# Model 325 Temperature Controller




## Model 325 features

- Operates down to 1.2 K with appropriate sensor
- Two sensor inputs
- Supports diode, RTD, and thermocouple sensors
- Sensor excitation current reversal eliminates thermal EMF errors in resistance sensors
- Two autotuning control loops: 25 W and 2 W maximum
- Control loop 2: variable DC voltage source from 0 to 10 V maximum
- IEEE-488 and RS-232C interfaces
- CE certification
- Full 3 year standard warranty

## Introduction

The Model 325 dual-channel temperature controller is capable of supporting nearly any diode, RTD, or thermocouple temperature sensor. Two independent PID control loops with heater outputs of 25 W and 2 W are configured to drive either a 50 Ω or 25 Ω load for optimal cryocooler control flexibility. Designed with ease of use, functionality, and value in mind, the Model 325 is ideal for general-purpose laboratory and industrial temperature measurement and control applications.

## Sensor inputs

The Model 325 temperature controller features two inputs with a high-resolution 24-bit analog-to-digital converter and separate current sources for each input. Constant current excitation allows temperature to be measured and controlled down to 2.0 K using appropriate Cernox® RTDs or down to 1.4 K using silicon diodes. Thermocouples allow for temperature measurement and control above 1,500 K. Sensors are optically isolated from other instrument functions for quiet and repeatable sensor measurements. The Model 325 also uses current reversal to eliminate thermal EMF errors in resistance sensors. Sensor data from each input is updated up to ten times per second, with display outputs twice each second.

Standard temperature response curves for silicon diodes, platinum RTDs, ruthenium oxide RTDs, and many thermocouples are included. Up to fifteen 200-point CalCurves™ (for Lake Shore calibrated temperature sensors) or user curves can be stored into non-volatile memory. A built-in SoftCal™[1] algorithm can be used to generate curves for silicon diodes and platinum RTDs for storage as user curves. The Lake Shore curve handler software program allows sensor curves to be easily loaded and manipulated.

Sensor inputs for the Model 325 are factory configured and compatible with either diodes/RTDs or thermocouple sensors. Your choice of two diode/RTD inputs, one diode/RTD input and one thermocouple input, or two thermocouple inputs must be specified at time of order and cannot be reconfigured in the field. Software selects appropriate excitation current and signal gain levels when the sensor type is entered via the instrument front panel.

## Temperature control

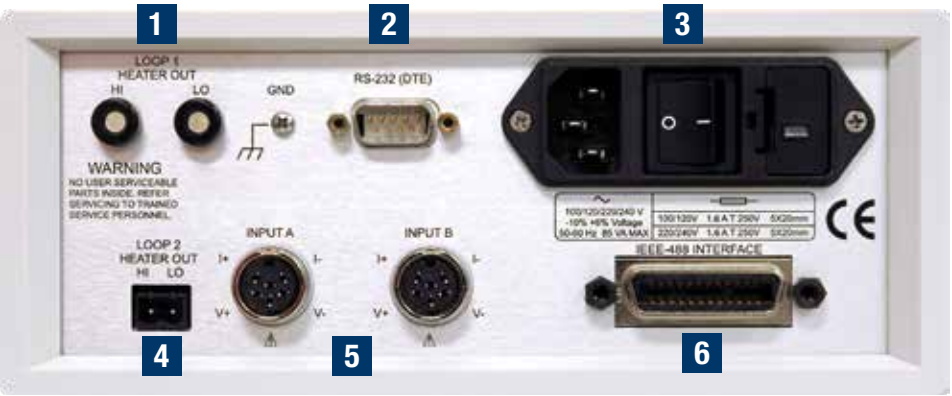
The Model 325 temperature controller offers two independent proportional-integral-derivative (PID) control loops. A PID algorithm calculates control output based on temperature setpoint and feedback from the control sensor. Wide tuning parameters accommodate most cryogenic cooling systems and many small high-temperature ovens. A high-resolution digital-to-analog converter generates a smooth control output. The user can set the PID values or the Autotuning feature of the Model 325 can automate the tuning process.

Control loop 1 heater output for the Model 325 is a well-regulated variable DC current source. The output can provide up to 25 W of continuous power to a 50 Ω or 25 Ω heater load, and includes a lower range for systems with less cooling power. Control loop 2 heater output is a single-range, variable DC voltage source. The output can source up to 0.2 A, providing 2 W of heater power at the 50 Ω setting or 1 W at the 25 Ω setting. When not being used for temperature control, the loop 2 heater output can be used as a manually controlled voltage source. The output voltage can vary from 0 to 10 V on the 50 Ω setting, or 0 to 5 V on the 25 Ω setting. Both heater outputs are referenced to chassis ground.

The setpoint ramp feature allows smooth continuous setpoint changes and can also make the approach to setpoint more predictable. The zone feature can automatically change control parameter values for operation over a large temperature range. Ten different temperature zones can be loaded into the instrument, which will select the next appropriate value on setpoint change.

Temperature limit settings for inputs are provided as a safeguard against system damage[1]. Each input is assigned a temperature limit, and if any input exceeds that limit, all control channels are automatically disabled.

[1] Firmware version 1.5 and later




## Model 325 rear panel

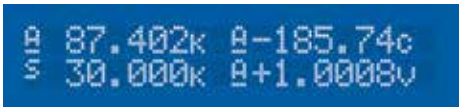
1 Loop 1 heater output
2 Serial (RS-232C) I/O (DTE)
3 Line input assembly
4 Loop 2 heater output
5 Sensor input connectors
6 IEEE-488 interface

## Interface

The Model 325 includes both parallel (IEEE-488) and serial (RS-232C) computer interfaces. In addition to data gathering, nearly every function of the instrument can be controlled via computer interface. Sensor curves can also be entered and manipulated through either interface using the Lake Shore curve handler software program.




**Normal (default) display configuration**
The display provides four reading locations. Readings from each input and the control setpoint can be expressed in any combination of temperature or sensor units, with heater output expressed as a percent of full scale current or power.




**Flexible configuration**
Reading locations can be configured by the user to meet application needs. The character preceding the reading indicates input A or B or setpoint S. The character following the reading indicates measurement units.




**Curve entry**
The Model 325 display offers the flexibility to support curve, SoftCal™, and zone entry. Curve entry may be performed accurately and to full resolution via the display and keypad as well as computer interface.

## Configurable display

The Model 325 offers a bright, easy to read LCD display that simultaneously displays up to four readings. Display data includes input and source annunciators for each reading. All four display locations can be configured by the user. Data from either input can be assigned to any of the four locations, and the user's choice of temperature or sensor units can be displayed. Heater range and control output as current or power can be continuously displayed for immediate feedback on control operation. The channel A or B indicator is underlined to indicate which channel is being controlled by the displayed control loop.

# Sensor Selection

## Sensor temperature range (sensors sold separately)

| | | Model | Useful range | Magnetic field use |
|---|---|---|---|---|
| **Diodes** | **Silicon diode** | DT-670-SD | 1.4 K to 500 K | T ≥ 60 K & B ≤ 3 T |
| | **Silicon diode** | DT-670E-BR | 30 K to 500 K | T ≥ 60 K & B ≤ 3 T |
| | **Silicon diode** | DT-414 | 1.4 K to 375 K | T ≥ 60 K & B ≤ 3 T |
| | **Silicon diode** | DT-421 | 1.4 K to 325 K | T ≥ 60 K & B ≤ 3 T |
| | **Silicon diode** | DT-470-SD | 1.4 K to 500 K | T ≥ 60 K & B ≤ 3 T |
| | **Silicon diode** | DT-471-SD | 10 K to 500 K | T ≥ 60 K & B ≤ 3 T |
| **Positive temperature coefficient RTDs** | **100 Ω platinum** | PT-102/3 | 14 K to 873 K | T > 40 K & B ≤ 2.5 T |
| | **100 Ω platinum** | PT-111 | 14 K to 673 K | T > 40 K & B ≤ 2.5 T |
| **Negative temperature coefficient RTDs[2]** | **Cernox®** | CX-1010 | 2 K to 325 K[5] | T > 2 K & B ≤ 19 T |
| | **Cernox®** | CX-1030-HT | 3.5 K to 420 K[3, 6] | T > 2 K & B ≤ 19 T |
| | **Cernox®** | CX-1050-HT | 4 K to 420 K[3, 6] | T > 2 K & B ≤ 19 T |
| | **Cernox®** | CX-1070-HT | 15 K to 420 K[3] | T > 2 K & B ≤ 19 T |
| | **Cernox®** | CX-1080-HT | 50 K to 420 K[3] | T > 2 K & B ≤ 19 T |
| | **Germanium** | GR-300-AA | 1.2 K to 100 K[4] | Not recommended |
| | **Germanium** | GR-1400-AA | 4 K to 100 K[4] | Not recommended |
| | **Rox™** | RX-102A | 1.4 K to 40 K[5] | T > 2 K & B ≤ 10 T |
| **Thermocouples** | **Type K** | 9006-006 | 3.2 K to 1505 K | Not recommended |
| | **Type E** | 9006-004 | 3.2 K to 934 K | Not recommended |

[2] Single excitation current may limit the low temperature range of NTC resistors
[3] Non-HT version maximum temperature: 325 K
[4] Low temperature limited by input resistance range
[5] Low temperature specified with self-heating error: ≤5 mK
[6] Low temperature specified with self-heating error: ≤12 mK

**Silicon diodes** are the best choice for general cryogenic use from 1.4 K to above room temperature. Diodes are economical to use because they follow a standard curve and are interchangeable in many applications. They are not suitable for use in ionizing radiation or magnetic fields.

**Cernox®** thin-film RTDs offer high sensitivity and low magnetic field-induced errors over the 2 K to 420 K temperature range. Cernox sensors require calibration.

**Platinum RTDs** offer high uniform sensitivity from 30 K to over 800 K. With excellent reproducibility, they are useful as thermometry standards. They follow a standard curve above 70 K and are interchangeable in many applications.

## Typical sensor performance—see Appendix F for sample calculations of typical sensor performance

| | Example Lake Shore sensor | Temperature | Nominal resistance/ voltage | Typical sensor sensitivity[7] | Measurement resolution: temperature equivalents | Electronic accuracy: temperature equivalents | Temperature accuracy including electronic accuracy, CalCurve™, and calibrated sensor | Electronic control stability[8]: temperature equivalents |
|---|---|---|---|---|---|---|---|---|
| **Silicon diode** | DT-670-SD-13 | 1.4 K | 1.664 V | -12.49 mV/K | 0.8 mK | ±13 mK | ±25 mK | ±1.6 mK |
| | with 1.4H | 77 K | 1.028 V | -1.73 mV/K | 5.8 mK | ±76 mK | ±98 mK | ±11.6 mK |
| | calibration | 300 K | 0.5596 V | -2.3 mV/K | 4.3 mK | ±47 mK | ±79 mK | ±8.7 mK |
| | | 500 K | 0.0907 V | -2.12 mV/K | 4.8 mK | ±40 mK | ±90 mK | ±9.6 mK |
| **Silicon diode** | DT-470-SD-13 | 1.4 K | 1.6981 V | -13.1 mV/K | 0.8 mK | ±13 mK | ±25 mK | ±1.6 mK |
| | with 1.4H | 77 K | 1.0203 V | -1.92 mV/K | 5.2 mK | ±68 mK | ±90 mK | ±10.4 mK |
| | calibration | 300 K | 0.5189 V | -2.4 mV/K | 4.2 mK | ±44 mK | ±76 mK | ±8.4 mK |
| | | 475 K | 0.0906 V | -2.22 mV/K | 4.6 mK | ±39 mK | ±89 mK | ±9.2 mK |
| **100 Ω platinum RTD** | PT-103 with | 30 K | 3.660 Ω | 0.191 Ω/K | 10.5 mK | ±23 mK | ±33 mK | ±21 mK |
| **500 Ω full scale** | 1.4J calibration | 77 K | 20.38 Ω | 0.423 Ω/K | 4.8 mK | ±15 mK | ±27 mK | ±9.6 mK |
| | | 300 K | 110.35 Ω | 0.387 Ω/K | 5.2 mK | ±39 mK | ±62 mK | ±10.4 mK |
| | | 500 K | 185.668 Ω | 0.378 Ω/K | 5.3 mK | ±60 mK | ±106 mK | ±10.6 mK |
| **Cernox®** | CX-1050-SD- | 4.2 K | 3507.2 Ω | -1120.8 Ω/K | 36 µK | ±1.4 mK | ±6.4 mK | ±72 µK |
| | HT[9] with 4M | 77 K | 205.67 Ω | -2.4116 Ω/K | 16.6 mK | ±76 mK | ±92 mK | ±33.2 mK |
| | calibration | 300 K | 59.467 Ω | -0.1727 Ω/K | 232 mK | ±717 mK | ±757 mK | ±464 mK |
| | | 420 K | 45.030 Ω | -0.0829 Ω/K | 483 mK | ±1.42 K | ±1.49 K | ±966 mK |
| **Germanium** | GR-300-AA | 1.2 K | 600 Ω | -987 Ω/K | 51 µK | ±345 µK | ±4.5 mK | ±101 µK |
| | with 0.3D | 1.4 K | 449 Ω | -581 Ω/K | 86 µK | ±481 µK | ±4.7 mK | ±172 µK |
| | calibration | 4.2 K | 94 Ω | -27 Ω/K | 1.9 mK | ±5.19 mK | ±10.2 mK | ±3.8 mK |
| | | 100 K | 2.72 Ω | -0.024 Ω/K | 2.1 K | ±4.25 K | ±4.27 K | ±4.20 K |
| **Germanium** | GR-1400-AA | 4 K | 1873 Ω | -1008 Ω/K | 50 µK | ±842 µK | ±5.0 mK | ±99 µK |
| | with 1.4D | 4.2 K | 1689 Ω | -862 Ω/K | 58 µK | ±900 µK | ±5.1 mK | ±116 µK |
| | calibration | 10 K | 253 Ω | -62 Ω/K | 807 µK | ±3.2 mK | ±8.2 mK | ±1.6 mK |
| | | 100 K | 2.80 Ω | -0.021 Ω/K | 2.4 K | ±4.86 K | ±4.884 K | ±4.81 K |
| **Thermocouple** | Type K | 75 K | -5862.9 µV | 15.6 µV/K | 26 mK | ±0.25 K[10] | Calibration not | ±52 mK |
| **50 mV** | | 300 K | 1075.3 µV | 40.6 µV/K | 10 mK | ±0.038 K[10] | available from Lake | ±20 mK |
| | | 600 K | 13325 µV | 41.7 µV/K | 10 mK | ±0.184 K[10] | Shore | ±20 mK |
| | | 1505 K | 49998.3 µV | 36.006 µV/K | 12 mK | ±0.73 K[10] | | ±24 mK |

[7] Typical sensor sensitivities were taken from representative calibrations for the sensor listed
[8] Control stability of the electronics only, in an ideal thermal system
[9] Non-HT version maximum temperature: 325 K
[10] Accuracy specification does not include errors from room temperature compensation

# Model 325 Specifications

## Input specifications

| | Sensor temperature coefficient | Input range | Excitation current | Display resolution | Measurement resolution | Electronic accuracy[11] | Electronic control stability[12] |
|---|---|---|---|---|---|---|---|
| **Diode** | negative | 0 V to 2.5 V | 10 µA ±0.05%[13, 14] | 100 µV | 10 µV | ±80 µV ±0.005% of rdg | ±20 µV |
| | negative | 0 V to 7.5 V | 10 µA ±0.05%[13, 14] | 100 µV | 20 µV | ±320 µV ±0.01% of rdg | ±40 µV |
| **PTC RTD** | positive | 0 Ω to 500 Ω | 1 mA[15] | 10 mΩ | 2 mΩ | ±0.004 Ω ±0.01% of rdg | ±4 mΩ |
| | positive | 0 Ω to 5000 Ω | 1 mA[15] | 100 mΩ | 20 mΩ | ±0.04 Ω ±0.02% of rdg | ±40 mΩ |
| **NTC RTD** | negative | 0 Ω to 7500 Ω | 10 µA ±0.05%[15] | 100 mΩ | 40 mΩ | ±0.1 Ω ±0.04% of rdg | ±80 mΩ |
| **Thermocouple** | positive | ±25 mV | NA | 1 µV | 0.4 µV | ±1 µV ±0.05% of rdg[16] | ±0.8 µV |
| | positive | ±50 mV | NA | 1 µV | 0.4 µV | ±1 µV ±0.05% of rdg[16] | ±0.8 µV |

[11] With current reversal enabled for RTD measurements
[12] Control stability of the electronics only, in an ideal thermal system
[13] Current source error has negligible effect on measurement accuracy
[14] Diode input excitation current can be set to 1 mA — refer to the Model 325 user manual for details
[15] Current source error is removed during calibration
[16] Accuracy specification does not include errors from room temperature compensation

## Thermometry

**Number of inputs** 2

**Input configuration** Each input is factory configured for either diode/RTD or thermocouple

**Isolation** Sensor inputs optically isolated from other circuits but not each other

**A/D resolution** 24-bit

**Input accuracy** Sensor dependent—refer to Input Specifications table

**Measurement resolution** Sensor dependent—refer to Input Specifications table

**Maximum update rate** 10 rdg/s on each input (except 5 rdg/s on input A when configured as thermocouple)

**User curves** Room for 15 200-point CalCurves™ or user curves

**SoftCal™** Improves accuracy of DT-470 diode to ±0.25 K from 30 K to 375 K; improves accuracy of platinum RTDs to ±0.25 K from 70 K to 325 K; stored as user curves

**Filter** Averages 2 to 64 input readings

## Control

**Control loops** 2

**Control type** Closed loop digital PID with manual heater output or open loop

**Tuning** Autotune (one loop at a time), PID, PID zones

**Control stability** Sensor dependent—see Input Specification table

**PID control settings**

- **Proportional (gain)** 0 to 1000 with 0.1 setting resolution
- **Integral (reset)** 1 to 1000 (1000/s) with 0.1 setting resolution
- **Derivative (rate)** 1 to 200% with 1% resolution
- **Manual output** 0 to 100% with 0.01% setting resolution

**Zone control** 10 temperature zones with P, I, D, manual heater out, and heater range

**Setpoint ramping** 0.1 K/min to 100 K/min

**Safety limits** Curve temperature, power up heater off, short circuit protection

## Sensor input configuration

| | Diode/RTD | Thermocouple |
|---|---|---|
| **Measurement type** | 4-lead differential | 2-lead differential, room temperature compensated |
| **Excitation** | Constant current with current reversal for RTDs | N/A |
| **Supported sensors** | Diodes: Silicon, GaAlAs RTDs: 100 Ω Platinum, 1000 Ω Platinum, Germanium, Carbon-Glass, Cernox®, and Rox™ | Most thermocouple types |
| **Standard curves** | DT-470, DT-500D, DT-670, PT-100, PT-1000, RX-102A, RX-202A | Type E, Type K, Type T, AuFe 0.07% vs. Cr, AuFe 0.03% vs Cr |
| **Input connector** | 6-pin DIN | Ceramic isothermal block |



## Loop 1 heater output

| | 25 Ω setting | 50 Ω setting |
|---|---|---|
| Type | Variable DC current source | |
| D/A resolution | 16-bit | |
| Max power | 25 W | |
| Max current | 1 A | 0.71 A |
| Voltage compliance | 25 V | 35.4 V |
| Heater load range | 20 Ω to 25 Ω | 40 Ω to 50 Ω |
| Heater load for max power | 25 Ω | 50 Ω |
| Ranges | 2 (2.5 W/25 W) | |
| Heater noise (<1 kHz) | 1 µA + 0.01% of output | |
| Grounding | Output referenced to chassis ground | |
| Heater connector | Dual banana | |

## Loop 2 heater output

| | 25 Ω setting | 50 Ω setting |
|---|---|---|
| Type | Variable DC voltage source | |
| D/A resolution | 16-bit | |
| Max power | 1 W | 2 W |
| Max voltage | 5 V | 10 V |
| Current compliance | 0.2 A | |
| Heater load range | ≥ 25 Ω | ≥ 50 Ω |
| Heater load for max power | 25 Ω | 50 Ω |
| Ranges | 1 | |
| Heater noise (<1 kHz) | 50 µV + 0.01% of output | |
| Grounding | Output referenced to chassis ground | |
| Heater connector | Detachable terminal block | |

## Front panel

**Display** 2-line × 20-character, liquid crystal display with 5.5 mm character height

**Number of reading displays** 1 to 4

**Display units** K, °C, V, mV, Ω

**Reading source** Temperature, sensor units

**Display update rate** 2 rdg/s

**Temp display resolution** 0.001° from 0° to 99.999°, 0.01° from 100° to 999.99°, 0.1° above 1000°

**Sensor units display resolution** Sensor dependent; to 5 digits

**Other displays** Setpoint, Heater Range, and Heater Output (user selected)

**Setpoint setting resolution** Same as display resolution (actual resolution is sensor dependent)

**Heater output display** Numeric display in percent of full scale for power or current

**Heater output resolution** 1%

**Display annunciators** Control Input, Remote, Autotune

**Keypad** 20-key membrane, numeric and specific functions

**Front panel features** Front panel curve entry, keypad lock-out

## Interface

**IEEE-488 interface**

| | |
|---|---|
| **Features** | SH1, AH1, T5, L4, SR1, RL1, PP0, DC1, DT0, C0, E1 |
| **Reading rate** | To 10 rdg/s on each input |
| **Software support** | LabVIEW™ driver (see www.lakeshore.com) |

**Serial interface**

| | |
|---|---|
| **Electrical format** | RS-232C |
| **Baud rates** | 9600, 19200, 38400, 57600 |
| **Connector** | 9-pin D-style, DTE configuration |
| **Reading rate** | To 10 rdg/s on each input |

## General

**Ambient temperature** 15 °C to 35 °C at rated accuracy, 5 °C to 40 °C at reduced accuracy

**Power requirement** 100, 120, 220, 240 VAC, +6%, -10%, 50 or 60 Hz, 85 VA

**Size** 216 mm W × 89 mm H × 368 mm D (8.5 in × 3.5 in × 14.5 in), half rack

**Weight** 4.00 kg (8.82 lb)

**Approval** CE mark, RoHS

## Ordering information

| Part number | Description |
|---|---|
| **325** | 2 diode/resistor inputs temperature controller, includes one dual banana jack heater output connector (106-009), two 6-pin DIN plug sensor input mating connectors (G-106-233), one 2-pin terminal block (106-735), a calibration certificate and a user's manual |
| **325-T1** | Model 325 with one diode/RTD and one thermocouple input |
| **325-T2** | Model 325 with two thermocouple inputs |

### Please indicate your power/cord configuration:

**1** 100 V—U.S. cord (NEMA 5-15)
**2** 120 V—U.S. cord (NEMA 5-15)
**3** 220 V—Euro cord (CEE 7/7)
**4** 240 V—Euro cord (CEE 7/7)
**5** 240 V—U.K. cord (BS 1363)
**6** 240 V—Swiss cord (SEV 1011)
**7** 220 V—China cord (GB 1002)

### Accessories

| | |
|---|---|
| **112-177** | Temperature controller cable, 3 m (10 ft)—IN STOCK |
| **112-178** | Temperature controller cable, 6 m (20 ft) |
| **112-180** | Temperature controller cable, 10 m (33 ft) |
| **6201** | 1 m (3.3 ft long) IEEE-488 (GPIB) computer interface cable assembly |
| **RM-1/2** | Kit for mounting one ½ rack temperature controller in a 482.6 mm (19 in) rack, 90 mm (3.5 in) high |
| **RM-2** | Kit for mounting two ½ rack temperature controllers in a 482.6 mm (19 in) rack, 135 mm (5.25 in) high |
| **G-106-735** | Terminal block, 2-pin |
| **G-106-233** | Sensor input mating connector (6-pin DIN plug) |
| **106-009** | Banana plug, dual |
| **CAL-325-CERT** | Instrument calibration with certificate |
| **CAL-325-DATA** | Instrument recalibration with certificate and data |
| **119-041** | Model 325 temperature controller manual |

All specifications are subject to change without notice

