OPERATING AND SERVICE MANUAL

MODEL 431C
POWER METER

SERIALS PREFIXED: 707-, 747

For instruments with serials prefixed 548, 618, 643, 648, and 651, see Manual prefixed 648.

1501 PAGE MILL ROAD, PALO ALTO, CALIFORNIA, U.S.A.

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SECTION I
GENERAL INFORMATION

1-1. DESCRIPTION

1-2. The Hewlett-Packard Model 431C Power Meter, with hp temperature-compensated thermistor mounts, measures RF power from 10 microwatts (-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 431C 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.

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:

+20°C to +35°C:

±1% (100 μW range and above)
±1.5% (30 μW range)
±2% (10 μW range)

0°C to +55°C:

±3% (all ranges)

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 1% of full scale when zeroed on most sensitive range.

Zero Balance: Continuous control about zero point.

DVM Output: 1.000V into open circuit corresponds to full scale meter deflection (1.0 on 0-1 scale) ±0.5%; 1 KΩ output impedance, BNC female connector; effect of loading impedance less than 10 MΩ must be accounted for.

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 115 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 size 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		
8478B		10 MHz to 18 GHz	200
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 Table 5-2. If there is any damage or deficiency, or if electrical performance is not within specifications, notify the carrier and your nearest Hewlett-Packard Sales and Service Office immediately.

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 1051A 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

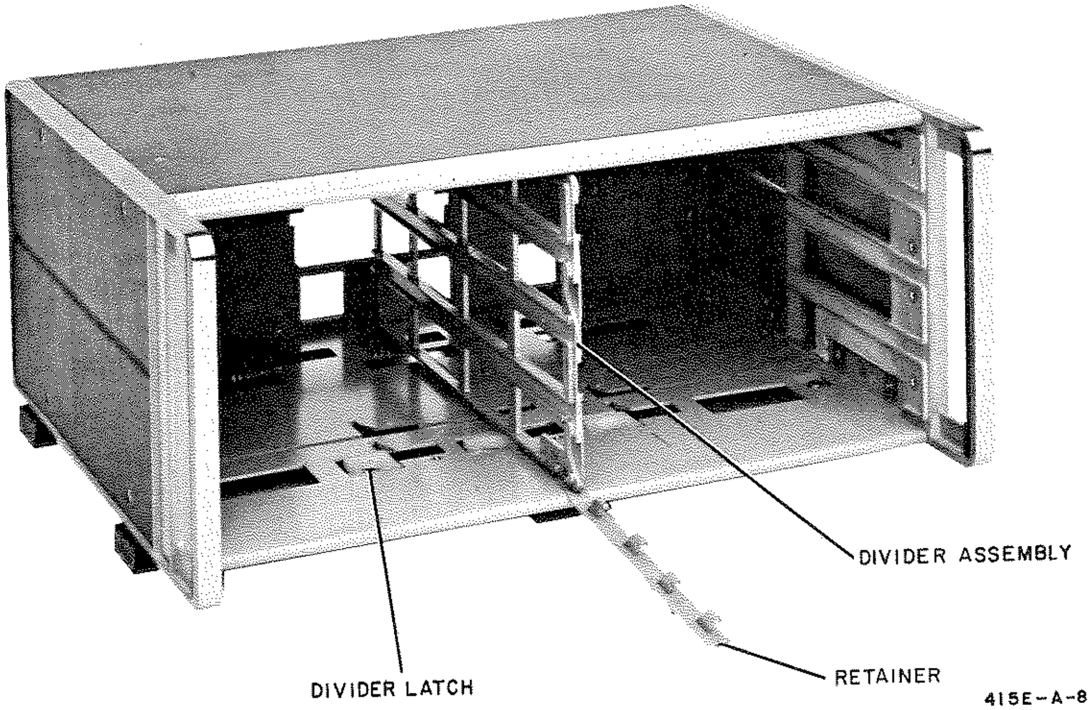


Figure 2-1. The Combining Case

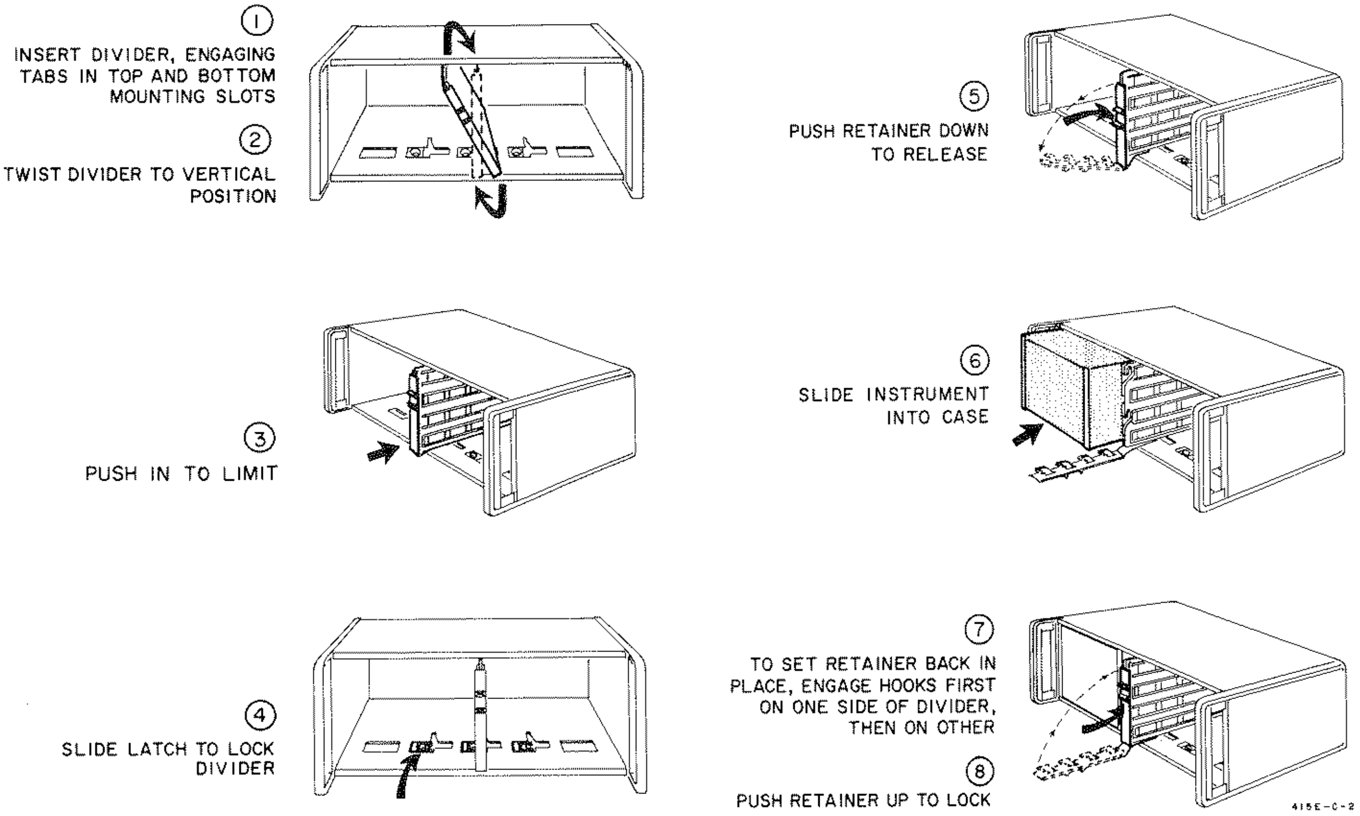


Figure 2-2. Steps to Place Instrument in Combining Case

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 power cord to the service outlet.

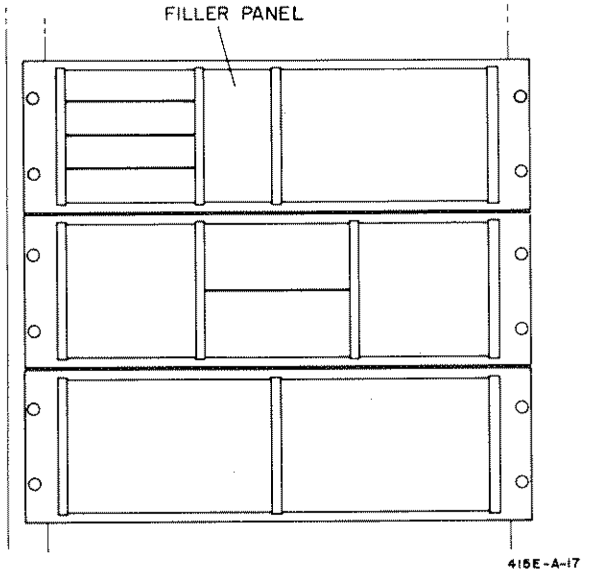


Figure 2-3. Adapter Frame Instrument Combinations

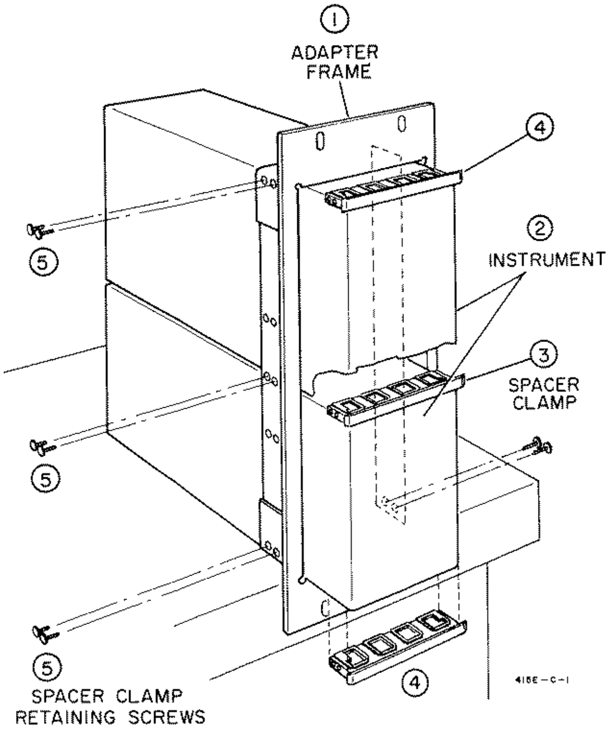
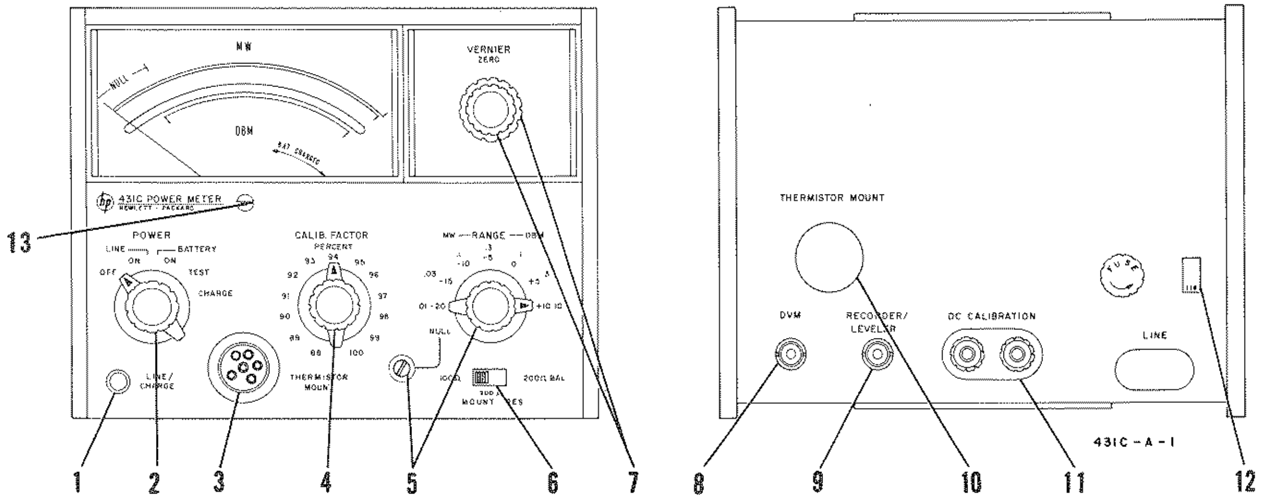


Figure 2-4. Two Half Modules in Rack Adapter

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 charge 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. A BNC type jack providing an output voltage linearly proportional to the meter indication. A DC voltmeter with an input impedance less than 10 M 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.

13. Mechanically zeroes meter. Refer to Figure 3-8.

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. A discussion of microwave power measurement with emphasis on modern techniques, accuracy considerations and sources of error is available in Application Note 64, available from any Hewlett-Packard Sales and Service Office.

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 8478B and 478A Coaxial and 486A Waveguide series. Power may be measured with these mounts in 50-ohm coaxial systems from 10 MHz to 18 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 ± 1% . 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 8478B, 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.

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 100Ω or 200Ω position, depending on the microwave band used (refer to Table 1-2). The 200Ω position is used with Model 478A thermistor mounts and the 200Ω BAL position is used with a balanced thermistor mount such as the 8478B.

CAUTION

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

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 option 01 can operate from 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. Option 01 installation instructions are given in Appendix I.

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. Store the battery at or below room temperature. Extended storage at high temperatures will reduce the cell charge but will not damage the battery if the temperature is below 140°F. 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 load. It is dependent on a Z_o 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. Limits of mismatch loss are generally determined by means of a chart such as the Mismatch Loss Limits charts in Application Note 64.*

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 and can be determined from the Mismatch Loss Limits charts in Application Note 64.

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.

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*Detailed analysis of accuracy degradation due to SWR in the transmission line is presented in Application Note 64. The Application Note may be obtained from any Hewlett-Packard Sales and Service Office.

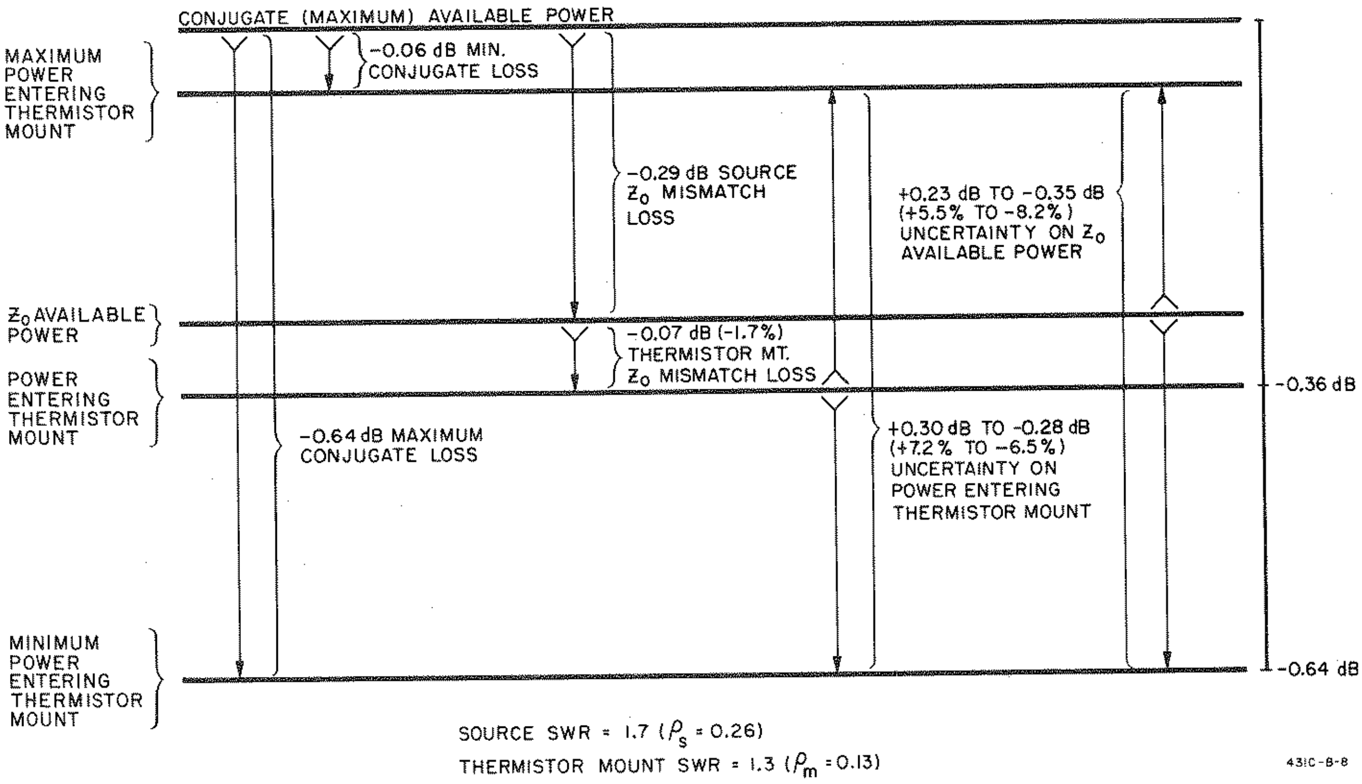

Figure 3-2. Mismatch Power Measurement Uncertainty

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 ±2% 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 microwave 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 Efficiency.

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.

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

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-microwave substitution error.

3-35. The CALIB FACTOR switch on the front panel 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 tuner. Under this condition, the power indicated is the power that would be delivered by the source to a load impedance equal to Z_0. This measured power is called Z_0 available power.

3-37. Calibration Factor correction ensures that a power measurement uncertainty range is centered on the Z_0 available power level instead of on the power delivered to the thermistor mount impedance. Total measurement uncertainty limits for 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_0 available power. Figure 3-3 shows the relationship and limits of error before correction. A source SWR of 1.7 and a thermistor mount SWR of 1.3 result in a Z_0 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 431C 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_0 available power uncertainties determines the limits of error before Calibration Factor correction. In this case, the limits are +2.5% to -17.2%.

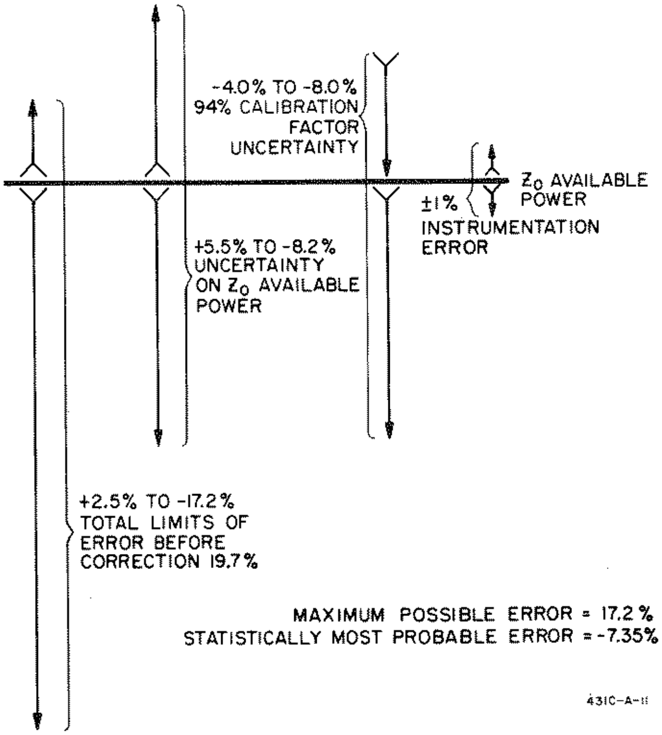

Figure 3-3. Limits of Error Before Correction

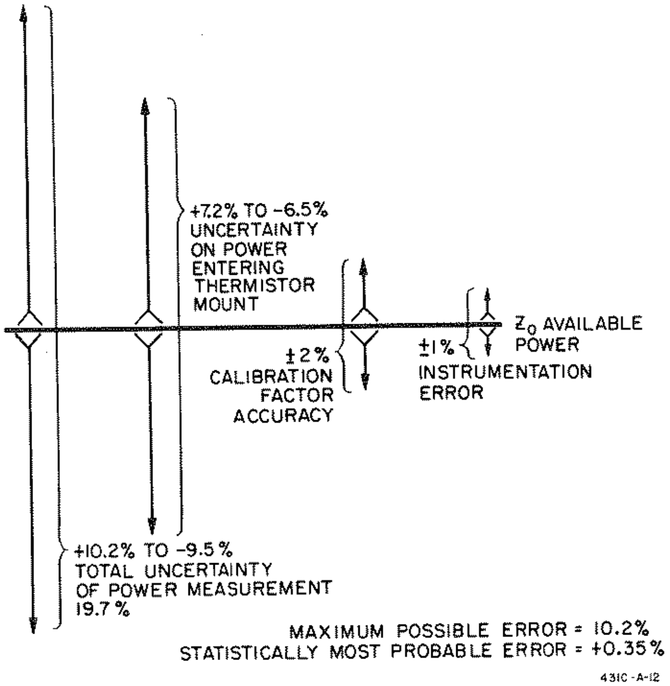

Figure 3-4. Total Uncertainty After Correction

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.

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.

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

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-mount 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 reading, 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

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*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
$\rho = \dfrac{\text{SWR} - 1}{\text{SWR} + 1}$

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 Waveguide 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 upon: 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 uncertainty of ±0.12%. This uncertainty includes a ±0.06% uncertainty 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 k ohms 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 output. 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 proportional to the square of the substituted current. Twice the voltage uncertainty is the power uncertainty introduced by the 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 METER 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. DETECTION 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 operating 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 true 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 values 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

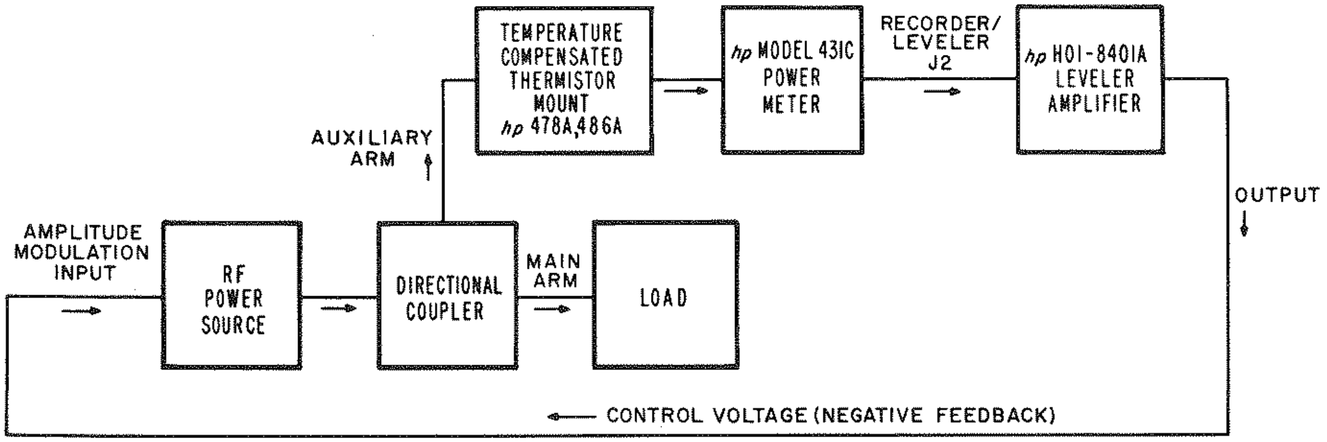


Figure 3-5. Output Power Leveling

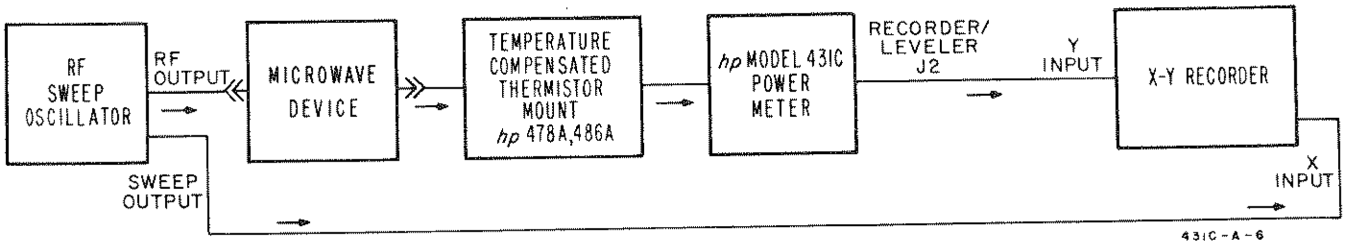


Figure 3-6. Insertion Loss or Gain Measurement

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. A discussion of microwave power measurement applications is available in Application Note 64, available from any Hewlett-Packard Sales and Service office. 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 loss or 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 second 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 circuits 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.

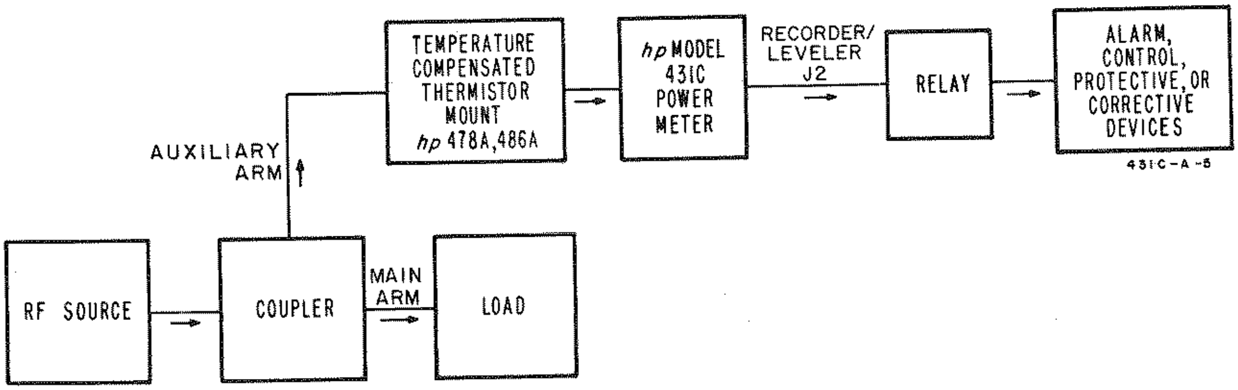
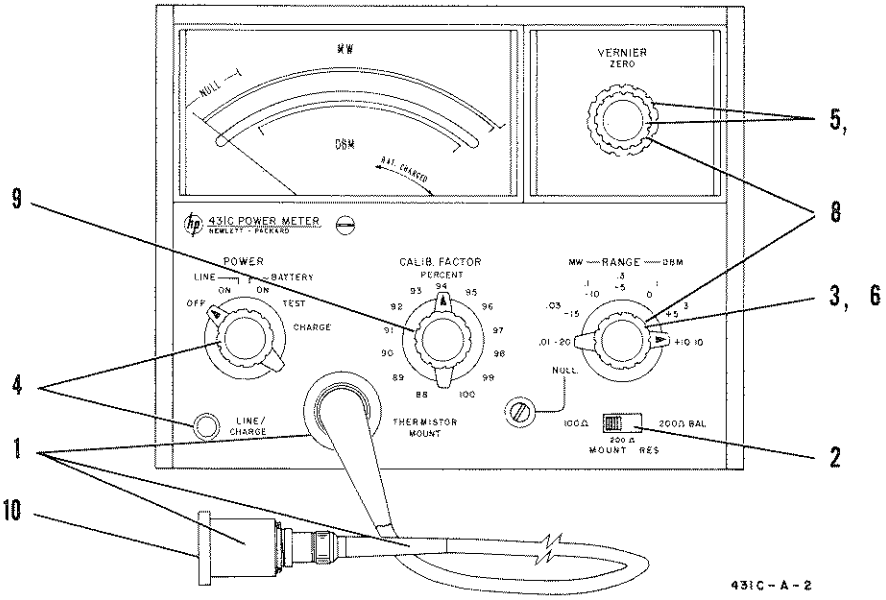


Figure 3-7. Control System Monitoring



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

   Meter Mechanical Zero:
   a. With instrument turned off, rotate meter adjustment screw clockwise until pointer approaches zero mark from the left.

   b. Continue rotating clockwise until pointer coincides with zero mark. If pointer overshoots, continue rotating adjustment screw clockwise until pointer once again approaches zero mark from the left.

   c. Rotate adjustment screw about three degrees counterclockwise to disengage screw adjustment from meter suspension.

Note

When using an hp Model 478A or other 200 ohm unbalanced 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.

CAUTION

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

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.

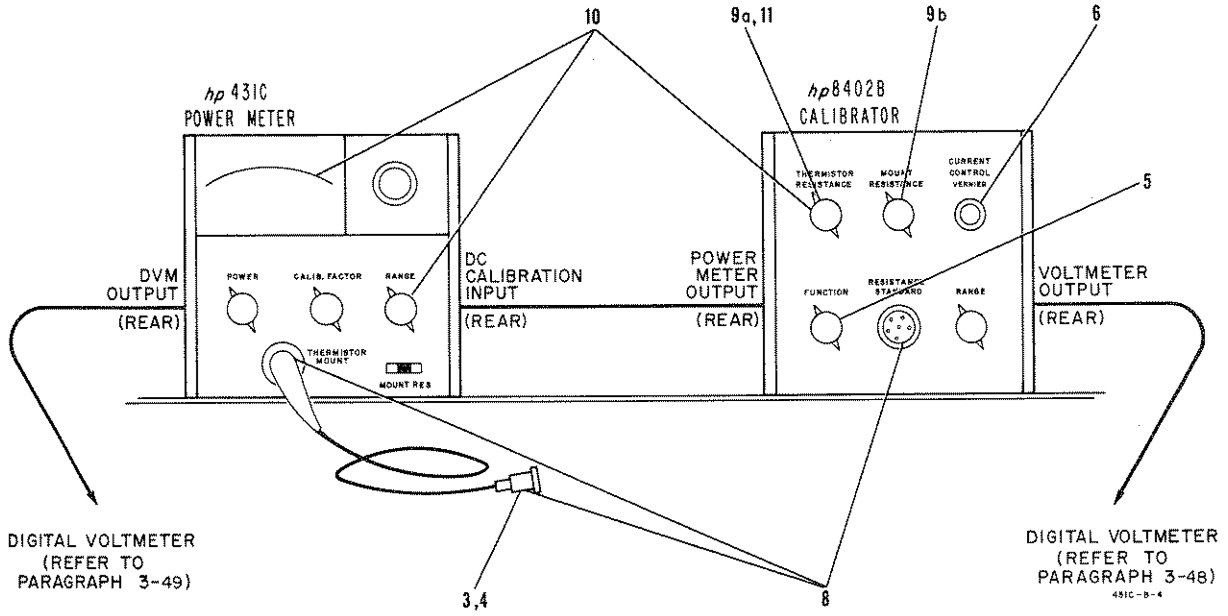
Note

Range-to-range zero carryover is less than ±1.0% if the meter has been properly adjusted mechanically (Step 1 above) and the instrument has been properly zero-set electrically on its most sensitive range. For maximum accuracy, zero-set the power 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.

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. Set CALIBRATION FACTOR to agree with Calibration Factor or Effective Efficiency data on mount (see Paragraph 3-32). Apply RF power to mount. Note reading obtained on digital voltmeter.

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. Set CALIBRATION FACTOR to 100%. Turn 8402B CURRENT CONTROL and VERNIER to duplicate reading obtained in step 3.
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 . . . +0.5%
   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 counterclockwise until the 431C Power Meter changes to a zero reading from 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

SECTION IV
PRINCIPLES OF OPERATION

4-1. BLOCK DIAGRAM.

4-2. The Model 431C Power Meter measures microwave power indirectly using two bridge circuits (refer to Figure 4-1). The detection bridge incorporates a 10-kHz oscillator whose amplitude is determined by the amount of microwave power heating the thermistors in that bridge.

4-3. The compensation and metering bridge contains thermistors that are immersed in the same thermal environment as those of the detection bridge. It is fed the same 10-kHz bias current that flows in the detection bridge.

4-4. Unbalance in the metering bridge produces 10-kHz error signal; this, plus 10-kHz bias taken directly from the oscillator-amplifier, are mixed in the synchronous detector to produce an error-proportional direct current. Fed back to the metering bridge, dc power substitutes for the 10-kHz power in heating the thermistors and drives the bridge toward balance.

4-5. The dc output of the synchronous detector also operates the meter circuit.

4-6. CIRCUIT DESCRIPTION.

4-7. RF DETECTION BRIDGE (Figure 4-2). The RF detection bridge and the 10 kHz oscillator-amplifier are connected in a closed loop (the detection loop) which provides positive feedback to cause oscillation. The RF bridge includes thermistor element R_d, the secondaries of transformer A1T2, capacitances C_a and C_b, and the resistive arm consisting of A1R10 and parallel resistors selected by the MOUNT RES switch.

4-8. When the power meter is off, thermistor R_d is at room temperature and its resistance is about 1500 ohms. The bridge is unbalanced. When the power meter is turned on, a large error signal is initially applied to the bridge. As this signal heats R_d, its resistance decreases toward the operating value of 100 or 200 ohms and the RF bridge approaches balance. The 10-kHz feedback diminishes until there is just sufficient power dissipated in the thermistors to maintain them at the operating resistance.

4-9. Microwave power, applied to the thermistors, heats them further; this decreases the error signal, reducing 10-kHz power just enough to balance out the microwave power.

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 200Ω 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 connected in series across the thermistors with their

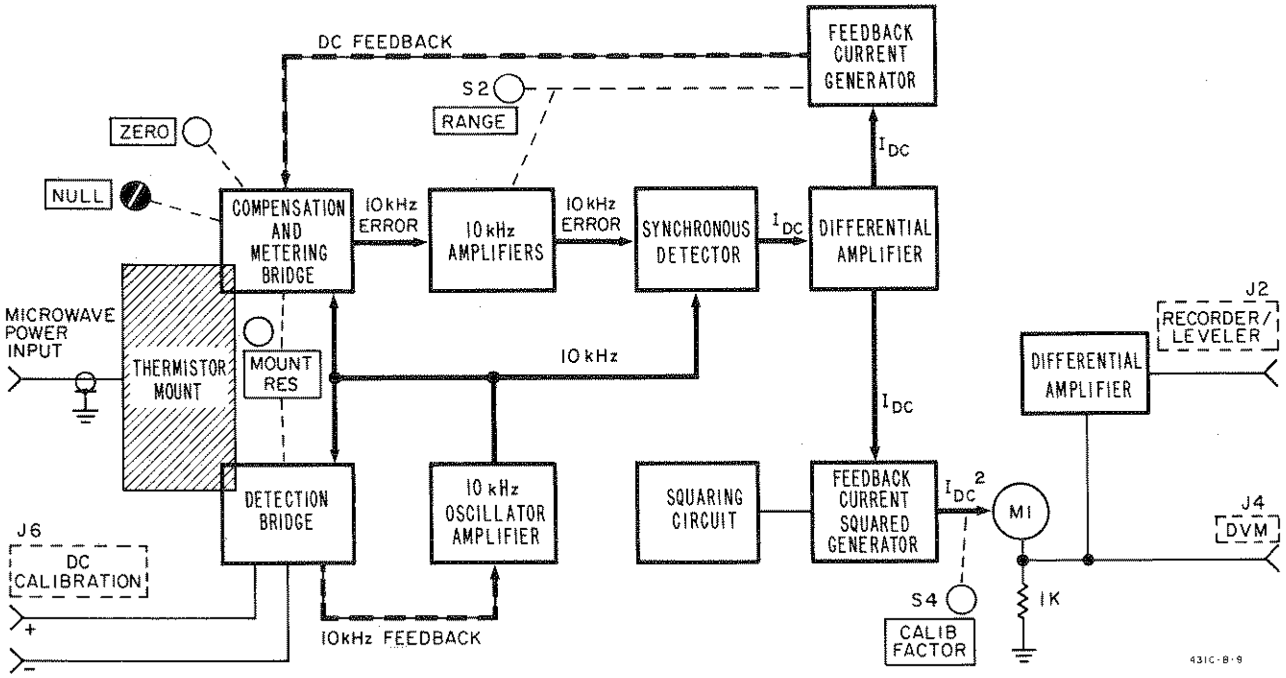


Figure 4-1. Block Diagram

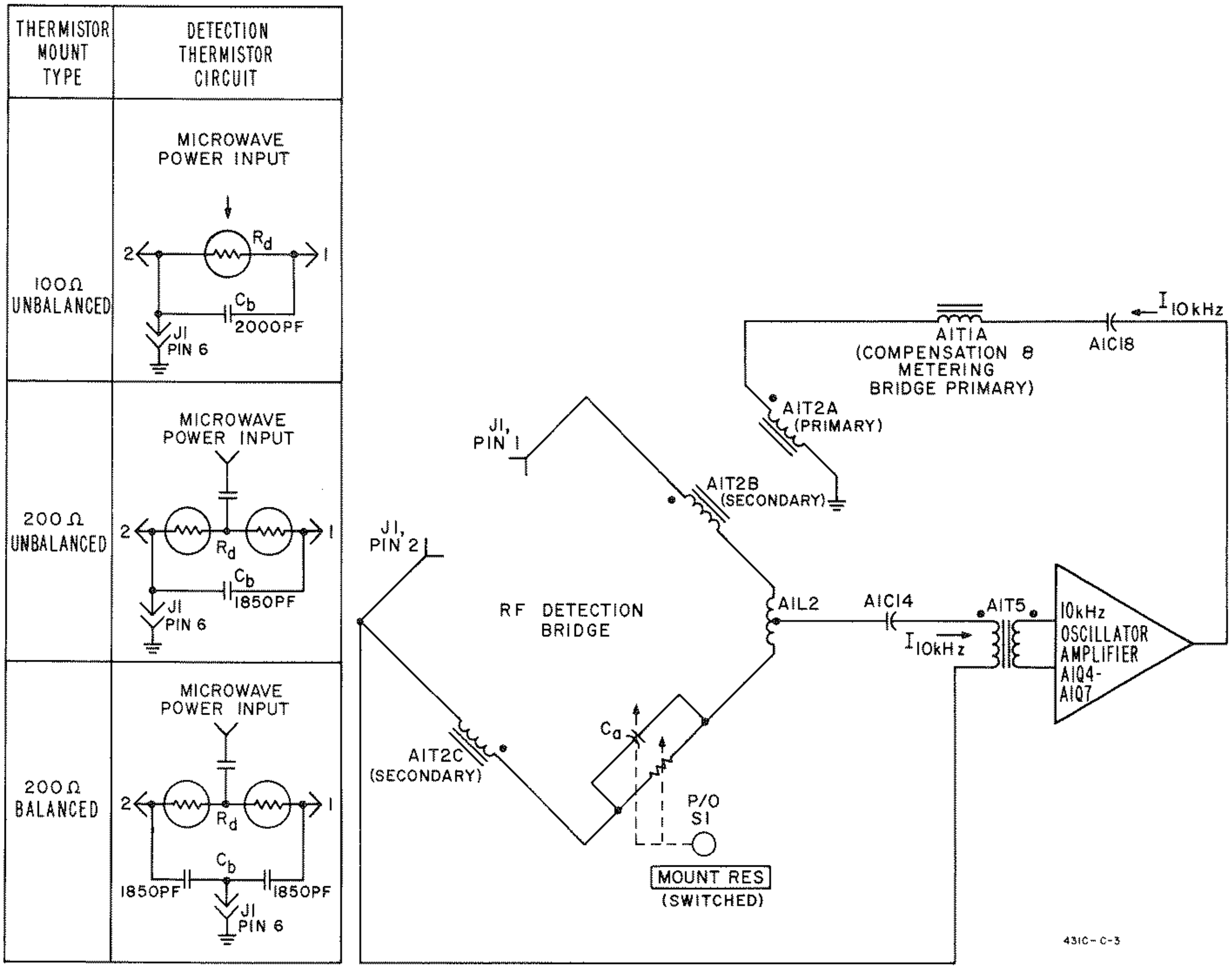


Figure 4-2. RF Detection Bridge

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 200Ω or 200Ω BAL position some of the feedback current is shunted to ground through R1. This maintains the I^2R function constant when mount resistance 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 bridges, 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 adjust 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 components 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 has a rectifier in series with a linearizing resistance in each of its arms. Two

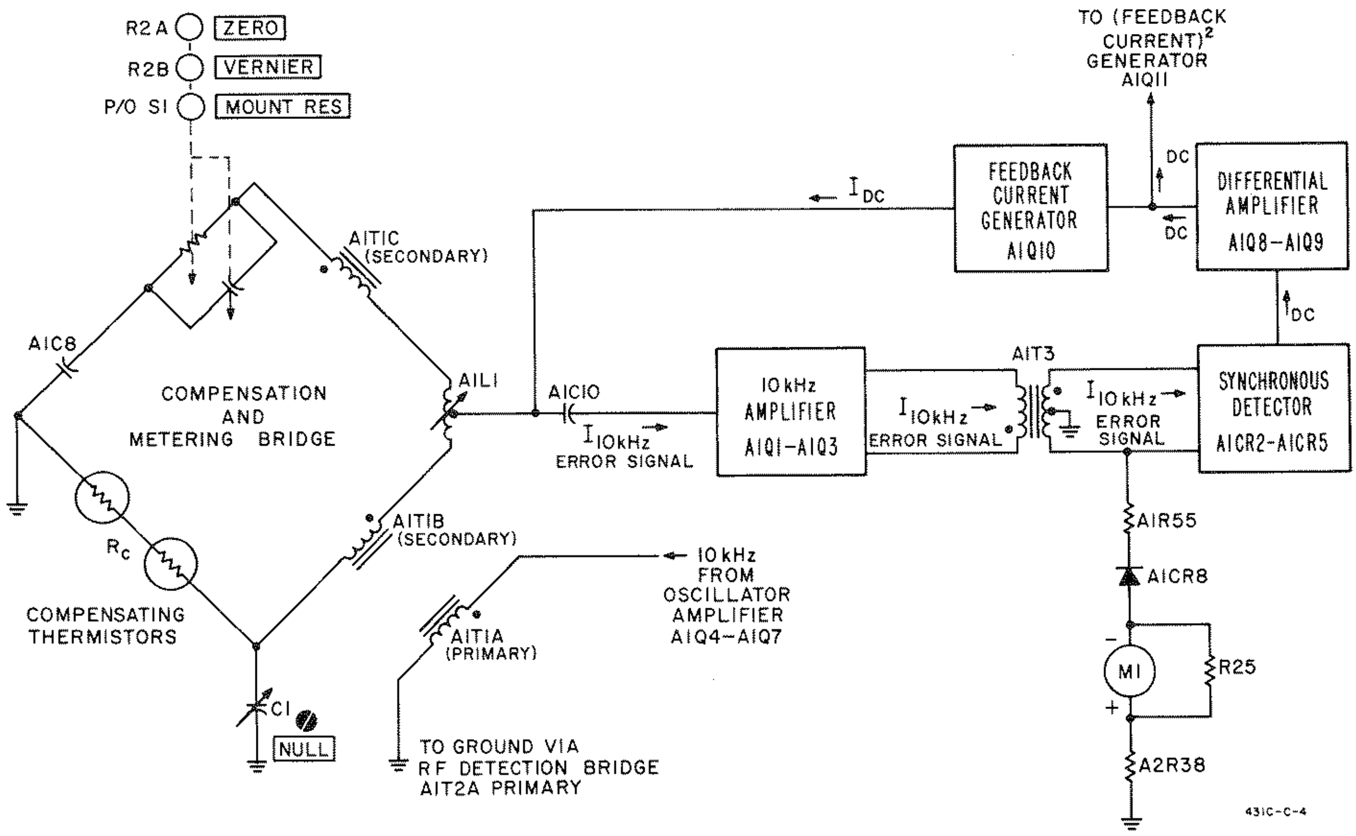
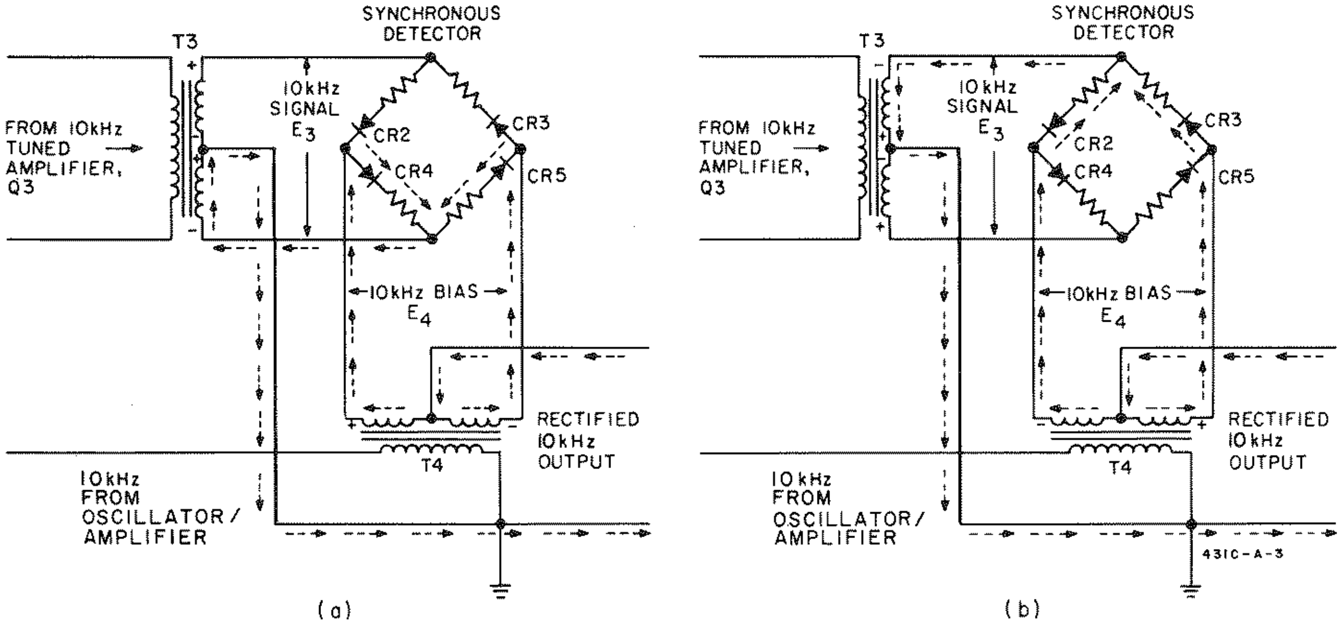


Figure 4-3. Compensation and Metering Bridge



Note: E_4 is much larger than E_3 in order to gate diodes CR2, CR3, CR4, and CR5.

Figure 4-4. Synchronous Detector

10 kHz 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 (a) of Figure 4-4 shows the current path through diodes A1CR2 and A1CR3 for a negative-going signal. The rectified output 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 E3 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 feedback current-squared generator A1Q11, and the feedback current generator A1Q10. Temperature compensation and low emitter circuit resistance for A1Q10 is provided by A1Q9. Diode A1CR7 protects A1Q10 and A1Q11 from excessive reverse bias when A1Q8 is not conducting.

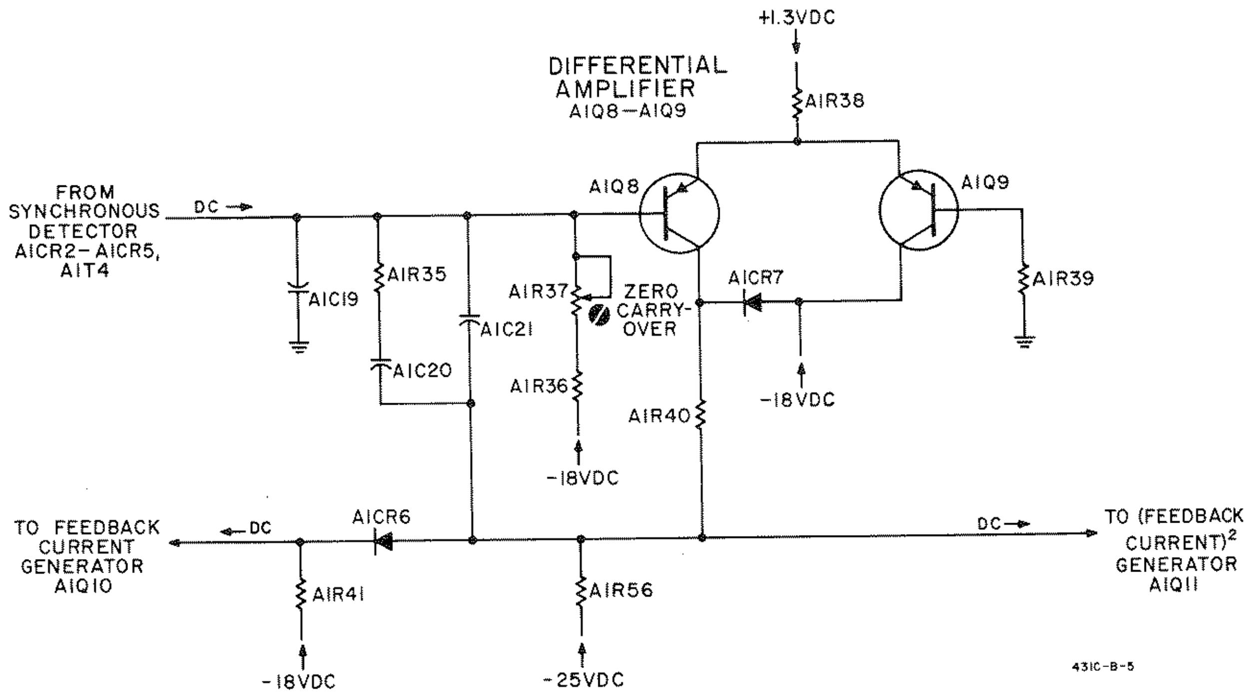


Figure 4-5. Feedback Differential Amplifier

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 voltage function, proportional to the square root of 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.

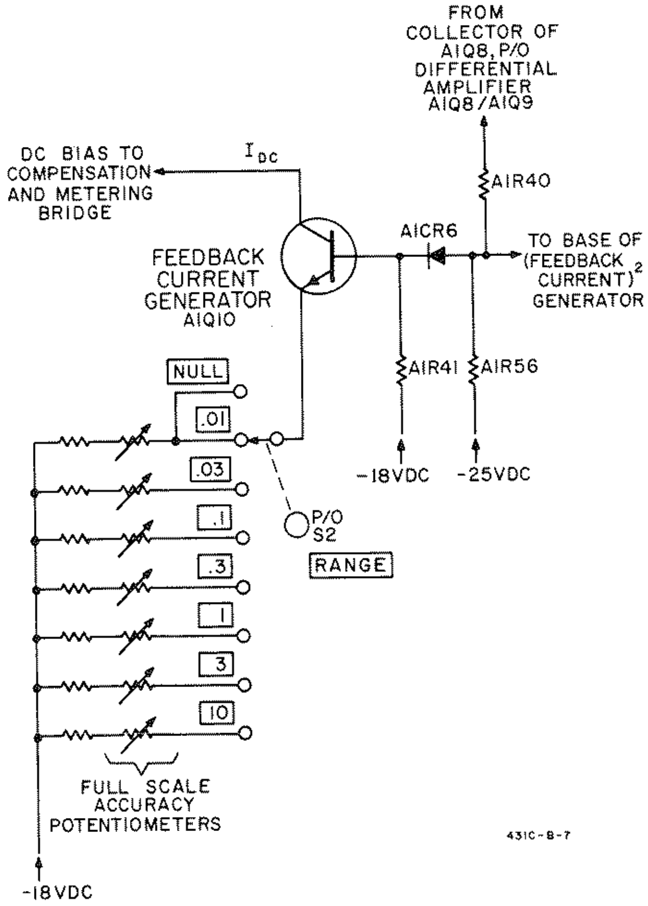


Figure 4-6. Feedback Current Generator

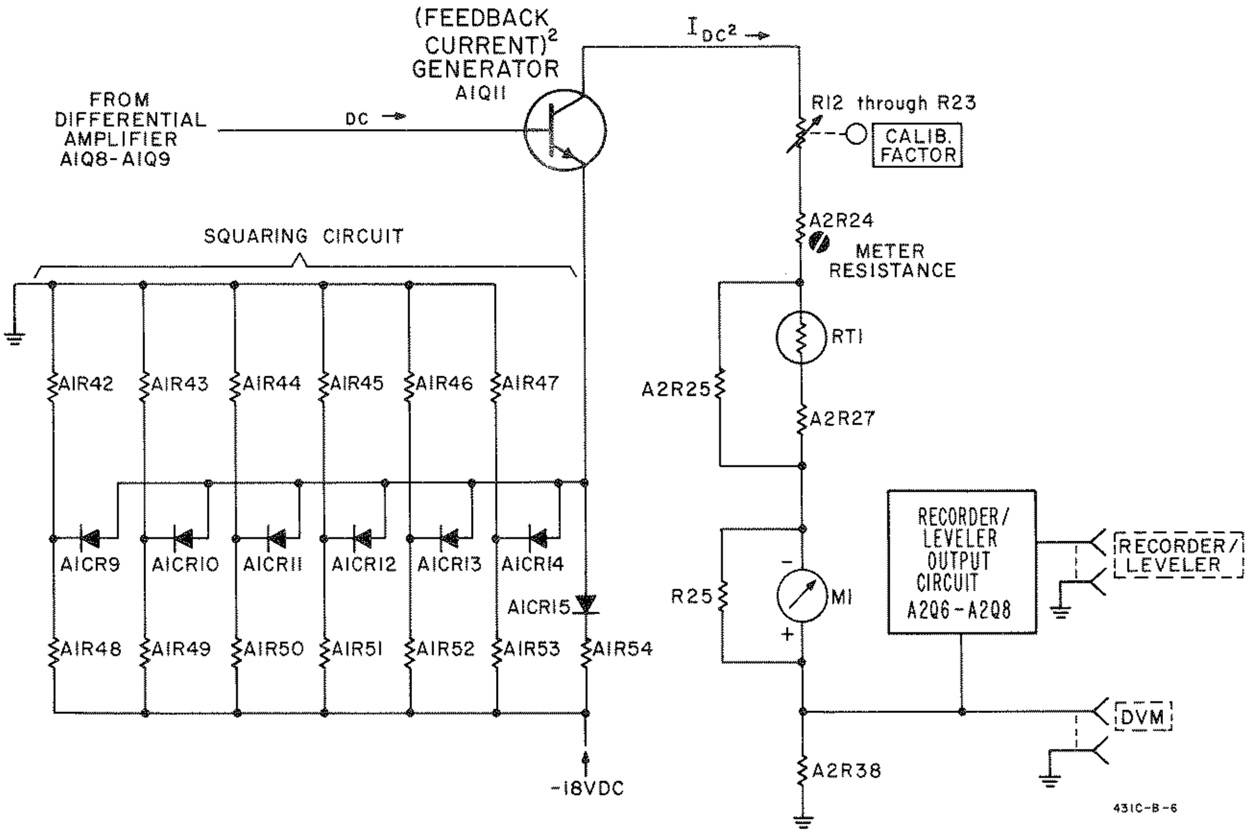


Figure 4-7. Meter Circuit

4-26. METERING CIRCUIT DIFFERENTIAL AMPLIFIER.

4-27. The metering circuit RECORDER/LEVELER output is a voltage of low source impedance necessary for isolation between a recorder or leveler amplifier and the metering circuit of the power meter. The isolation circuit 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 base 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 A1CR9-14, and resistors A1R42-54. Temperature compensation for the squaring circuit is provided by A1CR15.

4-29. 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

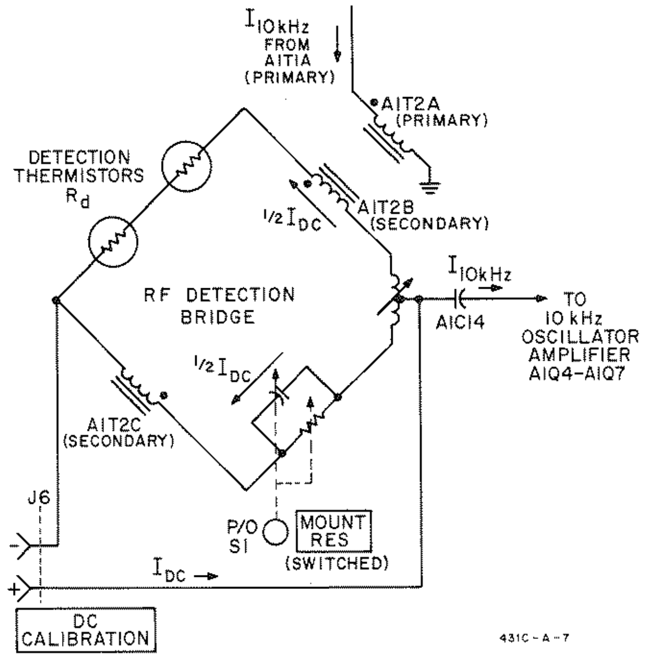


Figure 4-8. DC Calibration and Substitution

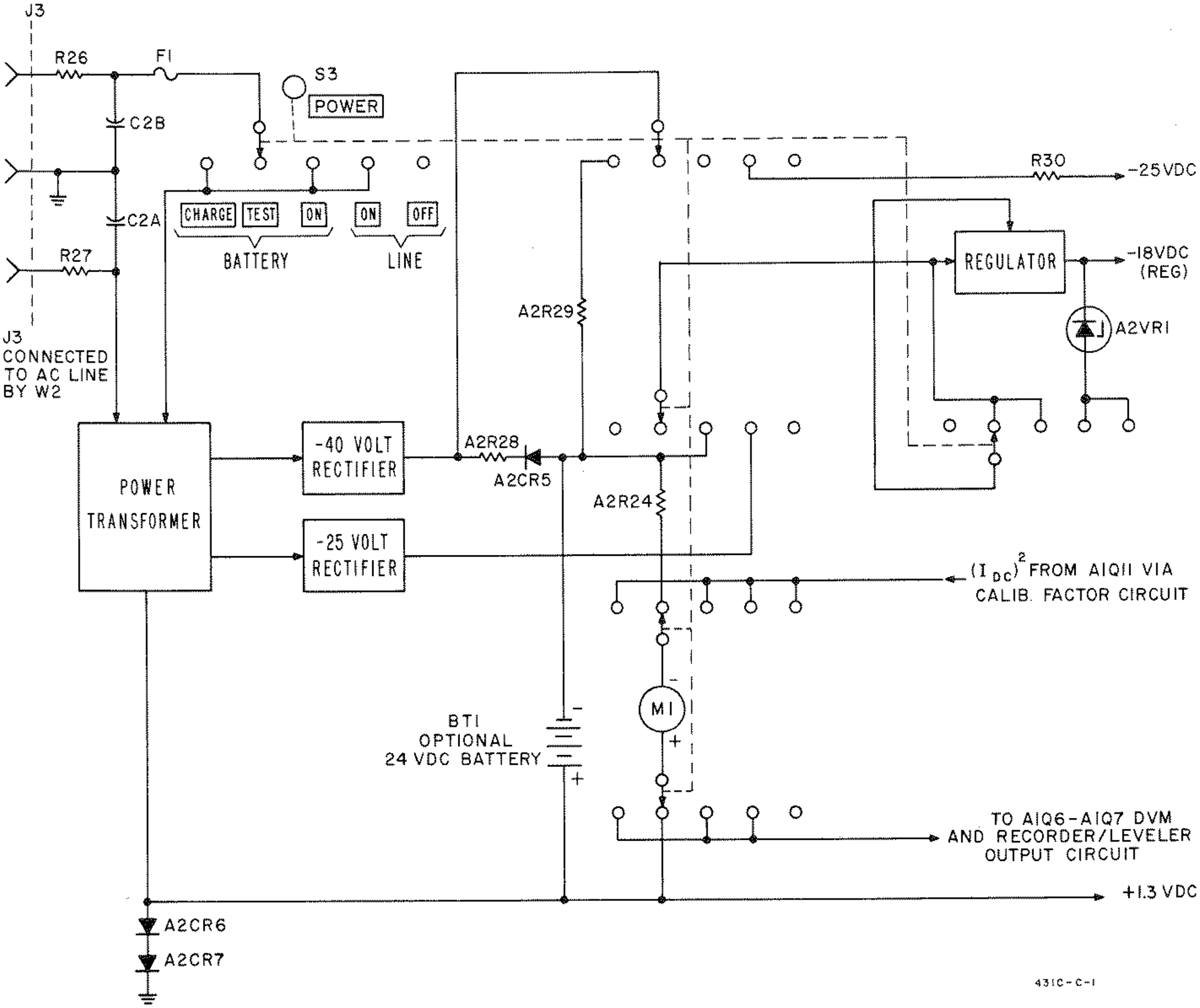


Figure 4-9. Power Switch Arrangement

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. The resistance of the Metering Bridge is never balanced. A small amount of unbalance must exist to provide error signal for the operation of the feedback loop. The Metering Bridge loop circuit is self balancing and uses DC feedback to rebalance the closed loop. Resistive balance is set by R2A and R2B ZERO controls, which are in one leg of the Metering Bridge. DC offset voltage on the base of A1Q8 determines the balance point of the close loop. A1R37, ZERO CARRYOVER sets the amount of this offset for about +50 millivolts.

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.