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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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

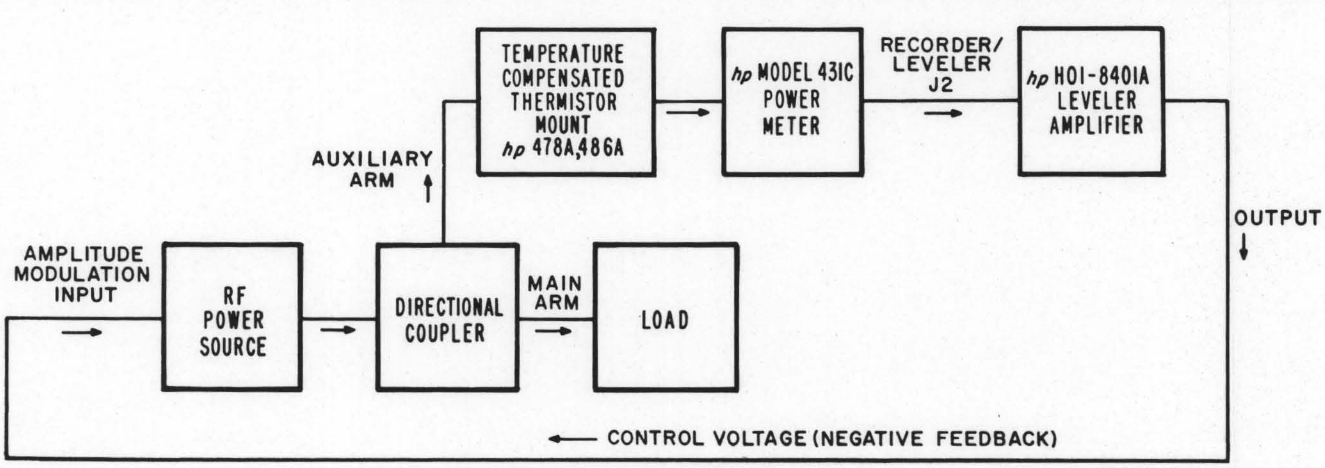

Figure 3-5. Output Power Leveling

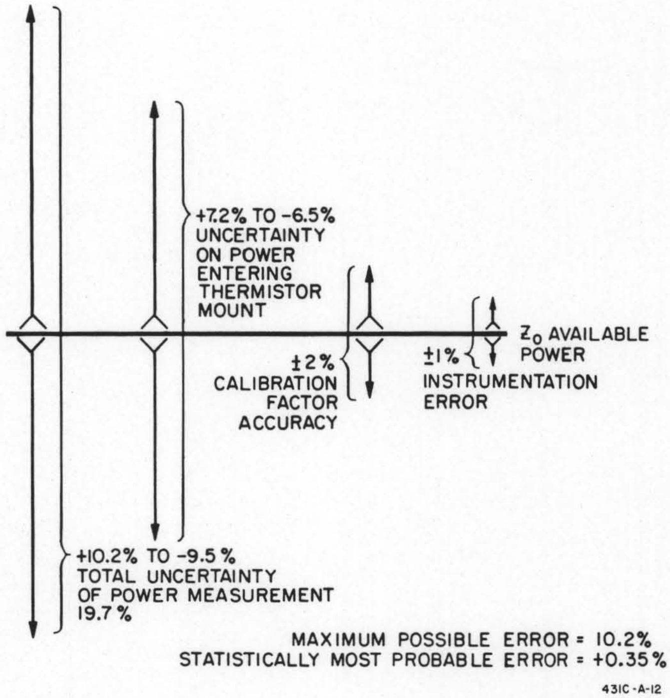

Figure 3-4. Total Uncertainty After Correction

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.

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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

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

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.

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

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

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.

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

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_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 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_O 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_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 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_O available power uncertainties determines the limits of error before Calibration Factor correction. In this case, the limits are +2.5% to -17.2%.

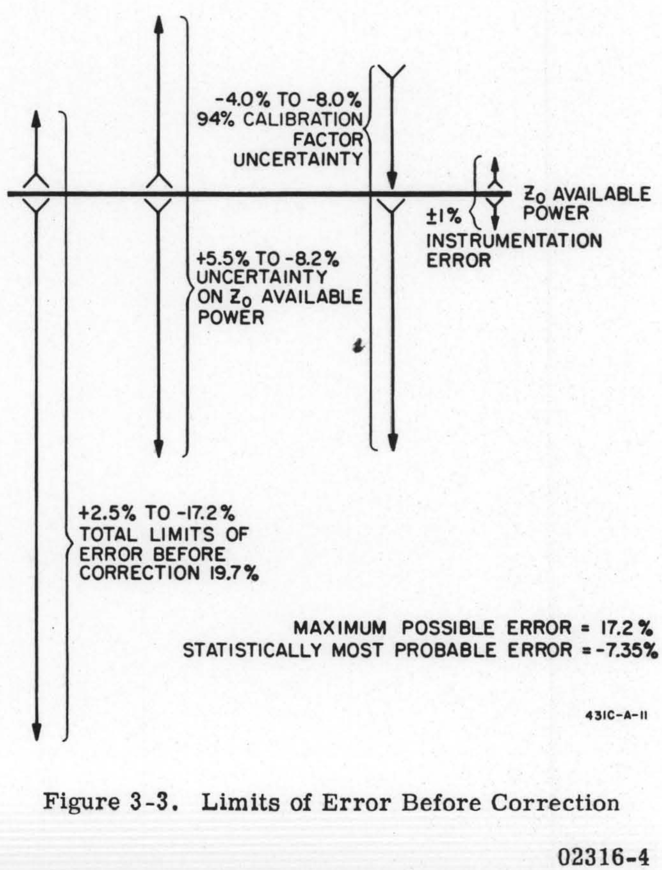


Figure 3-3. Limits of Error Before Correction

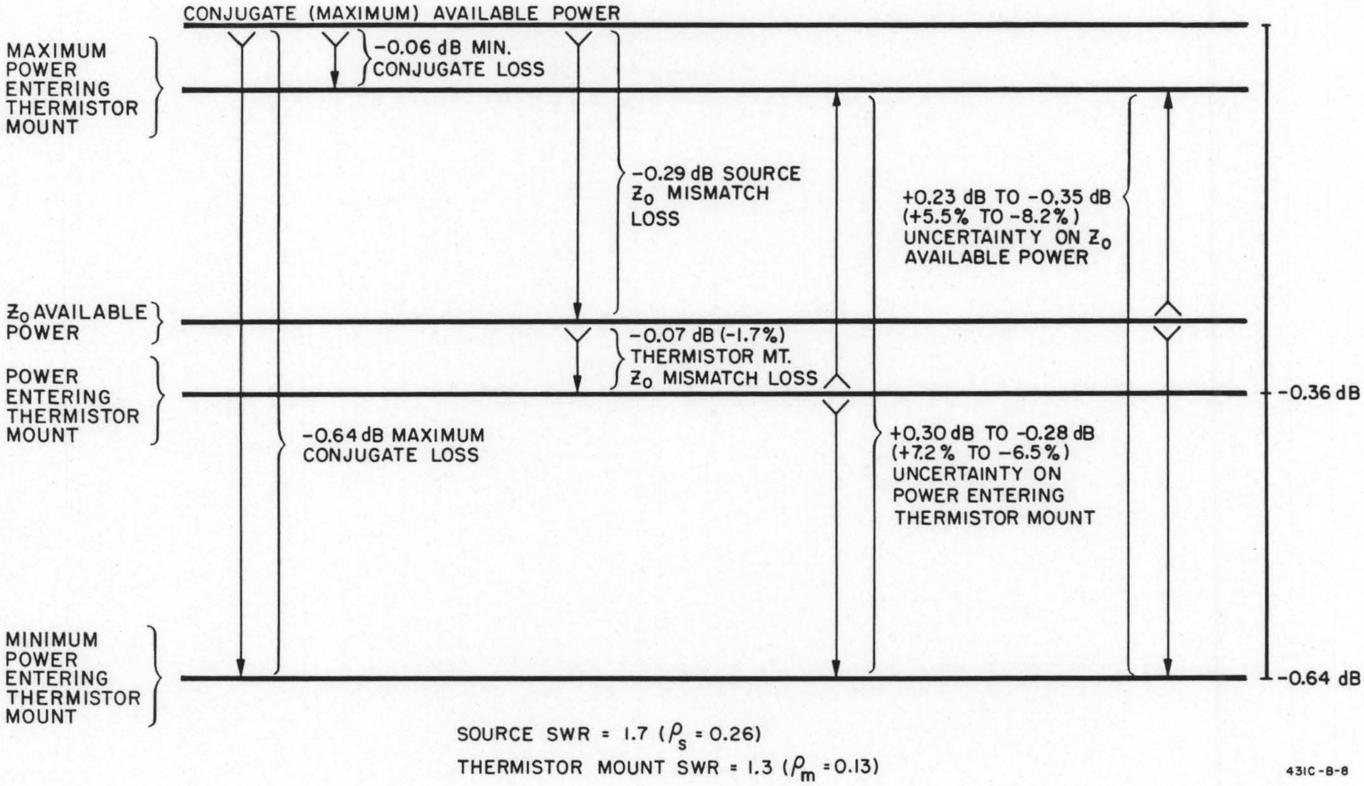


Figure 3-2. Mismatch Power Measurement Uncertainty

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.

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

3-14. 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_0 available power, conjugate match and mismatch, and Z_0 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_0 available power is the power a source will deliver to a Z_0 load. It is dependent on a Z_0 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_0.

3-22. In general, neither the source nor the thermistor mount has Z_0 impedance, and the actual impedances are known only as reflection coefficients, mismatch losses or SWR. 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_0 available power measurement situation can involve a source with an SWR of 1.7 (ρ_s = 0.26) and a thermistor mount with an SWR of 1.3 (ρ_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_0 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_0 available power. The thermistor mount Z_0 mismatch causes an additional power loss of -0.07 dB. However, on the thermistor mount Z_0 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_0 available power level is determined by algebraically adding the thermistor mount loss to the uncertainty caused by source and thermistor mount Z_0 mismatch SWR. Thus, the Z_0 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_0 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_0 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_0 available power.

*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.

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).

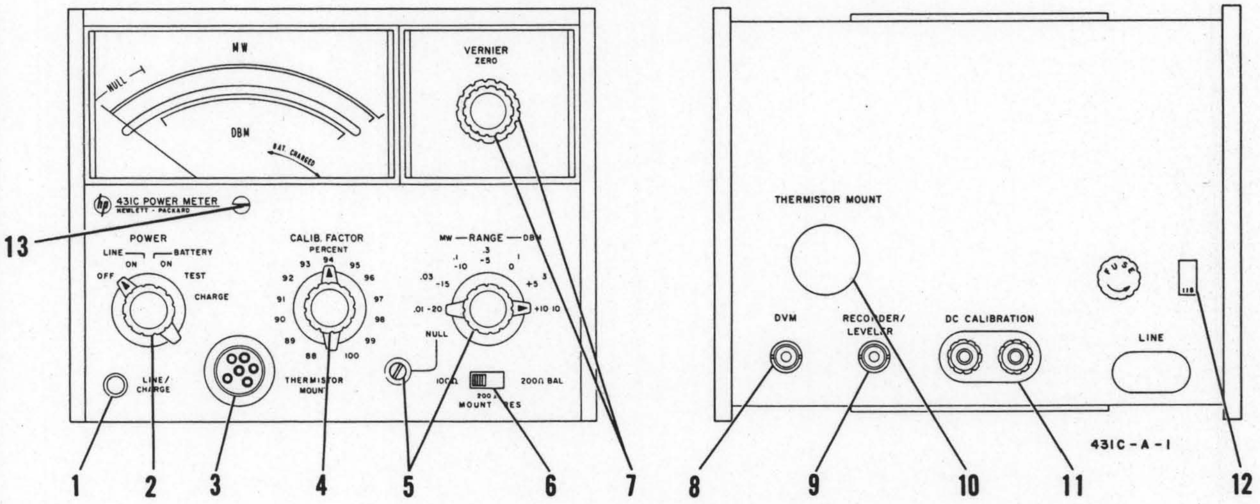
3-9. CONTROLS, CONNECTORS, AND INDICATORS.

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.



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.

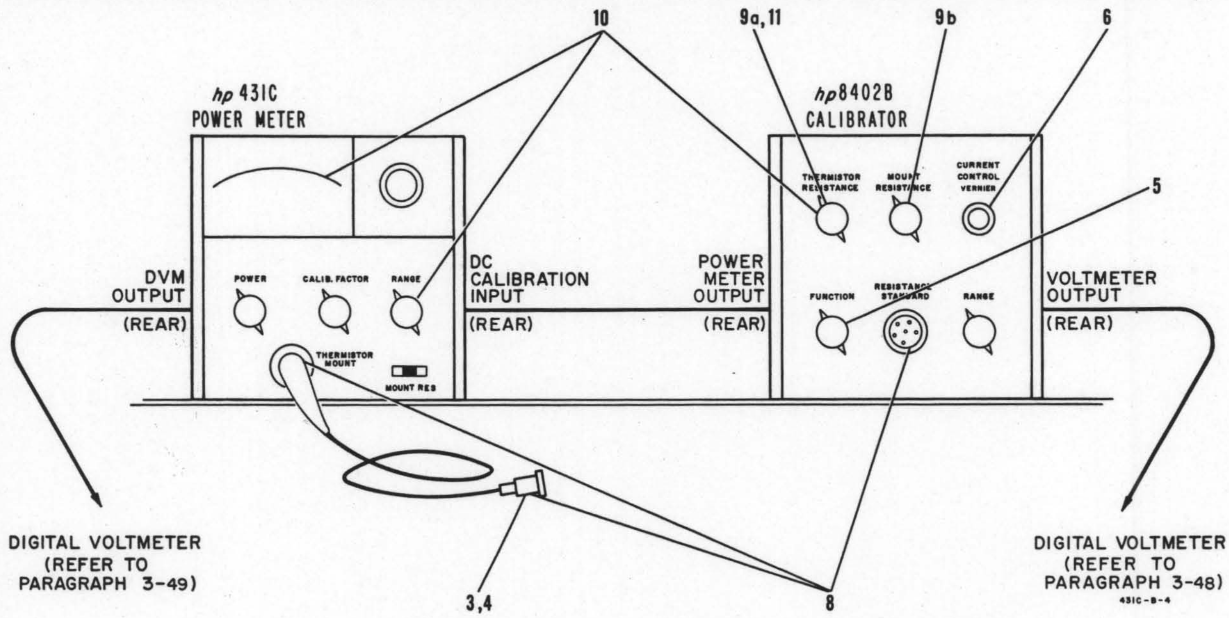
11. DC CALIBRATION. This connector permits a DC input for power meter calibration and DC substitution method of power measurement.

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

Figure 1-1. Model 431C Power Meter



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

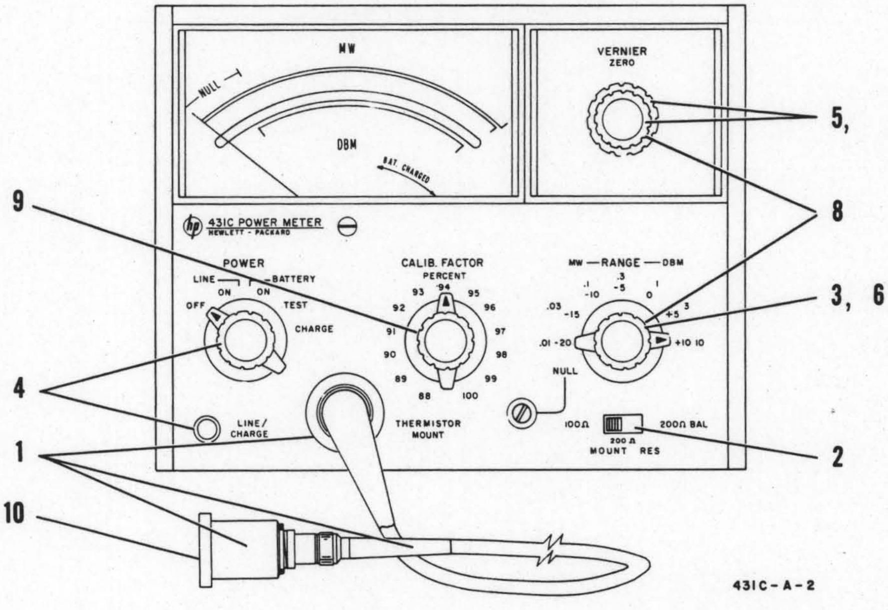
If the .01, .1, 1, or 10 mW power meter ranges are used, the digital voltmeter reads directly. If the .03, .3, or 3 mW power meter ranges are used, the digital voltmeter reading must be multiplied by .0316, .316, or 3.16 respectively.

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



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.

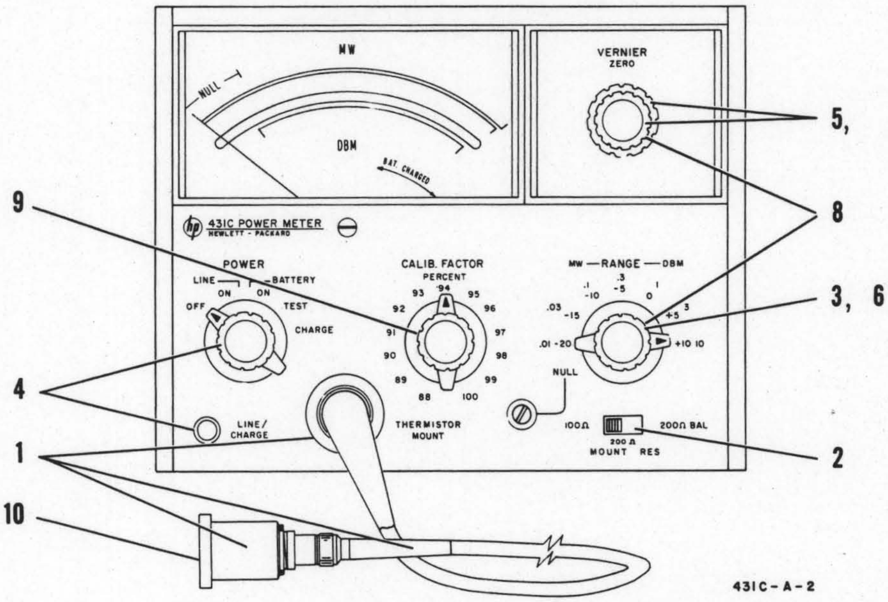
Note

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



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

Note

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Figure 3-8. Turn On and Nulling Procedure

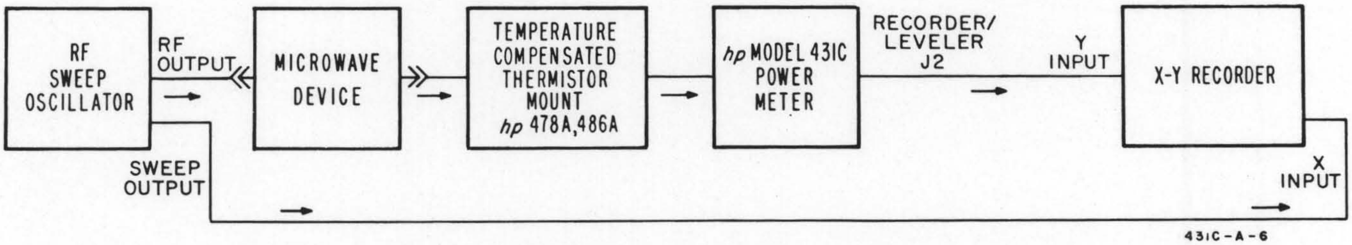


Figure 3-6. Insertion Loss or Gain Measurement

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.

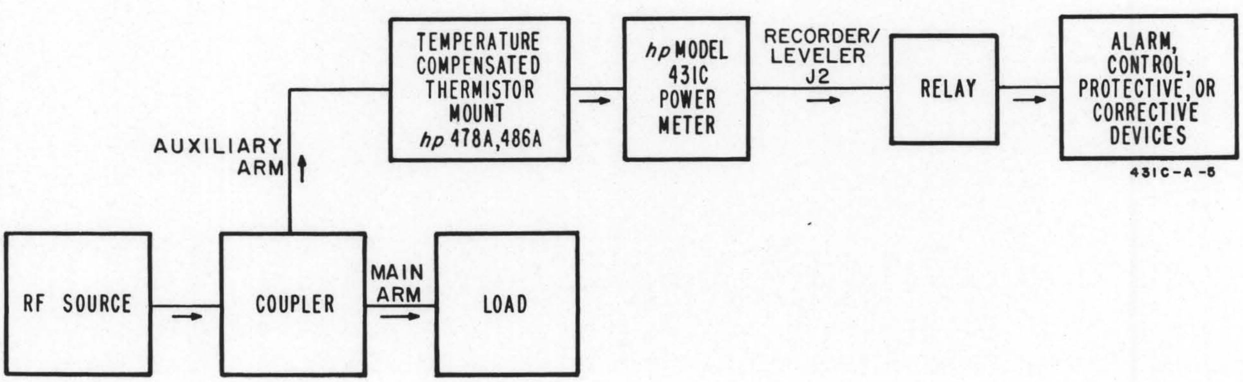
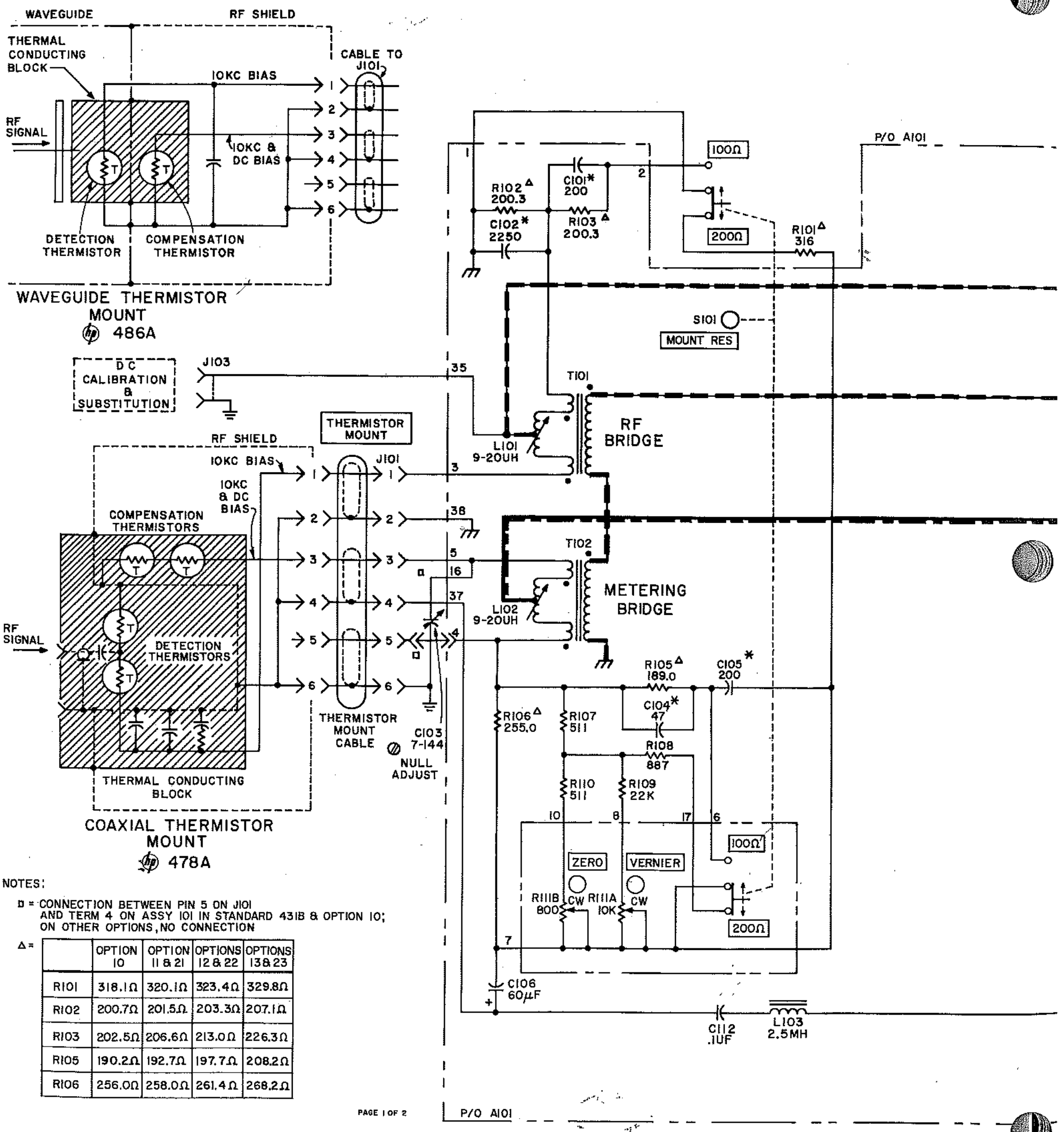


Figure 3-7. Control System Monitoring



NOTES:

□ = CONNECTION BETWEEN PIN 5 ON J101 AND TERM 4 ON ASSY 101 IN STANDARD 431B & OPTION 10; ON OTHER OPTIONS, NO CONNECTION

Δ =

	OPTION 10	OPTION 11 & 21	OPTIONS 12 & 22	OPTIONS 13 & 23
R101	318.1Ω	320.1Ω	323.4Ω	329.8Ω
R102	200.7Ω	201.5Ω	203.3Ω	207.1Ω
R103	202.5Ω	206.6Ω	213.0Ω	226.3Ω
R105	190.2Ω	192.7Ω	197.7Ω	208.2Ω
R106	256.0Ω	258.0Ω	261.4Ω	268.2Ω

Figure 5-3. Power Meter Assembly

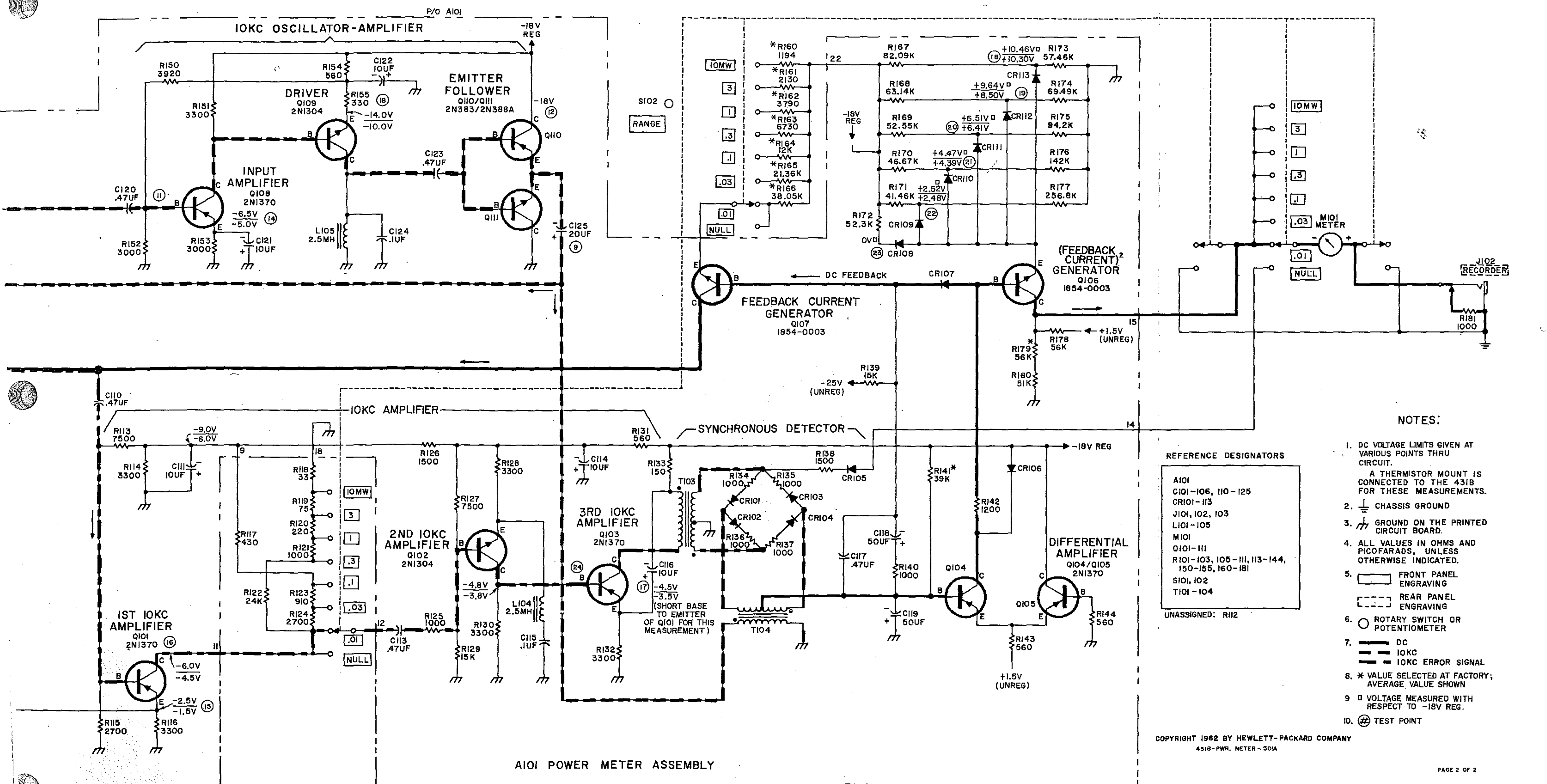


Figure 5-3. Power Meter Assembly