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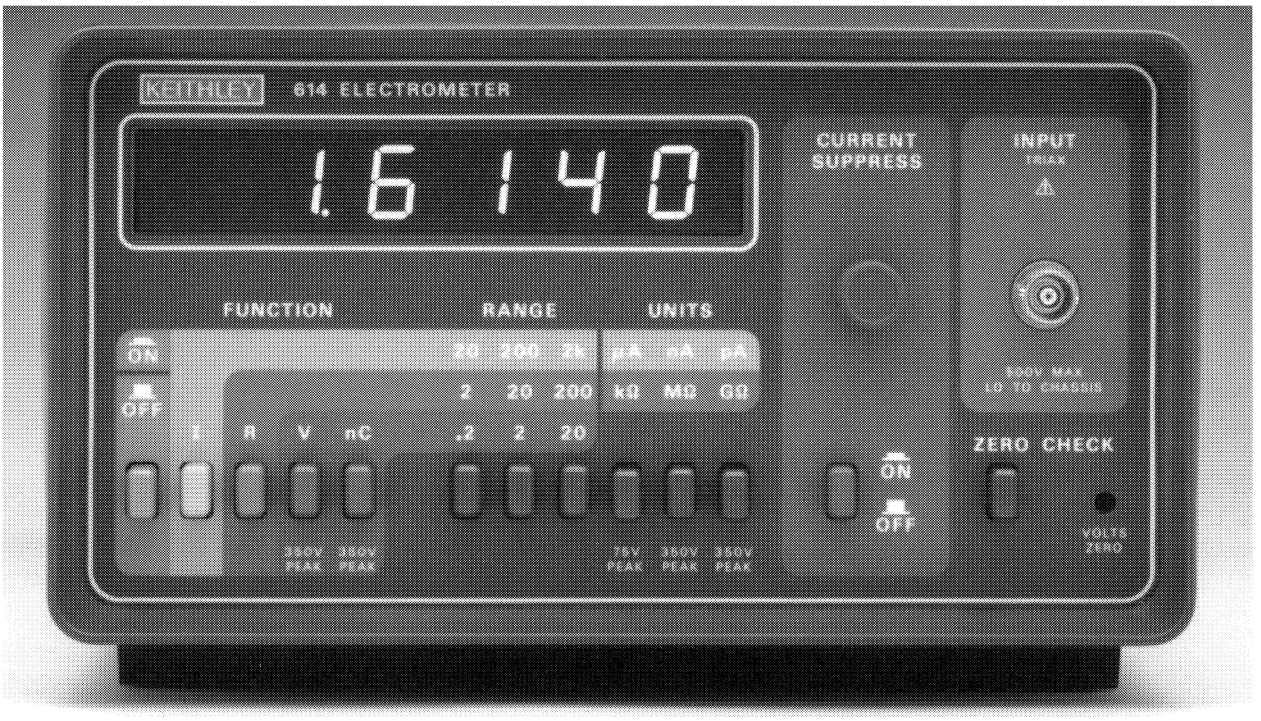
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Model 614
Electrometer
Instruction Manual



Contains Operating and Servicing Information

KEITHLEY

WARRANTY

Keithley Instruments, Inc. warrants this product to be free from defects in material and workmanship for a period of 1 year from date of shipment.

Keithley Instruments, Inc. warrants the following items for 90 days from the date of shipment: probes, cables, rechargeable batteries, diskettes, and documentation.

During the warranty period, we will, at our option, either repair or replace any product that proves to be defective.

To exercise this warranty, write or call your local Keithley representative, or contact Keithley headquarters in Cleveland, Ohio. You will be given prompt assistance and return instructions. Send the product, transportation prepaid, to the indicated service facility. Repairs will be made and the product returned, transportation prepaid. Repaired or replaced products are warranted for the balance of the original warranty period, or at least 90 days.

LIMITATION OF WARRANTY

This warranty does not apply to defects resulting from product modification without Keithley's express written consent, or misuse of any product or part. This warranty also does not apply to fuses, software, non-rechargeable batteries, damage from battery leakage, or problems arising from normal wear or failure to follow instructions.

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Model 614 Electrometer
Instruction Manual

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SPECIFICATIONS

VOLTAGE

RANGE	RESOLUTION	ACCURACY (1 YEAR) 18°-28°C ±(%rdg + digits)	TEMPERATURE COEFFICIENT 0°-18°C & 28°-35°C ±(%rdg + digits)/°C
0.2V	10 μV	0.08% + 2d*	0.005% + 2 d
2 V	100 μV	0.08% + 1d	0.005% + 0.2d
20 V	1mV	0.08% + 1d	0.005% + 0.1d

*When properly zeroed.

NMRR: Greater than 60dB at 50Hz and 60Hz.

CMRR: Greater than 120dB at DC, 50Hz and 60Hz.

INPUT IMPEDANCE: Greater than $5x10^{13}$ in parallel with 20pF.

MAXIMUM OVERLOAD: 350V peak.

CURRENT

RANGE	RESOLUTION	ACCURACY (1 YR.) 18°-28°C ±(%rdg + digits)	TEMPERATURE COEFFICIENT 0°-18°C & 28°-35°C ±(%rdg + digits)/°C	MAXIMUM SUPPRESSION
20pA	10fA	1.5% + 5d*	0.1 % + 1 d	± 20pA
200pA	100fA	1.5% + 3d	0.1 % + 0.3d	±200pA
2000pA	1pA	1.5% + 1d	0.1 % + 0.3d	±200pA
20nA	10pA	0.5% + 2d	0.02% + 0.3d	± 20nA
200nA	100pA	0.5% + 1d	0.02% + 0.3d	±200nA
2000nA	1nA	0.5% + 1d	0.02% + 0.3d	±200nA
20μA	10nA	0.3% + 2d	0.01% + 0.3d	± 20μA
200μA	100nA	0.3% + 1d	0.01% + 0.3d	±200μA
2000μA	1μA	0.3% + 1d	0.01% + 0.3d	±200μA

*With current suppress.

INPUT BIAS CURRENT: Less than 60fA at 23°C.

INPUT VOLTAGE BURDEN: Less than 200μV.

PREAMP SETTLING TIME (to 1% of final value): pA, 0.6s. **nA,** 5ms. **μA,** 2.5ms.

NMRR: pA and nA, 70dB. **μA,** 55dB. At 50Hz and 60Hz.

MAXIMUM OVERLOAD: pA and nA, 350V peak. **μA,** 75V peak.

RESISTANCE

RANGE	RESOLUTION	ACCURACY (1 YR.) 18°-28°C ±(%rdg + digits)	TEMPERATURE COEFFICIENT 0°-18°C & 28°-35°C ±(%rdg + digits)/°C	TEST CURRENT
2 kΩ	1 Ω	0.5% + 2d	0.03% + 0.3d	100μA
20 kΩ	10 Ω	0.5% + 2d	0.03% + 0.3d	100μA
200 kΩ	100 Ω	0.5% + 2d	0.03% + 0.3d	10μA
2MΩ	1 kΩ	0.8% + 2d	0.04% + 0.3d	100nA
20MΩ	10 kΩ	0.8% + 2d	0.04% + 0.3d	100nA
200MΩ	100 kΩ	0.8% + 2d	0.04% + 0.3d	100nA
2 GΩ	1MΩ	2.0% + 3d	0.12% + 0.3d	100pA
20 GΩ	10MΩ	2.0% + 2d	0.12% + 0.3d	100pA
200 GΩ	100MΩ	2.0% + 2d	0.12% + 0.3d	100pA

MAXIMUM OPEN CIRCUIT VOLTAGE: 32V DC.

MAXIMUM OVERLOAD: kΩ, 75V peak. **MΩ, GΩ,** 350V peak.

CHARGE

RANGE	RESOLUTION	ACCURACY (1 YEAR) 18°-28°C ±(%rdg + digits)
0.2nC	10fC	5% + 50d
2 nC	100fC	5% + 5d
20 nC	1pC	5% + 1d

INPUT BIAS CURRENT: Less than 60fA at 23°C.

MAXIMUM OVERLOAD: 350V peak.

GENERAL

DISPLAY: Five LED digits with appropriate decimal point, polarity and overload indication.

CURRENT SUPPRESS: Active in Current mode; allows correction for input currents on any given range.

CONVERSION TIME: 400ms.

2V ANALOG OUTPUT: 2V out for full range input. Inverting in Voltage and Resistance modes. Output impedance: 10kΩ.

PREAMP OUTPUT: Provides a guard output for Voltage and Resistance measurements. Can be used as an inverting output or with external feedback in Current and Coulombs modes. Output impedance: 1kΩ.

MAXIMUM COMMON MODE VOLTAGE: 500V peak.

CONNECTORS: Input: Triax. **Output:** 5-way binding posts.

ENVIRONMENT: Operating: 0°C to 35°C up to 70% relative humidity. **Storage:** −25°C to +65°C.

POWER: Line or battery operated. 105-125V or 210-250V (switch selected), 90-110V available. 50-60Hz, 5VA typical; 18VA maximum during battery charge. 10 hour operation from full charge, 20 hours to recharge.

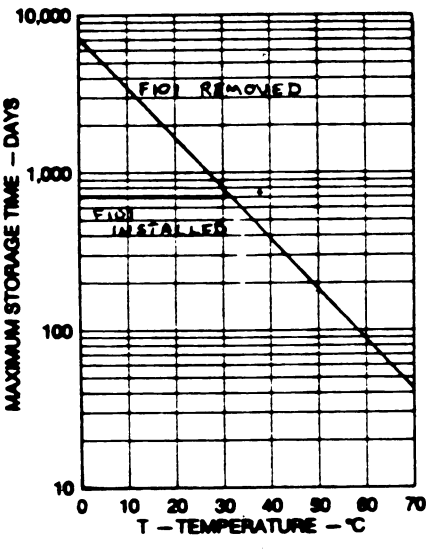
DIMENSIONS, WEIGHT: 127mm high × 216mm wide × 359mm deep (5" × 8½" × 14⅛"). Net weight 3.3kg (7.2 lbs.).

ACCESSORY SUPPLIED: Model 6011 Triaxial Input Cable.

ACCESSORIES AVAILABLE:
Model 1019 Universal Rack Mounting Kit
Model 6011 Input Cable
Model 6102A Voltage Divider Probe (up to 200V with 614)
Model 6103C Voltage Divider Probe (up to 20kV with 614)
Model 6104 Test Shield
Model 6105 Resistivity Chamber
Model 6146 Triax Tee Adapter
Model 6147 Triax to BNC Adapter
Model 6167 Guarded Adapter
Model 6301 Guarded Probe

Model 614 Specification Addenda

1. "When Properly Zeroed" refers to readjusting the Volts Zero pot after greater than 1°C change in ambient temperature or every 24 hours.
2. Normal mode rejection specification applies for signal and noise of less than full range.
3. "Preamp settling time to 1% of final value" assumes a step input from 0 to full range.
4. Overall specifications are valid for overload signals under 1kHz.
5. Model 614 storage time must be derated according to manufacturer's specification for the BA-35 Battery Pack at temperatures above 25°C.



Safety Precautions

The following safety precautions should be observed before using this product and any associated instrumentation. Although some instruments and accessories would normally be used with non-hazardous voltages, there are situations where hazardous conditions may be present.

This product is intended for use by qualified personnel who recognize shock hazards and are familiar with the safety precautions required to avoid possible injury. Read the operating information carefully before using the product.

The types of product users are:

Responsible body is the individual or group responsible for the use and maintenance of equipment, for ensuring that the equipment is operated within its specifications and operating limits, and for ensuring that operators are adequately trained.

Operators use the product for its intended function. They must be trained in electrical safety procedures and proper use of the instrument. They must be protected from electric shock and contact with hazardous live circuits.

Maintenance personnel perform routine procedures on the product to keep it operating, for example, setting the line voltage or replacing consumable materials. Maintenance procedures are described in the manual. The procedures explicitly state if the operator may perform them. Otherwise, they should be performed only by service personnel.

Service personnel are trained to work on live circuits, and perform safe installations and repairs of products. Only properly trained service personnel may perform installation and service procedures.

Exercise extreme caution when a shock hazard is present. Lethal voltage may be present on cable connector jacks or test fixtures. The American National Standards Institute (ANSI) states that a shock hazard exists when voltage levels greater than 30V RMS, 42.4V peak, or 60VDC are present. **A good safety practice is to expect that hazardous voltage is present in any unknown circuit before measuring.**

Users of this product must be protected from electric shock at all times. The responsible body must ensure that users are prevented access and/or insulated from every connection point. In some cases, connections must be exposed to potential human contact. Product users in these circumstances must be trained to protect themselves from the risk of electric shock. If the circuit is capable of operating at or above 1000 volts, **no conductive part of the circuit may be exposed.**

As described in the International Electrotechnical Commission (IEC) Standard IEC 664, digital multimeter measuring circuits (e.g., Keithley Models 175A, 199, 2000, 2001, 2002, and 2010) are Installation Category II. All other instruments' signal terminals are Installation Category I and must not be connected to mains.

Do not connect switching cards directly to unlimited power circuits. They are intended to be used with impedance limited sources. NEVER connect switching cards directly to AC mains. When connecting sources to switching cards, install protective devices to limit fault current and voltage to the card.

Before operating an instrument, make sure the line cord is connected to a properly grounded power receptacle. Inspect the connecting cables, test leads, and jumpers for possible wear, cracks, or breaks before each use.

For maximum safety, do not touch the product, test cables, or any other instruments while power is applied to the circuit under test. ALWAYS remove power from the entire test system and discharge any capacitors before: connecting or disconnecting cables or jumpers, installing or removing switching cards, or making internal changes, such as installing or removing jumpers.

Do not touch any object that 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.

The instrument and accessories must be used in accordance with its specifications and operating instructions or the safety of the equipment may be impaired.

Do not exceed the maximum signal levels of the instruments and accessories, as defined in the specifications and operating information, and as shown on the instrument or test fixture panels, or switching card.

When fuses are used in a product, replace with same type and rating for continued protection against fire hazard.

Chassis connections must only be used as shield connections for measuring circuits, NOT as safety earth ground connections.

If you are using a test fixture, keep the lid closed while power is applied to the device under test. Safe operation requires the use of a lid interlock.

If a  screw is present, connect it to safety earth ground using the wire recommended in the user documentation.

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

The  symbol on an instrument shows that it can source or measure 1000 volts or more, including the combined effect of normal and common mode voltages. Use standard safety precautions to avoid personal contact with these voltages.

The **WARNING** heading in a manual explains dangers that might result in personal injury or death. Always read the associated information very carefully before performing the indicated procedure.

The **CAUTION** heading in a manual explains hazards that could damage the instrument. Such damage may invalidate the warranty.

Instrumentation and accessories shall not be connected to humans.

Before performing any maintenance, disconnect the line cord and all test cables.

To maintain protection from electric shock and fire, replacement components in mains circuits, including the power transformer, test leads, and input jacks, must be purchased from Keithley Instruments. Standard fuses, with applicable national safety approvals, may be used if the rating and type are the same. Other components that are not safety related may be purchased from other suppliers as long as they are equivalent to the original component. (Note that selected parts should be purchased only through Keithley Instruments to maintain accuracy and functionality of the product.) If you are unsure about the applicability of a replacement component, call a Keithley Instruments office for information.

To clean an instrument, use a damp cloth or mild, water based cleaner. Clean the exterior of the instrument only. Do not apply cleaner directly to the instrument or allow liquids to enter or spill on the instrument. Products that consist of a circuit board with no case or chassis (e.g., data acquisition board for installation into a computer) should never require cleaning if handled according to instructions. If the board becomes contaminated and operation is affected, the board should be returned to the factory for proper cleaning/servicing.

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SECTION 1
GENERAL INFORMATION

1.1 INTRODUCTION

The Model 614 is an electrometer with 10^{-14} A sensitivity, and an input current less than 60fA at 23°C. Voltage sensitivity is 10μV to 20V with an input impedance of greater than 50TΩ ($5\times10^{13}\Omega$). Resistance sensitivity of the Model 614 is from 1Ω to $2\times10^{11}\Omega$ using the constant current technique. Charge sensitivity (nC) is from 10fC (10^{-14} Coulombs) to 20nC (2×10^{-8} Coulombs). See Figure 1-1 and 1-2 for front and rear panel detail.

1.2 FEATURES

The Model 614 includes the following features:

- 4½-digit display with appropriate decimal point.
- 2V Analog Output - The 2V Analog Output provides an analog signal with a scale of 2V for Full Range at the display. The output impedance is 10kΩ. The signal is inverted for the Volts and Resistance functions.
- Preamp Output, that can be used as a guard in the Volts and Resistance functions, and as an inverting output in the Current and Charge functions. The output impedance is 1kΩ. This output can be used for monitoring the input signal in applications requiring a buffer amplifier, and can also be used with external feedback.
- Current Suppress, which is available in the Current mode, allows correction for input offset currents on any given range. Does not affect accuracy or drift.
- Each Range has the following:
  1. Automatic polarity operation, minus sign displayed, plus sign implied.
  2. Effective input overload protection.
  3. Overrange indication (flashing 0000).
  4. Decimal point positioned by range push button.
- Battery pack standard. Complete portability. Full charge is maintained when the Model 614 is plugged in. Batteries at full charge will provide 10 hours of operation.
- Line power can also be used. Switch over from battery power to line power is automatic.
- Volts Zero sets "zero" on the .2V range and need not be readjusted on the other ranges.

1.3 WARRANTY INFORMATION

Warranty information is provided on the inside front cover of this manual. If there is a need to exercise the warranty, contact the Keithley representative in your area to determine the proper action to be taken. Keithley maintains complete repair and calibration 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 the above locations. Check the inside front cover of this manual for addresses.

1.4 MANUAL ADDENDA

Improvements or changes to this manual will be explained on an addendum attached to the inside back cover.

1.5 SAFETY SYMBOLS AND TERMS

Safety symbols used in this manual are as follows:

The symbol  on the instrument denotes that the user should refer to the operating instructions.

The symbol  on the instrument denotes that 1000V or more may be present on the terminal(s).

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

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

1.6 UNPACKING AND INSPECTION

The Model 614 is inspected both mechanically and electrically before shipment. Upon receiving the Model 614 unpack all items from the shipping container and check for any obvious damage that may have occurred during transit. Report any damage to the shipping agent. Retain and use the original packaging materials if reshipment is necessary. The following items are shipped with all Model 614 orders:

- A Model 614 Electrometer
- A Model 614 Instruction Manual
- A Model 6011 Input Lead
- Optional accessories per request

If an additional instruction manual is required, order the manual package (Keithley Part Number 31896-00). The manual package includes an instruction manual and all pertinent addenda.

1.7 SPECIFICATIONS

For Model 614 detailed specifications, refer to the specifications that precede this section.

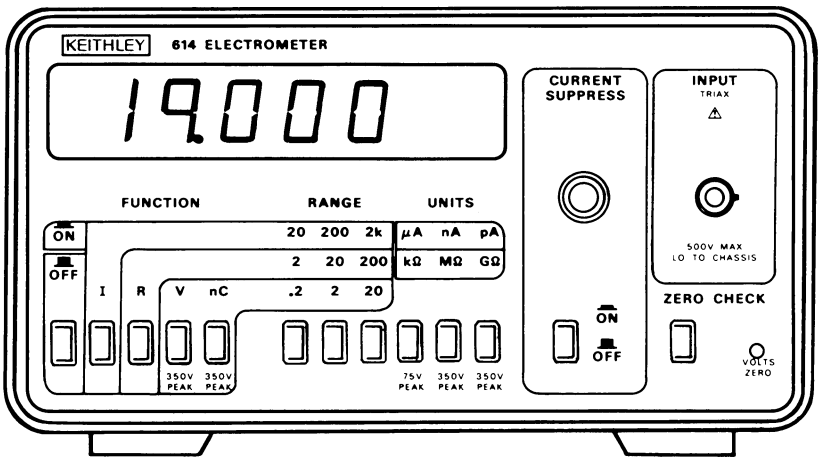


Figure 1-1. Model 614 Front Panel

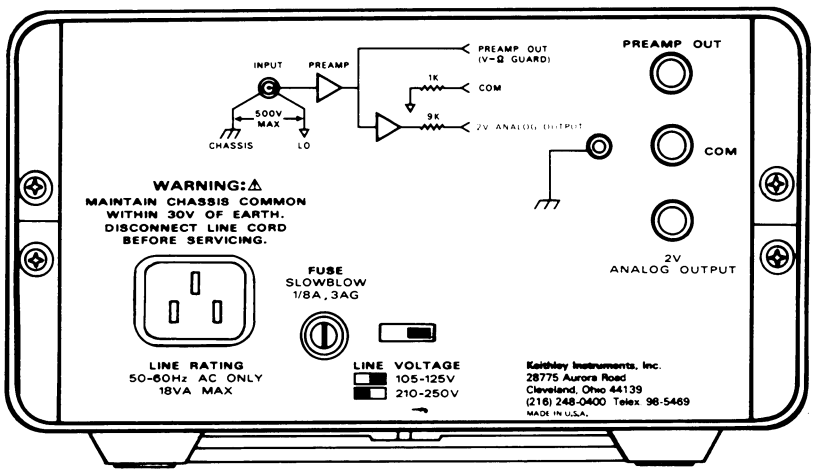


Figure 1-2. Model 614 Rear Panel

SECTION 2
OPERATION

2.1 INTRODUCTION

Procedures for operating the Model 614 for measurements of Voltage, Current, Charge and Resistance are contained in this section. Several practical applications are explained later in this section.

2.2 PREPARATION FOR USE

2.2.1 Battery Power

The Model 614 operates on either line or battery power. A rechargeable lead-acid pack is used in the Model 614. The pack will be charged (whether the instrument is on or off) in 20 hours from complete discharge. The Model 614 will operate for 10 hours after full charge. When the pack is discharged, the instrument automatically shuts off and will not operate until line power is connected. If the battery is completely discharged, line power operation may be delayed by 5 to 10 seconds. Switch over from line power to battery operation is automatic.

CAUTION

Do not store the Model 614 with a discharged battery pack for more than six weeks at a temperature greater than 25°C or damage to the battery pack may result. For long term storage (more than one month) charge the battery pack for 20 hours on line operation. Maximum shelf life after a full charge is two years.

2.2.2 Line Power

The AC input line voltage required to operate the Model 614 is 105V-125V or 210V-250V. The recessed LINE VOLTAGE switch on the rear panel, selects either 105V-125V or 210V-250V operation. F102 is the line fuse and is rated at 1/8A, 250V, 3AG for both 105V-125V and 210V-250V operation.

For units ordered for operation from 90V-110V or 180V-220V, F102 is rated the same as for 105V-125V or 210V-250V operation. Switching from line operation to battery operation involves removing the Model 614 from line power. As long as the Model 614 is operating on line power, the battery pack is charged or maintained at full charge. The Model 614 operates from 50Hz or 60Hz.

WARNING

When using line power, ground the Model 614 through a properly grounded receptacle before operation. Failure to ground the Model 614 can result in severe injury or death in the event of a short circuit or malfunction. When operating on battery power, maintain chassis common within 30V of earth ground.

2.3 OPERATING INSTRUCTIONS

2.3.1 Environmental Conditions

All measurements should be made at an ambient temperature within the range of 0°C to 35°C, and with a relative humidity of less than 70%. To maintain low input current (< 60fA), ambient temperature of up to 23°C is suggested.

2.3.2 Front Panel Controls

1. **ON/OFF Switch**—Depressing the push button turns the instrument on for either battery power or line power. Releasing this push button turns the instrument off.
2. **I**—Depressing this push button selects the Current function.
3. **R**—Depressing this push button selects the Resistance function.
4. **V**—Depressing this push button selects the Volts function.
5. **nC (nanocoulombs)**—Depressing this push button selects the Coulomb (Charge) function.
6. **UNITS**—Depressing any of these push buttons selects the appropriate scientific units of the parameter being measured.
7. **RANGE**—Depressing any of these push buttons selects the appropriate range and sensitivity of the parameter being measured.

Example 1: The current to be measured is on the order of 15μA.

A. Select Current (I).
B. Select Unit (μA).
C. Select Range (20).

Example 2: The resistance to be measured is on the order of 10GΩ.

A. Select Resistance function (R).
B. Select Unit (GΩ).
C. Select Range (20).

8. **CURRENT SUPPRESS ON/OFF**—Depressing this push button turns on the Current Suppress circuit. Releasing it disables the Current Suppress circuit.

NOTE

Current Suppress is active only when Current function (I) is selected.

9. **Current Suppress Potentiometer**—When the CURRENT SUPPRESS push button is depressed, the current suppress potentiometer can be used to zero out any input up to ±2000 counts (except ±200 counts on the 2000 μA, nA or pA ranges to prevent input overload without indication).

NOTE

The Current Suppress potentiometer must be readjusted when the range is changed.

10. **ZERO CHECK**—Depressing this push button places the Model 614 in the Zero Check mode by shorting the preamplifier feedback elements in the Current or Coulombs mode, or shorting the preamplifier input in the Volts or Resistance mode. Releasing the button takes the Model 614 out of the Zero Check mode. The Zero Check feature allows internal offsets to be corrected and also protects the sensitive input circuitry from charge build-up during overloads.

NOTE

The input impedance characteristics change when the ZERO CHECK button is depressed. See Figure 2-1.

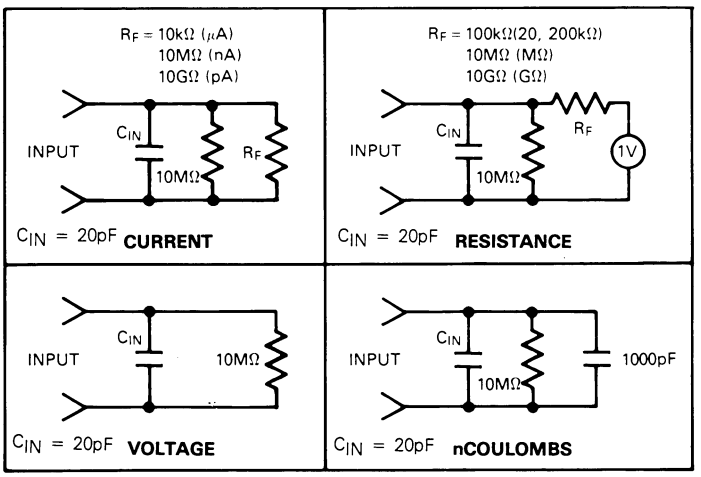


Figure 2-1. Equivalent Input Impedance Model with Zero Check Enabled.

11. **VOLTS ZERO**— Volts Zero adjusts the input amplifier offset. This is accomplished only in Zero Check, .2V range. Volts Zero Verification

A. Turn the Model 614 on and allow it one hour for warm-up.

B. Depress ZERO CHECK.

C. Select the Volts function and the .2V range.

D. The Model 614 should display .00000 ±1 digit. If the display is not .00000 ±1 digit, adjust the VOLTS ZERO potentiometer R103 (small hole directly under the Input connector) to obtain a displayed reading of .00000 ±1 digit.

E . The Model 614 input amplifier zero is now adjusted for all functions and ranges.

NOTE

Adjust Volts Zero only on the .2V range. Adjustment on the .2V range guarantees a proper zero on all other functions and ranges.

12. **Input**—The input connector is a Teflon® insulated female triax connector.

NOTE

The input connector must be kept clean to maintain high input impedance.

CAUTION

Do not exceed the maximum allowable input. Instrument damage may result. Maximum allowable inputs are stated in the specifications and are indicated on the front panel under the appropriate button. When switching between functions, where the possibility of overloads greater than 75V peak exist, be sure that μA (kΩ) is NOT depressed.

2.3.3 Rear Panel Description

1. **Line Plug**—The line plug mates with a 3-wire line cord which provides connections to line voltage (high, common and earth ground).

WARNING

When using line power, ground the Model 614 through a properly grounded receptacle before operation. Failure to ground the Model 614 can result in severe injury or death in the event of a short circuit or malfunction.

WARNING

When floating Input LO above 30V from earth ground, hazardous voltage will be present at the 2V Analog Output and the Preamp Output.

2. **FUSE**— The fuse is rated at 1/8A, 3AG, 250V.
3. **LINE VOLTAGE Switch**—The LINE VOLTAGE switch selects either 90V - 125V or 180V - 250V operation (see paragraph 2.2.2).
4. **Chassis Ground Terminal**—This terminal provides a connection to chassis ground (outside shell of input connector).
5. **LO**— This terminal provides a connection to input LO through a 1kΩ resistor (see rear panel schematic Figure 1-2).
6. **Preamp Out**—Preamp Out (V-Ω Guard) can be used as a guard in the Volts and Resistance functions. In the Current and nCoulombs functions, it can be used as an inverting output.
7. **2V Analog Output**—The 2V Analog Output provides an analog signal with a scale of 2V for Full Range at the display. The output impedance is 10kΩ. The signal is inverted for the Volts and Resistance functions.
   Example: With the Volts function selected and 1.9000V applied, the front panel display reads 1.9000. The 2V Analog Output will read -1.9000.

2.4 MEASUREMENT CONSIDERATIONS

2.4.1 Guarding

Guarding consists of surrounding the sensitive input with a conductor (the Guard) connected to a low impedance point which is at virtually the same potential as the high impedance signal.

For Example: A coaxial cable with a grounded shield and a voltage applied to the center conductor from a voltage source with a high internal resistance, has a reduced output voltage due to leakage resistance of the cable. If instead, the shield is connected to a low impedance voltage source of approximately the same potential as the high impedance source, leakage from the center conductor to the shield will nearly vanish. Even though leakage from the outer braid to ground may be considerable, this flow is inconsequential, since the current is supplied by the low impedance source.

The unguarded configuration shown in Figure 2-2 illustrates how leakage resistance causes erroneous results. The guarded configuration shown in Figure 2-3 illustrates how guarding eliminates the problem. The Model 6167 Guarded Adapter implements this configuration.

If long cables are used, the cable capacitance C_C (shunting R_L) becomes significant. The time constant R_SC_C determines the settling time of the measurement. If R_S and C_C are large (> $10^{10}\Omega$ and > 20pF respectively) response time is slow. Guarding the high impedance node eliminates this problem. (See Figure 2-3).

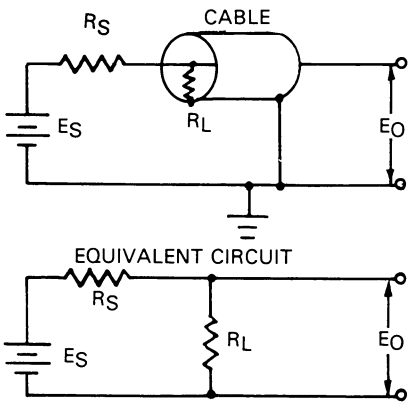
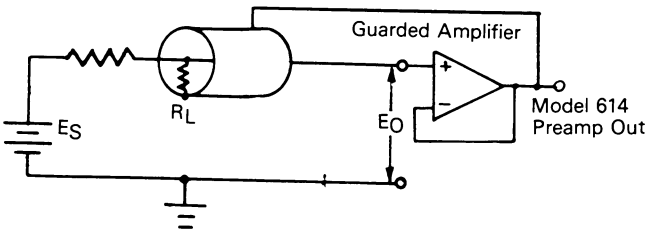


Figure 2-2. Unguarded Configuration



NO CURRENT FLOWS THROUGH R_L THEREFORE $E_O = E_S$

Figure 2-3. Guarded Configuration

2.4.2 Ground Loops

Ground Loops, that occur in multiple-instrument test setups, can cause erratic or erroneous measurements. A hookup as shown in Figure 2-4 introduces errors in two ways. Large ground currents flowing in one of the wires will encounter small resistances, either in the wires or in the interconnections. This results in voltage drops which may affect the measurement. Even if the ground currents are small, magnetic flux cutting across the large loops formed by the ground leads, can induce sufficient voltages to disturb sensitive measurements.

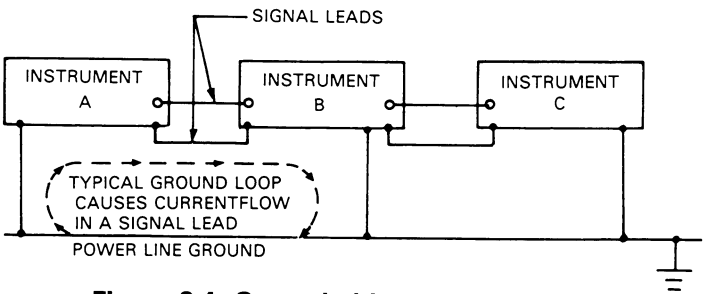


Figure 2-4. Grounded Loop Configuration

To prevent ground loops, the signal grounds on the instruments should be interconnected to a central node resembling a tree (see Figure 2-5). Experimentation is the simplest way to determine an acceptable arrangement. For extremely sensitive measurements, however, ground loops formed by capacitive coupling through the power transformer and power lines can be troublesome. In this case, the Model 614 can be isolated from the power line by utilizing battery power.

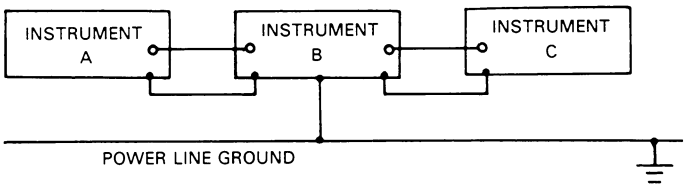


Figure 2-5. Ground "Tree" Configuration

2.4.3 Electrostatic Interference

Electrostatic interference occurs when an electrically charged object is brought near an uncharged object, thus inducing a charge on the uncharged object. Usually, this is not observed because low impedance levels allow the induced charge to quickly dissipate. However, the high impedance of electrometer measurements does not allow the charges to decay as rapidly and thus, erroneous or unstable readings may result. Erroneous or unstable readings may be caused in the following ways:

1. DC electrostatic field can cause undetected errors in the reading.
2. AC electrostatic fields can cause errors by driving the amplifier into saturation or through rectification that produces DC errors.

Electrostatic interference is first recognizable when hand or body movements near the experiment alter the electrometer reading. Pick up from AC fields can also be detected by observing the electrometer output on an oscilloscope. Line frequency signals on the output is an indication that electrostatic interference is present. Means of eliminating electrostatic interference include:

1. Shielding, is both effective and economical. Possibilities include: a shielded room, a shielded booth, shielding the sensitive circuit and using shielded cable. The shield should always be a solid conductor that is connected to a circuit ground. Meshed screen or loosely braided cable could be inadequate for high impedances or in strong fields. The Keithley Model 6104 Test Shield provides shielding under these circumstances. Note however, that shielding can increase capacitance in the measuring circuit.
2. Reduction of electrostatic fields. Moving power lines away from the experiment reduces electrostatic interference.

2.4.4 Thermal EMFs

Thermal EMFs are developed when a junction of dissimilar metals are at different temperatures. Low thermal connections are used to minimize thermal EMFs. Crimped or cadmium soldered copper to copper connections are ideal.

2.5 ELECTROMETER MEASUREMENTS

2.5.1 Voltage Measurement

The Model 614 is capable of making voltage measurements from high resistance sources (> $10^9\Omega$). Make voltage measurement as follows:

1. Turn the Model 614 on.
2. Depress ZERO CHECK.
3. Select Volts function and verify Volts Zero (paragraph 2.3.2).
4. Select the desired range.
5. Connect the source to the Model 614.
6. Release ZERO CHECK.
7. Take reading.

NOTE

Cable capacitance may increase the measurement response time. See paragraph 2.4.1.

CAUTION

Do not exceed the maximum input. Instrument damage may result.

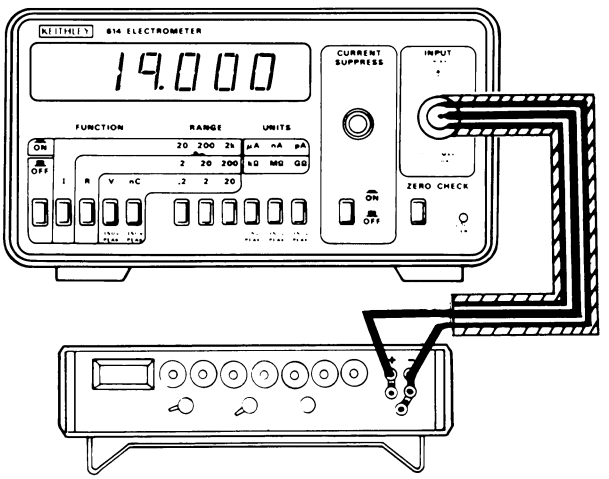


Figure 2-6. Voltage Measurement

2.5.2 Current Measurement

The Model 614 is capable of measuring current to 10^{-14}A. The feedback ammeter technique is used to measure the current. Low voltage burden and errors caused by inserting the ammeter into the circuit are reduced. Because the Model 614 employs the feedback technique for measuring current, cable capacitance and leakage are not significant problems. In fact, input capacitance may approach 0.1μF without degrading the measurement. Leakage resistance as low as $10^{10}\Omega$ will not degrade instrument performance. However, it is essential that the input cable be kept stationary during very sensitive measurements. Flexing or moving even the highest quality graphite lubricated low-noise cable may generate hundreds of femtoamps of currents due to the triboelectric effect. Make current measurement as follows:

1. Turn the Model 614 on and allow one hour warm up.
2. Depress ZERO CHECK.
3. Select Current Function.
4. Select units (μA, nA, or pA).
5. Select range (20, 200 or 2k).
6. Apply input and release ZERO CHECK.
7. Take reading. Displayed reading is in μA, nA, or pA depending on the units selected.

NOTE

After first turning on the Model 614 (after overload or after changing function), it may be necessary to allow the input to settle for about one minute before input bias current falls within specification. For severe overloads, several minutes may be required.

2.5.3 Current Suppress

This feature is provided so that offsets can be nulled out to observe input current changes more conveniently. Currents up to 200μA, 200nA or 200pA can be suppressed depending on the Units selected. To use Current Suppress:

1. Input a baseline current.
2. Depress CURRENT SUPPRESS button. Current function (I) must be selected.
3. Adjust Current Suppress knob until display reads zero.
4. Small changes in input signal can now be easily seen.
5. To observe original baseline depress ZERO CHECK. Original baseline is now displayed but with opposite polarity.

NOTE

Any time a range or units change is made, the Current Suppress should be readjusted.

6. To turn off Current Suppress, release CURRENT SUPPRESS button.

2.5.4 Resistance Measurement

The Model 614 is capable of measuring from 1Ω to $2x10^{11}\Omega$. For resistances greater than $2x10^{11}\Omega$, it is recommended that an external voltage be applied to the unknown and the Model 614 be used to measure the current through the unknown. As shown in Figure 2-8. For more information refer to paragraph 2.6.1. The Model 614 employs the constant current technique to measure resistance. Refer to Figure 2-7. Measure resistance as follows:

1. Turn the Model 614 on.
2. Depress ZERO CHECK.
3. Select Resistance function (R).
4. Select Units (kΩ, MΩ or GΩ).
5. Select Range (2, 20, 200).
6. Apply the input and release ZERO CHECK.
7. Take the reading. The reading is in kΩ, MΩ, or GΩ depending on the Units selected.

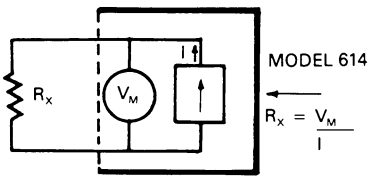


Figure 2-7. Constant Current Method Employed by the Model 614.

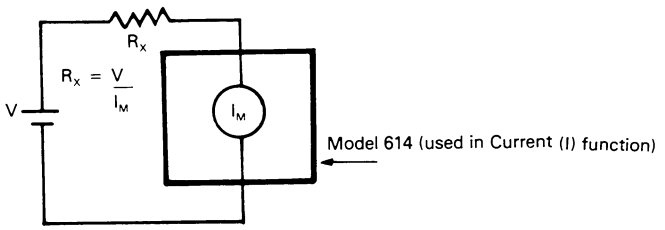


Figure 2-8. Technique for Measuring Resistance > $10^{11}\Omega$

NOTE

Stability with inductive sources: When using the Model 614 to measure resistances or voltages from sources having high Q series inductances, it may be necessary to bypass the inductance with a 0.01μF capacitor to prevent circuit instability. This situation may be encountered when attempting to measure the series resistance of an inductor above 10mHy. The 0.01μF capacitor provides a low impedance shunt to the inductor.

2.5.5 Charge Measurement (nC)

The Model 614 is capable of measuring Charge from 10fC to 20nC. The Model 614 measures charge as a feedback coulombmeter. Measurements should be made as quickly as possible since electrometer bias current introduces time dependent errors. The error due to bias current is 60fC/sec maximum at 23°C. Measure charge as follows:

1. Turn the Model 614 on and allow one hour warm up.
2. Depress ZERO CHECK.
3. Select Charge function (nC).
4. Select Range (.2, 2 or 20).
5. Release ZERO CHECK. A small Zero Check hop may occur. Less than 200fC hop is typical. On the .2nC range the effect of instrument input current can be seen. The display ramps at a rate of less than 60fC/sec (6 digits/sec).
6. Apply input. The displayed reading is the amount of charge transferred to the input. If the reading does not settle the amount of charge being transferred to input is changing with time. This means current is flowing in to or out of the Model 614 input. The current and charge can be related as follows:

$Q = IT$ Q = Charge in nanocoulombs
I = Current in nanoamperes
T = Time in seconds

2.5.6 2V Analog Output

This output can be used to drive a chart recorder. In the Volts and Resistance functions the 2V Analog Output signal is inverted.

WARNING

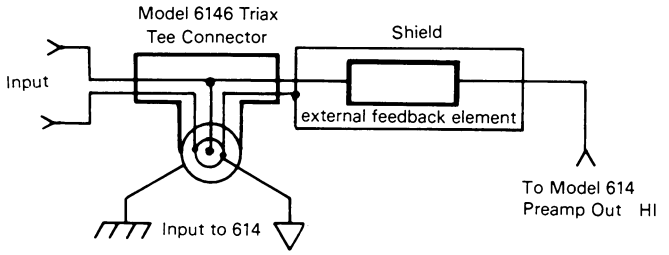
When floating Input Low above 30V from earth ground, hazardous voltage will be present at 2V Analog and Preamp Outputs.

2.5.7 Preamp Output

This output can be used as a guard in the Volts and Resistance functions. As a unity gain amplifier (in Volts function) this output is typically within better than 10ppm of the input (excluding offsets). The output resistance appears between input LO and output LO rather than in the Preamp Out HI lead. This keeps the 1kΩ protection resistor out of the loop when using external feedback elements. The Model 6146 Triax Tee Adapter may be used to provide high impedance interconnections between input and external feedback elements. External feedback can be used if non-decade or logarithmic gain is required, or if added Coulombs capability is necessary.

NOTE

To use external feedback elements with the Model 614 simply pop out all the UNITS buttons. This opens the feedback loop and allows external elements to complete the loop. This can only be accomplished in the Current (I) function. Connect the external feedback elements (R or C) from Preamp Out (rear panel) to the Model 614 input using the recommended shielded test box.



2.6 ELECTROMETER APPLICATIONS

2.6.1 Insulation Resistance

The Model 614 can directly measure resistances up to $2 \times 10^{11}\Omega$. Above $10^{10}\Omega$, or for cable length longer than three feet, the Model 6167 Guarded Adapter is recommended to allow quick and accurate measurements regardless of cable capacitance or cable leakage. The Model 614 uses the constant current measurement technique to measure Resistance. This means that the test current through the unknown is constant, but the voltage appearing across the unknown depends on the resistance being measured. The Model 614's low compliance voltage keeps the error due to the voltage coefficient of the unknown resistance small. A typical setup for measuring insulation resistance is shown in Figure 2-9.

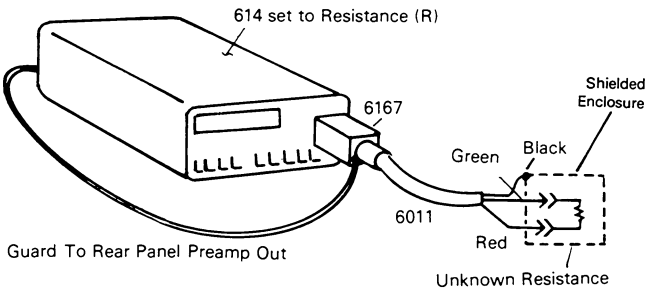


Figure 2-9. Insulation Resistance Measurement using the Model 6167.

It is necessary to shield resistances greater than $10^7\Omega$ if a stable reading is expected.

With the constant voltage method, the Model 614 is used as an ammeter to directly read the leakage current through the unknown resistance. This technique makes it possible to measure insulation resistances up to $10^{16}\Omega$. The voltage source is applied externally and the Model 614 is connected as shown in Figure 2-10. The insulation resistance can be found using any test voltage and can be calculated from:

$$R = \frac{V_t}{I_T}$$

where I_t = measure current on the Model 614.
V_t = applied voltage.

Example: V_t (applied voltage) = 100V, I_t (measure current) = 1pA.

$$R = \frac{100V}{1pA} = 10^{14}\Omega$$

An application in design where this range of resistance is common would be the measurement of printed circuit board resistance. Stray leakages between adjacent tape patterns often cause circuit problems. Using the Model 614 to measure these resistances it is possible to assess and correct the problem.

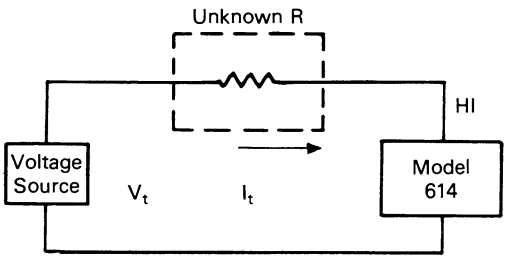


Figure 2-10. Constant Voltage Technique

2.6.2 High Impedance Voltmeter

The Model 614 is a high impedance voltmeter with greater than $5x10^{13}\Omega$ input resistance. Consider an example of a designer who wishes to measure the gate voltage on a precision JFET amplifier with a gate impedance of 100MΩ. The designer needs to measure this voltage to an accuracy of 1%. Refer to Figure 2-11.

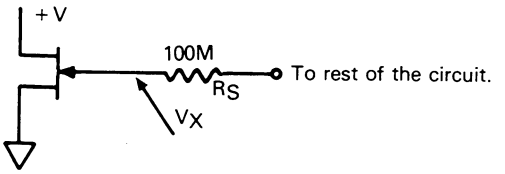


Figure 2-11. High Impedance FET Gate Voltage

The error due to loading a high impedance voltage source with a voltmeter can be expressed as:

$$\%error = \frac{Rs \quad x\ 100\%}{Rs + Rin}$$

Where: Rs = Source Resistance
Rin = Input Resistance of Meter

In this example, if a DMM with 10MΩ input resistance were used:

$$\%error = \frac{100M\Omega}{100M\Omega + 10M\Omega} \times 100\% = 91\% \text{ error}$$

If the high impedance DMM were used (Input resistance is $10^9\Omega$).

$$\%error = \frac{100M\Omega}{100M\Omega + 1G\Omega} \times 100\% = 9.1\% \text{ error}$$

A 9.1% error is not tolerable in this case, therefore the DMM could not be used. The Model 614 is capable of measuring voltages up to 20V with greater than $5 \times 10^{13}\Omega$ input impedance. In this example,

$$\%error = \frac{100M\Omega}{100M\Omega + 5x10^{13}\Omega} \times 100\% = .0002\% \text{ error due to input impedance.}$$

The input impedance is more than adequate for this application. The 4½-digit Volts resolution allows the designer enough precision to make use of the high input impedance.

2.6.3 Low Leakage Measurements:

The Model 614 is capable of measuring leakage currents to 10^{-14}A (10fA). A typical example of low leakage measurement is shown in Figure 2-12.

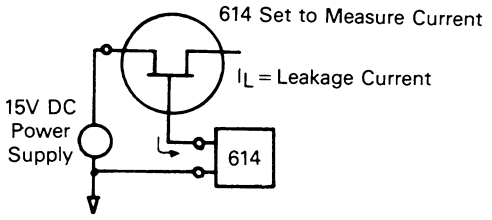


Figure 2-12. Leakage Current Measurement

In this example, the leakage current of a JFET needs to be measured. Even though the manufacturer may specify 1nA leakage at 30V, this test set up may show that at 15V (or other required voltage) the leakage current is much less.

Use of a shielded test enclosure such as the Model 6104 would help keep the measurement quiet and stable. The cable used to connect the Model 614 to the JFET and the power supply is the Model 6011 Shielded Test Cable which is provided with the Model 614.

Diode leakage (forward and reverse) can be measured in a similar way. The forward leakage (measured with voltage source set to less than 0.6V) can be measured using the Model 614. This is because error due to voltage burden is less than 0.1% with a 200mV source. High capacitance diodes (e.g. zeners) present no problem, since the Model 614 is insensitive to stray input capacitance up to 0.1μF.

2.6.4 Diode Characterization

With the constant current ohms configuration of the Model 614, it is possible to plot the I-V (current voltage characteristics of a diode over several decades). Refer to Table 2-1 for the range vs test current available with the Model 614.

Table 2-1. Ohms Ranges for Test Current

RANGES	TEST CURRENT	SCALE FACTOR
20kΩ, 2kΩ	100μA	.1
200kΩ	10μA	.01
ALL MΩ	100nA	.1
ALL GΩ	100pA	.1

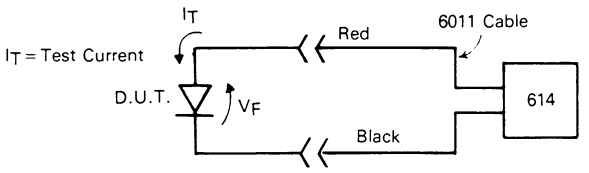


Figure 2-13. Characterizing a Diode with the Model 614.

The displayed reading on the Model 614 represents the voltage V_f when multiplied by the scale factor shown in Table 2-1. Figure 2-14 shows several examples of diodes whose curves are plotted using the method described above.

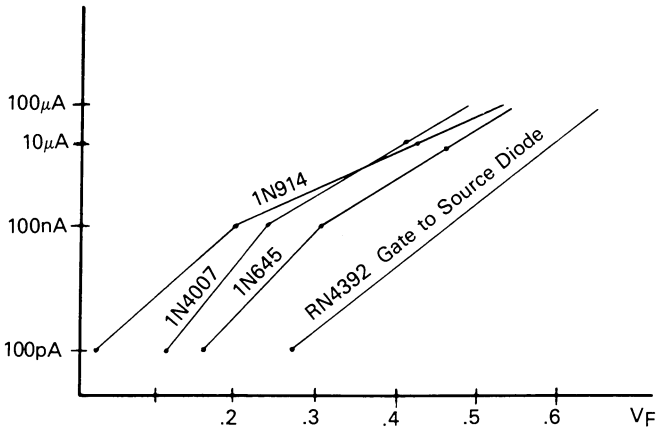


Figure 2-14. Diode Curves

SECTION 3
ACCESSORIES

3.1 INTRODUCTION

Section 3 lists each individual accessory that is available for the Model 614 Electrometer.

3.2 MODEL 1019 RACK MOUNTING KIT

The Model 1019 Rack Mounting Kit can accomodate one or two Model 614s. The dimensions are 133mm x 483mm (5¼" x 19").See Figure 3-1

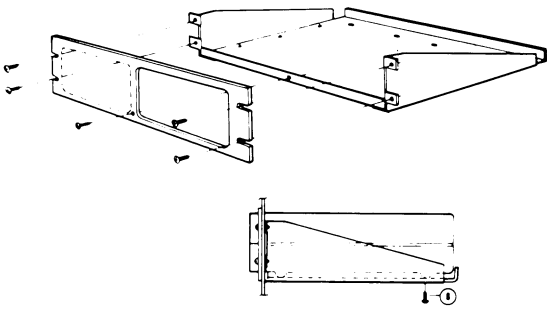


Figure 3-1. Model 1019

3.3 MODEL 6103C VOLTAGE DIVIDER PROBE

The Model 6103 Voltage Divider Probe extends voltage measurement to 20kV and has a 1000:1 division ratio. Accuracy is ±5% of reading. Input resistance of 4.5 x $10^{11}\Omega$ permits use with Keithley electrometers and other high impedance multimeters. It requires the Model 6012 Coaxial to Triaxial Adapter when used with the Model 614. Lead length is 0.8m (30"). See Figure 3-2.

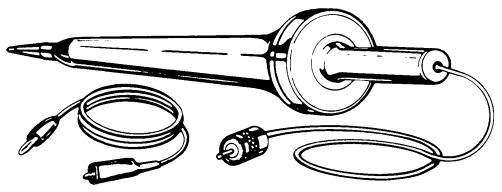


Figure 3-2. Model 6103C

3.4 MODEL 6104 TEST SHIELD

The Model 6104 Test Shield facilitates resistance, current or voltage measurements with either 2 or 3 terminal guarded connections. Voltage up to 1200V may be used. Model 6104 provides excellent electrostatic shielding, high isolation resistance and a means for easy connection to most Keithley electrometers and power supplies. Clips plug into banana jacks allowing user to fashion modified connections. Use with the Model 6147 Triax to BNC Adapter and the Model 4801 Input Cable.

3.5 MODEL 6105 RESISTIVITY CHAMBER

The Model 6105 Resistivity Chamber is a guarded test fixture for measuring volume and surface resistivity. It assures good electrostatic shielding and high insulation resistance. The chamber is designed in accordance with ASTM Standard Method of Test for Electrical Resistance of Insulating Materials. Resistivity can be determined by measuring the current through a sample with a known voltage impressed. The measurement can be calibrated in terms of surface or volume resistivity. The Keithley Model 6105 Resistivity Chamber has been designed for use with Keithley electrometers (Model 614) and an optional high voltage supply such as the Model 247. See Figure 3-3.

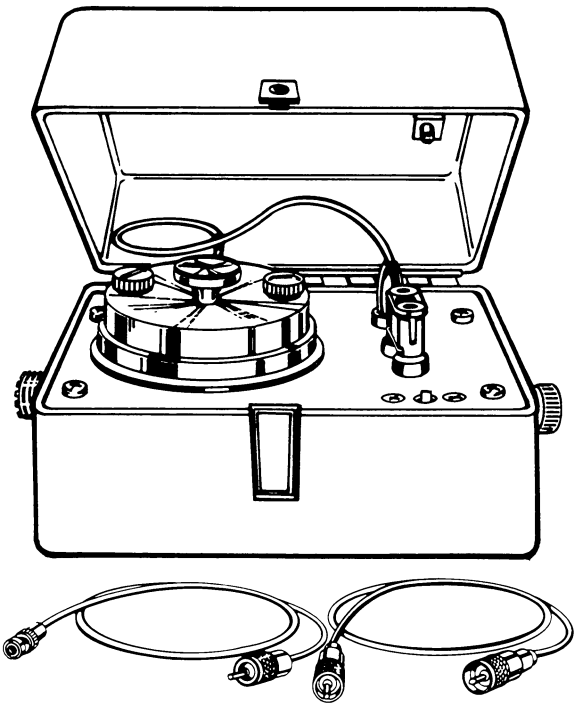


Figure 3-3. Model 6105

3.6 MODEL 6011 INPUT LEAD

The Model 6011 Input Lead is a shielded, low-noise triaxial cable 0.9m (three feet long) terminated with alligator clips. This cable mates directly with the Model 614 input. The Model 6011 is a supplied accessories. See Figure 3-4.

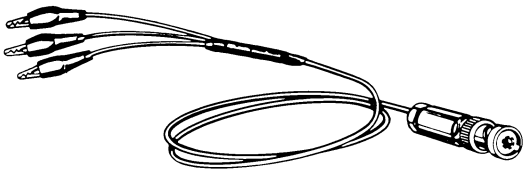


Figure 3-4. Model 6011

3.7 MODEL 6146 TRIAX TEE ADAPTER

The Model 6146 Triax Tee Adapter can be used to connect multiple inputs to the Model 614 and allows easy connection of external feedback elements.

3.8 MODEL 6147 TRIAX TO BNC CONNECTOR

The Model 6147 Triax to BNC Connector allows the Model 614 to be used with all Keithley acessories and cables requiring BNC connections.

3.9 MODEL 6167 GUARDED ADAPTER

The Model 6167 Guarded Adapter reduces effective cable capacity by driving the inner shield of a triaxial cable at guard potential. See Figure 3-5.

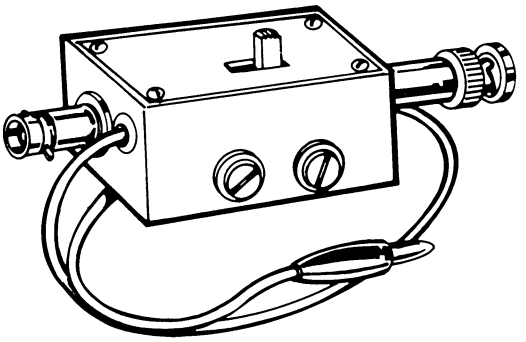


Figure 3-5. Model 6167

SECTION 4
PERFORMANCE VERIFICATION

4.1 INTRODUCTION

Performance verification may be done upon receipt of the instrument to ensure that no damage or misadjustment has occurred during transit. Verification may also be performed whenever there is question of the instrument's accuracy and following calibration if desired.

NOTE

For instruments that are still under warranty (less than 12 months since date of shipment), whose performance falls outside specifications at any point, contact your Keithley representative or the factory immediately.

4.2 ENVIRONMENTAL CONDITIONS

Measurements should be made at 18-28°C and at less than 70% relative humidity unless otherwise noted.

4.3 RECOMMENDED TEST EQUIPMENT

Table 4-1 lists all the test equipment required for verification. If alternate equipment is used, the alternate test equipment's specifications must be at least as good as the equipment specifications listed in Table 4-1.

4.4 PERFORMANCE VERIFICATION PROCEDURE

Use this procedure to verify the Model 614's accuracy. If the Model 614 is out of spec, proceed to maintenance (calibration) Section 6, unless the Model 614 is under warranty.

WARNING

Verification should be performed by qualified personnel using accurate and reliable test equipment.

4.5 INITIAL CONDITIONS

The Model 614 must be turned on and allowed one hour for warmup. If the instrument has been subjected to extremes of temperature, allow sufficient time for internal temperatures to reach normal operating conditions specified in paragraph 4.2. Typically it takes one hour to stabilize a unit that is 10°C (18°F) out of the specified temperature range.

CAUTION

Do not exceed maximum input. Instrument damage may result. Maximum input is stated in the specifications.

4.6 VOLTS VERIFICATION

Verify the voltage function as follows:

1. Depress ZERO CHECK and select Volts (V).
2. Select 0.2V range. Adjust VOLTS ZERO pot (R103) for .00000 ±1 digit on the display.
3. Apply input (see Figure 4-1) as specified in Table 4-2. Release ZERO CHECK.
4. Verify that reading is within specifications in Table 4-2.
5. Select remaining ranges and repeat steps 3 and 4.
6. Repeat steps 2 thru 5 with negative voltage.

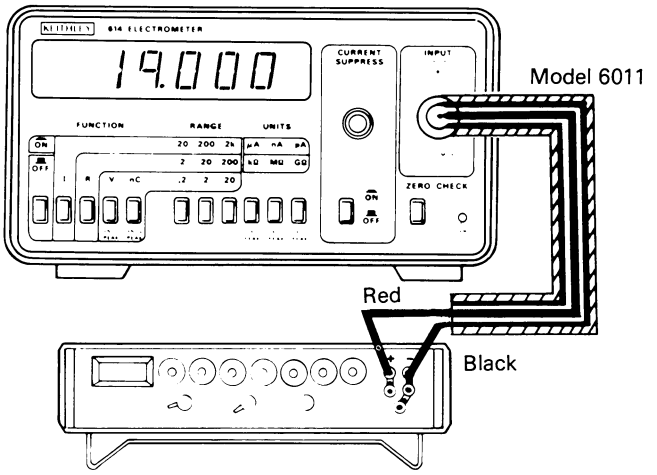


Figure 4-1. DC Volts Verification

Table 4-1. Performance Verfification Equipment

ITEM	DESCRIPTION	SPECIFICATION	MFR	MODEL
A	DC Calibrator	.19V, 1.9V, 19V .002%	Fluke	343A
B	DMM 5½-digit	.01% (2V range)	Keithley	191
C	$9.8 \times 10^9\Omega$ resistor	±2%, <.1%/°C	Keithley	R-289-9.8GΩ
D	1000pF Polystyrene	±2.5% <100ppm/°C	Keithley	C-252-.001
E	Decade Resistor	1Ω-10MΩ .03%	ESI	DB-62

Table 4-2. Volts Verification

RANGE	APPLIED INPUT FROM ITEM A TABLE 4-1	ALLOWABLE READING AT 18°C - 28°C
.2V	0.19000V	.18983 to .19017*
2V	1.9000V	1.8984 to 1.9016
20V	19.000V	18.984 to 19.016

*See Volts Zero Verification (paragraph 2.3.2).

4.7 CURRENT VERIFICATION

Make current verification as follows:

1. Select Current (I), 200μA range and depress ZERO CHECK
2. Configure the DC calibrator (Item A), decade resistor (Item E) and the Model 614 as shown in Figure 4-2.

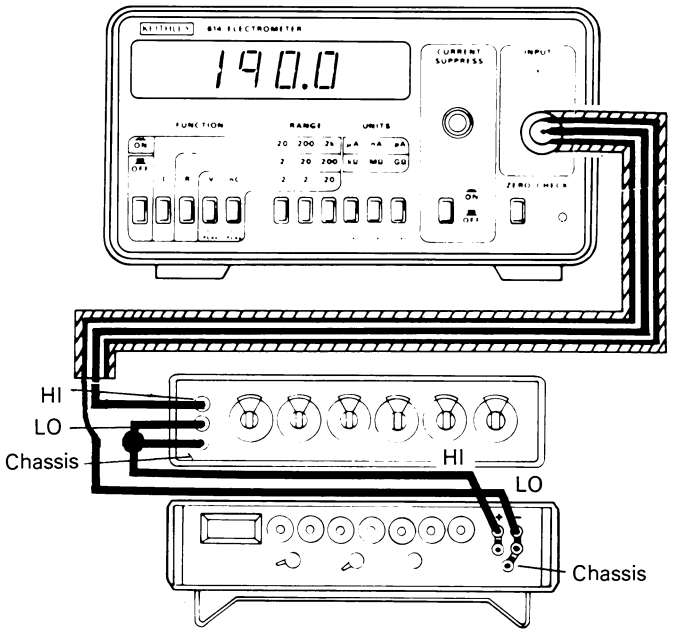


Figure 4-2. Current Verification

3. Set the decade resistor to 10.00kΩ and set the DC calibrator to 1.900V.
4. Release ZERO CHECK and verify that the display reads between 189.3 and 190.7.
5. Depress ZERO CHECK and select the 200nA range on the Model 614.
6. Repeat steps 3 and 4 using 10.00MΩ and 1.900V. Verify the reading is between 189.0 and 191.0.
7. Depress ZERO CHECK and select the 2000pA range.

NOTE

Step 8 may yield erroneous results if Volts Zero has not been verified (paragraph 4.6).

8. Repeat steps 3 and 4 using 10.00MΩ and .01900V. Verify that the reading is between 1871 and 1929.

4.8 INPUT CURRENT VERIFICATION

Make input current verification as follows:

NOTE

This must be performed at 23°C ±1°C.

1. Disconnect all cables from the Model 614 input.
2. Select Current (I), 20pA range and depress ZERO CHECK.
3. Connect Analog Output COM (rear panel) to Chassis Common.
4. Release ZERO CHECK. Allow one minute for the reading to stabilize.
5. Verify reading is less than six counts. Depress ZERO CHECK.
6. Disconnect Analog Output COM from Chassis Common.

4.9 RESISTANCE VERIFICATION

Make resistance verification as follows:

NOTE

DC Volts verification and Current verification must be performed before Resistance verification is performed.

1. Select Resistance (R), 20kΩ range and depress ZERO CHECK.
2. Configure the Model 614 and the decade resistor (Item E) as shown in Figure 4-3.
3. Set the decade resistor (Item E) to 19.000kΩ. Release ZERO CHECK.
4. Verify that the reading is within the limits specified in Table 4-3. Depress ZERO CHECK.

5. Select the remaining ranges listed in Table 4-3. and repeat steps 3 and 4 with the appropriate inputs as given in Table 4-3.

Table 4-3. Resistance Verification

RANGE	INPUT	ALLOWABLE READING 18°C - 28°C
20kΩ	19.00kΩ	18.89 to 19.11
200kΩ	190.0kΩ	188.9 to 191.11
20MΩ	10.00MΩ	9.90 to 10.10

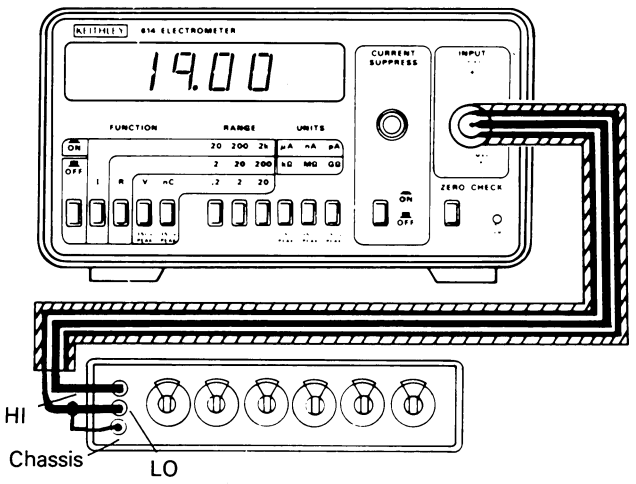


Figure 4-3. Resistance Verification

6. Verify the performance of the GΩ ranges using the following procedure:

A. Standardize the 9.8 x 10^9Ω resistor as follows:

(a) Select Current (I), 20nA range and depress ZERO CHECK.
(b) Configure the DC calibrator (Item A) decade resistor (Item E) and the Model 614 as shown in Figure 4-4.
(c) Set the DC calibrator to 0.1V and set the decade resistor to 10MΩ.
(d) Release ZERO CHECK. Take note of the displayed reading (approximately 10.00nA). Depress ZERO CHECK.
(e) Substitute the 9.8 x 10^9Ω resistor (Item C) for the decade resistor (it may be necessary to shield the resistor to obtain a stable reading). Release ZERO CHECK.

WARNING

The following step requires the use of high voltage. Take care to prevent contact with live circuits which could cause electrical shock resulting in injury or death.

(f) Dial the DC calibrator until the Model 614 display reads as in step (d). The calibrator voltage will be approximately 100V.
(g) Divide the calibrator voltage obtained in step (f) by 10 to obtain the value of the resistor in GΩ. Record this result. Depress ZERO CHECK.
(h) Dial the calibrator to Zero.

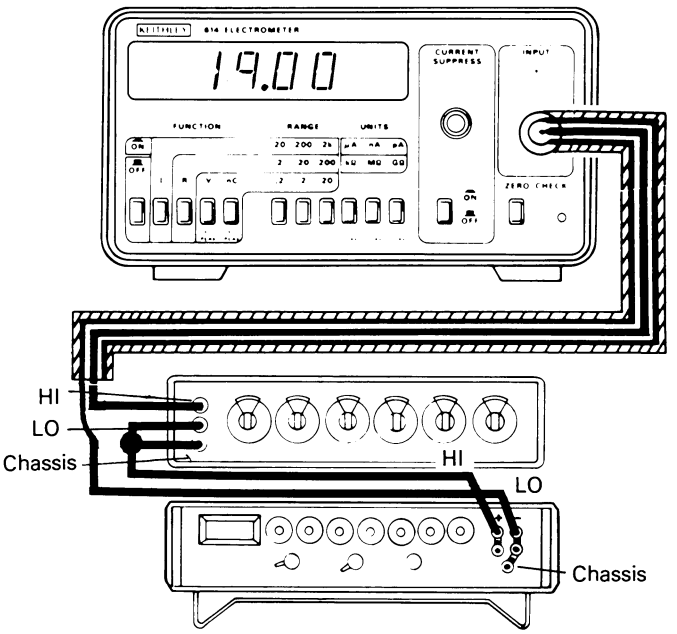


Figure 4-4. Resistor Standardization

B. Select the 20GΩ range. Apply the standardized resistor obtained in step A to the input.

NOTE

It may be necessary to shield the resistor (connect the shield to input LO) to obtain a stable reading. Do not handle the resistor by the body. This will contaminate the resistor and yield erroneous results. It is advisable to connect this resistor directly to Input HI. Any cables used to connect the resistor to the Model 614 must be guarded. See section 2.4.1.

C. Release ZERO CHECK. Verify that the reading is the same as in step A (g), ±2%.
D. Depress ZERO CHECK.
E. If the 20GΩ range is in order, it is only necessary to verify input impedance (on Volts) to guarantee proper operation of the 200GΩ range.
F. Input Impedance Verification.
   (a) Select Volts (V), 20V range and depress ZERO CHECK.
   (b) Apply 19.000V to the Model 614 from the DC calibrator. Release ZERO CHECK and note the reading.
   (c) Depress ZERO CHECK and place the 9.8 x $10^9\Omega$ resistor in series with input HI lead.

NOTE

It will be necessary to place the resistor as physically close to the Model 614 input as possible. This avoids errors due to cable resistance. If cables cannot be avoided, guarding must be employed. See section 2.4.1.

NOTE

It may be necessary to shield the resistor (shield connected to input LO) to avoid electrostatic interference and noise.

   (d) Repeat step (b). Wait a few seconds before noting the reading. This will allow the reading to settle.
   (e) Compare the reading obtained in step (b) to the reading obtained in step (d). Verify that the readings are within four digits (4mV) of each other.

4.10 CHARGE (nC) VERIFICATION

To confirm Coulombs operation, proceed as follows:
1. Turn the Model 614 on. Depress ZERO CHECK. Set the DC (Item A) calibrator to 00.000.
2. Connect the 1000pF capacitor, the calibrator, and the Model 614 as shown in Figure 4-5.
3. Select the 2nC range on the Model 614. Release ZERO CHECK.
4. Dial 1.0000V on the DC calibrator.
5. Verify that the display reads between 0.9500 and 1.0500 nC.
6. Depress ZERO CHECK and reduce calibrator output to 00000.

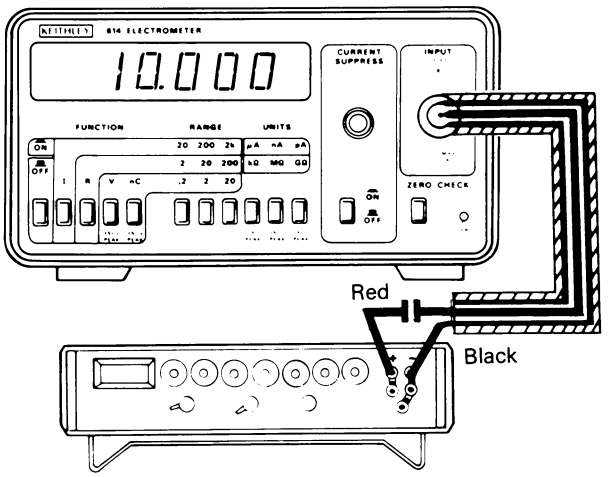


Figure 4-5. Charge Verification

SECTION 5
THEORY OF OPERATION

5.1 INTRODUCTION

The Model 614 Electrometer is a multifunction meter capable of detecting currents as low as 10^{-14}A, providing high input impedance ($5 \times 10^{13}\Omega$) on Volts and measuring up to 200GΩ with minimal error. To accomplish this, the Model 614 includes a special preamplifier circuit which gives it the electrometer characteristics. A second stage voltage amplifier scales the preamplifier output so that the A/D circuit will receive 2V input for full range. Figure 5-1 shows an overall block diagram for the Model 614.

5.2 INPUT PREAMPLIFIER

The Input Preamp is designed to provide high input impedance for the Volts and Resistance functions, and low input impedance (with 6×10^{-14}A input current) for the Current and Coulombs functions. Refer to Figure 5-2 for the basic circuit configurations provided for the different functions. The preamp becomes a high input impedance, unity-gain buffer amplifier in the Volts function. In the Resistance function, a boot-strapped voltage source in series with a range resistor drive a constant current through the

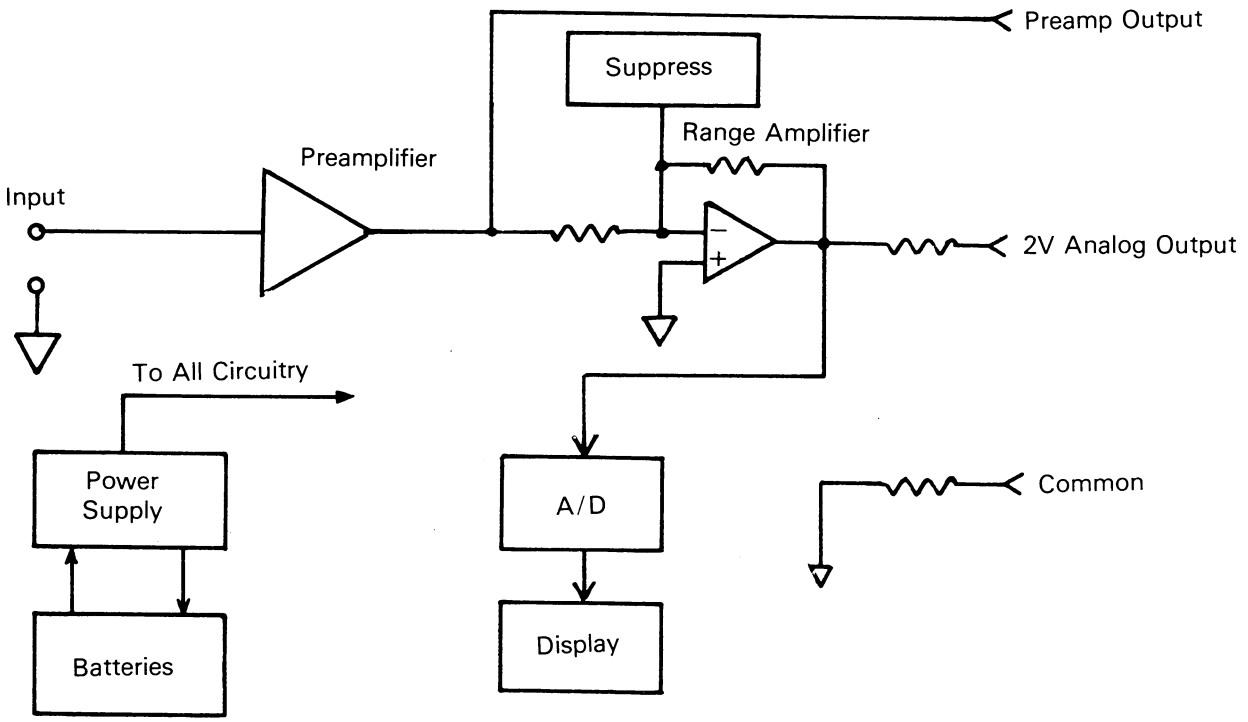


Figure 5-1. Model 614 Block Diagram

unknown. The voltage developed across the unknown resistance is proportional to its resistance. This voltage is present at the output of the unity-gain buffer, and thus provides an output voltage proportional to the resistance under test. In the Current (I) and Charge (nC) functions, the preamplifier is configured as a feedback current to voltage converter. Feedback resistor R is selected by the front panel buttons labeled μA, nA and pA. Each configuration will now be considered.

5.3 VOLTS

In the Volts function the Model 614 is configured as a high impedance unity-gain buffer amplifier capable of measuring up to 20V with >5 x $10^{13}\Omega$ input impedance. Refer to Figure 5-3. The JFET pair Q104 is the sensitive input device. U102, Q101, Q102, Q104, CR101 and CR102; and associated components are configured as a high impedance buffer amplifier. CR101 and CR102 provide a constant current 1mA bias for VR101 and VR102. Q101 and Q102 buffer this voltage and supply drive for U101 and U102. R113, C107, and R112 provide input protection without sacrificing stability. C101, C102, and C106 provide unity-gain frequency compensation to the amplifier. Resistors R115 and R116 are a matched pair, providing 30μA bias to Q104. If the input FET pair is ever replaced, reinstall jumpers W101 and W102 and follow the procedure for nulling the input offset voltage. This procedure is outlined in Paragraph 6.4.2.

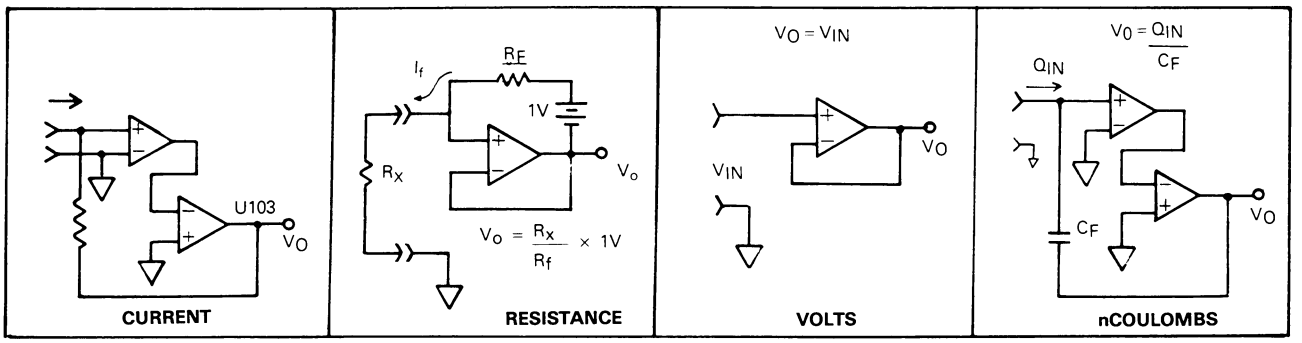


Figure 5-2. Basic Circuit Configurations

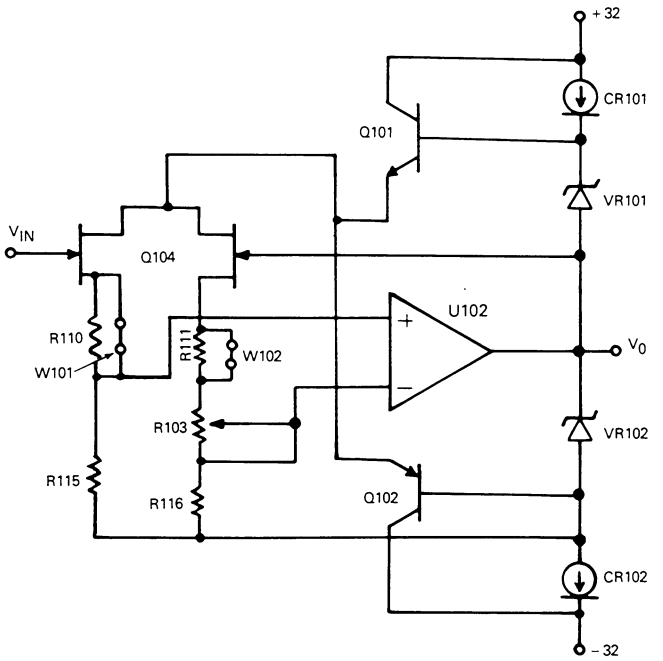


Figure 5-3. Volts Configuration

5.4 RESISTANCE

The Resistance function operates similar to the Volts function, except that a reference voltage of 1V is generated by U101, VR101, and associated components. Potentiometer R101 sets this voltage which can be measured between TP1 and TP2. Refer to Figure 5-4. R104, R105, C104, and C108 stabilize the reference.

The series feedback resistor is selected by the front panel buttons labeled kΩ, MΩ, GΩ. Table 5-1 summarizes this selection.

Table 5-1. Feedback Resistors

UNITS SELECTION	RELAY	R_{FB}	C_{FB}
kΩ	K103	R121, (R108 on 200Ω)	C112
MΩ	K102	R102,	C111
GΩ	K101	R117,	C109

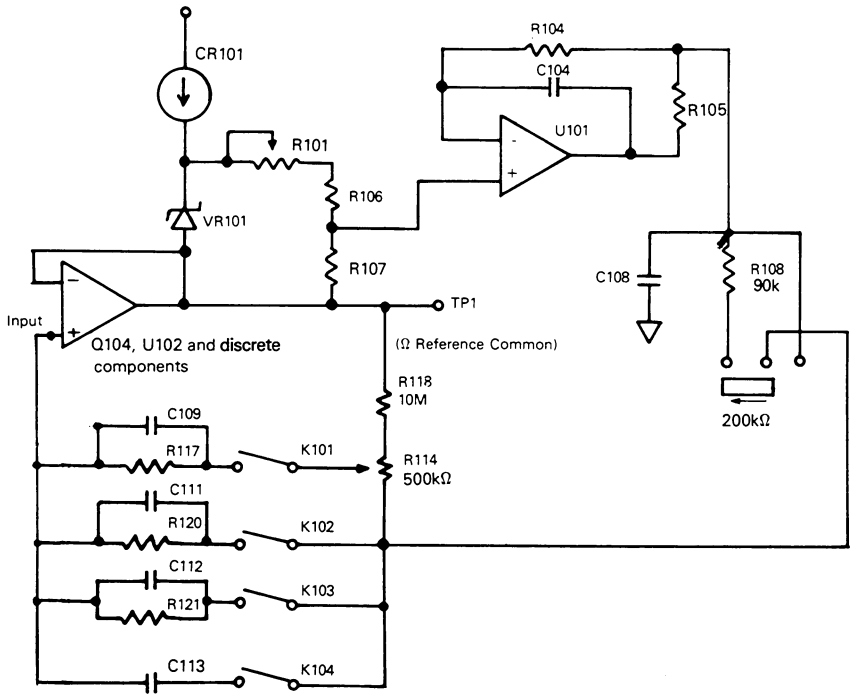


Figure 5-4. Resistance Configuration

Capacitors C109, C111, and C112 provide frequency stability to the feedback circuit.

No calibration is necessary for R120 and R121. However, R117 is a 9.8 x $10^9\Omega$ HI meg resistor requiring calibration. This is provided by R114. Resistors R114 and R113 form a voltage divider at the amplifier output which makes R117 "look" like its value is being calibrated.

NOTE

This calibration is done for the 2000pA range. Once it is set, the GΩ ranges are calibrated. It is not touched during Resistance calibration. Resitance calibration involves adjusting R101 and monitoring TP1 for 1.0000V ±500μV. See paragraph 6.4.3

For the 200kΩ range, it is necessary to switch R108 in series with the resistor R121. This keeps the compliance voltage across the unknown below 2V, thus limiting the power dissipation.

5.5 CURRENT AND CHARGE

When either the Current (I) or Charge (nC) function is selected, the input preamplifier configures itself as a current to voltage amplifier. Refer to Figure 5-5.

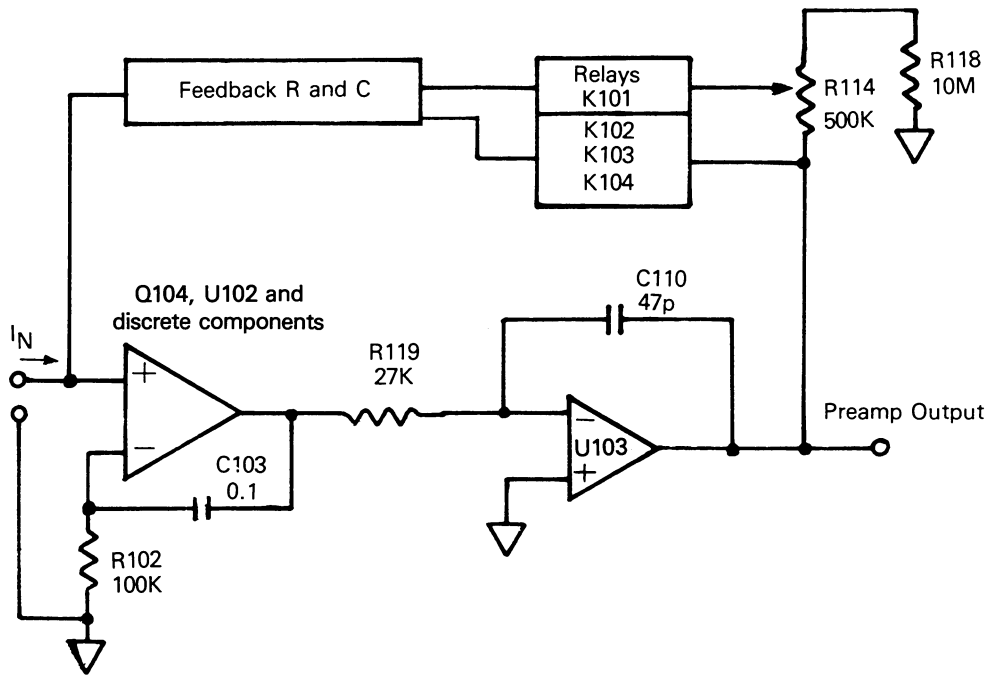


Figure 5-5. Model 614 Preamplifier Configured in Current or Coulombs

In this mode the output from the Volts input buffer is fed into U103 via R119 and C110. High voltage op amp U103 serves two purposes:

1. Provides ±20V swing necessary to cover all Current ranges.
2. Provides the inversion necessary for feedback current.

The supply voltages to U103 are regulated ±32V and are discussed in paragraph 5.8.3.

Since at DC U102 and U103 operate without local feedback, the DC loop gain exceeds 10^{10}. This means that the accuracy depends on the feedback resistor selected. To frequency compensate this circuit, multiple poles and zeroes are required. This compensation is provided by R102, C101, C103, R119, and C110.

Note that the composite current amplifier circuit behaves like an op amp with a single pole for frequencies above 10Hz.

The appropriate feedback element is selected by the μA, nA, pA, or nC buttons on the front panel. Table 5-2 is a list of the values selected.

Table 5-2. Feedback Elements

UNITS SELECTED	RELAY	ELEMENTS SELECTED
μA	K103	R121, C112
nA	K102	R120, C111
pA	K101	R117, C109
nC	K104	C113

Capacitors C109, C111, and C112 provide frequency compensation and cancel the effect of cable capacitance on the input. These capacitors also set the preamp settling time.

The only feedback resistor requiring calibration is R117. This resistor is calibrated by R114 on the 2000pA range.

The feedback relays K101 - K104 are low-leakage devices displaying > $10^{14}\Omega$ at environmental extremes.

5.6 ZERO CHECK

The Zero Check actuator is a mechanical spring, actuated by the ZERO CHECK button. when Zero Check is in, the input impedance of the instrument changes. For more detail, see Figure 2-1.

Resistor R113 prevents damage to the instrument during overload when Zero Check is operated. Resistors R112 prevents the use of the Zero Check function from damaging the input FETS.

5.7 RANGING CIRCUIT

The ranging circuit converts the output of the preamplifier into a ±2V output for a full range input. Refer to Figure 5-6. As seen, the circuit is a simple inverting amplifier with a gain of 10, 1, or 0.1. The gain is selected according to the range buttons on the front panel. The following table summarizes the gains selected.

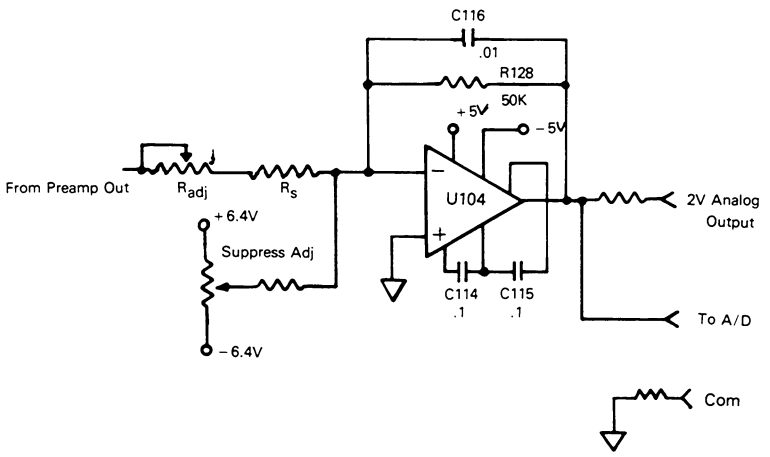


Figure 5-6. Model 614 Ranging Circuit

Table 5-3. Gain Selection

RANGE (VOLTS)	RESISTOR R_S	ADJUSTMENT	GAIN
.2	R125	R124	10
2	R129	R127	1
20	R130	R131	0.1

The only exception to Table 5-3 is the 200kΩ range, which selects R129 and R127. This is required to scale the 2V full range from the Resistance converter as described earlier.

U104, C114, and C115 comprise a high-performance chopper amplifier which eliminates the zero adjust for this stage. C116 and R128 are the feedback elements in this circuit which set the gain (along with R_S described above) and the response time at the 2V analog output. Q105 and Q106 provide overload protection to this circuit. R205, R122 and R126 provide the suppression feature.

Since this is an inverting amplifier, the output at the 2V analog output is inverted in Volts and Resistance. It is not inverted in Current and Charge, since it cancels the inversion the preamplifier provides.

5.8 POWER SUPPLY

The Power Supply can be broken down into several sections:

- Battery Charging Circuit
- Battery Shutdown Circuit
- DC - DC Converter

5.8.1 Battery Charging Circuit

The battery charging circuit is composed of U109, Q113, CR104, R141, R144, and C120. Transformer T101 and its associated components convert line voltage to 15VDC (present at TP3) which is filtered by C123. This voltage becomes the input to U109, which is an adjustable 3-terminal regulator. The output voltage from this regulator provides the float limit for the batteries of 9.5V. This voltage is set by R140.

During charge the output voltage will be in the range of 8V - 9.4V. The regulator will be saturated, which limits power dissipation. Maximum current drawn through the regulator is 600mA. When the batteries become fully charged (float charge), U109 trickle charges the batteries.

During float charge the battery voltage is maintained at 9.5V. As long as AC power is applied to the instrument, the batteries are maintained at this voltage. Current drawn from the regulator during float charge is essentially the current required to power the circuitry, which is 200mA assuming the instrument is turned on.

When the AC line is disconnected, the voltage at the anode of CR104 decays (in about five seconds) to zero volts. This causes Q113 to turn off, disconnecting the regulator from the circuit. Thus, the batteries cannot discharge through U109 and associated components. When the line is reconnected, Q113 turns back on, and causes U109 to regulate. Capacitor C120 stabilizes U109.

Battery fuse F101 will blow if the batteries are installed backwards or if a circuit fault develops which causes high battery currents to flow (> 2A).

5.8.2 Battery Shutdown Circuit

When the instrument is battery operated, it is necessary to limit the discharge level of the batteries to 7.4V. If this is not done, the ability of the batteries to hold a charge will be impaired.

To accomplish this, a low voltage detector consisting of U107 and associated components is used. When the battery voltage is above 7.4V, the input to U107 (pin 2) is above the nominal threshold voltage of 1.15V. As soon as the battery voltage drops below 7.4V, U107 senses this and the output pin 3 (open collector) pulls low, turning on Q107 and shutting off Q109. This shuts off power to the instrument.

To prevent chatter, and to guarantee that the instrument does not turn on again until the batteries are charged above 8V, R133 provides hysteresis of 0.6V (referred to the battery terminals). Capacitor C119 prevents oscillations during the switching of U107.

5.8.3 DC to DC Converter

The battery voltage is used directly to supply the input to U108, which provides a regulated 5V to the A/D and display circuit. However, a DC to DC converter is required to convert the unipolar battery voltage into a regulated ±32V and -5V required by the preamplifier.

The heart of this converter is T102, Q110, and Q111. The clock circuit generates 100kHz which is divided down by

U105 to 25 kHz. Complementary drive is available directly from U105 and is used to drive Q110 and Q111. These transistors are power FETS - they turn on with 5V gate to source voltage and turn off with zero volt gate to source voltage. Together they drive T102 to create an AC output voltage at the secondary of T102. This AC voltage is rectified and filtered by CR105-107 and C117, C121, and C122.

A portion of the +32V output is fed back to Q112 which operates as an error amplifier whose output drives Q108. The reference for this amplifier is the 5V output from U108. Since Q108 drives the primary of T102, the composite circuit acts as a regulator which maintains ±32V and -5V in spite of battery voltage variations.

5.9 A/D CONVERTER

The Model 614 A/D Converter operates on the dual slope principle. The A/D circuitry consists of an integrated circuit U202 and its associated components. Internally the A/D converter operates as a 4½-digit converter with 20,000 counts full scale. The Volts and Charge functions are 4½-digit resolution, while the Current and Resistance function are 3½-digit resolution. The timing of the A/D converter is divided into three periods and is described in the following:

5.9.1 Auto Zero

The Auto Zero period is 100msec long which corresponds to 10,000 clock pulses. During this period, the reference voltage is stored on C-204. Also a feedback loop is closed around the integrator and comparator, charging the auto-zero capacitor C-203 (Pin 5, U202) to compensate for offsets within U202.

5.9.2 Signal Integrate

The Signal Integrate period is also 100msec long. Positive signals generate a negative going ramp at the integrator output. Negative signals generate a positive going ramp at the integrator output. The level of the integrated signal at the end of the signal integrate period is proportional to the average of the applied signal during this period. Since the signal integrate period lasts 100msec, the A/D converter exhibits high normal mode rejection particularly 50 and 60Hz line frequencies. C202 is the integrator capacitor. R210, CR201 and R208 linearize the integrator.

5.9.3 Reference Integrate

The Reference Integrate period is 200msec long which corresponds to 20,000 clock pulses. During this period the integrator is returned to baseline level by applying a reference voltage of a polarity opposite to that of the signal. The number of clock pulses required for the integrator to return to baseline level is proportional to the input signal. These clock pulses are then counted and outputted to the display drivers U201 and U203 as multiplexed BCD data for DS201-DS206.

5.9.4 Zero Integrator

The final phase is zero integrator. During this phase the feedback loop is closed around input high, causing the integrator output (U202 Pin 4) to return to zero. Normally this phase will last from 1-2msec. During overrange this phase will last about 16msec.

5.9.5 Reference Circuit

A precision 1.0000V reference is generated using U204, R211, R213 and R214 to provide constant current bias for VR201. R203, R204 and R206 divide the 6.35V output of VR201 to the necessary 1V level required by U202. R203 calibrates the reference.

SECTION 6
MAINTENANCE

6.1 INTRODUCTION

This section contains information necessary to maintain the Model 614. Adjustment calibration, troubleshooting and fuse replacement procedures are provided.

6.2 RECOMMENDED TEST EQUIPMENT

Recommended test equipment for calibration is listed in Table 6-1. Alternate test equipment may be used. However, the accuracy of the alternate test equipment must be at least four times better than the Model 614 specifications or equal to Table 6-1 specifications.

6.3 ENVIRONMENTAL CONDITIONS

The environmental conditions for calibration are 23°C ±1°C and a relative humidity of less than 70%.

The Model 614 must be turned on and allowed one hour for warmup. If the instrument has been subjected to extremes of temperature , allow sufficient time for internal temperatures to reach normal operating conditions specified in paragraph 4.2. Typically it takes one hour to stabilize a unit that is 10°C (18°F) out of the specified temperature range.

6.4 CALIBRATION PROCEDURE

Perform the following calibration procedure and make the adjustments indicated to calibrate the Model 614.

WARNING

All service information is intended for qualified electronic maintenance personnel only.

WARNING

To prevent a shock hazard, remove the line cord and all test leads from the instrument before removing any cover.

6.4.1 Power Supply Calibration

1. Turn the Model 614 OFF. Remove top cover. Remove F101 and connect the line cord to AC power.
2. Monitor the output of U109 with the 5½-digit DMM (Item B, Table 6-1). Refer to Figure 6-1.
3. Adjust R140 for an output (from U109) of 9.50V ±10mV.
4. Disconnect the line cord from AC power and connect the H-P 6227B (Item F) supply in place of the battery pack. Be sure the supply is off. Replace F101. (Refer to Figure 6-1.)
5. Adjust R138 to full counterclockwise and set the supply voltage to 9V. Turn the Model 614 ON and the supply ON.
6. Set the supply voltage to 7.4V. Adjust R138 slowly clockwise until the instrument shuts OFF.
7. Increase the supply voltage until the instrument turns back ON. Verify that the instrument does not turn ON until the supply voltage reaches greater than 8V.
8. Decrease the supply voltage until the instrument turns OFF. Verify that the cutout voltage is 7.4V ±.1V.
9. Monitor the +32V test point with the DMM. If the voltage is less than 29V remove R147.
10. Verify that the voltage in Step 9 is 29V-32V. If the voltage is outside of specifications, do not proceed with calibration. Instead, refer to Troubleshooting paragraph 6.6.

CAUTION

Do not exceed maximum allowable input voltage. Instrument damage may occur. Maximum allowable inputs are stated in the specifications.

Table 6-1. Performance Verification Equipment

ITEM	DESCRIPTION	SPECIFICATION	MFR	MODEL
A	DC Calibrator	.19V, 1.9V, 19V .002%	Fluke	343A
B	DMM 5½-Digit	.01% (2V range)	Keithley	191
C	9.8 x $10^9\Omega$ Resistor	±2%, <.1%/°C <20ppm/V	Keithley	R-289-9.8GΩ
D	1000pF Polystyrene	±2.5% <1000 ppm/°C	Keithley	C-252-.001
E	Decade Resistor	1Ω - 10MΩ .03%	ESI	DB-62
F	Power Supply	1A, 10V	H-P	6227B

6.4.2 Volts Calibration

1. Turn ON the power to the Model 614 and depress ZERO CHECK.

NOTE

Steps 2 and 3 will only be necessary when FET pair Q104 is replaced and jumpers W101 and W102 are reinstalled.

2. Select Volts (V), .2V range and adjust R103 to full counterclockwise.
3. Take note of the offset present on the display. Follow Table 6-2 and remove the appropriate jumper.

Table 6-2. Offset Jumper Set Up

OFFSET	CUT JUMPER
> +400 counts	W101
> −400 counts	none
between +400 counts and −400 counts	W101 and W102

4. Adjust the VOLTS ZERO pot on the front panel (R103, located directly underneath the input connector) for a display of .00000 ±1 digit.
5. Connect the DMM (Item B, Table 6-1) to the Model 614's 2V Analog Output.
6. Select the 20V range and dial the DC calibrator to 19.000V. Adjust R131 for a displayed reading on the DMM of -1.90000 ±50μV.
7. Select 2V range and dial the DC calibrator (Item A) to 1.9000V. Adjust R127 for a displayed reading on the DMM of -1.90000V ±50μV.
8. Adjust R203 for a displayed reading on the Model 614 of 1.9000 ±1 digit. Reverse the polarity of the input and verify that the reversal error is less than three counts.
9. Select the .2V range, dial the DC calibrator to .19000V. Adjust R124 for a displayed reading on the DMM of −1.90000V ±50μV.

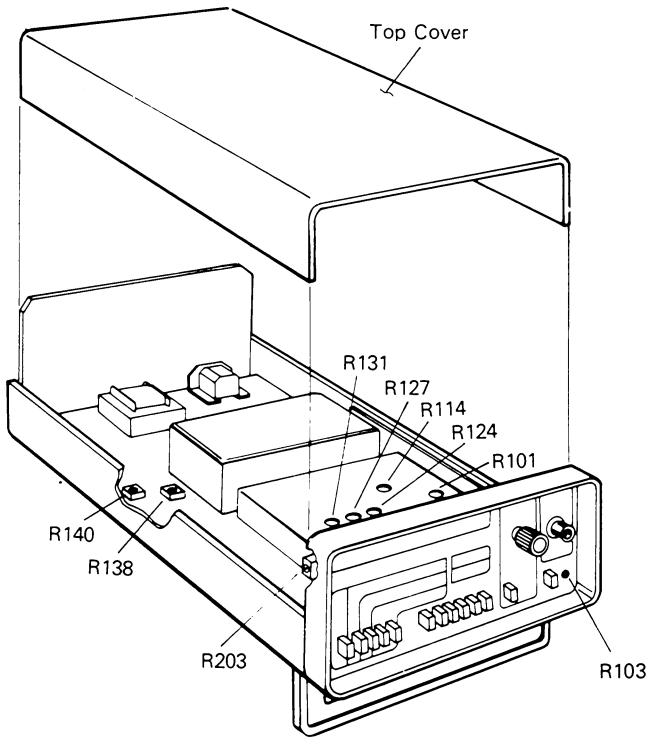


Figure 6-1. Top Cover Removal and Calibration Adjustment

6.4.3 Current and Resistance Calibration

NOTE

The Volts calibration must be completed before calibrating the Current and Resistance functions.

1. Verify VOLTS ZERO as described in paragraph 2.3.2
2. Select Current function, 2000pA range and depress ZERO CHECK.
3. Connect the DMM (Item B, Table 6-1) to TP1 and common.
4. Adjust R101 for a displayed reading on the Model 191 of 1.0000V $\pm$500μV. Disconnect the Model 191.
5. Connect the DB-62 (Item E), the DC calibrator (Item A), and the Model 614 as shown in Figure 6-2.

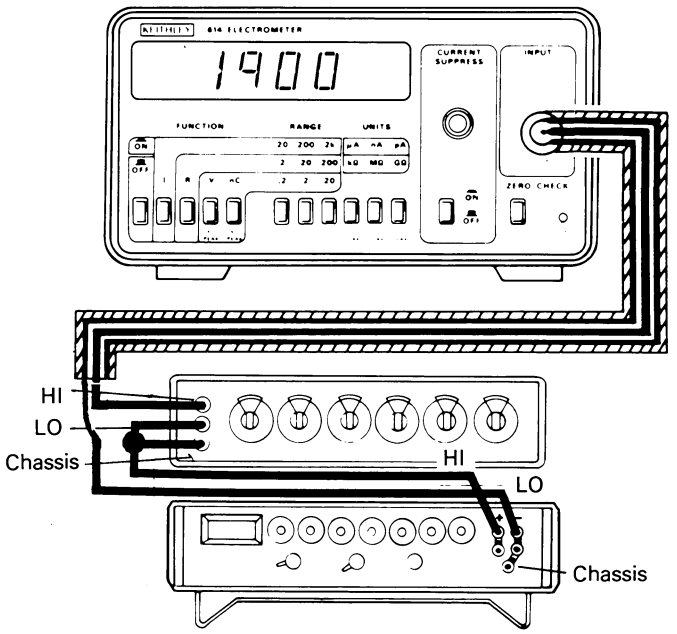


Figure 6-2. Current Calibration

6. Set the calibrator to 0.019000V. Set the DB-62 to 10 meg.

NOTE

It will be necessary to secure and shield the interconnects between the DB-62 and the Model 614 to prevent movement which will introduce noise into the measurement.

7. Release ZERO CHECK. Adjust R114 for a displayed reading of 1900 $\pm$1 count. This completes full calibration of Model 614.

6.5 SPECIAL HANDLING OF STATIC SENSITIVE DEVICES

CMOS devices are designed to function at high impedance levels. Normal static charge can destroy these devices. Table 6-3 lists all static sensitive devices for the Model 614. Step 1 through 7 provide instruction on how to avoid damaging these devices.

Table 6-3. Model 614 Static Sensitive Devices

REFERENCE DESIGNATION	KEITHLEY PART NUMBER
U105	IC-103
U106	IC-102
U202	LSI-41
Q110, Q111	TG-160

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 wriststrap.
3. Handle device by the body only.
4. PCBs must be grounded to bench while inserting devices.
5. Use antistatic solder suckers.
6. Use grounded tip soldering irons.
7. After devices are soldered or inserted into sockets they are protected and normal handling can resume.

6.6. TROUBLESHOOTING

The troubleshooting information in this section is intended for use by qualified personnel who have a basic understanding of the analog and digital circuitry used in a precision test instrument. Instructions have been written to assist in isolating the defective circuit. Isolating the defective component has been left to the troubleshooter. Refer to Table 6-4 for power supply checks, Table 6-5 for preamplifier circuitry checks and Table 6-6 for A/D converter checks.

NOTE

For instruments that are still under warranty (less than 12 months since date of shipment), if the instrument's performance is outside of specifications at any point, contact your Keithley representative or the factory before attempting troubleshooting or repair other than battery or fuse replacement.

Table 6-4. Power Supply Checks

STEP	ITEM/COMPONENT	REQUIRED CONDITON	REMARKS
		Unit on line power, F101 removed unless otherwise noted.	
1	TP3	14V to 19V	Output of CR103 Bridge Rectifier
2	CR104, cathode	Voltage in Step 1 minus .7V (diode drop)	
3	U109 output	+9.5V ±.1V at full charge	
4	U108 input	+8.5V ±0.25V	Input of +5V Regulator
5	U108 output	+5V ±0.25V	Output of +5V Regulator
6	Q110 drain (case)	0 to 11V square wave at 25kHz	Output of Inverter Drive
7	Q111 drain (case)	0 to 11V square wave at 25kHz	Output of Inverter Drive
8	CR105 cathode	+6V to −6V square wave at 25kHz	
9	CR107 cathode	+32V to −32V square wave at 25kHz	
10	−5V pad on PCB	−4.8V to −5.8V	−5V Supply
11	−32V pad on PCB	−29V to −32V	−32 Supply
12	+32V pad on PCB	+29V to +32V	+32V Supply

Table 6-5. Preamplifier Circuitry Checks

STEP	ITEM/COMPONENT	REQUIRED CONDITON	REMARKS
		Depress ZERO CHECK and select the Volts function 20V range.	
1	U102 pin 7	+5.8V ±5%	Preamp Floating Supply
2	U102 pin 4	−5.8V ±5%	Preamp Floating Supply
3	U102 pin 2 and pin 3	0 to 3V (within 10mV of each other)	FET Source Voltages
4	TP1	+1.0000V ±1mV	Ohms Reference
5	J1009 pin B	Adjust full span of R205 Current Suppress pot for +6.4 ±5% to −6.4 ±5%	Current Suppress Adjust
6	U104 pin 10	0V ±1mV	Range Amplifier Output
7		Input 10.000V	
8	U102 pin 6	10.000V ±1mV	Output of Voltage Buffer
9	U102 pin 7	+15.4V to +16.04V	Preamp Floating Supply
10	U102 pin 4	+3.9V to +4.9V	Preamp Floating Supply
11	U104 pin 10	−1.0000 ±.3mV	Range Amplifier Output
12		Select the Current function and the 2000μA range. Input 1mA ±5%	
13	U103 pin 6	−10V ±5%	

6.7 BATTERY REPLACEMENT

To replace batteries do the following procedure.

WARNING

To prevent a shock hazard, remove the line cord and all test leads from the instrument before removing any cover.

CAUTION

Take care not to short circuit battery terminals. Do not dispose of batteries by incineration.

1. Remove top cover.
2. Disconnect the two power leads from the battery terminals as shown in Figure 6-3, by removing the negative lead first.
3. Replace old batteries with a fresh battery pack (Keithley part number BA-35). Be careful to observe proper polarity, white lead is connected to battery + terminal; black is connected to − terminal.
4. Connect the power leads (positive lead first) and install top cover.

6.8 LINE FUSE REPLACEMENT

To replace F102 do the following procedure:

1. Turn the Model 614 off and unplug it (if it was plugged in).
2. Use a small screwdriver blade into the slot. Press gently and turn ¼ turn ccw. The fuse holder should pop out (refer to Figure 6-4).
3. Replace the fuse with the appropriate rating: 1/8A, 250V, 3AG (Keithley part number FU-20).

CAUTION

Installing a higher rated fuse than the one specified could result in damage to the instrument.

6.9 BATTERY FUSE REPLACEMENT

To replace F101 do the following:

1. Unplug the Model 614 and remove the top cover.
2. Carefully lift out F101. Replace with a fuse of appropriate rating (2A, 250V 3AG) Keithley part number FU-13.

Table 6-6. A/D Converter Checks

STEP	ITEM/COMPONENT	REQUIRED CONDITON	REMARKS
		Turn on power. Select 20V range, depress ZERO CHECK.	
1	Display	00.000	
2	U202 pin 10	0V ±0.1mV	A/D Input
3	U202 pin 2	1.0000V	Reference Voltage
4	U202 pin 22	0V to +5V square wave at 100kHz.	Clock input to the A/D Converter
5		Connect U202 pin 2 to U202 pin 10. Release ZERO CHECK	1V Reference connected to the A/D Input.
6	Display	−10.000 ±3 counts	If different, U202 is defective.

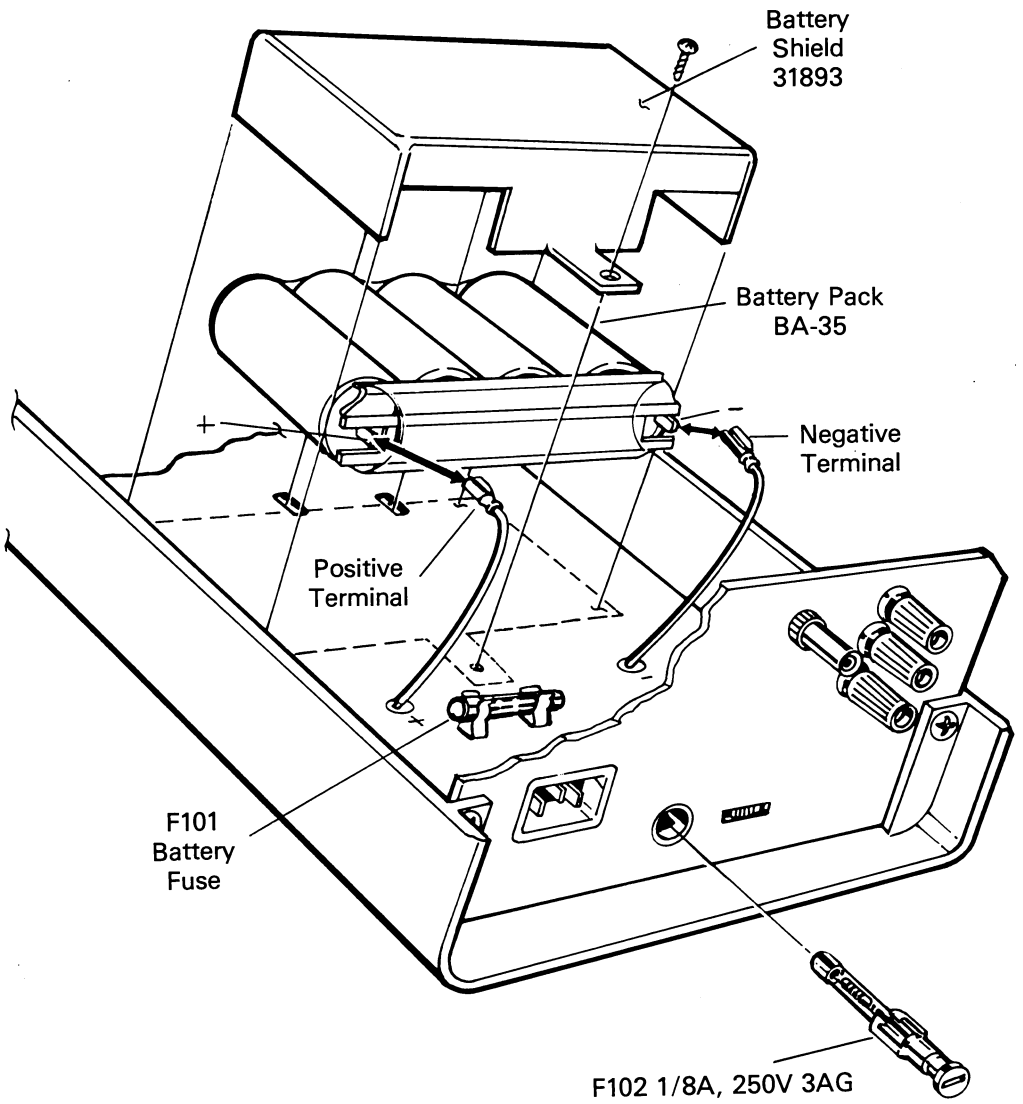


Figure 6-3. Battery Replacement

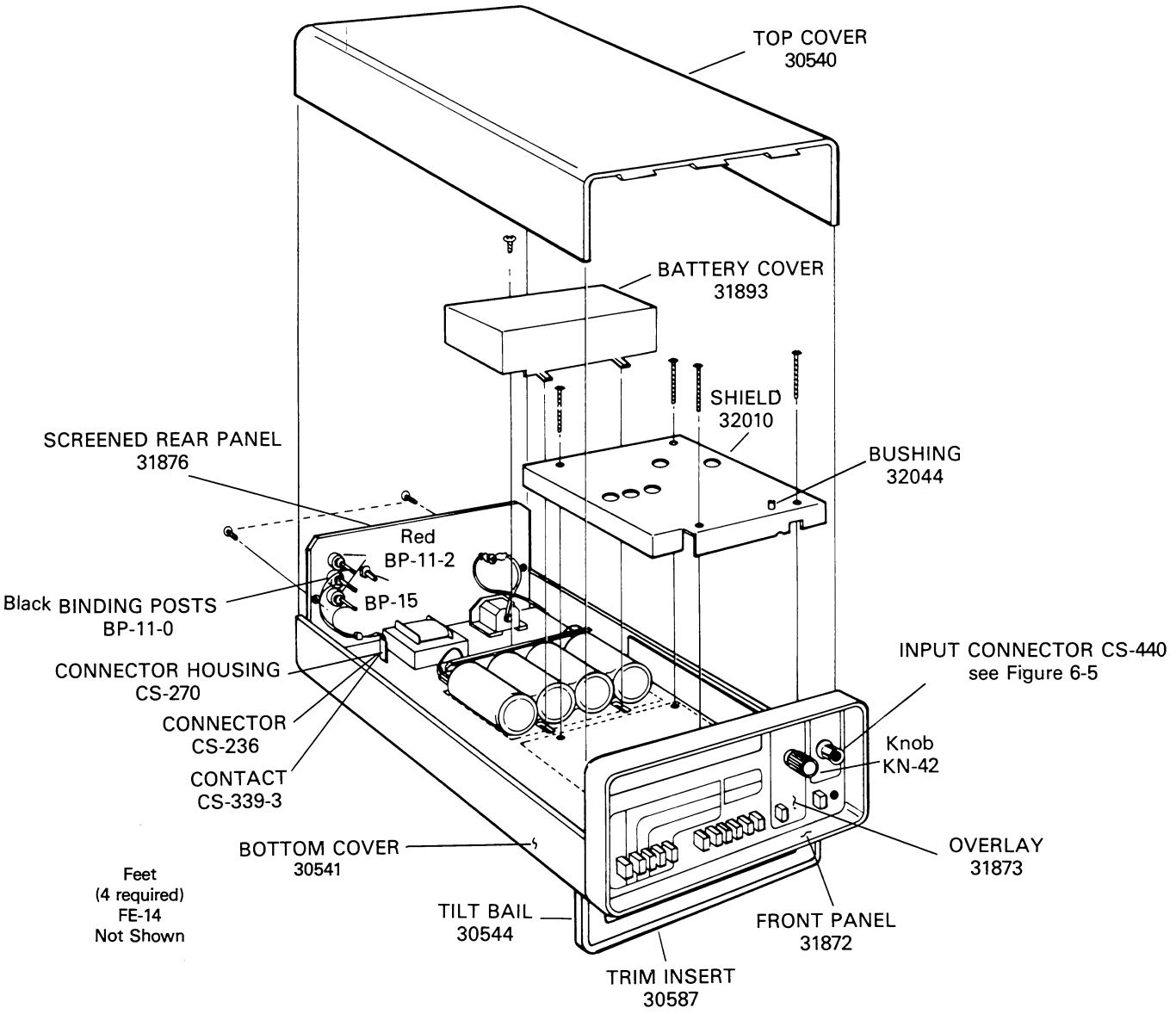
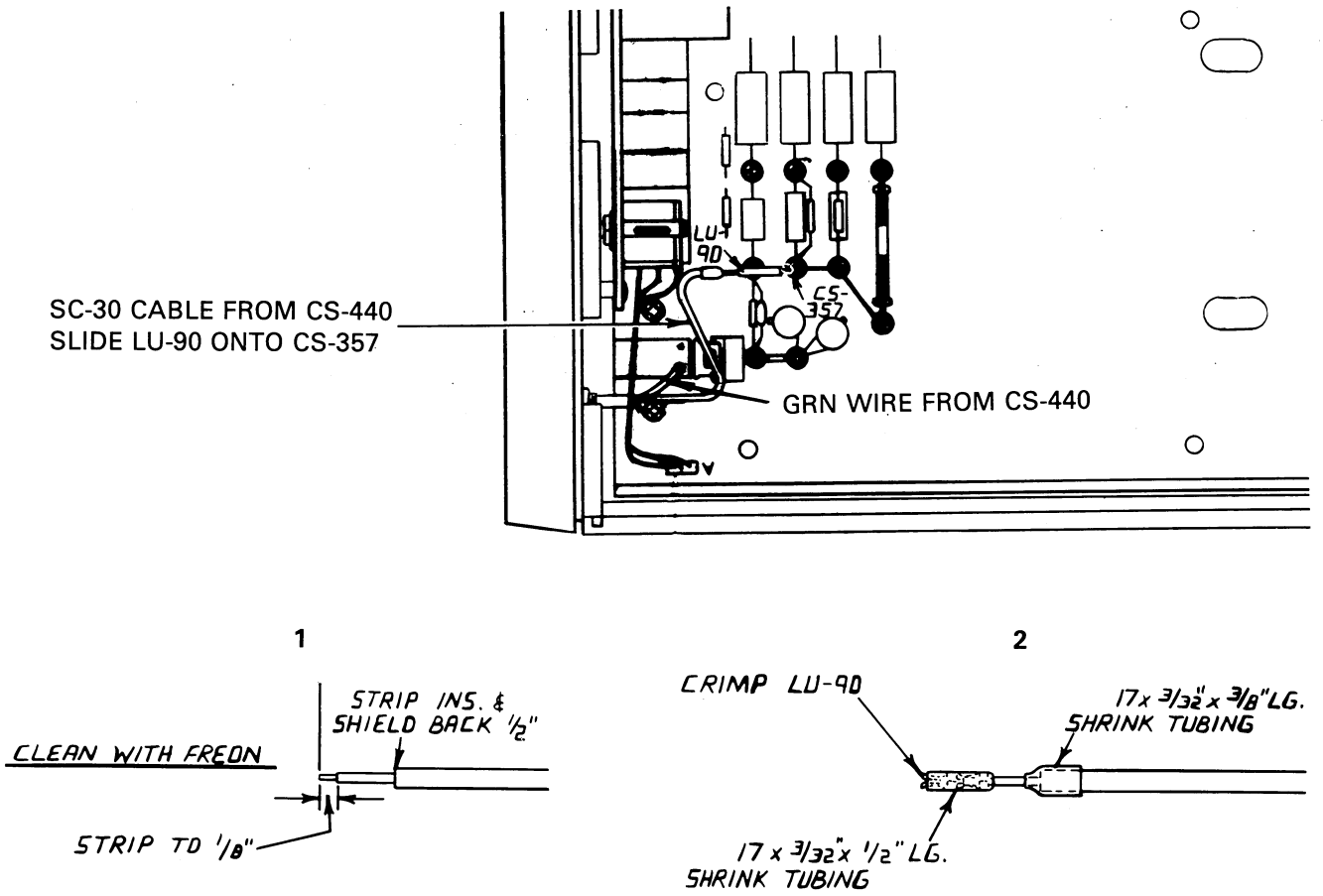


Figure 6-4. Exploded View



NOTE

After replacing any components related to the high impedance circuitry (e.g. input FETs, Feedback Resistors, Relays), do the following:

1. Clean with Methanol and clean cotton swab.
2. Blow dry with dry nitrogen gas.
3. Inspect for any residue (contamination) and repeat steps 1 and 2 if any residue is found.
4. Reassemble taking care not to touch the clean parts.

Figure 6-5. Input Connector Assembly

SECTION 7
REPLACEABLE PARTS

7.1 INTRODUCTION

This section contains replacement parts information, schematic diagrams, and component location drawings for the Model 614. A cross-reference table of manufacturers is also provided (see Table 7-1).

7.2 PARTS LIST

Parts are listed alphabetically in order of their circuit designations. Table 7-1 contains parts list information for the Model 614 Mother Board PC-596. Table 7-2 contains a parts list for the Model 614 Display Board PC-597.

7.3 ORDERING INFORMATION

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

1. Instrument Model Number
2. Instrument Serial Number
3. Part Description
4. Circuit Description (if applicable)
5. Keithley Part Number

If an additional instruction manual is required order the manual package (Keithley Part Number 31896-00). The manual package includes an instruction manual and all pertinent addenda.

7.4 FACTORY SERVICE

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

7.5 SCHEMATIC DIAGRAMS AND COMPONENT LOCATION DRAWINGS

Schematic diagrams and component location drawings follow the replaceable parts list information contained in this section. Figure 7-1 shows component location for the Electrometer Amplifier, Figure 7-2 shows component location for the Power Supply and Figure 7-3 contains component location information for the Display Board . Figure 7-4 is the schematic for the Model 614, Figure 7-5 is the schematic for the Power Supply and Figure 7-6 provides schematic information for the Display Board.

Table 7-1. Model 614 Mother Board PC-596

Circuit Desig.	Description	Location Sch	Location Pcb	Keithley Part No.
BT101	4 D-Size Lead-Acid Cells	A4	—	BA-35
C101	33p, 1000V, Cer D	D3	F1	C-64-33p
C102	.01μF, 100V, Mtl Poly	D3	F1	C-305-.01
C103	.1μF, 16V, Cer D	D3	F1	C-238-.1
C104	.1μF, 16V, Cer D	E2	F2	C-238-.1
C105	2200p, 500V, Phen	C2	E2	C-22-2200p
C106	2200p, 500V, Phen	C4	E2	C-22-2200p
C107	10p, 1000V, Cer D	B3	F2	C-64-10p
C108	2200p, 500V, Phen	E2	E2	C-22-2200p
C109	10p, 500V, Polysty	B1	F2	C-138-10p
C110	47p, 1000V, Cer D	F3	F3	C-64-47p
C111	100p, 630V, Polysty	B1	F3	C-252-100p
C112	.047μF, 250V, Metal Poly	B2	F3	C-178-.047
C113	1000p, 630V, Polysty	B2	F3	C-252-1000p
C114	.1μF, 100V, Metal Poly	G4	E3	C-305-.1
C115	.1μF, 100V, Metal Poly	G3	E3	C-305-.1
C116	.01μF, 100V, Metal Poly	G3	E4	C-305-.01
C117	22μF, 35V, Electro	E5	D5	C-309-22
C118	1.5μF, 25V, Alum	C5	E5	C-314-1.5
C119	3.3μF, 16V, Alum Elect	A4	C5	C-321-3.3
C120	10μF, 25V, Alum	C3	D5	C-314-10
C121	22μF, 35V, Electro	E5	D5	C-309-22
C122	10μF, 25V, Alum	E4	E5	C-314-10
C123	2200μF, 25V, Alum	B1	C5	C-314-2200
C124	10μF, 25V, Alum	E3	D5	C-314-10
C125	10μF, 25V, Alum	D4	E5	C-314-10
C126	100p, 1000V, Cer D	G6	F5	C-64-100p
CR101	Diode (JFET)	C2	E2	TG-159
CR102	Diode (JFET)	C4	E2	TG-159
CR103	Rectifier, Bridge	B2	B5	RF-48
CR104	Rectifier	A3	C5	RF-47
CR105	Rectifier	D5	E5	RF-28
CR106	Rectifier	D5	E5	RF-28
CR107	Rectifier	D5	E5	RF-28
CR108	Rectifier	C3	C4	RF-47
F101	Fuse, 2A, 250V, 3AG	A3	B2	FU-13
F102	Fuse, 1/8A, 250V, 3AG	A2	B3	FU-20
J1002	Pin	—	F2	CS-357
J1008	Display Socket	H3	F5	SO-65
J1009	Connector (FP Pot)	A5	G1	CS-339-3
J1011	Lug	—	C2	LU-87
J1012	Lug	—	C3	LU-87
P1002	Lug	—	—	LU-90
P1007	Connector	F1	B5	CS-270
P1010	Line Socket	—	—	CS-388
P1013	Lug	A3	—	LU-90
Q101	NPN, Transistor, MPS 8099	D2	E1	TG-157
Q102	PNP, Transistor, MPS 8599	D4	E1	TG-158
Q104	Selected TG-156	C3	F2	32012
Q105	JFET, N Channel, PF5301	G2	E4	TG-139

Table 7-1. Model 614 Mother Board PC-596 (Cont.)

Circuit Desig.	Description	Location Sch	Location Pcb	Keithley Part No.
Q106	JFET, N Channel, PF 5301	H2	E4	TG-139
Q107	Transistor, PNP, 2N3906	D2	D5	TG-84
Q108	Transistor, PNP, Darlington, MPS-U95	D3	D5	TG-133
Q109	Transistor, PNP, Darlington, MPS-U95	D2	D5	TG-133
Q110	MOS FET, VN 40 AF	C4	E5	TG-160
Q111	MOS FET, VN 40 AF	C6	E5	TG-160
Q112	Transistor, NPN, 2N3904	D3	D5	TG-47
Q113	Transistor, NPN, 2N3904	C4	C5	TG-47
R101	10k, 10%, Cermet	D2	E1	RP-97-10k
R102	100k, 5%, 1/4W, Carb	D2	F1	R-76-100k
R103	500Ω, 10%, 3/4W	C3	G1	RP-89-500
R104	10k, 5%, 1/4W, Carb	E2	E2	R-76-10k
R105	10k, 5%, 1/4W, Carb	E2	E2	R-76-10k
R106	49.9k, 1%, 1/8W, MtF	D2	E2	R-88-49.9k
R107	10k, .1%, 1/8W, MtF	D2	E2	R-176-10k
R108	90k, .1%, 1/8W, MtF	E3	E2	R-179-90k
R109	47Ω, 1/4W, Carb	C2	E2	R-76-47
R110	499Ω, 1%, 1/8W, MtF	C3	F2	R-88-499
R111	243Ω, 1%, 1/8W, MtF	C3	F2	R-88-243
R112	680k, 5%, 1/4W, Carb	B2	F2	R-76-680k
R113	10M, 10%, 1/4W, Carb	B2	F2	R-76-10M
R114	500k, 10%, Cermet	F2	E2	RP-97-500k
R115	Matched set with R116	C3	E2	R-306
R116	Matched set with R115	C3	F2	R-306
R117	9.8G, 2%, Epoxy Coated	B1	F2	R-289-9.8G
R118	10M, 10%, 1/4W, Carb	E2	E3	R-76-10M
R119	27k, 5%, 1/4W, Carb	E3	E3	R-76-27k
R120	10M, .25%, 1/8W, MtF	B2	F3	R-305-10M
R121	10k, .1%, 1/2W, MtF	B2	F3	R-169-10k
R122	150k, 1%, 1/8W, MtF	B5	G3	R-88-150k
R123	9.09k, 1%, 1/8W, MtF	H3	D3	R-88-9.09k
R124	50Ω, 10%, Cermet	F3	E3	RP-97-50
R125	5.025k, .1%, 1/10W, MtF	G3	E3	R-263-5.025k
R126	1.2M, 10%, 1/4W, Carb	C5	G3	R-76-1.2M
R127	500Ω, 10%, Cermet	F5	E3	RP-97-500
R128	50k, .1%, 1/10W, MtF	G3	E4	R-263-50k
R129	55.3k, .1%, 1/10W, MtF	G3	E4	R-263-55.3k
R130	498k, .1%, 1/10W, MtF	G4	F4	R-168-498K
R131	5k, 10%, Cermet	F4	E4	RP-97-5k
R132	100k, 5%, 1/4W, Carb	B3	C5	R-76-100k
R133	5.6M, 10%, 1/4W, Carb	B3	C5	R-76-5.6M
R134	90.9k, 1%, 1/8W, MtF	B4	C5	R-88-90.9k
R135	402k, 1%, 1/8W, MtF	B4	C5	R-88-402k
R136	100k, 1%, 1/8W, MtF	A3	C5	R-88-100k
R137	100k, 5%, 1/4W, Carb	B3	C5	R-76-100k
R138	100k, 10%, Cermet	A3	C5	RP-97-100k
R139	1k, 10%, 1/2W, Carb	G2	B5	R-1-1k
R140	200Ω, 10%, Cermet	C3	C5	RP-97-200
R141	866Ω, 1%, 1/8W, MtF	C4	C5	R-88-866
R142	10k, 5%, 1/4W, Carb	C3	C5	R-76-10k
R143	1.8k, 5%, 1/4W, Carb	C4	C5	R-76-1.8k
R144	150Ω, 1%, 1/8W, MtF	C3	C5	R-88-150
R145	100k, 5%, 1/4W, MtF	E3	D5	R-76-100k

Table 7-1. Model 614 Mother Board PC-596 (Cont.)

Circuit Desig.	Description	Location Sch	Location Pcb	Keithely Part No.
R146	24.9k, 1%, 1/8W, MtF	D4	D5	R-88-24.9k
R147	200k, 5%, 1/4W, MtF	E4	D5	R-76-200k
R148	3.83k, 1%, 1/8W, MtF	D4	D5	R-88-3.83k
R149	33k, 5%, 1/4W, Carb	D3	D5	R-76-33k
R150	22M, 5%, 1/4W, Carb	F5	E5	R-76-22M
R151	47k, 5%, 1/4W, Carb	G5	E5	R-76-47k
R152	150Ω, 5%, 1/4W, Carb	F3	F5	R-76-150
R153	100Ω, 5%, 1/4W, Carb	E4	D4	R-76-100
K101	Relay E-T R7526-1	B1,G5	F3	RL-70
K102	Relay E-T R7526-1	B2,G5	F3	RL-70
K103	Relay E-T R7526-1	B2,G5	F3	RL-70
K104	Relay E-T R7526-1	B2,G5	F3	RL-70
S101	Switch, Slide	A1	B3	SW-318
S102	Switch, Pushbutton	SEV	G2	SW-436
T101	Transformer, 115V Version	B1	B4	TR-168
T101	Transformer, 90V, Version	B1	B4	TR-169
T102	Transformer	D5	E5	TR-193
U101	Op Amp, AD741k	D2	E1	IC-97
U102	Op Amp, LM308A	D3	F1	IC-203
U103	Op Amp, LM343H	F3	E3	IC-254
U104	Op Amp, ICL 7650 CPD	G3	E3	IC-316
U105	D Flip Flop, Dual, 4013	B5	E5	IC-103
U106	2 Input Nand, Gate, Quad, 4011	SEV	F5	IC-102
U107	Micro Power Detector, ICL 8211CPA	B3	D5	IC-177
U108	3 Terminal +5V Regulator, 7805	D3	D5	IC-93
U109	3 Terminal Adjustable Regulator, LM317T	C3	C5	IC-317
VR101	Diode, Zener, 6.4V	D2	E2	DZ-60
VR102	Diode, Zener, 6.4V	D4	E2	DZ-60
VR103	Zener Diode, 4.7V ±5%	E2	E3	DZ-67
VR104	Zener Diode, 33V, ±5%	G2	E3	DZ-68
VR105	Zener Diode, 33V, ±5%	F2	E3	DZ-68
W101	Jumper	C3	G3	J-3
W102	Jumper	C3	G4	J-3
Y101	Crystal, 100kHz	G6	F5	CR-15

Table 7-2. Model 614 Display Board PC-597

Circuit Desig.	Description	Location Sch	Location Pcb	Keithley Part No.
C201	.15μF, 50V, Polyprop	B2	C2	C-269-.15
C202	.22μF, 50V, Polyprop	C2	C2	C-269-.22
C203	.22μF, 50V, Polyprop	C2	D2	C-269-.22
C204	1μF, 50V, Polycarb	C2	D2	C-215-1
C205	10μF, 25V, Alum	A6	B3	C-314-10
CR201	Rectifier	D1	D3	RF-28
DS201	Digital Display 7 Segment	B4	B2	DD-30
DS202	Digital Display 7 Segment	B4	B2	DD-30
DS203	Digital Display 7 Segment	C4	C2	DD-30
DS204	Digital Display 7 Segment	C4	C2	DD-30
DS205	Digital Display 7 Segment	C4	D2	DD-30
DS206	Digital Display 7 Segment	D4	D2	DD-30
P1008	Cable	A1	A2	CA-15-2
P1009	Connector	G4	C4	CS-270
R201	150Ω, 5%, 1/4W, Carb	B5	B1	R-76-150
R202	Thick Film	D5	E1	TF-102-4
R203	2k, 10%, 3/4W, Pot	D2	B2	RP-89-2k
R204	7.39k, .1%, 1/10W, MtF	D2	B2	R-263-7.39k
R205	50k, 5%, 2W, Pot	G4	E2	RP-108-50k
R206	38.6k, .1%, 1/10W	D1	B2	R263-38.6k
R208	100k, 5%, 1/4W, Carb	D2	C3	R-76-100k
R209	100k, 1%, 1/8W, MtF	B2	C3	R-88-100k
R210	33Ω, 5%, 1/4W, Carb	C1	C3	R-76-33
R211	32.4k, 5%, 1/8W, Carb	E2	C3	R-88-32.4k
R212	392k, 1%, 1/8W, MtF	C2	D3	R-88-392k
R213	1.74k, 1%, 1/8W, MtF	E1	B2	R-88-1.74k
R214	18.2k, 1%, 1/8W, MtF	E1	B2	R-88-18.2k
U201	BCD to 7 Segment Latch Driver, 4511	E4	E1	IC-168
U202	4 1/2 A/D Converter, ICL 7135CPI	Sev	D2	LSI-41
U203	MOS to LED Segment Driver, 75492	Sev	E3	IC-169
U204	Op Amp, 741	E1	B3	IC-42
VR201	6.35V Reference, Zener	E1	B2	DZ-58

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