

## Errata

**Title & Document Type:** 415E SWR Meter Operating and Service Manual

**Manual Part Number:** 00415-90009

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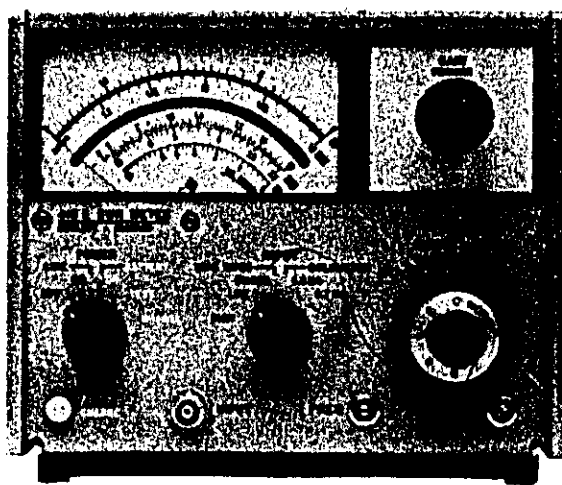


**Agilent Technologies**

# OPERATING AND SERVICE MANUAL

## SWR METER

415E



HEWLETT  PACKARD

HP 415E

## **CERTIFICATION**

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**SWR METER  
415E**

**Serial Prefix: 0990A-**

This manual applies directly to HP Model 415E  
SWR Meters having serial prefix number 0990A-

**Serial Prefixes Not Listed**

For serial prefixes above 0990A, a "Manual  
Changes" sheet is included with this manual.  
For serial prefixes below 0990A, refer to Ap-  
pendices I and II.

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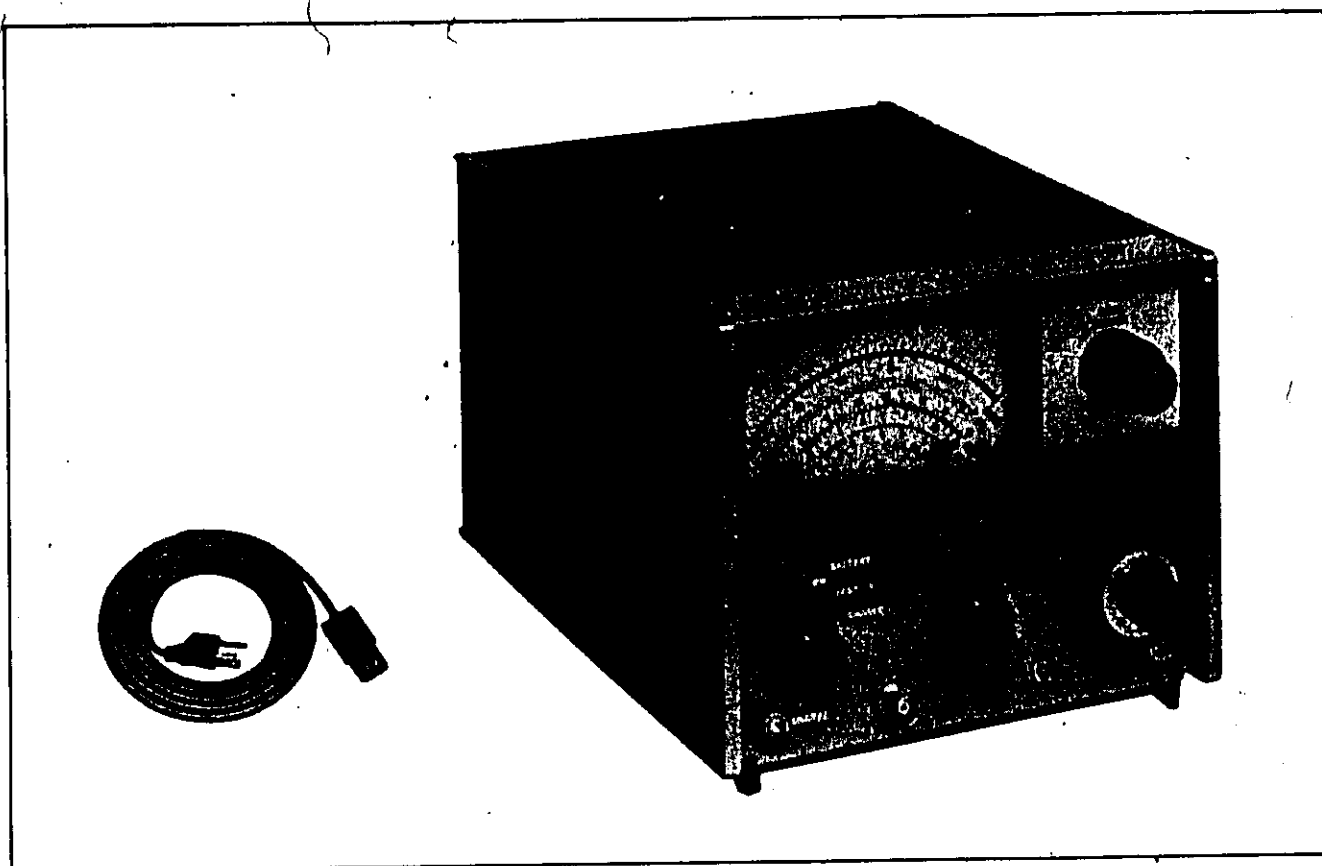


Figure 1-1. Model 415E SWR Meter

Table 1-1. Specifications

**Sensitivity:** 0.15  $\mu$ Vrms for full-scale deflection at maximum bandwidth (1  $\mu$ Vrms on high impedance crystal input).

**Noise:** At least 7.5 dB below full scale at rated sensitivity and 130-Hz bandwidth with input terminated in 100 or 5000 ohms. Noise figure less than 4 dB.

**Range:** 70 dB in 10- and 2-dB steps.

**Accuracy:**  $\pm 0.05$  dB/10-dB step; maximum cumulative error between any two 10-dB steps,  $\pm 0.10$  dB; maximum cumulative error between any two 2-dB steps,  $\pm 0.05$  dB. Linearity:  $\pm 0.02$  dB on expanded scales, determined by inherent meter resolution on normal scales.

**Input:** Unbiased low and high impedance crystal (50 to 200 and 2500 to 10,000 ohm optimum source impedance respectively for low noise); biased crystal (1V into 1K); low and high current bolometer (4.5 and 8.7 mA  $\pm 3\%$  into 200 ohms), positive bolometer protection. Input connector, BNC female.

**Input Frequency:** 1000 Hz, adjustable 7%. Other frequencies between 400 and 2500 Hz available on special order.

**Bandwidth:** Variable, 15 to 130 Hz. Typically less than 0.5-dB change in gain from minimum to maximum bandwidth.

**Recorder Output:** 0 to 1 Vdc into an open circuit from 1000 ohms source impedance for ungrounded recorders. Output connector, BNC female.

**Amplifier Output:** 0 to 0.3 Vrms (NORM), 0 to 0.8 Vrms (EXPAND) into at least 10,000 ohms for ungrounded equipment. Output connector, dual banana jacks.

**Meter Scales:** Calibrated for square-law detectors. SWR: 1 to 4, 3.2 to 10 (NORM); 1 to 1.25 (EXPAND). DB: 0 to 10 (NORM); 0 to 2.0 (EXPAND). Battery: change state.

**Meter Movement:** Taut-band suspension, individually calibrated mirror-backed scales; expanded dB and SWR scales greater than 4-1/4 inch (108 mm) long.

**RFI:** Conducted and radiated leakage limits are below those specified in MIL-I-6181D.

**Power:** 115 or 230 volts  $\pm 10\%$ , 50 to 400 Hz, 1 watt. Optional rechargeable battery provides up to 36 hours continuous operation.

**Weight:** Net, 9-1/2 lb (4.3 kg), 11 lb (4.9 kg) with battery.

**Options:**

01, 001. Rechargeable battery installed.

02, 002. Rear-panel input connector in parallel with front-panel connector.

## SECTION I GENERAL INFORMATION

### 1-1. INTRODUCTION

1-2. The Model 415E Standing Wave Ratio (SWR) Meter is a high-gain amplifier, tuned to an audio frequency, with a square-law calibrated meter-readout. The Model 415E is designed for use with square-law detectors in the measurement of SWR and power. In addition, because of high-sensitivity and narrow bandwidth, it can be used as a null detector for audio-frequency bridges. The Model 415E is shown in Figure 1-1. Operating specifications are given in Table 1-1.

1-3. The Model 415E is designed to operate at a mean frequency of 1000 Hz, with a variable bandwidth of 15 to 130 Hz. Operating center frequency and bandwidth are both adjustable at the front panel. The amplifier gain is only slightly changed due to change in bandwidth (typically less than 0.5 dB). In addition to the meter readout, provisions have been made on the rear panel to connect to external readout devices. Two outputs are available: an ac amplifier output is provided to allow using the Model 415E as a high-gain (126 dB) amplifier and a dc recorder output is provided to permit obtaining a permanent record of the measurement data. Either or both of these rear panel outputs can be used without affecting instrument meter operation provided no spurious signals, such as power line ground voltages, are introduced by the addition of external readouts. This can be checked by noting the reading on the meter both with and without the external readouts connected. If the meter readings change, additional voltage is being introduced from the external readout.

### 1-4. INSTRUMENTS COVERED BY MANUAL

1-5. This manual applies directly to the Model 415E SWR Meters having serial numbers prefixed 990 (first group of numbers of serial number). If the serial prefix on your instrument is other than 990, there are differences between the manual and your instrument which are described in a Manual Changes sheet included with the manual. If the Manual Changes sheet is missing, the information can be supplied by your nearest Hewlett-Packard Sales and Service office (see list at rear of this manual). The manual change sheet may also include an "ERRATA" section which describes manual correction information which applies to the manual for all instruments including instruments prefixed 990.

### 1-6. INSTRUMENT OPTIONS

1-7. This manual provides operating and servicing information for the standard Model 415E. In addition, operating and servicing information for Model 415E instruments with Options 01, 001, 02, and 002, described below, is also included.

a. Option 01, 001. Factory installed, 24-volt rechargeable battery capable of supplying up to 36 hours continuous operation of the Model 415E. If not initially installed as an option, the same battery is available on order from Hewlett-Packard (see paragraph 2-23).

b. Option 02, 002: Additional input connector on rear panel wires in parallel with the front panel INPUT connector. If not initially installed as an option, the connector-cable assembly is available on order from Hewlett-Packard (see paragraph 2-23).



## SECTION II INSTALLATION

### 2-1. INITIAL INSPECTION

#### 2-2. Mechanical Check

2-3. If damage to the shipping carton is evident, ask that the carrier's agent be present when the instrument is unpacked. Inspect for mechanical damage, such as scratches or dents. Also check the cushioning material for signs of severe stress (compacting).

#### 2-4. Electrical Check

2-5. The electrical performance should be verified as soon as possible after receipt. Refer to the Performance Test for further instructions.

#### 2-6. Claim for Damage

2-7. If there is mechanical damage or the instrument fails to meet electrical specifications upon receipt, notify the carrier and your nearest Hewlett-Packard office immediately (a list of offices is at the end of this manual). Retain the shipping carton and the padding material for the carrier's inspection.

### 2-8. INSTALLATION

2-9. The Model 415E 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).

#### 2-10. Rack Mounting

2-11. The Model 415E 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 HP combining case and adapter frame are designed specifically for this purpose.

2-12. **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.

2-13. **Adapter Frame.** The adapter frame is a rack frame that accepts any combination of submodular units. It can be rack mounted only.

#### 2-14. Three-Conductor Power Cable

2-15. To protect operating personnel, the National Electrical Manufacturer's 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.

2-16. 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.

### 2-17. PRIMARY POWER REQUIREMENTS

2-18. The Model 415E can be operated from an AC or DC primary power source. The AC source can be either 115 or 230 volts, 50 to 400 Hz. The DC source is a 24-volt rechargeable battery. The rechargeable battery is supplied with Option 01, 001 instruments only.

2-19. 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 1/16-ampere, 250-volt fuse is used for both 115- and 230-volt operation.

### CAUTION

To avoid damage to the instrument, set the 115 - 230-volt switch for the line voltage to be used before connecting the power cable.

#### 2-20. Initial Battery Check

2-21. The following applies to Option 01, 001 instruments or instruments that have field-installed batteries. When the battery is used as the power source for the first time, perform the following steps:

a. Connect Model 415E 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. Set POWER switch to TEST position, the meter needle indication should be within the BAT CHARGED area (see Figure 3-1).

### 2-22. INSTALLING BATTERY AND INPUT CONNECTOR

2-23. Available from Hewlett-Packard are parts required for modifying any Model 415E to correspond to those instruments with Option 01, 001 and/or Option 02, 002. A rechargeable Battery Installation Kit, HP Part No. 00415-606, contains the battery and necessary hardware for installation (corresponds to Option 01, 001). Installation instructions are detailed in Appendix I at rear of this manual. To obtain the parts required for an input connector on the rear panel (corresponding to Option 02, 002), order by HP Part Number as found in Table 6-1 (listed under option 02, 002). Instructions for installation of this additional connector are detailed in Appendix I at rear of this manual.

### 2-24. STORAGE AND SHIPMENT

#### 2-25. Shipping Environment

2-26. This instrument contains components which may be damaged by extremely low temperatures or water. Do not ship or store this instrument in temperatures below  $-40^{\circ}\text{C}$ . Allow the instrument to warm up to at least  $0^{\circ}\text{C}$  before attempting operation. This instrument will oper-

ate in any humidity up to 95% at  $+40^{\circ}\text{C}$ , but protect it from condensation when taking a cold instrument into a warm room by providing insulation (such as a blanket).

#### 2-27. Packaging

2-28. Using Original-Type Packaging. The same type containers and materials used in factory packaging can be obtained through the Hewlett-Packard offices listed at the end of this manual. If the instrument is being returned to Hewlett-Packard for servicing, attach a tag indicating the type of service, required, return address, model number, and full serial number. Also mark the container FRAGILE to assure careful handling. In any correspondence, refer to the instrument by model number and full serial number.

2-29. Using Other Packaging. The following general instructions should be used when repackaging with commercially-available materials:

a. Wrap the instrument in heavy paper or plastic. (If shipping to a Hewlett-Packard office, attach a tag indicating the type of service required, the return address, model number, and full serial number).

b. Use a strong shipping container. If a carton is used, a double-wall carton made of 350-pound test material is adequate).

c. Use enough shock-absorbing material (three- to four-inch layer) around all sides of the instrument to provide firm cushion and prevent movement inside the container. Protect the front panel with cardboard.

d. Seal the shipping container securely, and mark it FRAGILE to assure careful handling.

e. In any correspondence, refer to the instrument by model number and full serial number.

# OPERATION

## SECTION III OPERATION

### 3-1. INTRODUCTION

3-2. This section contains information and procedures for operation of the Model 415E (from either AC or battery power source) in making SWR and attenuation measurements. Also included is information on slotted line techniques, and a discussion of Model 415E noise performance with various source impedances and noise effect on meter indication.

### 3-3. FRONT AND REAR PANEL FEATURES

3-4. Figures 3-1 and 3-2 identify by number the front and rear panel features of the Model 415E. The descriptions are keyed by number to the figures. Further information regarding the various settings and uses of the controls, indicators, connectors, and adjustments is included in the procedures of this section. Information on the battery is found in paragraph 3-6.

### 3-5. GENERAL OPERATING AND MEASUREMENT CONSIDERATIONS.

#### 3-6. Battery Operation

3-7. The Model 415E may be operated from a battery instead of the 115- or 230-volt AC supply (see paragraph 2-18). Battery operation requires some slightly different procedures to prolong battery life and ensure proper results. The rechargeable nickel-cadmium battery is factory installed if ordered as Option 01, 001 (see paragraph 1-7). The same battery may be ordered and installed later. To obtain this battery, order HP Part No. 00415-606, Rechargeable Battery Installation Kit.

3-8. Initial Battery Use. When the Model 415E is to be battery operated for the first time, perform the following steps:

a. Switch the Model 415E POWER switch to BATTERY/TEST position and note meter pointer indication. A meter pointer indication in the BAT CHARGED area indicates the internal battery properly charged and ready for use. A meter pointer indication to the left of the BAT CHARGED area means that the battery must be charged as described below.

b. Connect the Model 415E to AC power source. Set POWER switch to BATTERY/CHARGE and charge the battery for a minimum of 16 hours or overnight.

c. After at least 16 hours of recharge time, switch POWER switch to BATTERY/TEST position and check battery charge. If the battery charge indication is still unsatisfactory, see Troubleshooting in Section V.

3-9. Optimum Battery Usage. It is recommended that the Model 415E be operated by the battery for up to eight hours, followed by 16 hours of recharge. If continuous battery operation is required for more than eight hours, the recharge time should be double the operating time. Continuous battery operation is possible for up to 36 hours but this must be followed by a prolonged recharge period.

3-10. Battery Storage. Storage of the battery at or below 70°F is best. Extended storage at high temperature will reduce the cell charge but not damage the battery if the storage temperature is less than 140°F. It is suggested that the battery be charged after removal from storage and before using the Model 415E for battery operation.

#### 3-11. Ground Loop Currents

3-12. The 415 SWR Meter audio amplifier has high sensitivity to low-level signals, such as ground loops. Ground loops occur when instruments are connected to 415E and grounded through power cords or rack mountings. The presence of ground loops can be detected by meter indications with no input at high-gain settings or by beats (a periodic waver) of the meter needle. Ground loops can be minimized in the following ways:

a. Operate at as high a signal level as the measurement will permit.

b. If ground loops occur, minimize them by changing all possible ground leads for the least beating in the measurement indication.

c. In difficult cases run separate ground leads to one central grounding point. Often, ground loops give trouble when the current from more than one instrument flows through the same wire. Current through a common impedance causes the potential on both ground terminals to vary as the current from one instrument varies.

#### 3-13. Bandwidth and Frequency Selection

3-14. Two front panel adjustments are provided to optimize operation of the Model 415E tuned

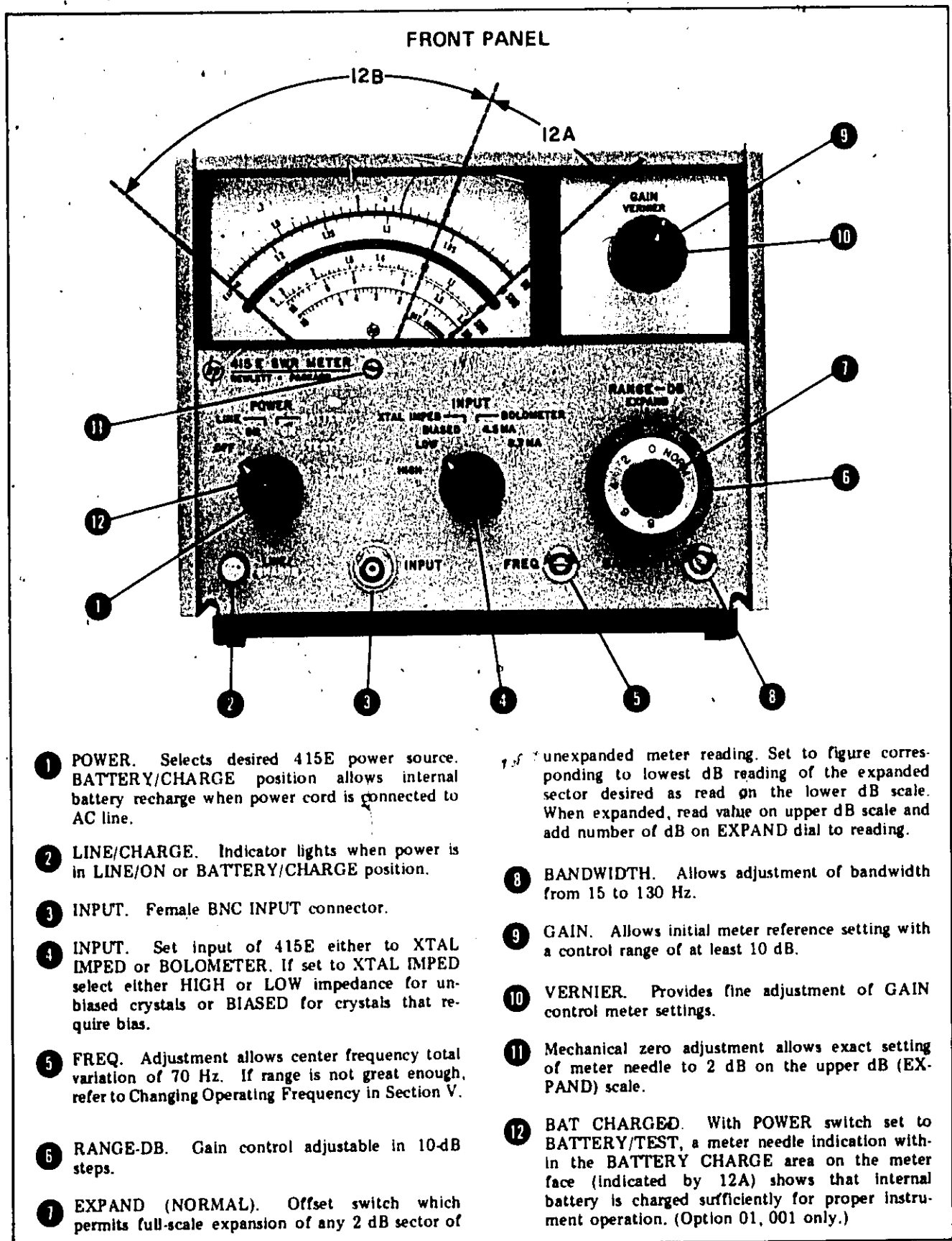


Figure 3-1. Front Panel Features

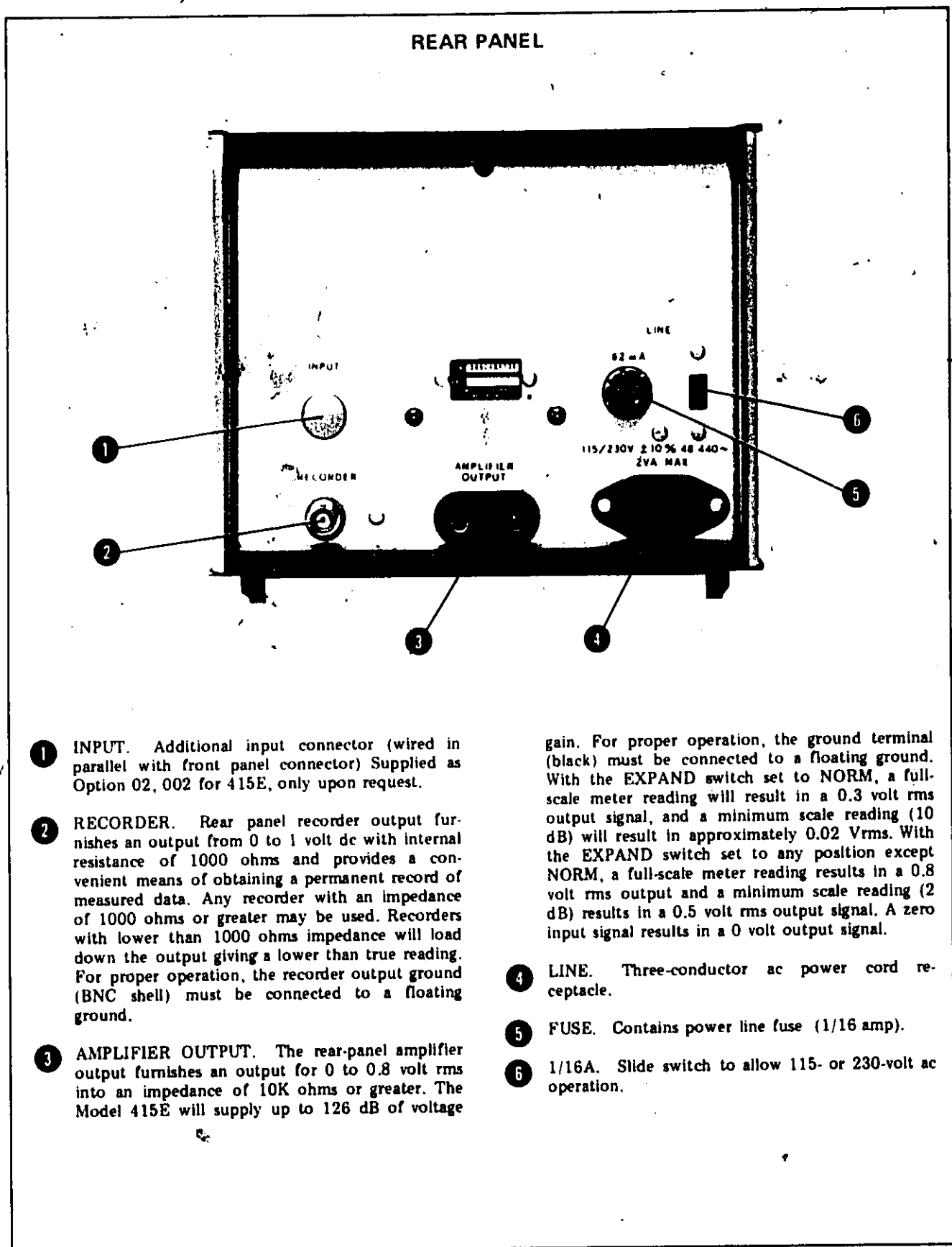


Figure 3-2. Rear Panel Features



amplifier. The FREQ (frequency) control allows a total variation of 7% of the center tuned frequency. When more than one Model 415E is included in the same measurement setup, the variable tuned frequency is used to set all the instruments to the exact frequency modulating the source. The high sensitivity and narrow bandwidth of the amplifier make the Model 415E valuable as a meter-indicating null detector for audio frequency bridges. The BANDWIDTH adjustment varies the tuned filter bandwidth from 15 to 130 Hz. A narrow bandwidth is best for low level signals as this improves the signal to noise ratio. A wide bandwidth would find more use in fast sweep rate measurements.

### 3-15. SWR MEASUREMENT EQUIPMENT AND TECHNIQUES

#### 3-16. Equipment

3-17. A typical setup of equipment used in SWR measurements is shown in Figure 3-3. The signal source is usually square-wave modulated at 1000 Hz since other modulating waveforms often cause undesirable frequency modulation of the source. Harmonics from the source sometimes cause trouble and can be eliminated with a low-pass filter.

3-18. The detector should be a square-law device (output voltage proportional to RF power input) such as a barretter or a crystal diode operated at

low signal levels. The meter of the 415E is calibrated for square-law detectors. Crystal diodes are normally more sensitive than barretters but barretters are square-law over a wider dynamic range. Both types of detector normally maintain accurate square-law response up to at least full scale deflection with the RANGE-DB switch set to the 30 dB position and coarse GAIN at maximum. (1 mVrms sine wave of 2.2 mV peak-to-peak square wave causes full scale deflection on HIGH XTAL IMPED position. On other positions of INPUT switch, 0.1 mVrms sine wave or 0.33 mV peak-to-peak square wave causes full-scale deflection.) Above this level these detectors should be individually checked for departure from square-law behavior or manufacturer's data should be consulted.

3-19. A short-circuit termination is useful in establishing reference positions along the transmission line and in measuring transmission line wavelengths.

#### 3-20. Slotted Line Probe Penetration

3-21. A general rule in slotted line measurement is to use minimum probe penetration that still picks up adequate signal to measure. The probe couples to the transmission line as a shunt admittance which increases (disturbing the transmission line more) as the probe penetrates farther. To find out whether a given probe penetration is too great or not, measure SWR, then change probe penetration and remeasure SWR. If the second reading is different, the probe is penetrating too far and loading the transmission line significantly.

#### 3-22. GENERAL TURN-ON PROCEDURE

3-23. Figure 3-4, General Turn-On Procedure, gives the turn-on procedure preliminary to making either SWR or power measurements. Do this procedure before proceeding to measurements. Scale functions are also indicated on Figure 3-4. Familiarity with these functions is necessary before making measurements.

#### 3-24. USE OF CRYSTAL DETECTORS

3-25. The input impedance of Model 415E must always be higher than the output or source impedance of a bolometer or crystal detector connected to the INPUT connector (see paragraph 4-21 for discussion). For low output impedance devices, such as 100 to 200 ohm detectors use 415A XTAL IMPED/LOW switch position. For high output impedance devices, such as HP Models 420B, 423B, 424B, or 786D, use 415E XTAL IMPED/HIGH position. If improper input impedance is selected, the crystal detector may depart from square-law for which 415E is calibrated. Paragraph 3-27 gives method of checking and calibrating a detector for square-law response.

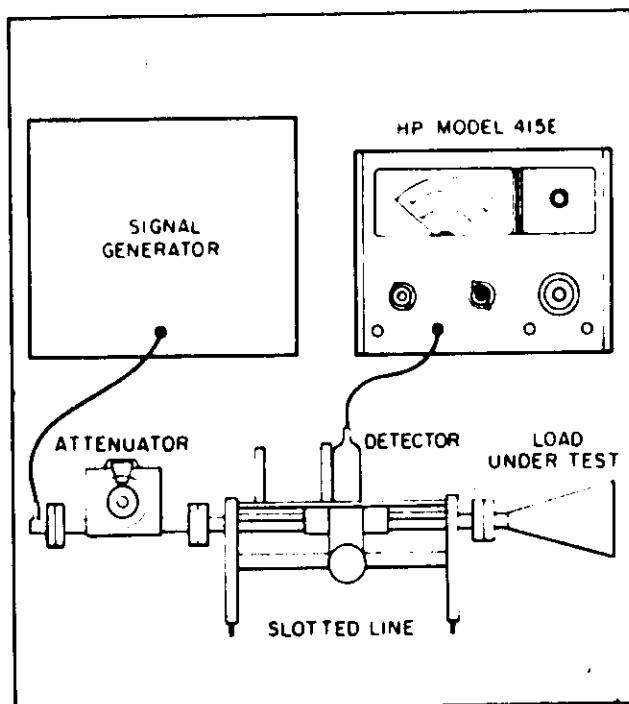
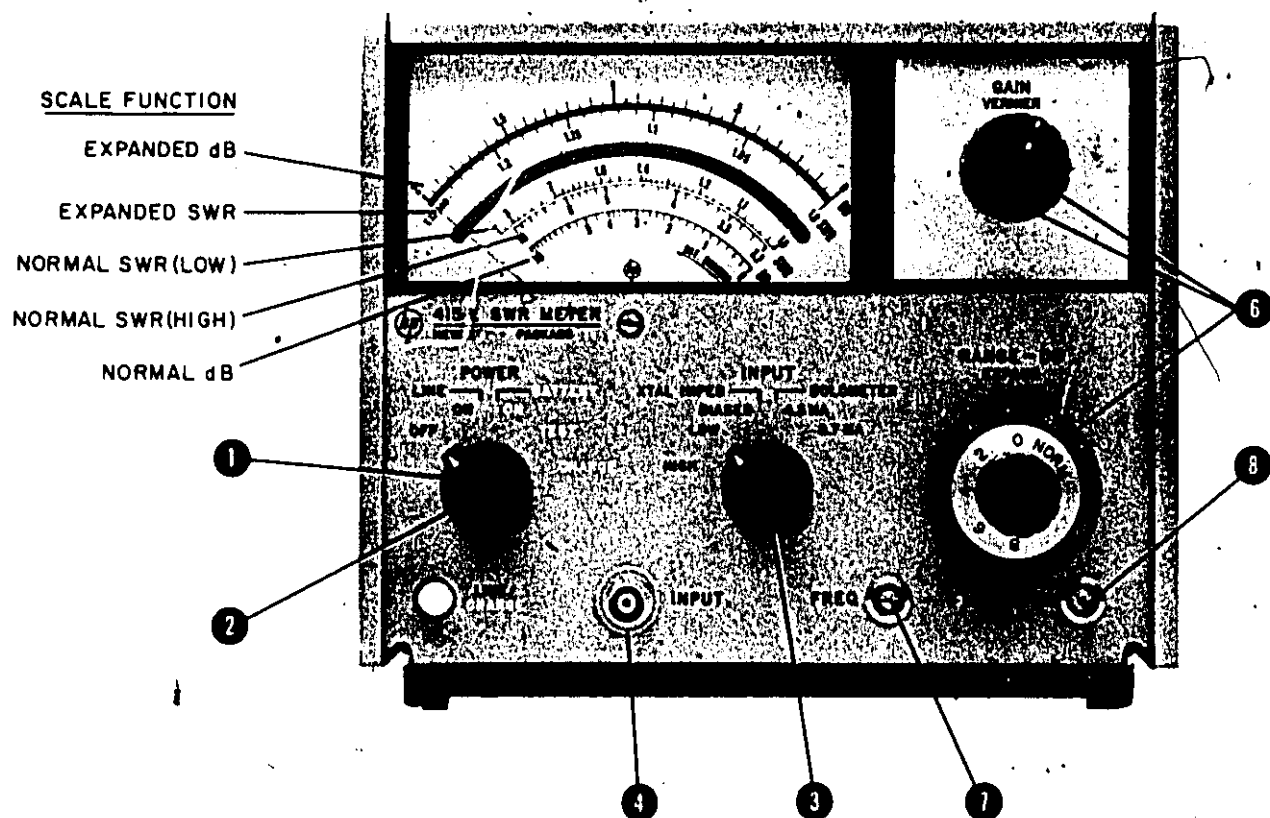


Figure 3-3. Typical SWR Measurement Setup

## TURN-ON PROCEDURE



1 Set POWER switch to OFF. Meter pointer should rest at 2 on the 0 to 2 dB EXPAND scale (if not, refer to paragraph 5-10 and mechanically zero meter).

2 Set POWER switch to LINE/ON (or BATTERY/ON).

## NOTE

If set to BATTERY/ON refer to paragraph 3-5 and check battery potential.

3 Set INPUT to desired input impedance. See Specifications for details.

## CAUTION

Do NOT switch to BIASED XTAL or BOLOMETER when using a crystal that does not require bias. The crystal may be damaged.

4 Connect audio source to INPUT (i.e., crystal detector, bolometer, audio oscillator, etc.).

5 Adjust modulation frequency of input signal to approximately 1000 Hz.

6 Adjust RANGE-DB, GAIN, and VERNIER controls and the amplitude of the input signal for a convenient meter reference near mid-scale. RANGE-DB indicates gain, not attenuation.

7 Adjust FREQ control for maximum meter pointer deflection.

8 Adjust BANDWIDTH control: fully counterclockwise rotation is minimum bandwidth and fully clockwise rotation is maximum bandwidth.

## NOTE

A narrow bandwidth is usually best for low level signals; 30 Hz is convenient for most CW applications; and a wide bandwidth is usually best for fast sweep-rate measurements.

Figure 3-4. General Turn-On Procedure



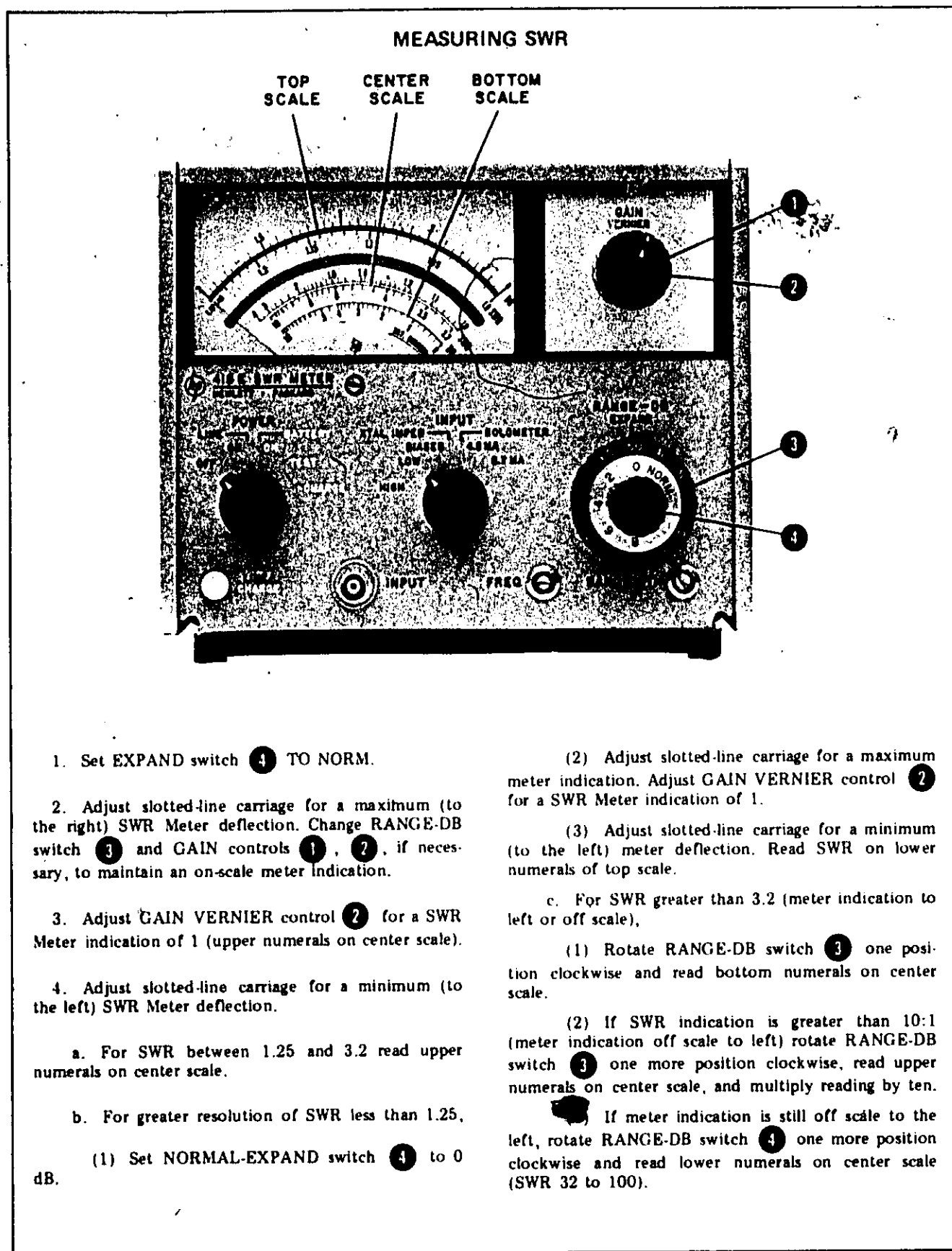


Figure 3-5. Measuring SWR

### 3-25. CHECKING SQUARE-LAW RESPONSE

3-27. Increase the power level to the crystal detector by known increments and note detector response on 415E.

#### NOTE

A deviation in square-law response may be due to excessive RF power to the crystal detector (see operating literature for specified response characteristics of crystal detector in use).\*

### 3-28. SWR MEASUREMENT PROCEDURE

3-29. Moderate SWR. Refer to Figure 3-3 for a typical SWR measurement setup. The scales of the 415E are calibrated to read standing-wave ratio directly. Figure 3-4 illustrates the function of each individual scale. Refer to Figure 3-5 for further operating information.

3-30. High SWR. High standing wave ratios (greater than 30, or sometimes 10) present problems because of excessive probe penetration (to lift the minimum above the noise level) and departure of detector behavior from square-law. Both problems are lessened or eliminated by measuring only the standing wave pattern near the voltage minimum, where probe loading effects are least disturbing.

3-31. Twice-Minimum Power Method. The basis for this method (and the Ten-Times Minimum Power Method) is the fact that for a high SWR, the standing wave pattern approximates a parabola in the vicinity of a voltage minimum. The slotted line carriage must have a good scale or dial indicator. Measure the distance ( $\Delta X$ ) between positions on the standing wave pattern where the voltage is 3 dB above the voltage at the minimum. Also measure the transmission line wavelength  $\lambda_g$  (standing wave pattern minima are one-half wavelength apart and the sharp minima resulting from short-circuiting the transmission line are easy to locate accurately). Compute the SWR from the following formula:

$$SWR = \lambda_g / \pi \Delta X$$

3-32. Ten-Times Minimum Power Method. Another convenient level above minimum method to use for computing SWR is a level 10 dB above minimum. The separation ( $\Delta X$ ) between these positions should be put in the following formula:

$$SWR = 3\lambda_g / \pi \Delta X$$

For standing wave ratios as low as 15 to 1, the accuracy of this method is within one percent.

\*For further information, see "Microwave Measurements by Edward K. Ginzton, pp 142-3, McGraw-Hill Book Co., N.Y.C.

3-33. SWR Measurement-Sources of Error. Several possibilities have already been mentioned: excessive frequency modulation of source (smears out sharp, deep nulls of high SWR pattern), harmonics of signal frequency from source, departure of detector from square-law behavior, and excessive probe penetration. Also reflects in the transmission line between the slotted line and device being measured must be minimized.

### 3-34. POWER MEASUREMENT PROCEDURE

3-35. The 415E will measure only relative power and voltage since the gain of the 415E can be adjusted by the GAIN control. Figure 3-6 shows a typical test setup for measuring attenuation. The 415E may be used for high-resolution insertion-loss measurements by inserting the device to be measured between the signal source and the detector while noting the change in dB indication. The continuous coverage of the EXPAND scales allows any attenuation measurement to be made to greater resolution on the EXPAND scale. For accurate results, both the signal source and the detector should be well matched. Impedance match of source and detector can be improved with padding attenuators, isolators, or tuners (CW only). Gain can be measured in a similar manner by inserting the device to be measured in place of the attenuator in Figure 3-6. To measure loss or gain refer to Figure 3-7.

### 3-36. SYSTEM ERRORS

3-37. Errors occur when making measurements on lower 415E ranges due to noise. For convenient reference, a graph (Figure 3-8) is shown to allow correction to the meter reading for any given measurement. To use this graph, make a

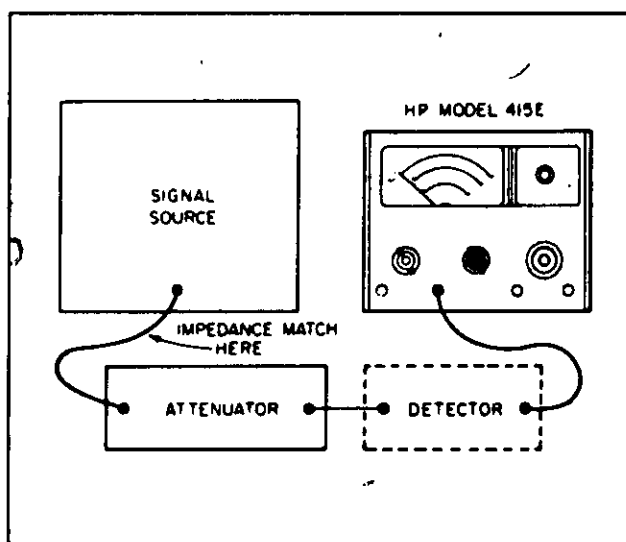


Figure 3-6. Attenuation Measurement Setup

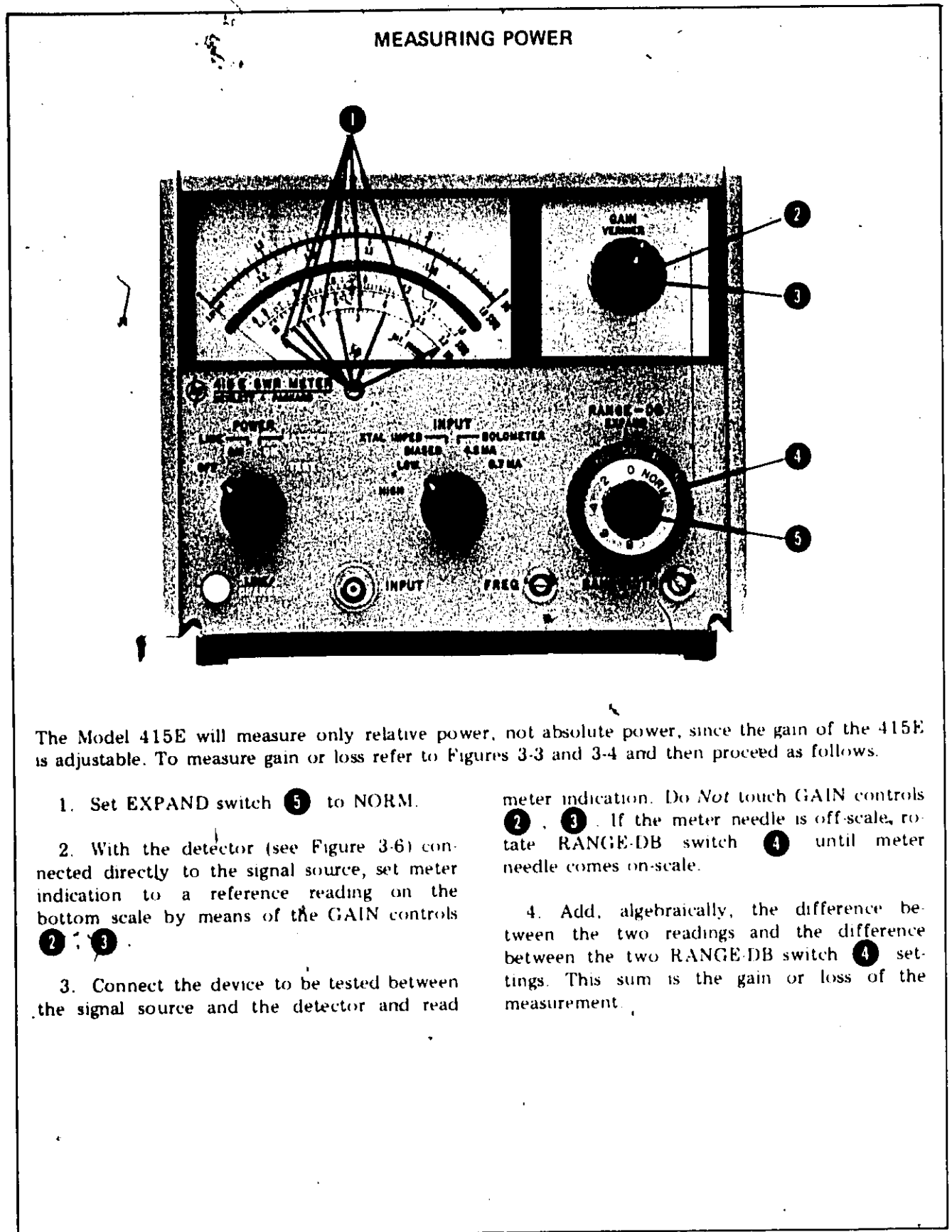


Figure 3-7. Measuring Power (1 of 2)

MEASURING POWER

EXPAND Scales

The expand scales enable you to expand any 2-dB sector of the normal scales to the full width of the meter scale for greater resolution. To use the expanded meter scales proceed as follows:

- 5. With EXPAND switch **5** set to NORM, read the meter needle on the bottom dB scale. Determine in which 2-dB segment **1** i.e., 0 to 2 dB, 2 to 4 dB, 4 to 6 dB, 6 to 8 dB or 8 to 10 dB, the needle lies.
- 6. Rotate EXPAND switch **5** out of NORM and to the lowest dB reading of the 2-dB segment determined in step 5.
- 7. Read the meter needle on the top scale and add the setting of step 6 to the observed value. When reading expanded scales the right end-scale value will be the same as the setting

in step 6 and the left end-scale value will be 2 dB higher.

Examples:

NORM Bottom Scale Reading	=	EXPAND Switch Reading	+	Top Scale Reading
1 dB		0 dB		1 dB
3 dB		2 dB		1 dB
5 dB		4 dB		1 dB
7 dB		6 dB		1 dB
9 dB		8 dB		1 dB

Figure 3-7. Measuring Power (2 of 2)

signal measurement, then turn RF power source off or disconnect detector from RF source and note average meter reading due to noise. The difference between these two readings is used to obtain the proper correction factor from Figure 3-8. For example, assuming an average noise level

of 9.5 dB and a measured signal level of 3.5 dB, the difference is 6 dB. Refer to Figure 3-8, where 6 dB corresponds to an error of 0.1 dB. This correction factor is always added to the measured signal. Hence, 3.5 + 0.1 = 3.6 dB, corrected meter reading.

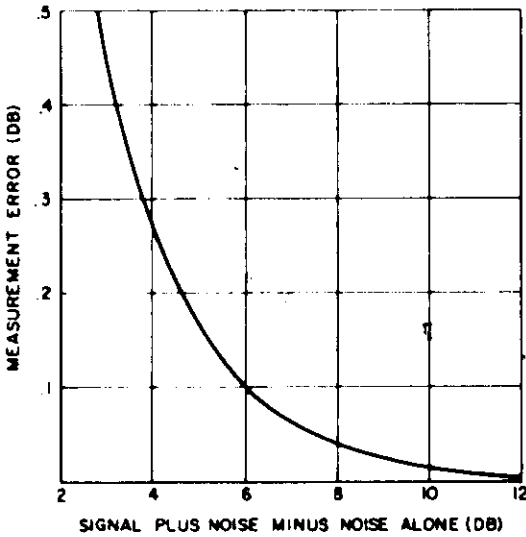


Figure 3-8. Meter Noise Correction Curve

3-38. MODEL 415E NOISE FIGURE

3-39. Figure 3-9 illustrates a typical value of Noise Figure that would be encountered in a Model 415E. The following example of Model 415E noise figure measurement is presented to illustrate the particular considerations that must be made to calculate instrument noise figure.

- a. Calculate the meter indication when a 5000 ohm resistor is connected as a source, assuming the Model 415E is noiseless (0 dB noise figure).
- b. Any excess indication of 415E meter is then one-half its noise figure.
- c. Calculation example:

1. Assume 415E with controls set for the following conditions. XTAL IMPED HIGH (input impedance 200K), 1  $\mu$ Vrms sine wave at input causes full scale deflection (0 on 0 to 10 dB scale), 130 Hz bandwidth at 3 dB points (1.5 dB points on Model 415E meter which is calibrated for square-law. Noise equivalent bandwidth is  $\pi/2$  times 3 dB bandwidth.)

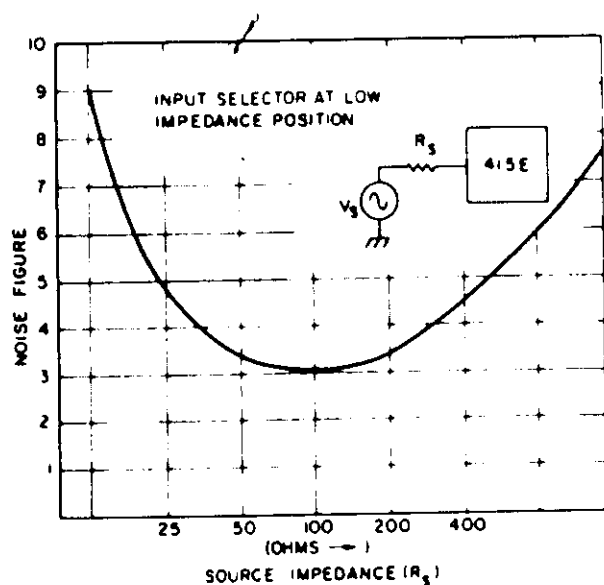
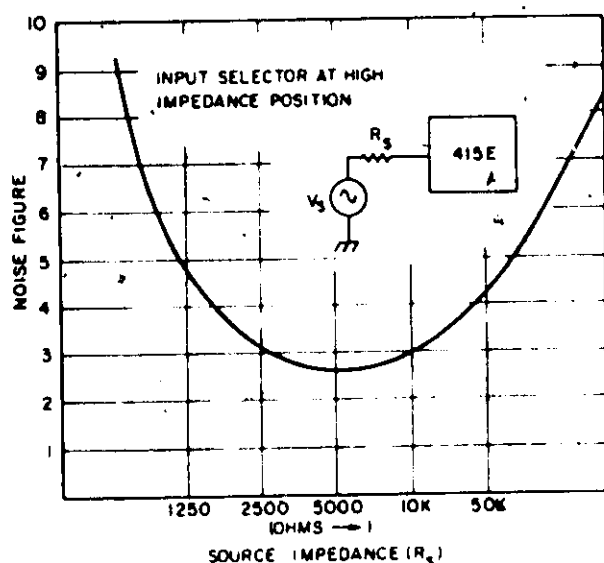


Figure 3-9. Noise Figure Curves

2. The open-circuit noise voltage across a 5000 ohm resistor at 295°K (22°C) in a bandwidth of (130 times  $\pi/2$ ) Hz is as follows:

$$V_n = 2 \sqrt{KTBR}$$

$$V_n = 2 \sqrt{(1.38 \times 10^{-23}) 295 (130 \times \pi/2) (5000)}$$

$$V_n = 0.129 \times 10^{-6} \text{ volts} = 0.129 \mu\text{V}$$

3. The 0.129  $\mu\text{V}$  open circuit voltage is reduced to 0.126  $\mu\text{V}$  by the 200K ohm input resistance of the 415E which is assumed to be noiseless.

4. 0.126  $\mu\text{V}$  is 18.0 dB below 1  $\mu\text{V}$  but square-law calibrated meter of the 415E, set as above, would indicate one-half of 18 dB or 9.0 dB below full scale. Also, since the 415E meter is average-reading and calibrated to read rms value of a sine wave, it reads 1.05 dB below the rms value of Gaussian noise. Therefore, the 415E reads one-half of 1.05 dB or 0.525 dB less than 9.0 and the 415E would read 9.525 dB with a 5000 ohm resistor connected to the input as described. Hence, a 7.525 dB (9.525 + 2) meter reading indicates a 4 dB noise figure.

### 3-40. SPECIAL APPLICATIONS

3-41. The Model 415E is equipped with outputs which allow applications other than as a meter indicating device for SWR or attenuation.

3-42. The Model 415E is especially useful as a tuned amplifier in a measurement setup using an oscilloscope and a sweep oscillator. Sweep speeds may be increased (over the speeds using a ratio meter in a reflectometer system) and the Model 415E, used as a high gain amplifier, provides the required sensitivity.\* The AMPLIFIER OUTPUT (AC) is often more useful for this purpose than the RECORDER OUTPUT (DC) since the DC output is filtered to reduce ripple and its response is too slow to make full use of maximum bandwidth.

3-43. On extreme sensitivity oscilloscope settings, the 1000 Hz frequency of the 415E may feed through, obscuring the true indication. A 1000 Hz filter is needed in this case, as shown in Figure 3-10. This filter should be installed between the output amplifier Q12, Q13, and the A4 power switch assembly. Note that the 1  $\mu\text{F}$  capacitor C26 is A3C26 on the A3 circuit board. It replaces a 6.8  $\mu\text{F}$  capacitor. Also note additional 50  $\mu\text{F}$  capacitor across the meter to smooth out any ripple.

\*See HP Application Note 65

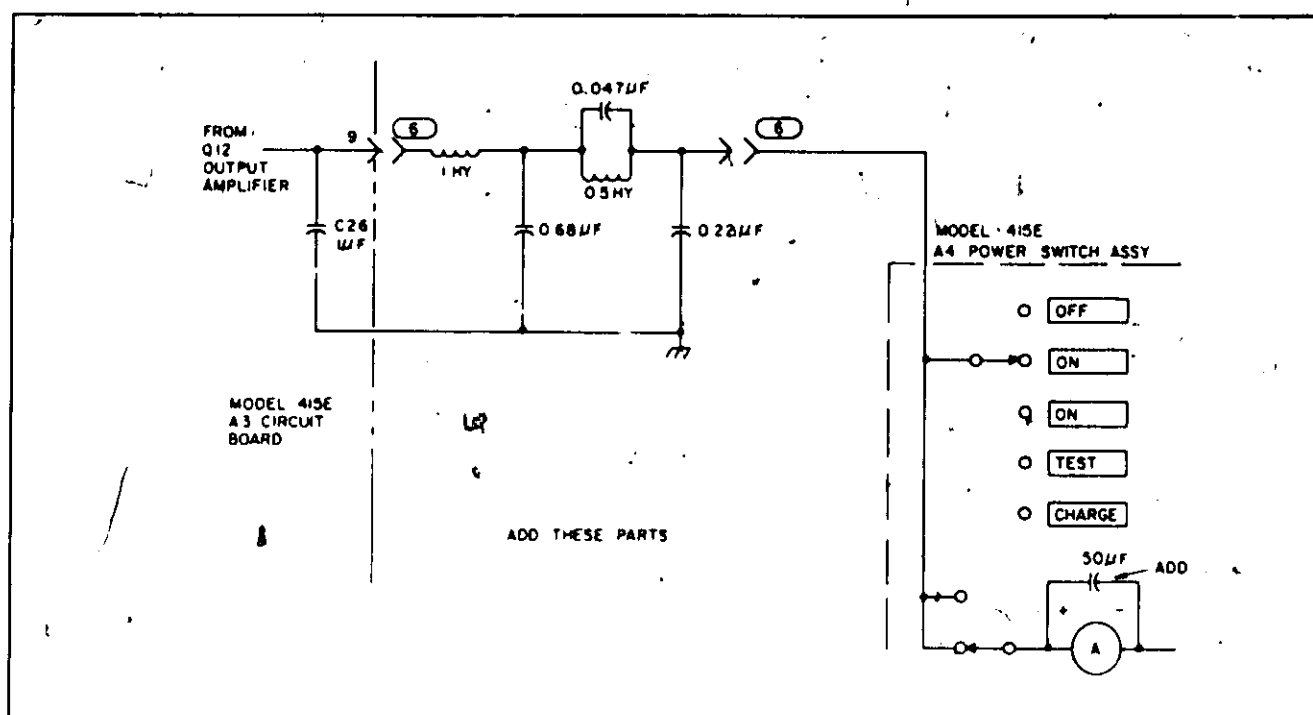


Figure 3-10. 1000 Hz Filter

# THEORY

## SECTION IV PRINCIPLES OF OPERATION

### 4-1. GENERAL

4-2. The 415E is a high-gain tuned amplifier which takes an input from a bolometer, crystal, or any audio source, amplifies it and applies it to

a meter calibrated for use with square-law detectors. With bolometer or biased crystal operation, the Model 415E supplies the appropriate bias current. Figure 4-1 is a block diagram which illustrates instrument operation. Refer also to the

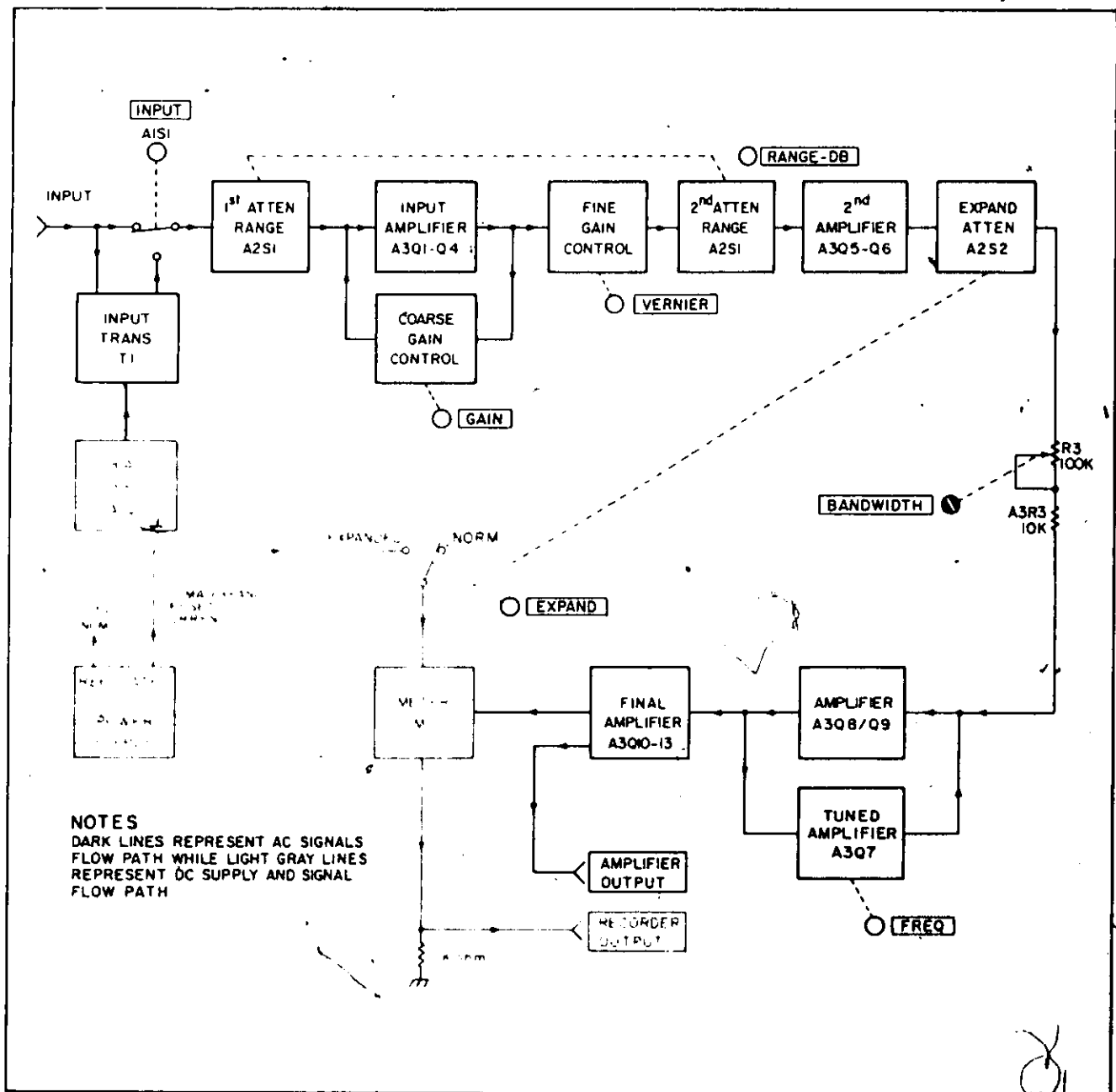


Figure 4-1. Block Diagram



schematic diagrams, Figures 5-10 and 5-11 which fold out of the manual for easy reference.

### 4-3. INPUT CIRCUITS

4-4. The input voltage is first routed through INPUT switch, A1S1. In the HIGH position it is applied directly to the first section of the range attenuator, A2S1. When the INPUT switch is set to any other position but HIGH, the input signal passes through transformer T1 whose turns ratio provides a 50 to 1 impedance transformation, converting a 50 to 200 ohm source to 2500 to 10,000 ohms (which is the range of best noise figure for the INPUT AMPLIFIER).

### 4-5. Range Attenuator

4-6. The signal from A1S1 is fed to the first section of the RANGE-DB switch, A2S1, and then to the input amplifier. The second section of A2S1 is located between the input amplifier and the second amplifier. The RANGE-DB switch positions are marked in 10 dB steps.

### 4-7. Input Amplifier

4-8. After passing through the first section of the range attenuator, A2S1, the signal goes to the input amplifier (A3Q1/Q2/Q3/Q4) which consists of four transistors in cascade. The input signal is applied to the base of A3Q1 and the final amplifier signal is taken from the collector of A3Q4. The GAIN and VERNIER controls are associated with this amplifier and vary its gain over a range of more than 10 to 1. GAIN control R1, the coarse control, is a 250K ohm variable resistor which adjusts the amount of negative feedback from the collector of A3Q4 to the emitter of A3Q1. VERNIER control, R2, is a fine gain control and changes gain by inserting 0 to 5000 ohms in series with the output signal.

### 4-9. Second Amplifier

4-10. Transistors A3Q5 and A3Q6 amplify the signal from the second section of the range attenuator. AC feedback provides gain stability and high input impedance. The output of the amplifier is applied through the EXPAND attenuator A2S2, to the third amplifier A3Q8 and A3Q9.

### 4-11. Expand Circuit

4-12. The function of the EXPAND switch A2S2, is to allow any signal level to be measured on an expanded scale with continuous coverage while maintaining the original reference level. Expansion is accomplished by applying a precise amount of DC-offset current from A3Q17 to the meter and simultaneously increasing the signal to the third amplifier. This increased gain allows a 2

dB change in signal level to deflect the meter across its full scale. The offset current places the zero signal indication off scale to the left.

### 4-13. FREQUENCY SELECTIVE CIRCUITS

4-14. The frequency response of the third amplifier, A3Q8 and A3Q9, is shaped by negative feedback. The feedback path includes a Wien-bridge and amplifier A2Q7. At the null frequency of the Wien-bridge, the negative feedback path is open and the gain of the amplifier is maximum. Off center-frequency the negative feedback through the Wien-bridge reduces gain. The amount of the off resonance gain reduction depends on the setting of the BANDWIDTH control, R3.

4-15. The Wien-bridge is adjusted for a sharp null at center frequency with BRIDGE STABILITY ADJUST A3R29. Actually, this control is set for a very slight bridge unbalance to produce just enough positive feedback so that signal current to the base of A3Q8 is supplied mainly by A3Q7. Thus, at resonance, negligible signal current flows through BANDWIDTH control, R3, and gain is independent of its setting. Center frequency is set by varying resistors R4 and R5 (these resistors are ganged and comprise the front panel FREQ control).

### 4-16. FINAL AMPLIFIER

4-17. The output amplifier consists of four transistors. The two output transistors, A3Q12 and A3Q13, operate as a push-pull class B amplifier with both collectors AC grounded. The emitters of these transistors are tied together and the AC amplifier output is taken from this point through a coupling capacitor, A3C28. Large negative feedback makes the gain of the output amplifier very nearly unity. The AC output voltage is developed across resistor S3R51: the current through A3R51 is supplied by A3Q12 and A3Q13 conducting, one at a time, on alternate half cycles (Class B operation) and the output signal sine wave is a composite of this half-cycle operation. In addition, the collector current of A3Q12 can drive the meter directly. No rectifier diodes are needed. This meter driving current is filtered by capacitor A3C26 and passes through the meter and a 1000 ohm resistor, R6, to develop a DC voltage for the recorder output.

### 4-18. GROUND LOOPS

4-19. The grounding technique used in the 415E consists of an input connector ground, a circuit board ground, and output connector grounds. These are floating grounds that are tied together and isolated from chassis ground except for a 46.4 ohm resistor, R7, and a 0.05  $\mu$ F capacitor, C1, connecting ground and chassis. A solid con-

nection to chassis-or-earth ground permits troublesome ground loop currents to flow causing erroneous instrument operation. For this reason, connecting grounded instruments to the 415E output connectors can cause erroneous readings. Most recorders and oscilloscopes that might be used with the 415E outputs have differential inputs available with neither side grounded (see paragraph 3-11).

#### 4-20. INPUT IMPEDANCE

4-21. The Model 415E is designed to have an input impedance much higher than that of any crystal detector or bolometer normally used with it. This results in lower noise figure and the highest possible input signal to the 415E. For example, with the 415E INPUT switched to LOW, the input impedance is approximately 2000 ohms while the output or source impedance of a bolometer is approximately 200 ohms.

4-22. This high input impedance effectively nearly doubles the output voltage of a source compared with an amplifier which matches the source resistance. It should be emphasized that the transformer turns ratio in the 415E is chosen for lowest noise figure rather than to match impedances.

#### 4-23. INPUT BIASING

4-24. When the 415E input switch is set to one of the biased positions (XTAL IMPED/BIASED, or 4.5 MA or 8.7 MA), a bias source is connected in series with INPUT connector. An emitter follower, A1Q1, in this bias current provides bolometer protection by limiting transients when a bolometer or crystal detector is connected or disconnected. Three calibrated levels of bias are

available: 1 volt into 1000 ohms (XTAL IMPED/BIASED), or 4.5 ma and 8.7 ma into 200 ohms, selected with the INPUT switch, A1S1. These bias levels are set within  $\pm 3\%$ , by adjusting the DC voltage potential of the positive power supply with resistor S3R54. A single adjustment suffices, since one percent resistors accurately determine the ratios between the three bias levels. The positive DC voltage is typically 13.2 volts DC but may be as low as +12 volts DC or as high as +14 volts DC for proper adjustment.

#### 4-25. POWER SUPPLY

4-26. The regulated power supplies are fed by either an internal battery, BT1 (Option 01, 001 instruments only), or a conventional AC supply consisting of transformer T2 and rectifier diodes A3CR4 and A3CR5. The power supply must provide two regulated outputs: +13 volts and -1.71 milliamperes offset current. The voltage reference diode A3CR10 (temperature compensated by diodes A3CR7 and A3CR8) and transistor A3Q17 form a constant-current source to provide the offset current. The voltage reference diode A3CR10 and transistor A3Q16 form a shunt-type regulator maintaining a nominal -7.5 volts.

4-27. In the LINE/ON position, about 3 ma trickle charge is supplied through A3R52 to the battery BT1 (Option 01, 001 only). If the POWER switch is set to BATTERY/ON position, battery current passes through diode A3CR6 to the regulators. The BATTERY/CHARGE position allows recharging of the battery by placing A3R52 and A4R2 in parallel. About 20 ma to 30 ma then flows to the battery depending upon the charge condition of the battery.



# MAINTENANCE

## SECTION V MAINTENANCE

### 5-1. INTRODUCTION

5-2. This section provides instructions for performance testing, calibrating, troubleshooting and repairing the SWR Meter.

### 5-3. PERFORMANCE TESTING

5-4. **Purpose.** The procedures listed in Table 5-2 check 415E performance for incoming inspection, periodic evaluation, calibration, and troubleshooting. The tests can be performed without access to the instrument interior. The specifications of Table 1-1 are the performance standards.

5-5. **Test Equipment Required.** The test instruments and accessories required to make the performance checks are listed in Table 5-1. Test instruments other than the ones listed can be used provided their performance equals or exceeds the Minimum Required Specifications.

5-6. **Isolating Attenuator.** In order to obtain accurate results when checking the Model 415E, it is necessary to maintain some attenuation between the source and the INPUT to compensate for a source impedance different from the calibrated attenuator used. The attenuator recommended for test and adjustment and performance testing has an impedance of 50 ohms. Therefore, a 5 to 10 dB, 50 ohm attenuator is suggested to be placed between the oscillator and the attenuators used in the test setup (Table 5-2). If a separate attenuator is not used, then one of the Model 355 Attenuators may be left in the setup set to 5 or 10 dB, or use an impedance matching transformer.

### 5-7. CALIBRATION

#### 5-8. General

5-9. The following procedures outline the adjustments necessary to calibrate the Model 415E. The actual adjustments should be made only when it is determined that the instrument is not operating properly. To determine proper performance, see Table 5-2. If the instrument fails to meet any of the given limits or indications, refer to the troubleshooting paragraph 5-40 for possible causes and corrective action. This procedure is sequential to some extent. The bias supplies should be set before any attempt to adjust the amplifier. Also check the mechanical meter ad-

justment before checking any indication on the Model 415E meter.

#### NOTE

To avoid errors due to possible ground loop currents isolate the Model 415E from ground used for other measuring instruments. It may be necessary to use adapters to unground all instruments except the Model 415E.

### 5-10. Mechanical Meter Adjustment

5-11. When the meter is properly adjusted, the pointer rests over 2 on the 0 to 2 dB scale, when the instrument is (1) at normal operating temperature, (2) in its normal operating position, and (3) turned off. Set the pointer as follows to obtain best accuracy and mechanical stability.

#### NOTE

If meter pointer adjustment is changed, EXPAND tracking (paragraph 5-16) must be checked and adjusted, if necessary.

- Turn instrument off.
- Rotate mechanical zero-adjustment screw clockwise until meter pointer is to left of 2 (on the 0 to 2 dB EXPAND scale) and moving to the right toward 2.
- Continue to rotate adjustment screw clockwise; stop when the pointer is exactly on 2. If the pointer overshoots 2, repeat steps b and c.
- When the pointer is exactly on 2, rotate the adjustment screw approximately 15 degrees counterclockwise. This is enough to free the adjustment screw from the meter suspension. If the pointer moves during this step, repeat steps b through d.

### 5-12. Bias/Power Supply Adjust

5-13. This adjustment sets the bias supply current and voltage levels which are supplied to the INPUT connector for use with bolometers or biased crystal detectors. This adjustment is accomplished by adjusting the potential of the positive DC power supply to an optimum value. The positive DC power supply is typically set to +12 volts or as high as +14 volts DC.

Table 5-1. Recommended Test Equipment (1 of 2)

Instrument Type	Minimum Required Specifications	USE/Check	Recommended Model
Audio Oscillator	Frequency Range: 400 to 2500 Hz Accuracy: $\pm 3\%$ Output: 10 volts into 600 ohms Distortion: less than 1%	All Performance Tests	HP 200CD
Electronic Counter	Frequency Range: 400 to 2500 Hz Accuracy: $\pm 1$ count $\pm 0.01\%$	Frequency and Bandwidth	HP 5512A (or 5212A)
AC Voltmeter	Voltage Range: 0.1 to 1 volt Accuracy: $\pm 1\%$ of full scale Frequency Range: 400 to 2500 Hz Input Impedance: 10 megohms	Sensitivity and Noise	HP 400H
DC Voltmeter	Voltage Range: $\pm 0.1$ to $\pm 30$ volts Input Impedance: 10 megohms Accuracy: $\pm 1\%$ of full scale	Sensitivity and Noise and General Purpose Circuit Voltage Checks	HP 412A (or 3440A with 3443A plug-in)
Attenuator Variable	Range: at least 130 dB in 10 and 1 dB steps Accuracy: Calibration must be known to $\pm 0.02$ dB for 1 dB steps to $\pm 0.017$ dB for first 20 dB step, $\pm 0.03$ dB for second 20 dB step, and $\pm 0.05$ dB for subsequent 20 dB steps.	EXPAND and RANGE attenuator accuracy	HP 355C and 355D, with calibration error chart
Feed-Thru Terminations	Value: 5000 ohms Accuracy: 10%	Noise	Shielded body: HP 11523-600 Resistor: HP 0683-5125
	Value: 100 ohm Accuracy: 10% (10100B)	Noise	HP 10100B
	Value: 50 ohm Accuracy: 10%	EXPAND and RANGE attenuator accuracy	HP 10100A
Oscilloscope	Vertical Sensitivity: 0.2 mV/cm up to 20 V/cm Bandwidth: Adjustable from 40 kHz to 400 kHz Sweep Time: 0.2 msec/cm to 5 msec/cm Input: AC coupled, floating (non-grounded)	General purpose check and troubleshooting	HP 140A (oscilloscope with HP 1420A (time base plug-in) and HP 1400A (differential amplifier plug-in)
Adapters and Cables	BNC Female-to-Female Adapter (one required)	All Performance	HP 1250-0080-9 (UG-914/UN)
	BNC to Dual Banana Adapter Post (two required)	All Performance	HP 10110A
	Male-to-Male BNC 50 ohm cable (one required)	Bandwidth	HP 10502A

Table 5-1. Recommended Test Equipment (2 of 2)

Instrument Type	Minimum Required Specifications	USE/Check	Recommended Model
	Dual Banana-to-Dual Banana Plugs on a 50 ohm cable (one required)	All performance checks	HP 11000A
	Dual Banana-to-BNC Male (two required)	Performance	HP 11001A
	Straight-through Voltage Probe (thin, flexible probe with small push button pincer jaws). Shunt capacity of 150 pF — terminated in shielded dual banana plug.	General purpose use with oscilloscope	HP 10025A

- a. Remove top and left side covers.

b. Connect a dual banana plug-to-male BNC connector. Connect a 200 ohm resistor between terminals of dual banana plug and connect to INPUT.

c. Connect a DC voltmeter across the 200 ohm resistor.
- d. Turn 415E on and set INPUT switch to BOLOMETER/8.7 MA. The DC voltmeter reading should be between 1.80 and 1.68 volts DC. If necessary, adjustment is made with variable resistor A3R54 (see Figure 5-9).

e. Switch 415E INPUT switch to BOLOMETER/4.5 MA. The DC voltmeter should read

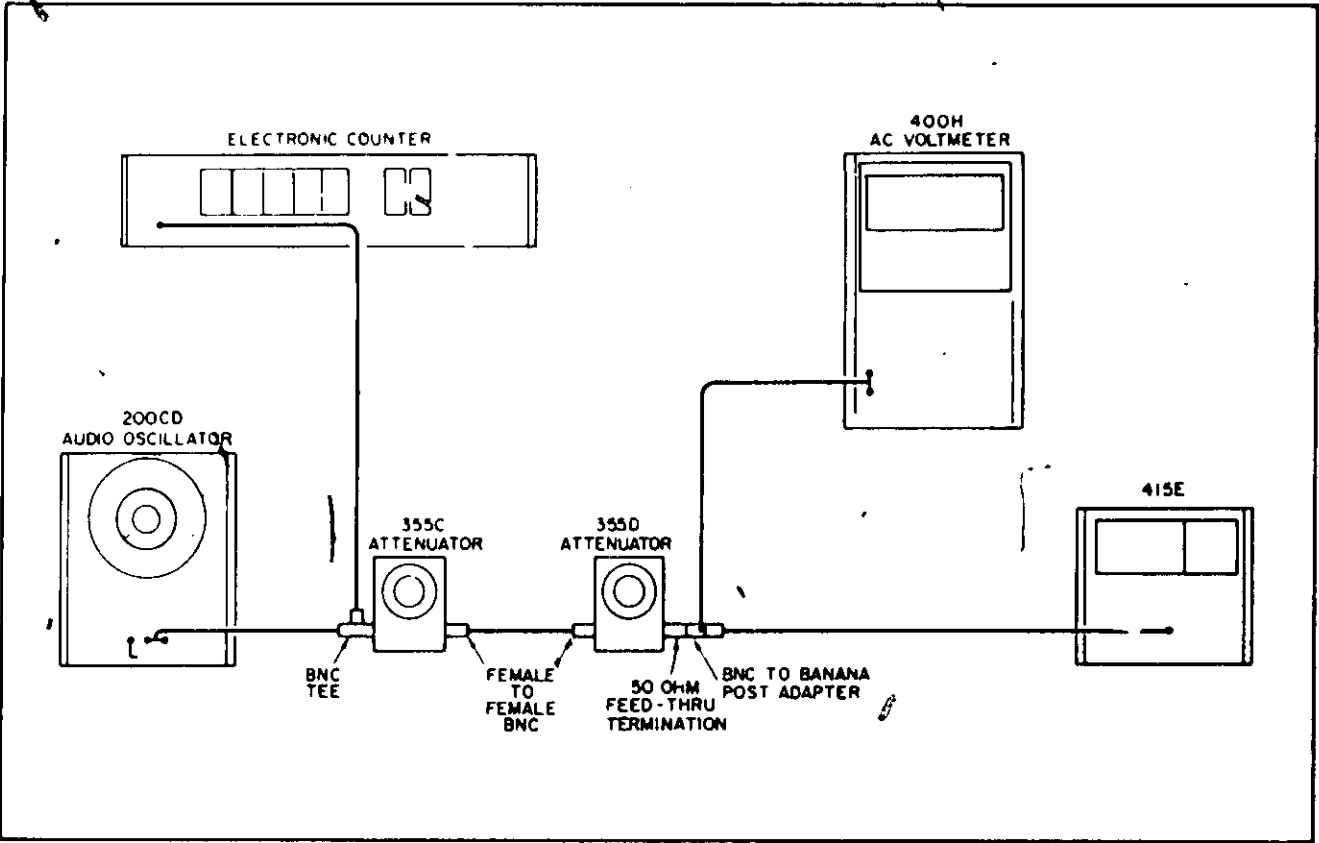


Figure 5-1. Test Setup

Table 5-2. Performance Tests (1 of 5)

1. SENSITIVITY: 0.15 $\mu$ Vrms at maximum bandwidth (1 $\mu$ Vrms on HIGH impedance crystal input):			
Procedure	Readings		
a. Connect equipment as shown in Figure 5-1 (omit 355D attenuator).	Min	Actual	Max
b. Set 415E to NORM, 0 dB, LOW, ON, with GAIN, VERNIER, and BANDWIDTH controls full clockwise.			0.15 Vrms
c. Set audio oscillator to 1000 Hz.			1.0 Vrms
d. Adjust 415E FREQ to peak meter (needle to right).			
e. Adjust oscillator output for 0 dB 415E meter reading.			
f. The AC voltmeter should read 0.15 volt rms or less. (This corresponds to a sensitivity of 0.15 $\mu$ V rms or greater on 60 dB range).			
g. Switch 415E INPUT to HIGH and adjust oscillator output for 0 dB 415E meter reading.			
h. The AC voltmeter should read 1.0 volt rms or less. (This corresponds to a sensitivity of 1.0 $\mu$ V rms or greater on 60 dB range.)			
2. NOISE. At least 7.5 dB below full scale at rated sensitivity and maximum bandwidth with input terminated in optimum source impedance.			
Procedure	Readings		
a. Connect equipment as shown in Figure 5-1 (omit 355D from setup).	Min	Actual	Max
b. Set 415E to NORM, 0 dB, HIGH and ON with GAIN, VERNIER, FREQ and BANDWIDTH controls full clockwise.		(High)	-7.2 dB
c. Set 355C to 0 dB and tune oscillator to peak 415E.		(Low)	-7.5 dB
d. Adjust oscillator output for 1.0 Vrms AC voltmeter reading.			
e. Adjust 415E GAIN for 0 dB meter reading and remove connections from 415E.			
f. Connect special 5000 ohm feedthru termination to INPUT (see Procedure 6 of this table).			



Table 5-2. Performance Tests (2 of 5)

<p>g. Set 415E RANGE-DB to 60. The average noise level indicated by meter pointer should be at least 7.5 dB down from 0 on the 0 to 10 dB scale.</p> <p>h. Switch INPUT to LOW and repeat steps b and c above.</p> <p>i. Adjust oscillator output for 0.5 Vrms AC voltmeter reading.</p> <p>j. Adjust 415E GAIN for 0 dB meter reading and remove connections to 415E.</p> <p>k. Connect Model 10100B feedthru termination to INPUT.</p> <p>m. Repeat step g above. The average noise level should be 7.5 dB down from 0 on 0 to 10 dB scale.</p>																						
<b>3A. RANGE ACCURACY: <math>\pm 0.05</math> dB/10 dB step; maximum cumulative error <math>\pm 0.10</math> dB</b>																						
<p><b>Procedure</b></p> <p>a. Connect 415E as shown in Figure 5-1 (omit counter and AC voltmeter).</p> <p>b. Set 415E to ON, LOW, 0 (RANGE-DB), 0 (EXPAND), with GAIN full counterclockwise.</p> <p>c. Set 355C to 5 dB and 355D to 0 and adjust oscillator frequency for peak 415E meter reading.</p> <p>d. Adjust oscillator output and 415E VERNIER for 1 dB meter reading on 0 to 2 dB scale.</p> <p>e. Switch 355D to 20 dB and 415E RANGE-DB to 10. The 415E meter reading should be <math>1.0 \pm 0.05</math> dB (see Note 1).</p> <p>f. Switch 355D to 40 dB and 415E to 10. 415E should read <math>1.0 \pm 0.1</math> dB.</p> <p>g. Switch 355D to 60 dB and 415E to 30. 415E should read <math>1.0 \pm 0.1</math> dB.</p> <p>h. Switch 355D to 40 dB and set 415E GAIN control to minimum. Adjust oscillator for 1.0 reading on 415E meter. Switch 415E to 40 dB and 355D to 60. 415E should read <math>1.0 \pm 0.1</math> dB.</p> <p>i. Switch 355D to 80 dB and 415E to 50. 415E should read <math>1.0 \pm 0.1</math> dB.</p> <p>j. Switch 355D to 100 dB and 415E to 60. 415E should read <math>1.0 \pm 0.1</math> dB.</p>	<p><b>Readings</b></p> <table><thead><tr><th>Min</th><th>Actual</th><th>Max</th></tr></thead><tbody><tr><td>9.95 dB</td><td>_____</td><td>10.05 dB</td></tr><tr><td>19.9 dB</td><td>_____</td><td>20.1 dB</td></tr><tr><td>29.9 dB</td><td>_____</td><td>30.1 dB</td></tr><tr><td>39.95 dB</td><td>_____</td><td>40.05 dB</td></tr><tr><td>49.9 dB</td><td>_____</td><td>50.1 dB</td></tr><tr><td>59.9 dB</td><td>_____</td><td>60.1 dB</td></tr></tbody></table>	Min	Actual	Max	9.95 dB	_____	10.05 dB	19.9 dB	_____	20.1 dB	29.9 dB	_____	30.1 dB	39.95 dB	_____	40.05 dB	49.9 dB	_____	50.1 dB	59.9 dB	_____	60.1 dB
Min	Actual	Max																				
9.95 dB	_____	10.05 dB																				
19.9 dB	_____	20.1 dB																				
29.9 dB	_____	30.1 dB																				
39.95 dB	_____	40.05 dB																				
49.9 dB	_____	50.1 dB																				
59.9 dB	_____	60.1 dB																				



Table 5-2. Performance Tests (3 of 5)

**3B. EXPANDED RANGE ACCURACY:** Maximum cumulative error between any two 2 dB steps:  $\pm 0.05$  dB accuracy on any 0 to 2 dB scale:  $\pm 0.02$  dB

**Procedure:**

a. Set 415E as in steps a and b of procedure 3A above.

b. Set 355D to 10 dB and 355C to 0 dB. (See Note 1.)

c. Adjust oscillator output and 415E VERNIER for 0 dB meter reading on 0 to 2 dB scale.

d. Switch 355C from 0 to 4 dB in 1 dB steps. The Model 415E meter reading should be as given below:

Model 355C	Model 415E
1 dB	$0.5 \pm 0.02$ dB
2 dB	$1.0 \pm 0.02$ dB
3 dB	$1.5 \pm 0.02$ dB
4 dB	$2.0 \pm 0.02$ dB

e. Change 355C to 0, adjust 200CD for 415E reading of 1.0 on 0 to 2 dB scale. Change EXPAND to 2 and 355C to 4. The Model 415E should indicate  $1 \pm 0.05$  dB on 0 to 2 dB scale.

f. Change 355C to 8 dB and EXPAND to 4. The 415E should read  $1 \pm 0.05$  dB.

g. Switch 355D to 20 dB and 355C to 2 dB and EXPAND to 6. The 415E should read  $1 \pm 0.05$  dB.

h. Switch 355C to 6 dB and EXPAND to 8. The 415E should read  $1 \pm 0.05$  dB.

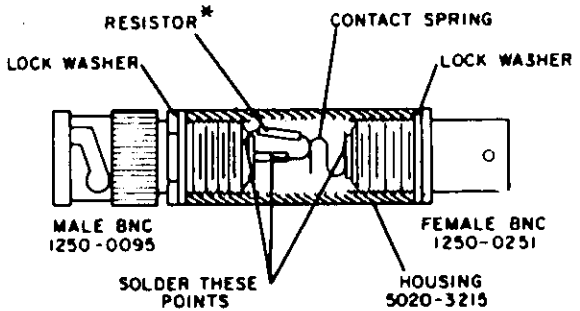
**Readings**

Min	Actual	Max
0.48 dB	_____	0.52 dB
0.98 dB	_____	1.02 dB
1.48 dB	_____	1.52 dB
1.98 dB	_____	2.02 dB
1.95 dB	_____	2.05 dB
3.95 dB	_____	4.05 dB
5.95 dB	_____	6.05 dB
7.95 dB	_____	8.05 dB

Table 5-2. Performance Tests (4 of 5)

4. INPUT FREQUENCY: 1000 Hz, adjustable 7% ( $\pm 35$ Hz)																	
<p><b>Procedure</b></p> <p>a. Connect equipment as shown in Figure 5-1 (omit 355D and AC voltmeter from setup).</p> <p>b. Set 355C to 10 dB.</p> <p>c. Set 415E to LOW, ON 0 (EXPAND), with GAIN, FREQ and VERNIER full clockwise.</p> <p>d. Tune oscillator to peak 415E (meter needle to right). Record counter reading.</p> <p>e. Turn FREQ full counterclockwise.</p> <p>f. Tune oscillator to peak 415E. Record counter reading. The difference between the recorded frequency readings of steps d and f must be at least 70 Hz and 1000 Hz must fall between the two frequencies.</p>	<p><b>Readings</b></p> <table> <tr> <th>Min</th><th>Actual</th><th>Max</th></tr> <tr> <td>1020 Hz</td><td>_____</td><td>—</td></tr> <tr> <td>—</td><td>_____</td><td>980 Hz</td></tr> <tr> <th>Actual</th><th>Actual</th><th>Diff</th></tr> <tr> <td>_____</td><td>_____</td><td>_____</td></tr> </table> <p>Difference = <math>&gt; 70</math> Hz</p>		Min	Actual	Max	1020 Hz	_____	—	—	_____	980 Hz	Actual	Actual	Diff	_____	_____	_____
Min	Actual	Max															
1020 Hz	_____	—															
—	_____	980 Hz															
Actual	Actual	Diff															
_____	_____	_____															
5. BANDWIDTH: Variable 15 to 130 Hz.																	
<p><b>Procedure</b></p> <p>a. Connect equipment as shown in Figure 5-1 (omit 355D and AC voltmeter).</p> <p>b. Set 415E to LOW, ON, NORM, 0 (RANGE-DB), with GAIN and VERNIER full clockwise.</p> <p>c. Turn BANDWIDTH full counterclockwise.</p> <p>d. Tune oscillator to peak 415E.</p> <p>e. Switch 415E EXPAND to 0 and retune oscillator to be sure that 415E is peaked at center frequency.</p> <p>f. Adjust GAIN control for a 0 dB meter reading.</p> <p>g. Tune oscillator slightly off tuned frequency causing meter reading to drop to exactly 1.5 dB and record counter reading.</p> <p>h. Tune oscillator back to tuned frequency and then off to other side of tuned frequency causing meter reading to drop to exactly 1.5 dB. Record counter reading.</p>	<p><b>Readings</b></p> <p>Actual — Actual = Difference (<math>&lt; 15</math> Hz)</p> <p>_____ — _____</p> <p>Actual — Actual = Difference (<math>&gt; 130</math> Hz)</p> <p>_____ — _____</p>																

Table 5-2. Performance Tests (5 of 5)

<p>i. The difference between the readings of steps g and h should be 15 Hz or less.</p> <p>j. Tune BANDWIDTH full clockwise and retune oscillator for peak 415E meter reading.</p> <p>k. Repeat steps f, g, and h above.</p> <p>m. The difference between the recorded frequency readings, this time, should be 130 Hz or greater.</p>	
<p><b>6. SPECIAL 5000 OHM FEEDTHRU TERMINATION:</b> In order to measure the 415E operating noise level, a special load must be used to terminate the INPUT in its optimum source impedance. For the LOW impedance INPUT, the HP Model 10100B (100 ohms) should be used. For the HIGH impedance INPUT, a special 5000 ohm termination must be built as detailed below (see Table 5-1 for part numbers).</p>	
<p><i>Procedure</i></p> <p>a. Refer to cut away view to left. Unscrew male BNC and lockwasher from housing by using a 3/8-inch open-end wrench and holding housing either in a vise or with gas pliers.</p> <p style="text-align: center;"><b>NOTE</b></p> <p>If gas pliers are used housing should be protected with tape or heavy paper.</p> <p>b. Solder 5000 ohm <math>\pm 10\%</math> 1/4W resistor to BNC.</p> <p>c. Let resistor cool, then check resistance from male BNC pin through resistor; resistance measured should be <math>\pm 10\%</math> that indicated by the coding.</p> <p>d. Replace lockwasher and male BNC.</p> <p>e. Check resistance from male-to-female BNC center conductor; resistance should be 0 or a few tenths of an ohm.</p> <p style="text-align: center;"><b>NOTE</b></p> <p>The attenuators used for checking 415E RANGE and EXPAND attenuators must be calibrated and an error chart used. Calibration requirements are given in Table 5-1.</p>	 <p style="text-align: center;">* RESISTOR VALUE: 50, 100, OR 5K OHM AS REQUIRED</p> <p style="text-align: center;">NOTE: ENTIRE ASSEMBLY MINUS RESISTOR IS AVAILABLE AS 11523-600.</p>

between 0.93 and 0.87 volt DC. If necessary, adjustment is made with A3R54.

f. Remove 200 ohm resistor from adapter and replace with a 1000 ohm 1% resistor. Switch INPUT switch to XTAL IMPED/BIASED. The DC voltmeter should read between 1.03 and 0.97 volt DC. If necessary, adjustment is made with A3R54.

g. Since one adjustment sets the bias level for all three of the bias supplies, measurement steps d, e and f must be repeated after any adjustment is made.

h. Remove DC voltmeter leads from 415E INPUT connector and measure DC potential at BATT + terminal of 415E circuit board assembly (circuit board socket and terminals are located beneath instrument top cover). DC potential should be between +12 and +14 volts (typically +13.2 volts DC).

#### NOTE

For all DC voltage measurements, voltmeter common lead should be connected to black terminal of rear panel AMPLIFIER OUTPUT connector. This is instrument ground.

#### 5-14. Stability Adjust

5-15. This adjustment sets the 415E so that a change in operating bandwidth will not affect any meter reading by more than 0.5 dB.

a. Turn 415E on and set as follows:

INPUT	HIGH
RANGE-DB	0 dB
EXPAND	NORM
GAIN	full CW
BANDWIDTH	full CW
FREQ	approximately centered

b. Connect an audio oscillator to the INPUT of 415E and adjust the output frequency and amplitude for a nearly full-scale reading.

c. Adjust 415E FREQ control to be sure that instrument is tuned to center frequency of input signal (maximum meter pointer deflection toward right side of instrument).

d. Switch EXPAND switch to 0 and using the GAIN control, set a reference of 1 on the 0 to 2 dB scale.

e. Turn the BANDWIDTH from fully clockwise to fully counterclockwise and retune. The meter reading change should not be more than 0.5 dB.

f. If the change in meter reading is greater than 0.5 dB, adjust A3R29 (see Figure 5-9) and

repeat step e until the meter reading change is less than 0.5 dB.

#### 5-16. Expand-Normal Adjust

5-17. The meter, M1, requires a special offset-current supply when using an EXPAND switch setting other than NORM. This current supply provides the zero reference signal to the meter and is adjusted as follows:

a. Perform steps a through d of Procedure 3B in Table 5-2.

b. If the meter tracking error is greater than  $\pm 0.02$  dB, adjust A3R57 (see Figure 5-9) and repeat measurement until meter tracking error is less than  $\pm 0.02$  dB.

#### 5-18. REPAIR AND REPLACEMENT

5-19. Certain procedures and precautions must be followed when repairing or replacing any component of the Model 415E. Most of the amplifier and power supply circuit components are located on the etched circuit board. Instructions for working on the etched circuit board are summarized in paragraph 5-20. Always disconnect the AC or battery power before replacing or soldering any parts. Instruction for removal and replacement of switches is detailed in paragraph 5-27.

#### 5-20. ETCHED CIRCUITS

5-21. The etched circuit board in the SWR Meter is of the plated-through type consisting of metallic conductors bonded to both sides of insulating material. Soldering can be done from either side of the board with equally good results. Table 5-3 lists required tools and materials. Following are recommendations and precautions pertinent to etched circuit repair work.

a. Avoid unnecessary component substitution: it can result in damage to the circuit board and/or adjacent components.

b. Do not use a high-power soldering iron on etched circuit boards. Excessive heat may lift a conductor or damage the board.

c. Use a suction device (Table 5-3) or wooden toothpick to remove solder from component mounting holes. *Do not use a sharp metal object such as an awl or twist drill for this purpose. Sharp objects may damage the plated-through conductor.*

d. After soldering, remove excess flux from the soldered area and apply a protective coating to prevent contamination and corrosion. See Table 5-3 for recommendations.

Table 5-3. Etched Circuit Soldering Equipment

Item	Use	Specification	Item Recommended
Soldering Tool	Soldering Unsoldering	Wattage Rating: 37.5W Tip Temperature: 750 – 800°F Tip Size: 1/8 inch OD	Ungar No. 776 Handle with Ungar No. 1237 Heating Unit
Soldering Tip, general purpose	Soldering Unsoldering	Shape: chisel Size: 1/8 inch	Ungar No. PL113
De-soldering aid	Unsoldering multiconnection components (e.g., tube sockets)	Suction device to remove molten solder from connection	Soldapullit by the Edsyn Company, Arleta, Calif.
Resin (flux) solvent	Remove excess flux from soldered area before application of protective coating.	Must not dissolve etched circuit base board material or conductor bonding agent	Freon Acetone Lacquer Thinner Isopropyl Alcohol (100% dry)
Solder	Component replacement Circuit board repair Wiring	Resin (flux) core, high tin content (60/40 tin/lead), 18 gauge (SWG) preferred	
Protective Coating	Contamination, corrosion protection after soldering	Good electrical insulation, corrosion-prevention properties	GE Dri-Film 88, General Electric Co., Silicone Products Dept. Waterford, N.Y.

## 5-22. Component Replacement

a. Remove defective component from circuit board.

b. Remove solder from mounting holes using a suction desoldering aid (Table 5-3) or wooden toothpick.

c. Shape leads of replacement component to match mounting hole spacing.

d. Insert component leads into mounting holes and position component as original was positioned. *Do not force leads of replacement component into mounting holes.* Sharp lead ends may damage plated-through conductor.

### NOTE

Axial lead components, such as resistors and tubular capacitors can be replaced without unsoldering. Clip leads near body of defective component, remove component and straighten leads left in board. Wrap leads of replacement component one turn around original leads. Solder wrapped connection and clip off excess lead.

**5-23. Etched Conductor Repair.** A broken or burned section of conductor can be repaired by bridging the damaged section with a length of tinned copper wire. Allow adequate overlap and remove any varnish from etched conductor before soldering wire into place.

## 5-24. Transistor Replacement

a. Do not apply excessive heat. See Table 5-3 for soldering tool specifications.

b. Use a heat sink such as pliers or hemostat between transistor body and hot soldering iron.

c. When installing a replacement transistor, ensure sufficient lead length to dissipate heat of soldering by maintaining about the same length of exposed lead as used for original transistor.

## 5-25. Diode Replacement

**5-26.** Solid state diodes are in many physical forms. This sometimes results in confusion as to which lead or connection is for the cathode (negative) or anode (positive), since not all diodes are marked with the standard symbols. Figure 5-2 shows examples of some diode marking methods. If doubt exists as to polarity, an ohmmeter may be used to determine the proper connection. It is

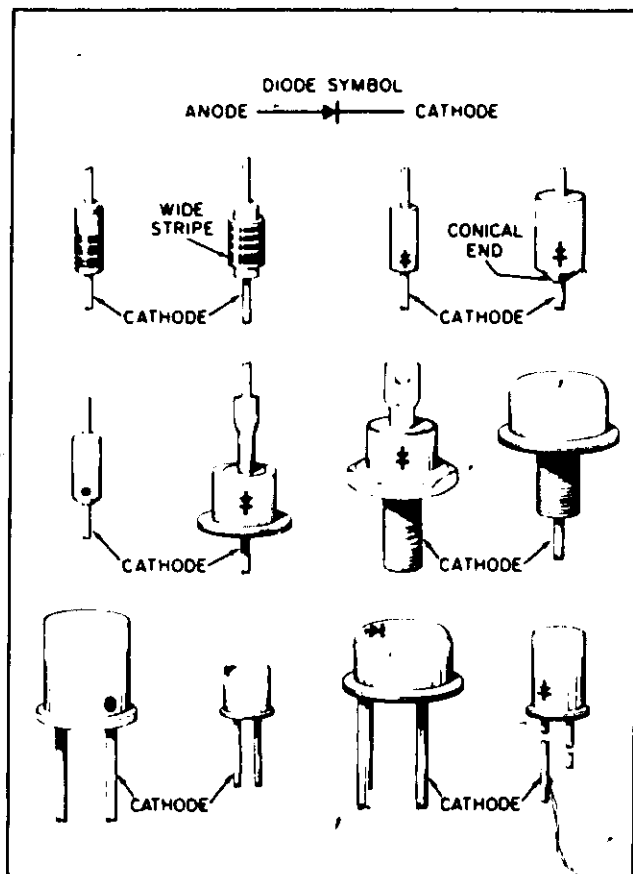


Figure 5-2. Examples of Diode Marking Methods

necessary to know the polarity of the ohm lead with respect to the common lead for the ohmmeter used. (For the HP Model 410B Vacuum Tube Voltmeter, the ohm lead is negative with respect to the common; for the HP Model 412A DC Vacuum Tube Voltmeter, the ohm lead is positive with respect to the common.) When the ohmmeter indicates the least diode resistance, the cathode of the diode is connected to the ohmmeter lead which is negative with respect to the other lead.

#### NOTE

Replacement instructions are the same as those listed for transistor replacement.

#### 5-27. Switch Repair or Replacement

5-28. The EXPAND and RANGE switches are on the same assembly, as are the GAIN and VERNIER controls. These assemblies, along with the POWER switch and the INPUT switch, may be removed by first taking off all instrument covers and using the applicable instructions which follow.

5-29. Gain/Vernier. Refer to Figure 5-3 and the schematic diagrams for component identification and location.

- Loosen setscrews in knobs and remove from shaft.
- Loosen and remove shaft nut from front panel.
- Pull assembly back and out of instrument removing lock washer and grounding lug from shaft. Also remove white GAIN/VERNIER instruction plate from front panel.
- Unsolder connecting wires. Mark each to indicate which lugs to resolder wires to.
- Replacement is reverse of removal.

5-30. RANGE-DB/EXPAND. Refer to Figure 5-3 and the schematic diagram for component identification and location.

- Loosen setscrews in knobs and remove from shaft.
- Loosen and remove shaft nut from front panel.
- Loosen the BANDWIDTH potentiometer to allow the switch assembly to be pulled free of the front panel.
- Unsolder connecting wires. Mark each to indicate which lugs to resolder wires to.
- Replacement is reverse of removal.

5-31. INPUT. Refer to Figure 5-3 and the schematic diagrams for component identification and location.

- Loosen setscrews in knob and remove from shaft.
- Loosen and remove shaft nut from front panel.
- Pull switch assembly free from front panel and unsolder connecting wires. Mark each to indicate which lugs to resolder wires to.
- Replacement is reverse of removal.

5-32. POWER. Refer to Figure 5-3 and the schematic diagrams for component identification and location.

- Loosen the two nuts holding circuit board in place and remove circuit board from instrument.
- Loosen setscrews in knob and remove from shaft.

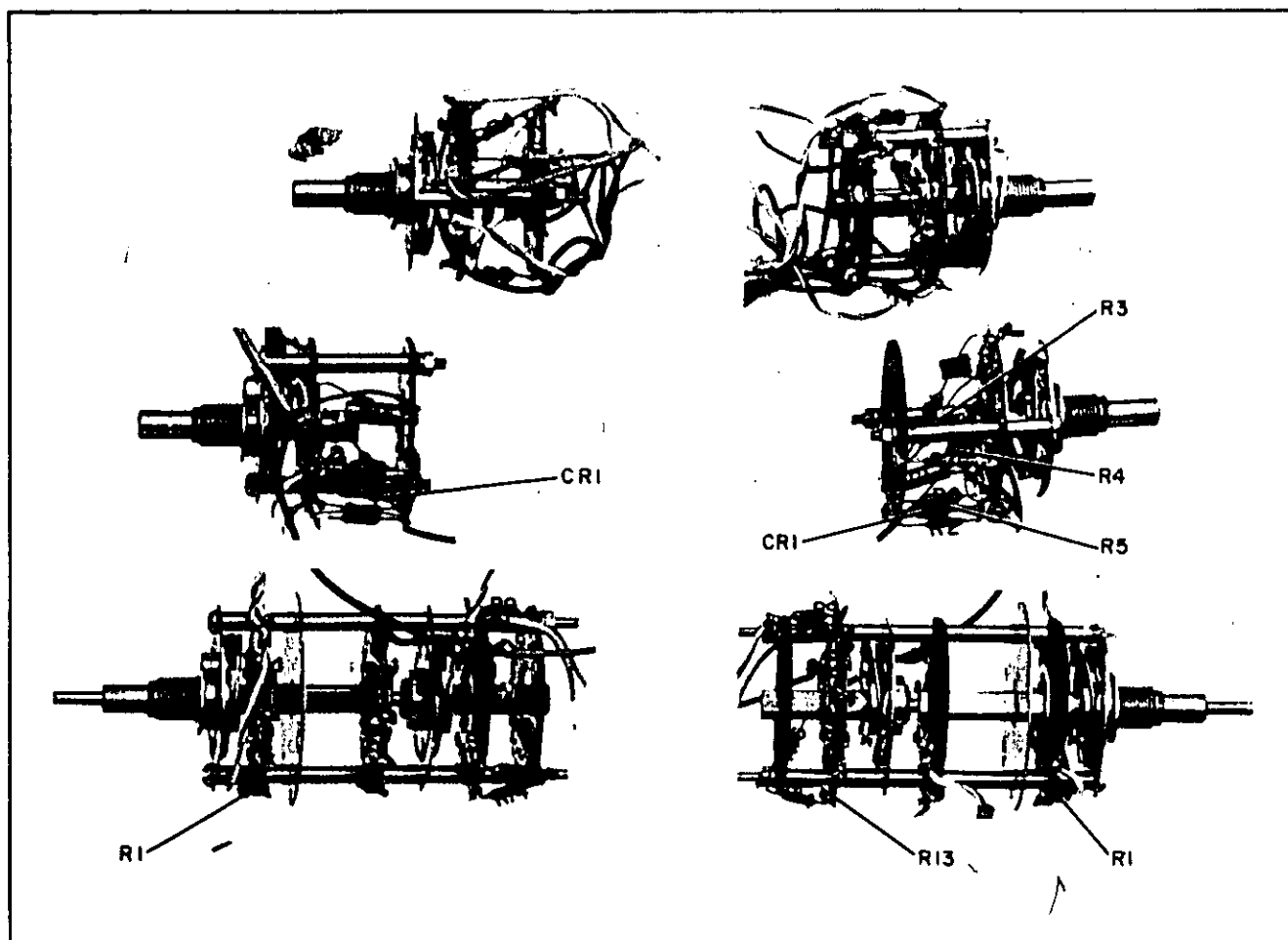


Figure 5-3. Switch Component Location

c. Loosen and remove shaft nut from front panel.

d. Pull switch assembly free from front panel and unsolder connecting wires. Mark each to indicate which lugs to resolder wires to.

e. Replacement is reverse of removal.

### 5-33. Maintenance of Options 01, 001 and 02, 002

5-34. Operating instructions for Model 415E instruments with Option 01, 001 (internally installed battery) and/or Option 02, 002 (rear panel input connector) are found in Section III. Paragraph 1-6 explains what is covered by these two options. Installation and removal instructions are given in the appendix at the rear of this manual.

### 5-35. CHANGING OPERATING FREQUENCY

5-36. In general, the frequency of the 415E can be changed over a range of 400 Hz to 2500 Hz

with no degradation of performance. Operation at frequencies from about 300 Hz to 10 kHz can be achieved with some loss of gain and a poorer noise figure. Note also that the attenuator of the 415E is precisely calibrated only at 1 kHz; this calibration should hold up to 10 kHz. However, it is possible that some inaccuracies of the extremely precise attenuator may occur. Changing the frequency of the 415E SWR Meter is relatively simple. Refer to Figure 5-11. This schematic contains the frequency determining bridge of the 415E.

5-37. For small changes of the center frequency ( $\pm 25\%$ ) it is possible to change only the value of A3R34 and A3R33. The values of these two resistors are equal and are selected so that the correct frequency occurs when FREQ control R4 is in the center of its range. To make it easier to select precise values, the printed circuit board has mounting holes to connect two resistors in parallel for each of A3R33 and A3R34. In this way,



padding resistors can be used to make the precise values required.

5-38. For larger frequency changes, it will also be necessary to change the values of A3C16 and A3C19. The frequency is inversely proportional to the value of these capacitors. For a frequency of 10 kHz, change the value of these capacitors from 0.01  $\mu$ F to 0.001  $\mu$ F. Use 1% mica capacitors; this is important so that the capacitors will be matched. If capacitors with poorer tolerances are used, try to select a pair with identical capacitances. Select new values for A3R33 and A3R34 to trim the frequency to the exact value.

5-39. The value of A3C18 must also be changed to optimize the amplifier feedback for the new frequency. The value of this capacitor for a 10 kHz bridge frequency should be about 180 pF. A 10% mylar capacitor is suitable for this capacitor.

## 5-40. TROUBLESHOOTING

### 5-41. Locating Trouble

5-42. Always start locating trouble with a thorough visual inspection for burned-out or loose components, loose connections or any conditions which suggest a source of trouble. Check the fuse to see that it is not open.

5-43. If trouble cannot be isolated to a bad component by visual inspection, the trouble should be isolated to a circuit section. Isolation to a circuit section can be accomplished by using the waveforms (Figures 5-4 through 5-7) and using the front panel performance tests (Table 5-2).

### 5-44. Power Supply Trouble

5-45. Correct operation of the power supply is vital to proper operation of the SWR Meter. Noise or variation in the regulated voltages causes erratic instrument operation. Noise or variation in the offset current supply causes erratic operation when the 415E is used for expanded operation (i.e., EXPAND control set to any position other than NORM). Refer to paragraph 4-25 for a discussion of power supply operation.

### 5-46. Component Trouble Isolation

5-47. The following procedures and data are given to aid in determining whether a transistor is operational. Tests are given for both in-circuit

and out-of-circuit transistors and should be useful in determining whether a particular section trouble is due to a faulty transistor or an associated component.

### 5-48. In-Circuit Testing

5-49. The common causes of transistor failures are internal short- and open-circuits. In transistor circuit testing the most important consideration is the transistor base-emitter junction. Like the control grid of a vacuum tube, this is the operational control point in the transistor. This junction is essentially a solid state diode. For the transistor to conduct, the diode must conduct; that is, the diode must be forward biased. As with simple diodes, the forward bias polarity is determined by the materials forming the junction. Use the transistor symbol on the schematic diagram to determine the bias polarity required to forward bias the base emitter junction. If the transistor base-emitter diode (junction) is forward biased the transistor conducts. If the diode is heavily forward biased, the transistor saturates. However, if the base emitter diode is reverse biased the transistor is cut off (open). The voltage drop across a forward biased emitter base diode varies with transistor collector current. For example, a germanium transistor has a typical forward bias, base emitter voltage of 0.2 – 0.3 volt when collector current is 1 – 10 ma, and 0.4 – 0.5 volt when collector current is 10 – 100-ma. In contrast, forward bias voltage for silicon transistors is about twice that for germanium types; about 0.5 – 0.6 volt when collector current is low, and about 0.8 – 0.9 volt when collector current is high.

5-50. When examining a transistor stage, first determine if the emitter base diode is biased for conductor (forward biased) by measuring the voltage difference between emitter and base. When using an electronic voltmeter, do not measure directly between emitter and base; there may be sufficient loop current between the voltmeter leads to damage the transistor. Instead, measure each voltage separately with respect to a voltage common point (e.g., chassis). If the emitter base diode is forward biased, check for amplifier action by short-circuiting base to emitter while observing collector voltage. The short-circuit eliminates base emitter bias and should cause the transistor to stop conducting (cut off). Collector voltage should then shift to near the supply voltage. Any difference is due to leakage current through the transistor and, in general, the smaller



this current, the better the transistor. If collector voltage does not change the transistor has either an emitter collector short-circuit or emitter base open-circuit.

#### 5-51. Out-of-Circuit Testing

5-52. The two common causes of transistor failure are internal short- and open-circuits. Remove the transistor from the circuit and use an ohmmeter to measure internal resistance. See Table 5-4 for measurement data.

#### CAUTION

Most ohmmeters can supply enough current or voltage to damage a transistor. Before using an ohmmeter to measure transistor forward or reverse resistance, check its open-circuit voltage and short-circuit current output *on the range to be used*. Open-circuit voltage must not exceed 1.5 volts and short-circuit current must be less than 3 ma. See Table 5-5 for safe resistance ranges for some common ohmmeters.

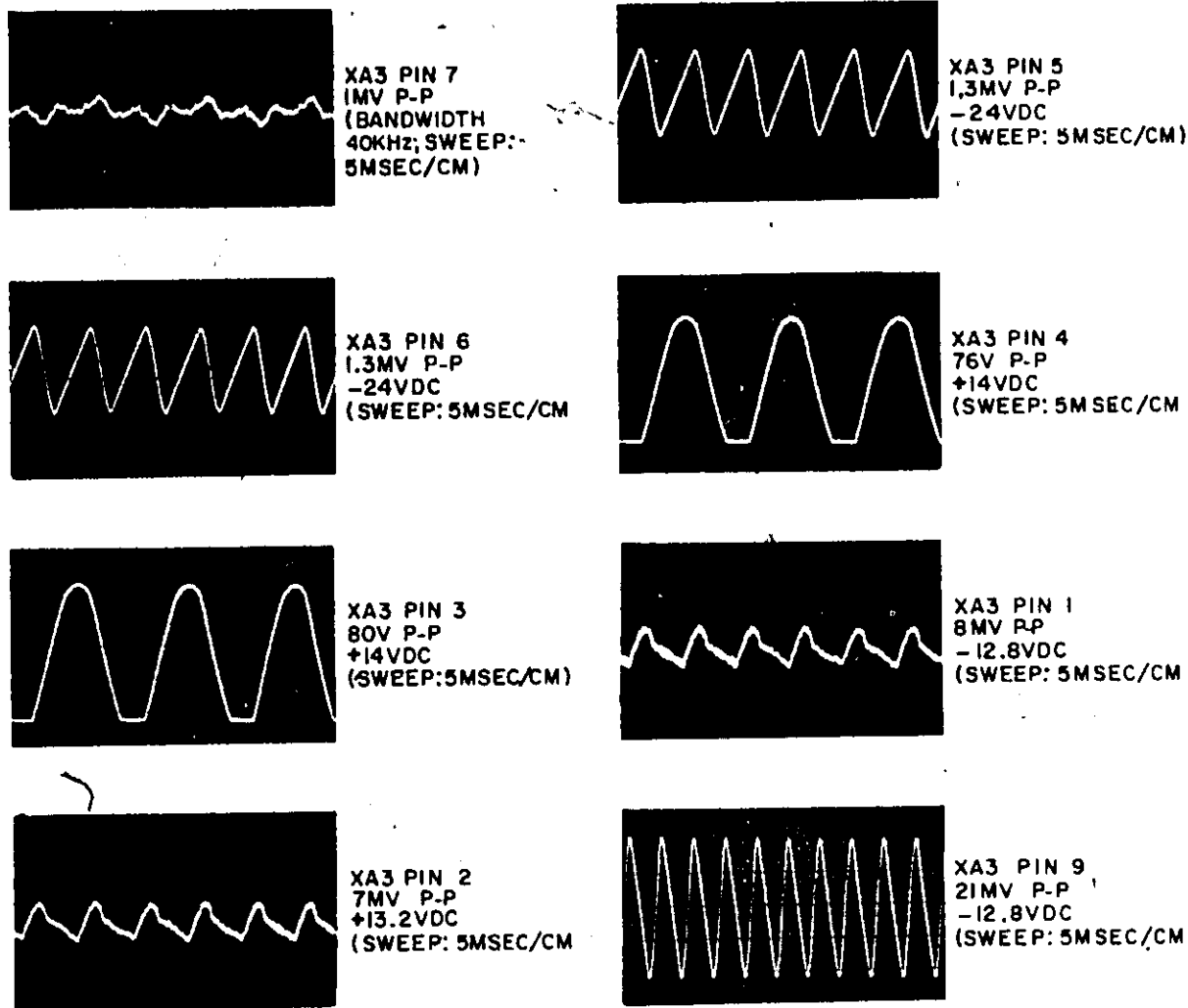
Table 5-4. Out-of-Circuit Transistor Resistance Measurements

Transistor Type		Connect Ohmmeter		Measure Resistance (Ohms)
		Positive Lead to	Negative Lead to	
PNP Germanium	Small Signal	emitter	base*	200 – 250
		emitter	collector	10K – 100K
	Power	emitter	base*	30 – 50
		emitter	collector	several hundred
NPN Silicon	Small Signal	base	emitter	1K – 3K
		collector	emitter	very high (might read open)
	Power	base	emitter	200 – 1000
		collector	emitter	High, often greater than 1M

\*To test for transistor action, add collector-base short. Measured resistance should decrease.

Table 5-5. Ohmmeter Ranges for Transistor Resistance Measurements

Ohmmeter	Safe Range(s)	Open Circuit Voltage	Short Circuit Current	Lead	
				Color	Polarity
HP 412A HP 427A	R x 1K R x 10K R x 100K R x 1M R x 10M	1.0V 1.0V 1.0V 1.0V 1.0V	1 ma 100 $\mu$ a 10 $\mu$ a 1 $\mu$ a 0.1 $\mu$ a	Red Black	+ —
HP 410C	R x 1K R x 10K R x 100K R x 1M R x 10M	1.3V 1.3V 1.3V 1.3V 1.3V	0.57 ma 57 $\mu$ a 5.7 $\mu$ a 0.5 $\mu$ a 0.05 $\mu$ a	Red Black	+ —
HP 410B	R x 100 R x 1K R x 10K R x 100K R x 1M	1.1V 1.1V 1.1V 1.1V 1.1V	1.1 ma 110 $\mu$ a 11 $\mu$ a 1.1 $\mu$ a 0.11 $\mu$ a	Black Red	+ —
Simpson 260	R x 100	1.5V	1 ma	Red Black	+ —
Simpson 269	R x 1K	1.5V	0.82 ma	Black Red	+ —
Triplet 630	R x 100 R x 1K	1.5V 1.5V	3.25 ma 325 $\mu$ a	Varies with serial number	
Triplet 310	R x 10 R x 100	1.5V 1.5V	750 $\mu$ a 75 $\mu$ a		

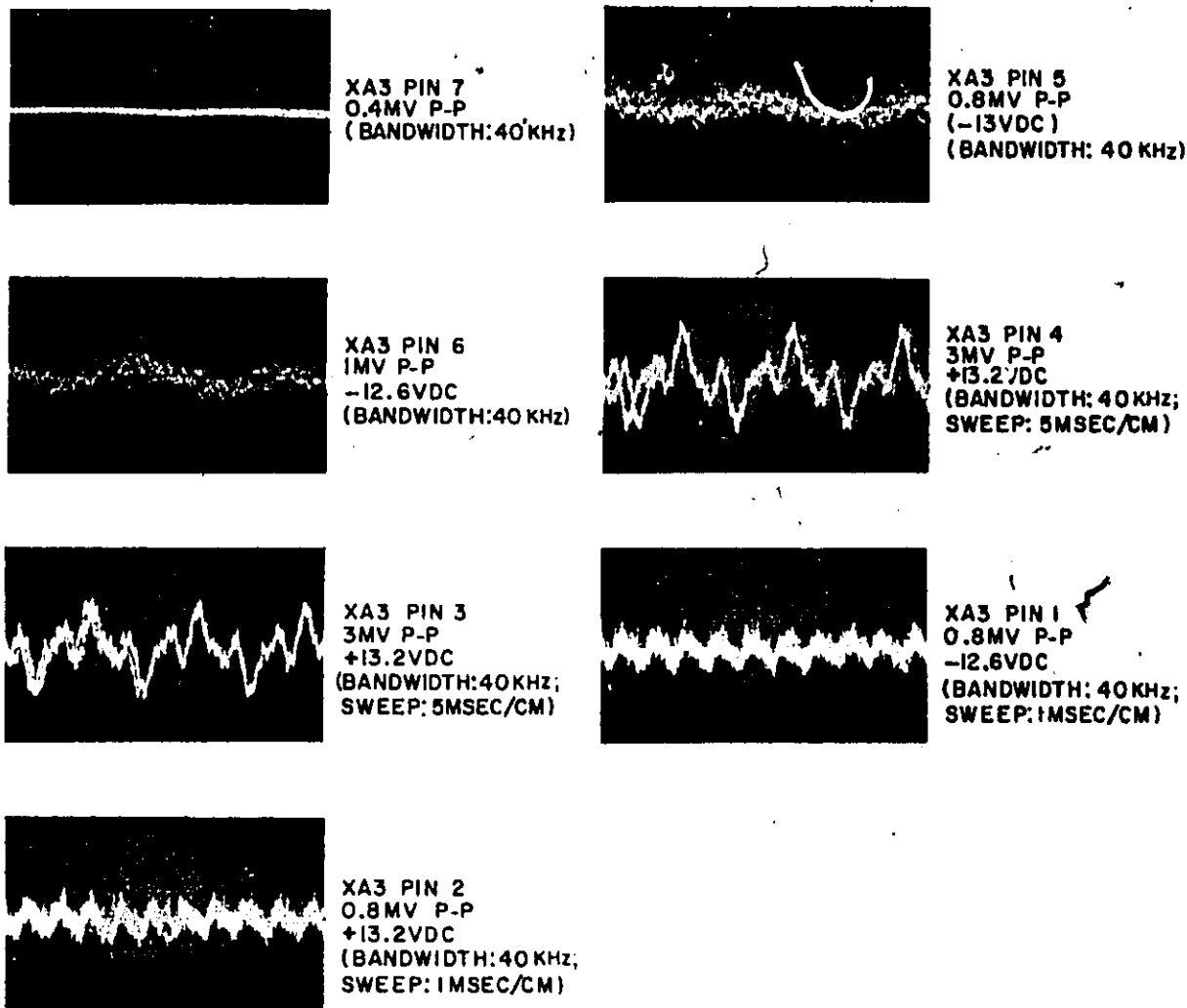


#### MEASUREMENT CONDITIONS (unless otherwise noted)\*

- Model 415E set to HIGH, NORM, RANGE 0, BANDWIDTH clockwise, FREQ centered, GAIN and VERNIER counterclockwise, LINE/ON.
- Model 140A with 1420A and 1400A set to 0.2 msec/cm, AC, 400 Hz, and appropriate vertical sensitivity.
- Model 200CD oscillator set to about 1000 Hz, and for 0 dB Model 415E meter reference.
- Model 412A DC voltmeter set to appropriate range.

\*All measurements made with respect to 415E common (black terminal rear panel AMPLIFIER OUTPUT connector).

Figure 5-4. Power Supply Waveforms (AC Operation Only)

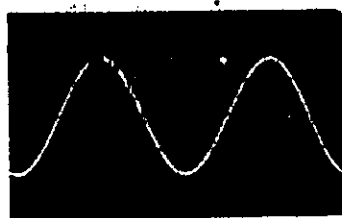


#### MEASUREMENT CONDITIONS (unless otherwise noted)\*

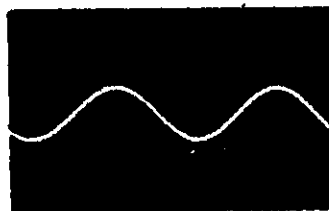
- Model 415E set to HIGH, NORM, RANGE 0, BANDWIDTH clockwise, FREQ centered, GAIN and VERNIER counterclockwise, BATTERY/ON.
- Model 140A with 1420A and 1400A set to 0.2 msec/cm, AC, 400 Hz, and appropriate vertical sensitivity.
- Model 200CD oscillator set to about 1000 Hz, and for 0 dB Model 415E meter reference.
- Model 412A DC voltmeter set to appropriate range.

\*All measurements made with respect to 415E common (black terminal rear panel AMPLIFEIR OUTPUT connector).

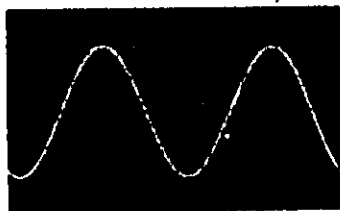
Figure 5-5. Power Supply Waveforms (Internal Battery Operation Only)



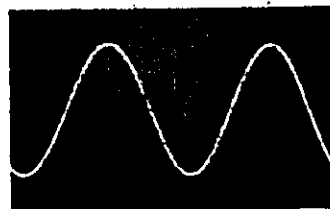
1000 CPS  
INPUT SIGNAL  
38V P-P



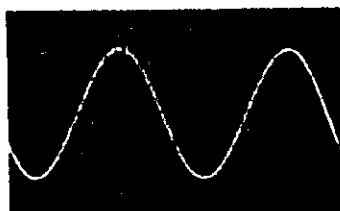
XA3 PIN 17  
3.8MV P-P  
40KHz BANDWIDTH  
+2.6VDC



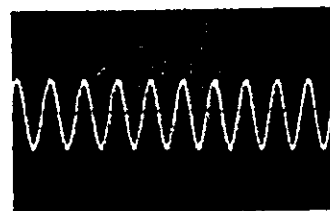
XA3 PIN 21  
37MV P-P



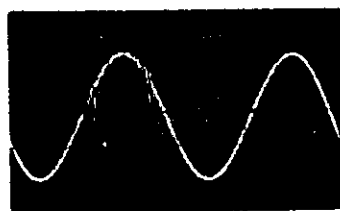
XA3 PIN 16  
170MV P-P



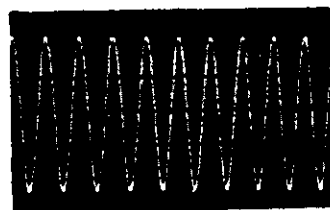
XA3 PIN 19  
4V P-P



XA3 PIN 11  
10MV P-P



XA3 PIN 18  
4V P-P  
+2.6VDC



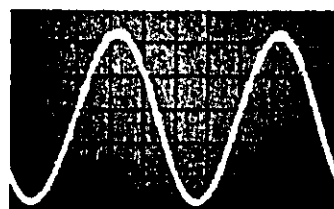
XA3 PIN 8  
0.9V P-P

#### MEASUREMENT CONDITIONS (unless otherwise noted)\*

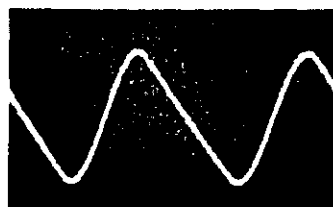
- Model 415E set to ON, HIGH, NORM, RANGE 0, BANDWIDTH clockwise, FREQ centered, GAIN and VERNIER counterclockwise.
- Model 140A with 1420A and 1400A set to 0.2 msec/cm, AC, 400 Hz, and appropriate vertical sensitivity.
- Model 200CD oscillator set to about 1000 Hz, and for 0 dB model 415E meter reference.
- Model 412A DC voltmeter set to appropriate range.

\*All measurements made with respect to 415E common (black terminal rear panel AMPLIFIER OUTPUT connector).

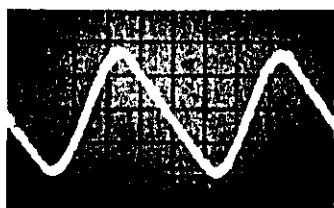
Figure 5-6. Signal Flow Waveforms (Input to Amplifier Output)



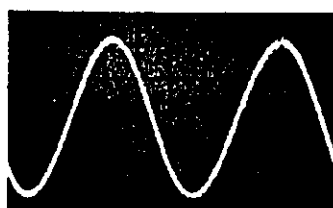
AMPLIFIER  
OUTPUT  
2.5V P-P  
(EXPAND: 0)



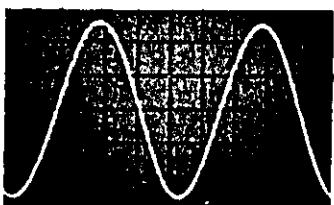
RECORDER  
OUTPUT  
0.2V P-P  
+1.0VDC  
(EXPAND: 0)



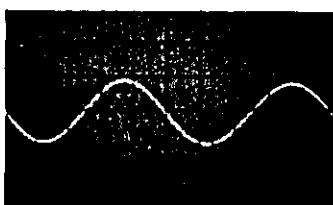
RECORDER  
OUTPUT  
72MV P-P  
+1.0VDC



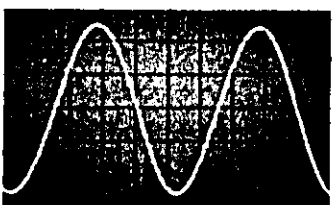
AMPLIFIER  
OUTPUT  
0.9V P-P



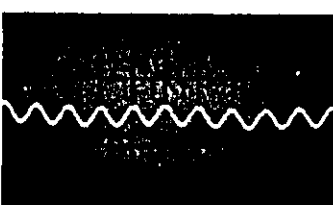
XA3 PIN 15  
0.25V P-P  
+1.4VDC



XA3 PIN 13  
3.8MV P-P  
(40KHz BANDWIDTH)  
+1.1VDC



XA3 PIN 14  
0.25V P-P  
+1.4VDC



XA3 PIN 12  
0.6MV P-P  
(BANDWIDTH 40 KHz)  
+1.1VDC

#### MEASUREMENT CONDITIONS (unless otherwise noted)\*

- Model 415E set to ON, HIGH, NORM, RANGE 0, BANDWIDTH clockwise, FREQ centered, GAIN and VERNIER counterclockwise.
- Model 140A with 1420A and 1400A set to 0.2 msec/cm, AC, 400 Hz, and appropriate sensitivity.
- Model 200CD oscillator set to about 1000 Hz, and for 0 dB model 415E meter reference.
- Model 412A DC voltmeter set to appropriate range.

\*All measurements made with respect to 415E common (black terminal rear panel AMPLIFIER OUTPUT connector).

Figure 5-7. Meter and Output Waveforms



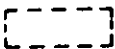
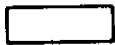







1. Resistance in ohms, "K" indicates thousands of ohms and "M" indicates millions of ohms.
2. Capacitance in microfarads unless otherwise indicated, "pf" indicates micro-microfarads.
3.  screwdriver adjustment  
 panel control
4.  rear panel designation  
 front panel designation
5.  circuit assembly borderline  
 switch assembly outline
6.  CW indicates movable contact position at clockwise rotation limit of control shaft (shaft viewed from knob or slotted end).
7.  Indicates socket connections of plug-in assembly
8.  Indicates plug-in socket pin number
9.  Voltage regulator (breakdown) diode.
10. "NOM" indicates positive DC power supply voltage is nominal and may vary from nominal value by  $\pm 1$  vdc (see Paragraph 4-24 INPUT BIASING).
11.  encloses wire color code. Wire color code same as resistor code. First number identifies ground color, second number identifies wider strip, third number identifies narrower strip. E.g., (947) denotes white ground, yellow wide stripe, violet narrow stripe.

Figure 5-8. Schematic Notes



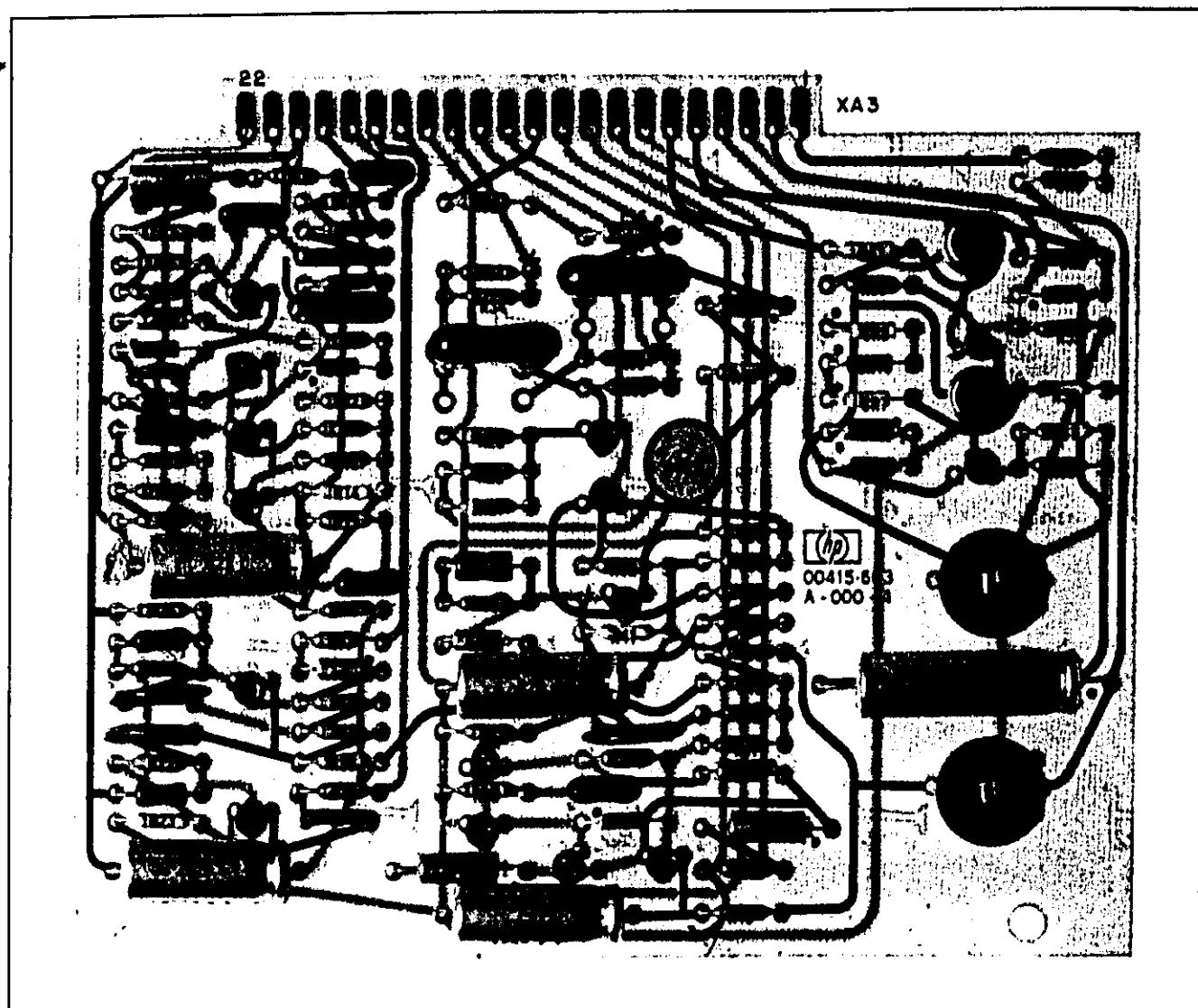


Figure 5-9 A3 Circuit Board Component Location for instruments Prefixed 545- and up.  
See Appendix II for Component Location of Instruments Prefixed 530-.

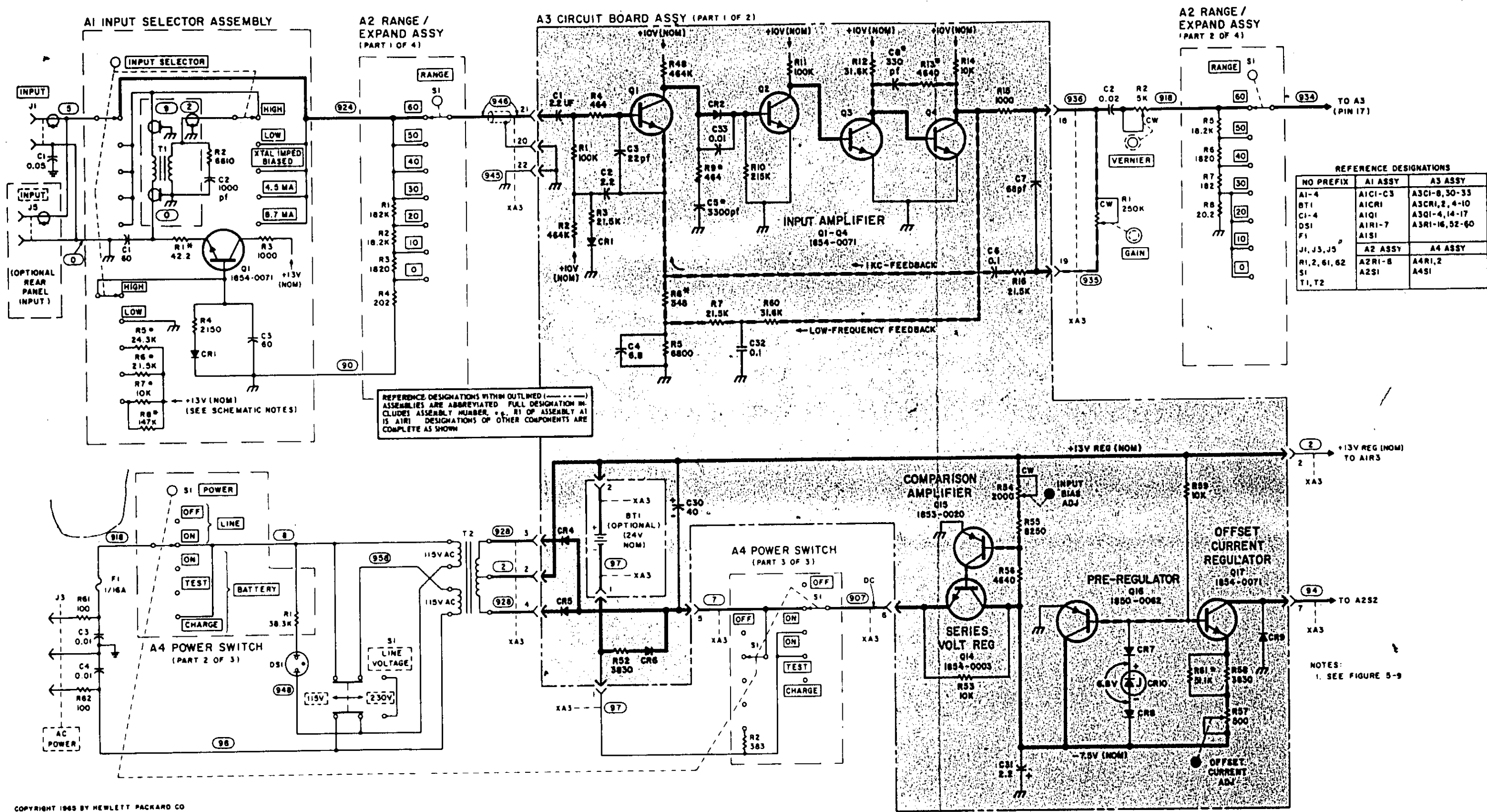


Figure 5-10. Power Supply and Input Circuit



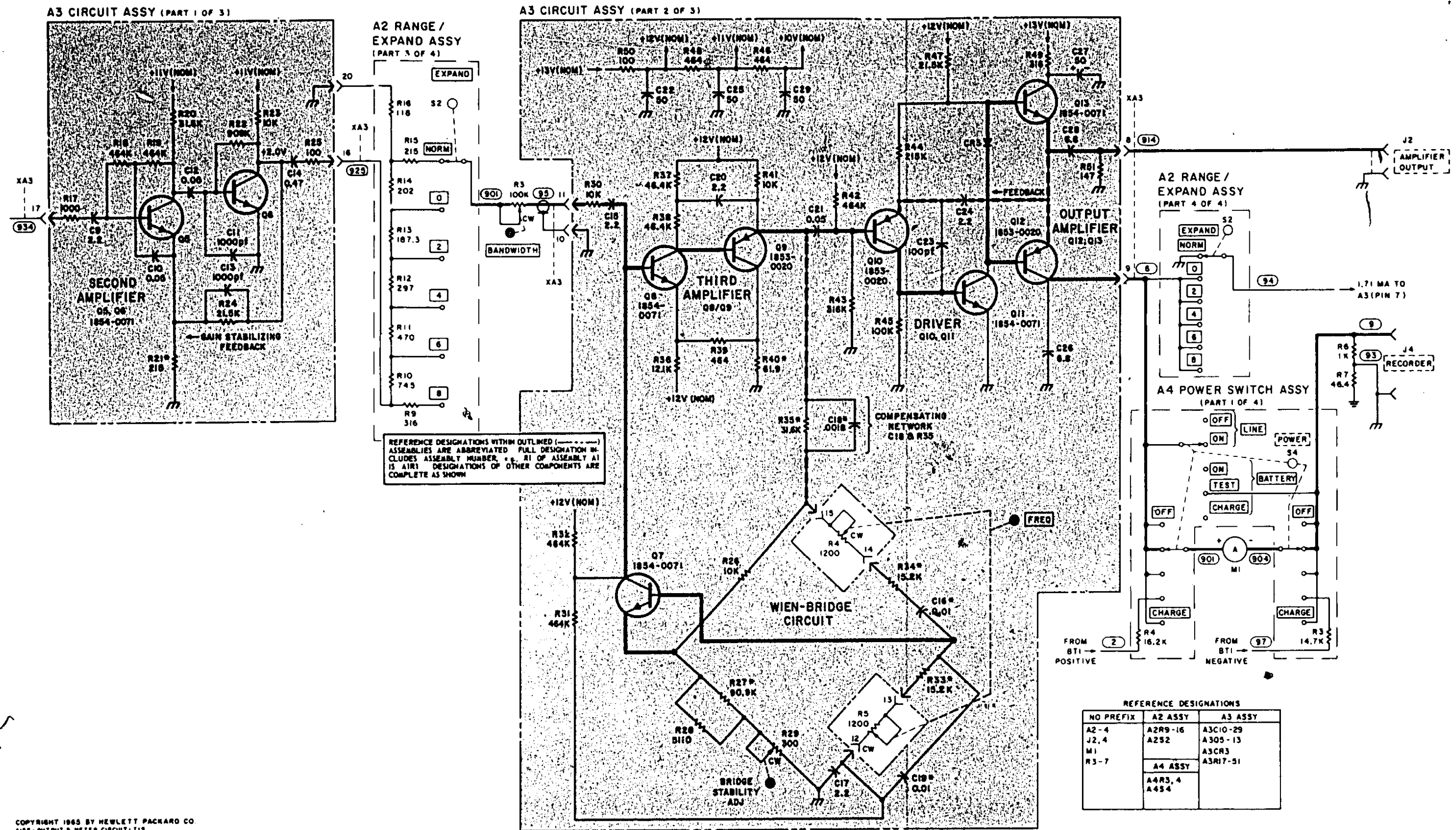


Figure 5-11. Output and Meter Circuit

# PARTS LIST

## SECTION VI

### REPLACEABLE PARTS

#### 6-1. INTRODUCTION

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

- a. Description of the part (see list of abbreviations, Table 6-1).
- b. Typical manufacturer of the part in a five-digit code; see list of manufacturers in Table 6-3.
- c. Manufacturer's part number.
- d. Total quantity used in the instrument (TQ column).

6-3. Miscellaneous parts are listed at the end of Table 6-2.

#### 6-4. ORDERING INFORMATION

6-5. To obtain replacement parts, address order or inquiry to your local Hewlett-Packard field office (see list at rear of this manual for addresses). Identify parts by their Hewlett-Packard part numbers.

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

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

Table 6-1. Reference Designators and Abbreviations

REFERENCE DESIGNATORS							
A	= assembly	F	= fuse	P	= plug	V	= vacuum tube, neon bulb, photocell, etc.
B	= motor	FL	= Filter	Q	= transistor	VR	= voltage regulator
BT	= battery	J	= jack	R	= resistor	W	= cable
C	= capacitor	K	= relay	RT	= thermistor	X	= socket
CP	= coupler	L	= inductor	S	= switch	Y	= crystal
CR	= diode	LS	= loud speaker	T	= transformer	Z	= tuned cavity, network
DL	= delay line	M	= meter	TB	= terminal board		
DS	= device signaling (lamp)	MK	= microphone	TP	= test point		
E	= misc electronic part	MP	= mechanical part	U	= integrated circuit		

ABBREVIATIONS							
A	= amperes	H	= henries	N/O	= normally open	RMO	= rack mount only
AFC	= automatic frequency control	HDW	= hardware	NOM	= nominal	RMS	= root-mean square
AMPL	= amplifier	HEX	= hexagonal	NPO	= negative positive zero (zero temperature coefficient)	RWV	= reverse working voltage
BFO	= beat frequency oscillator	HG	= mercury	NPN	= negative-positive-negative	S-B	= slow-blow
BE CU	= beryllium copper	HR	= hour(s)	NRFR	= not recommended for field replacement	SCR	= screw
BH	= binder head	H <sub>z</sub>	= Hertz	NSR	= not separately replaceable	SE	= selenium
BP	= bandpass	IF	= intermediate freq	OBD	= order by description	SECT	= section(s)
BRB	= brass	IMPG	= impregnated	OH	= oval head	SEMICON	= semiconductor
BWO	= backward wave oscillator	INCD	= incandescent	OX	= oxide	SI	= silicon
		INCL	= include(s)	P	= peak	SIL	= silver
		INS	= insulation(ed)	PC	= printed circuit	SL	= slide
		INT	= internal	PF	= picofarads = 10 <sup>-12</sup> farads	SPG	= spring
CCW	= counterclockwise	K	= kilo = 1000	PH BRZ	= phosphor bronze	SPL	= special
CER	= ceramic	LH	= left hand	PHL	= Phillips	SST	= Stainless steel
CMO	= cabinet mount only	LIN	= linear taper	PIV	= peak inverse voltage	SR	= split ring
COEF	= coefficient	LK WASH	= lock washer	PNP	= positive-negative-positive	STL	= steel
COM	= common	LOG	= logarithmic taper	P/O	= part of	TA	= tantalum
COMP	= composition	LPF	= low pass filter	POLY	= polystyrene	TD	= time delay
COMPL	= complete	M	= milli = 10 <sup>-3</sup>	PORC	= porcelain	TGL	= toggle
CONN	= connector	MEG	= meg = 10 <sup>6</sup>	POT	= potentiometer	THD	= thread
CP	= cadmium plate	MET FLM	= metal film	PP	= peak-to-peak	TI	= titanium
CRT	= cathode-ray tube	MET OX	= metallic oxide	PT	= point	TOL	= tolerance
CW	= clockwise	MFR	= manufacturer	PWV	= peak working voltage	TRIM	= trimmer
DEPC	= deposited carbon	MHz	= mega Hertz	RECT	= rectifier	TWT	= traveling wave tube
DR	= drive	MINAT	= miniature	RF	= radio frequency		
ELECT	= electrolytic	MOM	= momentary	RH	= round head or right hand		
ENCAP	= encapsulated	MOS	= metalized substrate				
EXT	= external	MTG	= mounting				
F	= farads	MY	= "mylar"				
FH	= flat head	N	= nano (10 <sup>-9</sup> )				
FIL H	= Fullister head	N/C	= normally closed				
FXD	= fixed	NE	= neon				
G	= giga (10 <sup>9</sup> )	NI PL	= nickel plate				
GE	= germanium						
GL	= glass						
GRD	= ground(ed)						

Table 6-2. Replaceable Parts

Reference Designation	HP Part Number	Qty	Description	Mfr Code	Mfr Part Number
A1	00415-401	1	SWITCH ASSY:INPUT	28480	00415-401
A1C1	0180-0106	2	CIFXD ELECT 40 UF 20% 5VDCM	28480	0180-0106
A1C2	0160-0153	3	CIFXD MY 0.001 UF 10% 200VDCM	56289	192P10292-PTS
A1C3	0180-0106	2	CIFXD ELECT 40 UF 20% 5VDCM	28480	0180-0106
A1CA1	1901-0023	6	DIODE: SILICON 100MA/1V	07263	FD 2367
A1Q1	1854-0071	12	TSTR:SI NPN:SELECTED FROM 2H3704)	28480	1854-0071
A1R1	0757-0316	1	RIFXD MET FLM 42.2 OHM 1% 1/8W	28480	0757-0316
A1R2	0757-0439	2	RIFXD MET FLM 6.81K OHM 1% 1/8W	28480	0757-0439
A1R3	0757-0280	4	RIFXD MET FLM 1K OHM 1% 1/8W	28480	0757-0280
A1R4	0698-0084	1	RIFXD MET FLM 2.15K OHM 1% 1/8W	28480	0698-0084
A1R5	0757-0451	1	RIFXD MET FLM 24.3K OHM 1% 1/8W	28480	0757-0451
A1R6	0757-0199	4	RIFXD MET FLM 21.5K OHM 1% 1/8W	28480	0757-0199
A1R7	0757-0443	1	RIFXD MET FLM 11.0K OHM 1% 1/8W	28480	0757-0443
A1R8	0698-3452	1	RIFXD MET FLM 147K OHM 1% 1/8W	28480	0698-3452
A1S1	3100-1805	1	SWITCH:ROTARY	28480	3100-1805
A2	00415-402	1	SWITCH ASSY:RANGE	28480	00415-402
A2R1	0698-6114	1	RIFXD FLM 182K OHM 0.25% 1/8W	28480	0698-6114
A2R2	0698-6109	2	RIFXD MET FLM 18.2K OHM 0.25% 1/8W	28480	0698-6109
A2R3	0698-6113	2	RIFXD MET FLM 1.82K OHM 0.25% 1/8W	28480	0698-6113
A2R4	0698-6112	2	RIFXD FLM 202 OHM 0.25% 1/8W	28480	0698-6112
A2R5	0698-6109	1	RIFXD MET FLM 18.2K OHM 0.25% 1/8W	28480	0698-6109
A2R6	0698-6113	1	RIFXD MET FLM 1.82K OHM 0.25% 1/8W	28480	0698-6113
A2R7	0698-6111	1	RIFXD FLM 182 OHM 0.25% 1/8W	28480	0698-6111
A2R8	0698-6110	1	RIFXD FLM 20.2 OHM 0.25% 1/8W	28480	0698-6110
A2R9	0698-3444	2	RIFXD MET FLM 316 OHM 1% 1/8W	28480	0698-3444
A2R10	0698-3531	1	RIFXD MET FLM 745 OHM 0.5% 1/8W	28480	0698-3531
A2R11	0698-3530	1	RIFXD MET FLM 470 OHM 0.5% 1/8W	28480	0698-3530
A2R12	0698-3529	1	RIFXD MET FLM 297 OHM 0.5% 1/8W	28480	0698-3529
A2R13	0698-3527	1	RIFXD MET FLM 187.3 OHM 0.5% 1/8W	28480	0698-3527
A2R14	0698-6112	1	RIFXD FLM 202 OHM 0.25% 1/8W	28480	0698-6112
A2R15	0698-3441	2	RIFXD MET FLM 215 OHM 1% 1/8W	28480	0698-3441
A2R16	0698-3525	1	RIFXD MET FLM 118 OHM 0.5% 1/8W	28480	0698-3525
A2S1	3100-1806	1	SWITCH:ROTARY	28480	3100-1806
A3	00415-403	1	BOARD ASSY:AMPLIFIER	28480	00415-403
A3C1	0180-0155	8	CIFXD ELECT 2.2 UF 20% 20VDCM	56289	1500225X0020A2-DYS
A3C2	0180-0155	1	CIFXD ELECT 2.2 UF 20% 20VDCM	56289	1500225X0020A2-DYS
A3C3	0140-0145	1	CIFXD MICA 22 PF 5%	28480	0140-0145
A3C4	0180-0116	3	CIFXD ELECT 6.8 UF 10% 35VDCM	56289	1500685X9035B2-DYS
A3C5	0160-0155	1	CIFXD MY 0.0033 UF 10% 200VDCM	56289	192P33292-PTS
A3C6	0150-0121	1	CIFXD CER 0.1 UF +80-20% 50VDCM	56289	5C50B15-CML
A3C7	0140-0192	1	CIFXD MICA 68 PF 5%	28480	0140-0192
A3C8	0140-0207	1	CIFXD MICA 330 PF 5%	28480	0140-0207
A3C9	0180-0155	1	CIFXD ELECT 2.2 UF 20% 20VDCM	56289	1500225X0020A2-DYS
A3C10	0160-2917	3	CIFXD CER 0.05 UF +80-20% 100VDCM	84411	TYPE TA
A3C11	0160-0153	1	CIFXD MY 0.001 UF 10% 200VDCM	56289	192P10292-PTS
A3C12	0160-2917	1	CIFXD CER 0.05 UF +80-20% 100VDCM	84411	TYPE TA
A3C13	0160-0153	1	CIFXD MY 0.001 UF 10% 200VDCM	56289	192P10292-PTS
A3C14	0160-0174	1	CIFXD CER 0.47 UF +80-20% 25VDCM	56289	5C11875-CML
A3C15	0180-0155	1	CIFXD ELECT 2.2 UF 20% 20VDCM	56289	1500225X0020A2-DYS
A3C16	0160-2120	2	CIFXD MICA 0.01UF 1%	04062	ADM30F103FC
A3C17	0180-0155	1	CIFXD ELECT 2.2 UF 20% 20VDCM	56289	1500225X0020A2-DYS
A3C18	0160-2223	1	CIFXD MICA 1600 PF 5%	28480	0160-2223
A3C19	0160-2120	1	CIFXD MICA 0.01UF 1%	04062	ADM30F103FC
A3C20	0180-0155	1	CIFXD ELECT 2.2 UF 20% 20VDCM	56289	1500225X0020A2-DYS
A3C21	0160-2917	1	CIFXD CER 0.05 UF +80-20% 100VDCM	84411	TYPE TA
A3C22	0180-0105	4	CIFXD ELECT SEMI-POLARIZED 50UF 25VDCM	56289	D34114
A3C23	0140-0176	1	CIFXD MICA 100 PF 5%	28480	0140-0176
A3C24	0180-0155	1	CIFXD ELECT 2.2 UF 20% 20VDCM	56289	1500225X0020A2-DYS
A3C25	0180-0105	1	CIFXD ELECT SEMI-POLARIZED 50UF 25VDCM	56289	D34114
A3C26	0140-0116	1	CIFXD ELECT 6.8 UF 10% 35VDCM	56289	1500685X9035B2-DYS
A3C27	0180-0105	1	CIFXD ELECT SEMI-POLARIZED 50UF 25VDCM	56289	D34114
A3C28	0180-0116	1	CIFXD ELECT 6.8 UF 10% 35VDCM	56289	1500685X9035B2-DYS
A3C29	0180-0105	1	CIFXD ELECT SEMI-POLARIZED 50UF 25VDCM	56289	D34114
A3C30	0180-0050	1	CIFXD ELECT 40 UF +75-10% 50VDCM	28480	0180-0050
A3C31	0180-0155	1	CIFXD ELECT 2.2 UF 20% 20VDCM	56289	1500225X0020A2-DYS
A3C32	0170-0C85	1	CIFXD MY 0.1UF 20% 50VDCM	84411	601PE STYLE 3
A3C33	0160-2930	1	CIFXD CER 0.01 UF +80-20% 100VDCM	91418	TA
A3CA1	1901-0023	1	DIODE: SILICON 100MA/1V	07263	FD 2367
A3CA2	1901-0023	1	DIODE: SILICON 100MA/1V	07263	FD 2367
A3CA3	1901-0023	1	DIODE: SILICON 100MA/1V	07263	FD 2367
A3CA4	1901-0033	2	DIODE: SILICON 100MA 180MV	07263	FD3369
A3CA5	1901-0033	2	DIODE: SILICON 100MA 180MV	07263	FD3369
A3CA6	1901-0023	1	DIODE: SILICON 100MA/1V	07263	FD 2367
A3CA7	1910-0016	2	DIODE: GERMANIUM 100MA/0.85V 60PIV	93332	D2361
A3CA8	1910-0016	2	DIODE: GERMANIUM 100MA/0.85V 60PIV	93332	D2361

See Introduction to this section for ordering information



Table 6-2. Replaceable Parts

Reference Designation	HP Part Number	Qty	Description	Mfr Code	Mfr Part Number
A3CA9	1901-0025	1	DIODE SILICON 100MA/1V	07263	FD 2387
A3CA10	1902-0048		DIODE BREAKDOWN 4.51V 5S	04713	S210939-134
A3Q1	1854-0071		TSTR:SI NPN SELECTED FROM 2N3704	28480	1854-0071
A3Q2	1854-0071		TSTR:SI NPN SELECTED FROM 2N3704	28480	1854-0071
A3Q3	1854-0071		TSTR:SI NPN SELECTED FROM 2N3704	28480	1854-0071
A3Q4	1854-0071	1	TSTR:SI NPN SELECTED FROM 2N3704	28480	1854-0071
A3Q5	1854-0071		TSTR:SI NPN SELECTED FROM 2N3704	28480	1854-0071
A3Q6	1854-0071		TSTR:SI NPN SELECTED FROM 2N3704	28480	1854-0071
A3Q7	1854-0071		TSTR:SI NPN SELECTED FROM 2N3704	28480	1854-0071
A3Q8	1854-0071		TSTR:SI NPN SELECTED FROM 2N3704	28480	1854-0071
A3Q9	1853-0020	4	TSTR:SI PNP SELECTED FROM 2N3702	28480	1853-0020
A3Q10	1853-0020		TSTR:SI PNP SELECTED FROM 2N3702	28480	1853-0020
A3Q11	1854-0071		TSTR:SI NPN SELECTED FROM 2N3704	28480	1854-0071
A3Q12	1853-0020		TSTR:SI PNP SELECTED FROM 2N3702	28480	1853-0020
A3Q13	1854-0071		TSTR:SI NPN SELECTED FROM 2N3704	28480	1854-0071
A3Q14	1854-0003	1	TSTR:SI NPN SELECTED FROM 2N1711	28480	1854-0003
A3Q15	1853-0020		TSTR:SI PNP SELECTED FROM 2N3702	28480	1853-0020
A3Q16	1850-0062	1	TSTR:GE ALLOY JUNCTION	01295	GA 267
A3Q17	1854-0071		TSTR:SI NPN SELECTED FROM 2N3704	28480	1854-0071
A3R1	0757-0445	3	RIFXD NET FLN 100K OHM 1% 1/8W	28480	0757-0445
A3R2	C498-3260		RIFXD NET FLN 444K OHM 1% 1/8W	28480	0498-3260
A3R3	0757-0199	5	RIFXD NET FLN 21.5K OHM 1% 1/8W	28480	0757-0199
A3R4	C498-0082		RIFXD NET FLN 444 OHM 1% 1/8W	28480	0498-0082
A3R5	0757-0439		RIFXD NET FLN 6.81K OHM 1% 1/8W	28480	0757-0439
A3R6	C498-3445		RIFXD NET FLN 348 OHM 1% 1/8W	28480	0498-3445
A3R7	0757-0199		RIFXD NET FLN 21.5K OHM 1% 1/8W	28480	0757-0199
A3R8	C498-3260	2	RIFXD NET FLN 444K OHM 1% 1/8W	28480	0498-3260
A3R9	0498-0082		RIFXD NET FLN 444 OHM 1% 1/8W	28480	0498-0082
A3R10	C498-3454		RIFXD NET FLN 215K OHM 1% 1/8W	28480	0498-3454
A3R11	0757-0445		RIFXD NET FLN 100K OHM 1% 1/8W	28480	0757-0445
A3R12	C498-3160	3	RIFXD NET FLN 31.6K OHM 1% 1/8W	28480	0498-3160
A3R13	0498-3155		RIFXD NET FLN 4.64K OHM 1% 1/8W	28480	0498-3155
A3R14	0757-0442		RIFXD NET FLN 10.0K OHM 1% 1/8W	28480	0757-0442
A3R15	0757-0280		RIFXD NET FLN 1K OHM 1% 1/8W	28480	0757-0280
A3R16	0757-0199		RIFXD NET FLN 21.5K OHM 1% 1/8W	28480	0757-0199
A3R17	0757-0280	1	RIFXD NET FLN 1K OHM 1% 1/8W	28480	0757-0280
A3R18	C498-3260		RIFXD NET FLN 444K OHM 1% 1/8W	28480	0498-3260
A3R19	0498-3260		RIFXD NET FLN 444K OHM 1% 1/8W	28480	0498-3260
A3R20	C498-3160		RIFXD NET FLN 31.6K OHM 1% 1/8W	28480	0498-3160
A3R21	C498-3441		RIFXD NET FLN 215 OHM 1% 1/8W	28480	0498-3441
A3R22	0757-0488	1	RIFXD NET FLN 909K OHM 1% 1/8W	28480	0757-0488
A3R23	0757-0442		RIFXD NET FLN 10.0K OHM 1% 1/8W	28480	0757-0442
A3R24	0757-0199		RIFXD NET FLN 21.5K OHM 1% 1/8W	28480	0757-0199
A3R25	0757-0401		RIFXD NET FLN 100 OHM 1% 1/8W	28480	0757-0401
A3R26	0757-0442		RIFXD NET FLN 10.0K OHM 1% 1/8W	28480	0757-0442
A3R27	0757-0444	1	RIFXD NET FLN 90.9K OHM 1% 1/8W	28480	0757-0444
A3R28	0757-0438		RIFXD NET FLN 5.11K OHM 1% 1/8W	28480	0757-0438
A3R29	2100-1611		RIVAR WM 300 OHM 5% TYPE H 1/4W	28480	2100-1611
A3R30	0757-0442		RIFXD NET FLN 10.0K OHM 1% 1/8W	28480	0757-0442
A3R31	0498-3260		RIFXD NET FLN 444K OHM 1% 1/8W	28480	0498-3260
A3R32	C498-3260	2	RIFXD NET FLN 444K OHM 1% 1/8W	28480	0498-3260
A3R33	0498-5001		RIFXD FLN 15.2K OHM 1% 1/8W	28480	0498-5001
A3R34	C498-5001		RIFXD FLN 15.2K OHM 1% 1/8W	28480	0498-5001
A3R35	0498-3449		RIFXD NET FLN 28.7K OHM 1% 1/8W	28480	0498-3449
A3R36	0757-0444		RIFXD NET FLN 12.1K OHM 1% 1/8W	28480	0757-0444
A3R37	0498-3162	2	RIFXD NET FLN 44.4K OHM 1% 1/8W	28480	0498-3162
A3R38	C498-3162		RIFXD NET FLN 44.4K OHM 1% 1/8W	28480	0498-3162
A3R39	0498-0082		RIFXD NET FLN 444 OHM 1% 1/8W	28480	0498-0082
A3R40	0757-0276		RIFXD NET FLN 61.9 OHM 1% 1/8W	28480	0757-0276
A3R40			FACTORY SELECTED PART		
A3R41	0757-0442	1	RIFXD NET FLN 10.0K OHM 1% 1/8W	28480	0757-0442
A3R42	C498-3260		RIFXD NET FLN 444K OHM 1% 1/8W	28480	0498-3260
A3R43	C498-3457		RIFXD NET FLN 316K OHM 1% 1/8W	28480	0498-3457
A3R44	C498-3454		RIFXD NET FLN 215K OHM 1% 1/8W	28480	0498-3454
A3R45	0757-0445		RIFXD NET FLN 100K OHM 1% 1/8W	28480	0757-0445
A3R46	C498-0082	1	RIFXD NET FLN 444 OHM 1% 1/8W	28480	0498-0082
A3R47	0757-0199		RIFXD NET FLN 21.5K OHM 1% 1/8W	28480	0757-0199
A3R48	C498-0082		RIFXD NET FLN 444 OHM 1% 1/8W	28480	0498-0082
A3R49	0498-3444		RIFXD NET FLN 316 OHM 1% 1/8W	28480	0498-3444
A3R50	0757-0401		RIFXD NET FLN 100 OHM 1% 1/8W	28480	0757-0401
A3R51	0498-3458	1	RIFXD NET FLN 147 OHM 1% 1/8W	28480	0498-3458
A3R52	0498-3153		RIFXD NET FLN 3.03K OHM 1% 1/8W	28480	0498-3153
A3R53	0757-0442		RIFXD NET FLN 10.0K OHM 1% 1/8W	28480	0757-0442
A3R54	2100-1613		RIVAR COMP 2K OHM 20% 1/4W	28480	2100-1613
A3R55	0757-0441		RIFXD NET FLN 8.25K OHM 1% 1/8W	28480	0757-0441

See Introduction to this section for ordering information

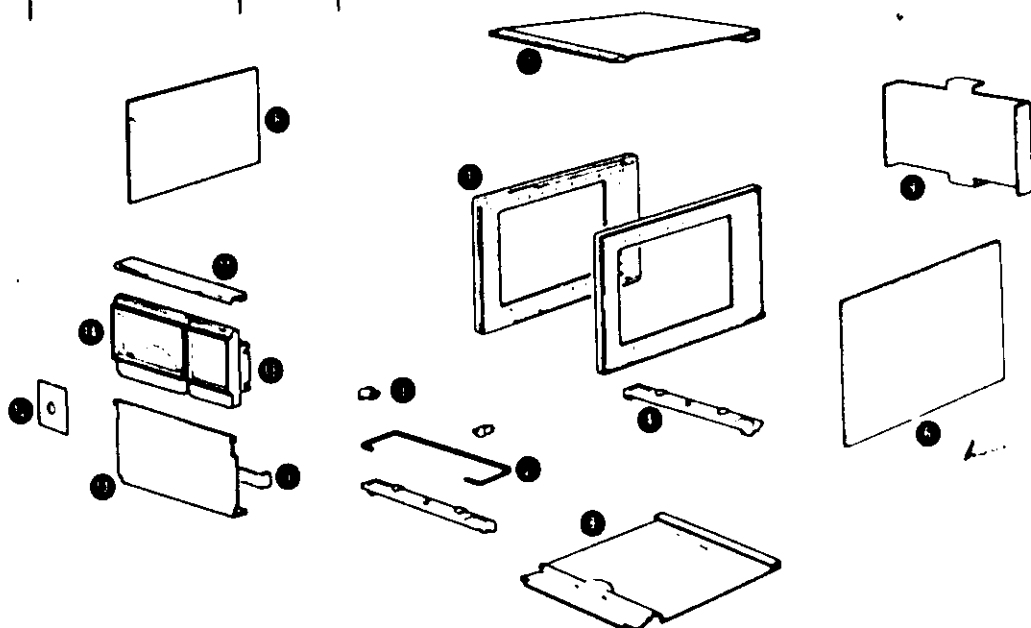
Table 6-2. Replaceable Parts

Reference Designation	HP Part Number	Qty	Description	Mfr Code	Mfr Part Number
A3R5	0698-3155	1	RIFXD MET FLN 4.64K OHM 1% 1/8W	28480	0698-3155
A3R57	2100-1612		RIVAR COMP 500 OHM 20% LIN 1/3W	28480	2100-1612
A3R58	0698-3153		RIFXD MET FLN 3.83K OHM 1% 1/8W	28480	0698-3153
A3R59	0757-0442		RIFXD MET FLN 10.0K OHM 1% 1/8W	28480	0757-0442
A3R60	0698-3160		RIFXD MET FLN 31.6K OHM 1% 1/8W	28480	0698-3160
A3R61	0757-0462	1	RIFXD MET FLN 75.0K OHM 1% 1/8W	28480	0757-0462
A4	00415-608	1	SWITCH ASSY:POWER	28480	00415-608
A4R1	0698-3161	1	RIFXD MET FLN 38.3K OHM 1% 1/8W	28480	0698-3161
A4R2	0698-3446	1	RIFXD MET FLN 383 OHM 1% 1/8W	28480	0698-3446
A4R3	0698-3156	1	RIFXD MET FLN 14.7K OHM 1% 1/8W	28480	0698-3156
A4R6	0757-0447	1	RIFXD MET FLN 16.2K OHM 1% 1/8W	28480	0757-0447
A4S1	3100-1807	1	SWITCH:ROTARY	28480	3100-1807
B			CHASSIS PARTS		
BT1	1420-0009	2	BATTERY:RECHARGEABLE 24V 1.25AH	28480	1420-0009
BT1			(OPTION 01 ONLY)		
C1	0150-0096	2	CIFXD CER 0.05 UF +80-20% 100VDCW	91418	TA
C2	0150-0096		CIFXD CER 0.05 UF +80-20% 100VDCW	91418	TA
C3	0150-0119	2	CIFXD CER 2 X 0.01 UF 20% 250MVAC	56289	56C219A2-CDH
C4	0150-0119		CIFXD CER 2 X 0.01 UF 20% 250MVAC	56289	56C219A2-CDH
DS1	1450-0491	1	LIGHT:INDICATOR, WHITE	28480	1450-0491
F1	2110-0011	1	FUSE:CARTRIDGE 3 AG 1/16 AMP 250V MAX	75915	312062
J1	1250-0118	3	CONNECTOR:BNC	24931	28JR 128-1
J2	1510-0006	1	BINDING POST ASSY:BLACK INSULATOR	28480	1510-0006
J2	1510-0007	1	BINDING POST ASSY:RED	28480	1510-0007
J2	0340-0086	1	INSULATOR:BP DOUBLE	28480	0340-0086
J2	0340-0090	1	INSULATOR:BINDING POST DOUBLE	28480	3340-0090
J3	1251-2357	1	SOCKET:3-PIN MALE POWER RECEPTACLE	82389	6AC-301
J4	1250-0118		CONNECTOR:BNC	24931	28JR 128-1
J5	1250-0118		CONNECTOR:BNC	24931	28JR 128-1
M1	1120-0392	1	METER	28480	1120-0392
R1	2100-1574	1	RIVAR COMP 250K 10% 20CHLOG 15K OHM20% PART OF R1	28480	2100-1574
R2			PART OF R1		
R3	2100-1578	1	RIVAR COMP 100K OHM 10% 20 CHWLOG 15W	28480	2100-1578
R4	2100-1577	1	RIVAR WM DUAL 1200 OHM 10% LIN TANDEM PART OF R4	28480	2100-1577
R5			PART OF R4		
R6	0757-0280	1	RIFXD MET FLN 1K OHM 1% 1/8W	28480	0757-0280
R7	0698-4037		RIFXD MET FLN 46.4 OHM 1% 1/8W	28480	0698-4037
R8			NOT ASSIGNED		
R60			NOT ASSIGNED		
A61	0757-0401		RIFXD MET FLN 100 OHM 1% 1/8W	28480	0757-0401
R62	0757-0401	1	RIFXD MET FLN 100 OHM 1% 1/8W	28480	0757-0401
S1	3101-1234		SWITCH:SLIDE DPDT	82389	11A-1242
T1	9100-0392		TRANSFORMER:POWER	28480	9100-0392
XA3	1251-0172		CONNECTOR:PRINTED CIRCUIT 22-CONN	28480	1251-0172
XF1	1400-0084		FUSEHOLDER:EXTRACTOR POST TYPE	75915	342014
	00415-606	1	MISCELLANEOUS BATTERY INSTALLATION KIT INCLUDES SAMPLE PARTS AS INSTALLED WITH OPTION 01 AND (4) 6-32 HEX NUTS FOR MOUNTING	28480	00415-606
	00415-003	1	DIAL ASSY:EXPAND	28480	00415-003
	0370-0062	1	KNOB:RED W/ARROW 3/4" OD 1/8" SHAFT	28480	0370-0062
	0370-0089	1	KNOB:ROUND BLACK 0.250" DIA SHAFT	28480	0370-0089
	0370-0112	1	KNOB:BLK BAR W/ARROW 1.00" DIA	28480	0370-0112
	0370-0106	1	KNOB	28480	0370-0106
	8120-1348	1	CABLE ASSY:POWER, DETACHABLE OPTIONS OPTION 01: BATTERY:RECHARGEABLE 24V 1.25AH COVER:BATTERY(OPT 01)	70903	RMS-7041
	1420-0009		BATTERY:RECHARGEABLE 24V 1.25AH	28480	1420-0009
	00415-006	1	COVER:BATTERY(OPT 01)	28480	00415-006
	2420-0001	1	NUT:HEX ST HP 6-32 X 5/16 W/LOCKWASHER NOTE: SEE MISC. SECTION FOR BATTERY INSTALLATION KIT STOCK NUMBERS	78189	0808
	00415-607	1	CABLE:SPECIAL PURPOSE ELECT(OPT 02)	28480	00415-607
	0340-0024	1	TERMINAL:SOLDER LUG 3/8" STUO	79963	508-W380
	1250-0001	1	CONNECTOR:IRF BNC BULKHEAD MOUNT JACK	28480	1250-0001
	2420-0001		NUT:HEX ST HP 6-32 X 5/16 W/LOCKWASHER	78189	0808
	3050-0100	1	WASHER:FLAT FOR #6 SCREW	00000	080
	3050-0018	2	WASHER:EXTRUDED FIBER	00000	080
	5040-0701	1	GAIN VERNIER FRAME	28480	5040-0701
	5101-0052	1	SWITCH:BIAS (SPECIAL M05)	28480	5101-0052
	5020-0705	1	METER TRIM (TOP RAIL)	28480	5020-0705
	1120-1514	1	METER (SPECIAL M05)	28480	1120-1514
	00415-007	1	BRACKET SHIELD FOR POWER SWITCH	28480	00415-007
	7120-2359	1	NAME PLATE SERIAL 1	28480	7120-2359

See Introduction to this section for ordering information

Table 6-2. Replaceable Parts

Reference Designation	HP Part Number	Qty	Description	Mfr Code	Mfr Part Number
			CABINET PARTS		
1	5060-0703	2	FRAME ASSY 16 X 11 SM	28480	5060-0703
2	1490-0032	1	STAND/TILT HALF-MODULE	28480	1490-0032
3	5040-0700	1	HINGE	28480	5040-0700
4	5060-0728	1	FOOT ASSY/HALF MODULE	28480	5060-0728
5	00415-005	1	PANEL BRACKET	28480	00415-005
6	2370-0015	2	SCREW/PH SLOT DR 6-32 X 0.375" LG	00000	080
7	5000-0703	2	SIDE COVER	28480	5000-0703
8	2370-0020	1	SCREW/35T FH PHIL DR 6-32 X 3/16	00000	080
9	5060-0720	1	COVER/HALF-RECESS TOP	28480	5060-0720
10	2370-0016	2	SCREW/FLAT HD PHIL DR 6-32 X 5/16" LG	00000	080
11	5000-0717	1	COVER/HALF-MODULE BOTTOM	28480	5000-0717
12	2370-0016	1	SCREW/FLAT HD PHIL DR 6-32 X 5/16" LG	00000	080
13	00415-00012	2	PANEL/REAR	28480	00415-00012
14	2370-0015	2	SCREW/PH SLOT DR 6-32 X 0.375" LG	00000	080
15	00415-002	1	PANEL/FRONT	28480	00415-002
16	2370-0002	1	SCREW/PH SLOT DR 6-32 X 0.375" LG	00000	080
17	5020-0705	1	METER TRIM: TOP RAIL	28480	5020-0705
18	00415-001	1	"GAIN VERNIER" PLATE	28480	00415-001
19	5040-0701	1	"GAIN VERNIER" PLATE TRIM BOX BLACK	28480	5040-0701
20	1170-0192	1	METER	28480	1170-0192



See Introduction to this section for ordering information

Table 6-3. Code List of Manufacturers

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.					
Code No.	Manufacturer	Address	Code No.	Manufacturer	Address
00000	U.S.A. Common . . .	Any Supplier of U.S.A.	56289	Sprague Electric Co.	N. Adams, Mass. 01247
01295	Texas Instruments Inc.		70903	Belden Corp. . . . .	Chicago, Ill. 60644
	Semiconductor Components		75915	Littlefuse Inc. . . . .	Des Plaines, Ill. 60016
	Division . . . . .	Dallas, Texas 75231	78189	Shakeproof Division	
04713	Motorola Semiconductor			Illinois Tool Works . . .	Elgin, Ill. 60120
	Products Inc. . . . .	Phoenix, Ariz. 85008	79963	Zierick Mfg. Co. . . .	Mt. Kisco, N.Y. 10549
07263	Fairchild Camera and		82389	Switchcraft Inc. . . . .	Chicago, Ill. 60630
	Instrument Corp., Semiconductor		84411	TRW Capacitor Div. . .	Ogallala, Neb. 69153
	Division . . . . .	Mountain View, Cal. 94040	91418	Radio Material Co. . . .	Chicago, Ill. 60646
24931	Specialty Connector		93332	Sylvania Electric Products	
	Co., Inc. . . . .	Indianapolis, Ind. 46227		Inc., Semicodncutor	
28480	Hewlett-Packard Co. .	Palo Alto, Cal. 94304		Division . . . . .	Woburn, Mass. 01801

# OPTIONS

## APPENDIX I

### OPTION 01, 001, 02 AND 002

The 415E-Option 01, 001 instrument consists of a standard Model 415E SWR Meter with a battery installed allowing either AC Line- or portable-operation of the instrument. The 415E Option 02, 002 instrument consists of a standard Model 415E SWR Meter with a rear panel INPUT connector installed and wired in parallel with the front panel connector. Either INPUT connector may be used at any one time. A Model 415E which is designated as 415E-Option 01-02 or Option 001-002 is merely an instrument with both the rear panel connector and the internal battery installed. Paragraph 3-6 explains operation of the instrument with a battery installed.

A list of component parts required for/or included with installation in your instrument is included in Table 6-2 of this manual. Instructions for installation or removal of either or both of these instrument options are given below.

#### INSTALLATION PROCEDURE

##### 1. Option 01, 001

- a. Set POWER switch to OFF and remove power plug from 415E.

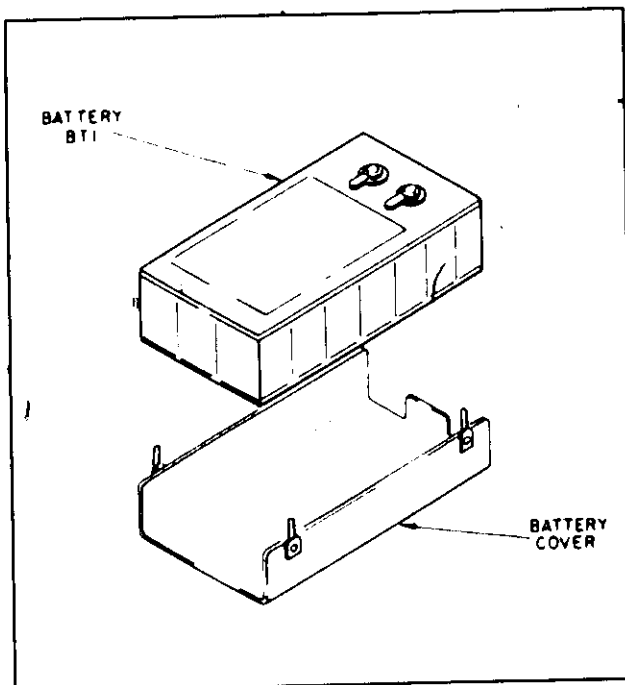


Figure I-1 Battery Cover Assembly

- b. Remove top and bottom instrument covers.

- c. Refer to Figure I-1 which shows the cover and battery disassembled and install from bottom of instrument into the top deck.

#### NOTE

The battery should be installed so that the two battery terminals are toward the top and front of the instrument.

- d. Using the four retaining nuts, fasten the battery cover tightly in place.

#### CAUTION

Do not short battery terminals at any time as this may cause battery cell damage.

- e. Using a low-heat soldering iron (see Table 5-3), solder a red lead wire (No. 22 gauge, stranded) between the plus battery terminal and the circuit board socket terminal marked BATT +.

- f. Solder a black lead wire (No. 22, stranded) between the negative battery terminal and the circuit board socket terminal marked BATT -.

- g. Removal is the reverse of installation.

##### 2. Option 02, 002

- a. Refer to Figure I-2 which shows the proper assembly of the rear panel connector and cable assembly.

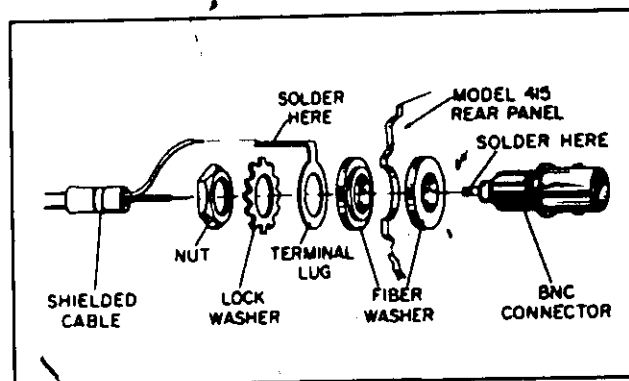


Figure I-2. Connector Assembly

b. The shielded cable ground for the rear panel connector must be connected to the front panel INPUT ground to minimize noise pickup and signal reference problems.

c. The center conductor must be connected to RANGE-DB switch, A1S1, at the same point as the green wire leading to the front panel BNC input connector.

### MAINTENANCE OF THE RECHARGEABLE NICKEL CADMIUM BATTERY

The maintenance of the rechargeable Nickel Cadmium battery poses two problems, both of which pertain to recharging the battery.

The first problem concerns damage to the battery because of improper maintenance. Damage during operation and storage will reduce the number of charging cycles and therefore the life of the battery.

The second problem concerns that of thermal runaway. As the Nickel Cadmium battery heats due to the charging current, the battery terminal voltage drops. The charging current will then increase if the recharging circuit consists of a constant voltage source. This thermal runaway will result in destruction of the battery. This problem, however, is alleviated in Hewlett-Packard instruments because a constant current source provides battery recharge.

Maintenance of the Nickel Cadmium battery can be summarized with several *do not's*.

1. *Do not* allow the battery to discharge below 6 volts per 5 cell battery (1.2 volts per cell). This will prevent reverse charging of one or more cells.

2. *Do not* fast charge for periods exceeding 75 hours because excessive heat generated may shorten battery life. Typical charging rates are a trickle charge of 4 mA to 7 mA and a fast charge rate of 16 mA to 18 mA, where applicable. The battery may be charged at a trickle rate indefinitely.

3. *Do not* charge the batteries in an environment with temperatures above 90°F (35°C) or below 32°F (0°C). Whenever possible charge the battery at moderate temperatures (70°F ±10°F, 21°C ±5.6°C). Operation of the battery in the same moderate temperatures as for battery charging will provide maximum performance.

4. *Do not* store the battery at temperatures above 122°F (50°C) or below -4°F (-20°C). Prolonged storage (90 days under ideal conditions) may require three to five charge-discharge cycles to reach full capacity.

5. *Do not* short-circuit the battery because the exceedingly low internal resistance will allow discharge at extremely high current levels. This will result in battery damage.



# **BACK DATING MANUAL CHANGES**

## APPENDIX II MANUAL CHANGES

To adapt this manual to instruments with Serial Numbers listed in the table below, make the indicated manual changes.

Information for adapting this manual to instruments with Serial Numbers not listed in the table below may be included in a yellow MANUAL CHANGES insert supplied with this manual. Information about Serial Numbers not covered in any of these ways can be obtained from the nearest Hewlett-Packard, office.

Serial Prefix or Number	Make Manual Changes	Serial Prefix or Number	Make Manual Changes
719-	1		
545-	1, 2		
530-	1, 2, 3		

### CHANGE 1

Table 6-2:

Change DS1 to HP Part No. 1450-0048; 1; Lamp: neon; 28480; 1450-0048.

Change J3 to HP Part No. 1251-0148; 1; Connector: power 3-pin male; 82389; 606-3.

Change S1 to HP Part No. 3101-0033; 1; Switch: slid DPDT; 82389; 11A-1242.

Change power cable (miscellaneous parts) to HP Part No. 8120-0078; 1; cable: power 7.5 ft; 70903; KHS-7041

### CHANGE 2

Table 6-2

Change A3C1 to HP Part No. 0160-0174; C fxd cer 0.47  $\mu$ F +80% 20% 25 Vdcw; 56289; 5C11B7S-CML.

Change A3R22 to HP Part No. 0698-3260; R: fxd met flm 464K ohm 1% 1/8W; 28480; 0698-3260.

### CHANGE 3

Page 5-21, Figure 5-9

Replace with Figure II-1

Page 5-21, Figure 5-10

Change A3R6 nominal value to 215 ohms

Page 5-23, Figure 5-11

Change A3R33 and A3R34 nominal values to 15.4K ohms.

Change A3R21 nominal value to 316 ohms.

Table 6-2

Change A3R6 to HP Part No. 0698-3441; R: fxd met flm 215 ohms 1% 1/8W; 28480; 0698-3441.

Change A3R21 to HP Part No. 0698-3444; R: fxd met flm 316 ohm 1% 1/8W; 28480; 0698-3444.

Change A3R33 and A3R34 to HP Part No. 0698-3540; R: fxd met flm 15.4K ohm; 28480; 0698-3540.

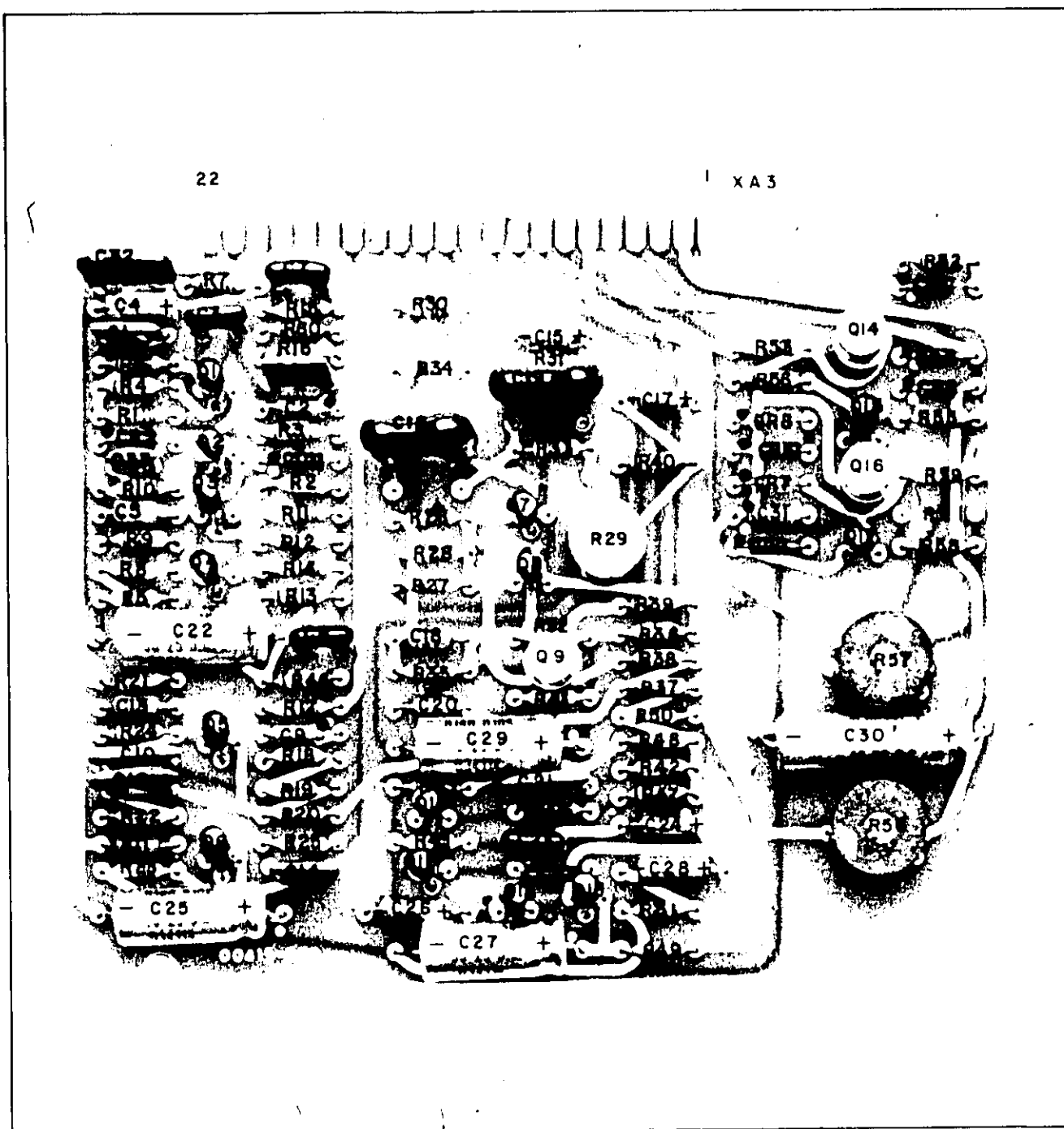


Figure II-1 A3 Circuit Board Component Locations for Instruments with Serials Prefixed 530

# **MANUAL SUPPLEMENT**

# MANUAL CHANGES

## MANUAL IDENTIFICATION

Model Number: 415E  
Date Printed: July 1971  
Part Number: 00415-90009

This supplement contains important information for correcting manual errors and for adapting the manual to instruments containing improvements made after the printing of the manual.

To use this supplement:

Make all ERRATA corrections

Make all appropriate serial number related changes indicated in the tables below.

Serial Prefix or Number	Make Manual Changes	Serial Prefix or Number	Make Manual Changes
1143A	1		

► NEW ITEM

## ERRATA

Page 6-5, Table 6-2:

Change DS1 to HP Part No. 1450-0-119 (description remains the same).

► Delete T1 and add the following:

T1 9100-0392 TRANSFORMER INPUT 28480 9100-0392

T2 9100-0393 TRANSFORMER: POWER 28480 9100-0393

Back Cover

Delete Microfiche number. (Correct microfiche number will be found on title page.)

## CHANGE 1

Page 6-6, Table 6-2:

Add the following note to Replaceable Parts as an aid in explaining the 415E color scheme.

### NOTE

This change implements a different color scheme for the standard instrument. Colors prior to this change are now available as options. Refer to the listing below.

415E STANDARD - Indicates color scheme for the 415E beginning with this change. (Includes MINT GRAY front panel and OLIVE GRAY cabinet.)

415E OPTION A85 - Indicates LIGHT GRAY front panel.

415E OPTION X95 - Indicates color scheme for the 415E prior to this change. (Includes LIGHT GRAY front panel and BLUE GRAY cabinet.)

### NOTE

Manual change supplements are revised as often as necessary to keep manuals as current and accurate as possible. Hewlett-Packard recommends that you periodically request the latest edition of this supplement. Free copies are available from all HP offices. When requesting copies quote the manual identification information from your supplement, or the model number and print date from the title page of the manual.

February 20, 1973

HEWLETT  PACKARD

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**CHANGE 1 (cont'd)**

Change HP Part No. 5000-0703 to:

HP Part No. 5000-8565 SIDE COVER (OLIVE GRAY) (STANDARD)

HP Part No. 5000-0703 SIDE COVER (BLUE GRAY) (OPTION X95)

Change HP Part No. 5060-0720 to:

HP Part No. 5060-8577 COVER:TOP (OLIVE GRAY) (STANDARD)

HP Part No. 5060-0720 COVER:TOP (BLUE GRAY) (OPTION X95)

Change HP Part No. 5000-0717 to:

HP Part No. 5000-8583 COVER:BOTTOM (OLIVE GRAY) (STANDARD)

HP Part No. 5000-0717 COVER:BOTTOM (BLUE GRAY) (OPTION X95)

Change HP Part No. 00415-002 to:

HP Part No. 00415-00013 PANEL:FRONT (MINT GRAY) (STANDARD)

HP Part No. 00415-002 PANEL:FRONT (LIGHT GRAY) (OPTION A85, X95)

Change HP Part No. 5020-0705 to:

HP Part No. 5020-7634 TRIM:METER (MINT GRAY) (STANDARD)

HP Part No. 5020-0705 TRIM:METER (LIGHT GRAY) (OPTION A85, X95)

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**CYPRUS**  
Kyprounics  
19 Gregorios & Ktenopoulos Road  
P.O. Box 1152  
Nicosia  
Tel: 45628/29  
Cable: Kyprounics Paphos

**ETHIOPIA**  
African Salespower & Agency  
Private Ltd., Co  
P.O. Box 718  
18, 55 Cunningham St  
Addis Ababa  
Tel: 12785  
Cable: ASACO Addis Ababa

**HONG KONG**  
Schmidt & Co. (Hong Kong) Ltd  
P.O. Box 297  
151 Prince's Building 151N Prince  
10, Chater Road  
Hong Kong  
Tel: 240188 232/35  
Cable: SCHMIDTCO Hong Kong

**INDIA**  
Blue Star Ltd  
Kasturji Buildings  
Janshedji Tata Rd  
Bombay 208R, India  
Tel: 29 50 21  
Telex: 3751  
Cable: BLUESTAR

Blue Star Ltd  
Band Box House  
Prashaddevi  
Bombay 250D India  
Tel: 45 73 01  
Telex: 3751  
Cable: BLUESTAR

Blue Star Ltd  
14, 40 Civil Lines  
Kanpur, India  
Tel: 6 84 82  
Cable: BLUESTAR

Blue Star Ltd  
7 Mare Street  
P.O. Box 506  
Calcutta 1 India  
Tel: 23-0131  
Telex: 655  
Cable: BLUESTAR

Blue Star Ltd  
Blue Star House  
34 Ring Road  
Lagat Nagar  
New Delhi 24 India  
Tel: 62 32 76  
Telex: 483  
Cable: BLUESTAR

Blue Star Ltd  
11 117 1  
Sarojini Devi Road  
Secunderabad 1  
Tel: 7 83 91 7 73 91  
Cable: BLUEFROST

Blue Star Ltd  
23 24 Second Line Beach  
Madras 1 India  
Tel: 2 39 55  
Telex: 3751  
Cable: BLUESTAR

Blue Star Ltd  
18 Kaiser Bungalow  
Dindli Road  
Jamshedpur India  
Tel: 38 04  
Cable: BLUESTAR

**INDONESIA**  
Bali Balam Trading Coy N.V.  
Dalah Merdeka 29  
Bandung  
Tel: 4915 51540  
Cable: ILMU  
Telex: 38 609

**IRAN**  
Multicomp International Ltd  
Avakhor Soraja 130  
P.O. Box 1212  
Tehran  
Tel: 61 10 35 39  
Cable: MULTICOMP Tehran  
Telex: 2891 mcl tr

**ISRAEL**  
Electronics & Engineering  
Div. of Motorola Israel Ltd  
17 Amnador Street  
Tel-Aviv  
Tel: 36841 (3 lines)  
Cable: BASTEL Tel-Aviv  
Cable: MOTIL IL

**JAPAN**  
Yokogawa-Hewlett-Packard Ltd  
Ohsaki Building  
1-59-1 Yoyogi  
Shibuya-Ku, Tokyo  
Tel: 03-370-2281 92  
Telex: 232 2024RHP  
Cable: YHPMARKET JON 21 724

Yokogawa-Hewlett-Packard Ltd  
Nishi Ibaragi Bldg  
2-8 Kasuga  
Ibaragi Shi  
Osaka  
Tel: 0726 23-1641  
Telex: 5312 385 YHP OSARA  
Yokogawa-Hewlett-Packard Ltd  
110 Building  
No. 59, Kotoricho  
Kamakura-Ku, Kanagawa City  
Tel: 052 551 0215

Yokogawa-Hewlett-Packard Ltd  
Nitto Bldg  
2-4-2 Shinohara Kita  
Kobaku Ku  
Yokohama 222  
Tel: 045-432 1504  
Telex: 182 1204 YHP YOK

Yokogawa-Hewlett-Packard Ltd  
Lhuo Bldg  
Rm 403 3  
J-Chome  
JUMI CHU  
Nito 310  
Tel: 0292 25 7470

**KENYA**  
Kenya Kinetics  
P.O. Box 1831  
Nairobi, Kenya  
Tel: 57726  
Cable: PROION

**KOREA**  
Amtron Corporation  
Industrial Products Div  
Seoul P.O. Box 1103  
8th Floor, Gokkyung Bldg  
107 Seong Ro  
Chongro-Ku, Seoul  
Tel: 19 4924 7  
Cable: AMTRACIO Seoul

**LEBANON**  
Cometant E. Macridis  
P.O. Box 7213  
Beirut  
Tel: 220846  
Cable: ELECTRONUCLEAR Beirut

**MALAYSIA**  
MECOMB Malaysia Ltd  
2 Lorong 11 SA  
Section 13  
Petaling Jaya, Selangor  
Cable: MECOMB Kuala Lumpur

**MOZAMBIQUE**  
A. N. Conceicao, LDA  
41 Apt. 14 Av. D. Luis  
P.O. Box 107  
Laurance Marques  
Cable: MECOM

**NEW ZEALAND**  
Hewlett-Packard N.Z. Ltd  
94-96 Dixon St  
P.O. Box 9443  
Courtenay Place  
Wellington, N.Z.  
Tel: 56-559  
Cable: NEWPAK Wellington

Hewlett-Packard N.Z. Ltd  
Box 51092  
Pukaranga  
Tel: 56 9837  
Cable: NEWPAK Auckland

**PAKISTAN**  
Mushko & Company Ltd  
Osman Chambers  
Abdullah Haroon Road  
Karachi 3  
Tel: 511022 512927  
Cable: COOPERATOR Karachi

Mushko & Company Ltd  
186 Salehite Town  
Rawalpindi  
Tel: 41924  
Cable: FEMUS Rawalpindi

**PHILIPPINES**  
Electronics Inc.  
5th Floor, Architekt  
Center Bldg  
Ayala Ave. Manila Rizal  
P.O. Box 1028  
Manila, Rizal  
Tel: 16 18 87 87 76 77  
Cable: ELEMER Manila

**SINGAPORE**  
Mechanical and Combustion  
Engineering Company Ltd  
9, Javan Kilang  
Mad Hill Industrial Estate  
Singapore, 3  
Tel: 642661 3 53261  
Cable: MECOMB Singapore

Hewlett-Packard Far East  
Area Office  
P.O. Box 87  
Raffles Post Office  
Singapore 3  
Tel: 533022  
Cable: NEWPAK SINGAPORE

**SOUTH AFRICA**  
Hewlett-Packard South Africa  
(Pty.), Ltd.  
P.O. Box 31716  
Braamfontein Transvaal  
Milverton  
50 De Beer Street  
Johannesburg  
Tel: 725 2080 725 2030  
Telex: 0226 JM  
Cable: NEWPAK Johannesburg

Hewlett-Packard South Africa  
(Pty.), Ltd.  
Greenacre House  
Dore Street  
Cape Town  
Tel: 1 6013, 1 6545  
Cable: NEWPAK Cape Town  
Telex: 5 0006

Hewlett-Packard South Africa  
(Pty.), Ltd.  
641 Ridge Road Durban  
P.O. Box 98  
Durban, Natal  
Tel: 86 8102  
Tel: 86 7954  
Cable: NEWPAK

Hewlett-Packard South Africa  
(Pty.), Ltd.  
641 Ridge Road Durban  
P.O. Box 98  
Durban, Natal  
Tel: 86 8102  
Tel: 86 7954  
Cable: NEWPAK

**TAIWAN**  
Hewlett-Packard Taiwan  
39 Chung Shiao West Road  
Sec. 1  
Overseas Insurance  
Corp. Bldg. 7th Floor  
Taipei  
Tel: 189160 1 2 375121  
Tel: 240 249  
Telex: 19824 NEWPAK  
Cable: NEWPAK Taipei

**THAILAND**  
UNIMESA Co. Ltd.  
Chongkuee Building  
36 Surawongse Road  
Bangkok  
Tel: 37956 31100 31307  
37540  
Cable: UNIMESA Bangkok

**UGANDA**  
Uganda Tele Electric Co. Ltd  
P.O. Box 4448  
Kampala  
Tel: 57279  
Cable: COMCO Kampala

**VIETNAM**  
Pacinaur Trading Inc.  
P.O. Box M-1  
216 Hien Young  
Saigon  
Tel: 70 805 93398  
Cable: PENTRA SAIGON 242

**ZAMBIA**  
E. I. Hlubry Zambia Ltd  
P.O. Box 2792  
Lusaka  
Zambia Central Africa  
Tel: 77975  
Cable: ARIATYET Lusaka

**MEDITERRANEAN AND MIDDLE EAST COUNTRIES NOT SHOWN PLEASE CONTACT:**  
Hewlett-Packard  
Coordination Office for  
Mediterranean and Middle  
East Operations  
Via Marconi 7  
I-00144 Rome Eur Italy  
Tel: 6 59 40 29  
Cable: NEWPAKIT Rome  
Telex: 61514

**OTHER AREAS NOT LISTED, CONTACT:**  
Hewlett-Packard  
INTERCONTINENTAL  
1200 N. Vineyard Ave.  
Palo Alto, California 94304  
Tel: 415-329 7000  
Fax: 415-329 1501  
TWX: 910-173-1267  
Cable: NEWPAK Palo Alto  
Telex: 034-8300 034-8493

**END**