HEWLETT-PACKARD COMPANY / OPERATING AND SERVICE MANUAL

431B

POWER METER

431B

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OPERATING AND SERVICE MANUAL

MODEL 431B

SERIALS PREFIXED: 233-

POWER METER

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SECTION I
GENERAL INFORMATION

1-1. DESCRIPTION.

1-2. The hp Model 431B Power Meter, with hp temperature compensated thermistor mounts, measures rf power from 10 microwatts (-20 dbm) to 10 milliwatts (+10 dbm) in the 10-mc to 40-gc frequency range. Direct reading accuracy of the instrument is ±3% of full scale. Instrument specifications are given in table 1-1.

1-3. The design of the Model 431B and its thermistor mount, results in almost complete freedom from measurement error caused by ambient temperature changes. The instrument incorporates two self-balancing bridges with one arm of each bridge being a thermistor. The two matched thermistors, both located within the mount, are thermally coupled, but electrically isolated. One thermistor is used to absorb rf power; the other is used to provide temperature compensation. Thus, the thermal drift problems normally associated with the thermistor-power meter arrangement have been greatly reduced. A single setting of the ZERO control on the most sensitive power range is maintained within 1% for all higher power ranges.

1-4. The temperature compensated thermistor mounts used with the instrument are specifically designed for hp Model 431A/B Power Meters. Coaxial and waveguide thermistor mounts cover the 10-mc to 40-gc frequency range. Table 1-2 gives thermistor mount operating frequency, mount configuration, and operating resistance.

Table 1-1. Specifications

Instrument Type:
Automatic, self-balancing for temperature compensated mounts

Power Ranges:
7 ranges with full scale readings of 10, 30, 100 and 300 μw; 1, 3 and 10 mw. Also calibrated in dbm from -20 to +10.

External Bolometer:
Temperature-compensated thermistor mounts required for operation (hp 478A and 486A series).

Accuracy:
±3% of full scale from +20°C to +35°C, ±5% of full scale from 0°C to +55°C

Zero Carry-Over:
Less than 1% of full scale when zeroed on most sensitive range

Recorder/Voltmeter Output:
Phone jack on rear with 1 ma maximum into 1000 ohms ±10%; one side grounded

Calibration Input:
Binding posts on rear for calibration of bridge with hp 8402A Power Meter Calibrator or precise dc standards

Power Supply:
115 or 230 volts ±10%, 50 to 1000 cps, 2-1/2 watts

Dimensions:
6-17/32 in. (16.6 cm) high, 7-25/32 in. (19.77 cm) wide, 12-1/2 in. (31.75 cm) deep

Weight:
Net 8 lb (3.63 kg) with cover and cables 11-1/2 lb (5.44 kg) including battery; shipping approx. 13 lb (5.9 kg)

Accessories Furnished:
5 ft (1.5 m) cable for hp temperature-compensated thermistor mounts. 7-1/2 ft (2.3 m) power cable, NEMA plug.

Accessories Available:
431A-95A Rechargeable Battery Pack for field installation.

hp Models 478A and 486A Thermistor Mounts

hp Model 8402A Power Meter Calibrator

hp Model H01-8401A Leveler Amplifier

Options:
01. Rechargeable battery installed, provides up to 24 hours continuous operation,
02. Rear input connector wired in parallel with front panel input connector,
10. With 20 foot cable for 100 Ω or 200 Ω mount,
11. With 50 foot cable for 100 Ω mount,
12. With 100 foot cable for 100 Ω mount,
13. With 200 foot cable for 100 Ω mount,
21. With 50 foot cable for 200 Ω mount,
22. With 100 foot cable for 200 Ω mount,
23. With 200 foot cable for 200 Ω mount.

Table 1-2. Model 431B Thermistor Mounts

Type		Frequency Range	Operating Resistance in ohms
Coaxial	Waveguide		
ⓗⓟ 478A		10 mc to 10 gc	200
	ⓗⓟ S486A	2.6 to 3.95 gc	100
	ⓗⓟ G486A	3.95 to 5.85 gc	100
	ⓗⓟ J486A	5.3 to 8.2 gc	100
	ⓗⓟ H486A	7.05 to 10.0 gc	100
	ⓗⓟ X486A	8.2 to 12.4 gc	100
	ⓗⓟ M486A	10.0 to 15.0 gc	100
	ⓗⓟ P486A	12.4 to 18.0 gc	100
	ⓗⓟ K486A ⓗⓟ K486AC*	18.0 to 26.5	200
	ⓗⓟ R486A ⓗⓟ R486AC*	26.5 to 40.0	200
* With circular contact flange adapter			

1-5. The Model 431B has provisions for using the dc substitution method of measurement and for checking calibration accuracy of the power meter. The dc substitution method of measurement which requires other equipment provides greater power measurement accuracies than can be obtained by the power meter alone. In addition a jack in series with the panel meter permits digital or chart recording of measurements, operation of alarm or control systems and use in a closed-loop leveling system.

1-6. ACCESSORIES.

1-7. Two accessories are supplied with the Model 431B Power Meter: a 7-1/2-foot, detachable power cable and a 5-foot cable that connects the thermistor mount to the Model 431B. Thermistor mounts are available (see table 1-2) but not supplied with the instrument. A rechargeable battery with installation kit is also available. A list of supplied and available accessories is given in table 1-1, Specifications.

1-8. INSTRUMENTS WITH OPTIONS.

1-9. The options available with the Model 431B Power Meter are given in table 1-1. The thermistor mount cable options require modification and recalibration of the Model 431B Power Meter. The recalibration procedures for the cables are given in section V, Maintenance. For further information as to the ordering of options etc., contact your local ⓗⓟ Engineering Representative.

1-10. INSTRUMENT IDENTIFICATION.

1-11. Hewlett-Packard uses a two-section eight-digit serial number (000-00000). If the first three digits of the serial number on your instrument do not agree with those on the title page of this manual, change sheets supplied with the manual will define differences between your instrument and the Model 431B described in this manual.

SECTION II
INSTALLATION

2-1. INSPECTION.

2-2. This instrument was carefully inspected both mechanically and electrically, before shipment. It should be physically free of mars or scratches and in perfect electrical order upon receipt. To confirm this, the instrument should be inspected for physical damage in transit. Also check for supplied accessories, and test the electrical performance of the instrument using the procedure outlined in paragraph 5-71. If there is damage or deficiency, see the warranty on the inside rear cover of this manual.

2-3. INSTALLATION.

2-4. The ⓗⓟ Model 431B is fully transistorized; therefore no special cooling is required. However, the instrument should not be operated where the ambient temperature exceeds 55°C (140°F).

2-5. RACK MOUNTING.

2-6. The Model 431B is a submodular unit that when used alone can be bench mounted only. However, when used in combination with other submodular units it can be bench and/or rack mounted. The ⓗⓟ combining case and adapter frame are designed specifically for this purpose.

2-7. COMBINING CASE. The combining case is a full-module unit which accepts varying combinations of submodular units. Being a full-module unit, it can be bench or rack mounted analogous to any full-module instrument. An illustration of the combining case is shown in figure 2-1. Instructions for installing the Model 431B in a combining case is given graphically in figure 2-2.

2-8. ADAPTER FRAME. The adapter frame is a rack frame that accepts any combination of submodular units. It can be rack mounted only. An illustration of the adapter frame is given in figure 2-3. Instructions are given below;

a. Place the adapter frame on edge of bench as shown in step (1), figure 2-4.

b. Stack the submodular units in the frame as shown in step (2), figure 2-4. Place the spacer clamps between instruments as shown in step (3), figure 2-4.

c. Place spacer clamps on the two end instruments (see step (4), figure 2-4) and push the combination into the frame.

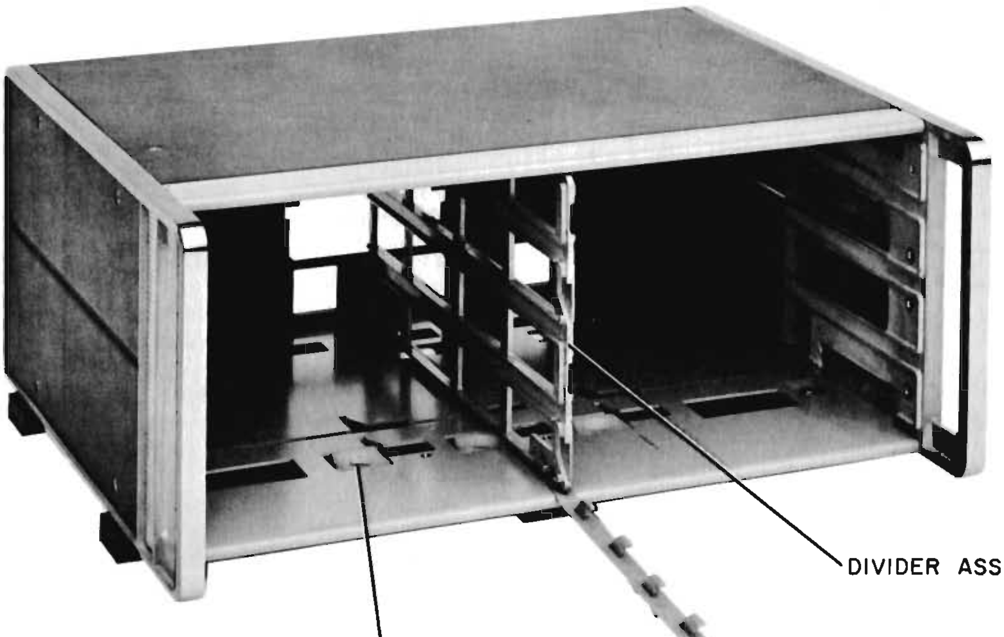


Figure 2-1. The Combining Case

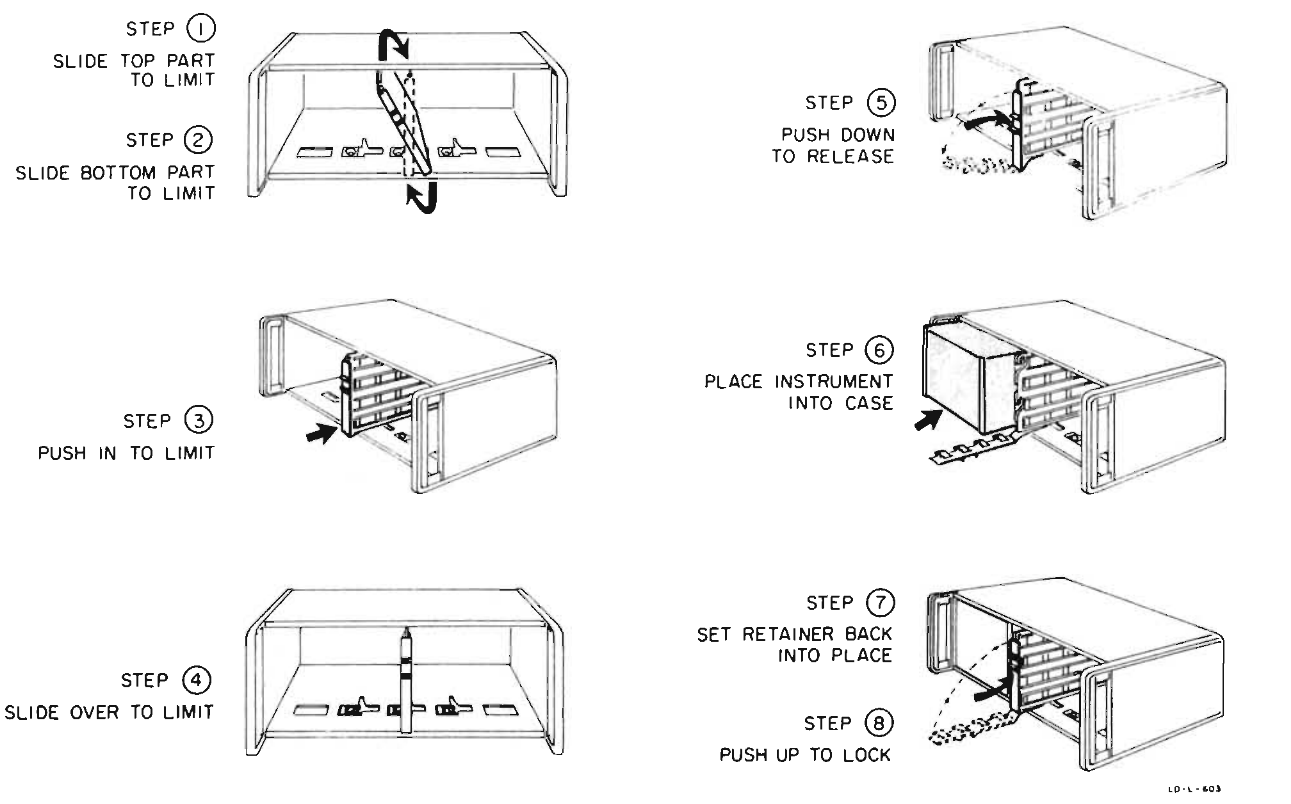


Figure 2-2. Steps to Place Instrument into Combining Case

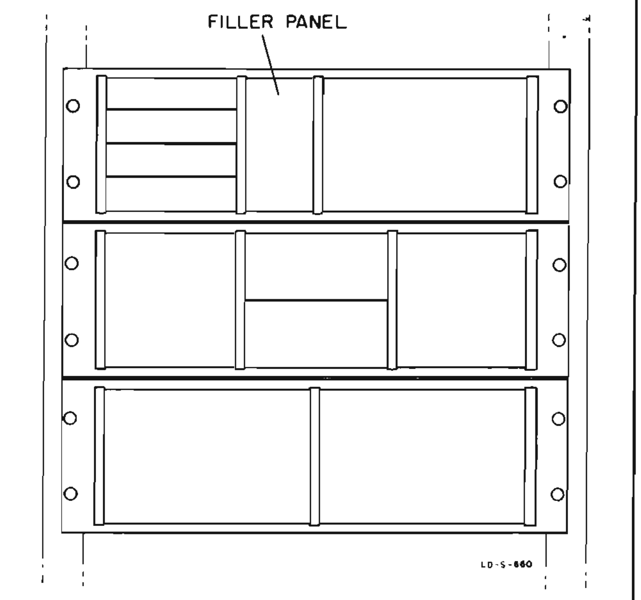


Figure 2-3. Adapter Frame Instrument Combinations

d. Insert screws on either side of frame, and tighten until submodular instruments are tight in the frame.

e. The complete assembly is ready for rack mounting.

2-9. THREE-CONDUCTOR POWER CABLE.

2-10. To protect operating personnel, the National Electrical Manufacturers' Association (NEMA) recommends that the instrument panel and cabinet be grounded. All Hewlett-Packard instruments are equipped with a three-conductor power cable which, when plugged into an appropriate receptacle, grounds the instrument. The offset pin on the power cable three-prong connector is the ground wire.

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

2-12. PRIMARY POWER REQUIREMENTS.

2-13. The Model 431B can be operated from an ac or dc primary power source. The ac source can be either 115 or 230 volts, 50 to 1000 cps. The dc source is a 24-volt rechargeable battery. The rechargeable battery is supplied with option 01 instruments only.

2-14. For operation from ac primary power, the instrument can be easily converted from 115- to 230-volt operation. The LINE VOLTAGE switch, S1 a two-position slide switch located at the rear of the instrument, selects the mode of ac operation. The line voltage for which the instrument is set to operate appears on the slider of the switch. A 15/100-ampere, slow-blow fuse is used for both 115- and 230- volt operation.

CAUTION

DO NOT CHANGE THE SETTING OF THE LINE VOLTAGE SWITCH WHEN THE POWER METER IS OPERATING.

2-15. INITIAL BATTERY OPERATION CHECK.

2-16. The following applies to option 01 instruments or instruments that have field-installed batteries. When the battery is used as the Model 431B power source for the first time, perform the following steps:

a. Connect Model 431B to ac source. Set POWER switch to CHARGE and charge battery for a minimum of 16 hours or overnight. Note: the battery can be maintained in the charging state indefinitely without damaging the battery. It will assume its full capacity, 1.25 ampere hour, and no more.

b. Perform turn-on procedure given in figure 3-2 with POWER at AC. If the procedure checks out normally, proceed to step c.

c. Repeat turn-on procedure given in figure 3-2 with POWER at BATTERY ON. If operation is not the same as that obtained with ac power applied, refer to section V paragraph 5-40, Battery and Charging Check.

2-17. REPACKAGING FOR SHIPMENT.

2-18. The Model 431B is shipped in a foam-pack and cardboard carton (see figure 2-5). When repackaging the instrument for shipment, the original foam-pack and cardboard carton can be used if available. If not available, they can be purchased from Hewlett-Packard Co. (refer to section VI, misc). Use the following as a general guide for repackaging the instrument.

a. Place the instrument in the foam-pack as shown in figure 2-5.

b. Mark the packing box with "Fragile", "Delicate Instrument", etc as appropriate.

Note

If the instrument is to be shipped to Hewlett-Packard for service or repair, attach to the instrument a tag identifying the owner and indicating the service or repair to be accomplished, include the model number, and full serial number, of the instrument. In any correspondence, identify the instrument by model number, serial number and serial number prefix.

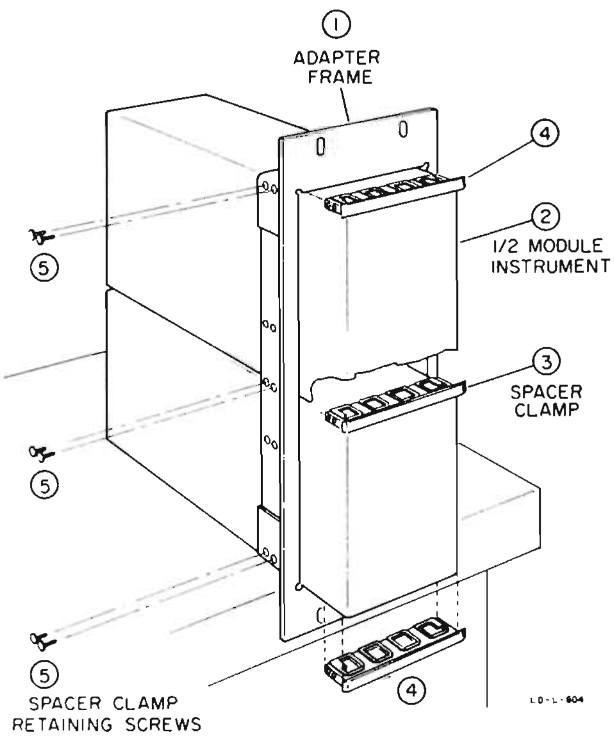


Figure 2-4. Two Half Module in Rack Adapter

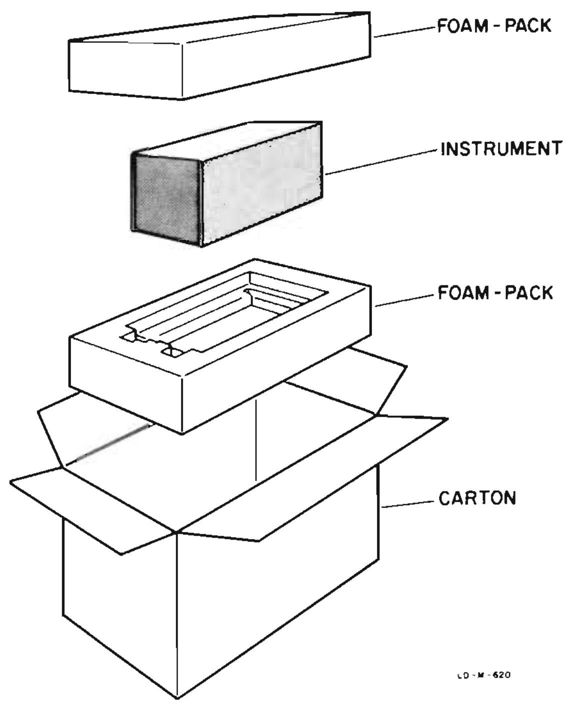


Figure 2-5. Repackaging for Shipment

SECTION III
OPERATION

3-1. INTRODUCTION.

3-2. The ⓗⓟ Model 431B Power Meter measures rf power ranging from .01 to 10 milliwatts with power meter accuracy of ±3%. Since the zero carries over within 1%, accuracies of at least ±4% can be obtained on any range by a single zeroing on only the lowest range.

3-3. MECHANICAL ADJUSTMENT OF METER ZERO.

3-4. The procedure for performing the mechanical adjustment of the meter zero is given in section V, paragraph 5-54.

3-5. CONTROLS AND INDICATORS.

3-6. The front and rear panel controls and connectors are explained in figure 3-1. The explanations are keyed to corresponding controls and indicator on the drawing of the front and rear panels of the instrument provided with the figure.

3-7. OPERATING INSTRUCTION.

3-8. Figure 3-2, Turn-On and Nulling Procedure, and figure 3-3, DC Substitution Technique, give step-by-step instructions for operating the Model 431B. In figure 3-2, each step is numbered to correspond with numbers on the accompanying drawing of the power meter.

3-9. BATTERY OPERATION.

3-10. The following applies to power meters having a factory or a field-installed rechargeable nickel-cadmium battery. See figure 3-1, Turn-On and Nulling Procedure, for step-by-step instructions for operating the Model 431B from a battery.

3-11. BATTERY CHARGING TIMES.

3-12. The battery used in the Model 431B requires two hours of charge time for one hour of battery operation. When the battery is fully charged, the Model 431B can be continuously operated for 24 hours with 48 hours of charge time. However, it is recommended that battery operated instruments be operated for eight hour periods with a 16 hour recharge time. This makes the Model 431B available for portable use daily, yet maintains the battery at full charge.

3-13. BATTERY CHARGE CHECK.

3-14. Under normal conditions, a fully charged battery will start at approximately 27 volts and drop to about 22 volts after 24 hours of continuous use at room temperature.

a. Connect the Model 431B to ac primary power. Set POWER to AC and perform the turn-on and nulling procedure given in figure 3-2. This will check for normal operation from ac primary power. If performance is normal proceed to step b.

b. Set POWER to BATTERY CHARGE: the AC CHARGE lamp will glow. Allow Model 431B to charge the battery for 48 hours. This will allow the battery to obtain a full charge.

c. After the recharge interval, set POWER to BATTERY ON. Since battery is now fully charged, you should be able to zero-set and null the meter (figure 3-2). If not the battery or battery charging circuit is at fault. Refer to Battery and Charging Checks paragraph 5-40.

3-15. MAJOR SOURCES OF ERROR, MICROWAVE POWER MEASUREMENTS.

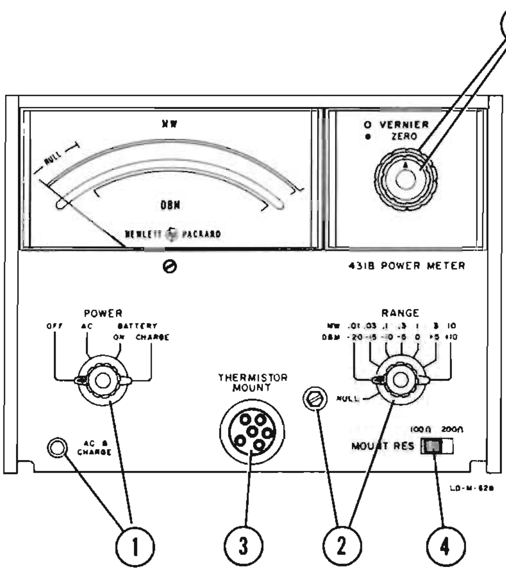
3-16. In microwave power measurements, the following are the major sources of error: 1) mismatch error or tuner loss (when a tuner is used to tune out mismatch error), 2) bolometer mount efficiency, 3) substitution error, 4) instrument error and 5) error due to the unilateral properties of a thermistor. Thus five errors must be known if accurate power measurements are to be obtained. Expressed mathematically:

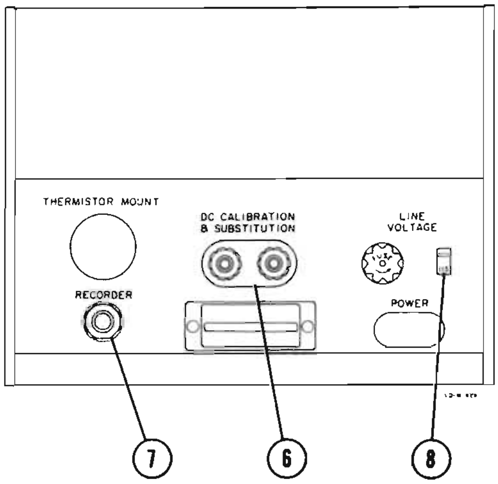
Total measurement error =

mismatch (or tuner) loss + calibration factor + instrument error + error due to the unilateral properties of a thermistor.

a. Mismatch Loss. Unless the mount and rf source are perfectly matched to the transmission system, a fraction of incident power is reflected and does not reach the thermistor. Since there generally is more than one source of mismatch in a microwave measurement system and the resulting error signals interact, loss cannot be calculated from the swr figure, it can only be expressed laying between two limits. Limits of mismatch loss generally are determined by means of a chart such as the Mismatch Loss Limits chart included in each of the thermistor mount Operating Notes. A tuner such as the ⓗⓟ Model 872A or 870A can be used to minimize loss, although the tuner itself will introduce some loss.

b. Bolometer Mount Efficiency and Substitution Error. Not all the rf power applied to the mount is used to heat the rf thermistor. Some of it is absorbed by the other elements in the mount, such as the walls of the rf chamber, the heat sinks, the leads, etc. Substitution error results because rf power does not affect the thermistor to the same degree as dc power. Substitution error and mount efficiency are often combined for a simplicity of measurement into what is termed "calibration factor". Typically, the calibration factor of the Model X486A waveguide mount is 97% to 98%.





1. POWER: The POWER switch sets up connections to the selected power sources or to the battery charging circuit. When the power switch is in the AC position, externally supplied 115 or 230 volts is applied to the instrument. If the instrument contains a battery, a trickle charge is applied to maintain the battery at full charge. With POWER at BATTERY ON, a 24-vdc battery within the instrument supplies primary power to the instrument. With POWER at CHARGE, 115- and 230-volt power is used to charge the battery (16 to 24 hours is required to obtain full battery charge). The instrument is inoperative in this position. Note: Batteries are installed at the factory for option 01 instruments only.

2. RANGE: The RANGE switch can be set for full scale power readings from .01 to 10 milliwatts in seven steps. It also includes a NULL position which, in conjunction with the adjacent null screwdriver adjust, insures that the metering bridge is reactively balanced.

3. THERMISTOR MOUNT: The THERMISTOR MOUNT connector is a female receptacle that accepts a specially-made cable which is supplied with the instrument. The cable connects the mount thermistors into their respective bridges within the power meter.

4. MOUNT RES: This two-position slide switch sets the power meter to accommodate thermistor mounts 100- or 200-ohm nominal resistance.

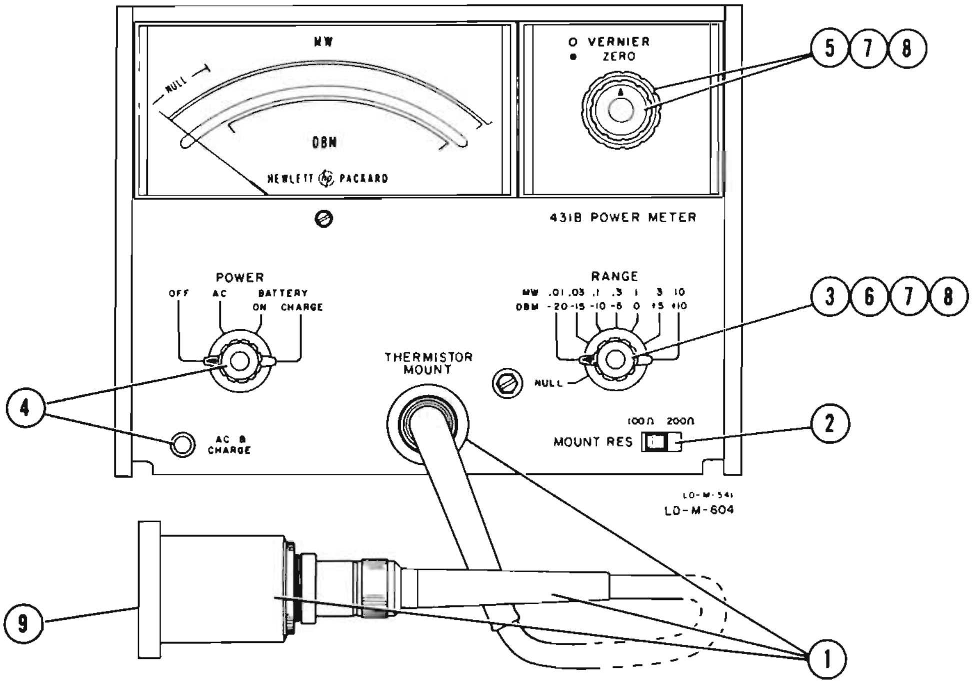
5. ZERO and VERNIER: The ZERO control coarsely sets the meter pointer near zero; the VERNIER control is a more exact adjustment which sets the meter pointer on zero.

6. DC CALIBRATION & SUBSTITUTION. This terminal permits application of known direct current to the rf bridge. The power reading obtained with the accurately known dc power applied is then compared with the reading obtained when rf power was applied. The dc substitution technique is used to both calibrate and increase the accuracy of 431B power measurement.

7. RECORDER: The RECORDER jack is a two-wire telephone jack (one side grounded) for monitoring the current which operates the Model 431B meter.

8. LINE VOLTAGE: The LINE VOLTAGE switch S1, is a two-position slide switch that selects the mode of ac operation. The line voltage for which the instrument is set to operate appears on the slider of the switch. A 15/100 slow-blow fuse is used for both 115 and 230 volt operation.

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



1. Connect thermistor mount and cable to the THERMISTOR MOUNT. ⓗⓟ thermistor mounts and their frequency ranges are given in table 1-2, Model 431B Thermistor Mounts.

Note

When possible, the Model 431B should be zeroed and nulled with the power source to be measured connected to the thermistor mount. If this is not possible, and a coaxial thermistor mount is used, terminate the rf input into a 50-ohm load. Power source should be off while zero and null-setting the Model 431B Power Meter.

2. Set MOUNT RES to match thermistor mount resistance (100 or 200 ohms).

3. Set RANGE to .01 MW.

4. Set POWER to AC; AC & CHARGE lamp will glow. If instrument is battery-operated, rotate POWER to BATTERY ON.

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

6. Rotate RANGE to NULL and adjust null screw-driver adjust (adjacent to NULL on RANGE switch) for a minimum reading in NULL region.

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

Note

If instrument is battery-operated and you are not able to zero the meter, or if meter pointer fluctuates rapidly, battery needs recharging. Refer to paragraph 3-11.

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

Note

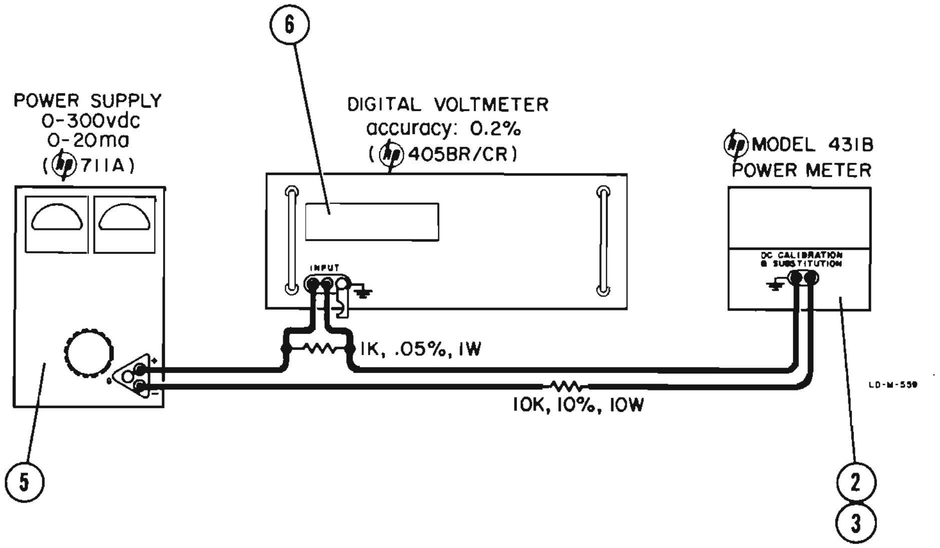
Zero-set accuracy of 1% can be obtained by zero setting the meter on the most sensitive range (.01 MW) only, and assuming the meter is properly zeroed on all less sensitive ranges. For maximum accuracy, zero set the meter on the range to be used.

9. Apply rf power at the thermistor mount and read power on Model 431B meter. Power is indicated on the meter directly in mw or dbm.

Note

This instrument is accurate to within ±3%. Accuracy to ±1%, or better, is possible using the dc substitution technique described in figure 3-3. See also paragraphs 3-15 and 3-17.

Figure 3-2. Turn-On and Nulling Procedure



1. With power supply turned off, connect the Model 431B as shown above.

2. Set the Model 431B for normal operation on the appropriate range using the procedure given in figure 3-2.

3. Apply rf power at the thermistor mount and note and record the reading of the Model 431B meter. This is the reference for the substitution measurement.

Note

A second digital voltmeter, in parallel with a 1000-ohm (±10%, 1 watt) resistor, connected in series with the RECORDER output of the Model 431B will increase accuracy of reference duplication.

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

5. Turn power supply on; adjust the output voltage of the power supply until the reference of step 3 is duplicated. A potentiometer arrangement may be substituted for the adjustable power supply. However, at least 10,000 ohms must remain in series with the supply.

CAUTION

Never apply more than 20 ma dc to the DC CALIBRATION SUBSTITUTION terminals of the Model 431B.

6. Read the voltmeter with monitors the substitution current. The voltmeter reading can be interpreted as current in milliamperes because the voltage is measured across 1000 ohms. This current is I_{dc}.

7. Calculate power in mw from the expression

$$\text{Power (MW)} = \frac{I^2_{dc} \; R_d}{4 \times 10^3}$$

where R_d = operating resistance of the termistor (100 or 200 ohms)

and I_{dc} = substitution current in milliamps (from step 6)

9. To minimize error due to drift in either the reference or substituted power level, steps 1 through 6 should be repeated.

Figure 3-3. DC Substitution Technique

c. Instrument Error. This is the inability of the power meter to accurately measure and interpret the information available at the thermistor element. In specifying the accuracy of a power meter, instrument error is the figure usually given. For the Model 431B, instrument error is ±3% of full scale, 20°C to 35°C. This error can be reduced by special techniques such as the dc substitution method discussed in para. 3-17.

d. Error Due to the Unilateral Properties of a Thermistor. The thermistor used in conjunction with the Model 431A/B exhibits unilateral properties which, when the source of power is a dc current, causes a slightly different indication of power than is obtained by the calculation of I^2R. Thus the dc power required to produce a reading on the Model 431A/B Power Meter is not the same as the rf power required to produce the same reading on the Model 431A/B Power Meter. The maximum error produced from this source of error is ±0.3 μwatts, typical error is ±0.1 μwatt. Since the order of magnitude of this error is small (0.3 μwatt) it need be minimized only on the two most sensitive ranges of the Model 431A/B Power Meter. Refer to the ⓗ Model 8402A Power Meter Calibrator manual for procedure used to minimize this error.

3-17. POWER METER ACCURACY OF 1% OR GREATER USING THE DC SUBSTITUTION METHOD.

3-18. Highly accurate instruments are available for measuring direct current. Thus, where optimum accuracy is required, there is considerable advantage in using a technique where the rf measurement is used only as a reference and the determination of rf power is based on precise dc measurements. In general the technique involves:

a. Applying rf power to the Model 431B in the usual manner, and noting the resulting meter indication for use as a reference.

b. Removing the rf power and applying sufficient dc at the DC CALIBRATION & SUBSTITUTION terminals to exactly duplicate the meter indication produced by the rf power.

c. Use the value of dc which duplicated the reference in calculating rf power.

3-19. 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 the dc substitution technique depends largely upon:

a. how precisely the reference is duplicated,

b. how accurately the value of the substituted dc is known,

c. the actual operating resistance of the thermistor, and

d. the actual ratio of current division in the rf bridge.

3-20. With precision components in the substitution setup and careful procedure, error produced by the Model 431B Power Meter can be reduced to 1% or less. This is assuming nominal thermistor mount resistance (100 or 200 ohms) and that half the applied dc flows through the rf thermistor. The dc substitution technique using the Model 431B is shown in figure 3-3.

3-21. EQUIPMENT USED FOR DC SUBSTITUTION.

3-22. The ⓗ Model 8402A Power Meter Calibrator was specifically designed to be used for calibration and dc substitution measurements of rf power. In addition, the instrument will accurately measure the operating resistance of the thermistor mount being used. Use the procedures given in the manual provided with the ⓗ Model 8402A Power Meter Calibrator to perform the dc substitution measurements.

3-23. Although the most convenient and accurate means of applying the dc substitution technique is by using ⓗ Model 8402A Power Meter Calibrator, it is also possible to accurately measure power using the dc substitution technique with the arrangement shown in figure 3-3. The digital voltmeter is used to monitor the substitution current. The power supply output and voltmeter input are ungrounded to eliminate ground currents.

3-24. ADDITIONAL APPLICATIONS.

3-25. At the RECORDER output, the Model 431B furnishes a current (0 to 1 ma dc) which is proportional to the power measured. This feature makes possible a measurement system with more capability than simply the indication of power on a meter. Some of the more sophisticated measurement systems are shown in block diagram form in figures 3-4 through 3-8.

3-26. PERMANENT RECORD. Use of a recorder in the measurement system is indicated in figure 3-4. Resistance across the Model 431B RECORDER output must be 1000 ohms. Any type of recorder may be used with the Model 431B; if input resistance exceeds 1000 ohms, use a shunt across the recorder input.

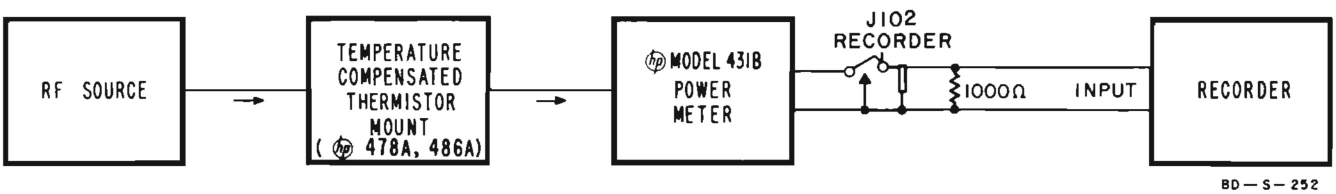


Figure 3-4. Permanent Record

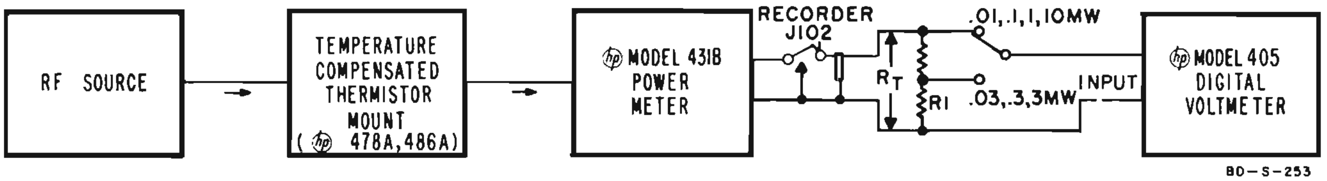


Figure 3-5. Increased Resolution

3-27. INCREASED RESOLUTION. Digital readout of power to three decimal places can be obtained with the arrangement shown in figure 3-5. The value of R1 is 316.2 ohms ±.1% and R_t is 1000 ohms ±.1%. Correct placement of the decimal in the readout is determined by the setting of the power meter RANGE switch. On the divider-switch arrangement at the voltmeter input may be replaced by a single 1000-ohm .1% resistor. With this arrangement, on the .01, .1, and 10 MW ranges, power is read in the same way as when the arrangement shown in figure 3-5 is used, decimal placement being determined by the setting of RANGE. On the .03, .3, and 3 MW ranges, however to obtain the power readings the voltmeter indication must be multiplied by the factor given in table 3-1.

Table 3-1. Voltmeter Readout to Power Multipliers

Range	Multiplier
.03 MW	0.0316
.3	0.316
3	3.16

3-28. LEVELER. Figure 3-6 is a block diagram of a closed-loop control circuit for maintaining output power at a constant level. It is recommended for use in leveling the output of various types of hp microwave equipment such as bwo sweep oscillators, twt micro-wave amplifiers, and rf generators. In addition to the Model 431B and its thermistor mount, such a leveling system requires the hp H01-8401A Leveler Amplifier and a directional coupler with good directivity such as one of the hp 752 series of waveguide couplers or 760 series of coaxial couplers. The output of the power source is sampled by the coupler and applied to the Model 431B. A dc signal, proportional to the power sample, is fed (from the Model 431B RECORDER jack) to the Leveler Amplifier. In the H01-8401A the signal from the Model 431B is compared to an internal reference voltage, and the difference is amplified and fed back as a control voltage to hold output power constant.

3-29. MONITOR CONTROL SYSTEMS. By adding a dc amplifier and relay circuit to the rf monitoring arm of a system, the dc signal provided by the Model 431B can be used to actuate alarm or control circuits. Arrangement of equipment to provide an alarm or control system is shown in block diagram form in figure 3-7.

3-30. DETERMINING INSERTION LOSS OR GAIN AS A FUNCTION OF FREQUENCY. Arrangement of a system to obtain information on insertion loss or gain as a function of frequency is indicated in figure 3-8. Initially, the device under test is not connected into the system; connect the thermistor mount directly to the sweep oscillator. Set the sweep oscillator for the band of interest, and record variations in amplitude as frequency is swept; this curve is the reference. Next, insert the device under test between the sweep oscillator and the thermistor mount, and again record frequency response. The difference between the second reading and the reference, at any one frequency, is the insertion loss or gain of the device at that frequency.

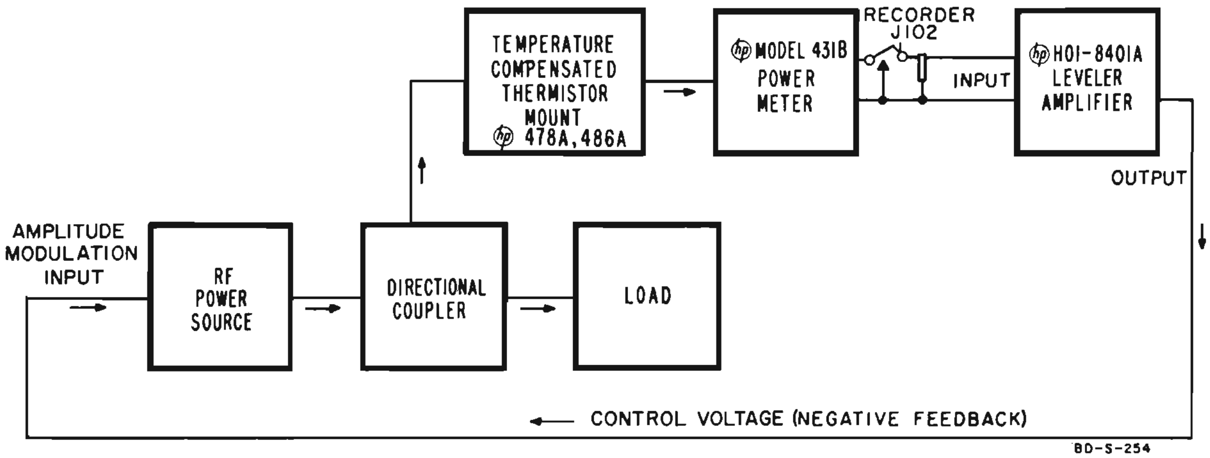


Figure 3-6. Leveler Setup

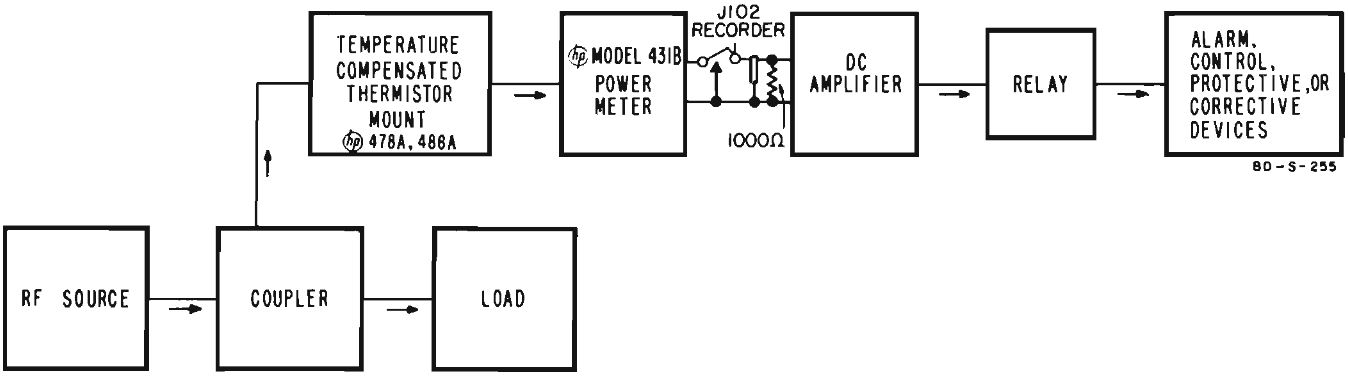


Figure 3-7. Monitor Control Systems

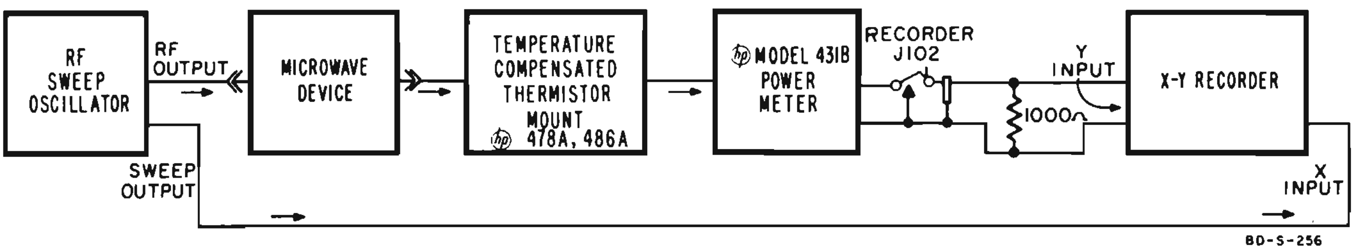


Figure 3-8. Determining Insertion Loss or Gain

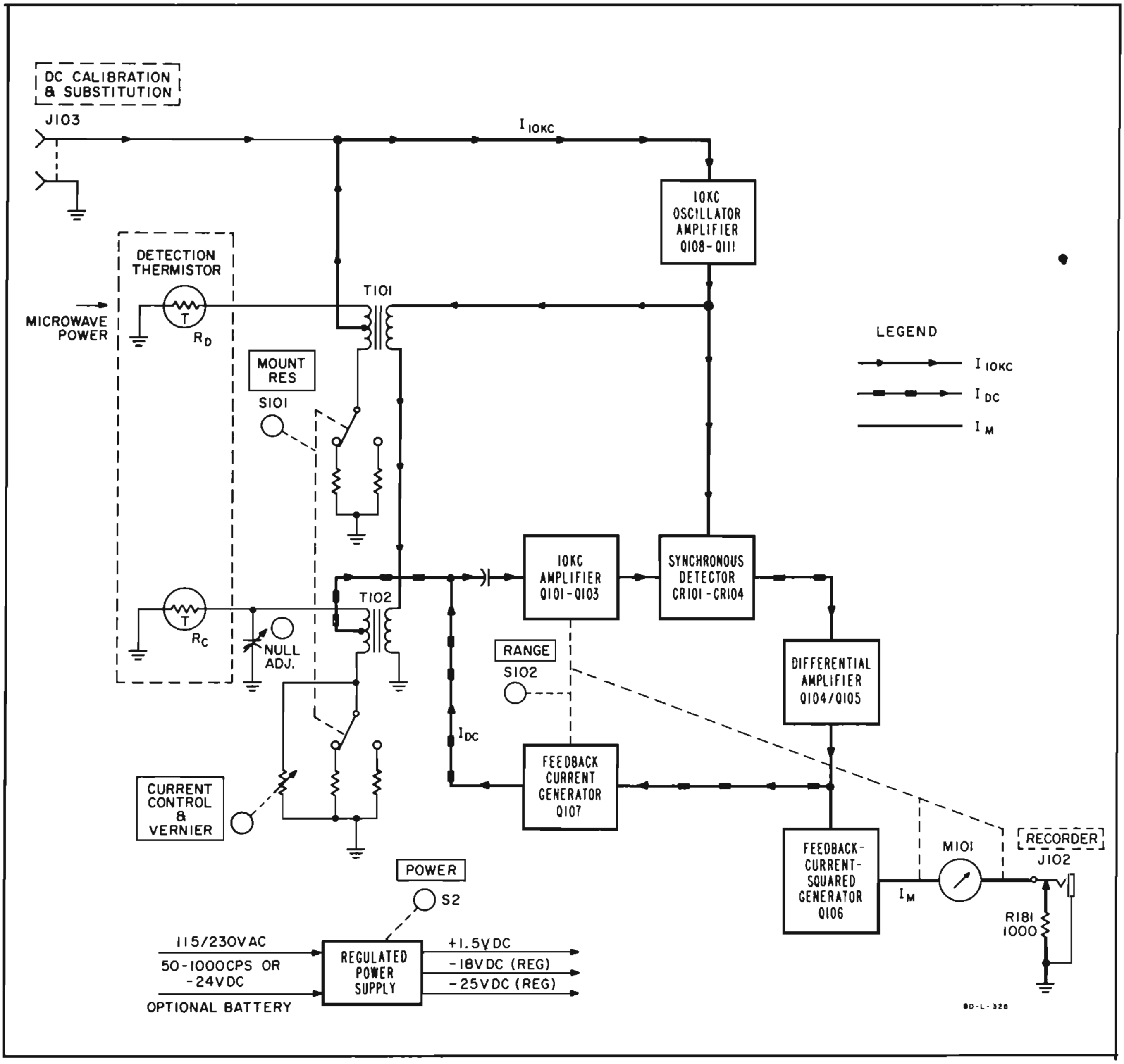


Figure 4-1. Block Diagram

SECTION IV
THEORY OF OPERATION

4-1. OVERALL DESCRIPTION.

4-2. Figure 4-1 is a block diagram which shows the Model 431B Power Meter and its associated thermistor mount. The thermistor mount contains two thermistor elements (R_d and R_c). Thermistor element R_d absorbs the rf power applied to the mount; thermistor element R_c converts the applied rf power to a meter indication and provides compensation 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. One thermistor element is used in one arm of each of the self-balancing bridges. In the detection loop, the 10 kc oscillator-amplifier supplies enough 10 kc power ($I_{10\,kc}$) to bias thermistor element R_d to the operating resistance which balances the rf bridge. The same amount of 10 kc power is also supplied to thermistor element R_c by the series-connected primaries of transformers T101 and T102.

4-4. When rf power is applied to thermistor element R_d, an amount of 10 kc power equal to the rf power is removed from thermistor element R_d by the self-balancing action of the rf bridge. Since the primaries of T101 and T102 are series-connected, the same amount of 10 kc power is also removed from thermistor element R_c, 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 kc power. Since the 10 kc power equaled the applied rf power, the substituted dc power is also equal to the applied rf power. Instead of metering the feedback current directly, which would require the use of a nonlinear meter scale, an analog current is derived which is proportional to the square of the feedback. Since power is a square-law function of current, the analog current thus derived is proportional to rf power, making possible the use of a linear scale on the meter.

4-5. There is little drift of the power meter zero point when ambient temperature at the thermistor mount changes. If, for example, 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 (figure 4-1) which reduces 10 kc power. The amount of dc power in the metering loop remains unchanged however, and since this dc power controls the meter action, the ambient temperature changes does 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 BRIDGE CIRCUIT.

4-8. A simplified schematic diagram of the rf bridge circuit is shown in figure 4-2. The rf bridge circuit consists of the rf bridge and 10-kc oscillator-amplifier. The rf bridge includes thermistor R_d, the secondary winding of T101, resistors R102 and R103, the MOUNT RES switch, S2, and capacitance represented by C_a and C_b. The rf bridge and 10 kc oscillator-amplifier are connected in a closed loop (the detection loop) which provides regenerative feedback for the oscillator-amplifier. This feedback causes the 10 kc oscillator-amplifier to oscillate.

4-9. When the power meter is off, thermistor R_d is at ambient temperature and its resistance is about 1500 ohms; the rf bridge is unbalanced. When the power meter is turned on this unbalance of the rf bridge causes a large error signal to be applied to the 10 kc oscillator-amplifier. Consequently maximum 10 kc bias voltage is applied to the rf bridge. As this 10 kc voltage biases R_d to its operating resistance (100 or 200 ohms) the rf bridge approaches a state of balance and regenerative feedback diminishes until there is just sufficient 10 kc bias power to hold R_d at operating resistance. This condition is equilibrium for the detection loop.

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

4-11. The MOUNT RES switch, S101, changes the resistance arm of the rf bridge so that the bridge will function with either a 100 or 200 ohm thermistor mount.

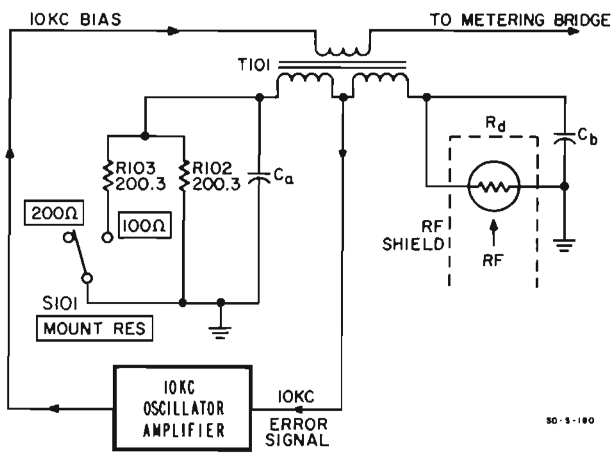


Figure 4-2. RF Circuit

4-12. METERING BRIDGE CIRCUIT.

4-13. A simplified schematic diagram of the metering bridge circuit is shown in figure 4-3. Operation of the metering bridge circuit is similar to the rf 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-kc power is used to rebalance the loop. The resistive balance point is adjusted by the ZERO and VERNIER controls which constitute one arm of the bridge. The MOUNT RES switch (not shown in figure 4-3) which is mechanically linked to both the rf bridge and metering bridge, changes metering bridge reference resistance from 100 to 200 ohms. When the MOUNT RES switch is in the 200-ohm position some of the feedback current is shunted to ground through R101. 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.

4-14. The same 10 kc power change produced in the rf bridge by rf power also affects the metering bridge through the series connection of T101 and T102 primaries. Although this change of 10-kc 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-kc bias power, but the 10-kc bias power does affect the metering circuit. Once a change in the 10-kc bias power has affected (unbalanced) the metering bridge, a separate, closed dc feedback loop (metering loop) re-establishes equilibrium in the metering circuit.

4-15. Variations in 10-kc bias level, initiated in the rf bridge circuit, cause proportional unbalance of the metering bridge, and there is a change in the 10-kc error signal ($S_{10\ kc}$) applied to the 10-kc tuned amplifiers in the metering loop. These error signal variations are amplified by three 10-kc amplifiers, and rectified by the synchronous detector. From the synchronous detector the dc equivalent (I_{dc}) of the 10-kc 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 bridge to its normal, near-balance condition.

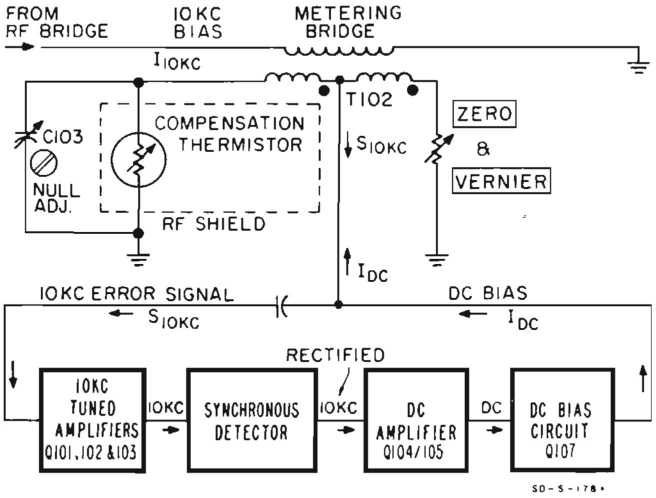


Figure 4-3. Metering Bridge Circuit

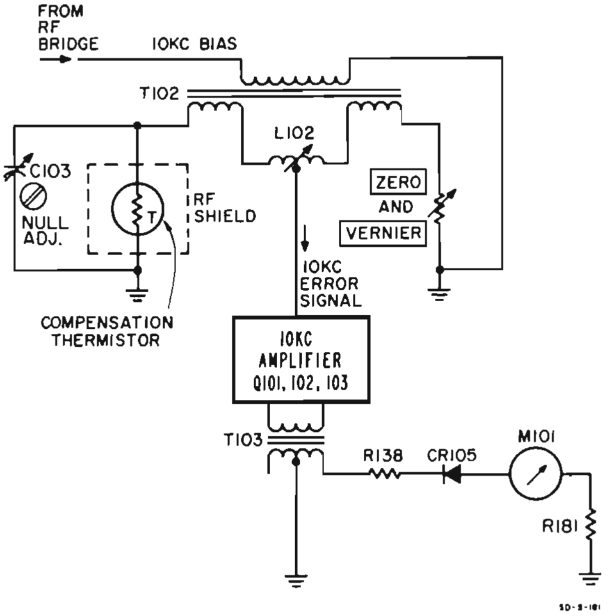


Figure 4-4. Nulling Circuit

4-16. The reactive components of the metering bridge are balanced with variable capacitor C103 and inductor L102. Null adjust, C103, is an operational adjustment and L102 is a maintenance adjustment. Null adjust C103, is adjusted with the RANGE switch in the NULL position. A simplified schematic diagram of the NULL circuit is shown in figure 4-4. The 10 kc signal is taken at the synchronous detector, rectified by CR105, and read on the meter. The rectified signal contains both reactive and resistive voltage components of the bridge unbalance.

4-17. SYNCHRONOUS DETECTOR.

4-18. The synchronous detector converts the 10-kc error signal from the metering bridge to a varying dc signal. A simplified schematic of the synchronous detector is shown in figure 4-5. The detector is a bridge rectifier which has a rectifier in series with a linearizing resistance in each of its arms. Two 10-kc voltages, designated E3 and E4 in figure 4-5, are applied to the bridge; 1) voltage E3, induced in the secondary of transformer T103, is proportional to the metering-bridge error signal and is incoming from 10-kc tuned amplifier Q103; 2) voltage E4, induced in the secondary of T104, is proportional to a voltage supplied by the 10-kc 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 4-5 shows the current path through diodes CR102 and CR104 for a positive-going signal; section B shows the current path through diodes CR101 and CR103 for a negative-going signal. The rectified output is taken at the center taps of transformers T103 and T104.

4-19. Operation of the circuit is as follows: When the left side of T104 is positive with respect to the right side (see figure 4-5A), diodes CR102 and CR104 conduct while diodes CR101 and CR103 are biased off. With the polarities reversed (see figure 4-5B), the

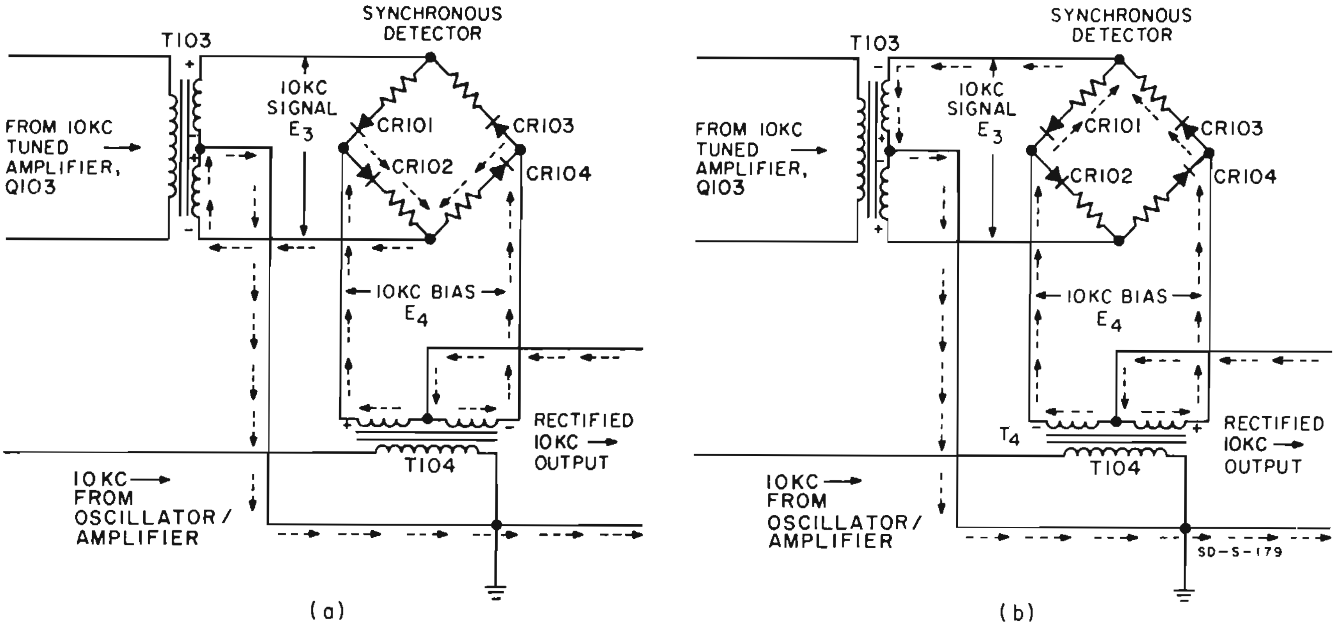


Figure 4-5. Synchronous Detector

diodes CR102 and CR104 are biased off. The resultant output is a pulsating dc signal equivalent to the applied 10-kc error signal. This pulsating dc signal is filtered and applied to differential amplifier Q104/Q105.

4-20. Proper synchronous detector output requires an in phase relationship between E3 and E4 and for amplitude of E4 to be larger than that of E3.

4-21. DIFFERENTIAL AMPLIFIER Q104/Q105.

4-22. A simplified schematic diagram of the amplifier is shown in figure 4-6. The pulsating dc from the synchronous detector is filtered by C117, C118, C119,

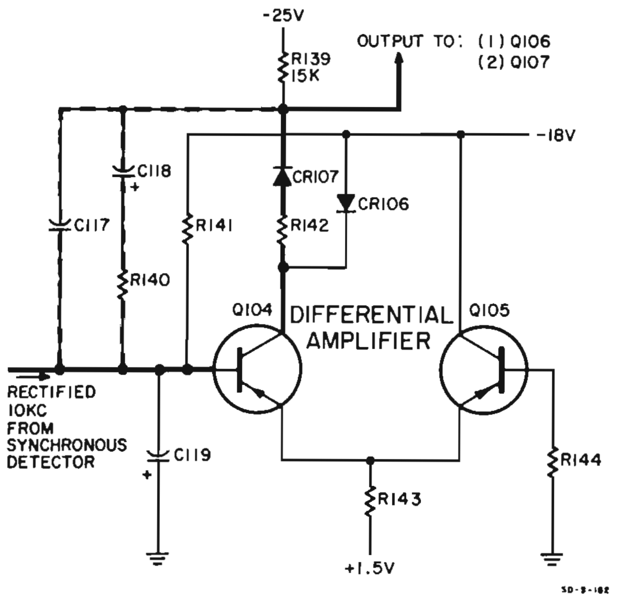


Figure 4-6. Differential Amplifier

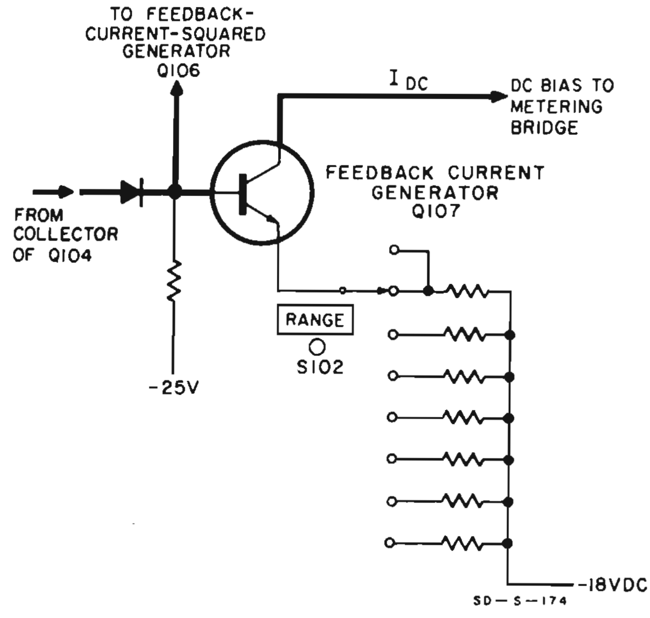


Figure 4-7. Feedback Current Generator

and R140, amplified by Q104 and fed to both the feedback current-squared generator, Q106 (figure 4-7) and feedback current generator Q107. Temperature compensation and low emitter circuit resistance for Q107 are provided by Q105. Diode CR106 protects Q106 and Q107 from excessive reverse bias when Q104 is cut off.

4-23. FEEDBACK CURRENT GENERATOR Q107.

4-24. A simplified schematic diagram of the feedback current amplifier is shown in figure 4-7. The dc signal from the differential amplifier is applied to feedback current generator Q107. Q107 has two functions: 1) it

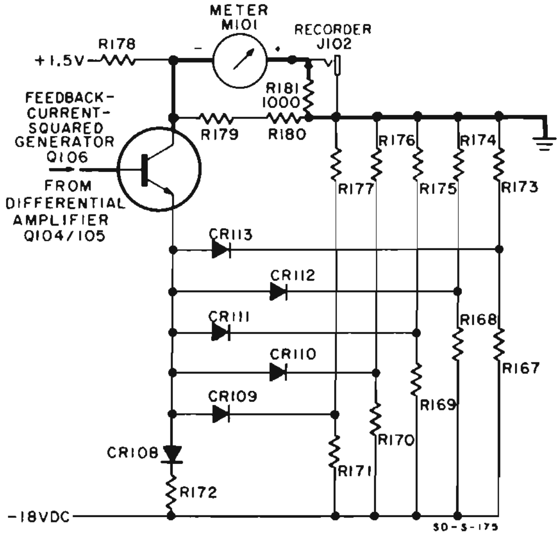


Figure 4-8. Meter Circuit

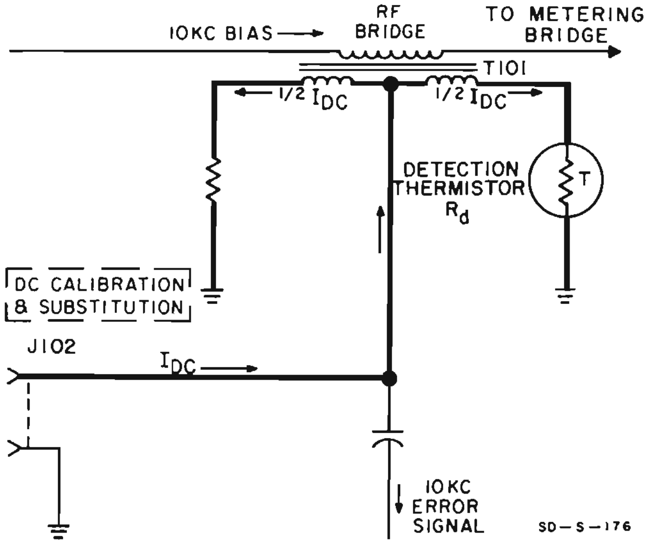


Figure 4-9. DC Calibration and Substitution

completes the metering loop to the metering bridge, and 2) it operates in conjunction with the first 10-kc amplifier, Q101, and the RANGE switch to change metering loop gain so that the meter will read full scale for each power range. Diode CR107 provides additional temperature compensation for Q107.

4-25. METER CIRCUIT.

4-26. The meter circuit is shown in figure 4-8. It includes feedback current-squared generator Q106, a squaring circuit, the meter, and RECORDER jack, J102. The purpose of the meter circuit is to convert a linear voltage function, proportional to applied power, to a squared function so that power may be indicated on a linear meter scale. The linear voltage function is applied to the base of Q106 and is converted to a square law function by the squaring circuit in series with Q106 emitter.

4-27. SQUARING CIRCUIT. The squaring circuit includes diodes CR109-113, and resistors R167-177. Temperature compensation for the squaring circuit is provided by CR108.

4-28. The design of the squaring circuit is such that individual diodes conduct at discrete values of emitter voltage so that emitter conductance approximates a square law function. Thus the collector current of Q106 is made to approximate a square law function, and the meter indicates power on a linear scale.

4-29. RECORDER OUTPUT. The current which drives the meter can be monitored at the RECORDER output, a telephone-type two-wire jack. A RESISTOR OF 1000 OHMS MUST REMAIN IN SERIES WITH THE METER FOR ALL APPLICATIONS USING THE METER-DRIVING CURRENT.

4-30. ZEROING. Perfect balance of the metering bridge would mean that no 10 kc error signal would be applied to the 10 kc amplifiers, there would be no dc feedback from Q107, and the metering loop would be open. With an open metering loop, zero reference could not be accurately established. In the Model 431B this occurrence is prevented by insuring a closed metering loop even when the ZERO control causes the meter pointer to deflect downscale from zero. By the combined actions of R141 and R179, 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 R141, while R179 provides a counter-action in the feedback current-squared generator, Q106, so that the meter can indicate zero even though the metering bridge is not perfectly balanced. Resistor R179 also sets the full scale accuracy of the meter.

4-31. DC CALIBRATION AND SUBSTITUTION.

4-32. A simplified schematic diagram of the dc calibration and substitution circuit is shown in figure 4-9. Highly accurate rf power measurements can be made using the dc substitution technique given in figure 3-3. In the dc substitution method dc is used to duplicate the rf power reading. An accurate, known current (I_{dc}) is supplied externally at the DC CALIBRATION and SUBSTITUTION terminals. Calculation of the substituted dc power gives an accurate measure of the rf power. Effectively, dc power is substituted for rf power.

4-33. REGULATED POWER SUPPLY.

4-34. A simplified schematic diagram of the power supply is shown in figure 4-10. The power supply operates from either a 115 or 230 volt, 50 to 1000 cps ac source or from an optional 24 volt, 30 ma rechargeable battery. Three voltages and two current outputs are provided by the power supply. Regulated voltages of -18 and -25 vdc and unregulated +1.5 vdc operate the power meter circuits. The current outputs are used for maintaining battery charge (trickle charge) for recharging the battery.

4-35. The -18 vdc is regulated by a conventional series regulator, Q1 through Q5. The -25 vdc is developed across CR9, a 6.8 volt zener diode referenced at -18 vdc. The unregulated +1.5 vdc is taken across the series diodes, CR5 and CR6. The -18 vdc supply is adjusted by R13.

4-36. POWER SWITCH.

4-37. A simplified schematic diagram of the power switching arrangement is shown in figure 4-11. The power switch, S2, has four positions: OFF, AC, BATTERY ON, and BATTERY CHARGE. In the AC position, the instrument operates from the conventional line voltage: if a battery has been installed in the instrument, a trickle charge is supplied to the battery. In the BATTERY ON position, instrument operation is entirely dependent on the battery. In the CHARGE position, supply A is connected to the battery for recharging: the Model 431B cannot be operated during this time. Approximately 37 ma dc is applied to the battery during charge time.

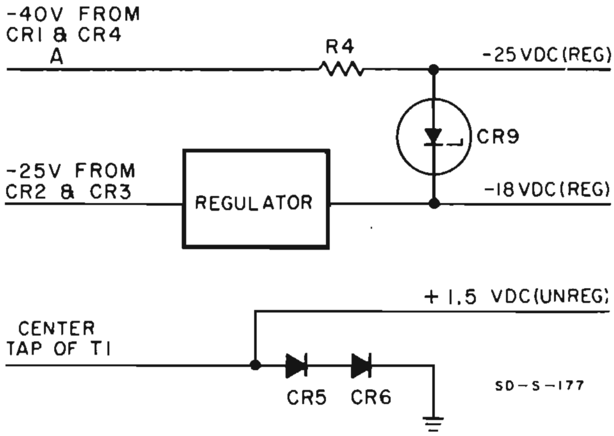


Figure 4-10. Regulated Power Supply

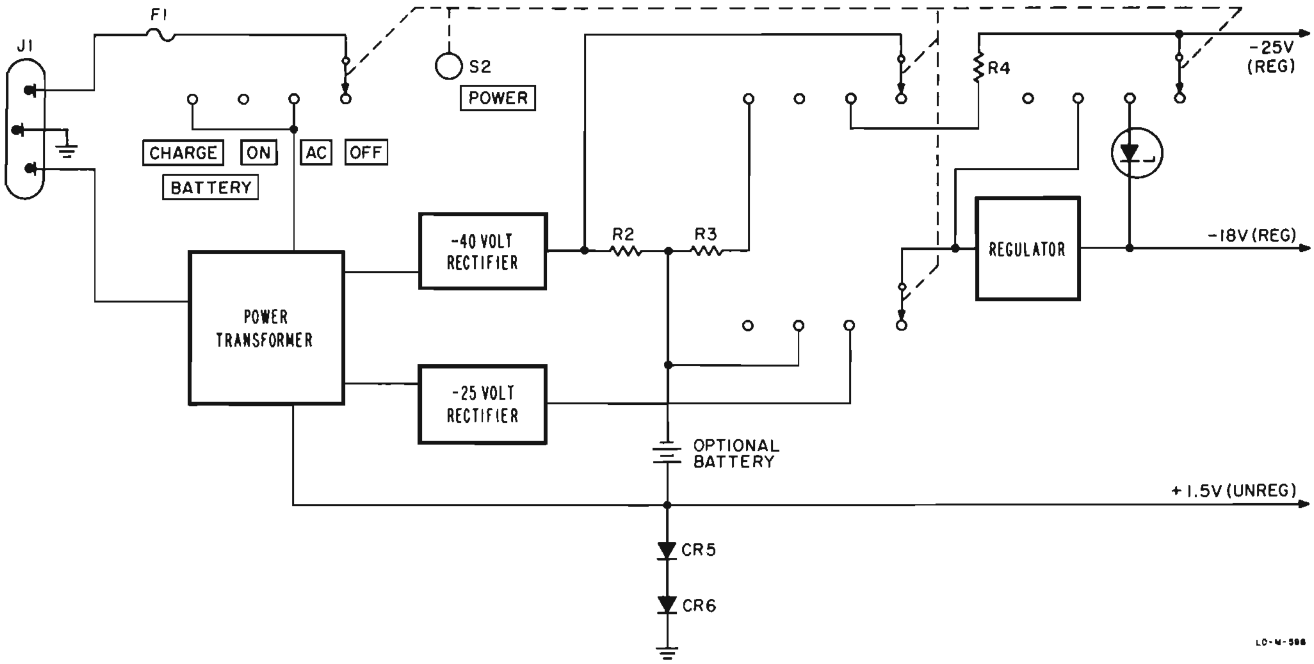


Figure 4-11. Power Switch Arrangement

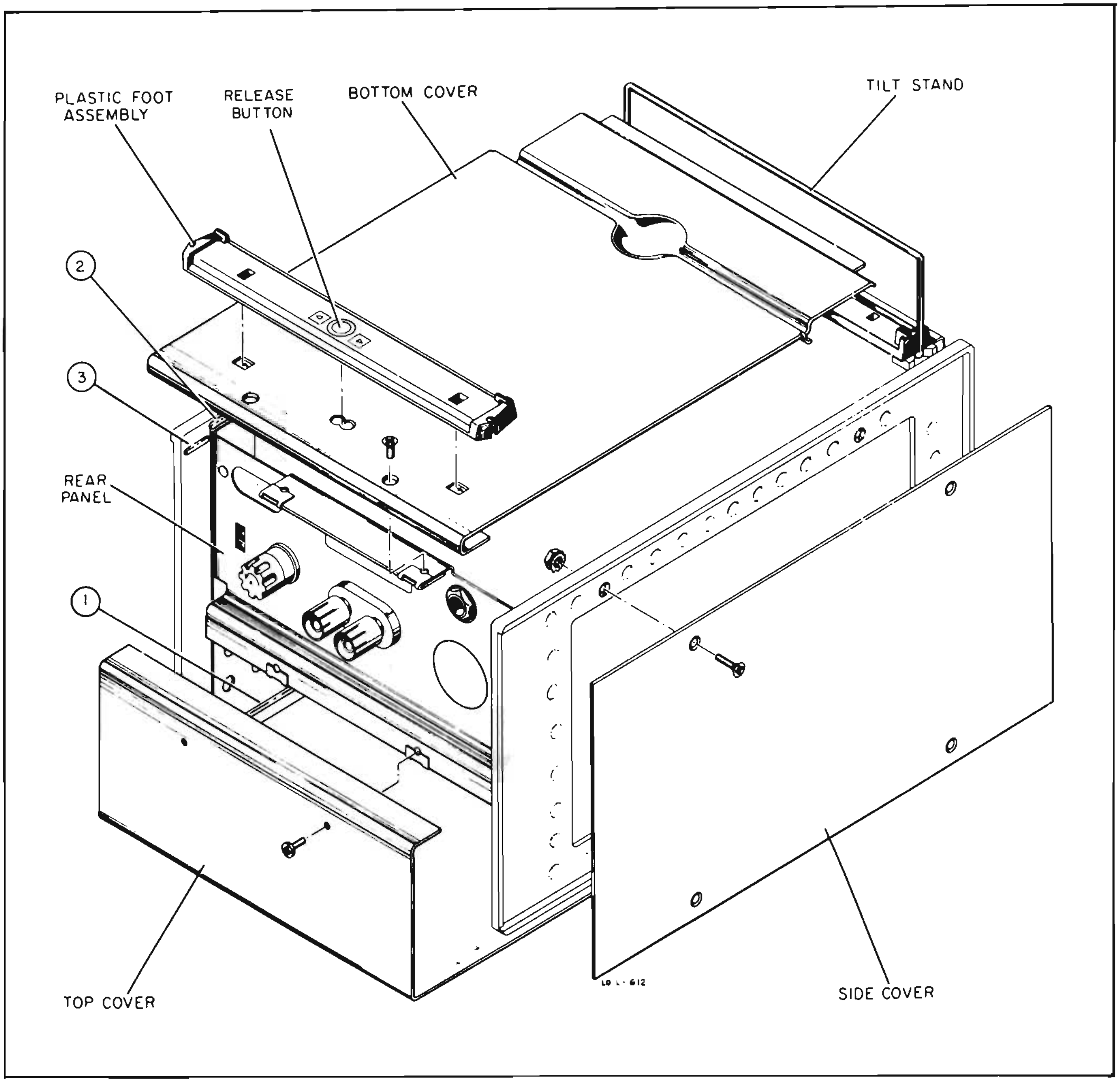


Figure 5-1. Cover Removal

SECTION V
MAINTENANCE

5-1. INTRODUCTION.

5-2. This section includes instructions and information for the maintenance, troubleshooting and repair of the Model 431B Power Meter.

5-3. The testing and repair of hp Model 486A and 478A thermistor mounts are not discussed in this manual. Complex procedures and special equipment are needed for these operations. Therefore, if the cause of trouble is proved to a thermistor mount, an hp Engineering Representative should be contacted or mount should be returned to factory (do not attempt to repair the thermistor mount).

5-4. COVER REMOVAL AND REPLACEMENT.

5-5. Refer to figure 5-1 when removing instrument covers. Removal of the top cover exposes the circuit areas shown in figure 5-2. Routine checks and adjustments can be performed without the removal of other covers. However, operations such as soldering on the circuit board and removal of the meter, RANGE POWER, or MOUNT RES switch would require the removal of the bottom cover and one, or both, of the side covers.

5-6. TOP COVER REMOVAL.

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

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

5-7. 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.

Table 5-1. Test Equipment

Instrument Type	Use	Critical Specifications		Instrument Recommended
DC voltmeter	DC voltage measurement Calibration accuracy check	Range: 0.5 to 50 volts dc Accuracy: ±0.2% Resolution: three digit		hp 405BR/CR
Ohmmeter	Continuity & resistance checks	Range: 1 ohm to 10 megohms Accuracy: 5% of full scale		hp 410B hp 412A
Precision milliammeter or Power Meter Calibrator	Calibration accuracy check	Milliammeter	Accuracy: 0.1% of full scale Range: 0 to 30 ma	Sensitive Research Instrument Corp Model B, Bamilek
		Calibrator	Current accuracy: 0.1% Resistance accuracy: 0.2%	hp 8402A Power Meter Calibrator
Milliammeter	Battery circuit check	Range: 3 to 60 ma Accuracy: 5%		hp 412A hp 428A/B
Oscilloscope or AC voltmeter	Power supply ripple check 10 kc oscillator-amplifier check 10 kc amplifier check 10 kc amplifier null adjust	Oscilloscope	Bandwidth: 100 kc Accuracy: 5% Input impedance: 1 megohm Sensitivity: 1 mw/cm	hp 130B/C hp 120B hp 122A
		AC voltmeter	Accuracy: 5% Input impedance: 1 megohm Range: .01 to 100 mv	hp 400D/H/L hp 403A/B

Table 5-1. Test Equipment (Cont'd)

Instrument Type	Use	Critical Specifications	Instrument Recommended
DC Source or Power Meter Calibrator	Calibration accuracy check	Range: 0 to 220 vdc or Current Output: 0 to 20 ma	ⓗⓟ 711A, 712B Power Supplies 8402A Power Meter Calibrator
Thermistor Mount	Completion of test circuit	See table 1-2 for list of suitable mounts	ⓗⓟ 478A, 486A
Transformer to vary line voltage	Power supply regulation check	Voltage Range: 103 to 127 vac 207 to 253 vac Current Rating: 1 amp	General Radio W5MT3A
Frequency counter	10 kc oscillator-amplifier check 10 kc oscillator-amplifier frequency adjust	5 place readout Min. input sensitivity: 4 v rms Max. frequency: greater than 10 kc Accuracy: better than 0.1%	ⓗⓟ 521C or E ⓗⓟ 5212A ⓗⓟ 5512A
Variable Transformer	Power supply adjustment	Range: 103 to 127 vac @ 7-1/2 amp 206 to 254 vac @ 4 amp Voltmeter range: 100 to 127 vac 200 to 254 vac Voltmeter accuracy: ±1 volt	General Radio type W10MT3A
Soldering Iron & Tips	Repair	Wattage rating: 50 watts Min tip temp: 800°F Tip size O.D.: 1/16" to 3/32	Ungar #776 soldering iron handle Ungar #PL333 tiplet Ungar #854 Cup tip
Resistor	Charging checks	Value: 780 Ω Accuracy: ±1% Wattage: 3 watts	Dale Type RS-2
Resistor	Charging checks	Value: 7500 Ω Accuracy: ±1% Wattage: 2 watts	Electra MF2, T-0
Decade Resistance Divider	Zero and vernier control adjustment Full scale accuracy adj	Range: 50 Ω to 50K Ω Multiple: 10 Ω Accuracy: 1% per decade	GR1432P Decade Resistance Box
Precision Resistor	Zero and vernier control adjustment	Value: 1000 Ω Accuracy: ±0.1% Wattage: 0.25 watts	Ultronex Type 205A
Decade Capacitors	Oscillator frequency adjustment Coarse null adjustment	Range: 10 to 1000 pf Capacitance per step: .0001 μfd Accuracy: .1% per decade	General Radio Type 1419-B

5-8. 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.

5-9. 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.

5-10. SIDE COVER REMOVAL.

5-11. The side covers cannot be removed until the top and bottom covers are off (see paragraphs 5-6 and 5-8). Each side cover is held in place by four screws retained by nuts which are not fastened to the side frames.

Note

Replace side covers before replacing either the top or the bottom cover.

5-12. TEST EQUIPMENT.

5-13. Any instrument which satisfies the specifications of table 5-1 can be used for the test described in this maintenance section.

5-14. TROUBLESHOOTING.

5-15. The first step in troubleshooting the Model 431B Power Meter should be isolation of trouble to the thermistor mount and thermistor mount cable or to the power meter itself. The thermistor match check in the maintenance section of the ⓗⓟ Operating Note pertaining to the thermistor mount in use will indicate a defective thermistor or thermistors. A simple ohmmeter continuity check and inspection of the thermistor mount cable and its connectors can be used to prove the cable.

5-16. Table 5-2, Troubleshooting, and the following detailed tests are given to aid in correcting trouble within the Model 431B. To make localizing of trouble easier, the 431B circuitry is divided into five sections; the power supply, the 10 kc oscillator-amplifier (including the rf bridge), the 10 kc amplifier (including the metering bridge), the dc metering and feedback amplifiers, and the squaring circuit. Tests are given for each of these sections.

5-17. THE POWER SUPPLY.

5-18. The dc test point voltages shown on the power supply schematic diagram, with two exceptions, apply to instruments operated from either ac or battery primary power. Voltage limits shown at C1 and C2 apply only to instruments operated from ac primary power. Refer to figure 5-2, Top View, for component location.

a. Connect Model 431B to a variable line transformer and set transformer for 115 vac (or 230 vac).

b. Connect a dc voltmeter (see table 5-1 for voltmeter requirements) between the negative terminal of C6 and Model 431B ground. The voltage here should be -18 vdc; adjust with potentiometer R13.

c. With the voltmeter connected as above, test the regulation of the power supply (for instruments

Table 5-2. Troubleshooting

Trouble Indication	Possible Cause
Null impossible	Thermistor mount Thermistor mount cable MOUNT RES switch T102
Meter does not indicate, does not zero but does null	Q106
Meter pointer drifts during readings	Thermistor mount Q106, Q107 Thermistor mount in unstable thermal environment RF source unstable DC calibration/substitution source unstable Oscillator-amplifier 10 kc amplifier Interference from external 10 kc signal
Rotation of the ZERO or VERNIER control results in erratic movement of the meter pointer on the .01 MW range	ZERO or VERNIER potentiometer
Movement of the thermistor mount cable causes abrupt flicker of the meter pointer on the .01 MW range	Thermistor mount Thermistor mount cable
Meter pointer stays down scale	T102 Thermistor mount Thermistor mount cable Power supply Meter RECORDER jack Q106 C102, C101 10 kc amplifier

Table 5-2. Troubleshooting (Cont'd)

Trouble Indication	Possible Cause
Meter pointer stays up scale	T102 Oscillator failure Thermistor mount cable Large unbalance in the metering bridge C105 C104 10 kc amplifier failure
Calibration inaccurate, all power ranges	Thermistor mount in strong rf field Interference from stray 10 kc signal Thermistor mount Meter not mechanically zero-set Meter MOUNT RES switch Power supply Battery 10 kc amplifier Collector resistor R101 Q107, Q106 Q102
Calibration inaccuracy, NOT all power ranges	Resistors emitter Q107 Q106 10 kc amplifier
Zero setting does not carry over from range to range within specification	Q106 R141 Q104

operated from ac primary power) by varying the line voltage ±10% about the nominal 115 or 230 vac. There should be no perceptible variation of the -18 vdc.

d. If -18 volts cannot be obtained by adjustment of R13, or if regulation is not satisfactory, proceed with the following test to determine the causes:

(1) Use a dc voltmeter (see table 5-1) to check the ac voltage limits at the points listed in table 5-3. See figure 5-2, top view, for component location. All voltages are measured with reference to the Model 431B ground.

(2) Check ripple voltages (ac operation), using an ac voltmeter or oscilloscope, at the points listed in table 5-4. Table 5-1 gives requirements for the voltmeter or oscilloscope.

5-19. If the power meter does not function normally (e.g., pointer driven to its limits, no power indication) and power supply regulation is unsatisfactory, another circuit area, such at the 10 kc oscillator-amplifier or 10 kc amplifier, could be the cause.

5-20. A -18 vdc supply which is set high or low causes calibration inaccuracy of the Model 431B.

5-21. 10-KC OSCILLATOR-AMPLIFIER CHECK.

5-22. Tests of the oscillator-amplifier should be made according to the step sequence in which they appear below. A dc voltmeter, an ac voltmeter or oscilloscope and a frequency counter are needed for the tests (see table 5-1 for test instrument specifications). Figure 5-2, Top View, shows component location.

5-23. STEP 1.

a. Connect the oscilloscope between the positive lead of C125 and ground, check the 10 kc oscillator-amplifier output amplitude and waveform. Output amplitude, with a 200 ohm thermistor mount connected to the Model 431B, should be 15 vac ±20% peak-to-peak. If a 100-ohm mount is used, the amplitude should be 8 vac ±20% peak-to-peak. The waveform must be sinusoidal with only slight cross-over distortion (caused by Q110 and Q111).

b. Check the frequency of the oscillator-amplifier. If a Model 478A thermistor mount is used, terminate the rf input to the mount in 50 ohms. A Model 486A thermistor mount does not require termination. Connect the frequency counter between the positive lead of C125 and ground. With Model 478A thermistor mount connected to the Model 431B, the oscillator-amplifier frequency should be 9750-10,000 cps. With a Model 486A thermistor mount connected, the frequency should be 10 kc ±50 cps.

5-24. STEP 2.

a. Connect the oscilloscope between the base of Q108 and ground; observe the amplitude of the feedback signal to the oscillator-amplifier. It must be less than 12 mv peak-to-peak: if not, 10 kc oscillator-amplifier gain is incorrect. The cause could be Q108, Q109, C124, L101, L105 or T101. If T101 is the cause of trouble use a special soldering tip to remove it from etched circuit board (see table 5-1).

Table 5-3. Power Supply DC Voltage Checks

Test Point	DC Voltage Limits	Voltage Out of Limits, Check
Minus end of C1	-38 to -43	ac line voltage, CR1, CR4, C1
Minus end of C2	-24 to -27	ac line voltage, CR2, CR3, C2, battery
Anode of CR8	-10.7 to -12.3	CR8
Anode of CR7	- 6.0 to - 7.5	CR7, Q3
Minus end of C6	-18	R13, Q5, Q2
Base of Q1	-18.3 to -18.6	Q1, Q3, Q2, CR7
Anode of CR9	-24.0 to -25.6	CR9, POWER switch
Plus end of C1	+ 1.4 to +1.5	CR5, CR6

Table 5-4. Power Supply Ripple Checks

Test Point	AC Voltage Limits		Voltage Out of Limits, Check
	R.M.S.	Peak-to-Peak	
Minus end of C1	1.8 v max.	5 v max.	CR1, CR4, C1
Minus end of C2	1.1 v max.	3 v max.	CR2, CR3, C2, C6, Q13
Minus end of C6	10.6 mv max.	30 mv max.	Q1 to Q5, CR7, CR15, C2, C6

Table 5-5. 10 KC Oscillator-Amplifier DC Voltage Checks

Test Point	DC Voltage Limits	Voltage Out of Limits, Check
Collector of Q110	-18	Power Supply
Emitter of Q109	-10.0 to -14.0	Q108, Q109, C122, C121
Minus end of C121	- 5.0 to - 6.5	C121, Q108, R153

Table 5-6. 10 KC Amplifier DC Voltage Checks

Test Point	DC Voltage Limits	Voltage Out of Limits, Check
Emitter of Q101	-1.5 to -2.5	C112, R116, R115, C110, Q101
Collector of Q101	-4.5 to -6.0	Q101, C113, R117 to R124
Positive end of C116*	-3.5 to -4.5	Q103, R132, Q102, C115
* Short base to emitter of Q101		

Table 5-7. DC Voltages in Squaring Circuit

Test Point	DC Voltage Limits	Voltage Out of Limits, Check
Cathode CR113	+ 10.30 to + 10.46	CR113, R167, R173
Cathode CR112	+ 8.50 to + 9.64	CR112, R174, R168
Cathode CR111	+ 6.41 to + 6.51	CR111, R175, R169
Cathode CR110	+ 4.39 to + 4.47	CR110, R176, R170
Cathode CR109	+ 2.48 to + 2.52	CR109, R177, R171
Cathode CR108	0	CR108, CR109 to CR113

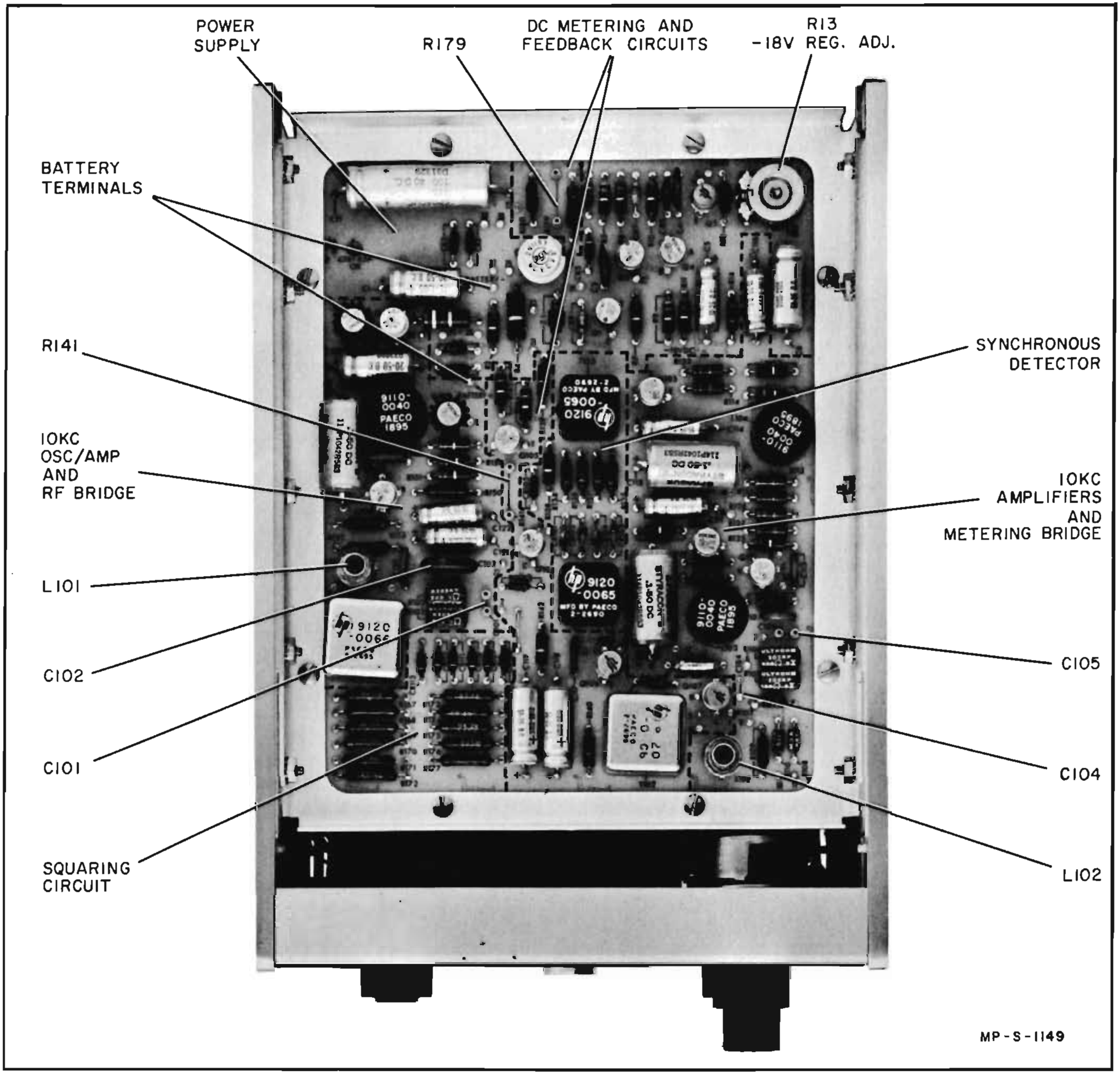


Figure 5-2. Top View

b. Using the dc voltmeter, make dc measurements at the points listed in table 5-5. If the presence of 10 kc signal interferes with the dc measurements, the 10 kc oscillator can be disabled, without appreciably affecting the dc voltages, by grounding the collector of Q109. DC voltages are measured with reference to the Model 431B ground.

5-25. STEP 3. If there is no 10 kc output from the oscillator-amplifier proceed as follows:

a. Disconnect the thermistor mount.

b. Disconnect the positive lead of C125 from the circuit board.

c. Make a direct connection between the positive lead of C125 and bridge side of C120 (terminal 35 on the underside of the circuit board).

d. Using the oscilloscope, monitor the output of the oscillator-amplifier. If oscillation is present, the metering and rf bridges should be examined for defect. The waveform of the oscillation under this condition may show limiting.

5-26. If component replacement is required as a result of the foregoing tests, note the following:

a. After replacement of Q110 or Q111, check the amplitude of the 10 kc oscillator-amplifier output (paragraph 5-23a).

b. If Q108 or Q109 has been replaced, check the output frequency of the oscillator-amplifier (para. 5-23b).

c. After replacement of L105 or C124, readjustment of the oscillator frequency could be necessary. See paragraph 5-58 for this procedure.

5-27. 10 KC AMPLIFIER CHECK.

5-28. A dc voltmeter and oscilloscope are needed for checking the 10 kc amplifier. Table 5-1, Test Equipment, gives equipment requirements. Refer to figure 5-2, Top View, for component location.

5-29. Table 5-6 lists dc voltage check points and possible causes for deviations from the given limits. All voltages are referenced to the Model 431B ground. If the presence of a 10-kc signal interferes with dc measurement, ground the center tap of L102.

5-30. Calibration inaccuracy, common to all power ranges, can be caused by the 10 kc amplifier. In particular, an out-of-tolerance resistor in the collector of Q101 or a defect in the Q102 stage, which results in improper gain, will produce calibration error.

5-31. An open signal path or very low gain in the 10-kc amplifier can drive the meter pointer to its downscale limit. For signal tracing, the 10 kc error signal from the metering bridge can be used, or C110 can be disconnected and used as a means of injecting a substitute 10 kc test signal.

Note

A special soldering tip is required to replace transformer T102. Refer to table 5-1 for the type of soldering tip to be used.

5-32. METERING AND FEEDBACK CIRCUIT.

5-33. Before performing this procedure refer to paragraphs 5-69 and 5-70 and check values of R141 and R179. The differential amplifier (Q104 and Q105), the feedback current squared generator (Q106), the feedback current generator (Q107), and the squaring circuit comprise the metering and feedback circuit. See figure 5-2, top view, for component location.

Note

Transistors Q106 and Q107 are selected for optimum calibration accuracy. If Q106 or Q107 is replaced, check calibration accuracy using procedure given in paragraph 5-76 or 5-78. It may be necessary to try several transistors to get proper calibration accuracy.

5-34. SQUARING CIRCUIT CHECKS.

5-35. A check of the squaring circuit is advisable if full scale or tracking accuracy of the Model 431B does not meet specifications. The squaring circuit includes CR108 through CR113 and R167 through R177. Figure 5-2, Top View, shows component location.

5-36. The squaring circuit is tested under two conditions: (1) when all diodes are conducting, and (2) when no diodes are conducting. Both conditions should be used whenever the squaring circuit is tested.

5-37. A digital voltmeter (see table 5-1) for specifications) is recommended for the following measurements.

5-38. DIODES CONDUCTING. The following procedure measures the forward voltage drop of each diode in the squaring circuit.

a. Set the Model 431B RANGE switch to 1 MW, and adjust the ZERO and VERNIER controls for exact full scale deflection of the meter pointer.

b. Disconnect the grounding link at the digital voltmeter input, and measure the voltage drop across the individual diodes of the squaring circuit. The requirement is 0.4 to 0.5 vdc.

5-39. DIODES OFF. The test points listed in table 5-7 are the midpoints of five two-resistor voltage dividers connected between -18 vdc and ground. This check verifies that each diode is properly back biased.

a. Adjust the Model 431B ZERO control for a below-zero deflection of the meter pointer.

b. Connect the voltmeter (ungrounded input) between the regulated -18 vdc supply and the test points listed in table 5-7. The voltmeter readings should be within the limits specified in the table.

5-40. BATTERY AND CHARGING CHECKS.

5-41. The information and procedures which follow pertain to power meters having the optional nickel cadmium battery. The battery is an assembly of 20 individual, permanently sealed cells connected in series. At full charge, battery terminal voltage should be 27 volts ±1 volt. An inoperative cell reduces terminal voltage by approximately 1.3 volts.

5-42. BATTERY CHECK.

5-43. BATTERY VOLTAGE. A dc voltmeter is needed for this test. See table 5-1 for voltmeter requirements.

a. Make sure that the Model 431B is disconnected from the ac line. Connect the dc voltmeter between the BATTERY - and BATTERY + terminals on the etched circuit board.

b. Set the POWER switch to BATTERY ON and observe the voltmeter reading. Battery voltage should be -24 to -27 volts. If it is not, and the battery has been charged, check the charging circuits and the current drain imposed by the Model 431B circuitry. If the state of charge of the battery is uncertain, allow a 48-hour recharge, then recheck the battery voltage. Check the charging circuits if the battery voltage is still not within 27 ±1 volt.

5-44. BATTERY CURRENT DRAIN. The current supplied by the battery to the Model 431B circuitry should be checked if the battery does not seem to maintain a charge. A clip-on or series-connected current meter (see table 5-1) is required for the following procedure.

a. Check that the Model 431B is disconnected from the ac line.

b. Connect the current meter to monitor the current in one of the leads between the battery terminals and the BATTERY - and BATTERY + terminals on the circuit board.

c. Set the POWER switch to BATTERY ON and observe the reading on the current meter; it should read 40 to 53 ma.

5-45. CHARGING CHECKS.

5-46. The following procedures test the recharge and trickle charge capability of the Model 431B. A direct current meter (see table 5-1), a 7500 ohm ±1%, 2 watt resistor and a 780 ohm ±1%, 3 watt resistor are required for these tests. The battery is disconnected from the BATTERY - and BATTERY + circuit board terminals during both tests.

5-47. TRICKLE CHARGE CURRENT. The following procedure is used to check the trickle charge current applied to the battery when the power meter is operated from ac primary power.

a. Connect the 7500 ohm 2-watt resistor between the BATTERY - and BATTERY + terminals of the circuit board.

b. Connect the current meter to monitor the current through the resistor.

c. Connect the Model 431B to the ac line, set the POWER switch to AC, and observe the reading of the current meter. Trickle-charge current should be 3.2 to 4.8 ma.

5-48. CHARGE CURRENT. The following procedure checks the current supplied for recharging the battery.

a. Connect the 780 ohm 3-watt resistor between the BATTERY - and BATTERY + terminals of the circuit board.

b. Connect the current meter to monitor current through the resistor.

c. Connect the Model 431B to the ac line, set the POWER switch to BATTERY CHARGE, and observe the reading of the current meter. Charging current should be 27 to 40 ma.

5-49. A battery which will not assume rated terminal voltage with proper charging current may have a defective cell or cells. In such cases the battery must be replaced (see section VI Table of Replaceable Parts).

5-50. BATTERY WARRANTY.

5-51. The warranty, appearing on the inside of the rear cover of this manual, also applies to the accessory battery (option 01). Within the warranty period, the battery may be returned to hp Customer Service for repair or replacement.

5-52. REPAIR.

5-53. The etched circuit board used in the Model 431B is of the plated-through type which consists of a base board and conductor. The board does not include funneled eyelets. The conductor material is plated to the wall of the holes; thus the conductor is effectively extended into the hole. This type of board can be soldered from either the conductor or component side of the board with equally good results. The rules given below should be followed when repairing a plated-through type etched circuit board.

a. Avoid applying excessive heat when soldering on the circuit board.

b. To remove a damaged component, clip component leads near the component; then apply heat and remove each lead with a straight upward motion.

c. Use a special tool to remove components having multiple connections, such as potentiometers, transformers, etc. Refer to table 5-1 for type of soldering tip required.

d. Use a toothpick to free hole of solder before installing a new component.

5-54. MECHANICAL ADJUSTMENT OF METER ZERO.

5-55. When meter is properly zero-set, pointer rests over the zero calibration mark on the meter scale when the instrument is 1) at normal operating temperature, 2) in its normal operating position, and 3) turned off. Zero-set as follows to obtain best accuracy and mechanical stability:

a. Allow the instrument to operate for at least 20 minutes; this allows the meter movement to reach normal operating temperature.

b. Turn instrument off and allow 30 seconds for all capacitors to discharge.

c. Rotate mechanical zero adjustment screw until pointer is on zero. Reverse direction of adjustment screw approximately 3° in order to free adjustment screw from meter movement. If the pointer moves while freeing the adjustment screw, this step must be repeated.

Note

Use of the parallax-eliminating mirror on the meter scale increases the accuracy of the mechanical zero-set.

5-56. ADJUSTMENTS.

5-57. POWER SUPPLY ADJUSTMENT.

a. Connect a dc voltmeter (see table 5-1 for required specifications) between the negative end of C6 and Model 431B ground.

b. Adjust -18 v REG. ADJ., R13, for -18 vdc.

c. Vary line voltage from 103 to 127 vac (207 to 253 vac): -18 vdc should not vary perceptibly.

5-58. OSCILLATOR FREQUENCY ADJUSTMENT.

5-59. If both 100 and 200 ohm thermistor mounts are to be used interchangeably with the Model 431B, the frequency of the 10 kc oscillator-amplifier should be adjusted in the following sequence: the 200 ohm mount procedure, paragraph 5-61, then the 100 ohm mount procedure, paragraph 5-62. If only one type of mount will be used with the power meter only the appropriate procedure is required.

5-60. An oscilloscope and frequency counter are needed for these adjustments. See table 5-1, Test Equipment for requirement. A plastic alignment tool should be used for the adjustment of L101 to avoid core damage.

5-61. 200 OHM MOUNT. The following procedure adjusts the 10 kc oscillator frequency when a 200 ohm thermistor mount is connected to the Model 431B.

a. Connect the 200 Ω thermistor mount and cable to the Model 431B; set the MOUNT RES switch to 200 Ω.

b. Connect the frequency counter between the plus end of C125 and ground; adjust L101 to give a frequency of 10,150 cps.

c. Connect the oscilloscope to the base of Q108 and observe the feedback signal amplitude. It should not exceed 12 mv peak-to-peak.

5-62. 100 OHM MOUNT. The following procedure adjusts the 10 kc oscillator frequency when a 100 ohm thermistor mount is connected to the Model 431B.

a. Connect the 100 ohm thermistor mount and cable to the Model 431B, and set MOUNT RES to 100 Ω.

b. Connect the frequency counter between the positive end of C125 and ground. The frequency should be 10 KC ±50 cps. If it is not, proceed with step c.

c. Substitute values of capacitance for C101 until the frequency is within the limits of step b.

Note

A decade capacitance box can be used to determine proper value of capacitance that must be used (see table 5-1).

5-63. COARSE NULL ADJUSTMENT.

5-64. If both 100 and 200 ohm thermistor mounts are to be used interchangeably with the Model 431B, the coarse null adjustment should be made in the following sequence; the procedure in paragraph 5-67 first, and then the procedure in paragraph 5-68.

5-65. If only a 200 ohm thermistor mount is to be used with the power meter, follow the procedure of paragraph 5-68. When only a 100 ohm thermistor mount is to be used, the procedure of paragraph 5-67 is sufficient.

5-66. An oscilloscope or ac vtvm is needed for these adjustments. See table 5-1, Test Equipment, for requirements. A plastic alignment tool should be used for the adjustment of L102 to avoid core damage.

5-67. 100 OHM MOUNT. The following procedure is used to make coarse adjustment of the null when a 100 ohm thermistor mount is connected to the Model 431B.

a. Set MOUNT RES to 100 Ω.

b. Observe the arrangement and travel of null capacitor C103, then mechanically center C103.

c. Connect the oscilloscope or ac vtvm between ground and the base of Q103.

d. Switch the Model 431B on and set RANGE to 10 MW.

e. Adjust the ZERO control to maintain a meter indication of less than 5% of full scale on the Model 431B while adjusting L102 for a minimum indication on the oscilloscope or vtvm.

f. Set RANGE to .01 MW and repeat step e, this time maintaining an on-scale meter indication on the Model 431B.

g. Move the oscilloscope or vtvm connection from the base of Q103 to the lead of R138 nearest T103.

h. Adjust null capacitor C103 to minimize the oscilloscope or vtvm indication. Minimum indication should occur with the capacitor near the center of its range.

Note

A decade capacitance box can be used to determine the value of capacitance to be added (refer to table 5-1).

i. Set Model 431B RANGE switch to NULL. Adjust the null capacitor, C103, for a minimum indication on the Model 431B meter. Minimum indication should occur at less than 4% of full scale and C103 should be near its mid-range.

5-68. 200 OHM. The following procedure is used to make coarse null full adjustment when a 200 ohm thermistor mount is connected to the Model 431B.

a. Set MOUNT RES to 200 Ω.

b. Set RANGE to .01 MW.

c. Connect the oscilloscope or vtvm between ground and the lead of R138 nearest T103.

d. Mechanically center the null capacitor, C103, by observing its rotor plates.

e. Using the ZERO and VERNIER controls, maintain an on-scale indication on the Model 431B meter while substituting values for C105 to obtain a minimum indication on the oscilloscope or vtvm.

f. Adjust C103, the null capacitor, to improve the minimum indication on the oscilloscope or vtvm. The null capacitor should be near mid-range.

Note

A decade capacitance box can be used to determine the value of capacitance to be added (see table 5-1).

g. Set RANGE to NULL. The Model 431B meter deflection should be less than 4% of full scale. If it is not, increase the value of C104 in approximately 50 pf increments to a maximum value of 500 pf. If 100 and 200 ohm thermistor mounts are to be used, repeat the null procedure for 100 ohm mounts (paragraph 5-67) after each increase in capacitance of C104.

5-69. ZERO AND VERNIER CONTROL ADJUSTMENT.

a. Connect a dc digital voltmeter (see table 5-1) at the Model 431B RECORDER jack. Use a special telephone-plug-to-dual-banana-plug cable assembly terminated with a 1000-ohm ±0.1% 0.25-watt wire-wound resistor.

b. Set Model 431B RANGE to .01 MW, and adjust Model 431B ZERO and VERNIER controls for zero meter reading on the Model 431B.

c. Set Model 431B RANGE to 10 MW.

d. Connect a decade resistance box across R141 (see figure 5-2), and adjust to obtain zero indication on Model 431B Power Meter.

e. Note amount of resistance required from resistance box to obtain zero indication.

f. Remove the decade resistance box, and replace with resistor of value noted in step e.

g. Check the Model 431B range-to-range zero drift by 1) setting Model 431B RANGE to .01 MW, and re-adjusting its VERNIER for zero meter reading, 2) switching the Model 431B through its complete range while observing the digital dc voltmeter reading. Test limits: digital dc voltmeter reading must not exceed +5 mv (+0.005V) on any Model 431B range.

5-70. FULL SCALE ACCURACY ADJUSTMENT.

a. Connect a ℎ𝑝 Model 8402A (see table 5-1) at the Model 431B POWER METER terminals. Check that Model 8402A OUTPUT CURRENT is off.

b. Set Model 431B RANGE to 10 MW; set Model 8402A RANGE (MW) to 10 MW, and FUNCTION to CAL.

c. Adjust the Model 431B ZERO and VERNIER controls for a zero indication on the meter.

d. Set Model 8402A OUTPUT CURRENT to ON; note and record the Model 431B percent-of-power-reading error.

e. Set Model 8402A OUTPUT CURRENT to off.

f. Set Model 431B RANGE to 3 MW; set Model 8402A RANGE (MW) to 3 MW.

g. Reset Model 431B VERNIER to zero the meter, if necessary.

h. Set Model 8402A OUTPUT CURRENT to ON; note and record the Model 431B percent-of-power-reading error (1.7%/division on 0-3 meter scale).

i. Repeat steps b through h for all Model 431B RANGE positions.

j. Connect a decade resistance box across R179 (see figure 5-2).

k. Select the resistance value which equalizes the magnitude of the largest positive and negative percent error.

m. Remove the decade resistance box, and replace with a resistor of the value selected in step k.

n. Check all Model 431B RANGE positions. Test limits. The Model 431B full-scale power-reading error must not exceed 1-1/2% on all range positions.

Note

When only a 100 ohm thermistor mount will be used with the Model 431B, the value of C104 may be changed to obtain the null requirements specified above.

5-71. PERFORMANCE CHECK.

5-72. The tests described below which verify that the Model 431B meets specifications, use only panel controls and connectors. These tests can be used for incoming quality control, for routine preventive maintenance, and after repair. A thermistor mount must be connected to the Model 431B for the performance checks, though no rf power will be applied.

Note

If there is possibility of rf pick-up, the thermistor mount should be appropriately shielded.

5-73. Check the mechanical zero-set of the Model 431B meter according to paragraph 5-54.

5-74. ZERO CARRY-OVER CHECK.

a. Set Model 431B RANGE to .01 MW.

b. Adjust ZERO and VERNIER controls to set the meter pointer over the zero calibration mark.

c. Rotate RANGE through its .03, .1, .3, and 10 MW positions, observing the accuracy of the zero setting at each position. The zero must carry over from range to range within ±1% of full scale.

5-75. CALIBRATION AND RANGE TRACKING ACCURACY.

5-76. Calibration and range tracking accuracy is verified by dc substitution. Briefly, dc substitution involves 1) applying enough direct current at the DC CALIBRATION & SUBSTITUTION terminals to obtain the desired meter indication 2) accurately determining the applied current and 3) calculating the dc power applied. The difference between the substituted dc power and the meter indication it produced is the calibration error. The ⓗⓟ Model 8402A Power Meter Calibrator, or other means of producing accurate direct currents, is used as the substitution source.

5-77. CALIBRATION AND TRACKING ACCURACY TEST USING THE ⓗⓟ MODEL 8402A POWER METER CALIBRATOR. The Model 8402A Power Meter Calibrator provides constant currents sufficient to cause full scale meter indication on each of the Model 431B power ranges. It also has provision for checking the tracking accuracy of the Model 431B on the 10 mw range.

5-78. Refer to the Operating and Service Manual of the Power Meter Calibrator for correct test procedure.

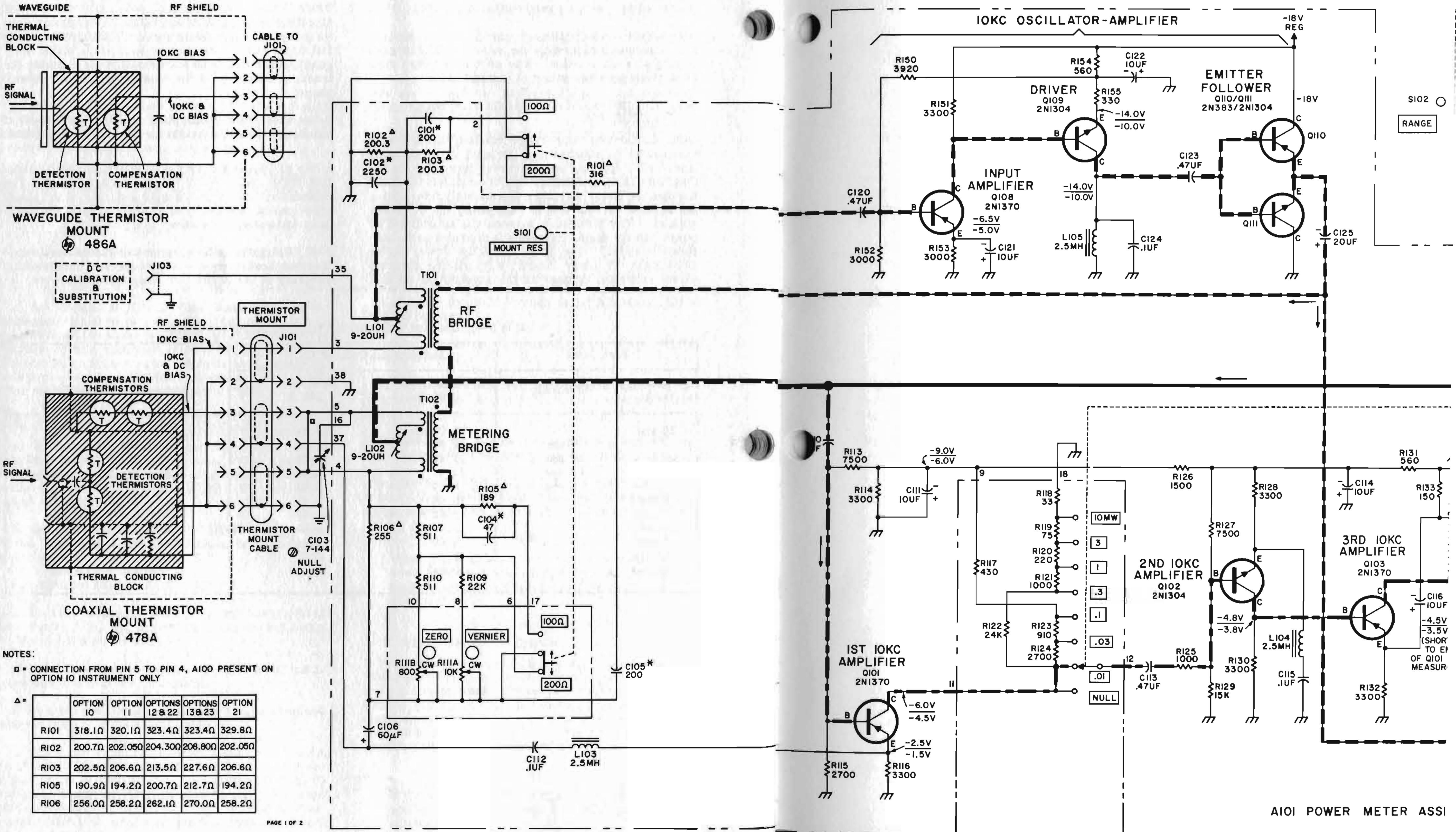
5-79. ALTERNATE METHOD FOR CHECKING CALIBRATION AND RANGE TRACKING ACCURACY. The calibration and range tracking accuracy of the Model 431B can be checked by dc substitution using the equipment and connections shown in figure 3-3.

5-80. Using the data in table 5-8 the full scale calibration accuracy of each range and the tracking accuracy of the 10 mw range can be tested.

Table 5-8. Data for Calibration, Tracking Accuracy Check

Test Point		Substitution Current (I_{dc})		Model 431B Meter Reads
Full Scale	Tracking	Mount Res 100 Ω	Mount Res 200 Ω	
10 mw		20.00 ma	14.14 ma	9.7 to 10.3 mw
	8 mw	17.89	12.65	7.76 to 8.24 mw
	6 mw	15.49	10.95	5.82 to 6.18 mw
	4 mw	12.65	8.94	3.88 to 4.12 mw
	2 mw	8.94	6.32	1.94 to 2.06 mw
3 mw		10.95	7.75	2.91 to 3.09 mw
1 mw		6.32	4.47	0.97 to 1.03 mw
.3 mw		3.46	2.45	0.291 to 0.309 mw
.1 mw		2.00	1.41	0.097 to 0.103 mw
.03 mw		1.10	0.775	0.0291 to 0.0309 mw
.01 mw		0.632	0.447	0.0097 to 0.0103 mw

Model 431B



NOTES:

□ = CONNECTION FROM PIN 5 TO PIN 4, A100 PRESENT ON OPTION 10 INSTRUMENT ONLY

Δ =

	OPTION 10	OPTION 11	OPTIONS 12 & 22	OPTIONS 13 & 23	OPTION 21
R101	318.1Ω	320.1Ω	323.4Ω	323.4Ω	329.8Ω
R102	200.7Ω	202.05Ω	204.30Ω	208.80Ω	202.05Ω
R103	202.5Ω	206.6Ω	213.5Ω	227.6Ω	206.6Ω
R105	190.9Ω	194.2Ω	200.7Ω	212.7Ω	194.2Ω
R106	256.0Ω	258.2Ω	262.1Ω	270.0Ω	258.2Ω

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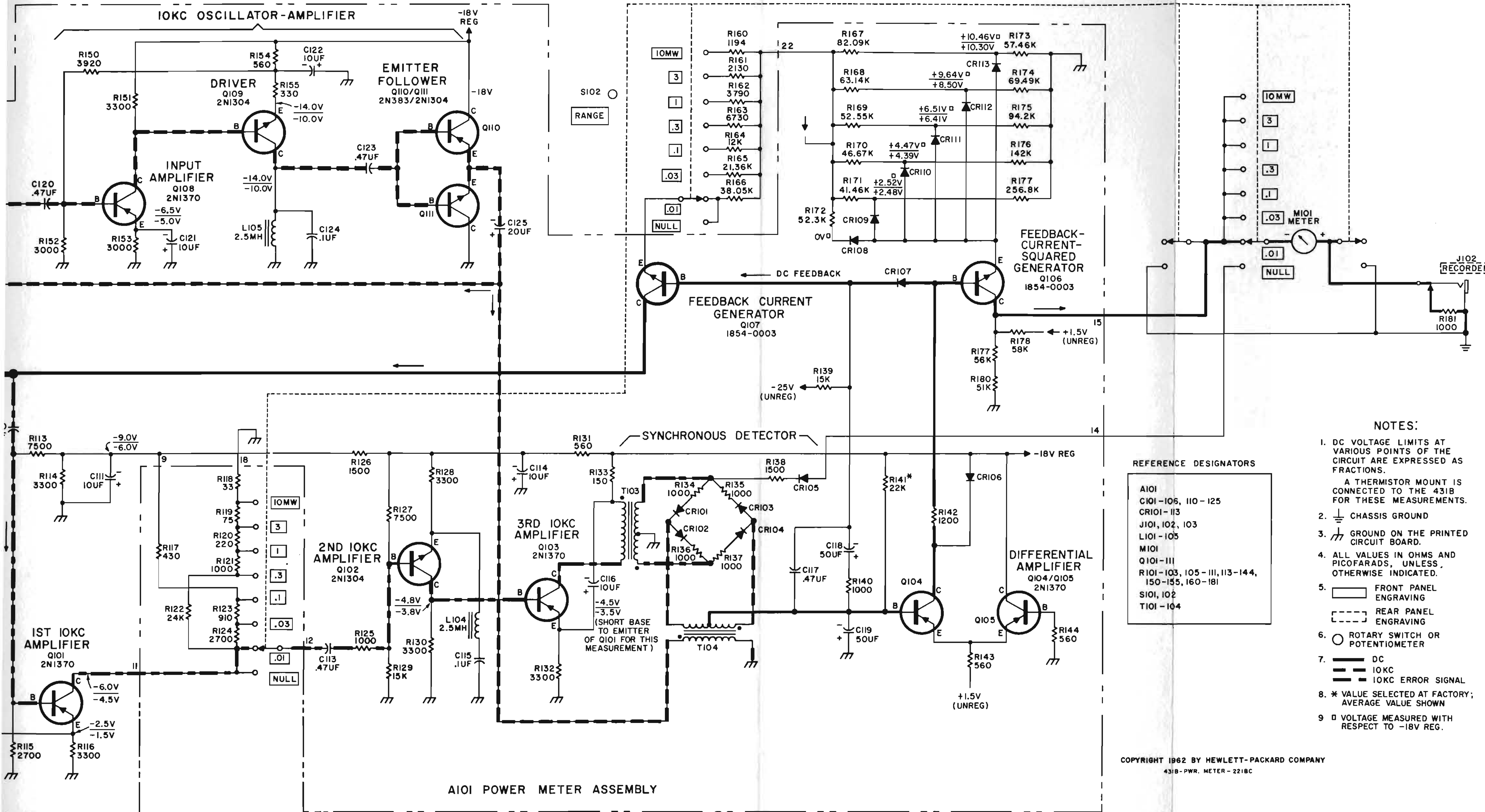
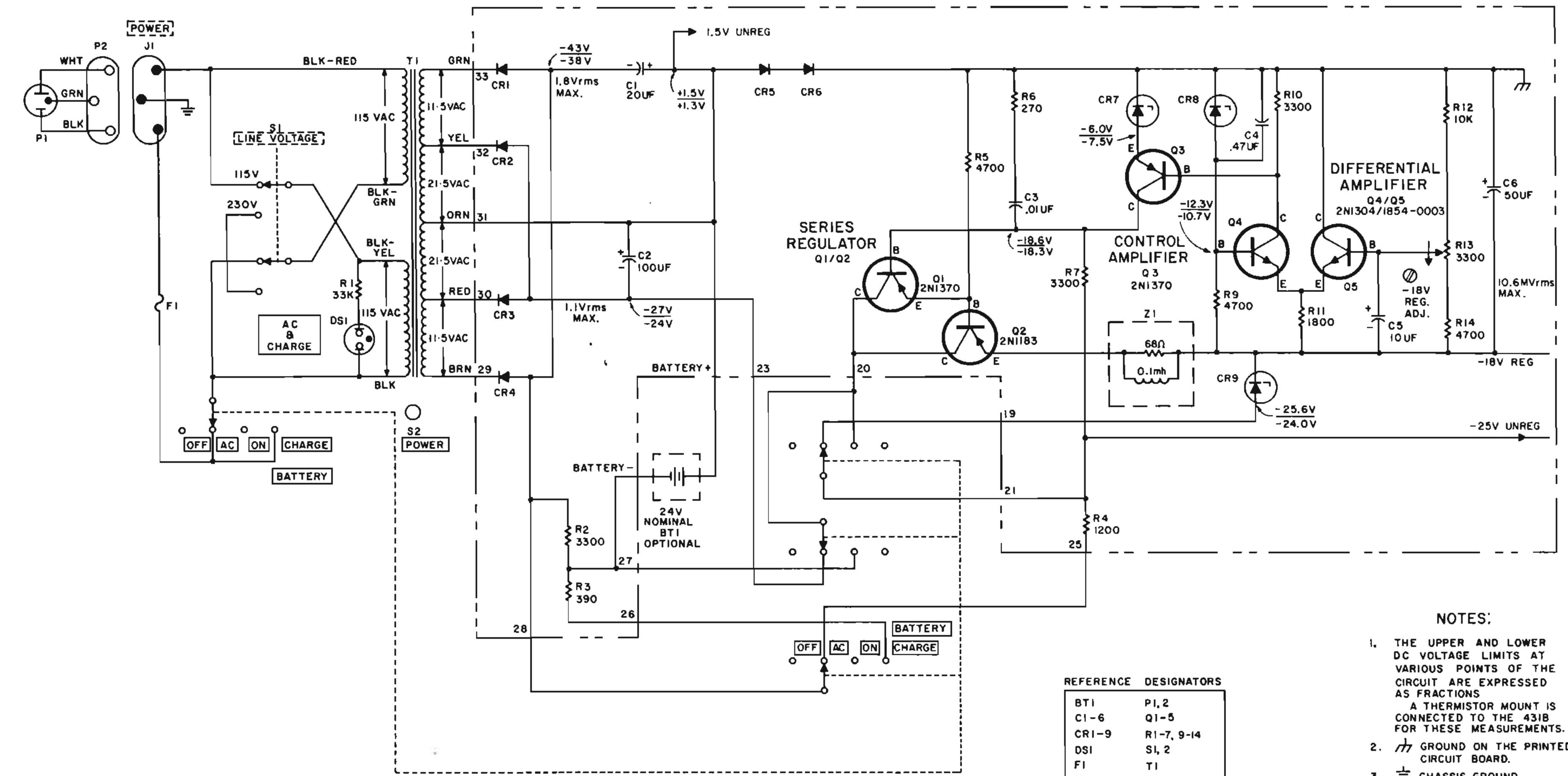


Figure 5-3. Power Meter Assembly



REFERENCE	DESIGNATORS
BT1	P1, 2
C1-6	Q1-5
CR1-9	R1-7, 9-14
DS1	S1, 2
F1	T1
J1	Z1

NOTES:

1. THE UPPER AND LOWER DC VOLTAGE LIMITS AT VARIOUS POINTS OF THE CIRCUIT ARE EXPRESSED AS FRACTIONS
   A THERMISTOR MOUNT IS CONNECTED TO THE 431B FOR THESE MEASUREMENTS.
2. ⏚ GROUND ON THE PRINTED CIRCUIT BOARD.
3. ⏚ CHASSIS GROUND.
4. ▭ FRONT PANEL ENGRAVING.
   ⌐- - -¬ REAR PANEL ENGRAVING.
5. ⊘ SCREWDRIVER ADJUSTMENT.
6. ○ ROTARY SWITCH

Figure 5-4. Power Supply

SECTION VI
REPLACEABLE PARTS

6-1. INTRODUCTION.

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

a. Description of the part (see list of abbreviations below).

b. Typical manufacturer of the part in a five-digit code; see list of manufacturers in appendix.

c. Manufacturer's stock number.

d. Total quantity used in the instrument (TQ column).

e. Recommended spare part quantity for complete maintenance during one year of isolated service (RS column).

6-3. Miscellaneous parts not indexed in table 6-1 are listed at the end of table 6-2.

6-4. ORDERING INFORMATION.

6-5. To order a replacement part, address order or inquiry either to your authorized Hewlett-Packard sales representative or to

CUSTOMER SERVICE
Hewlett-Packard Company
395 Page Mill Road
Palo Alto, California

or, in Western Europe, to

Hewlett-Packard S.A.
54-54bis Route des Acacias
Geneva, Switzerland

6-6. Specify the following information for each part:

a. Model and complete serial number of instrument.

b. Hewlett-Packard stock number.

c. Circuit reference designator.

d. Description.

6-7. To order a part not listed in tables 6-1 and 6-2, give a complete description of the part and include its function and location.

REFERENCE DESIGNATORS

A = assembly
B = motor
C = capacitor
CR = diode
DL = delay line
DS = device signaling (lamp)
E = misc electronic part
F = fuse
FL = filter
J = jack
K = relay
L = inductor
M = meter
MP = mechanical part
P = plug
Q = transistor
R = resistor
RT = thermistor
S = switch
T = transformer
V = vacuum tube, neon bulb, photocell, etc.
W = cable
X = socket
XF = fuseholder
XDS = lampholder
Z = network

ABBREVIATIONS

A = amperes
BP = bandpass
BWO = backward wave oscillator
CER = ceramic
CMO = cabinet mount only
COEF = coefficient
COM = common
COMP = composition
CONN = connection
CRT = cathode-ray tube
DEPC = deposited carbon
EIA = Tubes or transistors meeting Electronic Industries' Association standards will normally result in instrument operating within specifications; tubes and transistors selected for best performance will be supplied if ordered by ⓗ stock numbers.
ELECT = electrolytic
ENCAP = encapsulated
F = farads
FXD = fixed
GE = germanium
GL = glass
GRD = ground(ed)
H = henries
HG = mercury
HR = hour(s)
IMPG = impregnated
INCD = incandescent
INS = insulation (ed)
K = kilo = 1000
LIN = linear taper
LOG = logarithmic taper
M = meg = 10^6
MA = milliamperes
MINAT = miniature
METFLM = metal film
MFR = manufacturer
MTG = mounting
MY = mylar
NC = normally closed
NE = neon
NO = normally open
NPO = negative positive zero (zero temperature coefficient)
NSR = not separately replaceable
OBD = order by description
P = peak
PC = printed circuit board
PF = picofarads = 10^{-12} farads
PP = peak-to-peak
PIV = peak inverse voltage
POR = porcelain
POS = position(s)
POLY = polystyrene
POT = potentiometer
RECT = rectifier
ROT = rotary
RMS = root-mean-square
RMO = rack mount only
S-B = slow-blow
SE = selenium
SECT = section(s)
SI = silicon
SIL = silver
SL = slide
TA = tantalum
TD = time delay
TI = titanium dioxide
TOG = toggle
TOL = tolerance
TRIM = trimmer
TWT = traveling wave tube
U = micro = 10^{-6}
VAC = vacuum
VAR = variable
W/ = with
W = watts
WW = wirewound
W/O = without
* = optimum value selected at factory, average value shown (part may be omitted)
# = number

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Table 6-1. Index by Reference Designator

Circuit Reference	hp Stock No.	Description #	Note
A101	431B-65A	Assy, etched circuit, includes: C1 thru C6 C102, C106 C110 thru C125 CR1 thru CR9 CR101 thru CR113 L101 thru L105 Q1 thru Q5 Q101 thru Q111 R2 thru R7 R9 thru R14 R102, R103 R105 thru R110 R113 thru R116 R125 thru R140 R142 thru R144 R150 thru R155 R167 thru R178 R180 Z1	
BT1		See Option 01	
C1	0180-0049	C: fxd, aluminum elect, 20μf, 50 vdcw	
C2	0180-0138	C: fxd, aluminum elect, 100μf +100%-10%, 40 vdcw	
C3	0150-0012	C: fxd, cer, 0.01μf ±20%, 1000 vdcw	
C4	0160-0174	C: fxd, cer, 0.47μf +80%-20%, 25 vdcw	
C5	0180-0059	C: fxd, elect, 10μf +100%-10%, 25 vdcw	
C6	0180-0105	C: fxd, aluminum elect, 50μf, 25 vdcw	
C7 thru C100		Not assigned	
C101	0140-0220	C: fxd, mica, 200*pf ±1%, 300 vdcw	
C102	0160-0185	C: fxd, mica, 2100pf ±1%, 300 vdcw	
C103	0121-0035	C: var, air, 7.2 - 143.7pf	
C104	0140-0204	C: fxd, mica, 47*pf ±5%, 500 vdcw	
C105	0140-0220	C: fxd, mica, 200*pf ±1%, 300 vdcw	
C106	0180-0106	C: fxd, tantalum elect, 60μf ±20%, 6 vdcw	
C107 thru C109		Not assigned	
C110	0160-0174	C: fxd, cer, 0.47μf +80%	
C111	0180-0059	C: fxd, elect, 10μf +100%-10%, 25 vdcw	
C112	0170-0069	C: fxd, poly, 0.1μf ±2%, 50 vdcw	
C113	0160-0174	C: fxd, cer, 0.47μf +80%-20%, 25 vdcw	
C114	0180-0059	C: fxd, elect, 10μf +100%-10%, 25 vdcw	
C115	0170-0069	C: fxd, poly, 0.1μf ±2%, 50 vdcw	
C116	0180-0059	C: fxd, elect, 10μf +100%-10%, 25 vdcw	
C117	0160-0105	C: fxd, cer, 0.47μf +80%-20%, 25 vdcw	
C118, C119	0180-0105	C: fxd, aluminum elect, 50μf, 25 vdcw	

See introduction to this section

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

Circuit Reference	ⓗⓟ Stock No.	Description #	Note
C120	0160-0174	C: fxd, cer, 0.47μf +80%-20%, 25 vdcw	
C121, C122	0180-0059	C: fxd, elect, 10μf +100%-10%, 25 vdcw	
C123	0160-0174	C: fxd, cer, 0.47μf +80%-20%, 25 vdcw	
C124	0170-0069	C: fxd, poly, 0.1μf ±2%, 50 vdcw	
C125	0180-0049	C: fxd, aluminum elect, 20μf, 50 vdcw	
CR1 thru CR4	1901-0025	Diode, Si: 50 ma @+1V, 100 PIV	
CR5, CR6	1901-0026	Diode, Si	
CR7	1902-0017	Diode, Si: avalanche	
CR8	1902-0018	Diode, Si: avalanche, 1N941	
CR9	1902-0017	Diode, Si: avalanche	
CR10 thru CR100		Not assigned	
CR101 thru CR104	1910-0016	Diode, Ge: 100 ma @1V, 60 PIV	
CR105, CR106	1901-0025	Diode, Si: 50 ma @ +1V, 100 PIV	
CR107 thru CR113	1901-0024	Diode, Si	
DS1	1450-0048	Lamp, Ne: NE2H	
F1	2100-0017	Fuse, cartridge: 0.15 amp	
J1	1251-0148	Connector, POWER: male, 3 pin	
J2 thru J100		Not assigned	
J101	1251-0149	Connector, female, 6 contact	
J102	1251-0066	Jack, telephone, for 2 connector plug	
J103		DC CALIBRATION and SUBSTITUTION, consists of	
	AC-10C	Binding post: black	
	AC-10D	Binding post: red	
	AC-54A	Insulator: black, 2 hole (inside)	
	AC-54A-1	Insulator: black, 2 hole (outside)	
L1		Nsr: part of Z1	
L2 thru L100		Not assigned	
L101, L102	9140-0122	Coil, var, 2 windings, 9-20μh each	
L103 thru L105	9110-0040	Inductor, audio, 2.5mh	
M1 thru M100		Not assigned	
M101	431B-81A	Meter, calibrated	

See introduction to this section

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

Circuit Reference	ⓗⓟ Stock No.	Description #	Note
P1		Nsr; prat of W1	
P2		Nsr; part of W1	
Q1	1850-0065	Transistor, Ge: 2N1370	
Q2	1850-0064	Transistor: 2N1183	
Q3	1850-0065	Transistor: Ge, 2N1370	
Q4	1851-0017	Transistor, Ge: 2N1304	
Q5	1854-0003	Transistor, Si	
Q1 thru Q100		Not assigned	
Q101	1850-0065	Transistor: Ge, 2N1370	
Q102	1851-0017	Transistor, Ge: 2N1304	
Q103 thru Q105	1850-0065	Transistor, Ge: 2N1370	
Q106, Q107	1854-0003	Transistor, Si	
Q108	1850-0065	Transistor, Ge: 2N 1370	
Q109	1851-0017	Transistor, Ge: 2N1304	
Q110	1850-0040	Transistor: 2N383	
Q111	1851-0017	Transistor, Ge: 2N1304	
R1	0687-3331	R: fxd, comp, 33K ohms ±10%, 1/2W	
R2	0687-3321	R: fxd, comp, 3.3K ohms ±10%, 1/2W	
R3	0690-3911	R: fxd, comp, 390 ohms ±10%, 1W	
R4	0690-1221	R: fxd, comp, 1.2K ohms ±10%, 1W	
R5	0687-4721	R: fxd, comp, 4.7K ohms ±10%, 1/2W	
R6	0687-2711	R: fxd, comp, 270 ohms ±10%, 1/2W	
R7	0687-3321	R: fxd, comp, 3.3K ohms ±10%, 1/2W	
R8		Nsr; part of Z1	
R9	0687-4721	R: fxd, comp, 4.7K ohms ±10%, 1/2W	
R10	0687-3321	R: fxd, comp, 3.3K ohms ±10%, 1/2W	
R11	0687-1821	R: fxd, comp, 1.8K ohms ±10%, 1/2W	
R12	0758-0006	R: fxd, metallic oxide, 10K ohms ±5%, 0.5W	
R13	2100-0182	R: var, comp, lin, 3.3K ohms ±10%, 1/3W	
R14	0758-0005	R: fxd, metallic oxide, 4.7K ohms ±5%, 0.5W	
R15 thru R100		Not assigned	
R101	0727-0395	R: fxd, dep c, 316 ohms ±1/2%, 1/2W	
Option 10	0727-0483	R: fxd, dep c, 318.1 ohms ±1%, 1/2W	
Option 11	0727-0484	R: fxd, dep c, 320.1 ohms ±1%, 1/2W	
Option 12	0727-0485	R: fxd, dep c, 323.4 ohms ±1%, 1/2W	

See introduction to this section

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

Circuit Reference	hp Stock No.	Description #	Note
Option 21-23	0727- 0486	R: fxd, dep c, 329.8 ohms ±1%, 1/2W	
R102	0811-0051	R: fxd, ww, 200.3 ohms ±0.1%, 1/4W	
Option 10	0811-0100	R: fxd, ww, 200.7 ohms ±0.1%, 1/4W	
Option 11, 21	0811-0085	R: fxd, ww, 202.5 ohms ±0.1%, 1/4W	
Option 12, 22	0811-0086	R: fxd, ww, 204.3 ohms ±0.1%, 1/4W	
Option 13, 23	0811-0087	R: fxd, ww, 208.8 ohms ±0.1%, 1/4W	
R103	0811-0051	R: fxd, ww, 200.3 ohms ±0.1%, 1/4W	
Option 10	0811-0099	R: fxd, ww, 202.5 ohms ±0.1%, 1/4W	
Option 11, 21	0811-0088	R: fxd, ww, 206.6 ohms ±0.1%, 1/4W	
Option 12, 22	0811-0089	R: fxd, ww, 213.5 ohms ±0.1%, 1/4W	
Option 13, 23	0811-0090	R: fxd, ww, 227.6 ohms ±0.1%, 1/4W	
R105	0811-0063	R: fxd, ww, 189 ohms ±0.5%, 1/4W	
Option 10	0811-0094	R: fxd, ww, 190.9 ohms ±0.5%, 1/4W	
Option 11, 21	0811-0095	R: fxd, ww, 194.2 ohms ±0.5%, 1/4W	
Option12, 22	0811-0096	R: fxd, ww, 200.7 ohms ±0.5%, 1/4W	
Option 13, 23	0811-0101	R: fxd, ww, 212.7 ohms ±0.5%, 1/4W	
R106	0811-0064	R: fxd, ww, 255 ohms ±0.5%, 0.25W	
Option 10	0811-0091	R: fxd, ww, 256 ohms ±0.5%, 0.25W	
Option 11, 21	0811-0098	R: fxd, ww, 258.2 ohms ±0.5%, 0.25W	
Option 12, 22	0811-0092	R: fxd, ww, 262.1 ohms ±0.5%, 0.25W	
Option 13, 23	0811-0093	R: fxd, ww, 265.5 ohms ±0.5%, 0.25W	
R107	0811-0065	R: fxd, ww, 511 ohms ±1%, 0.08W	
R108	0811-0066	R: fxd, ww, 887 ohms ±1%, 0.08W	
R109	0758-0020	R: fxd, mfgl, 22K ohms ±5%, 1/2W	
R110	0811-0065	R: fxd, ww, 511 ohms ±1%, 0.08W	
R111A/B	2100-0342	R: var, concentric Front sect: ww, lin, 10K ohms ±10%, 2W Rear sect: ww, lin, 800 ohms ±10%, 2W	
R112		Not assigned	
R113	0686-7525	R: fxd, comp, 7.5K ohms ±5%, 1/2W	
R114	0686-3325	R: fxd, comp, 3.3K ohms ±5%, 1/2W	
R115	0686-2725	R: fxd, comp, 2.7K ohms ±5%, 1/2W	
R116	0686-3325	R: fxd, comp, 3.3K ohms ±5%, 1/2W	
R117	0683-4315	R: fxd, comp, 430 ohms ±5%, 1/4W	
R118	0683-3305	R: fxd, comp, 33 ohms ±5%, 1/4W	
R119	0683-7505	R: fxd, comp, 75 ohms ±5%, 1/4W	

See introduction to this section

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

Circuit Reference	hp Stock No.	Description #	Note
R120	0683-2215	R: fxd, comp, 220 ohms ±5%, 1/4W	
R121	0683-1025	R: fxd, comp, 1K ohms ±5%, 1/4W	
R122	0683-2435	R: fxd, comp, 24K ohms ±5%, 1/4W	
R123	0683-9115	R: fxd, comp, 910 ohms ±5%, 1/4W	
R124	0683-2725	R: fxd, comp, 2.7K ohms ±5%, 1/4W	
R125	0686-1025	R: fxd, comp, 1K ohms ±5%, 1/2W	
R126	0686-1525	R: fxd, comp, 1.5K ohms ±5%, 1/2W	
R127	0686-7525	R: fxd, comp, 7.5K ohms ±5%, 1/2W	
R128	0686-3325	R: fxd, comp, 3.3K ohms ±5%, 1/2W	
R129	0686-1535	R: fxd, comp, 15K ohms ±5%, 1/2W	
R130	0687-3321	R: fxd, comp, 3.3K ohms ±10%, 1/2W	
R131	0687-5611	R: fxd, comp, 560 ohms ±10%, 1/2W	
R132	0686-3325	R: fxd, comp, 3.3K ohms ±5%, 1/2W	
R133	0687-1511	R: fxd, comp, 150 ohms ±10%, 1/2W	
R134 thru R137	0758-0003	R: fxd, mfgl, 1K ohms ±5%, 1/2W	
R138	0687-1521	R: fxd, comp, 1.5K ohms ±10%, 1/2W	
R139	0687-1531	R: fxd, comp, 15K ohms ±10%, 1/2W	
R140	0686-1025	R: fxd, comp, 1K ohms ±5%, 1/2W	
R141	0687-3931	R: fxd, comp, 39K*ohms ±10%, 1/2W	
R142	0687-1221	R: fxd, comp, 1.2K ohms ±10%, 1/2W	
R143, R144	0687-5611	R: fxd, comp, 560 ohms ±10%, 1/2W	
R145 thru R149		Not assigned	
R150	0727-0131	R: fxd, dep c, 3920 ohms ±1%, 1/2W	
R151	0687-3321	R: fxd, comp, 3.3K ohms ±10%, 1/2W	
R152, R153	0727-0124	R: fxd, dep c, 3K ohms ±1%, 1/2W	
R154	0687-5611	R: fxd, comp, 560 ohms ±10%, 1/2W	
R155	0687-3311	R: fxd, comp, 330 ohms ±10%, 1/2W	
R156 thru R159		Not assigned	
R160	0727-0396	R: fxd, dep c, 1.194K ohms ±1/2%, 1/2W	
R161	0727-0397	R: fxd, dep c, 2.13K ohms ±1/2%, 1/2W	
R162	0727-0398	R: fxd, dep c, 3.79K ohms ±1/2%, 1/2W	
R163	0727-0399	R: fxd, dep c, 6.73K ohms ±1/2%, 1/2W	
R164	0727-0341	R: fxd, dep c, 12K ohms ±1/2%, 1/2W	

See introduction to this section

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

Circuit Reference	ⓗⓟ Stock No.	Description #	Note
R165	0727-0400	R: fxd, dep c, 21.36K ohms ±1/2%, 1/2W	
R166	0727-0342	R: fxd, dep c, 38.05K ohms ±1/2%, 1/2W	
R167	0727-0407	R: fxd, dep c, 82.09K ohms ±1/2%, 1/2W	
R168	0727-0346	R: fxd, dep c, 63.14K ohms ±1/2%, 1/2W	
R169	0727-0404	R: fxd, dep c, 52.55K ohms ±1/2%, 1/2W	
R170	0727-0402	R: fxd, dep c, 46.67K ohms ±1/2%, 1/2W	
R171	0727-0401	R: fxd, dep c, 41.46K ohms ±1/2%, 1/2W	
R172	0727-0403	R: fxd, dep c, 52.3K ohms ±1/2%, 1/2W	
R173	0727-0405	R: fxd, dep c, 57.46K ohms ±1/2%, 1/2W	
R174	0727-0406	R: fxd, dep c, 69.49K ohms ±1/2%, 1/2W	
R175	0727-0408	R: fxd, dep c, 94.2K ohms ±1/2%, 1/2W	
R176	0727-0409	R: fxd, dep c, 142K ohms ±1/2%, 1/2W	
R177	0727-0410	R: fxd, dep c, 256.8K ohms ±1/2%, 1/2W	
R178	0687-5631	R: fxd, comp, 56K ohms ±10%, 1/2W	
R179	0687-5631	R: fxd, comp, 56K*ohms ±10%, 1/2W	
R180	0758-0021	R: fxd, mfgl, 51K ohms ±5%, 1/2W	
R181	0727-0100	R: fxd, dep c, 1K ohms ±1%, 1/2W	
S1	3101-0033	Switch, sl: DPDT	
S2	3100-0370	Switch, rot: 1 sect, 4 pos, includes: 431B-16C	
S3 thru S100		Not assigned	
S101	3101-0032	Switch, sl: 4PDT	
S102	3100-0273	Switch, rot: 3 sect, 8 pos, includes: 431B-16B	
T1	9100-0141	Transformer, power	
T2 thru T100		Not assigned	
T101, T102	9120-0066	Transformer, audio	
T103, T104	9120-0065	Transformer, audio	
W1	8120-0078	Assy, power cable: smooth black, extra limp, 7.5ft. NEMA plug-in	
XF1	1400-0084	Fuseholder: extractor post type	
Z1	413A-60A	Assy, coil, includes: L1, R8	

See introduction to this section

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

Circuit Reference	Stock No.	Description #	Note
		MISCELLANEOUS	
	G74-AW	Knob: VERNIER	
	G74-BE	Knob: ZERO	
	G74-CW	Knob: POWER° RANGE	
	C144B-43B-1	Cover, 6 x 11	
	C144E-73A-1	Cover, half recess (top)	
	C144E-73C-1	Cover, half module (bottom)	
	C144H-18	Foot assy, half module	
	431A-16A	Assy, cable 5', THERMISTOR MOUNT	
	431B-19A	Assy, power switch, includes: R1, S2	
	431B-19B	Assy, MOUNT RES switch, includes: R101, S101	
	431B-19W	Assy, RANGE switch, includes: R117 thru R124, R160 thru R166; S102 Stock No. 431B-16A	
	0510-0123	Retainer, indicator light used w/ 1450-0048	
	1205-0002	Heat sink, transistor	
	9211-0160	Carton, corragated	
	9220-0225	Pad, foam	

See introduction to this section

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

Circuit Reference	hp Stock No.	Description #	Note
		OPTIONS	
		Option 01	
	1420-0009	Battery, rechargeable (BT1)	
	431A-64A	Support, battery	
	431A-64B	Cover, battery	
	431B-95A	Rechargeable battery installation kit	
		Option 02	
	431A-16G	Assy, cable, special purpose includes:	
	1251-0149	Connector, female	
		Option 10	
	431B-16D	Assy, cable 20' THERMISTOR MOUNT for use with hp Model 486A or 478A thermistor mount	
		Option 11	
	431B-16E	Assy, cable 50' THERMISTOR MOUNT for use with hp Model 486A thermistor mount	
		Option 12	
	431B-16F	Assy, cable 100' THERMISTOR MOUNT for use with hp Model 486A thermistor mount	
		Option 13	
	431B-16G	Assy, cable 200' THERMISTOR MOUNT for use with hp Model 486A thermistor mount	
		Option 21	
	431B-16E	Assy, cable 50' THERMISTOR MOUNT for use with hp Model 478A thermistor mount	
		Option 22	
	431B-16F	Assy, cable 100' THERMISTOR MOUNT for use with hp Model 478A thermistor mount	
		Option 23	
	431B-16G	Assy, cable 200' THERMISTOR MOUNT for use with hp Model 478A thermistor mount	

See introduction to this section

Table 6-2. Replaceable Parts

ⓗⓟ Stock No.	Description #	Mfr.	Mfr. Part No.	TQ	RS		
AC-10C	Binding post: black	28480	AC-10C	1	1		
AC-10D	Binding post: red	28480	AC-10D	1	1		
AC-54A	Insulator: black, 2 hole (inside)	28480	AC-54A	1	0		
AC-54A-1	Insulator: black, 2 hole (outside)	28480	AC-54A-1	1	0		
G74-AW	Knob: VERNIER	28480	G74-AN	1	0		
G74-BE	Knob: ZERO	28480	G74-BE	1	0		
G74-CW	Knob: POWER, RANGE	28480	G74-CW	2	0		
431A-16A	Assy, cable 5', THERMISTOR MOUNT MOUNT	28480	431A-16A	1	1		
431A-16G	Assy, cable, special purpose includes: Stock No. 1251-0149	28480	431A-16G	1	0		
431A-60A	Assy, coil, includes: L1, R8	28480	431A-60A	1	0		
431A-64A	Support, battery	28480	431A-64A	1	0		
431A-64B	Cover, battery	28480	431A-64B	1	0		
431B-16A	Wiring harness	28480	431B-16A	1	0		
431B-16C	Wiring harness	28480	431B-16C	1	0		
431B-16D	Assy, cable 20' THERMISTOR MOUNT for use with ⓗⓟ Model 486A or 478A thermistor mount	28480	431B-16D	1	0		
431B-16E	Assy, cable 50' THERMISTOR MOUNT for use with ⓗⓟ Model 486A thermistor mount	28480	431B-16E	1	0		
431B-16F	Assy, cable 100' THERMISTOR MOUNT						
	For use with ⓗⓟ Model 486A thermistor mount	28480	431B-16F	1	0		
	For use with ⓗⓟ Model 478A thermistor mount	28480	431B-16F	1	0		
431B-16G	Assy, cable 200' THERMISTOR MOUNT						
	For use with ⓗⓟ Model 486A thermistor mount	28480	431B-16G	1	0		
	For use with ⓗⓟ Model 478A thermistor mount	28480	431B-16G	1	0		
431B-19A	Assy, power switch, includes: R1, S2, Stock No. 4313-16C	28480	431B-19A	1	1		
431B-19B	Assy, mount RES switch, includes: R101, S101	28480	431B-19B	1	1		
431B-19W	Assy, rand switch, includes: R117 thru R166 Stock No. 431B-16A	28480	431B-19W	1	1		

See introduction to this section

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

hp Stock No.	Description #	Mfr.	Mfr. Part No.	TQ	RS		
431B-65A	Assy, etched circuit, includes: C1 thru C6 R102, R103 C102, C106 R105 thru R110 C110 thru C125 R113 thru R116 CR1 thru CR9 R125 thru R140 CR101 thru CR113 R142 thru R144 L101 thru L105 R150 thru R155 Q1 thru Q5 R167 thru R178 Q101 thru Q111 R180 R2 thru R7 Z1 R9 thru R14	28480	431B-65A	1	0		
431B-81A	Meter, calibrated	28480	431B-81A	1	1		
431B-95A	Recharageable battery installation kit	28480	431B-95A	1	0		
C144B-43A-1	Cover, 6x11	28480	C144B-43A-1	2	0		
C144E-73A-1	Cover, half recess (top)	28480	C144E-73A-1	1	0		
C144E-73C	Cover, half module (bottom)	28480	C144E-73C	1	0		
C144H-18	Foot assy, half module	28480	C144H-18	1	0		
0121-0035	C: var, air, 7.2-143.7pf	80486	CT1-0-143G (special)	1	1		
0140-0204	C: fxd, mica, 47pf ±5%, 500 vdcw	72136	DM15E470J	1	1		
0140-0220	C: fxd, mica, 200pf ±1%, 300 vdcw	72136	DM15F201F 300V	2	1		
0150-0012	C: fxd, cer, 0.01μf ±20%, 1000 vdcw	56289	29C14A3-H-1038	1	1		
0160-0174	C: fxd, cer, 0.47μf +80%-20%, 25 vdcw	56289	5C11A	6	2		
0160-0185	C: fxd, mica, 2100pf ±1%, 300 vdcw	14655	CD20F212F	1	1		
0170-0069	C: fxd, poly, 0.1μf ±2%, 50 vdcw	56289	114P1042R5S3	3	1		
0180-0049	C: fxd, aluminum elect, 20μf, 50 vdcw	56289	30D198A1	2	1		
0180-0059	C: fxd, elect, 10μf +100%-10%, 25 vdcw	56289	30D182A1	6	2		
0180-0105	C: fxd, aluminum elect, 50μf, 25 vdcw	56289	S97441	3	1		
0180-0106	C: fxd, tantalum elect, 60μf ±20%, 6 vdcw	56289	150D606X0006B2	1	1		

See introduction to this section

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

hp Stock No.	Description #	Mfr.	Mfr. Part No.	TQ	RS		
0180-0138	C: fxd, aluminum elect, 100μf +100%-10%, 40 vdcw	56289	Type 41D	1	1		
0510-0123	Retainer, indicator light used w/1450-0048	78553	C12008-014-4	1	0		
0683-1025	R: fxd, comp, 1K ohms ±5%, 1/4W	01121	CB1025	1	1		
0683-2215	R: fxd, comp, 220 ohms ±5%, 1/4W	01121	CB2215	1	1		
0683-2435	R: fxd, comp, 24K ohms ±5%, 1/4W	01121	CB2435	1	1		
0683-2725	R: fxd, comp, 2.7K ohms ±5%, 1/4W	01121	CB2725	1	1		
0683-3305	R: fxd, comp, 33 ohms ±5%, 1/4W	01121	CB3305	1	1		
0683-4315	R: fxd, comp, 430 ohms ±5%, 1/4W	01121	CB4315	1	1		
0683-7505	R: fxd, comp, 75 ohms ±5%, 1/4W	01121	CB7505	1	1		
0683-9115	R: fxd, comp, 910 ohms ±5%, 1/4W	01121	CB9115	1	1		
0686-1025	R: fxd, comp, 1K ohms ±5%, 1/2W	01121	EB1025	2	1		
0686-1525	R: fxd, comp, 1.5K ohms ±5%, 1/2W	01121	EB1525	1	1		
0686-1535	R: fxd, comp, 15K ohms ±5%, 1/2W	01121	EB1535	1	1		
0686-2725	R: fxd, comp, 2.7K ohms ±5%, 1/2W	01121	EB2725	1	1		
0686-3325	R: fxd, comp, 3.3K ohms ±5%, 1/2W	01121	EB3325	4	1		
0686-7525	R: fxd, comp, 7.5K ohms ±5%, 1/2W	01121	EB2725	2	1		
0687-1221	R: fxd, comp, 1.2K ohms ±10%, 1/2W	01121	EB1221	1	1		
0687-1511	R: fxd, comp, 150 ohms ±10%, 1/2W	01121	EB1511	1	1		
0687-1521	R: fxd, comp, 1.5K ohms ±10%, 1/2W	01121	EB1521	1	1		
0687-1531	R: fxd, comp, 15K ohms ±10%, 1/2W	01121	EB1531	1	1		
0687-1821	R: fxd, comp, 1.8K ohms ±10%, 1/2W	01121	EB1821	1	1		
0687-2711	R: fxd, comp, 270 ohms ±10%, 1/2W	01121	EB2711	1	1		
0687-3311	R: fxd, comp, 330 ohms ±10%, 1/2W	01121	EB3311	1	1		
0687-3321	R: fxd, comp, 3.3K ohms ±10%, 1/2W	01121	EB3321	5	2		
0687-3331	R: fxd, comp, 33K ohms ±10%, 1/2W	01121	EB3331	1	1		
0687-3931	R: fxd, comp, 39K ohms ±10%, 1/2W	01121	EB3931	1	1		
0687-4721	R: fxd, comp, 4.7K ohms ±10%, 1/2W	01121	EB4721	2	1		
0687-5611	R: fxd, comp, 560 ohms ±10%, 1/2W	01121	EB5611	4	1		
0687-5631	R: fxd, comp, 56K ohms ±10%, 1/2W	01121	EB5631	2	1		
0690-1221	R: fxd, comp, 1.2K ohms ±10%, 1W	01121	GB1221	1	1		
0690-3911	R: fxd, comp, 390 ohms ±10%, 1W	01121	GB3911	1	1		
0727-0100	R: fxd, dep c, 1K ohms ±1%, 1/2W	19701	DC1/2CR5 obd#	1	1		

See introduction to this section

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

Stock No.	Description #	Mfr.	Mfr. Part No.	TQ	RS		
0727-0124	R: fxd, dep c, 3K ohms ±1%, 1/2W	19701	DC1/2CR5 obd#	2	1		
0727-0131	R: fxd, dep c, 3920 ohms ±1%, 1/2W	19701	CD1/2CR5, obd#	1	1		
0727-0341	R: fxd, dep c, 12K ohms ±1/2%, 1/2W	19701	DC1/2AR5, obd#	1	1		
0727-0342	R: fxd, dep c, 38.05K ohms ±1/2%, 1/2W	19701	DC1/2AR5, obd#	1	1		
0727-0346	R: fxd, dep c, 63.14K ohms ±1/2% 1/2W	19701	DC1/2AR5, obd#	1	1		
0727-0395	R: fxd, dep c, 316 ohms ±1/2%, 1/2W	19701	DC1/2AR5, obd#	1	1		
0727-0396	R: fxd, dep c, 1.194K ohms ±1/2%, 1/2W	19701	DC1/2AR5, obd#	1	1		
0727-0397	R: fxd, dep c, 2.13K ohms ±1/2%, 1/2W	19701	DC1/2AR5, obd#	1	1		
0727-0398	R: fxd, dep c, 3.79K ohms ±1/2%, 1/2W	19701	DC1/2AR5, obd#	1	1		
0727-0399	R: fxd, dep c, 6.73K ohms ±1/2%, 1/2W	19701	DC1/2AR5, obd#	1	1		
0727-0400	R: fxd, dep c, 21.36K ohms ±1/2%, 1/2W	19701	DC1/2AR5, obd#	1	1		
0727-0401	R: fxd, dep c, 41.46K ohms±1/2%, 1/2W	19701	DC1/2AR5, obd#	1	1		
0727-0402	R: fxd, dep c, 46.67K ohms ±1/2%, 1/2W	19701	DC1/2AR5, obd#	1	1		
0727-0403	R: fxd, dep c, 52.3K ohms ±1/2%, 1/2W	19701	DC1/2AR5, obd#	1	1		
0727-0404	R: fxd, dep c, 52.55K ohms ±1/2%, 1/2W	19701	DC1/2AR5, obd#	1	1		
0727-0405	R: fxd, dep c, 57.46K ohms ±1/2%, 1/2W	19701	DC1/2AR5, obd#	1	1		
0727-0406	R: fxd, dep c, 69.49K ohms ±1/2%, 1/2W	19701	DC1/2AR5, obd#	1	1		
0727-0407	R: fxd, dep c, 82.09K ohms ±1/2%, 1/2W	19701	DC1/2AR5, obd#	1	1		
0727-0408	R: fxd, dep c, 94.2K ohms ±1/2%, 1/2W	19701	DC1/2AR5, obd#	1	1		
0727-0409	R: fxd, dep c, 142K ohms ±1/2%, 1/2W	19701	DC1/2AR5, obd#	1	1		
0727-0410	R: fxd, dep c, 256.8K ohms ±1/2%, 1/2W	19701	DC1/2AR5, obd#	1	1		

See introduction to this section

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

hp Stock No.	Description #	Mfr.	Mfr. Part No.	TQ	RS		
0727-0483	R: fxd, dep c, 318.1 ohms ±1%, 1/2W	28480	0727-0483	1	1		
0727-0484	R: fxd, dep c, 320.1 ohms ±1%, 1/2W	28480	0727-0484	1	1		
0727-0485	R: fxd, dep c, 323.4 ohms ±1%, 1/2W	28480	0727-0485	1	1		
0727-0486	R: fxd, dep c, 329.8 ohms ±1%, 1/2W	28480	0727-0486	1	1		
0758-0003	R: fxd, mfgl, 1K ohms ±5%, 1/2W	07115	C-20, obd#	4	1		
0758-0005	R: fxd, metallic oxide, 4.7K ohms ±5%, 0.5W	07115	C-20, obd#	1	1		
0758-0006	R: fxd, metallic oxide, 10K ohms ±5%, 0.5W	07115	C-20, obd#	1	1		
0758-0020	R: fxd, mfgl, 22K ohms ±5%, 1/2W	07115	C-20, obd#	1	1		
0758-0021	R: fxd, mfgl, 51K ohms ±5%, 1/2W	07115	C-20, obd#	1	1		
0811-0051	R: fxd, ww, 200.3 ohms ±0.1%, 1/4W	05347	205RP, obd#	2	1		
0811-0063	R: fxd, ww, 189 ohms ±0.5%, 1/4W	05347	205RP, obd#	1	1		
0811-0064	R: fxd, ww, 255 ohms ±0.5%, 0.25W	05347	205RP, obd#	1	1		
0811-0065	R: fxd, ww, 511 ohms ±1%, 0.08W	99957	M3 A, obd#	2	1		
0811-0066	R: fxd, ww, 887 ohms ±1%, 0.08W	99957	M3A, obd#	1	1		
0811-0085	R: fxd, ww, 202.5 ohms ±0.1%, 1/4W	28480	0811-0085	1	1		
0811-0086	R: fxd, ww, 204.3 ohms ±0.1%, 1/4W	28480	0811-0086	1	1		
0811-0087	R: fxd, ww, 208.8 ohms ±0.1%, 1/4W	28480	0811-0087	1	1		
0811-0088	R: fxd, ww, 206.6 ohms ±0.1%, 1/4W	28480	0811-0088	1	1		
0811-0089	R: fxd, ww, 213.5 ohms ±0.1%, 1/4W	28480	0811-0089	1	1		
0811-0090	R: fxd, ww, 227.6 ohms ±0.5%, 0.25W	28480	0811-0090	1	1		
0811-0091	R: fxd, ww, 256 ohms ±0.5%, 0.25W	28480	0811-0091	1	1		
0811-0092	R: fxd, ww, 262.1 ohms ±0.5%, 0.25W	28480	0811-0092	1	1		
0811-0093	R: fxd, ww, 265.5 ohms ±0.5%, 0.25W	28480	0811-0093	1	1		
0811-0094	R: fxd, ww, 190.9 ohms ±0.5%, 1/4W	28480	0811-0094	1	1		
0811-0095	R: fxd, ww, 194.2 ohms ±0.5%, 1/4W	28480	0811-0095	1	1		
0811-0096	R: fxd, ww, 200.7 ohms ±0.5%, 1/4W	28480	0811-0096	1	1		
0811-0098	R: fxd, ww, 258.2 ohms ±0.5%, 0.25W	28480	0811-0098	1	1		
0811-0099	R: fxd, ww, 202.5 ohms ±0.1%, 1/4W	28480	0811-0099	1	1		
0811-0100	R: fxd, ww, 200.7 ohms ±0.1%, 1/4W	28480	0811-0100	1	1		
0811-0101	R: fxd, ww, 212.7 ohms ±0.1%, 1/4W	28480	0811-0101	1	1		

See introduction to this section

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

ℎ𝑝 Stock No.	Description #	Mfr.	Mfr. Part No.	TQ	RS		
1205-0002	Heat sink, transistor	000II	3AL635-2R	2	1		
1251-0066	Jack, telephone, for 2 connector plug	82389	2J-1339	1	1		
1251-0148	Connector, POWER: male, 3 pin	0000U	H-1061 1G-3L	1	1		
1251-0149	Connector, female, 6 contact	02660	A1-PC6F-1000	1	1		
1400-0084	Fuseholder: extractor post type	75915	342014	1	1		
1420-0009	Battery, rechargeable, 1-25AH	88220	obd#	1	1		
1450-0048	Lamp, Ne: NE2H	08717	858-R	1	1		
1850-0040	Transistor, Ge: 2N383	94154	2N383	1	1		
1850-0064	Transistor, Ge: 2N1183	02735	2N1183	1	1		
1850-0065	Transistor, Ge: 2N1370	01295	2N1370	7	7		
1851-0017	Transistor, Ge: 2N1304	01295	2N1304	4	4		
1854-0003	Transistor, Si	07263	S-3056	3	3		
1901-0024	Diode, Si	82647	G-355-1	9	9		
1901-0025	Diode, Si: 50 ma @+1V, 100 PIV	98925	CSD2693	6	6		
1902-0017	Diode, Si: avalanche	01281	PS8135	2	2		
1902-0018	Diode, Si: avalanche	04713	1N941	1	1		
1910-0016	Diode, Ge: 100 ma @ 1V, 60 PIV	93332	D2361	4	4		
2100-0182	R: var, comp, lin, 3.3K ohms ±10%, 1/3W	11237	UPE-70	1	1		
2100-0342	R: var, concentric Front sect: ww, lin, 10K ohms ±10%, 2W Rear sect: ww, lin, 800 ohms ±10%, 2W	11237	C2-252	1	1		
2110-0017	Fuse, cartridge: 0.15 amp	75915	313.150	1	10		
3100-0273	Switch, rot: 3 sect, 8 pos	76854	213364-K3	1	1		
3100-0370	Switch, rot: 1 sect, 4 pos	76834	obd#	1	1		
3101-0032	Switch, sl: 4PDT	42190	6613M (special)	1	1		
3101-0033	Switch, sl: DPDT	42190	4633	1	1		
8120-0078	Assy, power cable: smooth black, extra limp, 7.5ft, NEMA plug-in	70903	KH-4147	1	1		

See introduction to this section

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

hp Stock No.	Description #	Mfr.	Mfr. Part No.	TQ	RS		
9100-0141	Transformer, power	98734	61277	1	1		
9110-0040	Inductor, audio	98734	1895	3	1		
9120-0065	Transformer, audio	98734	2-2690	2	1		
9120-0066	Transformer, audio	98734	2-2695	2	1		
9140-0122	Coil, var, 2 windings, 9-20μh each	09250	18-473	2	1		

See introduction to this section

APPENDIX
CODE LIST OF MANUFACTURERS (Sheet 1 of 2)

The following code numbers are from the Federal Supply Code for Manufacturers Cataloging Handbooks H4-1 (Name to Code) and H4-2 (Code to Name) and their latest supplements. The date of revision and the date of the supplements used appear at the bottom of each page. Alphabetical codes have been arbitrarily assigned to suppliers not appearing in the H4 handbooks.

CODE NO.	MANUFACTURER	ADDRESS
00334	Humidial Co.	Colton, Calif.
00335	Westrex Corp.	New York, N.Y.
00373	Garlock Packing Co., Electronic Products Div.	Camden, N.J.
00656	Aerovox Corp.	New Bedford, Mass.
00779	Amp, Inc.	Harrisburg, Pa.
00781	Aircraft Radio Corp.	Boonton, N.J.
00815	Northern Engineering Laboratories, Inc.	Burlington, Wis.
00853	Sangamo Electric Company, Ordill Division (Capacitors)	Marion, Ill.
00866	Goe Engineering Co.	Los Angeles, Calif.
00891	Carl E. Holmes Corp.	Los Angeles, Calif.
01121	Allen Bradley Co.	Milwaukee, Wis.
01255	Litton Industries, Inc.	Beverly Hills, Calif.
01281	Pacific Semiconductors, Inc.	Culver City, Calif.
01295	Texas Instruments, Inc. Transistor Products Div.	Dallas, Texas
01349	The Alliance Mfg. Co.	Alliance, Ohio
01561	Chassi-Trak Corp.	Indianapolis, Ind.
01589	Pacific Relays, Inc.	Van Nuys, Calif.
01930	Amerock Corp.	Rockford, Ill.
01961	Pulse Engineering Co.	Santa Clara, Calif.
02114	Ferroxcube Corp. of America	Saugerties, N.Y.
02286	Cole Mfg. Co.	Palo Alto, Calif.
02660	Amphenol-Borg Electronics Corp.	Chicago, Ill.
02735	Radio Corp. of America Semiconductor and Materials Div.	Somerville, N.J.
02771	Vocaline Co. of America, Inc.	Old Saybrook, Conn.
02777	Hopkins Engineering Co.	San Fernando, Calif.
03508	G.E. Semiconductor Products Dept.	Syracuse, N.Y.
03705	Apex Machine & Tool Co.	Dayton, Ohio
03797	Eldema Corp.	El Monte, Calif.
03877	Transitron Electronic Corp.	Wakefield, Mass.
03888	Pyrofilm Resistor Co.	Morristown, N.J.
03954	Air Marine Motors, Inc.	Los Angeles, Calif.
04009	Arrow, Hart and Hegeman Elect. Co.	Hartford, Conn.
04062	Elmenco Products Co.	New York, N.Y.
04222	Hi-Q Division of Aerovox	Myrtle Beach, S.C.
04298	Elgin National Watch Co., Electronics Division	Burbank, Calif.
04404	Dymec Division of Hewlett-Packard Co.	Palo Alto, Calif.
04651	Sylvania Electric Prods., Inc. Electronic Tube Div.	Mountain View, Calif.
04713	Motorola, Inc., Semiconductor Prod. Div.	Phoenix, Arizona
04732	Filtron Co., Inc. Western Division	Culver City, Calif.
04773	Automatic Electric Co.	Northlake, Ill.
04796	Sequoia Wire & Cable Company	Redwood City, Calif.
04870	P. M. Motor Co.	Chicago 44, Ill.
05006	Twentieth Century Plastics, Inc.	Los Angeles, Calif.
05277	Westinghouse Electric Corp., Semi-Conductor Dept.	Youngwood, Pa.
05347	Ultronix, Inc.	San Mateo, Calif.
05593	Illumitronic Engineering Co.	Sunnyvale, Calif.
05624	Barber Colman Co.	Rockford, Ill.
05729	Metropolitan Telecommunications Corp., Metro Cap. Div.	Brooklyn, N.Y.
05783	Stewart Engineering Co.	Santa Cruz, Calif.
06004	The Bassick Co.	Bridgeport, Conn.
06136	Ward Leonard Electric	Los Angeles, Calif.
06175	Bausch and Lomb Optical Co.	Rochester, N.Y.
06555	Beede Electrical Instrument Co., Inc.	Penacook, N.H.
06812	Torrington Mfg. Co., West Div.	Van Nuys, Calif.
07115	Corning Glass Works Electronic Components Dept.	Bradford, Pa.
07126	Digitran Co.	Pasadena, Calif.
07137	Transistor Electronics Corp.	Minneapolis, Minn.
07138	Westinghouse Electric Corp. Electronic Tube Div.	Elmira, N.Y.
07261	Avnet Corp.	Los Angeles, Calif.
07263	Fairchild Semiconductor Corp.	Mountain View, Calif.
07910	Continental Device Corp.	Hawthorne, Calif.
07933	Rheem Semiconductor Corp.	Mountain View, Calif.
07966	Shockley Semi-Conductor Laboratories	Palo Alto, Calif.
07980	Boonton Radio Corp.	Boonton, N.J.
08145	U.S. Engineering Co.	Los Angeles, Calif.
08358	Burgess Battery Co.	Niagara Falls, Ontario, Canada
08717	Sloan Company	Burbank, Calif.
08718	Cannon Electric Co. Phoenix Div.	Phoenix, Ariz.
08792	CBS Electronics Semiconductor Operations, Div. of C.B.S. Inc.	Lowell, Mass.
08984	Mel-Rain	Indianapolis, Ind.
09026	Babcock Relays, Inc.	Costa Mesa, Calif.
09134	Texas Capacitor Co.	Houston, Texas
09250	Electro Assemblies, Inc.	Chicago, Ill.
09569	Mallory Battery Co. of Canada, Ltd.	Toronto, Ontario, Canada
10214	General Transistor Western Corp.	Los Angeles, Calif.
10411	Ti-Tal, Inc.	Berkeley, Calif.
10646	Carborundum Co.	Niagara Falls, N.Y.
11236	CTS of Berne, Inc.	Berne, Ind.
11237	Chicago Telephone of California, Inc.	So. Pasadena, Calif.
11312	Microwave Electronics Corp.	Palo Alto, Calif.
11534	Duncan Electronics, Inc.	Santa Ana, Calif.
11711	General Instrument Corporation Semiconductor Division	Newark, N.J.
11717	Imperial Electronics, Inc.	Buena Park, Calif.
11870	Melabs, Inc.	Palo Alto, Calif.
12697	Clarostat Mfg. Co.	Dover, N.H.
14655	Cornell Dubilier Elec. Corp.	So. Plainfield, N.J.
15909	The Daven Co.	Livingston, N.J.
16688	De Jur-Amsco Corporation	Long Island City 1, N.Y.
16758	Delco Radio Div. of G. M. Corp.	Kokomo, Ind.
18873	E. I. DuPont and Co., Inc.	Wilmington, Del.
19315	Eclipse Pioneer, Div. of Bendix Aviation Corp.	Teterboro, N.J.
19500	Thomas A. Edison Industries, Div. of McGraw-Edison Co.	West Orange, N.J.
19701	Electra Manufacturing Co.	Kansas City, Mo.
20183	Electronic Tube Corp.	Philadelphia, Pa.
21520	Fansteel Metallurgical Corp.	No. Chicago, Ill.
21335	The Fafnir Bearing Co.	New Britain, Conn.
21964	Fed. Telephone and Radio Corp.	Clifton, N.J.
24446	General Electric Co.	Schenectady, N.Y.
24455	G.E., Lamp Division	Nela Park, Cleveland, Ohio
24655	General Radio Co.	West Concord, Mass.
26462	Grobet File Co. of America, Inc.	Carlstadt, N.J.
26992	Hamilton Watch Co.	Lancaster, Pa.
28480	Hewlett-Packard Co.	Palo Alto, Calif.
33173	G.E. Receiving Tube Dept.	Owensboro, Ky.
35434	Lectrohm Inc.	Chicago, Ill.
37942	P. R. Mallory & Co., Inc.	Indianapolis, Ind.
39543	Mechanical Industries Prod. Co.	Akron, Ohio
40920	Miniature Precision Bearings, Inc.	Keene, N.H.
42190	Muter Co.	Chicago, Ill.
43990	C. A. Norgren Co.	Englewood, Colo.
44655	Ohmite Mfg. Co.	Skokie, Ill.
47904	Polaroid Corp.	Cambridge, Mass.
48620	Precision Thermometer and Inst. Co.	Philadelphia, Pa.
49956	Raytheon Company	Lexington, Mass.
54294	Shallcross Mfg. Co.	Selma, N.C.
55026	Simpson Electric Co.	Chicago, Ill.
55933	Sonotone Corp.	Elmsford, N.Y.
55938	Sorenson & Co., Inc.	So. Norwalk, Conn.
56137	Spaulding Fibre Co., Inc.	Tonawanda, N.Y.
56289	Sprague Electric Co.	North Adams, Mass.
59446	Telex, Inc.	St. Paul, Minn.
61775	Union Switch and Signal, Div. of Westinghouse Air Brake Co.	Swissvale, Pa.
62119	Universal Electric Co.	Owosso, Mich.
64959	Western Electric Co., Inc.	New York, N.Y.
65092	Weston Inst. Div. of Daystrom, Inc.	Newark, N.J.
66295	Wittek Manufacturing Co.	Chicago 23, Ill.
66346	Wollensak Optical Co.	Rochester, N.Y.
70276	Allen Mfg. Co.	Hartford, Conn.
70309	Allied Control Co., Inc.	New York, N.Y.
70485	Atlantic India Rubber Works, Inc.	Chicago, Ill.
70563	Amperite Co., Inc.	New York, N.Y.
70903	Belden Mfg. Co.	Chicago, Ill.
70998	Bird Electronic Corp.	Cleveland, Ohio
71002	Birnbach Radio Co.	New York, N.Y.
71041	Boston Gear Works Div. of Murray Co. of Texas	Quincy, Mass.
71218	Bud Radio Inc.	Cleveland, Ohio
71286	Camloc Fastener Corp.	Paramus, N.J.
71313	Allen D. Cardwell Electronic Prod. Corp.	Plainville, Conn.
71400	Bussmann Fuse Div. of McGraw-Edison Co.	St. Louis, Mo.
71450	CTS Corp.	Elkhart, Ind.
71468	Cannon Electric Co.	Los Angeles, Calif.
71471	Cinema Engineering Co.	Burbank, Calif.
71482	C. P. Clare & Co.	Chicago, Ill.
71528	Standard-Thomson Corp., Clifford Mfg. Co. Div.	Waltham, Mass.
71590	Centralab Div. of Globe Union Inc.	Milwaukee, Wis.
71700	The Cornish Wire Co.	New York, N.Y.
71744	Chicago Miniature Lamp Works	Chicago, Ill.
71753	A. O. Smith Corp., Crowley Div.	West Orange, N.J.
71785	Cinch Mfg. Corp.	Chicago, Ill.
71984	Dow Corning Corp.	Midland, Mich.
72136	Electro Motive Mfg. Co., Inc.	Willimantic, Conn.
72354	John E. Fast & Co.	Chicago, Ill.
72619	Dialight Corp.	Brooklyn, N.Y.
72656	General Ceramics Corp.	Keasbey, N.J.
72758	Girard-Hopkins	Oakland, Calif.
72765	Drake Mfg. Co.	Chicago, Ill.
72825	Hugh H. Eby Inc.	Philadelphia, Pa.
72928	Gudeman Co.	Chicago, Ill.
72964	Robert M. Hadley Co.	Los Angeles, Calif.
72982	Erie Resistor Corp.	Erie, Pa.
73061	Hansen Mfg. Co., Inc.	Princeton, Ind.
73138	Helipot Div. of Beckman Instruments, Inc.	Fullerton, Calif.
73293	Hughes Products Division of Hughes Aircraft Co.	Newport Beach, Calif.
73445	Amperex Electronic Co., Div. of North American Phillips Co., Inc.	Hicksville, N.Y.
73506	Bradley Semiconductor Corp.	Hamden, Conn.
73559	Carling Electric, Inc.	Hartford, Conn.
73682	George K. Garrett Co., Inc.	Philadelphia, Pa.

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APPENDIX
CODE LIST OF MANUFACTURERS (Sheet 2 of 2)

CODE NO.	MANUFACTURER	ADDRESS
73734	Federal Screw Products Co.	Chicago, Ill.
73743	Fischer Special Mfg. Co.	Cincinnati, Ohio
73793	The General Industries Co.	Elyria, Ohio
73905	Jennings Radio Mfg. Co.	San Jose, Calif.
74455	J. H. Winns, and Sons	Winchester, Mass.
74861	Industrial Condenser Corp.	Chicago, Ill.
74868	R.F. Products Division of Amphenol-Borg Electronics Corp.	Danbury, Conn.
74970	E. F. Johnson Co.	Waseca, Minn.
75042	International Resistance Co.	Philadelphia, Pa.
75173	Jones, Howard B., Division of Cinch Mfg. Corp.	Chicago, Ill.
75378	James Knights Co.	Sandwich, Ill.
75382	Kulka Electric Corporation	Mt. Vernon, N.Y.
75818	Lenz Electric Mfg. Co.	Chicago, Ill.
75915	Littelfuse Inc.	Des Plaines, Ill.
76005	Lord Mfg. Co.	Erie, Pa.
76210	C. W. Marwedel	San Francisco, Calif.
76433	Micamold Electronic Mfg. Corp.	Brooklyn, N.Y.
76487	James Millen Mfg. Co., Inc.	Malden, Mass.
76493	J. W. Miller Co.	Los Angeles, Calif.
76530	Monadnock Mills	San Leandro, Calif.
76545	Mueller Electric Co.	Cleveland, Ohio
76854	Oak Manufacturing Co.	Crystal Lake, Ill.
77068	Bendix Pacific Division of Bendix Corp.	No. Hollywood, Calif.
77221	Phaostron Instrument and Electronic Co.	South Pasadena, Calif.
77252	Philadelphia Steel and Wire Corp.	Philadelphia, Pa.
77342	Potter and Brumfield, Div. of American Machine and Foundry	Princeton, Ind.
77630	Radio Condenser Co.	Camden, N.J.
77638	Radio Receptor Co., Inc.	Brooklyn, N.Y.
77764	Resistance Products Co.	Harrisburg, Pa.
78189	Shakeproof Division of Illinois Tool Works	Elgin, Ill.
78283	Signal Indicator Corp.	New York, N.Y.
78471	Tilley Mfg. Co.	San Francisco, Calif.
78488	Stackpole Carbon Co.	St. Marys, Pa.
78553	Tinnerman Products, Inc.	Cleveland, Ohio
78790	Transformer Engineers	Pasadena, Calif.
78947	Ucinite Co.	Newtonville, Mass.
79142	Veeder Root, Inc.	Hartford, Conn.
79251	Wenco Mfg. Co.	Chicago, Ill.
79727	Continental-Wirt Electronics Corp.	Philadelphia, Pa.
79963	Zierick Mfg. Corp.	New Rochelle, N.Y.
80031	Mepco Division of Sessions Clock Co.	Morristown, N.J.
80120	Schnitzer Alloy Products	Elizabeth, N.J.
80130	Times Facsimile Corp.	New York, N.Y.
80131	Electronic Industries Association Any brand tube meeting EIA standards	Washington, D.C.
80207	Unimax Switch, Div. of W. L. Maxson Corp.	Wallingford, Conn.
80248	Oxford Electric Corp.	Chicago, Ill.
80294	Bourns Laboratories, Inc.	Riverside, Calif.
80411	Acro Div. of Robertshaw Fulton Controls Co.	Columbus 16, Ohio
80486	All Star Products Inc.	Defiance, Ohio
80583	Hammerlund Co., Inc.	New York, N.Y.
80640	Stevens, Arnold, Co., Inc.	Boston, Mass.
81030	International Instruments, Inc.	New Haven, Conn.
81312	Winchester Electronics Co., Inc.	Norwalk, Conn.
81415	Wilkor Products, Inc.	Cleveland, Ohio
81453	Raytheon Mfg. Co., Industrial Components Div., Industr. Tube Operations	Newton, Mass.
81483	International Rectifier Corp.	El Segundo, Calif.
81860	Barry Controls, Inc.	Watertown, Mass.
82042	Carter Parts Co.	Skokie, Ill.
82142	Jeffers Electronics Division of Speer Carbon Co.	Du Bois, Pa.
82170	Allen B. DuMont Labs., Inc.	Clifton, N.J.
82209	Maguire Industries, Inc.	Greenwich, Conn.
82219	Sylvania Electric Prod. Inc., Electronic Tube Div.	Emporium, Pa.
82376	Astron Co.	East Newark, N.J.
82389	Switchcraft, Inc.	Chicago, Ill.

CODE NO.	MANUFACTURER	ADDRESS
82647	Metals and Controls, Inc., Div. of Texas Instruments, Inc., Spencer Prods.	Attleboro, Mass.
82866	Research Products Corp.	Madison, Wis.
82877	Rotron Manufacturing Co., Inc.	Woodstock, N.Y.
82893	Vector Electronic Co.	Glendale, Calif.
83053	Western Washer Mfr. Co.	Los Angeles, Calif.
83058	Carr Fastener Co.	Cambridge, Mass.
83086	New Hampshire Ball Bearing, Inc.	Peterborough, N.H.
83125	Pyramid Electric Co.	Darlington, S.C.
83148	Electro Cords Co.	Los Angeles, Calif.
83186	Victory Engineering Corp.	Union, N.J.
83298	Bendix Corp., Red Bank Div.	Red Bank, N.J.
83330	Smith, Herman H., Inc.	Brooklyn, N.Y.
83501	Gavitt Wire and Cable Co., Div. of Amerace Corp.	Brookfield, Mass.
83594	Burroughs Corp., Electronic Tube Div.	Plainfield, N.J.
83777	Model Eng. and Mfg., Inc.	Huntington, Ind.
83821	Loyd Scruggs Co.	Festus, Mo.
84171	Arco Electronics, Inc.	New York, N.Y.
84396	A. J. Glesener Co., Inc.	San Francisco, Calif.
84411	Good All Electric Mfg. Co.	Ogallala, Neb.
84970	Sarkes Tarzian, Inc.	Bloomington, Ind.
85454	Boonton Molding Company	Boonton, N.J.
85471	A. B. Boyd Co.	San Francisco, Calif.
85474	R. M. Bracamonte & Co.	San Francisco, Calif.
85660	Koiled Kords, Inc.	New Haven, Conn.
85911	Seamless Rubber Co.	Chicago, Ill.
86197	Clifton Precision Products	Clifton Heights, Pa.
86684	Radio Corp. of America, RCA Electron Tube Div.	Harrison, N.J.
87216	Philco Corp. (Lansdale Division)	Lansdale, Pa.
87473	Western Fibrous Glass Products Co.	San Francisco, Calif.
88140	Cutler-Hammer, Inc.	Lincoln, Ill.
88220	Gould-National Batteries, Inc.	St. Paul, Minn.
89473	General Electric Distributing Corp.	Schenectady, N.Y.
89636	Carter Parts Div. of Economy Baler Co.	Chicago, Ill.
89665	United Transformer Co.	Chicago, Ill.
90179	U.S. Rubber Co., Mechanical Goods Div.	Passaic, N.J.
90970	Bearing Engineering Co.	San Francisco, Calif.
91260	Connor Spring Mfg. Co.	San Francisco, Calif.
91345	Miller Dial & Nameplate Co.	El Monte, Calif.
91418	Radio Materials Co.	Chicago, Ill.
91506	Augat Brothers, Inc.	Attleboro, Mass.
91637	Dale Electronics, Inc.	Columbus, Nebr.
91662	Elco Corp.	Philadelphia, Pa.
91737	Gremar Mfg. Co., Inc.	Wakefield, Mass.
91827	K F Development Co.	Redwood City, Calif.
91921	Minneapolis-Honeywell Regulator Co., Micro-Switch Division	Freeport, Ill.
92196	Universal Metal Products, Inc.	Bassett Puente, Calif.
93332	Sylvania Electric Prod. Inc., Semiconductor Div.	Woburn, Mass.
93369	Robbins and Myers, Inc.	New York, N.Y.
93410	Stevens Mfg. Co., Inc.	Mansfield, Ohio
93983	Insuline-Van Norman Ind., Inc. Electronic Division	Manchester, N.H.
94144	Raytheon Mfg. Co., Industrial Components Div., Receiving Tube Operation	Quincy, Mass.
94145	Raytheon Mfg. Co., Semiconductor Div., California Street Plant	Newton, Mass.
94148	Scientific Radio Products, Inc.	Loveland, Colo.
94154	Tung-Sol Electric, Inc.	Newark, N.J.
94197	Curtiss-Wright Corp., Electronics Div.	East Paterson, N.J.
94310	Tru Ohm Prod. Div. of Model Engineering and Mfg. Co.	Chicago, Ill.
94682	Worcester Pressed Aluminum Corp.	Worcester, Mass.
95236	Allies Products Corp.	Miami, Fla.
95238	Continental Connector Corp.	Woodside, N.Y.
95263	Leecraft Mfg. Co., Inc.	New York, N.Y.
95264	Lerco Electronics, Inc.	Burbank, Calif.

CODE NO.	MANUFACTURER	ADDRESS
95265	National Coil Co.	Sheridan, Wyo.
95275	Vitramon, Inc.	Bridgeport, Conn.
95354	Methode Mfg. Co.	Chicago, Ill.
95987	Weckesser Co.	Chicago, Ill.
96067	Huggins Laboratories	Sunnyvale, Calif.
96095	Hi-Q Division of Aerovox	Olean, N.Y.
96256	Thordarson-Meissner Div. of Maguire Industries, Inc.	Mt. Carmel, Ill.
96296	Solar Manufacturing Co.	Los Angeles, Calif.
96330	Carlton Screw Co.	Chicago, Ill.
96341	Microwave Associates, Inc.	Burlington, Mass.
96501	Excel Transformer Co.	Oakland, Calif.
97464	Industrial Retaining Ring Co.	Irvington, N.J.
97539	Automatic and Precision Mfg. Co.	Yonkers, N.Y.
97966	CBS Electronics, Div. of C.B.S., Inc.	Danvers, Mass.
98141	Axel Brothers Inc.	Jamaica, N.Y.
98220	Francis L. Mosley	Pasadena, Calif.
98278	Microdot, Inc.	So. Pasadena, Calif.
98291	Sealectro Corp.	Mamaroneck, N.Y.
98405	Carad Corp.	Redwood City, Calif.
98734	Palo Alto Engineering Co., Inc.	Palo Alto, Calif.
98821	North Hills Electric Co.	Mineola, N.Y.
98925	Clevite Transistor Prod. Div. of Clevite Corp.	Waltham, Mass.
98978	International Electronic Research Corp.	Burbank, Calif.
99109	Columbia Technical Corp.	New York, N.Y.
99313	Varian Associates	Palo Alto, Calif.
99515	Marshall Industries, Electron Products Division	Pasadena, Calif.
99707	Control Switch Division, Controls Co. of America	El Segundo, Calif.
99800	Delevan Electronics Corp.	East Aurora, N.Y.
99848	Wilco Corporation	Indianapolis, Ind.
99934	Renbrandt, Inc.	Boston, Mass.
99942	Hoffman Semiconductor Div. of Hoffman Electronics Corp.	Evanston, Ill.
99957	Technology Instrument Corp. of Calif.	Newbury Park, Calif.

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

CODE NO.	MANUFACTURER	ADDRESS
0000F	Malco Tool and Die	Los Angeles, Calif.
0000I	Telefunken (c/o American Elite)	New York, N.Y.
0000M	Western Coil Div. of Automatic Ind., Inc.	Redwood City, Calif.
0000N	Nahm-Bros. Spring Co.	San Leandro, Calif.
0000P	Ty-Car Mfg. Co., Inc.	Holliston, Mass.
0000T	Texas Instruments, Inc. Metals and Controls Div.	Versailles, Ky.
0000U	Tower Mfg. Corp.	Providence, R.I.
0000W	Webster Electronics Co. Inc.	New York, N.Y.
0000X	Spruce Pine Mica Co.	Spruce Pine, N.C.
0000Y	Midland Mfg. Co. Inc.	Kansas City, Kans.
0000Z	Willow Leather Products Corp.	Newark, N.J.
000AA	British Radio Electronics Ltd.	Washington, D.C.
000BB	Precision Instrument Components Co.	Van Nuys, Calif.
000CC	Computer Diode Corp.	Lodi, N.J.
000EE	A. Williams Manufacturing Co.	San Jose, Calif.
000FF	Carmichael Corrugated Specialties	Richmond, Calif.
000GG	Goshen Die Cutting Service	Goshen, Ind.
000HH	Rubbercraft Corp.	Torrance, Calif.
000II	Birtcher Corporation, Industrial Division	Monterey Park, Calif.
000KK	Amatom	New Rochelle, N.Y.
000LL	Avery Label	Monrovia, Calif.
000MM	Rubber Eng. & Development	Hayward, Calif.
000NN	A "N" D Manufacturing Co.	San Jose 27, Calif.
000PP	Atohm Electronics,	Sun Valley, Calif.
000QQ	Cooltron	Oakland, Calif.
000RR	Radio Industries	Des Plaines, Ill.
000SS	Control of Elgin Watch Co.	Burbank, Calif.
000TT	Thomas & Betts Co., The	Elizabeth 1, N.J.

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WARRANTY

All our products are warranted against defects in materials and workmanship for one year from the date of shipment. Our obligation is limited to repairing or replacing products (except tubes) which prove to be defective during the warranty period. We are not liable for consequential damages.

For assistance of any kind, including help with instruments under warranty, contact your authorized hp Sales Representative for instructions. Give full details of the difficulty and include the instrument model and serial numbers. Service data or shipping instructions will be promptly sent to you. There will be no charge for repair of instruments under warranty, *except transportation charges.* Estimates of charges for non-warranty or other service work will always be supplied, if requested, before work begins.

CLAIM FOR DAMAGE IN SHIPMENT

Your instrument should be inspected and tested as soon as it is received. The instrument is insured for safe delivery. If the instrument is damaged in any way or fails to operate properly, file a claim with the carrier or, if insured separately, with the insurance company.

SHIPPING

On receipt of shipping instructions, forward the instrument prepaid to the destination indicated. You may use the original shipping carton or any strong container. Wrap the instrument in heavy paper or a plastic bag and surround it with three or four inches of shock-absorbing material to cushion it firmly and prevent movement inside the container.

GENERAL

Your authorized hp Sales Representative is ready to assist you in any situation, and you are always welcome to get directly in touch with Hewlett-Packard service departments:

CUSTOMER SERVICE

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Palo Alto, California, U.S.A.
Telephone: (415) 326-1755
TWX No. PAL AL 117-U
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