6220
6221

DC Current Source
AC and DC Current Source

6220 and 6221

- **Source and sink (programmable load) 100fA to 100mA**
- **$10^{14}\Omega$ output impedance ensures stable current sourcing into variable loads**
- **65000-point source memory allows executing comprehensive test current sweeps directly from the current source**
- **Built-in RS-232, GPIB, Trigger Link, and digital I/O interfaces**
- **Reconfigurable triax output simplifies matching the application's guarding requirements**
- **Model 220 emulation mode eliminates need to reprogram existing applications**

6221 Only

- **Source AC currents from 4pA to 210mA peak to peak for AC characterization of components and materials. The 6221's 10MHz output update rate generates smooth sine waves up to 100kHz**
- **Built-in standard and arbitrary waveform generators with 1mHz to 100kHz frequency range. Applications include use as a complex programmable load or sensor signal and for noise emulation**
- **Programmable pulse widths as short as 5µs, limiting power dissipation in delicate components. Supports pulsed I-V measurements down to 50µs when used with Model 2182A Nanovoltmeter**
- **Built-in Ethernet interface for easy remote control without a GPIB controller card**

The Model 6220 DC Current Source and Model 6221 AC and DC Current Source combine ease of use with exceptionally low current noise. Low current sourcing is critical to applications in test environments ranging from R&D to production, especially in the semiconductor, nanotechnology, and superconductor industries. High sourcing accuracy and built-in control functions make the Models 6220 and 6221 ideal for applications like Hall measurements, resistance measurements using delta mode, pulsed measurements, and differential conductance measurements.

The need for precision, low current sourcing. Device testing and characterization for today's very small and power-efficient electronics requires sourcing low current levels, which demands the use of a precision, low current source. Lower stimulus currents produce lower—and harder to measure—voltages across the device. Combining the Model 6220 or 6221 with a Model 2182A Nanovoltmeter makes it possible to address both of these challenges.

AC current source and current source waveform generator. The Model 6221 is the only low current AC source on the market. Before its introduction, researchers and engineers were forced to build their own AC current sources. This cost-effective source provides better accuracy, consistency, reliability, and robustness than "home-made" solutions. The Model 6221 is also the only commercially available current source waveform generator, which greatly simplifies creating and outputting complex waveforms.

Simple programming. Both current sources are fully programmable via the front panel controls or from an external controller via RS-232 or GPIB interfaces; the Model 6221 also features an Ethernet interface for remote control from anywhere there's an Ethernet connection. Both instruments can source DC currents from 100fA to 105mA; the Model 6221 can also source AC currents from 4pA to 210mA peak to peak. The output voltage compliance of either source can be set from 0.1V to 105V in 10mV steps. Voltage compliance (which limits the amount of voltage applied when sourcing a current) is critical for applications in which overvoltages could damage the device under test (DUT).

Drop-in replacement for the Model 220 current source. These instruments build upon Keithley's popular Model 220 Programmable Current Source; a Model 220 emulation mode makes it easy to replace a Model 220 with a Model 6220/6221 in an existing application without rewriting the control code.

Define and execute current ramps easily. Both the Models 6220 and 6221 offer tools for defining current ramps and stepping through predefined sequences of up to 65,536 output values using a trigger or a timer. Both sources support linear, logarithmic, and custom sweeps.

APPLICATIONS

- **Nanotechnology**
  - **Differential conductance**
  - **Pulsed sourcing and resistance**
- **Optoelectronics**
  - **Pulsed I-V**
- **Replacement for AC resistance bridges (when used with Model 2182A)**
  - **Measuring resistance with low power**
- **Replacement for lock-in amplifiers (when used with Model 2182A)**
  - **Measuring resistance with low noise**

Precision low current sourcing

LOW LEVEL MEASURE & SOURCE

6220
6221

DC Current Source
AC and DC Current Source

Ordering Information

6220 DC Precision Current Source

6221 AC and DC Current Source

6220/2182A Complete Delta Mode System, w/DC Current Source, Nanovoltmeter, and all necessary cables (GPIB cables not included)

6221/2182A Complete Delta Mode System, w/AC and DC Current Source, Nanovoltmeter, and all necessary cables (GPIB cables not included)

Accessories Supplied

237-ALG-2	6.6 ft (2m), Low Noise, Input Cable with Triax-to-Alligator Clips
8501-2	6.6 ft (2m) Trigger Link Cable to connect 622x to 2182A
CA-180-3A	Ethernet Crossover Cable (6221 only)
CA-351	Communication Cable between 2182A and 622x
CS-1195-2	Safety Interlock Connector

Instruction manual on CD

Getting Started manual (hardcopy)

Software (downloadable)

ACCESSORIES AVAILABLE

7006-*	GPIB Cable with Straight-On Connector
7007-1	Shielded IEEE-488 Cable, 1m (3.3 ft)
7007-2	Shielded IEEE-488 Cable, 2m (6.6 ft)
7078-TRX-5	5 ft (1.5m), Low Noise, Triax-to-Triax Cable (Male on Both Ends)
KPCI-488LPA	IEEE-488 Interface/Controller for the PCI Bus
KUSB-488B	IEEE-488 USB-to-GPIB Interface Adapter

SERVICES AVAILABLE

6220-3Y-EW	1-year factory warranty extended to 3 years from date of shipment
6221-3Y-EW	1-year factory warranty extended to 3 years from date of shipment
C/6220-3Y-ISO	3 (ISO-17025 accredited) calibrations within 3 years of purchase*
C/6221-3Y-ISO	3 (ISO-17025 accredited) calibrations within 3 years of purchase*

*Not available in all countries

The Model 6221's combination of high source resolution and megahertz update rates makes it capable of emulating high fidelity current signals that are indistinguishable from analog current ramps.

Free Instrument Control Example Start-up Software

The instrument control example software available for the sources simplifies both performing basic sourcing tasks and coordinating complex measurement functions with the Keithley Model 2182A. The software, developed in the LabVIEW® programming environment, includes a step-by-step measurement guide that helps users set up their instruments and make proper connections, as well as program basic sourcing functions. The advanced tools in the package support delta mode, differential conductance, and pulse mode measurements. From this package, users can print out the instrument commands for any of the pre-programmed functions, which provides a starting point for incorporating these functions into customized applications.

Differential Conductance

Differential conductance measurements are among the most important and critical measurements made on non-linear tunneling devices and on low temperature devices. Mathematically, differential conductance is the derivative of a device's I-V curve. The Model 6220 or 6221, combined with the Model 2182A Nanovoltmeter, is the industry's most complete solution for differential conductance measurements. Together, these instruments are also the fastest solution available, providing 10× the speed and significantly lower noise than other options. Data can be obtained in a single measurement pass, rather than by averaging the result of multiple sweeps, which is both time-consuming and prone to error. The Model 622X and Model 2182A are also easy to use because the combination can be treated as a single instrument. Their simple connections eliminate the isolation and noise current problems that plague other solutions.

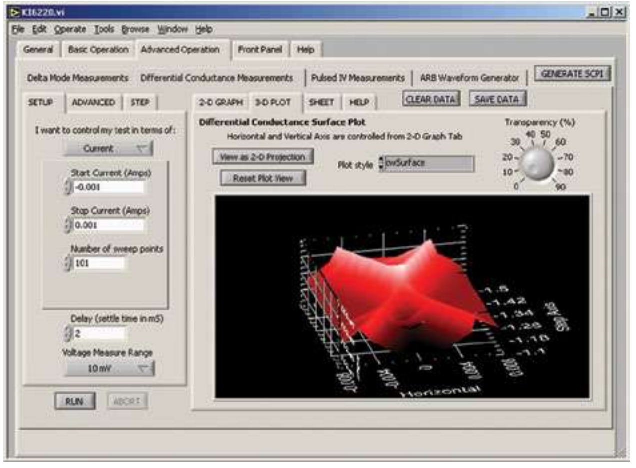

Figure 1. Perform, analyze, and display differential conductance measurements.

Delta Mode

Keithley originally developed the delta mode method for making low noise measurements of voltages and resistances for use with the Model 2182 Nanovoltmeter and a triggerable external current source. Essentially, the delta mode automatically triggers the current source to alternate the signal polarity, then triggers a nanovoltmeter reading at each polarity. This current reversal technique cancels out any constant thermoelectric offsets, ensuring the results reflect the true value of the voltage.

This same basic technique has been incorporated into the Model 622X and Model 2182A delta mode, but its implementation has been dramatically enhanced and simplified. The technique can now cancel thermoelectric offsets that drift over time, produce results in half the time of the previous technique, and allow the source to control and configure the nanovoltmeter, so setting up the measurement takes just two key presses. The improved cancellation and higher reading rate reduces measurement noise to as little as 1nV.

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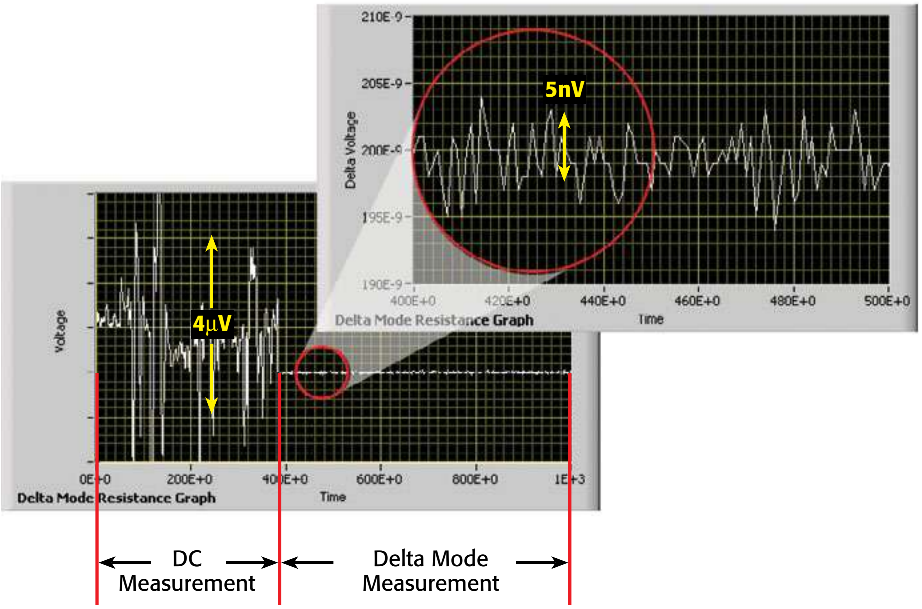

Figure 2. Delta mode offers 1000-to-1 noise reduction.

The delta mode enables measuring low voltages and resistances accurately. Once the Model 622X and the Model 2182A are connected properly, the user simply presses the current source's Delta button, followed by the Trigger button, which starts the test. The Model 622X and the Model 2182A work together seamlessly and can be controlled via the GPIB interface (GPIB or Ethernet with the Model 6221). The free example control software available for the Model 622X includes a tutorial that "walks" users through the delta mode setup process.

Pulsed Tests

Even small amounts of heat introduced by the measurement process itself can raise the DUT's temperature, skewing test results or even destroying the device. The Model 6221's pulse measurement capability minimizes the amount of power dissipated into a DUT by offering maximum flexibility when making pulsed measurements, allowing users to program the optimal pulse current amplitude, pulse interval, pulse width, and other pulse parameters.

The Model 6221 makes short pulses (and reductions in heat dissipation) possible with microsecond rise times on all ranges. The Model 6221/2182A combination synchronizes the pulse and measurement—a measurement can begin as soon as 16µs after the Model 6221 applies the pulse. The entire pulse, including a complete nanovolt measurement, can be as short as 50µs. Line synchronization between the Model 6221 and Model 2182A eliminates power line related noise.

Standard and Arbitrary Waveform Generator

The Model 6221 is the only low current AC source on the market. It can be programmed to generate both basic waveforms (sine, square, triangle, and ramp) and customizable waveforms with an arbitrary waveform generator (ARB) that supports defining waveforms point by point. It can generate waveforms at frequencies ranging from 1mHz to 100kHz at an output update rate of 10 megasamples/second.

Performance Superior to AC Resistance Bridges and Lock-In Amplifiers

The Model 622X/2182A combination provides many advantages over AC resistance bridges and lock-in amplifiers, including lower noise, lower current sourcing, lower voltage measurements, less power dissipation into DUTs, and lower cost. It also eliminates the need for a current pre-amplifier.

Models 6220 and 6221 vs. Homemade Current Sources

Many researchers and engineers who need a current source attempt to get by with a voltage source and series resistor instead. This is often the case when an AC current is needed. This is because, until the introduction of the Model 6220/6221, no AC current sources were available on the market. However, homemade current sources have several disadvantages vs. true current sources:

- **Homemade Current Sources Don't Have Voltage Compliance.** You may want to be sure the voltage at the terminals of your homemade "current source" never exceeds a certain limit (for example, 1–2V in the case of many optoelectronic devices). The most straightforward way to accomplish this is to reduce the voltage source to that level. This requires the series resistor to be reduced to attain the desired current. If you want to program a different current, you must change the resistor while the voltage is held constant! Another possibility is to place a protection circuit in parallel with the DUT. These do not have precise voltage control and always act as a parallel device, stealing some of the programmed current intended for the DUT.
- **Homemade Current Sources Can't Have Predictable Output.** With a homemade "current source" made of a voltage source and series resistor, the impedance of the DUT forms a voltage divider. If the DUT resistance is entirely predictable, the current can be known, but if the DUT resistance is unknown or changes, as most devices do, then the current isn't a simple function of the voltage applied. The best way to make the source predictable is to use a very high value series resistor (and accordingly high voltage source), which is in direct contradiction with the need for compliance.
- While it's possible to know (if not control) the actual current coming from such an unpredictable source, this also comes at a cost. This can be done with a supplemental measurement of the current, such as using a voltmeter to measure the voltage drop across the series resistor. This measurement can be used as feedback to alter the voltage source or simply recorded. Either way, it requires additional equipment, which adds complexity or error. To make matters worse, if the homemade current source is made to be moderately predictable by using a large series resistor, this readback would require using an electrometer to ensure accuracy.

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The Model 6221 can also expand the capabilities of lock-in amplifiers in applications that already employ them. For example, its clean signals and its output synchronization signal make it an ideal output source for lock-in applications such as measuring second and third harmonic device response.

Model 2182A Nanovoltmeter

The Model 2182A expands upon the capabilities of Keithley's original Model 2182 Nanovoltmeter. Although the Model 6220 and 6221 are compatible with the Model 2182, delta mode and differential conductance measurements require approximately twice as long to complete with the Model 2182 as with the Model 2182A. Unlike the Model 2182A, the Model 2182 does not support pulse mode measurements.

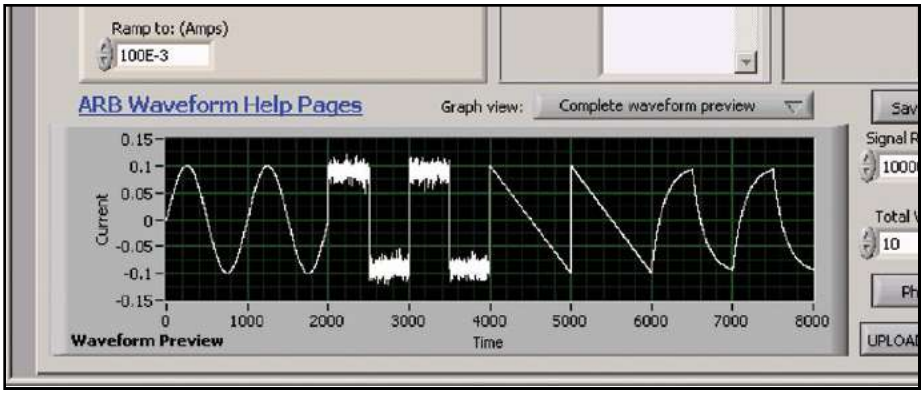

Figure 4. The Model 6221 and the free example start-up control software make it easy to create complex waveforms by adding, multiplying, stringing together, or applying filters to standard wave shapes.

APPLICATIONS OF 622X/2182A COMBINATION:

- Easy instrument coordination and intuitive example software simplifies setup and operation in many applications.
- Measure resistances from 10nΩ to 100MΩ. One measurement system for wide ranging devices.
- Low noise alternative to AC resistance bridges and lock-in amplifiers for measuring resistances.
- Coordinates pulsing and measurement with pulse widths as short as 50μs (6221 only).
- Measures differential conductance up to 10× faster and with lower noise than earlier solutions allow. Differential conductance is an important parameter in semiconductor research for describing density of states in bulk material.
- Delta mode reduces noise in low resistance measurements by a factor of 1000.
- For low impedance Hall measurements, the delta mode operation of the Model 622X/2182A combination provides industry-leading noise performance and rejection of contact potentials. For higher impedance Hall measurements (greater than 100MΩ), the Model 4200-SCS can replace the current source, switching, and multiple high impedance voltage measurement channels. This provides a complete solution with pre-programmed test projects.

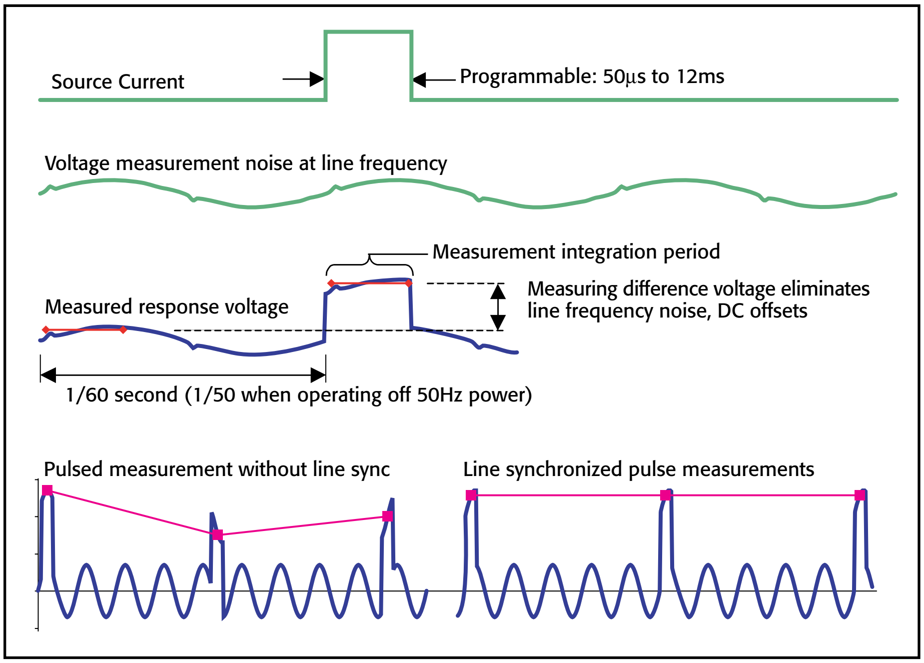

Figure 3. Measurements are line synchronized to minimize 50/60Hz interference.

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Source Specifications

Range (+5% over range)	Accuracy (1 Year) 23°C ±5°C ±(% rdg. + amps)	Programming Resolution	Temperature Coefficient/°C 0°–18°C & 28°–50°C	Typical Noise (peak-peak)/RMS [3] 0.1Hz–10Hz	6221 Only: Typical Noise (peak-peak)/RMS [3] 10Hz–(Bw)	6221 Only: Output Response Bandwidth (BW) Into Short	Settling Time [1,2] (1% of Final Value): Output Response Fast (Typical[3]) (6221 Only)	Settling Time [1,2] (1% of Final Value): 6220, 6221 with Output Response Slow (Max.)
2 nA	0.4 % + 2 pA	100 fA	0.02 % + 200 fA	400 / 80 fA	250 / 50 pA	10kHz	90 µs	100 µs
20 nA	0.3 % + 10 pA	1 pA	0.02 % + 200 fA	4 / 0.8 pA	250 / 50 pA	10kHz	90 µs	100 µs
200 nA	0.3 % + 100 pA	10 pA	0.02 % + 2 pA	20 / 4 pA	2.5 / 0.5 nA	100kHz	30 µs	100 µs
2 µA	0.1 % + 1 nA	100 pA	0.01 % + 20 pA	200 / 40 pA	25 / 5.0 nA	1MHz	4 µs	100 µs
20 µA	0.05% + 10 nA	1 nA	0.005% + 200 pA	2 / 0.4 nA	500 / 100 nA	1MHz	2 µs	100 µs
200 µA	0.05% + 100 nA	10 nA	0.005% + 2 nA	20 / 4 nA	1.0 / 0.2 µA	1MHz	2 µs	100 µs
2 mA	0.05% + 1 µA	100 nA	0.005% + 20 nA	200 / 40 nA	5.0 / 1 µA	1MHz	2 µs	100 µs
20 mA	0.05% + 10 µA	1 µA	0.005% + 200 nA	2 / 0.4 µA	20 / 4.0 µA	1MHz	2 µs	100 µs
100 mA	0.1 % + 50 µA	10 µA	0.01 % + 2 µA	10 / 2 µA	100 / 20 µA	1MHz	3 µs	100 µs

ADDITIONAL SOURCE SPECIFICATIONS

OUTPUT RESISTANCE: >10^{14}Ω (2nA/20nA range).

OUTPUT CAPACITANCE: <10pF, <100pF Filter ON (2nA/20nA range).

LOAD IMPEDANCE: Stable into 10µH typical, 100µH for 6220, or for 6221 with Output Response SLOW.

VOLTAGE LIMIT (Compliance): Bipolar voltage limit set with single value. 0.1V to 105V in 0.01V programmable steps.

MAX. OUTPUT POWER: 11W, four quadrant source or sink operation.

GUARD OUTPUT ACCURACY: ±1mV for output currents <2mA (excluding output lead voltage drop).

PROGRAM MEMORY: Number of Locations: 64K. Offers point-by-point control and triggering, e.g. sweeps.

MAX. TRIGGER RATE: 1000/s.

RMS NOISE 10Hz–20MHz (2nA–20mA Range): Less than 1mVrms, 5mVp-p (into 50Ω load).

SOURCE NOTES

1. Settling times are specified into a resistive load, with a maximum resistance equal to 2V/$I_{full\ scale}$ of range. See manual for other load conditions.
2. Settling times to 0.1% of final value are typically <2× of 1% settling times.
3. Typical values are non warranted, apply at 23°C, represent the 50th percentile, and are provided solely as useful information.

2182A MEASUREMENT FUNCTIONS

DUT RESISTANCE: Up to 1GΩ (1ns) (100MΩ limit for pulse mode).

DELTA MODE RESISTANCE MEASUREMENTS AND DIFFERENTIAL CONDUCTANCE: Controls Keithley Model 2182A Nanovoltmeter at up to 24Hz reversal rate (2182 at up to 12Hz).

PULSE MEASUREMENTS (6221 ONLY):

Pulse Widths: 50µs to 12ms, 1pA to 100mA.

Repetition Interval: 83.3ms to 5s.

ARBITRARY FUNCTION GENERATOR (6221 only)

WAVEFORMS: Sine, Square, Ramp, and 4 user defined arbitrary waveforms.

FREQUENCY RANGE: 1mHz to 100kHz.[5]

FREQUENCY ACCURACY[4]: ±100ppm (1 year).

SAMPLE RATE: 10 MSPS.

AMPLITUDE: 4pA to 210mA peak-peak into loads up to 10^{12}Ω.

AMPLITUDE RESOLUTION: 16 bits (including sign).

AMPLITUDE ACCURACY (<10kHz): [5]

Magnitude: ±(1% rdg + 0.2% range).

Offset: ±(0.2% rdg + 0.2% range).

SINE WAVE CHARACTERISTICS:

Amplitude Flatness: Less than 1dB up to 100kHz.[6]

SQUARE WAVE CHARACTERISTICS:

Overshoot: 2.5% max.[6]

Variable Duty Cycle: [4] Settable to 1µs min. pulse duration, 0.01% programming resolution.

Jitter (RMS): 100ns + 0.1% of period.[6]

RAMP WAVE CHARACTERISTICS:

Linearity: <0.1% of peak output up to 10kHz.[6]

ARBITRARY WAVE CHARACTERISTICS:

Waveform Length: 2 to 64K points.

Jitter (RMS): 100ns + 0.1% of period.[6]

WAVEFORM NOTES

4. Minimum realizable duty cycle is limited by current range response and load impedance.
5. Amplitude accuracy is applicable into a maximum resistive load of 2V/$I_{full\ scale}$ of range. Amplitude attenuation will occur at higher frequencies dependent upon current range and load impedance.
6. These specifications are only valid for the 20mA range and a 50Ω load.

GENERAL

COMMON MODE VOLTAGE: 250V rms, DC to 60Hz.

COMMON MODE ISOLATION: >10^9Ω, <2nF.

SOURCE OUTPUT MODES: Fixed DC level, Memory List.

REMOTE INTERFACE:

IEEE-488 and RS-232C.

SCPI (Standard Commands for Programmable Instruments).

DDC (command language compatible with Keithley Model 220).

PASSWORD PROTECTION: 11 characters.

DIGITAL INTERFACE:

Handler Interface: Start of test, end of test, 3 category bits, +5V@300mA supply.

Digital I/O: 1 trigger input, 4 TTL/Relay Drive outputs (33V@500mA, diode clamped).

OUTPUT CONNECTIONS:

Teflon insulated 3-lug triax connector for output.

Banana safety jack for GUARD, OUTPUT LO.

Screw terminal for CHASSIS.

DB-9 connector for EXTERNAL TRIGGER INPUT, OUTPUT, and DIGITAL I/O.

Two position screw terminal for INTERLOCK.

INTERLOCK: Maximum 10Ω external circuit impedance.

POWER SUPPLY: 100V to 240V rms, 50–60Hz.

POWER CONSUMPTION: 120VA.

ENVIRONMENT:

For Indoor Use Only: Maximum 2000m above sea level.

Operating: 0°–50°C, 70%R.H. up to 35°C. Derate 3% R.H./°C, 35°–50°C.

Storage: –25°C to 65°C, guaranteed by design.

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

SAFETY: Conforms to European Union Directive 73/23/EEC, EN61010-1.

VIBRATION: MIL-PRF-28800F Class 3, Random.

WARMUP: 1 hour to rated accuracies.

Passive Cooling: No fan.

DIMENSIONS:

Rack Mounting: 89mm high × 213mm wide × 370mm deep (3.5 in. × 8.375 in. × 14.563 in.).

Bench Configuration (with handle and feet): 104mm high × 238mm wide × 370mm deep (4.125 in. × 9.375 in. × 14.563 in.).