0375

HEWLETT PACKARD COMPANY

456A

AC CURRENT PROBE

SERIALS PREFIXED: 103-

OPERATING AND SERVICING MANUAL

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OPERATING AND SERVICING MANUAL

MODEL 456A

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AC CURRENT PROBE

1501 PAGE MILL ROAD, PALO ALTO, CALIFORNIA, U.S.A.

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Table 1-1. Specifications

SENSITIVITY:	1 ma/ma ±1% at 1 kc
FREQUENCY RESPONSE:	±2%, 100 cps to 3 mc; ±5%, 60 cps to 4 mc; -3 db at 25 cps and greater than 20 mc.
PULSE RESPONSE:	Rise time is less than 20 nanoseconds, sag is less than 16% per millisecond.
MAXIMUM INPUT:	1 amp rms; 1.5 amp peak. 100 ma above 5 mc.
EFFECT OF DC CURRENT:	No appreciable effect on sensitivity and distortion from dc current up to 0.5 amp.
INPUT IMPEDANCE:	(Impedance added in series with measured wire by probe.) Less than 50 milliohms in series with 0.05 μh. (This is approximately the inductance of 1-1/2 inches of hookup wire.)
PROBE SHUNT CAPACITY:	Approximately 4 pf added from wire to ground.
DISTORTION AT 1 KC:	For 1/2 amp input at least 50 db down. For 10 ma input at least 70 db down.
EQUIVALENT INPUT NOISE:	Less than 50 μa rms (100 μa when ac powered).
OUTPUT IMPEDANCE:	220 ohms at 1 kc. Approximately +1 volt dc component. Should work into load of not less than 100,000 ohms shunted by approximately 25 pf.
POWER:	Two Mallory Battery Co. TR 233R and one TR 234 batteries (hp stock # 1420-0005 and 1420-0006), battery life is approximately 400 hours. AC power supply optional at extra cost, 115/230 volts ±10%, 50 to 1000 cps, approximately 1 watt.
WEIGHT:	Net 3 lbs.
DIMENSIONS:	5 in. wide, 6 in. deep, 1-1/2 in. high. Probe cable is 5 ft long, output cable is 2 ft long and terminated with a dual banana plug.
ACCESSORY AVAILABLE:	456A-95B AC Supply for field installation.

SECTION I
GENERAL INFORMATION

1-1. GENERAL DESCRIPTION.

The Model 456A is an instrument for measuring ac current. It consists of a probe and amplifier, and is used together with an associated voltmeter or oscilloscope (see figure 1-1).

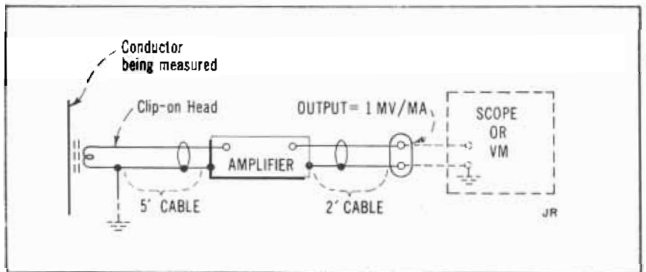


Figure 1-1. General Arrangement of Model 456A

Current is measured by merely clamping the probe of the Model 456A around the current carrying conductor. The probe operates with an accompanying small amplifier to convert the ac current being measured to a proportional voltage. The current-to-voltage conversion factor is 1 millivolt output for 1 milliampere flowing through the probe. Current readings can thus be taken directly from the voltage calibrations on the voltmeter or oscilloscope. Table 1-2 is a list of ⓗⓟ instruments which can be used with the probe.

Table 1-2. ⓗⓟ Instruments for use with 456A AC Current Probe

ⓗⓟ Voltmeters	ⓗⓟ Oscilloscopes
400D	120A
400H	122A
400L	130B
403A	150A
ⓗⓟ Wave Analyzer	160B
302A	170A

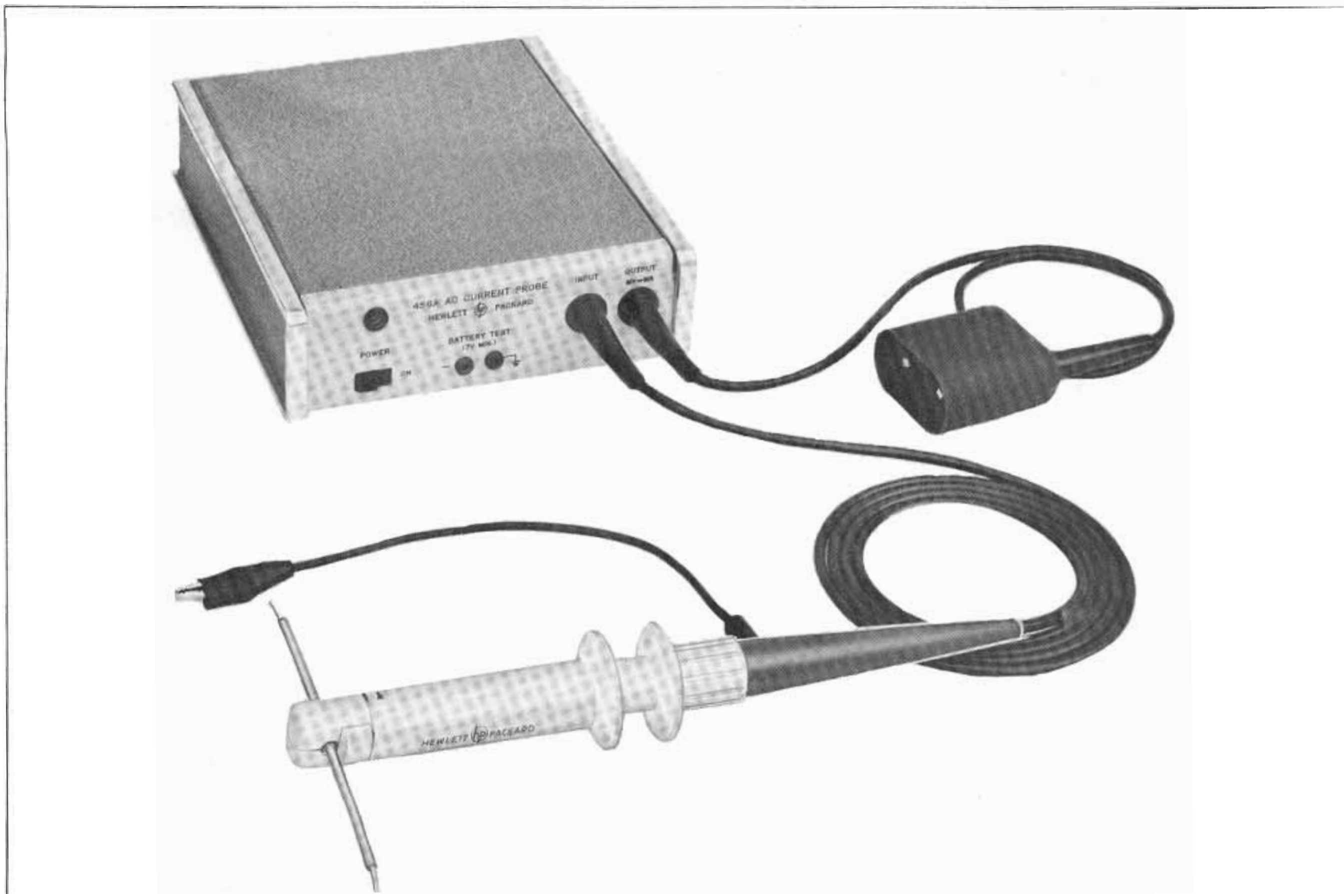


Figure 1-2. Model 456A AC Current Probe

For flat frequency response the shunt input impedance of the associated voltmeter or oscilloscope should be greater than 100K ohms in parallel with 25 pf or made to appear that value to the 456A.

Lower shunt resistance will change the accuracy equally at all frequencies, due to the low output impedance (about 200 ohms) of the Model 456A.

Different shunt capacitances have no effect on the low frequency response, but can affect the high frequency gain as shown in figure 1-3.

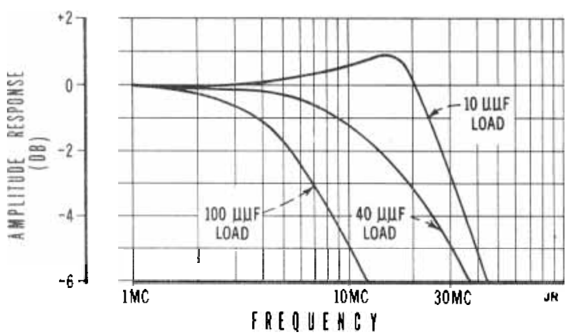


Figure 1-3. Typical Change in Frequency Response with Load Capacitance

The Model 456A output contains a dc component of approximately +1 vdc which must not be loaded excessively (less than 10K ohms shunt load is excessive). Almost all ac voltmeters and oscilloscopes have a dc blocking capacitor in the input circuit to take care of this requirement. DO NOT USE THIS INSTRUMENT WITH RECTIFIER TYPE METERS. The loading in this type of instrument is excessive and may affect the reading.

1-2. POWER REQUIREMENTS.

The Model 456A is available either as a battery powered or ac powered instrument. The AC Power Supply (hp stock #456A-95B) fits into the space normally occupied by the battery supply and takes the place of it electrically. The ac power supply must be ordered separately.

When the 456A is powered with its own internal batteries it is independent of power lines. It may be used in the field with battery operated voltmeters, such as the hp Model 403A AC Voltmeter, or battery powered oscilloscopes. Battery operation is also useful in the laboratory where complete isolation is desired. While battery operated the 456A may be used with the chassis off ground without difficulty. This type of operation may also be desired to isolate power line hum in a system where several instruments are used.

When the 456A is used with the ac power supply the chassis is automatically grounded through the third prong in the power plug. 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 protection of the operating personnel.

WARNING

When using a three-prong to two-prong adapter ground the third lead (green wire) externally.

SECTION II
OPERATING INSTRUCTIONS

2-1. GENERAL.

The Model 456A must be used with an ac voltmeter or an oscilloscope. Figure 2-2 shows a typical setup.

2-2. OPERATING INSTRUCTIONS.

Connect the shielded plug of the Model 456A OUTPUT cable to a voltmeter or oscilloscope of appropriate range. The conversion ratio is millivolts out equals milliamperes in. Thus the voltmeter should read in millivolts the expected milliamperes being measured. The current range of the Model 456A is less than 1 milliampere to 1 ampere. The ⓗⓟ Model 400D/H/L Vacuum Tube Voltmeter is ideal for this measurement as it covers the entire range and has a 3/4 inch spacing input jack.

WARNING

DO NOT PLUG THE OUTPUT CABLE OF THE 456A INTO A SOURCE OF AC OR DC VOLTAGE. Doing so will burn out the transistors and perhaps other components.

The spacing of the pins on the OUTPUT cable fits all standard 3/4 inch connectors, such as on Hewlett-Packard voltmeters, wave-analyzers, and oscilloscopes (when used with AC-76A adapter). See table 1-2 for a list of Hewlett-Packard instruments suitable for use with the Model 456A.

The ⓗⓟ Model 400D has an additional output terminal for viewing the voltage being measured with an oscilloscope. This may be very useful, for example, measuring the current at which a transistor starts clipping.

The Model 456A may be used to measure very low current, even below the noise level of the probe, if some provision is made to filter out the noise. The ⓗⓟ Model 302A Wave Analyzer is ideal for this purpose, particularly if the BFO of the 302A is used as the signal source (see figure 2-1).

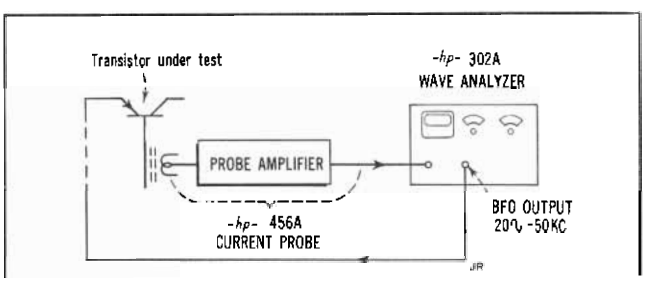


Figure 2-1. Probe can be used with ⓗⓟ 302A to measure distortion in current waveforms or to measure small audio current, as described in text

In this manner, currents even below 10 microamperes can be measured.

2-3. OPERATING THE PROBE.

The probe jaws may be operated with one hand. While holding the probe handle in the palm, squeeze the flanges together with the fingers. This action will open the jaws. Move the probe to the vicinity of the insulated wire being measured and slowly release the flanges until the jaws fit over the wire.

CAUTION

Do NOT let the jaws snap closed as they may be damaged.

Clip the probe over the wire with the arrow on the probe in the direction of conventional current flow for a positive-going output signal. This procedure is important when using an oscilloscope but it may also be important when using this probe to measure unsymmetrical waveforms with half-wave rectifier type meters. All Hewlett-Packard meters listed in table 1-2 are full-wave rectifier types so you will get the same reading whichever way the probe is clipped over the wire. However, with half-wave type meters the readings may be different. This action is a limitation of the meter and not a fault of the Model 456A. Refer to the Operating and Servicing Manual for the meter or change to one of the recommended meters.

2-4. INCREASING THE SENSITIVITY.

Sensitivity of the Model 456A may be increased by looping the wire carrying the current to be measured through the jaws more than once. The reading on the meter or oscilloscope will be multiplied by the number of times that the current passes through the jaws. To obtain the true reading divide the current indication by the number of turns enclosed by the jaws. The series loading effect of the probe on the circuit being measured is then multiplied by the square of the number of turns. This effect may have to be taken into account (see paragraph 2-5D).

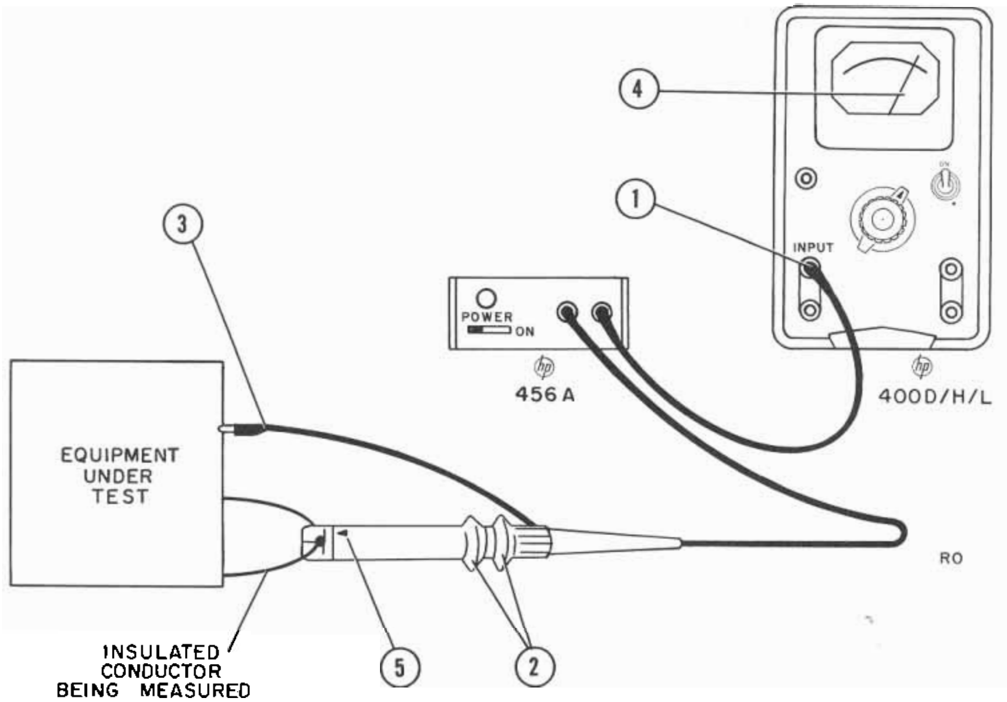
2-5. MEASUREMENT PRECAUTIONS.

Best performance will be achieved by observing the following precautions:

A. PROBE HANDLING

1) Do not snap the jaws closed by letting go of the probe flanges abruptly. This action may damage the shield or the jaws.

2) Do not drop the probe. The jaws are made from an



1. Connect output of 456A to a voltmeter or oscilloscope.
2. Clip probe around wire under test (open jaws by squeezing flanges on probe together).
3. Connect ground-clip to instrument under test, if necessary (see paragraph 2-5E).
4. Read current being measured on meter or oscilloscope (read millivolts as milliamperes).
5. Note direction of arrow on probe. Conventional current flow in direction of arrow gives positive going output voltage.

Figure 2-2. Operation

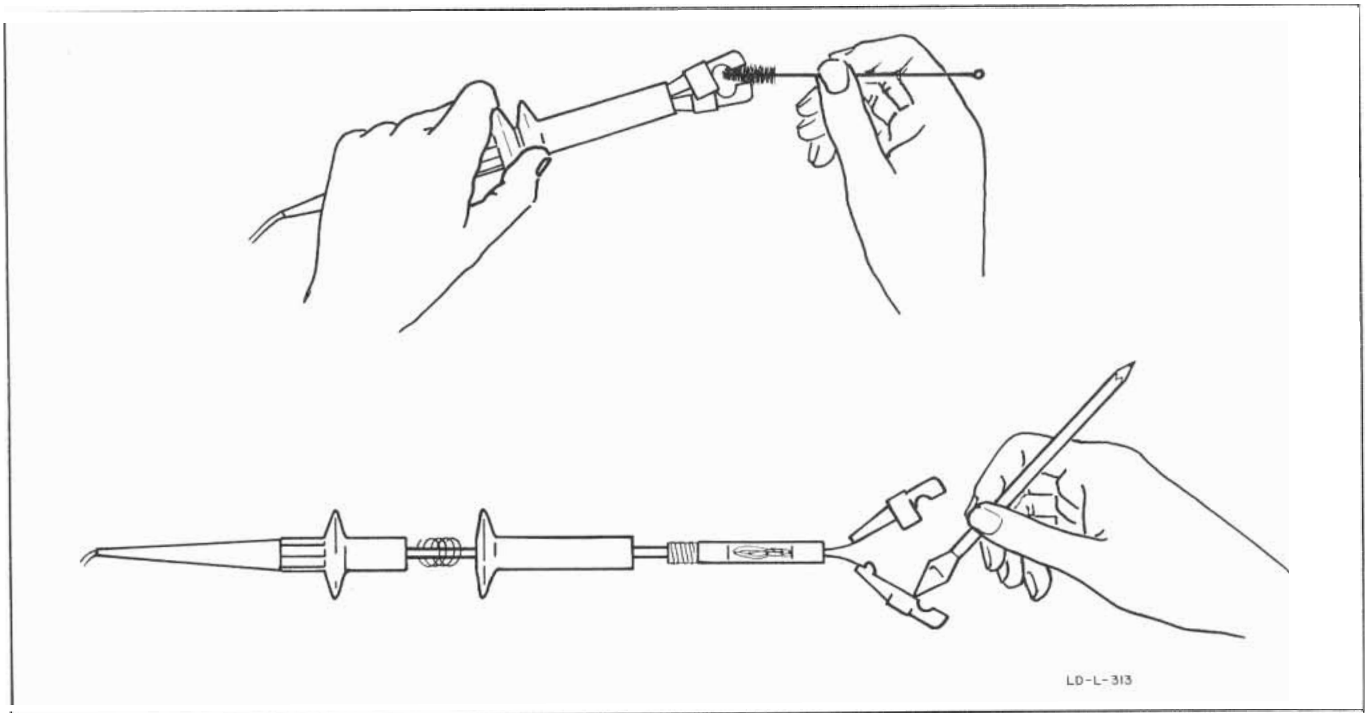


Figure 2-3. Cleaning Probe Jaws

alkyd material which is very durable in normal use, but is not made to withstand the shock of dropping.

3) Keep the probe jaws clean. If the jaws appear dirty or if the low frequency response drops off, clean the jaws as shown in figure 2-3 using carbon tetrachloride and the brush provided or, in extreme cases, a pencil eraser.

The probe jaws should mate perfectly with no air gap between the ferrite pole pieces. Foreign matter (dirt specks, wax from capacitors, sand particles, pieces of insulating tape etc.) may hold the pole pieces from closing perfectly. Normally the only effect will be to lower the gain at low frequencies (below 10 kc). Even as small an air gap as 0.0005 inch will lower the gain significantly at low frequencies.

4) Always clip the probe around insulated wire. If you must measure the current in a bare wire, first insulate the wire with tape or insulating tubing.

5) Do not expose the probe to high temperatures. Exposure to temperatures above 55°C is not recommended.

B. DIRECT CURRENT IN THE SIGNAL BEING MEASURED. Direct current in the signal being measured should preferably be kept below 1/2 ampere. Direct current below that value will have no effect on the measurement.

C. ALTERNATING CURRENT FIELDS. The probe is shielded against external ac magnetic and electric fields. Extremely strong fields may cause an erroneous reading. If a strong ac magnetic field is suspected, rotate the empty probe head with the jaws closed. If the reading changes, an ac field is affecting the probe.

D. GROUND LOOPS. With the ac supply avoid ground loops in test setups, such as those produced between the third prong on the ac cable and the ground on the indicating instrument. An easy method of testing for ground loops is to clip the probe over the 456A output cable. Any reading indicates the presence of ground loops.

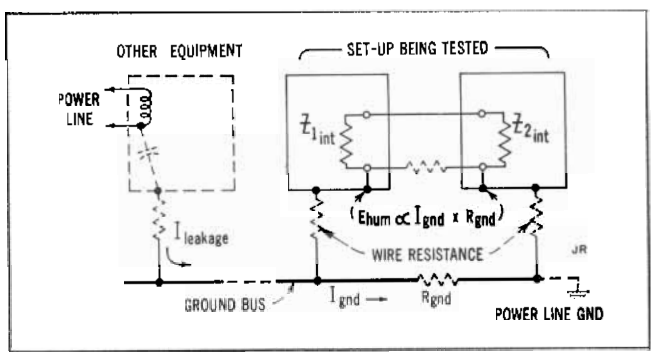


Figure 2-4. Illustrating Development of Ground Loops

Referring to figure 2-4, note that the leakage current $I_{leakage}$ causes a voltage drop across the ground lead resistance R_{gnd}. This appears as a voltage, in addition to the signal voltage, between the ac current probe Z_1 and the indicating device Z_2. An easy way of minimizing this problem is to connect both instruments to the same ac receptacle. Another method is to use a battery-powered Model 456A.

E. EFFECT OF PROBE ON CIRCUIT BEING MEASURED. The probe adds an inductance of less than 0.05 microhenries to the circuit under test. With almost all conditions this small an inductance will not affect the measurement.

However, if the measurement is made in a very low capacitance and very high impedance circuit, with high ac voltages, and at high frequencies, the shunt capacitance of the probe to ground must be taken into consideration. A capacitance is added from the measured wire to the grounded shield inside the 456A probe when the probe is clamped around the wire. This capacitance typically has a value anywhere from 1 pf to 5 pf, depending upon wire size, insulation and location within the probe aperture. This capacitance has two effects:

1) The measured wire is slightly "loaded" with a capacitance to ground of around 3 pf.

2) The capacitive current which flows to ground through this wire-to-probe capacitance can be measured by the probe, although it almost always adds a negligible amount to the reading of the actual current in the wire.

To test if this effect should be considered, solder one end of a short, stiff, piece of insulated wire to the circuit at the point where the measurement is to be made. Leave the other end of this wire unconnected. This wire will have voltage on it but no current through it. Clip the probe over this wire and read the meter. Reverse the direction that the probe is clipped on the wire (point arrow on probe in other direction) and read meter again. If there is no reading on the meter in either of these positions the probe capacitance has no effect. If there is a reading proceed to the next paragraph.

The shunt capacitance introduced by the probe is 1 to 5 pf (typically 3 pf). Assuming the worst case of 5 pf, a maximum error current of:

$$I = 0.03 \text{ ma} \times \text{volts} \times \text{megacycles}$$

can flow through the 5 pf to ground. That is, a 1 mc voltage of 1 volt impressed across this shunt capacitance will cause a reading of only 0.03 ma by the 456A. However, at higher frequencies the effect will increase proportionally.

Even with this effect you may choose which side of the circuit to measure the current. See figure 2-5.

Note in figure 2-5 the probe measures the current flowing in the circuit on the same side as the wide side of the arrow on the probe.

Occasionally at high frequencies (above 15 mc) a greatly magnified voltage effect exists at a particular frequency. This effect is caused by a resonance between excessive external ground lead lengths and stray capacities. The following steps are suggested to eliminate this type of problem:

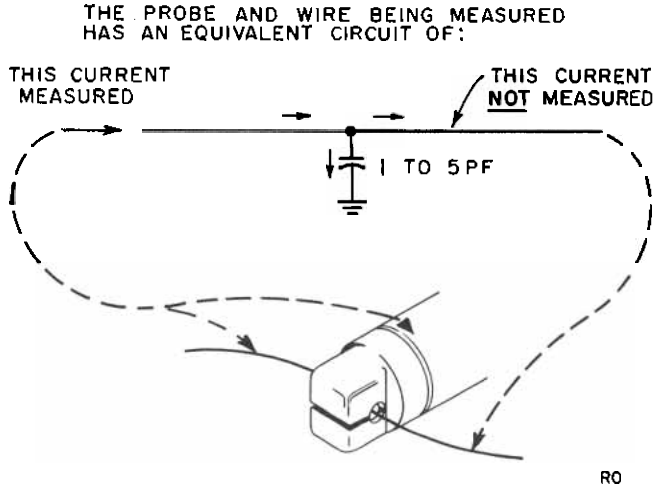


Figure 2-5. Illustrating Directional Effect of Current Measurement

1) Ground oscilloscope or voltmeter to equipment ground with as short leads as possible.

2) Connect special resistive ground lead (supplied) to the closest ground to the conductor being measured.

3) Space 456A cabinet away from grounded conductors (steel tables, etc).

4) Ground 456A to oscilloscope or voltmeter with a standard (non-resistive) short clip lead (not furnished).

2-6. SPECIAL MEASURING TECHNIQUES.

Since the probe is effectively a current transformer, it has the property that it will algebraically sum the instantaneous value of the currents in two or more conductors it may be clipped around. This property makes the probe a valuable and easily-applied tool in applications in which it is desired to equalize or balance ac currents. For example, in the class C amplifier shown in figure 2-6 it is possible to use this summing property to examine the plate current pulses exclusive of the current component flowing through the capacity of the tube. This arrangement will allow you to measure the true angle of conduction of the class C amplifier.

The method used to obtain the bucking current is indicated in figure 2-6. The probe was clipped around the plate lead of the tube, but at the same time a lead from an external variable capacitor was connected to the plate lead and passed through the probe as shown. By suitably adjusting the variable capacitor, a capacitive current equal to but in opposite phase to the capacitive current flowing at the plate can be applied to the probe.

Note that this arrangement provides a dynamic measure of the output capacity of the tube. This occurs because the final setting of the variable capacitor should be equal to the tube output capacity.

The probe is valuable in a number of other current-equalizing applications. Especially common among these are equalizing the input and output currents in push-pull and balanced circuits in both transistor and tube applications.

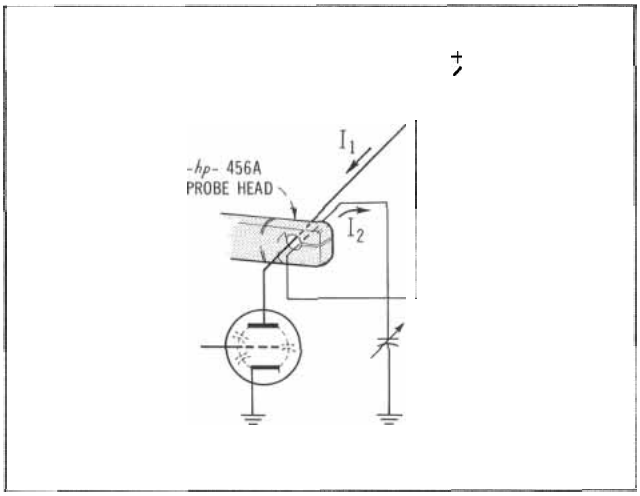


Figure 2-6. Bucking Out Capacitive Component of Plate Current

SECTION III
THEORY OF OPERATION

3-1. INTRODUCTION.

The Model 456A consists of a probe and an amplifier. Current to be measured flowing through a wire induces a current in the probe which is clamped around the wire. This current is then amplified in the amplifier.

3-2. PROBE HEAD.

The probe head acts as a 400:1 step-down current transformer. That is, 1 milliampere flowing in the wire around which the probe is clamped will induce 1/400th of 1 milliampere into the probe secondary. The output of the probe drives the amplifier.

3-3. AMPLIFIER.

The amplifier consists of a common-base circuit driving a common-emitter output stage. The first transistor is used for impedance transformation and the second transistor is used as a current amplifier. Referring to the schematic you will see that the ac signal from the probe is fed through coupling capacitor C2 to the emitter of Q1.

The first transistor Q1 is used as an input amplifier to match the low impedance of the probe to the higher impedance of transistor Q2. Transistor Q1 is connected in a common-base configuration for low input impedance and high output impedance. Even though the current leaving Q1 is slightly less than the current going into Q1, there is a power gain since the impedance level has been increased. Thus the signal that goes into Q1 comes out as a slightly smaller current but at a higher impedance level.

The signal then goes through CR1, an 8-volt breakdown diode that furnishes bias for Q2. The signal is applied to the base of Q2. Transistor Q2 is a common-emitter stage which amplifies and reverses the phase of the signal. This stage amplifies the current and feeds it back out-of-phase to the emitter of Q1. The output is fed back to the emitter of Q1 through R12, 9 and 10. A large amount of current feedback is used to feed back a signal 180° out-of-phase with the signal and in parallel with it. This parallel current feedback results in a better frequency response, lower input impedance, dc bias stability, lower distortion, etc.

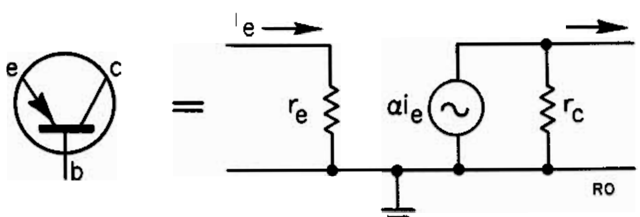


Figure 3-1. Equivalent Circuit

The equivalent circuit can be thought of as shown in figure 3-1, where α is the current gain of the transistor. The transistors have internal resistances as shown. Emitter resistance r_e is small, but relevant to this discussion, while the collector resistance r_c is so large that it may be neglected.

Referring to figure 3-2 note that the input current is applied to r_e. While this resistance is small the probe should work into zero resistance for best frequency response. So it is desirable to lower the input resistance still further.

Note that the current applied to r_e causes a current α times as large to flow out of the transistor. Since α is less than unity, the current flowing out will be slightly less than the current flowing in. Resistors R8 and r_c have resistance much higher than the Z_{in} of Q2 so most of the current is fed into Q2. Transistor Q2 amplifies and inverts the signal and feeds it back to r_e through R12, 9 and 10.

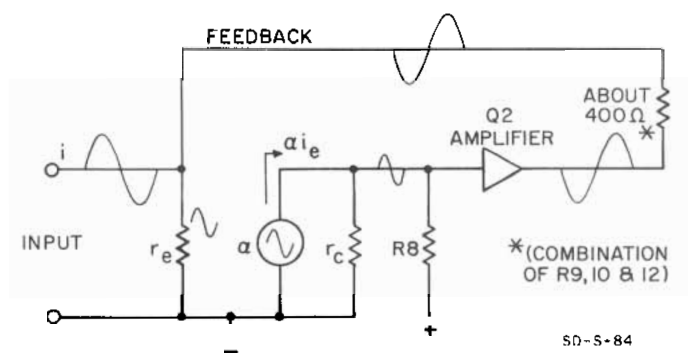


Figure 3-2. Feedback Circuit

This current is fed back out-of-phase and of an amplitude almost enough to cancel out the original signal. Thus any voltage developed across r_e by the initial current is almost cancelled out by the out-of-phase voltage caused by the current from Q2. For constant input current the amount of voltage developed at the input to a device is proportional to its input impedance. Since this voltage developed is reduced by the mechanism explained previously, the impedance is lowered.

This resistance consisting of R12, 10 and 9 is approximately 400 ohms and is used as a load across which the output voltage is developed. The value of 400 ohms is used to step-up voltage-to-current ratio 400 times.

The current in the amplifier has been reduced in the probe to 1/400th of the current being measured. The output voltage is made numerically 400 times this reduced current so that the millivolts at the output will exactly equal the number of milliamperes flowing in the wire being measured.

SERVICING ETCHED CIRCUIT BOARDS

Excessive heat or pressure can lift the copper strip from the board. Avoid damage by using a low power soldering iron (50 watts maximum) and following these instructions. Copper that lifts off the board should be cemented in place with a quick drying acetate base cement having good electrical insulating properties.

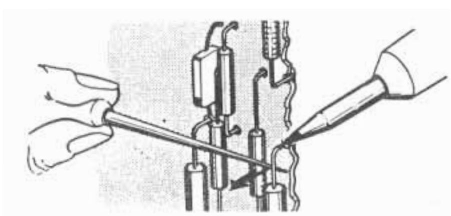
A break in the copper should be repaired by soldering a short length of tinned copper wire across the break.

Use only high quality rosin core solder when repairing etched circuit boards. NEVER USE PASTE FLUX. After soldering, clean off any excess flux and coat the repaired area with a high quality electrical varnish or lacquer.

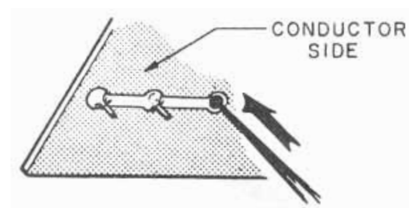
When replacing components with multiple mounting pins such as tube sockets, electrolytic capacitors, and potentiometers, it will be necessary to lift each pin slightly, working around the components several times until it is free.

WARNING: If the specific instructions outlined in the steps below regarding etched circuit boards without eyelets are not followed, extensive damage to the etched circuit board will result.

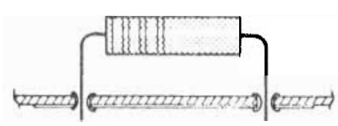
1. Apply heat sparingly to lead of component to be replaced. If lead of component passes through an eyelet in the circuit board, apply heat on component side of board. If lead of component <u>does not</u> pass through an eyelet, apply heat to <u>conductor</u> side of board.



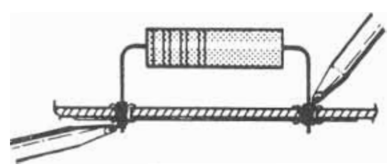
2. Reheat solder in vacant eyelet and quickly insert a small awl to clean inside of hole. If hole <u>does not</u> have an eyelet, insert awl or a #57 <u>drill</u> from conductor side of board.



3. Bend clean tinned leads on new part and carefully insert through eyelets or holes in board.

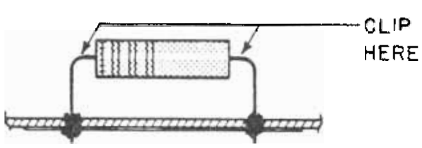


4. Hold part against board (avoid overheating) and solder leads. Apply heat to component leads on correct side of board as explained in step 1.

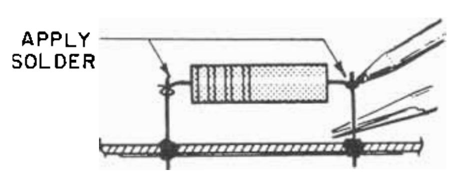


In the event that either the circuit board has been damaged or the conventional method is impractical, use method shown below. This is especially applicable for circuit boards without eyelets.

1. Clip lead as shown below.



2. Bend protruding leads upward. Bend lead of new component around protruding lead. Apply solder using a pair of long nose pliers as a heat sink.



This procedure is used in the field only as an alternate means of repair. It is not used within the factory.

Figure 4-1. Servicing Etched Circuit Boards

SECTION IV
MAINTENANCE

4-1. GENERAL.

The Model 456A should require very little maintenance. It is built with etched circuit wiring and transistors which should ensure long, trouble-free life. However, should trouble occur special care must be taken in servicing to avoid damage to the transistors or the etched circuit board.

REPLACING TRANSISTORS. The transistors are soldered in: substitution of transistors should not be resorted to unless there is some indication that they are faulty. Unless extreme care is taken when soldering, the transistor may be damaged. See figure 4-1.

CAUTION

Be careful not to short voltages across the transistors. Small bias changes may ruin a transistor due to excessive dissipation. Be sure to turn the unit off before doing any soldering. A small leakage current from the iron applied at the input may exceed ratings on the transistors at the output.

Components within ⓗ instruments are conservatively operated to provide maximum instrument reliability. In spite of this, parts within an instrument may fail. Usually, the instrument must be immediately repaired with a minimum of "down time". A systematic approach can greatly simplify and thereby speed up the repair.

Specifications for the Model 456A AC Current Probe are given in table 1-1. The procedures in this manual give additional tests and the data they contain are not to be considered as specifications.

Your Hewlett-Packard representative maintains complete facilities and specially trained personnel to assist you with any engineering, application, tests, or repair problems you may have with Hewlett-Packard instruments.

4-2. CABINET REMOVAL.

CAUTION

Remove power cord from receptacle if unit is equipped with ac supply.

The instrument may be taken from the cabinet by removing the two screws at the rear of the instrument and pulling the cabinet loose from the front panel and side frames.

4-3. OPERATION ON 230 VOLT AC.

The Model 456A is normally wired for 115 volt operation unless otherwise specified. It can be quickly and easily converted to operate from a nominal line voltage of either 115 or 230 volts and a frequency of 50 to 1000 cps. To convert for 230-volt operation remove the short across R90. Turn the instrument off before doing any soldering.

4-4. CHECKING THE BATTERIES.

Whenever trouble is encountered check the voltage at the BATTERY TEST terminals. If this voltage is below 7 volts replace all of the batteries. The BATTERY TEST terminals are across only part of the batteries. For this reason all of the batteries should be replaced if the voltage is below 7 volts. If some of the batteries are depleted the remaining batteries are probably low also. In addition, the batteries across the BATTERY TEST jacks could be fresh while the other battery could be depleted. If trouble is encountered, remove the cabinet and test the voltage of BT3 also. This voltage should be at least 4.7 volts. Discard battery if lower.

WARNING

Mercury batteries generate hydrogen gas at the end of their life or when they are shorted. Hydrogen gas is highly explosive and may be exploded by the heat of the battery. Observe the following precautions when using mercury batteries.

1) Never discharge a mercury-cell battery after its voltage falls below 70% of its nominal voltage, or when it fails to operate the equipment in which it is used.

2) Never place a direct short across a mercury cell battery.

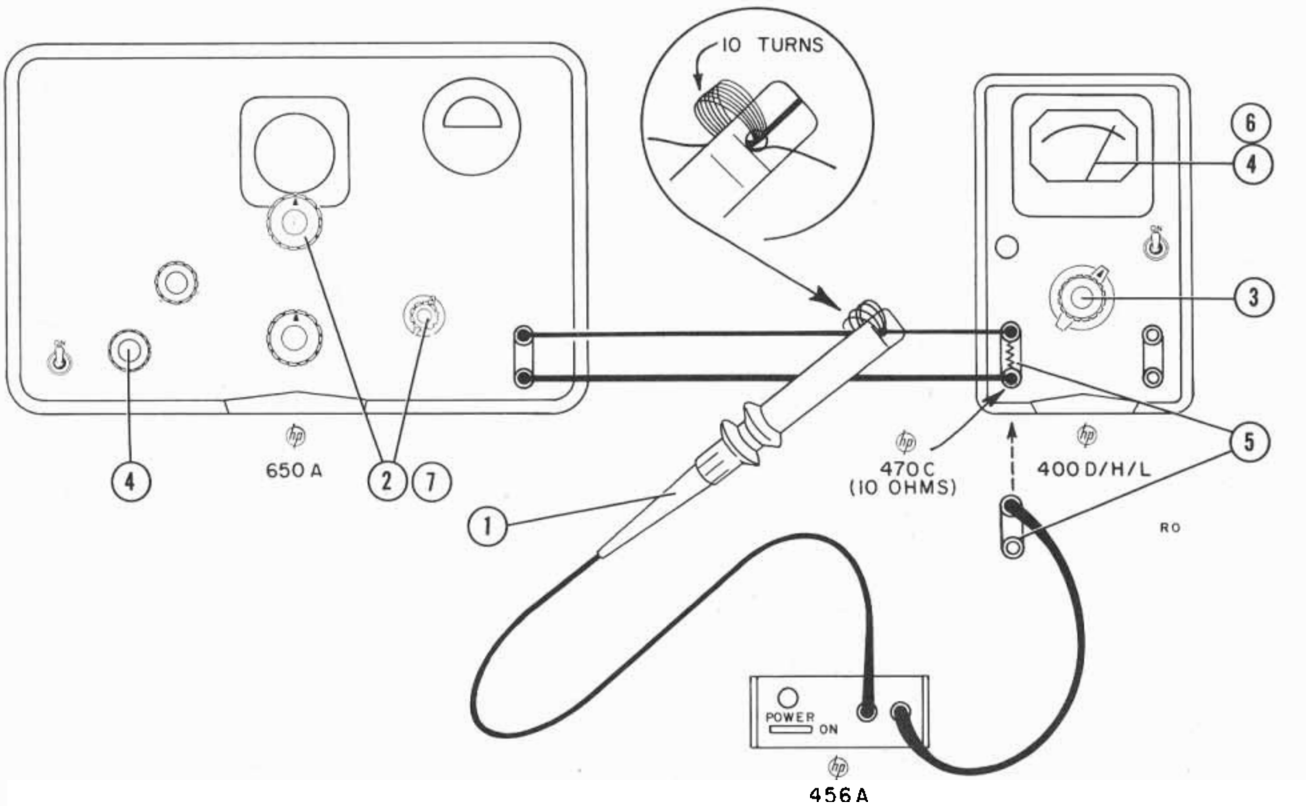
3) Never leave the POWER switch ON when the equipment is not in use, or after the battery fails to operate the equipment.

4) Never retain exhausted mercury-cell batteries. Discard dead batteries as soon as possible. Discard in garbage, NOT in waste basket. If battery is incinerated, in addition to the explosive hazard, mercury vapor is EXTREMELY TOXIC. DO NOT INCINERATE.

5) Store spare mercury-cell batteries in a cool, adequately ventilated area.

4-5. REPLACING THE BATTERIES.

Whenever the voltage at the BATTERY TEST terminals falls below 7 volts or if the batteries are suspected, replace the batteries. Turn the instrument OFF. Remove the cabinet as instructed in paragraph 4-2. Remove and discard all batteries. Replace the batteries with one Mallory Type TR 234 battery or



Since the calibration and frequency response of the Model 456A is usually much better than the accuracy of the best instruments generally available for this test, the purpose of this test is to determine easily only if there is something radically wrong with the Model 456A.

1. Connect probe to test setup as shown, looping the wire through the probe jaws ten times.
2. Set Model 650A to 1 KC and on the 3 VOLT range.
3. Set Model 400D/H/L to 0.1 VOLT range.
4. Adjust AMPLITUDE control on 650A until 400D/H/L reads exactly 0.1 volt.
5. Connect the OUTPUT cable of the 456A to the input of the 400D/H/L in place of the 470C. Leave the wires still connected to the 470C.
6. Read 400D/H/L. Reading should be within sum of specifications of the 470C and 456A.
7. Repeat above steps with 650A set at other frequencies up to 100 kc. If the 456A calibration or frequency response is poorer than test accuracy or specifications the probe may be bad. However, since the test accuracy is usually much poorer than the specifications the best way to test a probe is to repeat the above process with another probe known to be good and compare results.

Figure 4-2. Calibration and Frequency Response (approximate method) equivalent, and two Mallory Type TR 233R batteries in series. BE SURE TO INSTALL THE BATTERIES WITH THE SAME POLARITIES AS MARKED ON THE BATTERY HOLDER. Note that the small terminal on the battery is negative not positive as with dry cells.

BE SURE THE BATTERIES ARE MAKING GOOD CONTACT WITH THE BATTERY HOLDERS. If necessary, bend the battery holders so that they do make good contact. In the holder where two batteries are used in series cut off part of the cardboard tubing around the batteries at the ends which meet in order to get good contact between them.

4-6. CONVERTING TO AC-OPERATED MODEL.

The battery-operated model can be quickly and easily converted to an ac-powered model. Remove the instrument from the cabinet as instructed in paragraph 4-2. Unsolder the wires going to the battery holder at the battery holder end. Remove the two screws holding the battery holder chassis. Remove the battery holder chassis and batteries, if any. Substitute the ac power supply (hp stock #456A-95B) in the space formerly occupied by the battery holder chassis.

Fasten the supply with the same screws used to mount the battery holder chassis. Solder the loose wires to the terminals (marked with the corresponding colors) on the board. Replace the cabinet.

4-7. TEST EQUIPMENT REQUIRED.

The following test equipment is required to test the Model 456A:

1) Vacuum Tube voltmeter accurate to within ±1%, such as hp Model 403A or 400H/L.

2) Signal Generator with output to 4 mc, such as hp Model 650A.

3) Shunt Resistor of 10 ohms accurate to at least ±5% such as hp Model 470C.

4) DC Vacuum Tube Voltmeter, such as hp Models 410B or 412A.

5) Variable Transformer continuously adjustable from 100 to 130 volts, equipped with a monitor voltmeter accurate within ±1 volt.

6) Clip-On Milliammeter, such as hp Model 428A.

4-8. FRONT PANEL PERFORMANCE CHECK.

Perform this check upon receiving this instrument or whenever trouble is suspected.

A. NOISE.

1) To check ac-powered 456A turn instrument off and read the output noise on an oscilloscope or meter. If there is appreciable hum see paragraph 2-5D, Ground Loops. Follow the procedure in that paragraph until any appreciable hum is eliminated.

2) Turn on the 456A with no input to the probe. The noise as read on the meter or oscilloscope should be less than 75 μvolts (100 μvolts with ac-powered model). If not check C94, power supply capacitor (if ac powered), or try replacing CR1, Q1, or Q2. Check with 456A POWER switch off to see if ground loops exist. If they do, see paragraph 2-5D.

B. CALIBRATION AND FREQUENCY RESPONSE.
Perform the procedure illustrated in figure 4-2. Note that this test is used only for rough testing with readily available equipment. In almost all cases the test accuracy will be much poorer than the probe deviation from specification. In this case assume that the probe is within specifications.

4-9. TROUBLE LOCALIZATION.

Adopting a systematic approach to troubleshooting will enable you to find the trouble in the shortest possible time and eliminate the possibility of damaging the transistors or other parts of the instrument. Whenever trouble is suspected, perform the following steps in the order given until the trouble is located. After the trouble has been located proceed to the next paragraph.

1) Perform the front-panel performance check as given in paragraph 4-8. If instrument does not meet specifications proceed to next step.

2) Clean probe jaws as described in paragraph 2-5A3 and figure 2-3.

3) If instrument does not operate at all check continuity of both cables with an ohmmeter. Check probe by substitution if another probe assembly is available.

4) Check the voltage of the batteries as described in paragraph 4-4, Checking the Batteries. At the BATTERY TEST jacks on the front panel of an ac-operated instrument, the voltage should be approximately 8 volts ±10% with an input of 115 volts ac. If the voltage is much below 8 volts, either the supply is faulty or the instrument is drawing too much current.

5) Measure the current in the red (B+) lead running around the front of the etched-circuit board with a milliammeter, such as the hp Model 428A Clip-On Milliammeter. The current should be 5.5 ma ± 0.5 ma. If too high, check voltages across CR1, Q1, and Q2.

6) Measure current in violet-white lead (ground) going to switch. There should be less than 0.02 ma in this lead. If there is more current, something is wrong in the amplifier (provided the supply voltages are correct).

7) Measure the ripple on the ac supply by connecting an ac voltmeter, such as the hp Model 403A (or Model 400D/H/L), from any pink (B-) lead to any red (B+) lead. This is a very difficult measurement to make because eliminating all ground loops is necessary. Refer to paragraph 2-5D for instructions concerning

the elimination of ground loops. If, after eliminating the ground loops, the ripple is still too great check CR92 and Q90. Diode CR92 should have 14 volts ±2 volts across it.

8) If the instrument section is faulty, locate the trouble by measuring the voltages as shown on the schematic diagram.

CAUTION

TAKE CARE NOT TO SHORT THE WIRING WHEN TROUBLESHOOTING. EVEN A MOMENTARY SHORT MAY BURN OUT A TRANSISTOR OR DIODE.

The transistors can be checked in a similar manner. Since the transistors used in this instrument are of the pnp type the voltage at the emitter should be slightly positive (within 0.4 volt) of the voltage on the base. The voltage on the collector should be negative with respect to the base and of the value shown on the schematic diagram.

Unfortunately, due to the large amount of feedback any trouble may cause all of the voltages to be off. First, try to find the trouble by resistance measurements. If this fails you may have to remove the transistors and diode, and test them on a simple dc tester.

4-10. SEMI-CONDUCTOR REPLACEMENT.

Do NOT replace the transistors or diodes unless there is a definite indication that these components are faulty, as you may damage them. Turn the instrument OFF before doing any soldering as ac leakage from the soldering iron may overload and damage the transistors. In addition before using an iron on any semi-conductor lead, clip a pair of long-nosed pliers between the iron and semi-conductor. The pair of pliers will act as a heat sink and absorb heat helping to prevent damage to the semi-conductor.

Table 4-1 lists the tests which should be made after replacing the components.

4-11. CALIBRATION.

Perform the procedure in figure 4-2 at 1 kc. Adjust R9, Gain Set Potentiometer, so that the voltage out is exactly 0.1 volt (millivolts output equals milliamperes input). If you can't reach calibration, check R7, 9, 10 and 12, and the probe.

4-12. FREQUENCY RESPONSE.

Perform the procedure given in figure 4-2.

4-13. REPLACING THE PROBE CABLE.

A. GENERAL. The cable assembly used in the 456A-21A Probe Assembly includes in the probe cable assembly a special cable terminated at one end with a Microdot miniature connector and at the other end with a crimp-on ground lead. Both of these connectors may be replaced but it is recommended that a new probe cable assembly, ⓗⓟ stock #456A-21A-8, be installed instead because of difficulties encountered in replacement.

B. MIDRODOT MINIATURE CONNECTOR. The microdot connector terminates the end of the cable under the handle (see figure 4-3). To replace this connector four new parts and a special hand tool for assembly are required. See the operating note for the ⓗⓟ 425A-21B Microvolt Ammeter Probe for instructions.

C. CRIMP-ON GROUND CONNECTOR. This connector is crimped to avoid soldering and consequent melting of the cable insulation. Crimp the ground lead on again, if possible. If the ground lead must be soldered, clamp a pair of pliers between the iron and insulation to act as a heat sink.

Table 4-1. Replacement

Componen	Test
CR1	None
CR90	Check power supply (par. 4-9)
CR91	Check power supply (par. 4-9)
CR92	Check power supply (par. 4-9)
Q1	None
Q2	Check calibration (par. 4-11)
Q90	Check power supply (par. 4-9)
Probe	Check calibration (par. 4-11); check frequency response (par. 4-12)

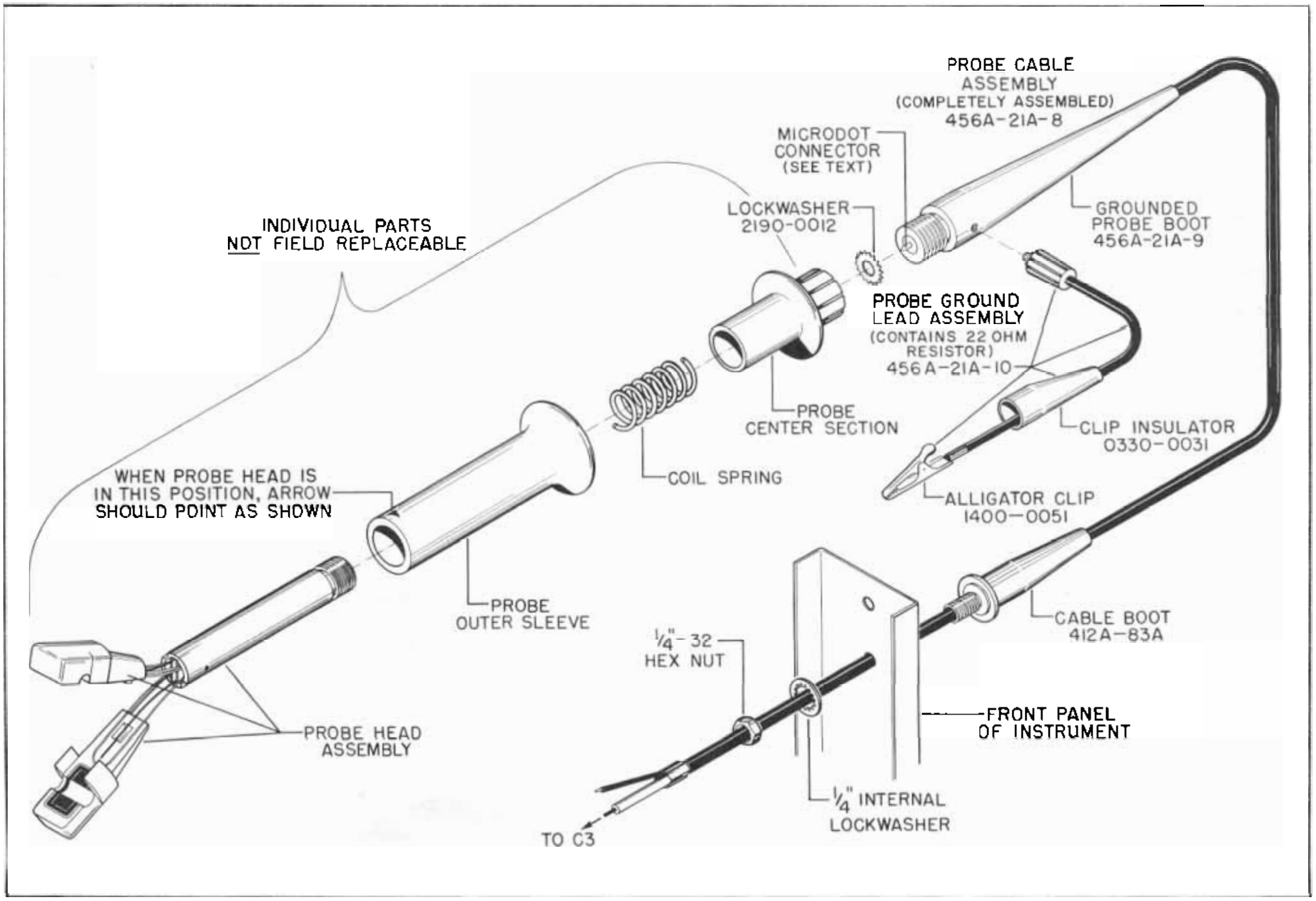


Figure 4-3. Exploded View of Probe Assembly

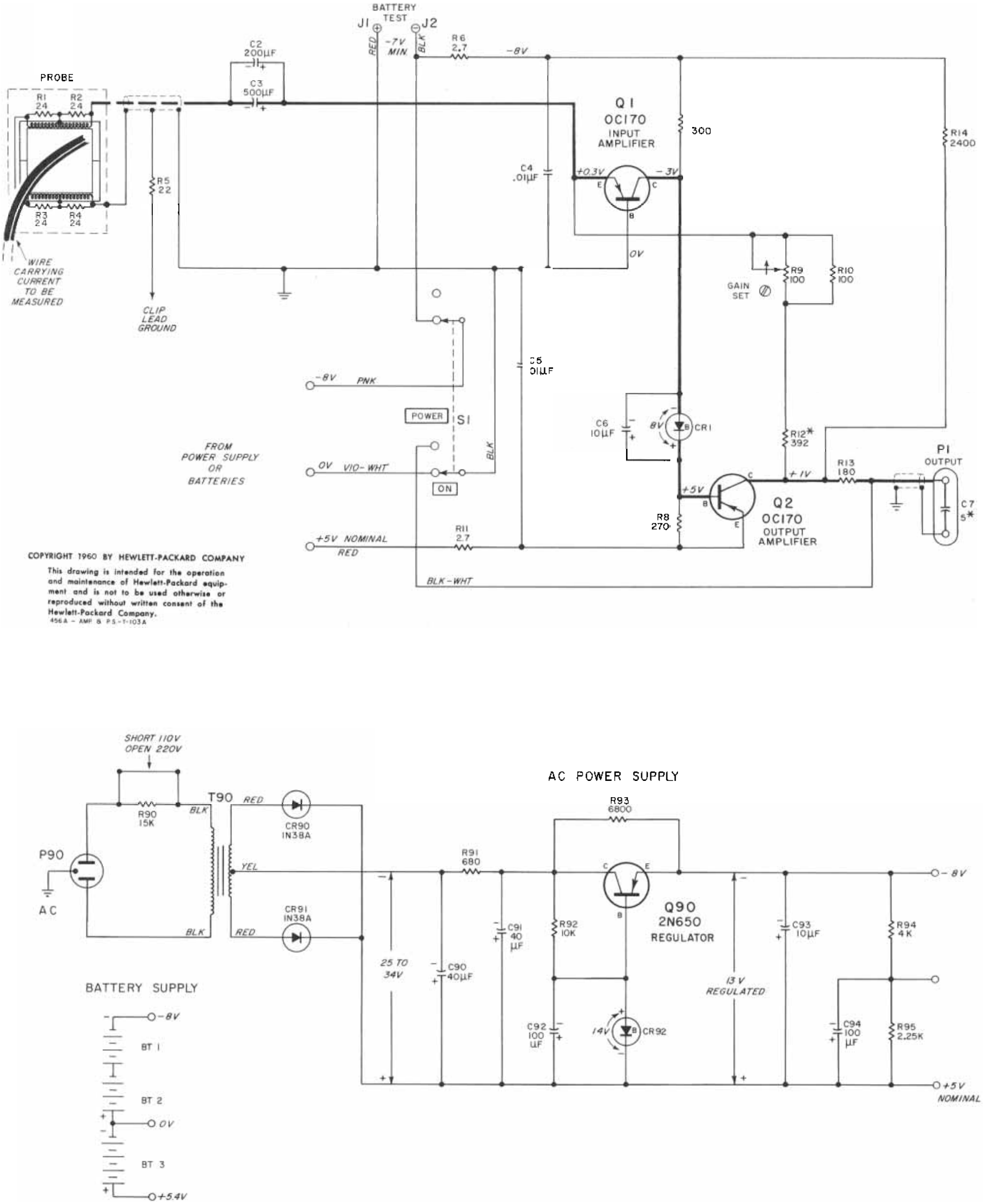


Figure 4-4. Model 456A AC Current Probe

SECTION V
REPLACEABLE PARTS

5-1. INTRODUCTION.

This section contains information for ordering replacement parts for the 456A AC Current Probe.

5-2. TABLE OF REPLACEABLE PARTS.

Table 5-1 lists replaceable parts in alpha-numerical order of reference designators. At the end of the table are listed miscellaneous items such as knobs which have no assigned reference designators.

Detailed information on a part used more than once is listed opposite the first reference designator applying to the part to appear in the table. Other reference designators applying to the same part reference the initial designator. The detailed information includes the following:

1) Full description of the part.

2) Manufacturer of the part in a five digit code -- see appendix codes, List of Manufacturers.

3) Total quantity used in the instrument (TQ column).

4) Recommended spare quantity for complete maintenance during one year of isolated service (RS column).

5-3. ORDERING INFORMATION.

To order a replacement part, address order or inquiry either to your authorized ⓗⓟ sales office or to

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

or, in Western Europe, to

Hewlett-Packard S. A.
Rue du Vieux Billard No. 1
Geneva, Switzerland

Specify the following information on a part:

1) Model and serial number of the instrument. Be sure to include the three-digit serial prefix.

2) ⓗⓟ stock number.

3) Circuit reference designator.

4) Description.

To order a part not listed in table 5-1, give a complete description of the part including its function and location in the circuit.

Table 5-1. Replaceable Parts (Sheet 1 of 4)

Ckt Ref.	Description	Mfr *	ⓗⓟ Stock No.	TQ*	RS*		
BT1, 2	Battery, mercury cell: 4V, TR 233R	37942	1420-0005	2	2		
BT3	Battery, mercury cell: 5.33V, TR 234	37942	1420-0006	1	1		
C1	Not assigned						
C2	Capacitor: fixed, electrolytic, 200 μf -10% +100%, 3 vdcw	56289	0180-0060	1	1		
C3	Capacitor: fixed, electrolytic, 500 μf -10% +100%, 3 vdcw	56289	0180-0063	1	1		
C4, 5	Capacitor: fixed, ceramic, .01 μf ±20%, 1000 vdcw	56289	0150-0012	2	1		
C6	Capacitor: fixed, electrolytic, 10 μf -10% +100%, 25 vdcw	56289	0180-0059	2	1		

* See introduction to this section

Table 5-1. Replaceable Parts (Sheet 2 of 4)

Ckt Ref.	Description	Mfr *	ⓗⓟ Stock No	TQ*	RS
C7	Capacitor: fixed, ceramic, 5 pf ±10%, 500 vdcw Optimum value selected at factory Average value shown	96095	0150-0008	1	1
C8 thru C89	Not assigned				
C90, 91	Capacitor: fixed, electrolytic, 40 μf -15% + 100%, 50 vdcw	56289	0180-0050	2	1
C92	Capacitor: fixed, electrolytic, 100 μf -10% + 100%, 15 vdcw	56289	0180-0061	1	1
C93	Same as C6				
C94	Capacitor: fixed, electrolytic, 100 μf, 12 vdcw	56289	0180-0039	1	1
CR1	Diode, silicon: breakdown	28480	G-29A-17	1	1
CR2 thru CR89	Not assigned				
CR90, 91	Diode, germanium: 1N38A	08792	1910-0002	2	2
CR92	Diode, silicon	28480	G-31A-15L	1	1
J1	Connector, female: red	00373	1251-0131	1	1
J2	Connector, female: black	00373	1251-0132	1	1
P1	Connector, male: output	24655	1250-0092	1	1
P2 thru P89	Not assigned				
P90	Cable, power	70903	8120-0037	1	1
Q1, 2	Transistor: 2N1516/OC170	73445	1850-0003	2	2
Q3 thru Q89	Not assigned				
Q90	Transistor: 2N650	04713	1850-0048	1	1
R1 thru R4	Resistor: fixed, composition, 24 ohms ±5%, .1 W	01121	0674-0002	4	1
R5	Resistor: fixed, composition, 22 ohms Part of Probe Ground Lead Assembly Component not separately replaceable				

* See introduction to this section

Table 5-1. Replaceable Parts (Sheet 3 of 4)

Ckt Ref.	Description	Mfr *	ⓗⓟ Stock No.	TQ*	RS*		
R6	Resistor: fixed, composition, 2.7 ohms ±10%, 1/2 W	01121	0699-0001	2	1		
R7	Resistor: fixed, composition, 3300 ohms ±10%, 1/2 W	01121	0687-3321	1	1		
R8	Resistor: fixed, composition, 2700 ohms ±10%, 1/2 W	01121	0687-2721	1	1		
R9	Resistor: variable, composition, linea taper, 100 ohms ±30%, 1/3 W	71450	2100-0108	1	1		
R10	Resistor: fixed, composition, 100 ohms ±10%, 1/2 W	01121	0687-1011	1	1		
R11	Same as R6						
R12	Resistor: fixed, deposited carbon, 392 ohms ±1%, 1/2 W	19701	0727-0301	1	1		
R13	Resistor: fixed, composition, 180 ohms ±10%, 1/2 W Optimum value selected at factory Average value shown	01121	0687-1811	1	1		
R14	Resistor: fixed, composition, 2400 ohms ±5%, 1/2 W	01121	0686-2425	1	1		
R15 thru R89	Not assigned						
R90	Resistor: fixed, composition, 15,000 ohms ±10%, 2 W	01121	0693-1531	1	1		
R91	Resistor: fixed, composition, 680 ohms ±10%, 1/2 W	01121	0687-6811	1	1		
R92	Resistor: fixed, composition, 10,000 ohms ±10%, 1/2 W	01121	0687-1031	1	1		
R93	Resistor: fixed, composition, 6800 ohms ±10%, 1/2 W	01121	0687-6821	1	1		
R94	Resistor: fixed, deposited carbon, 4000 ohms ±1%, 1/2 W	19701	0727-0132	1	1		
R95	Resistor: fixed, deposited carbon, 2250 ohms ±1%, 1/2 W	19701	0727-0120	1	1		
S1	Switch, slide: DPDT	42190	3101-0011	1	1		
T1 thru T89	Not assigned						
T90	Transformer, power	28480	9100-0120	1	1		

* See introduction to this section

Table 5-1. Replaceable Parts (Sheet 4 of 4)

Ckt Ref.	Description	Mfr *	Stock No.	TQ	RS*		
	MISCELLANEOUS						
	Battery holder: 4 cell	28480	G-64B	1	0		
	Battery holder: 6 cell	28480	G-64C	1	0		
	Brush, nylon (electric razor brush)		8520-0017	1	0		
	Cable Assembly: output consists of:	28480	456A-16A	1	1		
	Cable, delay line, 2 ft. long	99109	8120-0048	1	0		
	Plug, male	24655	1250-0091	1	0		
	Connector, male	24655	1250-0092	1	0		
	Can, shield	28480	456A-55A	1	0		
	Boot, cable	28480	412A-83A	1	0		
	Spacer, standoff	00866	0380-0048	1	0		
	Lead, probe ground includes R5	28480	456A-21A-1	1	1		

* See introduction to this section