

INSTRUCTION MANUAL

**MODEL 410A**

PICOAMMETER

KEITHLEY INSTRUMENTS



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INSTRUCTION MANUAL

MODEL 410A

Picoammeter

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## SPECIFICATIONS

**RANGE:**  $3 \times 10^{-13}$  ampere full scale to  $10^{-3}$  ampere in twenty 1x and 3x ranges, positive or negative currents.

**ACCURACY:**  $\pm 2\%$  of full scale on  $10^{-3}$  to  $10^{-8}$  ampere ranges;  $\pm 4\%$  of full scale on  $3 \times 10^{-9}$  to  $3 \times 10^{-13}$  ampere ranges.

**ZERO DRIFT:** Less than 0.5% of full scale per week plus 0.02% per  $^{\circ}\text{C}$  on  $10^{-3}$  to  $10^{-12}$  ampere ranges; less than 1.5% per week plus 0.06% per  $^{\circ}\text{C}$  on  $3 \times 10^{-13}$  ampere range after a 10-minute warm-up with source voltages greater than 1 volt.

**OFFSET CURRENT:** Less than  $10^{-14}$  ampere.

**INPUT VOLTAGE DROP:** Less than 1 millivolt for full-scale meter deflection on any range when properly zeroed.

**EFFECTIVE INPUT RESISTANCE:** Less than 1 ohm on  $10^{-3}$  ampere range, increasing to less than  $3 \times 10^9$  ohms on  $3 \times 10^{-13}$  ampere range.

**RISE TIME, MAXIMUM:** Seconds, from 10% to 90%.

| Range,<br>ampere    | With up to 500 pF<br>Across Input | With up to 5000 pF<br>Across Input |
|---------------------|-----------------------------------|------------------------------------|
| $10^{-12}$          | 2.5                               | 12                                 |
| $10^{-11}$          | 1.0                               | 2                                  |
| $10^{-10}$          | 0.25                              | 0.4                                |
| $10^{-9}$           | 0.1                               | 0.1                                |
| $10^{-8}$           | 0.1                               | 0.1                                |
| $10^{-7}$ and above | less than 0.001                   | less than 0.001                    |

**MAXIMUM INPUT OVERLOAD:**

**Transient:** 1000 volts for up to 3 seconds using a Keithley (or other 10 mA limited) High Voltage Supply.

**Continuous:** 600 volts on  $3 \times 10^{-13}$  to  $10^{-6}$  ampere ranges, decreasing to 12 volts on the  $10^{-2}$  ampere range.

**RECORDER OUTPUT:**

**Output:**  $\pm 1$  volt or 1 milliampere for full-scale meter deflection. Output polarity is opposite input polarity.

**Noise:** Less than 1% of full scale peak-to-peak on  $10^{-3}$  to  $10^{-11}$  ampere ranges, increasing to 5% peak-to-peak on  $3 \times 10^{-13}$  ampere range.

**CONNECTORS:** Input: Teflon-insulated UHF type.  
Output: Amphenol 80PC2F.

**POWER:** 105-125 or 210-250 volts (switch selected), 50-60 Hz, 5 watts.

**DIMENSIONS, WEIGHT:**  $5\frac{1}{2}$ " high x  $8\frac{1}{2}$ " wide x 10" deep; net weight, 10 pounds.

**ACCESSORIES SUPPLIED:** Mating input and output connectors.



## KEITHLEY INSTRUMENTS, INC.

INSTRUCTION MANUAL  
CHANGE NOTICE  
MODEL 410A PICOAMMETER

INTRODUCTION: Since Keithley Instruments is continually improving product performance and reliability, it is often necessary to make changes to Instruction Manuals to reflect these improvements. Also, errors in Instruction Manuals occasionally occur that require changes. Sometimes, due to printing lead time and shipping requirements, we can't get these changes immediately into printed Manuals. The following new change information is supplied as a supplement to this Manual in order to provide the user with the latest improvements and corrections in the shortest possible time. Many users will transfer this change information directly to a Manual to minimize user error. All changes or additions are indicated in *italics*.

CHANGES:PAGE 19

|      |                        |            |               |              |          |
|------|------------------------|------------|---------------|--------------|----------|
| Q103 | <i>PNP, Case R-110</i> | <i>F-I</i> | <i>S17638</i> | <i>TG-33</i> | <i>7</i> |
| Q104 | <i>PNP, Case R-110</i> | <i>F-I</i> | <i>S17638</i> | <i>TG-33</i> | <i>7</i> |

\*\*Replace Q101, Q102 or R116 by ordering Plug-in board 23733.

## SECTION 1. GENERAL DESCRIPTION

## 1-1. GENERAL.

a. The Keithley Model 410A is a sensitive, completely solid-state picoammeter which measures currents over 20 ranges from  $10^{-3}$  to  $3 \times 10^{-13}$  ampere full scale. Accuracy is  $\pm 2\%$  of full scale on the  $10^{-3}$  to  $10^{-8}$  ampere ranges and  $\pm 4\%$  of full scale on the  $3 \times 10^{-9}$  to  $3 \times 10^{-13}$  ampere ranges.

b. The Picoammeter employs matched MOS FET transistors in the input followed by a differential amplifier stage, a transistor driver and a transistor output stage. Negative feedback is used for stability and accuracy.

## 1-2. FEATURES.

a. A unique circuit provides complete overload protection for Model 410A without compromising the outstanding features of the MOS FET input. The Picoammeter will withstand transient overloads up to 1000 volts without damage, and overload recovery is almost instantaneous.

b. The time and temperature stability of the Model 410A Picoammeter is excellent. The Model 410A will operate for days without requiring rezeroing. Zero drift with time is less than 0.5% of full scale per week. Temperature drift is equally small — a change of  $10^{\circ}\text{C}$  affects the reading less than 0.2% of full scale on the  $10^{-3}$  to  $10^{-12}$  ampere ranges.

c. Fast warm-up is an inherent characteristic of the Picoammeter. It can be used almost immediately on its most sensitive range. For maximum stability, however, about 10 minutes warm-up should be allowed.

d. One volt or 1 milliampere at full scale deflection on all ranges is provided to drive chart recorders. The 1 milliampere recorder output will drive the Keithley 370 Recorder directly. When potentiometric recorders are used, the output voltage can be conveniently divided by a shunt resistor and adjusted for full scale with the rear panel Calibration potentiometer.





TABLE 2. Model 410A Front Panel Controls (Figure 1).

| Control           | Functional Description                                     | Par.    |
|-------------------|--|---------|
| AMPERES Switch    | Selects full-scale current range instrument is to measure. | 2-2     |
| METER Switch.     | Turns instrument on; selects meter polarity.               | 2-2,2-4 |
| ZERO ADJ. Control | Zeroes meter on any range.                                 | 2-2     |
| Pilot Light       | Glowes to indicate instrument is on.                       | ---     |
| ZERO CHECK Button | Checks zero on any range.                                  | ---     |

TABLE 3. Model 410A Rear Panel Controls (Figure 2).

| Control           | Functional Description  | Par.    |
|-------------------|---|---------|
| INPUT Receptacle  | Connects input to source. Receptacle is a Teflon-insulated UHF connector. | 2-1,2-2 |
| OUTPUT Receptacle | Connects output to monitoring device.                                     | 2-4     |
| 1 MA — 1 V Switch | Selects output of instrument: 1 milliamperere or 1 volt.                  | 2-4     |
| 1 MA CAL Control  | Adjusts output from 0.95 to 1.05 mA.                                      | 2-4     |
| 117-234 V Switch  | Sets instrument for 117 or 234 volt ac power line.                        | 2-2,2-5 |
| Fuse              | 3AG Slow-Blow. 117 volt - .125 A; 234 volt - .062 A.                      | 2-5     |

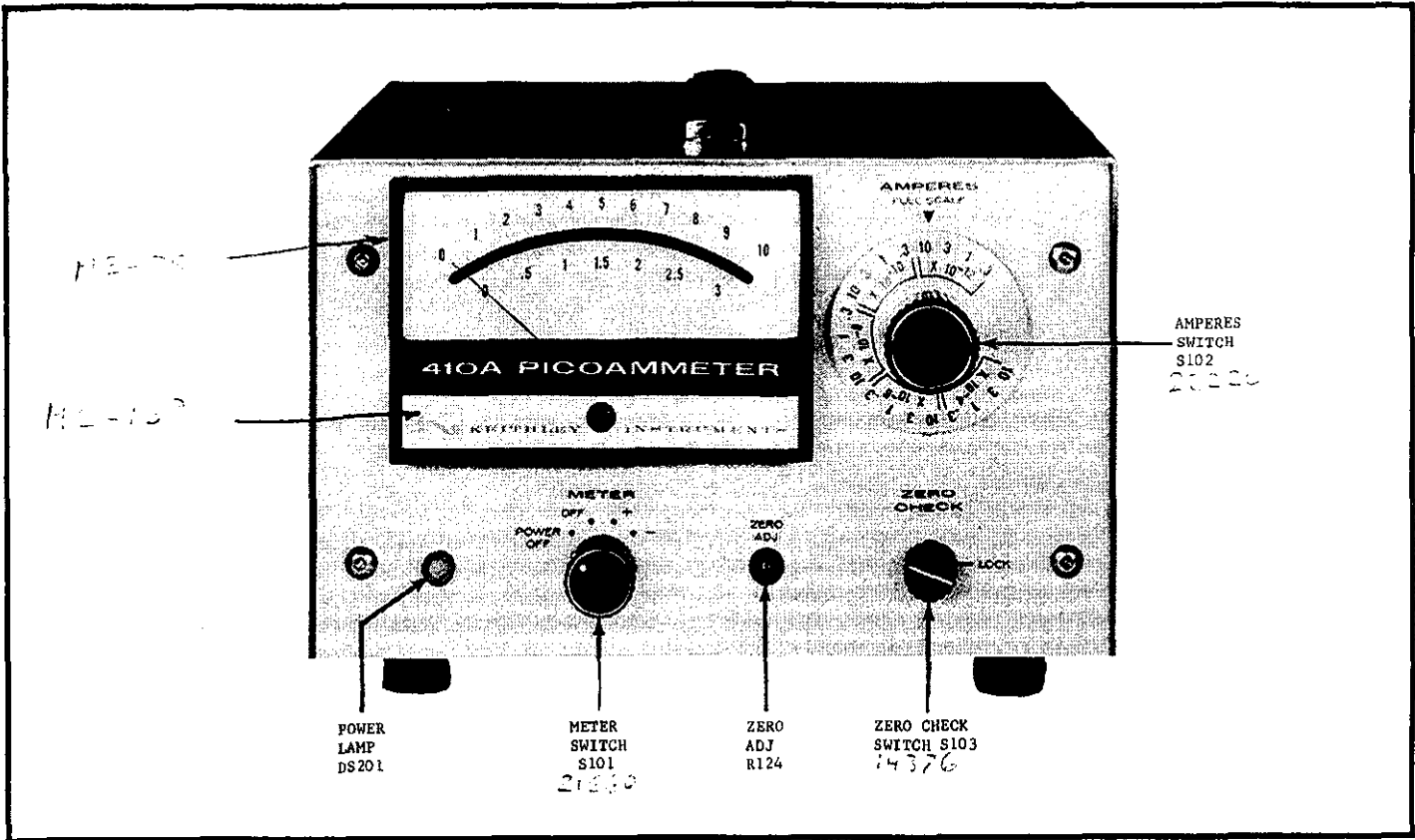


FIGURE 1. Front Panel Controls.

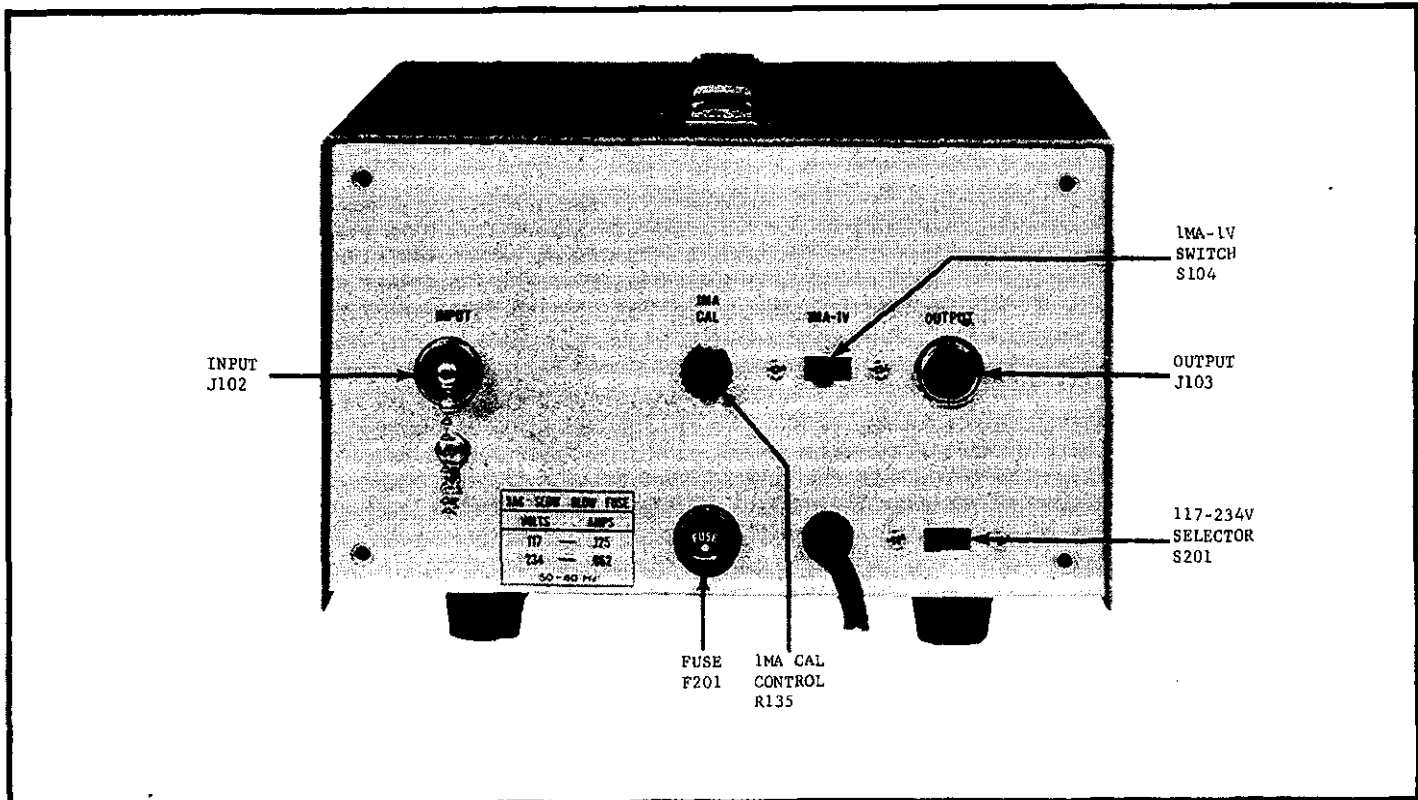


FIGURE 2. Rear Panel Controls.

## SECTION 2. OPERATION

2-1. INPUT CONNECTIONS. Use the following precautions when using the Picoammeter on the more sensitive ranges.

a. The INPUT Receptacle of the Model 410A is a Teflon-insulated UHF connector. The center terminal is the high impedance terminal, and the outer shield is case ground.

b. Carefully shield the input connection and the current source being measured, since power line frequencies are well within the pass band of the Picoammeter on all ranges. Unless the shielding is thorough, pick-up may cause definite meter disturbances.

c. Use high resistance, low-loss materials — such as polyethylene, polystyrene or Teflon — for insulation. The insulation resistance of test leads and fixtures should be several orders of magnitude higher than the source resistance. Excessive leakage will reduce accuracy. Any coaxial cable used should be a low-noise type which employs a graphite coating between the dielectric and the surrounding shield braid.

d. Any change in the capacitance of the measuring circuit to ground will cause disturbances in the reading, especially on the more sensitive ranges. Make the measuring setup as rigid as possible, and tie down connecting cables to prevent their movement. If a continuous vibration is present, it may appear at the output as a sinusoidal signal and other precautions may be necessary to isolate the instrument and the connecting cable from the vibration.

### 2-2. OPERATING PROCEDURES.

a. Check the fuse and the 117-234 Line Switch for the proper line voltage.

b. Connect the power cord to the power source.

c. Set the AMPERES Switch to  $10 \times 10^{-4}$  ampere and the METER Switch to (+). Within seconds the meter needle should read zero. Zero the meter with the ZERO ADJ. Control. After a few moments increase the current sensitivity by advancing the AMPERES Switch in decade steps to the  $.3 \times 10^{-12}$  ampere range. Continue zeroing with the ZERO ADJ. Control. The instrument is now ready to use.

d. If long term measurements are to be made, allow the instrument to warm up for at least 10 minutes.

e. Attach the current source to the INPUT Receptacle and turn the METER Switch to the polarity of the input signal, + or -. Increase sensitivity with the AMPERES Switch until the greatest on scale deflection is achieved.

1. When the AMPERES Switch is set to 10, 1, 0.1, etc. positions, use the upper meter scale. Full scale current range is equal to the AMPERES Switch setting.

2. When the AMPERES Switch is set to 3, 0.3, 0.03, etc. positions, use the lower meter scale. Full scale current range is equal to the AMPERES Switch setting.

### 2-3. MEASUREMENT CONSIDERATIONS.

a. The Picoammeter employs the fast method of current measurement — the measuring resistor is between the amplifier input and output in the feedback loop. This method largely neutralizes the effect of input capacity and greatly increases the response speed. Also, the input voltage drop is reduced to a maximum of one millivolt on any range.

b. Rise time varies with the current range and the input capacity (see specifications, Table 1). The rise time, though, is not affected with up to 500 picofarads across the input; however, it is better to place the Picoammeter nearer the current source than to the data reading instrument. Transmitting the input signal through long cables — with greater than 500 picofarads of capacitance — will increase response time and meter noise, especially on ranges below  $10^{-10}$  ampere.

c. The internal resistance of the unknown source should not be less than the reciprocal of the current range being used, otherwise the zero stability will be affected. The instrument will still be operable, however, but the sensitivity will be approximately

$$R_f/R_s \quad \text{Equation 1.}$$

where  $R_f$  is the feedback resistance in ohms;  
and  $R_s$  is the source resistance in ohms.

For example, if the source to be measured has a resistance of  $10^5$  ohms and the current is  $10^{-6}$  then the feedback resistor will be  $10^6$  ohms. This means that the gain of the Picoammeter is  $10^6/10^5 = 10$ . Then the zero stability of .5%/week will be  $.5\% \times 10 = 5\%$ /week, and the offset due to temperature will be  $.02\% \times 10 = .2\%$ /°C. This is the reason that it is advantageous to have the source resistance at least equal to the feedback resistor.

TABLE 4.  
Allowable Overloads on Ranges Above  $10^{-6}$  Ampere.

| Range       | Max. Continuous Voltage Overload | Max. Continuous Current Overload |
|-------------|----------------------------------|----------------------------------|
| $10^{-5}$ A | 300 V                            | 1 mA                             |
| $10^{-4}$ A | 120 V                            | 4 mA                             |
| $10^{-3}$ A | 30 V                             | 10 mA                            |
| $10^{-2}$ A | 12 V                             | 40 mA                            |

d. **Overload Protection.** A unique circuit provides complete overload protection for the Model 410A without compromising the features of the MOS FET input. Overload recovery is almost instantaneous on the  $10^{-10}$  ampere range and above. However, on the more sensitive ranges, especially on the  $3 \times 10^{-13}$  ampere range, the instrument may develop considerable offset which may take anywhere from a few minutes to a few hours to disappear.

1. On the  $10^{-6}$  ampere range and below the Picoammeter can withstand overloads of up to 1000 volts for 3 seconds and continuous overloads of up to 600 volts without damage.

2. For ranges above  $10^{-6}$  ampere, the maximum continuous overload is restricted due to the power dissipation of the feedback resistors (See Table 4).

3. For maximum protection, use a Keithley Model 240A Voltage Supply or some other 10 milliamper current limited supply in combination with the Picoammeter.

#### 2-4. RECORDER OUTPUTS.

a. For recording with the Model 410A, use the Keithley Model 370 Recorder for ease, economy, versatility and performance. The Model 370 is a pen recorder with 10 chart speeds and 1% linearity. The Model 370's input cable has a connector which mates directly with the OUTPUT Connector on the Picoammeter; this avoids interface problems often encountered between a measuring instrument and a recorder. The Picoammeter output, when set to the 1 MA Position, will drive the 370; no preamplifier is needed. No special wiring is required.

b. Other recorders, oscilloscopes and similar instruments can be used with the Model 410A. The Picoammeter has two outputs,  $\pm 1$  volt and  $\pm 1$  milliamper, to amplify signals for recorders, oscilloscopes and similar instruments. These can be used on all ranges.

c. **1-Volt Output.** Connect oscilloscopes and pen recorder amplifiers to the OUTPUT Receptacle. Pin no. 1 is the high terminal and pin no. 2 is ground. Set the 1 MA - 1 V Switch to 1 V. The Picoammeter output is now  $\pm 1$  volt for full scale meter deflection on any range. Internal resistance is approximately 1 kilohm. Noise is less than 1% of full scale peak-to-peak on the  $10^{-3}$  to  $10^{-11}$  ampere ranges, increasing to 5% peak-to-peak on the  $3 \times 10^{-13}$  ampere range. The METER Switch does not reverse the output polarity. Output polarity is always opposite input polarity.

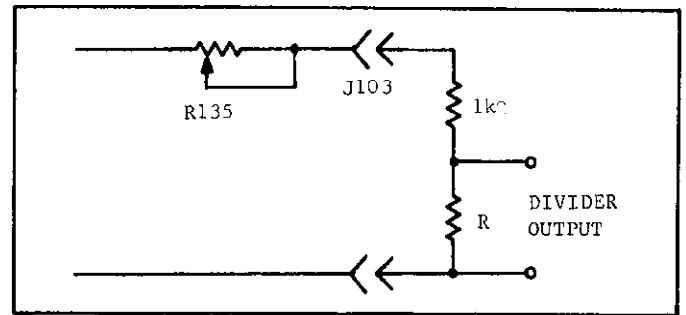


FIGURE 3. Divider Circuits Across Picoammeter Output for Driving 50 and 100-millivolt Recorders. Use 5% resistors in the dividers. The value of resistor R is one ohm for every 1 mV of output.

d. **1-Milliamper Output.** Connect 1-milliamper instruments to the OUTPUT Receptacle. Pin no. 1 is the high terminal. Set the 1 MA - 1V Switch to 1 MA. The output is approximately 1 milliamper for full-scale meter deflection on any range. For exact output, apply a known full scale signal to the Picoammeter and adjust the 1 MA CAL Control until the recorder reads full scale. Check the Recorder and meter zero and repeat adjustment if necessary. The METER Switch does not reverse the output polarity which is always opposite input polarity.

e. For servo rebalance recorders, use a divider across the Picoammeter Output Receptacle. See Figure 3. Set the OUTPUT Switch to 1 MA. Use the 1 MA CAL Control to trim the output for full-scale recorder deflection. Operation is the same as for current outputs.

2-5. **234-VOLT OPERATION.** The instrument is shipped for use with a 117-volt power source unless otherwise ordered. To convert the Picoammeter for 234-volt sources, use a screwdriver to change the slide switch on the back panel to the 234-volt position. Change the fuse from 0.125 ampere to .062 ampere. No other adjustment is necessary. To switch from 234 to 117-volt operation, reverse the procedures.

## SECTION 3. CIRCUIT DESCRIPTION

3-1. GENERAL. The Keithley Model 410A is a linear dc amplifier with a full scale sensitivity of 0.3, 1 or 3 volts. By using the front panel controls, shunt resistors are selected to make measurements over a total of 20 current ranges.

## 3-2. AMMETER OPERATION.

a. The amplifier has matched insulated-gate field-effect transistors followed by a differential transistor stage, a transistor amplifier and a transistor output stage. Figure 4 shows the simplified circuit for the Picoammeter.

b. If it is assumed that the input voltage drop,  $e_{in}$ , is negligible, then all the input current,  $i_{in}$ , flows through the measuring resistor,  $R_s$ , and

$$e_o = -i_{in} R_s \quad \text{Equation 2.}$$

But the output voltage,  $e_o$ , is also equal to the input voltage times the amplifier gain.

$$e_o = -A e_{in} \quad \text{Equation 3.}$$

Therefore, from equation 2 and 3, we get

$$e_{in}/i_{in} = R_s/A \quad \text{Equation 4.}$$

where  $e_{in}/i_{in}$  is the effective input resistance.

Thus, the input voltage drop is kept at a small fraction,  $1/A$ , of the output voltage, and the effective input resistance is  $1/A$  of the measuring resistor.

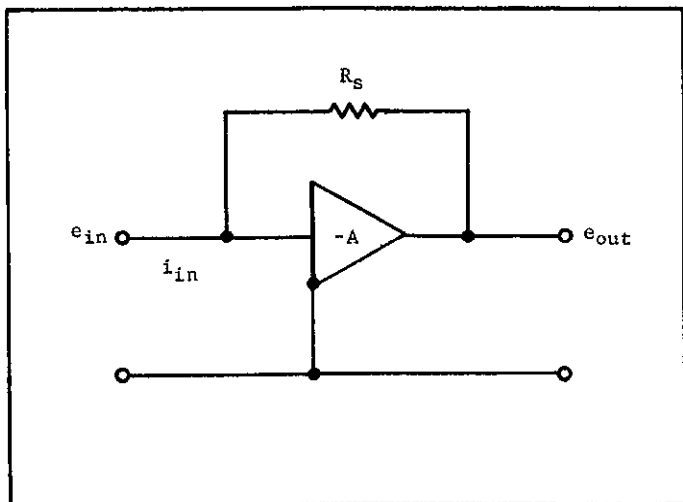


FIGURE 4. Simplified Diagram for Ammeter Circuit.

## 3-3. AMMETER CIRCUIT.

a. Two matched insulated-gate field-effect transistors, Q101 and Q102, are used for the amplifier input. Resistors R115 and R116 and circuit designation 21850B (see schematic) protect the gate of transistor Q101, the active field-effect transistor, from overloads. The gate of Q102 is returned to amplifier ground.

## NOTE

Refer to Schematic Diagram 22547E for circuit designations.

b. Turning the ZERO CK. Button to LOCK places a short from the input to the output and zeroes the instrument.

c. A differential amplifier stage, transistors Q103 and Q104, drives an amplifier stage, transistor Q105, which in turn drives the output emitter follower, transistor Q106.

d. Two zero controls are used. The Coarse Zero Control, R120, varies the source voltage of transistor Q101 with respect to the transistor Q102. The ZERO ADJ Control, R124, varies the drain voltage of transistor Q101 with respect to transistor Q102.

e. The DC Bal Potentiometer, R121, sets the drain current through transistors Q101 and Q102 by adjusting the source bias.

f. The voltage drop across R117 plus R118 plus R119, R118 plus R119, or R119 alone determines the full scale sensitivity of the amplifier — either 3 volts from  $10 \times 10^{-4}$  through  $3 \times 10^{-8}$ ,  $.3 \times 10^{-8}$ ,  $.3 \times 10^{-10}$  and  $3 \times 10^{-12}$  or 1 volt on  $10^{-8}$ ,  $10 \times 10^{-10}$ ,  $1 \times 10^{-10}$  and  $10 \times 10^{-12}$  ranges or .3 volt on  $.3 \times 10^{-12}$  ampere range. Applying a full scale signal to the input causes a 1 milliamper current to flow through R117, R118 and R119. The meter is connected across the 3-volt output. Resistors R131 and R132 set the meter current.

g. The full scale current sensitivity is determined by the range resistors R101 through R114 in combination with resistors R117, R118 and R119. The current measuring resistor is connected in the feedback loop. This configuration increases the response speed by minimizing the effects of input capacity. It also reduces the input voltage drop to less than 1 millivolt.

h. The 1 volt recorder output is derived from 1 milliamper flowing through resistor R136. In the 1 milliamper output mode an external load is substituted for R136. Potentiometer R135 varies the current to the external load.

## SECTION 4. SERVICING

4-1. GENERAL. Section 4 contains the maintenance and troubleshooting procedures for the Model 410A Picoammeter. Follow these procedures as closely as possible to maintain the performance of the instrument.

4-2. SERVICING SCHEDULE. The value of the high-megohm resistors, R111 through R114, should be checked approximately every six months for specified accuracy. Except for this the Model 410A requires no periodic maintenance beyond the normal care required of high-quality electronic equipment.

### 4-3. PARTS REPLACEMENT.

a. The Replaceable Parts List in Section 7 describes the electrical components of the Picoammeter. Replace components only as necessary. Use only reliable replacements which meet the specifications.

b. The MOS FET input transistors, Q101 and Q102, are specially selected and matched; order only as a plug-in unit, part number ~~23733~~, from Keithley Instruments, Inc. 23733

### 4-4. TROUBLESHOOTING.

a. The procedures which follow give instructions for repairing troubles which might occur in the Model 410A. Use the procedures outlined and use only specified replacement parts. Table 5 lists equipment recommended for troubleshooting. If the trouble cannot be readily located or repaired, contact Keithley Instruments, Inc., or its representative.

b. Table 6 contains the more common troubles which might occur. If the repairs indicated in the table do not clear up the trouble, find the difficulty

TABLE 5. Equipment Recommended for Model 410A Calibration and Troubleshooting. Use these instruments or their equivalents.

| Instrument  | Use   |
|---|---|
| Keithley Model 163 Digital Voltmeter.<br>1 $\mu$ V to 1000V, 0.1% accuracy  | General calibration.                          |
| Hewlett Packard 202A Function Generator   | Rise time check.                              |
| Keithley Instruments Model 153 Microvolt-Ammeter; 10 $\mu$ V to 1000 V, 200 M $\Omega$ input resistance; $\pm$ 1% accuracy; float $\pm$ 500 V off ground. | General circuit checking.                     |
| Keithley Instruments Model 261 Picoampere Source; 10 <sup>-14</sup> to 10 <sup>-4</sup> ampere.   | Source to calibrate current ranges.           |
| Keithley Instruments Model 2611 Test Cable; supplied with Model 261.  | Connecting cable for Models 410A and 261.     |
| Keithley Instruments Model 370 Recorder   | Monitor drift.                                |
| Keithley Instruments Model 515A Megohm Bridge   | Verify high megohm resistors in Range Switch. |
| Keithley Instruments Model 662 Guarded Differential Voltmeter; 100 $\mu$ V to 500 V, $\pm$ 0.01%.   | Calibrate Meter zero.                         |
| Shielded resistors of different values, and shielded 5 pF, 50 pF, 500 pF and 5000 pF polystyrene capacitors.  | Rise time check.                              |
| Tektronix Model 561A Oscilloscope   | Noise and rise time check.                    |

through a circuit-by-circuit check, such as given in paragraph 4-5. Refer to circuit description in Section 3 to find the more critical components and to determine their function in the circuit. The complete circuit schematic, 22547E, is in Section 7.

4-5. PROCEDURES TO GUIDE TROUBLESHOOTING.

a. If the instrument will not operate, check the power supplies. The typical voltage values, given on the schematic, are referenced to chassis ground. Make measurements with the Model 153 Microvolt Ammeter.

b. At times, the meter will not zero on any range with the METER Switch in the ZERO CK position. If this occurs, adjust the front panel ZERO ADJ. Control or, if necessary, the Coarse Zero Potentiometer, R120, located on the PC Board. If this does not work, inspect all PC boards for a possible break in the tapes. If these appear all right proceed with step c.

c. Amplifier.

1. To check the amplifier, disconnect the feedback loop by removing Q106, D102, D105 and R130 from the PC board. Check diodes D102 and D105

2. Connect a Model 153 between the bases of Q103 and Q104. Adjust the Coarse Zero Potentiometer, R120, and the front panel ZERO ADJ. Control for a null (it may be difficult to reach a steady null; however, it is sufficient to be able to swing through zero in a smooth manner). If this is not possible, remove Q103 and Q104 from the circuit and repeat the same process. If null can now be reached, replace Q103 and Q104. If it cannot be reached, Q101 and Q102 are faulty.

3. Check the next stage, Q105, by placing a Model 153 from the collector end of R129 to ground. Adjust the Model 410A Zero Controls for null. If this cannot be accomplished, check D101 for a possible open by shorting it with a clip lead. If null can now be reached, D101 is open and should be replaced. If null cannot be reached, replace Q105.

4. If null can now be attained at the collector of Q105, the trouble is in the output stage and Q106 should be replaced. If this does not cure the trouble, carefully check all the diodes associated with the output stage — D102, D103, D104 and D105

TABLE 6. Model 410A Troubleshooting.

| Difficulty                               | Probable Cause  | Solution                                |
|--|---|---|
| Excessive zero offset                    | Input transistors may be defective                                | Check Q101 and Q102; replace if faulty. |
|  | Power supply voltage low  | Check power supply.                     |
| Excessive offset current                 | Excessive temperature fluctuations or defective input transistors | Check Q101 and Q102; replace if faulty. |
| Cannot zero on any range                 | Refer to paragraph 4-5.   | Refer to paragraph 4-5.                 |
| Meter off scale on one of range settings | Faulty range resistor   | Check resistor; replace if faulty.      |
| One range out of specification           | Defective range resistor  | Check resistor; replace if faulty.      |

## SECTION 5. CALIBRATION

## 5-1. GENERAL.

a. The following procedures are recommended for calibrating the Model 410A. Use the equipment recommended in Table 5. If proper facilities are not available or if difficulty is encountered, contact Keithley Instruments, Inc., or its representatives to arrange for factory calibration.

b. If the Model 410A is not within specifications after the calibration, follow the troubleshooting procedures or contact Keithley Instruments, Inc., or its representatives.

## 5-2. PRELIMINARY PROCEDURES.

a. Make sure the 1 MA - 1 V and 117-234 V Switches in the rear panel are set to 1 V and 117V respectively. Set the front panel controls as follows:

|                   |                     |
|-------------------|---------------------|
| AMPERES Switch    | $10 \times 10^{-4}$ |
| METER Switch      | POWER OFF           |
| ZERO ADJ. Control | Mid-range           |
| ZERO CHECK Button | Unlock.             |

b. Set the DC Bal Potentiometer, R121, Coarse Zero Potentiometer, R120, and Meter Cal. Potentiometer, R132, near mid-range.

c. Zero the meter with the Mechanical Zero Control.

d. Plug the Model 410A into a 117 volt source and set the METER Switch to + and check zero with the ZERO CHECK Button.

1. If the Model 410A is operative, then the meter should read on scale for either polarity (+ or -). Adjust the Coarse Zero Potentiometer for a zero indication on the meter.

2. If the Coarse Zero Potentiometer, R120, can not zero the meter, check for a shorted heat sink on the MOS FET transistors, Q101 and Q102. The two halves of the heat sink must be insulated in order for the Coarse Zero Potentiometer to function properly.

5-3. POWER SUPPLY CHECK. (See Figure 6 for test points for the Power Supplies.

a. Check the positive and then the negative 26 volt supply by connecting the Model 163 between ground and the plus and minus 26 volt test points respectively (Fig. 6). The voltage should be plus and minus 26 volts  $\pm 3$  volts respectively. The ripple in each case should be less than 3 volts peak-to-peak.

b. Check the positive and then the negative 15 volt supplies by connecting the Model 163 between ground and the plus and minus 15 volt test points respectively (Figure 6). The voltage for the plus and minus 15 volt supplies should be plus and minus 15 volts  $\pm 2.0$  volts respectively. The ripple in each case should be less than 20 mV peak-to-peak.

c. Check the positive and then the negative 9 volt supplies by connecting the Model 163 between ground and the plus and minus 9 volt test points respectively (Figure 6). The voltage for these supplies must be plus and minus 9 volts  $\pm 1.0$  volt respectively. The ripple in each case should be less than 3 mV peak-to-peak.

d. Monitor the plus and minus 15 volt supplies as the line voltage is changed from 105 volts ac to 125 volts ac. The voltage change of the plus and minus 15 volt supplies should be less than  $\pm 0.2$  volt.

e. Turn the Model 410A off and prepare the Picoammeter for 234 volt, 50 Hz operation. Plug the Model 410A into a 220 volt ac, 50 Hz line and check the positive and negative 25 volt supplies per paragraph 5-3a above. The same readings as in subparagraph a above should be obtained except that an additional 1 volt tolerance should be allowed for each 10 volt difference between 234 volts ac and the actual line voltage.

## NOTE

The remaining calibration procedures should all be performed with the Model 410A operating from 117 volts ac, 60 Hz.



5-4. MOS FET CURRENT ADJUST.

- a. Set the Picoammeter AMPERES Switch to  $10 \times 10^{-4}$ , the METER Switch to + and check zero with the ZERO CHECK Button.
- b. Set the front panel ZERO ADJ. Control to approximately mid-range and adjust the Coarse Zero Potentiometer, R120, for a zero indication on the meter.
- c. Connect the Model 163 DVM across resistor R123 and adjust the DC BAL Potentiometer, R121, for an indication of -5.4 volts  $\pm 0.2$  volt.

NOTE

When making this measurement, be certain that the DVM common is above ground.

5-5. OFFSET CHECK.

- a. Set the Picoammeter AMPERES Switch to  $10 \times 10^{-4}$ , the METER Switch to + and check zero with the ZERO CHECK Button. Cap the INPUT Receptacle and connect the Model 410A to the Model 163 DVM.

NOTE

When checking the offset make sure the Model 410A cover is on.

- b. If necessary, adjust the ZERO ADJ. Control for zero volts at the output.
- c. Set the AMPERES Switch to  $.3 \times 10^{-12}$ . Make sure that the output remains at zero volts, adjusting the front panel ZERO ADJ. Control if necessary.
- d. Unlock the ZERO CHECK Button. Output voltage should be less than 33 mV ( $10^{-14}$  ampere). If the Meter has been calibrated, the offset should be less than two minor divisions on the lower meter scale.

5-6. METER AND IMA OUTPUT CALIBRATION.

- a. Set the AMPERES Switch to  $1 \times 10^{-6}$ . Connect the Model 261 Picoampere Source to the Model 410A INPUT Receptacle and connect the Model 163 DVM to the OUTPUT Receptacle.
- b. Set the Model 410A METER Switch to + and apply  $10^{-6}$  ampere with the Model 261. If necessary, adjust the ZERO ADJ. Control for exactly 1.000 volt at the output.
- c. Adjust the Meter Cal Potentiometer, R132, for full scale meter deflection.
- d. Load the Model 410A output with a 1.5 kilohm resistor and set the 1 V - 1 MA Switch to 1 MA.
- e. Adjust the rear panel 1 MA CAL Control and note that the output voltage can be adjusted at least 0.1 volt either side of 1.5 volts.
- f. Remove the 1.5 kilohm load and set the 1 V - 1 MA Switch to 1 V.
- g. Check zero with the ZERO CHECK Button and re-zero the output if necessary.

5-7. RANGE ACCURACY CHECK.

- a. Connect the Model 410A INPUT Receptacle to the Model 261. Connect the OUTPUT Receptacle to the Model 163.
- b. Check the full-scale accuracy of all positions on the AMPERES Switch. Check both positive and negative inputs to ensure proper operation of both polarities at various current input levels. Check the accuracy of the  $10 \times 10^{-4}$  through the  $1 \times 10^{-8}$  ranges to  $\pm 2\%$  of full scale at the output (1.0 volt  $\pm 20$  millivolts). Check the accuracy of the  $.3 \times 10^{-8}$  through the  $.3 \times 10^{-12}$  ranges to  $\pm 4\%$  of full scale at the output (1.0 volt  $\pm 40$  millivolts).

5-8. RISE TIME CHECK. To check the rise time of the Model 410A requires three different test set-ups. The first set-up is for checking rise times on the  $10 \times 10^{-4}$  through  $1 \times 10^{-8}$  ranges. The second set-up is for checking the rise times on the  $10 \times 10^{-10}$  and  $1 \times 10^{-10}$  ranges. The third set-up is for checking the rise times on the  $10 \times 10^{-12}$  and  $1 \times 10^{-12}$  ranges.

- a.  $10 \times 10^{-4}$  through  $1 \times 10^{-8}$  ranges. Set the test fixture up as illustrated in Figure 5.

1. Equipment used (Refer to Table 5): The Model 202A Function Generator, six shielded resistors ranging in value from 3 kilohms to 300 megohms (See Table 8), a UHF Tee connector, a 500 pF polystyrene shunt capacitor, the Model 410A and the Model 561A Oscilloscope. The oscilloscope used must be dc coupled.

2. Procedures:

- a) Apply a square wave from the Model 202A Function Generator across the selected series resistor, through the UHF Tee to the Model 410A INPUT Receptacle. Observe the output of the Model 410A with the Model 561A.
- b) For each Model 410A range, use the Model 202A frequency setting and the series resistor indicated in Table 8.

TABLE 8. Model 410A Rise Time Check for  $10 \times 10^{-4}$  Through  $1 \times 10^{-8}$  Ranges. The Table gives the Model 410A AMPERE Switch settings, the Function Generator frequency settings, the series resistor used for each AMPERE Switch setting, and the maximum allowable rise time.

| Model 410A AMPERE Switch Setting | Series Resistors | Function Generator Frequency (Hz) | Maximum Rise Time (milliseconds) |
|----------------------------------|------------------|-----------------------------------|----------------------------------|
| $10 \times 10^{-4}$              | 3 k $\Omega$     | 250                               | less than 1                      |
| $1 \times 10^{-4}$               | 30 k $\Omega$    | 250                               | less than 1                      |
| $10 \times 10^{-6}$              | 300 k $\Omega$   | 250                               | less than 1                      |
| $1 \times 10^{-6}$               | 3 M $\Omega$     | 250                               | less than 1                      |
| $10 \times 10^{-8}$              | 30 M $\Omega$    | 250                               | less than 1                      |
| $1 \times 10^{-8}$               | 300 M $\Omega$   | 2.5                               | 130                              |

b.  $10 \times 10^{-10}$  and  $1 \times 10^{-10}$  ranges. Set this test fixture up as illustrated in Figure 5, except use a 5000 pF shunt capacitor and substitute a shielded 50 pF polystyrene capacitor for the series resistors between the Function Generator and the UHF Tee.

1. Equipment Used: This test set-up uses the same equipment of the previous set-up with the exception of the 5000 pF and 50 pF polystyrene capacitors. The 50 pF series capacitor in this set-up serves a similar function as the series resistors in the previous test set-up.

2. Procedures:

a) Apply a triangular wave from the Model 202A across the capacitor, through the UHF Tee to the Model 410A INPUT Receptacle. Monitor the Model 410A output with the Model 561A. Use the proper Model 202A frequency setting as indicated in Table 9.

b) Adjust the Model 202A amplitude control as needed to obtain 2 volts peak-to-peak at the Model 410A output. Check the 10 - 90% rise time to the figures shown in Table 9.

TABLE 9. Model 410A Rise Time Check for  $10 \times 10^{-10}$  and  $1 \times 10^{-10}$  Ranges. The Table gives the Model 410A AMPERE Switch settings, the Function Generator frequency settings, and the maximum allowable rise time.

| Model 410A AMPERE Switch Setting | Function Generator Frequency (Hz) | Maximum Rise Time (milliseconds) |
|----------------------------------|-----------------------------------|----------------------------------|
| $10 \times 10^{-10}$             | 2.5                               | 100                              |
| $1 \times 10^{-10}$              | 1.0                               | 400                              |

c.  $10 \times 10^{-12}$  and  $1 \times 10^{-12}$  ranges. Set this test fixture up as in paragraph 5-8b above except use a 500 pF shunt capacitor and a 5 pF series capacitor between the Function Generator and the UHF Tee.

1. Equipment Used: Except for the values of the capacitors mentioned above, this set-up uses the same equipment as in paragraph 5-8b.

2. Procedures:

a) Set the Picoammeter AMPERES Switch to  $10 \times 10^{-12}$ . Apply a 0.5 Hz triangular wave from the Model 202A across the capacitor, through the UHF Tee to the Model 410A INPUT Receptacle.

b) Adjust the Model 202A amplitude control as needed to obtain 2 volts peak-to-peak at the Model 410A output. Check the 10 - 90% rise time on the Model 561A. It should be less than one second.

c) Set the Picoammeter AMPERES Switch to  $1 \times 10^{-12}$ . Apply a 0.05 Hz triangular wave from the Model 202A to the Model 410A.

d) Adjust the Model 202A amplitude control to obtain 2 volts peak-to-peak at the Model 410A output. Adjust the slide on resistor R114 to obtain between 2 to 2.5 seconds 10 - 90% rise time.

e) Replace the 500 pF shunt capacitor with a 5000 pF shunt capacitor.

f) Apply a triangular signal from the Function Generator to the Model 410A as listed in Table 10. Adjust the Model 202A amplitude control as needed to obtain 2 volts peak-to-peak at the Model 410A output. Check the 10 - 90% rise times to the figures in Table 10.

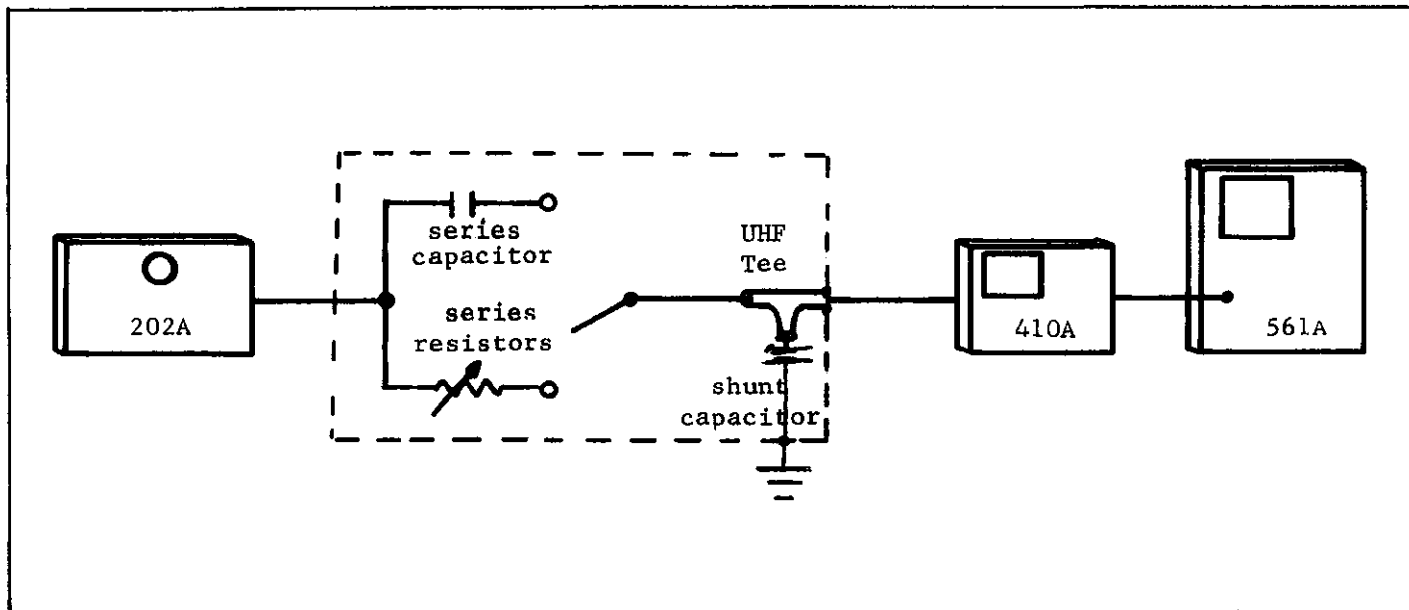


FIGURE 5. Test Set-up for Model 410A Rise Time Checks on all ranges. Make sure the series resistor or capacitor, and the UHF Tee and shunt capacitor are properly shielded.

TABLE 10. Model 410A Rise Time Check for  $10 \times 10^{-12}$  and  $1 \times 10^{-12}$  Ranges. The Table gives the Model 410A AMPERES Switch settings, the Function Generator frequency settings, and the maximum allowable rise time.

| Model 410A<br>AMPERES Switch<br>Setting | Function Generator<br>Frequency<br>(Hz) | Maximum<br>Rise Time<br>(seconds) |
|---|---|-----------------------------------|
| $10 \times 10^{-12}$                    | .05                                     | 2                                 |
| $1 \times 10^{-12}$                     | 02                                      | 12                                |

g) Cap the Model 410A INPUT Receptacle and check the output noise on the  $10 \times 10^{-12}$  and  $.3 \times 10^{-12}$  ranges. The noise must be less than 10 millivolts and 50 millivolts peak-to-peak respectively.

h) If the noise is high, readjust the  $10 \times 10^{-12}$  and  $1 \times 10^{-12}$  rise times prior to other corrective measures. High noise may be due to too fast rise times.

#### 5-9. NOISE CHECK.

a. Set the AMPERES Switch to  $10 \times 10^{-4}$ , METER Switch to + and check Picoammeter zero with the ZERO CHECK Button. Connect the Model 410A OUTPUT Receptacle to the Model 561A Oscilloscope and cap the Model 410A INPUT Receptacle. Set the oscilloscope to 5 mV/div dc coupled.

b. Unlock the ZERO CHECK Button and check the output noise on the  $10^{-4}$  through  $10^{-12}$  ampere ranges for less than 10 millivolts peak-to-peak.

c. Decrease the oscilloscope sensitivity to 10 or 20 mV/div dc coupled. Check the output noise on the  $3 \times 10^{-12}$  through  $.3 \times 10^{-12}$  ranges for less than 50 millivolts peak-to-peak.

#### 5-10. DRIFT VERIFICATION.

a. Shunt the Input of the Model 410A with a 10-kilohm resistor with the AMPERE Switch set to  $1 \times 10^{-6}$ , the METER Switch set to + or -, as necessary, and the ZERO CHECK Button unlocked. Using the shunt increases the sensitivity 100 times.

#### NOTE

While doing the drift run make sure the Model 410A cover is on.

b. Connect the Model 370 Recorder to the Model 410A. Set the Recorder attenuator to 1 volt (10 millivolts drift full scale) or 0.3 volts (3 millivolts full scale).

c. Set the METER Switch to + and adjust the ZERO ADJ Control for near zero volts output. The ZERO ADJ Control is very sensitive with the sensitivity increased 100 times. Set the METER Switch to - if the drift is negative.

d. After a 10-minute warm-up, the Model 410A may drift 700 microvolts per 24 hours plus or minus 200 microvolts per °C change in temperature.

e. In some cases, the 24-hour drift may appear marginal or it may be slightly out of specification due to a steep drift slope during the early part of the drift. If this is so, it may be desired to continue the drift for an additional 24 hours and calculate a weeks drift as follows:

1. Multiply drift during second 24-hour period times 6 and add the drift noted during the first 24-hour period.

2. Total drift should be less than 5 mV.

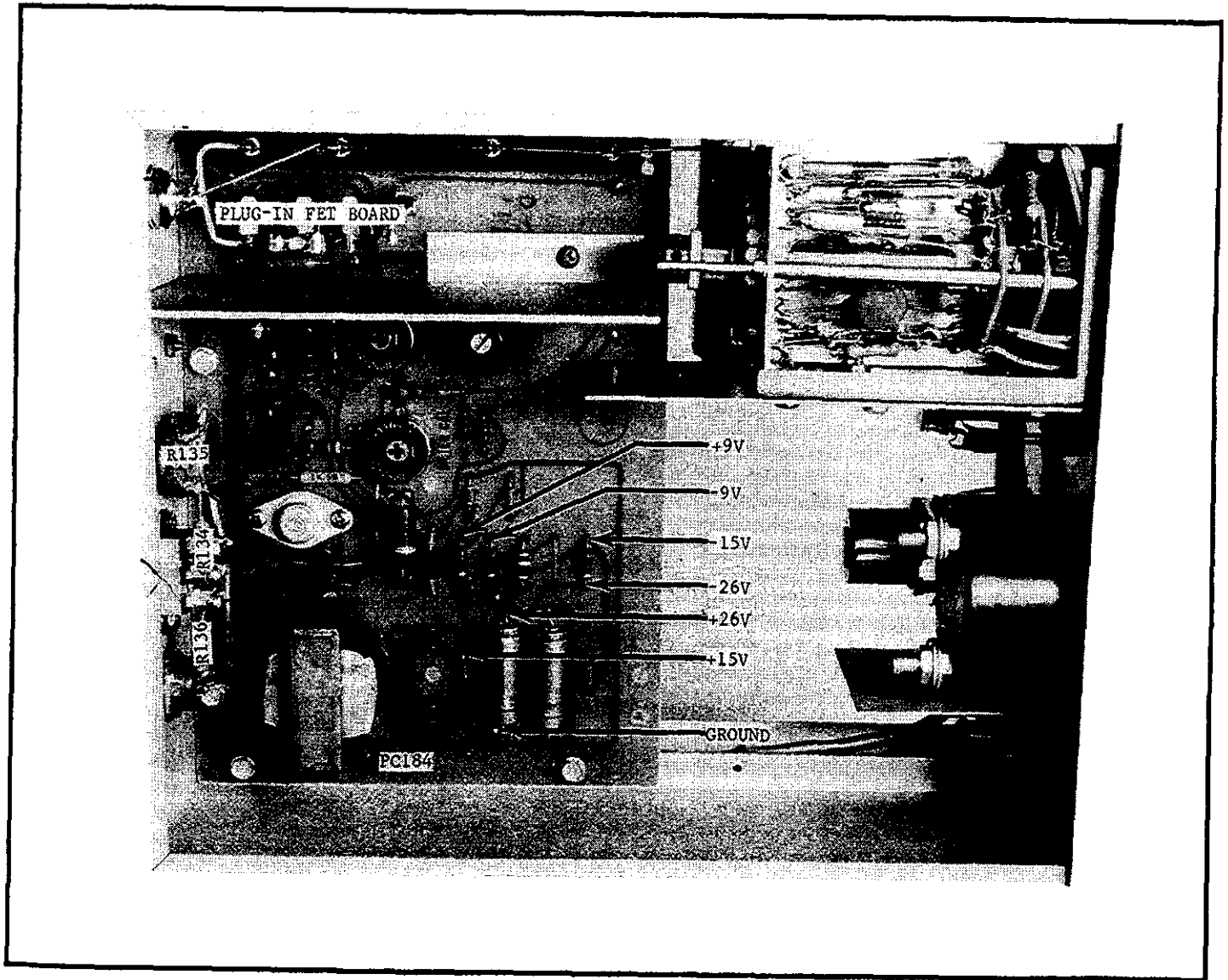


FIGURE 6. Chassis, Top View.

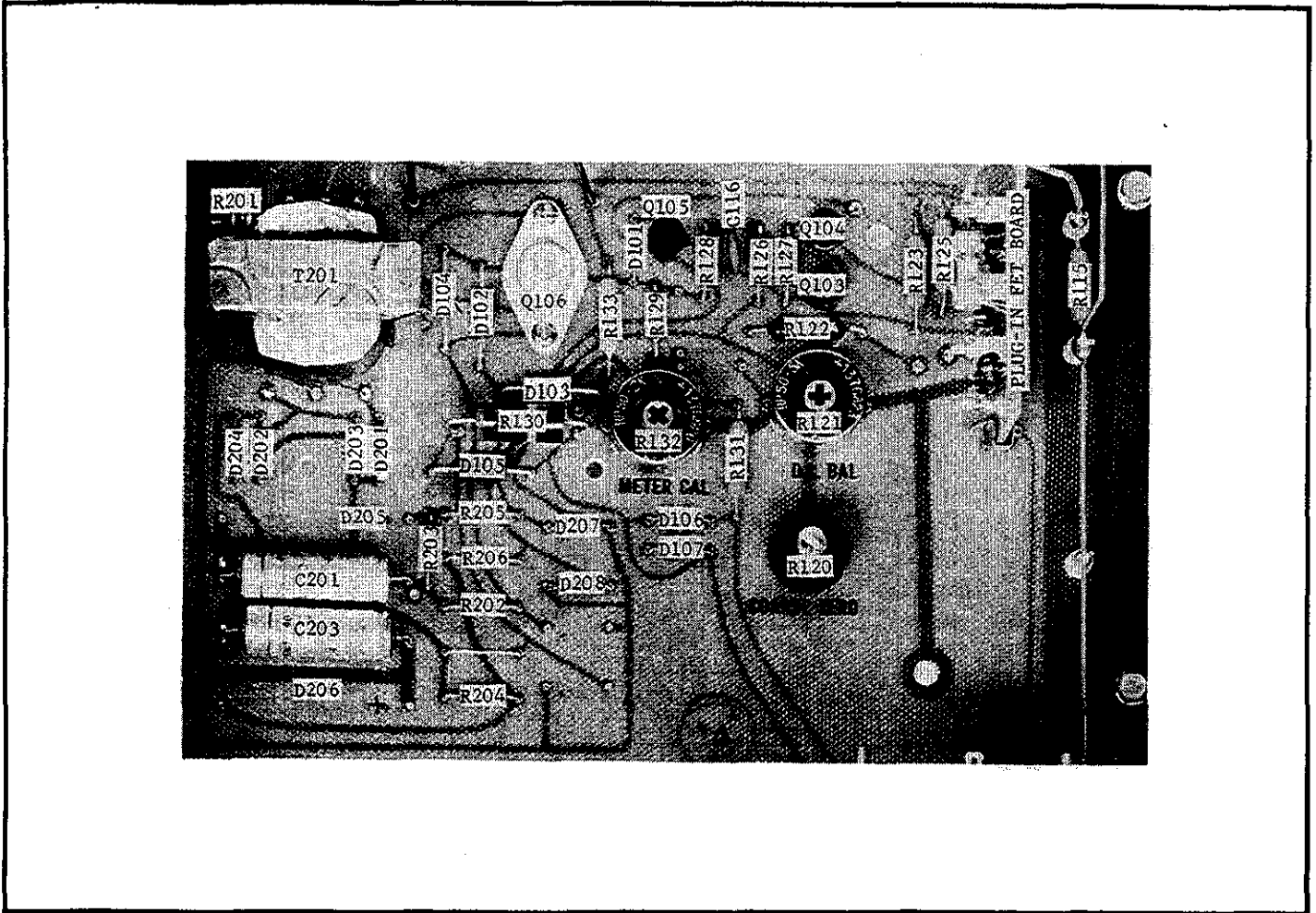


FIGURE 7. Component Layout, PC184.

## SECTION 6. ACCESSORIES

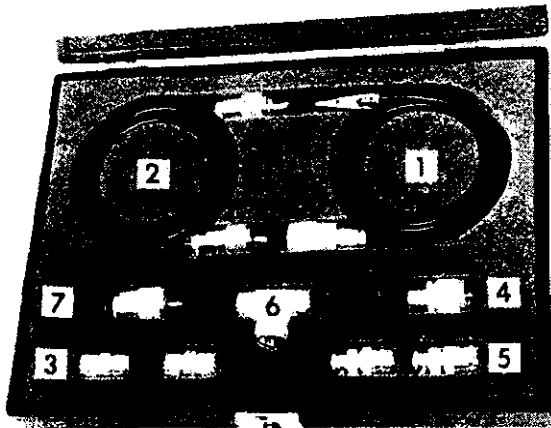
6-1. GENERAL. The following Keithley accessories can be used with the Model 410A to provide additional convenience and versatility.

6-2. OPERATING INSTRUCTIONS. A separate Instruction Manual is supplied with each accessory giving complete operating information.

## Model 6106 Electrometer Connection Kit

## Description:

The Model 6106 contains a group of the most useful leads and adapters for low current measurements. All components are housed in a rugged carrying case with individual compartments.



## Parts List:

| Description              | Item No. | Keithley Part No. |
|--------------------------|----------|-------------------|
| Cable, 30", UHF to clips | 1        | 19072C            |
| Cable, 24", UHF to UHF   | 2        | 18265C            |
| Connector, UHF to UHF    | 3        | CS-5              |
| Adaptor, UHF to BNC      | 4        | CS-115            |
| Adaptor, UHF to BNC      | 5        | CS-172            |
| Adaptor Tee, UHF to UHF  | 6        | CS-171            |
| Adaptor, Binding Post    | 7        | 19071B            |

The two cables (Items 1 and 2) are coaxial shielded leads useful for connections where low noise is essential. The 24" cable (Item 2) can be used to interconnect two instruments having UHF receptacles. The 30" cable (Item 1) can be used to connect to the circuit under test through the use of clip leads. A binding post adapter gives easy access to the electrometer "high" terminal. Two UHF female couplers (Item 3) permit cables to be connected together. The UHF "tee" connector simplifies galvanometric current measurements when using a current source and electrometer or picoammeter. Adapters (Items 4 and 5) are useful for conversion from UHF to BNC terminations.

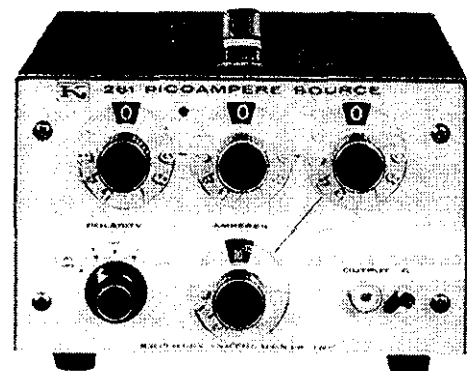
## Model 261 Picoampere Source

## Description:

The Model 261 is an accurate picoampere current source with 3 digit resolution. The output ranges are  $10^{-14}$  ampere to  $1.1 \times 10^{-4}$  ampere, positive or negative, in eight decade ranges. Accuracy is rated from  $\pm 0.25\%$  to  $\pm 1.6\%$  exclusive of input drop considerations.

## Application:

The Model 261 is a secondary standard for use in calibrating picoammeters and electrometers. It can also be used as an accurate current source for zero suppression and for galvanometric measurements.



## Models 240A, 244, 245, 246 Voltage Supplies

## Description:

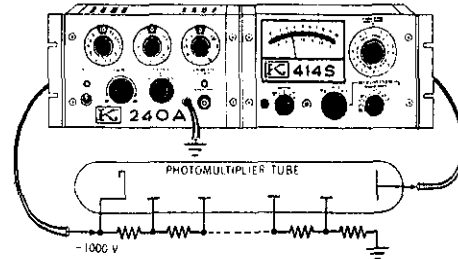
Keithley voltage supplies are highly-stable, low-noise power supplies for voltages up to  $\pm 3100$  volts dc.

## Application:

Keithley voltage supplies are commonly used with picoammeters in the measurement of resistance, light levels (photomultipliers), and radiation intensity (ion chambers). These high voltage supplies have been designed to operate with the Keithley line of electrometers, picoammeters and resistivity accessories. A typical application is shown using the Model 414S (or 414A) and the Model 240A in a photomultiplier experiment.

## Output Ranges:

| Model No. | Voltage           |
|-----------|-------------------|
| 240A      | 0 to $\pm 1200$ V |
| 244       | -200 to -2200V    |
| 245       | 0 to $\pm 2100$ V |
| 246       | 0 to $\pm 3100$ V |



## Model 4104 Electronic Trip

The Model 4104 is an electronic trip installed in the picoammeter to provide automatic current control. Combinations of high, low,  $\pm$  polarity, and latching is available.

## Model 4109 Polarizing Supply

The Model 4109 provides +300 volts at 1 mA for applications requiring a stable voltage source. The Model 4109 can be ordered installed in the picoammeter if desired.

Model 4003A Rack Mounting Kit

Description:

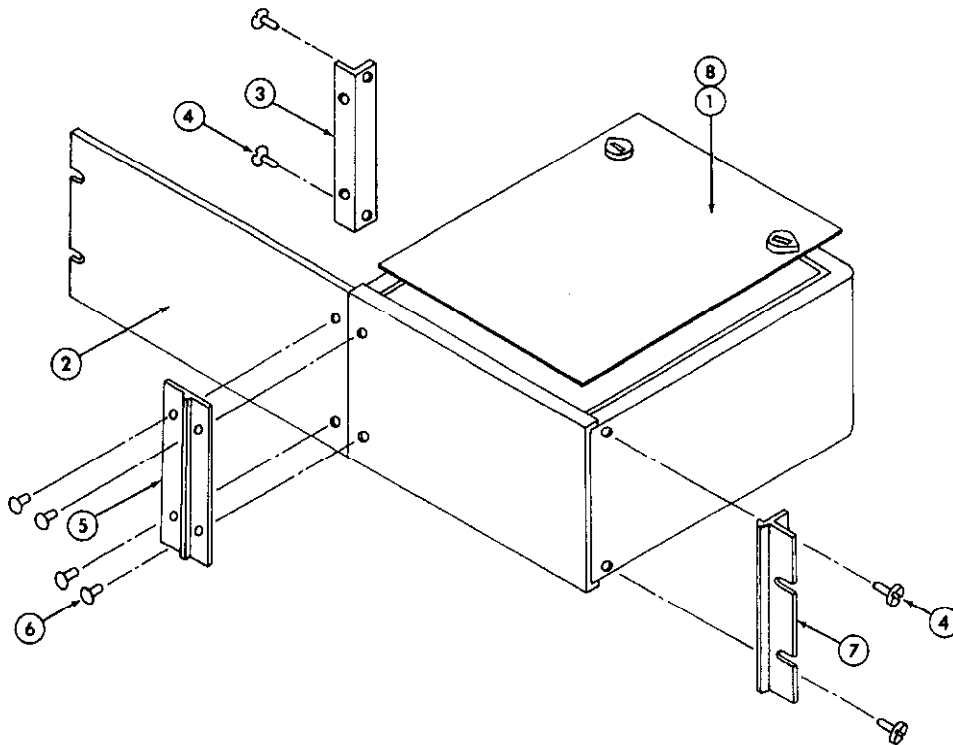
The Model 4003A is a rack mounting kit with overall dimensions, 5-1/4 inches high x 19 inches wide. Two top covers are provided for use with either 10 inch or 13 inch deep instruments.

Application:

The Model 4003A converts the instrument from bench mounting to rack mounting. It is suitable for mounting one instrument in one-half of a standard 19-inch rack.

Parts List:

| Item No. | Description         | Qty. Per Assembly | Keithley Part No. |
|----------|---------------------|-------------------|-------------------|
| 1        | Top Cover, 10"      | 1                 | 18554B            |
| 2        | Panel Adapter Plate | 1                 | 17452B            |
| 3        | Angle Support       | 1                 | 17476A            |
| 4        | Screw, #10 x 3/8"   | 4                 | ---               |
| 5        | Connecting Plate    | 1                 | 19126A            |
| 6        | Screw, #10 x 1/2"   | 4                 | ---               |
| 7        | Angle               | 1                 | 14624B            |
| 8        | Top Cover, 13"      | 1                 | 20015B            |



Model 4004A Dual Rack Mounting Kit

Description:

The Model 4004A is a rack mounting kit with overall dimensions, 5-1/4 inches high x 19 inches wide. Two top covers are provided for use with either 10 inch or 13 inch deep instruments.

Application:

The Model 4004A converts the instrument from bench mounting to rack mounting. It is suitable for mounting two instruments in a standard 19-inch rack.

Parts List:

| Item No. | Description       | Qty. Per Assembly | Keithley Part No. |
|----------|-------------------|-------------------|-------------------|
| 1        | Top Cover, 10"    | 2                 | 18554B            |
| 4        | Screw, #10 x 1/2" | 8                 | ---               |
| 5        | Connecting Plate  | 1                 | 19126A            |
| 6        | Screw, #10 x 1/2" | 4                 | ---               |
| 7        | Angle             | 2                 | 14624B            |
| 8        | Top Cover, 13"    | 2                 | 20015B            |
| 9        | Zee Bracket       | 1                 | 19144A            |
| 10       | Plate (not shown) | 1                 | 17454A            |



SECTION 7. REPLACEABLE PARTS

7-1. REPLACEABLE PARTS LIST. The Replaceable Parts List describes the components of the Model 410A. The List gives the circuit designation, the part description, a suggested manufacturer, the manufacturer's part number and the Keithley Part Number. The last column indicates the figure picturing the part. The name and address of the manufacturers listed in "Mfg. Code" column are in Table 14.

and serial number, the Keithley Part Number, the circuit designation and a description of the part. All structural parts and those coded for Keithley manufacture (80164) must be ordered through Keithley Instruments, Inc., or its representatives. In ordering a part not listed in the Replaceable Parts List, completely describe the part, its function and its location.

7-2. HOW TO ORDER PARTS.

b. Order parts through your nearest Keithley representative or the Sales Service Department, Keithley Instruments, Inc.

a. For parts orders, include the instrument's model

TABLE 13. Abbreviations and Symbols.

|       |                        |      |                           |      |                           |
|-------|------------------------|------|---------------------------|------|---------------------------|
| A     | Ampere                 | Fig. | Figure                    | Ω    | ohm                       |
| CbVar | Carbon Variable        | Gcb  | Glass enclosed carbon     | p    | pico (10 <sup>-12</sup> ) |
| CerD  | Ceramic, disc          |      |                           | Poly | Polystyrene               |
| Comp  | Composition            | k    | kilo (10 <sup>3</sup> )   | Ref. | Reference                 |
| DCb   | Deposited Carbon       | μ    | micro (10 <sup>-6</sup> ) | V    | Volt                      |
| EAl   | Electrolytic, Aluminum | M    | Mega (10 <sup>6</sup> )   | W    | Watt                      |
| F     | Farad                  | Mfg. | Manufacturer              | WVar | Wirewound Variable        |
|       |                        | MtF  | Metal Film                |      |                           |
|       |                        | My   | Mylar                     |      |                           |

MODEL 410A REPLACEABLE PARTS LIST  
(Refer to Schematic Diagram 22547E for Circuit Designations.)

CAPACITORS

| Circuit Desig. | Value      | Rating | Type | Mfg. Code | Mfg. Part No. | Keithley Part No. | Fig. Ref. |
|----------------|------------|--------|------|-----------|---------------|-------------------|-----------|
| C101           | .02 μF     | 400 V  | My   | 13050     | ED-.02        | C73-.02M          | 6         |
| C102           | .01 μF     | 400 V  | My   | 13050     | ED-.01        | C73-.01M          | 6         |
| C103           | .0047 μF   | 600 V  | CerD | 72982     | ED-.0047      | C22-.0047M        | 6         |
| C104           | .0015 μF   | 600 V  | CerD | 72982     | ED-.0015      | C22-.0015M        | 6         |
| C105           | 680 pF     | 600 V  | CerD | 72982     | ED-680        | C22-680P          | 6         |
| C106           | 330 pF     | 600 V  | CerD | 72982     | ED-330        | C22-330P          | 6         |
| C107           | 100 pF     | 600 V  | CerD | 72982     | ED-100        | C22-100P          | 6         |
| C108           | 22 pF      | 600 V  | CerD | 72982     | ED-22         | C22-22P           | 6         |
| C109           | 10 pF      | 500 V  | Poly | 71590     | CPR-10J       | C138-10P          | 6         |
| C110           | 220 pF     | 500 V  | Poly | 71590     | CPR-220J      | C138-220P         | 6         |
| C111           | 22 pF      | 500 V  | Poly | 71590     | CPR-22J       | C138-22P          | 6         |
| C112           | 5 pF       | 200 V  | Poly | 83125     | E1013-1       | C31-5P            | 6         |
| C113           | *          |        |      |           |               | 13410A            | 6         |
| C114           | *          |        |      |           |               | 13410A            | 6         |
| C115           | .02 μF     | 600 V  | CerD | 72982     | ED-.02        | C22-.02M          | 6         |
| C116           | .0068 μF** | 600 V  | CerD | 72982     | 851-Z5U0-682M | C22-.0068M        | 7         |
| C201           | 100 μF     | 400 V  | EAl  | 73445     | C437AR/G100   | C150-100M         | 7         |
| C202           | Not Used.  |        |      |           |               |                   |           |
| C203           | 100 μF     | 400 V  | EAl  | 73445     | C437AR/G100   | C150-100M         | 7         |

\* Capacitors C113 and C114 are a matched set of nominal value. Order only from Keithley Instruments as a set, part number 13410A.

\*\* Nominal value.

RESISTORS

| Circuit Desig. | Value              | Rating      | Type  | Mfg. Code | Mfg. Part No. | Keithley Part No.              | Fig. Ref.           |
|----------------|--------------------|-------------|-------|-----------|---------------|--------------------------------|---------------------|
| R101           | 3 kΩ               | 1%, 1/2 W   | DCb   | 91637     | DCF 1/2       | R12-3K                         | 6                   |
| R102           | 10 kΩ              | 1%, 1/2 W   | DCb   | 91637     | DCF 1/2       | R12-10K                        | 6                   |
| R103           | 30 kΩ              | 1%, 1/2 W   | DCb   | 07716     | DCC           | R12-30K                        | 6                   |
| R104           | 100 kΩ             | 1%, 1 W     | Epoxy | 91637     | MMF-1         | R150-100K                      | 6                   |
| R105           | 300 kΩ             | 1%, 1/2 W   | DCb   | 91637     | DCF 1/2       | R12-300K                       | 6                   |
| R106           | 1 MΩ               | 1%, 1/2 W   | DCb   | 07716     | DCC           | R12-1M                         | 6                   |
| R107           | 3 MΩ               | 1%, 1/2 W   | DCb   | 07716     | DCC           | R12-3M                         | 6                   |
| R108           | 10 MΩ              | 1%, 1/2 W   | DCb   | 91637     | DCF 1/2       | R12-10M                        | 6                   |
| R109           | 30 MΩ              | 1%, 1 W     | DCb   | 91637     | DC-1          | R13-30M                        | 6                   |
| R110           | 100 MΩ             | 1%, 2 W     | DCb   | 91637     | DC-2          | <del>R14-100M</del>            | 6 R-289-100M        |
| R111           | 10 <sup>9</sup> Ω  | 3%          | Gcb   | 63060     | RX-1          | <del>R20-10<sup>9</sup></del>  | 6 R-289-1G          |
| R112           | 10 <sup>10</sup> Ω | 3%          | Gcb   | 63060     | RX-1          | <del>R20-10<sup>10</sup></del> | 6 R-289-10G         |
| R113           | 10 <sup>11</sup> Ω | 3%          | Gcb   | 63060     | RX-1          | <del>R20-10<sup>11</sup></del> | 6 R-289-100G        |
| R114           | 10 <sup>12</sup> Ω | 3%          | Gcb   | 63060     | RX-1          | <del>R20-10<sup>12</sup></del> | no longer available |
| R115           | 1 MΩ               | 1%, 1/2 W   | DCb   | 07716     | DCC           | R12-1M                         | 7                   |
| R116**         | 100 kΩ             | 10%, 1/4 W  | Comp  | 01121     | CB            | R76-100K                       |                     |
| R117           | 2 kΩ               | 1/2%, 1/2 W | MtF   | 07716     | CEC           | R61-2K                         | 6                   |
| R118           | 700 Ω              | 1/2%, 1/2 W | MtF   | 07716     | CEC           | R61-700                        | 6                   |
| R119           | 300 Ω              | 1/2%, 1/2 W | MtF   | 07716     | CEC           | R61-300                        | 6                   |
| R120           | 1 kΩ               | 10%, 5 W    | WWVar | 71450     | AW            | RP34-1K                        | 7                   |
| R121           | 5 kΩ               | 20%, 2 W    | WWVar | 71450     | INS-115       | RP50-5K                        | 7                   |
| R122           | 9 kΩ               | 1%, 1/2 W   | DCb   | 07716     | DCC           | R12-9K                         | 7                   |
| R123           | 18 kΩ              | 1%, 1/2 W   | DCb   | 07716     | DCC           | R12-18K                        | 7                   |
| R124           | 2 kΩ               | 20%, 0.2 W  | CompV | 71450     | 70            | RP31-2K                        | 1                   |
| R125           | 18 kΩ              | 1%, 1/2 W   | DCb   | 07716     | DCC           | R12-18K                        | 7                   |
| R126           | 15 kΩ              | 10%, 1/2 W  | Comp  | 01121     | EB            | R1-15K                         | 7                   |
| R127           | 2.2 kΩ             | 10%, 1/2 W  | Comp  | 01121     | EB            | R1-2.2K                        | 7                   |
| R128           | 680 Ω              | 10%, 1/2 W  | Comp  | 01121     | EB            | R1-680                         | 7                   |
| R129           | 4.7 kΩ             | 10%, 1/2 W  | Comp  | 01121     | EB            | R1-4.7K                        | 7                   |
| R130           | 1.2 kΩ             | 10%, 1/2 W  | Comp  | 01121     | HB            | R3-1.2K                        | 7                   |
| R131           | 2 kΩ               | 1%, 1/2 W   | DCb   | 07716     | DCC           | R12-2K                         | 7                   |
| R132           | 2 kΩ               | 20%, 2 W    | WWVar | 71450     | INS-115       | RP50-2K                        | 7                   |
| R133           | 1 kΩ               | 1/2%, 1/2 W | MtF   | 07716     | CEC           | R61-1K                         | 7                   |
| R134           | 1 kΩ               | 1/2%, 1/2 W | MtF   | 07716     | CEC           | R61-1K                         | 6                   |
| R135           | 1 kΩ               | 10%, 5 W    | WWVar | 71450     | AW            | RP34-1K                        | 2,6                 |
| R136           | 1 kΩ               | 1/2%, 1/2 W | MtF   | 07716     | CEC           | R61-1K                         | 6                   |
| R201           | 27 kΩ              | 10%, 1/2 W  | Comp  | 01121     | EB            | R1-27K                         | 7                   |
| R202           | 390 Ω              | 10%, 1/2 W  | Comp  | 01121     | EB            | R1-390                         | 7                   |
| R203           | 820 Ω              | 10%, 1/2 W  | Comp  | 01121     | EB            | R1-820                         | 7                   |
| R204           | 820 Ω              | 10%, 1/2 W  | Comp  | 01121     | EB            | R1-820                         | 7                   |
| R205           | 820 Ω              | 10%, 1/2 W  | Comp  | 01121     | EB            | R1-820                         | 7                   |
| R206           | 820 Ω              | 10%, 1/2 W  | Comp  | 01121     | EB            | R1-820                         | 7                   |

TRANSISTORS

| Circuit Desig. | Number                | Mfg. Code | Keithley Part No. | Fig. Ref. |
|----------------|-----------------------|-----------|-------------------|-----------|
| Q101**         |                       | 80164     |                   |           |
| Q102**         |                       | 80164     |                   |           |
| Q103           |                       | 80164     | 21675A            | 7         |
| Q104           |                       | 80164     | 21675A            | 7         |
| Q105           | 2N3904                | 04713     | TG-47             | 7         |
| Q106           | NPN, Case TO-66 40513 | 02735     | TG-122            | 7         |

\*\* Replace Q101, Q102 or R116 by ordering Plug-in board 23735.

## DIODES

| Circuit Desig. | Type                | Number | Mfg. Code | Keithley Part No. | Fig. Ref. |
|----------------|---------------------|--------|-----------|-------------------|-----------|
| D101           | Silicon             | 1N645  | 01295     | RF-14             | 7         |
| D102           | Rectifier, 1A, 800V | 1N4006 | 04713     | RF-38             | 7         |
| D103           | Rectifier, 1A, 800V | 1N4006 | 04713     | RF-38             | 7         |
| D104           | Zener               | VR47   | 84970     | DZ-30             | 7         |
| D105           | Rectifier, 1A, 800V | 1N4006 | 04713     | RF-38             | 7         |
| D106           | Silicon             | 1N645  | 01295     | RF-14             | 7         |
| D107           | Silicon             | 1N645  | 01295     | RF-14             | 7         |
| D201           | Silicon             | 1N645  | 01295     | RF-14             | 7         |
| D202           | Silicon             | 1N645  | 01295     | RF-14             | 7         |
| D203           | Silicon             | 1N645  | 01295     | RF-14             | 7         |
| D204           | Silicon             | 1N645  | 01295     | RF-14             | 7         |
| D205           | Zener               | 1N718  | 12954     | DZ-18             | 7         |
| D206           | Zener               | 1N718  | 12954     | DZ-18             | 7         |
| D207           | Zener               | 1N935  | 04713     | DZ-7              | 7         |
| D208           | Zener               | 1N935  | 04713     | DZ-7              | 7         |

## MISCELLANEOUS PARTS

| Circuit Desig. | Description  | Mfg. Code | Keithley Part No. | Fig. Ref. |
|----------------|--|-----------|-------------------|-----------|
| 21850B         | MOS FET Input Plug-in Card   | 80164     | 23735             | 6         |
| DS201          | Pilot Light, Neon (Mfg. No. 2190)                                  | 91802     | PL-28             | 1         |
| F201 (117 V)   | Fuse, slow blow, 1/8 A (Mfg. Type MDL)                             | 71400     | FU-20             | 2         |
| F201 (234 V)   | Fuse, slow blow, 1/16 A (Mfg. Type MDL)                            | 71400     | FU-21             | 2         |
| ---            | Fuse Holder (Mfg. No. 342012)                                      | 75915     | FH-3              |           |
| J101           | Printed Circuit Contacts (Mfg. No. 02-005-113-6-200)               | 91662     | CS-199            |           |
| P101           | Printed Circuit Contacts, mate of J101 (Mfg. No. 02-005-111-5-200) | 91662     | CS-200            |           |
| J102           | Receptacle, UHF, INPUT (Mfg. No. 6804)                             | 91737     | CS-64             | 2         |
| ---            | (F) Plug, UHF, mate of J102 (Mfg. No. 83-822)                      | 02660     | CS-49             |           |
| ---            | Cap (Mfg. No. 7901)  | 91737     | CAP-4             |           |
| J103           | Receptacle, Microphone, OUTPUT (Mfg. No. 80-PC2F)                  | 02660     | CS-32             | 2,6       |
| ---            | (F) Plug, Microphone, mate of J103 (Mfg. No. 80-MC2M)              | 02660     | CS-32             |           |
| M101           | Meter  | 80164     | ME-79             | 6         |
| P201           | A.C. Power Cable, 6 feet (Mfg. No. 4638-13)                        | 93656     | CO-5              |           |
| S101           | Rotary Switch, METER   | 80164     | SW-264            | 1         |
| ---            | Knob Assembly, Meter Switch  | 80164     | 21660A            |           |
| S102           | Rotary Switch less components, AMPERES                             | 80164     | SW-268            | 1,6       |
| ---            | Rotary Switch with components, Amperes                             | 80164     | 22197B            |           |
| ---            | Knob Assembly, Amperes Switch                                      | 80164     | 22220A            |           |
| S103           | ZERO CHECK Button  | 80164     | SW-94             | 1         |
| ---            | Knob, Zero Check Button  | 80164     | 14376A            |           |
| S104           | Slide Switch, 1 MA - 1 V (Mfg. No. G326)                           | 79727     | SW-45             | 2         |
| S201           | Slide Switch, 117 V - 234 V  | 80164     | SW-151            | 2         |
| ---            | Knob Assembly, 1 MA CAL Control (R135)                             | 80164     | 16373A            |           |
| ---            | Zero ADJ Control, R124   | 80164     | RP66-2K           |           |
| T201           | Transformer  | 80164     | TR-112            | 7         |

(F) Furnished accessory.

TABLE 14.

Code List of Suggested Manufacturers. (Based on Federal Supply Code for Manufacturers, Cataloging Handbook H4-1.)

|       |  |       |   |
|-------|--|-------|---|
| 01121 | Allen-Bradley Corp.<br>1201 South 2nd Street<br>Milwaukee, Wis. 53204  | 71590 | Centralab Division of Globe-Union, Inc.<br>932 E. Keefe Avenue<br>Milwaukee, Wis. 53212     |
| 01295 | Texas Instruments, Inc.<br>Semiconductor-Components Division<br>13500 North Central Expressway<br>Dallas, Tex. 75231 | 72982 | Erie Technological Products, Inc.<br>644 W. 12th Street<br>Erie, Pa. 16512                  |
| 02660 | Amphenol Corp.<br>2801 South 25th Avenue<br>Broadview, Chicago, Illinois 60153                                       | 73445 | Amperex Electronic Co. Division of<br>North American Phillips Co., Inc.<br>Hicksville, N.Y. |
| 02735 | Radio Corp. of America Commercial Receiving<br>Tube and Semiconductor Division<br>Somerville, N.J.                   | 75915 | Littlefuse, Inc.<br>800 E. Northwest Highway<br>Des Plaines, Ill. 60016                     |
| 04713 | Motorola, Inc.<br>Semiconductor Products Division<br>5005 East McDowell Road<br>Phoenix, Arizona 85008               | 79727 | Continental-Wirt Electronics Corp.<br>Philadelphia, Pa.                                     |
| 07716 | International Resistance Co.<br>2850 Mt. Pleasant<br>Burlington, Iowa 52601  | 80164 | Keithley Instruments, Inc.<br>28775 Aurora Road<br>Cleveland, Ohio 44139                    |
| 12954 | Dickson Electronics Corp.<br>302 S. Wells Fargo Avenue<br>Scottsdale, Ariz.  | 83125 | General Instruments Corp.<br>Capacitor Division<br>Darlington, S.C.                         |
| 13050 | Potter Co.<br>Highway 51 N.<br>Wesson, Miss. 39191   | 84970 | Sarkes Tarzian, Inc.<br>E. Hillside Dr.<br>Bloomington, Ind.                                |
| 63060 | Victoreen Instrument Co.<br>5806 Hough Avenue<br>Cleveland, Ohio 44103   | 91637 | Dale Electronics, Inc.<br>P.O. Box 609<br>Columbus, Nebraska 68601                          |
| 71279 | Cambridge Thermionic Corp.<br>430 Concord Avenue<br>Cambridge, Mass.   | 91662 | Elco Corp.<br>Willow Grove, Pa.   |
| 71400 | Bussmann Mfg. Div. of McGraw Edison Co.<br>2538 W. University St.<br>St. Louis, Mo.                                  | 91737 | Gremer Mfg. Co., Inc.<br>7 North Avenue<br>Wakefield, Mass.                                 |
| 71450 | CTS Corp.<br>1142 W. Beardsley Avenue<br>Elkhart, Ind.   | 91802 | Industrial Devices Inc.<br>982 River Rd.<br>Edgewater, N.J. 07020                           |
|       |  | 93656 | Electric Cord Co.<br>1275 Bloomfield Avenue<br>Caldwell, N.J.                               |

TABLE 15.  
Mechanical Parts List

| Description                                | Quantity<br>Per Assembly | Keithley<br>Part No. | Fig.<br>Ref. |
|--|--------------------------|----------------------|--------------|
| 1) Chassis                                 | 1                        | 21659C               | 8            |
| 11) Front Panel                            | 1                        | 21767C               |              |
| Top Cover Assembly                         | ---                      | 18553B               | 8            |
| 12) Cover, Sheet Metal                     | 1                        | 17130D               |              |
| 13) Screws                                 | 4                        | ---                  |              |
| Handle Assembly                            | ---                      | ---                  |              |
| 14) Handle                                 | 1                        | HH-18                |              |
| 15) Screws #6-32 x 3/8" R.H. Slotted       | 2                        | ---                  |              |
| Bottom Cover Assembly                      | ---                      | 19298C               | 9            |
| 2) Cover                                   | 1                        | 19340B               |              |
| 3) Fastener                                | 2                        | FA-54                |              |
| Feet Assembly                              | ---                      | ---                  |              |
| 4) Feet                                    | 4                        | FE-5                 |              |
| 5) Ball                                    | 4                        | FE-6                 |              |
| 6) Screws #8-32 x 3/8" Phillips, Pan Head  | 4                        | ---                  |              |
| Tilt Bail Assembly                         | ---                      | ---                  |              |
| 7) Bail                                    | 1                        | 17147B               |              |
| 8) Right Assembly                          | 1                        | 19206B               |              |
| 9) Left Assembly                           | 1                        | 19205B               |              |
| 10) Screws #6-32 x 1/4" Phillips, Pan Head | 2                        | ---                  |              |

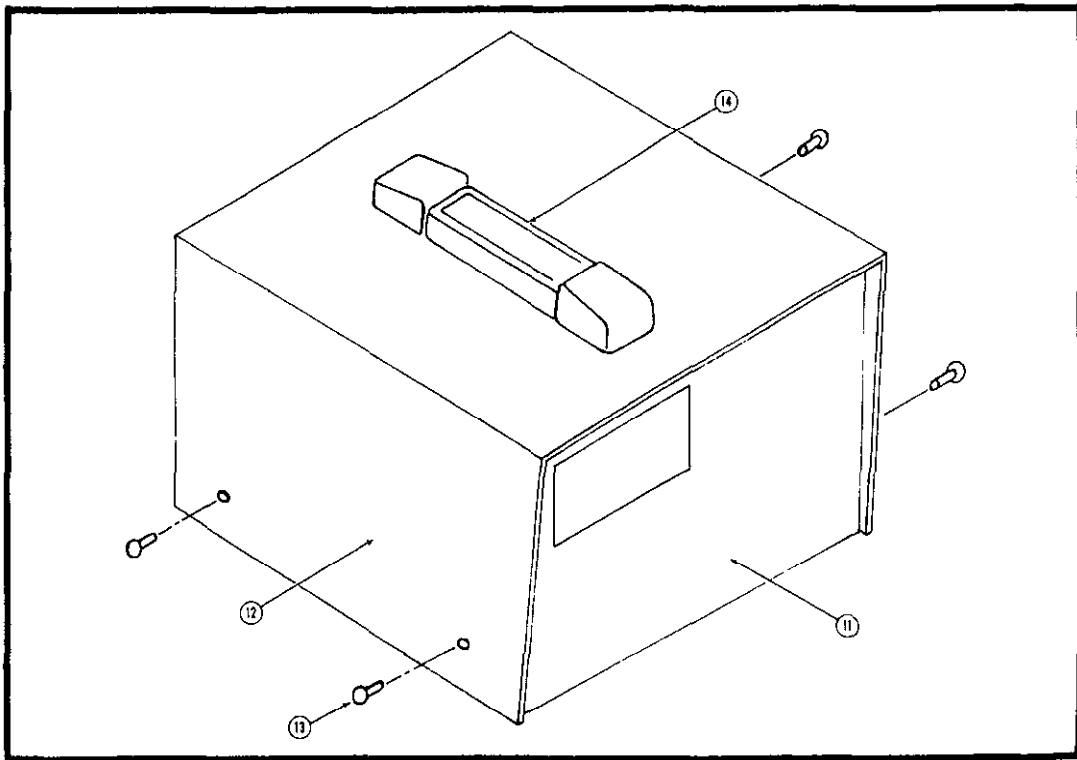


FIGURE 8. Top Cover Assembly.

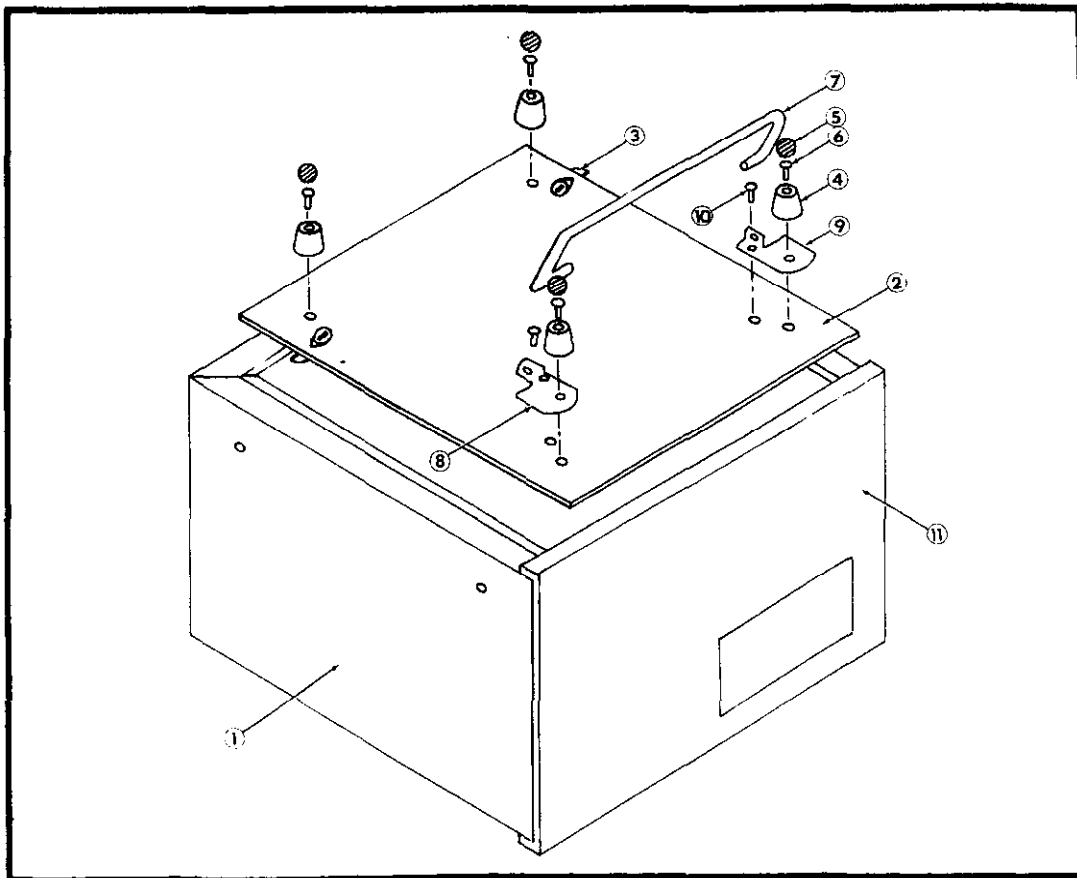


FIGURE 9. Bottom Cover Assembly.



KEITHLEY INSTRUMENTS, INC.

28775 AURORA ROAD

CLEVELAND, OHIO 44139

**SERVICE FORM**

MODEL NO. \_\_\_\_\_ SERIAL NO. \_\_\_\_\_ P.O. NO. \_\_\_\_\_ DATE \_\_\_\_\_ R-

NAME \_\_\_\_\_ PHONE \_\_\_\_\_

COMPANY \_\_\_\_\_

ADDRESS \_\_\_\_\_ CITY \_\_\_\_\_ STATE \_\_\_\_\_ ZIP \_\_\_\_\_

1. Describe problem and symptoms using quantitative data whenever possible (enclose readings, chart recordings, etc.) \_\_\_\_\_

\_\_\_\_\_ (Attach additional sheets as necessary).

2. Show a block diagram of your measurement system including all instruments connected (whether power is turned on or not). Also describe signal source.

3. List the positions of all controls and switches on both front and rear panels of the instrument. \_\_\_\_\_

4. Describe input signal source levels, frequencies, etc. \_\_\_\_\_

5. List and describe all cables used in the experiment (length, shielding, etc.). \_\_\_\_\_

6. List and describe all other equipment used in the experiment. Give control settings for each. \_\_\_\_\_

7. Environment:  
Where is the measurement being performed? (Factory, controlled laboratory, out-of-doors, etc.) \_\_\_\_\_  
What power line voltage is used? \_\_\_\_\_ Variation? \_\_\_\_\_ Frequency? \_\_\_\_\_  
Ambient temperature? \_\_\_\_\_ °F. Variation? \_\_\_\_\_ °F. Rel. Humidity? \_\_\_\_\_  
Other \_\_\_\_\_

8. Additional Information. (If special modifications have been made by the user, please describe below.) \_\_\_\_\_





**KEITHLEY INSTRUMENTS, INC.**

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TELEX: 98-5469 • CABLE: KEITHLEY