Cryogenic Temperature Controller
Model 24C

The Model 24C is a four-input, four-control loop cryogenic temperature controller designed for general purpose laboratory and industrial use. Each input is independent and capable of temperature measurement to <250mK with an appropriate temperature sensor. The Model 24C supports virtually any cryogenic temperature sensor produced by any manufacturer.

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

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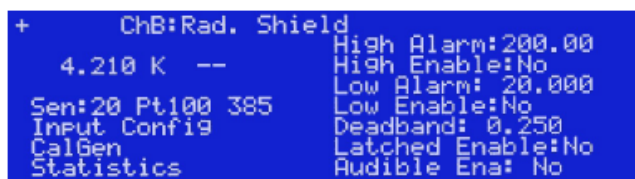

Major highlights of the Model 24C:

- Four multipurpose input channels support Diode, Platinum RTD and most cryogenic NTC resistive temperature sensors. Thermocouple inputs are optional.

- Operation from 250mK to over 1500K with an appropriate sensor. Constant-Voltage, AC excitation of resistive sensors minimizes errors and extends their useful temperature range.

- Four independent control loops: Loop #1: 50-Watt, three-range; Loop #2: 10-Watt; Loop #3 and #4: 10-Volt

- Large, bright and highly configurable display.

- Step-less Constant-Voltage AC sensor excitation for resistive temperature sensors.

- Synchronous input filter improves control accuracy and stability in cryocooler based systems.

- Two dry-contact relay outputs.

- Data logging to internal Non-Volatile memory.

- Table mode control automatically switches the loop input sensor to allow smooth, continuous control over a wide range of temperature.

- Remote interfaces include 100/10 Ethernet and RS-232 . USB 2.0 and IEEE-488.2 (GPIB) are available as field installable options. LabView™ drivers available for all interfaces.

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

```
1A Sample Space      2B Rad. Shield
      0.532k             4.210k
300.000K 1-Off-MID  100.000K 2-Off-10W
C:Cold Plate    --   D:Cryocooler    --
      77.332k          273.134k
```

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.

```
+       ChB:Rad. Shield
                    High Alarm:200.00
    4.210 K    --   High Enable:No
                    Low Alarm: 20.000
Sen:20 Pt100 385    Low Enable:No
Input Config        Deadband: 0.250
CalGen              Latched Enable:No
Statistics          Audible Ena: No
```

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

Flexible Inputs: The Model 24C has four identical input channels, each of which consists of an independent AC resistance bridge.

This bridge is used in a constant-voltage, auto-ranged AC mode to provide robust support for the Negative Temperature Coefficient (NTC) sensors including **Ruthenium-oxide**, **Carbon-Glass**, **Cernox™**, **Carbon-Ceramic**, **Germanium** and several others.

Silicon Diode sensors are supported over their full temperature range by using the bridge in a DC, constant-current mode.

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

Thermocouple sensors are supported by using an optional thermocouple module. This module is field installable and plugs into any of the input channels. Up to four modules can be connected to a single instrument.

Model 24C Supported Sensors		
	Temperature Range	**Example Sensors**
Diode	1.4 - 500K	Cryo-con S900, S800 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	250mK - 100K	Lakeshore GR-200A
Carbon Glass	1.4 - 325K	Lakeshore CGR-1-500
Cernox™	250mK - 325K	Lakeshore, all types
Carbon-Ceramic	250mK - 300K	TMi-A1
Ruthenium Oxide	250mK - 200K	Cryo-con R400 Cryo-con R500
Thermocouple	1.4 to 1500K	All thermocouple 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.

Input Specifications					
	Diode sensors	**PTC resistor sensors**	**NTC Resistor Sensors Constant-Current mode**	**NTC resistor sensors Constant-Voltage mode**	**Thermocouple**
Input Configuration	Constant-Current DC	Constant-Current Resistance Bridge	Constant-Current DC Resistance Bridge	Autoranging Constant-Voltage AC Resistance Bridge	DC voltage
Input Range	0.1V - 2.25V	1.0mA: 0.1 - 390Ω 100µA: 1.0 - 3.9KΩ 10µA: 10 - 39KΩ	100K - 225KΩ	Minimum: Range / 4 Maximum: Vbias / 300pA or 2.0MΩ	± 125mV
Accuracy: % Rdg ± % Range	0.004% ± 80µV	0.01% + 0.0005%	0.005% ± 25Ω	14 to 30K: 0.05% + 0.05% 0.5 to 2M: 0.15% + 0.15%	0.05%
Resolution: % Range	10µV	0.0003%	0.00004%	0.0003%	0.0003%
Excitation	10µA DC	1.0mA, 100µA, 10µA	10µA DC	100mV, 10mV, 1.0mV 20mA to 5nA continuously variable	N/A

Resistance Resolution			
Range	100mV	10mV	1.0mV
2Ω	(Excitation Resolution}	10mA 26μΩ	1.0mA 255μΩ
20Ω	10mA 2.6μΩ	1.0mA 255μΩ	100μA 2.6mΩ
200Ω	1.0mA 26μΩ	100μA 2.6mΩ	10μA 26mΩ
2KΩ	100μA 260μΩ	10μA 26mΩ	1.0μA 260mΩ
20KΩ	10μA 2.6mΩ	1.0μA 250mΩ	1.0μA 2.5Ω
Typical RMS resistance noise values measured at 50% of full-scale on a room-temperature resistor with a 3-Second analog time-constant.			

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

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 linear heater with that will provide 10-Watts into a 50Ω load.

Loop #3 and #4 are non-powered analog voltage outputs intended to control an external booster power supply. Output is zero to 10-Volts.

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.

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 point 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.

Warm-up Controller: In many applications, system throughput is limited by how fast a sample can be changed. Here, a warm-up function is used to apply heat to a cryostat in order to warm it to room temperature as rapidly as possible.

In warm-up mode, the Model 24C does not control temperature, rather it controls an external power supply to apply a fixed amount of power to a heater until a specified room-temperature setpoint is exceeded.

Virtually any power supply designed for Automatic Test Equipment (ATE) systems can be used with the Model 24C as an external warm-up supply.

Alarms and Relays: The Model 24C supports visual, remote and audible alarms. Additionally, there are two 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.

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

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

The Model 24C connects directly to any **100/10 Ethernet Local-Area-Network** (LAN).

The **TCP/IP data port server** brings fast Ethernet connectivity to all common data acquisition software programs including LabView™. TCP/IP implements an ASCII text based command language.

Using the Ethernet **HTTP** protocol, the instrument's **embedded web server** allows the instrument to be viewed and configured from any web browser.
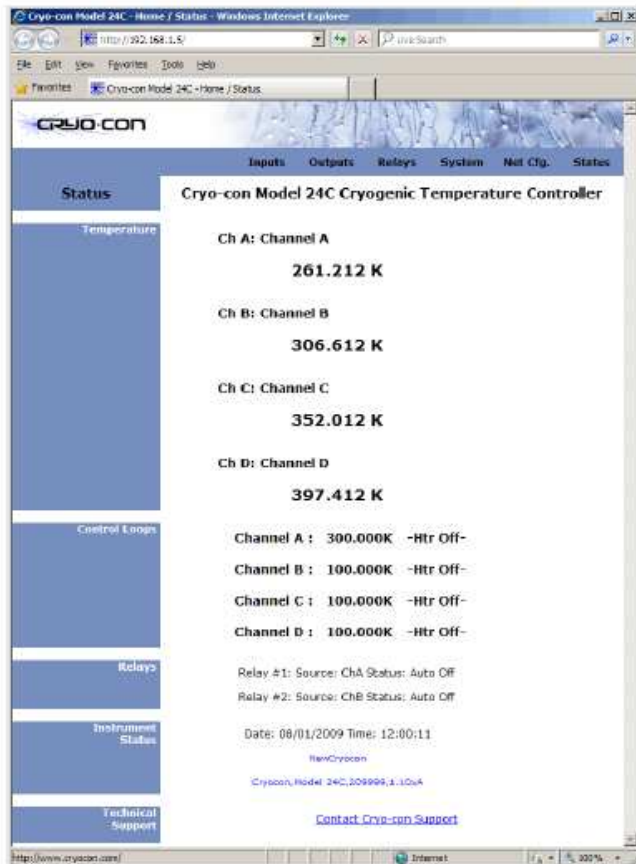
In order to eliminate ground-loop and noise pickup problems commonly associated with **IEEE-488** systems, the Model 24C moves the internal IEEE-488 circuitry to an optional module that interfaces directly to the Ethernet interface. This module is completely transparent to the IEEE-488 system.

LabView™ drivers are supplied for the Ethernet TCP/IP, IEEE-488, USB and RS-232 interfaces.

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

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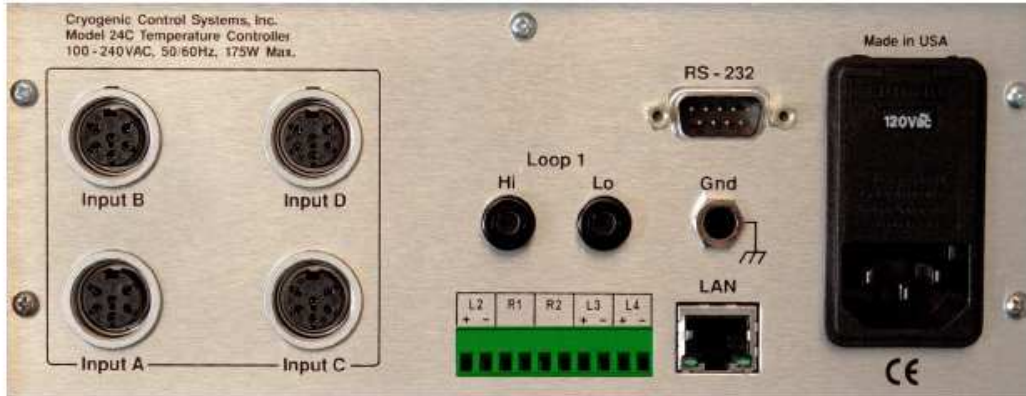
Utility Software: Utility software is provided that connects any Windows based personal computer to the Model 24C via any of its remote interfaces. This software provides a graphical control panel that greatly simplifies instrument setup and configuration. Features include:

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

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

Ethernet API: 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.

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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:** 10-Watt heater, part of a 10 pin detachable terminal block.
- **Loop #3 and #4:** 10-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:** Option, connects to Ethernet port.
- **RS-232:** Null-modem connector (DB-9, pins).
- **USB:** Option, connects to RS-232 port.
- **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, Cryo-con software CD, four input connectors, heater connector, terminal block plug, detachable power cord and a certificate of calibration.
	Specify AC Line Voltage when ordering:
	-100 Configured for 90 - 100VAC with detachable USA power cord.
	-110 Configured for 110 - 120VAC with detachable USA power cord.
	-220 Configured for 220VAC with detachable universal Euro (Shuko) line cord.
	-240 Configured for 240VAC with detachable universal Euro (Shuko) line cord.

Accessories	Description
04-0433	A Dual banana plug heater connector
04-0414	Din-6 Sensor Input Connector.
04-0007	Ten position terminal block receptacle.
4034-031	Two instrument shelf rack mount kit
4034-032	One instrument shelf rack mount kit

Thermocouple Option

The Thermocouple module plugs into any of the standard input channels and is powered by the instrument. It provides amplification, cold-junction compensation and connection to copper. Thermocouple types can be selected using internal switches. Up to four modules can be connected to a single instrument.

Both grounded and floating devices are supported. By connecting to copper as soon as possible, long thermocouple wires are eliminated and noise pickup is reduced.

Input connector is a standard thermocouple mini-spade.

Options	Description
TCM	Thermocouple Input Module. Field installable. Supports all thermocouple types.
GPIB	IEEE-488.2 (GPIB) Option. Field installable.
USB	USB Option. Serial Port Emulation. Field installable.

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Specifications

User Interface
Display Type: 240x64 graphics TFT LCD with LED back-light.
Number of Inputs Displayed: One to Four.
Keypad: Sealed Silicon Rubber.
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.
Sensor Types: See Supported Sensor Table.
Sensor Selection: Front Panel or remote interface.
Input Configurations: See input specifications table.
Bridge Modes: Constant-Current or Constant-Voltage.
Bridge type: Ratiometric resistance bridge.
AC Excitation Frequency: 1.625Hz bipolar square wave.
Voltage Excitations: 100mV, 10mV and 1.0mV. Minimum excitation current is 5nA, maximum is 20mA.
DC Offset: <3nA.
Sample Rate: 15Hz per channel.
Digital Resolution: 24 bits.
Measurement Accuracy: See input specifications table.
Measurement Drift: 15ppm/°C. <10Ω.: 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 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
50-Watt short circuit protected linear current source. Maximum compliance is selectable at 25V or 50V.
Ranges: Three output ranges of 1.0A, 333mA and 100mA full-scale, which correspond to 50W, 5.0W and 0.5W when used with 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.
Connection: Dual banana plug.

Loop #2 Heater Output
10-Watt, short circuit protected linear current source. Maximum compliance is 25V.
Load Resistance: 50Ω for 10-Watt output.
Minimum Load: 10Ω.
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
Loops #3 and #4 are analog voltage outputs that are intended to drive an external booster supply.
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. Both N.C. and N.O. contacts available. Contact ratings are 30VDC @ 1.0A.
Status reported via Remote Interface: Sensor fault, Heater over temperature fault.

Remote Interfaces
Maximum reading rate for all interfaces is >40 rdg/s.
Ethernet: Connects to any 10/100 Ethernet Local Area Network. Electrically isolated. **TCP/IP** provides 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 (GPIB): Optional, field installable at any time. Full IEEE-488.2 compliant.
USB 2.0: Optional, field installable at any time. Serial port emulation only. Transfer rates to 57,200 Baud.
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.

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 stand standard, rack mount kit optional.
Weight: 9 Lbs.
Power Requirement: 100, 120, 220 or 240VAC +5% -10%. 50 or 60Hz, 150VA.
Conformity: European CE certified.
Calibration: NIST traceable.

Contact Information