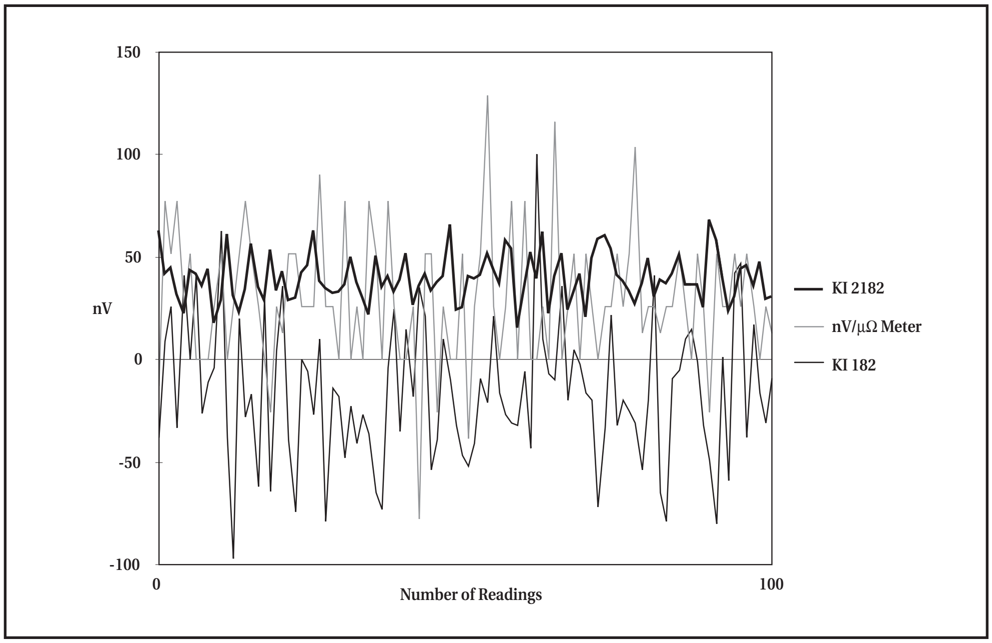
2182 Nanovoltmeter

NEW PRODUCT

- **LOW NOISE AT HIGH SPEEDS.** Typically 15nV p-p at 1s response time, 40–50nV p-p at 60ms response time.
- **DELTA MODE.** Coordinate measurements with a reversing current source at up to 8Hz with 30nV p-p noise (typical) for one reading. Average multiple readings for greater noise reduction.
- **SYNCHRONIZATION TO LINE.** Provides 110dB NMRR and minimizes the effect of AC common-mode currents.
- **DUAL CHANNELS.** For measuring voltage or temperature.
- **DIRECT READING OF RATIO.** Read the ratio of an unknown resistance to a reference resistor directly, using the second voltage channel.
- **Built-in thermocouple (J, K, N, T, E, R, S and B) linearization and cold reference junction**

Low levels of DC drift and noise are among the best-known attributes of DC nanovoltmeters. In a typical nanovoltmeter, acceptable noise levels can be achieved by using extended integration periods of 30 seconds or more and by filtering the response. When used in this way, Keithley's new Model 2182 Nanovoltmeter has lower noise than either earlier types of nanovoltmeters or sensitive DMMs. However, the Model 2182's design has been optimized to make low noise measurements in just a few seconds and to measure low-resistance materials or devices by using the reversed-current method. (Refer to the sidebar for more information on these types of measurements.) The result is a nanovoltmeter that provides significantly lower noise performance for real-world measurements made at higher speeds, in other words, rates faster than the thermal time constant of the sample. This makes the Model 2182 a much better choice than DMMs or earlier nanovoltmeters for research, metrology, and sophisticated low voltage testing applications. It also offers the greatest measurement value of any nanovoltmeter available. Not only is it priced lower than earlier models, but it reduces the need for a computer controller when making sensitive precision I-V measurements by providing the ability to coordinate control of an external source.

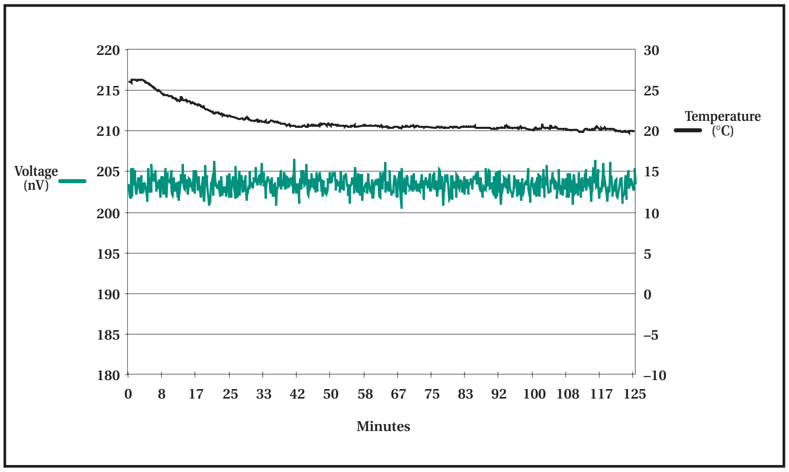
This graph compares the Model 2182's noise performance with that of the Model 182 and a Nanovolt/Micro-ohm Meter. All the data shown was taken at 10 readings per second with a low thermal short applied to the input.



2182 Nanovoltmeter

Research Applications

The Model 2182 can often simplify experiments by coordinating the operation of a current source with the nanovoltmeter and by making low noise measurements in a short time.



The Model 2182 measuring a 10mΩ resistor with a 20µA test current on the 10mV range using the Delta mode.

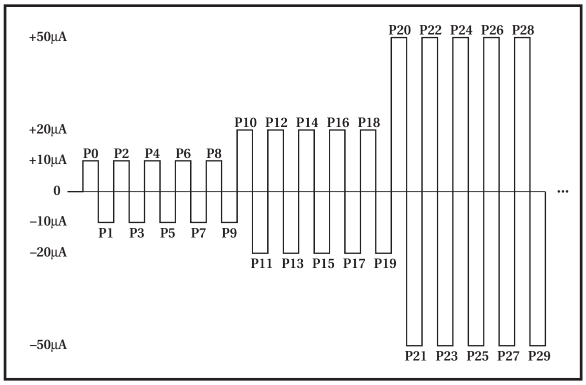
Built-in offset compensated volts—no computer required

The Model 2182's Delta Mode performs low voltage measurements easily and precisely using the current reversal method. When used with a triggerable external current source, such as an instrument in Keithley's Series 2400 Digital SourceMeter line, this Delta Mode automatically triggers the current source to alternate polarity, then triggers a reading at each polarity, for example, at t1 for the positive current and at t2 for the negative current. The Model 2182 then displays the "compensated" value:

$$\text{Delta V} = \frac{V_{t1} - V_{t2}}{2}$$

This approach ensures the true value is readily displayed, with the offsets already canceled out by the current reversal. The Model 2182 can make low voltage, low noise measurements quickly, so these reversals can be easily done at periods ranging from 0.12 to eight seconds, easily compensating for changing thermal offsets with longer time constants. Noise is further reduced by averaging the compensated readings internally. The nanovoltmeter and current source complete the measurement process without the need for an external computer controller. The Delta Mode can be programmed using either the front panel controls or via the IEEE-488 bus.

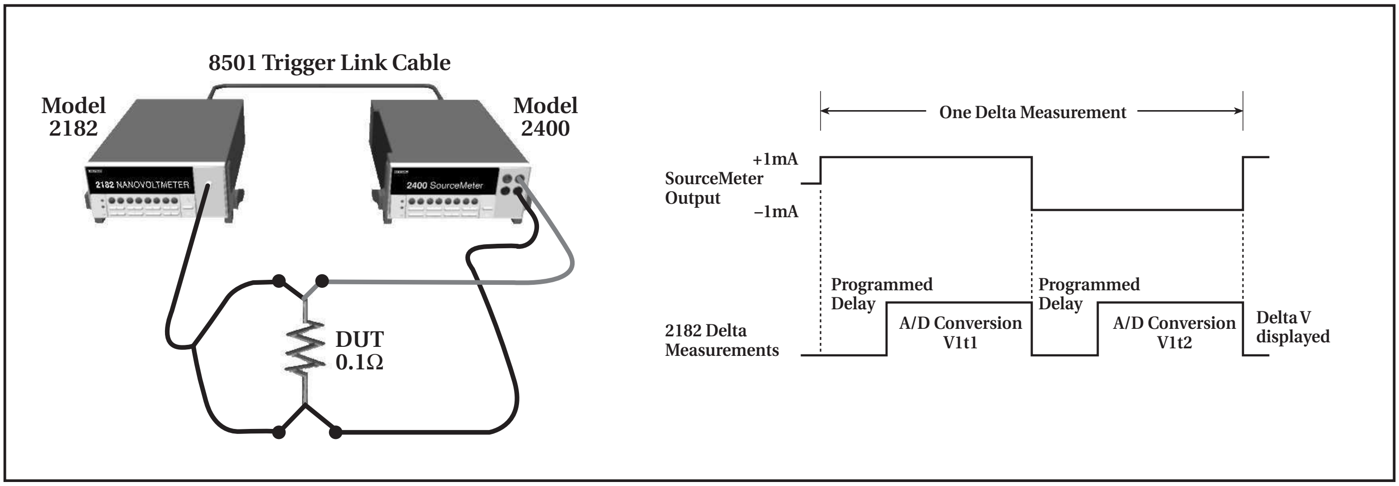
I -V Curves or Continuous I



The Model 2182 and a 2400 Series SourceMeter together provide a low-cost system for making precision I-V curves. Above is a preprogrammed current waveform that is easily stored in the SourceMeter. Using the Delta V mode, the Model 2182 can average five Delta V readings at 10µA (P0–P9), then five readings at 20µA (P10–P19), then five at 50µA (P20–P29). The result is a set of low-noise V and I data at 10, 20 and 50µA. For applications where one current level is sufficient, the Model 2182 is easily programmed to average Delta V readings at a single current in the same manner, providing a wide range of speed/noise trade-offs.

Flexible, Effective Speed/Noise Trade-offs

For simple low voltage measurements, choose the speed/filter combination that best fits the experiment's response time and noise level requirements. The Model



2182 Nanovoltmeter

NEW PRODUCT

Three Ways to Measure Nanovolts

DC nanovoltmeters. DC nanovoltmeters and sensitive DMMs both provide low noise DC voltage measurements by using *long integration times and highly filtered readings* to minimize the bandwidth near DC. Unfortunately, this approach has limitations, particularly the fact that thermal voltages developed in the sample and connections vary, so long integration times don't improve measurement precision. With a noise specification of just 6nV p-p, the Model 2182 is the lowest noise digital nanovoltmeter available, with the exception of the Keithley Model 2001 DMM/1801 Nanovolt Preamp combination, which has 0.6nV p-p noise.

AC technique. The limitations of the long integration and filtered readings technique have led many people to use an *AC technique* for measuring low resistances and voltages. In this method, an AC excitation is applied to the sample and the voltage is detected synchronously at the same frequency and an optimum phase. While this technique removes the varying DC component, in many experiments at high frequencies, users can experience problems related to phase shifts caused by spurious capacitance or L/R time constant. At low frequencies, as the AC frequency is reduced to minimize phase shifts, amplifier noise increases.

The current reversal method. The Model 2182 is optimized for the *current reversal method*, which combines the advantages of both earlier approaches. In this technique, the DC test current is reversed, then the difference in voltage due to the difference in current is determined. Typically, this measurement is performed at a few hertz, a frequency just high enough for the current to be reversed before the thermal voltages can change. The Model 2182's low noise performance at measurement times of a few hundred milliseconds to a few seconds means the reversal period can be set quite small in comparison with the thermal time constant of the sample and the connections, effectively reducing the impact of thermal voltages.

2182's wide variety of selectable response times simplifies optimizing these speed/noise tradeoffs. Noise levels are assured over a wide range of useful response times: <25nV p-p at 1s or <70nV at 60ms when integrating over a 60Hz line cycle and <6nV if a 25s response time can be used.

Metrology Applications

The Model 2182 combines the accuracy of a DMM with low noise at high speed for high-precision metrology applications. Its low noise, high signal observation time, fast measurement rates, and 2ppm accuracy provide the most cost-effective meter available for applications such as intercomparison of voltage standards and direct measurement of resistance standards.

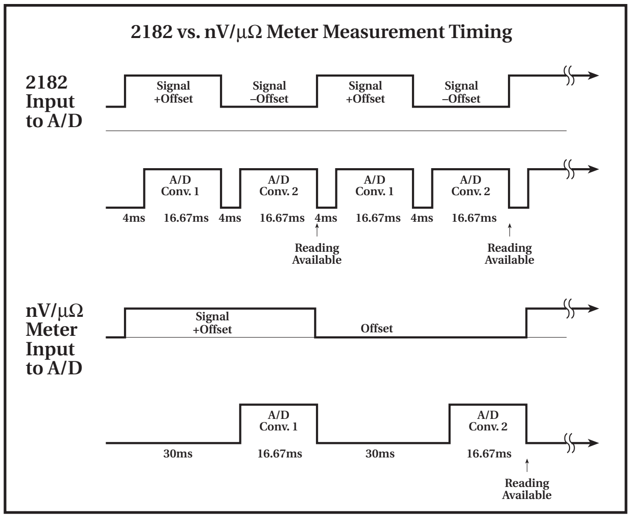
Little Things that Mean a Lot

Low-level measurement instruments are often accompanied by impressive specifications, but when connected to the experiment, major issues that weren't covered in the specifications may arise. For example, the level of transient current the instrument introduces to the sample is one of these issues Keithley has addressed in the design of the Model 2182. Transient currents generated in the input are lower than those in our previous nanovoltmeter, the Model 182 Sensitive Digital Voltmeter, which has lower transients than most sensitive DMMs or a Nanovolt/Micro-ohm Meter. That ensures the Model 2182 can be used effectively with Josephson Junction arrays and other sensitive devices with less disturbance than previous instruments.

Interference from power lines can be critical at nanovolt levels, so the Model 2182 has the ability to synchronize its measurement cycle to the line, minimizing variations due to readings that begin at different phases of the line cycle.

The result is unusually high immunity to line interference, minimizing shielding and filtering requirements.

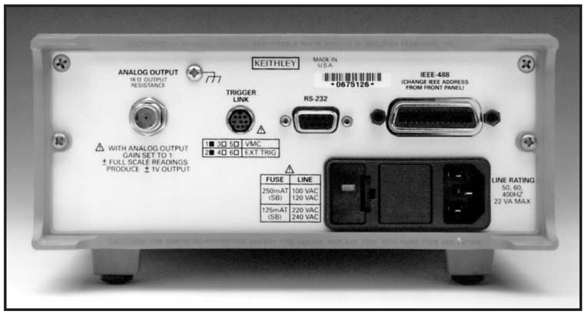
The Model 2182's unique measurement cycle is one of the reasons for its lower noise—the instrument observes the signal for nearly twice as long as any other nanovolt-level meter. This is particularly important in research and metrology work, where maximizing signal observation time to get the lowest noise reading as quickly as possible is vital.



The 2182 A/D observes the signal for a much higher percentage of time than DMMs or nV/μΩ meters, because the 2182 also "observes" the signal during the offset correction phase (but with the offset reversed).

Decades of Low-Level Measurement Expertise

Keithley has been an industry leader in the design and production of high accuracy nanovoltmeters for more than thirty years. The Model 2182 builds upon this expertise and incorporates the latest advances in the measurement of low-level phenomena. For more information on how it can help you make better nanovolt-level measurements, contact our Low-Level Measurement Experts by phone or e-mail.



QUESTIONS?
1-800-552-1115 (U.S. only)
Call toll free for technical assistance, product support or ordering information.

2182 Nanovoltmeter

NEW PRODUCT

Volts Specifications (20% over range)

CONDITIONS: 1PLC with 10 reading digital filter or 5PLC with 2 reading digital filter.

CHANNEL 1 RANGE	RESOLUTION	INPUT RESISTANCE	ACCURACY: ±(ppm of reading + ppm of range) (ppm = parts per million) (e.g., 10ppm = 0.001%) 24 Hour[1] T_{CAL} ±1°C	90 Day T_{CAL} ±5°C	1 Year T_{CAL} ±5°C	2 Year T_{CAL} ±5°C	TEMPERATURE COEFFICIENT 0°–18°C & 28°–50°C
10.000000 mV[2,3,4]	1 nV	>10 GΩ	20 + 4	40 + 4	50 + 4	60 + 4	(1 + 0.5)/°C
100.00000 mV	10 nV	>10 GΩ	10 + 3	25 + 3	30 + 4	40 + 5	(1 + 0.2)/°C
1.0000000 V	100 nV	>10 GΩ	7 + 2	18 + 2	25 + 2	32 + 3	(1 + 0.1)/°C
10.000000 V	1 µV	>10 GΩ	2 + 1[5]	18 + 2	25 + 2	32 + 3	(1 + 0.1)/°C
100.00000 V[4]	10 µV	10 MΩ ±1%	10 + 3	25 + 3	35 + 4	52 + 5	(1 + 0.1)/°C
CHANNEL 2[6,10]							
100.00000 mV	10 nV	>10 GΩ	10 + 6	25 + 6	30 + 7	40 + 7	(1 + 1)/°C
1.0000000 V	100 nV	>10 GΩ	7 + 2	18 + 2	25 + 2	32 + 3	(1 + 0.5)/°C
10.000000 V	1 µV	>10 GΩ	2 + 1[5]	18 + 2	25 + 2	32 + 3	(1 + 0.5)/°C

CHANNEL 1/CHANNEL 2 RATIO: Ratio accuracy = accuracy of selected Channel 1 range + accuracy of selected Channel 2 range.

($V1_{t1} - V1_{t2}$)/2 (DELTA): Delta accuracy = accuracy of selected Channel 1 range.

DC Noise Performance[7] (DC noise expressed in volts peak-to-peak)

Response time = time required for reading to be settled within noise levels from a stepped input, 60Hz operation.

RESPONSE TIME	NPLC, FILTER	10mV	100mV	RANGE 1V	10V	100V	NMRR[8]	CMRR[9]
CHANNEL 1								
25.0 s	5, 75	6 nV	20 nV	75 nV	750 nV	75 µV	110 dB	140 dB
4.0 s	5, 10	15 nV	50 nV	150 nV	1.5 µV	75 µV	100 dB	140 dB
1.0 s	1, 18	25 nV	175 nV	600 nV	2.5 µV	100 µV	95 dB	140 dB
667 ms	1, 10 or 5, 2	35 nV	250 nV	650 nV	3.3 µV	150 µV	90 dB	140 dB
60 ms	1, Off	70 nV	300 nV	700 nV	6.6 µV	300 µV	60 dB	140 dB
CHANNEL 2[10]								
25.0 s	5, 75	—	150 nV	200 nV	750 nV	—	110 dB	140 dB
4.0 s	5, 10	—	150 nV	200 nV	1.5 µV	—	100 dB	140 dB
1.0 s	1, 10 or 5, 2	—	175 nV	400 nV	2.5 µV	—	90 dB	140 dB
85 ms	1, Off	—	425 nV	1 µV	9.5 µV	—	60 dB	140 dB

Voltage Noise vs. Source Resistance[11]

(DC noise expressed in volts peak-to-peak)

SOURCE RESISTANCE	NOISE	ANALOG FILTER	DIGITAL FILTER
0 Ω	6 nV	Off	100
100 Ω	8 nV	Off	100
1 kΩ	15 nV	Off	100
10 kΩ	35 nV	Off	100
100 kΩ	100 nV	On	100
1 MΩ	350 nV	On	100

Temperature (Thermocouples)[12]

(Displayed in °C, °F, or K. Accuracy based on ITS-90, exclusive of thermocouple errors.)

TYPE	RANGE	RESOLUTION	ACCURACY 90 Day/1 Year 23° ±5°C Relative to Simulated Reference Junction
J	–200 to +760°C	0.001 °C	±0.2 °C
K	–200 to +1372°C	0.001 °C	±0.2 °C
N	–200 to +1300°C	0.001 °C	±0.2 °C
T	–200 to +400°C	0.001 °C	±0.2 °C
E	–200 to +1000°C	0.001 °C	±0.2 °C
R	0 to +1768°C	0.1 °C	±0.2 °C
S	0 to +1768°C	0.1 °C	±0.2 °C
B	+350 to +1820°C	0.1 °C	±0.2 °C

Operating Characteristics[13,14]

60Hz (50Hz) Operation

FUNCTION	DIGITS	READINGS/s	PLCs
DCV Channel 1, Channel 2, Thermocouple	7.5	3 (2)	5
	7.5[17,19]	6 (4)	5
	6.5[18,19]	18 (15)	1
	5.5[17,19]	80 (72)	0.1
	4.5[16,17,19]	115 (105)	0.01
Channel 1/Channel 2 (Ratio), ($V1_{t1} - V1_{t2}$)/2 (Delta), Scan	7.5	1.5 (1.3)	5
	7.5[17,19]	2.3 (2.1)	5
	6.5[18]	8.5 (7.5)	1
	5.5[17]	30 (29)	0.1
	4.5[17]	41 (40)	0.01

System Speeds[13,15]

RANGE CHANGE TIME:[14] <40 ms (<50 ms).
FUNCTION CHANGE TIME:[14] <45 ms (<55 ms).
AUTORANGE TIME:[14] <60 ms (<70 ms).
ASCII READING TO RS-232 (19.2K Baud): 40/s (40/s).
MAX. INTERNAL TRIGGER RATE:[16] 120/s (120/s).
MAX. EXTERNAL TRIGGER RATE:[16] 120/s (120/s).

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NEW PRODUCT

Measurement Characteristics

A-D LINEARITY: 0.8ppm of reading + 0.5ppm of range.

AUTOZERO OFF ERROR
- **10mV:** Add ±(8ppm of range + 100nV) for <10 minutes and ±1°C.
- **100mV–100V:** Add ±(8ppm of range + 10µV) for <10 minutes and ±1°C.

INPUT IMPEDANCE
- **10mV–10V:** >10GΩ, in parallel with <1.5nF.
- **100V:** 10MΩ ±1%.

INPUT BIAS CURRENT: <50pA DC at 23°C.

COMMON MODE CURRENT: <50nA p-p at 50Hz or 60Hz.

INPUT PROTECTION: 150V peak to any terminal. 70V peak Channel 1 LO to Channel 2 LO.

CHANNEL ISOLATION: >10GΩ.

EARTH ISOLATION: 350V peak, >10GΩ and <150pF any terminal to earth. Add 35pF/ft with Model 2107 Low Thermal Input Cable.

Analog Output

MAXIMUM OUTPUT: ±1.2V.

ACCURACY: ±(0.1% of output + 1mV).

OUTPUT RESISTANCE: 1kΩ ±5%.

GAIN: Adjustable from 10^{-9} to 10^{6}. With gain set to 1, a full range input will produce a 1V output.

OUTPUT REL: Selects the value of input that represents 0V at output. The reference value can be either programmed value or the value of the previous input.

Triggering and Memory

WINDOW FILTER SENSITIVITY: 0.01%, 0.1%, 1%, 10%, or full scale of range (none).

READING HOLD SENSITIVITY: 0.01%, 0.1%, 1% or 10% of reading.

TRIGGER DELAY: 0 to 99 hours (1ms step size).

EXTERNAL TRIGGER DELAY: 2ms + <1ms jitter with auto zero off, trigger delay = 0.

MEMORY SIZE: 1024 readings.

Math Functions

Rel, Min/Max/Average/Std Dev/Peak-to-Peak (of stored reading), Limit Test, %, and mX+b with user defined units displayed.

Specifications are subject to change without notice.

Remote Interface

Keithley 182 emulation.

GPIB (IEEE-488.2) and RS-232C.

SCPI (Standard Commands for Programmable Instruments).

GENERAL SPECIFICATIONS

POWER SUPPLY: 100V/120V/220V/240V ±10%.

LINE FREQUENCY: 45Hz to 66Hz and 360Hz to 440Hz, automatically sensed at power-up.

POWER CONSUMPTION: 22VA.

OPERATING ENVIRONMENT: Specified for 0° to 50°C. Specified to 80% RH at 35°C.

MAGNETIC FIELD DENSITY: 10mV range 4.0s response noise tested to 500 gauss.

STORAGE ENVIRONMENT: –40° to 70°C.

WARRANTY: 3 years.

SAFETY: Complies with European Union Directive 73/23/EEC (low voltage directive); meets EN 61010-1 safety standard. Installation category I.

EMC: Complies with European Union Directive 89/336/EEC (CE marking requirement), FCC part 15 class B, CISPR 11, IEC 801-2, IEC-801-3, IEC 801-4.

VIBRATION: MIL-T-28800E Type III, Class 5.

WARM-UP: 2.5 hours to rated accuracy.

DIMENSIONS: Rack Mounting: 89mm high × 213mm wide × 370mm deep (3.5 in × 8.375 in × 14.563 in). Bench Configuration (with handles and feet): 104mm high × 238mm wide × 370mm deep (4.125 in × 9.375 in ×14.563 in).

SHIPPING WEIGHT: 5kg (11 lbs).

Accessories Supplied

2107-4: Low Thermal Input Cable with spade lugs, 1.2m (4 ft).

User manual, service manual, contact cleaner, line cord, alligator clips.

Accessories Available

2107-30:	Low Thermal Input Cable with spade lugs, 9.1m (30 ft)
2182-KIT:	Low Thermal Connector with strain relief
2188:	Low Thermal Calibration Shorting Plug
4288-1:	Single Fixed Rack Mount Kit
4288-2:	Dual Fixed Rack Mount Kit
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)
8502:	Trigger-Link Adapter to 6 female BNC connectors
8503:	Trigger-Link Cable to 2 male BNC connectors

Notes

1. Relative to calibration accuracy.
2. With Analog Filter on, add 20ppm of reading to listed specification.
3. When properly zeroed using REL function. If REL is not used, add 100nV to the range accuracy.
4. Specifications include the use of ACAL function. If ACAL is not used, add 9ppm of reading/°C from T_{CAL} to the listed specification. T_{CAL} is the internal temperature stored during ACAL.
5. For 5PLC with 2-reading Digital Filter. Use ±(4ppm of reading + 2ppm of range) for 1PLC with 10-reading Digital Filter.
6. Channel 2 must be referenced to Channel 1. Channel 2 HI must not exceed 125% (referenced to Channel 1 LO) of Channel 2 range selected.
7. Noise behavior using 2188 Low Thermal Short after 2.5 hour warm-up. ±1°C. Analog Filter off. Observation time = 10× response time or 2 minutes, whichever is less.
8. For L_{SYNC} On, line frequency ±0.1%. If L_{SYNC} Off, use 60dB.
9. For 1kΩ unbalance in LO lead. AC CMRR is 70dB.
10. For Low Q mode On, add the following to DC noise and range accuracy at stated response time: 200nV p-p @ 25s, 500nV p-p @ 4.0s, 1.2µV p-p @ 1s, and 5µV p-p @ 85ms.
11. After 2.5 hour warm-up, ±1°C, 5PLC, 2 minute observation time, Channel 1 10mV range only.
12. For Channel 1 or Channel 2, add 0.3°C for external reference junction. Add 2°C for internal reference junction.
13. Speeds are for 60Hz (50Hz) operation using factory defaults operating conditions (*RST). Autorange Off, Display Off, Trigger Delay = 0, Analog Output off.
14. Speeds include measurements and binary data transfer out the GPIB. Analog Filter On, 4 readings/s max.
15. Auto Zero Off, NPLC = 0.01.
16. 10mV range, 80 readings/s max.
17. Sample count = 1024, Auto Zero Off.
18. For L_{SYNC} On, reduce reading rate by 15%.
19. For Channel 2 Low Q mode Off, reduce reading rate by 30%.