Innovative Solutions in Cryogenic Instrumentation

Cryogenic Impedance Bridge
and
Temperature Controller
Model 54

The model 54 is a next generation four-channel cryogenic impedance bridge capable of measuring resistance, inductance and mutual-inductance from milli-ohms to meg-ohms. Additionally, four control loop outputs support use as a cryogenic temperature controller.

Highlights of the Model 54:

- **Four input channels**, each capable of measuring resistance, mutual-inductance or inductance. Supported sensors include diode, resistance and mutual-inductance devices.
- **Operation from 50mK to over 1,000K** with an appropriate sensor.
- Expandable to 28 inputs by use of an Ethernet based distributed instrument connection.
- **Four Control Loops** add high accuracy temperature control.
- **Large color display** with capacitive touchscreen and full keypad.
- **Industrial grade security**: Configurable firewall, HTTPS encryption and authentication.
- Embedded web 2.0 server provides complete control, eliminates the need for external support software.
- Remote interfaces include Ethernet, USBA for data logging and a USBB serial port emulator. LabView™ drivers available, LXI Discovery supported.
- Remote command language is IEEE-488.2 SCPI compliant, ensuring your system software will not become obsolete.
- Distributed instrument networks supported by an embedded EPICS CA server.
- User programmable including web browser based editor and debugger.

Applications:

Ultra-Low Temperature Thermometry

- He3 refrigerators, some Dilution Refrigerators and ADRs.
- Each input supports resistor, diode and mutual-inductance temperature sensors.
- Step-less differential mode sine-wave excitation with constant-voltage settings down to 10μV.
- Easily expandable to 28 independent, non-multiplexed input channels.
- High precision heater outputs for excellent control stability.

Material Science

- Resistance, inductance and mutual-inductance measurement.
- Low resistance measurement.

Distributed instrumentation / Computer controller

- Secure Ethernet communications.
- Remote command language is IEEE-488 SCPI compliant, protects your system software from obsolescence.
- LabView™ drivers for all remote interfaces
- Built-in Embedded EPICS CA server supports large scale distributed instrumentation networks.

General purpose laboratory

- Cryogenic bridge measures resistance, inductance and mutual-inductance.
- Four inputs expandable to 28.
- Four independent control loops.

Cryogenic Impedance Bridge

Each of the four input channels of the Model 54 is fabricated using a Cryo-con proprietary signal processing chip that measures impedance by use of an auto-balancing, ratiometric AC bridge. Here, advanced signal processing functions are built into a digital signal processor thereby replacing large amounts of analog circuitry with higher precision and more sophisticated digital algorithms.

Impedance measurement in cryogenic systems often requires low level excitation followed by precision signal recovery. To implement this, the Model 54 uses a differential voltage-mode excitation scheme followed by bi-phase lock-in detection.

Differential mode excitation prevents electrical noise pickup currents from flowing through the sensor and the use of passive attenuation reduces the output impedance of the bridge. To further reduce noise, sine-wave excitation is used with user programmable frequencies.

The Model 54 performs signal recovery by first co-sampling excitation voltages and currents. The AC signal vector is then recovered by use of the bi-phase lock-in detector.

Cryogenic Thermometry

Negative-Temperature-Coefficient (NTC) resistors are often used as low temperature thermometers, especially at ultra-low temperature. Examples include Ruthenium-oxide, Carbon-Glass, Cernox™, Carbon-Ceramic, Germanium and several others. The Model 54 provides robust support for these sensors by using constant-voltage AC excitation.

Since NTC sensors have high resistance at low temperature, measurement errors can be introduced by the lead capacitance in the sensor connections. The Model 54 eliminates this error by recovering the complete AC signal vector and eliminating the capacitance component.

Another source of error at ultra-low temperature is sensor self-heating due to DC offsets produced by the measurement electronics. The Model 54 first measures the DC offset excitation current flowing through the sensor then actively tracks and cancels it.

Ultra-low temperature measurements can be negatively affected by coarse steps in sensor excitation current. The Model 54 prevents this by using a step-less, continuously variable excitation source. Since the excitation current is measured to higher accuracy than it can be set, precision is maintained, even with a continuously variable source.

Positive Temperature Coefficient (PTC) resistor temperature sensors use the bridge in a passive excitation mode where a selected excitation is set and remains relatively constant over the entire measurement range.

Silicon diode sensors are also supported. This is done by switching out bridge functions and providing a 10µA DC constant-current excitation mode.

Conversion to Temperature: The Model 54 includes built-in sensor calibration curves that support most industrial temperature sensors. Additionally, eight user calibration curves are available for custom or calibrated sensors
For all sensor types, conversion from a sensor reading 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.

Inductance and Mutual Inductance Measurement

The Model 54's bridge circuits are based on bi-phase lock-in detection, therefore inductance and mutual-inductance measurements can be made to high accuracy. The mutual-inductance based temperature sensors used in Milli-Kelvin thermometry are directly supported.

Since the Model 54 has four identical and independent inputs, a mix of mutual-inductance and resistance sensors can be used without the need for synchronization of the excitation signals.

Low Resistance Measurement

The Model 54 can accurately measure resistance down to less than 0.01Ω. Both R and ΔR measurements are available.

Virtual Inputs

The Model 54 can be expanded up to 28 input channels by connecting up to three Cryo-con 18i, 14i or 12i temperature monitors to the Ethernet remote interface. Once connected, these virtual inputs appear to the Model 54 as additional inputs. They can be used for temperature control, relays etc.

A Publish-Subscribe interface is used to communicate with remote monitors. Here, the monitors publish input channel data and the Model 54 subscribes.
Virtual input channels are updated in parallel at the full 15Hz rate of the monitors. There is no sequencing or multiplexing.

Four Temperature Control Loops

To support flexible cryogenic temperature control applications, the Model 54 has four independent control loops.

The **Loop #1** heater output is a linear, low noise current source. Four full-scale ranges are available from 75W down to 500mW. **Loop #2** is a three-range linear heater that will provide 10, 1.0 or 0.1-Watts. **Loop #3** is linear heater with an output 1.0W. **Loop #4** is a non-powered voltage output.

Control stability on each loop is enhanced by the use of an over-sample-plus-dither algorithm that increases output resolution well beyond the limit of the output quantizer.

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 field proven **Autotune** function of the Model 54 involves the use of a specific output waveform to first develop a process model, then generate the optimum P, I and D coefficients.

PID tables are available that can be used to store optimum control parameters vs. point temperature. Each entry of a PID table contains a setpoint, a control input, PID values and a heater output range setting. When the point is changed, the controller will automatically generate new PID values, a controlling input channel and heater range.

Cryostat Protection

Damage to a cryostat or critical sample is a serious problem with any cryogenic system.

The Model 54's Over Temperature Disconnect feature will disable the heater if an over temperature condition exists on any selected input channel. The Maximum Setpoint feature is used to prevent the user from inadvertently entering a higher point than the equipment can tolerate and a Maximum Power Limit will ensure that the controller can never exceed heater power output above the set limit.

Additionally, a fail-safe feature disconnects a control loop when the temperature on it's controlling input is outside a user specified window.

Alarms and Relays

Two 10A dry-contact relay outputs can be asserted based on temperature setpoints from user selected input channels.

Visual, remote and audible alarms are supported. Each may be programmed to assert or clear based on temperature setpoints.

Alarms may be latched. These are asserted on an alarm condition and will remain asserted until cleared by the user.

Lowest Noise

Since the Model 54 was designed for use in the extremely low noise environments it's shielding and grounding scheme effectively reduces or eliminates both radiated and conducted electrical noise. The grounding scheme facilitates the establishment of a single-point-ground that is essential to the elimination power-line and low frequency noise pickup. This ground reference point is usually taken from the instrument's earth ground connection but users may alternatively select an external reference. Radiated RF noise pickup is reduced by a shielding scheme that allows the construction of a complete RFI shield around the instrument and cryostat.

Remote Control

Standard Remote Interfaces are Ethernet and a USBB serial port emulator. An IEEE-488.2(GPIB) interface is optional.

Two USBA interfaces support memory sticks for data logging. They also support an external keyboard or mouse.

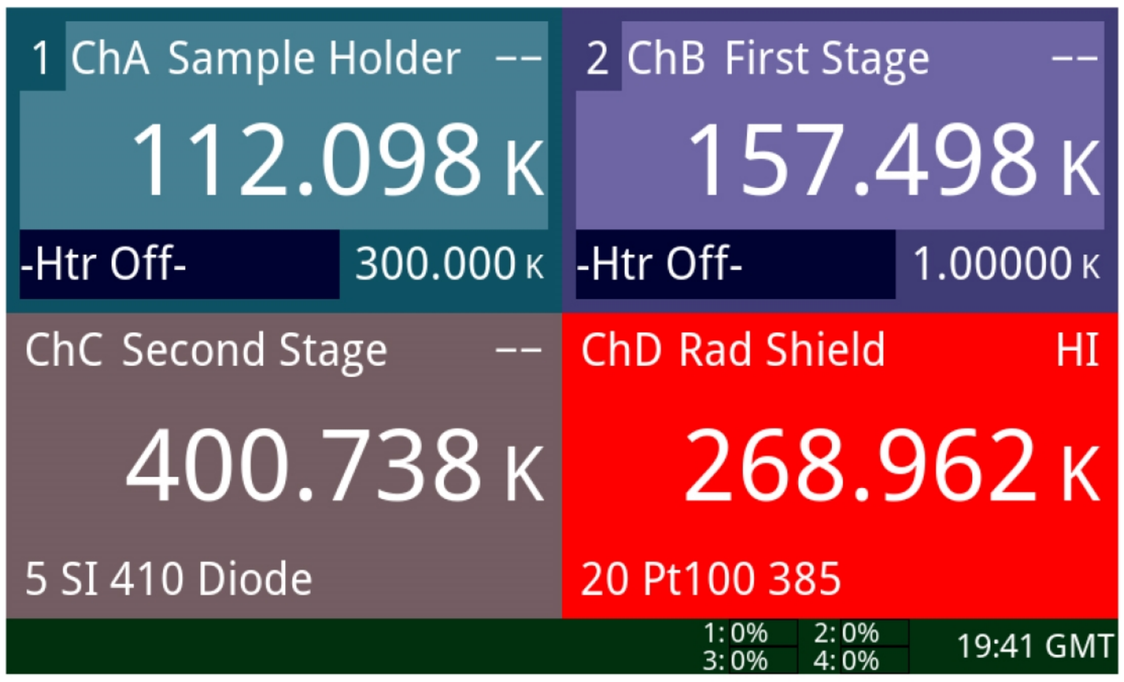
The TCP data port server brings fast Ethernet connectivity to data acquisition software including LabView™.

Remote interfaces implement an IEEE-488.2 SCPI compliant remote command language that is easy to read.

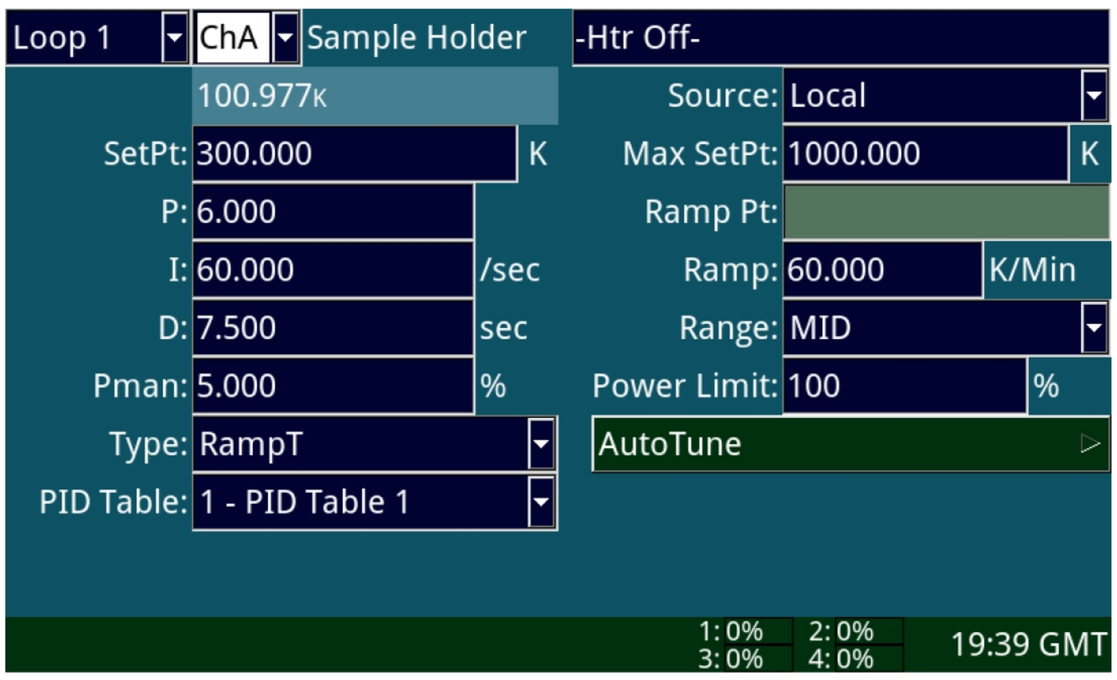
LabView™ drivers are available for all remote interfaces.

User Interface

The Model 54's user interface is based on a large, high resolution color graphics display with an integrated capacitive touchscreen plus a full 20-key keypad. Optionally, a USB keyboard or mouse may also be used.



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.



Configuration menus are designed to show real-time status information so the user can instantly view the results of any changes made.

Web 2.0 Server

Using secure Ethernet HTTPS protocol, the Model 54's embedded web server provides complete instrument control and configuration without the need for external platform-dependent software.
Instrument status can be viewed in real time and configured from any web browser.
Custom sensor calibration tables and data-logging files may be uploaded or downloaded.

EPICS CA Server

The Experimental Physics and Industrial Control System (EPICS) is a set of open source software tools that are used to create distributed real-time control systems for large scale scientific and industrial applications.

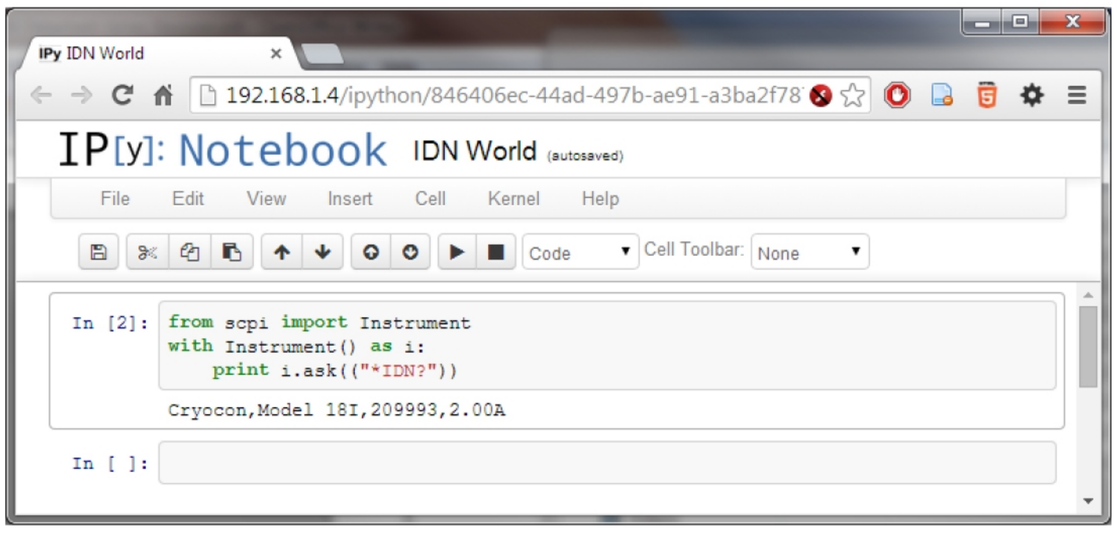
To support these applications, the Model 54 implements an embedded Channel Access server based on EPICS R3.15.

Firmware updates

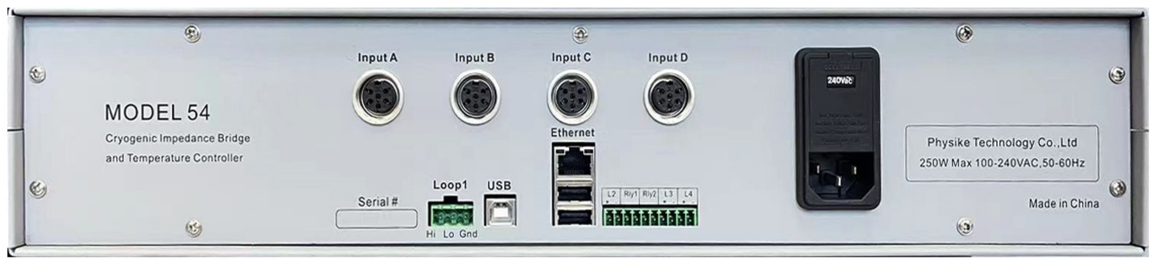
Full instrument firmware updates may be installed by using the Ethernet connection. Cryo-con provides firmware updates, on request, via e-mail. They are free of charge and generally include enhancements and new features as well as problem fixes.

User Programmable

The Model 54 can be programmed by the user using the IPython scripting language. All functions of the instrument are available to the programming interface and are executed as standard remote commands.
Python is a robust scripting language that includes conditional execution, loops and time delays.



Rear Panel Connections



- **Input Connectors:** DIN–6 recepticals provide 4–wire measurement connection plus a continuous shield through the backshell.
- **Loop #1:** 50-Watt heater output. 3 pin detachable terminal block.
- **Loop #2:** 10-Watt heater, part of a 10 pin detachable terminal block.
- **Loop #3 1.0-Watt heater**, part of a 10 pin detachable terminal block.
- **Loop #4:** 10 / 5.0-Volt output. Detachable terminal block.
- **Relay #1 and #2:** Relay N.O. Contacts.
- **Ethernet / 2x USBA:** RJ-45 with LAN activity indicator LEDs,USBA for external memory, mouse or keyboard.
- **USBB:** Serial Port Emulator.
- **AC Power:** RFI filtered Power Entry Module including fuse drawer and line voltage selector

Ordering Information

Product	Description
Model 54	Four channel cryogenic impedance bridge with four temperature control loops.
	Includes: User's Manual, four input connectors, heater connector, terminal block plug, detachable power cord and a certificate of calibration. Specify AC Line Voltage or required power cord when ordering (may be changed in the field): -**100** Configured for 90 - 100VAC with detachable USA power cord. -**120** Configured for 110 - 120VAC with detachable USA power cord. -**230** Configured for 220 - 230VAC with detachable universal Euro (Shuko) line cord. -**240** Configured for 240VAC with detachable universal Euro (Shuko) line cord.

Accessories	Description
4026-016	Additional input connector kit consisting of four 6-pin circular input connectors.
4026-018	Additional output connector kit consisting of a 3-pin heater connector and a 10-pin terminal block receptacle.
4122-030	Single instrument 2U rack mount kit.

Input Performance

Temperature Sensors / Inductance			
	Diodes	**PTC resistors**	**Inductance**
Input Configuration	Constant-Current DC	Passive AC Bridge	Constant-Voltage AC Bridge
Input Range	<2.25V	1.0mA: 0.1 - 500Ω 100µA: 1.0K – 5.0KΩ	Min: <10µH Max: 85mH
Accuracy: % Rdg	0.005% ± 80µV	100Ω: 0.01% ± 0.004Ω 1KΩ: 0.02%± 0.04Ω	0.05% ± 0.04%
Resolution: % Range	10µV	0.0003%	0.003%
Excitation	10µA DC	1.0mA, 100µA	100µV

C-V Resistance Measurement Accuracy	
10mV	1.0Ω to 100KΩ: 0.03%Rdg + 0.005% Range 0.2Ω to 1.0MΩ: 0.05%Rdg + 0.05% Range
1.0mV	1.0Ω to 10KΩ: 0.03%Rdg + 0.005% Range 0.1Ω to 100KΩ: 0.05%Rdg + 0.05% Range
100uV	0.15Ω to 10KΩ: 0.05%Rdg + 0.005% Range 0.01Ω to 100KΩ: 0.15%Rdg + 0.2% Range

C-V Resistance Measurement Resolution			
Range	**10mV**	**1.0mV**	**100uV**
0.01Ω			10mA 50µΩ
0.1Ω		10mA 15µΩ	1.0mA 50µΩ
1.00Ω	10mA 5µΩ	1.0mA 10µΩ	100µA 70µΩ
10.0Ω	1.0mA 21µΩ	100µA 41µΩ	10µA 390µΩ
100.0Ω	100µA 200µΩ	10µA 600µΩ	1.0µA 2.8mΩ
1.00KΩ	10µA 2mΩ	1.0µA 5.6mΩ	100nA 40mΩ
10.0KΩ	1.0µA 25mΩ	100nA 56mΩ	10nA 640mΩ
100KΩ	100nA 350mΩ	10nA 1.4Ω	1.0nA 150Ω

Specifications

User Interface

Display Type: 800x480 color graphics TFT LCD with a capacitive touchscreen.
Keypad: Sealed Silicon Rubber.

Input Channels

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

Sensor Connection: 4-wire differential. 6-pin snap-in connector.
Sensor Types: Resistance, mutual-inductance, diode.
Bridge type: Auto balancing ratiometric AC impedance bridge.
Bridge Modes: Constant Voltage or Constant-Current.
Excitation: 12 to 30Hz differential sine-wave.
Voltage Levels: 10mV to 10μV. Maximum excitation current: 10mA, minimum is 1.0nA.
DC Offset: <1nA by active cancellation.
Input Sample Rate: 256Hz per channel.
Signal Processor Functions: Sinewave generation, 4x parallel bi-phase lock-in detection, clipping and noise detection.
Measurement Drift:15ppm/°C. <10Ω. or >10KΩ: 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.

Control Outputs

Number of Independent Control Loops: Four.
Control Input: Any local or remote input.
Loop Update Rate: 1.024KHz per loop with signal dither to extend the dynamic range of the output quantizer.
Isolation: Control loop circuitry is referenced to chassis ground.
Control Type: PID table, Enhanced PID, Ramp or Manual.
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 Control Output

Short circuit protected linear current source.

Ranges: Four output ranges of 75W into 25Ω or 50W, 5.0W and 0.5W into 50Ω.
Resolution: 24 bits.
Readbacks: Heater output current, voltage, heatsink temperature.
Connection: Detachable terminal block.

Loop #2 Control Output

Short circuit protected linear current source.

Ranges: Three output ranges of 10W, 1.0W and 0.1W into 50Ω.
Resolution: 24 bits.
Readbacks: Heater output power, Heatsink temperature.
Connection: Detachable terminal block.

Loop #3 Control Output

Short circuit protected linear current source.

Output: 1.0W into a 100Ω load.
Resolution: 24 bits.
Connection: Detachable terminal block.

Loop #4 Analog Output

Voltage outputs that can be configured as control loops or scaled analog outputs.

Output: zero to 10 / 5.0-Volts. Output impedance: ~2,000Ω.
Resolution: 24bits.
Connection: Detachable terminal block.

Status Outputs

Audible and Visual Alarms: Independent audible remote and visual alarms.
Relays: Two dry-contact relays. N.O. contacts available. Ratings are 125VAC @ 10A. Maximum switching power: 150W.
Fault Monitors: Sensor fault, Heatsink temperature, OTD disconnect, Low heater load resistance, Fan fault.

Remote Interfaces

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

Ethernet: Connects to any Ethernet Local Area Network. Electrically isolated. **TCP/IP** server provides remote control by using an ASCII command language. **HTTP and HTTPS** provide built-in web server. **SMTP** sends e-mail based on alarm conditions. Built-in firewall.
USBB: Serial port emulator.
2x USBA: External memory sticks, mouse, keyboard.
IEEE-488.2 (GPIB): External Option, field installable. Electrically isolated.
Programming Language: IEEE-488.2 SCPI compatible.
LabVIEW™ drivers available for all interfaces. LXI discovery.

Firmware

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

Architecture

Microprocessor: 32-bit ARM9, 450Mhz.
OS: Embedded Linux, Kernel version 4.5.
Signal Processor: Cryo-con proprietary implementation using a Field Programmable Gate Array.

General

Ambient Temperature: 25°C ± 5°C for specified accuracy.
Mechanical: 436mmW × 87.3mmH × 305mmD
Weight: 5kg
AC Power Switch: Front panel.
Power Requirement: 100, 120, 220 or 240VAC +5% -10%. 50 or 60Hz, 150VA.
AC Power Switch: Front panel.
Approval: CE mark, RoHS
Calibration: NIST traceable.

Contact Information

Physike Technology Co., Ltd

First floor, Building 19, Guanghua Pioneer Park, No. 18 Anningzhuang East Road, Haidian District, Beijing, China

Phone: +86–10–62166302 / 82367826

Email: sales@physike.com

Website: www.physike.com