INSTRUCTION MANUAL

MODEL 260

NANOVOLT SOURCE

WARRANTY

We warrant each of our products to be free from defects in material and workmanship. Our obligation under this warranty is to repair or replace any instrument or part thereof which, within a year after shipment, proves defective upon examination. We will pay domestic surface freight costs.

To exercise this warranty, call your local field representative or the Cleveland factory, DDD 216-248-0400. You will be given assistance and shipping instructions.

REPAIRS AND RECALIBRATION

Keithley Instruments maintains a complete repair service and standards laboratory in Cleveland, and has an authorized field repair facility in Los Angeles and in all countries outside the United States having Keithley field representatives.

To insure prompt repair or recalibration service, please contact your local field representative or the plant directly before returning the instrument.

Estimates for repairs, normal recalibrations, and calibrations traceable to the National Bureau of Standards are available upon request.

TABLE OF CONTENTS

* Yellow Change Notice sheet is included only for instrument modifications affecting the Instruction Manual.

SECTION 1. GENERAL DESCRIPTION

1-1. GENERAL.

a. The Keithley Model 260 Nanovolt Source is a secondary standard for use in calibrating nanovoltmeters and microvoltmeters. Its output is from 10^{-10} volt to 1.11 volts, positive or negative, in nine decade ranges. The Source has 3-digit resolution for any value between 1 nanovolt and 1 volt.

b. Output accuracy is $\pm 0.25\%$ of setting at 10^{-3} volt and greater, $\pm 0.50\%$ of setting from 10^{-6} to 10^{-3} volt, and $\pm 0.75\%$ of setting for the smaller outputs. The Model 260 will operate within stated accuracy for one year.

c. The Model 260 is line operated; the low side of the output can be floated to avoid ground loops or for use in ungrounded systems. The Source is basically a stable power supply coupled with a precision divider network. The power supply uses solid-state components throughout, and it is highly regulated for stability.

1-2. FEATURES.

a. Thermal voltages generated by the Source are less than 10 nanovolts absolute when the unit is allowed to warm up for 1 hour. There is less than a 2-nanovolt change during a step temperature change of $1^{o}C$. The excellent thermal characteristics result from massive heat sinking, extensive thermal shielding and using pure copper resistive dividers, connections and terminals.

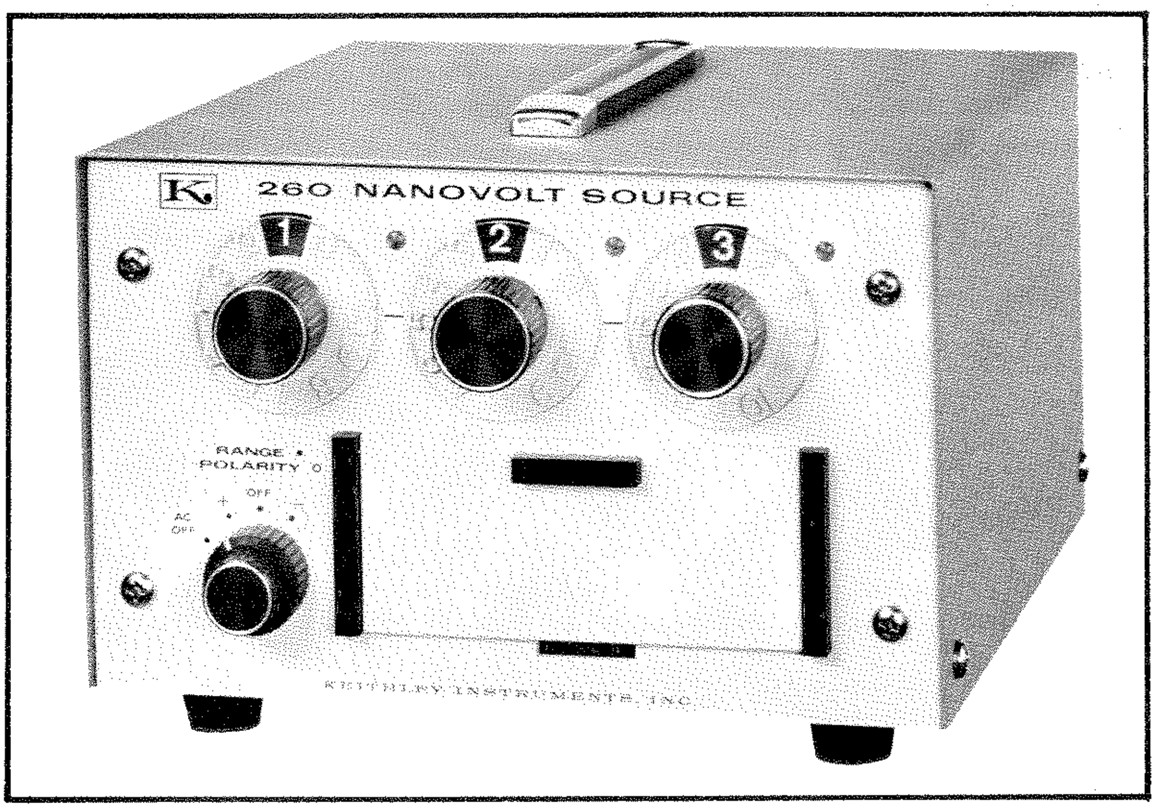


FIGURE 1. Keithley Instruments Model 260 Nanovolt Source

b. Using extremely low-impedance output dividers minimizes Johnson noise. Source resistance is only 1 ohm on the 1-nanovolt to 1.11-millivolt ranges, and 100 ohms on the 1-millivolt to 1.11-volt ranges. Extensive magnetic shielding around the output compartment and the final output divider also minimizes Johnson output noise.

1-3. SPECIFICATIONS.

OUTPUT: 10^{-10} volt to 1.11 volts, positive or negative, in nine decade ranges.

ACCURACY:
$\pm$0.25% of setting, 10^{-3} volt to 1.11 volts;
$\pm$0.5% of setting, 10^{-6} volt to 10^{-3} volt;
$\pm$0.75% of setting, 10^{-9} volt to 10^{-6} volt.

LONG-TERM STABILITY: Will operate within stated accuracy for six months.

TEMPERATURE COEFFICIENT: $\pm$0.1%/°C, 15°C to 30°C, on millivolt and microvolt ranges; $\pm$0.2%/°C on nanovolt ranges.

THERMAL VOLTAGES: Less than 10 nanovolts absolute when allowed to stabilize for 1 hour. Less than a 2-nanovolt change during a step temperature change of 1°C.

WARM-UP TIME: 1 hour.

LINE REGULATION: 0.01% for 10% change in line voltage.

SOURCE RESISTANCE: 1 ohm, 10^{-9} volt to 1.11 x 10^{-3} volt; 100 ohms, 10^{-3} volt to 1.11 volts.

RESOLUTION: Three significant figures from 1 nanovolt to 1.11 volts.

OUTPUT ISOLATION: Low to ground: greater than 10^9 ohms shunted by 0.001 microfarad.

CERTIFICATION: A Calibration Certificate is furnished including temperature and date of calibration. Certification traceable to the National Bureau of Standards is also available.

POWER: 105-125 or 210-250 volts (switch selected), 50 - 1000 cps, 6 watts.

CONNECTORS: Output: Binding posts. Low and Ground: Binding posts.

DIMENSIONS, WEIGHT: 5-1/2 inches high x 8-3/4 inches wide x 10 inches deep; net weight, 9 pounds.

ACCESSORIES SUPPLIED: Model 2601 Low-Thermal Output Cable with copper alligator clips.

1-4. APPLICATIONS.

a. Primarily, the Model 260 is used in calibrating nanovoltmeters and microvoltmeters, which have full-scale ranges anywhere from 10^{-9} to 1 volt.

b. The Model 260 may be used for zero suppression by placing its output in series with a nanovoltmeter and an unknown source. Its high stability permits suppression of voltages up to 1000 times full scale.

c. Potentiometric measurements are a special case of zero suppression. In this case, the nanovoltmeter is used as a null detector and the unknown voltage is read directly from the Model 260 dials. The accuracy of such a measurement is equal to the accuracy of the Model 260 plus any uncertainty due to thermal emf's.

1-5. ACCESSORIES.

a. Model 2602 Low-Thermal Calibration Cable connects the Nanovolt Source to the Keithley Models 149 and 150A. The Model 2603 Low-Thermal Calibration Cable connects the Nanovolt Source to the Keithley Models 147 and 148. Mating connector required by the Model is on the appropriate Cable.

b. Model 1483 Low-Thermal Connection Kit contains a crimp tool, pure copper lugs, cable and assorted hardware for making calibration setups which need the best low-thermal connections. Model 1484 Refill Kit contains replacement parts for the expendable items in the Model 1483 Kit. The parts list for both Kits is in Section 8.

c. Several mounting kits are available. The Model 4003 Rack Mounting Kit converts the Model 260 for mounting in a standard 19-inch rack. The Model 4004 Dual Rack Mounting Kit is for rack mounting two Model 260's or a Model 260 and a Model 261 Picoampere Source in one rack frame. Total dimensions for units in the Model 4004 Kit are 5-1/4 inches high x 19 inches wide x 10 inches deep. The Model 3004 Dual Bench Mounting Kit will hold two Model 260's or a Model 260 and a Model 261 Picoampere Source in one convenient configuration for bench use. The dual instruments will measure 5-1/2 inches high x 17-1/2 inches wide x 10 inches deep. See Section 7 for photographs and installation instructions.

1-6. EQUIPMENT SHIPPED. The Model 260 Nanovolt Source is factory-calibrated. It will remain within its rated specifications for at least 1 year after date of shipment. The signed Certificate of Compliance and Calibration furnished with each Source lists calibration data. The shipping carton also contains the Instruction Manual and the Model 2601 Low-Thermal Output Cable.

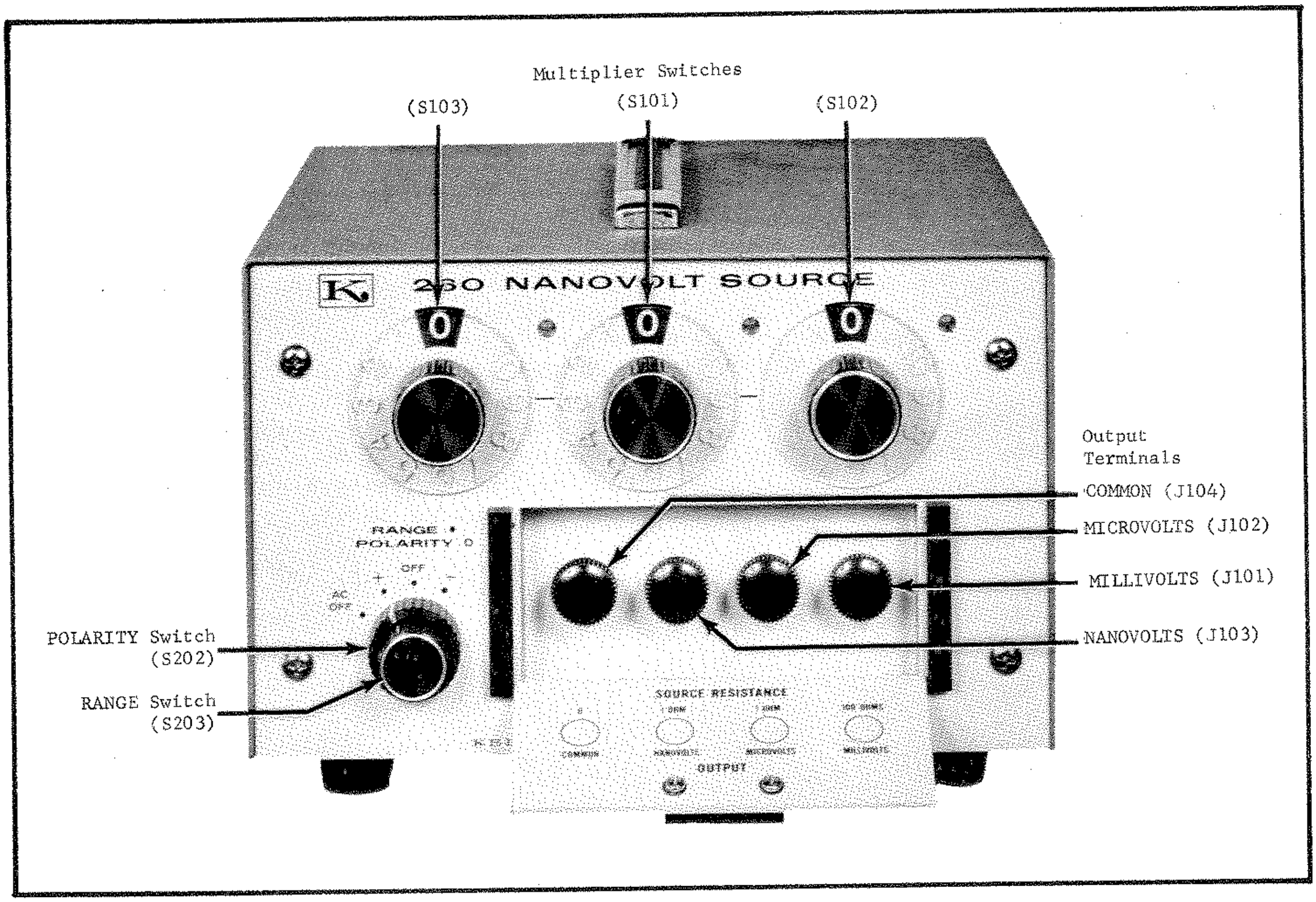


FIGURE 2. Model 260 Front Panel Controls and Terminals. Circuit designations refer to the schematic diagram.

SECTION 2. OPERATION

2-1. FRONT PANEL CONTROLS AND TERMINALS. (See Figure 2.)

a. POLARITY Switch. The control knob for this switch is the outer part of a dual concentric control. The POLARITY Switch has four positions: the + and - positions provide for either positive or negative voltage outputs. In the AC OFF position, the Model 260 power is disconnected. When the Switch is set to OFF, the power supply remains on, but there is zero output voltage.

b. RANGE Switch. The RANGE Switch, which is concentric with the POLARITY Switch, has three positions which determine the Model 260 output. Each position is indicated by an illuminated decimal point located after each Multiplier Dial. When the Switch is in the X1000 position, the far right decimal point is lit; in the X100, the middle decimal point; in the X10, the left decimal point.

c. Multiplier Switches. Three Switches provide multiplying values for the RANGE Switch. Each dial has 11 positions, from 0 to 10, providing overlapping multiplier values.

d. OUTPUT Terminals. Three output terminals and a common terminal are located behind the door on the front panel. All terminals are gold plated to minimize thermals. A slot in the hinged door allows the door to be closed with the Output Cable connected. This eliminates air currents from the terminal connections, which could cause errors in the output.

2-2. REAR PANEL CONTROLS AND TERMINALS.

a. 117-234 Switch. The screwdriver-operated slide switch sets the Model 260 for 117 or 234-volt ac power lines.

b. FUSE. For 105-125 volt operation, use a 1/16-ampere, 3 AG slow-blow fuse. For 210-250 volt operation, use a 1/32-ampere, 3 AG slow-blow fuse.

c. Power Cord. The 3-wire power cord with the NEMA approved 3-prong plug provides a ground connection for the cabinet. An adapter for use from 2-terminal lines is provided.

d. COM and GND Terminals. The green COM Binding Post is electrically connected to the common output terminal and the internal shield. The black GND Binding Post is connected directly to the chassis. A shorting link is provided to connect the two posts together and ground the low side of the output to the chassis.

2-3. OPERATING PROCEDURES.

a. Check the 117-234 Switch and the Fuse for the proper ac line voltage. Connect the power cord.

b. Set the Model 260 controls as follows:

POLARITY Switch	OFF
RANGE and Multiplier Switches	Desired voltage range

Disconnect the shorting link between the COM and GND Binding Posts.

NOTE

> Warm up the Nanovolt Source for 1 hour. This produces the best stability, especially on the nanovolt and microvolt ranges.

c. Connect the Model 260 to the nanovoltmeter with the Output or Calibration Cable. Insert the Output Cable through the input compartment door. Close the door during calibration, especially for the microvolt and nanovolt ranges, to eliminate air currents in the input compartment. These cause extraneous signals due to the thermal emf's generated at the terminal connection. Connect one spade lug on the Output Cable to the COMMON Terminal and the other to the terminal which furnishes the desired output range. The shield connection of the Model 2601 Cable may be connected to the nanovoltmeter case.

NOTE

> Ground loops may occur when equipment connected to the Model 260 has one side of the input grounded. In this case, disconnect the shorting link between the Model 260 COM and GND Binding Posts. The low side of the output is then floating.

d. Make sure all connectors, binding posts and lugs are clean and free of contamination before making the connection. Refer to paragraph 2-5. Make all connections in accordance with the precautions in paragraph 2-6.

e. Select ranges by connecting the Output Cable to one of the three OUTPUT Terminals. Use the Terminal which allows using the most significant figures on the Multiplier Switches. This gives the most accurate Model 260 output. Set the RANGE Switch so that the decimal appears as far to the right as possible. For example, NNN is better than NN.N or N.NN. Set the POLARITY Switch to + or - for the voltage of the needed polarity.

NOTE

> Because of switch contact resistance and connecting wire resistance, there is a residual output with the Multiplier Switches at zero.

f. The Model 260 source resistance is very low (values appear below the OUTPUT Terminals); errors due to a nanovoltmeter loading the Model 260 will be negligible in most cases. For example, on the microvolt range, the 100,000-ohm input resistance of the Keithley Model 148 or 149 will cause a loading error of only 0.001%. On the nanovolts range, the 1000-ohm input resistance of the Model 148 will cause only a 0.1% error in the calibration reading. Since these values are well within the span of the Model 260 accuracy specification, loading errors can generally be neglected when checking a nanovoltmeter.

NOTE

> Measuring in the nanovolt and microvolt ranges makes good connections necessary. The Keithley accessory cables are recommended to minimize many problems introduced by ordinary cables. Even using these accessories, careful procedures are necessary to minimize errors.

2-4. ACCESSORY CABLES. Keithley has three Cables to facilitate connections from the Model 260 to the nanovoltmeter. The Model 2601 Low-Thermal Output Cable can be used with any voltmeter; it is designed to minimize noise and thermal emf's. One end has a pair of copper spade lugs and the other end has a pair of copper alligator clips. The Model 2602 Low-Thermal Calibration Cable has a pair of copper spade lugs and a connector which mates with the input receptacle on the Keithley Models 149 and 150A. The Model 2603 Low-Thermal Calibration Cable has a connector which mates with the input receptacle on the Keithley Models 147 and 148.

2-5. MAKING OUTPUT CONNECTIONS.

a. When working on the microvolt and nanovolt ranges, all connections must use low thermal materials. This is why the Keithley accessory cables are recommended. Also, the Model 1483 Low-Thermal Connection Kit contains materials to make the best and easiest low-thermal connections. Before making a junction, clean the bare metal with a non-metalic abrasive, such as Scotch Brite or its equivalent. Crimp connections, as possible with the Model 1483 Kit, provide the best low-thermal connections.

b. If cadmium solder is used for a connection, make sure the soldering iron used is clean and that it has not been used with regular solder before. Use only rosin solder flux. If possible, heat sink all cadmium-soldered joints together to reduce generated thermal emf's.

c. Use crimp connections with copper wire and lugs for the best low-thermal joints. The Model 1483 Kit contains a crimp tool, shielded cable, an assortment of copper lugs, copper wire, cadmium solder and nylon bolts and nuts. It is a complete kit for making very low-thermal calibrating circuits. The Kit enables the user of the Model 260 to maintain the high thermal stability of the Source in his own circuit.

2-6. POINTS TO INCREASE CALIBRATION ACCURACY.

a. Thermal resistance noise, electrostatic and electromegnetic fields, thermoelectric voltages and motion of leads have a significant effect on the calibration voltage. This paragraph briefly outlines some likely sources of errors. Also read the more complete instructions in the Instruction Manual sent with the nanovoltmeter and the microvoltmeter.

b. Thermal agitation noise, or Johnson noise, is present in any resistance. The approximate equation for peak-to-peak Johnson noise at $300^{\circ}K$ is

$$E = 6.45 \times 10^{-10} (R\ F)^{1/2}$$

where E is the peak-to-peak Johnson noise in volts;
R is the resistance in ohms;
F is the amplifier bandwidth in cps.

For example, a 100-kilohm resistor develops about 0.2 microvolt peak-to-peak of noise at room temperature when the amplifier bandwidth is 1 cps. By comparison, a 100-ohm resistor under the same circumstances has noise of only about 6.5 nanovolts. Thus the value of the source resistance limits the usable voltage sensitivity.

c. Electrostatic and electromagnetic fields, if strong enough, can induce errors in nanovolt calibrations. To reduce such errors, use adequate shielding. Usually it is sufficient to connect the cases of all apparatus in the circuit together and to earth ground at one point. The "tree" grounding configuration also eliminates ground loops.

In areas where high ac magnetic fields exist, magnetic as well as electrostatic shielding may be required.

d. Thermoelectric voltages are produced when a temperature difference exists between two or more junctions of dissimilar metals. For this reason, all junctions should be copper-to-copper, or, if soldering is required, low-thermal solder should be used to keep these thermal emf's to a minimum. Refer to paragraph 2-5.

e. Any conductor moved through a magnetic field, including that of the earth, generates an emf. Calibration leads are no exception. If allowed to move during the calibration, they can induce significant errors. Electrostatic shields are provided on the cables to prevent extraneous signals due to stray electrostatic fields.

SECTION 3. APPLICATIONS

3-1. GENERAL. This Section discusses other uses for the Model 260 Nanovolt Source. Two applications are particularly well suited to the instruments: voltage suppression and potentiometric voltage measurements. These do not exhaust the possibilities of using the Model 260; instead, they illustrate techniques used for the most common applications other than in calibrating nanovoltmeters.

3-2. VOLTAGE SUPPRESSION.

a. The Model 260 can be used to buckout or suppress a constant voltage in order to use a more sensitive range on a nanovoltmeter to observe a superimposed signal. It can suppress voltages up to 1000 times full scale.

b. Operating Procedures.

1. The Model 260 must be floating; disconnect the shorting link between the LO and COM Binding Posts. Use either circuit shown in Figure 3 to connect the Model 260 and the nanovoltmeter to the unknown source. One circuit is for a line-operated voltmeter and the other for a battery-operated instrument.

2. Operate the Model 260 as instructed in paragraph 2-3. Set the Model 260 POLARITY Switch to the polarity opposite that of the unknown voltage. Set the voltage output to a value as near as possible to that of the voltage to be supressed. Set the nanovoltmeter to its least sensitive range; gradually increase sensitivity until a null is reached.

3. After reaching null, increase the nanovoltmeter's sensitivity. Small changes in the unknown voltage now may be observed.

3-3. POTENTIOMETRIC VOLTAGE MEASUREMENTS.

a. In this application, the Model 260 bucks out the unknown voltage and a null detector indicates null. The unknown voltage is read directly from the Model 260 setting.

b. Follow the same procedures generally as given in paragraph 3-2. In use, potentiometric voltage measurements are a special case of voltage suppression.

1. The Model 260 must be floating. Disconnect the shorting link between the LO and COM Binding Posts. If the shield connection to the Model 2601 Output Cable is used, connect it to the chassis ground of the Model 260 and the null detector. Use either circuit shown in Figure 3 to connect the Model 260 and the nanovoltmeter to the unknown source. One circuit is for a line-operated null detector and the other for a battery-operated instrument.

2. Follow the operating instruction in paragraphs 2-3 and 3-2. When a null is reached, the voltage indicated by the Nanovolt Source will be equal to the unknown voltage. The accuracy of this measurement is equal to the Model 260 accuracy plus any uncertainty due to emf's in the connections between instruments and the resolution of the null detector.

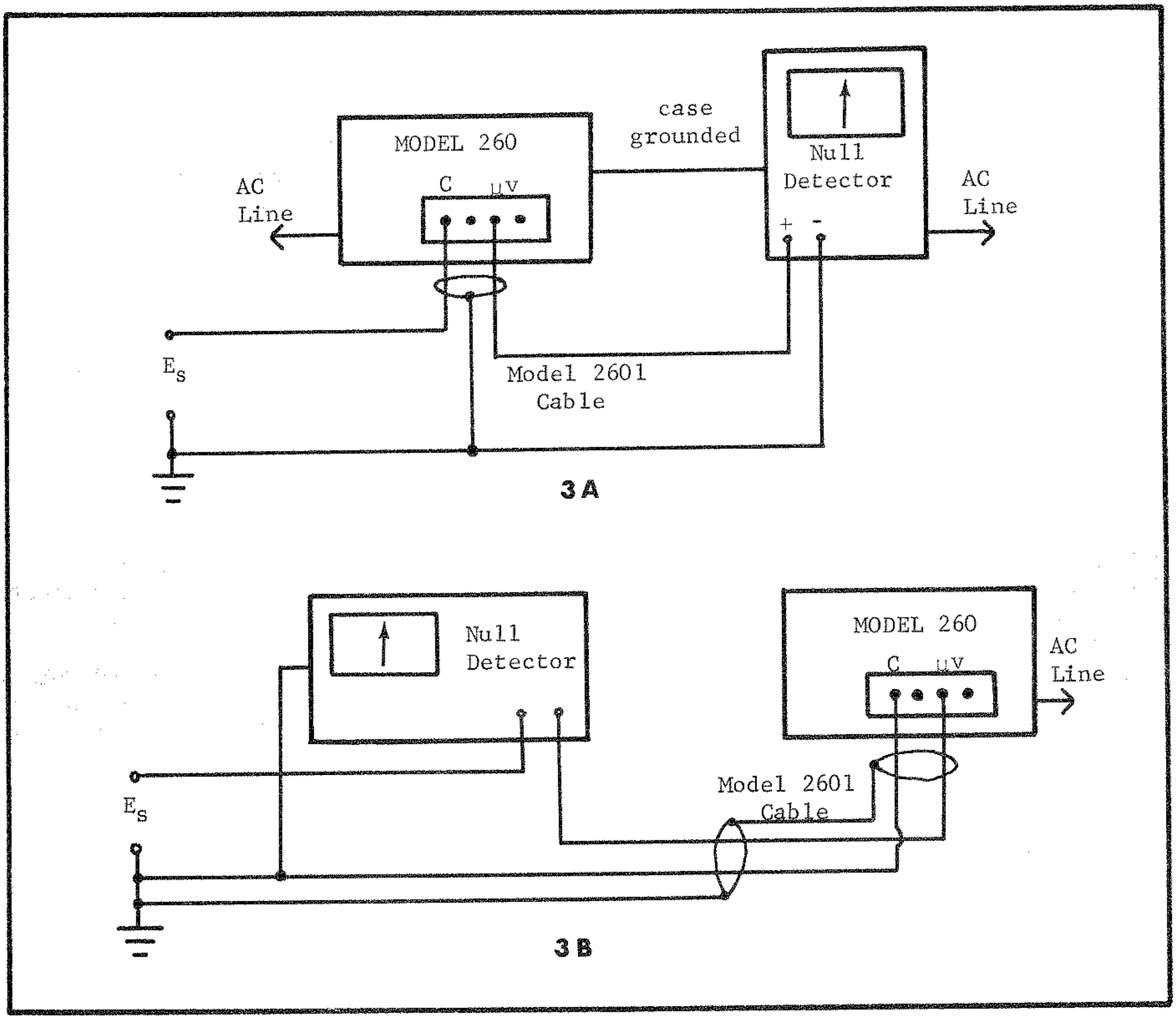


FIGURE 3. Circuits Using Model 260 for Voltage Suppression and Potentiometric Measurements. E_s is the unknown voltage.

Use the circuit in 3A when the voltmeter or null detector is line operated and therefore has capacity as well as shunt resistance from the low terminal to the chassis.

Use the circuit in 3B when the voltmeter or null detector is battery operated or can be completely isolated. With this circuit, capacity between the Model 260 low terminal and the chassis or line — even though slight — will not introduce an extraneous ac signal into the null detector input.

Note that the Model 260 is floating in both circuits; the shorting link is not connected between the LO and COM Posts.

SECTION 4. CIRCUIT DESCRIPTION

4-1. GENERAL.

a. The Keithley Model 260 Nanovolt Source is basically a high stability power supply coupled with a precision divider network (Figure 4). The power supply is used as a zener referenced constant current source which provides approximately 11 milliamperes. The current is used to develop accurate voltage drops across the divider network.

b. Four separate sections make up the divider network. The first is a 3-position attenuator that switches decades and automatically moves the illuminated decimal point. The second is a 3-dial "T" type attenuator which gives 3-digit resolution between the decades. These two attenuators cover the range from 1 volt to 1 millivolt. The third section extends the range from 1 millivolt to 1 microvolt by dividing the millivolt output with a pure copper 1000:1 divider. Shunt resistors are used to adjust its accuracy. The fourth section extends the range from 1 microvolt to 1 nanovolt by dividing the microvolt output with another ultra-low thermal 1000:1 divider.

c. The compartment containing the divider network is magnetically shielded, using special materials to prevent excessive pickup of nearby magnetic fields by the wirewound resistors. The resistors themselves are wound non-inductively to minimize pickup. Johnson noise is kept at a minimum through the use of extremely low impedance dividers.

4-2. CONSTANT CURRENT SUPPLY.

a. The current supply operates from either 117 or 234 volts, 50-1000 cps. It furnishes a stable constant current to the divider network. The supply uses a solid-state electronic regulator circuit. Line regulation for a 10% line voltage change is 0.01%. The power transformer is specially constructed and shielded to better than 10^9 ohm insulation shunted by 0.001-microfarad isolation from the secondary to ground or line.

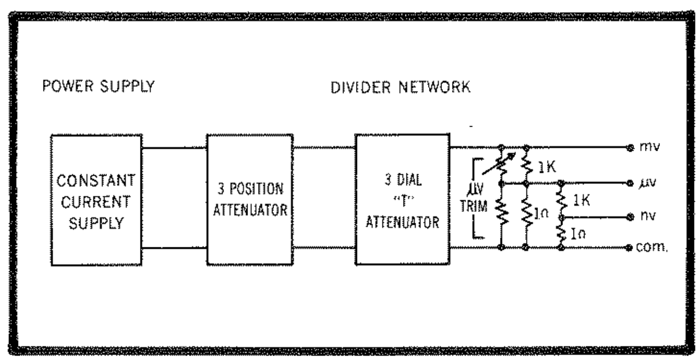


FIGURE 4. Model 260 Block Diagram.

b. The 15-volt rms output from the power transformer, T201, is full-wave rectified by diodes D201 and D202 and is filtered by capacitor C202 to approximately 17 volts dc.

c. To obtain a stable accurate current, the output of the series transistor regulator, Q202, is regulated by comparing a sample voltage from dividers R209 and R214 to the zener diode reference, D207. Any voltage difference which may exist between the sampling resistors and the reference diode is amplified by a differential amplifier, transistors Q204 and Q205. The signal is further amplified by transistor Q203. The output of Q203 is applied to the Darlington pair, transistors Q201 and Q202, to nullify input and load variations. Capacitor C203 prevents high-frequency oscillations. Resistor R214 of the voltage sampling network is variable to adjust the X1000 range and also to compensate for variations in zener voltage when the instrument is factory calibrated.

d. The current through the sampling resistors, R209 and R214, is kept constant within limits by the output of the supply, which normally operates at 12 volts. The RANGE Switch divider as well as the constant impedance Multiplier Switch dividers are connected between resistors R209 and R214 and the power supply output. A constant current, therefore, is maintained through these dividers by the power supply output.

e. Transistor Q203 operates at a high gain by connecting its collector load to a negative regulated supply. The circuit permits linear operation of transistor Q202 with widely varying input voltages. To supply transistor Q203, one side of the secondary of transformer T201 is half-wave rectified and filtered by diode D203 and capacitor C201, respectively. Resistor R201 and zener diode D204 regulate this voltage to a stable -6 volts referred to the collector of transistor Q202.

f. Resistors R202 and R203 and diode D205 provide current overload protection. Excessive current drawn from the power supply causes an increased voltage drop across resistor R202, which forward biases diode D205, thus preventing the collector of transistor Q203 from going more negative. Since the collector voltage cannot rise, further amplification is prevented, and further current increase is prevented.

4-3. 3-POSITION ATTENUATOR.

a. The 3-position attenuator is a current divider, allowing three extra decades for each output range selected with the output terminals. The Range Switch, S203, controls the divider, consisting of wirewound resistors R210 to R213 and R215. Potentiometers R212 and R213 adjust the X10 and X100 ranges respectively.

b. Another section of the Range Switch controls the pilot lamps, DS201 to DS203. The Range Switch position determines which decimal between the Multiplier Switches will light to indicate the proper range.

4-4. 3-DIAL ATTENUATOR.

a. The 3-dial attenuator, Multiplier Switches S101, S102 and S103, provides multiplying values for the voltage range selected. The attenuator allows 3-digit resolution between ranges; it also provides for outputs from 1 volt to 1 millivolt.

b. The attenuator maintains a constant output and nearly constant input impedance while accomplishing a voltage division when switches S101 and S103 are rotated. The third switch, S102, varies the input impedance only a small fraction. For the accuracy desired, however, a constant current feeds the divider to eliminate errors caused by this small change.

4-5. FIXED DIVIDERS.

a. Resistors R103 and R104 are the dividers for the nanovolt ranges; resistors R106 and R107 are the dividers for the microvolt ranges. A fixed resistor, R102, and a potentiometer, R101, shunt the microvolt divider to provide an adjustment for the microvolt and nanovolt outputs.

b. The fixed output dividers are pure copper wirewound resistors to minimize thermal emf's. All connections between the dividers and the output terminals are made with solid copper lugs and crimp connections to eliminate all foreign metals from the output circuit. A massive heat sink is thermally coupled to all critical junctions to reduce temperature differences. The thermal emf generated when the unit is stabilized at room temperature is less than 10 nanovolts.

SECTION 5. SERVICING

5-1. GENERAL. Section 5 contains the maintenance and troubleshooting procedures for the Model 260 Nanovolt Source. It is recommended that these procedures be followed as closely as possible to maintain the accuracy of the instrument.

5-2. SERVICING SCHEDULE.

a. The Model 260 requires no periodic maintenance beyond the normal care required of high-quality electronic equipment. No part should need replacement under ordinary use except the pilot lamp or the fuse.

b. Recommended recalibration is once a year; refer to Section 6. This will take care of possible deterioration of the copper wirewound resistors used in the microvolt and nanovolt dividers. Either the user or Keithley Instruments, Inc., can perform the calibration.

5-3. PARTS REPLACEMENT.

a. The Replaceable Parts List in Section 8 describes the electrical components of the Nanovolt Source. Replace components only as necessary. Use only reliable replacements which meet the specifications.

b. Resistors R103, R104, R106 and R107, used in the microvolt and nanovolt dividers, are special, pure-copper, wirewound resistors made to Keithley specifications. If their replacement is needed, purchase parts only from Keithley Instruments, Inc. Replace both R106 and R107, not just one resistor. Use the Keithley Part Number given in the Replaceable Parts List. Substitute resistors will not be properly matched, nor will they have the proper thermal characteristics to maintain the accuracy and thermal stability of the Model 260.

NOTE

When replacing the output dividers, thoroughly clean all copper leads with Scotch Brite or a similar non-metallic abrasive. Oxides on the copper will affect the Model 260 thermal characteristics. Make sure the copper nuts on all four terminals are tight. If copper lugs are not available, secure the leads by wrapping them around the terminal posts. Copper lugs for this use are in the Model 1483 Low-Thermal Connection Kit. Use only low-thermal cadmium-tin solder for soldered joints.

5-4. TROUBLESHOOTING.

a. The procedures which follow are for repairing troubles which might occur in the Model 260. Use these proceudres and use only specified replacement parts. Table 2 lists equipment recommended for troubleshooting. If the trouble cannot be readily located or repaired, Keithley Instruments or its representative can service the instrument.

b. Table 1 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-

Difficulty	Probable Cause	Solution
No output on any range or Multiplier Switch setting	Defective power supply	Check Q202 and R202 for "open"
	Defective divider resistor or switch	Check S101 and S103
No output or wrong output on microvolt or nanovolt range	Defective fixed divider resistor	Check R103, R104, R106, R107
No output on X100 or X10 ranges when POLARITY Switch is set to +.	Defective current divider resistor on switch	Check R210, R211, R215, S203
High residual output on millivolt range with dials at zero and Range Switch on X1000	Dirty or tarnished Multiplier Switches	Clean S101, S102, S103 Switch contacts with a commerical switch cleaner
Wrong output on all ranges	R214 out of adjustment	Adjust per paragraph 6-3

TABLE 1. Model 260 Troubleshooting.

circuit check, such as given in paragraph 5-5. Refer to the circuit description in Section 4 to find the more critical components and to determine their function in the circuit. The complete circuit schematic diagram, 18208H, is found at the back of the Manual.

5-5. PROCEDURES TO GUIDE TROUBLESHOOTING.

a. If the instrument will not operate, check the fuse, line cord and power source. If these are all found satisfactory, use the following procedures to isolate the trouble.

b. The schematic diagram indicates all the transistor terminal voltages referenced to J202. Check the Notes on the diagram for the settings used.

c. Power Supply.

1. Set the POLARITY Switch to + and connect the dc voltmeter between the red test jack, J202, and the emitter of transistor Q202 (Figure 7). The voltage should be -12 volts.

Instrument	Use
dc voltmeter, with minimum 100-megohm input resistance, 10% accuracy, range from one volt to 300 volts	Circuit checking

TABLE 2. Equipment Recommended for Model 260 Troubleshooting. Use these instruments or their equivalent.

2. If the voltage is not -12 volts, measure the voltage at the collector of transistor Q202. It should be -17.3 volts $\pm 20\%$. Presence of this voltage indicates the regulator circuitry is not operating or transistor Q202 is defective.

3. Measure the voltage at the anode of diode D204 (Figure 7). It should be -17 volts $\pm 10\%$. If this bootstrap voltage is not sufficient, transistor Q203 (Figure 7) will not operate and transistors Q201 and Q202 will be cut off.

4. Check the reference amplifier and amplifier stage using the schematic voltage values as a guide.

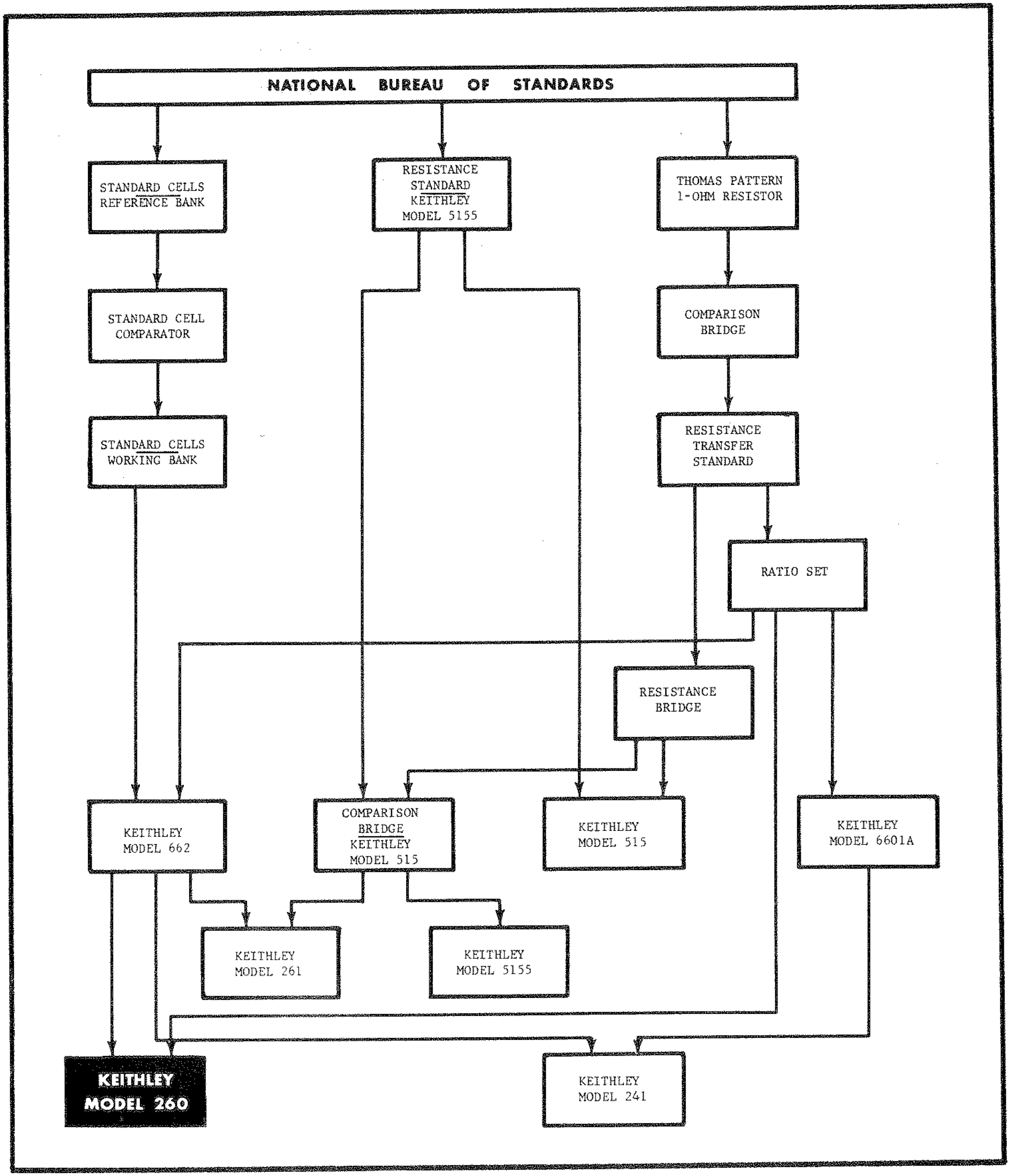


FIGURE 5. Model 260 Traceable Chart to National Bureau of Standards. Other Keithley instruments are also shown.

SECTION 6. CALIBRATION

6-1. GENERAL.

a. The following procedures are recommended for calibrating and adjusting the Model 260. Use the equipment recommended in Table 3. If proper facilities are not available or if difficulty is encountered, contact Keithley Instruments or its representative to arrange for factory calibration.

b. Calibration is done in five steps. The power supply and the millivolt output are adjusted (paragraph 6-3), and the difference between identical positive and negative outputs is checked (paragraph 6-4). The output voltage is calibrated (paragraph 6-5). The microvolt and nanovolt outputs are verified (paragraphs 6-6 and 6-7).

c. If the Model 260 is not within specifications after the calibration and adjustments, follow the troubleshooting procedures or contact Keithley Instruments or its nearest representative.

NOTE

Certification traceable to the National Bureau of Standards is available for the Model 260 from Keithley Instruments, Inc.

Instrument	Use
Electro Scientific Industries Model RV722 Decade Voltage Divider, 0.1 ppm resolution, ±1 ppm terminal linearity	Check microvolt range divider
Electro Scientific Industries Model 875B Lead Compensator	Compensate for slight differences between output voltages of two dividers
Keithley Instruments Model 148 Nanovoltmeter, 10-nanovolt full-scale sensitivity	Check output voltage on microvolt and nanovolt ranges.
Keithley Instruments Model 150A Microvolt-Ammeter, 10-microvolt full scale sensitivity	Null detector to check microvolt range divider
Keithley Instruments Model 241 Regulated High Voltage Supply, ±0.05% accuracy	Source to check microvolt range divider.
Keithley Instruments Model 662 Guarded DC Differential Voltmeter, ±0.01% limit of error, 100-microvolt full-scale sensitivity	Check output voltages.
Keithley Instruments Model 2603 Low-Thermal Connection Cable	Connect Models 260 and 148

TABLE 3. Equipment Recommended for Model 260 Calibration. Use these instruments or their equivalents.

Control	Circuit Desig.	Fig. Ref.	Refer to Paragraph
Microvolts Cal	R101	8	6-6
X10 Cal	R212	6	6-3
X100 Cal	R213	6	6-3
X1000 Cal	R214	6	6-3

TABLE 4. Model 260 Internal Controls. The Table lists all internal controls, the figure picturing the location and the paragraph describing the adjustment.

6-2. CALIBRATION SCHEDULE. Calibrate the Model 260 every twelve months. This is necessary to adjust for even small changes in component value and to maintain the specified accuracy. Also, recalibrate after replacing any transistors, any components in the input compartment, or any resistors in the Multiplier and Range Switches.

NOTE

Make the calibrations and adjustments in the order of paragraphs 6-3 to 6-7.

6-3. POWER SUPPLY ADJUSTMENT.

a. This adjustment sets the potential applied to the attenuators and the dividers. It is also the principal millivolt range adjustment. Normally, no adjustment will be necessary; checking the output value will be sufficient.

b. Procedures.

1. Warm up the Nanovolt Source for two hours. Check the power supply output across capacitor C204. Voltage between terminals J201 and J202 (Figure 7) should be 12 volts ±5%.

2. Connect the Model 662 Differential Voltmeter to the MILLIVOLT and COM Binding Posts in the output compartment. Set the RANGE Switch to the X1000 position. Set the first Multiplier Switch (S103, Figure 2) to 10. The Model 662 should read 1 volt ±1.8 millivolts. Adjust potentiometer R214 (Figure 6), if necessary, for this output.

NOTE

Adjusting potentiometer R214 affects the X100 and X10 ranges also. Potentiometers R212 and R213, however, are independent of any but their own range.

3. Change the RANGE Switch to the X100 position. The Model 662 should now read 0.1 volt ±180 microvolts. Adjust potentiometer R213 (Figure 6), if necessary, for this output.

4. Change the RANGE Switch to the X10 position. The Model 662 should now read 10 millivolts ±18 microvolts. Adjust potentiometer R212 (Figure 6), if necessary, for this output.

NOTE

During this and other adjustments, keep the Model 260 output compartment door closed to minimize thermal emf's. In general, follow the precautions outlined in Section 2.

6-4. VOLTAGE OFFSET ADJUSTMENT.

a. Switch the RANGE Switch back to X1000. Set all the Multiplier Switches to zero. Check the voltage output with either the Model 148 or 150A when the Model 260 POLARITY Switch is set to + and -. Voltage should be less than ±60 microvolts.

b. Set the RANGE Switch to X100. With all Multiplier Switches at zero, output voltage should be less than ±6 microvolts. Set the RANGE Switch to X10. With all Multiplier Switches at zero, output voltage should be less than ±0.6 microvolt.

6-5. VOLTAGE CALIBRATION.

a. Make sure the offset is within ±60 microvolts (paragraph 6-4) and the power supply is adjusted (paragraph 6-3). Connect the Model 662 to the MILLIVOLT and COM Binding Posts. Set the Model 260 RANGE and Multiplier Switches for a 120-millivolt output. Adjust potentiometer R214 (Figure 6), if necessary, for 120 millivolts ±0.05 millivolt. Switch the Multiplier Switches through the settings in Table 5. Set in the order given in the Table. The output and the Switch settings should agree within the maximum error. If any setting is out of tolerance, adjust potentiometer R214 slightly.

b. Set the RANGE Switch to X100. Set the Multiplier Switches to 12.0 mv. If necessary, adjust potentiometer R213 (Figure 6) for 12.0 millivolts ±0.005 millivolt when measured with the Model 662. Switch the Multiplier Switches through the settings in Table 6. Set

Multiplier Switch Setting (millivolts)	Maximum Error (±micro-volts)	Multiplier Switch Setting (millivolts)	Maximum Error (±micro-volts)	Multiplier Switch Setting (millivolts)	Maximum Error (±micro-volts)	Multiplier Switch Setting (millivolts)	Maximum Error (±micro-volts)
100	200	200	400	300	500	111	222
110	220	210	420	400	600	112	224
120	240	220	440	500	800	113	226
130	260	230	460	600	1000	114	228
140	280	240	480	700	1200	115	230
150	300	250	500	800	1400	116	232
160	320	260	520	900	1600	117	234
170	340	270	540	1000	1800	118	236
180	360	280	560			119	238
190	380	290	580				

TABLE 5. Voltage Calibration on X1000 Range. Set the Multiplier Switches to the listed outputs in order. The RANGE Switch is set to X1000. Output should be within the above tolerance. See paragraph 6-5.

Multiplier Switch Setting (millivolts)	Maximum Error (±micro-volts)	Multiplier Switch Setting (millivolts)	Maximum Error (±micro-volts)	Multiplier Switch Setting (millivolts)	Maximum Error (±micro-volts)	Multiplier Switch Setting (millivolts)	Maximum Error (±micro-volts)
10	20	20	40	30	50	11.1	22.2
11	22	21	42	40	60	11.2	22.4
12	24	22	44	50	80	11.3	22.6
13	26	23	46	60	100	11.4	22.8
14	28	24	48	70	120	11.5	23.0
15	30	25	50	80	140	11.6	23.2
16	32	26	52	90	160	11.7	23.4
17	34	27	54	100	180	11.8	23.6
18	36	28	56			11.9	23.8
19	38	29	58				

TABLE 6. Voltage Calibration on X100 Range. Set the Multiplier Switches to the listed outputs in order. The RANGE Switch is set to X100. Output should be within the above tolerance. See paragraph 6-5.

in the order given in the Table. The output and the Switch settings should agree within the maximum error. If any setting is out of tolerance, adjust potentiometer R213 slightly.

c. Note the percentage of error for the 100-millivolt setting in Table 6. Set the RANGE Switch to X10. Dial 10 millivolts on the Multiplier Switches. Adjust potentiometer R212 (Figure 6) to obtain the same percentage of error as occured on the 100-millivolt setting. For example, if the 100-millivolt range was 100 microvolts low, its error was -0.1%. On the 10-millivolt range, the error in output should be -10 microvolts.

6-6. MICROVOLT RANGE OUTPUT VERIFICATION.

a. The verification basically follows the procedures in paragraph 6-3. Use the Model 2603 Low-Thermal Connection Cable to connect the Model 148 Nanovoltmeter to the MICROVOLTS and COM Binding Posts in the output compartment. Set the first Multiplier Dial (S103, Figure 2) to 10. Set the RANGE Switch to the X1000, X100 and X10 positions. The Model 148 should read 1 millivolt, 100 microvolts and 10 microvolts respectively.

b. If the microvolt output is out of specifications, check the 1000:1 ratio of the microvolt divider, resistors R101 and R102. Normally, no adjustment is needed. If an adjustment is attempted, follow good standards laboratory techniques.

1. The ratio of the divider must be within 1 microvolt (0.1%). Set the Model 241 Voltage Supply for a 1-volt output. Set the Model RV722 Decade Voltage Divider for a 1000:1 ratio.

2. Connect the Model 875B Lead Compensator to the Model RV722 output and the Model 260 microvolt divider. Make sure the current leads applied to the low and high sides of the microvolt divider are always outside the voltage tap or divider tap lead (Figure 8). Also, adjust the Lead Compensator correctly for the low end of the divider. Any error in this adjustment will directly affect the measurement of the divider accuracy.

3. Connect the Model 150A as a null detector to the Lead Compensator. Set the Model 150A to its 10-microvolt range.

4. With one volt applied to the Decade Voltage Divider and to the microvolt divider, the null detector should not be more than 1 microvolt off null. If it is, adjust potentiometer R101 (Figure 8) until it is within the requirements.

6-7. NANOVOLT RANGE OUTPUT VERIFICATION. Connect the Model 148 Nanovoltmeter to the NANOVOLTS and COM Binding Posts in the output compartment. Set the first Multiplier Switch (S103, Figure 2) to 10. Set the RANGE Switch to the X1000, X100 and X10 position. The Model 148 should read 1 microvolt, 100 nanovolts and 10 nanovolts respectively.

NOTE

Do not adjust potentiometer R212, R213 and R214. The microvolt and nanovolt ranges are verified, not calibrated. Adjust the potentiometers only on the millivolt ranges.

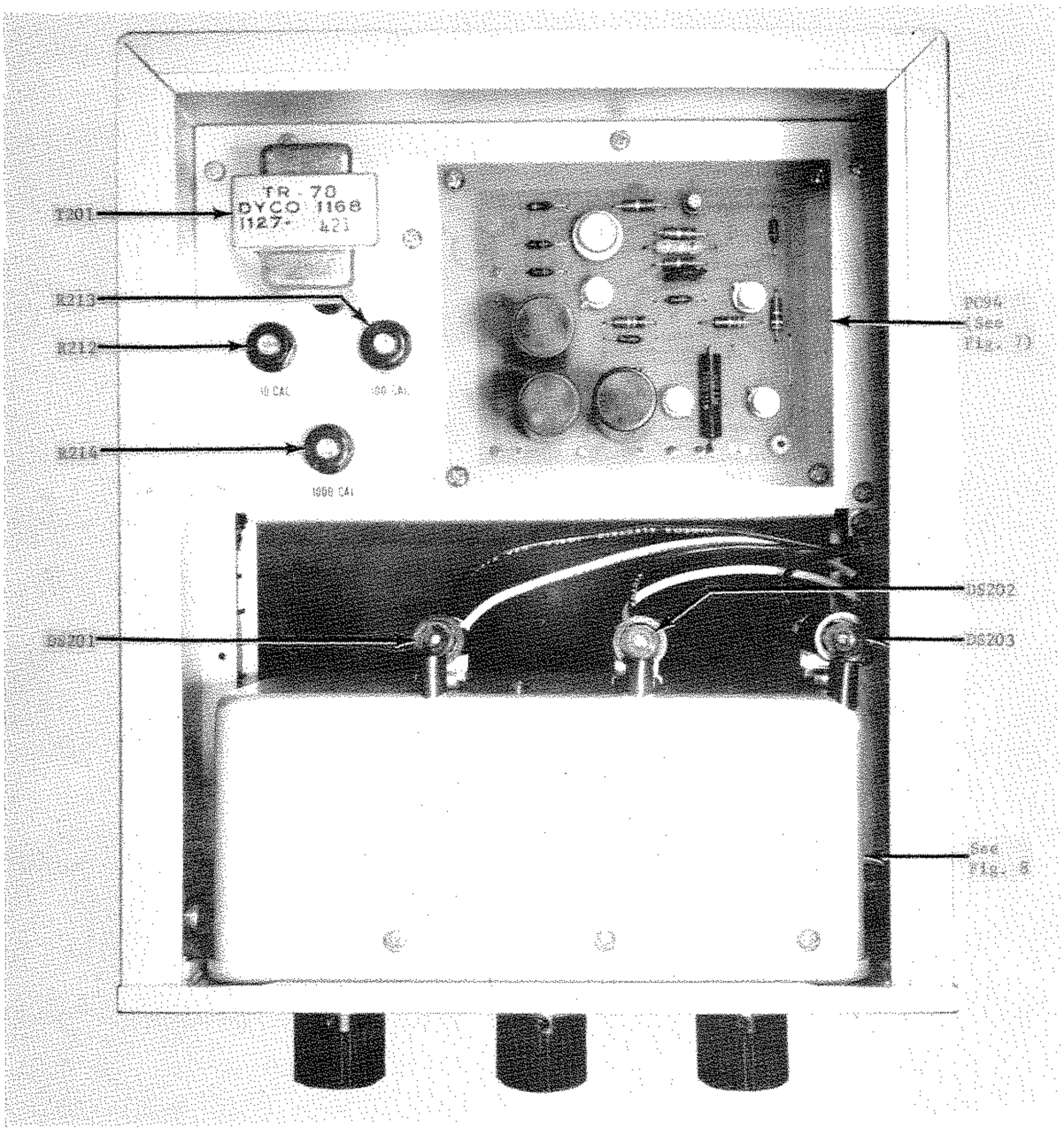


FIGURE 6. Top View of Model 260 Chassis. The front panel is along the bottom of the photograph. Location of components is shown. Refer to the Replaceable Parts List for circuit designations. Resistor R215 is located on the opposite side of the chassis.

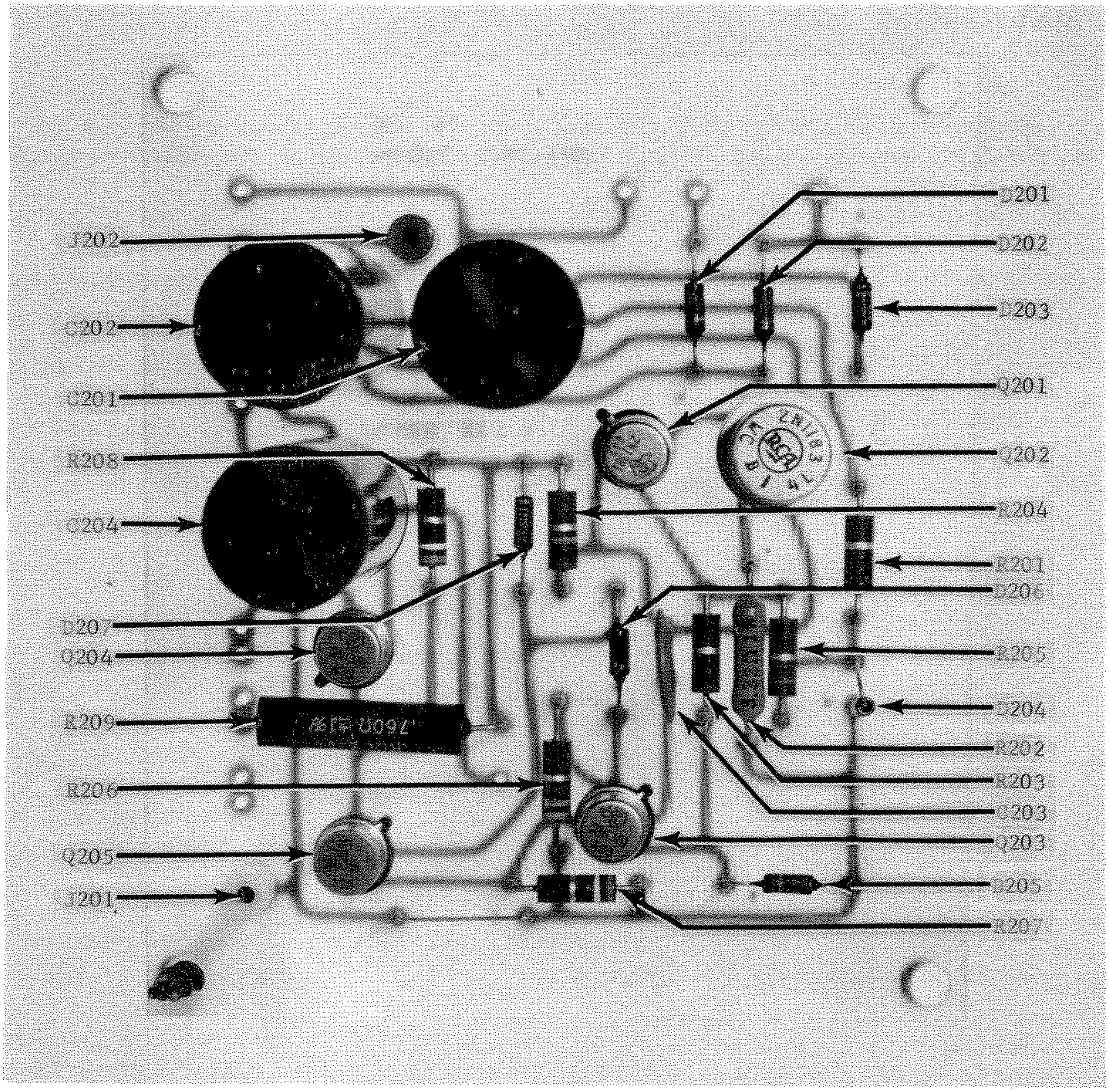


FIGURE 7. Component Locations on Printed Circuit PC-94.

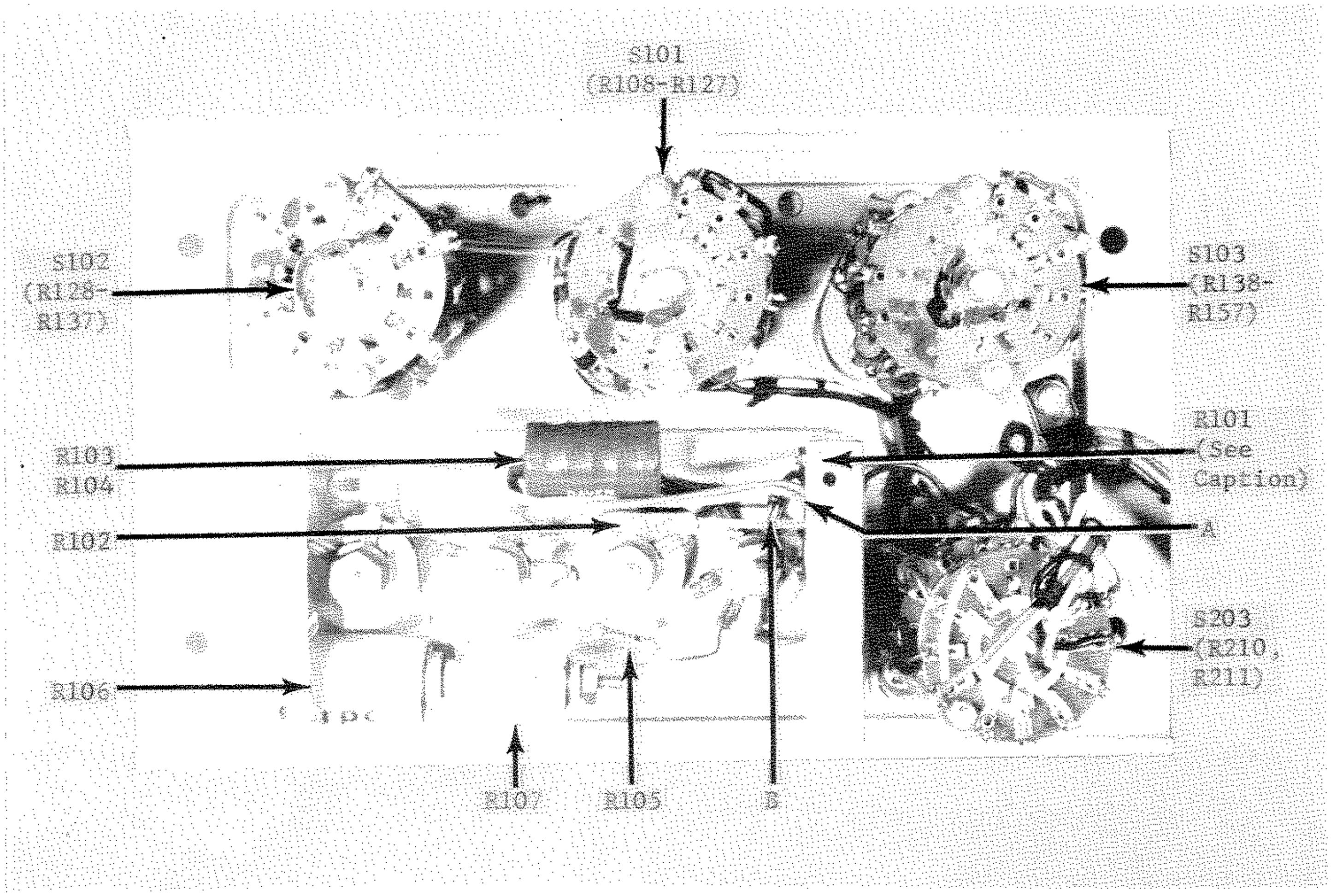


FIGURE 8. Component Locations of Output Compartment. R103 and R104 are one assembly. R101 is accessible from the bottom of the Model 260. The hole in the compartment cover is to reach the potentiometer. Point A is the red wire lead to the high side of the microvolt divider. Point B is the black wire lead to the low side of the microvolt divider.

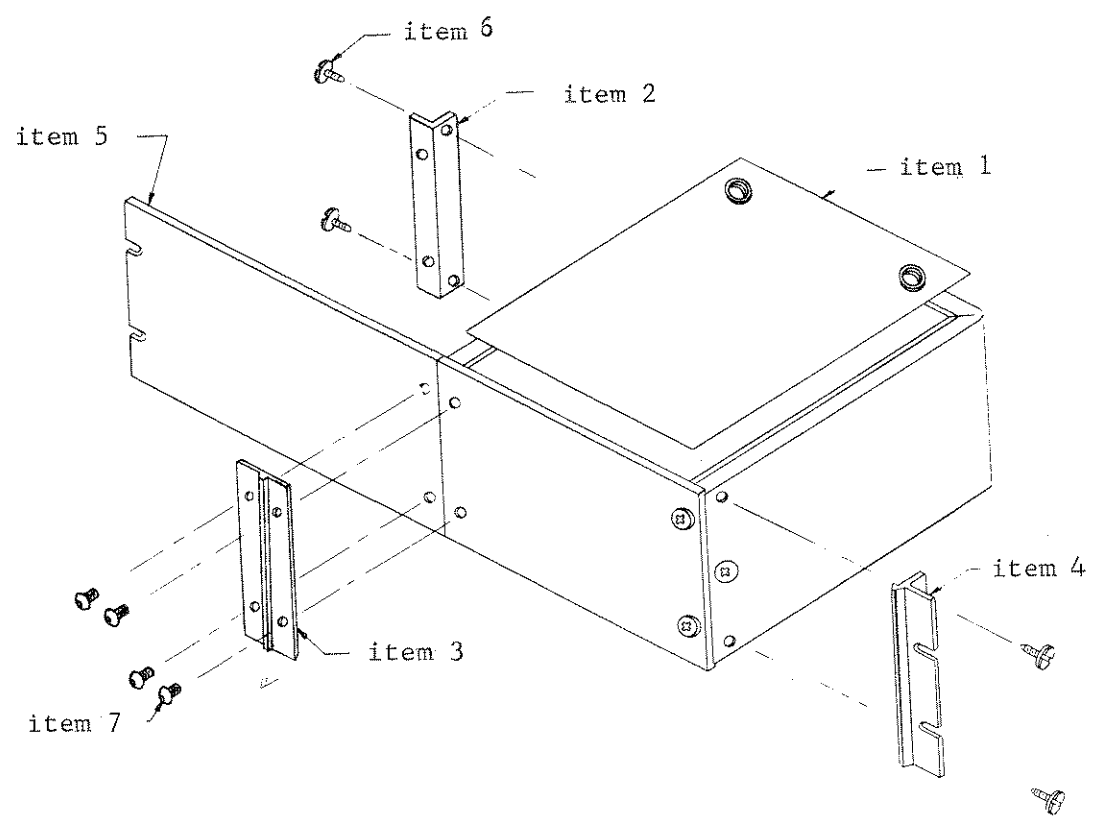


FIGURE 10. Assembly Drawing for Model 4003A Rack Mounting Kit.

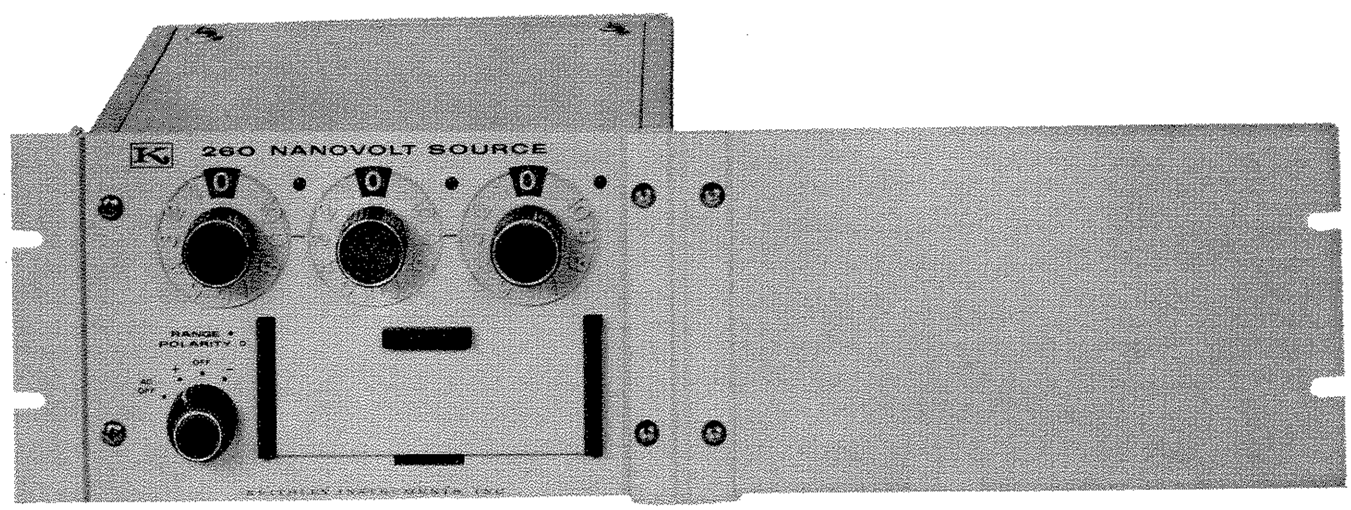


FIGURE 11. Model 260 Converted for Rack Mounting with Model 4003A Rack Mounting Kit.

SECTION 7. ACCESSORIES

7-1. GENERAL. This Section contains instructions on using Keithley accessories with the Model 260 Picoampere Source. The principal accessories described here are the rack and bench mounting kits. The Model 2601 Output Cable, furnished with the Source, is described in Section 2, along with the Low-Terminal Calibration Cables and Connection Kit.

7-2. MODEL 4003A RACK MOUNTING KIT.

a. The Model 4003A Kit converts the Model 260 from a bench model to rack mounting. Rack dimensions are 5-1/4 inches high x 19 inches wide x 10 inches deep. The Source converts to half-rack size, and the Kit contains a half-rack adapter panel.

b. Procedures. Remove the wrap-around cover on the Source by removing the two corner screws at the bottom of each side. Add the rack mounting parts to the Source as shown in Figure 10. Attach in this order: cover (1), rack angle (5), panel support angle (2), rack panel adapter (7), and chassis connecting plate (3).

Item (See Fig. 10)	Description	Keithley Part No.	Quantity
1	Cover Assembly	18554B	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, #10 x 1/2	---	4
7	Screw, rounded head, hex socket, #10 x 1/2	---	4

TABLE 7. Parts List for Model 4003A Rack Mounting Kit.

7-3. MODEL 4004A DUAL RACK MOUNTING KIT.

a. The Model 4004A Kit converts the Model 260 to rack mounting. The assembled Kit will contain either two Model 260's or one each of Models 260 and 261 Picoampere Source. Dimensions are 5-1/4 inches high x 19 inches wide x 10 inches deep.

b. Procedures. Remove the wrap-around cover on each Source by removing the two corner screws at the bottom of each side. Assemble the rack mounting parts as shown in Figure 12. Attach in this order: cover (1), two rack angles (5), chassis connecting plate (2), and chassis connecting plate (3).

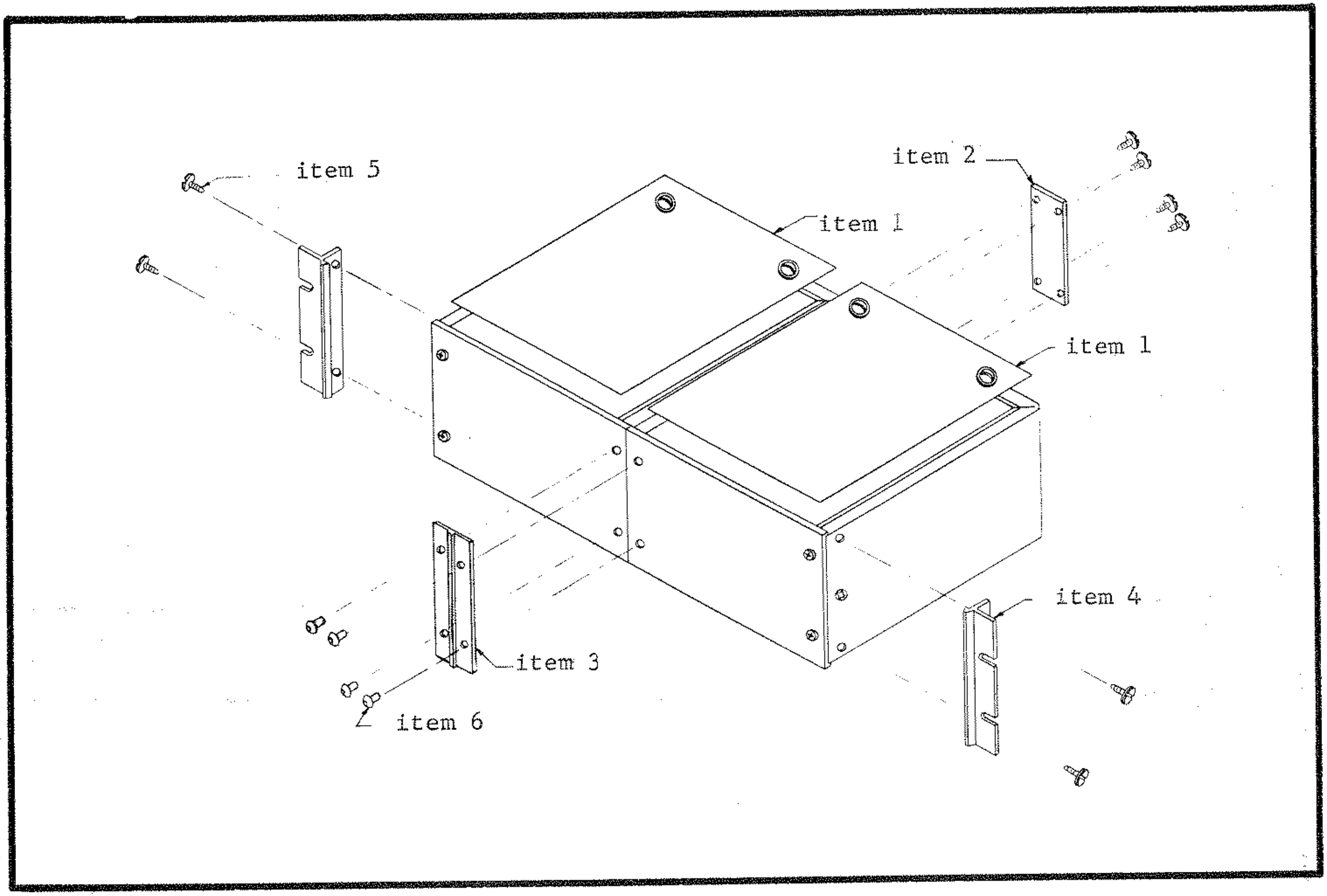


FIGURE 12. Assembly Drawing for Model 4004A Dual Rack Mounting Kit.

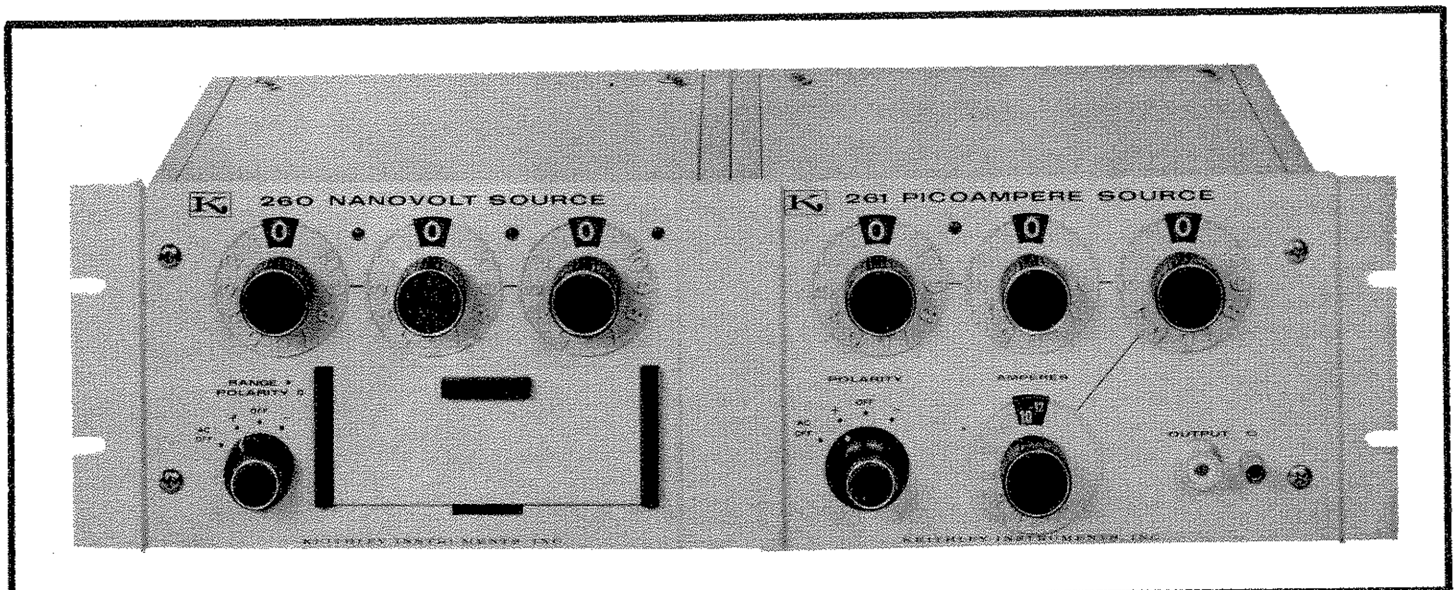


FIGURE 13. Models 260 and 261 in Dual Rack Mounting. Use the Model 4004A Kit.

Item (See Fig. 12)	Description	Keithley Part No.	Quantity
1	Cover Assembly	18554B	2
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

TABLE 8. Parts List for Model 4004A Rack Mounting Kit.

7-4. MODEL 3004 DUAL BENCH MOUNTING KIT.

a. The Model 3004 Kit, when assembled, will hold either two Model 260's or one each of the Models 260 and 261 Picoampere Source. The two instruments will be contained in one, easy-to-carry bench unit. Dimensions are 5-1/2 inches high x 17-1/2 inches wide x 10 inches deep.

b. Procedures. Remove the wrap-around cover on each Source by removing the two corner screws at the bottom of each side. Assemble the Kit as shown in Figure 14. Attach in this order: chassis connecting plate (2), chassis connecting plate (3), and cover (1).

Item (See Fig. 14)	Description	Keithley Part No.	Quantity
1	Cover Assembly	18555B	1
2	Chassis Connecting Plate	17454A	1
3	Chassis Connecting Plate	19126A	1
4	Screw, round head, hex socket, #10 x 1/2	---	4
5	Screw, slotted, #10 x 1/2	---	8

TABLE 9. Parts List for Model 3004 Dual Bench Mounting Kit.

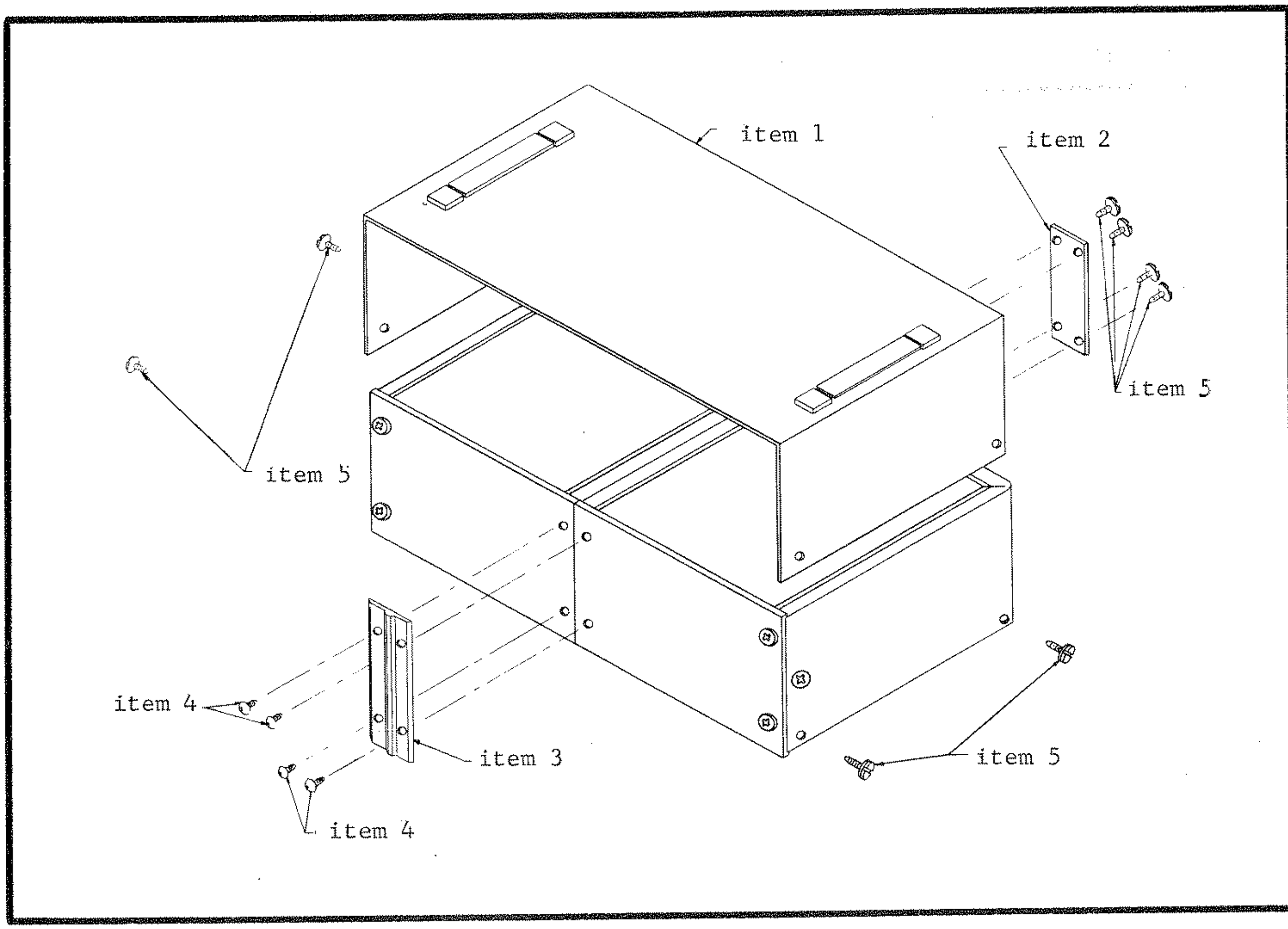


FIGURE 14. Assembly Drawing for Model 3004 Dual Bench Mounting Kit.

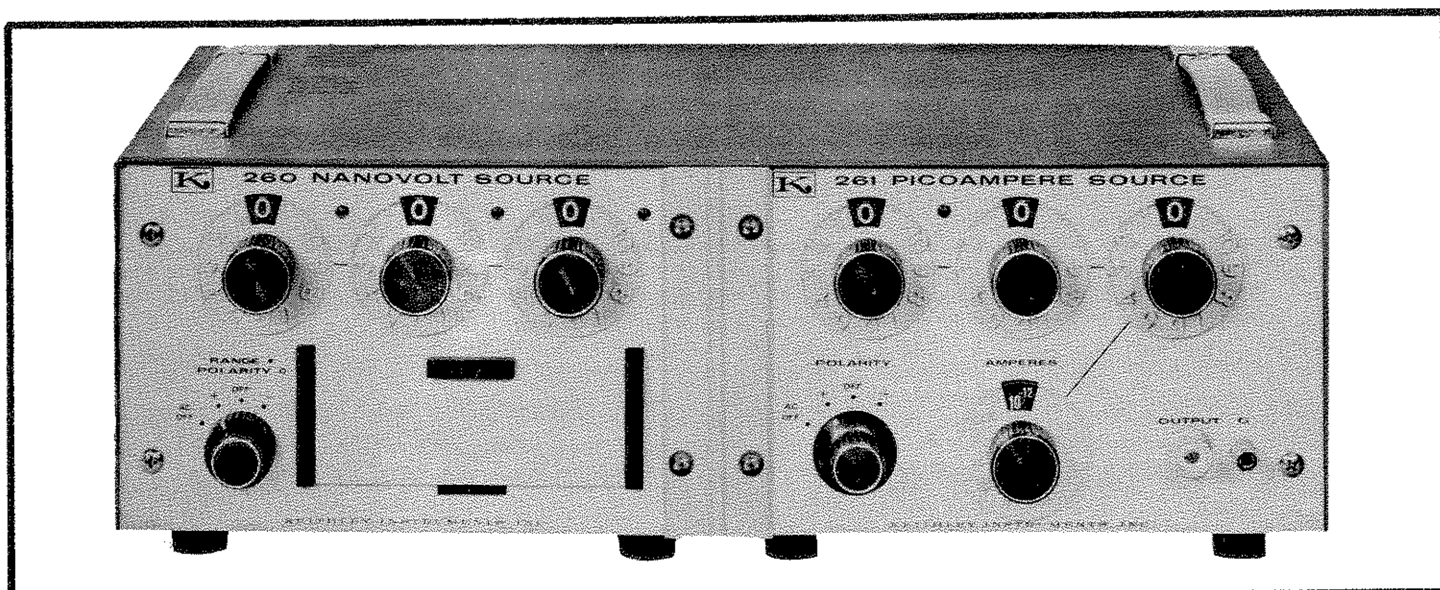


FIGURE 15. Models 260 and 261 in Dual Bench Mounting.

SECTION 8. REPLACEABLE PARTS

8-1. REPLACEABLE PARTS LIST. The Replaceable Parts List describes the components of the Model 260 and its accessories. The List gives the circuit designation, the part description, a suggested manufacturer, 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 11.

8-2. HOW TO ORDER PARTS.

a. For parts orders, include the instrument's model 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 from Keithley Instruments or its representative. In ordering a part not listed in the Replaceable Parts List, completely describe the part, its function and its location.

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

amp	ampere	MtF	Metal Film
		Mil. No.	Military Type Number
CbVar	Carbon Variable	My	Mylar
CerD	Ceramic, Disc		
Comp	Composition	Ω	ohm
DCb	Deposited Carbon	Poly	Polystyrene
		p	pico (10^{-12})
EAl	Electrolytic, Aluminum		
EMC	Electrolytic, metal cased	μ	micro (10^{-6})
ETT	Electrolytic, tantalum		
		v	volt
f	farad	Var	Variable
k	kilo (10^3)	w	watt
		WW	Wirewound
M or meg	mega (10^6) or megohms	WWVar	Wirewound Variable
m	milli (10^{-3})		
Mfg.	Manufacturer		

TABLE 10. Abbreviations and Symbols.

MODEL 260 REPLACEABLE PARTS LIST

(Refer to Schematic Diagram 18208H for circuit designations.)

CAPACITORS

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
C201	500 μf	25 v	EA1	56289	89D231	C94-500M	7
C202	500 μf	25 v	EA1	56289	89D231	C94-500M	7
C203	.01 μf	1000 v	CerD	72982	811Z5V103P	C22-.01M	7
C204	500 μf	25 v	EA1	56289	89D231	C94-500M	7

DIODES

Circuit Desig.	Type	Number	Mfg. Code	Keithley Part No.	Fig. Ref.
D201	Silicon	1N645	01295	RF-14	7
D202	Silicon	1N645	01295	RF-14	7
D203	Silicon	1N645	01295	RF-14	7
D204	Zener	1N706	12954	DZ-1	7
D205	Silicon	1N645	01295	RF-14	7
D206	Silicon	1N645	01295	RF-14	7
D207	Zener	1N936	04713	DZ-5	7

MISCELLANEOUS PARTS

Circuit Desig.	Description	Mfg. Code	Keithley Part No.	Fig. Ref.
DS201	Pilot Light Bulb (Mfg. No. 313)	08804	PL-21	6
DS202	Pilot Light Bulb (Mfg. No. 313)	08804	PL-21	6
DS203	Pilot Light Bulb (Mfg. No. 313)	08804	PL-21	6
---	Pilot Light Assembly for DS201, DS202, DS203 (Mfg. No. 3-03)	72619	PL-26	
F201 (117v)	Fuse, slow blow, 1/8 amp (Mfg. Type MDL)	71400	FU-20	
F201 (234v)	Fuse, slow blow, 1/16 amp (Mfg. Type MDL)	71400	FU-21	
---	Fuse Holder (Mfg. No. 342012)	75915	FH-3	
J101	Binding Post, MILLIVOLTS (Mfg. No. 124309)	35529	20391A	2
J102	Binding Post, MICROVOLTS (Mfg. No. 124309)	35529	20391A	2
J103	Binding Post, NANOVOLTS (Mfg. No. 124309)	35529	20391A	2
J104	Binding Post, COMMON (Mfg. No. 124309)	35529	20391A	2
J105	Binding Post, COM (Mfg. No. DF21BC)	58474	BP-11B	
J106	Binding Post, GND (Mfg. No. DF21GC)	58474	BP-11G	
---	Shorting Link (Mfg. No. 938-L)	24655	BP-6	
J201	Test Jack (Mfg. No. TJ300M)	81453	TJ-4C	7
J202	Test Jack (Mfg. No. TJ303R)	81453	TJ-5R	7

MISCELLANEOUS PARTS (Cont'd)

Circuit Desig.	Description	Mfg. Code	Keithley Part No.	Fig. Ref.
P201	Cord Set, 6 feet (Mfg. No. 4638-13)	93656	CO-5	
S101	Rotary Switch less components, X10 Multiplier	80164	SW-207	2
---	Dial Assembly, 0-10	80164	14829A	
S102	Rotary Switch less components, X1 Multiplier	80164	SW-185	2
---	Dial Assembly, 0-10	80164	14829A	
S103	Rotary Switch less components, X100 Multiplier	80164	SW-207	2
---	Dial Assembly, 0-10	80164	14829A	
S201	Slide Switch, 117-234 v	80164	SW-151	
S202	Rotary Switch, POLARITY	80164	SW-192	2
---	Knob Assembly, Polarity Switch	80164	16994A	
S203	Rotary Switch less components, RANGE	80164		2
---	Knob Assembly, Range Switch	80164	16993A	
T201	Transformer	80164	TR-78	6

RESISTORS

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
R101	50 kΩ	10%, 1/2 w	CbVar	91637	2319	RP39-50K	8
R102	35 kΩ	1%, 1/2 w	Comp	79727	CFE-15	R12-35K	8
R103	1 kΩ			80164		**17627A	8
R104	1 Ω			80164		**17627A	8
R105	50 Ω	1%, 1/2 w	DCb	79727	CFE-15	R12-50	8
R106	1 kΩ	1%	WW	80164		***R18-18-1K	8
R107	1 Ω	1%	WW	80164		***R18-18-1	8
R108	1 Ω	.1%, 1/2 w	WW	01686	7009	R95-1	8
R109	1 Ω	.1%, 1/2 w	WW	01686	7009	R95-1	8
R110	1 Ω	.1%, 1/2 w	WW	01686	7009	R95-1	8
R111	1 Ω	.1%, 1/2 w	WW	01686	7009	R95-1	8
R112	1 Ω	.1%, 1/2 w	WW	01686	7009	R95-1	8
R113	1 Ω	.1%, 1/2 w	WW	01686	7009	R95-1	8
R114	1 Ω	.1%, 1/2 w	WW	01686	7009	R95-1	8
R115	1 Ω	.1%, 1/2 w	WW	01686	7009	R95-1	8

** Resistors R103 and R104 are in a single case
*** Resistors R106 and R107 are matched ±0.5%; order replacements as pairs.

RESISTORS (Cont'd)

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
R116	1 Ω	.1%, 1/2 w	WW	01686	7009	R95-1	8
R117	1 Ω	.1%, 1/2 w	WW	01686	7009	R95-1	8
R118	1 Ω	1%, 1/2 w	DCb	79727	CFE-15	R12-1	8
R119	2 Ω	1%, 1/2 w	DCb	79727	CFE-15	R12-2	8
R120	3 Ω	1%, 1/2 w	DCb	79727	CFE-15	R12-3	8
R121	4 Ω	1%, 1/2 w	DCb	79727	CFE-15	R12-4	8
R122	5 Ω	1%, 1/2 w	DCb	79727	CFE-15	R12-5	8
R123	6 Ω	1%, 1/2 w	DCb	79727	CFE-15	R12-6	8
R124	7 Ω	1%, 1/2 w	DCb	79727	CFE-15	R12-7	8
R125	8 Ω	1%, 1/2 w	DCb	79727	CFE-15	R12-8	8
R126	9 Ω	1%, 1/2 w	DCb	79727	CFE-15	R12-9	8
R127	10 Ω	1%, 1/2 w	DCb	79727	CFE-15	R12-10	8
R128	.1 Ω	1%, 1/2 w	WW	01686	E-30	R58-.1	8
R129	.1 Ω	1%, 1/2 w	WW	01686	E-30	R58-.1	8
R130	.1 Ω	1%, 1/2 w	WW	01686	E-30	R58-.1	8
R131	.1 Ω	1%, 1/2 w	WW	01686	E-30	R58-.1	8
R132	.1 Ω	1%, 1/2 w	WW	01686	E-30	R58-.1	8
R133	.1 Ω	1%, 1/2 w	WW	01686	E-30	R58-.1	8
R134	.1 Ω	1%, 1/2 w	WW	01686	E-30	R58-.1	8
R135	.1 Ω	1%, 1/2 w	WW	01686	E-30	R58-.1	8
R136	.1 Ω	1%, 1/2 w	WW	01686	E-30	R58-.1	8
R137	.1 Ω	1%, 1/2 w	WW	01686	E-30	R58-.1	8
R138	10 Ω	.1%, 1/4 w	WW	01686	7009	R95-10	8
R139	10 Ω	.1%, 1/4 w	WW	01686	7009	R95-10	8
R140	10 Ω	.1%, 1/4 w	WW	01686	7009	R95-10	8
R141	10 Ω	.1%, 1/4 w	WW	01686	7009	R95-10	8
R142	10 Ω	.1%, 1/4 w	WW	01686	7009	R95-10	8
R143	10 Ω	.1%, 1/4 w	WW	01686	7009	R95-10	8
R144	10 Ω	.1%, 1/4 w	WW	01686	7009	R95-10	8
R145	10 Ω	.1%, 1/4 w	WW	01686	7009	R95-10	8
R146	10 Ω	.1%, 1/4 w	WW	01686	7009	R95-10	8
R147	10 Ω	.1%, 1/4 w	WW	01686	7009	R95-10	8
R148	10 Ω	1%, 1/2 w	DCb	79727	CFE-15	R12-10	8
R149	20 Ω	1%, 1/2 w	DCb	79727	CFE-15	R12-20	8
R150	30 Ω	1%, 1/2 w	DCb	79727	CFE-15	R12-30	8
R151	40 Ω	1%, 1/2 w	DCb	79727	CFE-15	R12-40	8
R152	50 Ω	1%, 1/2 w	DCb	79727	CFE-15	R12-50	8
R153	60 Ω	1%, 1/2 w	DCb	79727	CFE-15	R12-60	8
R154	70 Ω	1%, 1/2 w	DCb	79727	CFE-15	R12-70	8
R155	80 Ω	1%, 1/2 w	DCb	79727	CFE-15	R12-80	8

RESISTORS (Cont'd)

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
R156	90 Ω	1%, 1/2 w	DCb	79727	CFE-15	R12-90	8
R157	100 Ω	1%, 1/2 w	DCb	79727	CFE-15	R12-100	8
R201	1.5 kΩ	10%, 1/2 w	Comp	01121	EB	R1-1.5K	7
R202	3.3 Ω	1%, 1/2 w	DCb	79727	CFE-15	R12-3.3	7
R203	1.5 kΩ	10%, 1/2 w	Comp	01121	EB	R1-1.5K	7
R204	10 kΩ	10%, 1/2 w	Comp	01121	EB	R1-10K	7
R205	10 kΩ	10%, 1/2 w	Comp	01121	EB	R1-10K	7
R206	330 Ω	10%, 1/2 w	Comp	01121	EB	R1-330	7
R207	2.2 kΩ	10%, 1/2 w	Comp	01121	EB	R1-2.2K	7
R208	3.9 kΩ	10%, 1/2 w	Comp	01121	EB	R1-3.9K	7
R209	760 Ω	1%, 1/2 w	WW	01686	E-30	R58-760	7
R210	21.6 kΩ	1%, 1/2 w	WW	01686	E-30	R58-21.6K	8
R211	11 kΩ	1%, 1/2 w	WW	01686	E-30	R58-11K	8
R212	50 Ω	10%, 5 w	WWVar	71450	AW	RP3B-50	6
R213	100 Ω	10%, 5 w	WWVar	71450	AW	RP3B-100	6
R214	100 Ω	10%, 5 w	WWVar	71450	AW	RP3B-100	6
R215	200 Ω	1%, 1/2 w	WW	01686	E-30	R58-200	6
R216	120 Ω	1%, 1/2 w	WW	01686	E-30	R58-120	

TRANSISTORS

Circuit Desig.	Number	Mfg. Code	Keithley Part No.	Fig. Ref.
Q201	2N1381	01295	TG-8	7
Q202	2N1183	02735	TG-11	7
Q203	2N1381	01295	TG-8	7
Q204	2N1381	01295	TG-8	7
Q205	2N1381	01295	TG-8	7

MODELS 1483, 1484 REPLACEABLE PARTS LIST

Description	Quantity	Mfg. Code	Keithley Part No.	Used on Kit Model
Crimp Tool for Copper lugs	1	80164	TL-1	1483
#8 Nylon Screws	50	80164	---	1483, 1484
#8 Nylon Hex Nuts	50	80164	---	1483, 1484
Copper Bolt-on Lugs	100	80164	17340A	1483, 1484
Copper Spade Lugs	100	80164	17339A	1483, 1484
Copper Hook Lugs	100	80164	17336A	1483, 1484
Copper Splice Tubes	100	80164	17338A	1483, 1484
Low-Thermal Cadium-Tin Solder	10 feet	80164	---	1483, 1484
Copper Alligator Clips (Mfg. No. 6005)	10	76545	AC-9	1483, 1484

MODELS 1483, 1484 REPLACEABLE PARTS (Cont'd)

Description	Quantity	Mfg. Code	Keithley Part No.	Used on Kit Model
Shielded Cable	10 feet	80164	SC-5	1483, 1484
Insulated #20 Copper Wire	100 feet	80164	WS-1	1483, 1484
Non-metalic Abrasive	3 pads	80164	17774A	1483, 1484

MODEL 2601 REPLACEABLE PARTS LIST

Description	Mfg. Code	Keithley Part No.
Copper Spade Lugs (two)	80164	LU-21
Copper Alligator Clips, two (Mfg. No. 6005)	76545	AC-9
Cable Assembly	80164	

MODEL 2602 REPLACEABLE PARTS LIST

Description	Mfg. Code	Keithley Part No.
Copper Spade Lugs (two)	80164	LU-21
Plug, Special (Mates with Keithley 12450B on Models 149 and 150A)	80164	13011B
Cable Assembly		

MODEL 2603 REPLACEABLE PARTS LIST

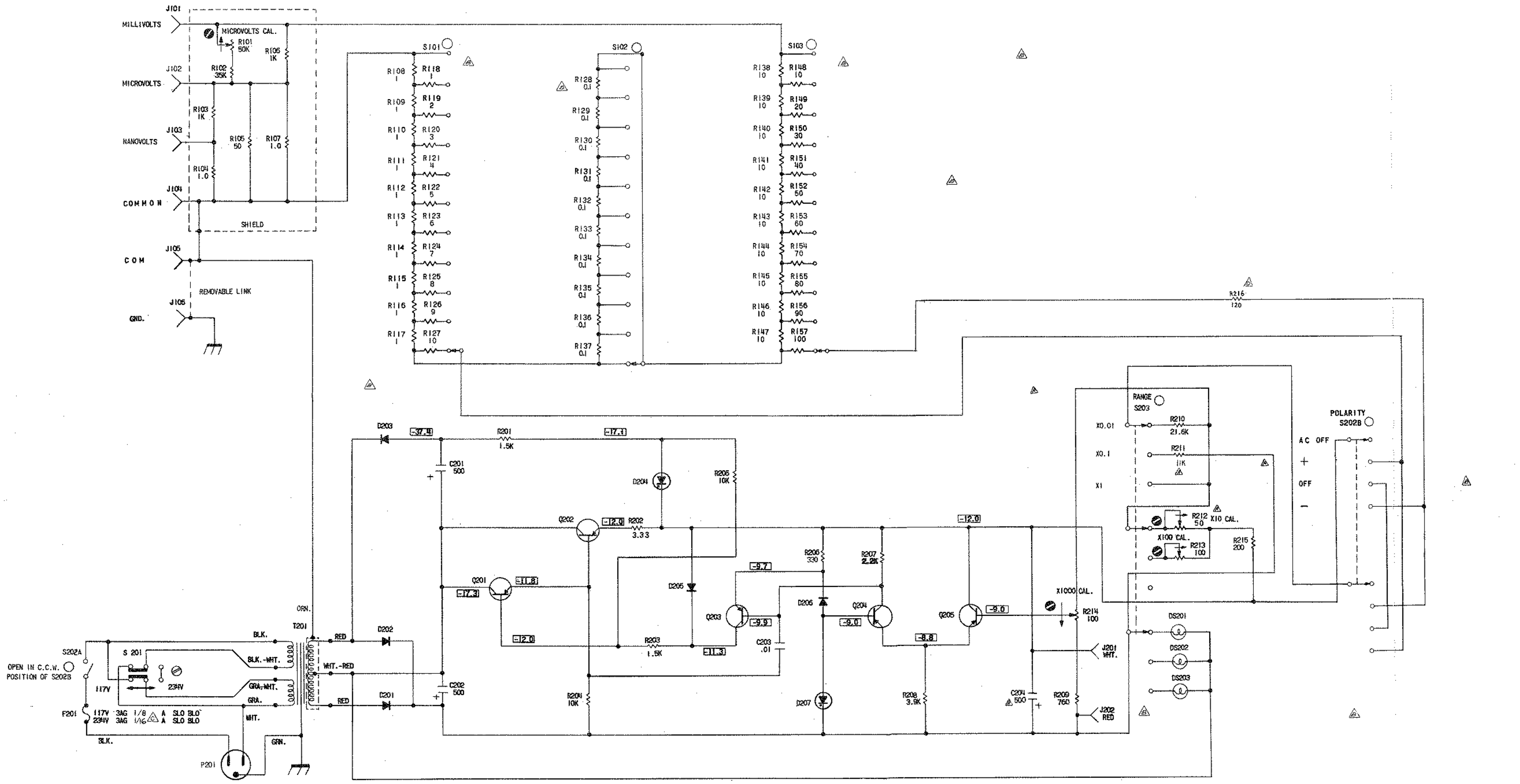
Description	Mfg. Code	Keithley Part No.
Copper Spade Lugs (two)	80164	LU-21
Plug, Special (Mates with Keithley 17638A on Models 147 and 148)	80164	CS-132
Cable Assembly		

01295	Texas Instruments, Inc. Semi Conductor-Components Division Dallas, Texas	04713	Motorola, Inc. Semiconductor Products Division Phoenix, Arizona
01686	RCL Electronics, Inc. Riverside, N. J.	08804	Lamp Metals and Components Department G. E. Co. Cleveland, Ohio
02735	Radio Corp. of America Commercial Receiving Tube and Semiconductor Division Somerville, N. J.	12954	Dickson Electronics Corp. Scottsdale, Ariz.

TABLE 11 (Sheet 1). Code List of Suggested Manufacturers. (Based on Federal Supply Code for Manufacturers, Cataloging Handbook H4-1.)

24655	General Radio Co. West Concord, Mass.	75915	Littelfuse, Inc. Des Plaines, Ill.
35529	Leeds and Northrup Co. Philadelphia, Pa.	76545	Mueller Electric Co. Cleveland, Ohio
56289	Sprague Electric Co. North Adams, Mass.	79727	Continental-Wirt Electronics Corp. Philadelphia, Pa.
58474	Superior Electric Co., The Bristol, Conn.	80164	Keithley Instruments, Inc. Cleveland, Ohio
71400	Bussmann Mfg. Div. of McGraw-Edison Co. St. Louis, Mo.	80294	Bourns Laboratories, Inc. Riverside, Calif.
71450	CTS Corp. Elkhart, Ind.	81453	Raytheon Co. Industrial Components Div. Industrial Tube Operation Newton, Mass.
72619	Dialight Corp. Brooklyn, N. Y.	83125	General Instrument Corp. Capacitor Division Darlington, S. C.
72982	Erie Technological Products, Inc. Erie, Pa.	93656	Electric Cord Co. Caldwell, N. J.

TABLE 11 (Sheet 2). Code List of Suggested Manufacturers. (Based on Federal Supply Code for Manufacturers, Cataloging Handbook H4-1.)



NOTES:
1. ALL RESISTANCE AND CAPACITANCE SHALL BE DESIGNATED IN OHMS AND MICROFARADS RESPECTIVELY UNLESS OTHERWISE NOTED
2. M = MEGOHMS
3. K = 1000 OHMS
4. pf = PICOFARADS
5. ↑ = CW ROTATION
6. ALL CONTROLS SHOWN IN C.C.W. POSITION
7. ◯ FRONT PANEL CONTROL.
8. INTERNAL SCREWDRIVER ADJUST.
9. REAR PANEL SCREWDRIVER ADJUST.
10. ▭ VOLTAGES REFERRED TO J202 WITH 10OM VTVM; POLARITY SWITCH ON + ; 117 VOLTS 60 CPS LINE VOLTAGE

HIGHEST REFERENCE DESIGNATION USED					
R157	R216	C204	D207	Q205	DS203
F201	S103	J105	S203	T201	P201
J202					

TITLE SCHEMATIC, NANOVOLT SOURCE (260)

KEITHLEY INSTRUMENTS CLEVELAND, OHIO

PART NUMBER 18208H