Innovative Solutions in Cryogenic Instrumentation

-Preliminary-

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. Additionally, four control loop outputs support use as a 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 thermometers.
- **Operation from <100mK to over 1500K** 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 touchscreen and full keypad.
- **Industrial grade security**: Configurable **firewall**, HTTPS **encryption** and **authentication**.
- **User programmable,** web browser based editor and debugger.
- Embedded **web 2.0 server** provides complete control, eliminates the need for external support software.
- Remote interfaces include **Ethernet, USBA** for data logging and **USBB** serial port emulator**.** LabView™ drivers available, LXI Discovery.
- Remote command language is IEEE-488.2 **SCPI** compliant.

Applications:

Ultra-Low temperature thermometry

- He3 refrigerators, Dilution Refrigerators, ADRs.
- Each input supports resistor, diode and mutual-inductance temperature sensors.
- Differential sinewave excitation. Step-less constant-voltage down to 100µV.
- High precision heater outputs for excellent control stability.
- Precision low power control outputs.

Material Science

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

General purpose laboratory

- Cryogenic bridge measures resistance, inductance and mutual-inductance.
- Cryogenic temperature controller. Four independent control loops. All types of thermometers supported including Diode sensors.
- Four inputs expandable to 28.
- Ethernet connectivity, Web 2.0.
- Data logging to external memory.
- Data acquisition / computer control

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 implementing an auto-blancing, 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, thereby reducing generated output noise. To further reduce noise, sine-wave excitation is used with 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 in the signal processor chip. Measurement accuracy is further enhanced by over-sampling and signal dither.

Cryogenic Thermometry

Negative-Temperature-Coefficient (NTC) resistors are often used as low temperature thermometers, especially at ultra-low temperature. The Model 54 provides robust support for these sensors by using constant-voltage AC excitation. In their warm region, these sensors have low resistance and low sensitivity. Maintaining a constant-voltage will increase excitation current to improve measurement accuracy. Conversely, at low temperature, measurement errors are dominated by sensor self-heating. In this region, constant-voltage excitation reduces self-heating by reducing excitation current as temperature decreases.

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

Errors in the conversion from measured data to temperature are reduced in all Cryo-con products by using a Cubic Spline interpolation algorithm. In addition to providing higher accuracy than conventional linear interpolation, the spline function eliminates discontinuities during temperature sweeps by ensuring that first and second derivatives are continuous.

Inductance and Mutual Inductance

Since the Model 54's bridge circuits are based on bi-phase lock-in detection, inductance and mutual-inductance measurements can be made to high accuracy. In this case, the bridge uses passive excitation with frequencies up to 60Hz. The mutual-inductance based temperature sensors used in Milli-Kelvin level 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

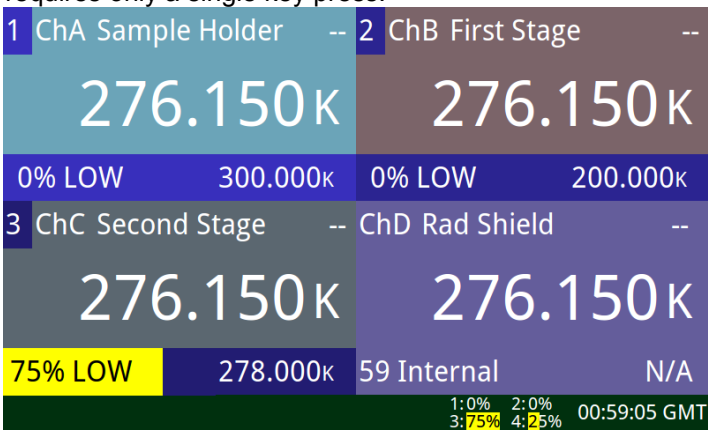
By using a low noise preamplifier, high excitation current and bi-phase lock-in detection, the Model 54 can accurately measure resistance down to less than 1.0mΩ. Both R and ΔR measurements are available.

To further reduce measurement noise for resistances below 10Ω, The Model 54 asserts a phase angle of zero so the low-level voltage measurement will not be corrupted by phase noise.

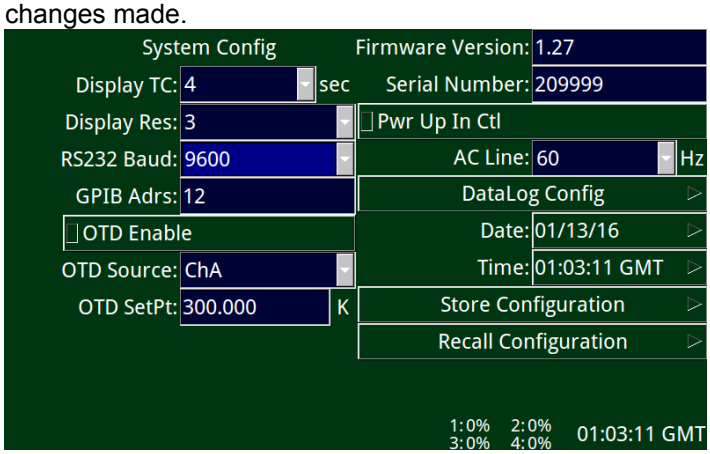
User Interface

The Model 54's user interface is based on a large, high resolution color graphics display with an integrated capacative 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.



Virtual Inputs

The Model 54 can be expanded up to 28 input channels by connecting up to three Cryo-con temperature monitors to the Ethernet remote interface. Once connected, these virtual inputs appear to the Model 54 as additional inputs.

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 use 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. Pickup is further reduced by the use of RFI filters.

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 a two-range linear heater with outputs of 1.0W or 100mW. **Loop #4** is a non-powered voltage output.

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

Remote Control

Standard Remote Interfaces include Ethernet, USBB and two USBA interfaces. An IEEE-488.2(GPIB) interface is optional.

The USBB connection is a serial port emulator and the dual USBA connections are for external memory.

The TCP and UDP data port servers bring fast Ethernet connectivity to data acquisition software including LabView™.

Remote interfaces implement an IEEE-488.2 SCPI compliant remote command language.

LabView™ drivers are available for all remote interfaces. LXI Discovery supported.

Security

The Model 54 provides industrial grade security. A built-in user configurable firewall protects the instrument from any unauthorized transactions. HTTP Digest access authentication protects the built-in web server. HTTPS provides authenticated, encrypted communication.

Web 2.0 Server

Using secure Ethernet HTTPS protocol, the monitor's embedded web server provides complete instrument control and configuration without the need for external platform-dependent software.

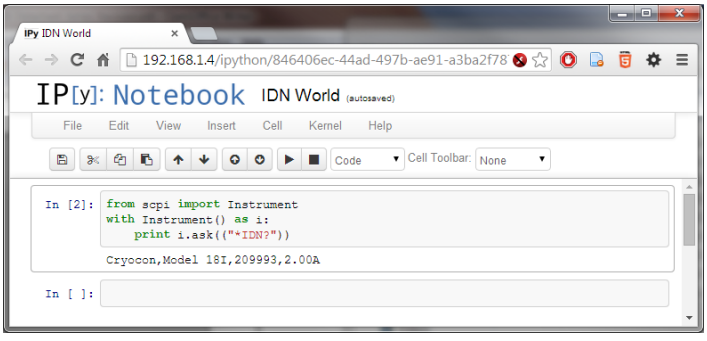
Instrument status can be viewed in real time and configured from any web browser.

Custom sensor calibration tables and data-logging files may be uploaded or downloaded.

Instrument firmware updates may be installed. Updates are free of charge and generally include enhancements and new features.

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.



Specifications

User Interface

Display Type: 800x480 color graphics TFT LCD with a capacitive touchscreen.
Keypad: Sealed Silicon Rubber.
Display Update Rate: 0.5 Seconds.

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, Constant-Current or Passive.
Excitation: 12 to 60Hz differential sine-wave.
Voltage Levels: 10mV, 3.0mV, 1.0mV, 300µV and 100µV. Minimum excitation current is 10nA, maximum is 10mA.
DC Offset: <8nA by active cancellation.
Sample Rate: 128Hz per channel.
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 sensor input.
Loop Update Rate: 1.024KHz per loop.
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, 50W, 5.0W and 0.5W.
Resolution: 22 bits.
Readbacks: Heater output current, voltage, heatsink temperature.

Loop #2 Control Output

Short circuit protected linear current source.

Ranges: Three output ranges of 10W, 1.0W and 1.0W into 50Ω.
Resolution: 22 bits.
Readbacks: Heater output power, Heatsink temperature.

Loop #3 Control Output

Short circuit protected linear current source.

Ranges: Two ranges of 1.0W and 100mW into a 100Ω load.
Resolution: 22 bits.

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: 22 bits.

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.
Status reported via Remote Interface: Sensor fault, Heater over temperature 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, mouse, keyboard.
IEEE-488.2 (GPIB): External Option, field installable.
Programming Language: IEEE-488.2 SCPI compatible.
LabVIEW™ drivers available for all interfaces. LXI discovery.

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, 230 or 240VAC +5% -10%. 50 or 60Hz, 150VA.
Conformity: European CE, RoHS compliant, Lead-free.
Calibration: NIST traceable.

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)

Accessories	Description
4024-016	Input connector kit consisting of four DIN-6 sensor input connectors.
4124-018	Output connector kit consisting of a dual banana plug heater connector and a 10-pin terminal block receptacle.
4122-030	Single instrument 2U rack mount kit.
4034-031	Two instrument shelf rack mount kit
4034-032	One instrument shelf rack mount kit

Contact Information

Cryogenic Control Systems, Inc.
PO Box 7012
Rancho Santa Fe, CA 92067
Tel: (858) 756-3900 Fax: (858) 759-3515
E-mail: sales@cryocon.com Web: www.cryocon.com