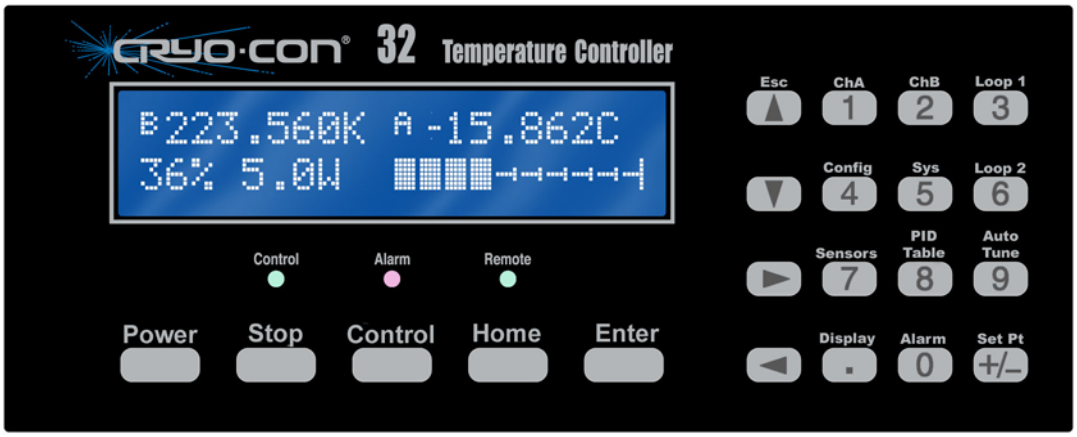
Cryogenic Temperature Controllers

Model 32/32B

The Model 32 sets the standard for simplicity, useable features and price. It is a cost-effective, two-channel controller designed for fixed cryogenic applications (i.e., cryostat and cryocooler) where measurement accuracy and control stability are the two primary requirements. The Cryo-con® Model 32 is a precision Cryogenic Temperature Controller designed for single control loop applications. The Model 32B adds a second, medium power output for systems that require dual-loop control in a single unit.



Major highlights of the Model 32:

- **Maximum flexibility: Two multipurpose input channels support Diode, Platinum RTD and most cryogenic NTC resistive temperature sensors. A Thermocouple input is optional.**
- **Constant-Voltage, AC excitation of resistive sensors extends their useful temperature range down to 200mK and improves accuracy at higher temperatures.**
- **Unique synchronous filter significantly improves control accuracy and stability with cryocooler systems.**
- **Loop #1 Primary control loop: 50 Watt, 50Ω, three-range linear heater output.**
- **Loop #2 Secondary control loop of the Model 32B is a 10 Watt, 50Ω, linear output. The standard Model 32 provides a second loop output of zero to ten volts.**
- **Fail-safe cryostat over-temperature protection features protect user equipment from damage.**
- **Extremely low noise design allows operation in the most demanding of cryogenic environments.**
- **CalGen® feature allows the user to custom fit any Diode, Thermocouple or resistor sensor calibration curve.**
- **Proven, tested autotuning optimized for cryogenic systems.**
- **Flexible, easy to configure VFD display.**
- **PC Windows® based Utility software provides a graphical control panel to simplify configuration, integration and testing.**
- **Remote interfaces include RS-232 and IEEE-488.2 (GPIB). Industry standard SCPI command language. National Instruments, Inc. LabVIEW™ drivers are available.**
- **NIST traceable calibration. European CE certified.**

Input Flexibility

The Model 32 has **two sensor inputs**, both of which can be easily configured to support virtually any type of cryogenic thermometer. Configuration is performed from the instrument's front panel or a remote interface.

Silicon Diode sensors from Cryo-con® or any other manufacturer are directly supported over their full 1.4 to 500K range using built-in calibration curves and sensor data. Plus, non-volatile Flash memory is available for several custom or calibrated sensors.

A unique feature of the Model 32 is the use of a ratiometric resistance bridge technique to measure Positive Temperature Coefficient (PTC) resistor sensors including **Platinum** and **Rhodium-Iron** RTDs. This significantly reduces low frequency noise and drift to provide rock-solid measurements

Platinum RTD sensors the use built-in DIN 43760 (IEC 750) standard curves for 100Ω, 1,000Ω or 10KΩ devices. The standard curve is used for temperatures from 70K to 1020K and is extended down to 30K for cryogenic use. Operation to about 14K is possible with user-supplied curves.

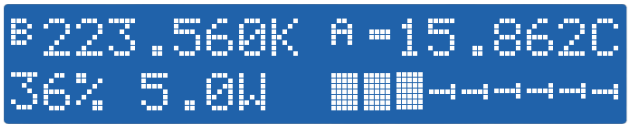
The Model 32 provides robust support for the Negative Temperature Coefficient (NTC) sensors commonly used by cryogenic applications. They include **Ruthenium-oxide**, **Cernox**™, **Carbon-Glass**™, **Germanium** and several others. Since they have a negative temperature coefficient, the constant-voltage measurement method will reduce, rather than increase, power dissipation in the sensor as temperature decreases. By maintaining the lowest possible power level, sensor self-heating is minimized and useful temperature range is greatly increased.

An additional advantage to constant-voltage biasing is that NTC resistors lose sensitivity in the upper part of their range. By auto-ranging excitation current to maintain a constant voltage, sensitivity and noise immunity in that range is greatly improved.

Sensor excitation used in conjunction with the constant-voltage feature is a 1.25Hz bipolar square wave. This effectively cancels thermal EMF induced offset errors that sometimes occur in cryogenic systems. The maximum and minimum sensor resistance that can be read is a function of the selected voltage bias.

Resistance Range Table		
Voltage Bias	**Min. Resistance**	**Max. Resistance**
10.0mV	10Ω	1.0MΩ
3.33mV	3.3Ω	430KΩ
1.0mV	1Ω	100KΩ

Thermocouple measurements are supported via a factory installed option on a single input channel. This option replaces the standard input connector with a spade type thermocouple connector. The Cold-Junction compensation temperature is measured in an internal, insulated space so that errors commonly caused by air currents are eliminated.



Measurement accuracy is obtained by using 24-bit analog to digital conversion at a minimum sample rate of 10Hz per channel and is further enhanced by extensive use of Digital Signal Processing (DSP).

Conversion of a sensor measurement into temperature is performed by using a Cubic Spline interpolation algorithm. The Model 32 includes built-in curves that support most industry standard temperature sensors. Additionally, **four user calibration curves** are available for custom or calibrated sensors. Each user curve may have up to 200 entries and may be entered from the front panel, or transferred via any of the available remote interfaces.

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

The Model 32 continuously tracks temperature history, independently on each input channel and provides a statistical summary that indicates the channel's minimum, maximum, average and standard deviation. Also shown are the slope and the offset of the best-fit straight line of temperature history data.

Dual Control Loops

The Loop #1 Heater channel is a linear, low noise RFI filtered current source that can provide up to 1.0 Ampere into 50Ω or 25Ω resistive loads. Three full-scale ranges are available in decade increments.

The standard Model 32 offers a 0 to 10 Volt output for a second control loop. This may be used with a programmable booster power supply where dual-loop or high power control is required.

For applications that require dual-loop control from a single instrument, the Model 32B features a 10W linear heater output as the Loop #2 output. The Loop #1 and Loop #2 heaters are completely independent and either heater can be controlled by either sensor input.

Control modes are **Manual**, **PID**, **Ramp** and **PID Table**. The industry standard Proportional-Integral-Derivative or PID control loop is implemented as a DSP algorithm and is enhanced to minimize set-point overshoot and differentiator noise.

For cryocooler applications, the Model 32 offers a **Cryocooler Filter** that will synchronously subtract the cooler's thermal signal from the input in order to provide a significant improvement in baseline temperature control. Since classic PID control loops often track and even amplify the low frequency signal generated by the cooler, synchronous filtering provides a major improvement in control accuracy and stability.

The direction of the control loop can be easily reversed to accommodate thermoelectric type coolers where power is applied to cool rather than heat.

The field proven **Autotune** function of the Model 32 involves the use of a specific output waveform to first develop a process model, then generate the optimum P, I and D coefficients.

Cryogenic systems often require stable control over a wide range of temperatures. Here, control loop tuning parameters can be significantly different at different temperatures. For this reason, the Model 32 offers **PID tables** that store optimum tuning parameters vs. setpoint temperature. Six PID tables are available. Each contains PID and heater range settings for up to 16 temperature set points.

The Model 32 will perform a **temperature ramp** function using a specified maximum 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.

Cryostat Protection

Damage to a cryostat or critical sample is a serious problem with any cryogenic system, so the Model 32 implements the most robust set of protection features in the industry.

The **Over Temperature Disconnect** feature will disable the heater if an over temperature condition exists on any selected input channel. A fail-safe mechanical relay is used to disconnect the controller's heater thereby ensuring that the user's equipment is always protected.

The **Maximum Setpoint** feature is used to prevent the user from inadvertently entering a higher setpoint than the equipment can tolerate.

Setting the **Maximum Power Limit** will ensure that the controller can never output a heater power above the set limit.

Alarms

The Model 32 supports visual, remote and audible alarms. Each may be independently programmed to assert or clear based on a high or low temperature condition or a detected sensor fault.

Latched alarms are asserted on an alarm condition and will remain asserted until cleared by the user.

Lowest Noise

The Model 32 was designed for use in extremely low noise environments that cryogenic systems often require. Linear-mode power supplies are used throughout and sensor excitation current sources are not multiplexed.

Modern components and proven noise management techniques were carefully applied to every sensor excitation and heater output circuit in order to minimize conducted noise.

Optical isolation is used to prevent noise pickup by sensitive analog circuits and to eliminate ground loops.

The enclosure of the Model 32 is all Aluminum with wide conductive overlaps on all mating metal surfaces so that radiated RFI noise is virtually eliminated. An effective shielding and grounding scheme further allows the user to minimize both conducted and radiated noise.

Easy to Use

The Model 32's user interface consists of a large, bright Vacuum Fluorescent display and a full, 20-key keypad. All features and functions of the instrument can be accessed via this simple and intuitive menu driven interface.

Accessing primary instrument functions, such as display units and heater set point, require only a single key press. More complex features can be accessed by scrolling through short menus.

Temperature displays are autoranged to show the most number of significant digits. Built-in filters can be used to smooth temperature data and display resolution can be selected for optimum viewing. Units of K, °C, °F, Volts or Ohms may be selected.

Remote Control

Standard Remote Interfaces include RS-232 and IEEE-488.2 (GPIB). Interfaces are electrically isolated to prevent ground loops.

The unit's firmware as well as all user and configuration data can be reprogrammed via either of these remote ports.

To further assist in the development of system software using the Model 32, a complete set of **LabVIEW™** drivers are available. These drivers support the GPIB and Serial interfaces.

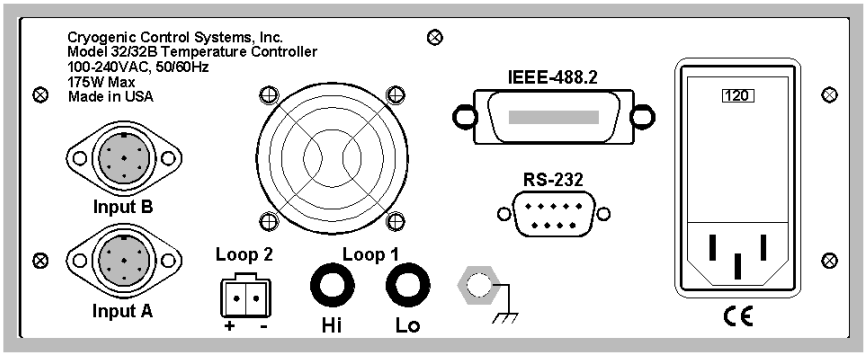
Utility Software

Utility software is provided that connects any Windows based personal computer to the Model 32 via either of its remote interfaces. This software provides a graphical control panel that greatly simplifies instrument setup and configuration.

Sensor calibration curves may be downloaded to the controller, viewed and edited. Most file formats are directly supported and can be easily converted to Cryo-con's® standard format.

Rear panel connections

- Input Connectors: Two DIN-5 recepticals provide 4-wire measurement connection. A thermocouple option is available that replaces the Input B receptical with a 2-pin spade type thermocouple connector.
- Loop #1 heater output: Stackable banana plugs.
- Loop #2 output: 2-pin detachable terminal block.
- IEEE-488: Standard IEEE-488.2 (GPIB) connector.
- RS-232: Null-modem connector (DB-9, pins).
- AC Power: RFI filtered Power Entry Module including fuse drawer and line voltage selector.



Ordering Information

Standard	Dual Loop	Description
Model 32	Model 32B	Controller with two standard multi-function sensor input channels.
Model 32-T	Model 32B-T	Controller with one standard input and one thermocouple input.

Sensor Performance Data

Sensor Type	Silicon Diode	100Ω Platinum DIN43760	1000Ω Platinum DIN43760	Ruthenium Oxide[2]	Carbon Glass™[2]	Cernox™[2]	Thermocouple
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	1.0K: 1260Ω/K 4.2K: 80.3Ω/K 20K: 3.96Ω/K	1.4K: 520KΩ/K 4.2K: 422Ω/K 77K: 0.1Ω/K 300K: 0.01Ω/K	1.4K: 240KΩ/K 4.2K: 2290Ω/K 77K: 2.15Ω/K 300K: 0.16Ω/K	4.2K: 0.9μV/K 300K: 41μV/K 1500K: 36μV/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	1.0K: 1.9Ω 4.2K: 1.4Ω 20K: 1.09Ω	1.4K: 728Ω 4.2K: 0.58Ω 77K: 014mΩ 300K: 0.02Ω	1.4K: 675Ω 4.2K: 5.1Ω 77K: 161mΩ 300K: 40mΩ	300K: 41μV 1500K: 2.5μV
Temperature Measurement Accuracy	300K: 8.7mK 77K: 12mK 4.2K: 1.6mK	800K: 6.7mK 300K: 6.2mK 77K: 2.8mK 30K: 9.8mK	600K: 10mK 300K: 6.2mK 77K: 2.8mK 30K: 9.8mK	1.0K: 1.9mK 4.2K: 17mK 20K: 275mK	1.4K: 1.4mK 4.2K: 1.4mK 77K: 150mK 300K: 2.1K	1.4K: 2.2mK 4.2K: 2.2mK 77K: 75mK 300K: 295mK	300K: 60mK[1] 1500K: 70mK[1]
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	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	300K: 0.5μV 1500K: 0.5μV
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	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	300K: 11mK 1500K: 13mK
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	2.0K: 0.15mK 4.2K: 0.15mK 20K: 2.9mK	4.2K: 0.15mK 77K: 35mK 300K: 250mK	4.2K: 0.15mK 77K: 0.15mK 300K: 3.5mK	300K: 11mK[1] 1500K: 13mK[1]
Power Dissipation	4.2K: 17μW 77K: 12μW	30K: 3.7μW 77K: 20μW	30K: 370nW 77K: 2.0nW	1.0K: 42nW 4.2K: 73nW	1.4K: 962pW 4.2K: 171nW	1.4K: 1.1nW 4.2K: 20nW	
Magneto-resistance	Very Large	Moderate	Moderate	<2% for H<2T	Moderate	<1% for H<2T	Very Large

[1]Plus any additional error from the Cold Junction Compensation method. [2] 10mV Constant-Voltage excitation

Silicon Diode sensors use a fixed excitation current of 10μA and an input voltage range of 0 to 2.5V.

Both Negative and Positive Temperature Coefficient (NTC) / (PTC) resistor sensors are supported using a ratiometric bridge technique to cancel low frequency noise.

PTC sensor types include **Platinum** and **Rhodium-Iron**. Excitation currents are 1.0mA, 100μA and 10μA DC. Corresponding full-scale resistance ranges are: 312Ω, 3.2K and 31KΩ.

NTC sensors include **Ruthenium Oxide**, **Carbon Glass™**, **Germanium** and **Cernox™.** Constant-voltage sensor excitation of 10.0mV, 3.3mV or 1.0mV allows the use of these sensors over an extended temperature range. Minimum excitation current is 10nA.

Thermocouple sensors are supported by ordering an optional Thermocouple input. This option provides a 2-pin spade type input connector with screw-terminal attachment to the thermocouple wires. An internal Cold Junction Compensation circuit is provided. Input voltage range is ±80mV. All thermocouple types are supported.

GaAlAs and GaAs Diode sensors are supported from 25 to 475K. The maximum input voltage range of the controller imposes this limitation.

Model 32 Supported Sensors

	Temperature Range	Example Sensors
Silicon Diode	1.4 – 500K	Cryo-con S900, S800 Si440, Si430, Si410 Lakeshore DT-670, DT-470
Platinum RTD	14 – 1200K	Cryo-con CP-100 Cryo-con GP-100
Rhodium-Iron	1.4 – 800K	Oxford PHZ 0002
Germanium	200mK – 100K	Lakeshore GR-200A
Carbon Glass™	1.4 – 325K	Lakeshore CGR-1-500
Cernox™	200mK – 325K	Lakeshore
Ruthenium Oxide	200mK – 200K	Cryo-con R400, R500
Thermocouple (optional)	K: 3.2 – 1500K E: 3.2 – 930K T: 3.2 – 670K U: 1.2 – 600K	All thermocouple types including AuFe 7%

Specifications

User Interface

Display Type: 20 x 2 character VFD, 9mm character height.
Number of Inputs Displayed: Two.
Keypad: Sealed Silicon Rubber.
Temperature Display: Six significant digits, autoranged.
Display Update Rate: 0.5 Seconds.
Display Units: K, C, F or native sensor units.
Display Resolution: User selectable to seven significant digits.

Input Channels

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

Sensor Connection: 4-wire differential. DIN-5 or DIN-6 Connectors. Thermocouple option uses a 2-pin spade type connector.
Sensor Types: See Supported Sensor Table.
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. Constant voltage: 10mV, 3.333mV and 1.0mV RMS. Excitation Current: 1.0mA to 10nA in steps of 5% of power.
Resistance Measurement type: Ratiometric bridge.
Resistance Range: Constant-voltage, Maximum resistance: 10mV = 1.0MKΩ, 3.3mV = 430KΩ, 1.0mV = 100KΩ.
AC Excitation Frequency: Resistor sensors in constant-voltage mode: 1.25Hz bipolar square wave.
Sample Rate: 10Hz per channel.
Measurement Resolution: Sensor Dependent. See Sensor Performance Data table.
Digital Resolution: 24 bits.
Measurement Drift: <15ppm/^{o}C.
Isolation: Input channel circuits are electrically isolated from all other internal **circuitry**.
Measurement Filter: 0.5, 1, 2, 4, 8, 16, 32 and 64 Seconds.
Calibration Curves: Built-in curves for industry standard sensors plus four user curves with up to 200 entries each. Interpolation is performed using a Cubic Spline.
CalGen®: Calibration curve generator fits any Diode, thermocouple or resistor sensor curve at 1, 2 or 3 user specified temperature points.
Thermocouples: Factory installed option on one channel only.
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 setpoint 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 selectable at 25V or 50V.
Ranges: Three output ranges of 1.0A, 0.33A and 0.10A full-scale, which correspond to 50W, 5.0W and 0.5W when used with a 50Ω load.
Load Resistance: 25Ω or 50Ω. Heaters down to 10Ω can be used with the 25Ω range.
Minimum Load: 10Ω in 25W setting, 40Ω in 50W setting.
Digital Resolution: 1.0ppm of full-scale power (20 bits).
Readbacks: Heater output power, Heatsink temperature.

Loop #2 Output, Standard Model 32

Type: Voltage output, 0 to 10 Volts. Input impedance is 500Ω.
Digital Resolution: 1.0ppm of full-scale power (20 bits).

Loop #2 Heater Output, Model 32B

Type: 10 Watt, short circuit protected linear current source. Maximum output is 0.45A at 25V.
Load Resistance: 50Ω (10Watts), 25Ω (4 Watts) or 10Ω (1.6 Watts).
Digital Resolution: 1.0ppm of full-scale power (20 bits).
Readback: Heater output power.

Status Outputs

Audible and Visual Alarms: Independent audible remote 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. Data rates are 300, 1200, 4800, 9600, 19,200 and 38,400 Baud.

IEEE-488 (GPIB): Full IEEE-488.2 compliant.

Remote Programming Language is IEEE SCPI compliant.

National Instruments LabVIEW™ drivers available.

User Setups

Four 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 request.

General

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

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