Simplifies measuring high resistances and the resistivity of insulating materials

LOW LEVEL MEASURE & SOURCE

# 6517B

# Electrometer/High Resistance Meter


Keithley's 5½-digit Model 6517B Electrometer/High Resistance Meter offers accuracy and sensitivity specifications unmatched by any other meter of this type. It also offers a variety of features that simplify measuring high resistances and the resistivity of insulating materials. With reading rates of up to 425 readings/second, the Model 6517B is also significantly faster than competitive electrometers, so it offers a quick, easy way to measure low-level currents.

- **Measures resistances up to $10^{16}\Omega$**
- **1fA–20mA current measurement range**
- **<20µV burden voltage on lowest current ranges**
- **200TΩ input impedance**
- **<3fA bias current**
- **Up to 425 rdgs/s**
- **0.75fA p-p noise**
- **Built-in ±1kV voltage source**
- **Unique voltage reversal method for high resistance measurements**
- **Optional plug-in scanner cards**

## Exceptional Performance Specifications

The half-rack-sized Model 6517B has a special low current input amplifier with an input bias current of <3fA with just 0.75fA p-p (peak-to-peak) noise and <20µV burden voltage on the lowest range. The input impedance for voltage and resistance measurements is 200TΩ for near-ideal circuit loading. These specifications ensure the accuracy and sensitivity needed for accurate low current and high impedance voltage, resistance, and charge measurements in areas of research such as physics, optics, nanotechnology, and materials science. A built-in ±1kV voltage source with sweep capability simplifies performing leakage, breakdown, and resistance testing, as well as volume (Ω-cm) and surface resistivity (Ω/square) measurements on insulating materials.

## Wide Measurement Ranges

The Model 6517B offers full autoranging over the full span of ranges on current, resistance, voltage, and charge measurements:

- Current measurements from 1fA to 20mA
- Voltage measurements from 10µV to 200V
- Resistance measurements from 50Ω to $10^{16}\Omega$
- Charge measurements from 10fC to 2µC

## Improved High Resistivity Measurements

Many test applications require measuring high levels of resistivity (surface or volume) of materials. The conventional method of making these measurements is to apply a sufficiently large voltage to a sample, measure the current that flows through the sample, then calculate the resistance using Ohm's Law (R=V/I). While high resistance materials and devices produce very small currents that are difficult to measure accurately, Keithley's electrometers and picoammeters are used successfully for such measurements.

Even with high quality instrumentation, inherent background currents in the material can make these measurements difficult to perform accurately. Insulating materials, polymers, and plastics typically exhibit background currents due to piezoelectric effects, capacitive elements charged by static electricity, and polarization effects. These background currents are often equal to or greater than the current stimulated by the applied voltage. In these cases, the result is often unstable, providing inaccurate resistance or resistivity readings or even erroneous negative values. Keithley's Model 6517B is designed to solve these problems and provides consistent, repeatable, and accurate measurements for a wide variety of materials and components, especially when used in combination with the Model 8009 Resistivity Test Fixture.

## Alternating Polarity Method

The Model 6517B uses the Alternating Polarity method, which virtually eliminates the effect of any background currents in the sample. First and second order drifts of the background currents are also canceled out. The Alternating Polarity method applies a voltage of positive polarity, then the current is measured after a specified delay (Measure Time). Next, the polarity is reversed and the current measured again, using the same delay. This process is repeated continuously, and the resistance is calculated based on a weighted average of the four most recent current measurements. This method typically

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## Ordering Information

**6517B** Electrometer/High Resistance Meter

### Accessories Supplied

**237-ALG-2 Low Noise Triax Cable, 3-slot Triax to Alligator Clips, 2m (6.6 ft)**

**8607 Safety High Voltage Dual Test Leads**

**6517-TP Thermocouple Bead Probe**

**CS-1305 Interlock Connector**

## ACCESSORIES AVAILABLE

| | |
|---|---|
| **CABLES** | |
| 6517B-ILC-3 | Interlock Cable |
| 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) |
| 8503 | Trigger Link Cable to 2 male BNCs, 1m (3.3 ft) |
| 8607 | 1kV Source Banana Cables |
| **PROBES** | |
| 6517-RH | Humidity Probe with Extension Cable |
| 6517-TP | Temperature Bead Probe (included with 6517B) |
| **TEST FIXTURE** | |
| 8009 | Resistivity Test Fixture |
| **OTHER** | |
| CS-1305 | Interlock Connector |
| **ADAPTERS** | |
| 237-BNC-TRX | Male BNC to 3-Lug Female Triax 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-BNC | 3-Slot Male Triax to BNC Adapter |
| 7078-TRX-GND | 3-Slot Male Triax to BNC Adapter with guard removed |
| 7078-TRX-TBC | 3-Lug Female Triax Bulkhead Connector with Cap |
| **RACK MOUNT KITS** | |
| 4288-1 | Single Fixed Rack Mounting Kit |
| 4288-2 | Dual Fixed Rack Mounting Kit |
| **SCANNER CARDS** | |
| 6521 | Low Current Scanner Card |
| 6522 | Voltage/Low Current Scanner Card |
| **GPIB INTERFACES** | |
| KPCI-488LPA | IEEE-488 Interface/Controller for the PCI Bus |
| KUSB-488B | IEEE-488 USB-to-GPIB Interface Adapter |

produces a highly repeatable, accurate measurement of resistance (or resistivity) by the seventh reversal on most materials (i.e., by discarding the first three readings). For example, a 1mm-thick sample of $10^{14}\Omega$-cm material can be measured with 0.3% repeatability in the Model 8009 test fixture, provided the background current changes less than 200fA over a 15-second period.

## Simple DMM-like Operation

The Model 6517B is designed for easy, DMM-like operation via the front panel, with single-button control of important functions such as resistance measurement. It can also be controlled via a built-in IEEE-488 interface, which makes it possible to program all functions over the bus through a computer controller.

## High Accuracy High Resistance Measurements

The Model 6517B offers a number of features and capabilities that help ensure the accuracy of high resistance measurement applications. For example, the built-in voltage source simplifies determining the relationship between an insulator's resistivity and the level of source voltage used. It is well suited for capacitor leakage and insulation resistance measurements, tests of the surface insulation resistance of printed circuit boards, voltage coefficient testing of resistors, and diode leakage characterization.

## Temperature and Humidity Stamping

Humidity and temperature can influence the resistivity values of materials significantly. To help you make accurate comparisons of readings acquired under varying conditions, the Model 6517B offers a built-in type K thermocouple and an optional Model 6517-RH Relative Humidity Probe. A built-in data storage buffer allows recording and recalling readings stamped with the time, temperature, and relative humidity at which they were acquired.

## Accessories Extend Measurement Capabilities

A variety of optional accessories can be used to extend the Model 6517B's applications and enhance its performance.

**Scanner Cards.** Two scanner cards are available to simplify scanning multiple signals. Either card can be easily inserted in the option slot of the instrument's back panel. The Model 6521 Scanner Card offers ten channels of low-level current scanning. The Model 6522 Scanner Card provides ten channels of high impedance voltage switching or low current switching.

**Test Fixture.** The Model 8009 Resistivity Chamber is a guarded test fixture for measuring volume and surface resistivities of sample materials. It has stainless-steel electrodes built to ASTM standards. The fixture's electrode dimensions are pre-programmed into the Model 6517B, so there's no need to calculate those values then enter them manually. This accessory is designed to protect you from contact with potentially hazardous voltages —opening the lid of the chamber automatically turns off the Model 6517B's voltage source.

## Applications

The Model 6517B is well suited for low current and high impedance voltage, resistance, and charge measurements in areas of research such as physics, optics, and materials science. Its extremely low voltage burden makes it particularly appropriate for use in solar cell applications, and its built-in voltage source and low current sensitivity make it an excellent solution for high resistance measurements of nanomaterials such as polymer based nanowires. Its high speed and ease of use also make it an excellent choice for quality control, product engineering, and production test applications involving leakage, breakdown, and resistance testing. Volume and surface resistivity measurements on non-conductive materials are particularly enhanced by the Model 6517B's voltage reversal method. The Model 6517B is also well suited for electrochemistry applications such as ion selective electrode and pH measurements, conductivity cells, and potentiometry.

## Model 6517B Enhancements

The Model 6517B is an updated version, replacing the earlier Model 6517A, which was introduced in 1996. Software applications created for the Model 6517A using SCPI commands can run without modifications on the Model 6517B. However, the Model 6517B does offer some useful enhancements to the earlier design. Its internal battery-backed memory buffer can now store up to 50,000 readings, allowing users to log test results for longer periods and to store more data associated with those readings. The new model also provides faster reading rates to the internal buffer (up to 425 readings/second) and to external memory via the IEEE bus (up to 400 readings/second). Several connector modifications have been incorporated to address modern connectivity and safety requirements.

## VOLTS

| 5½-DIGIT RANGE | RESOLUTION | ACCURACY (1 Year)[1] 18°–28°C ±(%rdg+counts) | TEMPERATURE COEFFICIENT 0°–18°C & 28°–50°C ±(%rdg+counts)/°C |
|---|---|---|---|
| 2 V | 10 μV | 0.025 + 4 | 0.003 + 2 |
| 20 V | 100 μV | 0.025 + 3 | 0.002 + 1 |
| 200 V | 1 mV | 0.06 + 3 | 0.002 + 1 |

**NMRR:** 2V and 20V ranges >60dB, 200V range >55dB. 50Hz or 60Hz[2].

**CMRR:** >120dB at DC, 50Hz or 60Hz.

**INPUT IMPEDANCE:** >200TΩ in parallel with 20pF, <2pF guarded (1MΩ with zero check on).

**SMALL SIGNAL BANDWIDTH AT PREAMP OUTPUT:** Typically 100kHz (–3dB).

### NOTES

1. When properly zeroed, 5½-digit, 1 PLC (power line cycle), median filter on, digital filter = 10 readings.
2. Line sync on.

## AMPS

| 5½-DIGIT RANGE | RESOLUTION | ACCURACY (1 Year)[1] 18°–28°C ±(%rdg+counts) | TEMPERATURE COEFFICIENT 0°–18°C & 28°–50°C ±(%rdg+counts)/°C |
|---|---|---|---|
| 20 pA | 100 aA[2] | 1 + 30 | 0.1 + 5 |
| 200 pA | 1 fA[2] | 1 + 5 | 0.1 + 1 |
| 2 nA | 10 fA | 0.2 + 30 | 0.1 + 2 |
| 20 nA | 100 fA | 0.2 + 5 | 0.03 + 1 |
| 200 nA | 1 pA | 0.2 + 5 | 0.03 + 1 |
| 2 μA | 10 pA | 0.1 + 10 | 0.005 + 2 |
| 20 μA | 100 pA | 0.1 + 5 | 0.005 + 1 |
| 200 μA | 1 nA | 0.1 + 5 | 0.005 + 1 |
| 2 mA | 10 nA | 0.1 + 10 | 0.008 + 2 |
| 20 mA | 100 nA | 0.1 + 5 | 0.008 + 1 |

**INPUT BIAS CURRENT:** <3fA at $T_{CAL}$. Temperature coefficient = 0.5fA/°C, 20pA range.

**INPUT BIAS CURRENT NOISE:** <750aA p-p (capped input), 0.1Hz to 10Hz bandwidth, damping on. Digital filter = 40 readings, 20pA range.

**INPUT VOLTAGE BURDEN at $T_{CAL}$ ±1°C:**
<20μV on 20pA, 2nA, 20nA, 2μA, and 20μA ranges.
<100μV on 200pA, 200nA, and 200μA ranges.
<2mV on 2mA range. <5mV on 20mA range.

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

**PREAMP SETTLING TIME (to 10% of final value) Typical:** 0.5sec (damping off) 2.0 sec (damping on) on pA ranges. 15msec on nA ranges damping off, 1msec on μA ranges damping off. 500μsec on mA ranges damping off.

**NMRR:** >60dB on all ranges at 50Hz or 60Hz[3].

### NOTES

1. When properly zeroed, 5½-digit, 1PLC (power line cycle), median filter on, digital filter = 10 readings.
2. aA = $10^{-18}$A, fA = $10^{-15}$A.
3. Line sync on.

## OHMS (Normal Method)

| RANGE | 5½-DIGIT RESOLUTION | ACCURACY[1] (10–100% Range) 18°–28°C (1 Year) ±(% rdg+counts) | TEMPERATURE COEFFICIENT (10–100% Range) 0°–18°C & 28°–50°C ±(% rdg+counts) | AUTO V SOURCE | AMPS RANGE |
|---|---|---|---|---|---|
| 2 MΩ | 10 Ω | 0.125 + 1 | 0.01 + 1 | 40 V | 200 μA |
| 20 MΩ | 100 Ω | 0.125 + 1 | 0.01 + 1 | 40 V | 20 μA |
| 200 MΩ | 1 kΩ | 0.15 + 1 | 0.015 + 1 | 40 V | 2 μA |
| 2 GΩ | 10 kΩ | 0.225 + 1 | 0.035 + 1 | 40 V | 200 nA |
| 20 GΩ | 100 kΩ | 0.225 + 1 | 0.035 + 1 | 40 V | 20 nA |
| 200 GΩ | 1 MΩ | 0.35 + 1 | 0.110 + 1 | 40 V | 2 nA |
| 2 TΩ | 10 MΩ | 0.35 + 1 | 0.110 + 1 | 400 V | 2 nA |
| 20 TΩ | 100 MΩ | 1.025 + 1 | 0.105 + 1 | 400 V | 200 pA |
| 200 TΩ | 1 GΩ | 1.15 + 1 | 0.125 + 1 | 400 V | 20 pA |

### NOTES

1. Specifications are for auto V-source ohms, when properly zeroed, 5½-digit, 1PLC, median filter on, digital filter = 10 readings. If user selectable voltage is required, use manual mode. Manual mode displays resistance (up to $10^{18}$Ω) calculated from measured current. Accuracy is equal to accuracy of V-source plus accuracy of selected Amps range.

**PREAMP SETTLING TIME:** Add voltage source settling time to preamp settling time in Amps specification. Ranges over 20GΩ require additional settling based on the characteristics of the load.

## OHMS (ALTERNATING POLARITY METHOD)

The alternating polarity sequence compensates for the background (offset) currents of the material or device under test. Maximum tolerable offset up to full scale of the current range used.

**Using Keithley 8009 fixture**

**REPEATABILITY:** $\Delta I_{BG} \times R/V_{ALT} + 0.1\%$ (1σ) (instrument temperature constant ±1°C).

**ACCURACY:** $(V_{SRC}Err + I_{MEAS}Err \times R)/V_{ALT}$

where: $\Delta I_{BG}$ is a measured, typical background current noise from the sample and fixture.
$V_{ALT}$ is the alternating polarity voltage used.
$V_{SRC}Err$ is the accuracy (in volts) of the voltage source using $V_{ALT}$ as the setting.
$I_{MEAS}Err$ is the accuracy (in amps) of the ammeter using $V_{ALT}/R$ as the reading.

## VOLTAGE SOURCE

| RANGE | 5½-DIGIT RESOLUTION | ACCURACY (1 Year) 18°–28°C ±(% setting + offset) | TEMPERATURE COEFFICIENT 0°–18°C & 28°–50°C ±(% setting+offset)/°C |
|---|---|---|---|
| 100 V | 5 mV | 0.15 + 10 mV | 0.005 + 1 mV |
| 1000 V | 50 mV | 0.15 + 100 mV | 0.005 + 10 mV |

**MAXIMUM OUTPUT CURRENT:**
**100V Range:** ±10mA, hardware short circuit protection at <14mA.
**1000V Range:** ±1mA, hardware short circuit protection at <1.4mA.

**SETTLING TIME:**
**100V Range:** <8ms to rated accuracy.
**1000V Range:** <50ms to rated accuracy.

**NOISE (typical):**
**100V Range:** <2.6mV rms.
**1000V Range:** <2.9mV rms.

## COULOMBS

| RANGE | 5½-DIGIT RESOLUTION | ACCURACY (1 Year)[1, 2] 18°–28°C ±(%rdg+counts) | TEMPERATURE COEFFICIENT 0°–18°C & 28°–50°C ±(%rdg+counts)/°C |
|---|---|---|---|
| 2 nC | 10 fC | 0.4 + 5 | 0.04 + 3 |
| 20 nC | 100 fC | 0.4 + 5 | 0.04 + 1 |
| 200 nC | 1 pC | 0.4 + 5 | 0.04 + 1 |
| 2 μC | 10 pC | 0.4 + 5 | 0.04 + 1 |

### NOTES

1. Specifications apply immediately after charge acquisition. Add

$$(4fA + \frac{|Q_{AV}|}{RC})\ T_A$$

where $T_A$ = period of time in seconds between the coulombs zero and measurement and $Q_{AV}$ = average charge measured over $T_A$, and RC = 300,000 typical.

2. When properly zeroed, 5½-digit, 1PLC (power line cycle), median filter on, digital filter = 10 readings.

**INPUT BIAS CURRENT:** <4fA at $T_{CAL}$. Temperature coefficient = 0.5fA/°C, 2nC range.

## TEMPERATURE (Thermocouple)

| THERMOCOUPLE TYPE | RANGE | ACCURACY (1 Year)[1] 18°–28°C ±(% rdg + °C) |
|---|---|---|
| K | –25°C to 150°C | ±(0.3% + 1.5°C) |

### NOTES

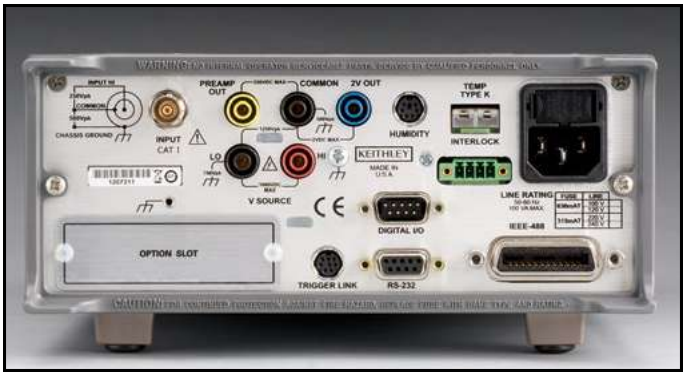
1. Excluding probe errors, $T_{cal}$ ± 5°C, 1 PLC integration time.

## HUMIDITY

| RANGE | ACCURACY (1 Year)[1] 18°–28°C, ±(% rdg + % RH) |
|---|---|
| 0–100% | ±(0.3% +0.5) |

### NOTES

1. Humidity probe accuracy must be added. This is ±3% RH for Model 6517-RH, up to 65°C probe environment, not to exceed 85°C.




**Model 6517B rear panel**

## IEEE-488 BUS IMPLEMENTATION

**IMPLEMENTATION:** SCPI (IEEE-488.2, SCPI-1999.0).

**TRIGGER TO READING DONE:** 150ms typical, with external trigger.

**RS-232 IMPLEMENTATION: Supports:** SCPI 1991.0. **Baud Rates:** 300, 600, 1200, 2400, 4800, 9600, 19.2k, 38.4k, 57.6k, and 115.2k.

**FLOW CONTROL:** None, Xon/Xoff.

**CONNECTOR:** DB-9 TXD/RXD/GND.

## GENERAL

**OVERRANGE INDICATION:** Display reads "OVERFLOW" for readings >105% of range. The display reads "OUT OF LIMIT" for excesive overrange conditions.

**RANGING:** Automatic or manual.

**CONVERSION TIME:** Selectable 0.01PLC to 10PLC.

**MAXIMUM INPUT:** 250V peak, DC to 60Hz sine wave; 10sec per minute maximum on mA ranges.

**MAXIMUM COMMON MODE VOLTAGE (DC to 60Hz sine wave):** Electrometer, 500V peak; V Source, 750V peak.

**ISOLATION (Meter COMMON to chassis):** $>10^{10}\Omega$, <500pF.

**INPUT CONNECTOR:** Three lug triaxial on rear panel.

**2V ANALOG OUTPUT:** 2V for full range input. Non-inverting in Volts mode, inverting when measuring Amps, Ohms, or Coulombs. 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.

**EXTERNAL TRIGGER:** TTL compatible External Trigger and Electrometer Complete.

**GUARD:** Switchable voltage guard available.

**DIGITAL I/O AND TRIGGER LINE:** Available, see manual for usage.

**EMC:** Conforms to European Union Directive 89/336/EEC, EN 61326-1.

**SAFETY:** Conforms to European Union Directive 73/23/EEC, EN 61010-1.

**READING STORAGE:** 50,000.

**READING RATES:**
**To Internal Buffer:** 425 readings/second[1].
**To IEEE-488 Bus:** 400 readings/second[1, 2].
**Bus Transfer:** 3300 readings/second[2].

1. 0.01PLC, digital filters off, front panel off, temperature + RH off, Line Sync off.
2. Binary transfer mode.

**DIGITAL FILTER:** Median and averaging.

**ENVIRONMENT: Operating:** 0°–50°C; relative humidity 70% non-condensing, up to 35°C. **Storage:** –25° to +65°C.

**ALTITUDE:** Maximum 2000 meters above sea level per EN 61010-1.

**WARM-UP:** 1 hour to rated accuracy (see manual for recommended procedure).

**POWER:** User selectable 100, 120, 220, 240VAC ±10%; 50/60Hz, 100VA max.

**PHYSICAL: Case Dimensions:** 90mm high × 214mm wide × 369mm deep (3½ in. × 8½ in. × 14½ in.).

**Working Dimensions:** From front of case to rear including power cord and IEEE-488 connector: 15.5 inches.

**Net Weight:** 5.4kg (11.8 lbs.).

**Shipping Weight:** 6.9kg (15.11 lbs.).

## SERVICES AVAILABLE

| | |
|---|---|
| 6517B-3Y-EW | 1-year factory warranty extended to 3 years from date of shipment |
| C/6517B-3Y-ISO | 3 (ISO-17025 accredited) calibrations within 3 years of purchase* |

*Not available in all countries