OPERATING AND SERVICE MANUAL

MODEL 415E
SWR METER

SERIALS PREFIXED: 719-

See Appendix I and II at rear of manual for:
a) 415E Options 01, 02, and
b) Serials Prefixed 530-, 545-

02152-4 00415-90007 Printed: JUNE 1967

LIST OF ILLUSTRATIONS

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Figure 1-1. Model 415E SWR Meter

Table 1-1. Specifications

Sensitivity: 0.15 μv rms at maximum bandwidth (1 μv rms on high impedance crystal input).

Noise: At least 7.5 db below full scale at rated sensitivity and maximum bandwidth with input terminated in optimum source impedance (see Input). 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 expand scales, determined by inherent meter resolution on normal scales.

Input: Unbiased low and high impedance crystal (100 and 5000 ohm optimum source impedance respectively); biased crystal (1 v 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 cps, adjustable 7%. Other frequencies between 400 and 2500 cps available on special order.

Bandwidth: Variable, 15 to 130 cps. Typically less than 0.5 db change in gain from minimum to maximum bandwidth.

Recorder Output: 0 to 1V, 1000 ohms source impedance, BNC female.

Amplifier Output: 0 to 0.3V rms (NORM), 0 to 0.8 rms (EXPAND) into at least 10K ohms, dual banana jacks.

Meter Scales: Calibrated for square-law detectors. SWR: 1 to 4, 3.2 to 10 (NORM); 1 to 1.24 (EXPAND). DB: 0 to 10 (NORM); 0 to 2.0 (EXPAND). Battery: charge state.

Meter Movement: 0.25% movement, taut-band suspension, mirror-backed scale with expanded db and swr scales greater than 4-1/4 in. (108 mm) long.

Power: 115 or 230 volts ±10%, 50 to 400 cps, 2 watts. Power line frequency or multiples thereof must not be at the tuned amplifier frequency. Optional rechargeable battery provides up to 36 hours continuous operation.

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

Weight: Net 7-7/8 lb (3, 5 kg), 9-7/8 lb (4, 4 kg) with battery.

Options:

01. Rechargeable battery installed.

02. Rear-panel input connector in parallel with the front-panel connector.

SECTION I
GENERAL INFORMATION

1-1. INTRODUCTION.

1-2. The Model 415E 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 attenuation. In addition, because of the high-sensitivity and tuned amplifier, it can be used as a null detector for audio frequency bridges. The Model 415E is shown in Figure 1-1. Operating Specifications for the Model 415E are given in Table 1-1.

1-3. The Model 415E is a tuned audio amplifier designed to operate at a mean center frequency of 1000 cps (Hz), adjustable 7% with a variable bandwidth of from 15 to 130 cps (Hz). Operating center frequency and bandwidth are both variable at instrument front panel. Tuned amplifier gain is only slightly changed due to any change in bandwidth and is typically less than 0.5 db. In addition to the front panel meter readout provided by the SWR Meter, two rear panel outputs are also available: An AC amplifier output is provided to allow using the 415E as a high-gain (126 db) tuned amplifier; a DC recorder output providing a convenient means of obtaining a permanent record of measurement data. Either or both of these rear panel outputs can be used without affecting instrument meter operation provided power line ground is not connected to the instrument through either rear panel connector.

1-4. INSTRUMENTS COVERED BY MANUAL.

1-5. This manual applies directly to the Model 415E SWR Meters having serial numbers prefixed 719 (first three numbers of serial number). If the serial prefix on your instrument is other than 719, 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 lists at the 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 719.

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 and/or 02, described below, is also included.

a. Option 01: 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 2-17).

b. Option 02: Additional input connector on rear panel wired 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 2-17).

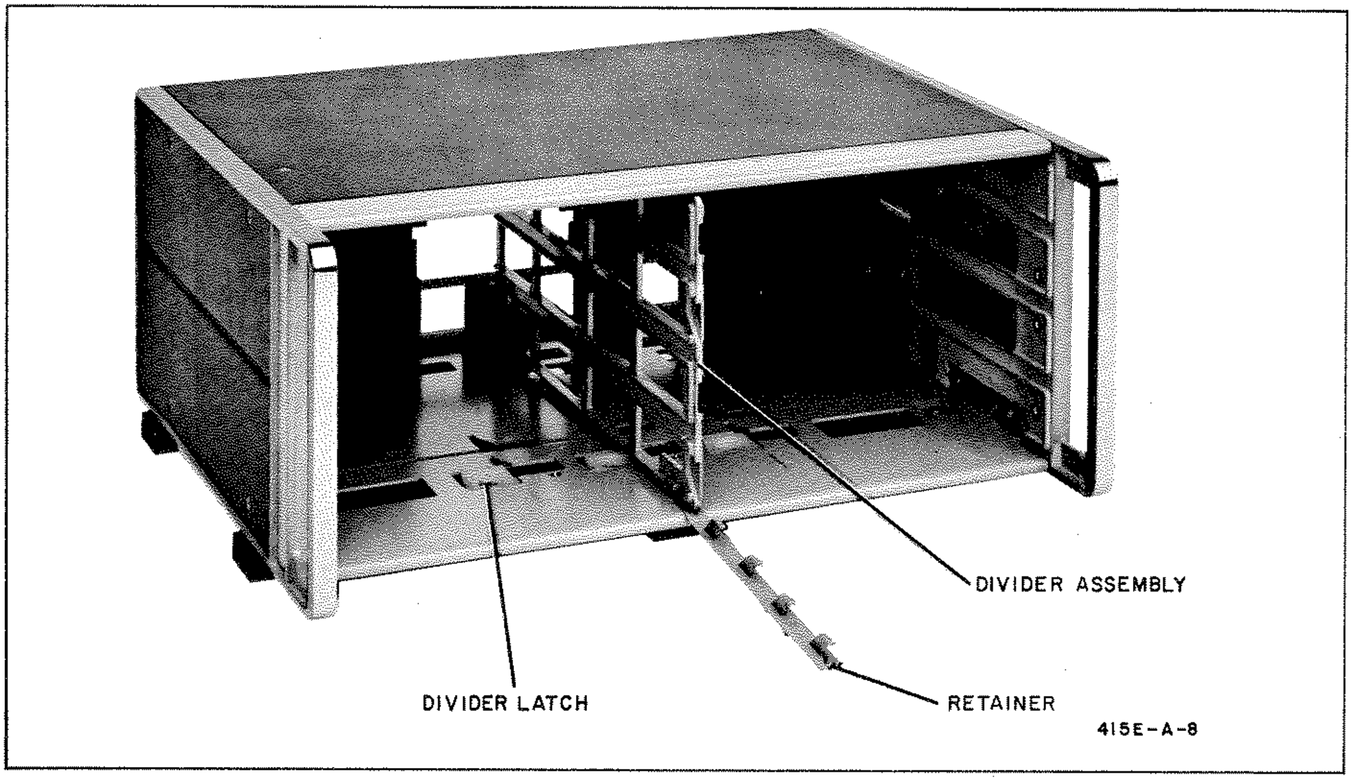


Figure 2-1. The Combining Case

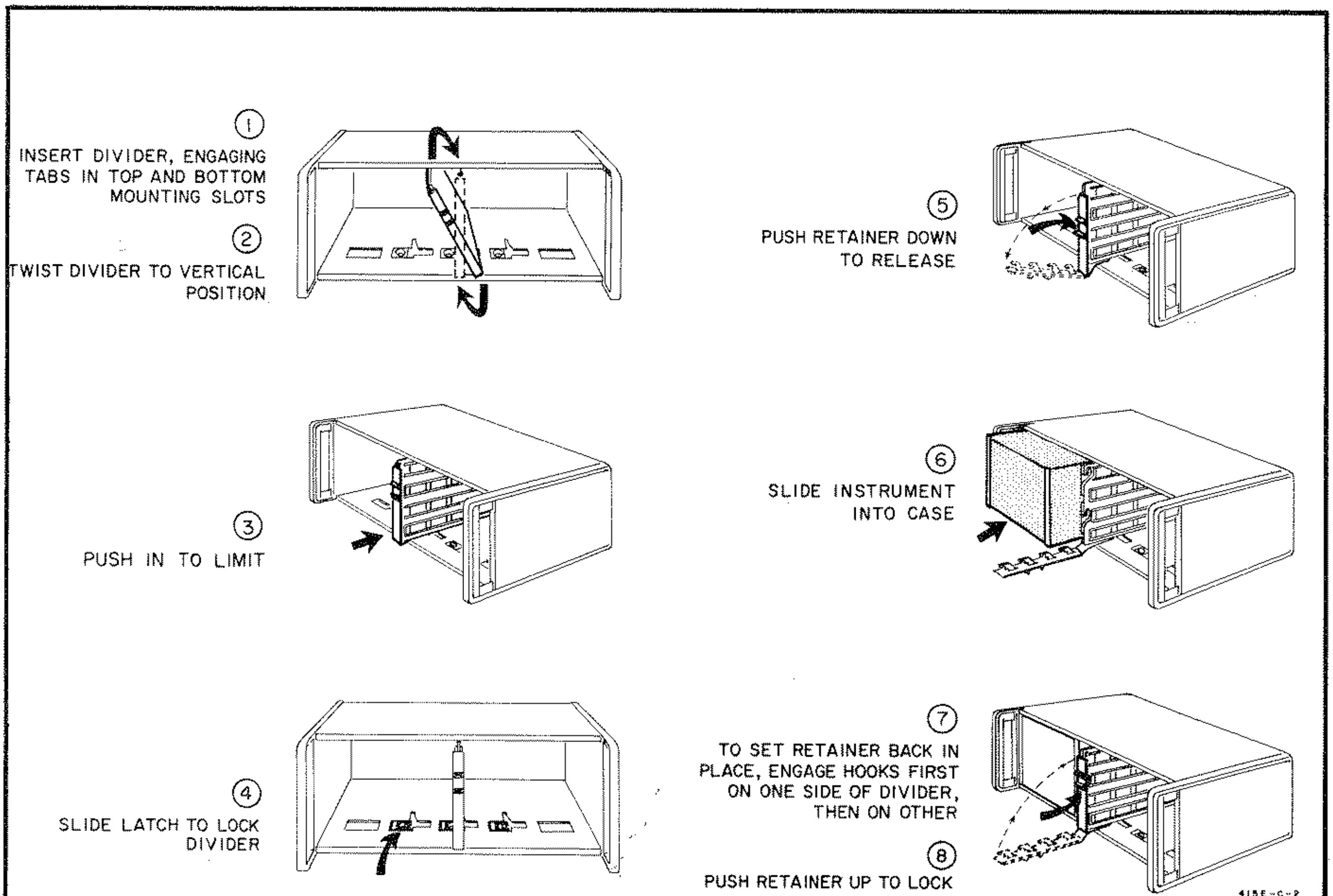


Figure 2-2. Steps to Place Instrument in Combining Case

SECTION II
PREPARATION FOR USE

2-1. INCOMING INSPECTION.

2-2. This instrument was inspected both mechanically and electrically before shipment. To confirm this, the instrument should be inspected for physical damage in transit. Also check for supplied accessories, and test the electrical performance of the instrument, using the procedure outlined in Paragraph 5-3. If there is damage or deficiency, see the warranty on the inside front cover of this manual.

2-3. INSTALLATION.

2-4. 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).

2-5. RACK MOUNTING.

2-6. 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.

2-7. COMBINING CASE. The combining case is a full-module unit which accepts varying combinations of submodular units. Being a full-module unit, it can be bench or rack mounted analogous to any full-module instrument. An illustration of the combining case is shown in Figure 2-1. Instructions for installing the Model 415E in a combining case are given graphically in Figure 2-2.

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

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

b. Stack the sub-modular units in the frame as shown in step 2, Figure 2-4. Place the spacer clamps between instruments as shown in step 3, Figure 2-4.

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

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

e. The complete assembly is ready for rack mounting.

2-9. THREE-CONDUCTOR POWER CABLE.

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

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

2-12. PRIMARY POWER REQUIREMENTS.

2-13. The Model 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 cps. The DC source is a 24-volt rechargeable battery. The rechargeable battery is supplied with option 01 instruments only.

2-14. For operation from AC primary power, the instrument can be easily converted from 115- to 230-volt operation. The LINE VOLTAGE switch, S1, a two-position slide switch located at the rear of the instrument, selects the mode of AC operation. The line voltage for which the instrument is set to operate appears on the slider of the switch. A 1/16-ampere, 250 volt fuse is used for both 115- and 230-volt operation.

CAUTION

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

2-15. INITIAL BATTERY CHECK.

2-16. The following applies to option 01 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:

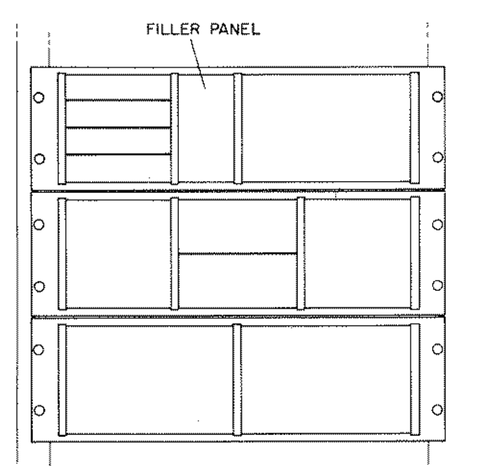


Figure 2-3. Adapter Frame Instrument Combinations

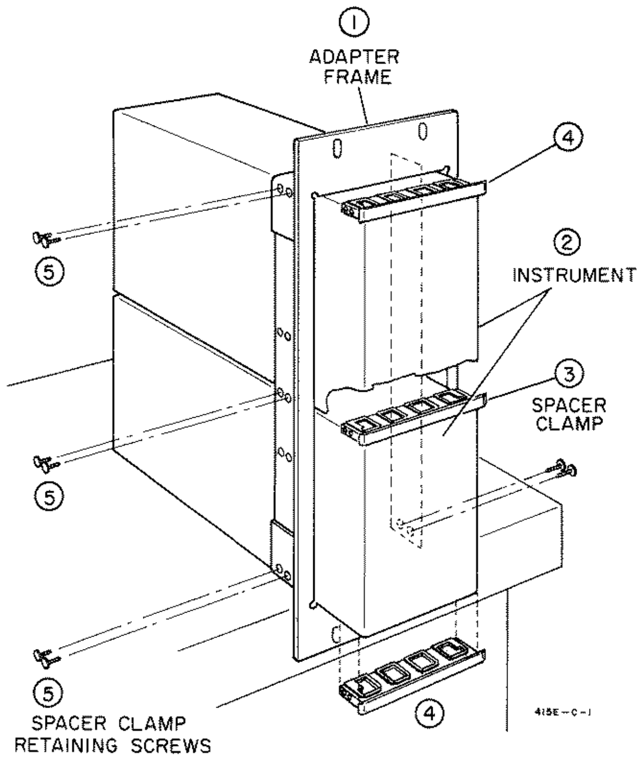


Figure 2-4. Two Half Modules in Rack Adapter

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).

2-17. INSTALLING BATTERY AND INPUT CONNECTOR.

2-18. Available from Hewlett-Packard are parts required for modifying any Model 415E to correspond to those instruments with Option 01 and/or Option 02. A rechargeable Battery Installation Kit, hp Part Number 00415-606, contains the battery and necessary hardware for installation (corresponds to Option 01). Installation instructions are detailed in Appendix at rear of this manual. To obtain the parts required for an input connector on the rear panel (corresponding to Option 02), order by hp Part Number as found in Table 6-1 (listed under Option 02). Instructions for installation of this additional connector are detailed in Appendix at rear of this manual.

2-19. REPACKAGING FOR SHIPMENT.

2-20. When returning an instrument to the Hewlett-Packard Company, use the original packing material (if foam type) if available or contact an authorized hp Sales Office for assistance. If this is not possible, first protect the instrument surfaces by wrapping in heavy Kraft paper or with sheets of cardboard flat against the instrument. Then protect the instrument on all sides (use approximately 4 inches of packing material designed specifically for package cushioning), pack in a durable container, mark container clearly for proper handling, and insure adequately before shipping.

Note

When an instrument is being returned to the Hewlett-Packard Company for service or repair, attach a tag to the instrument specifying the owner and desired action. All correspondence should identify the instrument by model number and the full (eight-digit) serial number.

SECTION III
OPERATING INSTRUCTIONS

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, instruction in the use of a Smith Chart for plotting load impedance, and discussion of Model 415E noise performance with various source impedances and noise effect on meter indication.

3-3. FRONT AND REAR PANEL FIXTURES.

3-4. Figures 3-1 and 3-2 identify by number the front and rear panel fixtures of the Model 415E. The descriptions in Table 3-1 are keyed by number (1-12 for front, 13-18 for rear) to the figures. Further information regarding the various settings and uses of the controls, indicators, connections, and adjustments is included in the procedures of this section. Information on 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 2-13). Battery operation requires some slightly different procedures to prolong battery life and to ensure proper results. The rechargeable nickel - cadmium battery is factory installed if ordered as Option 01 (see Paragraph 1-7). The same battery may be ordered and installed later. To obtain this, order hp Stock Number 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 internally 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 Paragraph 5-35.

3-9. OPTIMUM BATTERY USAGE. It is recommended that the Model 415E be operated by the battery for up to 8 hours, followed by 16 hours of recharge. If continuous battery operation is required for more than 8 hours, the recharge time should be double the operating time. Continuous battery operation is possible for up to 36 hours but this must be followed by a prolonged recharge period.

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

3-11. GROUNDLOOP CURRENTS.

3-12. The 415E SWR Meter audio amplifier has high sensitivity to low level signals. To reduce ground loop currents, the 415E grounds are isolated by a 46.4 ohm resistor. Ground loops occur when instruments are connected to 415E outputs and grounded through power cords or rack mountings. Ground loops can be minimized in the following ways:

a. Connect the 415E to instruments with floating inputs;

b. Connect the 415E to instruments with high input impedance; Connect only the signal wire between instrument and the 415E;

c. Operation at higher signal levels;

d. An Adapter on the power cord to float the instrument ground where not prohibited by safety regulations.

3-13. BANDWIDTH AND FREQUENCY SELECTION.

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

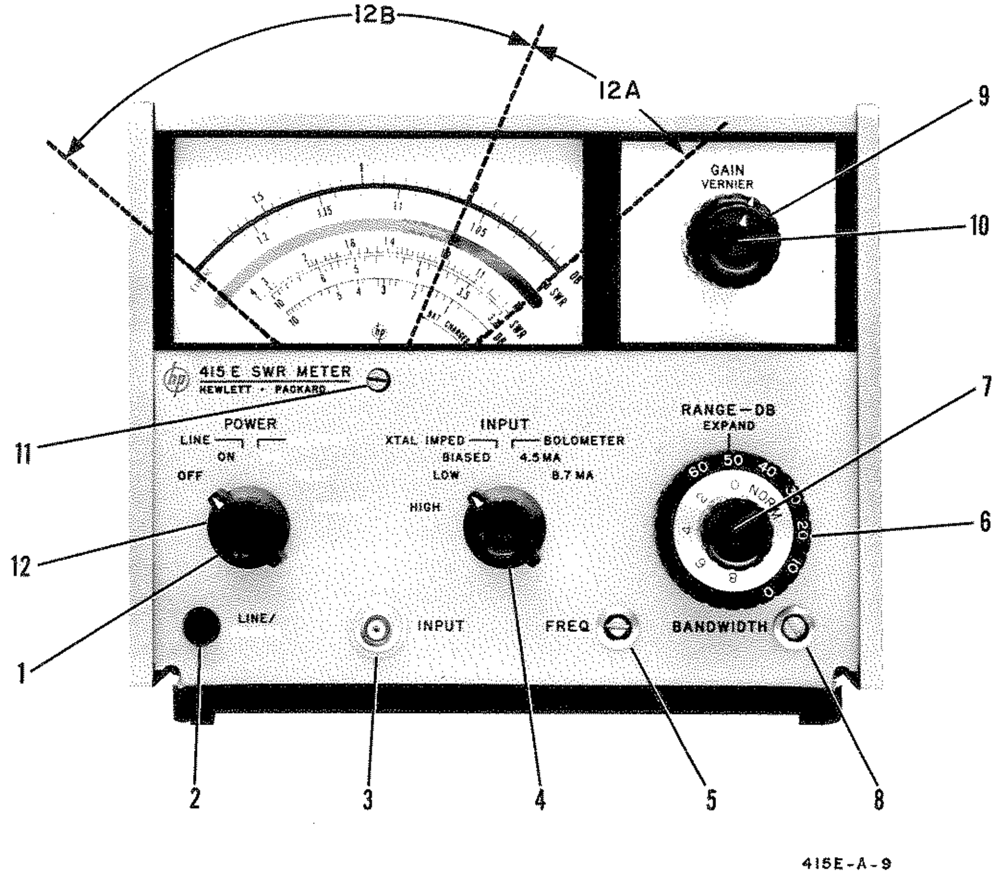


Figure 3-1. Front Panel Operating Controls and Connector

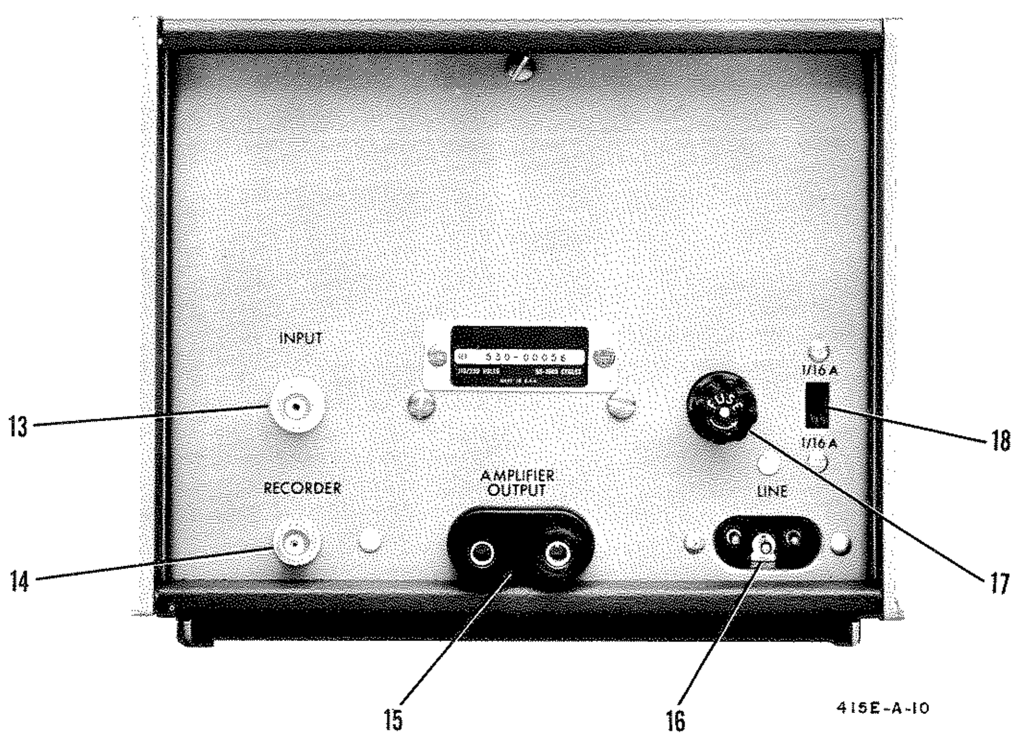


Figure 3-2. Rear Panel Operating Controls and Connectors

Table 3-1. Panel Descriptions

1. Selects desired 415E power source: BATTERY/CHARGE position allows internal battery recharge when power cord is connected to AC line.	11. Mechanical zero adjustment allows exact setting of meter needle to 2.0 db calibration mark.
2. Indicator lights when power switch is in LINE/ON or BATTERY/CHARGE position.	12. 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 415E operation; if needle indicator is to left (area 12B) of "BATTERY CHARGED" area, then battery is not charged sufficiently for proper instrument operation (option 01 - ONLY).
3. Female BNC INPUT connector.	
4. Set input of Model 415E for use with a bolometer or crystal detector mount. See Paragraph 3-53.	
5. Adjustment allows center frequency variation by 70 cps.	13. Additional input connector (wired in parallel with front panel connector); supplied as Option 02 for 415E only upon request.
6. Attenuator adjusts gain in 10 db steps.	14. DC output for recorder use (0 to 1 volt into open circuit or 1000 ohms).
7. Allows full scale expansion of any 2.0 db portion of the 10-db scale.	15. AC output for use as tuned amplifier output.
8. Changes bandwidth from 15 to 130 cps.	16. Three-conductor AC power cord receptacle (NEMA-type).
9. Allows initial meter reference setting with a control range of at least 10-db.	17. Contains power line fuse.
10. Provides fine adjustment of GAIN control meter settings.	18. Slide switch to allow 115- or 230-volt AC operation.

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 cps 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 30 position and coarse GAIN at maximum. (1 mv RMS sine wave or 2.2 mv peak-to-peak square wave causes full scale deflection on HIGH XTAL IMPED position. On other positions of INPUT switch, 0.15 mv RMS 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 behaviour or manufacturer's data should be consulted.

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

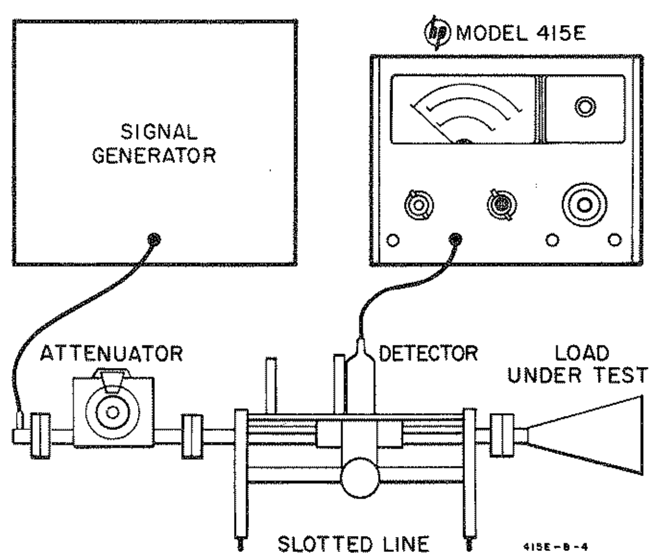
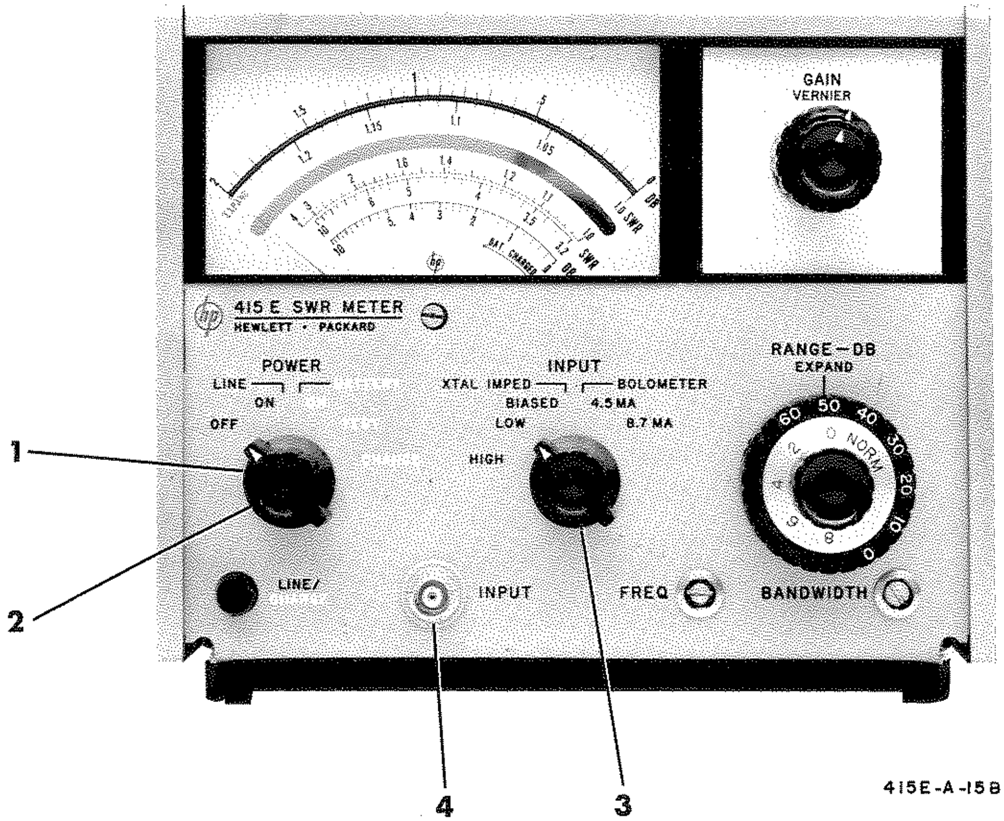


Figure 3-3. Typical SWR Measurement Setup



1. Set POWER switch to OFF. Meter pointer should rest at 2 on the 0-2 DB scale (if not refer to Paragraph 5-10).

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. (Note see Paragraph 3-55.)

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

5. Adjust modulation frequency (audio input signal) to approximately 1000 cps.

6. Adjust RANGE-DB, GAIN, and VERNIER controls and the amplitude of the input signal for a convenient meter reference near mid-scale.

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 cps is convenient for most applications; and a wide bandwidth is usually best for fast sweep rate measurements.

Figure 3-4. General Turn-On Procedure

transmission line as a shunt admittance which increases (disturbing the transmission line more) as the probe penetrates farther. To find out whether a given probe penetration is too great or not, measure SWR, then change probe penetration and remeasure SWR. If the second reading is different, the probe is penetrating too far and loading the transmission line significantly.

3-22. PROCEDURE.

3-23. MODERATE SWR. The scales of the 415E are calibrated for reading standing wave ratio directly from the meter. Set the slotted line probe at a voltage maximum and adjust the gain of the 415E with the RANGE-DB, GAIN, and VERNIER controls (EXPAND switch to NORM) for full scale deflection (1.0 on the 1.0 to 4 SWR scale). Now move the probe toward a minimum. If the meter drops below 3.2, rotate the RANGE-DB switch one position clockwise and read on the 3.2 to 10 SWR scale. If the pointer drops below this scale, rotate RANGE-DB switch one more position clockwise and read on the 1.0 to 4 scale and multiply by 10. This pattern continues for still higher SWR readings.

3-24. The DB scales can be used for a standing wave ratio measurement by setting the 415E to full scale at a voltage maximum, then turning the RANGE-DB switch clockwise for an on scale reading at a voltage minimum and noting the difference in DB readings at the maximum and minimum. A DB reading is obtained by adding RANGE-DB switch setting and meter indication.

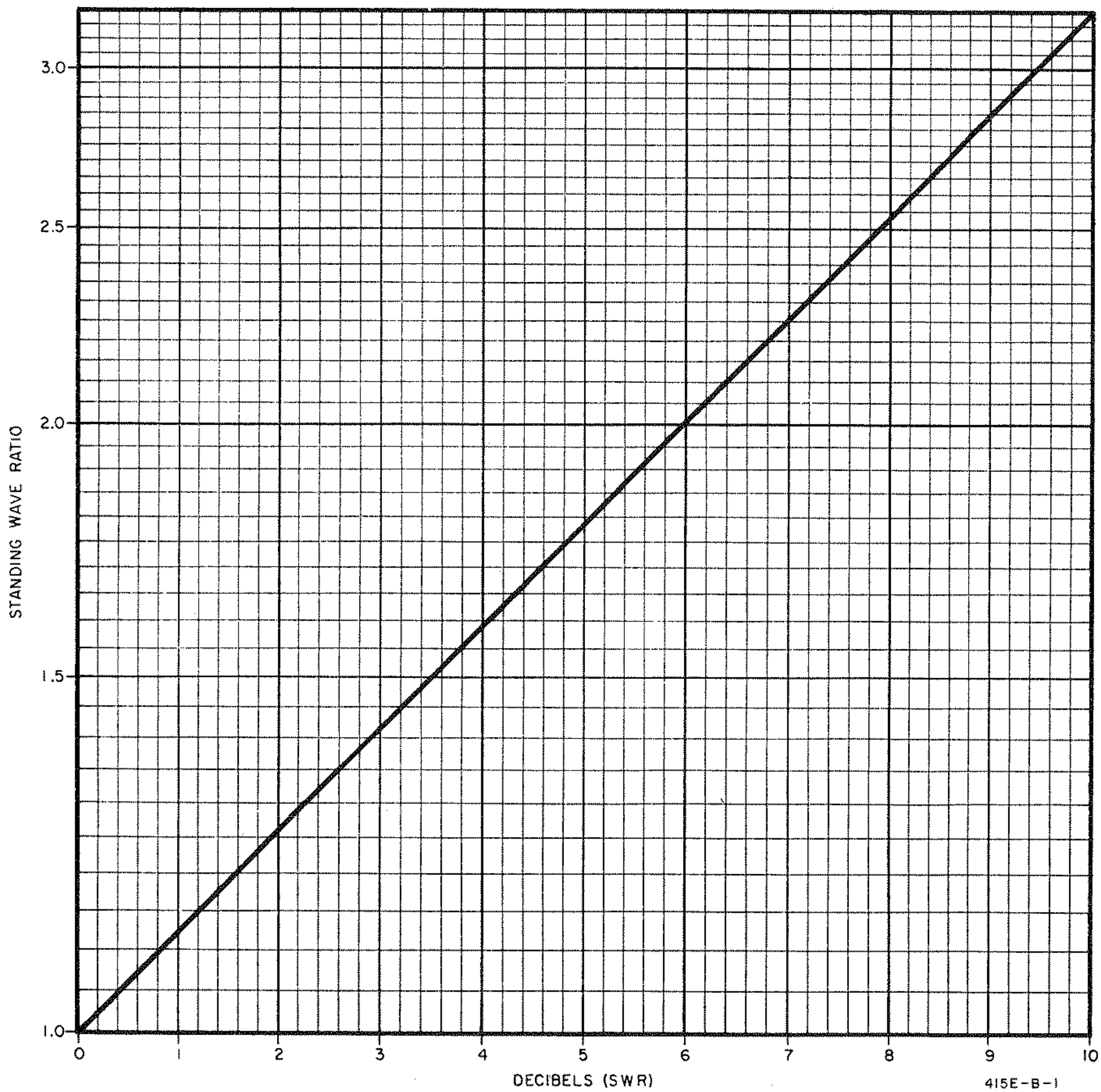


Figure 3-5. Expanded Section of Figure 3-6

3-25. LOW SWR. Standing wave ratio between 1.0 and 1.24 can be read quite accurately on the EXPAND scales of the meter when the EXPAND switch is set to any position other than NORM.

3-26. MODERATE SWR, HIGH RESOLUTION. The EXPAND and -DB scale can be used together with the EXPAND switch to read any SWR with high resolution in DB. Figure 3-5 and 3-6 are used to convert DB to SWR. The reference level (full scale meter deflection at a voltage maximum) can be used with the EXPAND switch at NORM (since 0 db NORM and 0 db EXPAND correspond) but greater accuracy is obtained by setting the reference level with the EXPAND switch to 0.

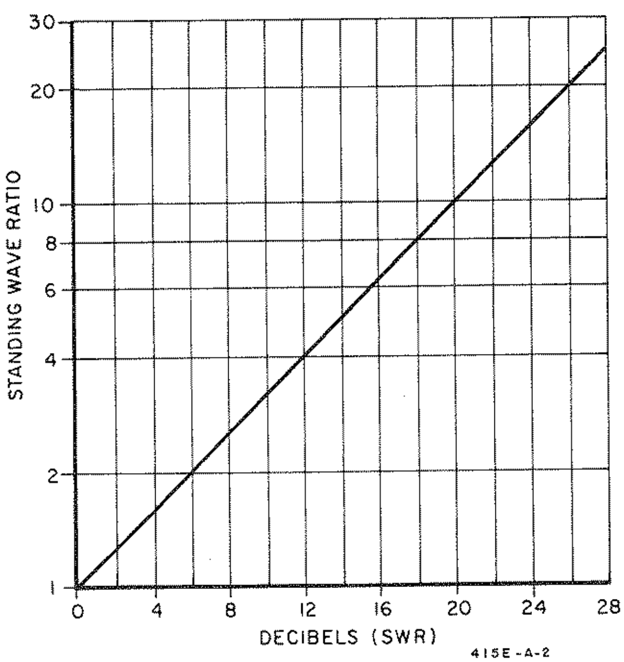


Figure 3-6. Converting Decibels to SWR

3-27. 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 behaviour 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.

3-28. 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 λg (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:

$$SWR = 1/\pi \left(\lambda g/\Delta X\right).$$

3-29. 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:

$$SWR = 3/\pi \left(\lambda g/\Delta X\right)$$

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

3-30. 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 behaviour, and excessive probe penetration. Also, reflections in the transmission line between the slotted line and device being measured must be minimized.

3-31. ATTENUATION MEASUREMENT.

3-32. The 415E may be used for high resolution insertion loss measurements simply by inserting the device to be measured between signal source and detector and noting the change in DB indication on the 415E. A typical measurement is shown in Figure 3-7. The continuous coverage of the EXPAND scales allows any attenuation measurement to be made on the EXPAND scales. For accurate results, both the signal source and the detector should be well matched. Impedance match of source and detector can be improved, if necessary, with padding attenuators, isolators, or tuners.

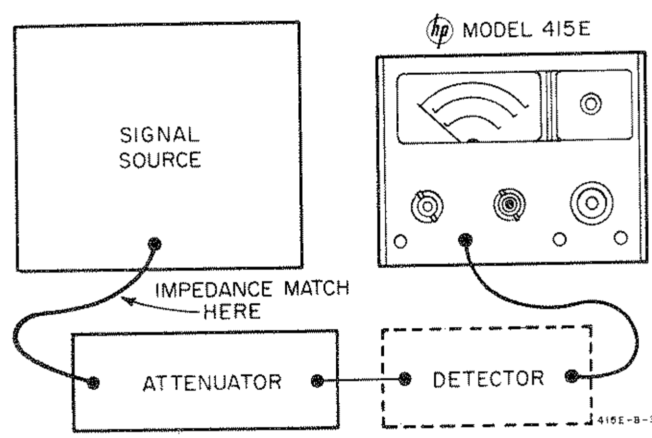


Figure 3-7. Attenuation Measurement Setup

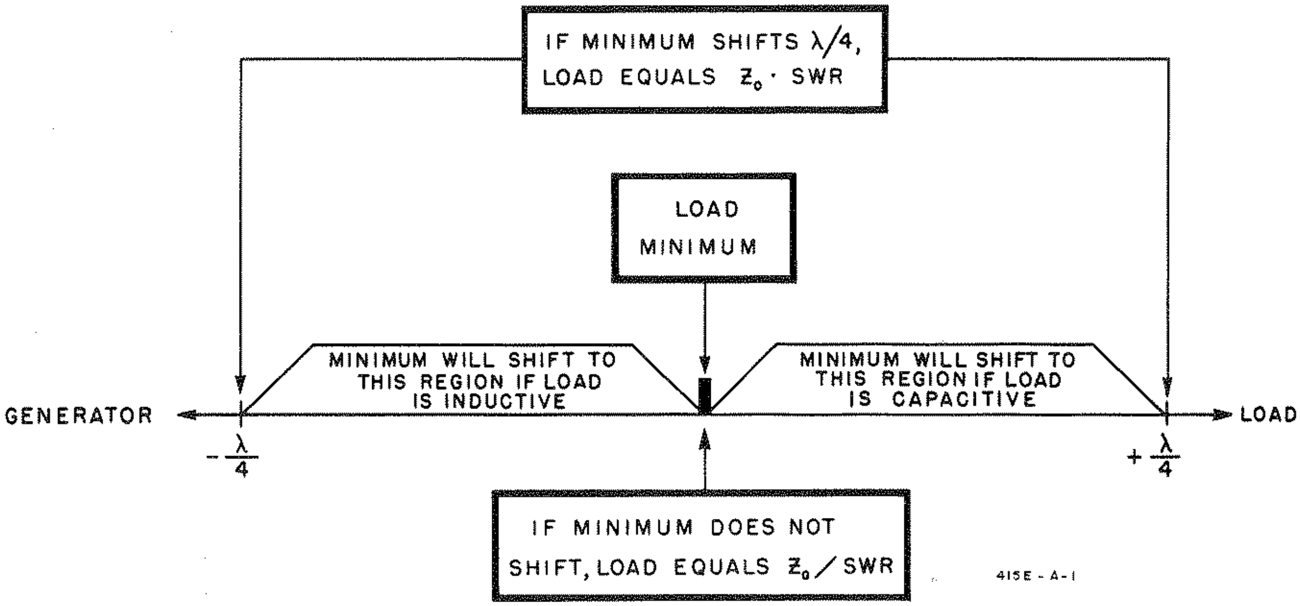


Figure 3-8. Impedance Measurement Rules Summary

3-32. LOAD IMPEDANCE MEASUREMENT.

3-33. GENERAL.

3-34. Slotted line techniques provide information to allow calculation of a load impedance. The following rules apply to the indications given by the voltage minimum when the load is replaced by a short. Figure 3-8 summarizes and graphically presents these impedance measurement rules. When the load is replaced by a short, then:

a. The shift in the minimum is never more than ±1/4 wavelength.

b. If the minimum moves toward the load, the load has a capacitive component.

c. If the minimum moves toward the generator, the load has an inductive component.

d. If the minimum does not move, the load is completely resistive and has a normalized value of 1/swr.

e. If the minimum shifts exactly one-quarter wavelength, the load is completely resistive and has a normalized value equal to the swr.

f. The minimum will always be at a multiple of a half wavelength from the load.

3-35. IMPEDANCE MEASUREMENT PROCEDURE.

3-36. The procedure for performing the actual impedance measurement with a slotted line is as follows:

a. Connect the load under test to the slotted line section and measure the swr (see Paragraph 3-26 or 3-28). Also note the position of the probe carriage at the minimum.

b. Replace the load under test with a short.

c. Locate the minimum with the line shorted.

d. Referring to Figure 3-9 and the following formulas, compute the normalized load impedance:

$$\text{Normalized } Z_L = \frac{1 - j(\text{swr}) \text{ Tan } X}{(\text{swr}) - j \text{ Tan } X}$$

$$\text{where } X = \frac{180° (\pm \Delta d)}{\lambda_g/2}$$

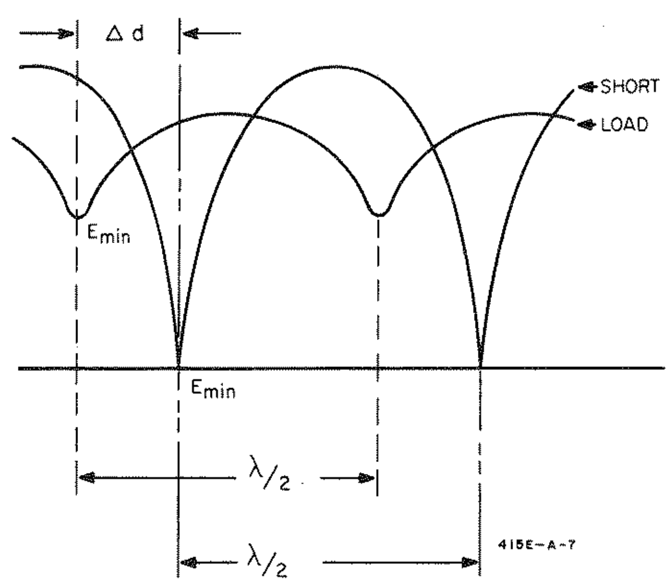


Figure 3-9. Shift of Minimum with Load and Short

and: $\pm\Delta d$ = Shift in centimeters of the minimum point when the short is used. Δd takes a positive sign (+) if the minimum shifts toward the load. Δd takes a negative sign (-) if the minimum shifts toward the generator.

$\lambda g/2$ = one-half guide wavelength, i.e., the distance in centimeters between two adjacent voltage minima.

Note

The above calculations are based on the assumption that no losses occur in the transmission line. It is assumed that the characteristic line impedance, Z_0, is resistive.

3-37. SMITH CHART EXPLANATION.

3-38. When data is obtained from a slotted line system, one of the best aids for determining impedance is the Smith Chart.* A Smith Chart with an example (see Paragraph 3-39) is shown in Figure 3-10. The values of resistance and reactance are based on a normalized value obtained by dividing the actual value by the characteristic impedance, Z_0, of the line. Thus if $Z = 5 + j\,25$ ohms and if $Z_0 = 50$ ohms, then $Z_N = 0.1 + j\,0.5$. On the Smith Chart, the circles which are tangent to the bottom of the chart are for a constant, normalized resistance; lines curving to the right from center are the normalized positive reactance components; lines curving to the left from center are the normalized negative reactance components; the straight line forming the vertical diameter is a line of zero reactance; the lower half of the zero reactance line (marked 1 through 50) also represents the standing wave ratio line.

* Smith, P. H., "Transmission-Line Calculator," Electronics, Jan. 1939, McGraw-Hill.

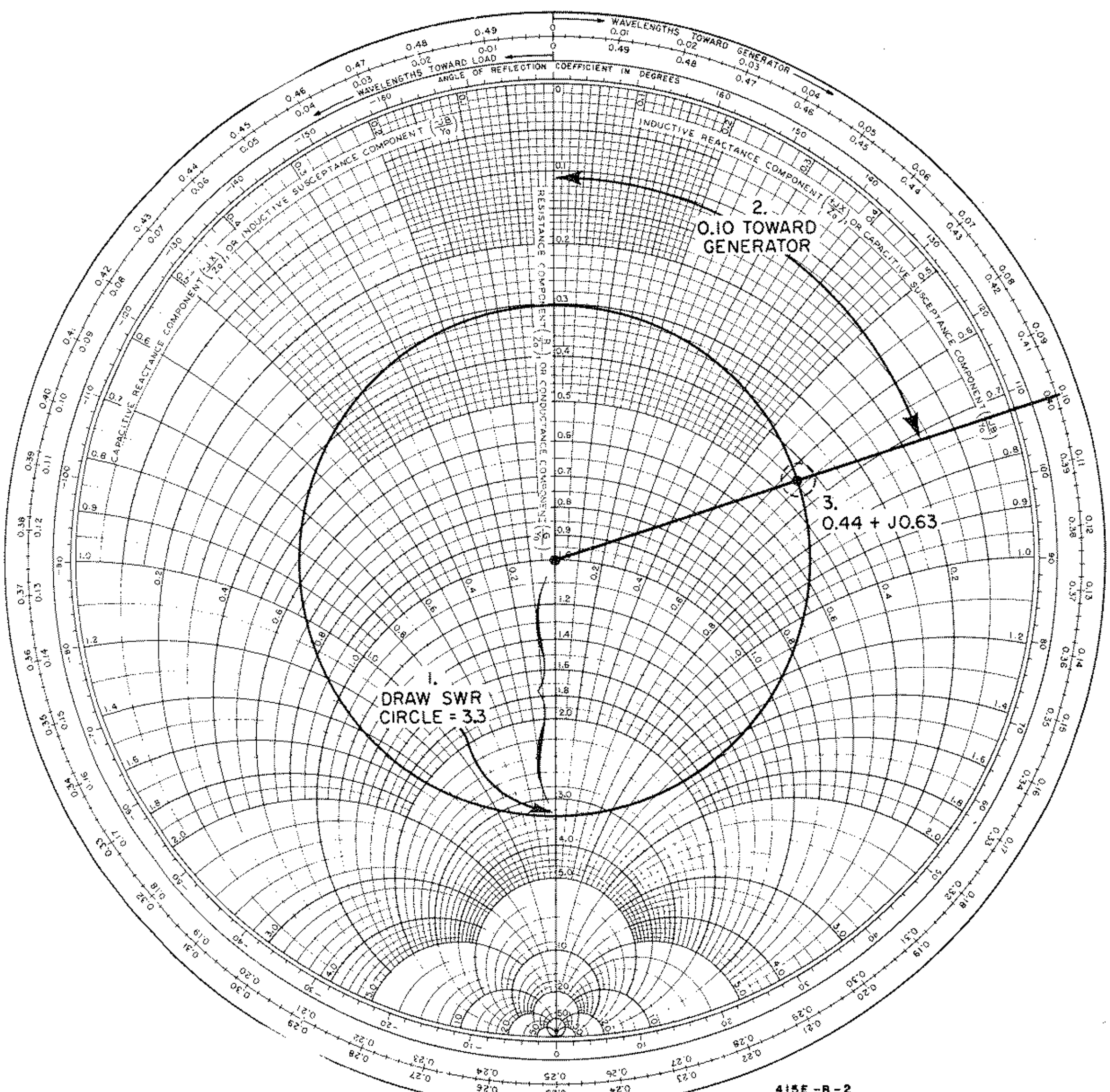


Figure 3-10. Example for Use of Smith Chart

3-39. SMITH CHART CALCULATIONS.

3-40. Use of the Smith Chart for calculating impedance is outlined below. Following the generalized procedure is a numerical example. Other methods are possible for first entering the Smith Chart, but the one suggested here is practical and easy to use.

a. Determine the guide wavelength, λ_g, as explained in Paragraph 3-28.

b. Measure the swr by the method in either Paragraph 3-26 or 3-28.

c. Locate a convenient minimum with the load still in place. Record the probe carriage reading.

d. Replace load by a short, relocate the minimum and record the probe carriage reading. Determine Δ d, the difference between this reading and the one from step c. Note whether the minimum was moved toward the load or toward the generator.

e. Calculate the shift of the minimum, in terms of wavelength:

$$\Delta = \frac{\Delta d}{\lambda g}$$

f. Start at center of Smith Chart and draw a circle with a radius equal to the swr.

g. Enter the Smith Chart at the top, move in the direction of probe movement noted in step d and a distance $\Delta\lambda$, computed in step e. Use wavelength scale at the periphery of the Smith Chart.

h. Draw a line from the $\Delta\lambda$ point to the center of the chart.

i. Locate the normalized impedance as the intersection of the swr circle and the line drawn in step h.

j. The actual impedance is the product of the normalized impedance from step i and Z_0, the line characteristic impedance.

Note

The convention of entering the chart as stated in step g applies only if the minimum is located first with the load on the line and relocated when the line is shorted. If it is necessary to first establish the shorted minimum point, the direction of $\Delta\lambda$ would be opposite to the direction of probe movement required to relocate the minimum with the load concerned.

3-41. The following example will clarify the above procedure. Figure 3-10 shows the important steps involving the Smith Chart. The assumed characteristic impedance is 50 ohms. The distance between adjacent minima is 15 cm, therefore λ_g = 30 cm. The swr is measured as 3.3. A minimum is located at 22 cm. The load is shorted and the minimum shifts to 19 cm, toward the generator.

$$\Delta d = 22 \text{ cm} - 19 \text{ cm} = 3 \text{ cm}$$

$$\Delta\lambda = \Delta d/\lambda_g = 3 \text{ cm}/30 \text{ cm} = 0.1 \text{ wavelength}$$

3-42. The following numbered steps refer directly to Figure 3-10.

(1) A circle for swr = 3.3 is drawn.

(2) A line is drawn from the 0.1λ point (toward the generator) to the center of the chart.

(3) The normalized impedance at the intersection of the circle and the line is 0.44 + j 0.63.

The impedance of the load (for Z_0 = 50Ω) is then:

$$50\,(0.44 + j\,0.63) = 22 + j\,31.5 \text{ ohms}$$

3-43. SPECIAL APPLICATIONS.

3-44. The Model 415E is equipped with outputs which allow applications other than as a meter indicating device for swr or attenuation.

3-45. RECORDER.

3-46. The 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. For proper operation, the recorder output ground (BNC shell) must be connected to a floating ground. Adapters are commonly available to float the ground of grounded input instruments at the power cord (see Paragraph 3-11).

3-47. AMPLIFIER OUTPUT.

3-48. The rear panel amplifier output furnishes an output from 0 to 0.8 volt RMS into 10K ohms or more. 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 (see Paragraph 3-11). With the 415E 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 0.03 volt RMS. With the 415E 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 zero volt output signal.

3-49. 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.

* See hp Application Notes 54, 61, 65, and 66.

3-50. MODEL 415E NOISE FIGURE.

3-51. Figure 3-11 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 of its noise figure.

c. Calculation example:

(1) Assume 415E with controls set for the following conditions: EXTAL IMPED HIGH (input impedance 200K), 1 μv RMS sine wave at input causes full scale deflection (0 on 0 to 10 DB scale), 130 cps 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).

(2) The open-circuit noise voltage across a 5000 ohm resistor at 295° K (22° C) in a bandwidth of (130 times $\pi/2$) cps 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 1/2 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 1/2 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.

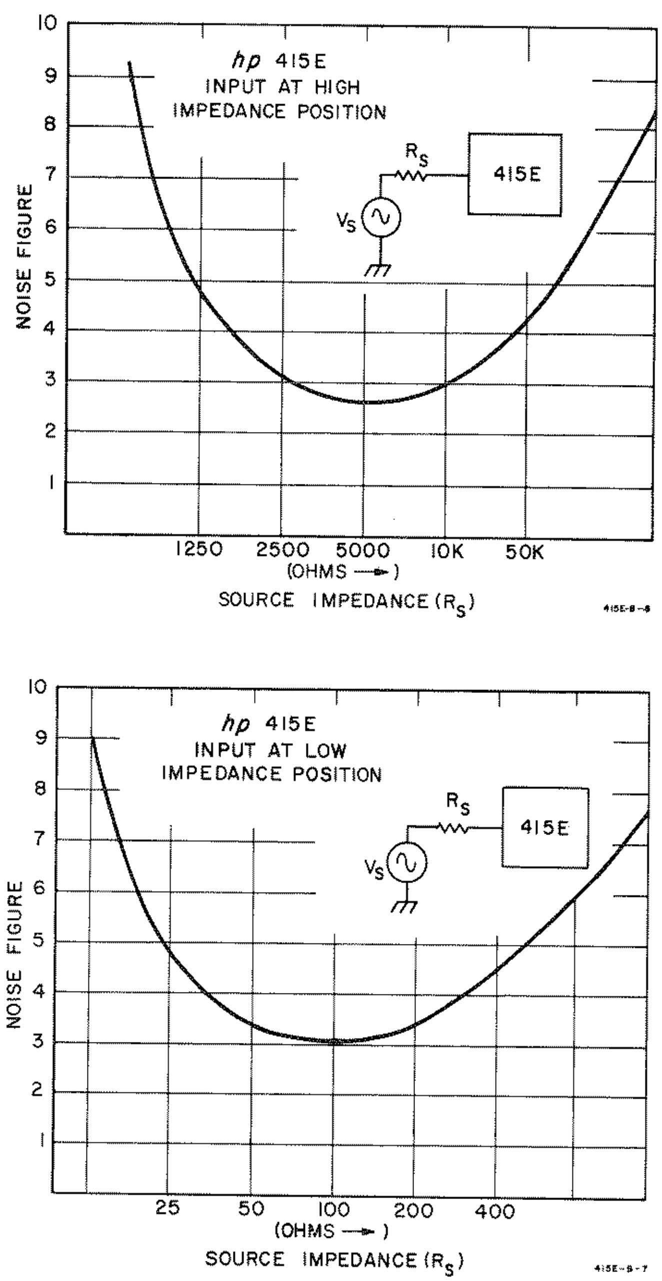


Figure 3-11. 415E Noise Figure Curves

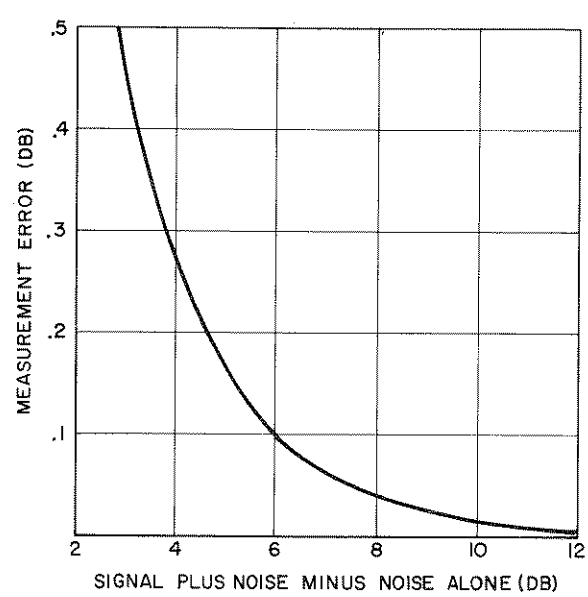


Figure 3-12. Meter Noise Correction Curve

3-52. A system error occurs when making measurements on lower 415E ranges due to noise. For convenient reference, a graph (Figure 3-12) is shown to allow correction to meter reading for any given measurement. To use this graph, make a 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 reading is used to obtain the proper correction factor from Figure 3-12. For example: if the average noise level is 9.5 db and the measured signal level is 3.5 db then the difference is 6 db. Refer to Figure 3-12, 6 db corresponds to an error of 0.1 db. This 0.1 db correction factor is always added to measured signal. Hence, 3.5 + 0.1 = 3.6 db (corrected meter reading).

3-53. USE OF CRYSTAL DETECTORS.

3-54. 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 415E 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 3-55 gives method of checking and calibrating a detector for square-law response.

3-55. CHECKING SQUARE-LAW RESPONSE.

3-56. Increase the power level to the crystal detector by known increments and note detector response on 415E. Note: a deviation in square-law response may be due to excessive RF power to the crystal detector (see Operating literature for specified response characteristics of crystal detector in use).

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 schematic diagrams, Figures 5-11 and 5-12 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).

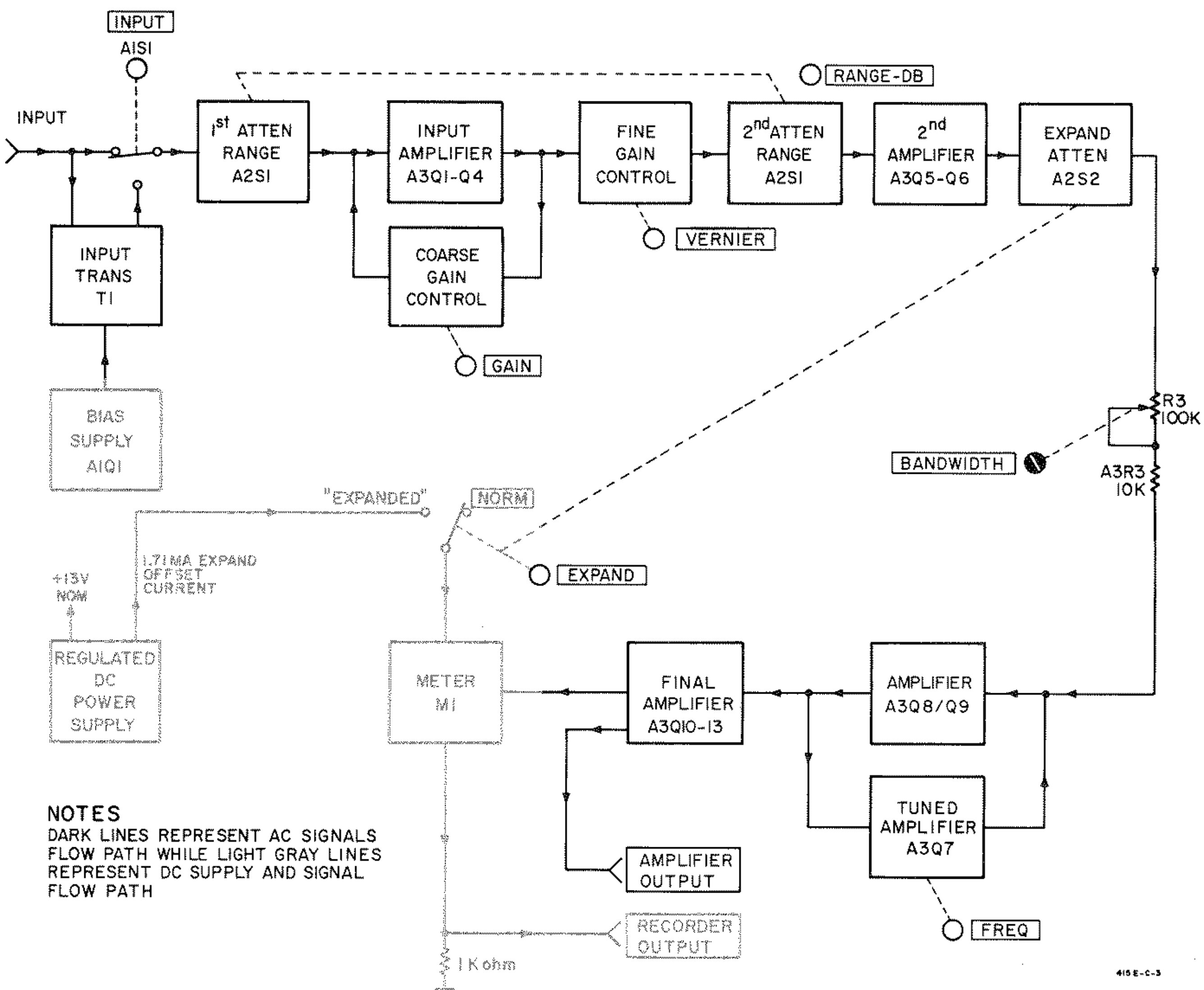


Figure 4-1. Block Diagram

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 3rd 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 A3R51: 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 A3Q13 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 uf 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 circuit 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 a specification, ±3%, by adjusting the DC voltage potential of the positive power supply with resistor A3R54. A single adjustment suffices since 1% resistors accurately determine the ratios between the 3 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 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 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.

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 5-35 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 groundloop 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 set, the pointer rests over the calibration (i.e., 2 on the 0 to 2 DB scale) on the meter scale when the instrument is (1) at normal operating temperature, (2) in its normal operating position, and (3) turned off. Set the pointer as follows to obtain best accuracy and mechanical stability:

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 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.

Table 5-1. Recommended Test Equipment

Instrument Type	Minimum Required Specifications	USE/Check	Recommended Model
Audio Oscillator	Freq. Range: 400 to 2500 cps Accuracy: ±3% Output: 10 volts into 600 ohms Distortion: less than 1%	All Performance Tests	hp 200CD
Electronic Counter	Freq. Range: 400 to 2500 cps 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 Freq. Range: 400 to 2500 cps Input Impedance: 10 megohms	Sensitivity, and Noise	hp 400H

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

Instrument Type	Minimum Required Specifications	USE/Check	Recommended Model
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 hp 355D, with calibration error chart
Feed-Thru Terminations	Value: 5000 ohms Accuracy: 10% (Met Film Resistor)	Noise	Shielded body: 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 Kc to 400 Kc 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 1400 A (Differential Ampl. Plug-in)
Adapters and Cables	BNC Female-to-Female Adapter (1-Required)	All Performance	hp 1250-0080-9 (UG-914/UN)
	BNC to Dual Banana Adapter Post (2-Required)	All Performance	hp 10110A
	Male-to-Male BNC 50 ohm cable (1-Required)	Bandwidth	hp 10502A
	Dual Banana-to-Dual Banana Plugs on a 50 ohm cable (1-Required)	All Performance Checks	hp 11000A
	Dual Banana-to-BNC Male (2-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

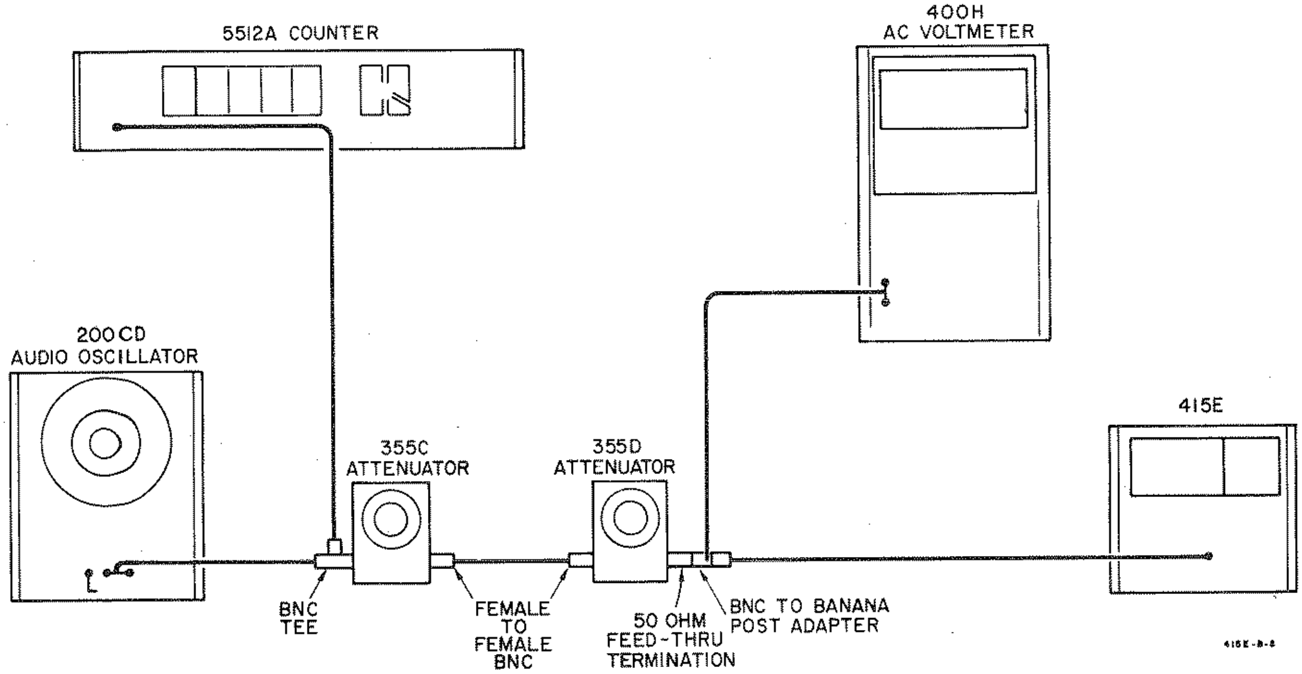


Figure 5-1. Test Set Up

Table 5-2. Performance Tests

1. SENSITIVITY: 0.15 μv RMS at max bandwidth (1 μv RMS on HIGH impedance crystal input).

Procedure.

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 Oscillator to 1000 cps.

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 μvolt 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 μvolt RMS or greater on 60 DB range).

Readings

Min		Act	Max
- -	0.128	.110 0.125	0.15 v RMS
- -	0.94	.786	1.0 v RMS

Table 5-2. Performance Tests (Cont'd)

2. NOISE: At least 7.5 db below full scale at rated sensitivity and maximum bandwidth with input terminated in optimum source impedance

Procedure.

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 volts RMS AC Voltmeter reading.

e. Adjust 415E GAIN for 0 db meter reading and remove connections from 415E.

f. Connect special 5000 ohm feed-thru termination to INPUT (See Procedure 6 of this table).

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 0.15 volt RMS AC Voltmeter reading.

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

k. Connect Model 10100B Feed-Thru 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.

Readings

Min	Act	Max
	-10 (High)	-7.5 db
	-9 (Low)	-7.5 db

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 db ±0.05 db (See Note 1).

f. Switch 355D to 40 db and 415E to 20. 415E to 20. 415E should read 1.0 db ±0.1 db.

Readings

Min	Act	Max
9.95 db	10.00	10.05 db
19.9 db	20.01	20.1 db
29.9 db	30.01	30.1 db
39.95 db	40.01	40.05 db
49.9 db	50.03	50.1 db
59.9 db	59.94	60.1 db

Table 5-2. Performance Tests (Cont'd)

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

h. Switch 355D to 40 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 ±0.05 db.

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

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

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 db ±0.05 db on 0 to 2 db scale.

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

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

h. Switch 355C to 6 db and EXPAND to 8. The 415E should read 1 db ±0.05 db.

Readings

Min	Act	Max
0.48 db	0.51	0.52 db
0.98 db	1.01	1.02 db
1.48 db	1.51	1.52 db
1.98 db	2.00	2.02 db
1.95 db	1.99	2.05 db
3.95 db	3.99	4.05 db
5.95 db	5.98	6.05 db
7.95 db	7.98	8.05 db

4. INPUT FREQUENCY: 1000 cps, adjustable 7% (±35 cps).

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. Tune 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 recorder frequency readings of steps d and f must be at least 70 cps with 1000 cps between the two frequencies.

Readings

Min	Act	Max
1020 cps	1036	- -
- -	960	980 cps

Act		Act		Diff
	−		=	76

Difference = > 70 cps

Table 5-2. Performance Tests (Cont'd)

5. BANDWIDTH: Variable 15 to 130 cps.

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.

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

j. Turn BANDWIDTH full clockwise and retune OSCILLATOR for peak 415E meter reading.

k. Repeat steps f, g, h above.

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

Readings

Act - Act = Difference (< 15 cps)

966 953 = 13

Act - Act = Difference (> 130 cps)

1028 896 = 132

6. SPECIAL 5000 OHM FEED-THRU 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 stock numbers).

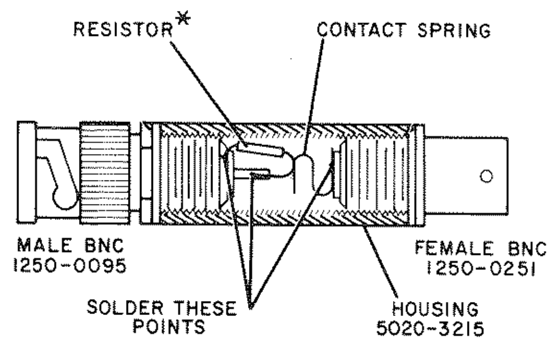
Procedure

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% 1/4 W resistor to BNC.



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

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

415E-A-23

b. If the meter tracking error is greater than ±0.02 db, adjust A3R57 (See Figure 5-10) 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.

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.

Table 5-3. Etched Circuit Soldering Equipment

Item	Use	Specification	Item Recommended
Soldering Tool	Soldering Unsoldering	Wattage rating: 37.5 Tip Temp: 750 - 800°F Tip Size: 1/8" OD	Ungar #776 Handle with Ungar #1237 Heating Unit
Soldering Tip, general purpose	Soldering Unsoldering	Shape: chisel Size: 1/8"	Ungar #PL113
De-soldering aid	Unsoldering multi-connection components (e.g., tube sockets	Suction device to remove molten solder from connection	Soldapullt by the Edsyn Company, Arleta, California
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	Krylon* #1302 Humiseal Protective Coating, Type 1B12 by Columbia Technical Corp. Woodside 77, New York

*Krylon Inc., Norristown, Pennsylvania

Table 5-2. Performance Tests (Cont'd)

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.	
Note 1. 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.	

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.

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.

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 5-10).

e. Switch 415E INPUT switch to BOLOMETER/4.5 MA. The DC Voltmeter should read between 0.93 and 0.87 volts 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 volts 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	O 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 near 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 5-10) 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.

5-33. MAINTENANCE OF OPTIONS 01 AND 02.

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

5-35. TROUBLESHOOTING.

5-36. LOCATING TROUBLE.

5-37. 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.

5-38. 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 5-5 through 5-8) and using the front panel performance tests (Table 5-2).

5-39. POWER SUPPLY TROUBLE.

5-40. 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.

5-41. COMPONENT TROUBLE ISOLATION.

5-42. The following procedures and data are given to aid in determining whether a transistor is operational. Tests are given for both in-circuit and out-of-circuit transistors and should be useful in determining whether a particular section trouble is due to a faulty transistor or an associated component.

5-43. IN-CIRCUIT TESTING.

5-44. 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 junc-

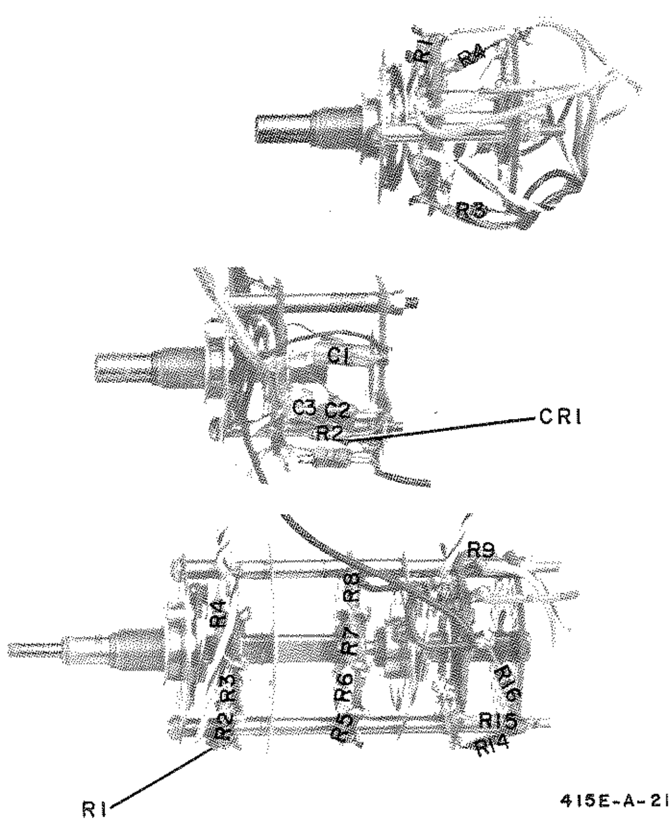


Figure 5-3A. Switch Component Location

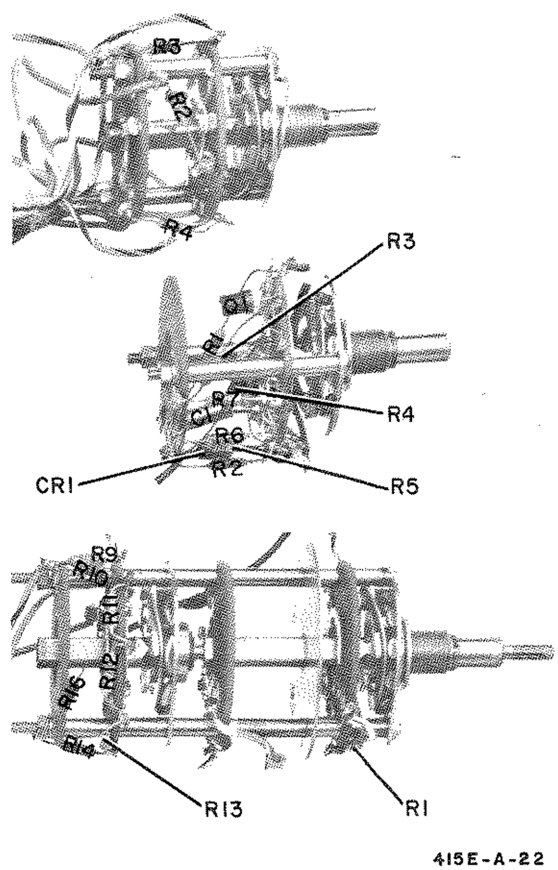


Figure 5-3B. Switch Component Location

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 necessary to know the polarity of the ohms lead with respect to the common lead for the ohmmeter used. (For the hp Model 410B Vacuum Tube Voltmeter, the ohms lead is negative with respect to the common; for the hp Model 412A DC Vacuum Tube Voltmeter, the ohms 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.

Note: For general soldering instructions, refer to Paragraph 5-24 and 5-25.

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 fromshaft.

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.

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.

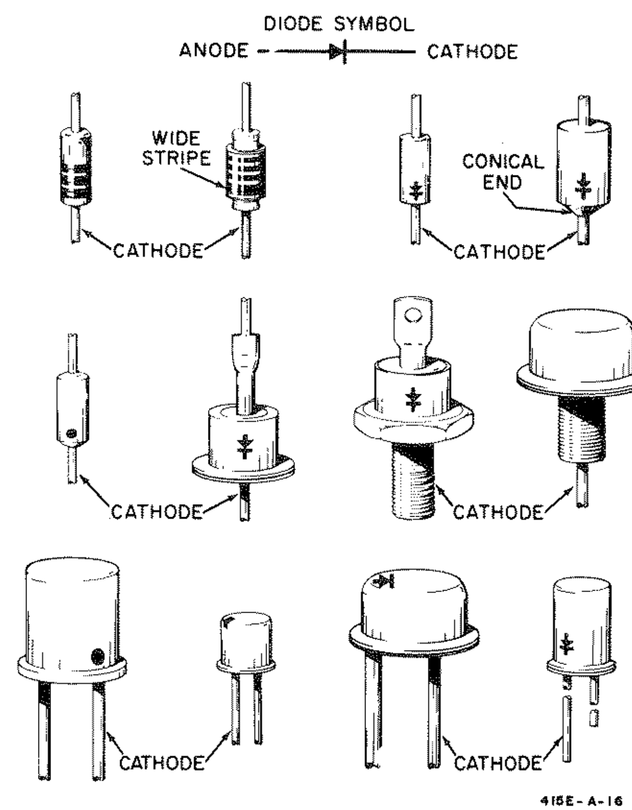


Figure 5-2. Examples of Diode Marking Methods

tion. Use the transistor symbol on the schematic diagram to determine the bias polarity required to forward-bias the base-emitter junction. The A part of Figure 5-4 shows transistor symbols withterminals labelled. Notice that the emitter arrow points toward the type N material. The other two columns of the illustration compare the biasing required to cause conduction and cut-off in transistors and vacuum tubes. If the transistor base-emmiter diode (junction) is forward-biased the transistor conducts. If the diode is heavily forward-biased, the transistor saturates. However, if the base-emitter diode is reverse-biased the transistor is cut off (open). The voltage drop across a forward-biased emitter-base diode varies with transistor collector current. For example, a germanium transistor has a typical forward-bias, base-emitter voltage of 0.2-0.3 volts when collector current is 1-10 ma, and 0.4-0.5 volts when collector current is 10-100 ma. In contrast, forward-bias voltage for silicon transistors is about twice that for germanium types: about 0.5-0.6 volts when collector current is low, and about 0.8-0.9 volts when collector current is high.

5-45. Figure 5-4, part B, shows simplified versions of the three basic transistor circuits and gives the operating characteristics of each. When examining a transistor stage, first determine if the emitter-base diode is biased for conduction (forward-biased) by measuring the voltage difference between emitter and base. When using an electronic voltmeter, do not measure directly between emitter and base: 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.

5-46. OUT-OF-CIRCUIT TESTING.

5-47. 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

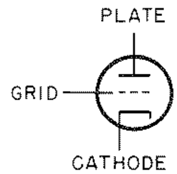
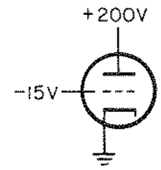
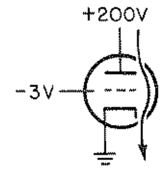
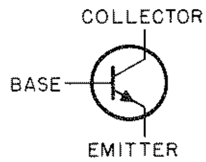
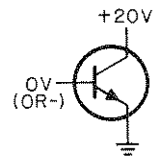
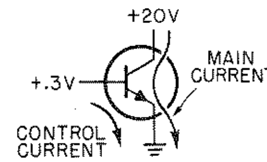
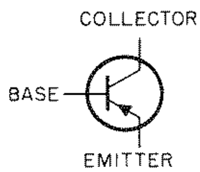
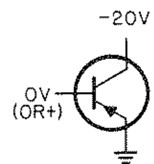
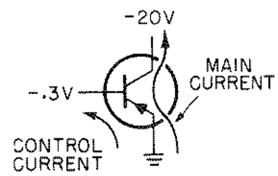
Transistor Type		Connect Ohmmeter		Measure Resistance (ohms)
		Pos. lead to	Neg. lead to	
PNP Germanium	Small Signal	emitter	base*	200-250
		emitter	collector	10K-100K
	Power	emitter	base*	30-50
		emitter	collector	several hundred
NPN Silicon	Small Signal	base	emitter	1K-3K
		collector	emitter	very high (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 Ckt Voltage	Short Ckt Current	Lead Color	Lead 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 100μa 10μa 1μa 0.1μa	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 57μa 5.7μa 0.5μa 0.05μa	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 110μa 11μa 1.1μa 0.11μa	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 325μa	Varies with Serial Number	
Triplett 310	R x 10 R x 100	1.5V 1.5V	750μa 75μa		

A. TRANSISTOR BIASING

DEVICE	SYMBOL	CUTOFF	CONDUCTING
VACUUM TUBE			
N P N TRANSISTOR			
P N P TRANSISTOR			

B. AMPLIFIER CHARACTERISTICS

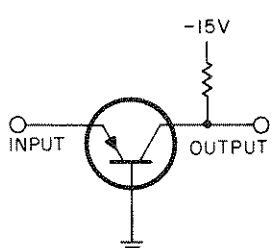
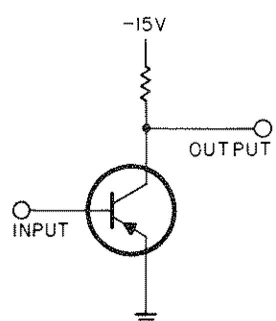
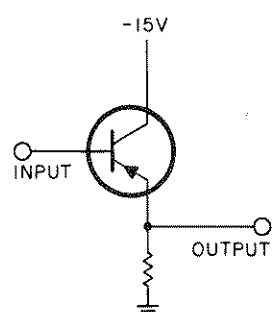
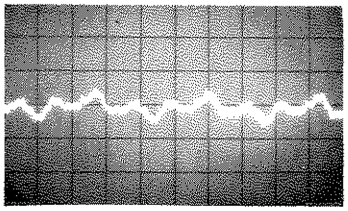
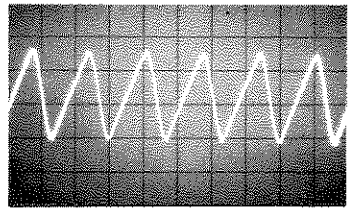
CHARACTERISTIC	COMMON BASE	COMMON EMITTER	COMMON COLLECTOR
INPUT Z	30-50 Ω	500-1500 Ω	20-500K Ω
OUTPUT Z	300-500K Ω	30-50K Ω	50-1000 Ω
VOLTAGE GAIN	500-1500	300-1000	<1
CURRENT GAIN	<1	25-50	25-50
POWER GAIN	20-30 db	25-40 db	10-20 db
			

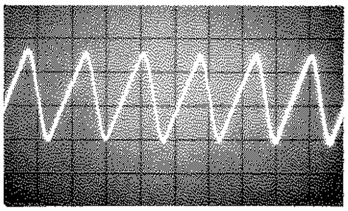
Figure 5-4. Transistor Biasing and Operating Characteristics



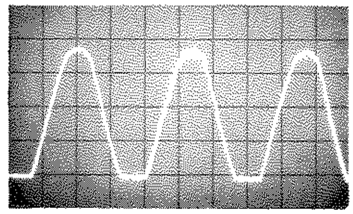
XA3 PIN 7
1MV P-P
(BANDWIDTH
40KC; SWEEP:
5MSEC/CM)



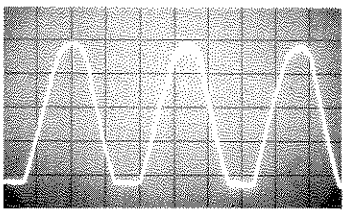
XA3 PIN 5
1.3MV P-P
-24VDC
(SWEEP: 5MSEC/CM)



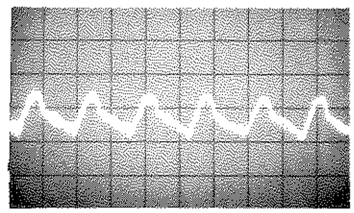
XA3 PIN 6
1.3MV P-P
-24VDC
(SWEEP: 5MSEC/CM



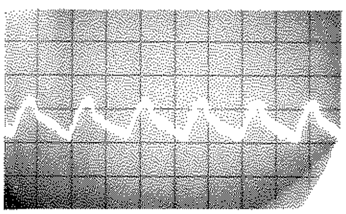
XA3 PIN 4
76V P-P
+14VDC
(SWEEP: 5MSEC/CM



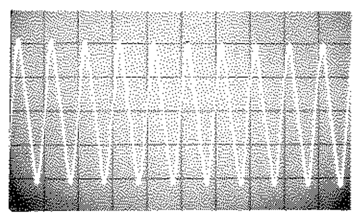
XA3 PIN 3
80V P-P
+14VDC
(SWEEP:5MSEC/CM)



XA3 PIN 1
8MV P-P
-12.8VDC
(SWEEP: 5MSEC/CM



XA3 PIN 2
7MV P-P
+13.2VDC
(SWEEP: 5MSEC/CM



XA3 PIN 9
21MV P-P
-12.8VDC
(SWEEP: 5MSEC/CM

415E-A-13

MEASUREMENT CONDITIONS (unless otherwise noted). *

a. Model 415E set to HIGH, NORM, RANGE 0, BANDWIDTH cw, FREQ centered, GAIN & VERNIER ccw, LINE/ON.

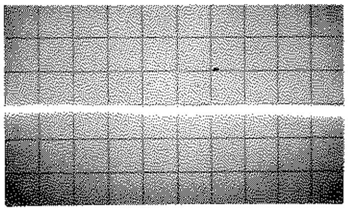
b. MODEL 140A with 1420A & 1400A set to 0.2 msec/cm, AC, 400 kc, and appropriate vertical sensitivity.

c. Model 200CE Oscillator set to about 1000 cps, and for 0 db Model 415E meter reference.

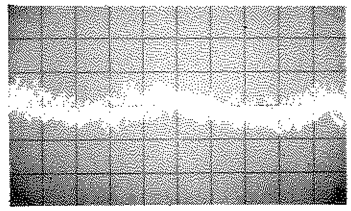
d. Model 412A DC Voltmeter set to appropriate range.

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

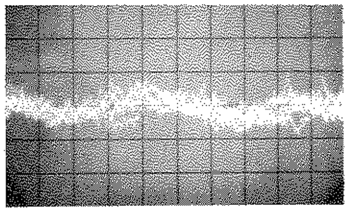
Figure 5-5. Power Supply Waveforms (AC OPERATION - ONLY)



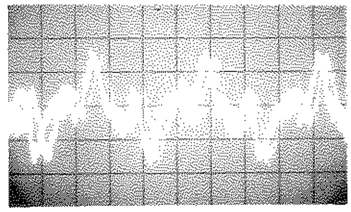
XA3 PIN 7
0.4MV P-P
(BANDWIDTH:40KC)



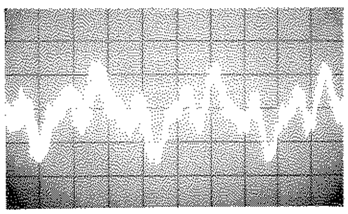
XA3 PIN 5
0.8MV P-P
(−13VDC)
(BANDWIDTH: 40KC)



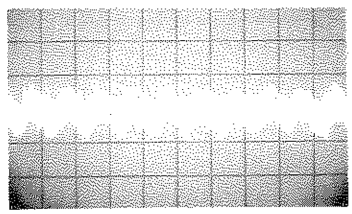
XA3 PIN 6
1MV P-P
−12.6VDC
(BANDWIDTH:40KC)



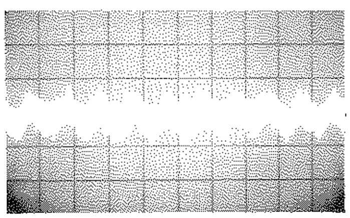
XA3 PIN 4
3MV P-P
+13.2VDC
(BANDWIDTH: 40KC;
SWEEP: 5MSEC/CM)



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



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



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

415E-A-11

MEASUREMENT CONDITIONS (unless otherwise noted).*

a. Model 415E set to HIGH, NORM, RANGE 0, BANDWIDTH cw, FREQ centered, GAIN & VERNIER ccw, BATTERY/ON.

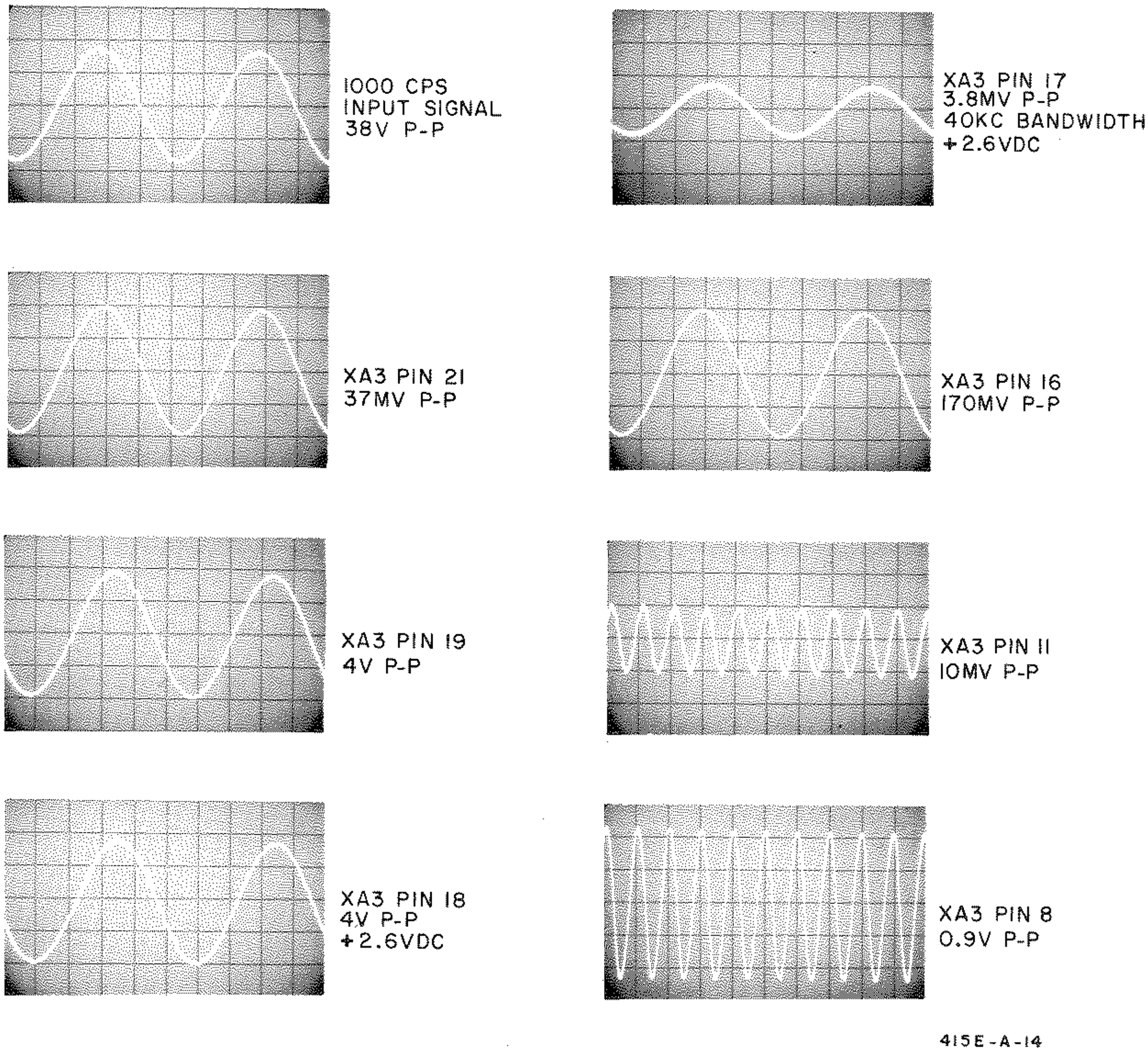
b. MODEL 140A with 1420A & 1400A set to 0.2 msec/cm, AC, 400 kc, and appropriate vertical sensitivity.

c. Model 200CE Oscillator set to about 1000 cps, 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. Power Supply Waveforms (INTERNAL BATTERY OPERATION - ONLY)



MEASUREMENT CONDITIONS (unless otherwise noted). *

a. Model 415E set to ON, HIGH, NORM, RANGE 0, BANDWIDTH cw, FREQ centered, GAIN & VERNIER ccw.

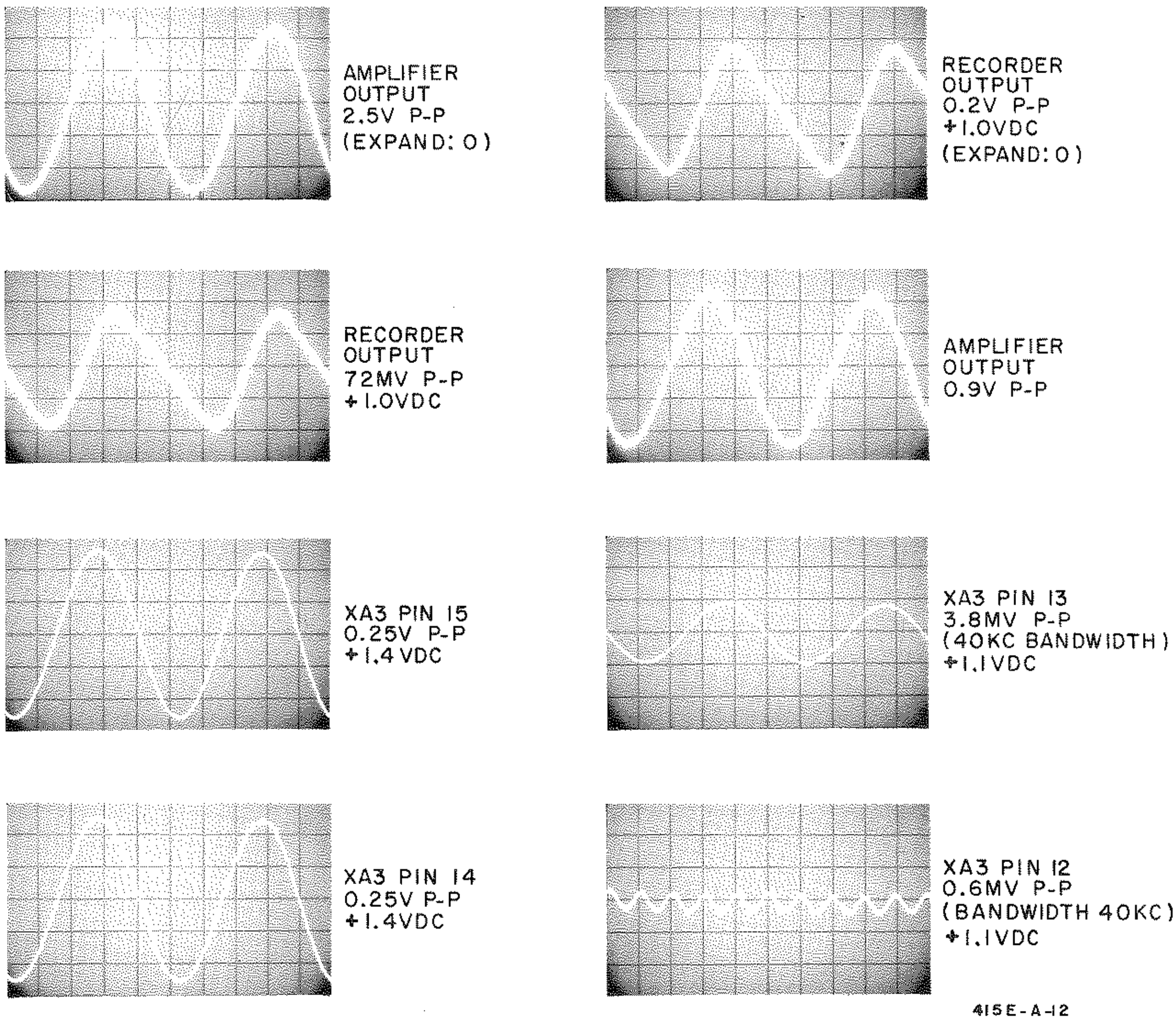
b. MODEL 140A with 1420A & 1400A set to 0.2 msec/cm, AC, 400 kc, and appropriate vertical sensitivity.

c. Model 200CE Oscillator set to about 1000 cps, 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. Signal Flow Waveforms (INPUT TO AMPLIFIER OUTPUT)



MEASUREMENT CONDITIONS (unless otherwise noted). *

a. Model 415E set to ON, HIGH, NORM, RANGE 0, BANDWIDTH cw, FREQ centered, GAIN & VERNIER ccw.

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

c. Model 200CE Oscillator set to about 1000 cps, 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 5-8. Meter and Output Waveforms

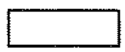
1. Resistance in ohms, "K" indicates thousands of ohms and "M" indicates millions of ohms.

2. Capacitance in microfarads unless otherwise indicated, "ρf" indicates micro-microfarads.

3.  screwdriver

 panel control

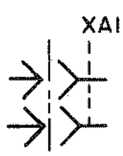
4.  rear panel designation

 front panel designation

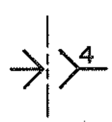
5. circuit assembly borderline

6. 

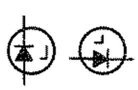
CW indicates movable contact position at clockwise rotation limit of control shaft (shaft viewed from knob or slotted end).

7. 

indicates socket connections of plug-in assembly

8. 

indicates plug-in socket pin number

9.  Voltage regulator (breakdown) diode.

10. "NOM" indicates positive DC power supply voltage is nominal and may vary from nominal value by ±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 5-9. Schematic Notes

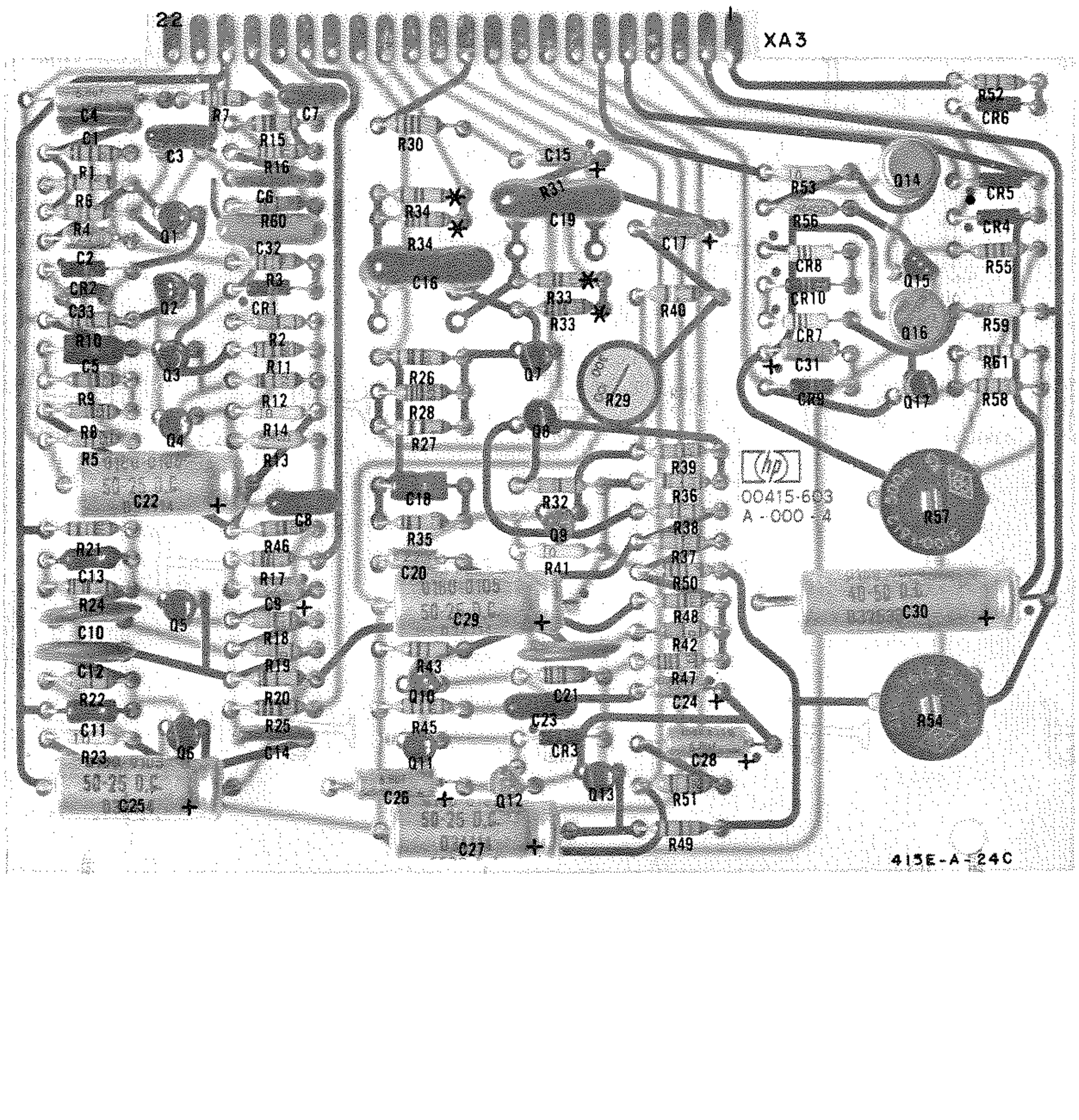
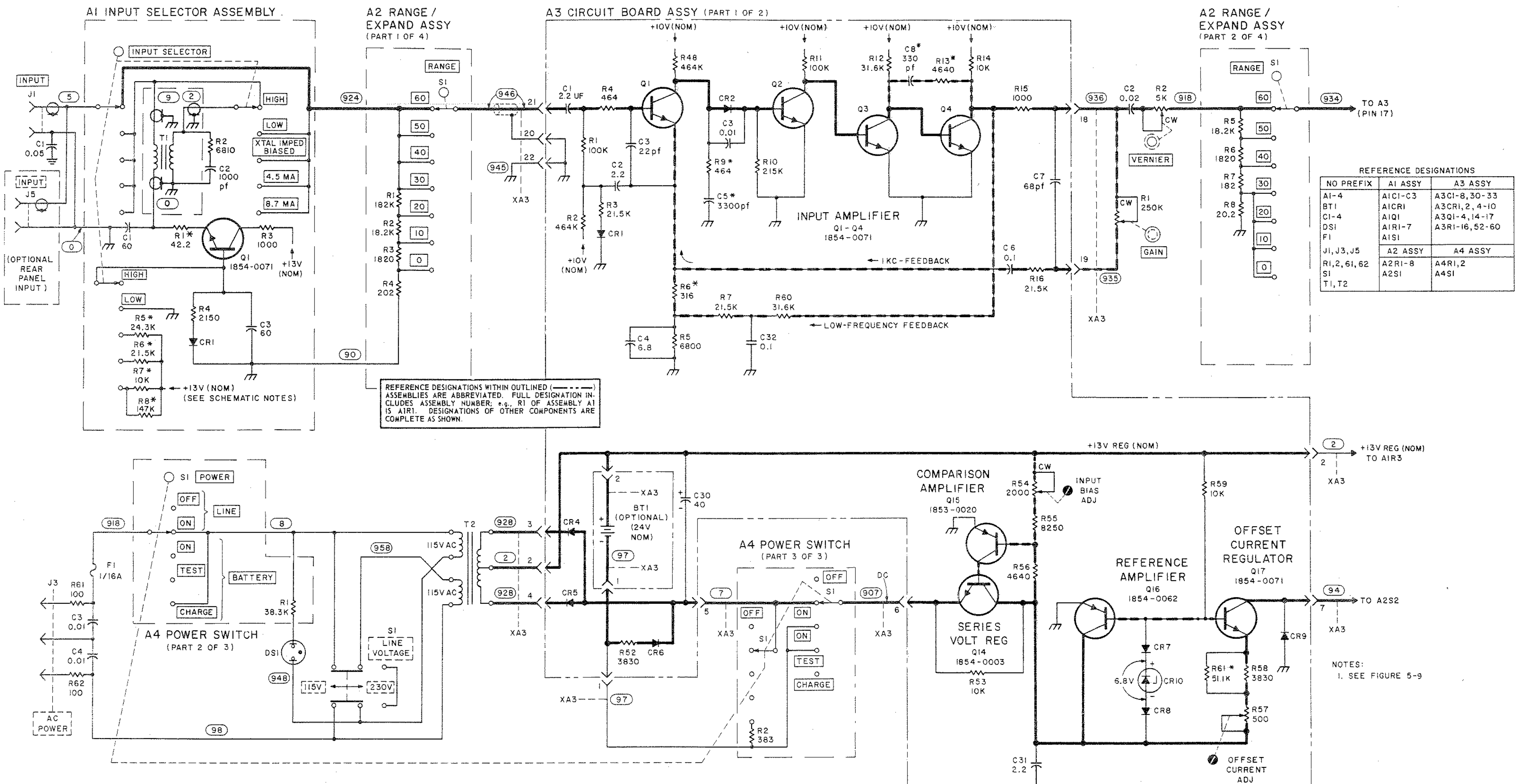
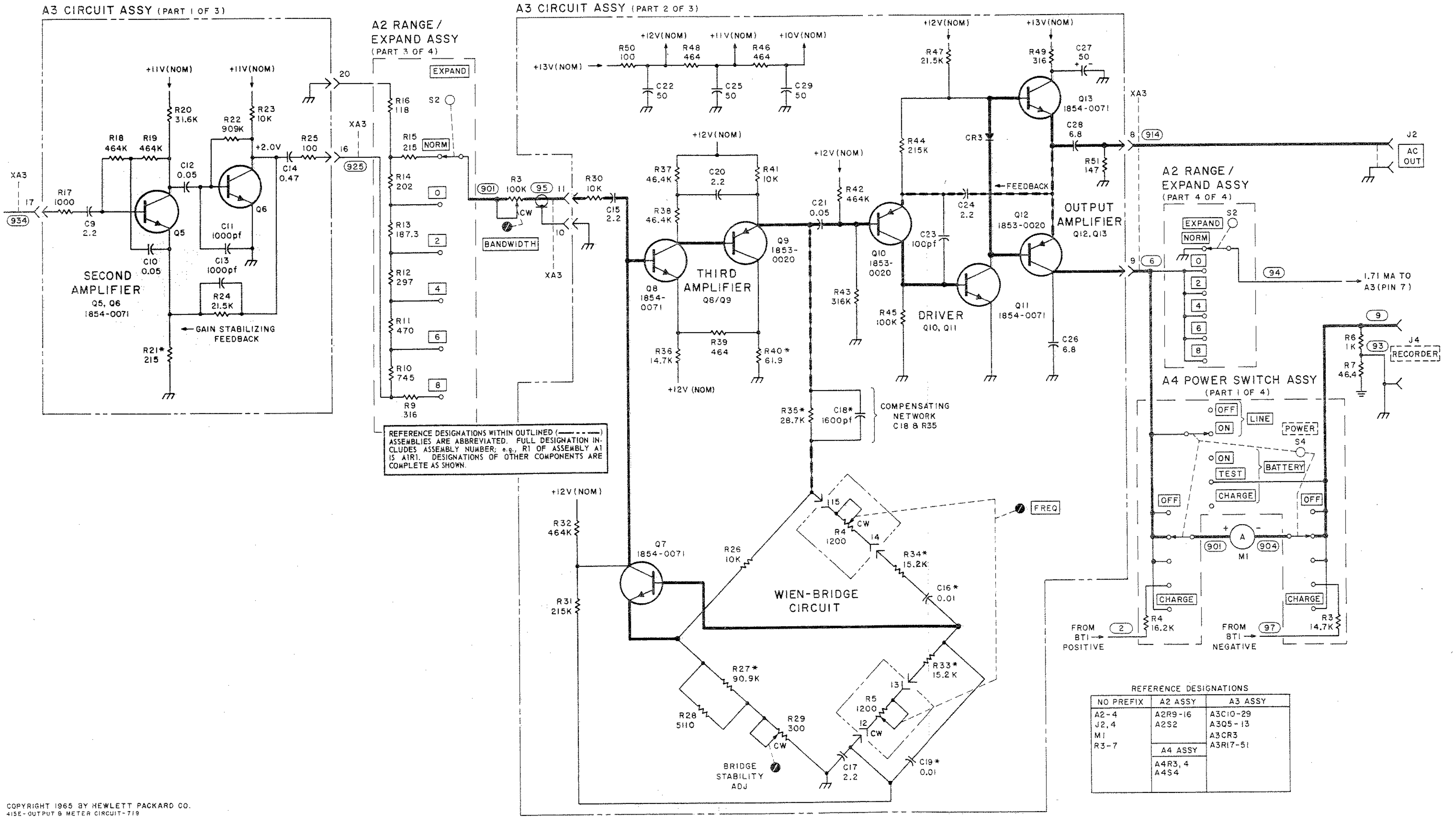


Figure 5-10. A3 Circuit Board Component Location for Instruments Prefixed 545-, and up. See Appendix II for Component Location of Instruments Prefixed 530-.



415E-REG. P.S. & INPUT CKT - 719

Figure 5-11. Power Supply and Input Circuit



415E-OUTPUT & METER CIRCUIT-719

Figure 5-12. Output & Meter Circuit

SECTION VI
REPLACEABLE PARTS

6-1. INTRODUCTION

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

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

b. Typical manufacturer of the part in a five-digit code; see list of manufacturers in 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 6-1.

6-4. ORDERING INFORMATION

6-5. To obtain replacement parts, address order or inquiry to your local Hewlett-Packard Field Office (see lists at rear of this manual for addresses). Identify parts by their Hewlett-Packard stock 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.

REFERENCE DESIGNATORS

A = assembly	E = misc electronic part	MP = mechanical part	TB = terminal board
B = motor	F = fuse	P = plug	TP = test point
BT = battery	FL = filter	Q = transistor	V = vacuum, tube, neon bulb, photocell, etc.
C = capacitor	J = jack	R = resistor	W = cable
CP = coupler	K = relay	RT = thermistor	X = socket
CR = diode	L = inductor	S = switch	Y = crystal
DL = delay line	M = meter	T = transformer	
DS = device signaling (lamp)			

ABBREVIATIONS

A = amperes
A.F.C. = automatic frequency control
AMPL = amplifier

B.F.O. = beat frequency oscillator
BE CU = beryllium copper
BH = binder head
BP = bandpass
BRS = brass
BWO = backward wave oscillator

CCW = counter-clockwise
CER = ceramic
CMO = cabinet mount only
COEF = coefficient
COM = common
COMP = composition
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

GE = germanium
GL = glass
GRD = ground(ed)

H = henries
HEX = hexagonal
HG = mercury
HR = hour(s)

IF = intermediate freq
IMPG = impregnated
INCD = incandescent
INCL = include(s)
INS = insulation(ed)
INT = internal

K = kilo = 1000

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
MINAT = miniature
MOM = momentary
MTG = mounting
MY = "mylar"

N = nano (10^{-9})

N/C = normally closed
NE = neon
NI PL = nickel plate
N/O = normally open
NPO = negative positive zero (zero temperature coefficient)
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
P/O = part of
POLY = polystyrene
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
RIV = reverse inverse voltage

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
SPL = special
SST = stainless steel
SR = split ring
STL = steel

TA = tantalum
TD = time delay
TGL = toggle
TI = titanium
TOL = tolerance
TRIM = trimmer
TWT = traveling wave tube

U = micro = 10^{-6}

VAR = variable
VDCW = dc working volts

W/ = with
W = watts
WIV = working inverse voltage
WW = wirewound
W/O = without

01194-11

Table 6-1. Reference Designation Index

Reference Designation	Stock No.	Description #	Note
A1	00415-601	SWITCH ASSEMBLY, INPUT	
A1C1	0180-0106	C:FXD ELECT 60 UF 20% 6VDCW	
A1C2	0160-0153	C:FXD MYLAR 0.001UF 10%	
A1C3	0180-0106	C:FXD ELECT 60 UF 20% 6VDCW	
A1CR1	1901-0025	DIODE,JUNCTION:100MA AT 1V 100 PIV	
A1Q1	1854-0071	TRANSISTOR:SILICON NPN 2N3391	
A1R1	0757-0316	R:FXD MET FLM 42.2 OHM 1% 1/8W	
A1R2	0757-0439	R:FXD MET FLM 6.81K OHM 1% 1/8W	
A1R3	0757-0280	R:FXD MET FLM 1.00K OHM 1% 1/8W	
A1R4	0698-0084	R:FXD MET FLM 2150 OHM 1% 1/8W	
A1R5	0757-0451	R:FXD MET FLM 24.3K OHM 1% 1/8W	
A1R6	0757-0199	R:FXD MET FLM 21.5K OHM 1% 1/8W	
A1R7	0757-0443	R:FXD MET FLM 11K OHM 1% 1/8W	
A1R8	0698-3452	R:FXD MET FLM 147K OHM 1% 1/8W	
A1S1	3100-1805	SWITCH:ROTARY	
A2	00415-602	SWITCH ASSEMBLY, RANGE	
A2R1	0698-6114	R:FXD MET FLM 182K OHM .25% 1/8W	
A2R2	0698-6109	R:FXD MET FLM 18.2 OHM .25% 1/8W	
A2R3	0698-6113	R:FXD MET FLM 1820 OHM .25% 1/8W	
A2R4	0698-6112	R:FXD MET FLM 202 OHM .25% 1/8W	
A2R5	0698-6109	R:FXD MET FLM 18.2 OHM .25% 1/8W	
A2R6	0698-6113	R:FXD MET FLM 1820 OHM.25% 1/8W	
A2R7	0698-6111	R:FXD MET FLM 182 OHM.25% 1/8W	
A2R8	0698-6110	R:FXD MET FLM 20.2 OHM.25% 1/8W	
A2R9	0698-3444	R:FXD MET FLM 316 OHM 1% 1/8W	
A2R10	0698-3531	R:FXD MET FLM 745 OHM 0.5% 1/8W	
A2R11	0698-3530	R:FXD MET FLM 470 OHM 0.5% 1/8W	
A2R12	0698-3529	R:FXD MET FLM 297 OHM 0.5% 1/8W	
A2R13	0698-3527	R:FXD MET FLM 187.3 OHM 0.5% 1/8W	
A2R14	0698-6112	R:FXD MET FLM 202 OHM.25% 1/8W	
A2R15	0698-3441	R:FXD MET FLM 215 OHM 1% 1/8W	
A2R16	0698-3525	R:FXD MET FLM 118 OHM 0.5% 1/8W	
A2S1	3100-1806	SWITCH:ROTARY	
A3	00415-603	BOARD ASSEMBLY: AMPLIFIER	
A3C1	0180-0155	C:FXD ELECT 2.2 UF 20% 20VDCW	
A3C2	0180-0155	C:FXD TA 2.2UF 20% 20VDCW	
A3C3	0140-0145	C:FXD MICA 22 PF 5% 500 VDCW	
A3C4	0180-0116	C:FXD ELECT TA 6.8 UF 10% 35VDCW	
A3C5	0160-0155	C:FXD MY 3300 PF 10%	
A3C6	0150-0121	C:FXD CER 0.1UF +80%-20% 50VDCW	
A3C7	0140-0192	C:FXD MICA 68PF 5% 300VDCW	
A3C8	0140-0207	C:FXD MICA 330PF 5% 500VDCW	
A3C9	0180-0155	C:FXD TA 2.2UF 20% 20VDCW	
A3C10	0150-0096	C:FXD CER 0.05UF 100VDCW	
A3C11	0160-0153	C:FXD MYLAR 0.001UF 10%	

See list of abbreviations in introduction to this section

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

Reference Designation	ⓗⓟ Stock No.	Description #	Note
A3C12	0150-0096	C:FXD CER 0.05UF 100VDCW	
A3C13	0160-0153	C:FXD MYLAR 0.001UF 10%	
A3C14	0160-0174	C:FXD CER 0.47UF +80-20% 25VDCW	
A3C15	0180-0155	C:FXD ELECT 2.2 UF 20% 20VDCW	
A3C16	0160-2120	C:FXD MICA 0.01UF 1%	
A3C17	0180-0155	C:FXD ELECT 2.2 UF 20% 20VDCW	
A3C18	0160-0299	C:FXD MYLAR .0018 UF 10% 200VDCW	
A3C19	0160-2120	C:FXD MICA 0.01UF 1%	
A3C20	0180-0155	C:FXD ELECT 2.2 UF 20% 20VDCW	
A3C21	0150-0096	C:FXD CER 0.05UF 100VDCW	
A3C22	0180-0105	C:FXD ELECT SEMI-POLARIZED 50UF 25VDCW	
A3C23	0140-0176	C:FXD MICA 100 PF 2% 300 VDCW	
A3C24	0180-0155	C:FXD ELECT 2.2 UF 20% 20VDCW	
A3C25	0180-0105	C:FXD ELECT SEMI-POLARIZED 50UF 25VDCW	
A3C26	0180-0116	C:FXD ELECT TA 6.8 UF 10% 35VDCW	
A3C27	0180-0105	C:FXD ELECT SEMI-POLARIZED 50UF 25VDCW	
A3C28	0180-0116	C:FXD ELECT TA 6.8 UF 10% 35VDCW	
A3C29	0180-0105	C:FXD ELECT SEMI-POLARIZED 50UF 25VDCW	
A3C30	0180-0050	C:FXD ELECT 40UF -15%+100% 50VDCW	
A3C31	0180-0155	C:FXD ELECT 2.2 UF 20% 20VDCW	
A3C32	0170-0085	C:FXD MY 0.1UF 20% 50VDCW	
A3C33	0150-0093	C:FXD CER 0.01UF +80-20% 100VDCW	
A3CR1	1901-0025	DIODE,JUNCTION:100 MA AT 1V 100 PIV	
A3CR2	1901-0025	DIODE,JUNCTION:100 MA AT 1V 100 PIV	
A3CR3	1901-0025	DIODE,JUNCTION:100 MA AT 1V 100 PIV	
A3CR4	1901-0033	DIODE,SILICON 100 MA AT +1V 180 WIV	
A3CR5	1901-0033	DIODE:SILICON 100 MA AT +1V 180 WIV	
A3CR6	1901-0025	DIODE:JUNCTION 100 MA AT 1V 100 PIV	
A3CR7	1910-0016	DIODE:GERMANIUM 100MA AT 0.85V 60PIV	
A3CR8	1910-0016	DIODE:GERMANIUM 100MA AT 0.85V 60PIV	
A3CR9	1901-0025	DIODE,JUNCTION:100 MA AT 1V 100 PIV	
A3CR10	1902-0048	SEMICON DEVICE:DIODE BREAKDOWN 6.8V 10%	
A3Q1	1854-0071	TRANSISTOR:SILICON NPN 2N3391	
A3Q2	1854-0071	TRANSISTOR:SILICON NPN 2N3391	
A3Q3	1854-0071	TRANSISTOR:SILICON NPN 2N3391	
A3Q4	1854-0071	TRANSISTOR:SILICON NPN 2N3391	
A3Q5	1854-0071	TRANSISTOR:SILICON NPN 2N3391	
A3Q6	1854-0071	TRANSISTOR:SILICON NPN 2N3391	
A3Q7	1854-0071	TRANSISTOR:SILICON NPN 2N3391	
A3Q8	1854-0071	TRANSISTOR:SILICON NPN 2N3391	
A3Q9	1853-0020	TRANSISTOR:SILICON PNP	
A3Q10	1853-0020	TRANSISTOR:SILICON PNP	
A3Q11	1854-0071	TRANSISTOR:SILICON NPN 2N3391	
A3Q12	1853-0020	TRANSISTOR:SILICON PNP	
A3Q13	1854-0071	TRANSISTOR:SILICON NPN 2N3391	
A3Q14	1854-0003	TRANSISTOR:NPN SILICON	
A3Q15	1853-0020	TRANSISTOR:SILICON PNP	
A3Q16	1850-0062	TRANSISTOR:GERMANIUM PNP 2N404	
A3Q17	1854-0071	TRANSISTOR:SILICON NPN 2N3391	
A3R1	0757-0465	R:FXD MET FLM 100K OHM 1% 1/8W	

See list of abbreviations in introduction to this section

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

Reference Designation	Stock No.	Description #	Note
A3R2	0698-3260	R:FXD MET FLM 464K OHM 1% 1/8W	
A3R3	0757-0199	R:FXD MET FLM 21.5K OHM 1% 1/8W	
A3R4	0698-0082	R:FXD MET FLM 464 OHM 1% 1/8W	
A3R5	0757-0439	R:FXD MET FLM 6.81K OHM 1% 1/8W	
A3R6	0698-3444	R:FXD MET FLM 316 OHM 1% 1/8W	
A3R7	0757-0199	R:FXD MET FLM 21.5K OHM 1% 1/8W	
A3R8	0698-3260	R:FXD MET FLM 464K OHM 1% 1/8W	
A3R9	0698-0082	R:FXD MET FLM 464 OHM 1% 1/8W	
A3R10	0698-3454	R:FXD MET FLM 215K OHM 1% 1/8W	
A3R11	0757-0465	R:FXD MET FLM 100K OHM 1% 1/8W	
A3R12	0698-3160	R:FXD MET FLM 31.6K OHM 1% 1/8W	
A3R13	0698-3155	R:FXD MET FLM 4640 OHM 1% 1/8	
A3R14	0757-0442	R:FXD MET FLM 10.0K OHM 1% 1/8W	
A3R15	0757-0280	R:FXD MET FLM 1.00K OHM 1% 1/8W	
A3R16	0757-0199	R:FXD MET FLM 21.5K OHM 1% 1/8W	
A3R17	0757-0280	R:FXD MET FLM 1.00K OHM 1% 1/8W	
A3R18	0698-3260	R:FXD MET FLM 464K OHM 1% 1/8W	
A3R19	0698-3260	R:FXD MET FLM 464K OHM 1% 1/8W	
A3R20	0698-3160	R:FXD MET FLM 31.6K OHM 1% 1/8W	
A3R21	0698-3441	R:FXD MET FLM 215 OHM 1% 1/8W	
A3R22	0757-0488	R:FXD MET FLM 909K OHM 1% 1/8W	
A3R23	0757-0442	R:FXD MET FLM 10.0K OHM 1% 1/8W	
A3R24	0757-0199	R:FXD MET FLM 21.5K OHM 1% 1/8W	
A3R25	0757-0401	R:FXD MET FLM 100 OHM 1% 1/8W	
A3R26	0757-0442	R:FXD MET FLM 10.0K OHM 1% 1/8W	
A3R27	0757-0464	R:FXD MET FLM 90.9K OHM 1% 1/8W	
A3R28	0757-0438	R:FXD MET FLM 5.11K OHM 1% 1/8W	
A3R29	2100-1611	R:VAR WW 300 OHM 5% 1W LIN 1/5W	
A3R30	0757-0442	R:FXD MET FLM 10.0K OHM 1% 1/8W	
A3R31	0698-3454	R:FXD MET FLM 215K OHM 1% 1/8W	
A3R32	0698-3260	R:FXD MET FLM 464K OHM 1% 1/8W	
A3R33	0698-5001	R:FXD MET FLM 15.2K OHM 1% 1/8W	
A3R34	0698-5001	R:FXD MET FLM 15.2K OHM 1% 1/8W	
A3R35	0698-3160	R:FXD MET FLM 31.6K OHM 1% 1/8W	
A3R36	0698-3156	R:FXD MET FLM 14.7K OHM 1% 1/8W	
A3R37	0698-3162	R:FXD MET FLM 4640 OHM 1% 1/8W	
A3R38	0698-3162	R:FXD MET FLM 4640 OHM 1% 1/8W	
A3R39	0698-0082	R:FXD MET FLM 464 OHM 1% 1/8W	
A3R40	0698-4037	R:FXD MET FLM 46.4 OHM 1% 1/8W	
A3R41	0757-0442	R:FXD MET FLM 10.0K OHM 1% 1/8W	
A3R42	0698-3260	R:FXD MET FLM 464K OHM 1% 1/8W	
A3R43	0698-3457	R:FXD MET FLM 316K OHM 1% 1/8W	
A3R44	0698-3454	R:FXD MET FLM 215K OHM 1% 1/8W	
A3R45	0757-0465	R:FXD MET FLM 100K OHM 1% 1/8W	
A3R46	0698-0082	R:FXD MET FLM 464 OHM 1% 1/8W	
A3R47	0757-0199	R:FXD MET FLM 21.5K OHM 1% 1/8W	
A3R48	0698-0082	R:FXD MET FLM 464 OHM 1% 1/8W	
A3R49	0698-3444	R:FXD MET FLM 316 OHM 1% 1/8W	
A3R50	0757-0401	R:FXD MET FLM 100 OHM 1% 1/8W	
A3R51	0698-3438	R:FXD MET FLM 147 OHM 1% 1/8W	
A3R52	0698-3153	R:FXD MET FLM 3830 OHM 1% 1/8W	

See list of abbreviations in introduction to this section

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

Reference Designation	ⓗ Stock No.	Description #	Note
A3R53	0757-0442	R:FXD MET FLM 10.0K OHM 1% 1/8W	
A3R54	2100-1613	R:VAR COMP 2K OHM 20% LIN 1/5W	
A3R55	0757-0441	R:FXD MET FLM 8.25K OHM 1% 1/8W	
A3R56	0698-3155	R:FXD MET FLM 4640 OHM 1% 1/8	
A3R57	2100-1612	R:VAR COMP 500 OHM 20% LIN 1/5W	
A3R58	0698-3153	R:FXD MET FLM 3830 OHM 1% 1/8W	
A3R59	0757-0442	R:FXD MET FLM 10.0K OHM 1% 1/8W	
A3R60	0698-3160	R:FXD MET FLM 31.6K OHM 1% 1/8W	
A3R61	0757-0462	R:FXD MET FLM 51.1K OHM 1% 1/8W	
A4	00415-608	SWITCH ASSEMBLY, POWER	
A4R1	0698-3161	R:FXD MET FLM 38.3K OHM 1% 1/8W	
A4R2	0698-3446	R:FXD MET FLM 383 OHM 1% 1/8W	
A4R3	0698-3156	R:FXD MET FLM 14.7K OHM 1% 1/8W	
A4R4	0757-0447	R:FXD MET FLM 16.2K OHM 1% 1/8W	
A4S1	3100-1807	SWITCH:ROTARY	
BT1	1420-0009	BATTERY:RECHARGEABLE 24V 1.25AH (OPTION 01 ONLY)	
C1	0150-0096	C:FXD CER 0.05UF 100VDCW	
C2	0150-0096	C:FXD CER 0.05UF 100VDCW	
C3	0150-0119	C:FXD CER 2X(0.01 UF) 20% 250VDCW	
C4	0150-0119	C:FXD CER 2X(0.01 UF) 20% 250VDCW	
DS1	1450-0048	LAMP:NEON	
F1	2110-0011	FUSE:CARTRIDGE 3 AG 1/16 AMP 250V MAX	
J1	1250-0118	CONNECTOR:BNC	
J2	1510-0006	BINDING POST ASSEMBLY:BLACK	
J2	1510-0007	BINDING POST ASSEMBLY:RED	
J2	0340-0086	INSULATOR:BINDING POST	
J2	0340-0090	INSULATOR:BINDING-POST DOUBLE	
J3	1251-0148	CONNECTOR:POWER 3 PIN MALE	
J4	1250-0118	CONNECTOR:BNC RECORDER	
J5	1250-0001	CONNECTOR:BNC (OPTION 02 ONLY)	
M1	1120-0392	METER	
R1	2100-1574	R:VAR COMP 250K 10% 20CWLOG 15K OHM20% LIN	
R2		PART OF R1	
R3	2100-1578	R:VAR COMP 100K OHM 10% 20 CCWLOG 13W	
R4	2100-1577	R:VAR WW DUAL 1200 OHM 10% LIN TANDEM	
R5		PART OF R4	
R6	0757-0280	R:FXD MET FLM 1000 OHM 1% 1/8W	
R7	0698-4037	R:FXD MET FLM 46.4 OHM 1% 1/8W	
R8 THRU			
R60		NOT ASSIGNED	
R61	0757-0401	R:FXD MET FLM 100 OHM 1% 1/8W	
R62	0757-0401	R:FXD MET FLM 100 OHM 1% 1/8W	
S1	3101-0033	SWITCH:SLIDE DPDT	
T1	9100-0392	TRANSFORMER:AUDIO	
T2	9100-0393	TRANSFORMER:POWER	
XA3	1251-0172	CONNECTOR:PRINTED CIRCUIT 22-CONN	

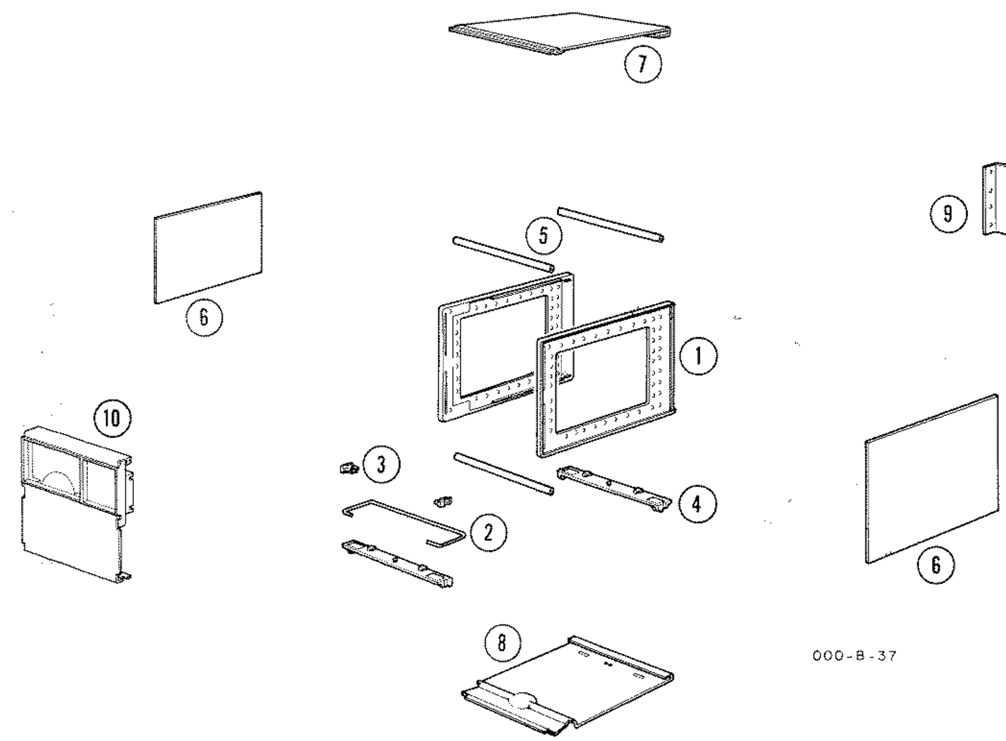
See list of abbreviations in introduction to this section

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

Reference Designation	ⓗ Stock No.	Description #	Note
XF1	1400-0084	FUSEHOLDER:EXTRACTOR POST TYPE	
		MISCELLANEOUS	
	00415-606	BATTERY INSTALLATION KIT,INCLUDES SAMPLE PARTS AS INSTALLED WITH OPTION 01 AND FOUR 6-32 HEX NUTS FOR MOUNTING	
	00415-003	DIAL-KNOB ASSY:EXPAND	
	0370-0062	KNOB:BLACK, VERNIER	
	0370-0089	KNOB:BLACK CONCENTRIC 1 IN. OD GAIN	
	0370-0104	KNOB:BLACK BAR W/ARROW 13/16 DIA 1/4" SHAFT	
	0370-0106	KNOB:RANGE	
	8120-0078	CABLE:POWER 7.5 FT	
		OPTIONS	
		OPTION 01:	
	1420-0009	BATTERY,RECHARGEABLE (BT1)	
	00415-006	COVER,BATTERY	
	2420-0001	HEX NUTS (QTY-4)	
		NOTE: SEE MISCELLANEOUS SECTION FOR BATTERY INSTALLATION KIT STOCK NUMBERS	
		OPTION 02:(J5)	
	00415-607	CABLE:SPECIAL PURPOSE ELECTRICAL	
	0360-0024	TERMINAL LUG	
	1250-0001	CONNECTOR:BNC	
	2420-0001	HEX NUT: 6-32 X 5/16	
	3050-0100	WASHER,LOCK NO. 6	
	3050-0018	WASHER,EXTRUDED FIBER (QTY-2)	

See list of abbreviations in introduction to this section

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



CABINET PARTS

Reference Designation	Stock No.	Description #	Note
1.	5060-0703	FRAME ASSEMBLY	
2.	1490-0032	STAND: TILT HALF-MODULE	
3.	5040-0700	HINGE	
4.	5060-0728	FOOT ASSEMBLY HALF MODULE	
5.	5020-0701	CABINET SPACER	
	2370-0015	LOCKWASHER: 6-32 X 0.375" FH SLOT DRIVE	
6.	5000-0703	COVER:SIDE	
	2370-0020	# 6-32 X 0.187" 100° FH, PHILLIPS DRIVE	
7.	5060-0720	COVER:TOP	
	2370-0016	# 6-32 X 0.373" 100° FH, PHILLIPS DRIVE	
8.	5000-0717	COVER:BOTTOM	
	2370-0016	# 6-32 X 0.373" 100° FH, PHILLIPS DRIVE	
9.	00415-004	PANEL:REAR	
	2370-0015	# 6-32 X 0.375" FH,SLOT DR W/ EXT LOCKWASHER	
10	00415-002	PANEL:FRONT	
	2370-0002	# 6-32 X 0.375" FH,SLOT DRIVE	

See list of abbreviations in introduction to this section

Table 6-2. Replaceable Parts

ⓗⓟ Stock No.	Description #	Mfr.	Mfr. Part No.	TQ	
0140-0145	C:FXD MICA 22 PF 5% 500 VDCW	04062	RDM15C220J5C	1	
0140-0176	C:FXD MICA 100 PF 2% 300 VDCW	04062	RDM15F101G3C	1	
0140-0192	C:FXD MICA 68PF 5% 300VDCW	04062	RDM15E680J3C	1	
0140-0207	C:FXD MICA 330PF 5% 500VDCW	04062	RDM15F331J5C	1	
0150-0093	C:FXD CER 0.01UF +80-20% 100VDCW	91418	TA	1	
0150-0096	C:FXD CER 0.05UF 100VDCW	91418	-TA	5	
0150-0119	C:FXD CER 2X(0.01 UF) 20% 250VDCW	56289	41C159A	2	
0150-0121	C:FXD CER 0.1UF +80%-20% 50VDCW	56289	5C50A	1	
0160-0153	C:FXD MYLAR 0.001UF 10%	28480	0160-0153	3	
0160-0155	C:FXD MY 3300 PF 10%	28480	0160-0155	1	
0160-0174	C:FXD CER 0.47UF +80-20% 25VDCW	56289	5C11A		
0160-0299	C:FXD MYLAR .0018 UF 10% 200VDCW	28480	0160-0299	1	
0160-2120	C:FXD MICA 0.01UF 1%	04062	RDM30F103F3C	2	
0170-0085	C:FXD MY 0.1UF 20% 50VDCW	84411	601PE STYLE 3	1	
0180-0050	C:FXD ELECT 40UF -15%+100% 50VDCW	56289	D32538	1	
0180-0105	C:FXD ELECT SEMI-POLARIZED 50UF 25VDCW	56289	D34114	4	
0180-0106	C:FXD ELECT TA 60UF 20% 6VDCW	56289	150D606X0006B2	2	
0180-0116	C:FXD ELECT TA 6.8 UF 10% 35VDCW	56289	150D685X9035B2	3	
0180-0155	C:FXD TA 2.2UF 20% 20VDCW	56289	150D225X0020A2		
0340-0086	INSULATOR:BINDING POST	28480	0340-0086	1	
0340-0090	INSULATOR:BINDING-POST DOUBLE	28480	0340-0090	1	
0360-0024	TERMINAL:LUG GROUNDING FOR POTENTIOMETERS	37942	A-131023-1	1	
0370-0062	KNOB	28480	0370-0062	1	
0370-0089	KNOB:BLK CONCENTRIC 1 IN. OD 17/64IN. HOLE	28480	0370-0089	1	
0370-0104	KNOB:BLACK BAR W/ARROW 13/16 DIA 1/4 SHAFT	28480	0370-0104	2	
0370-0106	KNOB	28480	0370-0106	1	
0380-0308	SPACER:CAPTIVE	28480	0380-0308	2	
0698-0082	R:FXD MET FLM 464 OHM 1% 1/8W	28480	0698-0082	5	
0698-0084	R:FXD MET FLM 2150 OHM 1% 1/8W	28480	0698-0084	1	
0698-3153	R:FXD MET FLM 3830 OHM 1% 1/8W	28480	0698-3153	2	
0698-3155	R:FXD MET FLM 4640 OHM 1% 1/8	28480	0698-3155	2	
0698-3156	R:FXD MET FLM 14.7K OHM 1% 1/8W	28480	0698-3156	2	
0698-3160	R:FXD MET FLM 31.6K OHM 1% 1/8W	28480	0698-3160	4	
0698-3161	R:FXD MET FLM 3830 OHM 1% 1/8W	28480	0698-3161	1	
0698-3162	R:FXD MET FLM 4640 OHM 1% 1/8W	28480	0698-3162	2	
0698-3260	R:FXD MET FLM 464K OHM 1% 1/8W	28480	0698-3260		
0698-3438	R:FXD MET FLM 147 OHM 1% 1/8W	28480	0698-3438	1	
0698-3441	R:FXD MET FLM 215 OHM 1% 1/8W	28480	0698-3441	2	
0698-3444	R:FXD MET FLM 316 OHM 1% 1/8W	28480	0698-3444	3	
0698-3446	R:FXD MET FLM 383 OHM 1% 1/8W	28480	0698-3446	1	
0698-3452	R:FXD MET FLM 147K OHM 1% 1/8W	28480	0698-3452	1	
0698-3454	R:FXD MET FLM 215K OHM 1% 1/8W	28480	0698-3454	3	
0698-3457	R:FXD MET FLM 316K OHM 1% 1/8W	28480	0698-3457	1	
0698-3525	R:FXD MET FLM 118 OHM 0.5% 1/8W	28480	0698-3525	1	
0698-3527	R:FXD MET FLM 187.3 OHM 0.5% 1/8W	28480	0698-3527	1	
0698-3529	R:FXD MET FLM 297 OHM 0.5% 1/8W	28480	0698-3529	1	
0698-3530	R:FXD MET FLM 470 OHM 0.5% 1/8W	28480	0698-3530	1	
0698-3531	R:FXD MET FLM 745 OHM 0.5% 1/8W	28480	0698-3531	1	
0698-4037	R:FXD MET FLM 46.4 OHM 1% 1/8W	28480	0698-4037	2	
0698-5001	R:FXD MET FLM 15.2K OHM 1% 1/8W	28480	0698-5001	2	

See list of abbreviations in introduction to this section

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

ⓗ Stock No.	Description #	Mfr.	Mfr. Part No.	TQ	
0698-6109	R:FXD MET FLM 18.2 OHM .25% 1/8W	28480	0698-6109	2	
0698-6110	R:FXD MET FLM 20.2 OHM .25% 1/8W	28480	0698-6110	1	
0698-6111	R:FXD MET FLM 182 OHM .25% 1/8W	28480	0698-6111	1	
0698-6112	R:FXD MET FLM 202 OHM .25% 1/8W	28480	0698-6112	2	
0698-6113	R:FXD MET FLM 1820 OHM .25% 1/8W	28480	0698-6113	2	
0698-6114	R:FXD MET FLM 182K OHM .25% 1/8W	28480	0698-6114	1	
0757-0199	R:FXD MET FLM 21.5K OHM 1% 1/8W	28480	0757-0199	6	
0757-0280	R:FXD MET FLM 1.00K OHM 1% 1/8W	28480	0757-0280	4	
0757-0316	R:FXD MET FLM 42.2 OHM 1% 1/8W	28480	0757-0316	1	
0757-0401	R:FXD MET FLM 100 OHM 1% 1/8W	28480	0757-0401	4	
0757-0438	R:FXD MET FLM 5.11K OHM 1% 1/8W	28480	0757-0438	1	
0757-0439	R:FXD MET FLM 6.81K OHM 1% 1/8W	28480	0757-0439	2	
0757-0441	R:FXD MET FLM 8.25K OHM 1% 1/8W	28480	0757-0441	1	
0757-0442	R:FXD MET FLM 10.0K OHM 1% 1/8W	28480	0757-0442	7	
0757-0443	R:FXD MET FLM 11 K OHM 1% 1/8W	28480	0757-0443	1	
0757-0447	R:FXD MET FLM 16.2K OHM 1% 1/8W	28480	0757-0447	1	
0757-0451	R:FXD MET FLM 24.3K OHM 1% 1/8W	28480	0757-0451	1	
0757-0462	R:FXD MET FLM 51.1K OHM 1% 1/8W	28480	0757-0462	1	
0757-0464	R:FXD MET FLM 90.9K OHM 1% 1/8W	28480	0757-0464	1	
0757-0465	R:FXD MET FLM 100K OHM 1% 1/8W	28480	0757-0465	3	
0757-1094	R:FXD MET FLM 1.47K OHM 1% 1/8W	28480	0757-1094	1	
1120-0392	METER	28480	1120-0392	1	
1250-0001	CONNECTOR:BNC	91737	5126	1	
1250-0118	CONNECTOR:BNC	91737	8427	2	
1251-0148	CONNECTOR:POWER 3 PIN MALE	60427	H-1061-2	1	
1251-0172	CONNECTOR:PRINTED CIRCUIT 22-CONN	28480	1251-0172	1	
1400-0084	HOLDER:FUSE POST TYPE 3AG	75915	342014	1	
1420-0009	BATTERY:RECHARGEABLE 24V 1.25AH(OPT 01)	28480	1420-0009	1	
1450-0048	LAMP:NEON	28480	1350-0048	1	
1490-0032	STAND:TILT HALF-MODULE	28480	1490-0032	1	
1510-0006	BINDING POST ASSEMBLY:BLACK	28480	1510-0006	1	
1510-0007	BINDING POST ASSEMBLY:RED	28480	1510-0007	1	
1850-0062	TRANSISTOR:GERMANIUM PNP 2N404	28480	1850-0062	1	
1853-0020	TRANSISTOR:SILICON PNP	28480	1853-0020	4	
1854-0003	TRANSISTOR:NPN SILICON	28480	1854-0003	1	
1854-0071	TRANSISTOR:SILICON NPN 2N3391	89473	16A792	12	
1901-0025	DIODE,JUNCTION:100MA AT 1V 100 PIV	28480	1901-0025	6	
1901-0033	DIODE:SILICON 100 MA AT +1V 180 WIV	28480	1901-0033	2	
1902-0048	SEMICON DEVICE:DIODE BREAKDOWN 6.8V 10%	28480	1902-0048	1	
1910-0016	DIODE:GERMANIUM 100MA AT 0.85V 60PIV	28480	1910-0016	2	
2100-1574	R:VAR COMP 250K 10% 20CWLOG 15K OHM20% LIN	28480	2100-1574	1	
2100-1577	R:VAR WW DUAL 1200 OHM 10% LIN TANDEM	28480	2100-1577	1	
2100-1578	R:VAR COMP 100K OHM 10% 20 CCWLOG 13W	28480	2100-1578	1	
2100-1611	R:VAR WW 300 OHM 5% 1W LIN 1/5W	28480	2100-1611	1	
2100-1612	R:VAR COMP 500 OHM 20% LIN 1/5W	28480	2100-1612	1	
2100-1613	R:VAR COMP 2K OHM 20% LIN 1/5W	28480	2100-1613	1	
2110-0011	FUSE:CARTRIDGE 3 AG 1/16 AMP 250V MAX	75915	312062	1	
3100-1805	SWITCH:ROTARY	28480	3100-1805	1	
3100-1806	SWITCH:ROTARY	28480	3100-1806	1	
3100-1807	SWITCH:ROTARY	28480	3100-1807	1	
3101-0033	SWITCH:SLIDE DPDT	42190	4633	1	
5000-0703	COVER:SIDE 6 X 11 SM	28480	5000-0703	2	
5000-0717	COVER:HALF-MODULE BOTTOM	28480	5000-0717	1	

See list of abbreviations in introduction to this section

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

ⓗⓟ Stock No.	Description #	Mfr.	Mfr. Part No.	TQ	
5020-0701	CABINET SPACER	28480	5020-0701	3	
5040-0700	HINGE	28480	5040-0700	2	
5060-0703	FRAME ASSEMBLY	28480	5060-0703	2	
5060-0720	COVER:HALF-RECESS TOP	28480	5060-0720	1	
5060-0728	FOOT ASSY:HALF MODULE	28480	5060-0728	2	
8120-0078	CABLE:POWER 7.5FT.	70903	KH4147	1	
9100-0392	TRANSFORMER:AUDIO	28480	9100-0392	1	
9100-0393	TRANSFORMER:POWER	28480	9100-0393	1	
00415-002	PANEL, FRONT	28480	00415-002	1	
00415-003	DIAL ASSY., EXPAND	28480	00415-003	1	
00415-004	PANEL, REAR	28480	00415-004	1	
00415-006	COVER, BATTERY(OPTION 01)	28480	00415-006	1	
00415-608	SWITCH ASSEMBLY, POWER	28480	00415-608	1	
00415-601	SWITCH ASSEMBLY, INPUT	28480	00415-601	1	
00415-602	SWITCH ASSEMBLY, RANGE	28480	00415-602	1	
00415-603	BOARD ASSEMBLY: AMPLIFIER	28480	00415-603	1	
00415-607	CABLE, SPECIAL PURPOSE ELECTRICAL(OPT 02)	28480	00415-607	2	

See list of abbreviations in introduction to this section

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. The date of revision and the date of the supplements used appear at the bottom of each page. Alphabetical codes have been arbitrarily assigned to suppliers not appearing in the H4 Handbooks.

Code No.	Manufacturer	Address
00000	U.S.A. Common	Any supplier of U.S.
00136	McCoy Electronics	Mount Holly Springs, Pa.
00213	Sage Electronics Corp.	Rochester, N.Y.
00287	Cemco Inc.	Danielson, Conn.
00334	Humidial	Colton, Calif.
00348	Microtron Co., Inc.	Valley Stream, N.Y.
00373	Garlock Inc., Electronics Products Div.	Camden, N.J.
00656	Aerovox Corp.	New Bedford, Mass.
00779	Amp. Inc.	Harrisburg, Pa.
00781	Aircraft Radio Corp.	Boonton, N.J.
00815	Northern Engineering Laboratories, Inc.	Burlington, Wis.
00853	Sangamo Electric Co., Pickens Div.	Pickens, S.C.
00866	Goe Engineering Co.	Los Angeles, Calif.
00891	Carl E. Holmes Corp.	Los Angeles, Calif.
00929	Microlab Inc.	Livingston, N.J.
01009	Alden Products Co.	Brockton, Mass.
01121	Allen Bradley Co.	Milwaukee, Wis.
01255	Litton Industries, Inc.	Beverly Hills, Calif.
01281	TRW Semiconductors, Inc.	Lawndale, Calif.
01295	Texas Instruments, Inc., Transistor Products Div.	Dallas, Texas
01349	The Alliance Mfg. Co.	Alliance, Ohio
01589	Pacific Relays, Inc.	Van Nuys, Calif.
01930	Amerock Corp.	Rockford, Ill.
01961	Pulse Engineering Co.	Santa Clara, Calif.
02114	Ferroxcube Corp. of America	Saugerties, N.Y.
02286	Cole Rubber and Plastics Inc.	Sunnyvale, Calif.
02660	Amphenol-Borg Electronics Corp.	Chicago, Ill.
02735	Radio Corp. of America, Semiconductor and Materials Div.	Somerville, N.J.
02771	Vocaline Co. of America, Inc.	Old Saybrook, Conn.
02777	Hopkins Engineering Co.	San Fernando, Calif.
03508	G.E. Semiconductor Prod. Dept.	Syracuse, N.Y.
03705	Apex Machine & Tool Co.	Dayton, Ohio
03797	Eldema Corp.	Compton, Calif.
03877	Transitron Electric Corp.	Wakefield, Mass.
03888	Pyrofilm Resistor Co., Inc.	Cedar Knolls, N.J.
03954	Singer Co., Diehl Div. Finderne Plant	Sumerville, N.J.
04009	Arrow, Hart and Hegeman Elect. Co.	Hartford, Conn.
04013	Taurus Corp.	Lambertville, N.J.
04222	Hi-Q Division of Aerovox	Myrtle Beach, S.C.
04354	Precision Paper Tube Co.	Chicago, Ill.
04404	Dymec Division of Hewlett-Packard Co.	Palo Alto, Calif.
04651	Sylvania Electric Products, Microwave Device Div.	Mountain View, Calif.
04713	Motorola, Inc., Semiconductor Prod. Div.	Phoenix, Arizona
04732	Filtron Co., Inc. Western Div.	Culver City, Calif.
04773	Automatic Electric Co.	Northlake, Ill.
04796	Sequoia Wire Co.	Redwood City, Calif.
04811	Precision Coil Spring Co.	El Monte, Calif.
04870	P.M. Motor Company	Westchester, Ill.
05006	Twentieth Century Plastics, Inc.	Los Angeles, Calif.
05277	Westinghouse Electric Corp. Semi-Conductor Dept.	Youngwood, Pa.
05347	Ultronix, Inc.	San Mateo, Calif.
05593	Illumitronic Engineering Co.	Sunnyvale, Calif.
05616	Cosmo Plastic (c/o Electrical Spec. Co.)	Cleveland, Ohio
05624	Barber Colman Co.	Rockford, Ill.
05728	Tiffen Optical Co.	Roslyn Heights, Long Island, N.Y.
05729	Metro-Tel Corp.	Westbury, N.Y.
05783	Stewart Engineering Co.	Santa Cruz, Calif.
05820	Wakefield Engineering Inc.	Wakefield, Mass.
06004	Bassick Co., The	Bridgeport, Conn.
06090	Raychem Corp.	Redwood City, Calif.
06175	Bausch and Lomb Optical Co.	Rochester, N.Y.
06402	E.T.A. Products Co. of America	Chicago, Ill.
06540	Amatom Electronic Hardware Co., Inc.	New Rochelle, N.Y.
06555	Beede Electrical Instrument Co., Inc.	Penacook, N.H.
06666	General Devices Co., Inc.	Indianapolis, Ind.
06751	Semcor Div. Components Inc.	Phoenix, Ariz.
06812	Torrington Mfg. Co., West Div.	Van Nuys, Calif.
06980	Varian Assoc. Eimac Div.	San Carlos, Calif.
07088	Kelvin Electric Co.	Van Nuys, Calif.
07126	Digitran Co.	Pasadena, Calif.
07137	Transistor Electronics Corp.	Minneapolis, Minn.
07138	Westinghouse Electric Corp. Electronic Tube Div.	Elmira, N.Y.
07149	Filmohm Corp.	New York, N.Y.
07233	Cinch-Graphik Co.	City of Industry, Calif.
07261	Avnet Corp.	Culver City, Calif.
07263	Fairchild Camera & Inst. Corp. Semiconductor Div.	Mountain View, Calif.
07322	Minnesota Rubber Co.	Minneapolis, Minn.
07387	Birtcher Corp., The	Monterey Park, Calif.
07700	Technical Wire Products Inc.	Cranford, N.J.
07910	Continental Device Corp.	Hawthorne, Calif.
07933	Raytheon Mfg. Co., Semiconductor Div.	Mountain View, Calif.
07966	Shockley Semi-Conductor Laboratories	Palo Alto, Calif.
07980	Hewlett-Packard Co., Boonton Radio Div.	Rockaway, N.J.
08145	U.S. Engineering Co.	Los Angeles, Calif.
08289	Blinn, Delbert Co.	Pomona, Calif.
08358	Burgess Battery Co.	Niagara Falls, Ontario, Canada
08664	Bristol Co., The	Waterbury, Conn.
08717	Sloan Company	Sun Valley, Calif.
08718	ITT Cannon Electric Inc., Phoenix Div.	Phoenix, Arizona
08792	CBS Electronics Semiconductor Operations, Div of C.B.S. Inc.	Lowell, Mass.
08984	Mel-Rain	Indianapolis, Ind.
09026	Babcock Relays Div.	Costa Mesa, Calif.
09134	Texas Capacitor Co.	Houston, Texas
09145	Atohm Electronics	Sun Valley, Calif.
09250	Electro Assemblies, Inc.	Chicago, Ill.
09569	Mallory Battery Co. of Canada, Ltd.	Toronto, Ontario, Canada
10214	General Transistor Western Corp.	Los Angeles, Calif.
10411	Ti-Tal, Inc.	Berkeley, Calif.
10646	Carborundum Co.	Niagara Falls, N.Y.
11236	CTS of Berne, Inc.	Berne, Ind.
11237	Chicago Telephone of California, Inc.	So. Pasadena, Calif.
11242	Bay State Electronics Corp.	Waltham, Mass.
11312	Teledyne Inc., Microwave Div.	Palo Alto, Calif.
11534	Duncan Electronics Inc.	Costa Mesa, Calif.
11711	General Instrument Corp., Semiconductor Div., Products Group	Newark, N.J.
11717	Imperial Electronic, Inc.	Buena Park, Calif.
11870	Melabs, Inc.	Palo Alto, Calif.
12136	Philadelphia Handle Co.	Camden, N.J.
12697	Clarostat Mfg. Co.	Dover, N.H.
12859	Nippon Electric Co., Ltd.	Tokyo, Japan
12881	Metex Electronics Corp.	Clark, N.J.
12930	Delta Semiconductor Inc.	Newport Beach, Calif.
12954	Dickson Electronics Corp.	Scottsdale, Arizona
13103	Thermolloy	Dallas, Texas
13396	Telefunken (GmbH)	Hanover, Germany
13835	Midland-Wright Div. of Pacific Industries, Inc.	Kansas City, Kansas
14099	Sem-Tech	Newbury Park, Calif.
14193	Calif. Resistor Corp.	Santa Monica, Calif.
14298	American Components, Inc.	Conshohocken, Pa.
14433	ITT Semiconductor, A Div. of Int. Telephone & Telegraph Corp.	West Palm Beach, Fla.
14493	Hewlett-Packard Company	Loveland, Colo.
14655	Cornell Dubilier Electric Corp.	Newark, N.J.
14674	Corning Glass Works	Corning, N.Y.
14752	Electro Cube Inc.	So. Pasadena, Calif.
14960	Williams Mfg. Co.	San Jose, Calif.
15203	Webster Electronics Co.	New York, N.Y.
15291	Adjustable Bushing Co.	N. Hollywood, Calif.
15558	Micron Electronics	Garden City, Long Island, N.Y.
15566	Amprobe Inst. Corp.	Lynbrook, N.Y.
15772	Twentieth Century Coil Spring Co.	Santa Clara, Calif.
15818	Amelco Inc.	Mt. View, Calif.
15909	Daven Div. Thomas A. Edison Ind. McGraw-Edison Co.	Long Island City, N.Y.
16037	Spruce Pine Mica Co.	Spruce Pine, N.C.
16179	Omni-Spectra Inc.	Detroit, Ill.
16352	Computer Diode Corp.	Lodi, N.J.
16688	Ideal Prec. Meter Co., Inc. De Jur Meter Div.	Brooklyn, N.Y.
16758	Delco Radio Div. of G.M. Corp.	Kokomo, Inc.
17109	Thermonetics Inc.	Canoga Park, Calif.
17474	Tranex Company	Mountain View, Calif.
17675	Hamlin Metal Products Corp.	Akron, Ohio
17745	Angstrohm Prec. Inc.	No. Hollywood, Calif.
18042	Power Design Pacific Inc.	Palo Alto, Calif.
18476	Ty-Car Mfg. Co., Inc.	Holliston, Mass.
18486	TRW Elect. Comp. Div.	Des Plaines, Ill.
18583	Curtis Instrument, Inc.	Mt. Kisco, N.Y.
18873	E.I. DuPont and Co., Inc.	Wilmington, Del.
18911	Durant Mfg. Co.	Milwaukee, Wis.
19315	Bendix Corp., The Eclipse-Poineer Div.	Teterboro, N.J.
19500	Thomas A. Edison Industries, Div. of McGraw-Edison Co.	West Orange, N.J.
19644	LRC Electronics	Horseheads, N.Y.
19701	Electra Mfg. Co.	Independence, Kansas
20183	General Atronics Corp.	Philadelphia, Pa.
21226	Executone, Inc.	Long Island City, N.Y.
21335	Fafnir Bearing Co., The	New Britain, Conn.
21520	Fansteel Metallurgical Corp.	N. Chicago, Ill.
23783	British Radio Electronics Ltd.	Washington, D.C.
24455	G.E. Lamp Division	Nela Park, Cleveland, Ohio
24655	General Radio Co.	West Concord, Mass.
26365	Gries Reproducer Corp.	New Rochelle, N.Y.
26462	Grobet File Co. of America, Inc.	Carlstadt, N.J.
26992	Hamilton Watch Co.	Lancaster, Pa.
28480	Hewlett-Packard Co.	Palo Alto, Calif.
33173	G.E. Receiving Tube Dept.	Owensboro, Ky.
35434	Lectrohm Inc.	Chicago, Ill.
36196	Stanwyck Coil Products Ltd.	Hawkesbury, Ontario, Canada
37942	P.R. Mallory & Co. Inc.	Indianapolis, Ind.
39543	Mechanical Industries Prod. Co.	Akron, Ohio
40920	Miniature Precision Bearings, Inc.	Keene, N.H.
42190	Muter Co.	Chicago, Ill.
43990	C.A. Norgren Co.	Englewood, Colo.

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TABLE 6-3.
CODE LIST OF MANUFACTURERS (Continued)

Code No.	Manufacturer	Address
44655	Ohmite Mfg. Co.	Skokie, Ill.
46384	Penn Eng. & Mfg. Corp.	Doylestown, Pa.
47904	Polaroid Corp.	Cambridge, Mass.
48620	Precision Thermometer & Inst. Co.	Southampton, Pa.
49956	Microwave & Power Tube Div.	Waltham, Mass.
52090	Rowan Controller Co.	Westminster, Md.
52983	Sanborn Company	Waltham, Mass.
54294	Shallcross Mfg. Co.	Selma, N.C.
55026	Simpson Electric Co.	Chicago, Ill.
55933	Sonotone Corp.	Elmsford, N.Y.
55938	Raytheon Co. Commercial Apparatus & Systems Div.	So. Norwalk, Conn.
56137	Spaulding Fibre Co., Inc.	Tonawanda, N.Y.
56289	Sprague Electric Co.	North Adams, Mass.
59446	Telex, Inc.	St. Paul, Minn.
59730	Thomas & Betts Co.	Elizabeth, N.J.
60741	Triplett Electrical Inst. Co.	Bluffton, Ohio
61775	Union Switch and Signal, Div. of Westinghouse Air Brake Co.	Pittsburgh, Pa.
62119	Universal Electric Co.	Owosso, Mich.
63743	Ward-Leonard Electric Co.	Mt. Vernon, N.Y.
64959	Western Electric Co., Inc.	New York, N.Y.
65092	Weston Inst. Inc. Weston-Newark	Newark, N.J.
66295	Wittek Mfg. Co.	Chicago, Ill.
66346	Revere Wollansak Div. Minn. Mining & Mfg. Co.	St. Paul, Minn.
70276	Allen Mfg. Co.	Hartford, Conn.
70318	Allmetal Screw Product Co., Inc.	Garden City, N.Y.
70485	Atlantic India Rubber Works, Inc.	Chicago, Ill.
70563	Amperite Co., Inc.	Union City, N.J.
70903	Belden Mfg. Co.	Chicago, Ill.
70998	Bird Electronic Corp.	Cleveland, Ohio
71002	Birnbach Radio Co.	New York, N.Y.
71041	Boston Gear Works Div. of Murray Co. of Texas	Quincy, Mass.
71218	Bud Radio, Inc.	Willoughby, Ohio
71286	Camloc Fastener Corp.	Paramus, N.J.
71313	Cardwell Condenser Corp.	Lindenhurst L.I., N.Y.
71400	Bussmann Mfg. Div. of McGraw-Edison Co.	St. Louis, Mo.
71436	Chicago Condenser Corp.	Chicago, Ill.
71447	Calif. Spring Co., Inc.	Pico-Rivera, Calif.
71450	CTS Corp.	Elkhart, Ind.
71468	ITT Cannon Electric Inc.	Los Angeles, Calif.
71471	Cinema Plant, Hi-Q Div. Aerovox Corp.	Burbank, Calif.
71482	C.P. Clare & Co.	Chicago, Ill.
71590	Centralab Div. of Globe Union Inc.	Milwaukee, Wis.
71616	Commercial Plastics Co.	Chicago, Ill.
71700	Cornish Wire Co., The	New York, N.Y.
71707	Coto Coil Co., Inc.	Providence, R.I.
71744	Chicago Miniature Lamp Works	Chicago, Ill.
71753	A.O. Smith Corp., Crowley Div.	West Orange, N.J.
71785	Cinch Mfg. Co., Howard B. Jones Div.	Chicago, Ill.
71984	Dow Corning Corp.	Midland, Mich.
72136	Electro Motive Mfg. Co., Inc.	Willimantic, Conn.
72354	John E. Fast Co., Div. Victoreen Instr. Co.	Chicago, Ill.
72619	Dialight Corp.	Brooklyn, N.Y.
72656	Indiana General Corp., Electronics Div.	Keasby, N.J.
72699	General Instrument Corp., Cap. Div.	Newark, N.J.
72765	Drake Mfg. Co.	Chicago, Ill.
72825	Hugh H. Eby Inc.	Philadelphia, Pa.
72928	Gudeman Co.	Chicago, Ill.
72964	Robert M. Hadley Co.	Los Angeles, Calif.
72982	Erie Technological Products, Inc.	Erie, Pa.
73061	Hansen Mfg. Co., Inc.	Princeton, Ind.
73076	H.M. Harper Co.	Chicago, Ill.
73138	Helipot Div. of Beckman Inst., Inc.	Fullerton, Calif.
73293	Hughes Products Division of Hughes Aircraft Co.	Newport Beach, Calif.
73445	Amperex Electronic Co., Div. of North American Phillips Co., Inc.	Hicksville, N.Y.
73506	Bradley Semiconductor Corp.	New Haven, Conn.
73559	Carling Electric, Inc.	Hartford, Conn.
73682	George K. Garrett Co., Div. MSL Industries Inc.	Philadelphia, Pa.
73734	Federal Screw Products Inc.	Chicago, Ill.
73743	Fischer Special Mfg. Co.	Cincinnati, Ohio
73793	General Industries Co., The	Elyria, Ohio
73846	Goshen Stamping & Tool Co.	Goshen, Ind.
73899	JFD Electronics Corp.	Brooklyn, N.Y.
73905	Jennings Radio Mfg. Corp.	San Jose, Calif.
74276	Signalite Inc.	Neptune, N.J.
74455	J.H. Winns, and Sons	Winchester, Mass.
74861	Industrial Condenser Corp.	Chicago, Ill.
74868	R.F. Products Division of Amphenol-Borg Electronics Corp.	Danbury, Conn.
74970	E.F. Johnson Co.	Waseca, Minn.
75042	International Resistance Co.	Philadelphia, Pa.
75378	CTS Knights Inc.	Sandwich, Ill.
75382	Kulka Electric Corporation	Mt. Vernon, N.Y.
75818	Lenz Electric Mfg. Co.	Chicago, Ill.
75915	Littlefuse, Inc.	Des Plaines, Ill.
76005	Lord Mfg. Co.	Erie, Pa.
76210	C.W. Marwedel	San Francisco, Calif.
76487	James Millen Mfg. Co., Inc.	Malden, Mass.
76493	J.W. Miller Co.	Los Angeles, Calif.
76530	Cinch-Monadnock, Div. of United Carr Fastener Corp.	San Leandro, Calif.
76545	Mueller Electric Co.	Cleveland, Ohio
76703	National Union	Newark, N.J.
76854	Oak Manufacturing Co.	Crystal Lake, Ill.
77068	Bendix Corp., The Bendix Pacific Div.	N. Hollywood, Calif.
77075	Pacific Metals Co.	San Francisco, Calif.
77221	Phanostran Instrument and Electronic Co.	South Pasadena, Calif.
77252	Philadelphia Steel and Wire Corp.	Philadelphia, Pa.
77342	American Machine & Foundry Co. Potter & Brumfield Div.	Princeton, Ind.
77630	TRW Electronic Components Div.	Camden, N.J.
77638	General Instrument Corp., Rectifier Div.	Brooklyn, N.Y.
77764	Resistance Products Co.	Harrisburg, Pa.
77969	Rubbercraft Corp. of Calif.	Torrance, Calif.
78189	Shakeproof Division of Illinois Tool Works	Elgin, Ill.
78283	Signal Indicator Corp.	New York, N.Y.
78290	Struthers-Dunn Inc.	Pitman, N.J.
78452	Thompson-Bremer & Co.	Chicago, Ill.
78471	Tilley Mfg. Co.	San Francisco, Calif.
78488	Stackpole Carbon Co.	St. Marys, Pa.
78493	Standard Thomson Corp.	Waltham, Mass.
78553	Tinnerman Products, Inc.	Cleveland, Ohio
78790	Transformer Engineers	San Gabriel, Calif.
78947	Ucinite Co.	Newtonville, Mass.
79136	Waldes Kohinoor Inc.	Long Island City, N.Y.
79142	Veeder Root, Inc.	Hartford, Conn.
79251	Wenco Mfg. Co.	Chicago, Ill.
79727	Continental-Wirt Electronics Corp.	Philadelphia, Pa.
79963	Zierick Mfg. Corp.	New Rochelle, N.Y.
80031	Mepco Division of Sessions Clock Co.	Morristown, N.J.
80120	Schnitzer Alloy Products Co.	Elizabeth, N.J.
80130	Times Telephoto Equipment	New York, N.Y.
80131	Electronic Industries Association. Any brand Tube meeting EIA Standards-Washington, DC.	
80207	Unimax Switch, Div. Maxon Electronics Corp.	Wallingford, Conn.
80223	United Transformer Corp.	New York, N.Y.
80248	Oxford Electric Corp.	Chicago, Ill.
80294	Bourns Inc.	Riverside, Calif.
80411	Acro Div. of Robertshaw Controls Co.	Columbus, Ohio
80486	All Star Products Inc.	Defiance, Ohio
80509	Avery Adhesive Label Corp.	Monrovia, Calif.
80583	Hammarlund Co., Inc.	New York, N.Y.
80640	Stevens, Arnold, Co., Inc.	Boston, Mass.
81030	International Instruments Inc.	Orange, Conn.
81073	Grayhill Co.	LaGrange, Ill.
81095	Triad Transformer Corp.	Venice, Calif.
81312	Winchester Elec. Div. Litton Ind., Inc.	Oakville, Conn.
81349	Military Specification	. . . . . .
81483	International Rectifier Corp.	El Segundo, Calif.
81541	Airpax Electronics, Inc.	Cambridge, Mass.
81860	Barry Controls, Div. Barry Wright Corp.	Watertown, Mass.
82042	Carter Precision Electric Co.	Skokie, Ill.
82047	Sperti Faraday Inc., Copper Hewitt Electric Div.	Hoboken, N.J.
82142	Jeffers Electronics Division of Speer Carbon Co.	Du Bois, Pa.
82170	Fairchild Camera & Inst. Corp., Defense Prod. Division	Clifton, N.J.
82209	Maguire Industries, Inc.	Greenwich, Conn.
82219	Sylvania Electric Prod. Inc. Electronic Tube Division	Emporium, Pa.
82376	Astron Corp.	East Newark, Harrison, N.J.
82389	Switchcraft, Inc.	Chicago, Ill.
82647	Metals & Controls Inc. Spencer Products	Attleboro, Mass.
82768	Phillips-Advance Control Co.	Joliet, Ill.
82866	Research Products Corp.	Madison, Wis.
82877	Rotron Mfg. Co., Inc.	Woodstock, N.Y.
82893	Vector Electronic Co.	Glendale, Calif.
83053	Western Washer Mfg. Co.	Los Angeles, Calif.
83058	Carr Fastener Co.	Cambridge, Mass.
83086	New Hampshire Ball Bearing, Inc.	Peterborough, N.H.
83125	General Instrument Corp., Capacitor Div.	Darlington, S.C.
83148	ITT Wire and Cable Div.	Los Angeles, Calif.
83186	Victory Engineering Corp.	Springfield, N.J.
83298	Bendix Corp., Red Bank Div.	Red Bank, N.J.
83315	Hubbell Corp.	Mundelein, Ill.
83330	Smith, Herman H., Inc.	Brooklyn, N.Y.
83385	Central Screw Co.	Chicago, Ill.
83501	Gavitt Wire and Cable Co. Div. of Amerace Corp.	Brookfield, Mass.
83594	Burroughs Corp. Electronic Tube Div.	Plainfield, N.J.
83740	Union Carbide Corp. Consumer Prod. Div.	New York, N.Y.
83777	Model Eng. and Mfg., Inc.	Huntington, Ind.
83821	Loyd Scruggs Co.	Festus, Mo.
83942	Aeronautical Inst. & Radio Co.	Lodi, N.J.
84171	Arco Electronics Inc.	Great Neck, N.Y.
84396	A.J. Glesener Co., Inc.	San Francisco, Calif.
84411	TRW Capacitor Div.	Ogallala, Neb.
84970	Sarkes Tarzian, Inc.	Bloomington, Ind.
85454	Boonton Molding Company	Boonton, N.J.

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CODE LIST OF MANUFACTURERS (Continued)

Code No.	Manufacturer	Address
85471	A.B. Boyd Co.	San Francisco, Calif.
85474	R.M. Bracamonte & Co.	San Francisco, Calif.
85660	Koiled Kords, Inc.	Hamden, Conn.
85911	Seamless Rubber Co.	Chicago, Ill.
86197	Clifton Precision Products Co., Inc.	Clifton Heights, Pa.
86579	Precision Rubber Products Corp.	Dayton, Ohio
86684	Radio Corp. of America, Electronic Comp. & Devices Div.	Harrison, N.J.
87034	Marco Industries	Anaheim, Calif.
87216	Philco Corporation (Lansdale Division)	Lansdale, Pa.
87473	Western Fibrous Glass Products Co.	San Francisco, Calif.
87664	Van Waters & Rogers Inc.	San Francisco, Calif.
87930	Tower Mfg. Corp.	Providence, R.I.
88140	Cutler-Hammer, Inc.	Lincoln, Ill.
88220	Gould-National Batteries, Inc.	St. Paul, Minn.
88421	Federal Telephone & Radio Corp.	Clifton, N.J.
88698	General Mills, Inc.	Buffalo, N.Y.
89231	Graybar Electric Co.	Oakland, Calif.
89665	United Transformer Co.	Chicago, Ill.
90179	US Rubber Co., Consumer Ind. & Plastics Prod. Div.	Passaic, N.J.
90970	Bearing Engineering Co.	San Francisco, Calif.
91260	Connor Spring Mfg. Co.	San Francisco, Calif.
91345	Miller Dial & Nameplate Co.	El Monte, Calif.
91418	Radio Materials Co.	Chicago, Ill.
91506	Augat Inc.	Attleboro, Mass.
91637	Dale Electronics, Inc.	Columbus, Nebr.
91662	Elco Corp.	Willow Grove, Pa.
91737	Gremar Mfg. Co., Inc.	Wakefield, Mass.
91827	K F Development Co.	Redwood City, Calif.
91929	Honeywell Inc., Micro Switch Div.	Freeport, Ill.
91961	Nahm-Bros. Spring Co.	Oakland, Calif.
92180	Tru-Connector Corp.	Peabody, Mass.
92367	Elgeet Optical Co. Inc.	Rochester, N.Y.
92196	Universal Industries, Inc.	City of Industry, Calif.
92607	Tensolite Insulated Wire Co., Inc.	Tarrytown, N.Y.
93332	Sylvania Electric Prod. Inc. Semiconductor Div.	Woburn, Mass.
93369	Robbins and Myers, Inc.	New York, N.Y.
93410	Stevens Mfg. Co., Inc.	Mansfield, Ohio
93929	G.V. Controls	Livingston, N.J.
94137	General Cable Corp.	Bayonne, N.J.
94144	Raytheon Co., Comp. Div., Ind. Comp. Operations	Quincy, Mass.
94148	Scientific Electronics Products, Inc.	Loveland, Colo.
94154	Tung-Sol Electric, Inc.	Newark, N.J.
94197	Curtiss-Wright Corp. Electronics Div.	East Paterson, N.J.
94222	South Chester Corp.	Chester, Pa.
94310	Tru-Ohm Products Memcor Components Div.	Huntington, Ind.
94330	Wire Cloth Products, Inc.	Bellwood, Ill.
94682	Worcester Pressed Aluminum Corp.	Worcester, Mass.
94696	Magnecraft Electric Co.	Chicago, Ill.
95023	George A. Philbrick Researchers, Inc.	Boston, Mass.
95236	Allies Products Corp.	Miami, Fla.
95238	Continental Connector Corp.	Woodside, N.Y.
95263	Leecraft Mfg. Co., Inc.	Long Island, N.Y.
95264	Lerco Electronics, Inc.	Burbank, Calif.
95265	National Coil Co.	Sheridan, Wyo.
95275	Vitramon, Inc.	Bridgeport, Conn.
95348	Gordos Corp.	Bloomfield, N.J.
95354	Methode Mfg. Co.	Chicago, Ill.
95712	Dage Electric Co., Inc.	Franklin, Ind.
95984	Siemon Mfg. Co.	Wayne, Ill.
95987	Weckesser Co.	Chicago, Ill.
96067	Huggins Laboratories	Sunnyvale, Calif.
96095	Hi-Q Div. of Aerovox Corp.	Olean, N.Y.
96256	Thordarson-Meissner Inc.	Mt. Carmel, Ill.
96296	Solar Manufacturing Co.	Los Angeles, Calif.
96330	Carlton Screw Co.	Chicago, Ill.
96341	Microwave Associates, Inc.	Burlington, Mass.
96501	Excel Transformer Co.	Oakland, Calif.
97464	Industrial Retaining Ring Co.	Irvington, N.J.
97539	Automatic & Precision Mfg.	Englewood, N.J.
97979	Reon Resistor Corp.	Yonkers, N.Y.
97983	Litton System Inc., Adler-Westrex Commun. Div.	New Rochelle, N.Y.
98141	R-Troncis, Inc.	Jamaica, N.Y.
98159	Rubber Teck, Inc.	Gardena, Calif.
98220	Hewlett-Packard Co., Moseley Div.	Pasadena, Calif.
98278	Microdot, Inc.	So. Pasadena, Calif.
98291	Sealectro Corp.	Mamaroneck, N.Y.
98376	Zero Mfg. Co.	Burbank, Calif.
98731	General Mills Inc., Electronics Div.	Minneapolis, Minn.
98734	Paeco Div. of Hewlett-Packard Co.	Palo Alto, Calif.
98821	North Hills Electronics, Inc.	Glen Cove, N.Y.
98978	International Electronic Research Corp.	Burbank, Calif.
99109	Columbia Technical Corp.	New York, N.Y.
99313	Varian Associates	Palo Alto, Calif.
99378	Atlee Corp.	Winchester, Mass.
99515	Marshall Ind. Elect. Products Div.	San Marino, Calif.
99707	Control Switch Division, Controls Co. of America	El Segundo, Calif.
99800	Delevan Electronics Corp.	East Aurora, N.Y.
99848	Wilco Corporation	Indianapolis, Ind.
99934	Renbrandt, Inc.	Boston, Mass.
99942	Hoffman Electronics Corp. Semiconductor Div.	El Monte, Calif.
99957	Technology Instrument Corp. of Calif.	Newbury Park, Calif.

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

0000F	Malco Tool and Die	Los Angeles, Calif.
0000M	Western Coil Div. of Automatic Ind., Inc.	Redwood City, Calif.
0000Z	Willow Leather Products Corp.	Newark, N.J.
000AA	British Radio Electronics Ltd.	Washington, D.C.
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000YY	S.K. Smith Co.	Los Angeles, Calif.

From: FSC. Handbook Supplements
H4-1 Dated JULY 1965
H4-2 Dated NOV. 1962

APPENDIX
OPTION 01—02

The 415E-Option 01 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 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 is merely an instrument with both the rear panel connector and the internal battery installed. Paragraph 3-8 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 on the next to last page of Table 6-1 in this manual. Instructions for installation or removal of either or both of these instrument options are given below.

INSTALLATION PROCEDURE.

1. OPTION 01

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

b. Remove top and bottom instrument covers.

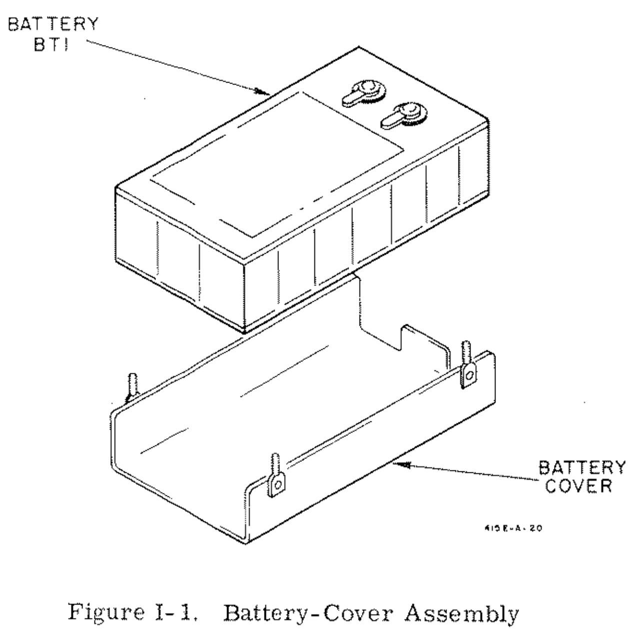

Figure I-1. Battery-Cover Assembly

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 (#22 gauge, stranded) between the + battery terminal and the circuit board socket terminal marked BATT +.

f. Solder a black lead wire (#22 gauge, stranded) between the negative battery terminal and the circuit board socket terminal marked BATT -.

g. Removal is the reverse of installation.

2. OPTION 02

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

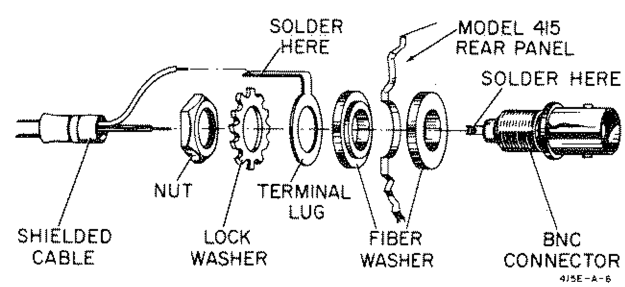

Figure I-2. Connector Assembly

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 generaged 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 95°F (35°C) or below 32°F (0°C). Whenever possible, charge the battery at moderate temperatures (70°F ±10°F, 21°C ±5.6°C). Operation of the battery in the same moderate temperatures as for battery charging will provide maximum performance.

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

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

APPENDIX II

Backdating information for Model 415E with Serials Prefixed 530-.

1) Substitute the component locations in Figure 1-1.

2) Page 5-19, Figure 5-11; A3R6: change to 215 ohms*
   Page 5-21, Figure 5-12; A3R33 and A3R34: change to 15.4 K ohms*
   A3R21: change to 316 ohms*

   Table 6-1; A3R6: change to 0698-3441; R: fxd met flm 215 ohm 1% 1/8W
   A3R21: change to 0698-3444; R: fxd met flm 316 ohm 1% 1/8W
   A3R33, and A3R34: change to 0698-3540; R: fxd met flm 15.4 K ohms 1% 1/8W

   Table 6-2; Add: 0698-3540 R: fxd met flm 15.4 K ohm 1% 1/8W; Mfr 28480; TQ 2
   Delete: 0698-5001 R: fxd met flm 15.2 K ohm 1% 1/8W; Mfr 28480; TQ 2

* Factory selected part. Average value shown.

Backdating information for Model 415E with serials prefixed 530- and 545-.

Instruments serial prefixed 530 and 545 contain the following component differences:

A3C1	0160-0174	C: FXD ELECT 2.2μF +80-20% 25 VDCW
A3R22	0698-3260	R: FXD MET FLM 464K 1% 1/8W

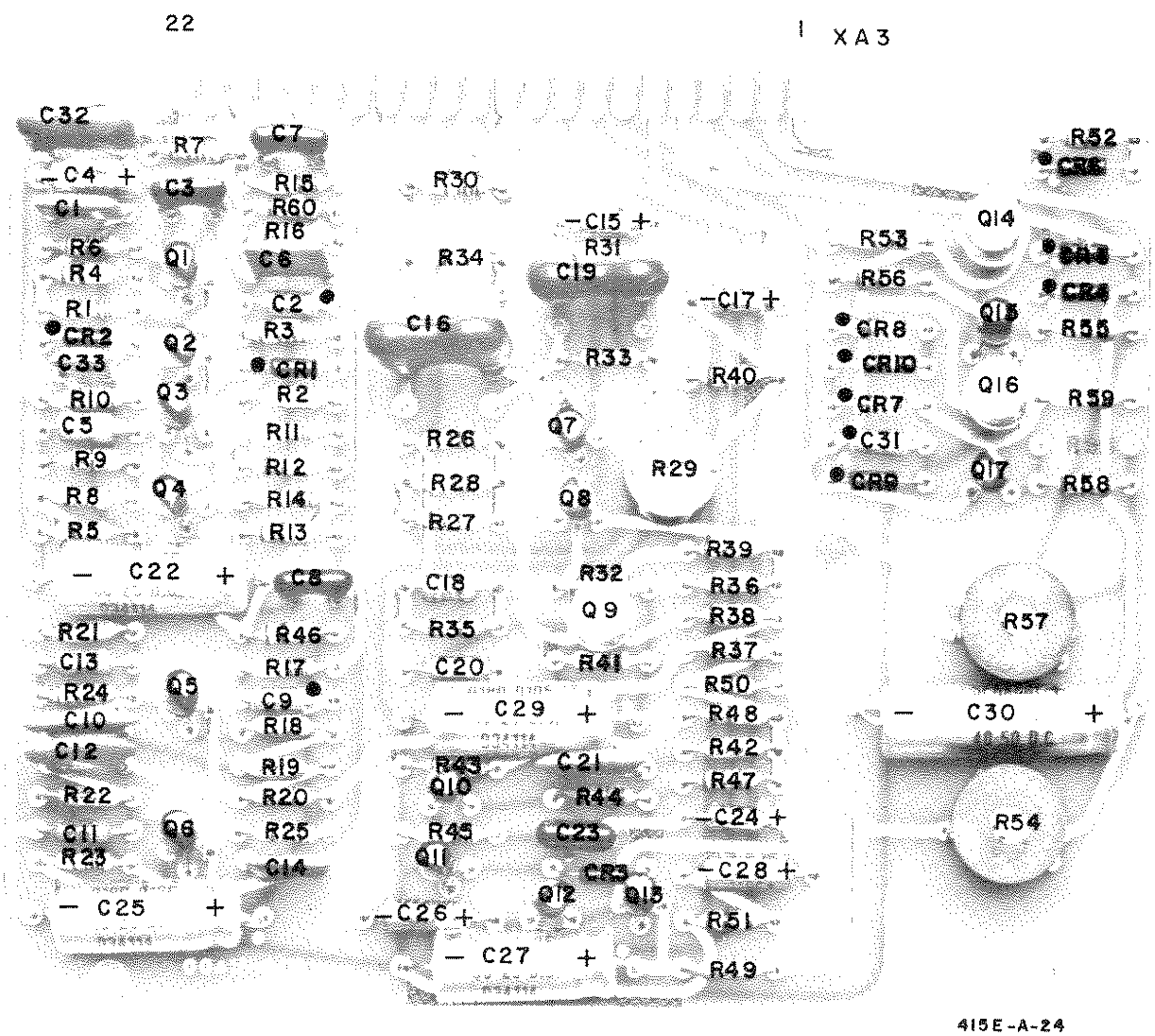

Figure I-1. Circuit Board Component Location for Instruments with serials prefixed 530-

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