Innovative Solutions in
Cryogenic Instrumentation

Cryogenic Temperature Controller

Model 44C

The Model 44C temperature controller is designed for use as a general purpose cryogenic instrument with extended operation into the ultra-low temperature range. Additionally, it provides an interface to control external equipment including cryocooler and He3 refrigerator systems, offering a complete 'one box' solution in many applications.

The Model 44C provides four sensor inputs, each of which support a wide range of temperature measurements by use of a ratiometric AC resistance bridge. This is extended into general purpose applications by supporting a DC mode for diode type sensors.

Three control loop outputs feature power levels as high as 50 Watt and as low as 50mW in order to support both high and ultra-low temperature operation. All control modes are available on all outputs.

The 44C front panel incorporates a large high resolution graphics TFT type Liquid Crystal Display with an exceptionally wide viewing angle. With it's bright white LED backlight, complete instrument status can be seen at a glance, even from across the room.

Highlights of the Model 44C:

- Maximum flexibility: Four multipurpose input channels support Diode, Platinum RTD and virtually all cryogenic NTC resistive temperature sensors.
- Operation from below 20mK to over 1020K with an appropriate sensor.
- Large, bright and highly configurable display.
- Step-less Constant-Voltage AC sensor excitation extends the useful temperature range of resistive temperature sensors.
- Programmable logic interface controls external equipment. This can provide a complete 'One Box' solution for many systems.
- Three Precision control loops. Loop #1: 50-Watt, four-range. Loop #2: 10-Watt, two-range. Loop #3: 10-Volts.
- Table control mode automatically switches the loop input sensor to allow smooth, continuous control over a wide range of temperature.
- Fail-safe cryostat protection features protect user equipment from damage.
- Remote interfaces include 10/100 Ethernet and RS-232 . USB 2.0 and IEEE-488.2 (GPIB) are available as field installable options. LabView™ drivers available for all interfaces.

User Interface: The Model 44C's user interface consists of a large, bright TFT type Liquid Crystal Display and a full 21-key keypad. In this user-friendly interface, all features and functions of the instrument can be accessed via this simple and intuitive menu driven interface.

The Home screen projects four user configurable zones that allow the real-time display of all input channel, control loop and instrument status information. From this screen, accessing any of the instrument's configuration menus requires only a single key press. As always, convenient names can be assigned to input channels.

Cryo-con's innovative instrument configuration menus show real-time status information so the user can *instantly* view the results of any changes made. On the input channel configuration menu, the current temperature, display units, over-range indicator and alarm status are shown.

On the control loop menu, the controlling source temperature, heater range and power output level can be observed while tuning a loop.

An essential feature for debugging system software is the Network Configuration Menu's ability to show remote commands as they are sent and received to the Model 44C.

Flexible Inputs: The Model 44C has four identical input channels, each of which can be easily configured to operate virtually any type of cryogenic thermometer.

A unique feature of the Model 44C is the use of a ratiometric AC resistance bridge to measure all types of temperature sensors. Excitation is a differential voltage-source followed by passive attenuators for minimum Johnson noise. Sensor voltage and excitation current are separately measured using dual matched amplifiers and dual analog-to-digital converters. This technique actively cancels gain, drift and low frequency noise measurement errors; thereby providing high accuracy even at extremely low excitation current.

The resistance bridge is used in a constant-voltage AC mode to provide robust support for the Negative Temperature Coefficient (NTC) sensors. These include **Ruthenium-oxide**, **Carbon-Glass**, **Cernox**™, **Carbon-Ceramic**, **Germanium** and several others. Since they have a negative temperature coefficient, the use of a constant-voltage measurement method will reduce, rather than increase, power dissipation in the sensor as temperature decreases. By maintaining the lowest possible power level, sensor self-heating is minimized and useful temperature range is greatly increased. An additional advantage of constant-voltage excitation is that NTC resistors lose sensitivity in the upper part of their range. By auto-ranging excitation current to maintain a constant voltage, sensitivity and noise immunity in that range is also improved.

At very low temperature, the predominant source of measurement errors is often sensor self-heating caused by excitation current. The Model 44C reduces this by offering excitation voltages as low as 10µV and currents as low as 500pA. DC offset in the instrument is held to <300pA.

The excitation source in the Model 44C is continuously variable so there are no steps in sensor self-heating. AC excitation used with resistor sensors is a 3.25Hz bipolar square wave. This effectively eliminates DC offset errors including the thermal EMF induced offsets that often occur in some cryogenic systems.

Positive Temperature Coefficient (PTC) resistor sensors including **Platinum** and **Rhodium-Iron** RTDs use the resistance bridge in its constant-current, AC mode. Platinum RTD sensors use a built-in DIN standard calibration curve that has been extended to 14K for cryogenic use. Measurement below that is possible with user supplied calibration curves.

Diode sensors are supported over their full temperature range by using the Model 44C's bridge in a DC, constant-current mode. This mode servos the excitation source to the sensor current to provide the constant-current required by these sensors.

Model 44C Supported Sensors		
	Temperature Range	**Example Sensors**
Diode	1.4 - 500K	Cryo-con S900 SI-440, 430, 410. Lakeshore DT-670, 470
Platinum RTD	14 - 1200K	Cryo-con CP-100 Cryo-con GP-100 Cryo-con XP-100 Cryo-con XP-1K
Rhodium-Iron	1.4 - 800K	Oxford PHZ 0002
Germanium	<100mK - 100K	Lakeshore GR-200A
Carbon Glass	1.4 - 325K	Lakeshore CGR-1-500
Cernox™	100mK - 325K	Lakeshore, all types
Carbon-Ceramic	100mK - 300K	TMi-A1
Ruthenium Oxide	20mK - 200K	Cryo-con R400 Cryo-con R500

Measurement accuracy is obtained by using 24-bit analog to digital converters at a minimum sample rate of 15Hz per channel.

Conversion of a sensor measurement into temperature is performed by using a Cubic Spline interpolation algorithm. In addition to providing higher accuracy than conventional linear interpolation, the spline function eliminates discontinuities during temperature ramps or sweeps by ensuring that the first and second derivatives are continuous.

Sensor Curves: The Model 44C includes built-in curves that support most industry standard temperature sensors. Additionally, eight **user calibration curves** are available for custom or calibrated sensors. Each user curve may have up to 200 entries and may be entered from the front panel, or transferred via any of the available remote interfaces.

New calibration curves may be generated using the **CalGen**® feature to fit any existing Diode, Platinum or NTC resistor calibration curve at up to three user specified temperature points. This provides an easy and effective method for obtaining higher accuracy temperature measurements without expensive sensor calibrations.

Data logging is performed by continuously recording to an internal 1,000 entry circular buffer. Data is time stamped so that the actual time of an event can be determined. Non-volatile memory is used so that data will survive a power failure.

Input Channel Statistics: The Model 44C continuously tracks temperature history independently on each input channel and provides a statistical summary that indicates the channel's minimum, maximum, average and standard deviation. Also shown are the slope and the offset of the best-fit straight line of temperature history data.

Input Specifications				
	Diode Sensors	**PTC Resistor Sensors**	**NTC Resistor Sensors Constant-Current mode**	**NTC resistor sensors Constant-Voltage mode**
Input Configuration	Constant-Current, DC	Constant-Current AC Resistance Bridge	Constant-Current DC Resistance Bridge	Constant-Voltage AC Resistance Bridge
Ranges	2.25V	390Ω, 3.9KΩ, 39KΩ	225KΩ	100mV, 10mV, 1.0mV, 300µV, 100µV, 100µV, 30µV or 10µV
Accuracy: % of Rdg + % of Range	0.004% + 80µV	0.01% + 0.0005%	0.005% + 25Ω	4 to 30K: 0.05% + 0.05% 0.04 to 1M: 0.15% + 0.15%
Resolution: % of Range	10µV	0.0003%	0.00004%	0.0003%
Excitation Current	10µA DC	1.0mA, 100µA, 10µA Max.	10µA DC	2.5mA to 500pA continuously variable, auto-ranged

Three Control Loops: The Loop #1 heater output is a linear, low noise RFI filtered current source that can provide up to 1.0 Ampere into 50Ω or 25Ω resistive loads. Four full-scale ranges are available in decade increments down to 50mW.

Loop #2 is a linear heater with two output ranges of 10-Watts and 1.0-Watt full-scale into a 50Ω load.

Loop #3 is a non-powered analog voltage output intended to control an external booster power supply. Output is zero to 10-Volts.

All control loops are completely independent and any loop may be controlled by any sensor input.

Control modes are **Manual**, **PID**, **Ramp, PID Table and Ramp Table**. The industry standard Proportional-Integral-Derivative or PID control loop is implemented as a DSP algorithm and is enhanced to minimize set-point overshoot and differentiator noise.

A special challenge to precision control at ultra-low temperature is the requirement to minimize the transient response of the control loop. Because of extremely low heat capacity and long settling times in this region, even the transient response generated by a small setpoint change can cause heating that may take hours to settle. The Model 44C minimizes this response by detecting a setpoint change and adjusting the loop state.

For use with thermoelectric coolers and Peltier devices, the direction of the control loop can be easily reversed so that power is applied to cool rather than heat.

Some cryogenic applications require very specific control loop configurations that cannot be included in a general purpose instrument. Examples include: High power warm-up, Low voltage TE coolers and Adiabatic refrigerators. For these reasons, the Model 44C offers a **third control loop** that is capable of driving a wide variety of external power supplies. This loop operates and tunes identically to the other loops. It will drive most power supplies designed for Automatic Test Equipment (ATE). A list of supplies that have been tested with the Model 44C is on the Cryo-con web site.

The field proven **Autotune** function of the Model 44C involves the use of a specific output waveform to first develop a process model, then generate the optimum P, I and D coefficients.

Cryogenic systems often require stable control over a wide range of temperatures since control loop tuning parameters can be significantly different at different temperatures. For this reason, the Model 44C offers **PID tables** that store optimum control parameters vs. setpoint temperature. Six PID tables are available, each contains a maximum of 16 entries.

Every entry of a PID table contains a setpoint, a control input, PID values and a heater output range setting. When the setpoint is changed, the controller will automatically update the control input channel and heater range. PID values will then be generated based on interpolation of the table. All settings generated by the table control mode can be viewed in real-time on the front panel display.

The Model 44C will perform a **temperature ramp** function using a specified maximum ramp rate and target setpoint. Once placed in a ramping control mode, a ramp is initiated by changing the setpoint. The unit will then progress to the new setpoint at the selected ramp rate. Upon reaching the new setpoint, ramp mode will be terminated and standard PID type regulation will be performed.

Cryostat Protection: Damage to a cryostat or critical sample is a serious problem with any cryogenic system. The Model 44C implements the most robust set of protection features in the industry.

The **Over Temperature Disconnect** feature will disable the heater if an over temperature condition exists on any selected input channel. A fail-safe mechanical relay is used to disconnect the controller's heater thereby ensuring that the user's equipment is always protected.

The **Maximum Setpoint** feature is used to prevent the user from inadvertently entering a higher setpoint than the equipment can tolerate.

Setting the **Maximum Power Limit** will ensure that the controller can never exceed heater power output above the set limit.

Alarms: The Model 44C supports visual, remote and audible alarms. Each may be independently programmed to assert or clear based on a high or low temperature condition or a detected sensor fault.

Latched alarms are asserted on an alarm condition and will remain asserted until cleared by the user.

Programmable Logic Interface: The Model 44C has four optically coupled digital outputs. These can be used to control a refrigerator system or other external equipment. This interface is often connected to an industrial Programmable Logic Controller (PLC).

Output signals are asserted or cleared based on the temperature reading of selected input channels. Each output has a high and low set-point that may be enabled from the front panel or a remote interface. Further, the signals can be manually asserted ON or OFF.

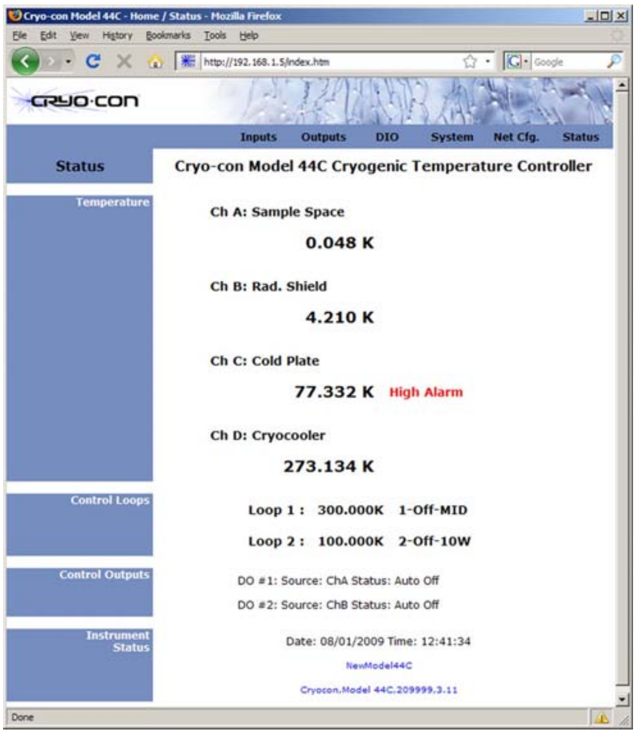
Lowest Noise: The Model 44C was designed for use in extremely low noise environments that cryogenic systems often require.

Electrical isolation is used to prevent noise pickup by sensitive analog circuits and to eliminate ground loops.

The enclosure of the Model 44C is all Aluminum with wide conductive overlaps on all mating metal surfaces so that radiated RFI noise is virtually eliminated.

Remote Control: Standard Remote Interfaces include 10/100 Ethernet and RS-232. IEEE-488.2(GPIB) and USB are optional.

The Model 44C connects directly to any **100/10 Ethernet Local-Area-Network** (LAN) to make measurements easily and economically. Connection to any existing LAN allows stable, precise, cost-effective measurements in laboratory or industrial environments as well as in remote, distributed data acquisition systems.



The **TCP/IP data port server** brings fast Ethernet connectivity to all common data acquisition software programs including LabView™. TCP/IP implements an ASCII text based command language similar to those commonly used with GPIB or RS-232 interfaces. This is the primary way that user software interfaces to the instrument.

Using the Ethernet **HTTP** protocol, the instrument's **embedded web server** allows the instrument to be viewed and configured from any web browser.

Using the Ethernet **SMTP** protocol, the controller will send e-mail based on selected alarm conditions. E-mail is configured by using the web page interface.

In order to eliminate ground-loop and noise pickup problems commonly associated with **IEEE-488** systems, the Model 44C moves the internal IEEE-488 circuitry to an inexpensive optional external module that interfaces directly to the electrically isolated and low noise Ethernet interface. This compact module is completely transparent to the IEEE-488 system and does not require changes to customer software or LabView drivers.

The **RS-232** serial interface is a standard null modem connection. Data rates are 9600, 19,200, 38,400 and 57,200 Baud.

A **USB 2.0 option** is available that emulates a serial port. To the user's computer, it looks like an additional serial port. This option is compact, self-powered and inexpensive.

Utility Software: Utility software is provided that connects any Windows based personal computer to the Model 44C via any of its remote interfaces. This software provides a graphical control panel that greatly simplifies instrument setup and configuration. Features include:

- Continuous strip-chart monitoring of all inputs and outputs.
- Downloading, uploading, viewing and editing of sensor calibration curves and PID tables and command scripts.
- Automated instrument calibration capability.

LabView™ drivers are supplied for the Ethernet TCP/IP, IEEE-488, USB and RS-232 interfaces.

Remote Command Language: The Model 44C's remote command language is **SCPI** compliant according to the IEEE-488.2 specification. SCPI establishes a common language and syntax across various types of instruments. It is easy to learn and easy to read.

The SCPI command language is identical across all Cryo-con products so that your investment in system software is always protected.

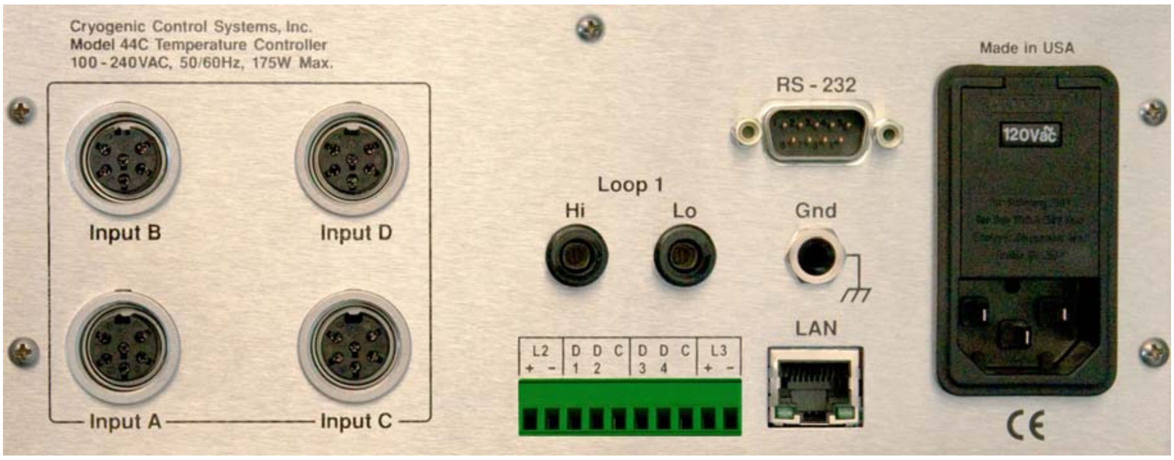
Command Scripts can be used to completely configure an instrument including setting custom sensor calibration curves and PID tables. Further, scripts can query and test data. They are commonly used in a manufacturing environment to set a baseline state and test a target product. In the laboratory, scripts can be used to save and restore configurations for various experiments.

XML (Extensible Markup Language) is used for the structure and format of script files. XML can be generated and edited with a standard text editor. Since it provides a structure and allows user documentation, it is easy to read and understand.

Firmware updates: Full instrument firmware updates may be installed by using the Ethernet connection. Cryo-con provides firmware updates, on request, via e-mail. They are **free of charge** and generally include enhancements and new features as well as problem fixes.

Ethernet API: An Applications Program Interface (API) package is supplied that facilitates communication with the instrument using the TCP/IP interface. It is supplied as a Microsoft Windows™ DLL that is easily linked with C, C++ or Basic programs.

Rear Panel Connections



- **Input Connectors:** DIN-6 recepticals provide 4-wire measurement connection plus shield.
- **Loop #1:** 50-Watt heater output. Dual Banana Plug with chassis ground lug.
- **Loop #2:** 10-Watt heater, part of a 10 pin detachable terminal block.
- **Loop #3:** 10-Volt output. Detachable terminal block.
- **Programmable Logic Outputs:** Optically coupled digital outputs. Detachable terminal block.
- **Ethernet:** RJ-45 with LAN activity indicator LEDs.
- **IEEE-488:** Option connects to Ethernet port.
- **RS-232:** Null-modem connector (DB-9, pins).
- **USB:** Option connects to RS-232 port.
- **AC Power:** RFI filtered Power Entry Module including fuse drawer and line voltage selector.

Ordering Information

Product	Description
Model 44C	Controller with four multi-function sensor input channels and three control loops.
	Controller includes: User's Manual, Cryo-con software CD, four input connectors, heater connector, terminal block plug, detachable power cord and a certificate of calibration. Specify AC Line Voltage when ordering: **-100** Configured for 90 - 100VAC with detachable USA power cord. **-110** Configured for 110 - 120VAC with detachable USA power cord. **-220** Configured for 220VAC with detachable universal Euro (Shuko) line cord. **-240** Configured for 240VAC with detachable universal Euro (Shuko) line cord.

Options	Description
GPIB	IEEE-488.2 (GPIB) Option. Field installable at any time.
USB	USB Option. Serial Port Emulation. Field installable at any time.

Accessories	Description
04-0433	A Dual banana plug Loop #1 connector .
04-0414	Din-6 Sensor Input Connector, Amphenol T3400 001
04-0007	Ten position terminal block receptacle. 3.5mm pitch.
04-0401	Din-8 Loop 2 Output Connector, Large cable exit (8mm), Amphenol T 3504 002
4034-032	One instrument shelf rack mount kit
4034-031	Two instrument shelf rack mount kit

Specifications

User Interface

Display Type: 240x64 graphics TFT LCD with LED back-light.
Keypad: Sealed Silicon Rubber.
Display Update Rate: 0.5 Seconds.
Display Units: K, C, F or native sensor units.
Display Resolution: User selectable to seven significant digits.

Input Channels

There are four input channels, each of which may be independently configured for any of the supported sensor type.

Sensor Connection: 4-wire differential. DIN-6 Connector.
Sensor Types: See Supported Sensor Section.
Sensor Selection: Front Panel or remote interface.
Input Configurations: See input specifications table.
Bridge Modes: Passive, Constant-Current, Constant-Voltage.
Bridge type: Ratiometric resistance bridge.
AC Excitation Frequency: 3.25Hz bipolar square wave.
Voltage Excitations: 100mV, 10mV, 1.0mV, 300μV, 100μV, 30μV and 10μV. Minimum excitation current is <500pA.
DC Offset: <300pA.
Sample Rate: 15Hz per channel, all sensor types.
Digital Resolution: 24 bits.
Measurement Accuracy: See input specifications table.
Measurement Drift: 15ppm/°C. <10Ω.: 30ppm/°C.
Isolation: Input channel circuits are electrically isolated from all other internal circuitry but not from each other.
Measurement Filter: 0.5, 1, 2, 4, 8, 16, 32 and 64 Seconds.
Calibration Curves: Built-in curves for industry standard sensors plus eight user curves with up to 200 entries each. Interpolation is performed using a Cubic Spline.
CalGen®: Calibration curve generator fits any Diode or resistor sensor curve at 1, 2 or 3 user specified temperature points.

Data Logging

Data logging is performed to an internal 1,000 entry circular buffer and is time-stamped with a real-time clock. Buffer memory is non-volatile and will retain valid data without AC power.

Control Outputs

Number of Independent Control Loops: Three.
Control Input: Any sensor input.
Loop Update Rate: 15Hz per loop.
Isolation: Control loop circuitry is referenced to chassis ground.
Control Type: PID table, Enhanced PID, Ramp or Manual.
Autotune: Minimum bandwidth PID loop design.
PID Tables: Six user PID tables available for storage of setpoint and heater range vs. PID and heater range. 16 entries/table.
Set-point Accuracy: Six+ significant digits.
Fault Monitors: Control loops are disconnected upon detection of a control sensor fault or excessive internal temperature.
Over Temperature Disconnect: Heater may be relay disconnected from user equipment when a specified temperature is exceeded on any selected input.

Loop #1 Primary Heater Output

50-Watt short circuit protected linear current source. Maximum compliance is selectable at 25V or 50V.

Ranges: Four output ranges of 1.0A, 333mA, 100mA and 33mA full-scale, which correspond to 50W, 5.0W, 0.5W and 50mW.
Load Resistance: Selectable at 25Ω or 50Ω.
Minimum Load: 10Ω in 25W setting, 40Ω in 50W setting.
Resolution: 1.0ppm of full-scale power (20 bits).
Readbacks: Heater output power, Heatsink temperature.
Connection: Dual banana plug.

Loop #2 Heater Output

10-Watt, short circuit protected linear current source. Maximum compliance is 25V.

Ranges: Two output ranges of 450mA and 140mA full-scale, which correspond to 10W and 1.0W into a 50Ω load.
Load Resistance: 50Ω for 10-Watt output.
Minimum Load: 10Ω.
Resolution: 1.0ppm of full-scale power (20 bits).
Readbacks: Heater output power, Heatsink temperature.
Connection: Detachable terminal block.

Loop #3 Control Output

Loop 3 is an analog voltage output that is intended to drive an external booster supply.

Resolution: 1.0ppm of full-scale power (20 bits).
Connection: Detachable terminal block.

Status Outputs

Programmable Logic Interface: Four independent, optically-coupled discrete outputs are available to control external equipment. Connector: Detachable terminal block.
Audible and Visual Alarms: Independent audible remote and visual alarms.
Status reported via Remote Interface: Digital Output status, Alarm status, Sensor fault, Heater over temperature fault.

Remote Interfaces

Maximum reading rate for all interfaces is >40 rdg/s.

Ethernet: Connects to any 10/100 Ethernet Local Area Network. Electrically isolated. **TCP/IP** provides remote control by using an ASCII command language. **HTTP/HTTPS** provides built-in web server. **SMTP** sends e-mail based on alarm conditions.
RS-232: Standard null modem. Data rates are 9600, 19,200, 38,400 and 57,200 Baud. Connector is a DB-9 plug.
IEEE-488 (GPIB): Optional, field installable at any time. Full IEEE-488.2 compliant.
USB 2.0: Optional, field installable at any time. Serial port emulation only. Transfer rates to 57,200 Baud.
Programming Language: IEEE-488.2 SCPI compatible.
LabVIEW™ drivers available for all interfaces.

Firmware

Instrument firmware can be updated in the field via the Ethernet connection. Firmware updates are available via the Internet.

User Setups

Four User Setups are available that save and restore the complete configuration of the instrument.

General

Ambient Temperature: 25°C ± 5°C for specified accuracy.
Mechanical: 8.5"W x 3.5"H x 12"D. One half-width 2U rack. Instrument bail standard, rack mount kit optional.
Weight: 9 Lbs.
Power Requirement: 100, 120, 220 or 240VAC +5% -10%. 50 or 60Hz, 150VA.
Conformity: European CE available soon.
Calibration: NIST traceable.

Contact Information

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