

**MODEL 602  
INSTRUCTION MANUAL**

**Instruction Manual  
Model 602  
Solid-State Electrometer**

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**Contains Operating and Servicing Information for the  
Model 602 Solid-State Electrometer**

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## SPECIFICATIONS

### AS A VOLTMETER:

**RANGE:** .001V full scale to 10V in nine 1X and 3X ranges.

**ACCURACY:**  $\pm 1\%$  of full scale on all ranges exclusive of noise and drift.

**ZERO DRIFT:** Less than 1mV per 24 hours, less than  $150\mu\text{V}$  per  $^{\circ}\text{C}$ .

**METER NOISE:**  $\pm 25\mu\text{V}$  maximum with input shorted on most sensitive range.

**INPUT IMPEDANCE:** Greater than  $10^{14}\Omega$  shunted by 20pF. Input resistance may also be selected in decade steps from 10 to  $10^{11}\Omega$ .

### AS AN AMMETER:

**RANGE:**  $10^{-14}\text{A}$  full scale to 0.3A in twenty-eight 1X and 3X ranges.

**ACCURACY:**  $\pm 2\%$  of full scale on 0.3 to  $10^{-11}\text{A}$  ranges using the smallest available multiplier setting;  $\pm 4\%$  of full scale on  $3 \times 10^{-12}$  to  $10^{-14}\text{A}$  ranges.

**METER NOISE:** Less than  $\pm 3 \times 10^{-15}\text{A}$ .

**OFFSET CURRENT:** Less than  $5 \times 10^{-15}\text{A}$ .

### AS AN OHMMETER:

**RANGE:** 100 $\Omega$ , full scale to  $10^{13}\Omega$  in twenty-three linear 1X and 3X ranges.

**ACCURACY:**  $\pm 3\%$  of full scale on 100 to  $10^9\Omega$  ranges using the largest available multiplier setting;  $\pm 5\%$  of full scale on  $3 \times 10^9$  to  $10^{13}\Omega$  ranges.

### AS AN COULOMB METER:

**RANGE:**  $10^{-13}\text{C}$  full scale to  $10^{-6}\text{C}$  in fifteen 1X and 3X ranges.

**ACCURACY:**  $\pm 5\%$  of full scale on all ranges. Drift due to offset current does not exceed  $5 \times 10^{-15}\text{C}$  per second.

### AS AN AMPLIFIER:

**INPUT IMPEDANCE:** Greater than  $10^{14}\Omega$  shunted by 20pF. Input resistance may also be selected in decade steps from 10 to  $10^{11}\Omega$ .

**OUTPUTS:** Unity-gain output and either voltage or current recorder output.

**UNITY-GAIN OUTPUT:** At DC, output is equal to input within 10 ppm, exclusive of noise and drift, for output currents of  $100\mu\text{A}$  or less. Up to 1mA

may be drawn for input voltages of 10V or less. Output polarity is same as input polarity.

**VOLTAGE RECORDER OUTPUT:**  $\pm 1\text{V}$  for full-scale input. Internal resistance is 910 $\Omega$ . Output polarity is opposite input polarity.

**Gain:** 0.1, 0.33, etc., to 1000.

**Frequency Response (within 3db):** DC to 40kHz at a gain of 1 and lower, decreasing to DC to 100Hz at maximum gain. Full output response limited to 3kHz on any gain.

**Noise:** Less than 3% rms of full scale at gain of 1000, decreasing to less than 0.5% at gains below 10.

**CURRENT RECORDER OUTPUT:**  $\pm 1\text{mA}$  for full-scale input, variable  $\pm 5\%$  with 1400 $\Omega$  recorders.

### GENERAL:

**ISOLATION:** Circuit ground to chassis ground: Greater than  $10^9\Omega$  shunted by  $.0015\mu\text{F}$ . Circuit ground may be floated up to  $\pm 1500\text{V}$  with respect to chassis ground.

**Polarity:** Meter switch selects left-zero (positive or negative) or center-zero scales. Meter switch does not reverse polarity of outputs.

**CONNECTORS:** Input: Teflon-insulated triaxial Bendix 33050-2. Low: Binding post. Voltage or current output: Amphenol 80-PC2F. Unity-gain output, chassis ground: Binding posts.

**BATTERY CHECK:** Condition of all batteries may be checked with front panel controls.

**BATTERIES:** Six 2N6 (or 246, VS305, NEDA 1602); one RM-1W. 1000 hours battery life.

**DIMENSIONS, WEIGHT:** Overall bench size 10 $\frac{3}{4}$  in. high  $\times$  7 in. wide  $\times$  11 $\frac{1}{2}$  in. deep (275  $\times$  175  $\times$  290mm). Net weight, 13 pounds (5.7kg).

**ACCESSORIES SUPPLIED:** Model 6011 Input Cable: 30" triaxial cable with triaxial connector and 3 alligator clips. Mating output connector.



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# SECTION 1 GENERAL DESCRIPTION

## 1.1 INTRODUCTION

The Keithley Model 602 Electrometer is a completely solid-state, battery operated instrument, which measures a wide range of DC voltage, current, resistance and charge. The Model 602's input resistance of greater than  $10^{14}\Omega$  is the result of extensive instrument development with high input impedance transistors. The Model 602 has all the capabilities of conventional VTVMs, but can also make more measurements without loading circuits.

The Model 602 has nine voltage ranges from 0.001V full scale to 10V, 28 current ranges from  $10^{-14}$ A full scale to 0.3A, 23 linear resistance ranges from  $100\Omega$  full scale to  $10^{13}\Omega$ , and 15 charge ranges from  $10^{-13}$ C full scale to  $10^{-6}$ C.

The Model 602 offers complete line isolation and excellent off-ground measuring capability. Up to 1500V may be applied between the input low terminal and the case, and stage operation is assured with the case grounded. A triaxial connector allows complete guarding of the high impedance input terminal.

The Model 602 employs matched insulated-gate field-effect transistors followed by transistor differential amplifier stages and a complimentary-output stage. A large amount of negative feedback is used for stability and accuracy.

## 1.2 MODEL 602 FEATURES

1. The Model 602 has excellent zero stability which permits accurate measurements with minimal adjustment. Short term zero drift is less than  $50\mu\text{V}$  per hour. Zero offset due to temperature change is less than  $150\mu\text{V}$  per  $^{\circ}\text{C}$  after 30 minute warm-up period. This offset, however, can easily be compensated for with the front panel zero controls.
2. Fast warm-up is an inherent characteristic of the Model 602. It can be operated 30 minutes after warm-up on the most sensitive range and almost immediately on less sensitive ranges.
3. Low offset current  $5 \times 10^{-15}$ A, minimizes zero offset with high source resistance and permits maximum resolution when measuring current and charge.
4. The 1000 hour life of the batteries enables usage in long term experiments without interruptions for recharging. Battery life is maintained even when the 10mA recorder output is used. For further convenience, battery condition is readily checked on the panel meter.
5. Excellent overload protection without degradation of performance is obtained by use of a unique input circuit. The Model 602 Electrometer will withstand damage and has good recovery.

## 1.3 WARRANTY INFORMATION


Warranty information may be found inside the front cover of this manual. Should it become necessary to exercise the warranty, contact your nearest Keithley representative or the factory to determine the correct course of action. Keithley Instruments maintains service facilities in the United States, West Germany, Great Britain, France, the Netherlands, Switzerland, and Austria. Information concerning the application, operation, or service of your instrument may be directed to the applications engineer at any of these locations. Check the inside front cover of this manual for addresses.


## 1.4 MANUAL ADDENDA

Information concerning improvements or changes to the instrument which occur after the printing of this manual will be found on an addendum sheet included with this manual. Be sure to review these changes before attempting to operate or service the instrument.

## 1.5 SAFETY SYMBOLS AND TERMS

The following safety symbols and terms are used in this manual or found on the Model 602.

The symbol  on the instrument indicates that the user should refer to the operating instructions in this manual.

The symbol  on the instrument indicates that a potential of 1000V or more may be present on the terminal(s). Standard safety precautions should be observed when such dangerous voltages are encountered.

The **WARNING** heading in this manual explains dangers that could result in personal injury or death.

The **CAUTION** heading in this manual explains hazards that could damage the instrument.

## 1.6 SAFETY PRECAUTIONS

1. This instrument is intended for use by qualified personnel who recognize the shock hazards and are familiar with the safety precautions required to avoid possible injury. Read over the manual carefully before operating this instrument.
2. Exercise extreme caution when a shock hazard is present at the instrument's input. The American National Standards Institute (ANSI) states that a shock hazard exists when voltage levels greater than 30V rms or 42.4V peak are present. A good safety practice is to expect that hazardous voltage is present in any unknown circuit before measuring.

3. Inspect the test leads for possible wear, cracks or breaks before each use. If any defects are found, replace with test leads that have the same measure of safety as those supplied with the instrument.
4. For optimum safety do not touch the test leads or the instrument while power is applied to the circuit under test. Turn the power off and discharge all capacitors, before connecting or disconnecting the instrument.
5. Do not touch any object which could provide a current path to the common side of the circuit under test or power line (earth) ground. Always make measurements with dry hands while standing on a dry, insulated surface, capable of withstanding the voltage being measured.
6. Exercise extreme safety when testing high energy power circuits (AC line or mains, etc). Refer to the operating section.
7. Do not exceed the instrument's maximum allowable input as defined in the specifications and operation section.

## 1.7 SPECIFICATIONS

Detailed Model 602 specifications may be found immediately preceding this section.

## 1.8 OPTIONAL ACCESSORIES

The following optional accessories can be used with the Model 602 to provide additional convenience and versatility.

### 1.8.1 Model 6101A Shielded Probe

The Model 6101A is a shielded cable with a needle point probe and 30 inches of low noise cable terminated by a UHF connector.

### 1.8.2 Model 6103C Divider Probe

The Model 6103C is a shielded cable with a needle point probe and 30 inches of low noise cable terminated by a UHF connector. The probe includes a 1000:1 voltage divider with a  $4.5 \times 10^{11} \Omega$  input resistance. Accuracy is  $\pm 5\%$  at 30kV.

### 1.8.3 Model 6104 Test Shield

The Model 6104 is a shielded test box for two-terminal or three-terminal connections. The INPUT terminal is Teflon<sup>®</sup> insulated.

**Two-Terminal Connections**—Resistance measurements can be made conveniently using the INPUT and GROUND terminals on the test box. Connect the electrometer to the BNC output. Use the electrometer in normal mode for ohms measurement.

**Three-Terminal Connections**—The GUARD output on the Model 602 Electrometer can be used for resistance measurements where the effects of cable capacitance may be significant. Connect the unknown between INPUT and EXT terminals. Connect the EXT terminal to the GUARD output on the electrometer. Use the electrometer in fast mode for ohms measurement.

### 1.8.4 Model 6105 Resistivity Chamber

The Model 6105 is a guarded test fixture for measurement of surface and volume resistivities. The chamber is designed in accordance with ASTM Standard Method of Test for Electrical Resistance of Insulated Materials, D257-66. The Model 6105 can be used in conjunction with an electrometer and voltage supply.

Resistivity can be determined by measuring the current through a sample with a known voltage impressed. The measurement can be made most conveniently when a set of electrodes are used which can be calibrated in terms of surface or volume resistivity. The Model 6105 has been designed for use with a Keithley electrometer and an optional high voltage supply such as the Model 247.

### 1.8.5 Model 2503 Static Detector Probe

Model 2503 is designed to detect voltage due to charge on relatively small surface areas. Solid coaxial 13mm ( $\frac{1}{2}$  inch) diameter tube used with 89mm ( $3\frac{1}{2}$  inch) head, 89mm ( $3\frac{1}{2}$  inch) coupler, 25mm (one inch) adapter and two 90° angle adapters which may be placed at various junctions along the tube. It gives a 10,000:1  $\pm 10\%$  division ratio when used with Model 610C and held 6mm ( $\frac{1}{4}$  inch) away from a charged plane of at least 13mm ( $\frac{1}{2}$  inch) diameter. Output is a UHF male plug.

### 1.8.6 Model 6011 Input Cable

The Model 6011 is a low-noise triaxial cable, 30 inches long, terminated by three color-coded alligator clips. This cable mates directly with the triaxial input. The cable is fabricated using a Keithley connector (P/N CS-141) and low-noise cable (P/N SC-22).

The Model 6011 may be used for measurements which require a triaxial connection, especially when the input LO is floated above CASE ground.

### 1.8.7 Model 6012 Triax-to-Coax Adapter

The Model 6012 is an adapter for mating the triaxial input and UHF (coax) type connectors. Permits using Models 220, 602, 614, 616 and 619 with all Keithley electromete accessories having UHF type connectors.

## SECTION 2 OPERATION

### 2.1 INTRODUCTION

A layout of the Model 602 front panel controls is contained in Figure 2-1, while Figure 2-2 contains a layout of the rear panel terminals. See the following paragraphs for Model 602 front panel controls and rear panel terminals.

### 2.2 FRONT PANEL CONTROLS

**Range Switch**—Selects the mode to be measured: voltage, current, resistance or charge.

**Multiplier Switch**—Determines full scale voltage sensitivity and can be used to multiply current, resistance and charge ranges on the range switch.

**METER Switch**—Checks battery condition, turns instrument off, disconnects meter, selects meter polarity, sets instrument for center zero operation.

**ZERO Control**—Allows precise meter zeroing.

**ZERO CHECK Switch**—Zeroes meter on any range.

**FEEDBACK Switch**—Determines the feedback connections within the instrument.

**INPUT Connector**—Connects input to source. Connector is a Teflon<sup>®</sup> insulated triaxial connector.

**LO Terminal**—Provides connection to input low.

### 2.3 REAR PANEL TERMINALS

**COARSE ZERO Switch**—Extends the zeroing capability of the front panel ZERO controls.

**1MA/1V Switch**—Selects the Model 602 output: 1mA or 1V. Must be in 1V position if the output is connected to a load of more than 2k $\Omega$ .

**1MA CAL Control**—Varies the output from 0.95 to 1.05mA.

**OUTPUT Connector**—Connects output to monitoring device.

**X1 OUTPUT and OHMS-GUARD Terminals**—For guarded measurements and for use as an extremely linear preamplifier.

**LO Terminal**—Provides an alternate connection to input low.

**CASE GND Terminals**—Connects to Model 602 cabinet and outside shell of input connector.

### 2.4 INPUT CONNECTIONS

The Model 602 INPUT connector is a Teflon<sup>®</sup> insulated triaxial connector. The center terminal is a high impedance terminal, the inner shield is a low impedance terminal and the outer shield is case ground (See Figure 2-3). The LO terminal, below the connector, is connected to the inner shield. It is

connected to case ground, only if the shorting link on the rear panel is connected.

The Model 6011 Input Cable is supplied with the instrument, Table 2-1 indicates the color coding of the alligator clips. The high impedance terminal is shielded by the inner braid of the triaxial cable up to the miniature alligator clip. If the unshielded clip causes pick-up from nearby electric fields, remove the clip, and connect the shielded lead directly to the source.

**Table 2-1. Color Coding of Alligator Clips For Model 6011 Input Cable**

Lead	Circuit	J101 Terminal
Heavy wire with red clip cover.	Input High	Center
Thin wire with black clip cover.	Input Low	Inner
Thin wire with green clip cover.	Case	Outer Shield

When working with a high impedance source carefully shield the input connection and the source since any variation in the electrostatic field near the input will cause definite meter disturbances.

Use high resistance, low loss material (such as, Teflon<sup>®</sup>, polyethylene or polystyrene) for insulation. The insulation leakage resistance of test fixtures and leads should be several orders of magnitude higher than the internal resistance of the source. Excessive leakage reduces the accuracy of reading from high impedance sources. The triaxial or coaxial cables used should be a low noise type which employs a graphite or other conductive coating between the dielectric and the surrounding shield braid. The Model 6011 input cable ensures good input connections.

When working with a high impedance source, any change in the shunt capacitance of the input circuit will cause disturbances in the reading. Make the measuring setup as rigid as possible, tie down connecting cables to prevent vibrations. A continuous vibration may appear at the output as a sinusoidal signal, and other precautions may be necessary to isolate the instrument and connecting cable from the vibrations.

#### NOTE

Clean, dry connections and cables are very important to maintain the value of all insulation materials. Even the best insulation will be compromised by dust, dirt, solder flux, films, oil or water vapor. A good cleaning agent is methyl alcohol, which dissolves most common dirt without chemically attacking the insulation. Air dry the cables or connections after washing with alcohol or use dry nitrogen or Freon.

20963 Top Cover  
 19117 Bottom cover (includes tilt bail.)  
 15004 Tilt bail (ONLY)

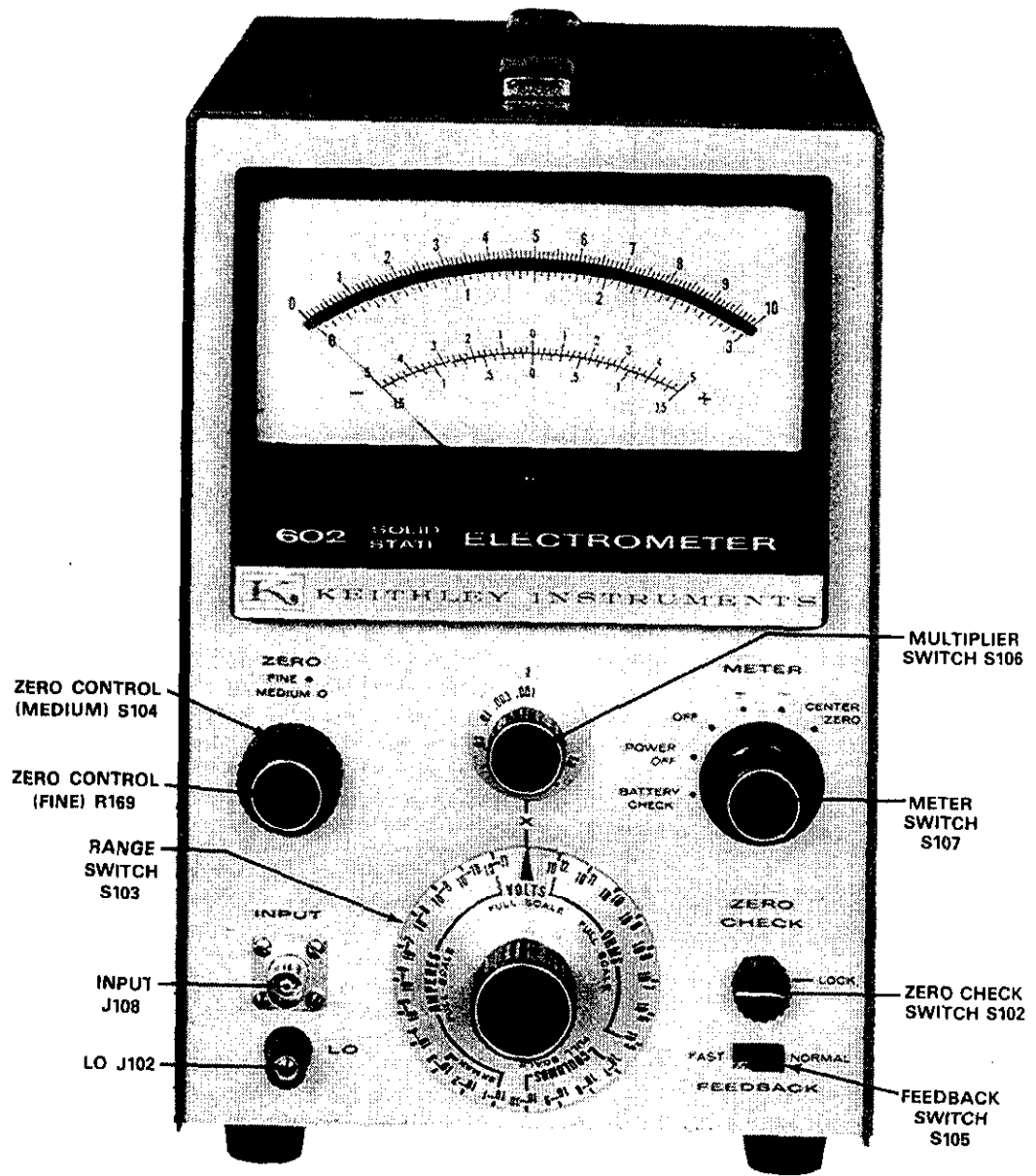


Figure 2-1. Model 602 Front Panel Controls

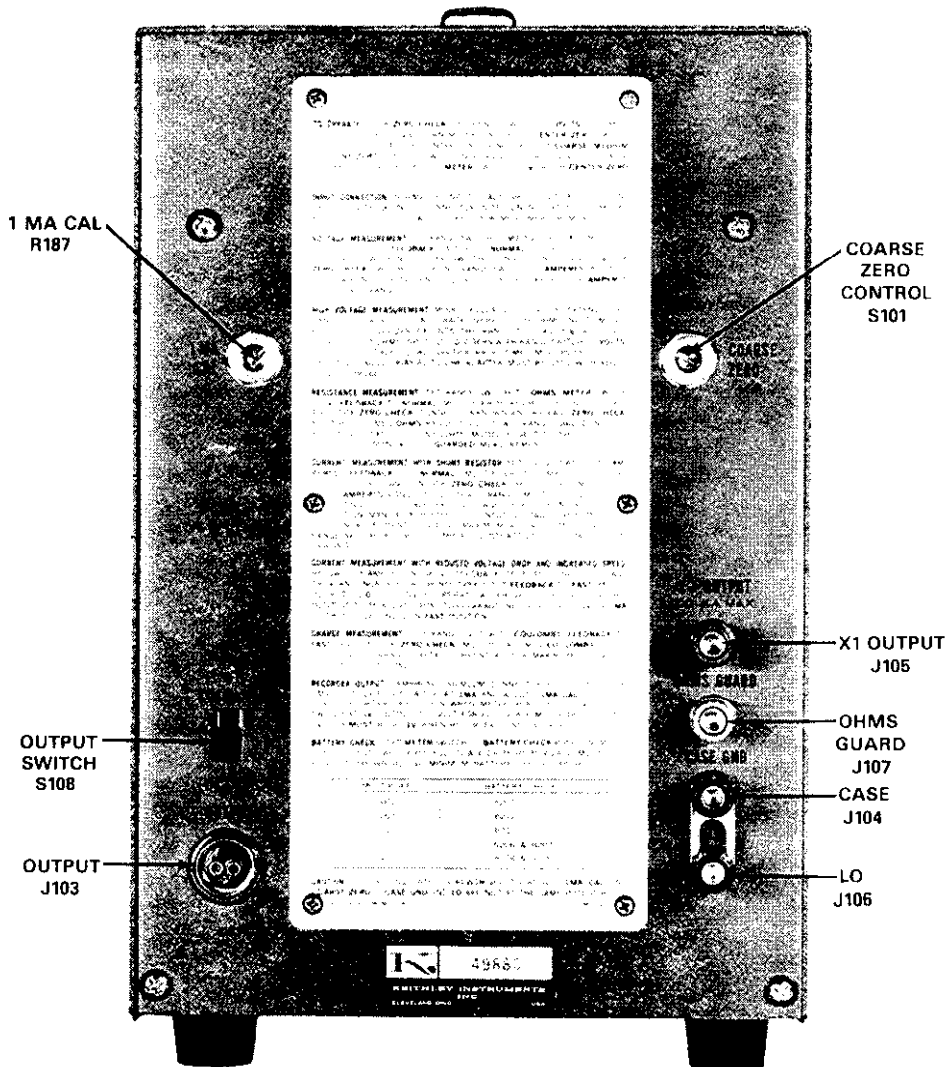


Figure 2-2. Model 602 Rear Panel Terminals

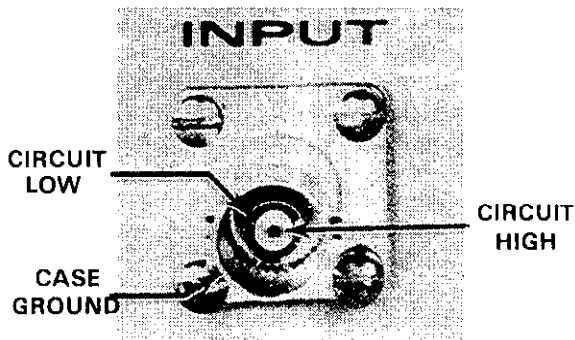


Figure 2-3. Triaxial Input

For low impedance measurements (below  $10^8\Omega$  or above  $10^{-8}\Omega A$ ) unshielded leads may be used. When the Model 602 is used on the most sensitive current range with the FEED-BACK switch at FAST, some insulators (such as Teflon®) may produce random signals which show up as erratic meter deflections. Insulation used in the Model 602 is carefully selected to minimize these spurious signals.

If a well shielded chamber and a well made high impedance transfer switch is available, it is advantageous to connect the Model 602 to the circuit only when a reading is being made. In some cases, the offset current can charge the external test circuitry. One example of this occurs when measuring a capacitor's leakage resistance by observing the decay of the terminal voltage. If the leakage current is less than the offset current (less than  $5 \times 10^{-15}A$  there may be no decay of the terminal voltage when the Model 602 is left connected across the capacitor's terminals.

**NOTE**

Keep the shield cap on the INPUT connector when the Model 602 is not in use.

The Model 6012 Triaxial-to-Coaxial Adapter permits use of cables and accessories with the Model 602 by adapting the triaxial INPUT connector to the UHF coaxial type.

**CAUTION**

The Model 6012 connects low to case ground. The Model 602 cannot be used off-ground when using the Model 6012. The instrument's cabinet will be at the same potential as the input low.

**2.5 PRELIMINARY PROCEDURES**

Check battery condition by holding the METER switch in the BATTERY CHECK position. Rotate the multiplier switch through the .001 to 0.1 positions and observe the meter readings. The meter should read at least two-thirds of full scale in each multiplier switch position. Table 2-2 shows the

batteries checked by position. If the reading for any battery other than B203 is below two-thirds, replace all batteries except for B203. If the reading for B203 is less than two-thirds full scale, replace it. Note, that, new batteries may cause the Model 602 to drift more than normal for at least 72 hours due to change in battery terminal voltage.

Set the controls as follows:

- ZERO CHECK Button LOCK
- Range Switch VOLTS
- Multiplier Switch 1
- FEEDBACK Switch NORMAL
- METER Switch POWER OFF

Table 2-2. Multiplier Switch Positions for Checking Conditions of Batteries

Multiplier Position	Battery Checked
.001	B203
.003	B202
.01	B201
.03	B206 & B207
0.1	B204 & B205

1. Turn the METER switch to CENTER ZERO. Within ten seconds, the meter needle should come to the center position. If not, adjust the meter zero with the MEDIUM and FINE ZERO controls. Normally, there is no need to use the COARSE ZERO switch.

**NOTE**

Using the center zero scales decreases accuracy 0.5% because the scale span is reduced.

2. After a few moments increase the voltage sensitivity by advancing the multiplier switch. Continue zeroing with the FINE ZERO control.
3. After long periods of storage or after an overload, the Model 602 may drift excessively. The input transistors are insensitive to mechanical shock; however, a severe input overload may cause a zero offset. This is corrected with the ZERO controls. Drifting can occur for several hours.

**NOTE**

If the Model 602 has been stored for some time, the offset current will exceed the specification when first used, then decrease to below the specified amount after one or two hours of use. This is an inherent characteristic of the input transistors; the instrument is not faulty.

4. Although the offset current of the Model 602 is below that found in conventional voltmeters, it can be observed on the meter. The current charges the input capacitance, and the Model 602 appears to drift when the input is open. Use the ZERO CHECK button to discharge the charge build-up. Depressing the ZERO CHECK button removes all signal from the amplifier and reduces the input impedance between HI and LO terminals of the INPUT connector to  $10M\Omega$ .

5. Follow the procedures in paragraphs 2.6 to 2.10 for measuring voltage, current, resistance and charge.

**NOTE**

When using multiplier switch settings of 10, 3 and 1 in the voltage, current, resistance and charge measuring modes, make sure the OUTPUT switch is set to 1V if the output is connected to a load of more than 2k $\Omega$ . Otherwise, the meter will not read full scale signals correctly. When the output is loaded, this effect is not present.

**2.6 VOLTAGE MEASUREMENTS**

The Model 602 can be used to measure voltages. In the normal method (FEEDBACK switch at NORMAL) the unknown voltage is connected to the INPUT connector. Input impedance with the range switch in the VOLTS position is 10<sup>14</sup> $\Omega$ , 20pF.

To reduce the effects of input cable capacity, use the fast method to measure the voltage. Set the FEEDBACK switch at FAST and drive the inner shield of the cable with the X1 OUTPUT which is connected to the LO terminal in the FAST position. A guarded circuit is possible this way. To reduce stray pick-up when making routine measurements (i.e. measuring from low impedance sources) the range resistors or capacitors may be used to shunt the input. Accessory probes extend the Model 602's range to 10kV.

**NOTE**

Locking the ZERO CHECK switch places 10M $\Omega$  between input high and low, which may temporarily cause instability in some types of high impedance sources.

**2.6.1 Normal Method Voltage Measurements**

Set the controls as follows:

ZERO CHECK Button	LOCK
Range Switch	VOLTS
Multiplier Switch	10
FEEDBACK Switch	NORMAL
METER Switch	CENTER ZERO

Connect the unknown voltage to the high (center) terminal of the INPUT connector and to the OHMS GUARD terminal on the rear panel. Use the LO terminal as a guard between circuit high and low. Unlock the ZERO CHECK button. Set the meter switch to + or -, as necessary. Increase sensitivity with the multiplier switch. Recheck zero setting after increasing sensitivity. To make off-ground voltage measurements, see paragraph 2.7.

**2.6.2 Guard Method Voltage Measurement**

This method reduces the effects of input cable capacity with very high impedance sources and allows guarded voltage measurements.

Set the controls as follows:

ZERO CHECK Button	LOCK
Range Switch	VOLTS
Multiplier Switch	10
FEEDBACK Switch	FAST
METER Switch	CENTER ZERO

Connect the unknown voltage to the high (center) terminal of the INPUT connector and to the OHMS GUARD terminal on the rear panel. Use the LO terminal as a guard between circuit high and low. Unlock the ZERO CHECK button. Set the METER switch to + or -, as necessary. Recheck zero setting after increasing sensitivity. To make off-ground voltage measurements, see paragraph 2.7.

**2.6.3 Low Impedance Sources**

To decrease input resistance, set the FEEDBACK switch to NORMAL and the range switch to one of the AMPERES ranges. The input resistance is now the reciprocal of the current range. For instance, to obtain an input resistance of 10<sup>7</sup> $\Omega$ , set the range switch to the 10<sup>-7</sup>A range. Set the full scale voltage range with the multiplier switch. Operating procedures are the same as paragraph 2.6.1. With reduced input resistance, the Model 602 will not be deflected off scale by stray fields when the input is left open.

**2.7 OFF-GROUND VOLTAGE MEASUREMENTS**

The Model 602 can measure an unknown voltage whose low impedance terminal is up to 1500V off-ground. Safe operation of the Model 602 is ensured by grounding the case (see paragraph 2.6).

**CAUTION**

**Operating the Model 602 more than 1500V off-ground may permanently damage the instrument. Isolation between circuit low and ground may break down somewhere in the instrument. Since these breakdowns are very difficult to locate, it might not be possible to float the instrument safely again.**

**2.7.1 FEEDBACK Switch Set To NORMAL**

Disconnect the shorting link between LO and CASE GROUND terminals on the rear panel. Make sure the Model 602 case is securely connected to an earth ground, and that the low of the unknown voltage is less than 1500V off-ground. Connect the unknown voltage directly to the INPUT connector. Operate the Model 602 as described for normal method voltage measurements.

**2.7.2 FEEDBACK Switch Set To FAST**

Disconnect the shorting link between the LO and CASE GROUND terminals on the rear panel. Make sure the Model 602 case is securely connected to an earth ground, and that

the low of the unknown voltage is less than 1500V off-ground. Connect the high of the unknown voltage to the center terminal of the INPUT connector. Connect the low to the OHMS GUARD terminal. Use the LO terminal or inner shield of the INPUT connector as a guard. Operate the Model 602 as described for fast method voltage measurements.

**WARNING**

If the output is used for recording when the Model 602 is off-ground in the normal or fast mode, make sure the shell of a mating plug to the OUTPUT connector is not connected to either pin in the connector. Also, the recorder output will be off-ground.

**WARNING**

Use only an insulated blade screwdriver to adjust the COARSE ZERO switch and 1 MA CAL control when floating the Model 602. An ordinary screwdriver could short the circuit low to case ground, creating a shock hazard and damaging the external circuitry.

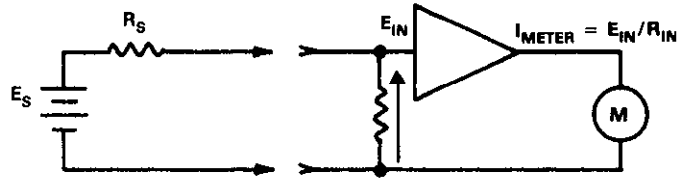
**2.8 CURRENT MEASUREMENTS**

The Model 602 can measure current three ways.

1. In the normal method (useable on any range) the current is determined by measuring the voltage drop across a resistor shunting the amplifier input. This method is useful when low noise is more important than fast response speed or if some damping is needed.
2. In the fast method (for use only below the  $10^{-15}A$  range) the shunt resistor is between the amplifier output and input in the feedback loop. This circuit largely neutralizes the effect of input capacity and greatly increases the response speed. Also, the input voltage drop is reduced to a maximum of 1mV on any range.
3. For galvanometric current measurements, the Model 602 acts as a null indicator between a known current and the unknown current source.

Rise time varies primarily with the current range, the input capacity and the method used. With the FEEDBACK switch in the FAST position, the rise time on the most sensitive range is less than 2sec and on the  $10^{-1}A$  range, less than 3msec. Given a choice, it is better to place the Model 602 nearer to the current source than to the data reading instrument. Transmitting the input signal through long cables slightly decreases the response speed and greatly increases noise due to cable capacitance.

To measure from a source with both terminals off-ground in either method, remove the link between the LO and CASE GROUND terminals on the rear panel. Connect the unknown current to the INPUT connector. The source must be less than  $\pm 1500V$  off-ground (see paragraph 2.7 and Figure 2-4).



$$I_s = E_s/R_s$$

$$ERROR = I_s - I_M$$

$$\%ERROR = E_{IN}/E_s \times 100$$

$$IF E_{IN} < E_s, THEN I_M = I_s.$$

NOTE: CURRENT SOURCES MAY BE CONSIDERED A VOLTAGE (E) IN SERIES WITH A RESISTANCE (R). THE CURRENT WITH THE AMMETER SHORT CIRCUITED IS  $I = E/R$ . WITH THE SHORT REMOVED, THE EFFECTIVE INPUT RESISTANCE OF THE AMMETER ( $R_{IN}$ ) IS IN SERIES WITH THE SOURCE RESISTANCE (R).

Figure 2-4. Error Due to Ammeter Resistance

**2.8.1 Normal Mode (0.3 to  $10^{-14}A$  Ranges)**

Set the controls as follows:

- ZERO CHECK Button LOCK
- Range Switch  $10^{-1}$  AMPERE
- Multiplier Switch 1
- FEEDBACK Switch NORMAL
- METER Switch CENTER ZERO

Connect the unknown current to the high terminal (center terminal) of the INPUT connector and use the low terminal (inner shield) for the return path. Unlock the ZERO CHECK button. Set the METER switch to + or -, as necessary. Increase the sensitivity with the range switch and the multiplier switch. Do not set the multiplier switch higher than 3 for range switch settings  $10^{-3}$  and above. Check zero with the ZERO CHECK button.

The full scale current range is multiplier switch setting times range switch setting. Use the smallest multiplier switch setting possible to minimize input voltage drop and thus obtain the best accuracy. The input resistor varies with the range switch setting, from  $10\Omega$ , to  $10^{-1}A$  to  $10^{11}\Omega$  for  $10^{-11}A$ . The full scale input voltage drop is equal to the multiplier switch setting.

**2.8.2 Fast Method (Current Below  $10^{-15}A$ )**

Set the controls as follows:

- ZERO CHECK Button LOCK
- Range Switch  $10^{-6}$  AMPERES
- Multiplier Switch 1
- FEEDBACK Switch FAST
- METER Switch CENTER ZERO

Connect the unknown source to the INPUT connector and lock the ZERO CHECK button. Set the METER switch to + or -, as necessary. Increase the sensitivity with the range switch and the multiplier switch. Check zero only with the ZERO CHECK button. Do not short the input, because this will remove the feedback from the circuit.



The full scale current range is the multiplier switch setting times the range switch setting. When selecting the multiplier switch setting, remember smaller settings permit lower source resistances, and larger settings improve instrument zero stability.

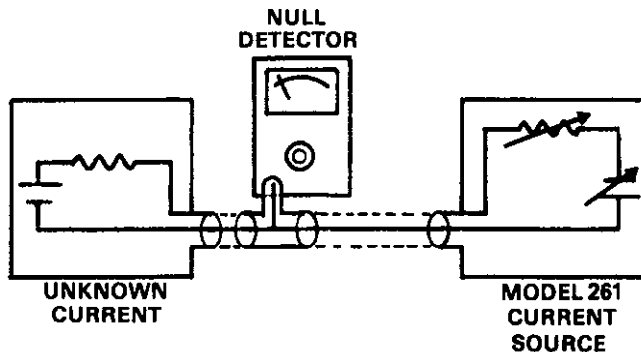
With the fast method, the input drop is reduced and the response speed is increased at least 100 times. However, the following safety precautions should be observed.

1. The internal impedance of the unknown current source should not be less than 0.1 of the value of the feedback resistor being used. Otherwise, adequate feedback voltage cannot be developed at the input and zero instability results. The feedback resistor value is the reciprocal of the AMPERES range of the range switch.
2. The low side (pin No. 2) of the OUTPUT connector is no longer connected to the low side of the INPUT connector. Therefore, do not use a grounded recorder. As an alternative use the unity-gain output. (See paragraph 2.12).
3. Use, with caution, the fast method to measure capacitor leakage. A very stable voltage supply must be used. Connecting a capacitor to the input changes the circuit to a differentiator, resulting in extreme sensitivity to very small voltage transients and an increase in meter noise.

### 2.8.3 Galvanometric Method

Operate the Model 602 as a picoammeter in the fast method. Use an accurate reference current source such as the Keithley Model 261 to buck out the unknown current source. Connect as shown in Figure 2-5.

Set the METER switch to CENTER ZERO and use the higher current ranges. Adjust the buck out current to indicate null on the Model 602. Increase the Model 602 sensitivity as needed. When the Model 602 is as close to null as possible, the unknown current is equal to the algebraic sum of the Model 261 setting and the Model 602 current reading.



**NOTE:** USE AN ACCURATE REFERENCE CURRENT SOURCE TO BUCK OUT THE UNKNOWN CURRENT SOURCE. THE MODEL 602, ON ITS CURRENT RANGES, SERVES AS A NULL DETECTOR. USE A UHF-TEE FITTING AND MODEL 6012 ADAPTER AT THE MODEL 602 INPUT. CONNECT THE MODEL 602 TO THE TWO SOURCES WITH COAXIAL CABLE. SELECT CABLE CAREFULLY FOR VERY LOW CURRENTS.

**Figure 2-5. Measuring Current by the Galvanometric Method**

## 2.9 RESISTANCE MEASUREMENTS

The Model 602 can measure resistance by two methods.

1. In the constant current method, the Model 602 measures the voltage drop across the unknown sample as a known, constant current flows through it. The voltage drop is proportional to the resistance of the sample. In this method the Model 602 can be used in one of two different modes: normal or fast. The normal mode is recommended for use from 100 to  $10^{11}\Omega$ . Above  $10^{11}\Omega$ , the fast method is preferred. It results in faster response speed and also nullifies leakage across the Model 602 input, since the potential across the input terminal is small.
2. In the preceding method, the voltage across the sample cannot be arbitrarily set. In some cases, as in measuring capacitor leakage, this results in excessively long testing time. In the voltmeter ammeter method, the Model 602 is used as a picoammeter. The unknown resistance sample is connected to an external known voltage source and the current through the sample is measured. Either the normal or fast method may be used. The resistance is calculated from the reading.

### NOTE

Discharge any capacitor completely before removing it from the circuit. Depressing the ZERO CHECK button shorts the input through a  $10M\Omega$  resistor, providing a discharge path.

### 2.9.1 Normal Constant Current Method

Set the controls as follows:

ZERO CHECK Button	LOCK
Range Switch	$10^{12}$ OHMS
Multiplier Switch	1
FEEDBACK Switch	NORMAL
METER Switch	+

Connect the high impedance side of the resistance sample to the high terminal (center terminal) of the INPUT connector and the low impedance side to the low terminal (inner shield) of the INPUT connector. Unlock the ZERO CHECK button. Check zero only with the ZERO CHECK button.

### NOTE

Do not open circuit Model 602 on the OHMS ranges; the input will increase up to 10V due to its constant current characteristic. Keep the input shorted or the ZERO CHECK button locked.

The full scale ohms range is the multiplier switch times the range switch setting. Use the smallest range switch setting possible to obtain the best accuracy.

Before making a final reading, manipulate the multiplier and range switches so the sample is tested at a number of test potentials. The applied test voltage is the percentage of full scale that the meter reads times the multiplier switch setting.

When the test current is applied, the high terminal of the INPUT connector is positive. The test current is the reciprocal of the OHMS range setting.

**NOTE**

Shield the input if the resistance sample exceeds  $10^8\Omega$ .

**2.9.2 Fast Constant Current Method**

Follow the instructions of paragraph 2.5. Set the controls as follows:

ZERO CHECK Button	LOCK
Range Switch	$10^{11}$ OHMS
Multiplier Switch	1
FEEDBACK Switch	FAST
METER Switch	+

Connect the high impedance side of the resistance sample to the center terminal of the INPUT connector and the low impedance side to the OHMS GUARD terminal. Unlock the ZERO CHECK button. Read the resistance.

The low terminal of the INPUT connector is now a driven guard. It may be used to minimize the effects of capacity between high and low and errors due to leakage resistance between high and low.

The Model 6011 Input Cable, supplied with the Model 602, provides a convenient means of making guarded resistance measurements. Connect the shorting link between the CASE GROUND and OHMS GUARD terminals on the rear panel. This allows the CASE GROUND or green test lead terminal to be connected to the low impedance side of the unknown resistance. The inner shield or the black test clip is the OHMS GUARD terminal.

**2.9.3 Voltmeter-Ammeter Method (To  $10^{16}\Omega$ )**

Turn the ZERO CHECK switch to LOCK. Connect sample between high terminal of the INPUT connector and power supply (See Figure 2-6). Put a switch in the high voltage line to connect the low impedance end of sample to input low when it is disconnected from the potential.

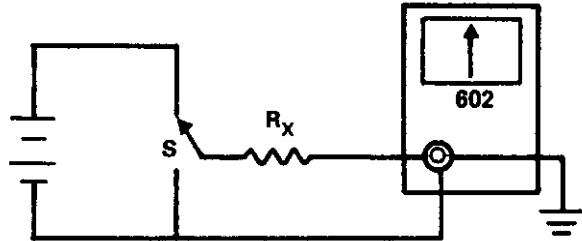
If the power supply must be floating, remove the link between the CASE GROUND and LO terminals and connect the CASE GROUND terminal to an earth ground.

Set the FEEDBACK switch to NORMAL. Usually this method is best, since instabilities can arise for resistance samples less than 0.1 the value of the feedback resistor.

To make a measurement, start with switch S as shown in Figure 2-6 and make sure the ZERO CHECK button is set to LOCK. Set switch S to apply a potential across the sample for a known period of time. Then unlock the ZERO CHECK button and take the reading. Set the range switch to  $10^{-11}A$  and increase sensitivity until a reading is obtained.

**NOTE**

Shield the input if the resistance sample exceeds  $10^8\Omega$ .



NOTE: A POTENTIAL FROM A KNOWN SOURCE, V, IS APPLIED TO THE KNOWN RESISTANCE SAMPLE,  $R_x$ . THE MODEL 602 MEASURES THE CURRENT THROUGH,  $R_x$ , FROM WHICH THE RESISTANCE IS CALCULATED. SWITCH S CONNECTS THE LOW END OF  $R_x$  TO INPUT LOW WHEN NO POTENTIAL IS APPLIED.

**Figure 2-6. Measuring Resistance By The External Voltage Method**

To remove the sample, set the ZERO CHECK button to LOCK and set switch S back to the position shown in Figure 2-6.

If the potential applied is at least 100 times the full scale input drop (multiplier switch setting), the resistance is equal to the applied potential divided by the current reading. The high voltage sensitivity of the Model 602, therefore, permits external voltages of 0.1V or more to be used.

If the potential applied is less than 100 times the input drop, the resistance is equal to the difference between the applied potential and the input drop all divided by the current reading.

If the current is read by the fast method, the input drop is so slight that it need not be included in the calculation. If the capacity shunted across the sample is large, such as encountered in capacitor leakage measurements, the faster method increases response speed and this connection is recommended. Note, however, that power supply transients will be magnified.

**2.10 CHARGE MEASUREMENTS**

Follow the instructions of paragraph 2.5. Set the controls as follows:

ZERO CHECK Button	LOCK
Range Switch	$10^{-7}$ COULOMBS
Multiplier Switch	.01
FEEDBACK Switch	FAST
METER Switch	CENTER ZERO

Unlock the ZERO CHECK button and then connect the unknown source to the INPUT connector. If the Model 602 reads off scale, increase the multiplier switch setting. If the sensitivity is not enough, decrease the multiplier switch setting until the reading is on scale. Changing the multiplier switch setting does not affect the transfer of charge from the unknown source to the instrument. If increasing sensitivity with the multiplier switch does not bring the reading on scale,

increase sensitivity with the range switch and repeat the preceding steps.

The full scale charge range is the range switch setting times the multiplier switch setting. Input offset contributes a charge of  $5 \times 10^{-15} \text{C}$  per second maximum.

Use the ZERO CHECK button to discharge the integrating capacitor. Discharge for at least 20sec on the  $10^{-7} \text{C}$  range before making another measurement. On the  $10^{-8} \text{C}$  range, discharge for at least two seconds.

## 2.11 RECORDER OUTPUTS

Recorders, oscilloscopes and similar instruments can be used with the Model 602. The Model 602 has two outputs,  $\pm 1\text{V}$  and  $\pm 1\text{mA}$ , to amplify signals within  $\frac{1}{2}\%$  for recorders, oscilloscopes and similar instruments. These can be used on all ranges of the Model 602.

### WARNING

The Model 602 may be used with the FEEDBACK switch in FAST position with other instruments. However, make sure there is no common ground connection between low terminals of the Model 602 and the other instrument.

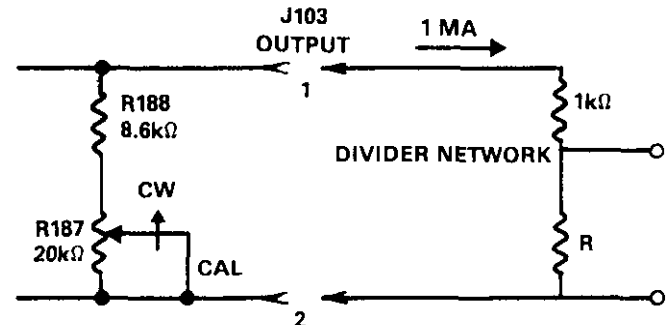
**1V Output**—Connect oscilloscopes and pen recorder amplifiers to the OUTPUT connector. Pin 1 is the output terminal and pin 2 is grounded when the FEEDBACK switch is set to NORMAL. Set the OUTPUT switch to 1V. The Model 602 output is now  $\pm 1\text{V}$  for full scale meter deflection on any range. Internal resistance is  $910\Omega$ . The frequency response ( $\pm 3\text{db}$ ) is DC to  $100\text{Hz}$  at a gain of 1000, rising to  $40\text{Hz}$  at gains of 1.0 and below. Noise is less than 3% rms of full scale at a gain of 1000, decreasing to less than 0.5% at gains of 10. The METER switch does not reverse the output polarity. Output polarity is opposite input signal polarity.

### WARNING

Neither terminal of the OUTPUT connector will be at case ground potential if the Model 602 is used off-ground. Make sure the shell of any mating plug is not connected to either terminal in the connector. Use a recorder with an isolated input when making off-ground measurements.

**1mA Output**—Connect 1mA instruments to the OUTPUT connector pin 1 is the negative terminal (for positive inputs). Set the OUTPUT switch to 1 MA. The output is approximately 1 milliampere for full scale meter deflection on any range. For exact output, adjust the meter on the .003V range with the FINE ZERO control for full scale deflection. Then 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. Use only insulated screwdriver to adjust the 1 MA CAL control.

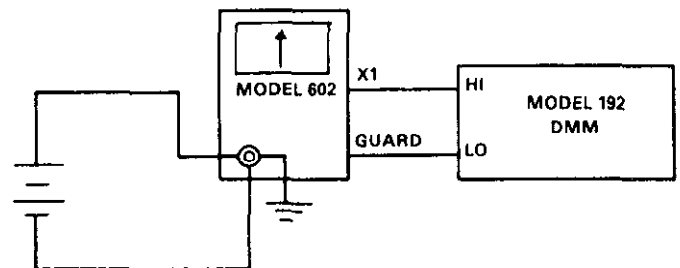
For servo rebalance recorders, use a divider of not greater than a total of  $2\text{k}\Omega$  across the Model 602 OUTPUT connector (See Figure 2-7). Set the OUTPUT switch to 1 MA. Use the 1 MA CAL control to trim the output for full scale recorder deflection. Operation is the same as for current outputs.



NOTE: USE 5% RESISTORS IN THE DIVIDERS. THE VALUE OF RESISTOR R IS  $1\Omega$  FOR EVERY  $1\text{mV}$  OF OUTPUT.

Figure 2-7. Divider Circuits Across Model 602 Output for Driving 50 and 100mV Recorders

When the FEEDBACK switch is in the NORMAL position, the negative side of the output terminal is connected to the LO terminal. Therefore, no difficulty will be experienced using oscilloscopes and recorders with the Model 602 set for normal operation. In FAST position, however, neither output terminal is common to the LO terminal. If this is used, make sure there is no common connection between the recorder or oscilloscope and the Model 602 LO terminal, or use the unity-gain output (See Figure 2-8).



NOTE: THE MODEL 602 IS USED BETWEEN A HIGH RESISTANCE SOURCE,  $V_x$ , AND A 0.01% VOLTMETER TO OBTAIN HIGH ACCURACY WITHOUT CAUSING CIRCUIT LOADING. THE DMM CONNECTS TO THE MODEL 602 UNITY-GAIN TERMINALS.

Figure 2-8. Measuring Potential of High Resistance Source with 0.025% Accuracy

## 2.12 UNITY-GAIN OUTPUT

The unity-gain amplifier can be used as an impedance matching device to minimize circuit loading errors or for convenient connections to a recorder when the FEEDBACK switch is in FAST position.

The unity-gain output is equal to the input within 10ppm when the load resistance is  $100\text{k}\Omega$  or greater. By placing the Model 602 between a  $10^{10}\Omega$  source, for example, and a

0.01% voltmeter with  $1M\Omega$  input resistance, overall accuracy better than 0.025% can be achieved.

1. Connect the voltmeter to the X1 OUTPUT and GUARD terminals as shown in Figure 2-8. The GUARD terminal is connected to LO terminal with the FEEDBACK switch in NORMAL. Maximum output amplitude is  $\pm 10V$ .
2. Adjust the Model 602 zero controls to obtain a zero voltage reading on the external voltmeter. Make sure the latter's sensitivity is high enough for a precise zero adjustment. This adjustment is necessary because a slight zero shift may occur when the Model 602 is changed from the 0.1V range or lower to a range above 0.1V. The shift,

caused by a gain-reducing network switched in by the amplifier on the 1V and higher ranges, is too slight to be read on the meter, but it can cause an error in accurate measurements using the unity-gain output.

3. To avoid the shift use the Model 602 with the multiplier switch set to 10.

When the FEEDBACK switch is in FAST position, the unity-gain terminals permit more convenient connections to oscilloscopes with a load resistance of greater than  $100k\Omega$  without special precautions. In this mode, the X1 OUTPUT terminal is common to the input low and the OHMS GUARD terminal delivers an output equal to the input signal.

## SECTION 3 THEORY OF OPERATION

### 3.1 INTRODUCTION

The Keithley Model 602 is an extremely stable and linear DC voltmeter with a full scale sensitivity of 1mV and an input impedance of  $10^{14}\Omega$  shunted by 20pF. By using the front panel controls, shunt resistors and capacitors are selected to make measurements over a total of 75 voltage, current resistance, and coulomb ranges. Current and resistance are measured using precision resistance standards, from  $10\Omega$  wirewound resistors to  $10^{11}\Omega$  glass sealed, deposited carbon resistors. Coulombs are measured using close tolerance polystyrene film capacitor standards. Batteries furnish the necessary amplifier power.

### 3.2 VOLTMETER OPERATION

The Model 602 uses matched insulated gate, field-effect transistors followed by a transistor differential amplifier with a high voltage complementary output stage. Figure 3-1 shows the block diagram for the voltmeter mode of operation. Voltmeter operation of the Model 602 is as follows.

1. The amplifier is always in a unity-gain, input voltage to output current converter configuration. The internal circuitry is arranged such that a full scale input voltage ( $e_i$ ) results in exactly a 1mA output current, through the divider string composed of  $R_m$ , R167 and the meter. Voltage gain of the circuit is determined by the ratio of R167 to  $R_m$ . Output is taken across R167.
2. The voltage drop across the amplifier is:

$$e_a = \frac{e_i}{K + 1}$$

where K is the amplifier loop gain, greater than  $10^6$  on all ranges.

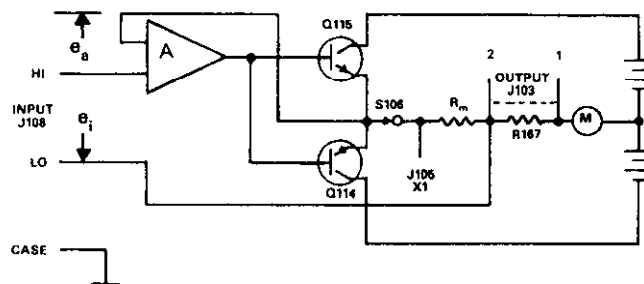
The complementary output stage, Q114 and Q115, drives the amplifier ground at the same potential as the input signal. Thus the impedance is maintained for any value input voltage and the need for input dividers is eliminated. The amplifier ground is not chassis ground, but is connected directly to J105, the unity-gain output.

#### NOTE

Refer to schematic diagram 21174E for circuit designations.

### 3.3 VOLTMETER CIRCUIT

1. The amplifier input stage is a pair of insulated gate, field-effect transistors, Q101 and Q102, in a differential configuration. The gate of Q102 is returned to amplifier common, the unity-gain output.



NOTE: CIRCUIT DESIGNATIONS REFER TO SCHEMATIC DIAGRAM. S106 IS THE MULTIPLIER SWITCH,  $R_m$  IS THE RESISTOR FOR A GIVEN SETTING.  $R_s$  IS THE RESISTOR SELECTED BY THE RANGE SWITCH, S102. S105 IS THE FEEDBACK SWITCH.

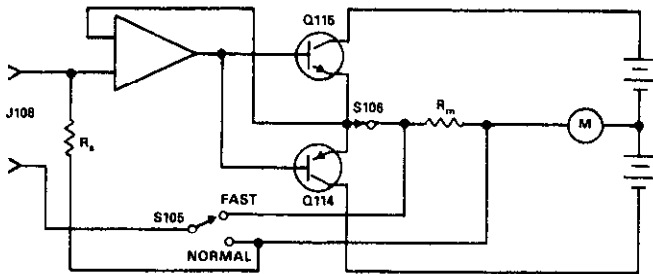
**Figure 3-1. Block Diagram of Model 602 in Voltmeter Mode.**

2. Depressing the ZERO CHECK button, S103, places the gate of the active insulated gate devices at zero potential.
3. The input stage is followed by a transistor differential amplifier, composed of Q103-Q110. Q108 and Q109 make up the output gain stage, which is utilized in a gain multiplier configuration. This stage provides the remainder of the high gain required by the amplifier. Also, this stage prevents fold-over and lock-up with positive input overloads. Diode D101, between base and emitter of Q110, prevents fold-over and lock-up under negative input overloads.
4. Frequency compensation is provided by capacitors C114, C115, resistors R145, R148 and capacitor C116. The compensation networks provide a controlled frequency characteristic to ensure stability under all conditions of capacitive loading on input and output while on any range.
5. The recorder output is derived from the current flow from Q114 and Q115 through the divider,  $R_m$ , R167 and the meter. With the 1V-1MA switch, S108 on 1V  $\pm$  1V for full scale deflection is obtained at output connector, J103, by  $\pm$  1.1mA flowing through the divider. With S108 at 1MA, R187 and R188 are connected across J103, allowing  $\pm$  1mA  $\pm$  5%, to pass through an external load.

### 3.4 AMMETER OPERATION

#### 3.4.1 Normal Method

In the normal method of current measurements (FEEDBACK switch in NORMAL position), one of the range switch resistors, R102 through R112, shunts the input (See Figure 3-2). The Model 602 then measures the voltage drop across the resistor. The meter is calibrated to read the current in amperes for the appropriate range.



NOTE: CIRCUIT DESIGNATIONS REFER TO SCHEMATIC DIAGRAM. S106 IS THE MULTIPLIER SWITCH;  $R_M$  IS THE RESISTOR FOR A GIVEN SETTING.  $R_X$  IS THE UNKNOWN RESISTANCE BEING MEASURED;  $E$  IS THE VOLTAGE SOURCE;  $R_S$  IS THE RANGE RESISTOR SELECTED WITH THE RANGE SWITCH.

Figure 3-2. Block Diagram of Model 602 as a Picoammeter.

### 3.4.2 Fast Method

In the fast method of current measurements (FEEDBACK switch in FAST position), the Model 602 functions as an ammeter with negative feedback. The differential amplifier output is divided by the multiplier switch resistors, R156 to R164, and fed back to the amplifier input through a feedback resistor selected with the range switch (See Figure 3-2). Floating ground is connected to the low impedance side of the input, and the output ground is floating. This method increases the response speed by minimizing the effects of input capacity; it also reduces the input drop to less than 1mV.

## 3.5 OHMMETER OPERATION

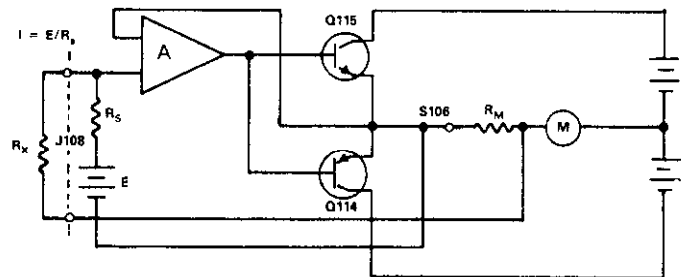
### 3.5.1 Normal Method

In the normal method of resistance measurements (FEEDBACK switch in NORMAL position) the Model 602 uses a constant-current, voltage drop circuit. Refer to Figure 3-3.  $R_X$  is the unknown resistor. A voltage source,  $E$ , applies a potential across  $R_X$ . The source is obtained from the batteries, B201 and B202, through the resistor divider network, R184, R142 and R143.  $E$  varies depending upon the OHMS range used. The voltage source is connected between floating ground and the input gate of Q101 through  $R_S$ , the range resistor.  $R_S$  is one of the resistors, R102 through R112.  $I$  is equal to  $E/R_S$ , regardless of the value of  $R_X$ , as long as the voltage drop across  $R_X$  does not exceed the multiplier switch

setting. This circuit provides a true source regardless of the input. The Model 602 can then measure the voltage drop across  $R_X$  and indicate the resistance value on its calibrated meter.

### 3.5.2 Guarded Method

In the guarded method of resistance measurements (FEEDBACK switch in FAST position and the sample resistance connected between the INPUT terminal, J108, and the GUARD terminal, J107) feedback is applied through the sample. Refer to Figure 3-2. The circuit is similar to the normal method, except for the feedback. This reduces slowing effect of the instrument's input capacity. Leakage error is also reduced since the potential across the input terminal is small. In this mode, floating ground is connected to the low impedance side of the input and the output ground is floating. The GUARD terminal is at output ground potential.



NOTE: CIRCUIT DESIGNATIONS REFER TO SCHEMATIC DIAGRAM. S106 IS THE MULTIPLIER SWITCH;  $R_M$  IS THE RESISTOR FOR A GIVEN SETTING.  $R_X$  IS THE UNKNOWN RESISTANCE BEING MEASURED;  $E$  IS THE VOLTAGE SOURCE;  $R_S$  IS THE RANGE RESISTOR SELECTED WITH THE RANGE SWITCH.

Figure 3-3. Block Diagram of Model 602 for Normal Method Measuring Resistance

## 3.6 COULOMBMETER OPERATION

The Model 602 circuit for measuring charge is similar to that used for an ammeter with the fast method. A negative feedback is applied around a shunt capacitor, C108 to C111, selected with the range switch. The shunt capacitor replaces  $R_S$  in Figure 3-2. The stored charge is proportional to the voltage across the capacitor, which is measured by the Model 602 voltmeter circuits.

## SECTION 4 SERVICING INFORMATION

### 4.1 INTRODUCTION

This section contains information necessary to maintain, calibrate and troubleshoot the Model 602 Electrometer.

#### WARNING

The procedures described in this section are for use only by qualified service personnel. Do not perform these procedures unless qualified to do so. Many of the steps covered in this section may expose the individual to potentially lethal voltages that could result in personal injury or death if normal safety precautions are not observed.

### 4.2 CALIBRATION

The calibration information provided is a method of checking the Model 602 to make sure it operates properly and within specification. See the specifications that precede Section 1.

#### 4.2.1 Recommended Equipment

Recommended calibration equipment is listed in Table 4-1. Alternate test equipment may be used as long as equipment accuracy is at least as good as the specifications listed in Table 4-1.

#### NOTE

Unless otherwise stated, all the following calibration procedures will be made with the FEEDBACK switch set to NORMAL and the 1V-1MA switch set to 1V.

#### 4.2.2 Calibration Schedule

1. Check offset current (paragraph 4.7) at regular intervals to make sure the input transistors are functioning correctly.
2. Verify the value of the high megohm resistors (paragraph 4.9) approximately every six months.
3. Calibrate the meter zero (paragraph 4.4) about once a year or when components are replaced.
4. Check the Model 602 accuracy (paragraph 4.10) once a year, after adjustment, or if improper operation is suspected.

### 4.3 PRELIMINARY PROCEDURES

**Battery Check**—Check the condition of the batteries as outlined in paragraph 2.5 and Table 2-2.

**Zero Balance**—Set the Model 602 to the 10V range and turn the instrument on. Set the ZERO CHECK button to lock.

1. If the unit is operative, the meter should be on scale + or -. Zero the meter with the COARSE, MEDIUM, and FINE controls. Increase the voltage sensitivity in steps to the 1mV range by advancing the multiplier switch. Zero the instrument on each range.
2. If the instrument is inoperative (meter pinned, etc.) check error in setup and obvious problems before troubleshooting.

**Isolation Check**—Set up the test circuit in Figure 4-1. Disconnect the shorting link from CASE to LO. Set the Model 480 to the 10nA range and zero check. Program the Model 230 to output 100V. Take the Model 480 out of zero check. The Reading on the Model 480 should be less than  $10^{-8}$ A (10nA). Using Ohms law calculate the isolation resistance. For example:  $R = E/I = 100V/10^{-8}A = 10^{10}\Omega$ .

**Table 4-1. Recommended Test Equipment**

Item	Description	Specification	Mfg.	Model
A	DMM	$1\mu V$ -1000V	Keithley	195
B	Voltage Source	100V	Keithley	230
C	Picoammeter	$10^{-9}$ A sensitivity	Keithley	480
D	RMS Voltmeter	—	H-P	3400A
E	Chart Recorder	—	H-P	7035B
F	Null Detector	100 $\mu$ V Null Resolution	Keithley	155
G	Current Source	$10^{-5}$ A to $10^{-1}$ A $\pm 0.2\%$	Keithley	220
H	$10^{-11}\Omega$ Resistor	$10^{11}\Omega \pm 2\%$	Keithley	R-289-10 <sup>11</sup>
I	Signal Generator	—	H-P	200CD
J	AC Voltmeter	—	H-P	400F
K	$10^{10}\Omega$ Resistor	$10^{10}\Omega \pm 2\%$	Keithley	R-289-10 <sup>10</sup>
L	$10^9\Omega$ Resistor	$10^9\Omega \pm 2\%$	Keithley	R-289-10 <sup>9</sup>
M	$10^8\Omega$ Resistor	$10^8\Omega \pm 2\%$	Keithley	R-289-10 <sup>8</sup>

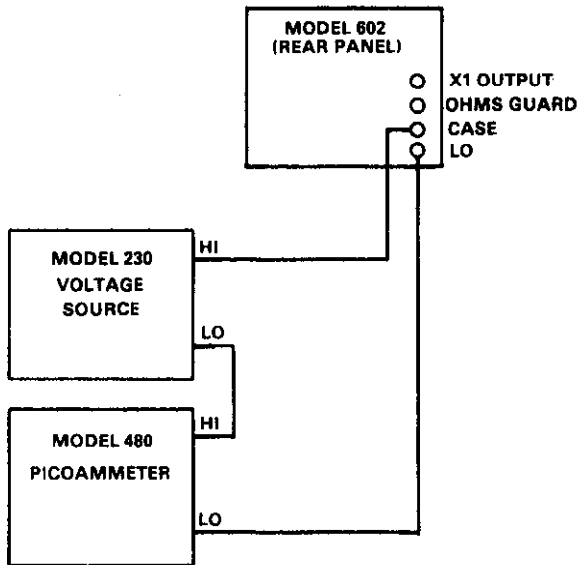


Figure 4-1. Model 602 Case To LO Isolation Check

#### 4.4 MECHANICAL METER SET AND METER ZERO CALIBRATION

Zero the Model 602 whenever adjustments are made. To set the mechanical zero meter, turn the METER switch to METER OFF and set the mechanical zero meter adjustment for zero meter reading (top-scale zero). Refer to Table 4-2 for Model 602 internal controls. To calibrate meter zero do the following:

1. Turn the Model 602 on. Zero the meter on the .001 multiplier switch setting. Set the multiplier switch to 1; apply  $1V \pm 0.05\%$  with the Model 230 to the Model 260 INPUT connector. Monitor the output with the Model 195. Adjust the FINE ZERO control for 1.000V at the output. Adjust the meter cal potentiometer, R177, for full scale meter reading.
2. Set the center zero by first zeroing the meter on the .001 multiplier switch setting. The switch to the 1 position. Set the METER switch to CENTER ZERO and adjust the CENTER ZERO CAL potentiometer, R179, for exact center-scale meter zero.

Table 4-2. Model 602 Internal Controls

Control	Circuit Desig.	Refer to Paragraph
Meter Calibration	R177	4-2
Center Zero Calibration	R179	4-2

#### 4.5 TRACKING CHECK AND 1MA OUTPUT CALIBRATION

**Tracking**—Set the METER switch to +, the multiplier switch to 1 and apply 1V with the Model 230 to the INPUT connector.

1. If the 1V range has good accuracy, the meter should indicate full scale. If not, use the .1 or 10 multiplier switch settings, whichever has the best full scale accuracy.
2. Check the meter 0-10 scale for no more than  $\frac{1}{2}\%$  ( $\frac{1}{2}$  division) tracking error going from zero to full scale in  $\frac{1}{10}$  of full scale voltage steps.

**1MA Output**—Load output of the Model 602 with a  $1400\Omega$  resistor.

1. Set the 1V-1MA switch to 1MA, the multiplier switch to 1 and apply 1V to INPUT connector with the Model 230.
2. Adjusting the 1MA CAL control (R187) should vary the output voltage from 1.33V to 1.47V, indicating a current variation from 0.95 to 1.05mA.
3. Depending on the exact value of the  $1400\Omega$  load, the voltage range may be slightly higher or lower than 1.33 to 1.47V (for example: 1.34 to 1.48V or 1.32 to 1.46V). This is at least 140mV and the maximum voltage is near 1.47V.
4. Remove the  $1400\Omega$  load and set the 1V-1MA switch to 1V when completed.

#### 4.6 NOISE CHECK

1. Zero check the unit and connect the output to a Model 3400A rms voltmeter.
  - A. Set the METER switch to CENTER ZERO and zero the Model 602 on the 1mV range.
  - B. The meter noise must be less than  $50\mu V$  peak-to-peak.
  - C. The output noise must be less than  $30\mu V$  rms.
2. Switch the Model 602 to the 300mV range. Output noise must be less than 5mV rms.
3. Typical rms output noise is approximately 20mV on the 1mV range and 1 to 2mV on the 300mV range.

#### 4.7 OFFSET CURRENT CHECK

Check offset current whenever excessive noise or drift is suspected. To read the offset current of the Model 602, set the front panel controls as follows:

ZERO CHECK Button	LOCK
Multiplier Switch	.003
Range Switch	$10^{-11}$ AMPERES
FEEDBACK Switch	FAST
METER Switch	+

Cap the INPUT connector and unlock the ZERO CHECK button. The offset current indicated on the meter should be less than  $5 \times 10^{-15}A$ . (This is less than 20% of full scale). If this is exceeded, check the battery condition and the input transistor Q101. If the instrument has not been used for a long time, allow it to run seven hours before checking the offset current.

#### 4.8 DRIFT CHECK

Set the front panel controls as follows:



ZERO Check Button	LOCK
Multiplier Switch	.01
Range Switch	VOLTS
FEEDBACK Switch	NORMAL
METER Switch	+

Set the OUTPUT switch on the back panel to 1V.

1. Connect Model 602 to the Model 7035B chart recorder. Adjust recorder sensitivity control for full scale deflection of +1V. Make sure Model 602 chassis cover is attached with at least two screws.
2. Make two drift runs with the Model 602 to determine time and temperature stability individually. For each run allow the Model 602 to warm up for half hour. A zero drift of less than 2mV after the first half hour is indicative of a satisfactory temperature coefficient. After the first half hour the time stability should be less than 1mV per 24 hours. The offset due to temperature should be less than  $150\mu\text{V}$  per  $^{\circ}\text{C}$ .
3. If the instrument does not meet the zero drift specification, check the batteries. If the batteries are satisfactory and the instrument still does not meet the zero drift specification, the input transistors are faulty.

#### NOTE

If new batteries have been installed, the Model 602 zero drift will be exceeded for at least 24 hours. Age the unit for 24 hours to enable the battery terminal voltages to stabilize.

### 4.9 HIGH-MEGOHM RESISTOR VERIFICATION

About every six months it is necessary to check the value of the high-megohm resistors, R110 to R112, on the range switch. The instrument should be within its rated accuracy for two or three years from the time it leaves the factory. After this, some of the resistors may drift out of tolerance and should be replaced. Faulty high-megohm resistors will affect the accuracy of measurements for the  $10^{-9}$  to  $10^{-11}$  AMPERES and the  $10^8$  to  $10^{12}\Omega$  settings of the range switch.

To check these resistors, it is necessary to use a bridge capable of better than 1% accuracy up to  $10^{11}\Omega$ . If such equipment is not available, either return the instrument to the factory for resistor calibration; or replace the high-megohm resistors periodically with a certified set from Keithley Instruments to assure absolute calibration accuracy.

### 4.10 ACCURACY CHECK

Checking the accuracy of the Model 602 is the quickest way to spot faulty operation. Perform a check of the unit about once a year, if components are replaced or if other adjustments are made. If accuracy is verified over all ranges, the Model 602 should be able to meet all specifications. If the accuracy must be checked often, check the stability.

#### 4.10.1 Voltage Accuracy Check

Connect the Model 602 input to the Model 230 and monitor

the output with the Model 195. First, set the Model 602 for the 10V range. Increase the input voltage in 1V steps from 0 to 10V. The Model 602 should indicate the input voltage to  $\pm 1\%$  of full scale. Make sure the OUTPUT switch is in the 1V position for the 1, 3 and 10V ranges (see note in paragraph 2.5 step 5).

#### 4.10.2 Current Accuracy Check

Connect the Model 602 to the Model 261 and monitor the output with the Model 195. Check the full scale accuracy of all the current positions on the range switch. For the  $10^{-5}$  to  $10^{-11}$ A ranges, set the FEEDBACK switch to FAST and the multiplier switch to 1. Check the output for  $1\text{V} \pm 2\%$ . For the ranges above  $10^{-5}$ A, use the Model 220. Set the Model 602 FEEDBACK switch to NORMAL and the multiplier switch to .01 when calibrating these ranges. Check the output for  $1\text{V} \pm 2\%$ .

#### NOTE

For  $10^{-1}$ A through  $10^{-5}$ A ranges, a larger multiplier switch setting will result in inaccuracies due to loading of the current source; hence the .01 multiplier switch setting must be used. The appropriate current source is two decades less than range setting; that is, on the  $10^{-1}$ A ranges use  $10^{-3}$ A source.

#### 4.10.3 Resistance Accuracy Check

Zero check the Model 602 and connect the input to a resistance source and the output to the Model 195. The cable between resistance source and the input must be as short as possible in order to obtain accurate readings. Set NORMAL/FAST switch to NORMAL.

1. Check the  $10^5\Omega$  range as follows:
  - A. Set Model 602 and resistance source to  $10^5\Omega$ .
  - B. Zero Model 602 with multiplier set at .001.
  - C. Switch multiplier to 1. A zero shift will be seen. Do not rezero.
  - D. Release ZERO CHECK and check for  $1\text{V} \pm 3\%$  at Model 602 output.
2. With multiplier at 1, do the following:
  - A. Check  $10^6$  through  $10^8\Omega$  ranges for  $1\text{V} \pm 3\%$  at Model 602 output. Use an appropriate resistance source for each range.
  - B. Check the  $10^9$  through  $10^{11}\Omega$  ranges for  $1\text{V} \pm 3\%$  at Model 602 output. Use appropriate resistance source (Items K, L and M Table 4-1) for each range.

#### NOTE

When working with high resistance ( $> 10^8\Omega$ ) always use a shielded enclosure for the resistors.

3. With multiplier set at .1, check  $10^{12}\Omega$  range for  $1\text{V} \pm 5\%$  at Model 602 output. Resistance source is  $10^{11}\Omega$ .
4. If difficulty is experienced in obtaining accurate readings

on the  $10^{11}$  and  $10^{12}$  ranges, use the FAST position and connect the shielded enclosure that contains the resistors to the Model 602 GUARD. The cable between the resistors and the input must be short as possible; a solid triax to BNC adapter is recommended (Keithley Model 6147).

- If all or most ranges are at or out of tolerance on the high side, the probable cause is that B203 battery voltage is too high. The battery terminal voltage should be  $1.34V \pm 0.02V$ . Age battery for 15 minutes if needed.

**Table 4-3. Coulomb Ranges Accuracy Check**

Multiplier Switch Setting	Coulombs Range	Rise Time, Zero to Full Scale (seconds)
.01	$10^{-7}$	10
.1	$10^{-8}$	10
1	$10^{-9}$	10
10	$10^{-10}$	10

#### 4.10.4 Charge Accuracy Check

To check the Model 602 as a charge amplifier, set the FEEDBACK switch to FAST. Apply 10V from the Model 230 voltage supply through a  $10^{11}\Omega$  resistor (R-20- $10^{11}$ ) to the Model 602 input. Set the multiplier switch to the settings given in Table 4-3. Use a stop watch or an oscilloscope to time the rise to full scale deflection. Check each range to  $\pm 5\%$ .

#### 4.11 UNITY-GAIN CHECK

- Zero check the Model 602 and set the instrument to the 10V range. Set up the circuit shown in Figure 4-2.
- Set the Model 155 to the  $300\mu V$  range. Zero the Model 155 with the Model 602 fine zero control.

##### NOTE

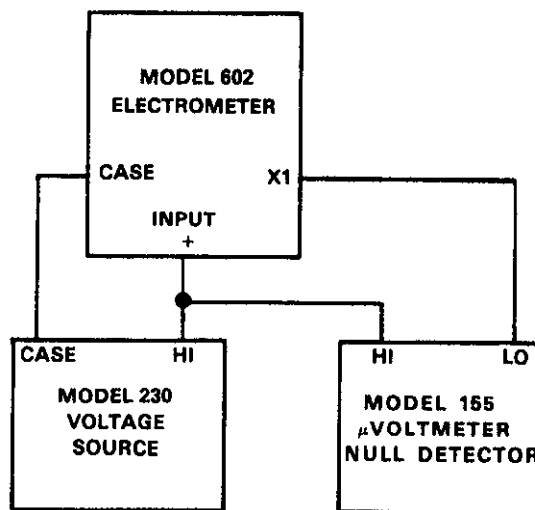
A transient of up to 10mV may be generated when the Model 230 is programmed from stand-by to output. To prevent false indication, program the Model 230 to output and program the voltage as indicated.

- With the Model 230 output at zero (output LED is on). Release the zero check on the Model 602. Notice the Model 155 reading remains the same.
- Program the Model 230 to output +10V. The Model 155 reading should not vary by more than  $100\mu V$ .
- Program the Model 230 to output zero volts. The Model 155 should return to the original reading in step 3 ( $\pm 50\mu V$  zero offset).
- Repeat steps 2 through 5 using -10V.

#### 4.12 FREQUENCY RESPONSE CHECK

- Zero check the unit. Connect a HP Model 200CD signal generator through a 1000:1 divider to the Model 602 input

and connect the Model 602 output to a Model 400F AC VTVM. Set the Model 602 FEEDBACK switch to NORMAL.



**Figure 4-2. Model 602 Unity-Gain Test Set-Up**

##### NOTE

If other than a constant amplitude signal generator is used, it will be necessary to monitor the output of the signal generator with another VTVM in order to maintain the same signal level at various frequencies specified.

- Zero the Model 602 on the 1mV range.
  - Set the signal generator to 20Hz at minimum output. Release the Model 602 ZERO CHECK button and increase the generator output to obtain 2V rms at the Model 602 output.
  - Set the generator to 100Hz. The Model 602 output voltage must be within  $\pm 3dB$  of the 20Hz 2V rms output.
- Zero the Model 602 on the 1V range and change the divider to 100:1.
  - Set the generator to 100Hz for minimum output. Release the Model 602 ZERO CHECK button and increase the generator output to obtain 0.1V rms at the Model 602 output.
  - Set the generator to 40kHz. The Model 602 output must be within  $\pm 3dB$  of the 100Hz 0.1V rms output.
- Zero the Model 602 on the 1V range and change the divider to 10:1.
  - Set the generator to 100Hz and for minimum output. Release the ZERO CHECK button and increase the generator output to obtain 2V rms at the Model 602 output.
  - Set the generator to 3kHz. The Model 602 output must be within  $\pm 3dB$  of the 100Hz 2V rms output.

#### 4.13 COMMON MODE REJECTION CHECK

Cap the INPUT connector and set the Model 602 front panel

controls as follows:

ZERO CHECK Button LOCK  
 Multiplier Switch 1  
 Range Switch 10<sup>-10</sup> AMPERES  
 FEEDBACK Switch NORMAL  
 METER Switch OFF

1. Connect the Model 200CD generator between the Model 602 LO and CASE GND terminals and connect an oscilloscope to the Model 602 OUTPUT connector.
2. Apply a 35V peak-to-peak, 60Hz signal to the Model 602 input. The output should be less than 35mV peak-to-peak.

#### 4.14 TROUBLESHOOTING

The procedures which follow give instructions for repairing troubles which might occur in the Model 602. Use the procedures outlined and use only specified replacement parts. Table 4-1 lists equipment recommended for troubleshooting. If the trouble cannot be readily located or repaired, contact a Keithley representative.

Table 4-4 lists 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 4.15. Refer to Section 3 to find the more critical components and to determine their function in the circuit.

##### 4.14.1 Servicing Schedule

Periodically check the condition of the batteries (See paragraph 2.5 and Table 2-2). Except for battery replacement, the Model 602 requires no periodic maintenance beyond the normal care required of high quality electronic equipment. The value of the high-megohm resistors, R110, R111 and R112 should be checked every six months for specified accuracy.

#### 4.14.2 Parts Replacement

The replaceable parts list in Section 5 describes the electrical components of the Model 602. Replace components only as necessary. Use only reliable replacements which meet the specifications. The MOSFET input transistors, Q101 and Q102, are specially selected and matched; order only as a plug-in unit (P/N 23733A) from Keithley Instruments.

#### 4.15 PROCEDURES TO GUIDE TROUBLESHOOTING

If the instrument will not operate, check the condition of the batteries and OUTPUT switch. This switch should be in the 1V position with no load. If these are found satisfactory, use the following procedures to isolate the trouble.

The schematic diagram indicates all transistor terminal voltages referenced to either floating ground or output ground; a properly operating Model 602 will have these values  $\pm 10\%$ , if operating from fresh batteries. The control settings for these values are: range switch at VOLTS, multiplier switch at 1, and the meter zeroed. Measurements are with the Model 195.

1. To check the amplifier, disconnect the feedback loop by removing batteries B204, B205, B206 and B207. This allows each stage of the amplifier to be individually checked. It also eliminates the possibility of applying excessive voltage to the input transistors, causing serious damage.
2. Connect the Model 195 between the drains of Q101 and Q102. Adjust the COARSE and MEDIUM ZERO controls for null. If null cannot be reached, check the COARSE and MEDIUM ZERO control circuits (resistors R114 to R135), and transistors Q103 and Q104. Check Q103 and Q104 by removing them and adjusting for null again. If null is now reached, replace the transistor pair with a new pair.
3. Check the next stage by connecting the Model 195 across the emitters of Q103 and Q104 and adjusting the COARSE

Table 4-4. Model 602 Troubleshooting

Difficulty	Probable Cause	Solution
Excessive zero offset.	Input transistors may be defective.	Check Q101 and Q102; replace if faulty.
	Batteries failing.	Replace batteries (paragraph 2-5).
Excessive offset current.	Excessive temperature fluctuation or defective input transistors.	Check Q101 and Q102; replace if faulty.
	Instrument not used.	Run for seven hours.
Cannot zero meter on any range.	See paragraph 4.15.	See paragraph 4.15, step 6.
Unable to zero meter on most sensitive range.	Incorrect gate voltages on input transistors.	Check per paragraph 4.15.
Meter will not zero on one multiplier switch setting.	Faulty resistor for setting of multiplier switch.	Check resistors; replace if faulty.
10 <sup>-10</sup> to 10 <sup>-14</sup> A current ranges are out of specification.	Defective high megohm resistors.	Check per paragraph 4.9.

and MEDIUM ZERO controls for null. If null is not reached, check this stage and the base circuit of the next stage. Check the base circuit by removing transistors Q105 and Q106 and again adjusting for null. If null is now reached, replace the transistor pair with a new pair.

4. Check the next stage by connecting Model 195 across the collectors of Q105 and Q106 and adjusting the COARSE and MEDIUM ZERO controls for null. If null is not reached, check this stage and check for shorts in the base circuit of Q107 and Q108.
5. Connect Model 195 to the collector of Q109. Adjust the FINE ZERO control for null. If null is reached, the DC amplifier is operating correctly. If null is not reached, check transistors Q107 through Q110 and diode D101.
6. The feedback loop includes the multiplier resistors, R156 through R164, the recorder output resistors, R167 on 1V position or R187 and R188 on 1 MA position and the meter. An opening of any of these components prevents zeroing for only that particular multiplier setting.
7. Replace batteries B204 through B207 and troubleshoot the output stages, transistors Q114 and Q115, by making

measurements with Model 195 to within  $\pm 10\%$  of the specified schematic value.

#### **4.16 SERVICING HIGH IMPEDANCE CIRCUITRY**

High impedance circuitry is sensitive and must be kept clean of oil, dirt, dust and contaminants. Replacing a component or components within a high impedance circuit requires special cleaning and handling to maintain the high impedance level of the circuit. After replacing any component in the high impedance circuitry or if the high impedance circuitry ( $10^{-8}$  to  $10^{-11}$ A range resistors) is contaminated, use the following procedure to clean the circuit:

1. Clean the entire high impedance circuit with methanol and a clean cotton swab.
2. Blow dry the circuit with dry nitrogen gas. Ordinary compressed air may contain contaminants such as oil or water.
3. Inspect the circuit for any residue (contamination) and repeat steps 1 and 2 if any residue is found.
4. Reassemble the circuit or instrument taking care not to touch the clean components.

# SECTION 5 REPLACEABLE PARTS

## 5.1 INTRODUCTION

This section contains an illustration of the chassis, Figure 5-1, replacement parts information, component location drawings and a schematic diagram of the Model 602.

## 5.2 PARTS LIST

Parts are listed alphabetically in order of their circuit designations. Table 5-2 contains the replaceable parts of the Model 602.

## 5.3 ORDERING INFORMATION

To place an order or to obtain information concerning replacement parts, contact a Keithley representative or the factory. See the inside front cover for addresses. When ordering include the following information:

- Instrument Model Number
- Instrument Serial Number
- Part Description
- Circuit Description (if applicable)
- Keithley Part Number

## 5.4 FACTORY SERVICE

If the instrument is to be returned to the factory for service, photocopy and complete the service form which follows this section and return it with the instrument.

## 5.5 SPECIAL HANDLING OF STATIC SENSITIVE DEVICES

MOS devices are designed to function at high impedance levels. Normal static charge can destroy these devices. Table

5-1 lists all the static sensitive devices of the Model 602. Steps 1 through 7 provide instruction on how to avoid damaging these devices.

**Table 5-1. Model 602 Static Sensitive Devices**

Reference Designation	Keithley Part No.
Q101, Q102	23733A

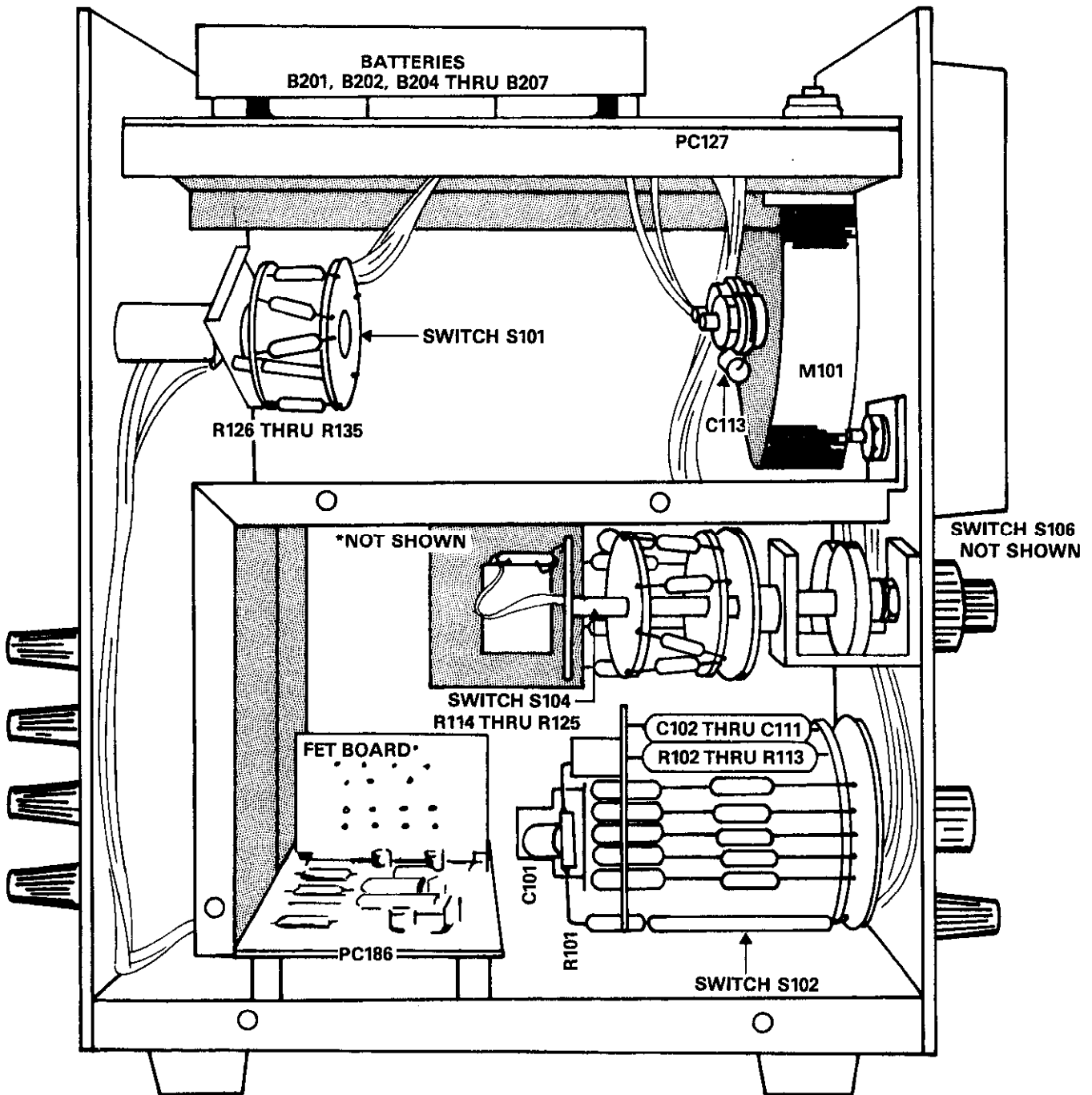
1. Devices should be handled and transported in protective containers, antistatic tubes or conductive foam.
2. Use a properly grounded work bench and a grounding wrist strap.
3. Handle device by the body only.
4. PC boards must be grounded to the bench while inserting the devices.
5. Use antistatic solder removers.
6. Use grounded tip soldering irons.
7. After devices are soldered or inserted into the socket they are protected and normal handling can resume.

## 5.6 COMPONENT LOCATION DRAWINGS

Figure 5-2 contains a drawing of the components for the RANGE switch, S102, while Figure 5-3 shows the component layout of the MULTIPLIER switch, S106. Figure 5-4 contains a component layout of PC186, while Figure 5-5 shows component locations for PC127.

## 5.7 SCHEMATIC DIAGRAM

A schematic diagram of the Model 602 is presented in Figure 5-6.



\*CONTAINED IN SHIELDED COMPARTMENT NOT SHOWN.  
 R136, R138, R139, R154 THRU R164 R169, R170 C112, C117

Figure 5-1. Model 602 Chassis Side View

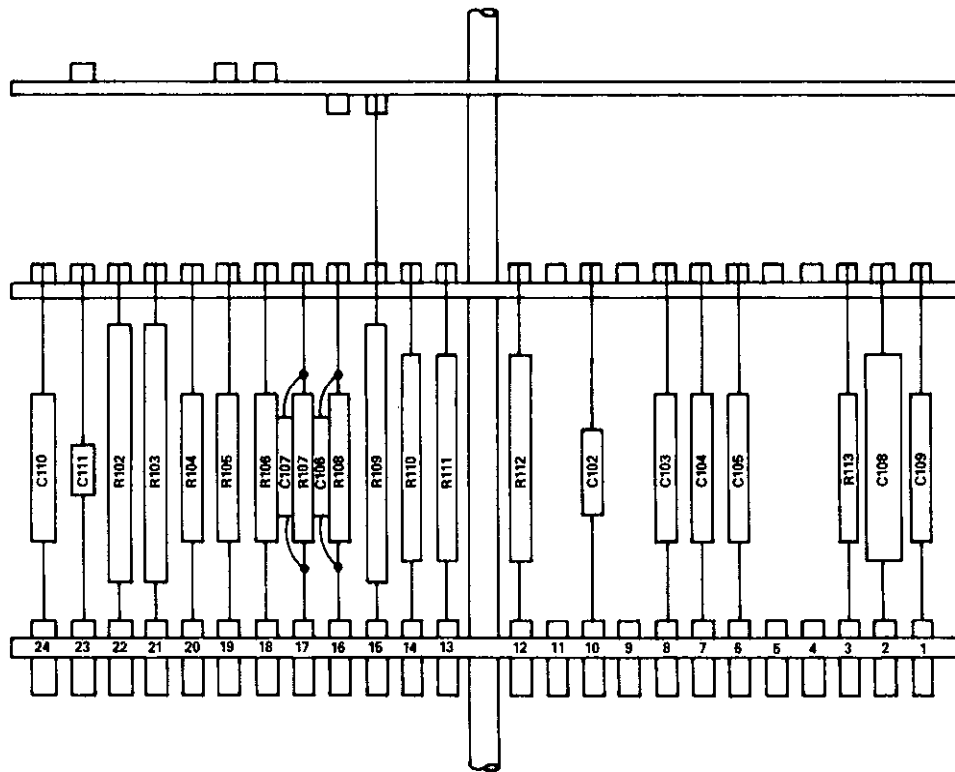


Figure 5-2. RANGE Switch, S102, Component Location Drawing

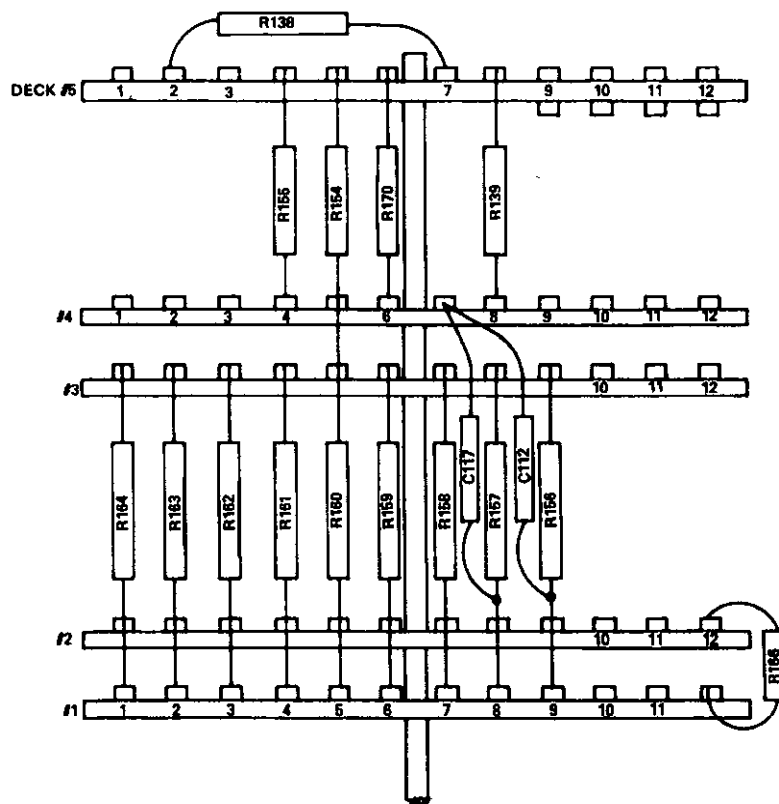


Figure 5-3. MULTIPLIER Switch, S106, Component Location Drawing

**Table 5-2. Model 6502 Replaceable Parts List**

<b>Circuit Desig.</b>	<b>Description</b>	<b>Keithley Part No.</b>
B201	Battery, 9V, Zinc Carbon	BA-17
B202	Battery, 9V, Zinc Carbon	BA-17
B203	Battery, 1.35V	BA-24
B204	Battery, 9V, Zinc Carbon	BA-17
B205	Battery, 9V, Zinc Carbon	BA-17
B206	Battery, 9V, Zinc Carbon	BA-17
B207	Battery, 9V, Zinc Carbon	BA-17
C101	Capacitor, 150pF, 600V, Ceramic Disc	C-22-150p
C102	Capacitor, 5pF, 200V, Polystyrene	C-31-5p
C103	Capacitor, 10pF, 500V, Polystyrene	C-138-10p
C104	Capacitor, 22pF, 500V, Polystyrene	C-138-22p
C105	Capacitor, 47pF, 500V, Polystyrene	C-138-47p
C106	Capacitor, 100pF, 200V, Polystyrene	C-108-100p
C107	Capacitor, 1000pF, 200V, Polystyrene	C-108-1000p
C108	Capacitor, .1 $\mu$ F, 200V, Polystyrene	C-251-.1
C109	Capacitor, .01 $\mu$ F, 200V, Polystyrene	C-108-.01
C110	Capacitor, .001 $\mu$ F, 200V, Polystyrene	C-108-.001
C111	Capacitor, 100pF, 200V, Polystyrene	C-108-100p
C112	Capacitor, .0047 $\mu$ F, 600V, Ceramic Disc	C-22-.0047
C113	Capacitor, 100 $\mu$ F, 15V, Electrolytic	C-3-100
C114	Capacitor, .033 $\mu$ F, 200V, Mylar	C-143-.033
C115	Capacitor, .033 $\mu$ F, 200V, Mylar	C-143-.033
C116	Capacitor, 150pF, 600V, Ceramic Disc	C-22-150p
C117	Capacitor, .001 $\mu$ F, 1000V, Ceramic Disc	C-64-.001
D101	Diode, Silicon, 1N645	RF-14
D102	Selected Low Leakage Transistor	24746A
D103	Diode, Silicon, 1N914	RF-28
D104	Diode, Silicon, 1N914	RF-28
J102	Binding Post, LO (Black)	BP-11B
J103	Receptacle, Microphone, Output	CS-32
J104	Binding Post, Case Ground (Green)	BP-11GRN
J105	Binding Post, X1 Output (Red)	BP-11R
J106	Binding Post, LO (Black)	BP-11B
J107	Binding Post, Guard (Blue)	BP-11BLU
J108	Receptacle, Triaxial, INPUT	CS-141 181
	Plug, Triaxial, Mate of J108	CS-141
	Cap, Input Receptacle	CAP-18
M101	Meter	ME-81
Q101*		
Q102*		
Q103	Transistor, NPN, Silicon, 2N3903	TG-49
Q104	Transistor, NPN, Silicon, 2N3903	TG-49
Q105	Transistor, NPN, Silicon, 2N3903	TG-49
Q106	Transistor, NPN, Silicon, 2N3903	TG-49
Q107	Transistor, NPN, Silicon, 2N3903	TG-49
Q108	Transistor, NPN, Silicon, 2N3903	TG-49
Q109	Transistor, PNP, Silicon, 2N3905	TG-53
Q110	Transistor, NPN, Silicon, 2N3903	TG-49
Q111	Transistor, PNP, Silicon, 2N3638A	TG-33
Q112	Transistor, PNP, Silicon, 2N3638A	TG-33
Q113	Transistor, PNP, Silicon, 2N3638A	TG-33
Q114	Transistor, PNP, Silicon, 2N3905	TG-53
Q115	Transistor, NPN, Silicon, 2N3903	TG-49

\*Q101 and Q102 are matched and mounted on a specially built plug-in card with built-in overload protection.



Table 5-2. Model 602 Replaceable Parts List (Cont.)

Circuit Desig.	Description	Keithley Part No.
R101	Resistor, 1M, 10%, ½W, Composition	R-1-1M
R102	Resistor, 10Ω, 1%, 10W, Wire Wound	R-34-10
R103	Resistor, 100Ω, 1%, 10W, Wire Wound	R-34-100
R104	Resistor, 1k, 1%, ½W, Carbon	R-12-1k
R105	Resistor, 10k, 1%, ½W, Carbon	R-12-10k
R106	Resistor, 100k, 1%, ½W, Carbon	R-12-100k
R107	Resistor, 1M, 1%, ½W, Carbon	R-12-1M
R108	Resistor, 10M, 1%, ½W, Carbon	R-12-10M
R109	Resistor, 100M, 5ppm/V, Glass Epoxy	R-289-100M
R110	Resistor, 1G, 5ppm/V, Glass Epoxy	R-289-1G
R111	Resistor, 10G, 5ppm/V, Glass Epoxy	R-289-10G
R112	Resistor, 100G, 5ppm/V, Glass Epoxy	R-289-100G
R113	Resistor, 135k, .5%, 1/8W, Metal Film	R-234-135k
R114	Resistor, 68.1k, 1%, ½W, Carbon	R-12-68.1k
R115	Resistor, 806Ω, 1%, ½W, Carbon	R-12-806
R116	Resistor, 806Ω, 1%, ½W, Carbon	R-12-806
R117	Resistor, 806Ω, 1%, ½W, Carbon	R-12-806
R118	Resistor, 806Ω, 1%, ½W, Carbon	R-12-806
R119	Resistor, 806Ω, 1%, ½W, Carbon	R-12-806
R120	Resistor, 806Ω, 1%, ½W, Carbon	R-12-806
R121	Resistor, 806Ω, 1%, ½W, Carbon	R-12-806
R122	Resistor, 806Ω, 1%, ½W, Carbon	R-12-806
R123	Resistor, 806Ω, 1%, ½W, Carbon	R-12-806
R124	Resistor, 806Ω, 1%, ½W, Carbon	R-12-806
R125	Resistor, 68.1k, 1%, ½W, Carbon	R-12-68.1k
R126	Resistor, 249Ω, 1%, ½W, Carbon	R-12-249
R127	Resistor, 249Ω, 1%, ½W, Carbon	R-12-249
R128	Resistor, 249Ω, 1%, ½W, Carbon	R-12-249
R129	Resistor, 249Ω, 1%, ½W, Carbon	R-12-249
R130	Resistor, 249Ω, 1%, ½W, Carbon	R-12-249
R131	Resistor, 249Ω, 1%, ½W, Carbon	R-12-249
R132	Resistor, 249Ω, 1%, ½W, Carbon	R-12-249
R133	Resistor, 249Ω, 1%, ½W, Carbon	R-12-249
R134	Resistor, 249Ω, 1%, ½W, Carbon	R-12-249
R135	Resistor, 249Ω, 1%, ½W, Carbon	R-12-249
R136	Resistor, 40.2k, 1%, ½W, Carbon	R-12-40.2k
R137	Resistor, 39k, 10%, ½W, Composition	R-1-39k
R138	Resistor, 20k, 1%, ½W, Carbon	R-12-20k
R139	Resistor, 20k, 1%, ½W, Carbon	R-12-20k
R140	Resistor, 34.8k, 1%, ½W, Metal Film	R-94-34.8k
R141	Resistor, 200k, 1%, ½W, Metal Film	R-94-200k
R142	Resistor, 9k, .5%, ½W, Metal Film	R-61-9k
R143	Resistor, 3.48k, 1%, 1/8W, Metal Film	R-88-3.48k
R144	Resistor, 200k, 1%, ½W, Metal Film	R-94-200k
R145	Resistor, 2.2k, 10%, ½W, Composition	R-1-2.2k
R146	Resistor, 36.5k, 1%, ½W, Metal Film	R-94-36.5k
R147	Resistor, 36.5k, 1%, ½W, Metal Film	R-94-36.5k
R148	Resistor, 2.2k, 10%, ½W, Composition	R-1-2.2k
R149	Resistor, 21.5k, 1%, ½W, Metal Film	R-94-21.5k
R150	Resistor, 7.15k, 1%, ½W, Metal Film	R-94-7.15k
R151	Resistor, 270k, 10%, ½W, Composition	R-1-270k
R152	Resistor, 2.7k, 10%, ½W, Composition	R-1-2.7k
R153	Resistor, 100k, 10%, ½W, Composition	R-1-100k
R154	Resistor, 10k, 1%, ½W, Carbon	R-12-10k
R155	Resistor, 1.5k, 1%, ½W, Carbon	R-12-1.5k

Table 5-2. Model 602 Replaceable Parts List (Cont.)

Circuit. Desig.	Description	Keithley Part No.
R156	Resistor, 9.1k, .5%, ½W, Metal Film	R-61-9.1k
R157	Resistor, 2.73k, .5%, ½W, Metal Film	R-61-2.73k
R158	Resistor, 910Ω, .5%, ½W, Metal Film	R-61-910
R159	Resistor, 273Ω, .5%, ½W, Metal Film	R-61-273
R160	Resistor, 91Ω, .5%, ½W, Metal Film	R-61-91
R161	Resistor, 27.3Ω, .5%, ½W, Metal Film	R-61-27.3
R162	Resistor, 9.1Ω, .5%, ½W, Wire Wound	R-123-9.1
R163	Resistor, 2.73Ω, .5%, ¼W, Wire Wound	R-123-2.73
R164	Resistor, 0.91Ω, .5%, ¼W, Wire Wound	R-123-.91
R165	Not Used	
R166	Resistor, 10Ω, 5%, ¼W, Composition	R-76-10
R167	Resistor, 910Ω, .5%, ½W, Metal Film	R-61-910
R168	Resistor, 10k, 10%, ½W, Composition	R-1-10k
R169	Pot, 10k	RP-42-10k
R170	Resistor, 10k	R-12-10k
R171	Resistor, 6.8k, 10%, ½W, Composition	R-1-6.8k
R172	Resistor, 6.8k, 10%, ½W, Composition	R-1-6.8k
R173	Resistor, 180k, 10%, ½W, Composition	R-1-180k
R174	Resistor, 180k, 10%, ½W, Composition	R-1-180k
R175	Resistor, 82k, 10%, ½W, Composition	R-1-82k
R176	Resistor, 120k, 10%, ½W, Composition	R-1-120k
R177	Pot, 2k	RP-34-2k
R178	Resistor, 120Ω, 10%, ½W, Composition	R-1-120
R179	Resistor, 8.06k, 1%, ½W, Metal Film	R-94-8.06k
R180	Pot, 15k	RP-3-15k
R181	Resistor, 120Ω, 10%, ½W, Composition	R-1-120
R182	Resistor, 10k, 10%, ½W, Composition	R-1-10k
R183	Resistor, 120k, 10%, ½W, Composition	R-1-120
R184	Resistor, 1k, .5%, ½W, Metal Film	R-61-1k
R185	Resistor, 28.7k, 1%, ½W, Metal Film	R-94-28.7k
R186	Resistor, 11.8k, 1%, ½W, Metal Film	R-94-11.8k
R187	Pot, 20k	RP-34-20k
R188	Resistor, 8.66k, 1%, ½W, Carbon	R-12-8.66k
R189	Resistor, 500Ω, 1%, ½W, Carbon	R-12-500
R190	Resistor, 6.8k, 10%, ½W, Composition	R-1-6.8k
R191	Resistor, 6.8k, 10%, ½W, Composition	R-1-6.8k
R192	Resistor, 6.8k, 10%, ½W, Composition	R-1-6.8k
S101	Rotary Switch less components, Coarse Zero	SW-166
	Rotary Switch with components	20924B
S102	Rotary Switch less components, Range	SW-204
	Rotary Switch with components	20922B
	Dial assembly, Range Switch	18039A
S103	Push button switch, Zero Check	14376A
S104	Rotary Switch less components, Medium Zero	SW-209
	Rotary Switch with components	20926B
	Knob assembly	18039A
S105	Slide Switch, Feedback	19089
S106	Rotary Switch less components, Multiplier	SW-205
	Rotary Switch with components	20929B
	Dial assembly, Multiplier Switch	19223A
S107	Rotary Switch less components, Meter	SW-320
	Rotary Switch with components	24278B
S108	Slide Switch, Output	SW-45
21850B	MOS FET Input Plug-in card	23733A
	Battery Snap, 6 required	BH-6
	Battery Holder	20944A

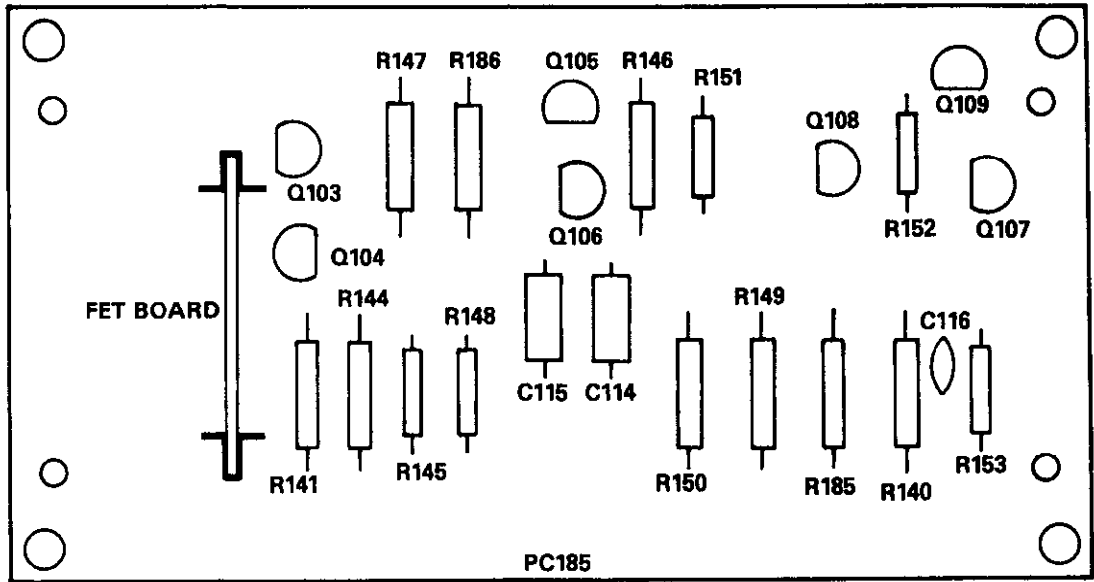


Figure 5-4. Model 602, PC186, Component Location Drawing

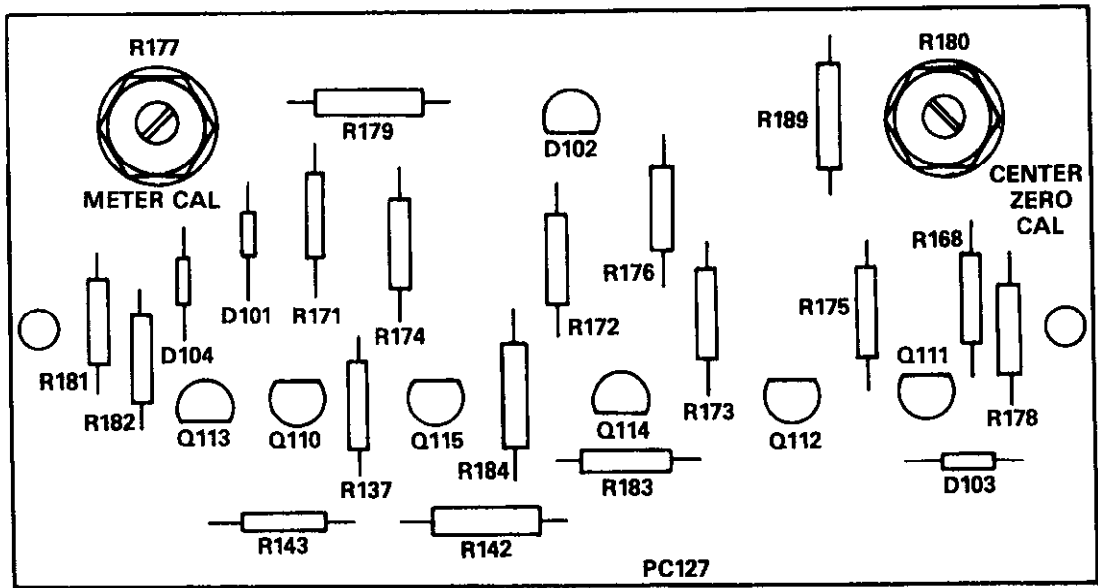
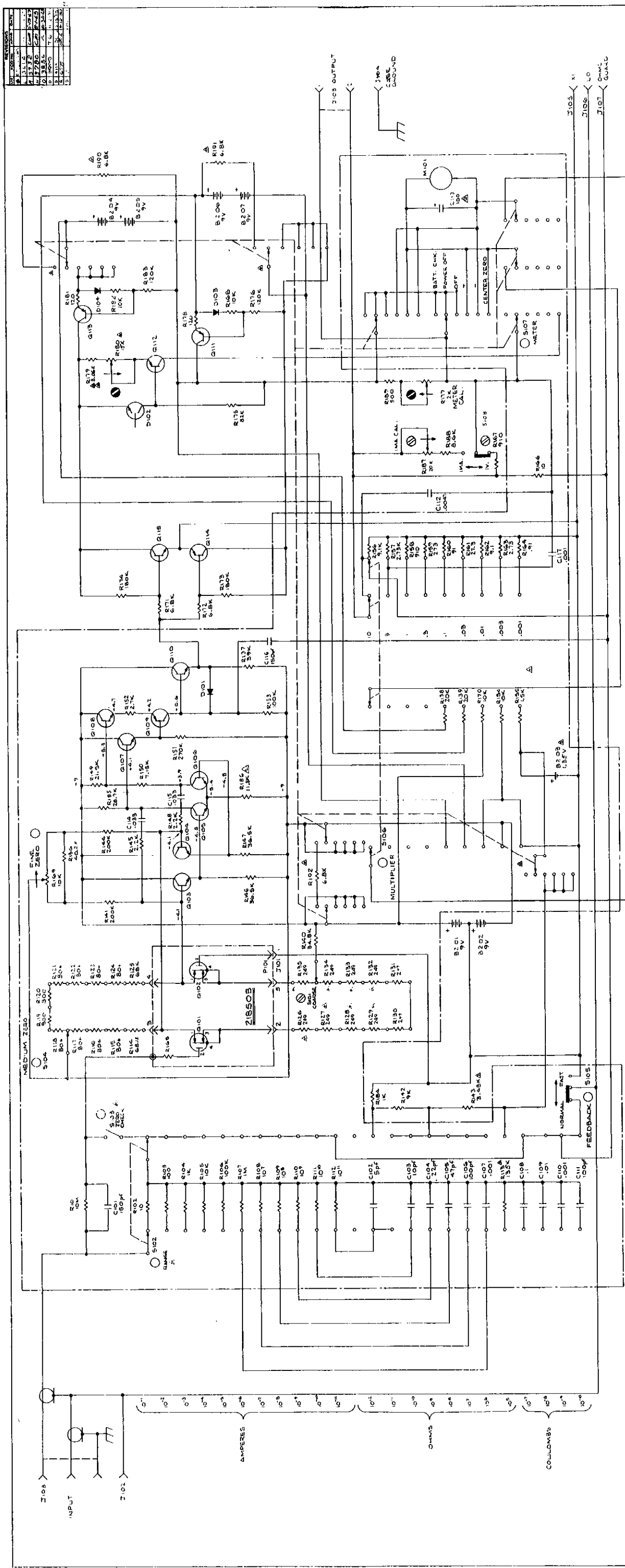


Figure 5-5. Model 602, PC127, Component Location Drawing





REVISED	DATE	BY	REASON	
1	11/15/54	W. S. KEITHLEY	DESIGN	
2	1/17/55	W. S. KEITHLEY	REVISED	
3	1/17/55	W. S. KEITHLEY	REVISED	
4	1/17/55	W. S. KEITHLEY	REVISED	
5	1/17/55	W. S. KEITHLEY	REVISED	
6	1/17/55	W. S. KEITHLEY	REVISED	
7	1/17/55	W. S. KEITHLEY	REVISED	
8	1/17/55	W. S. KEITHLEY	REVISED	
9	1/17/55	W. S. KEITHLEY	REVISED	
10	1/17/55	W. S. KEITHLEY	REVISED	

SCHEMATIC DISPOSITIONS USED	SCHEMATIC DISPOSITIONS	SCHEMATIC DISPOSITIONS	SCHEMATIC DISPOSITIONS	SCHEMATIC DISPOSITIONS

1. ALL RESISTANCE & CAPACITANCE SHALL BE DESIGNATED IN OHMS & MICROAMPERES UNLESS OTHERWISE NOTED.  
 2. FRONT PANEL CONTROL.  
 3. INTERNAL SCREWDRIVER ADJ.  
 4. REAR PANEL CONTROL.  
 5. REAR PANEL SCREWDRIVER ADJ.  
 6. K 1000 OHM  
 7. pf PICOFARAD  
 8. ↑ CLOCKWISE ROTATION.  
 9. K HESONH  
 10. ALL VOLTAGES MEASURED REFERRED TO CHASSIS GROUND, WITH S105 IN NORMAL.

Figure 5-6. Model 602, Schematic Diagram, Dwg. No. 21174

# KEITHLEY INSTRUMENTS

## SERVICE FORM

Model No. \_\_\_\_\_ Serial No. \_\_\_\_\_ Date \_\_\_\_\_

Name and Telephone No. \_\_\_\_\_

Company \_\_\_\_\_

List all control settings, describe problem and check boxes that apply to problem. \_\_\_\_\_

- |  |  |  |
|--|--|--|
| <input type="checkbox"/> Intermittent            | <input type="checkbox"/> Analog output follows display   | <input type="checkbox"/> Particular range or function bad; specify _____ |
| <input type="checkbox"/> IEEE failure            | <input type="checkbox"/> Obvious problem on power-up     | <input type="checkbox"/> Batteries and fuses are OK                      |
| <input type="checkbox"/> Front panel operational | <input type="checkbox"/> All ranges or functions are bad | <input type="checkbox"/> Checked all cables                              |

Display or output (circle one)

- |                                   |  |
|-----------------------------------|--|
| <input type="checkbox"/> Drifts   | <input type="checkbox"/> Unable to zero              |
| <input type="checkbox"/> Unstable | <input type="checkbox"/> Will not read applied input |
| <input type="checkbox"/> Overload |  |

- |   |  |
|---|--|
| <input type="checkbox"/> Calibration only | <input type="checkbox"/> C of C required |
| <input type="checkbox"/> Data required    |  |

(attach any additional sheets as necessary.)

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

Where is the measurement being performed? (factory, controlled laboratory, out-of-doors, etc.)

What power line voltage is used? \_\_\_\_\_ Ambient Temperature? \_\_\_\_\_ °F

Relative humidity? \_\_\_\_\_ Other? \_\_\_\_\_

Any additional information. (If special modifications have been made by the user, please describe.) \_\_\_\_\_

Be sure to include your name and phone number on this service form.

## Model 602 Solid-State Electrometer Addendum

### INTRODUCTION

This addendum to the Model 602 Solid-State Electrometer Instruction Manual is being provided in order to supply you with the latest information in the least possible time. Please incorporate this information into the manual immediately.

**Page 2-2;** Figure 2-1. Model 602 Front Panel Controls.

The circuit designations for the RANGE switch and ZERO CHECK switch on the front panel of the Model 602 are incorrectly stated. The correct designation for the RANGE switch is S102 and S103 for the ZERO CHECK switch.

**Page 5-6;** Replace Table 5-2 with the following:

**Table 5-2. Model 602 Replaceable Parts List (Cont.)**

<b>Circuit Desig.</b>	<b>Description</b>	<b>Keithley Part No.</b>
R156	Resistor, 9.1k, .5%, 1/2W, Metal Film	R-61-9.1k
R157	Resistor, 2.73k, .5%, 1/2W, Metal Film	R-61-2.73k
R158	Resistor, 910Ω, .5%, 1/2W, Metal Film	R-61-910
R159	Resistor, 273Ω, .5%, 1/2W, Metal Film	R-61-273
R160	Resistor, 91Ω, .5%, 1/2W, Metal Film	R-61-91
R161	Resistor, 27.3Ω, .5%, 1/2W, Metal Film	R-61-27.3
R162	Resistor, 9.1Ω, .5%, 1/2W, Wire Wound	R-123-9.1
R163	Resistor, 2.73Ω, .5%, 1/4W, Wire Wound	R-123-2.73
R164	Resistor, 0.91Ω, .5%, 1/4W, Wire Wound	R-123-.91
R165	Not Used	
R166	Resistor, 10Ω, 5%, 1/4W, Composition	R-76-10
R167	Resistor, 910Ω, .5%, 1/2W, Metal Film	R-61-910
R168	Resistor, 10k, 10%, 1/2W, Composition	R-1-10k
R169	Pot, 10k	RP-42-10k
R170	Resistor, 10k	R-12-10k
R171	Resistor, 6.8k, 10%, 1/2W, Composition	R-1-6.8k
R172	Resistor, 6.8k, 10%, 1/2W, Composition	R-1-6.8k
R173	Resistor, 180k, 10%, 1/2W, Composition	R-1-180k
R174	Resistor, 180k, 10%, 1/2W, Composition	R-1-180k
R175	Resistor, 82k, 10%, 1/2W, Composition	R-1-82k
R176	Resistor, 120k, 10%, 1/2W, Composition	R-1-120k
R177	Pot, 2k	RP-34-2k
R178	Resistor, 120Ω, 10%, 1/2W, Composition	R-1-120
R179	Resistor, 8.06k, 1%, 1/2W, Metal Film	R-94-8.06k
R180	Pot, 15k	RP-3-15k
R181	Resistor, 120Ω, 10%, 1/2W, Composition	R-1-120
R182	Resistor, 10k, 10%, 1/2W, Composition	R-1-10k
R183	Resistor, 120k, 10%, 1/2W, Composition	R-1-120
R184	Resistor, 1k, .5%, 1/2W, Metal Film	R-61-1k
R185	Resistor, 28.7k, 1%, 1/2W, Metal Film	R-94-28.7k
R186	Resistor, 11.8k, 1%, 1/2W, Metal Film	R-94-11.8k
R187	Pot, 20k	RP-34-20k
R188	Resistor, 8.66k, 1%, 1/2W, Carbon	R-12-8.66k
R189	Resistor, 500Ω, 1%, 1/2W, Carbon	R-12-500
R190	Resistor, 6.8k, 10%, 1/2W, Composition	R-1-6.8k
R191	Resistor, 6.8k, 10%, 1/2W, Composition	R-1-6.8k
R192	Resistor, 6.8k, 10%, 1/2W, Composition	R-1-6.8k
S101	Rotary Switch less components, Coarse Zero	SW-166
	Rotary Switch with components	20924B
S102	Rotary Switch less components, Range	SW-204
	Rotary Switch with components	20922B
	Knob, Range Switch	KN-51
S103	Knob, Zero Check	KN-47
S104	Rotary Switch less components, Medium Zero	SW-209
	Rotary Switch with components	20926B
	Knob	KN-45
S105	Slide Switch, Feedback	19089
S106	Rotary Switch less components, Multiplier	SW-205
	Rotary Switch with components	20929B
	Knob, Multiplier Switch	KN-49
S107	Rotary Switch less components, Meter	SW-320
	Rotary Switch with components	24278B
	Knob	KN-50
S108	Slide Switch, Output	SW-45
21850B	MOSFET Input Plug-in card	23733A
	Battery Snap, 6 required	BH-6
	Battery Holder	20944A