Errata

Title & Document Type: **428B Clip-On DC Milliammeter Operating and Service Manual**

Manual Part Number: **00428-90005**

Revision Date: **September 1983**

About this Manual

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

HP References in this Manual

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

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

Agilent Technologies

OPERATING AND SERVICE MANUAL

CLIP-ON DC MILLIAMMETER
428B

HEWLETT PACKARD

hp-428B

HEWLETT PACKARD

OPERATING AND SERVICE MANUAL

MODEL 428B
CLIP-ON DC MILLIAMMETER

Serials Prefixed: 0995A and above
Appendix A, Manual Backdating Changes
adapts this manual to instruments
with earlier serial prefixes.

WARNING

To help minimize the possiblity of electrical fire or shock hazard, do not expose this instrument to rain or excessive moisture.

-hp- Part No. 00428-90005
-hp- Microfiche No. 00428-90055

P.O. Box 301, Loveland, Colorado 80537 U.S.A.

Printed: September 1983

HEWLETT PACKARD

CERTIFICATION

Hewlett-Packard Company certifies that this product met its published specifications at the time of shipment from the factory. Hewlett-Packard further certifies that its calibration measurements are traceable to the United States National Bureau of Standards, to the extent allowed by the Bureau's calibration facility, and to the calibration facilities of other International Standards Organization members.

WARRANTY

This Hewlett-Packard instrument product is warranted against defects in materials and workmanship for a period of one year from date of shipment [,except that in the case of certain components listed in Section I of this manual, the warranty shall be for the specified period]. During the warranty period, Hewlett-Packard Company will, at its option, either repair or replace products which prove to be defective.

For warranty service or repair, this product must be returned to a service facility designated by -hp-. Buyer shall prepay shipping charges to -hp- and -hp- shall pay shipping charges to return the product to Buyer. However, Buyer shall pay all shipping charges, duties, and taxes for products returned to -hp- from another country.

Duration and conditions of warranty for this instrument may be superceded when the instrument is integrated into (becomes a part of) other -hp- instrument products.

Hewlett-Packard warrants that its software and firmware designated by -hp- for use with an instrument will execute its programming instructions when properly installed on that instrument. Hewlett-Packard does not warrant that the operation of the instrument, or software, or firmware will be uninterrupted or error free.

LIMITATION OF WARRANTY

The foregoing warranty shall not apply to defects resulting from improper or inadequate maintenance by Buyer, Buyer-supplied software or interfacing, unauthorized modification or misuse, operation outside of the environmental specifications for the product, or improper site preparation or maintenance.

NO OTHER WARRANTY IS EXPRESSED OR IMPLIED. HEWLETT-PACKARD SPECIFICALLY DISCLAIMS THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE.

EXCLUSIVE REMEDIES

THE REMEDIES PROVIDED HEREIN ARE BUYER'S SOLE AND EXCLUSIVE REMEDIES. HEWLETT-PACKARD SHALL NOT BE LIABLE FOR ANY DIRECT, INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES, WHETHER BASED ON CONTRACT, TORT, OR ANY OTHER LEGAL THEORY.

ASSISTANCE

Product maintenance agreements and other customer assistance agreements are available for Hewlett-Packard products.

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

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HEWLETT PACKARD

SAFETY SUMMARY

The following general safety precautions must be observed during all phases of operation, service, and repair of this instrument. Failure to comply with these precautions or with specific warnings elsewhere in this manual violates safety standards of design, manufacture, and intended use of the instrument. Hewlett-Packard Company assumes no liability for the customer's failure to comply with these requirements. This is a Safety Class 1 instrument.

GROUND THE INSTRUMENT

To minimize shock hazard, the instrument chassis and cabinet must be connected to an electrical ground. The instrument is equipped with a three-conductor ac power cable. The power cable must either be plugged into an approved three-contact electrical outlet or used with a three-contact to two-contact adapter with the grounding wire (green) firmly connected to an electrical ground (safety ground) at the power outlet. The power jack and mating plug of the power cable meet International Electrotechnical Commission (IEC) safety standards.

DO NOT OPERATE IN AN EXPLOSIVE ATMOSPHERE

Do not operate the instrument in the presence of flammable gases or fumes. Operation of any electrical instrument in such an environment constitutes a definite safety hazard.

KEEP AWAY FROM LIVE CIRCUITS

Operating personnel must not remove instrument covers. Component replacement and internal adjustments must be made by qualified maintenance personnel. Do not replace components with power cable connected. Under certain conditions, dangerous voltages may exist even with the power cable removed. To avoid injuries, always disconnect power and discharge circuits before touching them.

DO NOT SERVICE OR ADJUST ALONE

Do not attempt internal service or adjustment unless another person, capable of rendering first aid and resuscitation, is present.

DO NOT SUBSTITUTE PARTS OR MODIFY INSTRUMENT

Because of the danger of introducing additional hazards, do not install substitute parts or perform any unauthorized modification to the instrument. Return the instrument to a Hewlett-Packard Sales and Service Office for service and repair to ensure that safety features are maintained.

DANGEROUS PROCEDURE WARNINGS

Warnings, such as the example below, precede potentially dangerous procedures throughout this manual. Instructions contained in the warnings must be followed.

WARNING

Dangerous voltages, capable of causing death, are present in this instrument. Use extreme caution when handling, testing, and adjusting.

SAFETY SYMBOLS

General Definitions of Safety Symbols Used On Equipment or In Manuals.

Instruction manual symbol: the product will be marked with this symbol when it is necessary for the user to refer to the instruction manual in order to protect against damage to the instrument.

Indicates dangerous voltage (terminals fed from the interior by voltage exceeding 1000 volts must be so marked).

 OR 

Protective conductor terminal. For protection against electrical shock in case of a fault. Used with field wiring terminals to indicate the terminal which must be connected to ground before operating equipment.

Low-noise or noiseless, clean ground (earth) terminal. Used for a signal common, as well as providing protection against electrical shock in case of a fault. A terminal marked with this symbol must be connected to ground in the manner described in the installation (operating) manual, and before operating the equipment.

 OR 

Frame or chassis terminal. A connection to the frame (chassis) of the equipment which normally includes all exposed metal structures.

Alternating current (power line).

Direct current (power line).

Alternating or direct current (power line).

DANGER

The DANGER sign denotes a hazard. It calls attention to an operating procedure, practice, condition or the like, which could result in injury or death to personnel even during normal operation.

WARNING

The WARNING sign denotes a hazard. It calls attention to a procedure, practice, condition or the like, which, if not correctly performed or adhered to, could result in injury or death to personnel.

CAUTION

The CAUTION sign denotes a hazard. It calls attention to an operating procedure, practice, condition or the like, which, if not correctly performed or adhered to, could result in damage to or destruction of part or all of the product.

NOTE:

The NOTE sign denotes important information. It calls attention to procedure, practice, condition or the like, which is essential to highlight.

SECTION I

GENERAL INFORMATION

1-1. INTRODUCTION

1-2. The -hp- Model 428B Clip-On DC Milliammeter measures the magnetic field which exists around a wire carrying dc current. Operating the instrument is simple. After zero setting, the two jaws of the probe are clamped around the wire (arrow on probe head indicates direction of conventional current flow) and the meter will indicate the current.

1-3. There are nine current ranges from 1 mA to 10 amp full-scale deflection. The sensitivity can be increased even further by looping the wire several times through the opening in the probe. The current indication is virtually insensitive to superimposed ac signals and the series loading of the circuit is less than 0.5μH. A large amount of feedback provides great stability.

1-4. OTHER PROBE HEADS

1-5. Other probe heads are available to extend the usefulness of your Clip-On DC Milliammeter. Write to the nearest Sales and Service Office (listed in Appendix C) for further information. At the time of publication of this manual, the following accessory probe heads were available:

a. -hp- Model 3529A Magnetometer Probe (1 gauss - 1 amp).

b. -hp- Model 3529A Option C11 Magnetometer Probe (1 gauss - 1 mA).

1-6. Write to the nearest Sales and Service Office (listed in Appendix C) stating your complete requirements for information concerning special applications.

1-7. INSTRUMENT AND MANUAL IDENTIFICATION

1-8. Hewlett-Packard uses a two-section serial number. If the first section (serial prefix) of the serial number on your instrument does not agree with those on the title page of this manual, change sheets supplied with the manual will define the differences between your instrument and the Model 428B described in this manual. Some serial numbers may have a letter separating the two sections of the number. This letter indicates the country in which the instrument was manufactured.

1-9. An additional Operating and Service Manual may be ordered as Option 910.

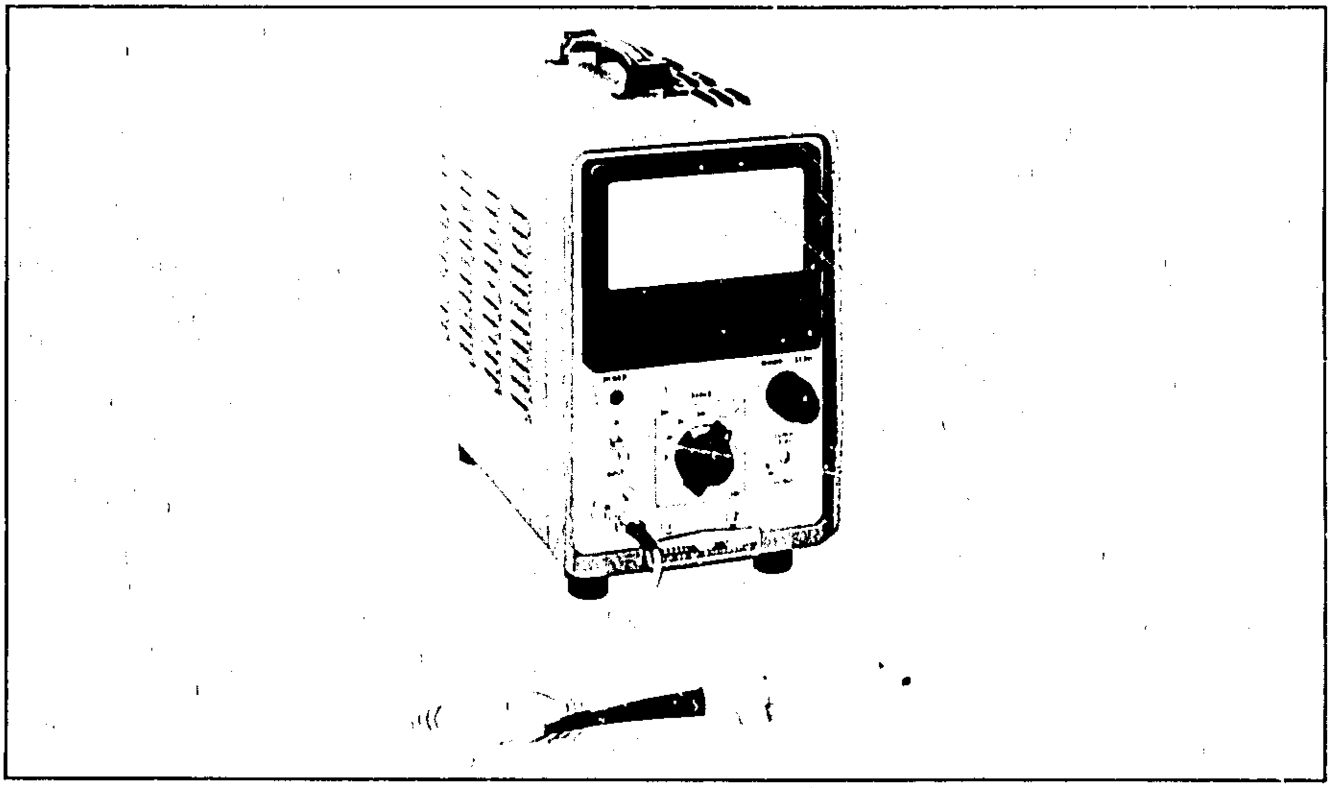


Figure 1-1. Model 428B Clip-On DC Milliammeter

428B SPECIFICATIONS
Table 1-1.

Current Range:
1 mA to 10 A full scale, nine ranges

Accuracy:
±3% of full scale ±0.15 mA, from 0°C to 55°C. (When instrument is calibrated to probe).

Probe Inductance:
Less than 0.5 μH.

Probe Induced Voltage:
Less than 15 mV peak (worst case at 20 kHz and harmonics).

Output:
Variable linear output level with switch position for calibrated 1V into open circuit (corresponds to full scale deflection).
1.5 V Max. into open circuit in uncalibrated position.
0.73 ± .01V into 1KΩ in calibrated position.

Noise:
1 mA Range, < 15 mV rms across 1 kΩ.
3 mA Range, < 5 mV rms across 1 kΩ.
10 mA thru 10 A Ranges, < 2 mV rms across 1 kΩ.

Frequency Range:
DC to 400 Hz (3 dB point).

AC Rejection:
Signals above 5 Hz with peak value less than full scale affect meter accuracy less than 2%. (Except at 40 kHz carrier frequency and its harmonics). On the 10 A range, ac peak value is limited to 4 A.

Probe Insulation:
300 V Max.

AC Power:
115 or 230 V ± 10%, 48 to 440 Hz, 71 W.

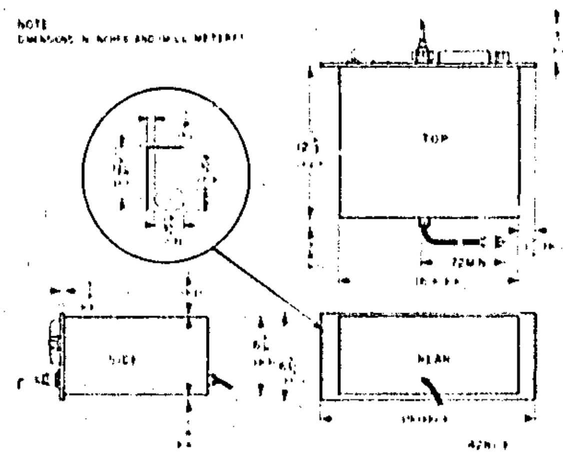
Operating Temperature:
-20°C to +55°C.

Weight:
Rack Mount
Instrument weight: 18 3/4 lbs. (8.5 kg)
Shipping weight: 30 lbs. 13.6 kg)
Cabinet Mount
Instrument weight: 15 5/8 lbs. (7.5 kg)
Shipping weight: 19 lbs. (8.6 kg)

Accessories Available:

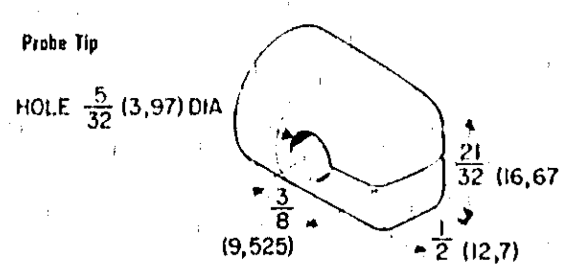
hp Model 3529A	Magnetometer Probe
hp Model 11035A	Output Cable
hp Model 10110A	Output Adapter

Dimensions:
Rack Mount
Note
Dimensions in inches and (millimeters)



Cabinet Mount:
7½" wide, 11½" high, 14½" deep (190,5 x 292,1 x 368,3 mm).

Probe Tip



SECTION II
INSTALLATION

2-1. UNPACKING AND MECHANICAL INSPECTION

2-2. Inspect instrument for signs of damage incurred in shipment. This instrument should be tested as soon as it is received. If it fails to operate properly, or is damaged in any way, a claim should be filed with the carrier. A full report of the damage should be obtained by the claim agent, and this report should be forwarded to us. We will then advise you of the disposition to be made of the equipment and arrange for repair or replacement. Include model number and serial number when referring to this instrument for any reason.

2-3. Hewlett-Packard Company warrants each instrument manufactured by them to be free from defects in material and workmanship. Our liability under this warranty is limited to servicing or adjusting any instrument returned to the factory for that purpose and to replace any defective parts thereof. Any damage to the instrument upon receipt is due to the carrier. File a claim with the carrier as instructed in the preceding paragraph.

2-4. OPERATION CHECK

2-5. This instrument should be checked as soon as it is received to determine that its electrical characteristics have not been damaged in shipment. Refer to the In-Cabinet Performance Checks of Section V in this manual.

2-6. INSTALLATION

2-7. See Paragraph 3-3 before operating this instrument.

2-8. POWER REQUIREMENTS

2-9. Power requirements are given in Specifications table at the front of this manual.

2-10. OPERATION ON 115 OR 230 VOLTS

2-11. This instrument may be used with either a 115 volt or 230 volt supply with a frequency of 48 to 440 Hz, single phase. This instrument is shipped from the factory ready for operation from a 115 volt source unless otherwise indicated.

2-12. To operate from a 230 volt source, the 115-230 switch on the rear apron must be flipped to 230. First turn the instrument off and pull the power cable from the socket. Place a pointed tool, such as the sharpened end of a pencil, in the slot of the switch and pull down. Replace the fuse with the one given in Table 6-1 for 230 volt operation.

2-13. THREE CONDUCTOR POWER CABLE

2-14. The three-conductor power cable supplied with the instrument is terminated in a polarized, three-prong male connector recommended by the National Electrical Manufacturers' Association (NEMA). **The third conductor grounds the instrument chassis for the PROTECTION OF THE OPERATING PERSONNEL.** When using a three-prong to two-prong adapter, ground third lead (green wire) externally.

2-15. RACK MOUNT MODEL

2-16. This instrument is available in a rack mount version in addition to the cabinet model shown in this manual. The rack mount version is identical electrically and similar physically except that the degausser has been moved to the front panel for greater convenience.

2-17. PREPARATION FOR STORAGE AND SHIPMENT

2-18. The best method for packing this instrument is in the original shipping carton with the original fillers packed in the same manner as when received from the factory. Therefore, when unpacking, note carefully the method of packing and save the original packing material for possible future reuse.

2-19. If the original container is not to be used, wrap the instrument in heavy anti static plastic and place it into an inner container. Wrap packing material around all sides of the instrument. Then place the instrument in the inner container into a heavy carton and seal the carton with strong tape or metal bands. Mark shipping container "FRAGILE", "DELICATE INSTRUMENT", etc.

2-20. STORAGE

2-21. No special precautions are necessary in storage except the usual protection against mechanical damage, salt air, etc.

SECTION III
OPERATING INSTRUCTIONS

3-1. INTRODUCTION

3-2. This section contains instructions and information necessary for operation of the Model 428B Clip-On DC Milliammeter.

3-3. OPERATING PRECAUTIONS

CAUTION

a. BEFORE APPLYING OPERATING POWER TO THE 428B, VERIFY THAT THE LINE VOLTAGE SWITCH ON THE REAR PANEL INDICATES THE LINE VOLTAGE TO BE USED AND THAT THE INSTRUMENT IS PROPERLY FUSED.

b. THE PROBE IS INSULATED TO WITHSTAND 300 VOLTS MAXIMUM. DO NOT USE THIS PROBE ON A BARE WIRE WHICH IS MORE THAN 300 VOLTS *PEAK* ABOVE GROUND.

c. DO NOT USE THE 428B PROBE IN THE PRESENCE OF STRONG RF FIELDS.

d. DO NOT EXPOSE THE 428B PROBE TO TEMPERATURES EXCEEDING 130°F (55°C). DO NOT LAY THE PROBE ON TOP OF THE 428B CABINET (OR ANY OTHER HOT SURFACE). PROBE UNBALANCE AND EVENTUAL DAMAGE WILL RESULT.

e. DO NOT DROP THE PROBE OR RELEASE THE FLANGES ABRUPTLY SO THAT THE JAWS SNAP TOGETHER.

f. DO NOT OPERATE THE DEGAUSSER FOR MORE THAN THREE MINUTES CONTINUOUSLY.

g. BECAUSE THE 428B IS COOLED BY CONVECTION, PLACE THE 428B WHERE AIR CAN CIRCULATE FREELY THROUGH THE INSTRUMENT.

h. DO NOT USE THE 428B TO MEASURE DC IN A WIRE WHICH CARRIES MORE AC THAN FULL-SCALE READING ON THE METER.

3-4. OPERATING CONSIDERATIONS

3-5. Interchanging Probe Heads

3-6. Each probe is calibrated at the factory with a particular instrument and carries the serial number of that instrument (serial number appears on probe connector). If a probe has to be replaced, a realignment and recalibration of the instrument is necessary (see also Section V Maintenance).

3-7. EFFECT OF MEASUREMENT ON CIRCUIT

3-8. Reflected Impedance

3-9. The probe will add a small inductance to the circuit of less than 0.5 microhenries due to the magnetic core and magnetic shield. This makes it ideal for measuring current in very low impedance paths such as ground loops where other instruments would disturb the circuit.

3-10. Induced Voltage

3-11. The gating signal, driving the core in and out of saturation, will induce a voltage in the wire carrying the dc current. This induced voltage is less than 15 millivolts peak. If more than one loop is passed through the probe the induced voltage will be multiplied by the number of loops.

3-12. EFFECT OF CIRCUIT ON MEASUREMENT

3-13. Circuit Impedance

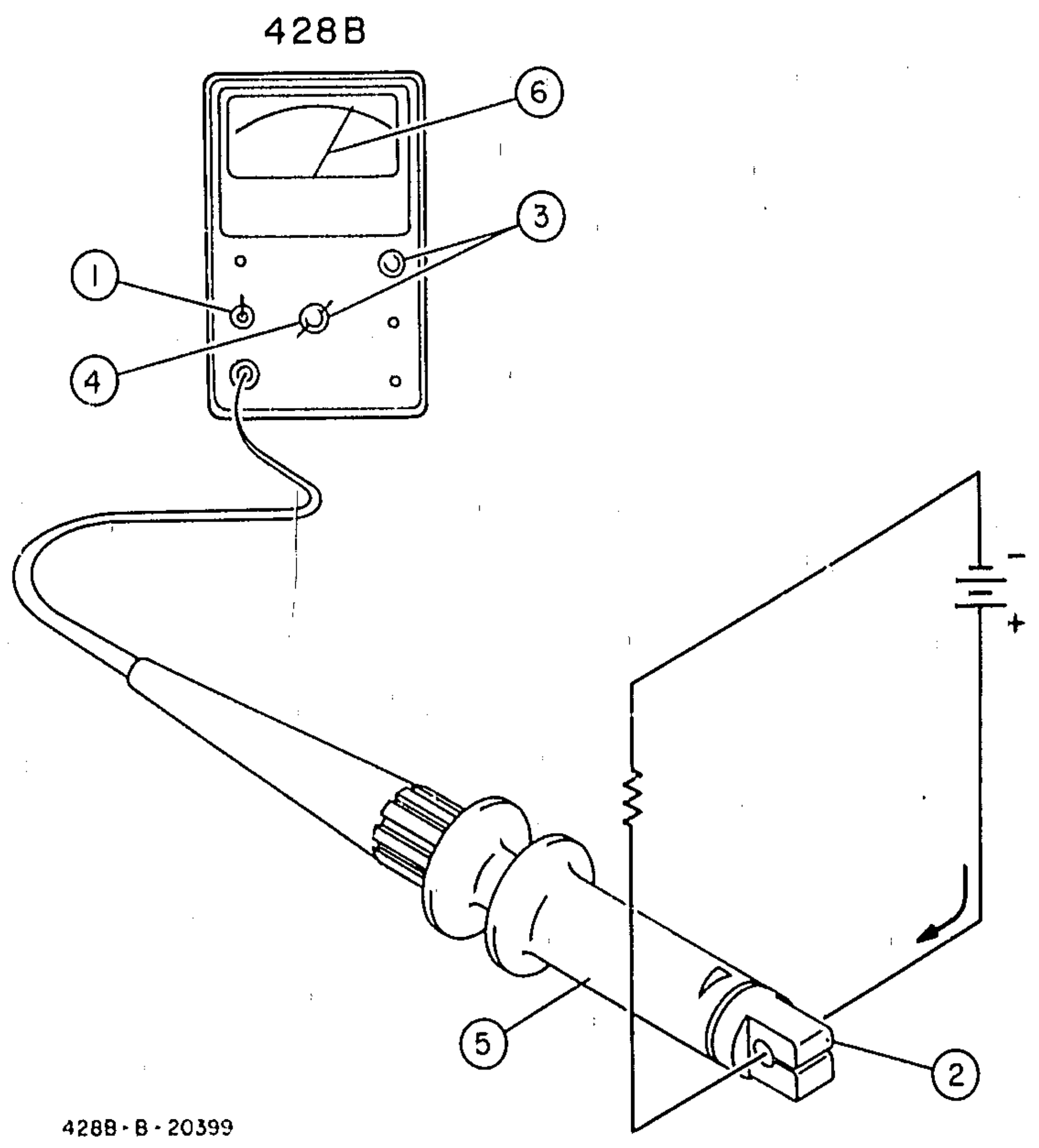
3-14. The impedance of the circuit being measured has practically no effect on the dc current measurement. A shorted loop inserted along with a wire carrying dc current will decrease the reading by only 0.2% of full scale.

3-15. AC Fields & Superimposed AC Current

3-16. The instrument is designed to allow a high amount of ac ripple in the dc being measured. The presence of ac whose peak value equals full-scale reading (limited to 4 amperes peak on 10-ampere range) will cause less than 2% error in the dc reading. Examples of such high ac currents are found in the input of dc filter sections of power supplies.

3-17. AC currents having frequency components of 40 kHz or harmonics thereof will cause an error, as such signals will interfere with the 40 kHz output signal of the probe. The meter will indicate a beat reading if the interfering frequency is within approximately 15 cycles of 40 kHz or its harmonics. Although this situation is very improbable, accurate dc current readings can be obtained by shifting the frequency of the external ac signal slightly.

3-18. The instrument as well as the probe head should not be used in strong ac stray fields. Such fields may exist in the vicinity of open core power transformers, or large dc filter chokes, etc.



1. Turn on power and allow approximately 2 minutes warmup time.

2. Check closure of probe jaws (see Paragraph 3-20).

3. Set RANGE switch to 1 mA. Zero set instrument with Zero control.

4. Set RANGE switch to a range that is higher than the anticipated current to be read.

5. Clip probe jaws around wire carrying dc current, pointing the arrow on the probe in the direction of conventional current (see arrows in figure above).

6. Read current on meter.

7. After use of the Model 428B on the 1 thru 10 AMP RANGE, degauss the probe head (Paragraph 3-29) if zero set cannot be accomplished.

Figure 3-1. Measurement Procedures

3-19. Magnetic Fields

3-20. If the jaws of the probe are incompletely closed, the magnetic shielding and the magnetic circuit will have an air gap. The result is that dc fields, not associated with the dc current being measured, will cause a shift in the meter reading.

3-21. However, there will be an indication of a *strong* external dc field even with the jaws perfectly closed. Usually zero setting with the ZERO control compensates such residual readings for a particular probe location.

3-22. EARTH'S MAGNETIC FIELD. The earth's magnetic field will affect the reading if the jaws of the probe are not completely shielded (jaws partially open). The effect of this field is relatively strong - comparable to deflection due to about 500 mA of current. Complete closure of the jaws can be checked by switching to the 1 mA range with no dc current input. If the jaws mate properly, the zero set should stay within 0.2 mA while rotating the probe head with respect to the earth's magnetic field (probe aligned in an East-West direction).

3-23. If the zero shift is greater, the mating surfaces of the jaws need to be cleaned or the probe wiring may be open (see Section V).

3-24. FIELDS OF PERMANENT MAGNETS. Meter magnets have strong stray fields, which can cause shift in the current indication. Such fields are detected by bringing the closed probe in the area where the measurement is to be made and observing the zero shift (1 mA range).

3-25. FERROUS WIRE. Wires made out of magnetic materials can cause a current reading of 2-3 mA without any connection to the wire. This fact is *important* as leads of most transistors are made out of magnetic material.

3-26. OPERATING PRACTICES

3-27. Mechanical Operation Of Probe

3-28. The probe jaws are opened by simply squeezing together the two flanges on the probe body. An internal spring returns the jaws to their proper position when the flanges are released. (See Paragraph 3-3e.).

3-29. Degaussing Of Probe Head

3-30. To demagnetize the probe, proceed as follows:

a. Insert probe into degausser at the rear of the instrument (located on front panel of rackmount models) with arrow on probe in same position as arrow marked on chassis.

b. Depress degausser switch S3 to energize degausser.

c. Withdraw probe very slowly for the first few inches while depressing the degausser switch until probe is removed approximately one foot.

d. Zero instrument on 1 mA range with ZERO control.

3-31. Under normal operating conditions, degaussing may be necessary after measuring current on the 1 thru 10 AMP RANGE.

3-32. Normally, it takes about 10 seconds to degaus the probe when using the above method (see Caution, Paragraph 3-31).

3-33. Electrical Zero Set

3-34. If the instrument cannot be zero set electrically (with ZERO control) there are two probable causes: 1) Incomplete closure of probe jaws, 2) Magnetization of probe head.

3-35. Dust deposits on the lapped surfaces of the probe jaws create an air gap. If the jaws are not completely closed, the earth's magnetic field will affect the reading. With the RANGE switch at 1 mA, rotation of the closed probe should not vary the zero set more than 0.2 mA. Cleaning of the jaws will restore proper operation conditions (see Section V, Cleaning of Probe Jaws).

3-36. Magnetic shields protect the probe head from stray magnetic fields. However, excessive dc currents (such as short circuit discharge currents from electrolytic capacitors, etc.) will magnetize the probe. For demagnetization of probe head, see Paragraph 3-29, Degaussing of Probe Head.

3-37. Polarity Of Current

3-38. The arrow on the probe head indicates the direction of the conventional current flow for upscale reading. Reversal of the current flow direction will reverse the indication on the meter (see Figure 3-2).

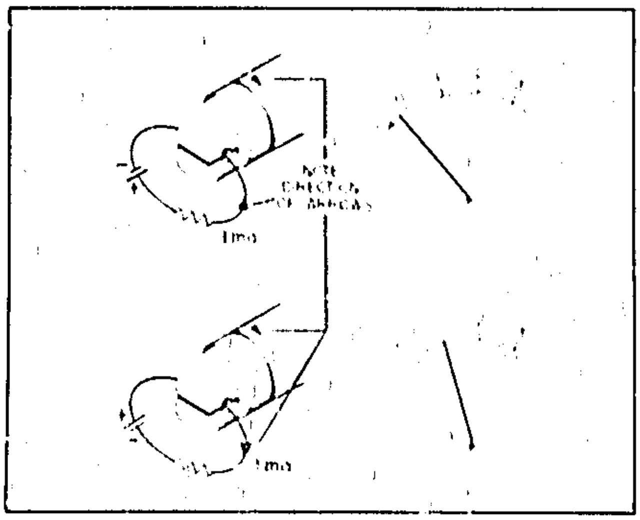


Figure 3-2. Polarity of Current

3-39. Increasing The Absolute Sensitivity

3-40. The sensitivity of the instrument can be increased by looping the wire (carrying the dc current) several times through the opening of the probe (see Figure 3-3). For example, three turns increase the sensitivity three times. With an increased sensitivity, however, the induced voltage between the probe and the circuit under measurement will increase also.

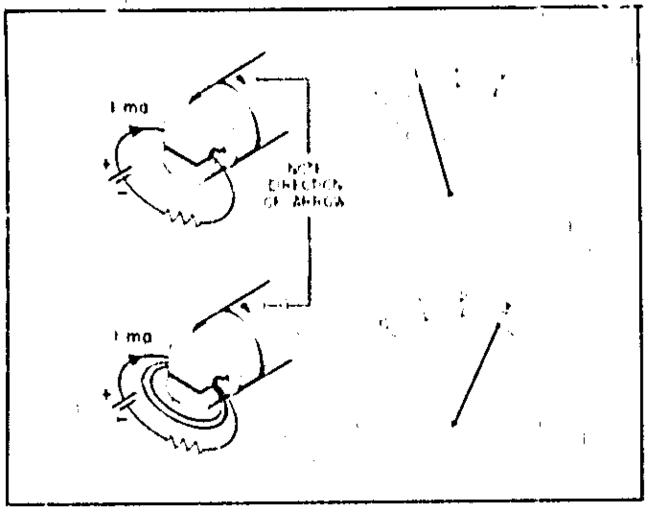


Figure 3-3. Increasing the Absolute Sensitivity

3-41. Current Check Loops

3-42. In restricted situations such as printed circuit boards, wire loops for the probe can be built into the circuit to allow convenient current measurements with the Model 428B. Here, currents can then be measured under operating conditions with the same ease as voltage measurements.

3-43. Circuits can also be modified to accept an impromptu loop for testing. As an example, to measure the collector current of a transistor for troubleshooting purposes, the collector lead can be removed from the board and a loop of fine wire soldered between the collector lead and the board. To measure current through a resistor, lift one lead and install a series loop, clip the 428B probe around the loop and measure current through the resistor. As an alternative, an equivalent resistor with long leads can be installed to replace the resistor in question.

3-44. Nulling Currents

3-45. The resolution of the 428B can be increased by nulling one current against another and measuring the difference between the two. To null the reading, clip the probe over both wires at once with the wires so arranged that the currents are going in opposite directions. The considerations mentioned in Paragraph 3-39 also apply to current nulling. For example, assume that a 0.6 A current source is to be tested against a 0.4 A standard. The 0.6 A supply should be looped twice through the probe jaws and the 0.4 A supply should be looped three times through the jaws such that the two currents oppose each other. It should be remembered when making such a measurement, that the absolute value of any deviations observed have been multiplied. If, in the above example, the 0.6 A supply wavered by .01 A, the change would be read as .02 A on the meter.

3-46. USE OF OUTPUT JACK

3-47. The OUTPUT jack enables the 428B to be used as a dc-coupled amplifier/I-E transducer/isolator. The basic action of the 428B (considered as an input/output device) is to sense the magnetic field around a current carrying wire and deliver a proportional voltage at the OUTPUT jack. The value of the output can be varied by using the OUTPUT LEVEL control to produce as much as 1½ volts at 1 mA. While the 428B meter registers average dc (ignoring ac), the output at the OUTPUT jack contains both the dc and ac components of the signal being measured.

3-48. With Oscilloscope

3-49. To display the output of the 428B on an oscilloscope:

a. If the oscilloscope is dc coupled, it can be calibrated as in Paragraph 3-51.

b. Clip the probe around the wire which contains the signal to be displayed.

c. Connect the oscilloscope input to the 428B OUTPUT jack.

d. Adjust the 428B RANGE switch to the appropriate range.

3-50. With Recorder

3-51. To record the output of the 428B on a graphic recorder:

a. Insure that the recorder's input impedance exceeds 1400 ohms.

b. Connect the recorder input to the 428B OUTPUT jack.

c. Zero the 428B on the 1 mA Range, turn OUTPUT LEVEL to minimum output.

d. Zero the recorder.

e. Adjust the 428B ZERO control for full-scale on the 428B meter.

f. Adjust the 428B OUTPUT LEVEL control for full scale on the recorder.

g. Zero the 428B, switch to the appropriate range and clamp the 428B probe around the wire which carries the signal to be measured.

3-52. When recording current variations with the 428B, it should be borne in mind that the 428B displays some long term zero drift. The 428B zero drift normally amounts to about 300 μA (indicated) per day so periodic checks should be made to determine whether or not the ZERO controls need adjustment.

SECTION IV
THEORY OF OPERATION

4-1. INTRODUCTION

4-2. This section describes the overall operation of the Model 428B, the operating principle of the current probe and the function of the different circuits of the instrument.

4-3. THEORY OF OPERATION

4-4. The simplified block diagram of Figures 4-1 and 4-2 shows the basic operation of the Model 428B Clip-On DC Milliammeter.

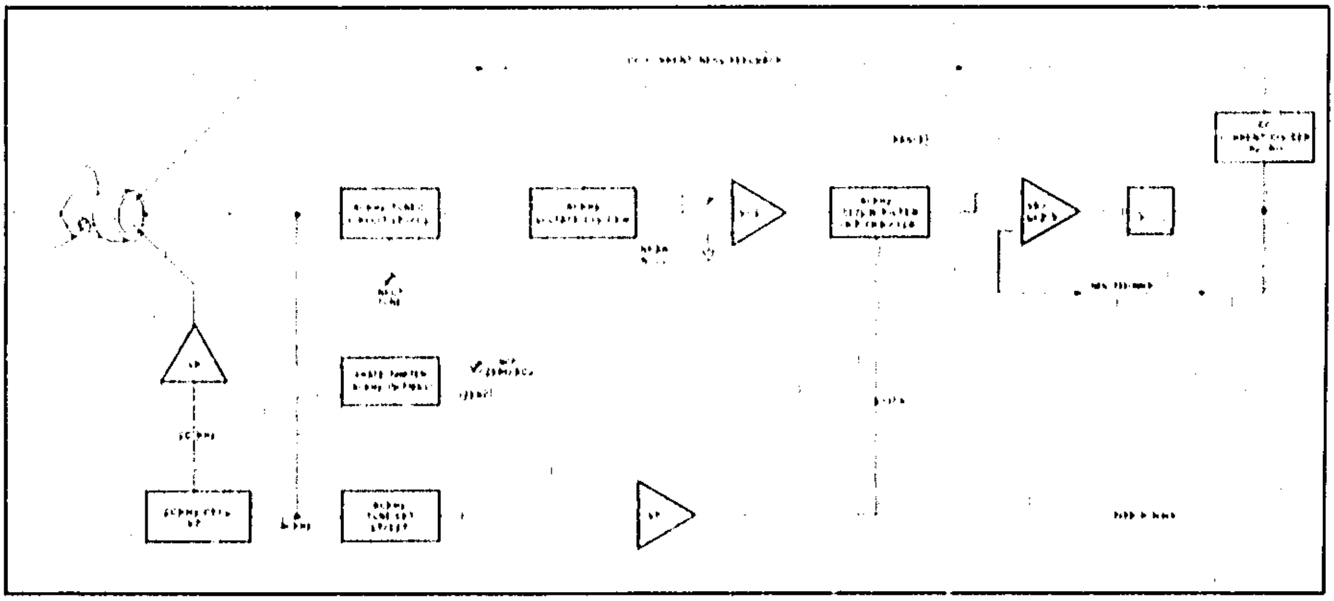


Figure 4-1. Block Diagram

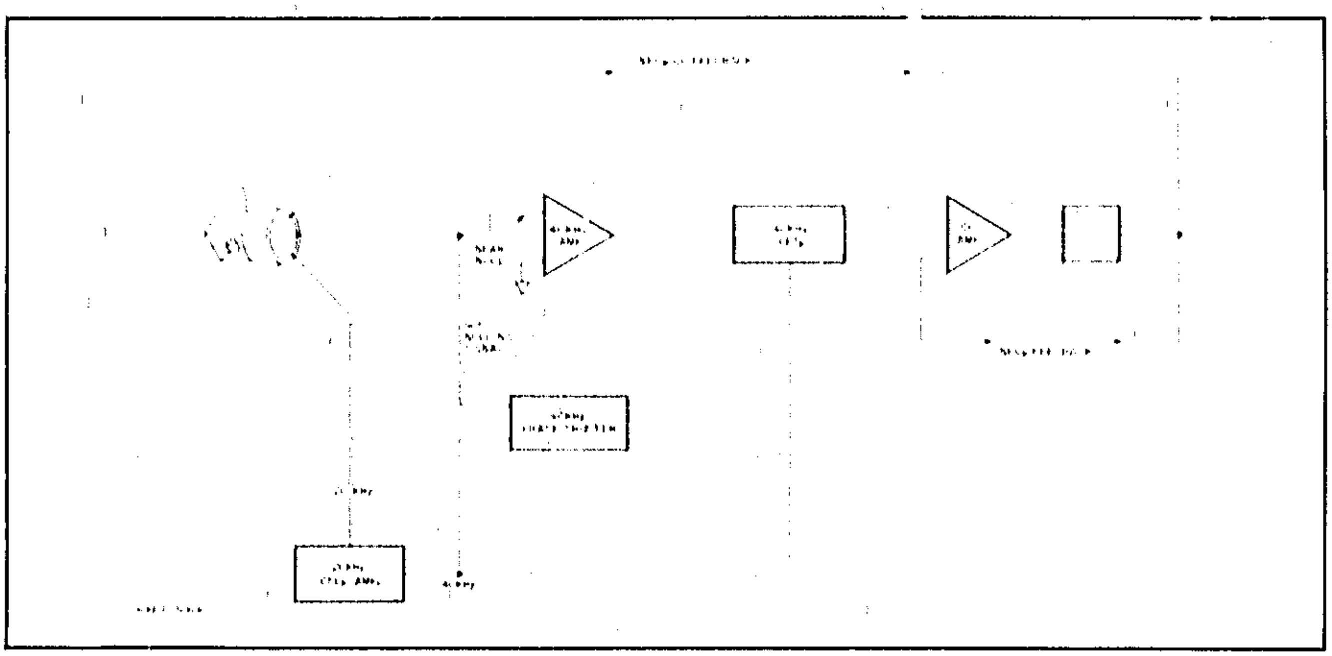


Figure 4-2. Simplified Block

4-5. The probe clips around a wire carrying dc current and delivers a 40 kHz output signal which is proportional to the dc current. For transducing the dc current into a 40 kHz signal, the probe requires a 20 kHz gating signal, as described in detail under Paragraph 4-9, Current probe.

4-6. The 40 kHz output signal of the probe is amplified, detected and fed back as negative feedback current to the probe head cancelling the effect of the measured dc current and thus reducing the 40 kHz output signal almost to zero. The negative feedback current, being proportional to and magnetically almost equal to the dc current of the inserted wire, is used to indicate the measured dc current.

4-7. The 20 kHz oscillator has two functions: First, it supplies a 20 kHz signal for driving the probe head, and also provides a 40 kHz (second harmonic) signal for gating the 40 kHz Synchronous Detector.

4-8. Due to slight unbalances, the probe head output contains a small 40 kHz signal, even with no dc current being measured. A 40 kHz phase-shifter output cancels such residual 40 kHz signal (zero-set controls).

4-9. CURRENT PROBE

4-10. The probe head is a specially designed second harmonic flux-gate type of magnetometer used to measure the magnetic field around a wire carrying direct current.

4-11. The flux gate principle is easily understood by referring to the mechanical model shown in Figure 4-3.

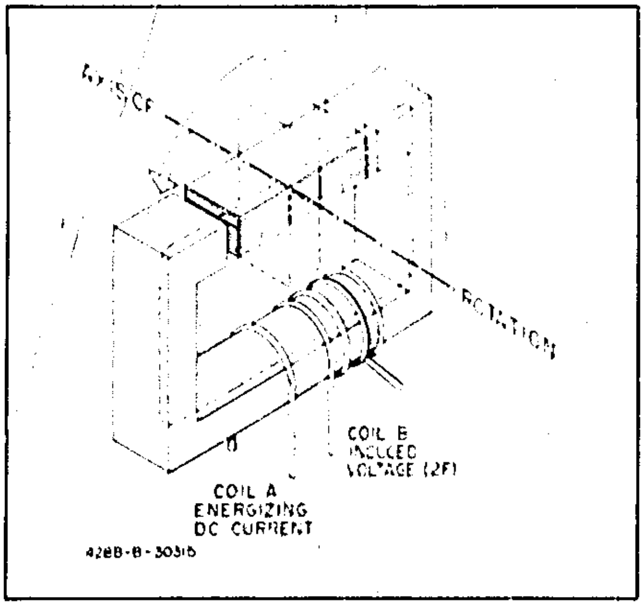


Figure 4-3. Magnetic Mechanical Analogy

4-12. Coil A (representing wire through probe), is energized with dc, producing a dc flux in the core. Armature is rotating at a constant rate (F), gating the flux 2F times per second inducing a voltage of 2 F frequency in coil B. The amplitude is determined by the dc in coil A.

4-13. The Model 428B head uses this principle in a similar way. Figure 4-4 shows the basic concept of a saturable flux gate.

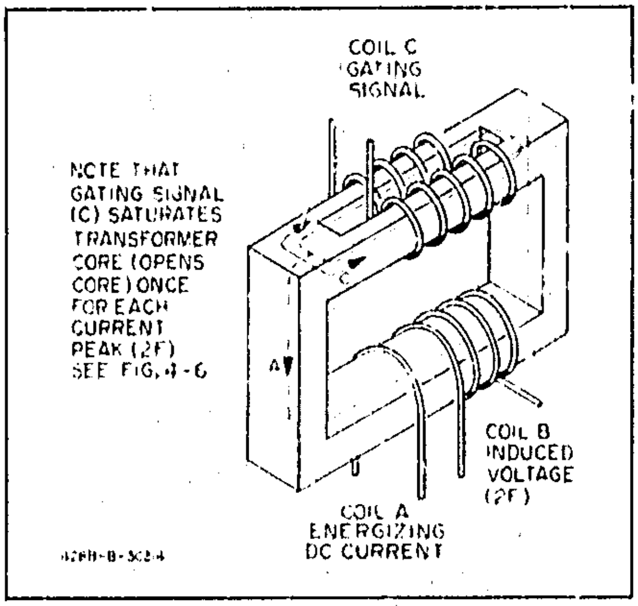


Figure 4-4. Basic Flux Gate

4-14. A magnetic core in saturation loses permeability and, therefore, is comparable to a core that has been mechanically opened (low permeability due to air gap).

4-15. Coil C saturates the core periodically with a 20 kHz signal, driving the small cores in and out of saturation twice per cycle or once for each peak (positive or negative) of the input current. (See Figure 4-6). **The only function of the 20 kHz signal is to gate the dc flux in the core of the current probe.**

4-16. The 428B probe head is actually analogous to the flux gate shown in Figure 4-5. The energizing dc current produces flux path "A". Flux path "A" is periodically interrupted by saturation of the (transformer type) core, a result of the two flux paths "C". Refer to Figure 7-3 and note that the current enters L3 and L4 from the same end and that the coils are wound in opposite directions causing opposite magnetic polarities and the consequent circular flux path (c).

4-17. The four coils in the 428B probe head serve 3 purposes: (a) To saturate the cores, a result of the 20 kHz current that flows between pins 1 and 2. This current is generated by the 20 kHz oscillator-amplifier circuits. (b) To act as a secondary, picking up a chopped signal from the wire that is clamped in the probe jaws. (c) To conduct the dc feedback current that tends to annul the energizing dc current from the wire being measured.

4-18. Because the coils are electrically arranged in a balanced bridge circuit, the 20 kHz signal is balanced at the output of the bridge (pins 3 and 4); and there is no 20 kHz differential signal at this point. The 40 kHz signal and the dc feedback current are also nulled out by the balanced bridge so that these signals do not appear as a differential voltage across pins 1 and 2. The dc feedback current is isolated from the 40 kHz amplifier by capacitor C11. The 40 kHz is kept out of the dc circuitry by RF choke L6.

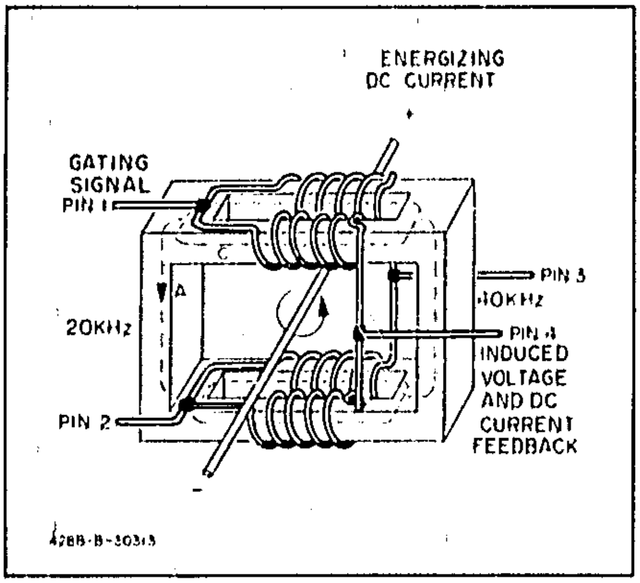


Figure 4-5. 428B Flux Gate

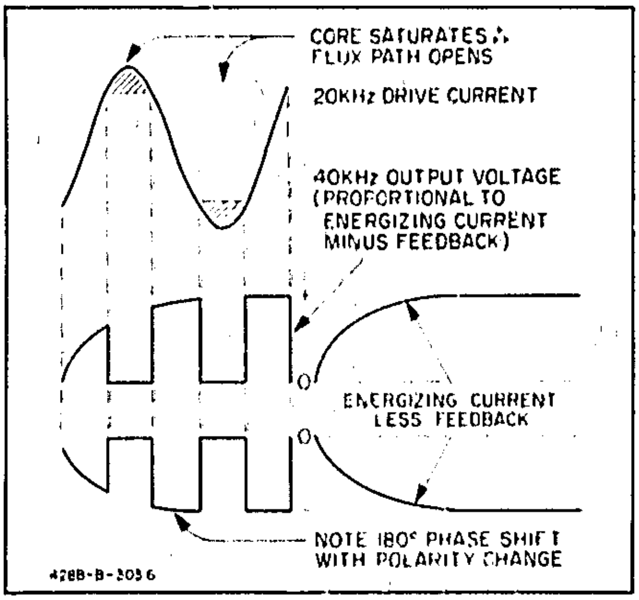


Figure 4-6. Waveforms

4-19. 20 kHz OSCILLATOR

4-20. The function of the 20 kHz oscillator is to generate a balanced 20 kHz signal which, after amplification, is used for driving the probe head in and out of saturation.

4-21. The circuit of the 20 kHz oscillator is shown in Figure 7-3. The oscillator V7 is operating in push-pull having a plate circuit tuned to 20 kHz. Transformer coupling provides positive feedback through resistors R94 and R95 to the oscillator control grids. The control grids of oscillator V7 supply the drive signal for the push-pull head drive amplifier V8. The oscillator level is adjusted by controlling the cathode current of V7.

4-22. The common cathodes of oscillator V7 supply the 40 kHz signal (2 pulses per 20 kHz cycle) needed for the synchronous detector gate amplifier V5 and the 40 kHz phase shifter.

4-23. HEAD-DRIVE AMPLIFIER

4-24. The head-drive amplifier V8 supplies the balanced 20 kHz signal for the probe head. Drive balance adjustment R98 controls the current ratio of the two triode sections, and hence the second harmonic output. The dc bias voltage for the oscillator and the head-drive amplifier is obtained from reference tube V11.

4-25. DETECTOR GATE AMPLIFIER

4-26. The 40 kHz resonant circuit C1, C2, and L5 increases the level of the gate signal and filters out all signals except 40 kHz. It also allows phase adjustment of the signal to correspond to the phase of the Synchronous Detector.

4-27. The operation of the Synchronous Detector requires a high level 40 kHz signal. The 40 kHz output signal of the oscillator V7 passes through a tuned circuit and drives the gate amplifier V5. The output of V5 delivers a 40 kHz gate signal to the Synchronous Detector.

4-28. 40 kHz INPUT/AMPLIFIER CIRCUIT

4-29. The 40 kHz output voltage of the probe head is resonated by a 40 kHz series resonant circuit (L5 and C1/C2). Resistor R1 broadens the resonance response by lowering the Q to minimize drift problems. The 40 kHz signal passes through a voltage divider S1B, which keeps the loop gain constant for all current ranges by maintaining a constant input level range to stage V1. The output of the 40 kHz amplifier V1 is band-pass coupled to the 40 kHz detector driver stage V2. The output signal of V2 is isolated from ground by transformer T2, and fed to the 40 kHz synchronous detector.

4-30. SYNCHRONOUS DETECTOR AND FILTER (C24)

4-31. The Synchronous Detector detects the amplitude and the phase of the 40 kHz signal. Phase detection is necessary to preserve negative feedback at all times. Since the probe may be clipped over the wire in either of two ways the phase of the signal may vary by 180°. If phase detection were not present this 180° phase reversal would cause positive feedback and the instrument would oscillate. With phase detection the polarity of the feedback will change also, maintaining the feedback negative around the system at all times.

4-32. The synchronous detector requires a large 40 kHz gating signal, having the frequency of the desired signal. Figure 4-7 shows the synchronous detector drawn as a bridge circuit.

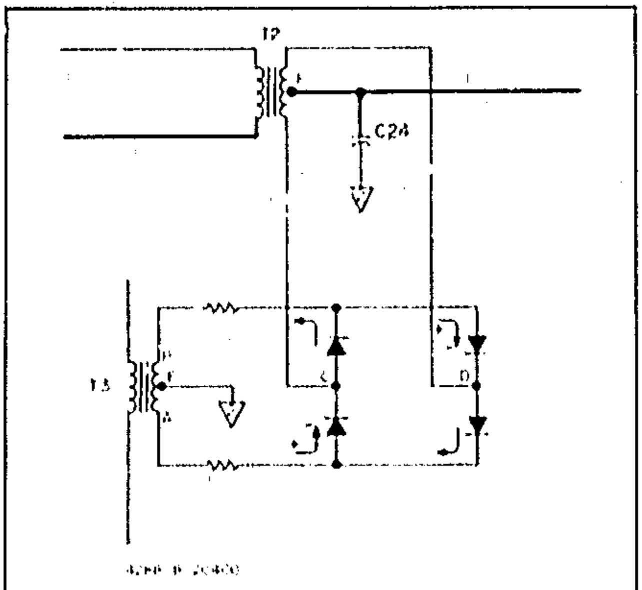


Figure 4-7. Detector Bridge

4-33. On one half cycle, with A much more positive than E and with B equally more negative than E, the balanced circuit ACB conducts hard, and C becomes effectively equal to point E. Circuit BDA is opened at this time by its back-biassed diodes, and only the signal that appears across the conducting half of the T2 (FC) will change C24.

4-34. On the next half-cycle BDA conducts, ACB becomes open, and the signal across FD will charge C24. If signal F is positive with respect to C on the first half-cycle, signal F will be positive with respect to D on the second half-cycle, and the top of C24 will consistently be charged positively. If the signal at F changes phase by 180° with respect to the gating signal at T3, the top of C24 will consistently be charged negatively.

4-35. In summary then, C and D are alternately grounded, and the polarity of the signal across T2 changes as C and D are switched to produce an output wherein the polarity is dependent on the phase of the input. Where C is in phase with A, F will be negative when C and D are grounded. Where C is 180° out of phase with A, F will be positive when C and D are grounded.

4-36. DC AMPLIFIER

4-37. The dc amplifier supplies a negative dc feedback current to the probe proportional to the output of the synchronous detector. The polarity of the negative feedback current changes if the polarity of the dc current (measured in the probe) changes. In this way the feedback of the system remains negative at all times thus maintaining the stability of the instrument.

4-38. In addition, this local negative feedback loop stabilizes the gain of the DC Amplifier.

4-39. Tube V6 is a differential amplifier in which a signal of approximately 1 volt (for full-scale deflection) is fed to pin 7 and compared with the signal on pin 2. The output of V6 is fed to the base of Q3.

4-40. Transistor Q3 drives the current-amplifiers Q1 and Q2 which are used as emitter-followers in a push-pull NPN-PNP pair combination.

4-41. The output current from the complimentary pair, Q1 and Q2, goes through the meter circuit to the current divider S1A which feeds a portion of this current, appropriate for the range this instrument is working on, to the probe head as negative current feedback.

4-42. After passing through S1A and the probe head, the combined current goes through the parallel resistor network R60-64. This develops a voltage at the junction of R61 and R62 which is proportional to the feedback current. This voltage is applied to pin 2 of V6 to complete the local feedback loop of the DC Amplifier. This circuit makes the output current of the DC Amplifier proportional to the voltage applied to the input grid, pin 7, of V6.

4-43. NEGATIVE FEEDBACK CURRENT CIRCUIT

4-44. The negative feedback current path is shown in Figure 4-8. Current divider S1A divides the feedback current in proportion to the dc current being measured*. For a dc input of 10 A, approximately 50 mA feedback current is fed to the probe head. Since an equal number of ampere turns are necessary for canceling the main dc flux, the feedback coil inside the head requires approximately 200 turns.

* Maintaining the current through meter M1 constant (1 mA maximum) for all current ranges. Inductance L6 isolates the 40 kHz signal from the dc current circuit.

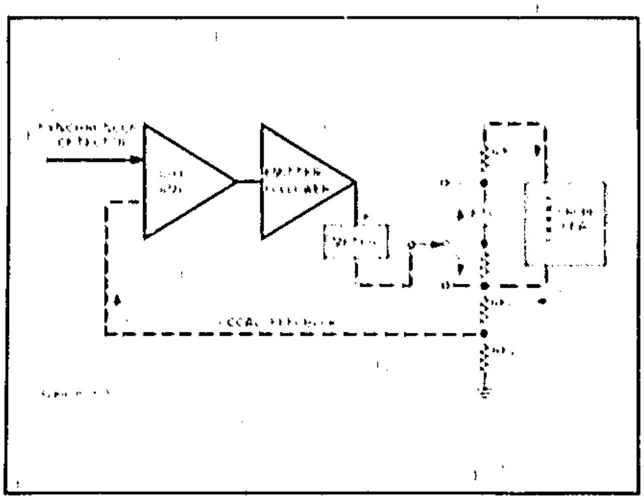


Figure 4-8. Negative Feedback

4-45. 40 kHz PHASE SHIFTER

4-46. The output of the 40 kHz phase shifter is fed to the head of the probe to cancel any residual 40 kHz output signal which exists when zero dc is being measured. The canceling signal is obtained by adding two voltages which are 90° out of phase and variable in amplitude. Figure 4-9 shows the circuit and the idealized phase relationship of the two output voltages with respect to the signal from the oscillator.

4-47. By adding the two output voltages (vector A and B) a 40 kHz signal is obtained, having phase angle and amplitude to cancel exactly the residual 40 kHz signal from the probe (vector C). Once the residual 40 kHz signal of the probe has been canceled, the ZERO control compensates for any normal variations of zero shift. This control is necessary only on the lower ranges.

4-48. POWER SUPPLY

4-49. A single series-regulated power supply of the conventional type provides 272 volts regulated for the circuits of the instrument. Voltage reference zener diodes CR10 and CR17 provide a constant cathode potential at control tube V10 and this is the reference potential for the control grid of V10.

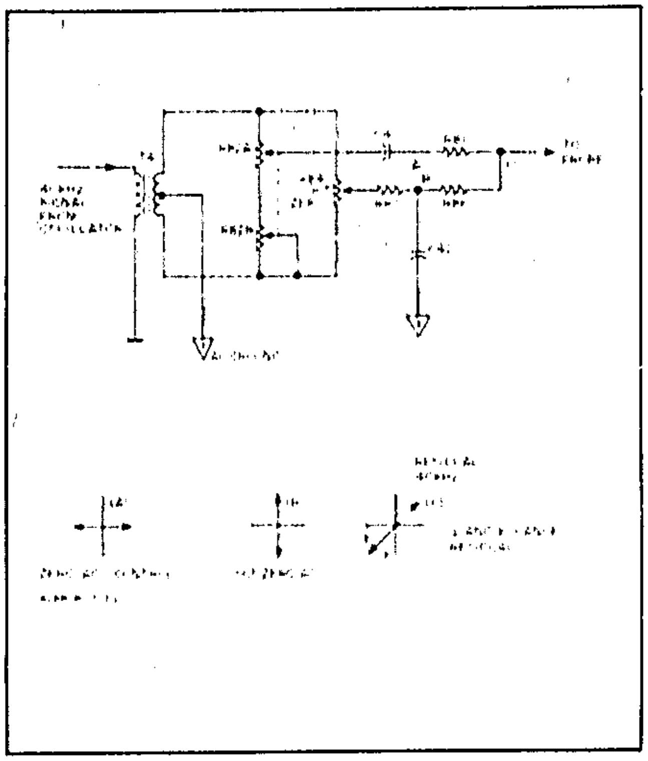


Figure 4-9. 90° Phase Shift

WARNING

Maintenance described herein is performed with power supplied to the instrument, and protective covers removed. Such maintenance should be performed only by service-trained personnel who are aware of the hazards involved (for example, fire and electrical shock). Where maintenance can be performed without power applied, the power should be removed.

SECTION V
MAINTENANCE

5-1. INTRODUCTION

5-2. This section contains the service information which is required to properly maintain the 428B Clip-On DC Milliammeter. Included are performance checks, adjustment and calibration procedures, and servicing and troubleshooting information. A Performance Check Test Card is provided at the end of this section.

5-3. TEST EQUIPMENT REQUIRED

5-4. The test equipment required to perform the operations outlined in this section is listed in Table 5-1. This table includes the type of equipment, critical specifications, purpose, and recommended model. If the model recommended is not available, equipment which meets or exceeds the critical specifications listed may be substituted.

Table 5-1. Recommended Test Equipment

Instrument Type	Required Characteristics	Recommended Model	Use
Meter Calibrator	Accuracy: ±0.1% FS ±0.2% of reading	hp Model 6920B Meter Calibrator	PAT
Variable Line Transformer	Input: 115V ac Output: 103V to 127V	Variac, General Radio W5MT3A	P
Function Generator	Output: dc to 400Hz, >10mA	hp Model 3310A Function Generator	P
Oscilloscope	Input: dc to 40kHz, 100mV/cm ±3%	hp Model 180C with 1801A Plug-in	PAT
Counter	Input: 40KHz ±20Hz	hp Model 5381A	AT
AC Voltmeter	Range: 0.01V to 3V Accuracy: ±3%	hp Model 403B	PAT
Multimeter	Range: 0 to 300v ac/dc Accuracy: ±0.1% dc ±1.6% ac	hp Model 3435A Multimeter	PAT

P Performance Test, A Adjustment Alignment, T Troubleshooting

Table 5-2. Recommended Components For Tests

Component	Sepcifications	Use	Recommended hp Part Number
Capacitor	.0082 μF ± 2%, 300 VDC	Alignment	0160-2102
Resistor	50 Ω ± 1%, 1 W	Performance Checks	0698-8165
Resistor	1 K ± 1%, 1/8 W	Alignment Performance Checks	0757-0280
Resistor	390 Ω ± 5%, 1/2 W	Alignment	0686-3915
Resistors(2)	10 K ± [illegible]%, 1/8 W, matched	Alignment	0757-0442

5-5. IN-CABINET PERFORMANCE CHECKS

5-6. The performance checks described in Paragraphs 5-7 through 5-24 are front panel procedures designed to compare the Model 428B with its published specifications. These tests may be incorporated into periodic maintenance, post repair, and incoming quality control checks. The performance checks should be conducted before any attempt is made to adjust or calibrate the instrument. During the in-cabinet performance checks, the Model 428B should be connected to the ac line through a variable line transformer so that line voltage may be varied ± 10% from 115 to 230 Vac to assure that the instrument operates correctly at various ac line voltages.

5-7. CLEANING OF PROBE JAWS

5-8. When the probe shows excessive sensitivity to the magnetic fields around it, the probe jaws should be cleaned (to determine excessive sensitivity, see Paragraph 5-24 Step a). Excessive sensitivity to external fields can be caused by foreign material between the probe jaws or by overheating (see Paragraph 3-3 Step d). The probe jaws should always be cleaned prior to calibration, adjustment or repair of the 428B.

NOTE

Each 428B probe is calibrated at the factory with a particular instrument (instrument serial number appears on the probe connector). If a probe is replaced, alignment and calibration of the 428B is required.

5-9. To clean the probe jaws, open the probe and brush off the mating surfaces with the brush which is supplied with the instrument. If the brush will not remove the contaminant, disassemble the probe and clean it with a pencil eraser as illustrated in Figure 5-1. When reassembling the probe, be sure that the arrow on the body of the probe points to the heavy red wire as shown in Figure 6-1.

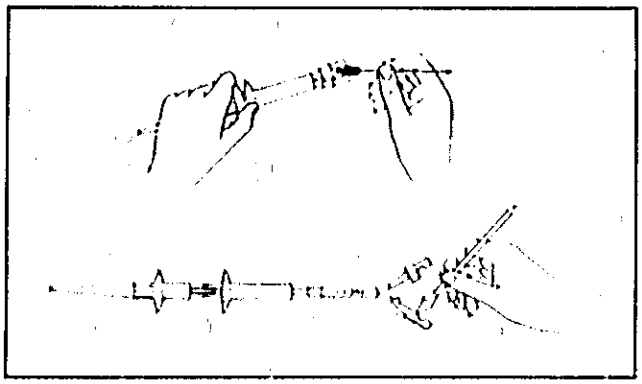


Figure 5-1. Cleaning Probe Jaws

5-10. ELECTRICAL ZERO SET

5-11. In the following procedure the numbers in parentheses refer to Figure 5-2.

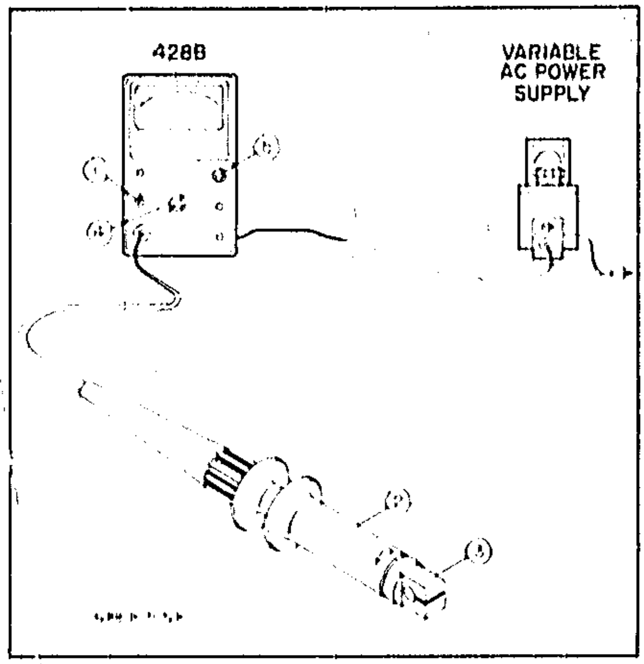


Figure 5-2. Electrical Zero Set

a. Connect the 428B to the power line through a variable transformer.

b. Turn on power (1) and allow about two minutes of warmup time.

c. Set RANGE switch (4) to 1 mA.

d. Place probe (2) away from any stray fields such as meter magnets or open core transformers. Point probe in an East-West direction.

e. Insure that the probe jaws (3) are completely closed (Paragraph 5-24 Step a, outlines a way to do so).

f. Zero-set the 428B with the ZERO (5) control. If the meter cannot be zeroed, degauss the probe (Paragraph 3-29) or clean the probe jaws (Paragraph 5-7).

g. Change the line voltage from 103 to 127 volts (± 10%) and read zero drift on the 428B meter. Zero drift should not exceed ± 0.2 mA.

5-12. Allow a 30 minute warmup and stabilization period before conducting the following performance checks.

5-13. RANGE CHECK

5-14. Set up and connect the 428B, shown in Figure 5-3, to the recommended meter calibrator. If the recommended meter calibrator (see Table 5-1 for the recommended model) is not available, any stable current source capable of operating over a range from 1 mA to 5 A may be used. This current source should be connected in series with a precision ammeter with the same range (1 mA to 5 A) and accuracy as the meter calibrator (see Table 5-1 for the required accuracy). Do the following:

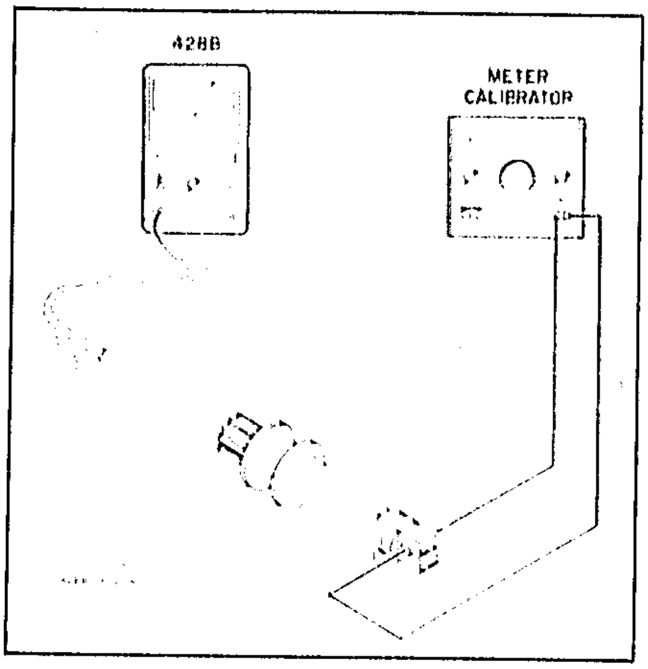


Figure 5-3. Range Check

a. Set the 428B to the 1 mA range. Degauss the 428B probe and zero the instrument using the procedure in paragraph 3-29.

b. Set the meter calibrator for a 1 mA output. Connect a test lead between the output terminals of the meter calibrator and loop (one loop) the test lead through the jaws of the 428B probe (see Figures 3-3 and 5-3). Make sure the reading on the 428B is 1 mA ± 180 μA.

c. Check the 428B 10 mA, 100 mA, and 1 A ranges by setting the meter calibrator for a 10 mA, 100 mA, and 1 A output, respectively. The readings on the 428B should be 10 mA ± 0.45 mA, 100 mA ± 3.15 mA, and 1 A ± 0.03 A.

d. Remove the 428B probe from the test lead and set the instrument to the 3 mA range. Degauss the probe and zero the instrument using the procedure in paragraph 3-29.

e. Set the meter calibrator for a 1 mA output. Loop the test lead through the jaws of the 428B probe (see Figures 3-3 and 5-3) three times instead of just once. Make sure the reading on the 428B is 3 mA ± 240 μA.

f. Check the 428B 30 mA, 300 mA, and 3 A ranges by setting the meter calibrator for a 10 mA, 100 mA, and 1 A output, respectively. The readings on the 428B should be 30 mA ± 1.05 mA, 300 mA ± 9.15 mA, and 3 A ± 0.09 A.

g. Check the 428B 10 A range by looping the test lead through the probe two times instead of three times. Set the 428B to the 10 A range and the meter calibrator to the 5 A range. Make sure the reading is 10 A ± 0.3 A.

h. Remove the test lead from the probe and degauss the probe using the procedure in paragraph 3-29.

5-15. METER TRACKING

5-16. The test arrangement and equipment required for this test are the same as for Paragraph 5-13.

a. Zero the 428B on the 1 mA range.

b. Switch the 428B to the 100 mA range. Switch the meter calibrator to the 10 mA range and adjust for 10 mA of output. Connect a long, thin test lead to the output terminals of the meter calibrator and loop the lead ten times through the jaws of the 428B probe. Read 100 mA ± 3.15 mA on the 428B. Remove the test lead from the probe jaws one loop at a time and check the meter linearity. Each reading should be within 3.15 mA of the nominal (e.g., 90 ± 3.15 mA, 80 ± 3.15 mA, etc.).

5-17. OUTPUT CALIBRATION

5-18. A meter calibrator, dc voltmeter and a one kilohm resistor are required for this test.

a. Switch the 428B and the meter calibrator to the 100 mA range. Set the 428B output level to the CAL position. Connect a test lead between the meter calibrator output leads and clip the 428B probe to the lead.

b. Set the meter calibrator to 100 mA output and read full-scale on the 428B.

c. Connect a voltmeter in parallel with the 1000 ohm resistor to the output jack of the 428B.

d. The voltmeter should read 0.73 V ± 10 mV.

5-19. FREQUENCY RESPONSE

5-20. A 50 ohm resistor, a function generator and oscilloscope are required to complete this check.

a. Connect a 50 ohm resistor across the output of the function generator.

b. Turn the 428B RANGE switch to 100 mA then clip the 428B probe around the resistor lead.

c. Apply a .0005 Hz square wave from the function generator. The 3310A function generator settings are:

Range: .0001	Function: Square
DC Offset: 0	Frequency Dial: 5

d. Set the function generator Output Level control for a full-scale reading on the 428B.

e. Connect the vertical input of the oscilloscope to the output jack of the 428B.

f. Set the coupling of the oscilloscope input to DC. Set sensitivity and vernier to display variations of the 428B output as a 10 centimeter peak-to-peak signal.

g. Set the function generator to the sine function.

h. Slowly raise the frequency of the function generator output using the frequency dial and function switch as necessary to bring the output to 400 Hz. Watch the oscilloscope, looking for the lowest amplitude of peak deflection.

i. The peak-to-peak level of the waveform should not drop below 7 centimeters (−3dB).

5-21. AC OVERLOAD

5-22. An oscillator or function generator, a 50 ohm resistor, an ac voltmeter or oscilloscope, and the meter calibrator are required to complete this check (a filament transformer and suitable current limiting resistors can be substituted for the oscillator shown in Figure 5-4).

a. Set the meter calibrator for 10 mA. With the 428B on the 10 mA range clip the 428B probe onto the lead which connects the calibrator terminals.

b. Note the 428B reading.

c. Set the function generator to 60 Hz, its output to generate a 10 mA peak sine wave into a 50 ohm resistor (1 volt peak-to-peak or 0.35 volt rms across a 50 ohm resistor).

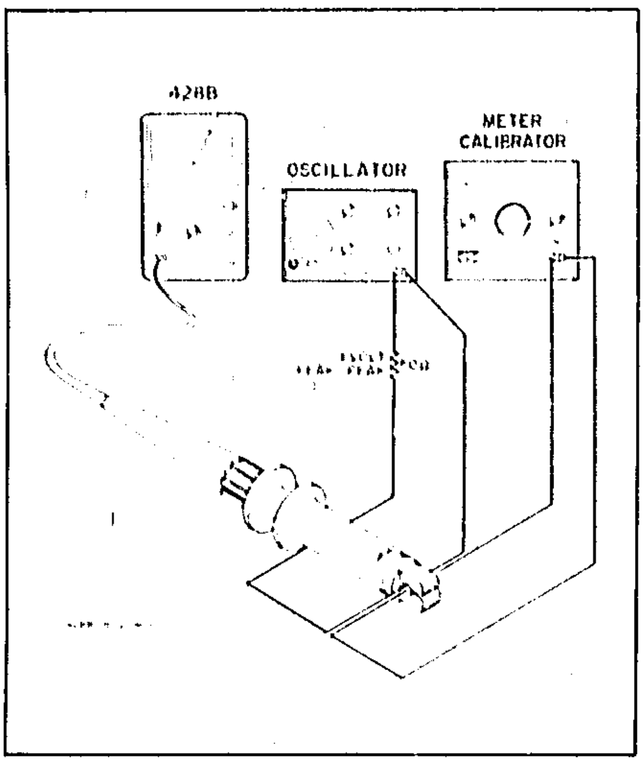


Figure 5-4. AC Overload

d. Clip the 428B probe onto *BOTH* the wire from the meter calibrator and the resistor lead from the function generator (see Figure 5-4).

e. The 428B should read within 2% of the reading noted in Step b.

5-23. NOISE CHECK

5-24. A battery operated ac voltmeter and a 1 kilohm resistor are required to complete this check.

a. Point probe East and West and rotate about its axis. Note peak-to-peak change in meter reading. If it doesn't exceed 0.2 mA on the 1 mA range, proceed. If the change is excessive, perform Paragraph 5-8.

b. Zero the Model 428B on the 1 mA range per Paragraph 5-11 d, e and f.

c. Connect the output of the 428B to the input of a battery operated ac voltmeter with a 1 kilohm resister in parallel with the voltmeter input.

d. With the 428B on the 1 mA Range check for a maximum of 15 mV reading on the Ac Voltmeter.

e. Switch the 428B to the 3 mA range. Check for a maximum of 5 mV reading on the AC Voltmeter.

f. Switch the 428B to the 10 mA range. Check for a maximum of 2 mV reading on the AC Voltmeter.

g. Check each range from 10 mA to 10 amps using the procedure of Step f. No ac output reading should exceed 2 mV.

5-25. ADJUSTMENT PROCEDURE

5-26. When the instrument shows signs of defective components, use the troubleshooting procedure to find and correct the problem. It is quite easy to compound a 428B trouble by misaligning the instrument in an attempt to adjust out the effects of a defective component.

5-27. Power Supply

5-28. The following steps verify adjustment of the power supply.

a. Connect a digital multimeter to test point 5 (Pin 1, V9) of the 428B. The voltage at this point should be 272 ±6 V; if not, adjust R109 for 272 V.

b. Measure +12 ±1 V dc between the cathode of CR10 and ground.

c. Measure −7 ±1 V dc between the anode of CR9 and ground.

5-29. Mechanical Zero Set

5-30. When meter is properly zero set, pointer rests over the zero calibration mark on the meter scale when instrument is (1) at normal operating temperature, (2) in its normal operating position, and (3) turned off. Zero set as follows to obtain best accuracy and mechanical stability:

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

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

c. Rotate mechanical zero adjustment screw clockwise until meter pointer is to left of zero and moving upscale toward zero.

d. Continue to rotate adjustment screw clockwise; stop when pointer is right on zero. If pointer overshoots zero, repeat Steps c and d.

e. When pointer is exactly on zero, rotate adjustment screw slightly counterclockwise to free adjustment screw from the meter suspension. If pointer moves during this step, repeat Steps c through e.

5-31. DC Amplifier Balance

5-32. Disconnect FEEDBACK DISCONNECT (see Figure 7-3), red wire. Place range switch in the 10 amp position. Adjust fine and course zero controls for center of travel. Adjust R46 for zero on front panel meter.

5-33. Reconnect FEEDBACK DISCONNECT.

5-34. ALIGNMENT

5-35. Oscillator Balance

5-36. Construct a probe as shown below:

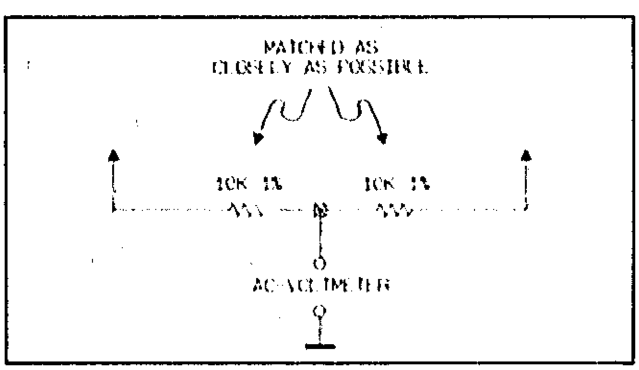


Figure 5-5. Oscillator Balance Probe

Connect the ends of the probe to the T5 side of R94 and R95. Connect an ac voltmeter between ground and the junction of the two probe resistors. To adjust oscillator balance, pad C53* or C54* for minimum reading (on instruments with serial prefixes of 601- or below, adjust the slug of T5). The ac reading at the junction of the probe resistors should be 50 mV or less. Remove the probe and meter before proceeding.

5-37. Oscillator Frequency

5-38. Connect an ac coupled electronic counter to test point 4. Adjust the slug of T5 to set the frequency measured to 40 kHz ± 200 Hz. If T5 doesn't have enough range, pad C52* (in instruments with serial prefixes of 601 or below do not use T5; use C52 only). Remove counter.

5-39. Oscillator Level

5-40. Connect an ac voltmeter to Test Point 6 (Pin 7, V7). Adjust R92 for 8 ± 0.4 V. Remove meter.

5-41. Detector Gate

5-42. Connect an ac voltmeter to Test Point 4 (Pin 7 of V5). Adjust L7 for a peak reading (2.5 - 3.3 V rms).

5-43. TUNED AMPLIFIER

5-44. Equipment Setup

5-45. Set an ac voltmeter to the 1 volt range and connect it to Test Point 3 (Pin 7, V2) of the 428B. Clip the 428B probe around a wire which is carrying 35 mA rms ac, f ≤400 Hz. This current can be generated by a filament transformer, as in Figure 5-6, or by an oscillator

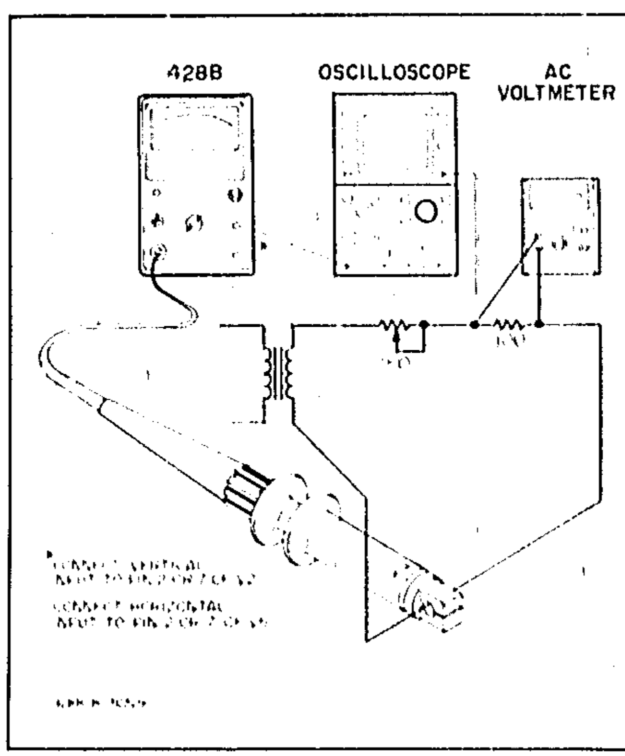


Figure 5-6. Detector Phase Adjustment

operating into its rated load as in Paragraph 5-20. Set the 428B RANGE switch to 100 mA. This arrangement will be used for input, interstage, and detector phase adjustments.

5-46. Input Alignment

5-47. Short TP1 and TP2 to ground, open the FEEDBACK DISCONNECT shown in Figure 7-3, then adjust C2 for a maximum ac reading at Test Point 3, Pin 7 of V2 (2 V - .4 V peak). Reconnect the FEEDBACK DISCONNECT.

5-48. Interstage Alignment

5-49. Set up equipment as in Paragraph 5-45, then:

a. Connect a .0082 microfarad capacitor across the brass pins which are connected to L10. Adjust L9 for maximum ac at Test Point 3 (Pin 7 of V2).

b. Remove the capacitor. Connect the .0082 microfarad capacitor across the brass pins which are connected to L9. Adjust L10 for maximum ac at TP3.

c. Remove the capacitor and voltmeter.

5-50. DETECTOR PHASE ADJUSTMENT

5-51. Do the following:

a. Using short clip leads, connect TP1 and TP2 to ground (ground the bases of Q2 and Q1, respectively).

b. Disconnect FEEDBACK DISCONNECT (red wire, see Figure 7-3) and install a 390 ohm resistor between the red feedback wire and the pin on the circuit board to which it normally connects.

c. Connect the horizontal input of an oscilloscope to V5 pin 7 (TP4) and the vertical input to V2 pin 7 (TP3).

d. Except for the ac voltmeter, set up the test equipment as explained in paragraph 5-45 (see Figure 5-6).

e. Adjust the oscilloscope's vertical and horizontal input level adjustments until a pattern similar to the ones in Figure 5-7 is displayed.

f. Turn the slug of L7 until the pattern looks like one of the correct patterns shown in Figure 5-7. If there is a diamond in the center of the pattern, make sure the diamond contains no traces.

g. Remove the 390 ohm resistor and oscilloscope from the 428B, and reconnect the FEEDBACK DISCONNECT.

5-52. INTERNAL ZERO ADJUSTMENTS

5-53. Preliminary Adjustment

5-54. Preset the controls as follows:

a. Set RANGE switch to 100 mA.

b. Adjust R84 for minimum ac at the wiper connection of R84. The reading should be less than 0.1 volts.

c. Adjust R82 for minimum ac out at the wiper of R82A. The reading should be ≤0.02 volts.

d. Thoroughly clean probe head jaws (see Paragraph 5-7).

e. Degauss probe head (see Paragraph 3-29).

5-55. Drive Balance Adjustment

5-56. With the 428B set to the 1 mA range, and with no input to the current probe, set R98 for a minimum ac reading at Test Point 3 (Pin 7 of V2). The minimum reading should be less than 0.5 volt.

5-57. Residual 40 kHz Cancellation

5-58. The residual output of the probe head is cancelled by means of the circuit discussed under Paragraph 4-45. This procedure assumes that the preliminary adjustments listed in Paragraph 5-54 have been completed.

a. Degauss the probe.

b. Zero the 428B meter with front panel ZERO control.

c. Adjust R84 for a minimum ac reading at Test Point 3 (Pin 7 of V2).

d. Continue to alternate Steps b and c until the adjustment cannot be further refined. The minimum reading in Step c should be approximately 0.02 volts or less.

5-59. Output Adjustment

5-60. A meter calibrator and a one kilohm resistor are required for this test.

a. Place RANGE switch in 10 amp position and adjust R46 for zero volts DC ± 0.2 mV at the Output Level jack.

b. Switch the 428B and the meter calibrator to the 100 mA range. Connect a test lead between the meter calibrator output leads and clip the 428B probe to the lead.

c. Set the meter calibrator to 100 mA output and read full-scale on the 428B. Adjust R69 if necessary.

d. Connect a voltmeter to the output jack of the 428B in parallel with the 1000 ohm resistor.

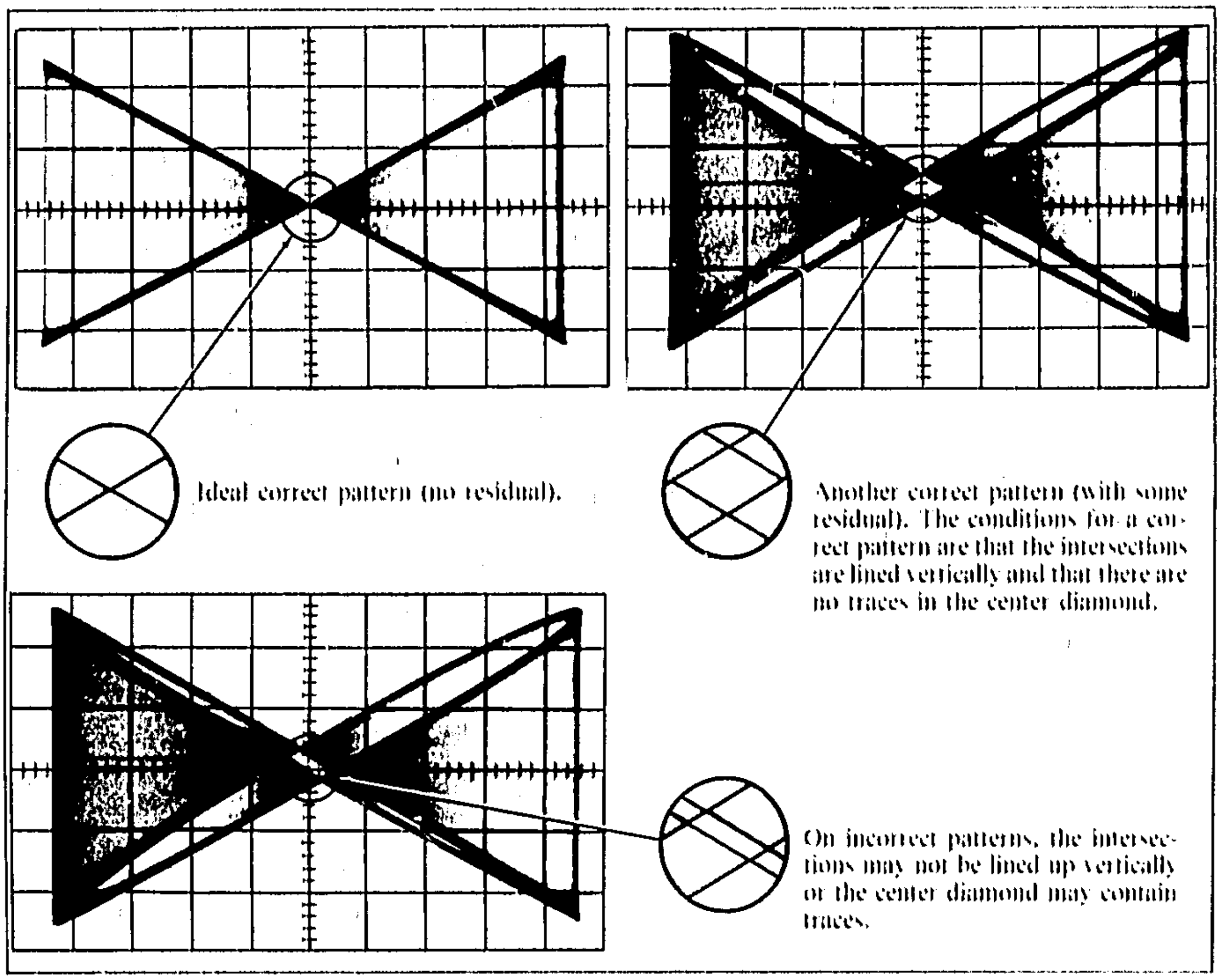


Figure 5-7. Detector Phase Display

e. The voltmeter should read 0.73 V ± 10 mV. Adjust R63 if necessary.

5-61. TROUBLESHOOTING

5-62. Front Panel Troubleshooting

5-63. The Front Panel Troubleshooting Tree was designed for use as a means to guide the repairman to a block of circuitry. This procedure, in combination with the adjustment, calibration, and performance checks should be adequate to repair most 428B's.

5-64. In any case where the front panel troubleshooting does not lead to the problem, it will be necessary to troubleshoot the instrument in detail.

5-65. DETAILED TROUBLESHOOTING

5-66. Probe Check

5-67. Resistance between pins 1-3, 1-4, 2-3, and 2-4 of the probe cable connector should be nearly identical and in the area of approximately 4½ to 5 ohms. Where a resistance measurement between any of the above pairs of pins is significantly higher than between the other pairs (by about 3 times), an open probe coil is indicated. Any open circuit indicates a broken conductor between the plug and the bridge. The broken conductor is probably a broken wire in the cable. Either condition could indicate a broken wire at the Probe Terminal Section (see wiring diagram, Figure 6-1).

5-68. Power Supply Check

5-69. To test the power supply:

a. Measure +272 ± 6 Vdc between Test Point 5 and ground.

b. Measure +12 ± 1 Vdc between the cathode of CR10 and ground.

c. Measure −7 ± 1 Vdc between the anode of CR9 and ground.

5-70. Where the +272 V and the +12 V have both failed, check the +12 first. Check CR10, Q1, C66, and C69.

5-71. Where the +272 V is at fault, try replacing V9, V10, CR10 or CR17. If the tubes are not defective, the voltage reference CR10 and CR17 may by faulty. Instruments with serial prefix 601- or below contain a voltage reference tube V11 in place of CR17.

5-72. Where the −7 V has failed, measure −17 Vdc at junction of R102 and C65. If less than −7 volts is measured at this point, check F3 and C65. If the junction of R102 and C65 measures more than −7 Vdc, check CR9 and Q2.

5-73. Oscillator - Buffer Amp. Check

5-74. Short Test Point 1 and Test Point 2 to ground.

5-75. Compare the waveform at pin 2 of J1 to the waveform shown at this point of the schematic diagram. If these waveforms are not comparable, check the waveform at Test Point 7 and follow the Troubleshooting Tree. If the waveform at pin 2 of J1 is acceptable, continue to the next paragraph.

5-76. Set up equipment as described in Paragraph 5-51. Compare the oscilloscope display to Figure 5-7.

5-77. If the display is unacceptable, clip the probe around 100 mAdc and downrange to the 1 mA range. Find a 2.5 V pk-pk sine wave at the junction of R1 and L5. If this waveform is unacceptable, adjust or repair the input tuning circuit (L5, C1, C2, and R1).

5-78. If the waveform described in Paragraph 5-75 is good, use the same test setup to find a 2.5 V pk-pk sine wave at pin 7 of V1. If this waveform is unacceptable, check V1 and the range switch.

5-79. If the waveform described in Paragraph 5-76 is good, use the same test setup to look for a 1 V pk-pk sine wave at pin 7 of V2. Follow this branch of the Troubleshooting Tree to its conclusion.

5-80. Detector Gate Amp. Check

5-81. No test equipment need be set up for these checks except an oscilloscope and a wire to ground TP1 and TP2.

5-82. Synchronous Detector

5-83. With TP1 and TP2 still grounded and on the 100 mA range, perform the test indicated. Beyond a tedious ohmmeter test of the circuitry between T3 and pin 7 of V6, little can be done to check the detector circuit. It should be noted, however, that R46 should be able to provide the +0.5 Vdc which is required at pin 7 of V6 during normal operation.

5-84. DC Amplifier Check

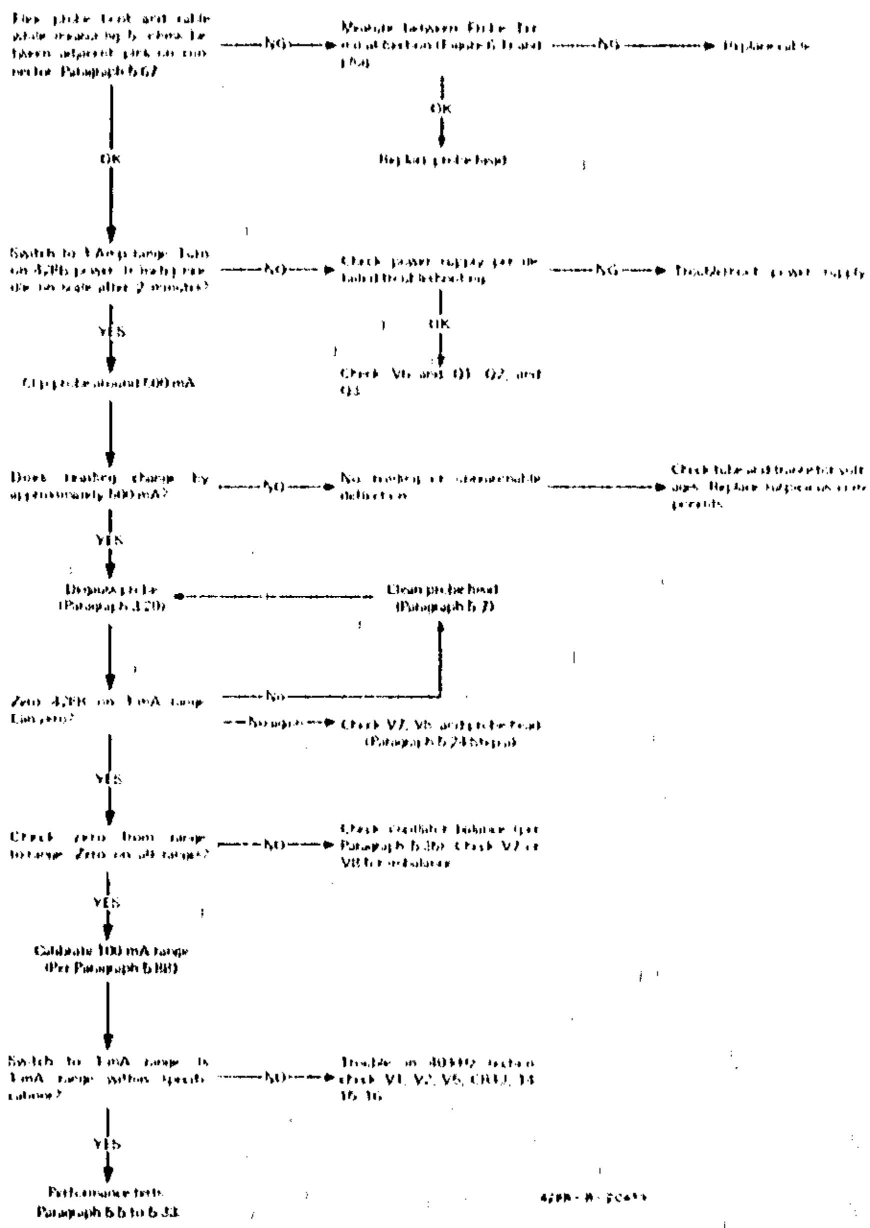
5-85. Remove the ground wire from Test Point 1 and Test Point 2 (installed for previous checks). Disconnect the probe from the 428B front panel. Set the 428B to the 300 mA range. Zero the 428B with the front panel ZERO control. Measure and note the voltages at pin 7 and pin 2 of V6. Turn the ZERO control to deliver a ±1 Vdc swing around the voltage noted for pin 2. The difference between the voltages at pins 7 and 2 of V6 should not exceed 0.05 Vdc at any point during this swing.

5-86. If the DC Amplifier tracks properly as tested in Paragraph 5-85, proceed with the performance checks. If the DC Amplifier has failed, continue to perform the tests in the Troubleshooting Tree.

5-87. CALIBRATION

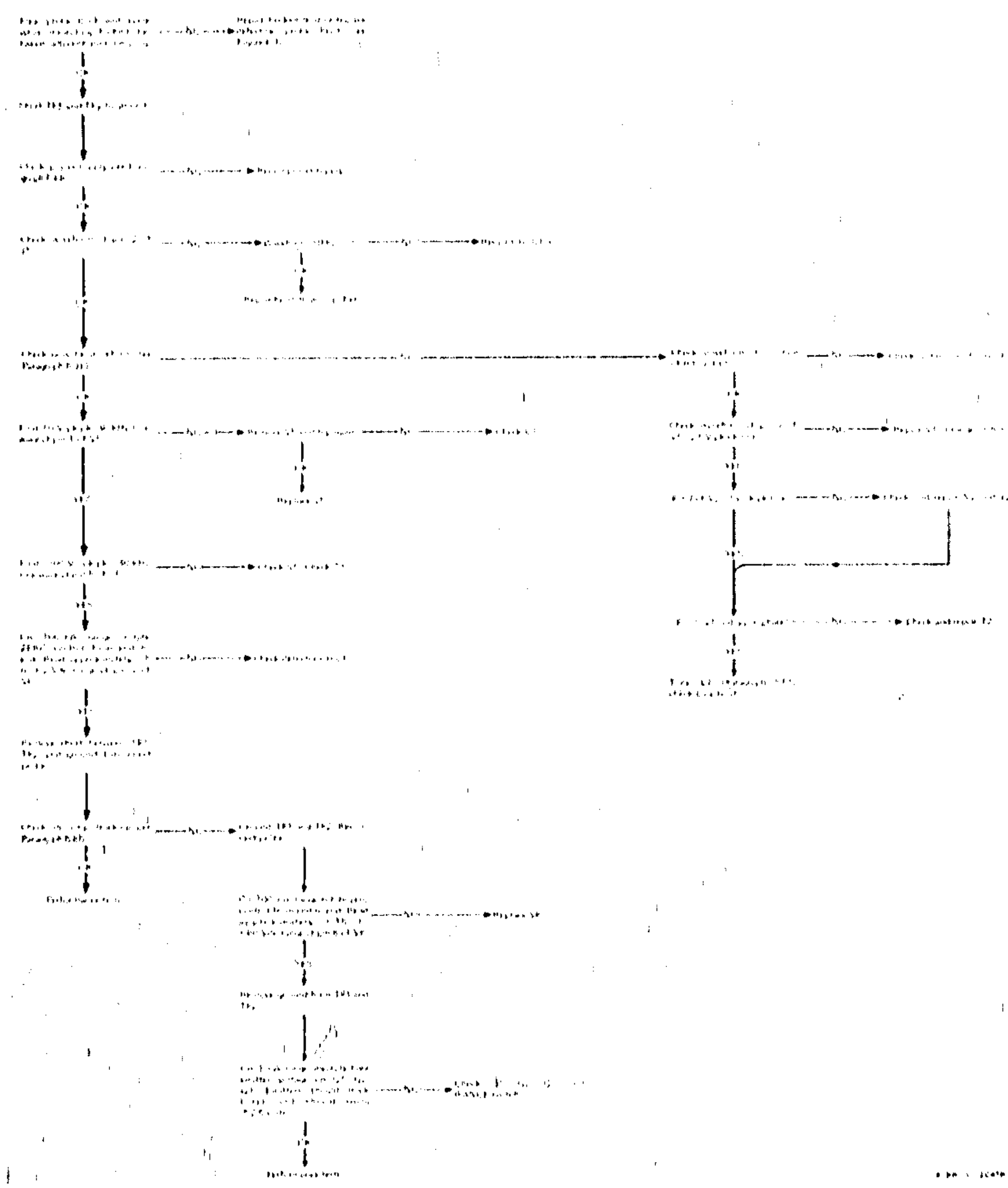
5-88. Zero the 428B on the 1 mA range using the front panel ZERO control Switch to the 100 mA range. Clip the probe around an accurate 100 mA current (as in Paragraph 5-14). Adjust Meter Cal, R69, for a meter reading of 100 mA. Connect a 1000 ohm ±1% resistor in parallel with an accurate (0.25%) voltmeter to the output jack of the 428B. Turn the front panel Output Level control full counterclockwise past the detent. Adjust the Output Cal control, R63, for a reading of exactly 0.73 V on the voltmeter.

5-89. Perform the entire In-Cabinet Performance tests (Paragraphs 5-5 through 5-24) to insure that the 428B meets all of its specifications.



Most 428B failures will be due to bad tubes or transistors. If enough tubes are available to check by replacement, this procedure will probably save time. Instructions to check a particular component imply a check of associated circuitry as well.

Figure 5-8. Front Panel Troubleshooting Tree



Instructions to check a particular component imply a check of associated circuitry as well.

Figure 5-9. Detailed Troubleshooting Tree

PERFORMANCE CHECK TEST CARD
MODEL 428 CLIP-ON DC MILLIAMMETER

Model 428B **Test performed by**
Serial No. ________ **Date** ________

RANGE CHECK: PARAGRAPH 5-13

428B Reading	Meter Calibrator Output	Loops	Limits	Reading
1mA	1mA	1	± 180μA	
10 mA	10 mA	1	± 0.45 mA	
100 mA	100 mA	1	± 3.15 mA	
1 A	1 A	1	± 0.03 A	
3 mA	1mA	3	± 240 μA	
30 mA	10 mA	3	± 1.05 mA	
300 mA	100 mA	3	± 9.15 mA	
3 A	1 A	3	± 0.09 A	
10 A	5 A	2	± 0.3 A	

METER TRACKING CHECK: PARAGRAPH 5-15

Meter Calibrator Output	Loops	428B Reading	Limits	Reading
10 mA	10	100 mA	± 3.15 mA	
10 mA	9	90 mA	± 3.15 mA	
10 mA	8	80 mA	± 3.15 mA	
10 mA	7	70 mA	± 3.15 mA	
10 mA	6	60 mA	± 3.15 mA	
10 mA	5	50 mA	± 3.15 mA	
10 mA	4	40 mA	± 3.15 mA	
10 mA	3	30 mA	± 3.15 mA	
10 mA	2	20 mA	± 3.15 mA	
10 mA	1	10 mA	± 3.15 mA	

OUTPUT CALIBRATION CHECK: PARAGRAPH 5-17

Meter Calibrator Output	428B Reading	DC Voltmeter	Limits	Reading
100 mA	100 mA	0.73 V	± 10 mV	

FREQUENCY RESPONSE CHECK: PARAGRAPH 5-19

428B Reading	Frequency Range	Limits	Reading
10 mA	DC – 400 Hz	< 7 cm	

AC OVERLOAD: PARAGRAPH 5-21

Meter Calibrator Output	428B Reading	Function Generator Output	Limits	Reading
10 mA	> 9.8 mA	10 mA P	< 2%	

NOISE CHECK: PARAGRAPH 5-23

428B Range	Limits	Reading
1 mA	< 15 mV	
3 mA	< 5 mV	
10 mA	< 2 mV	
30 mA	< 2 mV	
100 mA	< 2 mV	
300 mA	< 2 mV	
1 A	< 2 mV	
3 A	< 2 mV	
10 A	< 2 mV	

SECTION VI
REPLACEABLE PARTS

6-1. INTRODUCTION

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

a. The TQ column lists the total quantity of any part listed in the manual. The total quantity of a part is given the first time the part number appears.

b. Description of the part. (See list of abbreviations below.)

c. Typical manufacturer of the part in a five-digit code. (See Appendix B for list of manufacturers.)

d. Manufacturer's part number

6-3. Miscellaneous parts are listed at the end of Table 6-1.

6-4. ORDERING INFORMATION

6-5. To obtain replacement parts, address order or inquiry to your local Hewlett-Packard Field Office. (See Appendix C for list of office locations.) Identify parts by their Hewlett-Packard part numbers. Include instrument model and serial numbers.

6-6. NON-LISTED PARTS

6-7. To obtain a part that is not listed, include:

a. Instrument model number.

b. Instrument serial number.

c. Description of the part.

d. Function and location of the part.

ABBREVIATIONS

Ag	silver
Al	aluminum
A	ampere(s)
Au	gold
C	capacitor
cer	ceramic
coef	coefficient
com	common
comp	composition
conn	connection
dep	deposited
DPDT	double pole double throw
DPST	double pole single throw
elect	electrolytic
encap	encapsulated
F	farad(s)
FET	field effect transistor
fxd	fixed
GaAs	gallium arsenide
GHz	gigahertz = 10^{+9} hertz
gl	glass
Ge	germanium
gnd	ground(ed)
H	henry(ies)
Hg	mercury
Hz	hertz (cycle(s) per second)
ID	inside diameter
impg	impregnated
incd	incandescent
ins	insulation(ed)
kΩ	kilohm(s) = 10^{+3} ohms
kHz	kilohertz = 10^{+3} hertz
L	inductor
lin	linear taper
log	logarithmic taper
mA	milliampere(s) = 10^{-3} amperes
MHz	megahertz = 10^{+6} hertz
MΩ	megohm(s) = 10^{+6} ohms
met flm	metal film
mfr	manufacturer
ms	millisecond
mtg	mounting
mV	millivolt(s) = 10^{-3} volts
μF	microfarad(s)
μs	microsecond(s)
μV	microvolt(s) = 10^{-6} volts
my	Mylar®
nA	nanoampere(s) = 10^{-9} amperes
NC	normally closed
Ne	neon
NO	normally open
NPO	negative positive zero (zero temperature coefficient)
ns	nanosecond(s) = 10^{-9} seconds
nsr	not separately replaceable
Ω	ohm(s)
obd	order by description
OD	outside diameter
p	peak
pA	picoampere(s)
pc	printed circuit
pF	picofarad(s) 10^{-12} farads
piv	peak inverse voltage
p/o	part of
pos	position(s)
poly	polystyrene
pot	potentiometer
p-p	peak to peak
ppm	parts per million
prec	precision (temperature coefficient, long term stability and/or tolerance)
R	resistor
Rh	rhodium
rms	root mean square
rot	rotary
Se	selenium
sect	section(s)
Si	silicon
sl	slide
SPDT	single pole double throw
SPST	single pole single throw
Ta	tantalum
TC	temperature coefficient
TiO_2	titanium dioxide
tog	toggle
tol	tolerance
trim	trimmer
TSTR	transistor
V	volt(s)
vacw	alternating current working voltage
var	variable
vdcw	direct current working voltage
W	watt(s)
w/	with
wiv	working inverse voltage
w/o	without
ww	wirewound
*	optimum value selected at factory, average value shown (part may be omitted)
**	no standard type number assigned, selected or special type

® Dupont de Nemours

DECIMAL MULTIPLIERS

Prefix	Symbols	Multiplier	Prefix	Symbols	Multiplier
tera	T	10^{12}	centi	c	10^{-2}
giga	G	10^{9}	milli	m	10^{-3}
mega	M or Meg	10^{6}	micro	μ	10^{-6}
kilo	K or k	10^{3}	nano	n	10^{-9}
hecto	h	10^{2}	pico	p	10^{-12}
deka	da	10	femto	f	10^{-15}
deci	d	10^{-1}	atto	a	10^{-18}

STD B 2734

DESIGNATORS

A	assembly
B	motor
BT	battery
C	capacitor
CR	diode
DL	delay line
DS	lamp
E	misc electronic part
F	fuse
FL	filter
HR	heater
IC	integrated circuit
J	jack
K	relay
L	inductor
M	meter
MP	mechanical part
P	plug
Q	transistor
QCR	transistor diode
R	resistor
RT	thermistor
S	switch
T	transformer
TB	terminal board
TC	thermocouple
TP	test point
TS	terminal strip
U	microcircuit
V	vacuum tube, neon bulb, photocell, etc.
W	cable
X	socket
XDS	lampholder
XF	fuseholder
Y	crystal
Z	network

Table 6-1. Replaceable Parts

Reference Designation	HP Part Number	C D	Qty	Description	Mfr Code	Mfr Part Number
A1	428B-26A	6	2	ASSEMBLY: REGISTOR BW A1 INCLUDES R3 THRU R6	28480	428B-26A
A2	428B-26A	6		ASSEMBLY: REGISTOR BW A2 INCLUDES R2 THRU R10	28480	428B-26A
A3	428B-26B	0	1	ASSEMBLY: REGISTOR BW INCLUDES R2 AND R11	28480	428B-26B
C1	0160-0938	3	1	CAPACITOR FXD 1000PF +-5% 100VDC MICA	28480	0160-0938
C002	0131-0004	3	1	CAPACITOR-V TRMR MICA 25-150PF 175V	28480	0131-0004
C011	0150-0014	5	1	CAPACITOR FXD 5600PF +100-0% 500VDC CER	28480	0150-0014
C012	0180-0050	2	1	CAPACITOR FXD 40UF+75-10% 50VDC AL	56289	30D406G050DD2
C013	0160-0269	3	5	CAPACITOR FXD .1UF +-20% 500VDC CER	28480	0160-0269
C014	0140-0179	2		CAPACITOR FXD 1000PF +-2% 300VDC MICA	72136	DM19F102G0300WV1CR
C015	0150-0012	3	6	CAPACITOR FXD .01UF +-20% 1KVDC CER	56289	C023A102J103MS38
C016	0160-0269	3		CAPACITOR-FXD .1UF +-20% 500VDC CER	28480	0160-0269
C017	0160-0269	3		CAPACITOR FXD .1UF +-20% 500VDC CER	28480	0160-0269
C018	0140-0179	2		CAPACITOR FXD 1000PF +-2% 300VDC MICA	72136	DM19F102G0300WV1CR
C019	0150-0012	3		CAPACITOR FXD .01UF +-20% 1KVDC CER	56289	C023A102J103MS38
C021	0180-0059	1	1	CAPACITOR-FXD 10UF+75-10% 25VDC AL	56289	30D106G025BB2
C024*	0160-0310	3	2	CAPACITOR FXD .39UF +-10% 200VDC POLYE	84411	663UW39492W1
C025	0180-0058	0	2	CAPACITOR-FXD 50UF+75-10% 25VDC AL	56289	30D506G025CC2
C026	0150-0012	3		CAPACITOR FXD .01UF +-20% 1KVDC CER	56289	C023A102J103MS38
C027*	0140-0179	2	4	CAPACITOR FXD 1000PF +-2% 300VDC MICA	72136	DM19F102G0300WV1CR
C028	0150-0012	3		CAPACITOR FXD .01UF +-20% 1KVDC CER	56289	C023A102J103MS38
C029	0150-0012	3		CAPACITOR FXD .01UF +-20% 1KVDC CER	56289	C023A102J103MS38
C031	0170-0019	2	1	CAPACITOR FXD .1UF +-5% 200VDC POLYE	28480	0170-0019
C033*	0140-0149	6	2	CAPACITOR FXD 470PF +-5% 300VDC MICA	72136	DM15F471J0300WV1CR
C041	0140-0223	7	1	CAPACITOR FXD 260PF +-1% 300VDC MICA	72136	DM15F261F0300WV1C
C042	0160-2204	0		CAPACITOR-FXD 100PF +-5% 300VDC MICA	28480	0160-2204
C051	0160-0269	3		CAPACITOR FXD .1UF +-20% 500VDC CER	28480	0160-0269
C052*	0140-0178	1	1	CAPACITOR-FXD 560PF +-2% 300VDC MICA	72136	DM15F561G0300WV1CR
C053*	0140-0164	5	5	CAPACITOR-FXD 680PF +-5% 500VDC MICA	72136	DM15F681J0500WV1CR
C054*	0140-0164	5		CAPACITOR FXD 680PF +-5% 500VDC MICA	72136	DM15F681J0500WV1CR
C056*	0140-0197	4	2	CAPACITOR FXD 180PF +-5% 300VDC MICA	72136	DM15F181J0300WV1CR
C061	0180-2336	1	1	CAPACITOR FXD 200UF+50-10% 40VDC AL	28480	0180-2336
C062	0180-2337	2	1	CAPACITOR [illegible] 20/20UF 350V PC MTG	28480	0180-2337
C063	0160-2025	3	1	CAPACITOR-FXD 22PF +-5% 500VDC MICA	28480	0160-2025
C064	0150-0012	3		CAPACITOR FXD .01UF +-20% 1KVDC CER	56289	C023A102J103MS38
C065	0180-0058	0		CAPACITOR-FXD 50UF+75-10% 25VDC AL	56289	30D506G025CC2
C066	0180-0155	7	2	CAPACITOR FXD 2.2UF+75-10% 20VDC AL	56289	30D225G020BA2
C068	0160-0269	3		CAPACITOR-FXD .1UF +-20% 500VDC CER	28480	0160-0269
C069	0180-1104	7		CAPACITOR FXD 200UF+75-10% 12VDC AL	56289	30D207G012EE2
C070	0160-2203	9	1	CAPACITOR FXD 91PF +-5% 300VDC MICA 0+70	28480	0160-2203
C071	0160-0134	1	1	CAPACITOR FXD 220PF +-5% 300VDC MICA	28480	0160-0134
C072	0160-0174	9	1	CAPACITOR-FXD .47UF +80-20% 25VDC CER	28480	0160-0174
CR001	1901-0036	5	4	DIODE HV RECT 1KV 600MA DO-29	28480	1901-0036
CR003	1901-0036	5		DIODE HV RECT 1KV 600MA DO-29	28480	1901-0036
CR005	1901-0036	5		DIODE HV RECT 1KV 600MA DO-29	28480	1901-0036
CR007	1901-0036	5		DIODE HV RECT 1KV 600MA DO-29	28480	1901-0036
CR009	1902-0013	0	1	DIODE ZNR 6.19V 10% PD=1.2W TC=+.03%	28480	1902-0013
CR010	1902-0211	0	1	DIODE ZNR 12.1V 10% PD=1.5W TC=+.064%	28480	1902-0211
CR011	1901-0040	1	2	DIODE SWITCHING 30V 50MA 2NS DO-35	28480	1901-0040
CR012	1901-0040	1		DIODE SWITCHING 30V 50MA 2NS DO-35	28480	1901-0040
CR013	1906-0034	3	4	DIODE MATCHED	28480	1906-0034
CR014	1906-0034	3		DIODE MATCHED	28480	1906-0034
CR015	1906-0034	3		DIODE MATCHED	28480	1906-0034
CR016	1906-0034	3		DIODE MATCHED	28480	1906-0034
CR017	1902-3404	9	1	DIODE ZNR 82.5V 5% DO-7 PD=.4W TC=+.087%	28480	1902-3404
DS001	1450-0574	9	1	LIGHT IND CLR 3V .35 DIA [illegible] TERM	28480	1450-0574
F001	2110-0312	4	2	FUSE 1A 250V TD 1.25X.25 UL (115 VOLT OP)	71400	MDL 1
F002	2110-0312	4		FUSE 1A 250V TD 1.25X.25 UL	71400	MDL 1
F003	2110-0012	1	1	FUSE .5A 250V NTD 1.25X.25 UL	28480	2110-0012
F1	2110-0202	1	1	FUSE 500 IN. AT 250V (230V OPERATION)	71400	MDL 1/2
J001	1251-0089	9	1	CONNECTOR 4 PIN F [illegible]	28480	1251-0089
J002	1251-2357	8	1	CONNECTOR PC PWR 10 2 [illegible] MTG	28480	1251-2357
J003	1250-0118	3	1	CONNECTOR RF BNC FEM SGL HOLE FR 50 OHM	28480	1250-0118
L004	9100-1402	7	2	IND VAR,5.5-17.5MH RANGE,DV=500DC, HCK	28480	9100-1402
L010	9100-1402	7		IND VAR,5.5-17.5MH RANGE,DV=500DC, HCK	28480	9100-1402
L005	9100-1407	2	1	INDUCTOR 14.2MH 15% .5DX.90LG Q=3	28480	9100-1407
L006	9100-1408	3	1	INDUCTOR RF CH MLD 6.5MH .5D Q=5	28480	9100-1408
L007	9100-1409	4	1	COIL VAR 13.05MH 14.65MH PC MTG	28480	9100-1409
L008	9110-0026	3	1	COIL DEGAUSSING	28480	9110-0026

See introduction to this section for ordering information
*Indicates factory selected value

Table 6-1. Replaceable Parts (Cont'd)

Reference Designation	HP Part Number	C D	Qty	Description	Mfr Code	Mfr Part Number
M001	1120-0904	0	1	METER 6.00 IN; SPA 150; LINEAR; TAUT	28480	1120-0904
Q001	1854-0037	7	1	TRANSISTOR NPN 2N3053 SI TO-39 PD=1W	04713	2N3053
Q002	1853-0016	8	1	TRANSISTOR PNP SI TO-92 PD=300MW	28480	1853-0016
Q003	1854-0003	5	1	TRANSISTOR NPN SI TO-39 PD=800MW	28480	1854-0003
R001	0684-6801	1	1	RESISTOR 68 10% .25W FC TC=-400/+500	01121	CB6801
R012	0757-0346	2	1	RESISTOR 10 1% .125W F TC=0+-100	24546	C4-1/8-T0-10R0-F
R013	0757-0706	0	1	RESISTOR 24.3 1% .125W F TC=0+-100	19701	MF4C1/8-T0-24R3-F
R014	0757-0397	3	1	RESISTOR 68.1 1% .125W F TC=0+-100	24546	C4-1/8-T0-68R1-F
R015	0698-4421	5	1	RESISTOR 226 1% .125W F TC=0+-100	24546	C4-1/8-T0-226R-F
R016	0757-0419	0	1	RESISTOR 681 1% .125W F TC=0+-100	24546	C4-1/8-T0-681R-F
R017	0698-4433	0	1	RESISTOR 2.26K 1% .125W F TC=0+-100	24546	C4-1/8-T0-2261-F
R018	0698-4470	5	1	RESISTOR 6.98K 1% .125W F TC=0+-100	24546	C4-1/8-T0-6981-F
R019	0698-4406	3	1	RESISTOR 24.9K 1% .125W F TC=0+-100	24546	C4-1/8-T0-2492-F
R020	0698-4553	5	1	RESISTOR 66.5K 1% .125W F TC=0+-100	24546	C4-1/8-T0-6652-F
R021	0683-1345	6	1	RESISTOR 130K 5% .25W FC TC=-800/+900	01121	CB1345
R022	0698-2603	0	1	RESISTOR 43M 5% .5W FC TC=0+-1455	01121	EB4365
R024	0684-1021	7	4	RESISTOR 1K 10% .25W FC TC=-400/+600	01121	CB1021
R025	0684-1051	3	2	RESISTOR 1M 10% .25W FC TC=-800/+900	01121	CB1051
R026	0687-1031	5	1	RESISTOR 10K 10% .5W FC TC=0+765	01121	EB1031
R027	0684-1541	6	2	RESISTOR 150K 10% .25W FC TC=-800/+900	01121	CB1541
R028	0683-2515	4	1	RESISTOR 250 5% .25W FC TC=-400/+600	01121	CB2515
R029	0684-1541	6		RESISTOR 150K 10% .25W FC TC=-800/+900	01121	CB1541
R030	0687-5621	7	1	RESISTOR 5.6K 10% .5W FC TC=0+647	01121	EB5621
R031	0757-0353	1	1	RESISTOR 24.9K 1% .5W F TC=0+-100	28480	0757-0353
R032	0698-4965	3	1	RESISTOR 324K 1% .5W F TC=0+-100	28480	0698-4965
R033	0698-4712	8	1	RESISTOR 12.4K 1% .125W F TC=0+-100	24546	C4-1/8-T0-1242-F
R034	0684-4701	6	2	RESISTOR 47 10% .25W FC TC=-400/+500	01121	CB4701
R035	0687-4731	8	1	RESISTOR 47K 10% .5W FC TC=0+765	01121	EB4731
R036	0686-9115	0	1	RESISTOR 910 5% .5W CC TC=0+529	01121	EB9115
R037	0683-4715	0	1	RESISTOR 470 5% .25W FC TC=-400/+600	01121	CB4715
R041	0757-0283	6	4	RESISTOR 2K 1% .125W F TC=0+-100	24546	C4-1/8-T0-2001-F
R042	0757-0283	6		RESISTOR 2K 1% .125W F TC=0+-100	24546	C4-1/8-T0-2001-F
R043	0757-0283	6		RESISTOR 2K 1% .125W F TC=0+-100	24546	C4-1/8-T0-2001-F
R044	0757-0283	6		RESISTOR 2K 1% .125W F TC=0+-100	24546	C4-1/8-T0-2001-F
R045	0757-0327	9	1	RESISTOR 499K 1% .5W F TC=0+-100	19701	MF52C1/4-T0-4993-F
R046	2100-0331	6	1	RESISTOR-TRMR 5K 10% WW TOP ADJ 1-TRN	28480	2100-0331
R047	0689-3935	6	1	RESISTOR 39K 5% 1W CC TC=0+765	01121	GB3935
R048	0683-4715	0		RESISTOR 470 5% .25W FC TC=-400/+600	01121	CB4715
R049	0698-4594	4	1	RESISTOR 40[illegible] 1% .5W F TC=0+-100	24546	C5-1/4-T0-40[illegible]-F
R050	0684-5631	3	1	RESISTOR 56K 10% .25W FC TC=-800/+900	01121	CB5631
R051	0757-0982	2	1	RESISTOR 24.6K 1% .5W F TC=0+-100	28480	0757-0982
R052	0698-0058	7	1	RESISTOR 4.02K 1% .5W F TC=0+-100	91637	CMF-1/4-T1-4021-F
R061	0757-1039	2	1	RESISTOR 4[illegible] 1% .5W F TC=0+-100	24546	C5-1/4-T0-45R0-F
R060	0683-2715	5	2	RESISTOR 270 5% .25W FC TC=-400/+600	01121	CB2715
R062	0757-1047	2	1	RESISTOR 90 1% .5W F TC=0+-100	24546	C5-1/4-T0-90R0-F
R063	2100-0320	1	1	RESISTOR-TRMR 500 10% WW TOP ADJ 1-TRN	28480	2100-0320
R064	2100-0270	2	1	RESISTOR-VAR W/SW 50 10% LIN DPST NO NC	28480	2100-0270
R065	0698-3443	0	1	RESISTOR 287 1% .125W F TC=0+-100	24546	C4-1/8-T0-287R-F
R066	0684-4701	6		RESISTOR 47 10% .25W FC TC=-400/+500	01121	CB4701
R067	0812-0015	0	1	RESISTOR 8 3% 3W PW TC=0+50	28480	0812-0015
R068	0757-1043	8	1	RESISTOR 65 1% .5W F TC=0+-100	24546	C5-1/4-T0-65R0-F
R069	2100-1560	5	1	RESISTOR-TRMR 30 10% WW TOP ADJ 1-TRN	28480	2100-1560
R070	0684-1001	3	1	RESISTOR 10 10% .25W FC TC=-400/+500	01121	CB1001
R071	0764-0028	2	1	RESISTOR 100K 5% 2W MO TC=0+-200	28480	0764-0028
R073	0764-0003	3	1	RESISTOR 3.3K 5% 2W MO TC=0+-200	28480	0764-0003
R074	0698-4746	8	1	RESISTOR 55.6K 1% .5W F TC=0+-100	24546	C5-1/4-T0-5562-F
R075	0698-4711	7	1	RESISTOR 11.0K 1% .125W F TC=0+-100	28480	0698-4711
R076	0811-0007	8	1	RESISTOR 10K 1% 5W PW TC=0+-20	28480	0811-0007
R077	0684-6821	5	1	RESISTOR 6.8K 10% .25W FC TC=-400/+700	01121	CB6821
R078	0698-4953	9	1	RESISTOR 124K 1% .5W F TC=0+-100	28480	0698-4953
R079	0684-1021	7		RESISTOR 1K 10% .25W FC TC=-400/+600	01121	CB1021
R081	0683-6225	1	1	RESISTOR 6.2K 5% .25W FC TC=-400/+700	01121	CB6225
R082	2100-0197	2	1	RESISTOR VAR DUAL 2K 10% WW P10 20% CC	28480	2100-0197
R084	2100-0282	6	1	RESISTOR-TRMR 2K 20% WW TOP ADJ 1-TRN	28480	2100-0282
R085	0684-5621	1	1	RESISTOR 5.6K 10% .25W FC TC=-400/+700	01121	CB5621
R086	0684-1531	4	1	RESISTOR 15K 10% .25W FC TC=-400/+800	01121	CB1531
R091	0698-4931	5	1	RESISTOR 32.4K 1% .5W F TC=0+-100	28480	0698-4931
R092	2100-0094	8	2	RESISTOR-VAR CONTROL CP 50K 30% LIN	28480	2100-0094
R093	0684-1011	5	2	RESISTOR 100 10% .25W FC TC=-400/+500	01121	CB1011
R094	0684-1021	7		RESISTOR 1K 10% .25W FC TC=-400/+600	01121	CB1021
R095	0684-1021	7		RESISTOR 1K 10% .25W FC TC=-400/+600	01121	CB1021
R096	0683-4715	0		RESISTOR 470 5% .25W FC TC=-400/+600	01121	CB4715
R097	0684-1311	5		RESISTOR 130 10% .25W FC TC=-400/+500	01121	CB1311
R098	2100-0394	1	1	RESISTOR-TRMR 300 20% WW TOP-ADJ 1-TRN	28480	2100-0394

See introduction to this section for ordering information
*Indicates factory selected value

Table 6-1. Replaceable Parts (Cont'd)

Reference Designation	HP Part Number	C D	Qty	Description	Mfr Code	Mfr Part Number
R099	0698-3647	6	1	RESISTOR 15K 5% 2W MO TC=0+-200	27167	FP42-2-100 1502-J
R100	0690-1041	4	2	RESISTOR 100K 10% 1W CC TC=0+882	01121	GB1041
R101	0690-1041	4		RESISTOR 100K 10% 1W CC TC=0+882	01121	GB1041
R102	0811-0041	0	1	RESISTOR 169 1% 4W PW TC=0+-20	28480	0811-0041
R104	0684-2251	7	1	RESISTOR 2.2M 10% .25W CC TC=-900/+1100	01121	CB2251
R105	0683-4715	0		RESISTOR 470 5% .25W CC TC=-400/+600	01121	CB4715
R106	0757-0052	0	1	RESISTOR 82.5K 1% .5W F TC=0+-100	28480	0757-0052
R107	0698-4163	1	1	RESISTOR 9.31K 1% .5W F TC=0+-100	28480	0698-4163
R108	0698-4723	6	1	RESISTOR 402K 1% .25W F TC=0+-100	24546	C5-1/4-T0-4023-F
R109	2100-0094	0		RESISTOR-VAR CONTROL CP 50K 30% LIN	28480	2100-0094
R110	0698-4722	0	1	RESISTOR 170K 1% .25W F TC=0+-100	24546	C5-1/4-T0-1703-F
R111	0683-0475	1	2	RESISTOR 4.7 5% .25W CC TC=-400/+500	01121	CB47G5
R112	0683-0475	1		RESISTOR 4.7 5% .25W CC TC=-400/+500	01121	CB47G5
R113	0687-3331	2	1	RESISTOR 33K 10% .5W CC TC=0+765	01121	EB3331
R114	0684-1041	1	1	RESISTOR 100K 10% .25W CC TC=-400/+800	01121	CB1041
R115	0698-4262	6	1	RESISTOR 84.5K 1% .25W F TC=0+-100	24546	C5-1/4-T0-8452-F
R116	0684-1051	3		RESISTOR 1M 10% .25W CC TC=-800/+900	01121	CB1051
R117	0764-0006	6	4	RESISTOR 10K 5% 2W MO TC=0+-200	28480	0764-0006
R118	0764-0006	6		RESISTOR 10K 5% 2W MO TC=0+-200	28480	0764-0006
R119	0764-0006	6		RESISTOR 10K 5% 2W MO TC=0+-200	28480	0764-0006
R120	0764-0006	6		RESISTOR 10K 5% 2W MO TC=0+-200	28480	0764-0006
S001	00428-61901	0	1	RANGE SWITCH ASSEMBLY (INCL. R???)		00428-61901
S002	3101-2147	7	1	SWITCH-TGL BASIC SPST 2A 250VAC/DC	28480	3101-2147
S003	3101-0010	9	1	SWITCH-TGL BASIC SPST 10A 250VAC	28480	3101-0010
S005	3101-1234	3	1	SWITCH-SL DPDT STD 1.5A 250VAC SLDR LUG	28480	3101-1234
T002	9100-1401	6	1	TRANSFORMER SYNCHRONOUS DETECTOR, 150 MH	28480	9100-1401
T003	9100-1403	8	1	TRANSFORMER GATE DRIVE, 55 MH + 5 MH @ 1	28480	9100-1403
T004	9100-1404	9	1	TRANSFORMER ZERO BALANCE, 140 MH + 14 MH	28480	9100-1404
T005	9100-1405	0	1	TRANSFORMER ADJ (OSC) @ 1 KHZ VALTS MEAS	28480	9100-1405
T006	9100-1406	1	1	TRANSFORMER HEAD DRIVE, 1: @ 1 KHZ PINS	28480	9100-1406
T007	9100-3298	3	1	TRANSFORMER POWER HALF SHELL TYPE; 115	28480	9100-3298
V001	1923-0017	8	3	TUBE-ELECTRON 6AU6 PENTODE	33173	6AU6
V002	1923-0017	8		TUBE-ELECTRON 6AU6 PENTODE	33173	6AU6
V005	1923-0017	8		TUBE-ELECTRON 6AU6 PENTODE	33173	6AU6
V006	1932-0022	4	2	TUBE-ELECTRON 6DJ8 TRIODE DUAL	73445	6DJ8
V007	1932-0022	4		TUBE-ELECTRON 6DJ8 TRIODE DUAL	73445	6DJ8
V008	1932-0060	8	1	TUBE-ELECTRON 12AU7 DUAL TRIODE	28480	1932-0060
V009	1921-0010	7	1	TUBE-ELECTRON 12B4A TRIODE	33173	12B4A
V010	1923-0021	4	1	TUBE-ELECTRON 6AU6A/8425A PENTODE	33173	6AU6A
W001	0120-1340	6	1	CABLE ASSY 18AWG 3-CNDCT BLK-JKT	28480	8120-1340
				FACTORY SELECTED COMPONENTS		
C24*	0160-0318	3		CAPACITOR-FXD .39UF +-10% 200VDC POLYE	84411	663UW394920
	0160-0320	7	1	CAPACITOR-FXD .33UF +-10% 100VDC POLYE	84411	663UW334910
	0170-0070	3	1	CAPACITOR-FXD .47UF +-5% 150VDC POLYE	84411	663UW474515
C27*	0140-0179	2		CAPACITOR-FXD 1000PF +-2% 300VDC MICA	72136	DM15F102G0300WV1CR
	0160-0945	2	1	CAPACITOR-FXD 910PF +-5% 100VDC MICA	28480	0160-0945
	0160-3009	5	1	CAPACITOR-FXD 902PF +-1% 100VDC MICA	28480	0160-3009
C33*	0140-0149	6		CAPACITOR-FXD 470PF +-5% 300VDC MICA	72136	DM15F471J0300WV1CR
	0160-2207	3	1	CAPACITOR-FXD 300PF +-5% 300VDC MICA	28480	0160-2207
	0160-2209	5	1	CAPACITOR-FXD 360PF +-5% 300VDC MICA	28480	0160-2209
	0160-3535	2	1	CAPACITOR-FXD 560PF +-5% 300VDC MICA	28480	0160-3535
	0160-0363	8	2	CAPACITOR-FXD 620PF +-5% 300VDC MICA	28480	0160-0363
C52*	0140-0164	5		CAPACITOR-FXD 6800PF +-5% 500VDC MICA	72136	DM30F682J0500WV1CR
	0140-0210	2	1	CAPACITOR-FXD 270PF +-5% 300VDC MICA	72136	DM15F271J0300WV1CR
	0160-2940	1	1	CAPACITOR-FXD 470PF +-5% 300VDC MICA	28480	0160-2940
	0160-0363	8		CAPACITOR-FXD 620PF +-5% 300VDC MICA	28480	0160-0363
	0160-3530	5	1	CAPACITOR-FXD 750PF +-5% 100VDC MICA	28480	0160-3530
C53*	0140-0164	5		CAPACITOR-FXD 6800PF +-5% 500VDC MICA	72136	DM30F682J0500WV1CR
	0160-2373	4	2	CAPACITOR-FXD 4700PF +-2% 300VDC MICA	28480	0160-2373
C54*	0140-0164	5		CAPACITOR-FXD 6800PF +-5% 500VDC MICA	72136	DM30F682J0500WV1CR
	0160-2373	4		CAPACITOR-FXD 4700PF +-2% 300VDC MICA	28480	0160-2373
C55*	0140-0197	4		CAPACITOR-FXD 100PF +-5% 300VDC MICA	72136	DM15F101J0300WV1CR
	0160-2204	0	3	CAPACITOR-FXD 100PF +-5% 300VDC MICA	28480	0160-2204
	0140-0195	2	1	CAPACITOR-FXD 130PF +-5% 300VDC MICA	72136	DM15F131J0300WV1CR
	0140-0196	3	1	CAPACITOR-FXD 150PF +-5% 300VDC MICA	72136	DM15F151J0300WV1CR
	0160-2206	2	1	CAPACITOR-FXD 160PF +-5% 300VDC MICA	28480	0160-2206
	0140-0150	5	1	CAPACITOR-FXD 200PF +-5% 300VDC MICA	72136	DM15F201J0300WV1CR
	0140-0199	6	1	CAPACITOR-FXD 240PF +-5% 300VDC MICA	72136	DM15F241J0300WV1CR
	0140-0192	9	1	CAPACITOR-FXD 68PF +-5% 300VDC MICA	72136	DM15E680J0300WV1CR
	0160-2202	8	1	CAPACITOR-FXD 75PF +-5% 300VDC MICA	28480	0160-2202
	0140-0193	0	1	CAPACITOR-FXD 82PF +-5% 300VDC MICA	72136	DM15F820J0300WV1CR
	0160-2204	0		CAPACITOR-FXD 100PF +-5% 300VDC MICA	28480	0160-2204
	0160-2205	1	1	CAPACITOR-FXD 120PF +-5% 300VDC MICA	28480	0160-2205

See introduction to this section for ordering information
*Indicates factory selected value

Table 6-1. Replaceable Parts (Cont'd)

Reference Designation	HP Part Number	C D	Qty	Description	Mfr Code	Mfr Part Number
R60*	0683-2715	6		RESISTOR 270 5% .25W FC TC=-400/+600	01121	CB2715
	0683-1615	3	1	RESISTOR 160 5% .25W FC TC=-400/+600	01121	CB1615
	0683-2005	9	1	RESISTOR 200 5% .25W FC TC=-400/+600	01121	CB2005
	0683-3315	4	1	RESISTOR 330 5% .25W FC TC=-400/+600	01121	CB3315
				MISCELLANEOUS		
	00428-00204	8	1	DUST COVER (RACK MOUNT ONLY)	28480	00428-00204
	00428-62101	3	1	PROBE ASSEMBLY (SEE FIGURE 6-1)	28480	00428-62101
	4040-0364	3	1	ESCUTCHEON	28480	4040-0364
	00428-00201	5	1	PANEL (CABINET ONLY)	28480	00428-00201
	00428-00203	7	1	PANEL (RACK MOUNT ONLY)	28480	00428-00203
	00428-64411	1	1	ASSEMBLY, CABINET	28480	00428-64411
	0403-0004	0	1	BUMPER FOOT SCR 1-IN-MAX OD .812 IN THK	28480	0403-0004
	1440-0002	7	1	HANDLE SIL/FLOR 6-32 TH .31 DST THS	28480	1440-0002
	1490-0015	7	1	TILT STAND 2.5 IN W 5.438 IN OA-LG SST	28480	1490-0015
	5040-0616	5	1	DETENT, CABINET BAIL	28480	5040-0616
	00428-66501	6	1	ASSEMBLY, MOTHER BOARD	28480	00428-66501
	5020-6049	6	1	BEZEL	28480	5020-6049
	0340-0029	4	1	INSULATOR-ALGIR CL	76645	62
	0520-0017	1	1	BRUSH; NYLON	28480	0520-0017
	1410-0052	4	1	BUSHING PNL .272 ID .430 LG 3/8-32-THD	28480	1410-0052
	2110-0269	0	1	FUSEHOLDER CLIP TYPE .250 FUSE	28480	2110-0269
	2110-0740	6	1	FUSEHOLDER-BLOCK FOR .25X1.25 FUSE	28480	2110-0740
	1205-0011	0	1	HEAT SINK TO-5/TO-39 CS	28480	1205-0011
	0370-0029	9	1	KNOB DECAL-SKT,MINT GRA W/BLK GRAPHIC	28480	0370-0029
	0370-0031	2	1	KNOB, 1 INCH DIA BLACK CONC	28480	0370-0031
	0370-0035	6	1	KNOB SKIRT,BAR,BLK FOR .25SHFT,1.000D	28480	0370-0035
	0370-0064	1	1	KNOB RND,RED FOR .1075SHFT,1 ARD,.750D	28480	0370-0064
	0370-0023	0	1	KNOB DECAL-SKT,1/2 SLR,MINT GRA W/CB	28480	0370-0023
	0370-0024	1	1	KNOB RND,.250 BRN	28480	0370-0024
	0370-0025	2	1	KNOB RND,.250,YEL	28480	0370-0025
	0370-0026	3	1	KNOB DECAL-SKT,1/2 SLR,MINT GRA W/CB	28480	0370-0026
	7120-0192	4	1	NAMEPLATE (CABINET ONLY)	28480	7120-0192
	2950-0034	7	1	NUT-HEX DBL CHAM 3/8-32-THD .31 IN THK	00000	ORDER BY DESCRIPTION
	1200-0062	1	1	SOCKET TUBE 9 CONT DIP SLDR	28480	1200-0062
	1200-0053	0	1	SOCKET TUBE 7 CONT DIP SLDR	28480	1200-0053
	3100-0268	9	2	SWITCH ROTARY 1.662 CIRCUIT CIR SPECS (S1)	28480	3100-0268

See introduction to this section for ordering information
*Indicates factory selected value

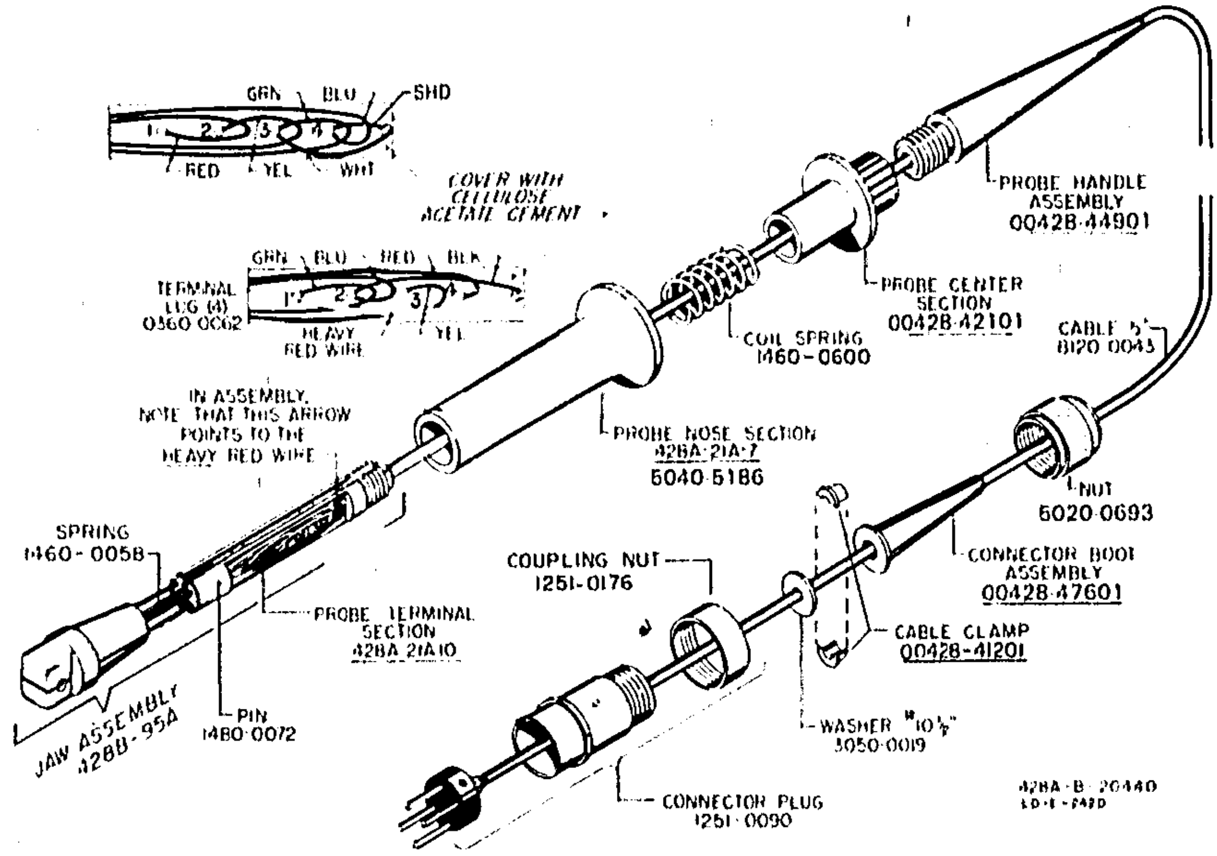


Figure 6-1. Parts Breakdown, current probe

SECTION VII
CIRCUIT DIAGRAMS

7-1. INTRODUCTION

7-2. This section contains the circuit diagrams necessary for the operation and maintenance of the Model 428B Clip-on DC Milliammeter. Included are a block diagram, schematics and component location diagrams.

7-3. BLOCK DIAGRAM

7-4. The block diagram shows the relationship between the assemblies of the instrument. Signal flow between assemblies and significant portions of assemblies as well as major feedback paths are shown. The block diagram is used to develop an understanding of the basic theory of operation.

7-5. SCHEMATIC DIAGRAMS

7-6. The circuitry contained within each assembly is shown in the schematic diagrams. These diagrams are used to develop an understanding of the detailed theory of operation of each assembly and as an aid in isolating troubles within an assembly.

7-7. COMPONENT LOCATION DIAGRAMS

7-8. The component location diagrams shown, the physical location of parts mounted on an assembly. Each part is identified by a reference designator.

SCHEMATIC NOTES

AC ground: referred to the center tap of T4.

Detector reference: referred to V6 bias source.

Chassis ground.

Earth ground.

† Waveforms where amplitude and waveform change with setting of ZERO control.

* Component selected at factory. Average value given. Component may be omitted.

Denotes main signal path.

Denotes feedback path.

MEASUREMENT CONDITIONS

Line voltage: 115V, 60 Hz
Range: 100 mA
Input: 100 mA

All voltages were measured with a high input impedance electronic voltmeter. A 10 megohm oscilloscope probe was used to measure the waveforms. The oscilloscope should be externally synchronized from pin 2 of V7 (through a 47 pF capacitor to avoid disturbing the circuit.

NOTE

Resistance is in ohms and capacitance in pF unless otherwise noted.

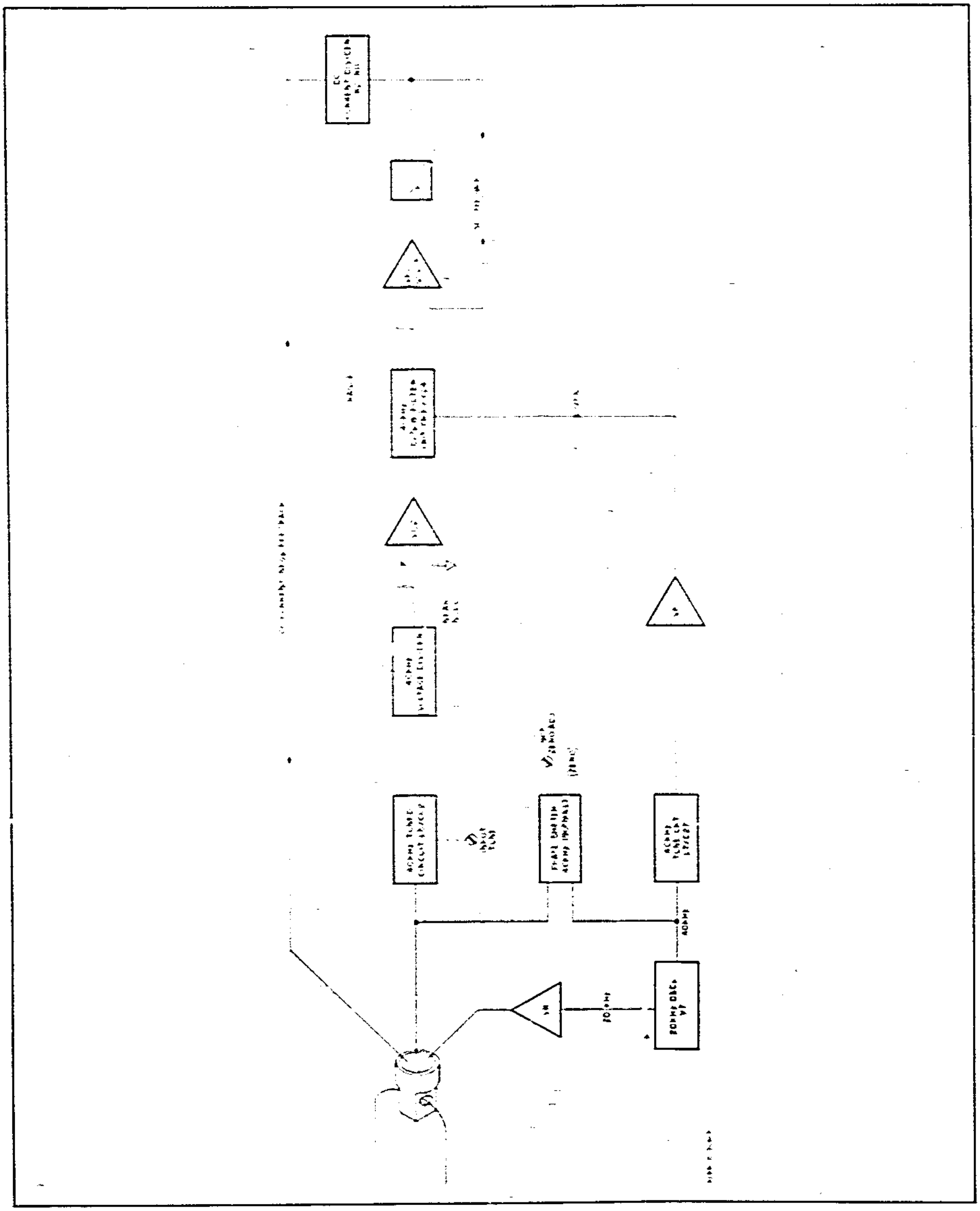
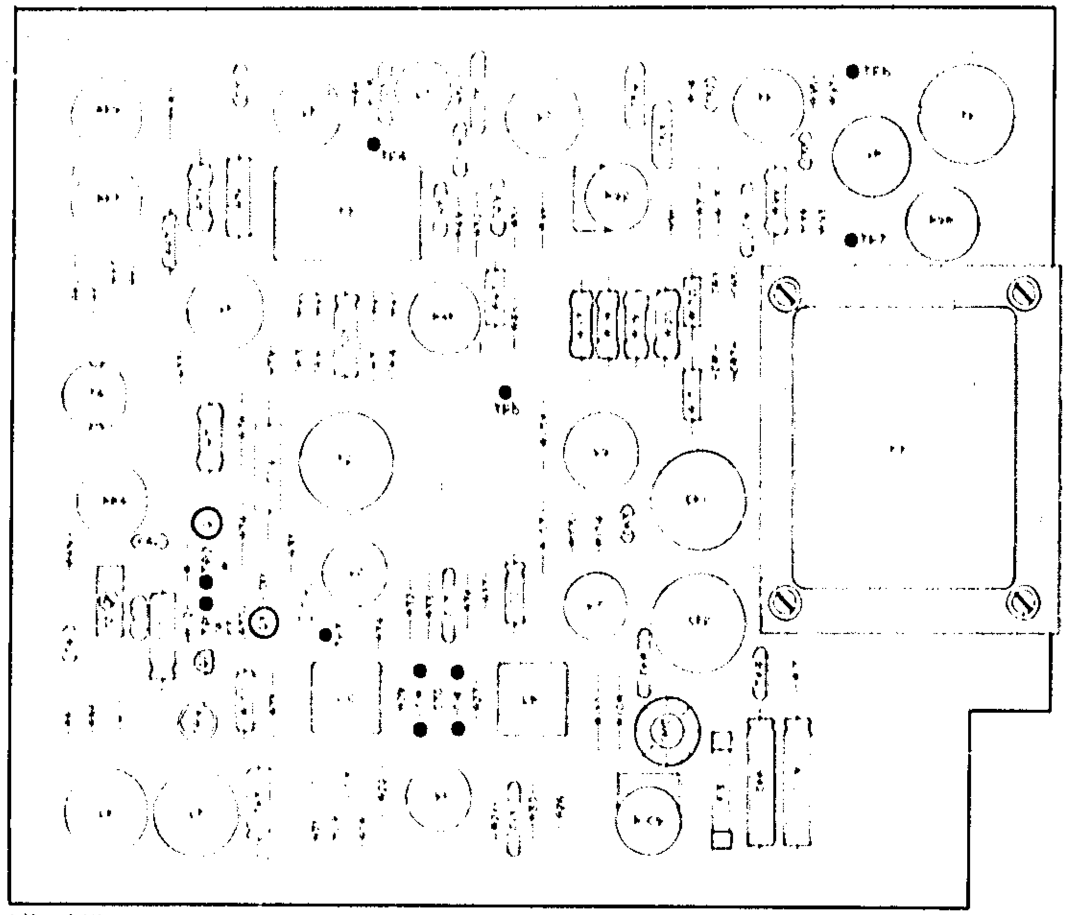
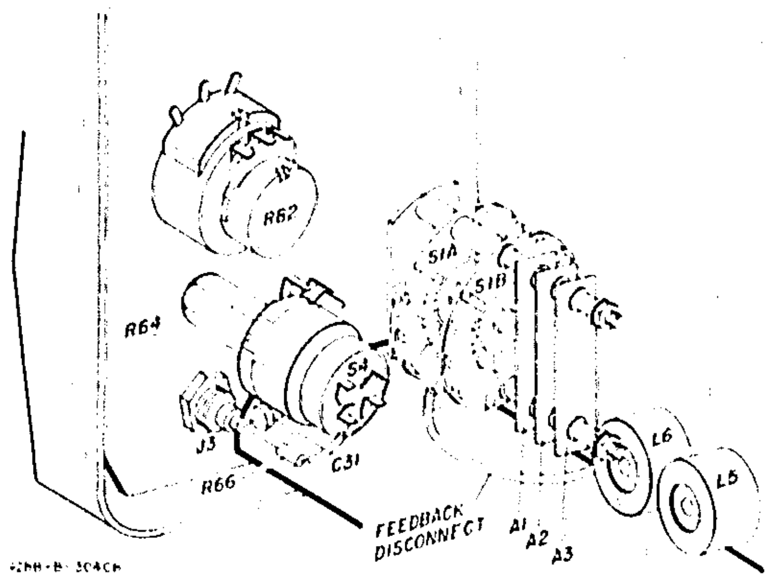


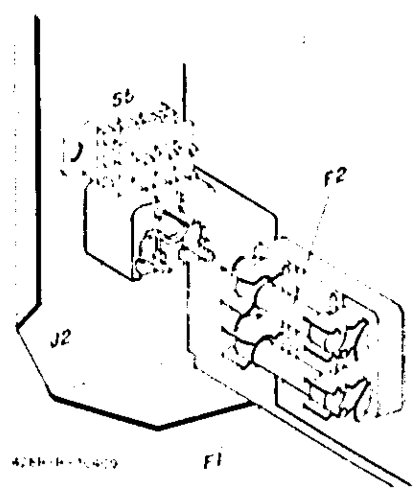
Figure 7-1. Block Diagram



Component Locator for Circuit Board Part No. 00428-66501



Front Panel Component Locator



Rear Panel Component Locator

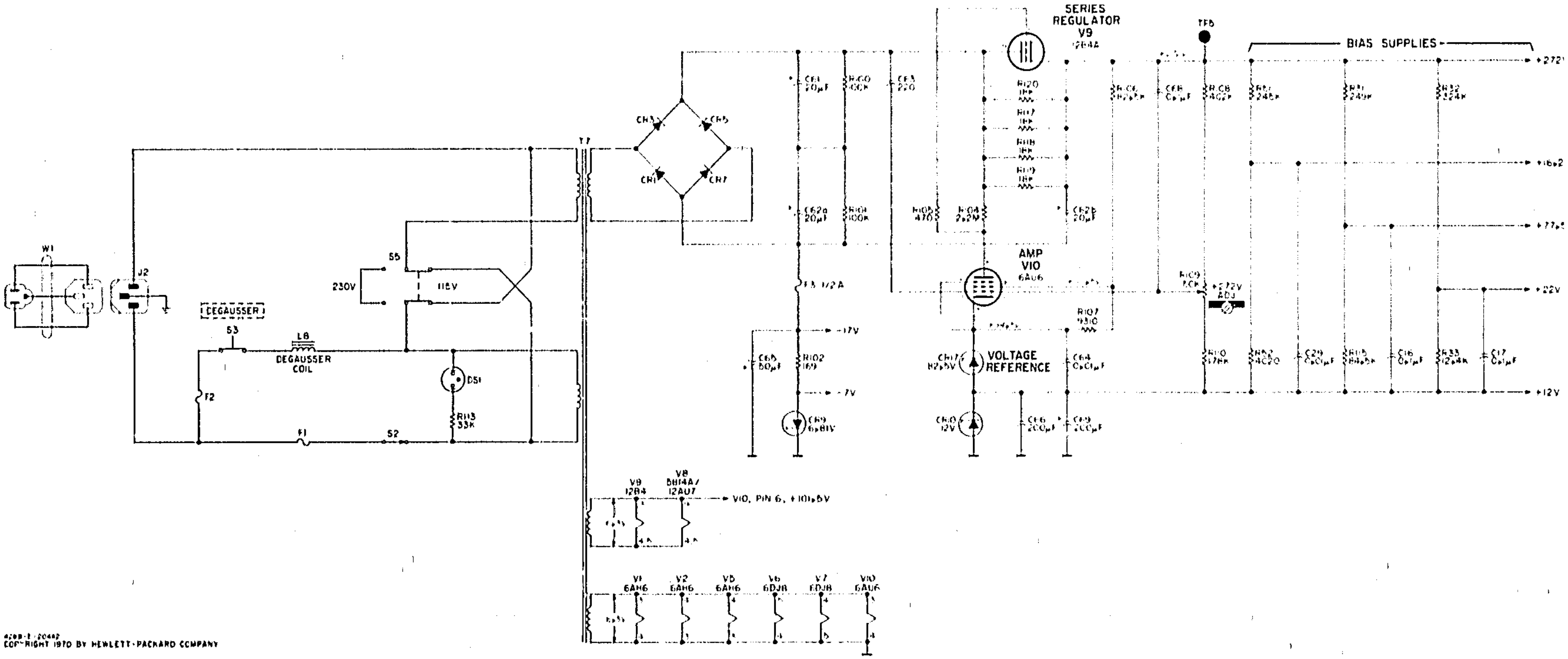
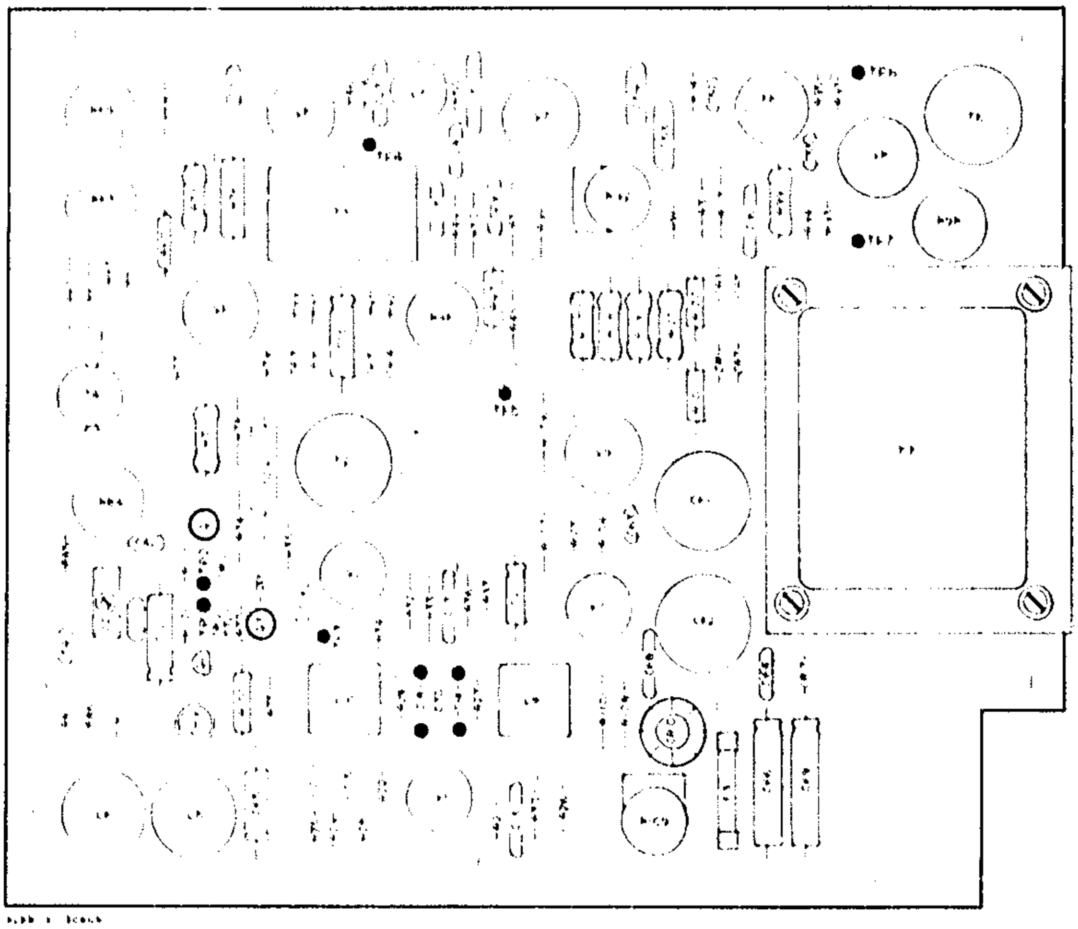
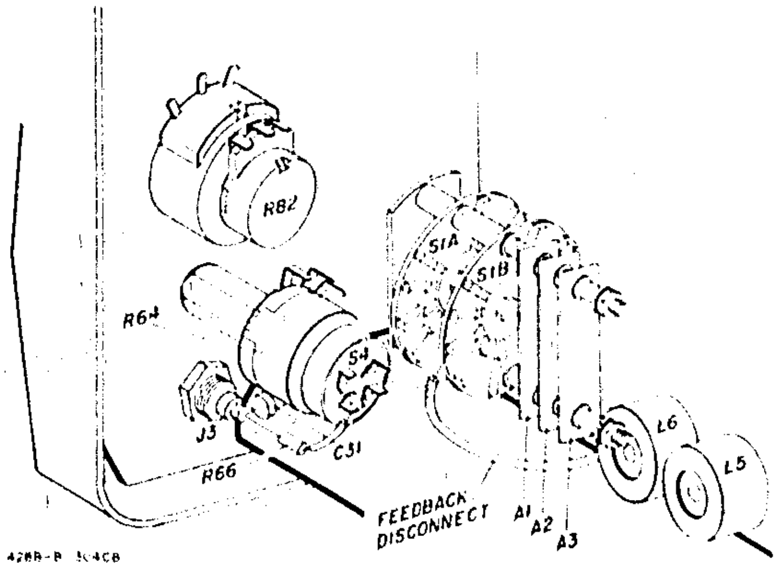


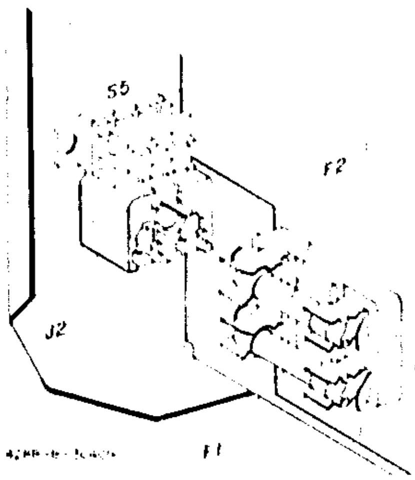
Figure 7-2. Power Supply



Component Locator for Circuit Board Part No. 00428-66501



Front Panel Component Locator



Rear Panel Component Locator

Figure 7-3. Metering Circuit

APPENDIX A
MANUAL BACKDATING CHANGES

Appendix A manual backdating information makes this manual applicable to earlier instruments. Instrument component values that differ from those in the manual, yet are not listed in this appendix, should be replaced using the part number given in Table 6-1.

Instrument Serial Prefix/Number	Make Manual Changes
All	Change 3
602 05250 and below	Change 1,2,3
Below 0955A06151	Change 2,3
Below 0955A09053	Change 4
Below 0955A09673	Change 5
Below 0955A10443	Change 6

CHANGE NO. 1:
Replace Figure 7-3 with backdating schematic, Figure A-2, Page A-7/A-8. Figure A-1, 428B Side Views apply. Replace items in Table 6-1 with parts list on Pages A-3 thru A-5. In Paragraph 4-49, replace "zener diodes CR10 and CR17 with "tube V11".

CHANGE NO. 2:
Delete C33* and C72* from Table 6-1 and Figure 7-3.

CHANGE NO. 3:
Part numbers in Table 6-1 are for brown instruments; part numbers for blue instruments are as follows:

Part No.	Description
428A-1C	Dust cover (rack only)
428A-21A	Probe Assembly (see Figure 6-1)
428B-2A	Panel (cabinet only)
428B-2R	Panel (rack only)
428B-44	Assembly: cabinet
4020-0653	Bezel

CHANGE NO. 4:
Table 6-1, Page 6-5. Change part number of the Cabinet Assembly from 00428-66411 to 00428-66401.

CHANGE NO. 5:
Table 6-1, Page 6-4. Change the part number and value of R68 as Follows:

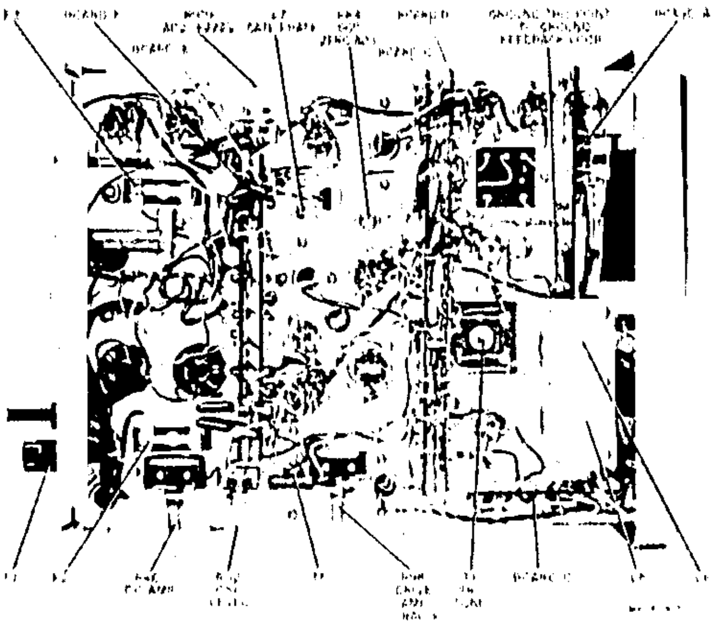
R68 0757-1041 R: fxd 50 ohms 1%

Figure 7-3, Page 7-5/7-6. Change the value of R68 from 65 ohms to 50 ohms.

CHANGE NO. 6:
Table 6-1, Page 6-3. Change the part number and value of R60* as follows:

R60 0683-2015 R: fxd comp 200 ohms 5%

Figure 7-3, Page 7-5/7-6. Change the value of R60* from 270 ohms to 200 ohms.



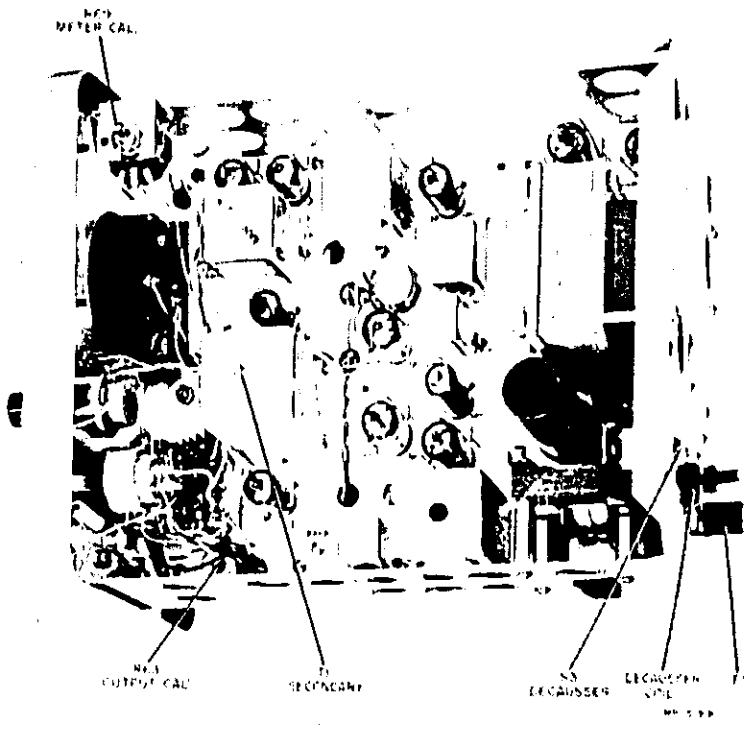
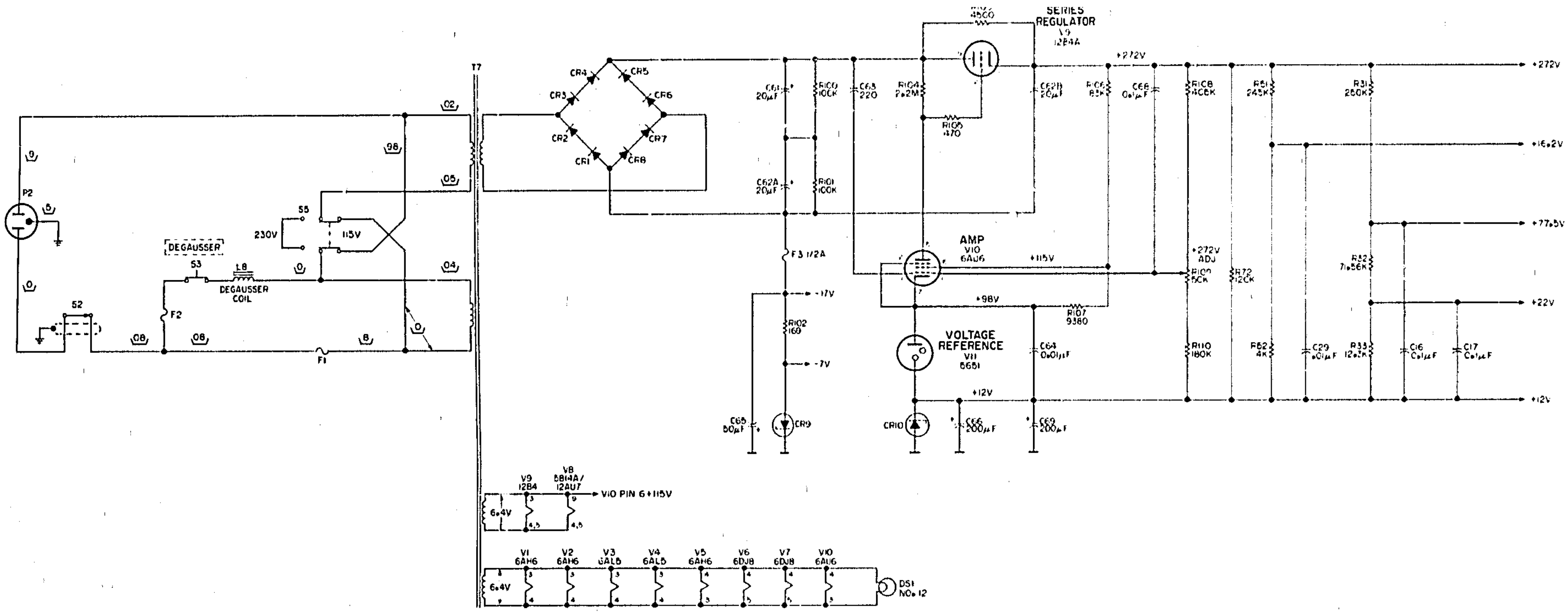


Figure A-1. 428B Side V:ews

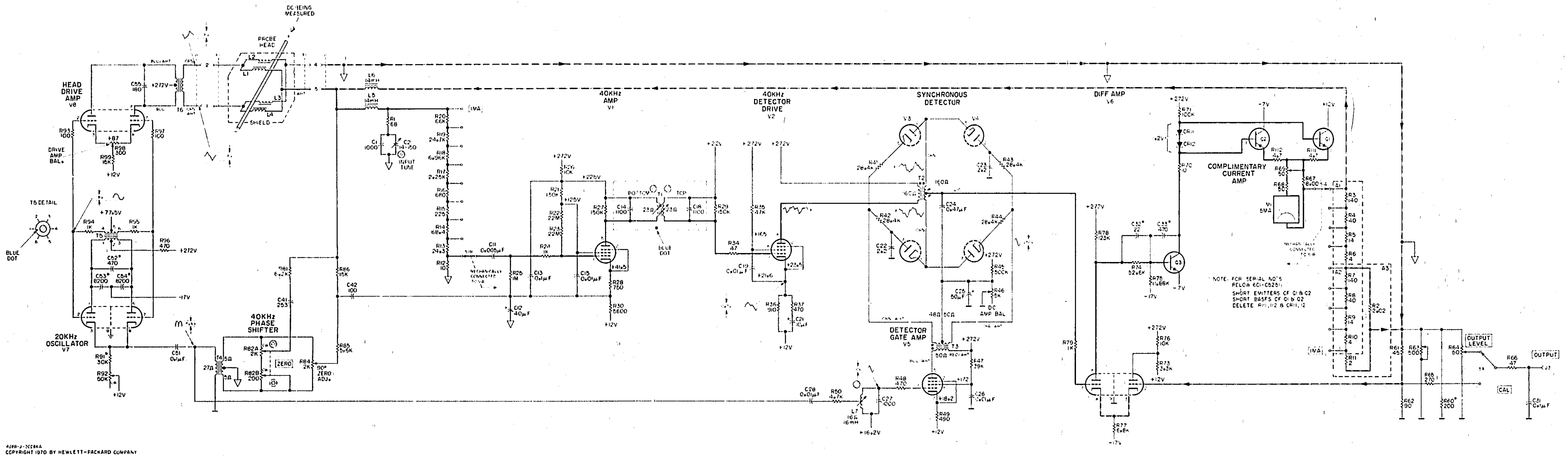
Circuit Reference	⅌ Stock No.	Description #
A1, 2	428B-26A	Assembly: ww resistor, A1 includes, R3 thru R6 A2 includes, R7 thru R10
A3	428B-26B	Assembly: ww resistor, includes R2, 11
C1	0140-0099	fxd, mica, 1K pf ±1%, 500 vdcw
C2	0131-0004	var, mica, 14-150 pf, 175 vdcw
C3 thru C10		Not Assigned
C11	0150-0014	fxd, cer, 5K pf, 500 vdcw
C12	0180-0050	fxd, elect, 40 uf -15% +100%, 50 vdcw
C13	0170-0022	fxd, my, 0.1 uf ±20%, 600 vdcw
C14		nsr, part of T1 assembly
C15	0150-0012	fxd, cer, 10K pf ±20%, 1000 vdcw
C16, 17	0170-0019	fxd, my, 0.1 uf ±5%, 200 vdcw
C18		nsr, part of T1 assembly
C19	0150-0012	fxd, cer, 10K pf ±20%, 1000 vdcw
C20		Not Assigned
C21	0180-0059	fxd, elect, 10 uf -10% +100%, 25 vdcw
C22, 23	0150-0015	fxd, TiO_2 2.2 pf ±10%, 500 vdcw
C24	0170-0078	fxd, my, 0.47 uf ±5%, 150 vdcw
C25	0180-0058	fxd, elect, 50 uf -10% +100%, 25 vdcw
C26	0150-0012	fxd, cer, 10K pf ±20% 1000 vdcw
C27	0140-0099	fxd, mica, 1K pf ±1%, 500 vdcw
C28, 29	0150-0012	fxd, cer, 10K pf ±20%, 1000 vdcw
C30		Not Assigned
C31	0170-0019	fxd, my, 0.1 uf ±5%, 200 vdcw
C32	0140-0034	fxd, mica, 22 pf ±5%, 500 vdcw
C33 thru C40		Not Assigned
C41	0140-0108	fxd, mica, 253 pf ±2%, 300 vdcw
C42	0140-0041	fxd, mica, 100 pf ±5%, 500 vdcw
C43 thru C50		Not Assigned
C51	0170-0019	fxd, my, 0.1 uf ±5%, 200 vdcw
C52	0140-0149	fxd, mica, 470 pf ±5%, 300 vdcw
C53, 54	0140-2102	fxd, mica, 8.2K pf ±2%, 500 vdcw
C55	0140-0147	fxd, mica, 180 pf ±5%, 500 vdcw
C56 thru C60		Not Assigned
C61	0180-0011	fxd, elect, 20 uf, 450 vdcw
C62A/B	0180-0012	fxd, elect, 2 sect, 20 uf/sect, 450 vdcw
C63	0140-0031	fxd, mica, 220 pf ±10%, 500 vdcw
C64	0150-0012	fxd, cer, 10K pf ±20%, 1000 vdcw
C65	0180-0058	fxd, elect, 50 µf -10% +100%, 25 vdcw
C66	0180-0104	fxd, elect, 200 µf, 15 vdcw
C67		Not Assigned
C68	0170-0022	fxd, my, 0.1 µf ±20%, 600 vdcw
C69	0180-0104	fxd, elect, 200 µf, 15 vdcw
CR1 thru CR8	1901-0028	Diode, Si
CR9	1902-0013	Diode, Si
CR10	1902-0014	Diode, Si
DS1	2140-0012	Lamp: indicating, #12, 2 pin base
F1, 2	2110-0007	Fuse: 1 amp, s-b (F1 115 V operation)
	2110-0008	Fuse: 1/2 amp, s-b (F) 230 V operation)
F3	2110-0012	Fuse: 1/2 amp
J1	1251-0080	Connector: female, 4 pin
J2		Not Assigned
J3	1250-0118	Connector: BNC, female
L1 thru L4		nsr; part of probe assembly (see misc.)
L5, 6	428B-60K	Assembly, choke
L7	9140-0049	Inductor: var, 16 mh
L8	9110-0025	Inductor: degaussing
M1	1120-0116	Meter: 0-5 ma, 6-10 ohms
P1	1251-0090	Connector: male, 4 pin
P2	8120-0050	Cable, power
Q1	1854-0039	Transistor: Si NPN 2N3053
Q2	1853-0016	Transistor: Si PNP 2N3638
Q3	1854-0003	Transistor: 2N1504
R1	0687-6801	fxd, comp, 68 ohms ±10%, 1/2 W
R2		nsr; part of A3 assembly
R3 thru R10		nsr; part of A1, A2 assembly
R11		nsr; part of A3 assembly
R12	0727-0335	fxd, dep c, 10 ohms ±10%, 1/2 W
R13	0757-0002	fxd, mfg, 24.3 ohms ±1%, 1/2 W
R14	0727-0035	fxd, dep c, 68.4 ohms ±1/2%, 1/2 W
R15	0727-0060	fxd, dep c, 225 ohms ±1%, 1/2 W
R16	0727-0085	fxd, dep c, 680 ohms ±1%, 1/2 W
R17	0727-0120	fxd, dep c, 2250 ohms ±1%, 1/2 W
R18	0727-0145	fxd, dep c, 6960 ohms ±1%, 1/2 W
R19	0727-0178	fxd, dep c, 24.7K ohms ±1%, 1/2 W

Circuit Reference	⚡ Stock No.	Description*
R20	0727-0108	fxd, dep c, 66K ohms ±1%, 1/2 W
R21	0686-1345	fxd, comp, 130K ohms ±5%, 1/2 W
R22, 23	0687-2261	fxd, comp, 22M ±10%, 1/2 W
R24	0687-1021	fxd, comp, 1K ohms ±10%, 1/2 W
R25	0687-1051	fxd, comp, 1M ±10%, 1/2 W
R26	0687-1031	fxd, comp, 10K ohms ±10%, 1/2 W
R27	0687-1541	fxd, comp, 150K ohms ±10%, 1/2 W
R28	0689-7515	fxd, comp, 750 ohms ±5%, 1 W
R29	0687-1541	fxd, comp, 150K ohms ±10%, 1/2 W
R30	0687-5621	fxd, comp, 5.6K ohms ±10%, 1/2 W
R31	0727-0226	fxd, dep c, 250K ohms ±1%, 1/2 W
R32	0727-0201	fxd, dep c, 71.56K ohms ±1%, 1/2 W
R33	0730-0032	fxd, dep c, 12.3K ohms ±1%, 1 W
R34	0687-4701	fxd, comp, 47 ohms ±10%, 1/2 W
R35	0690-4731	fxd, comp 47K ohms ±10%, 1 W
R36	0689-9115	fxd, comp, 910 ohms ±5%, 1 W
R37	0687-4711	fxd, comp, 470 ohms ±10%, 1/2 W
R38 thru R40		Not Assigned
R41 thru R44	0727-0184	fxd, dep c, 28.4K ohms ±1%, 1/2 W
R45	0727-0244	fxd, dep c, 500K ohms ±1%, 1/2 W
R46	2100-0006	var, ww, 5K ohms ±10%, 2 W
R47	0689-3935	fxd, comp, 39K ohms ±5%, 1 W
R48	0687-4711	fxd, comp, 470 ohms ±10%, 1/2 W
R49	0727-0075	fxd, dep c, 490 ohms ±1%, 1/2 W
R50	0687-4721	fxd, comp, 4.7K ohms ±10%, 1/2 W
R51	0730-0080	fxd, dep c, 245K ohms ±1%, 1 W
R52	0727-0132	fxd, dep c, 4K ohms ±1%, 1/2 W
R53 thru R59		Not Assigned
R60	0687-6811	fxd, comp, 680 ohms ±10%, 1/2 W
R61	0727-0021	fxd, dep c, 45 ohms ±1%, 1/2 W
R62	0727-0038	fxd, dep c, 90 ohms ±1%, 1/2 W
R63	2100-0022	var, ww, lin, 500 ohms ±20%, 1 W
R64	2100-0270	var, ww, lin, 50 ohms ±10%, 2 W
R65	0687-2711	fxd, comp, 270 ohms ±10%, 1/2 W
R66	0687-4701	fxd, comp, 47 ohms ±10%, 1/2 W
R67	0812-0015	fxd, ww, 8 ohms ±3%, 2 W
R68	0727-0023	fxd, dep c, 50 ohms ±1%, 1/2 W
R69	2100-0002	var, ww, 50 ohms ±10%, 2 W
R70	0687-1001	fxd, comp, 10 ohms ±10%, 1/2 W
R71	0693-1041	fxd, comp, 100K ohms ±10%, 2 W
R72	0690-1241	fxd, comp, 120K ohms ±10%, 1 W
R73	0764-0003	fxd, mfg, 330 ohms ±5%, 2 W
R74	0727-0196	fxd, dep c, 52.6K ohms ±1%, 1/2 W
R75	0727-0163	fxd, dep c, 11.66K ohms ±1%, 1/2 W
R76	0816-0008	fxd, ww, 10K ohms ±10%, 10 W
R77	0687-6821	fxd, comp, 6.8K ohms ±10%, 1/2 W
R78	0730-0072	fxd, dep c, 123K ohms ±1%, 1 W
R79	0687-1021	fxd, comp, 1K ohms ±10%, 1/w
R80		Not Assigned
R81	0686-6225	fxd, comp, 6.2K ohms ±5%, 1/2 W
R82A/B	2100-0197	var, comp, dual pot, ±10%, 2 W R82A, 2K ohms R82B, 200 ohms
R83		Not Assigned
R84	2100-0153	var, comp, 2K ohms ±20% 1/3 W
R85	0687-5621	fxd, comp, 5.6K ohms ±10%, 1/2 W
R86	0687-1531	fxd, comp, 15K ohms ±10%, 1/2 W
R87 thru R90		Not Assigned
R91	0727-0195	fxd, dep c, 50K ohms ±1%, 1/2 W
R92	2100-0013	var, comp, lin, 50K ohms ±20%
R93	0687-1011	fxd, comp, 100 ohms ±10%, 1/2 W
R94, 95	0687-1021	fxd, comp, 1K ohms ±10%, 1/2 W
R96	0687-4711	fxd, comp, 470 ohms ±10%, 1/2 W
R97	0687-1011	fxd, comp, 100 ohms ±10%, 1/2 W
R98	2100-0038	var, ww, 300 ohms
R99	0767-0010	fxd, mfg, 15K ohms ±5%, 3 W
R100, 101	0690-1041	fxd, comp, 100K ohms ±10%, 1 W
R102	0811-0041	fxd, ww, 169 ohms ±1%, 3 W
R103	0819-0011	fxd, ww, 4.5K ohms ±10%, 20 W
R104	0687-2251	fxd, comp, 2.2M ±10%, 1/2 W
R105	0687-4711	fxd, comp, 470 ohms ±10%, 1/2 W
R106	0730-0063	fxd, dep c, 83K ohms ±1%, 1 W
R107	0727-0154	fxd, dep c, 9380 ohms ±1%, 1/2 W
R108	0727-0240	fxd, dep c, 405K ohms ±1%, 1/2 W
R109	2100-0013	var, comp, lin, 50K ohms ±20%

Circuit Reference	ℎ Stock No.	Description*
R110	0727-0218	fxd, dep c, 180K ohms ±1%, 1/2 W
S1	428B-19A	Assembly: range switch, includes, R2 thru R20, R61, R62
S2	3101-0001	Switch: tog, SPST
S3	3101-0018	Switch: tog, SPST, momentary
S4		Not Assigned
S5	3101-0033	Switch, sl: DPDT
T1	9120-0052	Assembly: transformer, interstage, includes, C14, C18
T2	428A-60G	Transformer, detector signal
T3	428A-60C	Transformer, gate
T4	428B-60J	Transformer, zero balance
T5	9120-0051	Transformer, ..se
T6	428A-60D	Transformer, head drive
T7	9100-0104	Transformer, power
V1, 2	1923-0017	Tube, electron: 6AH6
V3, 4	1930-0013	Tube, electron: 6AL5
V5	1923-0017	Tube, electron: 6AH5
V6, 7	1932-0022	Tube, electron: 6DJ8/ECC88
V8	1932-0029	Tube, electron: 12AU7
V9	1921-0010	Tube, electron: 12B4A
V10	1923-0021	Tube, electron: 6AU6
V11	1940-0001	Tube, electron: 5651
		MISCELLANEOUS
	428A-21A	Assembly: probe, includes L1 thru L4, P1
	428B-65C	Assembly: circuit board "C" includes R65, R67, R68
	428B-75H	Assembly: circuit board "A" includes C32, C66, C69, CR9, CR10, Q1 thru Q3, R70, R71 R74, R75, R102
	428B-75B	Assembly: resistor board "B" includes C13 R26, 27 C15 R35, 36 C21 R41, 42 C25 R45 R21 thru R23 R73
	428B-75C	Assembly: circuit board "C" includes C16, C17, C24 C41, C42 R30 thru R33 R43, R44 R77 thru R79 R81 R85, R86
	428B-75D	Assembly: resistor board "D" includes C1, C2 C11, C12 R1 R25
	428B-75E	Assembly: resistor board "E" includes C27 thru C29 C51 R47 thru R52 R72 R91 R94 thru R96
	428B-75F	Assembly: resistor board "F" includes C53, C54 C68 CR1 thru CR8 R106 R108 R110
	G-74AW	Knob: red, 3/4" w/arrow
	G-74J	Knob: black, 1", concentric shaft ZERO
	G-74N	Knob: bar, RANGE
	1200-0003	Socket, tube: 9 pin miniat
	1200-0017	Socket, tube: 7 pin miniat
	1400-0008	Fuseholder
	1400-0084	Fuseholder
	1450-0020	Jewel, pilot light
	8520-0017	Electric shaver brush
	1205-0011	Heat dissipator, semiconductor



p/o Figure A-2. Backdating Schematics



p/o Figure A-2. Backdating Schematics

CODE LIST OF MANUFACTURERS

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

Code No	Manufacturer	Address
00000	U.S.A Common	Any supplier of U.S.
00136	McCoy Electronics	Mount Holly Springs, Pa.
00213	Sage Electronics Corp.	Rochester, N.Y.
00287	Cemco, Inc.	Danielson, Conn.
00334	Humidial	Colton, Calif.
00348	Mictron, Co., Inc.	Valley Stream, N.Y.
00373	Garlock Inc.	Cherry Hill, N.J.
00656	Aerovox Corp.	New Bedford, Mass.
00779	Amp. Inc.	Harrisburg, Pa.
00781	Aircraft Radio Corp.	Boonton, N.J.
00809	Croven, Ltd.	Whitby, Ontario, Canada
00815	Northern Engineering Laboratories, Inc.	Burlington, Wis.
00853	Sangamo Electric Co., Pickens Div.	Pickens, S.C.
00866	Goe Engineering Co.	City of Industry, Cal.
00891	Carl E. Holmes Corp.	Los Angeles, Cal.
00929	Microlab Inc.	Livingston, N.J.
01002	General Electric Co., Capacitor Dept.	Hudson Falls, N.Y.
01009	Alden Products Co.	Brockton, Mass.
01121	Allen Bradley Co.	Milwaukee, Wis.
01255	Litton Industries, Inc.	Beverly Hills, Cal.
01281	TRW Semiconductors, Inc.	Lawndale, Cal.
01295	Texas Instruments, Inc., Transistor Products Div.	Dallas, Texas
01349	The Alliance Mfg. Co	Alliance, Ohio
01538	Small Parts Inc.	Los Angeles, Cal.
01589	Pacific Relays, Inc.	Van Nuys, Cal.
01670	Gudebrod Bros. Silk Co.	New York, N.Y.
01930	Amerock Corp.	Rockford, Ill.
01960	Pulse Engineering Co	Santa Clara, Cal.
02114	Ferroxcube Corp. of America	Saugerties, N.Y.
02116	Wheelock Signals, Inc.	Long Branch, N.J.
02286	Cole Rubber and Plastics Inc	Sunnyvale, Cal.
02660	Amphenol-Borg Electronics Corp.	Broadview, Ill.
02735	Radio Corp. of America, Semiconductor and Materials Division	Somerville, N.J.
02771	Vocaline Co. of America, Inc.	Old Saybrook, Conn.
02777	Hopkins Engineering Co.	San Fernando, Cal.
02875	Hudson Tool & Die	Newark, N.J.
03296	Nylon Molding Corp.	Springfield, N.J.
03508	G.E. Semiconductor Prod. Dept.	Syracuse, N.Y.
03705	Apex Machine & Tool Co.	Dayton, Ohio
03797	Eldema Corp.	Compton, Calif.
03818	Parker Seal Co	Los Angeles, Cal
03877	Transitron Electric Corp.	Wakefield, Mass.
03888	Pyrofilm Resistor Co., Inc.	Cedar Knolls, N.J
03954	Singer Co., Diehl Div., Finderne Plant	Somerville, N.J.
04009	Arrow, Hart and Hegeman Elect. Co.	Hartford, Conn.
04013	Taruus Corp.	Lambertville, N.J
04062	Arco Electronic Inc.	Great Neck, N.Y.
04217	Essex Wire	Los Angeles, Cal.
04222	Hi-Q Division of Aerovox	Myrtle Beach, S.C.
04354	Precision Paper Tube Co.	Wheeling, Ill
04404	Palo Alto Division of Hewlett-Packard Co.	Palo Alto, Cal.
04651	Sylvania Electric Products, Microwave Device Div.	Mountain View, Cal
04673	Dakota Engr. Inc.	Culver City, Cal
04713	Motorola Inc. Semiconductor Prod. Div.	Phoenix, Arizona
04732	Filtron Co., Inc. Western Div.	Culver City, Cal
04773	Automatic Electric Co.	Northlake, Ill.
04796	Sequoia Wire Co.	Redwood City, Cal
04811	Precision Coil Spring Co.	El Monte, Cal.
04870	P.M. Motor Company	Westchester, Ill
04919	Component Mfg. Service Co.	W. Bridgewater, Mass
05006	Twentieth Century Plastics, Inc.	Los Angeles, Cal.
05277	Westinghouse Electric Corp. Semiconductor Dept	Youngwood, Pa
05347	Ultronix, Inc.	San Mateo, Cal.
05397	Union Carbide Corp., Elect. Div.	New York, N.Y.
05574	Viking Ind. Inc.	Canoga Park, Cal.
05593	Icore Electro-Plastics Inc.	Sunnyvale, Cal.
05616	Cosmo Plastic (c/o Electrical Spec. Co.)	Cleveland, Ohio
05624	Barber Colman Co.	Rockford, Ill.
05728	Tiffen Optical Co	Roslyn Heights, Long Island, N.Y.
05729	Metro-Tel Corp.	Westbury, N.Y.
05783	Stewart Engineering Co	Santa Cruz, Cal.
05820	Wakefield Engineering Inc.	Wakefield, Mass.
06004	Bassick Co., Div. of Stewart Warner Corp.	Bridgeport, Conn.
06090	Raychem Corp.	Redwood City, Cal.
06175	Bausch and Lomb Optical Co.	Rochester, N.Y.
06402	E.T.A. Products Co. of America	Chicago, Ill.
06540	Amatom Electronic Hardware Co., Inc.	New Rochelle, N.Y
06555	Beede Electrical Instrument Co., Inc.	Penacook, N.H.
06666	General Devices Co., Inc.	Indianapolis, Ind.
06751	Components Inc., Ariz. Div.	Phoenix, Arizona
06812	Torrington Mfg. Co., West Div.	Van Nuys, Cal.
06980	Varian Assoc. Eimac Div.	San Carlos, Cal.
07088	Kelvin Electric Co.	Van Nuys, Cal.
07126	Digitran Co.	Pasadena, Cal.
07137	Transistor Electronics Corp.	Minneapolis, Minn
07138	Westinghouse Electric Corp., Electronic Tube Div.	Elmira, N.Y.
07149	Filmohm Corp.	New York, N.Y.
07233	Cinch-Graphik Co.	City of Industry, Cal
07256	Silicon Transistor Corp.	Carle Place, N.Y.
07261	Avnet Corp.	Culver City, Cal.
07263	Fairchild Camera & Inst. Corp., Semiconductor Div.	Mountain View, Cal
07322	Minnesota Rubber Co.	Minneapolis, Minn.
07387	Birtcher Corp. The	Monterey Park, Cal.
07397	Sylvania Elect. Prod. Inc., Mt. View Operations	Mountain View, Cal
07700	Technical Wire Products Inc.	Cranford, N.J.
07829	Bodine Elect. Co.	Chicago, Ill
07910	Continental Device Corp.	Hawthorne, Cal
07933	Raytheon Mfg. Co., Semiconductor Div.	Mountain View, Cal.
07980	Hewlett-Packard Co., New Jersey Division	Rockaway, N.J.
08145	U.S. Engineering Co.	Los Angeles, Cal
08289	Blinn, Delbert Co.	Pomona, Cal
08358	Burgess Battery Co.	Niagara Falls, Ontario, Canada
08524	Deutsch Fastener Corp.	Los Angeles, Cal
08664	Bristol Co., The	Waterbury, Conn
08717	Sloan Company	Sun Valley, Cal
08718	ITT Cannon Electric Inc., Phoenix Div.	Phoenix, Arizona
08727	National Radio Lab. Inc.	Paramus, N.J
08792	CBS Electronics Semiconductor Operations, Div. of CBS Inc.	Lowell, Mass
08806	General Electric Co. Miniature Lamp Dept.	Cleveland, Ohio
08984	Mel-Rain	Indianapolis, Ind.
09026	Babcock Relays Div.	Costa Mesa, Cal
09097	Electronic Enclosures Inc.	Los Angeles, Calif.
09134	Texas Capacitor Co	Houston, Texas
09145	Tech. Ind. Inc. Atohm Elect.	Burbank, Cal
09250	Electro Assemblies, Inc	Chicago, Ill.
09353	C & K Components Inc.	Newton, Mass
09569	Mallory Battery Co. of Canada, Ltd.	Toronto, Ontario, Canada
09795	Pennsylvania Florocarbon	Clifton Heights, Penn.
09922	Burndy Corp.	Norwalk, Conn
10214	General Transistor Western Corp	Los Angeles, Cal
10411	Ti-Tal, Inc	Berkeley, Cal.
10646	Carborundum Co	Niagara Falls, N.Y.
11236	CTS of Berne, Inc.	Berne, Ind
11237	Chicago Telephone of California, Inc.	So. Pasadena, Cal.
11242	Bay State Electronics Corp.	Waltham, Mass.
11312	Teledyne Inc., Microwave Div.	Palo Alto, Cal
11314	National Seal	Downey, Cal.
11453	Precision Connector Corp.	Jamaica, N.Y
11534	Duncan Electronics Inc.	Costa Mesa, Cal.
11711	General Instrument Corp., Semiconductor Division Products Group	Newark, N.J.
11717	Imperial Electronic, Inc	Buena Park, Cal.
11870	Melabs, Inc.	Palo Alto, Cal.
12136	Philadelphia Handle Co.	Camden, N.J.
12361	Grove Mfg. Co., Inc.	Shady Grove, Pa.
12574	Gulton Ind. Inc., Data System Div.	Albuquerque, N.M.
12697	Clarostat Mfg. Co.	Dover, N.H.
12728	Elmar Filter Corp	W. Haven, Conn.
12859	Nippon Electric Co., Ltd.	Tokyo, Japan
12881	Metex Electronics Corp.	Clark, N.J.
12930	Delta Semiconductor Inc.	Newport Beach, Cal.
12954	Dickson Electronics Corp.	Scottsdale, Arizona
13019	Airco Supply Co., Inc.	Witchita, Kansas
13061	Wilco Products	Detroit, Mich
13103	Thermolloy	Dallas, Texas
13327	Solitron Devices Inc.	Tappan, N.Y.
13396	Telefunken (GmbH)	Hanover, Germany
13835	Midland-Wright Div. of Pacific Industries, Inc.	Kansas City, Kansas
14099	Sem-Tech	Newbury Park, Cal.
14193	Calif. Resistor Corp	Santa Monica, Cal
14298	American Components, Inc.	Conshohocken, Pa
14433	ITT Semiconductor, a Div. of Int. Telephone and Telegraph Corporation	West Palm Beach, Fla.
14493	Hewlett-Packard Company	Loveland, Colo
14655	Cornell Dubilier Electric Corp	Newark, N.J
14674	Corning Glass Works	Corning, N.Y
14752	Electro Cube Inc	San Gabriel, Cal
14960	Williams Mfg. Co.	San Jose, Cal
15106	The Sphere Co., Inc.	Little Falls, N.J.
15203	Webster Electronics Co.	New York, N.Y.
15287	Scionics Corp	Northridge, Cal
15291	Adjustable Bushing Co	N. Hollywood, Cal
15558	Micron Electronics	Garden City, Long Island, N.Y
15566	Amprobe Inst. Corp	Lynbrook, N.Y
15631	Cabletronics	Costa Mesa, Cal
15772	Twentieth Century Coil Spring Co.	Santa Clara, Cal
15801	Fenwal Elect. Inc.	Framingham, Mass
15818	Amelco Inc.	Mountain View, Cal
16037	Spruce Pine Mica Co.	Spruce Pine, N.C
16179	Omni-Spectra Inc	Detroit, Ill
16352	Computer Diode Corp	Lodi, N.J
16554	Electroid Co	Union, N.J
16585	Boots Aircraft Nut Corp	Pasadena, Cal
16688	Ideal Prec. Meter Co., Inc. De Jur Meter Div.	Brooklyn, N.Y
16758	Delco Radio Div. of G.M. Corp	Kokomo, Ind
17109	Thermonetics Inc	Canoga Park, Cal
17474	Tranex Company	Mountain View, Cal
17675	Hamlin Metal Products Corp	Akron, Ohio
17745	Angstrohm Prec. Inc	No. Hollywood, Cal
17856	Siliconix Inc.	Sunnyvale, Cal
17870	McGraw-Edison Co	Manchester, N.H
18042	Power Design Pacific Inc	Palo Alto, Cal
18083	Clevite Corp Semiconductor Div	Palo Alto, Cal
18324	Signetics Corp	Sunnyvale, Cal
18476	Ty-Car Mfg. Co., Inc	Holliston, Mass
18486	TRW Elect. Comp. Div	Des Plaines, Ill
18565	Chomerics	Plainville, Mass
18583	Curtis Instrument, Inc	Mt. Kisco, N.Y
18612	Vishay Instruments Inc	Malvern, Pa
18873	E.I. DuPont and Co., Inc.	Wilmington, Del
18911	Durant Mfg. Co	Milwaukee, Wis
19315	The Bendix Corp., Navigation & Control Div	Teterboro, N.J
19500	Thomas A. Edison Industries, Div. of McGraw-Edison	West Orange, N.J.
19589	Concoa	Baldwin Park, Cal.

CODE LIST OF MANUFACTURERS (Continued)

Code No.	Manufacturer	Address
19644	LRC Electronics	Horseheads, N.Y.
19701	Electra Mfg. Co	Independence, Kansas
20183	General Atronics Corp.	Philadelphia, Pa.
21226	Executone, Inc.	Long Island City, N.Y.
21355	Fafnir Bearing Co., The	New Britian, Conn.
21520	Fansteel Metallurgical Corp.	N. Chicago, Ill.
23020	General Reed Co	Metuchen, N.J.
23042	Texscan Corp	Indianapolis, Ind.
23783	British Radio Electronics Ltd.	Washington, D.C.
24455	G.E. Lamp Division, Nela Park,	Cleveland, Ohio
24655	General Radio Co.	West Concord, Mass.
24681	Memcor Inc., Comp Div.	Huntington, Ind.
26365	Gries Reproducer Corp	New Rochelle, N.Y.
26462	Grobert File Co of America, Inc	Carlstadt, N.J.
26851	Compac Hollister Co	Hollister, Cal
26992	Hamilton Watch Co	Lancaster, Pa.
28480	Hewlett-Packard Co.	Palo Alto, Cal.
28520	Heyman Mfg. Co.	Kenilworth, N.J.
30817	Instrument Specialties Co., Inc.	Little Falls, N.J.
33173	G.E. Receiving Tube Dept	Owensboro, Ky.
35434	Lectrohm Inc.	Chicago, Ill
36196	Stanwyck Coil Products, Ltd	Hawkesbury, Ontario, Canada
36287	Cunningham, W.H. & Hill, Ltd.	Toronto, Ontario, Canada
37942	P.R. Mallory & Co., Inc.	Indianapolis, Ind
39543	Mechanical Industries Prod. Co.	Akron, Ohio
40920	Miniature Precision Bearings, Inc.	Keene, N.H.
40931	Honeywell Inc.	Minneapolis, Minn.
42190	Muter Co.	Chicago, Ill.
43990	C.A. Norgren Co	Englewood, Colo.
44655	Ohmite Mfg. Co.	Skokie, Ill
46384	Penn Eng. & Mfg. Corp	Doylestown, Pa.
47904	Polaroid Corp.	Cambridge, Mass
48620	Precision Thermometer & Inst. Co	Southampton, Pa.
49956	Microwave & Power Tube Div.	Waltham, Mass.
52090	Rowan Controller Co.	Westminster, Md
52983	HP Co., Med. Elec. Div.	Waltham, Mass
54294	Shallcross Mfg. Co.	Selma, N.C.
55026	Simpson Electric Co.	Chicago, Ill
55933	Sonotone Corp.	Elmsford, N.Y.
55938	Raytheon Co. Commercial Apparatus & System Div.	So. Norwalk, Conn
56137	Spaulding Fibre Co., Inc	Tonawanda, N.Y.
56289	Sprague Electric Co.	North Adams, Mass
58474	Superior Elect. Co.	Bristol, Conn
59446	Telex Corp	Tulsa, Okla
59730	Thomas & Betts Co.	Elizabeth, N.J.
60741	Triplett Electrical Inst. Co.	Bluffton, Ohio
61775	Union Switch and Signal Div. of Westinghouse Air Brake Co	Pittsburgh, Pa.
62119	Universal Electric Co	Owosso, Mich
63743	Ward-Leonard Electric Co	Mt. Vernon, N.Y.
64959	Western Electric Co., Inc	New York, N.Y.
65092	Weston Inst. Inc Weston-Newark	Newark, N.J.
66295	Wittek Mfg. Co	Chicago, Ill
66346	Minnesota Mining & Mfg. Co. Revere Mincom Div.	St. Paul, Minn
70276	Allen Mfg. Co.	Hartford, Conn.
70309	Allied Control	New York, N.Y.
70318	Allmetal Screw Product Co., Inc.	Garden City, N.Y.
70417	Amplex, Div. of Chrysler Corp	Detroit, Mich.
70485	Atlantic India Rubber Works, Inc.	Chicago, Ill
70563	Amperite Co., Inc.	Union City, N.J.
70674	ADC Products Inc.	Minneapolis, Minn
70903	Belden Mfg. Co.	Chicago, Ill.
70998	Bird Electric Corp	Cleveland, Ohio
71002	Birnbach Radio Co	New York, N.Y.
71034	Bliley Elect. Co., Inc.	Erie, Pa
71041	Boston Gear Works Div. of Murray Co. of Texas	Quincey, Mass.
71218	Bud Radio, Inc.	Willoughby, Ohio
71279	Cambridge Thermionic Corp.	Cambridge, Mass
71286	Camloc Fastener Corp.	Paramus, N.J
71313	Cardwell Condenser Corp	Lindenhurst, L.I., N.Y.
71400	Bussmann Mfg. Div. of McGraw-Edison Co.	St. Louis, Mo
71436	Chicago Condenser Corp.	Chicago, Ill
71447	Calif. Spring Co., Inc.	Pico-Rivera, Cal
71450	CTS Corp.	Elkhart, Ind.
71468	ITT Cannon Electric Inc.	Los Angeles, Cal
71471	Cinema, Div. Aerovox Corp.	Burbank, Cal.
71482	C.P. Clare & Co	Chicago, Ill
71590	Centralab Div. of Globe Union Inc	Milwaukee, Wis
71616	Commercial Plastics Co	Chicago, Ill
71700	Cornish Wire Co., The	New York, N.Y
71707	Coto Coil Co., Inc	Providence, R.I
71744	Chicago Miniature Lamp Works	Chicago, Ill
71785	Cinch Mfg. Co., Howard B. Jones Div	Chicago, Ill
71984	Dow Corning Corp.	Midland, Mich
72136	Electro Motive Mfg. Co., Inc.	Willimantic, Conn
72619	Dialight Corp	Brooklyn, N.Y
72656	Indiana General Corp., Electronics Div	Keasby, N.J
72699	General Instrument Corp., Cap Division	Newark, N.J
72765	Drake Mfg. Co	Harwood Heights, Ill
72825	Hugh H. Eby Inc.	Philadelphia, Pa
72928	Gudeman Co	Chicago, Ill
72962	Elastic Stop Nut Corp.	Union, N.J
72964	Robert M. Hadley Co.	Los Angeles, Cal
72982	Erie Technological Products, Inc	Erie, Pa.
73061	Hansen Mfg. Co., Inc	Princeton, Ind
73076	H.M. Harper Co	Chicago, Ill
73138	Helipot Div. of Beckman Inst., Inc	Fullerton, Cal
73293	Hughes Products Division of Hughes Aircraft Co	Newport Beach, Cal
73445	Amperex Elect. Co	Hicksville, L.I., N.Y
73506	Bradley Semiconductor Corp	New Haven, Conn
73559	Carling Electric, Inc.	Hartford, Conn
73586	Circle F Mfg. Co.	Trenton, N.J
73682	George K. Garrett Co., Div. MSL Industries Inc.	Philadelphia, Pa.
73734	Federal Screw Products, Inc.	Chicago, Ill
73743	Fischer Special Mfg. Co.	Cincinnati, Ohio
73793	General Industries Co., The	Elyria, Ohio
73846	Goshen Stamping & Tool Co	Goshen, Ind
73899	JFD Electronics Corp	Brooklyn, N.Y.
73905	Jennings Radio Mfg. Corp	San Jose, Cal
73957	Groove-Pin Corp	Ridgefield, N.J
74276	Signalite Inc	Neptune, N.J
74455	J.H. Winns, and Sons	Winchester, Mass
74861	Industrial Condenser Corp	Chicago, Ill
74868	R.F. Products Division of Amphenol-Borg Electronic Corp.	Danbury, Conn.
74970	E.F. Johnson Co	Waseca, Minn
75042	International Resistance Co	Philadelphia, Pa
75263	Keystone Carbon Co., Inc	St. Marys, Pa.
75378	CTS Knights, Inc	Sandwich, Ill
75382	Kulka Electric Corp	Mt. Vernon, N.Y.
75818	Lenz Electric Mfg. Co	Chicago, Ill
75915	Littlefuse, Inc	Des Plaines, Ill.
76005	Lord Mfg. Co	Erie, Pa
76210	C.W. Marwedel	San Francisco, Cal
76433	General Instrument Corp., Micamold Division	Newark, N.J.
76487	James Millen Mfg. Co., Inc.	Malden, Mass
76493	J.W. Miller Co	Los Angeles, Cal
76530	Cinch-Monadnock, Div. of United Carr Fastener Corp	San Leandro, Cal
76545	Mueller Electric Co	Cleveland, Ohio
76703	National Union	Newark, N.J
76854	Oak Manufacturing Co	Crystal Lake, Ill
77068	The Bendix Corp., Electrodynamics Div	N. Hollywood, Cal
77075	Pacific Metals Co	San Francisco, Cal
77221	Phaostran Instrument and Electronic Co.	So. Pasadena, Cal
77252	Philadelphia Steel and Wire Corp	Philadelphia, Pa
77342	American Machine & Foundry Co, Potter & Brumfield Div.	Princeton, Ind.
77630	TRW Electronic Components Div	Camden, N.J
77638	General Instrument Corp., Rectifier Division	Brooklyn, N.Y
77764	Resistance Products Co	Harrisburg, Pa.
77969	Rubbercraft Corp. of Calif.	Torrance, Cal
78189	Shakeproof Division of Illinois Tool Works	Elgin, Ill
78277	Sigma	So. Braintree, Mass
78283	Signal Indicator Corp	New York, N.Y
78290	Struthers-Dunn Inc	Pitman, N.J
78452	Thompson-Bremer & Co	Chicago, Ill
78471	Tilley Mfg. Co	San Francisco, Cal
78488	Stackpole Carbon Co	St. Marys, Pa
78493	Standard Thomson Corp	Waltham, Mass
78553	Tinnerman Products, Inc	Cleveland, Ohio
78790	Transformer Engineers	San Gabriel, Cal
78947	Ucinite Co	Newtonville, Mass
79136	Waldes Kohinoor Inc	Long Island City, N.Y
79142	Veeder Root, Inc	Hartford, Conn
79251	Wenco Mfg. Co	Chicago, Ill
79727	Continental-Wirt Electronics Corp.	Philadelphia, Pa
79963	Zierick Mfg. Corp	New Rochelle, N.Y
80031	Mepco Division of Sessions Clock Co	Morristown, N.J.
80033	Prestole Corp	Toledo, Ohio
80120	Schnitzer Alloy Products Co	Elizabeth, N.J
80131	Electronic Industries Association, Standard tube or semiconductor device, any manufacturer	
80207	Unimax Switch, Div. Maxon Electronics Corp	Wallingford, Conn
80223	United Transformer Corp	New York, N.Y
80248	Oxford Electric Corp.	Chicago, Ill
80294	Bourns Inc.	Riverside, Cal
80411	Acro Div. of Robertshaw Controls Co	Columbus, Ohio
80486	All Star Products Inc.	Defiance, Ohio
80509	Avery Label Co.	Monrovia, Cal
80583	Hammarlund Co., Inc.	Mars Hill, N.C.
80640	Stevens, Arnold, Co., Inc	Boston, Mass
80813	Dimco Gray Co	Dayton, Ohio
81030	International Inst. Inc	Orange, Conn
81073	Grayhill Co.	LaGrange, Ill
81095	Triad Transformer Corp.	Venice, Cal
81312	Winchester Elec. Div. Litton Ind., Inc.	Oakville, Conn
81349	Military Specification	
81483	International Rectifier Corp	El Segundo, Cal
81541	Airpax Electronics, Inc	Cambridge, Maryland
81860	Barry Controls, Div. Barry Wright Corp	Watertown, Mass
82042	Carter Precision Electric Co.	Skokie, Ill
82047	Sperti Faraday Inc., Copper Hewitt Electric Div	Hoboken, N.J
82116	Electric Regulator Corp	Norwalk, Conn
82142	Jeffers Electronics Division of Speer Carbon Co.	Du Bois, Pa
82170	Fairchild Camera & Inst. Corp., Space & Defense Systems Div.	Paramus, N.J
82209	Maguire Industries, Inc	Greenwich, Conn
82219	Sylvania Electric Prod., Inc Electronic Tube Division	Emporium, Pa
82376	Astron Corp	East Newark, Harrison, N.J
82389	Switchcraft, Inc.	Chicago, Ill
82647	Metals & Controls Inc., Spencer Products	Attleboro, Mass
82768	Phillips-Advance Control Co	Joliet, Ill
82866	Research Products Corp	Madison, Wis
82877	Rotron Mfg. Co., Inc	Woodstock, N.Y
82893	Vector Electronic Co	Glendale, Cal
83058	Carr Fastener Co	Cambridge, Mass
83086	New Hampshire Ball Bearing, Inc	Peterborough, N.H
83125	General Instrument Corp., Capacitor Div	Darlington, S.C.
83148	ITT Wire and Cable Div	Los Angeles, Cal
83186	Victory Eng. Corp	Springfield, N.J
83298	Bendix Corp., Red Bank Div.	Red Bank, N.J
83315	Hubbell Corp	Mundelein, Ill
83324	Rosan Inc	Newport Beach, Cal
83330	Smith, Herman H., Inc	Brooklyn, N.Y
83332	Tech Labs	Palisades Park, N.J
83385	Central Screw Co	Chicago, Ill
83501	Gavitt Wire and Cable Co., Div. of Amerace Corp	Brookfield, Mass
83594	Burroughs Corp., Electronic Tube Div.	Plainfield, N.J
83740	Union Carbide Corp., Consumer Prod. Div	New York, N.Y
83777	Model Eng. and Mfg., Inc	Huntington, Ind
83821	Loyd Scruggs Co.	Festus, Mo
83942	Aeronautical Inst. & Radio Co	Lodi, N.J
84171	Arco Electronics Inc	Great Neck, N.Y
84396	A.J. Glesener Co., Inc	San Francisco, Ca.
84411	TRW Capacitor Div	Ogallala, Neb

From: Handbook Supplements H4-1 Dated January 1970

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CODE LIST OF MANUFACTURERS (Continued)

Code No.	Manufacturer	Address
84870	Sarkes Tarzian, Inc.	Bloomington, Ind.
85454	Boonton Molding Company	Boonton, N.J.
85471	A.B. Boyd Co.	San Francisco, Cal.
85474	R.M. Bracamonte & Co.	San Francisco, Cal.
85660	Koiled Kords, Inc.	Hamden, Conn.
85911	Seamless Rubber Co.	Chicago, Ill.
86174	Fafnir Bearing Co.	Los Angeles, Calif.
86197	Clifton Precision Products Co., Inc.	Clifton Heights, Pa.
86579	Precision Rubber Products Corp.	Dayton, Ohio
86684	Radio Corp. of America, Electronic Comp. & Devices Division	Harrison, N.J.
86928	Seastrom Mfg. Co.	Glendale, Cal.
87034	Marco Industries	Anaheim, Cal.
87216	Philco Corporation (Lansdale Division)	Lansdale, Pa.
87473	Western Fibrous Glass Products Co.	San Francisco, Cal.
87664	Van Waters & Rogers Inc.	San Francisco, Cal.
87930	Tower Mfg. Corp.	Providence, R.I.
88140	Cutler-Hammer, Inc.	Lincoln, Ill.
88220	Gould-National Batteries, Inc.	St. Paul, Minn.
88698	General Mills, Inc.	Buffalo, N.Y.
89231	Graybar Electric Co.	Oakland, Cal.
89473	G.E. Distributing Corp	Schenectady, N.Y.
89479	Security Co.	Detroit, Mich.
89665	United Transformer Co.	Chicago, Ill.
90030	United Shoe Machinery Corp.	Beverly, Mass.
90179	U.S. Rubber Co., Consumer Ind. & Plastics Prod. Div.	Passaic, N.J.
90365	Belleville Specialty Tool Mfg., Inc.	Belleville, Ill.
90763	United Carr Fastener Corp.	Chicago, Ill.
90970	Bearing Engineering Co.	San Francisco, Cal.
91146	ITT Cannon Elect. Inc., Salem Div.	Salem, Mass.
91260	Connor Spring Mfg. Co.	San Francisco, Cal.
91345	Miller Dial & Nameplate Co.	El Monte, Cal.
91418	Radio Materials Co.	Chicago, Ill.
91506	Augat Inc.	Attleboro, Mass.
91637	Dale Electronics, Inc.	Columbus, Nebr.
91662	Elco Corp.	Willow Grove, Pa.
91673	Epiphone Inc.	New York, N.Y.
91737	Gremar Mfg. Co., Inc.	Wakefield, Mass.
91827	K F Development Co.	Redwood City, Cal.
91886	Malco Mfg., Inc.	Chicago, Ill.
91929	Honeywell Inc., Micro Switch Division	Freeport, Ill.
91961	Nahm-Bros. Spring Co.	Oakland, Cal.
92180	Tru-Connector Corp.	Peabody, Mass.
92367	Elgeet Optical Co., Inc.	Rochester, N.Y.
92607	Tensolite Insulated Wire Co., Inc.	Tarrytown, N.Y.
92702	IMC Magnetics Corp.	Westbury, L.I., N.Y.
92966	Hudson Lamp Co.	Kearney, N.J.
93332	Sylvania Electric Prod. Inc., Semiconductor Div.	Woburn, Mass.
93369	Robbins & Myers Inc.	Pallisades Park, N.J.
93410	Stemco Controls, Div. of Essex Wire Corp.	Mansfield, Ohio
93632	Waters Mfg. Co	Culver City, Cal.
93929	G.V. Controls	Livingston, N.J.
94137	General Cable Corp.	Bayonne, N.J.
94144	Raytheon Co., Comp. Div., Ind. Comp. Operations	Quincy, Mass.
94148	Scientific Electronics Products, Inc.	Loveland, Colo.
94154	Wagner Elect. Corp., Tung-Sol Div.	Newark, N.J.
94197	Curtiss-Wright Corp., Electronics Div.	East Patterson, N.J.
94222	South Chester Corp.	Chester, Pa.
94330	Wire Cloth Products, Inc.	Bellwood, Ill.
94375	Automatic Metal Products Co.	Brooklyn, N.Y.
94682	Worcester Pressed Aluminum Corp.	Worcester, Mass.
94696	Magnecraft Electric Co.	Chicago, Ill.
95023	George A. Philbrick Researchers, Inc.	Boston, Mass.
95146	Alco Elect. Mfg. Co.	Lawrence, Mass.
95236	Allies Products Corp.	Dania, Fla.
95238	Continental Connector Corp.	Woodside, N.Y.
95263	Leecraft Mfg. Co., Inc.	Long Island, N.Y.
95265	National Coil Co.	Sheridan, Wyo.
95275	[illegible]tramon, Inc.	Bridgeport, Conn.
95348	Gordos Corp	Bloomfield, N.J.
95354	Methode Mfg. Co.	Rolling Meadows, Ill
95566	Arnold Engineering Co.	Marengo, Ill
95712	Dage Electric Co., Inc.	Franklin, Ind
95984	Siemon Mfg. Co.	Wayne, Ill
95987	Weckesser Co.	Chicago, Ill.
96067	Microwave Assoc., West, Inc.	Sunnyvale, Cal.
96095	Hi-Q Div. of Aerovox Corp.	Olean, N.Y.
96256	Thordarson-Meissner Inc.	Mt. Carmel, Ill.
96296	Solar Mfg. Co.	Los Angeles, Cal.
96396	Microswitch, Div. of Minn.-Honeywell	Freeport, Ill.
96330	Carlton Screw Co.	Chicago, Ill.
96341	Microwave Associates, Inc.	Burlington, Mass.
96501	Excel Transformer Co.	Oakland, Cal.
96508	Xcelite, Inc.	Orchard Park, N.Y.
96733	San Fernando Elec. Mfg. Co.	San Fernando, Cal.
96881	Thomson Ind. Inc.	Long Island, N.Y.
97464	Industrial Retaining Ring Co.	Irvington, N.J.
97539	Automatic & Precision Mfg.	Englewood, N.J.
97979	Reon Resistor Corp.	Yonkers, N.Y.
97983	Litton System Inc., Adler-Westrex Commun. Div.	New Rochelle, N.Y.
98141	R-Tronics, Inc.	Jamaica, N.Y.
98159	Rubber Teck, Inc.	Gardena, Cal.
98220	Hewlett-Packard Co., Medical Elec. Div.	Pasadena, Cal
98278	Microdot, Inc	So. Pasadena, Cal.
98291	Sealectro Corp	Mamaroneck, N.Y.
98376	Zero Mfg. Co	Burbank, Cal
98410	Etc Inc.	Cleveland, Ohio
98731	General Mills Inc., Electronics Div.	Minneapolis, Minn
98734	Paeco Division of Hewlett-Packard Co.	Palo Alto, Cal.
98821	North Hills Electronics, Inc.	Glen Cove, N.Y.
98978	International Electronic Research Corp	Burbank, Cal.
99109	Columbia Technical Corp.	New York, N.Y.
99313	Varian Associates	Palo Alto, Cal
99378	Atlee Corp	Winchester, Mass.
99515	Marshall Ind., Capacitor Div.	Monrovia, Cal
99707	Control Switch Division, Controls Co. of America	El Segundo, Cal.
99800	Delevan Electronics Corp.	East Aurora, N.Y.
99848	Wilco Corporation	Indianapolis, Ind
99928	Branson Corp	Whippany, N.J.
99934	Rembrandt, Inc	Boston, Mass
99942	Hoffman Electronics Corp., Semiconductor Division	El Monte, Cal
99957	Technology-Instrument Corp. of California	Newbury Park, Cal.

The following HP Vendors have no number assigned in the latest supplement to the Federal Supply Code for Manufacturers Handbook.

Code	Manufacturer	Address
0000F	Malco Tool and Die	Los Angeles, Calif.
0000Z	Willow Leather Products Corp.	Newark, N.J.
000AB	ETA	England
000BB	Precision Instrument Comp. Co.	Van Nuys, Cal.
000CS	Hewlett-Packard Co., Colorado Springs Div.	Colorado Springs, Colorado
000MM	Rubber Eng. & Development	Hayward, Cal.
000NN	A "N" D Mfg. Co.	San Jose, Cal
000QQ	Cooltron	Oakland, Cal
000WW	California Eastern Lab.	Burlington, Cal
000YY	S.K. Smith Co.	Los Angeles, Cal

SUPPLEMENTAL CODE LIST OF MANUFACTURERS

Code No	Manufacturer	Address
[illegible]	[illegible]	[illegible]

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Revised: May, 1970

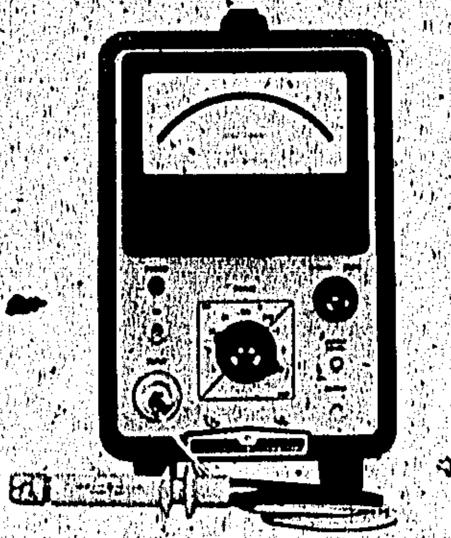
From Handbook Supplements H4-1 Dated January 1970

HP 428B

OPERATING AND SERVICE MANUAL

CLIP-ON DC MILLIAMMETER

428B



HEWLETT hp PACKARD

HP 428B

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CERTIFICATION

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

WARRANTY AND ASSISTANCE

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

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

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

OPERATING AND SERVICE MANUAL

-hp- Part No. 00428-90004

MODEL 428B
CLIP-ON DC MILLIAMMETER

Serials Prefixed: 0995A and above
Appendix A, Manual Backdating Changes
adapts this manual to instruments
with earlier serial prefixes.

P.O. Box 301, Loveland, Colorado, 80537 U.S.A.

Printed: September 1974

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428B SPECIFICATIONS

Table 1-1.

Current Range:
1 mA to 10 A full-scale, nine ranges.

Accuracy:
± 3% of full-scale ± 0.15 mA, from 0°C to 55°C. (When instrument is calibrated to probe).

Probe Inductance:
Less than 0.5 μH.

Probe Induced Voltage:
Less than 15 mV peak (worst case at 20 kHz and harmonics).

Output:
Variable linear output level with switch position for calibrated 1 V into open circuit (corresponds to full-scale deflection).
1.5 V Max. into open circuit in uncalibrated position.
0.73 ± .01 V into 1 kΩ in calibrated position.

Noise:
1 mA Range, < 15 mV rms across 1 kΩ.
3 mA Range, < 5 mV rms across 1 kΩ.
10 mA thru 10 A Ranges, < 2 mV rms across 1 kΩ.

Frequency Range:
DC to 400 Hz (3 dB point).

AC Rejection:
Signals above 5 Hz with peak value less than full-scale affect meter accuracy less than 2%. (Except at 40 kHz carrier frequency and its harmonics). On the 10 A range, ac peak value is limited to 4 A.

Probe Insulation:
300 V Max.

AC Power:
115 or 230 V ± 10%, 48 to 440 Hz, 71 W.

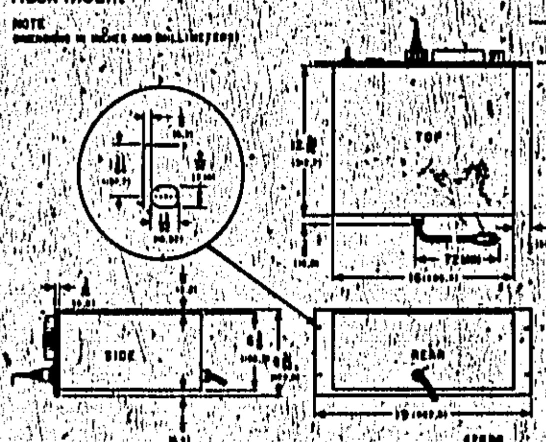
Operating Temperature:
20°C to + 55°C.

Weight:
Rack Mount
Instrument weight: 18 3/4 lbs. (8.5 kg)
Shipping weight: 30 lbs. (13.6 kg)
Cabinet Mount
Instrument weight: 16 5/8 lbs. (7.5 kg)
Shipping weight: 19 lbs. (8.6 kg)

Accessories Available:

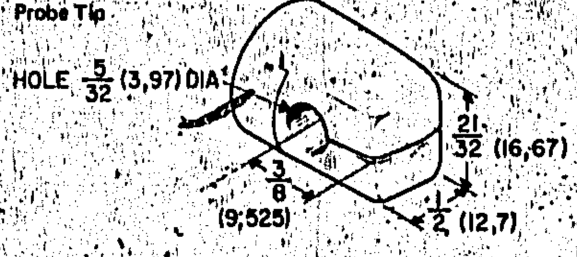
-hp- Model 3529A	Magnetometer Probe
-hp- Model 11035A	Output Cable
-hp- Model 10110A	Output Adapter

Dimensions:
Rack Mount



Cabinet Mount:
7½" wide, 11½" high, 14½" deep (190,5 x 292,1 x 368,3 mm).

Probe Tip



SECTION I
GENERAL INFORMATION

1-1. INTRODUCTION.

1-2. The -hp- Model 428B Clip-On DC Milliammeter measures the magnetic field which exists around a wire carrying dc current. Operating the instrument is simple. After zero setting, the two jaws of the probe are clamped around the wire (arrow on probe head indicates direction of conventional current flow) and the meter will indicate the current.

1-3. There are nine current ranges from 1 mA to 10 amp full-scale deflection. The sensitivity can be increased even further by looping the wire several times through the opening in the probe. The current indication is virtually insensitive to superimposed ac signals and the series loading of the circuit is less than 0.5 μH. A large amount of feedback provides great stability.

1-4. OTHER PROBE HEADS.

1-5. Other probe heads are available to extend the usefulness of your Clip-On DC Milliammeter. Write to the nearest Sales and Service Office (listed in Appendix C) for further information. At the time of publication of this manual, the following accessory probe heads were available:

a. -hp- Model 3529A Magnetometer Probe (1 gauss = 1 amp).

b. -hp- Model 3529A Option C11 Magnetometer Probe (1 gauss = 1 mA).

1-6. Write to the nearest Sales and Service Office (listed in Appendix C) stating your complete requirements for information concerning special applications.

1-7. INSTRUMENT AND MANUAL IDENTIFICATION.

1-8. Hewlett-Packard uses a two-section serial number. If the first section (serial prefix) of the serial number on your instrument does not agree with those on the title page of this manual, change sheets supplied with the manual will define the differences between your instrument and the Model 428B described in this manual. Some serial numbers may have a letter separating the two sections of the number. This letter indicates the country in which the instrument was manufactured.

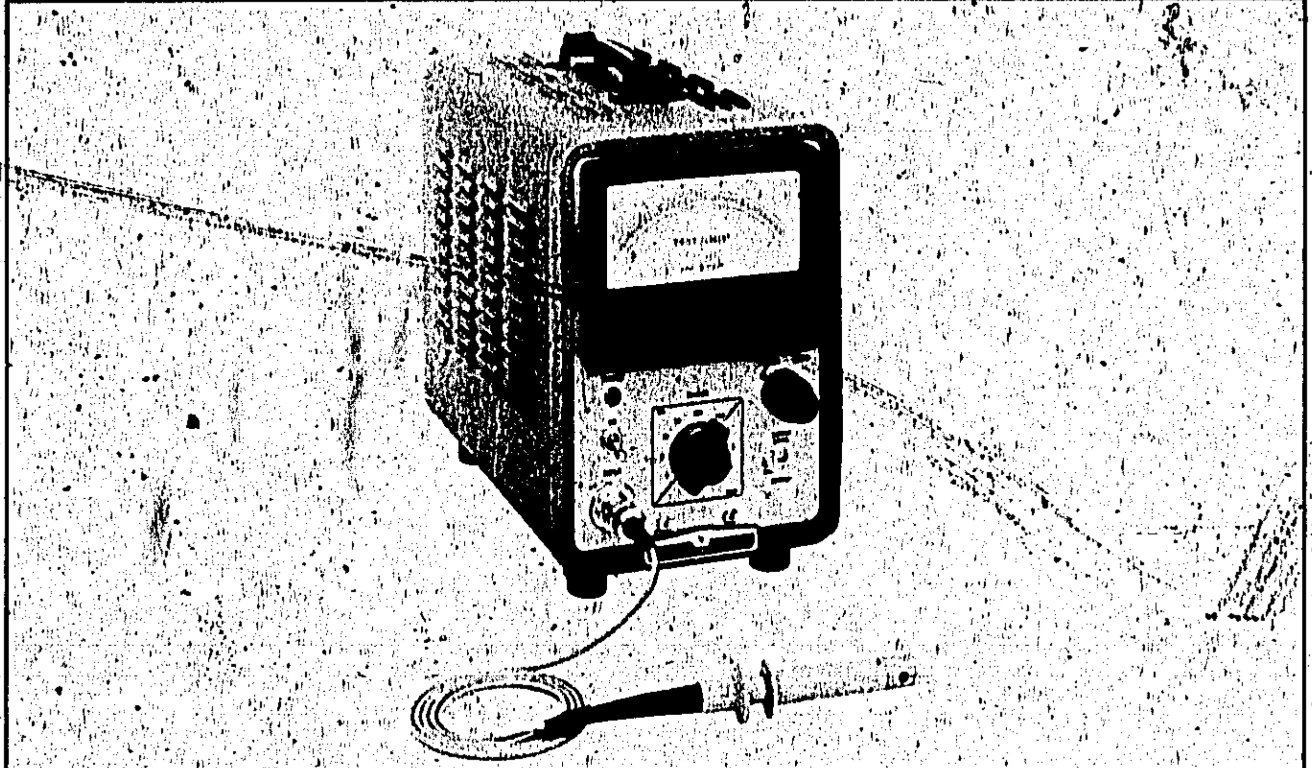


Figure 1-1. Model 428B Clip-On DC Milliammeter.

SECTION II
INSTALLATION

2-1. UNPACKING AND MECHANICAL INSPECTION.

2-2. Inspect instrument for signs of damage incurred in shipment. This instrument should be tested as soon as it is received. If it fails to operate properly, or is damaged in any way, a claim should be filed with the carrier. A full report of the damage should be obtained by the claim agent, and this report should be forwarded to us. We will then advise you of the disposition to be made of the equipment and arrange for repair or replacement. Include model number and serial number when referring to this instrument for any reason.

2-3. Hewlett-Packard Company warrants each instrument manufactured by them to be free from defects in material and workmanship. Our liability under this warranty is limited to servicing or adjusting any instrument returned to the factory for that purpose and to replace any defective parts thereof. Any damage to the instrument upon receipt is due to the carrier. File a claim with the carrier as instructed in the preceding paragraph.

2-4. OPERATION CHECK.

2-5. This instrument should be checked as soon as it is received to determine that its electrical characteristics have not been damaged in shipment. Refer to the In-Cabinet Performance Checks of Section V of this manual.

2-6. INSTALLATION.

2-7. See Paragraph 3-3 before operating this instrument.

2-8. POWER REQUIREMENTS.

2-9. Power requirements are given in Specifications table at the front of this manual.

2-10. OPERATION ON 115 OR 230 VOLTS.

2-11. This instrument may be used with either a 115 volt or 230 volt supply with a frequency of 48 to 440 Hz, single phase. This instrument is shipped from the factory ready for operation from a 115 volt source unless otherwise indicated.

2-12. To operate from a 230 volt source, the 115/230 switch on the rear apron must be flipped to 230. First turn the instrument off and pull the power cable from the socket. Place a pointed tool, such as the sharpened end of a pencil, in the slot of the switch and pull down. Replace the fuse with the one given in Table 6-1 for 230 volt operation.

2-13. THREE CONDUCTOR POWER CABLE.

2-14. The three-conductor power cable supplied with the instrument is terminated in a polarized, three-prong male connector, recommended by the National Electrical Manufacturers' Association (NEMA). The third conductor grounds the instrument chassis for the **PROTECTION OF THE OPERATING PERSONNEL.** When using a three-prong to two-prong adapter, ground third lead (green wire) externally.

2-15. RACK MOUNT MODEL.

2-16. This instrument is available in a rack mount version in addition to the cabinet model shown in this manual. The rack mount version is identical electrically and similar physically except that the degausser has been moved to the front panel for greater convenience.

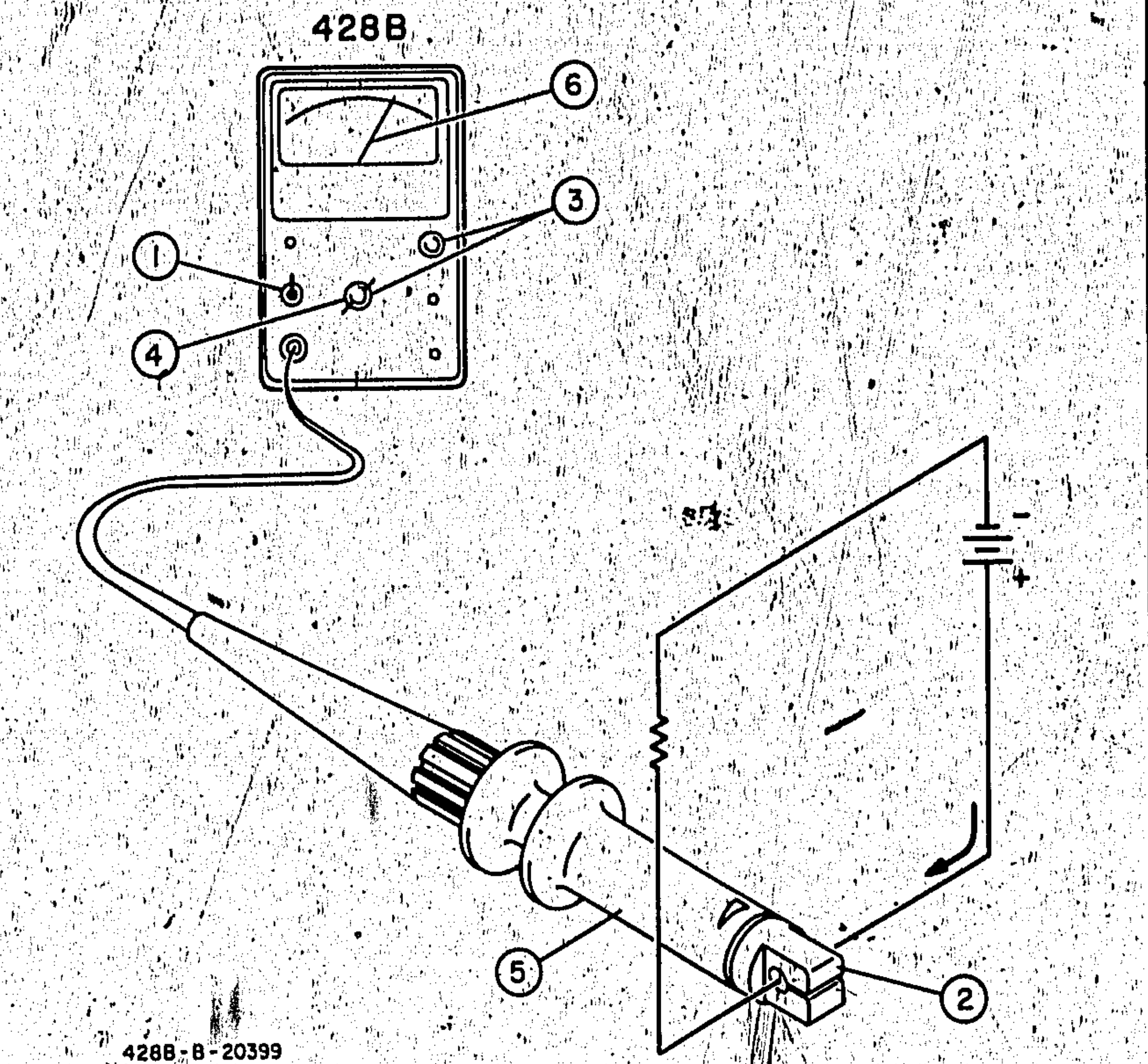
2-17. PREPARATION FOR STORAGE AND SHIPMENT.

2-18. The best method for packing this instrument is in the original shipping carton with the original fillers packed in the same manner as when received from the factory. Therefore, when unpacking, note carefully the method of packing and save the original packing material for possible future reuse.

2-19. If the original packing material is not available, and it is desired to package the instrument for storage or shipment, first wrap the instrument in heavy kraft paper to avoid scratching the paint. Then pack in a cardboard carton with a bursting strength of at least 150 lb per square inch. Pad the instrument on all sides with at least 2 inches of rubberized hair or at least 4 inches of tightly packed excelsior.

2-20. STORAGE.

2-21. No special precautions are necessary in storage except the usual protection against mechanical damage, salt air, etc.



1. Turn on power and allow approximately 2 minutes warmup time.
2. Check closure of probe jaws (see Paragraph 3-20).
3. Set RANGE switch to 1 mA. Zero set instrument with ZERO control
4. Set RANGE switch to a range that is higher than the anticipated current to be read.
5. Clip probe jaws around wire carrying dc current, pointing the arrow on the probe in the direction of conventional current (see arrows in figure above).
6. Read current on meter.
7. After use of the Model 428B on the 1 thru 10 AMP RANGE, degauss the probe head (Paragraph 3-29) if zero set cannot be accomplished.

Figure 3-1. Measurement Procedures.

SECTION III
OPERATING INSTRUCTIONS

3-1. INTRODUCTION.

3-2. This section contains instructions and information necessary for operation of the Model 428B Clip-On DC Milliammeter.

3-3 OPERATING PRECAUTIONS.

CAUTION

a. BEFORE APPLYING OPERATING POWER TO THE 428B, VERIFY THAT THE LINE VOLTAGE SWITCH ON THE REAR PANEL INDICATES THE LINE VOLTAGE TO BE USED AND THAT THE INSTRUMENT IS PROPERLY FUSED.

b. THE PROBE IS INSULATED TO WITHSTAND 300 VOLTS MAXIMUM. DO NOT USE THIS PROBE ON A BARE WIRE WHICH IS MORE THAN 300 VOLTS *PEAK* ABOVE GROUND.

c. DO NOT USE THE 428B PROBE IN THE PRESENCE OF STRONG RF FIELDS.

d. DO NOT EXPOSE THE 428B PROBE TO TEMPERATURES EXCEEDING 130° F (55°C). DO NOT LAY THE PROBE ON TOP OF THE 428B CABINET (OR ANY OTHER HOT SURFACE). PROBE UNBALANCE AND EVENTUAL DAMAGE WILL RESULT.

e. DO NOT DROP THE PROBE OR RELEASE THE FLANGES ABRUPTLY SO THAT THE JAWS SNAP TOGETHER.

f. DO NOT OPERATE THE DEGAUSSER FOR MORE THAN THREE MINUTES CONTINUOUSLY.

g. BECAUSE THE 428B IS COOLED BY CONVECTION, PLACE THE 428B WHERE AIR CAN CIRCULATE FREELY THROUGH THE INSTRUMENT.

h. DO NOT USE THE 428B TO MEASURE DC IN A WIRE WHICH CARRIES MORE AC THAN FULL-SCALE READING ON THE METER.

3-4. OPERATING CONSIDERATIONS.

3-5. INTERCHANGING PROBE HEADS.

3-6. Each probe is calibrated at the factory with a particular instrument and carries the serial number of that instrument (serial number appears on probe connector). If a probe has to be replaced, a realignment and recalibration of the instrument is necessary (see also Section V Maintenance).

3-7. EFFECT OF MEASUREMENT ON CIRCUIT.

3-8. Reflected Impedance.

3-9. The probe will add a small inductance to the circuit of less than 0.5 microhenries due to the magnetic core and magnetic shield. This makes it ideal for measuring current in very low impedance paths such as ground loops where other instruments would disturb the circuit.

3-10. Induced Voltage.

3-11. The gating signal, driving the core in and out of saturation, will induce a voltage in the wire carrying the dc current. This induced voltage is less than 15 millivolts peak. If more than one loop is passed through the probe the induced voltage will be multiplied by the number of loops.

3-12. EFFECT OF CIRCUIT ON MEASUREMENT.

3-13. Circuit Impedance.

3-14. The impedance of the circuit being measured has practically no effect on the dc current measurement. A shorted loop inserted along with a wire carrying dc current will decrease the reading by only 0.2% of full scale.

3-15. AC Fields & Superimposed AC Current.

3-16. The instrument is designed to allow a high amount of ac ripple in the dc being measured. The presence of ac whose peak value equals full-scale reading (limited to 4 amperes peak on 10-ampere range) will cause less than 2% error in the dc reading. Examples of such high ac currents are found in the input of dc filter sections of power supplies.

3-17. Ac currents having frequency components of 40 kHz or harmonics thereof will cause error, as such signals will interfere with the 40 kHz output signal of the probe. The meter will indicate a beat reading if the interfering frequency is within approximately 15 cycles of 40 kHz or its harmonics. Although this situation is very improbable, accurate dc current readings can be obtained by shifting the frequency of the external ac signal slightly.

3-18. The instrument as well as the probe head should not be used in strong ac stray fields. Such fields may exist in the vicinity of open core power transformers, or large dc filter chokes, etc.

3-19. Magnetic Fields.

3-20. If the jaws of the probe are incompletely closed, the magnetic shielding and the magnetic circuit will have an air gap. The result is that dc fields, not associated with the dc current being measured, will cause a shift in the meter reading.

3-21. However, there will be an indication of a *strong* external dc field even with the jaws perfectly closed. Usually zero setting with the ZERO control compensates such residual readings for a particular probe location.

3-22. EARTH'S MAGNETIC FIELD. The earth's magnetic field will affect the reading if the jaws of the probe are not completely shielded (jaws partially open). The effect of this field is relatively strong – comparable to deflection due to about 500 mA of current. Complete closure of the jaws can be checked by switching to the 1 mA range with no dc current input. If the jaws mate properly, the zero set should stay within 0.2 mA while rotating the probe head with respect to the earth's magnetic field (probe aligned in an East-West direction).

3-23. If the zero shift is greater, the mating surfaces of the jaws need to be cleaned or the probe wiring may be open (see Section V).

3-24. FIELDS OF PERMANENT MAGNETS. Meter magnets have strong stray fields, which can cause shift in the current indication. Such fields are detected by bringing the closed probe in the area where the measurement is to be made and observing the zero shift (1 mA range).

3-25. FERROUS WIRE. Wires made out of magnetic materials can cause a current reading of 2-3 mA without any connection to the wire. This fact is *important* as leads of most transistors are made out of magnetic material.

3-26. OPERATING PRACTICES.

3-27. MECHANICAL OPERATION OF PROBE.

3-28. The probe jaws are opened by simply squeezing together the two flanges on the probe body. An internal spring returns the jaws to their proper position when the flanges are released. (See Paragraph 3-3e.).

3-29. DEGAUSSING OF PROBE HEAD.

3-30. To demagnetize the probe, proceed as follows:

a. Insert probe into degausser at the rear of the instrument (located on front panel of rackmount models) with arrow on probe in same position as arrow marked on chassis.

b. Depress degausser switch S3 to energize degausser.

c. Withdraw probe very slowly for the first few inches while depressing the degausser switch until probe is removed approximately one foot.

d. Zero instrument on 1 mA range with ZERO control.

3-31. Under normal operating conditions, degaussing may be necessary after measuring current on the 1 thru 10 AMP RANGE.

3-32. Normally, it takes about 10 seconds to degauss the probe when using the above method (see Caution, Paragraph 3-31).

3-33. ELECTRICAL ZERO SET.

3-34. If the instrument cannot be zero set electrically (with ZERO control) there are two probable causes:
1) Incomplete closure of probe jaws, 2) Magnetization of probe head.

3-35. Dust deposits on the lapped surfaces of the probe jaws create an air gap. If the jaws are not completely closed, the earth's magnetic field will affect the reading. With the RANGE switch at 1 mA, rotation of the closed probe should not vary the zero set more than 0.2 mA. Cleaning of the jaws will restore proper operation conditions (see Section V, Cleaning of Probe Jaws).

3-36. Magnetic shields protect the probe head from stray magnetic fields. However, excessive dc currents (such as short circuit discharge currents from electrolytic capacitors, etc.) will magnetize the probe. For demagnetization of probe head, see Paragraph 3-29, Degaussing of Probe Head.

3-37. POLARITY OF CURRENT.

3-38. The arrow on the probe head indicates the direction of the conventional current flow for upscale reading. Reversal of the current flow direction will reverse the indication on the meter (see Figure 3-2).

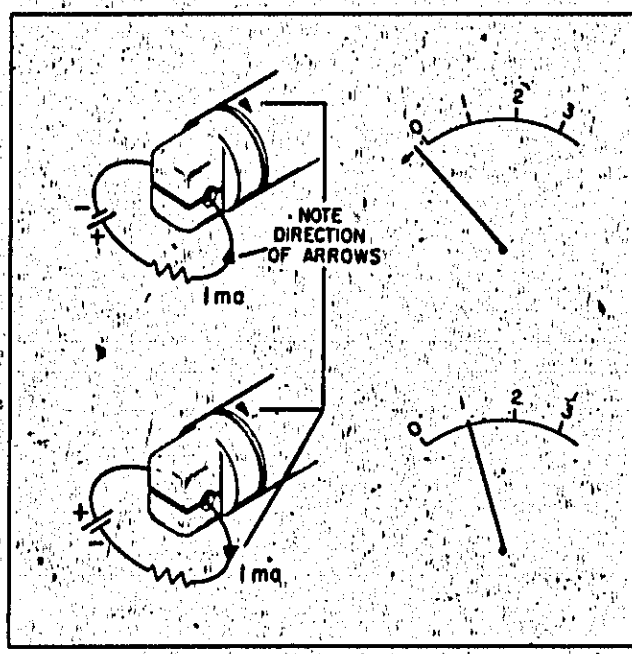


Figure 3-2. Polarity of Current.

3-39. INCREASING THE ABSOLUTE SENSITIVITY.

3-40. The sensitivity of the instrument can be increased by looping the wire (carrying the dc current) several times through the opening of the probe (see Figure 3-3). For example, three turns increase the sensitivity three times. With an increased sensitivity, however, the induced voltage between the probe and the circuit under measurement will increase also.

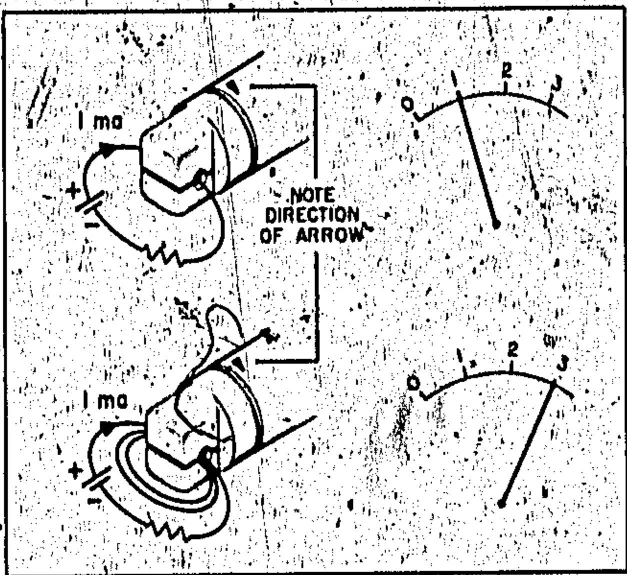


Figure 3-3. Increasing The Absolute Sensitivity.

3-41. CURRENT CHECK LOOPS.

3-42. In restricted situations such as printed circuit boards, wire loops for the probe can be built into the circuit to allow convenient current measurements with the Model 428B. Here, currents can then be measured under operating conditions with the same ease as voltage measurement.

3-43. Circuits can also be modified to accept an impromptu loop for testing. As an example, to measure the collector current of a transistor for troubleshooting purposes, the collector lead can be removed from the board and a loop of fine wire soldered between the collector lead and the board. To measure current through a resistor, lift one lead and install a series loop, clip the 428B probe around the loop and measure current through the resistor. As an alternative, an eqivalent resistor with long leads can be installed to replace the resistor in question.

3-44. NULLING CURRENTS.

3-45. The resolution of the 428B can be increased by nulling one current against another and measuring the difference between the two. To null the reading, clip the probe over both wires at once with the wires so arranged that the currents are going in opposite directions. The considerations mentioned in Paragraph 3-39 also apply to current nulling. For example, assume that a 0.6 A current source is to be tested against a 0.4 A standard. The 0.6 A supply should be looped twice through the probe jaws and the 0.4 A supply should be looped three times through the jaws such that the two currents oppose each other. It should be remembered when making such a measurement, that the absolute value of any deviations observed have been multiplied. If, in the above example, the 0.6 A supply wavered by .01 A, the change would be read as .02 A on the meter.

3-46. USE OF OUTPUT JACK.

3-47. The OUTPUT jack enables the 428B to be used as a dc-coupled amplifier/I-E transducer/isolator. The basic action of the 428B (considered as an input/output device) is to sense the magnetic field around a current carrying wire and deliver a proportional voltage at the OUTPUT jack. The value of the output can be varied by using the OUTPUT LEVEL control to produce as much as 1 1/2 volts at 1 mA. While the 428B meter registers average dc (ignoring ac), the output at the OUTPUT jack contains both the dc and ac components of the signal being measured.

3-48. With Oscilloscope.

3-49. To display the output of the 428B on an oscilloscope:

a. If the oscilloscope is dc coupled, it can be calibrated as in Paragraph 3-51.

b. Clip the probe around the wire which contains the signal to be displayed.

c. Connect the oscilloscope input to the 428B OUTPUT jack.

d. Adjust the 428B RANGE switch to the appropriate range.

3-50. With Recorder.

3-51. To record the output of the 428B on a graphic recorder:

a. Insure that the recorder's input impedance exceeds 1400 ohms.

b. Connect the recorder input to the 428B OUTPUT jack.

c. Zero the 428B on the 1 mA Range, turn OUTPUT LEVEL to minimum output.

d. Zero the recorder.

e. Adjust the 428B ZERO control for full-scale on the 428B meter.

f. Adjust the 428B OUTPUT LEVEL control for full scale on the recorder.

g. Zero the 428B, switch to the appropriate range and clamp the 428B probe around the wire which carries the signal to be measured.

3-52. When recording current variations with the 428B, it should be borne in mind that the 428B displays some long term zero drift. The 428B zero drift normally amounts to about 300 μA (indicated) per day so periodic checks should be made to determine whether or not the ZERO controls need adjustment.

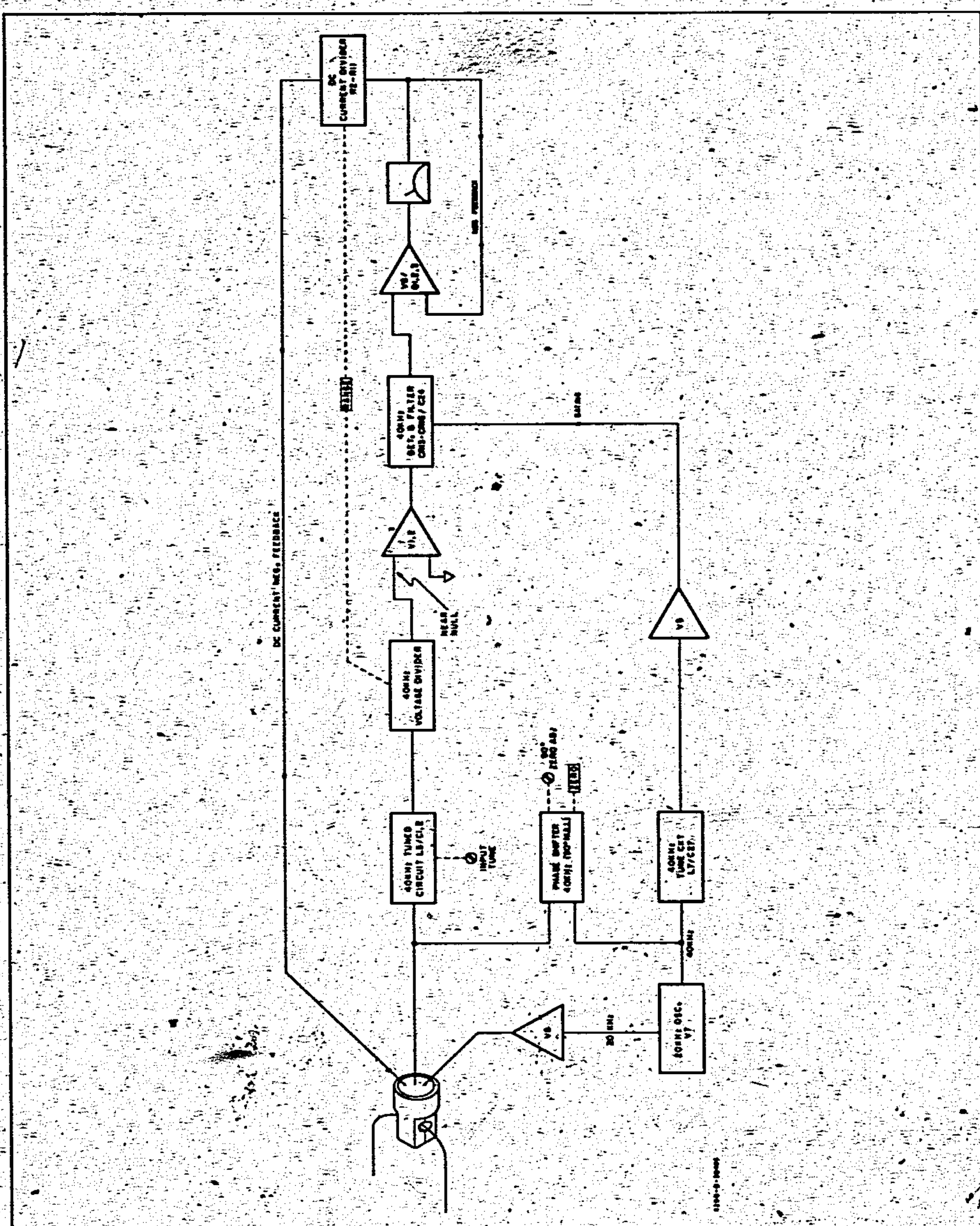


Figure 4-1. Block Diagram.

SECTION IV

THEORY OF OPERATION

4-1. INTRODUCTION.

4-2. This section describes the overall operation of the Model 428B, the operating principle of the current probe and the function of the different circuits of the instrument.

4-3. THEORY OF OPERATION.

4-4. The simplified block diagram of Figures 4-1 and 4-2 shows the basic operation of the Model 428B Clip-On DC Milliammeter.

4-5. The probe clips around a wire carrying dc current and delivers a 40 kHz output signal which is proportional to the dc current. For transducing the dc current into a 40 kHz signal, the probe requires a 20 kHz gating signal, as described in detail under Paragraph 4-9, Current probe.

4-6. The 40 kHz output signal of the probe is amplified, detected and fed back as negative feedback current to the probe head cancelling the effect of the measured dc current and thus reducing the 40 kHz output signal almost to zero. The negative feedback current, being proportional to and magnetically almost equal to the dc current of the inserted wire, is used to indicate the measured dc current.

4-7. The 20 kHz oscillator has two functions: First, it supplies a 20 kHz signal for driving the probe head, and also provides a 40 kHz (second harmonic) signal for gating the 40 kHz Synchrononous Detector.

4-8. Due to slight unbalances, the probe head output contains a small 40 kHz signal, even with no dc current being measured. A 40 kHz phase-shifter output cancels such residual 40 kHz signal (zero-set controls).

4-9. CURRENT PROBE.

4-10. The probe head is a specially designed second harmonic flux-gate type of magnetometer used to measure the magnetic field around a wire carrying direct current.

4-11. The flux gate principle is easily understood by referring to the mechanical model shown in Figure 4-3.

4-12. Coil A (representing wire through probe), is energized with dc, producing a dc flux in the core. Armature is rotating at a constant rate (F), gating the flux 2F times per second inducing a voltage of 2 F frequency in coil B. The amplitude is determined by the dc in coil A.

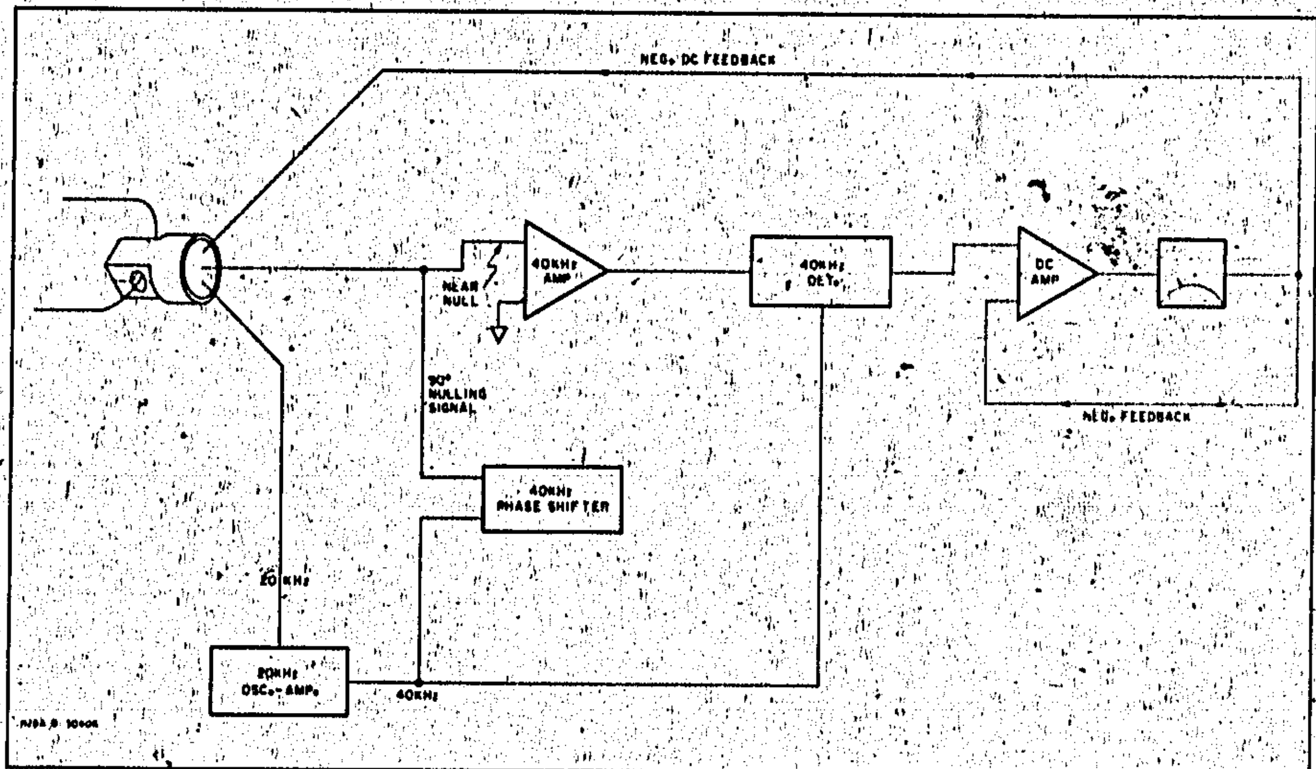


Figure 4-2. Simplified Block.

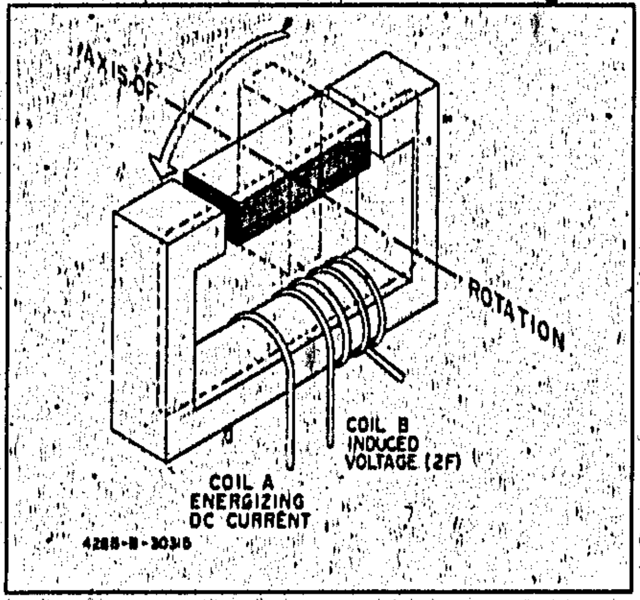


Figure 4-3. Magnetic Mechanical Analogy.

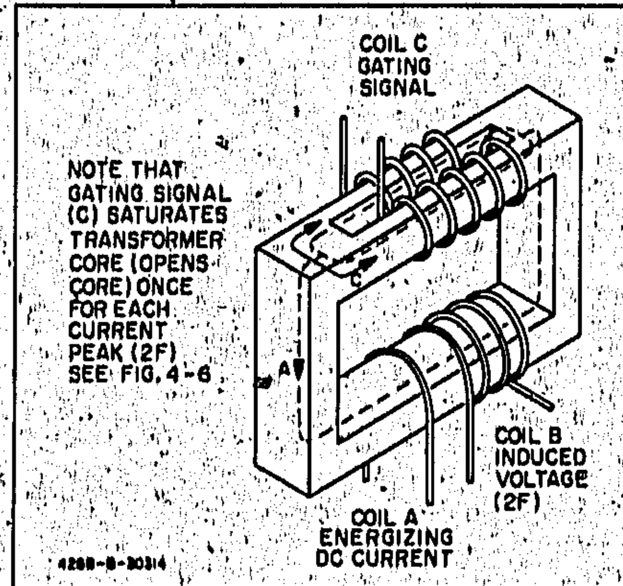


Figure 4-4. Basic Flux Gate.

4-13. The Model 428B head uses this principle in a similar way. Figure 4-4 shows the basic concept of a saturable flux gate.

4-14. A magnetic core in saturation loses permeability and, therefore, is comparable to a core that has been mechanically opened (low permeability due to air gap).

4-15. Coil C saturates the core periodically with a 20 kHz signal, driving the small cores in and out of saturation twice per cycle or once for each peak (positive or negative) of the input current.(See Figure 4-6) The only function of the 20 kHz signal is to gate the dc flux in the core of the current probe.

4-16. The 428B probe head is actually analogous to the flux gate shown in Figure 4-5. The energizing dc current produces flux path "A". Flux path "A" is periodically interrupted by saturation of the (transformer type) core, a result of the two flux paths "C". Refer to Figure 7-3 and note that the current enters L3 and L4 from the same end and that the coils are wound in opposite directions causing opposite magnetic polarities and the consequent circular flux path (c).

4-17. The four coils in the 428B probe head serve 3 purposes: (a) To saturate the cores, a result of the 20 kHz current that flows between pins 1 and 2. This current is generated by the 20 kHz oscillator-amplifier circuits. (b) To act as a secondary, picking up a chopped signal from the

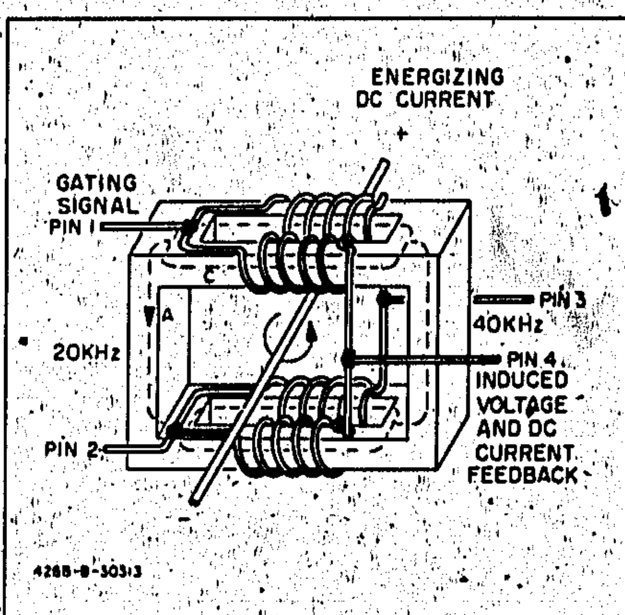


Figure 4-5. 428B Flux Gate.

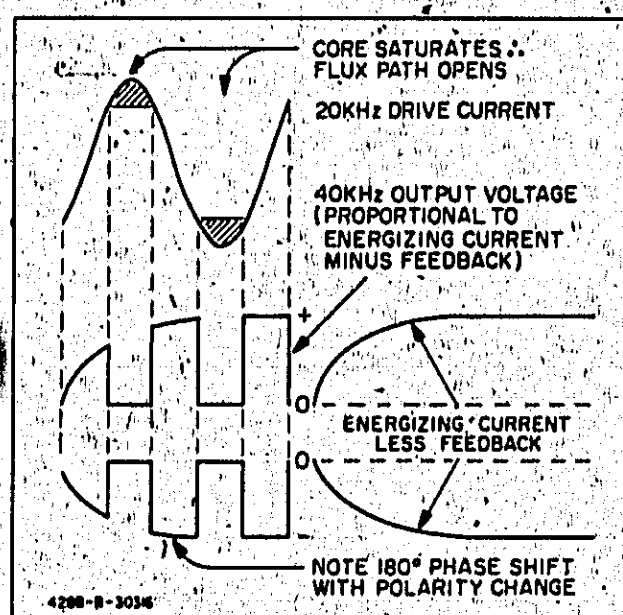


Figure 4-6. Waveforms.

wire that is clamped in the probe jaws. (c) To conduct the dc feedback current that tends to annul the energizing dc current from the wire being measured.

4-18. Because the coils are electrically arranged in a balanced bridge circuit, the 20 kHz signal is balanced at the output of the bridge (pins 3 and 4); and there is no 20 kHz differential signal at this point. The 40 kHz signal and the dc feedback current are also nulled out by the balanced bridge so that these signals do not appear as a differential voltage across pins 1 and 2. The dc feedback current is isolated from the 40 kHz amplifier by capacitor C11. The 40 kHz is kept out of the dc circuitry by RF choke L6.

4-19. 20 kHz OSCILLATOR.

4-20. The function of the 20 kHz oscillator is to generate a balanced 20 kHz signal which, after amplification, is used for driving the probe head in and out of saturation.

4-21. The circuit of the 20 kHz oscillator is shown in Figure 7-3. The oscillator V7 is operating in push-pull having a plate circuit tuned to 20 kHz. Transformer coupling provides positive feedback through resistors R94 and R95 to the oscillator control grids. The control grids of oscillator V7 supply the drive signal for the push-pull head drive amplifier V8. The oscillator level is adjusted by controlling the cathode current of V7.

4-22. The common cathodes of oscillator V7 supply the 40 kHz signal (2 pulses per 20 kHz cycle) needed for the synchronous detector gate amplifier V5 and the 40 kHz phase shifter.

4-23. HEAD-DRIVE AMPLIFIER.

4-24. The head-drive amplifier V8 supplies the balanced 20 kHz signal for the probe head. Drive balance adjustment R98 controls the current ratio of the two triode sections, and hence the second harmonic output. The dc bias voltage for the oscillator and the head-drive amplifier is obtained from reference tube V11.

4-25. DETECTOR GATE AMPLIFIER.

4-26. The 40 kHz resonant circuit C1, C2, and L5 increases the level of the gate signal and filters out all signals except 40 kHz. It also allows phase adjustment of the signal to correspond to the phase of the Synchronous Detector.

4-27. The operation of the Synchronous Detector requires a high level 40 kHz signal. The 40 kHz output signal of the oscillator V7 passes through a tuned circuit and drives the gate amplifier V5. The output of V5 delivers a 40 kHz gate signal to the Synchronous Detector.

4-28. 40 kHz INPUT/AMPLIFIER CIRCUIT.

4-29. The 40 kHz output voltage of the probe head is resonated by a 40 kHz series resonant circuit (L5 and C1/C2). Resistor R1 broadens the resonance response by lowering the Q to minimize drift problems. The 40 kHz signal passes through a voltage divider S1B, which keeps the loop gain constant for all current ranges by maintaining a constant input level range to stage V1. The output of the 40 kHz amplifier V1 is band-pass coupled to the 40 kHz detector driver stage V2. The output signal of V2 is isolated from ground by transformer T2, and fed to the 40 kHz synchronous detector.

4-30. SYNCHRONOUS DETECTOR AND FILTER (C24).

4-31. The Synchronous Detector detects the amplitude and the phase of the 40 kHz signal. Phase detection is necessary to preserve negative feedback at all times. Since the probe may be clipped over the wire in either of two ways the phase of the signal may vary by 180°. If phase detection were not present this 180° phase reversal would cause positive feedback and the instrument would oscillate. With phase detection the polarity of the feedback will change also, maintaining the feedback negative around the system at all times.

4-32. The synchronous detector requires a large 40 kHz gating signal, having the frequency of the desired signal. Figure 4-7 shows the synchronous detector drawn as a bridge circuit.

4-33. On one half-cycle, with A much more positive than E and with B equally more negative that E, the balanced circuit ACB conducts hard; and C becomes effectively equal to point E. Circuit BDA is opened at this time by its back-biassed diodes, and only the signal that appears across the conducting half of the T2(FC) will charge C24.

4-34. On the next half-cycle BDA conducts, ACB becomes open, and the signal across FD will charge C24. If signal F is positive with respect to C on the first half-cycle, signal F will be positive with respect to D on the second half-cycle, and the top of C24 will consistently be charged positively. If the signal at F changes phase by 180° with respect to the gating signal at T3, the top of C24 will consistently be charged negatively.

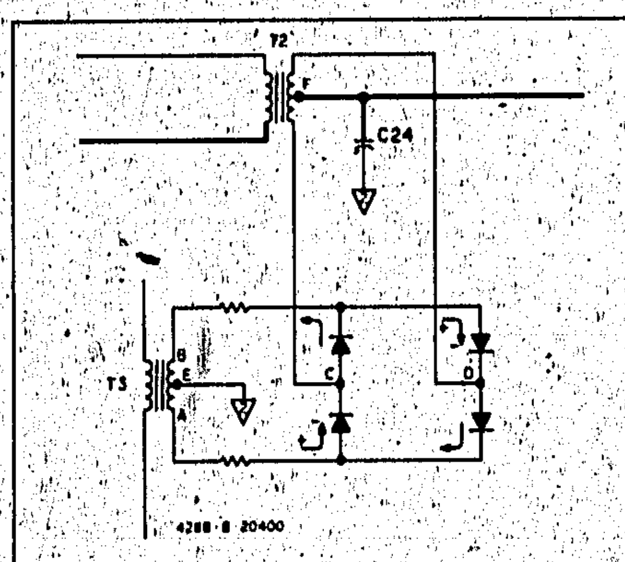


Figure 4-7. Detector Bridge.

4-35. In summary then, C and D are alternately grounded, and the polarity of the signal across T2 changes as C and D are switched to produce an output wherein the polarity is dependent on the phase of the input. Where C is in phase with A, F will be negative when C and D are grounded. Where C is 180° out of phase with A, F will be positive, when C and D are grounded.

4-36. DC AMPLIFIER.

4-37. The dc amplifer supplies a negative dc feedback current to the probe proportional to the output of the synchronous detector. The polarity of the negative feedback current changes if the polarity of the dc current (measured in the probe) changes. In this way the feedback of the system remains negative at all times thus maintaining the stability of the instrument.

4-38. In addition, this local negative feedback loop stabilizes the gain of the DC Amplifier.

4-39. Tube V6 is a differential amplifier in which a signal of approximately 1 volt (for full-scale deflection) is fed to pin 7 and compared with the signal on pin 2. The output of V6 is fed to the base of Q3.

4-40. Transistor Q3 drives the current-amplifiers Q1 and Q2 which are used as emitter-followers in a push-pull NPN-PNP pair combination.

4-41. The output current from the complimentary pair, Q1 and Q2, goes through the meter circuit to the current divider S1A which feeds a portion of this current, appropriate for the range this instrument is working on, to the probe head as negative current feedback.

4-42. After passing through S1A and the probe head, the combined current goes through the parallel resistor network R60-64. This develops a voltage at the junction of R61 and R62 which is proportional to the feedback current. This voltage is applied to pin 2 of V6 to complete the local feedback loop of the DC Amplifier. This circuit makes the output current of the DC Amplifier proportional to the voltage applied to the input grid, pin 7, of V6.

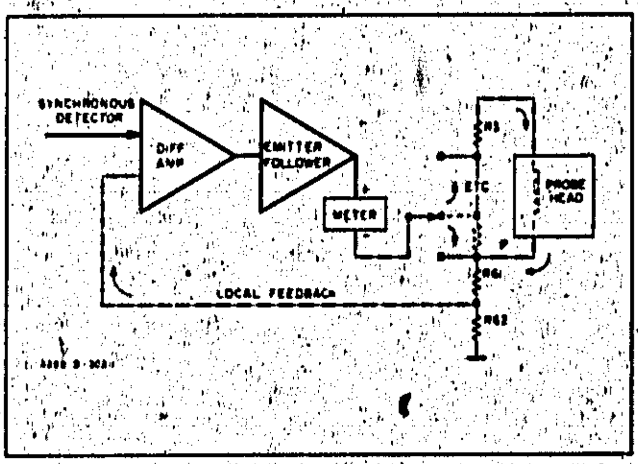


Figure 4-8. Negative Feedback.

4-43. NEGATIVE FEEDBACK CURRENT CIRCUIT.

4-44. The negative feedback current path is shown in Figure 4-8. Current divider S1A divides the feedback current in proportion to the dc current being measured*. For a dc input of 10 A, approximately 50 mA feedback current is fed to the probe head. Since an equal number of ampere-turns are necessary for canceling the main dc flux, the feedback coil inside the head requires approximately 200 turns.

* Maintaining the current through meter M1 constant (5 mA maximum) for all current ranges. Inductance L6 isolates the 40 kHz signal from the dc current circuit.

4-45. 40 kHz PHASE SHIFTER.

4-46. The output of the 40 kHz phase shifter is fed to the head of the probe to cancel any residual 40 kHz output signal which exists when zero dc is being measured. The canceling signal is obtained by adding two voltages which are 90° out of phase and variable in amplitude. Figure 4-9 shows the circuit and the idealized phase relationship of the two output voltages with respect to the signal from the oscillator.

4-47. By adding the two output voltages (vector A and B) a 40 kHz signal is obtained, having phase angle and amplitude to cancel exactly the residual 40 kHz signal from the probe (vector C). Once the residual 40 kHz signal of the probe has been canceled, the ZERO control compensates for any normal variations of zero shift. This control is necessary only on the lower ranges.

4-48. POWER SUPPLY.

4-49. A single series-regulated power supply of the conventional type provides 272 volts regulated for the circuits of the instrument. Voltage reference zener diodes CR10 and CR17 provide a constant cathode potential at control tube V10, and this is the reference potential for the control grid of V10.

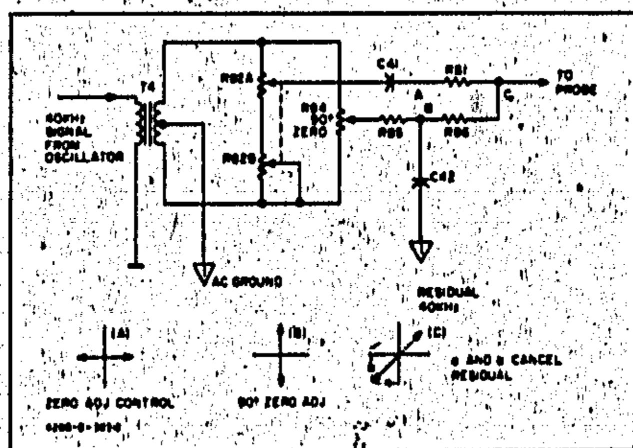


Figure 4-9. 90° Phase Shift.

SECTION V
MAINTENANCE

5-1. INTRODUCTION.

5-2. This section contains the service information which is required to properly maintain the 428B Clip-On DC Milliammeter. Included are performance checks, adjustment and calibration procedures, and servicing and troubleshooting information. A Performance Check Test Card is provided at the end of this section.

5-3. TEST EQUIPMENT REQUIRED.

5-4. The test equipment required to perform the operations outlined in this section is listed in Table 5-1. This table includes the type of equipment, critical specifications, purpose, and recommended model. If the model recommended is not available, equipment which meets or exceeds the critical specifications listed may be substituted.

5-5. IN-CABINET PERFORMANCE CHECKS.

5-6. The performance checks described in Paragraphs 5-7 through 5-24 are front panel procedures designed to compare the Model 428B with its published specifications. These tests may be incorporated into periodic maintenance, post repair, and incoming quality control checks. The performance checks should be conducted before any attempt is made to adjust or calibrate the instrument. During the in-cabinet performance checks, the Model 428B, should be connected to the ac line through a variable voltage device so that line voltage may be varied ± 10% from 115 or 230 Vac to assure that the instrument operates correctly at various ac line voltages.

5-7. CLEANING OF PROBE JAWS.

5-8. When the probe shows excessive sensitivity to the magnetic fields around it, the probe jaws should be cleaned (to determine excessive sensitivity, see Paragraph 5-24 Step a). Excessive sensitivity to external fields can be caused by foreign material between the probe jaws or by overheating (see Paragraph 3-3 Step d). The probe jaws should always be cleaned prior to calibration, adjustment or repair of the 428B.

5-9. To clean the probe jaws, open the probe and brush off the mating surfaces with the brush which is supplied with the instrument. If the brush will not remove the contaminant, disassemble the probe and clean it with a pencil eraser as illustrated in Figure 5-1. When reassembling the probe, be sure that the arrow on the body of the probe points to the heavy red wire as shown in Figure 6-1.

Table 5-1. Recommended Test Equipment.

Equipment	Required Characteristics	Use	Recommended Model
Variable Line Voltage Device	Input 115 V, output 103 - 127 V, 75 W	Alignment	Metered Variac, General Radio Co., Type W5MT3A
Meter Calibrator or other accurate current source	± 0.2% of reading ± 0.1% FS	Alignment Performance Checks	-hp- Model 6920B AC/DC Meter Calibrator
Function Generator	DC to 400 Hz > 10 mA output	Alignment	-hp- Model 3310A Function Generator
Oscilloscope	DC to 40 kHz 100 mV/cm ± 3%	Performance Checks Troubleshooting	-hp- Model 130C 200 µV/cm Oscilloscope
Oscilloscope Probe	Input impedance: 10 megohms	Troubleshooting	-hp- Model 10001A Resistive Divider Probe
Counter	Reads 40 kHz ± 20 Hz	Alignment Troubleshooting	-hp- Model 5300A with 5301A Module
Multimeter	DC: ± .25% at 730 mV AC: Resolves 2 mV Battery operated Ohms: Input impedance: > 1 megohm	Alignment Performance Checks Troubleshooting	-hp- Model 3470 System; Modules; 34740A Display, 34740A Battery Pack, 34702A Multimeter

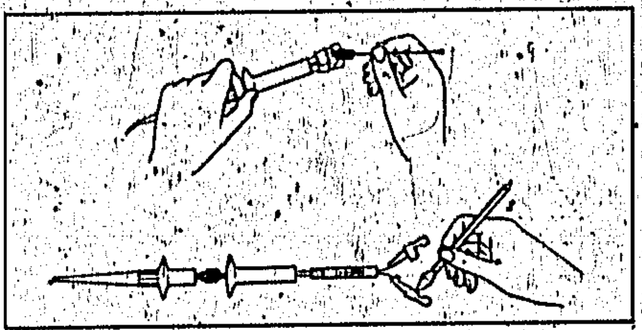


Figure 5-1. Cleaning Probe Jaws.

5-10. ELECTRICAL ZERO SET.

5-11. In the following procedure the numbers in parentheses refer to Figure 5-2.

a. Connect the 428B to the power line through a variable transformer.

b. Turn on power (1) and allow about two minutes of warmup time.

c. Set RANGE switch (4) to 1 mA.

d. Place probe (2) away from any stray fields such as meter magnets or open core transformers. Point probe in an East-West direction.

e. Insure that the probe jaws (3) are completely closed (Paragraph 5-24 Step a, outlines a way to do so).

f. Zero-set the 428B with the ZERO (5) control. If the meter cannot be zeroed, degauss the probe (Paragraph 3-29) or clean the probe jaws (Paragraph 5-7).

g. Change the line voltage from 103 to 127 volts (± 10%) and read zero drift on the 428B meter. Zero drift should not exceed ± .03 mA.

5-12. Allow a 30 minute warmup and stabilization period before conducting the following performance checks.

5-13. RANGE CHECK.

5-14. Figure 5-3 illustrates the test arrangement recommended. A dc calibrator is required for this test (see Table 1). If a meter calibrator is not available, any stable current source, which is capable of operating over a range of 1 mA to 5 mA, may be used. This source should be connected in series with a precision ammeter which can operate over the same range and has the accuracy prescribed for the calibrator as shown in Table 1.

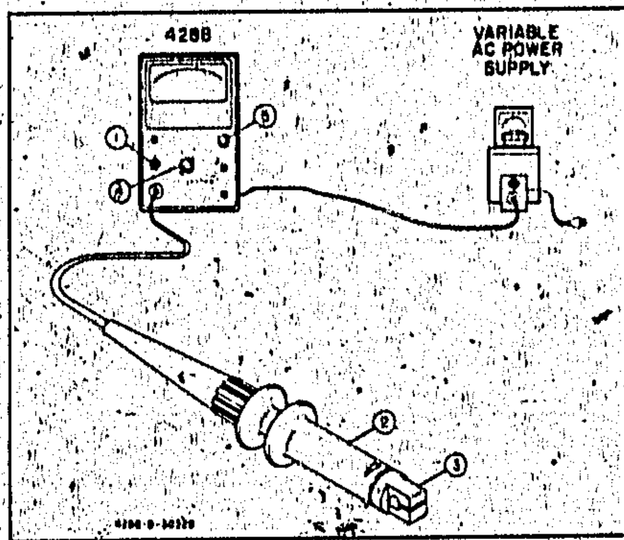


Figure 5-2. Electrical Zero Set.

a. Following the procedure of Paragraph 3-29, degauss the probe and zero the 428B on the 1 mA range.

b. Set the meter calibrator to provide a 1 mA output. Connect a test lead between the output terminals of the meter calibrator and loop the test lead through the probe jaws (one loop). See Figure 3-3 and Figure 5-3. The 428B should read 1 mA ± 30 μA.

c. Loop the test lead through the probe jaws to form three loops. The 428B should read 3 mA ± 90μA.

d. Switch the 428B to the 10 mA range and zero the instrument. Remove the extra loops through the probe so that the lead passes only once through the jaws. Set the meter calibrator to 10 mA; the 428B should read 10 mA ± 0.3 mA.

e. Switch the 428B to the 30 mA range and zero it. Leaving the calibrator set at exactly 10 mA, loop the lead

Table 5-2. Recommended Components For Tests.

Component	Specifications	Use	Recommended -hp- Part Number
Capacitor	.0082 μF ± 2%, 300 VDC	Alignment	0160-2102
Resistor	50 Ω ± 1%, 1 W	Performance Checks	0698-8155
Resistor	1 K ± 1%, 1/8 W	Alignment Performance Checks	0757-0280
Resistor	390 Ω ± 5%, 1/2 W	Alignment	0686-3915
Resistors (2)	10 K ± 1%, 1/8 W, matched	Alignment	0757-0442

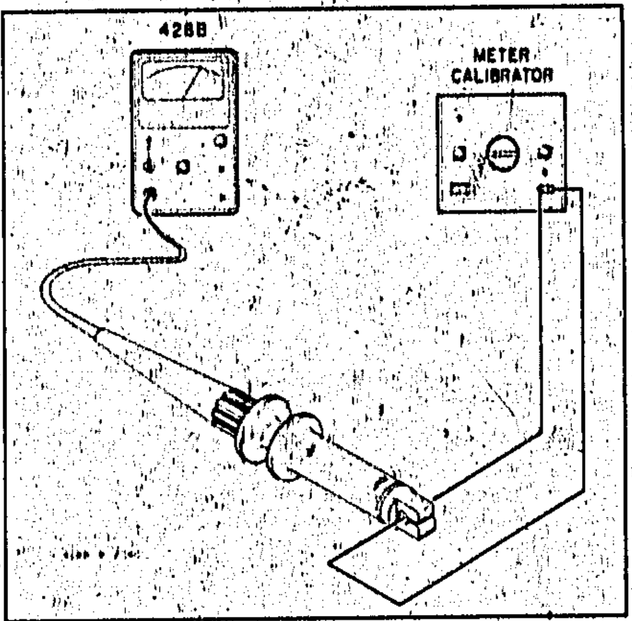


Figure 5-3. Range Check.

through the probe three times. The 428B should read 30 mA ± 0.9 mA.

f. Continue to up-range the 428B and the calibrator following the steps shown on the Performance Check Test Card. Observe that the 428B indications are within the tolerances given on the card.

g. After finishing the last step, with two loops of the test lead (carrying 5 A) through the jaws of the probe, it is advisable to degauss the probe as described in Paragraph 3-29.

5-15. METER TRACKING.

5-16. The test arrangement and equipment required for this test are the same as for Paragraph 5-13.

a. Zero the 428B on the 1 mA range.

b. Switch the 428B to the 100 mA range. Switch the meter calibrator to the 10 mA range and adjust for 10 mA of output. Connect a long, thin test lead to the output terminals of the meter calibrator and loop the lead ten times through the jaws of the 428B probe. Read 100 mA ± 3 mA on the 428B. Remove the test lead from the jaws of the probe one loop at a time and check the linearity of the readings. Each reading should be within 3 mA of nominal (e.g. 90 ± 3 mA, 80 ± 3 mA, etc.).

5-17. OUTPUT CALIBRATION.

5-18. A meter calibrator, dc voltmeter and a one kilohm resistor are required for this test.

a. Switch the 428B and the meter calibrator to the 100 mA range. Set the 428B output level to the CAL position. Connect a test lead between the meter calibrator output leads and clip the 428B probe to the lead.

b. Set the meter calibrator to 100 mA output and read full-scale on the 428B.

c. Connect a voltmeter in parallel with the 1000 ohm resistor to the output jack of the 428B.

d. The voltmeter should read 0.73 V ± 10 mV.

5-19. FREQUENCY RESPONSE.

5-20. A 50 ohm resistor, a function generator and oscilloscope are required to complete this check.

a. Connect a 50 ohm resistor across the output of the function generator.

b. Turn the 428B RANGE switch to 100 mA then clip the 428B probe around the resistor lead.

c. Apply a .0005 Hz square wave from the function generator. The 3310A function generator settings are:

Range: .0001	Function: Square
DC Offset: 0	Frequency Dial: 5

d. Set the function generator Output Level control for a full-scale reading on the 428B.

e. Connect the vertical input of the oscilloscope to the output jack of the 428B.

f. Set the coupling of the oscilloscope input to DC. Set sensitivity and vernier to display variations of the 428B output as a 10 centimeter peak-to-peak signal.

g. Set the function generator to the sine function.

h. Slowly raise the frequency of the function generator output using the frequency dial and function switch as necessary to bring the output to 400 Hz. Watch the oscilloscope, looking for the lowest amplitude of peak deflection.

i. The peak-to-peak level of the waveform should not drop below 7 centimeters (-3 dB).

5-21. AC OVERLOAD.

5-22. An oscillator or function generator, a 50 ohm resistor, an ac voltmeter or oscilloscope, and the meter calibrator are required to complete this check (a filament transformer and suitable current limiting resistors can be substituted for the oscillator shown in Figure 5-4).

a. Set the meter calibrator for 10 mA. With the 428B on the 10 mA range clip the 428B probe onto the lead which connects the calibrator terminals.

b. Note the 428B reading.

c. Set the function generator to 60 Hz; its output to generate a 10 mA peak sine wave into a 50 ohm resistor (1 volt peak-to-peak or 0.35 volt rms across a 50 ohm resistor).

d. Clip the 428B probe onto *BOTH* the wire from the meter calibrator and the resistor lead from the function generator (see Figure 5-4).

e. The 428B should read within 2% of the reading noted in Step b.

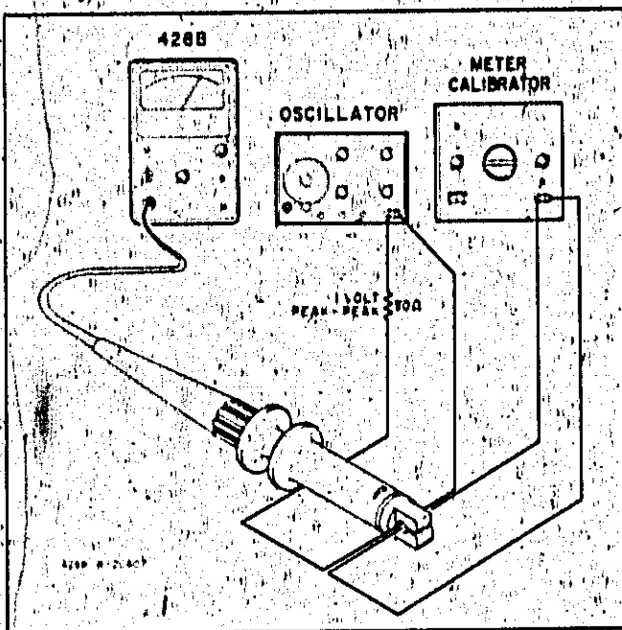


Figure 5-4. AC Overload.

5-23. NOISE CHECK.

5-24. A battery operated ac voltmeter and a 1 kilohm resistor are required to complete this check.

a. Point probe East and West and rotate about its axis. Note peak-to-peak change in meter reading. If it doesn't exceed 0.2 mA on the 1 mA range, proceed. If the change is excessive, perform Paragraph 5-8.

b. Zero the Model 428B on the 1 mA range per Paragraph 5-11 d, e and f.

c. Connect the output of the 428B to the input of a battery operated ac voltmeter with a 1 kilohm resistor in parallel with the voltmeter input.

d. With the 428B on the 1 mA Range check for a maximum of 15 mV reading on the AC Voltmeter.

e. Switch the 428B to the 3 mA range. Check for a maximum of 5 mV reading on the AC Voltmeter.

f. Switch the 428B to the 10 mA range. Check for a maximum of 2 mV reading on the AC Voltmeter.

g. Check each range from 10 mA to 10 amps using the procedure of Step f. No ac output reading should exceed 2 mV.

5-25. ADJUSTMENT PROCEDURE.

5-26. When the instrument shows signs of defective components, use the troubleshooting procedure to find and correct the problem. It is quite easy to compound a 428B trouble by misaligning the instrument in an attempt to adjust out the effects of a defective component.

5-27. POWER SUPPLY.

5-28. The following steps verify adjustment of the power supply.

a. Connect an electronic dc voltmeter to test point 5 (Pin 1, V9) of the 428B. The voltage at this point should be 272 ± 6 V; if not, adjust R109 for 272 V.

b. Measure +12 ± 1 V dc between the cathode of CR10 and ground.

c. Measure -7 ± 1 V dc between the anode of CR9 and ground.

5-29. MECHANICAL ZERO SET.

5-30. When meter is properly zero set, pointer rests over the zero calibration mark on the meter scale when instrument is (1) at normal operating temperature, (2) in its normal operating position, and (3) turned off. Zero-set as follows to obtain best accuracy and mechanical stability:

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

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

c. Rotate mechanical zero adjustment screw clockwise until meter pointer is to left of zero and moving upscale toward zero.

d. Continue to rotate adjustment screw clockwise; stop when pointer is right on zero. If pointer overshoots zero, repeat Steps c and d.

e. When pointer is exactly on zero, rotate adjustment screw slightly counterclockwise to free adjustment screw from the meter suspension. If pointer moves during this step, repeat Steps c through e.

5-31. DC AMPLIFIER BALANCE.

5-32. Disconnect FEEDBACK DISCONNECT (see Figure 7-3), red wire. Place range switch in the 10 amp position. Adjust fine and course zero controls for center of travel. Adjust R46 for zero on front panel meter.

5-33. Reconnect FEEDBACK DISCONNECT.

5-34. ALIGNMENT.

5-35. OSCILLATOR BALANCE.

5-36. Construct a probe as shown below:

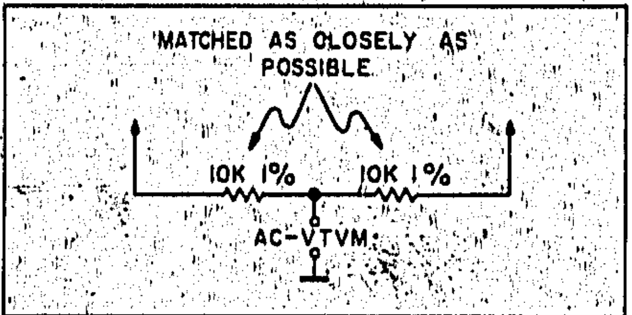


Figure 5-5. Oscillator Balance Probe.

Connect the ends of the probe to the T5 side of R94 and R95. Connect an ac voltmeter between ground and the junction of the two probe resistors. To adjust oscillator balance, pad C53 or C54 for minimum reading (on instruments with serial prefixes of 601 or below, adjust the slug of T5). The ac reading at the junction of the probe resistors should be 50 mV or less. Remove the probe and meter before proceeding.

5-37. OSCILLATOR FREQUENCY.

5-38. Connect an ac coupled electronic counter to test point 4. Adjust the slug of T5 to set the frequency measured to 40 kHz ± 200 Hz. If T5 doesn't have enough range, pad C52 (in instruments with serial prefixes of 601 or below do not use T5; use C52 only). Remove counter.

5-39. OSCILLATOR LEVEL.

5-40. Connect an ac voltmeter to Test Point 6 (Pin 7, V7). Adjust R92 for 8 ± 0.4 V. Remove meter.

5-41. DETECTOR GATE.

5-42. Connect an ac voltmeter to Test Point 4 (Pin 7 of V5). Adjust L7 for a peak reading (2.5 - 3.3 V rms).

5-43. TUNED AMPLIFIER.

5-44. Equipment Setup.

5-45. Set an ac voltmeter to the 1 volt range and connect it to Test Point 3 (Pin 7, V2) of the 428B. Clip the 428B probe around a wire which is carrying 35 mA rms ac, f ≤ 400 Hz. This current can be generated by a filament transformer, as in Figure 5-6, or by an oscillator operating into its rated load as in Paragraph 5-20. Set the 428B RANGE switch to 100 mA. This arrangement will be used for input, interstage, and detector phase adjustments.

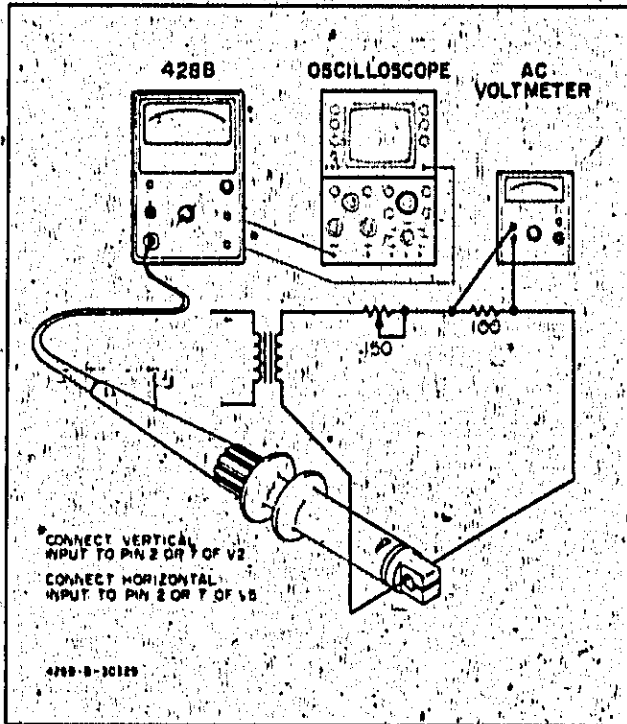


Figure 5-6. Detector Phase Adjustment.

5-46. Input Alignment.

5-47. Short TP1 and TP2 to ground, open the FEEDBACK DISCONNECT shown in Figure 7-3, then adjust C2 for a maximum ac reading at Test Point 3, Pin 7 of V2 (.2 V - .4 V peak). Reconnect the FEEDBACK DISCONNECT.

5-48. Interstage Alignment.

5-49. Set up equipment as in Paragraph 5-45, then:

a. Connect a .0082 microfarad capacitor across the brass pins which are connected to L10. Adjust L9 for maximum ac at Test Point 3 (Pin 7 of V2).

b. Remove the capacitor. Connect the .0082 microfarad capacitor across the brass pins which are connected to L9. Adjust L10 for maximum ac at TP3.

c. Remove the capacitor and voltmeter.

5-50. DETECTOR PHASE ADJUSTMENT.

5-51. With the bases of Q1 and Q2 (TP1 and TP2) grounded, open the feedback disconnect jumper (see Figure 7-3), and install a 390 ohm resistor between the feedback wire and the pin on the circuit board to which it normally connects. Connect the horizontal input of an oscilloscope to TP4 (Pin 7, V5). Connect the vertical to TP3 (Pin 7, V2). Except for the ac voltmeter, set up equipment as in Paragraph 5-45 (a proper setup is shown in Figure 5-6). Turn slug of L7 until the pattern looks like one of the correct patterns shown in Figure 5-7. If there is a diamond in the center of the pattern, the diamond should contain no traces. Remove the 390 ohm resistor and the voltmeter. Reconnect the FEEDBACK DISCONNECT.

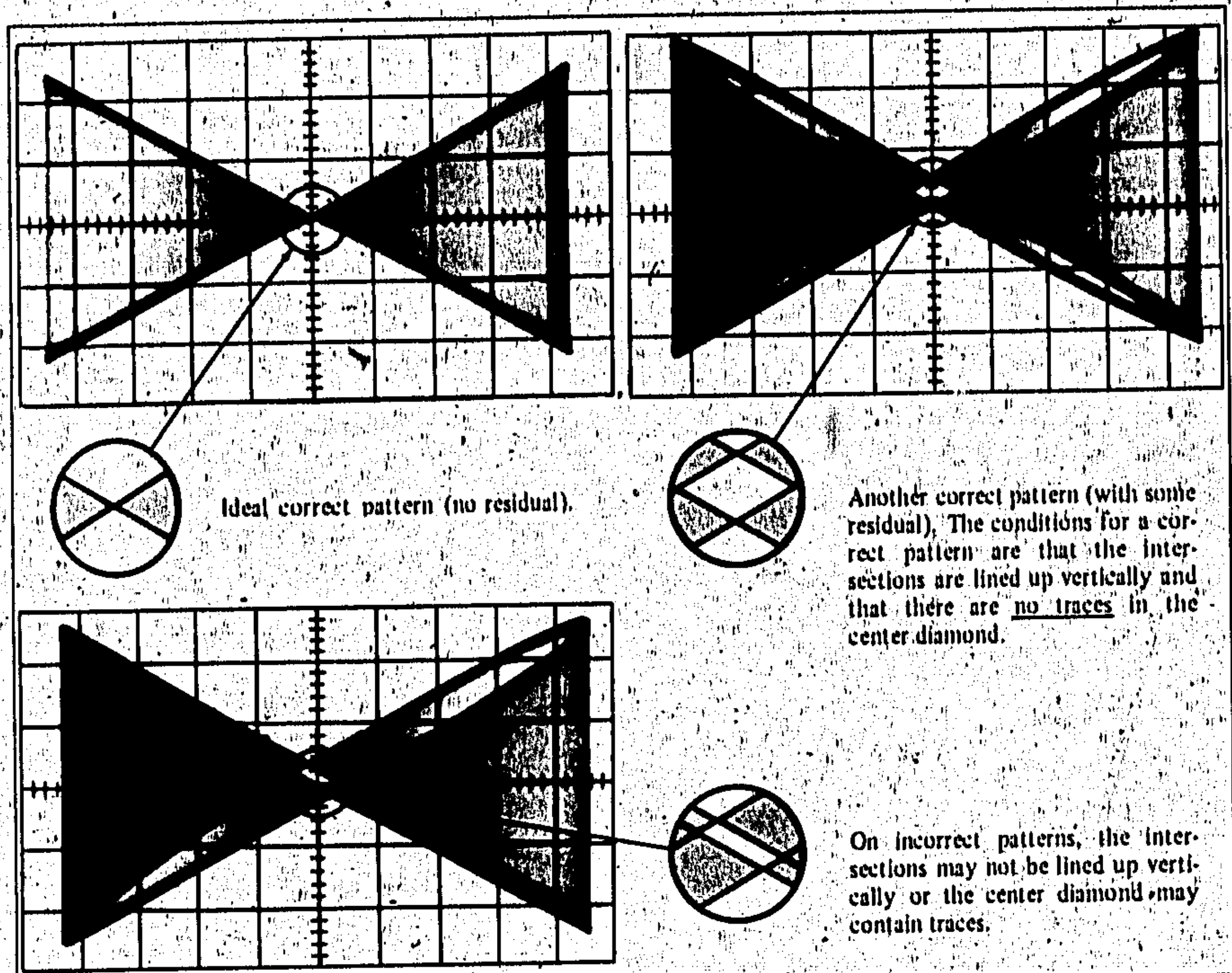


Figure 5-7. Detector Phase Display.

5-52. INTERNAL ZERO ADJUSTMENTS.

5-53. Preliminary Adjustment.

5-54. Preset the controls as follows:

a. Set RANGE switch to 100 mA.

b. Adjust R84 for minimum ac at the wiper connection of R84. The reading should be less than 0.1 volts.

c. Adjust R82 for minimum ac out at the wiper of R82a. The reading should be < 0.02 volts.

d. Thoroughly clean probe head jaws (see Paragraph 5-7).

e. Degauss probe head (see Paragraph 3-29).

5-55. Drive Balance Adjustment.

5-56. With the 428B set to the 1 mA range, and with no input to the current probe, set R98 for a minimum ac reading at Test Point 3 (Pin 7 of V2). The minimum reading should be less than 0.5 volt.

5-57. Residual 40 kHz Cancellation.

5-58. The residual output of the probe head is cancelled by means of the circuit discussed under Paragraph 4-45. This procedure assumes that the preliminary adjustments listed in Paragraph 5-54 have been completed.

a. Degauss the probe.

b. Zero the 428B meter with front panel ZERO control.

c. Adjust R84 for a minimum ac reading at Test Point 3 (Pin 7 of V2).

d. Continue to alternate Steps b and c until the adjustment cannot be further refined. The minimum reading in Step c should be approximately 0.02 volts or less.

5-59. Output Adjustment.

5-60. A meter calibrator and a one kilohm resistor are required for this test.

a. Place RANGE switch in 10 amp position and adjust R46 for zero volts DC ± 0.2 mV at the Output Level jack.

b. Switch the 428B and the meter calibrator to the 100 mA range. Connect a test lead between the meter calibrator output leads and clip the 428B probe to the lead.

c. Set the meter calibrator to 100 mA output and read full-scale on the 428B. Adjust R69 if necessary.

d. Connect a voltmeter to the output jack of the 428B in parallel with the 1000 ohm resistor.

e. The voltmeter should read 0.73 V ± 10 mV. Adjust R63 if necessary.

5-61. TROUBLESHOOTING.

5-62. FRONT PANEL TROUBLESHOOTING.

5-63. The Front Panel Troubleshooting Tree was designed for use as a means to guide the repairman to a block of circuitry. This procedure, in combination with the adjustment, calibration, and performance checks, should be adequate to repair most 428B's.

5-64. In any case where the front panel troubleshooting does not lead to the problem, it will be necessary to troubleshoot the instrument in detail.

5-65. DETAILED TROUBLESHOOTING.

5-66. Probe Check.

5-67. Resistance between pins 1-3, 1-4, 2-3, and 2-4 of the probe cable connector should be nearly identical and in the area of approximately 4 1/2 to 5 ohms. Where a resistance measurement between any of the above pairs of pins is significantly higher than between the other pairs (by about 3 times), an open probe coil is indicated. Any open circuit indicates a broken conductor between the plug and the bridge. The broken conductor is probably a broken wire in the cable. Either condition could indicate a broken wire at the Probe Terminal Section (see wiring diagram, Figure 6-1).

5-68. Power Supply Check.

5-69. To test the power supply:

a. Measure +272 ± 6 Vdc between Test Point 5 and ground.

b. Measure +12 ± 1 Vdc between the cathode of CR10 and ground.

c. Measure −7 ± 1 Vdc between the anode of CR9 and ground.

5-70. Where the + 272 V and the + 12 V have both failed, check the + 12 first. Check CR10, Q1, C66, and C69.

5-71. Where the + 272 V is at fault, try replacing V9, V10, CR10 or CR17. If the tubes are not defective, the voltage reference CR10 and CR17 may be faulty. Instruments with serial prefix 601- or below contain a voltage reference tube V11 in place of CR17.

5-72. Where the −7 V has failed, measure −17 Vdc at junction of R102 and C65. If less than −7 volts is measured at this point, check F3 and C65. If the junction of R102 and C65 measures more than −7 Vdc, check CR9 and Q2.

5-73. Oscillator—Buffer Amp. Check.

5-74. Short Test Point 1 and Test Point 2 to ground.

5-75. Compare the waveform at pin 2 of J1 to the waveform shown at this point of the schematic diagram. If these waveforms are not comparable, check the waveform at Test Point 7 and follow the Troubleshooting Tree. If the waveform at pin 2 of J1 is acceptable, continue to the next paragraph.

5-76. Set up equipment as described in Paragraph 5-51. Compare the oscilloscope display to Figure 5-7.

5-77. If the display is unacceptable, clip the probe around 100 mAdc and downrange to the 1 mA range. Find a 2.5 V pk-pk sine wave at the junction of R1 and L5. If this waveform is unacceptable, adjust or repair the input tuning circuit (L5, C1, C2, and R1).

5-78. If the waveform described in Paragraph 5-75 is alright, use the same test setup to find a 2.5 V pk-pk sine wave at pin 7 of V1. If this waveform is unacceptable, check V1 and the range switch.

5-79. If the waveform described in Paragraph 5-76 is alright, use the same test setup to look for a 1 V pk-pk sine wave at pin 7 of V2. Follow this branch of the Troubleshooting Tree to its conclusion.

5-80. Detector Gate Amp. Check.

5-81. No test equipment need be set up for these checks except an oscilloscope and a wire to ground TP1 and TP2.

5-82. Synchronous Detector.

5-83. With TP1 and TP2 still grounded and on the 100 mA range, perform the test indicated. Beyond a tedious ohmmeter test of the circuitry between T3 and pin 7 of V6, little can be done to check the detector circuit. It should be noted, however, that R46 should be able to provide the +0.5 Vdc which is required at pin 7 of V6 during normal operation.

5-84. DC Amplifier Check.

5-85. Remove the ground wire from Test Point 1 and Test Point 2 (installed for previous checks). Disconnect the probe from the 428B front panel. Set the 428B to the

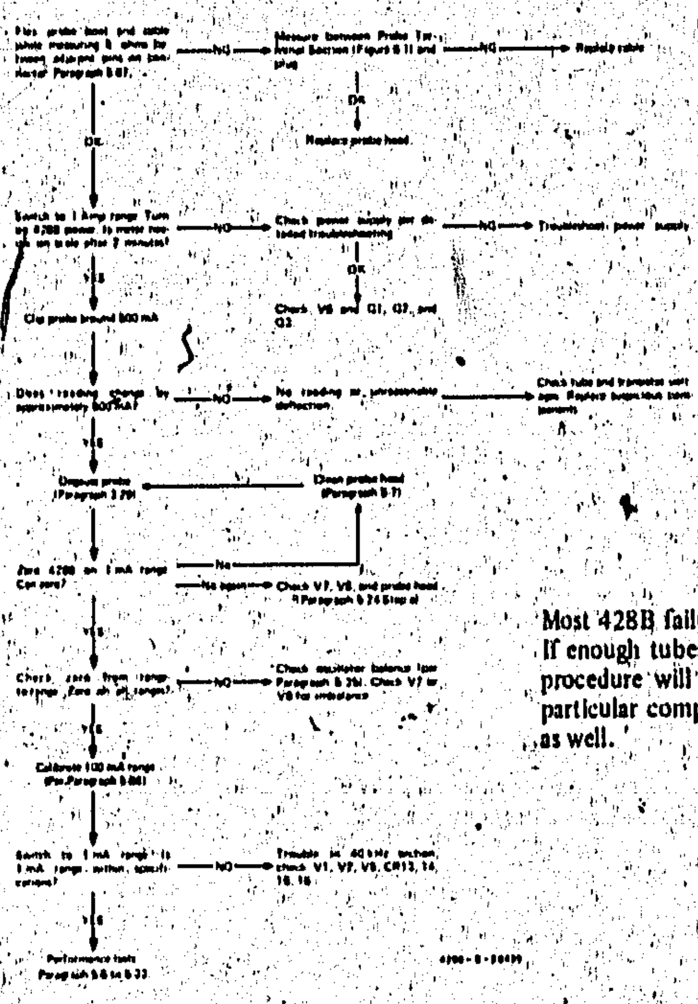
300 mA range. Zero the 428B with the front panel ZERO control. Measure and note the voltages at pin 7 and pin 2 of V6. Turn the ZERO control to deliver a ± 1 Vdc swing around the voltage noted for pin 2. The difference between the voltages at pins 7 and 2 of V6 should not exceed 0.05 Vdc at any point during this swing.

5-86. If the DC Amplifier tracks properly as tested in Paragraph 5-85, proceed with the performance checks. If the DC Amplifier has failed, continue to perform the tests in the Troubleshooting Tree.

5-87. CALIBRATION.

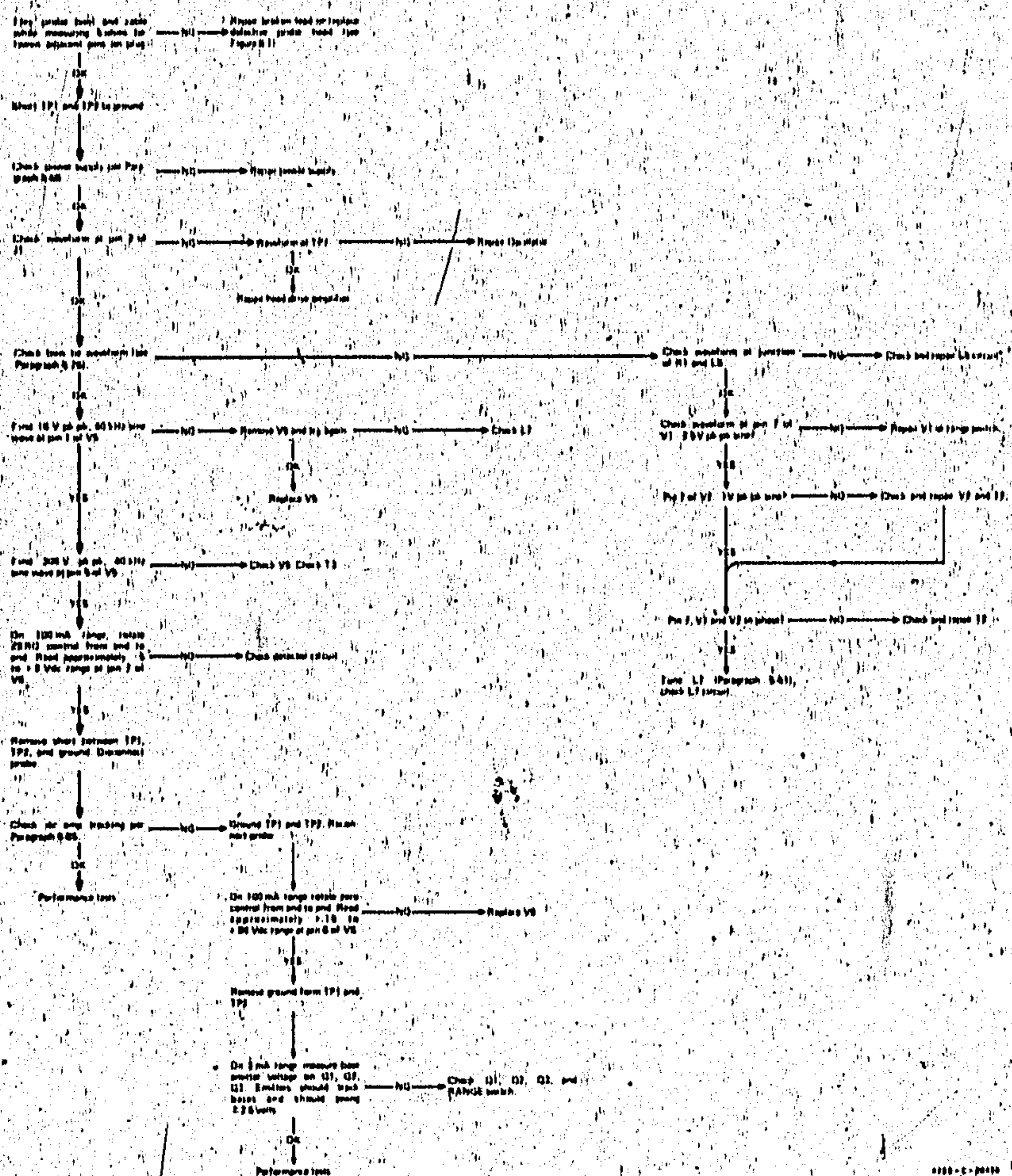
5-88. Zero the 428B on the 1 mA range using the front panel ZERO control. Switch to the 100 mA range. Clip the probe around an accurate 100 mA current (as in Paragraph 5-14). Adjust Meter Cal, R69, for a meter reading of 100 mA. Connect a 1000 ohm ± 1% resistor in parallel with an accurate (0.25%) voltmeter to the output jack of the 428B. Turn the front panel Output Level control full counterclockwise past the detent. Adjust the Output Cal control, R63, for a reading of exactly 0.73 V on the voltmeter.

5-89. Perform the entire In-Cabinet Performance Tests (Paragraphs 5-5 through 5-24) to insure that the 428B meets all of its specifications.



Most 428B failures will be due to bad tubes or transistors. If enough tubes are available to check by replacement, this procedure will probably save time. Instructions to check a particular component imply a check of associated circuitry as well.

Figure 5-8. Front Panel Troubleshooting Tree.



Instructions to check a particular component imply a check of associated circuitry as well.

Figure 5-9. Detailed Troubleshooting Tree.

PERFORMANCE CHECK TEST CARD

MODEL 428B CLIP-ON DC MILLIAMMETER

Model 428B
Serial No. ______________

Test performed by ______________
Date ______________

RANGE CHECK: PARAGRAPH 5-13

428B Reading	Meter Calibrator Output	Loops	Limits	Reading
1 mA	1 mA	1	± 30 µA	______
3 mA	1 mA	3	± 90 µA	______
10 mA	10 mA	1	± 0.3 mA	______
30 mA	10 mA	3	± 0.9 mA	______
100 mA	100 mA	1	± 3 mA	______
300 mA	100 mA	3	± 9 mA	______
1 A	1 A	1	± .03 A	______
3 A	1 A	3	± .09 A	______
10 A	5 A	2	± 0.3 A	______

METER TRACKING CHECK: PARAGRAPH 5-15

Meter Calibrator Output	Loops	428B Reading	Limits	Reading
10 mA	10	100 mA	± 3 mA	______
10 mA	9	90 mA	± 3 mA	______
10 mA	8	80 mA	± 3 mA	______
10 mA	7	70 mA	± 3 mA	______
10 mA	6	60 mA	± 3 mA	______
10 mA	5	50 mA	± 3 mA	______
10 mA	4	40 mA	± 3 mA	______
10 mA	3	30 mA	± 3 mA	______
10 mA	2	20 mA	± 3 mA	______
10 mA	1	10 mA	± 3 mA	______

OUTPUT CALIBRATION CHECK: PARAGRAPH 5-17

Meter Calibrator Output	428B Reading	DC Voltmeter	Limits	Reading
100 mA	100 mA	0.73 V	± 10 mV	______

FREQUENCY RESPONSE CHECK: PARAGRAPH 5-19

428B Reading	Frequency Range	Limits	Reading
10 mA	DC – 400 Hz	> 7 cm	______

AC OVERLOAD: PARAGRAPH 5-21

Meter Calibrator Output	428B Reading	Function Generator Output	Limits	Reading
10 mA	> 9.8 mA	10 mA P	< 2%	______

NOISE CHECK: PARAGRAPH 5-23

428B Range	Limits	Reading
1 mA	≤ 15 mV	______
3 mA	≤ 5 mV	______
10 mA	≤ 2 mV	______
30 mA	≤ 2 mV	______
100 mA	≤ 2 mV	______
300 mA	≤ 2 mV	______
1 A	≤ 2 mV	______
3 A	≤ 2 mV	______
10 A	≤ 2 mV	______

SECTION VI
REPLACEABLE PARTS

6-1. INTRODUCTION.

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

a. The TQ column lists the total quantity of any part listed in the manual. The total quantity of a part is given the first time the part number appears.

b. Description of the part. (See list of abbreviations below.)

c. Typical manufacturer of the part in a five-digit code. (See Appendix B for list of manufacturers.)

d. Manufacturer's part number.

6-3. Miscellaneous parts are listed at the end of Table 6-1.

6-4. ORDERING INFORMATION.

6-5. To obtain replacement parts, address order or inquiry to your local Hewlett-Packard Field Office. (See Appendix C for list of office locations.) Identify parts by their Hewlett-Packard part numbers. Include instrument model and serial numbers.

6-6. NON-LISTED PARTS.

6-7. To obtain a part that is not listed, include:

a. Instrument model number.

b. Instrument serial number.

c. Description of the part.

d. Function and location of the part.

ABBREVIATIONS

Ag	silver
Al	aluminum
A	ampere(s)
Au	gold
C	capacitor
cer	ceramic
coef	coefficient
com	common
comp	composition
conn	connection
dep	deposited
DPDT	double-pole double-throw
DPST	double-pole single-throw
elect	electrolytic
encap	encapsulated
F	farad(s)
FET	field effect transistor
fxd	fixed
GaAs	gallium arsenide
GHz	gigahertz = 10^{+9} hertz
gd	guard(ed)
Ge	germanium
gnd	ground(ed)
H	henry(ies)
Hg	mercury
Hz	hertz (cycle(s) per second)
ID	inside diameter
impg	impregnated
incd	incandescent
ins	insulation(ed)
kΩ	kilohm(s) = 10^{+3} ohms
kHz	kilohertz = 10^{+3} hertz
L	inductor
lin	linear taper
log	logarithmic taper
mA	milliampere(s) = 10^{-3} amperes
MHz	megahertz = 10^{+6} hertz
MΩ	megohm(s) = 10^{+6} ohms
met flm	metal film
mfr	manufacturer
ms	millisecond
mtg	mounting
mV	millivolt(s) = 10^{-3} volts
μF	microfarad(s)
μs	microsecond(s)
μV	microvolt(s) = 10^{-6} volts
my	Mylar®
nA	nanoampere(s) = 10^{-9} amperes
NC	normally closed
Ne	neon
NO	normally open
NPO	negative positive zero (zero temperature coefficient)
ns	nanosecond(s) = 10^{-9} seconds
nsr	not separately replaceable
Ω	ohm(s)
obd	order by description
OD	outside diameter
p	peak
pA	picoampere(s)
pc	printed circuit
pF	picofarad(s) 10^{-12} farads
piv	peak inverse voltage
p/o	part of
pos	position(s)
poly	polystyrene
pot	potentiometer
p-p	peak-to-peak
ppm	parts per million
prec	precision (temperature coeffient, long term stability and/or tolerance)
R	resistor
Rh	rhodium
rms	root-mean-square
rot	rotary
Se	selenium
sect	section(s)
Si	silicon
sl	slide
SPDT	single-pole double-throw
SPST	single-pole single-throw
Ta	tantalum
TC	temperature coefficient
TiO_2	titanium dioxide
tog	toggle
tol	tolerance
trim	trimmer
TSTR	transistor
V	volt(s)
vacw	alternating current working voltage
var	variable
vdcw	direct current working voltage
W	watt(s)
w/	with
wiv	working inverse voltage
w/o	without
ww	wirewound
*	optimum value selected at factory, average value shown (part may be omitted)
**	no standard type number assigned selected or special type

® Dupont de Nemours

DECIMAL MULTIPLIERS

Prefix	Symbols	Multiplier	Prefix	Symbols	Multiplier
tera	T	10^{12}	centi	c	10^{-2}
giga	G	10^{9}	milli	m	10^{-3}
mega	M or Meg	10^{6}	micro	μ	10^{-6}
kilo	K or k	10^{3}	nano	n	10^{-9}
hecto	h	10^{2}	pico	p	10^{-12}
deka	da	10	femto	f	10^{-15}
deci	d	10^{-1}	atto	a	10^{-18}

STD B-2734

DESIGNATORS

A	assembly
B	motor
BT	battery
C	capacitor
CR	diode
DL	delay line
DS	lamp
E	misc electronic part
F	fuse
FL	filter
HR	heater
IC	integrated circuit
J	jack
K	relay
L	inductor
M	meter
MP	mechanical part
P	plug
Q	transistor
QCR	transistor diode
R	resistor
RT	thermistor
S	switch
T	transformer
TB	terminal board
TC	thermocouple
TP	test point
TS	terminal strip
U	microcircuit
V	vacuum tube, neon bulb, photocell, etc.
W	cable
X	socket
XDS	lampholder
XF	fuseholder
Y	crystal
Z	network

Table 6-1. Replaceable Parts (Cont'd)

REFERENCE DESIGNATOR	-hp- PART NO.	TQ	DESCRIPTION	MFR.	MFR. PART NO.
A1, A2	428B-26A	2	Assembly: resistor ww A1 includes R3 thru R6 A2 includes R7 thru R10	-hp-	
A3	428B-26B	1	Assembly: resistor ww, includes R2, R11	-hp-	
C1	0160-0938	1	C: fxd 1000 pF 5%	14655	RDM15E102J1C obd
C2	0131-0004	1	C: var mica 16-150 pF 175 vdcw	72136	T51410-9
C3 thru C10			Not assigned		
C11	0150-0014	1	C: fxd cer .005 microfarad 500 vdcw	04222	D1-4 obd
C12	0180-0050	1	C: fxd 40 microfarads +75% -10% 50 vdcw	56289	30D406G050DD2-DS
C13	0160-0269	5	C: fxd cer .1 microfarad 20% 500 vdcw	56289	41C92B5-CDH
C14	0140-0179	3	C: fxd mica 1000 pF 2%	14655	RDM19F102G3C obd
C15	0150-0012	6	C: fxd cer .01 microfarad 20% 1000 vdcw	56289	29C214A3-CDH
C16, C17	0160-0269		C: fxd cer .1 microfarad 20% 500 vdcw	56289	41C92B5-CDH
C18	0140-0179		C: fxd mica 1000 pF 2%	14655	RDM19F102G3C obd
C19	0150-0012		C: fxd cer .01 microfarad 20% 1000 vdcw	56289	29C214A3-CDH
C20			Not assigned		
C21	0180-0059	1	C: fxd 10 microfarads +75% -10% 25 vdcw	56289	30D106G025BB2-DSM
C22, C23			Not assigned		
C24 *	0160-0138	1	C: fxd .39 microfarad 5% 200 vdcw	01002	AE17C473JT
C25	0180-0058	2	C: fxd 50 microfarads +75% -10% 25 vdcw	56289	30D506G025CC2-DSM
C26	0150-0012		C: fxd cer .01 microfarad 20% 1000 vdcw	56289	29C214A3-CDH
C27 *	0140-0179		C: fxd mica 1000 pF 2%	14655	RDM19F102G3C obd
C28, C29	0150-0012		C: fxd cer .01 microfarad 20% 1000 vdcw	56289	29C214A3-CDH
C30			Not assigned		
C31	0170-0019	1	C: fxd my 0.1 microfarad 5% 200 vdcw	56289	192P10452-PTS
C33 *	0140-0149	1	C: fxd 470 pF 300 V	72136	DM15F471J0300WV1CR
C32, C34 thru C40			Not assigned		
C41	0140-0223	1	C: fxd mica 260 pF 1%	14655	RDM15F261F3C obd
C42	0160-2204	1	C: fxd mica 100 pF 5%	72136	RDM15F101J3C obd
C43 thru C50			Not assigned		
C51	0160-0269		C: fxd cer .1 microfarad 20% 500 vdcw	56289	41C92B5-CDH
C52 *	0140-0178	1	C: fxd mica 560 pF 5% 300vdcw	72136	DM15F561G0300WV1CR
C53, C54	0140-0164	2	C: fxd mica 6800 pF 5%	14655	RDM30F682J5S obd
C55 *	0140-0197	1	C: fxd mica 180 pF 5% 300 vdcw	72136	DM15F181J0300WV1CR
C56 thru C60			Not assigned		
C61	0180-2336	1	C: fxd my 20 microfarads +50% -10% 450 vdcw	56289	68D10168
C62	0180-2337	1	C: fxd my 20-20 microfarads +50% 10% 450 vdcw	56289	68D20060
C63	0160-2025	2	C: fxd mica 220 pF 5% 500 V	28480	0160-2025
C64	0150-0012		C: fxd cer .01 microfarad 20% 1000 vdcw	56289	29C214A3-CDH
C65	0180-0058		C: fxd 50 microfarads +75 -10% 25 vdcw	56289	30D506G025CC2-DSM
C66	0180-0104	2	C: fxd 200 microfarads +75% -10% 15 vdcw	56289	30D207G015DF2-DSM
C67			Not assigned		
C68	0160-0269		C: fxd cer .1 microfarad 20% 500 vdcw	56289	41C92B5-CDH
C69	0180-0104		C: fxd 200 microfarads +75% -10% 15 vdcw	56289	30D207G015DF2-DSM
C70 *	0160-2203	1	C: fxd mica 91 pF 5%	14655	RDM15F910J3C obd
C71	0160-0134		C: fxd mica 220 pF 5%	14655	RDM15F221J3C obd
C72 *	0160-0174	1	C: fxd .47 microfarad 25 V	28480	0160-0174
CR1	1901-0036	4	Diode: si 1000 piv	04713	SR1358-12
CR2			Not assigned		
CR3	1901-0036		Diode: si 1000 piv	04713	SR1358-12
CR4			Not assigned		
CR5	1901-0036		Diode: si 1000 piv	04713	SR1358-12
CR6			Not assigned		
CR7	1901-0036		Diode: si 1000 piv	04713	SR1358-12
CR8			Not assigned		
CR9	1902-0013	1	Diode: breakdown 6.81 V 10%	04713	SZ1521-7
CR10	1902-0211	1	Diode: breakdown 12.1 V 10%	04713	SZ1521-79
CR11, CR12	1901-0040	2	Diode: si 30 wiv 50 mA 2 pF 2ns	01295	PG512
CR13 thru CR16	1906-0034	1	Diode: quad	28480	1906-0034
CR17	1902-3404	1	Diode: breakdown 82.5 V 5%	04713	SZ10939-446
DS1	1450-0049	1	Light Indicator: clear	72765	599-125(clear)

Table 6-1. Replaceable Parts (Cont'd)

REFERENCE DESIGNATOR	-hp- PART NO.	TQ	DESCRIPTION	MFR.	MFR. PART NO.
F1	2110-0202	1	Fuse: 500 mAT 250 V (for 230 V operation)	71400	MDL-1/12
F1	2110-0312	2	Fuse: 1 AT 250 V (for 115 V operation)	71400	MDL-1
F2	2110-0312		Fuse: 1 AT 250 V	-hp-	
F3	2110-0012	1	Fuse: 500 mAT 250 V	71400	AGC1/2
J1	1251-0089	1	Connector: female 4 pin	02660	91-PC4F
J2	1251-2357	1	Connector: male 3 pin power	-hp-	
J3	1250-0118	1	Connector: bulkhead, BNC female	24931	28JR128-1
L5	9100-1487	1	Choke	-hp-	
L6	9100-1488	1	Choke	-hp-	
L7	9100-1489	1	Coil: gate input filter	-hp-	
L8	9110-0025	1	Reactor: degausser	-hp-	
L9, L10	9100-1482	2	Coil: interstage	-hp-	
M1	1120-0904	1	Meter: 0 - 5 milliamps	-hp-	
Q1	1854-0039	1	TSTR: si NPN 2N3053	04713	2N3053
Q2	1853-0016	1	TSTR: si PNP 2N3638	04713	2N3638
Q3	1854-0003	1	TSTR: si NPN	01295	SM0843
R1	0684-6801	1	R: fxd comp 68 ohms 10% 1/4 W	CB6801	obd
R2 thru R11			NSR: part of A1, A2, and A3		
R12	0757-0346	1	R: fxd flm 10 ohms 1% 1/8 W	-hp-	
R13	0757-0386	1	R: fxd flm 24.3 ohms 1% 1/2 W	91637	CMF-1/10-32 T-1 obd
R14	0757-0397	1	R: fxd 68.1 ohms 1% 1/8 W	14674	C4 T-0 obd
R15	0698-4420	1	R: fxd flm 216 ohms 1% 1/8 W	14674	C4 obd
R16	0757-0419	1	R: fxd flm 681 1% 1/8 W	14674	C4 T-0 obd
R17	0698-4433	1	R: fxd flm 2.26 kilohms 1% 1/8 W	14674	C4 T-0 obd
R18	0698-4470	1	R: fxd flm 6.98 kilohms 1% 1/8 W	14674	C4 T-0 obd
R19	0698-4486	1	R: fxd flm 24.9 kilohms 1% 1/8 W	14674	C4 T-0 obd
R20	0698-4503	1	R: fxd flm 66.5 kilohms 1% 1/8 W	14674	C4 T-0 obd
R21	0683-1345	1	R: fxd comp 130 kilohms 5% 1/4 W	01121	CB1345
R22	0698-7683	1	R: fxd comp 43 megohms 5% 1/2 W	01121	EB4365
R23			Not assigned		
R24	0684-1021	4	R: fxd comp 1000 ohms 10% 1/4 W	01121	CB1021
R25	0684-1051	2	R: fxd comp 1 megohm 10% 1/4 W	01121	CB1051
R26	0687-1031	1	R: fxd comp 10 kilohms 10% 1/2 W	01121	EB1031
R27	0684-1541	2	R: fxd comp 150 kilohms 10% 1/4 W	01121	CB1541
R28	0683-7515	1	R: fxd comp 750 ohms 5% 1/4 W	01121	CB7515
R29	0684-1541		R: fxd comp 150 kilohms 10% 1/4 W	01121	CB1541
R30	0687-5621	1	R: fxd comp 5.6 kilohms 10% 1/2 W	01121	EB5621
R31	0757-0353	1	R: fxd flm 249 kilohms 1% 1/2 W	91637	MFF-1/2-10 T-1 obd
R32	0698-4966	1	R: fxd flm 324 kilohms 1% 1/2 W	91637	MFF-1/2-10 T-1 obd
R33	0698-4712	1	R: fxd flm 12.4 kilohms 1% 1/4 W	91637	MFF-1/8-32 T-1 obd
R34	0684-4701	2	R: fxd comp 47 ohms 10% 1/4 W	01121	CB4701
R35	0687-4731	1	R: fxd comp 47 kilohms 10% 1/2 W	01121	EB4731
R36	0686-9115	1	R: fxd comp 910 ohms 5% 1/2 W	01121	EB9115
R37	0684-4711	4	R: fxd comp 470 ohms 10% 1/4 W	01121	CB4711
R38 thru R40			Not assigned		
R41 thru R44	0757-0283	4	R: fxd flm 2 kilohms 1% 1/8 W	14674	C4 T-0
R45	0757-0327	1	R: fxd flm 499 kilohms 1% 1/4 W	91637	MFF-1/8-32, T-1 obd
R46	2100-0331	1	R: var 5 kilohms 10% ww 1.5 W	79727	E-870
R47	0689-3935	1	R: fxd comp 39 kilohms 5% 1 W	01121	GB3935
R48	0684-4711		R: fxd comp 470 ohms 10% 1/4 W	01121	CB4711
R49	0698-4594	1	R: fxd flm 487 ohms 1% 1/4 W	91637	MFF-1/8-32 T-1 obd
R50	0684-5631	1	R: fxd comp 56 kilohms 10% 1/4 W	01121	CB5631
R51	0757-0982	1	R: fxd flm 245 kilohms 1% 1/2 W	91637	MFF-1/2-10 T-1 obd
R52	0698-0058	1	R: fxd flm 4.02 kilohms 1% 1/4 W	91637	MFF-1/8-32 T-1 obd
R53 thru R59			Not assigned		
R60	0683-2015	1	R: fxd comp 200 ohms 5% 1/4 W	01121	CB2015

Table 6-1. Replaceable Parts (Cont'd)

REFERENCE DESIGNATOR	-hp- PART NO.	TQ	DESCRIPTION	MFR.	MFR. PART NO.
R61	0757-1039	1	R: fxd flm 45 ohms 1% 1/4 W	14674	C5 T-0 obd
R62	0757-1047	1	R: fxd flm 90 ohms 1% 1/4 W	19701	MF52C T-0
R63	2100-0328	1	R: var 500 ohms 10% ww 1.5 W	79727	E-870 obd
R64	2100-0270	1	R: var 50 ohms 10% ww 2 W	12697	obd
R65	0698-3443	1	R: fxd comp 287 ohms 1% 1/4 W	16299	C4-1/8-to-287-RF
R66	0684-4701		R: fxd comp 47 ohms 10% 1/4 W	01121	CB4701
R67	0812-0016	1	R: fxd prec 8 ohms 3% ww 3 W	91637	RS2B-95
R68	0757-1040	1	R: fxd flm 50 ohms 1% 1/4 W	14674	C5 T-0 obd
R69	2100-1560	1	R: var 30 ohms 10% ww 1.5 W	11236	110
R70	0684-1001	1	R: fxd comp 10 ohms 10% 1/4 W	01121	CB1001
R71	0764-0028	1	R: fxd 100 kilohms 5% 2 W	14674	C-42S obd
R72			Not assigned		
R73	0764-0003	1	R: fxd 3.3 kilohms 5% 2 W	14674	C-42S obd
R74	0698-4746	1	R: fxd flm 53.6 kilohms 1% 1/4 W	91637	MFF-1/8-32 T-1 obd
R75	0698-4711	1	R: fxd flm 11.8 kilohms 1% 1/4 W	91637	MFF-1/8-32 T-1 obd
R76	0811-0007	1	R: fxd prec 10 kilohms 1% ww 5 W	91637	RS5-78
R77	0684-6821	1	R: fxd comp 6.8 kilohms 10% 1/4 W	01121	CB6821
R78	0698-4953	1	R: fxd flm 124 kilohms 1% 1/2 W	91637	MFF-1/2-10 T-1 obd
R79	0684-1021		R: fxd comp 1000 ohms 10% 1/4 W	01121	CB1021
R80			Not assigned		
R81	0683-6225	1	R: fxd 6.2 comp kilohms 5% 1/4 W	01121	CB6225
R82	2100-0197	1	R: var 2 kilohms/200 ohms ww	11237	C252-45
R83			Not assigned		
R84	2100-0282	1	R: var 2 kilohms 20% ww 1.5 W	79727	E-870
R85	0684-5621	1	R: fxd comp 5.6 kilohms 10% 1/4 W	01121	CB5621
R86	0684-1531	1	R: fxd comp 15 kilohms 10% 1/4 W	01121	CB1531
R87 thru R90			Not assigned		
R91	0698-4931	1	R: fxd flm 32.4 kilohms 1% 1/2 W	91637	MFF-1/2-10 T-1 obd
R92	2100-0094	2	R: var comp 50 kilohms 30%	11236	UPM 70RE obd
R93	0684-1011	2	R: fxd comp 100 ohms 10% 1/4 W	01121	CB1011
R94, R95	0684-1021		R: fxd comp 1000 ohms 10% 1/4 W	01121	CB1021
R96	0684-4711		R: fxd comp 470 ohms 10% 1/4 W	01121	CB4711
R97	0684-1011		R: fxd comp 100 ohms 10% 1/4 W	01121	CB1011
R98	2100-0394	1	R: var 300 ohms 20% ww 1.5 W	79727	E-870 obd
R99	0698-3647	1	R: fxd 15 kilohms 5% 2 W	14674	FP-2 obd
R100, R101	0690-1041	2	R: fxd comp 100 kilohms 10% 1 W	01121	GB 1041
R102	0811-0041	1	R: fxd prec 169 ohms 1% ww 4 W	91637	RS2-64 obd
R103			Not assigned		
R104	0684-2251	1	R: fxd comp 2.2 megohm 10% 1/4 W	01121	CB2251
R105	0684-4711		R: fxd comp 470 ohms 10% 1/4 W	01121	CB4711
R106	0757-0857	1	R: fxd 82.5 kilohms 1% 1/2 W	91637	MFF-1/2-10 T-1 obd
R107	0698-4153	1	R: fxd flm 9.31 kilohms 1% 1/2 W	75042	CEC, T-0 obd
R108	0698-4793	1	R: fxd flm 402 kilohms 1% 1/4 W	91637	MFF-1/8-32 T-1 obd
R109	2100-0094		R: var comp 50 kilohms 30%	11236	UPM 70RE obd
R110	0698-4772	1	R: fxd flm 178 kilohms 1% 1/4 W	91637	MFF-1/8-32 T-1 obd
R111, R112	0683-0475	2	R: fxd comp 4.7 ohms 5% 1/4 W	01121	CB47G5
R113	0687-3331	1	R: fxd comp 33 kilohms 10% 1/2 W	01121	EB3331
R114	0684-1041	1	R: fxd comp 100 kilohms 10% 1/4 W	01121	CB1041
R115	0698-4752	1	R: fxd flm 84.5 kilohms 1% 1/4 W	91637	MFF-1/8-32 T-1 obd
R116	0684-1051		R: fxd comp 1 megohm 10% 1/4 W	01121	CB1051
R117 thru R120	0764-0006	4	R: fxd 18 kilohms 5% 2 W	14674	FP-2
S1	00428-61901	1	Assembly: Range Switch (incl. resistors)	-hp-	
S2	3101-0001	1	Switch: toggle SPST 3 A 250 vdcw	04009	80994-HB
S3	3101-0018	1	Switch: toggle (momentary) SPST	00LAF	8906K499
S4			Not assigned		
S5	3101-1234	1	Switch: slide DPDT	82389	11A-1242A
T1			Not assigned		
T2	9100-1481	1	Detector: signal trans.	-hp-	
T3	9100-1483	1	Gate transformer	-hp-	
T4	9100-1484	1	Zero balance trans	-hp-	
T5	9100-1485	1	Coil: osc.	-hp-	

Table 6-1. Replaceable Parts (Cont'd)

REFERENCE DESIGNATOR	-hp- PART NO.	TQ	DESCRIPTION	MFR.	MFR. PART NO.
T6	9100-1486	1	Transformer: head drive	-hp-	
T7	9100-3228	1	Transformer: power	-hp-	
V1, V2	1923-0017	3	Tube: electron 6AH6	33173	6AH6
V3, V4			Not assigned		
V5	1923-0017		Tube: electron 6AH6	33173	6AH6
V6, V7	1932-0022	2	Tube: electron 6DJ8	73445	obd
V8	5080-0041	1	Tube: electron selected 12AU7	-hp-	
V9	1921-0010	1	Tube: electron 12 B4A miniature 9 pin	33173	12B4A
V10	1923-0021	1	Tube: electron 6AU6 miniature 7 pin	33173	6AU6A
W1	8120-1348	1	Cable: AC power	-hp-	
			MISCELLANEOUS		
	00428-00204	1	Dust Cover (rack only)	-hp-	
	00428-62101	1	Probe Assembly (see Figure 6-1)	-hp-	
	428A-83A	1	Escutcheon	-hp-	
	00428-00201	1	Panel (cabinet only)	-hp-	
	00428-00203	1	Panel (rack only)	-hp-	
	00428-64401	1	Assembly: cabinet	-hp-	
	0403-0004	4	Bumper: rubber	000MM	obd
	1440-0002	1	Handle: leather	0000Z	obd
	1490-0015	1	Ball: cabinet tilt	00LAG	obd
	5040-0616	2	Detent: cabinet ball	-hp-	
	00428-66501	1	Assembly: P.C. Board	-hp-	
	5020-6849	1	Bezel	-hp-	
	00428-26501	1	Board: P.C.	-hp-	
	0330-0029	1	Boot (rack only)	76545	62 obd
	8520-0017	1	Brush: nylon	00LAH	obd
	1410-0052	1	Bushing: potentiometer	32016	obd
	2110-0269	2	Fuse: clip	91506	6008-32CN
	0510-0748	1	Fuse: holder	75915	357002
	1205-0011	1	Heat sink	98978	TXBF-032-0268 obd
	0370-0822	1	Knob: round, brown	-hp-	
	0370-0031	1	Knob: 1" dia. black conc.	-hp-	
	0370-0035	1	Knob: bar 1" dia. black	-hp-	
	0370-0064	1	Knob: 3/4" dia. red w/arrow	-hp-	
	0370-0823	1	Knob: red (for R63)	-hp-	
	0370-0824	1	Knob: orange (for R69)	-hp-	
	0370-0825	1	Knob: yellow (for R46)	-hp-	
	0370-0826	1	Knob: green (for R98)	-hp-	
	7121-0192	1	Nameplate (cabinet only)	91345	obd
	2950-0034	1	Nut: hexagonal	91961	obd
	1200-0062	4	Socket: 9 pin miniature tube	71785	121-51-11-060
	1200-0083	4	Socket: 7 pin miniature tube	91662	05-0730-02
	3100-0268	1	Switch: rotary	76854	216481-HZ obd
	00428-90004	1	Operating and Service Manual	-hp-	

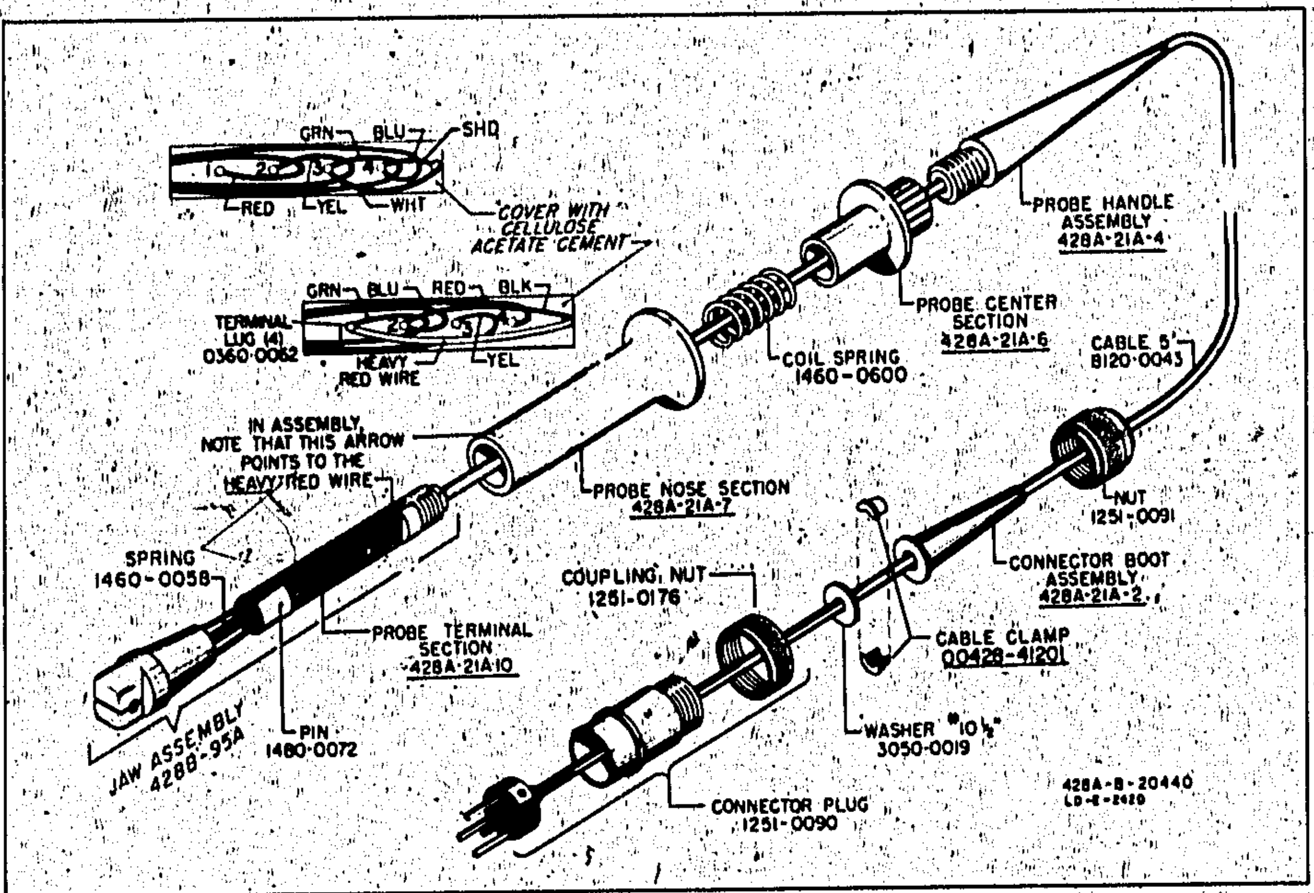


Figure 6-1. Parts Breakdown, current probe.

SECTION VII
CIRCUIT DIAGRAMS

7-1. INTRODUCTION.

7-2. This section contains the circuit diagrams necessary for the operation and maintenance of the Model 428B Clip-on DC Milliammeter. Included are a block diagram, schematics and component location diagrams.

7-3. BLOCK DIAGRAM.

7-4. The block diagram shows the relationship between the assemblies of the instrument. Signal flow between assemblies and significant portions of assemblies as well as major feedback paths are shown. The block diagram is used to develop an understanding of the basic theory of operation.

7-5. SCHEMATIC DIAGRAMS.

7-6. The circuitry contained within each assembly is shown in the schematic diagrams. These diagrams are used to develop an understanding of the detailed theory of operation of each assembly and as an aid in isolating troubles within an assembly.

7-7. COMPONENT LOCATION DIAGRAMS.

7-8. The component location diagrams show the physical location of parts mounted on an assembly. Each part is identified by a reference designator.

SCHEMATIC NOTES

AC ground; referred to the center-tap of T4.

Detector reference: referred to V6 bias source.

Chassis ground.

Earth ground.

† Waveforms where amplitude and waveform change with setting of ZERO control.

* Component selected at factory. Average value given. Component may be omitted.

———— Denotes main signal path.

———— Denotes feedback path.

MEASUREMENT CONDITIONS.

Line voltage:	115 V, 60 Hz
Range:	100 mA
Input:	100 mA

All voltages were measured with a high input impedance electronic voltmeter. A 10 megohm oscilloscope probe was used to measure the waveforms. The oscilloscope should be externally synchronized from pin 2 of V7 (through a 47 μF capacitor to avoid disturbing the circuit.

NOTE

Resistance is in ohms and capacitance in pF unless otherwise noted.

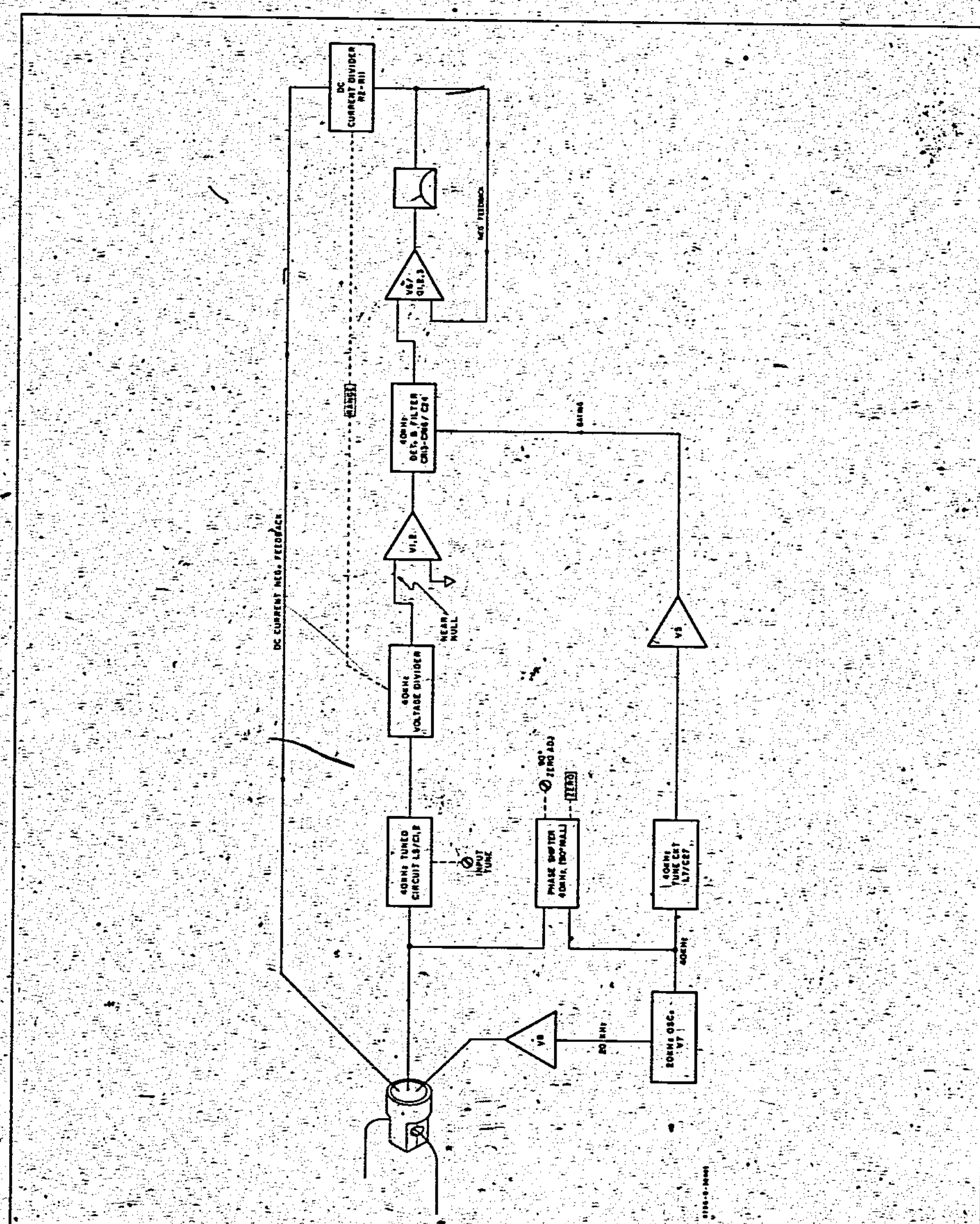
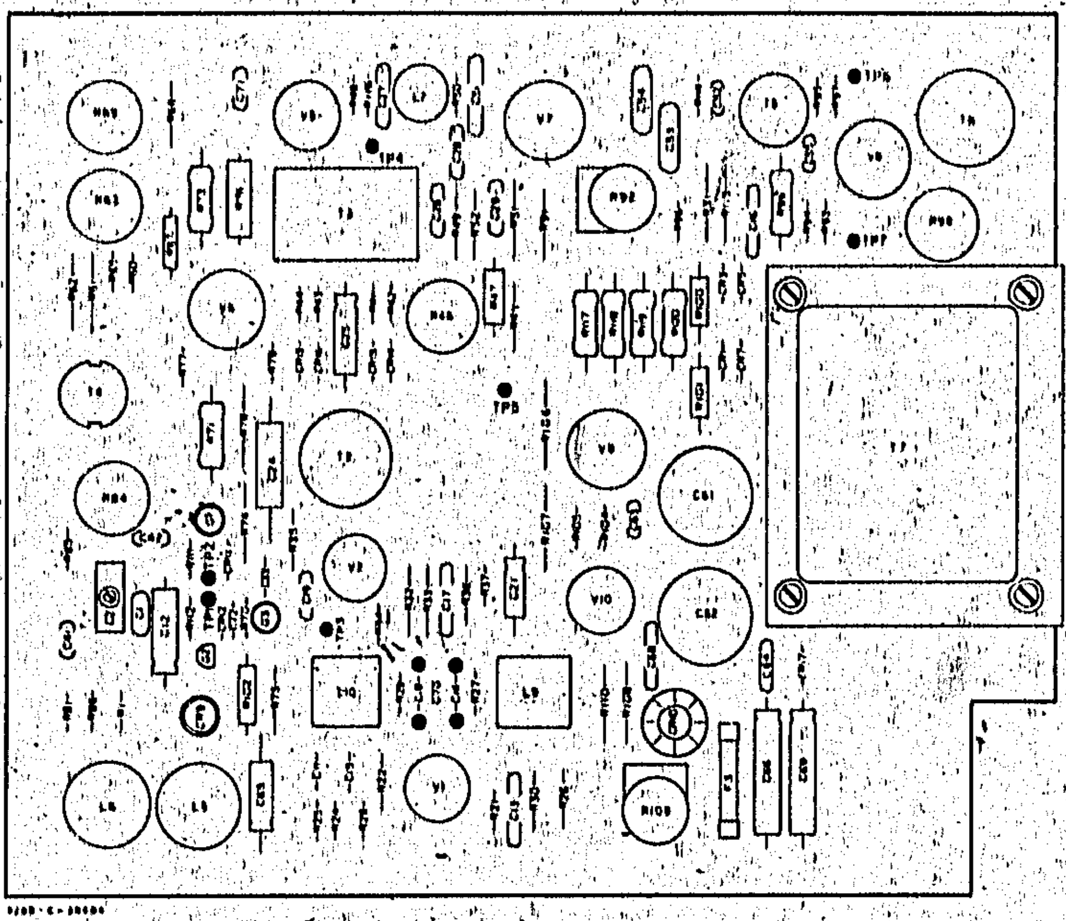
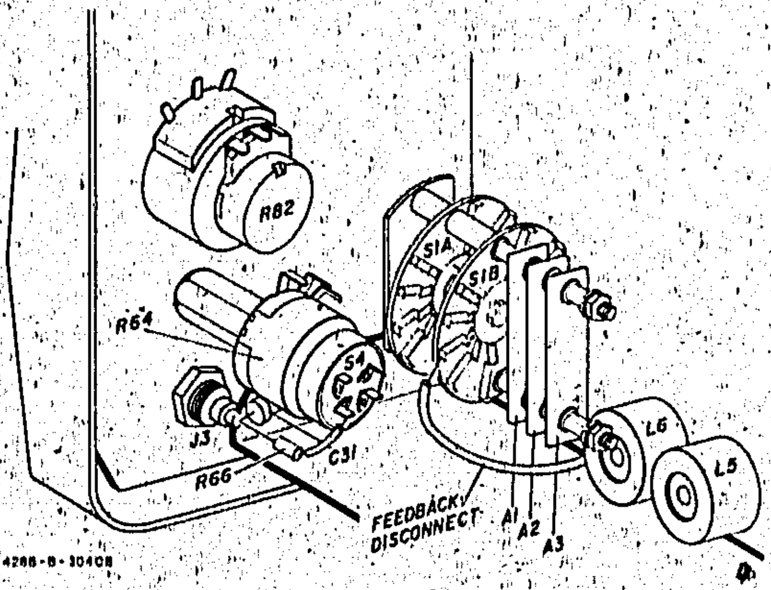


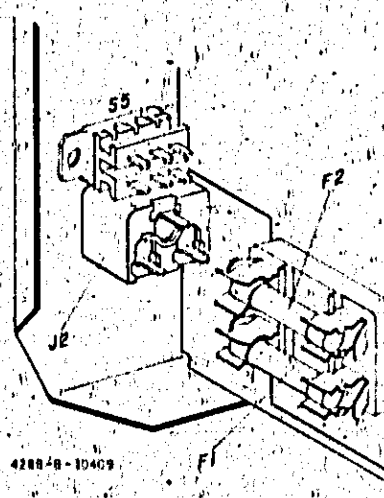
Figure 7-1. Block Diagram.



Component Locator for Circuit Board Part No. 00428-66501.



Front Panel Component Locator.



Rear Panel Component Locator.

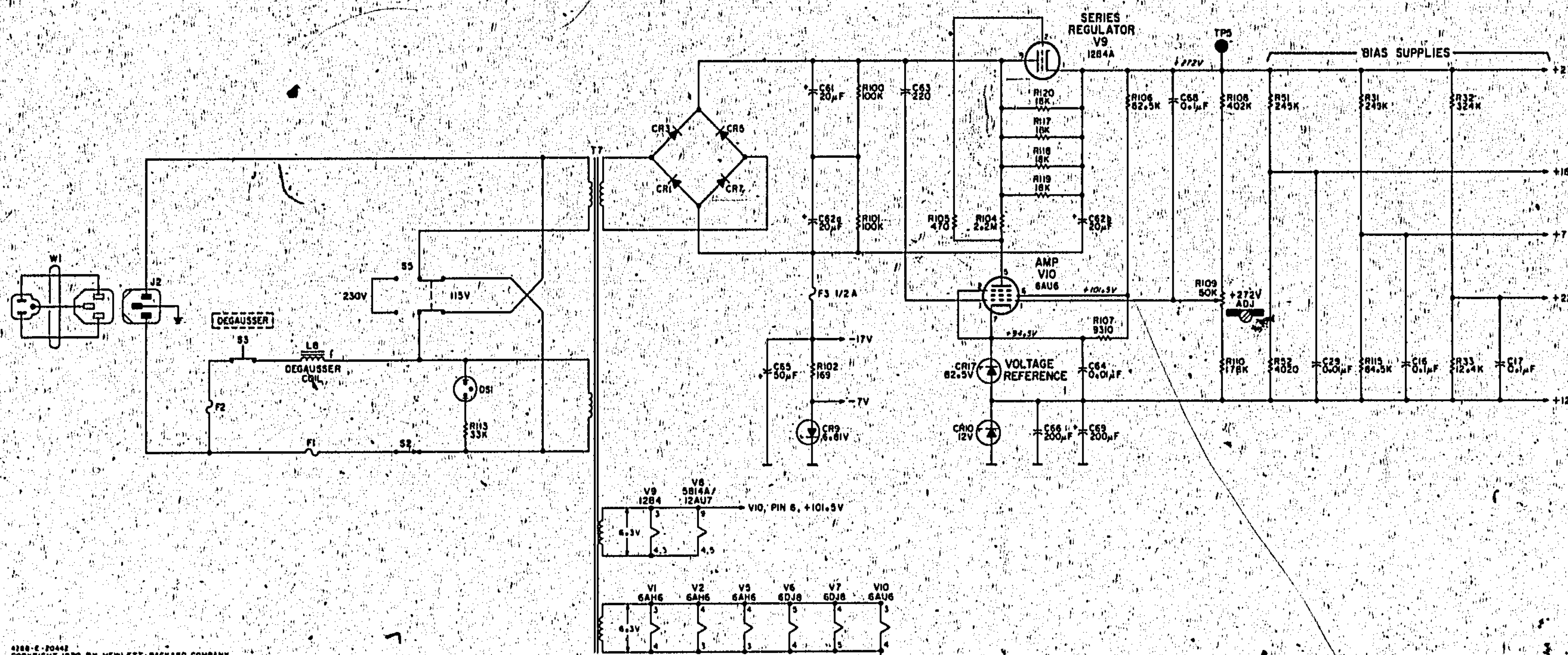
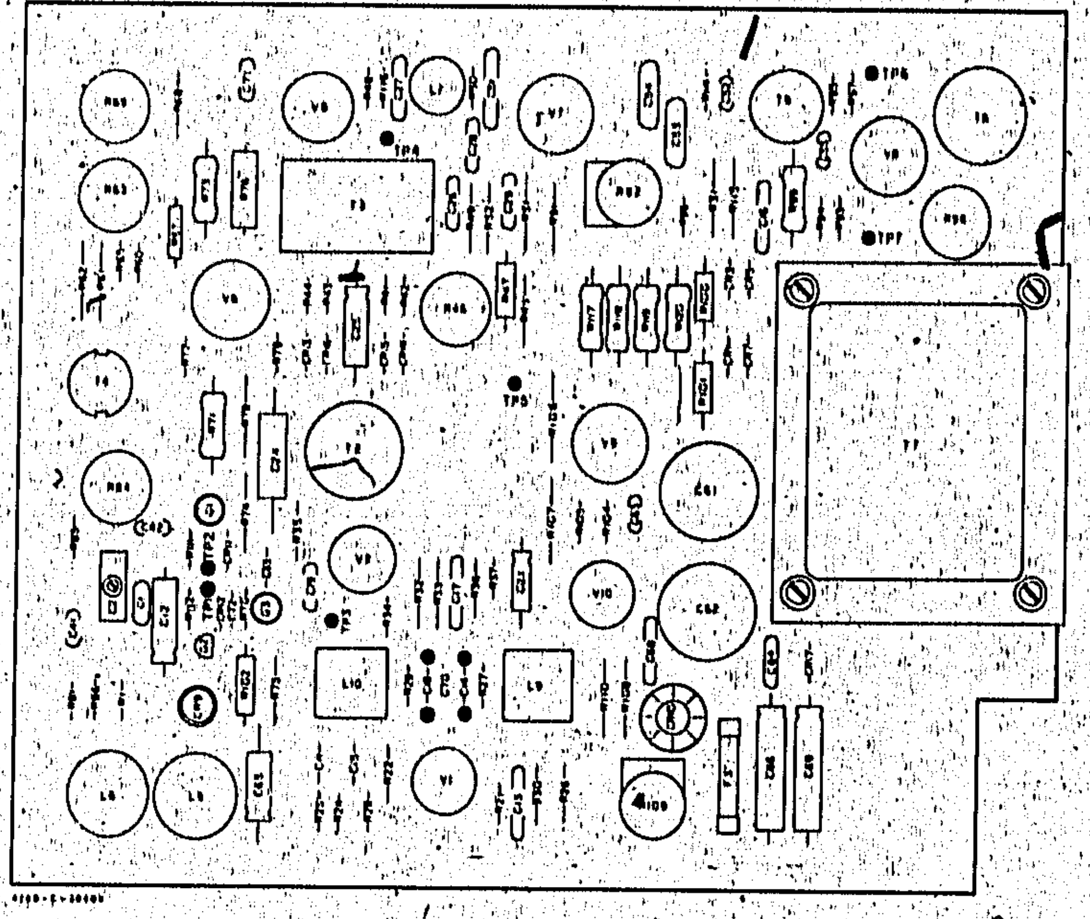
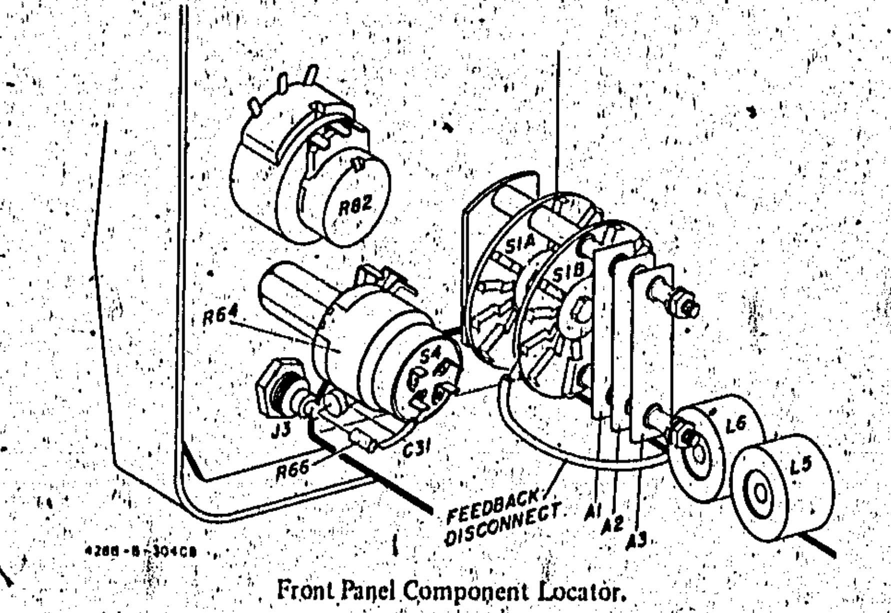


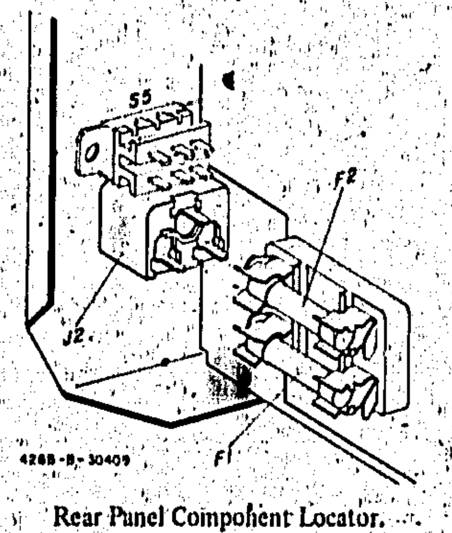
Figure 7-2. Power Supply.



Component Locator for Circuit Board Part No. 00428-66501.



Front Panel Component Locator.



Rear Panel Component Locator.

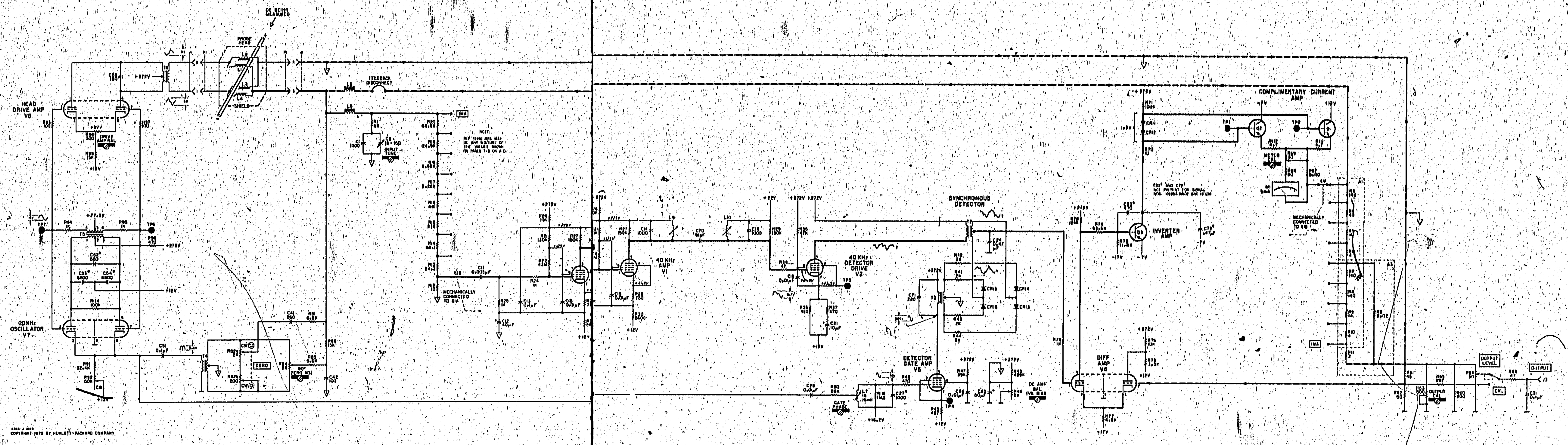


Figure 7-3. Metering Circuit.

MANUAL CHANGES

HP MODEL 428B

CLIP-ON DC MILLIAMMETER

Manual Part Number 00428-90005

CHANGE NO. 1. Applies to All Serial Numbers

Add the attached "DECLARATION" to the manual.

HEWLETT PACKARD

Herstellerbescheinigung

Hiermit wird bescheinigt, daß das Gerät/System HP 428B in Übereinstimmung mit den Bestimmungen von Postverfügung 1046/84 funkentstört ist.

Der Deutschen Bundespost wurde das Inverkehrbringen dieses Gerätes/Systems angezeigt und die Berechtigung zur Überprüfung der Serie auf Einhaltung der Bestimmungen eingeräumt.

Zusatzinformation für Meß- und Testgeräte

Werden Meß- und Testgeräte mit ungeschirmten Kabeln und/oder in offenen Meßaufbauten verwendet, so ist vom Betreiber sicherzustellen, daß die Funk-Entstörbestimmungen unter Betriebsbedingungen an seiner Grundstücksgrenze eingehalten werden.

Manufacturer's declaration

This is to certify that the equipment HP 428B is in accordance with the Radio Interference Requirements of Directive FTZ 1046/84. The German Bundespost was notified that this equipment was put into circulation, the right to check the series for compliance with the requirements was granted.

Additional Information for Test- and Measurement Equipment

If Test- and Measurement Equipment is operated with unscreened cables and/or used for measurements on open set-ups, the user has to assure that under operating conditions the Radio Interference Limits are still met at the border of his premises.

APPENDIX A

MANUAL BACKDATING CHANGES

Appendix A manual backdating information makes this manual applicable to earlier instruments. Instrument component values that differ from those in the manual, yet are not listed in this appendix, should be replaced using the part number given in Table 6-1.

Instrument Serial Prefix	Make Manual Changes
601-05250 and below	1, 2, 3
0995A06150 and below	2, 3
ALL	3

CHANGE NO. 1:
Replace Figure 7-3 with backdating schematic, Figure A-2, Page A-7/A-8. Figure A-1, 428B Side Views apply. Replace items in Table 6-1 with parts list on Pages A-3 thru A-5. In Paragraph 4-49, replace "zener diodes CR10 and CR17 with "tube V11".

CHANGE NO. 2:
Delete C33* and C72* from Table 6-1 and Figure 7-3.

CHANGE NO. 3:
Part numbers in Table 6-1 are for brown instruments; part numbers for blue instruments are as follows:

Part No.	Description
428A-1C	Dust cover (rack only)
428A-21A	Probe Assembly (see Figure 6-1)
428B-2A	Panel (cabinet-only)
428B-2R	Panel (rack only)
428B-44	Assembly: cabinet
5020-0653	Bezel

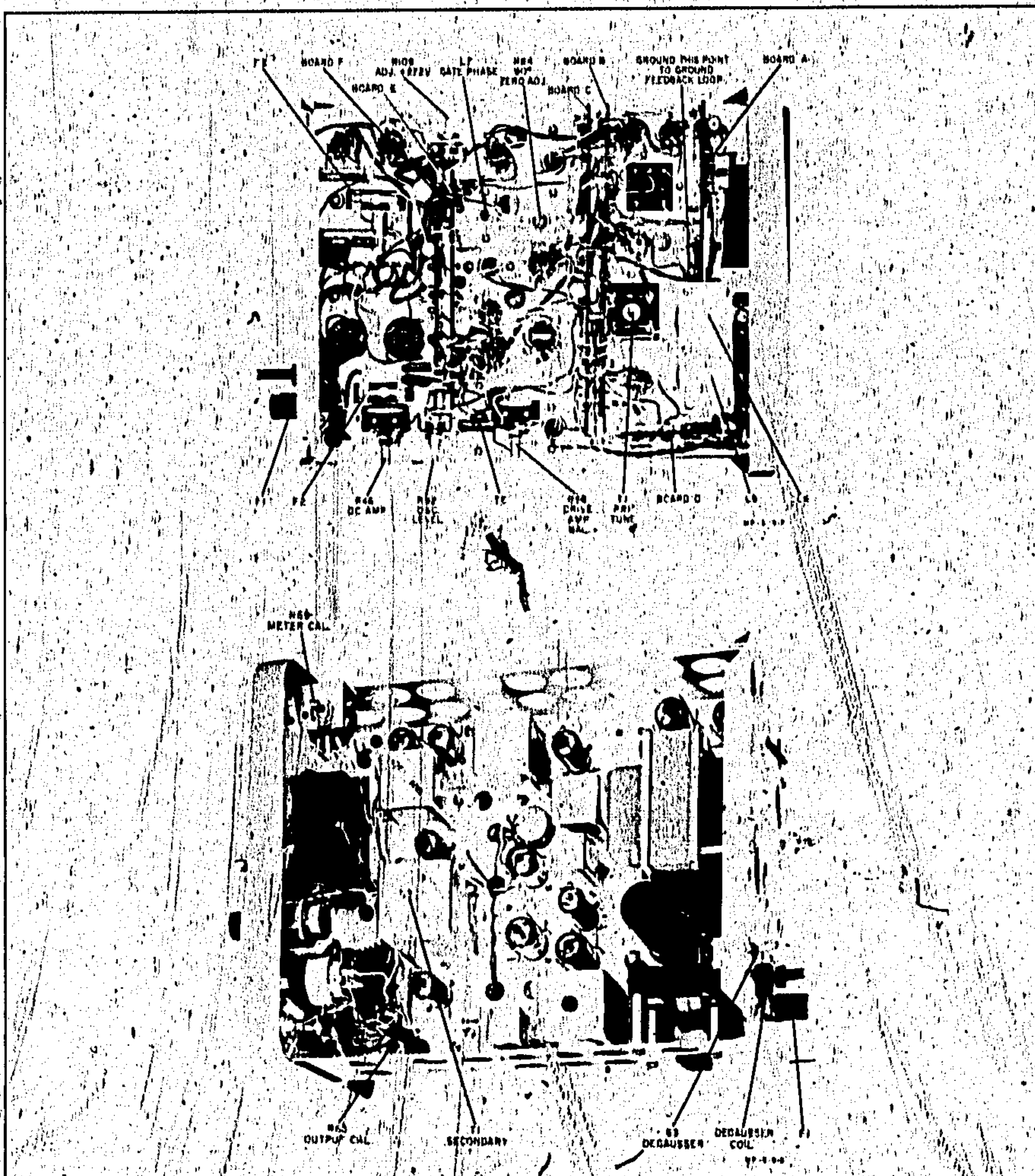
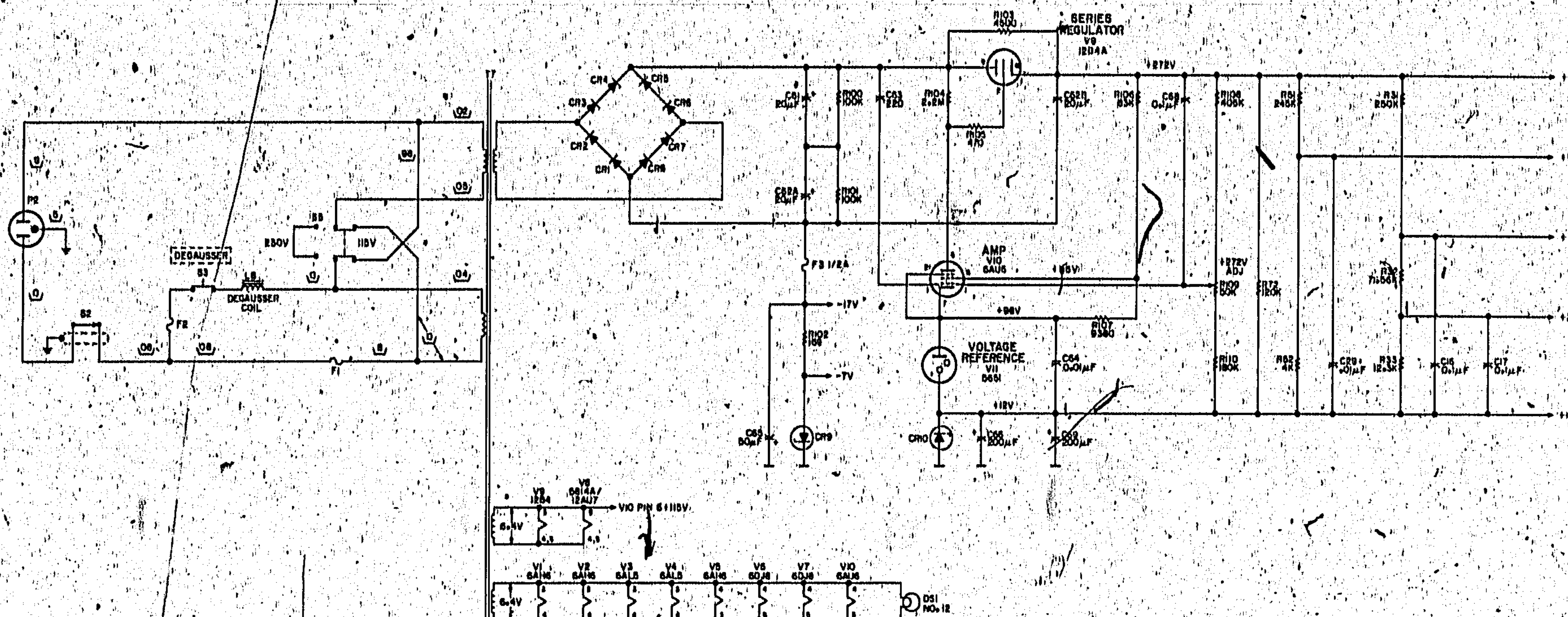


Figure A-1. 428B Side Views.

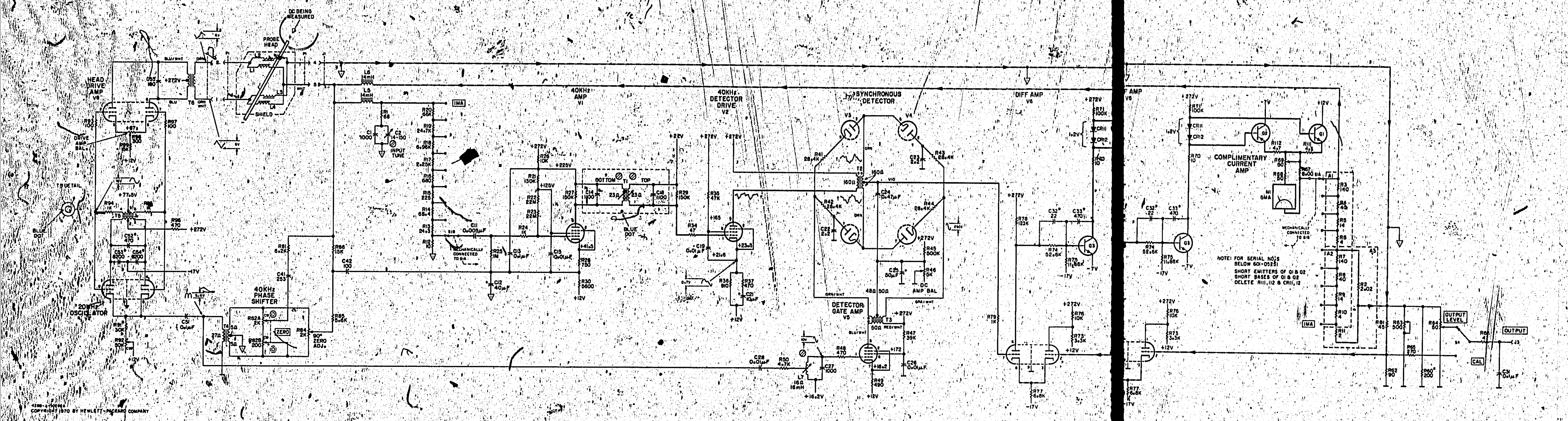
Circuit Reference	Stock No.	Description
A1, 2	428B-26A	Assembly: ww resistor, A1 includes, R3 thru R6 A2 includes, R7 thru R10
A3	428B-26B	Assembly: ww resistor, includes R2, 11
C1	0140-0099	fxd, mica, 1K pf ±1%, 500 vdcw
C2	0131-0004	var, mica, 14-150 pf, 175 vdcw
C3 thru C10		Not Assigned
C11	0150-0014	fxd, cer, 5K pf, 500 vdcw
C12	0180-0050	fxd, elect, 40 uf -15% + 100%, 50 vdcw
C13	0170-0022	fxd, my, 0.1 uf ±20%, 600 vdcw
C14		nsr, part of T1 assembly
C15	0150-0012	fxd, cer, 10K pf ±20%, 1000 vdcw
C16, 17	0170-0019	fxd, my, 0.1 uf ±5%, 200 vdcw
C18		nsr, part of T1 assembly
C19	0150-0012	fxd, cer, 10K pf ±20%, 1000 vdcw
C20		Not Assigned
C21	0180-0059	fxd, elect, 10 uf -10% + 100%, 25 vdcw
C22, 23	0150-0015	fxd, TiO_2 2.2 pf ±10%, 500 vdcw
C24	0170-0078	fxd, my, 0.47 uf ±5%, 150 vdcw
C25	0180-0058	fxd, elect, 50 uf -10% + 100%, 25 vdcw
C26	0150-0012	fxd, cer, 10K pf ±20% 1000 vdcw
C27	0140-0099	fxd, mica, 1K pf ±1%, 500 vdcw
C28, 29	0150-0012	fxd, cer, 10K pf ±20%, 1000 vdcw
C30		Not Assigned
C31	0170-0019	fxd, my, 0.1 uf ±5%, 200 vdcw
C32	0140-0034	fxd, mica, 22 pf ±5%, 500 vdcw
C33 thru C40		Not Assigned
C41	0140-0108	fxd, mica, 253 pf ±2%, 300 vdcw
C42	0140-0041	fxd, mica, 100 pf ±5%, 500 vdcw
C43 thru C50		Not Assigned
C51	0170-0019	fxd, my, 0.1 uf ±5%, 200 vdcw
C52	0140-0149	fxd, mica, 470 pf ±5%, 300 vdcw
C53, 54	0140-2102	fxd, mica, 8.2K pf ±2%, 500 vdcw
C55	0140-0147	fxd, mica, 180 pf ±5%, 500 vdcw
C56 thru C60		Not Assigned
C61	0180-0011	fxd, elect, 20 uf, 450 vdcw
C62A/B	0180-0012	fxd, elect, 2 sect, 20 uf/sect, 450 vdcw
C63	0140-0031	fxd, mica, 220 pf ±10%, 500 vdcw
C64	0150-0012	fxd, cer, 10K pf ±20%, 1000 vdcw
C65	0180-0058	fxd, elect, 50µf -10% + 100%, 25 vdcw
C66	0180-0104	fxd, elect, 200 µf, 15 vdcw
C67		Not Assigned
C68	0170-0022	fxd, my, 0.1 µf ±20%, 600 vdcw
C69	0180-0104	fxd, elect, 200 µf, 15 vdcw
CR1 thru CR8	1901-0028	Diode, Si
CR9	1902-0013	Diode, Si
CR10	1902-0014	Diode, Si
DS1	2140-0012	Lamp: indicating, #12, 2 pin base
F1, 2	2110-0007	Fuse: 1 amp, s-b (F1 115 V operation)
	2110-0008	Fuse: 1/2 amp, s-b (F1 230 V operation)
F3	2110-0012	Fuse: 1/2 amp
J1	1251-0089	Connector: female, 4 pin
J2		Not Assigned
J3	1250-0118	Connector: BNC, female
L1 thru L4		nsr; part of probe assembly (see misc.)
L5, 6	428B-60K	Assembly, choke
L7	9140-0049	Inductor: var, 16 mh
L8	9110-0025	Inductor: degaussing
M1	1120-0116	Meter: 0-5 ma, 6-10 ohms
P1	1251-0090	Connector: male, 4 pin
P2	8120-0050	Cable, power
Q1	1854-0039	Transistor: Si NPN 2N3053
Q2	1853-0016	Transistor: Si PNP 2N3638
Q3	1854-0003	Transistor: 2N1564
R1	0687-6801	fxd, comp, 68 ohms ±10%, 1/2 W
R2		nsr; part of A3 assembly
R3 thru R10		nsr; part of A1, A2 assembly
R11		nsr; part of A3 assembly
R12	0727-0335	fxd, dep c, 10 ohms ±10%, 1/2 W
R13	0757-0002	fxd, mfg, 24.3 ohms ±1%, 1/2 W
R14	0727-0035	fxd, dep c, 66.4 ohms ±1/2%, 1/2 W
R15	0727-0060	fxd, dep c, 225 ohms ±1%, 1/2 W
R16	0727-0085	fxd, dep c, 680 ohms ±1%, 1/2 W
R17	0727-0120	fxd, dep c, 2250 ohms ±1%, 1/2 W
R18	0727-0145	fxd, dep c, 6960 ohms ±1%, 1/2 W
R19	0727-0178	fxd, dep c, 24.7K ohms ±1%, 1/2 W

Circuit Reference	⊕ Stock No.	Description
R20	0727-0198	fxd, dep c, 68K ohms ±1%, 1/2 W
R21	0686-1345	fxd, comp, 130K ohms ±5%, 1/2 W
R22, 23	0687-2261	fxd, comp, 22M ±10%, 1/2 W
R24	0687-1021	fxd, comp, 1K ohms ±10%, 1/2 W
R25	0687-1051	fxd, comp, 1M ±10%, 1/2 W
R26	0687-1031	fxd, comp, 10K ohms ±10%, 1/2 W
R27	0687-1541	fxd, comp, 150K ohms ±10%, 1/2 W
R28	0689-7515	fxd, comp, 750 ohms ±5%, 1 W
R29	0687-1541	fxd, comp, 150K ohms ±10%, 1/2 W
R30	0687-5621	fxd, comp, 5.6K ohms ±10%, 1/2 W
R31	0727-0226	fxd, dep c, 250K ohms ±1%, 1/2 W
R32	0727-0201	fxd, dep c, 71.56K ohms ±1%, 1/2 W
R33	0730-0032	fxd, dep c, 12.3K ohms ±1%, 1 W
R34	0687-4701	fxd, comp, 47 ohms ±10%, 1/2 W
R35	0690-4731	fxd, comp 47K ohms ±10%, 1 W
R36	0689-9115	fxd, comp, 910 ohms ±5%, 1 W
R37	0687-4711	fxd, comp, 470 ohms ±10%, 1/2 W
R38 thru R40		Not Assigned
R41 thru R44	0727-0184	fxd, dep c, 28.4K ohms ±1%, 1/2 W
R45	0727-0244	fxd, dep c, 500K ohms ±1%, 1/2 W
R46	2100-0006	var, ww, 5K ohms ±10%, 2 W
R47	0689-3935	fxd, comp, 39K ohms ±5%, 1 W
R48	0687-4711	fxd, comp, 470 ohms ±10%, 1/2 W
R49	0727-0075	fxd, dep c, 490 ohms ±1%, 1/2 W
R50	0687-4721	fxd, comp, 4.7K ohms ±10%, 1/2 W
R51	0730-0080	fxd, dep c, 245K ohms ±1%, 1 W
R52	0727-0132	fxd, dep c, 4K ohms ±1%, 1/2 W
R53 thru R59		Not Assigned
R60	0687-6811	fxd, comp, 680 ohms ±10%, 1/2 W
R61	0727-0021	fxd, dep c, 45 ohms ±1%, 1/2 W
R62	0727-0036	fxd, dep c, 90 ohms ±1%, 1/2 W
R63	2100-0022	var, ww, lin, 500 ohms ±20%, 1 W
R64	2100-0270	var, ww, lin, 50 ohms ±10%, 2 W
R65	0687-2711	fxd, comp, 270 ohms ±10%, 1/2 W
R66	0687-4701	fxd, comp, 47 ohms ±10%, 1/2 W
R67	0812-0015	fxd, ww, 8 ohms ±5%, 2 W
R68	0727-0023	fxd, dep c, 50 ohms ±1%, 1/2 W
R69	2100-0002	var, ww, 50 ohms ±10%, 2 W
R70	0687-1001	fxd, comp, 10 ohms ±10%, 1/2 W
R71	0693-1041	fxd, comp, 100K ohms ±10%, 2 W
R72	0690-1241	fxd, comp, 120K ohms ±10% 1 W
R73	0764-0003	fxd, mfg, 3300 ohms ±5%, 2 W
R74	0727-0196	fxd, dep c, 52.6K ohms ±1%, 1/2 W
R75	0727-0163	fxd, dep c, 11.88K ohms ±1%, 1/2 W
R76	0816-0008	fxd, ww, 10K ohms ±10%, 10 W
R77	0687-6821	fxd, comp, 6.8K ohms ±10%, 1/2 W
R78	0730-0072	fxd, dep c, 123K ohms ±1%, 1 W
R79	0687-1021	fxd, comp, 1K ohms ±10%, 1/w
R80		Not Assigned
R81	0686-6225	fxd, comp, 6.2K ohms ±5%, 1/2 W
R82A/B	2100-0197	var, comp, dual pot, ±10%, 2 W R82A, 2K ohms R82B, 200 ohms
R83		Not Assigned
R84	2100-0153	var, comp, 2K ohms ±20% 1/3 W
R85	0687-5621	fxd, comp, 5.6K ohms ±10%, 1/2 W
R86	0687-1531	fxd, comp, 15K ohms ±10%, 1/2 W
R87 thru R90		Not Assigned
R91	0727-0195	fxd, dep c, 50K ohms ±1%, 1/2 W
R92	2100-0013	var, comp, lin, 50K ohms ±20%
R93	0687-1011	fxd, comp, 100 ohms ±10%, 1/2 W
R94, 95	0687-1021	fxd, comp, 1K ohms ±10%, 1/2 W
R96	0687-4711	fxd, comp, 470 ohms ±10%, 1/2 W
R97	0687-1011	fxd, comp, 100 ohms ±10%, 1/2 W
R98	2100-0038	var, ww, 300 ohms
R99	0767-0010	fxd, mfg, 15K ohms ±5%, 3 W
R100, 101	0690-1041	fxd, comp, 100K ohms ±10%, 1 W
R102	0811-0041	fxd, ww, 169 ohms ±1%, 3 W
R103	0819-0011	fxd, ww, 4.5K ohms ±10%, 20 W
R104	0687-2251	fxd, comp, 2.2M ±10%, 1/2 W
R105	0687-4711	fxd, comp, 470 ohms ±10%, 1/2 W
R106	0730-0063	fxd, dep c, 83K ohms ±1%, 1 W
R107	0727-0154	fxd, dep c, 9380 ohms ±1%, 1/2 W
R108	0727-0240	fxd, dep c, 405K ohms ±1%, 1/2 W
R109	2100-0013	var, comp, lin, 50K ohms ±20%

Circuit Reference	Stock No.	Description
R110	0727-0216	fxd, dep c, 180K ohms ±1%, 1/2 W
S1	428B-19A	Assembly: range switch, includes, R2 thru R20, R61, R62
S2	3101-0001	Switch: tog, SPST
S3	3101-0018	Switch: tog, SPST, momentary
S4		Not Assigned
S5	3101-0033	Switch, sl: DPDT
T1	9120-0053	Assembly: transformer, interstage, includes, C14, C18
T2	428A-60G	Transformer, detector signal
T3	428A-60C	Transformer, gate
T4	428B-60J	Transformer, zero balance
T5	9120-0051	Transformer, osc
T6	428A-60D	Transformer, head drive
T7	9100-0104	Transformer, power
V1, 2	1923-0017	Tube, electron: 6AH6
V3, 4	1930-0013	Tube, electron: 6AL5
V5	1923-0017	Tube, electron: 6AH6
V6, 7	1932-0022	Tube, electron: 6DJ8/ECC88
V8	1932-0029	Tube, electron: 12AU7
V9	1921-0010	Tube, electron: 12B4A
V10	1923-0021	Tube, electron: 6AU6
V11	1940-0001	Tube, electron: 5651
		MISCELLANEOUS
	428A-21A	Assembly: probe, includes L1 thru L4, P1
	428B-65C	Assembly: circuit board "C" includes R65, R67, R68
	428B-75H	Assembly: circuit board "A" includes C33, C66, C69, CR9, CR10, Q1 thru Q3, R70, R71 R74, R75, R102
	428B-75B	Assembly: resistor board "B" includes C13, R26, 27, C15, R35, 36, C21, R41, 42, C25, R45, R21 thru R23, R73
	428B-75C	Assembly: circuit board "C" includes C16, C17, C24, C41, C42, R30 thru R33, R43, R44, R77 thru R79, R81, R85, R86
	428B-75D	Assembly: resistor board "D" includes C1, C2, C11, C12, R1, R25
	428B-75E	Assembly: resistor board "E" includes C37 thru C39, C51, R47 thru R52, R72, R91, R94 thru R96
	428B-75F	Assembly: resistor board "F" includes C53, C54, C68, CR1 thru CR8, R106, R108, R110
	G-74AW	Knob: red, 3/4" w/arrow
	G-74J	Knob: black, 1", concentric shaft ZERO
	G-74N	Knob: bar, RANGE
	1200-0003	Socket, tube: 9 pin minist
	1200-0017	Socket, tube: 7 pin minist
	1400-0008	Fuseholder
	1400-0084	Fuseholder
	1450-0020	Jewel, pilot light
	8520-0017	Electric shaver brush
	1205-0011	Heat dissipator, semiconductor



p/o Figure A-2. Backdating Schematics.



p/o Figure A-2. Backdating Schematics.