User's Guide
Model 24C
Cryogenic Temperature Controller

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Safety

The Model 24C does not contain any user serviceable parts. Do not open the enclosure. Do not install substitute parts or perform any unauthorized modification to the product. For service or repair, return the product to Cryo-con or an authorized service center.

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Introduction

The Model 24C is a four-input, four-control loop cryogenic temperature controller designed for general purpose laboratory and industrial use. Each input is independent and capable of temperature measurement to <200mK with an appropriate temperature sensor. The Model 24C supports virtually any cryogenic temperature sensor produced by any manufacturer.

The four-output control loop circuits feature a primary 50W heater, a secondary heater of 10W and two 10-Volt non-powered outputs. All control modes are supported by all outputs.

The 24C front panel incorporates a large high resolution graphics TFT type Liquid Crystal Display with an exceptionally wide viewing angle. With it's bright white LED backlight, complete instrument status can be seen at a glance, even from across the room.

Sensor Inputs

A unique feature of the Model 24C sensor inputs is the use of a ratiometric AC resistance bridge to measure all types of temperature sensors. Excitation is a voltage-source followed by passive attenuators for minimum Johnson noise. Sensor voltage and excitation current are separately measured using dual amplifiers and dual analog-to-digital converters.

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

At very low temperature, the predominant source of measurement error is sensor self-heating that is induced by the applied excitation current. The Model 24C bridge reduces this by offering excitation voltages as low as 1.0mV and currents as low as 50nA.

At higher temperature, measurement errors are generally determined by the signal-to-noise ratio of the instrument. The Model 24C improves performance in this range by offering voltage bias values as high as 100mV. This is an excellent match for applications that operate above about 2.0K.

Sensor excitation is generated by a voltage-source followed by passive attenuators for minimum Johnson noise. Voltage-drop and excitation current are separately measured using dual matched amplifiers and dual analog-to-digital converters. This technique actively cancels gain, drift and low frequency noise measurement errors; thereby providing high accuracy even at extremely low excitation current. Excitation is continuously variable so there are no steps in sensor self-heating. Further, square-wave AC excitation is used with resistor sensors to eliminate DC offset errors that occur in some cryogenic systems. Dual 24-bit analog-to-digital converters are used on each input at a minimum sample rate of 15Hz. Measurement accuracy is then further increased by using digital signal processing techniques including over-sampling, signal dither, lock-in detection and digital filtering.

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

Silicon diode sensors are supported over their full temperature range by using the bridge in a DC, constant-current mode. This mode servos the excitation source to the sensor current to provide the 10μA constant-current required by these sensors.

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

Control Loops

There are four independent control loop outputs:

1. Loop #1 heater output is a linear, low noise RFI filtered current source that can provide up to 1.0 Ampere into 50Ω or 25Ω resistive loads. Four full-scale ranges are available in decade increments down to 50mW full-scale.
2. Loop #2 is a linear heater with two output ranges of 10-Watts and 1.0-Watt full-scale into a 50Ω load.
3. Loop #3 and #4 are a non-powered analog voltage output intended to control an external booster power supply. Output is zero to 10-Volts.

User Interface

The Model 24C's user interface consists of a large, bright TFT type Liquid Crystal Display and a full 21-key keypad. In this user-friendly interface, all features and functions of the instrument can be accessed via this simple and intuitive menu driven interface.

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

```
1A Sample Holder       2B First Stage
 251.445K               123.845K
 300.000K 1-Off-Low     100.000K 2-Off-Low
C: Second Stage        D:Rad Shield
   15.445K                 4.845K
 RO-600 RuOx  10mV        R500 RuOx  1.0mV
```

Cryo-con's innovative instrument configuration menus show real-time status information so the user can *instantly* view the results of any changes made.

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

```
     Loop 1A:Sample Holder
Set Pt:300.000K    A:   123.456K
Pgain: 6.000        Ramp 42% of Mid
Igain: 60.00S
Dgain: 7.500/S     Range: MID
Pman: 5.0000%      PID Table index: 2
Type: RampT        Htr Load: 50Ω
Input: ChA         Next2
```

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

```
     Network Configuration Menu
 Dev: M24C1234        00:50:C2:6F:40:3C
 DHCP Ena: On         IP: 192.168.0.198
 Msk:255.255.255.0    GWy:192.168.0.1

>input a:temp?;units?;name?;sys:time?
<0.5321;K;Sample Holder;14:37:25.
```

Sensor Curves: The Model 24C includes built-in curves that support most industry standard temperature sensors. Additionally, eight **user calibration curves** are available for custom or calibrated sensors. Each user curve may have up to 200 entries and are entered from the front panel, or transferred via any of the available remote interfaces.

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

Data logging is performed by continuously recording to an internal 1,365 entry circular buffer. Data is time stamped so that the actual time of an event can be determined. Non-volatile memory is used so that data will survive a power failure.

Input Channel Statistics: The Model 24C continuously tracks temperature history independently on each input channel and provides a statistical summary that indicates the channel's minimum, maximum, average and standard deviation. Also shown are the slope and the offset of the best-fit straight line of temperature history data.

Alarms: Visual, remote and audible alarms are independently programmed to assert, or clear based on high or low temperature condition, or a detected sensor fault. Latched alarms are asserted on an alarm condition and will remain asserted until cleared by the user.

Relays: The Model 24C has two dry-contact relays. These can be used to control a refrigerator system or other external equipment.

Each relay can be asserted or cleared based on the temperature reading of a selected input channel. High and low setpoints may be set from the front panel or a remote interface. Furthermore, the relays can be manually asserted ON or OFF.

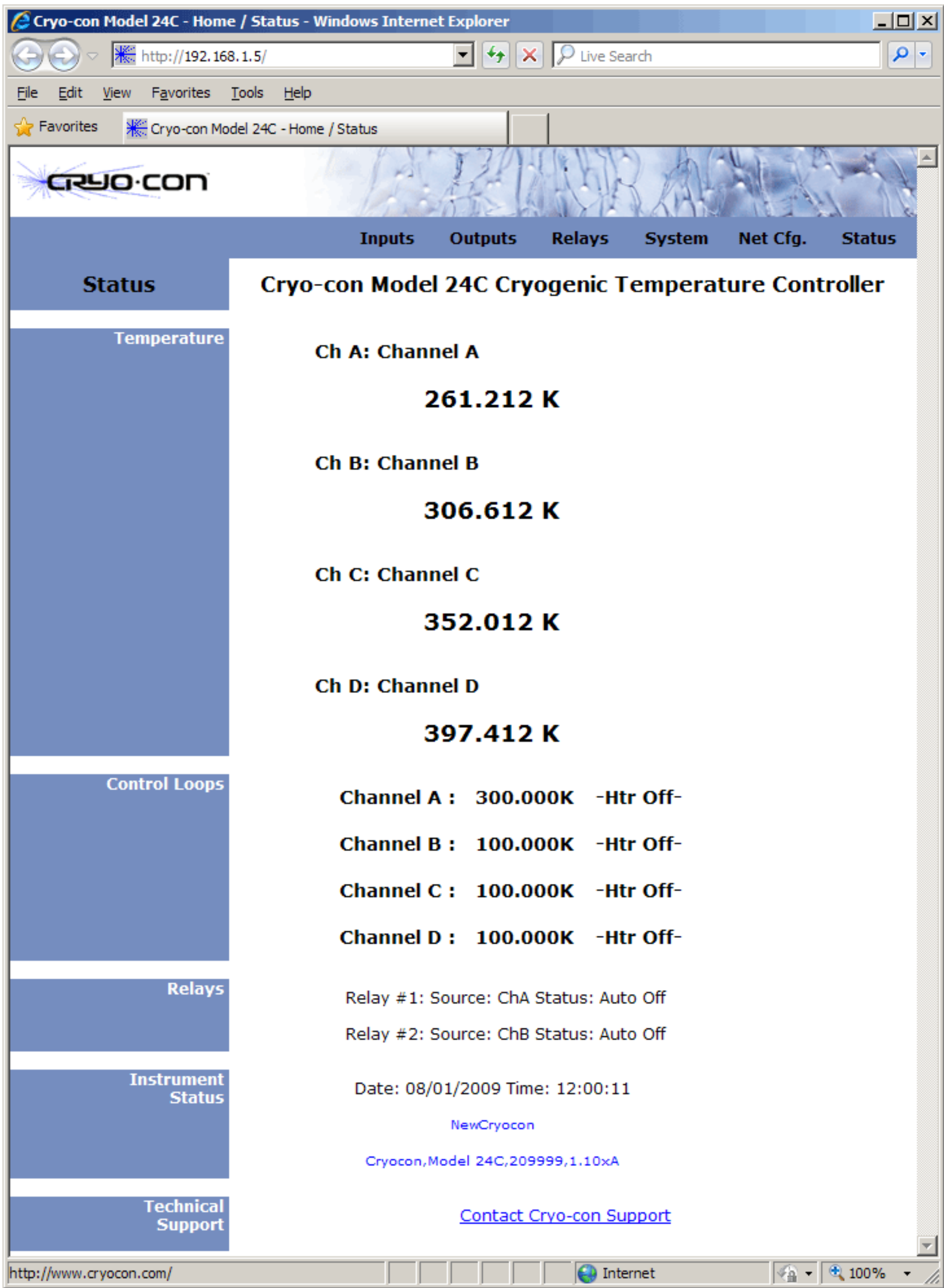
Remote Control

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

The Model 24C connects directly to any 100/10 Ethernet Local-Area-Network (LAN) to make measurements easily and economically. TCP/IP and UDP data port servers brings fast Ethernet connectivity to all common data acquisition software programs including LabView™. An ASCII text based command language identical to those commonly used with GPIB or RS-232 interfaces is implemented. This is the primary way that user software interfaces to the instrument.

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

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



In order to eliminate ground-loop and noise pickup problems commonly associated with IEEE-488 systems, the Model 24C moves the internal IEEE-488 circuitry to an optional external module that interfaces directly to the electrically isolated and low noise Ethernet interface. This compact module is completely transparent to the IEEE-488 system and does not require changes to customer software or LabView drivers.

Remote Command Language: The Model 24C's remote command language is SCPI compliant according to the IEEE-488.2 specification. SCPI establishes a common language and syntax across various types of instruments. It is easy to learn and easy to read.

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

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

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

Firmware updates: Instrument firmware updates may be installed by using the Ethernet connection. Cryo-con provides firmware updates, on request, via e-mail. They are free of charge and generally include enhancements and new features as well as problem fixes. Send e-mail to cctechsupport@cryocon.com

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

Preparing the controller for use

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

Supplied Items

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

- ❑ Model 24C Cryogenic Temperature Controller.
- ❑ This User's Manual.
- ❑ Cryo-con software CD.
- ❑ Input connector kit (4024-016) consisting of four screw-in DIN-6 input connectors (PN 04-0414).
- ❑ Output connector kit (4124-018) consisting of a 10-pin detachable terminal block (04-0007) and a dual banana plug(04-0433).
- ❑ Detachable 120VAC USA Line Cord (04-0310), or universal Euro cord.
- ❑ Certificate of Calibration.

Verify the AC Power Line Voltage Selection

The AC power line voltage is set to the proper value for your country when the controller is shipped from the factory. Change the voltage setting if it is not correct. The settings are: 100, 120 220, or 240 VAC. For 230 VAC operation, use the 240 VAC setting.

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

Apply Power to the Controller

Connect the power cord and turn the controller on by pressing the **Power** key for a minimum of 2 Seconds. The front panel will show a Power Up display with the model number and firmware revision.

```
    Cryogenic Control Systems, Inc.
    Model 24C SN:209999 Rev: 1.00A
IP:192.168.1.5     Static  Port: 5000
     MAC: 00:50:c2:6f:40:3E
  Calibration: Testing NVRAM: Testing
Device Name: NewCryocon      Connecting
   GPIB Adrs: 012  RS232: 9600
Status: Self Test
```

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

Caution: Do not remove the instrument’s cover or attempt to repair the controller. There are no user serviceable parts, jumpers or switches inside the unit. Further, there are no software ROM chips, trim pots, batteries or battery-backed memories.
All firmware installation and instrument calibration functions are performed externally via the remote interfaces.

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

Installation

General

The Model 24C can be used as a bench top instrument, or mounted in an equipment rack. In either case, it is important to ensure that adequate ventilation is provided.

Cooling airflow enters through the side holes and exhausts out the fan on the rear panel. It is important to allow at least ½" of clearance on the left and right sides and to ensure that the exhaust path of the fan is not blocked.

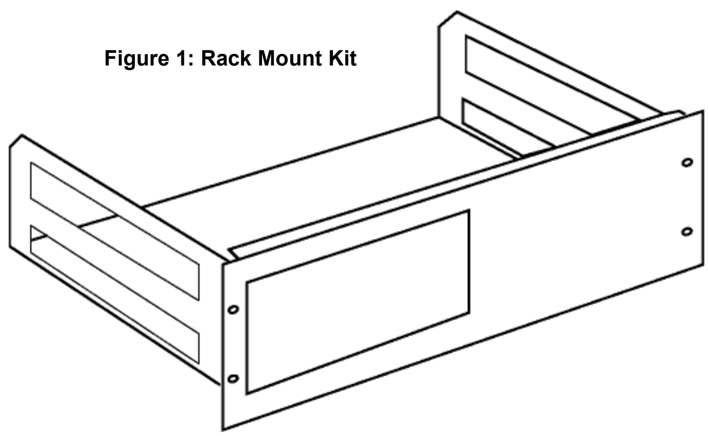
Rack Mounting

You can rack mount the controller in a standard 19-inch rack cabinet using the optional rack mount kit. Instructions and mounting hardware are included with the kit.

4034-032 Single instrument shelf rack mount kit.
4034-031 Dual instrument shelf rack mount kit.

Since the controller is an industry standard size, it is possible to mount any similar size instrument next to it in the rack.

Figure 1: Rack Mount Kit



Note that the rack mount extends the height of the controller from 2U (3½") to 3U (5¼").

To mount the controller, first remove the plastic feet and instrument bail on the bottom of the unit.

Next, lay the controller on the shelf and slide forward to line up with the front cutout.

Use four #6-1/4" screws to secure the controller using the same threaded holes as the plastic feet.

Warning: When rack mounting, do not use screws that protrude into the bottom of instrument more than ¼". Otherwise, they can touch internal circuitry and damage it.

Initial Setup and Configuration

Before attempting to control temperature, the following instrument parameters should be checked:

1. The Loop #1Heater resistance setting should match the actual heater resistance that you are going to use. Choices are 50Ω and 25Ω. A heater resistance of less than 25Ω should use the 25Ω setting. Using the 50Ω setting with a heater resistance much less than 50Ω may cause the instrument to overheat and disengage the control loops.

   Set the heater resistance by pressing the **Loop 1** key and refer to the Loop Configuration Menu section.
2. The Loop #1 heater range should be set to a range where the maximum output power will not damage the equipment. To set this parameter, press the **Loop 1** key and refer to the Loop Configuration Menu section.
3. The controller has an over-temperature disconnect feature that monitors a selected input and will disconnect both control loops if the specified temperature is exceeded. This feature should be enabled in order to protect your equipment from being over heated. To enable, press the **System** key and refer to the System Functions Menu section.

Factory Default Setup

A controller 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.

```
1A Sample Holder      2B First Stage
 251.445K              296.845K
 300.000K 1-Off-Low    100.000K 2-Off-Low
C: Second Stage       D:Rad Shield
 251.445K              296.845K
 RO-600 RuOx  10uV      R500 RuOx  1.0mV
```

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

Input Channel factory defaults are:

Sensor Units: Kelvin.
Sensor Type: PT100 385 (Standard 100Ω Platinum RTD)
Alarm Enables: Off

To change these, press the **ChA** , **ChB** , **ChC** or **ChD** key and refer to the Input Channel Configuration Menu section.

Control Loop #1 factory defaults are:

Setpoint: 300K. Control input channel: A.
P gain: 5.0, I gain: 60.0 Seconds, D gain: 7.5, Range: Low
Control Type: Manual, Output power, Pman: 5%
Heater Resistance:50Ω
Power Limit: 100%, Max Setpoint: 1000K
PID Table Index: 0, Ramp Rate: 0.1499/min.

Control Loop #2 factory defaults are:

Setpoint: 100K. Control input channel: A.
P gain: 1.0, I gain: 60.0 Seconds, D gain: 0, Range: Low
Control Type: Manual, Output power, Pman: 5%
Heater Resistance:50Ω
Power Limit: 100%, Max Setpoint: 1000K
PID Table Index: 0, Ramp Rate: 0.1499/min.

To change these, press the **Loop 1** or **Loop 2** key and refer to the Loop Configuration Menu section.

Instrument setup factory defaults are:

Display Filter Time Constant: 4.0 Seconds. Display Resolution: 3 digits.
Brightness: 50%
Over Temperature Disconnect: Off
RS-232 Baud Rate: 9600.
IEEE-488 (GPIB) Address: 12 (GPIB interface is optional)
Local Area Network:
IP: 192.168.1.5. Subnet Mask: 255.255.255.0, DHCP: Off
AC Power Line Frequency: 60Hz
Cryocooler Filter: Off, Sync Filter Taps: 11.
Control on power-up mode: OFF

To change these, press the **System** key and refer to the System Functions Menu section.

> ⓘ **NOTE:** Factory defaults may be restored at any time by use of the following sequence: 1) Turn AC power OFF. 2) Press and hold the Enter key while turning power back ON. This sequence will restore factory defaults including resetting user supplied sensor calibration curves and saved user configurations. However, it will NOT erase the instrument's internal calibration data.

Model Identification

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

Ordering Information

Standard	Description
Model 24C	Controller with four standard multi-function sensor input channels.
	Controller includes: User's Manual, Cryo-con software CD, four input connectors, heater connector, terminal block plug, detachable power cord and a certificate of calibration. Specify AC Line Voltage when ordering: **-100** Configured for 90 - 100VAC with detachable USA power cord. **-110** Configured for 110 - 120VAC with detachable USA power cord. **-220** Configured for 220VAC with detachable universal Euro (Shuko) line cord. **-240** Configured for 240VAC with detachable universal Euro (Shuko) line cord.

Options	Description
4039-004	Thermocouple Input Module. Field installable. Supports all thermocouple types. Controller supports up to 4 thermocouples.
4001-002	IEEE-488.2 (GPIB) Option. Field installable.
4001-001	USB Option. Serial Port Emulation. Field installable.

Technical Assistance.

Troubleshooting 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 92067-7012

Telephone: (858) 756-3900x100 FAX: (858) 759-3515
e-mail: cctechsupport@cryocon.com

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

Current Firmware Revision Level

As of May, 2011 the current firmware revision level for the Model 24C series is 1.17. Instrument firmware can be updated in the field via the LAN port. Updates are available on the Internet.

Current Hardware Revision Level

As of May 2011, the current hardware revision level for the Model 24C series is A. Hardware cannot be upgraded in the field.

Options and Accessories

Instrument Accessories

Cryo-con Part #	Description
4034-031	Two instrument shelf rack mount kit
4034-032	One instrument shelf rack mount kit
4034-035	Shielded IEEE-488.2 Interface Bus Cable, 6'6"
04-0310	AC Power Cord
04-0317	AC Power Cord, Cont. European (Shuko)
04-0414	Din-6 Sensor Input Connector, Amphenol T3400 001
04-0007	Ten-pin detachable terminal block for Loop 2 and relay connections.
04-0433	Dual banana plug for Loop 1 connection.
4042-040	8' Sensor cable, four wire, wired to DIN-6 connector.
3124-029	Additional User’s Manual/CD

Table 1: Model 24C Instrument Accessories

Cryogenic Accessories

Cryo-con Part #	Description
S900	S900 series Silicon diode Temperature Sensors. Temperature range: 1.4 to 500K
R400	Cryo-con R400 Ruthenium-Oxide temperature sensor. Temperature range: 2.0K to 273K. Optimized for use in Liquid Helium systems including superconducting magnets.
R500	Cryo-con R500 Ultra-low temperature Ruthenium-Oxide temperature sensor. Temperature range: <200mK to 40K.
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
3039-002	Cartridge Heater, Silicon free, 25Ω / 25 Watt, 1/4" x 1 1/8". Temperature range to 1,600K
3039-001	Cartridge Heater, Silicon free, 50Ω / 50 Watt, 1/4" x 1 1/8. Temperature range to 1,600K
4039-011	Pre-cut Nichrome wire heater w/connectors, 25Ω
4039-012	Pre-cut Nichrome wire heater w/connectors, 50Ω
3039-006	Bulk Nichrome Heater Wire, 32AWG, Polyamide insulation, 100’

Table 2: Cryogenic Accessories

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 92067-7012

A Quick Start Guide to the User Interface.

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

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

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

Home Status Display

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

The Home Status display consists of four zone quadrants. Each zone has 4 lines, containing 20 characters each, and can be individually configured to show useful information with minimum clutter.

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

Accessing the heater setpoint

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

Configuring a temperature sensor

Configuring an input sensor from the front panel is performed by using the Input Channel Configuration Menu. First, press input channel key **ChA** , **ChB** , **ChC** , or **ChD** to select the desired channel for configuration.

The first line of the Input Channel Configuration menu is used to change the sensor units. It shows the selected input channel, the current temperature (in real time) and the current units. An example is shown here.

```
+ 77.123K          --
```

To change the sensor units, use the **+** and **0** keys to scroll through the available options. When the desired units are shown, press the **Enter** key to make the selection. The display will now show the current temperature with the new units.

Next, go to the sensor selection field by pressing the down arrow navigation key. This field is used to select the actual sensor type. In the example shown below, the input channel is currently configured for a standard Cryo-con S900 diode sensor. Use the **+** and **0** keys to scroll through the available sensors including user sensors. When the desired sensor is shown, press the **Enter** key to make the selection. A complete listing of selectable sensors is given in Appendix A.

```
+Sen: 1 Cryocon S900
```

Before one of the user-supplied sensors can be used, the sensor’s calibration curve and configuration data must be installed. This is best done by using Cryo-con’s utility software.

This completes the process of configuring an input channel. Press the **Home** key to return to the Home Status display.

Configuring the Control Loops

Before using the Loop #1 (main heater) control output, it is essential that the proper load resistance and output range be selected. This is done using the Control Loop Setup menu as follows:

- Press the **Loop 1** key.
- In the Control Loop Configuration menu, Use the up, down, right and left keys to scroll to the **Htr Resistance** field. An example is shown here:
- Use the **+** and **0** keys to select between a 50-Ohm and a 25-Ohm heater and then press the **Enter** key.

```
+Htr Resistance:50Ω
```

- Use the navigation keys to scroll to the Range field and then select the desired heater range.

```
+Range:HI
```

Be sure to select a range that does not exceed the ratings of your cryostat. A summary of full-scale output power for the various ranges is given here:

Range	Max. Output Power	
	25Ω	50Ω
Hi	25 Watts	50 Watts
Mid	2.5 Watts	5.0 Watts
Low	0.25 Watts	0.50 Watts

Table 3: Loop #1 Output Summary

Next, the control type should be set by scrolling to the Type field and selecting the desired loop operating mode.

```
+Type: PID
```

A summary of control types is given here:

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

Table 4: Control Type Summary

Caution: The Model 24C has an automatic control-on-power-up feature. If enabled, the controller will automatically begin controlling temperature whenever AC power is applied. For a complete description of this function, please see the Auto Ctl function in the **System Functions menu** section.

Configuring the Loop #2 Output

The second control loop of a Model 24C controller is a 10-Watt output that is matched to a 50Ω resistive load. Therefore, there are no load resistance or range settings to configure.

All other configuration settings are identical for both Loop #1 and Loop #2.

Caution: The Model 24C has an automatic control-on-power-up feature. If enabled, the controller will automatically begin controlling temperature whenever AC power is applied. For a complete description of this function, please see the Auto Ctl function in the **System Functions menu** section.

Restoring Factory Defaults

Factory default settings may be restored with the following simple procedure:

1. Turn AC power OFF by pressing the **Power** key.
2. Press and hold the Enter key while turning AC power back ON. Keep the key pressed until you see the power-up display indicating that defaults have been restored.

ⓘ **NOTE:** Factory defaults may be restored at any time by use of the following sequence: 1) Turn AC power OFF. 2) Press and hold the Enter key while turning power back ON. This sequence will restore factory defaults including resetting user supplied sensor calibration curves and saved user configurations. However, it will NOT erase the instrument's internal calibration data.

Specifications, Features and Functions

Specification Summary

User Interface

Display Type*: 40 character by 8 line TFT LCD with LED backlight.*
Number of Inputs Displayed: Four.
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 Channels

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

Sensor Connection*:* 4-wire differential. Screw-in type DIN-6 circular. Connections are described in the Sensor Connections section.

Supported Sensors Include:

Type	Excitation	Temperature Range
Cernox™	Constant-Voltage AC	200mK to 420K
Ruthenium-Oxide	Constant-Voltage AC	200mK to 273K
Carbon-Ceramic	Constant-Voltage AC	200mK to 300K
Rhodium-Iron	Constant-Current, 1mA AC	1.4 to 800K
Germanium	Constant-Voltage AC	200mK to 100K
Carbon Glass	Constant-Voltage AC	1.4K to 325K
Silicon diode	10μA DC	1.4 to 475K
Platinum RTD	Constant-Current, 1mA AC	14 to 1200K
GaAlAs diode	10μA DC	25K to 325K
Thermocouple	None	1.4 to 1500K

Table 5: Supported Sensor Types

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

Sample Rate*:* 15Hz 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.

CalGen: Calibration curve generator fits any diode or resistor sensor curve at 1, 2 or 3 user specified temperature points.

Sensor Performance Specifications:

Diode Sensors

Configuration: Constant-Current mode, 10µA ± 0.05% DC excitation.
Input voltage range: 0 to 2.25VDC.
Accuracy: ±(60µV + 0.005% * reading)
Resolution: 2.3µV
Drift: <15ppm/ºC

PTC Resistor Sensors

Configuration: Constant-Current AC resistance bridge mode.
Drift: 15ppm/ºC
Excitation Frequency: 1.625Hz bipolar square wave.

Range	Max/Min Resistance	Excitation Current	Resolution	Accuracy
PTC100 1mA	750Ω 0.01Ω	1.0mA	0.1mΩ	± (0.002 + 0.01%)Ω
PTC1K 100µA	7.5KΩ 0.1Ω	100µA	1.0mΩ	± (0.03 + 0.02%)Ω
PTC10K 10µA	75KΩ 1.0Ω	10µA	10mΩ	± (3.0 + 0.02%)Ω

Table 6: Accuracy and Resolution for PTC Resistors

NTC Resistor Sensors, DC measurement

Configuration: NTC10uA

Excitations: Constant Current 10µA ± 0.5% DC
Measurement Drift: 25ppm/ºC
Range: 230KΩ to 50KΩ.
Accuracy: ± (3.0 + 0.02%)Ω
Resolution: 100mΩ

ⓘ **Note:** The NTC10uA range is intended for use with NTC sensors that have over 100KΩ of resistance. These sensors are commonly used in superconductor systems and include the Cryo-con R400 Ruthenium-Oxide devices. All other NTC resistor sensors should use the constant-voltage configurations.

Thermocouple Sensors

Thermocouple devices are supported by using an optional external module.

Measurement Drift: 15ppm/ºC **Input Range:** ±70mV
Accuracy: ±1.0µ V ± 0.05%. **Resolution:** 0.0003%

Installed Types: K, E, T and Chromel-AuFe (0.07%).
Input Connector: Isothermal, Screw-type terminals.

NTC Resistor Sensors

Type: Constant-Voltage AC resistance bridge with excitations of 100mV, 10mV and 1.0mV RMS. Fixed or auto-ranged.

Excitation Current: 15mA to 50nA.
Five ranges of 20KΩ, 2.0KΩ , 200Ω , 20Ω and 2Ω.

Excitation Frequency: 1.67Hz bipolar square wave.

Accuracy (% reading + % range):
Reading >4Ω and < 30KΩ : ±(0.05% + 0.05%).
Reading >0.04Ω and < 1.0MΩ : ±(0.15% + 0.15%).

Resolution: Shown below are typical RMS resistance noise values measured at 50% of full-scale on a room-temperature resistor with a 3-Second analog time-constant.

Drift: >10Ω, 15ppm/ºC. <10Ω, 25ppm/ºC

DC Offset Current: <30nA by continuous calibration.

Resistance Range: 0.5Ω to 2.0MΩ.
Minimum resistance is Range / 4
Maximum resistance is Vbias / 50nA with a maximum of 2.0MΩ

Resistance	100mV	10mV	1.0mV
Maximum	2.0MΩ	2.0MΩ	1.0MΩ
Minimum	5Ω	0.5Ω	0.5Ω

Table 7: Minimum and Maximum Resistance vs. Bias Voltage

Range	100mV	10mV	1.0mV
2Ω	**(Excitation Resolution}**	10mA 26µΩ	1.0mA 255µΩ
20Ω	10mA 2.6µΩ	1.0mA 255µΩ	100µA 2.6mΩ
200Ω	1.0mA 26µΩ	100µA 2.6mΩ	10µA 26mΩ
2KΩ	100µA 260µΩ	10µA 26mΩ	1.0µA 260mΩ
20KΩ	10µA 2.6mΩ	1.0µA 250mΩ	1.0µA 2.5Ω

Table 8: Accuracy and Resolution for NTC Resistors

Control Outputs

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

Loop #1 Primary Heater Output

Type: Short circuit protected linear current source. Maximum compliance is selectable at 25V or 50V.
Ranges: Three output ranges of 1.0A, 0.33A and 0.10A full-scale, which correspond to 50W, 5.0W and 0.5W when used with a 50Ω load.
Load Resistance: 25Ω or 50Ω. Heaters down to 10Ω can be used with the 25Ω range.
Minimum Load: 10Ω in 25Ω setting, 40Ω in 50Ω setting.
Digital Resolution: 1.0PPM of full-scale, corresponding to 20 bits.
Readback: Heater output power, Heatsink temperature.
Connector: Dual Banana-plug.

Loop #2 Heater Output

Type: Short circuit protected linear current source. Compliance is 24V.
Ranges: 10W into a 50Ω load.
Load Resistance: 50Ω.
Digital Resolution: 1.0PPM of full-scale, corresponding to 20 bits.
Readback: Heater output power.
Connector: 10-pin detachable terminal block.

Status Outputs

Audible and Visual Alarms: Independent audible and visual alarms.
Status reported via Remote Interface: Heater over temperature fault.

Loop #3 and #4 Outputs

Type: 0 - 10 Volt analog output. All control modes available.
Maximum Output Current: *20mA.*
Connector: *10-pin detachable terminal block.*

Relay Outputs

Number: 2
Type: Dry-contact.
Contact Rating: 1.0A @ 30VDC
Function: Asserted or cleared based on temperature setpoint data.
Deadband: User defined.
Connector: 10-pin detachable terminal block.

Remote Interfaces

Remote interfaces are electrically isolated to prevent ground loops.
10/100-BaseT Ethernet: Supported protocols include: HTTP, TCP/IP, UDP and SMTP. Electrically isolated.
RS-232: Serial port is an RS-232 standard null modem. Rates are 9600, 19,200, 38,400 and 57,200 Baud.
IEEE-488 (GPIB): External option. Full IEEE-488.2 compliant.
USB 2.0: External option. Serial port emulator.
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.
Ethernet API available for C++ and Basic.

User Setups

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

General

Ambient Temperature: 25°C ± 5°C for specified accuracy.
Mechanical: 8.5"W x 3.5"H x 12"D. One half-width 2U rack. Instrument bail standard, rack mount kit optional.
Weight: 9 Lbs.
Enclosure: Aluminum. Machined Aluminum front panel.
Power Requirement: 100, 120, 220 or 240VAC +5% -10%.
50 or 60Hz, 150VA max.

Performance Summary

Measurement Accuracy

Diode Sensors

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

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

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

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, to calculate the measurement accuracy of the Model 24C using a Cryo-con S900 sensor at 10K, look up the sensor reading and sensitivity in the S900 data table in Appendix G. At 10K, 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 MAV = 128μV and MAT = 49mK.

PTC Resistor Sensors (RTDs)

The formulas for PTC resistor sensor in the PTC100 range are:

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

$$\mathrm{MAT} = \frac{\mathrm{MAR}}{\mathrm{SenSen}}$$

Where:

MAR is the electronic Measurement Accuracy in Ohms
MAT is the Measurement Accuracy in Kelvin
SenVal is the sensor reading in Ohms at the desired temperature.
SenSen is the sensor sensitivity in Ohms / Kelvin at the desired temperature.

To calculate the measurement accuracy of the Model 24C using a 100Ω Platinum RTD in the PTC100 range with the sensor at 77.35K, look up the sensor reading and sensitivity in Appendix G. The appendix shows that SenRdg is 20.38Ω and SenSen is 0.423 Ω/Kelvin. Therefore, the computed values show that MAR = 0.004038Ω and MAT = 9.5mK.

For ranges other than PTC100, please refer to the PTC Specifications table.

NTC Resistor Sensors

The formulas for NTC resistor sensors are:

Where:

$$\mathrm{MAR} = 5.0 \cdot 10^{-5} \cdot \mathrm{SenVal} + 5.0 \cdot 10^{-5} \cdot \mathrm{Range}$$

$$\mathrm{MAT} = \frac{\mathrm{MAR}}{\mathrm{SenSen}}$$

MAR is the electronic Measurement Accuracy in Ohms
Range is the resistance range in Ohms (100, 1K or 10K)
MAT is the Measurement Accuracy in Kelvin
SenVal is the sensor reading in Ohms at the desired temperature.
SenSen is the sensor sensitivity in Ohms / Kelvin at the desired temperature.

To calculate the measurement accuracy of the Model 24C using a Cryo-con R500 Ruthenium-Oxide sensor in the 1KΩ range with the sensor at 1.0K, look up the sensor reading and sensitivity in Appendix G. SenVal is 2327Ω and SenSen is -1203Ω/Kelvin. Therefore the computed values equal MAR = 0.17Ω and MAT = 100μK.

Measurement Resolution and Control Stability

The input analog-to-digital converter used by the Model 24C is 24 bits with no missing codes. Thus, the measurement resolution is identifiable as one part in 2^{-24}. However, the only use for measurement resolution is to compute control stability. Since control stability is limited by the output DAC rather than the input, the measurement resolution specification is limited to one part in 2^{-20}.

$$MR = FullScale \cdot 2^{-20}$$

$$MRT = \frac{MR}{SenSen}$$

Where:

MR is the electronic measurement resolution in sensor units.
FullScale is the full scale range
MRT is the measurement resolution in temperature units.
SenSen is the sensor sensitivity at the measurement point.

Input Channel Characteristics

There are two or four independent, multi-purpose input channels; each of which can separately be configured for use with any supported sensor.

Input Configurations

A complete list of the sensor types supported by the Model 24C is shown below:

Sensor Type	Max. Voltage/ Resistance	Bias Type	Excitation Current	Typical Use
Diode	2.25V	CI	10μA DC	Silicon diode, GaAs diode.
ACR	10Ω to 2.0MΩ	CV	15mA - 50nA AC	NTC resistors including Ruthenium Oxide, Cernox™
PTC100	0.5 - 750Ω	CI	1.0mA DC	100Ω Platinum, Rhodium-Iron
PTC1K	5 - 7.5KΩ	CI	100uA DC	1,000Ω Platinum
PTC10K	50 75KΩ	CI	10uA DC	10KΩ Platinum
NTC10UA	240KΩ	CI	10uA DC	R400 Ruthenium Oxide
TC70	±70mV	None	0	All thermocouple types. (option)
None	0	None	0	Disable Input Channel

Table 9: Supported Sensor Configurations

Bias types are:

CI – Bridge maintains a constant current through the sensor.

CV – Bridge maintains a constant voltage-drop across the sensor.

> ⓘ **Note:** Any disconnected inputs to the Model 24C should be set to type 'None'. This will turn the input off.

Silicon Diode Sensors

Silicon diode sensors (2-volt diodes) are configured with a 10μA current source excitation and a 2.25 Volt input voltage range.

Gallium-Arsenide Diode Sensors

Gallium-Arsenide diodes or 6-Volt diodes are sometimes used in systems where magnetic fields are present. Use is limited to operation above about 30K with fields of less than 5T. The Model 24C supports these sensors down to 25K. If your requirements are for lower temperature operation, Ruthenium-Oxide is a better choice.

Gallium-Arsenide sensors do not fit standard calibration curves, therefore, the user must provide a sensor-specific curve before using this type of sensor.

PTC Resistor Sensor (RTDs)

The Model 24C supports all types of Positive-Temperature-Coefficient (PTC) resistive sensors using a constant-current AC resistance bridge technique.

Standard calibration curves are provided for DIN43760 and IEC751 Platinum sensors. These curves have been extended down to 14K. Below that, the sensors can be used with user supplied calibration curves.

A table of recommended setups for various types of PTC resistor sensors is shown here:

Type	Measurement Range	Sensor Excitation
Platinum, 100Ω	1.0KΩ - 0.01Ω	1.0mA, AC
Platinum, 1000Ω	10KΩ - 0.1Ω	100μA, AC
Platinum, 10KΩ	100KΩ - 1.0Ω	10μA, AC
Rhodium-Iron	1.0KΩ - 0.01Ω	1.0mA, AC

Table 10: PTC Resistor Sensor Configuration

NTC Resistor Sensors > 100KΩ

Ruthenium-Oxide sensors used in superconducting magnet systems commonly have a room temperature resistance of > 100KΩ. The Model 24C supports these devices using 10μA DC constant-current excitation. The maximum resistance is 220KΩ. DC excitation is used since the high resistance values do not benefit from AC excitation. In addition, 10μA constant-current is implemented because the extremely small current used by constant-voltage modes would lead to measurement noise.

Sensor self-heating caused by the high level excitation is calibrated out in the sensor's calibration curve. Since this self-heating is reproducible, high measurement accuracy is maintained.

Examples of high resistance sensors include the Cryo-con R400 and the Scientific Instruments RO-105.

NTC Resistor Sensors

The Model 24C supports almost all types of Negative-Temperature-Coefficient (NTC) resistive sensors by using a constant-voltage AC resistance bridge technique, these sensors can be used down to very low temperatures. Examples of NTC resistor sensors include: Ruthenium Oxide, Cernox™, Carbon Glass, Germanium and other thermistors.

Constant-voltage excitation is necessary since the resistance thermometers used below about 10K exhibit a negative temperature coefficient. Therefore, a constant-voltage measurement reduces the power dissipation in the sensor as temperature decreases. By maintaining low power levels, sensor self-heating errors that occur at very low temperatures are minimized.

In the constant-voltage mode, sensor excitation is a 1.67Hz bipolar square-wave. This provides DC offset cancellation without loss of signal energy. DC offsets are held to <30nA in order to minimize it's contribution to sensor self-heating.

For more information on using the Model 24C with NTC resistor sensors, please refer to the section titled "Selecting a Voltage Bias for NTC Sensors".

Power dissipation in the sensor is computed by:

$$P_d = \frac{V_{bias}^2}{R_{sensor}}$$

The actual power being dissipated in the sensor may be viewed in real-time by going to the Input Configuration Menu. An asterisk (*) character next to the temperature display indicates that the resistance bridge is not balanced at the proper voltage bias.

When used with high resistances, measurement accuracy steadily degrades due to the extremely low excitation current required. The trade-off in measurement accuracy vs. sensor excitation current is taken for two reasons:

1. The sensitivity of NTC resistor sensors is extremely high in the low temperature end of their range. Therefore the reduced measurement accuracy does not degrade temperature measurement accuracy.
2. The low current settings are required since sensor self-heating at low temperature is a very significant source of errors.

For more information please refer to the section titled "Selecting a Voltage Bias for NTC Sensors"

Calibration tables for NTC sensors may be entered either directly in Ohms or in (base 10) Log of Ohms to accommodate the generally logarithmic nature of their calibration curves.

CalGen Calibration Curve Generator

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

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

The CalGen function may be performed in the instrument by using the front panel. Alternatively, the feature is also implemented in the Cryo-con utilities software.

Input Channel Statistics

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

Statistics are:

- Minimum Temperature.
- Maximum Temperature.
- Temperature Variance.
- Slope and Offset of the best-fit straight line to temperature history.
- Accumulation Time

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

Electrical Isolation and Input Protection

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

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

Thermal EMF and AC Bias Issues

DC offsets build up in cryogenic temperature measurement systems due to thermocouple effects within the sensor wiring, though careful wiring minimizes these effects. However, in a few systems, measurement errors induced by thermal EMFs result in unacceptable measurement errors. These cases require the use of an AC bias, or chopped sensor excitation in order to remove DC offsets.

<u>Sensor Wiring</u>

Diode and Platinum RTD type sensors use a DC measurement scheme. Therefore, the only effective method of minimizing thermocouple (DC) offsets is to wire temperature sensors so that connections between dissimilar metals are grouped together. For example, the connection between sensor leads and cryostat wiring should be kept close together. This way, the thermocouple junctions formed by the connection have equal-but-opposite voltages and cancel each other.

In a four-wire measurement scheme, only connections in the voltage sense lines can cause measurement errors. Therefore, the sense wires should have adjacent contacts in a multi-pin connector in order to minimize any temperature difference between them.

Usually, the 'connection to copper' in a cryostat is made at the top of the cryostat. After this point, Thermal EMFs cannot be generated.

AC Excitation

When a resistance sensor is selected, the Model 24C uses a 3.50Hz square-wave sensor excitation. This eliminates DC offsets by computing the sensor resistance at two different excitation points.

Control Loop Outputs

Control Loop #1, Primary Heater Output

The Loop #1 heater output is a short circuit protected linear current source. This output is heavily regulated and RFI filtered. External filters should not be necessary.

Automatic shutdown circuitry is provided that will protect the heater output stage from excessive temperature. Here, the heater output will be turned off until the output stage returns to its Safe Operating Area (SOA), then the output will be returned to normal operation.

Load resistance values of either 25Ω or 50Ω may be selected. Using a 25Ω load, the heater will be automatically configured to have a compliance voltage of 25V. With a 50Ω load, the compliance voltage is 50V. In either case, the maximum output current is 1.0A.

There are four output ranges, which are manually selected in PID mode and automatically selected in the PID Table control mode. The ranges are High, Medium and Low.

Range	Compliance Voltage		Full-Scale Current	Max. Output Power	
	25Ω	50Ω		25Ω	50Ω
High	25	50	1.0A	25 Watts	50 Watts
Medium	25	50	0.333A	2.5 Watts	5.0 Watts
Low	25	50	0.100A	0.25 Watts	0.50 Watts

Table 11: Loop 1 Heater output ranges.

Take care to ensure that the proper load resistance is selected. Connection to a 25Ω load while a 50Ω is selected will result in overheating and eventual automatic heater shutdown. Conversely, connection to a 50Ω load while setting a 25Ω load will result in the dissipation of only one half of the indicated heater power in the load.

Load resistance and Full Scale Output Range are selected via the front panel, or any of the remote interfaces.

Heater output power displays are based on the heater read-back circuitry which measures output current independently of the actual heater circuitry. Thus, heater fault conditions are detected and their corresponding alarms asserted.

The resolution of the Loop #1 output is 1.0ppm of full scale (20 bits).

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

Control Loop #2, Secondary Heater Output

Control loop #2 is a constant current source similar to the Loop #1 heater. It will output10-Watts into a 50Ω load corresponding to a maximum current of 450mA. Compliance is 25V. Load resistance is 50Ω.

The resolution of the Loop 2 output is 1.0ppm of full scale (20 bits).

Control Types

There are four control types available in the Model 24C. They are Manual, PID, PID Table, Ramp and Ramp Table. All modes are available on all control loops.

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

PID control allows feedback control using an enhanced PID algorithm that is implemented using 32-bit floating point Digital Signal Processing techniques. Enhancements include:

1. Noise filtering on the derivative term. The D term will provide better control stability, but is often not used because, without filtering, it makes the control loop too sensitive to noise.
2. Integrator wind up compensation. While slewing to a new setpoint, the integrator in the PID loop can build up to a very large value. If no compensation is applied, overshoot and time to stability at the new setpoint can be delayed for an extremely long time. This is especially true in cryogenic environments where process time constants can be very long.
3. Dithering and filtering the outputs in order to increase output resolution and improve control stability.

The PID Table control mode is a PID control loop just as described above. However, it is used to look up PID and heater range values based on the specified setpoint. This is useful where a process must operate over a wide range temperature range since optimum PID values usually change with temperature.

To use the Table mode effectively, the user must first characterize the cryogenic process over the range of temperature that will be used, then generate PID and heater range values for various temperature zones. This is usually done using the autotune capability. Once the information is placed into a PID Table, the Model 24C will control in Table mode by interpolating optimum PID values based on setpoint.

The Model 24C allows for the entry of six independent PID Tables. Each table may contain up to 16 temperature zones.

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

Alarm Outputs

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

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

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

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

> ⓘ **Note:** A latched alarm may be cleared by pressing the Alarm key on the front panel. This will show the status of all alarms.

Relays

The Model 24C has two dry-contact mechanical relay outputs.

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

Normally-Open contacts are available on the rear panel. Contact rating is 1.0A.

Remote Interfaces

Ethernet LAN and RS-232 interfaces are standard. IEEE-488.2 (GPIB) and USB are external, field installable options. All functions and read-outs available from the instrument may be completely controlled by any of these interfaces.

The LAN interface is electrically isolated and is 10/100-BaseT compliant. Connection is made via the RJ-45 connector on the rear panel.

The Serial port is an RS-232 standard null modem with male DB9 connector. Rates are 9600, 19,200, 38,400 and 57,200 Baud.

When installed, the GPIB option is fully IEEE-488.2 compliant. Connection is made at the rear panel's LAN port.

The USB option is a serial port emulator.

The programming language used by the Model 24C is identical for all interfaces and is SCPI language compliant. The Standard Command Protocol for programmable Instruments (SCPI) is a sub section of the IEEE-488.2 standard and is a tree structured ASCII command language that is commonly used to program laboratory instruments.

Rear Panel

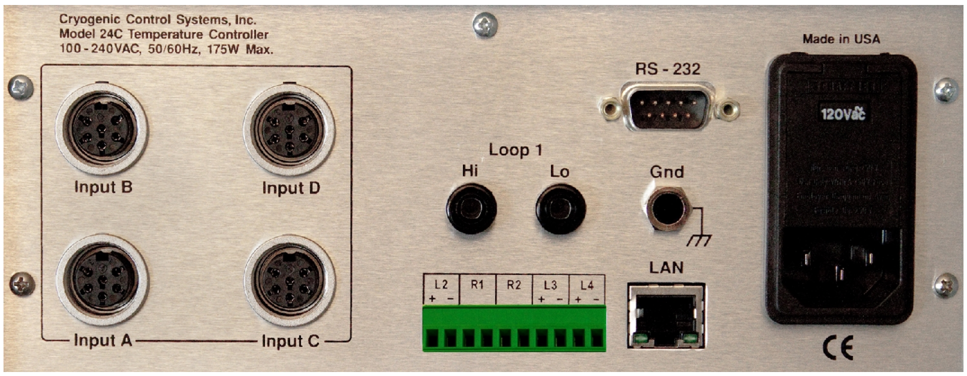


Figure 2: Model 24C Rear Panel Layout

AC Power Connection

The Model 24C requires single-phase AC power of 50 to 60 Hz. Voltages are set by the line voltage selector in the Power Entry Module on the rear panel. The power cord will be a standard detachable 3-prong type.

Line voltage selections are: 100, 120, 220 or 240VAC. Tolerance on voltages is +10% to -5% for specified accuracy and -10% for reduced full-scale heater output in the highest output range.

The power jack and mating plug of the power cable meet Underwriters Laboratories (UL) and International Electrotechnical Commission (IEC) safety standards.

User-replaceable fuses are incorporated in the Power Entry Module.

> ⓘ **Note:** The Model 24C uses a smart power on/off scheme. When the power button on the front panel is pressed to turn the unit off, the instrument's setup is copied to flash memory and restored on the next power up. If the front panel button is not used to toggle power to the instrument, the user should configure it and cycle power from the front panel button one time. This will ensure that the proper setup is restored when AC power is applied.

Caution: *Protective Ground:* To minimize shock hazard, the instrument is equipped with a three-conductor AC power cable. Plug the power cable into an approved three-contact electrical outlet or use a three-contact adapter with the grounding wire (green) firmly connected to an electrical ground (safety ground) at the power outlet.

Fuse Replacement and Voltage Selection

Access to the Model 24C's fuses and voltage selector switch is made by using a screwdriver to open fuse drawer in the power entry module. A slot is provided above the voltage selector window for this purpose.

The fuse and voltage selection drawer cannot be opened while the AC power cord is connected.

Voltage selection is performed by rotating the selector cams until the desired voltage shows through the window shown.

There are two fuses that may be removed by pulling out the fuse modules below the voltage selector. Fuses are specified according to the AC power line voltage used.

Line Voltage	Fuse	Example
100VAC, 120VAC	2.0A slow-blow	Littlefuse 313 002
220VAC, 240VAC	1.0A slow-blow	Littlefuse 313 001

Table 12. AC Power Line Fuses

Mechanical, Form Factors and Environmental

Enclosure

The Model 24C enclosure is standard 2-U half-width 17-inch rack-mountable type that may be used either stand-alone or incorporated in an instrument rack.

Dimensions are: 8.5"W x 3.5"H x 12"D. Weight is 9 Lbs.

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

Environmental and Safety Concerns.

Safety

The Model 24C 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.

- Grounding: To minimize shock hazard, the instrument is equipped with a three-conductor AC power cable. Plug the power cable into an approved three-contact electrical outlet only.

Safety Symbols

Direct current (power line).

Alternating current (power line).

Alternating or dirrect current (power line).

Three-phase alternating current (power line).

Earth (ground)terminal.

Protective conductor terminal.

Frame or Chassis terminal.

On (AC Power)

Off (AC Power)

Equipment protected throughout by double insulation or reinforced insulation (equivalent to Class II of IEC536).

Caution: High voltages; danger of electric shock. Background color: Yellow; Symbol and outline: Black.

Caution or Warning - See instrument documentation. Background color: Yellow; Symbol and outline: Black.

Fuse.

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 ±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.

Front Panel Operation

The user interface of the Model 24C Cryogenic Temperature Controller consists of a 40 character by eight line TFT LCD and a keypad. All features and functions of the instrument are accessed via this simple and intuitive menu-driven interface.

Figure 3: Model 24C Front Panel Layout

The Keypad

Function Keys

The Function Keys on the Model 24C are **Power** , **Stop** , **Control** , **Home** , and **Enter** . These buttons always perform the same function, regardless of the context of the display.

The **Power** key is used to turn AC power to the controller on or off. Note that this key must be pressed and held for one second in order to toggle AC power.

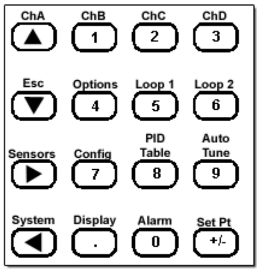
> ⓘ **Note:** The Model 24C uses a smart power on/off scheme. When the power button on the front panel is pressed to turn the unit off, the instrument's configuration is copied to flash memory and restored on the next power up. If the front panel button is not used to toggle power to the instrument, the user should configure the controller and cycle power from the front panel button one time. This will ensure that the proper setup is restored when AC power is applied.

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

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

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

The Keypad and Setup Menu Keys



The keypad keys on the far right side of the instrument serve a dual function. When the display is showing one of the configuration menus, the keypad is used for navigation and data entry. When the display is in the Home Status Display, their function is identified by a label printed just above the key and is as follows:

ChA, **ChB**, **ChC**, **ChD** - Go to the Input Channel Setup menu.

Loop 1, **Loop 2** - Go to the Control Loop Setup menu.

Auto Tune - Go to the auto-tuning menu for either loop.

Config - Go to the User Configurations menu.

Sensors - Go to the Sensors configuration menu, including sensor calibration curves.

PID Table - Go to the PID tables setup menu.

System - Go to the System setup menu. This includes fields for Remote Input / Output, Display filters and the Over Temperature Disconnect feature.

Display - Go to the Display setup menu. This allows configuration of the front panel display from a list of options

Alarm - Go to the Alarm Status menu.

Set Pt - Set the setpoint values for both control loops.

Options - Go to the Options Setup Menu.

Keypad Data Entry

The keypad is used to enter data and make selections in the various configuration menus. Fields require the entry of numeric or enumeration data.

Enumeration fields are display fields where the value is one of several specific choices. For instance, the Heater Range field in the Loop 1 setup menu may contain one of only three possible values: HIGH, MID and LOW. There are many enumeration fields that contain only the values ON and OFF.

Enumeration Fields

An enumeration is always indicated by the **+** character in the first column of the field.

To edit an enumeration field, place the cursor at the desired field by using the Navigation keys. Then, use the **+** or **0** keys to scroll through all of the possible choices in sequence.

When a field has been changed, the cursor will flash over the **+** symbol. To select the displayed value, press the **Enter** key. To cancel selection without updating the field, press the **Esc** key.

To select the displayed value, press the **Enter** key. To cancel selection without updating the field, press the **Esc** key. The cursor will then return to the **+** symbol.

Numeric Data Fields

Numeric data is indicated by a pound-sign (**#**) in the first column of the field.

The Keypad Keys are used to enter data into numeric fields. These keys are: the numerals **0** through **9**, the period key (**.**) and the **+/-** key.

When the cursor is positioned to a field that requires numeric data, the keypad keys become hot and pressing one of them will result in the field being selected and numeric entry initiated. This is indicated by a flashing cursor.

When the **Enter** key is pressed, numeric data in the selected field will be checked for range and the instrument's configuration is correspondingly updated.

> ⓘ **Note:** If the numeric entry is outside of the required range, an error is indicated by the display of the previous value of the field.

Once the entry of numeric data has started, it can be aborted by pressing the **Home** key. This will cause the field to be de-selected and its value will be unchanged. Pressing the **ESC (▶)**, key will exit data entry and restore the field to its previous value. The ◀ key can be used as a backspace.

> ⓘ Note: Up to 20 digits may be entered in a numeric field. When digit entry has exceeded the display field width, additional characters will cause the display to scroll from right to left. When entry is complete, the updated display field may not show all of the digits entered because of limited field width, however, the digits are retained to the full precision of the controller's internal 32 bit floating point format.

Summary of keypad functions

Key	Function	Description
	Power	Toggle power. Must be held in for two seconds.
	Stop	Disengage all control loops.
	Control	Engage all control loops.
	Enter	Enter key
	Home	Go to the Home Status Display.
▲	**ChA**	Input Channel Menu for Channel A. / Scroll Display UP
▼	**Esc**	If in data entry mode, Escape. Additionally, if the keypad has been locked by a remote interface, pressing this key will unlock it and clear the Remote LED / Scroll Display DOWN.
▶	**Sensors**	Go to the sensor setup menu / Scroll Display RIGHT
◀	**System**	If in data entry mode, backspace. From home display, go to the System setup menu / Scroll Display RIGHT.
.	**Display**	Go to the display configuration menu.
±	**Setpoint**	Change the setpoint value for either control loop. / Scroll to NEXT selection.
0	**Alarm**	Go to the Alarm Status menu. / Scroll to PREVIOUS selection
1	**ChB**	Input Channel Menu for Channel B.
2	**ChC**	Input Channel Menu for Channel C.
3	**ChD**	Input Channel Menu for Channel D.
4	**Options**	Options Setup Menu.
5	**Loop 1**	Go to the Loop 1 setup menu.
6	**Loop 2**	Go to the Loop 2 setup menu.
7	**Sensors**	Sensor data and calibration curve menu.
8	**PID Table**	PID table menu.
9	**Auto Tune**	Autotune menu.

Table 13: Keypad key functions.

The LED indicators and Audible Alarm

There are three LED indicators located just below the main display.

The blue **Control** LED is illuminated whenever either of the control loops are engaged and actively controlling temperature. To disengage the loops, press the **Stop** key.

The red **Alarm** LED is illuminated whenever a user programmed alarm has been triggered. To clear the alarm, the enabled event that is asserting the alarm must be disabled. Press the **Alarm** key to view the status of all alarms.

The green **Remote** LED can be turned on or off under program control by the remote interface. Use of this LED by a computer connected to the instrument is optional. This LED may also indicate that the keypad is locked out. To clear the LED and the keypad lockout, press the **Esc** key.

The Front Panel Display

Home Status Displays

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

The Home display is easily configured to show only desired data. There are four zones, each of which may be independently configured.

```
1A Sample Holder      2B First Stage
 251.445K              296.845K
 300.000K 1-Off-Low    100.000K 2-Off-Low
C: Second Stage       D:Rad Shield
 251.445K              296.845K
 RO-600 RuOx  10uV       R500 RuOx  1.0mV
```

Pressing the **Display** key will list the configuration of each zone.

To change the contents of a zone, scroll to the desired zone and press the Enter key. This will result in a display of all possible selections for the selected zone. A summary of the important selections is given below:

```
     Home Zone Configuration Menu
■ Zone 1    Loop 1 Status
  Zone 2    Loop 2 Status
  Zone 3    ChC Temperature
  Zone 4    ChD Temperature
```

Temperature

Displays an input channel temperature in 2x font. Above the temperature is the input channel indicator, name string and alarm status. Below is the sensor type and excitation level.

Loop Status Displays

These displays show the current status of a selected control loop. The control loop's input temperature is shown in 2x font. Above is the loop and channel indicator, the input channel's name string and alarm status. Below in 1x font is the loop's setpoint, heater range and percent-of-full-scale output power.

Input Channel Statistics Display

The Channel A, B, C and D statistics displays show the selected input channel temperature, the slope of the temperature history, the minimum and maximum temperatures.

The slope of the temperature history (M) is given in Display Units per Minute.

When any of the statistics pages are displayed, pressing the **Enter** key will reset the accumulation.

Temperature Displays

A typical Input Channel Temperature Display is shown on this page. It consists of the input channel designator, a Temperature reading and the current temperature units.

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

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

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

Temperature units are selected in the individual input channel setup menus, **ChA** , **ChB** , **ChC** or **ChD**. Temperature Units may be K, C or F. When Sensor Units (S) is selected, the raw input readings are exhibited. These will be in Volts or Ohms.

K	Kelvin
C	Celsius
F	Fahrenheit
Ω	Ohms
V	Volts

Table 14: Temperature Units

Sensor Fault Display

A sensor fault condition is identified by a temperature display of seven dash (**-**) characters as shown here. The sensor is open, disconnected or shorted.

-------K

Temperature Out of Range Display

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

.......K

> ⓘ **Note:** 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 controller's input preamplifier causes erratic voltage values when left unconnected. If an input is left unconnected, the sensor type should be set to type "None", which turns the input off.

Loop Status Displays

When the Model 24C is not controlling temperature, the status of the Loop output is shown.

The first character of the Loop Status Display is always the loop number, which will be either a superscripted 1 or 2 corresponding to Loop 1 or Loop 2.

The Loop number is accompanied by the heater status as follows:

1. **-OFF-** Indicates that heater output is functional and the control loop is off or disabled.

   `1-OFF-Low`

   For the primary heater, Loop 1, the range is also shown. Range settings may be either **Hi**, **Mid, Low** or **Min**. The range is set in the **Loop 1** menu.

   For the secondary output, or Loop 2, the range will be shown as **Hi** or **Low**. The range is set in the **Loop 2** menu.

2. **Overtemp** indicates that the controller's Internal Temperature Monitor circuit shut off the heater. This fault is usually the result of a shorted heater or use of a heater with significantly less resistance than the selected load resistance. After the controller has been allowed to cool to an acceptable temperature, pressing the **CONTROL** button will clear the error and restore control mode.

   `1 Overtemp`

3. **OTDisconn** indicates that the heater output was disconnected by the Over Temperature Disconnect Monitor. This monitor is configured by the user and functions to disable the heater if a specified over temperature condition exists on a selected input channel. See the **System** menu for information on how to configure and use this important feature.

   `1 OTDisconn`

If the Model 24C is controlling temperature (loop ON), the heater status display shows the loop output as a percentage of full scale.

This example shows the Heater Status for Loop 2 in a Model 24C controller. The unit is in control mode and is outputting 30% of full scale output current. This means that the output power is (30%)^2, or 9% of 10 Watts.

`2 30% HI`

Loop Bar Chart Display

The Loop Bar Chart is a 50-segment bar chart that shows the measured output of a selected loop output.

The bar is composed of ten blocks with five segments. Therefore, output current can be read to an accuracy of 2%.

Note that the bar chart does not have a loop number indicator.

Some examples are:

Loop ON, zero output:	`----------`
Loop OFF:	`-Htr-Off-`
Loop ON, 50% output:	`█████-----`

> ⓘ **Note**: The Model 24C uses an independent circuit to read current actually flowing through the load. The heater bar graph shows this measured current. If the unit is controlling temperature, but the bar graph indicates zero current flow, an error condition exists, possibly an open heater.

Front Panel Menu Operation

Instrument Setup Menus

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

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

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

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

Format indicators are:

- Numeric entry.

+ - Enumeration entry using the **+** and **0** keys.

▮ - The line is selected by pressing the **Select** key.

The Setpoint Menu

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

Press the **Home** key to exit the menu without update.

The Alarm Status Display Menu

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

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

When an alarm is asserted, the Alarm LED on the front panel will light. Pressing the **Alarm** key will display all of the alarms. Status is shown as follows:

—	No alarm
LO	Low temperature alarm
HI	High temperature alarm

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

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

Input Channel Configuration Menu

These menus contain all of the user-configurable parameters for a selected sensor input channel.

Use the navigation keys to move around the list.

When the cursor (**+**) is located to the left of the ChA indicator, channels B, C and D may be displayed by pressing the **+** key. To sequence in the reverse direction, press the **0** key.

```
       ChA:Sample Holder
                         High Alarm:100.00
+   1.543K --            High Alarm Enable:No
                         Low Alarm:   10.00
 Sen:32 RO-600           Low Alarm Enable:No
 Input Config            Deadband: 0.25
 CalGen                  Latched Enable:No
 Statistics              Audible Enable:No
```

Input Channel Configuration Menu		
1	+ 1.543K --	Input channel units. Selections are K, C, F or S. Here, S selects primitive sensor units. When S is selected, the actual sensor units of Volts or Ohms will be displayed.
2	+Sen:20 Pt100 385	Sensor type selection. Allows selection of any user or factory installed sensor. The 20 shown indicates that the current sensor is number 20.
3	■Input Config.	Go to the input configuration menu.
4	■CalGen	Go to the CalGen screen.
5	■Statistics	Go to the input channel statistics screen.
6	#High Alarm:200.000	Setpoint for the High Temperature alarm. Use the keypad for numeric entry and then press the **Enter** key.
7	+High Enable: No	High temperature alarm enable. Selections are Yes or No.
8	#Low Alarm: 200.000	Setpoint for the Low Temperature alarm.
9	+Low Enable: Yes	Enables latching alarms on the selected input channel.
10	#Deadband: 0.250	Alarm dead-band.
11	+Audible Ena: Yes	Enables the internal audio alarm to sound on any enabled alarm condition.
12	+Latch Enable: Yes	Enables or disables latching alarm conditions. A latched alarm is cleared by pressing the Alarm key followed by Home key.

Table 15: Input Channel Configuration Menu

Temperature Units Enumeration, Default: K

The Temperature Units field (line 1) assigns the units used to display temperature for the input channel. Options are K for Kelvin, C for Celsius, F for Fahrenheit and S for sensor units. Note that if the S option is selected, the actual sensor units will be displayed when the field is deselected. Available sensor units are V for Volts and Ω for Ohms.

Use the **+** or **0** key to scroll through all of the options. When the desired units are displayed, press the **Enter** key to make the selection. The display will now show the current temperature with the new units.

Sensor Type Selection Enumeration

Line 2 selects the Sensor type for the input channel. When this field is selected, the scroll keys are used to scroll through all of the available sensor types. Factory installed sensors appear first and then user sensors. For a list of both factory and user sensors, refer to Appendix A.

New user sensor types and calibration curves are added using the **Sensors** menu.

Setting a Temperature Alarm

The Alarm lines are used to setup alarm conditions. The Model 24C allows alarm conditions to be assigned independently to any of the input channels.

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

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

When the audible alarm is enabled, a high-pitched buzzer will sound when an alarm condition is asserted.

The Model 24C supports latched alarms. These are alarms that remain asserted even after the condition that caused the alarm has been cleared. To clear a latched alarm, first press **Alarm** to view the Alarm Status Display and then press the **Home** key to clear.

Input Channel Statistics

The Model 24C continuously tracks temperature history on each input channel. The Input Statistics shown in this menu provides a summary of that history.

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

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

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

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

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

Diode Sensor Configuration Sub-menu

Diode sensors do not have any user configurable parameters. The sub-menu is for information only.

Diode Sensor Configuration Sub-menu		
1	Input: 2.25V	Full-scale input voltage. This cannot be changed by the user.
2	Execitation: 10uA	Excitation current. This cannot be changed by the user.
3	Ret to Ch A Cfg ■	Return to the input channel configuration menu by pressing the **Enter** key.

PTC Sensor Configuration Sub-menu

The Model 24C supports all types of Positive-Temperature-Coefficient resistor sensors. Examples include Platinum and Rhodium-Iron.

There are three sub-menus, one for each of the types PTC100, PTC1K and PTC10K. An example of the PTC100 display is shown here:

PTC100 Sensor Configuration Sub-menu		
1	Input: 1.0K Ohms	Full-scale input resistance. This cannot be changed by the user.
2	Execitation: 1.0mA	Excitation current. This cannot be changed by the user.
3	Ret to Ch A Cfg ■	Return to the input channel configuration menu by pressing the **Enter** key.

In the case of a PTC1K device, the full-scale resistance range is 6.25K Ohms with 100uA excitation. The PTC10K has a full-scale resistance of 62.5K Ohms and uses an excitation current of 10uA.

Thermocouple Configuration Sub-menu

Note: thermocouple sensors require an optional thermocouple module.

Thermocouple Configuration Sub-menu		
1	FS Input: 70mV	Full-scale input voltage. This cannot be changed by the user.
2	TCoffset: 0.000K	Thermocouple offset value in Kelvin. This value is used to perform an offset calibration on an individual thermocouple device.
3	TCgain: 0.000V/V	Thermocouple gain value in volts / volt. This value is used to perform a gain calibration an individual thermocouple device.
4	Ret to Ch A Cfg ■	Return to the input channel configuration menu by pressing the **Enter** key.

Negative Temperature Coefficient Resistor Sub-menu

The Model 24C applies constant-voltage type excitation to all NTC resistors. In most applications, the user will set the Bias voltage to the desired value and set the Range field to Auto. This will allow the instrument to automatically select the Range in order to maintain the target voltage across the sensor.

```
        ChA:Sample Holder

+ 996.250Ω*             Bias Voltage: 10mV
 Pd: 1.00e-7W           Bridge Range: Auto

 Ret to ChA cfg.
```

In some advanced applications, the user may want to select a specific range. This will restrict the instrument to excitation levels within the selected range only. It is effectively a range-hold function.

The asterisk (*) character next to the sensor resistance reading indicates that the resistance bridge is not locked. This may indicate that it is still autoranging or that the sensor resistance is too high or too low for the selected voltage bias.

Configurable parameters for NTC sensors are shown here:

NTC Resistor Sensor Configuration Sub-menu	
+Bias Voltage: 10mV	Selects the bias voltage for constant-voltage excitation.
+Bridge Range: Auto	Bridge Range. Selects auto-ranging excitation vs. range-hold.
■Ret to Ch A Cfg	Return to the input channel configuration menu by pressing the **Enter** key.
Pd: 1.00e-11W	Shows the power dissipation in the sensor. Value is in Watts.

Bias Voltage Enumeration, Default: 10mV

Bias voltage is the voltage that the resistance bridge will hold constant across the sensor. Selection of higher voltages results in high measurement accuracy and low noise. Low voltages minimize sensor self-heating at low temperatures.

Bridge Range Enumeration, Default: Auto

Generally, the bridge range is set to ‘Auto’ for auto-ranging excitation. However, some applications require a fixed range to avoid possible temporary spikes in temperature measurements that are due to range switching.

CalGen Sub-menu
Selection of the CalGen field initiates the calibration curve generator feature. This feature is described in the section Using CalGen.

Setting a Temperature Alarm
The Alarm lines are used to setup alarm conditions. The Model 24C allows alarm conditions to be assigned independently to any of the input channels.

High temperature and low temperature alarms may be entered and enabled. Note that there is a 0.25K hysteresis in the assertion of high and low temperature alarms.

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 high-pitched buzzer will sound when an alarm condition is asserted.

The Model 24C supports latched alarms. These are alarms that remain asserted even after the condition that caused the alarm has been cleared. To clear a latched alarm, first press **Alarm** to view the Alarm Status Display and then press the **Home** key to clear.

Loop Configuration Menu

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

The Loop 1 menu is used to perform the setup of the primary 25/50 Watt heater output. This display was designed to provide all of the information required to tune heater parameters and is rather complex.

```
       Loop 1A:Sample Holder
Set Pt:300.000K     A:    1.234K
Pgain: 5.0000       1-Off-Low -Htr-Off
Igain: 60.000S
Dgain: 7.5000/S     Range: LOW
Pman:  5.0000%      PID Table index: 1
Type:  Man          Htr Load: 50Ω
Input: ChA          Next
```

Loop #1 and #2 menus can be accessed directly from the front panel. Loop #3 and #4 can be accessed by first pressing the **Options** key.

When the cursor is on the top line, the user can scroll through all of the control loop menus by pressing the **+** or **0** keys.

```
       Loop 3D:Booster Supply
Set Pt:300.000K     D:  211.234K
Pgain: 5.0000       3-Off-Low -Htr-Off
Igain: 60.000S
Dgain: 7.5000/S     Range: 10VDC
Pman:  5.0000%      PID Table index: 1
Type:  Man          Htr Load: N/A
Input: ChD          Next
```

Loop Configuration Menu		
1	#Set Pt:300.000K	Numeric setpoint entry.
2	A: 299.99K	Indicator of the controlling input channel and it's current temperature.
3	1-Off-LOW -Htr-Off-	Status indicator for the control loop.
4	#Pgain: 25.0000	Proportional gain, or P term for PID control.
5	#Igain: 71.0000S	Integrator gain term, in Seconds, for PID control.
6	#Dgain: 71.0000/S	Derivative gain term, in inverse-Seconds, for PID control.
7	#Pman:25.00%	Output power, as a percent of full scale, when controlling in the Manual mode.
8	+Input: ChA	Control input channel, ChA , ChB, ChC or ChD.
9	+Range:HI	Output power range. For loop 1, this will be HI, Mid, or Low. Loop #2 will always show 10W. Loops #3 and #4 will always show 10V.
10	+Type: PID	Control Type. Selections are: Off, Man, PID, RampP, Table and RampT.
11	#Power Limit: 100%	Power limit as a percent of full scale. On loop 1, this limit only applies to the HI range.
12	#Max Setpt:1000.00K	Maximum value allowed for the setpoint on this loop.
13	#PID Table index: 0	Table number for control in Table mode. The Model 24C has six PID tables numbered from zero through five.
14	+Htr Resistance:50Ω	Sets the heater load resistance. Selections are 25 and 50.
15	#Ramp: 0.10 /min	Ramp rate in temperature units per minute.
16	Next	Go to the next page of the control loop setup menu.

Table 16: Control Loop Setup Menus.

Setpoint Numeric Entry

In the first line of this menu the user can change the setpoint, while still viewing the temperature of the controlling source channel. This allows the user to view the temperature without leaving the setup menu.

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

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

Control Loop PID values Numeric Entry

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

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

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

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

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

> ⓘ **Note:** The Model 24C expresses heater output values in terms of percent of full-scale output power. The actual power, in Watts, applied to the load is proportional to the square-root of output current.

Control Source Input Channel Enumeration

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

Control Loop Range Enumeration, Default: Loop #1- Low

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

For Loop #1, settings are HI, MID, LOW and MIN. The actual full-scale output power is determined by this setting along with the load resistance. See the Heater Output Ranges Table for more information.

The full-scale output range for Loop #2 is 10W. A 50Ω load is assumed.

Control Types Enumeration, Default: Man

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

Loop control modes are:

1. **Man** for Manual control mode. Here, a constant heater output power is applied when the unit is controlling temperature. The Pman field selects the output as a percentage of full-scale.
2. **Table**. This is a PID control mode where the PID coefficients are generated from a stored PID table based on setpoint.
3. **PID** for standard PID control.
4. **Off**. In this mode, the controller will not apply power on this output channel. Note that the Model 24C is a dual-loop controller. The Off control mode is used if regulation is desired only on the other channel.
5. **RampP**. This is a temperature ramp mode. When a ramp operation is complete, the controller will revert to standard PID mode control at the final setpoint.
6. **RampT**. This is a temperature ramp mode that uses the PID tables to generate tuning parameters.

For more information on control algorithms, refer to the Heater Control Types table above.

For more information on temperature ramps, refer to the section on Temperature Ramping below.

Output Power Limit Numeric entry, Default: 100%

The Power Limit field defines the maximum output power that the controller is allowed to output. It is a percent of the maximum allowed output. Maximum value is 100% and minimum is 15%.

The Power Limit is applied to the HI range only.

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

Maximum Setpoint Numeric Entry, Default: 1000K

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

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

Setpoint values use the temperature units selected for the controlling input channel. See the section on Temperature Displays.

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

PID Table Index Numeric entry, Default: 0

The PID Table index line is used to identify the number of the user supplied PID Table that will be used when the Table control mode is selected. The Model 24C will store up to six PID Tables. They are numbered zero through five.

Heater Resistance Enumeration, Default: 25Ω

The heater resistance field is an enumeration that sets the value of the heater load resistance. Choices are 50Ω and 25Ω. When 50Ω is selected, the heater will output a maximum of 50 Volts at 1.0 Ampere or 50 Watts. When 25 Ohms is selected, the maximum heater voltage is 25 Volts and the output power is 25 Watts.

For additional information, please refer to the Loop 1 Heater output ranges or the Loop 2 Output Ranges tables.

Warning: It is necessary to set the Load resistance field to the actual value of the heater load resistance being used. If an incorrect value is selected, output power indications will be incorrect and non-linear heater operation may result. If the actual heater resistance is less than selected, the heater may overheat resulting in an automatic over temperature shutdown.

Ramping Rate Numeric entry, Default: 0.10/min

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

For more information on temperature ramps, refer to the section on Temperature Ramping.

User Configurations Menu

The User Configurations Menu is displayed by pressing the **Config** key. It is used to save or restore up to four instrument setups. Each setup saves the entire state of the Model 24C including setpoints, heater configurations, input channel data etc.

User Configurations Menu		
1	■Save	Pressing the **Enter** key saves the instrument setup to the selected configuration number.
2	■Recall	Pressing the **Enter** key restores a saved configuration.

Table 17: User Configurations Menu

Saving a User Configuration

In the **Config** menu, navigate to the Save field of the desired configuration. Press the **Enter** key to execute the save.

Restoring a User Configuration

First, press the **Config** key and navigate to the Recall field of the desired configuration. Press the **Enter** key to execute the restore.

The System Configuration Menu

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

```
     System Configuration Menu
Display TC:    4S   FW Rev:    1.00A
Display Res:    3
Network Config      Pwr Up In Ctl: No
RS232:       9600   AC Line:      60Hz
GPIB Adrs:     12
Datalog Config      Date: 08/01/2009
Over Temp Config    Time: 12:12:42
```

System Configuration Menu		
1	+Display TC: 4S	Sets the display time constant in seconds. Selections range from 0.5S to 64S
2	+Display Res: 3	Sets the resolution. Selections are: 1, 2, 3 or Full.
3	■Network Config	Press Enter to go to the network configuration menu.
4	+RS232: 9600	Sets RS-232 port baud rate. Selections range from 300 to 38K baud.
5	+GPIB Adrs 12	Sets GPIB I/O address. It is a numeric entry with a range of 1 to 31. Default is 12. (Note: GPIB is an external option)
6	■Datalog Config	Press **Enter** to go to the data logging setup screen.
7	■Over Temp Config	Press **Enter** to go to the Over Temperature Disconnect configuration screen.
8	FW Rev:1.01A	Displays the firmware revision level and hardware revision letter.
9	+Pwr Up In Ctl:	Power Up Mode. Off for normal operation. On to engage the control loops 10 seconds after power has been turned on.
10	+AC Line:	AC line frequency. Select 50 or 60Hz.

Table 18: System Configuration Menu

Display Time Constant Enumeration, Default: 2 Seconds

The **Display TC** field is used to set the display time-constant. This is an enumeration field that sets the time constant used for all temperature displays. Choices are 0.5, 1.0, 2.0, 4.0, 8.0, 16.0, 32.0 and 64 Seconds.

The time-constant selected is applied to all channels and is used to smooth data in noisy environments. The filtering only applies to displayed data; it is not used by the control loops.

Display Resolution Enumeration, Default: 3

The Display Resolution line (**Display Res**) is used to set the temperature resolution of the front panel display. Settings of 1, 2 or 3 will fix the number of digits to the right of the decimal point to the specified value. A setting of FULL will left-justify the display to show maximum resolution possible.

Note that the Display Resolution setting only formats the display as a user convenience. The internal resolution of the Model 24C is not affected by this setting.

Remote I/O Port Configuration

These lines are used to configure the Remote I/O interfaces including the LAN and RS-232.

Note that ‘GPIB’ is used to indicate the controller’s optional IEEE-488.2 interface.

The GPIB address line (GPIB Address) is a numeric field that may have a value between 1 and 31. The factory default is address 12. This field is used by the GPIB interface to select individual instruments. It is the user’s responsibility to configure the bus structure with unique addresses for each connected instrument.

RS232 Rate is an enumeration of the RS-232 baud rate. Choices are 9600, 19,200, 38,400 and 57,200.

Synchronous Filter Configuration Numeric Entry Default: 7

The Synchronous Filter is used to subtract synchronous noise from the input channel. An example of synchronous noise is the thermal signature of a cryocooler.

The default value of 7 taps is used for a line-frequency synchronous cryocooler. Values go from 1 (off) to 25 taps with 25 corresponding to 2.5 seconds of filtering.

This is an advanced setup function. Unless you are familiar with the synchronous noise source that you are trying to remove, leave this field at its default value of 7.

When the number of taps is changed, the control loops will have to be re-tuned because this filter affects the PID values.

AC Line Frequency Selection Enumeration, Default: 60Hz

Select the AC power line frequency. Choices are 50 or 60 Hz. This function only affects the operation of the Synchronous Filter described above.

Power-up in Control Mode. Default: Off

The Auto Ctl: field sets the power up mode of the controller's loops. Choose 'Off' for normal operation where the control loops are engaged by pressing the **Control** key and disengaged by pressing the **Stop** key. When on, the controller will power up, then after ten seconds, will automatically engage the control loops.

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

Over Temperature Disconnect Configuration

Navigate to the OTD Configuration menu by pressing the **System** key and then selecting the Over Temp Config field.

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

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

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

Finally, the OTD function must be enabled.

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

Over Temperature Disconnect Configuration		
1	`+OTD Enable:     Off`	Sets the Over Temperature Disconnect enable. Selections are On or Off.
2	`+OTD Source:     ChA`	Sets the Over Temperature Disconnect source input channel. Selections are ChA or ChB.
3	`#OTD T: 300.000`	Sets the Over Temperature Disconnect setpoint temperature.

Table 19: Over Temperature Disconnect Configuration

Data Logging Configuration Menu

> ⓘ **Note:** This section applies only to the internal data logging feature of the Model 24C. Remote data logging is also supported by the Cryo-con Utility Software program.

The Data Logging Configuration menu is used to start, stop and configure the data logging process. This menu is accessed from the System Menu.

The only user configurable parameter is the Interval in units of seconds. Once this is set, data logging starts when the State is ON and stops when the state is OFF.

The last line of the field can be used to clear the buffer.

```
      DataLogging Configuration Menu
+State: ON
#Interval: 5   Sec
 Count: 562
 Last Log: 8/1/2010 13:15:09
Press Enter to delete data log buffer
```

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

The log buffer is circular and contains 1365 entries. Then the maximum number of entries is exceeded, the oldest samples are written over. The buffer is maintained in Non-Volatile memory and will therefore survive a power failure.

DataLogging Configuration Menu	
+State: ON	Turns logging ON and OFF.
#Interval:5 Sec	Sets the Data Logging interval in units of Seconds. Minimum is 1 and maximum is 99,999.
Count:1365	Number of records in the log buffer.
Last Log: 8/1/2010 12:59:50	Date / time stamp of last record recorded.
Press Enter to delete data log buffer	

Logged data is read via any of the remote interfaces as follows:

- **Hyperterminal**: Enter the command DLOG?. Note: you should setup a Receive File to store the data before executing this command because a large volume of data is returned.
- **Cryocon Utility Software:** Click on the Upload Internal Datalog button. This will enable reading the log buffer to a spreadsheet .csv file.

Note: Reading a full log buffer takes about six minutes on any of the remote interfaces.

Network Configuration Menu
Navigate to this menu by pressing the **System** key and selecting the Network Config field.

Network Configuration Menu		
1	**Dev: M24C1234**	Instrument name reported over the LAN. May be modified by using the embedded web page.
2	**#IP: 192.168.1.5**	Network IP address. Numeric entry. Factory default is 192.168.1.5.
3	**#MSK: 255.255.255.0**	Network subnet mask. Numeric entry. Default is 255.255.255.0
4	**#Gwy: 192.168.0.1**	Network gateway. Only used if the instrument is to be connected through a gateway to the Internet. Default is 192.168.0.1.
5	**#Port: 5000**	TCP/IP port assignment. Default is 5000. The UDP port assignment is always the TCP/IP port plus 1 (Default: 5001).
6	**00:50:C2:6F:40:3F**	Media Access Control (MAC) address. Unique for each instrument.
6	**+DHCP Ena: OFF**	Enable DHCP IP address assignment.
8	**>**	Remote I/O: Last command received.
9	**<**	Remote I/O: Last response.

Table 20: Network Configuration Menu

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

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

The IP address uniquely identifies the instrument on the LAN. The factory default is 192.168.1.5. While any address can be entered, addresses usually begin with 192.168 which is a Class C network. Other addresses are used only when the instrument is directly connected to the Internet.

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

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

PID Tables Menu

The Model 24C can store six user generated PID tables. Each table may have up to sixteen setpoint zones.

Each setpoint zone in a table requires the entry of a setpoint along with corresponding values for P, I, D and full-scale heater range.

When controlling in the Table mode, the Model 24C will derive control loop PID coefficients and heater range by interpolation of the PID Table zones based on that zone's setpoint.

PID Tables can be used with both control loops.

Building a table from the front panel requires the entry of several numeric values. For this reason, the user may want to consider using one of the remote interfaces.

The start, and top level, of this process is the PID Tables menu. Two menu screens below this are used to enter numeric data. Here is an overview of the process:

1. The PID Tables menu is used to select the PID Table number (zero through three).
2. Once the table is identified, selecting the EDIT PID TABLE line will take the menu used to edit individual lines of the selected table.
3. To enter or edit an entry, set the desired entry index and enter the zone data on the following lines.
4. The last line of this menu is used to save the table when the entire table is complete.

When a table is saved, it is automatically conditioned so that it can be used directly by the control loop software. The conditioning deletes all entries with setpoint values of zero or less and sorts the table based on setpoint. Therefore, an entry may be deleted by setting the setpoint to any negative number.

The PID Table Menu

The PID Table Menu is accessed by pressing the **PID Table** key from the Home Display and then selecting a table.

The first line of this display shows which PID table is being edited. Placing the cursor on this line will allow the user to scroll through all of the tables.

```
        Edit PID Table 01
Table Index: 00
P:        1.60          Setpt: 300.00K
I:      160.0S          Ch: Default
D:       40.0/S         Range: HI
SaveTable&Exit
```

PID Table Edit Menu	
+Table Index	Sets the line number to edit.
#P	P gain value
#I:	I value in units of Seconds.
#D:	D value in units of inverse-Seconds.
#SetPt	Setpoint in units of temperature.
+Ch:	Input channel. Can be set to any input or to default where default is the input channel shown in the loop setup menu.
+Range:	Heater range setting.

Table 21: PID Table Edit Menu

Pressing the **Esc** key from this menu will abort the line entry process and return the display to the PID Table Menu above. Any edits made to the line will be lost.

When a table index is selected, all of the lines on this menu will be updated to show the selected line. Any data in the selected index will be displayed on the following lines.

The following data can be entered into the PID zone: Setpoint (SP), Proportional gain (P), Integral gain (I), Derivative gain (D) and heater range.

To delete a zone from the PID Table, enter zero or a negative number in the setpoint field. These entries will be rejected when the table is conditioned and stored in Flash memory.

Save the entire table by scrolling to the last line, SaveTable&Exit, then press the **Enter** key.

Sensor Setup Menu

The Sensor Setup menu is used to view and edit user temperature sensor data.

The Sensor Header Edit Menu

Pressing the **Sensor** key from the Home Status Display accesses the Sensor Setup Menu. From there, the Sensor Header Edit Menu can be accessed by by scrolling to the sensor and pressing **Enter**.

Definition of a sensor requires entering configuration data on this screen followed by entering a calibration curve.

Sensor Header Edit Menu	
+Type:Diode	Sets the Sensor Type.
#Mult: -1.0	Sets the sensor Temperature Coefficient and Calibration Curve Multiplier.
+Units: Volts	Sets Units of the sensor's Calibration Curve. Choices are: Ohms, Volts and LogOhm.

Table 22: Sensor Setup Menu

The first line on this menu is the sensor table index. Selecting this field allows the user to scroll through all of the sensors configured in the unit, including user sensors. The index is displayed along with the sensor name.

Note: the sensor name may be entered via any of the Remote I/O interfaces, but may not be changed from the front panel.

Sensor Type is an enumeration of all of the basic sensor types supported by the Model 24C. Choices are shown in the **Supported Sensor Configurations** table above.

The **Multiplier** field is a floating-point numeric entry and is used to specify the sensor's temperature coefficient and to scale the calibration curve. Negative multipliers imply that the sensor has a negative temperature coefficient. The absolute value of the multiplier scales the calibration curve. For example, the curve for a Platinum sensor that has 100Ω of resistance at 0°C may be used with a 1000Ω sensor by specifying a multiplier of 10.0. Also note that the temperature coefficient field is only used when the unit is controlling temperature based on the sensor units of Volts or Ohms.

Units is an enumeration field that identifies the primitive units used by the sensor's calibration curve. Choices are Volts, Ohms and LogOhm. LogOhm selects the base ten logarithm of ohms and is useful with sensors whose resistance vs. temperature curve is logarithmic.

The Calibration Curve Edit menu

From this screen, the user can input individual entries into a sensor calibration curve. Note that these curves can have up to 200 points requiring the entry of 400 floating point numeric values. For lengthy curves, you may want to consider using one of the remote interfaces. Cryocon provides a free PC utility that uploads or downloads curves which can be created by a text editor.

The Calibration Curve Edit menu is accessed by pressing the **Sensor** key, scrolling to the desired curve and then scrolling to the Edit field of that curve.

The procedure for entering or editing a calibration curve is summarized as follows:

1. First, set the index (IX) field to the curve entry that you want to enter. This will cause the display of data at that index.
2. Enter data points values by entering numeric data and pressing **Enter**.
3. Go to the next index by changing the IX field.
4. When all data points have been entered, the SaveCurve&Exit field is selected to save the curve.

Once complete, the controller will condition the curve by rejecting invalid entries, then sorting the curve in order of ascending sensor unit values. Therefore, an entry may be deleted by placing a zero or negative number in the temperature field.

Calibration Curve Menu	
#IX: 123	Sets the current index to an entry within the current table. Values are 0 to 159. When the **Enter** key is pressed, the following lines will display any data corresponding to the selected entry.
#T: 232.0050	Temperature. Units are always in Kelvin.
#S: 1.00002	Sensor reading. Units are taken from the Sensor Setup menu described above and may be Volts, Ohms or Logohms.
■SaveCurve&Exit	Pressing **Enter** save entered data and exit the menu. To exit without saving, press the **Home** key.

Table 23: Calibration Curve Menu

The Auto Tune Menu

The Model 24C can automatically tune both control loops. For a complete description of the autotune process including configuration of the tuning menus, refer to the section titled autotuning.

The autotuning menu entries are shown below:

Auto Tune Menu	
+Autotune: Loop 1	Sets the loop number for autotuning. Each control loop must be tuned separately.
#DeltaP: 5%	Sets the maximum power delta allowed during the tuning process. Value is a percent of full-scale output power for the selected loop.
Mode: PI-	Sets autotuning mode. Choices are P, PI or PID.
#Timeout: 180S	Sets the autotune timeout in seconds. If the process model has not converged within this time, tuning is aborted.
■Idle Go	Pressing **Enter** will initiate the autotune sequence. The current auto tune state is also shown.
#P=	Proportional gain term generated by autotune. This field will be blank until a successful autotune is completed
#I=	Integral gain term generated by autotune. This field will be blank until a successful autotune is completed.
#D=	Control Type. Selections are: Off, Man, PID, RampP and Table.
■Save & Exit	Derivative gain term generated by autotune. This field will be blank until a successful autotune is completed.

Table 24: Auto Tune Menu

The Options Menu

Press the **Options** key to access the Options Menu. This will display the following menu:

Options Menu	
■Relay 1	Go to the Relay 1 Configuration Menu
■Relay 2	Go to the Relay 2 Configuration Menu
■Control Loop 3	Go to the Loop #3 Configuration Menu
■Control Loop 4	Go to the Loop #4 Configuration Menu

The Relay Configuration Menu

The Relay Menu is accessed from the Options Menu described above. It is used to configure two relay outputs of the Model 24C.

Relay Configuration Menu	
Rly Status: ---	Status of the Relay.
+Mode:Auto	Output mode selection. Modes are: Auto, On and Off.
+Source:ChA	Select the input channel used as the source for controlling the output.
#High: 200.000	Set point for the High Temperature output. The output, when enabled, will be asserted when the input temperature is above this value.
+DO1:Enable: Yes	High temperature output enable. Selections are Yes or No.
#Low: 100.000	Set point for the Low Temperature output. The output, when enabled, will be asserted when the input temperature is below this value.
+DO1:Enable: No	Low temperature output enable.
#Deadband: 0.25	Deadband, or transition band, in units of the controlling input channel.

The first line of the display is an information only line that describes the state of the digital output and the current temperature on the source input channel. It is used to assist in the configuration of the digital outputs. Digital output status indicators are shown in the table below.

The deadband field sets the amount of hysteresis applied to the temperature before a digital output is set or cleared. Units for this field are in the same units as the controlling input channel. For example, if the deadband is set to 0.25K, a high temperature digital output will not assert until the current temperature exceeds the setpoint by 0.25K and will not clear until the temperature is 0.25K below the setpoint.

Relay Status Indicators	
---	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.

Table 25: digital output Status Indicators

Relay Modes are as follows:

Digital Output Modes	
Auto	Relay is controlled by enabled high and low setpoints.
ON	Relay is in manual mode and is asserted.
OFF	Relay is in manual mode and is clear.
Control	Relay is asserted whenever the controller is in Control mode. Useful in controlling external booster supplies.

Table 26: Digital Output Modes

Basic Setup and Operation

Configuring a Sensor

Before connecting a new sensor to the Model 24C, the instrument should be configured to support it. Most common sensors are factory installed while others require a simple configuration sequence.

A complete list of sensors installed at the factory is shown in Appendix A. To configure the instrument for one of these sensors, proceed as follows:

1. To install the sensor on Input Channel A, press the **ChA** key. For Channel B, press the **ChB** key etc. This will take you to the Input Channel Setup menu for the selected channel. The first line of this display will show the current temperature in real-time and allow you to select the desired display units. Press the **+** or **0** keys to sequence through the available options and press the **Enter** key to make the selection.
2. Use the navigation keys to go down to the **Sen:** filed. Press the **+** or **0** keys to scroll through all of the sensor types available. When the desired sensor is displayed, press the **Enter** key to configure the instrument.

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

   At the end of the factory-installed sensors, eight user-installed selections will be shown. The default name for these are User Sensor N. However, this name can be changed to give a better indication of the sensor type that is connected.

   For most sensor types installation is now complete; press the Home key to return to the Home Status display. The exceptions are NTC resistor sensors that use constant-voltage AC excitation. With these types of sensors, scroll down to the Bias Voltage field and select the desired constant-voltage excitation level.

   > ⓘ **Note:** Only NTC resistor sensors require the selection of a Bias Voltage.

Once sensor configuration is complete, review the section on Sensor Connections to connect the sensor to the instrument.

Using NTC Sensors

Negative-Temperature-Coefficient (NTC) resistors are often used as low temperature thermometers, especially at ultra-low temperature. Their resistance and sensitivity increase dramatically at low temperature but their sensitivity is often relatively poor at warmer temperatures. The Model 24C supports these sensors by using a constant-voltage AC resistance bridge:

- Measurement accuracy and temperature range are improved at low temperature because sensor self-heating errors are reduced or eliminated.
- Measurement accuracy is improved at warmer temperatures because the constant voltage circuit increases excitation power in that region.
- The control stability is improved in the warm region since higher excitation power reduces measurement noise.
- DC offsets in the resistance bridge can cause additional power dissipation at low excitation levels. The Model 24C holds offsets to a maximum of one-half of the minimum excitation current by use of an offset cancellation feedback loop.

Error Sources in NTC Sensor Measurements

At warm temperatures, the major source of error with NTC sensors is the measurement electronics itself. In a well designed instrument, accuracy is limited to a level established by the measurement's signal-to-noise-ratio, where the signal is the power dissipated in the sensor and noise is the collection of all noise sources. Thus, accuracy is generally improved by increasing the power dissipated in the sensor.

Conversely, at low temperature, NTC resistors have high resistance and the primary source of error is sensor self-heating caused by excitation power. The resistor has high sensitivity in this region, so measurement errors are small when viewed in units of temperature.

Constant-voltage sensor excitation increases signal power at warm temperature, thereby improving measurement accuracy in an area where the sensor is less sensitive. At low temperature, constant voltage excitation reduces the power dissipated in the sensor which reduces accuracy in units of Ohms, but more importantly, reduces sensor self-heating. Since low temperature is the sensor's most sensitive area, temperature measurement accuracy will not be degraded. The result is an accuracy improvement that extends the useful temperature range of a given sensor at both the warm and cold ends.

Voltage Bias Level Selection

The Model 24C offers constant-voltage sensor excitation with voltage levels of 100mV, 10mV and 1.0mV. Higher voltages improve accuracy at warm temperature and lower levels reduce self-heating at cold temperature. The user can select the best level for best accuracy over the desired temperature range.

NTC Sensor Configuration

NTC sensors are configured by first going to the input channel menu, selecting a NTC sensor and then selecting the Input Config field. An example NTC Input Configuration menu is shown here. A Cryo-con R500 sensor was selected.

```
      ChA:Sample Holder
     NTC Sensor Configuration

+   0.241K          Bias Voltage: 1.0mV
 Pd: 1.66e-10W      Bridge Range: Auto


 Return to ChA cfg
```

Temperature and sensor power dissipation are shown in real-time.

Bridge Range is generally set to Auto but may be set to hold a range in systems where transients due to autoranging are disruptive.

Fixed ranges of 20K, 2.0K, 200 or 2 Ohms are available. The minimum resistance that can be measured in a fixed range is the range resistance divided by four. Maximum is approximately range times 1000 but is affected by the selected bias voltage.

Voltage bias levels are 100mV, 10mV and 1.0mV. Higher voltages improve accuracy at warm temperature and lower levels reduce self-heating at cold temperature. The user must select a level that maximizes accuracy over the desired temperature range.

Generally, sensors operating above about 3K use the 100mV setting. Below that, selection is more difficult because it depends on the sensor resistance and thermal design. To select a voltage bias in the low temperature region:

1. Establish the sensor at the lowest possible temperature and use the lowest value of bias voltage that will read the sensor's resistance.
2. Increase the voltage bias until a rise in temperature is noted and then reset the bias to the just previous value.

Downloading a Sensor Calibration Curve

The Model 24C accommodates up to eight user-defined sensor calibration curves that can be used for custom or calibrated sensors. Since these curves have up to 200 entries, they are usually maintained on a computer as a text file and downloaded to the controller by using the Cryo-con Utility Software. However, curve data may also be entered and edited from the front panel.

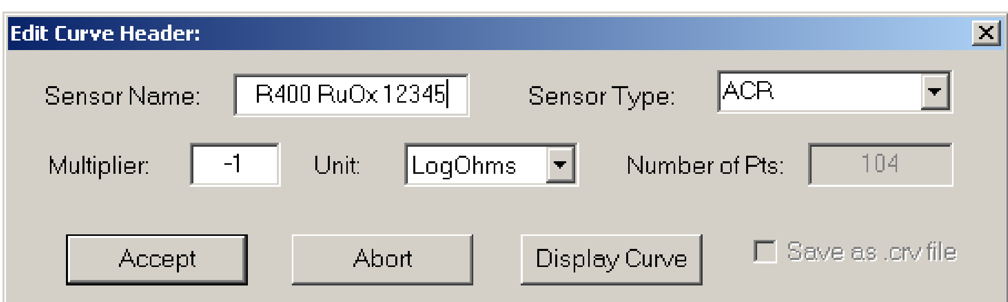
Cryo-con sensor calibration curves have a file extension of .crv. They may be opened and edited with any text editor. The format of the file is detailed in Appendix A.

The process for downloading a sensor calibration curve using the Cryo-con utility software is detailed in the section titled Downloading or Uploading a Sensor Calibration Curve. This section discusses how to set up a curve specifically for download to the Model 24C.

The Cryo-con utility software will read and attempt to 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. The Cryo-con utility software will convert these files into .crv format automatically.
SI .txt	No header information. Columns are reversed from other formats. Must be manually converted to a .crv file before use.
Other .txt	Software will attempt to parse any text file. If the file contains columns of sensor readings vs. temperature, the entries will be properly parsed and the curve can be used or converted to a .crv file after the header dialog box is filled out.

In order to download a file, run the utility software and select 'Sensor Curve Download'. The user will be prompted to select a file. Once the software has read the file, the header information dialog box will appear.



The Sensor Name can be any string, up to 15 characters, that helps identify the sensor. The Sensor Type, Multiplier and Unit fields affect how the instrument is configured, so they must be correctly set or unexpected results will be obtained.

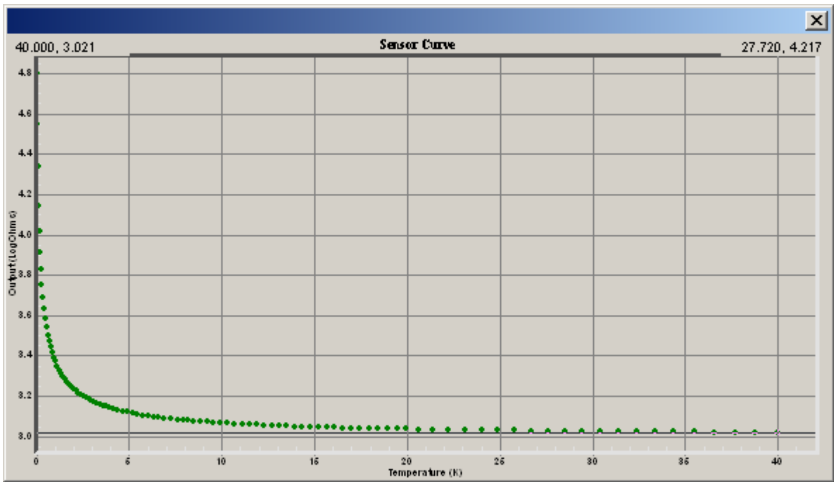
Sensor	Type	Multiplier	Units	Example
Cernox™	ACR	-1.0	LogOhms	CX1030E1.crv
Ruthenium-Oxide	ACR	-1.0	LogOhms	LSRX102.crv
Thermistors	ACR	-1.0	LogOhms	LSRX102.crv
Rhodium-Iron 27Ω	PTC100	1.0	Ohms	rhfe27.crv
Germanium	ACR	-1.0	LogOhms	LSRX102.crv
Carbon Glass	ACR	-1.0	LogOhms	LSRX102.crv
Silicon diode	Diode	-1.0	Volts	s900diode.crv
Carbon Ceramic	ACR	-1.0	LogOhms	LSRX102.crv
Platinum 100Ω	PTC100	1.0	Ohms	PT100385.crv
Platinum 1KΩ	PTC1K	1.0	Ohms	PT1K385.crv
Platinum 10KΩ	PTC10K	1.0	Ohms	PT10K385.crv
GaAlAs diode	Diode	-1.0	Volts	s900diode.crv

Table 27: Recommended Sensor Configuration Data

Note that NTC resistor data is generally in units of LogOhms. However, it can also be in units of Ohms. Be sure to check the curve data for reasonableness.

> ⓘ **Note:** One simple way to generate a sensor calibration curve is to open a similar sensor file with a text editor and paste in your own data. The example files in the above table are for that purpose. They are located in the Model 24C sub-directory of the Cryo-con utility software package.

At this point, it is a good idea to view a graph of the curve data.



The above graph is for a Ruthenium-Oxide sensor with units of LogOhms. It shows the typical highly non-linear curve for that type sensor. If the curve data was in units of Ohms, it would be so extremely non-linear that significant errors might result.

Check the graph for reasonableness and then dismiss it.

Proceed with downloading the curve to the instrument. Once complete, check and verify the result. The curve may be uploaded from the controller by using the Operations>Sensor Curve>Upload function of the utility software. Or it may be manually checked from the controller's front panel by pressing the **Sensors** key.

Autotuning

The Autotune Process

In performing autotuning, the Model 24C applies a generated waveform to the heater output and analyzes the resulting changes in process temperature. This is used to develop a process model, then a PID solution.

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

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

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

The Model 24C attempts to generate minimum overshoot solutions since many cryogenic temperature control applications require this. If the process is noisy, bandwidth is minimized as much as possible. If the process is very quiet, a more aggressive solution is generated subject to the minimum overshoot requirement.

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

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

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

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

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

System Noise and Tuning Modes

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

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

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

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

Sensor type has a significant impact on measurement noise.

The Model 24C uses a ratiometric technique to measure resistor sensors such as Thermistors, Platinum RTDs, Carbon Glass™ etc. This effectively cancels most of the measurement noise and allows effective use of PID control.

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

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

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

Pre-Tuning and System Stability.

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

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

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

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

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

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

System Characterization.

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

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

Autotune Setup and Execution

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

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

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

1. The Model 24C must be in Control mode.
2. Both the output power and the process temperature must be stable. The user must stabilize the process before the autotune function can accurately model it. If the process is not stable, erroneous values of P, I and D will be generated.
3. The input control channel units must be in temperature, not sensor units of Volts or Ohms. This is because PID control is a linear process and sensor output is generally non-linear. Note that the Model 24C can be manually tuned using sensor units but autotuning cannot be performed.

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

Table 28: Autotune Menu

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

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

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

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

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

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

Table 29: Autotune States

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

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

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

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

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

Temperature Ramping

Operation

The Model 24C performs a temperature ramp function using a specified ramp rate and target setpoint. Once placed in a ramping control mode, a ramp is initiated by changing the setpoint. The unit then progresses to the new setpoint at the selected ramp rate. Upon reaching the new setpoint, ramp mode is terminated and standard PID type regulation will be performed.

Ramping may be independently performed on control loop.

The procedure for temperature ramping is as follows:

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

As a variation on the above procedure:

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

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

Ramping Algorithm

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

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

Ramping Parameters and Setup

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

Summary

To perform a temperature ramp, proceed as follows:

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

Cryocooler Signature Subtraction

Cryocoolers often have a thermal signature that is associated with the mechanical cooling process. At the low end of their temperature range, this signature can have amplitudes of one or more Kelvin.

Since the thermal signature is related to the mechanical cooling process, it is low frequency and has an irregular shape that is rich in harmonics. With most coolers, the frequency will be a sub-multiple of the AC line frequency around 2Hz and the shape will be a narrow spike followed by a long lull.

If a conventional PID control loop is connected to a cryocooler, the thermal signature disrupts the loop and degrades the accuracy of control. If a fast PID loop is used, it attempts to track the signature, which usually results in placing a waveform on the loop output heater that causes control performance to degrade even further.

In still other systems, the thermal signature of the cryocooler is outside of the PID control loop bandwidth enough to cause a phase reversal that actually amplifies the signature causing the entire system to become unstable. These systems oscillate with a sine-wave at a very low frequency.

Faced with a significant thermal signature, users are generally required to de-tune the PID loop and live with the resulting inaccurate control. Here, there is still the possibility of instability.

The Model 24C uses a digital time-synchronous filter to actively subtract the cooler’s signature, resulting in much higher control accuracy and loop responsiveness.

With the Synchronous Filter enabled, the controller synchronously subtracts the thermal signal from the input temperature signal. Since synchronous subtraction is used to eliminate the undesired signature, there is no phase-shift or loss of signal energy, as would be the case if a classical notch or low-pass filter is used.

Subtraction is performed ahead of the PID control loop. Therefore, the input to the loop contains only the baseline temperature signal.

Using the Input Signature Subtraction filter gives much higher temperature measurement accuracy and allows the use of aggressive, high precision control. It is applicable to virtually any cryocooler system.

Synchronous Filter Setup

To use the synchronous filter, two parameters must be set:

- The AC Line Frequency setting must correspond to the actual power input AC frequency. The filter uses this to synchronize to the cooler.
- The Synchronous Filter Taps parameter must be set for the specific cryocooler type. This parameter gives the filter a starting point for the number of filter taps required to perform an accurate subtraction. Determination of a proper setting may require some experimentation.

To set the AC Line Frequency, go to the **System** menu and scroll down to the field *AC Line* field. Then, select 60 or 50 Hz as required.

```
#Sync Filt. Taps: 07
+AC Line:    60Hz
```

To set the Synchronous Filter Taps parameter, enter a number between 1 and 25 into the *Sync Filt. Taps* field. A setting of 1 turns the filter off.

Most cryocoolers use a setting of 7 since this is the most common sub-multiple of the AC line frequency applied.

> ⓘ **Note:** If you are not using a cryocooler, please leave the *Sync Filt. Taps* field set at the default of 7.

> ⓘ **Note:** If you change the setting the *Sync Filt. Taps* setting, you will need to re-tune the PID control loop.

Viewing a Cryocooler Thermal Signature

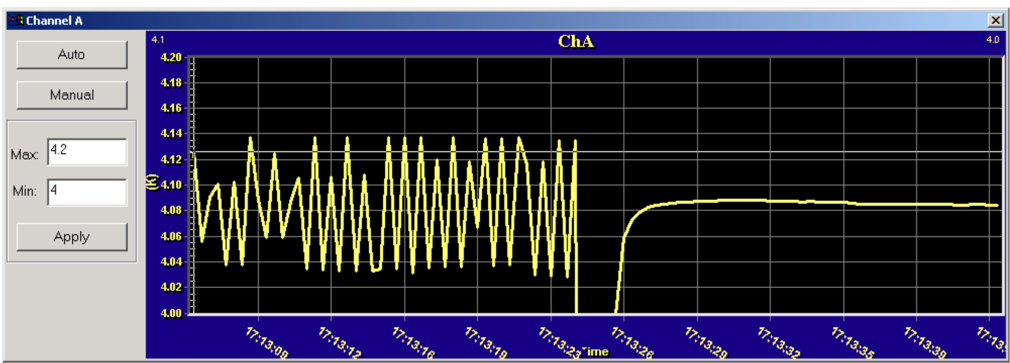
In order to view a cryocooler's thermal signature and experiment with the synchronous filter, the Cryo-con Utility Software may be used.

In the Data Logging menu, set the *interval* field to the minimum allowed value of 0.1 Seconds and then open a strip chart. Use the manual settings on the strip-chart to zoom in on the temperature. The signature with the chart set to the base temperature plus or minus about 0.5K should be observable.

In order to see the cooler signature, set the *Sync Filt. Taps* field to one. This disables the removal of the signature. From here, you can enter various values in order to see the affect of the synchronous filter.

Shown here is an example of a Cryomech PT403 pulse-tube refrigerator with a very low heat-capacity load. The first part of the graph is with the synchronous filter turned off and the second part shows a setting of 11 taps.

In most cases, a tap setting may be found that completely eliminates the signature.



Using an external power booster

Some systems require more power than the Model 24C can provide, or require a higher power secondary control loop. An auxiliary DC power supply or amplifier can be used for this purpose.

Programmable power supplies that can be programmed by an input voltage or current can be interfaced to either control loop of the Model 24C.

Both control loops of the Model 24C are unipolar current source outputs. This means that they will not have the ‘zero voltage’ drift problems that bipolar voltage source outputs exhibit.

Since both loops are current-source outputs, a programming resistor may be required to develop the voltage needed by the booster supply.

To use a booster supply with the Loop #1 output, setup the controller as follows:

1. Set the Loop 1 Load Resistance to 25Ω by using the Heater Configuration Menu.
2. On the Heater Setup Menu, set the Heater Range to Low. This causes the loop to output a full-scale programming current of 0.1A.
3. If the booster supply requires a voltage input, the loop output needs a programming resistor to set the full-scale programming voltage. This resistor can be installed across the input terminals of the power supply.
4. Connect the Loop #1 output to the booster supply to the programming input of the booster supply and set up the supply according to the manufacturer’s documentation.

Example: Many programmable power supplies require a zero to 10 Volt programming voltage. The value of the programming resistor is:
R = 10-Volts / 0.1mA = 100 Ohms.
Also note that the resistor must be capable of dissipating power:
Watts = 10-Volts * 0.1mA = 1.0-Watts.

To use a booster supply with the Loop #2 as follows:

1. Set the Loop #2 heater range to Low. This will cause the loop to output 1.0 Watts into a 50Ω load. Therefore, the output current is 141mA. To generate a zero to 10-Volt output, you must use a 72Ω programming resistor that can dissipate at least 2-Watts. Note: this resistor gets warm during normal operation.
2. Connect the Loop #2 output to the booster supply's programming input and set up the supply according to the manufacturer’s documentation.

Some inexpensive booster supplies that have been used with the Model 24C are:

Tenma 72-2005, 18V@3A, $159 (2005 price).
Tenma 72-2020, 30V@ 3A, $219 (2005 price).
Tenma 72-2015, 60V@1A, $229 (2005 price).

Power supplies designed for Automatic Test Equipment (ATE) usually have a remote on/off capability that can be controlled by one of the Model 24C's relays. To do this, set the relay mode to Control. In this mode, the relay will assert whenever the Model 24C is controlling temperature and will otherwise clear.

An ATE type power supply that has been tested with the Model 24C is the Lambda JWS-300 with the remote programming option. This is a 48V, 300W supply that will interface directly to the Model 24C.

Using CalGen

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

Most Cryo-con temperature controllers support CalGen directly on the instrument. However, the utility software package implements the same algorithm and can be used with virtually any instrument capable of measuring temperature.

Curves can be generated from any user selected sensor calibration curve and are 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 or thermocouple calibration curves require one or two data points. The generated curve is a best fit of the input curve to the two specified input points.

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

> ⓘ **Note:** CalGen is re-entrant. Therefore, the user can enter or exit the CalGen menus at any time without loss of previously captured data points. For example, a data point may be captured near 300K, next, the user may exit the CalGen process in order to stabilize the controller near 77K. When the CalGen menu is re-entered for curve generation, the point captured at 300K is still valid.

CalGen Initial Setup

Generation of a calibration curve using CalGen requires the measurement of various temperature points. Therefore, an input channel must be configured with the correct sensor before the CalGen process can start.

To initiate the curve generation, select the CalGen field on the Input Channel Setup menu. This takes the screen to a sub-menu for the specific sensor type.

> ⓘ **Note:** Before CalGen can be initiated, there must be a valid temperature reading on the selected input channel. If this is not the case, selecting the CalGen field will cause the display of an error message.

When the input channel has a valid reading, CalGen determines if the sensor is a diode or Platinum sensor. The calibration curve of the selected input sensor is used as the input to the curve generation process.

Using CalGen With Diode Sensors

Options for generating diode calibration curves are:

1. One point near 300K. The portion of a diode Sensor curve above 30K is fit to a user-specified point near 300K. This is a two-point fit where the 30K point is taken from the existing calibration curve. The portion of the curve below 30K is unaffected.
2. 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.
3. 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.
4. 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.

For a diode sensor, a sub-menu is displayed that allows the user to select the number of points desired for the CalGen fit.

First CalGen Menu, Diode Sensor	
■1pt CalGen @300K	Pressing the **Enter** key will select curve generation with a single point near 300K.
■2pt CalGen	Pressing the **Enter** key will select curve generation at two points where both points must be > 50K.
■3pt CalGen	Pressing the **Enter** key will select curve generation three points: Two above 50K and one near 4.2K.
■1pt CalGen @4.2K	Pressing the **Enter** key will select curve generation with a single point near 4.2K.

Table 30: First CalGen Menu, Diode Sensor

From this screen, select the desired number of points. For example, select ‘2 point’. This will take the display to the two-point curve generator screen shown here.

CalGen Menu, 2-point Diode Sensor	
#300.000 Capture	The exact temperature at a point near 300K is entered here. Note: if CalGen has not been used on this channel before, the word Capture will appear. Otherwise, the last captured sensor reading will appear.
■Unit: 0.98257V	Pressing the **Enter** key will capture the existing unit reading and associate it with the 300K point. The value will be displayed on line 1 above.
#77.000 Capture	The exact temperature at a point near 77K is entered here.
■Unit: 1.28257V	Pressing the **Enter** key will capture the existing unit reading and associate it with the 77K point. The value will be displayed on line 3 above.
■New Curve	Pressing the **Enter** key will initiate the generation of a new curve.

Table 31: CalGen Menu, 2-point Diode Sensor

The two temperature points, one near 300K and the other near 77K may be entered in any order.

To enter the 300K-point, change the field 300.000 to the exact required temperature. Then, allow the temperature measurement to stabilize. When the measurement is stable, select the Capture field next to the temperature field. This will cause the Model 24C to capture the sensor reading and associate it with the specified temperature.

When a sensor reading is captured, the actual reading will be displayed in place of the word Capture. Note that the user may capture a new reading by selecting this field again, even if it already contains a reading.

The Unit field of this screen will display the actual sensor reading in real time. This will allow the user to determine when the unit is stable at the required temperature.

Next, the second temperature must be entered in the same way as before.

When both temperature points have been entered, the user may select the New Curve field in order to generate the new curve. This will cause the display of a menu like the one shown here:

CalGen New Curve Menu	
# User Sensor 1	Sets the curve number for the generated curve. Numeric entry. Note: only the user curves can be written.
■ --Save--	Pressing the **Enter** key will cause the generation of a new curve. The curve will be stored at the curve number specified on line 1.

Table 32: CalGen New Curve Menu

From this screen, the user must select the target user curve for the generated curve.

Finally, select the Save field in order to generate the curve and store it in the selected user location.

Note: The CalGen process may be aborted by pressing the **Esc** or **Home** key.

Using 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. Therefore, the selection of the number of points is not required.

Warm-up Power Supply Operation

The Model 24C supports control of an external warm-up power supply by using one of the internal relays (Relay #2) to turn the supply on and off.

Function

The purpose of the warm-up function is to apply a significant amount of heat to a cryostat in order to warm it to room temperature as rapidly as possible. In many cryogenic systems throughput is limited by how fast a sample can be changed. In these systems, a rapid warm-up function significantly increases throughput.

The warm-up mode of the Model 24C does not control temperature, it simply applies a fixed amount of power to a heater and then disconnects it when the cryostat temperature exceeds a specified room-temperature setpoint.

Selecting a Power Supply

The warm-up function requires a user supplied external power supply that can be turned on and off by remote control. This includes many supplies designed for Automatic Test Equipment (ATE). The supply must be controllable with a remote dry-contact relay because the Model 24C does not output a control voltage.

A primary consideration for selecting a warm-up supply is how much power must be dissipated in the load (cryostat) during warm-up. Once this is determined, the supply voltage and load resistance can be determined.

For an example, a power supply that is commonly used with the Model 24C is the Lambda JWS-300. This is a single-output ATE supply that is available in a wide range of output voltages. It's maximum output power is 300-Watts and minimum is about 60-Watts. The actual power dissipated in the load is given by the formula:

$$Pd = \frac{\left(V_{supply}\right)^2}{R_{load}}$$

If a system requires a 300-Watt warm-up, use the 50-Volt model with an 8.3Ω heater load. For 100-Watts, one would use a 25Ω load etc. For even higher power, use the JWS-600 600-Watt supply.

External warm-up power supplies often output several hundred Watts in order to heat the cryostat rapidly. The user is responsible for configuring the supply and warm-up load in a way that does not cause damage to connected equipment.

The Over Temperature Disconnect feature will turn the external supply off when a specified temperature is exceeded. This is an important cryostat protection feature and the user is encouraged to enable it.

Connection

The external power supply remote control terminals are connected to the Model 24C's Relay #2 Normally Open contacts. This relay has contact ratings of 1.0A at 30VDC. When the warm-up function is enabled, Relay #2 becomes dedicated to controlling an external power supply and is no longer configured by the relay configuration menu.

Connections to Relay #2 are made using the Loop #2 connector on the rear panel. Refer to the Loop #2 and Relay Connections section.

The warm-up load, usually a resistive heater, is connected directly to the external power supply's output. The Model 24C will remotely turn the supply on and off; Therefore, switching the load is not required and is, in fact, undesirable.

Detailed Operation

The warm-up function has three states: *Idle*, *Control* and *Warm-up*.

State	Next State	Indication
Idle Control Loops OFF. Warm-up supply OFF.	Press the **Control** key to go to the *Control* state.	Control LED OFF Normal display
Control Control loops ON and controlling temperature. Warm-up supply OFF.	Press **Control** again to go to the *Warm-up* state. Press **Stop** to go to the *Idle* state.	Control LED ON Normal Display
Warm-up Control loops OFF. Warm-up supply ON and controlling the warm-up sequence.	Press **Stop** to go to the *Idle* state. Press **Control** to go to toggle back to the *Control* state. When the warm-up function is complete, the controller exits back to the *Idle* state.	Control LED flashing. Front panel shows 'warm-up" display. When *Warm-up* state exits, the alarm optionally sounds for five seconds.

Table 33: Warm-up Function State Table

The *Idle* and *Control* states are normal operating modes for the Model 24C. In the *Idle* state, the instrument indicates temperature but does not control it. In the *Control* state, the Model 24C controlstemperature as usual. When the warm-up function is enabled, the *Warm-up* state is added. In this state, the instrument is controlling the external warm-up power supply.

The **Control** key is used to toggle between the *Control* and *Warm-up* states. Therefore, warm-up is initiated by pressing the **Control** key when the instrument is already in the *Control* state. Warm-up is canceled by pressing the **Stop** key or pressing the **Control** key again.

When the Model 24C is in the *Warm-up* state, Relay #2 is asserted to turn the external power supply on whenever the controlling input temperature is below the target setpoint. When the setpoint is exceeded, the controller clears the relay and starts a timeout. If the temperature drops below the setpoint, the relay is again asserted and the timer is cleared.

When the temperature remains above the setpoint for the timeout period the audio alarm, if enabled, will assert for five seconds and the controller will revert to the *Idle* state.

> ⓘ **Note:** Warm-up or control functions may always be aborted by pressing the **Stop** key. Warm-up can also be aborted to the control state by pressing the **Control** key. The alarm will not sound.

The Over Temperature Disconnect feature will turn the external supply off and disconnect both control loops when a specified temperature is exceeded. This is an important cryostat protection feature and the user is encouraged to enable it.

Warm-up Display

When the controller is in *Warm-up* state, the Control LED on the front panel will flash and the display will show a warm-up message that includes the controlling input channel temperature, the warm-up setpoint, the status of the warm-up relay.

Warm-up Configuration Menus

To access the warm-up configuration menu, press the Options key and select the Warm-up field.

Warm-up Configuration Menu		
1	Off 123.456K	Information only. Current temperature on the source input channel and status of the warm-up relay.
2	+Enable Yes	Enable warm-up function.
3	+Source ChD	Select source input channel.
4	#Setpoint 325.00	Warm-up setpoint in units of the input channel.
5	#Timeout 123.4	Warm-up timeout in minutes. Zero indicates no timeout.
6	+Audio Enable: No	Select asserting the audio alarm for 5 seconds when the warm-up function exits.

Table 34: Warm-Up Configuration Menu

Enable Enumeration, Default: No

When disabled, the Model 24C functions normally, but all warm-up functions are disabled.

When enabled, the warm-up function is facilitated. Relay #2 becomes dedicated to the warm-up function and the **Control** key toggles the Model 24C between the *Control* and *Warm-up* states.

Source Enumeration, Default: ChD

Selects the input channel to be used as the temperature input to the warm-up function. May be any of the four input channels.

Setpoint Numeric Temperature, Default: 325.0

Setpoint for the warm-up function. Values between zero and 999K are acceptable, but normal use would require values near room temperature.

Timeout Numeric Minutes, Default: 0.0

Warm-up timeout. When the input temperature is above the setpoint for this timeout period, warm-up is canceled and the controller reverts to the *Idle* state. A value of zero turns the timeout OFF.

Audio Enable Enumeration, Default: No

Enables sounding the audio alarm for five seconds when the warm-up function is complete.

For detailed information on using the warm-up controller function, please refer to the section titled Warm-up Power Supply Operation.

Using Thermocouple Sensors

Thermocouple sensors have low sensitivity at cryogenic temperatures and are very susceptible to electrical noise. In order to obtain the best possible measurement accuracy, the recommendations given here should be carefully applied.

Installing the Thermocouple Module

All thermocouple sensors require the use of an optional Cryo-con external thermocouple module (4039-004). This module simply plugs into any sensor input channel of a Model 24C to support thermocouple measurements from cryogenic through oven temperatures. Up to four modules can be installed on a single instrument and they can easily be added or removed at any time. It is powered by the Model 24C and performs amplification, cold-junction compensation and connection to copper.

Internal switches are used to select the cold junction compensation for specific types. Open the module and use the switches to select types K, E, T, AuFe 0.7% or off.

The thermocouple device is connected to the module by using a mini-spade connector. Refer to the Thermocouple Connections section.

Gain and Offset Calibration

Thermocouple devices can vary significantly from their standard curves, especially at cryogenic temperatures where their sensitivity is reduced. To accommodate these variations, the Model 24C allows a user calibration for individual thermocouple devices. This can be a simple offset or a two-point offset and gain calibration. Note that device calibrations to not affect the instrument's basic calibration.

Device calibration is performed by using the instrument's Input Configuration menu. An example is shown here. Alternatively, calibration may be performed by using remote commands.

```
      ChA:Radiation Shield
   Thermocouple Sensor Configuration
+   1.543K              FS Input: 70mV

 TC offset: 0.000K
 TC gain:   1.000V/V

 Return to ChA cfg
```

This menu is selected by pressing the ChA key and then selecting the Input Config field. Selection of a thermocouple type sensor is assumed.

Device Offset Calibration

A simple offset, or one-point calibration is done as follows:

1. Connect the electronics as usual for thermocouple measurements. This procedure is done with the thermocouple cold-junction compensation ON. For best accuracy, be sure that ambient temperature doesn't vary.
2. From the instrument front panel, go to the input configuration menu and set the TC offset value to zero and the TC gain value to it's default of 1.0.
3. Allow the instrument to warm up for at least ½ hour without moving or handling the sensor.
4. Establish the thermocouple device at a precisely known temperature. When stable, compute the TC offset by subtracting the target temperature from the instrument's reading in Kelvin or Celsius.
5. Enter the computed value into the TC offset field to complete the procedure.

Device Two-Point Calibration

Thermocouples used over an extremely wide range that includes cryogenic temperatures usually require a two-point device calibration. This will require establishment of two target temperatures.

A simple offset, or one-point calibration is done as follows:

1. Connect the electronics as usual for thermocouple measurements. This procedure is done with the thermocouple cold-junction compensation ON. For best accuracy, be sure that ambient temperature doesn't vary.
2. From the instrument front panel, go to the input configuration menu and set the TC offset value to zero and the TC gain value to it's default of 1.0.
3. Allow the instrument to warm up for at least ½ hour without moving or handling the sensor.
4. Establish the thermocouple device at a precisely known high temperature and record this as the upper target temperature (Utgt). Record the instrument's reading in Kelvin or Celsius as the upper measurement temperature (Umeas).
5. Establish the device at a precisely known low temperature and record this as the lower target temperature (Ltgt). Record the instrument's reading in Kelvin or Celsius as the lower measurement temperature (Lmeas).
6. Compute the TC offset as follows:

$$Offset = \frac{Utgt \cdot Lmeas - Umeas \cdot Ltgt}{Lmeas - Umeas}$$

7. Compute the TC gain value as follows:

$$Gain = \frac{Utgt - Ltgt}{Umeas - Lmeas}$$

8. Enter the TC offset and TC gain values into the instrument to complete the procedure.

Check the calibration by verifying that the correct temperature is being read when the device is near the target temperature.

Grounded vs. Floating Thermocouples

Electrically floating devices are always recommended because they provide generally lower noise operation and cannot facilitate ground-loop conditions. However, the thermocouple module inputs are differential and have a high impedance to ground. This will allow operation with grounded devices in most systems. Always ensure that there is no more than a 5V difference between the grounded thermocouple and the instrument's chassis ground.

Common Error Sources

Cold Junction Compensation

Cold Junction Compensation in the Cryo-con thermocouple module is performed by a circuit that measures the temperature of the input connector pins. This reading is then used offset the device's output voltage. Errors can be minimized by reducing local air currents around the module.

Device Calibration Errors

Variation in the manufacture of thermocouple wire and it’s annealing over time can cause errors in temperature measurement.

Instruments that measure temperatures above about 0°C will usually allow the user to correct calibration errors by adjusting an offset in order to zero the error at room temperature. Unfortunately, in cryogenic applications, thermocouples lose sensitivity at low temperatures so a single offset voltage correction is insufficient.

Thermocouples used over a wide temperature range may need to be calibrated at two temperature extremes.

AC Power Line Noise Pickup

AC power noise pickup is indicated by temperature measurements that are significantly in error. In extreme cases, there may be no valid measurements at all.

When a grounded sensor is used, a poor quality ground may have sufficient AC voltage to exceed the input range of the module. This can often be corrected by running a copper connection from a point near the sensor ground and the chassis ground of the controller. Defective building wiring or insufficient grounding is usually the root cause.

General recommendations to minimize AC pickup include:

1. Minimize the length of the thermocouple wires. Connect the module as near as possible to the sensor so that thermocouple wires are converted to copper as soon as possible.
2. Twist the wires.
3. Avoid running sensor wires near, or parallel to AC power lines.

System Shielding and Grounding Issues

Grounding Scheme

The grounding scheme used in all of Cryo-con's instruments is based on a Single-Point-Ground and is designed to minimize ground-loop and noise pickup by assuming that the Sensor and Heater elements are electrically floating, but the remote interfaces are not.

The Single-Point-Ground

The internal Single-Point-Ground is the voltage reference point for the instrument's grounding scheme. All circuits are designed so that no current will normally flow through the connections to this ground. Therefore, it provides a good quality, low impedance path to ground for any undesired currents that are coupled into the equipment.

AC Power Entry

AC Power enters the instrument directly into a power entry module. This provides fusing, line voltage selection and RFI filtering.

The Building Ground, often referred to as Earth-Ground", Shield-Ground" or Third-Wire-Ground" is connected to the shield of the Power Entry RFI filter, then to the instrument's Single-Point-Ground. Since the grounding and shielding scheme depends on having a good quality ground, this Earth-Ground connection is extremely important. Noise and ground loop problems are often traced to how this connection is made.

If your facility does not provide a building ground, it is strongly recommended that one be fabricated.

Sensor Connection

For best performance, all sensors connected to the instrument should be electrically isolated (floating) from any other grounds.

Sensors used in cryogenic thermometry are often high impedance. For example, a Silicon diode temperature sensor will have about 160K ohms of impedance at 5K. Because of this, a very efficient antenna can develop around the sensor and its connections. Requiring these sensors to be floating and providing a low impedance path to ground is the most effective way to eliminate noise pickup from this antenna effect.

To ensure that the instrument's grounding scheme is working effectively:

1. Make sure that the sensors are floating.
2. Make sure that the input cable shields are connected to the connector's metal backshell.
3. Make sure that the Third-Wire-Ground is good quality and not conducting current.

Control Loops

The circuitry in the Control Loop Area provides power to external heater elements. The grounding of this area is identical to the Sensor Area described above. Note however that heater elements usually have very low impedance. Therefore, noise pickup issues are not near the problem that they are in the Sensor Area.

Digital Circuits

The digital circuits of the Model 24C cannot assume that its external connections are floating. Therefore, it is connected to the Single-Point-Ground through an RFI filter in order to prevent ground loops.

RS-232 connections bring a ground return connection from the host computer. This means that the Digital area must be at the same voltage as the host's circuit board ground; Otherwise, ground loop currents will flow from the host through the instrument and back into the Earth-Ground.

The LAN interface is electrically isolated and cannot introduce ground loops. Since it is isolated from the other areas of the circuit, no current carrying paths can flow through the sensitive analog circuits.

Cryo-con Utility Software

Cryo-con provides a PC compatible utility software package with all instruments. This is available on CD, or on the Internet.

Utility software can be used to control and configure any Cryo-con instrument via the RS-232, LAN, USB or IEEE-488 interface. It runs under all versions of the Windows operating system. This software provides several useful functions, including:

1. Real-time strip charts of temperature.
2. Data Logging. This function allows the user to record data from the instrument at a specified sample rate. The resulting file is compatible with most spreadsheet and data analysis software.
3. Download or upload sensor calibration curves. The software will accept curves in Cryo-con .CRV, Lakeshore .340 or Scientific Instrument's .txt format. In fact, it will read almost any table of temperature vs. sensor units.
4. Cryo-con's CalGen function is implemented. This function allows the user to fit an existing sensor calibration curve to one- two- or three user-specified points. The result is a high accuracy sensor calibration at low cost.
5. Upload and download PID tables to a Cryo-con temperature controller. These tables can be generated by using a simple text editor and downloaded to the controller.
6. Configuration of any of the instrument's remote interfaces.
7. Flexible 'Help' interface that documents all instrument remote commands with a cut-and-paste type interface.
8. 'Interactive Mode' provides interactive communication with the instrument over any of the remote interfaces.
9. Instrument calibration using a simple step-by-step menu driven process.
10. Uploading and downloading instrument firmware. Updates may be obtained on CD, or on the Internet.

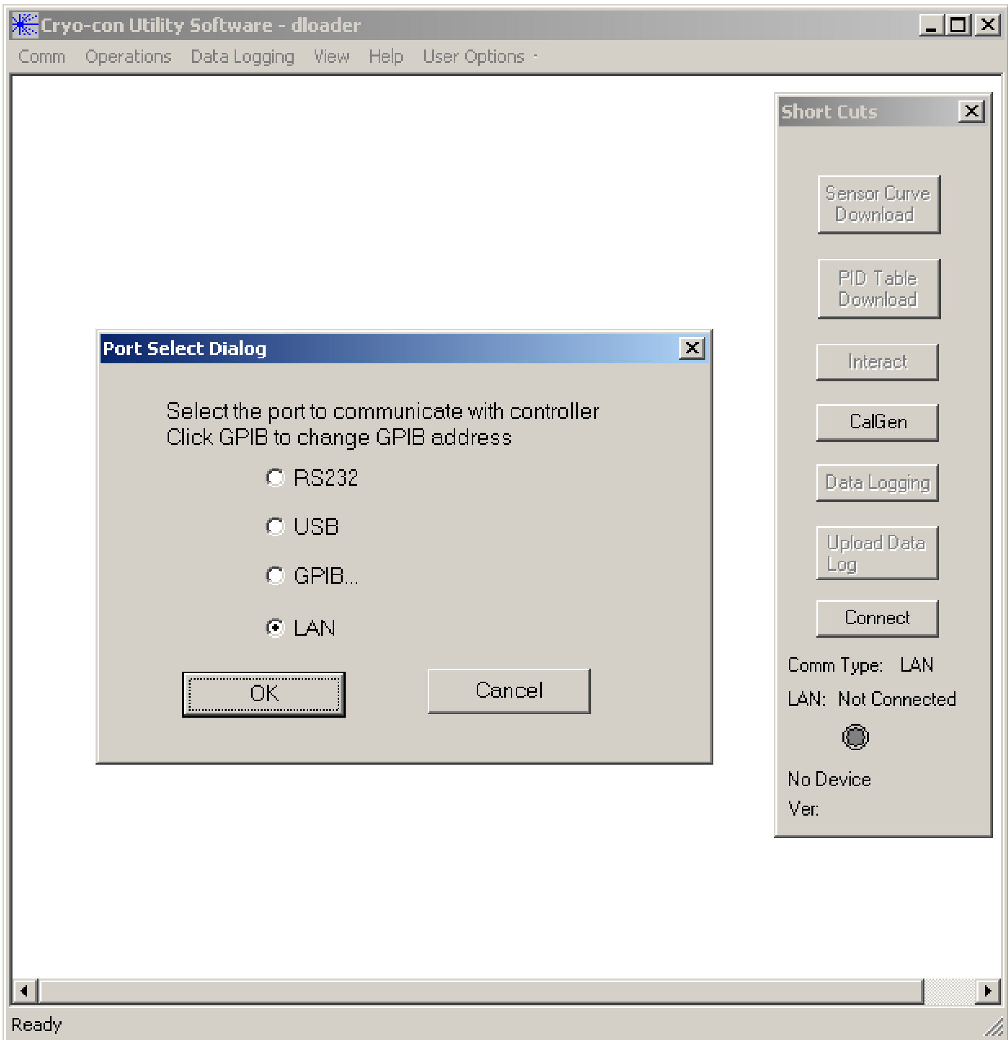
Installing the Utility Software

From a CD, the utility software package does not require installation. It can be executed from the CD directly by running the UTILITY.EXE program.

When the software is downloaded off of the Internet, it is in a self-extracting ZIP format and must first be un-zipped onto hard disk.

Connecting to an Instrument

The desired remote interface connection may be selected by clicking **Comm>Port Select** from the main menu.



Select the desired communications port and then click **OK**..

Click on the **Connect** button of the shortcut menu bar or on **Comm->Connect** from the main menu to connect to the instrument.

After a short delay, the connect LED should light and the instrument type is displays. Also, most of the grayed-out fields on the menu bars should activate.

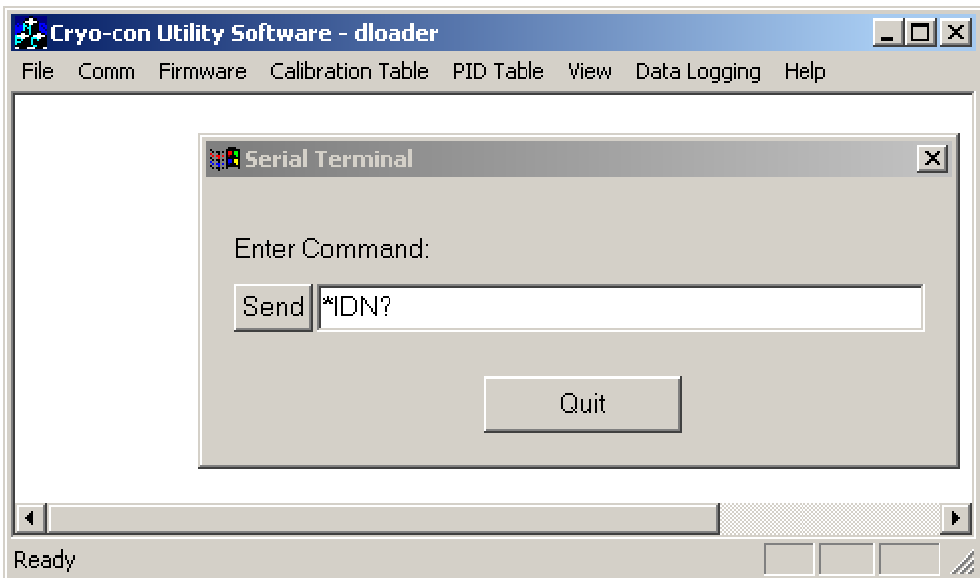
Using the Interactive Terminal

The Utility Software's Interactive Terminal mode allows the user to send commands to the instrument and view the response.

Select terminal mode by choosing **Comm>Interact** from the main menu or **Interact** from the shortcut bar. This will result in the display shown below.

To interact with the instrument, type a remote command into the dialog box and click **Send**. The command will be transmitted to the instrument and a response, if any, will be displayed on the background window.

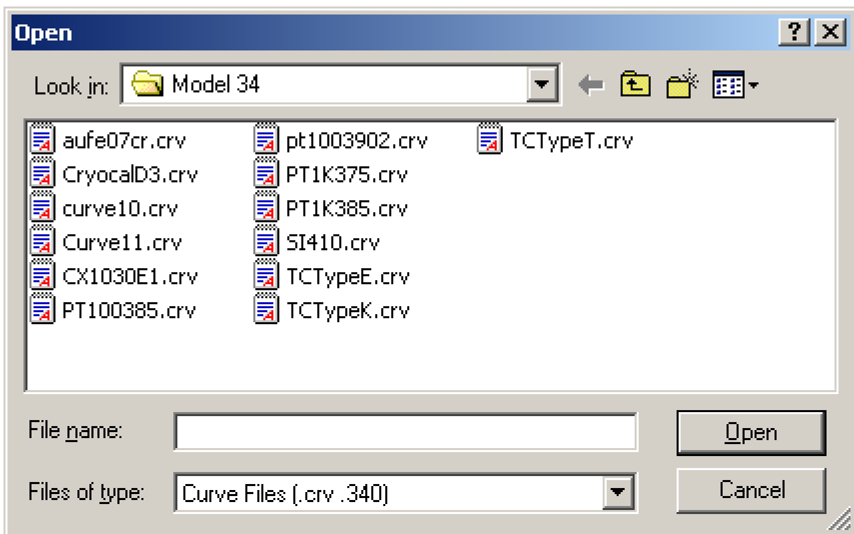
To exit terminal mode, click the **Quit** button on the dialog box.



Downloading or Uploading a Sensor Calibration Curve

Sensor calibration curves may be transferred between the PC and the instrument by using the Calibration Table menu.

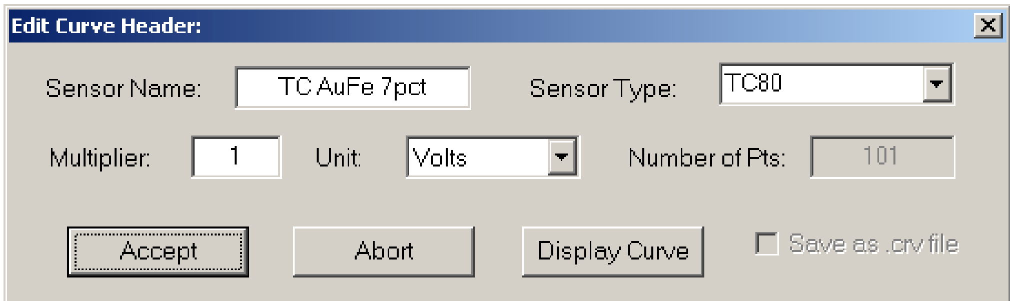
To download a curve (send it from the PC to the instrument), either select Sensor Curve Download" from the shortcut bar or **Operations>Sensor Curve>Download** from the main menu. This causes a file selection dialog box to appear as follows:



From this screen, the desired calibration curve is selected. Cryo-con calibration curves have the file extension of .CRV. Lakeshore curves with the extension .340 may also be selected. Scientific Instruments .txt files may be downloaded by first selecting a file type of *.* and then selecting the desired calibration curve file.

Cryo-con .CRV files are ASCII text files that may be edited by any text editor.

After selecting the file and clicking on **Open**, the selected file will be read and the Edit Curve Header dialog box will appear. This box contains information extracted from the curve file header that can be modified, if desired, before the curve is downloaded.



“Sensor Name" is any 15-character string and is only used to identify the sensor.

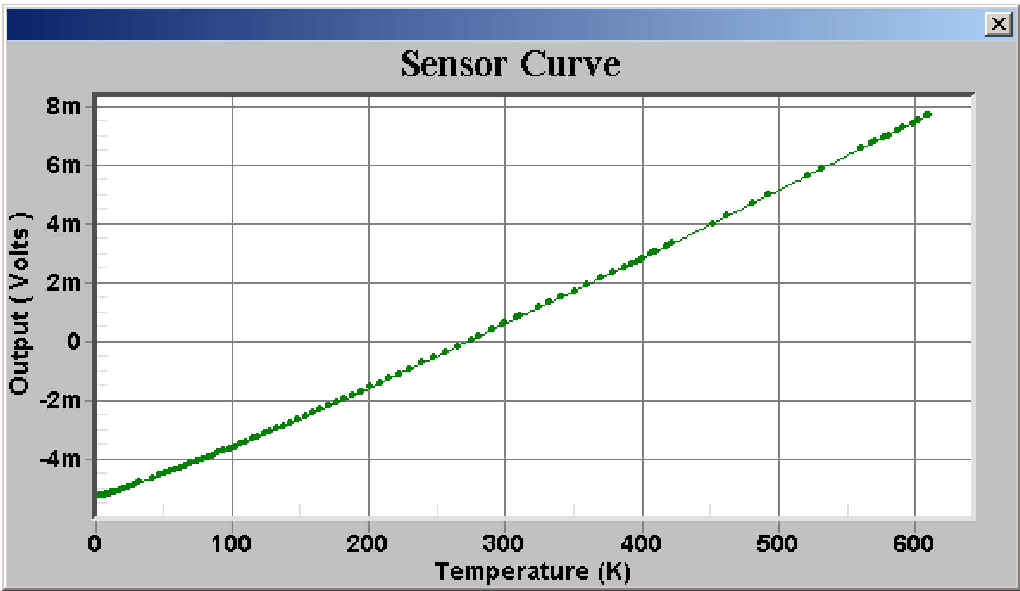
Sensor type can be selected from a pull-down menu or entered directly. Note that different models of Cryo-con instruments support different types of sensors. Therefore, it is important to enter a sensor type that is supported by the specific product. If the instrument receives a sensor type that it does not support, the ‘Diode’ type is selected. The section titled Supported Sensor Configurations" gives complete information on sensor types.

The Multiplier field is used to select the sign of the sensor’s temperature coefficient. A value of –1 selects a Negative-Temperature-Coefficient sensor while a value of 1 selects a Positive-Temperature-Coefficient.

The Unit field selects the units used in the calibration curve. Choices are: Volts, Ohms or LogOhm.

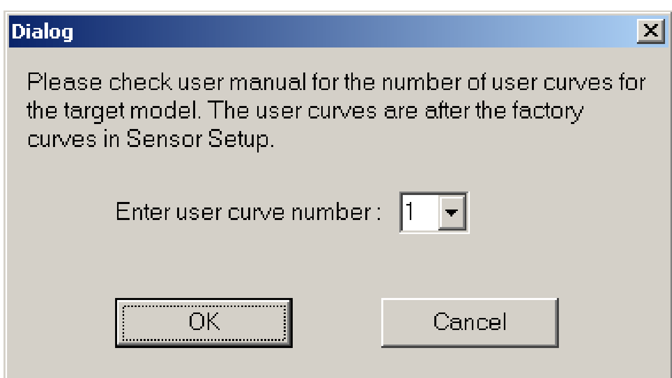
Checking the ‘Save as .crv’ will save the curve to disk as a Cryo-con .crv file.

The sensor curve may be viewed as a graph by clicking the ‘Display Curve’ button. An example plot is shown here:



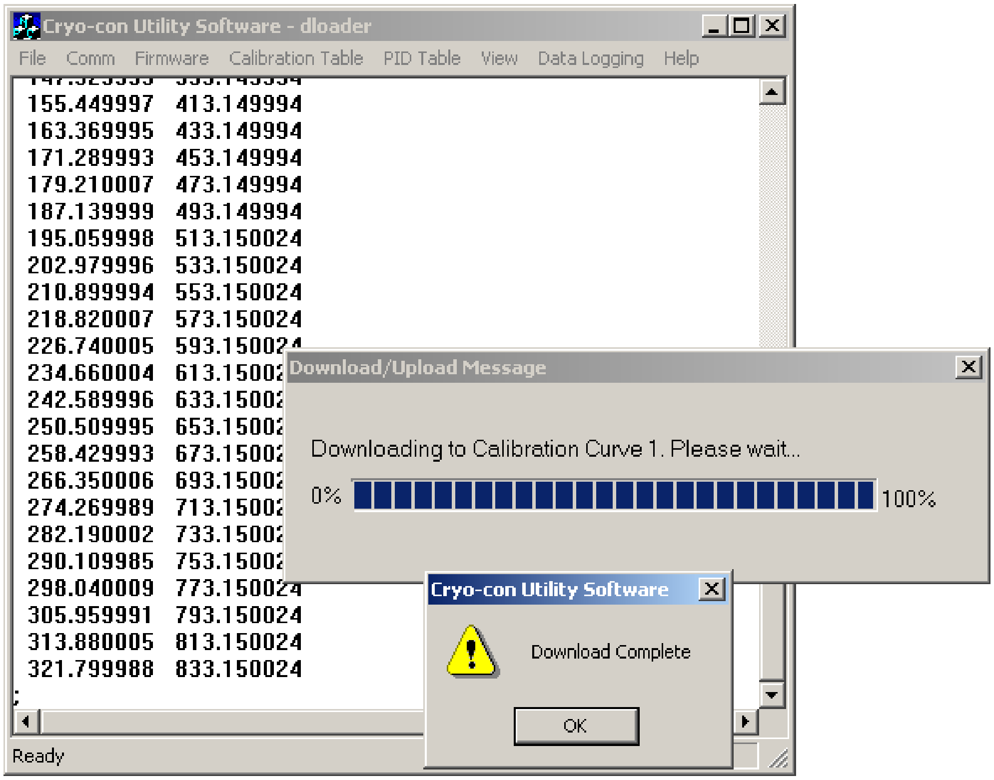
After completing any desired changes in the Edit Curve Header" dialog box, click ‘Accept’ to proceed. Then the, curve number dialog box will appear:

A user calibration curve should be entered here. For the Model 24C, user curves are 1 through 8.



When ‘OK’ is selected, the sensor calibration curve is downloaded to the instrument. During the transfer, curve data points will be displayed in the window’s main pane. Upon completion, the Download Complete dialog box will appear:

Dismiss this dialog box to complete the download process.



To upload a calibration curve, use the same procedure and select **Upload**. This will transfer a curve from the instrument to the PC.

Downloading or Uploading a PID Table

A PID table may be transferred to the instrument by selecting **PID Table>Download** from the main menu toolbar.

PID tables are transferred from the instrument to the PC by using **PID Table>Upload**.

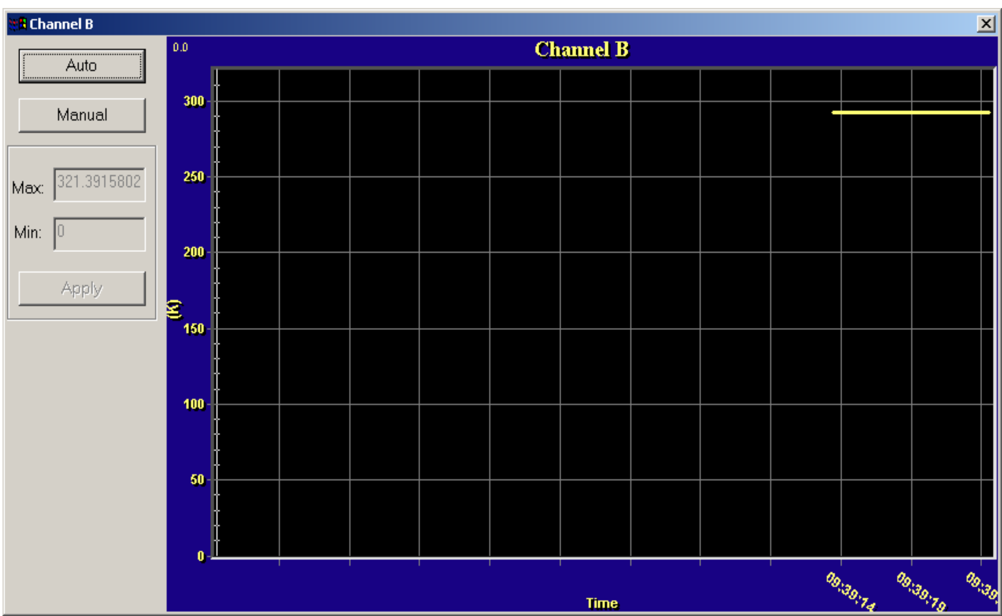
From this point, the sequence is identical to the calibration curve transfer process described above.

Using the Real-Time Strip Charts

The real-time strip chart feature of the Utility Software lets the user continuously display any combination of input channels on the computer display.

This function is initiated by selecting the **View** command on the Utility Software's main toolbar, then selecting the desired channels to monitor.

A strip chart will be displayed for each channel selected. The dialog box will show the channel's Input Identifier, Name String and a chart of current temperature.

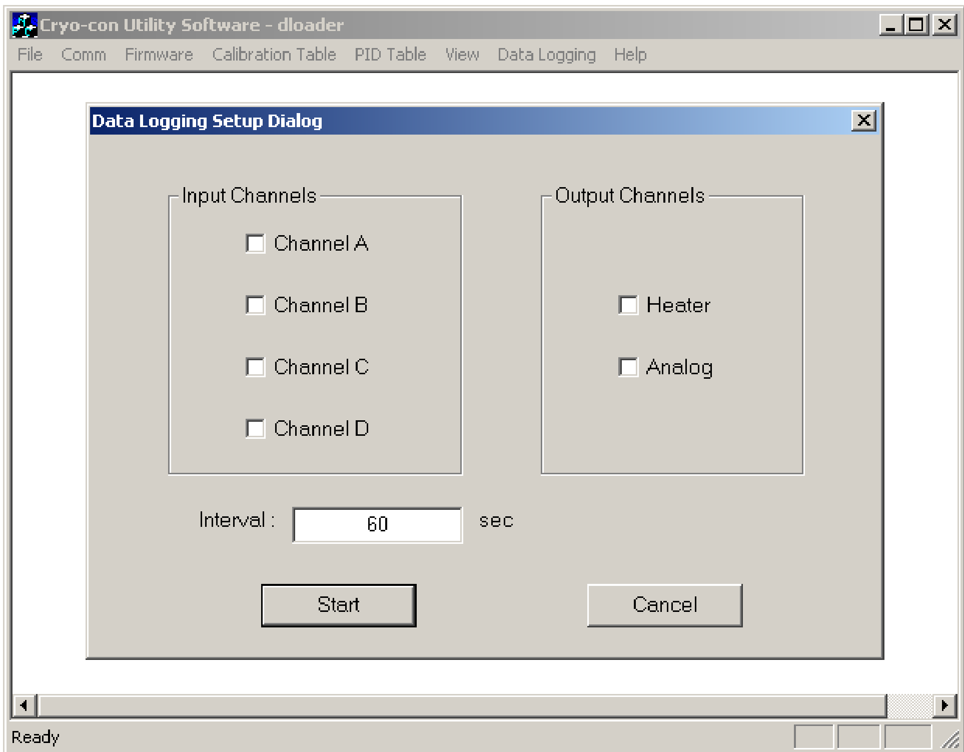


The update rate of the chart is locked to the program's Data Logging Interval. The section below details how to set this value.

Data Logging

The Utility Software will perform data logging on all of the instruments input and control output channels. The result is a disk file in Comma-Separated-Value, or CSV format. This format is compatible with any data analysis or charting software including Microsoft Excel.

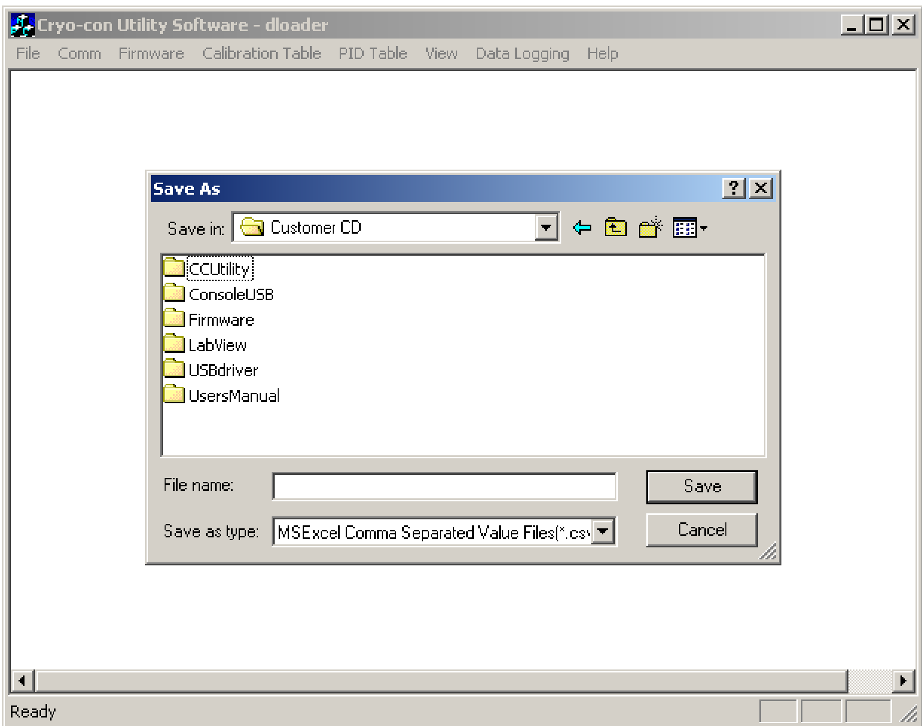
To initiate data logging, select the **Data Logging** button from the Utility Software's main menu. The Data Logging Setup dialog box will now appear.



On this dialog box, check the desired channels and set an Interval value in Seconds. The minimum interval is 0.1 Second.

When the **Start** button is clicked, a file selection dialog box will be shown.

From this dialog box, enter a file name and select the directory where data logging results will be saved.



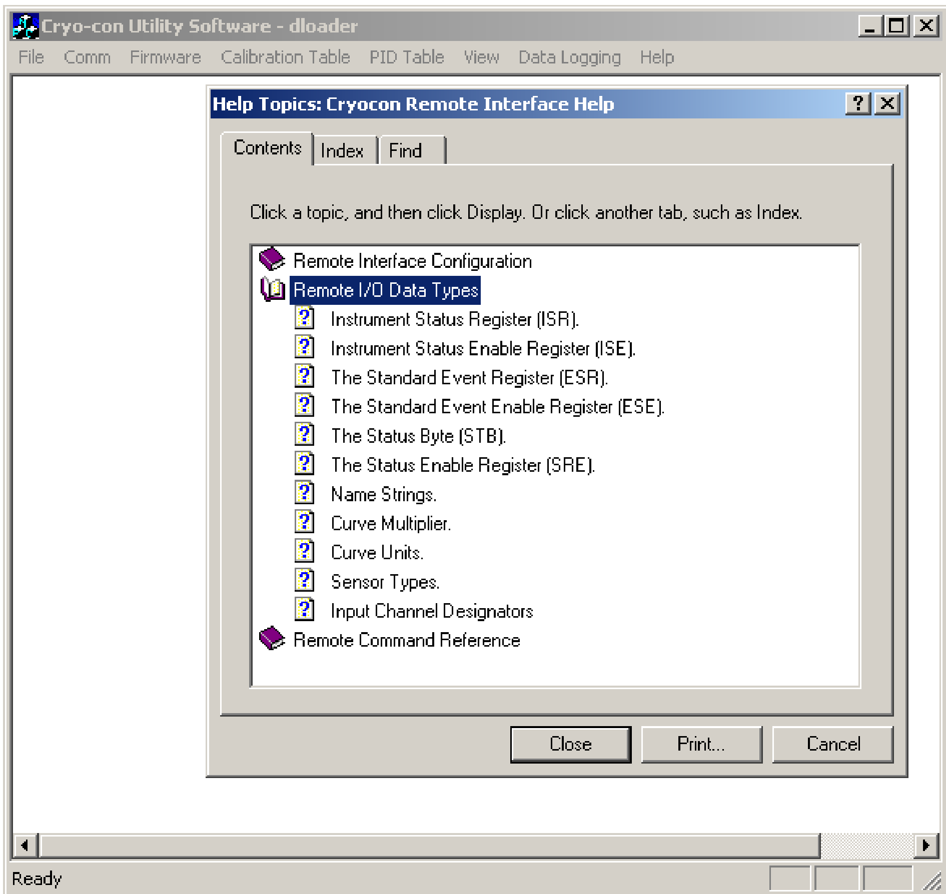
As soon as the **Save** button is clicked, the software will begin continuous data logging to the specified file.

While data logging is in progress, a dialog box is displayed that allows the user to stop logging. When this **Stop** button is clicked, logging is stopped and the log file is closed.

Remote I/O command HELP

Help for the remote interfaces and remote commands is available by clicking on the **HELP>Contents** button from the Utility Software's main menu.

A standard HELP screen will be shown that is indexed and searchable.



CalGen Calibration Curve Generator.

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.

Most Cryo-con™ temperature controllers support CalGen directly on the instrument. However, the utility software package implements the same algorithm and can be used with virtually any instrument capable of measuring temperature.

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

For diode sensors, the user may specify one, two or three data points. CalGen will generate the new curve based on fitting the input curve to the user specified points.

Platinum or other resistor calibration curves require one or two data points. The generated curve will be a best fit of the input curve to the two specified input points.

Since CalGen fits a sensor calibration curve to measured data, any errors in the instrument's measurement electronics are also effectively canceled.

CalGen Initial Setup

To start the CalGen process, either select **CalGen** from the shortcut bar, or select Operations>CalGen from the main menu. This initiates the process of generating a new sensor curve.

Using CalGen With Diode Sensors

Options for generating diode calibration curves are:

1. One point near 300K. The portion of a diode Sensor curve above 30K is fit to a user-specified point near 300K. This is a two-point fit where the 30K point is taken from the existing calibration curve. The portion of the curve below 30K is unaffected.
2. Two points: 300K and 77K. These 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.
3. 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.
4. 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.

Using CalGen With Resistor Sensors

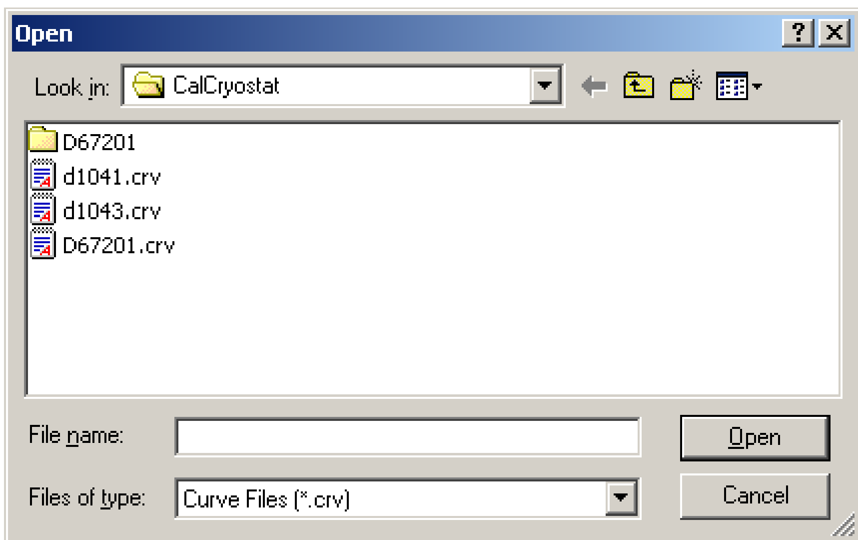
The calibration curve generation procedure for Platinum or other resistor sensors is the same as for the diode. However, these sensor curves are generated using two user specified points. Therefore, the selection of the number of points is not required.

Example CalGen Procedure

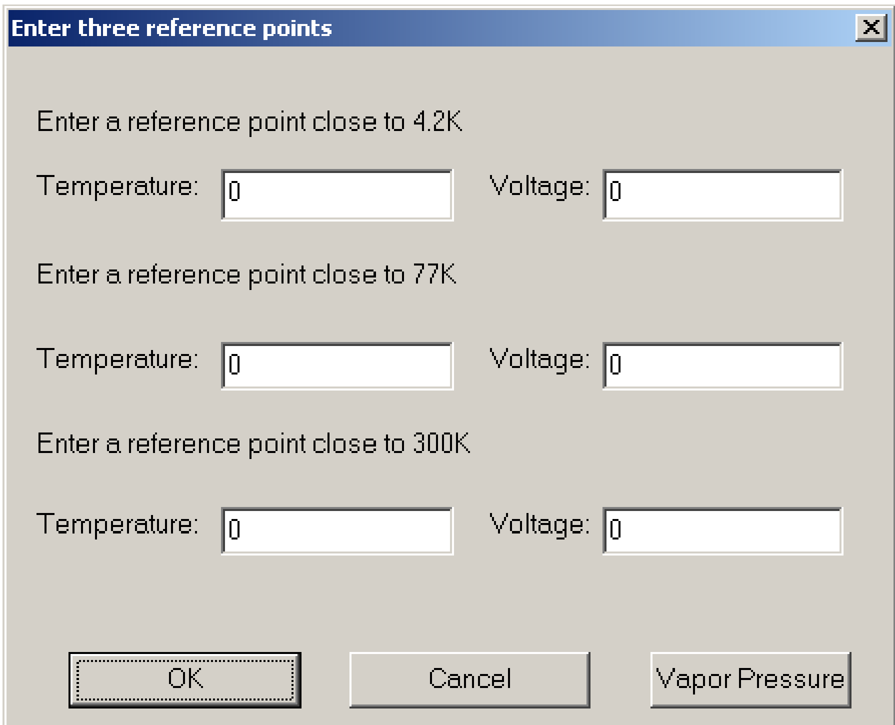
A complete procedure for calibrating a diode sensor at three points is shown here. Before the procedure can be started, the instrument must be connected and have a valid sensor connected.

The CalGen procedure requires the user to stabalize the input temperature at three user-selected points. It will capture data at each of these points and then generate a new curve from that data.

When a 3-point CalGen is started for a Silicon diode sensor, the reference curve must first be selected. This is the curve that will be rotated and shifted to fit the selected points.



When the curve has been selected, the following dialog box will appear:



The process requires the user to completely fill out this dialog box by selecting a temperature and then copying the voltage (or resistance) reading corresponding to that temperature from the instrument.

Note that the Vapor Pressure button takes the user to a convenient calculator that computes the temperature of various cryogens from the current barometric pressure.

Once the dialog box has been completed, click OK to proceed.

To finish the process, a prompt will require the user to save the modified calibration curve to a file. Once complete, the file can be transferred to any Cryo-con™ instrument.

Instrument Calibration

Calibration of the Model 24C controller requires the use of various voltage and resistance standards in order to generate calibration factors for the many measurement ranges available.

Calibration is ‘Closed-Case’. There are no internal mechanical adjustments required. The Model 24C 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 controller is due for calibration, contact Cryo-con for low-cost recalibration. The Model 24C is supported on our automated calibration systems which allow Cryo-con to provide this service at competitive prices.

Calibration Interval

The Model 24C should be calibrated at a regular interval determined by the measurement accuracy requirements of your application.

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

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

Minimum Required Equipment

All calibrations require a computer with an RS-232, LAN or IEEE-488 connection to the instrument. Additionally, reference standards are required for each input range as follows:

- The Silicon diode input range (Calibration Type I10UA and V10UA) requires voltage references of 0.5 and 1.5 Volts DC and a resistance standard of 100KΩ.
- The Constant-Voltage AC resistance ranges (Type AC10UA, AC100UA and AC10UA) require the use of 100KΩ, 10KΩ, 1KΩ, 100Ω and 10Ω resistances.
- The 100Ω Platinum range (Type R1MA) requires a 100Ω and a 10Ω resistor.
- The 1000Ω range (Type R100UA) requires 1K Ω and 100Ω resistors.
- The 10,000Ω range (Type R10UA) requires 10KΩ and 1KΩ resistors.

The test equipment recommended for complete calibration is a Fluke 5700A DMM calibrator.

The Calibration Sequence

There are two methods available for calibration:

1. Automatic. The software will recommend voltages and resistances. Set these values on the input channel and capture the instrument's actual readings. Then the software will automatically generate offset and gain values.
2. Manual: It is possible to manually enter Offset and Gain values and send them to the instrument.

Calibration of Silicon Diodes

Silicon diode sensors require the application of a precision 10µA current followed by reading the voltage-drop across the device. Therefore, calibration of a diode requires two steps: 1) Calibration of the input voltage reading and 2) Calibration of the 10µA current source.

Note that the voltage calibration must always be done first since the current source calibration requires a precise voltage reading.

Diode Voltage Calibration

To calibrate the diode voltage range, click on the **SI Diode V** tab and follow the sequence described above to send Gain and Offset values to the instrument.

The upper target requires connection of a 1.9 Volt source. The actual value is between 1.0 Volts and 2.4 Volts. If a precision voltage source is not available, substitute a 1.5 Volt battery by using a high precision volt meter to measure it's actual voltage.

The lower target requires connection of a 0.5 Volt source. The actual value is between zero Volts and 0.6 Volts. If a precision voltage source is not available, short the input channel for zero volts.

Constant-current Source Calibration

Calibration of the constant-current source is performed by using the **SI Diode I** tab. On this screen, only an upper target value is required since the current-source only requires a gain term.

The upper target requires connection of a 100KΩ resistor. The actual value should be within 10% of 100KΩ.

Calibration of PTC resistors

Positive-Temperature-Coefficient resistors include Platinum and Rhodium-Iron RTDs. Resistors required for calibration are as follows:

- **1mA AC:** Upper - 100Ω, Lower - 10Ω.
- **100uA AC:** Upper 1,000Ω, Lower - 100Ω
- **10uA AC:** Upper - 10,000Ω, Lower - 1,000Ω.

Calibration of NTC resistors

Negative-Temperature-Coefficient resistors include Ruthenium-Oxide and Cernox™ RTDs. Resistors required for calibration are as follows:

- **10ohm C-V AC:** Upper - 100Ω, Lower - 10Ω.
- **100ohm C-V AC:** Upper 1,000Ω, Lower - 100Ω
- **1.0K C-V AC:** Upper - 10,000Ω, Lower – 1,000Ω.
- **10K C-V AC:** Upper - 100,000Ω, Lower – 10,000Ω.

Automatic Calibration

First connect the Model 24C to a computer via any of the remote interfaces and then run the Utility Software provided with the controller. Version 10.1.0 or higher is required.

From the start-up menu of the Utility Software, click the Connect button in the bottom of the Short Cuts toolbar. The software will connect to the instrument and display the connection status below the button.

From the main menu, select Operations->Unit Cal.

Unit calibration requires the use of a password. This must be entered before the automatic calibration sequence can be entered. Once in the calibration process, the password can be changed. The default password is **Cryocon**.

The program will first read the current calibration values from the instrument and display a calibration screen as shown on the next page. All calibration operations can be performed by using this screen.

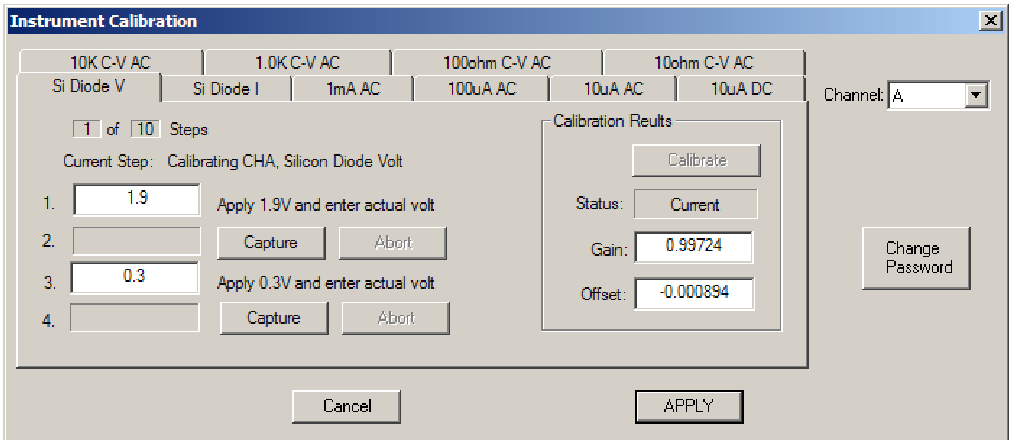


Figure 4: Instrument Calibration Screen

On the far right of the screen, a drop-down box selects the channel to be calibrated. Be sure to select the correct channel. In order to perform a complete calibration, calibrate each channel individually.

Along the top of the screen, there are tabs that show the types of calibration that are supported by the instrument. To perform a complete calibration of a single input channel, all calibration types must be calibrated.

Note the **Calibration Results** box on the screen. The **Status** field is initially set to 'Current' and the **Gain** and **Offset** values shown are those read from the instrument.

> ⓘ **Note:** If your calibration procedure requires saving historical values, you will want to record the Gain and Offset values shown on the initial screen before proceeding with actual calibration.

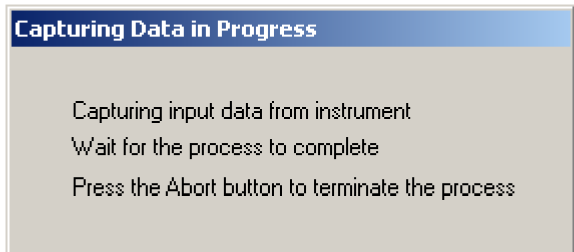
Automatic calibration uses the left-hand side of the calibration screen and is a four-step process:

1. Line 1 requires setting a upper target value on the input channel. Depending on the calibration range selected, this is in Volts or Ohms.

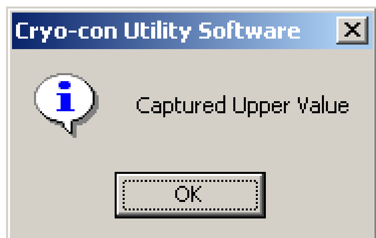
   First, establish a voltage or resistance on the selected input channel that is near the recommended value. Then, enter the actual value in the box provided.

2. Click the Capture button on Line 2. The software will wait for the reading to stabilize and then captures the reading and display it in the edit box on Line 2.

   While waiting for a stable reading, the following dialog box will be displayed:



   When the capture is complete, dismiss the following dialog:



3. Line 3 requires setting a lower target value on the input channel. Depending on the calibration range selected, this is in Volts or Ohms.

   First, establish a voltage or resistance on the selected input channel that is near the recommended value. Then enter the actual value in the box provided.
4. Click the Capture button on Line 4. The software will wait for the reading to stabilize and then capture the reading and display it in the edit box on Line 4.

When the above procedure is complete, upper and lower target values as well as upper and lower measurements are established The edit boxes on lines 2 and 4 contain the measured values. At this time the target values on line 1 and 3 can be edited if desired.

Now the required gain and offset values can be automatically computed by clicking on the **Calibrate** button in the **Calibration Results box**. This changes the **Status** field from ‘Current’ to ‘Calibrated’ and updates the **Offset** and **Gain** values with those calculated.

In order to send the offset and gain values to the instrument’s calibration memory, click the **APPLY** button. A confirmation is required to update calibration memory.

Manual Calibration

To manually calibrate a range, select the desired range from the range type tabs and enter the desired Gain and Offset values in the boxes given and then, click the **APPLY** button.

Gain is a unit-less gain factor that is scaled to a nominal value of 1.0. It is usually computed by:

gain = (UT – LT) / (UM – LM)

where:

UT is the upper target and LT is the lower target.
UM is the upper measurement and LM is the lower measurement.

Offset is in units of Volts or Ohms depending on the calibration type. Nominal value is 0.0. Positive or negative numbers are accepted. It is typically calculated by:

Offset = UT - gain * UM

Summary of Calibration Types

Calibration data must be generated for each input channel by sequencing through the various calibration types on each channel. A summary of types is given here:

Calibration Type	Voltage Range	Output Current	Description
SI DiodeV	0 – 2.5V	N/A	Voltage measurement for use with Silicon diode temperature sensors.
SI Diode I	N/A	10μA	10μA constant-current source used with Silicon diode sensors.
1mA AC	10mV, 1.25Hz	Autoranged	1mA range used with constant-voltage mode sensors.
100uA AC	10mV, 1.25Hz	Autoranged	100μA range used with constant-voltage mode sensors.
10uA AC	10mV, 1.25Hz	Autoranged	10μA range used with constant-voltage mode sensors.
1mA DC	0-2.5VDC	1.0mA	DC measurement of 100 Platinum RTD sensors.
100uA DC	0-2.5VDC	100μA	DC measurement of 1K Ohm Platinum RTDs
10uA DC	0-2.5VDC	10μA	DC measurement of 10K Ohm Platinum RTDs or other resistor sensors that use DC current excitation

Remote Operation

Remote Interface Configuration

The Model 24C has two remote interfaces: The 10/100-BaseT Ethernet LAN and the RS-232. There are also two external options: IEEE-488.2 (GPIB) and USB. Connection to all 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

HTTP: The Model 24C's HTTP server is used to implement the instrument's embedded web server. Up to five connections are supported simultaneously and connections are automatically closed after five minutes of inactivity.

SMTP: The Simple Mail Transport Protocol is used to send E-mail from the Model 24C 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 Model 24C will have to have an active mail server.

TIMEP: The Time Protocol allows a client to obtain the date and time from a host TIMEP server. If a time server is available on the Local Area Network, the Model 24C will periodically query it to update it’s internal real-time clock.

TCP/IP: The Transmission Control Protocol / Internet 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 Model 24C 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/IP.

In the Model 24C, a TCP/IP port is available for communication using an ASCII command language. This is how the instrument interfaces some data acquisition software packages, including LabView™. Where the user is implementing custom software, UDP is recommended because of it's lower overhead.

Ethernet Configuration

Each device on an Ethernet Local Area Network must have a unique IP Address. This is similar to IEEE-488 systems where each device required a unique ‘GPIB’ address. Further, the address assigned to the Model 24C must be within the range of the computers you want it to communicate with. The range is determined by the Subnet Mask.

To connect to a LAN switch or hub, use a standard Category 5 patch cable. To connect directly to a PC, use a Category 5 crossover type patch cable.

The Model 24C is shipped with a default IP address of **192.168.1.5** and Subnet Mask of **255.255.255.0**. Using these settings, the instrument communicates with any computer or device that has an IP addresses in the range of 192.168.1.0 through 192.168.1.255. The user can configure the Model 24C to use any other IP address by going to the Network Configuration Menu.

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 the older RS-232 style communications.

Before you can bind a UDP socket, you will need to know the instrument's IP address and port number. Both the IP and port number may be obtained from the front panel of the instrument or by using the discovery function of Cryo-con's utility software.

UDP uses a port that is the TCP port address plus one. The factory default is 5001.

TCP/IP Data Socket Configuration

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

Before you can bind a TCP/IP socket, you will need to know the instrument's IP address and port number. Both may be obtained from the front panel of the instrument or by using the discovery function of Cryo-con's utility software.

The default TCP/IP port address is 5000. This can be changed from the front panel by going to the Network Configuration Menu. The Model 24C will handle up to five TCP/IP connections simultaneously. Connections will be automatically closed after 5 minutes of inactivity.

Checking the TCP/IP connection with Hyperterminal

Hyperterminal, or any other TCP/IP communications program can be easily used to test the TCP/IP connection. Run the program and configure it with the IP (default: 192.168.1.5) and TCP/IP port (Default: 5000) and it should be possible to type in basic commands. For example:

*IDN?

should return:

Cryo-con,Model 24C,204683,1.01A

When working with the TCP/IP interface, it is often convenient to go to the Network Configuration Menu. The bottom two lines of this screen show the last line received and sent by the instrument.

Web site configuration

The Model 24C factory default settings are as follows:

IP address: 192.168.1.5
Subnet Mask: 255.255.255.0
Gateway: 192.168.0.1
TCP Data Socket: 5000, UDP Data Socket: 5001
DHCP: OFF

These settings are also entered into the Model 24C when the LAN Reset sequence is executed from the front panel.

The instrument's embedded web site may be opened in any web browser by typing **http://192.168.1.5** into the address bar, and the Model 24C’s Home Page should appear. Alternatively, if the network system has a DNS server, use the instrument's name instead of the IP address. The default name is: M24Cxxxx where xxxx is the last four digits of the instrument's serial number.

From the Model 24C's web page, configure the instrument to meet the network requirements.

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 address is set to 12 when the unit is shipped from the factory.

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 35: GPIB Host Setup Parameters

RS-232 Configuration

The user can select RS-232 Baud Rates between 300 and 38,400. The factory default is 9600.

The Baud Rate is changeable from the instrument's front panel by using the System Functions Menu.

Other RS-232 communications parameters are fixed in the instrument. They are set as follows:

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

The RS-232 interface uses a "New Line", or Line Feed character as a line termination. In the C programming language, this character is \n or hexadecimal 0xA.

When sending strings to the controller, any combination of the following characters must be sent to terminate the line: a) Carriage Return. b) Line Feed. c)Null.

The controller will always return the \n character at the end of each line.

> ⓘ **Note:** Some serial port software drivers allow the programmer to set a line termination character. This character is then appended to each string sent to the controller and stripped from returned strings. In this case, the \n (0xA) character should be selected.

Checking the RS-232 connection with Hyperterminal

Hyperterminal, or any other RS-232 communications program can be easily used to test the connection. Run the program and configure it with instrument's serial configuration in order to type in basic commands. For example:

*IDN?

should return:

Cryo-con,Model 24C,204683,1.01A

When working with the the RS-232 interface, it is convenient to go to the Network Configuration Menu. The bottom two lines of this screen show the last line received and sent by the instrument.

USB option configuration

Cryo-con's external USB option is automatically configured by the instrument when it is plugged into the RS-232 port. Your computer will see it as an extra COM port. Use it for communications just like any other RS-232 port.

Remote Programming Guide

General Overview

The IEEE-488.2 SCPI remote interface language is common to all Cryo-con products.

Since the language supports both simple and advanced functions, it may initially seem complex. However, the use of English language keywords and a consistent tree-structured architecture make it easy to read and learn.

Language Architecture

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

- The industry standard SCPI language defined by the IEEE-488.2 standard is used. Therefore, anyone with experience in test and measurement will find it familiar.
- All Cryo-con instruments use the same language and future instruments will continue in the same fashion. Therefore, your investment in system software will not be lost when a product is revised or replaced.
- Keywords used in commands are common English words, not cryptic acronyms. This makes command lines easy to read and understand, even for someone that is not familiar with the instrument.
- The SCPI is a 'tree structured' language where commands are divided into groups and associated commands into sub-groups. This architecture simplifies composing commands and improves readability.
- The command language is identical on each of the remote I/O ports including the Ethernet LAN, IEEE-488 USB 2.0 and RS-232 serial port.

Purpose

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

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

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

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

An Introduction to the SCPI Language

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

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

- INPut
  - TEMPerature
  - UNITs
  - VARIance
  - SLOPe
  - ALARm
  - NAMe
- SYSTem
  - BEEP
  - ADRS
  - LOCKout
- LOOP
  - SETPT
  - RANGe
  - RATe
- CONFig
  - SAVE
  - RESTore

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 all acceptable.

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

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

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

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

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

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

Command Separators

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

Compound Commands

A semicolon (;) is used as a terminator 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

The termination of a command line is determined by the type of interface being used.

For the RS-232 serial port interface, command lines are terminated with any of the following:

carriage-return (\n), *line-feed* (\r) or *null* (0).

On the Ethernet LAN and IEEE-488 (GPIB) interfaces, a hardware-handshake is used, so no termination character is required. If terminators are sent, they are ignored.

SCPI Common Commands

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

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

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

SCPI Parameter Types

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

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

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

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

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

```
CONFig 4:NAMe "Cold Plate"
```

Commonly Used Commands.

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

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

Function	Command	Comment
Instrument Identification		
Read the instrument identification string	***idn?**	Returns the instrument identification string in IEEE-488.2 format. For example:"Cryo-con,Model 24C,204683,1.01A" identifies the manufacturer followed by the model name, serial number and firmware revision code.
Input Channel Commands Parameter for the input is A, B, C or D corresponding to inputs A, B, C or D.		
Read the temperature on input channel B	**input? b**	Temperature is returned in the current display units. Format is a numeric string. For example: 123.4567
Set the temperature units on input channel A to Kelvin.	**input a:units k**	Choices are K- Kelvin, C- Celsius, F- Fahrenheit and S- native sensor units (Volts or Ohms).
Read the temperature units on channel B	**input b:units?**	Return is: K, C, F or S.
Control Loop Start/Stop commands		
Disengage all control loops.	**stop**	Both control loops are stopped.
Engage all control Loops.	**control**	Starts both control loops
Ask if control loops are on or off.	**control?**	Return is ON or OFF

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

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. Some commands require the instrument to write to non-volatile flash type memory, which can be time consuming. In order to avoid overrunning the instrument use compound commands that return a value, thus indicating that command processing is complete. For example:

   INPUT A:UNITS K;UNITS?

   will respond with the input units only after the command has completed. Another example:

   LOOP 1:SETPOINT 1234.5;:*OPC?

   Here, the operation complete command :*OPC? will return a '1' when command processing is complete.
3. It is often easiest to test commands by using the Cryo-con utility software. Run the program, connect to the instrument and use the Interact mode to send commands and view the response. Alternatively, any communications program like Windows Hyperterminal can be used to interact with the instrument via the LAN or serial ports.
4. For ease of software development, 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 last character 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 Status Registers

The Instrument Status Register

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

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

The ISR is defined as follows:

ISR

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

Where:

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

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

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

The Instrument Status Enable Register

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

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

The Standard Event Register

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

Bits in the ESR are defined as follows:

ESR

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

Where:

Bit7 – OPC: Indicates Operation Complete.

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

Bit4 – DE: Indicates a Device Error.

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

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

Bit0 – PWR: Indicates power is on.

The Standard Event Enable Register

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

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

The Status Byte

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

STB

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

Where:

Bit6 – RQS: Request for Service.

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

Bit4 – MAV: Message Available

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

The Status Byte Register

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

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

Remote Command Tree

Control Loop Start /Stop commands
STOP CONTrol CONTrol?

SYSTEM commands
SYSTem:LOCKout {ON | OFF} SYSTem:NVSave SYSTem:REMLed {ON | OFF} SYSTem:BEEP <seconds> SYSTem:DISTc {0.5 | 1 | 2 | 4 | 8 | 16 | 32 | 64} SYSTem:ADRes <address> SYSTem:RESeed SYSTem:HOMe SYSTem:SYNCtaps <taps> SYSTEM:NAME "name" SYSTem:HWRev? SYSTem:FWREV? SYSTem:LINefreq {60 | 50} SYSTem:DRES {FULL | 1 | 2 | 3} SYSTem:PUControl {ON | OFF} SYSTem:BAUD {9600 | 19200 | 38400 | 57200} SYSTem:DATe "mm/dd/yyyy" SYSTem:TIMe "hh:mm:ss"

Configuration Commands
CONFig <ix>:NAMe "name" CONFig <ix>:SAVe CONFig <ix>:RESTore

Input Commands
INPut? {A | B | C | D} or INPut {A | B | C | D}:TEMPerature?
INPut {A | B | C | D}:UNITs {K | C | F | S}
INPut {A | B | C | D}:NAMe Instrument Name"
INPut {A | B | C | D}:SENPr?
INPut {A | B | C | D}:VBIas {100MV | 10MV | 1.0MV}
INPut {A | B | C | D}:BRANge {Auto | 2 | 20 | 200 | 2.0K | 20K}
INPut {A | B | C | D}:SENsorix <ix>
INPut {A | B | C | D}:BRUNlock?
INPut {A | B | C | D}:POWer?
INPut {A | B | C | D}:ALARm?
INPut {A | B | C | D}:ALARm:HIGHest <setpt>
INPut {A | B | C | D}:ALARm:LOWEst <setpt>
INPut {A | B | C | D}:ALARm:DEAdband <setpt>
INPut {A | B | C | D}:ALARm:HIENa { YES | NO }
INPut {A | B | C | D}:ALARm:LOENa { YES | NO }
INPut {A | B | C | D}:Clear
INPut {A | B | C | D}:LTEna { YES | NO }
INPut {A | B | C | D}:AUDio { YES | NO }
INPut {A | B | C | D}:MINimum?
INPut {A | B | C | D}:MAXimum?
INPut {A | B | C | D}:VARiance?
INPut {A | B | C | D}:SLOpe?
INPut {A | B | C | D}:OFFSet?
INPut:STAts:TIMe?
INPut:STAts:RESet
INPut {A | B | C | D}:TCOFfset
INPut {A | B | C | D}:TCGAin

Loop Commands
LOOP {1 | 2 | 3 | 4}:SOURce {A | B | C | D}
LOOP {1 | 2 | 3 | 4}:SETPt <setpt>
LOOP {1 | 2 | 3 | 4}: TYPe { OFF | PID | MAN | TABLE | RAMPP | RAMPT}
LOOP {1 | 2 | 3 | 4}:TABelix <ix>
LOOP {1 | 2 | 3 | 4}:RANGe { HI | MID | LOW}
LOOP {1 | 2 | 3 | 4}:RAMP?
LOOP {1 | 2 | 3 | 4}:RATe <rate>
LOOP {1 | 2 | 3 | 4}:PGAin <gain>
LOOP {1 | 2 | 3 | 4}:IGAin <gain>
LOOP {1 | 2 | 3 | 4}:DGAin <gain>
LOOP {1 | 2 | 3 | 4}:PMAnual <pman>
LOOP {1 | 2 | 3 | 4}:OUTPwr?
LOOP {1 | 2 | 3 | 4}:HTRRead?
LOOP {1 | 2 | 3 | 4}:HTRHst?
LOOP {1}:LOAD {50 | 25}
LOOP {1 | 2 | 3 | 4}:MAXPwr <maxpwr>
LOOP {1 | 2 | 3 | 4}:MAXSet <maxset>

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

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

Sensor Calibration Curve Commands
CALcur SENSor <index>:NAMe name string" SENSor <index>:NENTry? SENSor <index>:UNITs {VOLTS | OHMS | LOGOHM} SENSor <index>: TYPe { DIODE | ACR | PTC100 | PTC1K | PTC10K | PTC10K | NTC10UA } SENSor <index>:MULTiply <multiplier>

Relay Commands
RELays? {0 | 1} RELays {0 | 1} :SOURce {A | B | C | D} RELays {0 | 1} :MODe {auto | control | on | off} RELays {0 | 1} :HIGHest <setpt> RELays {0 | 1} :LOWEST <setpt> RELays {0 | 1} :DEADband <deadband> RELays {0 | 1} :HIENa { YES | NO } RELays {0 | 1} :LOENa { YES | NO }

PID Table Commands
PIDTable? <num> PIDTable <num>:NAMe Name String" PIDTable <num>:NENTry? PIDTable <num> PIDTable <num>:TABLe

Network Commands
NETWork:IPADdress NETWork:MACaddress

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

IEEE Common Commands
*CLS *ESE *ESR *OPC *IDN? *RST *SRE *STB

Data-logging Commands
DLOG:STATe {ON | OFF} DLOG:INTerval <Seconds> DLOG:COUNt? DLOG? DLOG:READ? DLOG:RESEt DLOG:CLEAr

Remote Command Descriptions

IEEE Common Commands

*CLS

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

*ESE

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

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

*ESR

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

*OPC

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

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

*IDN?

The *IDN? Query causes the instrument to identify itself. The Model 24C will return the following string:

Cryocon, Model 24C,<serial number>,<firmware revision>

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

*RST

Reset the controller. This results in a hardware reset in the Model 24C. The reset sequence takes about 15 seconds to complete. During that time, the instrument is not accessible over any remote interface.

The *RST command sets the Model 24C to it’s last power-up default setting.

*SRE

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

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

*STB?

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

Control Loop Start / Stop Commands

STOP

Disengage both control loops.

CONTrol

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

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

System Commands.

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

SYSTem:LOCKout {ON|OFF}

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

To exit the keypad lock out from the front panel, push the **Esc** button. This will clear the Remote LED to indicate that the keypad is now unlocked.

SYSTem:NVSave

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

SYSTem:REMLed {ON|OFF}

Sets or queries the remote LED status indicator on the instrument's front panel. Note that the Remote LED is automatically handled by the GPIB interface but must optionally be turned on and off when using the LAN or RS-232 interface.

SYSTem:BEEP <seconds>

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

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:ADRS <address>

Selects 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:RESeed

Re-seeds the input channel’s averaging filter, allowing the reading to settle significantly faster. The display filter may have filter time-constants that are very long. The RESEED command inserts the current instantaneous temperature value into the filter history, thereby allowing it to settle rapidly.

> ⓘ **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:HOMe

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

SYSTem:SYNCtaps <taps>

Sets or queries the number of taps in the synchronous filter. This is an advanced setup function. The default is 7 taps.

SYSTEM:NAME "name"

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

SYSTem:HWRev?

Queries the instrument's hardware revision level.

SYSTem:FWREV?

Queries the instrument's firmware revision level.

SYSTem:LINefreq {60 | 50}

Sets or queries the AC Power Line frequency setting which may be either 50 or 60 for 50Hz or 60Hz. Command only affects the operation of the synchronous cryo-cooler filter.

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

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

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

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

The main use for this command is to eliminate the flicker in low order digits when the controller is used in a noisy environment.

SYSTem:PUControl {ON|OFF}

Sets or queries the controller's power up in control mode setting. Power-up in control mode causes the controller to automatically enter control mode 10 seconds after AC power is applied. Exercise caution when using this command as it can have unintended consequences.

SYSTem:BAUD {9600 | 19200 | 38400 | 57200}

Sets or queries the RS 232 Baud rate.

SYSTem:DATe "mm/dd/yyyy"

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

SYSTem: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.

Configuration Commands

CONFig <ix>:NAMe "name"

Instrument setups can be named for user convenience. This command sets and queries the user configuration names. The parameter <ix> is the configuration number, which is 0 through 5. The second parameter, "name", is a string with a maximum length of 15 ASCII characters.

CONFig <ix>:SAVe

Saves an the current instrument setup to a user setup. <ix> is the index number of the desired instrument setup. Values may be 0 through 5. Command only.

CONFig <ix>:RESTore

Restores a previously stored user instrument setup. <ix> is the index number of the desired instrument setup. Values may be 0 through 5. Command only.

Input Commands

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

Parameter references to the input channels may be:

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

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

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

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

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

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

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

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

The INPUT:SENPR query reports the 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|B|C|D}:
VBIas {100MV|10MV|1.0MV}

Sets or queries the constant-voltage mode voltage used on the specified input channel. This value only applies to sensors that use constant-voltage excitation. They are indicated by a sensor type of ACR. If this query is used with a sensor type other than ACR, it will always return N/A for not applicable.

INPut {A|B|C|D}
:BRANge {Auto|2 |20 |200|2.0K|20K}

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

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

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

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

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

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

Queries the bridge unlock indicator. Returns a space character if the bridge is locked or an asterisk (*) character if the bridge is unlocked.

If the bridge is unlocked, it is still searching for a balance point. The sensor reading will be correct, but the excitation current and power dissipation will be incorrect.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Clears any latched alarm on the selected input channel.

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

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

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

Queries the minimum temperature that has occurred on an input channel since the STATS:RESET command was issued.

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

Queries the maximum temperature that has occurred on an input channel since the STATS:RESET command was issued.

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

Queries the temperature variance that has occurred on an input channel since the STATS:RESET command was issued. Variance is calculated as the Standard Deviation squared.

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

Queries the input channel statistics. SLOPE is the slope of the best fit straight line passing through all temperature samples that have been collected since the STATS:RESET command was issued. SLOPE is in units of the input channel display per Minute.

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

Queries the input channel statistics. OFFSET is the offset of the best fit straight line passing through all temperature samples that have been collected since the STATS:RESET command was issued. OFFSET is in units of the input channel display.

INPut {A|B|C|D}:STAts:TIMe?

Queries the time duration over which input channel statistics have been accumulated. Time is reset by issuing the STAt:RESet command. Query only.

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

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

INPut {A|B|C|D}:TCOFfset <offset>

Sets or queries the offset value for thermocouple inputs. <offset> is the decimal value of offset and is in units of Kelvin. Refer to the section on Using Thermocouple Sensors for more information.

INPut {A|B|C|D}:TCGAin <gain>

Sets or queries the gain value for thermocouple inputs. <gain> is the decimal value of the gain applied to thermocouple readings and is in units of volts per volts. Refer to the section on Using Thermocouple Sensors for more information.

LOOP commands

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

Loop 1 is the controller’s primary heater output channel. The Model 24C has three ranges.

Loop 2 is a secondary output. The Model 24C has a single range linear heater.

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

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

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

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

LOOP {1|2|3|4}:TYPe { OFF|PID|MAN|TABLE|RAMPP }

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

Off - loop disabled
PID - loop control type is PID
Man - loop is manually controlled
Table - loop is controlled by PID Table lookup.
RampP - loop is controlled by PID, but is in ramp mode.
RampT - loop is controlled by PID Table lookup, but is in ramp mode.

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

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

LOOP {1}:RANGe{HI |MID|LOW}

Sets or queries the control loop's output range.

Range determines the maximum output power available and is different for a 50Ω load resistance than for a 25Ω load.

Values of heater range for Loop 1 are: Hi, Mid Low and Min. These correspond to the output power levels shown here.

The values for loop 2 is 10W, corresponding to 10W into a 50Ω load.

Range	50Ω Load	25Ω Load
Hi	50W	25W
Mid	5W	2.5W
Low	0.5W	0.25W

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

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

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

Sets and queries the ramp rate used by the selected control loop when performing a temperature ramp. <rage> is the ramp rate in Units / Minute. This may be a value between 0 and 100. Rate is in display units per Minute.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

LOOP {1}:LOAD {50 | 25}

Sets or queries the load resistance setting of the primary heater (Loop 1). Selections are:

50 for a 50Ω load and a 50W maximum output power.
25 for a 25Ω load and a 25W maximum output power.

Note: Loop 2 always requires a 50Ω load so this command is ignored.

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

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

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

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

Control Loop Autotune Commands

The Model 24C's control loop autotune functions can be configured and run entirely from the remote interface. The general sequence is:

1. Configure the autotune parameters.
2. Initiate the autotune sequence.
3. Read the autotune state and wait for the sequence to complete.
4. Execute the autotune save command to transfer the generated tuning parameters to the controller's PID values and continue with PID control.

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

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

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

Command to abort the autotune sequence.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

OVERTEMP commands

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

OVERtemp:ENABle {ON | OFF}

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

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

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

OVERtemp:TEMPerature <temp>

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

Relay Commands

The relay subsystem includes the two auxiliary relays in the Model 24C. Using the RELAYS commands, these relays are independently configured to assert or clear based on the status of any of the four sensor input channels.

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

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

RELays? {0 | 1}

Relay Status Query. The two auxiliary relays available in the Model 24C are addressed as 0 and 1. The RELAYS command can be used to query the status of each relay where:

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

RELays {0 | 1}:SOURce {A|B|C|D}

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

RELays {0 | 1}: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.

RELays {0 | 1}:MODe {AUTo | ON | OFF}

Set or query the relay mode. Modes are:

Auto	Relay is controlled by enabled high and low setpoints.
ON	Relay is in manual mode and is asserted.
OFF	Relay is in manual mode and is clear.
Control	Relay is asserted whenever the controller is in Control mode.

RELays {0 | 1}: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.

RELays {0 | 1}:HIENa {YES | NO }

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

RELays {0 | 1}:LOENa {YES | NO }

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

RELays {0 | 1}: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.

Warm-Up Commands

These commands control the warm-up function of the Model 24C. For information on warm-up functions, refer to the Warm-up Power Supply Operation section.

WARMup:ENable {YES | NO}

Sets or queries the warm-up enable.

WARMup:STATe {IDLE | CONTrol | WARMup}

Sets or queries the warm-up state.

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

Sets or queries the controlling input channel.

WARMup:SETPoint <setpoint>

Sets or queries the warm-up setpoint. Parameter is a floating-point decimal number with units of the controlling input channel.

WARMup:TIMeout <minutes>

Sets or queries the warm-up timeout. Parameter is a floating-point decimal number of minutes.

WARMup:AUDio {YES | NO}

Sets or queries the asserting the audible alarm for 5 seconds when warm-up state exits.

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 Model 24C, 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 sens 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.

SENSorix <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.

SENSorix <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.

SENSorix <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.

SENSorix <index>:
TYPe {DIODE |ACR | PTC100 | PTC100 | PTC100 | 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.

SENSorix <index>:MULTiply <multiplier>
Sets or queries the multiplier field of a user installed calibration curve at <index>. For information on the multiplier, refer to the User Calibration Curve File Format section.

PIDTABLE commands

The PIDTABLE commands are used to transfer PID tables between the Model 24C and the host controller. Use of the Cryo-con Utility software to transfer PID tables is recommended since the process is relatively complex.

PID Tables are referenced by their index number, which is between 0 and 5. Table data corresponding to a specific index may be identified using the PIDTABLE? query.

There is a maximum of 16 entries in each PID table. Each entry contains a setpoint, P, I and D coefficients and a heater range.

Either output channel may use any table.

The heater range field only applies to Loop #1. However, it must be specified in each entry.

The format of an entry is:

<setpoint> <P> <I> <D> <Input Channel> <Heater Range>

Fields are separated by a white space. The entry is terminated by a new line (\n) character.

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 heater range is an enumeration field that may have the following values: HI MID and LOW.

The file format of a PID table is shown below:

```
<name>
<entry 0>
<entry 1>
  *
  *
  *
<entry N>
;
```

Where:

<name> is the name of the table and is a maximum of 16 ASCII characters.
<entry> is a PID entry. <P> <I> <D> correspond to Pgain, Igain and Dgain. They are floating-point numbers.
<Input Channel> is the controlling source input channel and may be ChA, ChB, ChC, ChD or Default. Note that default selects the input channel from the loop's source setting.

A line that contains only a single semicolon indicates the end of the table.

An example of a sixteen entry PID Table is as follows:

```
PID Test 0
 300.00    1.60  160.00   40.00 ChA       HI
 280.00    1.50  150.00   30.00 ChA       HI
 260.00    1.40  140.00   30.00 ChA       HI
 240.00    1.30  130.00   30.00 ChA       HI
 220.00    1.20  120.00   30.00 ChA       HI
 200.00    1.10  110.00   20.00 ChA       HI
 180.00    1.00  100.00   20.00 ChA       MID
 160.00    0.90   90.00   20.00 ChC       MID
 140.00    0.80   80.00   20.00 ChC       MID
 120.00    0.70   70.00   10.00 ChC       MID
 100.00    0.60   60.00   10.00 ChB       MID
  80.00    0.50   50.00   10.00 ChB       MID
  60.00    0.40   40.00   10.00 ChB       LOW
  40.00    0.30   30.00    0.00 Default   LOW
  20.00    0.20   20.00    0.00 Default   LOW
  10.00    0.10   10.00    0.00 Default   LOW
;
```

Entries may be sent to the controller in any order. The unit sorts the table in ascending order of setpoint before it is copied to Flash RAM. Entries containing invalid numeric fields will be deleted.

PIDTable? <index>

Queries the name string of a PID table at a specified index.

PIDTable <index>:NAMe "Name"

Sets or queries the name string of the PID Table at a specified index. The name string is used to associate a convenient name with a PID table. It may include up to 15 ASCII characters.

PIDTable <index>:NENTry?

Queries the number of entries in a PID Table. This number is generated from the table itself and cannot be changed using this command.

PIDTable <index>:TABLe

Uploads or downloads a complete PID table in the following format:

PIDTABLE <index>:TABLE

<name>
<setpoint> <P> <I> <D> <Input Channel> <Heater Range>
<setpoint> <P> <I> <D> <Input Channel> <Heater Range>
<setpoint> <P> <I> <D> <Input Channel> <Heater Range>
*
*
<setpoint> <P> <I> <D> <Input Channel> <Heater Range>
;

Where <index> is a numeric index of the PID table and <name> is the table name string (15 characters maximum).

Fields within an entry are separated by one or more white space characters. The last entry in a calibration curve must be a single semicolon.

Network Commands

The following commands are used to configure the Model 24C's Ethernet interface.

NETWork:IPADdress "IPA"

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

NETWork:MACADdress?

Queries the controller's MAC address. The address is returned as an ASCII string. Cryo-con MAC addresses range from 00:50:C2:6F:40:00 to 00:50:C2:6F:4f:ff. They cannot be changed by the user.

Mail Commands

The Model 24C can send e-mail over the Ethernet port when an alarm condition is asserted on an enabled input channel. The following remote commands are used to configure e-mail. However, it is much easier to configure e-mail using the controller's embedded web server.

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

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

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

Set or query the 'from' e-mail address. Parameter is an ASCII String. For example: Model24C@mynetwork.com".

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

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

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

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

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

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

Data Logging Commands

DLOG:STATe {ON|OFF}

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

DLOG:INTerval <Seconds>

Sets the data logging time interval in seconds.

DLOG:COUNt?

Queries the number of entries in the log buffer.

DLOG?
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.

Code snippet in C++

The following code opens a Cryo-con instrument at address 192.168.1.5 on the Local Area Network. It is written in Microsoft Visual C++ and uses the eZNET LAN library provided on the Cryo-con utility CD.

```
// -----  Example Ethernet LAN program using C++  -----
// TCPIP declarations
#include "TCPIPdrv.h"

  TCPIPdrv LAN; //Define global LAN object
  char IPA[ ] = "192.168.1.5"; //Instrument's IP address on the
  LAN
  char tempstr[257]; //temporary character string

  //Open the instrument.
  If(!LAN.open(IPA)){
     //can't connect...
     LAN.close();
     throw ("Can't talk to instrument");
  };
  //read the IDN string
  LAN.IO("*IDN?",tempstr,256);
  printf("IDN is %s\n",tempstr); //Print IDN

  //read the MAC address
  LAN.IO("net:mac?",tempstr,256);
  printf("MAC is: %s\n",tempstr);

  //Start temperature control
  LAN.IO(control");

  //Stop temperature control
  LAN.IO(stop");

  //Read channel B input
  LAN.IO("input? B",tempstr,256);
  printf("Channel B temperature is: %s\n",tempstr);

  //send compound command to input channel A and wait for it
  to finish.
  LAN.IO("INPUT A:UNIT S;SENSOR 33;:*OPC?",tempstr,256);

  //close the instrument
  LAN.close();
```

EU Declaration of Conformity

According to ISO/IEC Guide 22 and EN 45014

Product Category: Measurement, Control and Laboratory

Product Type: Temperature Measuring and Control System

Model Numbers: Model 24C

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:

Emissions	Immunity	Safety
EN 55011,1998	EN 50082-1, 1997	EN 61010-1, 2001
		IEC 61010-1, 2001

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.
June 10, 2010

Appendix A: Installed Sensor Curves

Factory Installed Curves

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

Sensor IX	Name	Description
0	None	No Sensor. Used to turn the selected input channel off.
1	Cryo-con S900	Cryo-con S700 series Silicon diode. Range: 1.4 to 500K. 10μA constant current excitation.
2	LS DT-670	Lakeshore DT-670 series Silicon diode, Curve 11. Range: 1.4 to 500K. 10μA constant current excitation.
3	LS DT-470	Lakeshore DT-470 series Silicon diode, Curve 10. Range: 1.4 to 500K. 10μA constant current excitation.
4	CD-12A	Cryo Industries CD-12A Silicon diode. Range: 1.4 to 500K. 10μA constant current excitation.
5	SI 410 Diode	Scientific Instruments, Inc. 410 diode Curve. Range: 1.5 to 450K. 10μA excitation.
20	Pt100 385	DIN43760 standard 100Ω Platinum RTD. Range: 23 to 873K, 1mA excitation.
21	Pt1K 385	1000Ω at 0°C Platinum RTD using DIN43760 standard calibration curve. Range: 23 to 1023K, 100μA excitation.
22	Pt10K 385	10KΩ at 0°C Platinum RTD. Temperature coefficient 0.00385, Range: 23 to 873K, 10μA excitation.
23	RhFe 27, 1mA	Rhodium-Iron. 27Ω at 0°C. 1mA DC excitation. 1.5 to 873K
31	SI RO-105	Scientific Instruments Inc. RO-105 Ruthenium Oxide sensor. Temperature range is: 2 to 273K. Use with the NTC10uA input configuration only.
32	SI RO-600	Scientific Instruments Inc. RO-600 Ruthenium-Oxide sensor with constant-voltage AC excitation. Temperature range is: <50mK to 40K. Use 1.0mV bias.
33	Cryo-con R500	Cryocon R500 Ruthenium-Oxide sensor with constant-voltage AC excitation. Temperature range is: <50mK to 40K. Use 1.0mV bias.
34	Cryo-con R400	Cryocon R400 Ruthenium-Oxide sensor. Temperature range is: 2 to 273K. Use with the NTC10uA input configuration only.
45	TC Type K	Thermocouple, Type K. Range: 3.2 to 1643K
46	TC Type E	Thermocouple, Type E. Range: 3.2 to 1273K
47	TC Type T	Thermocouple, Type T. Range: 3.2 to 673K
48	TC AuFe .07%	Chromel-AuFe 7% thermocouple. Range: 3 to 610K

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

INPUT B SENSORIX 34 would set input B to use the R400 sensor.
INPUT A: SENSORIX 1 would set input A to use the S900 diode.
INPUT A: SENSORIX 0 would turn input A off by setting the sensor to ‘none’.
SENSORIX 1:NAME? Returns the name string at index 1.

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

User Installed Sensor Curves

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

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

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

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

ⓘ **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.

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. 10µA 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, 100Ω at 0°C. Range: 23 to 1020K
PT1K385.crv	DIN43760 or IEC751 standard Platinum RTD, 1000Ω at 0°C. Range: 23 to 1020K
PT1003902.crv	Platinum RTD, 100Ω at 0°C Temperature coefficient 0.003902 Ω/C. Range: 73K to 833K.
PT1K375.crv	Platinum RTD, 1000Ω at 0°C Temperature coefficient 0.00375 Ω/C. Range: 73K to 833K.
aufe07cr.crv	Chromel-AuFe 7% thermocouple. Range: 3 to 610K
TCTypeE.crv	Thermocouple, Type E. Range: 3.2 to 1273K
TCTypeK.crv	Thermocouple, Type K. Range: 3.2 to 1643K
TCTypeT.crv	Thermocouple, Type T. Range: 3.2 to 673K
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 Model 24C, selections are: DIODE, PTC100, PTC1K, PTC10K, 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 10KΩ Platinum RTD can use a calibration curve for a 100Ω Platinum RTD by using a multiplier of 100.0.

The fourth line of the header is the sensor units field. This may be Volts, Ohms or Logohm. Generally, diode type sensor curves will be in units of Volts and most resistance sensors will be in units of Ohms. However, many resistance sensors used at low temperature have highly nonlinear curves. In this case, the use of Logohm units give a more linear curve and provide better interpolation accuracy. Logohm is the base-10 logarithm of Ohms.

Examples of sensor calibration curves that are in units of Ohms include Platinum RTDs and Rhodium-Iron RTDs. Examples of sensors that best use Logohm include Cernox™, Ruthenium-Oxide and Carbon-Ceramic.

After the header block, there are two to 200 lines of sensor calibration data points. Each point of a curve contains a sensor reading and the corresponding temperature. Sensor readings are in units specified by the units line in the curve header. Temperature is always in Kelvin.

The format of an entry is:

<sensor reading> <Temperature>

Where <sensor reading> is a floating-point sensor reading and <Temperature> is a floating-point temperature in Kelvin. Numbers are separated by one or more white spaces.

Floating point numbers may be entered with many significant digits. They will be converted to 32 bit floating point which supports about six significant digits.

The last entry of a table is indicated by a semicolon (;) character with no characters on the line.

> ⓘ **NOTE:** All curves must have a minimum of two entries and a maximum of 200 entries.

Entries may be sent to the instrument in any order. The instrument will sort the curve in ascending order of sensor reading before it is copied to Flash RAM. Entries containing invalid numeric fields are deleted before the curve is stored.

The following is an example of a calibration curve transmitted to the instrument via the LAN interface:

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

In summary,

1. The first line is a name string that can be up to 15 characters. Longer strings are truncated by the instrument.

   The second line identifies the instrument's input configuration and must be one of the allowed selections described in the Supported Sensor Configurations section.
2. The third line is the multiplier field and is 1.0 for PTC sensors and -1.0 for NTC sensors or diodes.
3. The fourth line of the header is the sensor units and must be Volts, Ohms or Logohm.
4. Curve entries must be the sensor reading followed by the temperature in units of Kelvin. Values are separated by one or more white space or tab characters.
5. The last line in the file has a single semicolon (;) character. All lines after this are rejected.
6. It is recommended that the curve back is read after downloading to ensure that the instrument parsed the file correctly. This is easily done by using the Cryo-con utility software’s curve upload function under Operations>Sensor Curve>upload.

Appendix B: Updating Instrument Firmware

Updates require the use of the Cryo-con Firmware Update Utility software and a hex file containing the updated firmware. These are available on the Internet.

> ⓘ **Note:** Updating firmware in any instrument is not entirely without risk. Please only perform the procedure when some down time is available.
>
> The update will abort on the detection of a hardware malfunction. Also, the update may change instrument features that you are currently using in a different way. Factory defaults settings are restored that will erase any existing user calibration curves or PID tables.

Discussion

Cryo-con instruments have two blocks of flash type program memory. In the standard configuration, the Internal block contains a boot-loader program and the External block contains the actual instrument firmware.

During the normal power-up sequence, the boot-loader tests the external flash memory and then transfer execution to it in order to run the instrument's firmware. From there, the Cryo-con firmware update utility can be used to update instrument's firmware.

The firmware update sequence is as follows:

1. Connect the LAN port of the instrument to your PC, turn the instrument ON and then run the FWutility.exe.
2. Click the Connect button to connect the PC to the instrument using TCP/IP. If there is an error, a dialog box will appear. Correct the problem and re-try.
3. While connected, the instrument still functions normally. Click on the Set Flash Mode button to place the instrument in the firmware update mode. In this mode, the instrument executes the boot-loader from the Internal flash memory and is waiting to program the External memory with the new firmware.
4. Click Connect again and then click the Program / Verify button to start the update process.
5. When the update process is complete, the instrument will automatically reset itself and start running the updated firmware.

Updating unit firmware

Before starting, be sure to have the **FWutility.exe** file and a hex file that contains the desired firmware update.

On the instrument, check the current hardware and firmware revision by pressing the System key and scrolling down to the revision field. A typical display is:

FW Ver: 3.00D

meaning that the instrument has firmware revision 3.00 and hardware revision D.

The name of the hex file is used to identify the firmware update update. For example:

M24C_301.hex

specifies that this is revision 3.01 for a Model 24C with hardware revision C.

> ⓘ **Note:** The flash loader software does NOT check the hex file for compatibility with the target instrument. Please be sure that you are using the correct file.

Connecting a PC to the instrument

It is recommended that the instrument is connected directly to a PC using a LAN Crossover cable. The standard LAN patch cable is designed to connect a PC to a hub and will not work when used to connect to an instrument. The Crossover cable has the transmit and receive lines reversed, which allows direct connection to an instrument. These cables should be clearly marked with the word 'Crossover'.

From the PC, open the network connections dialog, select the network adapter that you are using with the Cryo-con instrument and select "Internet Protocol (TCP/IP). In the TCP/IP dialog box, select 'Use the following IP' addresses and enter following:

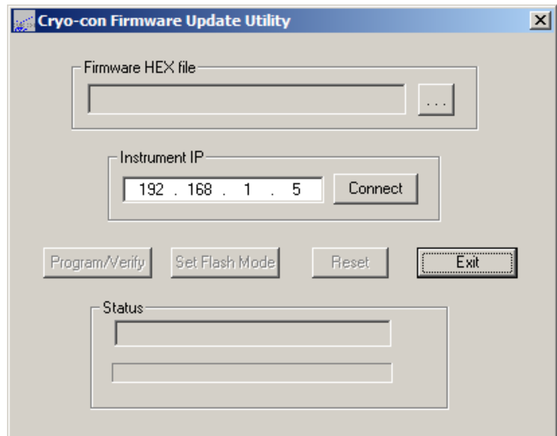
IP address: 192.168.1.10
Subnet mask: 255.255.255.0

Other fields are not used. Click OK. This should allow you to communicate with the instrument.

> ⓘ The advanced user can configure the Ethernet connection in any convenient way. The above procedure is given because it is known to work. The instrument will keep the assigned IP through the entire update process. However, when the update is complete, factory defaults are restored and the IP will be set to 192.168.1.5.

Loading Firmware

Start the firmware update by running the Cryo-con Firmware Utility. This launches a dialog box as shown here.



The instrument's default IP will appear in the dialog box. This can be changed if necessary.

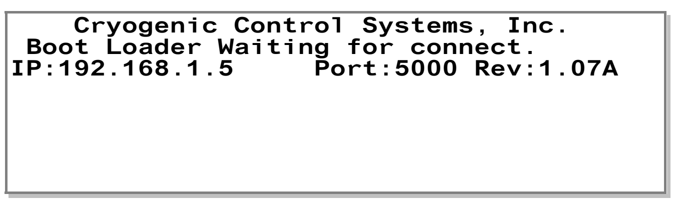
Click the **Connect** button. The status box should update to indicate a connection, but the instrument display will not change.

Next, the firmware update file needs to be selected. Click on the browse button (**. . .**) to launch a file selection dialog.

Select the firmware hex file and click **Open**. The Firmware HEX file field will be updated with the file name. Also, the **Set Flash Mode** button will become active.

Caution: Once you click the **Set Flash Mode** button, the instrument will enter the firmware update mode and will not function normally again until the entire firmware update process is complete without error. Be sure you have the correct hex file before proceeding.

Click the **Set Flash Mode** button to set the instrument into the flash programming mode. The instrument will reset and start in the flash load mode. This is indicated by the display shown.



Since the instrument was reset, click **Connect** again to re-establish contact. This activates the **Program/Verify** button. The instrument will now display “Connected...”

Click the **Program/Verify** button to start the firmware download.

The last few lines of the instrument's display will indicate the status. First, the flash memories are erased and then individual records are programmed and verified.

There are about 6800 records in a typical file and the programming process takes about ten minutes.

When programming is complete, the unit will automatically reset and begin running the updated firmware. Factory defaults are also restored.

It is possible to power the instrument OFF during the programming process. This will require a re-start of the entire process after powering ON again. Once the download progress starts, the instrument powers-up in the boot loader mode and will not run the normal instrument firmware until the entire download process is completed without error.

If an error occurs, an error message will display on the instrument's front panel for 20 seconds and then an alert box will show on the PC.

Types of errors are: 1) Failure to erase flash memory. 2) Write error and 3) Verify error.

If the error persists after several programming attempts, there is a hardware problem and you will need to contact Cryo-con.

Appendix C: Troubleshooting Guide

Error Displays

Display	Condition
A-------K Or, an erratic display of temperature.	Input channel voltage measurement is out of range. Ensure that the sensor is connected and properly wired. Ensure that the polarity of the sensor connections is correct. Refer to the Sensor Connections section. Many sensors can be checked with a standard Ohmmeter. For resistor sensors, ensure that the resistance is correct by measuring across both the Sense and Excitation contacts. For a diode sensor, measure the forward and reverse resistance to ensure a diode-type function.
A.......K	Input channel is within range, but measurement is outside the limits of the selected sensor's calibration curve. Check sensor connections as described above. Ensure that the proper sensor has been selected. Refer to the Input Channel Configuration Menu section. Change the sensor units to Volts or Ohms and ensure that the resulting measurement is within the selected calibration curve. Refer to the section on Input Channel Configuration Menu to display the calibration curve.

Control Loop and Heater Problems

Symptom	Condition
Overtemp displayed.	The control loops were disengaged by detection of an excessive internal temperature. Possible causes: Shorted heater. Check heater resistance. Selection of a heater resistance that is much greater than the actual heater resistance. Refer to the Control Loop Setup menu section. Selection of an AC Power line voltage that is much less than the actual voltage. Refer to the Fuse Replacement and Voltage Selection section. Check that the instrument's fan is running and that the sides and rear panel allow easy air flow.
Readback displayed.	The control loops were disengaged by the heater current read-back monitor. Most likely cause is an open heater.
SensorFLT displayed.	The control loops were disengaged by a sensor fault condition. Correct the input sensor fault condition to proceed. The control loops will only engage when there is a valid temperature reading on their input. The exception is when a loop is assigned a control mode of Off or Manual.
OTDisconn displayed.	The control loops were disengaged by the Over Temperature Disconnect monitor. This was done to protect user equipment from damage due to overheating. To configure the monitor, refer to the System Functions Menu section.
The heater output current monitor is jumping up and down by about 1%	This is normal and does not indicate unstable heater power. The output current monitor is coarsely quantized and is displayed only for an indication of proper function.
The controller should be applying power, but the display is showing 0% output.	The output indicated on the display is the actual measured output power of the control loop. A reading of 0% while the controller is attempting to output power usually indicates an open heater.
Unstable control.	If the system is oscillating, try de-tuning the PID values by decreasing P, increasing I and setting D to zero. If the oscillations cannot be stopped by this procedure, the cause is likely that your system has an excessive time delay. Linear control algorithms, including PID, cannot control systems with excessive time delay. These problems often occur in systems that use heat pipes, or depend on gas flow between the heater and temperature sensor elements. The only solution to such systems is to re-design the equipment to reduce the time delay, or to externally implement a time delay compensation algorithm, such as a Smith Predictor. Do not try to control on Ohms or Volts. The controller will work correctly with either of these sensor units, but the PID values required are significantly different and most sensors are non-linear. Furtherer, there is no advantage to controlling in sensor units. Optimize the control loop parameters by using the Autotune feature described in the Autotuning section. Most cryogenic systems require significantly different PID parameters at different temperatures. To ensure stable control over a wide temperature range, use the PID Table feature described in the PID Table Entry section. If the heater is controlling with an output power level less than 10%, switch to the next lower heater range.

Symptom	Condition
Autotune indicates a status of 'Abort' or 'Fail'.	Autotune will only abort if the control loops are not engaged or there is an invalid temperature reading on the control input channel. If it cannot generate a solution because of issues in the system dynamics, it will indicate a status of 'Fail'.
Autotune times out and does not generate effective PID parameters.	Extend the Display Filter time constant to reduce system level noise and try autotune again. The display filter is described in the System Functions Menu section. Systems using diode type sensors above 50K will usually require a 4 or 8 second time constant. This setting may be returned to any desired value once tuning is complete. Switch to the lowest possible heater range that will control at the target setpoint. Try autotuning in the PI- mode instead of PID. Most cryogenic systems do not benefit from the D term. If a Cryo-cooler is being used, set the controller's cryocooler filter to Input mode. This may be returned to Off or Cancel mode once tuning is complete. Experiment with the DeltaP parameter. Increasing it often improves autotune success.

Temperature Measurement Errors

Symptom	Condition
Noise on temperature measurements.	Possible causes: 1. 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. Note: Cryo-con controllers use a shielding scheme that is slightly different than some other controllers. If you are using cable sets made for use with other controllers, some shield connections may need to change. If pin 3 of the input connector is connected to the cable shield, disconnect it and either re-connect the shield to the backshell contact or leave the shield floating. No connection should ever be made to pin 3 of the input connector. 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. 2. Use a longer display filter time constant to reduce displayed noise.

Symptom	Condition
DC offset in temperature measurements.	Possible causes: 1. The wrong sensor type or sensor calibration curve is being used. Refer to the Input Channel Configuration Menu section. 2. DC offset in cryostat wiring. Review the Thermal EMF and AC Bias Issues section. Use AC bias, if necessary, to cancel the offset error. 3. A four-wire measurement is not being used. Some cryostats use a to a two-wire measurement internally. This can cause offset errors due to lead resistance. 4. Thermocouples: These sensors will often have DC offset errors. Use the CalGen feature to generate a new sensor calibration curve that corrects for these errors.
No temperature reading.	Review the Error Displays section above.

Remote I/O problems

Symptom	Condition
Can't talk to RS-232 interface.	Possible causes: 1. Ensure that the RS-232 port is selected. Press the System key and scroll down to the RIO-Port: field. 2. Ensure that the baud rate of the controller matches that of the host computer. To check the controller's baud rate, press the System key and scroll down to the RIO-RS232 field. 3. Ensure that the host computer settings are 8-bits, No parity, one stop bit. 4. The RS-232 port does not have an effective hardware handshake method. Therefore, terminator characters must be used on all strings sent to the controller. Review the RS-232 Configuration section. 5. Ensure that you are using a Null-Modem type cable. There are many variations of RS-232 cables and only the Null-Modem cable will work with Cryo-con controllers. This cable is detailed in the RS-232 Connections section. Debugging tip: Cryo-con utility software can be used to talk to the controller over the RS-232 port using the terminal mode. All command and response strings are displayed. This is a good way to establish a connection.
Intermittent lockup on RS-232 interface.	Possible causes: 1. Long cables. Try using a lower baud rate. In some cases, inserting a 50mS delay between commands will help. 2. Noise pickup. Try using shielded cables with the shield connected to a metal backshell at both ends. 3. Don't send reset (RST) commands to the controller before reading.

Symptom	Condition
Can't talk to IEEE-488 interface.	Possible causes: 1. Ensure that the GPIB port is selected. Press the **System** key and scroll down to the RIO-Port: field. 2. The IEEE-488 interface does not use terminator characters. Rather, it uses the hardware EOI handshake. Please review the GPIB Configuration section. 3. Check that the controller's address matches the host computer's assignment. Press the **System** key and scroll down to the RIO-Address: field. Debugging tip: Cryo-con utility software can be used to talk to the controller over the IEEE-488 port using the terminal mode. All command and response strings are displayed. Since the software provides the proper interface setup, it is a good way to establish initial connection.
Intermittent lockup on the IEEE-488 interface.	Possible causes: 1. Bus cables too long or too many loads on a single bus. 2. Don't send reset commands before each query. This was common in early IEEE-488 systems. 3. Ground loops: Some equipment manufacturers improperly connect the IEEE-488 Shield Ground wire to their circuit board ground. This can cause ground loops with equipment that is properly connected. Debug by disconnecting instruments from the bus. 4. Use of unshielded bus cables.

Symptom	Condition
Can't talk to the LAN interface.	Possible causes: 1. A Category 5 crossover patch cable is being used where a Category 5 patch cable should be used, or visa-versa. 2. The TCP settings between the monitor and the PC are incompatible. Review the network configuration section. 3. PC Client software not configured to use TCP Data Socket 5000. Debugging tip: Cryo-con utility software can be used to talk to the monitor over the LAN Data Socket port using the terminal mode. All command and response strings are displayed. Since the software provides the proper interface setup, it is a good way to establish initial connection.

General problems

Symptom	Condition
Controller periodically resets, or resets when **Control** key is pressed.	Generally caused by low AC line voltage. Check the AC voltage and ensure that it matches the instrument's voltage selection. AC line voltage selection is described in the Fuse Replacement and Voltage Selection section.
Complete failure.	Possible cause: 1. Blown fuse. Check line voltage selection before installing new fuses. Review the Fuse Replacement and Voltage Selection section. 2. Rack mounted instruments: Screws were used in the rack mount shelf that are too long and have penetrated the internal circuit board of the controller.

Appendix D: Tuning Control Loops

Introduction

Tuning PID loops to maintain high accuracy control can be a laborious process since the time-constants in cryogenic systems are often long. Further, some systems must operate over a very wide range of temperature, requiring different PID settings at different setpoints.

The following is a guide to various methods of obtaining PID control loop coefficients.

Various methods for obtaining PID coefficients

The system provider

If your controller was received as part of a cryogenic system, the PID control loops should already be setup for optimum control. If the system operates over a wide range of temperature, it will use one of the available Table control modes where PID values are listed for different setpoints.

If the installed PID values do not provide stable control, you should contact the system manufacturer for assistance.

Taking PID values from a different controller

If the PID values required to control a system are known from a different type controller, these values may be useful.

The Proportional, or P term is a unit-less gain factor. There is no industry standard definition for it and, therefore, it can vary significantly from one manufacturer to another. If the P term does not work well when used directly, try a using the value divided by ten. For further assistance, please contact Cryo-con support.

The Integral, or I term is in units of Seconds and should be the same for different controllers. Note however that some manufacturers use a ‘Reset’ value instead of directly using an Integral term. In this case, the Integral term is just the inverse of the Reset value.

The Derivative, or D gain term is in units of inverse Seconds and should be the same for various controllers.

Using Factory Default PID values

Controllers are shipped from the factory with very conservative PID values. They will give stable control in a wide range of systems, but will have very slow response times.

Often, the factory values provide a good start for the autotune process. The values are: P 0.1, I 5.0 and D 0.0.

Autotuning

Autotuning is the easiest way to obtain PID values, or optimize existing ones. Please review the Autotuning section of this manual.

Manual Tuning

The final, and most laborious method of tuning a control loop is manual tuning. This involves generating values for P, I and D by observing the system’s response to the stimulus of the heater output.

Various methods of manually tuning the controller are described below.

Manual Tuning Procedures

Manually tuning a PID control loop is relatively simple. It is greatly assisted by use of a data-logging program, such as the Cryo-con utility software package described in the Cryo-con Utility Software section.

Ziegler-Nichols Frequency Response Method

This method is based on the assumption that a critically damped system is optimal and the fact that stability and noise must be traded for response time. It requires driving your system into temperature oscillation. Care should be taken so that this oscillation does not cause damage.

Enable the Over Temperature Disconnect feature of the controller if there is concern over possible damage from overheating.

1. Enter a setpoint value that is a typical for the envisaged use of the system. Select a heater range that is safe for the equipment. Set initial PID values of Pgain=0.1, Igain=0 and Dgain=0.
2. Engage the control loops by pressing the **Control** key.
3. Increase the Pgain term until the system is just oscillating. Note the Pgain setting as the Ultimate Gain, *Kc*, and the period of oscillation as the Ultimate Period, *Tc*.
4. Set the PID values according to the following table:

Control Type	Pgain	Igain	Dgain
P only	0.5**Kc*	0	0
PI only	0.4**Kc*	0.8**Tc*	0
PID	0.6**Kc*	0.5**Tc*	0.85**Tc*

5. Wait for the system to stabilize. If the resultant heater power output reading is less than 10% of full scale, select the next lower heater range setting. A range change will not require re-tuning.

> ⓘ **Note:** In systems where there is high thermal noise, including cryocoolers, a Dgain value of zero is often used. The Dterm is a derivative action, which can introduce additional noise into the control process.

Alternate Methods

There are various other methods to manually tune PID loops. Most are based on graphical techniques and all use a stimulus-response technique.

For further reading:

Automatic Tuning of PID controllers
Instrument Society of America
67 Alexander Dr
PO Box 12277
Research Triangle Park, NC 27709

Appendix E: Sensor Data

Cryo-con S700 Silicon Diode

The Cryo-con S700 Silicon diode sensor with a 10μA excitation current.

	Volts	Temp(K)		Volts	Temp(K)		Volts	Temp(K)
1	0.1633	475.0000	41	0.6393	260.0000	81	1.2510	18.0000
2	0.1733	470.0000	42	0.6586	250.0000	82	1.2720	17.0000
3	0.1834	465.0000	43	0.6807	240.0000	83	1.2950	16.0000
4	0.1935	460.0000	44	0.7040	230.0000	84	1.3280	15.0000
5	0.2038	455.0000	45	0.7238	220.0000	85	1.3650	14.0000
6	0.2141	450.0000	46	0.7461	210.0000	86	1.4150	13.0000
7	0.2246	445.0000	47	0.7682	200.0000	87	1.4700	12.0000
8	0.2351	440.0000	48	0.7916	190.0000	88	1.5270	11.0000
9	0.2458	435.0000	49	0.8133	180.0000	89	1.5750	10.0000
10	0.2565	430.0000	50	0.8338	170.0000	90	1.5990	9.5000
11	0.2673	425.0000	51	0.8547	160.0000	91	1.6230	9.0000
12	0.2781	420.0000	52	0.8753	150.0000	92	1.6540	8.5000
13	0.2891	415.0000	53	0.8977	140.0000	93	1.6670	8.0000
14	0.3001	410.0000	54	0.9198	130.0000	94	1.6840	7.5000
15	0.3111	405.0000	55	0.9373	120.0000	95	1.7080	7.0000
16	0.3222	400.0000	56	0.9542	110.0000	96	1.7310	6.5000
17	0.3334	395.0000	57	0.9768	100.0000	97	1.7500	6.0000
18	0.3446	390.0000	58	0.9865	95.0000	98	1.7690	5.5000
19	0.3558	385.0000	59	0.9950	90.0000	99	1.7850	5.0000
20	0.3671	380.0000	60	1.0050	85.0000	100	1.7970	4.7500
21	0.3784	375.0000	61	1.0144	80.0000	101	1.8000	4.5000
22	0.3897	370.0000	62	1.0241	75.0000	102	1.8090	4.2500
23	0.4011	365.0000	63	1.0325	70.0000	103	1.8160	4.0000
24	0.4125	360.0000	64	1.0420	65.0000	104	1.8210	3.7500
25	0.4239	355.0000	65	1.0506	60.0000	105	1.8270	3.5000
26	0.4353	350.0000	66	1.0587	55.0000	106	1.8340	3.2500
27	0.4467	345.0000	67	1.0673	50.0000	107	1.8390	3.0000
28	0.4581	340.0000	68	1.0753	45.0000	108	1.8460	2.7500
29	0.4695	335.0000	69	1.0842	40.0000	109	1.8520	2.5000
30	0.4808	330.0000	70	1.0870	38.0000	110	1.8560	2.2500
31	0.4922	325.0000	71	1.0904	36.0000	111	1.8590	2.0000
32	0.5035	320.0000	72	1.0941	34.0000	112	1.8630	1.7500
33	0.5148	315.0000	73	1.0974	32.0000	113	1.8660	1.5000
34	0.5261	310.0000	74	1.1011	30.0000			
35	0.5373	305.0000	75	1.1054	28.0000			
36	0.5485	300.0000	76	1.1108	26.0000			
36	0.5596	295.0000	77	1.1238	24.0000			
38	0.5707	290.0000	78	1.1650	22.0000			
39	0.5900	280.0000	79	1.2070	20.0000			
40	0.6131	270.0000	80	1.2290	19.0000			

Cryo-con S900 Silicon Diode

The Cryo-con S900 Silicon diode sensor with a 10μA 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

Cryo-con R500 Ruthenium-Oxide Sensor

The Cryo-con R500 with 10μA DC excitation.

Temp(K)	Ohms	Ohms/K
20.00	1100.75	-4
15.00	1127.06	-7
10.00	1178.49	-15
9.00	1195.31	-19
8.00	1216.12	-24
7.00	1242.56	-30
6.00	1277.29	-41
5.00	1325.01	-58
4.50	1356.30	-70
4.00	1394.87	-88
3.90	1403.69	-93
3.80	1412.95	-97
3.70	1422.68	-102
3.60	1432.91	-108
3.50	1443.68	-114
3.40	1455.05	-120
3.30	1467.06	-127
3.20	1479.78	-135
3.10	1493.26	-143
3.00	1507.58	-152
2.90	1522.82	-163
2.80	1539.09	-174
2.70	1556.48	-186
2.60	1575.12	-200
2.50	1595.16	-216
2.40	1616.77	-234
2.30	1640.15	-254
2.20	1665.53	-277
2.10	1693.20	-303
2.00	1723.48	-343
1.90	1757.83	-355
1.80	1793.33	-396
1.70	1832.94	-445
1.60	1877.43	-503
1.50	1927.75	-574
1.40	1985.13	-661
1.30	2051.19	-769
1.20	2128.07	-906
1.10	2218.67	-1084
1.00	2327.06	-1203
0.99	2339.09	-1226
0.98	2351.35	-1251
0.97	2363.86	-1277
0.96	2376.63	-1303
0.95	2389.66	-1331
0.94	2402.97	-1359
0.93	2416.56	-1388
0.92	2430.44	-1417
0.91	2444.61	-1449
0.90	2459.10	-1481
0.89	2473.91	-1514
0.88	2489.05	-1548
0.87	2504.53	-1583
0.86	2520.36	-1621
0.85	2536.57	-1658
0.84	2553.15	-1697
0.83	2570.12	-1738
0.82	2587.50	-1781
0.81	2605.31	-1824
0.80	2623.55	-1869
0.79	2642.24	-1917
0.78	2661.41	-1966
0.77	2681.07	-2016
0.76	2701.23	-2070
0.75	2721.93	-2124
0.74	2743.17	-2182
0.73	2764.99	-2242
0.72	2787.41	-2304
0.71	2810.45	-2368
0.70	2834.13	-2436
0.69	2858.49	-2507
0.68	2883.56	-2580
0.67	2909.36	-2658
0.66	2935.94	-2738
0.65	2963.32	-2822
0.64	2991.54	-2911
0.63	3020.65	-3003
0.62	3050.68	-3100
0.61	3081.68	-3202
0.60	3113.70	-3309
0.59	3146.79	-3422
0.58	3181.01	-3540
0.57	3216.41	-3665
0.56	3253.06	-3796
0.55	3291.02	-3935
0.54	3330.37	-4082
0.53	3371.19	-4237
0.52	3413.56	-4401
0.51	3457.57	-4576
0.50	3503.33	-4760
0.49	3550.93	-4956
0.48	3600.49	-5164
0.47	3652.13	-5388
0.46	3706.01	-5624
0.45	3762.25	-5877
0.44	3821.02	-6149
0.43	3882.51	-6439
0.42	3946.90	-6751
0.41	4014.41	-7086
0.40	4085.27	-7447
0.39	4159.74	-7837
0.38	4238.11	-8259
0.37	4320.70	-8715
0.36	4407.85	-9212
0.35	4499.97	-9753
0.34	4597.50	-10343
0.33	4700.93	-10989
0.32	4810.82	-11699
0.31	4927.81	-12481
0.30	5052.62	-13345
0.29	5186.07	-14303
0.28	5329.10	-15369
0.27	5482.79	-16562
0.26	5648.41	-17901
0.25	5827.42	-19412
0.24	6021.54	-21126
0.23	6232.80	-23081
0.22	6463.61	-25325
0.21	6716.86	-27920
0.20	6996.06	-30943
0.19	7305.49	-34493
0.18	7650.42	-38706
0.17	8037.48	-43758
0.16	8475.06	-49892
0.15	8973.98	-57444
0.14	9548.42	-66902
0.13	10217.44	-78978
0.12	11007.22	-94764
0.11	11954.86	-116005
0.10	13114.91	-145658
0.09	14571.49	-189096
0.08	16462.45	-257192
0.07	19034.37	-375766
0.06	22792.03	-628083
0.05	29072.86	

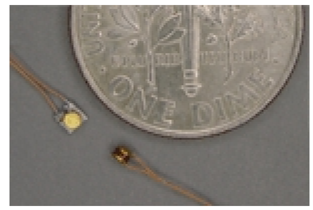
Cryo-con R400 Ruthenium-Oxide Sensor

The Cryo-con R400 with 100uV AC excitation.

Temp(K)	Ohms	Ohms/K	Temp(K)	Ohms	Ohms/K	Temp(K)	Ohms	Ohms/K
300.00	1000	-0.08	0.98	2351	-1251.00	0.49	3551	-4956.00
200.00	1008	-0.13	0.97	2364	-1277.00	0.48	3600	-5164.00
100.00	1025	-0.33	0.96	2377	-1303.00	0.47	3652	-5388.00
80.00	1032	-0.49	0.95	2390	-1331.00	0.46	3706	-5624.00
60.00	1042	-0.84	0.94	2403	-1359.00	0.45	3762	-5877.00
40.00	1058	-1.50	0.93	2417	-1388.00	0.44	3821	-6149.00
20.00	1101	-4.08	0.92	2430	-1417.00	0.43	3883	-6439.00
15.00	1127	-7.20	0.91	2445	-1449.00	0.42	3947	-6751.00
10.00	1178	-15.40	0.90	2459	-1481.00	0.41	4014	-7086.00
9.00	1195	-18.80	0.89	2474	-1514.00	0.40	4085	-7447.00
8.00	1216	-23.60	0.88	2489	-1548.00	0.39	4160	-7837.00
7.00	1243	-30.50	0.87	2505	-1583.00	0.38	4238	-8259.00
6.00	1277	-40.90	0.86	2520	-1621.00	0.37	4321	-8715.00
5.00	1325	-57.80	0.85	2537	-1658.00	0.36	4408	-9212.00
4.50	1356	-70.50	0.84	2553	-1697.00	0.35	4500	-9753.00
4.30	1371	-76.90	0.83	2570	-1738.00	0.34	4598	-10343.00
4.20	1378	-80.40	0.82	2588	-1781.00	0.33	4701	-10989.00
4.00	1395	-88.20	0.81	2605	-1824.00	0.32	4811	-11699.00
3.90	1404	-92.60	0.80	2624	-1869.00	0.31	4928	-12481.00
3.80	1413	-97.30	0.79	2642	-1917.00	0.30	5053	-13345.00
3.70	1423	-102.30	0.78	2661	-1966.00	0.29	5186	-14303.00
3.60	1433	-107.70	0.77	2681	-2016.00	0.28	5329	-15369.00
3.50	1444	-113.70	0.76	2701	-2070.00	0.27	5483	-16562.00
3.40	1455	-120.10	0.75	2722	-2124.00	0.26	5648	-17901.00
3.30	1467	-127.20	0.74	2743	-2182.00	0.25	5827	-19412.00
3.20	1480	-134.80	0.73	2765	-2242.00	0.24	6022	-21126.00
3.10	1493	-143.20	0.72	2787	-2304.00	0.23	6233	-23081.00
3.00	1508	-152.40	0.71	2810	-2368.00	0.22	6464	-25325.00
2.90	1523	-162.70	0.70	2834	-2436.00	0.21	6717	-27920.00
2.80	1539	-173.90	0.69	2858	-2507.00	0.20	6996	-30943.00
2.70	1556	-186.40	0.68	2884	-2580.00	0.19	7305	-34493.00
2.60	1575	-200.40	0.67	2909	-2658.00	0.18	7650	-38706.00
2.50	1595	-216.10	0.66	2936	-2738.00	0.17	8037	-43758.00
2.40	1617	-233.80	0.65	2963	-2822.00	0.16	8475	-49892.00
2.30	1640	-253.80	0.64	2992	-2911.00	0.15	8974	-57444.00
2.20	1666	-276.70	0.63	3021	-3003.00	0.14	9548	-66902.00
2.10	1693	-302.80	0.62	3051	-3100.00	0.13	10217	-78978.00
2.00	1723	-343.50	0.61	3082	-3202.00	0.12	11007	-94764.00
1.90	1758	-355.00	0.60	3114	-3309.00	0.11	11955	-116005.00
1.80	1793	-396.10	0.59	3147	-3422.00	0.10	13115	-145658.00
1.70	1833	-444.90	0.58	3181	-3540.00	0.09	14571	-189096.00
1.60	1877	-503.20	0.57	3216	-3665.00	0.08	16462	-257192.00
1.50	1928	-573.80	0.56	3253	-3796.00	0.07	19034	-375766.00
1.40	1985	-660.60	0.55	3291	-3935.00	0.06	22792	-628083.00
1.30	2051	-768.80	0.54	3330	-4082.00	0.05	29073	
1.20	2128	-906.00	0.53	3371	-4237.00			
1.10	2219	-1083.90	0.52	3414	-4401.00			
1.00	2327	-1203.00	0.51	3458	-4576.00			
0.99	2339	-1226.00	0.50	3503	-4760.00			

Sensor Packages

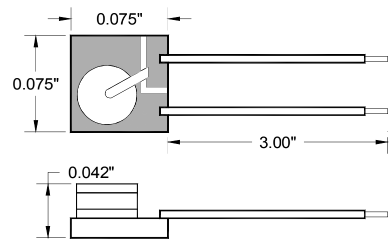
The SM and CP Sensor Packages



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.



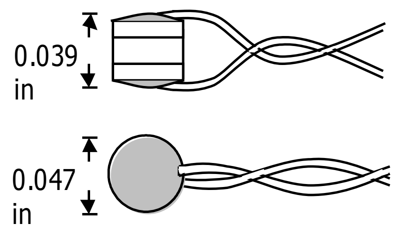
Sensor is easily installed by attaching the substrate directly to the desired surface using cryogenic varnish. Leads should be thermally anchored.

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 36: BB Package Specifications

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 Formvar™ 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.

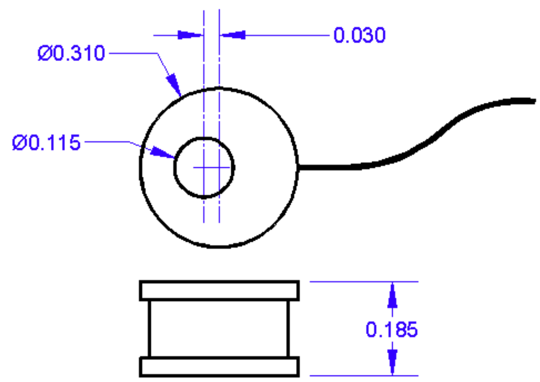
Cable Color Codes	
V+	Clear
V-	Green
I+	Black
I-	Red

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 Apiezon™ 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.



The Canister Sensor Package

Cryo-con's Ruthenium-Oxide sensors are available in a small 0.95" x 0.2" cylindrical canister package.

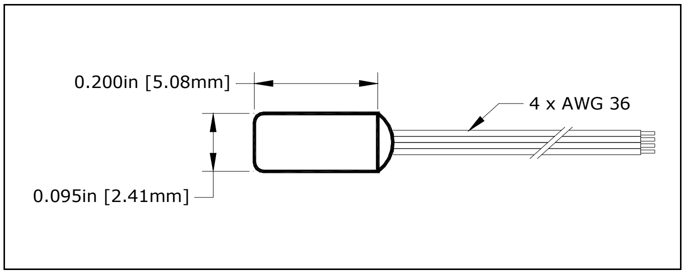
Construction: Gold-plated cylindrical OHFC copper canister, Stycast® epoxy filler. There is no internal atmosphere. Epoxy limits the maximum storage temperature to 400K.

Leads: Four, 36 AWG, Phosphor-Bronze, color coded. Formvar® insulation.

Mass: 0.4g.

Installation: Use a 0.101" diameter drill. Place a small amount of Apiezon® N grease in the hole before inserting the sensor. Ensure that the leads are thermally anchored.

Cable Color Code	
V+	Clear
V-	Green
I+	Black
I-	Red



Connection:

All connections should be 4-wire in order to eliminate errors due to lead resistance.

Leads are coated with Butyl and may be separated by dipping them in Isopropyl Alcohol.

Lead insulation is heavy Formvar® which is difficult to strip. Techniques include use of a mechanical stripper or scrapping with a razor blade.

Appendix F: Configuration Scripts

The Cryo-con Utility software package can be used to send configuration scripts to any Cryo-con instrument. These scripts consist mostly of standard remote commands and queries.

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

XML, or Extensible Markup Language, is used for the structure and format of script files. XML can be generated and edited with a standard text editor but advanced users may want to use one of the commonly available XML editors. Since it provides a structure and allows user documentation, it is easy to read and understand.

Configuration scripts have a file extension of .xml. These files are sent to an instrument by using the Operations->Send Command File function of the Cryo-con Utility Software.

Any remote command or query that is recognized by the instrument can be used in a script file. This includes commands that read and write user sensor calibration curves and PID tables. A complete description of available remote commands is given in the chapter titled Remote Programming Guide. The Remote Command Tree section is particularly useful for the advanced user.

Script File Structure

Header and Footer

Like all XML files, script files have the following header and footer:

```
<?xml version="1.0"?>
<Transactions>
        .
        .
        .
</Transactions>
```

All user supplied information is placed between the Transactions tags.

Basic XML Tags

Comment: <! >

Inserts a comment in the file for documentation and readability. The comment within the angle brackets after the exclamation is ignored by the software.

<!Download User Curve 4>
<!------------ Loop 1 --------------->

Model: <Model> </Model>

Contains the Crycon instrument model number for source/destination verification.

<Model>Model24 Version 2.03</Model>

Remote Command: <Command> </Command>

Send a remote command to the instrument. Commands can be any of the instrument's commands as described in the Remote Programming Guide.

<Command>input c:sensor 2</Command>
<Command>LOOP 1:SOURCE A;Setpt 20.0</Command>
<Command>OVERTEMP:ENABLE ON</Command>

Query: <Query> </Query>

Query data from the instrument. Queries can be any of the instrument's commands as described in the Remote Programming Guide. Query is generally used with a Response tag to compare the instrument's response to an expected value. If there is no Response tag, the result of the query is printed but not tested for errors.

<Query>input c:sensor?</Query>
<Query>input b:units K;units?</Query>

Response: <Response> </Response>

Identifies the expected response to a query. This tag must always follow a Query tag, otherwise, it is ignored. When the comparison fails, an error text message will be displayed and recorded to a file.

<Query>Relays? 0</Query>
<Response>Lo</Response>

<Query>input c:units?</Query>
<Response>K</Response> <! Should be Kelvin. Error if not >

Floating Point Response: <Floatresponse> <Floatresponse>
Compare the response returned from the instrument against an expected floating point number. This tag must always follow a Query tag; otherwise, it is ignored. When the comparison fails, an error text message will display. The returned value passes the test if within +/-2.5% of the expected value.

```
<Query>input a:ALAR:High?</Query>
<FloatResponse>200.000000</FloatResponse>
```

Pause: <Pause> </Pause>
Provide a pause for a specified number of milliseconds to allow the instrument to react to a command. Maximum 20 seconds. Generally, this is only used with the RS-232 serial interface where there is no hardware handshake.

```
<Pause>1000</Pause> <! Delay 1 second >
```

Group Tags
Any tag that is not defined is treated as a group tag. They are used to provide structure and enhance readability. Otherwise, they are ignored.

Complex Tags

Sending a user sensor calibration curve or a PID table to an instrument requires a complex tag because it can require many lines of data.

User Sensor Calibration Curve: <Calcur>
Send a sensor calibration curve to the instrument.

```
<!Download User curve 4>
    <CalCur>Calcur 4</CalCur>
    <!--Curve Name-->
        <CalCur>My Sensor</CalCur>
    <!--Curve Type-->
        <CalCur>Diode</CalCur>
    <!--Multiplier-->
        <CalCur>-1.000000</CalCur>
    <!--Units-->
        <CalCur>Volts</CalCur>
    <!--Curve Entries-->
        <CalCur>0.163300   475.000000</CalCur>
        <CalCur>0.173300   470.000000</CalCur>
        <CalCur>0.183400   465.000000</CalCur>
        <CalCur>1.866000     1.500000</CalCur>
    <!--Send the terminator character-->
    <CalCur>;</CalCur>
```

Transmission of the calibration curve starts with the first CALCUR tag and ends when the terminator character is sent. Comments are ignored.

PID tables are sent to the instrument by using standard command tags. For example:

```
<PIDtable> <!--Group tag is for documentation only--->
        <Command>PIDTABLE 0:TABLE</Command>
        <Command>PID table 1</Command>
        <Command>320.00 2 10 1 ChA LOW</Command>
        <Command>300.00 2 10 1 ChA LOW</Command>
        <Command>150.00 2 10 1 ChA LOW</Command>
        <Command>55.00   2 10 1 default LOW</Command>
        <Command>40.00   2 10 1 default MID</Command>
        <Command>30.00   2 10 1 default MID</Command>
        <Command>25.00   2 8.5 1 default MID</Command>
        <Command>20.00   2 4 1 default MID</Command>
        <Command>15.00   2 3 1 default MID</Command>
        <Command>10.00   2 2 1 default MID</Command>
        <!--Send terminator-->
        <Command>;</Command>
</PIDtable>
```

Script File Example

```
<?xml version="1.0"?>
<Transactions>
   <Model>Model44 Version 3.06</Model>
   <Input>
        <!----- CHA ----->
        <Command>input a:sensor 20</Command> <! Set to PT100>
        <Query>input a:temp?</Query>
        <Command>input a:sensor 21</Command> <! Set to PT1K>
        <Query>input a:temp?</Query> <! Ignore response>

        <!---- CHB------>
        <Command>input b:sensor 20</Command>
        <Query>input b:temp?</Query>
        <Response>K</Response>
        <Command>input b:sensor 21</Command>
        <Query>input b:temp?</Query>
   </Input>
```

```
<Loop>
    <!------------ Loop 1 --------------->
    <Command>Loop 1:SetPt 250</Command>
    <Command>Loop 1:Type MAN</Command>
    <Query>Loop 1:Type?</Query>
    <Command>Loop 1:Pman 20</Command>
    <Query>Loop 1:Pman?</Query>
    <Command>control</Command>
    <Query>Loop 1:Outp?</Query>
    <Command>Stop</Command>
</Loop>
<PIDTable>
    <!Download to table 6>
        <Command>PIDTABLE 5:table</Command>
    <!Table Name>
        <Command>LOOP1 Htr</Command>
    <!Table Entries>
        <Command>310.00   1.60  160.00   40.00 Default HI</Command>>
        <Command>280.00   1.50  150.00   30.00 Default HI</Command>
        <Command>260.00   1.40  140.00   30.00 Default HI</Command>
        <Command>240.00   1.30  130.00   30.00 Default HI</Command>
        <Command>220.00   1.20  120.00   30.00 Default HI</Command>
        <Command>200.00   1.10  110.00   20.00 Default HI</Command>
        <Command>180.00   1.00  100.00   20.00 ChA MID</Command>
        <Command>160.00   0.90   90.00   20.00 ChA MID</Command>
        <Command>140.00   0.80   80.00   20.00 ChA MID</Command>
        <Command>120.00   0.70   70.00   10.00 ChA MID</Command>
        <Command>100.00   0.60   60.00   10.00 ChA MID</Command>
        <Command>80.00   0.50   50.00   10.00 ChB MID</Command>
        <Command>60.00   0.40   40.00   10.00 ChB Low</Command>
        <Command>40.00   0.30   30.00    0.00 ChB Low</Command>
        <Command>20.00   0.20   20.00    0.00 ChB Low</Command>
        <Command>;</Command>
</PIDTable>
```

```
    <SensorCurve>
        <!User curve 4>
            <CalCur>CALCUR 4</CalCur>
        <!Curve Name>
            <CalCur>Test S700</CalCur>
        <!Curve Type>
            <CalCur>Diode</CalCur>
        <!Multiplier>
            <CalCur>-1.000000</CalCur>
        <!Unit>
            <CalCur>Volts</CalCur>
        <!Curve Entries>
            <CalCur>0.163300   475.000000</CalCur>
            <CalCur>0.173300   470.000000</CalCur>
            <CalCur>0.183400   465.000000</CalCur>
            <CalCur>0.193500   460.000000</CalCur>
            <CalCur>0.203800   455.000000</CalCur>
            <CalCur>0.214100   450.000000</CalCur>
            <CalCur>0.224600   445.000000</CalCur>
            <CalCur>0.235100   440.000000</CalCur>
            <CalCur>0.245800   435.000000</CalCur>
            <CalCur>0.256500   430.000000</CalCur>
            <CalCur>0.267300   425.000000</CalCur>
            <CalCur>0.278100   420.000000</CalCur>
            <CalCur>0.289100   415.000000</CalCur>
            <CalCur>0.300100   410.000000</CalCur>
            <CalCur>0.311100   405.000000</CalCur>
            <CalCur>0.322200   400.000000</CalCur>
            <CalCur>0.333400   395.000000</CalCur>
            <CalCur>0.344600   390.000000</CalCur>
            <CalCur>0.355800   385.000000</CalCur>
            <CalCur>0.367100   380.000000</CalCur>
            <CalCur>0.378400   375.000000</CalCur>
            <CalCur>0.389700   370.000000</CalCur>
            <CalCur>0.401100   365.000000</CalCur>
            <CalCur>0.412500   360.000000</CalCur>
            <CalCur>0.423900   355.000000</CalCur>
            <CalCur>0.435300   350.000000</CalCur>
        <CalCur>;</CalCur>
    </SensorCurve>
</Transactions>
```

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 10μA.

Cryo-con S900 Silicon Diode
Name: Cryocon S900 Configuration: Diode

T(K)	Volts	mV/K
1.4	1.63864	-36.56
4.2	1.53960	-33.91
10	1.35568	-26.04
20	1.18193	-11.34
30	1.10465	-3.12
50	1.07188	-1.46
77.35	1.02511	-1.69
100	0.98615	-1.85
150	0.88988	-2.03
200	0.78311	-2.17
250	0.67124	-2.28
300	0.55674	-2.36
355	0.42759	-2.33
400	0.32161	-2.38
450	0.20231	-2.37
500	0.09077	-2.12

Cryo-con S800 Silicon Diode
Name: Cryocon S800 Configuration: Diode

T(K)	Volts	mV/K
1.4	1.87515	-36.86
4.2	1.75099	-49.16
10	1.47130	-43.45
20	1.18867	-15.93
30	1.10594	-3.90
50	1.07079	-1.47
77.35	1.02356	-1.86
100	0.98170	-1.85
150	0.88365	-2.03
200	0.77887	-2.13
250	0.67067	-2.20
300	0.55955	-2.22
355	0.44124	-2.10
385	0.37611	-2.26

Scientific Instruments SI-430 and SI-440
Name: SI 430 Diode Configuration: Diode
Name: SI 440 Diode Configuration: Diode

T(K)	Volts	mV/K
1.4	1.63864	-36.56
4.2	1.53960	-33.91
10	1.36317	-26.04
20	1.17370	-11.34
30	1.10343	-3.12
50	1.07399	-1.46
77.35	1.02511	-1.69
100	0.98740	-1.85
150	0.89011	-2.03
200	0.78272	-2.17
250	0.67085	-2.28
300	0.55665	-2.36
355	0.42759	-2.33
400	0.32161	-2.38
450	0.20231	-2.37
500	0.09077	-2.12

Scientific Instruments SI-410 Name: SI 410 Diode Configuration: Diode		
T(K)	Volts	mV/K
1.4	1.71488	-10.54
4.2	1.64660	-32.13
10	1.39562	-35.28
20	1.17592	-20.43
30	1.10136	-1.75
50	1.06957	-1.59
77.35	1.14905	-1.72
100	0.98322	-1.82
150	0.88603	-2.00
200	0.78059	-2.14
250	0.67023	-2.23
300	0.55672	-2.28
350	0.44105	-2.32
400	0.32319	-2.36
450	0.20429	-2.38

Lakeshore DT-670 Silicon Diode Name: LS DT-670 Configuration: Diode		
T(K)	Volts	mV/K
1.4	1.64429	-12.49
4.2	1.57848	-31.59
10	1.38373	-26.84
20	1.19775	-15.63
30	1.10624	-1.96
50	1.07310	-1.61
77.35	1.02759	-1.73
100	0.98697	-1.85
150	0.88911	-2.05
200	0.78372	-2.16
250	0.67346	-2.24
300	0.55964	-2.30
350	0.44337	-2.34
400	0.32584	-2.36
450	0.20676	-2.39
500	0.09068	-2.12

Lakeshore DT-470 Silicon Diode Name: LS DT-470 Configuration: Diode		
T(K)	Volts	mV/K
1.4	1.6981	-13.1
4.2	1.6260	-33.6
10	1.4201	-28.7
20	1.2144	-17.6
30	1.1070	-2.34
50	1.0705	-1.75
77.35	1.0203	-1.92
100	0.9755	-2.04
150	0.8687	-2.19
200	0.7555	-2.31
250	0.6384	-2.37
300	0.5189	-2.4
350	0.3978	-2.44
400	0.2746	-2.49
450	0.1499	-2.46
475	0.0906	-2.22

GaAlAs Diode

GaAiAs diode sensors offer good sensitivity over a wide range of temperatures. However, they do not follow a standard calibration curve.

Useful in magnetic fields below 5T and a temperature above 30K. Outside of this range, a Ruthenium-Oxide sensor offers better performance.

GaAiAs diode sensors use a constant-current DC excitation of 10μA. The Model 24C limits low temperature operation to 25K since that is outside of the limits for use in magnetic fields.

Shaded entries are outside of the Model 24C's temperature range.

Lakeshore TG-120 GaAlAs Diode Name: User Supplied Configuration: Diode		
T(K)	**Volts**	**mV/K**
1.4	5.3909	-97.5
4.2	4.7651	-214
10	3.7521	-148
20	2.5341	-97.5
30	1.8056	-48.2
50	1.4637	-2.82
77.35	1.4222	-1.24
100	1.3918	-1.48
150	1.2985	-2.25
200	1.1738	-2.64
250	1.0383	-2.77
300	0.8978	-2.85
350	0.7531	-2.99
400	0.6066	-2.97
450	0.4556	-3.08
475	0.3778	-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 Model 24C uses 1.0mA Constant-Current AC excitation.

Platinum RTD, DIN43760 and IEC751 Name: Pt100 385 Configuration: PTC100 Name: Pt1K 385 Configuration: PTC1K Name: Pt10K 385 Configuration: PTC10K		
T(K)	**Ohms**	**Ω/K**
20	2.2913	0.085
30	3.6596	0.191
50	9.3865	0.360
77.35	20.380	0.423
100	29.989	0.423
150	50.788	0.409
200	71.011	0.400
250	90.845	0.393
300	110.354	0.387
400	148.640	0.383
500	185.668	0.378
600	221.535	0.372
700	256.243	0.366
800	289.789	0.360
900	324.302	0.318
1123	390.47	0.293

Rhodium-Iron

Rhodium-Iron sensors feature high stability, low magnetic field dependence and reasonable interchangeability.

The Model 24C 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 Model 24C supports Cernox™ using a 1.0mV or less Constant-Voltage AC excitation. This extends low temperature operation to 100mK. Please refer to the section titled "Selecting a Voltage Bias for NTC Sensors"

Lakeshore Cernox™ CX-1010 Name: User Supplied Config: ACR 1.0mV		
T(K)	**Ohms**	**Ω/K**
0.1	21389	-558110
0.2	4401.6	-38756
0.3	2322.4	-10788
0.4	1604.7	-4765.9
0.5	1248.2	-2665.2
1	662.43	-514.88
1.4	518.97	-251.77
2	413.26	-124.05
3	328.95	-58.036
4.2	277.32	-32.209
6	234.44	-17.816
10	187.11	-8.063
20	138.79	-3.057
30	115.38	-1.819
40	100.32	-1.252
50	89.551	-0.929
77.35	70.837	-0.510
100	61.180	-0.358
150	47.782	-0.202
200	39.666	-0.130
250	34.236	-0.090
300	30.392	-0.065

Lakeshore Cernox™ CX-1030 Name: User Supplied Config: ACR 10mV		
T(K)	**Ohms**	**Ω/K**
0.3	31312	-357490
0.4	13507	-89651
0.5	7855.7	-34613
1	2355.1	-3265.2
1.4	1540.1	-1264.9
2	1058.4	-509.26
3	740.78	-199.11
4.2	574.20	-97.344
6	451.41	-48.174
10	331.67	-19.042
20	225.19	-6.258
30	179.12	-3.453
40	151.29	-2.249
50	132.34	-1.601
77.35	101.16	-0.820
100	85.940	-0.552
150	65.864	-0.295
200	54.228	-0.184
250	46.664	-0.124
300	41.420	-0.088
350	37.621	-0.065
400	34.779	-0.050
420	33.839	-0.045

Lakeshore Cernox™ CX-1050 Name: User Supplied Config: ACR 10mV		
T(K)	**Ohms**	**Ω/K**
1.4	26566	-48449
2	11844	-11916
3	5733.4	-3042.4
4.2	3507.2	-1120.8
6	2252.9	-432.14
10	1313.5	-128.58
20	692.81	-30.871
30	482.88	-14.373
40	373.11	-8.392
50	305.19	-5.507
77.35	205.67	-2.412
100	162.81	-1.488
150	112.05	-0.693
200	85.800	-0.397
250	69.931	-0.253
300	59.467	-0.173
350	52.142	-0.124
400	46.782	-0.093
420	45.030	-0.089

Lakeshore Cernox™ CX-1070 Name: User Supplied Config: ACR 100mV		
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 100mV		
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

Cryo-con R500

The R500 Ruthenium-Oxide temperature sensor is designed primarily for ultra-low temperature operation. Features include interchangeability and operation in high magnetic fields.

The Model 24C will support the R500 down to <200mK. Please refer to the section titled "Selecting a Voltage Bias for NTC Sensors"

Cryo-Con R500 Ruthenium-Oxide Name: Cryocon R500 Config: ACR 1.0V		
T(K)	**Ohms**	**Ω/K**
0.05	29072	-628083
0.1	13114	-145658
0.2	6996	-30943
0.3	5053	-13345
0.5	3503	-4760
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

Cryo-con R400

The R400 Ruthenium-Oxide temperature sensor is designed for operation between 2.0K and 273K with high sensitivity below 40K. They feature interchangeability and operation in high magnetic fields.

Applications include low temperature superconducting magnet systems and liquid helium systems.

Using the NTC10uA input configuration will operate with the R400 over it's full temperature range.

Cryo-Con R400 Ruthenium-Oxide Name: Cryocon R400 Config: NTC10uA		
T(K)	Ohms	Ω/K
2	239556	-17787
3	221769	-13961
4	207807	-11343
6	187171	-7647
10	163317	-3907
20	138709	-1400
30	128199	-745
40	122128	-474
100	108595	-108
200	102432	-34
273	100604	-0.05

Scientific Instruments RO-600 Name: SI RO-600 Config: ACR 1.0mV		
T(K)	Ohms	Ω/K
0.05	29072	-628083
0.1	13114	-145658
0.2	6996	-30943
0.3	5053	-13345
0.5	3503	-4760
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

Scientific Instruments RO-105 Name: SI RO-105 Config: NTC10uA		
T(K)	Ohms	Ω/K
2	239556	-17787
3	221769	-13961
4	207807	-11343
6	187171	-7647
10	163317	-3907
20	138709	-1400
30	128199	-745
40	122128	-474
100	108595	-108
200	102432	-34
273	100604	-0.05

Thermocouples

An external thermocouple module is required.

Thermocouple Type E Name: TC type E Config: TC70		
K	**µV**	**µV/K**
3.2	-9834.9	1.59
4.2	-9833	2.09
10	-9813.3	4.66
20	-9747	8.51
30	-9643.8	12.1
40	-9505.5	15.5
50	-9334.2	18.7
75	-8777.7	25.6
100	-8063.4	31.4
150	-6238.1	41.2
200	-3967.4	49.3
250	-1328.7	56
273.15	0	58.5
300	1608	61.1
350	4777.7	65.6
400	8159.8	69.6
500	15426	75.3
600	23138	78.6
670	28694	80
700	31100	80.4
800	39179	81
900	47256	80.4
1000	55247	79.3
1100	63119	78.1
1200	70842	76.3
1270	76136	75.2

Thermocouple Type K Name: TC type K Config: TC70		
K	**µV**	**µV/K**
3.2	-6457.7	0.74
4.2	-6456.9	0.92
10	-6448.5	2.01
10.5	-6447.4	2.12
20	-6417.8	4.15
30	-6365.1	6.39
40	-6290	8.61
50	-6193.3	10.7
75	-5862.9	15.6
100	-5417.6	19.9
150	-4225.5	27.5
200	-2692.8	33.5
250	-897.6	38
273.15	0	39.4
300	1075.3	40.6
350	3135.8	41.5
400	5200	40.8
500	9215.6	40.3
600	13325	41.7
670	16264	42.2
700	17533	42.4
800	21789	42.6
900	26045	42.4
1000	30251	41.7
1100	34373	40.7
1200	38396	39.7
1270	41153	39
1300	42318	38.7
1400	46131	37.5
1500	49813	36.1
1600	53343	34.5
1640	54712	34

Thermocouple Type T
Name: TC type T **Config: TC70**

K	µV	µV/K
3.2	-6257.5	1.03
4.2	-6256.2	1.4
10	-6242.9	3.12
20	-6199.2	5.58
30	-6131.3	7.99
40	-6040	10.2
50	-5927.7	12.2
75	-5573.6	16
100	-5131.2	19.4
150	-4004.3	25.6
200	-2575.3	31.4
250	-872.57	38
273.15	0	39.4
300	1067.4	40.8
350	3215.5	45
400	5560.2	48.7
500	10735	54.6
600	16437	59.2
670	20677	61.7

Thermocouple Type Chromel-AuFe(0.07%)
Name: AuFe 0.07% **Config: TC70**

K	µV	µV/K
1.2	-5299.6	8.98
2	-5292	10.1
3.2	-5278.9	11.6
4.2	-5266.8	12.6
10	-5181.8	16
20	-5014	17
30	-4846.4	16.6
40	-4681.5	16.5
50	-4515.8	16.7
75	-4084.6	17.8
100	-3627	18.8
150	-2645.2	20.4
200	-1600.1	21.4
250	-512.81	22
300	597.44	22.4
350	1696.3	21.8
400	2805.7	22.7
500	5135.3	23.4
600	7470.7	23.4

Appendix H: Rear Panel Connections

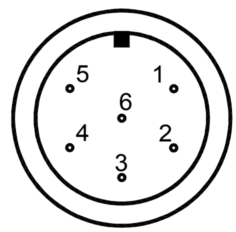
Sensor Connections

All sensor connections are made at the rear panel of the Model 24C using the two DIN-6 receptacles provided.

Silicon diode and all resistor type sensors should be connected to the Model 24C using the four-wire method. It is strongly recommended that sensors be connected using shielded, twisted pair wire. Wires are connected as shown below and the shield should be connected to the metal back-shell of the connector.

Pin	Function
1	Excitation (-), I-
2	Sense (-), V-
3	Aux Power: +5VDC @ 500mA
4	Sense (+), V+
5	Excitation (+), I+
6	Not Connected

Table 37: Input Connector Pin-out



Rear View

Caution: To ensure proper low noise operation, cable shields should be connected to the metal back-shell of the connector. A metal clip is provided with the connector for this purpose. Please refer to the section on shielding and grounding for further information.

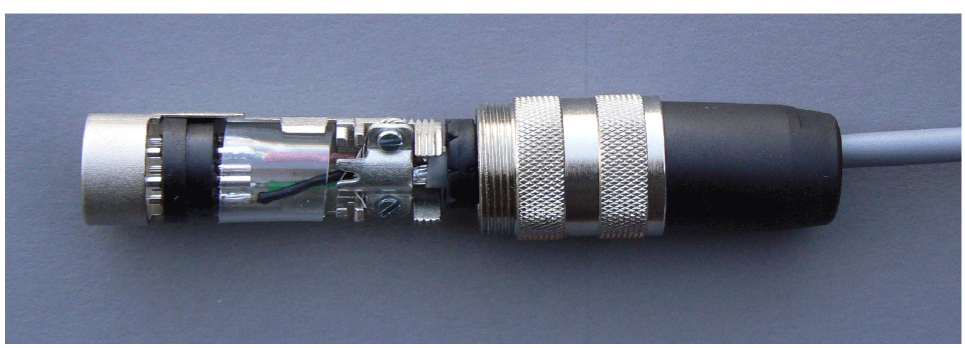


Figure 5: Proper Assembly of the Input Connector

Caution: Any disconnected inputs to the Model 24C should be configured to a sensor type of 'None'. This will turn the input off and prevent the high-impedance preamplifiers from drifting into a latch-up state.

ⓘ **Note:** The input connectors on the Model 24C will mate with either DIN-5 or DIN-6 plugs. Wiring is identical. If a DIN-6 plug is used, Pin 6 is not connected. Do not connect to pin 3 of either connector.

Recommended color codes for a sensor cable are as follows:

Color Code	Signal	Pin
White	Excitation(+)	5
Green	Excitation(-)	1
Red	Sense(+)	4
Black	Sense(-)	2

Table 38: Sensor Cable Color Codes

The cable used is Belden 8723. This is a dual twisted pair cable with individual shields and a drain wire. The shields and drain wire are connected to the connector's metal backshell in order to complete the shielding connection.

A four-wire connection is recommended in order to eliminate errors due to lead resistance. Cryogenic applications often use fine wires made from specialty metals that have low heat conduction. This results in high electrical resistance and, therefore, large measurement errors if the four-wire scheme is not used.

Four-wire connection to diode and resistive type sensors is diagrammed below:

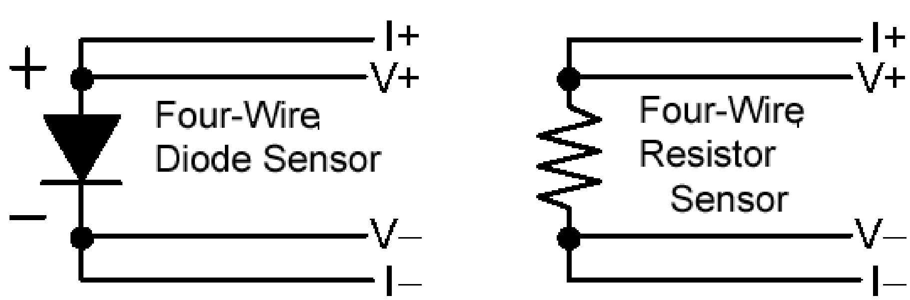
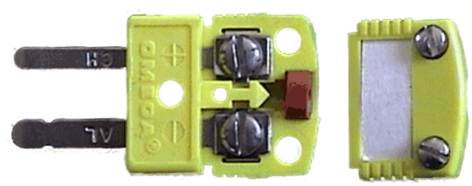


Figure 6: Diode and Resistor Sensor Connections

Thermocouple connections

Thermocouple sensors require the use of an external thermocouple module option. All thermocouple connections must be made at the module's input connector since this connector is thermally anchored to an internal sensor that is used for Cold Junction compensation.

Sensor connection is made at the screw terminals. Proper polarity of the sensor wires is required. Polarity is marked on the input connector and a summary of common thermocouple polarities is given in the table below. The input connector should have its plastic back-shell and rubber grommet installed in order to prevent local air currents from generating errors in the cold junction circuitry.



It is recommended that the thermocouple sensor be electrically isolated, or floating, from any surrounding circuits or grounds. This will ensure the highest possible measurement accuracy.

Additional discussion on thermocouple and grounding issues can be found below in the “Using Thermocouple Sensors” section below.

Type	(+) Terminal	(-)Terminal
E	Chrome, Purple	Constantan, Red
K	Chrome, Yellow	Aluminum, Red
T	Copper, Blue	Constantan, Red
Chromel-AuFe	Chromel, Silver	Gold, Gold

Table 39: Thermocouple Polarities

Control Loop #1 Connections

Connection to the heater output is made on the rear panel using the shielded 3-pin circular DIN connector provided.

Caution: The Model 24C has an automatic control-on-power-up feature. If enabled, the controller will automatically begin controlling temperature whenever AC power is applied. For a complete description of this function, please see the Auto-Ctl function in the **System Functions menu** section.

Rear panel Primary Heater Output (Loop #1) connections are made using a three-pin banana-plug on the rear panel.

Pin	Function
Hi	Heater Output High
Lo	Heater Output Low
EGND	Earth-Ground

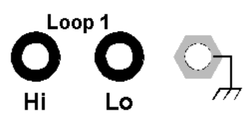


Table 40: Loop 1 Connections

Control Loop #2 and Relay Connections

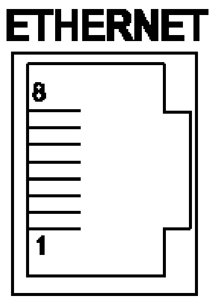
Connection to the Loop #2 Output is made on the rear panel using the 10-pin detachable terminal block provided.

Pin	Function
1	Loop #2 Heater Output High
2	Loop #2 Heater Output Low
3	Relay #1 N.O.
4	Relay #1 Common.
5	Relay #2 N.O.
6	Relay #2 Common.
7	Loop #3 output High
8	Loop #3 output Low
9	Loop #4 output High
10	Loop #4 output Low

Table 41: Loop #2 and Digital Output Connections

Ethernet (LAN) Connection

The 10/100-BaseT Ethernet network (RJ-45) system is used by the Model 24C for Ethernet network connectivity. The 10/100 Mbps twisted-pair Ethernet system operates over two pairs of wires. One pair is used for receiving data signals and the other pair is used for transmitting data signals. This means that four pins of the eight-pin connector are used.



Pin	Name	Description
1	+Tx	+ Transmit Data
2	-Tx	- Transmit Data
3	+RX	+ Receive Data
4	N/C	Not Connected
5	N/C	Not Connected
6	-Rx	- Receive Data
7	N/C	Not Connected
8	N/C	Not Connected

Figure 7: LAN RJ-45 Pinout

10/100-BaseT Straight Through (Patch) Cable

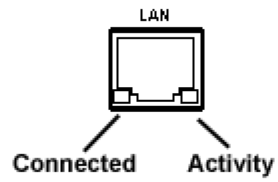
When connecting the Model 24C to a hub or switch, a standard Category 5 'patch' cable is used. This connects the instrument's transmit lines to the hub's receive lines etc.

10/100-BaseT Crossover Cable

When connecting the Model 24C directly to the computer, the transmit data pins of the computer should be wired to the receive data pins of the Model 24C, and vice a verse. The 10/100-BaseT **crossover cable** should be used for this purpose. A crossover cable is usually a different color than the straight through patch cable.

Ethernet (LAN) Connector LEDs

The RJ-45 LAN connector on the rear panel of the Model 24C has two green LEDs. The left most LED indicates that a valid connection has been made to a hub or computer.



If the LAN is plugged in and the 'Connected' LED is not on, there is a problem that must be addressed before you can communicate with the instrument. Possible problems are:

1. Using the wrong type of cable. For example, using a Crossover Cable to connect the Model 24C to a hub instead of a computer. See the sections above.
2. Connection to the wrong type of hub. The hub must be capable of accepting 10-BaseT connections. Some older hubs do not support this.

The right most LED indicates activity on the LAN. It should flicker periodically during normal operation.

IEEE-488.2 Connections

The optional IEEE-488.2 (GPIB) connection is installed by connecting the dongle to the Ethernet port using the crossover LAN cable provided. The interface will be configured by the instrument and will appear to your system as a standard IEEE-488.2 device.

RS-232 Connections

The Model 24C uses a Female DB-9 connector for RS-232 serial communications. The pin-out of this connector is as follows:

Pin	Function	Pin	Function
1	NC	6	NC
2	RXD, Receive data	7	NC
3	TXD, Transmit data	8	NC
4	NC	9	NC
5	Ground		

Table 42: RS-232 DB-9 Connector Pinout

The cable used to connect the Model 24C to a computer serial port is a Dual Female Null Modem cable. An example is Digikey Inc. part number AE1033-ND.

The wiring diagram for this cable is shown below. Note that communication with the Model 24C only requires connection of pins 2, 3 and 5. All other connections are optional.

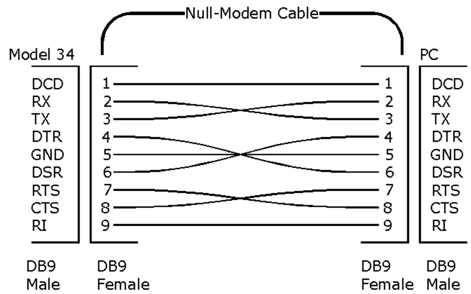


Figure 8: RS-232 Null Modem Cable

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