Cryogenic Temperature Controller

Model 22C

The model 22C is a two-input, four-control loop cryogenic temperature controller capable of operation to <200mK. While enhanced for ultra-low temperature operation, a wide variety of general purpose sensors and heaters are also supported.

Highlights of the Model 22C:

- **Two multipurpose input channels** support Diode, Platinum RTD and most cryogenic NTC resistance temperature sensors. Thermocouple inputs are a field installable option.
- **Operation from 200mK to over 1500K** with an appropriate sensor. Step-less constant-voltage AC excitation of resistance sensors minimizes errors and extends their useful temperature range.
- **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.**
- **Synchronous input filter** improves control accuracy and stability in cryocooler based systems.
- **Two large 10-Ampere dry-contact relays.**
- **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 Ethernet and USB 2.0.** LabView™ drivers available for all interfaces. IEEE-488.2 (GPIB) is a field installable option.

Applications:

**Helium 3 refrigerators and ULT:**
- Step-less constant-voltage AC sensor excitation with levels from 10mV to 1.0mV. Active DC offset removal reduces sensor self-heating.
- High precision heater outputs for excellent control stability.
- Low power heater ranges support ULT systems.

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

**General purpose laboratory:**
- Two 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

**Cryogen-Free systems:**
- Proprietary cryocooler thermal signature removal.
- Two input channels

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

The Model 22C has two 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 22C provides robust support for 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 22C 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 22C 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.

<table>
<thead>
<tr>
<th>Model 22C Supported Sensors</th>
<th>Temperature Range</th>
<th>Example Sensors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silicon Diode</td>
<td>1.4 - 500K</td>
<td>Cryo-con S950, S900, S1-440, 430, 410, Lakeshore DT-670, 470</td>
</tr>
<tr>
<td>Platinum RTD</td>
<td>14 - 1200K</td>
<td>Cryo-con CP-100, Cryo-con GP-100, Cryo-con XP-100, Cryo-con XP-1K</td>
</tr>
<tr>
<td>Rhodium-Iron</td>
<td>1.4 - 800K</td>
<td>Oxford PHZ 0002</td>
</tr>
<tr>
<td>Germanium Thermistor</td>
<td>200mK - 400K</td>
<td>AdSem, Inc.</td>
</tr>
<tr>
<td>CLTS</td>
<td>4 to 300K</td>
<td>Vishay CLTS-2B</td>
</tr>
<tr>
<td>Silicon Thermistor</td>
<td>0.5 - 720K</td>
<td>AdSem, Inc.</td>
</tr>
<tr>
<td>Cernox™</td>
<td>200mK - 325K</td>
<td>Lakeshore, all types</td>
</tr>
<tr>
<td>Carbon-Ceramic</td>
<td>200mK - 300K</td>
<td>Temati</td>
</tr>
<tr>
<td>Ruthenium Oxide</td>
<td>200mK - 270K</td>
<td>SI RO-600</td>
</tr>
<tr>
<td>Thermistor</td>
<td>193 - 523K</td>
<td>Measurement Specialties</td>
</tr>
<tr>
<td>Thermocouple</td>
<td>1.4 to 1500K</td>
<td>All thermocouple types.</td>
</tr>
</tbody>
</table>

Thermocouple sensors are supported by using an optional thermocouple module. This module plugs into any of the Model 22C’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

<table>
<thead>
<tr>
<th>Sensor Type</th>
<th>Diode</th>
<th>PTC resistors</th>
<th>Thermocouple (Option)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Range</td>
<td>0.1V - 2.25V</td>
<td>1.0mA: 0.1 - 500Ω, 100μA: 1.0K - 5.0KΩ</td>
<td>±70mV</td>
</tr>
<tr>
<td>Accuracy: % Rdg</td>
<td>0.005% ± 80μV</td>
<td>100Ω: 0.01% ± 0.004Ω, 1KΩ: 0.02% ± 0.04Ω</td>
<td>0.05%</td>
</tr>
<tr>
<td>Resolution: % Range</td>
<td>10μV</td>
<td>0.0003%</td>
<td>0.0003%</td>
</tr>
<tr>
<td>Excitation</td>
<td>10μA DC</td>
<td>1.0mA, 100μA</td>
<td>N/A</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NTC Resistance Measurement Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resistance</td>
</tr>
<tr>
<td>Maximum</td>
</tr>
<tr>
<td>Minimum</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>NTC Resistance Measurement Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excitation Range</td>
</tr>
<tr>
<td>1.0µA</td>
</tr>
<tr>
<td>100µA</td>
</tr>
<tr>
<td>10µA</td>
</tr>
<tr>
<td>1.0µA</td>
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</tbody>
</table>
The Model 22C 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 22C 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 oversample 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 22C 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 22C will perform a **temperature ramp** function using a specified maximum ramp rate and target setpoint.

**User Interface**

The Model 22C'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.

![User Interface Screen](image)

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.

![User Interface Screen](image)

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

![User Interface Screen](image)

**Cryostat Protection**

Damage to a cryostat or critical sample is a serious problem with any cryogenic system. The Model 22C 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 or the resistance of the connected load is too low.
**Lowest Noise**
The Model 22C 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 22C implements a shielding scheme that allows the construction of a complete RFI shield around the instrument and cryostat.

**Alarms and Relays**
The Model 22C 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 USB. IEEE-488.2(GPIB) is optional.

The Model 22C 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.

In order to eliminate ground-loop and noise pickup problems commonly associated with IEEE-488 (GPIB) systems, the Model 22C moved the internal GPIB circuitry to an optional module that connects directly to the Ethernet interface. This module is completely transparent to the GPIB system.

LabView™ drivers are supplied for the Ethernet TCP/IP, GPIB and USB interfaces.

The Model 22C’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.

**Utility Software:** Utility software is provided that connects any Windows based personal computer to the Model 22C 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.

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.
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 2 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: non-powered outputs. Detachable terminal block.

Relay #1 and #2: Dry contact relays. Detachable terminal block.

Ethernet: RJ-45 with LAN activity indicators.

IEEE-488.2: Option, connects to Ethernet port.

USB: USB B serial port emulator.

AC Power: RFI filtered Power Entry Module including fuse drawer and line voltage selector.

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### Ordering Information

<table>
<thead>
<tr>
<th>Product</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model 22C</td>
<td>Controller with two multi-function sensor input channels and four control loops. Controller includes: User’s Manual, Cryo-con software CD, two input connectors, heater connector, terminal block plug, detachable power cord and a certificate of calibration. Specify AC Line Voltage or required power cord when ordering (may be changed in the field):</td>
</tr>
<tr>
<td>-100</td>
<td>Configured for 90 - 100VAC with detachable USA power cord.</td>
</tr>
<tr>
<td>-120</td>
<td>Configured for 110 - 120VAC with detachable USA power cord.</td>
</tr>
<tr>
<td>-230</td>
<td>Configured for 220 - 230VAC with detachable universal Euro (Shuko) line cord.</td>
</tr>
<tr>
<td>-240</td>
<td>Configured for 240VAC with detachable universal Euro (Shuko) line cord.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>4039-004</td>
<td>Thermocouple Input Module. Field installable. Supports all thermocouple types.</td>
</tr>
<tr>
<td>4001-002</td>
<td>IEEE-488.2 (GPIB) Option, field installable.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Accessories</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>4022-016</td>
<td>Input connector kit consisting of two DIN-6 sensor input connectors.</td>
</tr>
<tr>
<td>4124-018</td>
<td>Output connector kit consisting of a dual banana plug heater connector and a 10-pin terminal block receptacle.</td>
</tr>
<tr>
<td>4022-030</td>
<td>Single instrument 2U rack mount kit.</td>
</tr>
</tbody>
</table>
Specifications

User Interface
Display Type: 240x64 graphics TFT LCD with LED back-light.
Number of Inputs Displayed: Two.
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 two 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 Modes: Passive, Constant-Current or Constant-Voltage.
Bridge type: Ratiometric resistance bridge. Two ADCs per input channel.

AC Excitation: 7.5Hz bipolar square wave.
Voltage Excitations: 10mV, 3.0mV and 1.0mV. 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. <10ppm 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 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.

Contact Information
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Rancho Santa Fe, CA 92067
Tel: (858) 756-3900 Fax: (858) 759-3515
E-mail: sales@cryocon.com Web: www.cryocon.com

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 25Ω setting, 40Ω in 50Ω setting.
Resolution: 1.0ppm of full-scale power (20 bits).
Readbacks: Heater output power, Heatsink temperature.
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 25Ω and 2.5Ω 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, Fan speed.
Connection: Detachable terminal block.

Loop #3 and #4 Control Outputs
Analog voltage outputs that are intended to drive an external booster supply.
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: 35 rdg/s.
Ethernet: Connects to any Ethernet Local Area Network. Electrically isolated, TCP/IP and UDP servers provide remote control by using an ASCII command language. HTTP provides built-in web server. SMTP sends e-mail based on alarm conditions.
IEEE-488.2 (GPIB): External Option, field installable.
USB 2.0: Serial port emulation. Baud Rates to 115.200.
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: 8.5”W x 3.5”H x 12”D. One half-width 2U rack. Instrument bail standard, rack mount kits optional.
Weight: 9 Lbs.
Power Requirement: 100, 120, 230 or 240VAC +5% -10%. 50 or 60Hz, 150VA. Field selectable.
Conformity: European CE certified, RoHS compliant, Lead-free.
Calibration: NIST traceable.

Specifications subject to change without notice.

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