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Model 325
Temperature Controller

LakeShore

- 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

Model 325 Temperature Controller

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.

[1] The Lake Shore SoftCal™ algorithm for silicon diode and platinum RTD sensors is a good solution for applications requiring more accuracy than a standard sensor curve but not in need of traditional calibration. SoftCal uses the predictability of a standard curve to improve the accuracy of an individual sensor around a few known temperature reference points.

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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*. Each input is assigned a temperature limit, and if any input exceeds that limit, all control channels are automatically disabled.

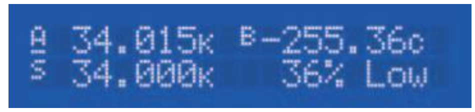
*Firmware version 1.5 and later

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.

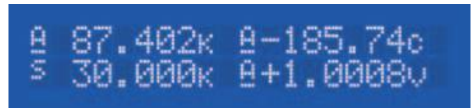
Configurable Display

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.



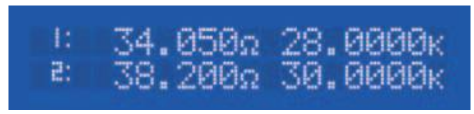
Normal (Default) Display Configuration

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.



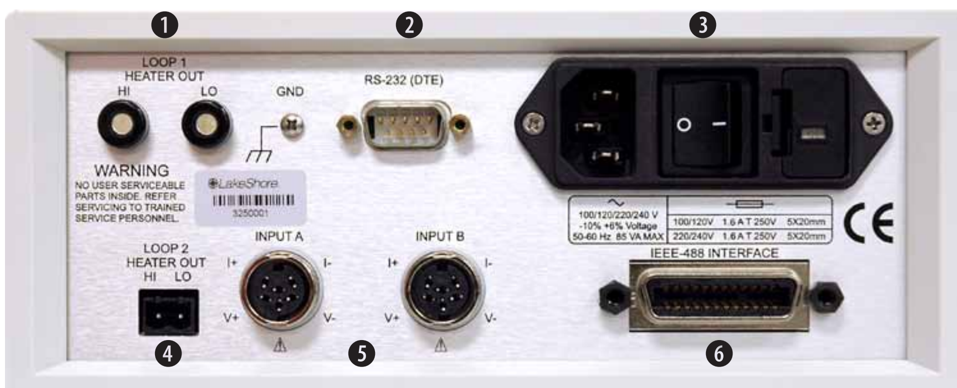
Flexible Configuration

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.*



Model 325 Rear Panel Connections

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

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
	GaAlAs Diode	TG-120-P	1.4 K to 325 K	T > 4.2 K & B ≤ 5 T
	GaAlAs Diode	TG-120-PL	1.4 K to 325 K	T > 4.2 K & B ≤ 5 T
	GaAlAs Diode	TG-120-SD	1.4 K to 500 K	T > 4.2 K & B ≤ 5 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
	Rhodium-Iron	RF-800-4	1.4 K to 500 K	T > 77 K & B ≤ 8 T
	Rhodium-Iron	RF-100T/U	1.4 K to 325 K	T > 77 K & B ≤ 8 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
	Carbon-Glass	CGR-1-500	4 K to 325 K[5]	T > 2 K & B ≤ 19 T
	Carbon-Glass	CGR-1-1000	5 K to 325 K[5]	T > 2 K & B ≤ 19 T
	Carbon-Glass	CGR-1-2000	6 K to 325 K[5]	T > 2 K & B ≤ 19 T
	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
	Chromel-AuFe 0.07%	9006-002	1.2 K to 610 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	Temp	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	1.644 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	0.5597 V	-2.3 mV/K	4.4 mK	±47 mK	±79 mK	±8.8 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	±69 mK	±91 mK	±10.4 mK
	calibration	300 K	0.5189 V	-2.4 mV/K	4.2 mK	±45 mK	±77 mK	±8.4 mK
		475 K	0.0906 V	-2.22 mV/K	4.6 mK	±39 mK	±89 mK	±9.2 mK
GaAlAs Diode	TG-120-SD	1.4 K	5.391 V	-97.5 mV/K	0.2 mK	±7 mK	±19 mK	±0.4 mK
	with 1.4H	77 K	1.422 V	-1.24 mV/K	16.2 mK	±180 mK	±202 mK	±32.4 mK
	calibration	300 K	0.8978 V	-2.85 mV/K	7 mK	±60 mK	±92 mK	±14 mK
		475 K	0.3778 V	-3.15 mV/K	6.4 mK	±38 mK	±88 mK	±12.8 mK
100 Ω Platinum RTD	PT-103	30 K	3.660 Ω	0.191 Ω/K	10.5 mK	±23 mK	±33 mK	±21 mK
500 Ω Full Scale	with 1.4J	77 K	20.38 Ω	0.423 Ω/K	4.8 mK	±15 mK	±27 mK	±9.6 mK
	calibration	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-HT[9]	4.2 K	3507.2 Ω	-1120.8 Ω/K	36 μK	±1.4 mK	±6.4 mK	±72 μK
	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
Carbon-Glass	CGR-1-2000	4.2 K	2260 Ω	-2060 Ω/K	20 μK	±0.5 mK	±4.5 mK	±40 μK
	with 4L	77 K	21.65 Ω	-0.157 Ω/K	255 mK	±692 mK	±717 mK	±510 mK
	calibration	300 K	11.99 Ω	-0.015 Ω/K	2.667 K	±7 K	±7.1 K	±5.334 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	±20 mK
		600 K	13325 μV	41.7 μV/K	10 mK	±0.184 K[10]	Lake 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	Electronic Control Stability[11]
Diode	negative	0 V to 2.5 V	10 µA ±0.05%[12, 13]	100 µV	10 µV	±80 µV ±0.005% of rdg	±20 µV
	negative	0 V to 7.5 V	10 µA ±0.05%[12, 13]	100 µV	20 µV	±80 µV ±0.01% of rdg	±40 µV
PTC RTD	positive	0 Ω to 500 Ω	1 mA[14]	10 mΩ	2 mΩ	±0.004 Ω ±0.01% of rdg	±4 mΩ
	positive	0 Ω to 5000 Ω	1 mA[14]	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%[14]	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[15]	±0.8 µV
	positive	±50 mV	NA	1 µV	0.4 µV	±1 µV ±0.05% of rdg[15]	±0.8 µV

[11] Control stability of the electronics only, in an ideal thermal system
[12] Current source error has negligible effect on measurement accuracy
[13] Diode input excitation current can be set to 1 mA – refer to the Model 325 user manual for details
[14] Current source error is removed during calibration
[15] 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, room temperature compensated
Excitation	Constant current with current reversal for RTDs	NA
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

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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 (consult factory for availability)
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

Ordering Information

Part number	Description
325	Two diode/RTD inputs
325-T1	One diode/RTD, one thermocouple input
325-T2	Two thermocouple inputs

Specify line power option*

VAC-100	Instrument configured for 100 VAC with U.S. power cord
VAC-120	Instrument configured for 120 VAC with U.S. power cord
VAC-120-ALL	Instrument configured for 120 VAC with U.S. power cord and universal Euro line cord and fuses for 220/240 VAC setting
VAC-220	Instrument configured for 220 VAC with universal Euro line cord
VAC-240	Instrument configured for 240 VAC with universal Euro line cord

**Other country line cords available, consult Lake Shore*

Accessories included

106-009	Heater output connector (dual banana jack)
G-106-233	Sensor input mating connector (6-pin DIN plug); 2 included
106-735	Terminal block, 2-pin
——	Calibration certificate
MAN-325	Model 325 user manual

Accessories available

6201	1 m (3.3 ft long) IEEE-488 (GPIB) computer interface cable assembly
8001-325	CalCurve™, factory installed – the breakpoint table from a calibrated sensor stored in the instrument (extra charge for additional sensor curves)
CAL-325-CERT	Instrument recalibration with certificate
CAL-325-DATA	Instrument recalibration with certificate and data
RM-½	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

All specifications are subject to change without notice

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Established in 1968, Lake Shore Cryotronics, Inc. is an international leader in developing innovative measurement and control solutions. Founded by Dr. John M. Swartz, a former professor of electrical engineering at the Ohio State University, and his brother David, Lake Shore produces equipment for the measurement of cryogenic temperatures, magnetic fields, and the characterization of the physical properties of materials in temperature and magnetic environments.