# **Errata**

# Title & Document Type: 431C Power Meter Operating and Service Manual

# Manual Part Number: 00431-9006

# **Revision Date: February 1966**

# About this Manual

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# OPERATING AND SERVICE MAN

# MODEL 431C

HP PART NUMBER 00431-9006 SERIALS PREFIXED: 548

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00431-9005

Printed: FEB 1966

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Number a Title	1 Page	Number	Title	gala an si dh	Page
<ul> <li>1-1. Specifications</li> <li>1-2. Model 431C Thermistor Mounts</li> <li>5-1. Recommended Test Equipment</li> <li>5-2. Performance Tests</li> <li>5-3. Circuit Requirements for Factory Selected Parts.</li> <li>5-4. Front Panel Trouble Isolation</li> </ul>	. 1-2 . 5-1 . 5-2	Measure 5-6. Safe Ohm Resistar 6-1. Reference 6-2. Replaceal	ircuit Transistor I ements. meter Range for 7 nce Measurements e Designation Inde ble Parts t of Manufacturers	Fransistor	5-7 5-9 6-2

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MODEL POWER METER

Manual Serial Prefixed: 548-Manual Printed: Feb 1966

CORRECTIONS IN THIS MANUAL ACCORDING TO ERRATA BELOW, THEN CHECK THE FOLLOWING TABLE FOR YOUR INSTRUMENT SERIAL PREFIX IS DIGITS) OR SERIAL NUMBER (8 DIGITS) AND MAKE ANY LISTED CHANGES) IN THE MANUAL. NEW TEM.

. F.,	SERIAL PREFIX OR NUMBER	DE MAKE MANUAL CHANGES	SERIAL PREFIX OR NUMBER	MAKE MANUAL CHANGES	Ĵ.
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ERRATA:

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Paragraph 3-21: Add the sentence, "Option 01 installation instructions are given in Appendix I.

Paragraph 3-29, step h: "...Power/= Change equation to read,

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Paragraph 4-34;

Change fourth sentence to read, "... and unregulated -25 VDC operate..

Paragraph 3-7 and Figure 3-8, step 2, add the following:

CAUTION

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

Figure 7-9: Add connection between terminal "V" and the -25V lead to R30.

Paragraph 4-25: Change third sentence to read:

"... proportional to the square root of applied power..."

Figure 7-5, 7-7 and Parts List: Change R6, A1C4, A1C5, and A1R36 to factory selected parts, typical value shown.

Figure 7-7; Change A1R47 to 259.6K.

Table 1-1:

Change Zero Carryover specification to read, "Zero-Carryover: Less than ±1.0% of full scale..."

Paragraph 3-4;

Change second sentence to read, "... is accurate to ±1.0%."

**Table**<sup>1</sup>**5-2:** 7

Change Performance Test 2, ZERO CARRYOVER to read, "Less than ±1.0% of full scale Change step c to read, "Adjust ZERO for 0.00 VDC.. Change step d to read, "...within 0.00 ±0.01 VDC...

Printed in U.S.A

Supplement A for 00431-9008

#### Supplement A for 00431-90006 4.Υ

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ERRATA (Cont'd): Paragraph 5-19: Change step b to read, "... within 0.00 ±0.01 VDC. Tables 6-1 and -2, add: A2Z1, choke, hp Stock No. 431A-60A

Substitute attached Figures 7-4 and 7-6 in place of Figure 7-4 and 7-6 in manual.

Page

Figure 3-8: 'Charge the Note following step'8 to read as follows:

Note

Range-to-range zero carryover is less than ±1.0% if the meter has been properly adjusted mechanically (Paragraph 5-4) 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. 11

Table 1-1, Specifications: Change as follows:

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

Tables 1-1 and 5-2, change "Accuracy" to read:Accuracy:(+20° C to +35°C)

±1% of full scale (.1 mw range and above) ±1.5% of full scale (:03 mw range) ±2% of full scale (.01 mw range)

1 (0° C to +55°C) ±3% of full scale on all ranges

Paragraph 1-2: Delete reference to 1% accuracy

CHANGE 2

CHANGE 1

Tables 6-1 and 6-2 Figure 7-9: o Change A2VR3 to: 1902-0596 Semicon Device: Diode silicon 9.0 volts Change A2R32 to: 0757-0274 1210 ohms. Change A2R33 and A2R37 to: 0757-0442 '10K. Change A2R34 to: 0757-0439 6810 ohms.

CHANGE 3

Change Figure 7-7 to include Test Points A, B and C. (Refer to attached Schematic diagram) Add to Tables 6-1 and 6-2, Jumper, Test Point: 00431-6021

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Supplement A for 00431-9006

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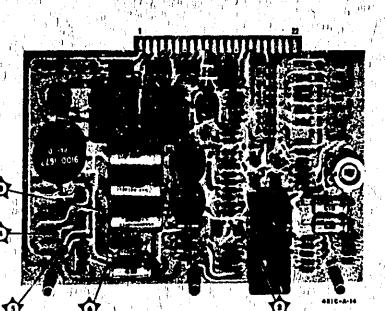


Figure 7-4. Power Meter Assembly A'l

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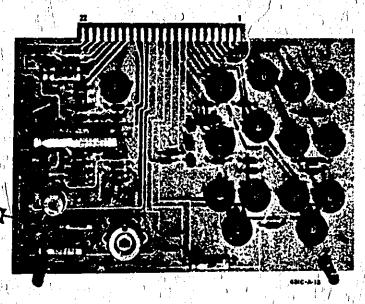
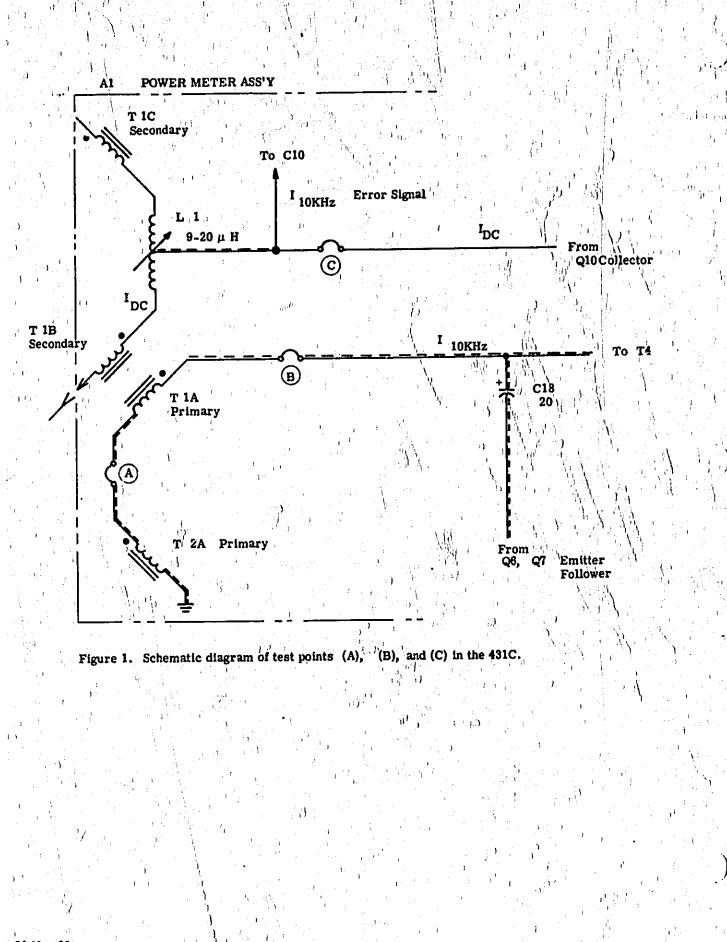


Figure 7-6. Power Supply Assembly A2

# Supplement A for 00431-9006

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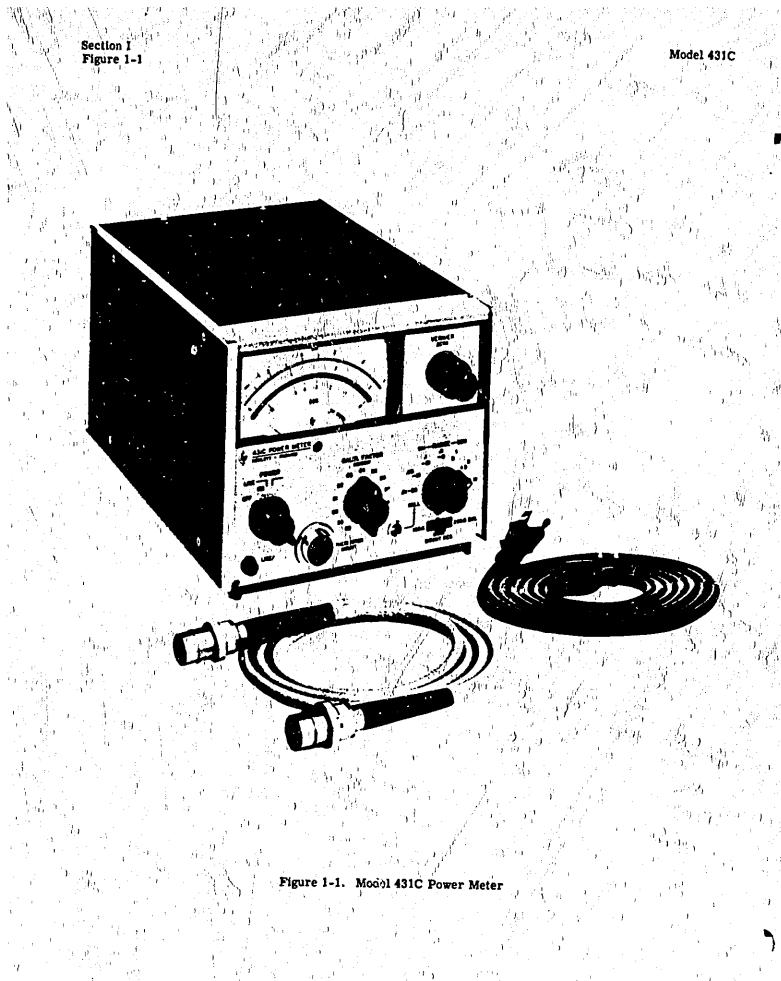
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#### Model 431C

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Model 431C

Section I Paragraphs 1-1 to 1-5

# SECTION I GENERAL INFORMATION

Table 1-1. Specifications

#### 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  $\pm 1\%$  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. For other serial numbers, see the change sheet enclosed with the manual.

1-5. ACCESSORIES. Two accessories are supplied with the Model 431C Powe; 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.

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

Accuracy:  $\pm 1\%$  of full scale from  $\pm 20\%$  to  $\pm 35\%$ ,  $\pm 2.5\%$  of full scale from 0% to  $\pm 55\%$ .

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

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

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

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

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

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

Recorder/Leveler Output: With load impedance of 600 ohms or more, output is approximately 1 volt dc at full scale meter deflection. BNC female connector, DC Calibration Input: Binding posts for calibration of bridge with hp 8402B Calibrator or precise dc standards.

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

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

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

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

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

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

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

H01-8401A Leveler Amplifier.

8402B Power Meter Calibrator.

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

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

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# Section I Tables 1-1 (cont'd) and 1-2

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Table 1-1. Specifi	ications (Cont'd)
Options:	11, With 50-foot (15240 mm) cable for 100Ω mount.
01. Rechargeable battery installed, provides up to 24 hours continuous operation.	12. With 100-foot (30480 mm) cable for 100Ω mount,
02. Rear thermistor mount input connector wired in parallel with front panel input connector.	13. With 200-foot (60960 mm) cable for 100Ω mount.
09. With 10-foot (3050 mm) cable for 100Ω or 200Ω	21. With 50-foot (15240 mm) cable for 2000 mount
10. With 20-foot (6100 mm) cable for 100Ω or 200Ω mount.	22. With 100-foot (30480 mm) cable for 200Ω mount 23. With 200-foot (60960 mm) cable for 200Ω mount.
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	Coaxial	Waveguide	Frequency'Range	Operating Resistance in Ohms
1	478A	N	10 MHz to 10 GHz	P 11 200 11 11
	· · · · · ·	S486A	2.6 to 3.95 GHz	100
	ting a state	G486A	3.95 to 5.85 GHz	100
		J486A	5.3 to 8.2 GHz	100 - 10 - 10 - 10 - 10 - 10 - 10 - 10
	stration in trij€ Stat	H486A	7.05 to 10.0 GHz	100
1		X486A	8.2 to 12.4 GHz	100 · · · · · · · · · · · · · · · · · ·
		M486A	10.0 to 15.0 GHz	
ł		P486A	12.4 to 18.0 GHz	100
		K486A	18.0 to 26.5 GHz	200
L	1997 (B. 1997)	R486A	26.5 to 40.0 GH2	200

Table	1-2,	Model	431C	Thermistor M	ounts

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Section D Paragraphs 2-1 to 2-6

# NSTALLATION

#### 2-1 INITIAL INSPECTION.

2-2 Before shipment this instrument was inspected and found free of mechanical or electrical defect. As soon as the instrument is unpacked, inspect for any damage that may have occurred in transit. Check for the supplied accessories. Electrical performance may be tested using the performance test procedure outlined in Paragraph 5-5. If there is any damage or deficiency, or if electrical performance is not within specifications, notify the carrier and your nearest Hewlett-Packard Sales and Service Office immediately.

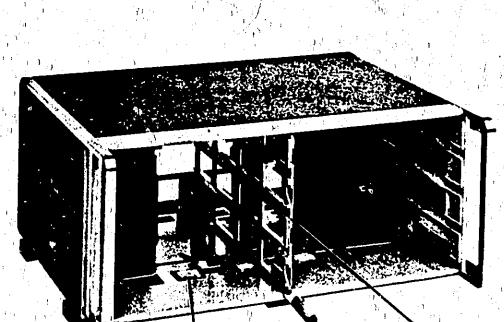
## 2-3. RACK MOUNTING,

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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 C: 3e 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



DIVIDER ASSEMBLY

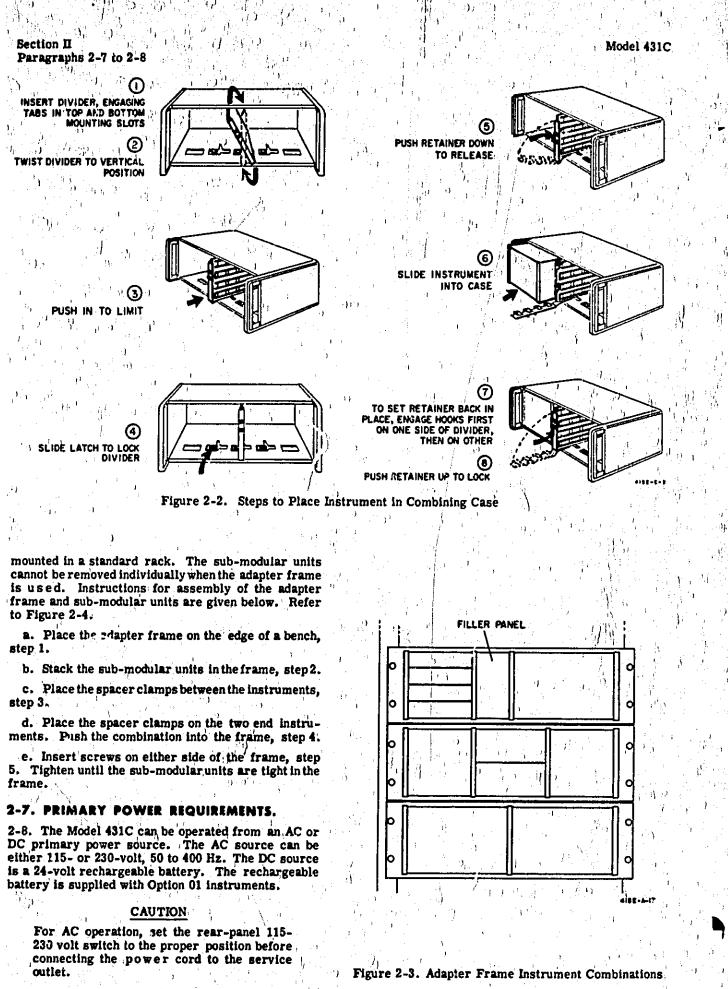
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RETAINER

DIVIDER LATCH

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Figure 2-1. The Combining Case



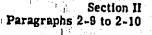
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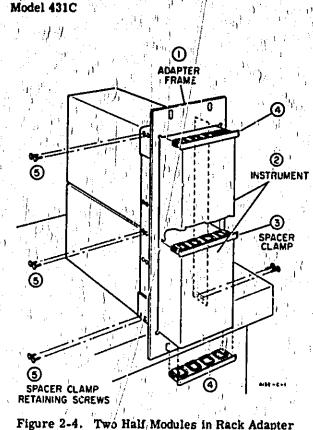
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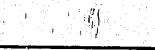
#### POWER CABLE. 2-9.

2-10. To protect operating personnel, the National Electrical Manufacturers' Association (NEMA) recom-mends 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 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,



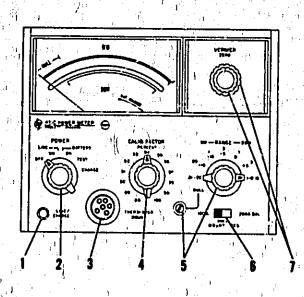
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Two Half Modules in Rack Adapter



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Section III

Figure 3-1

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#### 1. LINE/CHARGE. Lamplights when the POWER switch is in the LINE ON or BATTERY CHARGE position.

- 2. POWER. Determines connections to primary power sources and the battery charging circuit. LINE OFF: Instrument off.
  - LINE ON: Instrument on. Trickle charge applied to battery.
  - BATTERY ON: Instrument on, battery powered.
  - BATTERY TEST: Meter indicates battery ' charge.
  - BATTERY CHARGE: Instrument off. Trickle change applied to battery.
- 3. THERMISTOR MOUNT. Accepts the thermistor mount cable.
- 4. CALIB FACTOR. Switch compensates for the Calibration Factor of the thermistor mount. Calibration Factor values from 88% to 100% may be set in 1% steps.
- 5. 'RANGE.' Sets power range; also includes a NULL position which, in conjunction with the adjacent null screwdriver adjustment, ensures that the metering bridge is reactively balanced.

- 6. MOUNT RES. A three position slide switch which sets the power meter to accommodate thermistor mounts of 100 ohm, 200 ohm and 200 ohm balanced operating resistances.
- . ZERO and VERNIER. Sets the meter pointer over the zero mark. The VERNIER control is a fine adjustment of the ZERO control setting.
- DVM > 500 KΩ. A BNC type jack providing an output voltage linearly proportional to the meter indication. A DC voltmeter with an input impedance greater than 500 k ohms is required to minimize introduction of measurement error (refer to Paragraph 3-49).
- 9. RECORDER/LEVELER. A BNC type jack providing a DC voltage of low source impedance for a recorder or leveler amplifier.
- 10. In Option 02 instruments a thermistor mount connector is wired in parallel with the front panel connector. Two mounts cannot be connected simultaneously.
- 11. DC CALIBRATION. This connector permits a DC input for power meter calibration and DC substitution method of power measurement.
- 12. LINE VOLTAGE. Selects 115- or 230-volt line operation.

02316-1

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

Section III Paragraphs 3-1 to 3-13

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# 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 Model 478A Coaxial and Model 486A Waveguide series. Power may be measured with these mounts in 50-ohm coaxial systems from 10 MHz to 10 GHz, and in waveguide systems from 2.6 GHz to 40 GHz. Full-scale power ranges are 10 microwatts to 10 milliwatts and -20 dBm to +10 dBm. Extended measurements may be made to 1 microwatt and to -30 dBm. The total measurement capacity of the instrument is divided into seven ranges, selectable by a front panel RANGE switch.

3-4. ZERO and VELNIER zero-set controls zero the meter. Zero carry-over from the most sensitive range to the other six less sensitive ranges is accurate to 40.5%. Greater accuracy can be obtained by setting the zero point on the particular range to be used. When the RANGE switch is in the NULL position, the meter indicates inherent metering bridge unbalance, and a front panel NULL screwiriver 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 measureinent errors caused by substitution error and thermistor mount efficiency. The appropriate selection of a Calibration Factor value permits direct meter rending of the RF pover delivered to an impedance equal to the characteristic impedance ( $Z_0$ ) of the transmission line connecting the thermistor mount to the RF source. Calibration Factor values are determined from the data marked on the label of each hp Model 478A or 486A thermistor mount.

3.6. The Model 431C has a DC CALIBRATION jack on the rear panel that can be used for DC substitution method of power measurement. DC substitution is an extension of the power measurement technique normally used. Through the use of DC substitution, instrument error can be reduced from a nominal value of  $\pm 1\%$  to  $\pm 0.16\%$  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  $100\Omega$  or  $200\Omega$ position, depending on the microwave bandused (refer to Table 1-2). The  $200\Omega$  position is used with Model 478A thermistor mounts and the  $200\Omega$  BAL position is used with a balanced thermistor mount.

3-9. Two output BNC type jacks are provided on the rear panel of the instrument, labeled DVM and RE-CORDER/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 1500 k ohms on the range used. The RECORDER/ LEVELER jack furnishes a DC voltage of low source impedance necessary for isolation between a recorder or leveler amplifier and the metering circuit of the power meter. The output voltage is proportional to the power measured and is offset ±40 mV or less from its nominal value, depending on the load impedance. This output voltage allows the Model 431C to be used in a number of additional applications (refer to Paragraph 3-53).

#### 3-9. CONTROLS, CONNECTORS, AND INDICATORS.

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

#### 3-11. BATTERY OPERATION.

3-12. The Model 431C can be operated from a battery instead of a conventional 115- or 230-volt primary power source. A rechargeable Nickel-Cadmium battery is factory installed in Option 01 instruments. The same battery can be ordered and later installed in the basic instrument, thereby modifying the power meter to the Option 01 configuration. The rechargeable battery installation kit may be ordered by hp stock number 00415-606.

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

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

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

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

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

# 3-16. OPERATING INSTRUCTIONS.

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

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

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

<u>Conjugate power</u> 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,  $Z_0$ .

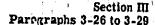
3-22. In general, neither the source nor the thermistor mount has  $Z_0$  impedance, and the actual impedances are known only as reflection coefficients, mismatch losses or SWR. These forms of information lack phase information data. As a result, the power delivered to the thermistor mount and hence 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./\*

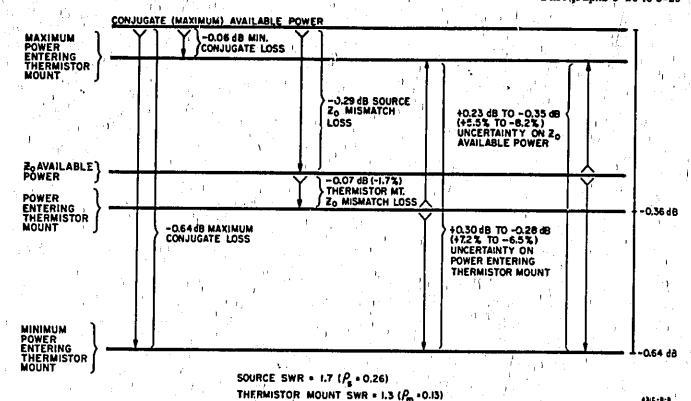
3-23. An example may explain how imperfect match ' affects the uncertainty of power measurement. A typical Z<sub>0</sub> available power measurement situation can involve a source with an SWR of 1.7 ( $\rho_5 = 0.26$ ) and a thermistor mount with on SWR of 1.3 ( $\rho_m = 0.13$ ). Figure 3-2 shows a plot of power levels and mismatch power uncertainties that result from source and thermistor mount mismatch. The source  $Z_0$  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 Zo 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<sub>0</sub> available power level is determined by algebraically adding the thermistor mount loss to the uncertainty caused by source and thermistor mount Z<sub>0</sub> mismatch SWR. Thus, the Z<sub>0</sub> 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<sub>0</sub> 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 Laragraphs 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.







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3-26. RF LOSSES AND DC-TO-MICROWAVE SUB-STITUTION 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. DCto-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  $\mu$ W and is typically 0.1  $\mu$ W on the .01 mW range.

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

a. Measure power.

b. Connect an hp Model 8402 Power Meter Calibra tor 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 <u>a</u>. 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.

3-3

Power =  $\frac{P_1 - P_2}{2}$ 

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Model 431C

#### Section III Paragraphs 3-30 to 3-38

3-30. INSTRUMENTATION ERROR. The degree of inability of the instrument to measure the true substitution audio bias or DC power supplied to the therm istor mount is called power meter accuracy or instrumentation error. Instrumentation error of the Model 431C is  $\pm 1\%$  of full scale,  $\pm 20$ °C to  $\pm 35$ °C. Instrumentation error can be reduced to  $\pm 0.16\%$  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 ine ficture of the thermistor mount. Effective Efficier.cy 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 mcirowave 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 atuner 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.

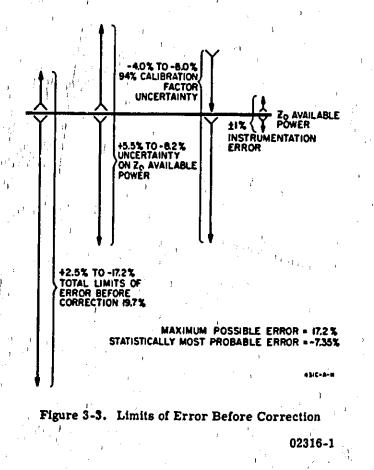
Calibration Factor =  $\frac{PDC \text{ Substituted}}{P_{\mu \text{wave Incident}}}$ 

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 measuremeni, 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.

3-33. 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 Zo 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 Zo 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  $(-6\%) + (\pm 2\%)$ , 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<sub>o</sub> available power uncertainties determines the limits of error before Calibration Factor correction. In this case, the limits are +2.5% to -17.2%.



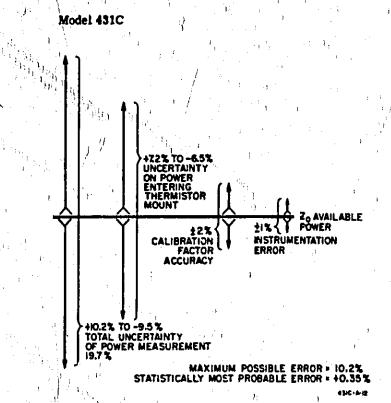


Figure 3-4. Total Uncertainty After Correction

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 Zo available power level.\* The total uncertainty after correction is the algebraic sum of the instrumentation error  $(\pm 1\%)$ , 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 Zo 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 Zo available power level.

\*The relationship between indicated power on the 431C and the Zo available power is given by the following equation:

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

Where:  $P_0 = Z_0$  available power

ρ<sub>B</sub> = source reflection coefficient

 $\rho_{m}$  = thermistor mount reflection coefficient  $\frac{SWR - 1}{SWR + 1}$ 

**¢**₀=

Section III Paragraphs 3-39 to 3-46

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.

# PDC Substituted P<sub>µwave</sub> Dissipated Effective Efficiency =

This power ratio corrects for RF losses and DC-tomicrowave 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 Zo 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 Zo 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 Zo 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. Zo available power is measured when a tunerthermistor, 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 Section III Paragraphs 3-47 to 3-52

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 atotal 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 kohms on lower ranges). This output impedance requires the use of a differential or high impedance voltmeter in order to obtain an accurate measurement of the calibrator 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

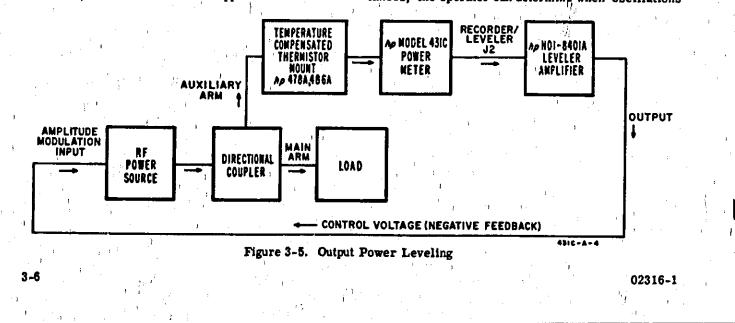
example is 0.2%. Corrections should be added to voltmeter readings since voltmeter impedance loading causes voltage measurements to decrease.

3-49. POWER METER DVM OUTPUT MEASURE-MENT, 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 easymethod 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 43IC 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 volumeter 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 (Rd) during a power measurement. The actual operating resistance of detection thermistors may deviate as much as  $\pm 0.5\%$ 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 THERMIS-TOR MOUNT and 8402B Calibrator RESISTANCE STANDARD connectors. By the THERMISTOR RESIS-TANCE switch, the 8402B Calibrator substitutes precision resistance vaules in place of the thermistor elements normally in the 431C bridge circuits. The switched resistances provide a method of determining a oscillation/no-oscillation state of the 431C Power Meter.

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



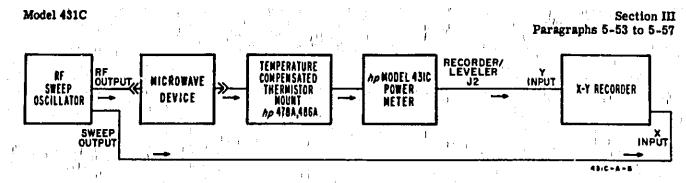


Figure 3-6. Insertion Loss or Gain Measurement

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. Ablock 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 n 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 neg2; refeedback 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.

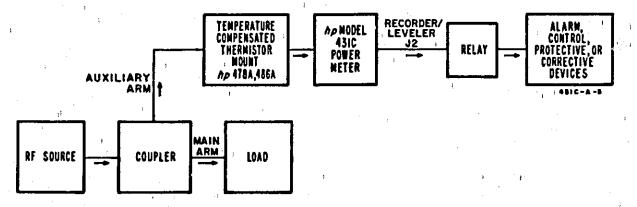
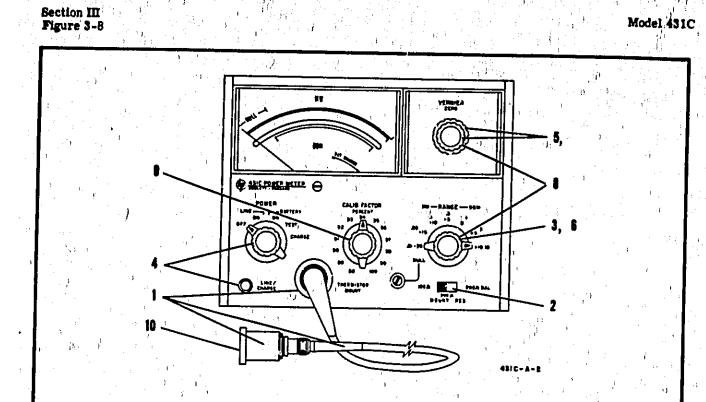


Figure 3-7. Control System Monitoring



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

#### Note

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

- 2. Set MOUNT RES switch to correspond to the operating resistance and type of thermistor mount used.
- 3. Set RANGE to .01 mW.

3-8

4. Set POWER to LINE ON. If instrument is to be battery operated, rotate POWER to BAT-TERY ON.

- 5. Adjust ZERO control for 25% to 75% of full scale on meter.
- 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 VER-NIER controls.

#### Note

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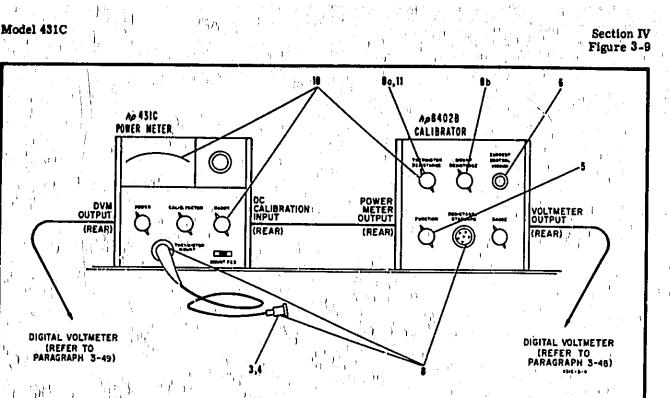
Range-to-range zero carryover is less than 0.5% if the zero is set on the most sensitive range. For maximum accuracy, zero set the meter on the range to be used.

- 9. Set CALIB FACTOR switch to correspond with Calibration Factor imprinted on hpthermistor mount label.
- 10. Apply RF power at the thermistor mount! Power is indicated on the meter directly in mW or dBm.

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Figure 3-8. Turn On and Nulling Procedure



9:

10.

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

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

Apply RF power to the thermistor mount; then note and record the reading of the power mater as indicated by the digital voltmeter. This recorded value is a reference to be precisely duplicated in the DC substitution measurement, step 613

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.

Note

4. Turn off, or disconnect, the P.F source.

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

6. Using 6402B Calibrator CURRENT CONTROL and VERNIER controls, adjust the substitution current until the reference reading of step 3 is precisely duplicated.

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

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

b. MOUNT RESISTANCE to correspond with resistance and type of thermistor mount used.

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

The operating resistance of the detection thermistor (Rd) is the nominal value, indicated on the thermistor mount label plus or minus the correction indicated by the setting of the THER-MISTOR RESISTANCE switch. The percentage correction is a value in-between the limits set by the two positions of the THERMISTOR 'RE-SISTANCE 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:

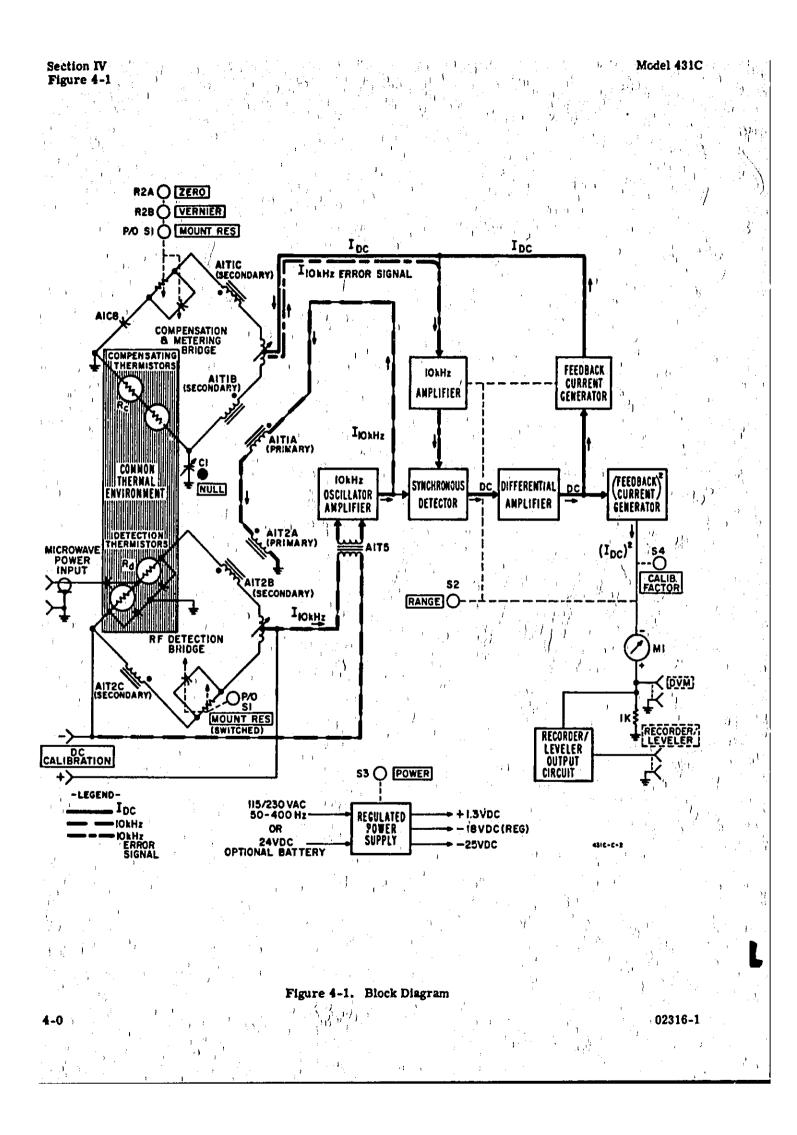
Power (mW) = 
$$\frac{(IDC)^2 (R_d) (10^{-3})}{10^{-3}}$$

Where: IDC = Substitution current in mA (from step 7) Rd = Operating resistance of the detection thermistor (from step 11)

Figure 3-9. DC Substitution

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Model 431C

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Section IV Paragraphs 4-1 to 4-10

#### DESCRIPTION.

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

4-3. The power meter circuitry incorporates two bridges which are made self-balancing by means of separate feedback loops. Regenerative (positive) feedback is used in the detection loop; degenerative feedback in the metering loop. Thermistor elements are ueed in one arm of each of the self-balancing bridges. In the detection loop, the 10 kHz oscillator-amplifier. supplies enough 10 kHz power (I10 kHz) to bias thermistor element Rd to the operating resistance which balances the RF bridge. The same amount of 10 kHz power is also supplied to thermistor element  $R_c$  by the series-connected primaries of transformers AIT1 and A1T2.

4-4. When RF power is applied to thermistor element Rd, an amount of 10 kHz power equal to the RF power is removed from thermistor element Rd by the selfbalancing action of the RF bridge. Since the primaries of AITI and AIT2 are series-connected, the same amount of 10 kHz power is also removed from thermistor element Rc, thus, the action which balances the RF bridge unbalances the metering bridge. The metering bridge loop automatically re-balances by substituting DC power for 10 kHz power. Since the 10 kHz power equaled the applied RF power, the substituted DC power is also equal to the applied RF? power. Instead of metering the feedback current di-rectly, which would require the use of a nonlinear meter scale, an analog current is derived which is proportional to the square of the feedback. Since power is a square-lawfunction of current, the analog current thus derived is proportional to RF power, making possible the use of a linear scale on the meter.

 ${\rm A}^4$ 4-5. There is little drift of the power meter zero point when ambient temperature at the thermistor mount changes because of compensating thermistors. For example, if the ambient temperature at the mount increases, a decrease in electrical power to the thermistors is required to hold their operating resistances constant. The decrease, for both thermistors, is made automatically by the detection loop which reduces 10 kHz power. The amount of DC power in the metering

 $1 \sim 10^{-1} {\rm M}_\odot {\rm Jm}^{-1}$ 

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loop remains unchanged however, and since this DC power controls the meter action, the ambient temperature changes do not affect the meter indication. The compensation capability depends upon the match of thermistor temperature characteristics. When thermistor mounts are built, the thermistors are selected to insure optimum match of thermal characteristics.

#### 4-6. CIRCUIT DESCRIPTION,

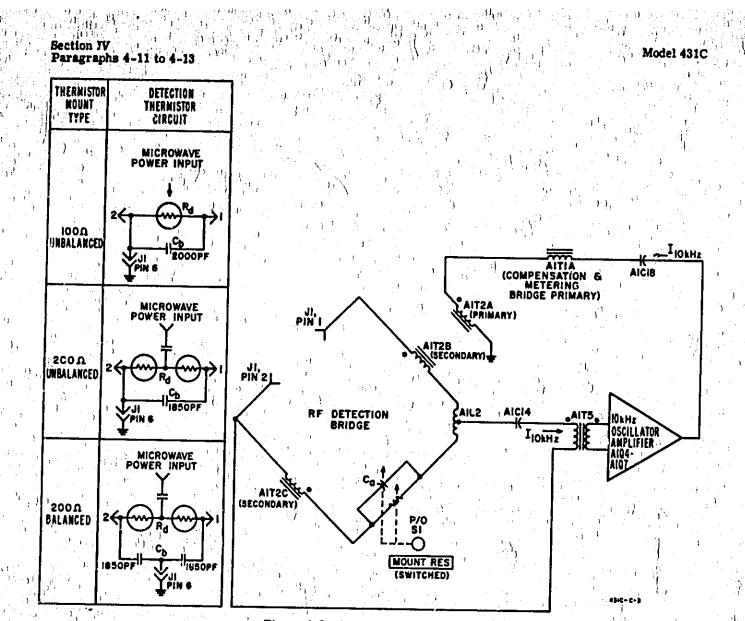
4-7. RF DETECTION BRIDGE. A simplified schematic diagram of the RF detection bridge is shown in Figure 4-2. The RF detection bridge combines with a high gain 10 kHz tuned amplifier to form a 10 kHz oscillator-amplifier. The bridge and amplifier are connected in a closed loop (the detection loop) which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

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

4-9. With application of RE power, the resistance of thermistor Rd decreases causing the regenerative signal from the RF bridge to decrease. Accordingly, 10 kHz power diminishes, the thermistor returns to operating resistance and the detection loop regains. equilibrium. 11.1

4-10. The MOUNT RES switch, S1; changes the resistance arm of the RF detection bridge so that the bridge will function with either a 100 ohm, 200 ohm, or 200 ohm balanced thermistor mount. The 200 $\Omega$  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

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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

4-2

of the bridge. The MOUNT RES switch, which is mechanically linked to both the RF bridge and metering bridge, changes meteringbridge reference resistance from 100 to 200 ohms. When the MOUNT RES switch is in the 200 $\Omega$  or 200 $\Omega$  BAL position some of the feedback current is shunted to ground through R1. This) maintains the I<sup>2</sup>R 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 AlT1 and AlT2 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.

## Model 431C

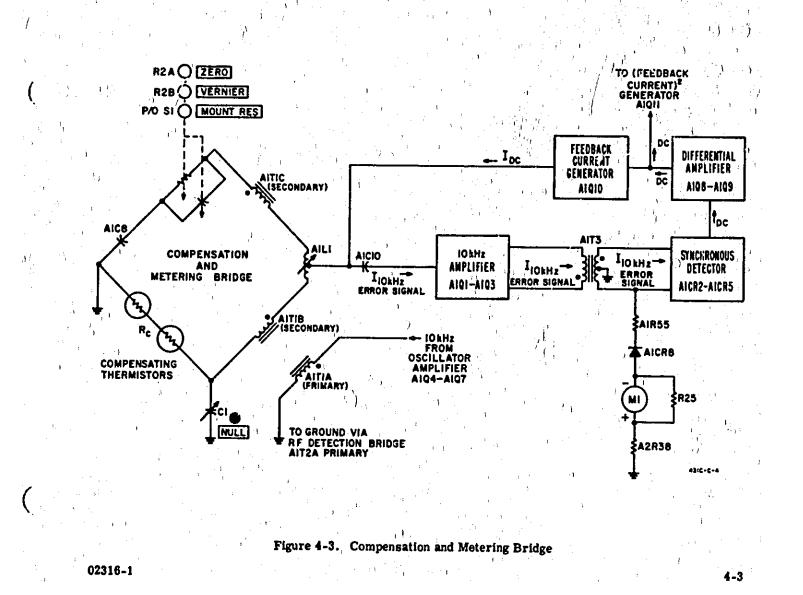
4-14. Variations in 10 kHz bias level, initiated in the RF bridge circuit, cause proportional unbalance of the metering bridge; and there is a change in the 10 kHz error signal (I<sub>10</sub> kHz) applied to the 10 kHz tuned amplifiers in the metering loop. These error signal variations are amplified by three 10 kHz amplifiers, and rectified by the synchronous detector. From the synchronous detector the DC equivalent (I<sub>DC</sub>) 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.

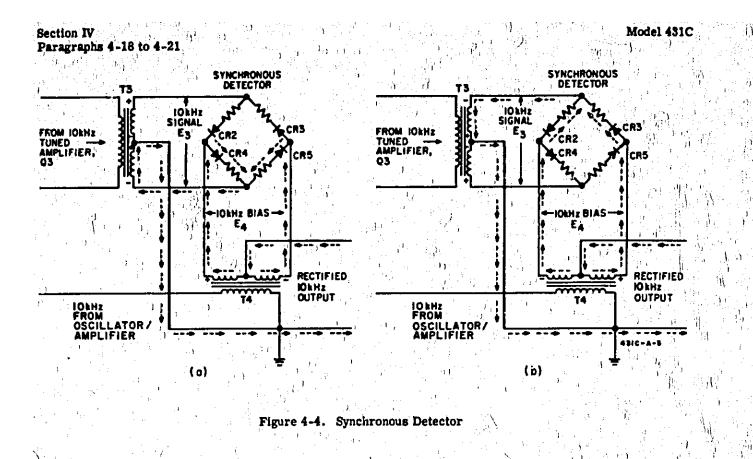
4-15. The reactive components of the metering bridge are balanced with variable capacitor C1 and inductor ;

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 as a rectifier in series with a linearizing resistance in each of its arms. Two





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 state 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 A1Q $\xi_i$  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.

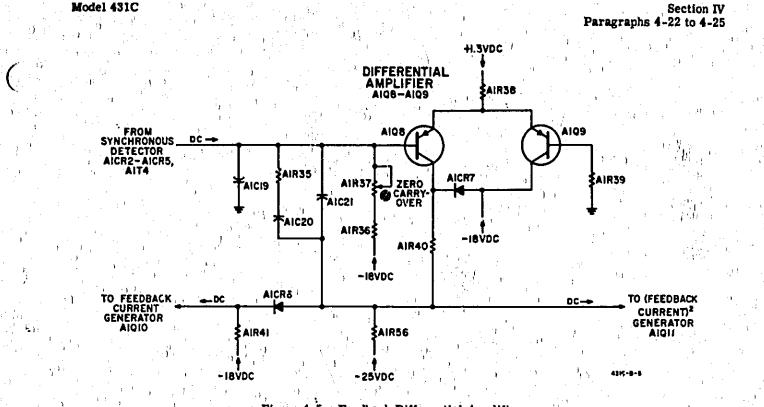


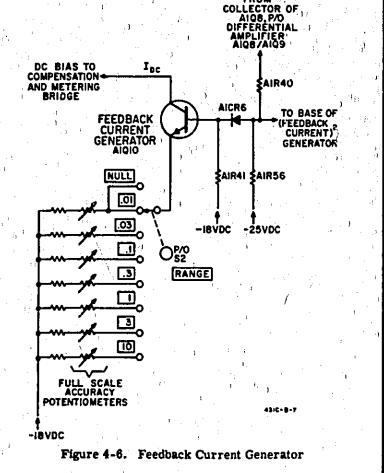
Figure 4-5. Feedback Differential Amplifier

# 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 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 lawfunction by the squaring circuit in series with A1Q11 emitter.



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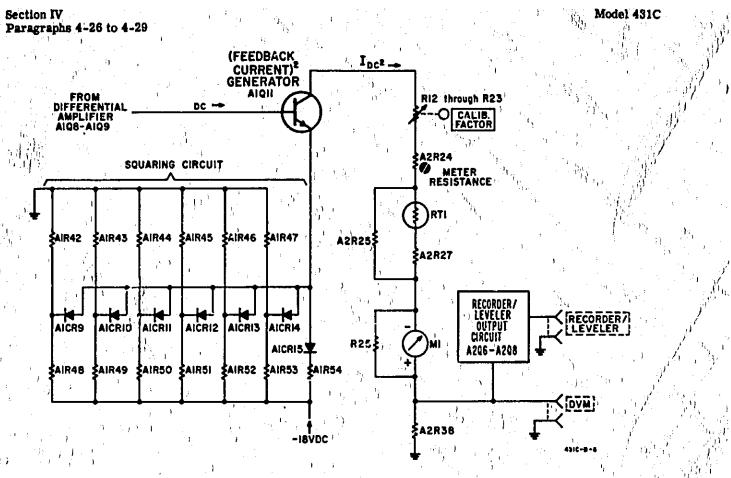


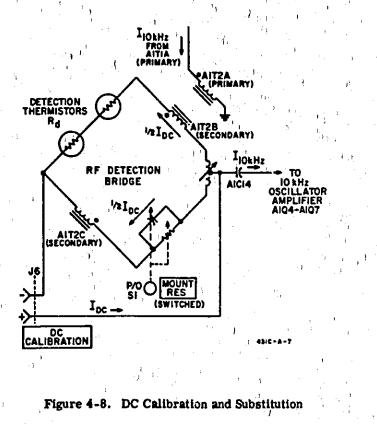
Figure 4-7. Meter Circuit

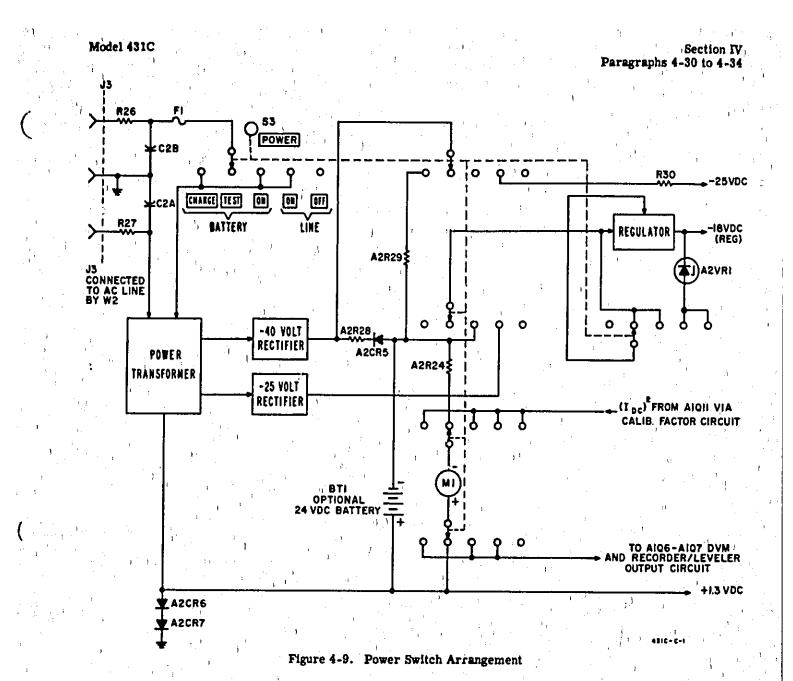
### 4-26. METERING CIRCUIT DIFFERENTIAL AMPLIFIER.

4-27. The metering circuit RECORDER/LEVELER output is a voltage of low source impedance necessary for isolation between a recorder or leveler amplifierand 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 voltige 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-blased. The diodes are blased so that they conduct one after another at discrete values of emitter voltage. This causes the emitter resistance to be proportionately greater for





larger currents. Thus, the collector current of AlQ11 is made to approximate a square law function, and the meter indicates power on a linear scale.

4-30. ZEROING. Perfect balance of the metering bridge would mean that no 10 kHz error signal would be applied to the 10 kHz amplifiers, there would be no DC feedback from AlQ10, and the metering loop would be open. With an open metering loop, zero reference could not be accurately established. In the Model 431C this occurrence is prevented by insuring a closed metering loop even when the ZERO control causes the meter pointer to deflect down-scale from zero, By the combined actions of A1R36 and A1R33, the zero setting of the meter pointer does not coincide with absolute balance of the metering bridge. A slight unbalance of the bridge is maintained by A1R36, while A1R33 provides a counter-action in the feedback currentsquared generator, A1Q11, so that the meter can in-dicate zero even though the metering bridge is not perfectly balanced.) Resistor A1R33 also sets the full scale accuracy of the meter.

# 4-31. DC SUBSTITUTION.

4-32. A simplified schematic diagram of the DC Substitution and Calibration circuit is shown in Figure 4-8. A block diagram of the auxiliary equipment required to perform DC substitution is presented in Figure 3-9 and discussed in Paragraphs 3-34 through 3-36. An accurately determined DC current, IDC, 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.

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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 cutputs are provided by the power supply. Regulated

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Model 431C

Section IV Paragraphs 4-35 to 4-37

voltages of -18, +1.3, and -25 VDC operate the power metercircuits. 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.

4-8

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.

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Model 431C

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Section V Paragraphs 5-1 to 5-4

# SECTION V

#### 5-1. INTRODUCTION.

5-2. This section provides instructions for performance testing, calibration adjustments, troubleshooting and repairing the 431C Power Meter. Front panel controlled performance tests allow the instrument to be checked for conformance to specifications. If performance is not within specifications, adjustment and troubleshooting instructions are provided.

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

5-4. MECHANICAL METER ADJUSTMENT. When the meter is properly zero-set, the pointer rests over

the zero mark on the meter scale when the instrument is: 1) at normal operating temperature, 2) in its normal operating position, and 3) turned off. Set the pointer as follows to obtain best accuracy and mechanical stability:

a. Turn instrument off.

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

c. When the pointer is exactly on zero, rotate the adjustment screw approximately 15 degrees counterclockwise. This frees the adjustment screw from the meter suspension. If the pointer moves during this step, repeat steps <u>b</u> and <u>c</u>.

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

Table 5-1. Recommended Test Equipment

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Section V Paragraphs 5-5 to 5-13

# 5-5. PERFORMANCE TESTS.

5-6. PURPOSE. The procedures listed in Table 5-2 test power meter performance for incoming inspection, periodic evaluation, calibration and troubleshooting. The tests can be performed without access to the instrument interior. Specifications in Table 1-1 are the performance standards. If the power meter fails to meet any of the performance test specifications, refer to the adjustment procedures. If a circuit malfunction is suspected refer to the troubleshooting paragraphs,

#### 5-7. ADJUSTMENTS.

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

5-9. To avoid errors due to possible ground loop currents, isolate the power meter from ground used for other auxiliary equipment. A power plug adapter that removes the ground connection at the line outlet can be used to isolate the power meter.

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

# 5-11, COVER REMOVAL AND REPLACEMENT.

5-12. The side covers can be removed and replaced independently of the top and bottom covers. Each side cover is held in place by four screws retained by nuts which are fastened to the side frames.

# 5-13. TOP COVER REMOVAL.

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

ACCURACY: ±1% of full scale from +20°C to +35°C.	2. ZERO CARRYOVER: Less than +0.5% of full scale when zeroed on most sensitive range.
Procedure	Procedure
<ul> <li>a. Connect equipment as shown in Figure 3-9.</li> <li>b. Set 8402B Calibrator controls as follows: FUNCTION.</li> <li>CURRENT OFF RANGE</li> <li>O1 mW MOUNT RESISTANCE to correspond with resis- tance and type of thermistor mount used.</li> <li>c. Set 431C Power Meter controls as follows: CALIB FACTOR.</li> <li>ON</li> </ul>	<ul> <li>a. Connect hp 3440A DC Voltmeter to DVM output jack on rear of 431C Power Meter (refer to Paragraph 3-49).</li> <li>b. Set power meter controls as follows:</li> <li>POWER</li></ul>
<ul> <li>RANGE</li></ul>	<ul> <li>c. Adjust ZERO for 0.000 VDC reading on 10 volt range of DC voltmeter.</li> <li>d. Rotate power meter RANGE switch clockwise through remaining ranges. Reading on DC voltmeter should remain within 0.000 ±.005 VDC on each range.</li> <li>3. VOLTMETER OUTPUT: 1.000 VDC ±0.3% into 500 k ohm or greater load at full scale meter</li> </ul>
RANGE switch on power meter to 10 mW.	deflection.
g. If necessary, adjust ZERO and VERNIER controls on power meter to obtain an exact 10 mW	<b>Procedure</b> a. Perform steps <u>a</u> through d of ACCURACY
reading. h. Successively set RANGE (mW) switch on cali- brator to 8, 6, 4, and 2 mW positions while ob- serving power meter reading. The power meter should read the power set on the calibrator with- in $\pm 1\%$ of full scale.	<ul> <li>a. Perform steps a through d of ACCURACY performance test.</li> <li>b. Set 8402B FUNCTION switch to CALIBRATE. Reading on DC voltmeter should be 0.997 to 1.003 VDC, and correspond with full scale meter reading of power meter.</li> </ul>

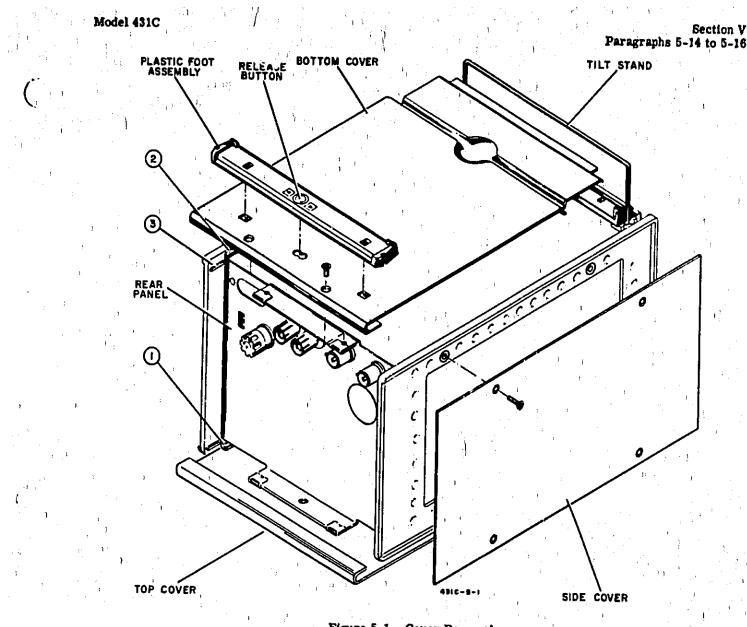


Figure 5-1. Cover Removal

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

# 5-14. 'TOP COVER REPLACEMENT.

a. Rest the cover flat on the cast guides projecting inward near the top of each side frame (see 1), Figure 5-1).

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

c. Replace the two cover retaining screws.

5-15. BOTTOM COVER REMOVAL.

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

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

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

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

5-16. BOTTOM COVER REPLACEMENT.

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

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

c. Slide the cover forward on the guides so that the formed portion at the rear of the cover slides over the two short projections at the rear corner of each side frame (see 3), Figure 5-1).

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

#### Section V Paragraphs 5-17 to 5-18

#### Table 5-3. Circuit Requirements for Factory Selected Parts

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

5-17. POWER SUPPLY ADJUSTMENT.

Procedure

	Note	1	
An adjustment of may require a rea accuracy potentior 5-18).	djustment of	the full i	scale
a. Connect a DC vol ground.	itmeter betw	een pinW,	<b>XA2 and</b> $y$
b. Adjust A2R36 for	-18.00 ±0.0	02 VDC.	
:	) 1	12	$\frac{1}{2} = \frac{1}{2} $
		1116746RAT	
5-18. FULL SCALE ACC	UKACTAD	, , ,	120• 21
Procedure.		11 -	
a. Connect equipme	nt as shown	in Figure	<b>3-9.</b> ()
b. Set 8402B Calibr	ator control	s as follow	78:

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(a)

c. Set 431C Power Meter as follows:

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

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

Range	8402B Calibrator	431C Pc	ower Meter
(mW)	Function	Adjust	Reading
.01	CURRENT OFF	ZERO	0.0
.01	CALIBRATE	A2R14	.01 mW
.03	CURRENT OFF	ZERO	0.0
.03	CALIBRATE	A2R13	.03 mW
.1	CURRENT OFF	ZERO	, 0.0
.1	CALIBRATE	A2R12	.1 mW
•.3	CURRENT OFF	ZERO	0.0
•.3	CALIBRATE	A2R11	.3 mW
1	CURRENT OFF	ZERO	0.0
	CALIBRATE	A2R10	1.0 mW
3	CURRENT OFF	ZERO	0.0
3	CALIBRATE	A2R9	3.0 mW
10	CURRENT OFF	ZERO	6.0
10	CALIBRATE	A2R8	10.0 mW

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

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

#### 5-19. ZERG AND VERNIER CONTROL ADJUSTMENT.

#### Procedure

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

5. Rotate 431C Power Meter RANGE switch clockwise through remaining ranges. Adjust AJR37 to hold DC voltmeter reading within 0.000  $\pm 0.005$  VDC on each range.

#### 5-20. COARSE NULL ADJUSTMENT.

#### Procedure

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100 OHM THERMISTOR MOUNT

a. Connect 100 ohm thermistor mount to power meter.

b. Connect oscilloscope or ACvoltmeter from A1R55 to ground.

c. Set power meter controls as follows:

POWER		•	•	•		•		- ON
RANGE								
CALIB FACTOR								100%
MOUNT RES.								

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

e. Mechanically center NULL capacitor, 'Cl.

f. Adjust AIL1 for a voltage null at A1R55. Fine adjust NULL capacitor C1 for less than 1.5 volts peak to peak.

g. Set power meter RANGE switch to NULL, and fine adjust NULL capacitor C1 for a zero power meter reading. C1 should remain near mechanical center of range  $\pm 10^{\circ}$ .

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

200 OHM THERMISTOR MOUNT

i. Connect 200 ohm thermistor mount to power meter.

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

k. Set power meter controls as follows:

POWER										ON
RANGE					٠		•			.01 mW
CALIB FACTOR		•				•				. 100%
MOUNT RES	٠	٠	•	٠	٠	•		٠	٠	. 200Ω

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

n. Mechanically center NULL capacitor C1,

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

p. Set power meter RANGE switch to NULL, and fine adjust NULL capacitor C1 for a zero power meter reading. C1 should remain near mechanical center of range  $\pm 45^{\circ}$ .

Section V Paragraphs 5-19 to 5-22

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#### Note

If a null cannot be obtained, do not select AlC1 for a value greater than 1000 pF. Increase AlC2 in 50 pF steps, and repeat steps d through g until limits are met.

#### 5-21. OSCILLATOR TANK CIRCUIT TUNING,

#### Procedure

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

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

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

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

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

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

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

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

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

#### 5-22. OSCILLATOR FREQUENCY ADJUSTMENT.

#### Procedure

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

#### Note

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

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

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

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

Section V

Paragraphs 5-23 to 5-28

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

#### 5-23. TROUBLESHOOTING.

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

5-25. The first step in troubleshooting the 431C is to isolate the trouble to either the thermistor mount and thermistor-mount cable combination or the power meter. The operating note furnished with hp thermistor mounts gives a procedure to check the thermistor mount. This procedure will indicate any deficient performance of the mount. An ohmmeter continuity check can be used to determine if the thermistor mount cable or cable connectors are defective. 5-26. TROUBLE ISOLATION. Circuits in the 431C can be divided into five basic functional units as foilows: 1) RF detection bridge and 10 kHz oscillatoramplifier (A1Q4-A1Q7), 2) compensation and metering bridge, 10 kHz amplifier (A1Q1-A1Q3) and synchronous detector, 3) differential amplifier (A1Q8-A1Q9) and feedback current generator (A1Q10), 4) feedback current-squared generator (A1Q11) and metering circuits, and 5) power supply.

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

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

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

Table 5-4. Front Panel Trouble Isolation

#### Model 431C

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Section V Paragraphs 5-29 to 5-35

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

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

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

5-31. DETAILED TROUBLESHOOTING. To assist detailed troubleshooting, normal-operation waveforms are given in Figures 7-3 and 7-8. Locations of test points and components are given in Figures 7-2, 7-4, and 7-6. In addition, normal-operation voltages relative to chassis ground are provided on the schematic diagrams for the collector, base and emitter of every transistor in the instrument. Waveforms and voltage measurements were made with a thermistor mount connected, and the instrument nulled, according to instructions given in Figure 3-8. The first detailed trcubleshooting checks should be performed in the following order: 1) check for power supply output voltages of +1.3, -18, and -25 VDC, 2) check at test point 6 to ensure that the 10 kHz oscillator - amplifier, A1Q4-AIG7, has the proper output waveform, 3) check at test point 2 for correct output of the 10 kHz amplifier, A1Q1-A1Q3. For signal tracing through the amplifier stages, capacitor A1C10 can be disconnected from A1L1 and used as a means to inject a 10 kHz test signal to the input of the first 10 kHz amplifier, A1Q1.

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

5-33. IN-CIRCUIT TESTING. The common causes of transistor failures are internal short- and open-circuits. In transistor circuit testing the most important consideration is the transistor base-emitter junction. Like the control grid of a vacuum tube, this is the operational control point in the transistor. This junction is essentially a solid-state diode. For the transistor to conduct, the diode must conduct; that is, the diode must be forward blased. As with simple diodes, the forward bias polarity is determined by the materials forming the junction. Use the transistor symbol on the schematic diagram to determine the bias polarity required to forward-bias the base-emitter junction. The A part of Figure 5-2 shows transistor symbols with terminals labeled. The emitter arrow points toward the type N material. The other two columns of the illustration compare the biasing required to cause conduction and cut-off in transistors and vacuum tubes. If the transistor base-emitter diode (junction) is forward-biased, the transistor conducts.' If the diode is heavily forward-biased, the transistor saturates. However, if the base-emitter diode is reverse biased, the transistor is cut off (no conduction). The voltage drop across a forward-biased emitter-base diode varies with transistor collector current. For

example, a germanium transistor has a typical forward bias, base – emitter voltage of 0.2 - 0.3 volts when collector current is 1 - 10 mA, and 0.4 - 0.5 volts when collector current is 10 - 100 mA. In contrast, forward-bias voltage for silicon transistors is about twice that for germanium types: about 0.5 - 0.6 volts when collector current is low, and about 0.8 - 0.9 volts when collector current is high.

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

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

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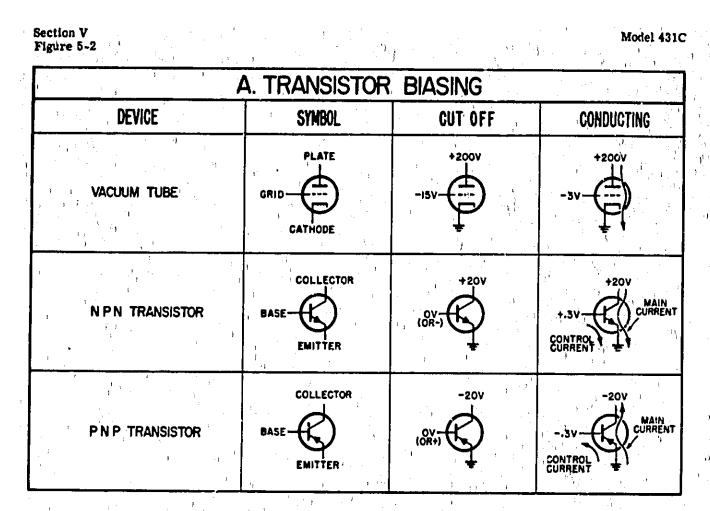
Transist	or	Connect O	Measure	
Туре		Pos. lead to	Neg. lead to	Resistance (ohms)
,	Small	emitter	base*	200-500
PNP	Signal	emitter	collector	10 k-100 k
Ger- manium	-	emitter	base*	30 - 50
	Power	emitter	collector	several hundred
	Small	base	emitter	1 k - 3 k
NPN Silicon	Signal	collector	emitter	very high (might read open)
:		base	emitter	200-1000
	Power	collector	emitter	high, ofter greater than 1M

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

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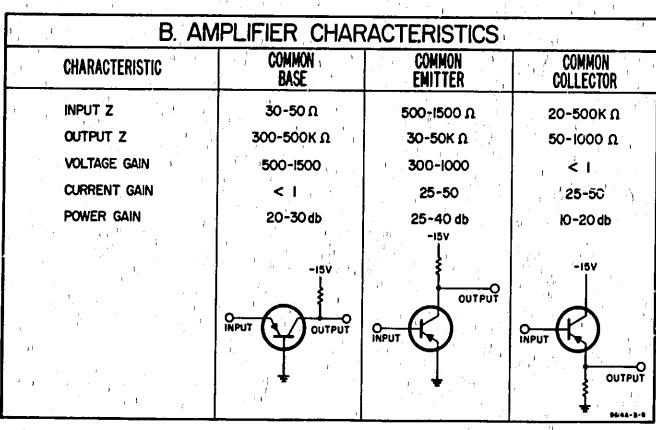


Figure 5-2. Transistor Biasing and Operating Characteristics

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### CAUTION

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

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

Obmmeter :	Ohmmeter Safe Range(s) Oper Volta		Short Ckt	Le	ad 1
			Current	Color	Polarity
hp 412A hp 427A	R x 1 k R x 10 k R x 100 k R x 100 k R x 1M R x 10M	1.0V 1.0V 1.0V 1.0V 1.0V	1 mA 100 μA 10 μA 1 μA 0.1 μA	Red Blk	
hp 410C	R x 1 k R x 10 k R x 100 k R x 100 k R x 1M R x 10M	1.3V 1.3V 1.3V 1.3V 1.3V 1.3V	0.57 mA 57 μA 5.7 μA 0.5 μA 0.05 μA	Red Blk	44 
hp 410B	R x 100 R x 1 k R x 10 k R x 100 k R x 100 k R x 1M	1.1V 1.1V 1.1V 1.1V 1.1V 1.1V	1.1 mA 110 μA 11 μA 1.1 μA 0.11 μA	Blk Red	1 - c 2 1 c 2
Simpson 260	R x 100	1.5V	1 mA	Red Blk	+
Simpson 269	Rxlk	1.5V	0.82 mA	Blk Red	• • • • • •
Triplett 630	R x 100 R x 1 k	1.5V 1.5V	3.25 mA 325 μA	Varies	
Triplett 310	R x 10 R x 100	1.5V 1.5V	750 μA 75 μA	Serial	Number

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Model 431C

Section VI: Paragraphs 6-1 to 6-6

# LACEABLE

#### 6-1. INTRODUCTION.

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

### a. Description.

b. Manufacturer of the part in a five-digit code; see list of manufacturers in Table 6-3.

- c. Manufacturer's part number.
- d. Total quantity used (TQ column).

#### 6-3. ORDERING INFORMAT non

6-4. To obtain replacement parts, address order or inquiry to your local Hewlett-Packard Field Office (see list at rear of this manual for addresses). Identify parts by their Hewlett-Packard stock numbers.

- 6-5. To obtain a part that is not listed, include:
  - a. Instrument model number.
  - Ъ. Instrument serial number.
- c. Description of the part.
- d. Function and location of the part.

#### **REFERENCE DESIGNATORS**

	_		_		· · · · ·	· · · · ·						and the first sector sector	
<u>^</u>	-	assembly	E		misc electronic part	MP	•	mechanical part		ГВ		terminal board	
B	•	motor	- <b>F</b>		fuse	₽ï		plug ) <sup>1</sup>		<b>FP</b>	1 P	test point	
BT	•	battery !	<b>FI</b>		filter 0	Q		translator	. , i t	7		vacuum, tube, neon	
С		capacitor.	J. J. C.		jack .	R	*	resistor		· , .		bulb, photoceli, etc.	
CP		coupler	- <b>エ</b> リー		relay	RT		thermistor	1	<b>V</b> 5	-	cable	
CR	Ъ.	diode	L	- e <sup>1</sup>	inductor .	S	-	switch		Ĉ.		socket	
DL	-	delay line	· • •	_	meter	T				2. 1.2			•
D6 .	-	device signaling (lamp)	- <b></b>	-	meret	*	. •	transformer	1			crystal	
		osvice signating (tamp)			1	2		5 E E	- 1	e. (	•		1.1
					ABBREVIATIO	NS :		and the second second second	1			1	. 7
•			:	- 1)	1			1					
*		Amperes	GE		germanium	N/C		normally closed	R	NO		rack mount only	1.1.1.1
A.F.C.		automatic frequency control	GL		glass	NE		beon	<b>. R</b>	MS	н.	root-mean square	
			GRD	÷.	ground(ed)	NI PL		nictel plate	' A	wv		reverse working	
	-	emploit.				N/O		normally open	•			voltage	1.1
1 A A			н	<u> </u>	benries	NPO		nagative positive zero		-В	·	slow-blow	
B. F.O.		beat frequency oscillator	HEX	1 T.	hexagonal	NPU.		(zero temperature		CR		ACTEW	· .
BE CU		beryllium copper	HG	- Ē.		,					٠ <b>Ξ</b> .		1.1
BH		binder head		-	mercury	· · · · · · · ·		conflicient)		E	•	selenium	1
BP		bandrass	HR	•	hour(s)	NRFR		not recommended for		ECT		section(s)	
BRS		braas	. 's		11 E 11 E 11 E			field replacement		F, MCCON		semiconductor	1.11
BWO			1 <b>17</b> 90		Intermediate freq	NSR	•	not separately	/ 5			atlicon	
BWU	•	hackward wave oscillator	DOPG	_	Impremated	· · · · · · · · · · · · · · · · · · ·		replaceable	5	ու չ		61.+er	
			INCD	-	Incandescent				8	L -	•	alide	14
ccw		counter-clockwise		· •		OBD		order by description	. 8	PL		special	1 1
CER		ceramic	DICL		luclude(s)	<b>ÖH</b>		oval head		ST		stainless steel	
CMO			INS		Insulation(ed)			oxide	5		-	split ring	
		cabinet mount only	INT		internal P	UA		blage		rL )	2	ateel	1.1
COEF		coefficient			- • · ·	P	. •		) B	16 /	•	HLEES .	1.2
COM		common	K /		kilo = 1000			peak 1	· · · (_				÷
COMP		composition				. PC	•	printed circuit		A		tantalum	
CONN		connector	LIN		linear taper	PF	•	picofarads = 10 <sup>-12</sup>		ΰ		time delay	1
CP		cadmium plate	LX WASH		lock washer		· . ·	farada	) <b>T</b>	GL .		toggle	
CRT		cathode-ray tube	LOG		logarithmic taper	PH BRZ	в.	phosphor bronze	7	1 ` ´		titanium	1.1
CW		clockwise	LPT			> PHL	•	Phillips	τ	OL.		tolerance	
	-		LFF	-	low pass filter	PIV		peak inverse voltage	े में	RIM		trimmer	
				:		P/0		part of		WT		traveling wave tube	1
DEPC		deposited carbon	M		milli = 10 <sup>-3</sup>			polystyrene	•	<b>**</b>			
DR		drive	MEG	-	mes. = 10 <sup>5</sup>	PORC		porcelain	ប		•	micro = 10-6	
			MET FLM		metal film	PORC		position(s)					
ELECT		electrolytic								AR		variable	
ENCAP		encapeulated	MET OX	-	metallic oxide	POT		potentiometer	v	DCW		dc working volts	
			MTR	-	manufacturer	PP 🔅		peak-to-peak			1	and the second	
EXT	۰.	external	MINAT		miniature	PT .		point	· 14	1	н.	with	TV 1
' i			MOM		momentary	PWV	•	peak working voltage	: 14	i '		watts	
7	-	farada	MTG	1 🗰 🗌	mounting	RECT		rectifier		TV		working averse	1.1
78		flat bend	MY	-	"mylar"	RF		radio frequency				voltage	
				÷ -,	-	RH		round head	. 13	w		wirewound	· · · ·
		fillister hand	N;	_	nano (10 <sup>-9</sup> )		-			/o ·		without	1
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	T	ble 6-1. Reference Designation Index	2 2
Reference Designation	Stock No.	Description #	Note
			note
1	00431-6 ت	BOARD ASSEMBLY, AMPLIFIER	0.5
	0140-0198	CIFXO MICA 200PF SN 300VDCW FACTORY SELECTED PARTI TYPICAL VALUE GIVEN	
102	0160-2201	GIPAD MICA 51 PF 5% FACTORY SELECTED BARTE TYPICAL VALUE RIVEN	х. - х
103	0140-019B	FACTORY SELECTED PARTI TYPICAL VALUE STURN	1
1C4: 1C5	0160-0185 0160-0185	CIFXD MICA 2100PF IN 300VDCW CIFXD MICA 2100PF IN 300VDCW	
1C6 1C7	0180-0116 0180-0116	CIFXD ELECT TA 6.8 UF 10% 35VDCW CIFXD ELECT TA 6.8 UF 10% 35VDCW	н
1C8 1C9	0180-0106 0170-0069	CIFXD ELECT TA 60UF 20% 6VDCW CIFXD POLY 0.1UF 2% 50VDCW	
1010	0160-0174	CIFXD CER 0.47UF +80-20% 25VDC#	t
1C11 1C12 1C13	0160-0174 0170-0069	CIFXD CER 0.47UF +80-208 25VDCW CIFXD POLY 0.1UF 28 50VDCW	
1C13 1C14 1C15	0180-0116 0160-0116 0170-0069	CIFXO ELECT TA JOB UF 10% 35VDCW CIFXD ELECT TA 608 UF 10% 35VDCW CIFXD POLY 001UF 2% 50VDCW	
	0180-0116	CIFXD ELECT TA 6.8 UF 10% 35VDCW	)
IC17 () () IC18 () () IC19	0180-0116 0180-0049	CIFXD ELECT TA 6.8 UF 10K 35VDCW	ſ
iC20	0180-0045 0180-0045	CIFXD ELECT 20UF 25VDCW CIFXD ELECT 20UF 25VDCW	۱, ۱
IC21 IC22	0160-0174 0140-0159	CIFXD CER 0.47UF +80-20% 25VDCW CIFXD MICA 3000PF 300VDCW FACTORY SELECTED PART: TYPICAL VALUE GIVEN	j
	1901-0025	DIODE JUNCTIONISHA AT IV 100 PIV	1 
CR2 CR3	1910-0016 1910-0016	DIODE:GERMANIUM 100HA AT 0.85V GOPIV DIODE:GERMANIUM 100HA AT 0.85V GOPIV	3
CR4	1910-0016 1910-0016	DIODEIGERMANIUM 100HA AT 0.85V GOPIV DIODEIGERMANIUM 100HA AT 0.85V GOPIV	: . t
	1901-0450 1901-0025	DIODEISILICON	
CRB	1901-0025 1901-0025 1901-0450	DIODE+JUNCTIONISHA AT 1V 100 PIV DIODE+JUNCTIONISHA AT 1V 100 PIV DIODE+SILICON	н 
	1901-0450	DIODEISILICON	
CR12	1901-0450 1901-0450	DIODEISILICON AND DIODEISILICON	
CR13 CR14	1901-0450 1901-0450	DIODE SILICON DIODE SILICON	
CR15	1901-0450	DIODEISILICON	
2 9	2140-0122	COILIVAR 2X 9-20 UNY EACH Coilivar 2X 9-20 UNY Each	· ·
A	110-0040 110-0040	INDUCTORIAUDIO INDUCTORIAUDIO	2.1 2.1
	853-0020	TRANSISTORISILICON PNP	
3 1	854-0071 853-0020 854-0071	TRANSISTORISILICON NPN 2N3391 TRANSISTORISILICON PNP TRANSISTORISILICON NP' 2N3391	
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# See list of abbreviations in introduction to this section \_\_\_\_\_ **1** ---- ••

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Section VI Table 6-1

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Reference Designation	\varTheta Stock No.	Description #	Note
- 7		$\langle \cdot \rangle$	
A105	1853-0020	TRANSISTORISILICON PNP	
A196	1854-0071	TRANSISTORISILICON NPN 2N3391	
A107	1053-0020	TRANSISTORISILICON PNP	÷ .
A105 A109	1853-0020	TRANSISTORISILICON PNP	u
PTAA P	1033-0020	TRANSISTORISILICON PNP	$p^{*} \rightarrow p^{*}$
A1010	1854-0071	TRANSISTORISILICON NPN 2N3391	
AIQII	1854-0071	TRANSISTORISILICON NPN 2N3391	
			1
AIRI AIRZ	0811-0066	RIFXD WW 887 OHM 18 8/100W	
AIR3	0811-0065	R#FXD WW 511 OHH 1.0% 1/20W R#FXD WW 511 OHH 1.0% 1/20W	
A1R4	0757-0199	RIFXD HET FLM 21.5K OHM 18 1/84	1.1
AIR5	0811-1571	RIFXD ## 189 OHM 0.18 1/8#	
1		1	
A1R6 A1R7	0811-1572	RIFXD WW 255 OHM 0.18 1/8W RIFXD HET FLM 61.9K OHM 18 1/80	
MANY -	0751-0400	FACTORY SELECTED PART, TYPICAL VALUE BIVEN	,
AlR8 -	0811-1645	RIFXD WW 202.1 OHN 0.1% 1/6W	
AIR9	0757-0123	RIFXD MET FLM 34-8K OHM 18 1/108	
A1R10	0011-1844	FACTORY SELECTED PART: TYPICAL VALUE GIVEN	3
MARIN	0811-1566	RIFXD WW 200 OHH 0.1% 1/8W	
AIRII	0757-0417	REFXD MET FLM 562 OHN 18 1/8W	
AIRI2	0757-1094	REFXD MET FLM 1.47K OHM 18 1/8#	
AIR13	0757-0279	RIFXD MET FLM 3-16K OHM 1N 1/8W	2.
A1R14	0698-0085	RIFXD MET FLM 2.61K OHH 18 1/88	
A1R15	V131-044V	RIFXD HET FLH 7.50K OHM 18 1/88	
AIR16	0757-0279	RIFXD MET FLH 3.16K OHM 18 1/88	· .
A1R17	0757-0280	RIFXD MET FLM 1.00K OHM 1% 1/8W	
A1R18 ,	0757-0440	RIFXD HET FLM 7.50K OHN 18 1/8W	
A1R19 A1R20	0698-3156	RIFXD MET FLH 14.7K OHM 18 1/8	÷
	0698-3157	RIFXD HET FLM 19.6K OHH 18 1/88	
A1R21	0698-3157	RIFXD HET FLH 19.6K OHH 18 1/88	1
A1R22	0757-0279	RIFXD MET FLM 3-16K OHM 18 1/8a	1
A1R23	0698-3438	ROFXD HET FLM 147 OHM IN 1/80	i
A1R24 A1R25	0757-0465	RIFXD HET FLM 100K OHM 18 1/88 RIFXD HET FLM 147K OHM 18 1/88	
A1R26	0698-3440	RIFXD MET FLH 196 OHH 18 1/8#	· · · ·
A1R27	0757-0442	RIFXD HET FLH 10.0K OHH IN 1/80	· · ·
A1R26 A1R29	0698-3160	RIFXD HET FLH 31.6K 1% 1/8m RIFXD HET FLH 21.5K OHH 1% 1/8m	
AIRJO	0757-0442	RIFXD HET FLH 20:0K OHH 1% 1/88	:
\			: }
AIRJI AIRJZ	0757-0280	RIFXD HET FLM 1.00K OHM 18 1/88	, <sup>1</sup>
A1R33	0757-0280	RIFXD MET FLM 1.00K OHM 18 1/88 RIFXD MET FLM 1.00K OHM 18 1/88	
A1R34	0757-0280	RIFXD MET FLM 1.00K OHM 18 1/88	
1R35	0498-0084	RIFXU MET FLM 2150 OHN 18 1/88	· 1
A1R36 A1R37	0498-3450 2100-0144	RIFXD HET FLM 42.2K OHM 1% 1/8m RIVAR COMP 250K OHM 30% LIN 1/5m	4
1R38	0698-3447	RIFXD MET FLM 422 OHM 18 1/8	:
1R39	0757-0417	RAFXD MET FLM 562 OHM 18 1/88	
N1R40 /	0757-0274	RIFXO MET FLM 1.21K OHH 18 1/88	,
1R41	0698-3449	RIFXO MET FLH 28.7K OHM 18 1/88	
		ALL AND A REAL PARTY ALL THE TABLE	
$\gamma = \beta_1$	$\gamma = -\sum_{i=1}^{n} \gamma_{i}$		
	$\left  \frac{1}{2} \right  = -\sum_{i=1}^{n} \left  \frac{1}{2} \right $		
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		list of abbreviations in introduction to this section	
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Table 6-1. Reference Designation Index (Cont'd)

Reference Designation	🕏 Stock No.	Description #			Note
1	₩ a	1			
A1R42	0698-4028	RIFXD HET FLH 48.64K OHH 1/28 1/88 FEB			
A1R43	0698-4029	RIFKO HET FLH 53.39K CHH 1/28 1/88			
A1844	0098-4027	RIFXD NET FLM 64.45K OHH 1/28 1/8W		χ	
A1R45 :	0698-4026 1	RIFXD MET FLM 89.90K OHH 1/28 1/88 RIFXD MET FLM 128.5K OHH 1/28 1/88			
		RIFAD DET FER 12010K UNN 1728 1788			
A1847	0698-4024	RIFXD HET FLH 259.6K OHH 1/28 1/88			1
AIR48	0698-4023	RIFXD MET FLM 130.4X OHH 1/28 1/88		1 1	
A1849	0698-4034	RIFXD HET FLM 84.32K OHN 1/28 1/88		.)	
AIRSO	9698-4033	RIFXD MET FLM 62.26K, OHH 1/28 1/88		ь — В.	
A1R51 5	0698-4032	RIFXD MET FLM 51.22% OHH 1/28 1/88		<ul> <li>1 No.</li> </ul>	
A1852	0698-4031	RIFXD HET FLH 43.25K OHH 1/28 1/88	14 J		1
A1853 -	0698-4030	RIFXD MET FLM 40.77K OHN 1/28 1/88			
A1R54	0698-4028	RIFXD HET FLM 48.64K OHH 1/28 1/88		1	
AIR55	0757-1094	RIFXD MET FLM 1.47% OHM IN 1/88			
A1R56	0698-3449	RIFXD HET FLH 28.7K OHH IN 1/88	:		
			1		I
A1T1 A1T2	9120-0066			,	;
A173	9120-0066	TRANSFORMERIAUDIO			. 1
A1T4	9120-0065	TRANSFORMERIAUDIO			
A115	9100-1677	TRANSFORMERIINPUT			
				1	
N2	00431-6009	BOARD ASSY POWER SUPPLY			
A2C1	0180-0138	CIFXD ELECT 100UF -10+1008 40VDCH		ta a secondaria de la composición de la	
202	0180-0049	CIFXD AL ELECT 20UF SOVDCW	1 *		
203;	0150-0093	CIFXD CER 0.01UF +80-208 100VDCW			2.4
204	0150-0012	CIFXD CER 0.01 UF 20% 1000VDCW			
1205	0160-0174	CIFXD CER 0.47UF +80-208 25VDC			
206	0180-0059	CIFXD ELECT 100F -108+1008 25VDCW		:	
	0180-0105	CIFXD ELECT IOUP -108+1008 25VDCW		· · · ·	
208	0150-0096	CIFXD CER 0.05UF 100VDCW	:	· · ·	
2C9 <sup>***</sup>	0180-0060	CIFXD ELECT 2000F -108+1008 3VDCB			
200	1001 0007				. 9
2CR1	1901-0025	DIODE JUNCTION SHA AT 1V 100 PIV			
2CR3	1901-0025	DIODE+JUNCTION+5HA AT 1V 100 PIV DIODE+JUNCTION+5HA AT 1V 100 PIV		· ·	
2CR4	1901-0025	DIODE JUNCTION SMA AT IV 100 PIV		, <b>1</b>	
2CR5	1910-0016	DIODEIGERMANIUM 100MA AT 0.65V 60PIV	i a i		
	1			Į	· .
2CR6	1901-0026	DIUDEISILICON 200 PIV 0.5 AMP			
2CR7	1901-0026	DIODEISILICCN 200 PIV 0.5 AMP	ł	,	
201	1853-0020	TRANSISTORISILICON PNP		)	
202	1850-0044	TRANSISTORISILICOR PNP TRANSISTORIGERMANIUM PNP 2N1183			
203	1853-0020	TRANSISTORISILICON PNP			
204	1854-0071	TRANSISTORISILICON NPN 2N3391			
295	1854-0071	TRANSISTOR SILICON NPN 2N3391		- 1 I	
				1	
206	1854-0071	TRANSISTORISILICON NPN 2N3391			
207	1854-0071 1853-0020	TRANSISTORISILICON NPN 2N3391 TRANSISTORISILICON PNP	2		
		INANGIGIVN'GALIGVA FAF			
2R1	2100-1613	RIVAR COMP 2K OHH 205 LIN 1/5#		Ì	
282	2100-1617	RIVAR COMP 1K OHM 20% LIN 1/5W			
283 1	2100-1612	RIVAR COMP 500 OHM 20% LIN 1/5#	2	1	
2R4	2100-1612	RIVAR COMP 500 OHM 20% LIN 1/5#			
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Reference	Stock No.	The southed as A	T
Designation		Description #	Note
			( ;
388 I			1
275 J	2100-1616	RIVAR COMP 200 OHH 20% LIN 1/5#	
287	2100-1615	RIVAR COMP 100 OHH 20% LIN 1/58 RIVAR COMP 100 OHH 20% LIN 1/58	
RB	2100-1615	RIVAR COMP 100 OHH 20% LIN 1/5#	1
289	2100-1615	RIVAR COMP 100 OHH 208 LIN 1/5#	
2R10	2100-1616	RIVAR COMP 200 OHN 20% LIN 1/5#	·
RLL	2100-1612	RIVAR COMP SOD OHM 20% LIN 1/5#	· ·
IR12 ( ),	2100-1612	IRIVAR COMP 500 OHM 20K LIN 1/5W	
R13 '	2100-1617	RIVAR COMP IN OHH 205 LIN 1/5W	1 .
R\$4	2100-1613	RIVAR COMP 2K OHN 2CH LIN 1/5W	1
R15	0698-3337	RIFXD HET FLM 1.37K OHH 18 1/28	
R16 1.2	0757-0826	RIFXO HET FLN 2.43K OHH 18 1/28	
R17	0757-0436	RIFXD MET FLH 4.32K OHM IN 1/8%	
R18 I	0757-0440	RIFXD NET FLM 7.50K OHN IN 1/AP	
R19	0698-3581	RIFXD MET FLM 13.7K OHN 18 1/8	
R20	0757-0451	RIFXD HET FLM 24.3K OHH 18 1/88	
R21	0757-0456	RIFXD HET FLM 43.2K OHM 18 1/88	1
R22	0698-3582	RIFXD MET FLM 41.2K OHM 18 1/88	1
R23	0698-0063	RIFXD HET FLM 5.23K OHH 18 1/8	l .
R24 , >	2100-1615	RIVAR COMP 100 OHN 208 LIN 1/58	
125	0757-0399	RIFXD MET FLM 82.5 OHM IN 1/8W	
126		NOT ASSIGNED	ĺ
R27	0811-1562	RIFXD WW & OHM 18 1/4W	
R28 · .	0757-0279	RIFXD HET FLM 3-16K OWN 18 1/84	
R29	0498-3155	RIFXD MET FLM 4640 OHN 18 1/8	; ; ;
830	0698-3132	RIFXD MET FLM 261 OHM IS 1/88	
R31 1	0757-0279	RIFXU HET FLM 3.16K OHM 18 1/88	
R32 -	0698-3155	RIFXD MET FLM 4640 OHM 18 1/8	1
R33	0757-0279 👘 👘	RIFXO MET FLM 3-16K OHM 18 1/8+	
R34	0757-0278	RIFXD HET FLM 1.78K OHM 18 1/88	
35	0757-0442	RIFXD HET FLM 10.0K OHM 18 1/84	
R36 · [	2100-0182	RIVAR COMP 3.3K OWN 108 LIN 0.150	
R37	0698-3155	RIFXD MET FLM 4640 OHN IN 1/A	
134	0698-3491	RIFXO MET FLM IK OHM O.IK I/AW	:
139	0757-0290	RIFXD HET FLM 6-19K OHH 18 1/8#	1.1
140	0757-0463	RIFXD MET FLM 02-5K 18 1/88	
	0757-0441	RIFXD HET FLM 8-25K OHH 18 1/88	1
142	0757-0180	RIFXD HET FLM "1.6 OHH 18 1/88	
T1	0839-0011	THERMISTOR 100 OHM LON	
	1902-0017	DIODE+BREAKDOWNIG.BIV IOB 400 MW	
	1902-0017 1902-0018	DIODE BREAKDOWNIG. BIV ION 400 MM	
1		SEMICON DEVICEIDIODE SILICON IN941 11.7V Chassis Parts	
	0121-0035	CIVAR AIR 7.2-143.7PF	• .
· · · ·	0150-0119	CIFXO CER 2 X 0.01 UF 208 250VACW	•
[	1450-0048		
Í	÷ .		
	2110-0017 1400-0084	FUSEICARTRIDGE 0.15 AMP SLOW BLOW	
1		HOLDER FUSE POST TYPE JAG	
	1251-0149	CONNECTORIS FEMALE CONTACTS	
, 1		THERMISTOR MOUNT	
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	;		
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Table 6-1. Reference Designation Index (Cont'd)

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Reference Designation	Stock No.	Description #	Note
			1
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13	1250-0083	CONNECTORIBNC	
J2	4430-0043	RECORDER LEVELER	5 P.S
J3 <sup>′</sup>	1251-0148	CONNECTORIPOWER 3 PIN MALE	
<b>J4</b> ( ) ( )	1250-0083	CONNECTORIBIC	
			1
15	1251-0149	CONNECTORIG FEMALE CONTACTS Thermistor Mount opt 2	
	_	CONNECTORIDE CALIBRATION INCLUDES!	
	and the second second		
	1510-0006	BINDING POST ASSEMBLY BLACK	
	1510-0007	BINDING POST ASSENBLY IRED	
	0340-0086	INSULATORIBINDING POST INSULATORIBINDING-POST DOUBLE	
	0340-0070	THOULAND THE THE THE THE THE THE THE	i l
11	1120-1101	KETER	
	· · · · · · ·		
R1	0698-3444	RIFXD MET FLM 316 OHM 18 1/8W	
R2	2100-0342	REVAR WE LOK 108 800 OHM 108 LIN 2W NOT ASSIGNED	
R3 R4	0698-3151	R2FXD HET FLH 2.67K OHM 18 1/88	
85	0757-0421	RIFXD HET FLM 825 OHH 18 1/8W	1 I
16	0698-3444	RIFKD HET FLM 316 OHN 18 1/80	
17	0698-3158	R#FXD MET FLM 23.7K OHM 1% 1/80 R#FXD MET FLM 1.00K OHM 1% 1/80	
<b>te</b> 2 L9 a -	0757-0280	RIFXD NET FLN 215 OHN 18 1/8W	
10	0757-0398	RIFAD HET FLH 75 OHH 1% 1/8W	
· • •			
11	0757-0180	RIFXD HET FLH 31.6 OHH 18 1/8W	4 I
12	0757-0277	RIFKD HET FLM 49.9 OHN 18 1/8W	. <b>I</b>
13	0757-0277	RIFXD MET FLM 49.9 OHM 1% 1/8W RIFXD MET FLM 49.9 OHM 1% 1/8W	Г.)
(14) (15)	0698-3566	RIFXD HET FLM 53.0 OHM IN 1/8W	
R16	0698-3566	RIFXD HET FLM 53+0 OHM 18 1/8W	
R17	0698-3566	RIFXD HET FLM 53-0 OHM 18 1/8W	
R16 , P	0757-0395	RIFXD MET FLM 56.2 OHM 1% 1/8W RIFXD MET FLM 56.2 OHM 1% 1/8W	:
R19 R20	0757-0395	RIFXD HET FLH 56.2 OHH 18 1/84	
	0131-0313		
21	0757-1104	RIFXD HET FLM 60.0 OHM IN 1/8W	
122	0757-1104	RIFXD MET FLM 60.0 OHM 18 1/8W	
R23	0757-1104	RIFXD MET FLM 60.0 OHM IN 1/8W	1
124	0698-3160	RIFXD MET FLM 31.6K 1N 1/8W RESISTOR: FIXED 17.8KOHM-TO INFINITY	1 .
		A REAL AND A REAL	
26	0757-0401	RIFXD HET FLM 100 OHM 18 1/8W	1 a 1
127	0757-0401	RIFXD HET FLM 100 OHN 18 1/88	2
R28	0698-3160	R#FXD MET FLM 31+6K 1% 1/8W R#FXD MET FLM 383 OHM 1% 1/2W	
129 130	0698-3404	RIFXD HET FLH 1-21K OHM 18 1/2W	
			· · ·
51 51	00431-6005	SWITCH ASSEMBLY. MOUNT RES INCLUDES R1	
52	00431-6002	SHITCH ASSEMBLY: RANGE, INCLUDES:	. i.
		R4 THRU R11	
	3100-1817	SWITCH:ROTARY' SWITCH ASSEMBLY: POWER INCLUDES:	
5 <b>3</b> - 10 - 10 - 10 - 10	00431-6004	R24,R28 THRU R30	
	3100-1820	SHITCHEROTARY	
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Reference Designation	· A Obach Ma		
Penie -	· 😔 Stock No.	Description #	Note
	1		a
<b>4</b>	00431-6003	SWITCH ASSEMBLY. CALIB INCLUCES: R12 THRU R23 SWITCH:ROTARY	
1	9100-0400	TRANSFORMERIPOVER	·
	00431-6011 8120-0078	CABLE ASSYTTHERMISTOR MOUNT, 5 FT.	
A1 A2	1251-0233 1251-0233	CONNECTORIPC 44 CONTACTS CONNECTORIPC 44 CONTACTS	
,	· ,	MISCELLANEOUS	
	0370-0064	KNOB	1
	0370-0067	KNOBIBLK CONCENTRIC 1 IN. OD 17/64IN. HOLE	:
	0370-0112	KNOBIBLK BAR W/ARROW 3/4 IN. OD 1/4 SHAFT Power Calib Factor	r
	5020-0705 5040-0701	RANGE TRIMIMETER EXTENDERIMETER CASE	, · ·
7	08431-0004	BRACKET PANEL	an th
	÷ 1	OPTION OL	
	09415-606	BATTERY INSTALLATION KIT+INCLUDESI	
n i	1420-0009	BATTERYIRECHARGEABLE 24V 1.25AH	
	00415-006 2420-0001	COVERIBATTERY NUTIHEX ST NP 6-32 X 5/16 W/LOCKWASHER	
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Reference Designation () Stock No (5)					
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			6	· · · ·	1
			-B - 37		
	· · · · · · · · · · · · · · · · · · ·	BINET PARTS		ц. Ц. 1. с. –	± 1 • 1
1 5060-0703	FRAME ASSEMBLY		- 1	;	
2 1490-0032 3 5040-0700	STANDETILT, HALF-		2	. i .	
4 5060-0728	FOOT ASSEMBLY HAL	F-MODULE	i 2		I
5 5020-0701 2370-0015	CABINET SPACER SCREWISS, FH, SLOT	3		ا دو	
6 5000-0703 2370-0020	COVER ISIDE SCREWISS,FM,PHILL	IPS OR 6-32 X 3/16	e J <b>™</b> to the transformed to th		)
7 5060-0720 2370-0016	COVER:TOP SCREW:SS,FH,PHILL	IPS DR 6-32 X 5/16	<b>)</b> ••	. 19	. •
8 5000-0717 2370-0016		IPS DR 6-32 X 5/16	,		, 1
9 00431-000 2370-0015	SCREWISS,FH,SLOT	DR 6-32 X 3/8",W/E	XT LOCKWASHER		
10 00431-000 2370-0002	PANEL IFRONT SCREWISS, FH, SLOT	DR 6-32 × 3/8"			

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1	Table 6-2. Replaceable Parts	:	. 1	
Stock No.	Description#	Mír.	Mír. Part No.	TQ
			1	
0121-0035 0140-0159	CIVAR AIR 7.2-143.7PF CIFXD MICA 3000PF 300VDCH	28460	0121-0035	
0140-0198	CIFXD MICA 200PF 55 300VDCH	1	RDM19F302G35 RDM15F201J3C	
0150-0012 0150-0093	CIFXD CER 0.01 UF 208 1000VDCB CIFXD CER 0.01UF +80-208 100VDCB		29C214A3-H-1038	
0150-0096	CIFXD CER 0.05UF 100VDCW	91418		
0150-0119 0160-0174	CIFXD CER 2 X 0.01 UF 20% 250VACH CIFXD CER 0.47UF +80-20% 25VDCH		36C219A 5C11A	Ī
0160-0185	CIFXD MICA 2100PF 18 300VDCW	14655	ROM20F212F3C	4
0160-2201	CIFXD MICA 51 PF 58	28480	0140-2201	Ī
0170-0069 0180-0045	CIFXO POLY 0.1UF 2% SOVDCW CIFXD ELECT 20UF 25VDCW	56289	114P1042R553 30D206-60-25VB-6M1	32
0180-0049 0180-0059	CIFXO AL ELECT 200F SOVDCW CIFXD ELECT 100F -108+1008 25VUCW	56289	30D206G050DC0M1	2
0180-0060	CIFXD ELECT 1000 -108+1008 2500CW		30D106G025884 30D2076003DC4	1
0180-0105	CIFXD ELECT SEMI-POLARIZED SOUF 25VDCW	56289	034114	
0180-0106 0180-0116	CIFXD ELECT TA GOUF 208 GVDCW CIFXD ELECT TA G.O UF 108 35VDCW	56289	150D606X000682 150D685X903582	i
0180-0138	CIFXD ELECT 100UF -10+100B 40VDCW INSULATORIBINDING POST	56289	D36254	· . 6
)340-0090			0340-0086	
370-0064	INSULATORIBINDING-POST DOUBLE KNOBIVERNIER		0340-0090	1
)370-0067 )370-0112	KNOBIBLE CONCENTRIC 1 IN. OD 17/64IN. HOLF	26480	0370-0067	
698-0063	KNOBIBLK BAR W/ARROW 3/4 IN. OD 1/4 SHAFT RIFAD MET FLM 5.23K OHM IN 1/88		0370-0112 0698-0063	1
698-0084	RIFXD HET FLH 2150 OHH IN 1/80	28480	0698-0084	
)698-0085 )698-3132 ,	RIFXD MET FLM 2.61K OHH IN 1/85 RIFXD MET FLM 261 OHH IN 1/85	28480	0698-0085	ī
698-3151	R2FXD MET FLM 2.87K OHH 18 1/88	28480	0698-3151	
698-3155	RIFXD MET FLM 4640 OHM 18 1/8		0698-3155	3
1698-3156 1698-3157	RIFXD MET FLM 14.7K OHM IN 1/8m RIFXD MET FLM 19.6K OHM IN 1/8m	28480	0698-3156	24
698-3158	RIFXD HET FLH 23.7K OHH IN 1/88	19701	0698-3157 B	2
698-3160 698-3337	RIFXD MET FLM 31.6K 1% 1/8m RIFXD MET FLM 1.37K OHM 1% 1/2m	28460	0698-3160 0698-3337	3
698-3404	REFAD MET FLM 303 OHM 18 1/20	28480	0698-3404	
698-3438 698-3440	RIFXD MET FLM 147 OHM 18 1/88 RIFXD MET FLM 196 OHM 18 1/88	26460	0698-3438	
698-3441	RIFXD HET FLM 215 OHH IN 1788	28480	0698-3440 0698-3441	
698-3444	RIFXD MET FLM JIG OHH IN 1/80	26480	0698-3444	2
698-3447 698-1449	RIFXO MET FLM 422 OHN 13 1/80 RIFXD MET FLM 28.7K OHM 13 1/80	28480	0698-3447 0698-3440	
698-3450 698-3452	RIFXD MET FLM 42.2K OHM 18 1/88	28480	0698-3450	2
69 <b>8-</b> 3491	RSFRU MET FLM 147K OHH 15 1/89 RSFRU MET FLM 1K OHM 0.15 1/89	28480 (	0698-3452 0698-3491	
698-3566	RIFXD MET FLM 53-0 OHH 18 1/88	28460	0698-3566	3
69 <b>8-3581</b> 698 <b>-358</b> 2		2040011	JOA9-3321	11
698-4023 698-4024	RIFXD MET FLM 130.4K OHM 1/28 1/8W	20400((	0698-3582 1698-4023	
· · · · · ·	RIFXD HET FLM 259.6K OHH 1/28 1/8W	1	698-4024	Ī
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Table 6-2. Replaceable Parts (Cont'd)

Stock No.	Description#	Mír.	Mír. Part No.	TQ
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0698-4025	RIFXO HET FLM 128.5K OHH 1/28 1/88	28480	0698-4025	11
0698-4026	RIFXD MET FLM 69.90K OHH 1/28 1/80 RIFXD MET FLM 64.45K OHH 1/28 1/80 RIFXD MET FLM 48.64K OHH 1/28 1/80 RIFXD MET FLM 48.64K OHH 1/28 1/80	28480	0698-4026	11
0698-4027	RIFXD HET FLM 64.45K OHH 1/28 1/88	28460	0698-4027	1 il
0698-4028	REFXD MET FLM 48.64K OHM 1/28 1/88	28460	0698-4028	
0698-4029	RIFXD MET FLM 53.39K OHH 1/28 1/88	28480	0698-4029	1.71
0698-4030	RIFXD MET FLM 40.77K OHH 1/28 1/88	28480	0698-4030	
		20400	0698-4031	
0698-4031	A FYD WET FUN DI OOK OUN LADE LAN	20400		11
0698-4032	RIFXD HET FLM 43.25K OHH 1/28 1/6W RIFXD HET FLM 51.22K OHH 1/28 1/6W	28480	0698-4032	
0698-4033	RIFXD MET FLM 62.26K OHH 1/28 1/88 V	_	0698-4033	1
0695-4034	RIFXD MET FLM 84-32K OHM 1/28 1/8W	28460	0698-4034	
0757-0123	RIFXD HET FLM 34.8K OHH 18 1/108 RIFXD HET FLM 31.6 OHH 18 1/88 RIFXD HET FLM 21.5K OHH 18 1/88 RJFXD HET FLM 1.21K OHH 18 1/88	28460	0757-0123	1.1
0757-0180	RIFXO HET FLM 31.6 OHM 18 1/88	28480	0757-0160	2
0757-0199	RIFXD HET FLM: 21.5K OHM 15 1/80	28480	0757-0199	2
0757-0274	RIFED NET FLN 1.21K OHH 18 1/AN	28480	0757-0274	
0757-0277	RIFXD MET FLM 49-9 OHM 18 1/88	28480	0757-0150 0757-0199 0757-0274 0757-0277	1 1
				[ <b>.</b> ]
0757-0278	RIEYO MET ELM 1. TRY OUN IN 1784	-	0787-0276	<b>.</b> .
	I DEFEND OF WELL A LAN AND AN AVEL	▲0480		
0757-0279	ATTAU HET PLH 3+10K OHM IN 1/01	26480	10757-0279	3
0757-0280	KIPKU MET FLM 1.00K OHM IN 1/80	1 28480	0757-0280	6
0757-0290	REFXD HET FLM 6.19K OHN 18 1/8m	28480	0757-0290	11
0757-0395	REFXO MET FLM 1.78K OHM 18 1/88 REFXD MET FLM 3.16K OHM 18 1/88 REFXD MET FLM 1.00K OHM 18 1/88 REFXD MET FLM 6.19K OHM 18 1/88 REFXD MET FLM 56.2 OHM 18 1/88	28480	0757-0395	5
,		1	0757-0395 0757-0398 0757-0399 0757-0401 0757-0417 0757-0421	
0757-0398	RIFXD HET FLM 75 OHM 18 I/88 Rifxd Het FLM 82:5 ohm 18 1/88	28480	0757-0398	
0757-0399	RIFXD HET FLM 8215 OHM IN 1/68	28480	0757-0399	
0757-0401	RIFED NET FLM 300 ONM IN 1/AM	20,000	0757-0401	2
0757-0417	RIFXD NET FLM 100 OHM 18 1/88 RIFXD HET FLM 562 OHM 18 1/88 RIFXD HET FLM 825 OHM 18 1/88	1 28460	0767-0017	
	A FUR NET FUR ARE AND AN AVE	40400	0757-0417	2
0757-0421	ATTAU RET PLA \$25 ONE 18 1/88	28480	0/57-0421	11
		1		
0757-0436	RIPAD HET FLM 4.32K OHN 18 1/08	24480	0757-0436	1
0757-0440	REFXD HET FLM 7.50K OHH 18 1/8%	28480	0757-0440	3
0757-0441	RIFXD MET FLM 8.25K OHM IN 1/84	28460	0757-0441	<b>i</b>
0757-0442	RIFXD MET FLM 10.0K OHM IN 1/88	28480	0757-0442	5
0757-0451	RIFXD HET FLM 4.32K OHM 18 1/88 RIFXD HET FLM 7.50K OHM 18 1/88 RIFXD HET FLM 8.25K OHM 18 1/88 RIFXD HET FLM 10.0K OHM 18 1/88 RIFXD HET FLM 24.3K OHM 18 1/88	28480	0757-0451	171
	······································			1 *
0757-0456	RIFED NET FLM ASIZK OHN 18 1/45	2040	0757-0456	
0757-0460	BIEND NET SIM ALLOY AND THE LAN	1 28480	0757-0460	P 🕈 📘
	ANEVO MET ELM DE EM LE LIGH	2040U	0757-0400	
0757-0463	THE AND ALL FLA SEAD AN AND AND A	1 20400	10/37-0403	1
0757-0465	RIFAU MET PEM 100K OHM IN 1/80	28480	0757-0465	11
0757-0821	RIFXD HET FLM 1.21K OHM 18 1/28	28480	0757-0821	
	RIFXD HET FLM 43:2K OHM 1X 1/85 RIFXD HET FLM 61.9K OHM 1X 1/85 RIFXD HET FLM 62.5K 1X 1/88 RIFXD HET FLM 100K OHM 1X 1/85 RIFXD HET FLM 1.21K OHM 1X 1/25	ľ		
0757-0826	RIFXD MET FLM 2.43K OHM 18 1/28	28480	0737-0826 0757-1094 0757-1104	1
0757-1094	AIFXD HET FLM 1.47K OHM IN 1/88	28480	0757-1094	2
0757-1104	RIFXD HET FLN 60.0 OHM 18 1/88	28480	0757-1104	
0811-0065	RIFXD WW 511 OHM 1.0% 1/20W	20000	0811-0065	2
0811-0065	RIFXD WW 587 OHM 18 8/100W		M3A/887-1%	
~~		7773/		*
0811-1562	RIFXD WW 8 OHM 18 1/4W			.
	1 NITAN RE D VINI 48 4/98			1
0811-1566	KIPAU WW 200 UMM 0+15 1/68		0811-1566	1
0811-1571	RIFXD WW 200 OHM 0.1% 1/8W RIFXD WW 189 OHM 0.1% 1/8W		0811-1571	11
0811-1572	KIFXU WW 255 OMM 0+1% 1/8W	28480	0811-1572	11
0811-1645		28480	0811-1645	I I I
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0839-0011	THERMISTORIIOO ONM 108	33173	20-204	1
1120-1101		28480	1120-1101	
1250-0083	CONNECTOR IBNC	20000	1120-1101 1250-0083	
1251-0148			H-1041-2	<b>4</b>
	CONNECTORIPOWER 3 PIN MALE			1
1251-0149	CONNECTORIG FEMALE CONTACTS	02660	91-PC6F-1000	2
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Section VI Table 6-2

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

Stock No,	Description#	Mír.	Mír.	Part No.		
		,	·	···	1	1
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1251-0233	CONNECTORIPC 44 CONTACTS	l sénes	1251-0233			
1400-0084	HOLCERIFUSE POST TYPE JAG				·   2	
			342014	\$	11	
1420-0009	BATTERYIRECHARGEABLE 24V 1.25AH	28480	1420-0009		11	Г×.
1450-0048	LAMPINEON	28480	1350-0048	10 C 10 C	lī	1
1490-0032	STANDITILT HALF-MODULE	25450	1490-0032	•	11	
1510-0006	BINDING POST ASSEMBLYIBLACK	28480	1510-0006			
1510-0007	BINDING POST ASSEMBLYIRED	28480	1510-0007	×1	11	
1850-0064	TRANSISTOR: GERMANIUM PNP 2N1185		2N1183		1.	
1853-0020	TRANSISTORISILICON PNP	201/20	1853-0020	1		
1854-0071	TRANSISTORISILICON NPN 2N3391		16A792	1	9	
1901-0025	DIODE+JUNCTION+SHALAT IV 100 PIV		j i i	1		
			1901-0025		7	
1901-0026	DIODEISILICON 200 PIV 0.5 AMP	28460	1901-0026		2	
1901-0450	DIODEISILICON	28480	1901-0450	1	1.4	
1902-0017	DIODE+BREAKDOWNIG.BIV LOB 400 MW	28480	1902-0017	•	Ž	
1902-0018	SEMICON DEVICE DIODE SILICON 18941 11.7V	04713			1	
1910-0016	DIODEIGERMANIUM 100MA AT 0.85V 60PIV	28480	1910-0016		5	
2100-0144	RIVAR COMP 250K OHM 30% LIN 1/5%					
2100-0182	RIVAR COMP 3.3K OHM 105 LIN 0.15W		2100-0144	1	1	<b>,</b> 1
2100-0342	BIVAR WE TOK TOK BOD AND TOK FIL DA		2100-0162		5 J 🕹	
2100-1612	RIVAR WE 10K 108 800 OHM 108 LIN 28 RIVAR COMP 500 OHM 208 LIN 1/58		2100-0342		1	
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2100-1613	RIVAR COMP 2K OHM 208 LIN 1/58	28480	2100-1613		2	
2100-1615	RIVAR COMP 100 OHM 208 LIN 1/58		2100-1615	۱. ۱	5	
2100-1616	RIVAR COMP 200 OHM 208 LIN 1/58		2100-1616		5	
2100-1617	REVAR COMP 1% OHM 205 LIN 1/58		2100-1617			
110-0017	FUSEICARTAIDEE 0.15 AMP SLOW BLOW	75915	313+150	and the	2	•
420-0001	NUTINEY ET NO ALTO Y BALA MA ORANASIAN					
	NUTIHEX ST NP 6-32 X 5/16 #/LOCKBASHER	78189		1 .	5	
5100-1817	SUITCHIROTARY	26480	3100-1817		11	
100-1818	SHITCHIROTARY	28480	3100-1818	,	i	
100-1820	SHITCHIROTARY		3100-1820		1	
000-0703	COVERISIDE 6X11 SM		5000-0703		'  i	
000-0717	COVERIMALF-MODULE BOTTOM	20400	5000-0717			
020-0701	SPACERICABINET			1 · ·	1 4	•
020-0705	TRIMIMETER		5020-0701			
040-0700			5020-0705		1 1	
	HINGE		5040-0700		1	
040-0701	EXTENDERIMETER CASE	28480	5040-0701		1	
060-0703	COVERIG X 11 SIDE	28480	5060-0703	1		
060-0720	COVERIHALF-RECESS TOP	28480	5060-0720	'	1 1	
060-0728	FOOT ASSYTHALF MODULE		5060-0728	· · · · ·		
120-0078	CABLEPPOWER 7.5FT.		KH4147	:		
100-0400	TRANSFORMER IPOWER		9100-0400			
100-1677	TRANSFORMER I INPUT					
110-0040			9106-1677		1	
	INDUCTORIAUDIO		9110-0040		2	Į
120-0065	TRANSFORMERIAUDIO		9120-0065	11 A.	21	1
120-0066	TRANSFORMERIAUDIO	28480	9120-0066	r - 1	2	ļ
140-0122	COILIVAR 2X 9-20 UHY EACH	28480	9140-0122	;	2	
0415-006	COVERIBATTERY	28480	00415-006	1		.
0415-606	BATTERY INSTALLATION KIT	2 Dahan	00415-606		1 11	]
0431-6001	BOARD ASSEMBLY, AMPLIFIER					1
0431-0002	PANEL+ FRONT		00431-6001		111	
0431-0003	PANELY REAR		00431-0002			
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## Table 6-2. Replaceable Parts (Cont'd)

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Stock No.	Description #	Mír.	Mfr. Part No.	TQ	- Station
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00431-0004 00431-6002 00431-6004 00431-6003 00431-6009	BRACKET: PANEL SWITCH ASSEMBLY: RANGE SWITCH ASSEMBLY: POWER SWITCH ASSEMBLY: CALIB BOARD ASSY.: POWER SUPPLY	28480 28460 28460 28460	00431-0004 00431-6002 00431-6004 00431-6003 00431-6003		
00431-6011	CABLE ASSYITHERMISTOR MOUNT 5 FT.	28460	00431-6011	1	: · ·
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Section VI Table 6-3

#### TABLE 6-3,

#### CODE LIST OF MANUFACTURERS

The following and a numbers are from the Federal Supply Code for Manufactures Cataloging Handbacks ( )4.3 (Hanna to Code) and (H-2 (Code to Hanna) and their factor supplements. The facto of residue and the facto of the supplements used appear of the factors of each acces. Altabachted and and a facto be activity of manufactor and the supplements and appear

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90001 623 M	t 19.5.A. Conupo L McCov Electronich - Ma	Any supplier of \$. 1. well Kelly Bynage, P.s.	0))25 07)37	i ilig Titi
00211 00231	Billey Electronist (B)   lage Electronist Corp.     Court loc.	Bacbenter, 8.7.	87)30	111 1
01334 01334 0137	i National	Anchestar, B.Y. Buniotusa, Caso. Calino, Calif.	1010	i di sta
	Einchnatts Products Bie.		1711 1781 1781	- Cui - Ave - Fai
001.14 00779	Annush Carp. 1 Ang, Inc.	Canden, R.J.   Non Bodford, Rosa.   Namsburg, Po.	. 1320	Hiti R
1079) 2011	L Auton Carn.	inenine. R.J	17111 17111	i i the
		Barbarba, Wis.	87786	TH
00033		Dels Bio. Picknes, S.C. Los Angeles, Dalif.	87910 87933	1.0
00055 00031 01121	i - Gan Englanning Co. i - Carl E., Halann Carp. i - Allan Bianlay Co.		1944	<b>D</b> e
6)16) 6)16) 6)16)	i Littaa jugasirsaa, jag.	Ørfonnkov, Brs. Dovorip Hella, Calif.	87968	Per
(11) (11) (11)	Teres besten pets, lot.	Lorodain, Colif.	00115	<b>0.</b> \$
11348	Titmbister Predects Dir.	Ballan, Tasan Altianca, Bara	00115 01253 00310	ja, 3 jana jana
11140	Pocific Baibys, Inc.	Altineen, Goon Van Bayn, Colif, Rechturd, 121.		
82830 81963	- papieca Corp. - Palae Englasoniae Co.	KANTA CIAPI. CAM.	96564 96737	jan Der
02334 11776.6	- Freestaba Cara, al Anonta	sangerbas, B. T. ; E faneyssie, Calif. Carp. Chicage, III.	1071)	111
82548		Corp. Chicago, Ill.	00792	
. 42735	and Material's Dry.	lanarelle, N.J.		Ņ
02771	Vecalies Co. of America, in	Eld Savarash, Casa,	0004.0 09125 09134 09134 09134	300-
82777 82888	Noobies Engisporing Es. B. E. Besicandecter Prid. B	Bid Saylorek, Colo. San Fernande, Calif	99)))) 10111	741) Лю
83765		lagt, Spiscass, B.Y. Baytan, Obin	11214 11148	
63797 1 63677	Eldras Corp. Transliton Electric Com.	· Boytao, Obie Cusolao, Cabit, Bakotiatit, Bass.		ijuli Çi
63348 13614	Presiden Pasistat Ca., Inc.	Cocor Baolio, H.J.	1837.0	£04
	Bieger Ca., Biebi Dir. Finderne Pipet Arrew, Hart and Bages an El	Basarnijia, B.J.	10411 1044 11734	TH
		Bartford, Cono.	iiin	<b>E11</b>
- 84613 84962	Taurais Corp. Eliannes Producta Co. NoQ Division of Astavas	Loobertville, B.J. Ben York, B.Y.	11337	(2)
84727 84354		Byrthe Boach, K.C.	11247 11337	Ber .
<b>Benta</b>	Bynet Bingies of Renists P	ALANE Co. Pala Alto, Cohit.	1153a 11713	-
H		Bidrett by B		- 91
6013	Povite Dis. Bolancia, Inc., Somitaodott	Boostana View, Cafil. 19 Pead. Biv.	1)/)/ 1(820	inge Bala
84732	Fitten Co., Inc. Western # (	Passes, Antasa	12134 12697	Phili Cipe
-		Calves Eity, Calif. Barthima, NI. Batwood Eity, Calif.	12130	1044 1011
14796	Semana Vice Co.	Roland City, Cohl.	11938	<b>Beil</b> u
- 641) 1475	P. U. Bothe Cangery	La maara, Cant, Vastebestar, Hi,	12954	Bick The
<b>ISAN</b> 6	Turrbath Century Plashts,	Inc. Los Angoles, Calif.	13394	Tele D:Pic
8,00	Pesbegbesse Electric Corp. Son - Conductor Depl.		14899	Les-
· 85347	Bitrana, Bet.	brangwood, Pa. Pas Botro, Cahl. Benyyolo, Cafil.	14111	Cahi
1160) 15416	Illumitront Englopping Co. Cases Plante		14718 [4933	Ann Itt:
81474	tern Cleeinent Iper. Co.) Barber Colurn Co.	Cleveland, Ghio Rockford, Jill,	14493	8 11 (m)
85778	Tilles Calical Ca		34615	(a.) (a.)
8173	Botta-Tat Corp.	is, Long Ibland, B.Y. Besibory, D.Y.	14717	E le ci
65783 654.78	Renard Engineering Co. Takahold Engineering Inc.	BACH CIPT, CANT. Tatabald, Bath.	14968 16767	Talla Tetts
06284	Basaich Co., The Bausch and Lowb Dolical Co	Bridgsport, Cook.	33293. 13339	Afai Diri
96482	I TA Products Co. of An.	into Chutnen III	13772	1996
96376 86348	Veslers Devites Inc. Austam Clectronit Harfeare	Co., Inc.		
<b>K555</b>	Boode Blackscal bestraeset (	CO., 196.	- 15838. 15969	Bare.
DEELE	Essent Bences Co., Inc.	Pungenab, B.B.	11437	ille Seret
06753	Consist Devices Co., Inc. Bacting Corp. of America U.S. Joncer Div. Tomogram Big. Co., Dest D	Plassia, Artesa	16179	003+ C103
864)2	Tumagine Big. Ca , Best D	. 1	1444	101117
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Section VII Paragraphs 7-1 to 7-7

## SECTION VII SCHEMATIC DIAGRAMS

#### 7-1. INTRODUCTION.

Model 431C

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

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

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

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

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

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

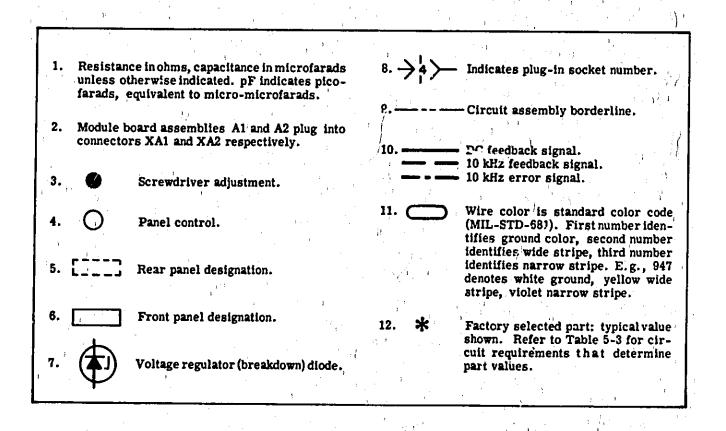
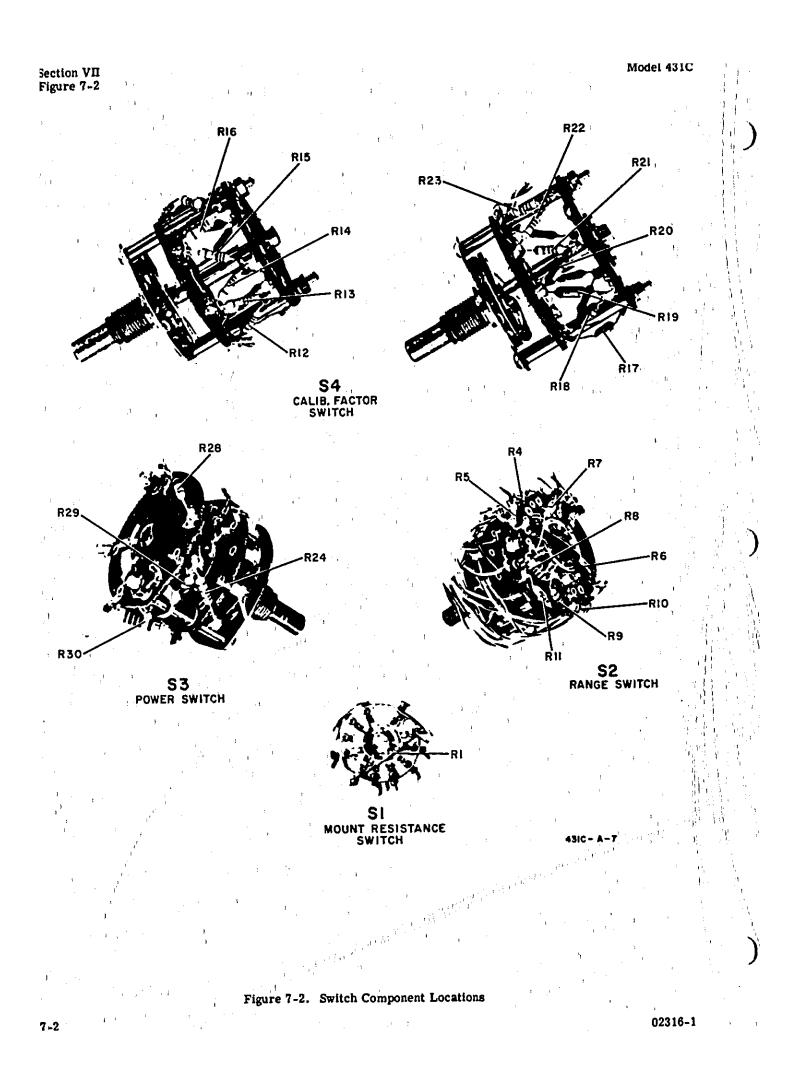
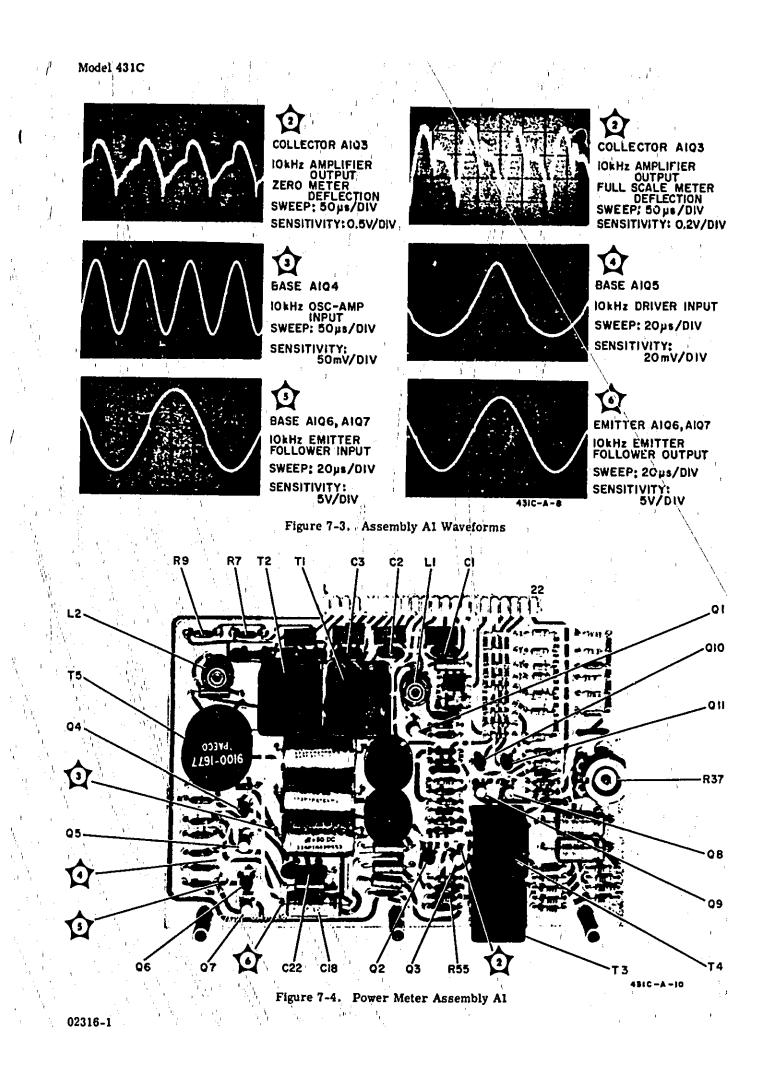
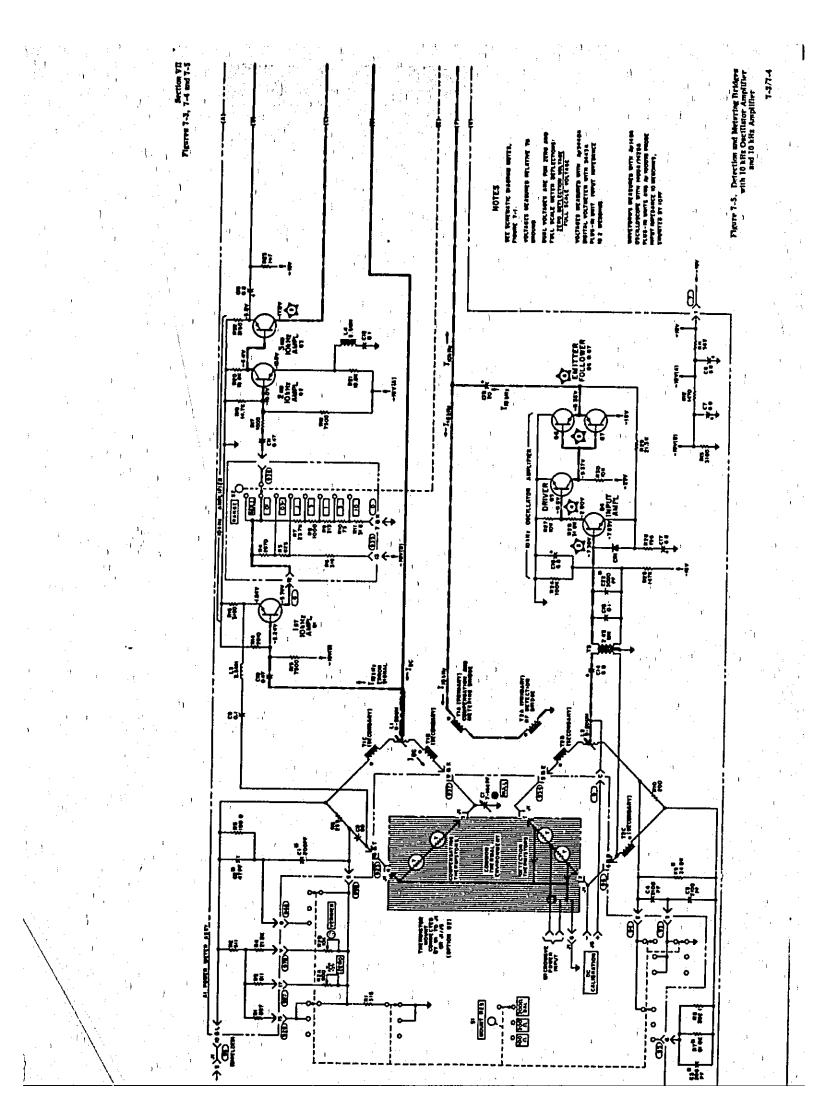
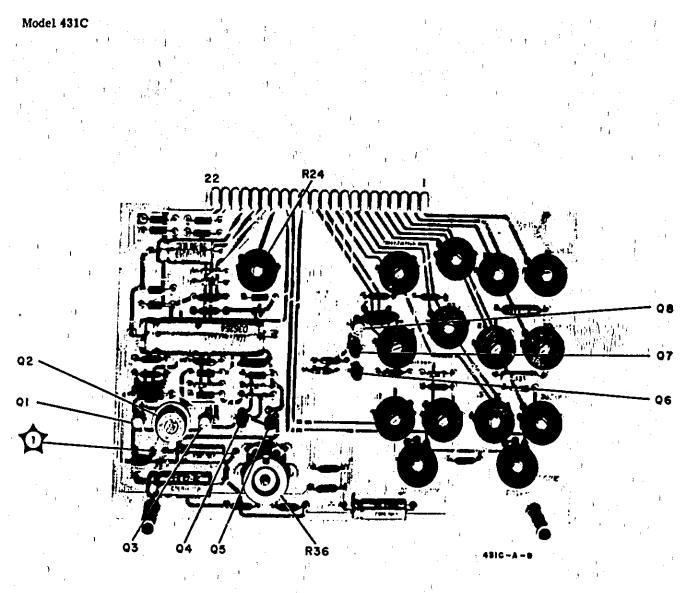


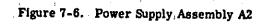
Figure 7-1. Schematic Diagram Notes

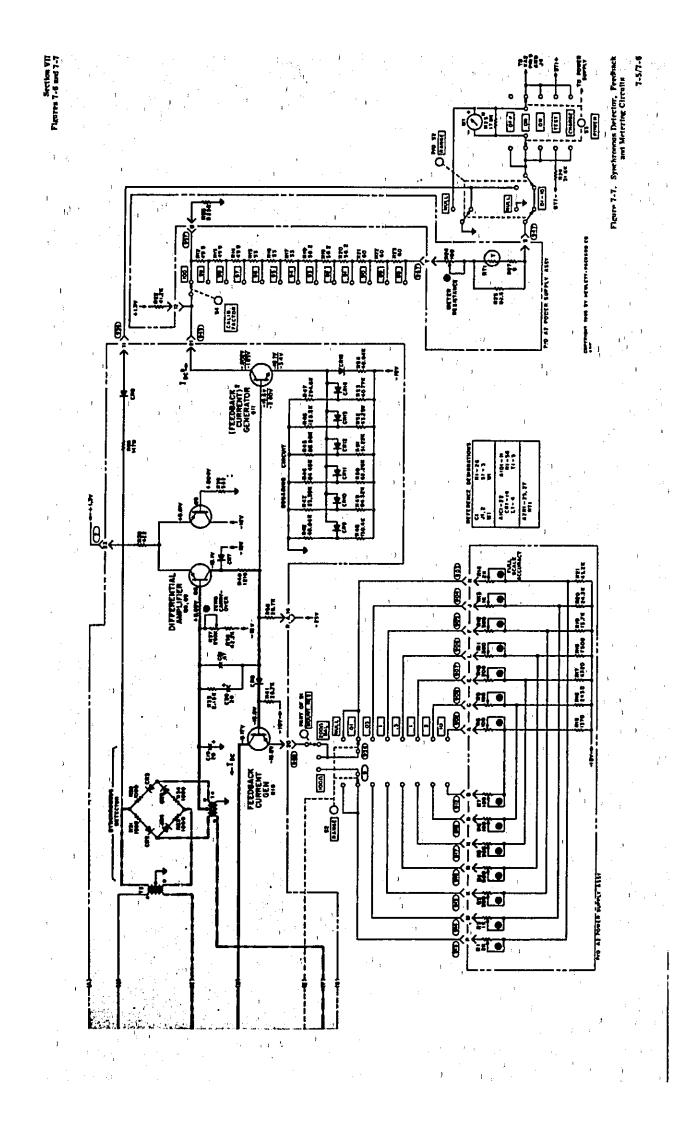












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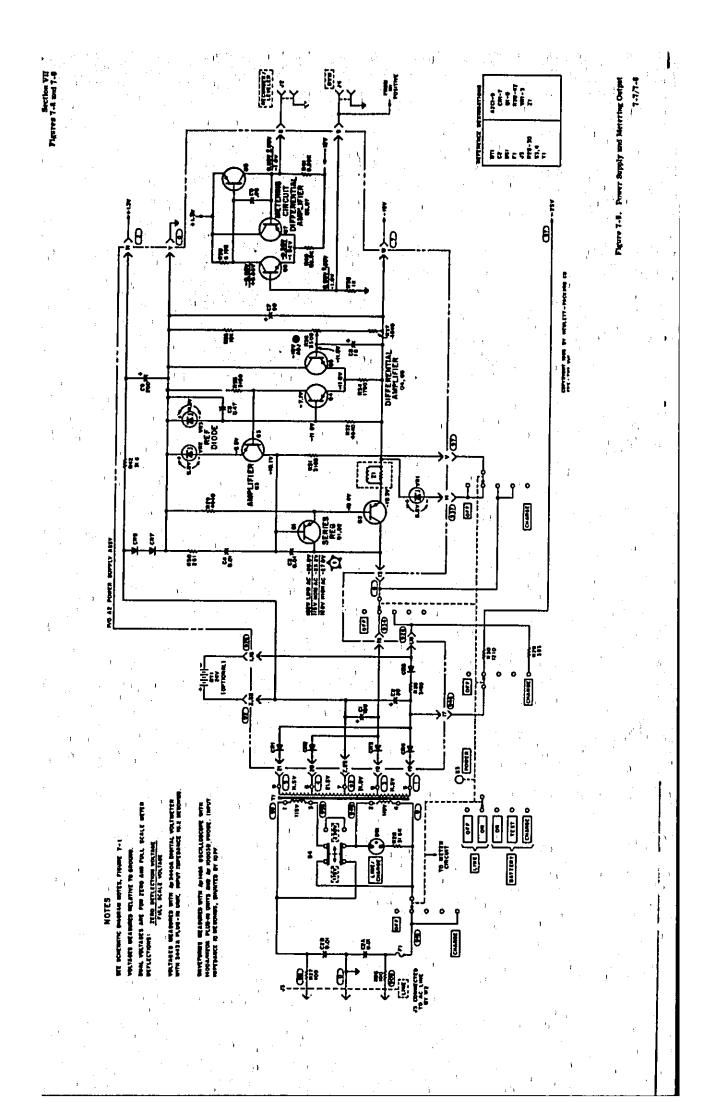
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COLLECTOR A201,A202 REGULATOR INPUT SWEEP: 5ms/DIV SENSITIVITY: 0.5V/DIV 431C-A-B

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ì Figure 7-8. Power Supply Waveform



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## APPENDIX I OPTION 01

Al-1. The 431C Option 01 instrument consists of a standard Model +31C Power Meter with a rechargeable battery installed. A list of Option 01 component parts is given in Table 6-1. Instruction for installation of the battery is given in the following paragraph.

#### A1-2. OPTION 01 INSTALLATION PROCEDURE.

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

b. Remove top and bottom instrument covers,

c. Refer to Figure A1-1 which shows the battery cover disassembled from the battery. Install the battery and battery cover from the bottom of the instrument into the top chassis. Note that the battery is installed so that the two battery terminals are toward the top and front of the instrument.

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

#### CAUTION

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

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

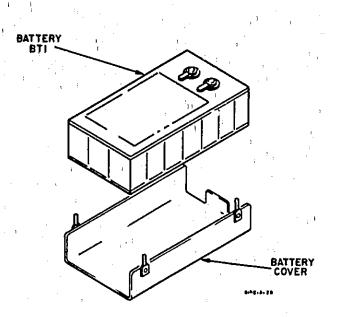
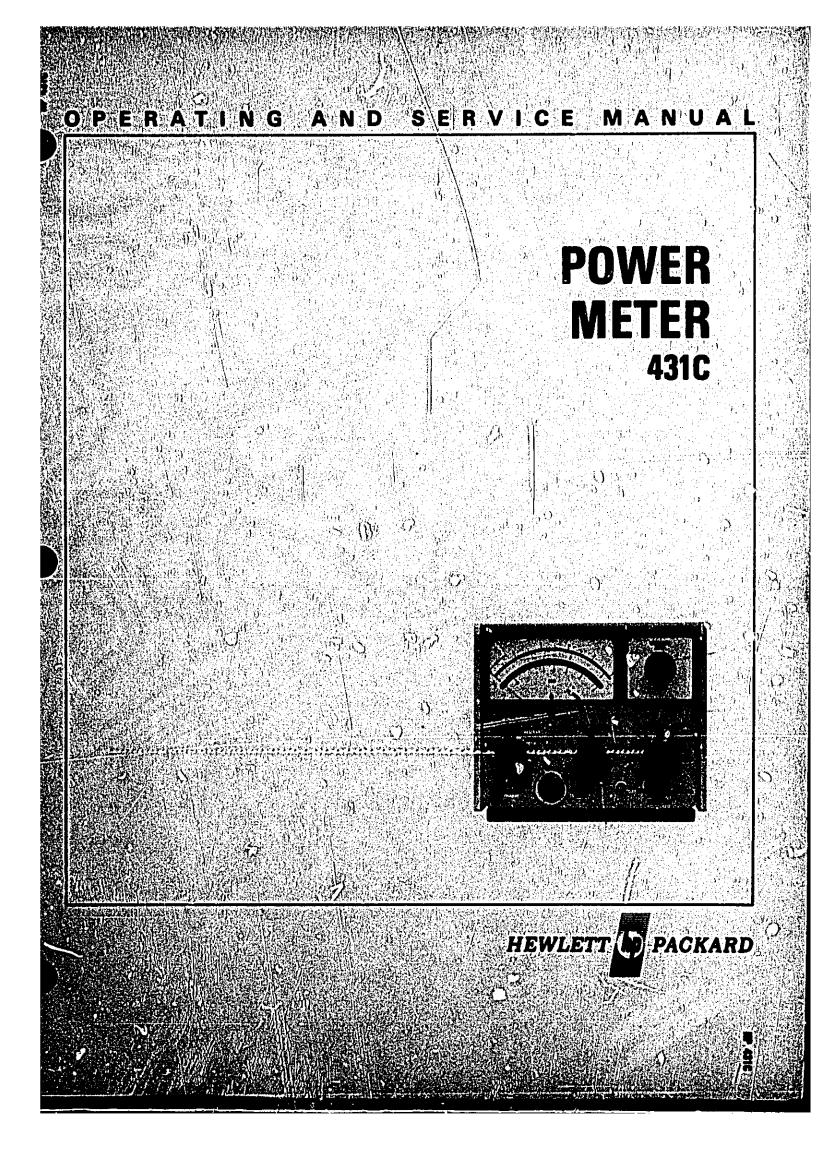


Figure A1-1. Battery and Battery Cover Assembly



# POWER METER 431C

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## H/P Part N0.00431-90017

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For instruments with serials prefixed 64t, 618, 643, 648, and 651, see Manual prefixed 648.

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Section I

## SECTION I ENERAL INFORMATION

### 1-1. DESCRIPTION

1-2. The Hewlett-Packard Model 431C Power Meter, with hp temperature-compensated thermistor mounts, measures RF power from 10 microvitts (-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  $\pm 1\%$  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 inanual applies directly to the instrument.

1-5. ACCESSORIES. Two accessories are supplied with the Model 431C Power Meter: a 7.5-foot (2200 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  $\mu$ W. 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 nounts 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** Cutput: 1.000V into open circuit corresponds to full scale meter deflection (1.0 on 0-1 scale)  $\pm 0.5\%$ ; 1'K $\Omega$  output impedance, BNC female connector; effect of loading impedance less than  $\pm 10$  M $\Omega$  must be accounted for.

Recorder/Leveler Output: With load impedance of 500 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  $\pm 10\%$ , 50 to 400 Hz, 2.5 walts. Optional rechargeable battery provides up to 24 hours continuous operation.
- Dimensions: 7-25/32 in. wide, 6-3/32 in. hlgh, 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

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.

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#### 11:00 Section I Tables 1-1 (cont'd) and 1-2

Options:

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-45 5 <b>1</b> 14			Table	1-1.	Specificatio	ons (Cont'd)		1 .4
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- 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 1000 or 2000 (1, q) (q) (q) (q) (q)mount,
- ,10. With 20-foot (6100 mm) cable for 100Ω or 200Ω mount. -11 2.4

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- or 100Ω mount. With 100-foot (30480 mm) cable for 1000 mount. 12. With 200-foot (60960 mm) cable for  $100\Omega$  mount. 13.
- With 50-foot (15240 mm) cable for  $200\Omega$  mount. 21.
- With 100-foot (30480 mm) cable for  $200\Omega$  mount. 22.
- With 200-foct (60960 mm) cable for  $200\Omega$  mount. 23.

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hp/1	ype	$ \frac{\partial f_{i}}{\partial t} = \frac{\partial f_{i}}{\partial t} + \frac{\partial f_{i}$			
Coaxial /	Waveguide	Frequency Range	Operating Resistance in Ohms		
8478B 478A	5486A	10 MHz to 18 GHz 10 MHz to 10 GHz 2.6 to 3.95 GHz	200 200 100		
	G486A J486A H486A	3.95 to 5.85 GHz 5.3 to 8.2 GHz 7.05 to 10.0 GHz	100 () 100 100		
	X486A M486A	8.2 to 12.4 GHz 10.0 to 15,0 GHz 12.4 to 18.0 GHz	100 100 100		
	P486A // K486A R486A	12.4 to 18.0 GHz 18 0 to 26.5 GHz 26.5 to 40.0 GHz	200 200		

Table 1-2, Model 431C Thermistor Mounts

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Model 4310

# SECTION II

# 2-1. INITIAL INSPECTION

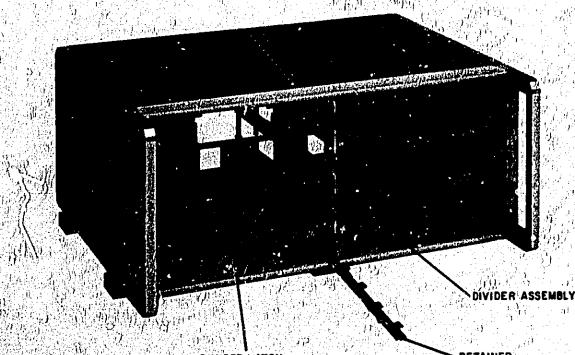
2-2. Before shipment this instrument was inspected, and found free of mechanical or electrical defect. As soon as the instrument is unpacked, inspect for any damage that may have occurred in transit. Check for the supplied accessories. Electrical performance may be tested using the performance, test 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.

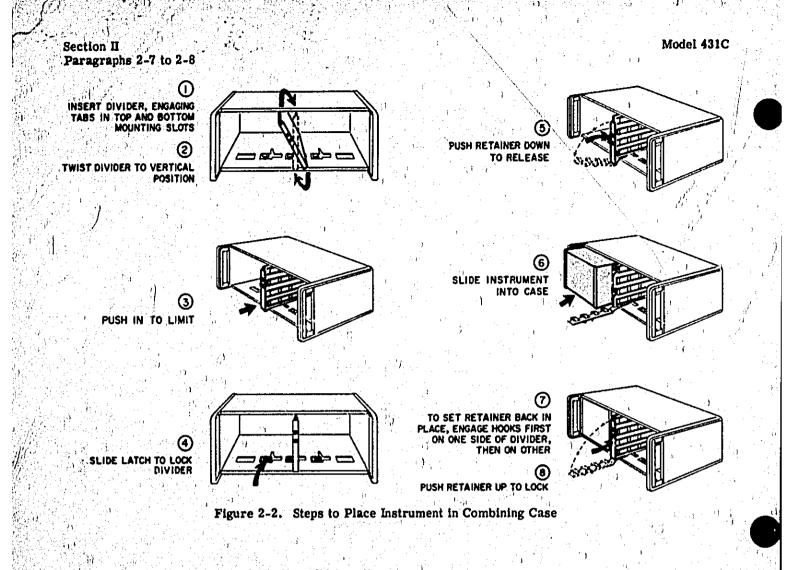
2-5. COMBINING CASE. The Model 1051A Combining Case is shown in Figures 2-1 and 2-2. This case is a full-rack width unit which accepts varying combinations of sub-modular instruments. The case itself is a full-module unit. It can be benchor rack mounted; a rack-mounting kit is supplied with the case.

2-6. ADAPTER FRAME. The 5060-0797 Adspter 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



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Figure 2-1. The 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 'jelow. 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, 59 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 if outlet.

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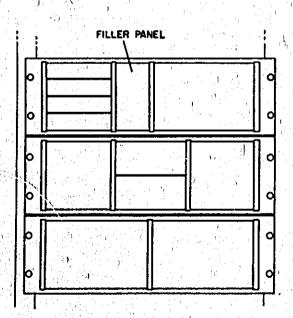


Figure 2-3. Adapter, Frame Instrument Combinations

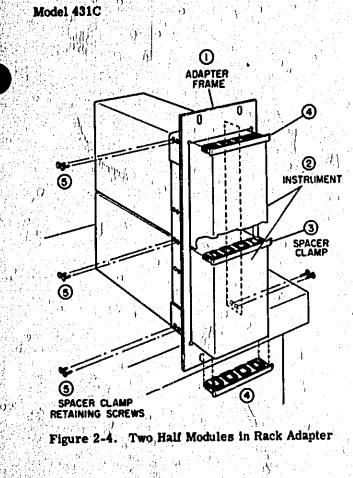
Section II Paragraphs 2-9 to 2-10

2-3

# 2-9, THREE-CONNECTOR POWER CABLE.

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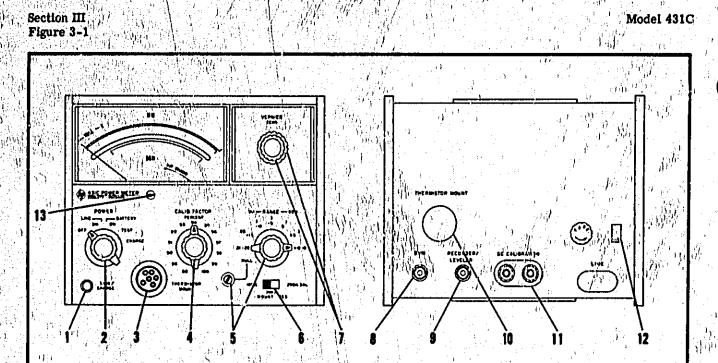
2-10. To protect operating personnel, the National Electrical Manufacturers' Association (NEMA) recommends that the instrument panel and cabinet be grounded. This instrument is equipped with a threeconductor power cable which, when plugged into an appropriate receptacle, grounds the instrument. The offset 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 ourlet, use a three-prong to two-prong adapter and connect the green pigtall on the adapter to ground.



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- 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.

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- 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.
- ZERO and VERNIER. Sets the meter pointer over the zero mark. The VERNIER control is a fine adjustment of the ZERO control setting.
- DVM. A BNC type jack providing an output voltage linearly proportional to the meter indication. A DC voltme<sup>2</sup> 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 cr 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.

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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  $\pm$  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 ( $Z_0$ ) 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  $100\Omega$  or  $200\Omega$ position, depending on the microwave band used (refer to Table 1-2). The  $200\Omega$  position is used with Model 478A thermistor mounts and the  $200\Omega$  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 RE-CORDER/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 log 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 user 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 in structions 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.

# Section III Paragraphs 3-14 to 3-25

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 point "Undication 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/Frocedure, 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-tomicrowave 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:

<u>Conjugate power</u> 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<sub>0</sub> available power is the power a source will deliver to a Z<sub>0</sub> load. It is dependent on a Z<sub>0</sub> match condition in which the impedance seen looking into a transmission line is equal to the characteristic impedance of the line.

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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<sub>0</sub> 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 Zo available power measurement situation can involve a source with an SWR of 1.7 ( $\rho_g = 0.26$ ) 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 Zo 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 Zo 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.

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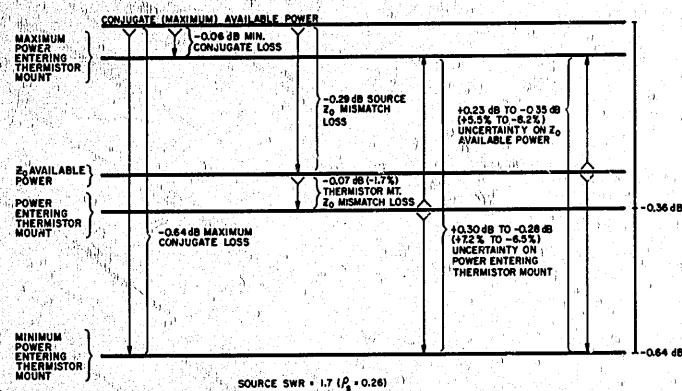
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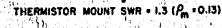
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3-25., Power measurement uncertainty caused by mismatch loss is one source of error to consider when measuring  $Z_0$  available power without a tuner. A continuation of this example is given in Paragraphs 3-38 through 3-39 to discuss the basic principle 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 Paragraphs 3-26 to 3-29





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Figure 3-2. Mismatch Power Measurement Uncertainty

3-26. RF LOSSES AND DC-TO-MICROWAVE SUB-) STITUTION 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. DCto-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.

Model 431C

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 measur sment. 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  $\mu$ W and is typically 0.1  $\mu$ W on the .01 mW range.

3-29. THERMOELECTRIC EFFECT ERROR COR-RECTION. 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.

Power =

d. By DC Substitution (see Figure 3-9), duplicate power measurement made in step a. Calculate and record substituted power as P1.

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 P2.

h. Calculate arithmetic mean of the two substitution powers P1 and P2. This mean power includes a correction for thermoelectric effect error. P1+ P2

3-3

# Section III

# Paragraphs 3-30 to 3-38

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  $\pm 2\%$  of full scale,  $\pm 20$  °C to  $\pm 35$  °C. Instrumentation error can be reduced to  $\pm 0.1\%$  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 microyave 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. How-... ever, 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 atuner 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.

Calibration Factor =  $\frac{PDC \text{ Substituted}}{P\mu \text{ wave Incident}}$ 

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Calibration Factor is a figure of merit assigned to a thermistor mount to correct for the following sources of error: 1) RF reflected by the mount due to mismatch, 2) RF loss caused by absorption within the mount but not in the thermistor element, and 3) DC-to-micro-// wave substitution error.

3.35. The CALIB FACTOR switch on the front 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.

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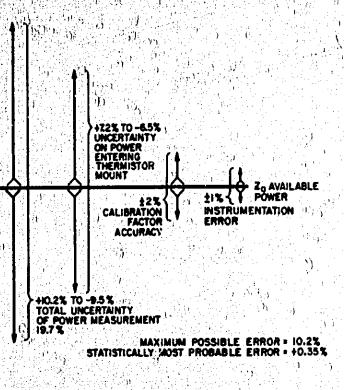
3-36. Calibration Factor is applied as a correction factor to all measurements made without a tuner. Under this condition, the power indicated is the power that would be delivered by the source to a load impedance equal to  $Z_0$ . This measured power is called  $Z_0$  available power.

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 Zo 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 Zo 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  $(-6\%) + (\pm 2\%)$ , or -4% to -8%. The 431C Power Meter has an instrumentation error of ±1% (maybe 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%.

-4.0% TO -8.0% 94% CALIBRATION FACTOR UNCERTAINTY +3.5% TO -8.2% UNCERTAINTY ON Zo AVAILABLE POWER HISTRUMENTATION ERROR -2.5% TO -17.2% TOTAL LIMITS OF ENTON BEFORE CORRECTION 18.7% STATISTICALLY MOST PROBABLE ERROR = 17.2% STATISTICALLY MOST PROBABLE ERROR = -7.35%

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Model 431C

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Figure 3-4. Total Uncertainty After Correction

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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 Zo 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 Zo 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 Zo 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 Zo available power level.

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

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 $P_0 = \frac{P \text{ indicated } (1 \pm \rho_e \rho_m)^2}{Calibration Factor}$ Where:  $P_0 = Z_0$  available power,  $p_{\rm S}$  = source reflection coefficient pm = thermistor mount reflection coefficient SWR - 1

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

Section III Paragraphs 3-39 to 3-46,

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

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

This power ratio corrects for RF losses and DC-tomicrowave 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 Zo 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 tunerthermistor 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  $\pm 1\%$ of full scale to  $\pm 0.16\%$  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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### Section III Paragraphs 3-47 to 3-52

substitution measurement. The hp Model 8402B Calibrator conveniently provides DC power and appropriate awitching to perform DC substitution measurement with the Model 431C. If the 431C is being used with a balanced 200 ohm thermisto 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 atotal 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

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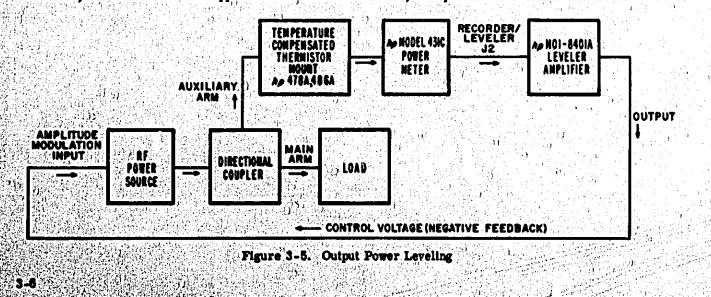
example is 0.2%. Corrections should be added to voltmeter readings since voltmeter impedance loading causes voltage measurements to decrease,

3-49, POWER METER DVM OUTPUT MEASURE-MENT, A digital voltmeter can be connected to the 451C 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 (Rd) during a power measurement. The actual operating resistance of detection thermistors may deviate as much as  $\pm 0.5\%$ 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 THERMIS-TOR MOUNT and 8402B Calibrator RESISTANCE STANDARD connectors. By the THERMISTOR RESIS-TANCE 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 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 osciliation state. While changing the substituted resistances, the operator can determine when oscillations



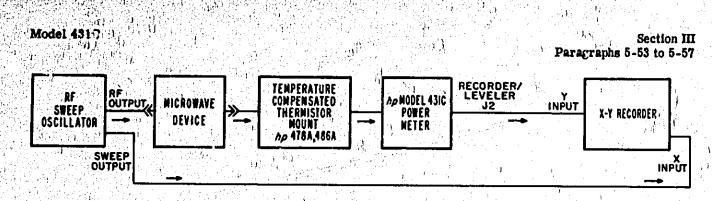


Figure 3-6. Insertion Loss or Gain Measurement

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 1 oss 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.

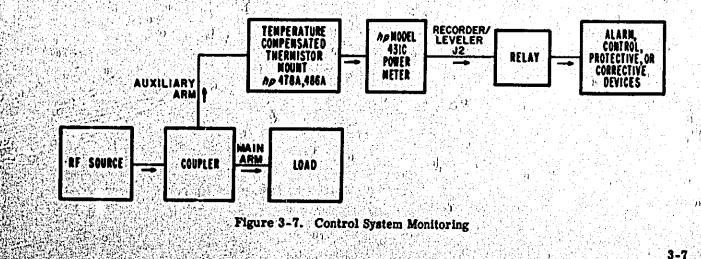
3-55. OUTPUT POWER LEVELING. A block diagram of an output power leveling system is shown in Figure 3-5. The power meter is used as an element in a control circuit that maintains a constant power level at a particular point in the system. The thermistor mount, connected to the auxiliary arm of a directional 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.

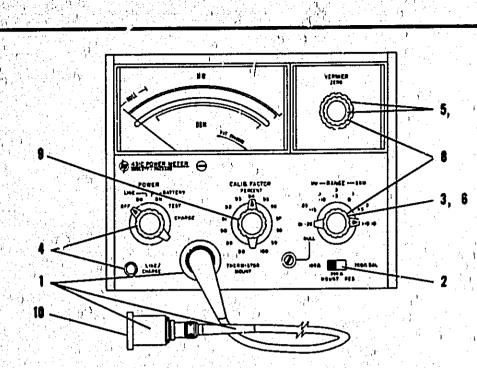
3-56. INSERTION LOSS OR GAIN. Figure 3-6 shows a block diagram of a system to determine insertion loss or gain as a function of frequency. Initially, the device to be tested is not connected into the system and the thermistor mount is connected directly to the sweep oscillator output. Variations in power 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.

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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.





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

Meter Mechanical Zero:

Section III Figure 3-8

1.

- 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 2pproaches zero mark from the left.
- c. Rotate adjustment screw about three degrees counterclockwise to disengage screw adjustment from meter suspension.

# Note

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When using an hp Model 478A or other 200 ohm unbalanced coaxial thermistor mount, the power meter should be zeroed and milled 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 kHs 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.

Model 431C

- 3. Set RANGE to .01 mW.
  - Set POWER to LINE ON. If instrument is to be battery operated, rotate POWER to BAT-TERY 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.
- Set RANGE switch to the power range to be used and zero-set the meter with ZERO and VER-NIER controls.

### Note

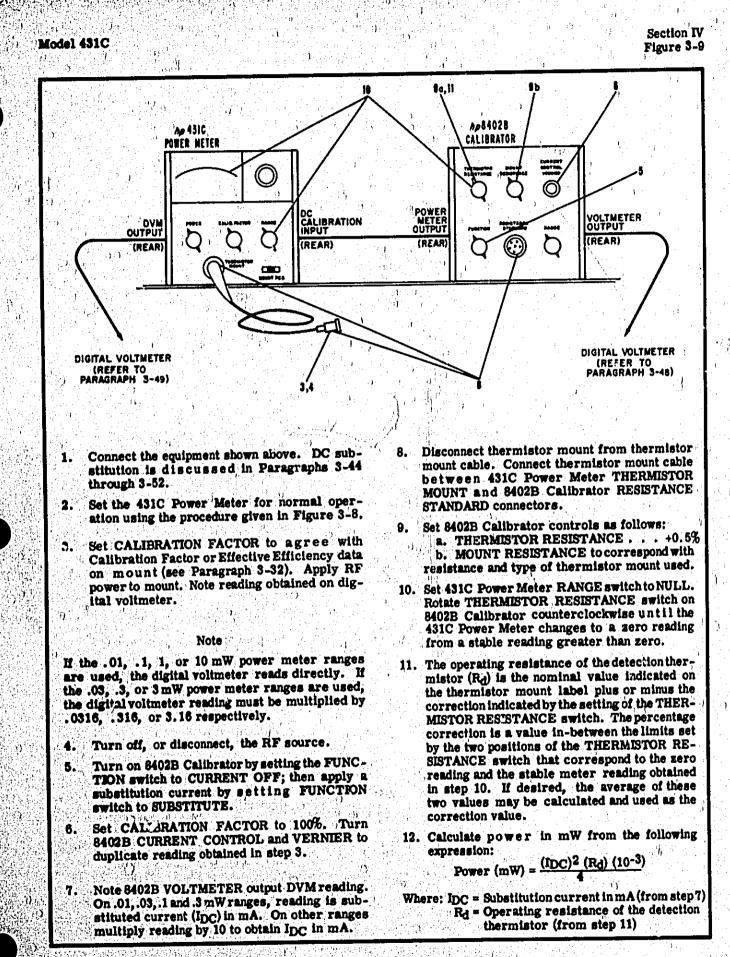
Range-to-range zero carryover is less than ±1.0% if the meter has been properly adjusted mechanically (Step 1 above) and the instrument has been properly zero-set electrically on its most sensitive range. For maximum accuracy, zero-set the power meter on the range to be used.

- 9. Set CALIB FACTOR switch to correspond with Calibration Factor imprinted on hpthermistor mount label.
- 10. Apply RF power at the thermistor mount. Power is indicated on the meter directly in mW or dBm.

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Figure 3-8. Turn On and Nulling Procedure

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Figure 3-9. DC Substitution

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# 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 10kHz 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.

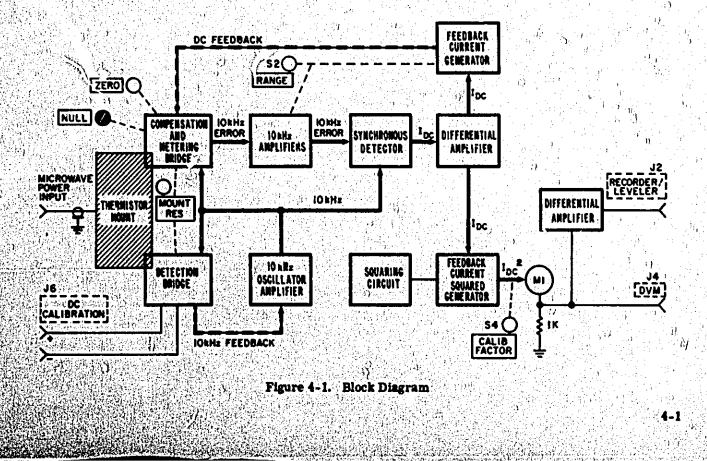
4-7. RF DETECTION BRIDGE (Figure 4-2). The RF detection bridge and the 10 kHz oscillator-amplifier are connected in a closed loop (the detection loop) which

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 2000 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



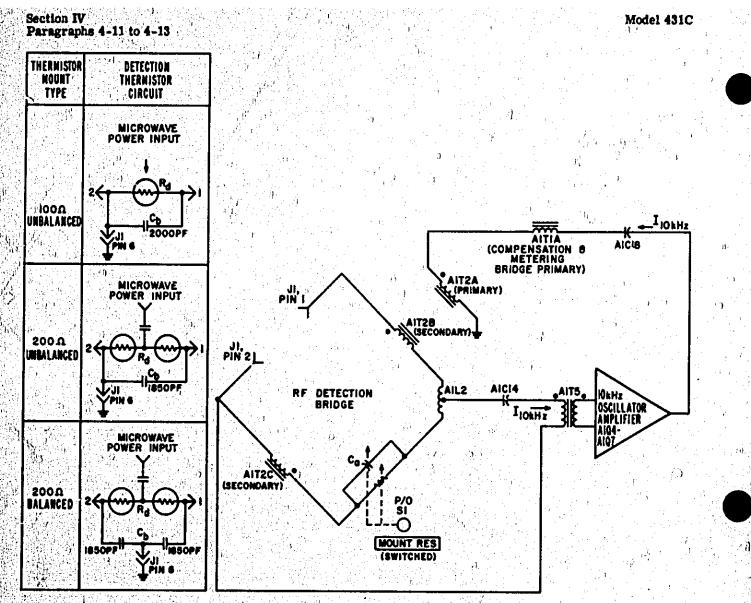


Figure 4-2. RF Detection Bridge

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common point grounded. Identical capacitors are connected in a similar manner across AIR10 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.

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# 4-31. 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 kHs power is used to re-balance the loop. The resistive balance point is adjusted by the ZERO and VERNIER controls which constitute one arm

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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 (unbal-anced) the metering bridge, a separate, closed DC feedback loop (metering loop) re-establishes equilibrium in the metering circuit.

Model 431C

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Section IV Paragraphs 4-14 to 4-17

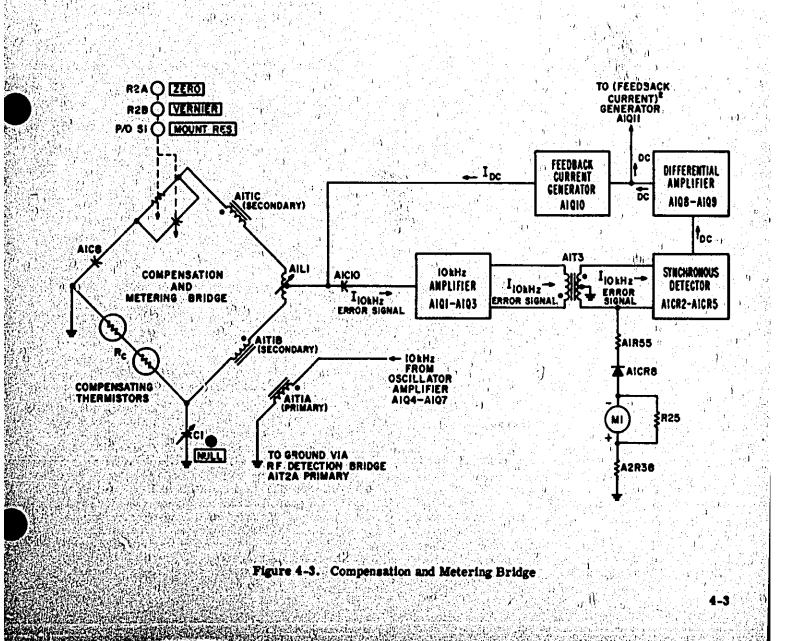
4-14. Variations in 10 kHz bias level, initiated in the RF bridge circuit, cause proportional unbalance of the metering bridge, and there is a change in the 10 kHz error signal (I<sub>10</sub> kHz) applied to the 10 kHz tuned amplifiers in the metering loop. These error signal variations are amplified by three 10 kHz amplifiers, and rectified by the synchronous detector. From the synchronous detector the DC equivalent (I<sub>DC</sub>) 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 bridged 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.

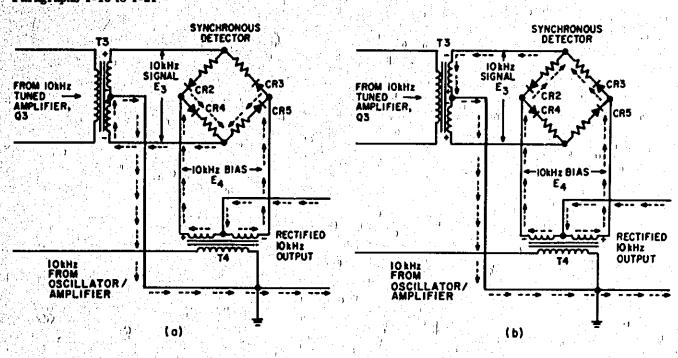
4-17. A simplified schematic of the synchronous detector is shown in Figure 4-4. The synchronous detector converts the 10 kHz error signal from the metering bridge to a varying DC signal. The detector is a bridge rectifier which has a rectifier in series with a linearizing resistance in each of its arms.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



## Section IV Paragraphs 4-18 to 4-21

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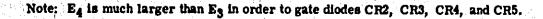


Figure 4-4. J Synchronous Detector

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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.

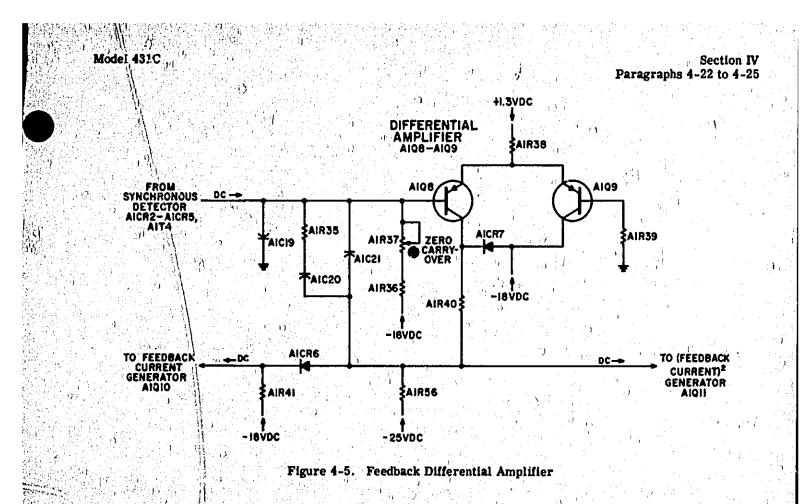
4-18. The synchronous detector operates in the following manner. When the left side of A1T4 is positive with respect to the right side, as in Figure 4-4(a), diodes A1CR4 and A1CR5 conduct while diodes A1CR2 and A1CR3 are biased off. With the polarities reversed, as in Figure 4-4(b), the diodes A1CR4 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. FIEDBACK 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.

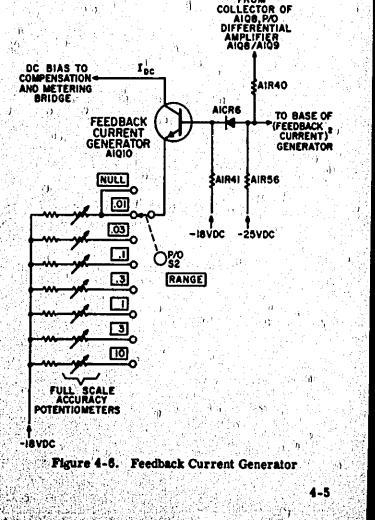


4-23. A simplified schematic diagram of the feedback current generator is shown in Figure 4-6. The DC signal from the differential amplifier is applied to the feedback current generator A1Q10. A1Q10 serves two functions: 1) it completes the metering loop to the metering bridge, and ?) it operates in 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.

# -24. METER CIRCUIT.

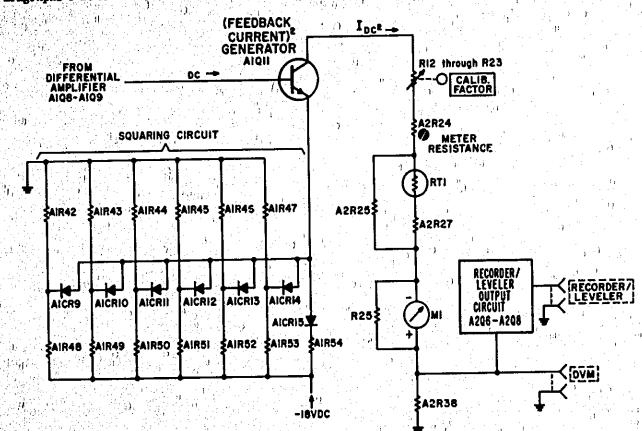
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4-25. A simplified schematic diagram of the meter circuit is shown in Figure 4-7. The meter circuit includes feedback current-squared generator A1Q11, a squaring circuit, the meter, RECORDER/LEVELER and DVM jacks, J2 and J4. The purpose of the meter 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 AlQII and is converted to a square law function by the squaring circuit in series with AlQ11 emitter.



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# 1.26. 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 A2Q6. 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-blased. The diodes are blased so that they conduct one after another at discrete values of emitter voltage. This causes the emitter resistance to be proportionately greater for

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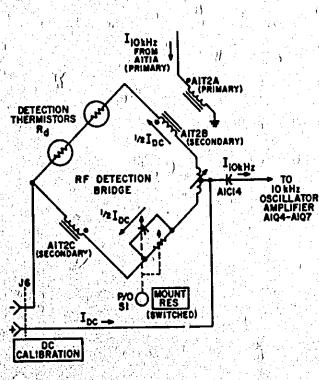


Figure 4-8. DC Calibration and Substitution

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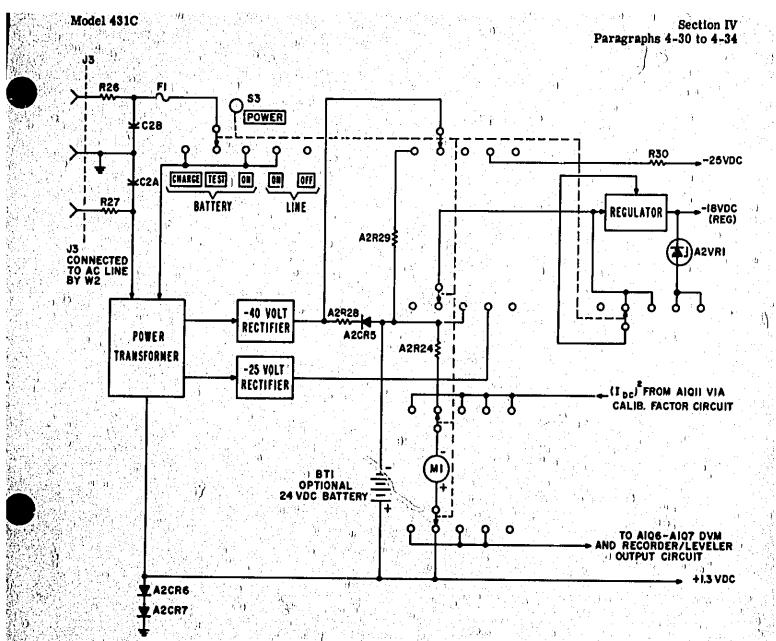


Figure 4-9. Power Switch Arrangement

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, IDC, 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

# Section IV Paragraphs 4-35 to 4-37

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 -16 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.

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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 OF, BATTERY TEST, and BATTERY CHARGE. In the LINE ON position the instrument operates from the conventional line voltage. If a rechargeable battery has been installed, a trickle charge is supplied to the battery. In the BATTERY ON position, instrument operation is dependent on the battery. In the BATTERY CHARGE position, -25 volts is connected to the battery for recharging. In the BATTERY TEST position, battery voltage can be measured on the 0-3 mW scale. Battery voltage is 10 times meter scale reading. Proper charge of the battery is indicated by a reading within the BAT CHARGED region on the bottom of the meter face.

Section V Paragraphs 5-1 to 5-4

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# ICTION

# 5-1. INTRODUCTION.

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5-2. This section provides instructions for performance testing, calibration adjustments, trouble-shooting and repairing the 431C Power Meter. Front panel controlled performance tests allow the instru-, ment to be checked for conformance to specifications. If performance is not within specifications, adjustment and troubleshooting instructions are provided.

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

5-4. MECHANICAL METER ADJUSTMENT. When the meter is properly zero-set, the pointer rests over

the zero markon the meter scale when the instrument is: 1) at normal operating temperature, 2) in its normal operating position, and 3) turned off. Set the pointer as follows to obtain best accuracy and mechanical stability;

a. Turn instrument off.

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

c. When the pointer is exactly on zero, rotate the adjustment screw approximately 3 degrees counterclockwise. This frees the adjustment screw from the meter suspension. If the pointer moves during this step, repeat steps b and c.

÷.,	Table	5-1.	Recomm	ended Tes	t Equipment

Instrument Type	Critical Specifications	Recommended Model
Direct Current Power Source	Range: 0.01 to 10 mW Accuracy: ±0.1%	hp 8402B
Electronic Counter	Sensitivity: 4V,rms Frequency: 10 kHz Accuracy: ±0.01% or better Resolution: Five digits	hp 5512A
DC Voltmeter	Range: 0.3 to 50 volts DC Accuracy: ±0.05% Input Impedance: 10 Megohms, floating	hp 3440A with 3443A plug-in or 3439A/3440A or 3430A
Ohmineter	Range: 1 ohm to 10 Megohms Accuracy: ±5%	hp 410B/C hp 412A hp 427A
AC Yolime*:r	Range: 10 to 100 mV Accuracy:: ±5% Input Impedance: 1 Megohm	hp 403A/B hp 427A
Oscilloscope	Bandwidth: 100 kHz Accuracy: ±5% Input Impedance: 1 Megohm Sensitivity: 1 mV/division	hp 140A with 1400A and 1402 plug-in units
Thermistor Mount	Refer to Table 1-2 for recommended thermistor mounts	hp 8478B hp 478A hp 486A Series
Decade Capacitor	Range: 0.0 to 0.01 uF Capacitance per step: 100 pF Accuracy: ±2%	General Radio 1419-B
Audio Oscillator	Frequency: 10 kHs Accuracy: ±2%	hp 200AB hp 200CD



# Section V Paragraphs 5-5 to 5-13

# 5-5. PERFORMANCE TESTS.

5-6. PURPOSE. The procedures listed in Table 5-2 test power meter performance for incoming inspection, periodic evaluation, calibration and troubleshooting. The tests can be performed without access to the instrument interior. Specifications in Table 1-1 are the performance, standards. If the power meter fails to meet any of the performance test specifications, refer to the adjustment procedures. If a circuit malfunction is suspected refer to the troubleshooting paragraphs.

# 5-7. ADJUSTMENTS.

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

5-9. To avoid errors due to possible ground loop currents, isolate the power meter from ground used for Table 5-2. R

1. ACCURACY: Refer to Table 1-1 Specifications.

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 clockwise until pointer once again approaches zero mark from the left.

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

### Procedure

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

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

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

f. Set RANGE (mW) switch on calibrator and

other auxiliary equipment. A power plug adapter that removes the ground connection at the line outlet can be used to isolate the power meter. Use with catuion and only where company rules permit.

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

# 5-11. COVER REMOVAL AND REPLACEMENT.

5-12. The side covers can be removed and replaced independently of the top and bottom covers. Each side cover is held in place by four screws retained by nuts which are fastened to the side frames.

### 5-13, TOP COVER REMOVAL.

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

Table 5-2. Performance Tests

RANGE switch on power meter to 10 mW.

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

h. Successively set RANGE (mW) switch on calibrator to 8, 6, 4, and 2 mW positions while observing power meter reading. The power meter should read the power set on the calibrator within limits in Table 1-1.

2. ZERO CARRYOVER: Less than 1% of full scale when zeroed on most sensitive range. Procedure

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

b. Set power meter controls as follows:

POWER		والودلو		15	, ON
RANGE					,01 mW
CALIB FACTOR				1 i i i i i i i i i i i i i i i i i i i	. 100%
MOUNT RES to c	orres	pond v	vith 1	esist	ance and
type of thermist			od -	1912 12	1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 -

c. Adjust ZERO for 0.00 VDC reading on 10 volt range of DC voltmeter.

d. Rotate power meter RANGE switch clockwise through remaining ranges. Reading on DC voltmeter should remain within  $0.00 \pm .01$  VDC on each range.

3. DVM OUTPUT: 1,000 VDC into open circuit corresponds to full scale meter deflection (1.0 on 0-1 scale)  $\pm 0.5\%$ ; 1 K  $\Omega$  output impedance, BNC female connector; effect of loading impedance less than 10 M  $\Omega$  must be accounted for. Procedure

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

b. Set 8402B FUNCTION switch to CALIBRATE. Reading on DC voltmeter should be 0.995 to 1.005 VDC, and correspond with full scale meter reading of power meter.



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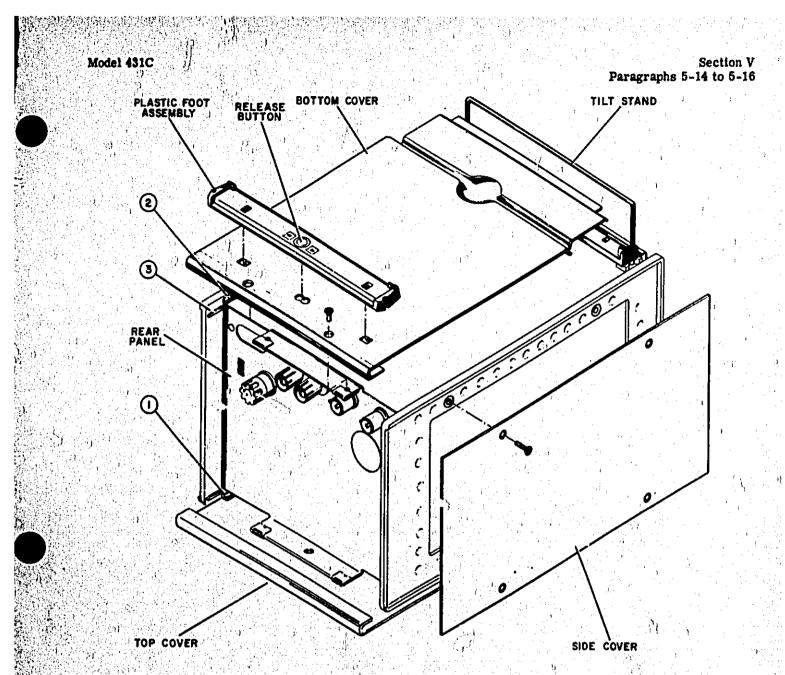


Figure 5-1. Cover Removal

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

5-14. TOP COVER REPLACEMENT.

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a. Rest the cover flat on the cast guides projecting inward near the top of each side frame (see 1), Figure 5-1).

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

c. Replace the two cover retaining screws.

5-15; BOTTOM COVER REMOVAL.

to the

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

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

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

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

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5-16. BOTTOM COVER REPLACEMENT.

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

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

c. Slide the cover forward on the guides so that the formed portion at the rear of the cover slides over the two short projections at the rear corner of each side frame (see(3), Figure 5-1).

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

# 5-17. POWER SUPPLY ADJUSTMENT.

Procedure

# CAUTION

5.3

Adjustment of the Power Supply voltage affects instrument accuracy. If voltages are in tolerance, <u>do not</u> adjust.

## Bection V Paragraphs 5-18 to 5-21

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

b. Adjust A2R36 for -18.00 ±0.02 VDC.

# 5-18. OSCILLATOR FREQUENCY ADJUSTMENT. Procedure

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

Note

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

b. Set power meter controls as follows:

POWER

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

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

- (1) 100 OHM THERMISTOR MOUNT. Use a decade capacitance to select a value for A1C3 (1000 pF maximum) that causes an oscillation frequency of 10.00 ±0.05 kHz. Install selected value of A1C3.
- (2) 200 OHM THERMISTOR MOUNT. Adjust A1L2 for an oscillation frequency of 10.00 ±0.01 kHz.

5-19, OSCILLATOR TANK CIRCUIT TUNING.

Adjust only if frequency determing components are replaced.

Procedure

5.4

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

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

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

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

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

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

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

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

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

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# 5-20, ZERO AND VERNIER CONTROL ADJUSTMENT.

### Procedure

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

b. Rotate 431C Power Meter RANGE switch clockwise through remaining ranges. Adjust A1R37 to hold DC voltmeter reading within  $(0.00 \pm .01)$  VDC on each range.

### 5-21. COARSE NULL ADJUSTMENT.

Procedure

ON

**100 OHM THERMISTOR MOUNT** 

a. Connect 100 ohm thermistor mount to power meter.

b. Connect oscilloscope or ACvoltmeter from A1R55 to ground.

c. Set power meter controls as follows:

nomen ()		1.1				•			s. 1	0.17
POWER.			•	. • . •	٠		•		٠	• • <b>ON</b>
RANGE .										
CALIB FA	CTOR	٤.		÷ •				ь 5°н		. 100%
MOUNT R										
and a second second		1.1		1					, î.,	

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

e. Mechanically center NULL capacitor, C1.

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

g. Set power meter RANGE switch to NULL, and fine adjust NULL capacitor C1 for a zero power meter reading. C1 should remain near mechanical center of range  $\pm 10^{\circ}$ .

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

200 OHM THERMISTOR MOUNT

i. Connect 200 ohm thermistor mount to power meier.

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

k. Set power meter controls as follows:

POWER	t		 121.14	ON
	FACTOR			
	RES			
		•••••	• • •	. =•••••

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

n. Mechanically center NULL capacitor C1.

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

p. Set power meter RANGE switch to NULL, and fine adjust NULL capacitor C1 for a zero power meter reading. C1 should remain near mechanical center of range  $\pm 45^{\circ}$ .



# Note

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

# 5-22. FULL SCALE ACCURACY ADJUSTMENTS.

Note

It may be necessary to adjust the -18 volt supply slightly to get all ranges within tolerance. Exercise caution when adjusting the -18 volt supply, as the adjustment of the supply affects instrument accuracy. Refer to Paragraph 5-17 for supply tolerance.

### Procedure.

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a. Measure from M1 negative terminal to ground, using the 3440A/3443A DVM.

b. Measure meter circuit current using a HP 428B clip-on DC Milliammeter.

c. Adjust ZBRO control for 1 mA through the meter circuit.

d. Maintain 1 mA through the meter circuitry, and adjust A2R34 for DVM reading of 1.248 ±.004 VDC.

- e. Connect equipment as shown in Figure 3-9.
  - f. Set 8402B Calibrator controls as follows:

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

g. Set 431C Power Meter as follows:

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

1. 200 OHM THERMISTOR MOUNT. Set calibrator and power meter controls and make corresponding adjustment as listed below.\*

Range	8402B Calibrator	431C Po	ver Meter
(mW)	Function	Adjust	Reading
.01	CURRENT OFF CALIBRATE	ZERO A2R14	0.0 .01 mW \
.03	CURRENT OFF CALIBRATE	ZERO A2R13	0.0 .0 mW
	CURRENT OFF	ZERO A2R12	0.0 .1 mW
1.3	CURRENT OFF CALIBRATE	ZERO A2R11	0.0 .3 mW
1	CURRENTO	ZERO A2R10	0.0 1.0 mW
3	CURRENTOF	ZERO A2R9	0.0 3.0 mW
10 10	CURRENT OFF	ZERO A2R8	0.0 10.0 mW

Section V Table 5-3

J. 100 OHM THERMISTO	R MOUNT.	Set calibrator
and power meter controls	and made	corresponding
djustments as listed below.	i € se se s	erte film T

Range	8402B Calibrator	431C Po	wer Meter
(mW)	Function	Adjust	Reading
.01	CURRENT OFF	ZERO	0.0
.01	CALIBRATE	A2R1	,01 mW
.03	CURRENT OFF	ZERO	0.0
.03	CALIBRATE	A2R2	.03 mW
<b>,1</b> 150 (	CURRENT OFF	ZERO	0.0
<b>.1</b>	CALIBRATE	A2R3	.1 mW
.9	CURRENT OFF	ZERO	0.0
.3	CALIBRATE	A2R4	.3 mW
1	CURRENT OFF	ZERO	0.0
<b>t</b> 🤤	CALIBRATE	A2R5	1.0 mW
3	CURRENT OFF	ZERO	0.0
8	CALIBRATE	A2R6	3.0 mW
10 \	CURRENT OFF	ZERO	0.0
10	CALIBRATE	A2R7	10.0 mW

\*(Refer to Para. 3-27 for thermo-electric 6, re: correction on lower ranges.)

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Table	5-3. CI	rcuit F	teaulr	emente	for
	Factory		-		

Part Ref. Desig.	Circuit Requirements
R25	Full scale deflection of meter M1 when 1 mA of DC flows through the combination of the meter and R25.
A1R5	Selected to set 10 KHz Amplifier attenuator accuracy over all bands.
A1R7	Balance of RF detection bridge when using a 100 ohm thermistor mount with no microwave power applied.
<b>A1R9</b>	Balance of RF detection bridge when using a 200 ohm thermistor mount with no microwave power applied.
A1R36	Sets coarse full scale accuracy on all ranges with A1R37 centered.
AICI	NULL capacitor, C1, set near mid- range for null when using a 200 ohm thermistor mount. Refer to Paragraph 5-21.
<b>N1C2</b>	NULL capacitor, C1, set near mid- range for null when using a 100 ohm thermistor mount. Refer to Paragraph 5-21.
<b>A1C3</b>	10 kHz output of oscillator amplifier, A1Q4-Q7, when using a 100 ohm thermistor mount. Refer to Paragraph 5-18.
<b>A1C4-5</b>	Must be within ±1% of same value. Set 10 kHz Oscillator Frequency with A1L2 centered.
<b>\1C22</b>	Frequency of 10 kHz for A1T5/ A1C15 tuned circuit combination. Refer to Paragraph 5-19.

Section V Paragraphs 5-23 to 5-28

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# 5-23. TROUBLESHOOTING.

5-24. Refer to Tables 5-7 through 5-21 for detailed circuit troubleshooting. Check the fuse. Make a visual inspection for burned, loose, or dirty components and connections. Often a visual check of the instrument will reveal sources of malfunction with no further troubleshooting. Do not adjust any internal circuit controls before a general idea of the trouble is formulated.

5-25. The first step in troubleshooting the 431C is to isolate the trouble to either the thermistor mount and thermistor-mount cable combination or the power meter. The operating note furnished with hp thermistor mounts gives a procedure to check the thermistor mount. This procedure will indicate any deficient performance of the mount. An ohmmeter continuity check can be used to determine if the thermistor mount cable or cable connectors are defective. 11.

5-26. TROUBLE ISOLATION. Circuits in the 431C can be divided into five basic functional units as follows; 1) RF detection bridge and 10 kHz oscillatoramplifier (A1Q4-A1Q7), 2) compensation and metering bridge, 10 kHz amplifier (A1Q1-A1Q3) and synchronous detector, 3) differential amplifier (A1Q8-A1Q0) and feedback current generator (A1Q10), 4) feedback current-squared generator (A1Q11) and metering circuits, and 5) power supply.

5-27. The procedure in Table 5-4 employs front panel controls for isolation of trouble to basic circuits. Tables 5-7 through 5-12 employ internal circuit indications for more detailed malfunction analysis.

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

Step	Instructions	Indication	Action or Trouble Circuit
1.	a. Connect thermistor mount	No meter reading	Proceed with step 2
	<ul> <li>b. Set RANGE to .01 mW</li> <li>c. Set POWER to ON</li> <li>d. Adjust ZERO for zero meter reading, if possible</li> <li>e. Rotate RANGE from .01 through 10 mW</li> </ul>	Meter reads below low scale limit or meter reads above high scale limit	Proceed with step 3
2.	a. Set RANGE to 10 mW	No meter reading	Proceed with step 3
	<ul> <li>b. Apply RF power to thermistor mount</li> <li>c. Decrease RANGE from 10 mW until reading is obtained</li> </ul>	Any meter reading	<ul> <li>a. Perform ACCURACY performance test, Figure 5-2. Particular range in- accuracy: check first for improper range resistance selected by RANGE switch (AIS2). All range inaccuracy: 10 kHz amplifier (A1Q1-A1Q3) and feedback current generator (A1Q10) combination or power supply.</li> <li>b. Proceed with step 3.</li> </ul>
3.	3. a. Remove RF power from thermistor mount b. Set RANGE to NULL	Meter reading that changes with NULL adjustment	Proceed with step 4
	c. Adjust NULL screwdriv ir adjustment	Meter reading that does not change with NULL adjustment	Compensation and metering bridge, 10 kHz amplifier (A1Q1-A1Q3) and synchronous detector combination
		No meter reading	RF detection bridge, and 10 kHz oscillator-amplifier (A1Q4-A1Q7) combination
			Power supply
	a. Set RANGE to . 01 mW b. Adjust ZERO for zero meter	Zero	Feedback current-squared generator (A1Q11) and metering circuits
	reading c. Rotate RANGE from .01 through 10 mW	No zero	Differential amplifier (A1Q8-A1Q9) and feedback current generator (A1Q10) combination
ある法	9 1927 - 1937 - 1937 - 1937 - 1937 - 1937 - 1937 - 1937 - 1937 - 1937 - 1937 - 1937 - 1937 - 1937 - 1937 - 1937 1937 - 1937 - 1937 - 1937 - 1937 - 1937 - 1937 - 1937 - 1937 - 1937 - 1937 - 1937 - 1937 - 1937 - 1937 - 1937 -	Zero does not carry- over within specifi- cations	Differential amplifier (A1Q8-A1Q9) and feedback current-squared generator (A1Q11) combination

Table 5-4. Front Panel Trouble Isolation



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

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

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

5-31, DETAILED TROUBLESHOOTING. To assist detailed troubleshooting, normal-operation waveforms are given in Figures 7-3 and 7-8. Locations of test points and components are given in Figures 7-2, 7-4, and 7-6. In addition, normal-operation voltages relative to chassis ground are provided on the schematic diagrams for the collector, base and emitter of every transistor in the instrument. Waveforms and voltage measurements were made with a thermistor mount connected, and the instrument nulled, according to instructions given in Figure 3-8. The first detailed troubleshooting checks should be performed in the following order: 1) check for power supply output voltages of +1.3, -18, and -25 VDC, 2) check at test point 6 to ensure that the 10 kHz oscillator - amplifier, AlQi-A1Q7, has the proper output waveform, 3) check at test point 2 for correct output of the 10 kHz amplifier, A1Q1-A1Q3. For signal tracing through the amplifier stages, capacitor A1C10 can be disconnected from A1L1 and used as a means to inject a 10 kHz test signal to the input of the first 10 kHz amplifier, A1Q1.

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

5-33. IN-CIRCUIT TESTING. The common causes of transistor failures are internal short- and open-circuits. In transistor circuit testing the most important consideration is the transistor base-emitter junction. Like the control grid of a vacuum tube, this is the operational control point in the transistor. This junction is essentially a solid-state diode. For the transistor to conduct, the diode must conduct; that is, the diode must be forward biased. As with 2. le diodes, the forward bias polarity is determined by the materials forming the junction. Use the transistor symbol on the schematic diagram to determine the bias polarity required to forward-bias the base-emitter junction. The A part of Figure 5-2 shows transistor symbols with terminals labeled. The emitter arrow points, toward the type N material. The other two columns of the illustration compare the biasing required to cause conduction and cut-off in transistors and vacuum tubes. If the transistor base-emitter diode (junction) is forward - blased, the transistor conducts. If the diode is heavily forward-blased, the transistor saturates. However, if the base-emitter diode is reverse biased, the transistor is cut off (no conduction). The voltage drop across a forward-blased emitter-base diode varies with transistor collector current. For

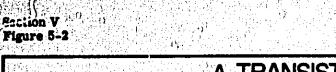
example, a germanium transistor has a typical forward bias, base - emitter voltage of 0.2 - 0.3 volts when collector current is 1 - 10 mA, and 0.4 - 0.5 volts when collector current is 10 - 100 mA. In contrast, forward-bias voltage for silicon transistors is about twice that for germanium types: about 0.5 - 0.6 volts when collector current is low, and about 0.8 - 0.9 volts when collector current is high.

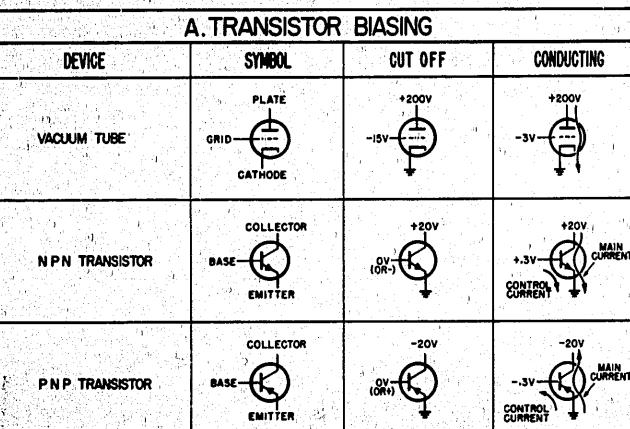
5-34. Figure 5-2, part B, shows simplified versions of the three basic transistor circuits and gives the operating characteristics of each. When examining a transistor stage, first determine if the emitter-base dlode is biased for conduction (forward-biased) by measuring the voltage difference between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

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

Transistor Type		Connect O	Measure	
		Pos. lead to	Neg. lead to	Resistance (ohms)
	Small	emitter	base*	200-500
PNP	Signal	emitter	collector	10 k-100 k
Ger- manium	er-	emitter	base*	30 - 50
	Power	emitter	collector	several hundred
	Small	base	emitter	1 k - 3 k
NPN Silicon	Signal	collector	emitter	very high (might read open)
		base	emitter	200-1000
	Power	collector	emitter .	high, often greater than 1M

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





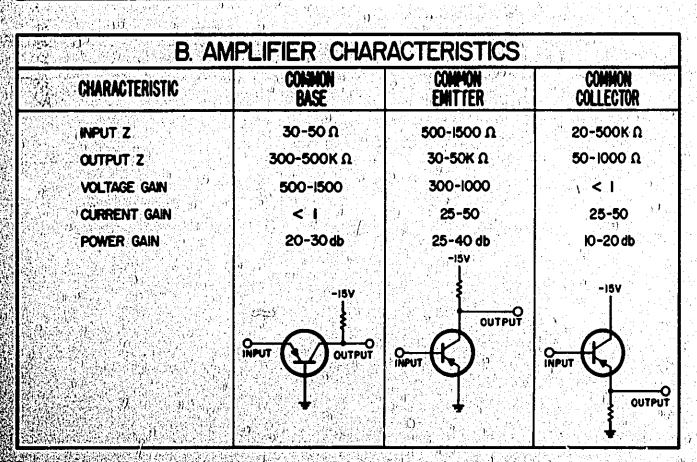


Figure 5-2. Transistor Biasing and Operating Characteristics

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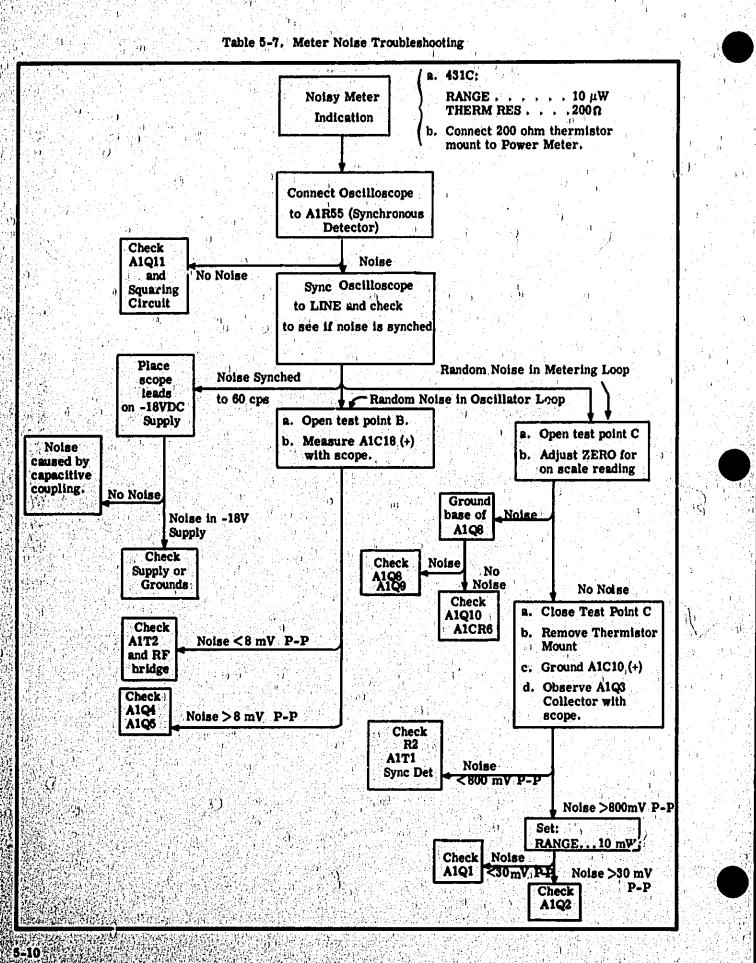
Most ohmmeters can supply enough current or voltage to damage a transistor. Be-fore using an ohmmeter to measure transistor forward or reverse resistance, check its open-circuit voltage and short-circuit current output ON THE RANGE TO BE USED. Open-circuit voltage must not exceed 1.5 volts and short-circuit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

2	Table 5-6.	Safe Ohmmeter	Range for 7	ransistor F	Resistance	Measurements	
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				x	1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 -		
- 2.7			A 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4	2.77 sec.			

Ohmmeter	Safe Range(s)	Open Ckt Voltage	Short Ckt	Lead		
			Current	Color	Polarity	
hp 412A hp 427A	R x 1 k R x 10 k R x 100 k R x 100 k R x 1M R x 10M	1.0V 1.0V 1.0V 1.0V 1.0V	1 mA 100 μA 10 μA 1 μA 0,1 μA	Red Blk	$\begin{array}{c} \mathbf{t} \\ $	
hp 410C	R x 1 k R x 10 k R x 100 k R x 100 k R x 1M R x 10M	1.3V 1.3V 1.3V 1.3V 1.3V 1.3V	0.57 mA 57 μA 5.7 μA 0.5 μA 0.05 μA	Red Blk		
hp 410B	R x 100 R x 1 k R x 10 k R x 100 k R x 100 k R x 1M	1.1V 1.1V 1.1V 1.1V 1.1V 1.1V 1.1V	1,1 mA 110 μA 11 μA 1,1 μA 0,11 μA	Blk Red		
Simpson 260	R x 100	<b>1.5V</b>	1 mA	Red Blk	1000 - 10000 - 10000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 - 1000 -	
Simpson 269	Rxlk	1.5¥	0.82 mA	Blk Red		
Triplett 630	R x 100 R x 1 k	1.5¥ 1.5¥	3.25 mA 325 μA	Varles		
Triplett 310	R x 10 R x 100	1.5V 1.5V	750 μΑ 75 μΑ	Serial Number		

Section V Table 5-7

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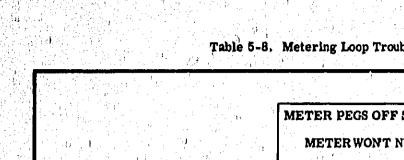
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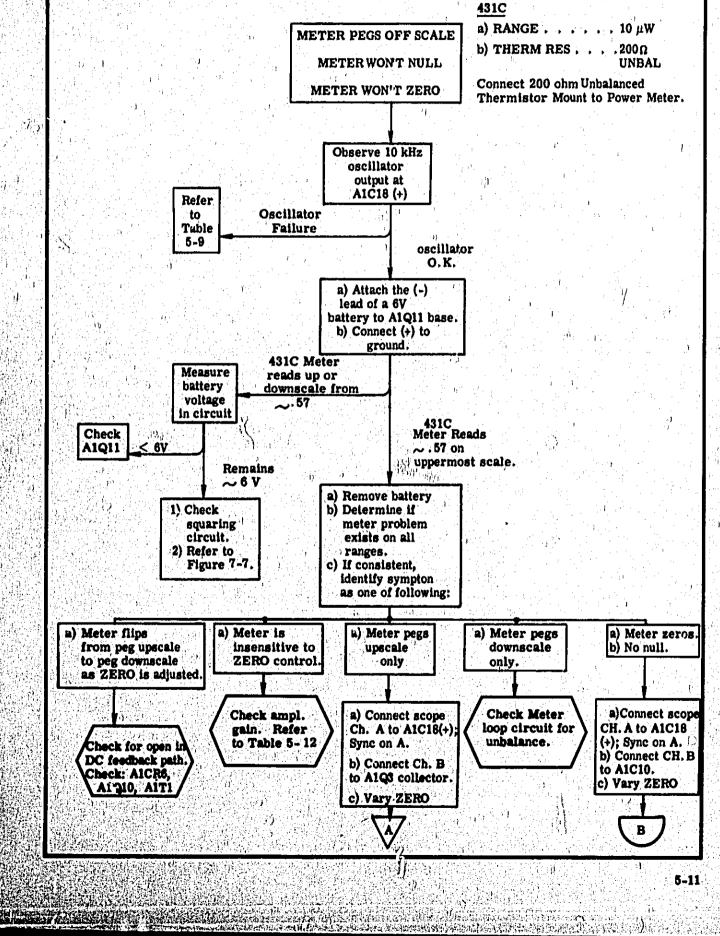
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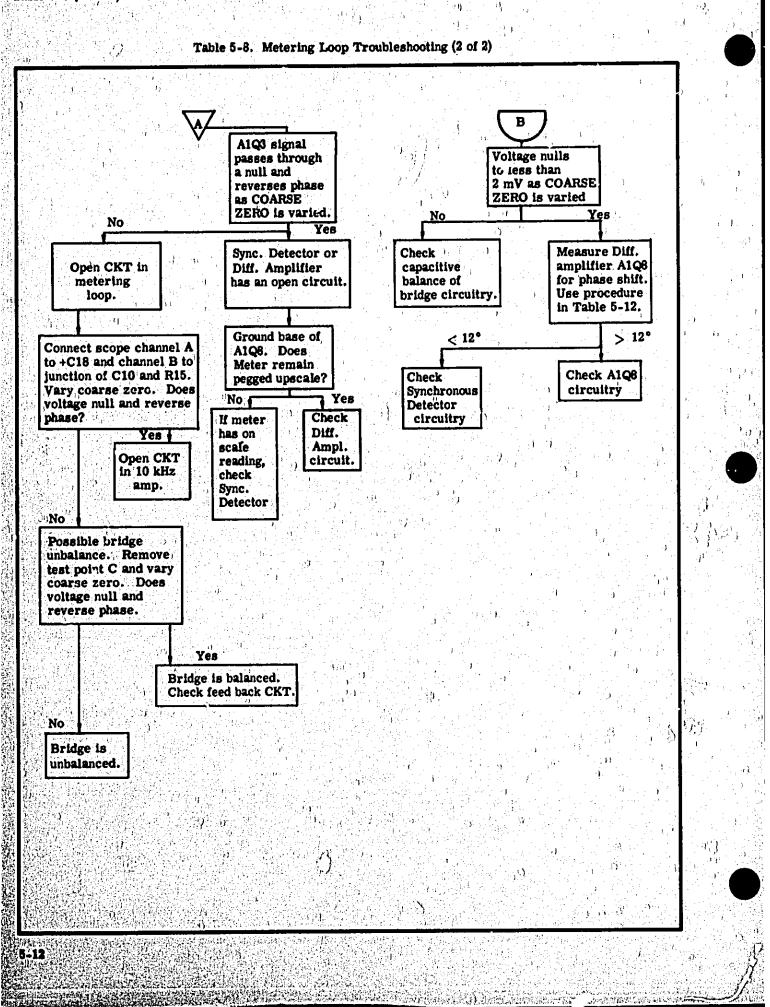
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Table 5-8. Metering Loop Troubleshooting (1 of 2)



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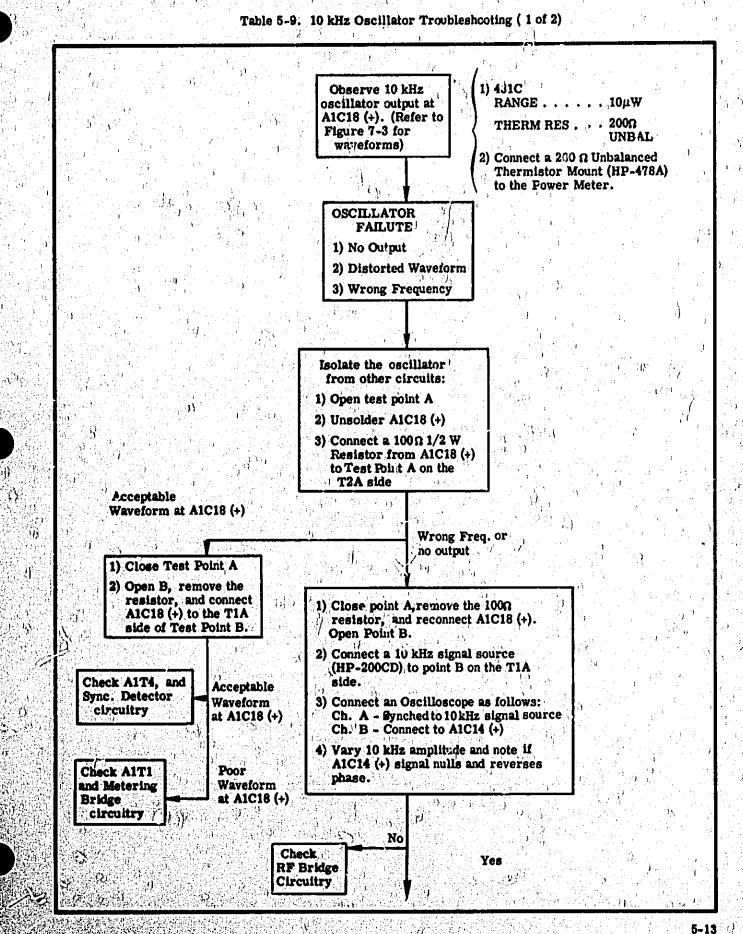
Section V Table 5-8 (Cont'd)



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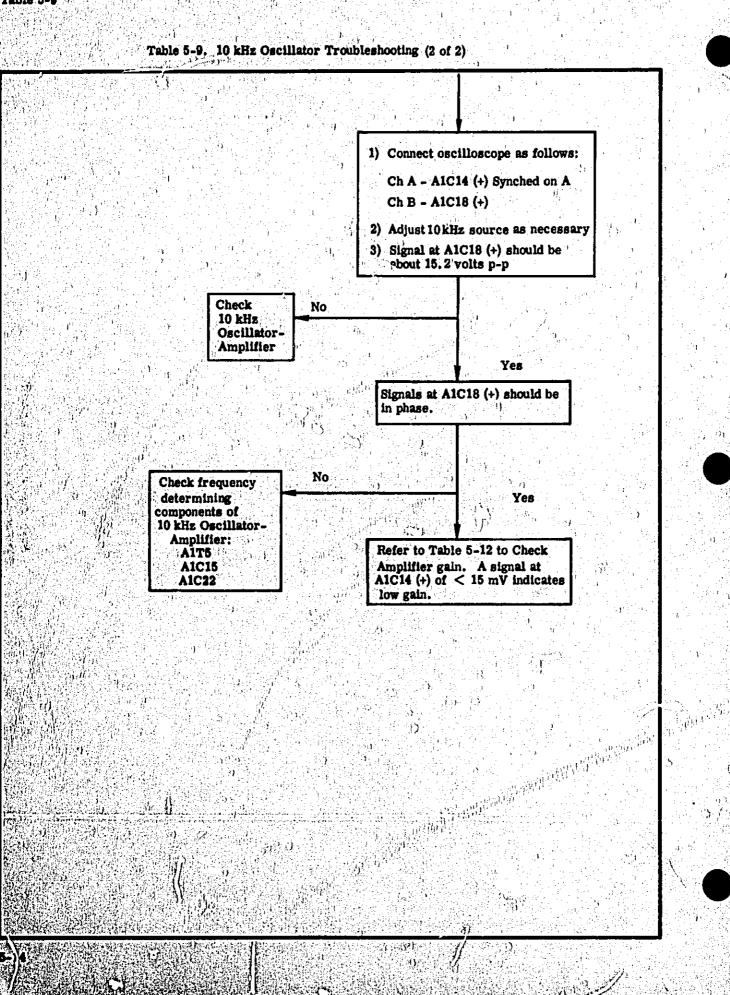
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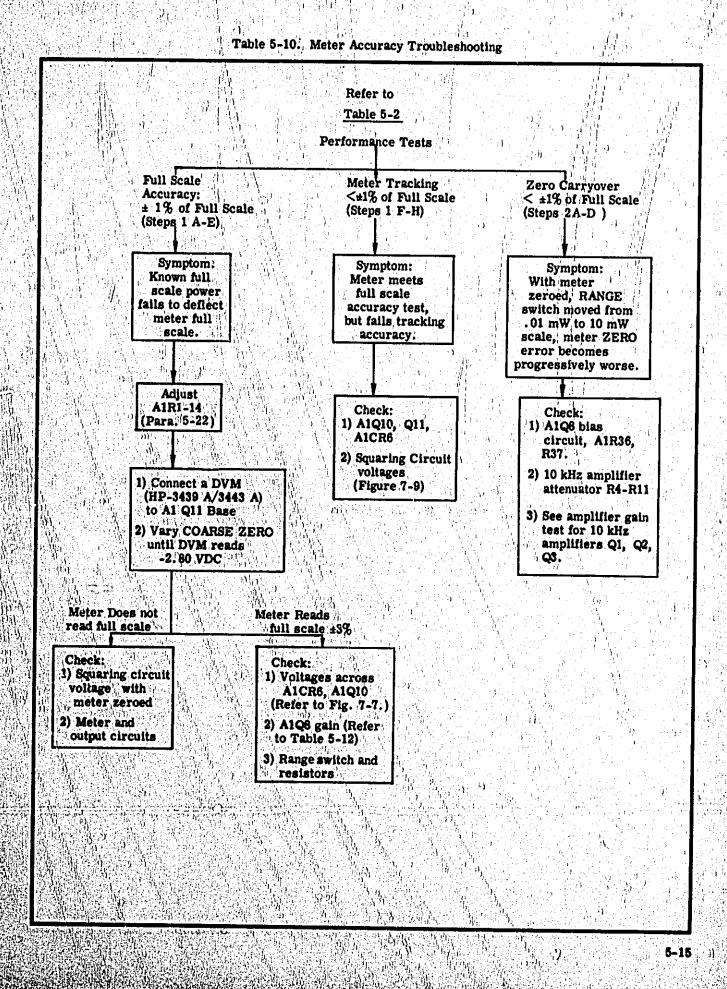
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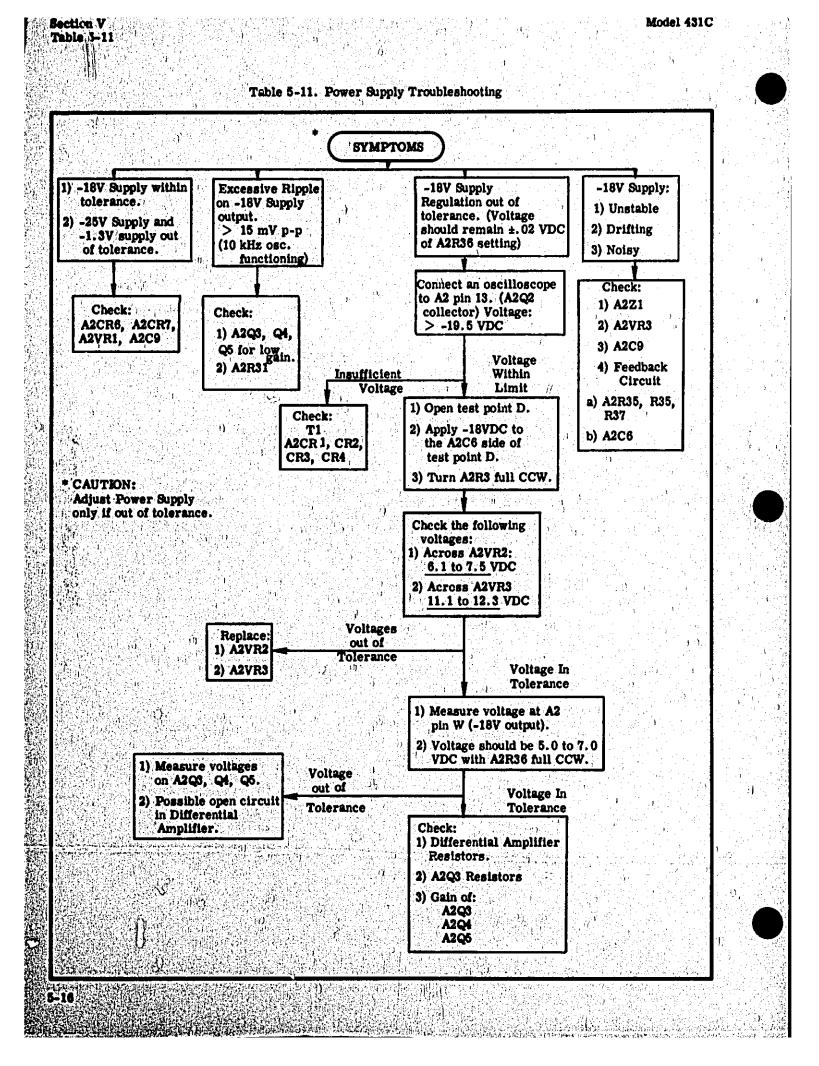
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Table 5-12, 10 kHz Amplifier Troubleshooting

## NOTE

The following tests gain of the 10 kHz <sup>1</sup> amplifier circuits.

- 1. Refer to the schematic diagram, Figure 7-5, and 7-7 to perform the amplifier gain test.
- 2. Use the following test equipment:

Wide-Range Oscillator

HP-355D

Attenuator Oscilloscope

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### Refer to Table 5-1

HP-200CD

3. Proceed as follows:

- $\mathbf{h}$ a. Open test point C by removing the jumper.
- b. Ground the (+) side of A1C18.
- c. Disconnect the bridge side of A1C10.
- d. Disconnect the collector of A1Q3, and insert a 5110 ohm resistor from the collector to the junction of A1R23 and A1C13.
- e. Attach the 355D Attenuator to the output of the oscillator. Set the attenuation to 10 dB.
- 1. Connect the oscilloscope to A1Q3 collector. g. Set the 431C RANGE to 10 mW.
- ĥ.
- Set the oscillator output control to 50. Connect the attenuator output to the disconnected) side of A1C10.
- i. Adjust oscillator output amplitude until A1Q3 collecter voltage equals 10 volts p-p, or until the signal just begins to clip, whichever occurs first.
  - J. Measure the voltage at the base of A1Q1, and at the base of A1Q3. Both voltages should be approximately 80 mV p-p.

k. To check amplifier gain on other 431C ranges, move the RANGE switch and attenuator setting as in the table below:

(Maintain the oscillator level as set in step i. above.)

431C RANGE	355D Atten.	A1Q3-Coll.	A1Q3-*
10 mW	10	9.6 Vp-p	80 mV p-p
3 mW	20	±25%	±25%
1 mW	30		
.3 mW	40		
1 mW ()	50		
.03 mW	60	<b>,</b>	
.01 mW	70		

### j. Phase Shift Test:

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1. Use the test setup described in Step a. through j. above.

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2. Connect a dual trace oscilloscope as follows:

Channel A .. SYNC on oscillator output

. 1992 Channel B .. Observe A1Q3 Collector

3. Compare the phase of the signal from the oscillator with the signal at A1Q3 collector. Phase shift should not'exceed 12 degrees.

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#### 6-1. INTRODUCTION.

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

a. Description.

b. Manufacturer of the part in a five-digit code; see list of manufacturers in Table 6-3.

c. Manufacturer's part number.

d. Total quantity used (TQ column).

#### 6-3. ORDERING INFORMATION.

6-4. To obtain replacement parts, address order or inquiry to your local Hewlett-Packard Field Office (see list at rear of this manual for addresses). Identify parts by their Hewlett-Packard stock numbers.  $\pi_{1} = \pi_{1} + \pi_{1} + \pi_{2} + \pi_{1} ЧĻ.

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6-5. To obtain a part that is not listed, include:

a. Instrument model number.

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- b. Instrument serial number.
- c. Description of the part.
- d. Function and location of the part.

### REFERENCE DESIGNATORS

			REFERENCE I	$-\hat{\mathbf{u}}_{1,j,k}$ with	그는 생각이 되었는 일이야.		
	= suembly = motor	P PL	= fure = Filter	P. Oli	= plug = transistor	V	<ul> <li>vacuum tube, neon bulb.</li> </ul>
BT	= battery		= jack	R	resistor		photocell, etc.
<b>. C</b> ).()	= capacitor		= relay	RT	# thermistor	VR	• voltage 🔅 👘 🧃
CP	eouplet	al <b>L</b> a Marana	= Inductor	ે ન <b>ક</b> ારના કે ક	= switch and the test		regulator
CR	- diođe	. <b>LS</b>	= loud speaker = meter	TB	= transformer = = = = = = = = = = = = = = = = = = =		= cable = aocket
DL )	= delay line = device signaling (lamp)	M MK	= meurr = microphone	TP	. test point	· <b>♀</b> · · · ¦;	
	= misc electronic part		= mechanical part	Ū,	= integrated circuit	<b>Z</b> ,	" tuned cavity, "
			ABBREV	IATIONS			network:
			• henries	N/O	= normally open	RMO	= rack mount only
AFC	= amperes = automatic frequency	HDW	= herdware	NOM	= nominal		= root-mean square
er er er er er er er er er er er er	control	HEX	bexagonal	NPO	· negative positive	RWV	- reverse working
AMPL	amplifier	HG S	mercury	3.55 C. 55	zero (zero tem-	et de la companya de la companya de la companya de la companya de la companya de la companya de la companya de	voltage
	战争时后来的 计算机 建口	HR	• hour(s)	1	perature coef-	S-B	• Now-blow
Bro	- beat frequency oscilla-	Hz	Heriz (Production)	NPN	= negative-positive-	SCR SE	= screw = selenjum
BECU	= beryllium copper	- IP ()	intermediate freq		negative	SECT	= section(s)
BH S	- binder head	IMPG ON	impregnated	NRFR	= not recommended	SEMICON	armiconductor
. <b>DP</b>	- bandpers	), <b></b>	incandescent,		for field re-		= allicon
BRS	m.pres 5}.est 265 gapter	INCL	ninchude(s)	NSR	placement	SIL SL	= silver
BWO	- backward wave oscilla-	INS INT	insulation(ed)	NOR	= not separately replaceable	SPG	- sucr = soring
					a an Francis and a second	SPL and a	apecial
CCW	· counterclockwise	K	= kilo = 1000	OBD	- order by	"SST	• Stainless steel 💠
CER	• ceramic			ОН	= description		nolis ring
CMO COEF	cabinet mount only coefficient	nin – Statistickies Vielenen Statistickies		ŏx	- oxide	STL	= steel
COM	= common		<ul> <li>left hand (1999) (1999)</li> <li>linear taper</li> </ul>		그는 그는 것을 가지 않는 것이다.	han bu the	
COMP 🔆	· composition	LK WASH	- lock washer	hi P PC	= peak = printed circuit	TA TD	= : tantalum = : time delay
COMPL	= complete		logarithmic taper		= picofarada = 10-12		toggie
CONN	= connector	e <b>l'en s</b> amé de la composition de la composit Composition de la composition de la c	- low pain filter	1995 B	farads		• thread
CRT	cadmium plate cathode-ray tube		- 网络短期的公司	PH BRZ	phosphor bronze ::::		= titanlum
CŴ	= clockwise		= milli = 10 <sup>,3</sup>	PHL	<ul> <li>Phillips</li> <li>peak inverse</li> </ul>	TOL	tolerance
68 H 6 7	都自己的问题。可以是我们的		• meg = 10 <sup>5</sup>		voltare	TWT	trimmier
DEPC	= deposited carbon	MET FLM	metal film	PNP	= positive-negative-	··. <b>▲₩</b> ▲?/); ··	tube
DR'A	- drive Skiel Galaxies (1)	MFR	= manufacturer		positive	1 > 1 + 1	
ELECT	= electrolytic	MHz	* mega Hertz	P/0	* part of	$\mathcal{T}$	micro = 10 <sup>-6</sup>
	· encapsulated		• ministure	POLY PORC	= polystrene = porcelain		
EXT	- external interior		momentary	POS	= position(s)	VAR	• variable
的原因对名。	영화 전에 관계 관계 전 것 같아.	MOS	metalized and a second	POT	= potentiometer	VDCW	de working volts
PH 20	farads	MTG	mounting	PP	· peak-to-peak		de worning rome
FIL H	- Fillister bead		"myler"	9 <b>PT</b> (-), (-),	= point is a second	117.4	with
TXD	· fixed	길 아이들 아이들		PWV	peak working volt-	W/	with the
the start of the	STANDAR AND AND AND AND AND AND AND AND AND AND	N	nano (10 <sup>-9</sup> )		가는 <b>이상은</b> 가지 않는 것은 것이 있는 것이다. 이 같은 것 같은 것 같은 것이 있는 것을 것		working inverse
G	- sign (109)	- N/C	• normally closed ( w).	RECT	= rectilier		voltage
GE	= germanium		neon which is the		= radio frequency = round head or		wirewound
GRD	= ground(ed)	NI PL	<ul> <li>nickel plate</li> </ul>		right hand	W/O	without
California (California)				1997년 1887 - 1997 -			
网络白垩石	<b>和</b> 他们不知道意味自己的"你。"		. 2017년 1월 2017년 1월 2017년 1월 2017년 1월 2017년 1월 2017년 1월 2017년 1월 2017년 1월 2017년 1월 2017년 1월 2017년 1월 2017년 1월 2				

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Reference Designation	Stock No.	Description #	Note
	00431-6018	BOARD ASSY AMPLIFIER	
A1C1	0140-0198	CIFXU MICA 200PF 5% 300VDCW	
일부 값이 들어져		FACTORY SELECTED PARTI TYPICAL VALUE GIVEN	
<b>*A1C2</b>	0160-2201	CIFXD MICA 51 PF 58 Factory selected part: typical value given	
AIC3	0140-0198	COFXD MICA 200PF 5% 300VDCW Factory Selected Part: Typical Value Given	
A1C4 A1C5	0160-0136 0160-0136	CIFXD MICA 2500PF IN JOOVDCW(FACTORY SELECTED PART) CIFXD MICA 2500PF IN JOOVDCW(FACTORY SELECTED PART)	
AIC6	0180-0116		
A1C7	0180-0116	CIFXD ELECT TA GIS UF LON 35VOCW CIFXD ELECT TA GIS UF 107 35VDCW	1
AICO	0180 0106	CIFXD ELECT TA GOUF 208 GVOCH CIFXD POLY 0.1UF 28 SOVACH	
A1C10	0160-0174	C1FXD CER 0.47UF +80-23% 25VDC#	
AIC11 AIC12	0160-0174	C+FXD CER 0.47UF +80-208 25VDCW ; C+FXD POLY C+1UF 28 50VDCW ;	
AICIJ AICI4	0180-0116	CIFXO ELECT TA 6.8 UF 108 35VDCW CIFXO ELECT TA 618 UF 108 35VDCW	
A1C15	0170-0069	CIFXD POLY 0.1UF 28 SOVDCW	-
A1C16	0180-0116	CIFXD ELECT TA 6.8 UF 108 35VDCW	
A1C17 A1C18	0180-0116	CIFXO ELECT TA 6.8 UF 10% 35VDCW CIFXO AL ELECT 200F 50VDCW	
A1C19 A1C20	0180-0045	CIFXD ELECT 20UF 25VDCW CIFXD ELECT 20UF 25VDCW	
A1C21	0160-0174	CIFX0 CEP. 0.47UF +80-20\$ 25VDC#	
A1C22	0140-0159	CIFAN MICA SOOOP SOOVDCW FACTORY SELECTED PARTIUSED ONLY FOR OPT 23.	
A1C23			
AICR1	1901-0025	DIODE-JUNCTIONISMA AT IV 100 PIV DIODEIGERMANIUM 100MA AT 0.85V 60PIV	
AICR3 AICR4	1910-0016	DIODEIGERMANIUM 100MA AT 0.85V 60PIV	
AICR5	1910-0016	DIODEIGERMANIUM IOOMA AT 0.85V 60PIV	
A1CR6 A1CR7	1901-0450 1901-0025	DIODEISILICON DIODEIJUNCTIONISMA AT IV 100 PIV	
AICR8 AICR9	1901-0025	DIODE-JUNCTION-5MA AT IV 100 PIV DIODE-SILICON	
AICRIO	1901-0450	CIODEISILICON	
AICRII	1901-0450	DIODEISILICON	
AICR12 AICR13	1901-0450	DIODEISILICON	
AICRIN AICRIS	1901-0450	DIODEISILICON DIODEISILICON	
AILI	9140-0122	COLLIVAR EX 9-20 UNY EACH	
AIL2 AIL3	9140-0122 9110-0040	COILIVAR 2X 9-20 UHY EACH	
AILS	9110-0040	INDUCTORIAUCIO	
A191	1853-0020	TRANSISTORISIL (CON PNP	
A102 A103	1854-0071 1853-0020	TRANSISTORISILICON NPN 2NJJ91 TRANSISTORISILICON PNP	
· · · · · · · · · · · · · · · · · · ·			
		na <mark>han sana sana sana sana sana sana sana s</mark>	
	5 (S. 4)	ee list of abbreviations in introduction to this section	

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		le 6-1. Reference Designation Index (Cont'd)	Table 6-1
Reference	Gtock No.	Description #	Note
A194	1854-0071	TRANSISTORISILICON NPN 2N3391	
A105 A106	1853-0020 1854-0071	TRANSISTORISTLICON PNP TRANSISTORISTLICON NPN 2N3391	
A197 A198	1853-0020 1853-0020	TRANSISTORISILICON PNP TRANSISTORISILICON PNP	
A109	1853-0020	TRANSISTORISTLICON PNP	<sup>1</sup> .
A1010 A1011	1854-0071 1854-0071	TRANSISTORISILICON NPN 2N3391 TRANSISTORISILICON NPN 2N3391	4.
Alri Airi	0811-0066	RIFXD WW SET ONH IN S/100W RIFXD WW SIL ONH 1.0N 1/20W	· 2
AIR3 AIR4	0811-0065	R4FX0 WW \$11 CHH 1.03 1/20W R4FX0 WW \$11 CHH 1.03 1/20W R4FXD MEY FLM 21.5K CHM 1% 1/8W	
AIRS	0811-1571	RIFXD WW 189 OHH 0.1% 1/8W	
AIR6 AIRT	0811-1572 0757-0460	RIFXD WW 255 OHM 0.18 1/8W RIFXD MET FLM 61.9K OHM 18 1/8m	
AlRe	0811-1645	FACTORY SELECTED PART. TYPICAL VALUE GIVEN RIFXD WW 202.1 OHM 0.1% 1/8W	1
AIR9	0757-0123	FACTORY SELECTED PART. TYPICAL VALUE GIVEN	
	0811-1566	RIFXD WW BOO CHM 0.13 1/8W	
A1R11 A1R12 A1R13	0757-0417 0757-1094 0757-0279	RIFXD MET FLM 562 OHM 1N 1/8W RIFXD MET FLM 1.47X OHM 1N 1/8W RIFYD MET FLM 1.47X OHM 1N 1/8W	
A1R14 A1R15	C698-0085	RIFXD MET FLM 3.16K OHM 18 1/88 RIFXD MET FLM 2.61K OHM 18 1/88 RIFXD MET FLM 7.50K OHM 18 1/88	
AIR16	0757-0279	RIFXO MET FLM' 3-16K OHM 18 1/8W	
AIR17 AIR18	0757-0280	RIFXD MET FLM 1.00K OHM 18 1/88 RIFXD MET FLM 7.50K OHM 18 1/88	
AIR19 AIR20	0698-3156 0698-3157	RIFXO HET FLM 14.7K OHM 18 1/8m RIFXD HET FLM 19.6K OHM 18 1/8m	
A1R21	0698-3157.)	RIFXD MET FLH 19.6K OHM 18 1/80	∦ 
A1R22 A1R23	0757-0279 0698-3438	RIFXD MET FLM 3.16K CHM 18 1/88 RIFXD MET FLM 147 CHH 18 1/88	
A1R24, A1R25	0757-0465 0698-3452	RSFXD MET FLN 100K OHM 18 1/8W RSFXD HET FLN 147K OHM 18 1/8W	
A1R26 A1R27	0698-3440 0757-0442	RIFXD MET FLM 196 OHM 18 1/88 RIFXD MET FLM 10.0K OHM 18 1/88	1
A1R28 A1R29	0698-3160	RIFXD HET FLH 31.6K 18 1/88 RIFXD HET FLH 21.5K OHM 18 1/88	
AIR30	0757-0442	RIFXD MET FLM 10.0K OHM 18 1/68	
A1RJ1 A1RJ2	0757-0280	RIFXD MET FLM 1. OK OHM IN 1/0W RIFXD MET FLM 1.00K OHM IN 1/00	
AIR33 AIR34	0757-0280 0757-0280	RIFXO MET FLM 1.00K OHM 18 1/88 RIFXO MET FLM 1.00K OHM 18 1/88	
A1R35	0698-0084	RIFXD MET FLM 2150 OHM IS 1/6W	
AIRJ6 AIRJ7	0698-3450 2100-0144	RIFXD MET FLM 42-2K OHM 1X 1/88-FACTORY SELECTED PART. RIVAR COMP 250K OHM 308 LIN 1/5W	n de la constante la constante de la constante F
AIRJB AIRJ9	0698-3447 0757-0417	RIFXD MET FLM 422 OHM 18 1/86 RIFXD MET FLM 562 OHM 18 1/86	
AIR40 AIR41	0757-0274	RIFXO MET FLM 1.21K OHM 1X 1/CH	
	0698-3449	RIFXO MET FLM 28.7X OHM 18 1/2W	

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Designation	Stock No.	Description #			- <b>1</b>	No
			1.201999 2011 -			
A1RA2 A1R45 A1R44 A1R45	0698-4028 0698-4029 0698-4027 0698-4027	R:FXD MET FLM 48.64K OHM 1/2% 1/8W R:FXD MET FLM 53.39K OHM 1/2% 1/8W R:FXD MET FLM 64.45K OHM 1/2% 1/8W R:FXD MET FLM 69.90K OHM 1/2% 1/8W				
A1R46	0698-4025	RIFXO MET FLM 128.5K OHH 1/25 1/85	1)  }		197 1	
A1R47 A1R40 A1R49 A1R50 A1R51	0698-4024 0698-4023 0698-4034 0698-4033 0698-4032	R4FXD HET FLH 259.6K OHM 1/2% 1/8W R4FXD HET FLM 130.4K OHM 1/2% 1/8% R4FXD HET FLM 184.32K OHM 1/2% 1/8% R4FXD HET FLM 62.26K OHM 1/2% 1/8W R4FXD HET FLM 51.22K OHM 1/2% 1/8W	1	 		
A1R52 A1R53 A1R54 A1R55 A1R56	0698-4031 0698-4030 0698-4028 0698-0082 0698-0082	R1FXD MET FLM: 43.25K OHM 1/28 1/8W R1FXD MET FLM: 40.77K OHM 1/28 1/8W R1FXD MET FLM: 40.67K OHM 1/28 1/8W R1FXD MET FLM: 464 OHM 18 1/8W R4FXD MET FLM: 464 OHM 18 1/8W R4FXD MET FLM: 28.7K OHM 18 1/86	1 			
AIR57	0698-3582	RIFXO MET FLM 41.2K OHM IN 1/8W		e Anglas anglas		
AITI AIT2 AIT3 AIT4 AIT5	9120-0066 9120-0066 9120-0065 9120-0065 9120-0065 9120-0065	TRANSFORMERIALDIO TRANSFORMERIAUDIO TRANSFORMERIAUDIO TRANSFORMERIAUDIO TRANSFORMERIAUDIO TRANSFORMERIINPUT				
A2	00431-6019	BOARD ASSY FONER SUPPLY				.*.
A2C1 A2C2 A2C3 A2C4 A2C5	0180-0138 0180-0049 0150-0093 0150-0012 0160-0174	CIFXD ELECT 100UF -10+100M 40VDCW CIFXD AL ELECY 20UF 50VDCW CIFXD CER 0.01UF +80-20M 100VDCW CIFXD CER 0.01 UF 20M 1000VDCW CIFXD CER 0.47UF +80-20M 25VDCM	4 H			
A2C6 A2C7 A2C9 A2C9	0180-0059 0180-0105 0150-0096 0180-0060	CIFXD ELECT 10UF -108+1008 25VDCW CIFXD ELECT SEMI-POLARIZED 5GUF 25VDCW CIFXD CER 0.05UF 100VDCW CIFXD ELECT 200UF -108+1008 3VDCW				
A2CR1 A2CR2 A2CR3 A2CR4 A2CR5	1901-0025 1901-0025 1901-0025 1901-0025 1901-0025 1910-0016	DIODE+JUNCTIONISMA AT IV 100 PIV DIODE+JUNCTIONISMA AT IV 100 PIV DIODE+JUNCTIONISMA AT IV 100 PIV DIODE+JUNCTIONISMA AT IV 100 PIV DIODE+GERMANIUM 100MA AY 0.85V 60PIV				
A2CR6 A2CR7	1901-0026 1901-0026	DIODEISILICON 200 PIV 0.5 AMP DIODEISILICON 200 PIV 0.5 AMP		- 		
A201 A202 A203 A204 A205	1853-0020 1850-0044 1853-0020 1854-0071 1854-0071	TRANSISTORISILICON PNP TRANSISTORIGERMANIUM PNP 2N1183 TRANSISTORISILICON PNP TRANSISTORISILICON NPN 2N3391 TRANSISTORISILICON NPN 2N3391				
A206 A207 A208	1854-0071 1854-0071 1853-0020	TRANSISTORISILICON NPN 2N3391 TRANSISTORISILICON NPN 2N3391 TRANSISTORISILICON PNP				
A2R1 A2R2	2100-1774 2100-1773	REVAR COMP 2K OHM 108 LIN 1/2W REVAR WE IN OHM 108 LIN 1/2W				

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Section VI Table 6-1

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Reference Designation	Stock No.	Description #	No
	$W_{i}$		
\2 <b>R</b> 3	2100-1772	RIVAR WW SOC OHM 105 LIN 1/2W	,
12R4 12R5	2100-1772 2100-1771	REVAR WW 500 OHN 10K LIN 1/28 REVAR WW 200 OHN 10K LIN 1/28	
A2R6 A2R7	2100-1770 2100-1770	RIVAR COMP 100 ORM 10% LIN 1/2W RIVAR COMP 100 ORM 10% LIN 1/2W	
12R8	2100-1771	RIVAR WW BUO OHH ION LIN 1/2W	
A2R9 A2R10	2100-1772	RIVAR WW SOC CHM 105 LIN 1/26 RIVAR WW SCO CHM 101 LIN 1/20	all and see and s
A2R11 A2R12	2100-1774	RIVAR COMP 2R OHM IOB LIN 1/2W RIVAR COMP 2R OHM IOB LIN 1/2W	
2R13	2100-1774	RIVAR COMP 2K OHM 108 LIN 1/2W	
V2R14 V2R15	2100-1774 0698-3337	REVAR COMP 28 OHH 10% LIN 1/2W REFXD MET FLM 1.37K OHH 1% 1/2W	
N2R16 N2R17	0757-0826	R#FXD MET FLM 2+43K OHM 18 1/2w R#FXD MET FLM 4+32K OHM 18 1/8w	
2R18	07=7-0440	RIFXD HET FLH 7.50K OHM 18 1/8	
2R19 2R20	0698-3581 0757-0451	RIFXD HET FLM 13.7K OHM 1% 1/8W RIFXD HET FLM 24.3K OHM 1% 1/8W	
2R21 2R22	0757-0456 0757-0401	R#FXD MET FLM 43.2K OHM 18 1/8 R#FXD MET FLM 100 OHM 18 1/8	
2R23 2R24	2100-1770	NOT ASSIGNED RIVAR COMP 100 ONM 108 LIN 1/20	
2R15	0757-0399	R#FXD MET FLM 82.5 OHH 18 1/8W	
2827	0699-0003	NOT ASSIGNED RIFXO COMP 8,2 OHM 10% 1/2W	
2820	0757-0279 0698-3155	RIFXD MET FLM 3.16K OHM 13 1/6W RIFXD MET FLM 4640 OHM 18 1/6	
2R30	0698-3132	RIFXD MET FLM 261 OHM 18 1/88 RIFXD MET FLM 3.16K OHM 18 1/88	
2832	0757-0274	RIFXO MET FLN 1.21K OHM 18 1/80	
2R33 2R34	0757-0442 0757-0439	RIFXD HET FLM LOK OHM 18 1/88 RIFXD HET FLM 6.81K OHM 18 1/88	
2R35 2R36	0757-0442	RIFXC MET FLM 10.0K OHM IN 1/8W RIVAR COMP 2K OHM 108 LIN 1/2W	· · · ·
2837	0757-0447	RIFXD MET FLM LON OHM IN 1/80	
2R38 2R39	0698-3491 0757-0290	RIFXD MET FLM 1K OHM 0.1% 1/80 RIFXD MET FLM 6.19K OHM 1% 1/80	
2R40 2R41	0757-0463 0757-0441	RIFXD MET FLM 02.5K 15 1/88 RIFXD MET FLM 0.25K 000 15 1/88	
2R42	0757-0180	RIFXD MET FLM 31.6 CHM 18 1/8W	
2R43 2R44	0757-0460 0757-0123	RIFXD MET FLM 61.9K OHM 18 1/8W RIFXD MET FLM 34.8K OHM 18 1/8W	
2R45 2R46	0757-0448 0757-0442	RIFXD MET FLM 18.2K OHM 18 1/8W	
2R47	0757-0290	RIFXD HET FLH 6.19K OHM 18 1/80	
2R48 2R49	0698-3411 0698-3407	RIFXD MET FLM 3.48K OHM 18 1/88 RIFXD MET FLM 1.96K OHM 18 1/28	
2811	0839-0011	THERMISTORI 168 OWN LOS	
2VR1	1902-0017	DIODE+BREAKCOWIS.SIV 105 400 MM	n og en læger er Senere af senere Senere af senere af s

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Reference	Stock No.	Description #	Note
Designation	COCK NO.		
		DIODE . BREAKCOWN 16. BIV 108 400 MW	
2VR2 2VR3	1902-0017 1902-0596	DIODE SILICON 9.0V	
221	431A-60A	COIL ASSEMBLY	
ана (1996) 1 <b>71</b> и станов 2010 г. П. С.	1420-0009	BATTERY:RECHARGEABLE 24V 1.25AH	
1	0121-0035	CIVAR AIR 7.2-143.7PF CIFXD CER 2 X 0.01 UF 20% 250VACW	
)51	1450-0046		
51 June 199	2110-0004	FUSEI250V +25A HOLDERIFUSE POST TYPE JAG	
	1400-0084	CONNECTORIS FEMALE CONTACTS	
JI	1251-1201	THERMISTOR MOUNT NUTIKNURLED	) t N
<b>J2</b>	1250-0083	CONNECTORIBNC Recorder Leveler Connectoripower 3 pin Male	
J3 - 11月 - 11日 川本 - 11日 - 11日 - 11日 - 11日 - 1100 - 1100 - 1100 - 1100 - 11000 - 11000 -	1251-0148 1250-0083	CONNECTOR I BNC	
JS	1251-1280	CONNECTORIS FEMALE CONTACTS	
JS	1251-1201	THERMISTOR MOUNT OPT 2 NUTIKNURLED CONNECTORIDC CALIBRATION INCLI	
<b>J6</b>	1510-0006	BINDING POST ASSEMBLYIBLACK BINDING POST ASSEMBLYIRED	
J6	0340-0086	INSULATOR BIND ING POST	
<b>J6</b>	0340-0090	INSULATOR IB IND ING-POST DOUBLE	1 (j) (
M1	1120-1101		
R1 R2 R3	<b>2100-</b> 2631	REVAR WW.1CK-108 800 OHM 108 LIN 28 THE STATE S	
RA RS	0698-3151 0757-0421	RIFXD HET FLM 825 OHH 18 1/8	
<b>1</b> 0	0698-3444	RIFXD MET FLM 316 OHM 18 1/88-FACTORY SELECTED PART. RIFXD MET FLM 23-TH OHM 18 1/88	
Ř7 R0 R9	0757-0280	RIFXO MET FLM 1.000 000 18 1/58	
R10	0757-0398	RIFXD HET FLM 75 0HH 18 1/88	
R11 R12	0757-0180 0757-0277	RIFXD MET FLM 31.6 OHM 18 1/60 RIFXD MET FLM 49.9 OHM 18 1/60 RIFXD MET FLM 49.9 OHM 18 1/60	
R13 R14	0757-0277 0757-0277 069 <b>8-3566</b>	RIFXD HET FLH 49.0 OHH 11 1/8W RIFXD HET FLH 53.0 OHH 11 1/8W	
R15 R16	0698-3566	· 영화에서 사람이 많이 있는 것 같은 것이 많은 것이 있는 것이 있는 것이 있는 것이 있는 것이 있는 것이 있는 것이 있는 것이 있는 것이 있는 것이 있는 것이 있는 것이 있는 것이 있는 것이 있는	
R17 R18	0698-3566 0757-0395	RIFXO MET FLM 53.0 OHH 18 1/8W RIFXO MET FLM 53.0 OHH 18 1/8W RIFXD MET FLM 56.2 OHH 18 1/8W RIFXD MET FLM 56.2 OHH 18 1/8W	
R19 R20	0757-0395 0757-0395	nte in <b>REFXEENET FUN BOOZ (OHROUN) 2/00</b> gesteren in die eenemen een gesteren in die een gesteren gesteren in die Gesteren gesteren gesteren gesteren gesteren die een gesteren die een die een die een die een die een die een d	
R21	0757-1104	RIFXD MET FLM 60.0 OHM 15 1/80	

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	Tabl	e 6-1. Reference Designation Index (Cont'd)	a posti Posti
Reference Designation	Btock No.	Description #	Note
R22	0757-1104	RIFXD MET FLM 60.0 OHM 18 1/8W	
R23 R24	0757-1104	RIFXD MET FLM 60.0 OHH 18 1/8W RIFXD MET FLM 28.7K OHH 18 1/8W	1
R25 R26	0698 4722 0757-0198	RESISTOR, FILED 17.8K OHM(FACTORY SELECTED PART) RIFXD HET FLM 100 OHM 1% 1/2W	
R27 R28	0757-0198 0698-3160	RIFXD MET FLM 100 OHM 18 1/28	
R29 R30	0698-3404	RIFXO MET FLM 31.6K 18 1/88 RIFXD MET FLM 383 3 18 1/28	
RJ1 THRU		RIFXD MET FLM 1.21K OHM 18 1/2W	
133	0698-0063	RIFXD MET FLM 5.23K OHM 18 1/8	
<b>1</b>	00431-6025	SWITCH ASSYIMOUNT RES	
52 52	00431-6002 3100-1817	SVITCH ASSYRANGE INCLIR4-R11 SDITCH ROTARY	a an an taon an
))  )	00431-6004 3100-1820	SWITCH ASSY IPOWER INCLIR24 (R28-R30 SWITCH ROTARY	
<b>i4</b> ■	00431-6024 3100-1818	SWITCH ASSYICAL INCLIRI2-R23,R33	
	9100-6400	SWITCHIROTARY TRANSFORMER IPOWER	
880.2005.200 ∎∎: 1989.200	8120-1082	CABLE ASSY THERHISTOR MOUNT 5.	
2	8120-0078	CABLEIPOWER 7.5FT.	
	1251-2239 1251-2239	CONNECTORIPC 44 CONTACTS Connectoripc 44 Contacts	
) Perla de grad		MISCELLANEOUS	
	0370-0064	KNOB VERNIER	
	0370-0067	KNOBIBLK CONCENTRIC I IN. OD 17/64IN. HOLE	
	0370-0112	KNOBIBLK BAR W/ARROW 3/4 IN. OD 1/4 SHAFT POBER	
		CALIB FACTOR RANGE	
	5020-0705 5040-0701	TRIMIMETER EXTENDERIMETER CASE	e e Norden En la subjective
	00431-0004	BRACKET. PANEL	
	00431-6021	JUNPER, TEST POINT(A.B.C)	4
		OPTION O1	
an an an an an an an an an an an an an a	C0431-0005	DECKIMAIN(CPT 01)	
	00415-606	BATTERY INSTALLATION KIT, INCLUDES	
	2420-0001	NUT THEX ST Nº 6-32 X 5/16 B/LOCKBASHER	
			1 - 1 <b>1</b> - 1 1 - 12 - 12 - 12 - 12 - 12 - 12 - 1
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			en en en en en en en en en en en en en e		
			ана (разлада) Сала (разлада)	(). }	
	2431-6102 2431-6109 2431-6110	OPT 02 CONVERSION N OPT 09 CONVERSION N OPT 10 CONVERSION N	(IT 10' CABLE		1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
.0	0431-6111 0431-6112	OPT 11 CONVERSION N OPT 12 CONVERSION N	IT 50 CABLE	n ( <b>C</b> ) Series (C) Series (C)	
0	0431-6121	OPT 13 CONVERSION P	IT SO' CABLE	<b>9</b>	1
0	0431-6122 0431-6123 0431-6124	OPT 221CONVERSION 1 OPT 231CONVERSION 1 OPT 241CONVERSION 1	(IT 100' CABLE (IT 200' CABLE	рания (р. 1997) 1997 — Прина Санарија 1997	
			(I) EAA, CHEE		9 19
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				)) 	
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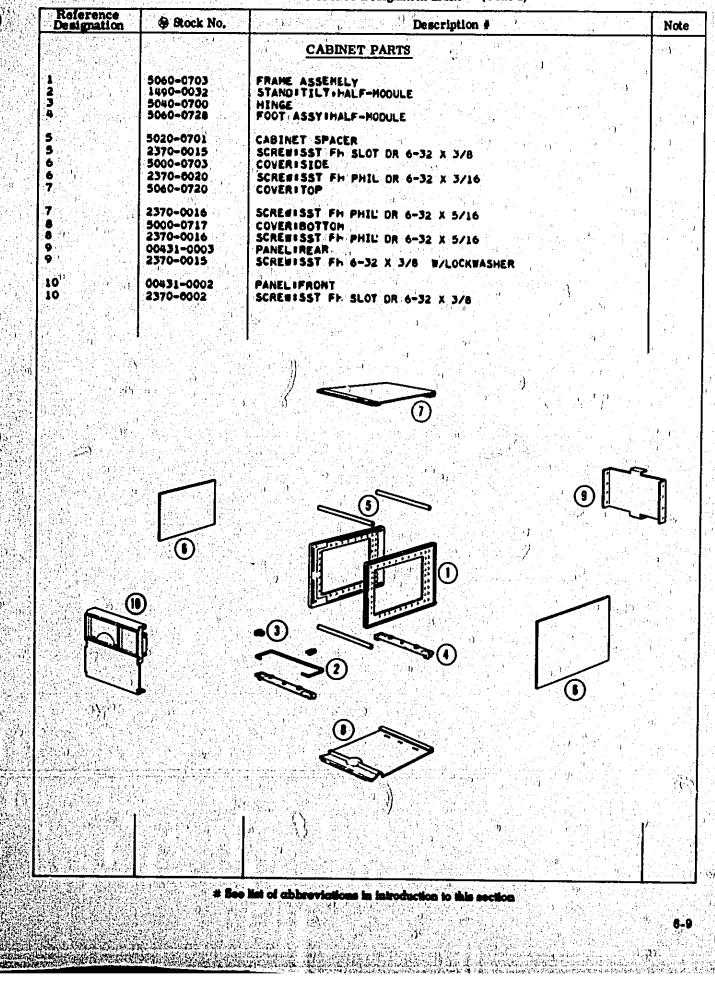
Model 431C

Section VI Table 6-1

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e Stock No.	Table 6-2. Replaceable Parts Description#	Mír.	Mír. Part No.	TQ
0121-0035 0140-0159 0140-0198 0150-0012 0150-0093	CIVAR AIR 7.2-143.7PF CIFXD MICA 3000PF 300VDCW CIFXD MICA 200PF 58 300VDCW CIFXD CER 0.01 UF 208 1000VDCW CIFXD CER 0.01UF +80-208 100VBCW	72136	0121-0035 RDH19F302G35 RDH15F201J3C 29C214A3-H-1038 TA	1 1 2 1 1 1 1 1
0150-0096 0150-0119 0160-0136 0160-0174 0160-2201	CIFXD CER 0.050F 100VDCW CIFXD CER 2 X 0.01 UF 208 250VACW CIFXD MICA 2500 PF 18 300VDCW CIFXD CER 0.47 UF +80-208 25VDCW CIFXD MICA 51 PF 58	04062	-TA 36C219A RDM20F252F3C 5C11A 0160-2201	1 124 1
0170-0069 0180-0045 0180-0049 0180-0059 0180-0060	CIFXD POLY 0.1UF 2N SOVDCW CIFXD ELECT 20UF 25VDCW CIFXD AL ELECT 20UF SOVDCW CIFXD ELECT 10UF -10N+100N 25VDCW CIFXD ELECT 200UF -10N+100N 3VDCW	56289 56289 56289	114P1042R553 30D206-60-25DB-6H1 30D2066050DC6H1 30D10660258B4 30D2076003DC4	3221
0180-0105 0180-0106 0180-0116 0180-0138 0346-0086	CIFXD ELECT SEMI-POLARIZED SOUF 25VDCW CIFXD ELECT TA 60UF 20% 6VDCW CIFXD ELECT TA 6.8 UF 10% 35VDCW CIFXD ELECT 100UF -10+100% 40VDCW INSULATORIBINDING POST	56289 56289 56289	D34114 150D606X000682 150D665X903582 036254 0340-0086	1 1 6 1 1
0340-0090 0370-0064 0370-0067 0370-0112 0698-0063	INSULATORIBINDING-POST DOUBLE KNOB KNOBIBLK CONCENTRIC J IN: OD 17/64 IN. HOLE KNOBIBLK BAR W/ARROW 3/4 IN. OD 1/4 SHAFT RIFXD MET FLM 5.23K OHM 1% 1/8%	28480 28460 28460	0340-0090 0370-0064 0370-0067 0370-0112 0698-0063	111111
0698-0082 0698-0084 0698-0085 0698-3132 0698-3151	RIFXD MET FLM 464 OHM 1\$ 1/8%         RIFXD MET FLM 2150 OHM 1\$ 1/8%         RIFXD MET FLM 2.61K OHM 1\$ 1/8%         RIFXD MET FLM 261 OHM 1\$ 1/8%         RIFXD MET FLM 261 OHM 1\$ 1/8%         RIFXD MET FLM 261 OHM 1\$ 1/8%         RIFXD MET FLM 261 OHM 1\$ 1/8%	28480	0698-0082 0698-0084 0698-0085 0698-3132 0698-3151	1
0698-3155 0698-3156 0698-3156 0698-3157 0698-3158 0698-3160	RIFXD MET FLM 4640 OHM IN 1/8 RIFXD MET FLM 14.7K OHM IN 1/8 RIFXD MET FLM 19.6K OHM IN 1/8 RIFXD MET FLM 23.7K OHM IN 1/8 RIFXD MET FLM 23.7K OHM IN 1/8 RIFXD MET FLM 31.6K IN 178	2848 2848 1970	0698-3155 0698-3156 0698-3157 MF5C T-0 0698-3160	
0498-3337 0498-3404 0498-3407 0498-3407 0498-3411 0498-3438	RIFXD MET FLM 1.37K OHM IS 1/20 RIFXD MET FLM 383 OHM IS 1/20 RIFXD MET FLM 1.96K OHM IS 1/20 RIFXD MET FLM 3.46K OHM IS 1/20 RIFXD MET FLM 3.46K OHM IS 1/00 RIFXD MET FLM 147 OHM IS 1/00	2848 2848 2848	0 0698-3337 0 0698-3404 0 0698-3407 0 0698-3411 0 0698-3438	
0678-3440 0678-3481 0678-3444 0678-3444 0678-3447	RIFXD HET FLM 196 OHM 1X 1/8W RIFXD HET FLM 215 OHM 1X 1/8W RIFXD HET FLM 316 OHM 1X 1/8W RIFXD HET FLM 422 OHM 1X 1/8W RIFXD HET FLM 422 OHM 1X 1/8W	2848 2848 2848	0 0698-3480 0 0698-3441 0 0698-3444 0 0698-3447 0 0698-3449	3
0698-3450 0698-3452 0698-3491 0698-3566	ASFXD HET FLH 42.2K OHN IS 1/88 ASFXD HET FLH 147K OHN IS 1/88 ASFXD HET FLH 147K OHN 0.18 1/88 ASFXD HET FLH 1K OHN 0.18 1/88 ASFXD HET FLH 33.0 OHN IS 1/88	2848	0 0698-3450 0 0698-3452 0 0698-3491 0 0698-3566	

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	Table 6-2. Replaceable Parts	(Cont'd)	
Ø Stock No.	Description #	Mír. Mír. Part No.	TQ
n Robert († 1945) 1957 - Friedrich Statistick, felsk († 1955) 1957 - Friedrich Statistick, felsk († 1955)			a l
	RIFXD HET FLH 41.2K OHN IN 1/84	28480 0698-3582	1
698-3582 698-4023	RI, " HET FLN 130.4K OHN 1/25 1/88	28480 0698-4023 28480 0698-4024	
698-4024 698-4025	RIF, )HET FLM 259.6K OHM 1/28 1/68 RIFXD HET FLM 128.5K OHM 1/28 1/68 RIFXD HET FLM 89.90K OHM 1/28 1/68	28480 0698-4025 28480 0698-4026	
698-4026		28460 0698-4027	1
698-4027	REFXD MET FLM 48.64K OHH 1/28 1/8W	28480 0698-4028	2
698-4029	REFXD HET FLH 53-39K OHH 1/25 1/8W REFXD HET FLH 40-77K OHH 1/25 1/8W	28480 0698-4030	
698-4031 698-4032	R:FXD NET FLM 43.25K OHM 1/28 1/88 R:FXD NET FLM 51.22K OHM 1/28 1/88	28480 0698-4031 28480 0698-4032	i
698-4033	RIFXD MET FLM 62.26K OHM 1/28 1/8W RIFXD MET FLM 84.32K OHM 1/28 1/8W	28480 0698-4033 28480 0698-4034	
698-4034 698-4722	REFXD HET FLM 17.8K OHH 1/28 1/8W	28480 0698-4722 28480 0699-0003	1
699-0003, 757-0123	RIFXD GOMP 8.2 OHM 10% 1/2W RIFXD MET FLM 34.8K OHM 1% 1/10W RIFXD MET FLM 31.6 OHM 1% 1/8W	28480 0757-0125 28480 0757-0180	222
757-0180 757-0198	RIFXD HET FLH 100 OHM 18 1/2W	28480 0757-0198	2
0757-0199 0757-0274	AIFXD HET FLH 21.5K OHH 18 1/88 RIFXD HET FLH 1.21K OHH 18 1/88	28480 0757-0274 28480 0757-0277	2
0757-0277	RIFXD HET FLM 49.9 OHM 18 1/88 RIFXD HET FLH 3.16K OHM 18 1/88	28450 0757-0279	5
0757-0280	RIFXD HET FLH LOOK OHH 18 1/88	28480 0757-0280	6
0757-0290	RIFXD HET FLH 6.19K OHM 18 1/88 RIFXD HET FLH 56.2 OHM 18 1/88	28480 0757-0395	3
0757-0398 0757-0398	RIFXD MET FLM 75 OHM 18 1/8W RIFXD MET FLM 82.5 OHM 18 1/8W	28480 0757-0398 28480 0757-0399	
0757-0401	RIFED MET FLM 100 OHM 15 1/8W	28480 0757-0401	
0757-0417	RIFID MET FLM 562 OHM 18 1/88 AFFYD MET FLM 825 OHM 18 1/88	28460 0757-0417	
0757-0421	RIFXD HET FLM 4.32K OHM 18 1/88 RIFXD HET FLM 6.81K OHM 18 1/88	28460 0757-0436 28480 0757-0439	
0757-0439	RIFAD HET FLN 7.50K OHN IN 1/8h	23480 0757-0440	3
0757-0440 0757-0441	RIFXD HET FLH 8.25K OHH IN 1/80 RIFXD HET FLH 10.0K OHH IN 1/80	28480 0757-0441	1
0757-0442	THE REFERENCE FLM 1842K OND 18 J/PP	28480 0757-0448 28480 0757-0451	
0757-0451	RIFXD MET FLM 24.3K CHM 15 1/88	28460 0757-0456	
0757-0456	RIFXD MET FLM 43.2K OHM 18 1/8h RIFXD MET FLM 61.9K OHM 18 1/8h	28480 0757-0460 28480 0757-0463	2
0757-0463	RIFXD HET FLH 82.5K 18 1/68	28480 0757-0465 28480 0757-0821	
0757-0821			
0757-0826	AIFXD HET FLM 2.43K OHN 18 1/28 RIFXD HET FLH 1.47K OHN 18 1/88	28480 0757-0826 28480 0757-1094	1
0757-1104	RIFXD NET FLM 60.0 OHM 15 1/80 ALFXD NU 511 OHM 1.03 1/200	28480 0757-1104 28480 0811-0065	2
0811-0066	RIFXO WW 867 OHN IS 8/100W	99957 NJA/887-1%	
l l	RIFXD W 200 CHH 0+15 1/8W	28480 0811-1566	1
0811-1546 0811-1571		28480 0811-1571 28480 0811-1572	1
0811-1572 0811-1645	RIFXD WW 255 0HM 0.1% 1/6W RIFXD WW 202.1 0HM 0.1% 1/8W	28480 0811-1645	- 19 - <b>1</b>

# See list of abbreviations in introduction to this section 41

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1.16 Section VI Table 6-2 ÷

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Stock No.	Table 6-2. Replaceable Parts	(Cont	<b>u</b>	· · · · · · · · · · · · · · · · · · ·	1.1.2.2
T MUUK NO,	Description#	m. Mir,	Mfr,	Part No,	TQR
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	合体理论的 建成合金 经公司 计算机分子的			ан 1910 - 1910 1910 - 1910 - 1910 - 1910 - 1910 - 1910 - 1910 - 1910 - 1910 - 1910 - 1910 - 1910 - 1910 - 1910 - 1910 - 1910 -	
0839-0011	THERMISTORI 100 OHM 108	3317	3 20-204	- -	
1250-0083	CONNECTOR IBNC	2848	0 1120-1101	•	
1251-0148	CONNECTORAPONER 3 PIN MALE	2846	0 1250-0083 7 H-1061-2	1. A	2
	CONNECTOR PC 6 FEMALE CONTACTS	2848	0 1251-1280	· · · ·	1
1251-1281 1251-2239	NUT: KNURLED CONNECTOR: PS 44 CONTACTS	2848	0 1251-1281		2
1400-0084	HOLDERIFUSE POST TYPE 3AG	2848(	0 1251-2239	j1	2
1420-0009	BATTERYIRECHARGEABLE 24V 1+25AH	28480	5 342014	1 1	111
1490-0032	- 남동 (金麗) 공격을 다 있는 것 같은 것 같은 것 같은 것 같은 것 같은 것 같은 것 같은 것 같	28480	1350-0048		
1510-0006	STANDITILT HALF - MODULE BINDING POST ASSEMBLY BLACK	28480	1490-0032	: 12 m 1	
1510-0007	BINDING POST ASSEMBLY LAFA	28480	1510-0006	 	
1850-0064	TRANSISTORIGERMANIUH PNP 2N1183 TRANSISTORISILICON PNP	02735	1510-0007 2N1183	· ·	1 4 04
		28480	1853-0020	· · · ·	\$ 9
1854-0071	TPANSISTORISILICON NPN 2N3391 DIODE JUNCTIONISMA AT 1V 100 PIV	89473	16A792	21 ( <sup>1</sup> )	99
1901-0026	UIVDEISILICON 200 PIV OLE AND	28480	1901-0025		7 7
1902-0017	DIODEISILICON DIODEIBREAKDOWNIG.81V 104 400 MM	28480	1901-0450		·· 2 2
902-0596		28480	1902-0017		2 1
910-0016	DIODEISILICON 9.0V	28480	1902-0596	$\frac{\partial f_{i}}{\partial t} = -i \frac{\partial Y_{i}}{\partial t} + i \frac{\partial F_{i}}{\partial t} + i \partial$	
100-0144	CIVAR COMP 250K OHM 30% LIN 1/5%	28480	1910-0016 2100-0144	and the second	5 5
100-1770	RIVAR COMP 100 OHM 10% LIN 1/20				
100-1771	RIVAR WE 200 OHM 10% LIN 1/28		2100-1770	1997 - 1997 -	3 1
100-1772	I REVAR THE SOUTH LOS LIN 1/200	28480	2100-1771		2 1
100-1773		20400	2100-1772 2100-1773		4
100-2631	R:VAR COMP, 2K OHM 108 LIN 1/2W R:VAR HW 10K 10\$ 800 OHM 10\$ LIN	28480	2100-1774		6 2
110-0004 370-0002	FUSE:250V.25A SCREWISST FH SLOT DR 6-32 X 378	28480	2100-2631 2110-0004		
370-0015	SCREWISST FH SLOT DR 6-35 X 376	63000	080		1
370-0016 370-0020	SCREWISST FH PHIL DR 6-32 X 5716 SCREWISST FH PHIL DR 6-32 X 3716	00000	OBD		2
420-0001	AUT HEX ST NP 6-32 X 5/16 W/LOCKWASHER		080		2
100-1817	SWITCHIROTARY			1	4
100-1818 100-1820	SVITCHIROTARY	28480	3100-1817 3100-1818		1 1
000-0703	SWITCHIROTARY COVERISIDE	28480	3100-1820		
000-0717	COVERIBOTTOM	28480	5000-0703		Ī
20-0701	CABINET SPACER		e de Alexa Techo		
20-0705	TRINIMETER	28480	5020-0701 5020-0705		1
40-0701	LXTENCERIMETER CASE	28480	5040-0700		
0-0703	EXTENDERIMETER CASE FRAME ASSEMBLY	28460	5040-0701		1,
60-0720 60-0728	COVERITOP		5060-0720		
20-0078	FOOT ASSY HALF-HODULE CABLE POWER 7.5FT.	28460 !	5060-0728		1,
20-1082	CABLE ASSY 15 FT.	70903	KH4147 3120-1082		1 1
00-1677	TRANSFORMER : POWER TRANSFORMER : INPUT	.; 28480  §	100-0400		
		28480	9107-1677		i i
医中心的 化乙基苯乙酸			MA INCOM	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	

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Section V Table 6-Section VI Table 6-2

11 Table 6-2. Replacerble Parts (Cont'd)

🗢 Stock No.	Description #	Mír,	) Mír. Part No. TQ
9110-0040 9120-0065 9120-0066 9140-0122 00415-006	INDUCTORIAUDIO TRANSFORMERIAUDIO TRANSFORMERIAUDIO COILIVAR 2X 9-20 UHY EACH COVERIBATTERY	28480	9110-0040 2 9120-0065 2 9120-0066 2 9140-0122 2 00415-006 1
00415-606 00431-0002 00431-0003 00431-0004 00431-0004	BATTERY INSTALLATION KIT PANEL FRONT PANEL FREAR BRACKET · PANEL DECK · MAIR(OPT 01)	28480 28480 28480	00415-606       1         00431-0002       1         00431-0003       1         00431-0004       1         00431-0005       1
00431-6002 00431-6004	SWITCH ASSYTRANGE INCLIR4-R11 SWITCH ASSYTPONER INCLIR24+R28-R30		00431-6002 1 00431-6004 1
00431-6018 00431-6019	BOARD ASSYLAMPLIFIER BOARD ASSYLPOWER SUPPLY		00431-6018 1 00431-6019 1
00431-6021 00431-6024 00431-6025 00431-6025 00431-6102 00431-6109	JUMPERITEST POINT(AIBIC) SWITCH ASSYICAL INCLIRI2-R23.R33 SWITCH ASSYIMOUNT RES OPT O2ICONVERSION KIT OPT O9ICONVERSION KIT 10° CABLE	28480 28480 28480	00431-6021     1       00431-6024     1       00431-6025     1       00431-6102     1       00431-6109     1
00431-6110 00431-6111 00431-6112 00431-6113 00431-6113 00431-6121	CPT 10:CONVERSION KIT 20" CABLE OPT 11:CONVERSION KIT 50" CABLE OPT 12:CONVERSION KIT 100" CABLE OPT 13:CONVERSION KIT 200" CABLE OPT 21:CONVERSION KIT 50" CABLE	28480 28480 28480	00431-6110     1       00431-6111     1       00431-6112     1       00431-6113     1       00431-6121     1
00431-6122 00431-6123 00431-6124 4314-604	OPT 22:CONVERSION KIT 100' CABLE OPT 23:CONVERSION KIT 200' CABLE OPT 24:CONVERSION KIT 200' CABLE COIL ASSEMBLY	28480	00431-6122 00431-6123 00431-6124 431A-60A
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	$\frac{1}{2} \sum_{i=1}^{N} \sum_{j=1}^{N} \frac{1}{2} \sum_{i=1}^{N} \sum_{j=1}^{N} \sum_{j=1}^{N} \sum_{i=1}^{N} \sum_{j=1}^{N} \sum_{j=1}^{N} \sum_{i=1}^{N} $		6-13
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The following code numbers are from the Federal Supply Code for Lianufacturers Cataloging Handbooks H4-1 (Name to Code) and H4-2 (Code to Name) and their latest supplements. The date of revision and the date of the supplements used appear at the bottom of each page, Alphabetical codes have been arbitrarily assigned to suppliers not appearing in the H4 Handbooks,

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	Manufecturer	AANOLI
0000	U.S.A. Connon	Any supplier of U.S.
00136	McCay Electronics 👘 No	unt Holly Springs, Pa.
00213	Sage Electronics Corp	nechester, H.Y.
00207		Denielsen, Conn.
	Humidiat	Sy - Collon, Colil.,
	Mitreiren Co., Inc.	Valley Stream, N.Y. Cherry Hill, N.J.
	- Gaiteck Inc. Aerovan Carp	- Catify Hill, N.J.
	Amp. Jac. garge to as	Now Bedferd, Mass, Harrisburg, Pa.
	Aircraft Radie Carp.	Bocaton, N. J.
00015	Northern Engineering Laborat	eties, jac,
		Betlington, Win.
	Sangamo Electric Co., Picke	
		Cily of Industry, Cal,
	Gee Engineering Co.	City of Industry, Car,
N4471	Catl E, Holmes Corp, Miscolab Inc.	Lon Angeles, Calif, Livingston, N.J.
01802	Gazaral Electric Co., Casaci	
6 . C. C. C. C.		Hudzon Palls, N.Y.
0.000	Alden Products Co.	Brochten, Mass,
S 01121	Allen Bradley Co, Harris Harris	Allwauhau, Wis, 7
01255	Lillon indoptrion, Inc. TRW Semiconductors, Inc.	Bayerly Hills, Calif.
er::: 01281	TRW Semicondeclers, Inc.	Laundale, Calif.
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A) 949	Transister Products Div.	Dallas, Texas
61526	The Alliance Mig. Co: Pacific Relays, Inc. Gudabred Bros. Silk Co;	Alliante, Ohle
A1678	Gudebred Bras. Silk Ca.	Van Nuys, Calif. New York, N. Y.
01010	Amerach Corp.	Rockford, III.
	Pulte Engineering Co.	Santa Clara, Celil.
	Fatroncube Corp. of America	Saugerties, N.Y.
82116	Whenlack Steanin, Inc. 2013	- Laan Braach, M. 1.
02286	Cole Rubber and Plastics Inc.	Surayvale, Calif.
<b> 026H0</b> _	Ampheeel-Borg Electronics Co	tp. Biendview, fil,
61113	Rodio Corp. of America, Som and Materials Div.	CONFECTOR
83771	Vacaliae Co. al America, fac	
		Old Saybreak, Cons.
02777	Hophing Engineering Co.	San Farnando, Calif.
62875	Hudson Tast & Die Co.	1 1 Newark, N. J.
03508	Nudson Taol & Die Co. G. E. Semiconductor Pred. Do Apex Waching & Taol Co. Eldenn Carn.	ipt. Sylocust, N.Y.
A S. 03705	Apez Machine & Tool Co.	🔆 🔄 Daylon, Ohio
	Eldenb Celp.	
03618		Los Angeles, Calif.
	B	Wakefield, Mass.
	Pyrofilm Resistat Co., jac. Singer Co., Djehl Div, Finderne Plant	a <b>Codor Kaolis; N. J.</b> a Perentre Manual Artes
	Finderne Plant	Somerville, N.J.
	Arrow, Hart ald Regenas Ele	el. Co.
	Arrow) Hart of & Regense Ele	
8 4401)	Joufus Colp.	🗄 Lombertvilla, 10, J.S.
	Arco Electronic Inc.	🖓 Great Neck, N.Y.
	HI-Q Division of Aurovoz	s Myrtta Beach, S. C.
₩.8.84354 ₩.8.84354	Precision Paper Tube Co, Dymec Division of Hawlett-Pa	Wheeling, III
2.1.2.	DINCE DIVISION OF MEMICLI-PA	CARLE LES SUSTERIO
	Sulvania Electric Priducts M	ierowayo NG S Science
	An Device Div, state the set	Invotato View / Call
94671	Dabata Engl. Inc.	Culver CIV. Calit.
4713	Matarala, Inc., Sem)conductor	Prod. Dive and
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記名6032。	Filtren Co., Ins. Western Div.	STORE CONTRACTOR
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S LABIE	Connect Mies Service Co.	aad Hoompoologia (1994) China ay ahaa ahaa ahaa
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10500 F	Twentieth Century Plastics. I	at. An April 19 19 19
Ser meterski	A PAGE SPREAK SKY HALL	Los Angeles. Calls.
a sur n	Sylvania Electric Priducts, U Davica Div Oakata Engr. Jac, Molarala, Iac., Seujconducta Filtran Co., Iac., Neutara Div Automatic Electric Co Sequela Wire Co. Procision Cell Spring Co. P.M. Molor Company Component Mire, Service Co. W Twenticth Contury Plastics, 1	行法会议自己的

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<ul> <li>Code ( No.11</li> </ul>	Manufacturer		Address	<u>;</u> :
05245	Components Co	10	Chicago, III.	
05277	Pestingkouse &	liectile Corp.		1
05347	: - Somi-Coaduc Ultrania, Jac.		Youngwood, Pa. San Maleo, Calif.	at a t Ca
05397	Union Corbide	Carp., Elect.	Div,	·
05574	)		New Yetz, N.Y.	5
05593	Viking Ind. Jac Icere Electro-P		Canego Park, Calif, Sunayvate, Calif,	· 1.
05616	Cosno Plastic			
03674	(c/a Electric Barber Colman		Cleveland, Ohio	•
: 0\$72B	Tilles Optical	Co		i i
05729	Metre-Tel Coro	Kessyn Height	s, Long Island, N.Y. Weathary, N.Y.	5- 1- 1 - 3
05783	Stewart Engine	ering Co.	Westbary, N.Y. Santa Crez, Catif, Wakofield, Mass.	
05820	Wahelield Engli Bassich Co., C	neeting lat, '	Wahofield, Mass. Warner Corn	
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06030	Raychen Corp.	nh Anlient Ca	Redwood City, Calif. Rechester, N.Y.	
06402	E.T.A. Produc	its Co. al Ana	nica Chicago, III.	
06540	Amalon Electro	nic Hardware.	Co., lac.	$\mathbf{I}$
06555	Beede Electric	at tastenment f	New Rochelle, R.Y. Io., Inc.	
4 - 1 - <sup>1</sup>	이 같은 것이 되어?		Panaccok, H. H.	
	General Device Components Inc		tadianapolin, Ind. Phoenin, Arlz.	n ta Sanat
06812	Terrington Mfg.	Co., West Di	<b>V.</b> 1999	
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07848	Kelvin Electric	Ce.	San Carlys, Calif. Yan Nuys, Calif.	÷.,
07126	Digittan Co. 🗄		Pasadena, Calif,	· 2
07138	Transister Elec Westinghouse E	tectric Corp.	Winneapolis, Minn.	'
(1) (9)	Electronic Tr	nde Div. 👘	Elaira, N.Y.	a e
07119	Filmshm Corp. Ciach-Graphik I		ily at Industry, Calif.	. • ÷.
07256 :	Silicon Transis	las Cerp, 👘	Carls Place, N.Y.	· ·
07261	Aveel Corp.		Culver City, Callf.	. • .
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07823	Bodine Elect. 1			· · · · ·
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07933	Raythean Mig. Semiconducto	LOWS	fountain View, Colif.	* -
07549	Hewleit-Pachat	d Co., Beesle	a Radie Div. 👘 👘	
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88524	Deutsch Fasten	er Cerp.	Los Angeles, Calif. Vaterbury, Cone, San Valley, Calif.	a Kula Tanan
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đ	09250 09353	Electro Assemblies, inc	Chicago, III, Newton, Nass.
	09569	Mailely Batlely Co., 61	
	01922	Burndy Corp. 114. Tor	solo, Oalario, Canado Normalh, Conn.
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	10411	Ti-Tal, loc.	Les Argeles, Calif. Berkeley, Calif.
-	10646	Carborunden Co.	Niegara Falls, N.Y.
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	11453	Precision Connector Corp. Duncan Electronics Inc.	Jamaica, M, Y.
<u></u>	inii	General Instrument Corp., Se	Gasta Nosa, Calif. micanductor
	*****	Div., Products Group Imperial Electronic, Inc.	Bewark, N. J. Buena Park, Calif,
	11717	Nelebs, lac.	Pale Alte, Calif,
	12040	National Semiconductor	Pale Alte, Calif, Danvery, Conn.
	12136 12361	Philadelphia Handle Co Grave Mfg. Co., Inc.	Camsen, N.J. Shidy Grove, Pa.
i.	12574	Guiton Ind, Inc. Data System	Div.
	12697	Clarestat Mig. Co.	Albuquerque, N.M. Dever, N.H.
	12728	Einas Filter Corp. 17	- W. Hoven, Cons.
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	12930	Delta Semicanductor Inc.	leupert Beach, Colif,
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ł.	11122	Midland-Wright Div. of Pacify	c Industries, Inc. : Konsos City, Konsos
	14099	Sem-Tech	Newbury Park, Calif.
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	14655	Cornell Dublier Etectric Corp	Laveland, Colo. Newark, M. J. Corolog, N. Y.
		Corning Glass Works Electro Cube Inc.	Corning, H.Y.
. 2	14960	Williams Mig Co.	San Gabriet, Catil, San Jese, Calil,
ļ,	15203	Webster Electronics Co. Scienics Corp.	
34	15291	Adjustable Bushing Co.	Northridge, Calif. N. Hollywood, Calif.
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ĝ	15566	"Amprobe lost, Corp	y, Lrag Island, N.Y. Lynbrook, N.Y.
ļ	15633	Cabletranics Twentieth Century Cuil Series	🕆 Casta Meso, Calif. 🗌
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÷.,		Fenwal Elect, Inc.	Fromingkam, Mass.
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16	16176	Omni-Sceetta Inc.	Entwinaton Mich
7	16585	Computet Diede Corp, Baels Aircraft Nut Corp,	Leti, N. J. Pasadana, Calif.
	16688	Ideal Pret. Meter Co., Int.	
ŀ	16758	Delco Radio Div. at G.W. Car	Breaklyn, N.Y. 2. Kakamo, tad.
	17169	Ideal Proc. Mater C., Inc. Da Jar Meter Div. Delco Radio Div. at G.M. Cor Thernanotics Inc. Troes Company	p. Kukamo, Ind. Canago Park, Calif.
	17474	Components Inc, Hamilio Melal Products Corp.	lountain View, Calif. Biddeford, Na,
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11414 M.A. Parts	
17870 McGraw-Edisan Co, 18642 Power Dasign Pacific Inc,	Monchenter, N. H.
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18483 Clavite Corp., Semicanductei	Div.
	Pale Alta, Calif, Seanyvale, Calif.
18324. Signatics Carp, 20	Scanyvale, Calif.
18476 Ty-Car Mig. Co., Inc.	Holliston, Moss,
18486 TRW Elect. Conp. Div.	Des Plaines III
18583 (Curlis Instrument, Inc.	Des Plaines, III, Nt. Kisce, N.Y,
18612 Vishey Instruments lee 3	Maluera Da
- [MJJ] E.I. DuPost and Co. Jun	Walvern, Pa, Wilmington, Del, Nilwönher, Wis,
18911 Durant Mfg. Co.	Mitmanhan Min
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13583 Concon	Baldwin Park, Calif. Horseboads, N.Y.
19640 LRC Electronics	Heisebands, N.Y.
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29183 General Atreaics Cerp.	Philadelphia, Pa. Ig Island City, N.Y.
21226 Executaes, Inc.	a leined Cibe III w
23325 Falnit Beating Co., The	Nam Britain Casal
21529 Fonsteel Matalturgical Cory,	Ren Britain, Conn.
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23042 Tenscan Corp. 23703 British Radio Electronics 1.14;	N. Chicago, III, Indianapolia, Ind.
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24635 General Radio Co. Noia Pa 24635 General Radio Co. Noi 24681 Moncer Inc., Comp. Div, 24796 Paroko Inc. San Joa 23365 Gries Reproducer Corp. J 26462 Grobot File Co. of Americo, In	rk, Cleveland, Ohio 🗌
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25365 Gries Reproducer Carp.	lew Rechetle In V 😳
26462 Grobet File Co. al America in	
26153 Compac/Millister Co. 26932 Mamiltan Watch Co. 27251 Specialities Mig. Co., jac, 28440 Newletl-Packard Co. 28520 Heyman Mig. Co.	Carlstadt, N. J.
26851 Pamap/Haltistas Pa	Carlstadt, N.J.
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A 1941 Paula Miller Maile Cu.	Loncaster, Po, Stratford, Conn. Pale Alto, Colif.
ereat aportantes mig. Co., iec.	Stratterd, Conn.
20400 Hawlett-Packars Ce.	Pale Atte, Calif,
28920 Heynes Mig. Co.	Kenilworta, N.J.
34817 Instrument Speciallies Co., Inc	
	Little Falls, N.J.
33173 G.E. Receiving Tube Dept.	Onensbere, Ky.
35434 Locirohm Inc.	Onensbete, Ky. Chicago, III,
36196 Staawych Coll Products Ltd.	
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42130 Muter Co. 43930 C. A. Margres Co. 44655 Obmite Mfg. Co.	Englewood, Colo.
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46384 Pean Eng. & Mig. Corp. 47904 Polarold Carp.	
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49956 Microways & Power Tube Div.	Waltham, Mass,
52090 Rowan Controller Co.	Westminster, Md.
52983 Sanborn Company	Waltham, Mass,
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65626 Simpsen Electric Co. 33 65933 Sonetane Corp.	Chicago, 11, Einsteid, N.Y,
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- i ii	743 Ward-Leonard Electric Co.	Wi Vernen M.V.
- 19 <b>6</b> 1	359 Western Electric Ce., Inc.	Baw Yath M V
11 F 14 - 65	052 Westen last, Inc. Weston-Ne	wath   Newark, M. J.
9 i <b>6</b>	795 Willeh Mfg. Co.	Chicaro, itt.
- 66	346 Minnesola Wining & Mig. Co. 376 Altan Min. Co.	Revere Mincom Div.
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70	309 Allied fantral 318 Alline'al Screw Product Co.,	The second second
704	127 Ampl 4, Div. of Chryster Co. 185 Alfant & India Rubber Works,	p. Detroit, Mich,
101	185 Altan' & India Rubber Works,	Jac. Chicago, III.
/V3 703	192 MMJ91317 LQ, 3 [8C, 33]	Union City, N.J. Minneapolis, Minn.
	174 ADC Profects lat,	Kinnespolis, Minn,
744	103 Belden Mfg. Ca. 198 Bird Electronic Carp.	Chicego, III. Cleveland, Chin New York, N.Y,
	134 Birabach Radia Ca	Cleveland, Ohio
216	102 Birabach Radio Co. 134 Billey Electric Co., Inc.	∴ ∴new yern, n.y,
210	143 Basten Gest Works Div, of Mi	Etie, Pa,
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712	al Toxas 18 Bud Radio, inc. 79 Combridge Thermionics Corp.	Willoughby, Ohio
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211	00 Bussmann Mig. Div, al McGra	W.Fditte Ca
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1 214	36 Chicego Condenser Corp.	Chicago III
98 - MA	36 Chicago Candensar Corp. 47 Calif. Spring Co., Inc. 50 CTS Corp.	Chicago, ill. Pico-Rivera, Calif.
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2.276	16 Connercial Plastics Co.	Chicago, Ill.
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7171	15 Cinch Mig. Co., Howard B. Jo	ees Div. 🔅
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7194		🔆 Midfand, Mich.
7213	b Electia Motive Mig. Co., inc.	", Willimantic, ' Conn.' "
116	9 Dialight Corp.	Breeklyn, N.Y.
1403	5 Indiana Ganarai Carp., Electro	iaics Div,
1269	Constant and an and from the	Keasby, N.J.
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3 2296	4 Robert M. Hadley Co.	UNION, M.J.
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2366	I. Hanten Mir. Co., Inc.	Delagatan lad
7307	H.H. Hatser Ca.	Phanes III
2213	Helinot Div. af Bechman last	tar
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	Industries Inc.	Philadelphia, Pa.
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J3859 JFD Etectronics Corp. 73905 Jannings Redio Mig. Corp.	Brocklyn, N.Y.
73505 Jennings Radio Mig. Corp.	San Jose, Catif.
. /JJJJ/ Glasv-Pia Celp,	San Jase, Catif, Ridgefield, N. J. Heptune, N. J. Winchester, Mass.
74276 Signalite inc.	Neptune, N. J.
76455 J.H. WIRNE, and Sons	Wischester, Mass,
74861 Industrial Condense; Corp. 74868 R.F. Products Division of	
74668 R. F. Praducts Division of Electroales Corp,	Amphenol-Borg ;
74970 E.F. Jahnson Co.	Danbury, Conn. Waneca, Mina, 9. Philadelphia, Pa.
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15263 Keystone Carbon Co., lac.	v. Pallautipara, Pa, St Marka Da
15263 Keystone Carbon Co., Inc. 75378 CTS Knights Inc.	St, Marys, Pa, Sandwich III
75382 Kalka Electric Corporation	Sandwich, 121, 1 ML, Vernau, N, Y.
JOBIB LEREZ LIRCINC MIN. CO.	Chicage, III,
75915 Littleføse, lac.	Des Plaines, Ill.
JERGS Land Mile Co.	Elie. Pa.
76210 C. W. Marmedet	San Francisco, Calif.
76433 General instrument Carp. ,	Niconsid Division
10400 A	Rewark, N. J.
76487 James Milten Mfg. Co., int	. Malden, Mass.
26493 J.W. Miller Ca.	Los Azgeles, Calif,
76530 Cinch-Monadnoch, Div, of	United Carr
76545 Muelter Efectsic Co.	Son Loandro, Calif,
· 76703 Hatianat Union	Cleveland, Oblo Newark, N. J.
76854 . Oak Manufacturing Ca.	Reward, H.J.
77068 Ton Bendin Carp., Etectrad	Crystal Lake, 11.
	N Wallymand Calif
17075 Pacific Malais Ca.	N. Hollywood, Calif. San Francisco, Calif.
177221 Phanastran Instrument and I	Electronic Co.
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	Carp.
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77342 American Machine & Foundr	u l'a ' Paltaz
E Bremfield Div,	Plinceton, Ind.
& Bremfield Div, 77630 TRW Electronic Components 77638 General Instrument Corp., A	Div, Canden, N. J.
77638 General Instrument Corp., A	
77764 Resistence Products Co.	Brooklya, N.Y.
	Hattisburg, Pa.
77969 Rubbercraft Corp. of Calif, 78189 Shakeproof Division of Itting	Terizace, Calif.
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78277 Signa	Etgia, III. Ta Menlatraa Maaa
78283 Signal Indicator Corp.	So. Braintre, Wass. New York, N.Y. Pilman, N.J.
78220 Struikers-Cann fac.	Pilman M )
78424 Speciality Leather Prod. Co.	Newark, N. J.
78452 Thampson-Bremer & Co.	Chicago, III,
- FRAFE THIRAY MIG. Co	San Francisco, Calif.
78488 Slachpole Carbon Co.	St Mätvit Pa '
78493 Standard Thomson Carp, 78553 Tinnermen Praducts, fac, 78790 Transformer Engineers	Waltham Mann -
74553 - Tinnerman Praducts, Inc.	Cleveland, Ohio San Gabriel, Colif. Newtonville, Wass.
JUJ90 . TIBASTOIMER Engineers	San Gabriel, Colif, -
74947 Ucinite Co. 79336 Waldes Rubinsor Inc.	Newtanyille, Mass.
20145 Heres Konigaor Iac. Li	
79251 Wenco Mig. Co.	Harlford, Conn.
79142 Vector Ront, Inc. 79253 Wenco Mfg. Co. 79257 Continental With Electronics	Chicago, III.
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79963 Zierich Mig. Corp.	Philadelphia, Pa.
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DALLS	All Ring Bandwells Inc.	Reflecte Alia		Radio Carp
	Ali Star Products Jac.	Defiance, Ohio Menrovia, Calif,		· Comp. &
80583	Avery Label Co. a Inc.	Mearevie, Celif, Mara Nill, N. C. Bestes, Mass.	86928	Seastrom M
- 50640 	Stevens, Arnold, Co., Inc., Dinco Gray Co.	Davlen, Ohin		Harco Indu Phileo Car
	International fastruments Inc.	Orbege, Cone.		
33 81073. © 81895	International fastruments Inc. Greybill Co. Harris Corp.	Laursage, III. Vanice, Calif.	\$/4/3	Vostern Fi
	- Minehaelae Fiee, Div." Littaa	184. lat.		Van Waters
	Military Specification International Restifier Corp. Airpan Electronics, Inc.	Oshville, Coss.	07930 11 07930	"Tower Mig. Cutter-Han
Ce 01403	International Restifier Corp.	Et Seguade, Calli.		Cutter-Han Gauld-Nati
. 81541	Airpan Electronics, lac,	Canbridge, Maryland		: General Mi - Graybar El
. <b>1100</b> A	Barry Controls, Div. Barry W	Watertawa, Mass.		G.E. Dist
82042	Carter Precision Electric Co. Sperti Faraday Jac., Copper	Skokio, ill.	89665	United Tra
82947	Sperti Faraday Inc., Copper	Kowiii Kabaken, M. J.		United Sho US Rubbar
82116	Electric Div. Corp. 30	(). Nerwold, Conn.	1. <sup>15</sup> 1	🖂 Prod. : D
	Jallers Electronics Division Carbon Co.		30970	Bearing Er ITT Canao
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2 12176	Astron Corp. East N Switchcraft, Jac.	ewara, Korrison, N. J. Chienen III	91662	·Elco Carp. ·Grenot Mi
82647	🗄 Millin 🖤 Plannoin int' shawi	6WF #708W618	91427	K F. Daval
				Honeywell
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	Retron Mig. Co., Inc.	Boedstock, H.Y.		Nahm-Bros
3289J	Vector Electronic Co.	) Glessalo, Calif.		Tra-Con Pa Eigeet Opi
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63186	TT Wire and Cable Div. Victory Eng. Corp. Bendix Corp., Red Back Div. Nabbell Corp. Rasan Inc. Smith, Norman H., Inc. Tack Labs Costral Screw Co. Gavitt Wire and Cable Co.	Los Asgulos, Calif. Socingfield, B. J.	93369	Robbins &
83238	Bendix Corp., Red Back Div	find Bank, R. J.		Stemce Ce
- <b>83315</b> - <b>83124</b>	Nabbell Corp. Resea las	Benent Bench, Calif.	93632	Waters Mig
	Smith, Norman H. ; Inc.	Brocklyn, M.Y.	91925	G.V. Cen
83332	7 Toch Labs Berger and Table	Paljadda's Park, N.J. Phirana Iti	- 94137 - 94142	General C. Phelps Du
	Central Screw Co. Gavitt Wire and Cable Co.		94144	Raytheon Camp. (
5 S.	1996 Div.; of America Core.; 11	- <b> </b>		Scientific
	Burroughs Corp. Electronic		8.7140	
83740	Union Carbide Corp. Consun	ter Pred. Div.	94154	Tagner Eli
14 (1) 13777	Union Carbide Corp. Consum Model Eng. and Mig., Inc. Loyd Scragge Co. Advanautical tast. & Radio C Arco Electronica Inc. A.J. Glescort Co., Inc.	Nuntington, ILS.	34131	Curtiss-Tr Contins-Tr
03421	Loyd Scruggs Co. Bordana	Festus, He.		i South Che
33942	Antonautical fast. & Radio C Aren Flactronien Inc	io, warde Lott, N.J. and Stat. Gront Mark . N. V. Stati		Wire Clath Automatic
84396	A.J. Glesener Co., lac.	San Francisco, Calif.	94687	Hatcestar
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्र <b>15474</b> २० <b>४८८८</b>	R.W. BISCONSCIE & Co.	San Francisco, Colif.	::::::::::::::::::::::::::::::::::::::	"Allies Pre Centionali
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THE FOLLOWING NP VENDORS HAVE NO NUMBER ASSIGNED IN THE LATEST SUPPLEMENT TO THE FEDERAL SUPPLY CODE FOR MANUFACTURERS NANDBOOK, A State State

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	Malco Tool and Die Willow Leather Products Co	Los Azgeles, Calif. 19. Nowark, N.J.
	ETA Precision Instrument Compo	ents Co
14. J. 19	Hewlatt-Packard Co., Colora	- Van Nuys, Calif.
QGOWN	Rubber Eng. & Developmen	ida Springs, Calacada
00000 00000	A "N" D Big. Co.	Dabland, Callf.
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# SECTION VII SCHEMATIC DIAGRAMS

#### 7-1. INTRODUCTION.

Model 431C

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

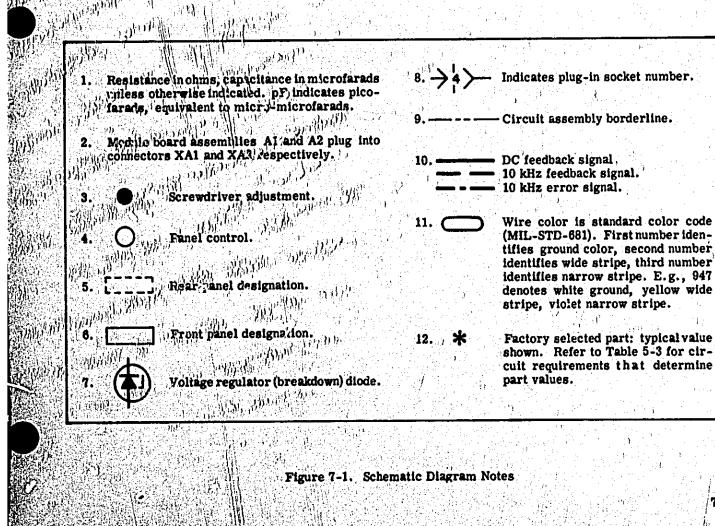
7-3. Some switch and circuit board assemblies are shown in part on different pages. To find a specific instrument component, refer to the "REFERENCE DESIGNATIONS" box which appears on each schematic diagram. Reference designations within assemblies are abbreviated. The full designation includes the assembly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

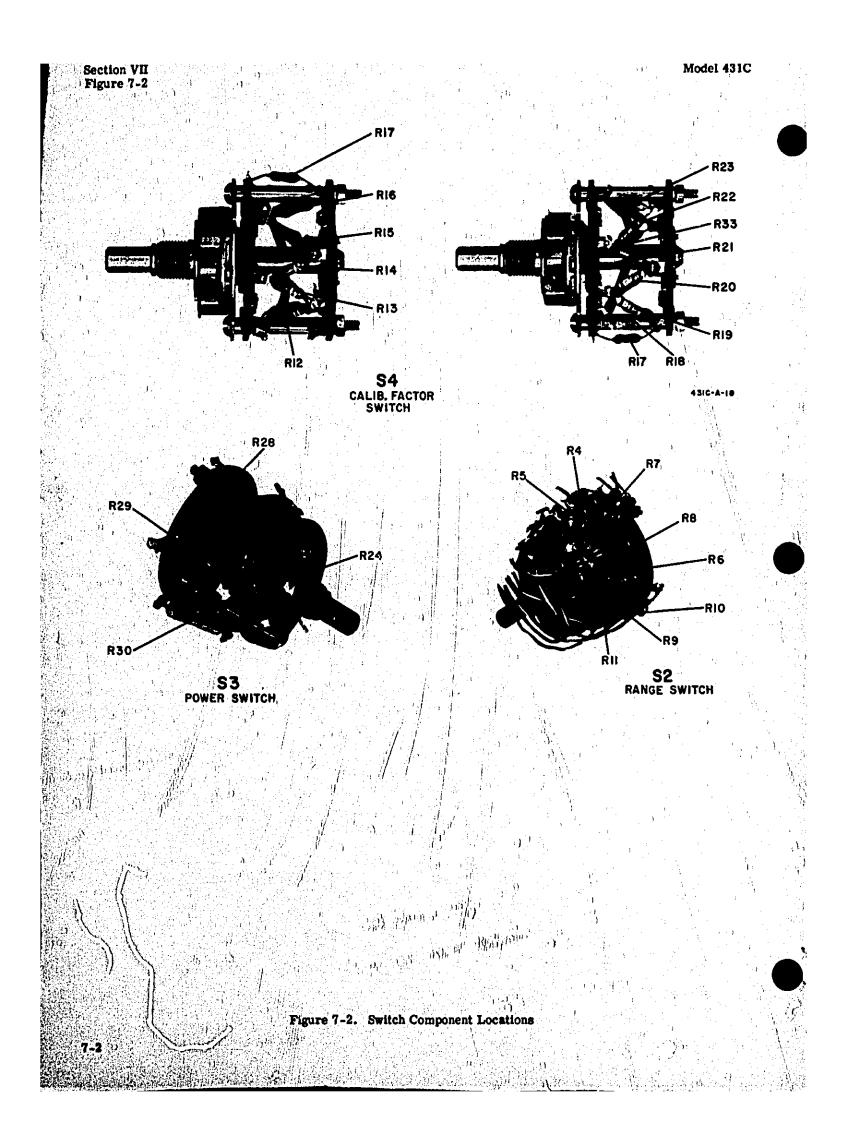
7-4. This section also contains information on component and test point locations within the instrument. Figure 7-4 shows the Power Meter Assembly, A1, and Figure 7-6 shows the Power Supply Assembly, A2. Figure 7-2 shows switch component locations.

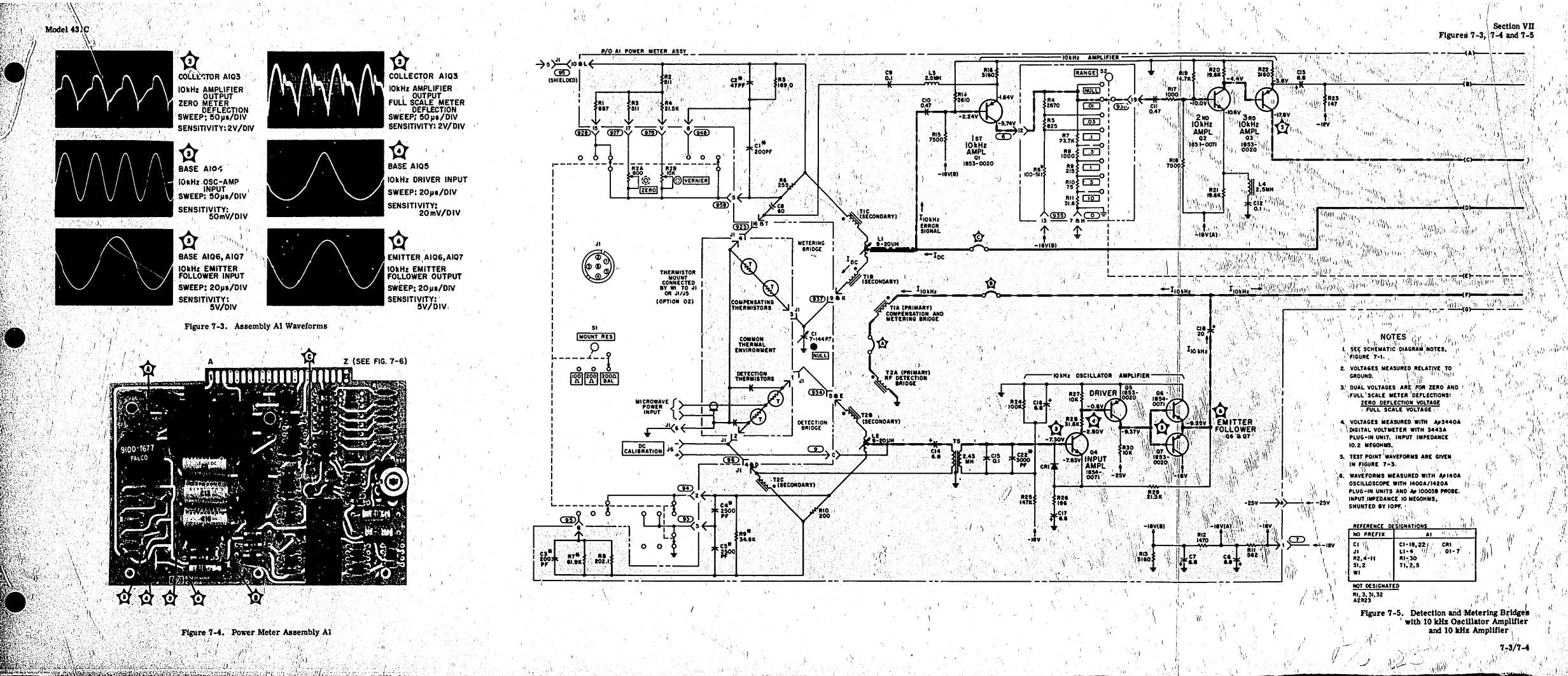
7-5. Figures 7-3 and 7-8 illustrate normal-operation waveforms obtained at test points 1 through 6. Normaloperation voltages are given on the schematic diagrams, adjacent to the point of measurement. All voltages and waveforms were taken with the instrument zeroed and nulled and a 200 ohm thermistor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

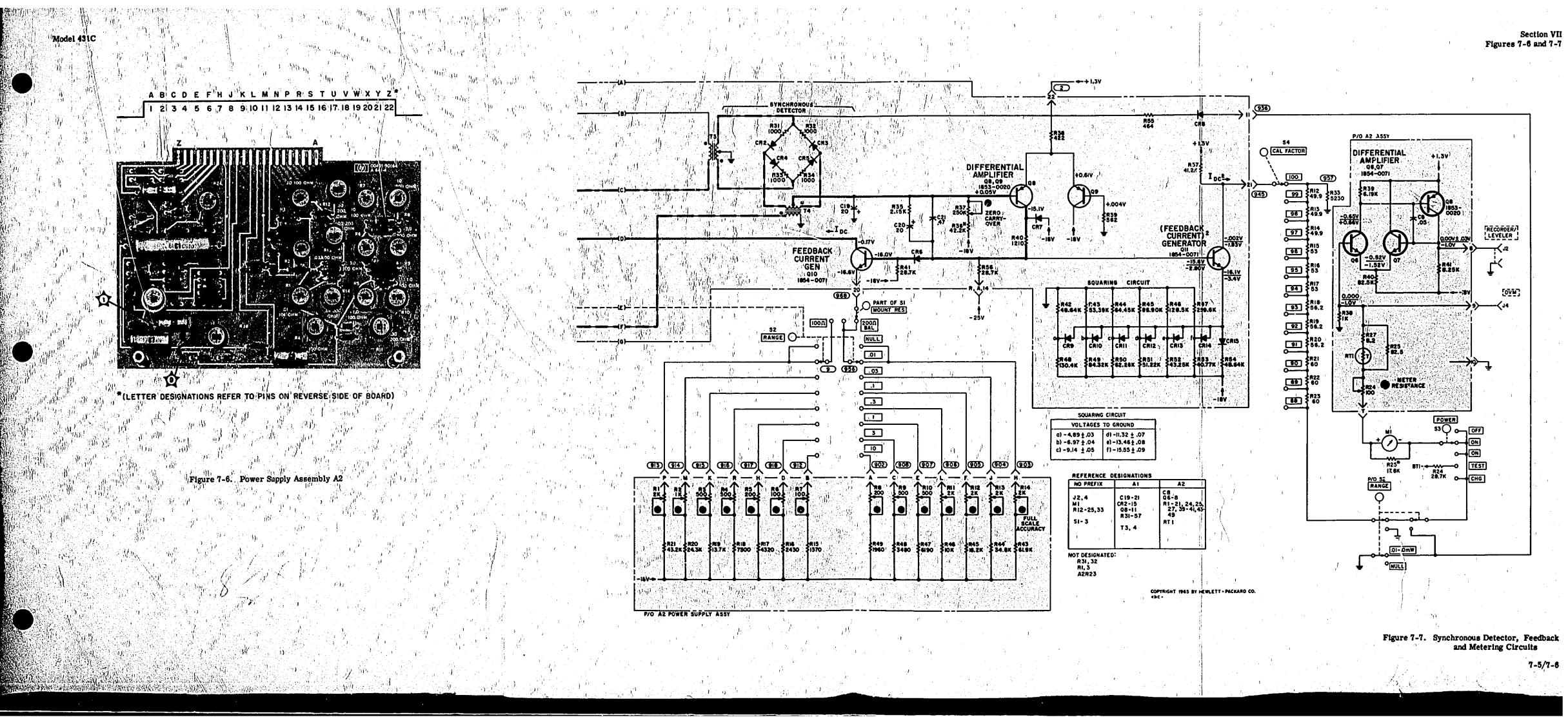
7-6. An asterisk indicates a factory selected part; the component value shown is the typical or most commonly selected value. Circuit requirements that determine the values of factory selected parts are listed in Table 5-3.

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











Model 431C

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COLLECTOR A201,A202 REGULATOR INPUT SWEEP: 5ms/DIV SENSITIVITY: 0.5V/DIV

Figure 7-8. Power Supply Waveform

- DEFLECTIONS

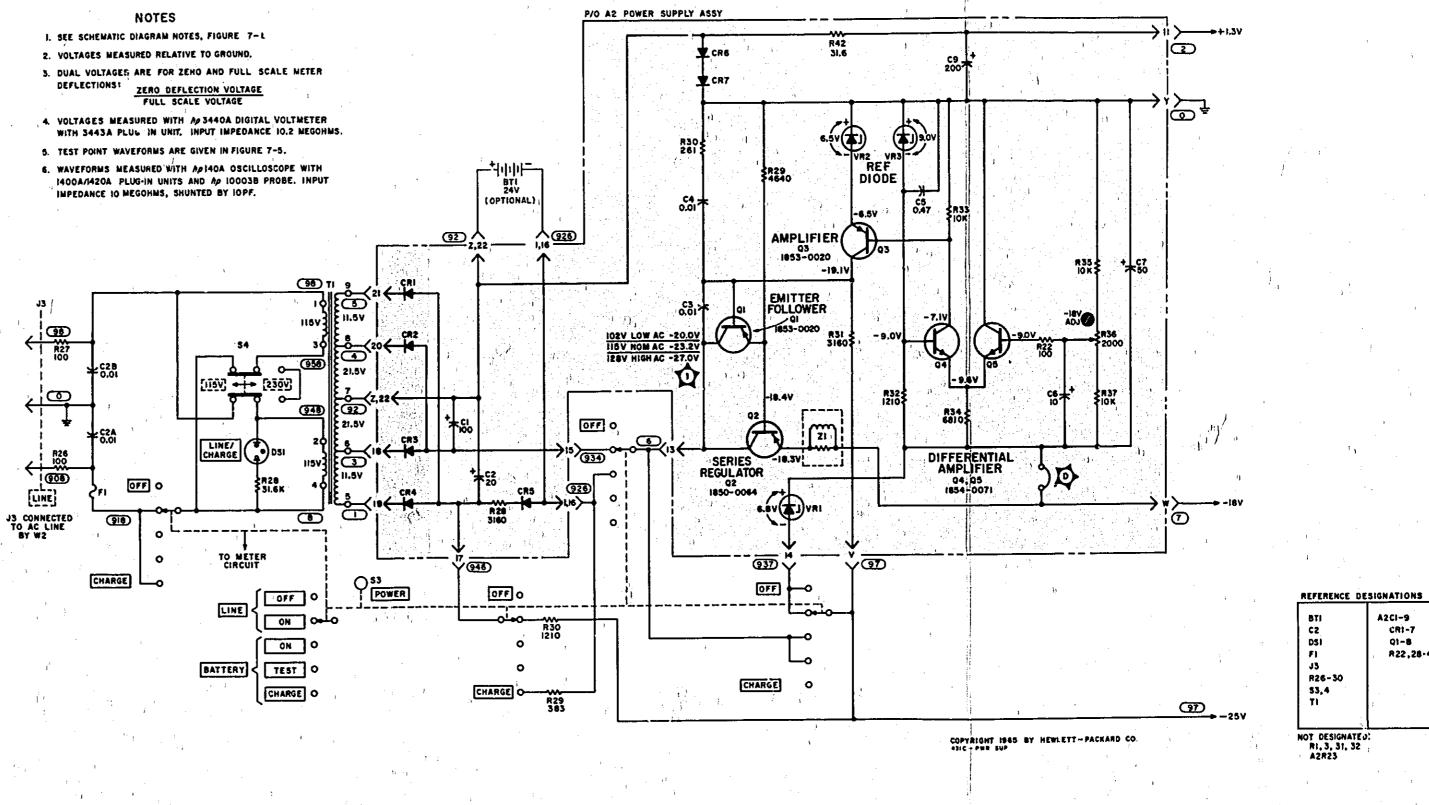
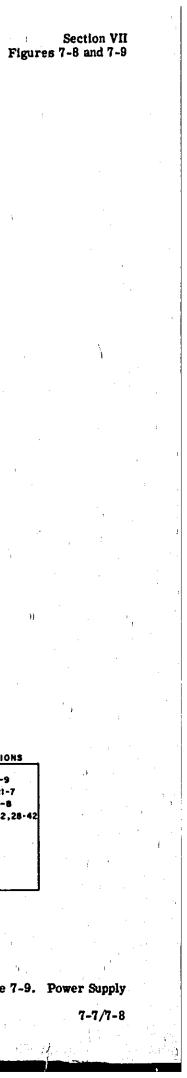


Figure 7-9. Power Supply

A2CI-9

CR1-7

Q1-8 R22,28-42



#### Model 491C

#### Appendix I Paragraphs A1-1 to A2-1

A1-1

# APPENDIX I OPTION 01

A1-1. The 431C Option 01 instrument consists of a standard Model 431C Power Meter with a rechargeable battery installed. A list of Option 01 component parts is given in Table 6-1. Instruction for installation of the battery is given in the following paragraph.

A1-2. OPTION 01 INSTALLATION PROCEDURE,

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

b. Remove top and bottom instrument covers.

c. Refer to Figure A1-1 which shows the battery cover disassembled from the battery. Install the battery and battery cover from the bottom of the instrument into the top chassis. Note that the battery is installed so that the two battery terminals are toward the top and front of the instrument.

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

#### CAUTION

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

e. Solder a red wire (No., 22 gauge, stranded) between the positive battery terminal and circuit board connector  $XA2_{i}$  pin Z.

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

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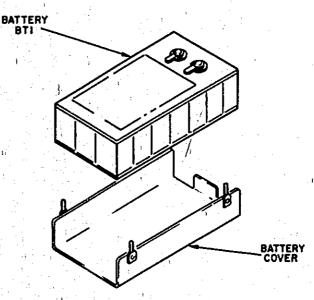


Figure A1-1. Battery and Battery Cover Assembly

# OPTION 02

A1-3. Option 02 consists of a standard panel mount cable connector which is installed on the rear panel of the meter in the place provided. Wiring is included. The front and rear panel cable connectors are connected parallel, but can not be operated simultaneously.

Kit stock No. 00431-6102

Includes:

ų .).

Wiring harness and connector .. 00431-6012 Nut, Knurled..... 1251-1281

Color codes remain the same for all wiring. Wires are connected in parallel with the front panel connector at XA1 and XA2.

# APPENDIX II INSTALLATION OF LONG CABLE OPTIONS

## A2-1. INTRODUCTION

A2-2. Information in this appendix describes installation of long cable options used with the 431C Power Meter. Table A2-1 lists cable lengths, stock numbers, and mount resistances by option number. Values of components supplied with the long cable options are nominal. Installation procedures adjust the Power Meter 10 kHz bias oscillator frequency, reset the bridge null balance, and reset the bridge resistances for optimum operation. At the completion of the installation procedure, the Power Meter should be recalibrated using the procedures outlined in Section V.

A2-3. Depending on the option selected, the following components are replaced with parts supplied with the option kit:

a. A1C3, A1C4, A1C5, A1C23+.

b. A1R7, A1R9.

Prior to beginning the regular installation procedure, remove the f; llowing components:

- a. AIC4, A1C5.
- b. A1R7, A1R9,

During installation the following equipment will be required:

HP 8402B Power Meter Calibrator

HP 175A or 140A Oscilloscope

HP 410B/C or 412A or 427A Ohmmeter

HP 5512A Electronic Counter

Table A	2-1. 431C Power	Meter T		• •
Option	Kit Stock Number	Cable Length (Feet)	Thermistor	
09 10 11 12 13 21	00431-6109 00431-6110 00431-6111 00431-6112 00431-6113 00431-6121	10 20 50 100 200 50	100 or 200 (Bal or Unbal) 100 or 200 (Bal or Unbal) 100 100 100 200 Unbalanced	
22 23 24	00431-6122 00431-6123 00431-6124	100 200 200	200 Unbalanced 200 Unbalanced 200 Balanced	

\*(A1C23 is installed between A1 pin 9 and A1 pin 7 for Option 13 only.)

# A2-4. OSCELLATOR FREQUENCY ADJUSTMENT.

A2-5. Connect the frequency counter from A1C18 (+) to ground to measure the output of the 10 kHz bias oscillator. Use the applicable procedures below according to the option selected. Install cable and mount, and turn 431C MOUNT RES switch to proper value.

#### NOTE

Supplied values of A1C4 and A1C5 (2000-2500 pF) are nominal. Values must be within  $\pm 1\%$  of each other.

A1C3 should not exceed 1000 pF.

- a. Options 09, 10 (100 Ohm Mounts):
  - 1. Center A1L2,
  - 2. Install supplied values for AIC4 and AIC5.
  - 3. Select and install A1C3 so that the oscillator frequency is 10 kHz ±0.05 kHz.
  - 4. Do not adjust A1L2,
- b. Options 09, 10 (200 Ohm Mounts):
  - 1. Center A1L2,
  - 2. Select and install values for A1C4 and A1C5 to produce an oscillator output frequency of 10 kHz ±0.1 kHz.
  - 3. Do not adjust A1L2.
- c. Options 09, 10 (200 Ohm Balanced Mounts:
  - 1. Center A1L2.
  - 2. Select and install values for A1C4 and A1C5 to produce an oscillator output frequency of 10 kHz  $\pm$  0.01 kHz.
  - 3. Do not adjust A1L2.

d. Options 11, 12, 13 (100 Ohm Mounts):

- 1. Center A1L2
- 2. Install supplied values for A1C4 and A1C5
- 3. Install supplied value for A1C3
- 4. Adjust A1L2 for an oscillator frequency of 10 kHz ± 0.05 kHz.
- e. Options 21, 22, 23 (200 Ohm Unbalanced Mounts):
  - 1. Center A1L2
  - 2. Install supplied values for A1C4 and A1C5 3. Adjust A1L2 for an oscillator frequency of 10 kHz  $\pm$  0.1 kHz.

A2-1

f. Option 24 (200 Ohm Balanced Mounts):

1. Center A1L2

Appendix II ...

Install supplied values for A1C4 and A1C5 2. Adjust A1L2 for an oscillator frequency of 3.

 $10 \text{ kHz} \pm 0.01 \text{ kHz}$ .

## A2-6. COARSE NULL ADJUSTMENTS.

A2-7. Options 09, 10, 11, 12, 13 (100 Ohm Thermistor Mount);

a. Connect 100 ohm thermistor mount to power meter.

b. Connections illoscope to junction of AIR55 and A1CR8. Com 1

c. Set power meter control as follows:

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POWER	 ON ON
RANGE	 01 mW
CALIB FACTOR	100%
MOUNT RES	 100 Ohm

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

e. Mechanically center Null capacitor, C1.

#### NOTE

For OPTION 13, install A1C23 between A1 pin 9 and A1 pin 7. Nominal value: 1600 pF. Pad If necessary to obtain null in step f.

f. Adjust AIL1 for a voltage null at AIR55. Adjust NULL capacitor C1 for a zero power meter reading. C1 should remain near mechanical center ±10".

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

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

## A2-8. Options 09, 10, 21, 22, 23, 24 (200 Ohm Thermistor Mount):

a. Connect200 ohm thermistor mount to power meter.

b. Connect; oscilloscope or AC voltmeter from A1R55 to ground. -2 I

c. Set power meter controls as follows:

POWER	n ng salit ni		1 (1) 11 • 1 • 1 • 1		. ON
RANGE					01 mW
CALIB	FACTO	R	•:•		100%
HOUNT	' RES .	• • • •	•••••	• • 2	00 Ohm

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

e. Mechanically center NULL capacitor C1.

f. Select capacitor AIC1 for a voltage null at AIR55. Fine adjust NULL capacitor C1 for less than 1.5 yolts peak-to-peak.

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

#### NOTE

If a null cannot be obtained, do not select A1C1 lor a value greater than 1000 pF. Increase A1C2 in 50 pF steps, and repeat procedure.

A2-9. Bridge Resistance Adjustment:

a. Connect the 431C Thermistor cable to the 8402B **RESISTANCE STANDARD** connector.

b. Set the 8402B Mount Resistance to the proper setting for the mount used and the 8402B THERMISTOR **RESIS', ANCE to 0.** 

1. Options 09, 10, 11, 12 (100 Ohm):

Connect the following circuit in place of A1R7.

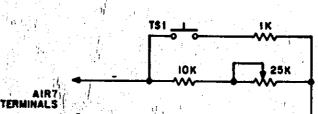


Figure A2-1. Test Network for 100 Ohm Calibration

- Observe the 10kHz oscillator output at A1C18 (+) with an oscilloscope.
- 3. Press TSI periodically while increasing resistance of the 25K pot. When oscillations cease, measure the total resistance of the network. Find the closest value in the chart below and install the next lowest value in place of A1R7.

## 100 Ohm

**Registance** Selection Chart

· · · <b>1.</b> ·	10K
2.	11K
3.	12.1K
4.	13.3K
5.	14.7K
6,	16.2K
7. 8.	17.8K
9.	19.6K 21.5K
10.	21.5K
	26.1K
and the second second second second second second second second second second second second second second second	28.7K

#### Appendix II

4. Recalibrate	the	431C	using the	procedu	res in
Section V.		internation internationalista internationalista internationalista	)		· 4

Model 431C

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- Options 09, 10, 21, 22, 23, 24 (200 Ohm and 200 Ohm Balance):
- 1. Observe the 10 kHz oscillator output at A1C18 AIRi0 (lugs provided on board).

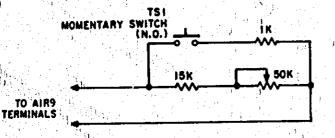


Figure A2-2. Test Network for 200 Ohm Calibration

- 3. Set the 50K pot to minimum resistance and press TS1 periodically. The oscilloscope display is the oscillator output; slowly increase resistance until oscillation stops.
- 4. Disconnect The resistance network and measure its total resistance. Take the value from the table below closest to the measured resistance, move back to the next lowest value and install a 1/8 watt meter film resistor of this value on the A1 board in the place provided for A1R9.

**Resistance** Selection Chart 1. 19,6K 21.5K 2. 23.7K 3. 26.1K 4. 28.7K Б. 6. . 31.6K 7. 34.8K 38.3K 8. 42.2K 9.) 46,4K 10. 11. 51.1K 12. 56.2K

200 Ohm and 200 Ohm Balance

5. Switch the 8402B THERMISTOR RESISTANCE between -.1, 0 and +.1%. The 431C meter shall read 0 and on-scale respectively, with THERMISTOR RESISTANCE settings of -.1% and 0, or 0 and +.1%, indicating that the bridge resistance error is less than ±.1%.

6. Recalibrate the 431C using the procedures in Section V.

Table A2-2, Conversion Kit Parts List

	HP Part No.			HP Part No.
OPTION 09 (100/2000)	00431-6109	OPTION 11	(50 ft) (1007) (Continued)	
Quantity Description	1	Quantity	Description	
1Nameplate, identification1Cable, 10 ft	00431-0009 8120-1083	1	Resistor, fixed 208.80 for R8 Nameplate, identification	0811-2090
OPTION 10 (20 ft) (1000 or 2000)	00431-6110	1	Cable, 50 ft	8120-1085
2 Capacitor, 2500 pF for C4, 5	0160-0147	OPTION 12	(100 ft) (1000)	00431-6112
1 Resistor, fixed 200.7Ω for R10	0811-2087	1	Capacitor, fixed 1100 pF for C5	0160-2219
1 Resistor, fixed 204.6Ω for R8	0811-2088		Resistor, fixed 323A for R1	0698-5662
1 Nameplate, identification	00431-0010	1	Resistor, fixed 195.59 for R5	0811-2086
1 Cable, 20 ft	8120-1084	1	Resistor, fixed 204.69 for R10	0811-2088
OPTION 11 (50 ft) (1007) 2 Capacitor, fixed 2700 pF	00431-6111 0160-2228		Resistor, fixed 216.00 for R8	0811-2091
for C4, 5 1 Resistor, fixed 202.18	0811-1645		Resistor, fixed 259.40 for R6	<b>0811-2093</b>
for R10		1	Nameplate, identification	00431-0012
Resistor; fixed 189.80 for R5	0811-2085	1	Cable, 100 ft	8120-1086

A2-3

Appendix II 

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Table A2-2. Conversion Kit Parts List (Cont.)

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	HP Part No.		na series Productional de la companya de la companya de la companya de la companya de la companya de la companya de la co	HP Part No.
OPTION 13 (200 ft) (1006)	00431-6113	OPTION 22	(100 ft) (2007) (Continued)	
Quantity Description	<u>n</u>	Quantity	Description	「単一」」。 「注意」」。 「注意」」。
1 Capacitor, fixed 910 for C5	pF 0160-2217	1,	Resistor, fixed 259.40 for R6	0811-2093
1 Capacitor, fixed 160 for C23	0 pF 0160-2223	1	Nameplate, identification	
1 Resistor, fixed 3300 for R1	0698-5663		Cable, 100 ft	8120-1086
1 Resistor, fixed 207.1 for R5	Ω 0811-2089	OPTION 23	(200 ft) (2000)	00431-6123
1 Resistor, fixed 208.4 for R10	3Ω 0811-2090	1	Capacitor, fixed 4300 pF for C5	0160-2036
1 Resistor, fixed 231.4 for R8	<b>IΩ</b> 0811-2092	) <b>1</b>	Resistor, fixed 3300 for R1	0698-5663
1 Resistor, fixed 265.2 for R6	Ω 0811-2094	1	Resistor, fixed 207.10 for R5	0811-2089
1 Nameplate, identific		1	Resistor, fixed 208.80 for R10	0811-2090
1 Cable, 200 ft OPTION 21 (50 ft) (2006)	8120-1087 000431-6121	1 5	Resistor, fixed 231.4Ω for R8	0811-2092
2 Capacitor, fixed 2700 for C4, 5		1	Resistor, fixed 265.20 for R6	0811-2094 j
1 Resistor, fixed 202.1 for R10	Ω 0811-1645	1	Nameplate, identification	and the second second second second second second second second second second second second second second second
1 Resistor, fixed 189.8 for R5	Ω 0811-2085	<b>↓</b>	Cable, 200 ft	8120-1087
1 Resistor, fixed 208.8 for R8	Ω 0811-2090	OPTION 24 MOUNT ON	(200 ft) 200 BALANCED	00431-6124
1 Nameplate, identifica	ution 00431-0021	2	Capacitor, fixed 3300 pF for C4, 5	0160-2230
1 Cable, 50 ft	8120-1085	1	Resistor, fixed 3300 for R1	0698-5663
OPTION 22 (100 ft) (2007) 2 Capacitor, fixed 3300	00431-6122 pF 0160-2230	1	Resistor, fixed 207.10 for R5	0811-2089
for C4, 5 1 Resistor, fixed 323.0	Ω 0698-5662	1	Resistor, fixed 208.89 for R10	0811-2090
for R1 1 Resistor, fixed 195.5 for R5	Ω 0811-2086		Resistor, fixed 231.49 for R8	0811-2092
1 Resistor, fixed 204.6 for R10	<b>G</b> 0811-2088		Resistor, fixed 265.2Ω for R6	0811-2094
1 Resistor, fixed 216.04	0811-2091		Nameplate, identification	00431-0024
for R8		sere <b>l</b> ise Sec <b>i</b> fication	Cable, 200 ft	8120-1087

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