Errata

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

Manual Part Number: **00415-90009**

Revision Date: **July 1971**

About this Manual

We've added this manual to the Agilent website in an effort to help you support your product. This manual provides the best information we could find. It may be incomplete or contain dated information, and the scan quality may not be ideal. If we find a better copy in the future, we will add it to the Agilent website.

HP References in this Manual

This manual may contain references to HP or Hewlett-Packard. Please note that Hewlett-Packard's former test and measurement, life sciences, and chemical analysis businesses are now part of Agilent Technologies. The HP XXXX referred to in this document is now the Agilent XXXX. For example, model number HP8648A is now model number Agilent 8648A. We have made no changes to this manual copy.

Support for Your Product

Agilent no longer sells or supports this product. You will find any other available product information on the Agilent Test & Measurement website:

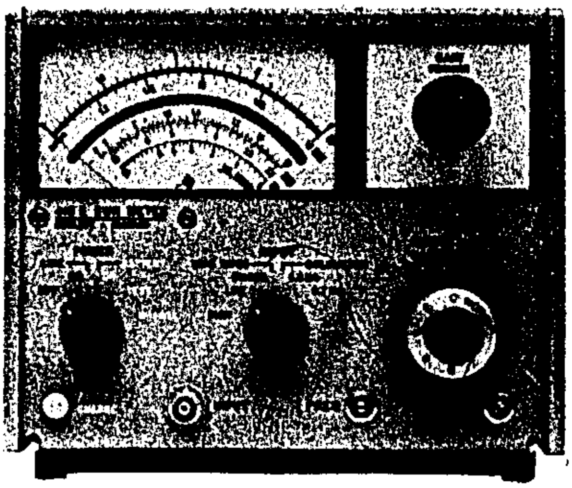
www.agilent.com

Search for the model number of this product, and the resulting product page will guide you to any available information. Our service centers may be able to perform calibration if no repair parts are needed, but no other support from Agilent is available.

OPERATING AND SERVICE MANUAL

SWR METER

415E



HEWLETT hp PACKARD

HP 415E

CERTIFICATION

The Hewlett-Packard Company certifies that this instrument was thoroughly tested and inspected and found to meet its published specifications when it was shipped from the factory. The Hewlett-Packard Company further certifies that its calibration measurements are traceable to the U.S. National Bureau of Standards to the extent allowed by the Bureau's calibration facility.

WARRANTY AND ASSISTANCE

All Hewlett-Packard products are warranted against defects in materials and workmanship. This warranty applies for one year from the date of delivery, or, in the case of certain major components listed in the operating manual, for the specified period. We will repair or replace products which prove to be defective during the warranty period provided they are returned to Hewlett-Packard. No other warranty is expressed or implied. We are not liable for consequential damages.

Service contracts or customer assistance agreements are available for Hewlett-Packard products that require maintenance and repair on-site.

For any assistance, contact your nearest Hewlett-Packard Sales and Service Office. Addresses are provided at the back of this manual.

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 Appendices I and II.

Manual Part No. 00415-90009
Microfiche Part No. 00415-90015

Printed: July 1971

HEWLETT PACKARD

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

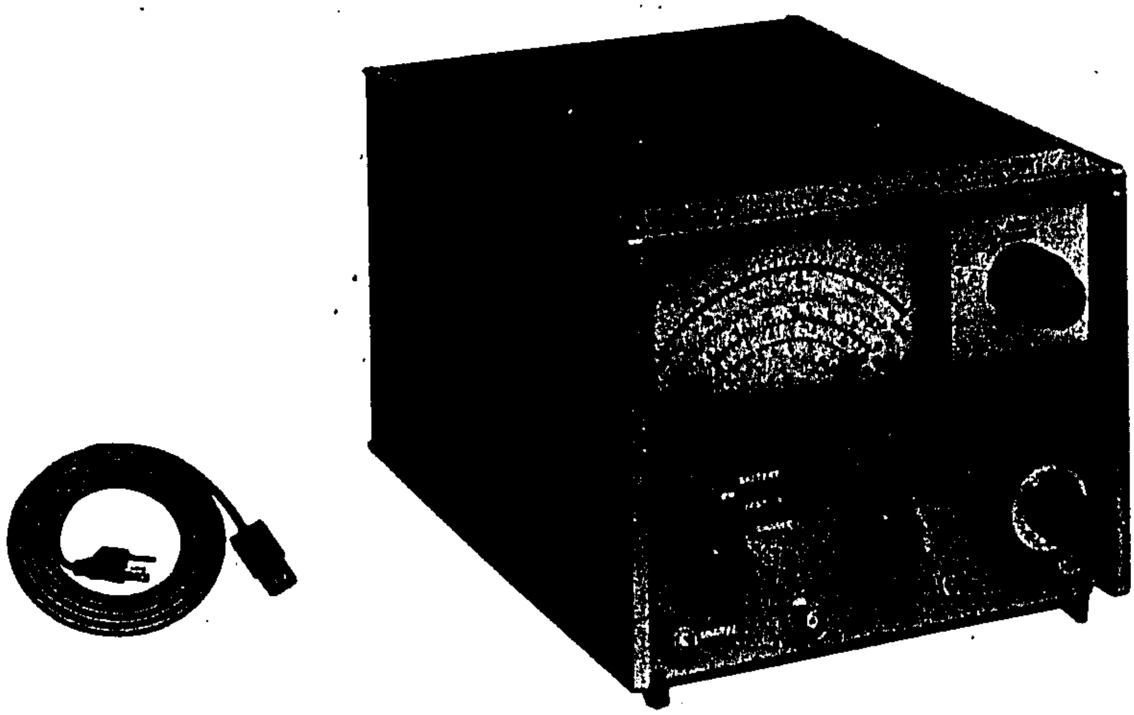


Figure 1-1. Model 415E SWR Meter

Table 1-1. Specifications

Sensitivity: 0.15 μVrms for full-scale deflection at maximum bandwidth (1 μVrms 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: ±0.05 dB/10-dB step; maximum cumulative error between any two 10-dB steps, ±0.10 dB; maximum cumulative error between any two 2-dB steps, ±0.05 dB. Linearity: ±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 ±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 ±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 reciept, 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°C. Allow the instrument to warm up to at least 0°C before attempting operation. This instrument will operate in any humidity up to 95% at +40°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 temperaure 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.

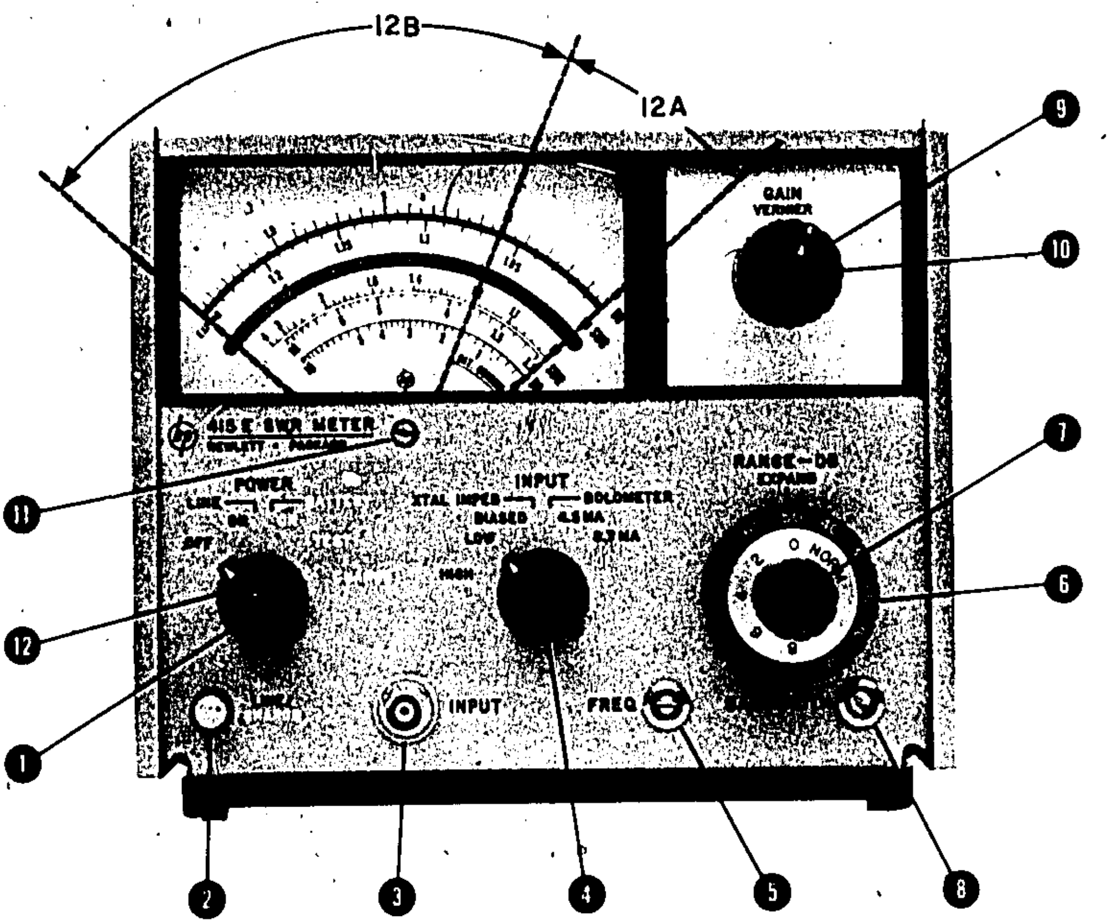
b. If ground loops occur, minimize them by changing all possible ground leads for the least beating in the measurement indication.

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

FRONT PANEL



1. POWER. Selects desired 415E power source. BATTERY/CHARGE position allows internal battery recharge when power cord is connected to AC line.

2. LINE/CHARGE. Indicator lights when power is in LINE/ON or BATTERY/CHARGE position.

3. INPUT. Female BNC INPUT connector.

4. INPUT. Set input of 415E either to XTAL IMPED or BOLOMETER. If set to XTAL IMPED select either HIGH or LOW impedance for unbiased crystals or BIASED for crystals that require bias.

5. FREQ. Adjustment allows center frequency total variation of 70 Hz. If range is not great enough, refer to Changing Operating Frequency in Section V.

6. RANGE-DB. Gain control adjustable in 10-dB steps.

7. EXPAND (NORMAL). Offset switch which permits full-scale expansion of any 2 dB sector of unexpanded meter reading. Set to figure corresponding to lowest dB reading of the expanded sector desired as read on the lower dB scale. When expanded, read value on upper dB scale and add number of dB on EXPAND dial to reading.

8. BANDWIDTH. Allows adjustment of bandwidth from 15 to 130 Hz.

9. GAIN. Allows initial meter reference setting with a control range of at least 10 dB.

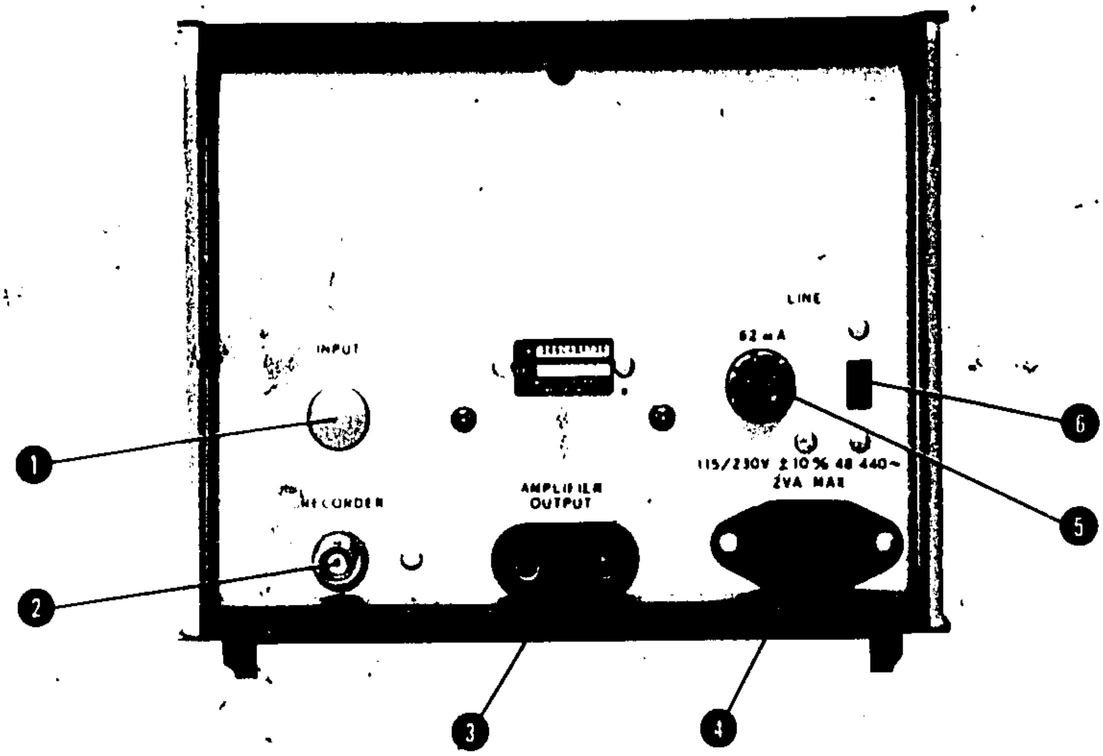
10. VERNIER. Provides fine adjustment of GAIN control meter settings.

11. Mechanical zero adjustment allows exact setting of meter needle to 2 dB on the upper dB (EXPAND) scale.

12. BAT CHARGED. With POWER switch set to BATTERY/TEST, a meter needle indication within the BATTERY CHARGE area on the meter face (indicated by 12A) shows that internal battery is charged sufficiently for proper instrument operation. (Option 01, 001 only.)

Figure 3-1. Front Panel Features

REAR PANEL



1. INPUT. Additional input connector (wired in parallel with front panel connector) Supplied as Option 02, 002 for 415E, only upon request.

2. RECORDER. Rear panel recorder output furnishes an output from 0 to 1 volt dc with internal resistance of 1000 ohms and provides a convenient means of obtaining a permanent record of measured data. Any recorder with an impedance of 1000 ohms or greater may be used. Recorders with lower than 1000 ohms impedance will load down the output giving a lower than true reading. For proper operation, the recorder output ground (BNC shell) must be connected to a floating ground.

3. AMPLIFIER OUTPUT. The rear-panel amplifier output furnishes an output for 0 to 0.8 volt rms into an impedance of 10K ohms or greater. The Model 415E will supply up to 126 dB of voltage gain. For proper operation, the ground terminal (black) must be connected to a floating ground. With the EXPAND switch set to NORM, a full-scale meter reading will result in a 0.3 volt rms output signal, and a minimum scale reading (10 dB) will result in approximately 0.02 Vrms. With the EXPAND switch set to any position except NORM, a full-scale meter reading results in a 0.8 volt rms output and a minimum scale reading (2 dB) results in a 0.5 volt rms output signal. A zero input signal results in a 0 volt output signal.

4. LINE. Three-conductor ac power cord receptacle.

5. FUSE. Contains power line fuse (1/16 amp).

6. 1/16A. Slide switch to allow 115- or 230-volt ac operation.

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 since 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.

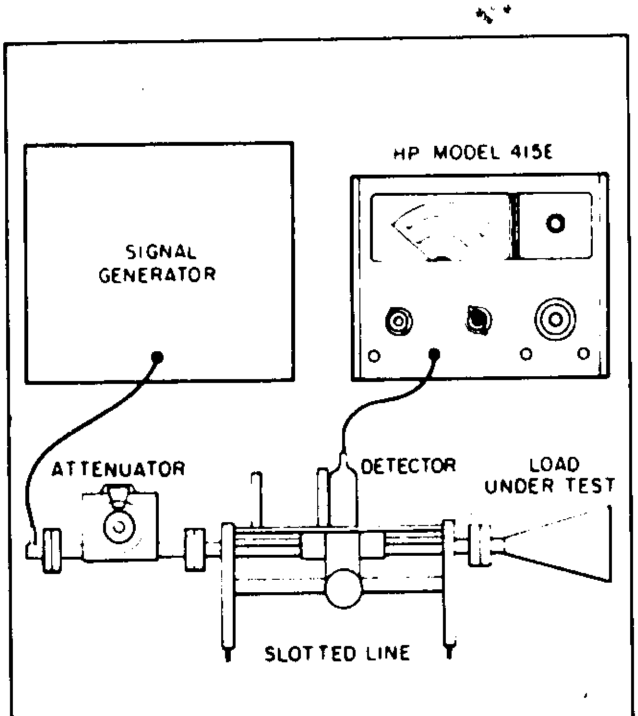


Figure 3-3. Typical SWR Measurement Setup

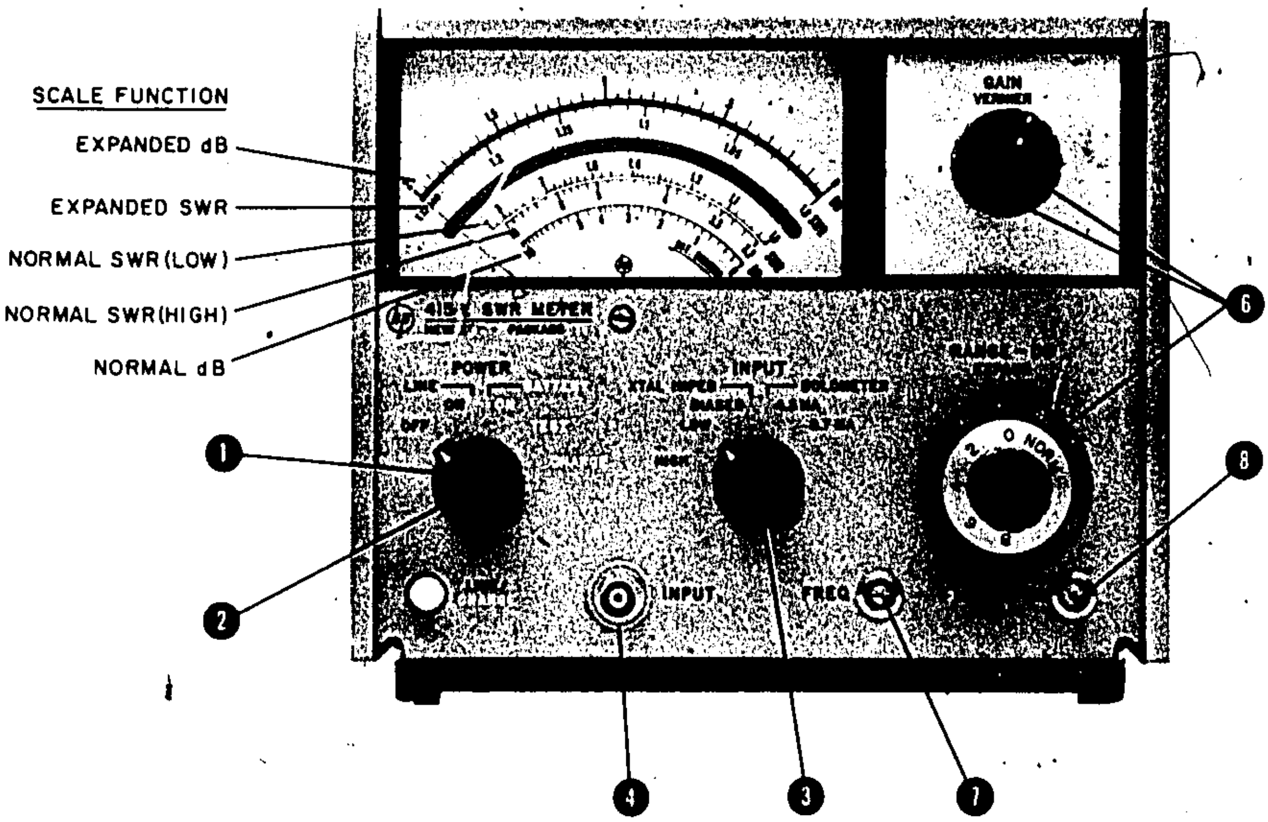
3-22. GENERAL TURN-ON PROCEDURE

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.

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.

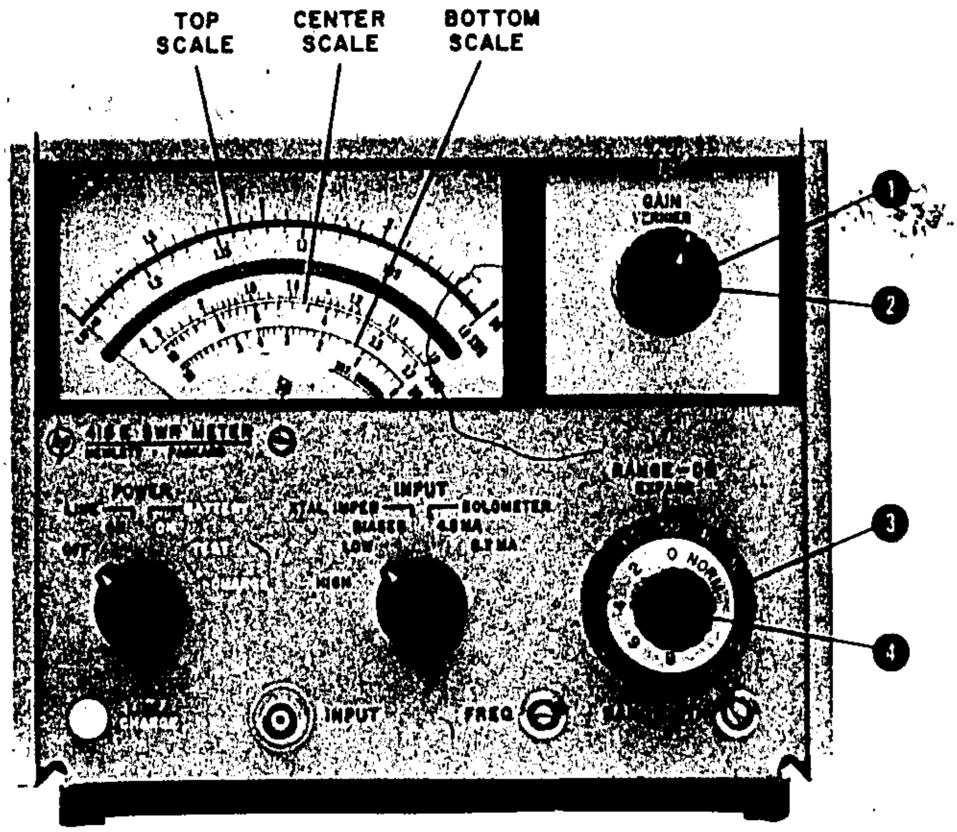
8. Adjust BANDWIDTH control: fully counterclockwise rotation is minimum bandwidth and fully clockwise rotation is maximum bandwidth.

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

MEASURING SWR



1. Set EXPAND switch ❹ TO NORM.

2. Adjust slotted-line carriage for a maximum (to the right) SWR Meter deflection. Change RANGE-DB switch ❸ and GAIN controls ❶, ❷, if necessary, to maintain an on-scale meter indication.

3. Adjust GAIN VERNIER control ❷ for a SWR Meter indication of 1 (upper numerals on center scale).

4. Adjust slotted-line carriage for a minimum (to the left) SWR Meter deflection.

a. For SWR between 1.25 and 3.2 read upper numerals on center scale.

b. For greater resolution of SWR less than 1.25,

(1) Set NORMAL-EXPAND switch ❹ to 0 dB.

(2) Adjust slotted-line carriage for a maximum meter indication. Adjust GAIN VERNIER control ❷ for a SWR Meter indication of 1.

(3) Adjust slotted-line carriage for a minimum (to the left) meter deflection. Read SWR on lower numerals of top scale.

c. For SWR greater than 3.2 (meter indication to left or off scale),

(1) Rotate RANGE-DB switch ❸ one position clockwise and read bottom numerals on center scale.

(2) If SWR indication is greater than 10:1 (meter indication off scale to left) rotate RANGE-DB switch ❸ one more position clockwise, read upper numerals on center scale, and multiply reading by ten.

[illegible] If meter indication is still off scale to the left, rotate RANGE-DB switch ❹ one more position clockwise and read lower numerals on center scale (SWR 32 to 100).

Figure 3-5. Measuring SWR

3-26. 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 reponse 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 (ΔX) 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 λ_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 (ΔX) 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 singal 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

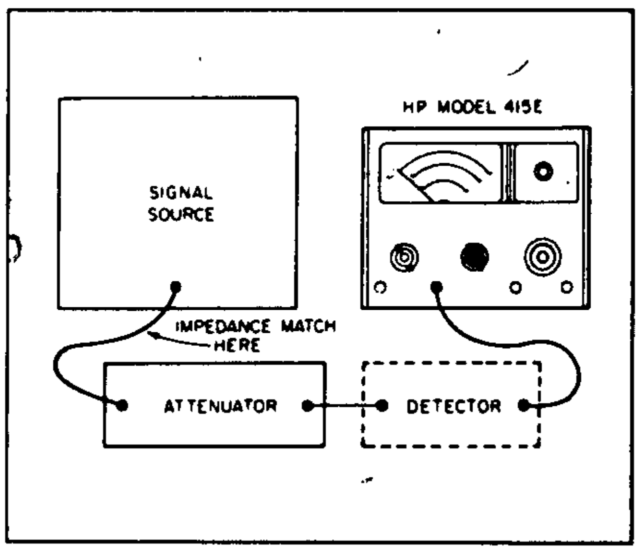
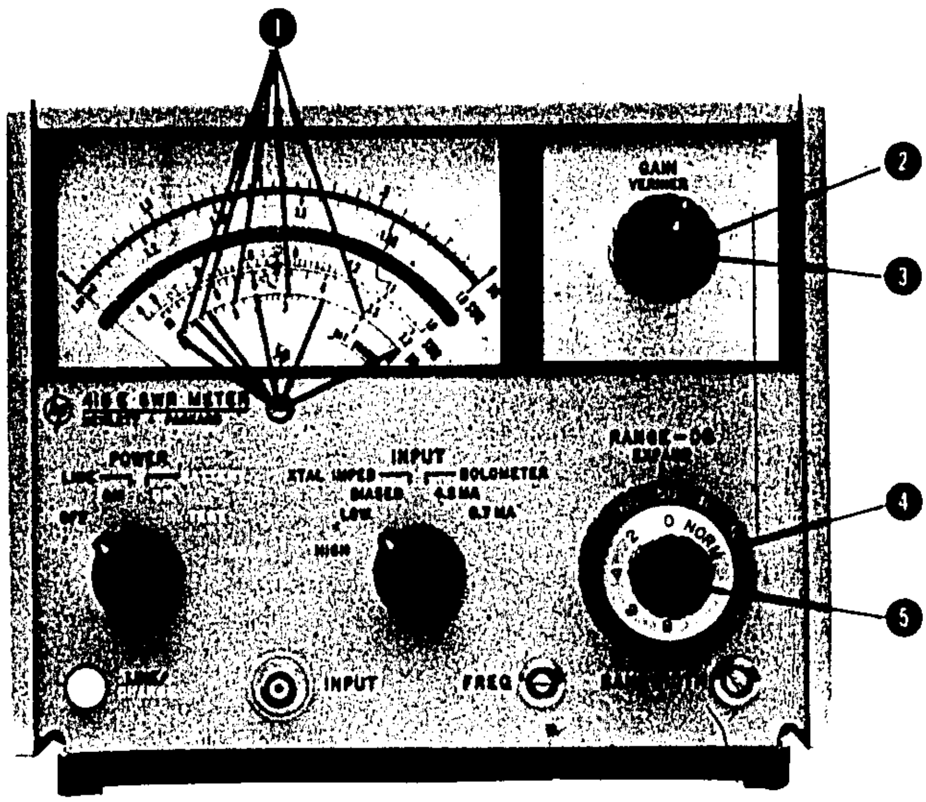


Figure 3-6. Attenuation Measurement Setup

MEASURING POWER



The Model 415E will measure only relative power, not absolute power, since the gain of the 415E is adjustable. To measure gain or loss refer to Figures 3-3 and 3-4 and then proceed as follows.

1. Set EXPAND switch (5) to NORM.

2. With the detector (see Figure 3-6) connected directly to the signal source, set meter indication to a reference reading on the bottom scale by means of the GAIN controls (2), (3).

3. Connect the device to be tested between the signal source and the detector and read meter indication. Do *Not* touch GAIN controls (2), (3). If the meter needle is off-scale, rotate RANGE-DB switch (4) until meter needle comes on-scale.

4. Add, algebraically, the difference between the two readings and the difference between the two RANGE-DB switch (4) settings. This sum is the gain or loss of the measurement.

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.

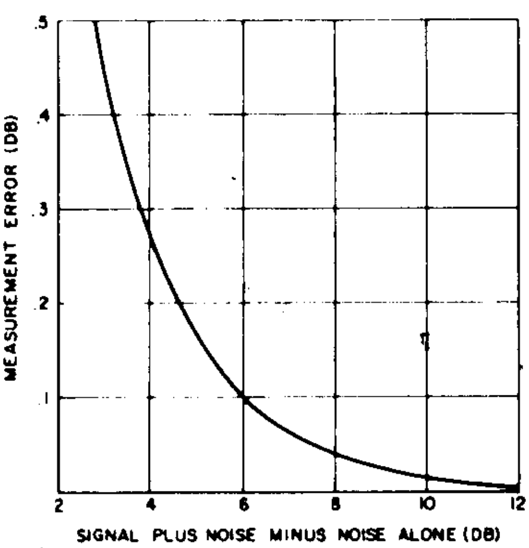


Figure 3-8. Meter Noise Correction Curve

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 μVrms 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.)

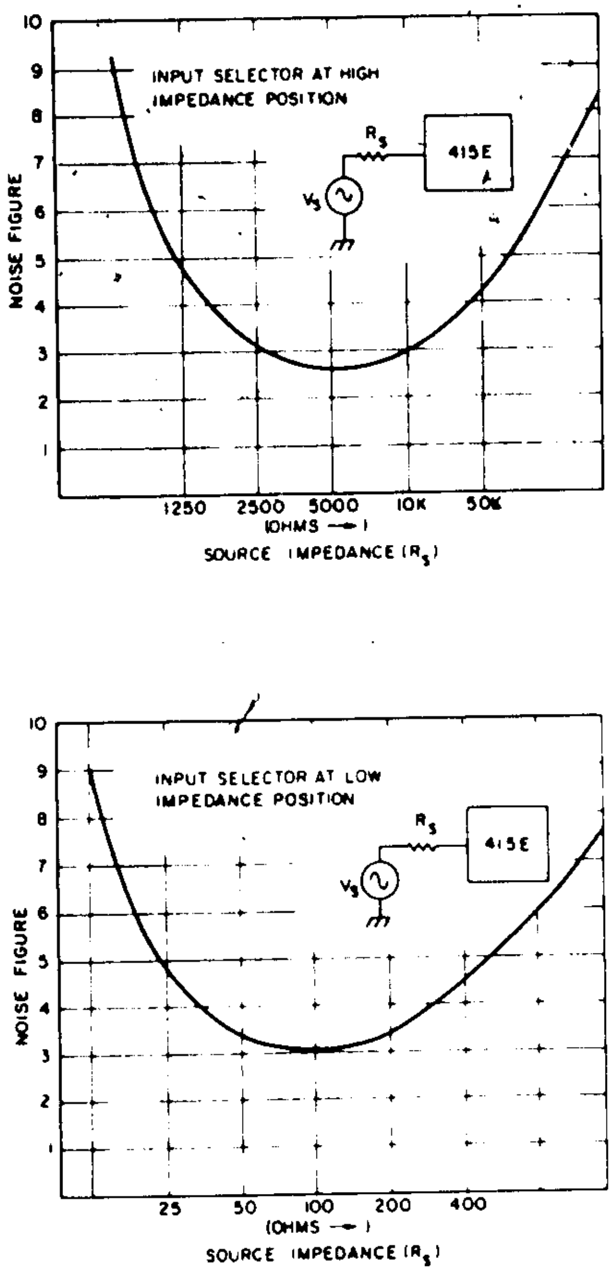


Figure 3-9. Noise Figure Curves

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:

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

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

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

3. The 0.129 μV open circuit voltage is reduced to 0.126 μV by the 200K ohm input resistance of the 415E which is assumed to be noiseless.

4. 0.126 μV is 18.0 dB below 1 μV 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 μF capacitor C26 is A3C26 on the A3 circuit board. It replaces a 6.8 μF capacitor. Also note additional 50 μF capacitor across the meter to smooth out any ripple.

*See HP Application Note 65

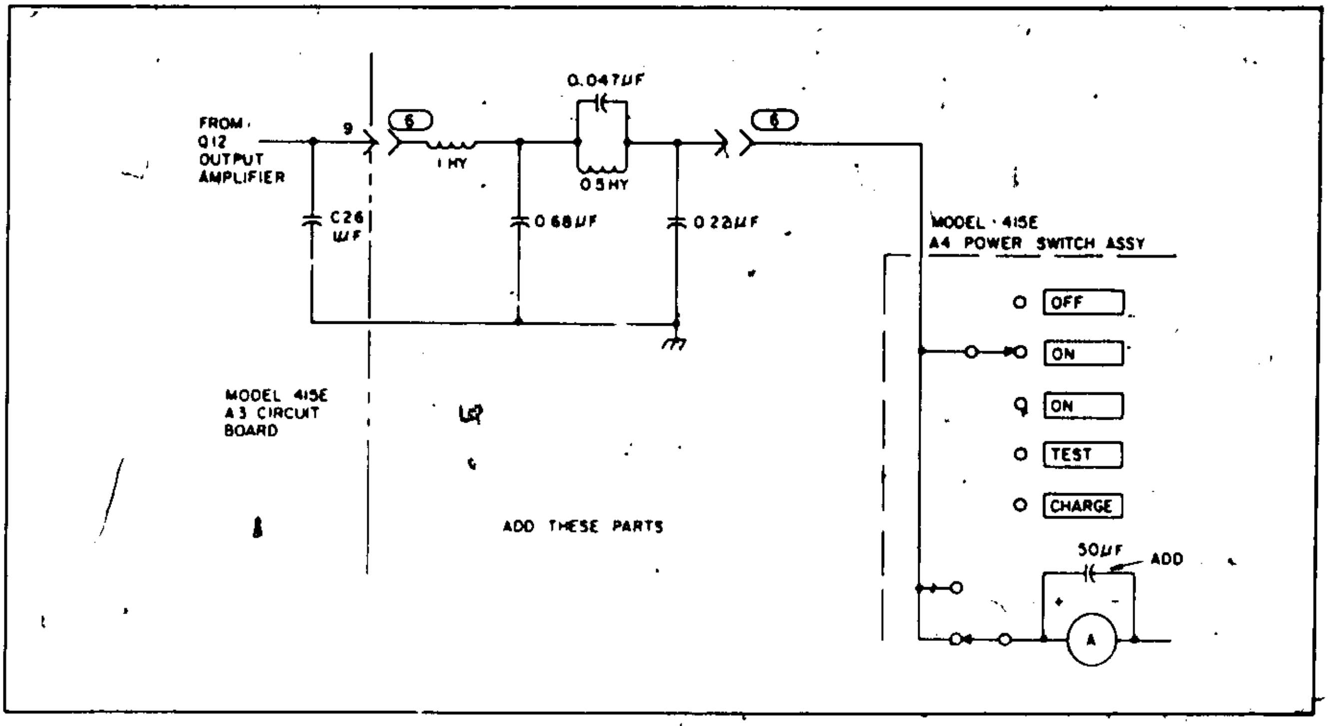


Figure 3-10. 1000 Hz Filter

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

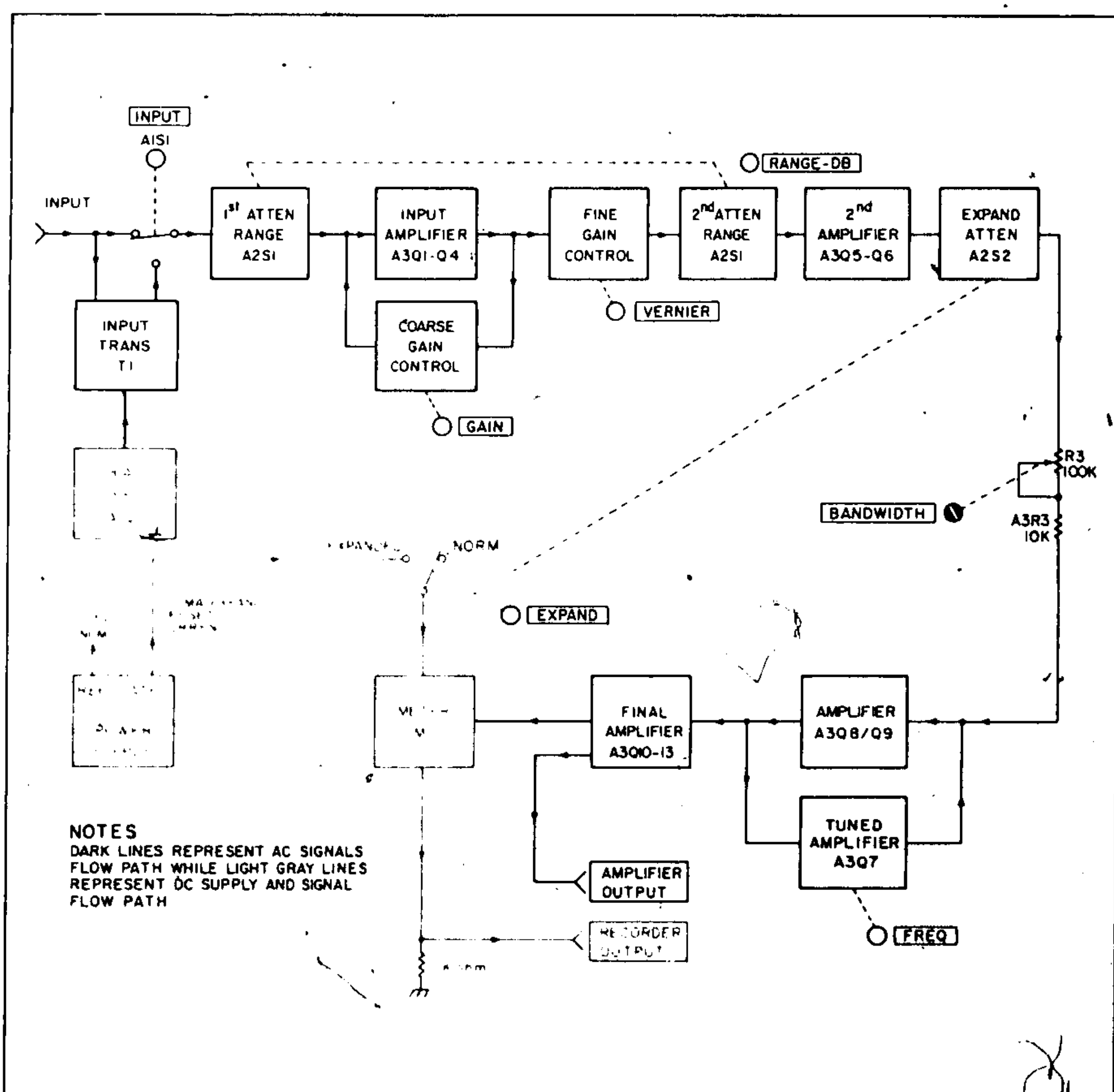


Figure 4-1. Block Diagram

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 μF capacitor, C1, connecting ground and chassis. A solid connection 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 ±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 adjustment 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.

a. Turn instrument off.

b. 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.

c. Continue to rotate adjustment screw clockwise; stop when the pointer is exactly on 2. If the pointer overshoots 2, repeat steps b and c.

d. 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: ±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: ±1 count ±0.01%	Frequency and Bandwidth	HP 5512A (or 5212A)
AC Voltmeter	Voltage Range: 0.1 to 1 volt Accuracy: ±1% of full scale Frequency Range: 400 to 2500 Hz Input Impedance: 10 megohms	Sensitivity and Noise	HP 400H
DC Voltmeter	Voltage Range: ±0.1 to ±30 volts Input Impedance: 10 megohms Accuracy: ±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 ±0.02 dB for 1 dB steps to ±0.017 dB for first 20 dB step, ±0.03 dB for second 20 dB step, and ±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

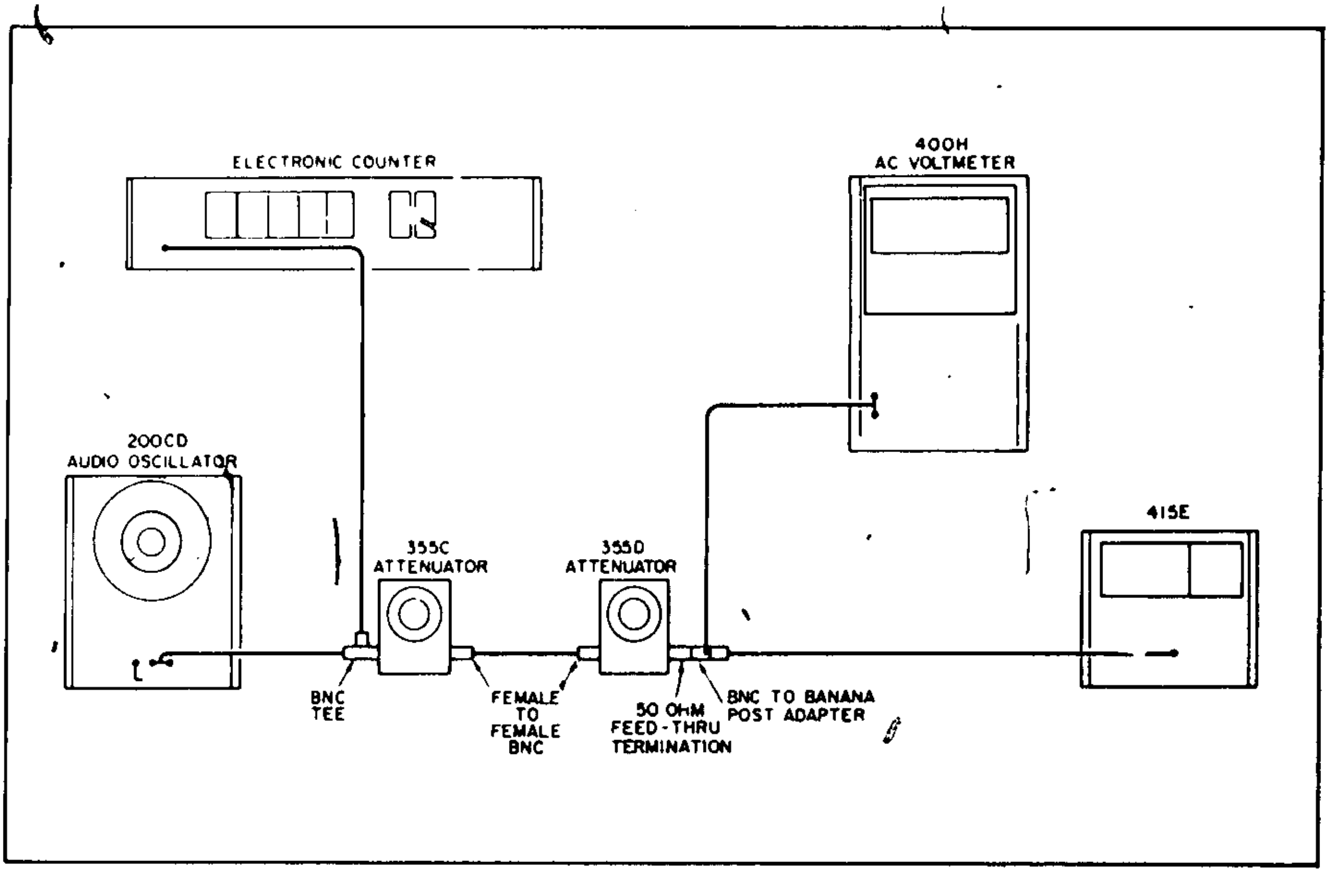


Figure 5-1. Test Setup

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

1. SENSITIVITY: 0.15 μVrms at maximum bandwidth (1 μVrms on HIGH impedance crystal input):

Procedure	Readings
a. Connect equipment as shown in Figure 5-1 (omit 355D attenuator). b. Set 415E to NORM, 0 dB, LOW, ON, with GAIN, VERNIER, and BANDWIDTH controls full clockwise. c. Set audio oscillator to 1000 Hz. 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 μV 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 μV rms or greater on 60 dB range.)	Min — Actual — Max __________ 0.15 Vrms __________ 1.0 Vrms

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). b. Set 415E to NORM, 0 dB, HIGH and ON with GAIN, VERNIER, FREQ and BANDWIDTH controls full clockwise. c. Set 355C to 0 dB and tune oscillator to peak 415E. 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).	Min — Actual — Max __________ (High) −7.2 dB __________ (Low) −7.5 dB

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

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.

h. Switch INPUT to LOW and repeat steps b and c above.

i. Adjust oscillator output for 0.5 Vrms AC voltmeter reading.

j. Adjust 415E GAIN for 0 dB meter reading and remove connections to 415E.

k. Connect Model 10100B feedthru termination to INPUT.

m. Repeat step g above. The average noise level should be 7.5 dB down from 0 on 0 to 10 dB scale.

3A. RANGE ACCURACY: ±0.05 dB/10 dB step; maximum cumulative error ±0.10 dB

Procedure

a. Connect 415E as shown in Figure 5-1 (omit counter and AC voltmeter).

b. Set 415E to ON, LOW, 0 (RANGE-DB), 0 (EXPAND), with GAIN full counterclockwise.

c. Set 355C to 5 dB and 355D to 0 and adjust oscillator frequency for peak 415E meter reading.

d. Adjust oscillator output and 415E VERNIER for 1 dB meter reading on 0 to 2 dB scale.

e. Switch 355D to 20 dB and 415E RANGE-DB to 10. The 415E meter reading should be 1.0 ±0.05 dB (see Note 1).

f. Switch 355D to 40 dB and 415E to 10. 415E should read 1.0 ±0.1 dB.

g. Switch 355D to 60 dB and 415E to 30. 415E should read 1.0 ±0.1 dB.

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 1.0 ±0.1 dB.

i. Switch 355D to 80 dB and 415E to 50. 415E should read 1.0 ±0.1 dB.

j. Switch 355D to 100 dB and 415E to 60. 415E should read 1.0 ±0.1 dB.

Readings

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: ±0.05 dB accuracy on any 0 to 2 dB scale: ±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 ±0.02 dB
2 dB	1.0 ±0.02 dB
3 dB	1.5 ±0.02 dB
4 dB	2.0 ±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 ±0.05 dB on 0 to 2 dB scale.

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

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

h. Switch 355C to 6 dB and EXPAND to 8. The 415E should read 1 ±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% (±35 Hz)

Procedure

a. Connect equipment as shown in Figure 5-1 (omit 355D and AC voltmeter from setup).

b. Set 355C to 10 dB.

c. Set 415E to LOW, ON 0 (EXPAND), with GAIN, FREQ and VERNIER full clockwise.

d. True oscillator to peak 415E (meter needle to right). Record counter reading.

e. Turn FREQ full counterclockwise.

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.

Readings

Min	Actual	Max
1020 Hz	______	–
–	______	980 Hz

Actual		Actual		Diff
______	–	______	=	______

Difference = >70 Hz

5. BANDWIDTH: Variable 15 to 130 Hz.

Procedure

a. Connect equipment as shown in Figure 5-1 (omit 355D and AC voltmeter).

b. Set 415E to LOW, ON, NORM, 0 (RANGE-DB), with GAIN and VERNIER full clockwise.

c. Turn BANDWIDTH full counterclockwise.

d. Tune oscillator to peak 415E.

e. Switch 415E EXPAND to 0 and retune oscillator to be sure that 415E is peaked at center frequency.

f. Adjust GAIN control for a 0 dB meter reading.

g. Tune oscillator slightly off tuned frequency causing meter reading to drop to exactly 1.5 dB and record counter reading.

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.

Readings

Actual – Actual = Difference (<15 Hz)

____ – ____________

Actual – Actual = Difference (>130 Hz)

____ – ____________

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

i. The difference between the readings of steps g and h should be 15 Hz or less.

j. Tune BANDWIDTH full clockwise and retune oscillator for peak 415E meter reading.

k. Repeat steps f, g, and h above.

m. The difference between the recorded frequency readings, this time, should be 130 Hz or greater.

6. SPECIAL 5000 OHM FEEDTHRU TERMINATION: 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).

Procedure

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.

NOTE

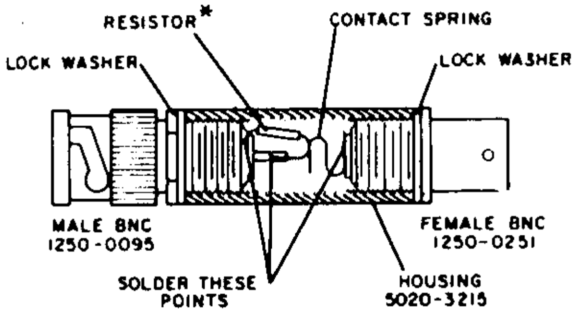
If gas pliers are used housing should be protected with tape or heavy paper.

b. Solder 5000 ohm ±10% 1/4W resistor to BNC.

c. Let resistor cool, then check resistance from male BNC pin through resistor; resistance measured should be ±10% that indicated by the coding.

d. Replace lockwasher and male BNC.

e. Check resistance from male-to-female BNC center conductor; resistance should be 0 or a few tenths of an ohm.



*RESISTOR VALUE: 50, 100, OR 5K OHM AS REQUIRED

NOTE: ENTIRE ASSEMBLY MINUS RESISTOR IS AVAILABLE AS 11523-600

NOTE

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.

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 ±0.02 dB, adjust A3R57 (see Figure 5-9) and repeat measurement until meter tracking error is less than ±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 Usoldering	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	Soldapullt 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

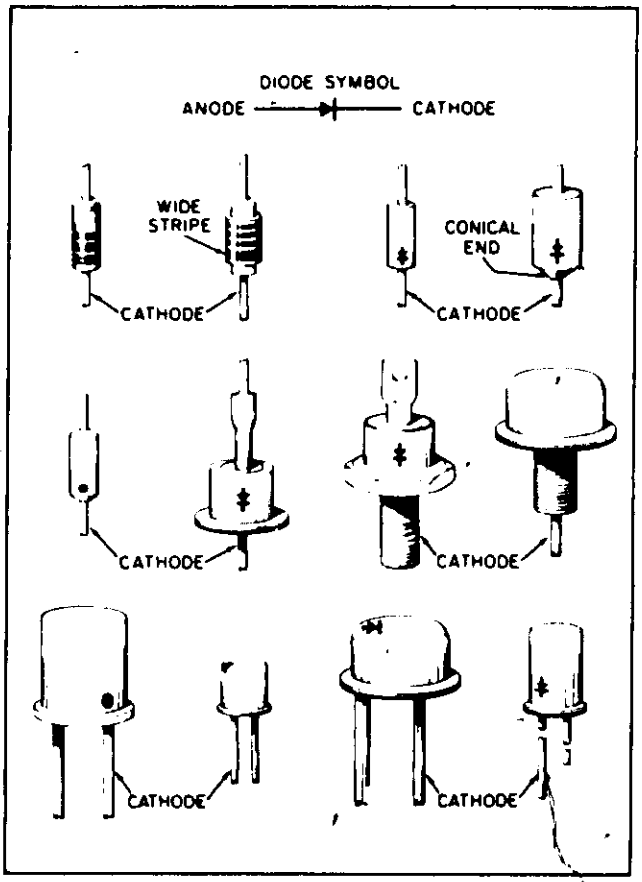


Figure 5-2. Examples of Diode Marking Methods

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.

a. Loosen setscrews in knobs and remove from shaft.

b. Loosen and remove shaft nut from front panel.

c. 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.

d. Unsolder connecting wires. Mark each to indicate which lugs to resolder wires to.

e. Replacement is reverse of removal.

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

a. Loosen setscrews in knobs and remove from shaft.

b. Loosen and remove shaft nut from front panel.

c. Loosen the BANDWIDTH potentiometer to allow the switch assembly to be pulled free of the front panel.

d. Unsolder connecting wires. Mark each to indicate which lugs to resolder wires to.

e. Replacement is reverse of removal.

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

a. Loosen setscrews in knob and remove from shaft.

b. Loosen and remove shaft nut from front panel.

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

d. Replacement is reverse of removal.

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

a. Loosen the two nuts holding circuit board in place and remove circuit board from instrument.

b. Loosen setscrews in knob and remove from shaft.

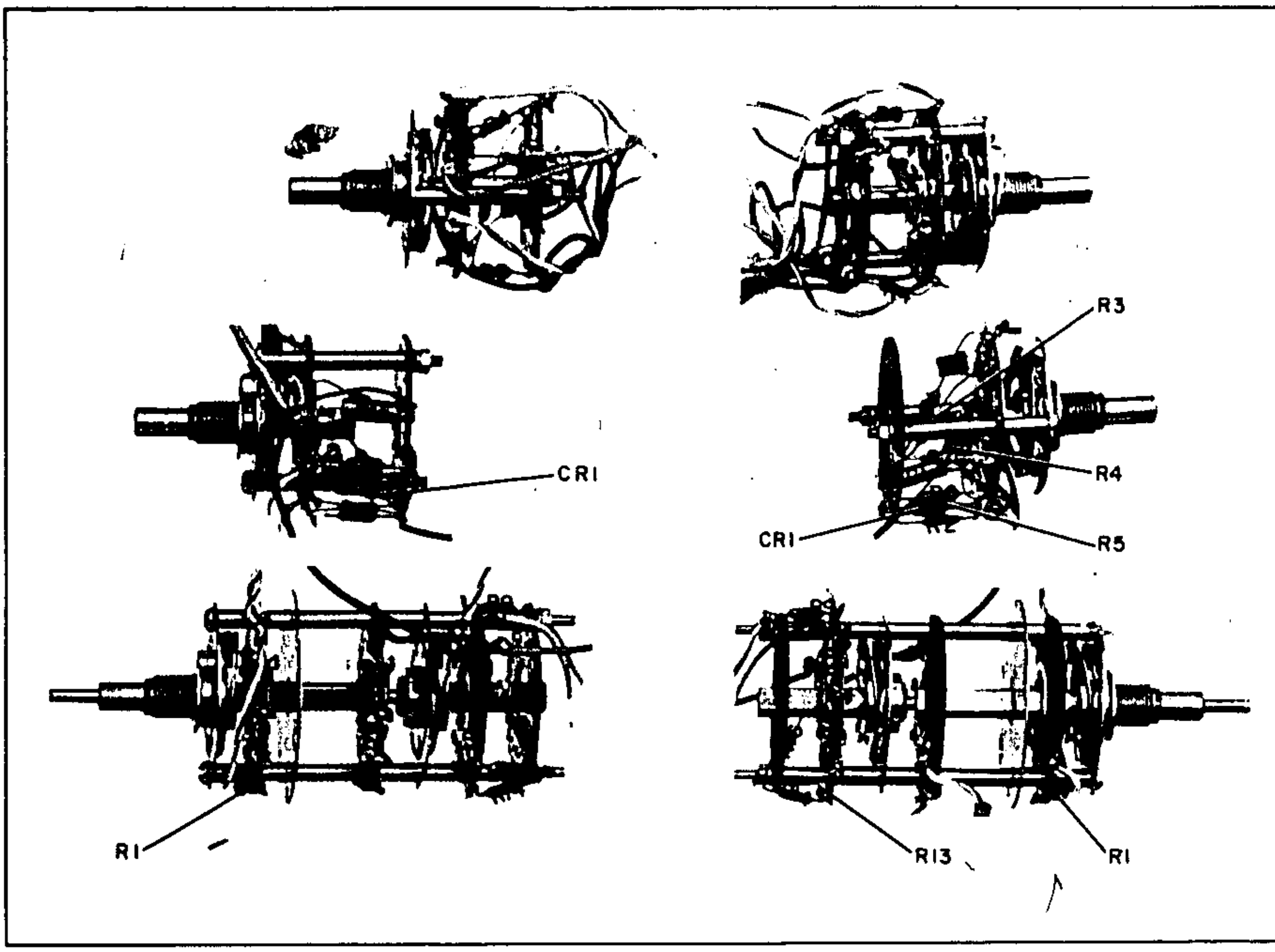


Figure 5-3. Switch Component Location

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 (±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 proprotional to the value of these capacitors. For a frequency of 10 kHz, change the value of these capacitors from 0.01 μF to 0.001 μF. 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 of 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 baised 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.

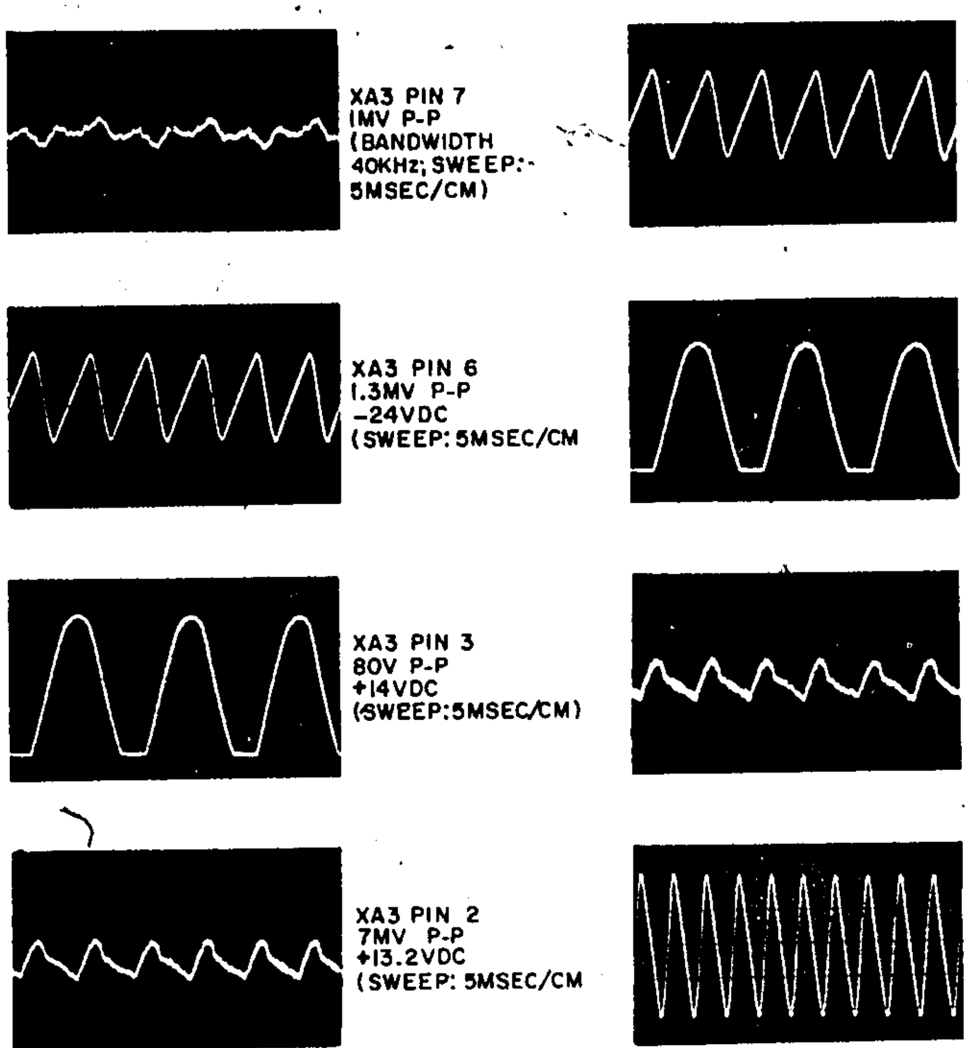
Table 5-4. Out-of-Circuit Transistor Resistance Measurements

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 μa 10 μa 1 μa 0.1 μa	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 μa 5.7 μa 0.5 μa 0.05 μa	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 μa 11 μa 1.1 μa 0.11 μa	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	+ —
Triplett 630	R x 100 R x 1K	1.5V 1.5V	3.25 ma 325 μa	Varies with serial number	
Triplett 310	R x 10 R x 100	1.5V 1.5V	750 μa 75 μa		



MEASUREMENT CONDITIONS (unless otherwise noted)*

a. Model 415E set to HIGH, NORM, RANGE 0, BANDWIDTH clockwise, FREQ centered, GAIN and VERNIER counterclockwise, LINE/ON.

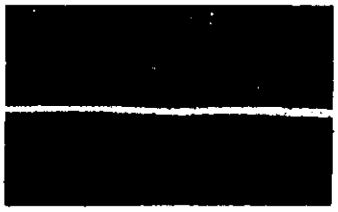
b. Model 140A with 1420A and 1400A set to 0.2 msec/cm, AC, 400 Hz, and appropriate vertical sensitivity.

c. Model 200CD oscillator set to about 1000 Hz, and for 0 dB Model 415E meter reference.

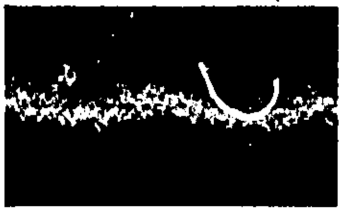
d. Model 412A DC voltmeter set to appropriate range.

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

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

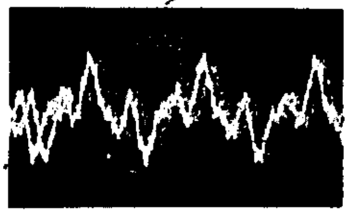


XA3 PIN 7
0.4MV P-P
(BANDWIDTH:40KHz)

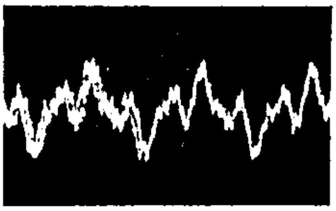


XA3 PIN 5
0.8MV P-P
(-13VDC)
(BANDWIDTH: 40 KHz)

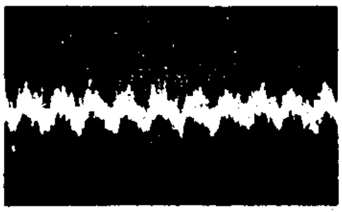
XA3 PIN 6
1MV P-P
-12.6VDC
(BANDWIDTH:40 KHz)



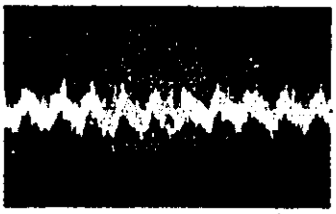
XA3 PIN 4
3MV P-P
+13.2VDC
(BANDWIDTH: 40KHz;
SWEEP: 5MSEC/CM)



XA3 PIN 3
3MV P-P
+13.2VDC
(BANDWIDTH:40KHz;
SWEEP: 5MSEC/CM)



XA3 PIN 1
0.8MV P-P
-12.6VDC
(BANDWIDTH: 40KHz;
SWEEP: 1MSEC/CM)



XA3 PIN 2
0.8MV P-P
+13.2VDC
(BANDWIDTH:40KHz;
SWEEP: 1MSEC/CM)

MEASUREMENT CONDITIONS (unless otherwise noted)*

a. Model 415E set to HIGH, NORM, RANGE 0, BANDWIDTH clockwise, FREQ centered, GAIN and VERNIER counterclockwise, BATTERY/ON.

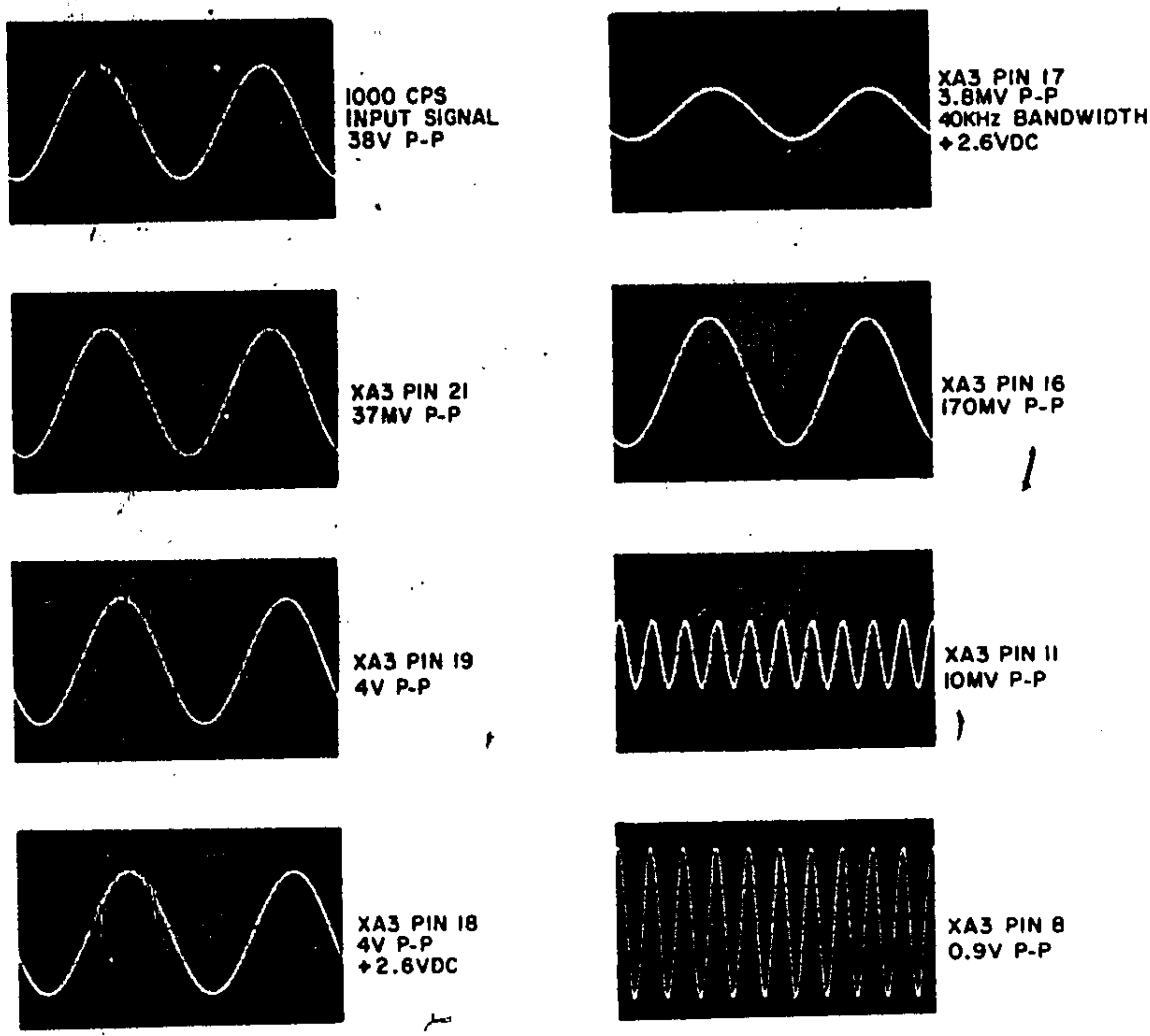
b. Model 140A with 1420A and 1400A set to 0.2 msec/cm, AC, 400 Hz, and appropriate vertical sensitivity.

c. Model 200CD oscillator set to about 1000 Hz, and for 0 dB Model 415E meter reference.

d. 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)



MEASUREMENT CONDITIONS (unless otherwise noted)*

a. Model 415E set to ON, HIGH, NORM, RANGE 0, BANDWIDTH clockwise, FREQ centered, GAIN and VERNIER counterclockwise.

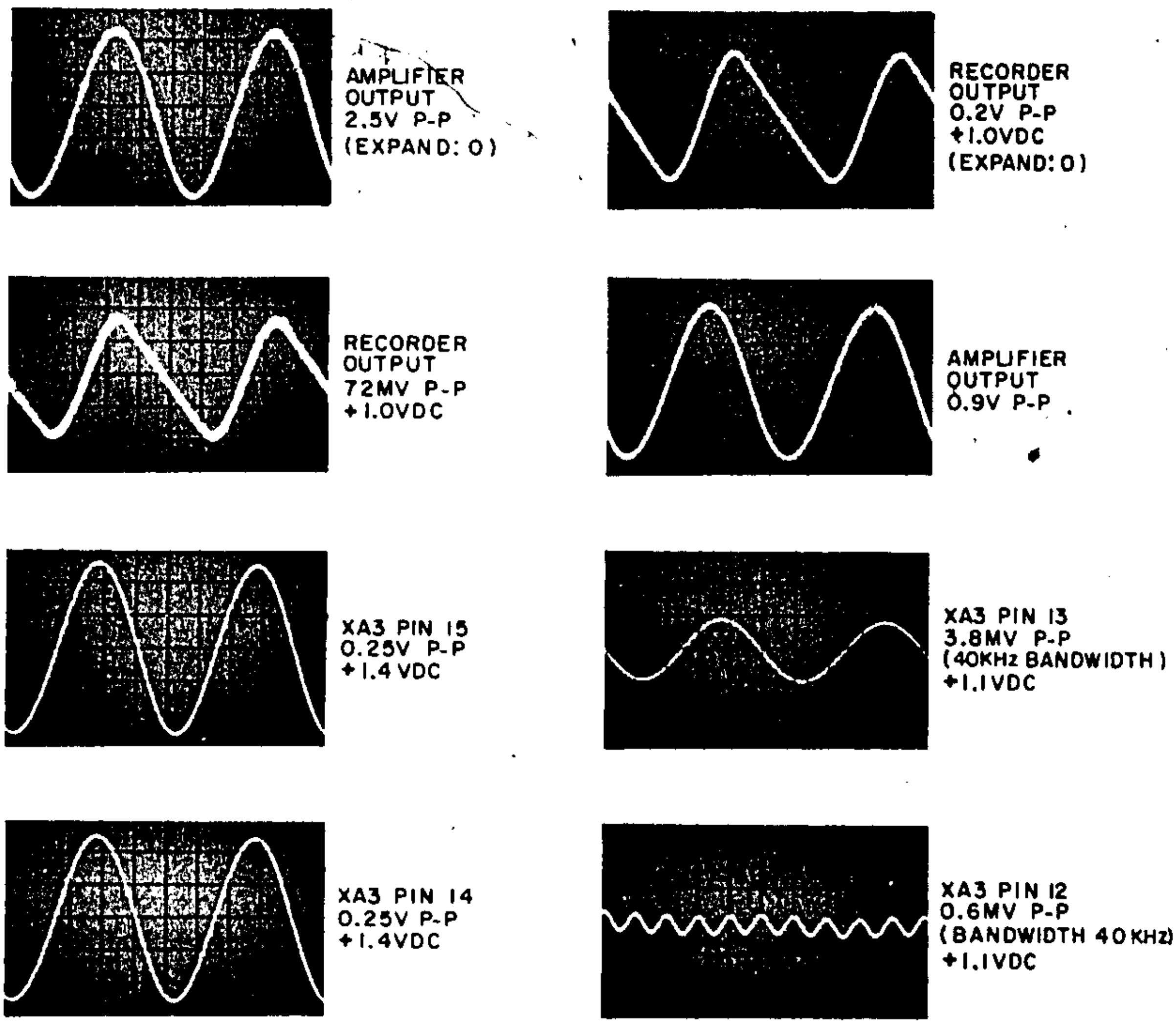
b. Model 140A with 1420A and 1400A set to 0.2 msec/cm, AC, 400 Hz, and appropriate vertical sensitivity.

c. Model 200CD oscillator set to about 1000 Hz, and for 0 dB model 415E meter reference.

d. 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)



MEASUREMENT CONDITIONS (unless otherwise noted)*

a. Model 415E set to ON, HIGH, NORM, RANGE 0, BANDWIDTH clockwise, FREQ centered, GAIN and VERNIER counterclockwise.

b. Model 140A with 1420A and 1400A set to 0.2 msec/cm, AC, 400 Hz, and appropriate sensitivity.

c. Model 200CD oscillator set to about 1000 Hz, and for 0 dB model 415E meter reference.

d. 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. XA1 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 ±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

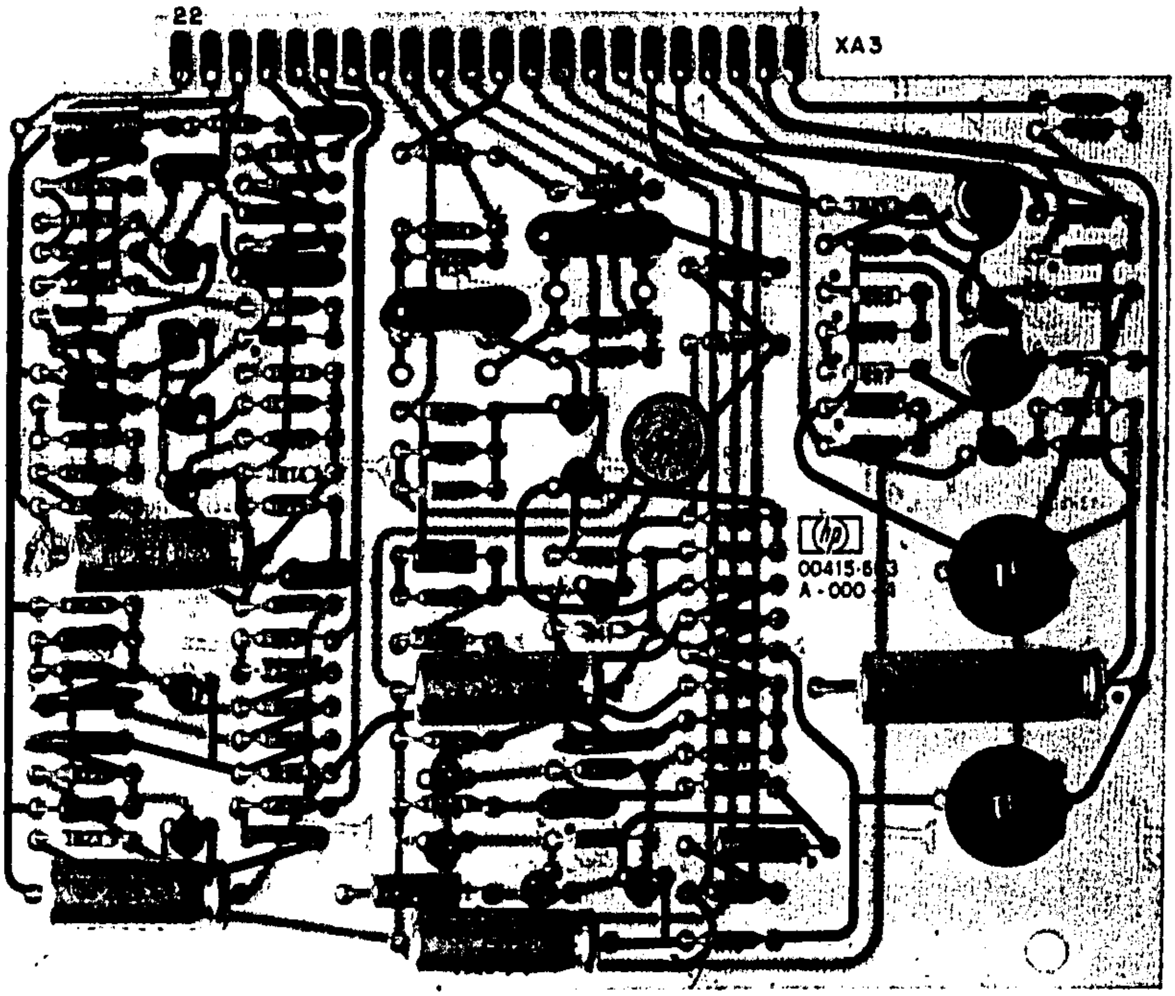
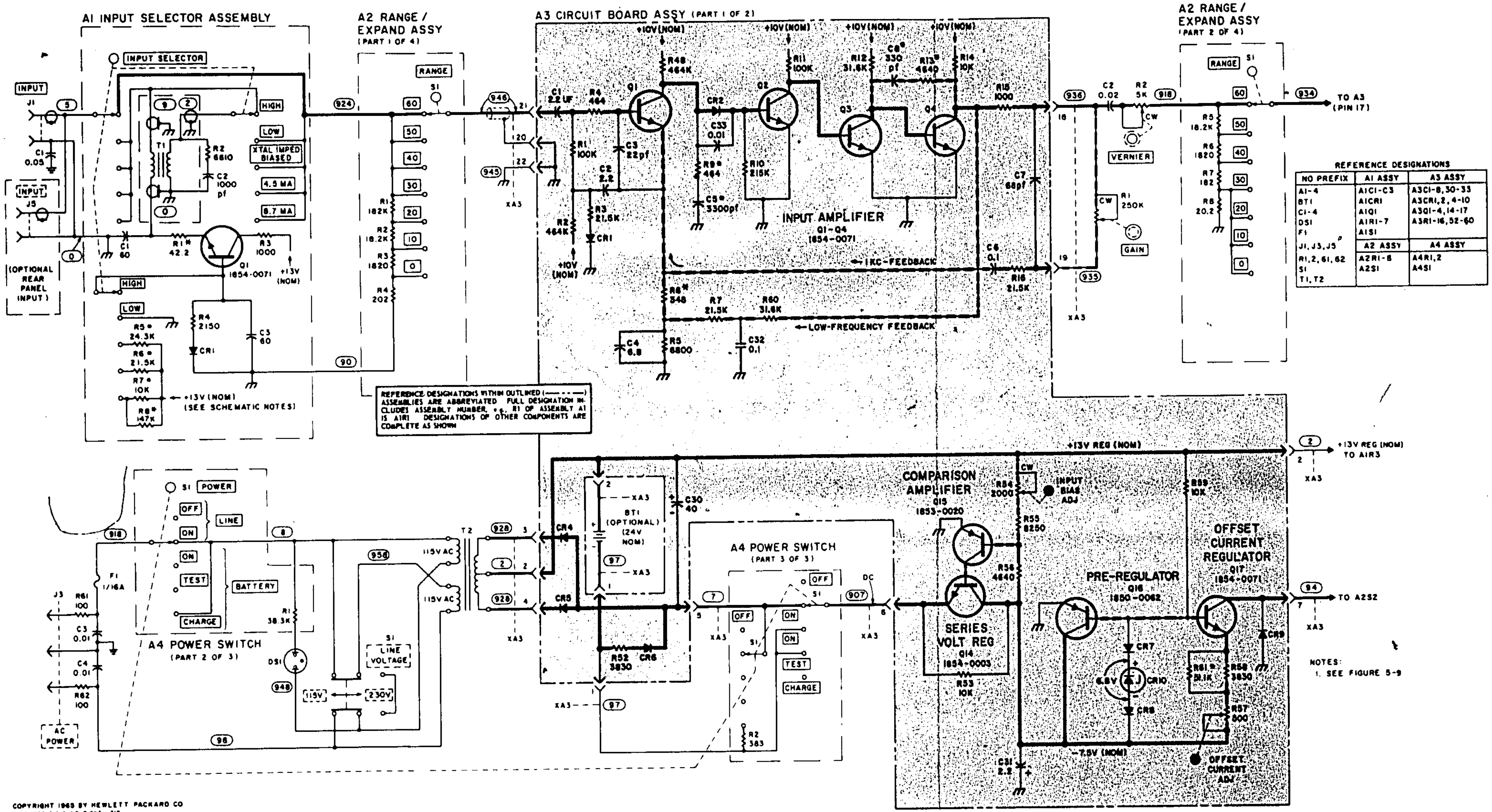


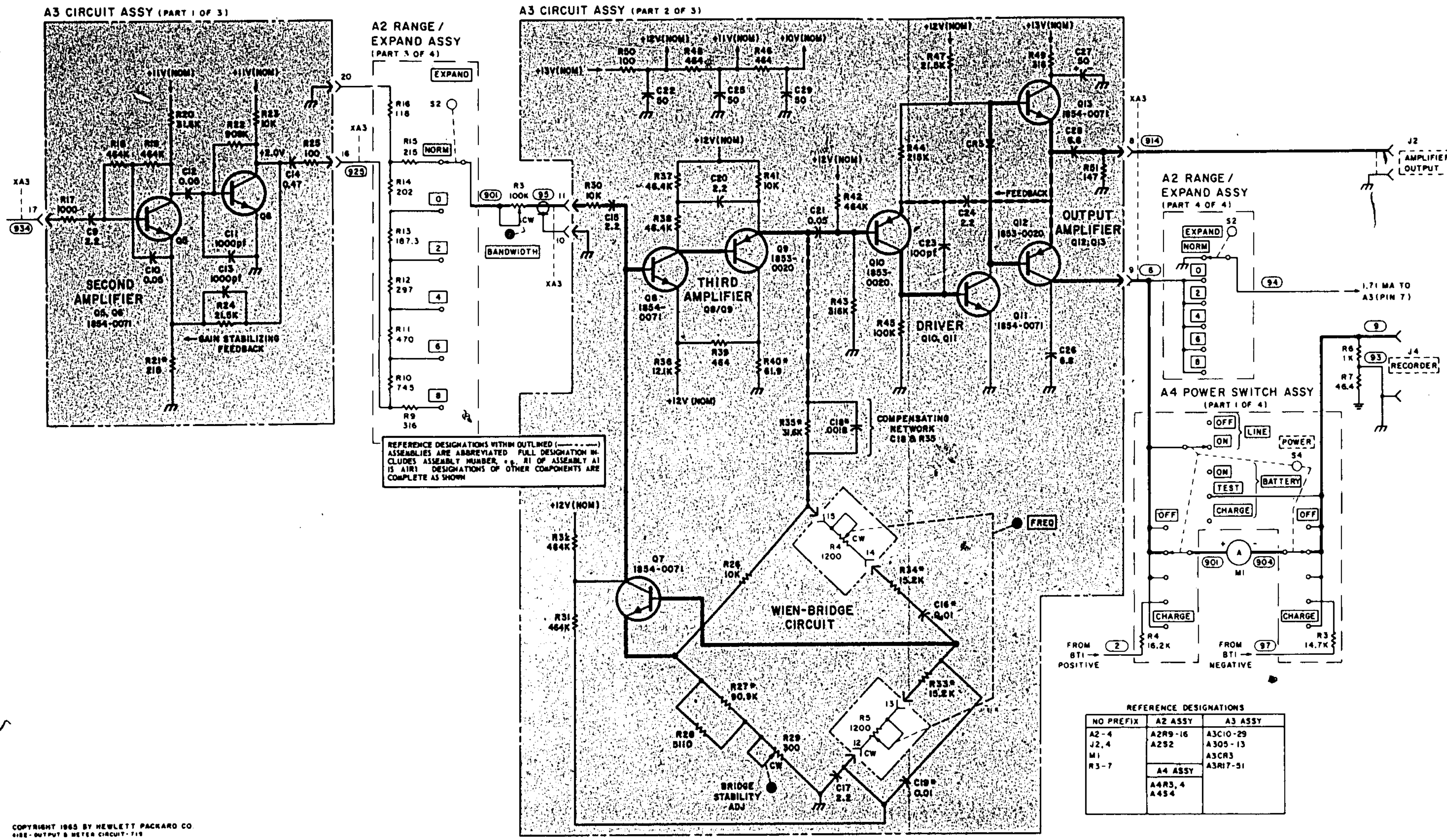
Figure 5-9 A3 Circuit Board Component Location for instruments Prefixed 545- and up. See Appendix II for Component Location of Instruments Prefixed 530-.



REFERENCE DESIGNATIONS

NO PREFIX	A1 ASSY	A3 ASSY
A1-4 BT1 C1-4 DS1 F1 J1, J3, J5	A1C1-C3 A1CR1 A1Q1 A1R1-7 A1S1	A3C1-8, 30-33 A3CR1, 2, 4-10 A3Q1-4, 14-17 A3R1-16, 52-60
	A2 ASSY	A4 ASSY
R1, 2, 61, 62 S1 T1, T2	A2R1-8 A2S1	A4R1, 2 A4S1

Figure 5-10. Power Supply and Input Circuit



REFERENCE DESIGNATIONS

NO PREFIX	A2 ASSY	A3 ASSY
A2-4 J2, 4 M1 R3-7	A2R9-16 A2S2 **A4 ASSY** A4R3, 4 A4S4	A3C10-29 A3Q5-13 A3CR3 A3R17-51

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

ABBREVIATIONS

A	= amperes
AFC	= automatic frequency control
AMPL	= amplifier
BFO	= beat frequency oscillator
BE CU	= beryllium copper
BH	= binder head
BP	= bandpass
BRS	= brass
BWO	= backward wave oscillator
CCW	= counterclockwise
CER	= ceramic
CMO	= cabinet mount only
COEF	= coefficient
COM	= common
COMP	= composition
COMPL	= complete
CONN	= connector
CP	= cadmium plate
CRT	= cathode-ray tube
CW	= clockwise
DEPC	= deposited carbon
DR	= drive
ELECT	= electrolytic
ENCAP	= encapsulated
EXT	= external
F	= farads
FH	= flat head
FIL H	= Fillister head
FXD	= fixed
G	= giga (10^9)
GE	= germanium
GL	= glass
GRD	= ground(ed)
H	= henries
HDW	= hardware
HEX	= hexagonal
HG	= mercury
HR	= hour(s)
Hz	= Hertz
IF	= intermediate freq
IMPG	= impregnated
INCD	= incandescent
INCL	= include(s)
INS	= insulation(ed)
INT	= internal
K	= kilo = 1000
LH	= left hand
LIN	= linear taper
LK WASH	= lock washer
LOG	= logarithmic taper
LPF	= low pass filter
M	= milli = 10^{-3}
MEG	= meg = 10^6
MET FLM	= metal film
MET OX	= metallic oxide
MFR	= manufacturer
MHz	= mega Hertz
MINAT	= miniature
MOM	= momentary
MOS	= metalized substrate
MTG	= mounting
MY	= "mylar"
N	= nano (10^{-9})
N/C	= normally closed
NE	= neon
NI PL	= nickel plate
N/O	= normally open
NOM	= nominal
NPO	= negative positive zero (zero temperature coefficient)
NPN	= negative-positive-negative
NRFR	= not recommended for field replacement
NSR	= not separately replaceable
OBD	= order by description
OH	= oval head
OX	= oxide
P	= peak
PC	= printed circuit
PF	= picofarads = 10^{-12} farads
PH BRZ	= phosphor bronze
PHL	= Phillips
PIV	= peak inverse voltage
PNP	= positive-negative-positive
P/O	= part of
POLY	= polystrene
PORC	= porcelain
POS	= position(s)
POT	= potentiometer
PP	= peak-to-peak
PT	= point
PWV	= peak working voltage
RECT	= rectifier
RF	= radio frequency
RH	= round head or right hand
RMO	= rack mount only
RMS	= root-mean square
RWV	= reverse working voltage
S-B	= slow-blow
SCR	= screw
SE	= selenium
SECT	= section(s)
SEMICON	= semiconductor
SI	= silicon
SIL	= silver
SL	= slide
SPG	= spring
SPL	= special
SST	= Stainless steel
SR	= split ring
STL	= steel
TA	= tantalum
TD	= time delay
TGL	= toggle
THD	= thread
TI	= titanium
TOL	= tolerance
TRIM	= trimmer
TWT	= traveling wave tube
μ	= micro = 10^{-6}
VAR	= variable
VDCW	= dc working volts
W/	= with
W	= watts
WIV	= working inverse voltage
WW	= wirewound
W/O	= without

Table 6-2. Replaceable Parts

Reference Designation	HP Part Number	Qty	Description	Mfr Code	Mfr Part Number
A1	00415-601	1	SWITCH ASSY:INPUT	28480	00415-601
A1C1	0180-0106	2	C:FXD ELECT 60 UF 20% 6VDCW	28480	0180-0106
A1C2	0160-0153	3	C:FXD MY 0.001 UF 10% 200VDCW	56289	192P10292-PTS
A1C3	0180-0106		C:FXD ELECT 60 UF 20% 6VDCW	28480	0180-0106
A1CR1	1901-0025	6	DIODE:SILICON 100MA/1V	07263	FD 2387
A1Q1	1854-0071	12	TSTR:SI NPN(SELECTED FROM 2N3704)	28480	1854-0071
A1R1	0757-0316	1	R:FXD MET FLM 42.2 OHM 1% 1/8W	28480	0757-0316
A1R2	0757-0439	2	R:FXD MET FLM 6.81K OHM 1% 1/8W	28480	0757-0439
A1R3	0757-0280	4	R:FXD MET FLM 1K OHM 1% 1/8W	28480	0757-0280
A1R4	0698-0084	1	R:FXD MET FLM 2.15K OHM 1% 1/8W	28480	0698-0084
A1R5	0757-0451	1	R:FXD MET FLM 24.3K OHM 1% 1/8W	28480	0757-0451
A1R6	0757-0199	6	R:FXD MET FLM 21.5K OHM 1% 1/8W	28480	0757-0199
A1R7	0757-0443	1	R:FXD MET FLM 11.0K OHM 1% 1/8W	28480	0757-0443
A1R8	0698-3452	1	R:FXD MET FLM 147K OHM 1% 1/8W	28480	0698-3452
A1S1	3100-1805	1	SWITCH:ROTARY	28480	3100-1805
A2	00415-602	1	SWITCH ASSY:RANGE	28480	00415-602
A2R1	0698-6114	1	R:FXD FLM 182K OHM 0.25% 1/8W	28480	0698-6114
A2R2	0698-6109	2	R:FXD MET FLM 18.2K OHM 0.25% 1/8W	28480	0698-6109
A2R3	0698-6113	2	R:FXD MET FLM 1.82K OHM 0.25% 1/8W	28480	0698-6113
A2R4	0698-6112	2	R:FXD FLM 202 OHM 0.25% 1/8W	28480	0698-6112
A2R5	0698-6109		R:FXD MET FLM 18.2K OHM 0.25% 1/8W	28480	0698-6109
A2R6	0698-6113		R:FXD MET FLM 1.82K OHM 0.25% 1/8W	28480	0698-6113
A2R7	0698-6111	1	R:FXD FLM 182 OHM 0.25% 1/8W	28480	0698-6111
A2R8	0698-6110	1	R:FXD FLM 20.2 OHM 0.25% 1/8W	28480	0698-6110
A2R9	0698-3444	2	R:FXD MET FLM 316 OHM 1% 1/8W	28480	0698-3444
A2R10	0698-3531	1	R:FXD MET FLM 745 OHM 0.5% 1/8W	28480	0698-3531
A2R11	0698-3530	1	R:FXD MET FLM 470 OHM 0.5% 1/8W	28480	0698-3530
A2R12	0698-3529	1	R:FXD MET FLM 297 OHM 0.5% 1/8W	28480	0698-3529
A2R13	0698-3527	1	R:FXD MET FLM 187.3 OHM 0.5% 1/8W	28480	0698-3527
A2R14	0698-6112		R:FXD FLM 202 OHM 0.25% 1/8W	28480	0698-6112
A2R15	0698-3441	2	R:FXD MET FLM 215 OHM 1% 1/8W	28480	0698-3441
A2R16	0698-3525	1	R:FXD MET FLM 118 OHM 0.5% 1/8W	28480	0698-3525
A2S1	3100-1806	1	SWITCH:ROTARY	28480	3100-1806
A3	00415-603	1	BOARD ASSY:AMPLIFIER	28480	00415-603
A3C1	0180-0155	8	C:FXD ELECT 2.2 UF 20% 20VDCW	56289	150D225X0020A2-DYS
A3C2	0180-0155		C:FXD ELECT 2.2 UF 20% 20VDCW	56289	150D225X0020A2-DYS
A3C3	0140-0145	1	C:FXD MICA 22 PF 5%	28480	0140-0145
A3C4	0180-0116	3	C:FXD ELECT 6.8 UF 10% 35VDCW	56289	150D685X9035B2-DYS
A3C5	0160-0155	1	C:FXD MY 0.0033 UF 10% 200VDCW	56289	192P33292-PTS
A3C6	0150-0121	1	C:FXD CER 0.1 UF +80-20% 50VDCW	56289	5C50B1S-CML
A3C7	0140-0192	1	C:FXD MICA 68 PF 5%	28480	0140-0192
A3C8	0140-0207	1	C:FXD MICA 330 PF 5%	28480	0140-0207
A3C9	0180-0155		C:FXD ELECT 2.2 UF 20% 20VDCW	56289	150D225X0020A2-DYS
A3C10	0160-2917	3	C:FXD CER 0.05 UF +80-20% 100VDCW	84411	TYPE TA
A3C11	0160-0153		C:FXD MY 0.001 UF 10% 200VDCW	56289	192P10292-PTS
A3C12	0160-2917		C:FXD CER 0.05 UF +80-20% 100VDCW	84411	TYPE TA
A3C13	0160-0153		C:FXD MY 0.001 UF 10% 200VDCW	56289	192P10292-PTS
A3C14	0160-0174	1	C:FXD CER 0.47 UF +80-20% 25VDCW	56289	5C11B7S-CML
A3C15	0180-0155		C:FXD ELECT 2.2 UF 20% 20VDCW	56289	150D225X0020A2-DYS
A3C16	0160-2120	2	C:FXD MICA 0.01UF 1%	04062	RDM30F103F3C
A3C17	0180-0155		C:FXD ELECT 2.2 UF 20% 20VDCW	56289	150D225X0020A2-DYS
A3C18	0160-2223	1	C:FXD MICA 1600 PF 5%	28480	0160-2223
A3C19	0160-2120		C:FXD MICA 0.01UF 1%	04062	RDM30F103F3C
A3C20	0180-0155		C:FXD ELECT 2.2 UF 20% 20VDCW	56289	150D225X0020A2-DYS
A3C21	0160-2917		C:FXD CER 0.05 UF +80-20% 100VDCW	84411	TYPE TA
A3C22	0180-0105	4	C:FXD ELECT SEMI-POLARIZED 50UF 25VDCW	56289	D34114
A3C23	0140-0176	1	C:FXD MICA 100 PF 2%	28480	0140-0176
A3C24	0180-0155		C:FXD ELECT 2.2 UF 20% 20VDCW	56289	150D225X0020A2-DYS
A3C25	0180-0105		C:FXD ELECT SEMI-POLARIZED 50UF 25VDCW	56289	D34114
A3C26	0180-0116		C:FXD ELECT 6.8 UF 10% 35VDCW	56289	150D685X9035B2-DYS
A3C27	0180-0105		C:FXD ELECT SEMI-POLARIZED 50UF 25VDCW	56289	D34114
A3C28	0180-0116		C:FXD ELECT 6.8 UF 10% 35VDCW	56289	150D685X9035B2-DYS
A3C29	0180-0105		C:FXD ELECT SEMI-POLARIZED 50UF 25VDCW	56289	D34114
A3C30	0180-0050	1	C:FXD ELECT 40 UF +75-10% 50VDCW	28480	0180-0050
A3C31	0180-0155		C:FXD ELECT 2.2 UF 20% 20VDCW	56289	150D225X0020A2-DYS
A3C32	0170-0085	1	C:FXD MY 0.1UF 20% 50VDCW	84411	601PE STYLE 3
A3C33	0160-2930	1	C:FXD CER 0.01 UF +80-20% 100VDCW	91418	TA
A3CR1	1901-0025		DIODE:SILICON 100MA/1V	07263	FD 2387
A3CR2	1901-0025		DIODE:SILICON 100MA/1V	07263	FD 2387
A3CR3	1901-0025		DIODE:SILICON 100MA/1V	07263	FD 2387
A3CR4	1901-0033	2	DIODE:SILICON 100MA 180WV	07263	FD3369
A3CR5	1901-0033		DIODE:SILICON 100MA 180WV	07263	FD3369
A3CR6	1901-0025		DIODE:SILICON 100MA/1V	07263	FD 2387
A3CR7	1910-0016	2	DIODE:GERMANIUM 100MA/0.85V 60PIV	93332	D2361
A3CR8	1910-0016		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
A3CR9	1901-0025		DIODE:SILICON 100MA/1V	07263	FD 2387
A3CR10	1902-0048	1	DIODE:BREAKDOWN 6.81V 5%	04713	SZ10939-134
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		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 287
A3Q17	1854-0071		TSTR:SI NPN(SELECTED FROM 2N3704)	28480	1854-0071
A3R1	0757-0465	3	R:FXD MET FLM 100K OHM 1% 1/8W	28480	0757-0465
A3R2	0698-3260	7	R:FXD MET FLM 464K OHM 1% 1/8W	28480	0698-3260
A3R3	0757-0199		R:FXD MET FLM 21.5K OHM 1% 1/8W	28480	0757-0199
A3R4	0698-0082	5	R:FXD MET FLM 464 OHM 1% 1/8W	28480	0698-0082
A3R5	0757-0439		R:FXD MET FLM 6.81K OHM 1% 1/8W	28480	0757-0439
A3R6	0698-3445	1	R:FXD MET FLM 348 OHM 1% 1/8W	28480	0698-3445
A3R7	0757-0199		R:FXD MET FLM 21.5K OHM 1% 1/8W	28480	0757-0199
A3R8	0698-3260		R:FXD MET FLM 464K OHM 1% 1/8W	28480	0698-3260
A3R9	0698-0082		R:FXD MET FLM 464 OHM 1% 1/8W	28480	0698-0082
A3R10	0698-3454	2	R:FXD MET FLM 215K OHM 1% 1/8W	28480	0698-3454
A3R11	0757-0465		R:FXD MET FLM 100K OHM 1% 1/8W	28480	0757-0465
A3R12	0698-3160	3	R:FXD MET FLM 31.6K OHM 1% 1/8W	28480	0698-3160
A3R13	0698-3155	2	R:FXD MET FLM 4.64K OHM 1% 1/8W	28480	0698-3155
A3R14	0757-0442	7	R:FXD MET FLM 10.0K OHM 1% 1/8W	28480	0757-0442
A3R15	0757-0280		R:FXD MET FLM 1K OHM 1% 1/8W	28480	0757-0280
A3R16	0757-0199		R:FXD MET FLM 21.5K OHM 1% 1/8W	28480	0757-0199
A3R17	0757-0280		R:FXD MET FLM 1K OHM 1% 1/8W	28480	0757-0280
A3R18	0698-3260		R:FXD MET FLM 464K OHM 1% 1/8W	28480	0698-3260
A3R19	0698-3260		R:FXD MET FLM 464K OHM 1% 1/8W	28480	0698-3260
A3R20	0698-3160		R:FXD MET FLM 31.6K OHM 1% 1/8W	28480	0698-3160
A3R21	0698-3441		R:FXD MET FLM 215 OHM 1% 1/8W	28480	0698-3441
A3R22	0757-0488	1	R:FXD MET FLM 909K OHM 1% 1/8W	28480	0757-0488
A3R23	0757-0442		R:FXD MET FLM 10.0K OHM 1% 1/8W	28480	0757-0442
A3R24	0757-0199		R:FXD MET FLM 21.5K OHM 1% 1/8W	28480	0757-0199
A3R25	0757-0401	4	R:FXD MET FLM 100 OHM 1% 1/8W	28480	0757-0401
A3R26	0757-0442		R:FXD MET FLM 10.0K OHM 1% 1/8W	28480	0757-0442
A3R27	0757-0464	1	R:FXD MET FLM 90.9K OHM 1% 1/8W	28480	0757-0464
A3R28	0757-0438	1	R:FXD MET FLM 5.11K OHM 1% 1/8W	28480	0757-0438
A3R29	2100-1611	1	R:VAR WW 300 OHM 5% TYPE H 1W	28480	2100-1611
A3R30	0757-0442		R:FXD MET FLM 10.0K OHM 1% 1/8W	28480	0757-0442
A3R31	0698-3260		R:FXD MET FLM 464K OHM 1% 1/8W	28480	0698-3260
A3R32	0698-3260		R:FXD MET FLM 464K OHM 1% 1/8W	28480	0698-3260
A3R33	0698-5001	2	R:FXD FLM 15.2K OHM 1% 1/8W	28480	0698-5001
A3R34	0698-5001		R:FXD FLM 15.2K OHM 1% 1/8W	28480	0698-5001
A3R35	0698-3449	1	R:FXD MET FLM 28.7K OHM 1% 1/8W	28480	0698-3449
A3R36	0757-0444	1	R:FXD MET FLM 12.1K OHM 1% 1/8W	28480	0757-0444
A3R37	0698-3162	2	R:FXD MET FLM 46.4K OHM 1% 1/8W	28480	0698-3162
A3R38	0698-3162		R:FXD MET FLM 46.4K OHM 1% 1/8W	28480	0698-3162
A3R39	0698-0082		R:FXD MET FLM 464 OHM 1% 1/8W	28480	0698-0082
A3R40	0757-0276	1	R:FXD MET FLM 61.9 OHM 1% 1/8W	28480	0757-0276
A3R40			*FACTORY SELECTED PART		
A3R41	0757-0442		R:FXD MET FLM 10.0K OHM 1% 1/8W	28480	0757-0442
A3R42	0698-3260		R:FXD MET FLM 464K OHM 1% 1/8W	28480	0698-3260
A3R43	0698-3457	1	R:FXD MET FLM 316K OHM 1% 1/8W	28480	0698-3457
A3R44	0698-3454		R:FXD MET FLM 215K OHM 1% 1/8W	28480	0698-3454
A3R45	0757-0465		R:FXD MET FLM 100K OHM 1% 1/8W	28480	0757-0465
A3R46	0698-0082		R:FXD MET FLM 464 OHM 1% 1/8W	28480	0698-0082
A3R47	0757-0199		R:FXD MET FLM 21.5K OHM 1% 1/8W	28480	0757-0199
A3R48	0698-0082		R:FXD MET FLM 464 OHM 1% 1/8W	28480	0698-0082
A3R49	0698-3444		R:FXD MET FLM 316 OHM 1% 1/8W	28480	0698-3444
A3R50	0757-0401		R:FXD MET FLM 100 OHM 1% 1/8W	28480	0757-0401
A3R51	0698-3438	1	R:FXD MET FLM 147 OHM 1% 1/8W	28480	0698-3438
A3R52	0698-3153	2	R:FXD MET FLM 3.83K OHM 1% 1/8W	28480	0698-3153
A3R53	0757-0442		R:FXD MET FLM 10.0K OHM 1% 1/8W	28480	0757-0442
A3R54	2100-1613	1	R:VAR COMP 2K OHM 20% LIN 1/5W	28480	2100-1613
A3R55	0757-0441	1	R:FXD MET FLM 8.25K OHM 1% 1/8W	28480	0757-0441

See introduction to this section for ordering information

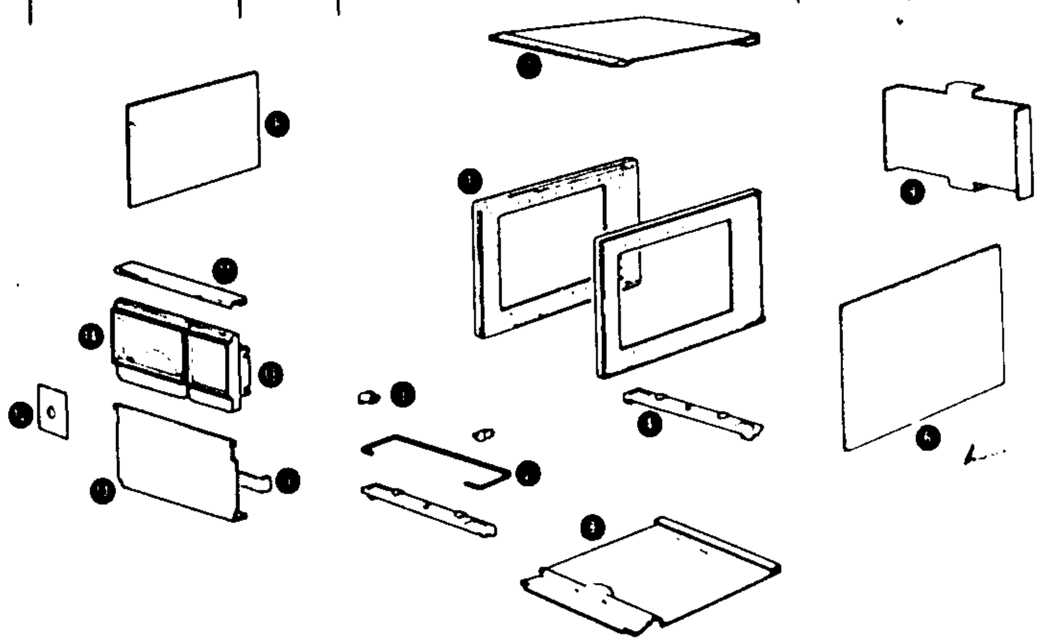
Table 6-2. Replaceable Parts

Reference Designation	HP Part Number	Qty	Description	Mfr Code	Mfr Part Number
A3R56	0698-3155		R:FXD MET FLM 4.64K OHM 1% 1/8W	28480	0698-3155
A3R57	2100-1612	1	R:VAR COMP 500 OHM 20% LIN 1/5W	28480	2100-1612
A3R58	0698-3153		R:FXD MET FLM 3.83K OHM 1% 1/8W	28480	0698-3153
A3R59	0757-0442		R:FXD MET FLM 10.0K OHM 1% 1/8W	28480	0757-0442
A3R60	0698-3160		R:FXD MET FLM 31.6K OHM 1% 1/8W	28480	0698-3160
A3R61	0757-0462	1	R:FXD MET FLM 75.0K OHM 1% 1/8W	28480	0757-0462
A4	00415-608	1	SWITCH ASSY:POWER	28480	00415-608
A4R1	0698-3161	1	R:FXD MET FLM 38.3K OHM 1% 1/8W	28480	0698-3161
A4R2	0698-3446	1	R:FXD MET FLM 383 OHM 1% 1/8W	28480	0698-3446
A4R3	0698-3156	1	R:FXD MET FLM 14.7K OHM 1% 1/8W	28480	0698-3156
A4R4	0757-0447	1	R:FXD MET FLM 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	C:FXD CER 0.05 UF +80-20% 100VDCW	91418	TA
C2	0150-0096		C:FXD CER 0.05 UF +80-20% 100VDCW	91418	TA
C3	0150-0119	2	C:FXD CER 2 X 0.01 UF 20% 250WVAC	56289	36C219A2-CDH
C4	0150-0119		C:FXD CER 2 X 0.01 UF 20% 250WVAC	56289	36C219A2-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	EAC-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	R:VAR COMP 250K 10% 20CWLOG 15K OHM20%	28480	2100-1574
R2			PART OF R1		
R3	2100-1578	1	R:VAR COMP 100K OHM 10% 20 CCWLOG 13W	28480	2100-1578
R4	2100-1577	1	R:VAR WW DUAL 1200 OHM 10% LIN TANDEM	28480	2100-1577
R5			PART OF R4		
R6	0757-0280		R:FXD MET FLM 1K OHM 1% 1/8W	28480	0757-0280
R7	0698-4037	1	R:FXD MET FLM 46.4 OHM 1% 1/8W	28480	0698-4037
R8			NOT ASSIGNED		
R60			NOT ASSIGNED		
R61	0757-0401		R:FXD MET FLM 100 OHM 1% 1/8W	28480	0757-0401
R62	0757-0401		R:FXD MET FLM 100 OHM 1% 1/8W	28480	0757-0401
S1	3101-1234	1	SWITCH:SLIDE DPDT	82389	11A-1242
T1	9100-0392	1	TRANSFORMER:POWER	28480	9100-0392
XA3	1251-0172	1	CONNECTOR:PRINTED CIRCUIT 22-CONN	28480	1251-0172
XF1	1400-0084	1	FUSEHOLDER:EXTRACTOR POST TYPE	75915	342014
			MISCELLANEOUS		
	00415-606	1	BATTERY INSTALLATION KIT	28480	00415-606
			INCLUDES SAMPLE PARTS AS INSTALLED		
			WITH OPTION 01 AND (4) 6-32 HEX NUTS		
			FOR MOUNTING		
	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	70903	KHS-7041
			OPTIONS		
			OPTION 01:		
	1420-0009		BATTERY:RECHARGEABLE 24V 1.25AH	28480	1420-0009
	00415-006	1	COVER:BATTERY(OPT 01)	28480	00415-006
	2420-0001	4	NUT:HEX ST NP 6-32 X 5/16 W/LOCKWASHER	78189	OBD
			NOTE: SEE MISC. SECTION FOR BATTERY		
			INSTALLATION KIT STOCK NUMBERS		
			OPTION 02: (J5)		
	00415-607	1	CABLE:SPECIAL PURPOSE ELECT(OPT 02)	28480	00415-607
	0360-0024	1	TERMINAL:SOLDER LUG 3/8" STUD	79963	508-H380
	1250-0001	1	CONNECTOR:RF BNC BULKHEAD MOUNT JACK	28480	1250-0001
	2420-0001		NUT:HEX ST NP 6-32 X 5/16 W/LOCKWASHER	78189	OBD
	3050-0100	1	WASHER:FLAT FOR #6 SCREW	00000	OBD
	3050-0018	2	WASHER:EXTRUDED FIBER	00000	OBD
	5040-0701	1	GAIN VERNIER FRAME	28480	5040-0701
	3101-0032	1	SWITCH:BIAS (SPECIAL H05)	28480	3101-0032
	5020-0705	1	METER TRIM (TOP RAIL)	28480	5020-0705
	1120-1514	1	METER (SPECIAL H05)	28480	1120-1514
	00415-007	1	BRACKET SHIELD FOR POWER SWITCH	28480	00415-007
	7120-2359	1	NAME PLATE SERIAL #	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	1	FRAME ASSY:6 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
	2370-0C15	2	SCREW:FH SLOT OR 6-32 X 0.375" LG	00000	080
6	5000-0703	1	SIDE COVER	28480	5000-0703
	2370-0020	1	SCREW:SST FH PHIL OR 6-32 X 3/16	00000	080
7	5060-0720	1	COVER:HALF-RECESS TOP	28480	5060-0720
	2370-0016	2	SCREW:FLAT HD PHIL OR 6-32 X 5/16" LG	00000	080
8	5000-0717	1	COVER:HALF-MODULE BOTTOM	28480	5000-0717
	2370-0016		SCREW:FLAT HD PHIL OR 6-32 X 5/16" LG	00000	080
9	00415-00012	2	PANEL:REAR	28480	00415-00012
	2370-0015		SCREW:FH SLOT OR 6-32 X 0.375" LG	00000	080
10	00415-002	1	PANEL:FRONT	28480	00415-002
	2370-0002	1	SCREW:FH SLOT OR 6-32 X 0.375" LG	00000	080
11	5020-0705	1	METER TRIM:TOP RAIL	28480	5020-0705
12	00415-001	1	"GAIN VERNIER"PLATE	28480	00415-001
13	5040-0701	1	"GAIN VERNIER" PLATE TRIM BOX BLACK	28480	5040-0701
14	1120-0392	1	METER	28480	1120-0392



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
00000	U.S.A. Common	Any Supplier of U.S.A.
01295	Texas Instruments Inc. Semiconductor Components Division	Dallas, Texas 75231
04713	Motorola Semiconductor Products Inc.	Phoenix, Ariz. 85008
07263	Fairchild Camera and Instrument Corp., Semiconductor Division	Mountain View, Cal. 94040
24931	Specialty Connector Co., Inc.	Indianapolis, Ind. 46227
28480	Hewlett-Packard Co.	Palo Alto, Cal. 94304
56289	Sprague Electric Co.	N. Adams, Mass. 01247
70903	Belden Corp.	Chicago, Ill. 60644
75915	Littlefuse Inc.	Des Plaines, Ill. 60016
78189	Shakeproof Division Illinois Tool Works	Elgin, Ill. 60120
79963	Zierick Mfg. Co.	Mt. Kisco, N.Y. 10549
82389	Switchcraft Inc.	Chicago, Ill. 60630
84411	TRW Capacitor Div.	Ogallala, Neb. 69153
91418	Radio Material Co.	Chicago, Ill. 60646
93332	Sylvania Electric Products Inc., Semicodncutor 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 siwtch to OFF and remove power plug from 415E.

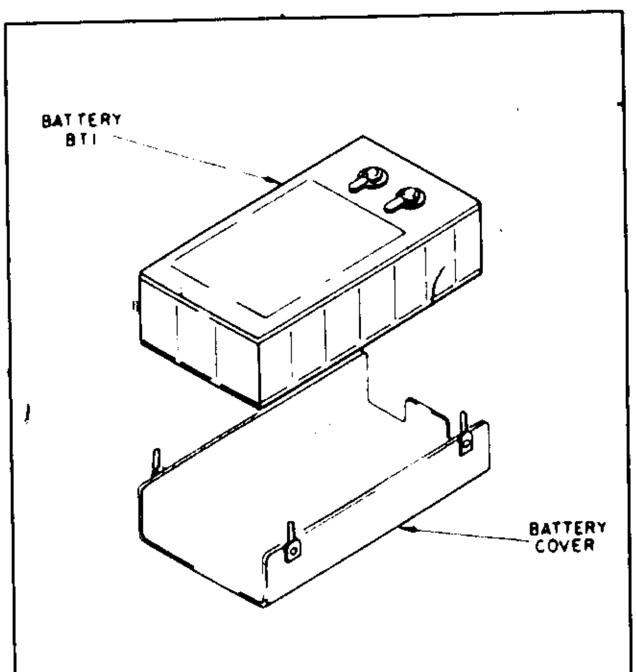


Figure I-1 Battery Cover Assembly

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.

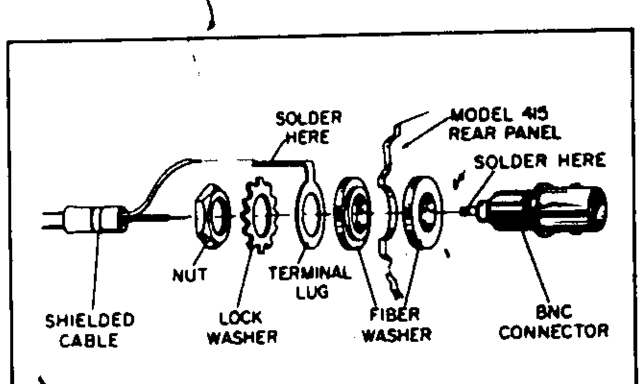


Figure I-2. Connector Assembly.

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°). 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 μF +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.

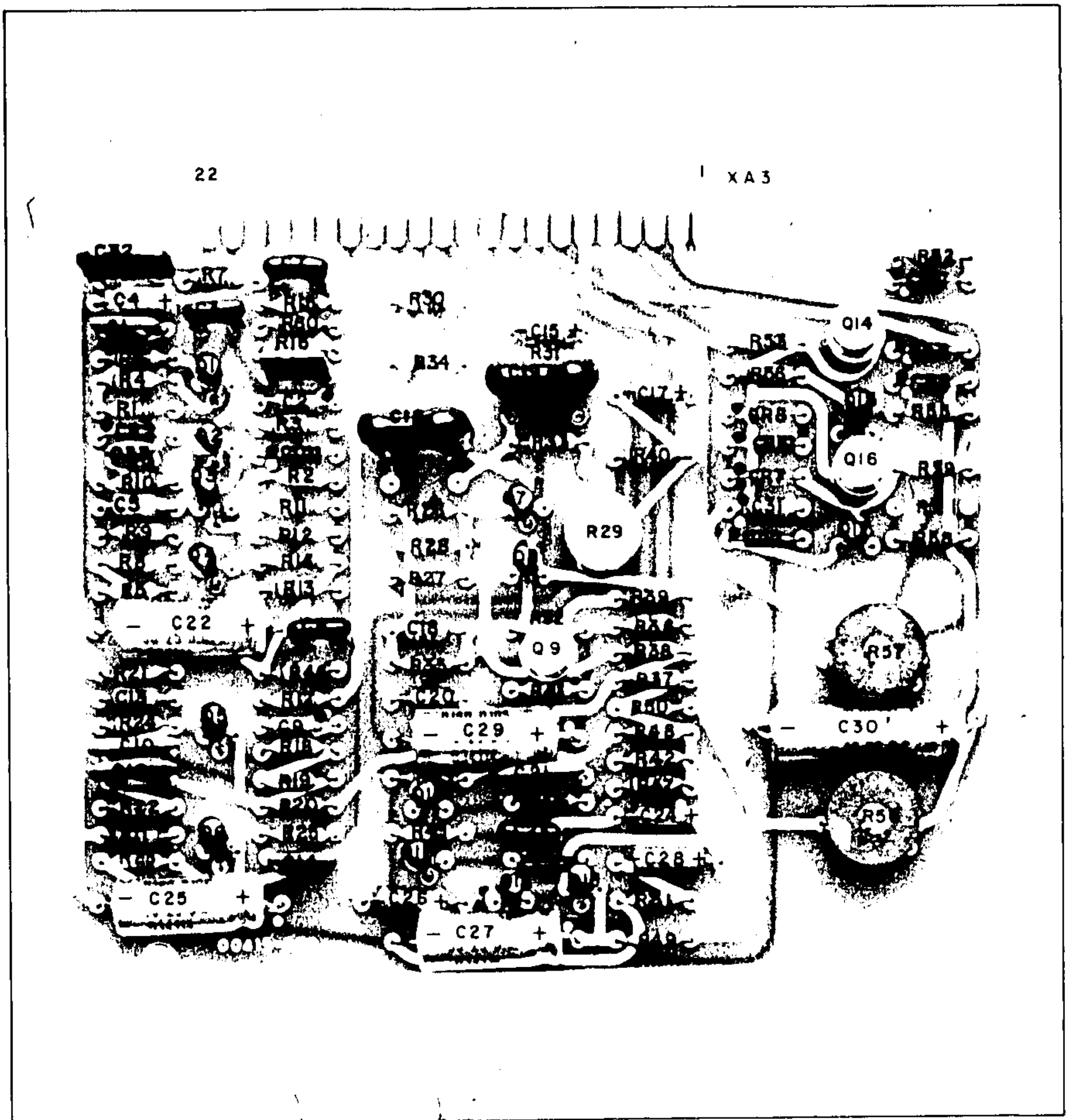


Figure II-1 A3 Circuit Board Component Locations for Instruments with Serials Prefixed 530

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. 1450-0119 (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 hp PACKARD

Printed in U.S.A.

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)

ELECTRONIC

SALES & SERVICE OFFICES

UNITED STATES

ALABAMA
P O Box 4207
2003 Byrd Spring Road S W
Huntsville 35802
Tel: (205) 881 4591
TWX 810-726-2204

ARIZONA
2336 E Magnolia St
Phoenix 85034
Tel (602) 252 5061
TWX 910-951 1330

5737 East Broadway
Tucson 85716
Tel (602) 298 7313
TWX 910 952 1162

CALIFORNIA
1430 East Orangethorpe Ave
Fullerton 92631
Tel (714) 870-1000

3939 Lankershim Boulevard
North Hollywood 91604
Tel (213) 877-1282
TWX 910-499-2170

1101 Embarcadero Road
Palo Alto 94303
Tel (415) 327 6500
TWX 910-373 1280

2220 Watt Ave
Sacramento 95825
Tel (916) 482 1463
TWX 910 367 2092

9606 Aero Drive
San Diego 92123
Tel (714) 279-3200
TWX 910 335 2000

COLORADO
7965 East Prentice
Englewood 80110
Tel (303) 771 3455
TWX 910-935 0705

CONNECTICUT
12 Lunar Drive
New Haven 06525
Tel (203) 389-6551
TWX 710-465-2029

FLORIDA
P O Box 24210
2806 W Oakland Park Blvd
Ft. Lauderdale 33307
Tel (305) 731-2020
TWX 510-955 4099

P O Box 13910
6177 Lake Ellenor Dr
Orlando, 32809
Tel: (305) 859 2900
TWX: 810-850-0113

GEORGIA
P.O Box 28234
450 Interstate North
Atlanta 30328
Tel: (404) 436-6181
TWX: 810-766-4890

HAWAII
2875 So King Street
Honolulu 96814
Tel (808) 955 4455

ILLINOIS
5500 Howard Street
Skokie 60076
Tel (312) 677 0400
TWX 910-223 3613

INDIANA
3839 Meadows Drive
Indianapolis 46205
Tel (317) 546-4891
TWX 810-341 3263

LOUISIANA
P O Box 856
1942 Williams Boulevard
Kenner 70062
Tel (504) 721 6201
TWX 810-955-5524

MARYLAND
6707 Whitestone Road
Baltimore 21207
Tel (301) 944-5400
TWX 710-862-9157

P O Box 1648
2 Choke Cherry Road
Rockville 20850
Tel (301) 948-6370
TWX 710-828-9684

MASSACHUSETTS
32 Hartwell Ave
Lexington 02173
Tel (617) 861 8960
TWX 710-326 6904

MICHIGAN
21840 West Nine Mile Road
Southfield 48075
Tel (313) 353-9100
TWX 810 224-4882

MINNESOTA
2459 University Avenue
St. Paul 55114
Tel (612) 645-9461
TWX 910-563 3734

MISSOURI
11131 Colorado Ave
Kansas City 64137
Tel: (816) 763-8000
TWX 910-771 2087

148 Weldon Parkway
Maryland Heights 63043
Tel: (314) 567-1455
TWX 910-764-0830

NEW JERSEY
W 120 Century Road
Paramus 07652
Tel (201) 265-5000
TWX 710-990-4951

1060 N Kings Highway
Cherry Hill 08034
Tel (609) 667-4000
TWX 710-892-4945

NEW MEXICO
P O Box 8366
Station C
6501 Lomas Boulevard N E
Albuquerque 87108
Tel (505) 265-3713
TWX 910-989-1665

156 Wyatt Drive
Las Cruces 88001
Tel. (505) 526-2485
TWX 910-983-0550

NEW YORK
6 Automation Lane
Computer Park
Albany 12205
Tel (518) 458 1550
TWX 710-441 8270

1219 Campville Road
Endicott 13760
Tel (607) 754-0050
TWX 510-252-0890

82 Washington Street
Poughkeepsie 12601
Tel (914) 454-7330
TWX 510-248-0012

39 Saginaw Drive
Rochester 14623
Tel (716) 473-9500
TWX 510-253-5981

5858 East Molloy Road
Syracuse 13211
Tel (315) 454-2486
TWX 710-541-0482

1 Crossways Park West
Woodbury 11797
Tel (516) 921-0300
TWX 510-223-0811

NORTH CAROLINA
P O Box 5188
1923 North Main Street
High Point 27262
Tel: (919) 885-8101
TWX 510-926-1516

OHIO
25575 Center Ridge Road
Cleveland 44145
Tel: (216) 835-0300
TWX 810-427-9129

3460 South Dixie Drive
Dayton 45439
Tel: (513) 298-0351
TWX 810-459-1925

1120 Morse Road
Columbus 43229
Tel (614) 846-1300

OKLAHOMA
6301 N Meridian Avenue
Oklahoma City 73122
Tel (405) 721-0200
TWX 910-830-6862

OREGON
Westhills Mall, Suite 158
4475 S.W. Scholls Ferry Road
Portland 97225
Tel: (503) 292-9171
TWX 910-464-6103

PENNSYLVANIA
2500 Moss Side Boulevard
Monroeville 15146
Tel (412) 271-0724
TWX 710-797-3650

1021 8th Avenue
King of Prussia Industrial Park
King of Prussia 19406
Tel: (215) 265-7000
TWX 510-660-2670

RHODE ISLAND
873 Waterman Ave
East Providence 02914
Tel (401) 434-5535
TWX 710-381-7573

***TENNESSEE**
Memphis
Tel (901) 274-7472

TEXAS
P O Box 1270
201 E. Arapaho Rd.
Richardson 75080
Tel: (214) 231-6101
TWX 910-867-4723

P O Box 27409
6300 Westpark Drive
Suite 100
Houston 77027
Tel: (713) 781-6000
TWX 910-881-2645

231 Billy Mitchell Road
San Antonio 78226
Tel: (512) 434-4171
TWX 910-871-1170

UTAH
2890 South Main Street
Salt Lake City 84115
Tel: (801) 487-0715
TWX 910-925-5681

VERMONT
P.O. Box 2287
Kennedy Drive
South Burlington 05401
Tel: (802) 658-4455
TWX 510-299-0025

VIRGINIA
P.O. Box 6514
2111 Spencer Road
Richmond 23230
Tel: (703) 285-3431
TWX 710-956-0157

WASHINGTON
433-108th N.E.
Bellevue 98004
Tel: (206) 454-3971
TWX 910-443-2303

***WEST VIRGINIA**
Charleston
Tel: (304) 768-1232

FOR U.S. AREAS NOT LISTED:
Contact the regional office nearest you: Atlanta, Georgia North Hollywood, California Paramus, New Jersey ... Skokie, Illinois. Their complete addresses are listed above

*Service Only

CANADA

ALBERTA
Hewlett-Packard (Canada) Ltd
11748 Kingsway Ave
Edmonton
Tel (403) 452-3670
TWX 610-831-2431

BRITISH COLUMBIA
Hewlett-Packard (Canada) Ltd
4519 Canada Way
North Burnaby 2
Tel (604) 433-8213
TWX 610-922-5059

MANITOBA
Hewlett-Packard (Canada) Ltd
513 Century St
Winnipeg
Tel (204) 786 7581
TWX 610-671 3531

NOVA SCOTIA
Hewlett-Packard (Canada) Ltd
2745 Dutch Village Rd
Suite 206
Halifax
Tel. (902) 455-0511
TWX 610-271 4482

ONTARIO
Hewlett-Packard (Canada) Ltd
1785 Woodward Dr
Ottawa 3
Tel: (613) 255-6180, 255 6530
TWX 610-562-1952

Hewlett-Packard (Canada) Ltd
50 Galaxy Blvd
Rexdale
Tel: (416) 677-9611
TWX 610-492-4246

QUEBEC
Hewlett-Packard (Canada) Ltd
275 Hymus Boulevard
Pointe Claire
Tel (514) 697-4232
TWX 610-422-3022
Telex: 01-20607

FOR CANADIAN AREAS NOT LISTED:
Contact Hewlett-Packard (Canada) Ltd. in Pointe Claire, at the complete address listed above.

CENTRAL AND SOUTH AMERICA

ARGENTINA
Hewlett-Packard Argentina
S.A.C.e.I
Lavalle 1171 - 3
Buenos Aires
Tel: 35-0436, 35-0627, 35-0431
Telex 012-1009
Cable HEWPACK ARG

BRAZIL
Hewlett-Packard Do Brasil
I.e.C Ltda
Rua Frei Caneca 1119
Sao Paulo 3, SP
Tel: 288-7111, 287-5858
Cable HEWPACK Sao Paulo

Hewlett-Packard Do Brasil
Praca Dom Feliciano 78
Salas 806/808
Porto Alegre
Rio Grande do Sul (RS)-Brasil
Tel: 25-8470
Cable: HEWPACK Porto Alegre

Hewlett-Packard Do Brasil
I.e.C. Ltda.
Rua da Matriz 29
Botafogo ZC-02
Rio de Janeiro, GB
Tel 246-4417, 246-2919
Cable HEWPACK Rio de Janeiro

CHILE
Héctor Calcagni y Cia, Ltda
Casilla 16 475
Santiago
Tel: 423 96
Cable: CALCAGNI Santiago

COLOMBIA
Instrumentacion
Henrik A. Langebaek & Kier S A
Carrera 7 No. 48-59
Apartado Aereo 6287
Bogota, 1 D.E
Tel: 45-78-06, 45-55-46
Cable: AARIS Bogota
Telex 44400INSTCO

COSTA RICA
Lic. Alfredo Gallegos Gurdián
Apartado 10159
San José
Tel: 21-86-13
Cable: GALGUR San José

ECUADOR
Laboratorios de Radio-Ingenieria
Calle Guayaquil 1246
Post Office Box 3199
Quito
Tel: 212-496, 219-185
Cable: HORVATH Quito

EL SALVADOR
Electronic Associates
Apartado Postal 1682
Centro Comercial Gigante
San Salvador, El Salvador C A
Paseo Escalon 4649-4° Piso
Tel: 23-44-60, 23-32-37
Cable ELECAS

GUATEMALA
IPESA
5a via 2-01, Zona 4
Guatemala City
Tel: 63-6-27 & 64-7-86
Telex 4176 Mahohegu

MEXICO
Hewlett-Packard Mexicana S A de C V
622 Adolfo Prieto
Col del Valle
Mexico 12, D.F
Tel: 543-4232; 523-1874
Telex 017 74-507

NICARAGUA
Roberto Terán G
Apartado Postal 689
Edificio Terán
Managua
Tel 3451 3452
Cable ROTERAN Managua

PANAMA
Electrónico Balboa, S.A
P.O. Box 4929
Ave. Manuel Espinosa No. 13-50
Bldg. Alina
Panama City
Tel 230833
Telex 3481003, Curundu Canal Zone
Cable ELECTRON Panama City

PARAGUAY
Z.J. Melamed S.R.L
Division Aparatos y Equipos Medicos
Salon de Exposicion y Escritorio
Chile 482
Edificio Victoria Planta Baja
Asuncion, Paraguay
Tel 4-5069, 4-6272
Cable RAMEL

PERU
Compañia Electro Medica S.A
Ave Enrique Canaval 312
San Isidro
Casilla 1030
Lima
Tel: 22-3900
Cable: ELMED Lima

PUERTO RICO
San Juan Electronics, Inc
P.O. Box 5167
Ponce de Leon 154
Pda. 3-PTA de Tierra
San Juan 00906
Tel: (809) 725-3342, 722-3342
Cable: SATRONICS San Juan
Telex SATRON 3450 332

URUGUAY
Pablo Ferrando S.A.
Comercial e Industrial
Avenida Italia 2877
Casilla de Correo 370
Montevideo
Tel: 40-3102
Cable: RADIUM Montevideo

VENEZUELA
Hewlett-Packard De Venezuela C.A.
Apartado 50933
Caracas
Tel: 71.88.05, 71.88.69, 71.99.30
Cable: HEWPACK Caracas
Telex: 21146 HEWPACK

FOR AREAS NOT LISTED,

CONTACT:
Hewlett-Packard
INTERCONTINENTAL
3200 Hillview Ave.
Palo Alto, California 94304
Tel: (415) 493-1501
TWX: 910-373-1267
Cable: HEWPACK Palo Alto
Telex: 034-8300, 034-8493

EUROPE

AUSTRIA
Hewlett-Packard Ges.m.b.H
Handelskai 52/3
P.O. Box 7
A-1205 Vienna
Tel: (0222) 33 66 06 to 09
Cable: HEWPAK Vienna
Telex: 75923 hewpak a

BELGIUM
Hewlett-Packard Benelux S.A./N.V.
Avenue du Col-Vert, 1
B-1170 Brussels
Tel: (02) 72 22 40
Cable: PALOBEN Brussels
Telex: 23 494

DENMARK
Hewlett-Packard A/S
Datavej 38
DK-3460 Birkerod
Tel: (01) 81 66 40
Cable: HEWPACK AS
Telex: 16640 hp as

Hewlett-Packard A/S
Torvet 9
DK-8600 Silkeborg
Tel: (06)-82-71-66
Telex: 16640 hp as
Cable: HEWPACKAS

FINLAND
Hewlett-Packard Oy
Bulevardi 26
P.O. Box 12185
SF-00120 Helsinki 12
Tel: (90) 13730
Cable: HEWPACKOY Helsinki
Telex: 12-1563 hel

FRANCE
Hewlett-Packard France
Quartier de Courtaboeuf
Boite Postale No. 6
F-91401 Orsay
Tel: (1) 907 78 25
Cable: HEWPACK Orsay
Telex: 60048

Hewlett-Packard France
4 Quai des Etroits
F-69321 Lyon Cedex 1
Tel: (78) 42 63 45
Cable: HEWPACK Lyon
Telex: 31617

Hewlett-Packard France
29 rue de la Gare
F-31700 Blagnac
Tel: (61) 85 82 29
Telex: 51957

GERMAN FEDERAL REPUBLIC
Hewlett-Packard Vertriebs-GmbH
Berliner Strasse 117
Postfach 560 140
D-6 Nieder-Eschbach, Ffm 56
Tel: (0611) 50-04-1
Cable: HEWPACKSA Frankfurt
Telex: 41 32 49 FRA

Hewlett-Packard Vertriebs-GmbH
Herrenbergerstrasse 110
D-7030 Böblingen, Württemberg
Tel: (07031) 66 72 87
Cable: HEPAK Böblingen
Telex: 72 65 739 bbn

Hewlett-Packard Vertriebs-GmbH
Vogelsanger Weg 38
D-4 Düsseldorf
Tel: (0211) 63 80 31 35
Telex: 85/86 533 hpdd d

Hewlett-Packard Vertriebs-GmbH
Wendenstr. 23
D-2 Hamburg 1
Tel: (0411) 24 05 51/52
Cable: HEWPACKSA Hamburg
Telex: 21 53 032 hphh d

Hewlett-Packard Vertriebs-GmbH
Unterhachinger Strasse 28
ISAR Center
D-8012 Ottobrunn
Tel: (0811) 601 30 61/7
Telex: 52 49 85
Cable: HEWPACKSA Muchen

(West Berlin)
Hewlett-Packard Vertriebs-GmbH
Wilmersdorfer Strasse 113/114
D-1000 Berlin W. 12
Tel: (0311) 3137046
Telex: 18 34 05 hpbln d

GREECE
Kostas Karayannis
18, Ermou Street
Athens 126
Tel: 3230-303
Cable: RAKAR Athens
Telex: 21 59 62 rkar gr

IRELAND
Hewlett-Packard Ltd
224 Bath Road
Slough, SL1 4 DS, Bucks
Tel: Slough (0753) 33341
Cable: HEWPIE Slough
Telex: 84413

Hewlett-Packard Ltd
The Graftons
Stamford New Road
Altrincham, Cheshire, England
Tel: (061) 928 8626
Telex: 668068

ITALY
Hewlett-Packard Italiana S.p.A
Via Amerigo Vespucci 2
I 20124 Milan
Tel: (2) 6251 (10 lines)
Cable: HEWPACKIT Milan
Telex: 32046

Hewlett-Packard Italiana S.p.A
Piazza Marconi
I-00144 Rome - Eur
Tel: (6) 5912544/5, 5915947
Cable: HEWPACKIT Rome
Telex: 61514

Hewlett-Packard Italiana S.p.A
Vicolo Pastori, 3
I-35100 Padova
Tel: (49) 66 40 62
Telex: 32046 via Milan

Hewlett-Packard Italiana S.p.A
Via Colli, 24
I-10129 Turin
Tel: (11) 53 82 64
Telex: 32046 via Milan

LUXEMBURG
Hewlett-Packard Benelux
S.A./N.V.
Avenue du Col-Vert, 1
B-1170 Brussels
Tel: (03 02) 72 22 40
Cable: PALOBEN Brussels
Telex: 23 494

NETHERLANDS
Hewlett-Packard Benelux N.V.
Weerdestein 117
P.O. Box 7825
Amsterdam, Z 11
Tel: 020-42 77 77
Cable: PALOBEN Amsterdam
Telex: 13 216 hepa nl

NORWAY
Hewlett-Packard Norge A/S
Box 149
Nesveien 13
N-1344 Haslum
Tel: (02)-53 83 60
Telex: 16621 hpnas n

PORTUGAL
Telectra-Empresa Tecnica de Equipamentos Electricos S.a.r.l.
Rua Rodrigo da Fonseca 103
P.O. Box 2531
P-Lisbon 1
Tel: (19) 68 60 72
Cable: TELECTRA Lisbon
Telex: 1598

SPAIN
Hewlett-Packard Española, S.A.
Jerez No 8
Madrid 16
Tel: 458 26 00
Telex: 23515 hpe

Hewlett-Packard Española, S.A.
Milanesado 21-23
E-Barcelona 17
Tel: (3) 203 62 00
Telex: 52603 hpbe e

SWEDEN
Hewlett-Packard Sverige AB
Enighetsvägen 1-3
Fack
S-161 20 Bromma 20
Tel: (08) 98 12 50
Cable: MEASUREMENTS Stockholm
Telex: 10721

Hewlett-Packard Sverige AB
Hagakersgatan 9C
S-431 41 Mölndal
Tel: (031) 27 68 00/01
Telex: 21 312 hpmindl s

SWITZERLAND
Hewlett-Packard (Schweiz) AG
Zürcherstrasse 20
P.O. Box 64
CH-8952 Schlieren Zurich
Tel: (01) 98 18 21/24
Cable: HPAG CH
Telex: 53933 hpag ch

Hewlett-Packard (Schweiz) AG
Rue du Bois-du-Lan 7
P.O. Box 85
1217 Meyrin 2 Geneva
Tel: (022) 41 54 00
Cable: HEWPACKSA Geneva
Telex: 27333 hpsa ch

TURKEY
Telekom Engineering Bureau
Saglik Sok No. 15/1
Ayaspasa-Beyoglu
P.O. Box 437 Beyoglu
Istanbul
Tel: 49 40 40
Cable: TELEMATION Istanbul

UNITED KINGDOM
Hewlett-Packard Ltd.
224 Bath Road
Slough, SL1 4 DS, Bucks
Tel: Slough (0753) 33341
Cable: HEWPIE Slough
Telex: 84413

Hewlett-Packard Ltd
The Graftons
Stamford New Road
Altrincham, Cheshire
Tel: (061) 928-8626
Telex: 668068

SOCIALIST COUNTRIES PLEASE CONTACT:
Hewlett-Packard Ges.m.b.H
Handelskai 52/3
P.O. Box 7
A-1205 Vienna
Ph: (0222) 33 66 06 to 09
Cable: HEWPACK Vienna
Telex: 75923 hewpak a

ALL OTHER EUROPEAN COUNTRIES CONTACT:
Hewlett-Packard S.A.
Rue du Bois-du-Lan 7
P.O. Box 85
CH-1217 Meyrin 2 Geneva
Switzerland
Tel: (022) 41 54 00
Cable: HEWPACKSA Geneva
Telex: 2 24 86

AFRICA, ASIA, AUSTRALIA

ANGOLA
Telectra-Empresa Técnica de Equipamentos Eléctricos SAR
Rua de Barbosa Rodrigues 42-1°
Box 6487
Luanda
Cable: TELECTRA Luanda

AUSTRALIA
Hewlett-Packard Australia Pty. Ltd.
22-26 Weir Street
Glen Iris, 3146
Victoria
Tel: 20-1371 (6 lines)
Cable: HEWPARD Melbourne
Telex: 31 024

Hewlett-Packard Australia Pty. Ltd.
Corner Bridge & West Streets
Pymble, New South Wales, 2073
Tel: 449 6566
Cable: HEWPARD Sydney
Telex: 21561

Hewlett-Packard Australia Pty. Ltd.
97 Churchill Road
Prospect 5082
South Australia
Tel: 65-2366
Cable: HEWPARD Adelaide

Hewlett-Packard Australia Pty. Ltd.
2nd Floor, Suite 13
Casablanca Buildings
196 Adelaide Terrace
Perth, W.A. 6000
Tel: 25-6800
Cable: HEWPARD Perth

Hewlett-Packard Australia Pty. Ltd.
10 Woolley Street
P.O. Box 191
Dickson A.C.T. 2602
Tel: 49-8194
Cable: HEWPARD Canberra ACT

Hewlett-Packard Australia Pty. Ltd.
5 Harvard Street
P.O. Box 135
Kenmore 4069 Queensland
Tel: 70-4050

CEYLON
United Electricals Ltd.
P.O. Box 681
Yahala Building
Staples Street
Colombo 2
Tel: 26696
Cable: HOTPOINT Colombo

CYPRUS
Kypronics
19 Gregorios & Xenopoulos Road
P.O. Box 1152
Nicosia
Tel: 45628/29
Cable: Kypronics Pandehis

ETHIOPIA
African Salespower & Agency Private Ltd., Co.
P.O. Box 718
58/59 Cunningham St.
Addis Ababa
Tel: 12285
Cable: ASACO Addisababa

HONG KONG
Schmidt & Co. (Hong Kong) Ltd.
P.O. Box 297
1511, Prince's Building 15th Floor
10, Chater Road
Hong Kong
Tel: 240168, 232735
Cable: SCHMIDTCO Hong Kong

INDIA
Blue Star Ltd.
Kasturi Buildings
Jamshedji Tata Rd.
Bombay 20BR, India
Tel: 29 50 21
Telex: 3751
Cable: BLUEFROST

Blue Star Ltd.
Band Box House
Prabhadevi
Bombay 25DD, India
Tel: 45 73 01
Telex: 3751
Cable: BLUESTAR

Blue Star Ltd.
14/40 Civil Lines
Kanpur, India
Tel: 6 88 82
Cable: BLUESTAR

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

Blue Star Ltd.
Blue Star House
34 Ring Road
Lajpat Nagar
New Delhi 24, India
Tel: 62 32 76
Telex: 463
Cable: BLUESTAR

Blue Star Ltd.
Blue Star House
11/11A Magarath Road
Bangalore, 25
Tel: 51473
Telex: 430
Cable: BLUESTAR

Blue Star, Ltd.
1-1-117/1
Sarojini Devi Road
Secunderabad 3
Tel: 7 63 91, 7 73 93
Cable: BLUEFROST

Blue Star Ltd.
23/24 Second Line Beach
Madras 1, India
Tel: 2 39 55
Telex: 379
Cable: BLUESTAR

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

INDONESIA
Bah Bolon Trading Coy. N.V.
Djalah Merdeka 29
Bandung
Tel: 4915, 51560
Cable: ILMU
Telex: 08-809

IRAN
Multicorp International Ltd.
Avenue Soraya 130
P.O. Box 1212
Teheran
Tel: 83 10 35-39
Cable: MULTICORP Tehran
Telex: 2893 mci tn

ISRAEL
Electronics & Engineering Div. of Motorola Israel Ltd.
17 Aminadav Street
Tel-Aviv
Tel: 36941 (3 lines)
Cable: BASTEL Tel-Aviv
Telex: MOTIL IL

JAPAN
Yokogawa-Hewlett-Packard Ltd.
Ohashi Building
1-59-1 Yoyogi
Shibuya-ku, Tokyo
Tel: 03-370-2281/92
Telex: 232-2024YHP
Cable: YHPMARKET TOK 23-724

Yokogawa-Hewlett-Packard Ltd.
Nisei Ibaragi Bldg.
2-2-8 Kasuga
Ibaragi-Shi
Osaka
Tel: (0726) 23-1641
Telex: 5332-385 YHP OSAKA

Yokogawa-Hewlett-Packard Ltd.
Ito Building
No. 59, Kotori-cho
Nakamura-ku, Nagoya City
Tel: (052) 551-0215

Yokogawa-Hewlett-Packard Ltd.
Nitto Bldg.
2-4-2 Shinohara-Kita
Kohoku-ku
Yokohama 222
Tel: 045-432-1504
Telex: 382-3204 YHP YOK

Yokogawa-Hewlett-Packard Ltd.
Chuo Bldg.
Rm. 603 3
2 Chome
IZUMI-CHO,
Mito, 310
Tel: 0292-25-7470

KENYA
Kenya Kinetics
P.O. Box 18311
Nairobi, Kenya
Tel: 57726
Cable: PROTON

KOREA
American Trading Company Korea, Ltd.
Industrial Products Div.
Seoul P.O. Box 1103
8th Floor, DaeKyung Bldg.
107 Sejong Ro
Chongro Ku, Seoul
Tel: 75-8924/7
Cable: AMTRACO Seoul

LEBANON
Constantin E. Macridis
P.O. Box 7213
RL-Beirut
Tel: 220846
Cable: ELECTRONUCLEAR Beirut

MALAYSIA
MECOMB Malaysia Ltd.
2 Lorong 13/6A
Section 13
Petaling Jaya, Selangor
Cable: MECOMB Kuala Lumpur

MOZAMBIQUE
A. N. Goncalves, LDA
4.1 Apt. 14 Av. D. Luis
P.O. Box 107
Lourenco Marques
Cable: NEGON

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

Hewlett-Packard (N.Z.) Ltd.
Box 51092
Pukuranga
Tel: 56-9837
Cable: HEWPACK, Auckland

PAKISTAN
Mushko & Company, Ltd.
Oosman Chambers
Abdullah Haroon Road
Karachi 3
Tel: 511027, 512927
Cable: COOPERATOR Karachi

Mushko & Company, Ltd.
388, Satellite Town
Rawalpindi
Tel: 41924
Cable: FEMUS Rawalpindi

PHILIPPINES
Electromex Inc.
5th Floor, Architects Center Bldg.
Ayala Ave., Makati, Rizal
C.C.P.O. Box 1028
Makati, Rizal
Tel: 86-18-87, 87-76-77
Cable: ELEMEX Manila

SINGAPORE
Mechanical and Combustion Engineering Company Ltd.
9, Jalan Kilang
Red Hill Industrial Estate
Singapore, 3
Tel: 642361-3, 63261
Cable: MECOMB Singapore

Hewlett-Packard Far East Area Office
P.O. Box 87
Alexandra Post Office
Singapore 3
Tel: 633022
Cable: HEWPACK SINGAPORE

SOUTH AFRICA
Hewlett Packard South Africa (Pty.), Ltd.
P.O. Box 31716
Braamfontein Transvaal
Milnerton
30 De Beer Street
Johannesburg
Tel: 725-2080, 725-2030
Telex: 0226 JH
Cable: HEWPACK Johannesburg

Hewlett Packard South Africa (Pty.), Ltd.
Breecastle House
Bree Street
Cape Town
Tel: 3-6019, 3-6545
Cable: HEWPACK Cape Town
Telex: 5-0006

Hewlett Packard South Africa (Pty.), Ltd.
641 Ridge Road, Durban
P.O. Box 99
Overport, Natal
Tel: 88-6102
Telex: 567954
Cable: HEWPACK

TAIWAN
Hewlett Packard Taiwan
39 Chung Shiao West Road
Sec. 1
Overseas Insurance Corp. Bldg. 7th Floor
Taipei
Tel: 389160,1,2, 375121
Ext. 240-249
Telex: TP824 HEWPACK
Cable: HEWPACK Taipei

THAILAND
UNIMESA Co., Ltd.
Chongkolnee Building
56 Suriwongse Road
Bangkok
Tel: 37956, 31300, 31307, 37540
Cable: UNIMESA Bangkok

UGANDA
Uganda Tele-Electric Co., Ltd.
P.O. Box 4449
Kampala
Tel: 57279
Cable: COMCO Kampala

VIETNAM
Peninsular Trading Inc.
P.O. Box H-3
216 Hien-Vuong
Saigon
Tel: 20-805, 93398
Cable: PENTRA, SAIGON 242

ZAMBIA
R. J. Tilbury (Zambia) Ltd.
P.O. Box 2792
Lusaka
Zambia, Central Africa
Tel: 73793
Cable: ARJAYTEE, Lusaka

MEDITERRANEAN AND MIDDLE EAST COUNTRIES NOT SHOWN PLEASE CONTACT:
Hewlett-Packard
Co-ordination Office for Mediterranean and Middle East Operations
Via Marocco, 7
I-00144 Rome-Eur, Italy
Tel: (6) 59 40 29
Cable: HEWPACKIT Rome
Telex: 61514

OTHER AREAS NOT LISTED, CONTACT:
Hewlett-Packard INTERCONTINENTAL
3200 Hillview Ave.
Palo Alto, California 94304
Tel: (415) 326-7000
(Feb. 71 493-1501)
TWX: 910-373-1267
Cable: HEWPACK Palo Alto
Telex: 034-8300, 034-8493

END