User's Guide

Model 34

Cryogenic Temperature Controller

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Certification

Cryogenic Control Systems, Inc. (Cryo-con) certifies that this product met its published specifications at the time of shipment. Cryo-con further certifies that its calibration measurements are traceable to the United States National Institute of Standards and Technology (NIST).

Warranty

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

For products returned to Cryo-con for warranty service, the Buyer shall prepay shipping charges and Cryo-con shall pay shipping charges to return the product to the Buyer.

However, the Buyer shall pay all shipping charges, duties, and taxes for products returned to Cryo-con from another country.

Warranty Service

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

Limitation of Warranty

The foregoing warranty shall not apply to defects resulting from improper or inadequate maintenance by the Buyer, Buyer supplied products or interfacing, unauthorized modification or misuse, operation outside of the environmental specifications for the product, or improper site preparation or maintenance.

The design and implementation of any circuit on this product is the sole responsibility of the Buyer. Cryo-con does not warrant the Buyer's circuitry or malfunctions of this product that result from the Buyer's circuitry.

In addition Cryo-con does not warrant any damage that occurs as a result of the Buyer's circuit or any defects that result from Buyer-supplied products.

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Safety

The Model 34 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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Preparing the controller for use.

The Model 34 is a cryogenic temperature controller that is intended for use in a laboratory environment.

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

Supplied Items.

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

- Model 34 Cryogenic Temperature Controller.
- This User's Manual (3034-029).
- Cryo-con software CD (4034-029).
- Two dual input connector/cable assemblies (4034-038).
- Connector kit consisting of:
    - Loop 1 Heater connector (2-pin Terminal block plug, 04-0301).
    - Loop 2 Analog Output connector
      (2-pin Terminal block plug, 04-0303).
    - Relay connector (6-pin terminal block plug, 04-0302).
- Heater connector, 2-pin Terminal block plug, 04-0301.
- Dual sensor input connector/cable assembly, 4034-038.
- RS-232 Null Modem cable (04-0420).
- Detachable 120VAC Line Cord (04-0310).
- 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 220 VAC setting. Input frequency range is 50 to 60 Hz.

On the rear panel of the instrument, the AC voltage selection can be seen 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 0.5 Seconds. The front panel will show a Power Up display with the model number and firmware revision.

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

```
NVRAM: Valid
RAM: Pass

Firmware Rev. 4.19B

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    Systems, Inc. 2006
```

☞ **NOTE:** 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, batteries or battery-backed memories.

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

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

Installation

General

The Model 34 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.

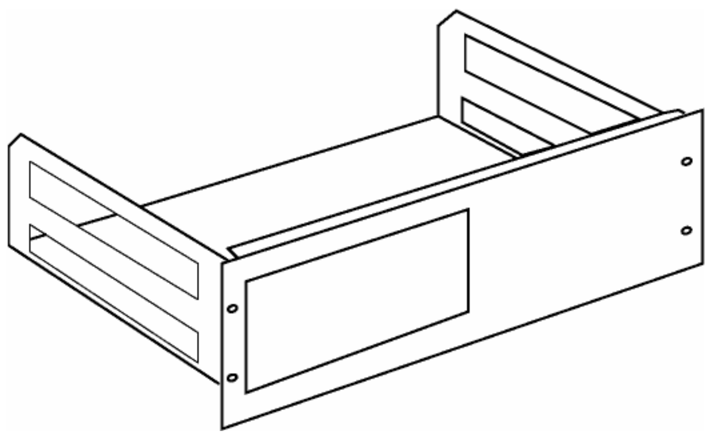
Cooling airflow enters through the side holes and exhausts out the fan on the rear panel. It is important to allow at least ½" of clearance on the left and right sides and to ensure that the exhaust path of the fan is not blocked.

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, you can mount any similar size instrument next to it in the rack.



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 used.

> ☞ **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 Control Loop Setup menu section.

2. The Loop #1 heater range should be set to a range where the maximum output power will not damage your equipment. To set this parameter, press the **Loop 1** key and refer to the Control Loop Setup 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 **Sys** 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.

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

```
ChA: Input Channel A
 ........K
ChB: Input Channel B
 --------K
HTR: ---OFF---   50W
HTR: Stpt: 305.000K
```

Input Channel factory defaults are:

Sensor Units: Kelvin.
Sensor Type: Lakeshore 11 (Lakeshore DT-670 Curve 11 Silicon Diode)
Bias Type: DC
Alarm Enables: Off

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

Output Channel factory defaults are:

Set Point: 100K
P gain: 0.1, I gain: 5.0 Seconds, D gain: 0.0, Manual output power, Pman: 5%
Control input channel: A for Loop 1, B for Loop 2
Loop 1 Range: Low
Control mode: Manual
Heater Resistance: 50Ω

To change these, press the Loop 1 or Loop 2 key and refer to the Control Loop Setup menu section.

Instrument setup factory defaults are:

Display Filter Time Constant: 2.0 Seconds. Display Resolution: 3 digits.
Over Temperature Disconnect: Off
Remote Interface: RS-232, RS-232 Baud Rate: 9600.
IEEE-488 (GPIB) Address: 12
AC Power Line Frequency: 60Hz
Cryocooler Filter: Off

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

Technical Assistance.

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

Technical assistance may be also be obtained by contacting Cryo-con as follows:

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

Telephone: 858 756-3900 FAX: 858 759-3515
e-mail: support@cryocon.com.

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

Returning Equipment

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

When requesting an RMA, please provide the following information:

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

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

Cryo-con's shipping address is:

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

Introduction

A Quick Start Guide to the User Interface.

The Model 34 Cryogenic Temperature controller's innovative user interface consists of a large, graphics type LCD display, a selector knob and a keypad. All features and functions of the instrument can be accessed via this simple and intuitive menu driven interface.

At the root of the instrument's menu tree is the basic Operate Display. This consists of four independent, user configurable zones. Therefore, displays can be configured that show only the desired information, without unnecessary clutter.

Navigation through the various fields of the Operate Display is accomplished by rotating the selector knob. Clockwise rotation increments through the various fields whereas counter-clockwise rotation decrements. The current zone is indicated by reverse video in the first character positions of the zone. Pressing the knob results in selection of the current zone and will be indicated by the entire line being displayed in reverse video.

Configuration of the Operate Display is easily performed by selecting a zone using the selector knob. While selected, rotation of the knob will scroll the selected zone through all of the options available for that field.

To instantly access the current heater set point from the Operate Display, press the **Enter** key. This is a shortcut that will take the display directly to the Heater Setup Menu. From this menu, either the **Home** or the **ESC** key may be pressed in order to return to the Operate Display.

Pressing the **STOP** key from any displayed menu will immediately disengage both control loops, pressing the **CONTROL** key will engage them. In either case, the displayed menu will not change, except to reflect the current heater state.

Pressing the **SETUP** key will take the controller directly to the top of the instrument's setup and configuration menu tree. Pressing the **HOME** button will return the screen to the Operate Display.

Pressing the **POWER** key will toggle the controller's AC power on and off.

There are three LED indicators on the left hand side of the instrument. The CONTROL LED indicates the status of the control loops, being illuminated when the heaters are on. The ALARM LED is illuminated whenever a user programmed alarm event is asserted. The REMOTE LED is illuminated whenever a remote interface command has been received that locks out the keypad.

Specifications and Primary Features

Specification Summary

User Interface

Display Type*:* Eight line by 21 character graphics-type LCD display.
Number of Inputs Displayed: Four.
Keypad*:* Sealed Silicon Rubber plus selector knob.
Temperature Display*:* Six significant digits, autoranged.
Display Update Rate: 0.5 Seconds.
Display Units: K, C, F or native sensor units (Volts or Ohms).
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 using two DB-9 receptacles. Connections are described in the "Sensor Connections" section.
Supported Sensors*:* See Supported Sensors table below.
Sensor Selection*:* Front Panel or remote interface. There are no internal jumpers or switches.
Sensor Resolution*:* Sensor Dependent. See Sensor Performance Data table.
Sensor Excitation*:* Constant current: 1mA, 100µA or 10µA.
Resistance Measurement type: Ratiometric bridge.
Sample Rate*:* 10Hz per channel in all measurement modes.
Measurement Resolution*:* Sensor Dependent. See Sensor Performance Data table.
Digital Resolution*:* 24 bits.
Measurement Drift*:* <15ppm/°C.
Measurement Filter: 0.5, 1, 2, 4, 8, 16, 32 and 64 Seconds.
Calibration Curves*:* Built-in curves for industry standard sensors plus twelve user curves with up to 200 entries each. Interpolation is performed using a Cubic Spline. A list of factory installed sensors is given in Appendix A.
CalGen®: Calibration curve generator fits any Diode, Thermocouple or resistor sensor curve at 1, 2 or 3 user specified temperature points.
Thermocouples: Most types supported via optional Thermocouple connector kit..
Cold Junction compensation*:* internal, enable/disable.

Control Outputs

Number of Loops: Two.
Control Input: Either sensor input.
Loop Update Rate: 10Hz per loop.
Control Type: PID table, Enhanced PID, Ramp or Manual.
Autotune: Minimum bandwidth PID loop design.
PID Tables: Six user PID tables available for storage of Set-point vs. PID and heater range. Up to 16 entries/table.
Set-point Accuracy: Six+ significant digits.
Fault Monitors: Control loops are disconnected upon detection of a control sensor fault or excessive internal temperature.
Over Temperature Disconnect: Heater may be relay disconnected from user equipment when a specified temperature is exceeded on any selected input.

Loop #1 Primary Heater Output

Type*:* Short circuit protected linear current source. Maximum compliance is 50V.
Connection: Two-pin, 5mm detachable terminal block.
Ranges*:* Four output ranges of 1.0A, 0.33A, 0.10A and 33mA corresponding to 50W, 5.0W, 0.5W and 0.05W 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*:* 0.0015% of full-scale range + signal dither.
Readback*:* Heater output power, Heatsink temperature.

Loop #2 Secondary Heater Output

The analog output channel may be used as an independent second control loop or as a scaled linear output.

Type*:* Short circuit protected linear 20mA current source with a compliance of 20V. May be connected directly to 20mA current loop process control devices.
Connection: Two-pin, 3.5mm detachable terminal block.
Load Resistance*:* 100Ω minimum.
Digital Resolution*:* 0.0015% of full-scale range.

Status Outputs

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

Remote Interfaces
Remote interfaces are electrically isolated to prevent ground loops.

RS-232: Serial port is an RS-232 standard null modem. Rates are 300, 1200, 4800, 9600, 19,200 and 38,400 Baud.
IEEE-488 (GPIB): Full IEEE-488.2 compliant.
Language: Remote interface language is IEEE SCPI compliant. National Instruments LabVIEW™ drivers available for all interfaces.

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

Firmware
Internal firmware and all data tables are maintained in FLASH type memory and may be upgraded via the remote interface ports. Instrument firmware updates are available on the Internet.

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 Extrusion. Machined Aluminum front and rear panels.
Power Requirement: 100, 120, 220 or 240VAC +5% -10%.
50 or 60Hz, 150VA.

Input Channels

There are four independent multi-purpose input channels, each of which can be configured to use any supported sensor.

Sensor type is selected by the user via the microprocessor. Values of excitation current, voltage gain etc. will be determined by the microprocessor and used to automatically configure the channel. There are no jumpers or optional cards required to configure the various sensors.

Resistance measurements made by the Model 34 are performed using a Ratiometric bridge technique. Here, the actual measurement is made as the ratio between the sensor resistance and an internal calibration standard resistance. This effectively cancels the DC drift and electronic noise associated with the internal voltage reference and associated circuitry.

Supported Sensor Types

A complete list of the sensor types supported by the Model 34 is shown below:

Sensor Type	Max. Voltage/ Resistance	Excitation Current	Typical Use
Diode	2.5V	10µA	Silicon Diode, All types.
R62K10UA	62.5KΩ	10µA	PT 10K / NTC Resistors.
R31K10UA	31.3KΩ	10µA	PT 10K / NTC Resistors.
R16K10UA	16KΩ	10µA	PTC/NTC Resistors.
R8K10UA	8KΩ	10µA	PTC/NTC Resistors.
R25K100UA	25KΩ	100µA	PTC/NTC Resistors.
R12K100UA	12.5KΩ	100µA	Platinum 1,000
R6K100UA	6.25KΩ	100µA	Platinum 1,000
R3K100UA	2KΩ	100µA	Platinum 1,000
R625R1MA	625Ω	1.0mA	Pt 100 > 800K.
R312R1MA	312Ω	1.0mA	Pt 100 < 800K.
R156R1MA	156Ω	1.0mA	RhFe
TC80	78mV	0	80mV Thermocouple
TC40	39mV	0	40mV Thermocouple

Table 1: Supported Sensor Types

For a list of factory installed sensors, see Appendix A. Additional devices can be added using the Sensor Setup procedure.

Silicon Diode Sensors
Silicon Diode sensors (2-volt diodes) are configured with a 10µA current source excitation and a two volt unipolar input voltage range.

Gallium-Arsenide Sensors
Gallium-Arsenide Diodes, or 6-Volt Diodes, can be used down to a minimum temperature of about 20K. This limitation is imposed by the fact that the controller's maximum input voltage is 2.5 Volts.

PTC Resistor Sensor Devices (RTDs)
The Model 34 supports all types of Positive-Temperature-Coefficient (PTC) resistive sensors. Various combinations of excitation current and full-scale input voltage allow the user to trade off accuracy vs. sensor self heating.

The Supported Sensors table above gives a complete list of combinations that can be selected.

Standard calibration curves are provided for DIN43760 and IEC751 Platinum sensors. While these curves are based on a 100Ω sensor, they may easily be extended to other resistance values by using the Multiplier field of the sensor setup.

NTC Resistor Sensor Devices
The Model 34 also supports almost all types of Negative-Temperature-Coefficient (NTC) resistive sensors. A minimum constant-current excitation of 10µA may limit the low temperature range of these sensors because of self-heating.

Examples of NTC resistor sensors include: Ruthenium-Oxide, Cernox™, Germanium, Carbon Glass™ and Thermistors.

Calibration tables may be entered either directly in Ohms or in (base 10) Log of Ohms.

Sensor Type	Silicon Diode	100Ω Platinum DIN43760	1000Ω Platinum
Sensor Sensitivity	300K: 2.4mV/K 77K: 1.9mV/K 4.2K: 30mV/K	800K: 0.36Ω/K 300K: 0.39Ω/K 77K: 0.42Ω/K 30K: 0.19Ω/K	600K: 3.7Ω/K 300K: 3.9Ω/K 77K: 4.2Ω/K 30K: 1.9Ω/K
Measurement Accuracy	300K: 21µV 77K: 23µV 4.2K: 44µV	800K: 2.4mΩ 300K: 2.4mΩ 77K: 1.2mΩ 30K: 1.2mΩ	600K: 38mΩ 300K: 38mΩ 77K: 4.7mΩ 30K: 4.7mΩ
Temperature Measurement Accuracy	300K: 8.7mK 77K: 12mK 4.2K: 1.6mK	800K: 6.7mK 300K: 6.2mK 77K: 2.8mK 30K: 6.3mK	600K: 10mK 300K: 10mK 77K: 1.1mK 30K: 2.5mK
Measurement Resolution	300K: 7.4µV 77K: 7.4µV 4.2K: 15µV	800K: 1.8mΩ 300K: 1.8mΩ 77K: 460µΩ 30K: 460µΩ	600K: 15mΩ 300K: 15mΩ 77K: 1.8mΩ 30K: 1.8mΩ
Temperature Resolution	300K: 3.0mK 77K: 3.8mK 4.2K: 500µK	800K: 5.1mK 300K: 4.7mK 77K: 1.1mK 30K: 2.4mK	600K: 4mK 300K: 4mK 77K: 0.5mK 30K: 1.0mK
Control Stability	300K: 3.0mK 77K: 3.8mK 4.2K: 500µK	800K: 5.1mK 300K: 4.7mK 77K: 1.1mK 30K: 2.4mK	600K: 4mK 300K: 4mK 77K: 0.5mK 30K: 1.0mK
Power Dissipation	4.2K: 17µW 77K: 12µW	30K: 3.7µW 77K: 20µW	30K: 37µW 77K: 200µW
Magneto-resistance	Very Large	Moderate	Moderate

Table 2: Sensor Performance, Diodes and Pt Sensors.

Sensor Type	Ruthenium Oxide	Carbon Glass™	Cernox™
Sensor Sensitivity	2.0K: 358Ω/K 4.2K: 80.3Ω/K 20K: 4.1Ω/K	4.2K: 422Ω/K 77K: 0.1Ω/K 300K: 0.01Ω/K	4.2K: 2290Ω/K 77K: 2.15Ω/K 300K: 0.13Ω/K
Measurement Accuracy	2.0K: 29mΩ 4.2K: 29mΩ 20K: 29mΩ	4.2K: 30mΩ 77K: 0.3mΩ 300K: 0.3mΩ	4.2K: 117mΩ 77K: 5mΩ 300K: 1.2mΩ
Temperature Measurement Accuracy	2.0K: 0.1mK 4.2K: 0.4mK 20K: 7.4mK	4.2K: 0.07mK 77K: 3mK 300K: 31mK	4.2K: 0.1mK 77K: 22mK 300K: 9mK
Measurement Resolution	2.0K: 11mΩ 4.2K: 11mΩ 20K: 11mΩ	4.2K: 11mΩ 77K: 0.2mΩ 300K: 0.2mΩ	4.2K: 46mΩ 77K: 1.8mΩ 300K: 0.5mΩ
Temperature Resolution	2.0K: 32μK 4.2K: 0.13mK 20K: 2.9mK	4.2K: 30μK 77K: 1.2mK 300K: 12mK	4.2K: 50μK 77K: 0.85mK 300K: 3.5mK
Control Stability	2.0K: 32μK 4.2K: 0.13mK 20K: 2.9mK	4.2K: 80μK 77K: 1.2mK 300K: 12mK	4.2K: 80μK 77K: 0.85mK 300K: 3.5mK
Power Dissipation	2.0K: 172nW 4.2K: 137nW	4.2K: 58nW 77K: 14μW	4.2K: 513nW 77K: 161μW
Magneto-resistance	<2% for H<2T	Moderate	<1% for H<2T

Table 3: Sensor Performance: NTC sensors.

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

Type	Range	Sensor Excitation	TC	Units
Platinum, 100Ω, < 800K	R312R1MA	1.0mA	(+)	Ohms
Platinum, 100Ω, >800K	R625R1MA	1.0mA	(+)	Ohms
Platinum, 1000Ω	R6K100UA	100µA	(+)	Ohms
Platinum, 10KΩ <425	R16K10UA	10µA	(+)	Ohms
Carbon Glass™*	R8K10UA	10µA	(-)	LogOhms
Germanium*	R8K10UA	10µA	(-)	LogOhms
Cernox™*	R8K10UA	10µA	(-)	LogOhms
Ruthenium Oxide*	R8K10UA	10µA	(-)	LogOhms
Thermistors	R8K10UA	10µA	(-)	LogOhms

* Depends on specific sensor resistance

Table 4: Resistor Sensor Configuration

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 loop outputs are provided with protection circuits. The differential voltage between sensor inputs should not exceed ±40V.

Input Channel Statistics

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

Statistics are:

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

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

CalGen™ Calibration Curve Generator

The CalGen™ feature 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.

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 Model 34 utilities software.

Adaptive Cryocooler Correction

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 an amplitude of one or more Kelvin.

The Model 34 uses digital adaptive filters to minimize the cooler’s signature, resulting in much higher control accuracy and loop responsiveness.

Output Channel Features

Control Loop #1, The 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 available. These are manually selected in PID or Manual control modes and automatically selected in the PID Table control mode. Ranges are dependent on load resistance and are as follows:

50 Watt Ranges	Compliance Voltage	Full Scale Current	Max. Output Power
50W	50 Volts	1.0A	50 Watts
5.0W	50 Volts	0.333A	5.0 Watts
0.5W	50 Volts	0.100A	0.50 Watts
0.05W	50 Volts	0.033A	0.05 Watts

Table 5: Loop 1 50 Watt Heater output ranges.

25 Watt Ranges	Compliance Voltage	Full Scale Current	Max. Output Power
25W	25 Volts	1.0A	25 Watts
2.5W	25 Volts	0.333A	2.5 Watts
0.25W	25 Volts	0.100A	0.25 Watts
0.03W	25 Volts	0.033A	0.025 Watts

Table 6: Loop 1 25 Watt Heater output ranges.

Care must be taken 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 only one half of the indicated heater power being dissipated 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 can be detected and their corresponding alarms asserted.

The temperature of the internal heater heat sink is continuously monitored used to generate over temperature fault conditions that will result in shut down of the control loop.

The absolute resolution of output heater current is 0.0015% of full scale (Sixteen bits). However, this resolution is significantly extended through the use of a dither signal that is applied to the Digital-to-Analog Converter and averaged by analog filtering in the output stage. The resulting output is an interpolation between the available quantization levels.

> ☞ **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, then multiply by the full-scale power.

Connection to the heater output is made on the rear panel using the terminal block provided on the rear panel.

Control Loop #2, The Analog Output

The analog output channel may be used as an independent second control loop, or as a scaled linear output. This is a short circuit protected linear 20mA current source with a compliance of 20V. It may be connected directly to 20mA current loop process control devices.

Absolute resolution of the Analog Output current is 0.0015% of full scale (Sixteen bits).

Connection to the Analog Output is made on the rear panel using the pluggable terminal block provided on the rear panel.

Relay Outputs

There are two auxiliary dry-contact relay outputs available on the rear panel. They may be independently asserted upon a high temperature, low temperature or sensor fault condition on any of the four input channels.

Both normally-open and normally-closed contacts are available at the rear panel. Contacts ratings are: 2 Amps @ 24VDC.

There is a 0.25K hysteresis built into the high and low temperature alarms.

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.

There is a 0.25K hysteresis built into the high and low temperature alarms.

Control Modes

There are four control modes available in the Model 34. They are Manual, PID, PID Table and Ramp. All modes are available on both the heater and the analog output channels.

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

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. Implementation of a user settable damping factor that can be used to minimize overshoot to a new set point without affecting the PID loop operation.
2. Noise filtering on the derivative term. The D term will provide better control stability, but is often not used because, without filtering, it can make the control loop too sensitive to noise.
3. Integrator wind up compensation. While slewing to a new set point, 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 set point can be delayed for an extremely long time. This is especially true in cryogenic environments where process time constants can be very long.
4. Dithering and filtering the outputs in order to increase output resolution and improve control stability.

The Table control mode is a PID control loop just as described above. However, it is used to look up P,I,D and heater range values based on the specified set point. 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 34 will control in Table mode by interpolating optimum PID values based on set point.

The Model 34 allows for the entry of four independent PID Tables. Each table may contain up to 16 temperature zones.

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

Remote Interfaces

Universal Serial Bus (USB), IEEE-488.2 and RS-232 interfaces are standard on the Model 34. All functions and read-outs available from the instrument may be completely controlled by any of these interfaces.

Universal Serial Bus is V1.1 compliant and implements the full speed 12Mbps protocol. Bi-directional Control, Interrupt and Bulk transfer modes are supported. Connection is made at the rear panel of the Model 34 using a USB type B connector.

> ☞ **NOTE:** The USB interface was discontinued on the Model 34 in January of 2005. Inexpensive USB-to-RS232 converters are available for users that require a USB interface. These devices are fully compatible with serial port software including LabView and add an important hardware handshake function to the RS232 connection.

The Serial port is an RS-232 standard null modem with male DB9 connector. Rates are 300, 1200, 4800, 9600, 19,200 and 38,400 Baud.

The GPIB is fully IEEE-488.2 compliant. Connection is made at the rear panel using the IEEE-488 standard connector.

The programming language used by the Model 34 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 Connections

The rear panel of the Model 34 is shown here:

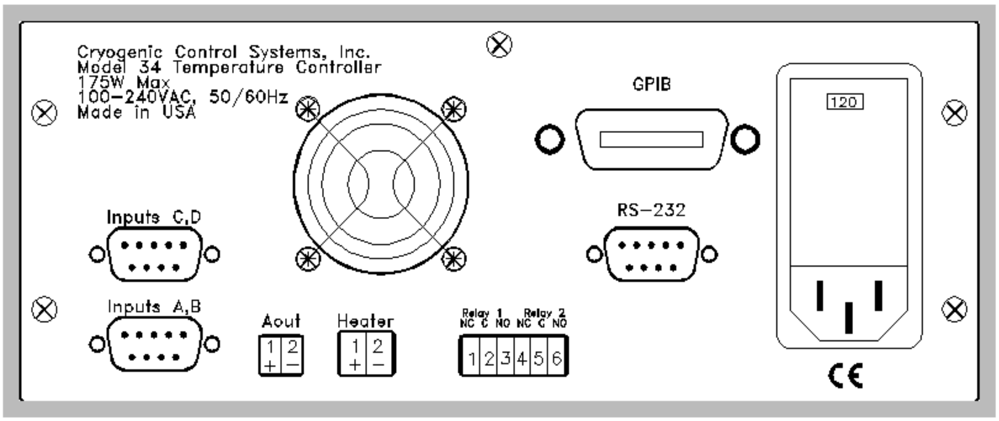


Figure 1: Model 34 Rear Panel Layout

Fuse Replacement / Voltage Selection

Access to the Model 34'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 made 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 Slow-Blow and 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 7. AC Power Line Fuses

Sensor Connections

All four sensor connections are made at the rear panel of the Model 34 using the two DB-9 receptacles provided. There are two channels on each connector.

Four Wire Sensor Connections

Silicon Diode and all resistor type sensors should be connected to the Model 34 using the four-wire method. It is strongly recommended that sensors be connected using shielded, twisted pair wire. Cable shields should be dressed for connection to the conductive backshell of the connector. Signal connection is as follows:

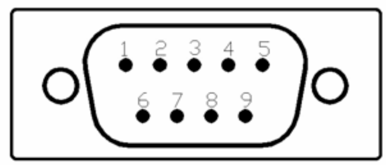


Figure 2: Input Connector

Input Channel	Connector	Signal	Pin
ChA	Lower	Current(+)	8
ChA	Lower	Current(-)	9
ChA	Lower	Sense(+)	4
ChA	Lower	Sense(-)	5
ChB	Lower	Current(+)	6
ChB	Lower	Current(-)	7
ChB	Lower	Sense(+)	1
ChB	Lower	Sense(-)	2
ChC	Upper	Current(+)	8
ChC	Upper	Current(-)	9
ChC	Upper	Sense(+)	4
ChC	Upper	Sense(-)	5
ChD	Upper	Current(+)	6
ChD	Upper	Current(-)	7
ChD	Upper	Sense(+)	1
ChD	Upper	Sense(-)	2

Table 8: Sensor Input Connector Pinout

Caution: To ensure proper low noise operation, cable shields should be connected to the metal backshell of the connector. Please refer to the section on shielding and grounding for further information.

Color codes for the Dual Sensor Cable (Cryo-con part number 4034-038) are as follows:

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

Table 9: Dual Sensor Cable Color Codes

The cable used is Belden 8723. This is a dual twisted pair cable with individual shields and a drain wire. The shields and drain wire are connected to the DB9 connector's metal backshell in order to complete the shielding connection.

Four wire connections to the sensor are shown here for Diode and Resistor sensors:

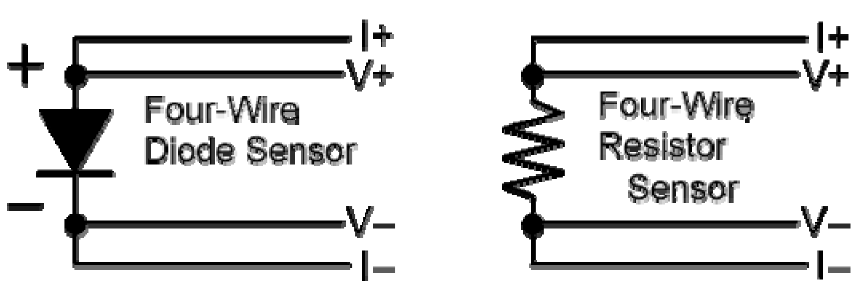


Figure 3: Sensor Connection

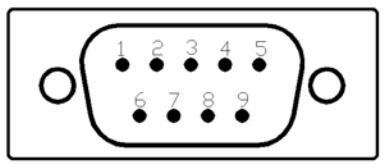
Thermocouple Sensor Connections

Thermocouple sensors require a two-wire connection to the Model 34. All thermocouple connections must be made at the sensor input connector since this connector is thermally anchored to an internal sensor that is used for Cold Junction compensation. The input connector should have a backshell installed in order to prevent local air currents from generating errors in the cold junction circuitry.

For information on the connection and use of Thermocouple sensors, please refer to the section below titled Using Thermocouple Sensors.

RS-232 Connections

The Model 34 uses a Female DB-9 connector for RS-232 serial communication. A Rear view of the connector, and it's pin-out are shown below.



Pin	Signal
1	NC
2	RXD, Receive data
3	TXD, Transmit data
4	NC
5	Ground
6	NC
7	NC
8	NC
9	NC

Table 10: RS-232 Connection

The cable used to connect the Model 34 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 34 only requires connection of pins 2, 3 and 5. All other connections are optional.

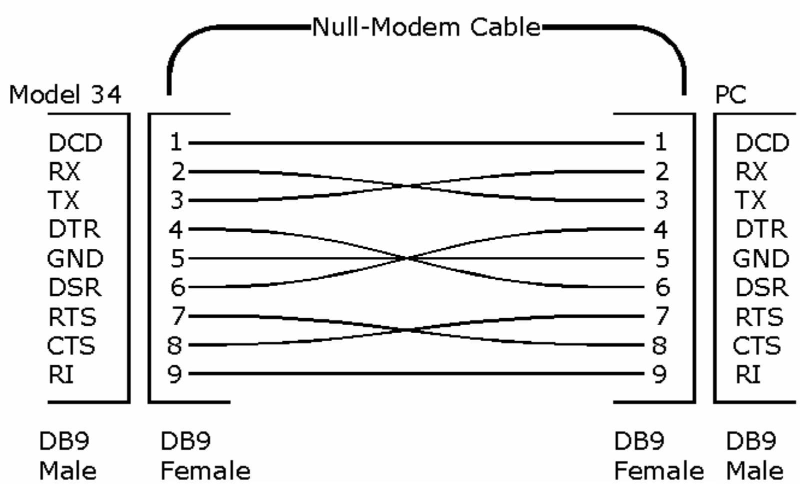


Figure 4: RS-232 Null Modem Cable

Relay Connections
Rear panel relay connections are made using the six pin pluggable 3.5mm terminal block provided. Pins are defined as follows.

Pin	Function
1	Relay 1 NC
2	Relay 1 Common
3	Relay 1 NO
4	Relay 2 NC
5	Relay 2 Common
6	Relay 2 NO

Table 11: Relay Connector Pinout

The six pin terminal block plug is a Weidmuller part number 161018. It is available from Digikey Inc. (281-1057-ND) or directly from Cryo-con (04-0302).

Analog Output Connections
Rear panel Analog Output connections are made using the two pin pluggable 3.5mm terminal block shown above. Pin One of this block (left hand pin) is the positive output and Pin Two is the return. The shield of the output cable may be connected to Pin Two.

The two pin terminal block plug is a Weidmuller part number 161567. It is available from Digikey Inc. (281-1054-ND) or Cryo-con (04-0303).

Heater Output Connections
Rear panel Heater Output connections are made using the two-pin pluggable 0.200" terminal block shown above. Pin One of this block (left hand pin) is the positive (+) output and Pin Two is the return (-). The shield of the output cable may be connected to Pin Two.

The two pin heater terminal block plug is an Augat part number 2ESDV-02. It is available from Cryo-con as part number 04-0301.

USB Connections
Connection to the Universal Serial Bus is made using a USB type A-B cable. This is a standard cable where the type A connector plugs into the host and the type B connector plugs into the Model 34.

USB A-B cables are available in various lengths. A 5' cable is available from Cryo-con, part number 11-0416.

IEEE-488.2 Connections
Rear panel connection to the IEEE-488.2 (GPIB) is performed using the GPIB connector.

GPIB cables are available in various lengths. However, this is an old style multi-signal bus where short cables will help ensure reliable communications.

Only shielded type assemblies should be used. Many of the molded GPIB cables are actually unshielded and can introduce excessive noise into your instrumentation environment. Examples of shielded GPIB cable assemblies are: Belden 49733 and Belden 49635.

AC Power

The Model 34 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.

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.

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.

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

Power requirement is 25 Watts plus the power being provided to the heater load.

The power cord will be a standard detachable 3-prong type.

User-replaceable fuses are incorporated in the Power Entry Module. See the section titled Fuse Replacement / Voltage Selection.

> ☞ **NOTE:** The Model 34 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.

Mechanical, Form Factors and Environmental

Display

The display is an eight line by twenty character dot-matrix LCD with sufficient back-lighting to allow a wide viewing angle. Temperature compensation circuitry is built in to allow high contrast displays over a wide range of ambient temperature.

Enclosure

The Model 34 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 10Lbs.

An instrument bail and feet are standard. Rack Mount kits are available for both single instrument or side-by-side dual configurations. Rack mount options are as follows:

4034-031	Side by side lock-link rack mount kit
4034-032	One or Two instrument shelf rack mount kit

Environmental and Safety Concerns.

<u>Safety</u>

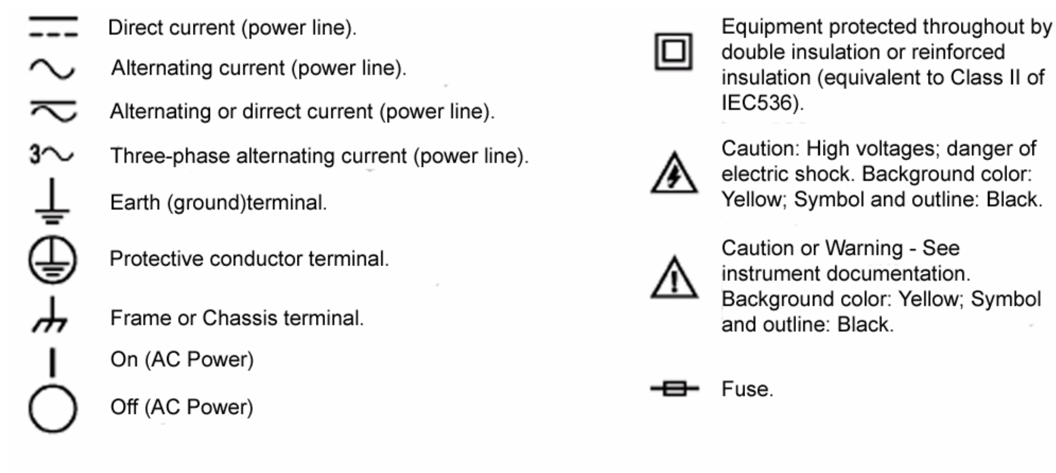
The Model 34 protects the operator and surrounding area from electric shock or burn, mechanical hazards, excessive temperature, and spread of fire from the instrument.

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

- Cleaning: Do not submerge instrument. Clean exterior only with a damp cloth and mild detergent only.

- 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).
3	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.

The User Interface

The user interface of the Model 34 Cryogenic Temperature Controller consists of an eight line by 21 character graphics-type LCD display, a selector knob, and a keypad. All features and functions of the instrument are accessed via this simple and intuitive menu-driven interface.

Figure 5: Model 34 Front Panel Layout

The Keypad

The Selector Knob

The Selector knob will rotate full circle in either direction through sixteen clicks per revolution. It can also be pressed.

Actions taken with the knob depend on the current select mode. The default mode is 'scroll' and is indicated by the presence of a cursor on any menu of the LCD display, or a four character reverse video on the Operate Display. In this mode, rotation of the knob will sequence the cursor forward or backward by one field for each click of the knob.

When the selector knob is pressed, the field at the current cursor location will be selected and 'scroll' mode will be entered. Now, rotation of the selector knob will sequence the selected field through all of the options available for that field.

Pressing the knob again will assert the selection and return to the scroll mode.

The Keypad Keys and Numeric Data Fields

The Keypad Keys include the numerals 0 through 9, the period key and the +/- key. These keys are used for entry of numeric data.

When the cursor is positioned to a field that requires numeric data, the Keypad Keys become hot and pressing any of them will result in the field being selected and numeric entry initiated.

A selected numeric field is indicated by the entire field being shown in reverse video.

When the **Enter** key is pressed, new data entered into the field will be asserted and the field de-selected. A valid entry will result in the field being updated and the new value displayed. An invalid entry will cause the display to revert back to it's previous value.

Once the entry of numeric data has started, it can be aborted by pressing the **ESC** key. This will cause the field to be de-selected and it's value will be unchanged.

Pressing the **Home** or **Setup** keys will also cause the entry of numeric data to be aborted without updating the field.

> ☞ **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.

Editing Enumeration Fields

Enumeration fields are fields where the value may be one of several specific choices. For example, the Heater Range field on a display may contain only one of four values: 50W, 5W, 0.5W and 0.05W.

There are many enumeration fields that contain only the values ON and OFF.

To edit an enumeration field, place the cursor over the field using the Selector Knob. Then, press the knob, which will select the field and display it in reverse video. Now, when the knob is rotated, the various possible values for the field are displayed.

Press the Selector Knob again to exit field editing mode and return to the normal scrolling mode.

To abort editing without making changes to the field data, press the **ESC** key.

Enumeration field data is actually entered into the controller when the field editing mode is exited by pressing the selector knob.

Editing String Fields

String fields are user editable fields of characters. Examples include input channel names, sensor names etc.

To edit a string field, first position the cursor at the string field and press the selector knob to select the field. The field, except for the first character, will then be displayed in reverse video.

In the string edit mode, the selected character in a field is displayed as normal video and the rest of the field is in reverse video. Rotation of the selector knob will move the selected character to the left or right within the field.

The selected character can be changed by pressing the **Enter** key and then rotating the selector knob through all of the available characters. To accept the character shown and return to scrolling through the field, press the **Enter** key again. To exit string editing, press the selector knob.

To return to scrolling through the field, press the enter key again. To exit string editing, press the selector knob.

The Operate Screen

At the top of the instrument's menu tree is the basic Operate Screen. This display can be selected from anywhere in the instrument's menu tree by pressing the HOME key. Note that pressing the Home key will abort any data entry operation that is in-progress.

```
ChB: Second Stage
  229.956K
Setpoint
  330.853K
HTR: ---OFF---  50W
HTR: Stpt: 305.000K
```

The Operate Display offers four independent, user-configurable zones. This permits configuring displays to have only the desired information, eliminating unnecessary clutter.

The first two zones of the Operate Display occupy three lines each on the LCD display whereas the last two zones occupy a single line. Therefore, more information can be displayed in zones 1 and 2 than in 3 or 4. The large font displays shown are only available in zone 1 and 2.

Configuration of the zones is easily accomplished by scrolling the cursor to the desired zone with the selector knob and selecting a zone by pressing the knob. When selected, the first line of the zone will appear in reverse video. Rotating the knob will cause the display to sequence through all of the displays available for that zone.

Pressing the selector knob again will deselect the zone.

> ☞ **NOTE:** When the Operate Screen is displayed, the heater set point may be easily changed by pressing the **Enter** key. This will cause the controller to immediately display the Heater Setup Menu. To return to the Operate Screen, press either **Home** or **Esc**.

The Input Channel Temperature Displays

A typical Input Channel Temperature Display is shown here. It consists of a Temperature reading and the current temperature units.

The temperature is a seven-character field and is affected by the Display Resolution setting in the **Sys** menu. This setting will 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 display the maximum number of significant digits possible.

87.4567K

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

K	Kelvin
C	Celsius
F	Fahrenheit
Ω	Ohms
V	Volts

Table 12: Temperature Units

Sensor Fault Condition

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

Reading Out of Range Condition

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.

The Three Line Zone Displays

The first two zones of the display contain three lines each. The following sub displays may be selected in either of these two zones:

1. The Channel Temperature Status display. This displays any of the four input channels including the channel indicator, channel name and the corresponding temperature in large font. The channel indicator is an enumeration that may be ChA, ChB, ChC or ChD corresponding to the four input channels. The channel name is a fifteen character string data field that may be assigned by the user. Temperature is displayed in an eight character large font that is left justified and autoranged to give the maximum number of digits to the right of the decimal point. Temperature units are displayed as K, C, F or Sensor units, where sensor units will be either V for Volts or Ω for Ohms depending on the sensor type.

```
ChA: First Stage
   223.456K
```

2. The Heater Status display. This display continuously updates the heater output power. Also displayed are the heater range, control mode and PID coefficients

```
HTR:   22% of 50W
Man Setpt=123.200K
P=23.2 I=71.1 D= 50.2
```

3. The Analog Output Status display. This display shows the status of the analog output channel. The output current is continuously displayed as a percentage of full scale. If the output is in SCALE mode, Gain and Offset will be shown. If the channel is in a heater mode, the display will be similar to the heater status display shown above.

```
ANA:  Aout   22%
Gain: 2.000
Offset: 100.00K
```

4. The Setpoint display. This display shows the current set point of the heater output.

```
Setpoint:
 100.000K
```

The One Line Zone Displays

The bottom two lines on the LCD display are one line zones. The following displays may be selected:

1. The Heater Status / Bar Graph display. When the Model 34 is controlling temperature, this shows a bar

```
HTR: ---Off--- 5.0W
```

graph of heater output power and the heater range. The bar chart is continuously updated. When the unit is not in control mode, the status of the heater output is shown instead of the bar graph. Heater status indicators are:

---OFF--- Indicates that heater output is functional and turned off.

Overtemp indicates that the heater control loop was shut off by excessive internal temperature monitor. This fault is usually caused by a shorted heater or use of a heater with less than the selected load resistance.

Readback indicates that the heater was shut off by the current Readback monitor. This monitor compares the actual heater output current with the indicated output current and asserts a fault condition if there is a difference. This fault is usually caused by a broken heater cable or an open heater.

SensorFLT indicates that the heater was shut down by a fault condition on the on the controlling input channel. This is usually caused by an error in the sensor or sensor cables.

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 is exists on a selected input channel. See the Heater Configuration menu for information on how to configure and use this monitor.

2. The Analog Output bar Graph display. This shows the output of the analog channel and the mode. Configuration may be Scale or Heater. In Scale, the Analog Output channel output is proportional to the set point. In the Heater configuration, the Analog Output is configured as a heater and may be in any of the allowed heater control modes. As with the heater status display described above, the Analog Output status indicator is displayed in place of the bar graph when the unit is not in control mode. Valid status indicators for the analog output channel are --**----OFF---** , **SensorFLT** and **HighTemp.**

   `ANA: ---Off--- Htr`

3. The Heater or AOUT Set point status display.

   `Htr: SetPt: 305.000K`

4. The one line input channel temperature status displays. Note that this display can be used to display all four input channels on a single Operate Screen.

   ChA: 28.00377K

5. The Alarm status display. Shows the status of all four input channel alarm indicators. The indicators are:

   -- No alarm.
   HI Over temperature alarm.
   LO Low temperature alarm.
   SF Sensor fault asserted.

   Alarms: -- HI LO SF

6. The blank line display. This is useful for reducing clutter on the screen.

7. The IN and OUT display are usefull when debugging the remote interfaces. The IN display shows the last command received by the controller and the OUT display shows the last response. These displays are continuously updated so that the software engineer can view the actual interaction with the controller.

   IN: *IDN?

The Heater Setpoint Menu

The Heater Setpoint Menu is accessed from the Operate Screen by pressing the **Enter** key. This display was designed to the heater output channel (OC1:) to be easily configured.

```
Heater Setpoint Menu
Source: ChA 68.2272K
Set Point:   70.000K

P: 10.0   I:   20.0
D:  4.0   Pman:  25%

PID at 20% of 5.0W
```

The second line of this display shows the Source control input channel indicator (ChA) for the heater as well as that channels current temperature.

Directly below the current temperature is the actual heater set point which is a numeric field that may be edited on this screen. Upon entry, the cursor is placed at this set point field.

Next is the heater control mode, which is an enumeration field and may be PID, Table or Manual.

The PID and Pman coefficients are numeric fields that control the heater feedback loop.

The last line of this display shows the actual output power as a percentage of the heater range. The heater full-scale range is an enumeration and may be 50W, 5W, 0.5W or 0.05W with a 50Ω load.

> ☞ **NOTE:** From the Heater Setup Menu, press either the Home or **ESC** key to return directly to the Operate Screen.

Speed Keys

All features and functions of the Model 34 may be accessed from the front panel by navigation through the menu tree described in the next section. However, many of the primary instrument setup menus may be directly accessed by using Speed Keys.

Speed keys are active when the Operate Screen is being displayed. Here, the keypad keys will take the unit directly to selected menus as follows:

Speed Key	Target Menu
ENTER	Heater Setpoint Menu
1	Input Channel A Setup
2	Input Channel B Setup
3	Input Channel C Setup
4	Input Channel D Setup
5	Heater Output Menu
6	Analog Output Menu
7	Autotune
8	System Functions
9	User Configurations
.	Aux Relay Setup
0	Alarm Configuration
+/-	Remote I/O Setup

Table 13. Speed Key Index

Speed keys offer a shortcut single key press method of accessing most menus. Note that, in order to return from any menu back to the Operate Screen, press the **Home** key.

The Instrument Setup Menu Tree

Model 34 setup and configuration can be performed using the menu driven front panel user's interface. The top of the setup menu tree can always be accessed by pressing the Setup key. This will cause the LCD display to show the Instrument Setup menu, which is the root of the setup and configuration menu tree.

The Instrument Setup Menu

The Instrument setup menu provides a listing of setup screens that may be directly accessed to configure various subsystems of the Model 34.

This menu scrolls through selections by rotating the Selector Knob in either direction. When the cursor is at the bottom of the screen, the display will scroll upwards by one line with each additional clock-wise rotation of the knob.

```
  Instrument Setup
ChA: Cold Plate
ChB: Second Stage
ChC: First Stage
ChD: Jacket
OC1: Heater
OC2: Aout
  System Functions
```

Subsystem configuration menus can selected by scrolling the cursor to the desired field and pressing the Selector Knob. This will take the display to the selected configuration menu.

A complete list of the subsystem menus that can be selected from the Instrument Setup menu is as follows:

ChA: ---Name---	Input channel A configuration
ChB: ---Name---	Input channel B configuration
ChC: ---Name---	Input channel C configuration
ChD: ---Name---	Input channel D configuration
OC1: ---Name---	Output 1, Heater, configuration
OC2: ---Name---	Output 2, Analog Output
System Functions	System settings, Remote ports
Sensor Setup	Sensor definition tables
Relays	Relay configuration.
PID Tables	PID vs. set point tables
Over Temp Disconnect	Over temperature disconnect feature.

Pressing either the **Home** or the **ESC** key will cause the display to return to the Operate Display.

The Input Channel Setup Menu

The Input Channel Setup menu is used to configure each of the four input channels.

The first field on the input channel setup display is the input Channel Indicator (ChC:). When this field is selected, rotation of the Selector Knob will result in the sequential display of all four input channels. This allows a 'horizontal' scrolling through the input channel setup menus.

The second field is the user assigned input channel name. This field may be edited using the string editing function described above. A channel name has a maximum of 15 characters.

```
Input Channel Setup
ChC: First Stage
Units: V
Sensor:
 TC type E
CalGen   CJcomp: ON
Statistics
Setup Alarms
```

The Units field assigns the units that are 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.

Next is the Sensor type (TC type E). When this field is selected, rotation of the selector knob will scroll through all of the available sensor types.

New sensor types are added using the Sensor Types screen. New sensor calibration tables are entered using the Calibration Tables screen.

Selection of the CalGen™ field initiates the calibration curve generator feature. This feature is described in the next section.

The CJcomp field is used to enable or disable Cold Junction Compensation for Thermocouple sensors. For more information on this, refer to the section "Using Thermocouples".

Selection of the Statistics field will take the display to the Input Statistics menu.

The final field on the Input Channel setup menu is "Setup Alarms". When this field is selected, the display will transition to the Alarm Configuration menu.

Pressing the **ESC** key will return the display to the Instrument Setup menu.

The Input Statistics Menu

The Model 34 continuously tracks temperature history on each input channel. The Input Statistics menu provides a summary of that history.

The channel history is reset whenever the channel is initialized and can also be reset by selection of the Reset field on this screen. Immediately to the left of the Reset field is a timer that shows the length of time that the channel history has been accumulating.

```
  Input Statistics
103.25Min.     Reset
Min: 102.340K
Max:102.850K
 S2: 0.02
  M: 0.250K/min
  b: 102.00K
```

The Minimum and Maximum temperature recorded since the last reset are shown. S2 is the 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.

All fields on this display are continuously updated.

The Alarm Configuration Menu

Alarm conditions can be assigned independently to any of the four input channels.

The first field of this display is the input channel indicator (ChD:). Selecting this field allows scrolling through all of the four input channels. The current temperature for the selected channel is displayed below this field and is updated in real time.

```
Alarm Configuration
ChD: Jacket Temp
    28.0904K
High:200.000 Ena:No
 Low:100.000 Ena:Yes
Sensor Fault Ena:No
     Audible Ena:No
```

High temperature, low temperature and sensor fault alarms may be entered and enabled or disabled. The audible alarm may be independently enabled or disabled. Note that there is a 0.25K hysteresis in the assertion of high and low temperature alarms.

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

Press the **ESC** key to return to the Input Channel Setup menu.

The Control Loop Setup Menu

The Heater Setup menu is used to perform the basic setup of the 50 Watt heater output channel. This display was designed to provide all of the information required to tune heater parameters and is, therefore rather complex.

```
 OC1: Heater
Source: ChA 20.6023K
 Set Point:  111.000K
P: 10.0      I: 20.0
D:  0.0 Pman: 100%
    Autotune
   Heater Config
Man  at   0% of  5.0W
```

The first field is the output channel indicator (OC1:). When this field is selected, rotation of the selector knob will scroll through the heater (OC1:) and the analog output (OC2:) channels. After the indicator field is the channel name. This is a user supplied fifteen-character name and may be edited using the string field edit procedure.

The source line of the display shows the input channel source for the heater control loop and the current temperature of that channel. The source may be changed by selecting the input channel indicator (ChA) and scrolling through the four input channels. Next to the channel indicator is a display of the current temperature for that channel. This field is continuously updated so that the controlling temperature will be visible while the heater parameters are being adjusted.

The heater set point field is just below the controlling channel's temperature display. This is a floating-point field and up to 20 digits may be entered.

The P, I and D coefficients 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. It is internally scaled so that, with a gain of 1.0, a full-scale temperature error will correspond to a full scale power output. In the Model 34, gain is also scaled to reflect the actual heater range and the load resistance.

Integral gain values range from zero to 10,000. The units of this term are Seconds. Values of less than 0.01 turn the integral control 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 in percent of full-scale output current (Amperes) and may have values from zero to 100%.

> ☞ **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 power.

Heater control mode is set by selecting the mode field (Man) on the bottom left-hand corner of the screen. This is an enumeration field and the control choices are:

1. **Man** for Manual control mode. Here, a constant heater output power is applied when the unit is controlling temperature.
2. **Table**. This is a PID control mode where the PID coefficients are generated from a stored PID table based on set point.
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 34 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 set point.
6. **RampT**. Ramp mode with PID table. When a ramp operation is complete, the controller will regulate temperature in Table mode.

Heater range is selected by using the bottom right hand field (5.0W). Choices for a 50Ω load are 50W, 5.0W, 0.5W and 0.05W. For a 25Ω load, the choices will be 25W, 2.5W, 0.3W and 0.03W.

The Autotune menu is selected on this screen by moving the cursor to the Autotune field and pressing the selector knob.

Additional heater setup functions can be performed by selecting the Heater Config. field.

> ☞ **NOTE:** The CONTROL key may be pressed at any time to engage the heater. Stop will disengage it without affecting the display.

The Analog Output Configuration Menu

Configuration of the Analog Output channel is essentially the same as for the heater. This output has only one range and that is a 20mA constant current source with a maximum voltage compliance of 22 volts.

```
 OC2: Analog Out
Source: ChA 20.6023K
 Set Point:  111.000K
P: 10.0      I: 20.0
D:   0.0 Pman: 100%
    Autotune

PID  at   0% of Scale
```

The analog channel can be used as a second control loop or as a scaled temperature output. This selection is made using the output type field in the lower right hand of the display (Scale). This is an enumeration field and the choices are Scale for scaled temperature output and Htr for a control loop type output.

To use the analog channel as an independent second control loop, a load resistance of 1000Ω should be used. This will correspond to a 400mW output. A load resistance of more than 1000Ω will result in non-linear control since the voltage compliance of the current source will be exceeded. A minimum value of 100Ω is required to prevent the output circuitry from over heating and going into thermal shut-down.

In the Scale mode, the analog output is scaled relative to the set point. Therefore, the Set Point field of the display is used as the zero output temperature offset and the Proportional gain (P:) field is used as the scale factor.

Note that the actual analog output is a unipolar current from zero to 20mA. This will allow direct interface to industrial 20mA current loops available on most strip chart recorders and controlled power supplies. If a voltage output is desired, a resistor should be connected across the output pins in parallel with the load. The value of this resistance will set the current-to-voltage conversion factor.

The Autotune Menu

The Autotune menu can be reached from either of the output channel menus, or from the Operate Screen by pressing the '7' key.

Before attempting an autotune, the user should thoroughly review the Autotuning section of the next chapter.

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

The Heater Configuration Menu

This menu is accessed only from the Heater Setup menu. The analog output channel does not have a corresponding screen.

```
Heater Configuration
    Table: 2
    Load: 50Ω
    Ramp: 0.10/min
```

The Table field is numeric and 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 34 will store up to four PID Tables. They are numbered zero through three.

Load is an enumeration field and identifies the value of the heater load resistance. Choices are 50Ω and 25Ω. When 50 Ohms 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.

> ☞ **NOTE:** 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.

The System Functions Menu

The first field of the System Functions menu is Display TC which is an enumeration field that sets the time constant used for temperature displays. Choices are 0.5, 1.0, 2.0, 4.0, 8.0, 16.0 32.0 and 64.0 Seconds.

```
System Functions
Display TC: 2S
Display Res: FULL
LCD Contrast: 3
Line Frequency: 60Hz
Auto Control: Off
User Configurations
  Setup Remote I/O
```

The time constant selected is applied to all channels and is used to smooth data in noisy environments. The filtered data is also used by the control loop in order to improve control stability. This is particularly important in systems where an aggressive Derivative term is used.

The Display Resolution (Display Res:) field 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 display the maximum resolution possible.

Note that the Display Resolution setting only formats the LCD display as a user convenience. The internal resolution of the Model 34 is not affected by this setting.

The LCD Contrast field is used to adjust the contrast of the front panel LCD. Values from 1 (low) to 9 (high) are permitted.

The AC power line frequency selection should be set to the proper value for the input power connection. However, this setting only has a significant effect when the user is attempting to synchronize the controller with a cryocooler.

Selecting the User Configurations field will take the Model 34 to the User Configurations menu where instrument setups can be saved and recalled.

The Auto Control: 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 Auto Control is turned on, the controller will power up, then after ten seconds will automatically engage the control loops.

The User Configurations Menu

The menu is used to save and restore up to six instrument setups. Each setup saves the entire state of the Model 34 including set points, heater configurations, input channel data etc.

```
User Configurations
0. User Config 0
1. User Config 1
2. User Config 2
3. User Config 3
4. User Config 4
5. User Config 5
```

The initial menu contains a list of setup names as shown. If desired, the user can edit these names to be more meaningful.

To save or restore a setup, scroll the cursor to the desired entry and press the selector knob. The sub-menu for the selected setup will now appear.

From this sub-menu, the name may be edited using the string edit procedure.

Selecting Save will save the current instrument state. Selecting Recall will recall a previously saved setup.

```
User Configurations

Configuration Name:
     User Config 0
Save
Recall
```

The Remote I/O Setup menu

This menu used to configure the Remote I/O interfaces including the USB, GPIB and RS-232.

Note that 'GPIB' is used to indicate the controller's IEEE-488.2 interface.

```
   Remote I/O Setup

Port Select: USB
    Address: 12
 RS232 Rate: 38K
Name: Model 34 Unit 0
 in:*IDN?
out:Cryocon Model 34
```

Port Select is an enumeration field that sets the active remote port. The controller can only have one active port at a given time. Inactive ports are disabled. Choices are RS232 which activates the RS-232 port, USB and GPIB.

Selection of the USB on this screen will result in automatic configuration and the host computer will identify the Model 34 and load the proper drivers.

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 and USB interfaces 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 300, 1200, 2400, 4800, 9600, 19k for 19,200 and 38K for 38,400.

This menu sets up the GPIB and RS-232 interfaces. It is also used to select the Universal Serial Bus interface, but the USB does not require configuration.

The Name field allows the assignment of a unique name to the instrument. This name string is useful in USB applications since the USB assigns addresses to devices based on the sequence in which they are connected to the bus. If there are multiple Model 34 units connected, the name string can be read by the host computer in order to uniquely identify each unit, independent of it's USB address.

The bottom two lines show the last command received by the Model 34 over a remote interface and the last response generated. These two fields are extremely useful in debugging remote operation sequences.

The Relay Setup menus

There are two relays available in the Model 34. They can be independently programmed by using this screen.

The first field on the screen may be selected to scroll between the Relay #1 and #2 setup menus.

```
   Relay #1 Setup
ChA: Cold Plate
     110.636K
High:100.000 Ena: No
Low:  50.000 Ena: Yes
Sensor Fault Ena: No
```

Next is the controlling input channel indicator and name. The channel indicator may be selected to scroll through all four input channels. The current temperature of the selected channel is displayed below the channel name and is continuously updated to allow visibility while configuring the relays.

The various conditions that can cause a relay to assert may be enabled or disabled by using the Ena: fields provided.

High and Low temperature points are entered as floating point numeric values. There is a 0.25K hysteresis between the asserted and de-asserted states.

Relays in the Model 34 are dry contact. When a relay is de-asserted contact is made between the Common and Normally Closed (NC) output pins and contact is open between the Common and Normally Open (NO) pins. When asserted, connection is made between the Common and NO pins and opened between the Common and NC pins.

The PID Tables menu

The Model 34 can store four user generated PID tables. Each table may have up to sixteen set-point zones.

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

```
     PID Tables
01: PID Table 2
N: 12



EDIT PID TABLE
```

When controlling in the Table mode, the Model 34 will derive control loop PID coefficients and heater range by interpolation of the PID Table zones based on that zone's set-point.

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:

Building a PID Table from the front panel requires the entry of several numeric values. 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) and to edit the name of the table.

2. Once the table is identified, selecting the EDIT PID TABLE field will take the display to a menu that displays a list of set points vs. their index within the table.

3. To enter or edit an entry, scroll to the desired index / set point and press the selector knob.

4. The display will now show a menu that allows editing of all of the individual fields.

Once entry of a table is complete, the table is automatically conditioned so that it can be used directly by the control loop software. The conditioning deletes all entries with set point values of zero or less and sorts the table based on set point.

The first field on the PID Tables menu is the table index number and the user supplied name. Selecting the index number will allow scrolling through all four of the available tables. The table name can be entered using the string editing procedure.

Below this is N, the number of valid entries in the table. This number is generated when the user entered table is conditioned and cannot be changed using this menu.

The ENTER PID TABLE field is selected to enter and edit zones within the selected table.

The next step in PID Table entry is a menu that lists index values and their corresponding set points. The set point fields are generated from table data and cannot be changed here.

All sixteen zones of the PID Table may be viewed and selected by rotation of the selector knob. Selection of an index is made by pressing the knob. This will take the screen to the zone edit menu.

Pressing the **ESC** key at any time will abort the table data entry process and return the display to the PID Tables menu. All of the edits made to the table will be lost.

Pressing **Enter** will save the edits, condition the table and exit to the PID Tables menu.

When an index / set point is selected, the display transitions to a menu that allows editing all of the values in the selected entry. Here, the set point, P, I and D values are floating point numeric fields and the heater range is an enumeration of the four heater range values.

```
01: PID Table 2
Index:    2
Setpt:    1.4000
    P:    102.40
    I:     33.00
    D:      2.00
Range:  0.05W
 Save & Exit
```

On this screen, the Index field is a numeric entry and may be changed to edit a different zone without returning to the next menu above.

To delete a zone in the PID Table, enter zero or a negative number in the set point field. These entries will be rejected when the table is conditioned and stored in non-volatile memory.

From the PID edit menu, pressing the **ESC** key will exit the screen and discard any edits. Selection of the Save & Exit field will save all entered data and return to the index / set point menu.

The Sensor Setup Menu

The Sensor Setup menu is used to define sensors used by the Model 34. Definition of a sensor requires entering configuration data on this screen and assigning a calibration curve.

Several sensors types are built in to the Model 34 and there is memory available for twelve user defined sensors. When a built-in sensor is displayed on the Sensor Setup menu, the words “No Edit” will appear on the third line of the display indicating that configuration data cannot be changed.

```
    Sensor Setup
01: User Sensor B
Type: Diode
Multiplier:      -1.0
Units: Volts
N: 124

Edit Cal Curve
```

The first field on the display is the sensor table index. Selecting this field will allow scrolling through all of the sensors configured in the unit, including user sensors. The index is displayed along with the sensor name. The name is a fifteen character string and may be entered using the string edit procedure.

Sensor Type is an enumeration of all of the basic sensor types supported by the Model 34. Choices are shown in the Supported Sensors Table.

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.

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

The N field is the number of valid points in the calibration curve and is generated from the entries made during the editing process.

Selecting the ‘EDIT CAL CURVE’ field will cause the screen to go to the Calibration Curve menu for the selected sensor. Here, the calibration curve may be entered or edited.

The Calibration Curves menu

The Calibration Curve menu is the first screen used in the process of building 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 will upload or download curves.

```
 10:My Curve
Index  Unit Temp(K)
  2   0.5432 77.333
  3   0.5234 82.222
  4   0.6323 89.333
  5   0.8332 99.444
  6   0.9432 99.999
Ent=Save&Ext, Esc=Ext
```

The entry of a sensor calibration curve is essentially identical to the process used to enter PID Tables.

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

1. The Calibration curves menu is used to select the calibration curve and to edit the name of the curve.

2. Once the curve has been is identified, selecting the EDIT CAL CURVE field will take the display to a menu that displays a list the curve's entries. An entry number, unit value and temperature are shown. The unit field corresponds to the entries value in Volts, Ohms or LogOhms as selected above.

```
 10:My Curve

Index:    5
Unit  :  0.8332
Temp  : 99.444


Save & Exit
```

3. To enter or edit an entry, scroll to the desired index and press the selector knob.

4. The display will now show a menu that allows editing of all of the individual fields.

When entry of a curve is complete, the instrument 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 either the temperature or sensor units field.

Over Temperature Disconnect Menu

The Over Temperature Disconnect feature is enabled from this screen. This feature allows the user to specify an over temperature condition on any of the input channels.

When an over temperature condition exists on the specified channel, the heater and analog output channels are disconnected and the heater status indicator is set to "OTDisconn".

```
Over Temp Disconnect
    Enable: Off
    Source: ChA
      Temp: 300.000
```

Both the Aout and Heater channels are disconnected when an over temperature condition exists. A mechanical relay is used so that the load is protected, even if the condition was caused by a fault in the Model 34'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 Set-point must be specified. This is the temperature at which an over temperature shut down will be asserted. Temperature units are taken from the source input channel.

Finally, the OTD function must be enabled.

Basic Setup and Operating Procedures.

Autotuning

The Autotune Process

The Model 34 performs autotuning by applying a generated waveform to the heater output and analyzing the resulting changes in process temperature. This is used to develop a process model, then a PID solution.

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

As a result, 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 will vary only in the resultant closed loop bandwidth. Low bandwidth solutions will be slower to respond to changes in set point or load disturbances. High bandwidth solutions will result be responsive but can exhibit overshoot and damped oscillation.

The Model 34 attempts to generate minimum overshoot solutions since many cryogenic temperature control applications require this. If the process is noisy, bandwidth will be minimized as much as possible. If the process is very quiet, a more aggressive solution will be generated subject to the minimum overshoot requirement.

The autotune algorithm will produce 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 that the user constrain the amplitude and duration of the heater output waveform by using the DeltaP and Timeout parameters.

Small values for DeltaP will force the use of small changes in heater power. This will make 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 will also corrupt the tuning result. Worse, it may allow application of too much heater power and may cause an over temperature condition.

Experience indicates that most cryogenic systems will autotune properly using a DeltaP of 10% whereas a noisy system will require 20% or more. A common example of a noisy cryogenic system is one where a Silicon Diode sensor is used with a set point 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 will result in the maximum value for P that will not cause oscillation. The process temperature will stabilize at some point near the set point.

Using PI or PID control will result in stable control at the set point.

The Derivative, or D, term in PID is used to make the controller more responsive to changes in set point 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 34 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 set point 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 set point temperatures. Therefore, the pre-tuning process should result in a temperature near the desired set point.

Pre-tuning does NOT require that the user establish stable control at the target set point. 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 set point minus some constant offset. Increasing the P value will reduce the offset amount. When P is too large, the system will oscillate.

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 set point.

System Characterization.
System characterization is the process of using autotune to generate optimal PID coefficients for each set point over a wide range of possible set points.

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

Autotune Setup and Execution
The Autotune menu can be reached from either of the output channel menus, or by pressing the '7' key from the Operate Screen.

```
      Autotune
OC1: Heater Output
   Go      Save&Exit
    Running |
DeltaP:  10% Mode: PI-
Timeout: 300
P=       I=
D=
```

Upon entry, the autotune state variable will be 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 34 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 34 can be manually tuned using sensor units but autotuning cannot be performed.

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% will allow use full-scale power increments. A value of 20% will use 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.

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 will be 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.

Ramping

Operation

The Model 34 will perform a temperature ramp function using a specified ramp rate and target set point. Once placed in a ramping control mode, a ramp is initiated by changing the set point. The unit will then progress to the new set point at the selected ramp rate. Upon reaching the new set point, ramp mode will be terminated and standard PID type regulation will be performed.

Ramping may be independently performed on both the Heater and Analog output channels.

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 a ramping Control Mode. There are two types: 1) RampP which will perform a ramp using the current PID parameters, and 2) RampT which will ramp using PID parameters derived from a specified PID Table. The RampP mode will perform a ramp, then perform temperature regulation using the standard PID mode. The RampT function will perform a ramp, then perform regulation using the PID Table control mode.
3. Press **Control**. Now, the controller will begin temperature regulation at the current set point.
4. Enter a new set point. The controller will now enter ramping mode, and ramp to the target set point at the specified rate.
5. When the new set point is reached, ramping mode will terminate and temperature regulation will begin at the new set point.
6. Entry of a different set point 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 set point.

The current status of the ramp function may be seen on the Operate Screen by using the Ramp One Line display. It may also be queried via any of the remote ports using the HEATER:RAMP? Command.

Ramping Algorithm

The ramp algorithm uses a basic PID type control loop and continuously varies the set point until the specified temperature is reached. This means that the PID control loop will continuously track the moving set point. 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 Heater Configuration Menu. Note that the ramp rate on the Heater channel is independent of the rate on the Analog channel.

An example configuration menu is shown here. The Ramp: field identifies a ramp rate of 0.10/min. If the input channel controlling the heater has measurement units of Kelvin, a ramp rate of Kelvin per Minute is selected.

```
Heater Configuration
    Table: 2
    Load: 50Ω
    Ramp: 0.10/min
```

The control mode must also be set to one of the two ramping modes, RampP or RampT. These modes are selected using either the Heater Setup Menu or the Heater Setpoint Menu.

An example of the Heater Setup Menu for the Analog Output channel is shown here. The control mode is set to RampT.

```
 OC2: Analog Out
Source: ChA 20.6023K
 Set Point:  111.000K
P: 10.0      I: 20.0
D:  0.0 Pman: 100%
    Autotune

RampT  at   0% of Htr
```

Adaptive Cryocooler Signature Cancellation

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 an amplitude of one or more Kelvin.

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

Faced with a significant thermal signature, users are generally required to de-tune the PID loop and live with the resulting inaccurate control.

The Model 34 uses digital adaptive filters to actively minimize the cooler's signature, resulting in much higher control accuracy and loop responsiveness.

Adaptive cryocooler correction involves two separate Linear-Mean-Square adaptive filters. The first filter performs Input Signature Subtraction and the second performs Active Signature Cancellation.

Signature Subtraction

With Signature Subtraction enabled, the controller will first measure and characterize the input temperature signal, then extract the cryocooler thermal signature. After this brief extraction phase, the controller will synchronously subtract 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.

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.

To use the subtraction filter, three 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 Cryocooler Filter Type must be set to 'Input'.
- The Cryocooler 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. In the future, this will be

generated automatically; However, at this time, determination of a proper setting will require either some experimentation, or contacting Cryo-con with specific cryocooler information.

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

```
System Functions
Display TC: 2S
Display Res: FULL
LCD Contrast: 3
Line Frequency: 60Hz
User Configurations

  Setup Remote I/O
```

To setup the other input subtraction filter parameters, go the Cryocooler Filter menu from the Setup menu.

For the Loop parameter, enter either 1 or 2 for the control loop to filter. Input subtraction will be applied to the source input channel of the selected loop. Therefore, if Loop 1 is being controlled by input B, selecting Loop 1 will cause input subtraction to be performed on input B only.

```
  Cryocooler Filter

Control Loop:1
Type: Input
Step Size: 0.0010
Taps: 10

       RESET
```

Next, scroll to the Type field and select ‘Input’ for input subtraction.

Finally, scroll down to the Taps field and enter the Taps parameter. If you are experimenting with this value, Ten is a good starting point.

Active Signature Cancellation

Active Signature Cancellation involves use of the controller’s heater to buck the cooler’s thermal signature, resulting in full or partial reduction of the signature’s amplitude.

Cancellation is a much more difficult operation than subtraction. It depends significantly on the characteristics of the cryogenic system and may not be useful in some applications.

For example, a cooler where the thermal link between the controller’s heater element and the cold-plate temperature sensor is weak. This will require significant swings in heater power that may limit the useful temperature range.

The algorithm proceeds in the same extraction-adaptation sequence as the input filter described above. After the extraction phase, continuous adaptation is performed in order to generate a heater waveform that minimizes the signal energy in the measured thermal signature.

This filter is reset whenever the set-point is changed, or the baseline temperature changes by more than 2K. This is required because the structure of the thermal signature changes significantly with temperature.

To setup the cancellation filter, the same parameters described for the subtraction filter must be entered followed by the cancellation parameters.

From the ‘Cryocooler Filter’ menu:

- Select the Control Loop as above.
- Set the Type field to ‘Cancel’.
- Set the Step Size to the desired adaptation rate for the filter. If this value is large, adaptation will be fast and the filter may oscillate. If the number is small, adaptation will be slow. A good starting point is 0.001.
- Set the Taps field as above.

The cancellation filter may be manually reset by selecting the ‘RESET’ field.

CalGen™ Calibration Curve Generator.

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.

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

The user may specify one, two or three data points. Then, CalGen™ will generate the new curve based on fitting the input curve to the user specified points.

Diode calibration curves may be generated as follows:

1. User input of one data point near 300K. This will result in a generated output curve that will fit the specified 300K point and the 30K point on the input curve. The area of the curve below 30K will be unaffected.
2. User input of two points: The first near 300K and the second near 77K. This will generate a curve that fits the 300K and 77K data and leaves the area of the input curve below 30K unaffected.
3. User input of three points: The first near 300K, second near 77K and the third near 4.2K. This will generate a curve that fits all three data points.
4. User input of a single point near 4.2K. This will generate a new curve that fits the 4.2K input and the point on the input curve at 30K. The area of the curve above 30K is unaffected.

Platinum calibration curves require 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 actual measured data, any errors in the Model 34's measurement electronics are also effectively cancelled.

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

> ☞ **NOTE:** The user can enter or exit the CalGen™ menus at any time without loss of previously captured data points.

Using CalGen™ With Diode Sensors

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

To setup an input channel, go to the Input Channel Setup menu for the desired channel. For example, if input ChA is desired, press the 1 key to take the unit to the setup screen for ChA.

```
Input Channel Setup
 ChA Input Channel A
  Units: K
 Sensor:
  SI 410
 CalGen
 Statistics
 Setup Alarms
```

From this menu, select the desired sensor. The calibration curve of the selected sensor will be used as the input curve to the CalGen™ process.

To initiate the curve generation process, select the CalGen™ field on that same screen.

Note that, 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™ will determine if the sensor is a Diode or Platinum sensor.

For a Diode Sensor, a sub-menu will be displayed that allows the user to select the number of points required for the CalGen™ fit. For a Diode sensor, the selections are:

```
CalGen
 Select Method

   1 point at 300K
   2 point
   3 point
   1 point at 4.2K
```

One point near 300K
Two points: 300K and 77K
Three points: 300K, 77K and 4.2K
One point near 4.2K

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.

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

To enter the near 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 34 to capture the sensor reading and associate it with the specified temperature.

```
CalGen
 Temperature   Unit
 300.000      Capture
 77.0000      Capture


 Unit: 1.08400  V
 New Curve  ESC=abort
```

When a sensor reading has been 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

Save the new curve to:
10:User Cal Cur 1



 Save         ESC=abort
```

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 that, at any time, the CalGen™ process may be aborted by pressing the **ESC**, **Home** or **Setup** keys.

Using CalGen™ With Platinum Sensors
The calibration curve generation procedure for Platinum sensors is the same as for the diode sensors described above. However, Platinum sensor curves are generated using two user specified points. Therefore, the selection of the number of points is not required.

Using Thermocouple Sensors

Thermocouple sensors have low sensitivity and are very susceptible to electrical noise. Therefore, they are often difficult to apply. In order to obtain the best possible measurement accuracy, the recommendations given here should be carefully applied.

Cold Junction Compensation

Direct Connection

The Model 34 supports direct connection to Thermocouple sensors by using a based software Cold Junction Compensation scheme as follows:

1. The sensor input connection on the rear panel of the instrument is thermally anchored to a temperature sensor that is used for Cold Junction Compensation.
2. The Cold Junction Temperature is continuously monitored and converted to a Cold Junction Voltage by a performing a ‘reverse lookup’ of the sensor’s calibration curve.
3. When a sensor reading is taken, the Cold Junction Voltage is subtracted from the measured voltage. This result is then used to compute actual sensor temperature by using a ‘forward lookup’ of the calibration curve.

It is important that Thermocouple sensors be connected directly to the input connector as described in the section below. For example, if the Thermocouple wires were first connected to Copper wires, then to the Model 34 input, the Cold Junction Compensation cannot function properly and measurement errors will result.

The Cold Junction Compensation function may be turned On or Off for each input channel. This is done by using the “CJcomp” field of the Input Channel Setup Menu.

Adding New Thermocouple Types

New thermocouple types may be added to the Model 34 by adding a new user sensor type and corresponding calibration curve. This procedure is described in the section below titled Adding a New Sensor.

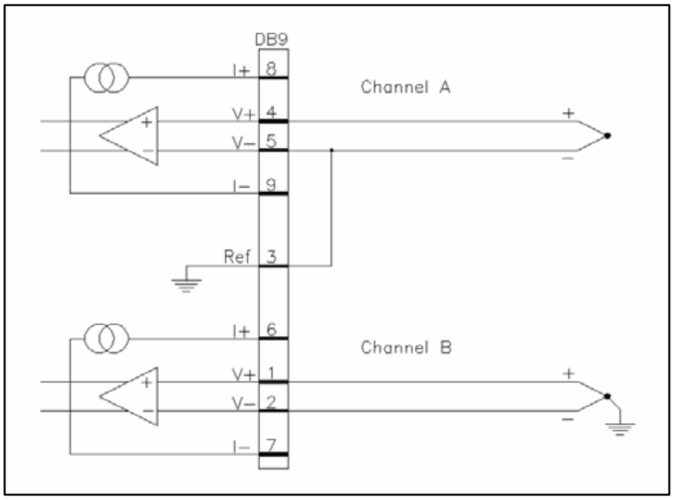
Since the software Cold Junction Compensation technique used by the Model 34 depends on the thermocouple's calibration curve, it is important to note that the temperature range of the curve must include room temperature.

The Model 34 has two full-scale input range selections for Thermocouples. They are TC80 for ±80mV and TC40 for ±40mV. Using the TC40 range will provide better measurement resolution but may limit the maximum temperature reading.

Connecting Grounded and Floating Thermocouples

For best performance, Thermocouple sensors should be floating. This will ensure that no noise currents can flow in the sensor leads and that no common-mode noise voltage will be directly coupled into the controller.

The diagram below shows the input schematic for a typical Cryo-con controller and it's connection to both a floating and a grounded Thermocouple sensor.



Note that the controller's input amplifier is differential so both connections to the sensor have very high input impedance. This was done to optimize the noise performance for sensors that use Four-Wire measurements.

Thermocouples do not require excitation from the controller's internal current source and cannot be connected for Four-Wire measurements. Therefore, when a floating Thermocouple is used, a ground potential reference point must be established. If this is not done, the high impedance of the input will allow the common-mode voltage of the Thermocouple to float up to the power supply rail of the amplifier and will result in erratic readings.

Floating Thermocouples

For floating Thermocouples, an external Ground Reference is established by connecting Pin 3 of the input connector to the negative sensor input pin. This is shown in the figure above for Channel A where Pin 3 is connected to Pin 5. A Ground Reference connection must be made to the negative side of each FLOATING Thermocouple connected to the instrument.

Grounding Thermocouples

The connection of a grounded Thermocouple is shown above on Channel B. Note that the external ground reference connection is NOT made at the sensor connector as it was in the floating sensor case. This is because the ground reference is established externally by the Thermocouple itself.

For this scheme to operate properly, the ground voltage established by the Thermocouple must fall within the range of the instrument's input amplifier, which is

±5 Volts. Further, to improve accuracy, noise on this ground, relative to the controller, should be minimized.

Since the Controller's input amplifier is very high impedance, ground-loop currents cannot flow from the grounded Thermocouple into the instrument's grounding scheme. If a ground is made at the controller, noise current could flow from the Thermocouple ground, through the leads and complete a ground loop through the connection at the controller. The result would be extremely poor accuracy and erratic readings.

If more than one Thermocouple is grounded, the noise problem is compounded. However, good performance should still be attainable if attention is paid to good quality system grounds.

Thermocouple Connection Summary

For each floating (un-grounded) Thermocouple, a connection on the controller must be made from the negative side of the sensor to the Ground Reference (Pin 3).

For each grounded Thermocouple, NO Ground Reference connection should be made.

The requirement for an external Ground Reference may seem inconvenient at first. However, if the controller established this reference internally (as many instruments do), accuracy would be reduced in either the grounded or floating Thermocouple case.

Input Connections (DB9) to Thermocouple Sensors

The Model 34 controllers use a DB9 type connector for Thermocouple inputs. The Pin-out and a REAR view of this connector is shown here.

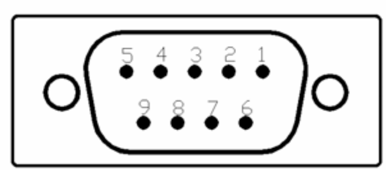


Figure 6: Thermocouple Input Connector

Thermocouple sensors require a two-wire connection to the Model 34. All thermocouple connections must be made at the sensor input connector since this connector is thermally anchored to an internal sensor that is used for Cold Junction compensation. The input connector should have a backshell installed in order to prevent local air currents from generating errors in the cold junction circuitry.

When using a standard Solder Cup type DB9 connector, connections may be soldered into the input connector.

Some types of Thermocouples are fabricated from material that is difficult to solder to. In this case, the use of crimp type connectors is recommended.

For best performance with any Thermocouple, crimp type connectors should be used where the crimp contacts are fabricated from the same type material as the Thermocouple metal itself. These connectors are available as kits from Cryo-con for Type K, T, J and E Thermocouples. Other types of Thermocouples may be supported using

Copper contacts.

Input Channel	Floating Thermocouples		
	Connector	Signal	Pin
ChA	Lower	V+	4
ChA	Lower	V-, Ref	5&3
ChB	Lower	V+	1
ChB	Lower	V-, Ref	2&3
ChC	Upper	V+	4
ChC	Upper	V-, Ref	5&3
ChD	Upper	V+	1
ChD	Upper	V-, Ref	2&3

Table 14: Floating Thermocouple Connection

Input Channel	Grounded Thermocouples		
	Connector	Signal	Pin
ChA	Lower	V+	4
ChA	Lower	V-	5
ChB	Lower	V+	1
ChB	Lower	V-	2
ChC	Upper	V+	4
ChC	Upper	V-	5
ChD	Upper	V+	1
ChD	Upper	V-	2

Table 15: Grounded Thermocouple Connection

Common Error Sources

<u>Cold Junction Compensation</u>

Cold Junction Compensation is required for any instrument to measure Thermocouple sensors accurately. The most accurate method for performing this is by using an external ‘Ice Bath’ setup. However, this is usually impractical.

Cold Junction Compensation in the Model 34 controller is performed by a circuit that measures the temperature of the input connector pins. This reading is then used to look up a compensating voltage from the Thermocouple’s calibration curve.

The major source of error in this process is the accuracy of measuring the temperature of the input pins. This is usually a ‘tracking’ type error relating to the response time of the sensor rather than an absolute error in the actual measurement. For example, if the controller itself is maintained at a very accurate ambient temperature, readings from the Thermocouple will be very accurate and stable.

However, if the ambient temperature changes significantly, there will be a time lag where the measured temperature will be slightly off until the ambient temperature stabilizes again.

The backshell of the input connector should always be installed. This will minimize errors caused by local air currents.

To further minimize Cold Junction Compensation errors, it is recommended that crimp type pins made from Thermocouple metal be used in the input connector. This process is described in the previous section.

In summary, Cold Junction Compensation errors are indicated by Thermocouple temperature measurements that vary when ambient temperature changes and stabilize as ambient temperature stabilizes.

Cold Junction errors may be minimized in the Model 34 by the use of special input connectors. Further, implementing an external 'Ice Bath' correction scheme can eliminate them completely.

<u>Calibration Errors</u>
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 $0^{o}C$ 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. For example, if calibration errors for a Type K Thermocouple are zeroed at room temperature, a reading near Liquid Nitrogen temperatures may have an error of 5K.

Correction of Calibration Errors over a wide range of temperature can be made by using the Model 34's CalGen™ feature. Here, the controller should be stabilized at both temperature extremes. Then, CalGen™ will generate a new sensor calibration curve that best fits the two points to the actual sensor voltage readings.

Often, CalGen™ is be done by taking a reading at room temperature, then a second reading with the sensor in Liquid Nitrogen. Since a Thermocouple's sensitivity is relatively constant above room temperature, this procedure will give good accuracy over a wide range of temperature.

<u>AC Power Line Noise Pickup</u>
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.

Thermocouples have relatively high resistance leads, and each lead is made from a different material. Therefore, they are much more sensitive to AC pickup than sensors using copper wires.

A ground loop will cause significant AC coupling into the sensor. However, if the connection procedures described above are carefully followed, ground loops through the sensor leads will be avoided.

When a grounded sensor is used, a poor quality ground may have sufficient AC voltage to exceed the input range of the controller. 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 of this type problem.

Most common AC noise pickup problems are caused by capacitive or magnetic coupling into the sensor wires. Again, the Thermocouple's high resistance leads make this type coupling very efficient. General recommendations to minimize coupling include:

1. Minimize the length of Thermocouple wires. For example, use a Thermocouple Module near the sensor to convert the Thermocouple wires to copper as soon as possible.
2. Twist the wires. Twisted wire for various types of Thermocouples is available from several vendors.
3. Avoid running sensor wires near, or parallel to AC power lines.
4. Use the largest diameter sensor wires possible (Lowest AWG). This will reduce the lead resistance and, therefore, reduce coupling. However, in many cryogenic applications, wire size must be kept small because Thermocouple wire is a good heat conductor.

<u>Grounded Thermocouple Issues.</u>
Assuming that a grounded Thermocouple is properly connected, as described above, the controller should operate properly. If this is not the case, the problem can usually be tracked to the ground connection made at the sensor relative to the ground at controller.

As noted above, the ground potential at the Thermocouple sensor must fall within the ±5 volt input range of the controller.

Usually, the voltage difference between the sensor ground and the controller's ground is an AC power line signal. It can be seen with a battery powered AC voltmeter connected between the controller's chassis and a ground point near the sensor.

If there is a significant voltage difference, a safety hazard may be present. Building wiring should be tested before proceeding.

A voltage difference caused by a loose, or non-existent, ground reference can be corrected by:

1. Establishing a good quality ground point that the controller and sensor grounds are both connected to.
2. Running a ground strap. The preferred connection of the ground strap would be from a ground point near the sensor to the Third-Wire ground connection of the controller’s AC power cord. If this is not available, the strap can be connected to the controller’s chassis.

Adding a New Sensor

This procedure identifies how to add a new sensor type to the controller. If the desired sensor is already installed as a factory installed sensor or previously installed user sensor, this procedure is not required. These sensors can be simply assigned to an input channel by using the Input Channel Setup Menu described above.

Adding a new sensor to the Model 34 is a two-step process. First, the sensor type must be defined using the Sensor Setup Menu. Next, the sensor's calibration curve must be entered by using the Calibration Curve Menu.

Note that, if the new sensor has a long calibration curve, this entry from the front panel may be tedious. In these cases, the user may consider entering the sensor via the remote interfaces using the controller's utility software.

To add a sensor using one of the remote interfaces, please refer to the Remote I/O section command syntax etc.

Sensor Setup

The new sensor type is defined using the Sensor Setup Menu. An example is shown here.

```
     Sensor Setup
14: User Curve 9
Type: Diode
Multiplier:      -1.0
Units: Volts
 N: 144

EDIT CAL CURVE
```

The first line of this menu includes the Sensor Index (14) and the name (User Curve 9).

When the sensor type index field is selected, rotation of the Selector Knob will cause the Model 34 to rotate through all available sensor types, including factory installed sensors.

Note that, if a factory sensor is selected, the words No Edit will appear indicating that this sensor may not be changed by the user.

In order to install a new sensor, one of the twelve user sensors should be selected.

Next, the type of sensor should be defined. Choices are: Silicon Diodes, various resistors and Thermocouples. This selection will identify the excitation current and voltage input range that the controller must use to interface with the sensor. Selections are given in the Supported Sensors Table.

The Multiplier field specifies a multiplier that is applied to the sensors calibration curve. The sign of this field indicates the temperature coefficient.

Most commonly, the multiplier field contains a value of plus or minus 1.0. This causes the controller to apply the sensor calibration curve directly, without first scaling it. Further, a negative value will indicate that the sensor has a negative temperature coefficient and a positive value will indicate a positive coefficient.

Diode sensors will generally have a Multiplier of –1.0 since their temperature coefficient is negative and no scale is applied to the calibration curve.

100Ω Platinum sensors will use a Multiplier of 1.0. However, if a 1000Ω sensor is used with a calibration curve for 100Ω sensors, a Multiplier of 10.0 should be used.

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

The LogOhms selection is only used with Negative-Temperature-Coefficient resistor sensors, where it acts to improve the accuracy of interpolation.

The N field is the number of valid points in the calibration curve and is generated from the entries made during the editing process.

Selecting the 'EDIT CAL CURVE' field will cause the screen to go to the Calibration Curve menu for the selected sensor. Here, the calibration curve may be entered or edited.

<u>Selecting Sensor Units</u>
Before setting up a sensor calibration curve, the primitive units of the curve must be selected. As described in the above section, units may be Ohms, Volts or LogOhms. This selection determines how sensor readings are converted to temperature. It also affects how measurements are made by the controller.

Diode and Thermocouple type sensors must use calibration curves that are in units of Volts. This will cause the controller to make a voltage-mode reading and apply it to the sensor's calibration curve to determine temperature.

Resistive sensors should use Ohms or LogOhms setting. This will cause the controller to perform a Ratiometric reading of resistance.

Most Positive-Temperature-Coefficient resistors have a relatively linear calibration curve, so units of Ohms should be used. These sensors include Platinum RTDs.

Negative-Temperature-Coefficient (NTC) resistor sensors have a calibration curve that is more linear in Logarithm-of-Ohms and should use the LogOhms selection. This will cause the controller to compute the base 10 Logarithm of the resistance measurement before applying it to the calibration curve to look up temperature. This will significantly improve the accuracy of the calibration curve interpolation algorithm and result in higher accuracy readings.

Examples of NTC sensors include: Ruthenium-Oxide, Cernox™, Carbon Glass™, Germanium and Thermistors.

Cubic Spline Interpolation

Cryo-con controller products compute temperature by using a Cubic Spline Interpolation algorithm on the sensor'' calibration curve. This is a higher-order interpolation than the common straight-line algorithms and results in higher accuracy.

A straight-line interpolation will look at a point above and a point below the current sensor reading and compute temperature based on the assumption that the actual calibration curve is a straight line connecting the two points.

The Cubic Spline algorithm looks at two points above and two points below the current sensor reading and computes temperature by assuming that the sensor's calibration curve is a continuous curve fitted through the four points.

To get best accuracy from the Cubic Spline, the sensor's calibration curve must be at least two points above and two points below every point in the sensor's operating range. If a sensor reading is taken at the top or bottom of the curve, the Spline algorithm will degenerate to straight-line interpolation.

Calibration Curve Entry

Once a sensor type is defined, the calibration curve for that sensor may be entered. This may be done by using the Calibration Curves Menu described above, or, using any of the remote I/O ports, or using the Model 34 Utility Software package.

One very efficient way to enter a new calibration curve is to use the instrument's CalGen™ feature to generate a new curve from an existing one. Operation of this feature is described below.

Using an external power booster

Some systems require more power than the Model 34 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 34.

Both control loops of the Model 34 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 0.05W. This will cause the loop to output a full-scale programming current of 0.033A.
3. If the booster supply requires a voltage input, the loop output will need 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.

To use a booster supply with the Loop 2 output, setup as follows:

1. On the Analog Output Configuration Menu, set the Output Type to 'Htr'. This will configure Loop 2 to operate as a standard heater output. Full Scale programming current will be 20mA.
2. If the booster supply requires a voltage input, the loop output will need a programming resistor to set the full-scale programming voltage. This resistor can be installed across the input terminals of the power supply.
3. Connect the Loop #2 output to the booster supply to the programming input of the booster supply and set up the supply according to the manufacturer's documentation.

Since most booster supplies are programmed by a voltage input instead of a current, a programming resistor will be required to match the current output of the Model 34's control loops to the supply. The value of this resistor is:

R = Vprogram / Iout

Where Vprogram is the booster supply's programming voltage, usually either 10 Volts or 5 Volts and Iout is the full-scale programming current output of the control loop.

Therefore, if Loop 1 is being used, the programming resistor value is:

R = Vprogram/0.033

Or, for Loop 2:

R = Vprogram/0.020

Be careful that the maximum power dissipation of the programming resistor is not exceeded.

In the case of Loop 1, the power dissipated in the programming resistor is:

Pd = R * 0.0011

Or, for Loop 2:

Pd = R * 0.0004

Instrument Calibration

Calibration of the Model 34 controller requires the use of various voltage and resistance standards in order to generate calibration factors for the many measurement ranges available.

The Model 34 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 34 is supported on our automated calibration systems, which allow Cryo-con to provide this service at competitive prices.

Calibration Interval

The Model 34 should be calibrated on a regular interval determined by the measurement accuracy requirements of your application.

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

Whatever calibration interval you select, Cryo-con recommends that complete re-adjustment should always be performed at the calibration interval. This will increase your confidence that the instrument will remain within specification for the next calibration interval. This criteria 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 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 100 Ω resistors.
- The 10,000Ω range (Type R10UA) requires 10KΩ and 1KΩ resistors.
- The 80mV Thermocouple (optional) range requires voltages of +0.075 and –0.075 Volts.

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

The Basic Calibration Sequence

You must first connect the Model 34 to a computer via the RS-232 (Serial) or IEEE-488 (GPIB) interface and then run the Utility Software provided with the controller. The Utility Software must be version 7.4.2 or higher.

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.

In case of an error, please correct the port connection settings and try again.

From the main menu, select Operations->Unit Cal. The program will read the current calibration values from the instrument and display a calibration screen as shown below. All calibration operations can be performed by using this screen.

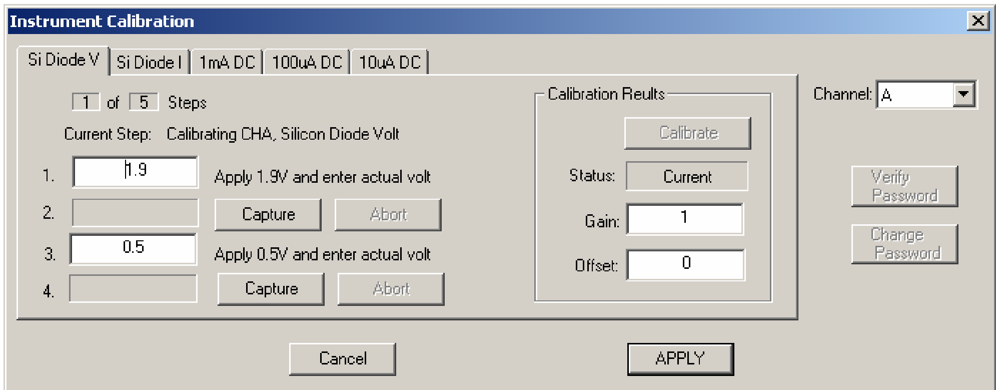


Figure 7: Instrument Calibration Screen

☞ **Note:** Newer Cryo-con instruments will require a password before calibration data can be saved. The utility software will allow you to enter and change the password. The default password is: **cryocon**

On the far right of the screen, a drop-down box selects the channel to be calibrated. Be sure you have selected the correct channel. In order to perform a complete calibration, you will need to 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 will initially be set to 'Current' and the **Gain** and **Offset** values shown will be 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.

There are two methods available for calibration:

1. Automatic. The software will recommend voltages and resistances. You can set these values on the input channel and capture the instrument's actual readings. Then, the software will automatically generate offset and gain values for you.
2. Manual: You can manually enter Offset and Gain values and send them to the instrument.

Manual Calibration

Input Ranges

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.

Gain values greater than 1.2 or less than 0.8 are rejected as out of range.

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 usually calculated by:

Offset = UT - gain * UM

Constant-Current Source Trim Pots

> ☞ **Note:** The only internal adjustments in the Model 34 are trim-pots that adjust the 10μA constant-current sources that are used for measurements with diode sensors. They do not affect the measurement of resistor sensors.

There are four trim-pots, one for each input channel, located near the rear panel of the instrument.

To manually calibrate the constant-current sources, remove the top cover of the instrument and apply a 100KΩ resistor to the desired input channel.

From the input setup menu, select any diode sensor as an input sensor and set the **Units** field to S. Then, press the **Home** key.

Adjust the trim-pot for each channel to read 1.0000 Volts with the 100KΩ resistor on the input.

Automatic Calibration

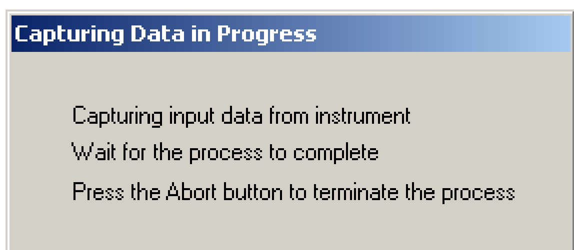
Automatic calibration uses the left-hand side of the calibration screen and is a four-step process:

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

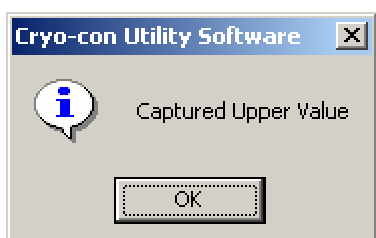
   First, establish a voltage or resistance on the selected input channel that is near the recommended value. Then, enter the actual value in the box provided.

2. Click the Capture button on Line 2. The software will wait for the reading to stabilize and then will capture 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 will be 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 will capture the reading and display it in the edit box on Line 4.

When the above procedure is complete, you will have established upper and lower target values as well as upper and lower measurements. The edit boxes on lines 2 and 4 will contain the measured values. At this time, you may still change the target values on line 1 and 3 if desired.

Now, you can automatically compute the required gain and offset values by clicking on the **Calibrate** button in the **Calibration Results box**. This will change the **Status** field from ‘Current’ to ‘Calibrated’ and will update the **Offset** and **Gain** values with those calculated.

At this point, no values have been transmitted to the instrument.

In order to send the offset and gain values to the instrument’s calibration memory, click the **APPLY** button. You will be required to confirm that you really want to update calibration memory.

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 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
VTC80	+80mV to –80mV	N/A	Thermocouple measurements.

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 precision voltage reading.

Diode Voltage Calibration

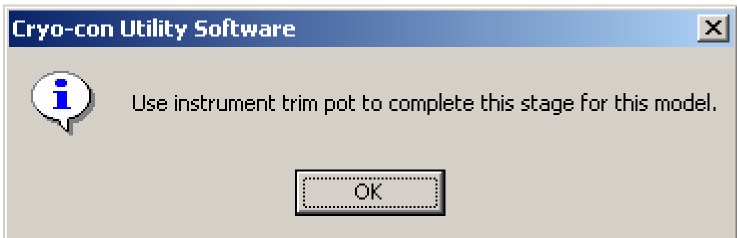
To calibrate the diode voltage range, click on the **SI Diode V** tab and follow the sequence described above to send Gain and Offset values to the instrument.

The upper target requires connection of a 1.9 Volt source. The actual value is between 1.0 Volts and 2.4 Volts. If you do not have a precision voltage source, you can use 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 you do not have a precision voltage source, you can 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. When you click on this tab, the following dialog box will appear:



The only internal adjustments in the Model 34 are trim-pots that adjust the 10µA constant-current sources that are used for measurements with diode sensors.

There are four trim-pots, one for each input channel, located near the rear panel of the instrument. To access these, you will need to remove the instrument's top cover.

Calibration requires connection of a 100KΩ resistor. The actual value should be within 10% of 100KΩ and should be accurately measured. The utility software will set the Model 34 into a measurement mode that will allow trim-pot adjustment.

Adjust the trim-pot for the selected input channel to read 1.0000 Volts with the 100KΩ resistor on the input.

When complete, dismiss the dialog box by clicking on OK.

Calibration of DC resistors

Resistor sensors that use direct current excitation are calibrated by using the **1mA DC**,
100uA DC and **10uA DC** tabs.

Resistors required for calibration are as follows:

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

Cryo-con Utility Software

Cryo-con provides a PC compatible utility software package with it's controllers. This is available on CD, or on the Internet.

Utility software can be used to control any Cryo-con controller via the RS-232, USB or IEEE-488 interface. It runs under all versions of the Windows operating system. Note, consult factory for the availability of USB drivers for Windows 2000.

This software provides several useful functions, including:

1. Instrument monitoring, including continuous displays of temperature and heater power. All input and output channels on the controller may be displayed.
2. Data Logging. This function allows the user to record data from the controller to hard disk at a specified sample rate. The resulting disk file is compatible with most spreadsheet and data analysis software.
3. Uploading and downloading controller firmware. Updates may be obtained on CD, or on the Internet.
4. Download or upload sensor calibration curves. The software will accept curves in either Cryo-con .CRV format, or Lakeshore .340 format.
5. Cryo-con's CalGen™ function is implemented in this software, in addition to being in the controller itself. 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.
6. Upload and download PID tables to the controller. These tables can be generated by using a simple text editor and downloaded to the controller.
7. Configuration of any of the controller's three remote interfaces.
8. Flexible 'Help' interface that documents all controller remote commands with a cut-and-paste type interface.
9. 'Terminal Mode' provides interactive communication with the controller over any of the remote interfaces.

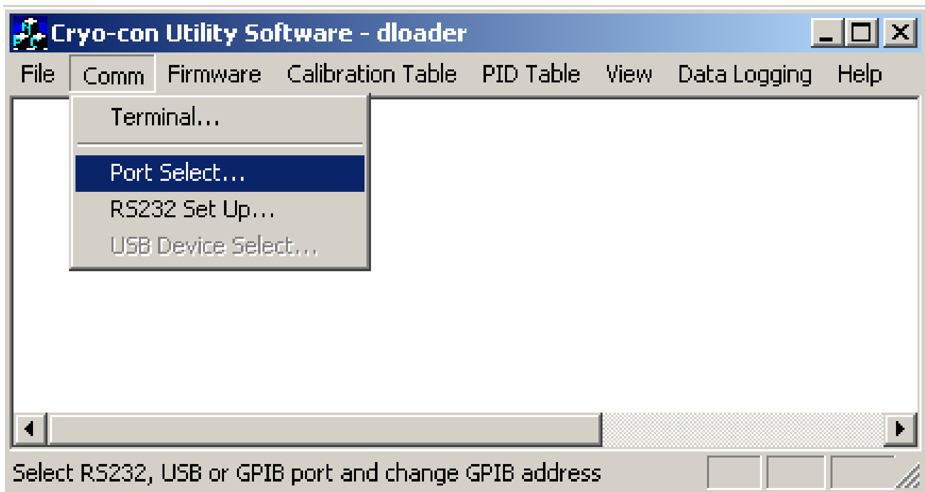
Installing the Utility Software

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.

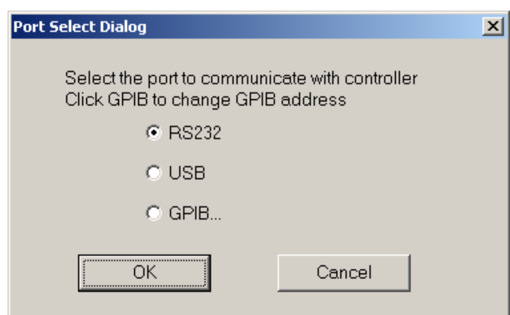
Selecting a Remote Interface Connection

The desired remote interface connection may be selected by first selecting Comm, then Port Select as shown below:



This will bring up the Port Select dialog box where the desired remote port can be selected.

When the **OK** button is clicked, the Utility Software will display further dialog boxes to configure the selected port.



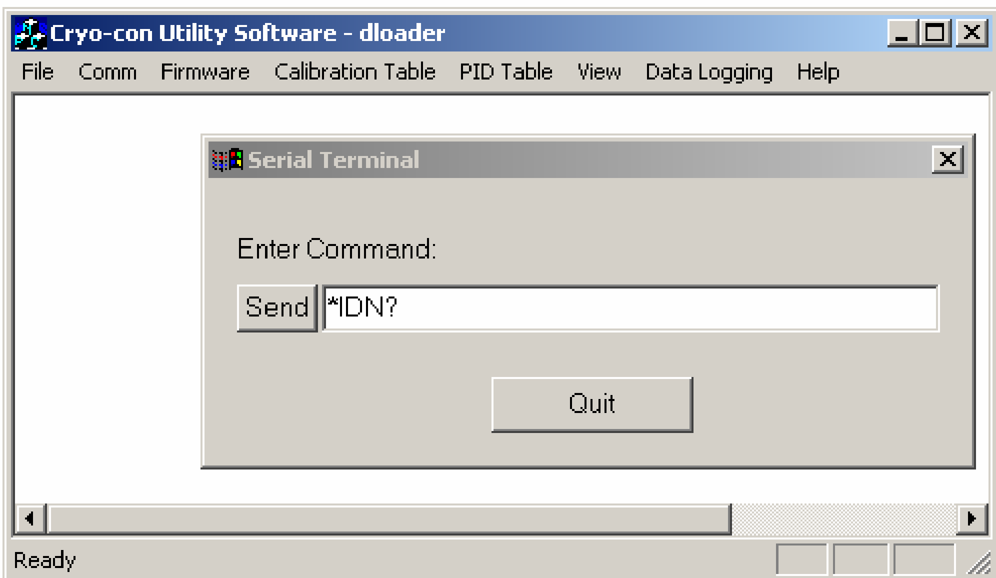
Using the Interactive Terminal

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

Terminal mode is selected by selecting **Comm>Terminal**. This will result in the display shown below.

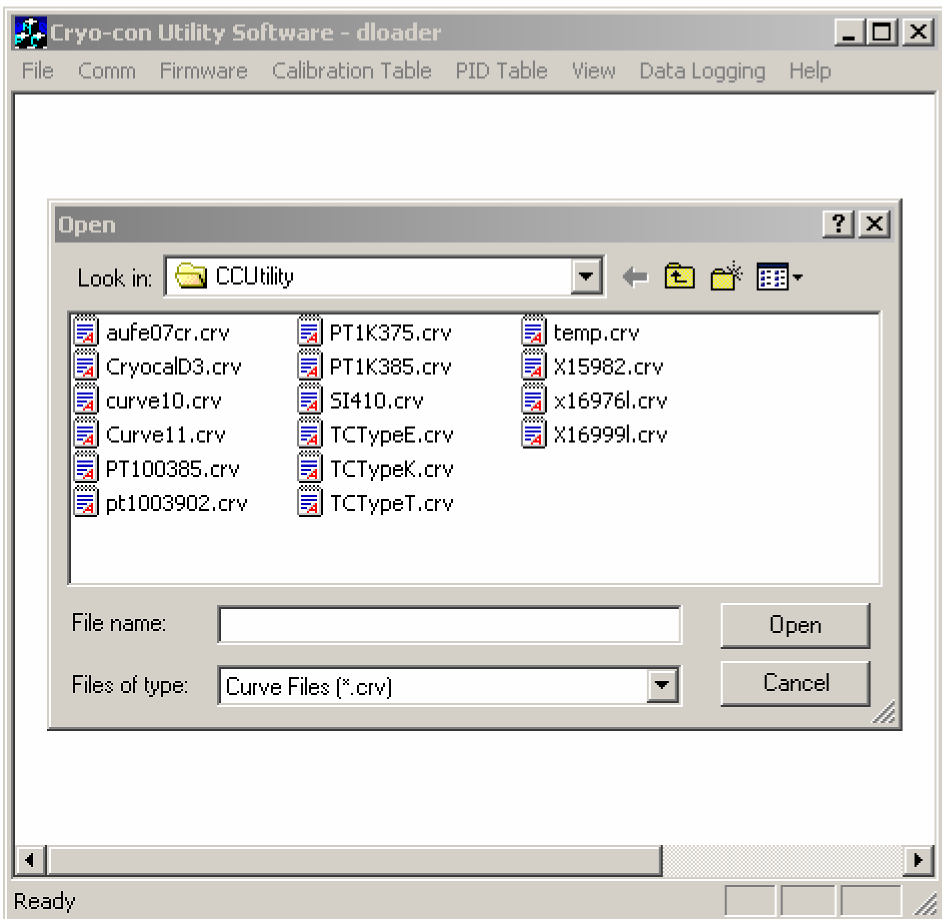
To interact with the controller, type a remote command into the dialog box and click **Send**. The command will be transmitted to the controller and a response, if any, will be displayed on the background pane.

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 controller by using the Calibration Table menu.

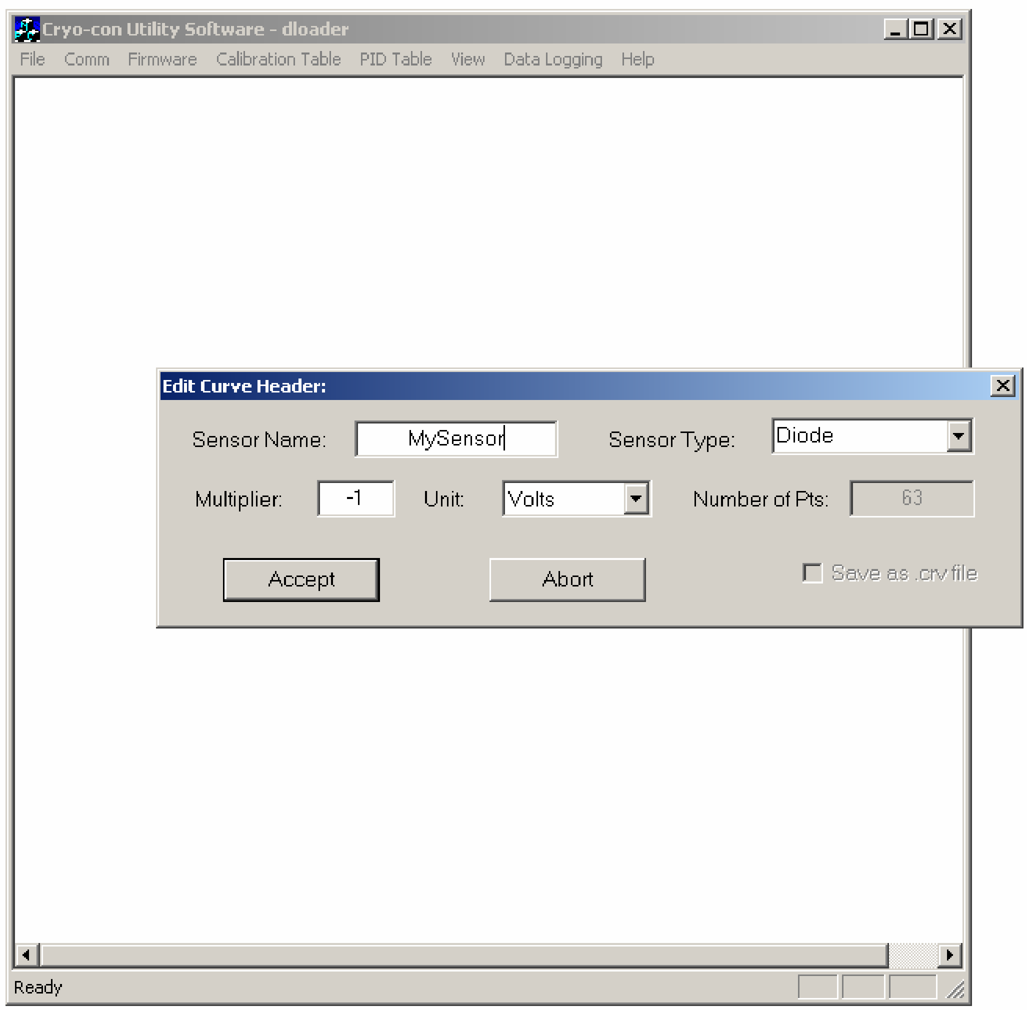
To download a curve (send it from the PC to the controller), select Calibration **Table>Download** on the main tool bar. This will cause a file selection dialog box to appear as follows:



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.

Cryo-con .CRV files are ASCII text files that may be edited by any text editor. The format of the curve is available in the Utility Software's HELP menu and is described in the section titled CALCUR commands.

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.

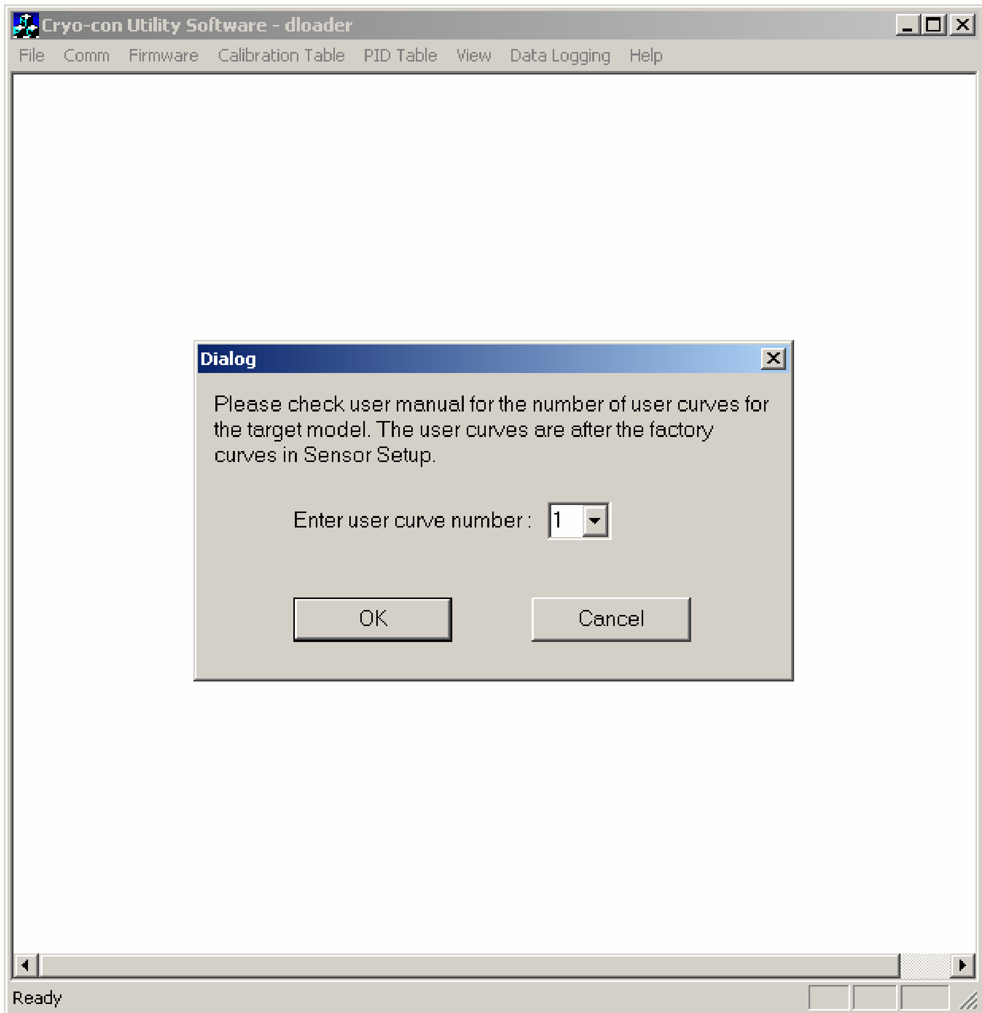
Sensor type can be selected from a pull-down menu or entered directly. Note that different models of Cryo-con instruments support different types of sensors. Therefore, it is important to enter a sensor type that is supported by the specific product. If the controller receives a sensor type that it does not support, the 'Diode' type is selected. The section titled Supported Sensors 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 may be: Volts, Ohms or LogOhm.

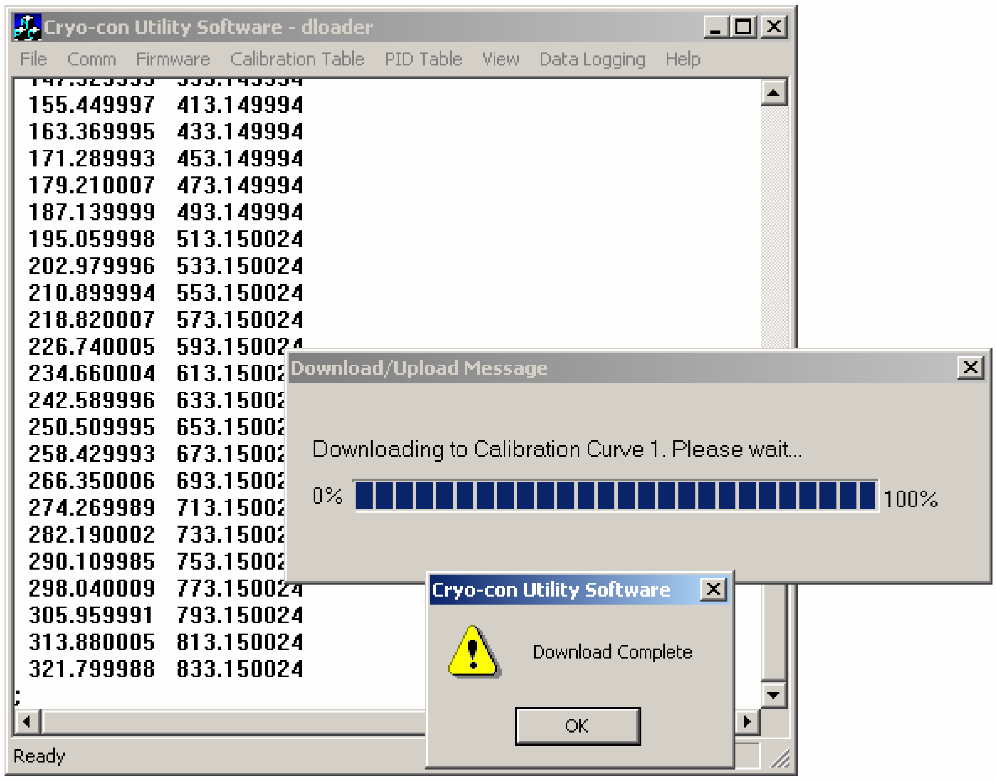
Checking the 'Save as .crv' will save the curve to disk as a Cryo-con .crv file.

After completing the curve header dialog box, click 'Accept' and the, curve number dialog box will appear:



A user calibration curve should be entered here. For the Model 32, user curves are 1 through 4. For the Model 34 and Model 62, user curves are 1 through 12.

When OK is selected, the sensor calibration curve will be downloaded to the controller. 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 controller to the PC.

Downloading or Uploading a PID Table

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

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

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

Downloading Instrument Firmware

A primary feature common to all of Cryo-con's instruments is the ability to download new firmware. As new firmware is released, it is posted on our web site. Further, the firmware that was originally installed in the instrument is available on the CD included in the shipment.

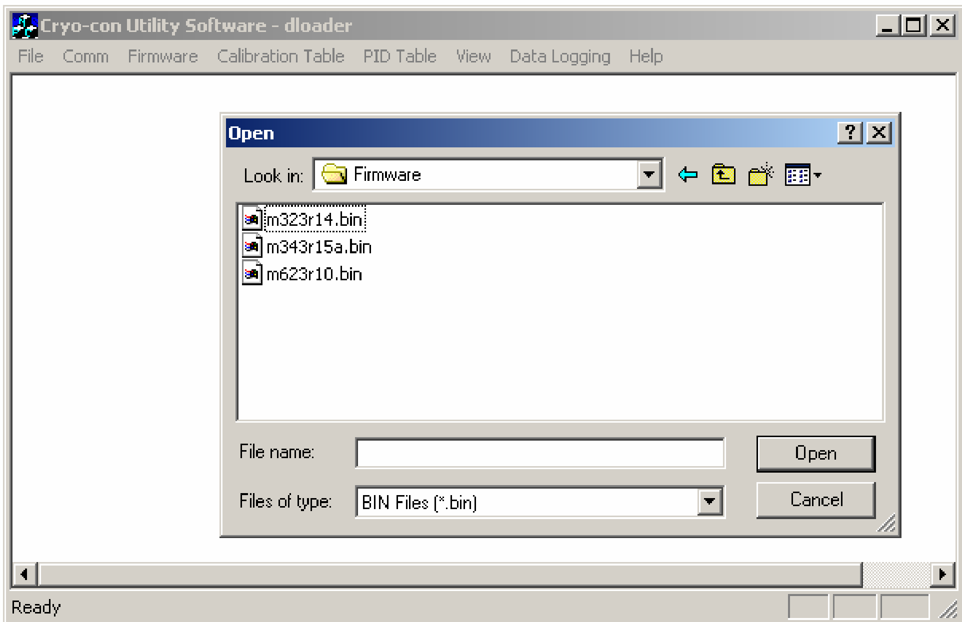
Firmware updates include the addition of new features as well as bug fixes. Installing a new revision writes to all of the available FLASH type memory in the instrument. Therefore, existing calibration curves, instrument setups and PID tables are reset to factory defaults. If user information, such as sensor calibration curves, has been installed, it is recommended that these be uploaded to the computer before new firmware is installed. This way, they can be re-installed after the new firmware.

Firmware download does NOT erase the instrument's calibration data.

Note that FLASH memory is inherently non-volatile and may be re-written in excess of 100,000 times. Therefore, the user need not be concerned about excessive re-writing.

> ☞ **NOTE:** Firmware can only be downloading using the RS-232 serial interface. It cannot be downloaded via the USB or GPIB. Therefore, make sure that you have a null-modem RS-232 cable attached to the controller and that the Utility Software is configured to use RS-232 at a baud rate of 9600. Do NOT use baud rates above 9600 since the firmware update speed is limited by the programming speed of the flash memories.

To download new firmware, select **Firmware>Download** from the Utility Software's main menu. This will result in the display of a file selection dialog box as shown below:



In this dialog box, firmware file names are coded as shown below:

MmmRev.BIN

Where mm is the Model Number, eg: 34, 62 etc. and Rev is the revision code in the format XrXX where the lower case r indicates a period character.

The file extension is always BIN.

☞ **NOTE:** The Utility Software will query the controller before initiating a firmware download. This will prevent inadvertently loading incompatible firmware.

From the file dialog box, find and select the desired firmware file. Then click on the Open button in order to initiate the firmware download.

☞ **NOTE:** Firmware download will be initiated immediately after the Open button is clicked. Once download has started, you should not attempt to stop it.

When a firmware download has successfully started, the LCD display will continuously display the number of records transmitted as shown here. There are 1008 records in a complete firmware download. The process should take about 15 minutes.

```
Records: 0180
Retries: 0
```

The PC screen will show a bar-graph of progress during download.

When the download is complete, the controller will freeze and the PC will display a 'Download Complete' dialog box.

IMPORTANT: At this point, dismiss the dialog box and completely exit the utility software. Do NOT unplug the controller.

Within 15 seconds of exiting the Utility Software, the controller will automatically reset and will launch its power-up sequence with the new firmware revision.

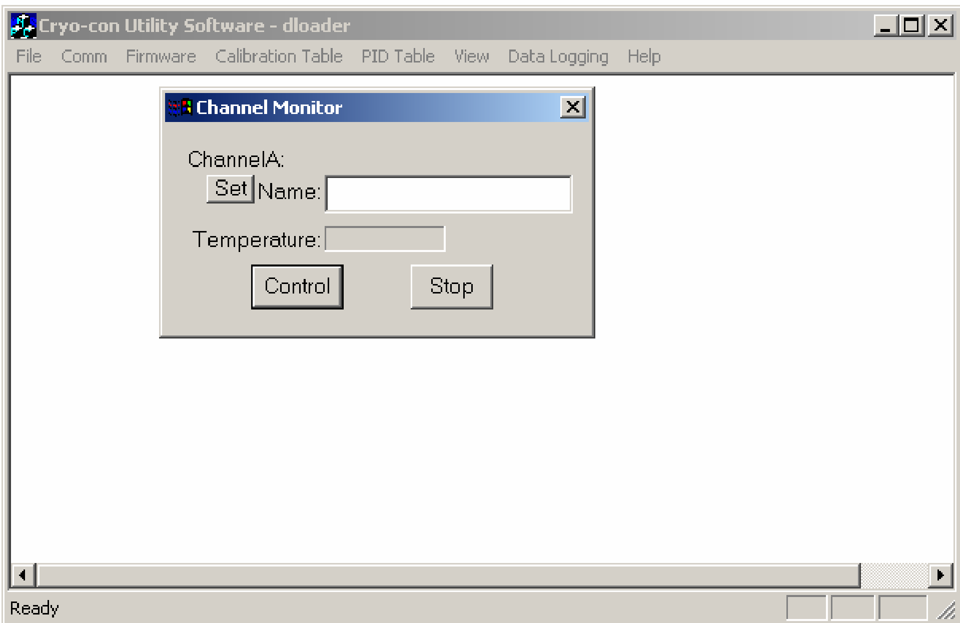
It is recommended that the controller be power-cycled from the front panel one time before it is unplugged from AC power.

If a non-recoverable communications error occurs during firmware download, the controller will power up in an error mode where it is looking for a new firmware transfer on the serial port. The LCD screen will display the transfer display shown above. In this case, repeat the above procedure until the entire firmware transfer sequence works correctly.

Using the Real Time Monitor
The Real Time Monitor 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 dialog box will be displayed for each monitored channel. The dialog box will show the channels Input Identifier, Name String and current temperature.

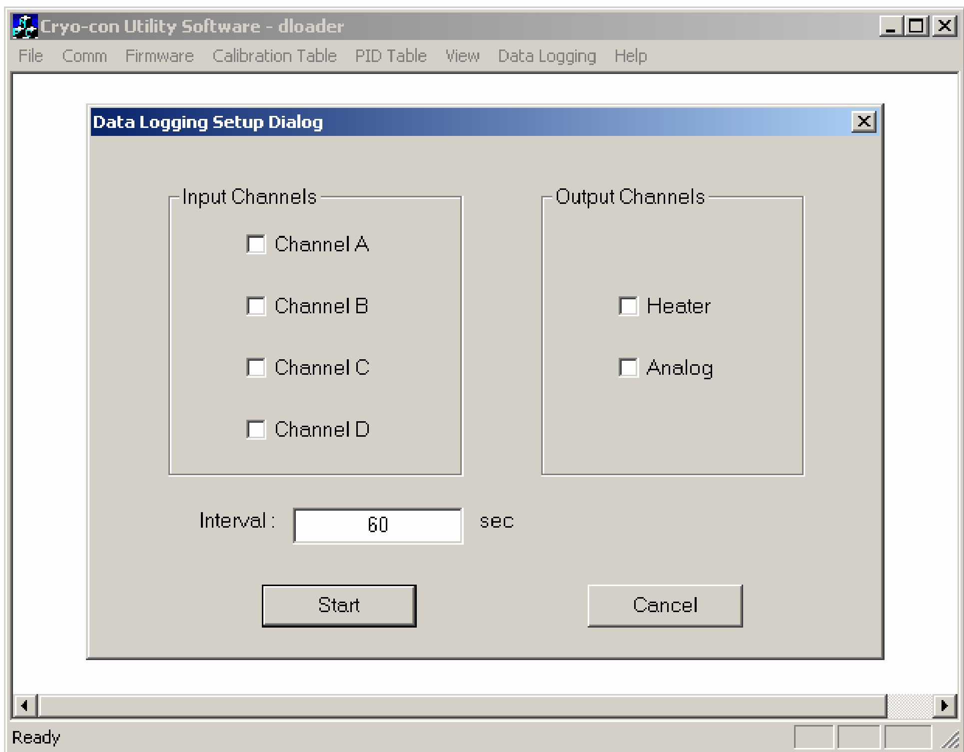


If desired, a new Name String may be entered in the Monitor dialog box. Clicking on the **Set** button will transmit the name to the controller.

The controller's control loops may be started or stopped by clicking on the Control or Stop buttons. The function of these buttons is the same as the Control and Stop buttons on the front panel of the instrument.

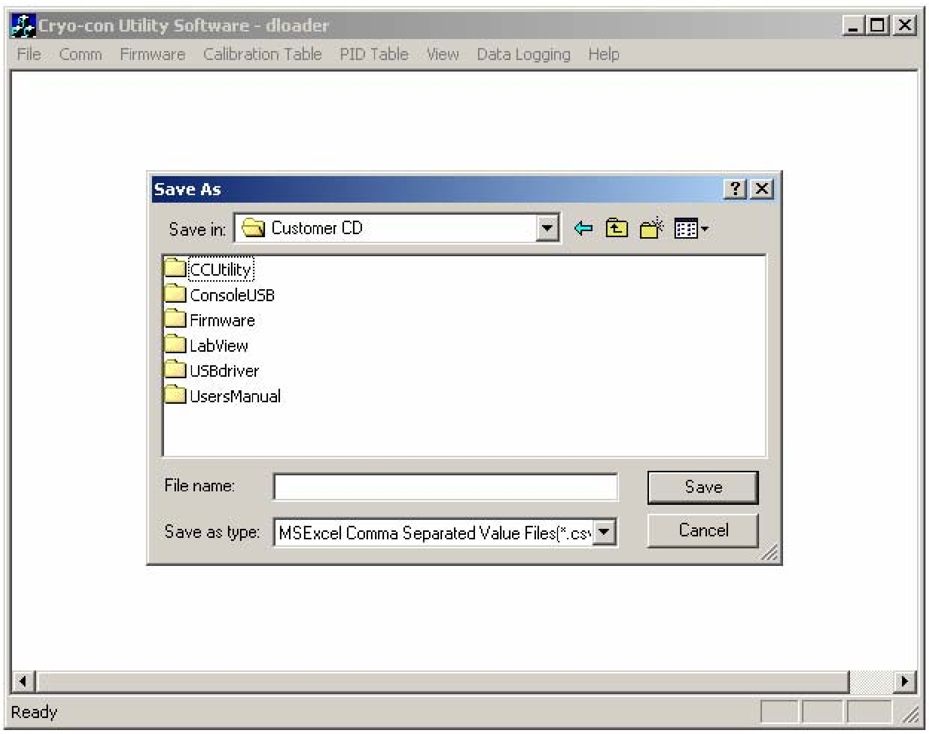
Data Logging
The Utility Software will perform data logging on all of the controllers input and control output channels. The result is a disk file in Comma-Separated-Value, or CSV format. This format is compatible with any data analysis or charting software including Microsoft Excel.

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.

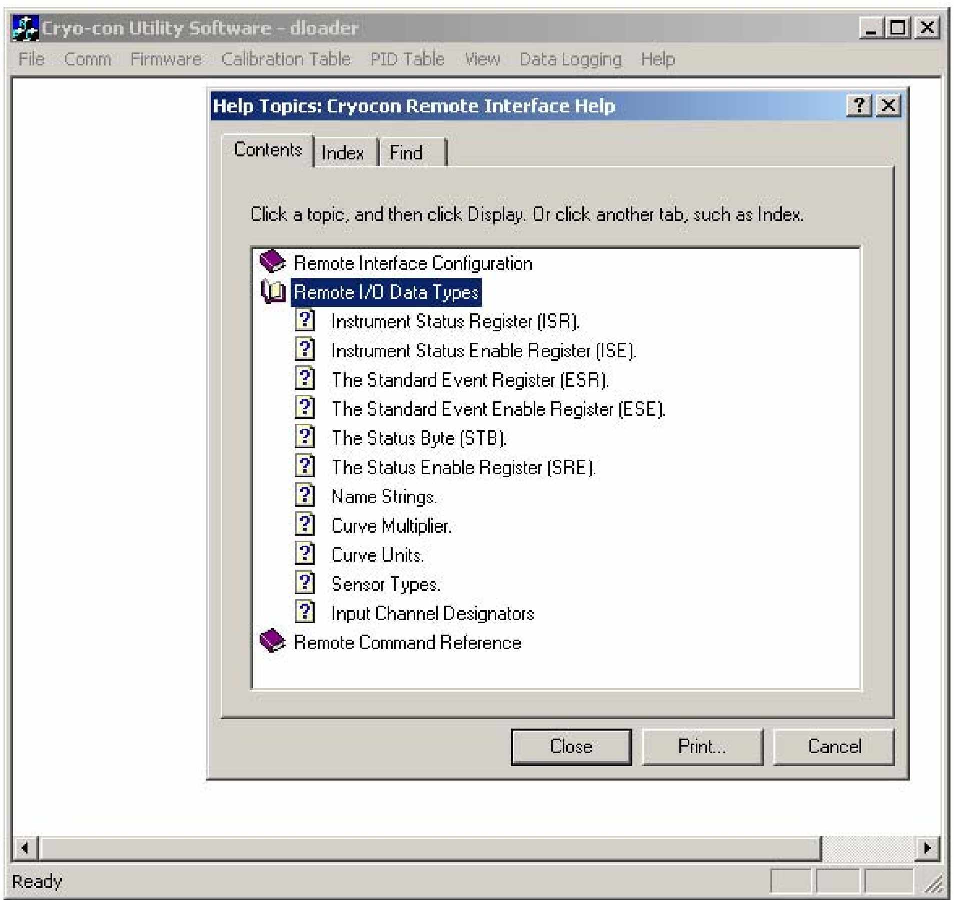
As soon as the **Save** button is clicked, the software will begin continuous data logging to the specified file.

While data logging is in progress, a dialog box will be 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.



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

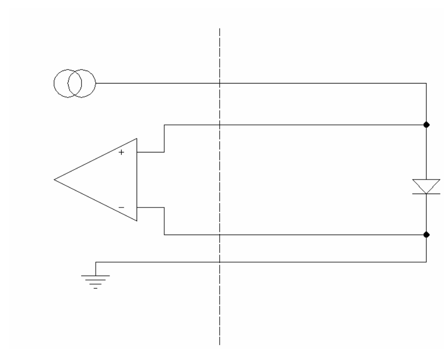
AC Power enters the instrument directly into a power entry module. This provides fusing, line voltage selection and RFI filtering.

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 is fabricated.

Sensor Connection

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



A typical 4-wire measurement scheme is shown here.

Internally, a non-current carrying connection is made from the Sensor Area to the Single-Point-Ground. This connection will "short-circuit" the antenna formed by the analog area and the sensor connections.

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 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 34 cannot assume that its external connections are floating. Therefore, it is connected to the Single-Point-Ground through a Resistor-Capacitor network.

RS-232, GPIB and USB connections all 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 R-C network has a low enough impedance to eliminate common-mode voltages from the unit's power supply, but also has a high enough impedance to reduce ground-loop current flow.

Further, since it is isolated from the other areas of the circuit, no current carrying paths can flow through the other, more sensitive analog circuits.

<u>The USB and RS-232 Connections</u>
The USB and RS-232 connections are three-wire serial communication schemes. Two wires carry signals and the third carries a ground reference.

When either of these interfaces is connected to a Cryo-con controller, the voltage of the digital area is established by the ground reference of the connected interface.

Because of the internal R-C network connection to ground, little if any current can flow back through the system grounds.

Unlike the RS-232, the USB is a differential communications bus, so high speed communication is supported while minimizing EMI radiation.

The GPIB Connection

The GPIB is a 24-wire communications protocol that has six control signal grounds, one data signal ground and one shield ground.

In the Cryo-con controller, the control and signal grounds are connected together and used to establish the ground reference potential for the digital area.

The Shield ground connection is connected to the instrument's Single-Point-Ground through a jumper. The jumper is available since some manufacturers connect the GPIB's shield ground to their circuit board ground and, therefore, ground loops are established through the shields.

Remote Operation

Remote Interface Configuration

The Model 34 has three remote interfaces: The Universal Serial Bus (USB), The GPIB (IEEE-488.2) and the RS-232. Connection to these interfaces is made on the rear panel of the instrument. For specifics about the connectors and cables required, refer to the section above on Rear Panel Connections.

Configuration of the remote interfaces is done at the instrument's front panel by using the Remote I/O Setup Menu.

An example of the Remote I/O Setup Menu is shown here.

```
   Remote I/O Setup

Port Select: USB
   Address:  12
 RS232 Rate: 9600
Name: Model 34 Unit 0
 in:HEATER:PGAIN?
out:123.454
```

The bottom two lines of this display are common to all three remote interfaces. The in: line shows the last command received by the instrument and the out: line shows the response generated by that command.

The Name field is a fifteen character string field that can be used to assign a unique name to each controller. Using this, unique labels may be assigned to each controller in a multi-unit environment.

All configuration information shown on this screen is stored in non-volatile memory and, once setup, will not change when power is turned off or a remote interface is reset.

GPIB Configuration

To configure the GPIB, or IEEE-488.2 interface from the Remote I/O Setup menu, use the Selector Knob to move the cursor to the Port Select field and select this field by pressing the knob.

Next, rotate the knob until GPIB is displayed. Press the knob to select the GPIB interface.

The only other GPIB configuration required is setting the address. This is done by moving the cursor to the Address field, typing an address and pressing the ENTER key.

Note that each device on the GPIB interface must have a unique address. You can 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 controller's 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.

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

Table 16: Recommended GPIB: Host Setup Parameters

Universal Serial Bus (USB) Configuration
The Universal Serial Bus is fast, easy to use and inexpensive. Cryo-con provides USB drivers, Dynamic Link Libraries, extensive software examples, Terminal interface software and LabView® drivers for the USB.

The USB is supported on computers running the Windows 98/2000/NT operating systems. For Windows 98, Release 2 is recommended as it provides improved USB error support. Windows 95 is not recommended, even with the USB service patch. Configuration of the USB requires a one time installation of instrument drivers on the computer.

To install the USB drivers on a personal computer, have the Cryo-con USB driver files available on your hard drive. The Windows 98 installation process will copy these files into a system area. After a one time installation, the computer will automatically recognize the instrument whenever the USB connection is made.

The one-time driver installation sequence is:

1. Download CCUSBDLL from the Cryo-con web page at http://www.cryocon.com/ccsupport.htm. Unzip the resulting ccusbio.zip file into a sub-directory of your hard disk. This file contains the actual driver files, ccusbio.inf and ccusbio.sys, as well as the header and Dynamic Link Library files required by applications that communicate with the USB.
2. Connect a USB type AB cable between the PC and the instrument. From the front panel of the Model 34, go to the Remote I/O Setup Menu and move the cursor to the Port Select field. Press the Selector Knob to select the field and rotate the knob until USB is displayed. Press the knob again to select USB.
3. Windows 98 will now display a "Installing New Hardware" message. Proceed through the hardware installation wizard. When you are asked for the location of the drivers, select "BROUSE" and enter the directory of the Cryo-con USB drivers.

When the installation wizard is complete, the PC will recognize the controller each time it is connected and configured for the USB.

Software may be developed for the USB using Microsoft Visual C++®, Visual Basic®, LabWindows/CVI® or LabView®.

The USB is also supported by Cryo-con's Utility Software package, available on our web page.

Programming the USB Interface with Visual C++
Notes on programming Cryocon instruments over the USB are:

1. Input and Output strings on the USB interface are limited to 64 characters.
2. The file CCUSBIO.H must be included at the beginning of the file in order to link to the Dynamic Link Library, CCUSBIO.DLL. This include file documents the functions available as well as error codes etc.
3. The CCUSBIO.DLL file must reside in the same sub-directory as the final executable.

The following example code shows how to perform a simple query of the controller's identification string:

```
#include <stdio.h>
// The file CCUSBIO.H must be included to connect to the USB DLL
#include "CCUSBIO.h"

int main( int argc, char *argv[ ], char *envp[ ] ){
    char InBuf[65];     //Max char buffer is 64 plus null terminator
    int errcode;     //Error codes

    //Open all controller on the USB and report the number.
    int NumUnits = CCUSBOpen();
    if (NumUnits > 0){
        //Error, Number of units on the USB should be > 0
    };

    //Read Instrument Identification String from Device 0
    //... The first unit recognized on the USB.
    DevNo = 0;
    errcode = CCUSBIO(DevNo , "*IDN?", InpBuf);

    //Print the string.
    printf("%s\n",InpBuf);

    //Close all controllers
    CCCloseAll();
    return 0;
};
```

Table 17: USB Software Example in Visual C++

RS-232 Configuration

The user can select RS-232 Baud Rates between 300 and 38,400. The factory default is 9600.

The Baud Rate can be changed from the instrument's front panel as follows:

Go to the Remote I/O Setup Menu.
Move the cursor to the RS232 Rate field.
Press the selector knob to select the field.
Rotate the knob until the desired rate is displayed.
Press the knob to de-select the field.

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 sends 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:

1. Carriage Return, Hex 0xD.
2. Line Feed, \n, Hex 0xA.
3. Null, 0.

☞ **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.

Introduction to Remote Programming

Instructions

Instructions (both commands and queries) normally appear as a string embedded in a statement of your host language, such as BASIC or C

Instructions are composed of two main parts: The header, which specifies the command or query to be sent; and the parameters, which provide additional data needed to clarify the meaning of the instruction.

An instruction header is comprised of one or more keywords separated by colons (:). Queries are indicated by adding a question mark (?) to the end of the header. Many instructions can be used as either commands or queries, depending on whether or not you have included the question mark. The command and query forms of an instruction usually have different parameters. Many queries do not use any parameters.

The white space is used to separate the instruction header from the instruction parameters. If the instruction does not use any parameters, you do not need to include any white space. White space is defined as one or more spaces. ASCII defines a space to be character 32 (in decimal).

Instruction parameters are used to clarify the meaning of the command or query. They provide necessary data, such as whether a function should be on or off, which input channel controls the heater output etc. Each instruction's syntax definition shows the parameters, as well as the values they accept.

Headers

There are three types of headers: Simple Command; Compound Command; and Common Command.

Simple command headers contain a single keyword. CONTROL and STOP are examples of single command headers. The syntax is:

<function><terminator>

When parameters (indicated by <data>) must be included with the simple command header (for example, INPUT CHA) the syntax is:

<function><white space><data><terminator>

Compound command headers are a combination of two or more keywords. The first keyword selects the subsystem, and the last keyword selects the function within that subsystem. Sometimes you may need to list more than one subsystem before being allowed to specify the function. The keywords within the compound header are separated by colons. For example:

SYSTEM:AMBIENT?

To execute a single function within a subsystem, use the following:

:<subsystem>:<function><white space><data><terminator>

Command headers control IEEE 488.2 defined functions within the instrument (such as clear status, etc.). Their syntax is:

*<command header><terminator>

No space or separator is allowed between the asterisk and the command header. *CLS is an example of a common command header.

To execute more than one function within the same subsystem a semi-colon (;) is used to separate the functions:

:<subsystem>:<function><white space><data>

<function><white space><data><terminator>

Command headers immediately followed by a question mark (?) are queries. After receiving a query, the instrument interrogates the requested function and places the response in it's output queue. The output message remains in the queue until it is read or another command is issued.

Query commands are used to find out how the instrument is currently configured. They are also used to get results of measurements

> ☞ **NOTE:** The output queue must be read before the next command is sent. For example, when you send the query, you must follow it with an input statement.

Truncation of Keywords

If a keyword contains more than four characters, it may be truncated to four or less characters to simplify programming.

The truncated 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.

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) or an interrupt packet (USB) 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	Rly1	Rly0	Htr	SFD	SFC	SFB	SFA

Where:

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

Bit6 – Rly1: Indicates that Relay #1 has toggled. Use the RELAYS command to query individual relays.

Bit5 – Rly0: Indicates that Relay #0 has toggled.

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

Bit3 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 Status Event bit in the Status Byte (STB) register. This can cause an interrupt packet (USB) or 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 often 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, or an interrupt packet for the USB.

Remote Commands

IEEE488 Common commands.

The Common Commands are defined by the IEEE-488.2 standard and are supported by the Model 34 on the GPIB port as well as all of the remote interface ports.

The common commands control some of the basic instrument functions, such as instrument identification and reset. They also provide an instrument status reporting mechanism.

*CLS Clear Status

Clear Status

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

Command Syntax: *CLS

Command Example: *CLS

***ESE** Event Status Enable

Event Status Enable.

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 will enable the corresponding bit in the SEV register. A zero will disable the bit.

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

Command Syntax: *ESE <mask>

Query Syntax: *ESE?

Command Example: *ESE 32
Query Response: <mask>

This will set the CME, or Command Error, bit enable. Therefore, when a command error occurs, the event summary bit (ESB) in the Status Byte Register will also be set.

Query Example: *ESE?
Query Response: 16
Bit 4, or the Execution Error bit has been enabled. All other standard events are disabled.

***ESR Query Event Status Register**

Query Event Status Register.

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

Query Syntax: *ESR?
Query Response: <status>
Where status is a number between 0 and 255.

*IDN? Query unit Identification

Query unit identification string.

The *IDN? Query will cause the instrument to identify itself. The Model 34 will return the following string:

"Cryocon Model 34 Rev <fimware rev code><hardware rev code>"

Where <fimware rev code> is the revision level of the unit's firmware and <hardware rev code> is the hardware revision code. Current hardware revision codes are A and X3.

Query Syntax: *IDN?
Query Response: <Instrument Identification String>

*OPC Operation Complete

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

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

Command Syntax: *OPC

Query Syntax: *OPC?
Query Response: 1

***RST** Reset

Reset the controller. This will cause a hardware reset in the Model 34. The reset sequence will take about 15 seconds to complete. During that time, the instrument will not be accessible over any remote interface.

The *RST command sets the Model 34 to it's last power-up default setting.

Command Syntax: *RST

Control Loop Start/Stop commands

STOP Disengage control loops

The STOP command will disengage both control loops and disconnect the heater.

If the Analog Output loop is set to SCALE mode (vs a control mode), it will be active regardless of the loop state.

Command Syntax: STOP

CONTROL Engage Control Loops

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.

As a query, the command will report the status of the loops as ON or OFF.

Command Syntax: CONTROL

Command Example: CONT

Query Syntax: CONTROL?
Query Response: <status>
Where <status> is ON or OFF.

Query Example: CONT?
Example Response: OFF
Indicating that the control loops are OFF, or disengaged.

Short Form: CONT

SYSTEM commands

SYSTEM commands are a group of commands associated with the overall status and configuration of the Model 34 rather than a specific internal subsystem.

SYSTEM:LOCKOUT: Keypad Lockout.

Sets or queries the remote lockout status indicator.

This command is used to enable or lock out the front panel keypad of the Model 34, thereby allowing or preventing keypad entry during remote operation.

The default condition for this indicator is OFF.

Command Syntax: SYSTEM:LOCKOUT <status>
Where <status> is either ON or OFF. A <status> of ON will lock out the front panel keypad.

Query Syntax: SYSTEM:LOCKOUT?
Query Response: <status>

Query Example: SYSTEM:LOCKOUT?
Example Response: OFF
Indicating that the front panel keypad is enabled.

Short Form: SYST:LOCK

SYSTEM:BEEP: Sound the audible alarm

Asserts the audible alarm for a specified number of seconds.

Command Syntax: SYSTEM:BEEP <Sec>
Where <Sec> is the number of seconds to beep the audible alarm.

Command Example: SYSTEM:BEEP 10
Sounds the audible alarm for 10 seconds.

Short Form: SYST:BEEP

SYSTEM :REMLED: Front Panel Remote LED

Sets or queries the remote LED status indicator on the Model 34 front panel.

The default condition for this indicator is OFF.

Note that the Remote LED is automatically handled by the GPIB interface but must be turned on and off when using the RS-232 or the USB interface.

Command Syntax: SYSTEM:REMLED <status>
Where <status> is either ON or OFF. A <status> of ON will illuminate the front panel Remote LED

Query Syntax: SYSTEM:REMLED?
Query Response: <status>

Query Example: SYSTEM:REMLED?
Example Response: OFF
Indicating that the Remote LED is OFF.

Short Form: SYST:REML

SYSTEM:LOOP: Control Loop On/Off

Reports the status of the two temperature control loops.

A status of OFF indicates that both loops are disabled and the output power levels are zero. A status of ON indicates that the loops are engaged and actively controlling temperature.

Command Syntax: N/A
The CONTROL command is used to engage the control loops and the STOP command is used to disengage them.

Query Syntax: SYSTEM:LOOP?
Query Response: <status>

Query Example: SYSTEM:LOOP?
Example Response: OFF
Indicating that both control loops are disengaged.

Short Form: SYST:LOOP

SYSTEM:CONTRAST: LCD Contrast.

The SYSTEM:CONTRAST command is used to set or query the contrast of the front panel LCD display.

Contrast is a single digit from 1(lowest) to 9 (highest).

Command Syntax: SYSTEM:CONTRAST <contr>
Where <contr> is the desired display contrast from 1-9.

Query Syntax: SYSTEM:CONTRAST?
Query Response: <contr>

Command Example: SYSTEM:CONTRAST 5
This command will set the display contrast to 5, or mid range.

Query Example: SYSTEM:CONTRAST?
Example Response: 2
Which indicates that the display contrast is 2, or low.

Short Form: SYST:CONT

SYSTEM:DISTC: Display Filter Time Constant.

The SYSTEM:DISTC command is used to set or query the display filter time constant.

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

Command Syntax: SYSTEM:DISTC <tc>
Where <tc> is the display filter time constant, in seconds, selected from the following list: 0.5, 1, 2, 4, 8, 16,32,64.

Query Syntax: SYSTEM:DISTC?
Query Response: <tc>

Command Example: SYSTEM:DISTC 8
This command will set the display time constant to 8 Seconds.

Query Example: SYSTEM:DISTC?
Example Response: 2
Which indicates that the display filter has a 2 Second time constant.

Short Form: SYST:DIST

SYSTEM:ADRS: GPIB, USB unit address.

Selects the address that the IEEE-488.2 and USB remote interfaces will use.

The address is a numeric value between 1 and 31. The factory default is address 12.

The addresses assigned to units must be unique on each GPIB or USB bus structure. Multiple units with the same address on a single bus structure will cause errors.

Command Syntax: SYSTEM:ADRS <adrs>
Where <adrs> is the desired unit address. The IEEE-488.2 interface on the Model 34 will be re-initialized using <adrs> as it's address.

Query Syntax: SYSTEM:ADRS?
Query Response: <adrs>

Command Example: SYSTEM:ADRS 14
Sets the Model 34 IEEE-488.2 port and USB address to 14.

Query Example: SYSTEM:ADRS?
Example Response: 12
Indicates that the current GPIB address is 12.

Short Form: SYST:ADRS

SYSTEM:REMOTE: Select Remote Interface

Queries or selects the port that the Model 34 will use for all remote communication.

Available ports are:

USB for the Universal Serial Bus port.
GPIB for the IEEE-488.2 port.
RS232 for the RS-232 port.

Command Syntax: SYSTEM:REMOTE <port>
Where <port> is the remote port selection. The Model 34 will first disable all remote ports, then initialize and re-enable the selected port.

This command can be used as a port reset.

Query Syntax: SYSTEM:REMOTE?
Query Response: <port>

Command Example: SYSTEM:REMOTE USB
Selects the USB remote port. If the USB is already selected, it is re-initialized and enabled.

Query Example: SYSTEM:REMOTE?
Example Response: RS232
Indicates that the current remote port is RS-232

Short Form: SYST:REMO

SYSTEM:NVSAVE Save NVRAM to flash

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.

Command Syntax: SYSTEM:NVSAVE

Short Form: SYST: NVS

SYSTEM:AMBIENT Query Internal Temperature.

The Model 34 incorporates a temperature sensor into it's internal voltage reference as part of the active ambient temperature feedback scheme. This temperature is essentially the internal temperature of the instrument and may be queried using the SYSTEM:AMBIENT command.

Query Syntax: SYSTEM:AMBIENT?
Query Response: <temp>
Where <temp> is the internal temperature of the Model 34 in degrees Celsius.

Query Example: SYSTEM:AMB?
Example Response: +25C
Indicates that the current temperature of the Model 34's internal voltage reference is 25°C.

Short Form: SYST:AMB
Where AMBIENT is truncated to four characters, then to three since the fourth character is a vowel.

SYSTEM:HTRREAD: Heater read back current.

The output current of the main heater in the Model 34 is continuously monitored by an independent read-back circuit. This is used internally to detect and report heater fault conditions and may be queried using the SYSTEM:HTRREAD command.

Read-back current will be reported as a percent of full scale. The absolute value of full scale is determined by the selected heater range as follows:

Heater Range	Full Scale Current
50 / 25 Watt	1.0A
5 / 2.5 Watt	0.333A
0.5 / 0.25 Watt	0.1A
0.05 / 0.03 Watt	33m A

Query Syntax: SYSTEM:HTRREAD?
Query Response: <current>
Where <current> is the heater output current as a percent of full scale.

Query Example: SYSTEM:HTRR?
Example Response: 33%
Indicates that the heater output current has been measured at 33% of full scale by the heater read-back circuit.

Short Form: SYST:HTRR

SYSTEM:HTRHST: Heater heat sink temperature.

The temperature of the Model 34's internal heater circuit heat sink is continuously monitored and used to initiate the automatic shutdown sequence when a heater fault is detected. This temperature may be queried using the SYSTEM:HTRHST command.

Query Syntax: SYSTEM:HTRHST?
Query Response: <temp>
Where <temp> is the temperature of the internal heater output stage's heat sink in Celsius.

Query Example: SYSTEM:HTRH?
Example Response: +62C
Indicates that the heat sink is at 62°C.

Short Form: SYST:HTRH

SYSTEM:HOME: Display Operate Screen.

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

Command Syntax: SYSTEM:HOME

Command Example: SYSTEM:HOME

Short Form: SYST:HOME

SYSTEM:NAME Unit Name

The controller contains a unit name string that may be set or queried using this command. This name is useful when using the USB interface since the USB assigns addresses to devices based on the sequence that they are attached to the bus. Here, the unit name can be used to assign a descriptive name to the instrument.

Use the SYSTEM:ADRS command to assign a unique address to the unit on the USB or GPIB interfaces.

Command Syntax: SYSTEM:NAME <name>
Where <name> is the desired system name string and is a maximum of 15 ASCII characters.

Command Example: SYSTEM:NAME "Cryocooler Four"
This assigns the name "Cryocooler Four" to the unit so that it may be uniquely identified on the USB.

Query Syntax: SYSTEM:NAME?
Query Response: <name>
Where <name> is the temperature of the internal heater output stage's heat sink in Celsius.

Query Example: SYSTEM:NAME?
Example Response: Model 34 Unit 0

Short Form: SYST:NAM

SYSTEM:HWREV: Instrument Hardware Revision Level

Queries the instrument’s hardware revision level.

Query Syntax: SYSTEM:HWREV?

Query Example: SYSTEM: HWREV?
Example Response: A
Indicating that the instrument’s hardware is revision level A.

Short Form: SYST:HWR

SYSTEM:FWREV: Instrument Firmware Revision Level

Queries the instrument's firmware revision level.

Query Syntax: SYSTEM:FWREV?

Query Example: SYSTEM:FWREV?
Example Response: 3.18
Indicating that the instrument's firmware is revision level 3.18.

Short Form: SYST:FWR

SYSTEM:CJTEMP: Cold Junction Temperature Query

Queries the internal Cold Junction Temperature used for Thermocouple sensors.

Query Syntax: SYSTEM:CJTEMP?

Query Example: SYSTEM:CJTEMP?
Example Response: +28C
Indicating that the current cold junction compensation temperature is 28C.

Short Form: SYST:CJT

SYSTEM:LINEFREQ: AC Power Line Frequency.

Sets or queries the AC Power Line frequency setting.

Command Syntax: SYSTEM:LINEFREQ <freq>
Where <freq> is the AC Power Line Frequency and may be either 50 or 60 for 50Hz or 60Hz.

Command Example: SYSTEM:LINEFREQ 60
Sets the AC Power Line Frequency setting to 60 Hz.

Query Syntax: SYSTEM: LINEFREQ?
Query Response: <freq>
Where <freq> is the line frequency setting.

Query Example: SYSTEM: LINEFREQ?
Example Response: 50

Short Form: SYST:LIN

SYSTEM:DRES: Display Resolution.

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

FULL: The LCD will display temperature with the maximum possible resolution.

1, 2 or 3: The LCD display will display 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 LCD. 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.

Command Syntax: SYSTEM:DRES <res>
Where <res> is the display resolution as follows: FULL, 1, 2, 3.

Command Example: SYSTEM:DRES 2
Causes the LCD display to show temperature with two digits to the right of the decimal point..

Query Syntax: SYSTEM:DRES?
Query Response: <res>
Where <res> is the display resolution

Query Example: SYSTEM:DRES?
Example Response: FULL

Short Form: SYST:DRES

SYSTEM:SETUP commands

The SYSTEM:SETUP commands are used to save and restore any of the six available user instrument setups. Each setup contains the complete state of the controller.

SYSTEM:SETUP:NAME: User Setup Name.

Instrument setups can be named for user convenience. The SYSTEM:SETUP:NAME command sets and queries these names.

Command Syntax: SYSTEM:SETUP <ix>:NAME <name>
Where <ix> is the index number of the desired instrument setup. Values may be 0 through 5. <name> is the desired name string and is a maximum of 15 ASCII characters.

Command Example: SYSTEM:SETUP 3:NAME "Product Alpha"
This assigns the name "Product Alpha" to instrument setup #3.

Query Syntax: SYSTEM:SETUP <ix>:NAME?
Query Response: <name>
Where <name> is the temperature of the internal heater output stage's heat sink in Celsius.

Query Example: SYSTEM:SETUP 0NAME?
Example Response: "Dewar Two"

Short Form: SYST:SETUP:NAM

SYSTEM:SETUP:SAVE: Save User Configuration.

Saves the current instrument setup to a user setup.

Command Syntax: SYSTEM:SETUP <ix>:SAVE
Where <ix> is the index number of the desired instrument setup. Values may be 0 through 5.

Command Example: SYSTEM:SETUP 1:SAVE
Saves the controller's current setup to user setup #1.

Short Form: SYST:SETUP:SAV

SYSTEM :SETUP:RESTORE: Restore User Configuration.

Restores a previously stored user instrument setup.

Command Syntax: SYSTEM:SETUP <ix>:RESTORE
Where <ix> is the index number of the desired instrument setup. Values may be 0 through 5.

Command Example: SYSTEM:SETUP 0:RESTORE
Restores the controller's setup from user setup #0.

Short Form: SYST:SETUP:REST

STATS commands, Input channel statistics

Temperature statistics on every enabled input channel are continuously accumulated.

Accumulation is initialized whenever a channel is first enabled, or, when a reset command is received.

The STATS commands include the RESET command and a TIME command that queries the duration of the accumulation. Queries of statistical data are made using the INPUT commands.

STATS:TIME Accumulation time

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

TIME is reset by issuing the STAT:RESET command.

Query Syntax: STATS:TIME?
Query Response: <time>
Where <time> is the time, in Minutes, that has elapsed since the channel statistics were reset.

Query Example: STATS:TIME?
Example Response: 2.32
Indicating 2.32 Minutes have elapsed.

Short Form: STAT:TIM?

STATS:RESET Reset Statistics

Resets the accumulation of input channel statistical data.

Command Syntax: STATS:RESET
Resets the accumulation of input channel statistics.

Command Example: STATS:RESET

Short Form: STAT:RES

INPUT commands

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

INPUT may also be a stand alone query. For example: INPUT? A will return the current temperature on input channel A.

Parameter references to the input channels may be:

- Numeric ranging in value from zero to three.
- Channel ID tags including CHA, CHB, CHC and CHD.
- Alphabetic including A, B, C or D.

INPUT: Input Channel Temperature Query.

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 Syntax: INPUT ? <channel>
Where <channel> is the input channel parameter.
Query Response: <temp>
Where <temp> is the temperature of the specified input channel in display units (K, F, C or S). Floating Point string.

Query Example: INPUT? B
Example Response: 123.4567

Alternate Form: INPUT <channel>:TEMP?

Short Form: INP

INPUT:TEMPER: Input Temperature.

The INPUT:TEMPER query is identical to the input query described above. It 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 Syntax: INPUT <channel>:TEMPER?
Where <channel> is the input channel parameter.
Query Response: <temp>
Where <temp> is the temperature of the specified input channel in display units (K, F, C or S). Floating Point string.

Query Example: INP C:TEMP?
Example Response: 12.45933

Short Form: INP <channel>:TEMP?

INPUT:UNITS Input channel units

Sets or reports the display units of temperature used by the specified input channel.

Command Syntax: INPUT <channel>:UNITS <units>
Where <channel> is the input channel parameter and <units> is the display units indicator.

<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 selected for the input channel.

Query Syntax: INPUT <channel>:UNITS?
Where <channel> is the input channel indicator.
Query Response: <units>
Where <units> is the display units indicator which will be K, C, F, V for Volts or O for Ohms.

Command Example: INPUT C:UNITS F

Query Example: INP A:UNIT?
Example Response: K

Query Example: INP A:TEMP?;UNIT?
Example Response: 27.9906K

Short Form: INP:UNIT

INPUT:SENIX Sensor index

Sets or queries the sensor index number assigned to an input channel. This command is used to assign the sensor type to a channel. Sensor types and configurations are accessed using the SENTYPE commands.

Sensor index zero indicates that there is no sensor connected to the selected input channel. This will disable all readings on the channel.

Command Syntax: INPUT <channel>:SENIX <ix>
Where <channel> is the input channel parameter and <ix> is the desired sensor index.

Query Syntax: INPUT <channel>:SENIX?
Where <channel> is the input channel indicator.
Query Response: <ix>
Where <ix> is the sensor index for the selected input channel.

Command Example: INPUT C:SENIX 0
This command sets the sensor index for input channel C to zero (disabled).

Query Example: INP A:SENIX?
Example Response: 02

This indicates that sensor 02 is assigned to input channel A. The name and configuration of sensor 02 may be accessed using the SENTYPE commands.

Short Form: INP:SEN

INPUT:NAME: Input Channel Name String

Sets or reports the name string of the specified input channel.

Command Syntax: INPUT <channel>:NAME <name>
Where <channel> is the input channel indicator and <name> is a character string enclosed in double quotes.

The channel name may be up to 15 characters and may include any valid ASCII character.

Query Syntax: INPUT <channel>: NAME?
Query Response: <name>
Where <channel> is the input channel indicator and <name> is the channel's name string.

Command Example: INPUT D:NAME "Fred's Cooler"

Query Example: INP A:TEMP?;UNIT?;NAME?
Example Response: 27.9906;K;Fred's Cooler

Short Form: INP <channel>:NAM

INPUT:ALARM?: Input Channel Alarm Status.

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

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

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

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

Query Syntax: INPUT <channel>: ALARM?
Query Response: <alarm>
Where <channel> is the input channel indicator and <alarm> is the alarm status indicators for that channel.

Query Example: INP A:ALARM?
Example Response: --
Which indicates that no alarm is asserted for input channel A.

Short Form: INP <channel>:ALAR?

INPUT:ALARM:HIGHEST: Alarm High Set Point.

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

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

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

Command Syntax: INPUT <channel>:ALARM:HIGHEST <temp>
Where <channel> is the input channel indicator and <temp> is the alarm set point temperature. . Temperature is a floating point string that may be up to 20 characters.

Query Syntax: INPUT <channel>: ALARM:HIGHEST?
Query Response: <temp>
Where <channel> is the input channel indicator and <temp> is the temperature setting of the high temperature alarm for <channel>. Temperature is reported to the full precision of 32 bit floating point.

Command Example: INP A:ALARM:HIGH 200.5
Sets the high temperature alarm set point for input channel A to 200.5.

Query Example: INP A:ALARM:HIGHEST?
Example Response: 125.4321
If the display units setting for input channel A are Kelvin, this response is also in units of Kelvin.

Short Form: INP <channel>:ALAR:HIGH

INPUT:ALARM:LOWEST: Alarm Low Set Point.

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

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

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

Command Syntax: INPUT <channel>:ALARM:LOWEST <temp>
Where <channel> is the input channel indicator and <temp> is the alarm set point temperature. Temperature is a floating point string that may be up to 20 characters.

Query Syntax: INPUT <channel>: ALARM:LOWEST?
Query Response: <temp>
Where <channel> is the input channel indicator and <temp> is the temperature setting of the low temperature alarm for <channel>. Temperature is reported to the full precision of 32 bit floating point.

Command Example: INP A:ALARM:LOW 100.5
Sets the low temperature alarm set point for input channel A to 100.5.

Query Example: INP B:ALARM:LOW?
Example Response: 25.43210
If the display units setting for input channel B are Celsius, this response is also in units of Celsius.

Short Form: INP <channel>:ALAR:LOW

INPUT:ALARM:HIENA: Alarm High Enable.

Sets or queries the high temperature alarm enable for the specified input channel.

An alarm must be enabled before it can be asserted.

Command Syntax: INPUT <channel>:ALARM:HIENA <status>
Where <channel> is the input channel indicator and <status> is the status of the high temperature alarm enable. <status> may be either YES or NO.

Query Syntax: INPUT <channel>: ALARM:HIENA?
Query Response: <status>
Where <channel> is the input channel indicator and <status> is the setting of the high temperature alarm enable for <channel>. <status> will be either YES or NO.

Command Example: INPUT A:ALARM:HIENA NO
Disables the high temperature alarm for input channel A.

Query Example: INP B:ALARM:HIEN?
Example Response: YES

Query / Command Example: INP B:ALARM:HIGH?;HIEN NO
Example Response: 154.2323
The high temperature alarm set point for channel B is reported then the high temperature alarm for channel B is disabled.

Short Form: INP <channel>:ALAR:HIEN

INPUT:ALARM:LOENA: Alarm Low Enable.

Sets or queries the low temperature alarm enable for the specified input channel.

An alarm must be enabled before it can be asserted.

Command Syntax: INPUT <channel>:ALARM:LOENA <status>
Where <channel> is the input channel indicator and <status> is the status of the low temperature alarm enable. <status> may be either YES or NO.

Query Syntax: INPUT <channel>: ALARM:LOENA?
Where <channel> is the input channel indicator.

Query Response: <status>
Where <status> is the setting of the low temperature alarm enable for <channel>. <status> will be either YES or NO.

Command Example: INPUT A:ALARM:LOENA YES
Enables the low temperature alarm for input channel A.

Query Example: INP B:ALARM:LOEN?
Example Response: NO

Query Example: INP B:ALARM:HIENA?;LOENA?
Example Response: YES;NO
The high temperature alarm enable for input channel B is reported followed by the low temperature alarm enable.

Short Form: INP <channel>:ALAR:LOEN

INPUT:ALARM:FAULT: Alarm on Sensor Fault.

Sets or queries the sensor fault alarm enable for the specified input channel.

An alarm must be enabled before it can be asserted.

Command Syntax: INPUT <channel>:ALARM:FAULT <status>
Where <channel> is the input channel indicator and <status> is the status of the sensor fault alarm enable. <status> may be either YES or NO.

Query Syntax: INPUT <channel>: ALARM:FAULT?
Where <channel> is the input channel indicator.

Query Response: <status>
Where <status> is the setting of the sensor fault alarm enable for <channel>. <status> will be either YES or NO.

Command Example: INPUT A:ALARM:FAULT YES
Enables the sensor fault alarm for input channel A.

Query Example: INP B:ALARM:FAULT?
Example Response: NO
Indicating that the sensor fault alarm enable for channel B is disabled.

Query Example: INP B:ALARM:HIENA?;LOENA?;FAULT?
Example Response: YES;NO;NO
Indicates that channel B high temperature alarm is enabled, low temperature alarm is disabled and sensor fault alarm is disabled.

Short Form: INP <channel>:ALAR:FAUL

INPUT:ALARM:AUDIO: Audible Alarm Enable.

The Model 34 contains an audible alarm. This alarm may be optionally sounded when any alarm condition is asserted.

The INPUT:ALARM:AUDIO command is used to set or query the audible alarm enable for the selected input channel.

Command Syntax: INPUT <channel>:ALARM:AUDIO <status>
Where <channel> is the input channel indicator and <status> is the status of the audible alarm enable. <status> may be either YES or NO.

Query Syntax: INPUT <channel>: ALARM:AUDIO?
Where <channel> is the input channel indicator.

Query Response: <status>
Where <status> is the setting of the audible alarm enable for <channel>. <status> will be either YES or NO.

Command Example: INPUT A:ALARM:AUDIO YES
Enables the audible alarm for input channel A alarm conditions.

Command Example: INPUT A:ALARM:HIEN OFF;AUDIO OFF
This command will disable the high temperature alarm and disable the audio alarm for input channel A.

Query Example: INP B:ALARM:AUDIO?
Example Response: NO

Short Form: INP <channel>:ALAR:AUD?
Where AUDIO can be truncated to four characters, then to three characters because the fourth character is a vowel.

INPUT:MINIMUM: Statistical Minimum.

Queries the minimum temperature that has occurred on an input channel since the STATS:RESET command was issued.

Query Syntax: INPUT <channel>: MINIMUM?
Where <channel> is the input channel indicator.

Query Response: <temp>
Where <temp> is the minimum temperature.

Query Example: INP B:MIN?
Example Response: 90.2322

Short Form: INP <channel>:MIN?

INPUT:MAXIMUM MAXIMUM Statistical Maximum.

Queries the Maximum temperature that has occurred on an input channel since the STATS:RESET command was issued.

Query Syntax: INPUT <channel>: MAXIMUM?
Where <channel> is the input channel indicator.

Query Response: <temp>
Where <temp> is the maximum temperature.

Query Example: INP B:MAX?
Example Response: 90.2322

Short Form: INP <channel>:MAX?

INPUT:VARIANCE: Statistical 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.

Query Syntax: INPUT <channel>: VARIANCE?
Where <channel> is the input channel indicator.

Query Response: <temp>
Where <temp> is the statistical variance of temperature.

Query Example: INP B:VAR?
Example Response: 1.2223

Short Form: INP <channel>:VAR?

INPUT:SLOPE: Statistical 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 degrees per Minute.

Query Syntax: INPUT <channel>: SLOPE?
Where <channel> is the input channel indicator.

Query Response: <temp>
Where <temp> is the temperature slope.

Query Example: INP B:SLOPE?
Example Response: 1.2323

Short Form: INP <channel>:SLOP?

INPUT:OFFSET: Statistical 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 degrees.

Query Syntax: INPUT <channel>: OFFSET?
Where <channel> is the input channel indicator.

Query Response: <temp>
Where <temp> is the temperature offset.

Query Example: INP B: OFFSET?
Example Response: 124.25

Short Form: INP <channel>:OFFS?

LOOP commands

Loop commands are used to configure and monitor Model 34's control loops.

Note: LOOP 1 may also be referred to as HEATER and LOOP 2 may be referred to as AOUT.

Loop 1 is the controller's primary heater output channel.

Loop 2 is can be configured to operate as an analog output, or as a secondary heater. In the analog output mode, the loop's output current is proportional to the measured temperature on the controlling source input channel. Here, the set point, SETPT, is a temperature offset and the proportional gain term, PGAIN, is gain.

In the Heater mode, Loop 2 becomes a second heater output channel. Control type is determined by TYPE just as with the heater output channel.

LOOP:SOURCE: Control loop Source Input Channel.

Sets and queries the selected control loop's controlling input channel.

Command Syntax: LOOP <no>:SOURCE <chan>
Where <no> is the loop number, 1 or 2, and <chan> is the designator of the controlling input channel.

Query Syntax: LOOP <no>::SOURCE?
Query Response: <chan>
Where <chan> is the designator of the controlling input channel.

Command Example: LOOP 1:SOUR CHA
Sets the control loop feedback loop to be controlled by input channel A.

Command Example: LOOP 1:SOUR CHB;SETPT 123.4;PGAIN 120
This command will set control loop 1's set point to 123.4, the proportional gain term to 120 and the control input channel to B.

Query Example: LOOP 2:SOURCE?
Example Response: CHB
Which indicates that the control loop 2 is being controlled by input channel B.

Short Form: LOOP:SOUR

LOOP:SETPT: Control loop Set Point.

Sets and queries the selected control loop's set point. This is a numeric value that has units determined by the display units of the controlling input channel.

Allowed values are 0K to 1000K.

Command Syntax: LOOP <no>::SETPT <temp>
Where <no> is the loop number, 1 or 2, and <temp> is the desired set point.

Query Syntax: LOOP 1:SETPT?
Query Response: <temp>
Where <temp> is the set point temperature in units of the controlling input channel.

Command Example: LOOP 1:SETPT 100.4
Sets loop 1's set point to 100.4. If the controlling input channel units are Kelvin, this command will result in a set point of 100.4K.

Multiple Command Example: LOOP 2:SETPT 123.4;PGAIN 120
This command will set the loop 2 set point to 123.4 and the proportional gain term to 120.

Query Example: LOOP 1:SETPT?
Example Response: 143.1293

Short Form: LOOP:SETP

LOOP:TYPE: Control loop Control Type.

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 Table, but is in ramp mode.

Command Syntax: LOOP <ch>:TYPE <type>
Where <no> is the loop number, 1 or 2, and <type> is the loop's control type from the above list.

Query Syntax: LOOP <ch>:TYPE?
Query Response: <type>
Where <type> is the loop type from the above list.

Command Example: LOOP 1:TYPE PID
Sets the loop 1 control mode to PID.

Query Example: LOOP 1:TYPE?
Example Response: TABLE
Which indicates that the Loop 1 is controlling based on PID Table lookup.

Short Form: LOOP:TYPE

LOOP 1:RANGE: Control Loop 1 Output Range.

Sets or queries the control loop #1, or the primary heater, output range.

Range determines the maximum output power available and is different for a 50Ω load resistance than for a 25Ω load.

For a 50Ω load, values for heater range are: 50W, 5.0W, 0.5W and 0.05W.

For a 25Ω load, values for heater range are: 25W, 2.5W, 0.3W and 0.03W.

Command Syntax: LOOP 1:RANGE <range>
Where <range> is the desired heater output range from the above list.

Query Syntax: LOOP 1:RANGE?
Query Response: <range>

Command Example: LOOP 1:RANGE 5.0W
Sets the heater power output range to 5.0W full scale.

Query Example: LOOP 1:RANGE?
Example Response: 0.05W

Short Form: LOOP:RANG

LOOP:RAMP?: Control Loop Ramp Status.

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.

Command Syntax: N/A

Query Syntax: LOOP <ch>:RAMP?
Where <no> is the loop number, 1 or 2.
Query Response: ON or OFF.

Query Example: LOOP 2:RAMP?
Example Response: OFF

Short Form: LOOP:RAMP

LOOP:RATE: Control Loop Ramp Rate.

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

Command Syntax: LOOP <ch>:RATE <Value>
Where <no> is the loop number, 1 or 2, and <Value> is the ramp rate in Units / Minute. This may be a value between 0 and 100.

Command Example: LOOP 1:RATE 0.02
This will set the loop 1 temperature ramp rate to 0.02. If the controlling input channel has units of Kelvin, the heater rate will be set to 0.02K/min.

Query Syntax: LOOP <ch>:RATE?
Query Response: <Value>

Query Example: LOOP 2:RATE?
Example Response: 0.0100

Short Form: LOOP:RAMP

LOOP:NAME: Control Loop Name String.

Sets or queries the name string for the selected control loop. This string is up to 15 ASCII characters. This name is a user convenience feature and does not affect loop operation.

Command Syntax: LOOP <ch>:NAME <name>
Where <no> is the loop number, 1 or 2, and <name> is a name string to be assigned to the heater output channel. Maximum length is 15 characters.

Query Syntax: LOOP <ch>:NAME?
Query Response: <name>

Command Example: LOOP 1:NAME "Cooler 4 CP"
Sets the heater output channel name to "Cooler 4 CP".

Query Example: LOOP 2:NAME?
Example Response: Analog Output

Short Form: LOOP:NAM

LOOP:PGAIN: Control Loop Proportional Gain term.

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.

The P gain term is applied to the control loop when controlling in a PID mode.

Command Syntax: LOOP <ch>:PGAIN <value>
Where <no> is the loop number, 1 or 2, and <value> is the desired P term for the control loop.

Query Syntax: LOOP <ch>:PGAIN?
Query Response: <value>

Command Example: LOOP 1:PGAIN 123
Sets the heater P term to 123

Query Example: LOOP 1:PGAIN?
Example Response: 0.49723

Short Form: LOOP:PGA

LOOP:IGAIN: Control Loop Integral Gain term.

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

The integrator gain term is applied to the selected control loop when controlling in a PID mode.

Command Syntax: LOOP <ch>:IGAIN <value>
Where <no> is the loop number, 1 or 2, and <value> is the desired Integral Gain term for the control loop in seconds.

Query Syntax: LOOP <ch>:IGAIN?
Query Response: <value>

Command Example: LOOP 1:IGAIN 12.422
Sets the Loop 1 integrator feedback term to 12.422 Seconds.

Query Example: LOOP 2:IGAIN?
Example Response: 18.23
Indicates that the Loop 2 channel I feedback term is 18.23 Seconds.

Short Form: LOOP:IGA

LOOP:DGAIN: Control Loop Derivative Gain term.

Sets and queries the differentiator feedback 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.

The D gain term is applied to the selected control loop when controlling in a PID mode.

Note: Use of the D gain term can add significant noise. In most cryogenic applications, it is set to zero.

Command Syntax: LOOP <ch>:DGAIN <value>
Where <no> is the loop number, 1 or 2, and <value> is the desired D term for the selected control loop in inverse Seconds.

Query Syntax: LOOP <ch>:DGAIN?
Query Response: <value>

Command Example: LOOP 1:DGAIN 4.3
Sets control loop 1 differentiator feedback term to 4.3/Seconds.

Query Example: LOOP 1:DGAIN?
Example Response: 8.23
Indicates that the D feedback term for loop 1 is 8.23/Seconds.

Short Form: LOOP:DGA

LOOP:HTRREAD: Control loop Output Current.

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

Query Syntax: LOOP <ch>: HTRREAD?
Where <no> is the loop number, 1 or 2.
Query Response: <value>
Where <value> is the selected control loop output power setting in percent.

Query Example: LOOP 2: HTRR?
Example Response: 22%
Indicates that the control loop 2 is attempting to output 22% of full scale current.

Short Form: LOOP:HTRR

LOOP 1:LOAD: Heater Load Resistance Select.

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.

Command Syntax: LOOP 1:LOAD <load>
Where <load> is the desired resistance of the selected control loop load from the above list.

Query Syntax: LOOP 1:LOAD?
Query Response: <LOAD>

Command Example: LOOP 1:LOAD 50
Sets the primary heater output for a 50Ω load.

Query Example: LOOP 1:LOAD?
Example Response: 25

Short Form: LOOP:LOAD

LOOP:PMANUAL: Control Loop Manual Power Output Setting.

Sets and queries the output power level used by the selected control loop feedback when it is in Manual control mode. This value may be changed at any time, but is only used during Manual operation.

PMANUAL is a numeric field that is a percent of full scale selected control loop output current. Actual selected control loop output power will depend on the selected control loop range setting.

Command Syntax: LOOP <ch>:PMANUAL <value>
Where <no> is the loop number, 1 or 2, and <value> is the desired selected control loop output current as a percent of full scale.

Query Syntax: LOOP <ch>:PMANUAL?
Query Response: <value>
Where <value> is the desired output power as a percent of full scale.

Command Example: LOOP 1:PMAN 50
Sets the control loop 1's output power to 50% of full scale when the loop is in manual control mode.

Query Example: LOOP 1:PMAN?
Example Response: 25.000
Indicates that loop 1 has a manual output power setting of 25%.

Short Form: LOOP:PMAN

LOOP 2:MODE: Control loop 2, Analog Output Mode.

Sets or queries the mode of the analog output channel. Modes are:

Scale	-AOUT is in set point relative scale mode.
Htr	-AOUT is in heater control mode.

The Scale mode is a temperature relative output that is intended for use with a strip-chart recorder or other temperature monitoring device. Output current is:

$$Vout = Pgain * (Temperature - Setpt) * 20mA$$

In the Htr mode, the analog output operates as a second control loop. Control type is identified by the LOOP 2:TYPE command listed above.

Command Syntax: LOOP 2: MODE <mode>
Where <mode> is the desired mode for the analog output channel from the above list.

Query Syntax: LOOP 2: MODE?
Query Response: <mode>

Command Example: AOUT: MODE HTR
Sets the Loop 2 output channel to heater feedback loop mode.

Query Example: LOOP 2: MODE?
Example Response: HTR
Indicates that the loop 2 channel is in heater output mode.

Short Form: LOOP: MODE

OVERTEMP commands

These commands are associated with the heater's Over Temperature Disconnect feature.

This feature is used to disconnect the heater if a specified temperature is exceeded on a selected input channel.

OVERTEMP:ENABLE: OTD Enable.

Sets and queries the over temperature disconnect enable.

Command Syntax: OVERTEMP:ENABLE <enab>
Where <enab> is the desired enable status, which may be ON or OFF.

Query Syntax: OVERTEMP:ENABLE?
Query Response: <enab>
Where <enab> is the status of the over temperature disconnect enable.

Command Example: OVERTEMP:ENABLE OFF
Sets the over temperature disconnect feature to OFF.

Query Example: OVERTEMP:ENABLE?
Example Response: YES
Indicating that the over temperature disconnect feature is enabled

Short Form: OVER:ENAB

OVERTEMP:SOURCE: OTD Source Input Channel.

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

Command Syntax: OVERTEMP:SOURCE <chan>
Where <chan> is the designator of the controlling input channel.

Query Syntax: OVERTEMP:SOURCE?
Query Response: <chan>
Where <chan> is the designator of the input channel.

Command Example: OVER:SOUR A
Sets the over temperature disconnect to monitor channel ChA.

Query Example: OVERTEMP:SOURCE?
Example Response: CHB
Which indicates that the over temperature disconnect is set to monitor input channel ChB.

Short Form: OVER:SOUR

OVERTEMP:TEMP: OTD Maximum Temperature.

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.

Command Syntax: OVERTEMP:TEMP <temp>
Where <temp> is the desired temperature.

Query Syntax: OVERTEMP:TEMP?
Query Response: <temp>
Where <temp> is the set point temperature in units of the controlling input channel.

Command Example: OVER:TEMP 123.4
Sets the over temperature disconnect to trip when a temperature of 123.4 is exceeded.

Query Example: OVERTEMP:TEMP?
Example Response: 54.23
Which indicates that the over temperature disconnect is set to a temperature of 54.23.

Short Form: OVER:TEMP

CCFILTER commands

These commands are associated with the cryocooler filter feature of the controller.

CCFILTER: STATUS: Cryocooler filter status query.

Query the status of the cryocooler filter. Results are:

Stabilize – The filter stabilizing power and temperature.
Capture – The filter is capturing cooler signature data.
Canceling – The filter is performing cancellation and input filtering.
Running - The filter is performing input cancellation only.
Off – The filter is disengaged.

Query Syntax: CCFILTER:STATUS?
Query Response: <status>
Where <status> is the current status of the cryocooler filter.

Query Example: CCFILTER:STATUS?
Example Response: Canceling
Which indicates that the cryocooler cancellation filter is in cancellation mode.

Short Form: CCF:STAT

CCFILTER: RESET: Cryocooler filter reset.

Resets the cryocooler filter to Stabilize status.

Command Syntax: CCFILTER:RESET

Command Example: CCFILTER: RESET

Short Form: CCF:RESET

CCFILTER: TYPE: Cryocooler filter type.

Sets and queries the cryocooler filter type. Options are:

Off – The filter is disengaged.
Input – The filter is performing input cancellation only.
Cancel – The filter is performing cancellation and input filtering.

Command Syntax: CCFILTER:TYPE <type>
Where <type> is the desired filter type from the above list.

Command Example: CCFILTER:TYPE CANCEL
Sets the filter type to cancellation.

Query Syntax: CCFILTER:TYPE?
Query Response: <type>
Where < type > is the filter type.

Query Example: CCFILTER:TYPE?
Example Response: Off
Which indicates that the cryocooler filter is off.

Short Form: CCF:TYP

CCFILTER: STEP: Cryocooler filter adaptation step size.

Sets and queries the cryocooler filter adaptation step size.

Command Syntax: CCFILTER:STEP <size>
Where <size> is the desired filter step size. This is a floating-point value between 0.00001 and 10.0.

Command Example: CCFILTER:STEP 0.002
Sets the filter step size to 0.002.

Query Syntax: CCFILTER:STEP?
Query Response: <step>
Where <step> is the filter adaptation step size.

Query Example: CCFILTER:STEP?
Example Response: 0.04

Short Form: CCF:STEP

CCFILTER: LOOP: Cryocooler filter control loop number

Sets and queries the cryocooler filter adaptation control loop number.

Command Syntax: CCFILTER:LOOP <loop>
Where <loop> is the desired control loop number to filter.

Command Example: CCFILTER:LOOP 2
Sets the filter to control Loop 2.

Query Syntax: CCFILTER:LOOP?
Query Response: <loop>
Where <loop> is the filter control loop number.

Query Example: CCFILTER:LOOP?
Example Response: 1

Short Form: CCF:LOOP

CCFILTER: NTAPS: Number of taps in the Cryocooler filter.

Sets and queries the number of taps in the cryocooler filter.

Command Syntax: CCFILTER:TAPS <taps>
Where <taps> is the number of taps in the cryocooler adaptation filter. This is an integer between 2 and 60.

Command Example: CCFILTER: TAPS 10
Sets the filter to 10 taps.

Query Syntax: CCFILTER:TAPS?
Query Response: <taps>
Where <taps> is the number of taps in the filter.

Query Example: CCFILTER:TAPS?
Example Response: 10

Short Form: CCF:TAPS

CALCUR commands

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

Curves are referenced by an index number. In the Model 32, there are four user curves numbered 1 through 4. In the Model 34 and 62, there are 12 user curves, numbered 1 through 12.

The CALCUR data block consists of a header, multiple curve entries and a terminator character.

The header consists of four lines as follows:

Sensor Name:	Sensor name string, 15 characters max
Sensor Type:	Enumeration, See Sensor Types table
Multiplier:	Signed numeric
Units:	Units of calibration curve: OHMS, VOLTS or LOGOHM

Each entry of a curve contains a sensor reading and the corresponding temperature. Sensor readings are in units specified by the units of the curve using the CALDATA:UNITS command. These units may be OHMS, VOLTS or LOGOHM. 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.

> ☞ **NOTE:** Using the RS-232 interface, each line must be terminated by a New Line, a Carriage Return, a Line Feed or a Null character. This character is not used with the GPIB or USB interfaces since the end of a line is signaled by the interface itself. Here, lines are transmitted to the controller by using sequential write commands.

Floating point numbers may be entered with many significant digits. They will be converted to 32 bit floating point. This supports about six significant digits.

The last entry of a table is indicated by a semicolon (;) character with no values in the numeric fields.

> ☞ **NOTE:** All curves must have a minimum of two entries and a maximum of 200 entries.

Entries may be sent to the controller in any order. The unit will sort the curve in ascending order of sensor reading before it is copied to Flash memory.

Entries containing invalid numeric fields will be deleted before they are stored.

The following is an example of a calibration curve transmitted to the controller via the GPIB interface:

```
CALCUR 1
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
;
```

The controller would sort the above table in ascending order of volts, then write it to FLASH memory as user curve #1. The curve name will be "Good Diode" and the native units are volts.

When a complete curve is received, it is conditioned, sorted and copied to FLASH memory. This process can take as long as 250 milliseconds with a long table.

> ☞ **NOTE:** When using the RS-232 interface, a time delay should of about 500mS should be inserted after sending the last line of a calibration table. This will allow the flash memory update to complete. Other remote interfaces do not require a delay.

> ☞ **NOTE:** Factory installed calibration curves may not be changed or deleted with these commands.

CALCUR: Calibration Curve Set or Query.

Sets or queries sensor calibration curve data.

Command Syntax:

CALCUR <index>
<sensor name>
<sensor type>
<multiplier>
<curve units>
<sensor reading 1> <Temperature 1>
<sensor reading 2> <Temperature 2>
•
•
<sensor reading N> <Temperature N>
;

Note: A new line (\n) character must be appended to each line when using the RS-232 serial port. They should not be included when using the GPIB or USB interfaces.

Note: The maximum number of entries in a curve is 200 and the minimum is 2.

<index> is a numeric index to the user calibration curve list. Values are 1 through 4 in the Model 32 and 1 through 11 in the Model 34 and 62.

<curve name> is a name to be assigned to the calibration curve. It is a minimum of 4 and a maximum of 15 ASCII characters.

<sensor type> is from the following list: Diode, ACR, 31kR, 3.1kR, 312R, 625R, TC80, TC40 and None. If the sensor type cannot be identified, Diode is used. Sensor Types are described in the section on Supported Sensors above.

<multiplier> is the temperature coefficient and curve multiplier. If this field cannot be identified, a value of –1.0 is assumed. This field is described in the section Sensor Setup Menu above.

<curve units> is the units of the curve. Choices are OHMS, VOLTS or LOGOHM.

The last entry in a calibration curve must be a single semicolon.

Query Syntax: CALCUR? <index>
Query Response: <calibration curve>

Short Form: CALC

PIDTABLE commands

The PIDTABLE commands are used to transfer PID tables between the Model 32 and the host controller.

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 set point, 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:

<set point> <P> <I> <D> <Heater Range>

Fields are separated by a white space. The entry is terminated by a new line (\n) character if the table is transmitted via the RS-232 interface and is not terminated for all others.

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 for a 50 Ohm load: 50W. 5.0W, 0.5W and 0.05W. Values for a 25 Ohm load are: 25W, 2.5W, 0.25W and 0.03W.

The file format of a PID table is shown below:

```
<name>
<entry 0>
<entry 1>
  *
  *
  *
<entry N>
;
```

Where:

<name> is the name of the table and is a maximum of 16 ASCII characters.
<entry> is a PID entry.

A line that contains only a single semicolon indicates the end of the table.

An example of a sixteen entry PID Table is as follows:

```
PID Test 0
 300.00    1.60  160.00   40.00 HI
 280.00    1.50  150.00   30.00 HI
 260.00    1.40  140.00   30.00 HI
 240.00    1.30  130.00   30.00 HI
 220.00    1.20  120.00   30.00 HI
 200.00    1.10  110.00   20.00 HI
 180.00    1.00  100.00   20.00 MID
 160.00    0.90   90.00   20.00 MID
 140.00    0.80   80.00   20.00 MID
 120.00    0.70   70.00   10.00 MID
 100.00    0.60   60.00   10.00 MID
  80.00    0.50   50.00   10.00 MID
  60.00    0.40   40.00   10.00 LOW
  40.00    0.30   30.00    0.00 LOW
  20.00    0.20   20.00    0.00 LOW
  10.00    0.10   10.00    0.00 LOW
;
```

Entries may be sent to the controller in any order. The unit will sort the table in ascending order of set point before it is copied to Flash RAM. Entries containing invalid numeric fields will be deleted.

PIDTABLE: PID Table Name Query.

Queries the name string of a PID table at a specified index.

Query Syntax: PIDTABLE? <index>
Query Response: <name>
Where <index> is the index to the PID table list and <name> is the name string associated with the specified table. Index may be from zero to five.

Query Example: PIDT? 2
Example Response: Joe's Cooler
Indicates that PID table #2 is named Joe's Cooler.

Short Form: PIDT?

PIDTABLE:NAME: PID Table 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.

Command Syntax: PIDTABLE <index>:NAME <name>
Where <index> is a numeric index (0-3) to the PID table list and <name> is an ASCII name string in double quotes.

Query Syntax: PIDTABLE <index>:NAME?
Query Response: <name>
Where <index> is the index to the calibration curve list. <name> is the name string associated with the specified curve.

Command Example: PIDTABLE 1:NAME "Ed's table"
This command will assign the name of "Ed's table" to PID table located at index number 1.

Query Example: PIDTABLE 3:NAME?
Example Response: Mary's project
Indicates that the PID table at index 3 is named Mary's project.

Short Form: PIDT:NAM

PIDTABLE:NENTRY: Number of Entries.

Queries the number of entries in a PID Table. This number is generated from the table itself and cannot be changed using this command.

The maximum number of entries in a table is 16.

Query Syntax: PIDTABLE <index>:NENTRY?
Query Response: <number>
Where <index> is the index to the PID table list and <number> is the number of entries in the indexed table

Query Example: PIDTABLE 1:NENTRY?
Example Response: 5
Indicates that there are 5 entries in PID table 1.

Short Form: PIDT:NENT

PIDTABLE:TABLE: PID Table Set/Query.

Sets or queries the entries in a PID table.

Command Syntax:
PIDTABLE <index>:TABLE

<name>
<set point> <P> <I> <D> <Heater Range>
<set point> <P> <I> <D> <Heater Range>
<set point> <P> <I> <D> <Heater Range>
•
•
•
<set point> <P> <I> <D> <Heater Range>
;

Where <index> is a numeric index of the PID table and <name> is the table name (15 characters maximum). Table entries are made according to the above description.
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.

Query Syntax: PIDTABLE <index>:TABLE
Query Response: <Table entries>
Where <Table entries> are the entries of the selected PID table.

Relay Commands

The relay subsystem includes the two auxiliary relays in the Model 34. Using the RELAYS commands, these relays may be 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.

RELAYS? Relay Status Query.

The two auxiliary relays available in the Model 34 are addressed as 0 and 1. The RELAYS command can be used to query the status of each relay where:

--	Relay is clear.
SF	Relay is asserted by a Sensor Fault condition.
HI	Relay is asserted by a high temperature condition.
LO	Relay is asserted by a low temperature condition.

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

Query Syntax: RELAYS? <num>
Query Response: <status>
Where <num> is the relay number and is 0 or 1. <status> is the assertion status of relay <num> and is selected from the above list.

Query Example: RELAY? 1
Example Response: HI
This response indicating that relay #1 is asserted by a high temperature condition.

Query Example: RELAY? 0
Example Response: --
Indicating that relay #0 is not asserted.

Short Form: REL?
The short form is truncated to three characters since the fourth character is a vowel.

RELAYS: SOURCE: Relay Input Source.

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

Command Syntax: RELAYS <num>:SOURCE <chan>
Where <num> is the relay number and is 0 or 1. <chan> is source input channel and may be any of the Model 34's four sensor inputs.

Query Syntax: RELAYS <num>:SOURCE?
Where <num> is the relay number.
Query Response: <chan>
Where <chan> is the source input channel for relay <num> and will be ChA, ChB, ChC or ChD.

Command Example: RELAY 0:SOUR D
Causes relay 0 to be asserted or cleared based on the condition of input channel D.

Query Example: RELAY 1:SOUR?
Example Response: CHC

Short Form: REL:SOUR

RELAYS: HIGHEST: Relay High Set Point.

Sets or queries the temperature setting of the high temperature set point for the specified relay. When this temperature is exceeded on the source input channel, a high temperature condition will cause the specified relay to be asserted.

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

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

Command Syntax: RELAYS <num>:HIGHEST <temp>
Where <num> is the relay number and is 0 or 1. <temp> is the set point temperature. . Temperature is a floating point string that may be up to 20 characters.

Query Syntax: RELAYS <num>:HIGHEST?
Where <num> is the relay number.

Query Response: <temp>
Where <temp> is the value of the set point for relay <num>. Temperature is reported to the full precision of 32 bit floating point.

Command Example: RELAY 0:HIGHEST 25.947
Sets the high temperature set point for relay 0 to 25.947

Query Example: RELAY 1:HIGHEST?
Example Response: 125.4321
If the display units setting for the source input channel are Kelvin, this response is also in units of Kelvin.

Short Form: REL:HIGH

RELAYS:LOWEST: Relay Low Set Point.

Sets or queries the temperature setting of the low temperature set point for a specified relay. When the source input channel temperature is below this value, an enabled low temperature condition will be asserted.

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

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

Command Syntax: RELAYS <num>:LOWEST <temp>
Where <num> is the relay number and is 0 or 1. <temp> is the set point temperature. Temperature is a floating point string that may be up to 20 characters.

Query Syntax: RELAYS <num>:LOWEST?
Where <num> is the relay number.
Query Response: <temp>
Where <temp> is the low temperature set point. Temperature is reported to the full precision of 32 bit floating point.

Command Example: RELAY 1:LOW 100.5
Sets the low temperature set point for relay 1 to 100.5.

Query Example: RELAY 0:LOW?
Example Response: 25.43210

Short Form: REL:LOW

RELAYS: HIENA: Relay High Enable.

Sets or queries the high temperature enable for the specified relay.

A relay must be enabled before it can be asserted.

Command Syntax: RELAYS <num>:HIENA <status>
Where <num> is the number of the relay and is 0 or 1. <status> is the status of the high temperature enable. <status> may be either YES or NO.

Query Syntax: RELAYS <num>:HIENA?
Query Response: <status>
Where <num> is the relay number and <status> is the setting of the high temperature enable for relay <num>. <status> will be either YES or NO.

Command Example: RELAY 1:HIENA NO
Disables the high temperature alarm assertion of relay number 1.

Query Example: REL 0:HIEN?
Example Response: YES

Query / Command Example: RELAY 1:HIGH?;HIEN NO
Example Response: 154.2323
The high temperature alarm set point for relay 1 is reported then the high temperature enable for relay 1 is disabled.

Short Form: REL:HIEN

RELAYS:LOENA: Relay Low Enable.

Sets or queries the low temperature enable for the specified relay.

A relay must be enabled before it can be asserted.

Command Syntax: RELAYS <num>:LOENA <status>
Where <num> is the relay number and is 0 or 1. <status> is the status of the low temperature enable. <status> may be either YES or NO.

Query Syntax: RELAYS <num>:LOENA?
Query Response: <status>
Where <num> is the relay number and <status> is the setting of the low temperature alarm enable for <channel>. <status> will be either YES or NO.

Command Example: RELAY 1:LOENA YES
Enables low temperature assertion for relay #1.

Query Example: RELAY 0:LOEN?
Example Response: NO

Query Example: REL 0:HIENA?;LOENA?
Example Response: YES;NO
Indicates that relay 0 will assert on a high temperature condition but not on a low temperature condition.

Short Form: REL:LOEN

RELAYS:FAULT: Relay enable for sensor fault.

Sets or queries the sensor fault enable for the specified relay.

A relay must be enabled before it can be asserted.

Command Syntax: RELAYS <num>:FAULT <status>
Where <num> is the relay number and is 0 or 1. <status> is the status of the sensor fault enable. <status> may be either YES or NO.

Query Syntax: RELAYS <num>:FAULT?
Where <num> is the relay number.
Query Response: <status>
Where <status> is the setting of the sensor fault enable for relay <num>.
<status> will be either YES or NO.

Command Example: RELAY 0:FAULT YES
Enables the sensor fault alarm for relay 0.

Query Example: REL 0:FAULT?
Example Response: NO
This indicates that the sensor fault enable for relay 0 is disabled.

Short Form: REL:FAUL

SENTYPE Commands Overview.

The SENTYPE commands are used to add, delete or edit input sensor types installed in the Model 34. These commands are the remote equivalent of the front panel Sensor Setup menu.

Sensor types are maintained in the Model 34's Master Sensor Table. This table is indexed by a numeric value. Index zero is a null sensor.

> ☞ **NOTE:** Factory installed sensors may not be changed or deleted with these commands.

SENTYPE Sensor Type.

Reports the name of the sensor in the Sensor Table at a specified index.

Query Syntax: SENTYPE? <index>
Query Response: <name>
Where <index> is the index to the Master Sensor Table and <name> is the name string for the indexed sensor type.

Query Example: SENT? 12
Example Response: Thermocouple E.
Indicates that the sensor installed at index 12 is "Thermocouple E".

Short Form: SENT?

SENTYPE:NAME Sensor Name

Sets or queries the sensor name at a specified index to the Master Sensor Table.

The sensor name string is used to assign a convenient name to a sensor type. It has a maximum of 15 characters.

Command Syntax: SENTYPE <index>:NAME <name>
Where <index> is the index to the Master Sensor Table and <name> is a name string enclosed in double quotes.

Query Syntax: SENTYPE <index>:NAME?
Query Response: <name>
Where <index> is the index to the Master Sensor Table and <name> is the name string for the sensor at <index>.

Command Example: SENT 14:NAME "Special Diode"
This command assigns the name "Special Diode" to the sensor at index 14.

Query Example: SENT 10:NAME?
Example Response: Pt100 375

Short Form: SENT:NAM

SENTYPE:TYPE: Sensor Type.

Sets or queries the sensor type at a Master Sensor Table index.

Supported sensor types are described above in the "Supported Sensors" section. For purposes of the SENTYPE:TYPE command, types are:

Diode for Silicon Diodes.

R16K10UA, **R8K10UA**, **R6K100UA**, **R2K100UA**, **R625R1MA** and **R312R1MA** for resistor sensors.

Snone to disable the input channel.

TC80 for a ±80mV Thermocouple and **TC40** for a ±40mV Thermocouple.

Command Syntax: SENTYPE <index>:TYPE <stype>
Where <index> is the index to the Master Sensor Table and <stype> the sensor type selected from the above list.

Query Syntax: SENTYPE <index>:TYPE?
Query Response: <stype>
Where <index> is the index to the Master Sensor Table and <stype> is the sensor type.

Command Example: SENT 11:TYPE DIODE
This command assigns the Silicon Diode sensor type to the sensor at index 11.

Query Example: SENT 10:TYPE?
Example Response: TC80
This response indicates that the sensor at index 10 is a Thermocouple.

Short Form: SENT:TYP

SENTYPE:MULTIPLY: Calibration Curve Multiplier.

Sets or queries the Multiplier of the sensor entry at a specified index of the Master Sensor Table.

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, a 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.

Command Syntax: SENTYPE <index>:MULTIPLY <val>
Where <index> is the index to the Master Sensor Table and <val> the multiplier.

Query Syntax: SENTYPE <index>:MULTIPLY?
Query Response: <val>
Where <index> is the index to the Master Sensor Table and <val> is the sensor type multiplier.

Command Example: SENT 15:MULT -10
This command sets the calibration table multiplier for sensor 15 to 10 and identifies it as having a negative temperature coefficient.

Query Example: SENT 10:MULT?
Example Response: 1.000000
This response indicates that the sensor at index 10 has a positive temperature coefficient and a calibration curve multiplier of 1.0.

Short Form: SENT:MULT

AUTOTUNE commands

Autotuning via the remote interface requires the following sequence:

1. As with tuning from the front panel, the Model 34 must be controlling temperature and the loop must be stable in terms of both temperature and output power.
2. Values for Delta Power and Timeout should be set.
3. The Autotune process model is initiated by the command AUTOTUNE:START.
4. Status can be monitored using the AUTOTUNE:STATUS command.
5. When a status of complete is indicated, the generated values for P,I and D may be read.
6. Execution of the AUTOTUNE:SAVE command will transfer the generated PID coefficients to the actual loop coefficients and continue controlling the process in PID mode.
7. Execution of the AUTOTUNE:EXIT command at any time will abort the autotune process and discard any generated PID values.

AUTOTUNE:START: Initiate Autotune.

Initiates the autotune sequence.

Command Syntax: <oc>:AUTOTUNE:START
Where <oc> is the output channel to tune and may be either HEATER or AOUT.

Command Example: HEATER:AUTOTUNE: START
Initiates autotuning the heater.

Short Form: **AUT:STAR**

AUTOTUNE:DELTAP: Maximum Delta in Power.

Sets and queries the maximum allowed change in heater output power that is allowed during the process modeling phase of the autotuning process.

This a numeric field that is expressed as a percent of full scale heater output power. The actual power output depends on the range setting of the heater. If a value of 100% is used, the controller may use any output power within the current range.

Command Syntax: <oc>:AUTOTUNE:DELTAP <value>
Where <oc> is the output channel to tune and may be either HEATER or AOUT. <value> is the maximum allowed change in output power expressed as a percent of full scale.

Query Syntax: <oc>:AUTOTUNE:DELTAP?
Query Response: <value>
Where <oc> is the output channel to tune and may be either HEATER or AOUT. <value> is the current Delta Power setting.

Command Example: HEATER:AUTOTUNE:DELTAP 100
This sets the maximum change in output power to 100% of full scale. This will allow the tuning process to use any output level.

Query Example: AOUT:AUTOTUNE:DELTAP?
Example Response: 25.0000
This response says that the maximum change in output power used by autotune will be ±25% of the current output power level.

Short Form: AUT:DELT

AUTOTUNE:TIMEOUT: Autotune Timeout.

Sets and queries the timeout value of the autotune process. This is a numeric field that specifies the maximum time, in seconds, that the autotune process model will wait for it's internal error vector to converge without declaring a timeout condition.

Command Syntax: <oc>:AUTOTUNE: TIMEOUT <value>
Where <oc> is the output channel to tune and may be either HEATER or AOUT. <value> is the timeout period in seconds.

Query Syntax: <oc>:AUTOTUNE: TIMEOUT?
Query Response: <value>
Where <oc> is the output channel to tune and may be either HEATER or AOUT. <value> is the timeout period in seconds.

Command Example: AOUT:AUTOTUNE: TIMEOUT 200
Sets the autotune timeout period to 200 Seconds.

Query Example: HEATER:AUTOTUNE:TIME?
Example Response: 250.000
Identifies the autotune timeout period as 250 seconds.

Short Form: AUT:TIM

AUTOTUNE:EXIT: Abort Autotune.

Aborts and exits the autotune process.

Command Syntax: <oc>:AUTOTUNE: EXIT
Where <oc> is the output channel to tune and may be either HEATER or AOUT.

Command Example: HEATER:AUTOTUNE: EXIT
Aborts autotuning.

Short Form: AUT:EXIT

AUTOTUNE:SAVE: Save PID Coefficients.

When an autotune sequence has successfully completed, this command will save the generated PID values to the control loop PID values and change the autotune state from 'complete' to 'idle'.

Command Syntax: <oc>:AUTOTUNE:SAVE
Where <oc> is the output channel to tune and may be either HEATER or AOUT.

Command Example: AOUT:AUTO:SAVE

Short Form: AUT:SAVE

AUTOTUNE:PGAIN: Proportional Gain.

When an autotune sequence has successfully completed, the AUTOTUNE:PGAIN command can be used to query the generated P, or P gain, term.

Query Syntax: <oc>:AUTOTUNE:PGAIN?
Query Response: <value>
Where <oc> is the output channel to tune and may be either HEATER or AOUT. <value> is the generated P gain feedback coefficient.

Query Example: AOUT:AUTO:PGA?
Example Response: 125.0000
Indicates that the generated P gain term is 125.

Short Form: AUT:PGA

AUTOTUNE:IGAIN: Integral Gain

When an autotune sequence has successfully completed, the AUTOTUNE:IGAIN command can be used to query the generated I, or integrator gain, term.

Query Syntax: <oc>:AUTOTUNE:IGAIN?
Query Response: <value>
Where <oc> is the output channel to tune and may be either HEATER or AOUT. <value> is the generated I feedback term in Seconds.

Query Example: HEATER:AUTO:IGA?
Example Response: 225.0000
Indicates that the generated I gain term is 225. Seconds.

Short Form: AUT:IGA

AUTOTUNE: DGAIN: Derivative Gain.

When an autotune sequence has successfully completed, the AUTOTUNE:DGAIN command can be used to query the generated D, or differentiator gain, term.

Query Syntax: <oc>:AUTOTUNE:GAIN?
Query Response: <value>
Where <oc> is the output channel to tune and may be either HEATER or AOUT. <value> is the generated D feedback term in inverse Seconds.

Query Example: AOUT:AUTO:DGA?
Example Response: 22.0000
Indicates that the generated D gain term is 22 / Seconds.

Short Form: AUT:DGA

AUTOTUNE:STATUS: 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.

Query Syntax: <oc>:AUTOTUNE:STATUS?
Query Response: <status>
Where <oc> is the output channel to tune and may be either HEATER or AOUT. <status> is the current status of the autotune process from the above list

Query Example: HEATER:AUTO:STATUS?
Example Response: COMPLETE
Indicates that autotune has successfully completed and generated values for PID are available.

Short Form: AUT:STAT?

INSTCAL commands

The INSTCAL commands are used to calibrate the Model 34 input sensor measurement circuitry. They should only be used in association with the instrument's calibration procedure.

Instrument calibration requires the use of various transfer standard resistance and voltage references.

In order to calibrate the Model 34, the calibration mode must first be turned on by using the INST:MODE ON command. Issuing this command will cause the unit to copy the actual calibration data from flash memory to temporary RAM. Further, the unit will display raw voltage data that has had the RAM calibration coefficients applied.

The temporary RAM calibration data is manipulated using the OFFSET and GAIN and TYPE commands for each input channel. RAM is copied back to the actual FLASH memory calibration data table using the SAVE command.

The Model 34 is returned to normal operation by using the INSTCAL:MODE OFF command. Note that this does not write data to the calibration FLASH memory area.

INSTCAL:MODE

Queries or sets the instrument calibration mode. Calibration mode must be turned on before most instrument calibration commands are effective.

Command Syntax: INSTCAL <chan>:MODE <mode>
Where <chan> is the input channel number (required but not used) and <mode> is the desired mode, which may be either ON or OFF.

Command Example: INST A:MODE ON
Places the Model 34 in calibration mode.

Query Syntax: INSTCAL <chan>:MODE?
Where <chan> is the input channel number (required but not used).

Query Response: <mode>
Where <mode> is the calibration mode indicator and will be either ON or OFF.

Query Example: INSTCAL <chan>:MODE?
Example Response: OFF
Indicates that the Model 34 is not in calibration mode

Short Form: INST <chan>:MOD

INSTCAL:SAVE

This command copies the temporary RAM calibration data table to the actual FLASH memory instrument calibration area. It can only be used when the instrument is in calibration mode; Otherwise, it does nothing.

Command Syntax: INSTCAL <chan>:SAVE
Where <chan> is the input channel number (required but not used) Note that, even though a channel indicator is specified, the entire RAM table for all four input channels is copied to FLASH memory. Therefore, this command should only be issued once when the entire procedure is complete.

Command Example: INST A:SAVE

Short Form: INST <chan>:SAVE

INSTCAL:TYPE

Sets or queries the type of calibration that is being applied to a specified input channel. This command is only effective when the unit is in calibration mode.

Calibration types are shown below:

V10UA - Voltage calibration. Full scale is 2.5V
R1MA - Resistance calibration. Full scale is 2500Ω.
R100UA - Resistance calibration. Full scale is 25KΩ.
R10UA - Resistance calibration. Full scale is 250KΩ.

Command Syntax: INSTCAL <chan>:TYPE <type>
Where <chan> is the input channel indicator and <type> is the desired calibration type from the above list.

Command Example: INST A:TYPE R10UA
Places the calibration type to R10UA.

Query Syntax: INSTCAL <chan>:TYPE?
Where <chan> is the input channel indicator.

Query Response: <type>
Where <type> is the calibration type from the above list.

Query Example: INSTCAL <chan>:TYPE?
Example Response: V10UA
Indicates that the calibration type is V10UA

Short Form: INST <chan>:TYP

INSTCAL:GAIN

Sets or queries gain calibration factor that is applied to the specified input channel.

GAIN is a floating point number with a nominal value of 1.000.

There is a GAIN factor for each calibration type within a channel. Therefore, before the INST:GAIN is used, the INST:TYPE command should be used to set the calibration type.

Command Syntax: INSTCAL <chan>:GAIN <gain>
Where <chan> is the input channel indicator and <gain> is the desired gain calibration factor.

Command Example: INST A:GAIN 0.999423
Sets the gain calibration factor for input channel A to 0.999423.

Query Syntax: INSTCAL <chan>:GAIN?
Where <chan> is the input channel indicator.

Query Response: <gain>
Where <gain> is the gain calibration factor.

Query Example: INSTCAL B:GAIN?
Example Response: 0.994321
Indicates that the gain calibration factor for input channel B is 0.994321

Short Form: INST <chan>:GAIN

INSTCAL:OFFSET

Sets or queries offset calibration factor that is applied to the specified input channel.

OFFSET is an integer that is in ADC counts and may be either positive or negative.

There is an OFFSET factor for each calibration type within a channel. Therefore, before the INST:OFFSET is used, the INST:TYPE command should be used to set the calibration type.

Command Syntax: INSTCAL <chan>: OFFSET <offset>
Where <chan> is the input channel indicator and <offset> is the desired offset calibration factor.

Command Example: INST B: OFFSET -321
Sets the offset calibration factor for input channel B to -321.

Query Syntax: INSTCAL <chan>: OFFSET?
Where <chan> is the input channel indicator.

Query Response: <offset>
Where <offset> is the offset calibration factor.

Query Example: INSTCAL B: OFFSET?
Example Response: 23
Indicates that the offset calibration factor for input channel B is 23

Short Form: INST <chan>:OFFS

Remote Command Summary

Command	Function
IEEE Common Commands	
*ESE, *ESE?	The *ESE command sets and queries the Standard Event Status Enable (ESE) Register bits.
*ESR?	Returns the Standard Event (SEV) register.
*IDN?	Returns Instrument Identification String.
*OPC?	Set the operation complete bit in the Standard Event (SEV) status register when all pending device operations have finished.
*RST	Reset the controller.
Control Loop Start/Stop commands	
STOP	Disengage control loops
CONTROL CONTROL?	Engage all control Loops. Query if the loops are engaged.
SYSTEM commands	
SYSTEM:LOCKOUT SYSTEM:LOCKOUT?	Sets or queries the remote lockout status indicator.
SYSTEM:BEEP	Asserts the audible alarm for a specified number of seconds.
SYSTEM:REMLED SYSTEM:REMLED	Sets or queries the remote LED status indicator on the front panel.
SYSTEM:LOOP?	Reports the status of the two temperature control loops.
SYSTEM:DISTC SYSTEM:DISTC?	Set or query the display filter time constant. Available time constants are 0.5, 1, 2, 4, 8, 16, 32 or 64 Seconds.
SYSTEM:ADRS SYSTEM:ADRS?	Set or query the address that the IEEE-488.2 and USB interfaces will use. (Optional on USB).
SYSTEM:REMOTE	Sets the remote interface port. Choices are: USB, GPIB and RS232.

Command	Function
SYSTEM:AMBIENT?	Query the temperature of the controller's internal voltage reference. Example Output: +25C
SYSTEM:HTRHST?	Query the temperature of the internal heater heatsink. Example output: +62C
SYSTEM:HOME	Causes the display on the front panel to go to the Operate Screen.
SYSTEM:NAME SYSTEM:NAME?	Set or query the instrument's name string. Example: SYSTEM:NAME "Cryocooler Four"
SYSTEM:DRES SYSTEM:DRES?	Sets or queries the controller's display resolution. Choices are: Full, 1, 2 or 3.
SYSTEM:SETUP:NAME	Sets or queries the name of a user setup
SYSTEM:SETUP:SAVE	Saves the current instrument setup to a user setup.
SYSTEM:HWREV?	Queries the instrument's hardware revision level.
SYSTEM:FWREV?	Queries the instrument's firmware revision level.
SYSTEM:ERROR?	Queries the instrument's error queue.
SYSTEM:CJTEMP?	Queries the internal Cold Junction Compensation temperature for Thermocouple sensors.
SYSTEM:LINEFREQ SYSTEM:LINEFREQ?	Sets or queries the AC Power Line frequency setting.
SYSTEM:SETUP:RESTORE	Saves the current instrument setup to a user setup.
SYSTEM:NVSAVE	Save the instrument configuration to flash memory so that it will be restored on the next power-up.
SYSTEM:CONTRAST SYSTEM:CONTRAST?	Set or query the contrast of the front panel VFD display. (Model 34, 62 Only)

Command	Function
Input Channel Commands	
INPUT? INPUT:TEMPER?	Query the current temperature reading on any of the input channels.
INPUT:UNITS INPUT:UNITS	Sets or reports the display units of temperature used by the specified input channel.
INPUT:SENIX INPUT:SENIX	Sets or queries the sensor index number assigned to an input channel.
INPUT:BIAS INPUT:BIAS?	Set or query the channels bias type. (Model 32, 34 only)
INPUT:NAME INPUT:NAME?	Sets or queries the name string of the specified input channel.
INPUT:ALARM?	Queries the alarm status of the specified input channel.
INPUT:ALARM:HIGHEST INPUT:ALARM:HIGHEST?	Sets or queries the temperature setting of the high temperature alarm for the specified input channel.
INPUT:ALARM:LOWEST INPUT:ALARM:LOWEST?	Sets or queries the temperature setting of the low temperature alarm for the specified input channel.
INPUT:ALARM:HIENA INPUT:ALARM:HIENA?	Sets or queries the high temperature alarm enable for the specified input channel.
INPUT:ALARM:LOENA INPUT:ALARM:LOENA?	Sets or queries the low temperature alarm enable for the specified input channel.
INPUT:ALARM:FAULT INPUT:ALARM:FAULT?	Sets or queries the sensor fault alarm enable for the specified input channel.
INPUT:ALARM:AUDIO INPUT:ALARM:AUDIO?	Set or query the audible alarm enable for the selected input channel.
INPUT:ALARM:FAULT INPUT:ALARM:FAULT?	Sets or queries the sensor fault alarm enable for the specified input channel.

Command	Function
Input Channel Statistics	
INPUT:MINIMUM?	Queries the minimum temperature that has occurred on an input channel since the STATS:RESET command was issued.
INPUT:MAXIMUM?	Queries the Maximum temperature that has occurred on an input channel since the STATS:RESET command was issued.
INPUT:VARIANCE?	Queries the temperature variance that has occurred on an input channel since the STATS:RESET command was issued.
INPUT: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.
INPUT: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.
STATS:TIME?	Queries the time duration over which input channel statistics have been accumulated.
STATS:RESET	Resets the accumulation of input channel statistical data.

Command	Function
LOOP Commands	
LOOP:SOURCE LOOP:SOURCE?	Sets and queries the selected control loop's controlling input channel.
LOOP:SETPT LOOP:SETPT?	Sets and queries the selected control loop’s set point.
LOOP:TYPE LOOP:TYPE?	Sets and queries the selected control loop’s control type.
LOOP 1:RANGE LOOP 1:RANGE?	Sets or queries the control loop #1, or the primary heater, output range.
LOOP:RAMP?	Queries the unit to determine if a temperature ramp is in progress on the specified control loop.
LOOP:TABLEIX LOOP:TABLEIX?	Sets or queries the table number that is used with control modes that use PID tables.
LOOP:RATE LOOP:RATE?	Sets and queries the ramp rate used by the selected control loop when performing a temperature ramp.
LOOP:NAME LOOP:NAME?	Sets or queries the name string for the selected control loop.
LOOP:PGAIN LOOP:PGAIN?	Sets or queries the selected control loop’s proportional gain term.
LOOP:IGAIN LOOP:IGAIN	Sets and queries the integrator feedback term used by the selected control loop.
LOOP:DGAIN LOOP:DGAIN	Sets and queries the differentiator feedback term used by the selected control loop.
LOOP:HTRREAD?	Queries the output current of the selected control loop.
LOOP 1:LOAD LOOP 1:LOAD?	Sets or queries the load resistance setting of the primary heater (Loop 1).
LOOP:PMANUAL LOOP:PMANUAL?	Sets and queries the output power level used by the selected control loop feedback when it is in Manual control mode.

Command	Function
Over Temperature Disconnect Commands	
OVERTEMP:ENABLE OVERTEMP:ENABLE?	Sets and queries the over temperature disconnect enable.
OVERTEMP:SOURCE OVERTEMP:SOURCE?	Sets and queries the input channel that is used as the source for the Over Temperature Disconnect feature.
OVERTEMP:TEMP OVERTEMP:TEMP?	Sets and queries the temperature used by the over temperature disconnect feature.
Sensor Calibration Curve Commands	
CALCUR CALCUR?	Sets or queries sensor calibration curve data.
PID Table Commands	
PIDTABLE PIDTABLE?	Queries the name string of a PID table at a specified index.
PIDTABLE:NENTRY PIDTABLE:NENTRY?	Queries the number of entries in a PID Table.
PIDTABLE:TABLE PIDTABLE:TABLE?	Sets or queries the entries in a PID table.

Command	Function
Relay Commands (Model 34 and 62 only)	
RELAYS?	Relay Status Query.
RELAYS: SOURCE RELAYS: SOURCE?	Sets or queries the source input channel for a specified relay.
RELAYS: HIGHEST RELAYS: HIGHEST?	Sets or queries the temperature setting of the high temperature set point for the specified relay.
RELAYS:LOWEST RELAYS:LOWEST?	Sets or queries the temperature setting of the low temperature set point for a specified relay.
RELAYS: HIENA RELAYS: HIENA?	Sets or queries the high temperature enable for the specified relay.
RELAYS:LOENA RELAYS:LOENA	Sets or queries the low temperature enable for the specified relay.
RELAYS:FAULT RELAYS:FAULT	Sets or queries the sensor fault enable for the specified relay.
Sensor Setup Commands	
SENTYPE?	Reports the name of the sensor in the Master Sensor Table at a specified index.
SENTYPE:NAME SENTYPE:NAME?	Sets or queries the sensor name at a specified index to the Master Sensor Table.
SENTYPE:TYPE SENTYPE:TYPE?	Sets or queries the sensor type at a Master Sensor Table index.
SENTYPE:MULTIPLY SENTYPE:MULTIPLY?	Sets or queries the Multiplier of the sensor entry at a specified index.

Command	Function
Autotune Commands	
AUTOTUNE:DELTAP AUTOTUNE:DELTAP?	Sets and queries the maximum allowed change in heater output power that is allowed during the process modeling phase of the autotuning process.
AUTOTUNE:TIMEOUT AUTOTUNE:TIMEOUT?	Sets and queries the timeout value of the autotune process.
AUTOTUNE:START	Initiates the autotune sequence.
AUTOTUNE:EXIT	Aborts and exits the autotune process.
AUTOTUNE:SAVE	When an autotune sequence has successfully completed, this command will save the generated PID values to the control loop PID values and change the autotune state from 'complete' to 'idle'.
AUTOTUNE:PGAIN?	Query the generated P gain term generated by autotune.
AUTOTUNE:IGAIN?	Query the generated I gain term generated by autotune.
AUTOTUNE:DGAIN?	Query the generated D gain term generated by autotune.
AUTOTUNE:STATUS?	Queries the status of the autotune process.
Cryocooler Filter Commands (Model 34, 32 Only)	
CCFILTER: STATUS?	Query Cryocooler filter status.
CCFILTER: TYPE CCFILTER: TYPE?	Set or query filter type. Types are: OFF, Input or Cancel.
CCFILTER: STEP CCFILTER: STEP?	Set or query the filter adaptation step size.
CCFILTER: LOOP CCFILTER: LOOP?	Set or query the control loop number controlled by the cryocooler filter.
CCFILTER: NTAPS CCFILTER: NTAPS?	Set or query the number of taps in the filter.
CCFILTER:RESET	Reset the Cryocooler filter.

Table 18: Remote Command Summary

EU Declaration of Conformity

According to ISO/IEC Guide 22 and EN 45014

Product Category:	Process Control Equipment
Product Type:	Temperature Measuring and Control System
Model Numbers:	Model 34
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"

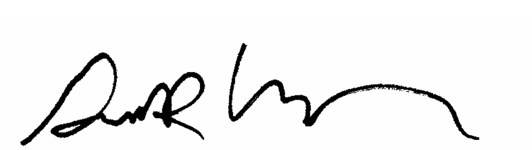
73/23/EEC, "Council Directive of 19 February 1973 on the harmonization of the laws of Member States relating to electrical equipment designed for use within certain voltage limits".

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, 1994 A2: May 96

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

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



Guy D. Covert
President, Cryogenic Control Systems, Inc.
October 15, 2005

Appendix A: Installed Curves

Factory Installed Curves

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

Index	Name	Description
0	None	No Sensor. Used to turn the selected input channel off.
1	Cryocon S700	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	SI 410 Diode	Scientific Instruments, Inc. 410 Diode Curve. Range: 1.5 to 450K. 10μA excitation.
5	Pt100 385	DIN43760 standard 100Ω Platinum RTD. Range: 23 to 873K, 1mA excitation.
6	Pt1K 385	1000Ω at 0°C Platinum RTD using DIN43760 standard calibration curve. Range: 23 to 873K, 100μA excitation.
7	Pt10K 385	10KΩ at 0°C Platinum RTD. Temperature coefficient 0.00385, Range: 23 to 873K, 10μA excitation.
8	RuOx 1K Ohm	Ruthenium Oxide sensor, 1000Ω at room temperature. Range: 0.050 to 40K, 10μA constant current excitation.
9	RuOx 2K Ohm	Ruthenium Oxide sensor, 2000Ω at room temperature. Range: 0.050 to 40K, 10μA constant current excitation.
10	TC type K	Thermocouple type K
11	TC type E	Thermocouple type E
12	TC type T	Thermocouple type T
13	AuFe 0.07%	AuFe Thermocouple

User Installed Sensor Curves

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

Senix index	User Number	Default Name
10	**1**	User Sensor 1
11	**2**	User Sensor 2
12	**3**	User Sensor 3
13	**4**	User Sensor 4
14	**5**	User Sensor 5
15	**6**	User Sensor 6
16	**7**	User Sensor 7
17	**8**	User Sensor 8
18	**9**	User Sensor 9
19	**10**	User Sensor A
20	**11**	User Sensor B
21	**12**	User Sensor C

When using the CALCUR commands, only user curves are addressed, therefore, the User Number shown above is used.

The Senix, or sensor index, commands address all of the factory installed curves. Therefore, the Senix index shown above is used.

For example:

CALCUR 2 would address user curve #2.

INPUT A:SENIX 20 would set input A to use User Curve B.

INPUT A:SENIX 1 would set input A to use the S700 Diode.

INPUT A:SENIX 0 would turn input A off by setting the sensor to ‘none’.

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

Appendix B: 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 Setup Menus 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 Sensor Setup to display the calibration curve.

Display	Condition
Reading Record: 0000 Errors: 00	The controller's firmware has been corrupted (Invalid Checksum). Locate new instrument firmware and utility software on the Cryo-con web site or the CD supplied with the controller. Re-load the unit's firmware. Refer to the section Downloading Instrument Firmware.
ADC Failure!	The input temperature measurement circuitry has failed. Contact Cryo-con technical support.
Memory Error!	The self-test procedure detected an error in the controller's RAM memory. Contact Cryo-con Support.

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 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.

Symptom	Condition
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 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 set point. 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: 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. Use a longer display filter time constant to reduce displayed noise.

Symptom	Condition
DC offset in temperature measurements.	Possible causes: The wrong sensor type or sensor calibration curve is being used. Refer to the Input Channel Setup Menu section. DC offset in cryostat wiring. 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. 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: Ensure that the RS-232 port is selected. Press the $\boxed{\text{Sys}}$ key and scroll down to the Port: field. Ensure that the baud rate of the controller matches that of the host computer. To check the controller's baud rate, press the $\boxed{\text{Sys}}$ key and scroll down to the RIO-RS232 field. Ensure that the host computer settings are 8-bits, No parity, one stop bit. 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. 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: Long cables. Try using a lower baud rate. In some cases, inserting a 50mS delay between commands will help. Noise pickup. Try using shielded cables with the shield connected to a metal backshell at both ends.

Symptom	Condition
Can't talk to IEEE-488 interface.	Possible causes: Ensure that the GPIB port is selected. Press the Sys key and scroll down to the RIO-Port: field. The IEEE-488 interface does not use terminator characters. Rather, it uses the hardware EOI handshake. Please review the GPIB Configuration section. Check that the controller's address matches the host computer's assignment. Press the Sys 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: Bus cables too long or too many loads on a single bus. Don't send reset commands before each query. This was common in early IEEE-488 systems. 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. Use of unshielded bus cables.

Symptom	Condition
Can't talk to USB interface.	Possible causes: Ensure that the USB port is selected. Press the Sys key and scroll down to the RIO-Port: field. USB drivers not installed. Review the Universal Serial Bus (USB) ConfigurationGPIB Configuration section. The USB interface uses a hardware handshake method. Therefore, line terminator characters are not used. Check that the controller's address is unique on the USB. Press the Sys 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 USB 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: Blown fuse. Check line voltage selection before installing new fuses. Review the Fuse Replacement and Voltage Selection section. 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 C: Application Note on Signal Dither.

Using Dither in Digital Control Loops

"Dither", as a signal or image processing technique, is a method of extending dynamic range by first perturbing (dithering) then averaging. The technique was first developed to enhance the performance of RADAR target algorithms and is now applied to a wide range of applications including navigation systems and consumer audio CD recordings.

Perhaps the most common example of a dithering technique is the synthesis of an artificial color on a computer screen by grouping available colors at adjacent pixels. When viewed by the user, the spatial averaging effect of the eye generates a color that is not available on the computer's color palette.

In Cryo-con's temperature controllers, dither is used to extend the dynamic range of a temperature control loop by outputting available power levels in a controlled sequence so that the average power is somewhere between the levels available in the controller's hardware. Here, the averaging function is performed by the system dynamics.

Control Accuracy

Major error sources in a digital control loop are: the input quantizer (ADC), the Digital Signal Processing mathematical operations and the output quantizer (DAC).

Cryo-con controllers use a 24-bit Analog-to-Digital converter. This is the best available with modern components and it establishes the measurement resolution of the controller. If all other functions were perfect, this ADC would also establish the accuracy of the control loop.

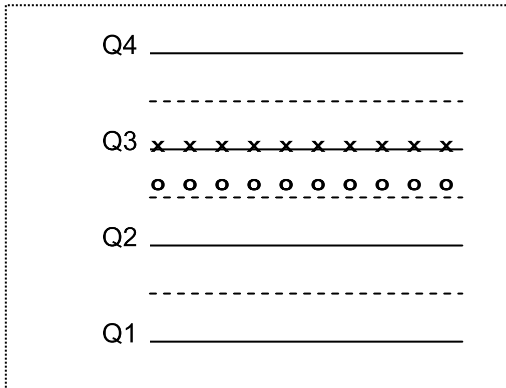
In order to preserve accuracy, the mathematical operations in a digital control loop must be performed to a much higher resolution than the input ADC. Therefore, Cryo-con controllers all use 32-bit floating-point arithmetic.

Finally, a high precision loop output value reaches the output quantizer, which is usually a 16- or 18- bit Digital-to-Analog converter. Since this DAC has much less resolution than the earlier stages, it generally establishes the accuracy of the accuracy of the entire loop. A loop output value has been generated to a very high precision, but the DAC throws away most of this precision to fit its available output levels.

Like the color synthesis example above, signal dithering can be applied to the digital control loop so that the average output value converges to the high precision value computed before output quantization. The result is much greater control accuracy.

Conventional Control Loop Output

The diagram to the right shows the conventional method of generating an analog output from a digital control loop. Here, a high precision loop output value is computed, then the value is truncated or rounded to fit the precision of the output DAC. Precision above the resolution of the DAC is lost.



In this example, the output DAC has four quantization levels labeled Q1 through Q4. Dashed lines show the mid-points between adjacent levels.

Here, the desired high-precision control loop output (o) is between levels Q2 and Q3. For simplicity, ten output intervals of a DC level are shown.

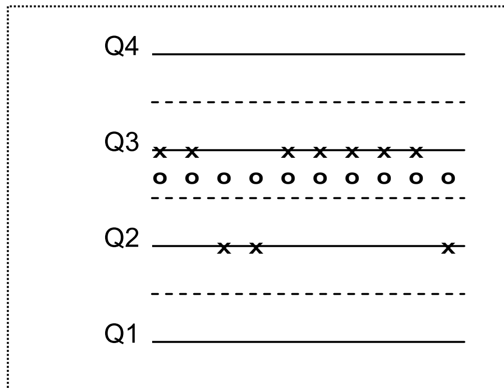
Using an arithmetic 'rounding' scheme, if the desired output is above the mid-point between two quantization levels, the DAC output will be at the higher level. If the value is below the mid-point, the DAC will output the lower level. Therefore, the DAC output (x) for the input shown will simply be Q3.

As can be seen, the average value of the DAC output is equal to the nearest quantization level. In this example, the output (Q3) is slightly higher than the value required to accurately control at the selected set point. Therefore, the control loop will integrate downwards until the DAC output jumps down to Q2. This process of jumping between Q2 and Q3 will continue, establishing an oscillation with an amplitude of one quantization level and a frequency related to the system's closed-loop time constant.

The Dither Algorithm

The signal dithering algorithm used in Cryo-con's digital control loop first generates a dither signal that is a random number within the range of ±0.5 of a quantization level. This is then added to the loop output value just before placing it in the DAC.

If the sum of the desired output plus the dither value is above the midpoint between Q2 and Q3, the DAC will output Q3. If it is below the midpoint, the DAC will output Q2. Therefore, the DAC output to toggles randomly between Q2 and Q3, but the number of times at one level vs. the other is weighted by how close the desired output is to the nearest quantization level.



In this example, the desired output is 25% of the distance from Q3 to Q2. Therefore, 75% of the DAC output samples will be Q3 and the remaining at Q2.

Most importantly, the average value of the DAC output converges to the desired output loop value.

Using this dither technique, the control loop output accuracy will improve as the number of averages increases; up to the limits imposed by the other elements of the control loop.

Fortunately, the number of samples averaged in a given system is proportional to its closed-loop bandwidth, which can be controlled by adjusting PID parameters.

How much improvement does dither provide?

Dither causes the average value of the control loop output to converge to the actual desired output. How close depends on the number of averages accumulated within the closed-loop system.

The accuracy of an estimate of average value for a fixed number of samples is given by the Chi-squared distribution. The 'degrees of freedom' used by this function is the number of samples accumulated.

Using the Cryo-con Model 32, the loop output rate is 10 samples per second. Therefore, if the process being controlled has a time constant on the order of 1.6 seconds, a total of 16 samples will be averaged, resulting in a factor of four improvement in control accuracy. This is equivalent to adding two bits to the output DAC.

Since the Model 34 uses a 16-bit output DAC, a 1.6 second closed-loop time constant will result in the equivalent of an 18-bit DAC. Note that 1.6 seconds is an extremely short time constant for a cryogenic temperature process.

Further Reading: “Introduction to Signal Processing”, Sophocles J. Orfanidis, August 1995. Prentice Hall**,** ISBN: 0-13-209172-0
http://www.ece.rutgers.edu/~orfanidi/intro2sp/

Appendix D: Tuning the 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 set points.

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 set points.

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 you are concerned about possible damage from overheating.

1. Enter a set-point value that is a typical for the envisaged use of the system. Select a heater range that is safe for your equipment. Set initial PID values of Pgain=0.1, Igain=0 and Dgain=0.
2. Engage the control loops by pressing the **Control** key and then increase, or decrease 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*.
3. 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*

4. 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.

Most cryogenic systems use a Dgain value of zero. This is because Dgain adjusts how fast the loop responds to changes in heat load, which is uncommon in cryogenic equipment. Further, the Dterm is a derivative action, which can introduce 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

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