KEITHLEY

Low Current, High Resistance

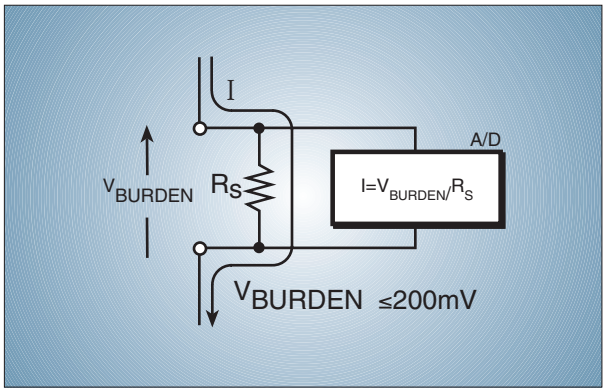
Measurement Solutions

High accuracy solutions for

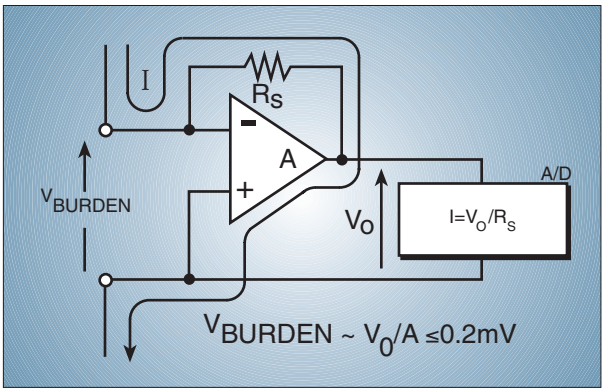
WIDE MEASUREMENT RANGES

low current applications

Measuring low DC currents often demands a lot more than a digital multimeter can deliver. Generally, DMMs lack the sensitivity required to measure currents less than 100nA. Even at higher currents, a DMM's input voltage drop (voltage burden) of hundreds of millivolts can make accurate current measurements impossible, as the figures below indicate. Electrometers can measure low currents very accurately, but the circuitry needed to measure extremely low currents, combined with functions like voltage, resistance, and charge measurement, can increase an electrometer's cost significantly. Keithley's line of picoammeters combines the economy and ease of use of a DMM with low current sensitivity near that of an electrometer.



The shunt ammeter technique used in DMMs can introduce hundreds of millivolts of voltage burden.



The feedback ammeter technique used in Keithey's picoammeters limits voltage burden to 200μV.

Low currents without the high cost

Keithley brings more than half a century of expertise in designing and manufacturing sensitive instrumentation to our new low current measurement solutions. Our picoammeters combine high accuracy with sensitivity as good as 10fA. They have always provided exceptional voltage burden specifications and wide measurement ranges; our newest instruments offer higher measurement speeds than ever before, up to 1000 readings per second on the Model 6485. Our family of instruments offers economical alternatives to other low current measurement solutions, such as optical power meters or user-designed instrumentation.

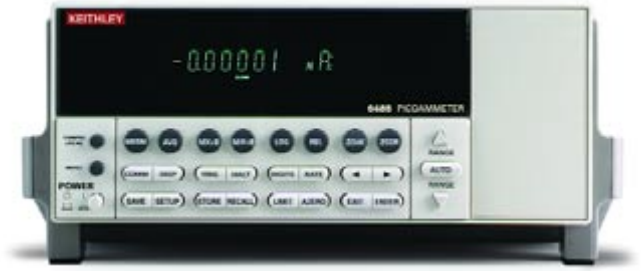
Typical picoammeter applications

- Materials and components characterization, including resistivity and leakage current measurements
- Insulation resistance measurements
- Device I-V characterization
- Photodiode current measurements
- Dark current (photodiode leakage)
- Fiber alignment
- Photomultiplier current measurements
- SEM beam current measurements
- Particle and beam monitoring
- Thermal luminescence glow current measurements
- Fluorometer and spectrometer measurements
- Circuit test and analysis
- Sensor characterization
- Teaching labs

Model 6485 Picoammeter

Exceptional low current

SUPERIOR LOW CURRENT SENSITIVITY



The **Model 6485** is Keithley's most modern 5½-digit picoammeter. It employs the latest current measurement technology but it is significantly less expensive than other instruments that perform similar functions, such as optical power meters, competitive picoammeters, or user-designed solutions. With eight current measurement ranges and high speed autoranging, the Model 6485 can measure currents from 20fA to 20mA. The Model 6485's superior sensitivity allows characterizing low current phenomena, while its 20mA range lets it measure currents high enough for 4-20mA sensor loops.

Low voltage burden

While DMMs typically employ shunt ammeter circuitry to measure current, the Model 6485 is a feedback picoammeter. This design reduces voltage burden by several orders of magnitude, resulting in a voltage burden of less than 200μV on the lower measurement ranges. The low voltage burden makes the Model 6485 function much more like an ideal ammeter than a DMM, so it can make current measurements with high accuracy, even in circuits with very low source voltages.

Just like before, only better

The Model 6485 expands on the capabilities of one of Keithley's most popular picoammeters, the Model 485, offering an additional 20mA measurement range, as well as dramatically higher measurement speeds. A built-in emulation mode simplifies upgrading existing applications originally configured with a Model 485. With a top speed of up to 1000 readings per second, the Model 6485 is the fastest picoammeter Keithley has ever made. It offers ten times greater resolution than the Model 485 on every range. A time-stamped 2500-reading data buffer provides minimum, maximum, and standard deviation statistics.

Flexible interface options

The Model 6485 is designed for easy connection to other instruments and voltage sources. For example, the built-in Trigger Link interface allows synchronizing two or more instruments. It combines six independent selectable trigger lines on a single connector for simple, direct control over all instruments in a system. A CE-approved IEEE-488 interface is included for controlling the instrument via the GPIB bus with a PC. The Model 6485 also offers an RS-232 interface.

Low current measurements made easy

A variety of additional instrument features simplify measuring low currents accurately. The Model 6485's rear panel BNC inputs allow the use of inexpensive, easy-to-use BNC cables. Its 220V overload protection on all ranges and robust design let it withstand abusive overflows. A REL function permits making relative readings with respect to a baseline value; the LOG function displays the logarithm of the absolute value of the measured current. The Model 6485 can calculate resistance by dividing an externally sourced voltage value by the measured current. The instrument can be digitally calibrated using the front panel controls or via the IEEE-488 bus. A scaled voltage analog output makes it simple to transmit measurement results to devices like DMMs, data acquisition cards, oscilloscopes, or strip chart recorders. For research on light-sensitive components, such as measuring the dark currents of photodiodes, the front panel display can be switched off to avoid introducing light that could significantly reduce the accuracy of the results.

Powerful software options

To simplify integrating the Model 6485 into PC-based test systems, the instrument comes with Keithley's ExceLINX, an add-in utility for Microsoft® Excel. Within minutes of installing ExceLINX on a PC, users can acquire data directly from the Model 6485 instrument, then employ Excel's graphics, charting and analysis capabilities to turn that data into useful information. No programming is required to use ExceLINX—a few mouse clicks are all it takes. Keithley also provides a 6485 instrument driver for use with Application Development Environments such as LabVIEW™, LabWindows™/CVI, Visual Basic, C/C++, and TestPoint. This IVI-style driver (VISA based) supports all of the functionality of the Model 6485. Numerous examples and an online help utility are provided to help programmers get their applications "Up & Running" quickly.

performance at an affordable price

Condensed Model 6485 specifications

RANGE	5½ DIGIT DEFAULT RESOLUTION	ACCURACY[1] ±(%rdg + offset) 18-28°C, 0-50% RH	TYPICAL RMS NOISE[2]	ANALOG RISE TIME 10% to 90%	NMRR[1] (50 or 60Hz)	MAXIMUM CONTINUOUS INPUT VOLTAGE
2 nA	10 fA	0.4% + 400 fA	20 fA	8 ms	60 dB	220 VDC
20 nA	100 fA	0.4% + 1 pA	100 fA	8 ms	60 dB	220 VDC
200 nA	1 pA	0.2% + 10 pA	1 pA	500 μs	60 dB	220 VDC
2 μA	10 pA	0.15% + 100 pA	10 pA	500 μs	60 dB	220 VDC
20 μA	100 pA	0.1% + 1 nA	100 pA	500 μs	60 dB	220 VDC
200 μA	1 nA	0.1% + 10 nA	1 nA	500 μs	60 dB	220 VDC
2 mA	10 nA	0.1% + 100 nA	10 nA	500 μs	60 dB	220 VDC
20 mA	100 nA	0.1% + 1 μA	100 nA	500 μs	60 dB	220 VDC

INPUT VOLTAGE BURDEN: <200μV on all ranges except <1mV on 20mA range.
LANGUAGE EMULATION: Keithley Model 485 command emulation.
TEMPERATURE COEFFICIENT: 0°-18°C & 28°-50°C For each °C, add 0.1 of accuracy spec.
ANALOG OUTPUT: Scaled voltage output (inverting 2V full scale on all ranges) 3% ± 2mV, 1kΩ impedance.

[1]At 1 PLC – limited to 60 rdgs/sec under this condition
[2]At 6 PLC – limited to 10 rdgs/sec under this condition

Typical Model 6485 applications

- Beam monitoring and radiation monitoring
- Leakage current testing in insulators, switches, relays, and other components
- Optoelectronic device testing and characterization
- Fiber alignment
- Circuit test and analysis in DCLF circuits
- Sensor characterization
- I-V measurements of semiconductors and other devices

KEITHLEY'S FASTEST PICOAMMETER EVER

Other low current measurement solutions

Model 486 Picoammeter
Model 487 Picoammeter/Source

The **Model 486** is a 5½-digit picoammeter with 10fA sensitivity. It can measure currents from 10fA to 2mA. The Model 486 offers a shorter rise time than the Model 6485 does on the higher current ranges. It also has a triax connector that extends the range over which the instrument can float. The **Model 487** adds a built-in ±500V source to the Model 486's capabilities. This combination makes the Model 487 a powerful high resistance meter and fast picoammeter in one instrument. Two voltage source ranges are available: a 500V range with 10mV resolution and a 50V range with 1mV resolution. This source allows the Model 487 to measure resistances from 5Ω to 10^{14}Ω. For tests that require a preset soak time, such as insulation resistance measurements, the Model 487 can be programmed with reading intervals from 10ms to 1000s.

The Model 486 is a good choice for applications such as:

- PMT current measurements
- Mass spectrometer current measurements
- Probe current measurements in electrochemistry
- Plasma generated current measurements
- Ion chamber current measurements

The Model 487's built-in voltage source makes it ideal for:

- Resistivity measurements
- I-V characterization
- Component leakage tests
- Insulation resistance testing

Model 428 Current Amplifier

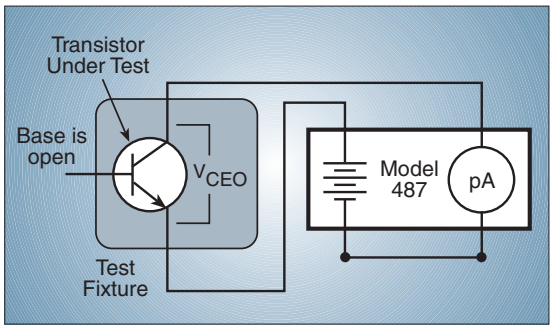
The **Model 428** is designed to convert small current transients into voltages that can be displayed on a scope or waveform analyzer. A feedback circuit design gives the Model 428 both fast rise times and sub-picoamp noise. Rise times from 2μs to 300ms can be selected. The amplifier gain can be adjusted in decade steps from 10^{3}V/A to 10^{11}V/A. Like Keithley's picoammeters, the Model 428 has zero check and offset functions to enhance the integrity of signals with voltage offsets. Up to 5mA of current can be suppressed, which can be useful for nulling out a residual or offset current present at the Model 428's input. A choice of three display intensities–bright, dim, and off–makes it suitable for use in light-sensitive environments.

Applications for the Model 428 include:

- Surface science studies
  - Amplifier for a Scanning Electron Microscope (SEM)
  - Observing secondary electron emission, as in X-ray and beam line currents
- Laser and light measurements
  - Amplifier for use with PMTs and photodiodes
  - Analysis of fast photoconductive materials
  - IR detector amplifier
- Transient phenomena
  - Current DLTS studies
  - Breakdown in devices and dielectrics
- Front-end amplifier/converter for oscilloscopes or waveform digitizers
- Fiber alignment

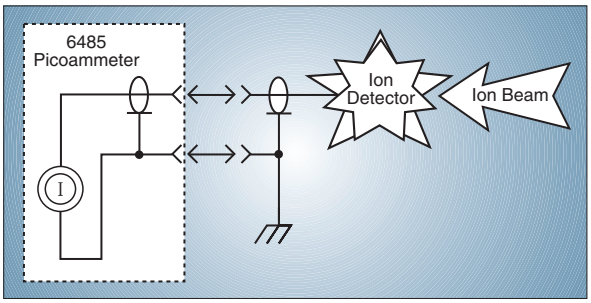
Common picoammeter applications

Transistor Leakage Current Testing



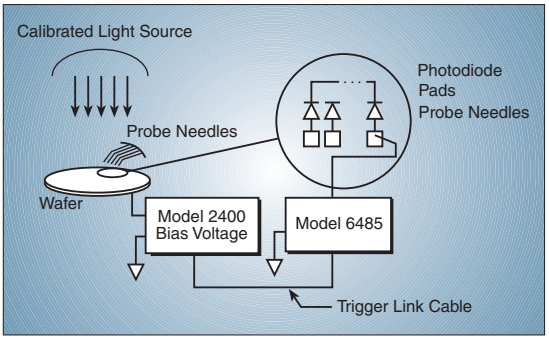
Testing bipolar transistors typically involves two leakage current measurements: I_{CEO} (collector-emitter with base open) and I_{CBO} (collector-base with emitter open). To measure the leakage current, a voltage potential is placed across two terminals with the third terminal open, and the resulting current is measured. The Model 487 is ideal for this application because of its integrated voltage source. Its low voltage burden allows measuring small leakage currents without degrading the measurement. The instrument's internal memory can store results as the test runs, then the data can be recalled and plotted.

Monitoring and control of focused ion beam currents



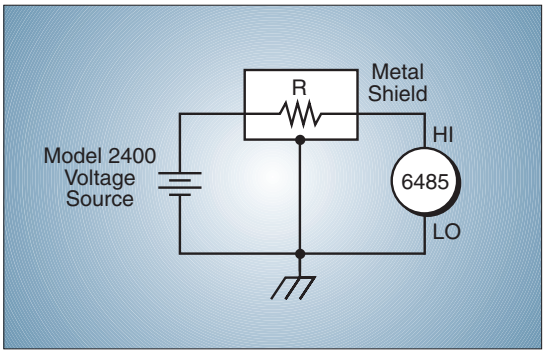
In semiconductor fabrication, focused ion beam systems are often used for nanometer-scale imaging, micromachining, and mapping. Careful monitoring of the magnitude of the beam current with an ion detector is critical. The ion detector generates a secondary current that's proportional to the current of the primary ion beam. When this secondary current is measured, it can be used to control the intensity of the primary beam. However, this secondary current is very low, often just a few picoamps, so the instrumentation measuring it must provide high measurement accuracy and repeatability, as well as sub-picoamp resolution. The Model 6485's wide measurement range and 5½-digit resolution make it ideal for this application. Signal connections to the Model 6485 are made through the instrument's BNC connector.

Wafer-level photodiode testing



The Model 6485 Picoammeter can be paired with a triggerable voltage source, such as the Model 2400 SourceMeter® instrument, a calibrated light source, and a probing fixture to create a cost-effective photodiode test system. Multiple Model 6485s can be connected to the DUT's probe pads to provide photocurrent readings or, with the addition of a switch matrix, one or more picoammeters can take current measurements from multiple pads. The Trigger Link interface available on both the Model 6485 and Model 2400 simplifies synchronizing these instruments, providing control over triggering voltage sourcing and photocurrent measurement. In the first step of the measurement process, performed in total darkness, the Model 2400 produces a voltage sweep and the Model 6485 measures the resulting dark current. In the second step, a voltage bias is applied and the resulting photocurrent is measured while the light level is increased in calibrated steps. The same basic test configuration can be used for testing positive intrinsic negative (PIN) and avalanche photodiodes (APDs).

High Resistance Measurements



The Model 487's integrated voltage source is specifically designed for making high resistance measurements. If paired with an external voltage source, either the Model 6485 or Model 486 Picoammeter can be used to make measure high resistances (>1GΩ) in applications such as insulation resistance testing. A constant voltage source is placed in series with the unknown resistance and the picoammeter. The voltage drop across the picoammeter is negligible, so essentially all the voltage appears across the unknown resistance. The resulting current is measured by the picoammeter and the resistance is calculated using Ohm's Law (R=V/I). To prevent generated current due to electrostatic interference, the unknown resistance is housed in a shielded test fixture.

All the support you need

Informative reference materials

Visit our web site, **www.keithley.com,** to access our reference library, including:

Low Level Measurements

This informative handbook describes theoretical and practical considerations involved in the measurement of low DC currents, high resistances, low DC voltages, and low resistances.

Application Notes

These helpful notes include practical, real-world answers to many application questions related to low level measurements.

Lab Exercises

Keithley's suite of lab exercises is designed to help students learn about making electrical and physical measurements through hands-on experience. Many lab exercises are available for free downloading from our website. For example:

- Energy Gap in a Semiconductor
- Digital Multimeter and Oscilloscope
- Linear Op Amp Circuits
- Step Response of Passive Circuits
- The Electric Field
- Field Effect Transistors
- Non-Linear Op Amp Circuits
- Frequency Domain Analysis of Signals

Service you can depend on

When you need help, contact us at www.keithley.com or call us at **1-888-KEITHLEY (534-8453)**. Whatever your application, Keithley's application engineers are ready to help you meet its challenges, before and after the sale. You can rely on us to suggest the most effective system configurations and to provide prompt, reliable applications support once your system is set up.

The next time you're faced with a challenging application, give us a call. We'll offer you a cost-effective solution that will help you improve your product quality, throughput, and yield.

A greater measure of confidence

With more than a half-century of expertise in making demanding low level measurements, Keithley offers its customers a greater measure of testing confidence on the production floor, in the QA lab, and in R&D. For more information on how Keithley test solutions can help you keep pace with changing technologies, call your local Keithley sales engineer or visit our website.

KEITHLEY

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