Innovative Solutions in
Cryogenic Instrumentation

Cryogenic Temperature Controller

Model 24C

The model 24C is a four-input, four-control loop cryogenic temperature controller capable of operation to 300mK. While enhanced for low temperature operation, a wide variety of general purpose sensors and heaters are supported.

Highlights of the Model 24C:

- **Operation from 300mK to over 1500K** with an appropriate sensor.
- **Four multipurpose input channels.** Each input is enhanced for operation with the NTC resistance sensors commonly used at low temperature while still supporting a wide variety of general purpose devices including Diodes and Platinum RTDs. Thermocouple inputs are a field installable option.
- **Four independent control loops:** Loop #1: 50-Watt, three-range; Loop #2: 25-Watt two-range; Loop #3 and #4: 10-Volt two-range.
- Large, bright and highly configurable display.
- Two large 10-Ampere dry-contact relays.
- Data logging to internal Non-Volatile memory.
- Remote interfaces include **Ethernet** and RS-232. IEEE-488.2 (GPIB) is a field installable option**.**
- Protect your system software: Remote command language is **IEEE-488.2 SCPI** compliant.
- **LabView**™ drivers available for all interfaces.

Applications:

Helium 3 refrigerators and ULT:

- Step-less constant-voltage AC sensor excitation with levels from 10mV to 100µV. Active DC offset removal reduces sensor self-heating.
- High precision heater outputs for excellent control stability.
- Low power heater ranges support ULT systems.

Cryogen-Free systems:

- Proprietary cryocooler thermal signature removal.
- Four input channels

Superconducting Magnets:

- Robust support for the NTC temperature sensors used in magnet systems.
- Continuous data logging to non-volatile memory.

General purpose laboratory:

- Four inputs support a wide variety of temperature sensors.
- Four independent control loops.
- Ethernet connectivity for ease of remote control.
- Internal data logging.
- Temperature activated relays and alarms.
- Instrument status and control via a standard web browser. E-mail on alarms.
- Data acquisition / computer control

For applications that require high output power, consider the Model 26C.

Flexible Sensor Inputs

The Model 24C has four independent and identical input channels, each of which support all temperature sensor types in any combination.

An important feature of the input channels is that they support resistor temperature sensors by implementing a ratio-metric AC resistance bridge. This bridge uses separate, balanced circuits to simultaneously measure both the voltage drop across the sensor and the current flowing through it. By measuring current with higher accuracy than it can be set, precision resistance measurements are obtained, even at low excitation levels.

Negative-Temperature-Coefficient (NTC) resistors are often used as low temperature thermometers, especially at ultra-low temperature. Examples include Ruthenium-oxide, Carbon-Glass, Cernox™, Carbon-Ceramic, Germanium and several others. The Model 24C provides robust for support these sensors by using constant-voltage AC excitation. In their warm region, these sensors have low resistance and low sensitivity. Maintaining a constant-voltage will increase excitation current to improve measurement accuracy. Conversely, at low temperature, measurement errors are dominated by sensor self-heating. In this region, constant-voltage excitation reduces excitation current as temperature decreases.

Another source of error at low temperature is sensor self-heating due to DC offsets produced by the measurement electronics. The Model 24C first measures the DC offset excitation current flowing through the sensor then actively tracks and cancels it.

Ultra-low temperature measurements can be negatively affected by coarse steps in sensor excitation current. The Model 24C prevents this by using a step-less, continuously variable excitation source. Since the excitation current is measured to higher accuracy than it can be set, precision is maintained, even with a continuously variable source.

Positive Temperature Coefficient (PTC) resistor sensors including Platinum, CLTS and Rhodium-Iron RTDs use the resistance bridge in a constant-current, AC or DC excitation mode.

Platinum RTD sensors use a built-in DIN standard calibration curve that has been extended to 14K for cryogenic use. Lower temperature use is possible with custom calibrations.

Silicon diode sensors are supported over their full temperature range by using 10µA DC constant-current excitation.

Model 24C Supported Sensors		
	Temperature Range	**Example Sensors**
Silicon Diode	1.4 - 500K	Cryo-con S950, S900 SI-440, 430, 410 Lakeshore DT-670, 470
Platinum RTD	14 - 1200K	Cryo-con CP-100 Cryo-con GP-100 Cryo-con XP-100 Cryo-con XP-1K
Rhodium-Iron	1.4 - 800K	Oxford PHZ 0002
Germanium Thermistor	100mK - 400K	AdSem, Inc.
CLTS	4 to 300K	Vishay CLTS-2B
Silicon Thermistor	0.5 - 720K	AdSem, Inc.
Cernox™	100mK - 325K	Lakeshore, all types
Carbon-Ceramic	100mK - 300K	Temati
Ruthenium Oxide	100mK - 270K	SI RO-600
Thermistor	193 - 523K	Measurement Specialties
Thermocouple	1.4 to 1500K	All thermocouple types
ZrON®	100mK to 425K	ZrON®

Thermocouple sensors are supported by using an optional thermocouple module. This module plugs into any of the Model 24C's input channels. It is powered by the instrument to provide amplification, cold-junction compensation and connection to copper. Up to two modules can be connected to a single instrument.

Input Specifications

Sensor Type	Diode	PTC resistors	Thermocouple (Option)
Input Range	0.1V - 2.25V	1.0mA: 0.1 - 500Ω 100µA: 1.0K – 5.0KΩ	±70mV
Accuracy: % Rdg	0.005% ± 80µV	100Ω: ± (0.004 + 0.01%)Ω 1KΩ: ± (0.05 + 0.01%)Ω	0.05%
Resolution: % Range	10µV	0.0003%	0.0003%
Excitation	10µA DC	1.0mA, 100µA	N/A

NTC Resistance Measurement Range						
Resistance	**10mV**	**3.0mV**	**1.0mV**	**300µV**	**200µV**	**100µV**
Maximum	1.0MΩ	300KΩ	100KΩ	30KΩ	20KΩ	10KΩ
Minimum	8Ω	2.4Ω	0.8Ω	0.24Ω	0.16Ω	0.08Ω

NTC Resistance Measurement Accuracy, Vbias = 10mV		
Excitation Range	**Resolution**	**Accuracy**
1.0mA	0.1mΩ	± (0.04% reading + 0.001)Ω
100µA	1.0mΩ	± (0.04% reading+ 0.01)Ω
10µA	10mΩ	± (0.04% reading+ 0.1)Ω
1.0µA	100mΩ	± (0.04% reading+ 1)Ω

The Model 24C includes built-in **sensor calibration curves** that support most industry standard temperature sensors. Additionally, eight **user calibration curves** are available for custom or calibrated sensors. Each user curve may have up to 200 entries.

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

New calibration curves may be generated using the **CalGen™** feature. This provides an easy and effective method for obtaining higher accuracy temperature measurements without expensive sensor calibrations.

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

Data logging is performed by continuously recording input temperature data to an internal 1,365 entry buffer. Data is time stamped. Non-volatile memory is used so that data will survive a power failure.

Four Control Loops

The **Loop #1** heater output is a linear, low noise RFI filtered current source that can provide up to 1.0 Ampere into 50Ω or 25Ω resistive loads. Three full-scale ranges are available in decade increments down to 500mW.

Loop #2 is a two-range linear heater with that will provide 25 or 2.5-Watts into a 50Ω load.

Loop #3 and #4 are non-powered analog voltage outputs designed to control an external booster power supply. Output is zero to 10-Volts or zero to 5-Volts by user selection. The controller's relays may be used to turn the external supply on or off.

Control stability is enhanced by the use of an over-sample plus dither algorithm that increases output resolution beyond the limit of the output quantizer.

All control loops are completely independent and any loop may be controlled by any sensor input. Control modes are **Manual**, **PID**, **Ramp, PID Table and Ramp Table**.

The field proven **Autotune** function of the Model 24C involves the use of a specific output waveform to first develop a process model, then generate the optimum P, I and D coefficients.

PID tables are available that can be used to store optimum control parameters vs. point temperature. Each entry of a PID table contains a setpoint, a control input, PID values and a heater output range setting. When the point is changed, the controller will automatically generate new PID values, a controlling input channel and heater range.

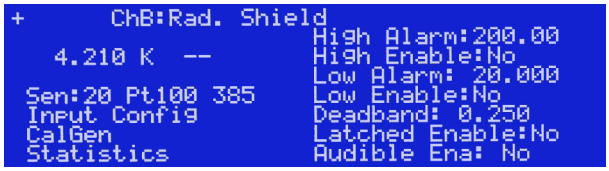
The Model 24C will perform a **temperature ramp** function using a specified maximum ramp rate and target setpoint.

User Interface

The Model 24C's user interface is based on a large, high resolution display plus a full 21-key keypad. With this bright and exceptionally wide viewing angle display, complete instrument status can be seen at a glance, even from across the room.

In this user-friendly interface, all features and functions of the instrument can be accessed via this simple and intuitive menu driven interface.

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



Innovative instrument configuration menus show real-time status information so the user can *instantly* view the results of any changes made.

As with all Cryo-con products, unique labels may be assigned to each sensor input or control loop output.

Cryostat Protection

Damage to a cryostat or critical sample is a serious problem with any cryogenic system. The Model 24C 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 point than the equipment can tolerate and a **Maximum Power Limit** will ensure that the controller can never exceed heater power output above the set limit.

Control loop faults will also be generated if the temperature of the output circuits is too high, the fan is not at full speed or the resistance of the connected load is too low.

Lowest Noise

The Model 24C was designed for use in the extremely low noise environments that cryogenic systems often require.

The grounding scheme facilitates the establishment of a single-point-ground. This is essential to the elimination of ground-loops and power-line noise pickup, especially in systems that require multiple instruments.

To minimize radiated noise pickup, The Model 24C implements a shielding scheme that allows the construction of a complete RFI shield around the instrument and cryostat.

Alarms and Relays

The Model 24C supports visual, remote and audible alarms. Additionally, there are two 10-Ampere dry-contact mechanical relays. Each may be independently programmed to assert or clear based on a high or low temperature condition or a detected sensor fault.

A fail-safe mode is implemented that will activate a relay only when the input temperature is within specified limits.

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

Remote Control

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

The Model 24C connects directly to any **Ethernet Local-Area-Network** (LAN) to bring fast Ethernet connectivity to all common data acquisition software programs including LabView™.

The instrument's **embedded web server** allows the instrument to be viewed and configured from any web browser.

LabView™ drivers are supplied for the Ethernet TCP/IP, IEEE-488.2, USB and RS-232 interfaces.

The Model 24C's **remote command language** is **SCPI** compliant according to the IEEE-488.2 specification. SCPI establishes a common language and syntax across various types of instruments. It is easy to learn and easy to read. The SCPI command language is identical in all Cryo-con products so that your investment in system software is always protected.

Command Scripts can be used to completely configure an instrument including setting custom sensor calibration curves and PID tables. Further, scripts can query and test data.

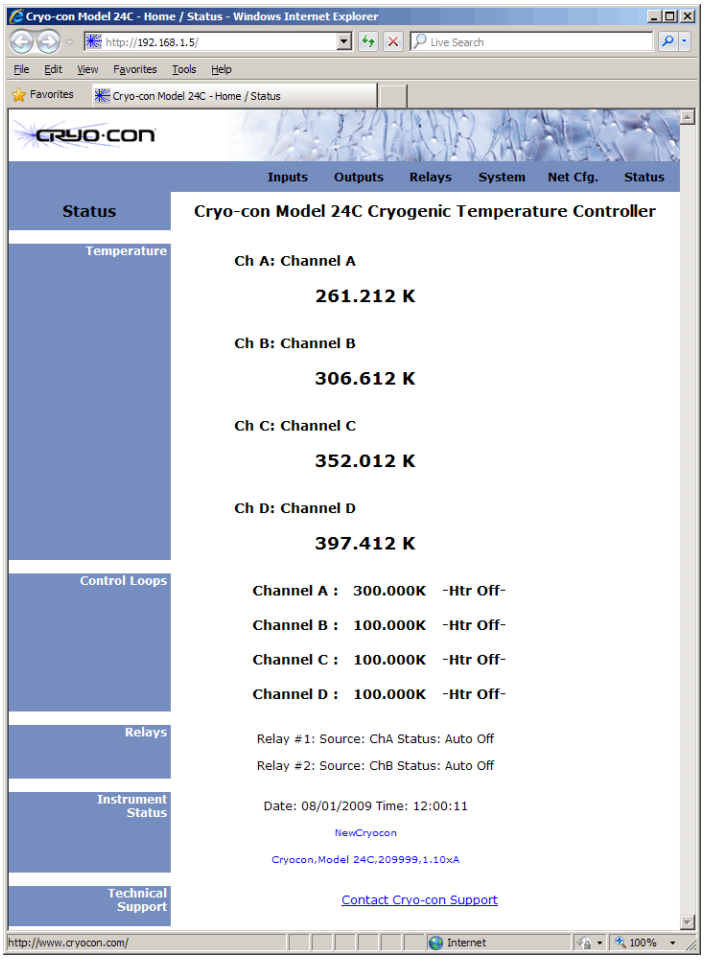
An **Applications Program Interface (API)** package is supplied that facilitates communication with the instrument using the TCP/IP interface. It is supplied as a Microsoft Windows™ DLL that is easily linked with C, C++ or Basic programs.

Firmware updates

Full instrument firmware updates may be installed by using the Ethernet connection. Cryo-con provides firmware updates, on request, via e-mail. They are free of charge and generally include enhancements and new features as well as problem fixes.

Utility Software: Utility software is provided that connects any Windows based personal computer to the Model 24C via any of its remote interfaces. This software provides a graphical control panel that greatly simplifies instrument setup and configuration. Features include:

- Continuous strip-chart monitoring of all inputs and outputs.
- Downloading, uploading, viewing and editing of sensor calibration curves and PID tables and command scripts.

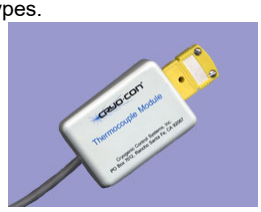


Rear Panel Connections

- **Input Connectors:** DIN-6 recepticals provide 4-wire measurement connection plus a continuous shield through the backshell.
- **Thermocouple Option:** Connects to any of the input connectors. Up to 4 modules supported.
- **Loop #1:** 50-Watt heater output. Dual Banana Plug with chassis ground lug.
- **Loop #2:** 25-Watt heater, part of a 10 pin detachable terminal block.
- **Loop #3 and #4:** 10 / 5.0-Volt output. Detachable terminal block.
- **Relay #1 and #2:** Dry contact relay. Detachable terminal block.
- **Ethernet:** RJ-45 with LAN activity indicator LEDs.
- **IEEE-488.2:** Option, connects to Ethernet port.
- **RS-232:** Null-modem connector (DB-9, pins).
- **AC Power:** RFI filtered Power Entry Module including fuse drawer and line voltage selector

Ordering Information

Product	Description
Model 24C	Controller with four multi-function sensor input channels and four control loops.
	Controller includes: User's Manual ,USB drive,four input connectors,Output connector kit ,L-shaped mounting,detachable power cord and a Certificate of Conformity. Specify AC Line Voltage or required power cord when ordering (may be changed in the field: -**100** Configured for 90 - 100VAC with detachable USA power cord. -**120** Configured for 110 - 120VAC with detachable USA power cord. -**230** Configured for 220 - 230VAC with detachable universal Euro (Shuko) line cord. -**240** Configured for 240VAC with detachable universal Euro (Shuko) line cord.

Options	Description
4039-004	Thermocouple Input Module. Field installable. Supports all thermocouple types. 
4001-002	IEEE-488.2 (GPIB) Option, field installable. 

Accessories	Description
4024-016	Input connector kit consisting of four DIN-6 sensor input connectors.
4124-018	Output connector kit consisting of a dual banana plug heater connector and a 10-pin terminal block receptacle.
4122-030	Single instrument 2U rack mount kit.

Specifications

User Interface

Display Type: 240x64 dot matrix STN LCD with LED back-light.
Number of Inputs Displayed: One to Four.
Keypad: 21 key Latex.
Temperature Display: Six significant digits, auto-ranged.
Display Update Rate: 0.5 Seconds.
Display Units: K, C, F or native sensor units.
Display Resolution: User selectable to seven significant digits.

Input Channels

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

Sensor Connection: 4-wire differential. DIN-6 Connector.
Thermocouple Connection: External option. Field installable.
Sensor Types: See Supported Sensor Table.
Sensor Selection: Front Panel or remote interface.
Input Configurations: See input specifications table.
Bridge type: Ratiometric resistance bridge.
Bridge Modes: Constant-Current or Constant-Voltage. AC or DC.
AC Excitation Frequency: 7.5Hz bipolar square wave.
Voltage Excitations: 10mV, 3.0mV, 1.0mV, 300µV, 200µV and 100µV. Minimum excitation current is <10nA, maximum is 1.25mA.
DC Offset: <8nA by active cancellation.
Sample Rate: 15Hz per channel.
Digital Resolution: 24 bits.
Measurement Accuracy: See input specifications table.
Measurement Drift:15ppm/°C. <10Ω. or >10KΩ: 30ppm/°C.
Isolation:Input channel circuits are electrically isolated from all other internal circuitry but not from each other.
Measurement Filter: 0.5, 1, 2, 4, 8, 16, 32 and 64 Seconds.
Calibration Curves: Built-in curves for industry standard sensors plus eight user curves with up to 200 entries each. Interpolation is performed using a Cubic Spline.
CalGen®: Calibration curve generator fits any Diode or resistor sensor curve at 1, 2 or 3 user specified temperature points.

Data Logging

Data logging is performed to an internal 1,365 entry circular buffer and is time-stamped with a real-time clock. Buffer memory is non-volatile and will retain valid data without AC power. All four input channel temperatures are recorded.

User Setups

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

Control Outputs

Number of Independent Control Loops: Four.
Control Input: Any sensor input.
Loop Update Rate: 15Hz per loop.
Isolation: Control loop circuitry is referenced to chassis ground.
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 and heater range vs. PID and heater range. 16 entries/table.
Set-point Accuracy: Six+ significant digits.
Fault Monitors: Control loops are disconnected upon detection of a control sensor fault, fan 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

Short circuit protected linear current source.

Ranges: Three output ranges of 1.0A, 333mA and 100mA full-scale, correspond to 50W, 5.0W and 0.5W into a 50Ω load.
Load Resistance: Selectable at 25Ω or 50Ω.
Minimum Load: 10Ω in 25W setting, 40Ω in 50W setting.
Resolution: 1.0ppm of full-scale power (20 bits).
Readbacks: Heater output power, Heatsink temperature, Fan speed.
Connection: Dual banana plug.

Loop #2 Heater Output

Short circuit protected linear current source.

Ranges: Two output ranges of 710mA and 224mA full-scale, which correspond to 25W and 2.5W into a 50Ω load.
Load Resistance: 50Ω for maximum output
Resolution: 1.0ppm of full-scale power (20 bits).
Readbacks: Heater output power, Heatsink temperature.
Connection: Detachable terminal block.

Loop #3 and #4 Control Outputs

Voltage outputs that can be configured as control loops or scaled analog outputs.

Output: zero to 10 / 5.0-Volts. Output impedance: ~2,000Ω.
Resolution: 1.0ppm of full-scale power (20 bits).
Connection: Detachable terminal block.

Status Outputs

Audible and Visual Alarms: Independent audible remote and visual alarms.
Relays: Two dry-contact relays. N.O. contacts available. Ratings are 125VAC @ 10A. Maximum switching power: 150W.
Status reported via Remote Interface: Sensor fault, Heater over temperature, Fan fault.

Remote Interfaces

Maximum reading rate for all interfaces is 10 rdg/s.

Ethernet: Connects to any Ethernet Local Area Network. Electrically isolated. **TCP/IP** server provide remote control by using an ASCII command language. **HTTP** provides built-in web server. **SMTP** sends e-mail based on alarm conditions.
RS-232: Standard null modem. Data rates are 9600, 19,200, 38,400 and 57,200 Baud. Connector is a DB-9 plug.
IEEE-488.2 (GPIB): External Option, field installable.
Programming Language: IEEE-488.2 SCPI compatible.
LabVIEW™ drivers available for all interfaces.

Firmware

Instrument firmware can be updated in the field via the Ethernet connection. Firmware updates are available via the Internet free of charge.

General

Ambient Temperature: 25°C ± 5°C for specified accuracy.
Mechanical: 436mmW x 87.3mmH x 305mmD.
Weight: 5.15kg .
Power Requirement: 100, 120, 230 or 240VAC +5% -10%.
50 or 60Hz, 150VA.
Conformity: European CE certified, RoHS compliant.
Calibration: NIST traceable.

RoHS Compliant

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