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INSTRUCTION MANUAL

MODEL 414A

PICOAMMETER

KEITHLEY INSTRUMENTS



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## SECTION 1. GENERAL DESCRIPTION

## 1-1. GENERAL.

a. The Keithley Model 414A is a completely solid-state picoammeter which measures currents over 17 ranges from  $10^{-2}$  to  $10^{-10}$  ampere full scale. Accuracy is  $\pm 2\%$  of full scale on the  $10^{-2}$  to  $10^{-8}$  ampere ranges and  $\pm 4\%$  of full scale on the  $3 \times 10^{-9}$  to  $10^{-10}$  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. The time and temperature stability of the 414A Picoammeter is unmatched by any other inexpensive picoammeter. The Model 414A 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 0.5% of full scale on the most sensitive range.

b. A unique circuit provides complete overload protection for Model 414A 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.

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 time should be allowed.

d. One volt or 1 milliamperes at full-scale deflection on all ranges is provided to drive chart recorders. The 1 milliamperes 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 1. Model 414A Specifications.

RANGE:  $10^{-10}$  ampere full scale to  $10^{-2}$  ampere in seventeen 1x and 3x ranges, positive or negative currents.

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

ZERO DRIFT: Less than 0.5% of full scale per week plus 0.05% per  $^{\circ}\text{C}$  on any range after a 10-minute warm-up and with source voltages greater than 1 volt.

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

EFFECTIVE INPUT RESISTANCE: Less than 0.1 ohm on  $10^{-2}$  ampere range, increasing to less than  $10^7$  ohms on  $10^{-10}$  ampere range.

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

Range, ampere	With up to 500 pF Across Input
$10^{-10}$	0.75
$10^{-9}$	0.15
$10^{-8}$	0.13
$10^{-7}$	0.09
$10^{-6}$	0.05
$10^{-5}$ and above	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  $10^{-10}$  to  $10^{-6}$  ampere ranges, decreasing to 12 volts on the  $10^{-2}$  ampere range.

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

## RECORDER OUTPUT:

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

Noise: Less than 1% of full scale peak-to-peak.

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

DIMENSIONS, WEIGHT: 5-1/2" high x 8-1/2" wide x 10" deep; net weight, 8 pounds.

ACCESSORIES SUPPLIED: Mating input and output connectors.

TABLE 2. Model 414A Front Panel Controls (Figure 1).

Control	Functional Description	Paragraph
RANGE Switch	Selects full-scale current range instrument is to measure.	2-2
METER Switch	Turns instrument on; selects meter polarity; checks instrument zero.	2-2,2-4
ZERO ADJ. Control	Zeroes meter on any range.	2-2
Pilot Light	Glows to indicate instrument is on.	---

TABLE 3. Model 414A Rear Panel Controls (Figure 2).

Control	Functional Description	Paragraph
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 milliampere 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.	2-2, 2-5

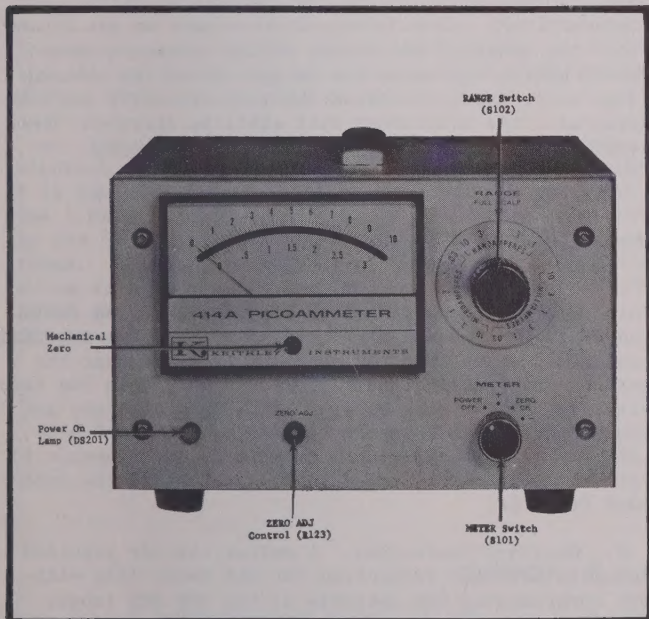


FIGURE 1. Model 414A Front Panel Controls.

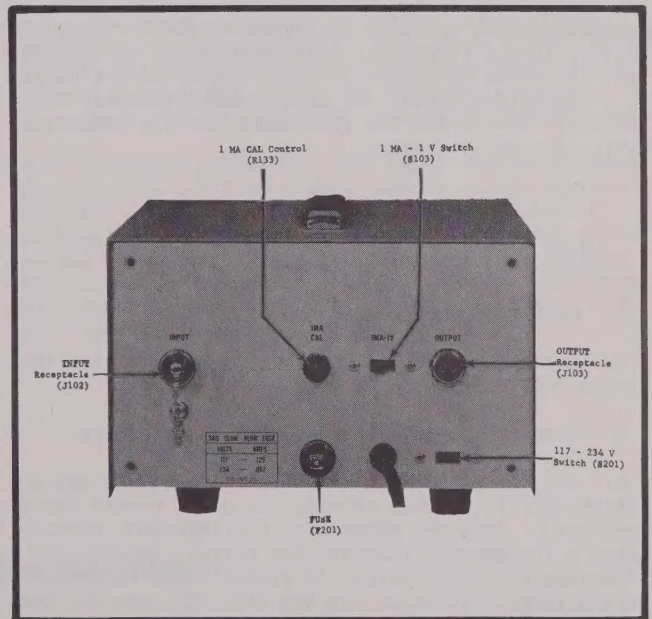


FIGURE 2. Model 414A Rear Panel Controls.

## SECTION 2. OPERATION

2-1. INPUT CONNECTIONS. Use the following precautions when using the Picoammeter on the more sensitive ranges. These precautions need not necessarily be followed if measurements are to be made only on the less sensitive ranges.

a. The INPUT Receptacle of the Model 414A 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 shielding is thorough, pickup 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.

## NOTE

Keep the shield cap on the INPUT Receptacle when the Picoammeter is not in a circuit.

## 2-2. OPERATING PROCEDURES.

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

b. Connect the power cord to the power source.

c. Set the RANGE Switch to  $10^{-2}$  ampere, 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 RANGE Switch in decade steps to the  $10^{-10}$  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 RANGE Switch until the greatest on scale deflection is achieved.

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

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

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

$$R_f/R_s$$

Equation 1.

where  $R_f$  is the feedback resistance in ohms;  
 $R_s$  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  $.05\% \times 10 = .5\%$ /°C. This is the reason that it is advantageous to have the source resistance at least equal to the feedback resistor.

d. Overload Protection. A unique circuit provides complete overload protection for the Model 414A without compromising the features of the MOS FET input. Overload recovery is almost instantaneous.

1. At 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 dis-

sipation of the feedback resistors (See Table 4).

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

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

#### 2-4. RECORDER OUTPUTS.

a. For recording with the Model 414A, 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 414A. The Picoammeter has two outputs,  $\pm 1$  volt and  $\pm 1$  milliampere, 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% peak-to-peak of full scale. The METER Switch does not reverse the output polarity. Output polarity is always opposite input polarity.

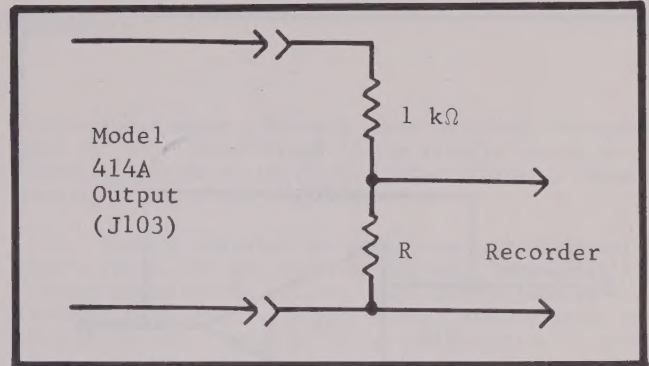


FIGURE 3. Divider Circuits Across Picoammeter Output for Driving 50 and 100-Millivolt Recorders. Use 5% resistors in the dividers. The value of resistors R is one ohm for every 1 mV of output.

d. 1-Milliampere Output. Connect 1-milliampere instruments to the OUTPUT Receptacle. Pin no. 1 is the high terminal. Set the 1 MA - 1 V Switch to 1 MA. The output is approximately 1 milliampere 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 deflections. 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 414A is a linear dc amplifier with a full scale sensitivity of either 1 or 3 volts. By using the front panel controls, shunt resistors are selected to make measurements over a total of 17 current ranges. (Refer to schematic diagram 22223D for circuit designations.)

#### 3-2. AMMETER OPERATION.

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

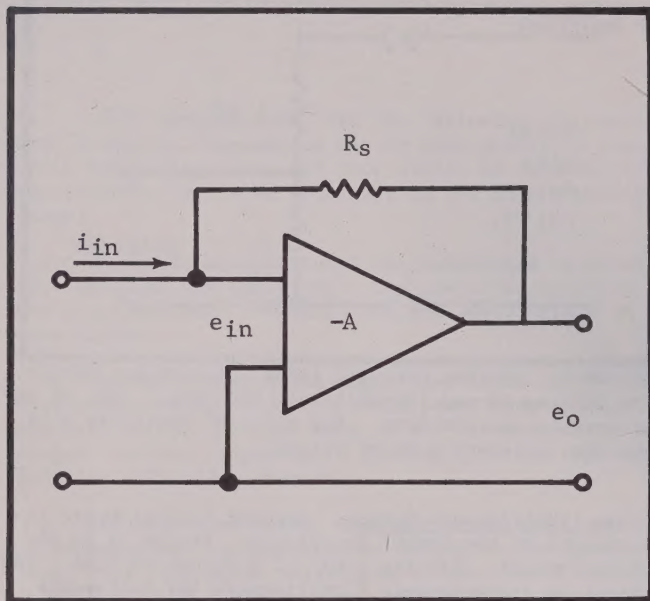


FIGURE 4. Simplified Diagram for Ammeter Circuit.

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 equations 2 and 3 we get

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

From whence,

$$e_{in}/i_{in} = R_S/A. \quad \text{Equation 5.}$$

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.

### 3-3. AMMETER CIRCUIT.

a. Two balanced insulated-gate field-effect transistors, Q101 and Q102, are used for the amplifier input. Resistors R117 and R118 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 22223D for circuit designations.

b. Turning the METER Switch to ZERO CK position 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 transistor Q102. The ZERO ADJ Control, R123, varies the drain voltage of transistor Q101 with respect to transistor Q102.

e. The DC Bal Potentiometer, R119, sets the drain current through transistors Q101 and Q102 by varying the source bias.

f. The voltage drop across R115 plus R116, or R116 alone, determines the full scale sensitivity of the amplifier — either 3 volts from  $10^{-2}$  through  $3 \times 10^{-8}$  and  $3 \times 10^{-9}$  and  $3 \times 10^{-10}$  or 1 volt on  $10^{-8}$ ,  $10^{-9}$  and  $10^{-10}$  ranges. Applying a full scale signal to the input causes a 1 milliamperere current to flow through R115 and R116. The meter is connected across the 3-volt output. Resistors R130 and R131 set the meter current.

g. The full scale current sensitivity is determined by the range resistors R101 through R114 in combination with resistors R115 and R116. 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 milliamperere flowing through resistor R135. In the 1 milliamperere output mode an external load is substituted for R135. Potentiometer R133 varies the current to the external load.

3-4. POWER SUPPLIES. The Model 414A has positive and negative supplies, which provide power to the amplifier and output.

a. +25 and +11 volt supply. The power supplied from secondary of transformer T201 is rectified by diodes D201 and D203 and filtered by capacitor C201 to provide +25 volts for the output. Zener diode, D205, is used to provide a regulated +11 volts for the amplifier.

b. -25 and -11 volt supply. This supply uses diodes D202 and D204, capacitor C202 and zener D206 to perform the same functions as the positive supply.



## SECTION 4. SERVICING

4-1. GENERAL. Section 4 contains the maintenance and troubleshooting procedures for the Model 414A 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, R113 and R114, should be checked approximately every six months for specified accuracy. Except for this the Model 414A 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 21850B, from Keithley Instruments, Inc.

### 4-4. TROUBLESHOOTING.

a. The Procedures which follow give instructions for repairing troubles which might occur in Model 414A. 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 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, 22223D, 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. Zero the Model 414A meter and make measurements with a Model 153.

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.

TABLE 5.

Equipment Recommended for Model 414A Troubleshooting and Calibration. Use these instruments or their equivalents.

Instruments	Use
Fairchild 7050 DVM, 1.5 to 100 volts full scale, 0.1% accuracy, 1.5 k $\Omega$ to 15 M $\Omega$ input resistance.	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 volts 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.
Keithley Instruments Model 370 Recorder	Monitor drift.
Keithley Instruments Model 515 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.
RCA Model WV98C Senior Voltohmyst, 11 M $\Omega$ input resistance, $\pm$ 3% accuracy, 0 to 1500 volts dc.	General circuit checking.
Shielded resistors of different values, and shielded 50 pF and 500 pF polystyrene capacitors.	Rise time check.
Tektronix Model 561A Oscilloscope	Noise and rise time check.

TABLE 6. Model 414A 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 of ranges out of specification	Defective range resistor	Check resistor; replace if faulty.

## c. Amplifier.

1. To check the amplifier, disconnect the feedback loop by removing Q106, D102, D105 and R129 from the PC board. Check diodes D102 and D105 with the Model WV98C, used as an ohmmeter, for shorts.

2. Connect a Model 153 between the bases of Q103 and Q104. Adjust Coarse Zero Potentiometer, R120, and 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 R128 to ground. Adjust the Model 414A Zero Controls for a 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.

## SECTION 5. CALIBRATION

## 5-1. GENERAL.

a. The following procedures are recommended for calibrating the Model 414A. 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 414A 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 on the rear panel are set to 1V and 117V respectively. Set the Front Panel Controls as follows:

RANGE Switch	10 MILLIAMPERES
METER Switch	POWER OFF
ZERO ADJ. Control	Mid-range.

b. Set the DC Bal Potentiometer, R119, Coarse Zero Potentiometer, R120, and Meter Cal. Potentiometer, R131, near mid-range.

c. Zero the meter with the Mechanical Zero Control.

d. Plug the Model 414A into a 117 volt source and set the METER Switch to ZERO CK.

1. If the Model 414A 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

TABLE 7. Model 414A Internal Controls

The Table lists all internal controls, the figure picturing the location and the paragraph describing the adjustment.

Control	Circuit Desig.	Fig. Ref.	Refer to Paragraph
DC Bal.	R119	9	5-2, 5-4
Coarse Zero	R120	9	5-2, 5-4
Meter Cal	R131	9	5-2, 5-6

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 9 for test points for the Power Supplies.)

a. Check the positive and then the negative 25 volt supply by connecting the Model 7050 across capacitors C201 and C202 respectively (Figure 8). The voltage should be plus and minus 25 volts  $\pm 2$  volts respectively. The ripple in each case should be less than 3 volts peak-to-peak.

## NOTE

For all these power supply checks make sure the Model 7050 is connected between ground and the test points (Figure 9).

b. Check the positive and then the negative 11 volt supply by connecting the Model 7050 across Resistors R202 and R205 respectively. The voltage for the plus and minus 11 volt supplies should be plus and minus 11 volts  $\pm 1.10$  volts respectively. The ripple in each case should be less than 30 mV peak-to-peak.

c. Monitor the plus and minus 11 volt supplies as the line voltage is changed from 105 volts ac to 125 volts ac. The voltage change of the plus and minus 11 volt supplies should be less than  $\pm 0.15$  volt. Observe the zener noise on the ripple. If the noise exceeds 5mV peak-to-peak, or if large random spikes are observed replace the zener (D205 for the plus 11 volt and D206 for the minus 11 volt supply).

d. Turn the Model 414A off and prepare the Picoammeter for 234 volt, 50 Hz operation. Plug the Model 414A into a 220 volt ac, 50 cycle 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 414A operating from 117 volts ac, 60 Hz.

5-4. MOS FET CURRENT ADJUST.

a. Set the Picoammeter RANGE Switch to 10 MILLIAMPERES and the METER Switch to ZERO CK.

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 7050 DVM across resistor R122 and adjust the DC BAL Potentiometer, R119, 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.

d. If necessary, repeat steps b and c above.

5-5. OFFSET AND NOISE CHECKS.

a. To check the offset:

1. Set the Picoammeter RANGE Switch to 10 MILLIAMPERES and the METER Switch to ZERO CK. Cap the INPUT Receptacle and connect the Model 414A to the Model 7050 DVM.

## NOTE

When checking the offset noise, make sure the Model 414A cover is on.

2. If necessary, adjust the ZERO ADJ. Control for zero volts at the output.

3. Set the RANGE Switch to .1 NANOAMPERES. Make sure that the output remains at zero volts, adjusting the front panel ZERO ADJ. Control if necessary.

4. Set the METER Switch to +. The output should remain within  $\pm 10$  millivolts.

b. To check the noise:

1. Connect the Model 414A OUTPUT Receptacle to the Model 561A Oscilloscope.

2. Set the METER Switch to + and vary the line voltage from 105 volts ac to 125 volts ac. The output noise should be less than 10 millivolts peak-to-peak on all ranges. High noise is usually indicative of faulty Zener Diodes D205 and D206.

5-6. METER AND IMA OUTPUT CALIBRATION.

a. Set the RANGE Switch to 1 MICROAMPERE. Connect the Model 261 Picoampere Source to the Model 414A INPUT Receptacle and connect the Model 7050 DVM to the OUTPUT Receptacle.

b. Set the Model 414A 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, R131, for full scale meter deflection.

d. Load the Model 414A output with a 1.5 kilohm resistor and set the 1 V - 1 MA Switch to 1 MA.

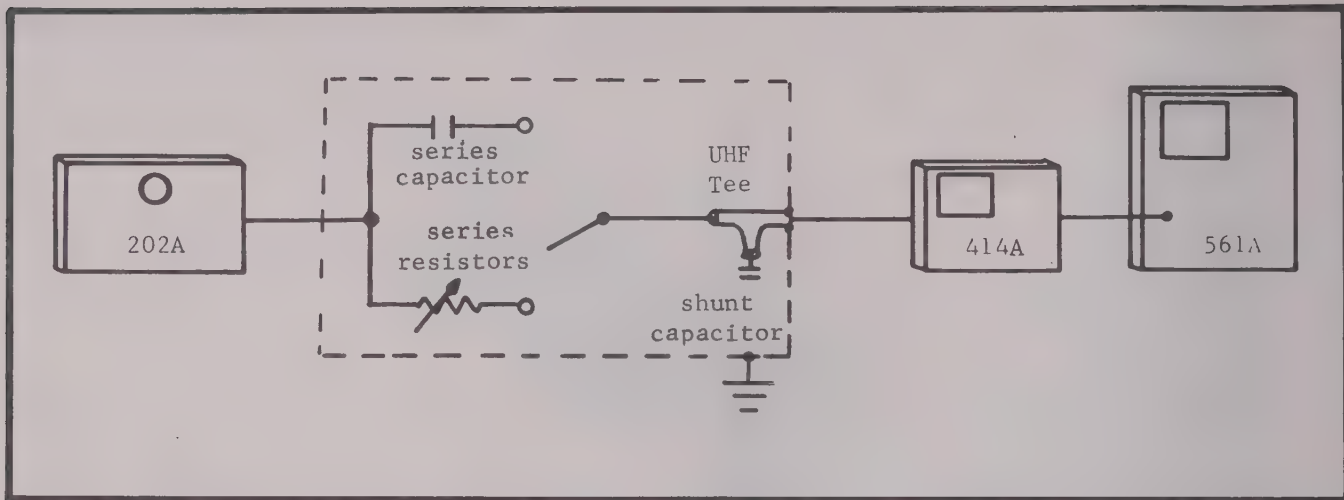


FIGURE 5. Test Set-up for Model 414A Rise Time Check on all ranges. Be sure to properly shield the series resistors or capacitor, UHF-Tee and the Shunt Capacitor.

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 1V - 1MA Switch to 1.V.

g. Set the METER Switch to ZERO CK and re-zero the output if necessary.

5-7. RANGE ACCURACY CHECK.

a. Connect the Model 414A INPUT Receptacle to the Model 261. Connect the OUTPUT Receptacle to the Model 7050 DVM.

b. Check the full-scale accuracy of all positions on the RANGE 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 MILLIAMPERES through the 10 NANOAMPERES ranges to  $\pm 2\%$  of full scale at the output (1.0 volt  $\pm 20$  millivolts). Check the accuracy of the 3 NANOAMPERES through the .1 NANOAMPERES 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 414A requires two different test set-ups. The first set-up is for checking the rise times on the 1 MILLIAMPERES through 10 NANOAMPERES ranges. The second set-up is for checking the rise times on the ranges 1 NANOAMPERES and below.

a. 1 MILLIAMPERE through 10 NANOAMPERE ranges. Set the test fixture 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 414A 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 414A INPUT Receptacle. Observe the output of the Model 414A with the Model 561A

b) For each Model 414A range, use the Model 202A frequency setting and the series resistor indicated in Table 8.

c) Adjust the Model 202A amplitude control as needed to obtain 2 volts peak-to-peak at the Model 414A output. Check the 10 - 90% rise time to the figures shown in Table 8.

b. 1 NANOAMPERE and .1 NANOAMPERES ranges. Set this test fixture up as illustrated in Figure 5, except that a shielded 50 pF polystyrene capacitor should be substituted for the series resistors between the Function Generator and the UHF Tee.

TABLE 8. Model 414A Rise Time Check for 1 MILLIAMPERES through 10 NANOAMPERES Ranges. The Table gives the Model 414A RANGE Switch settings, the Function Generator frequency settings, the series resistor used for each RANGE Switch setting, and the maximum allowable rise time.

Model 414A RANGE Switch Setting	Series Resistors	Function Generator Frequency (Hz)	Maximum Rise Time (milliseconds)
1 MILLIAMPERES	3 k $\Omega$	250	less than 1
.1 MILLIAMPERES	30 k $\Omega$	250	less than 1
10 MICROAMPERES	300 k $\Omega$	250	less than 1
1 MICROAMPERES	3 M $\Omega$	2.5	50
.1 MICROAMPERES	30 M $\Omega$	2.5	90
10 NANOAMPERES	300 M $\Omega$	2.5	130

1. Equipment Used: This test set-up uses the same equipment of the previous set-up with the exception of the 50 pF polystyrene capacitor. The 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 414A INPUT Receptacle. Monitor the Model 414A 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 414A output. Check the 10 - 90% rise time to the figures shown in Table 9.

TABLE 9. Model 414A Rise Time Check for 1 NANOAMPERES and .1 NANOAMPERES Ranges. The Table gives the Model 414A RANGE Switch settings, the Function Generator frequency settings, and the maximum allowable rise time.

Model 414A RANGE Switch Setting	Function Generator Frequency (Hz)	Maximum Rise Time (milliseconds)
1 NANOAMPERES	1.0	150
.1 NANOAMPERES	0.25	750

5-9. DRIFT VERIFICATION.

a. Shunt the Input of the Model 414A with a 10-kil-

ohm resistor with the RANGE Switch set to 1 MICROAMP-ERE and the METER Switch set to + or -, as necessary. Using the shunt increases the sensitivity 100 times.

NOTE

While doing the drift run make sure the Model 414A cover is on.

b. Connect the Model 370 Recorder to the Model 414A. Set the Recorder attenuator to 1 volt (10 millivolts drift full scale) or 0.3 volts (3 mV 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 414A may drift 700 microvolts per 24 hours plus or minus 500 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 the drift during second 24-hour period times 6 and add the drift noted during the first 24-hour period.

2. Total drift must add up to 5 mV or less.

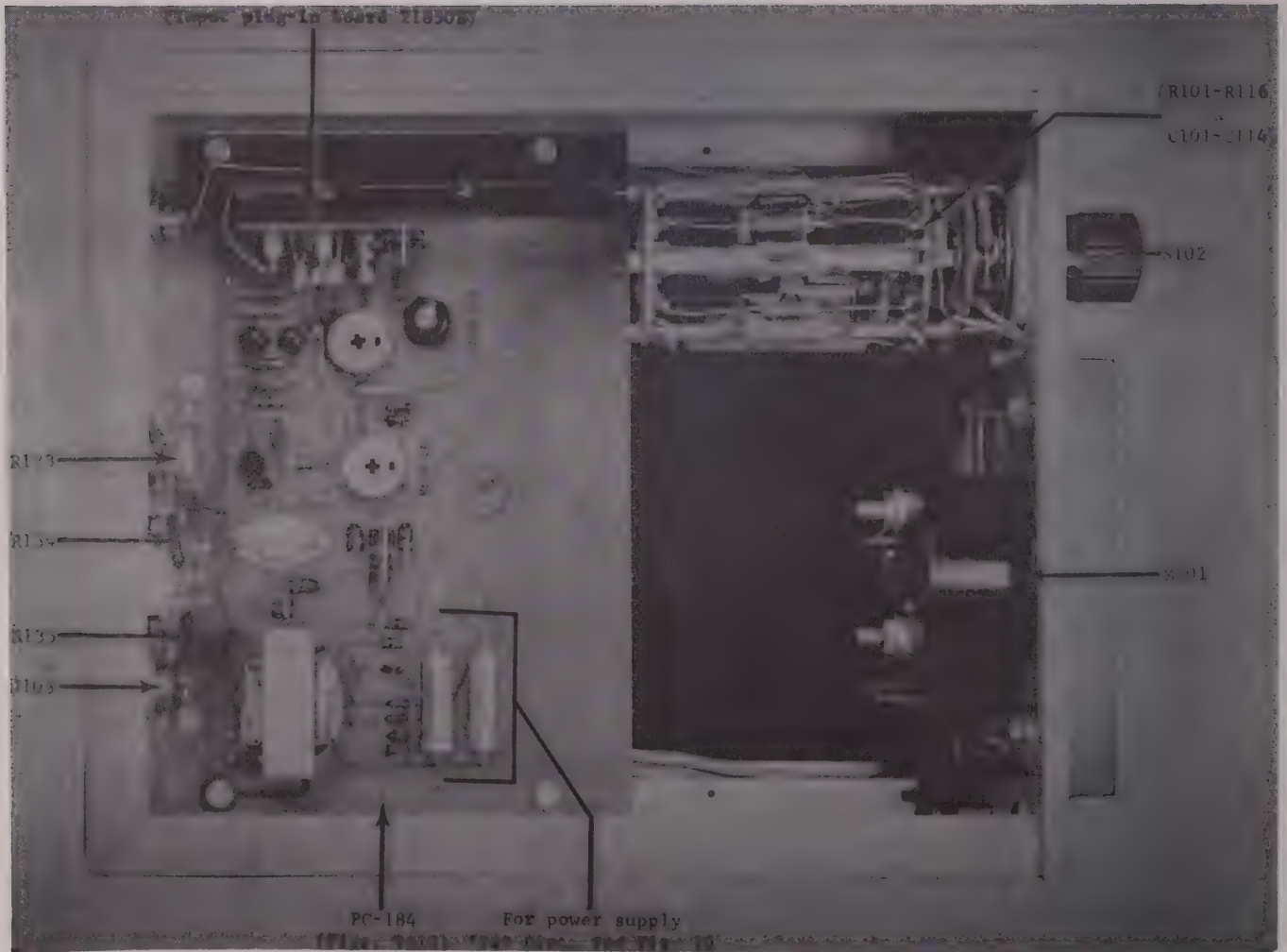


FIGURE 6. Top View, Model 414A Main Chassis. Front panel faces right. Figure shows locations of capacitors, connectors, meter, pc boards, resistors and switches. For bottom view see Figure 7.

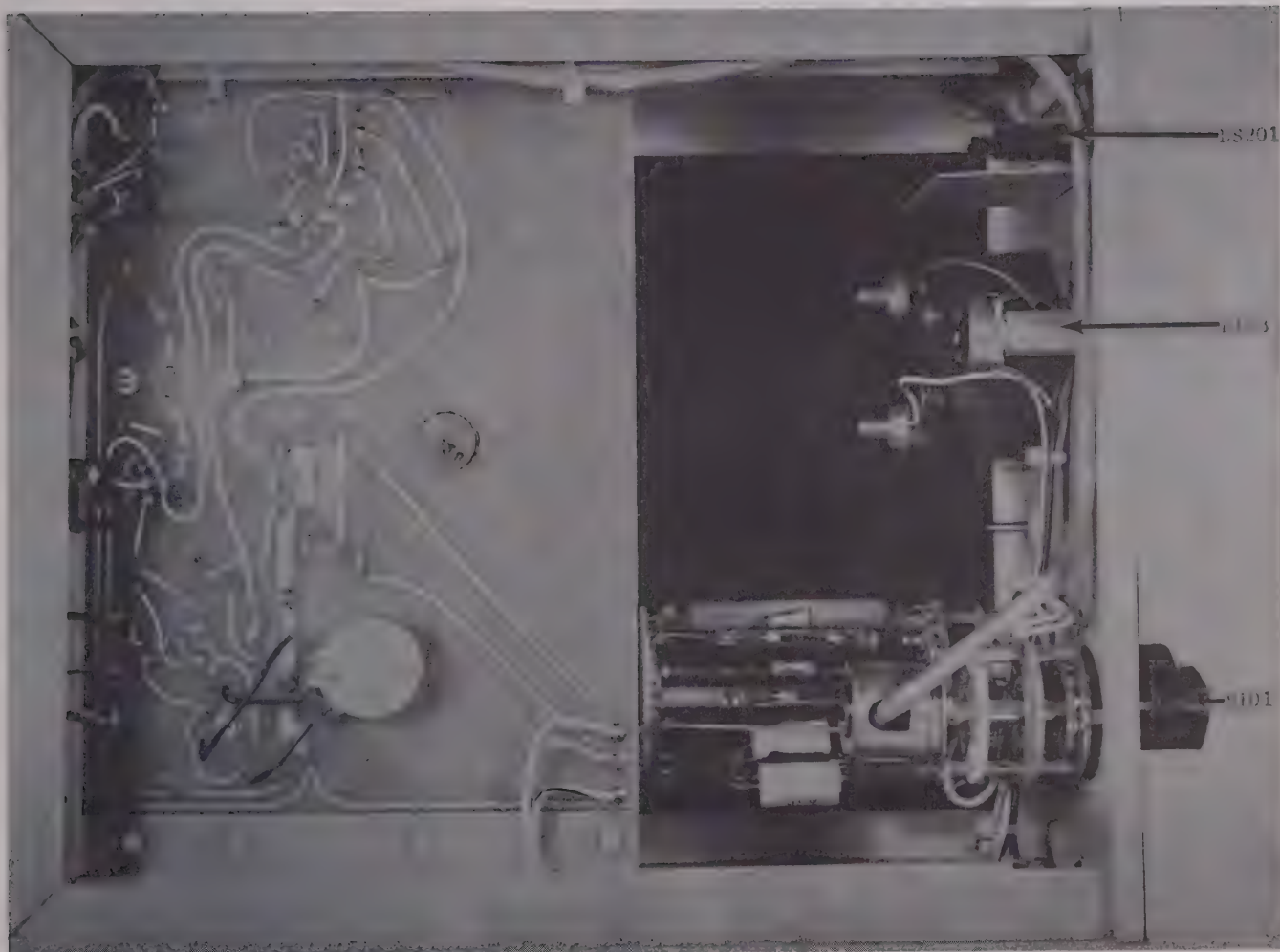


FIGURE 7. Bottom View Model 414A Main Chassis. Front panel faces right. View shows location of lamp, resistor and switch. For top view of main chassis, see Figure 6.

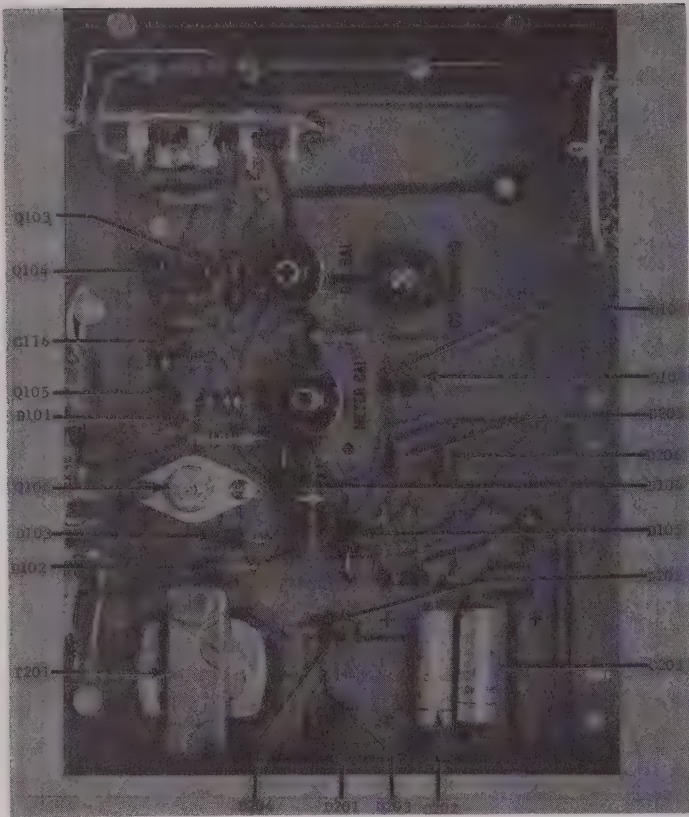
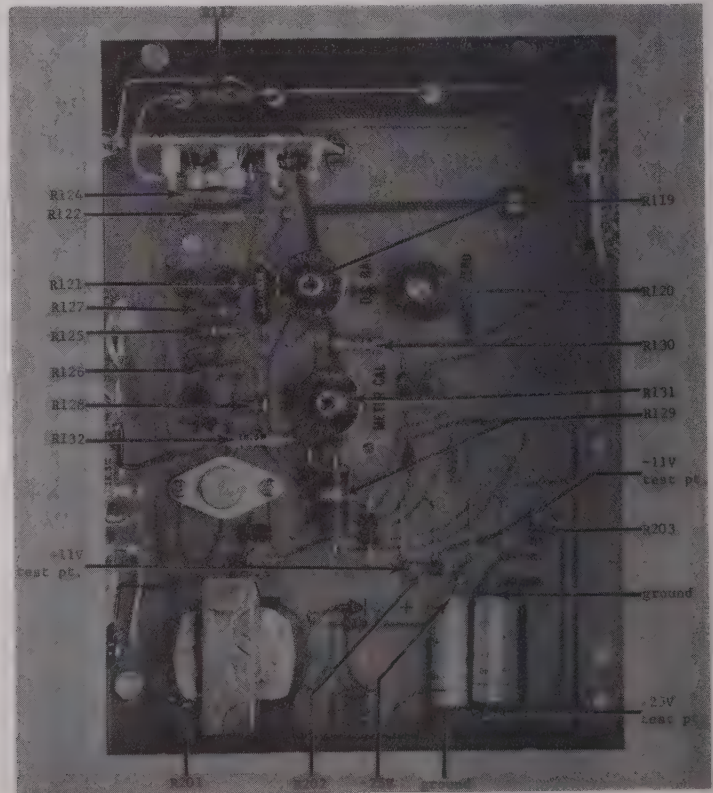


FIGURE 8. Capacitor, Diode, Transformer and Transistor Locations on PC-184. For resistor and power supply test points, see Figure 9.

FIGURE 9. Resistor and Power Supply Test Point Locations on PC-184. For other component locations, see Figure 8.





## SECTION 6. ACCESSORIES

6-1. GENERAL. This Section contains instructions on using Keithley accessories with the Model 414A Picoammeter. The principal accessories described here are the rack and bench mounting kits, the Model 6106 Electrometer Connection Kit, accessory voltage supplies, Model 370 Recorder, the Model 261 Picoampere Source, the Model 4109 Biasing Supply and the Model 4104 Trip.

## 6-2. MODEL 4003A RACK MOUNTING KIT.

a. The Model 4003A Kit converts the Model 414A from a bench model to rack mounting. Rack dimensions are 5-1/4 inches high x 19 inches wide x 10 inches deep.

The Picoammeter converts to half-rack size, and the Kit contains a half-rack adapter panel. The Kit accommodates any Keithley 5-1/4 inch high half-rack instrument whether 10 or 13 inches deep.

b. Procedures. Remove the wrap-around cover on the Picoammeter by removing the two corner screws at the bottom of each side. Add the rack mounting parts to the Picoammeter as shown in Figure 10. Attach in this order: cover (1), rack angle (4), panel support angel (2); rack panel adapter (5), and chassis connecting plate (3).

TABLE 10. Parts List for Model 4003A Rack Mounting Kit.

Item (See Fig. 10)	Description	Keithley Part No.	Quantity
1	Cover Assembly (cover for 10" models)	18554B	1
---	Cover Assembly (cover for 13" models)	20015B	1
2	Panel Support Angle	17476A	1
3	Chassis Connecting Plate	19126A	1
4	Rack Angle	14624B	1
5	Rack Adapter Panel	17452B	1
6	Screw, slotted head, #10 x 1/2	---	4
7	Screw, round head, hex socket, #10 x 1/2	---	4

## 6-3. MODEL 4004A DUAL RACK MOUNTING KIT.

a. The Model 4004A Kit converts the Model 414A to rack mounting. The assembled Kit will contain either two Model 414A's, or one each of the Model 414A and the Keithley Model 240A High Voltage Supply or any two 5-1/4" high Keithley half-rack instruments. Dimensions are 5-1/4 inches high x 19 inches wide x 10 inches deep.

instrument by removing the two corner screws at the bottom of each side. Assemble the rack mounting parts as shown in Figure 11. If rack mounting two 10 inches deep instruments or two 13 inches deep instruments, attach in this order: cover (1), two rack angles (5), chassis connecting plate (2), and chassis connecting plate (3). If rack mounting one each 10-inch deep instrument and 13-inch deep instrument attach in this order: cover (1), two rack angles (4), chassis connecting plate (3), and zee bracket (7).

b. Procedures. Remove the wrap-around cover on each

TABLE 11. Parts List for Model 4004A Rack Mounting Kit.

Item (See Fig. 11)	Description	Keithley Part No.	Quantity
1	Cover Assembly (2 covers for 10" models)	18554B	1
---	Cover Assembly (2 covers for 13" models)	20015B	1
2	Chassis Connecting Plate	17454A	1
3	Chassis Connecting Plate	19126A	1
4	Rack Angle	14624B	2
5	Screw, slotted, #10 x 1/2	---	8
6	Screw, round head, hex socket, #10 x 1/2	---	4
7	Zee Bracket	17454A	1

## 6-4. MODEL 6106 ELECTROMETER CONNECTION KIT.

a. The Model 6106 Kit contains a group of the most useful leads and adapters for use in calibrating the Model 414A and for measurements in general. The Kit case is 2 inches high x 12 inches wide x 8 inches deep with polyethylene foam compartments. It weighs approximately three pounds.

b. The Kit contains two leads made with 30-inch low-noise coaxial shielded cable (RG58A/U). One lead has two UHF plugs, which allow easy connections between the Model 414A and Keithley electrometers. The second lead has a UHF plug and two alligator clips. Adapters are also supplied for UHF-to-BNC conversion. For more information on the Kit, contact Keithley Instruments, Inc.

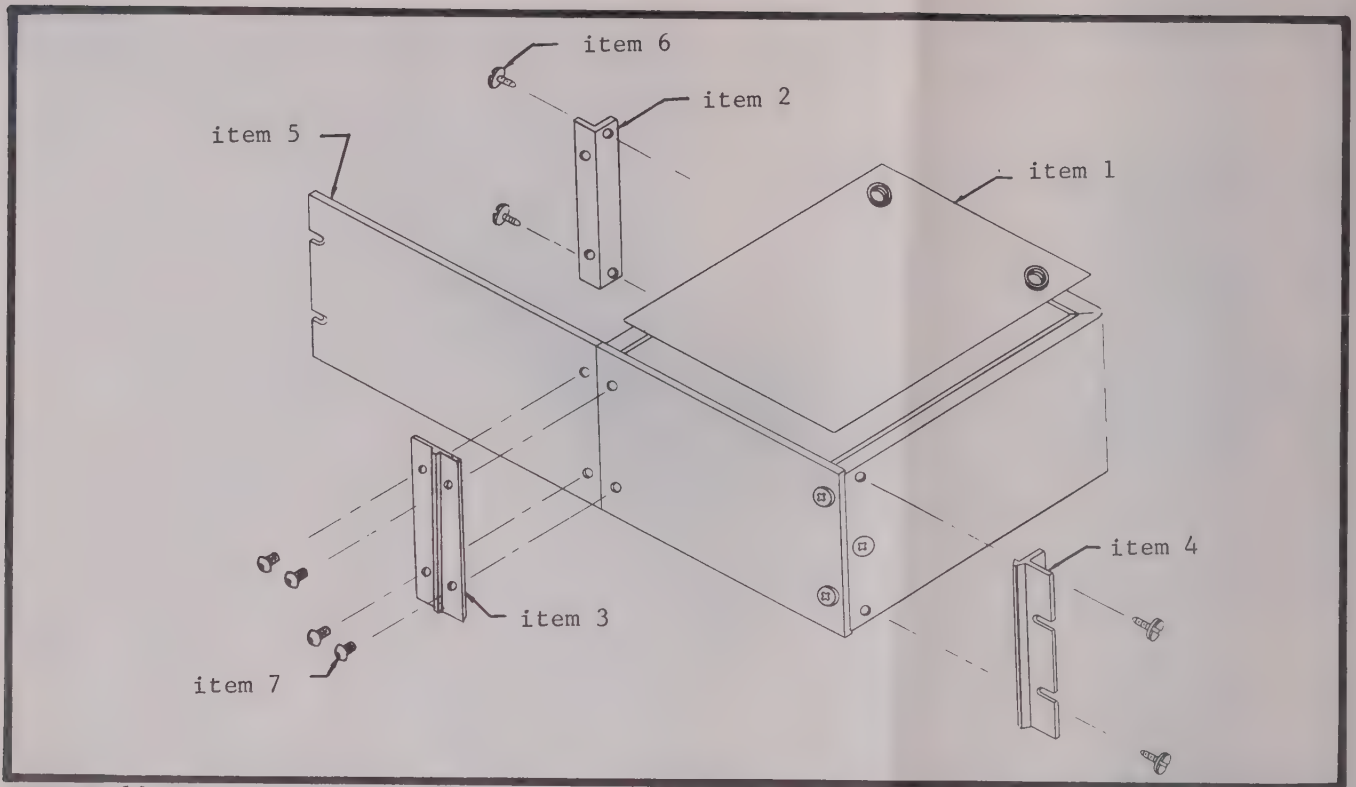


FIGURE 10. Exploded View of Model 4003A Rack Mounting Kit. See Table 10 also.

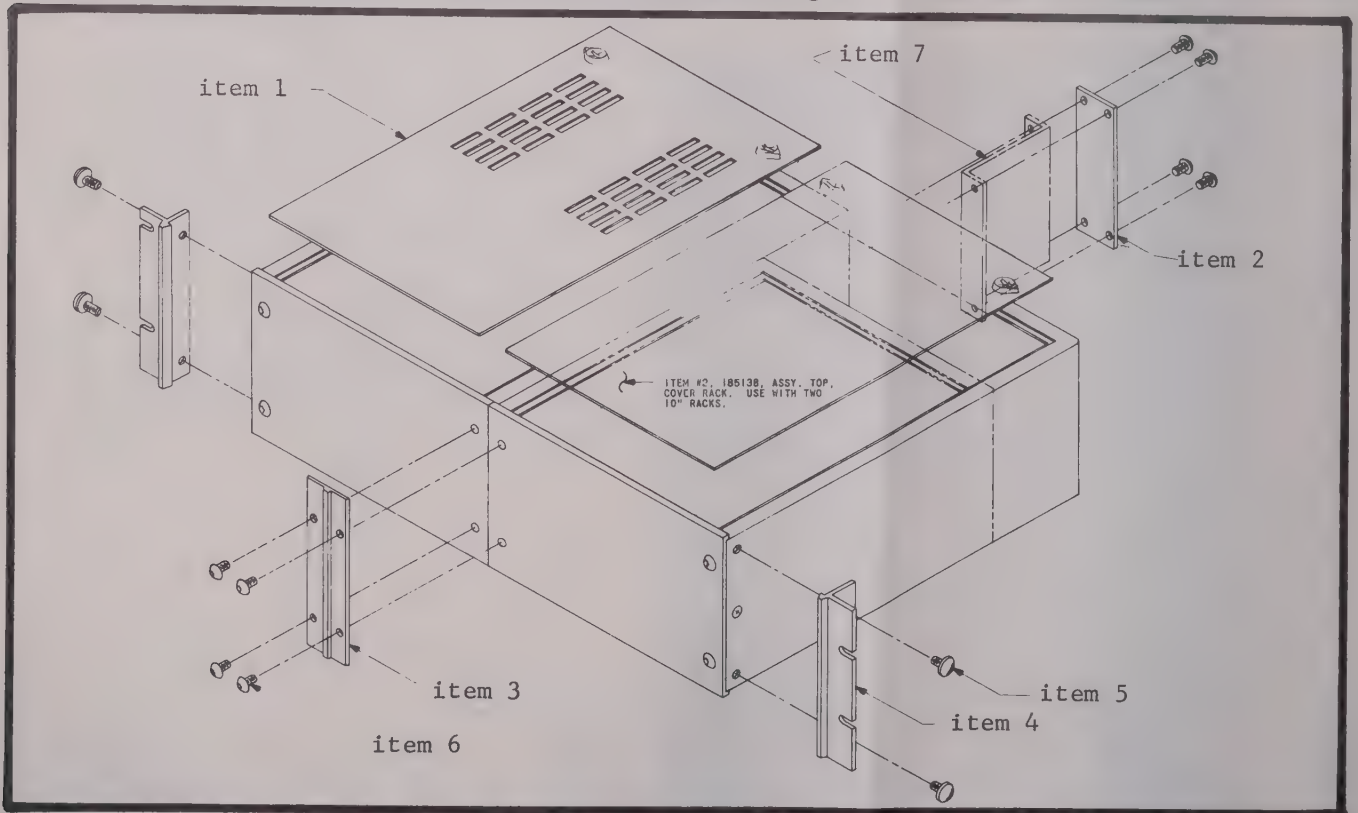


FIGURE 11. Exploded View of Model 4004A Dual Rack Mounting Kit. See Table 11 also.

6-5. VOLTAGE SUPPLIES. The Keithley Models 240A, 245 and 246 High Voltage Supplies are designed for complete compatibility with the Model 414A as well as with other Keithley picoammeters. The supplies deliver voltages of 0-1200, 0-2100 and 0-3100 volts respectively for easy use with the Picoammeter in many different applications. Besides being completely compatible with the Model 414A, the Model 240A Voltage Supply is of half-rack size and can be conveniently rack mounted with the Picoammeter using the 4004A Dual Rack Mounting Kit (paragraph 6-3). For more information on these supplies write to Keithley Instruments, Inc.

6-6. MODEL 370 RECORDER.

a. The Model 370 Recorder is uniquely compatible with the Model 414A as well as other Keithley picoammeters, microvoltmeters and electrometers. The Recorder is a high quality economical instrument that epitomizes the performance of the Model 414A, and many other Keithley instruments, even in the most critical applications. The Model 370 can be used with the Model 414A to record currents over the Model 414A's entire range.

b. The Model 414A has the output necessary to drive the Recorder directly (1 volt, 1 milliampere), thus eliminating the need for a pre-amplifier. The Model 370 floats  $\pm 500$  volts off ground. The recorder is specially shielded to avoid pickup of extraneous signals. The response time of the Model 370 Recorder is 0.5 second; linearity is  $\pm 1\%$  of full scale. Ten chart speeds — from 3/4 inch per hour to 12 inches per minute — are selectable with front panel controls. The 6-inch chart has a rectilinear presentation. The Model 370 Recorder has a self-priming inking system. Chart paper and ink refills are easy to install.

c. The Model 370 is very easy to use with the Model 414A. Just connect the Model 414A's OUTPUT Receptacle to the Model 370 with the furnished 3701 Input Cable and adjust an easily accessible control for full-scale recorder deflection.

6-7. MODEL 261 PICOAMPERE SOURCE.

a. The Model 261 is completely compatible with the Model 414A. It is an ideal source for calibrating the Model 414A over the Picoammeter's entire range.

b. The Model 261 is very easy to use with the Model 414A. Just connect the Model 261 to the Model 414A INPUT Receptacle with the furnished 2611 Cable and apply the required signal. Also, the Model 261 is half-rack size and can be conveniently rack mounted with the Picoammeter using the Model 4004A Dual Rack Mounting Kit (paragraph 6-3).

6-8. MODEL 4109 BIASING POTENTIAL. The Keithley Model 4109 is a biasing potential that may be internally mounted in the Model 414A and can be used to supply a polarizing potential of up to +300 volts for use in different applications. The Model 4109 has an output of +300 volts at 1 milliampere, regulation of  $\pm 0.02\%$ , 2 millivolts rms noise, overload protection to 2 milliamperes and a stability of  $\pm 0.1\%$ . The Potential may also be ordered with a negative polarity output (-300V) rather than the standard positive output. For more information on the Model 4109, contact Keithley Instruments, Inc.

6-9. MODEL 4104 TRIP.

a. The Keithley Model 4104 is a completely solid-state electronic trip that provides automatic control in many applications. The Trip has a wide range of trip modes. It can be preset for a trip level from 0.1 to 3.5 volts. When ordered, the Model 4104 comes installed in the Picoammeter.

b. The standard Trip has a high trip limit, negative polarity, and is latching. However, the Model 4104 is available with seven other options than the standard. For more information on the Trip, contact Keithley Instruments, Inc.

**SECTION 7. REPLACEABLE PARTS**

7-1. REPLACEABLE PARTS LIST. The Replaceable Parts List describes the components of the Model 414A. 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 the "Mfg. Code" column are in Table 13.

and serial number, the Keithley Part Number, the circuit designation and a description of the part. All structural parts and those parts 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 12. Abbreviations and Symbols.

A	Ampere	Fig.	Figure	$\Omega$	ohm
CbVar	Carbon Variable	GCb	Glass Enclosed carbon	p	pico ( $10^{-12}$ )
CerD	Ceramic, disc			Poly	Polystyrene
Comp	Composition	k	kilo ( $10^3$ )	Ref.	Reference
DCb	Deposited Carbon	$\mu$	micro ( $10^{-6}$ )	V	Volt
EA1	Electrolytic, Aluminum	M	Mega ( $10^6$ )	W	Watt
		Mfg.	Manufacturer	WWVar	Wirewound Variable
		Mtf	Metal Film		
F	Farad	My	Mylar		

MODEL 414A REPLACEABLE PARTS LIST  
(Refer to Schematic Diagram 22223D for circuit designations.)

CAPACITORS

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
C101	.25 $\mu$ F	400 V	My	13050	SM1A	C73-.25M	6
C102	.1 $\mu$ F	400 V	My	13050	SM1A	C73-.1M	6
C103	.02 $\mu$ F	600 V	CerD	72982	ED-.02	C22-.02M	6
C104	.02 $\mu$ F	600 V	CerD	72982	ED-.02	C22-.02M	6
C105	.0047 $\mu$ F	600 V	CerD	72982	ED-.0047	C22-.0047M	6
C106	.0022 $\mu$ F	600 V	CerD	72982	ED-.0022	C22-.0022M	6
C107	680 pF	600 V	CerD	72982	ED-680	C22-680P	6
C108	.01 $\mu$ F	600 V	CerD	72982	ED-.01	C22-.01M	6
C109	.0033 $\mu$ F	600 V	CerD	72982	ED-.0033	C22-.0033M	6
C110	.0022 $\mu$ F	600 V	CerD	72982	ED-.0022	C22-.0022M	6
C111	680 pF	600 V	CerD	72982	ED-680	C22-680P	6
C112	220 pF	500 V	Poly	71590	CPR-220J	C138-220P	6
C113	47 pF	500 V	Poly	71590	CPR-47J	C138-47P	6
C114	22 pF	500 V	Poly	71590	CPR-22J	C138-22P	6
C115	.02 $\mu$ F	600 V	CerD	72982	ED-.02	C22-.02M	6
C116	.0047 $\mu$ F	600 V	CerD	72982	ED-.0047	C22-.0047M	8
C201	100 $\mu$ F	400 V	EA1	73445	C437AR/G100	C150-100M	8
C202	100 $\mu$ F	400 V	EA1	73445	C437AR/G100	C150-100M	8

## DIODES

Circuit Desig.	Type	Number	Mfg. Code	Keithley Part No.	Fig. Ref.
D101	Silicon	1N645	01295	RF-14	8
D102	Zener	VR47	84970	DZ-30	8
D103	Silicon	1N3255	02735	RF-17	8
D104	Silicon	1N3255	02735	RF-17	8
D105	Silicon	1N3255	02735	RF-17	8
D106	Silicon	1N645	01295	RF-14	8
D107	Silicon	1N645	01295	RF-14	8
D201	Silicon	1N645	01295	RF-14	8
D202	Silicon	1N645	01295	RF-14	8
D203	Silicon	1N645	01295	RF-14	8
D204	Silicon	1N645	01295	RF-14	8
D205	Zener	1N715	12954	DZ-22	8
D206	Zener	1N715	12954	DZ-22	8

## MISCELLANEOUS PARTS

Circuit Desig.	Description	Mfg. Code	Keithley Part No.	Fig. Ref.
21850B	MOS FET Input Plug-In Card	80164	23734A	6
DS 201	Pilot Light, Neon (Mfg. No. 2190)	91802	PL-28	1,7
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	
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-MG2M)	02660	CS-33	
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-244	1,7
---	Knob Assembly, Meter Switch	80164	21660A	
S102	Rotary Switch less components, RANGE	80164	SW-243	1,6
---	Rotary Switch with components, Range	80164	21848B	
---	Knob Assembly, Range Switch	80164	21649A	
S103	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, Calibration Control	80164	16373A	
T201	Transformer	80164	TR-112	8

(F) Furnished Accessory.

## RESISTORS

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
R101	300 $\Omega$	1%, 1/2 W	DCb	91637	DCF 1/2	R12-300	6
R102	1 k $\Omega$	1%, 1/2 W	DCb	91637	DCF 1/2	R12-1K	6
R103	3 k $\Omega$	1%, 1/2 W	DCb	07716	DCC	R12-3K	6
R104	10 k $\Omega$	1%, 1/2 W	DCb	07716	DCC	R12-10K	6
R105	30 k $\Omega$	1%, 1/2 W	DCb	91637	DCF 1/2	R12-30K	6
R106	100 k $\Omega$	1%, 1 W	Epoxy	91637	MMF-1	R150-100K	6
R107	300 k $\Omega$	1%, 1/2 W	DCb	07716	DCC	R12-300K	6
R108	1 M $\Omega$	1%, 1/2 W	DCb	91637	DCF 1/2	R12-1M	6
R109	3 M $\Omega$	1%, 1/2 W	DCb	91637	DCF 1/2	R12-3M	6
R110	10 M $\Omega$	1%, 1/2 W	DCb	07716	DCC	R12-10M	6
R111	30 M $\Omega$	1%, 1 W	DCb	91637	DC-1	R13-30M	6
R112	100 M $\Omega$	1%, 2 W	DCb	91637	DC-2	R14-100M	6
R113	10 <sup>9</sup> $\Omega$	3%	Gcb	63060	RX-1	R20-10 <sup>9</sup>	6
R114	10 <sup>10</sup> $\Omega$	3%	Gcb	63060	RX-1	R20-10 <sup>10</sup>	6
R115	2 k $\Omega$	1/2%, 1/2 W	MtF	07716	CEC	R61-2K	6
R116	1 k $\Omega$	1/2%, 1/2 W	MtF	07716	CEC	R61-1K	6
R117	1 M $\Omega$	1%, 1/2 W	DCb	91637	DCF 1/2	R12-1M	9
R118**	100 k $\Omega$	10%, 1/4 W	Comp	01121	CB	R76-100K	
R119	5 k $\Omega$	20%, 2 W	WWVar	71450	1NS-115	RP50-5K	9
R120	1 k $\Omega$	10%, 5 W	WWVar	71450	AW	RP34-1K	9
R121	11.8 k $\Omega$	1%, 1/2 W	MtF	07716	CEC	R94-11.8K	9
R122	18 k $\Omega$	1%, 1/2 W	DCb	07716	DCC	R12-18K	9
R123	2 k $\Omega$	20%, 0.2 W	CompV	71450	70	RP31-2K	1,7
R124	18 k $\Omega$	1%, 1/2 W	DCb	07716	DCC	R12-18K	9
R125	15 k $\Omega$	10%, 1/2 W	Comp	01121	EB	R1-15K	9
R126	680 $\Omega$	10%, 1/2 W	Comp	01121	EB	R1-680	9
R127	2.2 k $\Omega$	10%, 1/2 W	Comp	01121	EB	R1-2.2K	9
R128	4.7 k $\Omega$	10%, 1/2 W	Comp	01121	EB	R1-4.7K	9
R129	1.2 k $\Omega$	10%, 2 W	Comp	01121	HB	R3-1.2K	9
R130	2 k $\Omega$	1%, 1/2 W	DCb	07716	DCC	R12-2K	9
R131	2 k $\Omega$	20%, 2 W	WWVar	71450	1NS-115	RP50-2K	9
R132	1 k $\Omega$	1/2%, 1/2 W	MtF	07716	CEC	R61-1K	9
R133	1 k $\Omega$	10%, 5 W	WWVar	71450	AW	RP34-1K	2,6
R134	1 k $\Omega$	1/2%, 1/2 W	MtF	07716	CEC	R61-1K	2,6
R135	1 k $\Omega$	1/2%, 1/2 W	MtF	07716	CEC	R61-1K	2,6
R201	27 k $\Omega$	10%, 1/2 W	Comp	01121	EB	R1-27K	9
R202	1 k $\Omega$	10%, 1/2 W	Comp	01121	EB	R1-1K	9
R203	1 k $\Omega$	10%, 1/2 W	Comp	01121	EB	R1-1K	9

## TRANSISTORS

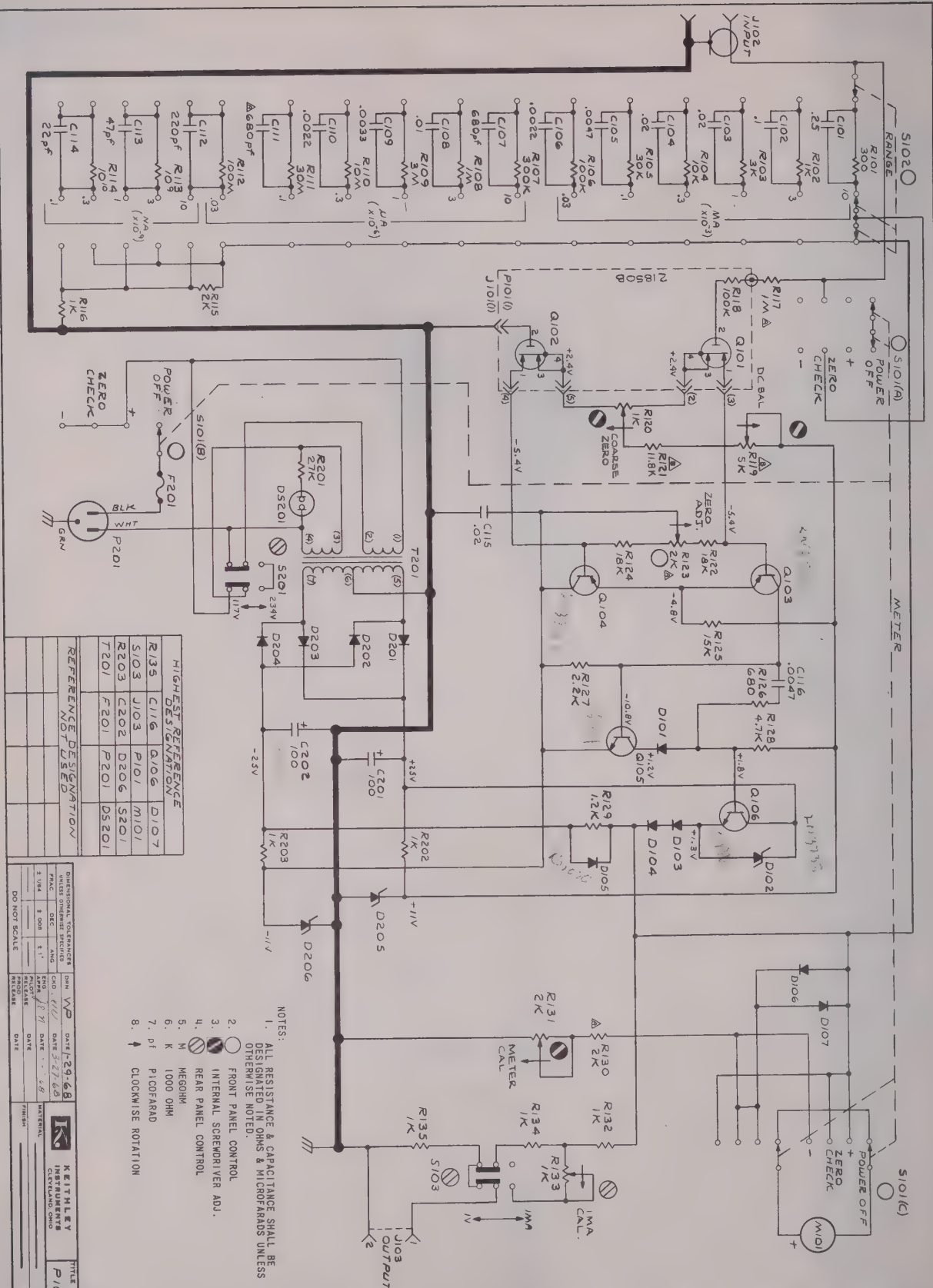
Circuit Desig.	Number	Mfg. Code	Keithley Part No.	Fig. Ref.
Q101**		80164		
Q102**		80164		
Q103		80164	21675A	8
Q104		80164	21675A	8
Q105	2N3904	04713	TG-47	8
Q106	ES-5321	71279	TG-54	8

\*\* Replace R118, Q101 or Q102 by ordering Plug-in Board 21850B.

TABLE 13.

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

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



HIGHEST REFERENCE DESIGNATION			
R135	C116	Q106	D107
S103	J103	P101	M101
R203	C202	D206	S201
T201	F201	P201	D5201

REFERENCE DESIGNATION NOT USED			

- NOTES:
1. ALL RESISTANCE & CAPACITANCE SHALL BE OTHERWISE NOTED.
  2. FRONT PANEL CONTROL
  3. INTERNAL SCREWDRIVER ADJ.
  4. REAR PANEL CONTROL
  5. MEGOHM
  6. K 1000 OHM
  7. pf PICOFARAD
  8. CLOCKWISE ROTATION

DIMENSIONAL TOLERANCES UNLESS OTHERWISE INDICATED		FORM	VP	DATE	7-29-68
FRAC	DEC	ANG	NO	REV	DATE
2/164	3/1008	1°	1	1	7-27-68
DO NOT SCALE		REVISE	DATE	REVISE	DATE
		DATE	DATE	DATE	DATE

MATERIAL: KEITHLEY INSTRUMENTS CLEVELAND, OHIO

TITLE: SCHEMATIC PICOAMMETER

PART NUMBER: 22223D

SCALE: USED ON

QTY	6010	7000	2470
A1350	1	1	1
B3510	1	1	1



REPAIR AND CALIBRATION FORM

For repair or calibration, please fill out this form and return it with your instrument to:  
 Sales Service Department  
 Keithley Instruments, Inc.  
 28775 Aurora Road  
 Cleveland, Ohio 44139

R- \_\_\_\_\_  
 Do not write in this space.

User's Name \_\_\_\_\_ Telephone \_\_\_\_\_ Ext. \_\_\_\_\_  
 Company \_\_\_\_\_ Address \_\_\_\_\_  
 Division \_\_\_\_\_ City \_\_\_\_\_ State \_\_\_\_\_ Zip \_\_\_\_\_  
 Date \_\_\_\_\_ Model No. \_\_\_\_\_ Serial No. \_\_\_\_\_

1. Reason for Return  
 Repair and Recalibration  
 Recalibration only (No report, except as specified in item 4 on reverse)\*  
 \*If repairs are necessary to meet specifications, they will be in addition to the calibration.
2. Calibration Report Desired  
 Report of Calibration Certified Traceable to N.B.S.  
 Calibration Report  
 Certificate of Compliance  
 None  
 (for details, see reverse side of this form)

3. To help repair the instrument, briefly describe the problem: \_\_\_\_\_  
 \_\_\_\_\_

4. Is the problem  Constant  Intermittant  
 Under what conditions does the problem occur:
- a) Control setting \_\_\_\_\_  
 \_\_\_\_\_  
 e) Line voltage \_\_\_\_\_  
 f) Other (such as line transients, line variations, etc.) \_\_\_\_\_
- b) Approx. Temperature \_\_\_\_\_ °F  
 c) Approx. Temperature variation ± \_\_\_\_\_ °F  
 d) Approx. Humidity (high, medium, low) \_\_\_\_\_

5. Please draw a block diagram of the system using the Keithley. List any other pertinent data which can help in the repair. Include charts or other data if available.  
 Signal Source \_\_\_\_\_  
 Source Impedance \_\_\_\_\_  
 Readout Device:  
 Recorder  
 Oscilloscope  
 Other  
 None  
 Lengths & Types of Connecting Cables \_\_\_\_\_

6. What repairs or modifications have been made on this instrument which are not on file with the Keithley Repair Department? \_\_\_\_\_  
 \_\_\_\_\_

7. Please enclose any other pertinent data and charts which you feel might help the Repair and Calibration Department

\_\_\_\_\_  
 Signature Title

CALIBRATIONS AVAILABLE AT KEITHLEY INSTRUMENTS.

Listed and defined below are the four types of calibrations and their associated report formats which are presently available at Keithley Instruments. They fall into the following categories:

1. Report of Calibration Certified Traceable to the National Bureau of Standards
2. Calibration Report
3. Certificate of Compliance
4. Recalibration

All calibration and certification performed by Keithley Instruments is in accord with MIL-C-45662A.

Prices shown below are in addition to repair charges for any work necessary to place a customer's unit into first class condition prior to the calibration.

1. Report of Calibration Certified Traceable to the National Bureau of Standards.

This is a completely documented report, including all basic errors or deviations from nominal settings on appropriate ranges, terminals, dials, etc. Work is performed using the primary standards of the company with secondary transfers kept to a minimum. The NBS test numbers for the latest recalibration of the primary standards are furnished.

By definition, the above is performed in our Standards Laboratory so that random operator induced error is minimized and maximum protection to the equipment used is maintained.

This type of calibration is not recommended for instruments with a basic inaccuracy of 1% or greater. The precision involved in this report makes it uneconomical for such instruments. The Calibration Report listed below (No. 2) would be better suited in this case.

As of 11/1/69 the Report of Calibration Certified Traceable to the National Bureau of Standards is available on the following instruments at the prices listed:

Model 140 . . . . .	\$275	Model 5155 (Complete Set) . . .	\$295
Model 260 . . . . .	\$225	Model 5155-10 <sup>8</sup> . . . . .	\$ 50
Model 261 . . . . .	\$375	Model 5155-10 <sup>9</sup> . . . . .	\$ 50
Model 515 . . . . .	\$375	Model 5155-10 <sup>10</sup> . . . . .	\$ 50
Model 630 . . . . .	\$275	Model 5155-10 <sup>11</sup> . . . . .	\$ 60
Model 660A . . . . .	\$250	Model 5155-10 <sup>12</sup> . . . . .	\$ 60
Model 662 . . . . .	\$275	Model 5155-10 <sup>13</sup> . . . . .	\$ 80

2. Calibration Report.

This report shows only the cardinal range, terminal, dial, etc. errors as determined by production calibration equipment and personnel. The production equipment is maintained traceable by transfer techniques against the primary standards maintained by the company. We attest to this fact and list basic deviations from nominal but the conditions of calibration are not as precisely controlled as the previous report nor are NBS test numbers supplied.

This report is available for any instrument in our line. As of November 1, 1969, only the following price has been established for this report:

Model 261 . . . . .	\$ 55
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Prices for other units can be estimated upon request.

3. Certificate of Compliance.

This is merely a restatement of the basic guarantee that the instrument was calibrated on equipment that is maintained by our standards personnel against primary standards. No report is issued.

This Certificate of Compliance is available at no charge for any instrument with the exception of the Model 261.

A newly purchased Model 261 or one returned for repair or recalibration is automatically supplied with a Calibration Report (as described in (2) above). The nature of this instrument makes it necessary to complete this report to ascertain specified accuracy. This Calibration Report is forwarded to the customer with the instrument. The \$55 charge is incorporated as part of the normal calibration charge of the Model 261.

4. Recalibration.

This is a recalibration of the instrument according to our factory calibration procedures. The prices for this as of November 1, 1969 are as follows:

Model 260 . . . . .	\$ 85	(No report supplied. A Certificate of Compliance can be had at no charge if requested).
Model 261 . . . . .	\$ 55	(Calibration Report as described in (2) above is supplied. See (3) for explanation).

All other instruments are on a time and material basis for the particular unit involved.





KEITHLEY INSTRUMENTS, INC.

28775 AURORA ROAD • CLEVELAND, OHIO 44139 • (216) 248-0400  
TELEX: 98-5469 • CABLE: KEITHLEY