



*Innovative Solutions in  
Cryogenic Instrumentation*

# Cryogenic Temperature Controller

## Model 26C



The Model 26C cryogenic temperature controller combines the wide temperature measurement range of the Model 24C with the high output power control loops of the original Model 26. Four inputs and four independent control loops provide a total output power of 150W.

### Highlights of the Model 26C:

- **Operation from 100mK 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 ultra-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 high-power independent control loops:** Loop #1: 100-Watt, four-range; Loop #2: 50-Watt three-range; Loop #3 and #4: 5/10 Volt.
- **Large, bright and highly configurable display.**
- Two large **10-Ampere** dry-contact relays.
- **Data logging** to internal Non-Volatile memory.
- Fail-safe cryostat protection features protect user equipment from damage.
- Remote interfaces include **Ethernet** and USB serial port emulator. Optional IEEE-488.2 (GPIB).
- Protect your system software: Remote command language is **IEEE-488.2 SCPI** compliant.
- National Instruments, Inc. **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 eliminates sensor self-heating.
- High power, high precision heater outputs.

#### Large cryocoolers

- High power outputs control large cryocoolers over a wide range that includes room temperature.
- Proprietary cryocooler thermal signature removal.

#### General purpose laboratory

- Four inputs, four independent control loops.
- Ethernet connectivity for ease of remote control.
- Temperature activated relays and alarms.
- Instrument control via any web browser.

#### Superconducting Magnets

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

## Flexible Sensor Inputs

The Model 26C 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 26C 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 26C 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 26C 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 26C 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 26C'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: % R <sub>dg</sub>	0.005% ± 80µV	100Ω: 0.01% ± 0.004Ω 1KΩ: 0.02% ± 0.04Ω	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, V <sub>bias</sub> = 10mV		
Excitation Range	Resolution	Accuracy
1.0mA	0.1mΩ	±0.03% rdg ±0.0004Ω
100µA	1.0mΩ	± 0.03% rdg ±0.04Ω
10µA	10mΩ	± 0.04% rdg ±0.4Ω
1.0µA	100mΩ	± 0.05% rdg ±4Ω

The Model 26C 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 26C 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 100W into 25Ω or 50W into 50Ω resistive loads. Four full-scale ranges are available in decade increments down to 500mW.

**Loop #2** is a three-range linear heater with that will provide up to 50 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 5.0-Volts by user selection. The controller's relays may be used to turn the external supply on and 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 26C 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 26C will perform a **temperature ramp** function using a specified maximum ramp rate and target setpoint.

### User Interface

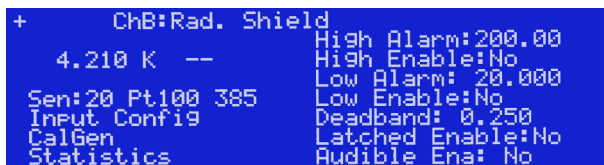
The Model 26C's user interface is based on a large, high resolution display plus a full 21-key keypad. With this bright and exceptionally wide viewing angle display, complete instrument status can be seen at a glance, even from across the room.

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



```
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
4.210 K --
Sen: 20 Pt100 385
Input Conf19
CalGen
Statistics
High Alarm: 200.00
High Enable: No
Low Alarm: 20.000
Low Enable: No
Deadband: 0.250
Latched Enable: No
Audible Ena: No
```

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



```
Loop1A: Loop 1
Set Pt: 300.000K A: 0.532K
Pgain: 6.0000 1-Off-MID -Htr-Off-
Igain: 60.000S
Dgain: 7.5000/S Range: MID
Pman: 5.0000% PID Table index: 1
Type: Man Htr Load: 50
Input: ChA •Next
```

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

### Cryostat Protection

Damage to a cryostat or critical sample is a serious problem with any cryogenic system. The Model 26C 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 26C 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 26C implements a shielding scheme that allows the construction of a complete RFI shield around the instrument and cryostat.

## Alarms and Relays

The Model 26C 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 26C 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 26C moves 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.

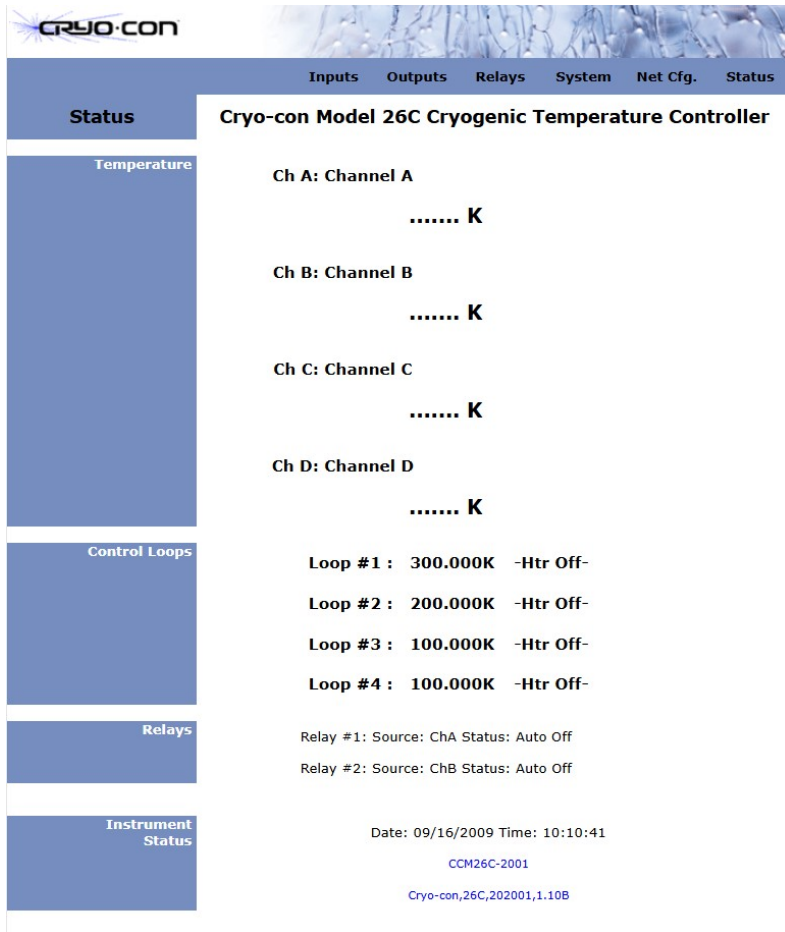
The Model 26C's **remote command language** is **SCPI** compliant according to the IEEE-488.2 specification. SCPI establishes a common language and syntax across various types of instruments. It is easy to learn and easy to read. The SCPI command language is identical in all Cryo-con products so that 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.

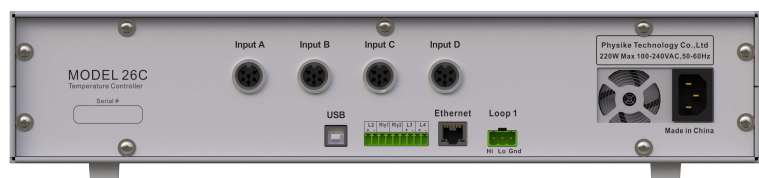


**Utility Software:** Utility software is provided that connects any Windows based personal computer to the Model 26C via any of its remote interfaces. This software provides a graphical control panel that greatly simplifies instrument setup and configuration. Features include:

- 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:** 6-pin 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:** 100-Watt heater output. Three-pin detachable terminal block.
- **Loop #2:** 50-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.
- **USB:** USB client serial port emulator.
- **AC Power:** RFI filtered Power Entry Module.

## Ordering Information

Product	Description
<b>Model 26C</b>	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 power cord when ordering: - <b>120</b> Detachable USA power cord. - <b>230</b> Detachable universal Euro (Shuko) line cord.

Options	Description
<b>4039-005</b>	Thermocouple Input Module. Field installable. Supports all thermocouple types. 
<b>4001-002</b>	IEEE-488.2 (GPIB) Option, field installable. 

Accessories	Description
<b>4026-016</b>	Additional input connector kit consisting of four 6-pin circular input connectors.
<b>4026-018</b>	Additional output connector kit consisting of a 3-pin heater connector and a 10-pin terminal block receptacle.
<b>4122-030</b>	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. Six-pin snap-in 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, 300 $\mu$ V, 200 $\mu$ V and 100 $\mu$ V. 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/ $^{\circ}$ C. <10 $\Omega$ : 30ppm/ $^{\circ}$ 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<sup>®</sup>:** 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 Configurations

Four user configurations 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

Short circuit protected linear current source.  
**Ranges:** Four output ranges of 100W, 50W, 5.0W and 500mW.  
**Resolution:** 1.0ppm of full-scale power (20 bits).  
**Readbacks:** Heater output power, Heatsink temperature, Fan speed.  
**Connection:** Detachable terminal block.

## Loop #2 Heater Output

Short circuit protected linear current source.  
**Ranges:** Three output ranges of 50W, 5.0W and 5.0W into 50 $\Omega$ .  
**Resolution:** 1.0ppm of full-scale power (20 bits).  
**Readbacks:** Heater output power, Heatsink temperature.  
**Connection:** Detachable terminal block.

## Loop #3 and #4 Analog Outputs

Analog voltage outputs that are intended to drive an external booster supply.  
**Output:** zero to 10 / 5.0-Volts. Output impedance: ~2,000 $\Omega$ .  
**Resolution:** 4.0ppm of full-scale power (16 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: 10 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.  
**USB 2.0:** serial port emulator. Data rates to 115,200 Baud.  
**IEEE-488.2 (GPIB):** External Option, field installable.  
**Programming Language:** IEEE-488.2 SCPI compatible.  
**LabVIEW<sup>™</sup>** 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 $^{\circ}$ C  $\pm$  5 $^{\circ}$ C for specified accuracy.  
**Mechanical:** 436mmW x 87.3mmH x 305mmD  
**Weight:** 3.2kg  
**Power Requirement:** 90–240VAC, 50-60Hz, 220VA.  
**Conformity:** CE, RoHS.  
**Calibration:** NIST traceable.



## Contact Information

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