

User's Guide
Model 54
Cryogenic Temperature Controller

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Printing History

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Certification

Cryogenic Control Systems, Inc. (Cryo-con) certifies that this product met its published specifications at the time of shipment.

Warranty

This product is warranted against defects in materials and workmanship for a period of one year from date of shipment. During this period Cryo-con will, at its option, either repair or replace products which prove to be defective.

Warranty Service

For warranty service or repair, this product must be returned to a service facility designated by Cryo-con.

Limitation of Warranty

The foregoing warranty shall not apply to defects resulting from improper or inadequate maintenance by the Buyer, Buyer supplied products or interfacing, unauthorized modification or misuse, operation outside of the environmental specifications for the product, or improper site preparation or maintenance. The design and implementation of any circuit on this product is the sole responsibility of the Buyer. Cryo-con does not warrant the Buyer's circuitry or malfunctions of this product that result from the Buyer's circuitry. In addition Cryo-con does not warrant any damage that occurs as a result of the Buyer's circuit or any defects that result from Buyer-supplied products.

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Safety

The Model 54 does not contain any user serviceable parts. Do not open the enclosure. Do not install substitute parts or perform any unauthorized modification to the product. For service or repair, return the product to Cryo-con or an authorized service center.

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Introduction

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 cryogenic temperature controller. All inputs are identical and independent, with each capable of supporting the same wide range of sensors.

The controller's front panel user's interface consists of a large, full color TFT-LCD display, a capacitive touch screen, and a back-lit 20-key keypad.

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 10 μ A 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.

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

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

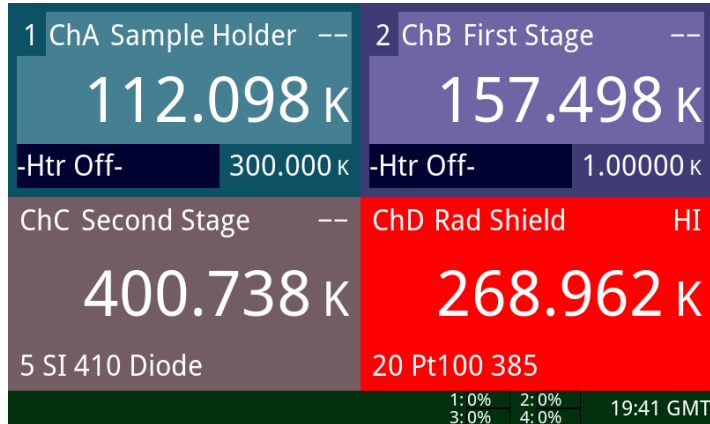
The Model 54 can accurately measure resistance down to less than 0.01 Ω . Both R and ΔR measurements are available.

User Interface

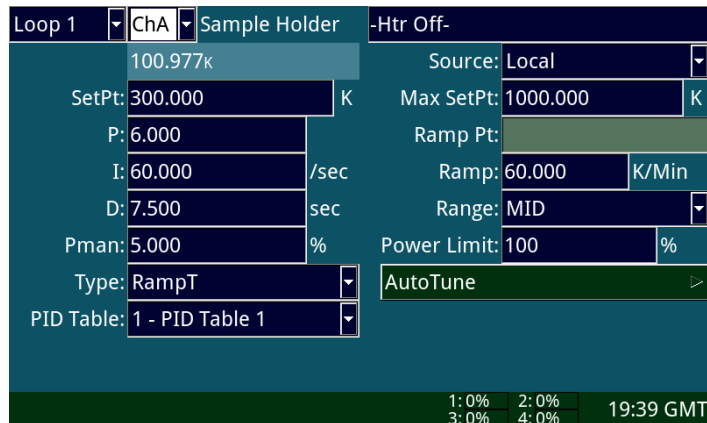
The Model 54's user interface is based on a large, high resolution color graphics display with an integrated capacitive touchscreen plus a full 20-key keypad.

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.



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.

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 and remote 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.

Remote Interfaces

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

Ethernet: 100/10-BaseT. Electrically isolated.

USBB: Serial port emulator. Baud Rates are 9600, 19,200, 38,400, 557,600 and 115,200 Baud. Not electrically isolated.

IEEE-488 (GPIB): External option (4001-002). Full IEEE-488.2 compliant. Isolated.

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

Remote interfaces implement an IEEE-488.2 SCPI compliant remote command language that is easy to use and read. Further, it is identical within the entire Cryo-con instrument line.

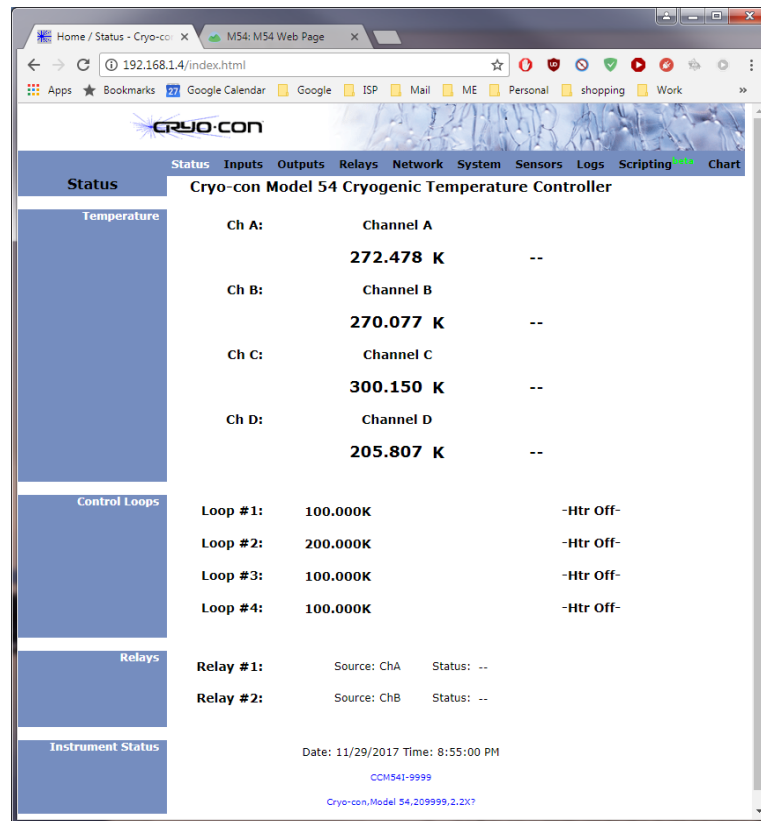
LabView™ drivers are available for all remote interfaces.

Embedded 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.



Note: The web server's default user name is **admin** and the default password is **cryocon**. This may be changed by the user by going to the Network page of the embedded web server. Resetting the instrument's password can only be done from the front panel. Navigate to the Network Setup menu and use the Reset Password field.

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.

Preparing the controller for use

The following steps help you verify that the controller is ready for use.

Supplied Items

Confirm that you have received the following items with your controller. If anything is missing, contact Physike Technology Co.,Ltd directly.

- ☐ Model 54 Cryogenic Temperature Controller.
- ☐ Input connector kit (4026-016) consisting of four snap-in circular input connectors (04-0068).
- ☐ User's Manual
- ☐ AC Power Cord
- ☐ L-shaped mounting plate

Verify the AC Power Line Voltage Selection

The AC power line voltage is set to the proper value for your country when the controller is shipped from the factory. Change the voltage setting if it is not correct. The settings are: 100, 120 230, or 240 VAC.

Note: For 235VAC operation, use the 240 VAC setting.

On the rear panel of the instrument, the AC voltage selection is on the power entry module. If the setting is incorrect, please refer to section [Fuse Replacement and Voltage Selection](#) to change it.

Apply Power to the Controller

Connect the power cord ,the front panel will show a Power Up display with the model number and firmware revision.

While the Power Up display is shown, the controller is performing a self-test procedure that verifies the proper function of internal data and program memories, remote interfaces and input/output channels. If an error is detected during this process, the controller will freeze operation with an error message display. In this case, turn the unit off and contact Physike support.



Caution: Do not remove the instrument's cover or attempt to repair the controller. There are no user serviceable parts, jumpers or switches inside the unit. Further, there are no software ROM chips, trim pots, batteries or battery-backed memories.

All firmware installation and instrument calibration functions are performed externally via the remote interfaces.

After about fifteen seconds, the self-test will complete and the controller will begin normal operation.

Installation

General

The Model 54 can be used as a bench top instrument, or mounted in an equipment rack. In either case, it is important to ensure that adequate ventilation is provided.

Cooling airflow enters through the side holes and exhausts out the fan on the rear panel. It is important to allow at least $\frac{1}{2}$ " of clearance on the left and right sides and to ensure that the exhaust path of the fan is not blocked.

Rack Mounting

You can rack mount the controller using the optional rack mount kit. Instructions and mounting hardware are included with the kit.

- 4122-030 Single instrument 2U rack mount kit.
- 4034-032 Single instrument shelf rack mount kit.
- 4034-031 Dual instrument shelf rack mount kit.

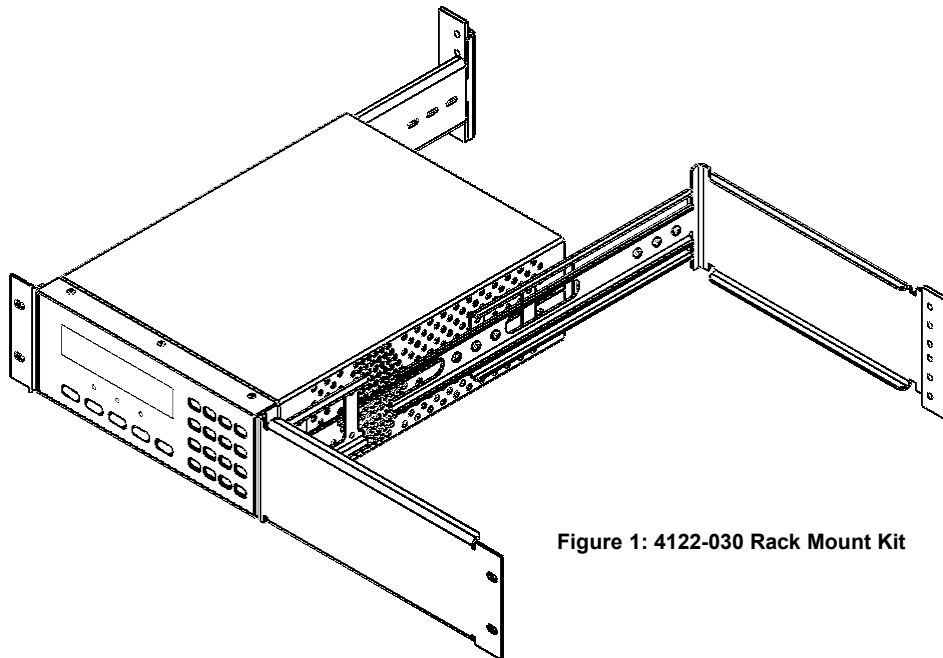


Figure 1: 4122-030 Rack Mount Kit

Model Identification

The model number of all Cryo-con controllers is identified on the front and rear panel of the instrument as well as in various instrument displays.

Ordering Information

Product	Description
Model 54	Four channel cryogenic impedance bridge with four temperature control loops.
	Includes: User's Manual ,four input connectors, detachable power cord and a Certificate of Conformity. 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. - 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
4001-002	IEEE-488.2 (GPIB) Option. Field installable.

Technical Assistance

Troubleshooting guides and user's manuals are available on our web page at <http://www.cryocon.com>.

Technical assistance may also be obtained by contacting Physike as follows:

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

For updates to LabView™ drivers, Cryo-con utility software and product documentation, go to our web site and select the Download area.

Current Firmware Revision Level

As of July, 2019 the firmware revision level for the Model 54 series is 3.05. Instrument firmware can be updated in the field via the embedded web browser. Updates can be obtained by contacting Physike support.

Current Hardware Revision Level

As of June, 2018, the hardware revision level for the Model 54 series is C.

Returning Equipment

If an instrument must be returned to Cryo-con for repair or re-calibration, a Return Material Authorization (RMA) number must first be obtained from the factory. This may be done by Telephone, FAX or e-mail.

When requesting an RMA, please provide the following information:

1. Instrument model and serial number.
2. User contact information.
3. Return shipping address.
4. If the return is for service, please provide a description of the malfunction.

If possible, the original packing material should be retained for reshipment. If not available, consult factory for packing assistance.

The shipping address is:

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

Instrument Accessories

Cryo-con Part #	Description
04-0310	AC Power Cord. North American
04-0317	AC Power Cord, Cont. European (Shuko)
04-0068	Circular input connector. T3400001U.
4026-016	Input connector kit consisting of four PN 04-0068.
04-0007	Ten-pin detachable terminal block for Loop 2 and relay connections.
4026-018	Output connector kit consisting of a 3-pin heater connector and a 10-pin terminal block receptacle.

Table 1: Model 54 Instrument Accessories**Cryogenic Accessories**

Cryo-con Part #	Description
S950	S950 series Silicon diode Temperature Sensors. Temperature range: 1.4 to 400K
CP-100	CP-100 series Ceramic Wound RTD, 100 Ω
GP-100	GP-100 series Glass Wound RTD, 100 Ω
XP-100	XP-100 series Thin Film Platinum RTD, 100 Ω
XP-1K	XP-1K series Thin Film Platinum RTD, 1,000 Ω
3039-002	Cartridge Heater, Silicon free, 25 Ω / 25 Watt, 1/4" x 1 1/8". Temperature range to 1,600K
3039-001	Cartridge Heater, Silicon free, 50 Ω / 50 Watt, 1/4" x 1 1/8". Temperature range to 1,600K
4039-011	Pre-cut Nichrome wire heater w/connectors, 25 Ω
4039-012	Pre-cut Nichrome wire heater w/connectors, 50 Ω
3039-006	Bulk Nichrome Heater Wire, 32AWG, Polyamide insulation, 100'

Table 2: Cryogenic Accessories

Specifications, Features and Functions

User Interface

Display Type: 800x480 color LCD and capacitive touch screen.

Keypad: 25 key Silicon Rubber.

Temperature Display: Seven significant digits, autoranged.

Display Units: K, C, F or native sensor units.

Input Channels

There are four input channels, each of which may be independently configured for any of the supported sensor types. Additionally, up to 24 additional inputs may be connected via the Ethernet remote interface.

Sensor Connection: 4-wire differential. 6-pin snap-in connector.

Sensor Types: Resistance, inductance, mutual-inductance, diode.

Bridge type: Auto balancing ratiometric AC impedance bridge.

Bridge modes: Constant-Voltage or Passive.

Excitation: Differential voltage source, sine-wave, 12 to 30Hz. (Default: 17)

Excitation Voltage Levels: 10mV to 10.0μV. Maximum excitation current is 10mA, minimum is 1.0nA.

DC Offset: <1nA by active cancellation.

Input Sample Rate: 256Hz per channel. Simultaneous sampling of excitation current and voltage on each input channel.

Signal Processor Functions: Sinewave generation, 4x parallel bi-phase lock-in detection, clipping and noise detection.

Ambient Temperature: 25°C ± 5°C for specified accuracy.

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: 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.

Input Configurations

A list of the sensor input configurations is shown below:

Type	Excitation	Use
Diode	Constant-Current 10 μ A DC	Silicon diodes
PTC100, PTC1K	Passive 1.0mA AC or 100 μ A AC	Platinum, PTC RTDs
ACR	Constant-Voltage AC	NTC thermistors
LF ACI	Constant-Voltage AC inductance	Low frequency inductance including CMR and other mutual-inductance.
Low R	Constant-Voltage AC. Fixed 1.0mV excitation	Low resistance measurement.

Table 3: Supported Sensor Configurations

Input Performance

Diode Sensors (Diode)

Configuration: Constant-Current mode, 10 μ A $\pm$ 0.05% DC excitation.

Note: Current source error has negligible effect on measurement accuracy.

Input voltage range: 0 to 2.00VDC.

Accuracy: $\pm(80\mu\text{V} + 0.005\% \cdot \text{reading})$

Resolution: 2.3 μ V

Drift: 25ppm/ $^{\circ}$ C over an ambient temperature range of 25 $^{\circ}$ C $\pm$ 5 $^{\circ}$ C.

PTC Resistor Sensors (PTC100, PTC1K)

Configuration: Passive AC resistance bridge mode.

Ratiometric measurement cancels any error in excitation current.

Excitation Frequency: User selectable 12 to 30Hz differential sine-wave.
Default is 17Hz.

Drift: 20ppm/ $^{\circ}$ C over an ambient temperature range of 25 $^{\circ}$ C $\pm$ 5 $^{\circ}$ C.

Range	Max/Min Resistance	Excitation Current	Resolution	Accuracy
PTC100 1mA	400 Ω 0.01 Ω	1.0mA	0.1m Ω	$\pm (0.004 + 0.01\%) \Omega$
PTC1K 100 μ A	4.0K Ω 0.1 Ω	100 μ A	1.0m Ω	$\pm (0.05 + 0.02\%) \Omega$

Table 4: Accuracy and Resolution for PTC Resistors

Constant-Voltage NTC Resistors (ACR)

Type: Constant-Voltage AC resistance bridge with excitation levels from 10mV to 10.0μV RMS. Fixed or auto-ranged.

Excitation Current: 10mA to 1.0nA, Continuously variable.

Excitation Frequency: 12 to 30Hz differential sine-wave. Default is 17Hz.

Drift: >10Ω and <10KΩ: 15ppm/°C

<10Ω or >10KΩ: 25ppm/°C

over an ambient temperature range of 25°C± 5°C.

DC Offset Current: <1/2 excitation current by active cancellation.

Electronic 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

100μV: 0.15Ω to 10KΩ: 0.05%Rdg + 0.005% Range

0.01Ω to 100KΩ: 0.15%Rdg + 0.2% Range

Resolution: Values shown are for typical RMS resistance noise measured at 50% full scale on a room temperature resistor with a 4 second output time constant.

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

Table 5: Constant-Voltage AC Resistance Resolution

Shaded ranges are synthesized and will have reduced accuracy.

① Note: The excitation voltage applied to the sensor is the product of the voltage range and the Vlevel attenuator. Maximum accuracy is obtained with the Vlevel control set at 100%.

Low resistance measurement

Type: Constant-Voltage AC resistance with a fixed excitation of 100 μ V RMS.

Excitation Current: 10mA to 100 μ A, Continuously variable.

Excitation Frequency: 12 to 30Hz differential sine-wave. Default is 17Hz.

Measurement Range: 1.0 Ω to 0.001 Ω .

Accuracy: 2.0%.

Inductance / Mutual-Inductance

Type: Constant-Voltage AC inductance bridge.

Excitation Voltage: 100 μ V RMS

Excitation: 12 to 100Hz differential sine-wave. Default is 17Hz.

Measurement Range: <10 μ H to 85mH @ 17Hz.

Accuracy: 10mH to 10 μ H @ 17Hz: 0.5% at 17Hz.

Input Channel Statistics

Input temperature statistics are continuously maintained on each input channel. This data may be viewed in real time on the Input Channel menu, or accessed via any of the remote I/O ports.

Statistics are:

Minimum Temperature.

Maximum Temperature.

Temperature Variance.

Slope and Offset of the best-fit straight line to temperature history.

Accumulation Time

The temperature history may be cleared using a reset command provided.

CalGen® Calibration Curve Generator

The CalGen® feature generates new calibration curves for Silicon diode or Platinum sensors. This provides a method for obtaining higher accuracy temperature measurements without expensive sensor calibrations.

Curves can be generated from any user-selected curve and are written to a specified internal user calibration curve area.

The CalGen® function may be performed in the instrument by using the web browser.

Control Loop Outputs

The Model 54 has four control loop outputs. Loop #1, Loop #2 and Loop #3 are powered outputs that directly drive a heater load. Loop #4 is a non-powered output that is intended to control an external device.



Caution: The Model 54 has an automatic control-on-power-up feature. If enabled, the controller will automatically begin controlling temperature whenever AC power is applied.

Control Input: Any sensor input including virtual inputs.

Control Type: PID, Table, Ramp or Manual.

Autotune: Minimum bandwidth PID loop design.

PID Tables: Six user PID tables available for storage of Setpoint vs. PID and heater range. Up to 16 entries/table.

Setpoint Accuracy: Six+ significant digits.

Control Loop #1, Primary Heater

The Loop #1 heater output is a four-range, short circuit protected linear current source.

Range	Compliance Voltage		Full-Scale Current	Max. Output Power	
	25Ω	50Ω		25Ω	50Ω
75W	50V	—	1.7A	75W	N/A
High	25V	50V	1.0A	25W	50W
Medium	25V	25V	0.316A	2.5W	5.0W
Low	25V	25V	0.100A	0.25W	0.50W

Table 6: Loop #1 Heater output ranges.

Minimum Load: 10Ω. in all ranges.

Digital Resolution: 24-bits by over-sampling plus dither.

Read-back: Heater output power, load resistance, load voltage, heatsink temperature.

Connector: 3-pin detachable terminal block.

Control Loop #2, Secondary Heater Output

The Loop #2 heater output is a three-range, short circuit protected linear current source.

Range	Compliance Voltage	Full-Scale Current	Max. Output Power	
			25Ω	50Ω
High	28V	0.447A	5W	10W
Mid	28V	141mA	0.5W	1.0W
Low	28V	45ma	50mW	100mW

Table 7: Loop 2 Heater output ranges.

Minimum Load: 10Ω. in all ranges.

Digital Resolution: 24-bits by over-sampling plus dither.

Read-back: Heater output power, load resistance, load voltage, heatsink temperature.

Connector: 10-pin detachable terminal block.

Control Loop #3, Heater Output

The Loop #3 heater output is a one-range, short circuit protected linear current source.

Compliance Voltage	Full-Scale Current	Max. Output Power 100Ω load	Minimum Load
10V	100mA	1.0W	25Ω

Digital Resolution: 24-bits by over-sampling plus dither.

Read-back: Heater output power, load resistance, load voltage, heatsink temperature.

Connector: 10-pin detachable terminal block.

Digital Resolution: 24-bits by over-sampling plus dither.

Connector: 10-pin detachable terminal block.

Control Loop #4 Voltage Output

Control loop #4 is a non-powered voltage output that can be set for either 0 – 10 or 0 – 5.0 Volts. All control modes available.

Short-Circuit Output Current: 1.0mA.

Output Impedance: 2,000Ω

Digital Resolution: 24-bits by over-sampling plus dither.

Connector: 10-pin detachable terminal block.

① Note: Heater output displays are given as a percentage of output power, not output current or voltage. In order to compute actual output power, multiply this percentage by the full-scale power of the selected range. However, to compute actual output current, you must first take the square root of the percentage and then multiply by the full-scale current.

Control Types

A summary of control types is given here:

Type	Description
Off	Control loop is disabled.
Man	Manual control mode. Here, a constant heater output power is applied. The Pman field selects the output power as a percentage of full-scale.
Table	PID control mode where the PID coefficients are generated from a stored, user supplied PID table.
PID	Standard PID control.
RampP	Temperature ramp control. Uses PID control to perform a temperature ramp.
RampT	Temperature ramp control using a PID table. Uses PID control to perform a temperature ramp.

Table 8: Control Type Summary

Manual operation allows setting the loop output power manually as a percentage of full-scale.

PID control allows feedback control using a standard PID algorithm.

The **PID Table** control mode is a standard PID control loop a table is used to look up PID and heater range values based on the specified setpoint. This is useful where a process must operate over a wide range temperature range since optimum PID values usually change with temperature. The Model 54 allows for the entry of six independent PID Tables. Each table may contain up to 16 temperature zones.

In the **Ramp** control mode, the controller approaches a new setpoint at a user specified rate. When this setpoint is reached, the controller will revert to PID control.

Control Loop Fault Monitors

Loop #1 and #2 heater outputs will be automatically shut down when a fault condition is detected. Here, the heater output will be turned off until the output stage returns to its safe operating area.

If the control loop was disengaged by a detected error condition, the heater status field shows an indicator of the error as follows:

Control Loop Status Indications	
-Htr Off-	Normal display for a control loop that is OFF.
24% HI	Active loop controlling temperature. Percent output power and range are indicated in real time.
-Overtemp-	Indicates that the controller's internal temperature monitor circuit shut off the heater because the internal heat-sink temperature is too high. After the controller has been allowed to cool to an acceptable temperature, pressing the CONTROL button will clear the error and re-start control. Note: The current temperature of the internal heat-sinks for Loop #1 and Loop #2 are displayed in the heater configuration menu.
-Readback-	An independent read-back of the heater output current differs significantly from the current that the controller is attempting to set. This is usually caused by an open heater or a load resistance that is too high.
OTDisconn	Indicates that the control loop was disconnected by the Over Temperature Disconnect Monitor. This monitor is configured by the user and functions to disable the heater if a specified over temperature condition exists on an input channel.
Htr-Low-R	Indicates that the resistance of the heater is too low and can cause overheating of the controller's internal circuits. For Loop #1 set to a 50Ω load, the actual resistance must be >40Ω. With a 25Ω load selected, the resistance must be >10Ω.
Fan Fault	The internal fan speed is too low. This may be caused by blocked air flow or a defective fan.
Control LED ON but no heater output	The controller's watchdog timer has detected an internal fault. If this persists, please contact factory.

Table 9: Control Loop Fault Monitors

General

Electrical Isolation and Input Protection

The input channel measurement circuitry is electrically isolated from other internal circuits. However, the common mode voltage between an input sensor connection and the instrument's ground should not exceed $\pm 40V$.

Sensor inputs and outputs are provided with protection circuits. The differential voltage between sensor inputs should not exceed $\pm 15V$.

Relays

The Model 54 has two dry-contact mechanical relay outputs.

Relays 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. Furthermore, relays can be manually asserted ON or OFF.

Normally-Open contacts are available on the rear panel. Contact rating is 10A @125 VAC, 5A @250 VAC or 5A @30 VDC for resistive loads. Maximum switching power is 150W.

Alarm Outputs

Alarm outputs include an audible alarm, on-screen display and remote reporting.

Alarms may be asserted based on high temperature, low temperature, input sensor fault or heater fault conditions.

A user selectable dead-band is applied to all alarms.

The High and Low temperature alarms may be latched. See the Input Channel Configuration Menu.

Note: To clear a latched alarm, first press the Alarm key and then press the Home key.

Mechanical, Form Factors and Environmental

The Model 54 enclosure may be used either stand-alone or incorporated in an instrument rack.

Dimensions are: 436mmW x 87.3mmH x 305mmD. Weight is 5kg.

An instrument bail and feet are standard. Rack Mount kits are available from Cryo-con for both single instrument or side-by-side dual configurations. A rack mount kit is optional.

Front Panel Operation

The user interface of the Model 54 consists of a color graphics LCD with a touchscreen and a keypad. All features and functions of the instrument are accessed via this simple and intuitive menu-driven interface.



Figure 2: Model 54 Front Panel Layout

The Keypad

Function Keys

The Function Keys on the Model 54 are **Stop**, **Control**, **Home**, **Set Pt** and Enter(●). These buttons always perform the same function, regardless of the context of the display. Navigation keys are **Up**(▲), **Down**(▼) and backspace(←).

Press and hold the **Stop** key for two seconds to toggle AC power.

❶ **Note:** The Model 54 uses a smart power on/off scheme. When the power button on the front panel is pressed to turn the unit off, the instrument's configuration is copied to flash memory and restored on the next power up. If the front panel button is not used to toggle power to the instrument, the user should configure the controller and cycle power from the front panel button one time. This will ensure that the proper setup is restored when AC power is applied.

The **Stop** and **Control** keys are used to disengage or engage the instrument's output control loops. Pressing **Control** will immediately turn on all enabled heater outputs and pressing **Stop** will turn them both off. To enable or disable an individual loop, go to the [Loop Configuration Menu](#) menu and select the desired 'Type' of OFF.

The **Enter** key is used to enter numeric data or selections.

The **Home** key is used to take the display to one of the Home Status displays. These displays show the full status of the instrument.

The **Set Pt** key provides immediate access to the setpoints of all control loops.

The Keypad and Setup Menu Keys

The keypad keys can serve a dual function. When the display is showing one of the configuration menus, the keypad is used for navigation and data entry. When on the Home display, their function is identified by a label printed just below the key and is as follows:

- Input (1) – Input configuration menu.
- Loop (2) – Control loop configuration menu.
- Relay(3) – Relay configuration menu.
- Alarm(5) – Alarm menu, cancel a latched alarm.
- Display(7) – Home screen configuration menu.
- Network(8) – Network configuration menu.
- System(9) – System configuration menu.

Summary of keypad functions

Key	Function	Description
	Stop	Disengage all control loops. If pressed and held for more than 2 seconds, toggle AC power.
	Control	Engage all control loops.
	Enter	Enter key
	Home	Go to the Home Status Display.
	Setpoint	Change the setpoint value for either control loop. / Scroll to NEXT selection.
▲		Navigate UP
▼		Navigate Down
←	Backspace	Backspace or Escape
•	Enter	Enter
1	Input	Go to the Input configuration menus
2	Loop	Go to the Loop configuration menus.
3	Relay	Go to the Relay configuration menus.
5	Alarm	Go to the Alarm Status menu.
7	Display	Go to the display configuration menu.
8	Network	Go to the Network configuration menu
9	System	Go to the System setup menu

Table 10: Keypad key functions.

A Quick Start Guide to the User Interface.

Pressing the **Power** key will toggle the controller's AC power on and off. This key must be pressed and held for two seconds before power will toggle.

Pressing the **Stop** key will immediately disengage both control loops. Pressing the **Control** key will engage them.

Use the **ESC** key to exit an erroneous entry.

Home Status Display

Pressing the **Home** key will return the screen to the Home Display from anywhere in the sub-menus. The Home Display is the primary display for instrument status information.

The Home Status display consists of four zone quadrants. Each zone can be individually configured to show useful information with minimum clutter.

To configure zone displays, press the **Display** key.

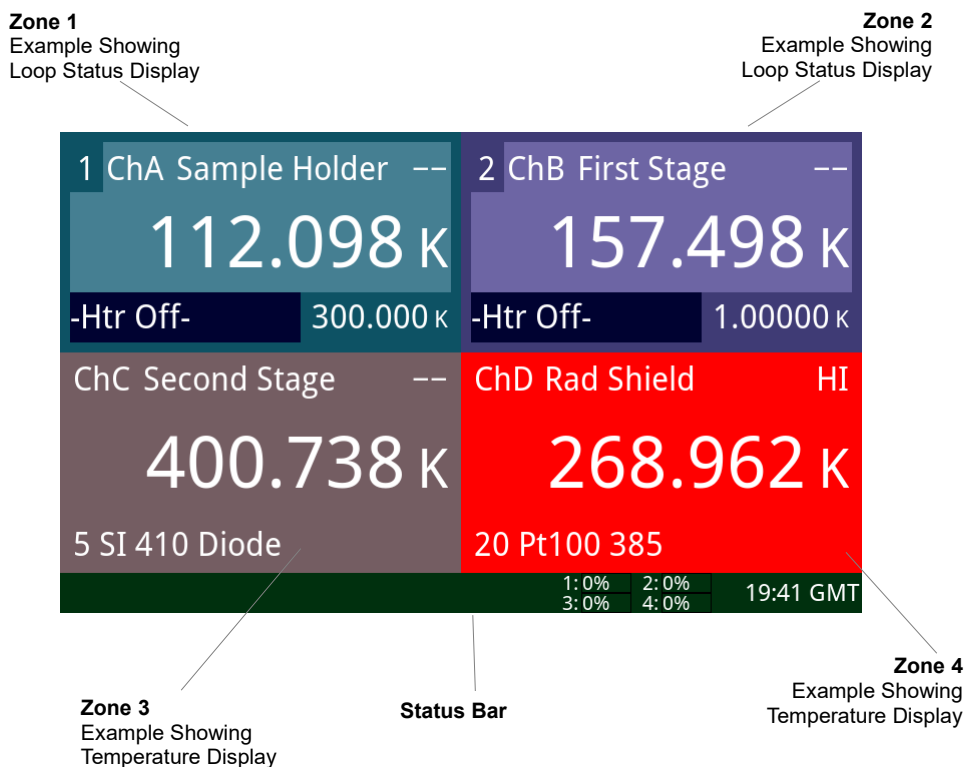
Accessing the heater setpoint

To instantly access the setpoint for either control loop, press the **Set Pt** key.

Home Status Displays

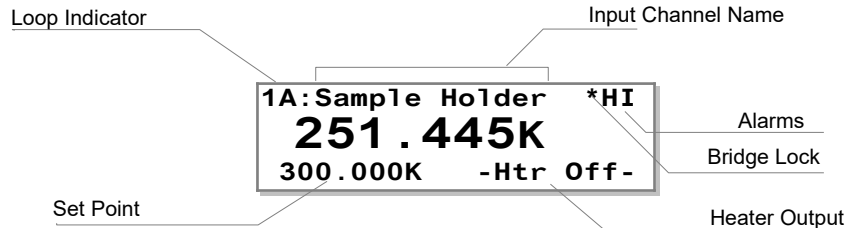
At the top of the instrument's menu tree are the home status displays. They can be selected from anywhere in the instrument's menu tree by pressing the **Home** key.

There are four zones, each of which may be independently configured.



① Note: An asterisk (*) character may appear above the temperature measurement units indicator. This is a Bridge Lock Indicator: Blank indicates that the bridge is locked and tracking, an asterisk indicates that the bridge is searching for balance or that it cannot establish the selected sensor excitation voltage. A flickering asterisk indicates excessive noise pickup.

Loop Status Display



The loop indicator of 1A in the upper left corner indicates Loop #1 with a source input channel of A.

If the control loop is OFF and there are no error conditions, the heater output field simply shows OFF.

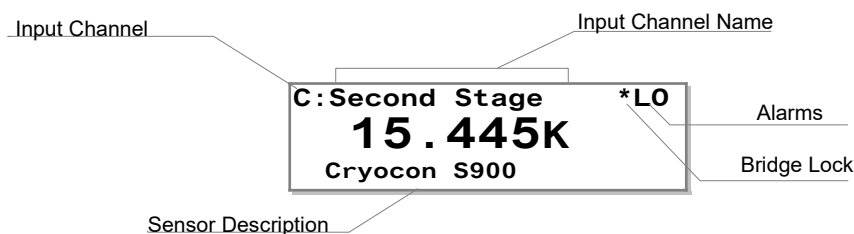
If the control loop was disengaged by a detected error condition, the heater output field shows a fault indicator.

If the control loop is actively engaged, bar chart showing the heater range and output level is displayed. For a detailed description of control loop status, press the Loop 1 or Loop 2 keys to go to the heater configuration menu. Here, complete status is displayed in real-time.

Note: The Model 54 uses an independent circuit to read current actually flowing through the load. If the unit is controlling temperature, but the bar graph indicates zero current flow, an error condition exists.

Temperature Display

A typical Input Channel Temperature Display consists of the input channel indicator, a Temperature reading and the current temperature units. Optionally, a description of the temperature sensor may be shown.



The temperature, a seven-character field, is affected by the Display Resolution setting in the **System** menu. It may be 1, 2, 3 or Full. Settings of 1, 2, or 3 indicate the number of digits to the right of the decimal point to display whereas the Full setting causes the display to be left justified in order to show the maximum number of significant digits possible.

The Display Resolution setting does not affect the internal accuracy of arithmetic operations. It is generally used to eliminate the display of unnecessary digits that are beyond the sensor's actual resolution.

If the Input Channel has been disabled, a blank display is shown.

Temperature Units may be K, C or F. When Sensor Units (S) is selected, the raw input readings are shown. These will be in Volts, Ohms, milli-Ohms or micro-Henries.

K	Kelvin
C	Celsius
F	Fahrenheit
Ω	Ohm
mΩ	milliohm
V	Volt
μH	micro-Henry

Table 11: Display Units

The Bridge Lock Indicator

An asterisk (*) character may appear above the temperature measurement units indicator. This is a Bridge Lock Indicator: Blank indicates that the bridge is locked and tracking, an asterisk indicates that the bridge is searching for balance or that it cannot establish the selected sensor excitation voltage. A flickering asterisk indicates excessive noise pickup.

Sensor Fault Display

If a temperature reading is within the measurement range of the instrument but is not within the specified Sensor Calibration Curve, a display of seven dot (.) characters is shown.

.....K

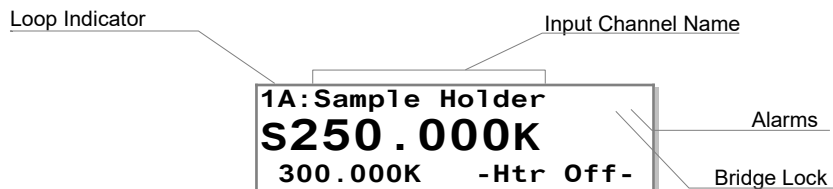
If the input channel has an over-voltage condition, a clipping or clamping message will be shown.

..C11p..

Control Loop Setpoint Display

The control loop setpoint display shows the setpoint for a selected control loop. Frequently, this display is set directly below the loop status display so both the current temperature and the setpoint are shown in large fonts.

!C1amp!



Instrument Setup Menus

To access the various instrument setup menus, press one of the Setup Menu keys. The display must be in 'Home Status' in order for these keys to be active.

The user may exit a Setup Menu and return to the Home Status display at any time by pressing the **Home** key.

Menus contain several lines, so scroll through the display using the Navigation keys.

The last character of each line in a setup menu is the format indicator. The indicator will be blank until the cursor is moved to the line.

The Setpoint Menu

The setpoint menu is accessed by pressing the **Set Pt** key. This gives one-key access to the setpoints for all of the control loops.

The Alarm Status Display Menu (Key 5)

The current status of the temperature alarms may be viewed by pressing the **Alarm** key.

Alarms are set for each input channel using the Input Channel Setup menu described below.

Pressing the **Alarm** key will display all of the alarms. Status is shown as follows:

—	No alarm
LO	Low temperature alarm
HI	High temperature alarm

The letter **L** at the end of the line indicates that the alarm is latched. A latched alarm is asserted when the alarm condition is set. It stays asserted until it is manually cleared by the user.

① **Note:** To clear a latched alarm, first press the **Alarm** key to view the alarms and then press the **Home** key to clear the latch and return to the Home display.

Input Channel Configuration Menu

These menus contain all of the user-configurable parameters for a selected input channel. The menu will adapt based on the type of sensor selected. This menu can be accessed by pressing the '1' key from the home display.

The left side of the display shows status and configuration information for the selected sensor while the right side shows temperature alarms and channel statistics.

ChA	Channel A	--	High Alarm: 100.00	Ω
19406.5 Ω			Low Alarm: 10.000	Ω
			Deadband: 0.250	Ω
Sensor: 32 RO-600C			Latch Alarm	Audible Alarm
Bridge Range: Auto			Offset: 0.000000 Ω	
Bias Range: 10mV			Clear Offset	
Bias Level: 100 %			Capture Reading	
Pd: 4.99e-09 W			Max: 19419.2Ω	M= -56.2Ω /Min
Phase angle: -2.812160°			Min: 19406.7Ω	b= 19418Ω
			S2: 13.174Ω	0 d, 00:00:14
Reset Statistics				
		1: 0%	2: 0%	21:45 GMT
		3: 0%	4: 0%	

Setting a Temperature Alarm

The Alarm lines are used to setup alarm conditions. The Model 54 allows alarm conditions to be assigned independently to any of the input channels.

High temperature and low temperature alarms may be entered and enabled. Note that a user selected dead-band is applied to the assertion of high and low temperature alarms.

Alarm conditions are indicated on the front panel by the various display fields. They are also reported via the remote interfaces.

When the audible alarm is enabled, an audio alarm will sound when an alarm condition is asserted.

The Model 54 supports latched alarms. These are alarms that remain asserted even after the condition that caused the alarm has been cleared. To clear a latched alarm, first press **Alarm** to view the Alarm Status Display and then press the **Home** key to clear.

Input Channel Statistics

The Model 54 continuously tracks temperature history on each input channel. The Input Statistics shown in this menu provides a summary of that history.

The channel history is reset whenever the channel is initialized and can also be reset by pressing the **Enter** key while the cursor is on any of the statistics lines.

The **Accum** line shows the length of time that the channel history has been accumulating. It is in units of Minutes.

The **Minimum** and **Maximum** temperature lines show the temperatures from during the accumulation time. Values are shown in the currently selected display units.

S2 is the temperature variance, which is computed as standard deviation squared.

The **M** and **b** fields display the slope and the offset of the LMS best-fit straight line to the temperature history data.

Setting Delta-R measurements

The Delta-R measurement mode is set by first waiting for a stable measurement then tapping the Capture Reading field. In this mode, measurements will show the delta symbol. To exit the Delta-R mode, tap the Clear Offset field.

Loop Configuration Menu

These menus contain all of the user-configurable parameters for the selected control loop.

Loop 1	ChA	Sample Holder	-Htr Off-
222.282k		Source: Local	
SetPt:	300.000K	K	Max SetPt: 1000.00K
P:	5.0000		Ramp Pt:
I:	60.000	/sec	Ramp: 60.000 K/Min
D:	7.5000	sec	Range: 75W
Pman:	5.0000	%	Power Limit: 100 %
Type:	PID		
PID Table:	1 - Sample Holder - L1		
		AutoTune	
		1: 0% 2: 0% 3: 0% 4: 0%	21:35 GMT

Table 12: Control Loop Setup Menu.

Setpoint

Numeric Entry

In the first line of this menu the user can change the setpoint, while still viewing the temperature of the controlling source channel.

Note: Entry of a setpoint can be overridden by the Maximum Setpoint field described below. The instrument will not accept an entry that exceeds the maximum.

Control loop setpoints may also be entered by using the **Set Pt** key.

Control Loop PID values

Numeric Entry

The Pgain, Igain and Dgain lines correspond to the Proportional, Integral and Derivative coefficients of the control loop. Pman is the output power that will be applied to the load if the manual control mode is selected.

Values for the Proportional, or P, gain term range from zero to 1000. This is a unit-less gain term that is applied to the control loop. Gain is scaled to reflect the actual heater range and the load resistance.

Integrator gain values range from zero to 10,000. The units of this term are Seconds. A value of zero turns the integration function off.

Derivative gain values have units of inverse Seconds and may have values from zero to 1000. A value of zero turns the Derivative control function off.

The Pman field is only used when the heater output is in manual control mode. The value is represented in percent of full-scale output power (Watts) and may have values from zero to 100%.

① Note: The Model 54 expresses heater output values in terms of percent of full-scale output power. The actual power, in Watts, applied to the load is proportional to the square-root of output current.

Control Source Input Channel

Enumeration

The input field selects the control loop source input. Any input channel may be selected.

Control Loop Range

Enumeration, Default: Low

The Range field selects the full-scale output for the selected control loop.

Control Types

Enumeration, Default: Man

The Type field selects the actual control algorithm used for the selected loop.

Output Power Limit

Numeric entry, Default: 100%

The Power Limit field defines the maximum output power that the controller is allowed to output. It is a percent of the maximum possible output for each control loop. Maximum value is 100% and minimum is 1%.

The Power Limit is applied to all ranges. For example, The maximum output power from Loop #1 is 75W, so an output power limit of 50% would limit the maximum output to $75 * 50\% = 37.5W$. This would limit the 75W range to 50% of full-scale and the HI (50W) range to 75%. The MID and LOW ranges will still output 100%.

① Note: The maximum output power for Loop #1 is 75W and Loop #2 is 50W.

① Note: Output Power Limit is an important cryostat protection feature. The user is encouraged to apply it.

Maximum Setpoint

Numeric Entry, Default: 1000K

The Maximum Setpoint field is used to prevent the casual user from inadvertently entering a temperature that might damage the cryostat.

Maximum value is 10,000K and minimum is 0K.

Setpoint values use the temperature units selected for the controlling input channel. See the section on [Temperature Displays](#).

① Note: The Maximum Setpoint selection is an important cryostat protection feature. The user is encouraged to apply it.

PID Table Index

Numeric entry, Default: 0

The PID Table index line is used to identify the number of the user supplied PID Table that will be used when the Table control mode is selected. The Model 54 will store up to six PID Tables. They are numbered zero through five.

Ramping Rate

Numeric entry, Default: 0.10/min

When performing a temperature ramp, the Ramp field defines the ramp rate. Units are display units per minute. In the default case, this means Kelvin per minute.

For more information on temperature ramps, refer to the section on [Temperature Ramping](#).

The System Configuration Menu

This menu is accessed by pressing the **System** key from the Home Status Display or by navigating to the System page of the web browser. It is used to set many of the instrument's parameters including display resolution, I/O port settings etc.

System Configuration Menu		
1	Display TC	Sets the display time constant in seconds. Selections range from 2S to 64S
2	Display Res	Sets the resolution. Selections are: 1, 2, 3 or Full.
3	USB Baud	Sets the USB serial port baud rate
4	GPIB Adrs 12	Sets GPIB I/O address. (Note: GPIB is an external option). Displays – if option not connected.
5	OTD Enable: Off	Sets the Over Temperature Disconnect enable. Selections are On or Off.
6	OTD Source: ChA	Sets the Over Temperature Disconnect source input channel. Selections are ChA or ChB.
7	OTD SetPt	Sets the Over Temperature Disconnect setpoint temperature.
8	Pwr Up In Ctl:	Power Up Mode. Off for normal operation. On to engage the control loops 10 seconds after power has been turned on.
9	Excitation Freq: 17Hz	Resistance bridge AC excitation frequency. Default is 17Hz.
10	DataLog Config	Configure Data Logging.
11	Store / Restore configuration	Save or restore an instrument configuration.

Table 13: System Configuration Menu



Caution: When enabled, the Power-Up in Control mode feature causes the controller to engage the control loops automatically whenever AC power is applied. Please exercise caution in the use of this feature.

The Over Temperature Disconnect (OTD) feature monitors a selected input channel for an over temperature condition. If this exists, all heaters outputs are disconnected and the Loop Status indicator is set to "OTDisconn". A mechanical relay is used for the disconnect so that the load is protected, even if the condition was caused by a fault in the controller's output circuitry.

The OTD must first be configured to monitor one of the input channels. Note that the OTD feature is completely independent of control loop function and may monitor any input.

Next, an OTD Setpoint must be specified. This is the temperature at which an over temperature shut down is asserted. Temperature units are taken from the source input channel.

Finally, the OTD function must be enabled.



Important: The Over Temperature Disconnect is an important cryostat protection feature. The user is encouraged to apply it.

The Data Logging Configuration is used to start, stop and configure the data logging process. This menu is accessed from the System Menu on the front panel or the Logs page of the web browser.

The only user configurable parameter is the Interval in units of seconds. Once this is set, data logging while enabled.

The minimum data logging interval is 1.0S.

The data logging function records all input temperatures along with a real-time clock stamp.

When enabled, internal logging continuously records to an internal memory.

Additionally, if a memory stick is inserted into either of the USB-A ports on the rear panel, the controller will create a .csv file and log to it in parallel with internal logging.

Internal logged data can be read by going to the Logs page and clicking on Download Log. The full log will appear on the computer screen and can be saved to a file by using the browser's Save As function.

Network Configuration Menu

Navigate to this menu by pressing the **Network(8)** key from the Home screen.

Network Configuration		Firewall Configuration	
Device Name:	M54-1234	☐ SCPI TCP	
	00:50:c2:6f:44:50	☐ SCPI UDP	
SCPI TCP Port:	5000	☐ Modbus	
☐ DHCP		☐ HTTP	
IP Address:	192.168.1.4	☐ HTTPS	
Subnet Mask:	255.255.255.0	☐ Discovery	
Gateway:	192.168.1.1	☐ NTP	
Reset Password:	No	☐ Remote Inputs	
Remote Sources		☐ VXI-11	
		☐ EPICS CA	
		1: 0% 2: 0% 3: 0% 4: 0%	19:39 GMT

Table 14: Network Configuration Menu

Local Area Network Configuration

Setup of the Local Area Network requires a device name, an IP address, a subnet mask and a gateway.

The device name is any 15 character string. It is reported on the display, but can only be changed via a remote command. The name is used by LAN systems that have name servers. In this case, the instrument can be addressed by it's name rather than it's IP address.

The IP address uniquely identifies the instrument on the LAN. The factory default is 192.168.1.4.

The subnet mask is used to divide the LAN addresses into segments. The default subnet mask is 255.255.255.0.

A gateway IP address need only be entered if the instrument communicates with the Internet via a gateway. The factory default gateway is 192.168.0.1, which is used in systems with Internet Connection Sharing.

Firewall Settings

The right side of the Network Configuration Menu shows the internal firewall settings. Generally, any protocols that are not being used should be disabled.

Basic Setup and Operation

Configuring an Input

Before connecting a new sensor to the controller, the instrument must be configured to support it. Many temperature sensors are pre-installed in the Model 54. In this case, configuration is as easy as selecting it. Otherwise, for custom or calibrated sensors, a configuration and calibration curve must be installed first. Installation can be done in the following ways:

- Downloading a configuration and calibration curve via the web server. For information, refer to the section [“Downloading a Sensor Calibration Curve”](#).
- Generating a curve using the CalGen[®] function. Refer to the section titled [“Using CalGen[®] to Generate a Sensor Curve”](#).

Note: A complete list of sensors installed at the factory is shown in [Appendix A](#).

Selecting a Sensor using a Web Browser

Open the instrument's web page and navigate to the **Inputs** page. A sample is shown below.

The screenshot shows a web browser window with the address bar displaying '192.168.14/input.html'. The page title is 'Input Channels - Cryo-con Model 54'. The main navigation bar includes 'Status', 'Inputs', 'Outputs', 'Relays', 'Network', 'System', 'Sensors', 'Logs', and 'Scripting'. The 'Inputs' tab is selected, and the page title is 'Cryo-con Model 54 Cryogenic Temperature Controller'. On the left, there is a sidebar with 'Input Ch A' selected. The main content area shows the configuration for 'Channel A'. The current reading is '98.836 Ω'. The configuration fields are as follows:

Field	Value	Field	Value
Name	Channel A	Units	Ω
High Alarm	100.00	Enable	No
Low Alarm	10.000	Enable	No
Latch Alarm	No		
Audible	No		
Deadband	0.250		
Sensor	Pt100 385		
Bias Voltage	% of N/A		
Bridge	Auto		

At the bottom of the configuration area, there are three buttons: 'Update', 'Cancel', and 'CalGen™'.

Figure 3: Configuring an Input

Configure the sensor by filling out the form:

- The sensor name is a user convenience. Choose a name that helps to associate the input channel with it's function.
- Select the displayed units of temperature from the drop-down box.
- Select the basic sensor from the drop down box.
- Optionally set an alarm.
- Click Update to transmit this configuration to the instrument.

Selecting a Sensor from the Front Panel.

To configure an input from the front panel, proceed as follows:

1. Press the **Input(1)** key from the Home screen. An input channel configuration menu will be shown.
2. Select the desired input channel by using the drop-down box in the upper right corner. When this field is selected, you can press the 1 key for input A, 2 for B etc.
3. Configure the input by using the drop-down and data entry fields similar to the web page menu.

Note: Select **None** to disable the input channel.

The above display is typical of an input configuration menu. Some fields will adapt to the sensor selected. On this screen, the input channel measurement is shown in real-time.

Selecting the Sensor: field will take the display to a grid of all of the available sensor types. Select the desired sensor by tapping the display or navigate to it by using the navigation keys and pressing Enter. The backspace key will exit the selection without updating.

ChA	Channel A	--	High Alarm:	100.00	Ω
19406.5 Ω			Low Alarm:	10.000	Ω
			Deadband:	0.250	Ω
Sensor:	32 RO-600C		Latch Alarm	Audible Alarm	
Bridge Range:	Auto		Offset:	0.000000	Ω
Bias Range:	10mV		Clear Offset	Capture Reading	
Bias Level:	100	%	Max:	19419.2Ω	M= -56.2Ω /Min
Pd:	4.99e-09	W	Min:	19406.7Ω	b= 19418Ω
Phase angle:	-2.812160°		S2:	13.174Ω	0 d, 00:00:14
			Reset Statistics		
			1: 0%	2: 0%	21:45 GMT
			3: 0%	4: 0%	

Using NTC Sensors (Type: ACR)

The Model 54 supports all types of Negative-Temperature-Coefficient (NTC) resistor sensors that are often used as low temperature thermometers, especially at ultra-low range. Examples include Ruthenium-oxide (RuOx), Carbon-Glass, Cernox™, Carbon-Ceramic, Germanium and several others.

Error Sources in NTC Sensor Measurements

When used with NTC thermometers, the electronic measurement accuracy of the Model 54 steadily degrades with lower temperature due to the low sensor excitation levels that these sensors require. This trade-off in measurement accuracy vs. sensor excitation current is taken for two reasons:

1. The sensitivity of NTC resistor sensors is highest in the low temperature end of their range. Therefore, reduced measurement accuracy does not usually reduce measurement accuracy in units of temperature. Here, sensor self-heating is usually the dominant source of measurement error.
2. NTC sensors are the least sensitive in the high temperature end of their range. Here, the dominant source of error is the measurement accuracy of the room-temperature electronics. Therefore, the Model 54 constant-voltage algorithm applies a higher sensor excitation level to maximize its electronic accuracy.

Selecting a Voltage Bias for NTC resistance sensors

① Note: If you are using NTC sensors above about 1.5K, set Vbias to 10mV and Vlevel to 100%. Below that temperature, you will need the information found in this section.

The ACR constant-voltage sensor type applies a constant-amplitude AC voltage excitation across the sensor. The RMS amplitude of this excitation is determined by the product of the Voltage Bias (Vbias) and Voltage Level (Vlevel) settings. Voltage Bias settings are 10mV, 1.0mV and 100uV and Voltage Level is an adjustable attenuator ranging from 100% to 10%. Using the Vbias and Vlevel setting together, the Model 54 can apply sensor excitation voltages with RMS amplitudes from 10.0mV to 20.0μV. For example, you can set a sensor excitation voltage of 63μV by setting Vbias to 100μV and a Vlevel to 63%.

The Model 54 Voltage Bias (Vbias) settings are calibrated for maximum accuracy and the Vlevel attenuator adjusts the excitation level within each setting. Lower Vlevel settings result in lower measurement accuracy and lower sensor self-heating. Therefore, the user can accurately adjust the excitation level to minimize the total error.

The user must find a voltage excitation level that maximizes the total accuracy over the desired temperature range. Generally, sensors operating above about 2K can use the 10mV setting. Below that, selection is more difficult because it depends on the sensor's resistance and cryostat's thermal design.

To select a voltage bias in the low temperature region:

1. Stabilize the sensor at the lowest temperature of interest and set a sensor voltage excitation voltage recommended in the sensor's data sheet. Otherwise, use a setting of 10mV for $T > 1.2K$ and 1.0mV for $T > 300mV$.
2. Using the Vlevel and Vbias controls, adjust the sensor excitation voltage until the minimum temperature reading is found.

The actual power being dissipated in the sensor may be viewed in real-time by going to the Input Configuration Menu.

Since the Model 54 does an excellent job of low-level signal recovery, a voltage excitation can usually be found that will covers a wide temperature range with an acceptable measurement error.

Selecting a Bridge Range

Bridge Range controls the excitation current ranges that the bridge is allowed to use. It is generally set to Auto so that the optimum excitation is automatically selected.

Some systems are sensitive to the brief transients that auto-ranging can generate. In this case, the bridge range can be fixed at 1.00, 10.0, 100.0, 1.00K or 10.0K Ohms. The setting is near the minimum value of resistance that can be measured by that range.

Remote Commands commonly used with ACR sensors

The following remote commands that are commonly used with ACR type sensors:

INPut:SENPr? reports the primitive reading on a selected input channel. For diode sensors, the reading is in Volts while resistor sensors are reported in Ohms. The reading is not filtered by the display time-constant filter. Useful whenever measurements of both temperature and sensor resistance are required.

INPut:VBias Sets or queries the sensor voltage excitation setting.

INPut:VLEVel Sets or queries the Vlevel setting that applies to the attenuator on Vbias. Levels are a percent of full scale. So, to obtain a voltage excitation level of 10uV, set a Vbias of 100uV and a Vlevel of 10.

INPut:BRANge Sets or queries the resistance bridge range. Default is Auto.

INPut:CBR? Queries the current bridge range setting. Useful to find the actual range setting when Bridge Range is set to Auto.

INPut:POWER? Queries the instantaneous power being dissipated in the sensor.

INPut:BRUNlock? Queries the Bridge Lock Indicator indicator.

Downloading a Sensor Calibration Curve

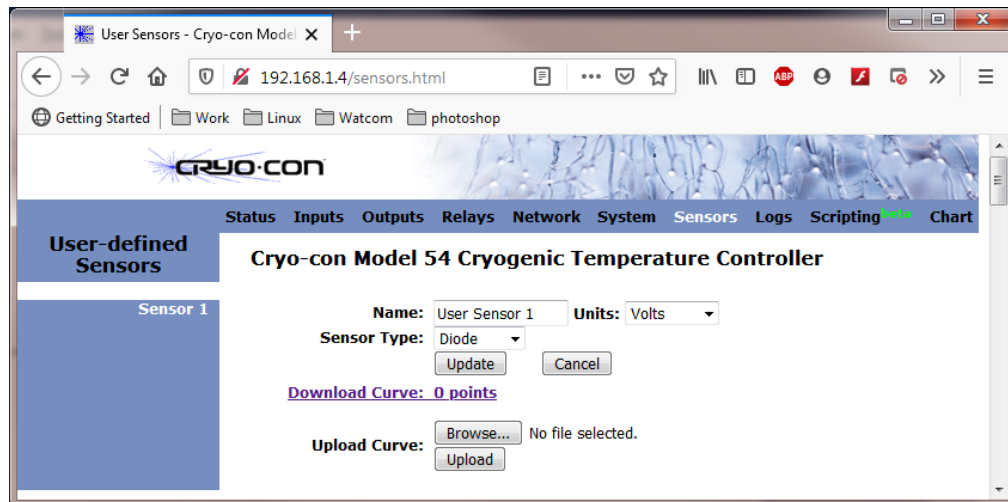
The Model 54 accommodates up to eight user-defined sensor calibration curves that can be used for custom or calibrated sensors. Curves can be uploaded using the Sensors page of the web browser.

Cryo-con sensor calibration curves have a file extension of .crv. They may be opened and edited with any text editor. The format of the file is detailed in [Appendix A](#).

The Model 54 supports the following file types:

Sensor Curve File Types	
Cryo-con .crv	Directly supported.
Lakeshore .340	Supported. Reads curve data. Header information must be entered by using the header dialog box. The Cryo-con utility software will convert these files into .crv format automatically.
Lakeshore .DAT	Supported and recommended if available.

To download a curve, open the Model 54's embedded web site with any browser and go to the Sensors page as shown here:



Autotuning

The Autotune Process

In performing autotuning, the Model 54 applies a generated waveform to the heater output and analyzes the resulting changes in process temperature. This is used to develop a process model, then a PID solution.

It is important to note that a range of PID combinations exist, which provide accurate control for a given process. Furthermore, process modeling is a statistical method affected by noise and system non-linearity.

Consequently, multiple autotuning of the same process may yield different results. However, if the process model has not corrupted, any of the generated results will provide equally stable temperature control.

For further explanation, the different PID solutions generated by autotuning vary only in the resultant closed loop bandwidth. Low bandwidth solutions are slower to respond to changes in setpoint or load disturbances. High bandwidth solutions are responsive but can exhibit overshoot and damped oscillation.

The Model 54 attempts to generate minimum overshoot solutions since many cryogenic temperature control applications require this. If the process is noisy, bandwidth is minimized as much as possible. If the process is very quiet, a more aggressive solution is generated subject to the minimum overshoot requirement.

The autotune algorithm produces a heater output waveform in order to force the process model to converge. In general, a large amplitude waveform will provide the best possible signal-to-noise ratio, resulting in a faster and more accurate solution.

However, it is important in some systems for the user to constrain the amplitude and duration of the heater output waveform by using the DeltaP and Timeout parameters.

Small values for DeltaP force the use of small changes in heater power. This makes the process model more susceptible to corruption by noise.

Large values of DeltaP will allow the use of large heater power swings, but this may also drive the process into non-linear operation, which also corrupts the tuning result. Worse, it may allow the application of too much heater power, which causes an over temperature condition.

Experience indicates that most cryogenic systems autotune properly using a DeltaP of 5% whereas a noisy system requires 10% or more. A common example of a noisy cryogenic system is one where a Silicon diode sensor is used with a setpoint near room temperature.

System Noise and Tuning Modes

Three modes of autotuning may be selected. They are: P only, PI and PID.

Using P only autotuning gives the maximum value for P that will not cause oscillation. The process temperature stabilizes at some point near the setpoint.

Using PI or PID control results in stable control at the setpoint.

The Derivative, or D, term in PID is used to make the controller more responsive to changes in setpoint or thermal load. It does not affect the control accuracy when the system has stabilized. However derivative action, by its nature, amplifies noise. Therefore, PID autotuning and control should only be used with very quiet systems. PI control should be used with all others.

Sensor type has a significant impact on measurement noise.

The Model 54 uses a ratiometric technique to measure resistor sensors such as Thermistors, Platinum RTDs, Carbon Glass etc. This effectively cancels most of the measurement noise and allows effective use of PID control.

Voltage mode sensors, which include diodes and thermocouples, cannot benefit from ratiometric measurement, therefore, PI control is recommended.

It is a very common mistake to attempt PID control using a diode sensor above 70K. This is the least sensitive region of the sensor so measurement noise is very high. PI control is recommended.

Below about 20K, the sensitivity of the diode increases significantly and PID control may be used effectively.

Pre-Tuning and System Stability.

Before autotuning can be initiated by the controller, the system must be stable in terms of both temperature and heater output power. This requires the user to perform a basic pre-tuning operation before attempting the first autotune.

The goal of pre-tuning is to stabilize the process at a temperature near the desired setpoint so that the tuning algorithm can use this as a baseline to model the process.

Cryogenic systems will usually require different PID values at different setpoint temperatures. Therefore, the pre-tuning process should result in a temperature near the desired setpoint.

Pre-tuning does NOT require that the user establish stable control at the target setpoint. This is the job of the autotuning algorithm and is much more difficult than the stability required by pre-tuning.

One method of pre-tuning is to use PID control with a small initial value for P and zero for I and D. This will result in stability at a temperature of the setpoint minus some constant offset. Increasing the P value reduces the offset amount. When P is too large, the system oscillates.

Another pre-tuning technique is to Manual control mode with some fixed value of output power. When the system becomes stable at a temperature corresponding to the set heater power level, a system characterization process is performed using that temperature as an initial setpoint.

System Characterization.

System characterization is the process of using autotune to generate optimal PID coefficients for each setpoint over a wide range of possible setpoints.

The characterization process is performed once. Then, the setpoints and corresponding generated PID values are transferred to an internal PID table. Thereafter, the system is efficiently controlled using the Table control mode.

Autotune Setup and Execution

The Autotune menu for either control loop is accessed by pressing the **Auto Tune** key from the Home Operate Screen.

Upon entry, the autotune state variable is set to Idle and the P, I and D fields on the bottom of the display will be blank.

As described above, various setup conditions must be met before autotune can be performed:

1. The Model 54 must be in Control mode.
2. Both the output power and the process temperature must be stable. The user must stabilize the process before the autotune function can accurately model it. If the process is not stable, erroneous values of P, I and D will be generated.
3. The input control channel units must be in temperature, not sensor units of Volts or Ohms. This is because PID control is a linear process and sensor output is generally non-linear. Note that the Model 54 can be manually tuned using sensor units but autotuning cannot be performed.

Autotune Menu	
+Autotune: Loop 2	Sets the loop number for autotuning. Each control loop must be tuned separately.
#DeltaP: 20%	Sets the maximum power delta allowed during the tuning process. Value is a percent of full-scale output power.
+Mode: PI-	Sets autotuning mode. Choices are P, PI or PID.
#Timeout: 180S	Sets the autotune timeout in seconds. If the process model has not converged within this time, tuning is aborted.
308.112K	Real-time display of the temperature on the input channel being tuned.
•GO	Pressing Enter will initiate the autotune sequence.
Idle	Autotune status. Display only
P=	Proportional gain term generated by autotune. This field will be blank until a successful autotune is completed.
I=	Integral gain term generated by autotune. This field will be blank until a successful autotune is completed.
D=	Derivative gain term generated by autotune. This field will be blank until a successful autotune is completed.
•Save & Exit	Pressing Enter cause the controller to transfer the generated PID coefficients to the selected loop, initiate control with the new parameters and exit to the Home Operate Display.

Table 15: Autotune Menu

The Delta P field is in percent and is the maximum change in output power that the controller is allowed to apply during the modeling process. A value of 100% allows use of full-scale power increments. A value of 20% uses a maximum power increment of $\pm 20\%$ of the current heater output.

The Mode field tells autotune to generate coefficients for P only, PI only, or PID. Choices are: P--, PI- and PID.

The Timeout field is in units of Seconds and indicates the maximum period of time that the process model will run before aborting. This value should be set to at least two or three times the estimated maximum time constant of the process.

ⓘ Note: Depending on the setup configuration, the autotune algorithm may apply full-scale heater power to the process for an extended time. Therefore, care should be taken to ensure that autotune does not overheat user equipment. If overheating is a concern, the Over Temperature Disconnect Monitor should be configured to disconnect the heater and abort the autotune process when an input temperature exceeds the specified maximum.

The autotune sequence is initiated by selecting the Go field. If the initialization of process modeling is successful, the status display line will change from idle to Running. If initialization is not successful, one of the above listed conditions has not been met.

State	
Idle	Idle.
Stabilize	Waiting for input temperature and output power to stabilize.
Running	Actively autotuning.
Complete	Successful completion.
Failed	Failed due to processing error. Usually, this is because the process model did not converge. Try a smaller DeltaP setting.
Abort	Aborted by the user.

Table 16: Autotune States

① Note: When autotuning is initiated, the algorithm will stay in the 'Stabilize' state until the output power and the input temperature are stable. Time in this state is not part of the selected timeout. If the system is not stable, the autotuning process will stay in the Stabilize state indefinitely. To abort, press the **Home** key.

When the tuning process is successfully completed, a status of Complete will be indicated and the values of P, I and D will be updated with the generated values. To accept these values and save them as the loop PID coefficients, select the Save&Exit field. To reject the values and exit, press the **ESC(▼)** key.

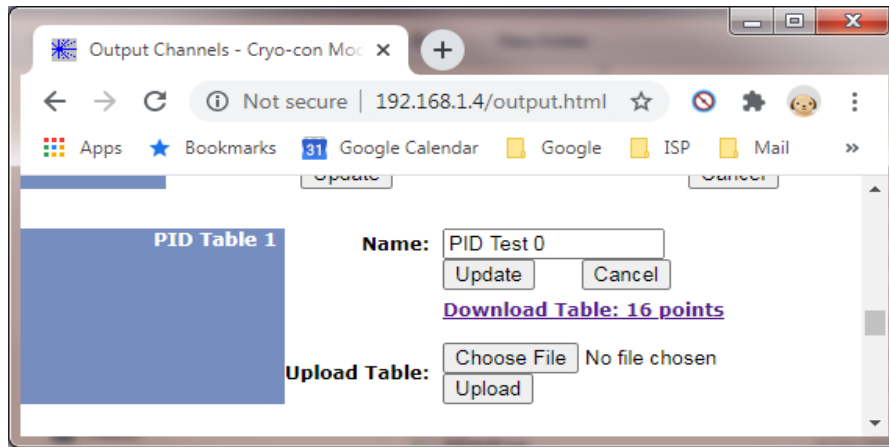
Autotune may always be aborted by pressing the **ESC(▼)** key.

An unsuccessful autotune is indicated by one of the following status lines:

1. Failed. This indicates that the process model did not converge or that PID values could not be generated from the result.
2. Aborted. Autotune was aborted by user intervention such as pressing the Stop key.

Downloading a PID table

PID tables are uploaded or downloaded by using the embedded web server. Open a browser and access the Model 54 web site, then select the Outputs page. Scroll down to view the PID Table fields. An example is shown here:



To download a PID table, first select Choose File and select the desired table file. Then click on Upload. This will read and install the selected table. Optionally, you can enter a new name for the table and click Update.

To use the table with a control loop, go to the Outputs page and scroll down to the desired control loop. Then, select the desired PID table from the PID Table drop-down box.

The PID table may also be selected on the front panel by going to the Control Loop Configuration menu.

Note: The file format for a PID table is given in the [PID file format](#) section.

Using CalGen to Generate a Sensor Curve

The CalGen[®] feature is used to generate new calibration curves for Silicon diode or resistor sensors. This provides a method for obtaining higher accuracy temperature measurements without expensive sensor calibrations.

Curves can be generated from any user selected sensor calibration curve in the instrument, including curves that the user has installed. The result is written to a specified internal user curve location.

For diode sensors the user may specify one, two or three data points. CalGen[®] generates the new curve based on fitting the input curve to the user specified points. Platinum, resistor or thermocouple calibration curves require one or two data points. The generated curve is a best fit of the input curve to the specified input points.

Since CalGen[®] fits a sensor calibration curve to measured data, any errors in the measurement electronics are also effectively canceled.

To initiate curve generation, open your web browser and go to the CalGen[®] page.

CalGen With Diode Sensors

Options for generating diode calibration curves are:

1. Two points: 300K and 77K. Here, two user-specified points are taken to fit the diode curve region above 30K. The entire curve is offset to match the 77K point, then, the >30K region is fit to the two points.
2. Three points: 300K, 77K and 4.2K. Two points above 30K are fit as in the selection above. Then, a third point is used to fit a single point in the high-sensitivity region below 20K.
3. One point near 4.2K. This is a two-point fit where the 20K point is taken from the existing calibration curve. The portion of the curve above 20K is unaffected.

CalGen With Platinum and Resistor Sensors

The calibration curve generation procedure for Platinum or Resistor sensors is the same as for the diode sensors described above. However, these curves are generated using two user specified points.

Data Logging

The Model 54 has an internal data logging capability that uses non-volatile memory. Logging of input channel temperature data is performed to a 2GB circular buffer. Each sample contains all eight temperature readings plus a time stamp from a real time clock. Logs may also be recorded on a memory stick inserted into the USB interface on the rear panel.

The minimum data logging interval is 1.0S.

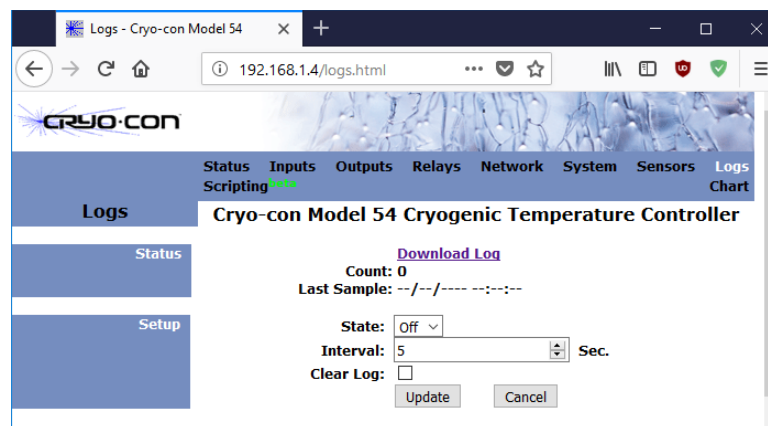
Data Logging Setup

The best way to setup data logging is by using the embedded web server. However, it can also be performed from the front panel.

The first step is to ensure that the instrument's real-time clock is set to the current time. This can be done by opening the embedded web page. The current time is shown on the bottom of the [Status Page](#) and the clock may be set by going to the [System page](#). If precision time-stamps are required, please use the NTP network interface.

Data logging can be configured and enabled and downloaded from the embedded web server's Logs page. The Logging Enable field turns logging on and off and the Interval field sets the logging sample rate. The Current Count field shows how many samples have been accumulated.

Once enabled, data logging will continue until stopped. When the input buffer is full, new samples will over-write the oldest samples.



Logging to a memory stick

The data logging function will record to a memory stick by simply plugging it into one of the USB ports on the rear panel.

To record data logs to a memory stick, stop the logging process, insert the memory stick and then start the logging process.

To stop, first stop the logging process then unplug the memory stick.

ⓘ Note: To safely remove a USB memory stick, first stop the data logging process.

Reading the Data Log Buffer

Reading, or uploading, the Model 54 data logging buffer is done by clicking on the Download Log field. This will initiate a file dialog box where you can set the destination file.

The file format is .csv.

Using Relays

The relay configuration menu is used to configure the two relay outputs of the Model 54 from the front panel. To access this menu, press the Relay(3) key from the home screen. Configuration can also be done from the embedded web server.

The relay source may be selected as any of the available input channels and the Mode setting controls relay operation.

The dead-band field sets the amount of hysteresis applied to the input temperature measurement before a relay is activated. Units for this field are in the same units as the controlling input channel.

Relay Auto Mode

Auto mode is used to implement simple high and low operation. Setting a relay to assert on a high temperature condition requires setting Auto mode, setting a high setpoint then enabling the high setpoint. Similarly for a low setpoint, the low setpoint must be enabled and set.

Example: To assert a relay when a temperature measurement exceeds 330K or drops below 250K, set the **Mode** field to Auto, the **High** field to 330, the **High Enable** to Yes, the **Low** field to 250 and the **Low Enable** to Yes.

Assuming a deadband of 0.25K, the relay will assert high at 330.25K and clear at 329.75K. It will also assert low at 249.75K and clear again at 250.25K.

Relay Modes	
Auto	Relay is controlled by enabled high and low setpoints.
Within	Inverse operation of Auto mode. Used for fail-safe configurations.
ON	Relay is in manual mode and is asserted.
OFF	Relay is in manual mode and is clear.
Control	Relay is asserted whenever the controller is in Control mode.

Table 17: Digital Output Modes

Relay Status Indicators	
--- or OFF	Relay is not asserted
HI	Asserted by a high temperature condition.
LO	Asserted by a low temperature condition.
ON	Asserted.

Table 18: Relay Status Indicators

Relay Within Mode

The Within mode is the logical complement of Auto mode. This will assert a relay when the input temperature is within a window.

The primary use of Within mode is to implement a fail-safe function. Here, the relay will only be asserted when an input temperature reading is both valid and within the high and low setpoints. Presumably, the process being monitored would only function when the relay is asserted.

To set a fail-safe function, the user must a) Set the Mode field to Within, b) Set both the high enable and low enable to Yes and c) Enter a high and low setpoint.

Example: To set a fail-safe function that asserts a relay when the input temperature is valid and within the range of 250K to 310K, do the following:

- Set the relay **Mode** to Within.
- Set both the **high** and **low enables** to Yes.
- Set the **High Setpoint** to 310K and the **Low Setpoint** to 250K.

Relay Control Mode

The relay Control mode asserts a relay when the controller is actively controlling temperature. It's primary use is with a booster power supply connected to control loops #3 and #4. Here, the relay can be used to turn on AC power to the booster supply only when it is needed. The desirable result is that the booster supply will be turned off when it is not being used so there will be no leakage power or noise driven into the user's system.

Relay ON and OFF Modes

The ON and OFF modes manually assert or clear a relay. They are primarily used during remote control. For example, the remote command that turns relay #1 ON is:

RELAY 1 : MODE ON

Temperature Ramping

Operation

The Model 54 performs a temperature ramp function using a specified ramp rate and target setpoint. Once placed in a ramping control mode, a ramp is initiated by changing the setpoint. The unit then progresses to the new setpoint at the selected ramp rate. Upon reaching the new setpoint, ramp mode is terminated and standard PID type regulation will be performed.

Ramping may be independently performed on control loop.

The procedure for temperature ramping is as follows:

1. Set the Ramp Rate in the Heater Configuration Menu. This parameter specifies the ramp rate in Units Per Minute, where Units are the measurement units of the input channel controlling the heater. For example, if the input channel units are Kelvin, the ramp rate is in K/min.
2. Select the ramping Control Mode, RampP.
3. Press CONTROL. Now, the controller will begin temperature regulation at the current setpoint.
4. Enter a new setpoint. The controller will enter ramping mode, and ramp to the target setpoint at the specified rate.
5. When the new setpoint is reached, ramping mode terminates and temperature regulation will begin at the new setpoint.
6. Entry of a different setpoint will initiate another ramp.

As a variation on the above procedure:

1. The controller may be regulating temperature in any available control mode. This mode can be changed to a ramping mode without exiting the control loop. This will not result in a 'glitch' in heater output power.
2. Once a ramp mode is selected, ramping is performed, as above, by changing the setpoint.

The current status of the ramp function may be seen on the Operate Screen. When a ramp is active, the word RMP will appear in the control loop status displays. It may also be queried via any of the remote ports using the LOOP 1:RAMP? Command.

Ramping Algorithm

The ramp algorithm uses a basic PID type control loop and continuously varies the setpoint until the specified temperature is reached. This means that the PID control loop will continuously track the moving setpoint. The result is that there will be small time lag between the target ramp and the actual temperature.

Although not normally a problem, the ramp time lag may be minimized by using aggressive PID values. This is accomplished by increasing P, decreasing I and setting D to zero.

Ramping Parameters and Setup

The Ramp Rate is set on the Control Loop Setup menu. Note that the ramp rate on Loop 1 is independent of the rate on Loop 2.

Now, you can begin ramping by changing the setpoint to the *end* of the ramp. The display will indicate that a ramp is in-progress. In this example, the setpoint was changed to 190 and the controller is ramping from 180.000. Notice that the loop status area now indicates a ramp is in progress. The Ramp Pt: field shows where the ramp should be and is continuously updated until the new setpoint is attained. The input temperature should track the Ram Pt: field, indicating that the ramp is progressing as it should.

Ramping will continue until the setpoint is attained. Then, the loop status will return to normal PID control and the controller will maintain the setpoint.

From here, each time you change the setpoint, the controller will ramp to the new value and control temperature there.

Summary

To perform a temperature ramp, proceed as follows:

1. Set the control loop P, I and D parameters to allow stable control at both ends of the desired ramp. This is usually done by using 'slow' PID values (Low values for P, high for I and zero for D).
2. Set the Ramp Rate in the Heater Configuration Menu. Set the setpoint to the starting value for the ramp.
3. Press CONTROL. Now, the controller will begin temperature regulation at the current setpoint.
4. Enter a new setpoint. The controller will enter ramping mode, and ramp to the target setpoint at the specified rate. The word RMP will appear in the control loop menu.
5. When the new setpoint is reached, ramping mode terminates and temperature regulation begins at the new setpoint.

Using Temperature Alarms

The Model 54 provides programmable temperature alarms on each input channel. High and low temperature alarms may be entered and enabled.

Alarm conditions are indicated on the front panel by various display fields. They are also reported via the remote interfaces.

When the audible alarm is enabled, a buzzer will sound whenever an alarm is asserted.

Alarm Status Indicators	
---	No alarm.
HI	Asserted by a high temperature condition.
LO	Asserted by a low temperature condition.
	A latched alarm is indicated by appending the letter L to the status indicator.

Table 19: Alarm Status Indicators

Latched alarms are also supported. These must be manually cleared as they remain asserted even after the condition that caused them has been cleared.

Note: To clear a latched alarm, press any of the keys on the front panel.

Alarm Configuration

Alarm configuration can be done from the front panel, the embedded web server or by using remote commands. From the front panel, the Input Channel Setup Menu is used. This is accessed from the Home menu by pressing the **Enter** key and then selecting an input channel for the alarm.

Basic configuration is done by entering a setpoint and then enabling the desired alarm. The Deadband field sets the amount of hysteresis applied to the temperature measurement before an alarm is toggled.

As an example, if the deadband is set to 0.25K, a high temperature alarm will not assert until the input channel's temperature exceeds the setpoint by 0.25K and will not clear until the temperature drops back to 0.25K below the setpoint.

From this menu, latched and audio alarms can also be set.

Setting an Ambient Temperature Alarm

The sensor type 'Internal' reads an internal temperature sensor located near the instrument's primary voltage reference. This measurement should read slightly above ambient temperature and is useful to track variations in ambient temperature for correlation with external events. It can also be used to set alarms for when the ambient temperature is outside the range where your measurements are at specified accuracy.

To configure an ambient temperature alarm, set the sensor type to Internal and then proceed as with any other alarm.

Displaying Strip-charts

Strip-charts for all enabled input channels can be viewed by going to the Chart page on the embedded web page. An example is shown here:

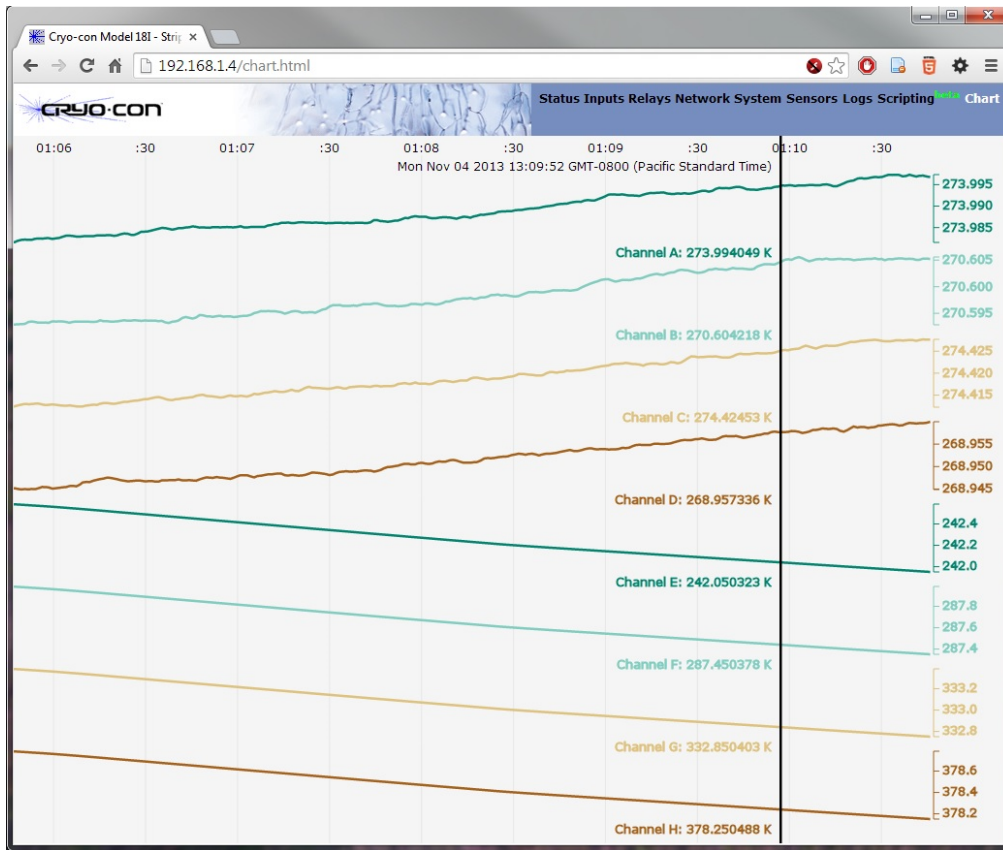


Figure 4: Real-time strip chart display

A cursor is provided that will display exact measurements at a selected time.

① **Note:** The strip-chart function uses features of the HTML5 mark-up language that are only supported in newer web browsers. In older browsers, this page will be blank.

Saving and Restoring Instrument Configurations

Complete instrument configuration information can be saved and restored by using a web browser.

To save a complete instrument configuration to your computer, open the web browser and navigate to the System page. Then, in the Instrument Configuration area, click on "Download Current Configuration". You will be prompted to save the file.

Note: the configuration file is not human readable.
--

To restore a saved configuration, go to the Upload New Config: field and click the Browse button. You will be prompted for a file. Once the file is selected, click on the Upload button to restore the configuration.

Saving or restoring the instrument configuration does not affect user installed sensor curves. These should be separately uploaded or downloaded by using the Sensors page.

Using Modbus

Modbus is an industrial protocol that connects the Model 54 to supported devices including Programmable Logic Controllers (PLCs). It is supported by the Model 54 on the TCP interface.

The Model 54 implements an IEC-1131 Modbus slave (server) with commands in Conformance Class 1.

Information about Open Modbus, including serial and TCP specifications is available at <http://www.modbus.org/>.

Although intended for communications with industrial automation controllers, the Model 54 implementation can also connect with LabView™. Information is available at: <http://www.ni.com/white-paper/7675/en/>

Configuration

Modbus TCP is supported connecting to TCP port 502. There are no other configuration options. The SCPI ASCII command language is still available by connecting on the user-defined TCP port (default: 5000).

ⓘ Note: Modbus is supported on TCP by using port 502. This cannot be changed. Do NOT set the TCP communications port (Default: 5000) in the instrument to 502 because that will result in a conflict between the two protocols.

ⓘ Note: Before using Modbus, ensure that the 54's embedded firewall is set to enable it. This is the default.

IEC-1131 data types

All IEC-1131 data types are represented in little-endian form. Examples follow:

Type	Size	Format
BYTE	8-bit	Bits 7 - 0 of register = Bits 7 - 0 of BYTE
DINT, UDINT	32-bit	Bits 15 - 0 of first register = bits 15 - 0. Bits 15 - 0 of second register = bits 31 - 16
INT, UINT	16-bit	Bits 15 - 0 of register = bits 15 - 0.
REAL	32-bit	Bits 15 - 0 of first register = bits 15 - 0 (bits 15 - 0 of significand). Bits 15 - 0 of second register = bits 31 - 16 (exponent + bits 23 - 16 of significand).

Table 20: Modbus IEC-1131 data types

Read Coils Command

Request:

Byte 0: FC = 01
 Byte 1-2: Reference number
 Byte 3-4: Bit count (1-2000)

Response

Byte 0: FC = 01
 Byte 1: Byte count of response ($B = (\text{bit count} + 7) / 8$)
 Byte 2-(B+1): Bit values (least significant bit is first coil!)

Exceptions

Byte 0: FC = 81 (hex)
 Byte 1: exception code = 01 or 02

Example: Read 1 coil at reference 0 resulting in value 1

0x01 0x00 0x00 0x00 0x01 => 0x01 0x01 0x01

ADDR	Input Channel	Type	Access
0x00	A	Low Alarm	Read Only
0x01	A	High Alarm	Read Only
0x02	B	Low Alarm	Read Only
0x03	B	High Alarm	Read Only
0x04	C	Low Alarm	Read Only
0x05	C	High Alarm	Read Only
0x06	D	Low Alarm	Read Only
0x07	D	High Alarm	Read Only
0x08	E	Low Alarm	Read Only
0x09	E	High Alarm	Read Only
0x0A	F	Low Alarm	Read Only
0x0B	F	High Alarm	Read Only
0x0C	G	Low Alarm	Read Only
0x0D	G	High Alarm	Read Only
0x0E	H	Low Alarm	Read Only
0x0F	H	High Alarm	Read Only

Table 21: Modbus Coil Addresses 0 through 15, Alarms

ADDR	Relay	Type	Status	Access
0x10	1	On	High	Read Only
0x11	1	On	Low	Read Only
0x12	1	On	Manual	Read Only
0x13	2	On	High	Read Only
0x14	2	On	Low	Read Only
0x15	2	On	Manual	Read Only

Table 22: Modbus Coil Addresses 16 through 21, Relays

Read Temperature Command

Temperature data is in Registers 0 through 15 as little-endian 32-bit floats.

Request:

Byte 0: FC = 0x04
 Byte 1-2: Reference number
 Byte 3-4: Word count (1-125)

Response:

Byte 0: FC = 0x04
 Byte 1: Byte count of response (B=2 x word count)
 Byte 2-(B+1): Register values

Exceptions:

Byte 0: FC = 84 (hex)
 Byte 1: exception code = 01 or 02

Examples:

Read 1 input register at reference 0 (30001 in Modicon 984) resulting in value 1234 hex:

0x04 0x00 0x00 0x00 0x01 => 0x04 0x02 0x12 0x34

Read all 16 input registers at reference 0:

0x04 0x00 0x00 0x00 0x10 => 0x04 0x20 . . .

Register	Input Channel	Data
0	A	Bits 15-0
1	A	Bits 31-16
2	B	Bits 15-0
3	B	Bits 31-16
4	C	Bits 15-0
5	C	Bits 31-16
6	D	Bits 15-0
7	D	Bits 31-16

Table 23: Modbus Input Register Mapping, Temperature Measurements

Exception Codes

All exceptions are signaled by adding 0x80 to the function code of the request, and following this byte by a single exception code byte.

Exception codes are as follows:

0x01 ILLEGAL FUNCTION

The function code received in the query is not an allowable action for the slave. This may be because the function code is only applicable to newer controllers, and was not implemented in the unit selected. It could also indicate that the slave is in the wrong state to process a request of this type, for example because it is unconfigured and is being asked to return register values.

0x02 ILLEGAL DATA ADDRESS

The data address received in the query is not an allowable address for the slave. More specifically, the combination of reference number and transfer length is invalid. For a controller with 100 registers, a request with offset 96 and length 4 would succeed, a request with offset 96 and length 5 will generate exception 02.

The User Scripting Language

The 54 supports user scripts using the powerful IPython language by running IPython Notebook in the embedded web server. Scripts, or user programs, can be edited, debugged and run in the browser window.

An introduction to IPython Notebook can be found at: <http://ipython.org/notebook.html>. Documentation is at: <http://ipython.org/ipython-doc/dev/notebook/>. To use it, open the Model 54's web page and click on Scripting in the navigation bar.

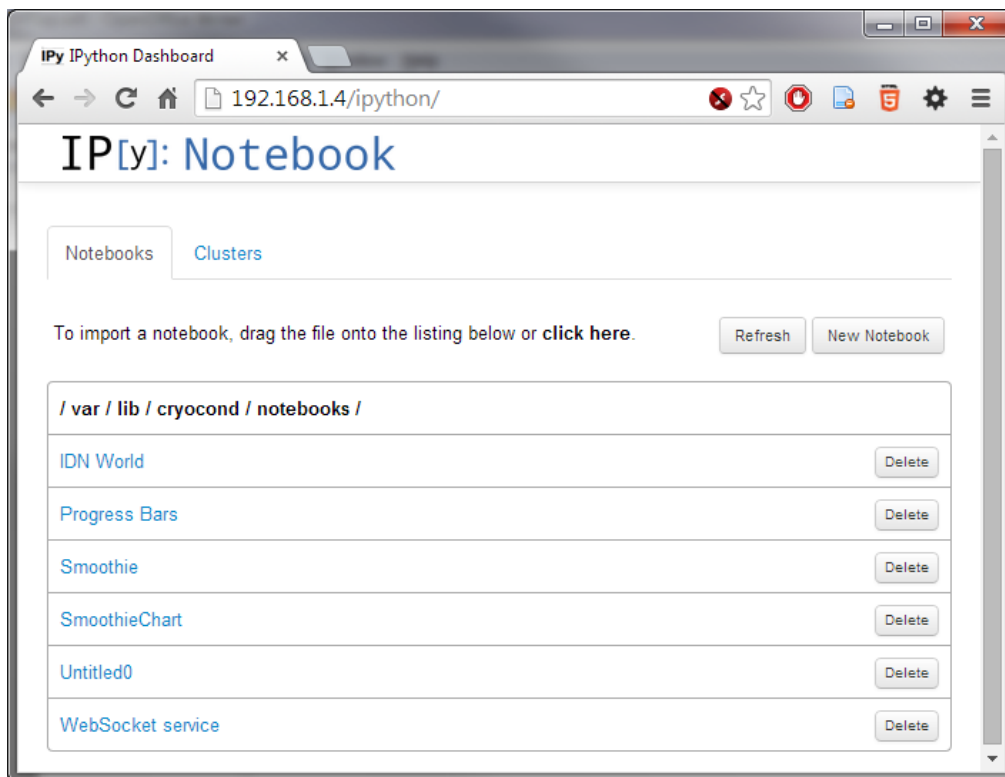


Figure 5: IPython Notebook with example scripts

The default notebook includes several example scripts.

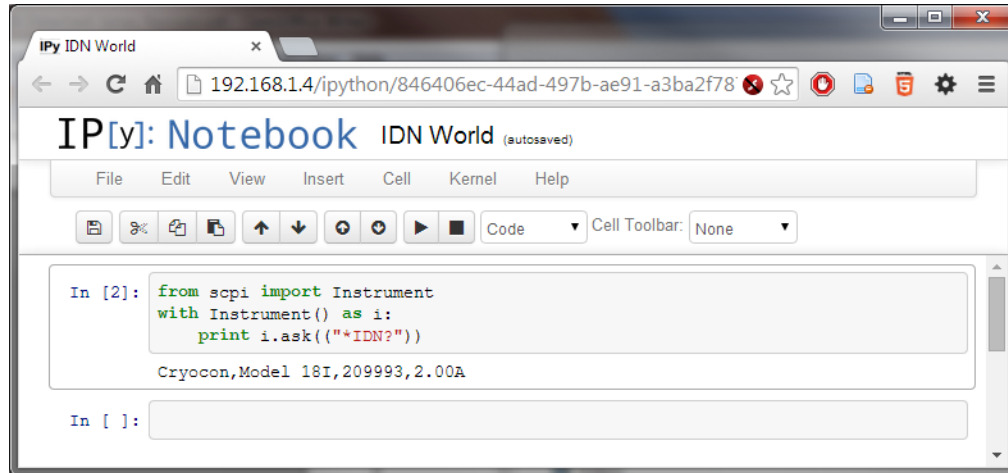


Figure 6: Example Scripts

Scripts are run from the web browser and communicate with the instrument using the SCPI remote command language. In the example above, the query *IDN? is sent and the resulting instrument identification string is displayed.

To the instrument, the script processor appears as any other remote interface. All of the commands and queries supported by the remote command language are available.

Ethernet as a backplane

Python scripts running in the Model 54 can create Ethernet TCP connections to any external device that is Ethernet connected. Therefore, scripts are able to autonomously control entire system sequences without the supervision of a computer.

Examples of instruments that can be controlled by scripts running on the Model 54 include magnet power supplies, PLCs, lock-in detectors, relay boards etc.

Note: The scripting function uses features of the HTML5 mark-up language that are only supported in newer web browsers. In older browsers, this page will be blank.

Note: Cryo-con cannot provide assistance for the development or debugging of user programs.

The EPICS CA server

Overview

As defined by Argonne National Laboratory, Experimental Physics and Industrial Control System (EPICS) is a set of open source software tools, libraries, and applications developed collaboratively and used worldwide to create distributed real-time control systems for large scale scientific and industrial applications. These applications often require hundreds of devices to communicate over a single network to form large distributed control systems. EPICS provides the standards and tools necessary to make this kind of communication possible.



Starting with firmware revision 2.00, the Model 54 implemented a Channel Access server based on EPICS R3.15. This was the first version of EPICS that supports the Linux / ARM-9 target used in the Model 54.

For extensive information about the EPICS system, please refer to the Argonne National Laboratory web site at: <https://epics-controls.org/>

The Model 54 EPICS server implementation

EPICS utilizes the IP based Channel Access (CA) network protocol. Channel Access is an application layer built on UDP and TCP that allows many devices to communicate at high speeds on the same network. Channel Access protocol provides the level of speed, bandwidth and reliability necessary for EPICS applications.

EPICS implements a client/server architecture. The Model 54 acts as a Channel Access Server (CA Server) for its own Input/Output Controller (IOC). This CA Server publishes data to and reads data from the network as Process Variables (PV). In contrast, Channel Access Clients (CA Clients) monitor the network for updates to process variables. Examples of CA Clients include Human Machine Interfaces and data analysis programs.

Initial Configuration

Before connection to an EPICS network, a new Model 54 needs to be configured.

1. The network configuration must be set.
2. The name of a new Model 54 is CCM54-xxxx, where xxxx is the last four digits of the unit's serial number. This name will become the EPICS instrument name that will be used to access process variables. It should be changed to something that the user will recognize on their CA network.
3. Optionally, the names of the individual input channels can be changed to be more meaningful on the CA network.
4. The internal firewall must be set to allow EPICS communication.

Network Configuration

With the exception of the Net Name and firewall, the network configuration can be set by using the front panel, the web page or the Ethernet port via use of SCPI commands. The firewall can only be set from the front panel and the Net Name can only be set by the web browser or SCPI commands.

The web page is, by far, the easiest way to configure the instrument. Launching the embedded web page is done by opening any web browser and typing the Model 54's IP address into the address bar. For a new unit, the default is 192.168.1.4. Next, navigate to the Network page and set the Server Configuration fields, including the desired Net Name. Click the Update button and the Model 54 will re-boot with the new network configuration.

The name entered in the Net Name field will then become the instrument's name on the EPICS network that is used to access its process variables.

Once network configuration is complete, be sure to set "EPICS CA" to "Allow" in the firewall. This can only be done from the front panel. Firewall configuration is located in the Network Setup menu.

Input Channel Name Configuration

The default input channel names for the eight input channels are Channel A, Channel B etc. These can optionally be changed to something that is more EPICS friendly.

To change input names from the web browser, navigate to the Inputs page, change the name field and click the Update key for each input channel.

The Model 54 also can access a specific input channel by using a Channel Indicator. These are ChA through ChH and cannot be changed. They are always available in the instrument's processes variables and can be used as absolute addresses to the input channels.

By using Channel Indicators, input channel names can be changed within EPICS to set the input name process variable. For example: If the instrument's name is qchamber, input channel B's name can be set by using:

```
% caput qchamber:ChB:NAME "TopLeft"
```

ⓘ NOTE: Once the instrument has been configured, be sure to save the configuration to the instrument's internal non-volatile memory so it will power-up in the same state. To do this, power-cycle one time from the front panel, send the SCPI command `system:nvsave` or set the EPICS process variable NVSAVE.

Process Variables

A Process Variable (PV) is the representation of a single value within an EPICS host. They can be read-only, write-only or read-write.

There are many remote commands available on the M54 to read data and set the instrument's configuration. Since EPICS is a data acquisition system, most of the configuration variables were not implemented since it is expected that configuring the instrument would be done by the web browser interface during initialization.

The input channel indicator process variable defined above, CHx, is a DBR_CTRL_DOUBLE, so it includes alarm status and limits. For example:

```
% caget -d DBR_CTRL_DOUBLE qchamber:cha  
returns:
```

```
qchamber:cha  
Native data type: DBF_DOUBLE  
Request type: DBR_CTRL_DOUBLE  
Element count: 1  
Value: -253.286  
Status: NO_ALARM  
Severity: NO_ALARM  
Units: F  
Precision: 4  
Lo disp limit: -441.67  
Hi disp limit: -277.649  
Lo alarm limit: -441.67  
Lo warn limit: -441.67  
Hi warn limit: -277.649  
Hi alarm limit: -277.649  
Lo ctrl limit: -441.67  
Hi ctrl limit: -277.649
```

Alarm enable/disable is not currently included as an EPICS process variable, so they need to be enabled from the front panel, web interface, or as an SCPI remote command.

PV	SCPI equivalent	Read/ Write	Function
ID	*IDN?	R	Get instrument name string.
NVSAVE	SYST:NVSA	W	Save configuration to NV memory.
CHx	INP:TEMP?	R	Get the current reading on an input channel. Reading is reported in displayed units of K, C, F or S
CHx:RDG CHx.VAL	INP:TEMP?	R	Get the current reading on an input channel. Reading is reported in displayed units of K, C, F or S
CHx:SRDG CHx.RVAL	INP:SENP?	R	Reports the raw sensor reading. For diode sensors, the reading is in Volts while resistor sensors are reported in Ohms.
Chx.PREC		R	Precision. Always returns 4.
Chx.NAME	INP:NAME	RW	Input channel name as ASCII string.
Chx.HIGH CHx.HIHI	INP:ALAR:HIGH	RW	Input channel alarm high setpoint.
Chx.LOW CHx.LOLO	INP:ALAR:LOW	RW	Input channel alarm low setpoint.
CHx.EGU	INP:UNITS	RW	Input channel units.

Table 24: EPICS Process Variables

Using Virtual Input Channels

Introduction

Up to three Cryo-con temperature monitors may be connected to a Model 54 by using the Ethernet interface to establish remote, virtual input channels. This gives the ability to add up to 24 input channels.

Once configured, the connected monitors are visible to the Model 54 that can be used for most of the functions of a standard input channel.

When remote monitors are connected, input channels are indexed as follows:

1. Local channels are indexed as ChA through ChD as before.
2. Remote inputs are indexed by the remote monitor number plus the channel indicator. Remote monitors are numbered R0, R1 and R2 in the order that they were selected. A monitor configured as remote #2 will have it's input G indexed as R2G.

Configuring Remote Devices

First, you must connect the Model 54 and all desired remote monitors to an Ethernet LAN. Configure the network as follows:

1. Each instrument must be on the same network segment, but have different Network Names and different static IP addresses. They must have the same sub-net mask and gateway address. The TCP port setting should be 5000.
2. The internal firewall must allow at least Discovery and Remote Inputs (default).

Once connected, you can add a remote monitor to the Model 54 by pressing the Network(8) key, then touching Remote Sources field. Alternatively, from the Model 54 web browser, select the Network page and the simple remote configuration menu will appear as shown below:

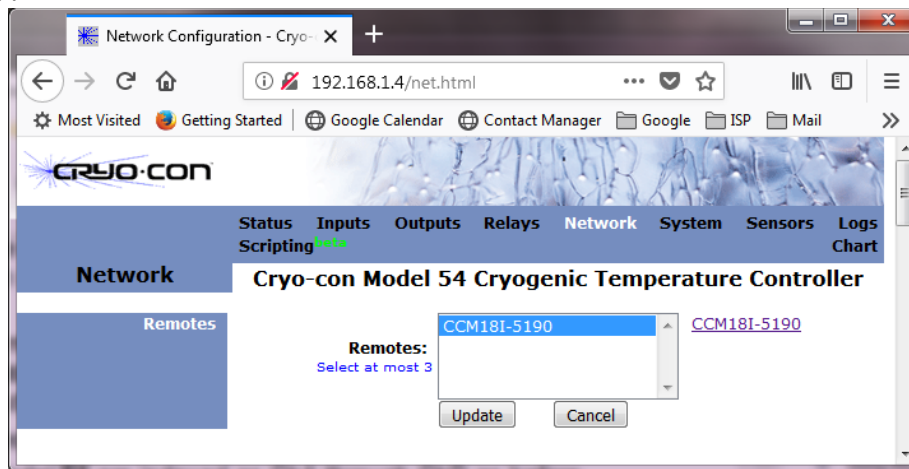


Figure 7: Remote Input Configuration

As soon as the remotes menu is displayed, the Model 54 will use the Ethernet Discovery function to locate all Cryo-con instruments connected to it's LAN. The discovered instruments will be shown as a list. Select an instrument for remotes R0, R1 and R2, then click Update.

As a convenience, the web server for a remote instrument may be accessed by clicking on the name field to the right of the Remotes selection box.

This completes the configuration process. The virtual inputs are now ready to use and will appear in the Model 54's input channel selection drop-down boxes wherever they are appropriate.

① Note: After you have completed the remote configuration process, be sure to power-cycle all of the instruments from the front panel. This will ensure that the configuration is saved.

Selecting a remote input

Remote input channels can be selected for the following functions of the Model 54:

1. An input source for a control loop. This provides temperature control from a remote input.
2. An input source for the relays.

Additionally, remote inputs are visible to the Model 54's Python scripting processor.

To select a remote channel from the web browser, simply go to the desired page and click on the Source drop-down box. For example, to select the source input for control loop #1, go to the Outputs web page and click the Source drop-down box for Loop #1. All local and remote channels will be shown. Click on the desired input, then Update.

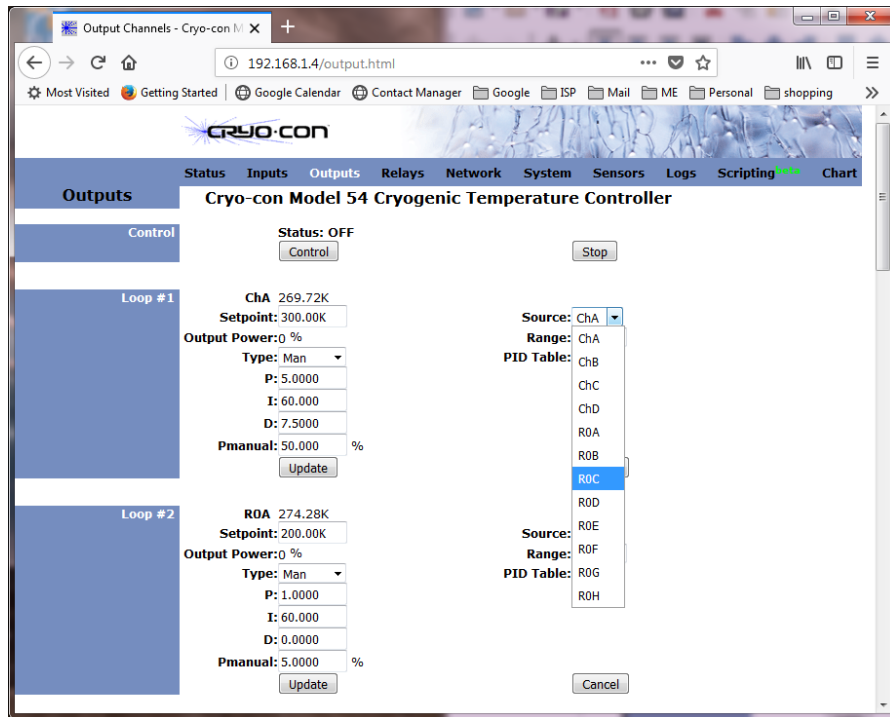


Figure 8: Selecting a remote channel for temperature control

Remote Input Channel Operation

The Model 54 and all Cryo-con monitors use a Publish-Subscribe interface to communicate remote channel information. Here, the monitors publish and the Model 54 subscribes.

Remote input channels are updated in parallel at the full native sample rate of the instrument. There is no sequencing or multiplexing involved. The Model 54 update rate is 16Hz and Cryo-con monitors update at 15Hz.

Sensor selection, units, display format, averaging filters etc. are set on the remote monitor itself. They cannot be configured from the Model 54.

Temperature control with remote inputs

Since all remote channels are updated at a minimum of 15Hz, there is no difference in the quality of temperature control for local vs. remote inputs.

When using a Cryo-con monitor as input to a Model 54 control loop, the monitor's Display TC setting should be set to the minimum value, usually 0.5S.

Shielding and Grounding

The Model 54 supports a single-point grounding scheme to prevent ground loops and low frequency power-line noise pickup.

A single-point-ground scheme starts with the establishment of a good quality ground point somewhere in your system. All components of the system, including the cryostat and connected instruments, should have a direct low impedance connection to this point.

In many systems, the ground point can be the third-wire-ground connection of the AC power outlet. If your facility does not provide a good quality ground in it's AC power distribution scheme, it is strongly recommended that one be fabricated. Noise pickup and ground loop problems are usually traced to how this connection is made.

To minimize RFI noise pickup, The Model 54 implements a shielding scheme that allows the construction of a complete shield around the instrument and cryostat. The instrument's enclosure is all Aluminum with wide conductive overlaps on all mating surfaces. Connecting cable shields to this enclosure on one end and to the cryostat on the other completes a continuous shield, thus forming a Faraday Cage RFI shield around the entire system.

In order for the instrument's grounding and shielding scheme is working effectively:

1. All sensors and heaters must be electrically floating with respect to ground.
2. The instrument side of all sensor cable shields must be connected to their connector's metal back-shell. Heater cables should have their shields connected to the chassis ground lug.
3. At least one cable must have it's shield connected to the connector's back-shell on the cryostat end.
4. A good quality earth-ground point must be established. All instruments and the cryostat should have a direct connection to this point.

ⓘ Note: There is some possibility that a ground-loop will be formed when a sensor cable shield is connected at both the cryostat and instrument end. If this happens, it is recommended that the ground-loop first be fixed and then the connection be made. Ground-loops are usually fixed by properly implementing a single-point-ground scheme.

ⓘ Note: The Ethernet LAN interface is electrically isolated and cannot introduce ground loops.

Instrument Calibration

Calibration of the Model 54 controller requires the use of various voltage and resistance standards in order to generate calibration factors for the many measurement ranges available.

Calibration is 'Closed-Case'. There are no internal mechanical adjustments required. The Model 54 cannot be calibrated from the front panel.

Calibration data is stored in the instrument's non-volatile memory and is accessed only via the remote interfaces.

A calibration procedure document may be obtained by contacting the technical support at sales@physike.com.

Cryo-con Calibration Services

When the controller is due for calibration, contact Cryo-con for low-cost recalibration. The Model 54 is supported on our automated calibration systems which allow Cryo-con to provide this service at competitive prices.

Calibration Interval

The Model 54 should be calibrated at a regular interval determined by the measurement accuracy requirements of your application.

A 90-day interval is recommended for the most demanding applications, while a 1-year or 2-year interval may be adequate for less demanding applications. Cryo-con does not recommend extending calibration intervals beyond 2 years.

Whatever calibration interval is selected, Cryo-con recommends that complete re-adjustment should always be performed at the calibration interval. This will increase user confidence that the instrument will remain within specification for the next calibration interval. This criterion for re-adjustment provides the best measure of the instrument's long-term stability. Performance data measured using this method can easily be used to extend future calibration intervals.

Remote Operation

Remote Interface Configuration

Ethernet Configuration

The Model 54 is shipped with a default IP address of **192.168.1.4** and Subnet Mask of **255.255.255.0**. Using these settings, the instrument communicates with any computer or device that has an IP addresses in the range of 192.168.1.0 through 192.168.1.255. The user can configure the Model 54 to use any other IP address by going to the [Network Configuration Menu](#).

TCP/IP Data Socket Configuration: The default TCP/IP port address is 5000. This can be changed from the front panel by going to the [Network Configuration Menu](#). Be sure to enable TCP communications on the internal firewall.

UDP Configuration: UDP uses a port that is the TCP port address plus one. Therefore, the factory default is 5001.

USBB configuration

The USBB connection on the Model 54 is a simple serial port emulator. Therefore, installation of drivers is not generally required. Once connected, configuration and use is identical to a standard RS-232 serial port.

The USBB serial port emulator interface supports Baud Rates of 9600, 19,200, 38,400, 57,600 and 115200. The factory default is 9600.

Other USBB communications parameters are fixed in the instrument. They are:

Parity: None, Bits: 8, Stop Bits: 1, Mode: Half Duplex

① **Note:** Ensure that the baud rate expected by your computer matches the baud rate set in the instrument. The rate is changeable from the instrument's front panel by using the [System Functions Menu](#). Default is 9600.

USB drivers generally assign the next available COM port to the Model 54 when it is connected. This selection can be changed by setting parameters in the driver software.

① **Note:** The USB interface uses a "New Line", or Line Feed character as a line termination. In LabView or the C programming language, this character is \n or hexadecimal 0xA. The controller will always return the \n character at the end of each line.

Remote Programming Guide

General Overview

The IEEE-488.2 SCPI remote interface language is common to all Cryo-con products. Since the language supports both simple and advanced functions, it may initially seem complex. However, the use of English language keywords and a consistent tree-structured architecture make it easy to read and learn.

Language Architecture

The programming language used by all Cryo-con instruments is described as follows:

- The industry standard SCPI language defined by the IEEE-488.2 standard is used. Therefore, anyone with experience in test and measurement will find it familiar.
- All Cryo-con instruments use the same language and future instruments will continue in the same fashion. Therefore, your investment in system software will not be lost when a product is revised or replaced.
- Keywords used in commands are common English words, not cryptic acronyms. This makes command lines easy to read and understand, even for someone that is not familiar with the instrument.
- The SCPI is a 'tree structured' language where commands are divided into groups and associated commands into sub-groups. This architecture simplifies composing commands and improves readability.

Purpose

If the user's intent is to remotely program a Cryo-con instrument with fairly simple sequences, skip to the section titled [Commonly Used Commands](#). This is a simple cheat-sheet format list of the commands that are most frequently used.

For an advanced user familiar with the SCPI programming language, the section titled [Remote Command Descriptions](#) is a complete reference to all commands.

If you are unfamiliar with the SCPI language, but it is necessary to perform advanced programming tasks, SCPI is introduced in the next section.

For all users, the section titled "[Debugging Tips](#)" is often helpful and the "[Remote Command Tree](#)" is a single page listing that shows the syntax of each command.

An Introduction to the SCPI Language

SCPI is an acronym for **S**tandard **C**ommands for **P**rogrammable Instruments. Commonly pronounced 'skippy', it is an ASCII-based instrument command language defined by the IEEE-488.2 specification and is commonly used by test and measurement instruments.

SCPI commands are based on a hierarchical structure, also known as a tree system. In this system, associated commands are grouped together under a common node or root, thus forming subsystems. A portion the command tree for a Cryo-con instrument is shown here:

INPut	SYSTem
TEMPerature	BEEP
UNITs	ADRS
VARiance	LOCKout
SLOPe	
ALARm	
NAME	
LOOP	CONFig
SETPT	SAVE
RANGe	RESTore
RATE	

In the above, INPut and LOOP are root keywords whereas UNITs and RATE are second-level keywords. A *colon* (:) separates a command keyword from lower-level keyword.

Command Format

The format used to show commands is shown here:

INPut { A | B } : ALARm : HIGH <value> ; NAME "name" ;

The command language is case-insensitive, but commands are shown here as a mixture of upper and lower case letters. The upper-case letters indicate the abbreviated spelling for the command. For shorter program lines, send the abbreviated form. For better program readability, send the long form.

For example, in the above statement, INP and INPUT are all acceptable.

Braces ({ }) enclose the parameter choices for a given command string. The braces are not sent as part of the command string.

A *vertical bar* (|) separates multiple parameter choices for a given command string.

Triangle brackets (< >) indicate that you must specify a numeric value for the enclosed parameter.

Double-quote (") marks must enclose string parameters.

Commands are terminated using a semicolon (;) character. The semicolon at the end of the line is assumed and is optional.

The { }, |, <> and " characters are for the illustration of the command syntax and not part of the command syntax.

Command Separators

A *colon* (:) is used to separate a command keyword from a lower-level keyword. It is necessary to insert a *blank space* to separate a parameter from a command keyword.

Compound Commands

A semicolon (;) is used as a separator character that separates commands within the same subsystem. For example, sending the following command string:

```
INPut A:UNITs K;TEMPer?;
```

has the same effect as sending the following two commands:

```
INPut A:UNITs K;  
INPut A:TEMPer?;
```

If multiple commands address different subsystems, the combination of a semicolon (;) and a colon (:) are used. The semi-colon terminates the previous command and the colon indicates that the next command is in a different subsystem. For example:

```
INPut A:TEMPer?;:LOOP 1:SETPt 123.45;
```

has the effect of sending the following two commands:

```
INPut A:TEMPer?;  
LOOP 1:SETPt 123.45;
```

Queries

You can query the current value of most parameters by adding a question mark (?) to the command. For example, the following command set the setpoint on control loop 1 to 123.45:

```
LOOP 1:SETPt 123.45;
```

You can change it into a query that reads the setpoint by using the following:

```
LOOP 1:SETPt?;
```

The instrument's response will be a numeric string such as: 123.45.

Compound queries are commonly used to save programming steps. For example, the query:

```
LOOP 1:SETPt?;PGAin?;IGAin?;DGAin?;
```

reports the loop 1 setpoint, P-gain, I-gain and D-gain. An example response is:

```
123.45;20.0;60;12.5;
```

Note that the response is also separated by semicolons.

The representation of the decimal symbol for floating point numbers must be a period, '.', instead of comma, ',' as is customary used in some European countries.

Command Terminators

Each command must be terminated with a *line-feed* (\n) character.

SCPI Common Commands

The IEEE-488.2 SCPI standard defines a set of common commands that perform basic functions like reset, self-test and status reporting. Note that they are called common commands because they must be common to all SCPI compliant instruments, not because they are commonly used.

Common commands always begin with an asterisk (*), are four to five characters in length and may include one or more parameters. Examples are:

```
*IDN?  
*CLS  
*OPC?
```

SCPI Parameter Types

The SCPI language defines several different data formats to be used in program messages and response messages.

Numeric Parameters: Commands that require numeric parameters will accept all commonly used decimal representations of numbers including optional signs, decimal points and scientific notation.

Enumeration Parameters: These are used to set values that have a limited number of choices. Query responses will always return an enumeration parameter in upper-case letters. Some examples of commands with enumeration parameters are:

```
INPUt {A|B|C|D}:UNITs {K | C | F | S}  
LOOP {1 | 2}:TYPE {OFF | MAN | PID | TABLE | RAMPP}
```

String Parameters: String parameters can be up to 15 characters in length and contain any ASCII characters excluding the double-quote ("). String parameters must be enclosed in double-quotes ("). For example:

```
CONFIg 4:NAMe "CoId Plate"
```

Commonly Used Commands.

A complete summary of remote commands is given in the User's Manual chapter titled "Remote Command Summary". The manual also has complete descriptions of all remote commands. This section is intended to show a few of the more commonly used commands.

① **NOTE:** Remote commands are not case sensitive.

Function	Command	Comment
Instrument Identification		
Read the instrument identification string	*idn?	Returns the instrument identification string in IEEE-488.2 format. For example: "Cryo-con,54,204683,1.01A" identifies the manufacturer followed by the model name, serial number and firmware revision code.
Input Channel Commands Parameter for the input is A, B, C or D corresponding to inputs A, B, C or D.		
Read the temperature on input channel B	input? b	Temperature is returned in the current display units. Format is a numeric string. For example: 123.4567
Set the temperature units on input channel A to Kelvin.	input a:units k	Choices are K- Kelvin, C- Celsius, F- Fahrenheit and S- native sensor units (Volts or Ohms).
Read the temperature units on channel B	input b:units?	Return is: K, C, F or S.
Control Loop Start/Stop commands		
Disengage all control loops.	stop	Both control loops are stopped.
Engage all control Loops.	control	Starts both control loops
Ask if control loops are on or off.	control?	Return is ON or OFF

Function	Command	Comment
LOOP Commands. Configure control loop outputs. Parameter is 1 or 2 corresponding to Loop 1 or Loop 2.		
Set the setpoint for control loop 1	loop 1:setpt 1234.5	Sets the loop 1 setpoint to 1234.5. Units are taken from the controlling input channel.
Read the setpoint for control loop 1	loop 1:setpt?	Reads the loop 1 setpoint as a numeric string.
Set the controlling source input for loop 1	loop 1:source a	Sets the Loop 1 controlling source to input channel A. Choices are any input channel.
Set the loop 2 P gain term for PID control.	loop 2:pgain 123.5	P gain is unit-less.
Set the loop 1 I gain term.	loop 1:igain 66.1	I gain has units of seconds.
Set the loop 2 D gain term.	loop 2:dgain 10.22	D gain has units of inverse-seconds.
Set the heater range for loop 1	loop 1:range hi	Choices are hi- high, mid- medium and low- low.
Read the loop 1 heater range	loop 1:range?	Reports HI, MID, LOW
Read the control mode for loop 1	loop 1:type?	Returns the control loop type. Choices are: OFF, MAN, PID, TABLE, RAMPT or RAMPP.
Set the control mode for loop 2	loop 2:type rampp	Choices are OFF, PID, MAN, TABLE and RAMPP
Set the output power level for manual control.	loop 1:pman 25	Sets the power output of loop 1 to 25% of full scale when the loop is in the manual output mode.
Read the current output power level	loop 2:htrread?	Reports the current output power as a percentage of full scale.

Using the CATalog? Query

As a convenience for software development, the CATalog? query may be attached to any command that requires a parameter. The instrument will return a comma delimited list of allowed values. Examples are:

```
INPut:CATalog?
Returns: ChA,ChB,ChC,ChD,
RELay:CATalog?
Returns: 1,2,
RELay:MODE:CATalog?
Returns: Auto,Off,On ,
```

Debugging Tips

1. You can view the remote commands being sent or received by the instrument over any of the remote interfaces on the Home screen. Press the Display key, select a zone for SCPI I/O display then select (7)SCPI IO. This will set a zone on the home display that shows the last SCPI command received and the response it generated. Even garbled commands are shown.
2. In order to avoid overrunning the instrument use commands that return a value. When the value is returned, command processing is complete. For example:
 INPUT A:UNITS K;UNITS?
 will respond with the input units only after the command has completed.
3. If you are unsure of the values allowed for a parameter, use the CATalog? query.
4. It is often easiest to test commands by using a simple terminal emulator that can be used to interact with the instrument via the LAN or serial ports. One example is The PuTTY program available at <http://www.putty.org/>. Configuring PuTTY for Ethernet communications with the M54 is shown here.
5. Keywords in all SCPI commands may be shortened. The short form of a keyword is the first four characters of the word, except if the fourth is a vowel. If so, the truncated form is the first three characters of the word. Some examples are: inp for input, syst for system alar for alarm etc.
6. Use the catalog query described above to find the parameters for a remote command.

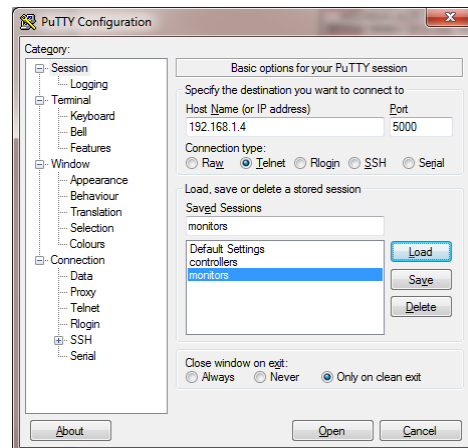


Figure 9: Example Terminal Configuration

SCPI Status Registers

The Instrument Status Register

The Instrument Status Register (ISR) is queried using the SYSTEM:ISR? command.

The ISR is commonly used to generate a service request (GPIB) when various status conditions occur. In this case, the ISR is masked with the Instrument Status Enable (ISE) register.

The ISR is defined as follows:

ISR

Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
Alarm			Htr			SFB	SFA

Where:

Bit7 – Alarm: Indicates that an alarm condition is asserted. Use the ALARM commands to query individual alarms.

Bit4 – Htr: Indicates a heater fault condition. Use the HEATER commands to query the heater.

Bit1 to Bit0 – SFx: Indicates that a sensor fault condition is asserted on an input channel. Use the INPUT commands to query the input channels.

The Instrument Status Enable Register

The Instrument Status Enable (ISE) Register is a mask register. It is logically ANDed with the contents of the ISR in order to set the Instrument Event (IE) bit in the Status Byte (STB) register. This can cause a service request (GPIB) to occur.

Bits in the ISE correspond to the bits in the ISR defined above.

The Standard Event Register

The Standard Event Register (ESR) is defined by the SCPI to identify various standard events and error conditions. It is queried using the Common Command *ESR?. This register is frequently used to generate an interrupt packet, or service request when various I/O errors occur.

Bits in the ESR are defined as follows:

ESR

Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
OPC		QE	DE	EE	CE		PWR

Where:

Bit7 – OPC: Indicates Operation Complete.

Bit5 – QE: Indicates a Query Error. This bit is set when a syntax error has occurred on a remote query. It is often used for debugging.

Bit4 – DE: Indicates a Device Error.

Bit3 – EE: Indicates an Execution Error. This bit is set when a valid command was received, but could not be executed. An example is attempting to edit a factory supplied calibration table.

Bit2 – CE: Indicates a Command Error. This bit is set when a syntax error was detected in a remote command.

Bit0 – PWR: Indicates power is on.

The Standard Event Enable Register

The Standard Event Enable Register (ESE) is defined by the SCPI as a mask register for the ESR defined above. It is set and queried using the Common Command *ESE.

Bits in this register map to the bits of the ESR. The logical AND of the ESR and ESE registers sets the Standard Event register in the Status Byte (STB).

The Status Byte

The Status Byte (STB) is defined by the SCPI and is used to collect individual status bits from the ESE and the ISR as well as to identify that the instrument has a message for the host in it's output queue. It is queried using the Common Command *STB?. Bits are defined as follows:

STB

Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
	RQS	SE	MAV	IE			

Where:

Bit6 – RQS: Request for Service.

Bit5 – SE: Standard Event. This bit is set as the logical 'AND' of the ESR and ESE registers.

Bit4 – MAV: Message Available

Bit3 – IE: Instrument Event. This bit is set as the logical 'AND' of the ISR and ISE registers.

The Status Byte Register

The Status Enable Register (SRE) is defined by the mask register for the STB. It is set and queried using the Common Commands *SRE.

The logical 'AND' of the SRE and STB registers is used to generate a service request on the optional GPIB interface.

Remote Command Tree

Control Loop Start /Stop commands

STOP
CONTRol
CONTRol?

SYSTEM commands

SYSTem:LOCKout {ON | OFF}
SYSTem:NVSave
SYSTem:BEEP <seconds>
SYSTem:CONTRast? <brightness 1-7>
SYSTem:DISTc { 2 | 4 | 8 | 16 | 32 | 64}
SYSTem:GPIB <address>
SYSTem:RESeed
SYSTem:HOME
SYSTem:NAME "name"
SYSTem:HWRev?
SYSTem:FWREV?
SYSTem:DRES {FULL | 1 | 2 | 3}
SYSTem:PUControl {ON | OFF}
SYSTem:BAUD {9600 | 19200 | 38400 | 57600 | 115200}
SYSTem:DATE "mm/dd/yyyy"
SYSTem:TIME "hh:mm:ss"
SYSTem:FANRpm?

Input Commands
INPut {A B C D} or INPut {A B C D}:TEMPerature?
INPut {A B C D}:UNITs {K C F S}
INPut {A B C D}:NAME Instrument Name"
INPut {A B C D}:SENPr?
INPut {A B C D}:VBIas {10MV 1.0MV 100UV}
INPut {A B C D}:VLEVel <100 to 10>
INPut {A B C D}:BRANge {Auto 1.00 10.0 100.0 1.00K 10.0K}
INPut {A B C D}:CBR?
INPut {A B C D}:SENsorix <ix>
INPut {A B C D}:BRUNlock?
INPut {A B C D}:POWER?
INPut {A B C D}:ALARm?
INPut {A B C D}:ALARm:HIGHeSt <setpt>
INPut {A B C D}:ALARm:LOWEst <setpt>
INPut {A B C D}:ALARm:DEAdband <setpt>
INPut {A B C D}:ALARm:HIENa { YES NO }
INPut {A B C D}:ALARm:LOENa { YES NO }
INPut {A B C D}:LTENa { YES NO }
INPut {A B C D}:AUDio { YES NO }
INPut {A B C D}:MINimum?
INPut {A B C D}:MAXimum?
INPut {A B C D}:VARiance?
INPut {A B C D}:SLOpe?
INPut {A B C D}:OFFSet?
INPut:TIME?
INPut:RESet

Loop Commands
LOOP {1 2 3 4}:SOURce {A B C D}
LOOP {1 2 3 4}:SETPt <setpt>
LOOP {1 2 3 4}:TYPE { OFF PID MAN TABLE RAMPP RAMPT}
LOOP {1 2 3 4}:TABelix <ix>
LOOP {1 2}:RANge { HI MID LOW}
LOOP {1 2 3 4}:RAMP?
LOOP {1 2 3 4}:RATe <rate>
LOOP {1 2 3 4}:PGAin <gain>
LOOP {1 2 3 4}:IGAin <gain>
LOOP {1 2 3 4}:DGAin <gain>
LOOP {1 2 3 4}:PMAInal <pman>
LOOP {1 2 3 4}:OUTPwr?
LOOP {1 2 3 4}:HTRRead?
LOOP {1 2 3 4}:HTRHst?
LOOP {1 2 3 4}:MAXPwr <maxpwr>
LOOP {1 2 3 4}:MAXSet <maxset>

Autotune Commands

```

LOOP {1 | 2 | 3 | 4}:AUTotune:STARt
LOOP {1 | 2 | 3 | 4}:AUTotune:EXIT
LOOP {1 | 2 | 3 | 4}:AUTotune:SAVE
LOOP {1 | 2 | 3 | 4}:AUTotune:MODE {P | PI | PID}
LOOP {1 | 2 | 3 | 4}:AUTotune:DELTap <num>
LOOP {1 | 2 | 3 | 4}:AUTotune:TIMEout <num>
LOOP {1 | 2 | 3 | 4}:AUTotune:PGAin?
LOOP {1 | 2 | 3 | 4}:AUTotune:PGAin?
LOOP {1 | 2 | 3 | 4}:AUTotune:DGAin?
LOOP {1 | 2 | 3 | 4}:AUTotune:STATus?

```

OVERTEMP commands

```

OVERtemp:ENABLE {ON | OFF}
OVERtemp:SOURce {A | B | C | D}
OVERtemp:TEMPerature <temp>

```

Relay Commands

```

RELay? {1 | 2}
RELay {1 | 2}:SOURce {A | B | C | D}
RELay {1 | 2}:MODE {auto | within | control | on | off}
RELay {1 | 2}:HIGHest <setpt>
RELay {1 | 2}:LOWEST <setpt>
RELay {1 | 2}:DEADband <deadband>
RELay {1 | 2}:HIENa { YES | NO }
RELay {1 | 2}:LOENa { YES | NO }

```

PID Table Commands

```

PIDTable? <num>
PIDTable <num>:NAME Name String"
PIDTable <num>:NENTry?
PIDTable <num>

```

Network Commands

NETWork:IPAdDress
NETWork:PORT <port number>
NETWork:MACAdDress
NETWork:NAME "Name"
NETWork:DHCP {ON | OFF}

Mail Commands

MAIL {A | B | C | D} :ADDR "IPA"
MAIL {A | B | C | D} :FROM "from e-mail address"
MAIL {A | B | C | D} :DEST to e-mail address"
MAIL {A | B | C | D} :PORT <port number>
MAIL {A | B | C | D} :STATE {ON | OFF}

IEEE Common Commands

*CLS
*ESE
*ESR
*OPC
*IDN?
*RST
*SRE
*STB

Data-logging Commands

DLOG:STATe {ON | OFF}
DLOG:INTerval <Seconds>
DLOG:COUNt?
DLOG:RESEt
DLOG:CLEAR

Remote Command Descriptions

IEEE Common Commands

*CLS

The *CLS common command clears the status data structures, including the device error queue and the MAV (Message Available) bit.

*ESE

The *ESE command sets the Standard Event Status Enable (ESE) Register bits. The ESE Register contains a bit mask for the bits to be enabled in the Standard Event Status (SEV) Register. A one in the ESE register enables the corresponding bit in the SEV register. A zero disables the bit.

The *ESE? Query returns the current contents of the ESE register.

*ESR

The *ESR query returns the contents of the Standard Event (SEV) status register.

*OPC

The *OPC command causes the instrument to set the operation complete bit in the Standard Event (SEV) status register when all pending device operations have finished.

The *OPC Query places an ASCII '1' in the output queue when all pending device operations have completed.

*IDN?

The *IDN? Query causes the instrument to identify itself. The Model 54 will return the following string:

Cryo-con, 54,<serial number>,<firmware revision>

Where: <serial number> is the unit's serial number and <firmware revision> is the revision level of the unit's firmware

*RST

Reset the Model 54. This results in a hardware reset. This sequence takes about 15 seconds to complete.

*SRE

The *SRE command sets the Status Byte Enable (SRE) Register bits. The SRE Register contains a bit mask for the bits to be enabled in the Status Byte (STB) Register. A one in the SRE register will enable the corresponding bit in the STB register. A zero will disable the bit.

The *SRE? Query returns the current contents of the SRE register.

*STB?

The *STB query returns the contents of the Status Byte Register.

Control Loop Start / Stop Commands**STOP**

Disengage both control loops.

CONTRo1

The control command will cause the instrument to enter the control mode by activating enabled control loops. To disable an individual loop, set its control type to OFF.

① **Note:** To disengage temperature control, use the STOP command.

System Commands.

System commands are a group of commands associated with the overall status and configuration of the instrument rather than a specific internal subsystem.

SYSTem:LOCKout {ON | OFF}

Sets or queries the remote lockout status indicator. Used to enable or lock-out the front panel keypad of the instrument, thereby allowing or preventing keypad entry during remote operation. When the keypad is locked, most of the keys on the keypad will not function. However, the **Stop** key will disengage all control loops.

To exit the keypad lock out from the front panel, push the **Esc** button.

SYSTem:NVSave

Save NV RAM to Flash. This saves the entire instrument configuration to flash memory so that it will be restored on the next power-up. Generally only used in environments where AC power is not toggled from the front panel. This includes remote and rack-mount applications.

SYSTem:BEEP <seconds>

Asserts the audible alarm for a specified number of seconds. Command only.

SYSTem:CONTrast?

Set or query the LCD brightness. Values are 1 to 7.

SYSTem:DISTc {2 | 4 | 8 | 16 | 32 | 64}

Set or query the display filter time constant. The display filter is time-constant filter that is applied to all reported or displayed temperature data. Available time constants are 0.5, 1, 2, 4, 8, 16, 32 or 64 Seconds.

SYSTem:FANRpm?

Queries the speed of the internal fan. Typically about 2900RPM.

SYSTem:GPIB <address>

Selects the address that the IEEE-488.2 (GPIB) remote interface option will use. The address is a numeric value between 1 and 31 with a factory default of 12. The addresses assigned to instruments must be unique on each GPIB bus structure.

SYSTem: RESeed

Re-seeds the input channel's averaging filter, allowing the reading to settle significantly faster.

SYSTem: HOMe

Causes the front panel display to go to the Operate Screen.

SYSTem: NAME "name"

The controller contains a unit name string that may be set or queried using this command. This can be used to assign a descriptive name to the instrument.

SYSTem: HWRev?

Queries the instrument's hardware revision level.

SYSTem: FWREV?

Queries the instrument's firmware revision level.

SYSTem: DRES {FULL | 1 | 2 | 3}

Sets or queries the controller's display resolution. Choices are:

- FULL: The display will show numbers with the maximum possible resolution.
- 1, 2 or 3: The display will show the specified number of digits to the right of the decimal point.

NOTE: This command only sets the number of digits displayed on the front panel display. It does NOT affect the internal accuracy of the instrument or the format of measurements reported on the remote interfaces.

SYSTem: PUControl {ON | OFF}

Sets or queries the controller's power up in control mode setting. This mode causes the controller to automatically enter control mode 10 seconds after AC power is applied. Please exercise caution when using this command.

SYSTem: BAUD {9600 | 19200 | 38400 | 57600 | 115200}

Sets or queries the RS 232 Baud rate.

SYSTem: DATE "mm/dd/yyyy"

Sets or queries the instrument's date. Date is in string format and is surrounded by double-quotes. Format is mm/dd/yyyy for month / day / year.

SYSTem: EFREq <frequency>

Default: 17Hz

Sets or queries the bridge excitation frequency in Hz. The numeric range is 10 to 30Hz.

SYSTem: TIME "hh:mm:ss"

Sets or queries the instrument's time. Time is in string format and is surrounded by double-quotes. Format is hh:mm:ss for hour:mm:ss. Twenty-four hour format is used.

Input Commands

The INPUT group of commands are associated with the configuration and status of the four input channels.

Parameter references to the input channels may be:

- Numeric ranging in value from zero to two.
- Channel ID tags including CHA or CHB.
- Alphabetic including A or B.

INPut? {A | B | C | D} or INPut {A | B | C | D}:TEMPerature?

The INPUT query reports the current temperature reading on any of the input channels. Temperature is filtered by the display time constant filter and reported in display units. Query only.

INPut {A | B | C | D}:UNITs {K | C | F | S}

Sets or queries the display units of temperature used by the specified input channel. Units may be K for Kelvin, C for Celsius, F for Fahrenheit or S for primitive sensor units. In the case of sensor units, the instrument will determine if the actual units are Volts or Ohms based on the actual sensor type.

INPut {A | B | C | D}:NAME Name String"

Sets or queries the name string for the selected input channel. The name string can be up to 15 ASCII characters. The string is used to name the input channel in order to clarify it's use.

INPut {A | B | C | D}:SENPr?

The INPUT:SENPR query reports the primitive reading on a selected input channel. For diode sensors, the reading is in Volts while resistor sensors are reported in Ohms. The reading is not filtered by the display time-constant filter. Useful whenever measurements of both temperature and sensor resistance are required. Query only.

INPut {A | B | C | D}:VBIas {10MV | 1.0MV | 100UV}

Sets or queries the voltage excitation used on an input channel. This value only applies to sensors that use constant-voltage excitation. Used with the Vlevel command.

INPut {A | B | C | D}:VLEVel <100 to 10> Default: 100

Sets or queries the Vlevel setting that applies to the attenuator on Vbias. Levels are a percent of full scale. So, to obtain a voltage excitation level of 10uV, set a Vbias of 100uV and a Vlevel of 10.

INPut {A | B | C | D} BRANge**{Auto | 1.00 | 10.0 | 100.0 | 1.00K | 10.0K}**

Sets or queries the resistance bridge range. This is a range-hold function. Normally, this is set to auto so that the instrument will autorange excitation. For special applications, it may be set to a specific excitation range.

INPut {A | B | C | D} CBR?

Queries the current bridge range setting. Useful to find the actual range setting when Bridge Range is set to Auto.

INPut {A | B | C | D}: SENSor <ix>

Sets or queries the sensor index number. <ix>, is taken from Appendix A

INPut {A | B | C | D}: POWer?

Queries the sensor power dissipation in Watts. Response is in scientific notation.

INPut {A | B | C | D}: BRUNlock?

Queries the Bridge Lock Indicator. Returns a space character if the bridge is locked or an asterisk (*) character if the bridge is unlocked. If the bridge is unlocked, it is still searching for a balance point.

INPut {A | B | C | D}: ALARm?

Queries the alarm status of the specified input channel. Status is a two character string where:

--	indicates that no alarms are asserted
SF	indicates a Sensor Fault condition.
HI	indicates a high temperature alarm
LO	indicates a low temperature alarm.

The user selectable display time constant filter is applied to input channel temperature data before alarm conditions are tested.

INPut {A | B | C | D}: ALARm: HIGHest <setpt>

Sets or queries the temperature setting of the high temperature alarm for the specified input channel. When this temperature is exceeded an enabled high temperature alarm condition is asserted.

INPut {A | B | C | D}: ALARm: LOWEst <setpt>

Sets or queries the temperature setting of the low temperature alarm for the specified input channel. When the input channel temperature is below this, an enabled low temperature alarm condition is asserted.

Temperature is assumed to be in the display units of the selected input channel.

INPut {A | B | C | D}: ALARm: DEAdband <setpt>

Sets or queries the dead-band setting. Dead-band is assumed to be in the display units of the selected input channel.

INPut {A | B | C | D}: ALARm: HIENa { YES | NO }

Sets or queries the high temperature alarm enable for the specified input channel. An alarm must be enabled before it can be asserted.

INPut {A|B|C|D}:ALARm:LOENa {YES | NO }

Sets or queries the low temperature alarm enable for the specified input channel. An alarm must be enabled before it can be asserted.

INPut {A|B|C|D}:ALARm:LTENa {YES | NO }

Sets or queries the latched alarm enable mode. When an alarm is latched, it can be cleared by using the CLEar command.

INPut {A|B|C|D}:ALARm:CLEar

Clears any latched alarm on the selected input channel.

INPut {A|B|C|D}:ALARm:AUDio {YES | NO }

Sets or queries the audio alarm enable. When enabled, an audio alarm will sound whenever an alarm condition is asserted.

INPut {A|B|C|D}:MINimum?

Queries the minimum temperature that has occurred on an input channel since the statistics were reset.

INPut {A|B|C|D}:MAXimum?

Queries the maximum temperature that has occurred on an input channel since the statistics were reset.

INPut {A|B|C|D}:VARiance?

Queries the temperature variance that has occurred on an input channel since the statistics were reset. Variance is calculated as the Standard Deviation squared.

INPut {A|B|C|D}:SLOpe?

Queries the input channel statistics. SLOPE is the slope of the best fit straight line passing through all temperature samples that have been collected since the statistics were reset. SLOPE is in units of the input channel display per Minute.

INPut {A|B|C|D}:OFFSet?

Queries the input channel statistics. OFFSET is the offset of the best fit straight line passing through all temperature samples that have been collected since the statistics were reset. OFFSET is in units of the input channel display.

INPut {A|B|C|D}:STATs:TIME?

Queries the time duration over which input channel statistics have been accumulated. Query only.

INPut {A|B|C|D}:STATs:RESet

Resets the accumulation of input channel statistical data. Command only affects the selected input channel.

LOOP commands

Loop commands are used to configure and monitor the controller's temperature control loops.

LOOP {1 | 2 | 3 | 4}:SOURce {A | B | C | D}

Sets and queries the selected control loop's controlling input channel, which may be any one of the four input channels.

LOOP {1 | 2 | 3 | 4}:SETPt <setpt>

Sets and queries the selected control loop's setpoint. This is a numeric value that has units determined by the display units of the controlling input channel. Values above the one set in the maximum setpoint, or below zero are rejected.

LOOP {1 | 2 | 3 | 4}:TYPE

{ OFF | PID | MAN | TABLE | RAMPP | SCALE }

Sets and queries the selected control loop's control type. Allowed values are:

- Off** - loop disabled
- PID** - PID
- Man** - manually controlled
- Table** - PID with Table lookup.
- RampP** - Ramping.
- RampT** - Ramping with table.

LOOP {1 | 2 | 3 | 4}:TABLEix <ix>

Sets and queries the number of the PID table used when controlling in Table mode. Six PID tables are available to store PID parameters vs. setpoint and heater range. <ix> is the loop's control PID table index.

Table index is in the range of 1 through 6.

LOOP {1 | 2 | 3 | 4} : RANGe {...}

Sets or queries the control loop's output range.

Values for Loop 1 are: 75W, Hi, Mid and Low. Loop 2: Hi, Mid and Low. Loop #4: 10V and 5V.

LOOP {1 | 2 | 3 | 4} : RAMP?

Queries the unit to determine if a temperature ramp is in progress on the specified control loop. Note that temperature ramps on the Loop 1 and Loop 2 channels are independent of each other. Query response is ON or OFF.

LOOP {1 | 2 | 3 | 4} : RATE <rate>

Sets and queries the ramp rate used by the selected control loop when performing a temperature ramp. <rate> is the ramp rate in Units / Minute.

This may be a value between 0 and 100. Rate is in display units per Minute.

LOOP {1 | 2 | 3 | 4} : PGAin <gain>

Sets or queries the selected control loop's proportional gain term. This is the P term in PID and is a unit-less numeric field with values between 0 (off) and 1000.

LOOP {1 | 2 | 3 | 4} : IGAin <gain>

Sets and queries the integrator gain term used by the selected control loop.

This is a numeric field with units of seconds. Allowed values are 0 (off) through 1000 seconds.

LOOP {1 | 2 | 3 | 4} : DGAin <gain>

Sets and queries the differentiator gain term used by the selected control loop. This is a numeric field with units of inverse seconds. Allowed values are 0 (off) through 1000/Seconds.

Note: Use of the D gain term can add significant noise. It should never be set to a value greater than 1/4 of the integrator gain.

LOOP {1 | 2 | 3 | 4} : PMANua1 <pman>

Sets and queries the output power level used by the selected control loop when it is in the manual control mode. <value> is the desired selected control loop output power. This is a numeric field in units of percent of full scale. Actual output power will depend on the loop range setting.

LOOP {1 | 2 | 3 | 4} : OUTPwr?

Queries the output power of the selected control loop. This is a numeric field that is a percent of full scale.

LOOP {1 | 2 | 3 | 4} : HTRRead?

Queries the actual output power of either control loop. The output current of the heaters is continuously monitored by an independent read-back circuit. The read-back power reported by this command is a percent of full scale. The absolute value of full scale is determined by the selected heater range.

Note that the read-back value is a percent of full-scale power. To compute the output current, first compute the square-root of the read-back value.

LOOP {1 | 2 | 3 | 4} : MAXPwr <maxpwr>

Sets or queries the maximum output power setting of the selected control loop. <MaxPwr> is the maximum output power limit expressed as a percentage of full scale.

LOOP {1 | 2 | 3 | 4} : MAXSet <maxset>

Sets or queries the maximum allowed set point for the selected control loop. <MaxSet> is the desired maximum set point. Setpoint values are in units of the controlling input channel.

LOOP {1 | 2 | 3 | 4} : VSENse?

Queries the control loop output voltage. If the instrument is not controlling temperature, return is 0.00V.

LOOP {1 | 2 | 3 | 4} : ISENse?

Queries the control loop output current. If the instrument is not controlling temperature, return is 0.00A.

LOOP {1 | 2 | 3 | 4} : LSENse?

Queries the control sensed load resistance. If the instrument is not controlling temperature, return is -1.00.

LOOP {1 | 2} : HTRHst?

Queries the temperature of the control loop's heat sink. Returns temperature in °C.

Control Loop Autotune Commands

The Model 54's control loop autotune functions can be configured and run entirely from the remote interface.

LOOP {1 | 2 | 3 | 4}:AUTotune:START

Command to initiate the autotune sequence on the selected control loop.

LOOP {1 | 2 | 3 | 4}:AUTotune:EXIT

Command to abort the autotune sequence.

LOOP {1 | 2 | 3 | 4}:AUTotune:SAVE

Command to save the autotune generated PID values to the selected control loop and continue with PID regulation.

LOOP {1 | 2 | 3 | 4}:AUTotune:MODE {P | PI | PID}

Set or query the autotune mode. Choices are P to generate P only tuning values, PI for PI values and PID for all values. Recommended value is PID.

LOOP {1 | 2 | 3 | 4}:AUTotune:DELTAp <num>

Set or query the maximum allowed change in output power that the controller is allowed to generate. Parameter is numeric and is in percent of full-scale output power. A common value is 5 for 5%.

LOOP {1 | 2 | 3 | 4}:AUTotune:TIMEout <num>

Set or query the autotune timeout. Parameter is numeric and is in units of Seconds.

LOOP {1 | 2 | 3 | 4}:AUTotune:PGAin?

Query the autotune generated proportional or P-gain parameter. This query will return a value of -1 until the autotune status is Complete".

LOOP {1 | 2 | 3 | 4}:AUTotune:PGAin?

Query the autotune generated integrator or I-gain parameter. This query will return a value of -1 until the autotune status is Complete".

LOOP {1 | 2 | 3 | 4}:AUTotune:DGAin?

Query the autotune generated derivative or D-gain parameter. This query will return a value of -1 until the autotune status is Complete".

LOOP {1 | 2 | 3 | 4}:AUTotune:STATus?

Queries the status of the autotune process. Return values are:

IDLE	- Autotune has not started.
RUNNING	-Autotune is running.
COMPLETE	-Autotune successfully completed.
FAILED	-Unable to generate PID values.
ABORT	-Aborted by operator intervention.

OVERTEMP commands

These commands are associated with the heater's Over Temperature Disconnect (OTD) feature. This is used to disconnect the heater if a specified temperature is exceeded on any selected input channel.

OVERtemp:ENABLE {ON | OFF}

Sets and queries the Over Temperature Disconnect enable. The OTD does not function if disabled.

OVERtemp:SOURce {A | B | C | D}

Sets and queries the input channel that is used as the source for the Over Temperature Disconnect feature.

OVERtemp:TEMPerature <temp>

Sets and queries the temperature used by the over temperature disconnect feature. Note that this temperature has the same units of the source input channel.

Relay Commands

The relay subsystem includes the two auxiliary relays in the Model 54. Using the RELAYS commands, these relays are independently configured to assert or clear based on the status of any of the four sensor input channels.

Relay outputs are dry-contact and are available on the rear panel of the instrument.

The user selectable display time constant filter is applied to input channel temperature data before relay conditions are tested. The user selectable relay deadband is also applied.

RELay? {1 | 2}

Relay Status Query. The two auxiliary relays available in the Model 54 are addressed as 0 and 1. The RELAYS command can be used to query the status of each relay where:

--	Relay is in Auto mode and is clear.
HI	Relay is asserted by a high temperature condition.
LO	Relay is asserted by a low temperature condition.
ON	Relay is in manual mode and is asserted.
OFF	Relay is in manual mode and is clear.

RELay {1 | 2} :SOURce {A | B | C | D}

Relay Input Source. Sets or queries the source input channel for a specified relay.

RELay {1 | 2}:HIGHest <setpt>

Relay High setpoint. Sets or queries the temperature setting of the high temperature setpoint for the specified relay. Parameter <setpt> is floating-point numeric and is in units of the controlling input channel.

RELay {1 | 2}:MODE {AUTO | WITHIN | ON | OFF | CONTROL}

Set or query the relay mode. Modes are:

Auto	Relay is controlled by enabled high and low setpoints.
Within	Operation is inverse of Auto mode. Used for fail-safe operation.
ON	Relay is in manual mode and is asserted.
OFF	Relay is in manual mode and is clear.
Control	Relay is asserted whenever the controller is in Control mode.

RELay {1 | 2}:LOWest <setpt>

Relay Low setpoint. Sets or queries the temperature setting of the low temperature setpoint for a specified relay. Parameter <setpt> is floating-point numeric and is in units of the controlling input channel.

RELay {1 | 2}:HIENa {YES | NO }

Relay High Enable. Sets or queries the high temperature enable for the specified relay.

RELay {1 | 2}:LOENa {YES | NO }

Relay Low Enable. Sets or queries the low temperature enable for the specified relay.

RELAy {1 | 2}:DEAdband <dead-band>

Sets or queries the dead-band parameter. This controls the amount of hysteresis that is applied before a relay is asserted or cleared. Parameter <dead-band> is floating-point numeric and is in units of the controlling input channel.

Sensor commands

Sensor commands are used to set and query information about the sensors installed in the controller. Both factory and user installed sensors can be queried, but only user sensors may be edited.

① **NOTE:** Factory installed sensors are indexed from 0 to 61. User installed sensors have index values from 61 to 68 corresponding to user curves 1 through 8. For additional information, refer to [Appendix A](#).

SENSor <index>:name "Name String"

Sets and queries the name string of the user-installed sensor at index <index>. The name string can be up to 15 ASCII characters.

SENSor <index>:NENTry?

Queries the number of entries in the user-installed sensor at index <index>. Response is a decimal integer ranging from zero to 200.

SENSor <index>:UNITs {VOLT| LOGOHM| OHMS}

Sets or queries the units of a user installed calibration curve at <index>. For information on the curve units, refer to the [User Calibration Curve File Format](#) section.

SENSor <index>:**TYPE {DIODE | ACR| PTC100| PTC1K}**

Sets or queries the type of sensor at <index>.

SENSor <index>:MULTiplier <multiplier>

Sets or queries the multiplier field of a user installed calibration curve at <index>. For information on the multiplier, refer to the [User Calibration Curve File Format](#) section.

PIDTABLE commands

The PIDTABLE commands are used to transfer PID tables between the Model 54 and the host computer. Use of the embedded web server to transfer PID tables is recommended since the process is relatively complex.

PID Tables are referenced by their index number, which is between 1 and 6. Table data corresponding to a specific index may be identified using the PIDTABLE? query.

Network Commands

The following commands are used to configure the Model 54's Ethernet interface.

NETWork:IPADdress "IPA"

Sets or queries the controller's IP address. The address is expressed as an ASCII string, so the input parameter must be enclosed in quotes. For example, the default IP address parameter is 192.168.1.5".

NETWork:PORT <port number>

Sets or queries the controller's TCP port number. Default is 5000.

NETWork:NAME "Name"

Sets or queries the controller's network name. This name is expressed as an ASCII string, so the input parameter must be enclosed in quotes. Maximum of 15 characters.

NETWork:DHCP {ON | OFF}

Sets or queries the controller's DHCP status.

NETWork:MACADdress?

Queries the controller's MAC address. The address is returned as an ASCII string.

Mail Commands

The Model 54 can send e-mail over the Ethernet port when an alarm condition is asserted on an enabled input channel. The following remote commands are used to configure e-mail. However, it is much easier to configure e-mail using the controller's embedded web server.

MAIL {A | B | C | D}:ADDR "IPA"

Set or query the e-mail server IP address. Parameter format is an ASCII string and must be enclosed in quotation marks. For example: 192.168.0.1".

MAIL {A | B | C | D}:FROM "from e-mail address"

Set or query the 'from' e-mail address. Parameter is an ASCII String. For example: Model54@mynetwork.com".

MAIL {A | B | C | D}:DEST "to e-mail address"

Set or query the 'to' e-mail address. Parameter is an ASCII String. For example: Model24@mynetwork.com".

MAIL {A | B | C | D}:PORT <port number>

Set or query the e-mail port. Parameter is integer and default is 25.

MAIL {A | B | C | D}:STATE {ON | OFF}

Set or query the input channel e-mail send enables. If a channel is enabled, e-mail will be sent when an alarm condition is asserted on the selected input channel.

Data Logging Commands**DLOG:STATE {ON | OFF}**

Turns the data logging function ON or OFF. Equivalent to Start / STOP.

DLOG:INTERVAL <Seconds>

Sets the data logging time interval in seconds.

DLOG:COUNT?

Queries the number of entries in the log buffer.

DLOG:RESET

Sets the logging record number to zero.

DLOG:CLEAR

Clears the data logging buffer.

EU Declaration of Conformity

Product Category: Measurement, Control and Laboratory
Product Type: Temperature Measuring and Control System
Model Numbers: Model 54
Manufacturer's Name: Cryogenic Control Systems, Inc.
Manufacturer's Address:

P. O. Box 7012
Rancho Santa Fe, CA 92067
Tel: (858) 756-3900, Fax: (858) 759-3515

The before mentioned products comply with the following EU directives:

2004/108/EC, EMC, Electromagnetic compatibility.

2006/95/EC, LVD, Electrical equipment designed for use within certain voltage limits.

2011/65/EU, RoHS, Restriction of the use of certain hazardous substances in electrical and electronic equipment.

The compliance of the above mentioned product with the Directives and with the following essential requirements is hereby confirmed:

Emissions

EN 55011, 1998

Immunity

EN 50082-1, 1997

Safety

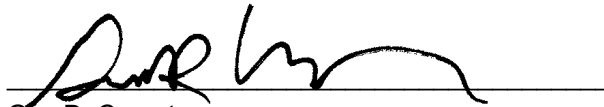
EN 61010-1:2010

IEC 61010-1:2010

RoHS

50581:2012

As the manufacturer we declare under our sole responsibility that the above mentioned products comply with the above named directives.



Guy D. Covert
President, Cryogenic Control Systems, Inc.
June 10, 2010

Appendix A: Sensor Curves and PID tables

Factory Installed Curves

The following is a list of factory-installed sensors and the corresponding sensor index.

Sensor IX	Name	Description
0	None	No Sensor. Used to turn the selected input channel off.
1	Cryo-con S900	Cryo-con S700 series Silicon diode. Range: 1.4 to 500K. 10 μ A constant current excitation.
2	LS DT-670	Lakeshore DT-670 series Silicon diode, Curve 11. Range: 1.4 to 500K. 10 μ A constant current excitation.
3	LS DT-470	Lakeshore DT-470 series Silicon diode, Curve 10. Range: 1.4 to 500K. 10 μ A constant current excitation.
4	Cryo-con S950	Cryo-con S950 series Silicon diode. Range: 1.4 to 400K. 10 μ A constant current excitation.
5	SI 410 Diode	Scientific Instruments, Inc. 410 diode Curve. Range: 1.5 to 450K. 10 μ A excitation.
20	Pt100 385	DIN43760 standard 100 Ω Platinum RTD. Range: 23 to 873K, 1mA excitation.
21	Pt1K 385	1000 Ω at 0°C Platinum RTD using DIN43760 standard calibration curve. Range: 23 to 1023K, 100 μ A excitation.
22	Low R	Low Resistance range.
23	RhFe 27, 1mA	Rhodium-Iron. 27 Ω at 0°C. 1mA DC excitation. 1.5 to 873K
32	RO-600c	Scientific Instruments Inc. RO-600 Ruthenium-Oxide sensor with constant-voltage AC excitation. Temperature range is: 1.0K to 40K.
34	LF ACI	Inductance measurement.
59	Internal	Internal reference temperature.
60	Simulate	Simulated temperature process.

The SENSOR remote commands are used to query and edit sensors installed in the controller. For example, the command:

INPUT B SENSOR 32 would set input B to use the ACR sensor.
 INPUT A: SENSOR 1 would set input A to use the S900 diode.
 INPUT A: SENSOR 0 would turn input A off by setting the sensor to 'none'.
 SENSOR 1:NAME? Returns the name string at index 1.

Factory installed sensors may not be edited by using these commands.

User Installed Sensor Curves

The user may install up to four custom sensors. This table shows the sensor index and default name of the user curves:

User Curve	Sensor IX	Default Name
0	61	User Sensor 1
1	62	User Sensor 2
2	63	User Sensor 3
3	64	User Sensor 4
4	65	User Sensor 5
5	66	User Sensor 6
6	67	User Sensor 7
7	68	User Sensor 8

Using the above table, the SENSORIX commands can be used to address the user curves. For example:

INPUT B SENSORix 62 assigns input B to user sensor #2.
 SENSORix 64:NAME? Returns the name string of user sensor 4
 SENSORix 63:TYPE ACR sets the type of user sensor #3 to ACR.

❶ NOTE: Factory installed sensors are indexed from 0 to 60. User installed sensors have index values from 61 to 68 corresponding to user curves 1 through 8.

Sensor Curves on USB drive

The following sensors are available on the USB drive supplied:

File	Description
Cryocon S700	Cryo-con S700 series Silicon diode. Range: 1.4 to 500K. 10 μ A constant current excitation.
CryocalD3.crv	Cryocal D3 Silicon diode. Range: 1.5 to 300K
SI410.crv	Scientific Instruments, Inc. SI-410 Silicon diode. Range: 1.5 to 450K
Curve10.crv	Lakeshore Curve 10 Silicon diode curve for DT-470 series diodes. Range: 1.4 to 495K.
Curve11.crv	Lakeshore Curve 10 Silicon diode curve for DT-670 series diodes. Range: 1.4 to 500K.
PT100385.crv	Cryocon CP-100, DIN43760 or IEC751 standard Platinum RTD, 100 Ω at 0°C. Range: 23 to 1020K
PT1K385.crv	DIN43760 or IEC751 standard Platinum RTD, 1000 Ω at 0°C. Range: 23 to 1020K
PT1003902.crv	Platinum RTD, 100 Ω at 0°C Temperature coefficient 0.003902 Ω /C. Range: 73K to 833K.
PT1K375.crv	Platinum RTD, 1000 Ω at 0°C Temperature coefficient 0.00375 Ω /C. Range: 73K to 833K.

Sensor Calibration Curve File Format

① Note: One simple way to generate a sensor calibration curve is to open a similar sensor file with a text editor and paste in your own data. The example files in the above table are for that purpose. They are located crv_files sub-directory of the Cryo-con utility software package. For NTC thermistors, try the AB270.crv file, for Diodes the S900.crv file and PTC RTDs use the PT100385.crv

Sensor calibration curves may be sent to any Cryo-con instrument using a properly formatted text file. This file has the extension .crv. It consists of a header block, lines of curve data and is terminated by a single semicolon (;) character.

The header consists of four lines as follows:

```

Sensor Name: Sensor name string
Sensor Type: Enumeration
Multiplier: Signed numeric
Units: Units of calibration curve: {OHMS | VOLTS | LOGOHM}

```

The Sensor Name string can be up to 15 characters and is used to identify the individual sensor curve. When downloaded to a Cryo-con instrument, this name appears in the sensor selection menu of the embedded web server and will appear on all sensor selection fields on the front panel.

The Sensor Type Enumeration identifies the required input configuration of the input channel. For the Model 54, selections are: DIODE, PTC100, PTC1K, NONE and ACR. These configurations are described in the section titled [Supported Sensor Configurations](#).

Note that, when type ACR is selected, the default voltage bias may be entered next to it. If no voltage is selected, the default of 10mV will be used.

The Multiplier field is a signed, decimal number that identifies the sensor's temperature coefficient and curve multiplier. Generally, for Negative-Temperature-Coefficient (NTC) sensors, the value of the multiplier is -1.0 and for a Positive-Temperature-Coefficient (PTC) sensor, the value is 1.0.

As an advanced function, the multiplier field can be used as a multiplier for the entire calibration curve. For example, a 10K Ω Platinum RTD can use a calibration curve for a 100 Ω Platinum RTD by using a multiplier of 100.0.

The fourth line of the header is the sensor units field. This may be Volts, Ohms or Logohm. Generally, diode type sensor curves will be in units of Volts and most resistance sensors will be in units of Ohms. However, many resistance sensors used at low temperature have highly nonlinear curves. In this case, the use of Logohm units give a more linear curve and provide better interpolation accuracy. Logohm is the base-10 logarithm of Ohms.

Examples of sensor calibration curves that are in units of Ohms include Platinum RTDs and Rhodium-Iron RTDs. Examples of sensors that best use Logohm include Cernox™, Ruthenium-Oxide and Carbon-Ceramic.

After the header block, there are two to 200 lines of sensor calibration data points. Each point of a curve contains a sensor reading and the corresponding temperature. Sensor readings are in units specified by the units line in the curve header. Temperature is always in Kelvin.

The format of an entry is:

<sensor reading> <Temperature>

Where <sensor reading> is a floating-point sensor reading and <Temperature> is a floating-point temperature in Kelvin. Numbers are separated by one or more white spaces.

Floating point numbers may be entered with many significant digits. They will be converted to 32 bit floating point which supports about six significant digits.

The last entry of a table is indicated by a semicolon (;) character with no characters on the line.

ⓘ NOTE: All curves must have a minimum of two entries and a maximum of 200 entries.

Entries may be sent to the instrument in any order. The instrument will sort the curve in ascending order of sensor reading before it is copied to Flash RAM. Entries containing invalid numeric fields are deleted before the curve is stored.

The following is an example of a calibration curve transmitted to the instrument via the LAN interface:

```
Good Diode
Diode
-1.0
volts
0.34295 300.1205
0.32042 273.1512
0.35832 315.0000
1.20000 3.150231
1.05150 8.162345
0.53234 460.1436
;
```

In summary,

1. Lines must always be terminated by a line-feed character (\n). Carriage-return characters (\r) are ignored.
1. The first line is a name string that can be up to 15 characters. Longer strings are truncated by the instrument.
The second line identifies the instrument's input configuration and must be one of the allowed selections described in the [Supported Sensor Configurations](#) section.
2. The third line is the multiplier field and is 1.0 for PTC sensors and -1.0 for NTC sensors or diodes.
3. The fourth line of the header is the sensor units and must be Volts, Ohms or Logohm.
4. Curve entries must be the sensor reading followed by the temperature in units of Kelvin. Values are separated by one or more white space or tab characters.
5. The last line in the file has a single semicolon (;) character. All lines after this are rejected.
6. It is recommended that the curve back is read after downloading to ensure that the instrument parsed the file correctly. This is easily done by using the Cryo-con utility software's curve upload function under Operations>Sensor Curve>upload.

PID table file format

There is a maximum of 16 entries in each PID table. Each entry contains a setpoint, P, I and D coefficients, a heater range and an input channel. Usually, the input channel is set to the value of Default to select the input source channel of the control loop.

Note: There are example PID table on the User CD in the Sensors\crv_files directory. The Loop 1 file is PIDtbl54L1.txt and Loop 2 is PIDtbl54L2.txt. It may be easiest to edit your own values into these examples.

The file format of a PID table is shown below:

```
<name>
<entry 0>
<entry 1>
*
*
*
```

```
<entry N>
```

```
;Where:
```

<name> is the name of the table and is a maximum of 16 ASCII characters.

<entry> is a PID entry.

A line that contains only a single semicolon indicates the end of the table.

The format of an entry is:

```
<Setpt> <P> <I> <D> <range> <Source>
```

Fields are separated by a white space. The entry is terminated by a new line (\n) character.

<Setpt> <P> <I> <D> are floating-point numbers that correspond to Setpoint, Pgain, Igain and Dgain.

<range> is the heater range string. Range strings for Loop 1 are **LOW**, **MID**, **HI** and **75W**. For Loop 2, they are **LOW**, **MID** and **HI**

<Input Channel> is the controlling source input channel and may be **ChA**, **ChB**, **ChC**, **ChD** or **Default**. Note that default selects the input channel from the control loop's source setting.

Floating point numbers may be entered with many significant digits. They will be converted to 32 bit floating point, which supports about six significant digits.

An example of a sixteen entry PID Table is as follows:

```

PID Test 0
300.00 1.60 160.00 40.00 HI Default
280.00 1.50 150.00 30.00 HI Default
260.00 1.40 140.00 30.00 HI Default
240.00 1.30 130.00 30.00 HI Default
220.00 1.20 120.00 30.00 HI Default
200.00 1.10 110.00 20.00 HI Default
180.00 1.00 100.00 20.00 MID Default
160.00 0.90 90.00 20.00 MID Default
140.00 0.80 80.00 20.00 MID ChB
120.00 0.70 70.00 10.00 MID ChB
100.00 0.60 60.00 10.00 MID ChB
80.00 0.50 50.00 10.00 MID ChB
60.00 0.40 40.00 10.00 LOW ChA
40.00 0.30 30.00 0.00 LOW ChA
20.00 0.20 20.00 0.00 LOW ChA
10.00 0.10 10.00 0.00 LOW ChA
;

```

Entries may be sent to the controller in any order. Entries containing invalid numeric fields will be deleted.

Appendix B: Updating Instrument Firmware

Updating from a file

In order to update the M54 using a firmware image file, first contact us at sales@physike.com. You will then receive a link to the requested firmware update file. The file format will look like:

M54-3.01-alpha2.tar.bz2.gpg

The .gpg extension is a security wrapper that ensures the integrity of the update.

To apply the up date, first open the M54 in a web browser and navigate to the Network page and ensure that the instrument's date and time settings are correct. The update file contains a security certificate and the instrument checks these settings to ensure that the certificate hasn't expired. If a problem is detected, the firmware update process will abort with a signature verification error.

Next, navigate to System page's Update fields and click on Choose File to select the desired firmware image. Click Upload to start the update process.

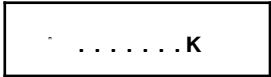
The firmware update process will take several minutes. Progress will be displayed on the instrument's front panel and in the browser's window. When complete, the web page will switch to a log file. If this log indicates that the update was not successful, please copy the page and e-mail it to sales@physike.com.

ⓘ NOTE: The firmware update process can take several minutes. Please wait until the firmware it is complete and the instrument has re-booted before navigating your web browser away from the firmware update page.

ⓘ NOTE: In the event of a failed or corrupt firmware image, the instrument freeze on power up but a firmware update web page can still be accessed from a web browser.

Appendix C: Troubleshooting Guide

Error Displays

Display	Condition
 Or, an erratic display of temperature.	Input channel voltage measurement is out of range. Ensure that the sensor is connected and properly wired. Ensure that the polarity of the sensor connections is correct. Refer to the Sensor Connections section. Many sensors can be checked with a standard Ohmmeter. For resistor sensors, ensure that the resistance is correct by measuring across both the Sense and Excitation contacts. For a diode sensor, measure the forward and reverse resistance to ensure a diode-type function.
	Input channel is within range, but measurement is outside the limits of the selected sensor's calibration curve. Check sensor connections as described above. Ensure that the proper sensor has been selected. Refer to the Input Channel Configuration Menu section. Change the sensor units to Volts or Ohms and ensure that the resulting measurement is within the selected calibration curve. Refer to the section on Input Channel Configuration Menu to display the calibration curve.

Temperature Measurement Errors

Symptom	Condition
Noise on temperature measurements.	Possible causes: - Excessive noise pickup, especially AC power line noise. Check your wiring and shielding. Sensors must be floating, so check that there is no continuity between the sensor connection and ground. Review the System Shielding and Grounding Issues section. - Use a longer display filter time constant to reduce displayed noise. Check for shielding problems by temporarily removing the input connector's backshell. If the noise changes significantly, current is being carried by the shields and is being coupled into the controller.

Appendix D: Tuning Control Loops

Introduction

Tuning PID loops to maintain high accuracy control can be a laborious process since the time-constants in cryogenic systems are often long. Further, some systems must operate over a very wide range of temperature, requiring different PID settings at different setpoints.

The following is a guide to various methods of obtaining PID control loop coefficients.

Various methods for obtaining PID coefficients

The system provider

If your controller was received as part of a cryogenic system, the PID control loops should already be setup for optimum control. If the system operates over a wide range of temperature, it will use one of the available Table control modes where PID values are listed for different setpoints.

If the installed PID values do not provide stable control, you should contact the system manufacturer for assistance.

Taking PID values from a different controller

If the PID values required to control a system are known from a different type controller, these values may be useful.

The Proportional, or P term is a unit-less gain factor. There is no industry standard definition for it and, therefore, it can vary significantly from one manufacturer to another. If the P term does not work well when used directly, try using the value divided by ten. For further assistance, please contact Cryo-con support.

The Integral, or I term is in units of Seconds and should be the same for different controllers. Note however that some manufacturers use a 'Reset' value instead of directly using an Integral term. In this case, the Integral term is just the inverse of the Reset value.

The Derivative, or D gain term is in units of inverse Seconds and should be the same for various controllers.

Using Factory Default PID values

Controllers are shipped from the factory with very conservative PID values. They will give stable control in a wide range of systems, but will have very slow response times.

Often, the factory values provide a good start for the autotune process. The values are: P 0.1, I 5.0 and D 0.0.

Autotuning

Autotuning is the easiest way to obtain PID values, or optimize existing ones. Please review the [Autotuning](#) section of this manual.

Manual Tuning

The final, and most laborious method of tuning a control loop is manual tuning. This involves generating values for P, I and D by observing the system's response to the stimulus of the heater output.

Various methods of manually tuning the controller are described below.

Manual Tuning Procedures

Manually tuning a PID control loop is relatively simple. It is greatly assisted by use of a data-logging program, such as the Cryo-con utility software package described in the [Cryo-con Utility Software](#) section.

Ziegler-Nichols Frequency Response Method

This method is based on the assumption that a critically damped system is optimal and the fact that stability and noise must be traded for response time. It requires driving your system into temperature oscillation. Care should be taken so that this oscillation does not cause damage.

Enable the Over Temperature Disconnect feature of the controller if there is concern over possible damage from overheating.

1. Enter a setpoint value that is a typical for the envisaged use of the system. Select a heater range that is safe for the equipment. Set initial PID values of Pgain=0.1, Igain=0 and Dgain=0.
2. Engage the control loops by pressing the **Control** key.
3. Increase the Pgain term until the system is just oscillating. Note the Pgain setting as the Ultimate Gain, K_c , and the period of oscillation as the Ultimate Period, T_c .
4. Set the PID values according to the following table:

Control Type	Pgain	Igain	Dgain
P only	$0.5 * K_c$	0	0
PI only	$0.4 * K_c$	$0.8 * T_c$	0
PID	$0.6 * K_c$	$0.5 * T_c$	$0.85 * T_c$

5. Wait for the system to stabilize. If the resultant heater power output reading is less than 10% of full scale, select the next lower heater range setting. A range change will not require re-tuning.

Note: In systems where there is high thermal noise, including cryocoolers, a Dgain value of zero is often used. The Dterm is a derivative action, which can introduce additional noise into the control process.

Alternate Methods

There are various other methods to manually tune PID loops. Most are based on graphical techniques and all use a stimulus-response technique.

For further reading:

Automatic Tuning of PID controllers
Instrument Society of America
67 Alexander Dr
PO Box 12277
Research Triangle Park, NC 27709

Appendix E: Sensor Data**Cryo-con S950 Silicon Diode**

The Cryo-con S950 Silicon diode sensor with a 10 μ A excitation current.

Temp(K)	Volts	Temp(K)	Volts	Temp(K)	Volts
370.00	0.392610	40.00	1.088210	11.50	1.327203
360.00	0.416200	39.00	1.089830	11.00	1.337854
350.00	0.439760	38.00	1.091450	10.50	1.349047
340.00	0.463300	37.00	1.093060	10.00	1.360897
330.00	0.486810	36.00	1.094680	9.50	1.373526
320.00	0.510240	35.00	1.096290	9.00	1.387055
310.00	0.533560	34.00	1.097910	8.50	1.401595
300.00	0.556740	33.00	1.099520	8.00	1.417234
290.00	0.579800	32.00	1.101240	7.50	1.434022
280.00	0.602790	31.00	1.102950	7.00	1.451961
270.00	0.625730	30.00	1.104650	6.80	1.459447
260.00	0.648550	29.00	1.106430	6.60	1.467099
250.00	0.671240	28.00	1.108280	6.40	1.474908
240.00	0.693790	27.00	1.109960	6.20	1.482860
230.00	0.716240	26.00	1.112170	6.00	1.490940
220.00	0.738610	25.00	1.114800	5.80	1.499128
210.00	0.760940	24.00	1.118280	5.60	1.507404
200.00	0.783110	23.00	1.124250	5.40	1.515741
190.00	0.805080	22.00	1.138410	5.20	1.524110
180.00	0.826800	21.00	1.162460	5.00	1.532477
170.00	0.848180	20.00	1.181930	4.80	1.540805
160.00	0.869210	19.50	1.190399	4.60	1.549103
150.00	0.889880	19.00	1.198550	4.40	1.557380
140.00	0.910210	18.50	1.206400	4.20	1.565604
130.00	0.930080	18.00	1.214061	4.00	1.573730
120.00	0.949270	17.50	1.221594	3.80	1.581750
110.00	0.967940	17.00	1.229179	3.60	1.589600
108.00	0.971610	16.50	1.236925	3.40	1.597250
107.00	0.973440	16.00	1.244891	3.20	1.604760
106.00	0.975270	15.50	1.253099	3.00	1.612101
100.00	0.986150	15.00	1.261547	2.80	1.619259
90.00	1.003930	14.50	1.270227	2.60	1.626214
80.00	1.021270	14.00	1.279123	2.40	1.632905
75.00	1.029850	13.50	1.288232	2.20	1.639304
70.00	1.038390	13.00	1.297560	2.00	1.645318
60.00	1.055280	12.50	1.307131	1.80	1.650844
50.00	1.071880	12.00	1.316990	1.60	1.655871
				1.40	1.660321

Cryo-con S900 Silicon Diode

The Cryo-con S900 Silicon diode sensor with a 10 μ A excitation current.

Volts	Temp(K)	Volts	Temp(K)	Volts	Temp(K)
0.09077	500.00	0.86921	160.00	1.06858	52.00
0.09281	499.00	0.87959	155.00	1.07023	51.00
0.11153	490.00	0.88988	150.00	1.07188	50.00
0.13320	480.00	0.90008	145.00	1.07353	49.00
0.15565	470.00	0.91021	140.00	1.07517	48.00
0.17873	460.00	0.92022	135.00	1.07681	47.00
0.20231	450.00	0.93008	130.00	1.07844	46.00
0.22623	440.00	0.93976	125.00	1.08008	45.00
0.25016	430.00	0.94927	120.00	1.08171	44.00
0.27403	420.00	0.95867	115.00	1.08334	43.00
0.29785	410.00	0.96794	110.00	1.08497	42.00
0.32161	400.00	0.97710	105.00	1.08659	41.00
0.34532	390.00	0.98615	100.00	1.08821	40.00
0.34768	389.00	0.99510	95.00	1.08983	39.00
0.36898	380.00	1.00393	90.00	1.09145	38.00
0.39261	370.00	1.00569	89.00	1.09306	37.00
0.41620	360.00	1.00744	88.00	1.09468	36.00
0.43976	350.00	1.00918	87.00	1.09629	35.00
0.46330	340.00	1.01093	86.00	1.09791	34.00
0.48681	330.00	1.01267	85.00	1.09952	33.00
0.51024	320.00	1.01439	84.00	1.10124	32.00
0.52192	315.00	1.01612	83.00	1.10295	31.00
0.53356	310.00	1.01785	82.00	1.10465	30.00
0.54516	305.00	1.01957	81.00	1.10643	29.00
0.55674	300.00	1.02127	80.00	1.10828	28.00
0.56828	295.00	1.02299	79.00	1.10996	27.00
0.57980	290.00	1.02471	78.00	1.11217	26.00
0.59131	285.00	1.02642	77.00	1.11480	25.00
0.60279	280.00	1.02814	76.00	1.11828	24.00
0.61427	275.00	1.02985	75.00	1.12425	23.00
0.62573	270.00	1.03156	74.00	1.13841	22.00
0.63716	265.00	1.03327	73.00	1.16246	21.00
0.64855	260.00	1.03498	72.00	1.18193	20.00
0.65992	255.00	1.03669	71.00	1.19816	19.00
0.67124	250.00	1.03839	70.00	1.21325	18.00
0.68253	245.00	1.04010	69.00	1.22816	17.00
0.69379	240.00	1.04179	68.00	1.24342	16.00
0.70503	235.00	1.04349	67.00	1.25932	15.00
0.71624	230.00	1.04518	66.00	1.27621	14.00
0.72743	225.00	1.04687	65.00	1.29401	13.00
0.73861	220.00	1.04856	64.00	1.31277	12.00
0.74978	215.00	1.05024	63.00	1.33317	11.00
0.76094	210.00	1.05192	62.00	1.35568	10.00
0.77205	205.00	1.05360	61.00	1.37998	9.00
0.78311	200.00	1.05528	60.00	1.40827	8.00
0.79412	195.00	1.05696	59.00	1.44098	7.00
0.80508	190.00	1.05863	58.00	1.47740	6.00
0.81599	185.00	1.06029	57.00	1.51590	5.00
0.82680	180.00	1.06196	56.00	1.55483	4.00
0.83754	175.00	1.06362	55.00	1.59108	3.00
0.84818	170.00	1.06528	54.00	1.62255	2.00
0.85874	165.00	1.06693	53.00	1.64342	1.00

Sensor Packages

The SM and CP Sensor Packages

The S900-SM is mounted in a rugged surface-mounted package. This compact package features a low thermal mass and is easy to install.

Package material is gold plated OHFC copper on an Alumina substrate. Solder limits the temperature range to 400K.

Leads are 3 inches, material is 37 AWG copper with Polyimide insulation. Positive connection is Red and negative is Black.

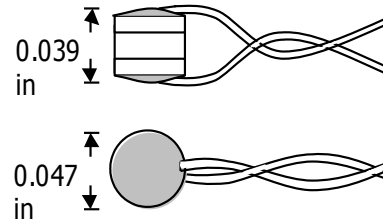
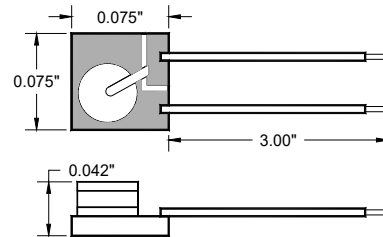
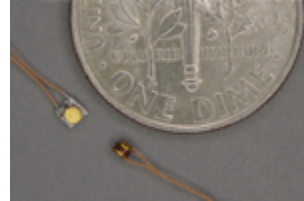
Sensor is easily installed by attaching the substrate directly to the desired surface using cryogenic varnish. Leads should be thermally anchored.

The CP is an ultra-compact 'CP'. It features low thermal mass and operation to 500K.

Package material is gold plated OHFC copper.

Leads are 3 inches. Material is 37 AWG copper with Polyimide insulation. Positive connection is Red and negative is Black.

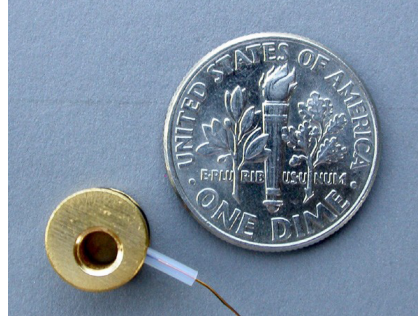
This package is extremely small and has a low thermal mass.



The BB Sensor Package

The BB package is an industry standard 0.310" bobbin package that features excellent thermal contact to the internal sensing element. This ensures a rapid thermal response and minimizes thermal gradients between the sensing element and the sensor package. Mechanical integrity of the sensor assures reliable performance even in severe applications.

With the bobbin package, the lead wires are thermally anchored to the sensor mounting. This is essential for accurate sensor readings.



Bobbin Package Specifications	
Bobbin Material	Gold plated Oxygen free hard Copper.
Marking	Individual serial number.
Sensor Bonding	Stycast® epoxy.
Mass	1.1g excluding leads.
Leads	36 inches, 36AWG Phosphor-Bronze. Four-lead color coded cryogenic ribbon cable. Insulation is heavy Formvar®.
Mounting	4-40 machine screw.
Temperature	400K Maximum.

Table 25: BB Package Specifications

Cable Color Codes	
V+	Clear
V-	Green
I+	Black
I-	Red

Table 26: Cable Color Code

Connections to the BB package are made using a color-coded four-wire, 36 AWG cryogenic ribbon cable.

Wires may be separated by dipping in Isopropyl Alcohol and then wiping clean.

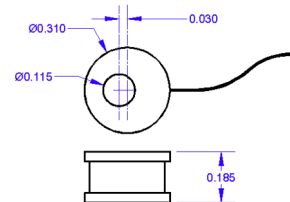
Insulation is Formvarf and is difficult to strip. Techniques include use of a mechanical stripper, scraping with a razor blade and passing the wire quickly over a low flame.

The BB package is easily mounted with a #4-40 brass screw. A brass screw is recommended because thermal stress will be reduced at cryogenic temperature.

The mounting surface should be clean. A rinse with Isopropyl Alcohol is recommended.

First, apply a small amount of Apiezonf N grease to the threads of the screw and on the mounting surface of the sensor package.

Next, place the bobbin on the mounting surface, insert screw through bobbin and lightly tighten.



Appendix G: Sensor Data Tables

Silicon Diode

Silicon diode sensors offer good sensitivity over a wide temperature range and are reasonably interchangeable.

Use in magnetic fields is not recommended.

Silicon diode sensors use a constant-current DC excitation of 10 μ A.

Cryo-con S900 Silicon Diode

Name: Cryocon S900 Configuration: Diode

T(K)	Volts	mV/K
1.4	1.63864	-36.56
4.2	1.53960	-33.91
10	1.35568	-26.04
20	1.18193	-11.34
30	1.10465	-3.12
50	1.07188	-1.46
77.35	1.02511	-1.69
100	0.98615	-1.85
150	0.88988	-2.03
200	0.78311	-2.17
250	0.67124	-2.28
300	0.55674	-2.36
355	0.42759	-2.33
400	0.32161	-2.38
450	0.20231	-2.37
500	0.09077	-2.12

Cryo-con S800 Silicon Diode

Name: Cryocon S800 Configuration: Diode

T(K)	Volts	mV/K
1.4	1.87515	-36.86
4.2	1.75099	-49.16
10	1.47130	-43.45
20	1.18867	-15.93
30	1.10594	-3.90
50	1.07079	-1.47
77.35	1.02356	-1.86
100	0.98170	-1.85
150	0.88365	-2.03
200	0.77887	-2.13
250	0.67067	-2.20
300	0.55955	-2.22
355	0.44124	-2.10
385	0.37611	-2.26

Scientific Instruments SI-430 and SI-440

Name: SI 430 Diode Configuration: Diode

Name: SI 440 Diode Configuration: Diode

T(K)	Volts	mV/K
1.4	1.63864	-36.56
4.2	1.53960	-33.91
10	1.36317	-26.04
20	1.17370	-11.34
30	1.10343	-3.12
50	1.07399	-1.46
77.35	1.02511	-1.69
100	0.98740	-1.85
150	0.89011	-2.03
200	0.78272	-2.17
250	0.67085	-2.28
300	0.55665	-2.36
355	0.42759	-2.33
400	0.32161	-2.38
450	0.20231	-2.37
500	0.09077	-2.12

Scientific Instruments SI-410		
Name: SI 410 Diode Configuration: Diode		
T(K)	Volts	mV/K
1.4	1.71488	-10.54
4.2	1.64660	-32.13
10	1.39562	-35.28
20	1.17592	-20.43
30	1.10136	-1.75
50	1.06957	-1.59
77.35	1.14905	-1.72
100	0.98322	-1.82
150	0.88603	-2.00
200	0.78059	-2.14
250	0.67023	-2.23
300	0.55672	-2.28
350	0.44105	-2.32
400	0.32319	-2.36
450	0.20429	-2.38

Lakeshore DT-670 Silicon Diode		
Name: LS DT-670 Configuration: Diode		
T(K)	Volts	mV/K
1.4	1.64429	-12.49
4.2	1.57848	-31.59
10	1.38373	-26.84
20	1.19775	-15.63
30	1.10624	-1.96
50	1.07310	-1.61
77.35	1.02759	-1.73
100	0.98697	-1.85
150	0.88911	-2.05
200	0.78372	-2.16
250	0.67346	-2.24
300	0.55964	-2.30
350	0.44337	-2.34
400	0.32584	-2.36
450	0.20676	-2.39
500	0.09068	-2.12

Lakeshore DT-470 Silicon Diode		
Name: LS DT-470 Configuration: Diode		
T(K)	Volts	mV/K
1.4	1.6981	-13.1
4.2	1.6260	-33.6
10	1.4201	-28.7
20	1.2144	-17.6
30	1.1070	-2.34
50	1.0705	-1.75
77.35	1.0203	-1.92
100	0.9755	-2.04
150	0.8687	-2.19
200	0.7555	-2.31
250	0.6384	-2.37
300	0.5189	-2.4
350	0.3978	-2.44
400	0.2746	-2.49
450	0.1499	-2.46
475	0.0906	-2.22

Platinum RTD

Platinum RTD sensors feature high stability, low magnetic field dependence and excellent interchangeability. They conform to the DIN43760 standard curve.

Platinum RTD, DIN43760 and IEC751

Name: Pt100 385 Configuration: PTC100
Name: Pt1K 385 Configuration: PTC1K

T(K)	Ohms	Ω/K
20	2.2913	0.085
30	3.6596	0.191
50	9.3865	0.360
77.35	20.380	0.423
100	29.989	0.423
150	50.788	0.409
200	71.011	0.400
250	90.845	0.393
300	110.354	0.387
400	148.640	0.383
500	185.668	0.378
600	221.535	0.372
700	256.243	0.366
800	289.789	0.360
900	324.302	0.318
1123	390.47	0.293

Rhodium-Iron

Rhodium-Iron sensors feature high stability, low magnetic field dependence and reasonable interchangeability.

The Model 54 supports them with 1.0mA Constant-Current AC excitation.

Rhodium-Iron 27 Ω

Name: RhFe 27 1mA Configuration: PTC100

T(K)	Ohms	Ω/K
1.4	1.5204	0.178
4.2	1.9577	0.135
10	2.5634	0.081
20	3.1632	0.046
30	3.5786	0.040
50	4.5902	0.064
77.4	6.8341	0.096
100	9.1375	0.106
150	14.463	0.105
200	19.641	0.102
250	24.686	0.101
300	29.697	0.101
350	34.731	0.101
400	39.824	0.103

Cryogenic Linear**Temperature Sensor (CLTS)**

CLTS sensors are inexpensive and offer excellent interchangeability. The Model 54 supports them with 100uA Constant-Current AC excitation.

CLTS-2B

Name: CLTS	Configuration: CLTS	
T(K)	Ohms	Ω/K
4.15	220	0.24
45	229.73	0.24
75	236.91	0.24
105	244.08	0.24
195	265.6	0.24
250	278.75	0.24
273.15	295.71	0.24
300	290.71	0.24

Cernox™

Cernox™ temperature sensors do not follow a standard calibration curve. Data shown here is for typical sensors.

The Model 54 supports Cernox™ using a 10mV or less Constant-Voltage AC excitation. Please refer to the section titled "[Voltage Bias Selection](#)"

Lakeshore Cernox™ CX-1010		
Name: User Supplied		Config: ACR 10mV Below 2.0K 3.0mV
T(K)	Ohms	Ω/K
0.1	21389	-558110
0.2	4401.6	-38756
0.3	2322.4	-10788
0.4	1604.7	-4765.9
0.5	1248.2	-2665.2
1	662.43	-514.88
1.4	518.97	-251.77
2	413.26	-124.05
3	328.95	-58.036
4.2	277.32	-32.209
6	234.44	-17.816
10	187.11	-8.063
20	138.79	-3.057
30	115.38	-1.819
40	100.32	-1.252
50	89.551	-0.929
77.35	70.837	-0.510
100	61.180	-0.358
150	47.782	-0.202
200	39.666	-0.130
250	34.236	-0.090
300	30.392	-0.065

Lakeshore Cernox™ CX-1030		
Name: User Supplied		Config: ACR 10mV Below 2.0K 3.0mV
T(K)	Ohms	Ω/K
0.3	31312	-357490
0.4	13507	-89651
0.5	7855.7	-34613
1	2355.1	-3265.2
1.4	1540.1	-1264.9
2	1058.4	-509.26
3	740.78	-199.11
4.2	574.20	-97.344
6	451.41	-48.174
10	331.67	-19.042
20	225.19	-6.258
30	179.12	-3.453
40	151.29	-2.249
50	132.34	-1.601
77.35	101.16	-0.820
100	85.940	-0.552
150	65.864	-0.295
200	54.228	-0.184
250	46.664	-0.124
300	41.420	-0.088
350	37.621	-0.065
400	34.779	-0.050
420	33.839	-0.045

Lakeshore Cernox™ CX-1050		
Name: User Supplied		Config: ACR 10mV
T(K)	Ohms	Ω/K
1.4	26566	-48449
2	11844	-11916
3	5733.4	-3042.4
4.2	3507.2	-1120.8
6	2252.9	-432.14
10	1313.5	-128.58
20	692.81	-30.871
30	482.88	-14.373
40	373.11	-8.392
50	305.19	-5.507
77.35	205.67	-2.412
100	162.81	-1.488
150	112.05	-0.693
200	85.800	-0.397
250	69.931	-0.253
300	59.467	-0.173
350	52.142	-0.124
400	46.782	-0.093
420	45.030	-0.089

Lakeshore Cernox™ CX-1070		
Name: User Supplied		Config: ACR 10mV
T(K)	Ohms	Ω/K
4.2	5979.4	-2225.3
6	3577.5	-794.30
10	1927.2	-214.11
20	938.93	-46.553
30	629.90	-20.613
40	474.89	-11.663
50	381.42	-7.490
77.35	248.66	-3.150
100	193.29	-1.899
150	129.60	-0.854
200	97.626	-0.477
250	78.723	-0.299
300	66.441	-0.201
350	57.955	-0.143
400	51.815	-0.106
420	49.819	-0.094

Lakeshore Cernox™ CX-1080		
Name: User Supplied		Config: ACR 10mV
T(K)	Ohms	Ω/K
20	6157.5	-480.08
30	3319.7	-165.61
40	2167.6	-79.551
50	1565.3	-45.401
77.35	836.52	-15.398
100	581.14	-8.213
150	328.75	-3.057
200	220.93	-1.506
250	163.73	-0.863
300	129.39	-0.545
350	106.98	-0.368
400	91.463	-0.261
420	86.550	-0.231

Ruthenium-Oxide

SI RO-600

The Scientific Instruments Inc. RO-600 is a Ruthenium-Oxide temperature sensor. Features include interchangeability and operation in high magnetic fields.

Scientific Instruments RO-600		
Name: SI RO-600		Config: ACR 10mV Below 1.0K 1.0mV
T(K)	Ohms	Ω/K
1	2327	-1203
1.4	1985	-660.6
2	1723	-343.5
3	1508	-152.4
4.2	1378	-80.4
6	1277	-40.9
10	1178	-15.4
20	1101	-4.08
30	1053	-4.0
40	1009	-3.5

Appendix H: Rear Panel Connections

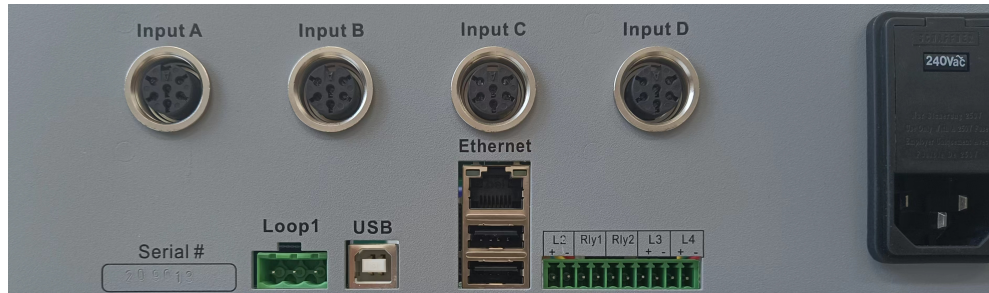


Figure 10: Model 54 Rear Panel Layout

AC Power Connection

The Model 54 requires single-phase AC power of 50 to 60 Hz. Voltages are set by the line voltage selector in the Power Entry Module on the rear panel. The power cord will be a standard detachable 3-prong type.

Line voltage selections are: 100, 120, 220 or 240VAC. Tolerance on voltages is +10% to -5% for specified accuracy and -10% for reduced full-scale heater output in the highest output range.

The power jack and mating plug of the power cable meet Underwriters Laboratories (UL) and International Electrotechnical Commission (IEC) safety standards.

User-replaceable fuses are incorporated in the Power Entry Module.

Note: The Model 54 uses a smart power on/off scheme. When the power button on the front panel is pressed to turn the unit off, the instrument's setup is copied to flash memory and restored on the next power up. If the front panel button is not used to toggle power to the instrument, the user should configure it and cycle power from the front panel button one time. This will ensure that the proper setup is restored when AC power is applied.



Caution: Protective Ground: To minimize shock hazard, the instrument is equipped with a three-conductor AC power cable. Plug the power cable into an approved three-contact electrical outlet or use a three-contact adapter with the grounding wire (green) firmly connected to an electrical ground (safety ground) at the power outlet.

Fuse Replacement and Voltage Selection

Access to the Model 54's fuses and voltage selector switch is made by using a screwdriver to open fuse drawer in the power entry module. A slot is provided above the voltage selector window for this purpose.

The fuse and voltage selection drawer cannot be opened while the AC power cord is connected.

Voltage selection is performed by rotating the selector cams until the desired voltage shows through the window shown.

There are two fuses that may be removed by pulling out the fuse modules below the voltage selector. Fuses are specified according to the AC power line voltage used.

Line Voltage	Fuse	Example
100VAC, 120VAC	2.0A slow-blow	Littlefuse 313 002
220VAC, 240VAC	1.0A slow-blow	Littlefuse 313 001

Table 27. AC Power Line Fuses



Caution: Be sure to use the proper fuse for the selected line voltage. Use of an incorrect fuse can cause serious damage to the instrument.

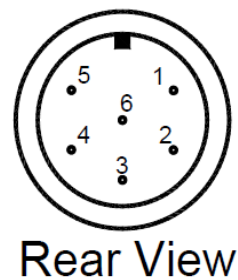
Sensor Connections

All sensor connections are made at the rear panel of the Model 54 using the four 6-pin circular connectors provided.

All sensor types should be connected to the Model 54 using a four-wire connection. It is strongly recommended that sensors be connected using shielded, twisted pair wire. Wires are connected as shown below and the shield should be connected to the special shield pin shown here.

Pin	Function
1	Excitation (-), I-
2	Sense (-), V-
3	Aux Power: +5VDC @ 500mA (NC)
4	Sense (+), V+
5	Excitation (+), I+
6	Not Connected

Table 28: Input Connector Pin-out



Rear View



Caution: To ensure proper low noise operation, cable shields or drain wires should be connected to the shield pin on the input connector.



Figure 11: Proper Assembly of the Input Connector

① Assembly Aid: To screw the threaded back-shell over the connector body, insert the body part way into the receptacle on the rear panel of the 54. This will hold it in place so the back-shell can be tightly screwed in.



Caution: Any disconnected inputs to the Model 54 should be configured to a sensor type of 'None'. This will turn the input off and prevent the high-impedance per-amplifiers from drifting.

Recommended color codes for a sensor cable are as follows:

Color Code	Signal	Pin
White	Excitation(+)	5
Green	Excitation(-)	1
Red	Sense(+)	4
Black	Sense(-)	2

Table 29: Sensor Cable Color Codes

The cable used is Belden 8723. This is a dual twisted pair cable with individual shields and a drain wire. The shields and drain wire are connected to the connector's metal back-shell in order to complete the shielding connection.

A four-wire connection is recommended in order to eliminate errors due to lead resistance. Cryogenic applications often use fine wires made from specialty metals that have low heat conduction. This results in high electrical resistance and, therefore, large measurement errors if the four-wire scheme is not used.

Four-wire connection to diode and resistive type sensors is diagrammed below:

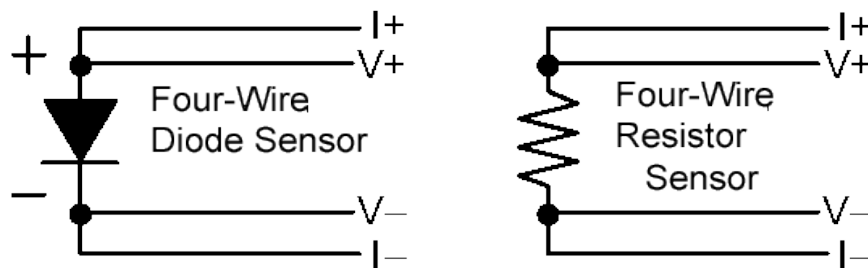


Figure 12: Diode and Resistor Sensor Connections

Control Loop #1 Connections

Rear panel Primary Heater Output (Loop #1) connections are made using a 3 pin detachable terminal block on the rear panel.

Pin	Function
Hi	Heater Output High
Lo	Heater Output Low
GND	Cable Shield Ground

Table 30: Loop #1 Connections



Caution: The Model 54 has an automatic control-on-power-up feature. If enabled, the controller will automatically begin controlling temperature whenever AC power is applied. For a complete description of this function, please see the Auto-Control function in the [System Functions menu](#) section.

Control Loop #2 and Relay Connections

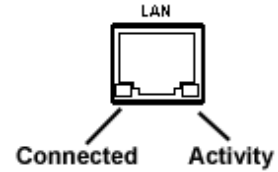
Connection to the Loop #2 Output is made on the rear panel using the 10-pin, 3.5mm detachable terminal block provided. The replacement part number is OSTTJ1011530 and is available and from digikey.com.

Pin	Function
1	Loop #2 Heater Output High
2	Loop #2 Heater Output Low
3	Relay #1 N.O.
4	Relay #1 Common.
5	Relay #2 N.O.
6	Relay #2 Common.
7	Loop #3 output High
8	Loop #3 output Low
9	Loop #4 output High
10	Loop #4 output Low

Table 31: Loop #2 and Digital Output Connections

Ethernet (LAN) Connection

The Ethernet connection on the Model 54 is a standard RJ-45 connector with two status LEDs. The left most LED indicates that a valid connection has been made to a hub or computer and the right most LED indicates activity on the LAN.



USB Connections

USBB: Connection to the USB serial port emulator is done with a full-size USB type B connector located on the rear panel.

USBA: The 54 has two USBA ports that can serve as a host connection for external memory sticks, a mouse or a keyboard. When a memory stick is inserted, data logs are continuously written to it.

IEEE-488.2 Connections

The optional IEEE-488.2 (GPIB) connection is installed by connecting the dongle to the Ethernet port using a LAN cable. The interface will be configured by the instrument and will appear to your system as a standard IEEE-488.2 device.

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