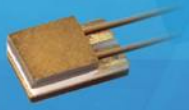
MODEL 350
ULTRA-LOW CRYOGENIC
TEMPERATURE CONTROLLER

Ideal for use with He-3 systems and other ultra-low temperature refrigeration platforms down to 100 mK



OPTIMIZED
CERNOX™
PERFORMANCE

LakeShore

Model 350 Ultra-Low Cryogenic Temperature Controller

- Ideal for use with He-3 systems and other ultra-low temperature refrigeration platforms down to 100 mK
- Optimized performance with Cernox™ RTDs
- Patented low-noise input circuitry enables super low excitation power for minimal self-heating and high resolution measurement
- 4 independent control loops and a broad range of I/O configurations can eliminate need for additional instrumentation
- 4 PID-controlled outputs: 75 W warm-up heater, 1 W sample heater, and 2 auxiliary 1 W ±10 V outputs
- Proven, intuitive interface
- Performance assurance even at the extremes, with verifiable product specifications
- Full 3 year standard warranty

A Powerful Ultra-Low Temperature Physics Tool

The Model 350 is designed for the demands of pumped He-3 refrigerators and other ultra-low and low temperature platforms. It provides excellent measurement performance, superior control accuracy, and convenient operation in a wide range of advanced research applications. Whether the need is for high accuracy with minimal thermal impact, or precise temperature control in high magnetic fields, or dependable measurement in radiation environments, the new Model 350 controller matched with Lake Shore's industry-leading Cernox™ sensors provides a cryogenic solution that's demonstrably best-in-class.

The patented noise reduction input circuitry of the Model 350 is just one reason why this controller works so well for ultra-low temperature (ULT) applications, all the way down to 100 mK. When combined with precision Cernox sensors, this performance-optimized design allows as little as 10 nA of excitation current to be used, minimizing self-heating effects, and ensures best possible measurement accuracy throughout the entire temperature range.

This single instrument offers extraordinary capability and flexibility, often eliminating the need for additional instrumentation in a refrigeration control system. Its four input channels and four independent control outputs are configurable to support a broad range of I/O requirements, including the heaters and auxiliary devices typical of ULT refrigeration systems, as well as other cryogenic sensor types like ruthenium oxide and platinum RTDs. Standard computer interfaces enable remote communications, control and coordination with other systems.

In short, the Model 350 cryogenic temperature controller brings a new level of power, precision, and performance to critical low temperature physics research. It is ideal for use with He-3 systems, adiabatic demagnetization refrigerators (ADRs), certain dilution refrigerators, and many other applications demanding low thermal power and high measurement precision.

Application Versatility

Designed to support a broad range of sensor types, the Model 350 is performance-optimized for use over the entire temperature range of Cernox™ sensors, making it the instrument of choice for ULT environments as well as other cryogenic systems where errors due to magneto-resistive or radiation effects need to be minimized.

4 standard sensor input channels

The Model 350 comes with four standard sensor inputs supporting Cernox™, ruthenium oxide, platinum RTDs, and other NTC RTD sensors. Inputs can be configured to accept any of the supported input types. Each sensor input channel has its own current source, providing fast settling times. The four sensor inputs are optically isolated from other circuits to reduce noise and to provide repeatable sensor measurements. Current reversal eliminates thermal electromotive force (EMF) errors in resistance sensors. Nine excitation currents facilitate temperature measurement and control down to 100 mK, with the nominal temperature range (using Cernox™ sensors) spanning to 420 K. The instrument automatically selects the optimal current and gain levels for you once the

sensor type is selected, and automatically scales current to minimize self-heating effects at low temperatures. The patented input circuitry eliminates any errors associated with grounding inconsistencies, making it easier to achieve reliable measurements at ultra-low temperatures. With the ability to label each sensor input channel with a customized name, it's also easy to identify the measured values being displayed.

3 option cards for more inputs and a wider range of applications

Field installable input option cards can expand your sensor selection to include silicon diodes (like DT-670), capacitance sensors or thermocouples. Once installed, the option input can be selected and named from the front panel like any other input type. These option cards further expand the application versatility of the Model 350 temperature controller by allowing specialized sensors to be switched in and out to achieve specific measurement objectives. For example, addition of the thermocouple input option enables continuous measurement to 1000 K and above. Alternatively, the capacitance sensor option card enables a magnetics-impervious capacitance temperature sensor to be temporarily switched in for elimination of magneto-resistive effects while taking low temperature sample measurements under high or changing fields. Diode sensor support is provided by the 4-channel expansion card, which also enables use of additional Cernox™ sensors for supplemental monitoring.

4 PID controlled outputs

For convenient integration into a wide range of systems, the Model 350 offers four PID-controlled outputs. Variable DC current source outputs include a 75 W output for direct control of the typical main warm-up heater, and a 1 W output for fine control of the sample heater. Two additional 1 W variable DC voltage source outputs can be used to power auxiliary devices like a still heater in a dilution refrigerator, or to control a magnet power supply driving an ADR. The ability to dynamically select an input to associate with the controlled output provides additional flexibility in setting up the control scheme.

Precision temperature control

The Model 350 calculates the precise control output based on your temperature setpoint and feedback from the control sensor. You can manually set the PID values for fine control, or the temperature control loop autotuning feature can automate the tuning process for you. The setpoint ramp feature provides smooth, continuous setpoint changes and predictable setpoint approaches without the worry of overshoot or excessive settling times. When combined with the zone setting feature, which enables automatic switching of sensor inputs and scales current excitation through ten different preloaded temperature zones, the Model 350 provides continuous measurement and control over the entire temperature range required.

Simple and Increased Productivity

With remote control and automated features, the Model 350 will simplify your temperature control processes and increase your productivity in the laboratory.

3 interfaces for remote control

The Model 350 temperature controller includes Ethernet, USB, and IEEE-488 interfaces. In addition to gathering data, nearly every function of the instrument can be controlled through a computer interface. Ethernet provides the ability to access and monitor instrument activities via the internet from anywhere in the world, allowing distributed sharing of the controller and the controlled system. You can download the Lake Shore curve handler software to your computer to easily enter and manipulate sensor calibration curves for storage in the instrument's non-volatile flash memory.

Simple automation

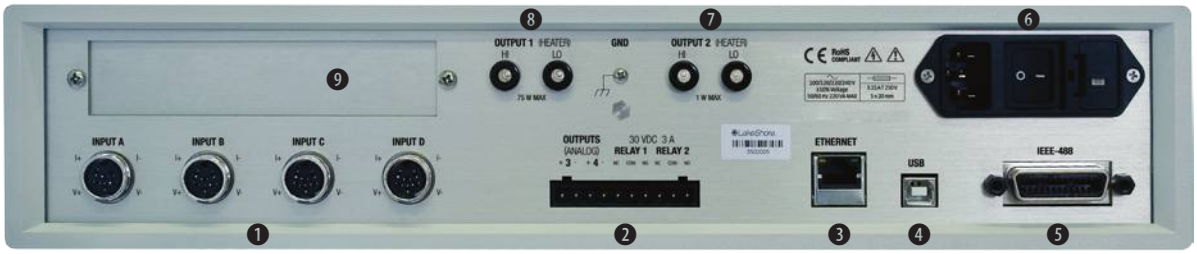
Each sensor input has a high and low alarm that offer latching and non-latching operation. The two relays can be used in conjunction with the alarms to alert you of a fault condition

and perform simple on/off control. Relays can be assigned to any alarm or operated manually. Choosing appropriate PID control settings for a closed loop system can be tedious, but the Model 350 provides the temperature control loop autotuning feature to simplify the process. It's an automated process that measures system characteristics and computes setting values for P, I, and D for you. Once PID tuning parameters are chosen for a given setpoint, the zone tuning feature automatically switches sensor inputs for new setpoints, enabling you to control temperatures from 100 mK to over 1000 K without interrupting your experiment.

Performance You Can Count On

As with all Lake Shore products, the Model 350 product specifications are documented and verifiable in keeping with Lake Shore's tradition of performance assurance even at application extremes. The product is supported by a 3-year standard warranty, our confirmation of quality and commitment for the long term. Choosing the Model 350 for your ultra-low temperature application means you'll have the ultimate confidence in meeting your integration, measurement and control needs, now and into the future.

Model 350 Rear Panel Connections



1. Sensor inputs
2. Terminal block (analog outputs & relays)
3. Ethernet interface
4. USB interface
5. IEEE-488 interface
6. Line input assembly
7. Output 2 heater
8. Output 1 heater
9. Option card slot

www.lakeshore.com Lake Shore Cryotronics, Inc. (614) 891-2244 fax: (614) 818-1600 e-mail: info@lakeshore.com

Configurable Display

The Model 350 offers a bright, graphic liquid crystal display with an LED backlight that simultaneously displays up to eight readings. You can show all four loops, or if you need to monitor one input, you can display just that one in greater detail. Or you can custom configure each display location to suit your experiment. Data from any input can be assigned to any of the locations, and your choice of temperature or sensor units can be displayed. For added convenience, you can also custom label each sensor input, eliminating the guesswork in remembering or determining the location to which a sensor input is associated.

Four Input/Output Display with Labels
Standard display option featuring all four inputs and associated outputs.

Two Input/Output Display with Labels
Reading locations can be user configured to meet application needs. Here, the input name is shown above each measurement reading along with the designated input letter.

Intuitive Menu Structure
Logical navigation allows you to spend more time on research and less time on setup.

Use Additional Input Types with Option Cards

The field installable input option cards add additional input types. The Model 3060 adds thermocouple capability. The Model 3061 adds capacitance sensor inputs. The Model 3062 adds 4 Cernox™/diode inputs. While the option cards can be easily removed, it is not necessary as the standard inputs remain functional when the options are not being used.

Sensor Selection

Sensor Temperature Range (sensors sold separately)

		Model	Useful range	Magnetic field use
Negative Temperature Coefficient RTDs	Cernox™	CX-1010	0.1 K to 325 K[1]	T > 2 K & B ≤ 19 T
	Cernox™	CX-1030-HT	0.3 K to 420 K[1,]	T > 2 K & B ≤ 19 T
	Cernox™	CX-1050-HT	1.4 K to 420 K[1]	T > 2 K & B ≤ 19 T
	Cernox™	CX-1070-HT	4 K to 420 K[1]	T > 2 K & B ≤ 19 T
	Cernox™	CX-1080-HT	20 K to 420 K[1]	T > 2 K & B ≤ 19 T
	Germanium	GR-300-AA	0.35 K to 100 K	Not recommended
	Germanium	GR-1400-AA	1.8 K to 100 K	Not recommended
	Rox™	RX-102B	0.1 K to 40 K	T > 2 K & B ≤ 10 T
	Rox™	RX-103	1.4 K to 40 K	T > 2 K & B ≤ 10 T
	Rox™	RX-202	0.5 K to 40 K	T > 2 K & B ≤ 10 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
Diodes ***3062 (coming soon)***	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
Capacitance ***3061***		CS-501	1.4 K to 290 K	T > 4.2 K & B ≤ 18.7 T
Thermocouples ***3060-F***	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

[1] *Non-HT version maximum temperature: 325 K*

Cernox™ thin-film RTDs offer high sensitivity and low magnetic field-induced errors over the 0.1 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.

Silicon diodes are the best choice for general cryogenic use from 1.4 K to above room temperature. Silicon 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.

Capacitance sensors are ideally suited for use in strong magnetic fields because they exhibit virtually no magnetic field dependence. They can be used from 1.4 K to 290 K.

Typical Sensor Performance

	Example Lake Shore Sensor	Temperature (K)	Nominal Resistance/ Voltage	Typical Sensor Sensitivity[2]	Measurement Resolution: Temperature Equivalents	Electronic Accuracy: Temperature Equivalents	Temperature Accuracy including Electronic Accuracy, CalCurve™, and Calibrated Sensor	Electronic Control Stability[3]: Temperature Equivalents
Cernox™ (1 mV)	CX-1010-SD with 0.1L calibration	0.1 0.3 0.5 4.2 300	21389 Ω 2322.4 Ω 1248.2 Ω 277.32 Ω 30.392 Ω	-558110 Ω/K -10785 Ω/K -2665.2 Ω/K -32.209 Ω/K -0.0654 Ω/K	5.4 µK 28 µK 113 µK 931 µK 153 mK	±69 µK ±272 µK ±938 µK ±6.5 mK ±1.7 K	±4.1 mK ±4.3 mK ±4.9 mK ±11 mK ±1.8 K	±10.8 µK ±55.6 µK ±225 µK ±1.9 mK ±306 mK
Cernox™ (10 mV)	CX-1050-SD-HT[4] with 1.4M calibration	1.4 4.2 77 420	26566 Ω 3507.2 Ω 205.67 Ω 45.03 Ω	-48449 Ω/K -1120.8 Ω/K -2.4116 Ω/K -0.0829 Ω/K	6.2 µK 89 µK 1.2 mK 12 mK	±261 µK ±2.1 mK ±38 mK ±338 mK	±4.3 mK ±6.1 mK ±50 mK ±412 mK	±12.4 µK ±178 µK ±2.5 mK ±24.1 mK
Germanium (1 mV)	GR-50-AA with 0.05A calibration	0.1 0.3 0.5 1.4 4.2	2317 Ω 164 Ω 73.8 Ω 24.7 Ω 13.7 Ω	-71858 Ω/K -964 Ω/K -202.9 Ω/K -13.15 Ω/K -1.036 Ω/K	4.2 µK 31.1 µK 49.3 µK 228 µK 2.9 mK	±14 µK ±78 µK ±195 µK ±904 µK ±7.2 mK	±4.0 mK ±4.1 mK ±4.2 mK ±4.9 mK ±11 mK	±8.3 µK ±62.2 µK ±98.6 µK ±456 µK ±5.8 mK
Germanium (10 mV)	GR-300-AA with 0.3D calibration	0.3 1.4 4.2 100	35180 Ω 448.6 Ω 94.46 Ω 2.72 Ω	-512200 Ω/K -581.3 Ω/K -26.56 Ω/K -0.024 Ω/K	2 µK 17 µK 38 µK 4.2 mK	±47 µK ±481 µK ±1.8 mK ±151 mK	±4.0 mK ±4.5 mK ±5.8 mK ±171 mK	±3.9 µK ±34.4 µK ±75.3 µK ±8.3 mK
Germanium (10 mV)	GR-1400-AA with 1.4D calibration	1.4 4.2 77 100	35890 Ω 1689 Ω 3.55 Ω 2.8 Ω	-94790 Ω/K -861.9 Ω/K -0.05 Ω/K -0.021 Ω/K	11 µK 35 µK 2 mK 4.8 mK	±257 µK ±900 µK ±83 mK ±175 mK	±4.3 mK ±4.9 mK ±94 mK ±195 mK	±21.1 µK ±69.6 µK ±4 mK ±9.5 mK
Rox™ (1 mV)	RX-102B-CB with 0.02C calibration	0.1 0.5 1.4 4.2 40	3549 Ω 2188 Ω 1779 Ω 1546 Ω 1199 Ω	-12578 Ω/K -1056 Ω/K -198 Ω/K -40.0 Ω/K -3.41 Ω/K	79.5 µK 284 µK 1.5 mK 7.5 mK 88 mK	±908 µK ±2.7 mK ±13.7 mK ±65.4 mK ±727 mK	±4.9 mK ±6.7 mK ±18 mK ±69 mK ±803 mK	±159 µK ±568 µK ±3.0 mK ±15.0 mK ±176 mK
Platinuim RTD 500 Ω Full Scale	PT-103 with 14J calibration	30 77 300 500	3.66 Ω 20.38 Ω 110.35 Ω 185.668 Ω	0.191 Ω/K 0.423 Ω/K 0.387 Ω/K 0.378 Ω/K	0.5 mK 0.7 mK 7.8 mK 7.9 mK	±22 mK ±34 mK ±140 mK ±223 mK	±31 mK ±44 mK ±164 mK ±274 mK	±1.0 mK ±1.4 mK ±15.5 mK ±15.9 mK
Silicon Diode	DT-670-CO-13 with 1.4H calibration	1.4 77 300 500	1.664 V 1.028 V 0.5596 V 0.0907 V	-12.49 mV/K -1.73 mV/K -2.3 mV/K -2.12 mV/K	0.8 mK 5.8 mK 4.3 mK 4.7 mK	±13 mK ±76 mK ±47 mK ±40 mK	±20 mK ±113 mK ±82 mK ±94 mK	±1.6 mK ±11.6 mK ±8.7 mK ±9.4 mK
Silicon Diode	DT-470-SD-13 with 1.4H calibration	1.4 77 300 475	1.6981 V 1.0203 V 0.5189 V 0.0906 V	-13.1 mV/K -1.92 mV/K -2.4 mV/K -2.22 mV/K	0.8 mK 5.2 mK 4.2 mK 4.5 mK	±13 mK ±68 mK ±44 mK ±38 mK	±20 mK ±105 mK ±79 mK ±87 mK	±1.5 mK ±10.4 mK ±8.3 mK ±9.0 mK
GaAlAs Diode	TG-120-SD with 1.4H calibration	1.4 77 300 475	5.3909 V 1.4222 V 0.8978 V 0.3778 V	-97.5 mV/K -1.24 mV/K -2.85 mV/K -3.15 mV/K	0.21 mK 16 mK 7 mK 6.3 mK	±6 mK ±179 mK ±60 mK ±37 mK	±13 mK ±216 mK ±95 mK ±86 mK	±410 µK ±32.3 mK ±14.0 mK ±12.7 mK
Capacitance	CS-501	4.2 77 200	6.0 nF 9.1 nF 19.2 nF	27 pF/K 52 pF/K 174 pF/K	7.4 mK 3.9 mK 12 mK	Not applicable	Calibration not available from Lake Shore	±14.8 mK ±7.7 mK ±23 mK
Thermocouple	Type K	75 300 600 1500	-5862.9 µV 1075.3 µV 13325 µV 49813 µV	15.6 µV/K 40.6 µV/K 41.7 µV/K 36.1 µV/K	26 mK 9.9 mK 9.6 mK 11 mK	±252 mK[5] ±38 mK[5] ±184 mK[5] ±718 mK[5]	Calibration not available from Lake Shore	±51.3 mK ±19.7 mK ±19.2 mK ±22.2 mK

[2] *Typical sensor sensitivities were taken from representative calibrations for the sensor listed*

[3] *Control stability of the electronics only, in an ideal thermal system*

[4] *Non-HT version maximum temperature: 325 K*

[5] *Accuracy specification does not include errors from room temperature compensation*

Model 350 Specifications

Input Specifications

Standard inputs	Sensor temperature coefficient	Input range	Excitation current	Display resolution	Measurement resolution[6]	Electronic accuracy (at 25 °C)	Measurement temperature coefficient	Electronic control stability[7]
NTC RTD/ PTC RTD 10 mV	Negative/ Positive	0 Ω to 10 Ω	1 mA[9]	0.1 mΩ	0.1 mΩ	±0.002 Ω ±0.06% of rdg	(0.01 mΩ + 0.001% of rdg)/°C	±0.2 mΩ
		0 Ω to 30 Ω	300 µA[9]	0.1 mΩ	0.3 mΩ	±0.002 Ω ±0.06% of rdg	(0.03 mΩ + 0.001% of rdg)/°C	±0.6 mΩ
		0 Ω to 100 Ω	100 µA[9]	1 mΩ	1 mΩ	±0.01 Ω ±0.04% of rdg	(0.1 mΩ + 0.001% of rdg)/°C	±2 mΩ
		0 Ω to 300 Ω	30 µA[9]	1 mΩ	3 mΩ	±0.01 Ω ±0.04% of rdg	(0.3 mΩ + 0.001% of rdg)/°C	±6 mΩ
		0 Ω to 1 kΩ	10 µA[9]	10 mΩ	10 mΩ	±0.1 Ω ±0.04% of rdg	(1 mΩ + 0.001% of rdg)/°C	±20 mΩ
		0 Ω to 3 kΩ	3 µA[9]	10 mΩ	30 mΩ	±0.1 Ω ±0.04% of rdg	(3 mΩ + 0.001% of rdg)/°C	±60 mΩ
		0 Ω to 10 kΩ	1 µA[9]	100 mΩ	100 mΩ	±1.0 Ω ±0.04% of rdg	(10 mΩ + 0.001% of rdg)/°C	±200 mΩ
		0 Ω to 30 kΩ	300 nA[9]	100 mΩ	300 mΩ	±2.0 Ω ±0.04% of rdg	(30 mΩ + 0.001% of rdg)/°C	±600 mΩ
		0 Ω to 100 kΩ	100 nA[9]	1 Ω	1 Ω	±10.0 Ω ±0.04% of rdg	(100 mΩ + 0.001% of rdg)/°C	±2 Ω
		0 Ω to 300 kΩ	30 nA[9]	1 Ω	3 Ω	±30 Ω ±0.04% of rdg	(300 mΩ + 0.001% of rdg)/°C	±6 Ω
NTC RTD 1 mV	Negative	0 Ω to 10 Ω	100 µA[9]	0.1 mΩ	1 mΩ	±0.01 Ω ±0.04% of rdg	(0.1 mΩ + 0.001% of rdg)/°C	±2 mΩ
		0 Ω to 30 Ω	30 µA[9]	0.1 mΩ	3 mΩ	±0.01 Ω ±0.04% of rdg	(0.3 mΩ + 0.001% of rdg)/°C	±6 mΩ
		0 Ω to 100 Ω	10 µA[9]	1 mΩ	10 mΩ	±0.1 Ω ±0.04% of rdg	(1 mΩ + 0.001% of rdg)/°C	±20 mΩ
		0 Ω to 300 Ω	3 µA[9]	1 mΩ	30 mΩ	±0.1 Ω ±0.04% of rdg	(3 mΩ + 0.001% of rdg)/°C	±60 mΩ
		0 Ω to 1 kΩ	1 µA[9]	10 mΩ	100 mΩ	±1.0 Ω ±0.04% of rdg	(10 mΩ + 0.001% of rdg)/°C	±200 mΩ
		0 Ω to 3 kΩ	300 nA[9]	10 mΩ	300 mΩ	±2.0 Ω ±0.04% of rdg	(30 mΩ + 0.001% of rdg)/°C	±600 mΩ
		0 Ω to 10 kΩ	100 nA[9]	100 mΩ	1 Ω	±10.0 Ω ±0.04% of rdg	(100 mΩ + 0.001% of rdg)/°C	±2 Ω
		0 Ω to 30 kΩ	30 nA[9]	100 mΩ	3 Ω	±30 Ω ±0.04% of rdg	(300 mΩ + 0.001% of rdg)/°C	±6 Ω
		0 Ω to 100 kΩ	10 nA[9]	1 Ω	10 Ω	±100 Ω ±0.04% of rdg	(1 Ω + 0.001% of rdg)/°C	±20 Ω

Scanner option *Model 3062*	Sensor temperature coefficient	Input range	Excitation current	Display resolution	Measurement resolution	Electronic accuracy (at 25 °C)	Measurement temperature coefficient	Electronic control stability[7]
Diode	Negative	0 V to 2.5 V	10 µA ±0.05%[8]	10 µV	10 µV	±80 µV ±0.005% of rdg	(10 µV + 0.0005% of rdg)/°C	±20 µV
	Negative	0 V to 10 V	10 µA ±0.05%[8]	100 µV	20 µV	±160 µV ±0.01% of rdg	(20 µV + 0.0005% of rdg)/°C	±40 µV
PTC RTD	Positive	0 Ω to 10 Ω	1 mA[9]	0.1 mΩ	0.2 mΩ	±0.002 Ω ±0.01% of rdg	(0.01 mΩ + 0.001% of rdg)/°C	±0.2 mΩ
		0 Ω to 30 Ω	1 mA[9]	0.1 mΩ	0.2 mΩ	±0.002 Ω ±0.01% of rdg	(0.03 mΩ + 0.001% of rdg)/°C	±0.4 mΩ
		0 Ω to 100 Ω	1 mA[9]	1 mΩ	2 mΩ	±0.004 Ω ±0.01% of rdg	(0.1 mΩ + 0.001% of rdg)/°C	±4 mΩ
		0 Ω to 300 Ω	1 mA[9]	1 mΩ	2 mΩ	±0.004 Ω ±0.01% of rdg	(0.3 mΩ + 0.001% of rdg)/°C	±4 mΩ
		0 Ω to 1 kΩ	1 mA[9]	10 mΩ	20 mΩ	±0.04 Ω ±0.02% of rdg	(1 mΩ + 0.001% of rdg)/°C	±40 mΩ
		0 Ω to 3 kΩ	1 mA[9]	10 mΩ	20 mΩ	±0.04 Ω ±0.02% of rdg	(3 mΩ + 0.001% of rdg)/°C	±40 mΩ
		0 Ω to 10 kΩ	1 mA[9]	100 mΩ	200 mΩ	±0.4 Ω ±0.02% of rdg	(10 mΩ + 0.001% of rdg)/°C	±400 mΩ
NTC RTD 10 mV	Negative	0 Ω to 10 Ω	1 mA[9]	0.1 mΩ	0.15 mΩ	±0.002 Ω ±0.06% of rdg	(0.01 mΩ + 0.001% of rdg)/°C	±0.3 mΩ
		0 Ω to 30 Ω	300 µA[9]	0.1 mΩ	0.45 mΩ	±0.002 Ω ±0.06% of rdg	(0.03 mΩ + 0.0015% of rdg)/°C	±0.9 mΩ
		0 Ω to 100 Ω	100 µA[9]	1 mΩ	1.5 mΩ	±0.01 Ω ±0.04% of rdg	(0.1 mΩ + 0.001% of rdg)/°C	±3 mΩ
		0 Ω to 300 Ω	30 µA[9]	1 mΩ	4.5 mΩ	±0.01 Ω ±0.04% of rdg	(0.3 mΩ + 0.0015% of rdg)/°C	±9 mΩ
		0 Ω to 1 kΩ	10 µA[9]	10 mΩ	15 mΩ +0.002% of rdg	±0.1 Ω ±0.04% of rdg	(1 mΩ + 0.001% of rdg)/°C	±30 mΩ ±0.004% of rdg
		0 Ω to 3 kΩ	3 µA[9]	10 mΩ	45 mΩ+0.002% of rdg	±0.1 Ω ±0.04% of rdg	(3 mΩ + 0.0015% of rdg)/°C	±90 mΩ ±0.004% of rdg
		0 Ω to 10 kΩ	1 µA[9]	100 mΩ	150 mΩ+0.002% of rdg	±1.0 Ω ±0.04% of rdg	(10 mΩ + 0.001% of rdg)/°C	±300 mΩ ±0.004% of rdg
		0 Ω to 30 kΩ	300 nA[9]	100 mΩ	450 mΩ+0.002% of rdg	±2.0 Ω ±0.04% of rdg	(30 mΩ + 0.001% of rdg)/°C	±900 mΩ ±0.004% of rdg
		0 Ω to 100 kΩ	100 nA[9]	1 Ω	1.5 Ω+0.005% of rdg	±10.0 Ω ±0.04% of rdg	(100 mΩ + 0.002% of rdg)/°C	±3 Ω ±0.01% of rdg

Thermocouple option *Model 3060-F*	Sensor temperature coefficient	Input range	Excitation current	Display resolution	Measurement resolution	Electronic accuracy (at 25 °C)	Measurement temperature coefficient	Electronic control stability[7]
Thermocouple	Positive	±50 mV	NA	0.1 µV	0.4 µV	±1 µV ±0.05% of rdg[10]	(0.1 µV + 0.001% of rdg)/°C	±0.8 µV

Capacitance option *Model 3061*	Sensor temperature coefficient	Input range	Excitation current	Display resolution	Measurement resolution	Electronic accuracy (at 25 °C)	Measurement temperature coefficient	Electronic control stability[7]
Capacitance	Positive or Negative	0.1 to 15 nF	3.496 kHz 1 mA square wave	0.1 pF	0.05 pF	±50 pF ±0.4% of rdg	2.5 pF/°C	0.1 pF
		1 to 150 nF	3.496 kHz 10 mA square wave	1 pF	0.5 pF	±50 pF ±0.4% of rdg	5 pF/°C	1 pF

[6] *Measurement resolution measured at 4.2 K to remove the thermal noise of the resistor*
[7] *Control stability of the electronics only, in ideal thermal system*
[8] *Current source error has negligible effect on measurement accuracy*
[9] *Current source error is removed during calibration*
[10] *Accuracy specification does not include errors from room temperature compensation*

Thermometry

Number of inputs	4 (8 with scanner option)
Input configuration	Inputs can be configured from the front panel to accept any of the supported input types. Thermocouple, capacitance and diode inputs require an optional input card that can be installed in the field.
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 non-scanned input, 2 rdg/s on each scanned input (scanner option only)
Autorange	Automatically selects appropriate NTC RTD or PTC RTD range
User curves	Room for 39 200-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
Math	Maximum and minimum
Filter	Averages 2 to 64 input readings

Control

Control outputs	4

Heater outputs (Outputs 1 & 2)

Control type	Closed loop digital PID with manual heater output or open loop
Update rate	10/s
Tuning	Autotune (one loop at a time), PID, PID zones
Control stability	Sensor dependent, see Input Specifications table
PID control settings	
Proportional (gain)	0 to 9999 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, heater range, control channel, ramp rate
Setpoint ramping	0.001 K/min to 100 K/min

Output 1

	25 Ω setting	50 Ω setting
Type	Variable DC current source	
D/A resolution	16-bit	
Max power	75 W	50 W
Max current	1.732 A	1 A
Voltage compliance (min)	50 V	50 V
Heater load for max power	25 Ω	50 Ω
Heater load range	10 Ω to 100 Ω	
Ranges	5 (decade steps in power)	
Heater noise	1.2 µA RMS (dominated by line frequency and its harmonics)	
Grounding	Output referenced to chassis ground	
Heater connector	Dual banana	
Safety limits	Curve temperature, power up heater off, short circuit protection	

Output 2

Type	Variable DC current source
D/A resolution	16-bit
Max power	1 W
Max current	100 mA
Voltage compliance (min)	10 V
Heater load for max power	100 Ω
Heater load range	25 Ω to 2 kΩ
Ranges (100 Ω load)	1 W, 100 mW, 10 mW, 1 mW, 100 µW
Heater noise	<0.005% of range
Grounding	Output referenced to measurement common
Heater connector	Dual banana
Safety limits	Curve temperature, power up heater off, short circuit protection

Sensor Input Configuration

	RTD	Diode (option)	Thermocouple (option)	Capacitance (option)
Measurement type	4-lead differential	4-lead differential	2-lead differential, room temperature compensated	4-lead differential, variable duty cycle
Excitation	Constant current with current reversal	10 µA constant current	N/A	Constant current, 3.496 kHz square wave
Supported sensors	100 Ω Platinum, 1000 Ω Platinum, Germanium, Carbon-Glass, Cernox™, and Rox™	Silicon, GaAlAs	Most thermocouple types	CS-501GR
Standard curves	PT-100, PT-1000, RX-102A, RX-202A	DT-470, DT-670, DT-500-D, DT-500-E1	Type E, Type K, Type T, AuFe 0.07% vs. Cr, AuFe 0.03% vs Cr	N/A
Input connector	6-pin DIN	6-pin DIN	Screw terminals in a ceramic isothermal block	6-pin DIN

Analog outputs (Outputs 3 & 4)

Control type	Closed loop PID, PID zones, warm up heater mode, still heater, manual output, or monitor output
Warm up heater mode settings	
Warm up percentage	0 to 100% with 1% resolution
Warm up mode	Continuous control or auto-off
Monitor output settings	
Scale	User selected
Data source	Temperature or sensor units
Settings	Input, source, top of scale, bottom of scale, or manual
Type	Variable DC voltage source
Update rate	10/s
Range	±10 V
Resolution	16-bit, 0.3 mV
Accuracy	±2.5 mV
Noise	0.3 mV RMS
Maximum current	100 mA
Maximum power	1 W (into 100 Ω)
Minimum load resistance	100 Ω (short-circuit protected)
Connector	Detachable terminal block

Front Panel

Display	8-line by 40-character (240 × 64 pixel) graphic LCD display module with LED backlight
Number of reading displays	1 to 8
Display units	K, °C, V, mV, Ω, nF
Reading source	Temperature, sensor units, max, and min
Display update rate	2 rdg/s
Temperature display resolution	0.00001° from 0° to 9.99999°, 0.0001° from 10° to 99.9999°, 0.001° from 100° to 999.999°, 0.01° above 1000°
Sensor units display resolution	Sensor dependent, to 6 digits
Other displays	Input name, setpoint, heater range, heater output, and PID
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	0.01%
Display annunciators	Control input, alarm, tuning
LED annunciators	Remote, Ethernet status, alarm, control outputs
Keypad	27-key silicone elastomer keypad
Front panel features	Front panel curve entry, display contrast control, and keypad lock-out

Lake Shore Cryotronics, Inc.
575 McCorkle Boulevard
Westerville, OH 43082-8888 USA
Tel 614-891-2244
Fax 614-818-1600
e-mail info@lakeshore.com
www.lakeshore.com

Interface

IEEE-488.2

Capabilities	SH1, AH1, T5, L4, SR1, RL1, PP0, DC1, DT0, C0, E1
Reading rate	To 10 rdg/s on each input
Software support	LabVIEW™ driver (contact Lake Shore for availability)

USB

Function	Emulates a standard RS-232 serial port
Baud rate	57,600
Connector	B-type USB connector
Reading rate	To 10 rdg/s on each input
Software support	LabVIEW™ driver (contact Lake Shore for availability)

Ethernet

Function	TCP/IP, web interface, curve handler, configuration backup, chart recorder
Connector	RJ-45
Reading rate	To 10 rdg/s on each input
Software support	LabVIEW™ driver (contact Lake Shore for availability)

Alarms

Number	4, high and low for each input
Data source	Temperature or sensor units
Settings	Source, high setpoint, low setpoint, deadband, latching or non-latching, audible on/off, and visible on/off
Actuators	Display annunciator, beeper, and relays

Relays

Number	2
Contacts	Normally open (NO), normally closed (NC), and common (C)
Contact rating	30 VDC at 3 A
Operation	Activate relays on high, low, or both alarms for any input, or manual mode
Connector	Detachable terminal block

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, ±10%, 50 or 60 Hz, 220 VA
Size	435 mm W × 89 mm H × 368 mm D (17 in × 3.5 in × 14.5 in), full rack
Weight	7.6 kg (16.8 lb)
Approval	CE mark (contact Lake Shore for availability)

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.

Ordering Information

Part number	Description
350	4 input and 4 control output temperature controller
3060-F	Thermocouple input option
3061	Capacitance input option
3062	4-channel scanner option for diodes and RTDs *(coming soon)*

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); 4 included
G-106-750	Terminal block, 10-pin
——	Calibration certificate
MAN-350	Model 350 user manual

Accessories available

6201	1 m (3.3 ft long) IEEE-488 (GPIB) computer interface cable assembly
8001-350	CalCurve™, factory installed—the breakpoint table from a calibrated sensor stored in the instrument (extra charge for additional sensor curves)
CAL-350-CERT	Instrument recalibration with certificate
CAL-350-DATA	Instrument recalibration with certificate and data

All specifications are subject to change without notice 112912