

# ULTRA-SENSITIVE MEASUREMENT INSTRUMENTS

Scientists and researchers worldwide rely on Keithley Electrometers, Picoammeters, and Nanovoltmeters for making low-level measurements beyond the capabilities of a typical digital multimeter. Keithley Electrometers and Picoammeters provide low current and high resistance measurements and Keithley Nanovoltmeters measure low voltages.



	2182A NANOVOLTMETER	6220 / 6221 CURRENT SOURCES	6485 / 6487 / 6482 PICOAMMETERS / PICOAMMETER & VOLTAGE SOURCE	6514 / 6517B / 6430 ELECTROMETERS
<b>Current Min/Max</b>	—	100fA / 100mA	1fA / 20mA	1aA/100mA
<b>Voltage Min/Max</b>	1nV / 100V	—	—	1 $\mu$ V / 200V
<b>Resistance Min/Max</b>	10n $\Omega$ / 1G $\Omega$ (with Model 6220 or 6221)	10n $\Omega$ /1G $\Omega$ (with Model 2182A)	10 $\Omega$ /1P $\Omega$ (with Model 6487)	1 $\mu\Omega$ - 1000P $\Omega$
<b>Resolution</b>	7½ Digits	4½ Digits	5½ Digits (6485, 6487) 6½ Digits (6482)	5½ Digits (6514) 6½ Digits (6517B, 6430)
<b>Input Connection / Interface</b>	Low Thermal / GPIB, RS-232	3 Slot Triax / GPIB, RS-232 (LAN on 6221)	BNC (6485) 3 Slot Triax (6482, 6487) / GPIB, RS-232	3 Slot Triax / GPIB, RS-232

## CHOOSING YOUR SPECIALIZED LOW LEVEL INSTRUMENT

To help you choose the appropriate specialized low level instrument for your application, the most common selection criteria are listed below, including helpful tips for determining the correct specialized low level instrument for your requirements.

### 1 Resolution

Resolution means how fine a meter's measurement is and lets you determine if it's possible to see a small change in the signal. Resolution is described by digits and counts. A 6.5-digit instrument can display six full digits ranging from 0 to 9, and one "half" digit that displays either a 1 or is left blank. A 6.5-digit instrument can display up to 1,999,999 counts of resolution.

### 2 Accuracy

Accuracy is the largest allowable error that will occur under specific operating conditions and is an indication of how close the instrument's displayed measurement is to the actual value of the signal measured. Accuracy is typically expressed as a percent of reading. For example, an accuracy of 1% of reading means that, for a displayed reading of 100 volts, the actual value of the voltage is between 99 volts and 101 volts.

### 3 Low Current/High Resistance Measurements

Low current/high resistance measurements evaluate the insulation qualities of materials or components. Typically, a voltage up to 500 or 1000 volts is applied and the resulting current is measured, which can be in the range of picoamperes (10E-12A) or lower. A digital multimeter may seem like the right instrument for these measurements. But if the current is below 1 $\mu$ A or the resistance is above 10M $\Omega$ , the correct solution is an Electrometer or Picoammeter.

### 4 Low Voltage/Low Resistance Measurements

Low resistance/low voltage measurements evaluate the conduction or contact qualities of materials or components. Typically, a current under 100mA but as low as 1 $\mu$ A is applied and the resulting voltage is measured, which can be in the range of microvolts and even nanovolts. For low voltage, choose a Nanovoltmeter or low noise multimeter. For low resistance, a Nanovoltmeter/current source combination or switch/multimeter is the correct solution.

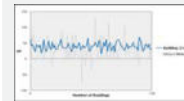


## 2182A Nanovoltmeter

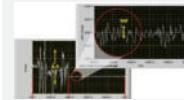
The two-channel Model 2182A Nanovoltmeter is optimized for making stable, low noise voltage measurements and for characterizing low resistance materials and devices reliably and repeatably. It provides higher measurement speed and significantly better noise performance for voltage meters than alternative low voltage measurement solutions.

### PRODUCT HIGHLIGHTS

- Low noise voltage measurements at high speeds
- Delta mode coordinates measurements with a reversing current source at up to 24Hz with 30nV p-p noise (typical) for one reading. Averages multiple readings for greater noise reduction
- Built-in thermocouple linearization and cold junction compensation
- Dual channels



Comparison of the Model 2182A's DC noise performance with a nanovolt/micro-ohmmeter's.



Results from a Model 2182A and Model 6220 using the delta mode to measure a 10mΩ resistor with a 20μA test current.

MODEL	VOLTAGE	TEMPERATURE	RESISTANCE	CHANNELS	CURRENT SOURCE
2182A	1nV – 100V	-200°C – 1820°C		2	—
6220/2182A*	1nV – 100V	-200°C – 1820°C	10nΩ – 1GΩ	—	±100fA – 100mA
6221/2182A*	1nV – 100V	-200°C – 1820°C	10nΩ – 1GΩ	—	±100fA – 100mA, with 1mHz – 100kHz, 10Msamples/s, 64k arbitrary waveform generator

### RECOMMENDED ACCESSORIES

4288-1	Single Fixed Rack Mounting Kit
4288-2	Dual Fixed Rack Mounting Kit
KPCI-488LPA	IEEE-488 Interface/Controller for the PCI Bus
KUSB-488B	IEEE-488 USB-to-GPIB Interface Adapter
2107-30	Low Thermal Input Cable with spade lugs, 9.1m (30 ft)
2182-KIT	Low Thermal Test Lead Kit
2187-4	Input Cable with safety banana plugs

### RECOMMENDED ACCESSORIES

2188	Low Thermal Calibration Shorting Plug
7007-1	Shielded GPIB Cable, 1m (3.2 ft)
7007-2	Shielded GPIB Cable, 2m (6.5 ft)
7009-5	Shielded RS-232 Cable, 1.5m (5 ft)
8501-1	Trigger Link Cable, 1m (3.2 ft)
8501-2	Trigger Link Cable, 2m (6.5 ft)
8503	Trigger Link Cable to 2 male BNC connectors

### SHIPS WITH PRODUCT

- 2107-4 Low Thermal Input Cable with Spade Lugs, 1.2m (4 ft)
- User Documentation
- Contact Cleaner
- Power Cord
- Alligator Clips

### LEARN MORE

with the “Low-Level Pulsed Electrical Characterization using Model 6221/2182A Combination” Application Note.





## 6220 / 6221 Current Sources

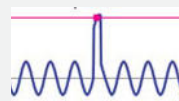
Keithley precision current sources include both broad-purpose Model 6220 and high-performance Model 6221. Their high sourcing accuracy and built-in control functions make them ideal for Hall Effect, resistance (using delta mode), pulsed, and differential conductance measurements. Programmable pulse widths limit power dissipation.

### PRODUCT HIGHLIGHTS

- $10^{14}\Omega$  output impedance ensures stable current sourcing into variable loads
- 64k-point source memory for comprehensive test current sweeps
- (Model 6221) Source AC currents from 4pA to 210mA peak to peak for AC characterization of components and materials. The 10MHz output update rate generates smooth sine waves up to 100kHz



Perform, analyze, and display differential conductance measurements.



Measurements are line synchronized to minimize 50/60Hz interference.

MODEL	CURRENT SOURCE	ARBITRARY WAVEFORM GENERATOR	PULSE GENERATOR	RESISTANCE	PC INTERFACE
6220	$\pm 100\text{fA} - 100\text{mA}$	—	—	—	GPIB, RS-232
6221	$\pm 100\text{fA} - 100\text{mA}$	1mHz – 100kHz, 10Msamples/s sample rate, 64k point waveform length	Programmable, 5 $\mu\text{s}$ minimum width	—	GPIB, RS-232, Ethernet
6220/2182A	$\pm 100\text{fA} - 100\text{mA}$	—	—	10n $\Omega$ – 1G $\Omega$	GPIB, RS-232
6221/2182A	$\pm 100\text{fA} - 100\text{mA}$	1mHz – 100kHz, 10Msamples/s sample rate, 64k point waveform length	Programmable, 50 $\mu\text{s}$ minimum width, for pulsed I-V measurements	10n $\Omega$ – 1G $\Omega$	GPIB, RS-232, Ethernet

\*Delta Mode Resistance Measurement System

### RECOMMENDED ACCESSORIES

237-ALG-2	Low Noise Triax Cable, 3-slot triax to alligator clips
7007-1	Shielded GPIB Cable, 1m (3.2 ft)
7007-2	Shielded GPIB Cable, 2m (6.5 ft)
7007-4	Shielded IEEE-488 Cable, 4m (13.1 ft)
7009-5	Shielded RS-232 Cable, 1.5m (5 ft)
7078-TRX-3	Low Noise Triax Cable, 3-Slot Triax Connectors, 0.9m (3 ft)
7078-TRX-5	Low Noise Triax Cable, 3-Slot Triax Connectors, 1.5m (5 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)
CA-180-3A	LAN Crossover Cable (3 m)

### RECOMMENDED ACCESSORIES

8501-1	Trigger Link Cable with male Micro-DIN connectors at each end, 1m (3.3 ft)
4288-1	Single Fixed Rack Mounting Kit
4288-2	Dual Fixed Rack Mounting Kit
KPCI-488LPA	IEEE-488 Interface/Controller for the PCI Bus
KUSB-488B	IEEE-488 USB-to-GPIB Interface Adapter

### SHIPS WITH PRODUCT

- 237-ALG-2 Low Noise, Input Cable with Triax-to-Alligator Clips 6.6 ft (2 m)
- 8501-2 Trigger Link Cable to connect 622x to 2182A 6.6 ft (2 m)
- 174694600 Ethernet Crossover Cable (1.5 m) (6221 only)
- CA-351 Communication Cable between 2182A and 622x
- CS-1195-2 Safety Interlock Connector
- User Documentation
- Getting Started manual (hardcopy)
- Software (downloadable)

### LEARN MORE

with the “Determining Resistivity and Conductivity Type using a Four-Point Collinear Probe and the Model 6221 Current Source” Application Note.





## 6485 Picoammeter, 6487/6482 Picoammeter & Voltage Sources

Keithley Picoammeters combine sensitive current measurement with high speed. The Model 6485 Picoammeter offers fast, sensitive current measurement. The Model 6487 offers improved measurement capability, and adds a high resolution 500V source. The Model 6482 offers two independent Picoammeter/voltage source channels.

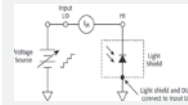
DATA SHEET 6485

DATA SHEET 6487

DATA SHEET 6482

### PRODUCT HIGHLIGHTS

- Measure currents down to 1fA
- Voltage and resistance measurement options
- Voltage burden <200µV (most models)
- 5½- to 6½-digit resolution (most models)
- Feedback ammeter design for higher accuracy



Dark current characterization of a photodiode using Picoammeter and voltage source (such as the Model 6482).



MOSFET sub-threshold voltage test using Picoammeters and voltage sources (such as the Model 6482).

MODEL	CHANNELS	CURRENT	RESISTANCE	READING RATE	VOLTAGE SOURCE
6482	2	1fA – 20mA (2 ch)	N/A	900 rdgs/s	2, ±30V
6487	1	10fA – 20mA	Up to 10 <sup>15</sup> Ω	1000 rdgs/s	±500V
6485	2	10fA – 20mA	N/A	1000 rdgs/s	—

### RECOMMENDED ACCESSORIES

4802-10	Low noise BNC Input Cable, 3m (10ft) (for 6485)
4803	Low Noise Cable Kit (for 6485)
6517-ILC-3	Interlock Cable for 8009 Resistivity Test Fixture (6487 Only)
7007-1	Shielded IEEE-488 Cable, 1m (3.3 ft)
7007-2	Shielded IEEE-488 Cable, 2m (6.6 ft)
7007-4	Shielded IEEE-488 Cable, 4m (13.1 ft)
7009-5	RS-232 Cable
7078-TRX-10	Low Noise Triax Cable, 3.0m (10 ft) (6487 Only)
7078-TRX-20	Low Noise Triax Cable, 6.0m (20 ft) (6487 Only)
7754-3	BNC to Alligator Cable (for 6485)
8501-1	Trigger Link Cable with male Micro-DIN connectors at each end, 1m (3.3 ft)

### RECOMMENDED ACCESSORIES

CS-565	BNC Barrel (for 6485)
237-TRX-BAR	Triax Barrel (for 6487)
7078-TRX-BNC	Triax-to-BNC Adapter
8009	Resistivity Test Fixture (for 6487)
4288-1	Single Fixed Rack Mounting Kit
4288-2	Dual Fixed Rack Mounting Kit
KPCI-488LPA	IEEE-488 Interface/Controller for the PCI Bus
KUSB-488B	IEEE-488 USB-to-GPIB Interface Adapter

### SHIPS WITH PRODUCT

- 7078-TRX-BNC Triax-to-BNC Connector (2x) (Model 6482)
- CA-186-1B Ground Connection Cable, Banana to Screw-Lug (Model 6487)
- CAP-31 Protective Shield/Cap (3-lug) (Model 6487)
- CS-459 Safety Interlock Plug (Model 6487)
- 7078-TRX-3 Low Noise Triax Input Cable, 1m (3 ft) (Model 6487)
- 8607 High Voltage Banana Cable Set for Voltage Source Output (Model 6487)
- CAP-18 Protective Shield/Cap (2-lug) (Model 6485)
- 4801 Low Noise BNC Input (Model 6485)
- User Documentation

### LEARN MORE

with the “Low Current Measurements” Application Note.





## 6514 /6517B /6430 Electrometers

Our Electrometers provide a voltage source and the most current sensitivity to make extremely high resistivity measurements. They combine flexible interfacing capabilities with high impedance voltage measurement, charge measurement capabilities, resolution, and speed. The Model 6430 offers unmatched low current sensitivity.

MODEL	CURRENT	VOLTAGE	RESISTANCE	CHARGE	SOURCES
6517B	10aA - 20mA	1μV - 200V	1Ω - 1000PΩ	1fC - 2μC	±5mV to 1000V
6514	100aA - 20mA	10μV - 200V	10mΩ - 200GΩ	10fC - 20μC	—
6430	1aA - 100mA	100nV - 200V	1μΩ - >20TΩ	—	±5μV to 200V, ±50aA to 100mA

### RECOMMENDED ACCESSORIES

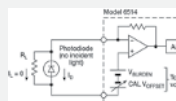
237-ALG-2	Low Noise Triax Cable, 3-slot triax to alligator clips
6517B-ILC-3	Interlock Cable (For 6517B only)
7078-TRX-3	Low Noise Triax Cable, 3-Slot Triax Connectors, 0.9m (3 ft)
7007-1	Shielded IEEE-488 Cable, 1m (3.2 ft)
8501-1	Trigger Link Cable, 1m (3.3 ft)
8503	Trigger Link DIN-to-BNC Trigger Cable
8607	1kV Source Banana Cables (for 6517B only)
6517-RH	Humidity Probe with Extension Cable (6517B only)
6517-TP	Temperature Bead Probe (included with 6517B) (6517B only)
8009	Resistivity Test Fixture (for 6517B)
KICKSTARTFL-HRMA Hig	High Resistance Measurement Application for KickStart Instrument Control Software (6517B only)  Fixture (for 6517B)

### RECOMMENDED ACCESSORIES

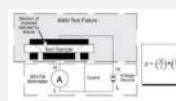
237-BNC-TRX	Male BNC to 3-Lug Female Triax Adapter (for 6517B)
237-TRX-NG	Triax Male-Female Adapter with Guard Disconnected
7078-TRX-BNC	3-Slot Male Triax to BNC Adapter
7078-TRX-GND	3-Slot Male Triax to BNC Adapter with guard removed (for 6517B)
4288-1	Single Fixed Rack Mounting Kit
4288-2	Dual Fixed Rack Mounting Kit
6521	Low Current Scanner Card (for 6517B)
6522	Voltage/Low Current Scanner Card (for 6517B)
KPCI-488LPA	IEEE-488 Interface/Controller for the PCI Bus
KUSB-488B	IEEE-488 USB-to-GPIB Interface Adapter

### PRODUCT HIGHLIGHTS

- Measure low current & high voltage, resistance, and charge
- Resistance measurements to 1000P± (6517B)
- Current sensitivity as low as 1aA (6430)
- Voltage burden as low as 200μV
- Superior accuracy and sensitivity
- Perform insulation resistivity measurements in accordance with ASTM D257 standard



This illustrates how the Model 6514's measurement can be adjusted to reflect the true dark current of the photodiode.



A Model 6517B is well suited for applications where the volume resistivity needs to be measured.

### SHIPS WITH PRODUCT

- 237-ALG-2 Low Noise Triax Cable, 3-slot triax to alligator clips (2 m) (6514, 6517B)
- 6430-322-1B Low noise Triax Cable, 3-slot triax to alligator clips (20cm) (6430)
- 8607 Safety High Voltage Dual Test Leads (6430, 6517B)
- 6517-TP Thermocouple Bead Probe (6517B)
- CS-1305 Interlock Connector (6517B)
- PreAmp Cable 2m (6.6ft) (6430)
- User Documentation

### LEARN MORE

with the "Volume and Surface Resistivity Measurements of Insulating Materials Using the Model 6517A Electrometer/High Resistance Meter" Application Note.



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