ Model 431. Check for proper null and zero.

g. If desired, check VSWR and efficiency. The Mount VSWR has been adjusted at the factory to be about equal at 9 Gc. and 10 Gc. and less than 1.5. The adjustment is made with the 5/16-23 set screw which is secured by a lock nut. The set screw should not be moved unless VSWR 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.

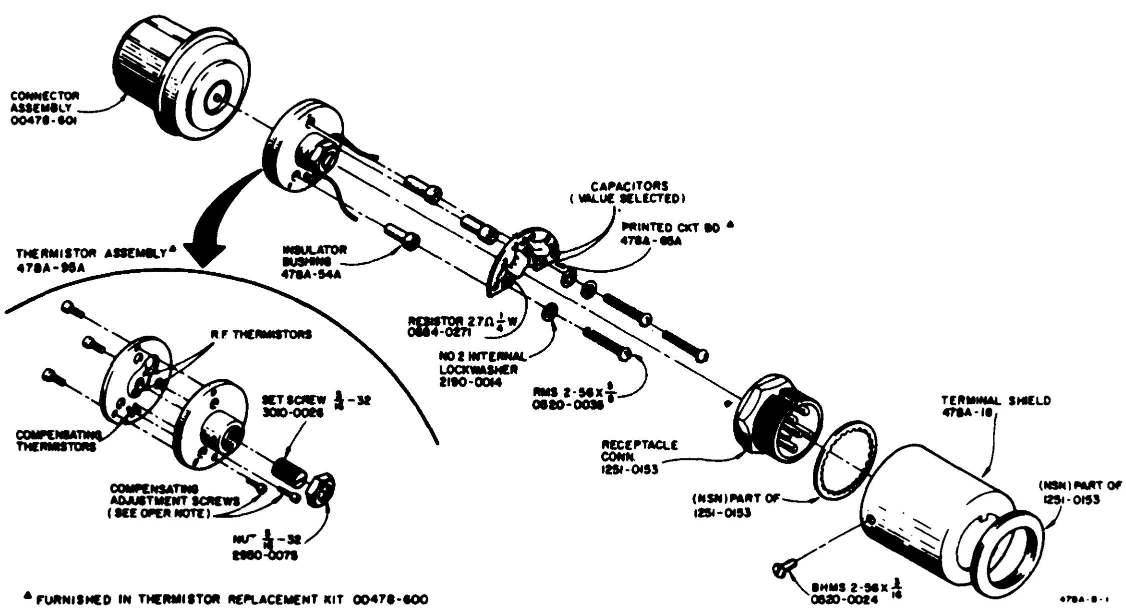

Figure 8-11. Model 478A Thermistor Mount Assembly

APPENDIX A
MAINTENANCE ALLOCATION

Section I. INTRODUCTION

A-1. General

This appendix provides a summary of the maintenance operations for Test Set, Radio Frequency Power AN/USM-260. It authorizes categories of maintenance for specific maintenance functions on repairable items and components and the tools and equipment required to perform each function. This appendix may be used as an aid in planning maintenance operations.

A-2. Maintenance Function

Maintenance functions will be limited to and defined as follows:

a. Inspect. To determine the serviceability of an item by comparing its physical, mechanical, and/or electrical characteristics with established standards through examination.

b. Test. To verify serviceability and to detect incipient failure by measuring the mechanical or electrical characteristics of an item and comparing those characteristics with prescribed standards.

c. Service. Operations required periodically to keep an item in proper operating condition, i.e., to clean (decontaminate), to preserve, to drain, to paint, or to replenish fuel, lubricants, hydraulic fluids, or compressed air supplies.

d. Adjust. To maintain, within prescribed limits, by bringing into proper or exact position, or by setting the operating characteristics to the specified parameters.

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

f. Calibrate. To determine and cause corrections to be made or to be adjusted on instruments or test measuring and diagnostic equipments used in precision measurement. Consists of comparisons 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.

g. Install. The act of emplacing, seating, or fixing into position an item, part, module (component or assembly) in a manner to allow the proper functioning of the equipment or system.

h. Replace. The act of substituting a serviceable like type part, subassembly, or module (component or assembly) for an unserviceable counterpart.

i. Repair. The application of maintenance services (inspect, test, service, adjust, align, calibrate, replace) or other maintenance actions (welding, grinding, riveting, straightening, facing, remachining, or resurfacing) to restore serviceability to an item by correcting specific damage, fault, malfunction, or failure in a part, subassembly, module (component or assembly), end item, or system. This function does not include the trial and error replacement of running spare type items such as fuses, lamps, or electron tubes.

j. Overhaul. That maintenance effort (service/action) necessary to restore an item to a completely serviceable/operational condition as prescribed by maintenance standards (i.e., DMR) in appropriate technical publications. Overhaul is normally the highest degree of maintenance performed by the Army. Overhaul does not normally return an item to like new condition.

k. Rebuild. Consists of those services/actions necessary for the restoration of unserviceable equipment to a like new condition in accordance with original manufacturing standards. Rebuild is the highest degree of materiel maintenance applied to Army equipment. The rebuild operation includes the act of returning to zero those age measurements (hours, miles, etc.) considered in classifying Army equipments/components.

A-3. Column Entries

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, Compment/Assembly. Column 2 contains the noun names of components, assemblies, subassemblies, and modules for which maintenance is authorized.

c. Column 3, Maintenance Functions. Column 3 lists the functions to be performed on the item listed in column 2. When items are listed without maintenance functions, it is solely for purpose of having the group numbers in the MAC and RPSTL coincide.

d. Column 4, Maintenance Category. Column 4 specifies, by the listing of a "work time" figure in the appropriate subcolumn(s), the lowest level of maintenance authorized to perform the function listed in column 3. This figure represents the active time required to perform that maintenance function at the indicated category of maintenance. If the number or complexity of the tasks within the listed maintenance function vary at different maintenance categories, appropriate "work time" figures will be shown for each category. The number of task-hours specified by the "work time" figure represents the average time required to restore an item (assembly, subassembly, component, module, end item or system) to a serviceable condition under typical field operating conditions. This time includes preparation time, troubleshooting time, and quality assurance/quality control time in addition to the time required to perform the specific tasks identified for the maintenance functions authorized in the maintenance allocation chart. Subcolumns of column 4 are as follows:

C — Operator/Crew
O — Organizational
F — Direct Support
H — General Support
D — Depot

e. Column 5, Tools and Equipment. Column 5 specifies by code, those common tool sets (not individual tools) and special tools, test, and sup port equipment required to perform the designated function.

f. Column 6, Remarks. Column 6 contains an alphabetic code which leads to the remark in section IV, Remarks, which is pertinent to the item opposite the particular code.

A-4. Tool and Test Equipment Requirements (Sec. III)

a. Tool or Test Equipment Reference Code. The numbers in this column coincide with the numbers used in the tools and equipment column of the MAC. The numbers indicate the applicable tool or test equipment for the maintenance functions.

b. Maintenance Category. The codes in this column indicate the maintenance category allocated the tool or test equipment.

c. Nomenclature. This column lists the noun name and nomenclature of the tools and test equipment required to perform the maintenance functions.

d. National/NATO Stock Number. This column lists the National/NATO stock number of the specific tool or test equipment.

e. Tool Number. This column lists the manufacturer's part number of the tool followed by the Federal Supply Code for manufacturers (5 digit) in parentheses.

A-5. Remarks

a. Reference Code. This code refers to the appropriate item in section II, column 6.

b. Remarks. This column provides the required explanatory information necessary to clarify items appearing in section II.

SECTION II MAINTENANCE ALLOCATION CHART
FOR
TEST SET, RADIO FREQUENCY POWER AN/USM-260

(1) GROUP NUMBER	(2) COMPONENT/ASSEMBLY	(3) MAINTENANCE FUNCTION	(4) MAINTENANCE CATEGORY C	O	F	H	D	(5) TOOLS AND EQPT.	(6) REMARKS
00	TEST SET, RADIO FREQUENCY POWER AN/USM-260	Inspect Test		0.2 0.3				Visual 1 thru 9	
		Test				0.8		1 thru 10	
		Service Adjust		0.4		 0.5		9 1 thru 9	
		Repair		0.2				1 thru 9	
		Repair				0.6		1 thru 10	
		Overhaul				2.0		1 thru 9	
01	TEST SET, RADIO FREQUENCY POWER TS-2557/U	Inspect Service Adjust		0.2 0.4		 0.5		Visual 9 1 thru 9	
		Repair		0.2				1 thru 9	
		Repair				0.6		1 thru 10	
		Overhaul				2.0		1 thru 10	
02	POWER CABLE CX-10546/U	Inspect Replace		0.1 0.1				Visual 9	
03	POWER CABLE CX-10547/U	Inspect Replace		0.1 0.1				Visual 9	

SECTION III. TOOL AND TEST EQUIPMENT REQUIREMENTS
FOR
TEST SET, RADIO FREQUENCY AN/USM-260

TOOL OR TEST EQUIPMENT REF CODE	MAINTENANCE CATEGORY	NOMENCLATURE	NATIONAL/NATO STOCK NUMBER	TOOL NUMBER
1	H,D	D.C. POWER SOURCE AN/USM-317	6625-00-706-7645	
2	H,D	ELECTRONIC COUNTER AN/USM-207	6625-00-911-6368	
3	H,D	MULTIMETER ME-26D/U	6625-00-913-9781	
4	H,D	A.C. VOLTMETER ME-260( )/U	6625-00-965-1534	
5	H,D	OSCILLOSCOPE AN/USM-281(A)	6625-00-228-2201	
6	H,D	TEST SET, RADIO FREQUENCY POWER AN/USM-161	6625-00-892-5541	
7	H,D	DECADE CAPACITOR ZM-59/U	6625-00-935-1469	
8	H,D	SIGNAL GENERATOR SG-377( )/URM-127	6625-00-783-5965	
9	O	TOOLS AND EQUIPMENT AVAILABLE TO REPAIR TECHNICIAN BECAUSE OF HIS/HER ASSIGNED MISSION.		
10	H,D	TOOLS AND TEST EQUIPMENT MOUNTED IN AN/TSM-55(V)		

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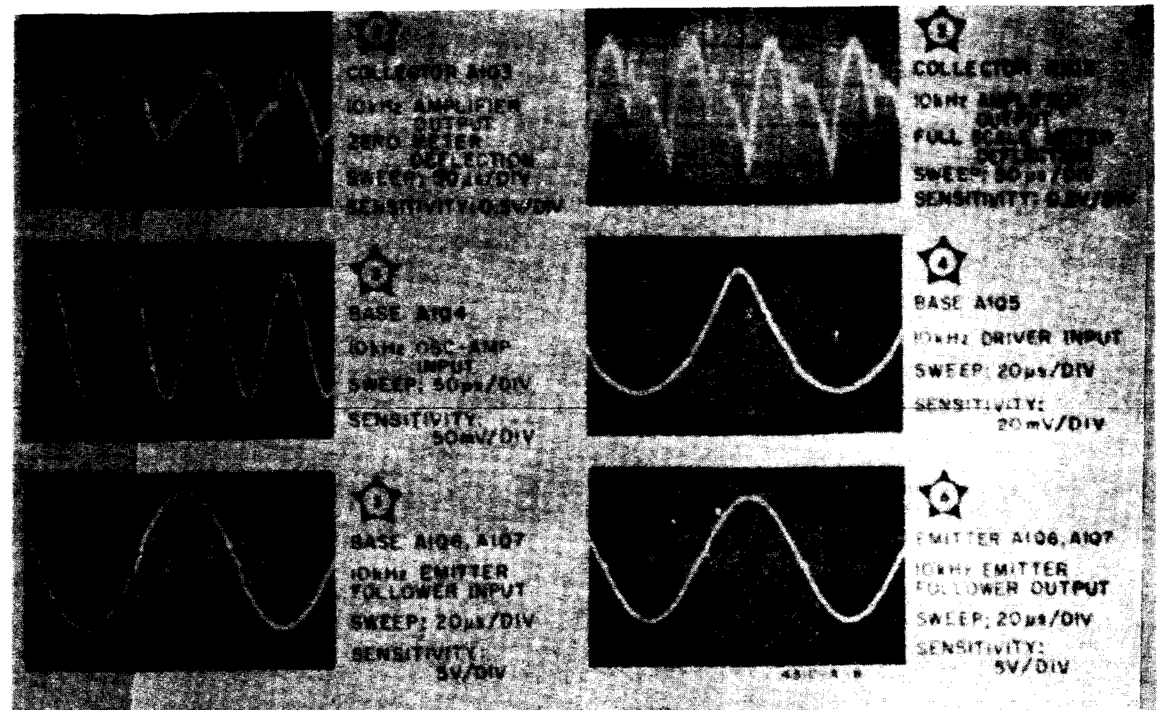


Figure 7-3. Assembly A1 Waveforms

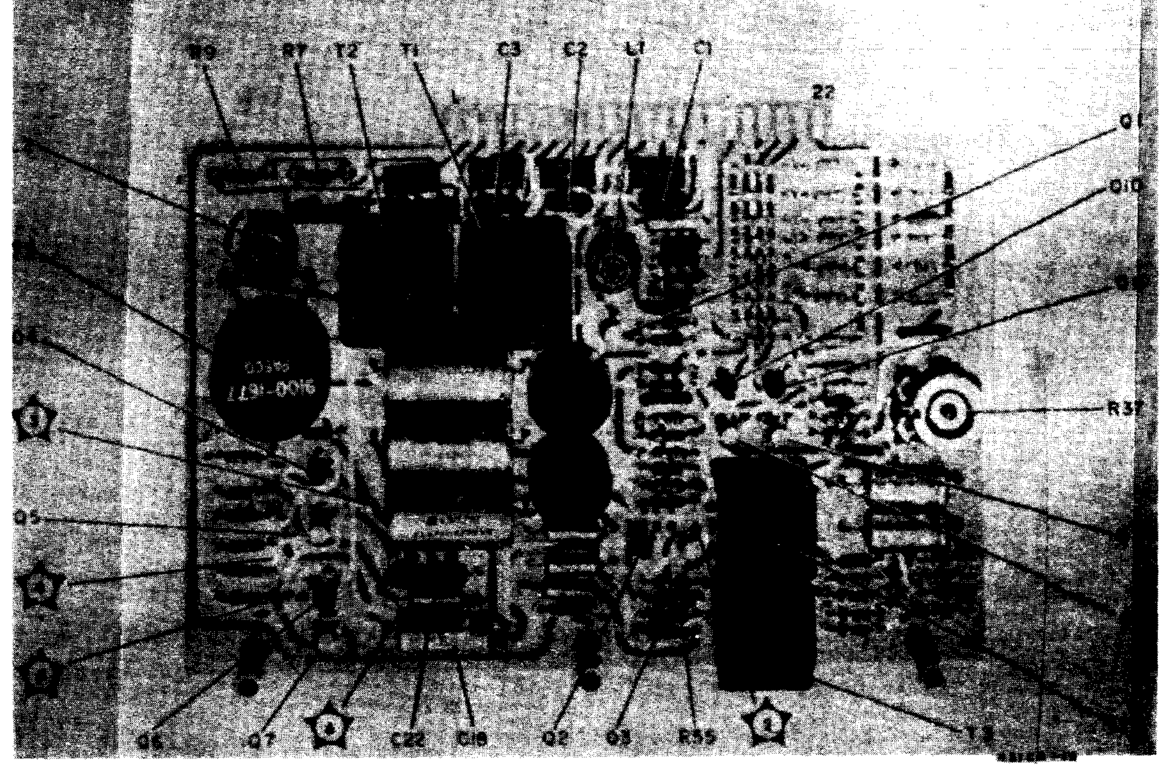
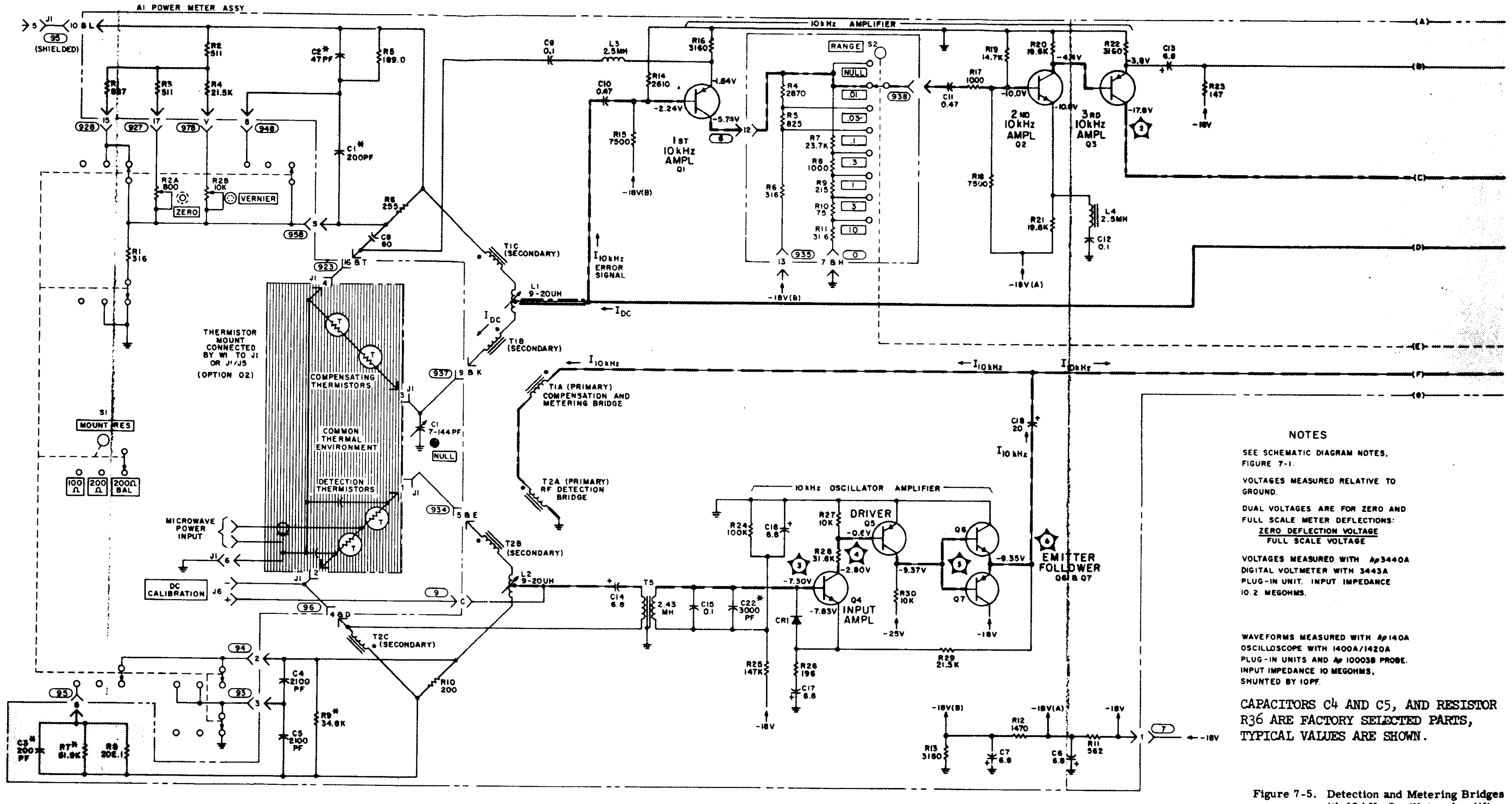


Figure 7-4. Power Meter Assembly A1



NOTES

SEE SCHEMATIC DIAGRAM NOTES, FIGURE 7-1.

VOLTAGES MEASURED RELATIVE TO GROUND.

DUAL VOLTAGES ARE FOR ZERO AND FULL SCALE METER DEFLECTIONS: $\frac{\text{ZERO DEFLECTION VOLTAGE}}{\text{FULL SCALE VOLTAGE}}$

VOLTAGES MEASURED WITH hp3440A DIGITAL VOLTMETER WITH 3443A PLUG-IN UNIT. INPUT IMPEDANCE 10.2 MEGOHMS.

WAVEFORMS MEASURED WITH hp140A OSCILLOSCOPE WITH 1400A/1420A PLUG-IN UNITS AND hp 10003B PROBE. INPUT IMPEDANCE 10 MEGOHMS, SHUNTED BY 10PF.

CAPACITORS C4 AND C5, AND RESISTOR R36 ARE FACTORY SELECTED PARTS, TYPICAL VALUES ARE SHOWN.

Figure 7-5. Detection and Metering Bridges with 10 kHz Oscillator Amplifier and 10 kHz Amplifier

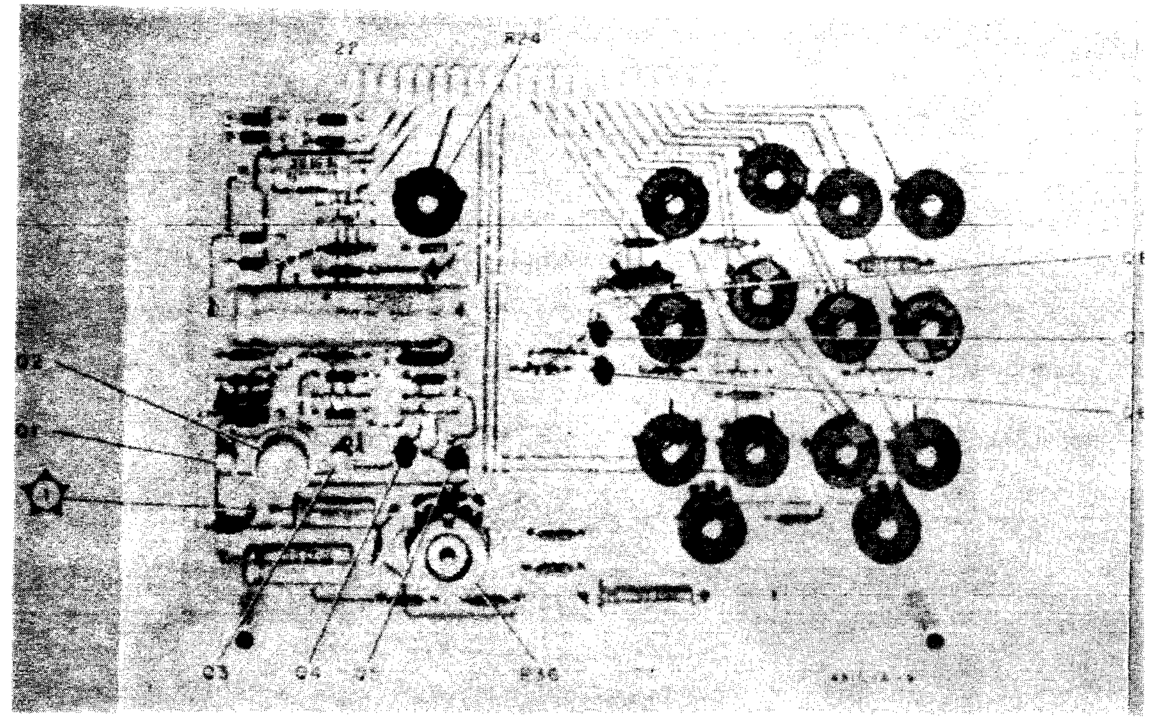
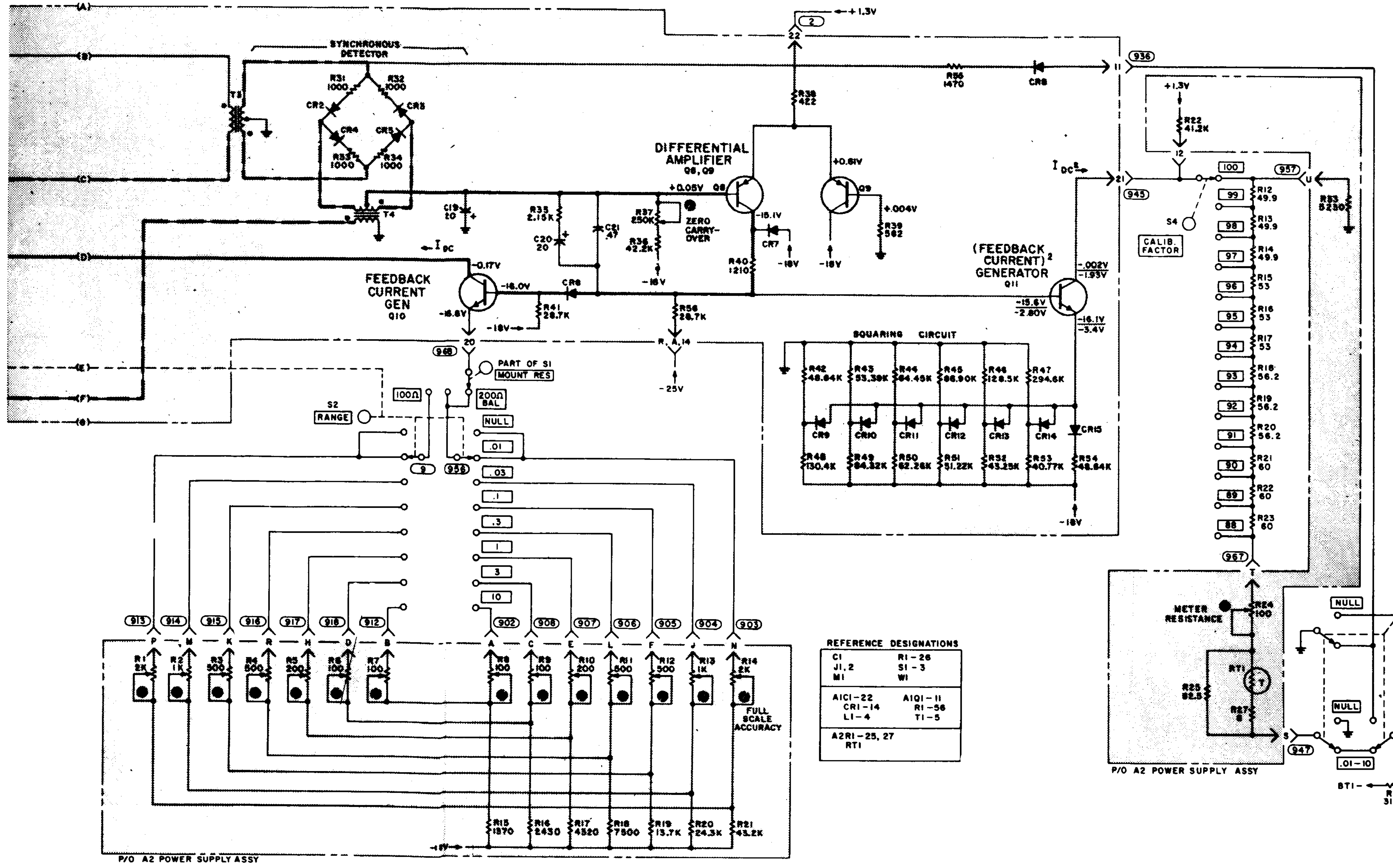


Figure 7-6. Power Supply Assembly A2



NOTE

CAPACITORS C4 AND C5, RESISTOR R36 ARE FACTORY SELECTED PARTS, TYPICAL VALUES ARE SHOWN.

Figure 7-7. Synchronous Detector, Feedback and Metering Circuits

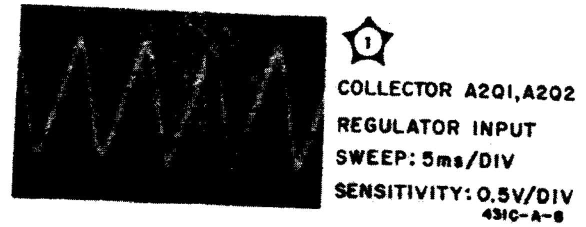


Figure 7-8. Power Supply Waveform

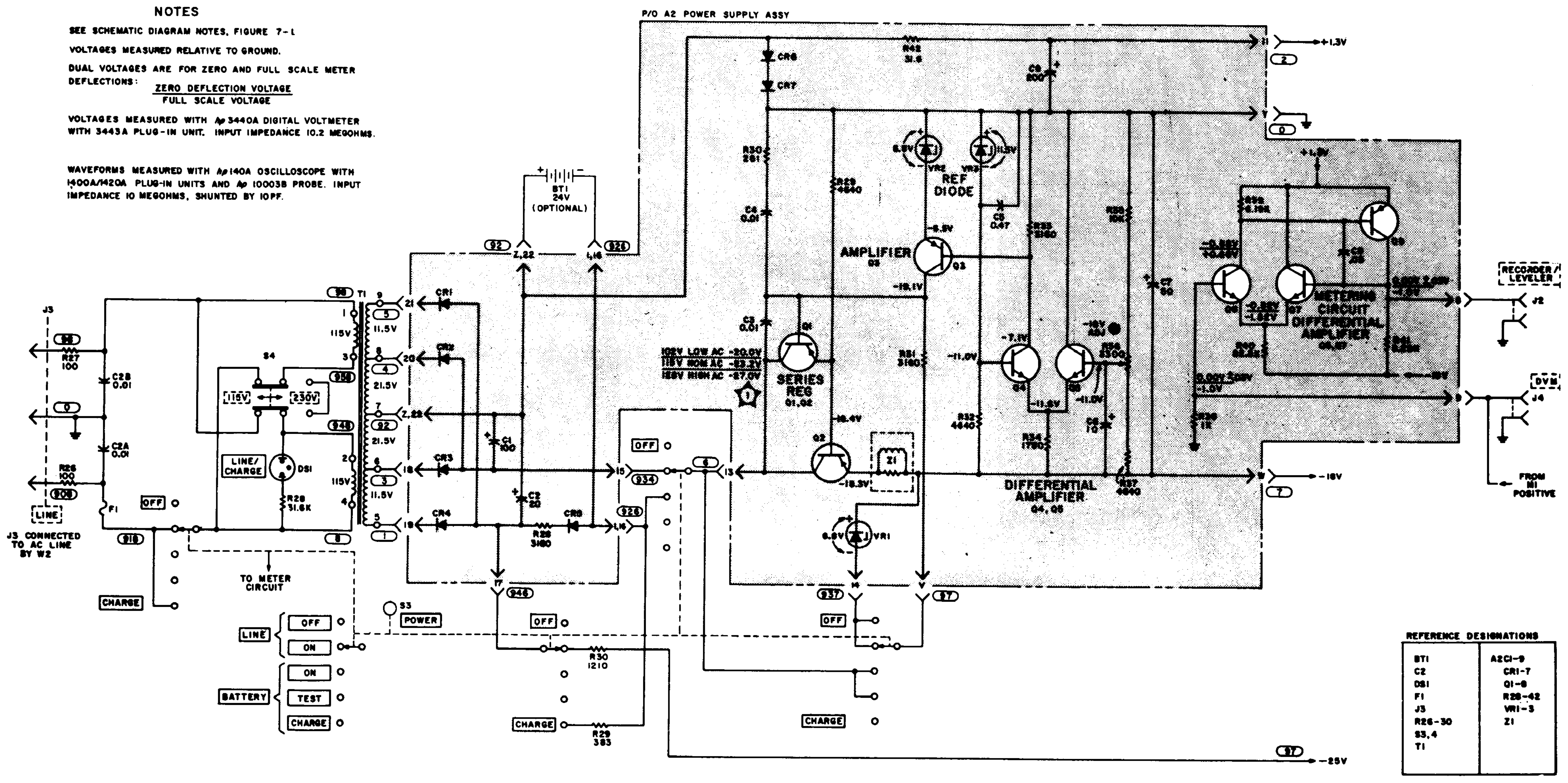


Figure 7-9. Power Supply and Metering Output

By Order of the Secretary of the Army:

HAROLD K. JOHNSON,
General, United States Army,
Chief of Staff.

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

Distribution:
Active Army:
USAMB (1)
USACDCEC (1)
USACDCCEA (1)
USACDCCEA:
Ft Huachuca (1)
Eighth USA (6)
SAAD (5)
TOAD (5)
LEAD (3)
NG: None.
USAR : None.
For explanation of abbreviations used, see AR 320-50.

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