HEWLETT PACKARD COMPANY

428A

CLIP-ON MILLIAMMETER

SERIALS PREFIXED: 022-

OPERATING AND SERVICING MANUAL

PRINTED 9/60

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MODEL 428A
CLIP-ON MILLIAMMETER
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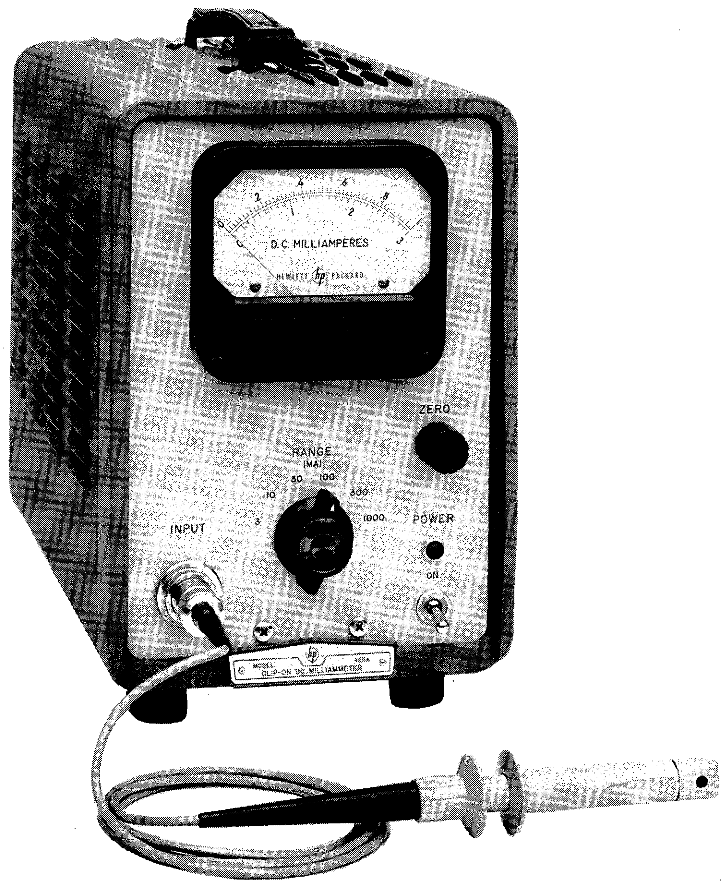
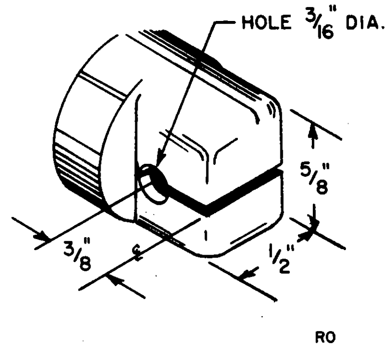


SPECIFICATIONS

RANGE:	3 ma to 1 a full scale. Six ranges in a 3, 10, 30...sequence.
ACCURACY:	Within ±3% of full scale ±0.1 ma.
INDUCTANCE:	Less than 0.5 μh will be introduced into measured circuit.
INDUCED VOLTAGE:	Less than 15 mv peak into measured circuit.
AC REJECTION:	AC with a peak value less than full scale effects accuracy less than 2% at frequencies different from the carrier (≈ 40 kc) and its harmonics.
PROBE INSULATION:	300 volts when used on bare wire.
POWER:	115/230 volts ±10%, 50-60 cps, 70 watts.
DIMENSIONS:	Cabinet Mount: 7-1/2 in. wide, 11-1/2 in. high, 14-1/4 in. deep Rack Mount: 19 in. wide, 7 in. high, 13 in. deep behind panel
PROBE DIMENSIONS:	3/16 in. hole diameter



WEIGHT:	Cabinet Mount: Net 19 lbs., shipping 24 lbs Rack Mount: Net 24 lbs., shipping 35 lbs

CONTENTS

SECTION I GENERAL

1-1 INTRODUCTION

For a long time the design engineer in the laboratory or the technician in the field has been in need of an instrument that would measure dc currents without breaking the leads. Since the introduction of the transistor, which is a current device, the need for a fast, convenient method for measuring dc currents became even more apparent.

The ⓗⓟ Model 428A Clip-On Milliammeter realizes the above stated objectives in a unique way. The instrument measures the magnetic field, which exists around the wire carrying dc current. Operating the instrument is simple. After zero setting, the two jaws of the probe are clamped around wire (arrow on probe head indicates direction of conventional current flow) and the meter will indicate the current.

There are six current ranges starting from 3 ma to 1000 ma full scale deflection. The sensitivity can be increased even further by looping the wire several times through the opening in the probe. For example, three turns increase the maximum sensitivity to 1 ma full scale. 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. With the 428A, currents can be measured as easily as measuring voltages with a voltmeter.

1-2 INSTALLATION

The ⓗⓟ Model 428A depends on natural air convection cooling. Therefore it is advisable to place the instrument on the table or work bench so that the air can circulate freely through the instrument.

CAUTION

The current probe should not be exposed to temperatures exceeding 55°C (131°F), as high temperatures seriously affect the head of the probe, resulting in unbalance and eventual damage of the probe. Do not leave probe on top of a 428A instrument (or any other hot instrument).

1-3 THREE CONDUCTOR POWER CABLE

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.

1-4 230-VOLT OPERATION

The instrument is factory wired for operation from a 115-volt source. Operation from a 230-volt supply is possible by changing jumper connections in the primary circuit of the power transformer. Refer to the schematic diagram of figure 4-16 for details.

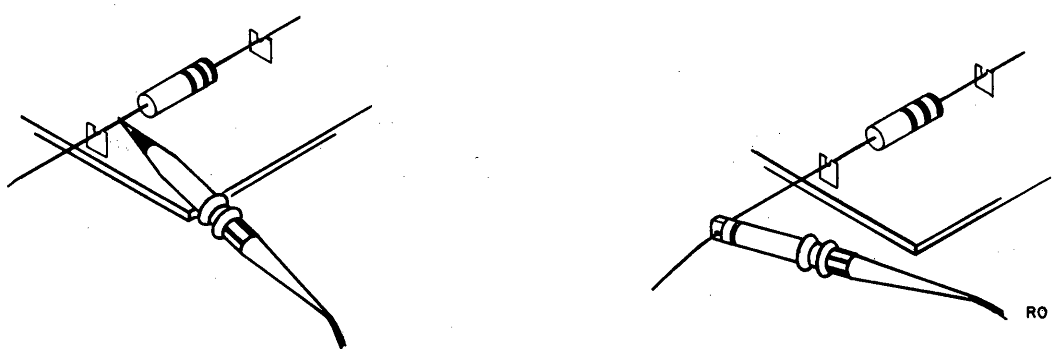
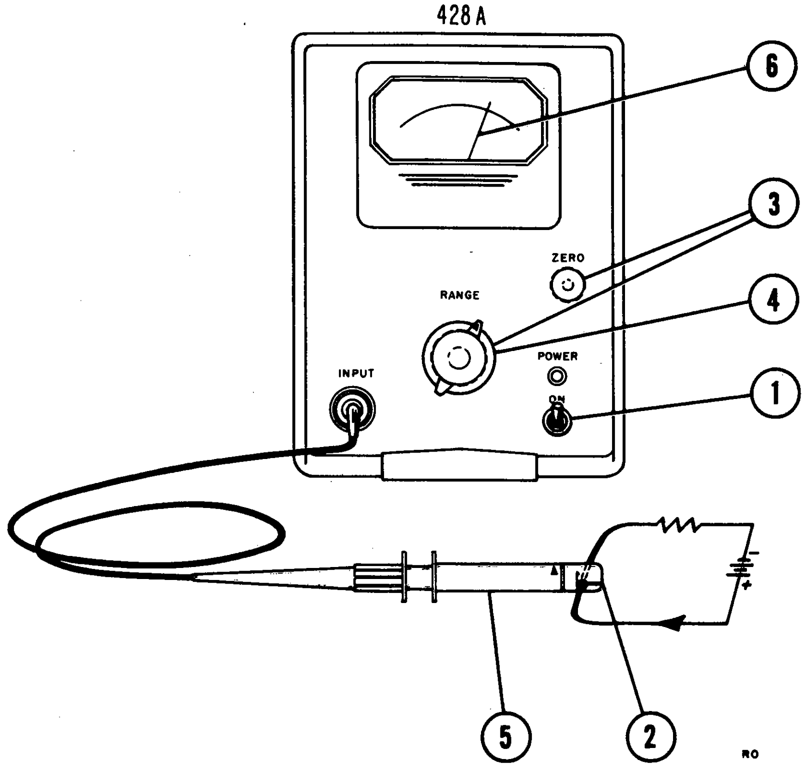


Figure 1-1. Voltage and Current Measurement

Usual clip-on voltmeter measurement of voltage without breaking circuit.

Clip-on measurement of current with Model 428A without breaking circuit.

MEASUREMENT PROCEDURE



1. Turn ON power and allow approximately 2 minutes warm-up time.
2. Check closure of probe jaws. Incomplete closure of the jaws is indicated by excessive zero-shift on the 3 ma current range when probe is rotated in earth's magnetic field. Clean probe jaws if necessary (see paragraph 4-3 Cleaning Probe Jaws).
3. Set RANGE switch to 3 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.

Figure 2-1

SECTION II
OPERATION

2-1 TURN-ON PROCEDURE

Before operating the instrument, check the mechanical zero position of the meter. For the mechanical zero setting of the meter movement, refer to paragraph 4-2.

Figure 2-1 illustrates the measurement procedure for the instrument.

Note: Read paragraph 2-5, Measurement Precautions, before operating the instrument for the first time.

2-2 MECHANICAL OPERATION OF PROBE

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.

Warning: Do NOT release the flanges abruptly so that the jaws snap together. This may cause binding and zero-shift.

2-3 ELECTRICAL ZERO SET

If the instrument cannot be zero set electrically (with ZERO control) there are two probable causes: (a) Incomplete closure of probe jaws; (b) Magnetization of probe head.

A. INCOMPLETE CLOSURE OF PROBE JAWS

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 3 ma, rotation of the closed probe should not vary the zero-set more than 0.1 ma. Cleaning of the jaws will restore proper operation conditions (see paragraph 4-3, Cleaning of Probe Jaws).

B. MAGNETIZATION OF PROBE HEAD

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 shields. For demagnetization of probe head, see paragraph 2-4, Degaussing of Probe Head.

2-4 DEGAUSSING OF PROBE HEAD

For demagnetizing the probe proceed as follows:

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

2) Depress switch S3 to energize degausser.

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

4) Zero instrument on 3 ma range with ZERO control.

Under normal operating conditions degaussing is not necessary.

CAUTION

> The degausser is designed for intermittent operation only. It may be operated for periods up to three minutes continuously without excessive heating. Normal degaussing only takes about 10 seconds.

2-5 MEASUREMENT PRECAUTIONS

It is recommended that this paragraph be read carefully before operating the 428A Clip-On Milliammeter for the first time. In general, currents can be measured with the 428A as conveniently as voltages with a vacuum tube voltmeter. However, there are situations that can cause inaccurate current readings. These situations are described in this paragraph as follows:

A. Handling of Probe
B. Magnetic Fields
C. AC Fields & Superimposed AC Currents
D. Effect of Instrument on Circuit
E. Effect of Circuit on Instrument

A. HANDLING OF PROBE

1) Mechanical Handling of Probe:
Do not close the jaws by letting go of the probe flanges abruptly (snapping), as this may magnetize the head. Also, do not drop the probe. The jaws are made from an alkyd material, which is very durable under normal use, but is not made to withstand the shock of dropping.

For the cleaning of the probe jaws, refer to paragraph 4-3.

2) Exposure to High Temperature:
The probe must not be subjected to temperatures exceeding 131°F (55°C), as higher temperatures affect the calibration and permanently increase the susceptibility to stray fields. Do not lay the probe on top of the cabinet, as hot air from the instrument can heat the probe.

3) Voltage Insulation:
It is preferable to clip the probe around insulated wire. However, the probe is insulated to make current measurements on bare wire at potentials up to 300 volts maximum, with respect to ground.

Caution: Do not use this probe on bare wire with over 300 volts peak on it.

4) Interchanging Probe Heads:
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 re-alignment and re-calibration of the instrument is necessary (see also section IV, Maintenance).

B. MAGNETIC FIELDS

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 strong dc fields, not associated with the dc current being measured, will cause a shift in the meter reading.

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.

1) 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 15 ma of current. Complete closure of the jaws can be checked by switching to the 3 ma range with no dc current input. If the jaws mate properly, the zero set should stay within 0.1 ma while rotating the probe head with respect to the earth's magnetic field.

If the zero shift is greater, the mating surfaces of the jaws need to be cleaned (see paragraph 4-3).

2) 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 (3 ma range).

3) Ferrous Wire:
Wires made out of magnetic materials can cause a current reading of 2-3 ma (wire concentrates earth's magnetic field), without any connection to the wire. This fact is important as leads of most transistors are made out of magnetic substances.

C. AC FIELDS & SUPERIMPOSED AC CURRENT

1) AC with DC being Measured:
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 of the 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.

Caution: Do not use this probe to measure dc in a wire carrying more ac than full-scale reading on meter.

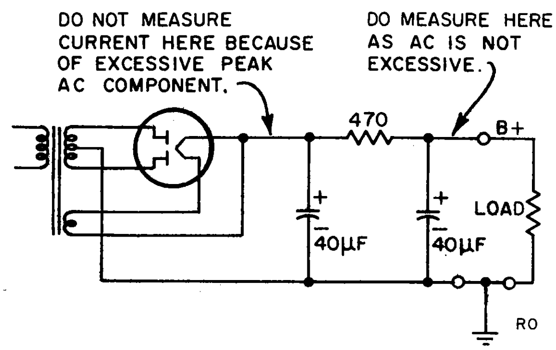


Figure 2-2. Typical Power Supply

2) 40 KC with DC being Measured:
AC currents having frequency components of 40 kc or harmonics thereof will cause error, as such signals will interfere with the 40 kc output signal of the probe. The meter will indicate a beat reading if the interfering frequency is within approximately 15 cycles of 40 kc or its harmonics. Although this situation is very improbable, accurate dc current readings can be obtained by slightly shifting the frequency of the external ac signal.

3) Stray AC Fields:
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 transformer, or large dc filter chocks, etc. Caution: Do not use this probe in the presence of strong rf fields.

D. EFFECT OF INSTRUMENT ON CIRCUIT

1) Reflected Impedance:
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 any other instrument would disturb the circuit.

2) Induced Voltage:
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.

E. EFFECT OF CIRCUIT ON INSTRUMENT

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.

2-6 MEASUREMENT PRACTICES

A. POLARITY OF CURRENT

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 2-3).

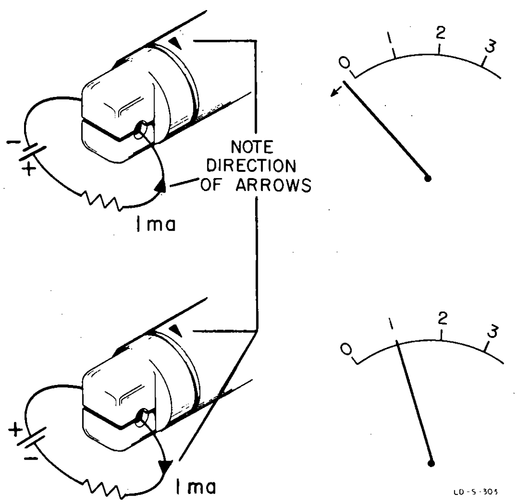


Figure 2-3. Clip Probe Around Wire with Arrow Pointing in Direction of Conventional Current

B. INCREASING THE ABSOLUTE SENSITIVITY

The sensitivity of the instrument can be increased by looping the wire (carrying the dc current) several times through the opening of the probe. For example,

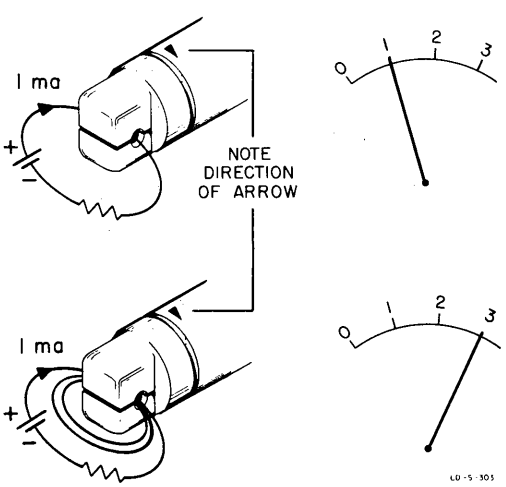


Figure 2-4. Increasing the Absolute Sensitivity by Looping Current Path through Jaws Several Times

three turns increase the sensitivity three times, giving the instrument a maximum sensitivity of 1 ma (full scale). With an increased sensitivity however, the induced voltage between the probe and the circuit under measurement will increase also (see figure 2-4).

C. CURRENT CHECK LOOPS

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 428A. Here, currents can then be measured under operating conditions with about the same ease as voltage measurement.

2-7 OPERATION WITH GRAPHIC RECORDER

The 428A Clip-On Milliammeter can be operated with a graphic recorder. Figure 2-4 illustrates how the separate potential output for the recorder is obtained.

1) Add a 18K (±10%, fixed, 1 watt) resistor to each cathode of V6, 6DJ8, pin 3 and 8. Bring leads from each 18K resistor to rear of chassis with a .01 µf condenser across the terminals.

2) Mount a two-terminal "Jones" type plug in the rear of chassis.

3) Connect a recorder with a <u>floating input</u> to new jack. Operation voltage for both leads approximately +18 volts. Recommended recorder type: Varian Type G11, Mosely Type 3.

4) A potentiometer (shown dotted) may be used between the terminals and the recorder to allow full-scale adjustment.

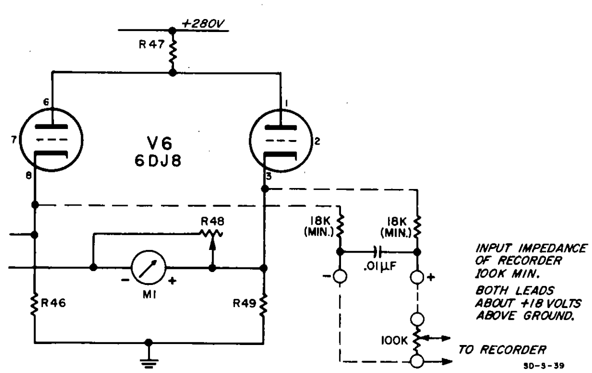


Figure 2-5. Output for Graphic Recorder

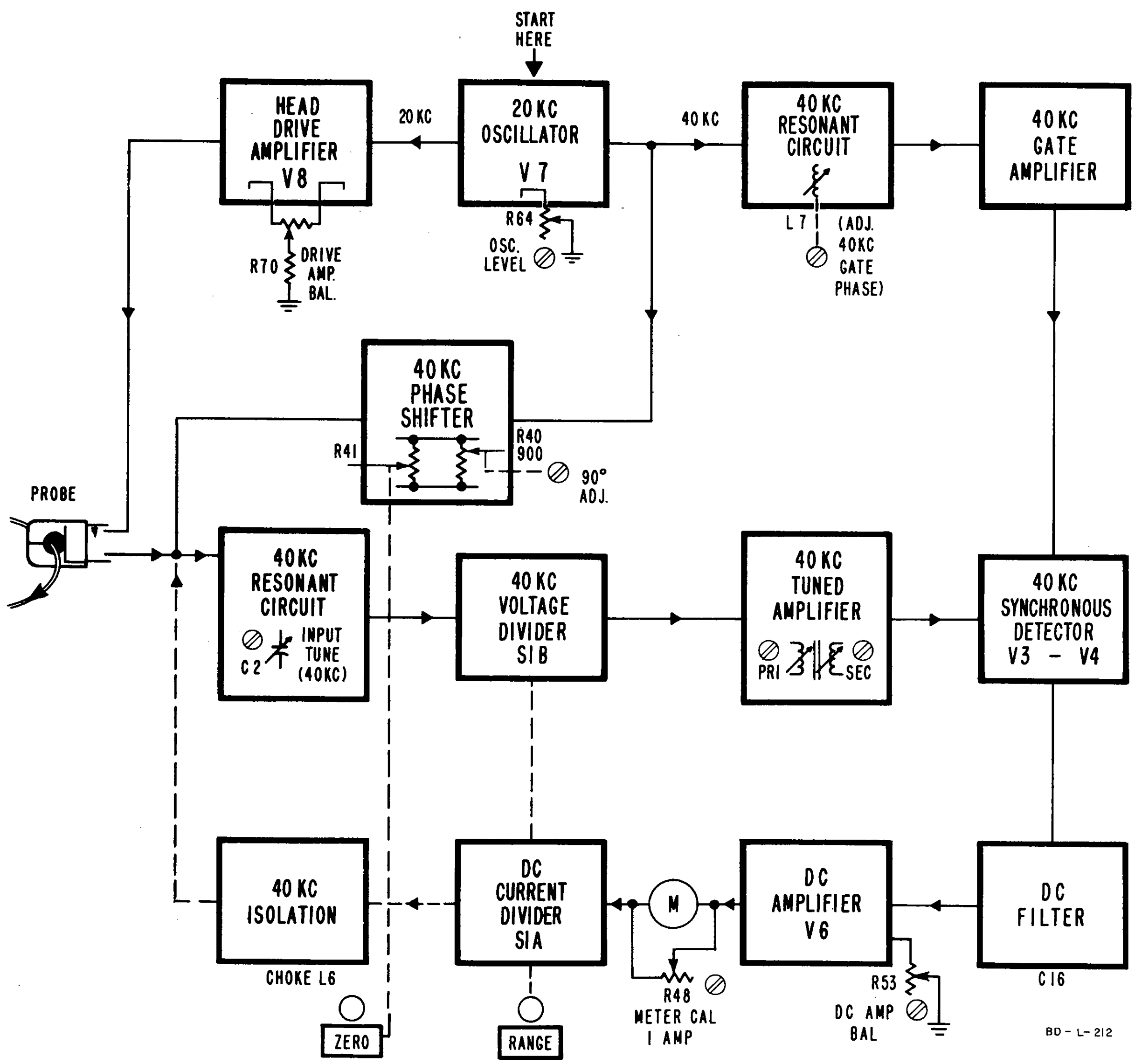


Figure 3-1. Block Diagram Model 428A

SECTION III THEORY

3-1 INTRODUCTION

This section describes the overall operation of the 428A, the operating principle of the current probe and the function of the different circuits of the instrument.

3-2 OVERALL OPERATION

The simplified block diagram of figure 3-2 shows the basic operation of the 428A Clip-On Milliammeter.

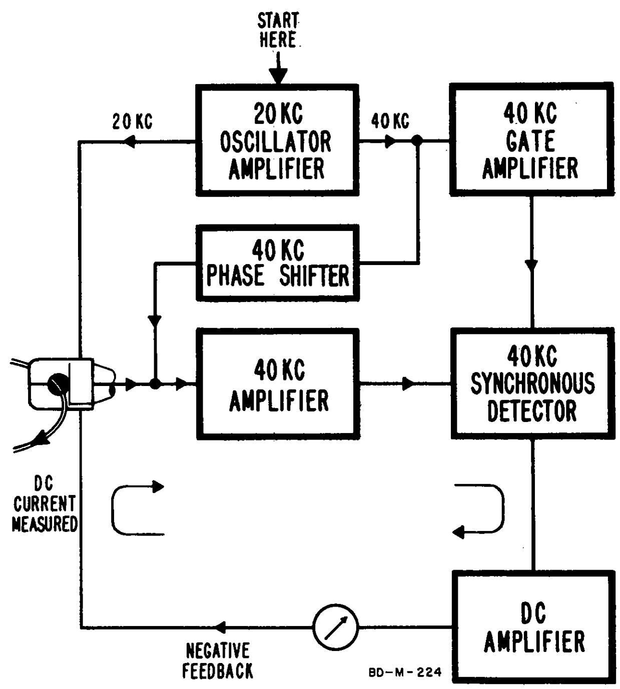


Figure 3-2. Simplified Block Diagram

The probe clips around a wire carrying dc current and delivers a 40 kc output signal which is proportional to the dc current. For transducing the dc current into a 40 kc signal, the probe requires a 20 kc gating signal, as described in detail in paragraph 3-5, 20 KC Head-Drive Amplifier.

The 40 kc 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 kc output signal almost to zero. The negative feedback current being proportional, and almost equal to, the dc current of the inserted wire, is used to indicate the measured dc current.

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

Due to slight unbalances, the probe head output shows a small 40 kc signal, even with no dc current being measured. A 40 kc phase-shifter output cancels such residual 40 kc signal (ZERO-SET controls).

3-3 CURRENT PROBE

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

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

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

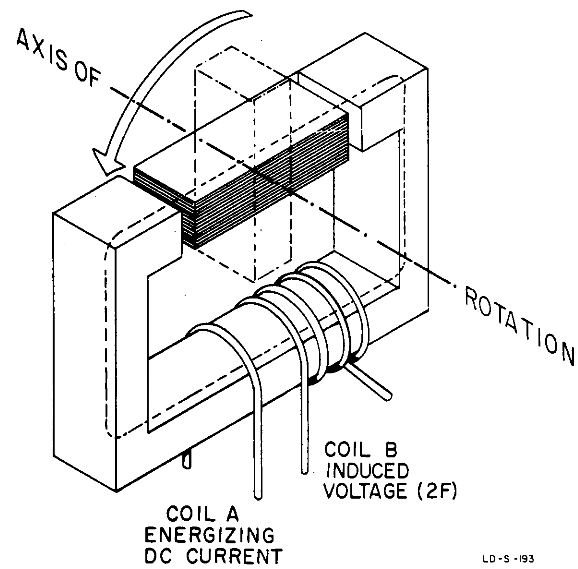


Figure 3-3. Mechanical Flux Gate

The 428A probe head uses this principle in a similar way. Figure 3-4 shows the basic concept of a saturable flux gate.

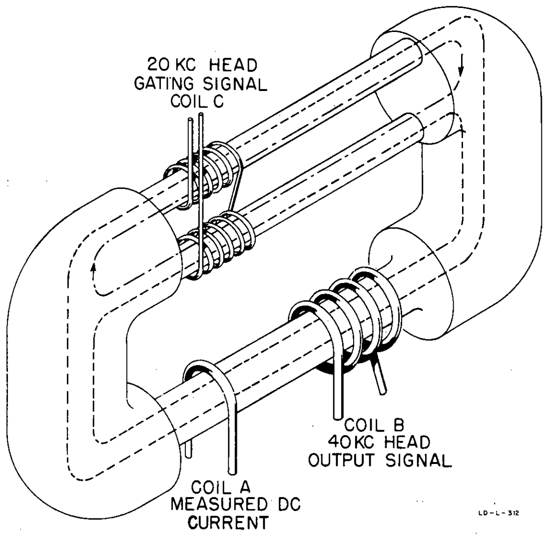


Figure 3-4. Saturable Flux Gate

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

Coil C saturates the core periodically with a 20 kc signal, driving the small cores in and out of saturation twice per cycle. This is the only function of the 20 kc signal, and this signal can be disregarded in further discussion. Coil A represents the wire through the probe carrying the dc current to be measured. This dc current determines the main flux between the two saturation phases. The resulting 40 kc signal is induced in coil B.

In the actual head there are four coils connected in a bridge configuration as shown in figure 3-5A. The cores of the coils are periodically saturated by a balanced 20 kc signal at points C and D.

With no dc being measured, no signal will appear between points A and B, since they are balanced as far as the 20 kc is concerned and since no dc flux exists, no 40 kc is generated.

When the probe jaws are clipped over a wire carrying dc, the instantaneous 40 kc voltages induced by the gated dc flux has the polarities shown in figure 3-5B and a 40 kc signal appears at points A and B. (If the direction of the measured dc changes, the phase of the instantaneous voltages will change by 180°.)

3-4 20 KC OSCILLATOR

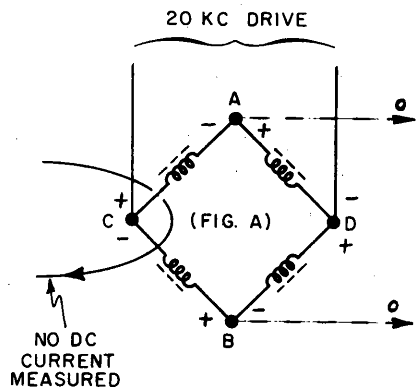
The function of the 20 kc oscillator is to generate a balanced 20 kc signal, which after amplification is used for driving the probe head in and out of saturation.

The circuit of the 20 kc oscillator is shown in figure 4-15. The oscillator V7 is operating in push-pull having a plate circuit tuned to 20 kc. Transformer coupling provides positive feedback through resistor R66 and R67 to the oscillator control grid. 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.

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

3-5 20 KC HEAD-DRIVE AMPLIFIER

The head-drive amplifier V8 supplies the balanced 20 kc signal for the probe head. Drive balance adjustment R70 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.



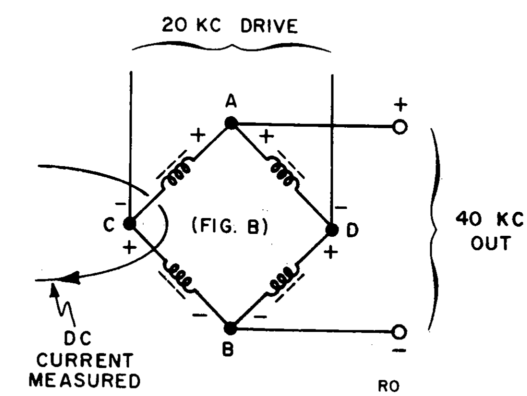


Figure 3-5. Current Probe Bridge Circuit

3-6 40 KC SYNCHRONOUS DETECTOR AMPLIFIER

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

The operation of the Synchronous Detector requires a high level 40 kc signal. The 40 kc output signal of the oscillator V7 passes through a tuned circuit and drives the gate amplifier V5. The output of V5 delivers about a 300-volt peak 40-kc gate to the Synchronous Detector. The function and the adjustment of the Synchronous Detector Gate Amplifier will be discussed in paragraph 3-8.

3-7 40 KC INPUT/AMPLIFIER CIRCUIT

The 40 kc output voltage of the probe head is resonated by a 40 kc series resonant circuit (L5 and C1/C2). Resistor R1 broadens the resonance response by lowering the Q to minimize drift problems. The 40 kc signal passes through a voltage divider S1C, 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 kc amplifier V1 is bandpass coupled to the 40 kc detector driver stage V2. The output signal of V2 is isolated from ground by transformer T2, and fed to the 40 kc synchronous detector.

3-8 40 KC SYNCHRONOUS DETECTOR AND FILTER (C16)

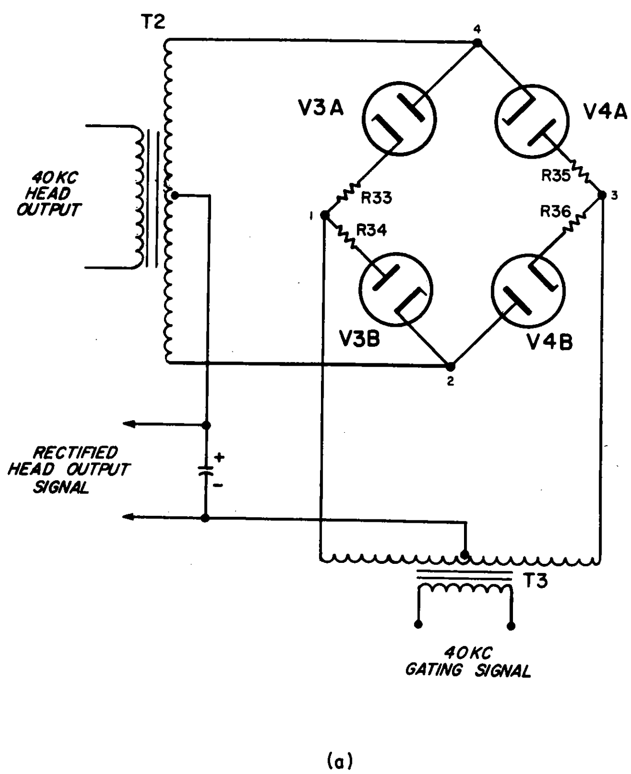
The Synchronous Detector detects the amplitude and the phase of the 40 kc signal. Phase detection is necessary to preserve negative feedback at all times. Since the probe may be clipped over the wire in either of two ways the phase of the signal may vary by 180°. If phase detection were not present this 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.

Operation of the Detector

The synchronous detector requires a large 40 kc gating signal, having the frequency of the desired signal. Figure 3-6 shows the synchronous detector drawn as a bridge circuit.

A large gating signal (300 volts peak) is fed to point 1 and 3 of the bridge. Each half cycle of the gating signal drives the diodes of branch (123) and branch (341) alternately into strong forward conduction (dotted line in figure 3-6b). The diodes function as switches operating at a rate of 40 kc (the gating frequency).

The 40 kc amplifier output transformer is returned to point 2 and 4 of the bridge, and its signal is



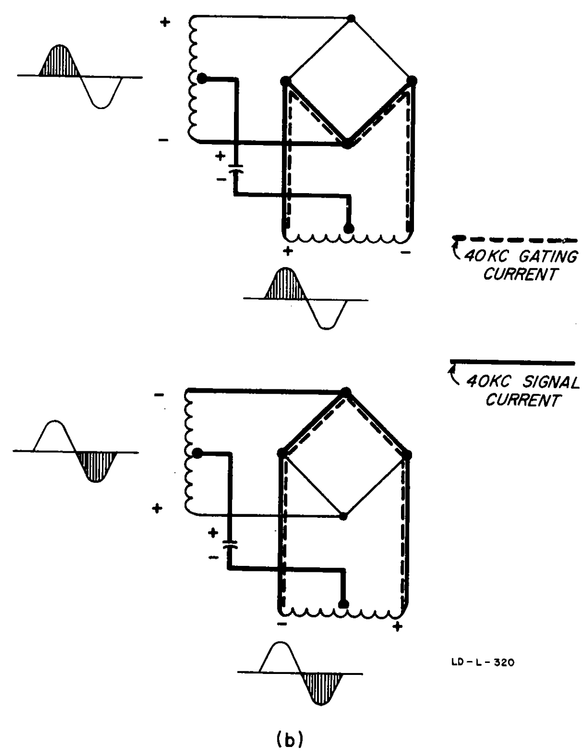


Figure 3-6. Synchronous Detector

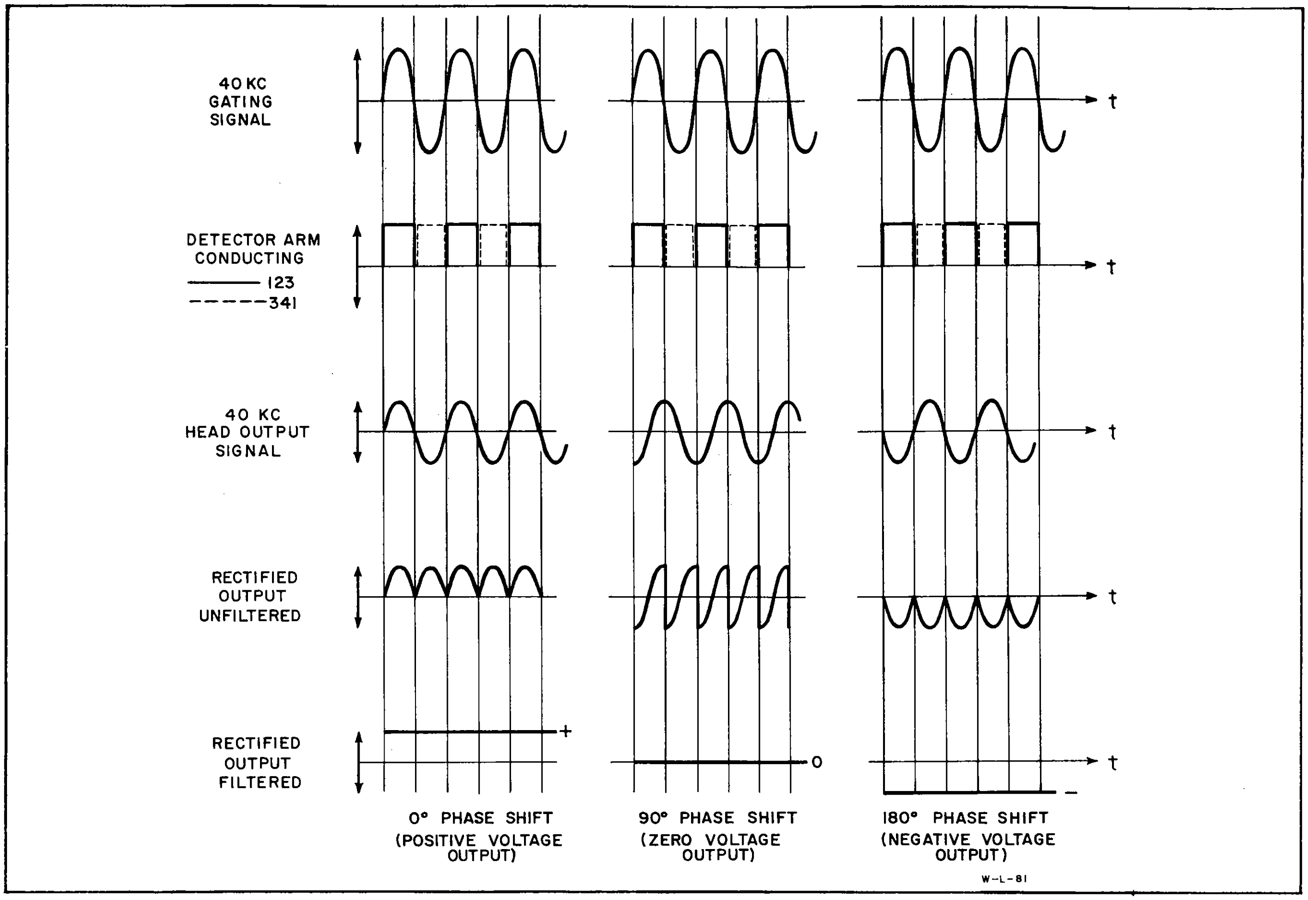


Figure 3-7. Change of Output of Synchronous Detector with Phase

superimposed on the gating signal (indicated by heavy line in figure 3-6b). Since the 40 kc output signal is considerably smaller than the 40 kc gating signal, the action of the gated diodes is to alternately return the top and bottom end of T_2 secondary to T_3 secondary center tap. The 40 kc output signal appears rectified across C16 (figure 3-7 shows the phase and amplitude relationship in the synchronous detector). Referring to figure 3-6, resistors R33 through R36 provide a bias voltage for the diodes in cutoff. In other words, when diodes V3A and V4A conduct, the voltage drop across R33 supplies a negative bias for V3B and the voltage drop across R35 supplies the back-bias voltage for diode V4B.

The input of the gate amplifier V5 contains a tunable 40 kc resonant circuit, also used as a phase shifter for the 40 kc gating signal. The phase of the 40 kc gating signal is adjusted to synchronize exactly with the probe output signal as it appears at V2.

3-9 DC AMPLIFIER

The dc amplifier supplies a negative dc feedback current to the probe which is 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.

Triode section V6A is a cathode follower, used to lower the source impedance of the synchronous detector output, and provide the dc feedback current. Cathode follower V6B provides a low impedance return path for the feedback current. The cathode of V6B also serves as the ac ground of the 40 kc head-output signal.

With no dc input at the probe, the dc output of the detector bridge is zero, the two cathodes of V6 have equal voltages, and there is no feedback current flowing through the meter to the probe head. DC amplifier balance is accomplished by varying the bias of V6A by means of R53.

When full-scale dc is being measured (e.g. 3 ma on the 3 ma range) the control grid of V6A raises by approximately 1.3 volts. The increased cathode potential of V6A causes feedback current to flow, which is returned through the feedback current divider and the probe head, to cathode of V6B. The negative feedback reduces the original flux of the dc input current (of clamped wire) to approximately 1%, corresponding to 40 db of negative feedback.

3-10 NEGATIVE FEEDBACK CURRENT CIRCUIT

The negative feedback current path is shown in figure 3-8. Current divider S1B divides the feedback current in proportion to the dc current being measured*. For a dc input of 1 ampere, approximately 5 ma feedback current is fed to the probe head. Since an equal number of ampere-turns is necessary for canceling the main dc flux, the feedback coil inside the head requires approximately 200 turns.

3-11 40 KC PHASE SHIFTER

The output of the 40 kc phase shifter is fed to the head of the probe to cancel any residual 40 kc 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 3-9 shows the circuit and the idealized phase relationship of the two output voltages with respect to the 40 kc signal from the oscillator.

By adding the two output voltages (point A and B) a 40 kc signal is obtained, having a phase angle within 0-360° and a given maximum amplitude (point C). Once the residual 40 kc 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.

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

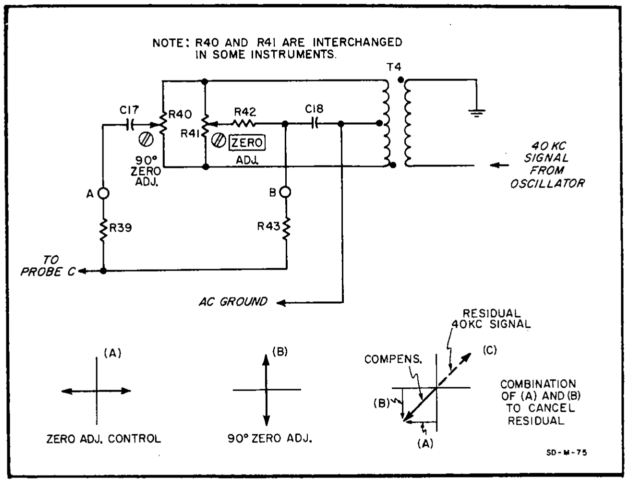


Figure 3-9. 40 KC Phase Shifter

3-12 POWER SUPPLY

A single series-regulated power supply of the conventional type provides 280 volts regulated for the circuits of the instrument. Voltage reference tube V11 provides a constant cathode potential at control tube V10 and this is the reference potential for the control grid of V10.

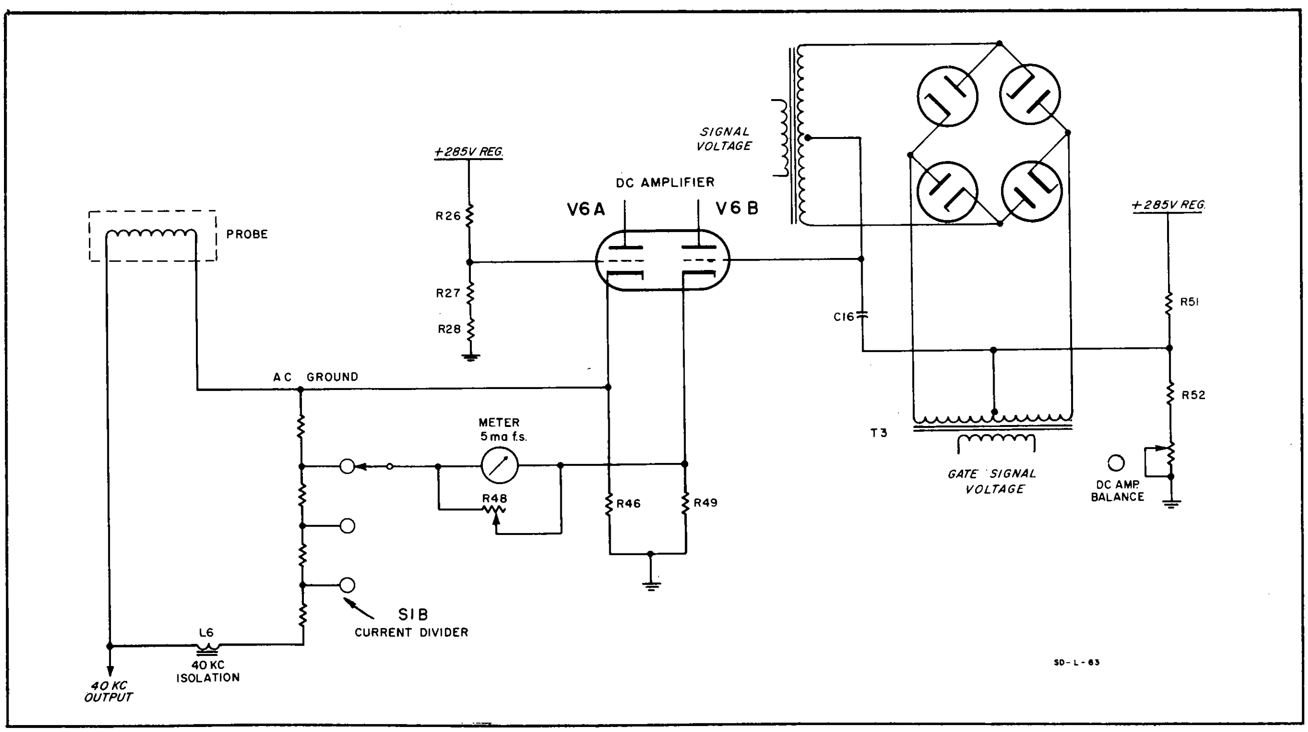


Figure 3-8. Feedback Current Circuit

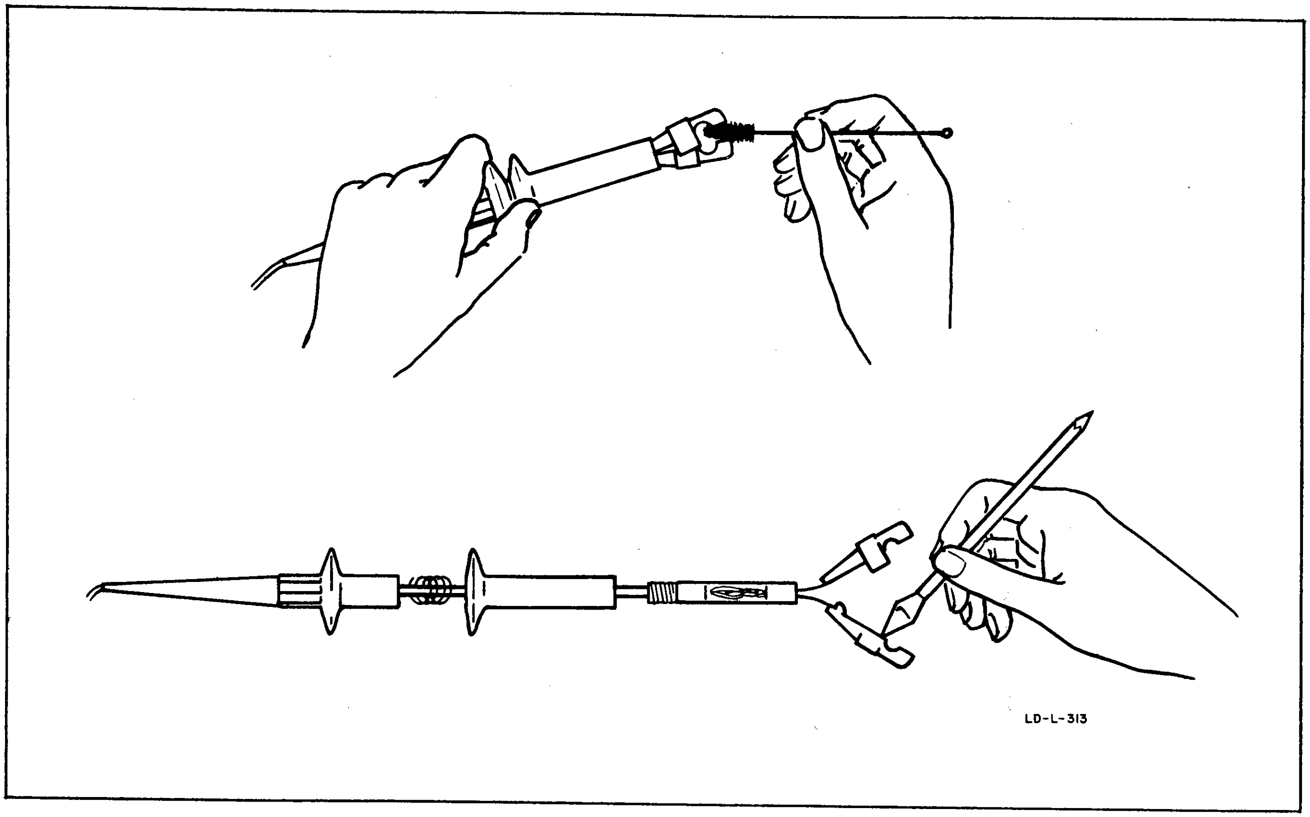


Figure 4-1. Cleaning Probe Jaws

Shows proper method of cleaning mating surfaces of probe jaws. If normal cleaning of jaws with brush will not permit jaws to mate perfectly, clean with pencil eraser. See paragraph 4-3, Cleaning of Probe Jaws.

SECTION IV MAINTENANCE

4-1 INTRODUCTION

This section contains information about servicing and maintaining the Model 428A.

A performance check is included in this section to be used to verify instrument operation without removing the instrument from the cabinet. This is a good test as part of preventive maintenance and incoming quality control inspection.

A tube replacement chart (table 4-1) has been included. Most tubes may be replaced without requiring adjustment because of the large amount of negative feedback. However, the performance check should be done when replacing any tube. If the instrument does not meet the performance check then the tests indicated under that particular tube in the tube replacement chart should be performed.

A trouble-shooting section which will help you find troubles more easily has been included. This section consists of a series of waveforms covering systematically the 40 kc signal, gate and oscillator circuits.

A complete test procedure covering all adjustments has been included. Normally only those parts of the procedure concerned with the particular section of the instrument that was faulty should be done. Do NOT perform this entire procedure as a part of preventive maintenance.

4-2 MECHANICAL ZERO-SET

If the meter pointer does not align with the zero mark, when the instrument is turned off, the mechanical meter zero needs to be reset. Before making the adjustment, let instrument warm up for approximately 15 minutes. Turn off instrument and after approximately one minute zero-set the meter movement.

The meter pointer should rest directly over zero when the instrument is turned off. Best accuracy is obtained if you observe this with one eye only. To avoid parallax, position your head so the meter scale, pointer, and your eye are all in line.

A mechanically stable adjustment can only be made when the direction of pointer travel is opposite to the direction or rotation of the adjust screw. The adjusting screws may be turned in either direction, but a good method is to turn the screw clockwise until the pointer swings up scale and then starts to swing down scale towards zero (i.e. counterclockwise). Continue turning the screw clockwise until the pointer (now moving to the left) is directly over the zero mark. If you overshoot, continue turning the screw clockwise until the pointer is again traveling down scale towards zero.

4-3 CLEANING OF PROBE JAWS

Cleaning of the probe jaws is done by squeezing together the probe flanges and cleaning the two mating surfaces with a brush (supplied with the instrument). If the foreign matter cannot be removed by the brush, then the probe head must be disassembled and the surfaces cleaned with an eraser (see figure 4-1). To disassemble the probe head, grasp the probe head in the palm of one hand and unscrew the probe center section (see figure 4-12) with the other hand. Make sure that you do not twist the cable while doing this.

In reassembling the probe, be sure that the polarity arrow on the probe points <u>toward</u> the side of the terminal strip with the <u>heavy red lead</u> of the probe cable.

4-4 TEST EQUIPMENT

This paragraph lists all the test equipment and auxiliary equipment necessary for completely servicing and adjusting the Model 428A.

A. <u>TEST INSTRUMENTS</u>

1) Oscilloscope with dual channel plug-in, such as ⓗⓟ Model 150A, 160 or equivalent.
2) AC Vacuum Tube Voltmeter, such as ⓗⓟ Model 400D or equivalent.
3) DC Vacuum Tube Voltmeter, such as ⓗⓟ Model 412A, 410B or equivalent (1% accuracy at 280v).
4) Electronic Counter, such as ⓗⓟ Model 522B, 523B etc., or equivalent.

B. <u>AUXILIARY EQUIPMENT</u>

1) Oscillator Balance Probe, as indicated in fig. 4-2.
2) One 1.0 μf capacitor; one 0.0082 μf capacitor.
3) Supply of small fixed mica padding capacitors (up to 500 pf).

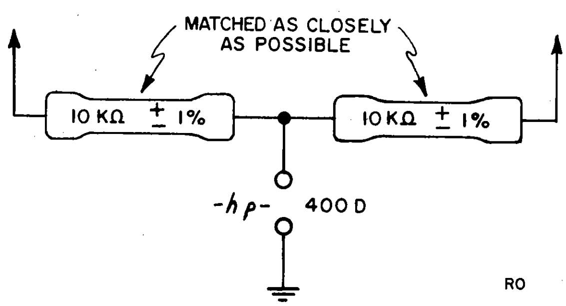


Figure 4-2. Oscillator Balance Probe

4) Supply of 1/2 watt resistors (680 to 10K, Allen Bradley or equivalent).

5) AC voltage source (6.3 volts), 60 cps.

6) Precision resistor, 500 ohms ±1%, 1 watt; 1K potentiometer, 2 watts.

7) Variable ac power supply, such as variable autotransformer.

8) Variable dc power supply, such as ⓗ Model 711A Laboratory Power Supply.

4-5 FRONT PANEL PERFORMANCE CHECK

Three simple tests performed with the instrument in its cabinet indicate whether the circuits are operating normally. The tests can be used as incoming inspection checks and are not intended to check the accuracy of the instrument. See the following figures:

Figure 4-3. Electrical Zero Set
Figure 4-4. DC Current Indication
Figure 4-5. AC Overload

4-6 ACCURACY CHECK

For the accuracy check use set-up of figure 4-4, DC Current Indication.

The accuracy check consists of: (A) Range Calibration, (B) Meter Tracking.

A. RANGE CALIBRATION

Check: Zero 428A on 3 ma range. Switch to 100 ma current range.

1) Feed 100 ma dc current through probe (monitored with external dc ammeter accurate to .25% or better). Adjust R48 (Cal. Adj.) for 100 ma.

2) Change line voltage from 103 to 127 volts. Calibration change should stay within 0.2%.

3) Repeat step 1 for all other current ranges, i.e. 300 ma, 100 ma etc. Full-scale reading should remain within 1% on all ranges. If not, check range switch.

Note: Be sure that zero-set is adjusted each time in this check. If the meter is zero-set on 3 ma range and current ranges are gradually increased to the 1000 ma range, it is normal if the zero-set is off when the instrument is returned to the 3 ma range. This is caused by a slight residual magnetism induced by the 1000 ma of current into the mu-metal shield. Subsequent repetition of this sequence of operation should cause very little additional shift.

B. METER TRACKING

Check: Zero 428A on 3 ma range. Switch to 100 ma range.

Feed 100 ma dc current through probe. Monitor dc current with external ±0.25% accuracy or better dc ammeter. Reduce current and check tracking of 428A meter with inserted dc ammeter. Reading should stay within 1% of full scale at any point of the range.

4-7 ADJUSTMENT AFTER TUBE REPLACEMENT

Experience has shown this instrument to be very reliable. Most troubles will be due to faulty tubes. Never disturb any adjustment until extensive tests have indicated adjustment is necessary!!

This instrument is very sensitive to phase shifts. If any adjustments which affect phase are disturbed, complete alignment will be necessary.

Phase shifts can be caused by changes in the 20 kc oscillator frequency. Normal variations in interelectrode capacities of the oscillator tubes will not change the oscillator frequency enough to require realignment, provided the rest of the circuitry was previously adjusted properly.

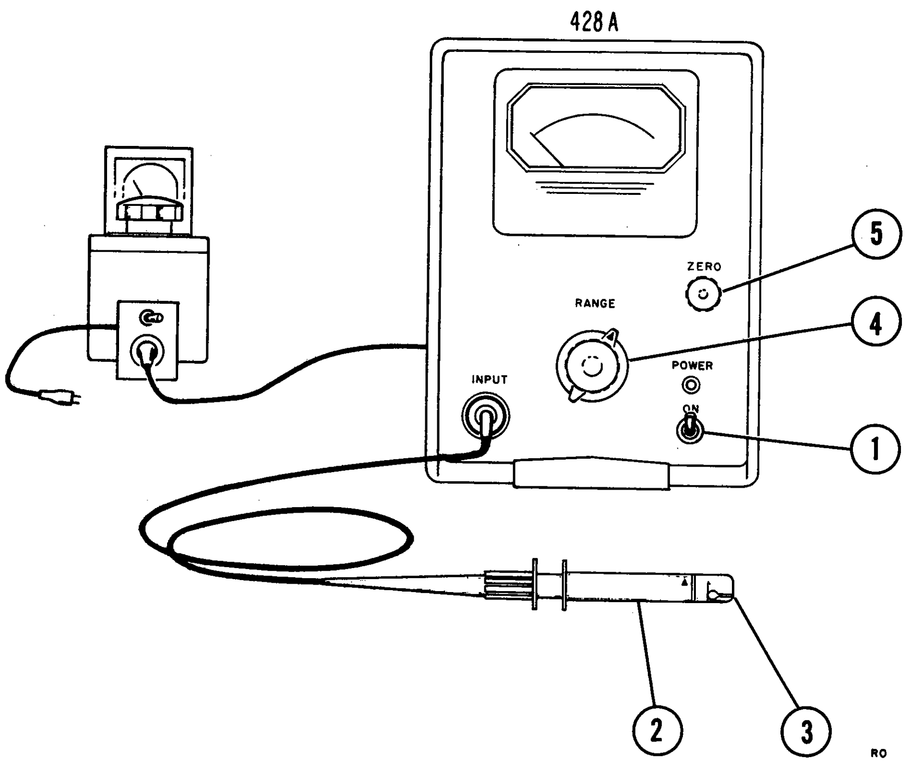
Some tubes may shift the frequency too much. In this case you must re-align the instrument. Perhaps an easier way is to select an oscillator tube which makes the circuit oscillate at the same frequency (approximately) as the old tube. This can save considerable time if a choice of tubes is available.

Table 4-1 lists possible adjustment or checks after a tube has been replaced. Consult table 4-1 only if instrument does not meet specifications.

TABLE 4-1. TUBE REPLACEMENT

Tube	Type	Function	Check
V1	6AU6	40 kc Amplifier	No adjustment
V2	6AH6	40 kc Detector Driver	No adjustment
V3/4	6AL5	Synchronous Detector	No adjustment
V5	6AH6	Detector Gate Amplifier	No adjustment
V6	6DJ8	DC Amplifier	DC Ampl. Bal. Table 4-2 Adj. Procedure
V7	6DJ8	20 kc Oscillator	No adjustment
V8	5814/ 12AU7	20 kc Head Drive	Drive Bal. Adj.
V9	12B4	Series Regulator Tube	No adjustment
V10	6AU6	Control Tube	No adjustment
V11	5651	Reference Tube	Power Supply Table 4-2, 2

ELECTRICAL ZERO-SET



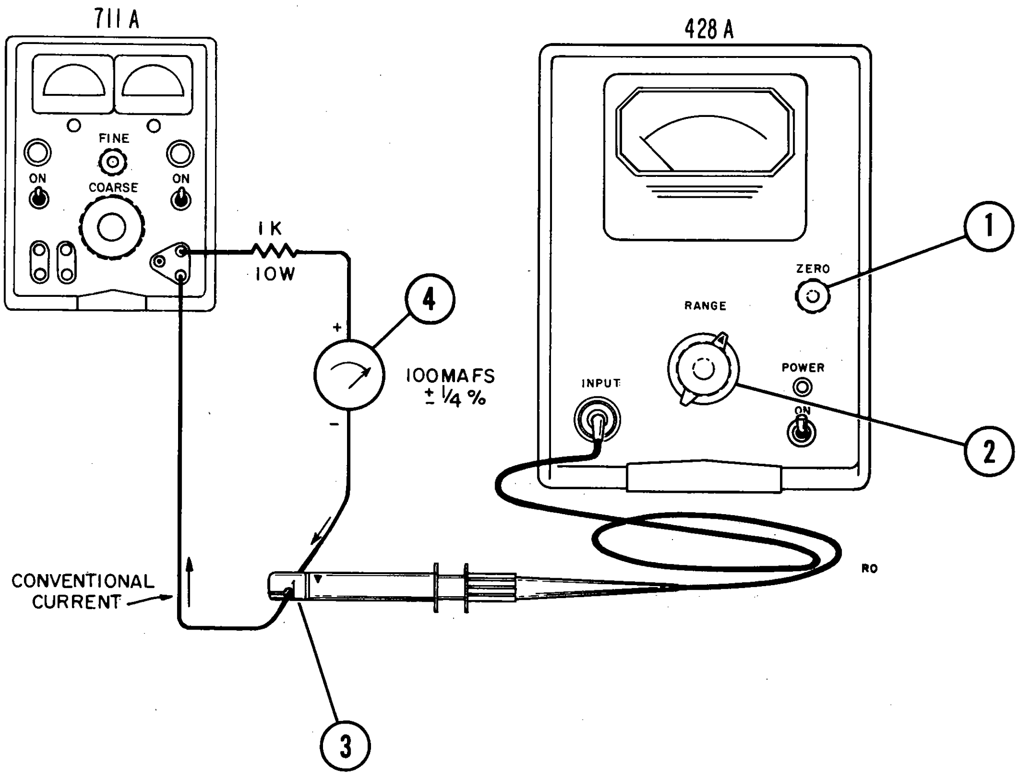
Connect 428A to a variable voltage supply, such as an autotransformer.

1. Turn ON power and allow approximately 2 minutes warm-up time.
2. Place probe away from any stray fields (meter magnets, open-core transformers, etc.).
3. Check for complete closure of probe jaws (see paragraph 2-3).
4. Set RANGE switch to 3 ma.
5. Zero-set instrument with ZERO control. If zero-setting is not possible see paragraph 2-4.

Check: Change line voltage from 103 to 127 v and observe meter on 428A. Zero-drift should remain within ± 0.5 ma.

Figure 4-3

DC CURRENT INDICATION

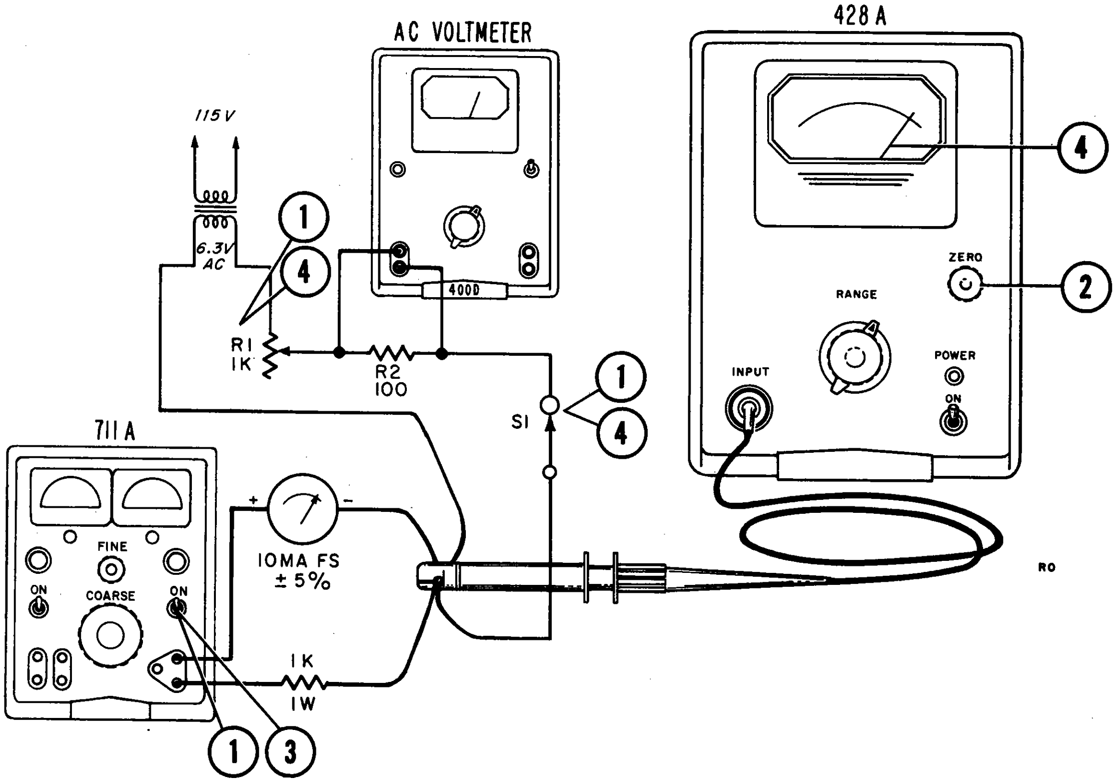


1. Zero-set 428A on 3 ma range, with no direct current input to probe.
2. Switch current RANGE to 100 ma.
3. Clip probe around wire carrying current to be measured, pointing arrow on probe in direction of the conventional current flow (see arrows in figure above).
4. Increase current until milliammeter reads 100 ma.

Check: Reading on Model 428A should agree within ± 3%.

Figure 4-4

AC OVERLOAD



Connect equipment as shown.

1. Open S1, set R1 to center and turn power supply off.
2. Zero-set 428A on 10 ma range with no input to probe.
3. Turn on power supply and adjust for 10 ma dc.
4. Close S1 and adjust R1 until 428A meter reading drops by approximately 2%.

Check: AC voltmeter should read 0.7 vrms (10 ma peak, 7 ma rms), or more.

Figure 4-5

4-8 TROUBLE LOCALIZATION

PERFORM THE STEPS IN THIS SECTION BEFORE ADJUSTING THE ALIGNMENT.

Do NOT attempt alignment before determining the location of the trouble. If alignment is attempted first, in addition to the alignment not working, trouble shooting may be made more difficult. For instance, if the original trouble was a faulty component, you would have to find the misalignment in addition to the faulty component. Finding two troubles in an instrument is usually much more difficult than finding a single trouble.

A. TROUBLE-SHOOTING PROCEDURE

Proceed with the following steps until the trouble is found.

1) The first check to make after you determine that the instrument does not meet specifications is to check the probe. Remove probe connector from instrument and measure resistance between connector pins. The coils in the probe head are connected in the form of a bridge with each pin connected to a corner. The resistance between any adjacent pair of pins should be about 5 ohms.

If not, one of the coils in the probe is probably open. If the reading is ∞ the cable is probably open. If the probe tests all right, connect it back to the instrument and degauss the probe.

2) Remove the instrument from the cabinet by removing the two screws at the rear of the instrument and pushing the chassis free from the cabinet. Connect a voltmeter such as the ⓗⓟ Model 410 or 412A Vacuum Tube Voltmeter, to any red lead on terminal board 428A-95C (rearmost board). It is assumed in all these directions that the ground lead will be connected to the chassis unless specifically instructed otherwise. This voltage should be 280 ±6 volts. If not, try adjusting R83 (Adj +280V) or replacing V9, 10 or 11.

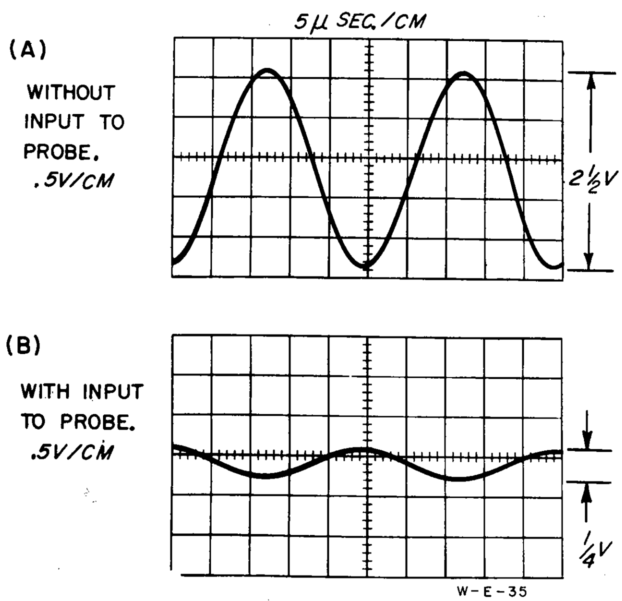
Connect a variable power line voltage source, such as an adjustable autotransformer, to the 115V input of the 428A. Vary the input voltage from 103 to 127 vac. The dc voltage should not vary more than ±2 vdc. If it does, try replacing V9, 10 or 11.

3) Check the waveforms on the schematic in numerical order starting with test-point ① and going to ⑩. Note the conditions of measurement of these waveforms on the schematic. No waveforms are shown for the output of the probe because the signal at this point is largely a residual of the drive signal and the waveform varies with different probes. No waveforms are shown at the input to the 40 kc Amplifier either, since, with feedback the amount of signal at this point is so low that it cannot be seen on most oscilloscopes. These circuits will be checked in step 5 when the feedback is disconnected.

BETWEEN DIFFERENT INSTRUMENTS THESE WAVEFORMS MAY VARY, particularly at testpoints ⑧ (usually blue wire), ⑨ (usually orange wire), and ⑩ (usually green wire) on T2. The waveform at ⑨ should be somewhat similar to that on ⑧. The waveform at ⑩ should be 180° out-of-phase with that at ⑨. The reason for the distorted waveforms at the transformer is the interaction from the gating action of the Synchronous Detector tubes V3 and V4.

When a particular waveform is not correct, the trouble is generally between this test-point and the immediately preceding correct test-point. Use normal trouble-shooting techniques to isolate the trouble within the stage. If C16 is open, the instrument will oscillate with a self-quenching parasitic oscillation at about a 1 kc rate. If the trouble cannot be found in this way, proceed with the following more detailed steps:

4) With the RANGE switch still on the 100 ma range check the unit by temporarily connecting a 1.5 volt dry cell (standard flashlight cell with soldered-on leads) across C16. Capacitor C16 will be found on the rear side of terminal board 428A-95B near the top of the board. Connect the dry cell with the polarity indicated on the schematic. The meter on the 428A should indicate roughly full scale. If it does the dc amplifier is functioning properly. Now check the waveform at pin 7 of V2 (see waveform in figure 4-6A). The corresponding waveform with 100 ma input to the probe is shown in figure 4-6B. If waveform A remains the same while moving the RANGE switch throughout all ranges, look for trouble in the Synchronous Detector. If these waveforms are not somewhat



(WAVEFORM AT PIN 7 OF V2 WITH 1.5 VOLT CELL CONNECTED ACROSS C16)

Figure 4-6. Trouble Localization Waveforms

similar to those shown in figure 4-6 and the trouble is not evident, trace the signal as explained in the next step. Remove battery.

5) Signal tracing by means of waveforms with feedback connected is not always satisfactory. The signal, reduced by feedback, is so small it cannot be seen on an oscilloscope throughout much of the input circuit. Also the logical place to start signal tracing is in the probe. However, the signal at this point is largely a residual of the drive signal which depends upon the probe. The useful signal is the second harmonic which is at a very low level. For these reasons, signal tracing will be started after the tuned circuit (C1, C2 and L5) has filtered and amplified the useful signal (by resonance).

To view these waveforms proceed as follows:
Disconnect jumper across Test Disconnect terminals on terminal board 428A-75A (board nearest front panel). This jumper will be found across the terminals nearest the front panel. Clip probe over wire carrying 100 ma dc (see figure 4-4).

Check waveform at junction of R1 and L5 (on terminal board nearest front panel). Correct waveform is shown in figure 4-7A. If this waveform is not similar to that shown, check L5, C1, C2 and R1. Turning RANGE switch should have no effect. This waveform, as well as those that follow, should vary slightly as the ZERO control is rotated.

Connect oscilloscope probe to pin 7 of V2. Waveforms with and without 100 ma input to the probe are shown in figure 4-7C and D. The phase of the signal without an input (figure 4-7D) will vary as the ZERO control is rotated (when the ZERO control is in the center position there will be NO signal at this point).

6) Clip the probe around a wire carrying 100 ma (see figure 4-4) and set the RANGE switch to 1000 ma (1 ampere). Remove the dc amplifier tube V6. When this tube is removed insufficient current is drawn from the power supply to keep it in regulation. To increase the current drawn from the power supply, remove the current shunt R78 across V9. This resistor is the 20 watt, 400 ohm resistor mounted on the rear chassis. Remove the single wire from the furthest forward end of the resistor. Measure the voltage appearing across C16 with a vtvm, such as the ⓗⓟ Model 410B or 412A. Measure the voltage of each side of the capacitor separately and subtract the difference. CAUTION: Do NOT connect voltmeters other than ⓗⓟ 412A across C16 as most voltmeters have one lead grounded and both sides of this capacitor are above ground. This voltage should be approximately 20 volts.

Check the waveforms at all terminals of T2. The waveform at testpoint (9) (usually orange wire) should be somewhat similar to the waveform at (8) (usually blue wire). The waveform at (10) (usually green wire) should be 180° out-of-phase with the waveform at (9). The waveforms for a typical instrument are shown in figure 4-8.

If these waveforms are not similar to those shown, proceed to the next step. Do not replace the wire removed from R78.

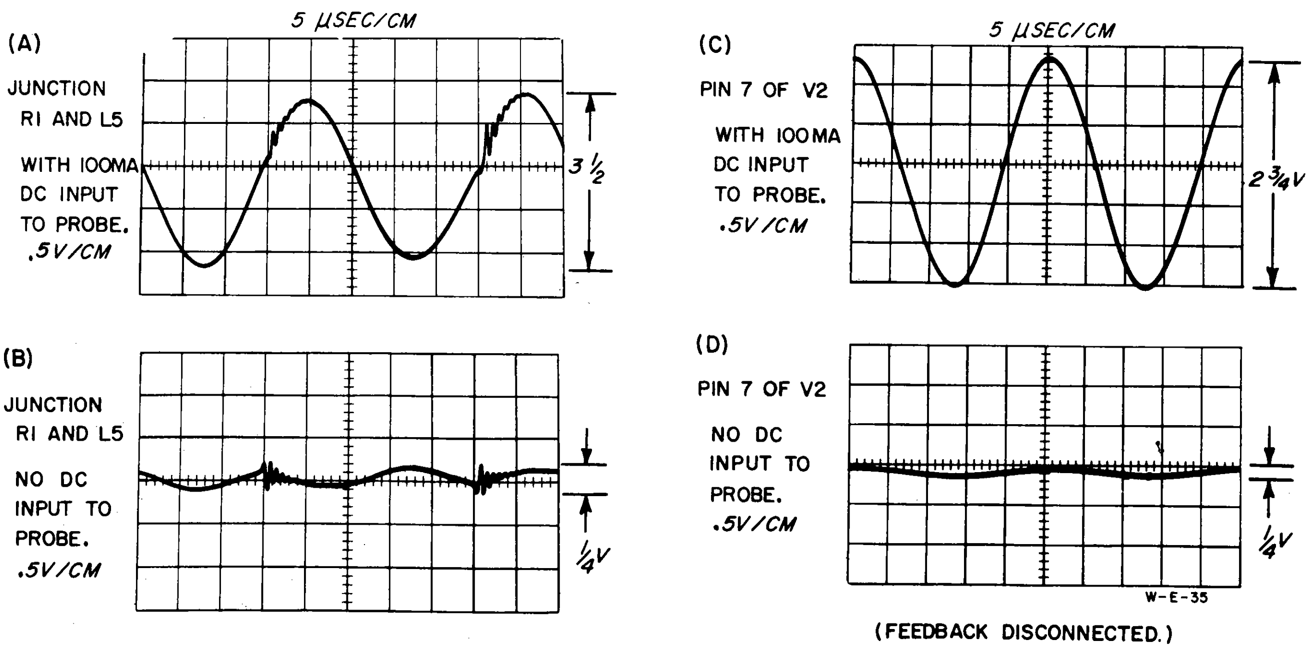


Figure 4-7. Trouble Localization Waveforms

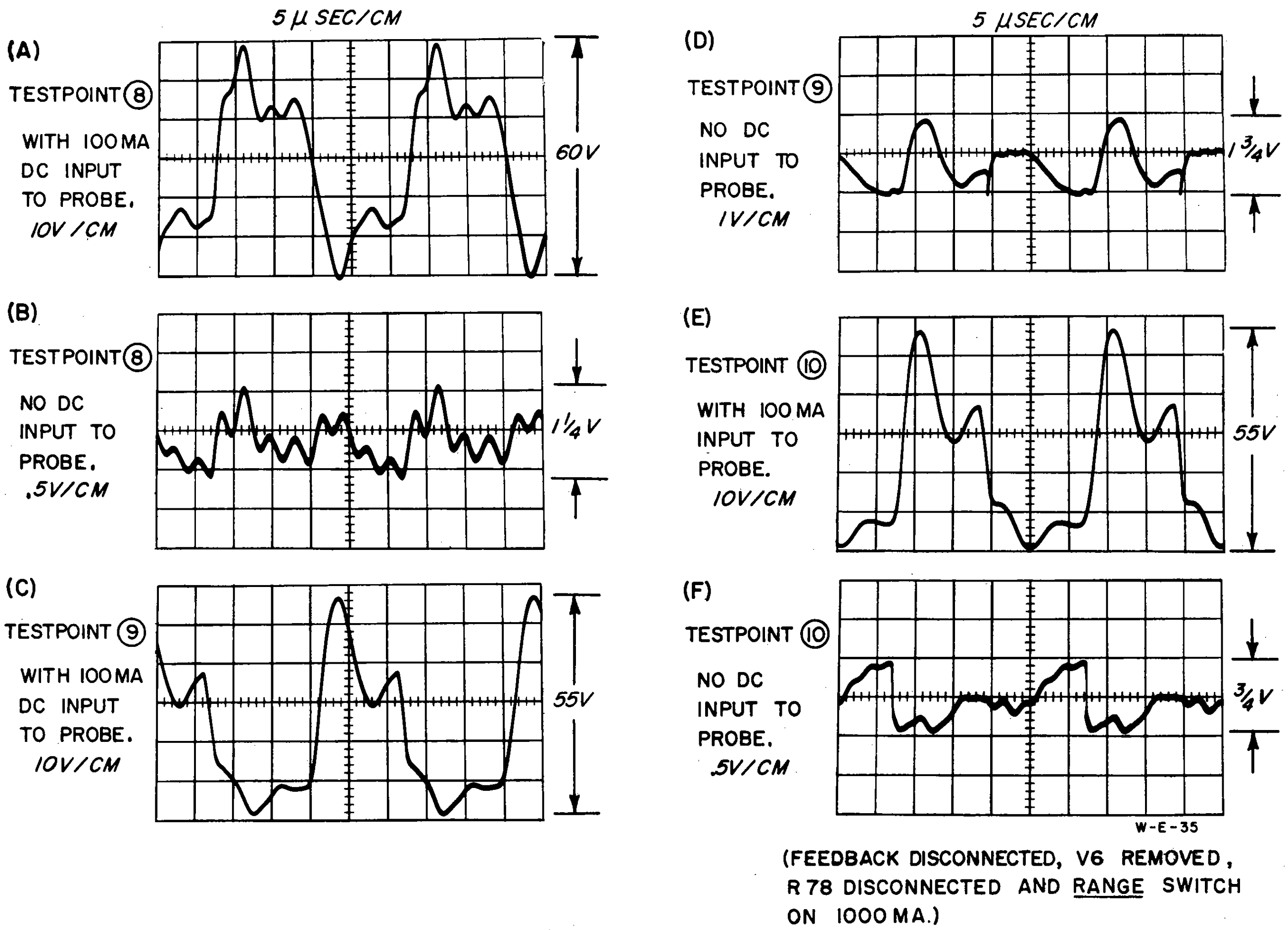


Figure 4-8. Trouble Localization Waveforms

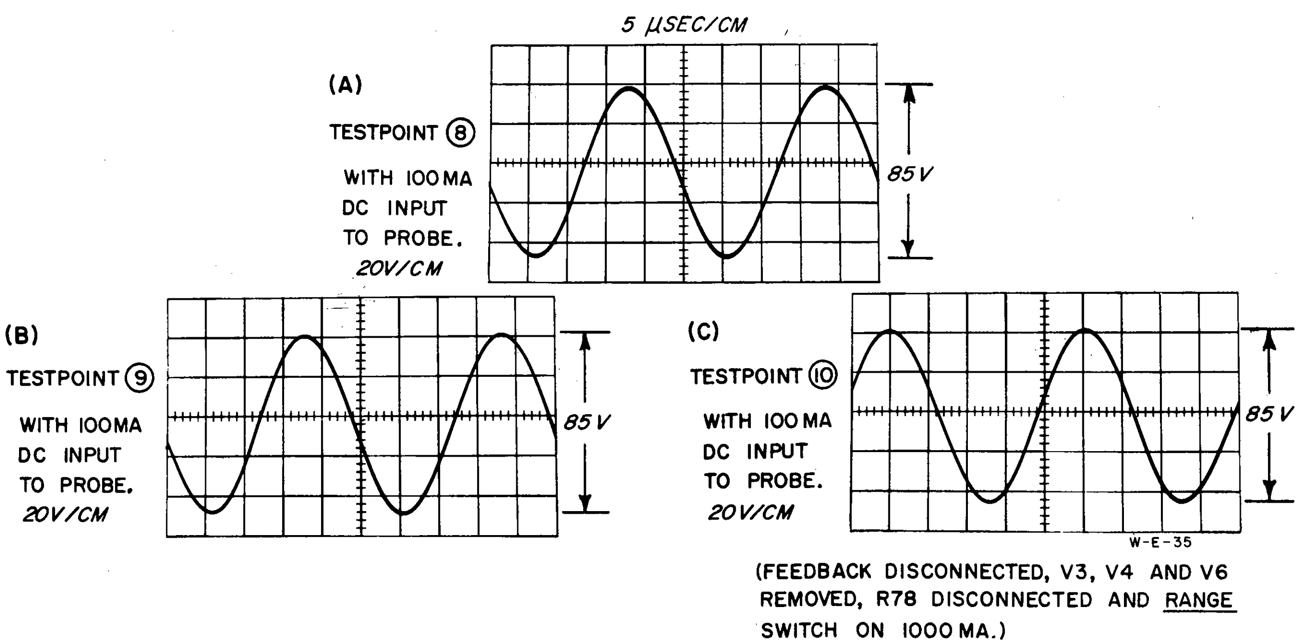


Figure 4-9. Trouble Localization Waveforms

7) To check the waveform developed by the input signal, without the interacting effect of the Synchronous Detector as described in step 2, remove V3 and V4. Tube V6 should also be removed if it was not already removed. Check the waveforms on the terminals of T2. With the probe clipped around a wire carrying 100 ma and the RANGE switch set to 1000 ma (1 ampere) these waveforms should be fairly close to sine waves (see figure 4-9). Check these waveforms at the points indicated in figure 4-9. If these waveforms are correct, replace V3, V4, V6, the wire to R78 removed in the previous step, and the feedback jumper removed in step 4. Recheck the instrument under normal operation as instructed in step 2. If the waveforms still do not agree with the waveforms on the schematic, check V3, V4 and Synchronous Detector circuitry.

4-9 ADJUSTMENT AFTER CURRENT PROBE REPLACEMENT

If the current probe has to be replaced, it is not necessary to perform the complete adjustment procedure. In table 4-2 perform only step 16 through 23.

4-10 COMPLETE ADJUSTMENT PROCEDURE

BEFORE CHANGING ANY ADJUSTMENT IN THE 428A, BE SURE THAT AN ADJUSTMENT IS NECESSARY AS INDICATED BY THE TROUBLE LOCALIZATION PROCEDURE (paragraph 4-8). ALWAYS CONSULT THE TROUBLE LOCALIZATION PROCEDURE FIRST TO DETERMINE THE SECTIONS OF THE ADJUSTMENT PROCEDURE TO PERFORM. DO NOT PERFORM THE COMPLETE ADJUSTMENT PROCEDURE EITHER AS A TROUBLE LOCALIZATION OR PREVENTIVE MAINTENANCE PROCEDURE.

The procedure given in table 4-2 is complete and enables you to do a systematic alignment of all circuits. Refer to paragraph 4-4, Test Equipment, listing auxiliary equipment needed for adjustment.

TABLE 4-2. ADJUSTMENT PROCEDURE

Step 1
PRELIMINARY ADJUSTMENT

The feedback loop must be disconnected for all tests up to step 18. Disconnect bare wire jumper on terminal board 428A-75A (board nearest front panel). Zero-set the mechanical zero on the meter (see paragraph 4-2). Clean probe jaws (see paragraph 4-3).

Note: In the following instructions directions are given for connecting only single leads of the voltmeters, etc. In each case it is understood that the ground lead will be connected to the 428A chassis, unless otherwise specified.

Step 2
POWER SUPPLY CHECK

Plug Model 428A into 115-volt line. Turn on and allow to warm up 15 minutes.

a. Connect a vtvm, such as the ℏp Model 410B Vacuum Tube Voltmeter, to any red lead on 428A-75C (rearmost) terminal board. This voltage should be 274.4 to 285.6 volts. If not, adjust R83 (Adj. +280V) for 280 volts.

b. Connect ac voltmeter, such as ℏp Model 400D/H/L Vacuum Tube Voltmeter to same red lead as in step a. Ripple should be less than 50 mv. Vary input voltage from 103 to 127 volts. Voltage measured should stay within ±2 volts of +280 volts and ripple should remain less than 50 mv. If not, try replacing V9, 10, 11. Remove both voltmeters.

Step 3
OSCILLATOR BALANCE

Refer to paragraph 4-4B, Test Equipment (Auxiliary), for the construction of the Oscillator Balance Probe necessary for this test. Connect oscillator balance test assembly to transformer T5 side of R66 and R67 (usually green and green-white wires). Connect an ac voltmeter, such as the ℏp Model 400D/H/L, to the center point of the test assembly. With 400D/H/L set to 0.1 volt range, adjust oscillator balance slug T5 for minimum reading (should be less than 50 millivolts). Lock slug and remove meter and probe.

Step 4
CHECK OSCILLATOR FREQUENCY

Connect electronic counter, such as ℏp Models 522/523/524 Electronic Counters to one side of T3 secondary--usually orange-white or green-white wires at top of 428A-75B (center) terminal board. Frequency should be 40 kc ±200 cycles. If not, pad C25 to set the frequency. Remove counter.

Step 5
CHECK OSCILLATOR LEVEL

Connect ac voltmeter, such as ℏp Model 400D/H/L, to transformer T5 side of either R66 or R67 (usually green and green-white wire) on terminal board 428A-75C (board furthest from front panel). Level should be 7.1 to 7.9 volts rms. If not, adjust Oscillator Level control R64 to adjust level to 7.5 volts rms. Remove meter.

TABLE 4-2. ADJUSTMENT PROCEDURE (Cont'd)

Step 6
CHECK DETECTOR GATE

Connect ac voltmeter, such as ⓗⓟ Model 400D/H/L, to pin 2 or 7 of V5. Adjust L7 for peak. Voltage should be 3.5 to 4.7 volts rms. If not, replace V5. Remove voltmeter.

Step 7
RECHECK OSCILLATOR LEVEL

If L7 was adjusted in step 6, repeat step 5.

Step 8
CHECK DC AMPLIFIER ZERO SET

Zero-set mechanical zero (see paragraph 4-2). Set 428A RANGE switch to 100 ma. Connect a 1μfd low leakage capacitor, such as mylar, between pin 1 of V2 and ground. Zero-set panel meter by turning R53 (DC Amp. Bal). Remove the capacitor.

Step 9
SET-UP FOR ALIGNMENT OF TUNED AMPLIFIER

Connect an ac voltmeter, such as the ⓗⓟ Model 400D/H/L, to pin 2 or 7 of V2. Set 400D/H/L to 1 volt range. Clip 428A probe around wire carrying 35 ma rms ac monitored by an external meter as shown in the ac generator portion of figure 4-5. Adjust R3 until 3.5 volts appears across the 100 ohm resistor. Set 428A RANGE switch to 100 ma. Keep this setup for the next three steps.

Step 10
INPUT ALIGNMENT

Adjust Input Tune C2 on 425A-75A (smallest) terminal board for a maximum reading on 400D (approximately 0.5 volt). Leave setup connected.

Step 11
INTERSTAGE PRIMARY ALIGNMENT

Connect a 0.0082 μfd capacitor from chassis ground to terminal on T1 which has 47 ohm resistor attached. Adjust bottom (primary) slug of T1 for maximum 400D/H/L reading (0.01 volt range) and lock slug. Remove capacitor but leave rest of setup.

Step 12
INTERSTAGE SECONDARY ALIGNMENT

Connect a 0.0082 μfd capacitor from pin 5 of V1 to ground. Adjust top (secondary) slug of T1 for maximum reading of 400D/H/L (.01 volt range) and lock slug. Remove capacitor and setup.

Step 13
DETECTOR PHASE ADJUSTMENT

Connect the horizontal input of an oscilloscope, such as the ⓗⓟ Model 120A/130B/150A/160B, to pin 2 or 7 of V5. Connect the vertical input to pin 2 or 7 of V2. Leave 428A probe around wire carrying 35 ma ac (3.5 vac) across 100 ohm monitored by an external meter (see figure 4-10). Turn 428A to 100 ma range. Turn slug L7 so pattern on oscilloscope looks like a "bow tie" with its knot symmetrical (see figure 4-11A or B). Note that in addition to the top and bottom intersections being in a vertical line, the center section must be free of traces. It is possible to get the top and bottom intersections in a vertical line with traces in the center section but this is not a correct adjustment. Lock L7. Figure 4-11C illustrates an incorrect adjustment with the top intersection not over the bottom intersection.

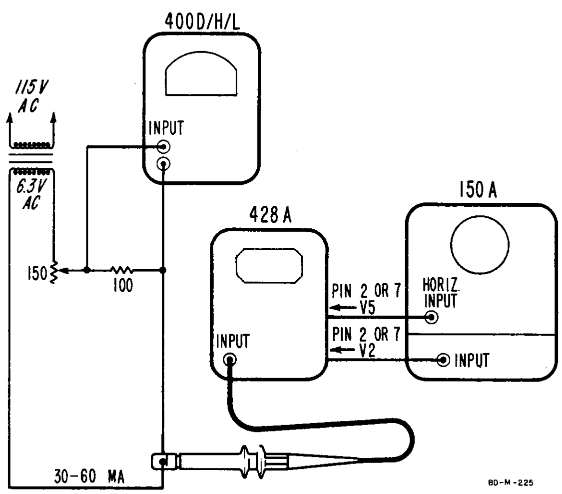


Figure 4-10. Detector Phase Adjustment Setup

Step 14
CHECK TUNED AMPLIFIER GAIN SETTING

Turn Calib. Adj. R48 fully clockwise for maximum resistance (this control is next to the meter and V3). Set RANGE switch to 100 ma. Zero-set 428A meter mechanically (see paragraph 4-2). Clip 428A probe around wire carrying 1 ma dc monitored by an external meter (similar to figure 4-4). The 428A meter should read from 90 to 110. If not, replace V1, 2 or 6. If replacing tubes will not obtain the correct reading pad R32 on resistor board 428A-75B. Remove setup.

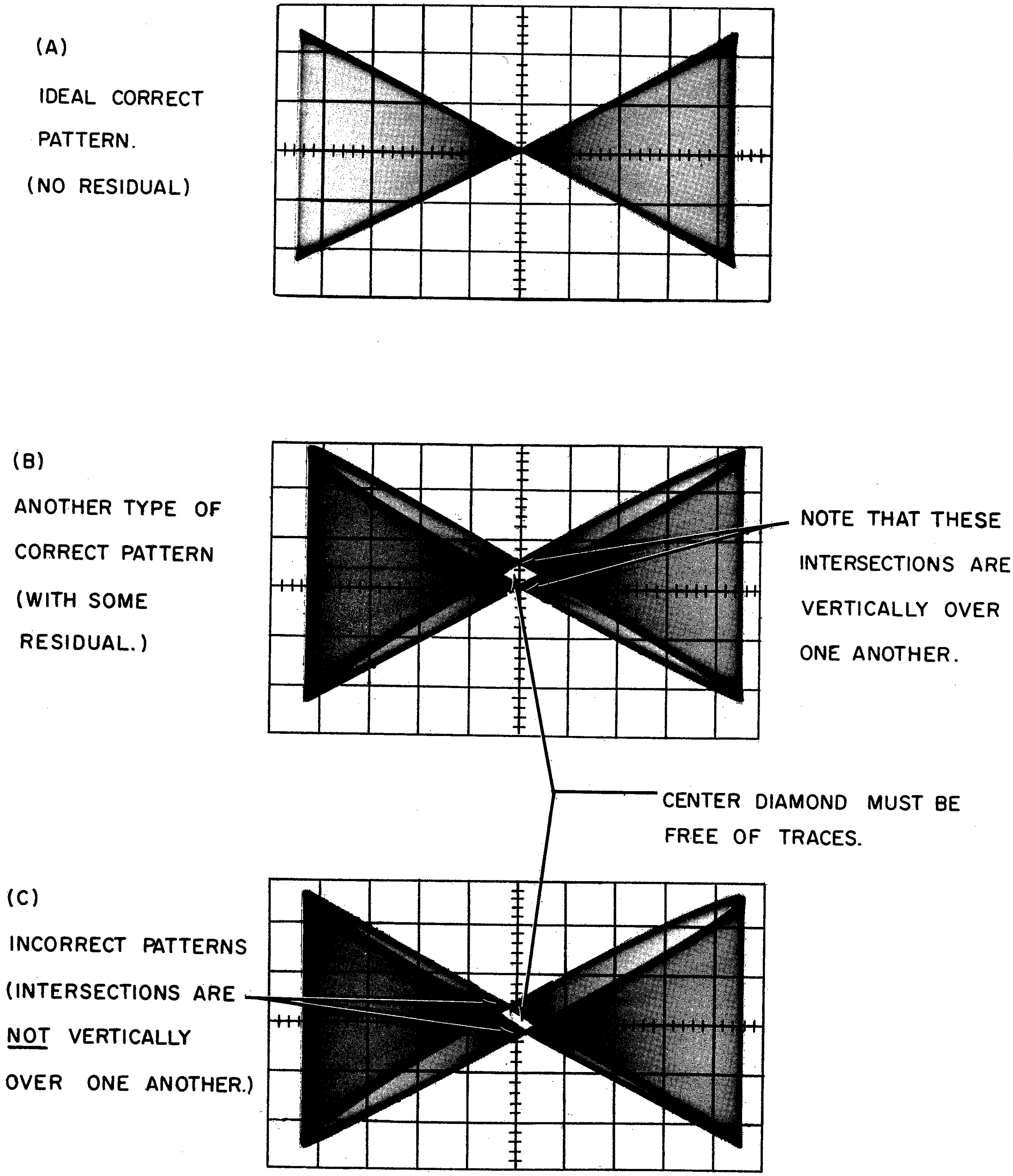


Figure 4-11. Detector Phase Adjustment Waveforms

TABLE 4-2. ADJUSTMENT PROCEDURE (Cont'd)

Step 15

CHECK NOISE

Turn 428A on with no input to probe, feedback still disconnected. Set RANGE switch to 10 ma. In any 5 sec period to peak-to-peak swing of the needle should be less than 5 ma. If noise is excessive, one of the coils in the head may be open. Remove probe connector from instrument and measure resistance between connector pins. The coils in the probe head are connected in the form of a bridge with each pin connected to a corner. The resistance between any adjacent pair of pins should be about 5 ohms. If not, one of the coils in the probe is probably open. If the reading is ∞ the cable is probably open.

Step 16

PRELIMINARY ADJUSTMENT OF ZERO POTS

Always perform this step before steps 17 and 18. Do NOT alter the position of these potentiometers until step 18. Turn the 90° Zero Adj. R40 and front panel ZERO potentiometer R41 to center position as follows:

Turn 428A RANGE switch to 300 ma. Connect an ac voltmeter, such as the ℏ Model 400D/H/L Vacuum Tube Voltmeter, to the center arm of the 90° Zero Adj. potentiometer R40. Adjust R40 for minimum reading on the 400D/H/L (0.1 volt range). Connect 400D/H/L to center arm of ZERO adjust potentiometer R41. Adjust R41 for minimum reading on the 400D/H/L. Minimum is approximately 0.02 volt.

Note: Do NOT alter this position of the potentiometers until step 18.

Step 17

CHECK DRIVE BALANCE ADJUSTMENT

Thoroughly clean probe head jaws (see paragraph 4-3). Degauss probe head completely (see paragraph 2-4). Set 428A RANGE switch to 3 ma. Connect an ac voltmeter, such as the ℏ Model 400D/H/L, to pins 2 or 7 of V2. With no input to 428A probe set Dr. Amp. Bal. potentiometer R70 for a minimum reading on the 400D/H/L. On the .1 volt range of the 400D/H/L the minimum should be less than .05 volt. If no minimum can be reached, replace V8. Leave 400D/H/L connected.

Step 18

RECONNECT FEEDBACK AND CHECK CANCELLATION OF HEAD RESIDUAL OUTPUT

Replace the lead removed in step 1. Leave 400 D/H/L connected to pins 2 or 7 of V2. Leave 428A on 3 ma range. Zero 428A meter with front panel ZERO adjustment knob (see figure 2-1 step 3). With 400D/H/L set to 0.3 volt range, adjust 90° Zero Adj. potentiometer R40 for a minimum 400D reading (approximately .02 volt). Adjusting R40 will throw off the setting of the ZERO adjust knob, so repeat this procedure until both controls are set properly. Remove the 400D/H/L.

Step 19

CHECK EARTH'S FIELD EFFECT

Point probe east and west, and rotate about its axis. Note peak-to-peak change in meter reading on the 3 ma range. This swing should not exceed about 0.15 ma. If it does, the probe head is not sufficiently shielded, probably because the jaws are not completely closed. Check jaws for alignment and for foreign material. If an open lead in the head is suspected check as in step 15.

Step 20

RANGE TO RANGE ZERO CHECK

Turn 428A RANGE switch to 3 ma. Zero-set meter with ZERO panel knob R41. Turn RANGE switch slowly through all ranges and check if zero falls right on for all ranges. If the needle doesn't fall on zero (±1/2%) for all ranges, recheck steps 16, 17 and 18. Recheck the mechanical zero setting.

Step 21

CHECK ZERO CONTROL RANGE

Switch 428A RANGE switch to 10 ma. Zero meter with ZERO control knob R41. Clip 428A probe around wire carrying 5 ma dc monitored by an external meter (see figure 4-4). Note reading on 428A. Turn ZERO control in both directions: 428A should have at least 2 ma zero adjustment range in each direction.

Step 22

CHECK CHANGE OF ZERO SETTING WITH LINE VOLTAGE

Connect the 428A to a variable source of line voltage, such as a variable autotransformer. Set the needle on a scale division with the ZERO adjust knob R41. Change the line voltage from 103 to 127 volts. The needle should change less than 0.5 ma. If not, try several V8's and repeat steps 16, 17, 18, 20, and 21.

TABLE 4-2. ADJUSTMENT PROCEDURE (Cont'd)

Step 23
RANGE CALIBRATION

Set 428A RANGE switch to 3 ma. Zero-set needle with ZERO panel knob R41. Set RANGE switch to the 100 ma range.

a. Feed 100 ma dc through probe (monitored with external dc ammeter, accurate to 1/4%). Adjust Meter Cal. R48 so meter reads 100 ma exactly.

b. Change line voltage from 103 to 127 volts. Calibration should stay within 0.2%.

c. Check calibration on all other current ranges, i.e. 300 ma, 100 ma, etc. Full scale reading should remain within 2% on all ranges.

Caution: Check zero-set on 3 ma range between each current range check.

Step 24
AC OVERLOAD

Zero-set 428A on 3 ma range. Set RANGE switch to 10 ma range. Feed 10 ma dc through probe. In addition supply ac through probe (see figure 4-5). Increase ac until dc indication on 428A drops 2%. This ac voltage should be at least 1 volt rms (14 ma peak, 10 ma rms). If not, replace V5.

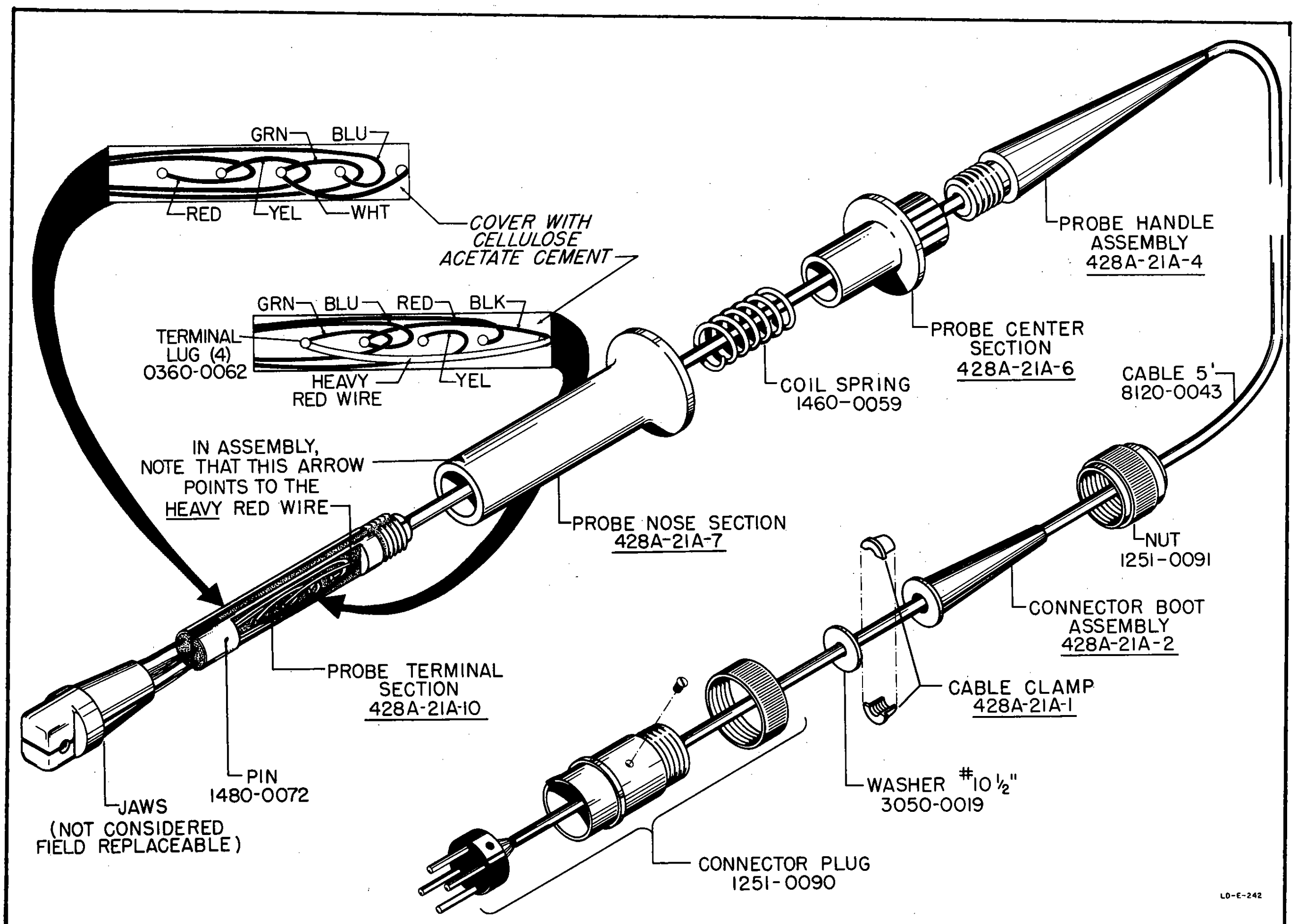


Figure 4-12. Exploded View of Probe

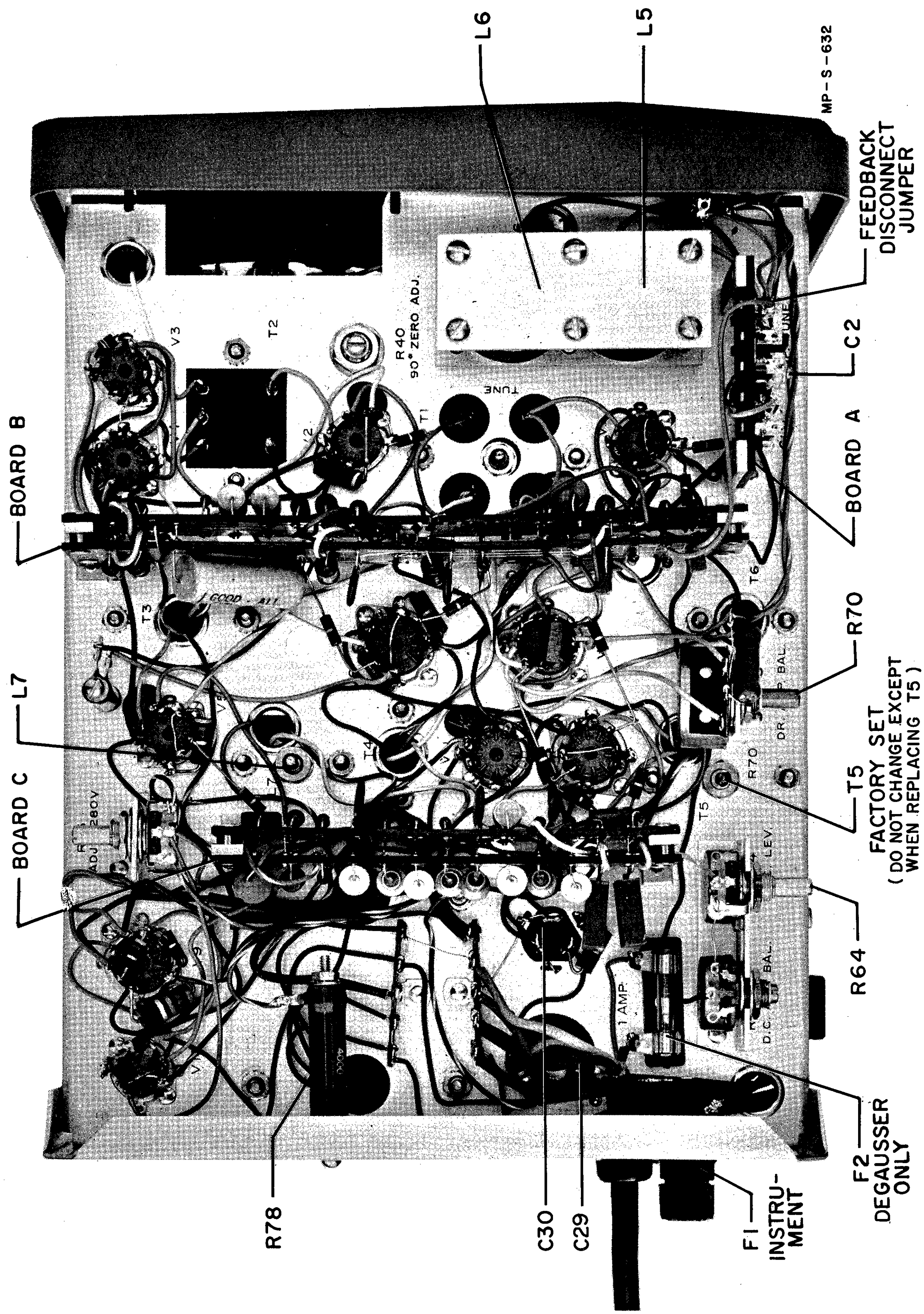


Figure 4-13. Left Side Internal View Model 428A

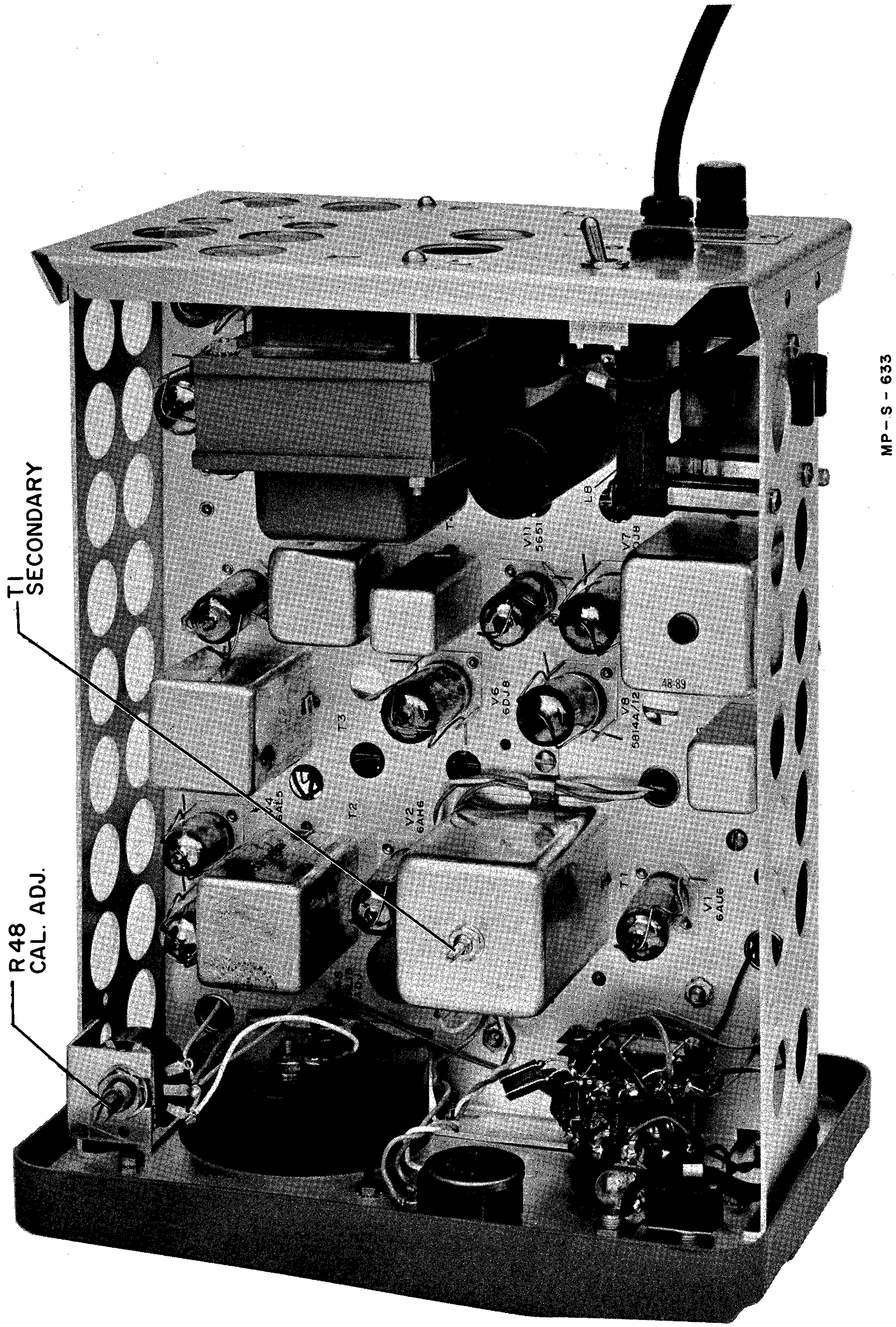


Figure 4-14. Right Side Internal View Model 428A

428A-OSC.& PS-T389ABCD

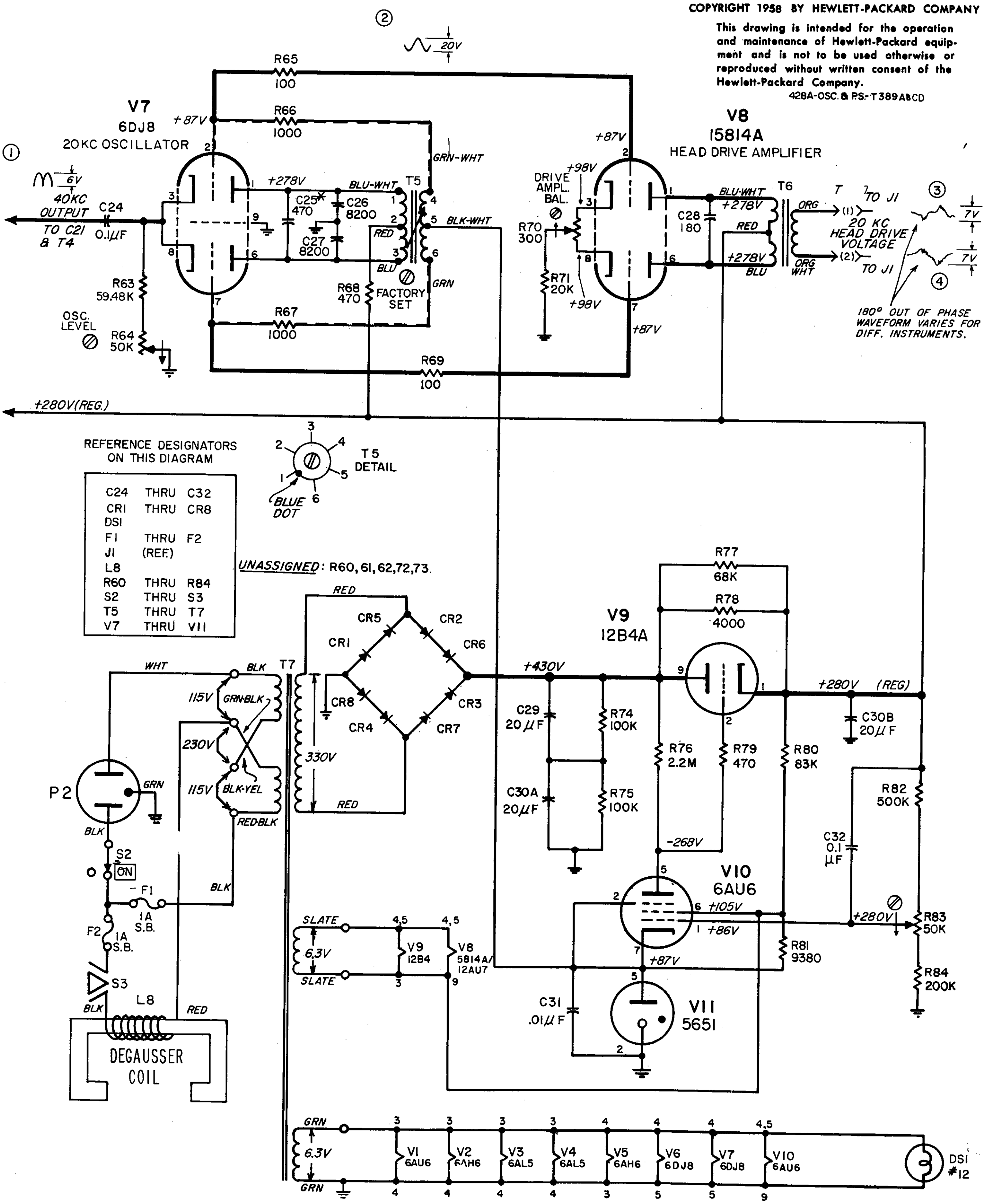


Figure 4-15. Oscillator and Power Supply

REFERENCE DESIGNATORS ON THIS DIAGRAM

C1 THRU C23
J1 — P1
L1 THRU L7
M1
R1 THRU R59
S1A,B,C
T1 THRU T4
V1 THRU V6

UNASSIGNED: C3, C4, R37, R38, R44

NOTES:

1. RANGE SWITCH SHOWN AS VIEWED FROM FRONT PANEL.
2. MEASUREMENT CONDITIONS: LINE VOLTAGE SET AT 115V,60∿. RANGE SWITCH SET ON 100 MA POSITION, 100 MA DC INPUT. VALUES SHOWN WERE MEASURED ON A TYPICAL INSTRUMENT WITH FEEDBACK DISCONNECT IN CLOSED (NORMAL) CONDITION.
3. DC VOLTAGES MEASURED WITH VTVM OF 122 MEGOHM INPUT IMPEDANCE.
4. WAVEFORMS MEASURED WITH -hp- MODEL 150A CATHODE-RAY OSCILLOSCOPE; -hp-MODEL 152B DUAL-TRACE PRE-AMPLIFIER; AND AC-21A, 10 TO 1 DIVIDER PROBES TO OBTAIN 10 MEGOHMS INPUT IMPEDANCE. TYPICAL WAVEFORM SHOWN.
5. USE EXTERNAL SYNC OBTAINED FROM PIN 2 OF V7 THROUGH A 47 μμF CAPACITOR TO AVOID DISTURBING CIRCUIT
6. ALL WAVEFORMS ARE SHOWN IN PHASE WITH EACH OTHER AND ARE SYNCHRONIZED WITH THE SIGNAL ON TESTPOINT ②

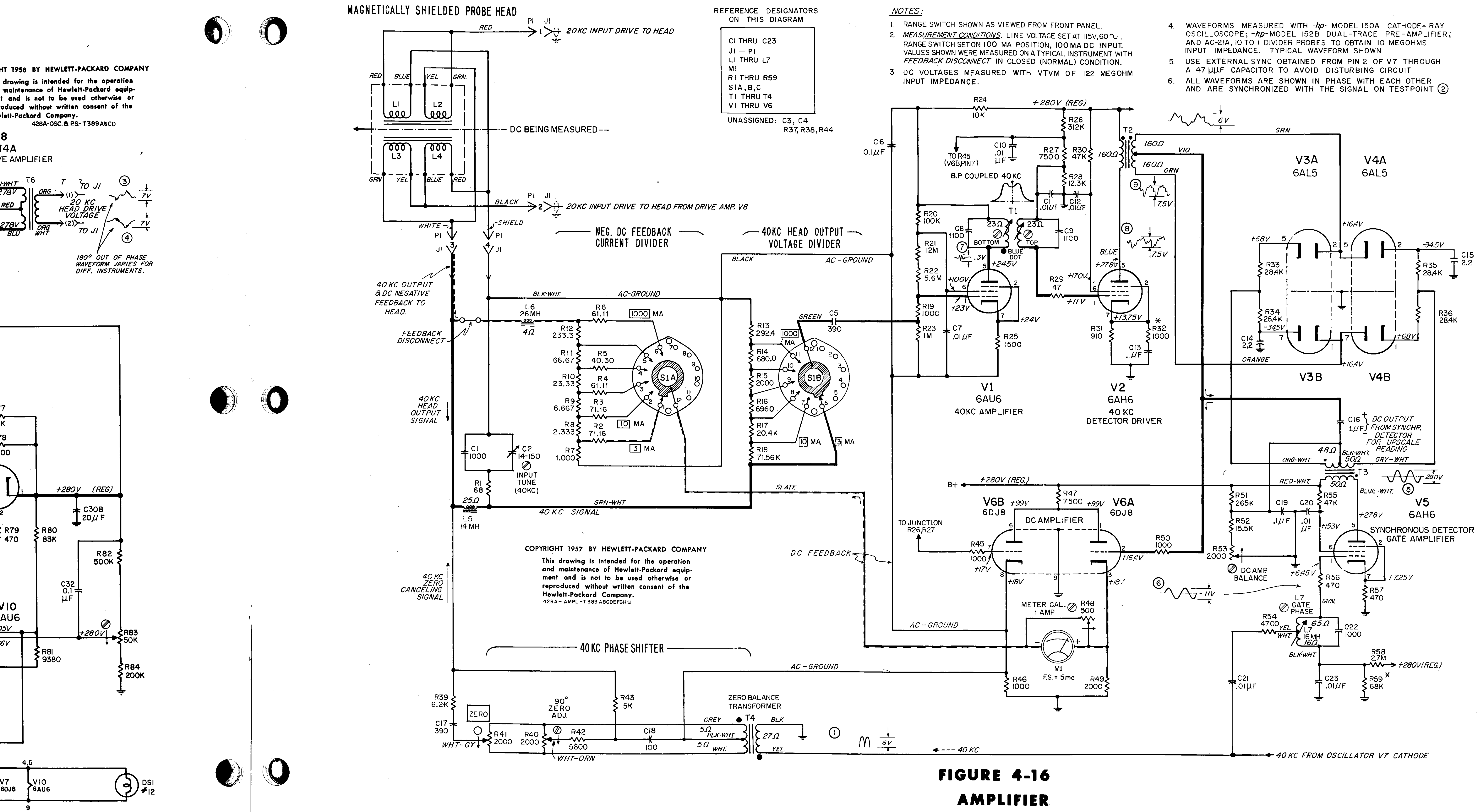


FIGURE 4-16

AMPLIFIER

SECTION V
REPLACEABLE PARTS

RECOMMENDED SPARE PARTS LIST

Standard components have been used in this instrument, whenever possible. Special components may be obtained from your local Hewlett-Packard representative or from the factory.

When ordering parts always include:

1. ⓗⓟ Stock Number.
2. Complete description of part including circuit reference.
3. Model number and serial number of instrument.
4. If part is not listed, give complete description, function and location of part.

Corrections to the Table of Replaceable Parts are listed on an Instruction Manual Change sheet at the front of this manual.

NOTE

Column RS in the Table lists the recommended spare parts quantities to maintain one instrument for one year of isolated service. Order complete spare parts kits from the Factory Parts Sales Department. ALWAYS MENTION THE MODEL AND SERIAL NUMBERS OF INSTRUMENTS INVOLVED.

TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION, MFR. * & MFR. DESIGNATION	ⓗ STOCK NO.	TQ	RS		
C1	Capacitor: fixed mica, .001 μf ±1%, 500 vdcw Z*	15-133	2	1		
C2	Capacitor: variable, mica, 14-150pf, 175 vdcw Electromotive Manufacturing Co., Inc.	13-33	1	1		
C3, 4	These circuit references not assigned					
C5	Capacitor: fixed, mica, 390pf ±5%, 500 vdcw V*	14-72	2	1		
C6	Capacitor: fixed, mylar, .1 μf ±20%, 600 vdcw Texas Cap.	16-110	2	1		
C7	Capacitor: fixed, ceramic, .01 μf ±20%, 1000 vdcw CC*	15-43	8	2		
C8, 9	Part of T1 Components not separately replaceable					
C10 thru C12	Same as C7					
C13	Capacitor: fixed, mylar, .1 μf ±5%, 200 vdcw CW*	16-103	3	1		
C14, 15	Capacitor: fixed, titanium dioxide, 2.2pf ±10%, 500 vdcw DD*	15-52	2	1		
C16	Capacitor: fixed, mylar, 1 μf ±5%, 200 vdcw CW*	16-102	1	1		
C17	Same as C5					
C18	Capacitor: fixed, mica, 100pf ±5%, 500 vdcw V*	14-76	1	1		
C19	Same as C13					
C20, 21	Same as C7					
C22	Same as C1					
C23	Same as C7					
C24	Same as C13					

* See "List of Manufacturers Code Letters For Replaceable Parts Table".
TQ - Total quantity used in the instrument.
RS - Recommended spares for one year isolated service for one instrument.

TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION, MFR. * & MFR. DESIGNATION		ⓗ STOCK NO.	TQ	RS		
C25	Capacitor: fixed, mica, 470pf ±5%, 500 vdcw Optimum value selected at factory. Average value shown.	J*	15-141	1	1		
C26, 27	Capacitor: fixed, mica, 8200pf ±2%, 500 vdcw	J*	15-169	2	1		
C28	Capacitor: fixed, mica, 180pf ±5%, 500 vdcw	J*	15-140	1	1		
C29	Capacitor: fixed, electrolytic, 20 μf, 450 vdcw	CC*	18-20HP	1	1		
C30	Capacitor: fixed, electrolytic, 2 sections/20 μf, 450 vdcw	CC*	18-22HP	1	1		
C31	Same as C7						
C32	Same as C6						
CR1 thru CR8	Diode, silicon: 500 ma, 400 PIV	R*	212-147	8	8		
DS1	Lamp, incandescent: 2 pin base, 6.3V, type 12	N*	211-78	1	1		
F1, 2	Fuse, cartridge: slow-blow, 1 amp, 250V	E*	211-18	2	20		
J1	Connector, female: 4 pin	HH*	125-130	1	1		
L1 thru L4	Part of Current Probe Assembly (See Miscellaneous) Components not separately replaceable						
L5, 6	Choke Assembly	HP*	428A-60H	1	1		
L7	Inductor: 16 mh	Electro	48-88	1	1		

* See "List of Manufacturers Code Letters For Replaceable Parts Table".
TQ - Total quantity used in the instrument.
RS - Recommended spares for one year isolated service for one instrument.

TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION, MFR. * & MFR. DESIGNATION		ⓗⓟ STOCK NO.	TQ	RS		
L8	Degauser Coil	HP*	911-68	1	1		
M1	Meter	BF*	112-97	1	1		
P1	Connector, male: 4 pin	HH*	125-131	1	1		
R1	Resistor: fixed, composition, 68 ohms ±10%, 1/2 W	B*	23-68	1	1		
R2, 3	Resistor: fixed, deposited carbon, 71.16 ohms ±1%, 1/2 W	NN*	33-71.16	2	1		
R4	Resistor: fixed, deposited carbon, 61.11 ohms ±1%, 1/2 W	NN*	33-61.11	2	1		
R5	Resistor: fixed, deposited carbon, 40.3 ohms ±1%, 1/2 W	NN*	33-40.3	1	1		
R6	Same as R4						
R7 thru R12	Part of Range Switch Assembly Components not separately replaceable						
R13	Resistor: fixed, deposited carbon, 292.4 ohms ±1/2%, 1/2 W	NN*	33-292.4	1	1		
R14	Resistor: fixed, deposited carbon, 680 ohms ±1%, 1/2 W	NN*	33-680	1	1		
R15	Resistor: fixed, deposited carbon, 2,000 ohms ±1%, 1/2 W	NN*	33-2K	2	1		
R16	Resistor: fixed, deposited carbon, 6,960 ohms ±1%, 1/2 W	NN*	33-6.96K	1	1		
R17	Resistor: fixed, deposited carbon, 20,400 ohms ±1%, 1/2 W	NN*	33-20.4K	1	1		
R18	Resistor: fixed, deposited carbon, 71,560 ohms ±1%, 1/2 W	NN*	33-71.56K	1	1		
R19	Resistor: fixed, composition, 1,000 ohms ±10%, 1/2 W	B*	23-1K	6	2		

*** See "List of Manufacturers Code Letters For Replaceable Parts Table".**
TQ - Total quantity used in the instrument.
RS - Recommended spares for one year isolated service for one instrument.

TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION, MFR. * & MFR. DESIGNATION	MFR.	ⓗⓟ STOCK NO.	TQ	RS		
R20	Resistor: fixed, composition, 100,000 ohms ±10%, 1/2 W	B*	23-100K	1	1		
R21	Resistor: fixed, composition, 12 megohms ±10%, 1/2 W	B*	23-12M	1	1		
R22	Resistor: fixed, composition, 5.6 megohms ±10%, 1/2 W	B*	23-5.6M	1	1		
R23	Resistor: fixed, composition, 1 megohm ±10%, 1/2 W	B*	23-1M	1	1		
R24	Resistor: fixed, composition, 10,000 ohms ±10%, 1/2 W	B*	23-10K	1	1		
R25	Resistor: fixed, composition, 1,500 ohms ±5%, 1 W	B*	24-1.5K-5	1	1		
R26	Resistor: fixed, deposited carbon, 312,000 ohms ±1%, 1/2 W	NN*	33-312K	1	1		
R27	Resistor: fixed, deposited carbon, 7,500 ohms ±1%, 1 W	NN*	31-7.5K	1	1		
R28	Resistor: fixed, deposited carbon, 12,300 ohms ±1%, 1 W	NN*	31-12.3K	1	1		
R29	Resistor: fixed, composition, 47 ohms ±10%, 1/2 W	B*	23-47	1	1		
R30	Resistor: fixed, composition, 47,000 ohms ±10%, 1W	B*	24-47K	2	1		
R31	Resistor: fixed, composition, 910 ohms ±5%, 1 W	B*	24-910-5	1	1		
R32	Same as R19 Optimum value selected at factory. Average value shown.						
R33 thru R36	Resistor: fixed, deposited carbon, 28,400 ohms ±1%, 1/2 W	NN*	33-28.4K	4	1		
R37, 38	These circuit references not assigned						
R39	Resistor: fixed, composition, 6,200 ohms ±5%, 1/2 W	B*	23-6.2K-5	1	1		
R40	Resistor: variable, composition, linear, 2,000 ohms ±20%, 1/3 W	BO*	210-205	2	1		

* See "List of Manufacturers Code Letters For Replaceable Parts Table".
TQ - Total quantity used in the instrument.
RS - Recommended spares for one year isolated service for one instrument.

TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION, MFR. * & MFR. DESIGNATION	ⓗⓟ STOCK NO.	TQ	RS		
R41	Resistor: variable, wirewound, linear, 2,000 ohms ±10%, 2 W BO*	210-6	1	1		
R42	Resistor: fixed, composition, 5,600 ohms ±10%, 1/2 W B*	23-5.6K	1	1		
R43	Resistor: fixed, composition, 15,000 ohms ±10%, 1/2 W B*	23-15K	1	1		
R44	This circuit reference not assigned					
R45	Same as R19					
R46	Resistor: fixed, composition, 1,000 ohms ±10%, 1 W B*	24-1K	1	1		
R47	Resistor: fixed, wirewound, 7,500 ohms ±10%, 10 W S*	26.9	1	1		
R48	Resistor: variable, wirewound, 500 ohms ±10%, 2 W G*	210-73	1	1		
R49	Same as R15					
R50	Same as R19					
R51	Resistor: fixed, deposited carbon, 265,000 ohms ±1%, 1 W NN*	31-265K	1	1		
R52	Resistor: fixed, deposited carbon, 15,500 ohms ±1%, 1/2 W NN*	33-15.5K	1	1		
R53	Same as R40					
R54	Resistor: fixed, composition, 4,700 ohms ±10%, 1/2 W B*	23-4.7K	1	1		
R55	Same as R30					
R56	Resistor: fixed, composition, 470 ohms ±10%, 1/2 W B*	23-470	3	1		
R57	Resistor: fixed, composition, 470 ohms ±10%, 1 W B*	24-470	1	1		
R58	Resistor: fixed, composition, 2.7 megohms ±10%, 1/2 W B*	23-2.7M	1	1		

*** See "List of Manufacturers Code Letters For Replaceable Parts Table".**
TQ - Total quantity used in the instrument.
RS - Recommended spares for one year isolated service for one instrument.

TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION, MFR. * & MFR. DESIGNATION	ⓗ STOCK NO.	TQ	RS		
R59	Resistor: fixed, composition, 68,000 ohms ±10%, 1/2 W B*	23-68K	1	1		
R60 thru R62	These circuit references not assigned					
R63	Resistor: fixed, deposited carbon, 59,480 ohms ±1%, 1/2 W NN*	33-59.48K	1	1		
R64	Resistor: variable, composition, linear 50,000 ohms ±20%, 1/2 W G*	210-18	2	1		
R65	Resistor: fixed, composition, 100 ohms ±10%, 1/2 W B*	23-100	2	1		
R66, 67	Same as R19					
R68	Same as R56					
R69	Same as R65					
R70	Resistor: variable, wirewound, 300 ohms ±20%, 2 W BO*	210-53	1	1		
R71	Resistor: fixed, metal film, 20,000 ohms ±5%, 3 W AB*	333-20K-5	1	1		
R72, 73	These circuit references not assigned					
R74, 75	Resistor: fixed, composition, 100,000 ohms ±10%, 1 W B*	24-100K	2	1		
R76	Resistor: fixed, composition, 2.2 megohms ±10%, 1/2 W B*	23-2.2M	1	1		
R77	Resistor: fixed, composition, 68,000 ohms ±10%, 2 W B*	25-68K	1	1		
R78	Resistor: fixed, wirewound, 4,000 ohms ±5%, 20 W S*	27-7	1	1		
R79	Same as R56					
R80	Resistor: fixed, deposited carbon, 83,000 ohms ±1%, 1 W NN*	31-83K	1	1		

*** See "List of Manufacturers Code Letters For Replaceable Parts Table".**
TQ - Total quantity used in the instrument.
RS - Recommended spares for one year isolated service for one instrument.

TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION, MFR. * & MFR. DESIGNATION		ⓗⓟ STOCK NO.	TQ	RS		
R81	Resistor: fixed, deposited carbon, 9, 380 ohms ±1%, 1/2 W	NN*	33-9. 38K	1	1		
R82	Resistor: fixed, deposited carbon, 500, 000 ohms ±1%, 1/2 W	NN*	33-500K	1	1		
R83	Same as R64						
R84	Resistor: fixed, deposited carbon, 200, 000 ohms ±1%, 1/2 W	NN*	33-200K	1	1		
S1	Range Switch Assembly	HP*	428A-19W	1	1		
S2	Switch, toggle: SPST, 3 amp, 250V	Fisher Switches, Inc.	310-11	1	1		
S3	Switch, toggle: SPST, 10 amp, 250V	Fisher Switches, Inc.	310-247	1	1		
T1	B. P. Coupled Transformer: 13 mh	Electro	48-90	1	1		
T2	Detector Signal Transformer	HP*	428A-60G	1	1		
T3	Gate Transformer	HP*	428A-60C	1	1		
T4	Zero Balance Transformer	HP*	428A-60A	1	1		
T5	Oscillator Transformer: 14. 4 mh	Electro	48-89	1	1		
T6	Head-drive Transformer	HP*	428A-60D	1	1		
T7	Transformer: power	HP*	910-176	1	1		
V1	Tube, electron: 7 pin, 6AU6	ZZ*	212-6AU6	2	2		
V2	Tube, electron: 6AH6	ZZ*	212-6AH6	2	2		
V3, 4	Tube, electron: 6AL5	ZZ*	212-6AL5	2	2		
V5	Same as V2						
V6, 7	Tube, electron: 6DJ8	ZZ*	212-6DJ8	2	2		

*** See "List of Manufacturers Code Letters For Replaceable Parts Table".**
TQ - Total quantity used in the instrument.
RS - Recommended spares for one year isolated service for one instrument.

TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION, MFR. * & MFR. DESIGNATION		ⓗⓟ STOCK NO.	TQ	RS		
V8	Tube, electron: 12AU7	ZZ*	212-12AU7	1	1		
V9	Tube, electron: 9 pin, 12B4A	ZZ*	212-12B4A	1	1		
V10	Same as V1						
V11	Tube, electron: 7 pin, 5651	ZZ*	212-5651	1	1		
	MISCELLANEOUS						
	Brush	HP*	852-24	1	0		
	Knob: Zero Control	HP*	G-74C	1	0		
	Knob: Range Switch	HP*	G-74N	1	0		
	Current Probe Assembly	HP*	428A-21A	1	0		

*** See "List of Manufacturers Code Letters For Replaceable Parts Table".**
TQ - Total quantity used in the instrument.
RS - Recommended spares for one year isolated service for one instrument.

MODEL 428A

CLIP-ON MILLIAMMETER

If the serial number of your instrument falls within the following groups, make the changes listed <u>and all those following</u> in your instruction manual.

SERIAL OR TYPE NO.	REFERENCE DESIGNATOR	MAKE THE FOLLOWING CHANGES
351 and below	C4	Add capacitor, fixed, mica, 15pf ±10%, 500 vdcw; -hp- Stock No. 0140-0004, Mfr., V Connected between pin 7 of S1A and the bottom of R18.
550 and below and some units 745 and below	V8	Wire filaments as shown on schematic. Note the connection to pin 6 of V10. For instructions write for Service Note 428A-2.
(389-)00626 and below	C25	Delete
	R63	Change to resistor, fixed, deposited carbon, 67,500 ohms ±1%, ½ W; -hp- Stock No. 0727-0199, Mfr., NN
(389-)00951 and below	C17	Change to capacitor, fixed, mica, 220pf ±10%, 500 vdcw; -hp- Stock No. 0140-0031, Mfr., V
	C18	Change to capacitor, fixed, mica, 820pf ±5%, 500 vdcw; -hp- Stock No. 0140-0091, Mfr., Z
	C21	Change to capacitor, fixed, ceramic, .Cluf ±20%, 1000 vdcw; -hp- Stock No. 0150-0012, Mfr., CC
	C28	Delete

MANUAL CHANGES

MODEL 428A

CLIP-ON MILLIAMMETER

Manual printed: 9-60
For Serials Prefixed: 022-

ERRATA:

Make the following changes in your instruction manual:

Section II, page 2, paragraph 2-5, C 3), Stray AC Fields: the second sentence should read "Such fields may exist in the vicinity of open core power transformers, or large dc filter chokes," etc.

Section II, page 3, paragraph 2-7, OPERATION WITH GRAPHIC RECORDER: change Figure 2-4 to read Figure 2-5.

Section III, page 3, paragraph 3-6, 40 KC SYNCHRONOUS DETECTOR AMPLIFIER: the first sentence should read "The 40 kc resonant circuit C22 and L7 ..."

Section III, page 3, paragraph 3-7, 40 KC INPUT/AMPLIFIER CIRCUIT: the third sentence should read "The 40 kc signal passes through a voltage divider S1B ..."

Section III, page 5, Figure 3-8, Feedback Current Circuit: interchange V6A and V6B.

Section IV, page 7, step 6): sentences 4 and 5 should read "To increase the current drawn through V9, remove the current shunt R78 across V9. This resistor is the 20 watt, 4000 ohm resistor mounted on the rear chassis."

Section IV, page 12, Step 17, next to the last sentence should read "On the 1 volt range of the 400D/H/L the minimum should be less than 0.5 volt."

Section IV, page 16, Figure 4-15, Oscillator and Power Supply and parts list: V8 should read "5814A/12AU7." The 5814A is preferred.

Figure 4-16, Amplifier: At T2 test point, 10 should appear at the 6 volt waveform on the green wire.

9/23/60

LIST OF CODE LETTERS USED IN TABLE OF REPLACEABLE PARTS TO DESIGNATE THE MANUFACTURERS

CODE LETTER	MANUFACTURER	ADDRESS
A	Aerovox Corp.	New Bedford, Mass.
B	Allen-Bradley Co.	Milwaukee 4, Wis.
C	Amperite Co.	New York, N. Y.
D	Arrow, Hart & Hegeman	Hartford, Conn.
E	Bussman Manufacturing Co.	St. Louis, Mo.
F	Carborundum Co.	Niagara Falls, N. Y.
G	Centralab	Milwaukee 1, Wis.
H	Cinch-Jones Mfg. Co.	Chicago 24, Ill.
HP	Hewlett-Packard Co.	Palo Alto, Calif.
I	Clarostat Mfg. Co.	Dover, N. H.
J	Cornell Dubilier Elec. Co.	South Plainfield, N. J.
K	Hi-Q Division of Aerovox	Olean, N. Y.
L	Erie Resistor Corp.	Erie 6, Pa.
M	Fed. Telephone & Radio Corp.	Clifton, N. J.
N	General Electric Co.	Schenectady 5, N. Y.
O	General Electric Supply Corp.	San Francisco, Calif.
P	Girard-Hopkins	Oakland, Calif.
Q	Industrial Products Co.	Danbury, Conn.
R	International Resistance Co.	Philadelphia 8, Pa.
S	Lectrohm Inc.	Chicago 20, Ill.
T	Littlefuse Inc.	Des Plaines, Ill.
U	Maguire Industries Inc.	Greenwich, Conn.
V	Micamold Radio Corp.	Brooklyn 37, N. Y.
W	Oak Manufacturing Co.	Chicago 10, Ill.
X	P. R. Mallory Co., Inc.	Indianapolis, Ind.
Y	Radio Corp. of America	Harrison, N. J.
Z	Sangamo Electric Co.	Marion, Ill.
AA	Sarkes Tarzian	Bloomington, Ind.
BB	Signal Indicator Co.	Brooklyn 37, N. Y.
CC	Sprague Electric Co.	North Adams, Mass.
DD	Stackpole Carbon Co.	St. Marys, Pa.
EE	Sylvania Electric Products Co.	Warren, Pa.
FF	Western Electric Co.	New York 5, N. Y.
GG	Wilkor Products, Inc.	Cleveland, Ohio
HH	Amphenol	Chicago 50, Ill.
II	Dial Light Co. of America	Brooklyn 37, N. Y.
JJ	Leecraft Manufacturing Co.	New York, N. Y.
KK	Switchcraft, Inc.	Chicago 22, Ill.
LL	Gremar Manufacturing Co.	Wakefield, Mass.
MM	Carad Corp.	Redwood City, Calif.
NN	Electra Manufacturing Co.	Kansas City, Mo.
OO	Acro Manufacturing Co.	Columbus 16, Ohio
PP	Alliance Manufacturing Co.	Alliance, Ohio
QQ	Arco Electronics, Inc.	New York 13, N. Y.
RR	Astron Corp.	East Newark, N. J.
SS	Axel Brothers Inc.	Long Island City, N. Y.
TT	Belden Manufacturing Co.	Chicago 44, Ill.
UU	Bird Electronics Corp.	Cleveland 14, Ohio
VV	Barber Colman Co.	Rockford, Ill.
WW	Bud Radio Inc.	Cleveland 3, Ohio
XX	Allen D. Cardwell Mfg. Co.	Plainville, Conn.
YY	Cinema Engineering Co.	Burbank, Calif.
ZZ	Any brand tube meeting RETMA standards.	
AB	Corning Glass Works	Corning, N. Y.
AC	Dale Products, Inc.	Columbus, Neb.
AD	The Drake Mfg. Co.	Chicago 22, Ill.
AE	Elco Corp.	Philadelphia 24, Pa.
AF	Hugh H. Eby Co.	Philadelphia 44, Pa.
AG	Thomas A. Edison, Inc.	West Orange, N. J.
AH	Fansteel Metallurgical Corp.	North Chicago, Ill.
AI	General Ceramics & Steatite Corp.	Keasbey, N. J.
AJ	The Gudeman Co.	Sunnyvale, Calif.
AK	Hammerlund Mfg. Co., Inc.	New York 1, N. Y.
AL	Industrial Condenser Corp.	Chicago 18, Ill.
AM	Insuline Corp. of America	Manchester, N. H.
AN	Jennings Radio Mfg. Corp.	San Jose, Calif.
AO	E. F. Johnson Co.	Waseca, Minn.
AP	Lenz Electric Mfg. Co.	Chicago 47, Ill.
AQ	Micro-Switch	Freeport, Ill.
AR	Mechanical Industries Prod. Co.	Akron 8, Ohio
AS	Model Eng. & Mfg., Inc.	Huntington, Ind.
AT	The Muter Co.	Chicago 5, Ill.
AU	Ohmite Mfg. Co.	Skokie, Ill.
AV	Resistance Products Co.	Harrisburg, Pa.
AW	Radio Condenser Co.	Camden 3, N. J.
AX	Shallcross Manufacturing Co.	Collingdale, Pa.
AY	Solar Manufacturing Co.	Los Angeles 58, Calif.
AZ	Sealectro Corp.	New Rochelle, N. Y.
BA	Spencer Thermostat	Attleboro, Mass.
BC	Stevens Manufacturing Co.	Mansfield, Ohio
BD	Torrington Manufacturing Co.	Van Nuys, Calif.
BE	Vector Electronic Co.	Los Angeles 65, Calif.
BF	Weston Electrical Inst. Corp.	Newark 5, N. J.
BG	Advance Electric & Relay Co.	Burbank, Calif.
BH	E. I. DuPont	San Francisco, Calif.
BI	Electronics Tube Corp.	Philadelphia 18, Pa.
BJ	Aircraft Radio Corp.	Boonton, N. J.
BK	Allied Control Co., Inc.	New York 21, N. Y.
BL	Augat Brothers, Inc.	Attleboro, Mass.
BM	Carter Radio Division	Chicago, Ill.
BN	CBS Hytron Radio & Electric	Danvers, Mass.
BO	Chicago Telephone Supply	Elkhart, Ind.
BP	Henry L. Crowley Co., Inc.	West Orange, N. J.
BQ	Curtiss-Wright Corp.	Carlstadt, N. J.
BR	Allen B. DuMont Labs	Clifton, N. J.
BS	Excel Transformer Co.	Oakland, Calif.
BT	General Radio Co.	Cambridge 39, Mass.
BU	Hughes Aircraft Co.	Culver City, Calif.
BV	International Rectifier Corp.	El Segundo, Calif.
BW	James Knights Co.	Sandwich, Ill.
BX	Mueller Electric Co.	Cleveland, Ohio
BY	Precision Thermometer & Inst. Co.	Philadelphia 30, Pa.
BZ	Radio Essentials Inc.	Mt. Vernon, N. Y.
CA	Raytheon Manufacturing Co.	Newton, Mass.
CB	Tung-Sol Lamp Works, Inc.	Newark 4, N. J.
CD	Varian Associates	Palo Alto, Calif.
CE	Victory Engineering Corp.	Union, N. J.
CF	Weckesser Co.	Chicago 30, Ill.
CG	Wilco Corporation	Indianapolis, Ind.
CH	Winchester Electronics, Inc.	Santa Monica, Calif.
CI	Malco Tool & Die	Los Angeles 42, Calif.
CJ	Oxford Electric Corp.	Chicago 15, Ill.
CK	Camloc-Fastener Corp.	Paramus, N. J.
CL	George K. Garrett	Philadelphia 34, Pa.
CM	Union Switch & Signal	Swissvale, Pa.
CN	Radio Receptor	New York 11, N. Y.
CO	Automatic & Precision Mfg. Co.	Yonkers, N. Y.
CP	Bassick Co.	Bridgeport 2, Conn.
CQ	Birnbach Radio Co.	New York 13, N. Y.
CR	Fischer Specialties	Cincinnati 6, Ohio
CS	Telefunken (c/o MVM, Inc.)	New York, N. Y.
CT	Potter-Brumfield Co.	Princeton, Ind.
CU	Cannon Electric Co.	Los Angeles, Calif.
CV	Dynac, Inc.	Palo Alto, Calif.
CW	Good-All Electric Mfg. Co.	Ogallala, Nebr.

CLAIM FOR DAMAGE IN SHIPMENT

The 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.

WARRANTY

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. Klystron tubes as well as other electron tubes, fuses and batteries are specifically excluded from any liability. This warranty is effective for one year after delivery to the original purchaser when the instrument is returned, transportation charges prepaid by the original purchaser, and when upon our examination it is disclosed to our satisfaction to be defective. If the fault has been caused by misuse or abnormal conditions of operation, repairs will be billed at cost. In this case, an estimate will be submitted before the work is started.

If any fault develops, the following steps should be taken:

1. Notify us, giving full details of the difficulty, and include the model number and serial number. On receipt of this information, we will give you service data or shipping instructions.

2. On receipt of shipping instructions, forward the instrument prepaid, to the factory or to the authorized repair station indicated on the instructions. If requested, an estimate of the charges will be made before the work begins provided the instrument is not covered by the warranty.

SHIPPING

All shipments of Hewlett-Packard instruments should be made via Truck or Railway Express. The instruments should be packed in a strong exterior container and surrounded by two or three inches of excelsior or similar shock-absorbing material.

DO NOT HESITATE TO CALL ON US

HEWLETT-PACKARD COMPANY

Laboratory Instruments for Speed and Accuracy

275 PAGE MILL ROAD PALO ALTO, CALIF. U.S.A.

CABLE "HEWPACK"