6514 Programmable Electrometer

- <1fA noise
- >200TΩ input impedance on voltage measurements
- Charge measurements from 10fC to 20pC
- High speed—up to 1200 readings/second
- Interfaces readily with switches, computers, and component handlers
- Cancel voltage and current offsets easily

ACCESSORIES AVAILABLE

CABLES
- 237-ALG-2 Low Noise Triax Cable, 3-Slot Triax to Alligator Clips
- 7007-1 Shielded IEEE-488 Cable, 1m (3.2 ft)
- 7007-2 Shielded IEEE-488 Cable, 2m (6.5 ft)
- 7009-5 RS-232 Cable
- 7078-TRX-3 Low Noise Triax Cable, 3-Slot Triax Connectors, 0.9m (3 ft)
- 7078-TRX-10 Low Noise Triax Cable, 3-Slot Triax Connectors, 3m (10 ft)
- 7078-TRX-20 Low Noise Triax Cable, 3-Slot Triax Connectors, 6m (20 ft)
- 8501-1 Trigger-Link Cable, 1m (3.3 ft)
- 8501-2 Trigger-Link Cable, 2m (6.6 ft)

ADAPTERS
- 7078-TRX-BNC 3-Lug Triax to BNC Adapter
- 237-TRX-NG Triax Male-Female Adapter with Guard Disconnected
- 237-TRX-T 3-Slot Male Triax to Dual 3-Lug Female Triax Tee Adapter
- 237-TRX-TBC 3-Lug Female Triax Bulkhead Connector (1.1kV rated)
- 7078-TRX-TBC 3-Lug Female Triax Bulkhead Connector with Cap

SOFTWARE
- TestPoint Software Package

RACK MOUNT KITS
- 4288-1 Single Fixed Rack Mounting Kit
- 4288-2 Dual Fixed Rack Mounting Kit

OTHER
- KPCI-488 IEEE-488 Interface/Controller for the PCI Bus
- KPC-488.2AT IEEE-488 Interface Card for IBM PC/AT (full slot)
- KPC-TM Trigger Master Interface
- 1050 Padded Carrying Case
- 5156 Calibration Standard Set
- 6514-EW 1 Year Warranty Extension

For more than 40 years, Keithley electrometers have been recognized as industry standards for low-level measurements. The Model 6514 Electrometer is Keithley’s latest innovation in sensitive instrument design. It combines flexible interfacing capabilities with current sensitivity, charge measurement capabilities, resolution, and speed that are equal or superior to our earlier electrometers. The Model 6514’s built-in IEEE-488, RS-232, and digital I/O interfaces make it simple to configure fully automated, high-speed systems for low-level testing.

The 6½-digit Model 6514 is designed for applications that demand fast, yet precise measurements of low currents, voltages from high-resistance sources, charges, or high resistances.

The Model 6514’s exceptional measurement performance comes at an affordable price. While its cost is comparable with that of many high-end DMMs, the Model 6514 offers far greater current sensitivity and significantly lower voltage burden (as low as 20µV) than other instruments can provide.

R&D on a Budget

The Model 6514 offers the flexibility and sensitivity needed for a wide array of experiments, providing better data far faster than older electrometer designs. Applications include measuring currents from light detectors and other sensors, beam experiments, and measuring resistances using a current source. In addition to use by researchers in areas such as physics, optics, and materials science, the 6514’s affordable price makes it an attractive alternative to high-end DMMs for low-current measurement applications, such as testing resistance and leakage current in switches, relays, and other components. For more information on how the 6514 does this, refer to the section titled “Low Voltage Burden.”

The Model 6514 builds on the features and capabilities of the Keithley electrometers that preceded it. For example, like those instruments, a built-in constant current source simplifies measuring resistance. By forcing a known current through the unknown resistance, the resulting voltage is measured with a high input impedance circuit, and the result is expressed as a resistance measurement.

Two analog outputs—a 2V output and a preamp output—are available for recording data with strip-chart recorders.

ORDERING INFORMATION

6514 Electrometer with 237-ALG-2 Low Noise Triax Cable

This product is available with an Extended Warranty. See page 635 for complete ordering information.

ACCESSORIES AVAILABLE

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See page 235 for descriptions of all accessories.
6514 Programmable Electrometer

**Economical Component Testing**

Once, electrometers were simply considered too slow to keep up with the high throughput that production test applications demand. The Model 6514 is designed for fast, sensitive measurements, providing speeds up to 1200 readings per second with fast integration or 17 measurements per second with 60Hz line-cycle integration. It offers 10fA resolution on 2nA signals, settling to within 10% of the final value in just 15ms. A normal-mode rejection ratio (NMRR) of 60dB allows making accurate low current measurements, even in the presence of line frequency induced currents, which is a common concern in production floor environments. The instrument's sensitivity makes it easy to determine the leakage resistance on capacitances up to 10nF or even on higher capacitances when a series resistor is used.

While the Model 6514 can be easily operated manually using the front panel controls, it can also be externally controlled for automated test applications. Built-in IEEE-488 and RS-232 interfaces make it possible to program all instrument functions over the bus through a computer controller. The instrument's interfaces also simplify integrating external hardware, such as sources, switching systems, or other instruments, into the test system. A digital I/O interface can be used to link the Model 6514 to many popular component handlers for tight systems integration in binning, sorting, and similar applications.

These features make the Model 6514 a powerful, low-cost tool for systems designed to test optical devices and leakage resistance on low-value capacitors, switches, and other devices, particularly when the test system already includes a voltage source or when the source current/measure voltage technique is used to determine resistance.

**Low Voltage Burden**

The Model 6514's feedback ammeter design minimizes voltage offsets in the input circuitry, which can affect current measurement accuracy. The instrument also allows active cancellation of its input voltage and current offsets, either manually via the front panel controls or over the bus with IEEE-488 commands.

**Dark Current Measurements**

When measuring dark currents (Figure 1) from a device such as a photodiode, the ammeter reads the sum of two different currents. The first current is the dark current (I_D) generated by the detector with no light falling upon the device (in other words, the signal of interest); the second one is the leakage current (I_L) generated by the voltage burden (V_BURDEN) appearing at the terminals of the ammeter. In a feedback ammeter, the primary "voltage burden" is the amplifier offset voltage. This leakage current represents an error current. Without the use of cancellation techniques, I_L = V_BURDEN/RL. Figure 2 illustrates how the Model 6514's CAL V_OFFSET is adjusted to cancel V_BURDEN to within the voltage noise level of a few microvolts, so the measured current is only the true dark current (I_D) of the photodiode. In a similar manner, offset currents can also be cancelled. Earlier electrometers used an internal numerical correction technique in which the voltage burden was still present, so the measured dark current included the error term I_L = V_BURDEN/RL.
6514 Programmable Electrometer

Voltage Burden and Measurement Error

Electrometers provide current measurement with lower terminal voltage than is possible when making DMM measurements. As shown in Figure 3, DMMs measure current using a shunt resistance that develops a voltage (typically 200mV full-range) in the input circuit. This creates a terminal voltage (V_{BURDEN}) of about 200mV, thereby lowering the measured current. Electrometers reduce this terminal voltage by using the feedback ammeter configuration illustrated in Figure 1. The Model 6514 lowers this terminal voltage still further—to the level of the voltage noise—by canceling out the small offset voltage that remains, as shown in Figure 2. Any error signals that remain are negligible in comparison to those that can occur when measuring current with a DMM.

The example at the right compares a DMM’s voltage burden errors with the 6514’s.

DMM Offset Currents

Typically, offset currents in DMMs are tens or hundreds of picoamps, which severely limits their low-current measuring capabilities compared to the 6514 with 3fA input bias current.

Model 6514 Electrometer Specifications

<table>
<thead>
<tr>
<th>AMPS</th>
<th>5½-DIGIT RESOLUTION</th>
<th>ACCURACY (1 Year)</th>
<th>TEMPERATURE COEFFICIENT 0°–18°C &amp; 28°–50°C (% rdg+counts) °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>RANGE</td>
<td>10 aA</td>
<td>±(5% rdg+counts)</td>
<td>±(5% rdg+counts)/°C</td>
</tr>
<tr>
<td>20 pA</td>
<td>100 aA</td>
<td>±(5% rdg+counts)</td>
<td>±(5% rdg+counts)/°C</td>
</tr>
<tr>
<td>200 pA</td>
<td>10 aA</td>
<td>±(5% rdg+counts)</td>
<td>±(5% rdg+counts)/°C</td>
</tr>
<tr>
<td>2 nA</td>
<td>10 µA</td>
<td>±(5% rdg+counts)</td>
<td>±(5% rdg+counts)/°C</td>
</tr>
<tr>
<td>200 nA</td>
<td>100 aA</td>
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</tr>
<tr>
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<td>200 µA</td>
<td>1000 aA</td>
<td>±(5% rdg+counts)</td>
<td>±(5% rdg+counts)/°C</td>
</tr>
<tr>
<td>2 mA</td>
<td>10000 aA</td>
<td>±(5% rdg+counts)</td>
<td>±(5% rdg+counts)/°C</td>
</tr>
<tr>
<td>20 mA</td>
<td>100 aA</td>
<td>±(5% rdg+counts)</td>
<td>±(5% rdg+counts)/°C</td>
</tr>
</tbody>
</table>

Notes:
1. When properly zeroed, 5½-digit. Rate: Slow (100ms integration time).
2. aA =10⁻¹⁸A, fA=10⁻¹⁵A.

INPUT BIAS CURRENT: <3fA (user adjustable). Temperature coefficient = 0.5fA/°C.

INPUT BIAS CURRENT NOISE: typically <1nA (user adjustable): 
- <200nV on 2nA range.
- <50nV on 20mA range.

TEMPERATURE COEFFICIENT OF INPUT VOLTAGE BURDEN: <10µV/°C on pA, nA, µA ranges.

PREAMP SETTLING TIME (to 10% of final value): 2.5s typical on pA ranges, damping off. 3s typical on pA ranges damping on, 15ms on nA ranges, 5ms on µA and mA ranges.

NMMR: >95dB on pA, 60dB on nA, µA, and mA ranges at 50Hz or 60Hz ±0.1%. Digital Filter = 40.

Figure 3. Errors Due to Burden Voltage when Measuring with a DMM

If:  V_{SOURCE} = 1V, R = 50kΩ

The desired current reading is: \( I = \frac{V_{SOURCE}}{R} \)

Actual Reading (20µA range on DMM):
\( V_{BURDEN} = 200mV \)
\( I = \frac{1V - 200mV}{50kΩ} = 0.008 + 2 \)

6514 Actual Reading: \( V_{BURDEN} = 10µV \)
\( I = \frac{0.999990V}{50kΩ} = 19.9998µA = 0.001% \) Burden error with the 6514

Figure 2. Comparing a DMM's Voltage Burden Error with a DMM.
## 6514 Programmable Electrometer

### COULOMBS

<table>
<thead>
<tr>
<th>RANGE</th>
<th>6½-DIGIT RESOLUTION</th>
<th>ACCURACY (1 Year)</th>
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<tbody>
<tr>
<td>20 nC</td>
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<td>±(%rdg+counts)</td>
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<td>±(%rdg+counts)/°C</td>
</tr>
</tbody>
</table>

Notes:
1. Charge acquisition time must be <1000s, derate 2% for each additional 10,000s.
2. When properly zeroed, 6½-digit. Rate: Slow (100ms integration time).
3. INPUT BIAS CURRENT: <4fA at T<sub>cal</sub>. Temperature coefficient = 0.5fA/°C.

### GENERAL

- **DISPLAY:** 6½-digit vacuum fluorescent.
- **OVERRANGE INDICATION:** Display reads “OVRFLOW.”
- **RANGING:** Automatic or manual.
- **CONVERSION TIME:** Selectable 0.01 PLC to 10 PLC.
- **PROGRAMS:** Provide front panel access to IEEE address, choice of engineering units or scientific notation, and digital calibration.
- **MAXIMUM INPUT:** 250V peak, DC to 60Hz sine wave; 10s per minute maximum on mA ranges.
- **MAXIMUM COMMON MODE VOLTAGE (DC to 60Hz sine wave):** Electrometer, 500V peak.
- **INPUT CONNECTOR:** Three lug triaxial on rear panel.
- **2V ANALOG OUTPUT:** 2V for full range input. Inverting in Amps and Coulombs mode. Output impedance 10kΩ.
- **PREAMP OUTPUT:** Provides a guard output for Volts measurements. Can be used as an inverting output or with external feedback in Amps and Coulombs modes.
- **DIGITAL INTERFACE:**
  - **Handler Interface:** Start of test, end of test, 3 category bits.
  - **Digital I/O:** 1 Trigger input, 4 outputs with 500mA sink capability.
- **Connector:** 9 Pin D subminiature, male pins.
- **EMC:** Conforms to European Union Directive 89/336/EEC.
- **GUARD:** Switchable voltage and ohm guard available.
- **TRIGGER LINE:** Available, see manual for usage.
- **READING STORAGE:** 2500 readings.
- **READING RATE:**
  - To internal buffer: 1200 readings/second
  - To IEEE-488 bus: 500 readings/second
  - To front panel: 17 readings/second at 60Hz
  - 15 readings/second at 50Hz

Notes:
1. 0.01 PLC, digital filters off, front panel off, auto zero off.
2. 1.00 PLC, digital filters off.
3. Binary transfer mode.

### IEEE-488 BUS IMPLEMENTATION

- **MULTILINE COMMANDS:** DCL, LLO, SDC, GET, GTL, UNL, UNT, UNL, SPE, SPD.
- **IMPLEMENTATION:** SCPI (IEEE-488.2, SCPI-1996.0); DDC (IEEE-488.1).
- **UNILINE COMMANDS:** IFC, REN, EOI, SRQ, ATN.
- **INTERFACE FUNCTIONS:** SH1, AH1, T5, TE0, L4, LE0, SR1, RL1, PP0, DC1, DT1, C0, E1.
- **PROGRAMMABLE PARAMETERS:** Function, Range, Zero Check, Zero Correct, EOI (DDC mode only), Trigger, Terminator (DDC mode only). Data Storage 2500 Storage, Calibration (SCPI mode only), Display Format, SRQ, REL, Output Format, Guard, V-offset Cal, I-offset Cal.
- **ADDRESS MODES:** TALK ONLY and ADDRESSABLE.
- **LANGUAGE EMULATION:** 6512, 617, 617-HIQ emulation via DDC mode.
- **TRIGGER TO READING DONE:** 150ms typical, with external trigger.
- **RS-232 IMPLEMENTATION:**
  - Supports: SCPI 1996.0.
  - Baud Rates: 300, 600, 1200, 2400, 4800, 9600, 19.2k, 38.4k, 57.6k.
  - Protocol: Xon/Xoff, 7 or 8 bit ASCII, parity-odd/even/none.
  - Connector: DB-9 TXD/RXD/GND.

### COULOMBS ACCURACY TEMPERATURE (1 Year)

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Notes:
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### PHYSICAL

- **Case Dimensions:** 90mm high x 214mm wide x 369mm deep (31⁄2 in. x 83⁄8 in. x 149⁄16 in.)
- **Working Dimensions:** From front of case to rear including power cord and IEEE-488 connector: 15.5 inches.
- **Net Weight:** <4.6 kg (<10.1 lbs).
- **Shipping Weight:** <9.5 kg (<21 lbs).
- **ACCESSORIES SUPPLIED:** 237-ALG-2 Low Noise Triax Cable with Alligator Clips, 2m (6.6 ft)