



HEWLETT-PACKARD COMPANY / OPERATING AND SERVICE MANUAL

415C

**STANDING WAVE
RATIO METER**

CERTIFICATION

THE HEWLETT-PACKARD COMPANY CERTIFIES
THAT THIS INSTRUMENT WAS THOROUGHLY
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MEET ITS PUBLISHED SPECIFICATIONS WHEN
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MEASUREMENTS ARE TRACEABLE TO THE
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OPERATING AND SERVICE MANUAL

MODEL 415C

SERIALS PREFIXED: 218-

STANDING WAVE
RATIO METER

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Figure 1-1. Model 415C Standing Wave Ratio Meter

Table 1-1. Specifications

Input: Crystal - 200 ohms and 200K ohms input impedance. Bolometer - 200 ohms input impedance; bias provided for 8.7 ma (high) and 4.3 ma (low) current bolometers; bias variable $\pm 10\%$; positive bolometer protection.

Input Connector: BNC

Sensitivity: 0.1 μ volt rms at 30 cps bandwidth and 25° to 55°C (decreases to approximately 0.2 μ volt at 0°C).

Noise: 5 db below full scale with 0.1 μ volt rms sensitivity and 30 cps bandwidth.

Frequency: 1000 cps, adjustable 5%. Other frequencies between 400 and 2500 cps available.

Bandwidth: Variable, 15 to 100 cps

Range: 70 db in 10 and 2.5 db steps

Accuracy: $\pm 0.1/10$ db step, maximum cumulative ± 0.2 db; ± 0.1 db when switching from any 10 db step (NORM) to any 2.5 db step (EXPAND), except ± 0.05 db when switching to 0.0 (EXPAND). ± 0.02 db linearity on EXPAND scales.

Output: DC: - 0-1ma into 1500 ohms maximum at the recorder jack (one side grounded). AC: 0-1 volt rms into 10K ohms minimum at the ac amplifier terminals.

Meter Scales: Calibrated for square law detectors. SWR: 1-4, 3.2-10, 1-1.3 (EXPAND). DB: 0-10, 0-2.5 (EXPAND). Bolometer Current: 8.7 ma and 4.3 ma adjustable $\pm 10\%$.

Power: 115 or 230 volts $\pm 10\%$, 50 to 1000 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: 6-1/2 inches high, 7-3/4 inches wide, 12 inches deep.

Weight: Net 8 lb, 11 lb with battery

Accessories Available: 415C-95A rechargeable battery installation kit
AC-16D and AC-16K Cable Assemblies

Accessory Furnished: Φ 8120-0078 7-1/2 ft power cord set

Options:

1. Rechargeable battery installed.
2. Rear panel input connector wired in parallel with front panel input connector.

SECTION I

GENERAL INFORMATION

1-1. DESCRIPTION AND PURPOSE.

1-2. The  Model 415C Standing Wave Ratio Meter (figure 1-1) is a transistorized instrument designed for measuring standing wave ratios and attenuation. The instrument is essentially a high-gain amplifier, tuned to an audio frequency, with a calibrated meter output. Specifications for this instrument are given in table 1-1. The Model 415C is calibrated to accept inputs from square-law detectors, but because of the high sensitivity and tuned amplifier it is also useful as a null detector for audio frequency bridges.

1-3. Normally the signal input to the Model 415C is taken from either crystal (200-ohm or 200K-ohm) or bolometer (4.3 ma or 8.7 ma) detectors. Bolometer bias is adjustable by $\pm 10\%$ and circuit protection prevents damage to a barretter-type bolometer if connected or disconnected while bias current is being supplied. SWR and attenuation are measured with high accuracy and resolution by expanding selected segments of the normal scales to a full scale presentation. SWR may also be measured accurately in terms of db and then converted to a swr.

1-4. This instrument is capable of portable operation when equipped with a battery. A battery for this use is available initially as Option 1 and later as a  stock item. The Model 415C has a variable tuned amplifier and an adjustable bandwidth (15 cps to 100 cps) to meet a variety of measurement conditions. An ac Amplifier Output is provided on the rear panel for using the Model 415C as a high-gain (140 db) tuned amplifier. A Recorder jack on the rear panel permits operation with a dc recorder.

1-5. MODELS COVERED.

1-6. This manual provides operating and servicing information for the Model 415C including instruments with the following options:

a. Option 1: Factory installed, 24-volt rechargeable battery capable of supplying up to 36 hours continuous operation of the Model 415C. If not initially obtained as an option, the same battery is available on order from Hewlett-Packard Company (see paragraph 2-9).

b. Option 2: Additional Input connector on rear panel, wired in parallel with front panel INPUT connector.

1-7. DIFFERENCES BETWEEN INSTRUMENTS.

1-8. The Hewlett-Packard Company uses a two-section eight-digit serial number to identify instruments (e.g. 000-00000). If the first three digits of the serial number on an instrument are not the same as those on the title page of this manual, change sheets included

with the manual will define differences between that instrument and the Model 415C described herein.

1-9. EQUIPMENT AVAILABLE.

1-10. The Hewlett-Packard Company manufactures a line of microwave equipment and accessory items which complement and extend the usefulness of the Model 415C. These items are listed in the  equipment catalog and in a separate  Microwave Catalog. The latter catalog and information on all equipment are available from  sales representatives. A brief description of the groups of some microwave items is available as follows:

a. Crystal Detectors: Used for input to Model 415C. Square law detection with crystals over a wide range of microwave frequencies.

b. Bolometers and Barretters: Used for input to the Model 415C.

c. Probes and Probe Carriages: Probes cover microwave frequency range and probe penetration is variable. Probe carriages permit readings to 0.01 mm.

d. Slotted Line Sections: Accurately machined slotted sections cover microwave frequency range. Used with probes and probe carriage.

Note

Other equipment available includes the Rechargeable Battery Installation Kit (equivalent to Option 1) and a rear panel Input connector (equivalent to Option 2). See paragraphs 2-9 and 5-11 for more information on these.

1-11. THREE-CONDUCTOR POWER CABLE.

1-12. For the protection of operating personnel, National Electrical Manufacturers' Association (NEMA) recommends that the instrument panel and cabinet be grounded. The Model 415C is equipped with a detachable three-conductor power cable which, when plugged into an appropriate receptacle, grounds the instrument. The offset (round) pin on the power cable connector is the ground connection.

1-13. To preserve the protection feature when operating the instrument from a two-contact outlet, use a three-conductor to two-conductor adapter and connect the adapter green pigtail wire to a suitable ground.

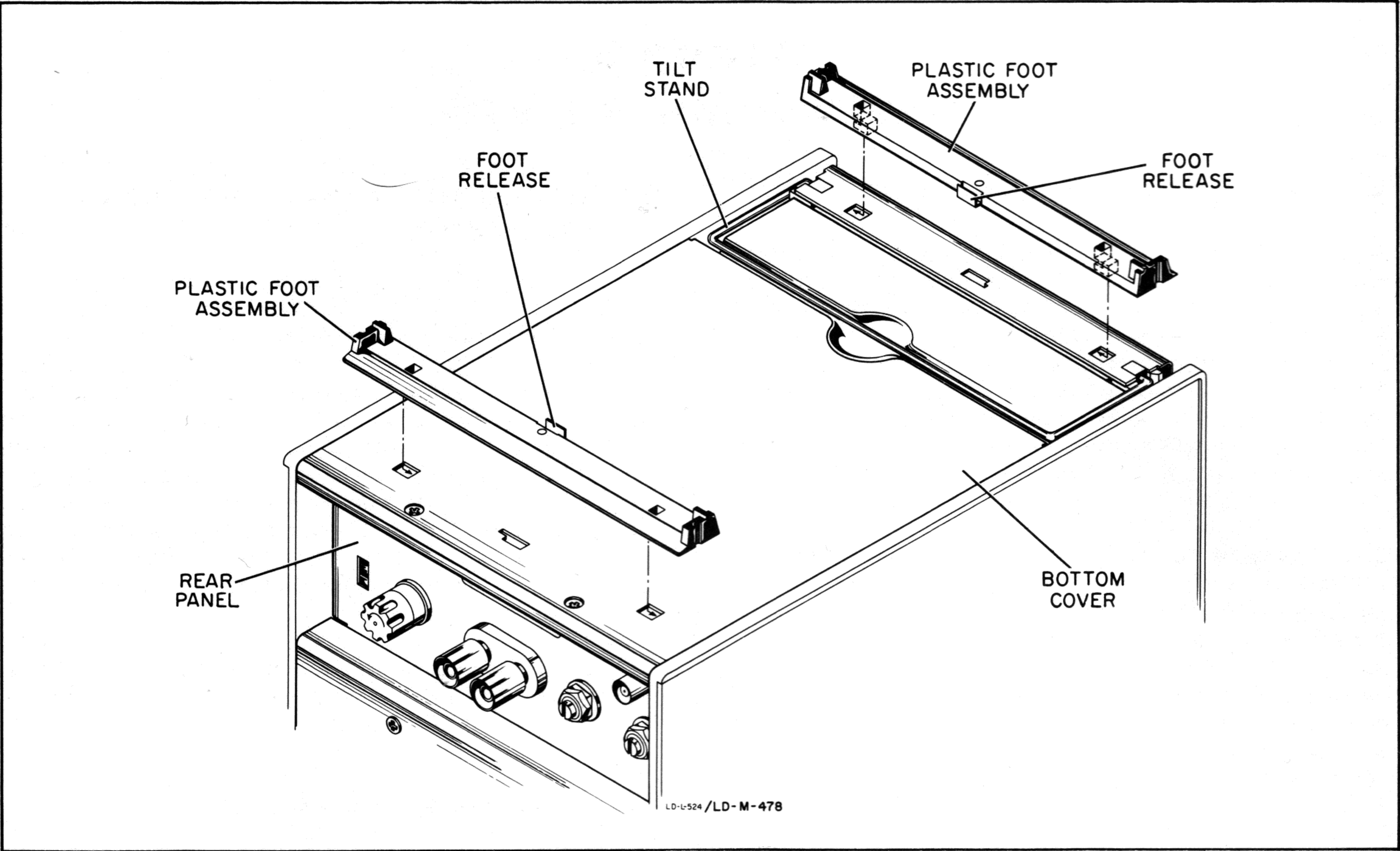


Figure 2-1. Removal of Plastic Feet

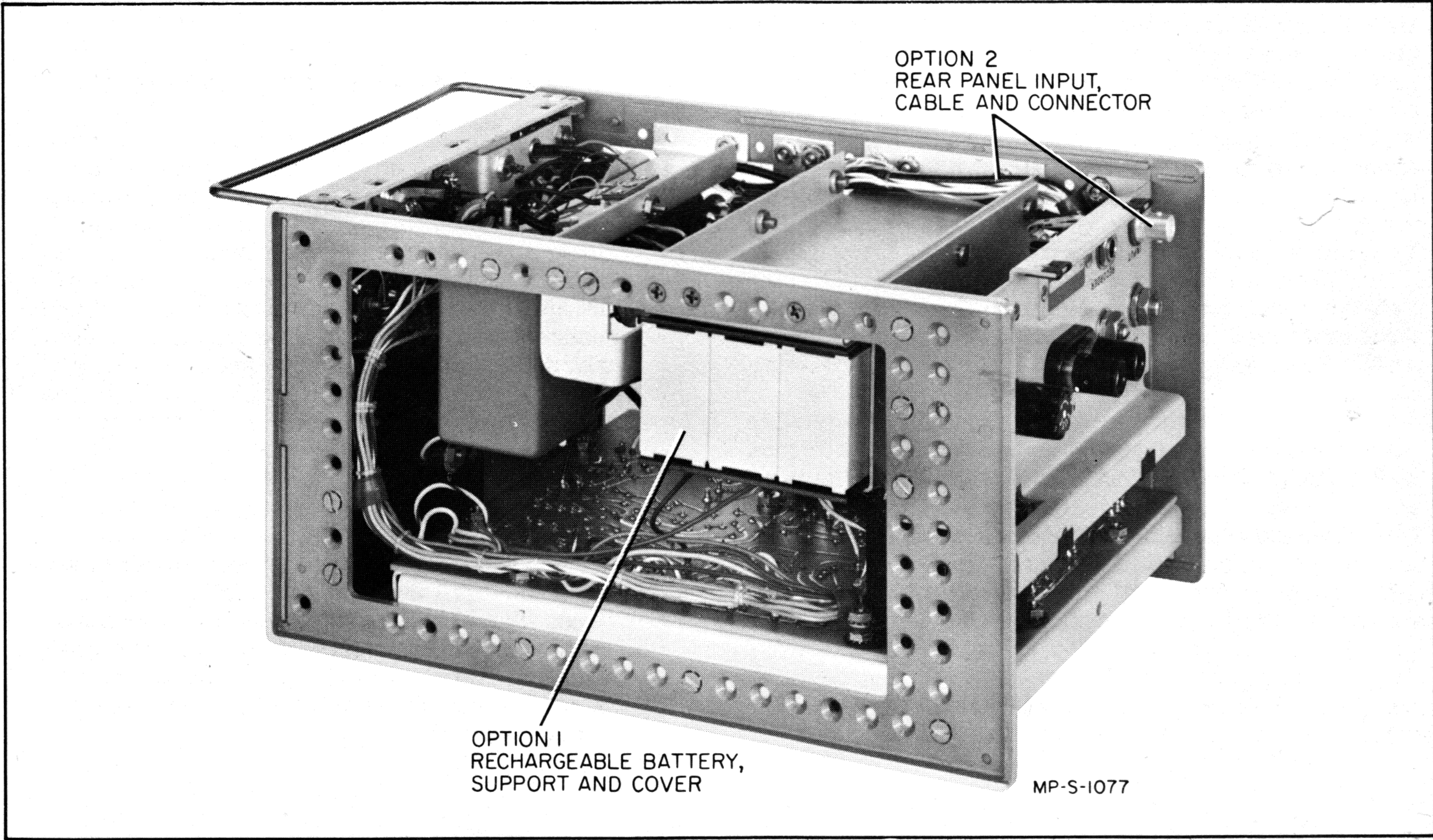


Figure 2-2. Options 1 and 2 Installed

SECTION II

PREPARATION FOR USE

2-1. INITIAL INSPECTION.

2-2. Upon receipt of the Model 415C, check the contents against the packing list. Inspect the instrument for any physical damage, such as a scratched panel surface, broken knobs, etc, incurred in transit. To facilitate possible reshipment, keep the original packing material until a satisfactory performance check is completed (see paragraph 5-80). If damage is found, file a claim with the carrier and refer to the warranty page of this manual.

2-3. INCOMING QUALITY CONTROL CHECK.

2-4. Section V of this manual provides the information for verifying the specifications of the Model 415C. Paragraph 5-80 provides an "in the cabinet" check on the general performance and specifications of the instrument. Paragraph 5-61 is a complete test and adjustment procedure which, when completed, should place the Model 415C within correct operating limits.

2-5. RACK/BENCH INSTRUCTIONS.

2-6. The Model 415C is initially shipped with the plastic feet and the tilt stand attached, ready for use as a bench-type instrument (unless ordered specifically as a rack-type model). The instrument may be adapted to mount in a standard 19-inch wide rack, alone or alongside another instrument of the same width and height dimensions (the Model 431 Power Meter). Figure 2-1 illustrates the correct removal of the plastic feet from the instrument, prior to rack mounting. Pull foot release toward center of bottom cover, slide foot assembly toward side and then lift to remove from instrument. Complete information for rack mounting the Model 415C is available directly from the Hewlett-Packard Company or from a sales representative. Specify the instrument and complete serial number (see paragraph 1-7) when requesting information.

2-7. AC POWER SOURCE.

2-8. The Model 415C may be operated from an ac source of 115 or 230 volts at 50 to 1000 cps (power line frequency should not be harmonically related to the Model 415C tuned amplifier frequency). With the instrument disconnected from the ac power, move the slide switch (located on the rear panel) to the desired position. A screwdriver may be used to operate the switch. See paragraph 3-6 for battery operation.

2-9. INSTALLING BATTERY AND INPUT CONNECTOR.

2-10. Available from hp are parts required for modifying any Model 415C to correspond to those instruments with Option 1 and/or Option 2. A Rechargeable Battery Installation Kit, hp stock number 415C-95A, contains the battery and necessary hardware for installation (corresponds to Option 1). hp Service Note 415C-1 is included with the kit to cover installation procedure. See table 6-1 for parts listings for the kit and Option 1. To obtain the parts required for an input connector on the rear panel (corresponds to Option 2), order by stock number as found in table 6-1 (listed under Option 2). Instructions for installing the additional input connector will be provided by the hp Customer Service when requested. Figure 2-2 shows the Model 415C with battery and input connector in place. Section V covers the maintenance of instruments equipped as shown in figure 2-2.

2-11. TEMPERATURE LIMITS.

2-12. The Model 415C is designed to operate within the specified 0.1 μvolt sensitivity over a temperature range of 25°C to 55°C (with the bandwidth set to 30 cps). The sensitivity at 30 cps bandwidth is reduced to approximately 0.2 μvolt if operated at 0°C.

2-13. REPACKAGING FOR SHIPMENT.

2-14. 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.

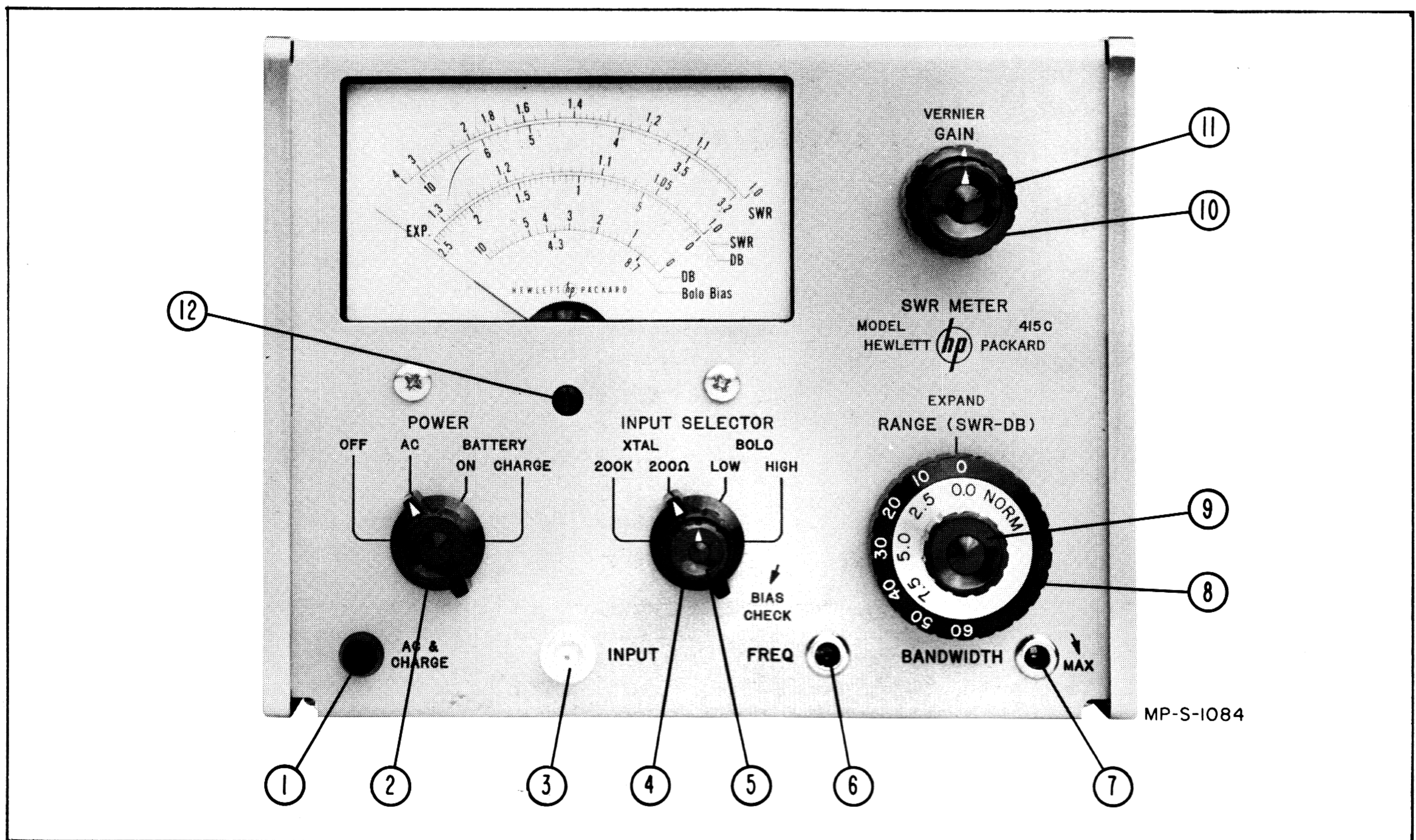


Figure 3-1. Front Panel Operating Controls and Connector

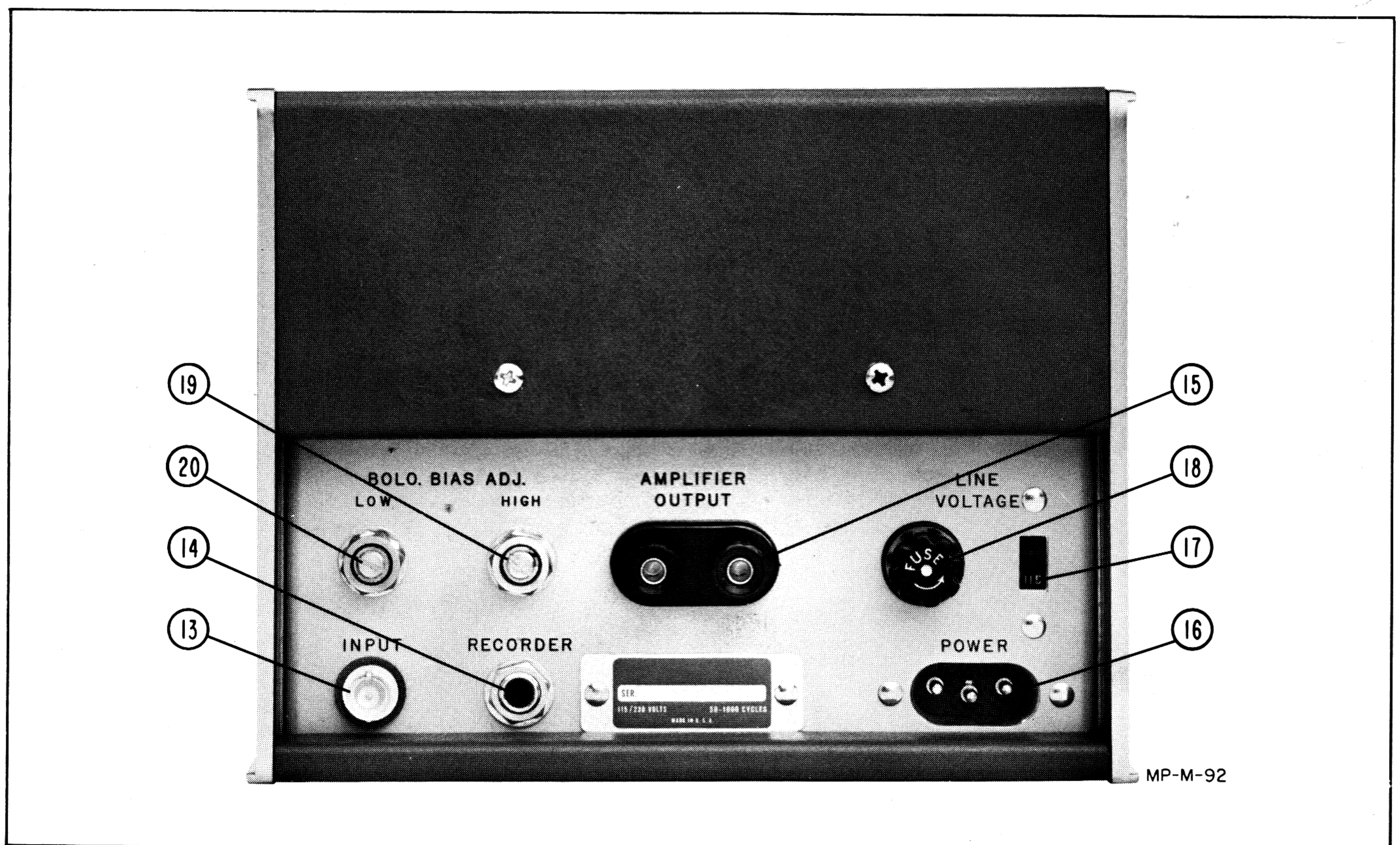


Figure 3-2. Rear Panel Operating Controls and Connectors

SECTION III

OPERATING INSTRUCTIONS

3-1. INTRODUCTION.

3-2. This section contains information and procedures for operation of the Model 415C (from either ac or battery power source) in making swr and attenuation measurements. Also included is a procedure for finding a load impedance using the Model 415C and an impedance chart. Additional information in this section includes measurement considerations when using slotted line techniques and equipment.

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 415C. The descriptions in table 3-1 are keyed by number (1-12 for front, 13-20 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.

Table 3-1. Panel Descriptions

1. AC AND CHARGE: Indicator lights when POWER switch is in AC or BATTERY CHARGE position. 2. POWER: This switch selects the desired power source to the Model 415C. The BATTERY CHARGE position allows recharging the battery when the Model 415C is connected to an ac line. 3. INPUT: BNC connector for an input from the signal source. 4. INPUT SELECTOR: The XTAL 200K or the 200Ω positions take an input from a crystal detector matched for one of these impedances. The BOLO LOW position will furnish 4.3 ma to a bolometer, barretter, or instrument fuse while the BOLO HIGH position provides 8.7 ma. 5. BIAS CHECK: When turned clockwise, bolometer bias is read directly on the meter. 6. FREQ: This adjustment allows variation of the center frequency of the tuned amplifier by 5% when using 1000 cps. 7. BANDWIDTH: This adjustment changes the bandwidth: 15 cps to 100 cps. 8. RANGE: Settings of this switch provide different signal input attenuation values. Steps are indicated in 10-db increments which correspond to 20 db from an external source attenuator. (See note following paragraph 5-82.)	9. EXPAND: Settings of this switch allow full scale expansion of 2.5 db portions of the 10-db meter scale. 10. GAIN: This variable control allows an initial setting of a reference on the meter. 11. VERNIER: This variable control provides a fine adjustment of the initial reference. 12. Meter Mechanical Adjustment: Adjustment screw for exact setting of meter needle 2.5 db calibration mark (see paragraph 5-64). 13. Input: Location for an additional input connector (see paragraph 1-5). 14. Recorder: Jack provides dc output for recorder use (one side grounded). 15. Amplifier Output: This connection provides ac output for use as a tuned amplifier. 16. Power: Connector for the three-conductor ac power cord. 17. 115-230 Volt Switch: Slide switch to allow 115 or 230 volt operation. 18. Fuse Holder: Contains power line fuse, 1/32 ampere. 19. Bolo Bias Adj., High: Adjustment for 8.7 ma bias 20. Bolo Bias Adj., Low: Adjustment for the 4.3 ma bias
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3-5. GENERAL OPERATING AND MEASUREMENT CONSIDERATIONS.

3-6. BATTERY OPERATION.

3-7. The Model 415C may be operated from a battery instead of the 115 or 230 volt ac supply (see paragraph 2-7). Battery operation requires some slightly different procedures to prolong battery life and to insure proper results. The rechargeable nickel-cadmium battery is factory installed if ordered as Option 1 (see paragraph 1-5). The same battery may be ordered and installed later. To obtain this, order ~~the~~ stock number, 415C-95A, Rechargeable Battery Installation Kit.

3-8. INITIAL BATTERY USE. When the Model 415C is to be battery operated for the first time, perform the following steps:

a. Connect the Model 415C to ac power source. Set POWER switch to BATTERY CHARGE position and charge the battery for a minimum of 16 hours.

b. Perform either swr measurement of paragraph 3-34 or the attenuation measurement of paragraph 3-35. If satisfactory, perform step c.

c. Change POWER switch to BATTERY ON position and repeat the same measurement as performed in step b for comparison. If unsatisfactory, see paragraphs 5-35 through 5-40.

3-9. POWER SWITCH EXPLANATION. The following explanation relates the POWER switch positions to battery operation.

a. OFF: All power disconnected and instrument is inoperative.

b. AC: AC power is applied to the Model 415C and the pilot light is on. Approximately 4 ma dc "trickle charge" keeps the battery fully charged.

c. BATTERY ON: AC voltage to the instrument power supply is disconnected and the battery supplies the power. The pilot light is off. The Model 415C chassis is grounded to the power line ground unless the power cord is removed. The battery supplies approximately 30 ma (with bolometer high bias about 38 ma) to the power supply and all circuits are dc regulated.

d. BATTERY CHARGE: AC power is supplied to the instrument and the pilot light is on. The Model 415C is inoperative and approximately 30 ma dc charging current is supplied to the battery. The instrument may be left in the BATTERY CHARGE position and the cell charge limits the current.

3-10. OPTIMUM BATTERY USAGE. It is recommended that the Model 415C 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.

3-11. 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 415C for battery operation.

3-12. GROUNDLOOP CURRENTS.

3-13. Groundloop currents will cause erroneous readings, particularly with low level signals. In battery operation (with power cord removed), no problem is encountered with groundloops. In ac use, if all the instruments in a test or measurement are connected to the ~~power~~ line ground, the Model 415C meter will not track properly. To avoid difficulties with groundloops, use adapters (without attaching the grounding wire) to unground all instruments except the Model 415C. An alternative is to isolate the Model 415C with an adapter and ground all other instruments.

3-14. BANDWIDTH AND FREQUENCY SELECTION.

3-15. Two front panel adjustments are provided to optimize operation of the Model 415C tuned amplifier. The FREQ (frequency) control allows a total variation of 5% from the center tuned frequency. When more than one Model 415C 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 single tuned frequency of the amplifier make the Model 415C valuable as a meter-indicating null detector for audio frequency bridges. The BANDWIDTH adjustment varies the tuned filter bandwidth from 15 to 100 cps. Paragraph 5-72 explains the procedure for setting a specific bandwidth. A narrow bandwidth is best for low level signals as this improves the signal to noise ratio. A bandwidth of 30 cps is considered the most useful in many applications. A wide bandwidth would find more use in fast sweep rate measurements (see paragraph 3-65).

3-16. SWR MEASURING EQUIPMENT AND TECHNIQUES.

3-17. EQUIPMENT SETUP AND CHARACTERISTICS.

3-18. A typical setup of equipment used in swr measurements is shown in figure 3-3. The following is a brief description of this equipment and some of the desired characteristics.

a. Signal Generator. The signal generator should cover the desired frequency range and be amplitude modulated at the tuned frequency of the Model 415C amplifier. If the klystron of a signal generator is modulated at the grid or repeller, undesirable harmonics and frequency modulation effects will be present. Square wave modulation reduces these effects. If the signal source is pulse-modulated, the duty cycle should be not less than 40%. Short pulse type signals can introduce measurement errors in the Model 415C. In many uses, it is necessary to minimize interaction between the signal generator and the load. In these cases, an isolating device should be used. For versatility, the signal source should indicate power output, and should include an accurately calibrated attenuator.

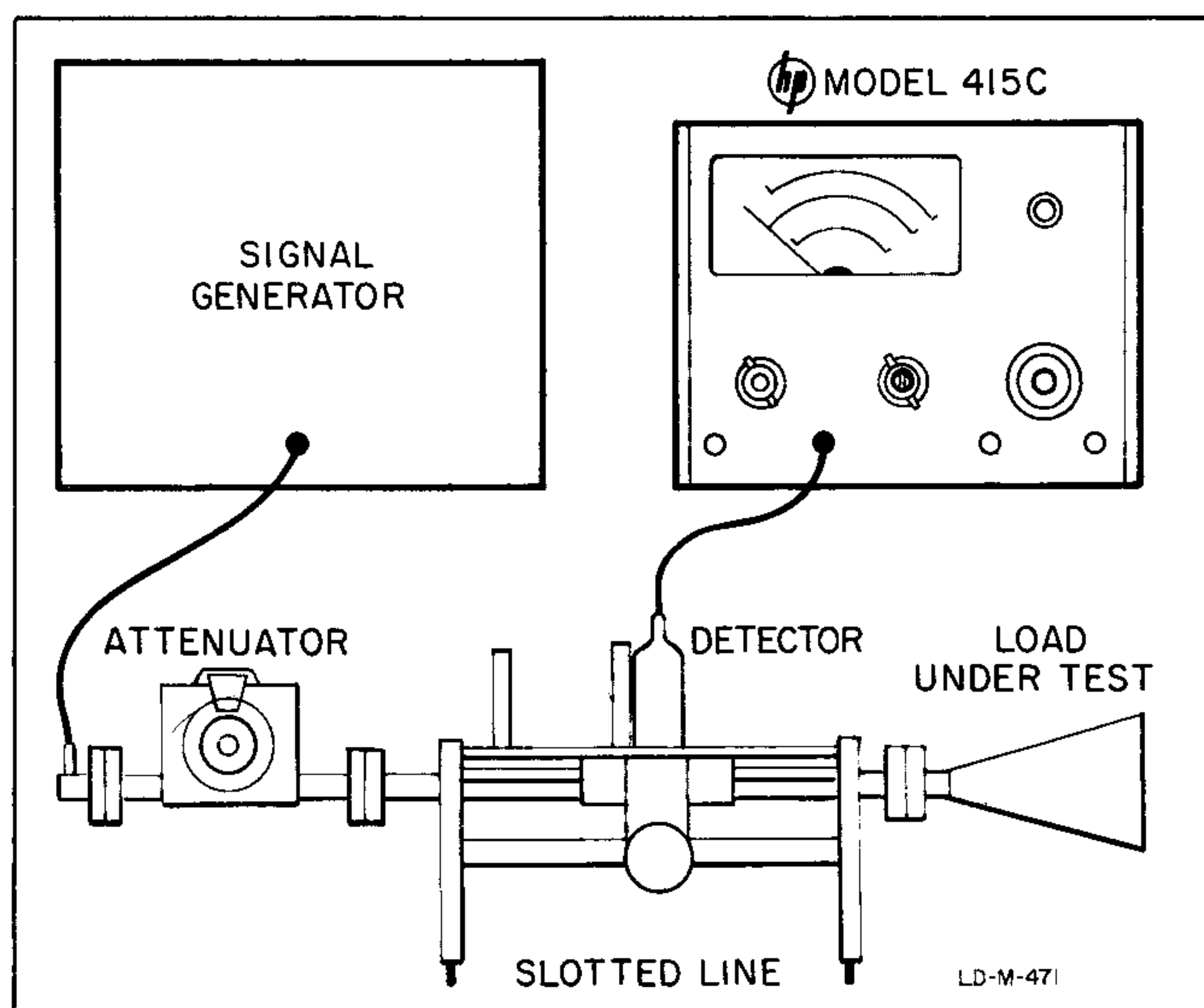


Figure 3-3. Typical SWR Measurement Setup

b. Cables or Waveguides. The cable or waveguide used for connecting the source to the slotted section should match the source impedance over the desired frequency range.

c. Slotted Section. The slotted section should cover the desired frequency and be equipped with an accurate scale or distance indicator.

d. Detector. 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. A barretter is reasonably square-law when used at low signal levels, but crystal diodes may vary slightly. However, the sensitivity of crystals is considerably better than barretters and crystals are more widely used as detectors for swr measurements.

e. Known Loads. Different terminations of known value are needed to establish reference points and to aid in calibrating the test setup. A fixed and movable short are most useful.

3-19. DETECTOR PROBE PENETRATION.

3-20. A general rule in slotted line measurements is to use minimum penetration of the detector sampling probe. The power picked up by the sampling probe causes a distortion in the standing wave pattern. The effect on the pattern is greater as the probe penetration is increased and this may be explained by considering the probe as an admittance shunting the line. The impedance in a standing wave pattern is greatest at a voltage maximum. A shunt admittance such as the probe lowers these impedances, causing the measured swr to be lower than the true swr. The maxima and minima are shifted from their natural position and this effect is more pronounced at a voltage maximum than at a voltage minimum.

3-21. Besides absorbing power and affecting the standing wave pattern, the probe will also cause reflections in the line. The reflections will travel toward the

signal source. If the signal source is not properly matched, these reflections are again directed toward the load and will cause additional errors in low swr measurements. An exception to the minimum penetration rule occurs when it is desired to examine in detail a voltage minimum in a high swr measurement. For this, greater probe penetration can be tolerated since the voltage minimum corresponds to a low impedance point in the line. This applies only at the voltage minimum.

3-22. USE OF CRYSTAL DETECTORS.

3-23. When a crystal detector with a matched load resistor is used, the Model 415C INPUT SELECTOR must be set to the XTAL 200K position to obtain accurate square-law response. With an unloaded crystal, use the setting which gives maximum sensitivity, usually the XTAL 200Ω position. However, some crystal diodes will give a higher output in the XTAL 200K position. With maximum sensitivity from the detector, probe penetration may be kept small. When the rf power exceeds a few microwatts, a crystal diode may depart from the ideal square-law response for which the Model 415C has been calibrated. This undesirable characteristic of crystal diodes is minimized in hp crystal detectors by addition of a load resistor to give optimum square-law response. Paragraph 3-24 gives a method of checking and calibrating a detector for square-law work.

3-24. CHECKING SQUARE-LAW RESPONSE.

3-25. Any new crystal being used for the first time should be checked for square-law response, as there may be a significant variation between crystals. Data should be taken in both XTAL positions of the Model 415C to determine the best setting for an individual crystal diode.

3-26. A simple method for calibrating or checking a detector is by increasing the power level in the slotted line in known increments and noting the detector response on the Model 415C. Another method for calibrating a detector is to use a load having a unity reflection coefficient (usually a short circuit). This load will then set up an electric field between adjacent minima in the slotted line closely approximating half of a sine wave, thus giving a relative voltage that is a known function of the probe carriage position.*

3-27. LOCATING MAXIMUM OR MINIMUM.

3-28. It is more desirable to locate a voltage minimum than a voltage maximum, since the former results in less probe loading on the line. With a low swr, the voltage minimum is fairly broad, and locating the exact point of the minimum is difficult with a single measurement. A more accurate procedure is to note the probe carriage position at two equal output readings on either side of the minimum, then average the two readings.

* Ginzton, Edward L., Microwave Measurements, pp 142-144, McGraw-Hill Book Company, Inc., New York, N.Y., 1957.

3-29. ERRORS FROM SIGNAL SOURCES.

3-30. Signal sources may introduce some undesirable characteristics in slotted line measurement techniques. When possible, the effect of rf harmonics, incidental fm signals, and spurious signals should be minimized. Paragraphs 3-31, 3-32, and 3-33 will briefly discuss the results of such characteristics and suggest possible means of avoiding their effect.

3-31. RF HARMONICS. Harmonics are a common cause of errors in swr measurements. These harmonics are generally excessive only with a coaxial signal output, since this type output often passes harmonics more efficiently than the fundamental. With coaxial systems it is common for the harmonic standing wave pattern to be equal to or greater than the fundamental standing wave. Thus the slotted line probe may be erroneously tuned to a second harmonic. Even if a probe is tuned properly, the presence of harmonics may still couple sufficient energy into the probe to give wrong readings. To minimize the possible effects from harmonics, a signal generator used as the source should be rated low in harmonic content. Suitable low pass filters may be inserted between the signal source and the other equipment to reduce harmonic effects.

3-32. INCIDENTAL FM SIGNALS. The effect of excessive incidental frequency modulation on swr is illustrated in figure 3-4. The trough at the minimum does not reach the normal value, instead appearing at a higher level. Other parts of the pattern may also be distorted by excessive incidental fm, and careful measurements are required for correct swr readings. With a klystron-type signal source, fm may occur if the klystron power supply is not properly filtered.

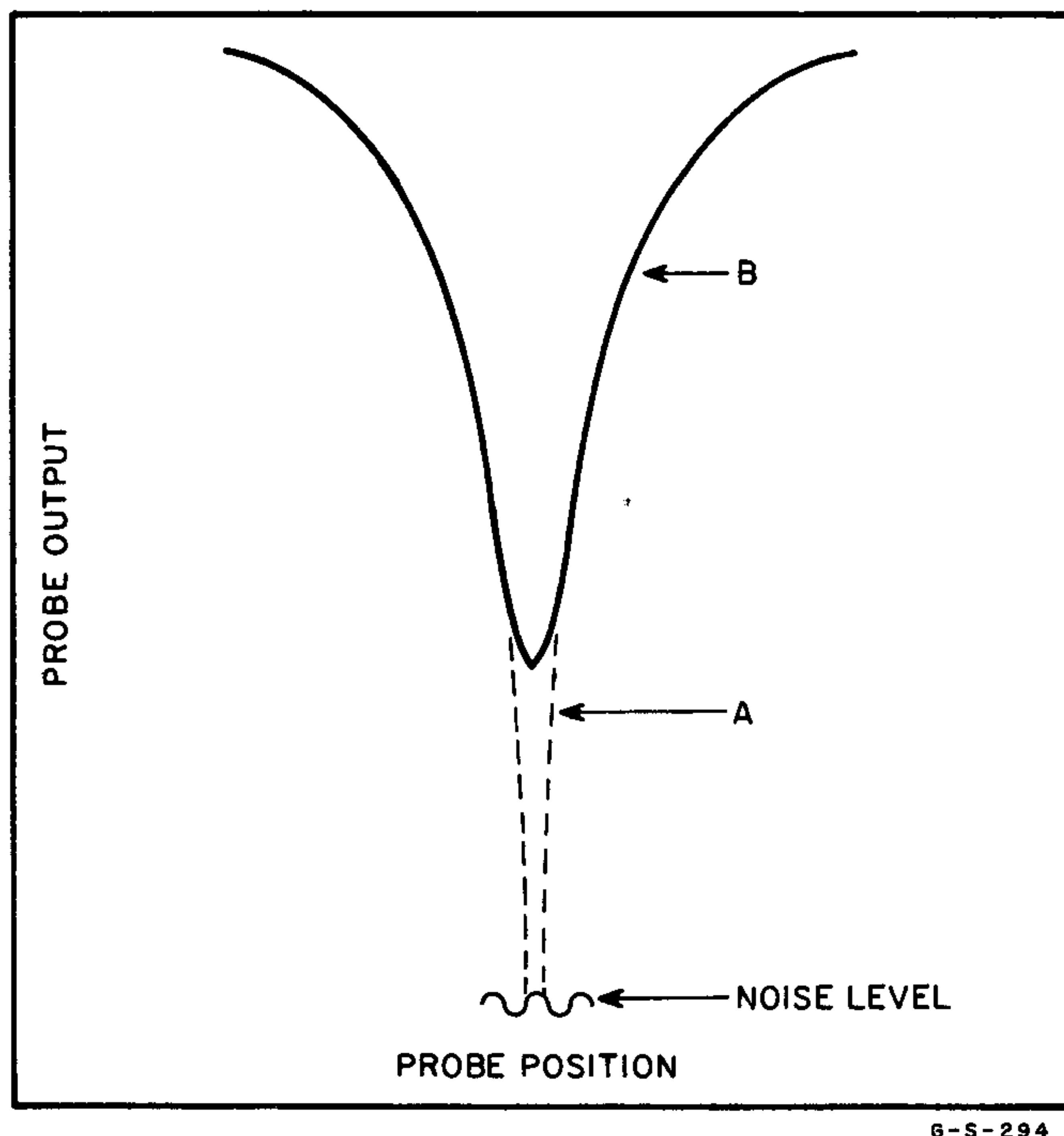


Figure 3-4. High Standing Wave Ratio Pattern
(A) Free of FM (B) With Moderate FM

Sine wave modulation of a klystron will result in incidental fm in the source output. (See paragraph 3-18 for information on signal sources.) The presence of incidental fm can be detected by investigating the depth of a minimum when the load is a short as in figure 3-4.

3-33. SPURIOUS SIGNALS. In tuning a klystron, ordinarily the repeller voltage is adjusted for maximum power at a desired frequency. Then if square wave modulation of the klystron is added without regard to the operating voltages, the repeller voltage excursions will be incorrect. On square wave peaks the repeller voltage will not stabilize at maximum power output but will swing between two points which may not lie in the desired, or even the same mode. The result is two closely-spaced frequencies and the typical result on a standing wave pattern is illustrated in figure 3-5. Precautions should be taken whenever square wave modulation is applied to the repeller through a capacitor (this is usually the case with a general-purpose klystron supply). When square wave modulation is used, it is necessary to adjust the repeller voltage and the modulating voltage so the modulating peaks will lie in the desired repeller mode and the modulating troughs do not lie in a mode that will not permit the tube to oscillate. It is also desirable that the rising and falling portions of the modulating voltage do not pass through undesired modes.

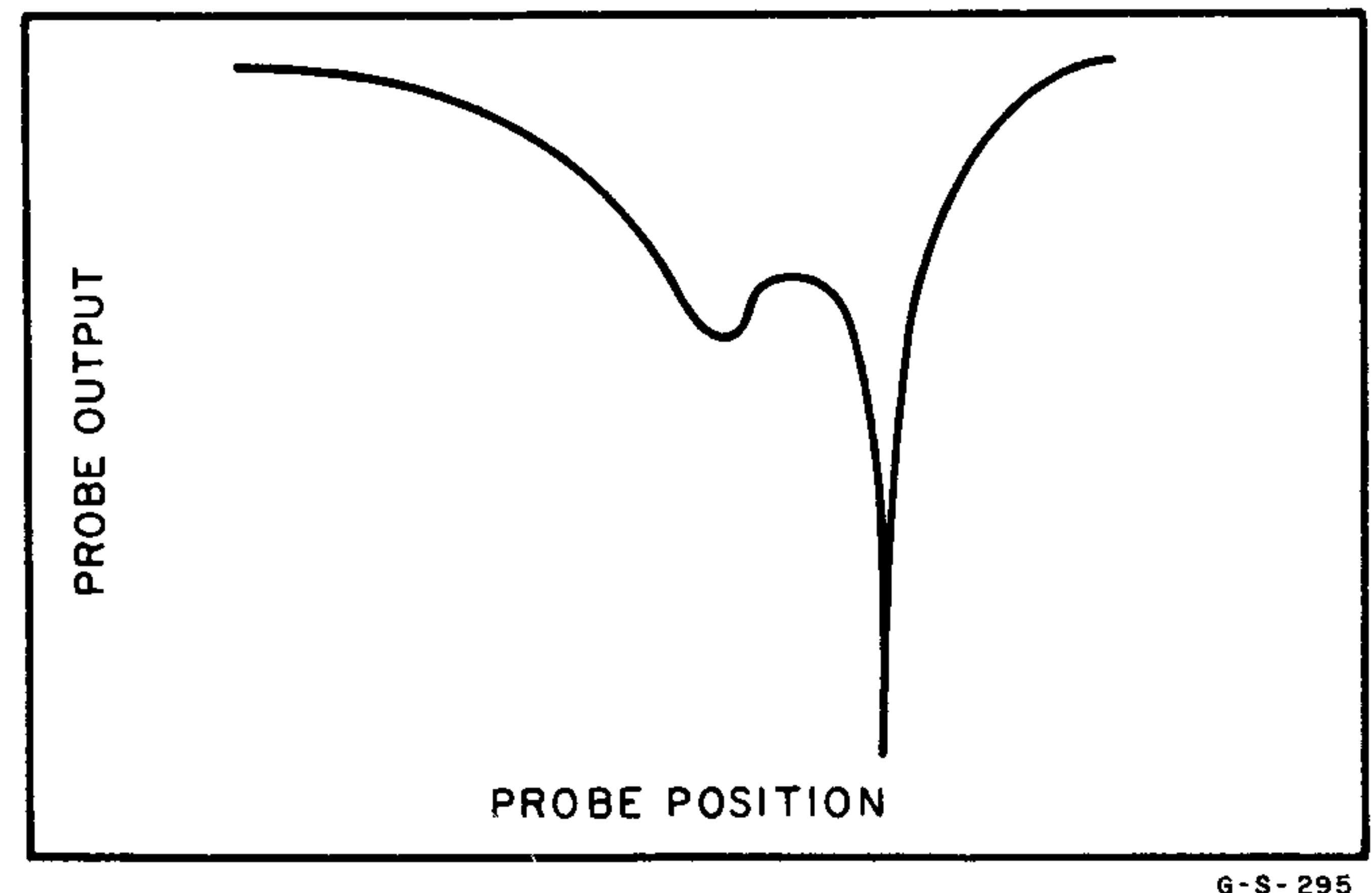


Figure 3-5. Typical High SWR Pattern with Spurious Frequency in Signal Source

3-34. **SWR MEASUREMENT PROCEDURE.**

3-35. GENERAL.

3-36. The Model 415C may be used to measure a standing wave ratio as a direct reading or as a decibel reading to be converted to swr. Figure 3-3 illustrates a typical equipment setup suitable for measuring swr with the below procedures. Normally the measurement of swr will lie in a range from 1:1 to 10:1 (low). However, measurements greater than 10:1 (high) may be made and read on the Model 415C as swr, or other techniques using the Model 415C as the indicator may be used. The EXPAND switch of the Model 415C allows full scale presentation of any 2.5 db segment of the 10-db steps, and figure 3-6 permits conversion of

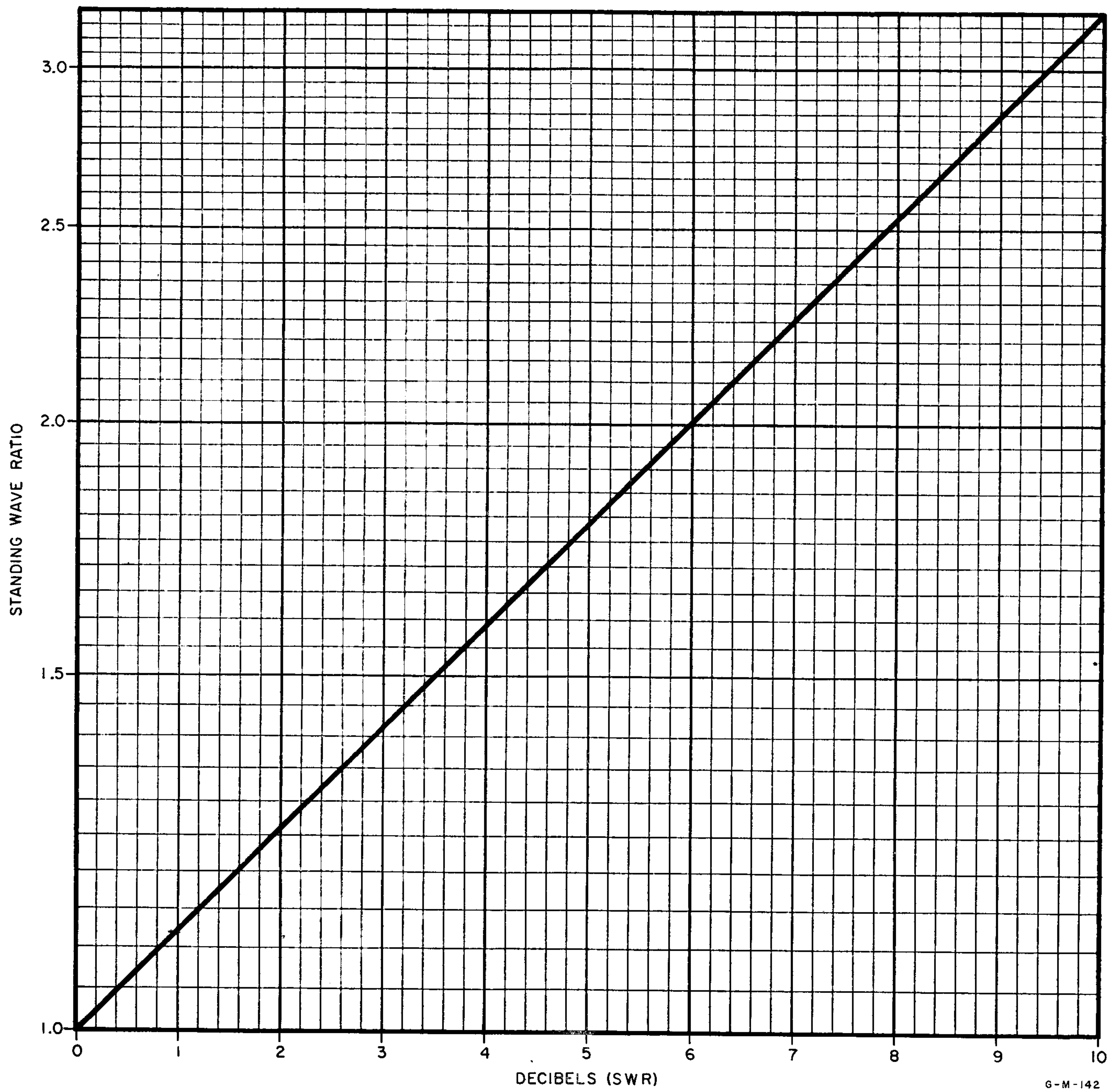


Figure 3-6. Expanded Section of Figure 3-7

db to swr with very high accuracy in this 0 to 10 db range. For graphical conversion of db to swr over a wider db range, figure 3-7 is included.

Note

Before making any measurements with the Model 415C, check to see that the meter pointer zeroes properly. Refer to paragraph 5-64 for the meter pointer adjustment procedure.

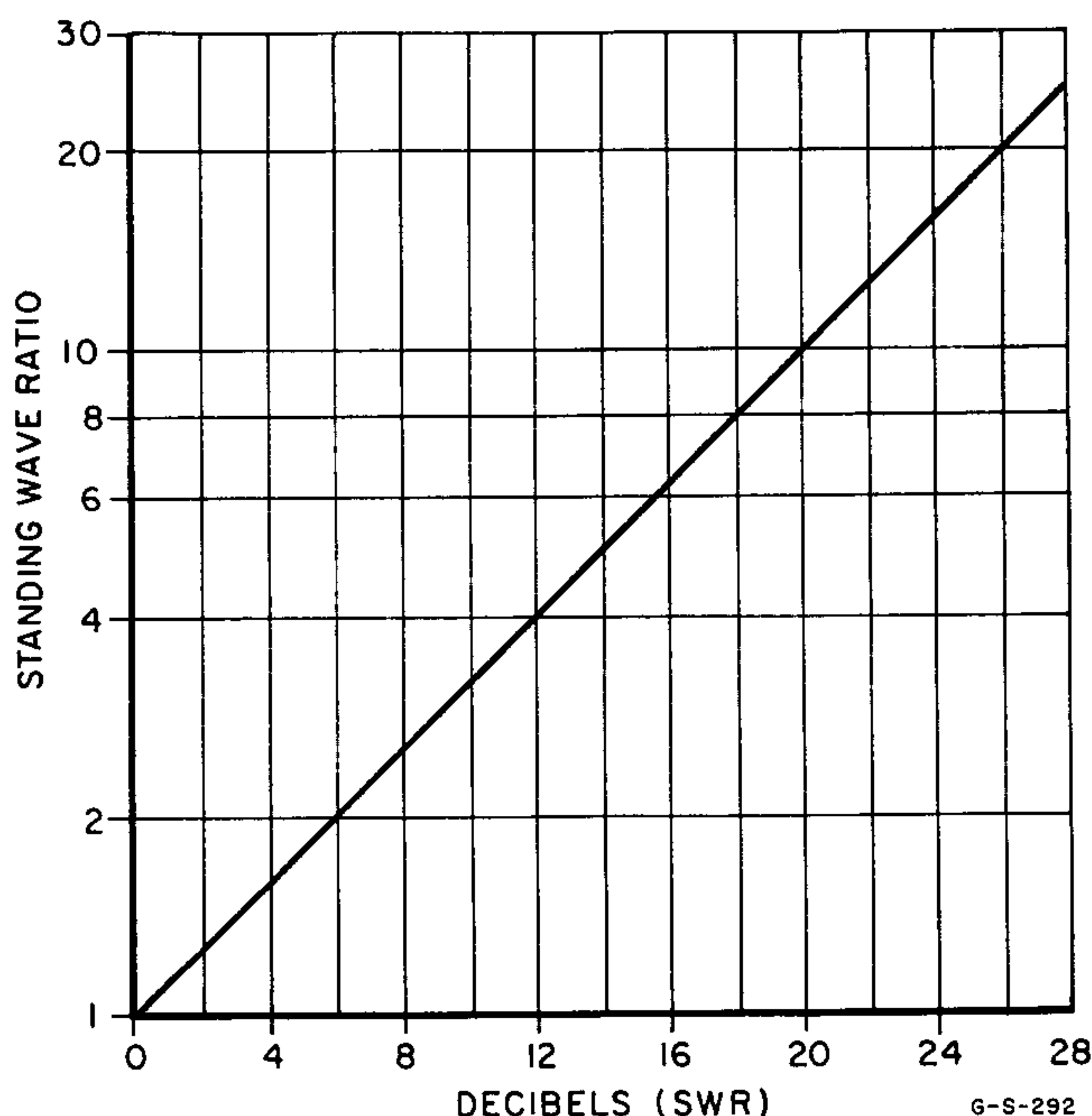


Figure 3-7. Converting Decibels to SWR

3-37. LOW SWR (1:1 to 10:1).

3-38. When measuring swr in the low range, proceed as follows:

a. Turn Model 415C POWER switch to AC (or BATTERY ON, if used; see paragraph 3-6 for Battery Operation). No warmup time required.

b. Set INPUT SELECTOR for type detector being used. BOLO (Bolometer) bias may be checked by turning BIAS CHECK knob clockwise and reading the current value on the meter. The XTAL (crystal) 200K position gives the proper load on crystal detectors for optimum square law detection. The 200K position is also best when using the Model 415C as a null detector.

c. Connect detector cable to INPUT.

d. Set GAIN and VERNIER controls to about 1/2 maximum.

e. Set RANGE switch to 40 db or 50 db, EXPAND switch to NORM (normal) position. Adjust probe penetration to obtain an on-scale reading.

f. Peak the Model 415C meter (i.e. move needle to right) by adjusting the modulation frequency of the signal source, if adjustable. Frequency peaking is also achieved by adjusting the FREQ (frequency) control on the front panel of the Model 415C. Reduce probe penetration to keep needle on scale.

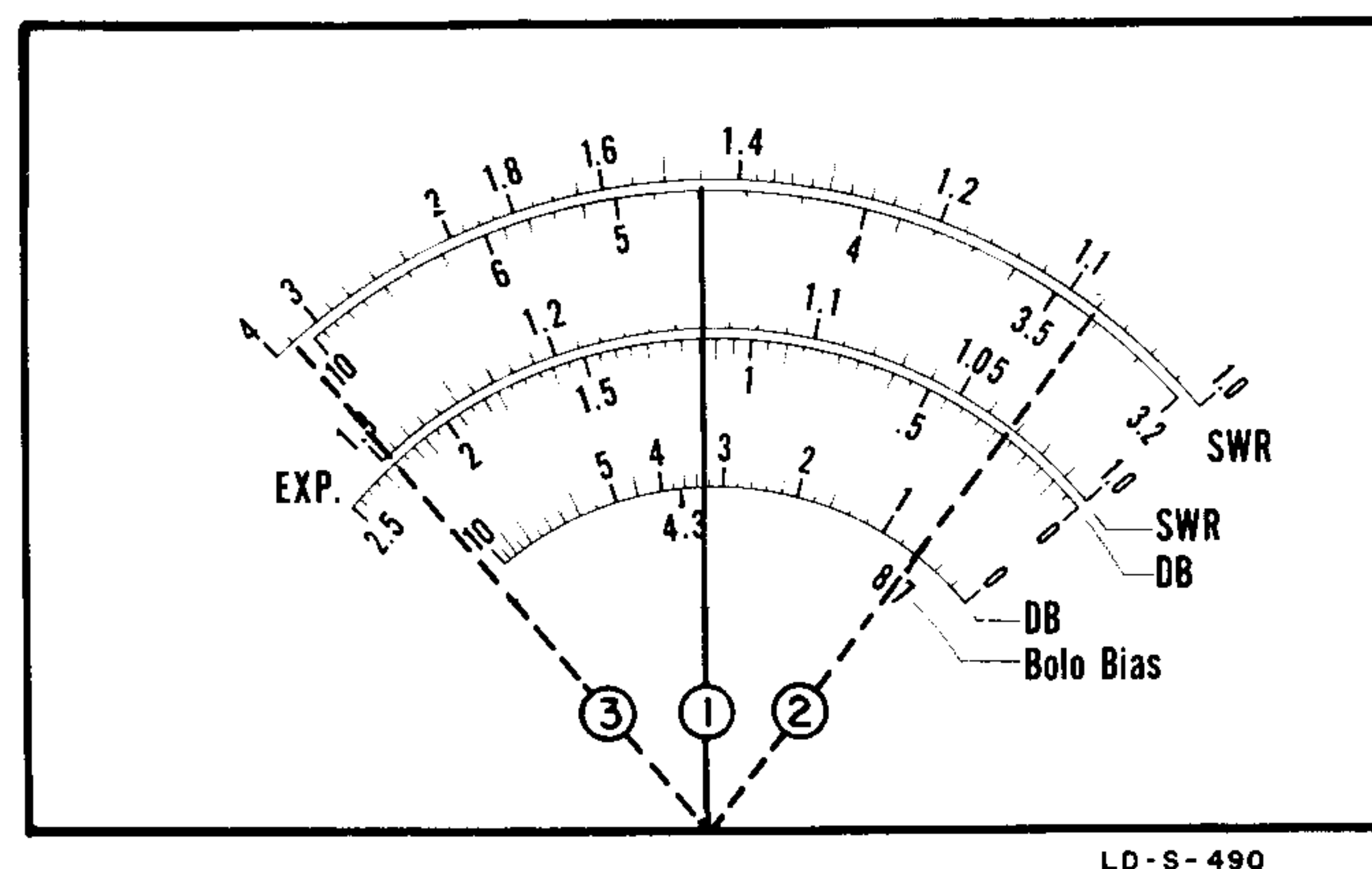
g. Peak the Model 415C meter by tuning the probe detector, if tunable. Reduce probe penetration to keep needle on scale.

h. Peak the Model 415C meter by moving the probe along the line, reducing probe penetration to keep needle on scale.

i. Adjust GAIN and VERNIER of Model 415C and/or output power from signal source to obtain a swr reading of exactly 1.0.

j. Move the probe along the line to a voltage minimum (needle moves to left). Do not retune probe or detector.

k. If the indicated swr is between 1 and 3.2, greater accuracy in a reading is possible if the Model 415C EXPAND function is used. For a swr between 1 and 1.3, a swr scale is provided for a direct reading when the EXPAND switch is changed to the 0.0 position. If the swr is between 1.3 and 3.2, the EXPAND db scale may be used to obtain an accurate db reading for conversion to swr using figure 3-6. For swr between 3.2 and 10, a scale on the meter provides the reading. Refer to figure 3-8 and obtain the swr reading as follows:



LD-S-490

Figure 3-8. Meter Scale Detail

(1) For a reading between 1 and 1.3 on the 1 to 4 SWR scale after step j above, change the EXPAND switch to 0.0. This swr segment is then expanded to full scale and the reading is taken from the 1 to 1.3 DB scale.

(2) If needle is between 1.3 and 3.2 after step j, note the reading on the 0 to 10 DB scale and change EXPAND switch to a position which normalizes the beginning of the proper 2.5 db segment. For example, if the reading is approximately 8.4 db, then change EXPAND switch to 7.5. The reading is then the sum of

the needle indication on the 0 to 2.5 DB scale and the EXPAND switch setting (for example, $0.95 + 7.5 = 8.45$ db). Locate this db reading on figure 3-6 and note the corresponding swr value (8.45 db is read as swr of 2.66).

- (3) After step j, if the needle is to the left of 3.2 (possibly to the left, off-scale) on the 1 to 4 SWR scale, change the RANGE switch to the next 10 db position above the initial setting. The swr is then indicated directly on the 3.2 to 10 DB scale.

3-39. HIGH SWR (ABOVE 10:1).

3-40. GENERAL. A reading is possible on the Model 415C for swr greater than 10. If the indication is more than 10 after step k (3) of paragraph 3-37, change the RANGE switch to the next 10 db position (now two steps, or 20 db, above the initial setting). Read the swr on the top (1 to 4 SWR) scale and multiply the reading by ten. Here, again, a db reading may be converted to swr using figure 3-6. The reading used for converting is the amount of db above the initial RANGE switch setting in step e, of paragraph 3-37.

3-41. When a swr is nominally higher than 10, probe coupling must be increased if a reading is to be obtained at the voltage minimum. However, at the voltage maximum, this high probe coupling may result in a deformation of the standing wave pattern, with a consequent error in reading. In addition to the error from probe loading, there is also possible error from a change in detector characteristics as the rf level changes. Because of the problems with measuring high swr, special techniques (described below) may be used with the Model 415C as the indicating device.

3-42. TWICE-MINIMUM-POWER. A convenient technique for measuring high swr values is the twice-minimum-power method. This method is approximately 1% accurate down to a point where conventional methods are applicable. The basis for this method is the fact that a high swr pattern approximates a parabola in the vicinity of a voltage minimum.

3-43. In using the twice-minimum-power method, it is necessary to establish the distance between two points where the power is twice that at the voltage minimum. Since half power is approximately 3 db, this measurement is easily made with the Model 415C as the indicator. Figure 3-9 illustrates the physical aspects of the twice-minimum-power method and the below procedure should be followed. A sliding probe carriage, with a metric scale, to hold the slotted section and probe, is recommended.

a. Repeat steps a through g of the low swr procedure in paragraph 3-37.

b. Move the probe carriage along the line to a voltage minimum (needle moves to left), and note the reading on the probe carriage distance scale.

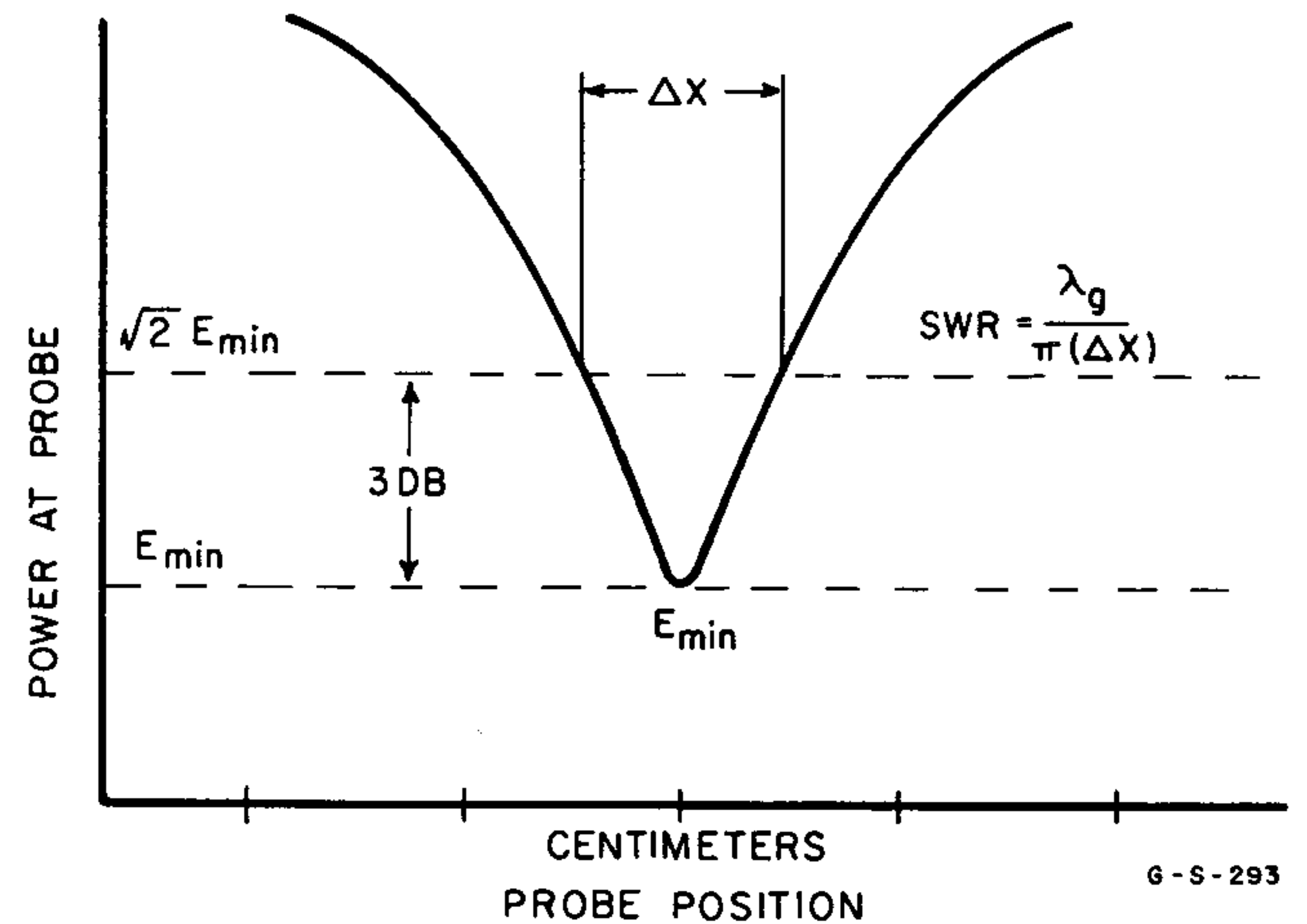


Figure 3-9. SWR Using Twice-Minimum-Power Method

c. For a reference, adjust the Model 415C GAIN and VERNIER controls to obtain a reading of 3.0 on the 0 to 10 db scale.

d. Move the probe carriage along the line to obtain a reading of "0" on the DB scale on one side of the voltage minimum. Record the carriage scale reading in cm.

e. Move the probe carriage to the other side of the voltage minimum for a reading of "0" db. Record the carriage scale reading in cm. The difference between this distance and that recorded in step d is ΔX .

f. Replace the load with a short and measure the distance between two successive voltage minima (i.e. dip the meter, needle moves to the left, by moving probe along the line and record the probe carriage scale reading; move probe in either direction to next minimum and record the carriage scale reading). Twice this distance is λ_g , the guide wavelength.

g. Compute the swr from the following expression:

$$SWR = \frac{\lambda_g}{\pi (\Delta X)}$$

3-44. TEN-TIMES POWER. In measuring a high swr, at frequencies where the wavelength is short, it is difficult to determine the distance between the 3 db points as in the twice-minimum-power method. A ten-times-minimum-power method may be used at high frequencies if accuracy is not of prime importance. The same basic procedure as in paragraph 3-42 is followed except the points are located where the power is ten times (corresponds to 10 db) that at the minimum (this determines ΔX). The guide wavelength is found as in step f of paragraph 3-43 and the following expression is now used:

$$swr = \frac{\lambda_g}{\Delta X}$$

3-45. CALIBRATED ATTENUATOR METHOD. Another method for measuring a high swr is to use a calibrated variable rf attenuator between the signal source and the slotted line. This method overcomes much of the effect of detector variations from a square-law characteristic. However, the effect of probe loading remains and minimum probe penetration should always be used. A procedure for this method follows:

- Repeat steps a through g from paragraph 3-37.
- Move the probe carriage along the line to a voltage minimum, and adjust the rf attenuator to give a convenient reference on the Model 415C meter. Record the rf attenuator setting.
- Move the probe carriage along the line to a voltage maximum, and adjust the rf attenuator to give the same indication on the Model 415C meter as in step b. Record the rf attenuator setting.
- The swr in db is the difference between the rf attenuator readings of step b and c. Use figure 3-6 or 3-7 to convert to swr.

3-46. ATTENUATION MEASUREMENT PROCEDURE.

3-47. Because of the high resolution possible for db measurements using the Model 415C, the insertion attenuation in a line may be measured (within the accuracy of the detector). With this same basic procedure, the accuracy of any variable attenuator may be checked. The procedure and a numerical example follow. Figure 3-10 shows the instrument setup necessary to make attenuation measurements and figure 3-11 illustrates the Model 415C settings and indications to read the attenuation as given in the example.

Note

For accurate results an impedance match should be made between the source and the attenuator.

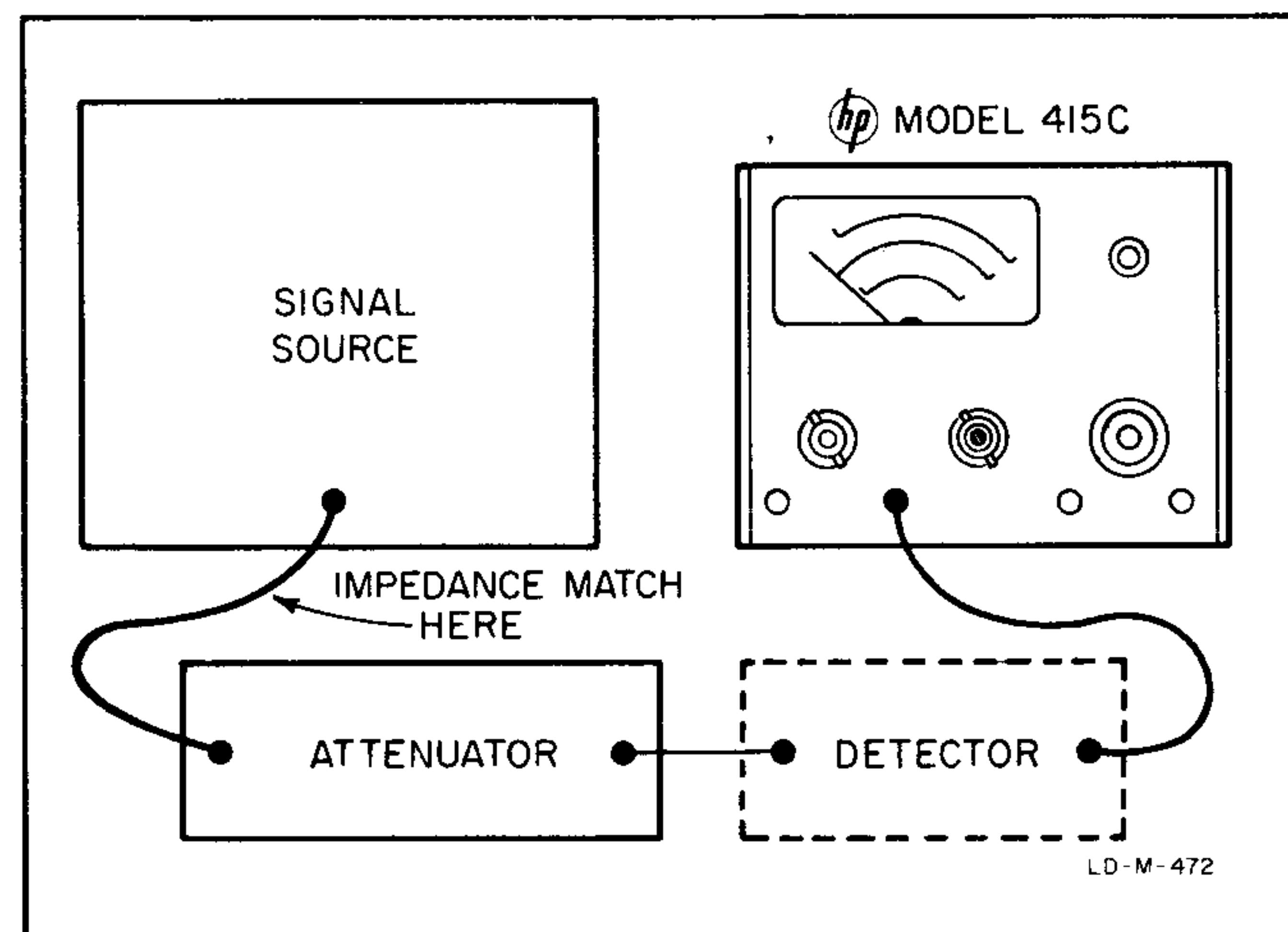


Figure 3-10. Attenuation Measurement Setup

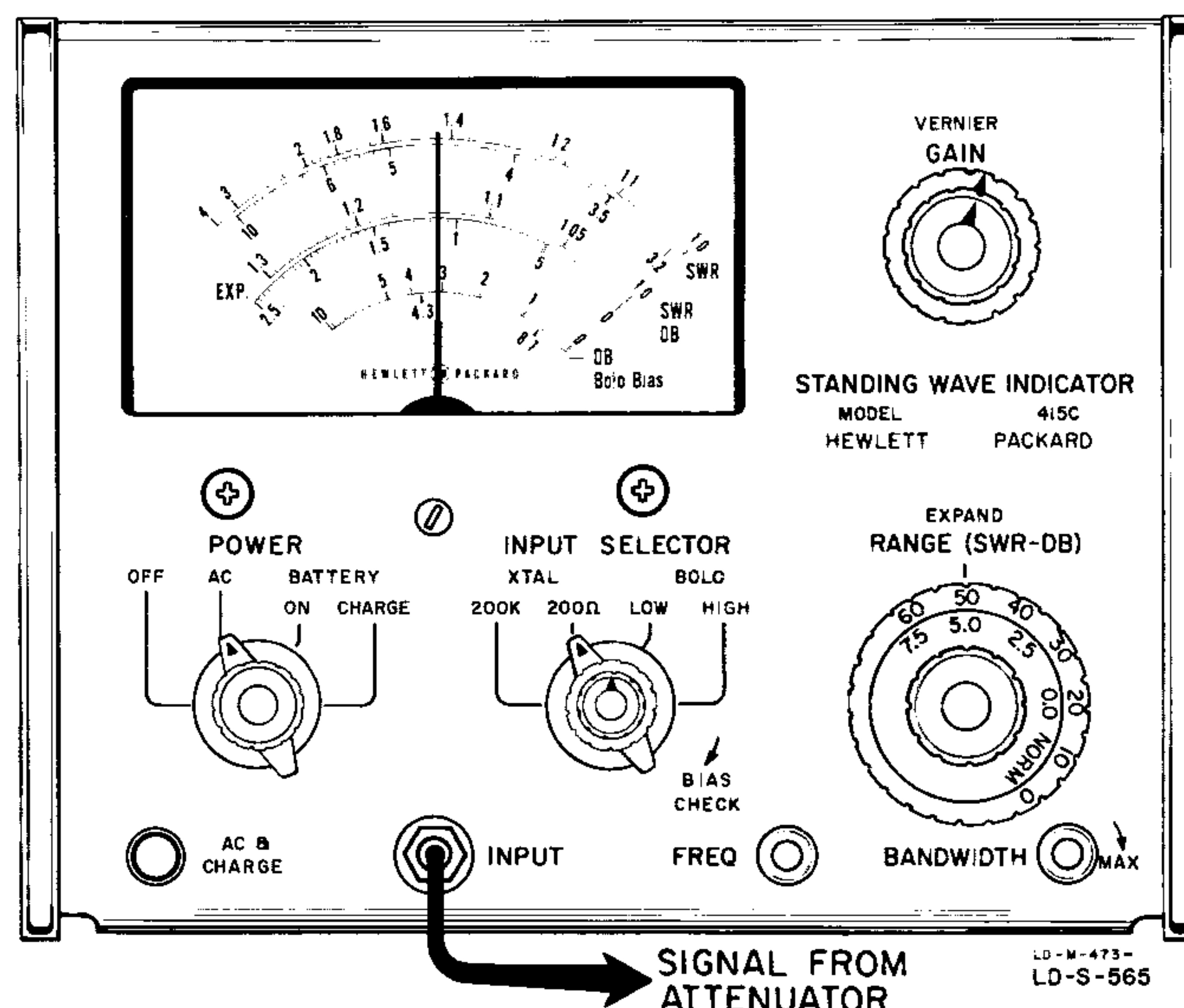


Figure 3-11. Instrument Settings for Attenuation Measurement Example

- With the attenuation to be measured out of the circuit, select an appropriate RANGE switch setting (for an example, select 40).
- Set the EXPAND switch to NORM and adjust the GAIN and VERNIER control for "0" db reference.
- Insert the attenuation to be measured and change RANGE switch for an on-scale reading on the 0 to 10 DB scale (for example, assume the Model 415C indicates approximately 6 db when the RANGE switch is changed to 50).
- Observe which 2.5 db segment the meter needle lies within (5 to 7.5 db for example) and set EXPAND switch to select this segment (set to 5.0). This then expands the selected segment to a full scale presentation while automatically normalizing the selected beginning of the scale (5.0) to "0" on the DB scale.
- Read the indication on the 0 to 2.5 DB scale (assume 1.1 for the example).
- The total attenuation inserted = (RANGE switch setting) + (EXPAND switch setting) + (meter reading on 0 to 2.5 DB scale) - (initial RANGE switch setting). (For example use: 50 db + 5 db + 1.1 db - 40 db = 16.1 db.)

3-48. LOAD IMPEDANCE MEASUREMENT.

3-49. GENERAL.

3-50. 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 3-12 summarizes and graphically presents these impedance measurement rules. When the load is replaced by a short, then:

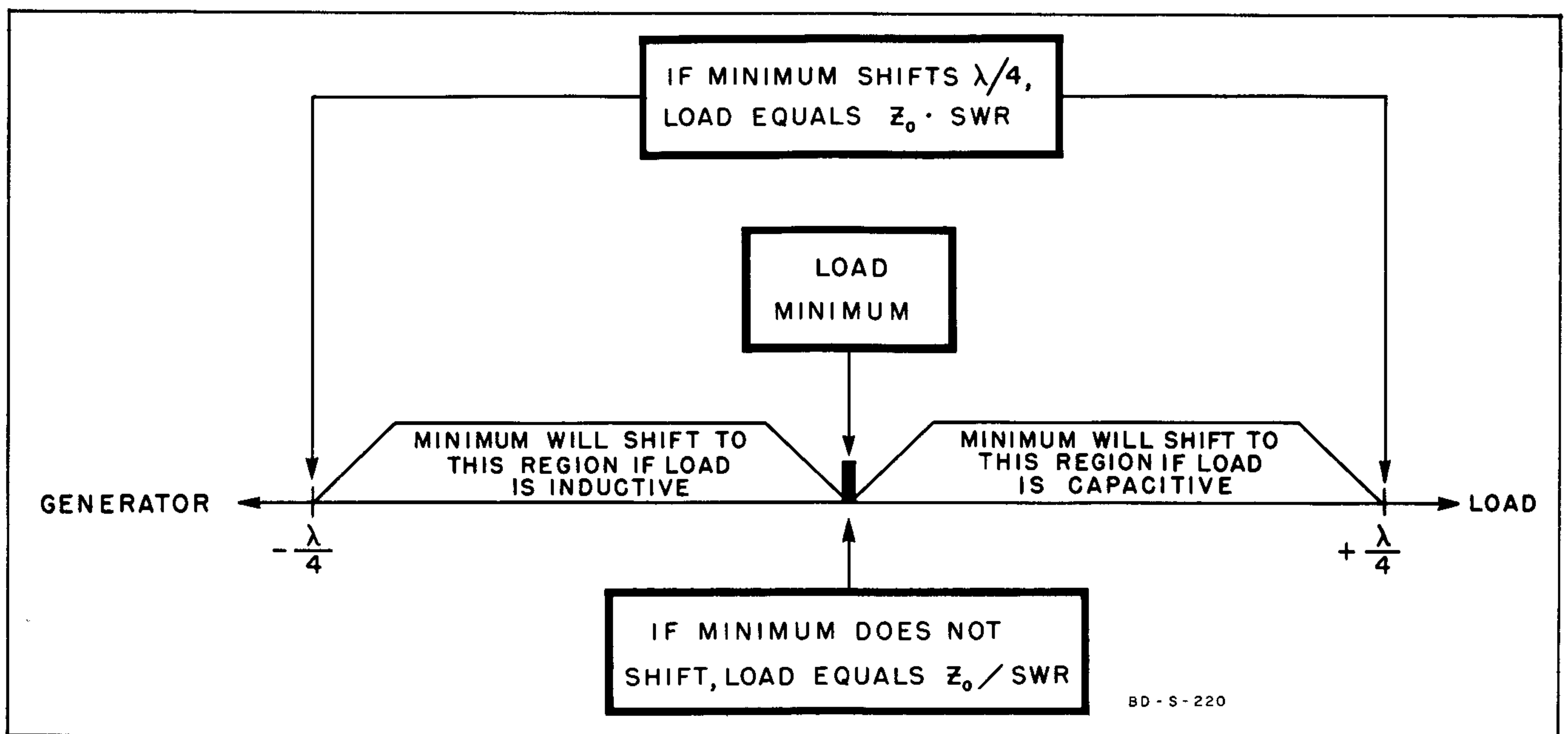


Figure 3-12. Impedance Measurement Rules Summary

a. The shift in the minimum is never more than $\pm 1/4$ 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 $1/\text{swr}$.

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.

3-51. IMPEDANCE MEASUREMENT PROCEDURE.

3-52. 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 3-37 or 3-39). 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 3-13 and the following formulas, compute the normalized load impedance:

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

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

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.

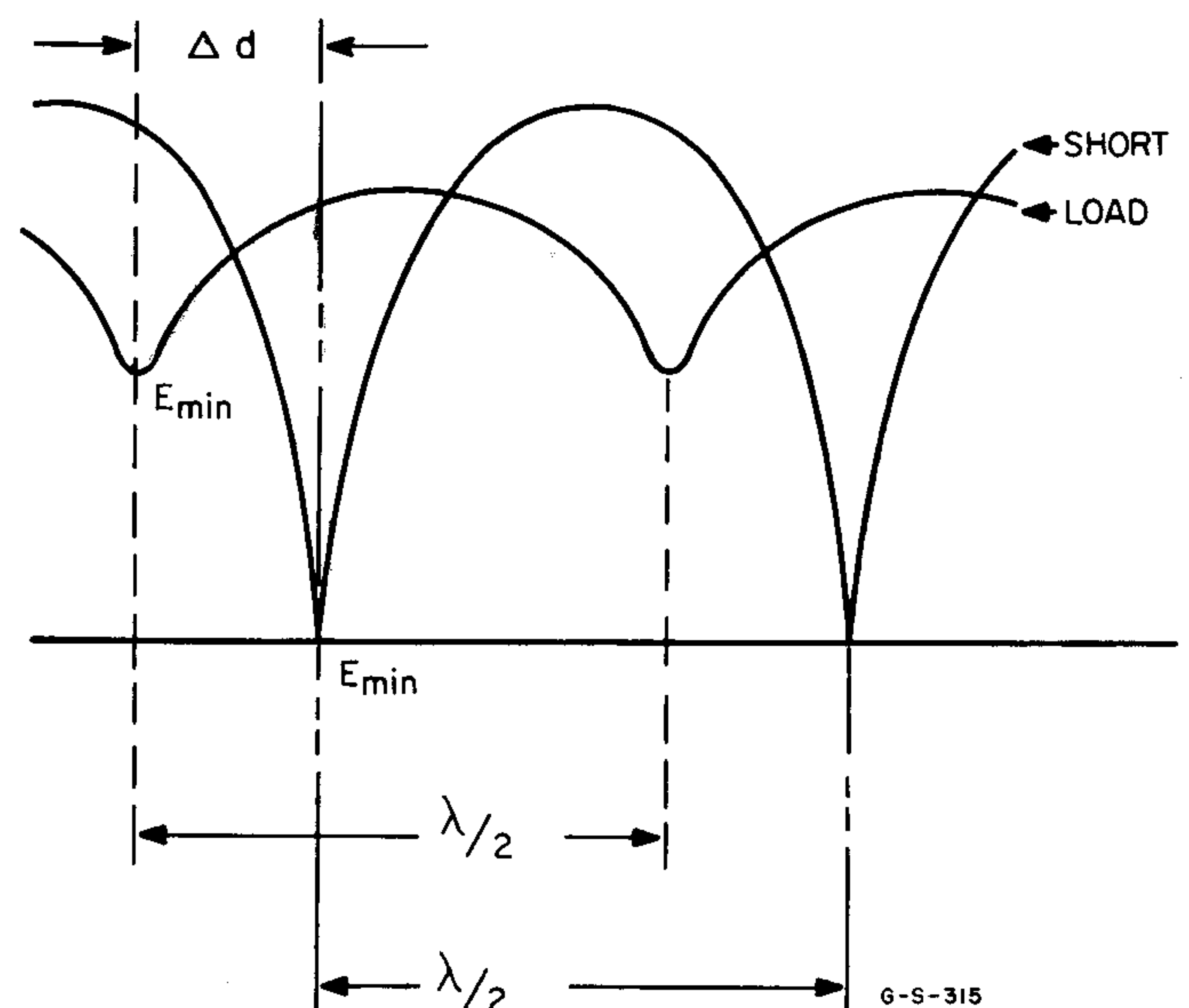


Figure 3-13. Shift of Minimum with Load and Short

3-53. SMITH CHART EXPLANATION.

3-54. 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 3-57) is shown in figure 3-14. 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 component; 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.

3-55. SMITH CHART CALCULATIONS.

3-56. 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 3-43, step f.

b. Measure the swr by the method in either paragraph 3-37 or 3-39.

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 Δd , 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:

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

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 connected.

3-57. The following example will clarify the above procedure. Figure 3-14 shows the important steps involving the Smith Chart. The assumed characteristic impedance is 50 ohms. The distance between adjacent minima is 15 cm, therefore $\lambda_g = 30$ 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.

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

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

3-58. The following numbered steps refer directly to figure 3-14.

- (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 $0.44 + j0.63$.

The impedance of the load (for $Z_0 = 50\Omega$) is then:

$$50 (0.44 + j0.63) = 22 + j31.5 \text{ ohms}$$

3-59. SPECIAL APPLICATIONS.

3-60. The Model 415C is equipped with outputs which allow applications other than as a meter indicating device for swr or attenuation.

3-61. RECORDER.

3-62. A Recorder jack on the rear panel permits use with an unbalanced-to-ground recorder having 1ma full scale deflection and a maximum input resistance of 1500 ohms. Use a three-conductor plug with a half inch diameter body (e.g., a Switchcraft No. 267 type A) to insure clearance. Figure 3-15 shows the connections for a shunting 1500 ohm 1/4 watt resistor in a plug for use with a high impedance device.

CAUTION

To avoid possible damage to the Model 415C meter, be sure the leads from the plug are not open when the plug is inserted in the RECORDER jack. To change external connections, first remove the plug or turn the Model 415C POWER switch to OFF.

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

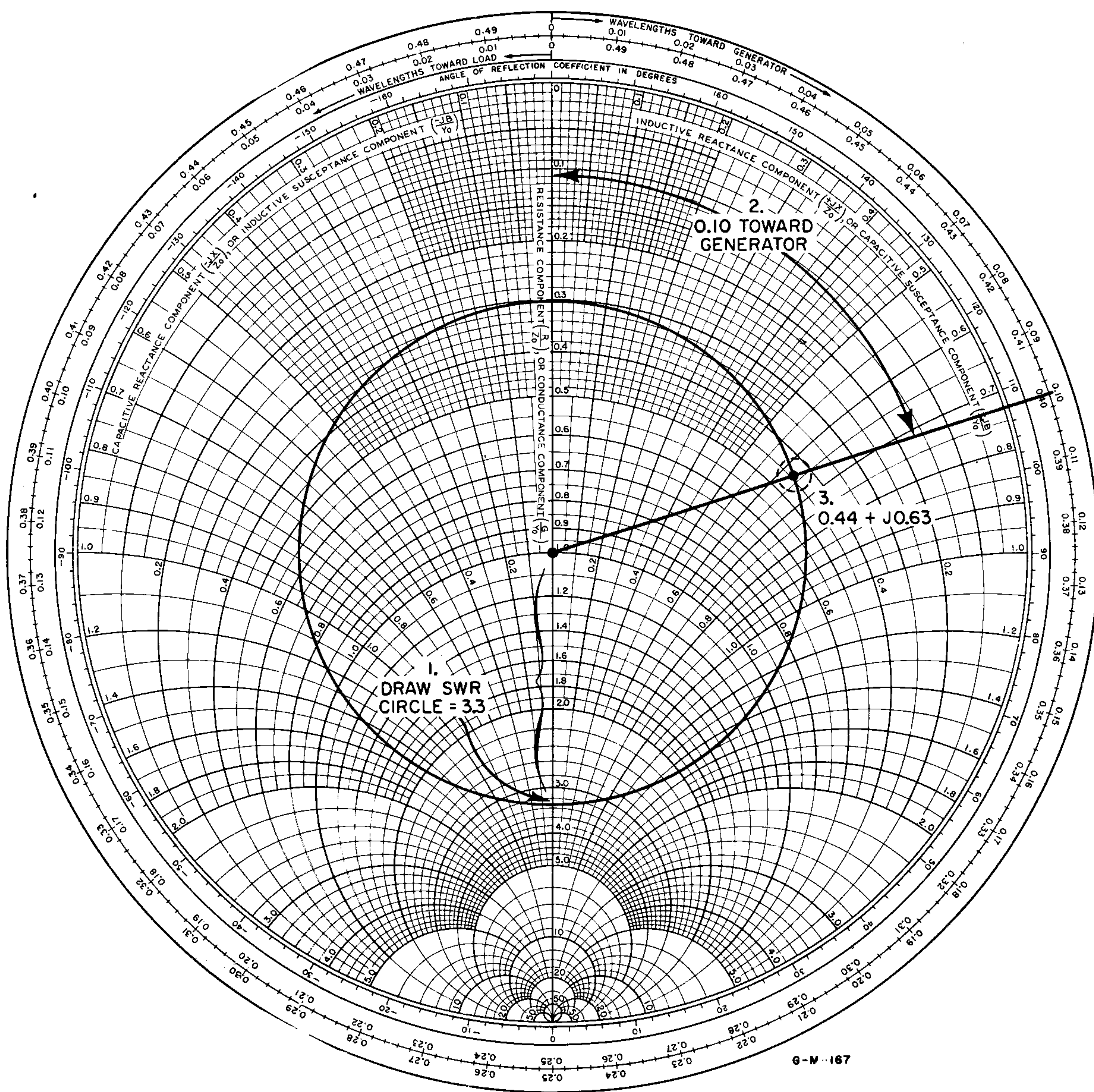


Figure 3-14. Example for Use of Smith Chart to Determine Impedance

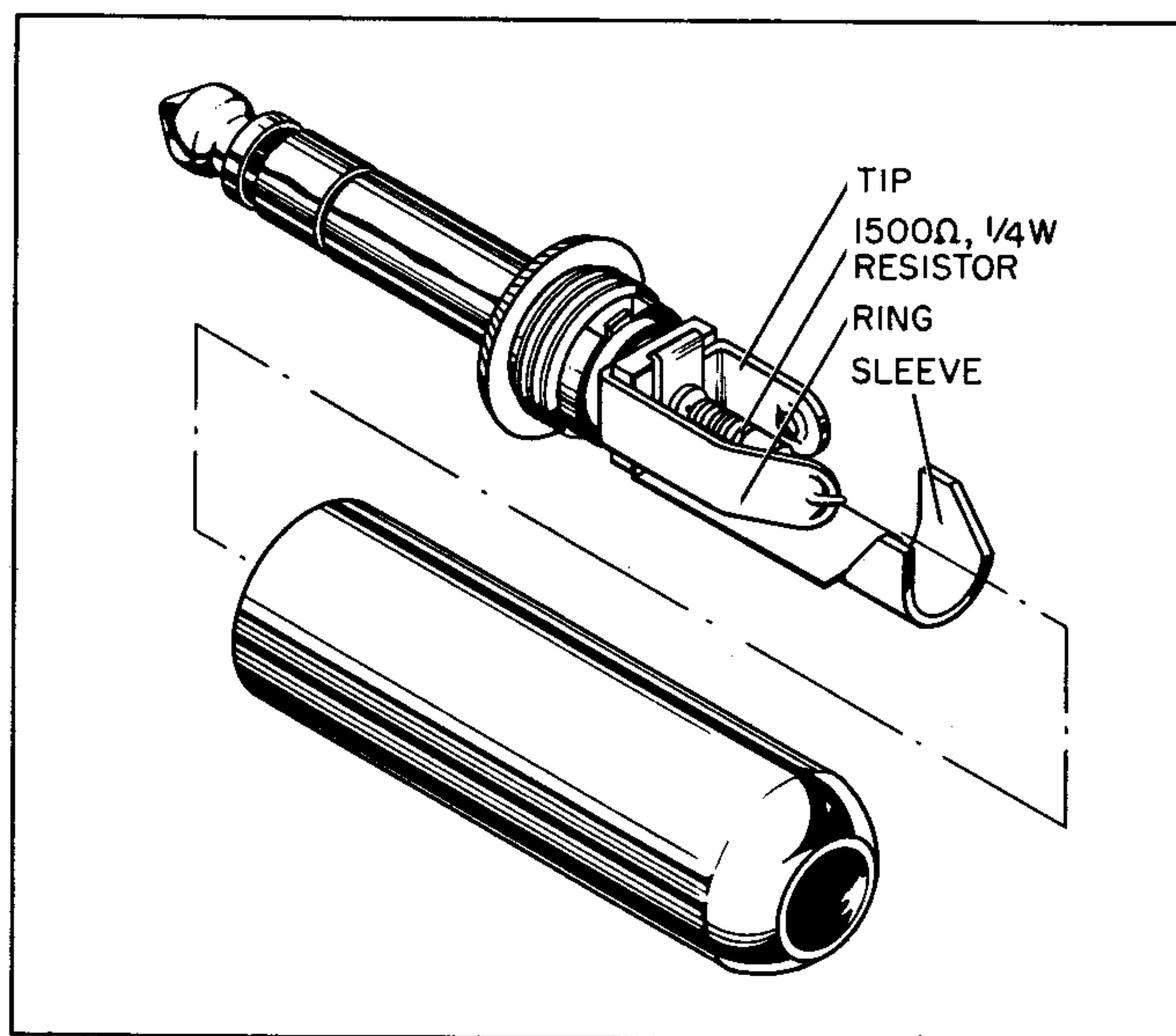


Figure 3-15. Recorder Plug with 1500-ohm Resistor

3-63. AMPLIFIER OUTPUT.

3-64. The Amplifier Output terminals furnish an output from 0 to 1 volt rms across a resistance of 10K ohms or more. The Model 415C amplifier will supply up to 140 db of gain. Although the amplifier is normally tuned to 1000 cps, other frequencies are available from 400 to 2500 cps. A frequency may be specified when ordering an instrument or a modification, described in paragraph 5-58, may be made.

3-65. The Model 415C is especially useful as a tuned amplifier in a measurement setup using an oscilloscope and a sweep generator. Sweep speeds may be increased (over the speeds using a ratio meter in a reflectometer system) and the Model 415C, used as a high gain amplifier, provides the required sensitivity.*

* See  Application Note 54, "Improvements in Microwave Swept Frequency Techniques".

SECTION IV

PRINCIPLES OF OPERATION

4-1. GENERAL.

4-2. The Model 415C is essentially a high-gain tuned amplifier which takes an input from either a bolometer or crystal, amplifies it, and applies it to a meter calibrated for use with a square law detector. With bolometer operation, the Model 415C supplies the bias current to the bolometer element to bring the resistance up to its operating point. Figure 4-1 is a block diagram which will help in understanding the following principles of operation discussion. Refer also to the schematic diagrams, figures 5-14 and 5-15.

4-3. INPUT CIRCUITS.

4-4. The input voltage, which is proportional to the modulated rf, is first routed through S101D of the INPUT SELECTOR to transformer T101. T101 provides an input impedance of 200 ohms or 200K ohms, depending on the setting of S101. On BOLO position, S101A connects a bias current source in series with the INPUT connector. An emitter follower, Q111, in this bias circuit helps provide the bolometer protection for

barretters. This transistor limits the transient current when a bolometer is connected. Two calibrated levels of bolometer bias are available: 4.3 ma (LOW) and 8.7 (HIGH), selected by S101. Resistor R103 sets the bias current on the BOLO LOW position and R104 sets the BOLO HIGH bias current. Another adjustment, R101, Meter Bias Current Calibration, calibrates the Model 415C meter to indicate bolometer current directly when S104 is switched to the BIAS CHECK position.

4-5. RANGE ATTENUATOR.

4-6. The input signal is fed from T101 through S101C to the first section, S102ABCD, of the RANGE switch S102. The first section, S102ABCD, is located before transistor Q101, and provides attenuation to 80 db in 20 db steps. The second section, S102EG, located after Q105, provides up to 40 db attenuation in 20 db steps. The RANGE switch positions are indicated in 10 db steps to obtain square law calibration. Thus the meter reads directly when used with square law devices.

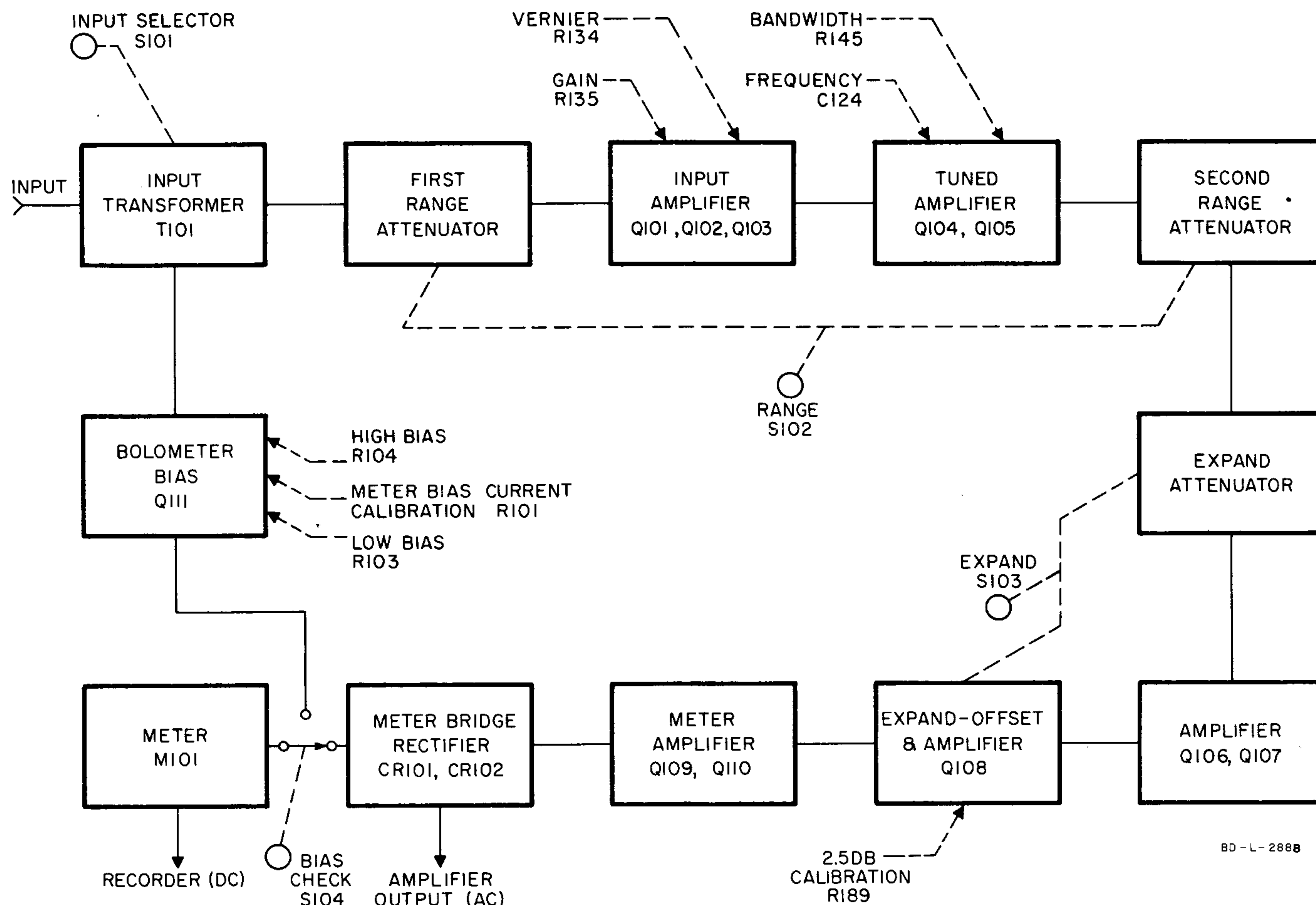


Figure 4-1. Block Diagram

4-7. INPUT AMPLIFIER.

4-8. After passing through the first section of the RANGE attenuator, S102, the signal goes to an emitter follower transistor, Q101, and is then fed directly to the base of Q102. Transistor Q102 amplifies the signal and C112 couples the signal to the next stage. Transistor Q103 is an amplifier with two variable controls in its collector circuit. The GAIN control, R135, varies the gain of Q103 by adjusting its ac collector load. The VERNIER control, R134, also changes the amplifier gain by inserting 0 to 2500 ohms in series with the signal to the base circuit of transistor Q104.

4-9. TUNED AMPLIFIER.

4-10. Transistor Q104, along with C123, C124, L101 and R145, comprise a variable frequency, variable bandwidth, tuned amplifier. This amplifier is normally tuned to 1000 cps (see paragraphs 3-63 and 5-58), but this frequency is adjustable over a range of 5% by changing C124, the FREQ (frequency) control. The BANDWIDTH adjustment R145, varies the bandwidth of the tuned network (see paragraph 3-14).

4-11. The tuned amplifier signal is next fed to transistor Q105, amplified, and routed to the second section of S102 where attenuation occurs depending on the setting of the RANGE switch. Next, the signal goes to the EXPAND switch S103.

4-12. EXPAND CIRCUIT.

4-13. The function of the EXPAND switch S103, is to allow any 2.5 db increment to fill the entire meter scale while maintaining the original reference level. This is accomplished by applying a precise amount of current from Q108 through S103C to the meter and, at the same time, changing the attenuation of the amplifier circuit with S103A and S103B. Also for EXPAND operation, S103D removes R208 from a negative feedback circuit, further changing the amplifier gain. This gain change compensates for the effect of an increased signal at the rectifier diodes in the meter bridge.

4-14. METER AMPLIFIERS.

4-15. Transistors Q106, Q107, and Q108 amplify the signal from S103B. An ac feedback loop between Q107 and Q106 provides gain stability and impedance matching. Resistor, R189, 2.5 DB Cal., in the emitter

circuit of Q108, adjusts the dc offset current to the meter in EXPAND operation. From Q108, the signal passes through an emitter follower, Q109, to Q110. The signal is amplified by Q110 and fed to the meter bridge.

4-16. METER CIRCUIT.

4-17. Two crystal diodes, CR101 and CR102, and capacitors C150 and C151, make up the meter bridge. The rectified output current deflects the meter, M101, according to the average value of the output waveform. The output signal is recombined across R211, and fed back to the base of Q109 in the form of negative current feedback. This feedback helps linearize the conversion of ac to dc using the nonlinear diodes. The meter is calibrated for use with square law detectors which have a voltage output varying directly with power input (see note following paragraph 5-82).

4-18. OUTPUT CIRCUITS.

4-19. The recombined signal voltage across R211 is fed through C155 to the Amplifier Output connector, J103, so the Model 415C may be used as a high-gain tuned amplifier. The meter current also flows through R216 on J102, the Recorder jack. One side of J102 is grounded, permitting operation with an unbalanced-to-ground recorder. When a recorder is used with the Model 415C, R216 is automatically taken out of the circuit as the recorder is plugged in. See paragraph 3-61 and figure 3-15 for Recorder operation information.

4-20. POWER SUPPLY.

4-21. When the POWER switch, S2A and S2B, is in the AC position, an ac voltage from transformer T1 is rectified by CR1 to CR4 and this voltage is passed to the regulating circuitry. The power supply voltage is regulated by differential amplifiers Q2-Q3 and Q4-Q5, and series regulator Q1, and provides -18 volts (adjusted by R21) dc to the amplifier circuit transistors. Temperature compensation is provided by diodes CR7 through CR10. In the AC position, about 4 ma "trickle charge" is supplied through R4 to the battery, BT1. If S2 is set to the BATTERY ON position, battery current passes through diode CR5 to the regulators. The BATTERY CHARGE position allows recharging of the battery by placing R4 in parallel with R5 and about 30 ma then flows to the battery.

SECTION V MAINTENANCE

5-1. INTRODUCTION.

5-2. This section contains test and maintenance information to aid in keeping the Model 415C operating properly. Procedures are included to help locate and replace defective components and also included are the adjustments and checks necessary to restore the Model 415C to normal operating condition. A procedure to verify the Model 415C specifications as given in table 1-1 is provided in paragraph 5-80, Performance Verification. This requires test instruments but

may be accomplished with no internal adjustments or connections to the Model 415C. The Performance Verification is useful as an incoming quality control check or as a part of routine maintenance.

5-3. TEST EQUIPMENT REQUIRED.

5-4. Table 5-1 lists the test equipment needed to check the specifications and for maintenance of the Model 415C. All test instruments should be recently

Table 5-1. Test Equipment Required

Description	Minimum Required Specifications	Use	Recommended Equipment
DC Voltmeter	Voltage Range: 0.1 volt to at least 50 volts. Input Impedance: 10 megohms Accuracy: $\pm 1\%$ of full scale reading, all ranges.	Power Supply regulation and circuit voltage checks.	Ⓜ Model 412A DC Vacuum Tube Voltmeter (or Model 405 Digital DC Voltmeter)
AC Voltmeter	Voltage Range: 0.1 volt to 1 volt. Accuracy: $\pm 1\%$ of full scale reading.	Amplifier Sensitivity check.	Ⓜ Model 400H Vacuum Tube Voltmeter
Oscillator	Frequency Range: 400 to 2500 cps Accuracy: $\pm 3\%$ Output: 2.5 volts rms into 600 Ω Distortion: Less than 1%	Input to Model 415C for circuit calibration and checks	Ⓜ Model 204B Portable Oscillator
Electronic Counter	Range: 400 to 2500 cps Accuracy: ± 1 count $\pm 0.01\%$	Monitor oscillator frequency for check and adjustment of Model 415C	Ⓜ Model 5212A (or 5512A) Electronic Counter
Variable Power Transformer	Variation: from 103 to 127 volts	Power Supply Regulation check	General Radio W5MT3A Metered Variac [®] Auto-transformer
DC Voltage Source	Range and Accuracy: stable source which can be set between 17.5 volts and 18.5 volts	Power Supply Regulation check	Battery with Variable Resistor Divider
Attenuator	Procedures require two. Range: at least 60 db in 10 and 1 db steps Accuracy: Calibration must be known to ± 0.02 db for 1 db steps; to ± 0.03 db for first 20 db step and to ± 0.07 db for subsequent 20 db steps.	EXPAND and RANGE attenuator tracking and calibration	Ⓜ Model 350B Attenuator Set, with calibration error chart see paragraph 5-5
Load Test Resistor	Value: 200 ohms Accuracy: 1%	Load on Model 415C input for bolometer bias adjustment	
Isolating Attenuator	Range: 10 db Impedance: 600 ohms	Isolates signal source and maintains impedance for attenuators	See paragraph 5-5

calibrated and allowed the warmup time suggested by the manufacturer, before using in any of the procedures outlined in section V.

5-5. ISOLATING ATTENUATOR.

5-6. In order to obtain accurate results when checking the Model 415C, it is necessary to maintain some attenuation at the input to compensate for a source impedance different from the calibrated attenuator used. The attenuator recommended for the test and adjustment and performance verification procedures in section V has an impedance of 600 ohms. Therefore, a 10-db, 600-ohm attenuator pad is suggested to be placed in the equipment setup shown in figure 5-1. If a separate attenuator pad is not used, then one of the Model 350B Attenuators may be left in the circuit and set to 10 db. If this method is used, the attenuator calibration specified in paragraph 5-7 must be extended to 60 db above the 10-db pad value. Also, if one of the Model 350B's (or any external attenuator) is used to provide the 10-db isolating pad, all settings of this attenuator in the procedures of section V must be increased by 10 db (i.e. the 10-db point becomes a reference for the attenuator setting).

5-7. ACCURACY OF EQUIPMENT.

5-8. Verifying test limits or specifications is not possible unless the accuracy of the test equipment is known within the values given in table 5-1. The counter is not required as a monitoring device if the signal source frequency is accurately calibrated. The attenuators used in the adjustments and checks must be calibrated and an error chart used, especially in checking the tracking of both the RANGE and EXPAND

attenuators. Calibration to ± 0.02 db for 1-db steps, to ± 0.03 db for first 20-db step, and to ± 0.07 db for subsequent 20-db steps (to a total of 60 db) is suggested for each attenuator. If one attenuator is used for the 10-db pad (paragraph 5-5), this attenuator must be calibrated to 70 db.

5-9. **INSTRUMENT COVER REMOVAL.**

5-10. Figure 5-2 shows how to remove the Model 415C instrument covers. The etched circuit board components are accessible by removing only the top cover. The top and bottom covers must be removed to reach the nuts on the bolts holding the side covers. It should only require removal of the top and bottom covers for access to any components or test points in the test or adjustment procedures. The side panels must be taken off to remove or install a battery. If a check or adjustment is to be made with the power turned on, remove necessary instrument covers first.

5-11. **MAINTENANCE OF OPTIONS 1 AND 2.**

5-12. Operation and maintenance of the Model 415C with Option 1 and/or Option 2 is found in sections III and V. Paragraphs 1-5 and 2-9 explain what is covered by the two options as well as how to obtain the parts for later installation. Figure 2-2 shows both options already installed in the instrument. The rear panel Input connector is wired in parallel with the front panel INPUT connector and either one may be used at any time. Figure 5-3 shows proper assembly of the optional INPUT connector. The shielded cable ground for the rear panel connector is returned to the front panel INPUT ground to minimize noise pickup and signal reference problems. The center of the

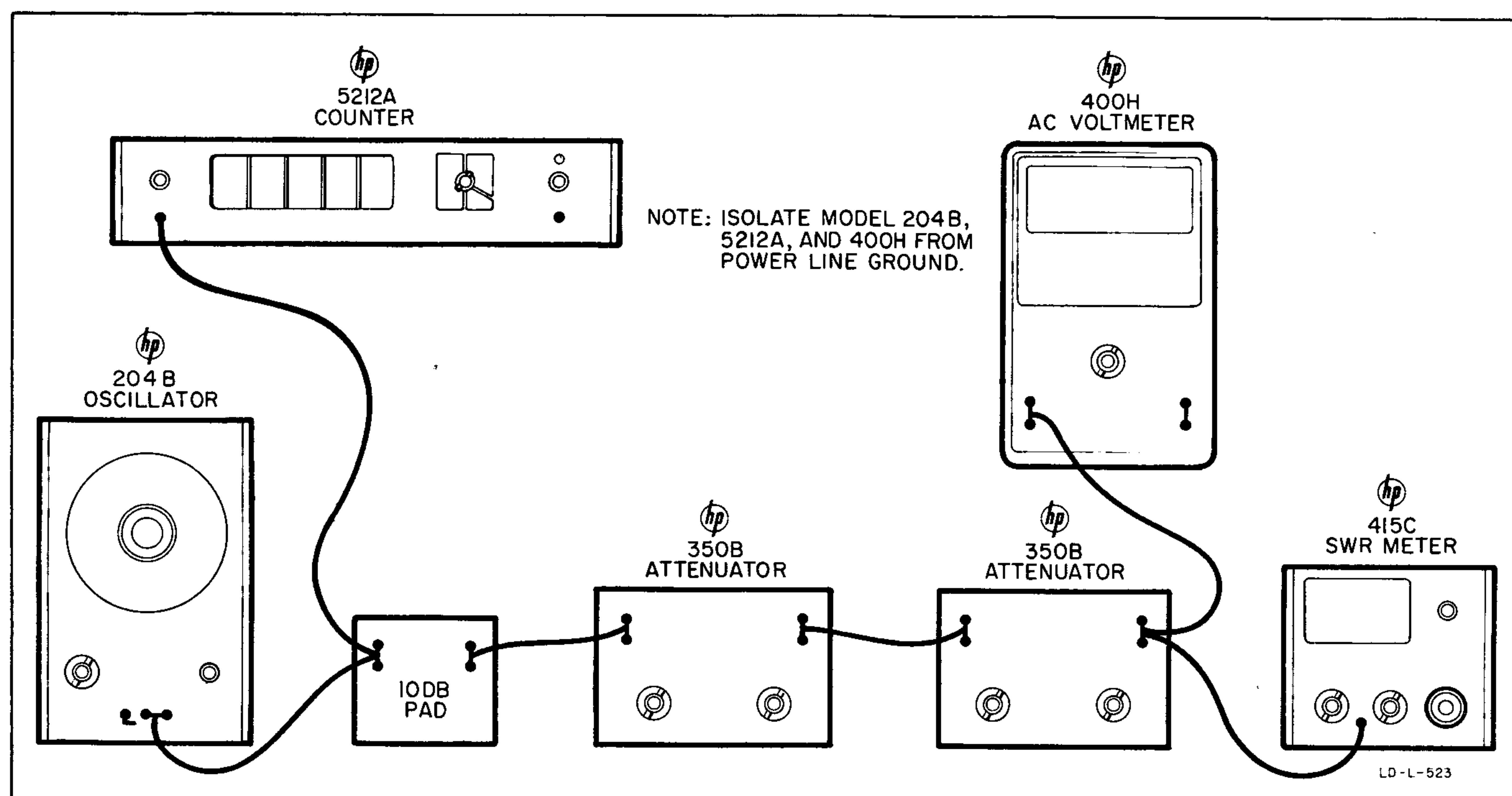


Figure 5-1. Test and Calibration Instrument Setup

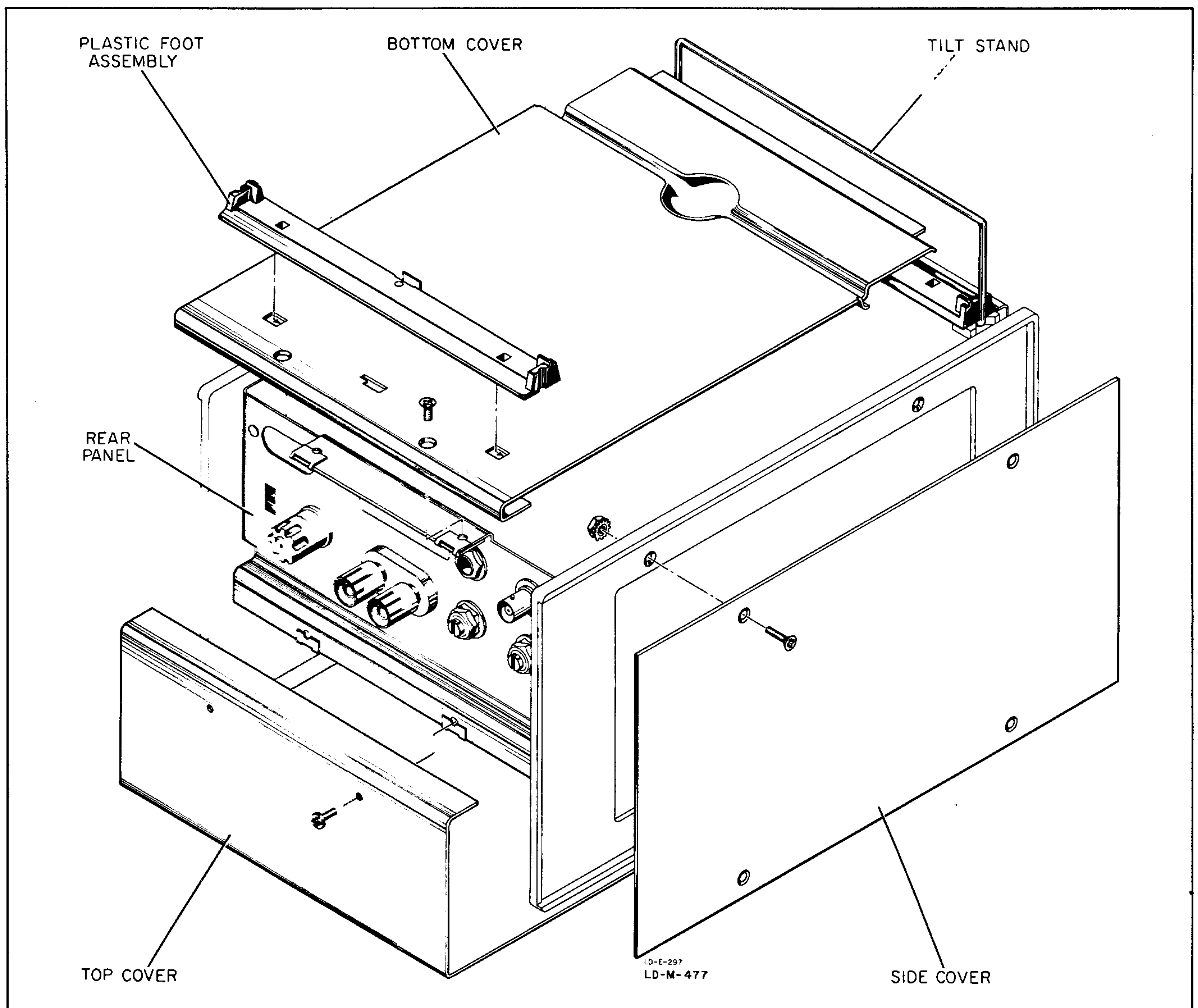


Figure 5-2. Removal of Instrument Covers

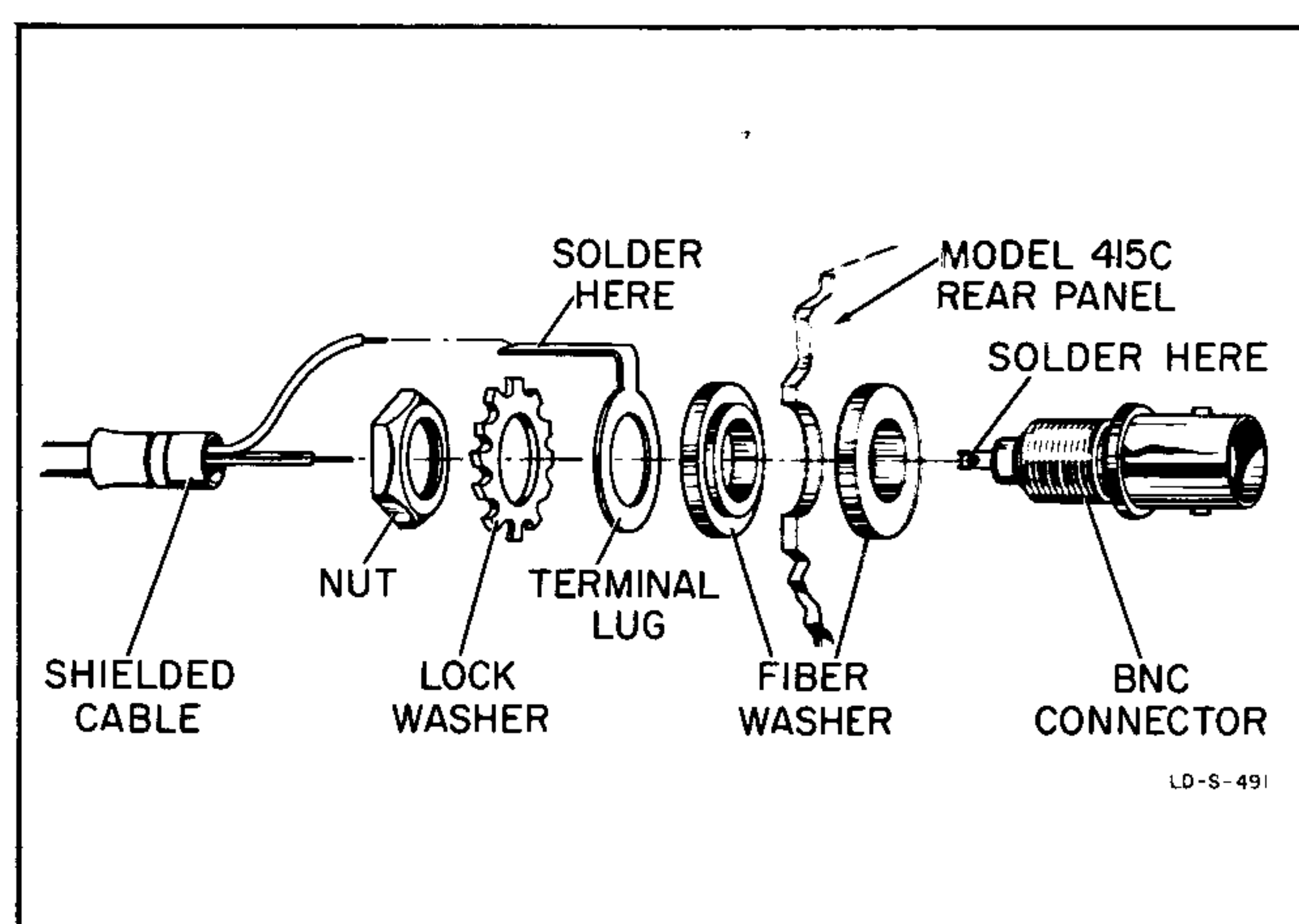


Figure 5-3. Option 2 Connector Assembly

cable connects to S102D at the same point as the green wire leading to the BNC INPUT connector. For some maintenance of the Model 415C, it will be necessary, or more convenient, to remove the battery. Figure 5-4 shows the battery, the support, and the cover as disassembled. To remove a battery installation from the Model 415C, proceed as follows:

- Set POWER switch to OFF and remove power plug from the Model 415C.
- Remove all instrument covers as shown in figure 5-2.
- Unsolder the two lead wires from the battery terminals.

CAUTION

Do not short the battery terminals at any time as this may result in damage to the individual cells comprising the battery.

d. Remove the screws from each side casting of the Model 415C which hold the battery support in place. Note which holes in the casting are used, to ensure proper alignment when the battery is reinstalled. Remove the battery assembly through the right side casting (as viewed when facing the instrument front panel).

e. To complete removal of the battery, remove the screws holding the battery cover to the battery support.

Note

If a defective component is located, see paragraph 5-43 for Repair and Replacement Procedures. This explains the checks and adjustments required when certain parts are replaced.

5-16. CIRCUIT VOLTAGE CHECKS.

5-17. The schematic diagrams, figures 5-14 and 5-15 have typical voltages indicated at the base, emitter, and collector of all transistors. See the note on figure 5-14 for the conditions present when the voltages were measured. These voltages should be checked to help locate a faulty component. For example, the same voltage at the collector of one transistor and the base of the next transistor could indicate the coupling capacitor is shorted. These voltage checks may also determine if a particular transistor is drawing abnormal current, thus possibly leading to a bad part.

5-18. NOISE LEVEL.

5-19. If the procedure of paragraph 5-85 indicates abnormal amplifier noise, several sources are possibly causing it. The following components should be checked:

a. Any of the transistors Q101 through Q110 may introduce noise. A check may be made to determine if the noise is primarily due to the transistor circuits before or after the second RANGE attenuator section, S102EG. After completing the procedure of paragraph 5-85 and noting a high noise level, change the RANGE switch to 0 position and note the indication as follows:

- (1) If average noise indication is at least 10 db down from "0" on the 0 to 10 db scale, the noisy component is probably before S102EG. Check Q101 through Q103 first.
- (2) If noise indication is to the right of 10 on the 0 to 10 db scale, the noisy source is probably a transistor after S102EG. Check Q106 and Q107.

b. CR10, a breakdown diode, in the power supply could be noisy and the noise may be coupled into the amplifier through the regulated voltage.

c. R122 or R123 at the base of Q101 could be introducing a noise source.

5-20. POWER SUPPLY.

5-21. GENERAL. If the meter of the Model 415C is tracking improperly during EXPAND operation, the power supply may not be regulating properly. If a trouble is suspected in the power supply, make the check on voltage regulation, paragraph 5-22 and also check the power supply voltage as in paragraph 5-66. Voltage checks (typical values on the schematic diagram, figure 5-15), at the transistor connections should be helpful. If the gain of one or more of the power supply transistors is low, regulation will be

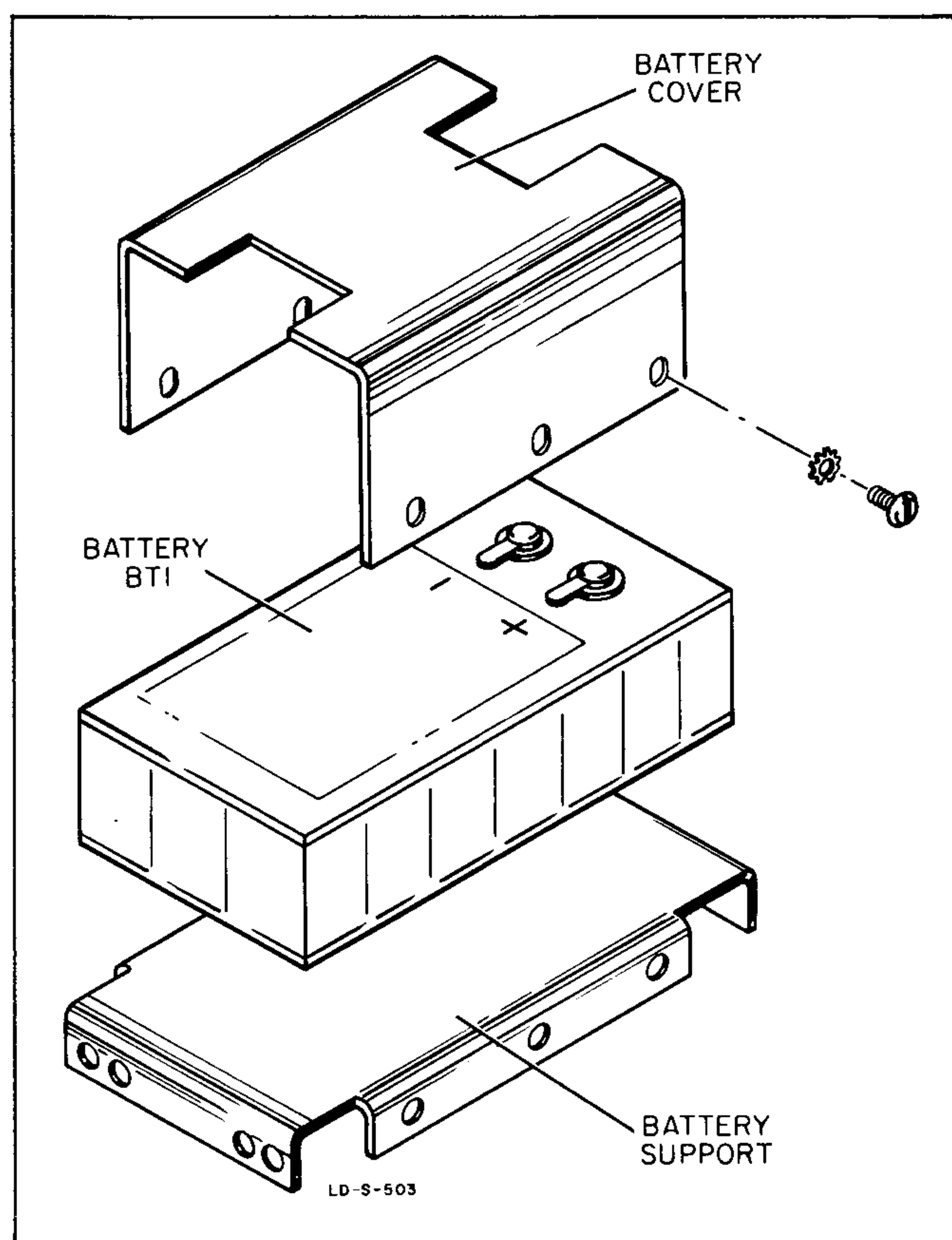


Figure 5-4. Option 1 Battery Assembly

5-13. TROUBLESHOOTING.

5-14. GENERAL.

5-15. The following procedures are intended as a guide in locating a defective component in the Model 415C. The fact that a trouble exists will likely be obvious from some front panel indication on the meter when the switches are changed during a measurement. Tracking errors and overall performance errors may not be obvious unless the Model 415C is being checked by a calibrated test setup as suggested in paragraph 5-91. Other indications of trouble may occur when a bias check is made, the FREQ or BANDWIDTH controls changed, either HIGH or LOW bolometer bias is adjusted, or when using either the Amplifier Output or Recorder jack output. Carefully noting improper front or rear panel indications may aid in isolating the trouble to a particular circuit or part of the instrument.

affected. Should CR1, CR2, CR3, or CR4 become defective, regulation within limits of paragraph 5-22 will not be possible. The battery charging function would also be affected by a diode failure. If a defective diode is suspected, check the voltage at the anode side of the diode. A voltage check between the connections of CR7, CR8, CR9, and CR10 should determine if one is defective.

5-22. REGULATION CHECK. The following procedure may be used to determine if the Model 415C power supply is regulating properly.

a. Connect dc source (see table 5-1), dc voltmeter and Model 415C Power Supply as shown in figure 5-5. Plug the Model 415C into the variable power transformer (table 5-1) and set to normal line voltage, 115 volts.

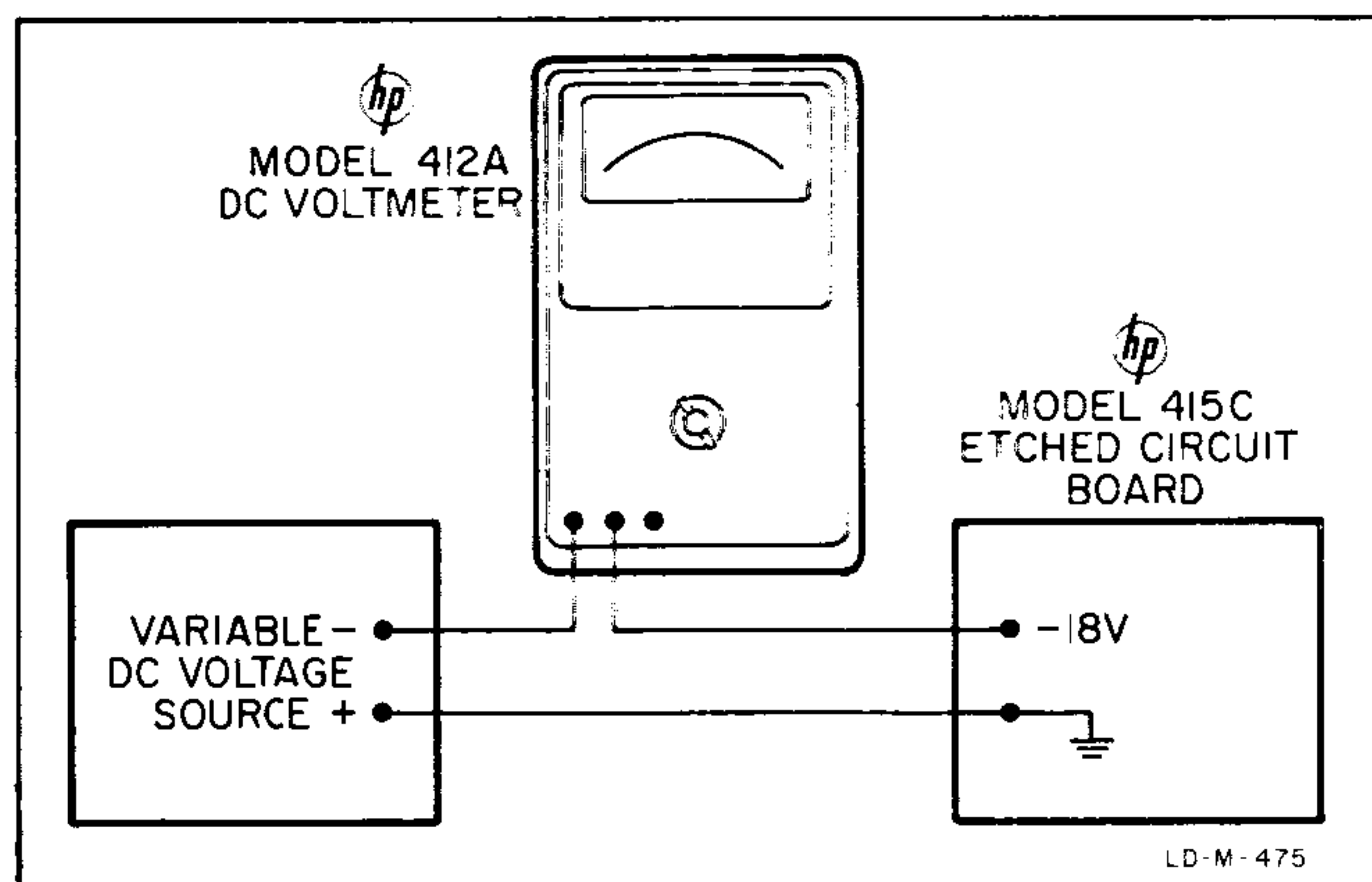


Figure 5-5. Power Supply Regulation Setup

b. Adjust the test dc source to give 100 millivolts $\pm$ 50 millivolts as indicated on the dc voltmeter.

c. Change the line voltage by $\pm 10\%$ from 115 volts.

d. The voltmeter reading should change by less than 15 millivolts from the voltage set in step b.

5-23. BOLOMETER BIAS CIRCUITRY.

5-24. The bolometer bias is set and checked in the procedure of paragraph 5-68, and this should determine if the circuit works correctly. If only low bias is affected, R103, R105, S101A and connecting leads are possible defective components. If only high bias is affected, the possible cause is narrowed to R104, S101A, or connecting leads.

5-25. EXPAND CIRCUIT

5-26. Paragraphs 5-76 and 5-78 outline the necessary steps to calibrate the EXPAND circuit when all components are good. If the Model 415C meter needle fails to maintain a reference at the 0db position when the EXPAND switch is changed from NORM position to 0.0, either the offset current through Q108 and S103C or the attenuation circuit of S103A and S103C may not be functioning properly.

5-27. METER CIRCUIT.

5-28. Should a meter movement begin sticking, inconsistent readings in a particular area of the meter face would be noticed. The meter movement in the Model 415C is checked for stickiness and tracking error, and an individually calibrated scale face is attached before the meter is installed in the instrument. Problems with the meter itself are thus minimized. However, the current flowing through the meter, causing needle deflection, may be affected by failure of several components. If a short (or open) occurs in either CR101 or CR102, the meter will not deflect. A check of the voltage at the points shown on the schematic diagram should determine the defective component.

5-29. GAIN CONTROLS.

5-30. The amplifier gain is changed by variable resistors for the GAIN and VERNIER settings. The following check will determine if the GAIN and VERNIER controls allow the proper variation in gain.

a. Connect test equipment as in figure 5-1, omitting both attenuators (see paragraph 5-5) and the ac voltmeter.

b. Set the Model 415C POWER switch to AC (or BATTERY ON), INPUT SELECTOR to 200 Ω , RANGE switch to 0, EXPAND switch to NORM, and GAIN control fully clockwise.

c. Tune the oscillator to the Model 415C center frequency and adjust the oscillator output and/or Model 415C VERNIER control for a 0 db reference on the meter.

d. Turn the Model 415C GAIN control fully counterclockwise and change the RANGE switch to 10. The Model 415C meter should now indicate between 0 and 5 db on the 0 to 10 DB scale.

e. Set the VERNIER control fully clockwise and adjust the GAIN control for a 0 db reference on the meter.

f. Turn the VERNIER control fully counterclockwise. The Model 415C meter should indicate between 0.7 and 2.0 db on the 0 to 10 DB scale.

5-31. SWITCH COMPONENTS.

5-32. If a trouble is suspected in one of the Model 415C switches, use the schematic diagrams, figures 5-14 and 5-15, to help isolate a defective part. The schematics show how each switch section routes the signal and also included with figure 5-14 are simplified switching diagrams showing what happens with different RANGE and INPUT SELECTOR switch settings. Refer to figures 5-6, 5-7, and 5-8 for component and terminal location on the switches. Paragraph 5-51 details the procedure for removing the switch assemblies from the instrument.

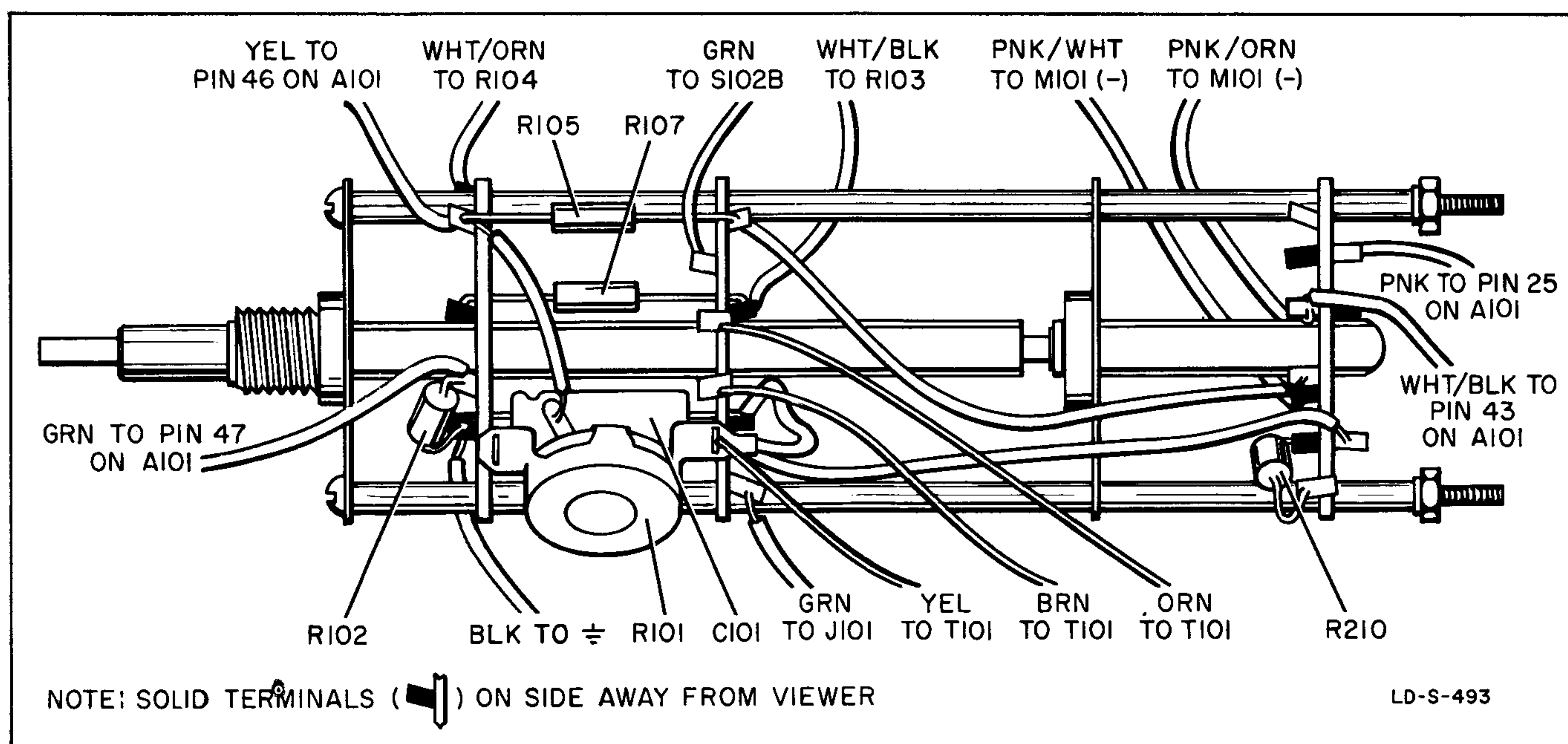


Figure 5-6. S101-S104 INPUT SELECTOR-BIAS CHECK Switch Component Identification

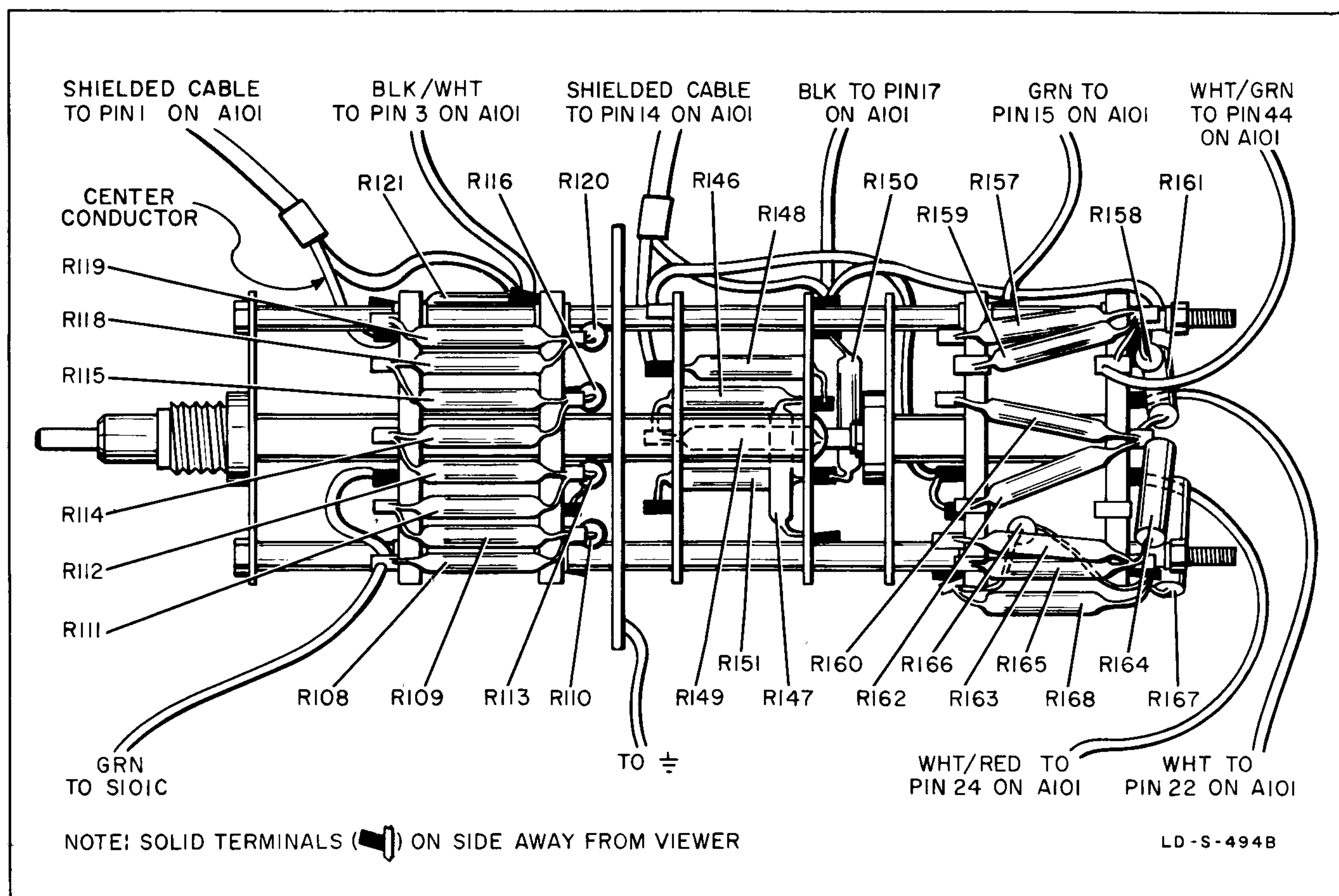


Figure 5-7. S102-S103 RANGE-EXPAND Switch Component Identification

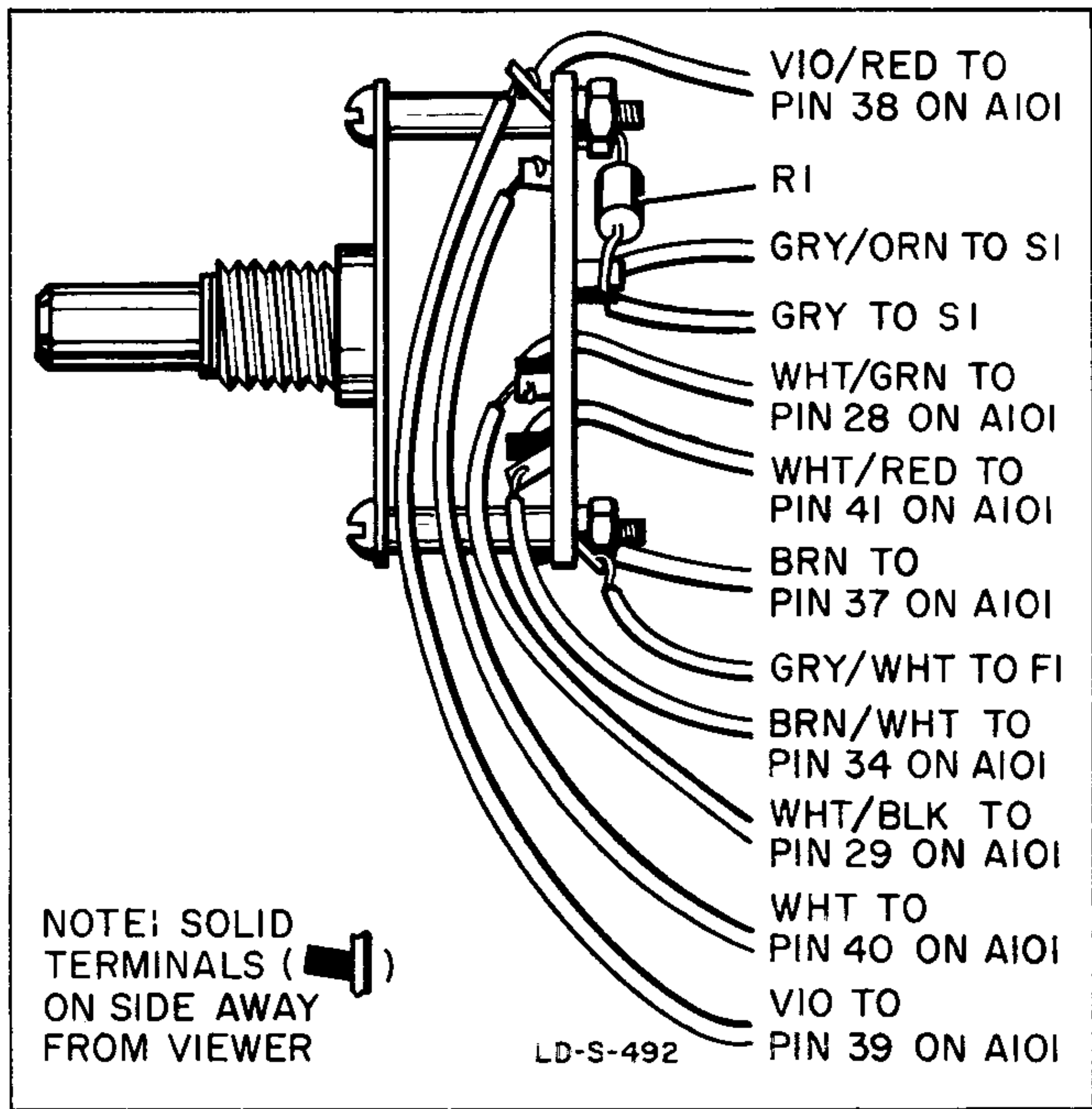


Figure 5-8. S2 POWER Switch
Component Identification

5-33. AMPLIFIER GAIN.

5-34. The gain for sections of the Model 415C amplifier may be checked to locate a low gain section. A convenient method is to apply a signal of approximately 40 μ volts at the input to the amplifier, and measure the gain between selected points with a voltmeter having a sensitivity of 30 μ volts (e.g., the Φ Model 302 Wave Analyzer). Figure 5-9 shows the test points for obtaining the results as shown in table 5-2. Values for gain are approximate.

a. Remove the Model 415C top cover. Turn the Model 415C POWER switch to AC or BATTERY ON, INPUT SELECTOR to 200 Ω , EXPAND switch to NORM, RANGE switch to 30, GAIN and VERNIER controls fully clockwise, and set the bandwidth to 30 cps.

b. Connect the oscillator output to pin 1 on the etched circuit board. Tune the oscillator frequency to the center frequency of the Model 415C. Adjust the output of the oscillator until the Model 415C meter indicates full scale.

c. After measuring the input at pin 1, measure the gain between the points indicated in figure 5-9, comparing results with table 5-2.

Table 5-2. Approximate Amplifier Gain

Between Points	Approximate Gain
A and B	40 db
B and C	22 db
D and E	40 db
F and G	63 db
G and H	43 db

5-35. BATTERY CIRCUIT.

5-36. The following checks will help determine if the battery is functioning properly and also if the battery charging circuit is providing the required current. The two battery checks should be performed as a part of routine maintenance to determine (1) if a battery needs recharging and (2) if the battery has been recharged sufficiently. Before removing a possibly defective battery from the instrument (see paragraph 5-11) after attempting to recharge it, check the charging circuit as suggesting in paragraph 5-39. Specific information relating to proper battery care and operation is found in Section III of this manual.

5-37. DISCHARGE CHECK.

a. Connect the test equipment as shown in figure 5-1, omitting both attenuators (see paragraph 5-5) and the ac voltmeter.

b. Set Model 415C POWER switch to BATTERY ON, INPUT SELECTOR to 200 Ω , RANGE switch to 0, and EXPAND switch to NORM.

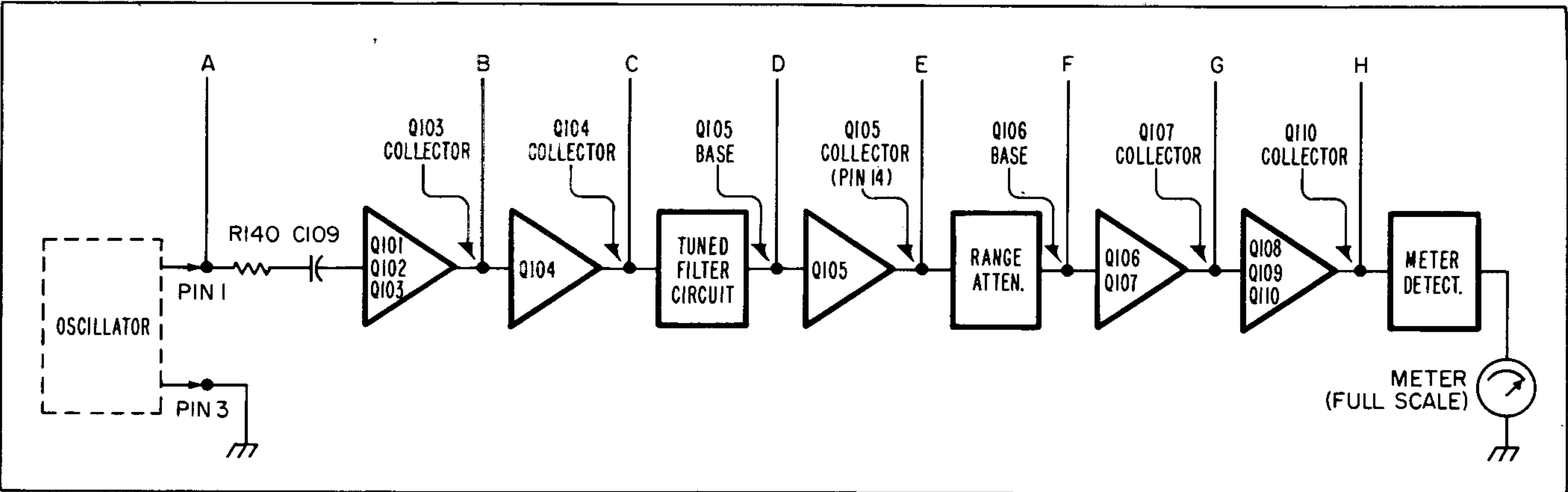


Figure 5-9. Amplifier Gain Test Points

c. Tune the oscillator to the Model 415C center frequency. Adjust the oscillator output and/or Model 415C GAIN and VERNIER controls to give 0 db reference on the Model 415C meter.

d. Change EXPAND switch to 0.0 position. Needle should not move from 0 db by more than ± 0.05 db on the 0 to 2.5 DB scale. The same limits apply if the EXPAND switch is first set to 0.0, a 0 db reference obtained and EXPAND switch is then changed to NORM.

e. To insure that the battery caused the meter indication (rather than another part in the power supply or EXPAND circuit) in step d, change the POWER switch to the AC position and connect the instrument to an ac source. Set the 0 db reference as in step c and then repeat step d. If the reference is now maintained, the battery needs recharging. If the reference is not maintained, a trouble may exist in the regulated power supply or Q108 circuitry which provide the meter off-set current for EXPAND operation.

5-38. CHARGE CHECK. Normally a fully charged battery will drop in voltage from about 27 volts to 22 volts after 36 hours continuous operation at room temperature. The battery consists of 20 cells (individually replaceable only at the factory) in series and the internal shorting of one cell will reduce the battery terminal voltage. The following procedure will aid in determining if the battery holds a charge properly.

a. Connect the Model 415C to ac power and set the POWER switch to AC. Perform tracking checks of paragraph 5-91. This will check for normal operation; if not normal, consult the troubleshooting paragraph 5-13.

b. Change POWER switch to BATTERY CHARGE position and allow a 48-hour period to obtain a full charge on the battery.

c. Turn the POWER switch to OFF and remove the ac cord from the instrument. Remove top cover and connect a dc voltmeter (at least 10,000 ohms per volt sensitivity) to pins 35 and 45 (on the etched circuit board), observing the correct polarity.

d. Set the Model 415C POWER switch to the BATTERY ON position and the voltmeter should read 27 volts ± 1 volt. If the battery voltage is less, check the battery charging circuit (paragraph 5-39) before removing the battery.

5-39. CHARGING CIRCUIT CHECK. Two methods may be used to check the battery charging circuit. The first method, and simplest, uses a Φ Model 428 Clip-On DC Milliammeter. The Model 415C should be connected to ac power, the POWER switch set to the BATTERY CHARGE position. Clip the probe of the Model 428 around one of the battery terminal leads and the milliammeter should indicate about 25 to 40 millamps charging current. The second method involves a voltage check with the battery disconnected.

a. Unsolder the battery connecting leads to the etched circuit board.

b. With the POWER switch turned to the OFF position, connect a $1K\Omega$, 1% test resistor from pin 35 (Bat +) to pin 45 (Bat -) on the etched circuit board.

c. Connect the dc voltmeter (see table 5-1) across the test resistor, observing correct polarity.

d. Change Model 415C POWER switch to BATTERY CHARGE position and voltmeter should indicate between 26 and 32 volts.

e. Turn Model 415C POWER switch to OFF. Change the test resistor to a $10K\Omega$, 1% value and reconnect the voltmeter across it.

f. Change Model 415C POWER switch to the AC position. The voltmeter should again indicate between 26 and 32 volts.

5-40. BATTERY WARRANTY. The battery used in the Model 415C is warranted for one year. Should a failure occur, the battery may be returned to the Hewlett-Packard Company for replacement. If the warranty has expired, there will be a repair or exchange charge.

5-41. TROUBLESHOOTING SUMMARY.

5-42. All the possibilities for trouble cannot be mentioned specifically but some general symptoms and likely causes may be helpful. Table 5-3 is a summary of some suggestions for troubleshooting.

5-43. REPAIR AND REPLACEMENT.

5-44. Certain procedures and precautions must be followed when repairing or replacing any component of the Model 415C. Most of the amplifier and power supply circuit parts are located on the etched circuit board (below the top cover). Instructions for working on the etched circuit board are summarized in paragraph 5-45. Always disconnect the ac or battery power before replacing or soldering any parts. Paragraph 5-58 gives the information for making the modification to change the tuned amplifier center frequency.

5-45. SERVICING ETCHED CIRCUIT BOARDS.

5-46. The Model 415C circuitry is located primarily on an etched circuit board with components on one side and the conductor on the opposite side of the board. A metal funnel-shaped eyelet is inserted in most holes in the board to hold the component lead and provide strength for the solder connection to the conductor. Since the conductor part of the board is formed from a copper plating, covered by solder, care must always be taken to avoid overheating and lifting of the copper from the board. The recommended procedure for replacement of the different components varies slightly. With the single-sided, eyeletted board used in the Model 415C, it is recommended that the heat from a soldering iron be applied to the funnel eyelet and component lead on the conductor (not component) side of the board. The leads from the larger components such as potentiometers (and tube sockets used in some instruments) do not pass through an

Table 5-3. Troubleshooting Summary

Indication	Possible Cause
High noise level from amplifier	Q101, Q102, Q103, Q106, Q107, or CR10 noisy.
Meter needle does not normalize when EXPAND switch is changed	Power supply not regulating; meter rectifier circuit malfunctioning; battery charge low.
Intermittent indication on meter or from other Model 415C output	Any switching contacts or connecting leads. Connections between test or measurement instruments.
Meter linearity error	Non-linear transistor in amplifier; meter movement sticking.
Range to range tracking error	Groundloop current present; defective amplifier feedback circuit; incorrect input impedance to Q101 or Q106; bad attenuator circuit.
Bolometer bias incorrect or inoperative	Incorrect regulated voltage to bias circuit; S101A contacts bad; R101, R103, or R104 misadjusted; Q111 bad.
EXPAND operation defective	Q108 bad; R189 misadjusted; S103 contacts bad; power supply not regulating properly; R205 wrong value
Low amplifier sensitivity	Low gain transistor Q101 through Q110; RANGE attenuator defective; R138 wrong value; BANDWIDTH set too wide, decreasing gain.
Instrument inoperative in BATTERY ON position only (ac is satisfactory)	Battery defective or charge low (R4 or R5 open; CR5 defective; S2A contacts bad.

eyelet. These parts may be removed by rotating the soldering iron from lead to lead and applying steady pressure to lift the part free. Other components (transistors, capacitors, diodes, resistors) may be removed, one lead at a time, by applying heat and pulling up on the lead from the component side of the board. The hole in the board or eyelet should be cleared of solder before inserting a new component. This may be done by heating the solder in the hole and quickly inserting a pointed non-metallic object, such as a toothpick. Shape the new component leads and clip to the proper length. Insert the leads in the

eyelet or hole and apply heat and solder, on the conductor side, as necessary to obtain a good connection between component lead, conductor, and/or eyelet. If the conductor side of an etched circuit board with eyelets is not easily accessible, a component may be replaced by holding the soldering iron tip to the component side. Greater care is then required to prevent damage to the component (especially true for diodes) and to insure a good connection for lead, conductor and/or eyelet when the new component is soldered in place.

5-47. SPECIALIZED COMPONENT REPLACEMENT.

5-48. The values and characteristics of some Model 415C components are closely specified to obtain proper operation. The resistors in the RANGE and EXPAND attenuators are precise values with 1/2% accuracy and must be replaced by comparable resistors, if found defective. The components in the tuned amplifier circuit must also be replaced by comparable parts to maintain the specified accuracy and range for the Bandwidth and Frequency adjustments. Transistors Q101, Q102, Q105, Q108, Q4, and Q5 are selected for certain characteristics and, to insure proper operation when replacement is necessary, should be ordered by the Φ stock number. These transistors may also be replaced directly by a 2N1711, (or one with equivalent characteristics) available from many transistor manufacturers. See section VI, Replaceable Parts, for more information on particular components used in the Model 415C.

5-49. DIODE MARKINGS.

5-50. Solid state diodes may be packaged 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 symbol as shown in figure 5-10. Figure 5-10 also shows examples of some diode marking methods. If the cathode marking is removed, or 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 Φ Model 410B Vacuum Tube Voltmeter, the ohms lead is negative with respect to the common; for the Φ 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.

5-51. SWITCH REPAIR OR REPLACEMENT.

5-52. The EXPAND and RANGE switches are on the same assembly, as are the INPUT SELECTOR and BIAS CHECK switches and the GAIN and VERNIER controls. These assemblies, along with the POWER switch, may be removed by first taking off all instrument covers and using the applicable instructions which follow.

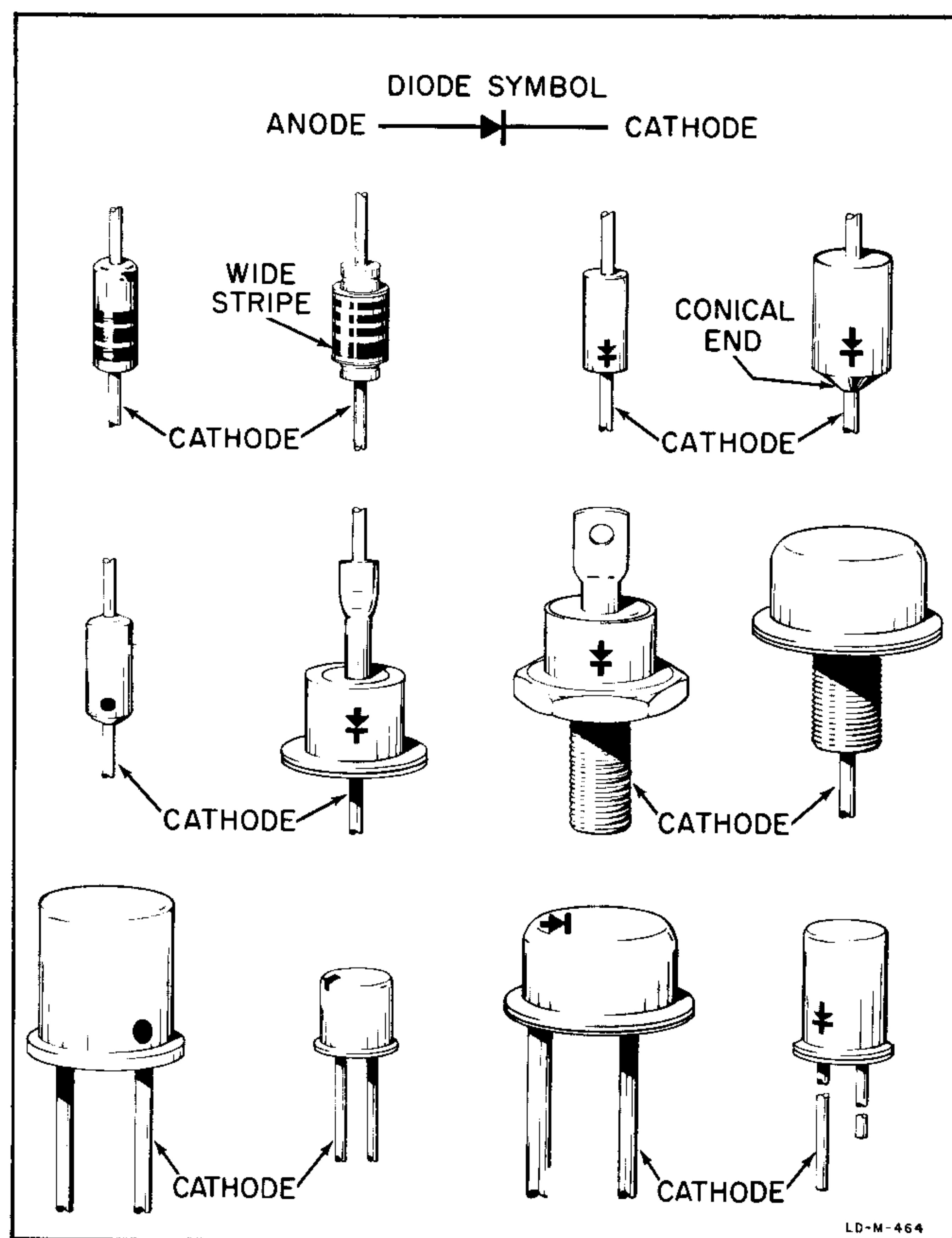


Figure 5-10. Examples of Diode Marking Methods

5-53. GAIN-VERNIER AND POWER.

- Loosen setscrew(s) in knob(s) and remove knob(s) from shaft.
- Loosen and remove shaft nut from front panel side of instrument.
- Unsolder connecting wires. Mark each to indicate which lugs to resolder wires to. See figure 5-8 for wire colors and connections for POWER switch.
- Pull switch assembly away from front panel and remove from the instrument.

5-54. INPUT SELECTOR-BIAS CHECK.

- Loosen setscrew(s) in knob(s) and remove knob(s) from shaft.
- Loosen and remove shaft nut from front panel side of the instrument.
- Remove screws from side casting which hold the switch mounting bracket at the back end of the INPUT SELECTOR-BIAS CHECK and the EXPAND-RANGE assemblies.
- Remove the two nuts holding the INPUT SELECTOR-BIAS CHECK assembly to the bracket.

e. Unsolder connecting wires. Mark each to indicate which lugs to resolder wires to. See figure 5-6 for wire colors and connections.

f. Pull switch assembly away from front panel and remove from the instrument.

5-55. EXPAND-RANGE.

- Loosen setscrews in knobs and remove knobs from shaft.
- Loosen and remove shaft nut from front panel side of the instrument.
- Remove screws from side casting which hold (1) the mounting bracket at the back end of the INPUT SELECTOR-BIAS CHECK and the EXPAND-RANGE assemblies and (2) the metal cross member on which the input transformer T101 is mounted. Use care to avoid damage to leads from T101.
- Remove the two nuts holding EXPAND-RANGE assembly to the bracket.
- Unsolder connecting wires. Mark each to indicate which lugs to resolder wires to. See figure 5-7 for wire colors and connections.
- Pull switch assembly away from front panel and remove from the instrument.

5-56. CHECK FOLLOWING REPLACEMENT.

5-57. Because of the slight variations in electronic components, some adjustment and calibration may be required after replacement. Table 5-4 specifies the paragraphs and procedures to follow after making the change listed.

Table 5-4. Checks Following Replacement

Change Made	Action Required
Q101 through Q110	Follow paragraphs 5-74 and 5-83
Q108, CR101, CR102, L102	Follow paragraphs 5-74, 5-76, 5-78, 5-83 and 5-94
Q111, (or any Q111 circuit components) M101	Follow paragraphs 5-68
Q1 through Q5; CR6 through CR11	Follow paragraphs 5-22, 5-66, 5-68, 5-76, 5-78 and 5-94
Regulated voltage changed	Follow paragraphs 5-68, 5-76, 5-78 and 5-94

5-58. TUNED AMPLIFIER MODIFICATION.

5-59. The center frequency of the Model 415C tuned amplifier may be set at any frequency between 400 and 2500 cps by changing inductor, L101 and capacitor, C123. L101 is available according to the information

in table 5-5. The value of C123 for any frequency may be calculated from the equation for resonance (high Q circuit), i.e. where capacitive reactance equals inductive reactance. The basic equation is:

$$(2\pi f)^2 = \frac{1}{LC_T} \quad (1)$$

where f = desired center frequency for tuned amplifier

L = inductance of coil = 4.65 henrys

$$C_T = C_i + C_f$$

and C_T = total capacitance of resonant circuit

C_i = (geometric mean value of C124) + (stray capacitance)

= 680 picofarads + 70 picofarads

= 750 picofarads

C_f = fixed capacitance needed for C123

Substituting these values in equation (1) and solving for C_f in picofarads (i.e. 10^{-12} farads) gives:

$$C_f = \frac{5.43 \times 10^9}{f^2} - 750 \quad \text{picofarads} \quad (2)$$

Table 5-5. Inductors Available

Tuned Amplifier Frequency	Ⓜ Stock Number
400 to 650 cps	9110-0045
650 to 950 cps	9110-0046
950 to 1500 cps	9110-0044
1500 to 2500 cps	9110-0047

5-60. The procedure and full information for making the tuned amplifier center frequency modification are available in the Ⓜ Service Note 415C-2. When the value for C123 is calculated using equation (2), a capacitor should be chosen which is a dipped mica type with a low temperature coefficient such as E or F. If the center frequency is changed above 1000 cps, then C124 will allow more than the 5% variation in frequency. Conversely, C124 will have less effect on a center frequency below 1000 cps. When the modification is completed, follow paragraph 5-70 to tune the exact center frequency. C124 should be approximately mechanically centered when the new center frequency is set. If it is nearer the clockwise extreme, C123 should be a slightly lower value; if nearer counterclockwise extreme, increase C123 slightly. If C123 is changed from the value used first, repeat the procedure of paragraph 5-70. After changing L101 and/or C123, recheck the Model 415C sensitivity (see paragraph 5-83).

5-61. CALIBRATION AND ADJUSTMENT.

5-62. GENERAL.

5-63. The following procedures outline the adjustments necessary to calibrate the Model 415C. The actual adjustments should be made only when it is determined that the instrument is not operating properly. To determine proper performance, see paragraph 5-80. If the instrument fails to meet any of the given limits or indications below or in paragraph 5-80, refer to the troubleshooting paragraph 5-13 for possible causes and corrective action. This procedure is sequential to some extent. The power supply voltage should be set before any attempt is made to adjust the amplifier or bias circuits. Also check the mechanical adjustment of the meter pointer (paragraph 5-64) before checking any indication on the Model 415C meter. See figures 5-11 and 5-12 to help locate parts.

Note

To avoid errors due to possible groundloop currents either isolate the Model 415C from the ground used for other measuring instruments or else use an adapter to unground all instruments except the Model 415C.

5-64. METER POINTER ADJUSTMENT.

5-65. When the meter is properly set, the pointer rests over the calibration mark (i.e. 2.5 on the 0 to 2.5 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 the meter pointer adjustment is changed, EXPAND tracking (paragraph 5-94) must be checked and adjusted if necessary according to paragraph 5-76.

a. Turn instrument off.

b. Rotate mechanical zero-adjustment screw clockwise until the meter pointer is to the left of 2.5 (on the 0 to 2.5 DB scale) and moving to the right toward 2.5.

c. Continue to rotate adjustment screw clockwise; stop when the pointer is exactly on 2.5. If the pointer overshoots 2.5, repeat steps b and c.

d. When the pointer is exactly on 2.5, 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.

5-66. POWER SUPPLY ADJUST.

5-67. The following procedures set the correct regulated voltage. A check on the power supply regulation is outlined in paragraph 5-22.

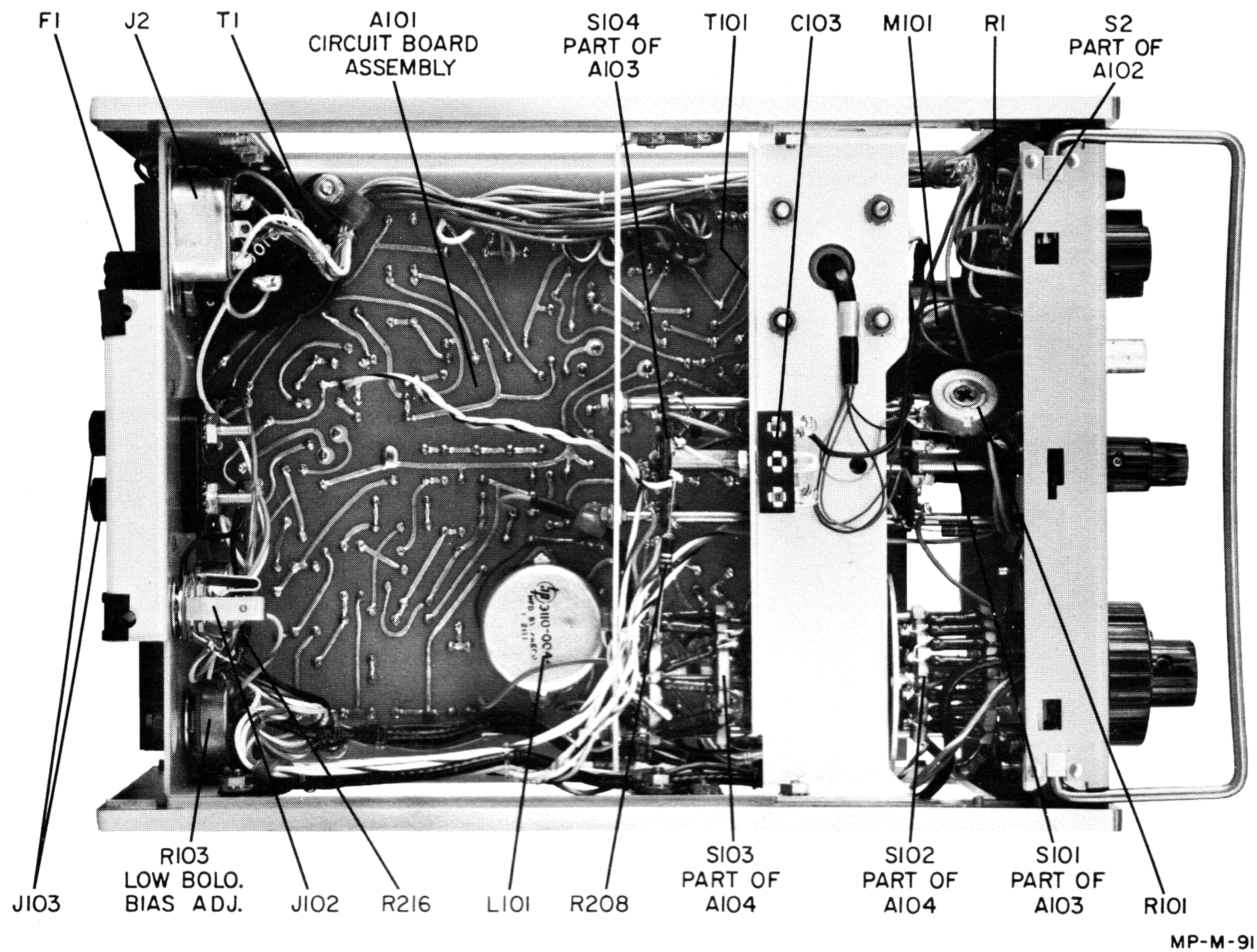


Figure 5-11. Model 415C Bottom View

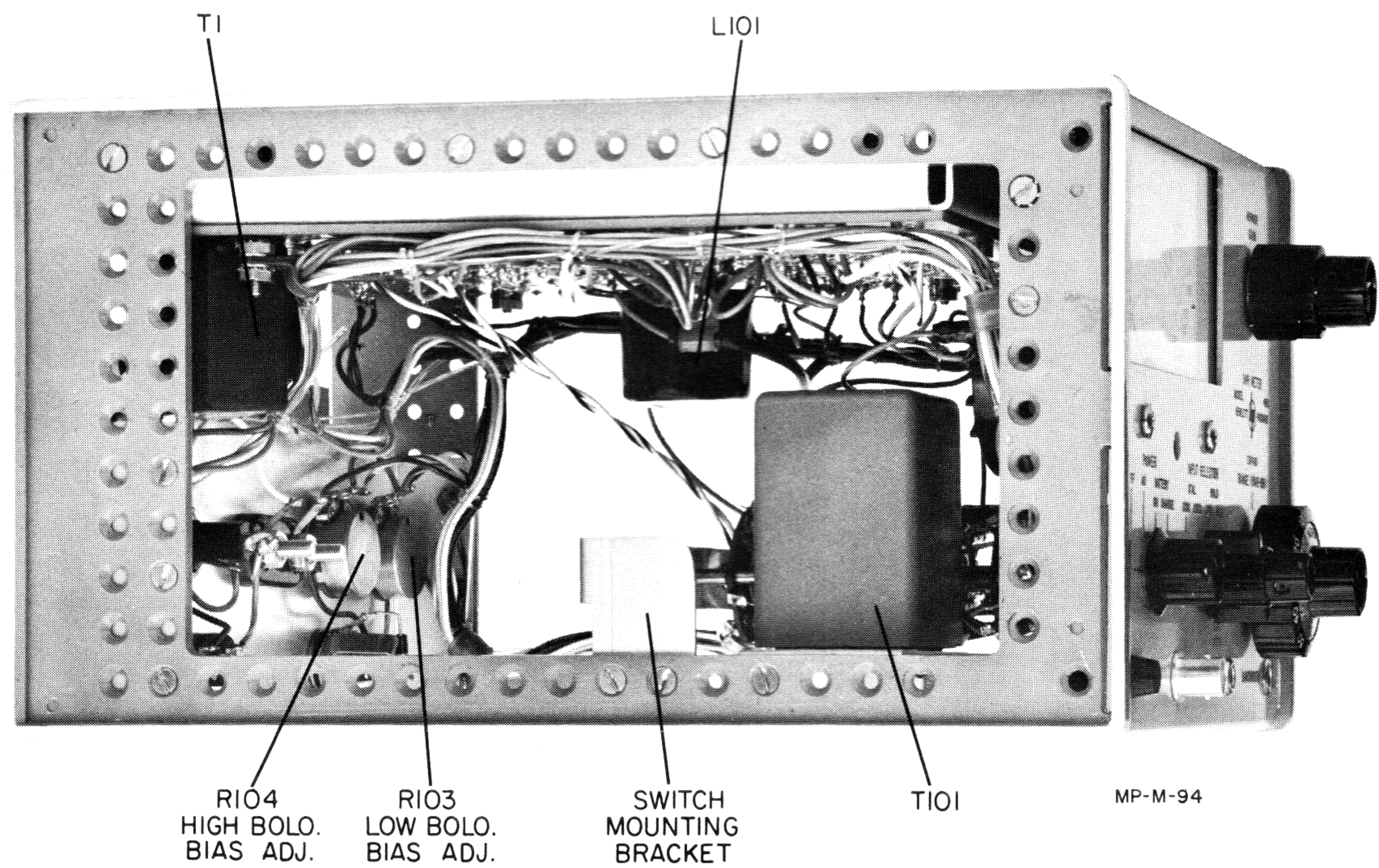


Figure 5-12. Model 415C Left Side View

- a. Remove top cover from the instrument.
- b. Provide power from 115-volt ac (or 230 volts ac, if available and paragraph 2-7 is followed) or from the Model 415C battery source.
- c. Set Model 415C POWER switch to AC (or BATTERY ON).
- d. Connect the dc voltmeter to the -18 volt point (marked on the etched circuit board) and circuit ground.
- e. Adjust R21 until the voltmeter indicates -18.0 volts. This power supply regulated voltage should remain the same if the Model 415C is now operated from any of the three power sources mentioned in step b.

5-68. BOLO BIAS METER ADJUST.

5-69. This adjustment will set the HIGH and LOW bolometer bias and the Model 415C meter so a direct reading is obtained for both values.

- a. Remove top and bottom covers from Model 415C.
- b. Connect a 200-ohm, 1% test resistor to the INPUT connector. One lead of the resistor goes to the center conductor, the other to the outside rim. A BNC connector with a short coaxial lead may be used and the resistor connected between the center conductor and the outer shield. A stock item, AC-76A BNC-to-Binding-Post Adapter, is available for connecting any test input or signal source input from a lead not of the BNC type.
- c. Set Model 415C INPUT SELECTOR to BOLO HIGH position and POWER switch to AC position (or BATTERY ON).
- d. Connect dc voltmeter from pin 47 (base of Q111) on the etched circuit board to circuit ground. Adjust R104 (High Bolo Bias Adjust) to indicate 3.45 volts on the voltmeter.
- e. Connect dc voltmeter across the input test resistor.
- f. Hold BIAS CHECK knob in a clockwise position and adjust R101 (Meter Bias Current Calibration located on switch S101) for an indication of 8.7 ma on the Model 415C Bolo Bias scale.
- g. Note the voltage across the test resistor and set R104 to give a voltage halfway between this value and the final value of 1.74 volts.
- h. Repeat step f. This should result in a bias current of 8.7 ma on the Model 415C meter and a voltage of 1.74 volts across the test resistor. Since R101 and R104 interact, repeat steps f and g if necessary, to obtain these values.
- i. Set INPUT SELECTOR switch to BOLO LOW position.

- j. Hold BIAS CHECK knob clockwise and adjust R103 (Low Bolo Bias Adjust) for 4.3 ma on the Model 415C Bolo Bias scale.

5-70. CENTER FREQUENCY ADJUST.

5-71. This procedure will set the Model 415C tuned amplifier to the center frequency point. See paragraph 5-58 for the procedure to change the center frequency.

- a. Connect test equipment as shown in figure 5-1, omitting both attenuators (see paragraph 5-5) and the ac voltmeter.
- b. Set Model 415C POWER switch to AC (or BATTERY ON) position, INPUT SELECTOR switch to 200Ω position, EXPAND switch to NORM position, GAIN and VERNIER controls at mid-point, and RANGE switch to 0 position.

c. Monitor oscillator frequency with counter and set oscillator to desired center frequency of Model 415C amplifier.

d. Adjust oscillator output and/or Model 415C GAIN and VERNIER controls for an on-scale reading of the Model 415C meter.

e. Adjust C124 to peak (needle maximum to right) the Model 415C meter. This sets the tuned amplifier to the Model 415C center frequency. A fine adjustment may be made by changing the EXPAND switch to a setting other than NORM, and re-peaking the meter with C124.

5-72. BANDWIDTH ADJUST.

5-73. The Model 415C is initially shipped with the bandwidth of the tuned amplifier set to 30 cps. The BANDWIDTH control allows a variation of at least 15 cps to 100 cps as checked in paragraph 5-89. If a particular bandwidth is desired, the following procedure and figure 5-13 should be used. Figure 5-13 is a curve resulting from plotting the Bandwidth against the number of db, observed on the Model 415C meter, from a reference set when the BANDWIDTH control is at minimum, i.e. fully counterclockwise.

- a. Connect the test equipment as shown in figure 5-1, omitting both attenuators (see paragraph 5-5) and the ac voltmeter.
- b. Set the Model 415C POWER switch to AC (or BATTERY ON), INPUT SELECTOR to 200Ω, EXPAND switch to NORM, RANGE switch to 0, GAIN and VERNIER controls at mid-point, and BANDWIDTH adjustment fully counterclockwise.
- c. Monitor oscillator frequency with the counter and tune the oscillator to the Model 415C center frequency. Adjust the oscillator output and/or Model 415C GAIN control for a 0 db reference on the meter.
- d. Rotate the BANDWIDTH adjustment until the Model 415C meter indicates the number of db (on the 0 to 10 DB scale) obtained from figure 5-13 for the desired bandwidth.

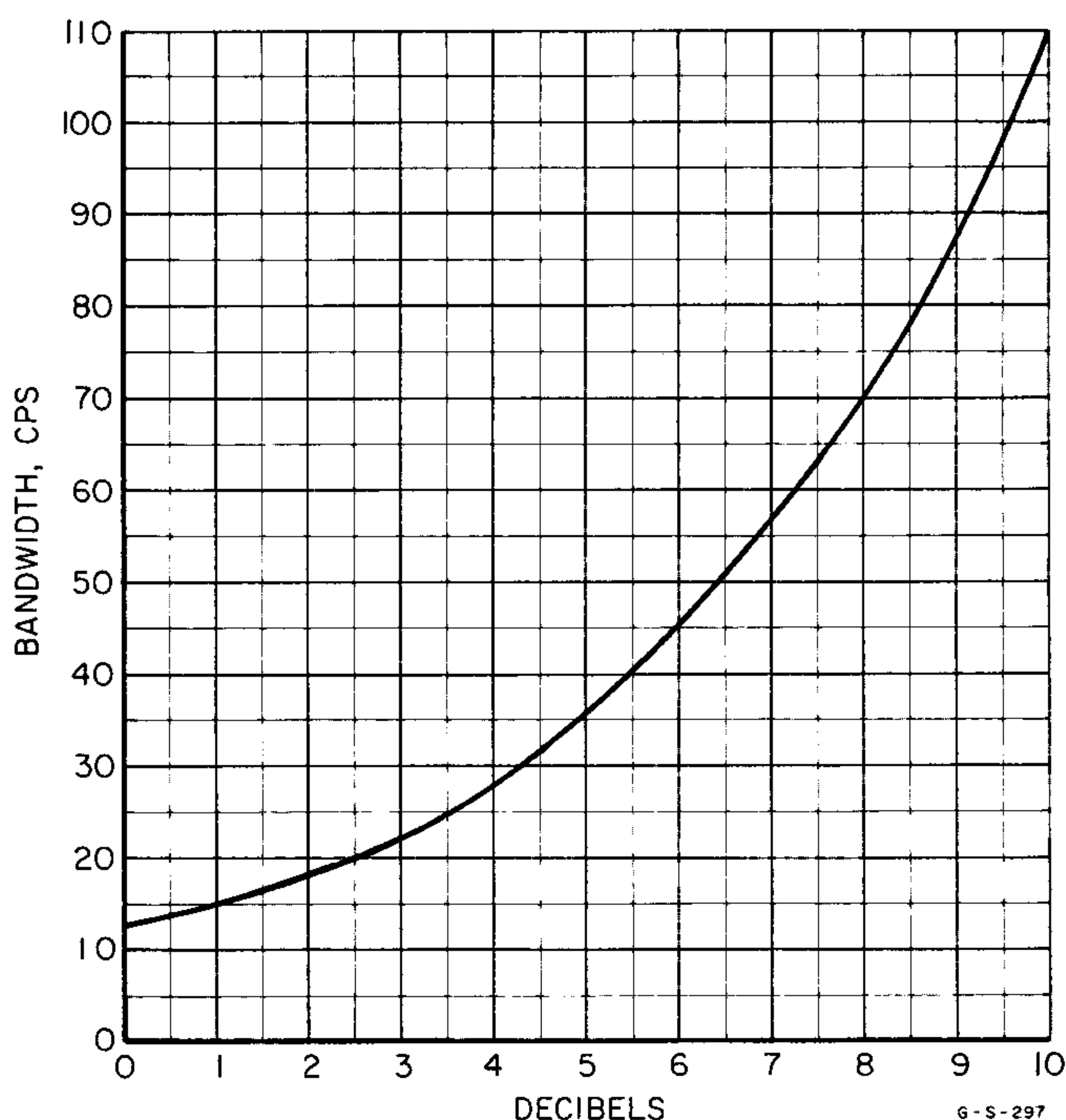


Figure 5-13. Graph to Set Model 415C Bandwidth

e. Change the EXPAND switch to 0.0. Using the Model 415C GAIN and VERNIER controls, set a reference of 0 on the 0 to 2.5 DB scale.

f. Change the oscillator frequency above the Model 415C center frequency until the meter indicates 1.5 db on the 0 to 2.5 DB scale. Note the frequency on the counter.

g. Decrease the oscillator frequency below the Model 415C center frequency until the meter indicates 1.5 db on the 0 to 2.5 DB scale. Note the frequency on the counter.

h. Calculate the difference between the frequencies noted in steps f and g. The difference should be equal to the desired bandwidth. If not the desired bandwidth, change the BANDWIDTH adjustment a small amount and repeat steps e through h until the desired setting is obtained.

5-74. SENSITIVITY ADJUST.

5-75. The sensitivity of the Model 415C is given in the table 1-1 and this may be checked in paragraph 5-83. The component which is adjusted for correct sensitivity is R138 in the emitter circuit of Q104. R138 may require changing if Q104 or any component in the tuned amplifier circuit is replaced. The sensitivity should be checked when any of the amplifier transistors are replaced.

a. Perform steps a through e of paragraph 5-83.

b. If the ac voltmeter does not indicate the value specified, R138 may be replaced by a resistor of a different value. A resistor substitution box is useful

for determining the value for R138 but individual resistors of various values may be used.

5-76. EXPAND SCALE CALIBRATION.

5-77. This procedure calibrates the Model 415C meter scale for EXPAND operation. Extreme accuracy is required for all measurements and adjustments in this procedure.

a. Remove the top cover from the Model 415C.

b. Connect test equipment as in figure 5-1, omitting the ac voltmeter and one attenuator (see paragraph 5-5).

c. Set Model 415C INPUT SELECTOR to 200Ω, RANGE switch to 20, EXPAND switch to 0.0, GAIN and VERNIER controls fully counterclockwise, and POWER switch to AC (or BATTERY ON).

d. Set attenuator to 40 db position.

e. Tune oscillator for peak on Model 415C meter and adjust the output and/or Model 415C VERNIER for 0.00 db reference on the meter.

f. Change attenuator to 45 db position. The Model 415C meter should read 2.50 db on the 0 to 2.5 DB scale.

g. If reading of step f is incorrect, adjust R189, 2.5 db Calibration, to move the needle a distance equal to the error, opposite side of the 2.5 db point on the scale.

h. A slight interaction occurs between the VERNIER setting for 0.00 db and the adjustment of R189. Repeat steps d through g until 0.00 and 2.50 db are repeatable with insertion and removal of the additional 5 db on the attenuator.

5-78. EXPAND-NORMAL ADJUST.

5-79. The amplifier circuit is changed when using an EXPAND switch setting other than NORM, and the gain change requires a different feedback circuit. R208 is in a feedback loop from the meter circuit to Q108 when the EXPAND switch is in the NORM position, and R208 is removed by S103D for any other EXPAND setting. R208 may require a different value if any component is replaced in the circuit of Q108, or in the meter diode circuit.

a. Perform steps a through e of paragraph 5-76.

b. Change the EXPAND switch to NORM position. The Model 415C meter should indicate 0 ± 0.02 db. If not, change R208 to a different 5% tolerance resistor and repeat the check. The minimum value for R208 is 100KΩ. A resistor substitution box or assorted values of fixed resistors will be necessary to determine R208 accurately by changing values.

5-80. PERFORMANCE VERIFICATION.**5-81. GENERAL.**

5-82. The following procedure is to verify proper operation of the Model 415C and to check the specifications listed in table 1-1. These checks may be completed without removing any of the instrument covers and are recommended for routine maintenance checks, after repair or replacement, after any circuit adjustment, or as an incoming quality control inspection. If the instrument fails to meet any of the specifications, refer to paragraph 5-13 for troubleshooting suggestions or paragraph 5-61 for adjustment procedures. The instruments required and their accuracy are given in paragraphs 5-3 through 5-8 and table 5-1. See paragraph 3-12 for information on errors due to possible groundloop currents.

Note

The Model 415C is calibrated for use with square wave detectors such as crystals and bolometers. The output voltage of such detectors varies directly with input power. In any of the procedures and checks in section V where the input is controlled by an external attenuator calibrated in decibels, the Model 415C meter will indicate 1 db change for each 2 db inserted in the input. A 10-db change in the Model 415C RANGE switch corresponds to a 20-db change in the input source attenuator.

5-83. SENSITIVITY.

5-84. The specification of 0.1 microvolt rms is given for 30 cps bandwidth and a temperature of 25° to 55°C. Refer to paragraph 5-72 to determine if the bandwidth is 30 cps.

a. Connect test equipment as in figure 5-1, omitting one attenuator (see paragraph 5-5) from the setup.

b. Set the Model 415C EXPAND switch to NORM, RANGE switch to 0, INPUT SELECTOR to 200Ω, POWER switch to AC (or BATTERY ON), GAIN and VERNIER controls fully clockwise.

c. Set attenuator to 20 db position.

d. Tune the oscillator frequency for a peak on the Model 415D meter, then adjust the output for 0 db reference on the meter.

e. The ac voltmeter should indicate 0.1 volt or less. With the RANGE attenuation (120 db) between the INPUT connector and the output of the amplifier, this voltmeter reading corresponds to a sensitivity of 0.1 μvolt rms. If the indication is in error, refer to paragraph 5-74 for the adjustment procedure.

5-85. NOISE.

5-86. The specification of 5 db below full scale is for 0.1 μvolt sensitivity and a 30 cps bandwidth. Refer to paragraph 5-83 to verify the sensitivity specification before checking the noise.

a. Connect test equipment as in figure 5-1, omitting one attenuator (see paragraph 5-5) from the setup.

b. Set the Model 415C EXPAND switch to NORM, RANGE switch to 0, INPUT SELECTOR to 200Ω, POWER switch to AC (or BATTERY ON), GAIN and VERNIER controls fully clockwise.

c. Set attenuator to 20 db position.

d. Tune the oscillator frequency for a peak indication on the Model 415C meter, then adjust the output for 0 db reference on the meter.

e. Remove the signal from the INPUT connector.

f. Set RANGE switch to 60, and note the average noise level indicated by the meter pointer. It should be at least 5 db down from 0 on the 0 to 10 DB scale.

g. Set the INPUT SELECTOR switch to the 200KΩ position. The average noise level should again be 5 db down.

5-87. FREQUENCY.

5-88. The specification is given for a center frequency of 1000 cps for the tuned amplifier. Other frequencies are available from 400 to 2500 cps and for information on this, see paragraph 5-58.

a. Connect test equipment as shown in figure 5-1, omitting both attenuators (see paragraph 5-5) and the ac voltmeter from the setup.

b. Set the Model 415C POWER switch to AC (or BATTERY ON), INPUT SELECTOR to 200Ω, EXPAND switch to NORM, GAIN and VERNIER fully clockwise.

c. Monitor the oscillator frequency with the counter.

d. Turn the Model 415C FREQ control (C124) maximum clockwise.

e. Tune the oscillator frequency to peak the Model 415C meter (needle to right). Record the frequency from the counter. The frequency should be above 1000 cps.

f. Turn the FREQ control maximum counterclockwise.

g. Tune the oscillator frequency to peak the Model 415C meter. Record the frequency from the counter. The frequency should be below 1000 cps.

h. The difference between the frequencies recorded in steps e and g must be at least 50 cps (5%) and 1000 cps must lie between the two frequencies.

5-89. BANDWIDTH.

5-90. The specification for Bandwidth is that it is variable, 15 cps to 100 cps. Paragraph 5-72 gives the procedure for setting a desired bandwidth with R145. The center frequency should be set to 1000 cps (see paragraph 5-70).

a. Connect test equipment as shown in figure 5-1, omitting both attenuators (see paragraph 5-5) and the ac voltmeter.

b. Set Model 415C POWER switch to AC (or BATTERY ON), INPUT SELECTOR to 200 Ω , EXPAND switch to NORM, RANGE switch to 20, GAIN and VERNIER controls fully clockwise, and turn BANDWIDTH control fully counterclockwise.

c. Monitor the oscillator frequency with the counter and tune the oscillator to the Model 415C center frequency. Adjust the Model 415C GAIN control for 0 db reference on the meter.

d. Change the oscillator frequency above 1000 cps until the Model 415C meter indicates 1.5 db on the 0 to 10 DB scale. Note the frequency on the counter.

e. Decrease the oscillator frequency below 1000 cps until the Model 415C meter indicates 1.5 db on the 0 to 10 DB scale. Note the frequency on the counter.

f. Calculate the difference between the frequencies noted in steps d and e. The difference is the minimum bandwidth of the Model 415C and it should be 15 cps or less.

g. Adjust the Model 415C BANDWIDTH control fully clockwise.

h. Tune the oscillator frequency for maximum Model 415C meter deflection and then use the Model 415C GAIN control to set a 0 db reference.

i. Increase the oscillator frequency above 1000 cps until the Model 415C meter indicates 1.5 db on the 0 to 10 DB scale. Note the frequency on the counter.

j. Decrease the oscillator frequency below 1000 cps until the Model 415C meter indicates 1.5 db on the 0 to 10 DB scale. Note the frequency on the counter.

k. Calculate the difference between the frequencies noted in steps i and j. The difference is the maximum bandwidth of the Model 415C and it should be 100 cps or more.

5-91. TRACKING ACCURACY.

5-92. The tracking accuracy specification may be checked by following the procedure below. Maximum

cumulative error of 0.2 db is the largest error difference between any two positions of the RANGE switch.

Note

If ground loop currents are present the Model 415C will not track properly. See paragraph 3-12 for information about avoiding ground-loop current problems.

5-93. RANGE TRACKING.

a. Connect test equipment as shown in figure 5-1, omitting the ac voltmeter (see paragraph 5-5).

b. Set the Model 415C POWER switch to AC (or BATTERY ON), RANGE switch to 0, EXPAND switch to 0.0, INPUT SELECTOR to 200 Ω , GAIN control fully counterclockwise.

c. With attenuators set to 0 db (see paragraph 5-5), adjust the oscillator output and/or the Model 415C VERNIER for 1.00 db on the 0 to 2.5 DB scale.

d. Switch one attenuator by 20 db and the Model 415C RANGE switch to 10. Record the reading of the Model 415C on the 0 to 2.5 DB scale.

e. Continue switching the same attenuator in 20-db increments and increasing the Model 415C RANGE switch by 10 each time until the attenuator indicates 60 db above initial setting and the RANGE switch is set to 30. Record the reading of the Model 415C on the 0 to 2.5 DB scale at each RANGE position.

f. Begin switching the second attenuator in 20-db increments and the Model 415C RANGE switch in corresponding steps of 10. Record the reading of the Model 415C on the 0 to 2.5 DB scale at each RANGE position until both attenuators and the Model 415C RANGE switch are on the "60" position.

g. Subtract each Model 415C meter reading from the previous reading. This tracking error should be within the specification of ± 0.1 db or less for any two successive steps. The largest difference between any two readings should be 0.2 db (maximum cumulative).

5-94. EXPAND TRACKING.

a. Connect test equipment as shown in figure 5-1 omitting one attenuator (see paragraph 5-5) and the ac voltmeter.

b. Set the Model 415C POWER switch to AC (or BATTERY ON), INPUT SELECTOR to 200 Ω , RANGE switch to 0, EXPAND switch to 0.0, and GAIN control fully counterclockwise.

c. Adjust the oscillator output and/or VERNIER control for 0 db reference on the Model 415C meter.

Table 5-6. EXPAND Tracking Error

Model 350B	Model 415C
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
5 db	2.5 ± 0.02 db

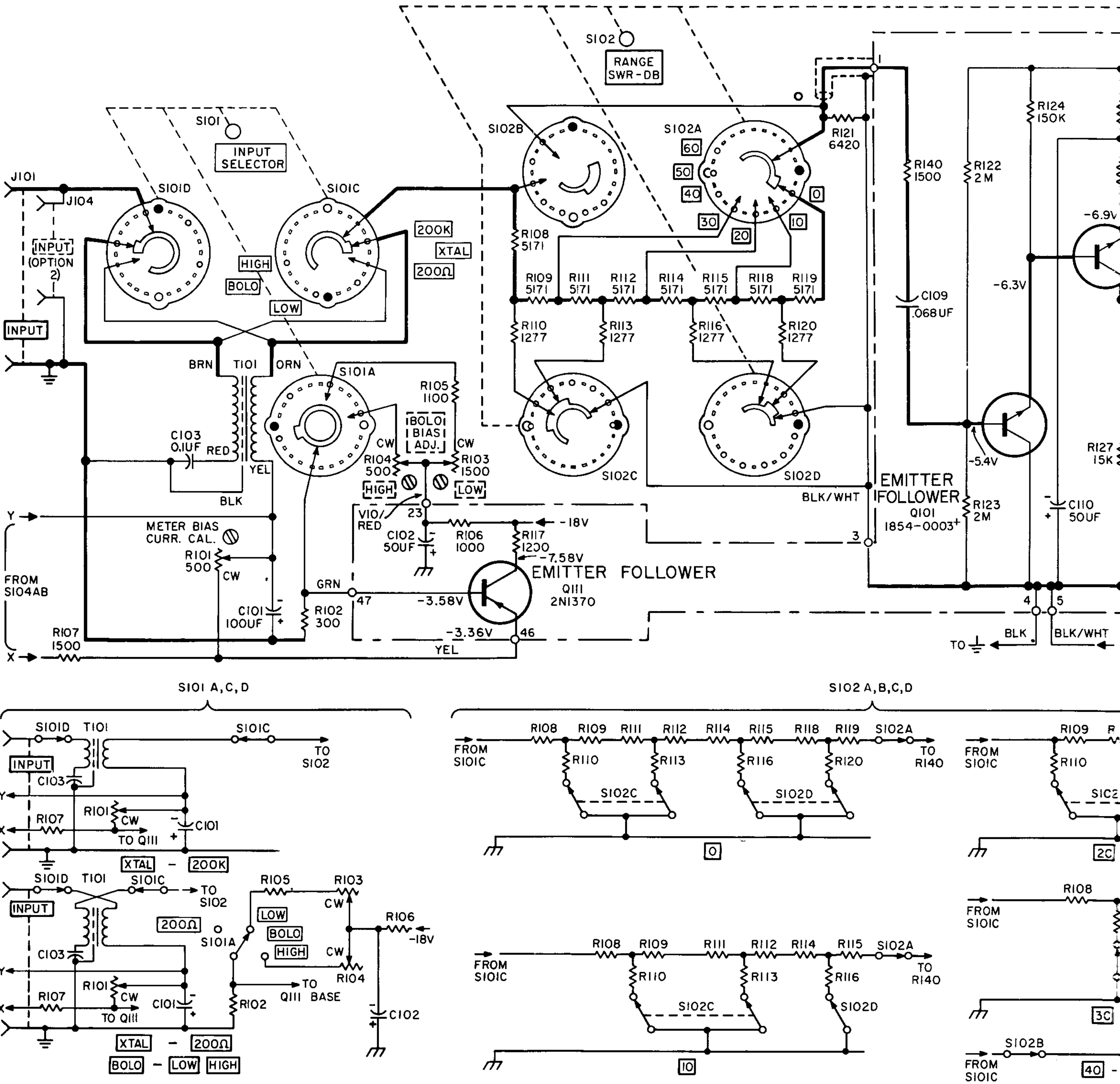
d. Switch the attenuator from 0 to 5 db in 1-db steps. The Model 415C meter reading should be as given in table 5-6.

e. Change EXPAND to 2.5. The Model 415C should indicate 0 db ± 0.1 db on the 0 to 2.5 DB scale.

f. Change EXPAND to 5.0 and attenuator to 10 db. The Model 415C should indicate 0 db ± 0.1 db.

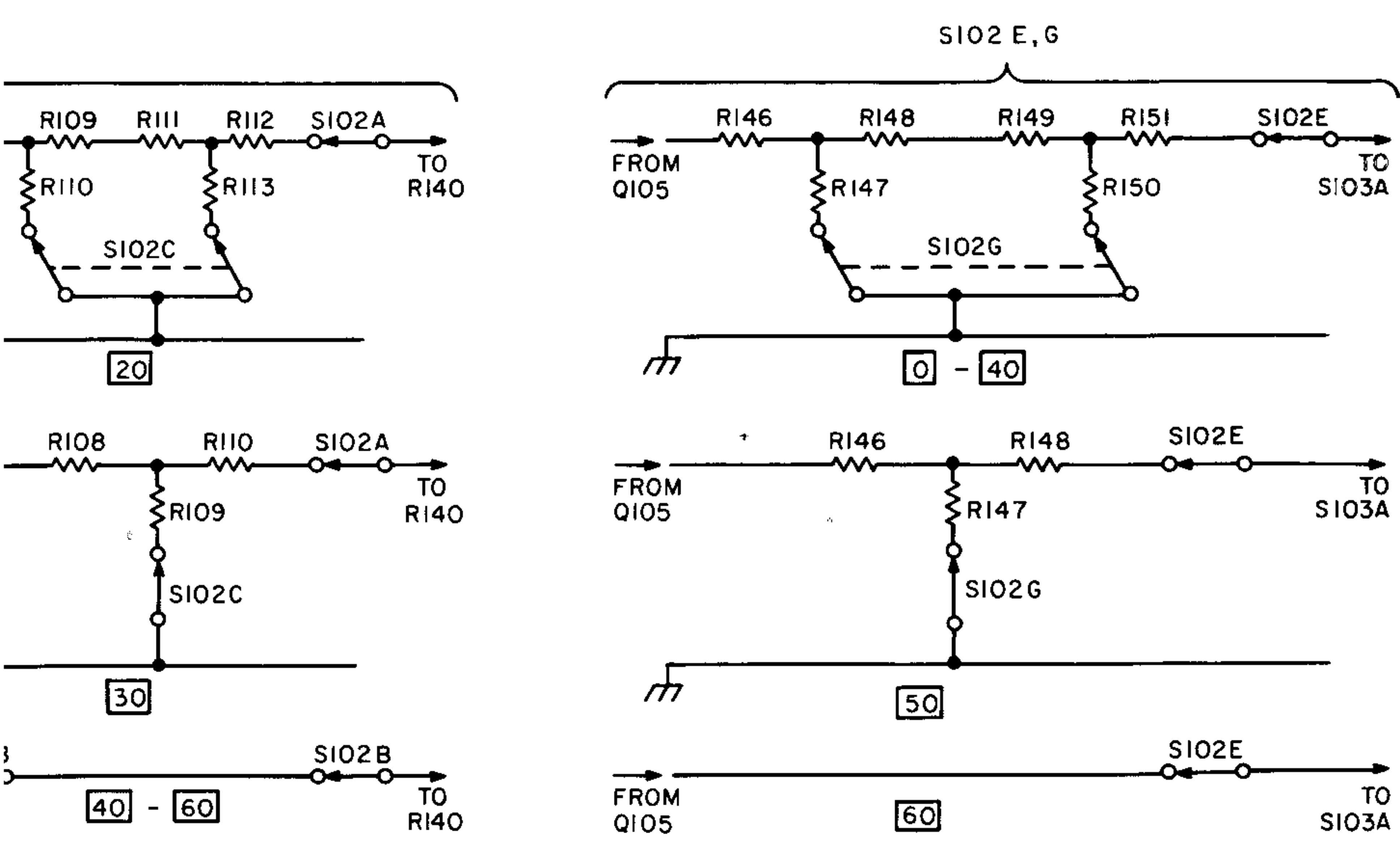
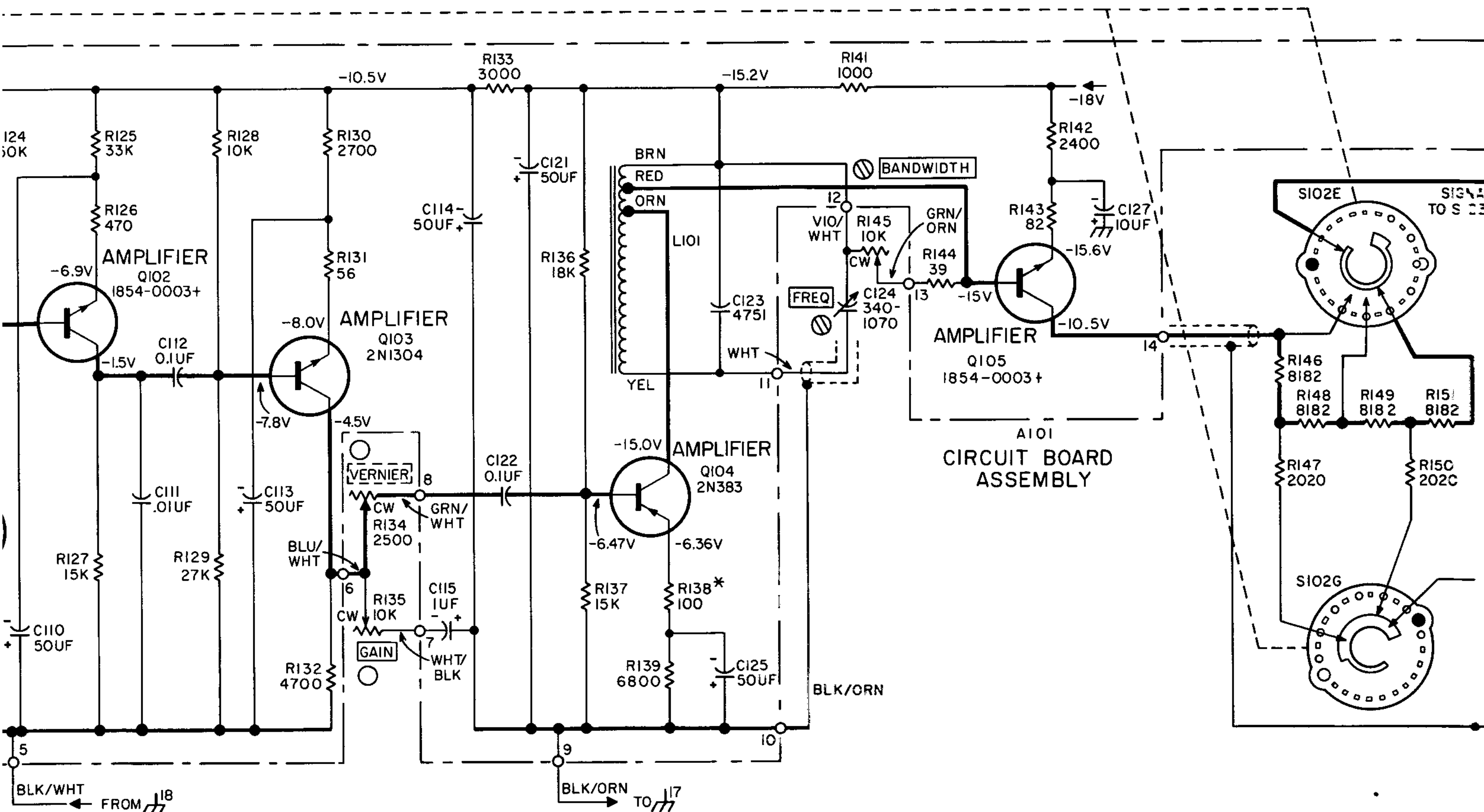
g. Change EXPAND to 7.5 and attenuator to 15 db. The Model 415C should indicate 0 db ± 0.1 db.

h. Change EXPAND to NORM and attenuator to 0. The Model 415C should indicate 0 db ± 0.05 db.



SIMPLIFIED SWITCHING DIAGRAMS

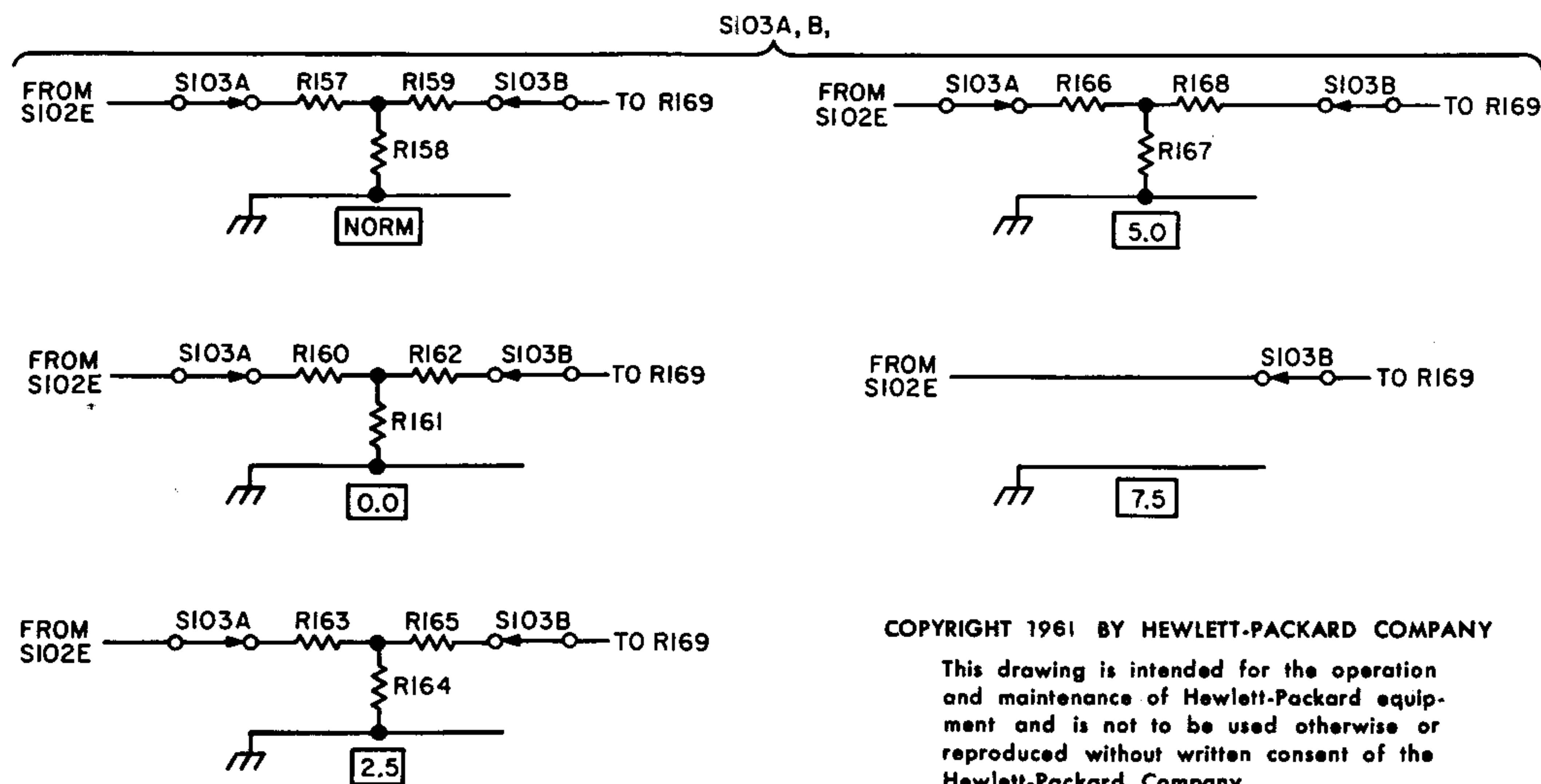
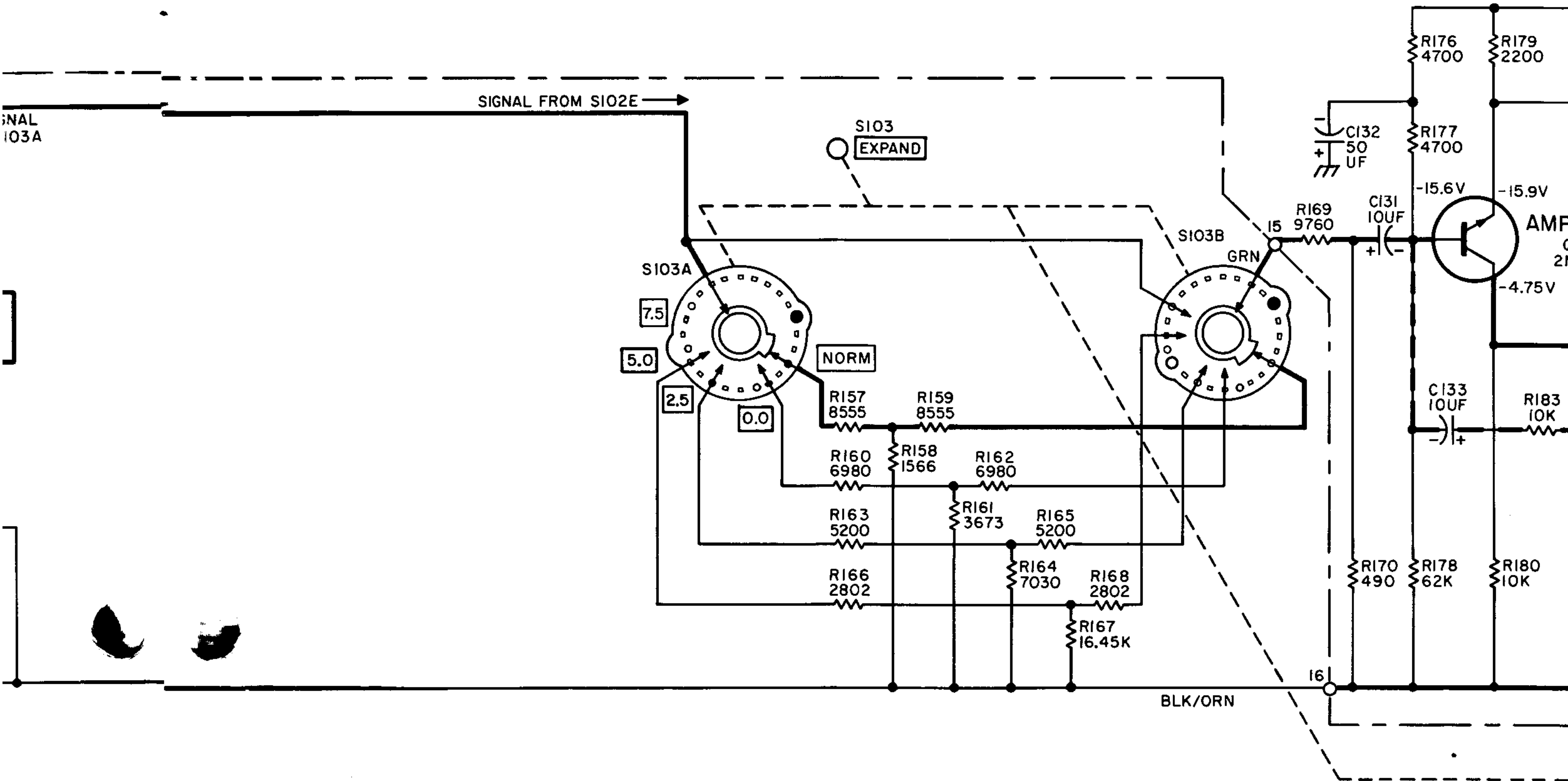
Figure 5-14. Standing Wave Ratio Meter
(Sheet 1 of 2)



- A 101
- C 101-103, 109-115, 121-125, 127
- L 101
- Q 101-105, 111
- R 101-140, 141-151
- S 101, 102
- T 101
- J 101, J104

UNASSIGNED:
C 104-108, 116-120, 126, 128-130
R 152-156

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4-5C-SWR METER-218A

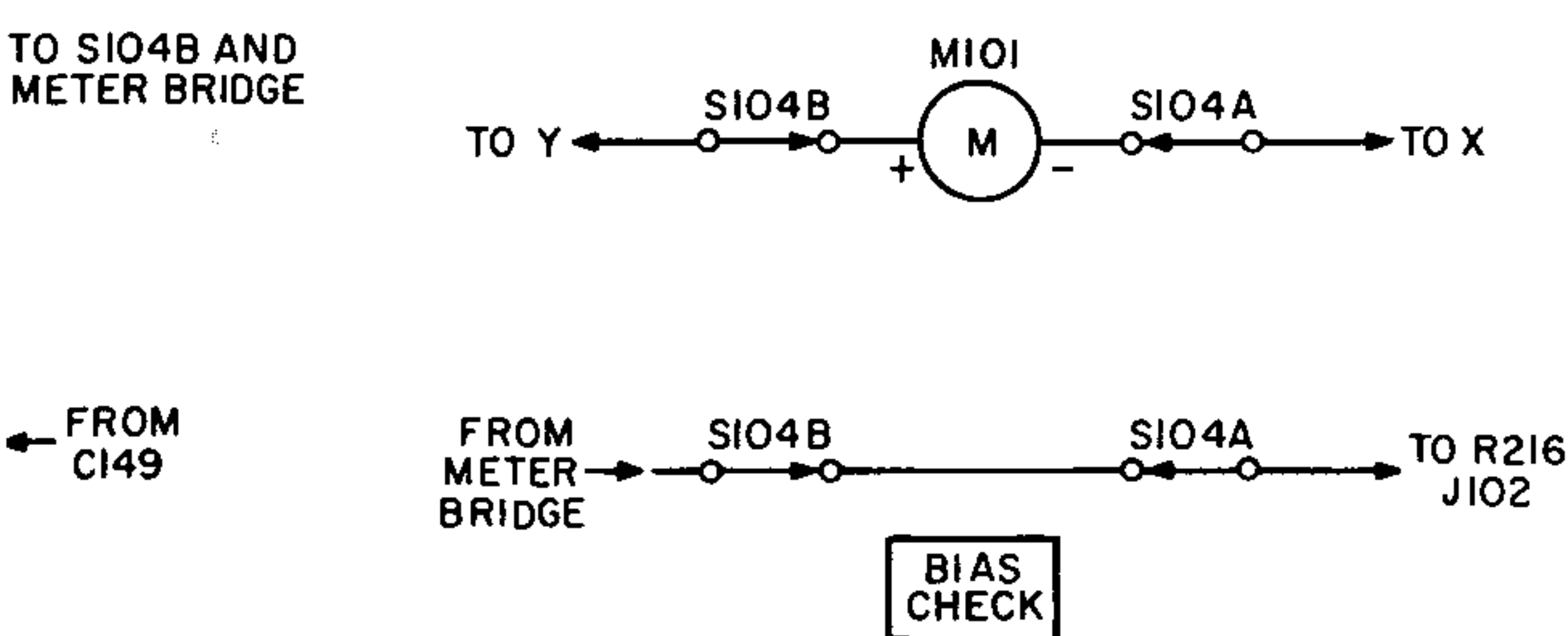
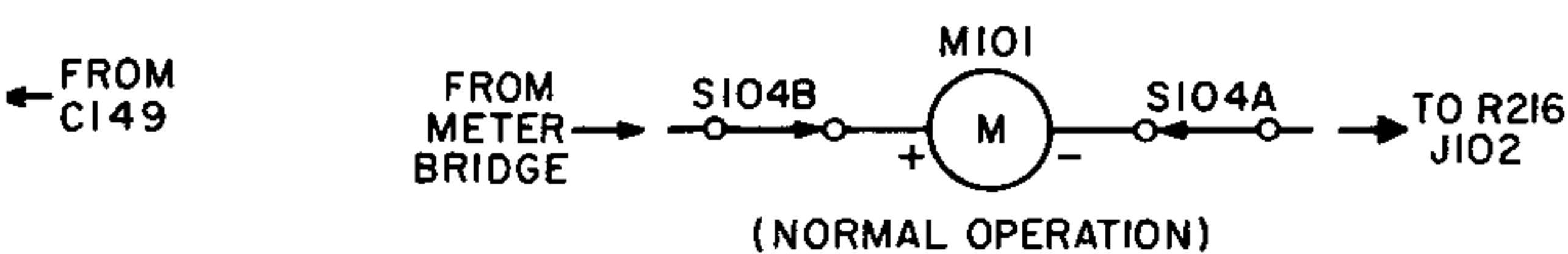
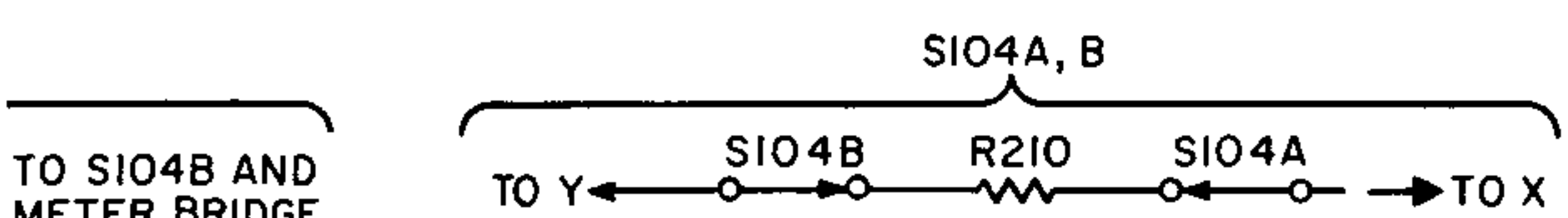
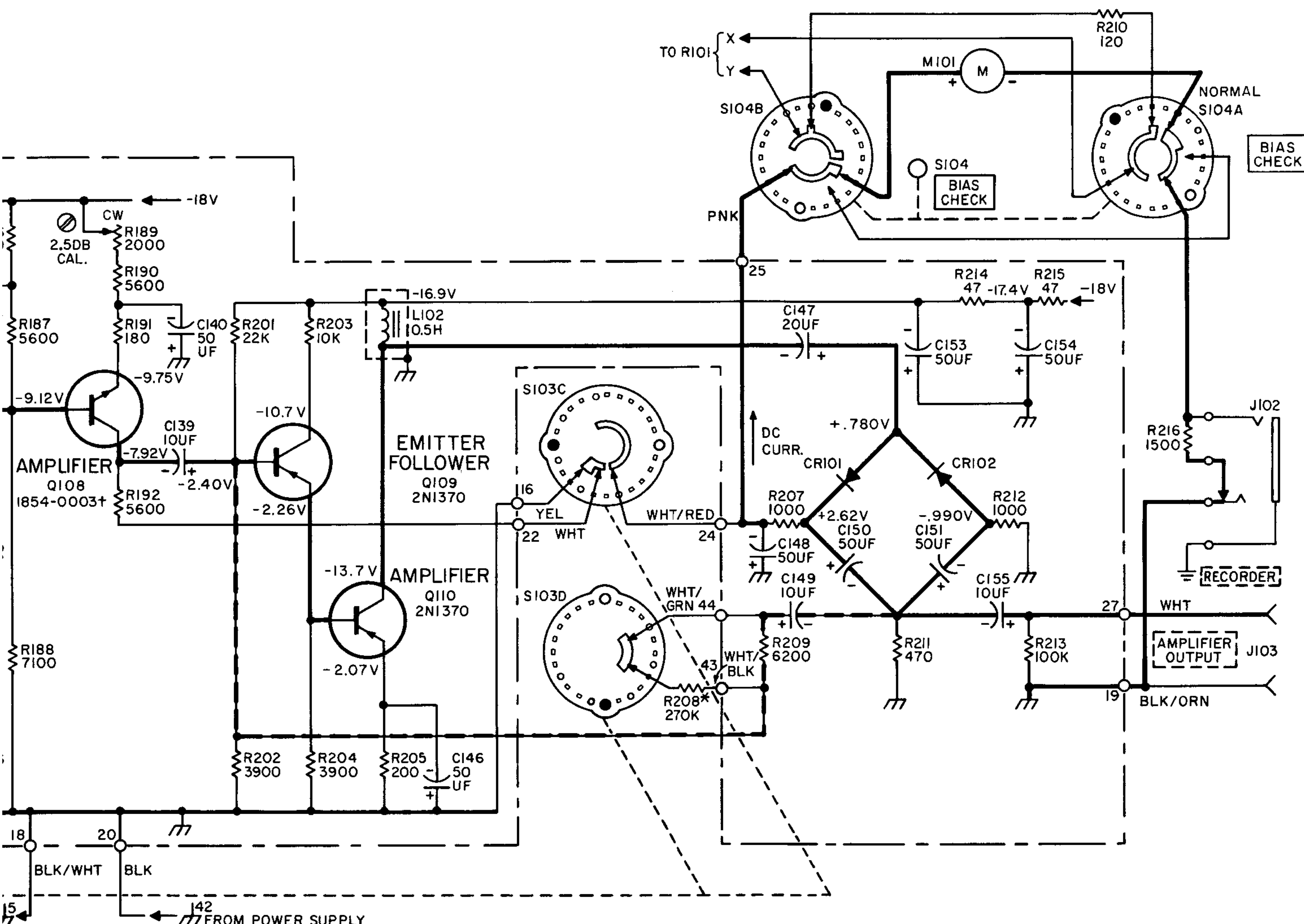


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415C-SWR METER- 218A

SIMPLIFIED



NOTES

- ALL SWITCHES SHOWN FULLY COUNTER CLOCKWISE, DRAWN AS VIEWED FROM FRONT PANEL. SOLID DOTS ON SWITCH WAFERS INDICATE REFERENCE POINTS. WAFERS ARE IDENTIFIED BY LETTERS STARTING WITH THE WAFER NEAREST THE FRONT PANEL (A= FRONT SIDE OF FIRST WAFER, B= REAR SIDE OF FIRST WAFER, ETC.)
- ALL RESISTANCES IN OHMS UNLESS OTHERWISE NOTED.
- --- = COMMON FLOATING GROUND.
 - --- = CABINET GROUND.
 - + = SELECTED PART, SEE PARTS LIST FOR DESCRIPTION.
 - * = AVERAGE VALUE SHOWN, OPTIMUM VALUE SELECTED AT FACTORY.
- DC VOLTAGES TAKEN WITH FULL SCALE METER DEFLECTION, INPUT SELECTOR ON CRYSTAL 200K, ELECTRONIC VOLTMETER HAVING AT LEAST 10MEGΩ INPUT RESISTANCE. VOLTAGES AT Q110 ONLY TAKEN WITH INPUT SELECTOR ON HIGH BOLO, 200Ω LOAD ACROSS J101. VOLTAGES REFERENCED TO --- .

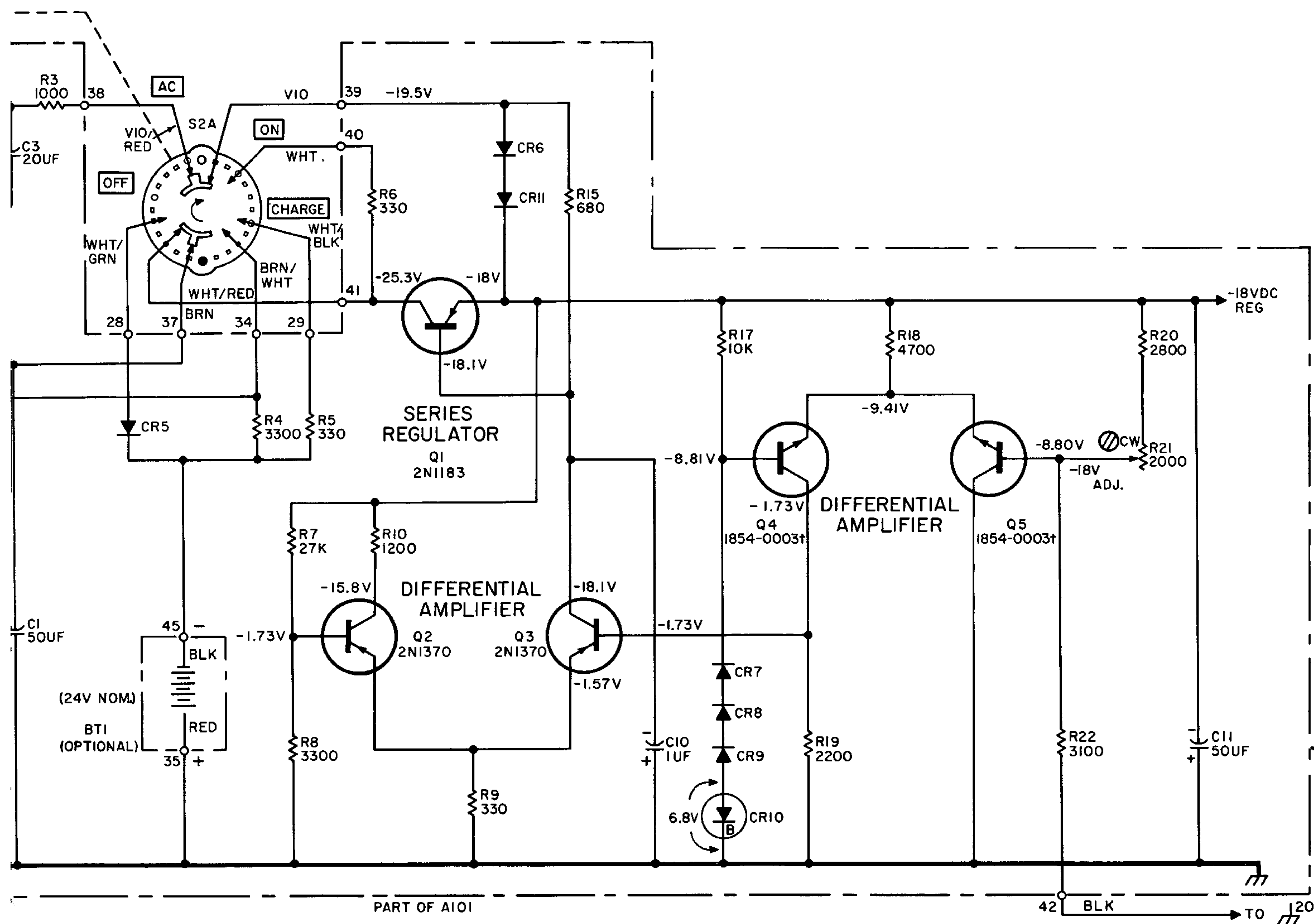
REFERENCE DESIGNATORS

C 131-140, 146-151, 153-155
CR 101, 102
J 102, 103
L 102
M 101
Q 106-110
R 157-170, 176-192, 201-205, 207-216
S 103, 104

UNASSIGNED:
C 141-145, 152,
R 171-175,
193-200, 206

GRAMS

Figure 5-14. Standing Wave Ratio Meter
(Sheet 2 of 2)



REFERENCE DESIGNATORS

A IOI
BT I
C1 - C3, C10, C11
CR1 - CR11
DS I
FI
J2
PI, P2
Q1 - Q5
RI - R10, R15, R17-R22
SI - S2
TI

UNASSIGNED:
R11-R14
C4-C9

DELETED:
R16, R23

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Figure 5-15. Power Supply

SECTION VI

REPLACEABLE PARTS

6-1. INTRODUCTION.

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

- a. Description of the part (see list of abbreviations below).
- b. Typical manufacturer of the part in a five-digit code; see list of manufacturers in appendix.
- c. Manufacturer's stock number.
- d. Total quantity used in the instrument (TQ column).
- e. Recommended spare part quantity for complete maintenance during one year of isolated service (RS column).

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

6-4. ORDERING INFORMATION.

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

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

or, in Western Europe, to

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

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

- a. Model and complete serial number of instrument.
- b. Hewlett-Packard stock number.
- c. Circuit reference designator.
- d. Description.

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

REFERENCE DESIGNATORS

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

ABBREVIATIONS

a = amperes	elect = electrolytic	mtg = mounting	rot = rotary
bp = bandpass	encap = encapsulated	my = mylar	rms = root-mean-square
bwo = backward wave oscillator	f = farads	NC = normally closed	rmo = rack mount only
c = carbon	fxd = fixed	Ne = neon	s-b = slow-blow
cer = ceramic	Ge = germanium	NO = normally open	Se = selenium
cmo = cabinet mount only	grd = ground (ed)	NPO = negative positive zero (zero temperature coefficient)	sect = section(s)
coef = coefficient	h = henries	nsr = not separately replaceable	Si = silicon
com = common	Hg = mercury	obd = order by description	sil = silver
comp = composition	imp = impregnated	p = peak	sl = slide
conn = connection	incd = incandescent	pc = printed circuit board	td = time delay
crt = cathode-ray tube	ins = insulation (ed)	pf = picofarads = 10^{-12} farads	TiO ₂ = titanium dioxide
dap = deposited	K = kilo = 1000	pp = peak-to-peak	tog = toggle
EIA = Tubes or transistors meeting Electronic Industries' Association standards will normally result in instrument operating within specifications; tubes and transistors selected for best performance will be supplied if ordered by hp stock numbers.	lin = linear taper	piv = peak inverse voltage	tol = tolerance
	log = logarithmic taper	pos = position(s)	trim = trimmer
	m = milli = 10^{-3}	pot = potentiometer	tw = traveling wave tube
	M = megohms	rect = rectifier	var = variable
	ma = milliamperes		w/ = with
	μ = micro = 10^{-6}		W = watts
	minat = miniature		ww = wirewound
	mfgl = metal film on glass		w/o = without
	mfr = manufacturer		* = optimum value selected at factory, average value shown (part may be omitted)

Table 6-1. Reference Designation Index

Circuit Reference	Stock No.	Description #	Note
A1 thru A100		Not assigned	
A101	415C-65A	Assy, etched circuit: includes C1 thru C3 CR1 thru CR11 R122 thru R133 C10, C11 CR101, CR102 R136 thru R144 C102 L101, L102 R169, R170 C109 thru C115 Q1 thru Q 5 R176 thru R192 C121 thru C123 Q101 thru Q111 R201 thru R205 C125 R2 thru R10 R207 C127 R15 thru R23 R209 C131 thru C140 R106 R211 thru R215 C146 thru C151 R117 C153 thru C155	
A102	415C-19A	Assy, switch, power: includes R1 S2	
A103	415C-19B	Assy, switch-input selector and bias check, includes, C101 R210 R101, R102 S101 R105 S104 R107	
A104	415C-19W	Assy, switch, range/expand: includes, R108 thru R116 R157 thru R168 R118 thru R121 S102, 103 R146 thru R151	
BT1		See option 1 at end of this table	
C1	0180-0058	C: fxd, elect, 50uf+ 100%-10%, 25 vdcw	
C2, 3	0180-0049	C: fxd, elect, 20 uf, 50 vdcw	
C4 thru C9		Not assigned	
C10	0180-0119	C: fxd, elect, 1uf+ 100%-10%, 25 vdcw	
C11	0180-0058	C: fxd, elect, 50uf+ 100%-10%, 25 vdcw	
C12 thru C100		Not assigned	
C101	0180-0039	C: fxd, elect, 100uf, 12 vdcw	
C102	0180-0058	C: fxd, elect, 50uf+ 100%-10%, 25 vdcw	
C103	0170-0055	C: fxd, my, 0.1 uf ±20%, 200 vdcw	
C104 thru C108		Not assigned	
C109	0170-0084	C: fxd, my, 0.068uf ±20%, 50 vdcw	
C110	0180-0058	C: fxd, elect, 50uf + 100% -10%, 25 vdcw	
C111	0150-0012	C: fxd, cer, 0.01uf ±20%, 1000 vdcw	
C112	0150-0084	C: fxd, cer, 0.1uf + 80% -20%, 50 vdcw	
C113, 114	0180-0058	C: fxd, elect, 50uf+ 100%-10%, 25 vdcw	
C115	0180-0119	C: fxd, elect, 1uf+ 100%-10%, 25 vdcw	
C116 thru C120		Not assigned	
C121	0180-0058	C: fxd, elect, 50uf+ 100%-10%, 25 vdcw	
C122	0150-0084	C: fxd, cer, 0.1uf+ 80%-20%, 50 vdcw	

See introduction to this section

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

Circuit Reference	Stock No.	Description #	Note
C123	0140-0163	C: fxd, mica, 4751pf $\pm$ 1%, 300 vdcw	
C124	0131-0007	C: var, mica, 340-1070pf, 500 vdcw	
C125	0180-0058	C: fxd, elect, 50uf+ 100%-10%, 25 vdcw	
C126		Not assigned	
C127	0180-0059	C: fxd, elect, 10uf+ 100%-10%, 25 vdcw	
C128 thru C130		Not assigned	
C131	0180-0059	C: fxd, elect, 10uf+ 100%-10%, 25 vdcw	
C132	0180-0058	C: fxd, elect, 50uf+ 100%-10%, 25 vdcw	
C133	0180-0059	C: fxd, elect, 10uf+ 100%-10%, 25 vdcw	
C134	0180-0058	C: fxd, elect, 50uf+ 100%-10%, 25 vdcw	
C135	0150-0012	C: fxd, cer, 0.01uf $\pm$ 20%, 1000 vdcw	
C136	0180-0058	C: fxd, elect, 50uf+ 100%-10%, 25 vdcw	
C137	0150-0084	C: fxd, cer, 0.1uf+ 80%-20%, 50 vdcw	
C138, 139	0180-0059	C: fxd, elect, 10uf+ 100%-10%, 25 vdcw	
C140	0180-0058	C: fxd, elect, 50uf+ 100%-10%, 25 vdcw	
C141 thru C145		Not assigned	
C146	0180-0058	C: fxd, elect, 50uf+ 100%-10%, 25 vdcw	
C147	0180-0045	C: fxd, elect, 20uf, 25 vdcw	
C148	0180-0105	C: fxd, elect, 50uf, 25 vdcw	
C149	0180-0059	C: fxd, elect, 10uf+ 100%-10%, 25 vdcw	
C150	0180-0105	C: fxd, elect, 50uf, 25 vdcw	
C151	0180-0058	C: fxd, elect, 50uf+ 100%-10%, 25 vdcw	
C152		Not assigned	
C153, 154	0180-0058	C: fxd, elect, 50uf+ 100%-10%, 25 vdcw	
C155	0180-0059	C: fxd, elect, 10uf+ 100%-10%, 25 vdcw	
CR1 thru CR4	1901-0025	Diode, Si	
CR5	1910-0016	Diode, Ge	
CR6	1902-0022	Diode, Si: avalanche (instruments serial prefixed 212- or 214-)	
	1901-0025	Diode, Si: (instruments serial prefixed 218- and above)	
CR7 thru CR9	1901-0025	Diode, Si	
CR10	1902-0017	Diode, Si: avalanche	
CR11	1901-0025	Diode, Si	
CR12 thru CR100		Not assigned	
CR101, 102	1901-0025	Diode, Si	
DS1	1450-0048	Lamp, neon: NE2H	
F1	2110-0031	Fuse, cartridge, s-b, 1/32 amp	
J1		Not assigned	
J2	1251-0148	Connector, power: male, 3 pin	
J3 thru J100		Not assigned	
J101	1250-0083	Connector, BNC: female	
J102	1251-0070	Connector, telephone: for 3 cond, plug	

See introduction to this section

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

Circuit Reference	Ⓜ Stock No.	Description #	Note
J103		Amplifier output: includes	
	AC-10C	Binding post, black	
	AC-10D	Binding post, red	
	AC-54A	Insulator, inside	
	AC-54E	Insulator, outside	
J104		See option 2 at end of this table	
L1 thru L100		Not assigned	
L101	9110-0044	Inductor, audio	
L102	9110-0041	Inductor, audio	
M1 thru M100		Not assigned	
M101	415C-81A	Meter, calibrated	
P1	8120-0078	Cord set, power, removable	
P2		nsr: part of P1	
Q1	1850-0064	Transistor, Ge: 2N1183	
Q2,3	1850-0065	Transistor, Ge: 2N1370	
Q4,5	1854-0003	Transistor, NPN Si: Ⓜ type 1854-0003 (May be replaced with 2N1711)	
Q6 thru Q100		Not assigned	
Q101, 102	1854-0003	Transistor: NPS Si: Ⓜ type 1854-0003(may be replaced with 2N1711)	
Q103	1851-0017	Transistor, Ge: 2N1304	
Q104	1850-0040	Transistor, Ge: 2N383	
Q105	1854-0003	Transistor, NPN Si: Ⓜ type 1854-0003 (May be replaced with 2N1711)	
Q106	1851-0017	Transistor, Ge: 2N1304	
Q107	1850-0040	Transistor, Ge: 2N383	
Q108	1854-0003	Transistor, NPN Si: Ⓜ type 1854-0003 (May be replaced with 2N1711)	
Q109 thru Q111	1850-0065	Transistor, Ge: 2N1370	
R1	0687-3931	R: fxd, comp, 39K ohms ±10%, 1/2 W	
R2, 3	0687-1021	R: fxd, comp 1K ohms ±10%, 1/2 W	
R4	0687-3321	R: fxd, comp, 3.3K ohms ±10%, 1/2 W	
R5	0690-3311	R: fxd, comp, 330 ohms ±10%, 1 W	
R6	0687-3311	R: fxd, comp, 330 ohms ±10%, 1/2 W	
R7	0687-2731	R: fxd, comp, 27K ohms ±10%, 1/2 W	
R8	0687-3321	R: fxd, comp 3.3K ohms ±10%, 1/2 W	
R9	0687-3311	R: fxd, comp, 330 ohms ±10%, 1/2 W	
R10	0687-1221	R: fxd, comp, 1.2K ohms ±10%, 1/2 W	
R11 thru R14		Not assigned	
R15	0687-6811	R: fxd, comp, 680 ohms ±10%, 1/2 W	
R16	0687-1801	R: fxd, comp, 18 ohms ±10%, 1/2 W	
R17	0687-1031	R: fxd, comp, 10K ohms ±10%, 1/2 W	

See introduction to this section

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

Circuit Reference	Ⓢ Stock No.	Description #	Note
R18	0687-4721	R: fxd, comp, 4.7K ohms $\pm 10\%$, 1/2 W	
R19	0687-2221	R: fxd, comp, 2.2K ohms $\pm 10\%$, 1/2 W	
R20	0812-0026	R: fxd, ww, 2.8K ohms $\pm 5\%$, 3 W	
R21	2100-0239	R: var, ww, lin, 2K ohms $\pm 20\%$, 1-1/4 W	
R22	0812-0027	R: fxd, ww, 3.1K ohms $\pm 5\%$, 3W	
R23	0687-1801	R: fxd, comp, 18 ohms $\pm 10\%$, 1/2 W	
R24 thru R100		Not assigned	
R101	2100-0022	R: var, ww, lin, 500 ohms $\pm 20\%$, 1 W	
R102	0686-3015	R: fxd, comp, 300 ohms $\pm 5\%$, 1/2 W	
R103	2100-0284	R: var, comp, lin, 1.5K ohms $\pm 20\%$, 1/2 W	
R104	2100-0283	R: var, comp, lin, 500 ohms $\pm 20\%$, 1/2 W	
R105	0686-1125	R: fxd, comp, 1.1K ohms $\pm 5\%$, 1/2 W	
R106	0686-1025	R: fxd, comp, 1K ohms $\pm 5\%$, 1/2 W	
R107	0686-1525	R: fxd, comp, 1.5K ohms $\pm 5\%$, 1/2 W	
R108, 109	0727-0363	R: fxd, dep c, 5171 ohms $\pm 1/2\%$, 1/2 W	
R110	0727-0358	R: fxd, dep c, 1277 ohms $\pm 1/2\%$, 1/2 W	
R111, 112	0727-0363	R: fxd, dep c, 5171 ohms $\pm 1/2\%$, 1/2 W	
R113	0727-0358	R: fxd, dep c, 1277 ohms $\pm 1/2\%$, 1/2 W	
R114, 115	0727-0363	R: fxd, dep c, 5171 ohms $\pm 1/2\%$, 1/2 W	
R116	0727-0358	R: fxd, dep c, 1277 ohms $\pm 1/2\%$, 1/2 W	
R117	0687-1221	R: fxd, comp, 1.2K ohms $\pm 10\%$, 1/2 W	
R118, 119	0727-0363	R: fxd, dep c, 5171 ohms $\pm 1/2\%$, 1/2 W	
R120	0727-0358	R: fxd, dep c, 1277 ohms $\pm 1/2\%$, 1/2 W	
R121	0727-0390	R: fxd, dep c, 6420 ohms $\pm 1/2\%$, 1/2 W	
R122, 123	0727-0287	R: fxd, dep c 2M $\pm 1\%$, 1/2 W	
R124	0687-1541	R: fxd, comp, 150K ohms $\pm 10\%$, 1/2 W	
R125	0687-3331	R: fxd, comp, 33K ohms $\pm 10\%$, 1/2 W	
R126	0687-4711	R: fxd, comp, 470 ohms $\pm 10\%$, 1/2 W	
R127	0758-0018	R: fxd, mfgl, 15K ohms $\pm 5\%$, 1/2 W	
R128	0687-1031	R: fxd, comp, 10K ohms $\pm 10\%$, 1/2 W	
R129 /	0687-2731	R: fxd, comp, 27K ohms $\pm 10\%$, 1/2 W	
R130	0687-2721	R: fxd, comp, 2700 ohms $\pm 10\%$, 1/2 W	
R131	0687-5601	R: fxd, comp, 56 ohms $\pm 10\%$, 1/2 W	
R132	0687-4721	R: fxd, comp, 4700 ohms $\pm 10\%$, 1/2 W	
R133	0686-3025	R: fxd, comp, 3K ohms $\pm 5\%$, 1/2 W	
R134	2100-0307	R: var, comp: rear sect, VERNIER control, lin, 2.5K ohms $\pm 20\%$, 1/2 W; nsr, ganged w/R 135	
R135	2100-0307	R: var, comp: front sect, GAIN control, cw log 10K ohms $\pm 20\%$, 1/2 W; nsr, ganged w/R 134	
R136	0687-1831	R: fxd, comp, 18K ohms $\pm 10\%$, 1/2 W	

See introduction to this section

Table 6-2. Reference Designation Index (Cont'd)

Circuit Reference	Ⓢ Stock No.	Description	Note
R137	0687-1531	R: fxd, comp, 15K ohms $\pm 10\%$, 1/2 W	
R138	0687-1011	R: fxd, comp, 100* ohms $\pm 10\%$, 1/2 W	
R139	0687-6821	R: fxd, comp, 6.8K ohms $\pm 10\%$, 1/2 W	
R140	0758-0017	R: fxd, mfgl, 1.5K ohms $\pm 5\%$, 1/2 W	
R141	0686-1025	R: fxd, comp, 1K ohms $\pm 5\%$, 1/2 W	
R142	0686-2425	R: fxd, comp, 2.4K ohms $\pm 5\%$, 1/2 W	
R143	0687-8201	R: fxd, comp, 82 ohms $\pm 10\%$, 1/2 W	
R144	0687-3901	R: fxd, comp, 39 ohms $\pm 10\%$, 1/2 W	
R145	2100-0285	R: var, comp, lin, 10K ohms $\pm 20\%$, 3/10 W	
R146	0727-0369	R: fxd, dep c, 8182 ohms $\pm 1/2\%$, 1/2 W	
R147	0727-0360	R: fxd, dep c, 2020 ohms $\pm 1/2\%$, 1/2 W	
R148, 149	0727-0369	R: fxd, dep c, 8182 ohms $\pm 1/2\%$, 1/2 W	
R150	0727-0360	R: fxd, dep c, 2020 ohms $\pm 1/2\%$, 1/2 W	
R151	0727-0369	R: fxd, dep c, 8182 ohms $\pm 1/2\%$, 1/2 W	
R152 thru R156		Not assigned	
R157	0727-0370	R: fxd, dep c, 8555 ohms $\pm 1/2\%$, 1/2 W	
R158	0727-0359	R: fxd, dep c, 1566 ohms $\pm 1/2\%$, 1/2 W	
R159	0727-0370	R: fxd, dep c, 8555 ohms $\pm 1/2\%$, 1/2 W	
R160	0727-0367	R: fxd, dep c, 6980 ohms $\pm 1/2\%$, 1/2 W	
R161	0727-0362	R: fxd, dep c, 3673 ohms $\pm 1/2\%$, 1/2 W	
R162	0727-0367	R: fxd, dep c, 6980 ohms $\pm 1/2\%$, 1/2 W	
R163	0727-0364	R: fxd, dep c, 5.2K ohms $\pm 1/2\%$, 1/2 W	
R164	0727-0368	R: fxd, dep c, 7030 ohms $\pm 1/2\%$, 1/2 W	
R165	0727-0364	R: fxd, dep c, 5.2K ohms $\pm 1/2\%$, 1/2 W	
R166	0727-0361	R: fxd, dep c, 2802 ohms $\pm 1/2\%$, 1/2 W	
R167	0727-0372	R: fxd, dep c, 16.45K ohms $\pm 1/2\%$, 1/2 W	
R168	0727-0361	R: fxd, dep c, 2802 ohms $\pm 1/2\%$, 1/2 W	
R169	0727-0371	R: fxd, dep c, 9760 ohms $\pm 1/2\%$, 1/2 W	
R170	0727-0075	R: fxd, dep c, 490 ohms $\pm 10\%$, 1/2 W	
R171 thru R175		Not assigned	
R176, 177	0687-4721	R: fxd, comp, 4.7K ohms $\pm 10\%$, 1/2 W	
R178	0686-6235	R: fxd, comp, 62K ohms $\pm 5\%$, 1/2 W	
R179	0687-2221	R: fxd, comp, 2.2K ohms $\pm 10\%$, 1/2 W	
R180	0687-1031	R: fxd, comp, 10K ohms $\pm 10\%$, 1/2 W	
R181	0687-6821	R: fxd, comp, 6.8K ohms $\pm 10\%$, 1/2 W	
R182	0687-3911	R: fxd, comp, 390 ohms $\pm 10\%$, 1/2 W	

See introduction to this section

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

Circuit Reference	Stock No.	Description	Note
R183	0687-1031	R: fxd, comp, 10K ohms $\pm 10\%$, 1/2 W	
R184	0687-4701	R: fxd, comp, 47 ohms $\pm 10\%$, 1/2 W	
R185	0687-1031	R: fxd, comp, 10K ohms $\pm 10\%$, 1/2 W	
R186	0812-0025	R: fxd, ww, 1.6K ohms $\pm 5\%$, 3 W	
R187	0812-0028	R: fxd, ww, 5.6K ohms $\pm 5\%$, 3 W	
R188	0812-0029	R: fxd, ww, 7.1K ohms $\pm 5\%$, 3 W	
R189	2100-0239	R: var, ww, lin, 2K ohms $\pm 20\%$, 1-1/4 W	
R190	0812-0028	R: fxd, ww, 5.6K ohms $\pm 5\%$, 3 W	
R191	0687-1811	R: fxd, comp, 180 ohms $\pm 10\%$, 1/2 W	
R192	0687-5621	R: fxd, comp, 5.6K ohms $\pm 10\%$, 1/2 W	
R193 thru R200		Not assigned	
R201	0686-2235	R: fxd, comp, 22K ohms $\pm 5\%$, 1/2 W	
R202	0686-3925	R: fxd, comp, 3.9K ohms $\pm 5\%$, 1/2 W	
R203	0687-1031	R: fxd, comp, 10K ohms $\pm 10\%$, 1/2 W	
R204	0687-3921	R: fxd, comp, 3.9K ohms $\pm 10\%$, 1/2 W	
R205	0686-2015	R: fxd, comp, 200 ohms $\pm 5\%$, 1/2 W	
R206		Not assigned	
R207	0687-1021	R: fxd, comp, 1K ohms $\pm 10\%$, 1/2 W	
R208	0686-2745	R: fxd, comp, 270*K ohms $\pm 5\%$, 1/2 W	
R209	0686-6225	R: fxd, comp, 6.2K ohms $\pm 5\%$, 1/2 W	
R210	0687-1211	R: fxd, comp, 120 ohms $\pm 10\%$, 1/2 W	
R211	0687-4711	R: fxd, comp 470 ohms $\pm 10\%$, 1/2 W	
R212	0687-1021	R: fxd, comp, 1K ohms $\pm 10\%$, 1/2 W	
R213	0687-1041	R: fxd, comp 100K ohms $\pm 10\%$, 1/2 W	
R214, 215	0687-4701	R: fxd, comp, 47 ohms $\pm 10\%$, 1/2 W	
R216	0687-1521	R: fxd, comp, 1.5K ohms $\pm 10\%$, 1/2 W	
S1	3101-0033	Switch, sl: DPDT	
S2	3100-0279	Switch, rot: 1 sect, 4 pos	
S3 thru S100		Not assigned	
S101		Nsr: part of A103	
S102		Nsr: part of A104	
S103		Nsr: part of A104	
S104		Nsr: part of A103	
T1	9100-0148	Transformer, power	
T2 thru T100		Not assigned	
T101	9120-0064	Transformer, audio	
XF1	1400-0084	Fuseholder, extractor post type	

See introduction to this section

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

Circuit Reference	Stock No.	Description #	Note
		<u>MISCELLANEOUS</u>	
	G-74AU	Knob, 3/4" diameter, red	
	G-74CF	Knob, 1" diameter, black	
	G-74CR	Knob, bar, concentric, 5/8" diameter	
	G-74CW	Knob, bar, 5/8" diameter	
	G-74CY	Knob, 1-5/8" diameter	
	G-75DA	Knob, bar, 1/2" diameter	
	C144B-43A-1	Cover, 6x11 side	
	C144E-73A-1	Cover, half recess top	
	C144E-73C-1	Cover, half module bottom	
	C144H-02	Handle, half module	
	C144H-05	Foot assy, half module	
	415C-74A	Knob, 3/4" diameter w/skirt	
	415C-95A	Battery installation kit, includes same parts as installed with optional 1 and all necessary hardware	
	1205-0002	Heat sink-transistor (for Q110)	
		<u>OPTIONS</u>	
		Option 1:	
	1420-0009	Battery, rechargable (BT1)	
	431A-64A	Support, battery	
	431A-64B	Cover, battery	
		NOTE: See miscellaneous section for Battery Installation Kit Stock number	
		Option 2 (J104)	
	415C-16F	Cable, special purpose electrical	
	0360-0024	Terminal lug	
	1250-0118	Connector, receptable BNC	
	1400-0053	Cable clamp, 3/16"	
	2370-0002	Flat head screw, 6/32x3/8	
	2420-0001	Hex nut, 6/32x5/16	
	3050-0018	Washer, extruded fiber	
	3050-0100	Washer, no. 6	

See introduction to this section.

Table 6-2. Replaceable Parts

Stock No.	Description #	Mfr.	Mfr. Part No.	TQ	RS		
AC-10C	Binding Post: black	28480	AC-10C	1	1		
AC-10D	Binding Post: red	28480	AC-10D	1	1		
AC-54A	Insulator, inside	28480	AC-54A	1	0		
AC-54E	Insulator, outside	28480	AC-54E	1	0		
415C-19A	Assy, switch: power, includes, R1 S2	28480	415C-19A	1	1		
415C-19B	Assy, switch-input selector and bias check, includes, C101 R210 R101, 102 S101 R105 S104 R107	28480	415C-19B	1	1		
415C-19W	Assy, switch, range/expand, includes R108 thru R116 R157 thru R168 R118 thru R120 S102, 103 R146 thru R151	28480	415C-19W	1	1		
415C-65A	Assy, etched circuit, includes, C1 thru C3 Q101 thru Q110 C10, 11 R2 thru R10 C102 R15 thru R23 C109 thru C115 R106 C121 thru C123 R117 C125 R121 thru R129 C127 R132 thru R136 C131 thru C140 R141 thru R144 C146 thru C151 R169, 170 C153 thru C155 R176 thru R192 CR1 thru CR10 R201 thru R205 CR101, 102 R207 L101, 102 R209 Q1 thru Q5 R211 thru R215	28480	415C-65C	1	0		
415C-81A	Meter, Calibrated	28480	415C-81A	1	1		
0131-0007	C: var, mica, 340-1070pf, 500 vdcw	72136	PD 52714	1	1		
0140-0163	C: fxd, mica, 4751pf $\pm 1\%$, 300 vdcw	72136	DM20F4751F	1	1		
0150-0012	C: fxd, cer, 0.01uf $\pm 20\%$, 1000 vdcw	56289	29C214A3-H-1038	2	1		
0150-0084	C: fxd, cer, 0.1uf $+ 80\%$ -20%, 50 vdcw	72982	845-222-Y5VO-1042	3	1		
0170-0055	C: fxd, my, 0.1 $\pm 20\%$, 200 vdcw	56289	192P10402	1	1		
0180-0039	C: fxd, elect, 100uf, 12 vdcw	56289	30D154A1	2	1		
0180-0045	C: fxd, elect, 20uf, 25 vdcw	56289	Type 30D, obd#	1	1		
0180-0049	C: fxd, elect, 20uf, 50 vdcw	56289	30D198A1	2	1		

See introduction to this section

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

Stock No.	Description	Mfr.	Mfr. Part No.	TQ	RS		
0180-0049	C: fxd, elect, 20uf, 50 vdcw	56289	30D198A1	2	1		
0180-0058	C: fxd, elect, 50uf + 100% -10%, 25 vdcw	56289	30D186A1	16	4		
0180-0059	C: fxd, elect, 10uf + 100% -10%, 25 vdcw	56289	30D1S2A1	7	2		
0180-0105	C: fxd, elect, 50uf, 25 vdcw	56289	S97441	2	1		
0180-0119	C: fxd, elect, 1uf + 100% -10%, 25 vdcw	56289	30D175A1	2	1		
0686-1025	R: fxd, comp, 1K ohms $\pm 5\%$, 1/2 W	01121	EB1025	2	1		
0686-1125	R: fxd, comp, 1.1K ohms $\pm 5\%$, 1/2 W	01121	EB1125	1	1		
0686-1525	R: fxd, comp, 1.5K ohms $\pm 5\%$, 1/2 W	01121	EB1525	1	1		
0686-2015	R: fxd, comp, 200 ohms $\pm 5\%$, 1/2 W	01121	EB2015	1	1		
0686-2235	R: fxd, comp, 22K ohms $\pm 5\%$, 1/2 W	01121	EB2235	1	1		
0686-2425	R: fxd, comp, 2.4K ohms $\pm 5\%$, 1/2 W	01121	EB2425	1	1		
0686-2745	R: fxd, comp, 270K ohms $\pm 5\%$, 1/2 W	01121	EB2745	1	1		
0686-3015	R: fxd, comp, 300 ohms $\pm 5\%$, 1/2 W	01121	EB3015	1	1		
0686-3025	R: fxd, comp, 3K ohms $\pm 5\%$, 1/2 W	01121	EB3025	1	1		
0686-3925	R: fxd, comp, 3.9K ohms $\pm 5\%$, 1/2 W	01121	EB3925	1	1		
0686-6225	R: fxd, comp, 6.2K ohms $\pm 5\%$, 1/2 W	01121	EB6225	1	1		
0686-6235	R: fxd, comp, 62K ohms $\pm 5\%$, 1/2 W	01121	EB6235	1	1		
0687-1011	R: fxd, comp, 100 ohms $\pm 10\%$, 1/2 W	01121	EB1011	1	1		
0687-1021	R: fxd, comp, 1K ohms $\pm 10\%$, 1/2 W	01121	EB1021	4	2		
0687-1031	R: fxd, comp, 10K $\pm 10\%$, 1/2 W	01121	EB1031	6	2		
0687-1041	R: fxd, comp, 100K ohms $\pm 10\%$, 1/2 W	01121	EB1041	1	1		
0687-1211	R: fxd, comp, 120 ohms $\pm 10\%$, 1/2 W	01121	EB1211	1	1		
0687-1221	R: fxd, comp, 1.2K ohms $\pm 10\%$, 1/2 W	01121	EB1221	2	1		
0687-1521	R: fxd, comp, 1.5K ohms $\pm 10\%$, 1/2 W	01121	EB1521	1	1		
0687-1531	R: fxd, comp, 15K ohms $\pm 10\%$, 1/2 W	01121	EB1531	1	1		
0687-1541	R: fxd, comp, 150K ohms $\pm 10\%$, 1/2 W	01121	EB1541	1	1		
0687-1801	R: fxd, comp, 18 ohms $\pm 10\%$, 1/2 W	01121	EB1801	2	1		
0687-1811	R: fxd, comp, 180 ohms $\pm 10\%$, 1/2 W	01121	EB1811	1	1		
0687-1831	R: fxd, comp, 18K ohms $\pm 10\%$, 1/2 W	01121	EB1831	1	1		
0687-2221	R: fxd, comp, 2.2K ohms $\pm 10\%$, 1/2 W	01121	EB2221	2	1		
0687-2721	R: fxd, comp, 2.7K ohms $\pm 10\%$, 1/2 W	01121	EB2721	1	1		
0687-2731	R: fxd, comp, 27K ohms $\pm 10\%$, 1/2 W	01121	EB2731	2	1		
0687-3311	R: fxd, comp, 330 ohms $\pm 10\%$, 1/2 W	01121	EB3311	2	1		
0687-3321	R: fxd, comp, 3.3K ohms $\pm 10\%$, 1/2 W	01121	EB3321	2	1		
0687-3331	R: fxd, comp, 33K ohms $\pm 10\%$, 1/2 W	01121	EB3331	1	1		
0687-3901	R: fxd, comp, 39 ohms $\pm 10\%$, 1/2 W	01121	EB3901	1	1		

See introduction to this section

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

Stock No.	Description	Mfr.	Mfr. Part No.	TQ	RS		
0687-3911	R: fxd, comp, 390 ohms $\pm 10\%$, 1/2 W	01121	EB3911	1	1		
0687-3921	R: fxd, comp, 3.9K ohms $\pm 10\%$, 1/2 W	01121	EB3921	1	1		
0687-3931	R: fxd, comp, 39K ohms $\pm 10\%$, 1/2 W	01121	EB3931	1	1		
0687-4701	R: fxd, comp, 47 ohms $\pm 10\%$, 1/2 W	01121	EB4701	3	1		
0687-4711	R: fxd, comp, 470 ohms $\pm 10\%$, 1/2 W	01121	EB4711	2	1		
0687-4721	R: fxd, comp, 4.7K ohms $\pm 10\%$, 1/2 W	01121	EB4721	4	1		
0687-5601	R: fxd, comp, 56 ohms $\pm 10\%$, 1/2 W	01121	EB5601	1	1		
0687-5621	R: fxd, comp, 5.6K ohms $\pm 10\%$, 1/2 W	01121	EB5621	1	1		
0687-6811	R: fxd, comp, 680 ohms $\pm 10\%$, 1/2 W	01121	EB6811	1	1		
0687-6821	R: fxd, comp, 6.8K ohms $\pm 10\%$, 1/2 W	01121	EB6821	2	1		
0687-8201	R: fxd, comp, 82 ohms $\pm 10\%$, 1/2 W	01121	EB8201	1	1		
0690-3311	R: fxd, comp, 330 ohms $\pm 10\%$, 1 W	01121	GB3311	1	1		
0727-0075	R: fxd, dep c, 490 ohms $\pm 10\%$, 1/2 W	19701	DC1/2CR5, obd#	1	1		
0727-0287	R: fxd, dep c, 2M ohms $\pm 1\%$, 1/2 W	19701	DC1/2CR5, obd#	2	1		
0727-0358	R: fxd, dep c, 1277 ohms $\pm 1/2$ W	82647	CD1/2MR, obd#	4	1		
0727-0359	R: fxd, dep c, 1566 ohms $\pm 1/2\%$, 1/2 W	19701	DC1/2AR5, obd#	1	1		
0727-0360	R: fxd, dep c, 2020 ohms $\pm 1/2\%$, 1/2 W	19701	DC1/2AR5, obd#	2	1		
0727-0361	R: fxd, dep c, 2802 ohms $\pm 1/2\%$, 1/2 W	19701	DC1/2AR5, obd#	2	1		
0727-0362	R: fxd, dep c, 3673 ohms $\pm 1/2\%$, 1/2 W	19701	DC1/2AR5, obd#	1	1		
0727-0363	R: fxd, dep c, 5171 ohms $\pm 1/2\%$, 1/2 W	82647	CD1/2MR, obd#	8	2		
0727-0364	R: fxd, dep c, 5.2K ohms $\pm 1/2\%$, 1/2 W	19701	DC1/2AR5, obd#	2	1		
0727-0367	R: fxd, dep c, 6980 ohms $\pm 1/2\%$, 1/2 W	19701	DC1/2AR5, obd#	2	1		
0727-0368	R: fxd, dep c, 7030 ohms $\pm 1/2\%$, 1/2 W	19701	DC1/2AR5, obd#	1	1		
0727-0369	R: fxd, dep c, 8182 ohms $\pm 1/2\%$, 1/2 W	82647	CD1/2MR, obd#	4	1		
0727-0370	R: fxd, dep c, 8555 ohms $\pm 1/2\%$, 1/2 W	19701	DC1/2AR5, obd#	2	1		
0727-0371	R: fxd, dep c, 9760 ohms $\pm 1/2\%$, 1/2 W	19701	DC1/2AR5, obd#	1	1		
0727-0372	R: fxd, dep c, 16.45K ohms $\pm 1/2\%$, 1/2 W	19701	DC1/2AR5, obd#	1	1		
0727-0390	R: fxd, dep c, 6420 ohms $\pm 1/2\%$, 1/2 W	19701	DC1/2AR5, obd#	1	1		
0758-0017	R: fxd, mtgl, 1500 ohms $\pm 5\%$, 1/2 W	07115	C-20, obd#	1	1		
0758-0018	R: fxd, mfgl, 15K ohms $\pm 5\%$, 1/2 W	07115	C-20, obd#	1	1		
0812-0025	R: fxd, ww, 1.6K ohms $\pm 5\%$, 3 W	35434	VTA3, obd#	1	1		
0812-0026	R: fxd, ww, 2.8K ohms $\pm 5\%$, 3 W	35434	VTA3, obd#	1	1		
0812-0027	R: fxd, ww, 3.1K ohms $\pm 5\%$, 3 W	35434	VTA3, obd#	1	1		
0812-0028	R: fxd, ww, 5.6K ohms $\pm 5\%$, 3 W	35434	VTA3, obd#	2	1		
0812-0029	R: fxd, ww, 7.1K ohms $\pm 5\%$, 3 W	35434	VTA3, obd#	1	1		
1250-0083	Connector, BNC: female	91737	UG-1094/U	1	1		

See introduction to this section

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

Ⓜ Stock No.	Description	Mfr.	Mfr. Part No.	TQ	RS		
1251-0070	Connector, telephone: for 3 cond, plug	82389	2J-1581	1	1		
1251-0148	Connector, power: male, 3 pin	0000U	H-10611G-3L	1	1		
1400-0084	Fuseholder, extractor post type	75915	342014	1	1		
1450-0048	Lamp, Neon: NE2H	08717	858-R	1	1		
1850-0040	Transistor, Ge: 2N383	94154	2N383	2	2		
1850-0064	Transistor, Ge: 2N1183	02735	2N1183	1	1		
1850-0065	Transistor, Ge: 2N1370	01295	2N1370	5	5		
1851-0017	Transistor, Ge: 2N1304	01295	2N1304	2	2		
1854-0003	Transistor, NPN Si: Ⓜ type 1854-0003 (may be replaced w/2N1711)	01281	PT 1844	6	6		
1901-0025	Diode, Si	07933	RD 1526, obd#	11	11		
1902-0017	Diode, Si: avalanche	01281	PS 8135	1	1		
1902-0022	Diode, Si: avalanche	01281	PS 8136	1	1		
1910-0016	Diode, Ge	93332	D 2361	1	1		
2100-0022	R: var, ww, lin, 500 ohms $\pm 20\%$, 1 W	11236	Type 112	1	1		
2100-0239	R: var, ww, lin, 2K ohms $\pm 20\%$, 1-1/4 W	11236	Type 110	2	1		
2100-0283	R: var, comp, lin, 500 ohms $\pm 20\%$, 1/2 W	11237	LT 45, obd#	1	1		
2100-0284	R: var, comp, lin, 1.5K ohms $\pm 20\%$, 1/2 W	11237	LT 45, obd#	1	1		
2100-0285	R: var, comp, lin, 10K ohms $\pm 20\%$, 3/10 W	11237	obd#	1	1		
2100-0307	R: var, comp, $\pm 20\%$, 1/2 W front sect: cw log, 10K ohms rear sect: lin, 2.5K ohms	71590	Model 2, obd#	1	1		
2110-0031	Fuse, cartridge, s-b, 1/32 amp	75915	313032	1	10		
3100-0279	Switch, rot: 1 sect, 4 pos	76854	213481-K1	1	1		
3101-0033	Switch, s1: DPDT	42190	4633	1	1		
8120-0078	Cord set, power, removable	70903	KH-4147	1	1		
9100-0148	Transformer, power	98734	6-1582	1	1		
9110-0041	Inductor, audio	98734	1-2109	1	1		
9110-0044	Inductor, audio	98734	1-2111	1	1		
9120-0064	Transformer, audio	98734	2614	1	1		
<u>MISCELLANEOUS</u>							
G-74AU	Knob, 3/4" diameter, red	28480	G-74AU	1	0		
G-74CF	Knob, 1" diameter, black	28480	G-74CF	1	0		
G-74CR	Knob, bar, concentric, 5/8" diameter	28480	G-74CR	1	0		
G-74CW	Knob, bar, 5/8" diameter	28480	G-74CW	1	0		
G-74CY	Knob, 1-5/8" diameter	28480	G-74CY	1	0		
G-74DA	Knob, bar, 1/2" diameter	28480	G-74DA	1	0		

See introduction to this section

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

Stock No.	Description	Mfr.	Mfr. Part No.	TQ	RS		
<u>MISCELLANEOUS (Cont'd)</u>							
C144B-43A-1	Cover, 6x11 side	28480	C144B-43A-1	2	0		
C144E-73A-1	Cover, half recess top	28480	C144E-73A-1	1	0		
C144E-73C-1	Cover, half module bottom	28480	C144E-73C-1	1	0		
C144H-02	Handle, half module	28480	C144H-02	1	0		
C144H-05	Foot assy, half module	28480	C144H-05	2	0		
415C-74A	Knob, 3/4" diameter, w/skirt	28480	415C-74A	1	0		
415C-95A	Battery installation kit, includes same parts as installed with option 1 and all necessary hardware	28480	415C-95A	0	0		
1205-0002	Heat sink-transistor (for Q110)	00011	3AL 635-2R	1	1		
<u>OPTIONS</u>							
Option 1							
1420-0009	Battery, rechargeable	88220	obd#	1	0		
431A-64A	Support, battery	28480	431A-64A	1	0		
431A-64B	Cover, battery	28480	431A-64B	1	0		
Option 2 (J104)							
415C-16F	Cable, special purpose electrical	28480	415C-16F	1	0		
0360-0024	Terminal lug	37942	A-131023-1	1	0		
1250-0118	Connector, receptacle BNC	91737	8427	1	0		
1400-0053	Cable clamp, 3/16"	95987	3/16-4	2	0		
2370-0002	Flat head screw, 6/32 x 3/8	80120	obd#	1	0		
2420-0001	Hex nut, 6/32 x 5/16	78189	obd#	1	0		
3050-0018	Washer, extruded fiber	73734	1466	2	0		
3050-0100	Washer for no. 6 screw	83053	obd#	2	0		

See introduction to this section

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

Stock No.	Description	Mfr.	Mfr. Part No.	TQ	RS		
<u>MISCELLANEOUS (Cont'd)</u>							
C144B-43A-1	Cover, 6x11 side	28480	C144B-43A-1	2	0		
C144E-73A-1	Cover, half recess top	28480	C144E-73A-1	1	0		
C144E-73C-1	Cover, half module bottom	28480	C144E-73C-1	1	0		
C144H-02	Handle, half module	28480	C144H-02	1	0		
C144H-05	Foot assy, half module	28480	C144H-05	2	0		
415C-74A	Knob, 3/4" diameter, w/skirt	28480	415C-74A	1	0		
415C-95A	Battery installation kit, includes same parts as installed with option 1 and all necessary hardware	28480	415C-95A	0	0		
1205-0002	Heat sink-transistor (for Q110)	00011	3AL 635-2R	1	1		
<u>OPTIONS</u>							
Option 1							
1420-0009	Battery, rechargeable	88220	obd#	1	0		
431A-64A	Support, battery	28480	431A-64A	1	0		
431A-64B	Cover, battery	28480	431A-64B	1	0		
Option 2 (J104)							
415C-16F	Cable, special purpose electrical	28480	415C-16F	1	0		
0360-0024	Terminal lug	37942	A-131023-1	1	0		
1250-0118	Connector, receptacle BNC	91737	8427	1	0		
1400-0053	Cable clamp, 3/16"	95987	3/16-4	2	0		
2370-0002	Flat head screw, 6/32 x 3/8	80120	obd#	1	0		
2420-0001	Hex nut, 6/32 x 5/16	78189	obd#	1	0		
3050-0018	Washer, extruded fiber	73734	1466	2	0		
3050-0100	Washer for no. 6 screw	83053	obd#	2	0		

See introduction to this section

APPENDIX

CODE LIST OF MANUFACTURERS (Sheet 1 of 2)

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

CODE NO.	MANUFACTURER	ADDRESS	CODE NO.	MANUFACTURER	ADDRESS	CODE NO.	MANUFACTURER	ADDRESS
00334	Humidial Co.	Colton, Calif.	07137	Transistor Electronics Corp.	Minneapolis, Minn.	47904	Polaroid Corp.	Cambridge, Mass.
00335	Westrex Corp.	New York, N.Y.	07138	Westinghouse Electric Corp. Electronic Tube Div.	Elmira, N.Y.	48620	Precision Thermometer and Inst. Co.	Philadelphia, Pa.
00373	Garlock Packing Co., Electronic Products Div.	Camden, N.J.	07261	Avnet Corp.	Los Angeles, Calif.	49956	Raytheon Company	Lexington, Mass.
00656	Aerovox Corp.	New Bedford, Mass.	07263	Fairchild Semiconductor Corp.	Mountain View, Calif.	54294	Shallcross Mfg. Co.	Selma, N.C.
00779	Amp, Inc.	Harrisburg, Pa.	07910	Continental Device Corp.	Hawthorne, Calif.	55026	Simpson Electric Co.	Chicago, Ill.
00781	Aircraft Radio Corp.	Boonton, N.J.	07933	Rheem Semiconductor Corp.	Mountain View, Calif.	55933	Sonotone Corp.	Elmsford, N.Y.
00853	Sangamo Electric Company, Ordill Division (Capacitors)	Marion, Ill.	07980	Boonton Radio Corp.	Boonton, N.J.	55938	Sorenson & Co., Inc.	So. Norwalk, Conn.
00866	Goe Engineering Co.	Los Angeles, Calif.	08145	U.S. Engineering Co.	Los Angeles, Calif.	56137	Spaulding Fibre Co., Inc.	Tonawanda, N.Y.
00891	Carl E. Holmes Corp.	Los Angeles, Calif.	08358	Burgess Battery Co.	Niagara Falls, Ontario, Canada	56289	Sprague Electric Co.	North Adams, Mass.
01121	Allen Bradley Co.	Milwaukee, Wis.	08717	Sloan Company	Burbank, Calif.	59446	Telex, Inc.	St. Paul, Minn.
01255	Litton Industries, Inc.	Beverly Hills, Calif.	08718	Cannon Electric Co. Phoenix Div.	Phoenix, Ariz.	61775	Union Switch and Signal, Div. of Westinghouse Air Brake Co.	Swissvale, Pa.
01281	Pacific Semiconductors, Inc.	Culver City, Calif.	08792	CBS Electronics Semiconductor Operations, Div. of C.B.S. Inc.	Lowell, Mass.	62119	Universal Electric Co.	Owosso, Mich.
01295	Texas Instruments, Inc. Transistor Products Div.	Dallas, Texas	09026	Babcock Relays, Inc.	Costa Mesa, Calif.	64959	Western Electric Co., Inc.	New York, N.Y.
01349	The Alliance Mfg. Co.	Alliance, Ohio	09134	Texas Capacitor Co.	Houston, Texas	65092	Weston Inst. Div. of Daystrom, Inc.	Newark, N.J.
01561	Chassi-Trak Corp.	Indianapolis, Ind.	09250	Electro Assemblies, Inc.	Chicago, Ill.	66346	Wollensak Optical Co.	Rochester, N.Y.
01589	Pacific Relays, Inc.	Van Nuys, Calif.	09569	Mallory Battery Co. of Canada, Ltd.	Toronto, Ontario, Canada	70276	Allen Mfg. Co.	Hartford, Conn.
01930	Amerock Corp.	Rockford, Ill.	10214	General Transistor Western Corp.	Los Angeles, Calif.	70309	Allied Control Co., Inc.	New York, N.Y.
01961	Pulse Engineering Co.	Santa Clara, Calif.	10411	Ti-Tal, Inc.	Berkeley, Calif.	70485	Atlantic India Rubber Works, Inc.	Chicago, Ill.
02114	Ferroxcube Corp. of America	Saugerties, N.Y.	10646	Carborundum Co.	Niagara Falls, N.Y.	70563	Amperite Co., Inc.	New York, N.Y.
02286	Cole Mfg. Co.	Palo Alto, Calif.	11236	CTS of Berne, Inc.	Berne, Ind.	70903	Belden Mfg. Co.	Chicago, Ill.
02660	Amphenol-Borg Electronics Corp.	Chicago, Ill.	11237	Chicago Telephone of California, Inc.	So. Pasadena, Calif.	70998	Bird Electronic Corp.	Cleveland, Ohio
02735	Radio Corp. of America Semiconductor and Materials Div.	Somerville, N.J.	11312	Microwave Electronics Corp.	Palo Alto, Calif.	71002	Birnbach Radio Co.	New York, N.Y.
02771	Vocaline Co. of America, Inc.	Old Saybrook, Conn.	11711	General Instrument Corporation Semiconductor Division	Newark, N.J.	71041	Boston Gear Works Div. of Murray Co. of Texas	Quincy, Mass.
02777	Hopkins Engineering Co.	San Fernando, Calif.	11717	Imperial Electronics, Inc.	Buena Park, Calif.	71218	Bud Radio Inc.	Cleveland, Ohio
03508	G.E. Semiconductor Products Dept.	Syracuse, N.Y.	11870	Melabs, Inc.	Palo Alto, Calif.	71286	Camloc Fastener Corp.	Paramus, N.J.
03705	Apex Machine & Tool Co.	Dayton, Ohio	12697	Clarostat Mfg. Co.	Dover, N.H.	71313	Allen D. Cardwell Electronic Prod. Corp.	Plainville, Conn.
03797	Eldema Corp.	El Monte, Calif.	14655	Cornell Dubilier Elec. Corp.	So. Plainfield, N.J.	71400	Bussmann Fuse Div. of McGraw-Edison Co.	St. Louis, Mo.
03877	Transitron Electronic Corp.	Wakefield, Mass.	15909	The Daven Co.	Livingston, N.J.	71450	CTS Corp.	Elkhart, Ind.
03888	Pyrofilm Resistor Co.	Morristown, N.J.	16688	De Jur-Amsco Corporation	Long Island City 1, N.Y.	71468	Cannon Electric Co.	Los Angeles, Calif.
03954	Air Marine Motors, Inc.	Los Angeles, Calif.	16758	Delco Radio Div. of G. M. Corp.	Kokomo, Ind.	71471	Cinema Engineering Co.	Burbank, Calif.
04009	Arrow, Hart and Hegeman Elect. Co.	Hartford, Conn.	18873	E. I. DuPont and Co., Inc.	Wilmington, Del.	71482	C. P. Clare & Co.	Chicago, Ill.
04062	Elmenco Products Co.	New York, N.Y.	19315	Eclipse Pioneer, Div. of Bendix Aviation Corp.	Teterboro, N.J.	71528	Standard-Thomson Corp., Clifford Mfg. Co. Div.	Waltham, Mass.
04222	Hi-Q Division of Aerovox	Myrtle Beach, S.C.	19500	Thomas A. Edison Industries, Div. of McGraw-Edison Co.	West Orange, N.J.	71590	Centralab Div. of Globe Union Inc.	Milwaukee, Wis.
04298	Elgin National Watch Co., Electronics Division	Burbank, Calif.	19701	Electra Manufacturing Co.	Kansas City, Mo.	71700	The Cornish Wire Co.	New York, N.Y.
04404	Dymec Division of Hewlett-Packard Co.	Palo Alto, Calif.	20183	Electronic Tube Corp.	Philadelphia, Pa.	71744	Chicago Miniature Lamp Works	Chicago, Ill.
04651	Sylvania Electric Prods., Inc. Electronic Tube Div.	Mountain View, Calif.	21520	Fansteel Metallurgical Corp.	No. Chicago, Ill.	71753	A. O. Smith Corp., Crowley Div.	West Orange, N.J.
04713	Motorola, Inc., Semiconductor Prod. Div.	Phoenix, Arizona	21335	The Fafnir Bearing Co.	New Britain, Conn.	71785	Cinch Mfg. Corp.	Chicago, Ill.
04732	Filtron Co., Inc. Western Division	Culver City, Calif.	21964	Fed. Telephone and Radio Corp.	Clifton, N.J.	71984	Dow Corning Corp.	Midland, Mich.
04773	Automatic Electric Co.	Northlake, Ill.	24446	General Electric Co.	Schenectady, N.Y.	72136	Electro Motive Mfg. Co., Inc.	Willimantic, Conn.
04870	P M Motor Co.	Chicago, Ill.	24455	G.E., Lamp Division	Nela Park, Cleveland, Ohio	72354	John E. Fast & Co.	Chicago, Ill.
05006	Twentieth Century Plastics, Inc.	Los Angeles, Calif.	24655	General Radio Co.	West Concord, Mass.	72619	Dialight Corp.	Brooklyn, N.Y.
05277	Westinghouse Electric Corp., Semi-Conductor Dept.	Youngwood, Pa.	26462	Grobet File Co. of America, Inc.	Carlstadt, N.J.	72656	General Ceramics Corp.	Keasbey, N.J.
05347	Ultronix, Inc.	San Mateo, Calif.	26992	Hamilton Watch Co.	Lancaster, Pa.	72758	Girard-Hopkins	Oakland, Calif.
05593	Illumitronic Engineering Co.	Sunnyvale, Calif.	28480	Hewlett-Packard Co.	Palo Alto, Calif.	72765	Drake Mfg. Co.	Chicago, Ill.
05624	Barber Colman Co.	Rockford, Ill.	33173	G.E. Receiving Tube Dept.	Owensboro, Ky.	72825	Hugh H. Eby Inc.	Philadelphia, Pa.
05729	Metropolitan Telecommunications Corp., Metro Cap. Div.	Brooklyn, N.Y.	35434	Lectrohm Inc.	Chicago, Ill.	72928	Gudeman Co.	Chicago, Ill.
05783	Stewart Engineering Co.	Santa Cruz, Calif.	37942	P. R. Mallory & Co., Inc.	Indianapolis, Ind.	72982	Erie Resistor Corp.	Erie, Pa.
06004	The Bassick Co.	Bridgeport, Conn.	39543	Mechanical Industries Prod. Co.	Akron, Ohio	73061	Hansen Mfg. Co., Inc.	Princeton, Ind.
06555	Beede Electrical Instrument Co., Inc.	Penacook, N.H.	40920	Miniature Precision Bearings, Inc.	Keene, N.H.	73138	Helipot Div. of Beckman Instruments, Inc.	Fullerton, Calif.
06812	Torrington Mfg. Co., West Div.	Van Nuys, Calif.	42190	Muter Co.	Chicago, Ill.	73293	Hughes Products Division of Hughes Aircraft Co.	Newport Beach, Calif.
07115	Corning Glass Works Electronic Components Dept.	Bradford, Pa.	43990	C. A. Norgren Co.	Englewood, Colo.	73445	Amperex Electronic Co., Div. of North American Phillips Co., Inc.	Hicksville, N.Y.
07126	Digitran Co.	Pasadena, Calif.	44655	Ohmite Mfg. Co.	Skokie, Ill.	73506	Bradley Semiconductor Corp.	Hamden, Conn.
						73559	Carling Electric, Inc.	Hartford, Conn.
						73682	George K. Garrett Co., Inc.	Philadelphia, Pa.
						73734	Federal Screw Products Co.	Chicago, Ill.
						73743	Fischer Special Mfg. Co.	Cincinnati, Ohio
						73793	The General Industries Co.	Elyria, Ohio
						73905	Jennings Radio Mfg. Co.	San Jose, Calif.
						74455	J. H. Winns, and Sons	Winchester, Mass.
						74861	Industrial Condenser Corp.	Chicago, Ill.

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APPENDIX **CODE LIST OF MANUFACTURERS (Sheet 2 of 2)**

CODE NO.	MANUFACTURER	ADDRESS	CODE NO.	MANUFACTURER	ADDRESS	CODE NO.	MANUFACTURER	ADDRESS
74868	R.F. Products Division of Amphenol-Borg Electronics Corp.	Danbury, Conn.	82893	Vector Electronic Co.	Glendale, Calif.	95354	Methode Mfg. Co.	Chicago, Ill.
74970	E. F. Johnson Co.	Waseca, Minn.	83053	Western Washer Mfr. Co.	Los Angeles, Calif.	95987	Weckesser Co.	Chicago, Ill.
75042	International Resistance Co.	Philadelphia, Pa.	83058	Carr Fastener Co.	Cambridge, Mass.	96067	Huggins Laboratories	Sunnyvale, Calif.
75173	Jones, Howard B., Division of Cinch Mfg. Corp.	Chicago, Ill.	83086	New Hampshire Ball Bearing, Inc.	Peterborough, N.H.	96095	Hi-Q Division of Aerovox	Olean, N.Y.
75378	James Knights Co.	Sandwich, Ill.	83125	Pyramid Electric Co.	Darlington, S.C.	96256	Thordarson-Meissner Div. of Maguire Industries, Inc.	Mt. Carmel, Ill.
75382	Kulka Electric Corporation	Mt. Vernon, N.Y.	83148	Electro Cords Co.	Los Angeles, Calif.	96296	Solar Manufacturing Co.	Los Angeles, Calif.
75818	Lenz Electric Mfg. Co.	Chicago, Ill.	83186	Victory Engineering Corp.	Union, N.J.	96330	Carlton Screw Co.	Chicago, Ill.
75915	Littelfuse Inc.	Des Plaines, Ill.	83298	Bendix Corp., Red Bank Div.	Red Bank, N.J.	96341	Microwave Associates, Inc.	Burlington, Mass.
76005	Lord Mfg. Co.	Erie, Pa.	83330	Smith, Herman H., Inc.	Brooklyn, N.Y.	96501	Excel Transformer Co.	Oakland, Calif.
76210	C. W. Marwedel	San Francisco, Calif.	83501	Gavitt Wire and Cable Co., Div. of Amerace Corp.	Brookfield, Mass.	97464	Industrial Retaining Ring Co.	Irvington, N.J.
76433	Micamold Electronic Mfg. Corp.	Brooklyn, N.Y.	83594	Burroughs Corp., Electronic Tube Div.	Plainfield, N.J.	97539	Automatic and Precision Mfg. Co.	Yonkers, N.Y.
76487	James Millen Mfg. Co., Inc.	Malden, Mass.	83777	Model Eng. and Mfg., Inc.	Huntington, Ind.	97966	CBS Electronics, Div. of C.B.S., Inc.	Danvers, Mass.
76493	J. W. Miller Co.	Los Angeles, Calif.	83821	Loyd Scruggs Co.	Festus, Mo.	98141	Axel Brothers Inc.	Jamaica, N.Y.
76530	Monadnock Mills	San Leandro, Calif.	84171	Arco Electronics, Inc.	New York, N.Y.	98220	Francis L. Mosley	Pasadena, Calif.
76545	Mueller Electric Co.	Cleveland, Ohio	84396	A. J. Glesener Co., Inc.	San Francisco, Calif.	98278	Microdot, Inc.	So. Pasadena, Calif.
76854	Oak Manufacturing Co.	Chicago, Ill.	84411	Good All Electric Mfg. Co.	Ogallala, Neb.	98291	Sealectro Corp.	Mamaroneck, N.Y.
77068	Bendix Pacific Division of Bendix Corp.	No. Hollywood, Calif.	84970	Sarkes Tarzian, Inc.	Bloomington, Ind.	98405	Carad Corp.	Redwood City, Calif.
77221	Phaotron Instrument and Electronic Co.	South Pasadena, Calif.	85454	Boonton Molding Company	Boonton, N.J.	98734	Palo Alto Engineering Co., Inc.	Palo Alto, Calif.
77342	Potter and Brumfield, Div. of American Machine and Foundry	Princeton, Ind.	85474	R. M. Bracamonte & Co.	San Francisco, Calif.	98821	North Hills Electric Co.	Mineola, N.Y.
77630	Radio Condenser Co.	Camden, N.J.	85660	Koiled Kords, Inc.	New Haven, Conn.	98925	Clevite Transistor Prod. Div. of Clevite Corp.	Waltham, Mass.
77638	Radio Receptor Co., Inc.	Brooklyn, N.Y.	85911	Seamless Rubber Co.	Chicago, Ill.	98978	International Electronic Research Corp.	Burbank, Calif.
77764	Resistance Products Co.	Harrisburg, Pa.	86197	Clifton Precision Products	Clifton Heights, Pa.	99109	Columbia Technical Corp.	New York, N.Y.
78189	Shakeproof Division of Illinois Tool Works	Elgin, Ill.	86684	Radio Corp. of America, RCA Electron Tube Div.	Harrison, N.J.	99313	Varian Associates	Palo Alto, Calif.
78283	Signal Indicator Corp.	New York, N.Y.	87216	Philco Corp. (Lansdale Division)	Lansdale, Pa.	99515	Marshall Industries, Electron Products Division	Pasadena, Calif.
78471	Tilley Mfg. Co.	San Francisco, Calif.	87473	Western Fibrous Glass Products Co.	San Francisco, Calif.	99707	Control Switch Division, Controls Co. of America	El Segundo, Calif.
78488	Stackpole Carbon Co.	St. Marys, Pa.	88140	Cutler-Hammer, Inc.	Lincoln, Ill.	99800	Delevan Electronics Corp.	East Aurora, N.Y.
78553	Tinnerman Products, Inc.	Cleveland, Ohio	88220	Gould-National Batteries, Inc.	St. Paul, Minn.	99848	Wilco Corporation	Indianapolis, Ind.
78790	Transformer Engineers	Pasadena, Calif.	89473	General Electric Distributing Corp.	Schenectady, N.Y.	99934	Renbrandt, Inc.	Boston, Mass.
78947	Ucinite Co.	Newtonville, Mass.	89636	Carter Parts Div. of Economy Baler Co.	Chicago, Ill.	99942	Hoffman Semiconductor Div. of Hoffman Electronics Corp.	Evanston, Ill.
79142	Veeder Root, Inc.	Hartford, Conn.	89665	United Transformer Co.	Chicago, Ill.	99957	Technology Instrument Corp. of Calif.	Newbury Park, Calif.
79251	Wenco Mfg. Co.	Chicago, Ill.	90179	U.S. Rubber Co., Mechanical Goods Div.	Passaic, N.J.			
79727	Continental-Wirt Electronics Corp.	Philadelphia, Pa.	90970	Bearing Engineering Co.	San Francisco, Calif.			
79963	Zierick Mfg. Corp.	New Rochelle, N.Y.	91260	Connor Spring Mfg. Co.	San Francisco, Calif.			
80031	Mepco Division of Sessions Clock Co.	Morristown, N.J.	91418	Radio Materials Co.	Chicago, Ill.			
80120	Schnitzer Alloy Products	Elizabeth, N.J.	91506	Augat Brothers, Inc.	Attleboro, Mass.			
80130	Times Facsimile Corp.	New York, N.Y.	91637	Dale Electronics, Inc.	Columbus, Nebr.			
80131	Electronic Industries Association Any brand tube meeting EIA standards	Washington, D.C.	91662	Elco Corp.	Philadelphia, Pa.			
80207	Unimax Switch, Div. of W. L. Maxson Corp.	Wallingford, Conn.	91737	Gremer Mfg. Co., Inc.	Wakefield, Mass.			
80248	Oxford Electric Corp.	Chicago, Ill.	91827	K F Development Co.	Redwood City, Calif.			
80294	Bourns Laboratories, Inc.	Riverside, Calif.	91921	Minneapolis-Honeywell Regulator Co., Micro-Switch Division	Freeport, Ill.			
80411	Acro Div. of Robertshaw Fulton Controls Co.	Columbus 16, Ohio	92196	Universal Metal Products, Inc.	Bassett Puente, Calif.	0000F	Malco Tool and Die	Los Angeles, Calif.
80486	All Star Products Inc.	Defiance, Ohio	93332	Sylvania Electric Prod. Inc., Semiconductor Div.	Woburn, Mass.	0000I	Telefunken (c/o American Elite)	New York, N.Y.
80583	Hammerlund Co., Inc.	New York, N.Y.	93369	Robbins and Myers, Inc.	New York, N.Y.	0000L	Winchester Electronics, Inc.	Santa Monica, Calif.
80640	Stevens, Arnold, Co., Inc.	Boston, Mass.	93410	Stevens Mfg. Co., Inc.	Mansfield, Ohio	0000M	Western Coil Div. of Automatic Ind., Inc.	Redwood City, Calif.
81030	International Instruments, Inc.	New Haven, Conn.	93983	Insuline-Van Norman Ind., Inc. Electronic Division	Manchester, N.H.	0000N	Nahm-Bros. Spring Co.	San Leandro, Calif.
81415	Wilkor Products, Inc.	Cleveland, Ohio	94144	Raytheon Mfg. Co., Industrial Components Div., Receiving Tube Operation	Quincy, Mass.	0000P	Ty-Car Mfg. Co., Inc.	Holliston, Mass.
81453	Raytheon Mfg. Co., Industrial Components Div., Industr. Tube Operations	Newton, Mass.	94145	Raytheon Mfg. Co., Semiconductor Div., California Street Plant	Newton, Mass.	0000T	Texas Instruments, Inc. Metals and Controls Div.	Versailles, Ky.
81483	International Rectifier Corp.	El Segundo, Calif.	94148	Scientific Radio Products, Inc.	Loveland, Colo.	0000U	Tower Mfg. Corp.	Providence, R.I.
81860	Barry Controls, Inc.	Watertown, Mass.	94154	Tung-Sol Electric, Inc.	Newark, N.J.	0000W	Webster Electronics Co. Inc.	New York, N.Y.
82042	Carter Parts Co.	Skokie, Ill.	94197	Curtiss-Wright Corp., Electronics Div.	East Paterson, N.J.	0000X	Spruce Pine Mica Co.	Spruce Pine, N.C.
82142	Jeffers Electronics Division of Speer Carbon Co.	Du Bois, Pa.	94310	Tru Ohm Prod. Div. of Model Engineering and Mfg. Co.	Chicago, Ill.	0000Y	Midland Mfg. Co. Inc.	Kansas City, Kans.
82170	Allen B. DuMont Labs., Inc.	Clifton, N.J.	94682	Worcester Pressed Aluminum Corp.	Worcester, Mass.	0000Z	Willow Leather Products Corp.	Newark, N.J.
82209	Maguire Industries, Inc.	Greenwich, Conn.	95236	Allies Products Corp.	Miami, Fla.	000AA	British Radio Electronics Ltd.	Washington, D.C.
82219	Sylvania Electric Prod. Inc., Electronic Tube Div.	Emporium, Pa.	95238	Continental Connector Corp.	Woodside, N.Y.	000BB	Precision Instrument Components Co.	Van Nuys, Calif.
82376	Astron Co.	East Newark, N.J.	95263	Leecraft Mfg. Co., Inc.	New York, N.Y.	000CC	Computer Diode Corp.	Lodi, N.J.
82389	Switchcraft, Inc.	Chicago, Ill.	95264	Lerco Electronics, Inc.	Burbank, Calif.	000EE	A. Williams Manufacturing Co.	San Jose, Calif.
82647	Metals and Controls, Inc., Div. of Texas Instruments, Inc., Spencer Prods.	Attleboro, Mass.	95265	National Coil Co.	Sheridan, Wyo.	000FF	Carmichael Corrugated Specialties	Richmond, Calif.
82866	Research Products Corp.	Madison, Wis.	95275	Vitramon, Inc.	Bridgeport, Conn.	000GG	Goshen Die Cutting Service	Goshen, Ind.
82877	Rotron Manufacturing Co., Inc.	Woodstock, N.Y.				000HH	Rubbercraft Corp.	Torrance, Calif.
						000II	Birtcher Corporation, Industrial Division	Monterey Park, Calif.

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

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WARRANTY

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

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

CLAIM FOR DAMAGE IN SHIPMENT

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

SHIPPING

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

GENERAL

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

CUSTOMER SERVICE

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Palo Alto, California, U.S.A.
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Modena Italy

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