Model 350
Temperature controller

Model 350 features

- 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
- CE certification
- Full 3 year standard warranty

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Lake Shore CRYOTRONICS

Model 350
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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.

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.

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.

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.

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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

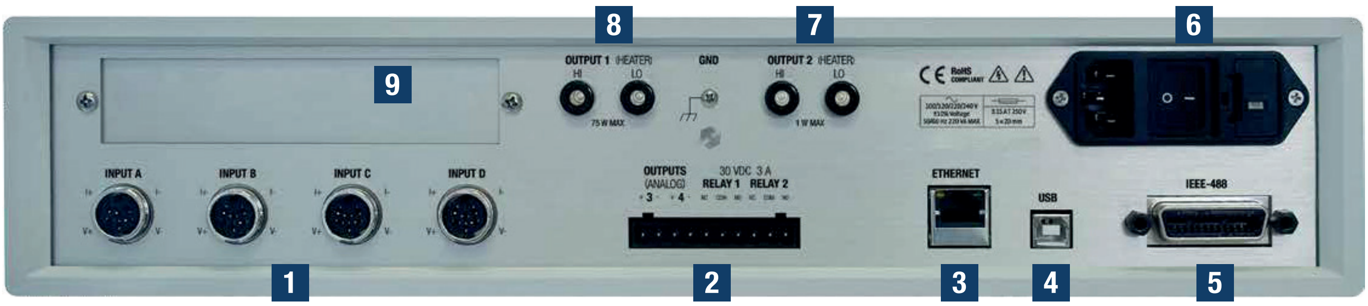
Each sensor input has a high and low alarm that offer latching and non-latching operation. The two relays can be used in conjunction with the alarms to alert you of a fault condition and perform simple on/off control. Relays can be assigned to any alarm or operated manually. Choosing appropriate PID 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.

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.



Model 350 rear panel

1 Sensor inputs
2 Terminal block (analog output and 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

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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, all inputs, 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.

Intuitive menu structure
Logical navigation allows you to spend more time on research and less time on setup.

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.

Sensor selection

Sensor temperature range (sensors sold separately)

		Model	Useful range	Magnetic field use
Negative temperature coefficient RTDs	Cernox™	CX-1010-HT	0.1 K to 420 K[1,2]	T > 2 K & B ≤ 19 T
	Cernox™	CX-1030-HT	0.3 K to 420 K[1,2]	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	0.3 K to 100 K	Not recommended
	Germanium	GR-1400-AA	1.4 K to 100 K	Not recommended
	Rox™	RX-102B	0.1 K to 40 K[2]	T > 2 K & B ≤ 10 T
	Rox™	RX-103	1.4 K to 40 K	T > 2 K & B ≤ 10 T
	Rox™	RX-202	0.1 K to 40 K[2]	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 *Option—3062*	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 *Option—3061*		CS-501	1.4 K to 290 K	T > 4.2 K & B ≤ 18.7 T
Thermocouples *Option—3060*	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*
[2] *Low temperature specified with self-heating error: ≤ 5 mK*

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.

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

	Example Lake Shore sensor	Temperature (K)	Nominal resistance/ voltage	Typical sensor sensitivity[3]	Measurement resolution: temperature equivalents	Electronic accuracy: temperature equivalents	Temperature accuracy including electronic accuracy, CalCurve™, and calibrated sensor	Electronic control stability[4]: temperature equivalents
Cernox™	CX-1010-SD	0.1	21389 Ω	-558110 Ω/K	5.4 µK	±69 µK	±3.1 mK	±10.8 µK
(1 mV)	with 0.1L	0.3	2322.4 Ω	-10785 Ω/K	28 µK	±272 µK	±3.8 mK	±56.0 µK
	calibration	0.5	1248.2 Ω	-2665.2 Ω/K	113 µK	±938 µK	±5.4 mK	±225 µK
		4.2	277.32 Ω	-32.209 Ω/K	931 µK	±6.5 mK	±11.5 mK	±1.9 mK
		300	30.392 Ω	-0.0654 Ω/K	153 mK	±1.7 K	±1.8 K	±306 mK
Cernox™	CX-1050-SD-HT[5]	1.4	26566 Ω	-48449 Ω/K	6.2 µK	±261 µK	±5.3 mK	±12.4 µK
(10 mV)	with 1.4M	4.2	3507.2 Ω	-1120.8 Ω/K	89 µK	±2.1 mK	±7.1 mK	±178 µK
	calibration	77	205.67 Ω	-2.4116 Ω/K	1.2 mK	±38 mK	±54 mK	±2.4 mK
		420	45.03 Ω	-0.0829 Ω/K	12 mK	±338 mK	±378 mK	±24 mK
Germanium	GR-50-AA with	0.1	2317 Ω	-71858 Ω/K	4.2 µK	±14 µK	±3.2 mK	±8.4 µK
(1 mV)	0.05A calibration	0.3	164 Ω	-964 Ω/K	31.1 µK	±78 µK	±3.8 mK	±62.2 µK
		0.5	73.8 Ω	-202.9 Ω/K	49.3 µK	±195 µK	±4.5 mK	±98.6 µK
		1.4	24.7 Ω	-13.15 Ω/K	228 µK	±904 µK	±4.9 mK	±456 µK
		4.2	13.7 Ω	-1.036 Ω/K	2.9 mK	±7.2 mK	±11 mK	±5.8 mK
Germanium	GR-300-AA	0.3	35180 Ω	-512200 Ω/K	2 µK	±47 µK	±3.7 mK	±4.0 µK
(10 mV)	with 0.3D	1.4	448.6 Ω	-581.3 Ω/K	17 µK	±481 µK	±4.5 mK	±34 µK
	calibration	4.2	94.46 Ω	-26.56 Ω/K	38 µK	±1.8 mK	±5.8 mK	±76 µK
		100	2.72 Ω	-0.024 Ω/K	4.2 mK	±151 mK	±181 mK	±8.4 mK
Germanium	GR-1400-AA	1.4	35890 Ω	-94790 Ω/K	11 µK	±257 µK	±4.3 mK	±21.1 µK
(10 mV)	with 1.4D	4.2	1689 Ω	-861.9 Ω/K	35 µK	±900 µK	±4.9 mK	±69.6 µK
	calibration	77	3.55 Ω	-0.05 Ω/K	2 mK	±83 mK	±99 mK	±4 mK
		100	2.8 Ω	-0.021 Ω/K	4.8 mK	±175 mK	±191 mK	±9.5 mK
Rox™	RX-102B-CB	0.1	3549 Ω	-12578 Ω/K	79.5 µK	±908 µK	±3.8 mK	±159 µK
(1 mV)	with 0.02C	0.5	2188 Ω	-1056 Ω/K	284 µK	±2.7 mK	±5.7 mK	±568 µK
	calibration	1.4	1779 Ω	-198 Ω/K	1.5 mK	±13.7 mK	±18.7 mK	±3.0 mK
		4.2	1546 Ω	-40.0 Ω/K	7.5 mK	±65.4 mK	±81.4 mK	±15.0 mK
		40	1199 Ω	-3.41 Ω/K	88 mK	±727 mK	±764 mK	±176 mK
Platinuim RTD	PT-103 with	30	3.66 Ω	0.191 Ω/K	0.5 mK	±22 mK	±32 mK	±1.0 mK
500 Ω full scale	14J calibration	77	20.38 Ω	0.423 Ω/K	0.7 mK	±34 mK	±46 mK	±1.4 mK
		300	110.35 Ω	0.387 Ω/K	7.8 mK	±140 mK	±163 mK	±15.6 mK
		500	185.668 Ω	0.378 Ω/K	7.9 mK	±223 mK	±269 mK	±15.8 mK
Silicon diode	DT-670-CO-13	1.4	1.664 V	-12.49 mV/K	0.8 mK	±13 mK	±25 mK	±1.6 mK
	with 1.4H	77	1.028 V	-1.73 mV/K	5.8 mK	±76 mK	±98 mK	±11.6 mK
	calibration	300	0.5596 V	-2.3 mV/K	4.3 mK	±47 mK	±79 mK	±8.7 mK
		500	0.0907 V	-2.12 mV/K	4.7 mK	±40 mK	±90 mK	±9.4 mK
Silicon diode	DT-470-SD-13	1.4	1.6981 V	-13.1 mV/K	0.8 mK	±13 mK	±25 mK	±1.6 mK
	with 1.4H	77	1.0203 V	-1.92 mV/K	5.2 mK	±68 mK	±90 mK	±10.4 mK
	calibration	300	0.5189 V	-2.4 mV/K	4.2 mK	±44 mK	±76 mK	±8.4 mK
		475	0.0906 V	-2.22 mV/K	4.5 mK	±38 mK	±88 mK	±9.0 mK
GaAlAs diode	TG-120-SD	1.4	5.3909 V	-97.5 mV/K	0.21 mK	±8.8 mK	±21 mK	±410 µK
	with 1.4H	77	1.4222 V	-1.24 mV/K	16 mK	±373 mK	±395 mK	±32.3 mK
	calibration	300	0.8978 V	-2.85 mV/K	7 mK	±144 mK	±176 mK	±14.0 mK
		475	0.3778 V	-3.15 mV/K	6.3 mK	±114 mK	±164 mK	±12.6 mK
Thermocouple	Type K	75	-5862.9 µV	15.6 µV/K	26 mK	±252 mK[6]	Calibration not available	±52 mK
50 mV		300	1075.3 µV	40.6 µV/K	9.9 mK	±38 mK[6]	from Lake Shore	±19.6 mK
Option—3060		600	13325 µV	41.7 µV/K	9.6 mK	±184 mK[6]		±19.2 mK
		1505	49998.3 µV	36.0 µV/K	11 mK	±730 mK[6]		±22.2 mK
Capacitance	CS-501	4.2	6.0 nF	27 pF/K	1.9 mK	Not applicable	Calibration not available	±3.8 mK
Option—3061		77	9.1 nF	52 pF/K	1.0 mK		from Lake Shore	±2.0 mK
		200	19.2 nF	174 pF/K	2.9 mK			±5.8 mK

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

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Input specifications

Standard inputs	Sensor temperature coefficient	Input range	Excitation current	Display resolution	Measurement resolution[7]	Electronic accuracy (at 25 °C)	Measurement temperature coefficient	Electronic control stability[8]
NTC RTD/ PTC RTD 10 mV	Negative/ Positive	0 Ω to 10 Ω	1 mA[10]	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[10]	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[10]	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[10]	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[10]	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[10]	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[10]	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[10]	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[10]	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[10]	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[10]	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[10]	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[10]	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[10]	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[10]	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[10]	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[10]	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[10]	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[10]	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[8]
Diode	Negative	0 V to 2.5 V	10 μA ±0.05%[9]	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%[9]	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[10]	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[10]	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[10]	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[10]	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[10]	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[10]	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[10]	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[10]	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[10]	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[10]	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[10]	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[10]	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[10]	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[10]	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[10]	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[10]	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*	Sensor temperature coefficient	Input range	Excitation current	Display resolution	Measurement resolution	Electronic accuracy (at 25 °C)	Measurement temperature coefficient	Electronic control stability[8]
Thermocouple	Positive	±50 mV	NA	0.1 μV	0.4 μV	±1 μV ±0.05% of rdg[11]	(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[8]
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

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

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Lake Shore CRYOTRONICS

Model 350
Temperature controller

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

Maximum update rate (scanner) The maximum update rate for a scanned input is 10 rdg/s distributed among the enabled channels. Any channel configured as 100 kΩ RTD with reversal on changes the update rate for the channel to 5 rdg/s.

Scanner channels enabled*	Update rate
1	10 rdg/s (100 ms/rdg)
2	5 rdg/s (200 ms/rdg)
3	3⅓ rdg/s (300 ms/rdg)
4	2½ rdg/s (400 ms/rdg)
5	2 rdg/s (500 ms/rdg)

** No channels configured for 100 kΩ NTC RTD*

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

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

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	100 Ω Platinum ... Carbon-Glass, Cernox™, and Rox™	Silicon	Most thermocouple	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

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Model 350
Temperature controller

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

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 (see www.lakeshore.com)

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 (see www.lakeshore.com)

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 (see www.lakeshore.com)

Alarms

Number	4 (8 with scanner option), 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, RoHS

Ordering information

Part number	Description
350	2 diode/resistor inputs temperature controller, includes one dual banana jack heater output connector, four 6-pin DIN plug sensor input mating connectors, one 10-pin terminal block, a calibration certificate and a user's manual
350-3060	Model 350 with a 3060 option card installed
350-3061	Model 350 with a 3061 option card installed
350-3062	Model 350 with a 3062 option card installed
3060	2-thermocouple input option for 350/336, field-installable
3061	Capacitance input option for 350/336, field-installable
3062	4-channel scanner option for diodes and RTD sensors for 350/336, field-installable

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	Rack mount kit for mounting one full rack temperature instrument
G-106-233	Sensor input mating connector (6-pin DIN plug)
G-106-755	Terminal block, 10-pin
106-009	Banana plug, dual
CAL-350-CERT	Instrument calibration with certificate
CAL-350-DATA	Instrument recalibration with certificate and data
119-057	Model 350 temperature controller manual

All specifications are subject to change without notice

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