

User's Guide
Model 18*i* / 14*i* / 12*i*
Cryogenic Temperature Monitors

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Printing History

Revision 3d, February 2017

Certification

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Safety

The monitor 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 Models 18i and 14i are eight- and four-channel cryogenic temperature monitors. All inputs are identical and independent, with each capable of supporting the same wide range of sensors. Except for the difference in input channel count, the monitors are identical.

Easy to use: The monitor's front panel consists of a large, bright TFT-LCD display a 4-key keypad, an audio alarm and three status LEDs. Several display formats may be selected. Up to eight temperature readings may be displayed simultaneously or two channels with input names and temperature shown in a large easy to read font. Additional screens include temperature readings along with relay and alarm status information.

A single key press takes the screen to a menu tree where most features and functions of the instrument can be configured.

The status of built-in alarms and relays is indicated by LEDs located below the display.

Input Flexibility: Silicon (2-Volt) and GaAlAs (6-Volt) diode sensors are supported over their full temperature range by using 10 μ A constant-current DC excitation.

Positive Temperature Coefficient (PTC) resistor sensors including Platinum and Rhodium-Iron RTDs use constant-current, AC excitation.

Auto-ranged, constant-voltage AC excitation is used to provide robust support for cryogenic Negative Temperature Coefficient (NTC) sensors including Ruthenium-oxide, Carbon-Glass, Cernox™, Carbon-Ceramic, Germanium and several others.

Input Power: The monitors are shipped with a 12VDC@1A external power supply but may be powered by any source providing 10 to 30 Volts DC or up to 24 Volts AC.

The IEEE 802.3af Power-over-Ethernet (PoE) specification is also supported, allowing the monitor to be powered by it's local area network connection. Since PoE provides both instrument power and data over a single cable, remote data acquisition and high channel count systems can be simplified. PoE requires the use of a powered hub or power injector. The Model 18i / 14i / 12i will budget 13 Watts from the hub. Ethernet cables up to 300 meters may then be used.

Data logging: Data Logging is performed by continuously recording temperature and status to an internal circular memory buffer. Data is time stamped so that the actual time of an event can be determined. Non-volatile memory is used so that data will survive a power failure. With about 2.0GB of memory available, the monitors will retain over a month of historical data. Each sample includes readings for all input channels.

Alarms and Relays: Two 10.0A dry-contact relay outputs are available that can be asserted based on temperature setpoints from user selected input channels. These relays are large enough to switch most cryogenic valves. A fail-safe mode is available that activates a relay only when the source input channel temperature is within a specified range.

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

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

Remote Control: The standard remote interface is Ethernet. An IEEE-488.2 GPIB interface is optional and may be field installed at any time. The option, 4001-002, consists of an external module that is automatically configured by the monitor.

Remote interfaces implement an IEEE-488.2 SCPI compliant remote command language that is easy to learn and easy to read. This language is identical across all Cryo-con products to ensure that your investment in system software is always protected.

LabView™ drivers are available for all remote interfaces.

The monitor connects directly to any **Ethernet Local-Area-Network** (LAN). TCP and UDP data port servers bring fast Ethernet connectivity to data acquisition software including LabView™.

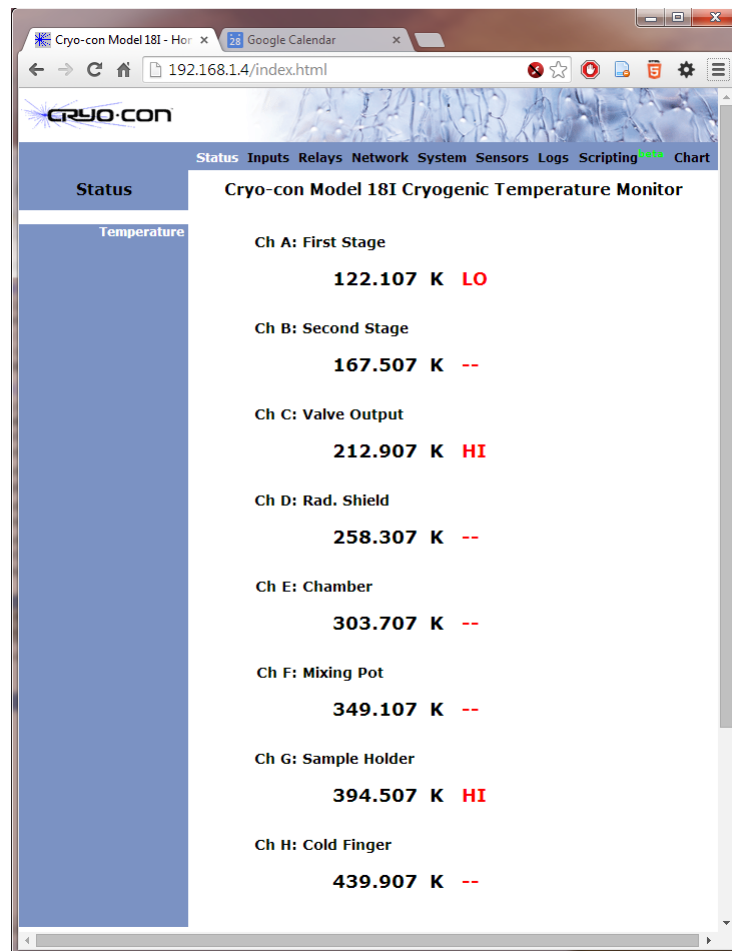
Using the SMTP protocol, the monitor will send e-mail based on selected alarm conditions.

Open Modbus: This open industrial automation protocol is implemented on the Model 18i / 14i / 12i, allowing them to interface directly to most Programmable Logic Controllers using the TCP interface.

EPICS CA server: To support distributed instrumentation applications, the monitors implement an EPICS Channel Access server.

Embedded Web Server: An embedded web 2.0 server allows the instrument to be viewed and configured in real time from any web browser. The instrument can be completely configured from the web page, including downloading sensor calibration curves, data-logging and firmware updates.

Firmware Updates: Full instrument firmware updates may be installed by using the embedded web server. Updates are free of charge and generally include enhancements and new features.



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.

Preparing the Monitor for Use

Model Identification

The model number is identified on the front and rear panel of the instrument as well as in various instrument displays.

| Part Number | Description |
|------------------|--|
| Model 18i | Eight-channel monitor. Includes 12VDC external power supply. |
| Model 14i | Four-channel monitor. Includes 12VDC external power supply. |
| Model 12i | Two-channel monitor. Includes 12VDC external power supply. |
| 4001-002 | IEEE-488.2 (GPIB) Option. Field installable. |
| 4001-001 | USB 2.0 Option. Serial Port Emulation. Field installable. |
| 04-0281 | Relay connector. 4-pin detachable terminal block. |

Table 1: Model Identification

Supplied Items

Verify that you have received the following items with your monitor. If anything is missing, contact Cryogenic Control Systems, Inc. directly.

- Cryogenic Temperature Monitor.
- User's Manual (PN 3118-029).
- Cryo-con software CD, Version 12 or above (PN 4134-029).
- Dual-input connector/cable assemblies (PN 4034-038). Four for the Model 18i and two for the Model 14i and one for the Model 12i.
- External Power Supply. 12VDC @ 2.0A. Universal Voltage Input. (PN 05-0006).
- Certificate of Calibration.

Apply Power to the Monitor

The external power supply provided with the monitor accepts 100 – 240VAC @ 50 – 60Hz and outputs 12VDC @ 1.0A. This may be plugged directly into the monitor's power jack on the rear panel. Alternatively, any supply from 10 to 30Volts DC or 24 Volts AC with a capacity of greater than 10VA may be used.

The monitor supports Power-Over-Ethernet so that power and communications can both be provided by the Ethernet input. An IEEE-802.3af Power-Over-Ethernet hub or injector is required. Simply plug the cable from this device into the Ethernet input of the monitor. In this case, the power jack should not used.



IMPORTANT: The monitor requires an Earth Ground reference connection to the rear panel. Failure to provide this connection will result in erratic measurements and can even damage input circuits.

Note: The monitor has a power key on the front panel. To turn power ON or OFF, press and hold the power (■) key for two seconds.

Note: The monitor 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: Do not remove the instrument's covers or attempt to repair it. There are no user serviceable parts, jumpers or switches inside the unit. Further, there are no software ROM chips, batteries or battery-backed memories. All firmware installation and instrument calibration functions are performed externally via the remote interfaces.

Factory Default Setup

A monitor with factory default settings will have an operational display like the one shown here. The dash (-) or dot (.) characters indicate that there is no sensor connected.

Note that, in some cases, there will be an erratic temperature display when no sensor is connected. This is not an error condition. The high input impedance of the monitor's input preamplifier causes erratic voltage values when unconnected.

Input Channel factory defaults are:

Sensor Units: Kelvin.

Sensor: Pt100 385 (DIN standard 100Ω Platinum RTD)

Alarm Enables: Off

To change these, press the **Enter**  key then go to the Input Channel Setup Menu section.


| | | | |
|----|---------|---|----|
| A: | 263.000 | K | -- |
| B: | 271.322 | K | Hi |
| C: | 279.643 | K | -- |
| D: | 287.964 | K | -- |
| E: | 296.285 | K | -- |
| F: | 304.606 | K | Lo |
| G: | 312.928 | K | -- |
| H: | 321.249 | K | Lo |

Instrument setup factory defaults are:

Display Filter Time Constant: 4.0 Seconds.

Display Resolution: 3 digits.

Data Logging: Off





To change these, press the **Enter**  key and then select the System Setup Menu.

Default network settings are:

IP Address: 192.168.1.4.

Subnet Address: 255.255.255.0

User: Admin Password:cryocon

ⓘ NOTE: Factory defaults may be restored at any time by use of the following sequence: 1) Turn power to the monitor OFF by pressing the **Enter**  key for about two seconds. 2) Press and hold the **Right**  key while turning power back ON. The monitor will display the message "Set Factory Defaults?". Then, press the **DEC**  key to restore defaults or the **INC**  key to continue without resetting.

ⓘ 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.

Technical Assistance

Trouble shooting guides and user's manuals are available on our web page at <http://www.cryocon.com>. Technical assistance may be also be obtained by contacting Cryo-con as follows:

Cryogenic Control Systems, Inc.
PO Box 7012
Rancho Santa Fe, CA 92067

e-mail: cctechsupport@cryocon.com

For updates to LabView™ drivers, Cryo-con utility software and product documentation, go to our web site at <http://www.cryocon.com> and select the Download area.

Returning Equipment

If an instrument must be returned to Cryo-con for repair or recalibration, 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.

Cryo-con's shipping address is:

Cryogenic Control Systems, Inc.
17279 La Brisa
Rancho Santa Fe, CA 92067

e-mail: sales@cryocon.com
Tel: 858-756-3900
Fax: 858-759-3515

Options and Accessories

Instrument Accessories

| Cryo-con Part # | Description |
|-----------------|--|
| 4034-038 | Dual Sensor Cable, 2 x 8 foot |
| 4034-033 | Shielded Sensor Connector Kit (DB9) |
| 3012-020 | Panel Mount hardware kit. See Appendix C |
| 3012-021 | Bench top instrument stand. See Appendix C |
| 4001-003 | Single Power-over-Ethernet Power injector. |
| 4001-002 | IEEE-488.2 (GPIB) Option. Field installable. |
| 4001-001 | USB 2.0 Option. Serial Port Emulation. |

Table 2: monitor Instrument Accessories

Cryogenic Accessories

| Cryo-con Part # | Description |
|-----------------|--|
| S950 | S950 series Silicon Diode Temperature Sensors. Temperature range: 1.4 to 375K. |
| S900 | S900 series Silicon Diode Temperature Sensors. Temperature range: 1.4 to 375K. |
| CP-100 | CP-100 series Ceramic Wound RTD, 100Ω |
| GP-100 | GP-100 series Glass Wound RTD, 100Ω |
| XP-100 | XP-100 series Thin Film Platinum RTD, 100Ω |
| XP-1K | XP-1K series Thin Film Platinum RTD, 1,000Ω |

Table 3: Cryogenic Accessories

A Quick Start Guide to the User Interface.



Figure 1: Model 18i Front Panel

Home Status Displays

The instrument powers up with the home status display. This is a status-only display and the contents are user selectable.

The factory default display is shown here. It shows all eight channels plus alarm indicators. The monitor has nine different Home Status displays that can be viewed and selected

by pressing the **Right ▶** key.

| | | | |
|----|---------|---|----|
| A: | 263.000 | K | -- |
| B: | 271.322 | K | Hi |
| C: | 279.643 | K | -- |
| D: | 287.964 | K | -- |
| E: | 296.285 | K | -- |
| F: | 304.606 | K | Lo |
| G: | 312.928 | K | -- |
| H: | 321.249 | K | Lo |


Several displays show temperature information in a large, easy to read font. Also shown is the input channel name. This name is a convenience that allows easy association of the input channel with it's actual connection. Channel names may be entered by use of the embedded web site or via any of the remote interfaces.




| | |
|----|-----------------|
| A: | Sample Holder |
| | 123.456K |
| B: | Rad. Shield |
| | 234.567K |

Under certain conditions, a **notifications** display will appear. This can be dismissed by pressing the **Right ▶** key.

| | | | |
|-------------------------------|----------|------|------|
| Firmware Download Complete | | | |
| A:-- | B:-- | C:-- | D:-- |
| E:-- | F:-- | G:-- | H:-- |
| Rly1:ChA | 123.456K | -- | |
| Rly2:ChB | 234.567K | -- | |







Navigating the Menu Tree







Setup and configuration functions are performed by working with the monitor’s menu tree. To access this tree from the Home Status display, press the **Enter**  key.

Navigation through all menus is performed by pressing the **INC**  or **DEC**  keys. A cursor will scroll up or down to show additional lines. Moving up the tree is done by pressing the **Right**  key. Note that the Home Status display is at the top of the tree.

The left most character on each line of a menu is the cursor. These cursors are used as follows:

 Indicates a selectable line. Pressing the **Enter**  key will select the function described on the menu line.

+ Indicates that the line is an enumeration field. Pressing the **Enter**  key will cause the cursor to flash. Then, pressing the **INC**  or **DEC**  keys will sequence through the allowed choices for the line. To make a selection, press the **Enter**  key again. To abort the selection process without making any change, press either the **INC**  or **DEC**  key.

Indicates that the selection is a numeric entry field. To change the value displayed, press the **Enter**  key and the cursor will flash. Then, press the **INC**  key to increment the number or the **DEC**  key to decrement the number. When the desired value is shown, press the **Enter**  key. Or, to abort entry without making any changes, press either the **INC**  or **DEC**  key.

Note that it is much easier to enter numbers from the embedded web page or from a remote interface.





| Key | Description |
|---|---|
|  Enter | 1) From Home screen, go to the top level setup menu. 2) Within a setup menu, Enter data or select a field (cursor display will indicate function). 3) Press and hold this key for two seconds to toggle AC power. |
|  INC | 1) Scroll Display UP. 2) When in a field selection mode, abort entry and return to scroll mode. 3) In a numeric field, increment. |
|  DEC | 1) Scroll Display DOWN. 2) When in a field selection mode, abort entry and return to scroll mode. 3) In a numeric field, decrement. |
|  Right | 1) Move up the menu tree one level eventually returning to the Home Status display. 2) In selection mode, scroll to next selection. |

Table 4: Function Key Descriptions.

Example Menu

Shown here is an example input channel setup menu with all of the cursor characters displayed.

Pressing the **INC ▲** or **DEC ▼** keys will move the cursor. Additional lines will be displayed after the last line shown.

The first line is the channel indicator and channel name. pressing the **Enter ■** key will cause the cursor to flash, then, each time an **INC ▲** or **DEC ▼** key is pressed, the next sequential input channel will be shown. Finally, pressing the **Enter ■** key again will select the displayed channel menu.

```
+ChA: Sample Holder
      123.456 K
A: 20 Pt100 385
A: BiasVoltage: N/A
A: Bridge: Auto
A: Hi Alarm: 100.00
A: Hi Alarm Ena: No
A: Lo Alarm: 10.000
```

The second line is an enumeration. It shows the temperature reading in real-time and allows the selection of temperature units. Pressing the **Enter ■** key will cause the cursor to flash. Then, pressing the

Right ► key will sequence through the allowed choices of K, C, F or S. To make a selection, press the **Enter ■** key again.

The sixth line is a numeric entry. To change the value displayed, press the **Enter ■** key and the cursor will flash. Then, press the **INC ▲** key to increment the number or the **DEC ▼** key to decrement the number. When the desired value is shown, press the **Enter ■** key.

LED indicators

There are three LED indicators below the display. They indicate the following:

Alarm (Red) – An enabled alarm condition is asserted.

Relay 1 (Green) and Relay 2 (Green) - Relay asserted.

Input Channel Displays

Temperature Units may be K, C or F. When Sensor Units (S) is selected, the raw input readings are displayed. These will be in Volts or Ohms depending on the specific sensor.

If the sensor type is set to None, the Input Channel has been disabled and a blank line is shown.

A sensor fault condition is identified by a temperature display of seven dash (-) characters. This indicates an open, disconnected or shorted sensor.

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.

If the input voltage is clipping, a display of ..clip. will be shown. This indicates that the input voltage is within the instrument's input range but is too large existing sensor configuration.

A display of !CLAMP! Indicates that the maximum input voltage is being exceeded. This can cause damage to the input circuits. The over-voltage condition should be addressed immediately.

| | |
|---|------------|
| K | Kelvin |
| C | Celsius |
| F | Fahrenheit |
| Ω | Ohms |
| V | Volts |

Table 5: Temperature Units

| | |
|---------|---|
| | Blank: The sensor type is set to None. |
| ----- | Sensor fault, The sensor is open, disconnected or shorted. |
| | Measurement is within the range of the instrument but is not within the sensor's calibration curve. |
| ..clip. | Input is clipping. |
| !CLAMP! | Input voltage exceeds the maximum. Damage may result. |

Table 6: Input Channel Error Displays

Power ON / OFF

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

ⓘ Note: The monitor 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.

Specifications, Features and Functions

Specification Summary

User Interface

Display Type: 21 x 8 character or 128x64 graphics TFT LCD.

Number of Inputs Displayed: Up to Eight.

Keypad: Sealed Silicon Rubber.

Temperature Display: Six significant digits, autoranged.

Display Update Rate: 0.5 Seconds.

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

Display Resolution: User selectable to seven significant digits.

Input Power

Input voltage is 10 to 30V DC or up to 24V AC, 10VA.

1. External transformer (Provided). Input 100 – 240VAC @ 50 – 60Hz.
2. IEEE-802.3af Power-Over-Ethernet (requires powered hub or injector).

Input Channels

Input channels are identical and each may be independently configured for any of the supported sensors.

Sensor Connection: 4-wire differential. DB-9 receptacles connect two channels. Connections are described in the “[Sensor Connections](#)” section.

Isolation: Sensor circuits are not electrically isolated from other internal circuits. However, there is a ‘single point’ internal connection to Earth (or Shield) ground in order to minimize noise coupling.

Input Protection: The common mode voltage between an input sensor connection and the instrument's ground must not exceed $\pm 40V$. The differential voltage between sensor inputs must not exceed $\pm 15V$.

Selection: Front Panel or remote interface. There are no internal jumpers or switches.

Sample Rate: 15 Hz per channel in all measurement modes.

Digital Resolution: 24 bits.

Measurement Filter: 0.5, 1, 2, 4, 8, 16, 32 and 64 Seconds.

Calibration Curves: Built-in curves for industry standard sensors plus eight user curves with up to 200 entries each. Interpolation is performed using a Cubic Spline.

Sensor Performance: Ambient Temperature is $25^{\circ}C \pm 5^{\circ}C$ for specified accuracy.

Diode Sensors

Configuration: Constant-Current, $10\mu A \pm 0.05\%$ DC excitation. Note: Current source error has negligible effect on measurement accuracy.

Input voltage range: Silicon Diodes: 0 to 2.50VDC, GaAIAs Diodes: 0 to 7.20VDC

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

Resolution: $2.3\mu V$

Drift: $<25\text{ppm}/^{\circ}C$

PTC Resistor Sensors**Configuration:** Constant-Current AC resistance.**Drift:** 25ppm/°C**Excitation Frequency:** 1.625Hz bipolar square wave.

| Range | Max/ Min Resistance | Excitation Current | Resolution | Accuracy |
|-----------------------|---------------------|--------------------|------------|--------------------|
| PTC100 1mA | 450Ω 0.01Ω | 1.0mA | 0.1mΩ | ± (0.004 + 0.01%)Ω |
| PTC1K 100μA | 4.5KΩ 0.1Ω | 100μA | 1.0mΩ | ± (0.05 + 0.02%)Ω |

Table 6: Accuracy and Resolution for PTC Resistors**NTC Resistor Sensors****Configuration:** Constant-Voltage AC measurement**Excitation Type:** Constant-Voltage AC resistance bridge, 10mV RMS.**Excitation Current:** 1.25mA to 100nA, continuously variable.**Excitation Frequency:** 1.67Hz bipolar square wave.**Accuracy (% reading + % range):** Reading >4Ω and < 30KΩ : ±(0.05% + 0.05%).**Drift:** >10Ω, 30ppm/°C. <10Ω, 35ppm/°C**Resistance Reading Range:** 0 to 100KΩ**Data Logging**

Data logging of input channel data is performed into an internal, 2GB byte circular buffer and is time-stamped with a real-time clock. Buffer memory is non-volatile and will retain valid data indefinitely without AC power. The monitor will log about 35 days of data where each entry contains eight temperature readings.

Status Outputs

Visual Alarms: Independent visual alarms can be configured for each input. They are displayed on the front panel as text characters and an LED indicator.

Audible Alarms: Enabled or disabled for each input channel.

Relay Outputs

Number: 2

Type: Dry-contact.

Contact ratings: 10A@125 VAC, 5A@250VAC or 5A@30VDC.

Remote Interfaces

Ethernet: Industry standard 10/100-BaseT. Electrically isolated

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

Language: Remote interface language is IEEE-488.2 SCPI compliant. Further, it is identical within the entire Cryo-con instrument line.

Compatibility: National Instruments LabView™ drivers available for all interfaces. LXI discovery.

Input Channel Characteristics

There are eight or four independent input channels; each of which can separately be configured for use with any supported sensor.

The sensor is selected by the user and this establishes the input configuration. Values of excitation current, voltage gain etc. will be determined by the microprocessor and used to automatically configure the channel. There are no jumpers or optional cards required to configure the various sensors.

Input Configurations

A complete list of the input configurations supported by the monitor is shown below:

| Sensor Type | Max. Voltage/ Resistance | Excitation | Use |
|-------------|-----------------------------|------------------------------------|--|
| Diode | 2.50V | 10 μ A DC CI | Silicon Diodes |
| GAAS | 7.2V | 10 μ A DC CI | GaAlAs Diode |
| NTC10UA | 250K Ω | 10 μ A DC CI | SI RO-105 RuOx sensor |
| ACR | 5 Ω to 100K Ω | 1.0mA to 0.1 μ A AC 10mV CV | NTC thermistors |
| PTC100 | 0.5 - 450 Ω | 1.0mA DC CI | 100 Ω Platinum |
| PTC1K | 5 - 4.5K Ω | 100 μ A DC CI | 1.0K Ω Platinum |
| Simulate | - | - | Simulated temperature process. Used for testing |
| Internal | - | - | Internal reference temperature |
| None | 0 | 0 | Disable input |

Table 7: Input Configurations

Bias types are:

CI – Constant Current through the sensor.

CV – Constant Voltage-drop across the sensor.

Note: A complete listing of factory installed sensors and their characteristics can be found in [Appendix A](#).

Specialized Sensors

The sensor type 'Simulate' reads the result of an internal simulated temperature process. This is often helpful for testing, demonstrations training.

The sensor type 'Internal' reads an internal temperature sensor located near the instrument's primary voltage reference. This measurement should be fairly close to ambient temperature and is useful to track variations in internal or 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.

Measurement Accuracy

Diode Sensors

The formulas for computing measurement accuracy while using diode sensors are:

$$MAV = 60 \cdot 10^{-6} + 5 \cdot 10^{-5} \cdot \text{SenRdg}$$

$$MAT = \frac{MAV}{\text{SenSen}}$$

Where:

MAV is the electronic Measurement Accuracy in Volts

MAT is the Measurement Accuracy in Kelvin

SenRdg is the sensor reading in Volts at the desired temperature.

SenSen is the sensor sensitivity in Volts / Kelvin at the desired temperature.

For example, if we want to calculate measurement accuracy using a Cryo-con S900 sensor at 10K, we would look up the sensor reading and sensitivity in the S900 data table in [Appendix E](#). At 10K, we see that SenRdg is 1.36317 Volts and SenSen is 0.002604 Volts/Kelvin. Therefore,

$$MAV = 60 \cdot 10^{-6} + 5 \cdot 10^{-5} \cdot 1.36317$$

and

$$MAT = \frac{MAV}{0.002604}$$

The result is that MAV = 128 μ V and MAT = 49mK.

PTC and NTC Resistor Sensors

The formulas for PTC and NTC resistor sensors are stated above. As an example, here is a computation for a PTC resistor with the PTC100 input configuration:

Where:

$$MAR = 0.002 + 1.0 \cdot 10^{-4} \cdot \text{SenVal}$$

$$MAT = \frac{MAR}{\text{SenRdg}}$$

MAR is the electronic Measurement Accuracy in Ohms

MAT is the Measurement Accuracy in Kelvin

SenRdg is the sensor reading in Ohms at the desired temperature.

SenSen is the sensor sensitivity in Ohms / Kelvin at the desired temperature.

To calculate measurement accuracy using a 100 Ω Platinum RTD in the PTC100 range with the sensor at 77.35K, we would look up the sensor reading and sensitivity in [Appendix E](#). and see that SenRdg is 20.38 Ω and SenSen is 0.423 Ω /Kelvin. Therefore, we compute MAR = 0.004038 Ω and MAT = 9.5mK.

Sensor Curves

The Model 18i / 14i / 12i includes built-in curves that support most industry standard temperature sensors. Additionally, eight user calibration curves are available for custom or calibrated sensors. Each user curve may have up to 200 entries. Custom curves are downloaded by using the embedded web server.

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

CalGen[®] is accessed through the web browser. Refer to the chapter on using CalGen[®].

Mechanical, Form Factors and Environmental

Enclosure is an Aluminum Extrusion with Aluminum front and rear panels.

The monitor is bench mountable. Panel mounting can be done by using an optional panel mount kit.

Dimensions are: 5.75"W x 2.875"H x 8.75"D. Weight is 3Lbs.

Environmental and Safety Concerns.

Note: The Model 18i / 14i / 12i is a lead free assembly and is RoHS compliant.

Safety

The monitor protects the operator and surrounding area from electric shock or burn, mechanical hazards, excessive temperature, and spread of fire from the instrument.

- **Keep Away From Live Circuits:** Operating personnel must not remove instrument covers. There are no internal user serviceable parts or adjustments. Refer instrument service to qualified maintenance personnel. Do not replace components with power cable connected. To avoid injuries, always disconnect power and discharge circuits before touching them.
- **Cleaning:** Do not submerge instrument. Clean exterior only with a damp cloth and mild detergent only.

Environmental Conditions

Environmental conditions outside of the conditions below may pose a hazard to the operator and surrounding area:

- Indoor use only.
- Altitude to 2000 meters.
- Temperature for safe operation: 5 °C to 40 °C.
- Maximum relative humidity: 80% for temperature up to 31 °C decreasing linearly to 50% at 40 °C.
- Power supply voltage fluctuations not to exceed $\pm 10\%$ of the nominal voltage.
- Over voltage category II.
- Pollution degree 2.
- **Ventilation:** The instrument has ventilation holes in its side covers. Do not block these holes when the instrument is operating.
- Do not operate the instrument in the presence of flammable gases or fumes. Operation of any electrical instrument in such an environment is a definite safety hazard.

Basic Operating Procedures

Configuring an Input

Before connecting a new sensor to the monitor, the instrument must be configured to support it. Many temperature sensors are pre-installed in the monitor. 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](#)”.

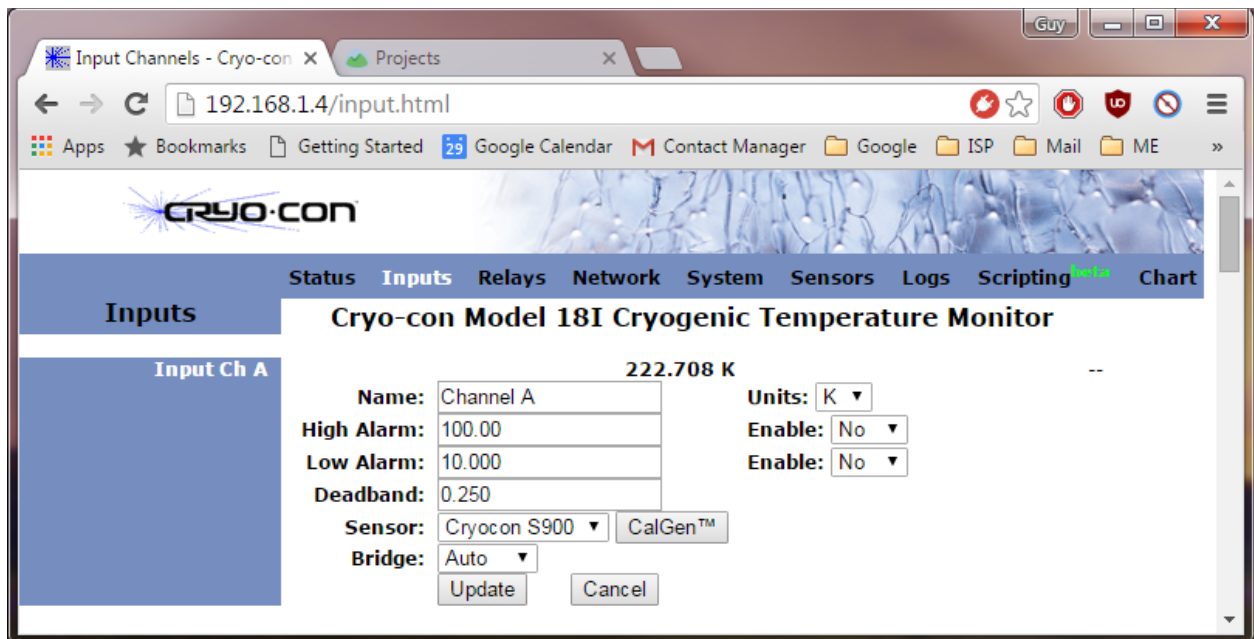
Note: A complete list of sensors installed at the factory is shown in [Appendix A](#).

Selecting a Sensor using a Web Browser

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

Configure the sensor by filling out the form:

- The sensor name is a user convenience. Use 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.



The screenshot shows a web browser window displaying the configuration page for the Cryo-con Model 18I Cryogenic Temperature Monitor. The browser address bar shows the URL 192.168.1.4/input.html. The page features a navigation menu with options: Status, Inputs, Relays, Network, System, Sensors, Logs, Scripting^{beta}, and Chart. The 'Inputs' section is active, showing a table with one entry for 'Input Ch A' with a temperature reading of 222.708 K. Below the table is a configuration form for 'Channel A' with the following fields: Name (Channel A), High Alarm (100.00), Low Alarm (10.000), Deadband (0.250), Sensor (Cryocon S900), Bridge (Auto), Units (K), and two Enable (No) options. 'Update' and 'Cancel' buttons are at the bottom.

| Input Ch A | 222.708 K | -- |
|---------------|--------------|------------|
| Name: | Channel A | Units: K |
| High Alarm: | 100.00 | Enable: No |
| Low Alarm: | 10.000 | Enable: No |
| Deadband: | 0.250 | |
| Sensor: | Cryocon S900 | CalGen™ |
| Bridge: | Auto | |
| Update Cancel | | |

Selecting a Sensor from the Front Panel.

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

1. Navigate to the Input Channel Setup menu for the desired channel. The second line of this menu will show the current temperature in real-time. This field also lets you select the desired display units.
2. Use the **Up ▲** or **Down ▼** keys to go to the **Sen:** field then press **Enter ■** to scroll through a list of available sensors. When the desired sensor is seen, press the **Enter ■** again to make the selection.

From this point, you can continue to add an alarm or view the statistics of the selected input. The full input channel configuration menu is shown here for reference.

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

```
+ChA: Channel A
      77.123K
A:Sen:Pt100 385
A:Bridge: Auto
A:High Alarm:200.000
A:High Enable: No
A:Low Alarm: 200.000
A:Low Alarm Ena:Yes
A:Deadband:0.250
A:Latched Enable:No
A:Max:      123.00K
A:Min:      23.00K
A:Accum: 1.0000 Min
A:S2: 0.0123
A:M: -0.030K/Min
A:b: 0.500K
A:Reset Statistics
```

Downloading a Sensor Calibration Curve

The monitor accommodates up to eight user-defined sensor calibration curves that can be used for custom or calibrated sensors.

The embedded web server will read and parse 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. |
| SI .txt | Columns are reversed from other formats. Must be manually converted to a .crv file before use. |
| Other .txt | Must be converted to a .crv file before use. |

To download a sensor curve, open the embedded web page and click on Sensors. Next, go to the desired user sensor area and fill out the header and click Update.

Click on Choose File to select your user curve then click Upload to transfer the file.

When the curve upload is complete, the number of points successfully parsed will be shown.

To download a user curve, click on the Download Curve field.

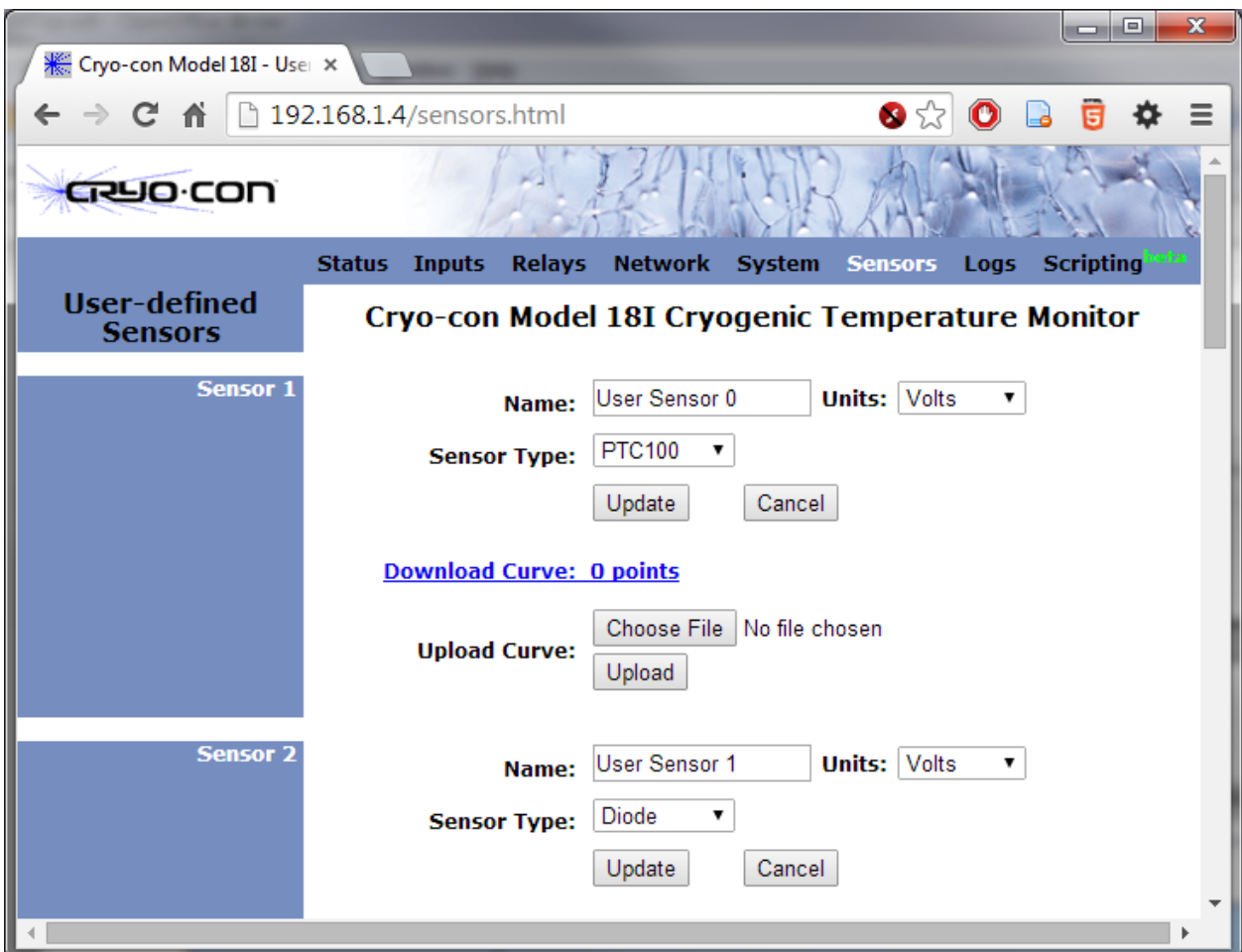


Figure 2: Sensor Curve Downloading Web Page

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.

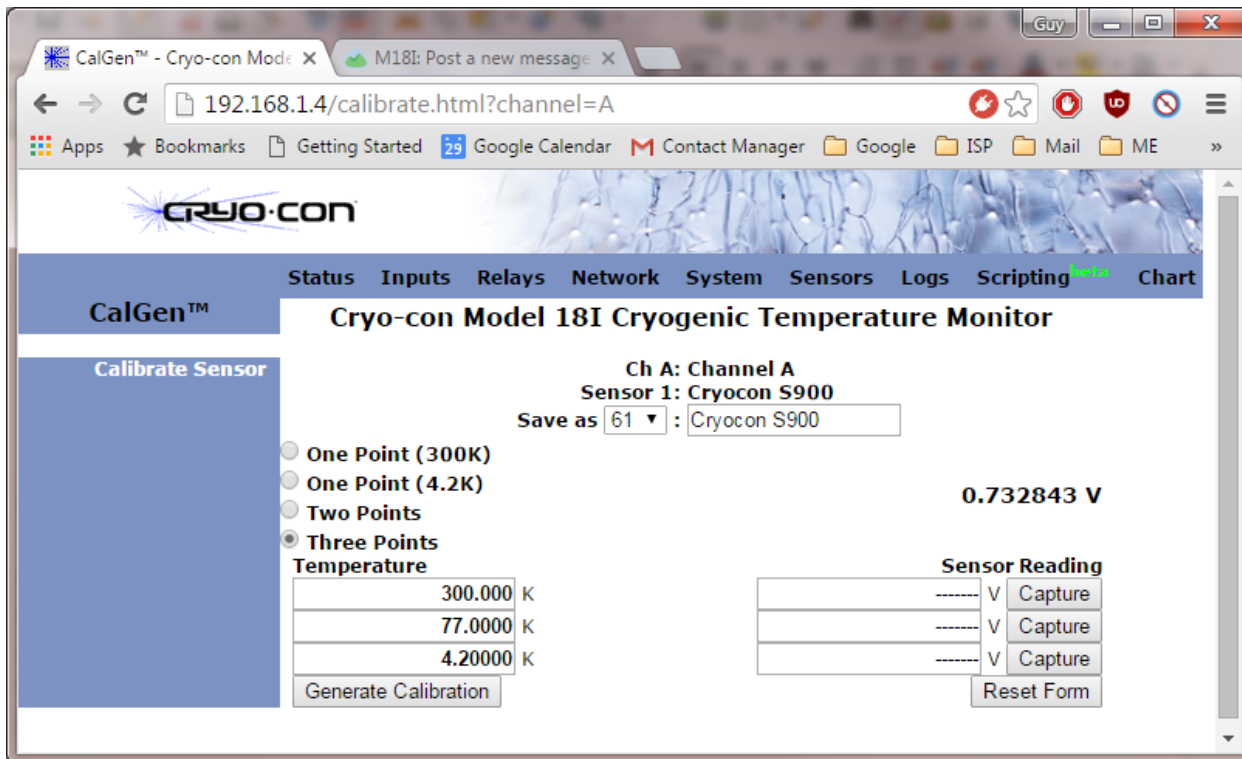
Curves can be generated from any user selected sensor calibration curve in the instrument, including curves that the user has installed. The result is written to a specified internal user curve location.

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 monitor 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.

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](#).

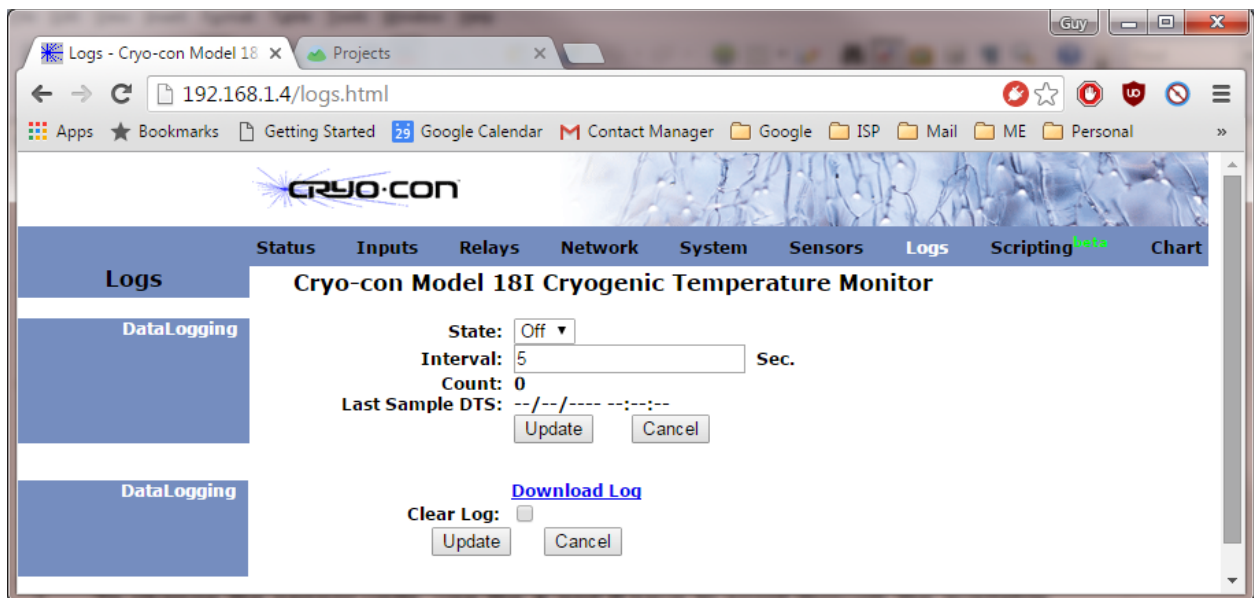
Data logging can be configured and enabled and downloaded from the embedded web server's Logs page. The Logging Enable field turns logging on and off and the Interval field sets the logging sample rate. The Current Count field shows how many samples have been accumulated.

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

Reading the Data Log Buffer

Reading, or uploading, the monitor 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 Model 18i / 14i / 12i has two relays that can be used to control external processes. Able to switch up to 10 Amperes, they can even be used with large solenoid valves or motors.

Relays can be configured for several modes of operation. **Auto** is the basic way of setting the controller to assert a relay based on a high or low temperature setpoint. **Within** mode is the logical inverse of **Auto** mode in that it asserts the relay when a temperature measurement is within a high and low limit rather than outside of it. The **On** and **Off** modes simply assert or clear a relay under remote control and the Control mode asserts a relay whenever the controller is actively controlling temperature.

| 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. |

Table 8: Relay Modes

Relay status indicators are used to show the status of a relay. These indicators are the same when viewed on the front panel, the embedded web page or from a remote command. Additionally, there are two LEDs on the front panel that illuminate whenever their relay is asserted.

| 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 9: Relay Status Indicators

Relay Configuration

Relay configuration can be done from the front panel, the embedded web server or by using remote commands.

From the front panel, the Relay Setup Menu is used for configuration. This menu is accessed from the Home menu by pressing the **Enter** key and then selecting Relay 1 or 2. Here, the relay Source input may be selected as any of the input channels and the Mode field controls relay operation. The Deadband field sets the amount of hysteresis applied to the temperature measurement before a relay is toggled.

As an example, if the deadband is set to 0.25K, a high temperature relay condition 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.

```
+Relay1 Setup Menu
1:Source:ChA
1:Src Temp:273.123
1:Rly Status: --
1:Mode: Auto
1:Deadband: 0.25
1:High: 200.00
1:High Enable: No
1:Low: 100.00
1:Low Enable: No
```

Relay Auto Mode

Auto mode is used to implement simple high and low setpoint 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 Within Mode

The Within 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 continue to function when the relay is asserted.

To set a fail-safe function, the user must a) Set the Mode to Within, b) Set both the high enable and low enable to Yes and c) Set a window by entering 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 ON and OFF Modes

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

RELAY 1 : MODE ON

Using Temperature Alarms

The Model 18i / 14i / 12i monitors provide 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 the Alarm LED and 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.

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

| 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 10: Alarm Status Indicators

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.

```
+ChA: Channe1 A
      77.123K
A:Sen:Pt100 385
A:Bridge: Auto
A:High Alarm:200.000
A:High Enable: No
A:Low Alarm: 200.000
A:Low Alarm Ena:Yes
A:Deadband:0.250
A:Latched Enable:No
A:Audio Enable: No
```

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:

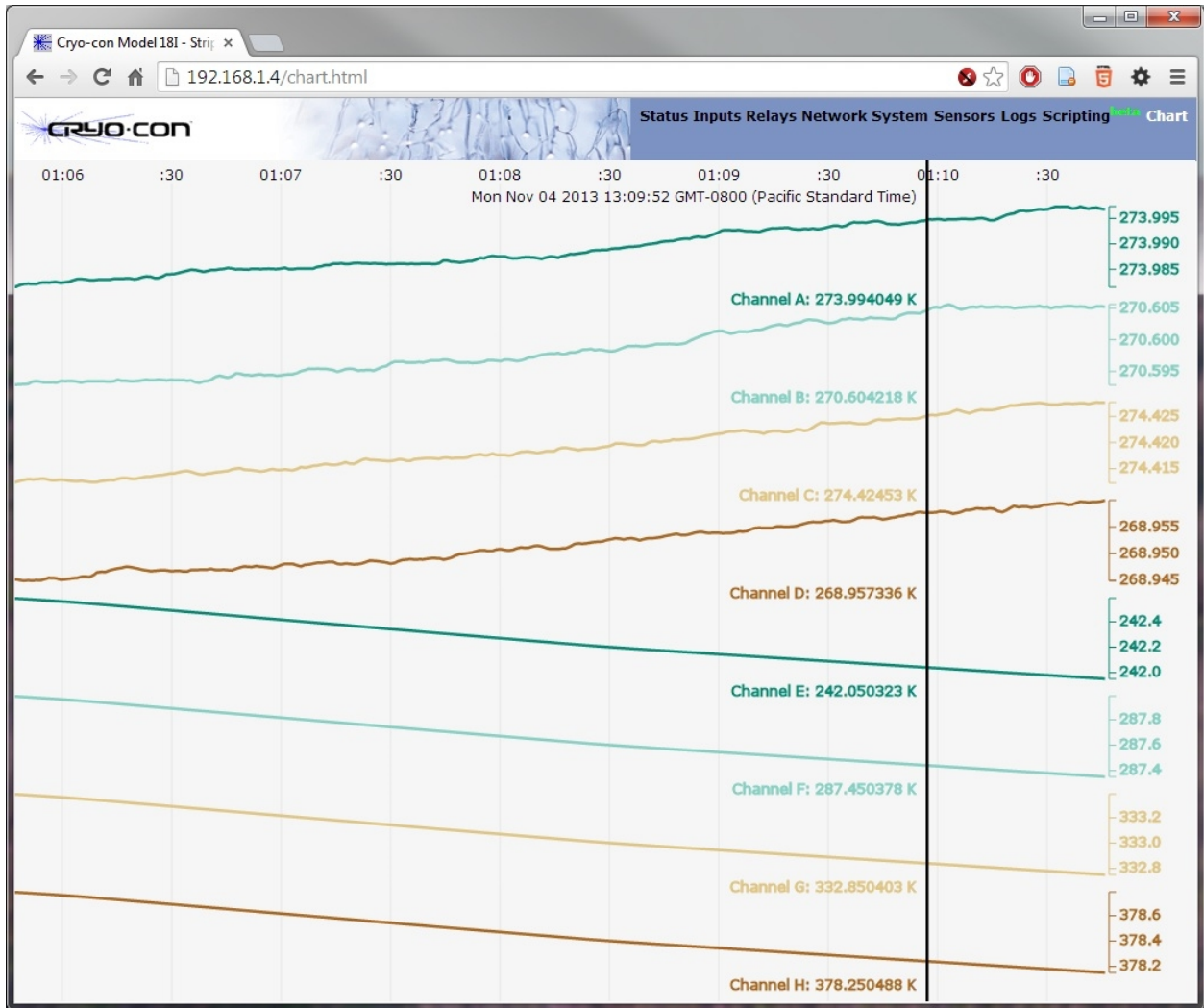


Figure 3: Real-time strip chart display

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

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.

Using Modbus

Modbus is an industrial protocol that connects the monitor to supported devices including Programmable Logic Controllers (PLCs). It is supported by the Model 18i / 14i / 12i on the TCP interface.

The Model 18i / 14i / 12i 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 18i / 14i / 12i 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 18i / 14i / 12i'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 11: 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=(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 12: 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 13: 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 |
| 8 | E | Bits 15-0 |
| 9 | E | Bits 31-16 |
| 10 | F | Bits 15-0 |
| 11 | F | Bits 31-16 |
| 12 | G | Bits 15-0 |
| 13 | G | Bits 31-16 |
| 14 | H | Bits 15-0 |
| 15 | H | Bits 31-16 |

Table 14: 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 18i / 14i / 12i 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 monitors web page and click on Scripting in the navigation bar.

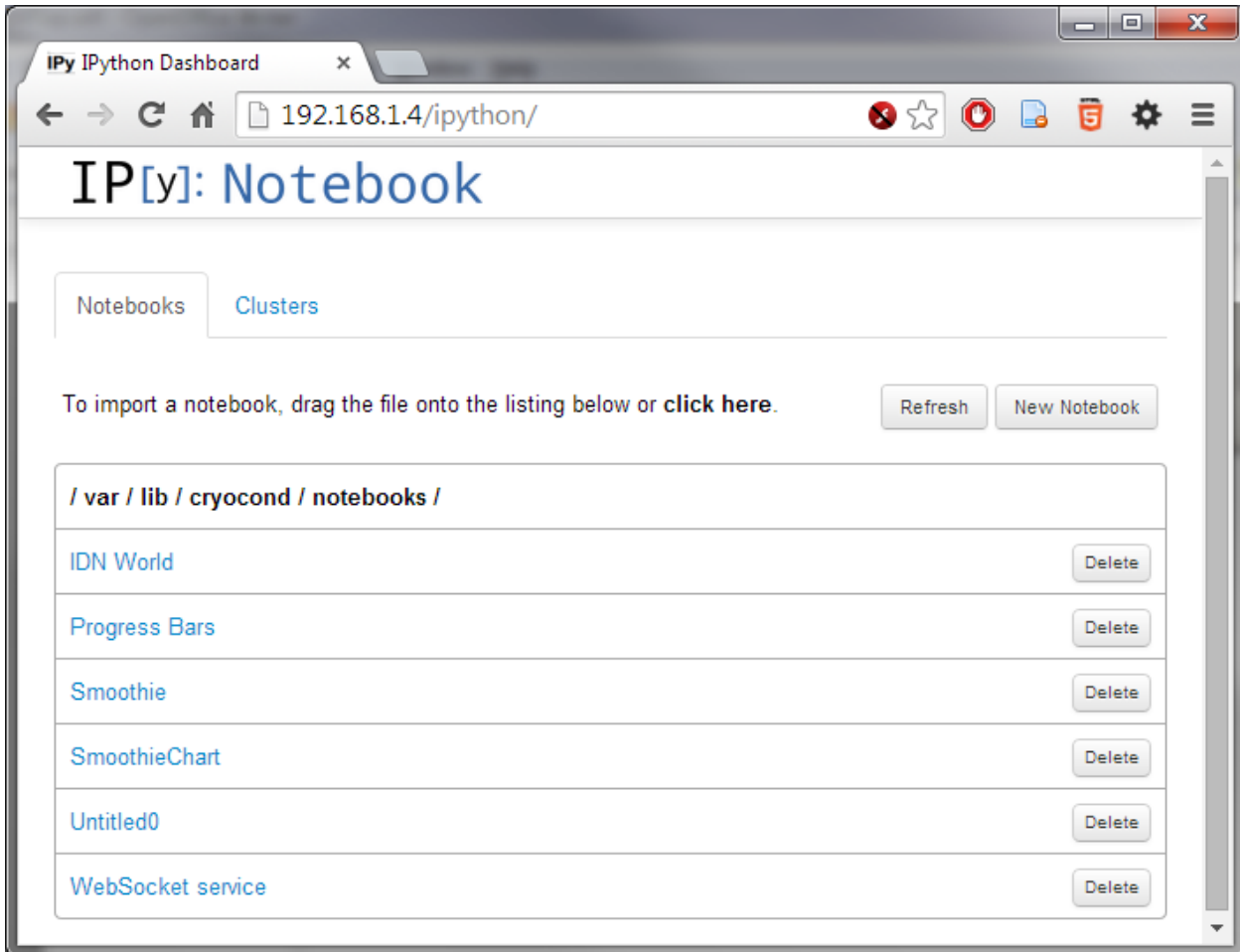


Figure 4: IPython Notebook with example scripts

The default notebook includes several example scripts.

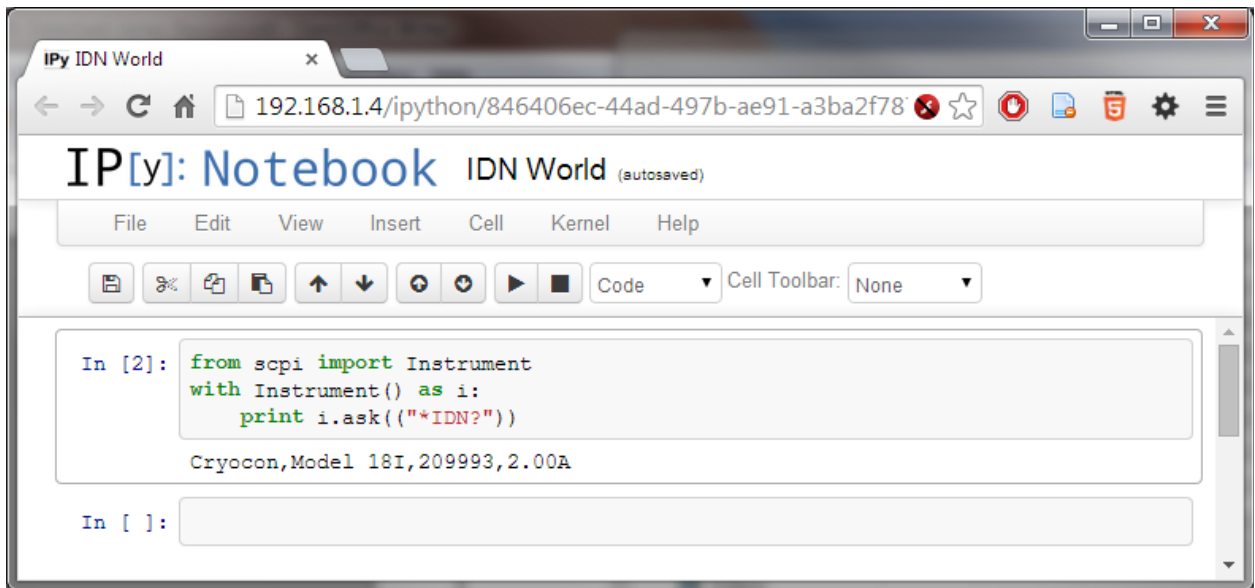


Figure 5: Example Scripts

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.

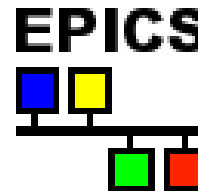
Note: The scripting function uses features of the HTML5 mark-up language that are only supported in newer web browsers. In older browsers, this page will be blank.

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 18i 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 18i.

For extensive information about the EPICS system, please refer to the Argonne National Laboratory web site at: <http://www.aps.anl.gov/epics/index.php>.

The Model 18i 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 18i 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 18i needs to be configured.

1. The network configuration must be set.
2. The name of a new Model 18i is CCM18i-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 18i'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 monitor 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 18i 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 M18i 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 15: EPICS Process Variables

Shielding and Grounding Issues

Grounding

Power supplied to the instrument by an external supply or via Power-Over-Ethernet does not provide an earth ground reference. In order to minimize noise coupling into the instrument and customer's equipment, connection to an earth ground reference should be established by some other means. Common methods include:

1. Connecting the sensor cable shield to the instrument's chassis on one end and to the cryostat ground on the other.
2. Connection of a ground wire from the instrument's rear panel to a ground reference.



IMPORTANT: The monitor requires that an Earth Ground reference connection is made at the rear panel. Failure to provide this connection will result in erratic measurements and can even damage input circuits.

The sensor cables provided connect their shields to the monitor's chassis; Therefore, the required Earth Ground can be made by connecting the shield wire at the opposite end to a ground reference point. This is usually done by connecting it to the back-shell of the cryostat connector.

The Single-Point-Ground

The Model 18i / 14i / 12i 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 its 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.

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

1. All sensors 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.
3. At least one cable must have its shield connected to the connector's back-shell on the cryostat end. This will complete a Faraday Cage RFI shield around the system.
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 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. However, the serial port connects instrument grounds and can cause problems.

Instrument Calibration

Calibration of the monitor 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 monitor 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. Calibration of a measurement range is the simple process of generating an offset and gain value. However, since there are several input ranges available on each sensor input, the process can be time consuming.



Caution: Any calibration procedure will require the adjustment of internal data that can significantly affect the accuracy of the instrument. Failure to completely follow the instructions in this chapter may result in degraded instrument performance. The Cryo-con utility software used in this procedure will first read all calibration data out of the instrument before any modifications. It is good practice to record these values for future reference and backup.

Cryo-con Calibration Services

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

Calibration Interval

The monitor should be calibrated on 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 you select, Cryo-con recommends that complete re-adjustment should always be performed at the calibration interval. This will increase your 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.

Calibration Procedure

Please contact Cryo-con for a complete calibration procedure.

Remote Operation

Remote Interface Configuration

The monitor has a 10/100-BaseT Ethernet LAN connection. There is also an external IEEE-488.2 (GPIB) option that is field installable. Connection to either of these interfaces is made on the rear panel of the instrument. For specifics about the connectors and cables required, refer to the section on Rear Panel Connections.

Supported Ethernet Protocols

HTTPS: The monitor's secure HTTPS server is used to by the instrument's embedded web server. Advanced users can install their own security certificates.

HTTP: Non-secure version of HTTPS.

SMTP: The Simple Mail Transport Protocol is used to send E-mail from the monitor to a selected address. E-mail is used to report instrument status and is triggered by various user selected events. If sending e-mail over the Internet is desired, the local area network connected to the monitor will have to have an active mail server.

NTP: The Network Time Protocol allows a client to obtain the date and time from a host NTP server. If a time server is available on the Local Area Network, the monitor will periodically query it to update it's internal real-time clock.

TCP: The Transmission Control Protocol provides reliable, flow-controlled, end-to-end, communication between two connected devices. TCP operates even if packets are delayed, duplicated, lost, delivered out of order, or delivered with corrupted or truncated data.

UDP: The User Datagram Protocol implemented on the monitor is similar to TCP but is connectionless. Since a connection does not need to be negotiated or maintained, UDP has a much lower overhead than TCP.

Discovery (IGMP): Allows the monitor to be discovered using the IGMP protocol.

LXI / VXI-11 Discovery: The LXI / VXI-11 discovery protocol is implemented primarily as a convenience to LabView users.

Modbus: This is an industrial protocol that connects the monitor to supported devices including industrial Programmable Logic Controllers (PLCs). It is supported on the LAN interface.

SCPI: This is an industry standard ASCII command language whose syntax is specified in the IEEE-488.2 specification. It is the standard language for remote commands. SCPI is supported for TCP and UDP. Advanced users can also use encrypted SCPI with the HTTPS protocol.

Ethernet Configuration

Each device on an Ethernet Local Area Network must have a unique IP Address. Further, the address assigned to the monitor must be within the range of the computers you want it to communicate with. This range is determined by the Subnet Mask.

The monitor factory default settings are as follows:

- IP address: 192.168.1.4
- Subnet Mask: 255.255.255.0
- Gateway: 192.168.0.1
- TCP Data Socket: 5000, UDP Data Socket: 5001

UDP Configuration

UDP is a simple connection-less protocol that can be used to communicate with Cryo-con instruments. The user binds a UDP socket and communicates with the instrument in a fashion similar to RS-232 style communications.

TCP Data Socket Configuration

TCP is a connection orientated protocol that is more complex and has higher overhead than UDP. The user must bind a TCP socket and negotiate a connection before communicating with an instrument.

Web site configuration

The instrument's embedded web site may be opened in any web browser by typing **http://192.168.1.4** into the address bar, and the monitor's Home Page should appear.

Ethernet Firewall

The monitor has a built-in firewall that provides a substantial degree of added security. The firewall can only be accessed from the front panel by going to the Network menu and then the Firewall Config menu. For the best security, any protocol or service that is not being used should be turned OFF.

| | |
|------------------------|--------------|
| SCPI TCP : | Allow |
| SCPI UDP : | Allow |
| Modbus : | Allow |
| HTTP : | Allow |
| HTTPS : | Allow |
| Discovery : | Allow |
| NTP : | Allow |
| Remote Inputs : | Allow |
| VXI-11 : | Allow |

Note: Disabling HTTP also disables user scripts.

IEEE-488 (GPIB) Option Configuration

The only configuration parameter for the optional GPIB interface is to set the address. This is done by using the [System Functions Menu](#) described above. Once the external GPIB interface is connected to the controller's LAN port, configuration is performed by the instrument.

Note that each device on the GPIB interface must have a unique address. Set the instrument's address to any value between 1 and 31. The factory default is 0 indicating that the option is disabled.

The GPIB interface does not use a termination character, or EOS. Rather, it uses the EOI hardware handshake method to signal the end of a line. Therefore, the host must be configured to talk to the instrument using EOI and no EOS.

| | |
|-----------------------------------|------|
| Primary Address: | 1-31 |
| Secondary Address: | None |
| Timeout | 2S |
| Terminate Read on EOS | NO |
| Set EOI with EOS on Writes | YES |
| EOS byte | N/A |

Table 16: GPIB Host Setup Parameters

SCPI Programming Guide

General Overview

This brief is intended to assist the user interested in remote programming of any Cryo-con instrument. The 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 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 obsoleted.
- 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 your intent is to remotely program a Cryo-con instrument with fairly simple sequences, you can skip to the section titled "[Commonly Used Commands](#)". This is a simple cheat-sheet format list of the commands that are most frequently used.

If you are an advanced user with a familiarity of the SCPI programming language, the section titled "[Remote Command Descriptions](#)" is a complete reference to all commands.

If you are not familiar with the SCPI language but need to perform advanced programming tasks, the 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 **I**nstruments. Commonly called '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 |
| VARlance | 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 | C | D}: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 both 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. You must 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

Commands must be terminated by an ASCII 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 can 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 SCPI commands is given in the User's Manual chapter titled "SCPI Command Summary". The manual also has complete descriptions of all SCPI commands. This section is intended to show a few of the more commonly used commands.

NOTE: SCPI commands are not case sensitive.

| Function | Command | Comment |
|--|------------------------------|---|
| Instrument Identification | | |
| Read the instrument identification string | <code>*idn?</code> | Returns the instrument identification string in IEEE-488.2 format. For example: "Cryocon,Model 18I,204683,1.00" 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 | <code>input? b</code> | 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. | <code>input a:units k</code> | Choices are K- Kelvin, C- Celsius, F- Fahrenheit and S- native sensor units (Volts or Ohms). |
| Read the temperature units on channel B | <code>input b:units?</code> | Return is: K, C, F or S. |

Table 17: Commonly Used SCPI Commands

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 selections. Examples are:

```
INPut:CATalog?
    Returns: ChA,ChB,ChC,ChD,ChE,ChF,ChG,ChH,
RELay:CATalog?
    Returns: 1,2,
RELay:MODe:CATalog?
    Returns: Auto ,Off,On ,
```

Debugging Tips

1. To view the last command that the instrument received and the last response it generated, press the System key and then select the Network Configuration Menu. The last two lines of this menu show > and < characters. These two lines show the last command received by the instrument and the last response generated.
2. If you are unsure of the values allowed for a parameter, use the CATalog? query.
3. 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.chiark.greenend.org.uk/~sgtatham/putty/download.html>.
4. 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.

SCPI Command Tree

SYSTEM commands

```

SYSTem:ADRes <address>
SYSTem:AMBient?
SYSTem:BAUD {9600 | 19200 | 38400 | 57200}
SYSTem:BEEP <seconds>
SYSTem:DATE "mm/dd/yyyy"
SYSTem:DISPlay {ON | OFF}
SYSTem:DISPlay :TEXT "Display Text"
SYSTem:DISTc {0.5 | 1 | 2 | 4 | 8 | 16 | 32 | 64}
SYSTem:DRES {FULL | 1 | 2 | 3}
SYSTem:FWREV?
SYSTem:HOME
SYSTem:HWRev?
SYSTem:RESeed
SYSTem:NAME "name"
SYSTem:NVSave
SYSTem:RESeed
SYSTem:TIME "hh:mm:ss"

```

Input Commands

```

INPut? {A | ... | H} or INPut {A | ... | H}:TEMPerature?
INPut {A | ... | H}:UNITs {K | C | F | S}
INPut {A | ... | H}:NAME "Input Channel Name"
INPut {A | ... | H}:SENPr?
INPut {A | ... | H}:BRANge {Auto | 1.0mA | 100uA | 10uA}
INPut {A | ... | H}::SENSor <ix>
INPut {A | ... | H}:ALARm?
INPut {A | ... | H}:ALARm:HIGHest <setpt>
INPut {A | ... | H}:ALARm:LOWest <setpt>
INPut {A | ... | H}:ALARm:HIENa { YES | NO }
INPut {A | ... | H}:ALARm:LOENa { YES | NO }
INPut {A | ... | H}:ALARm:Clear
INPut {A | ... | H}:ALARm:LTEna { YES | NO }
INPut {A | ... | H}:ALARm:AUDio { YES | NO }
INPut {A | ... | H}:MINimum?
INPut {A | ... | H}:MAXimum?
INPut {A | ... | H}:VARiance?
INPut {A | ... | H}:SLOpe?
INPut {A | ... | H}:OFFSet?
INPut {A | ... | H}:TIME?
INPut {A | ... | H}:RESet
INPut {A | ... | H}:TCOffset
INPut {A | ... | H}:TCGAin

```

Sensor Calibration Curve Commands

```

CALcur
SENSor <index>:NAME "name string"
SENSor <index>:NENTry?
SENSor <index>:UNITs {VOLTS | OHMS | LOGOHM}
SENSor <index>:
  TYPE { DIODE | GAAS | ACR | PTC100 | PTC1K | NTC10UA }
SENSor <index>:MULTiPLY <multiplier>

```

Data Logging Commands

```
DLOG:RUN {OFF | ON}
DLOG:TIME <Seconds>
DLOG:COUNt?
DLOG:READ?
DLOG:RESET
DLOG:CLEAR
```

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 }
RELAy {1 | 2} :TEMP?
```

Network Commands

```
NETWork:DHCP {ON | OFF}
NETWork:IPADdress "IPA"
NETWork:MACAddress?
NETWork:NAME "name"
NETWork:PORT <port number>
NETWork:SUBnet "Subnet Mask"
NETWork:GATeway "Gateway"
NETWork:NTPServer "IPA"
NETWork:DNSServer "IPA"
```

Mail Commands

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

IEEE Common Commands

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


SCPI Command Descriptions

IEEE Common Commands

*OPC

The *OPC command will cause 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 will cause the instrument to identify itself. The Model 18i / 14i / 12i will return the following string:

Cryocon, Model 18i / 14i / 12i,<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

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:ADRes <address>

Sets and queries the address that the IEEE-488.2 (GPIB) remote interface 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. This command has no effect on other interfaces.

SYSTEM:AMBIent?

Queries the internal reference junction temperature. Value reported as a decimal number in units of Celsius.

SYSTEM:BEEP <seconds>

Asserts the audible alarm for a specified number of seconds. Command only, no query.

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:DISPlay {ON | OFF}

Turn the front panel ON or OFF. In the OFF mode, the LCD display, display back-light and all LED indicators are OFF. Power-cycling the instrument returns to front panel ON. Note that all other functions of the monitor continue to work normally.

SYSTEM:DISPlay:TEXT "display text"

Displays a text message in the notifications area on the front panel display. This area has four lines and 20 characters per line. The display text string can be up to 80 characters but cannot include formatting characters. Upon receipt of this command, the front panel automatically switches to the notification screen and displays the specified text.

SYSTEM:DISTc {0.5 | 1 | 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:DRES {FULL | 1 | 2 | 3}

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

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

SYSTem : FWREV?

Queries the instrument's firmware revision level.

SYSTem : HOMe

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

SYSTem : HWRev?

Queries the instrument's hardware revision level.

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 : 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.

SYSTem : RESeed

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

Note: The RESEED command is useful in systems where a computer is waiting for a reading to settle. Issuing the RESEED command will reduce the required settling time of the reading.

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 seven.
- Channel ID tags including CHA or CHB.
- Alphabetic including A or B.

INPut? {A | ... | H} or**INPut {A | ... | H} : 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 | ... | H} : 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 | ... | H} : 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 its use.

INPut {A | ... | H} : BRANge {Auto | 1.0mA | 100uA | 10uA}

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

INPut {A | ... | H} : SENPr?

The INPUT:SENPR query reports the 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. However, the synchronous input filter has been applied. Query only.

INPut {A | ... | H} : SENSor <ix>

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

INPut {A | ... | H}: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. |

There is a 0.25K hysteresis in the assertion of a high or low temperature alarm condition.

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

INPut {A | ... | H}: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 will be asserted.

INPut {A | ... | H}: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 will be asserted.

<setpt> is the alarm setpoint temperature.

INPut {A | ... | H}: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 | ... | H}: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 | ... | H}: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 | ... | H}:ALARm:CLEar

Clears any latched alarm on the selected input channel.

INPut {A | ... | H}: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 | ... | H}:MINimum?

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

INPut {A | ... | H}:MAXimum?

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

INPut {A | ... | H}: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 | ... | H}: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 | ... | H}: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 | ... | H}:TIME?

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

INPut {A | ... | H}:RESet

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

Relay Commands**RELay? {1 | 2}**

Relay Status Query. The two auxiliary relays available in the monitor are addressed as 0 and 1. The RELAY 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} :TEMP?

Query the current temperature reading on the relay's source input.

RELay {1 | 2} :SOURCE {A | ... | H}

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}

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. |

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 Calibration Curve Commands

The CALCUR commands are used to transfer sensor calibration curves between the instrument and the host controller.

Curves are referenced by an index number. In the monitor, there are eight user curves numbered 1 through 8.

The CALCUR data block consists of many lines of ASCII text. The format is the same as the file format for user calibration curves, which is detailed in the section [User Calibration Curve File Format](#).

CALCUR <index>

Sets or queries sensor calibration curve data.

Uses a fragmented message protocol to send many lines of ASCII text to the instrument.

Note: It is much easier to use Cryo-con's Utility Software to send and receive sensor calibration curves.

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.

ⓘ 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 | GAAS | ACR | PTC100 | PTC1K | NTC10UA}

Sets or queries the type of sensor at <index>. For more information on sensor types, please refer to the [Input Configurations](#) section. Index is 0 through 7.

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.

Network Commands

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

NETWork:DHCP {ON | OFF}

Set or query DHCP enable. Changes do not take effect until the next power cycle.

NETWork:IPAdDress "IPA"

Sets or queries the instrument'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 "192.168.1.4".

NETWork:MACAddress?

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

NETWork: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. This command is the same as the SYSTem:NAME command.

NETWork:PORT <port number>

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

Mail Commands

MAIL {A | ... | H}: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 | ... | H}:FROM "from e-mail address"

Set or query the 'from' e-mail address. Parameter is an ASCII String. For example: "model18@mynetwork.com".

MAIL {A | ... | H}:DEST "to e-mail address"

Set or query the 'to' e-mail address. Parameter is an ASCII String. For example: "model18@mynetwork.com".

MAIL {A | ... | H}:PORT <port number>

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

MAIL {A | ... | H}: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?**DLOG : READ?**

Reads the entire contents of the log buffer. Each record is sent on a single line. Format is:

<#>, MM/DD/YYYY, HR,MN,SC, ChA, CHB, ChC,ChD

where:

<#> is the record number.

MM/DD/YYYY is the date in Month, Day, Year format.

HR,MN,SC is the time in Hour, Minute, Second format.

Lines end with a <CR><LF> sequence. End of transmission is indicated by a line that only contains a semi-colon.

DLOG : RESEt

Sets the logging record number to zero.

DLOG : CLEAR

Clears the data logging buffer.

EU Declaration of Conformity

According to ISO/IEC Guide 22 and EN 45014

Product Category: Process Control Equipment
Product Type: Temperature Measuring System
Model Numbers: Model 18i / 14i / 12i
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:

89/336/EEC, "Council Directive of 3 May 1989 on the approximation of the laws of the Member States relating to electromagnetic compatibility"

73/23/EEC, "Council Directive of 19 February 1973 on the harmonization of the laws of Member States relating to electrical equipment designed for use within certain voltage limits".

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

| | | |
|------------------|------------------|------------------------------|
| <u>Emissions</u> | <u>Immunity</u> | <u>Safety</u> |
| EN 55011,1998 | EN 50082-1, 1997 | EN 61010, 1994 A2: May 96 |

The technical files and other documentation are on file with Mr. Guy Covert, President and CEO.

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.
July 15, 2013

Appendix A: Installed Sensor Curves

Factory Installed Curves

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

| Sensor # | Name | Description |
|----------|---------------|--|
| 0 | None | No Sensor. Used to turn the selected input channel off. |
| 1 | Cryo-con S900 | Cryo-con S900 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. |
| 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 $^{\circ}$ C Platinum RTD using DIN43760 standard calibration curve. Range: 23 to 1023K, 100 μ A excitation. |
| 31 | SI RO-105 | Scientific Instruments Inc. RO-105 Ruthenium Oxide sensor. Temperature range is: 2 to 273K. Use with the NTC10 μ A input configuration only. |
| 32 | SI RO-600C | Scientific Instruments Inc. RO-600 Ruthenium-Oxide sensor with constant-voltage AC excitation. Temperature range is: 1.0K to 300K. |
| 59 | Internal | Internal reference temperature. |

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

INPUT B SENSor 21 would set input B to use the Pt1K 385 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 eight custom sensors. This table shows the sensor index and default name of the user curves:

| User Curve | Sensor # | 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 SENSor commands can be used to address the user curves. For example:

INPUT B SENSor 62 assigns input B to user sensor #2.

SENSor 64:NAME? Returns the name string of user sensor 4

SENSor 63:TYPE ACR sets the type of user sensor #3 to ACR.

ⓘ 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 CD

The following sensors are available on the CD 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. |
| CX1030E1.crv | Cernox™ CX1030 example curve. Range: 4 to 325K |

User Calibration Curve File Format

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 monitor, selections are: DIODE, GAAS, PTC100, PTC1K, NTC10UA and ACR. These configurations are described in the section titled [Supported Sensor Configurations](#).

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:

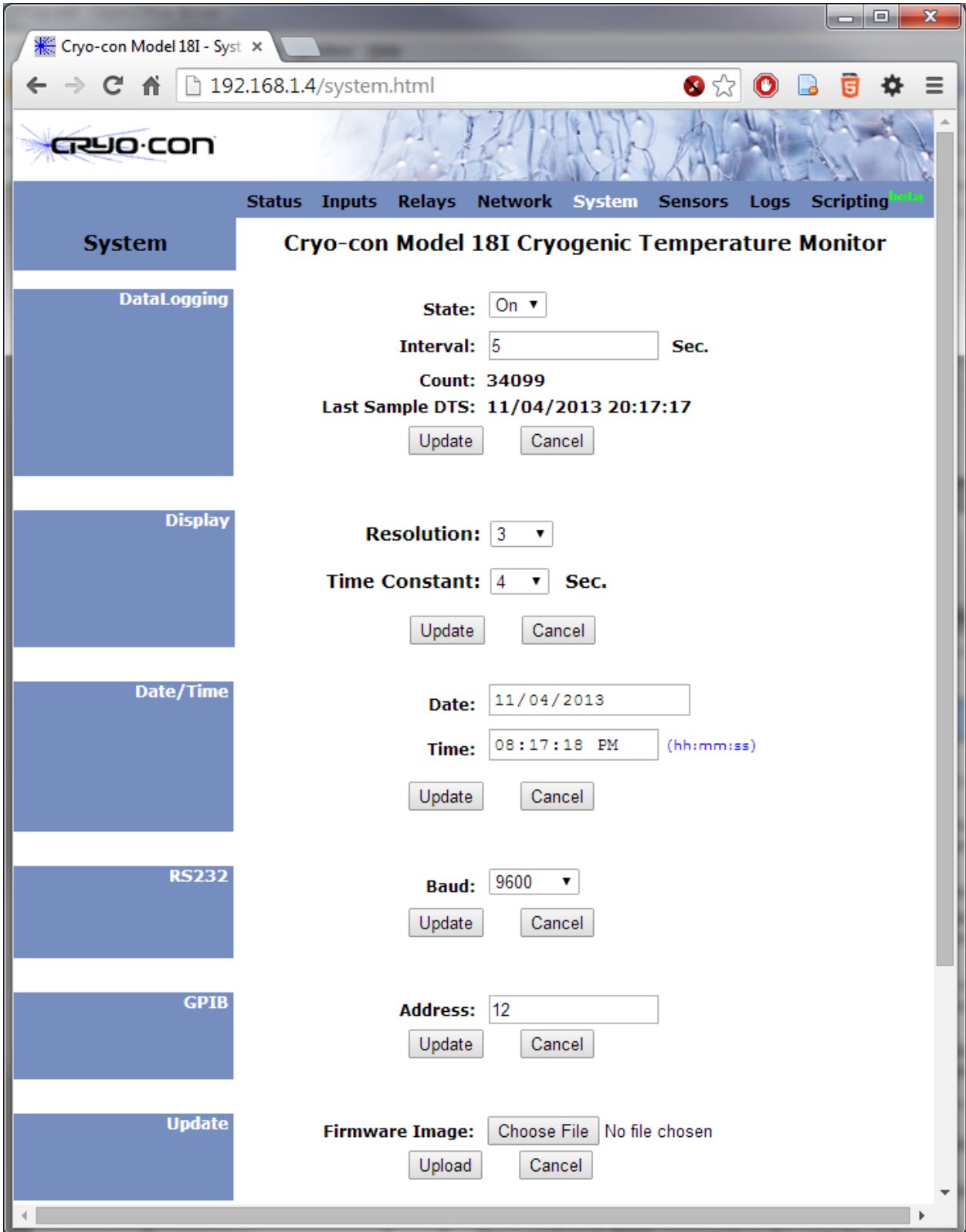
```
Good Diode
Diode
-1.0
volts
0.34295 300.1205
0.32042 273.1512
0.35832 315.0000
1.20000 3.150231
1.05150 8.162345
0.53234 460.1436
;
```

In summary,

1. 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.
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.
6. It is recommended that the curve back is read after downloading to ensure that the instrument parsed the file correctly.

Appendix B: Updating Instrument Firmware

Updating instrument firmware is done via the embedded web page as shown below:



Go to the Firmware Image section and click on Choose File, then select the desired firmware image. The name of the file is something similar to image.tar.gz.gpg. Next, click Upload.

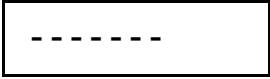
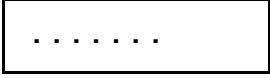


The firmware update process will take several seconds. When complete, the web page will switch to a log file. If this log indicates that the update was not successful, please copy the page and e-mail it to cctechsupport@cryocon.com.

ⓘ 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. 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. Ensure that the proper sensor has been selected. Change the sensor units to Volts or Ohms and ensure that the resulting measurement is within the selected calibration curve. |
|  | Input is clipping. Ensure that the sensor is connected and properly wired. |
|  | Input is over-voltage. External current is flowing into the instrument's input. Damage may result. |

Temperature Measurement Errors

| Symptom | Condition |
|------------------------------------|---|
| Noise on temperature measurements. | Possible causes: <ol style="list-style-type: none"> 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. 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. Use a longer display filter time constant to reduce displayed noise. |

Appendix D: Enclosure Options

Panel Mounting

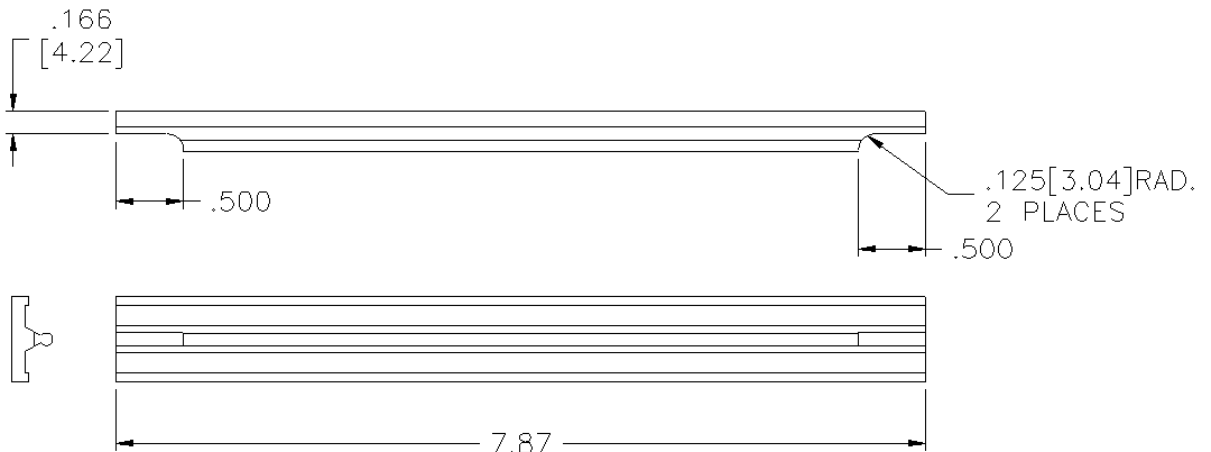
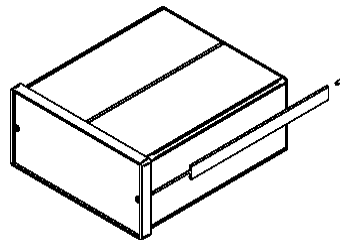
Panel Cutout

Shown here is a cut-out drawing for panel mounting of the monitor.



Panel Mount Kit

The monitor mounts to panel by sliding the enclosure through a panel cut-out hole and then installing the panel mount kit, Cryo-con part number 4012-020. Drawings and assembly of the panel mount kit are shown here.



Instrument Stand

The Instrument Stand accessory, Cryo-con part number 4012-021, is used to mount the monitor on a bench top. It tilts the instrument up by 15° for an improved viewing angle.



Appendix E: Sensor Data

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.

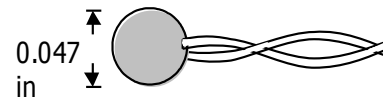
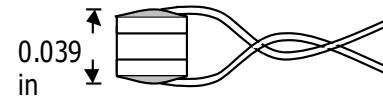
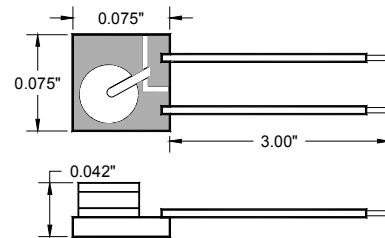
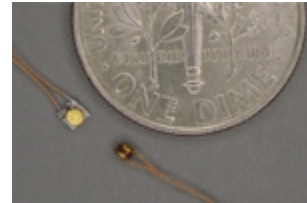
Sensor is easily installed by attaching the substrate directly to the desired surface using cryogenic varnish. Leads should be thermally anchored.

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 18: BB Package Specifications

| Cable Color Codes | |
|-------------------|-------|
| V+ | Clear |
| V- | Green |
| I+ | Black |
| I- | Red |

Table 19: 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.

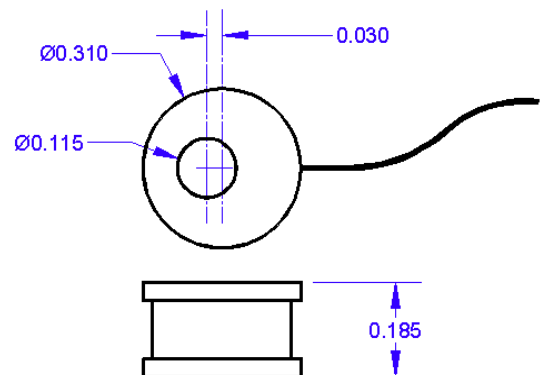
Insulation is Formvarf and is difficult to strip. Techniques include use of a mechanical stripper, scrapping with a razor blade and passing the wire quickly over a low flame.

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 |

| 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 |

GaAlAs, GaAs Diodes

GaAlAs and GaAs diodes offer good sensitivity over a wide temperature range but are not interchangeable.

Useful in magnetic fields.

Silicon diode sensors use a constant-current DC excitation of 10 μ A.

| LS TG-120 GaAlAs Diode Example | | |
|---------------------------------------|---------|---------------------|
| User Supplied | | Configuration: GAAS |
| T(K) | Volts | mV/K |
| 1.4 | 5.39090 | -97.5 |
| 4.2 | 4.76510 | -214 |
| 10 | 3.75210 | -148 |
| 20 | 2.53410 | -97.5 |
| 30 | 1.80560 | -48.2 |
| 50 | 1.46370 | -2.8 |
| 77.35 | 1.42220 | -1.24 |
| 100 | 1.39180 | -1.48 |
| 150 | 1.29850 | -2.25 |
| 200 | 1.17380 | -2.64 |
| 250 | 1.03830 | -2.77 |
| 300 | 0.89780 | -2.85 |
| 400 | 0.60660 | -2.97 |
| 450 | 0.45560 | -3.08 |
| 475 | 0.37780 | -3.15 |

Platinum RTD

Platinum RTD sensors feature high stability, low magnetic field dependence and excellent interchangeability. They conform to the DIN43760 standard curve.

The monitor uses 1.0mA Constant-Current AC excitation.

| 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 monitor supports them with 1.0mA Constant-Current AC excitation.

| Rhodium-Iron 27Ω 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 |

Cernox™

Cernox™ temperature sensors do not follow a standard calibration curve. Data shown here is for typical sensors.

The monitor supports Cernox™ using a 10mV Constant-Voltage AC excitation. This extends low temperature operation to about 2.0K.

| Lakeshore Cernox™ CX-1010 Name: User Supplied Config: ACR | | |
|--|--------|---------|
| T(K) | Ohms | Ω/K |
| 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 | | |
|--|--------|---------|
| T(K) | Ohms | Ω/K |
| 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 |
| 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 |
| 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 |
| 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

Ruthenium-Oxide (RuOx) temperature feature high stability, low magnetic field dependence and good interchangeability.

The monitor supports them using a 10mV Constant-Voltage AC excitation. This extends low temperature operation to about 1.0K.

| Scientific Instruments RO-600 | | |
|--------------------------------------|------|-------------|
| Name: ACR | | Config: ACR |
| 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

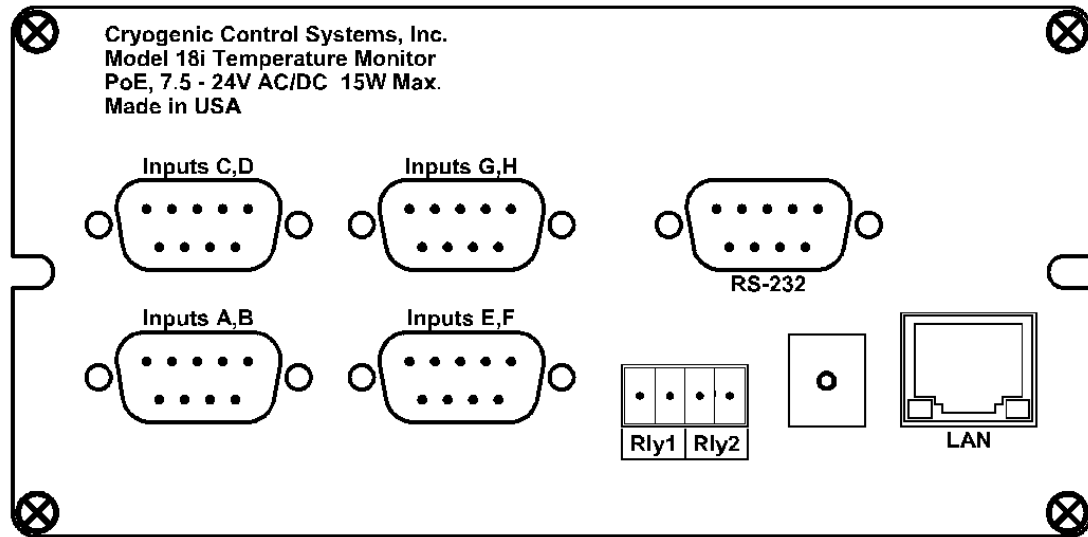


Figure 6: Model 18i Rear Panel

Power input

The external power supply provided with the monitor accepts 100 – 240VAC @ 50 – 60Hz and outputs 12VDC @ 1.0A. This may be plugged directly into the monitor's power jack. Alternatively, any supply from 10 to 30V DC or up to 24V AC with a capacity of greater than 10VA may be used. The jack is 2.1mm with positive voltage on the center and negative on the sleeve.

Power-Over-Ethernet is also supported. An IEEE-802.3af Power-Over-Ethernet hub or injector is required. Plug the cable from this device into the Ethernet input of the monitor. In this case, the power jack should not be used.



IMPORTANT: The monitor requires that an Earth Ground reference connection is made at the rear panel. Failure to provide this connection will result in erratic measurements and can even damage input circuits.

The sensor cables provided connect their shields to the monitor's chassis; Therefore, the required Earth Ground can be made by connecting the shield wire at the opposite end to a ground reference point. This is usually done by connecting it to the back-shell of the cryostat connector.

Sensor Connections

All sensor connections are made at the rear panel of the monitor using the two DB-9 receptacles provided. There are two channels on each connector. Sensors should be connected to the monitor using the four-wire method. Signal connection is as follows:

| Input Channel | Color Code | Signal | DB9 Pin |
|---------------|------------|------------|---------|
| ChA | White | Current(+) | 8 |
| ChA | Green | Current(-) | 9 |
| ChA | Red | Sense(+) | 4 |
| ChA | Black | Sense(-) | 5 |
| ChB | White | Current(+) | 6 |
| ChB | Green | Current(-) | 7 |
| ChB | Red | Sense(+) | 1 |
| ChB | Black | Sense(-) | 2 |

Table 20: Dual 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 DB9 connector's metal back-shell in order to complete the shielding connection.

Relay Connections

Relay connections are made on the rear panel using the 3.5mm, 4-pin detachable terminal block provided.

Terminal block contacts are rated at 10.0A. Relay contact ratings are 10A@125 VAC, 5A@250VAC or 5A@30VDC.

| Pin | Function |
|-----|------------------|
| 1 | Relay #1 N.O. |
| 2 | Relay #1 Common. |
| 3 | Relay #2 N.O. |
| 4 | Relay #2 Common. |

Table 21: Relay Connections

Ethernet (LAN) Connection

The Ethernet connection on the Model 18i / 14i / 12i 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.

The instrument may be powered by an IEEE-802.3af Power-Over-Ethernet compatible powered hub or power injector. When connected to the RJ-45 input, the instrument will negotiate power requirements with the hub and then power itself from the Ethernet cable. Since power and data are taken from a single cable, wiring can be simplified.

Power-Over-Ethernet supplies are NOT earth ground referenced. Some other connection between the instrument's chassis and earth ground should be fabricated in order to minimize noise coupling. Please refer to the section on grounding and shielding.

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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