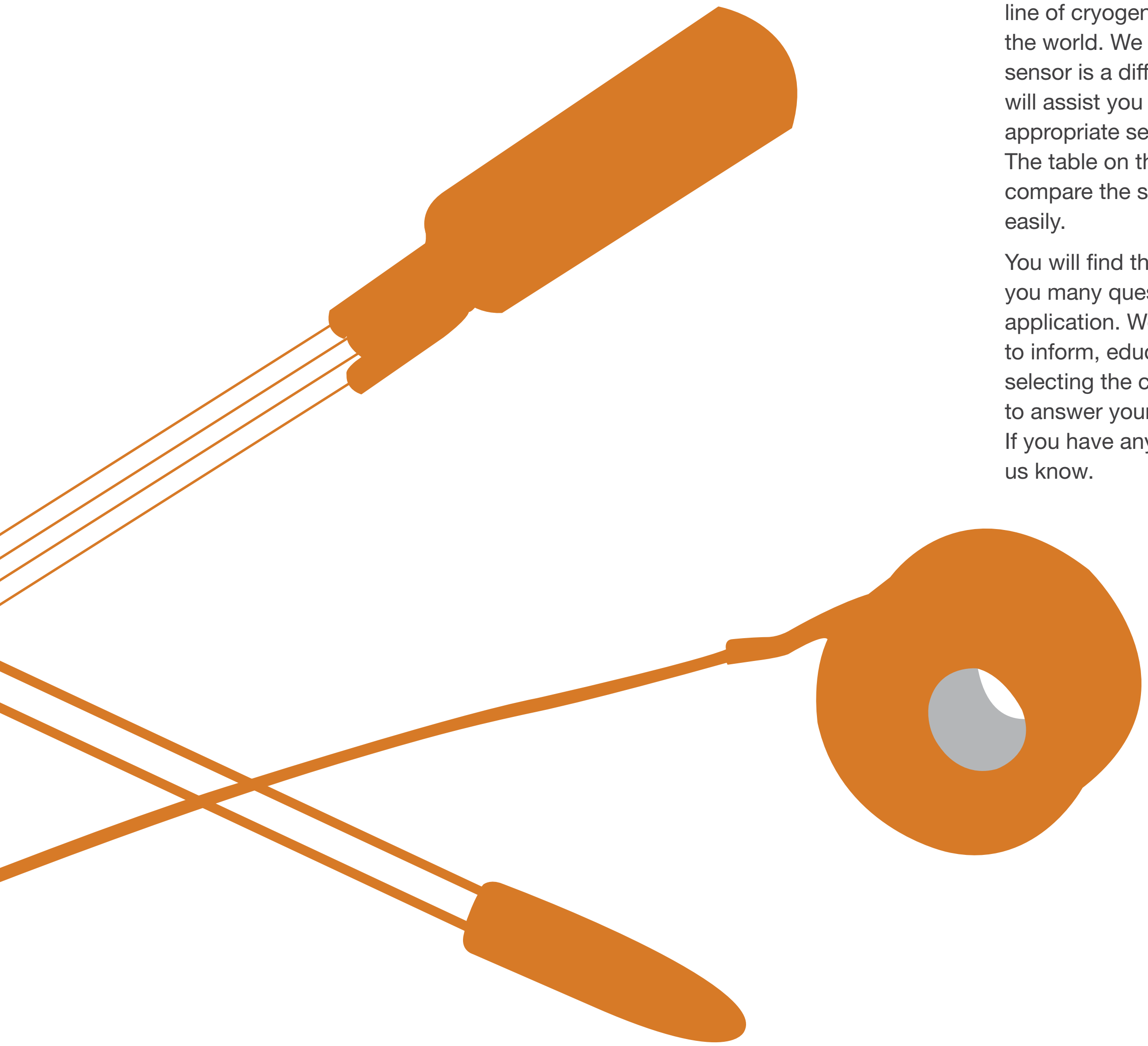
Sensors

Sensor Selection Guide



How to select a temperature sensor for your application

Lake Shore offers the most comprehensive line of cryogenic temperature sensors in the world. We understand that selecting a sensor is a difficult procedure. This catalog will assist you in selecting the most appropriate sensor for your application. The table on the next page is designed to compare the sensor characteristics more easily.

You will find that our sales staff will ask you many questions regarding your application. We ask a lot of questions to inform, educate, and to assist you in selecting the correct sensor. We are here to answer your questions and concerns. If you have any specific needs, please let us know.

Any one or several of the following environmental factors may be important to you in selecting a sensor:

- Temperature range
- Package size
- Fast thermal response time
- Fast electrical response time
- Heat sinking
- Small thermal mass
- Robustness
- Compatibility with harsh environments
  - Magnetic fields
  - Ionizing radiation
  - Ultra high vacuum (UHV)
  - Vibration/mechanical shock
  - Thermal shock
  - Temperatures above 323 K
- Easily measured signal
- Compatibility with sources of error
  - Thermal EMFs
  - Self-heating
  - Noise pickup
- High sensitivity
- High accuracy†
- High repeatability—long and short term
- Low power dissipation
- Interchangeability
- Ease of use
- Low cost
- Available accessories
- Available instrumentation

Sensor overview

	Temperature range	Standard curve	Below 1 K	Can be used in radiation	Performance in magnetic field
Diodes					
Silicon	1.4 K to 500 K	×			Fair above 60 K
Positive temperature coefficient RTDs					
Platinum	14 K to 873 K	×		×	Fair above 30 K
Negative temperature coefficient RTDs					
Cernox®	0.10 K to 420 K		×	×	Excellent above 1 K
Germanium	0.05 K to 100 K		×	×	Not recommended
Rox™*	0.01 K to 40 K	×	×	×	Good below 1 K
Other					
Thermocouples	1.2 K to 1543 K	×			Fair
Capacitance	1.4 K to 290 K				Excellent

*RX-102B not recommended for use in magnetic fields

Unfortunately, you can't have it all in one sensor. The most stable and accurate temperature sensors are very large, have slow response times and are extremely fragile. The sensors with the highest sensitivity and resolution have the smallest range. Choosing the appropriate sensor for a particular application necessitates prioritizing the requirements for that application.

The sensors described in this catalog are manufactured for the rigors of cryogenic environments, and are designed with specific applications in mind. For much of its history, Lake Shore has focused on cryogenic sensors used for the precise measurement of temperatures from near absolute zero to well above room temperature.

As you continue through the Sensor section of the catalog, you will notice that information is presented in both graphical format as well as in more detailed specifications, pertaining to topics such as the sensor's highlights, typical magnetic field-dependent data, resistance, and sensitivity values.

Characteristics such as packaging are incorporated into each sensor's design with the customer in mind. To learn more about what package would be best for your application, please refer to the Sensor Packages and Mounting Adapters section. For more detailed information, see Appendix C.

† The use of the terms accuracy and uncertainty throughout this catalog are used in the more general and conventional sense as opposed to following the strict metrological definitions. For more information, see Appendix B: Accuracy versus Uncertainty.

Sensor Types

Cernox®

Cernox® sensors can be used from 100 mK to 420 K with good sensitivity over the whole range. They have a low magnetoresistance, and are the best choice for applications with magnetic fields up to 30 T (for temperatures greater than 2 K). Cernox® are resistant to ionizing radiation, and are available in robust mounting packages and probes. Because of their versatility, they are used in a wide variety of cryogenic applications, such as particle accelerators, space satellites, MRI systems, cryogenic systems, and research science.

Silicon diodes

Silicon diodes are the best choice for general-purpose cryogenic use. The sensors are interchangeable (they follow a standard curve) and are available in robust mounting packages and probes. Silicon diodes are easy and inexpensive to instrument, and are used in a wide variety of cryogenic applications, such as cryo-coolers, laboratory cryogenics, cryo-gas production, and space satellites.

Germanium

Germanium RTDs have the highest accuracy, reproducibility, and sensitivity from 0.05 K to 100 K. They are resistant to ionizing radiation, but are not recommended for use in magnetic fields. Germanium RTDs are used mostly in research settings when the best accuracy and sensitivity are required. Germanium and Ruthenium oxide are the only two sensors that can be used below 100 mK.

Ultra low temperature Rox™

ULT ruthenium oxide RTDs can be used to below 10 mK. Along with germanium, they are the only sensors that can be used below 100 mK. Calibrations for these sensors are available down to 10 mK, and can include additional extrapolated points to 5 mK. Optical shielding of the RS package reduces unwanted sensor heating, making this sensor ideal for temperature monitoring or controlling below 50 mK.

Interchangeable Rox™

These interchangeable ruthenium oxide temperature sensors are thick-film resistors. Each interchangeable Rox™ model adheres to a single resistance versus temperature curve. They are often used for applications that require a standard curve in magnetic fields, such as MRI systems. Their upper temperature range is limited to 40 K, and Cernox® are better in magnetic fields above 2 K.

Platinum

Platinum RTDs are an industry standard. They follow an industry standard curve from 73 K to 873 K with good sensitivity over the whole range. Platinum RTDs can also be used down to 14 K. Because of their high reproducibility, they are used in many precision metrology applications. Platinum RTDs have limited packaging options, but they are inexpensive and require simple instrumentation. They are widely used in cryogenic applications at liquid nitrogen temperatures or greater.

Capacitance

Capacitance sensors are ideally suited for use as temperature control sensors in strong magnetic fields because they exhibit virtually no magnetic field dependence. Small variations in the capacitance/temperature curves occur upon thermal cycling. It is recommended that temperature in zero field be measured with another temperature sensor, and that the capacitance sensor be employed as a control element only.

Thermocouples

Thermocouples can be used over an extremely wide range and in harsh environmental conditions, and follow a standard response curve. Less accurate than other sensors, special techniques must be employed when using thermocouples to approach temperature accuracies of 1% of temperature. Thermocouples are used for their small size, extremely wide temperature range (exceeding high temperature limits of platinum RTDs), and simple temperature measurement methodology.

Lake Shore calibrations

Lake Shore offers complete calibration services from 50 mK to 800 K. Above 0.65 K, Lake Shore calibrations are based on the International Temperature Scale of 1990 (ITS-90). For temperature below 0.65 K, calibrations are based on the Provisional Low Temperature Scale of 2000 (PLT-2000).

Each scale is maintained on a set of germanium, rhodium-iron, and/or platinum resistance secondary thermometers standards. These secondary standards are calibrated at various national labs: NIST, PTB, and NPL. Working thermometers are calibrated against, and routinely intercompared with these secondary standards. For PLTS-2000 calibrations, working sensors are also compared to a superconducting fixed-point set and nuclear orientation thermometer.

Lake Shore offers sensor calibrations down to 10 mK. Our enhanced ultra-low temperature calibration facility includes dilution refrigerators, a nuclear orientation thermometer, and a superconducting fixed point set.

All calibration reports include:

- Certificate of calibration
- Calibration test data and data plot
- Polynomial fit equations and fit comparisons
- Interpolation tables
- Instrument breakpoint tables and data files

Lake Shore offers three classifications of calibration:		
Good	Uncalibrated	Silicon diodes follow standard curve
		Platinum resistors follow standard curve
		Interchangeable Rox™ follow standard curve
		Cernox®, germanium, and ULT Rox™ sensors can be purchased uncalibrated but must be calibrated by the customer
Better	SoftCal™	An abbreviated calibration (2-point: 77 K and 305 K; or 3-point: 77 K, 305 K, and 480 K) that is available for platinum sensors
Best	Calibration	All sensors can be calibrated in various pre-defined temperature ranges for each sensor type. The digits represent the lower range in kelvin, and the letter corresponds to high temperature limit, where: A = 6 K B = 40 K D = 100 K L = 325 K M = 420 K H = 500 K J = 800 K For example: The calibration range “1.4L” would result in a sensor characterized from 1.4 K to 325 K.

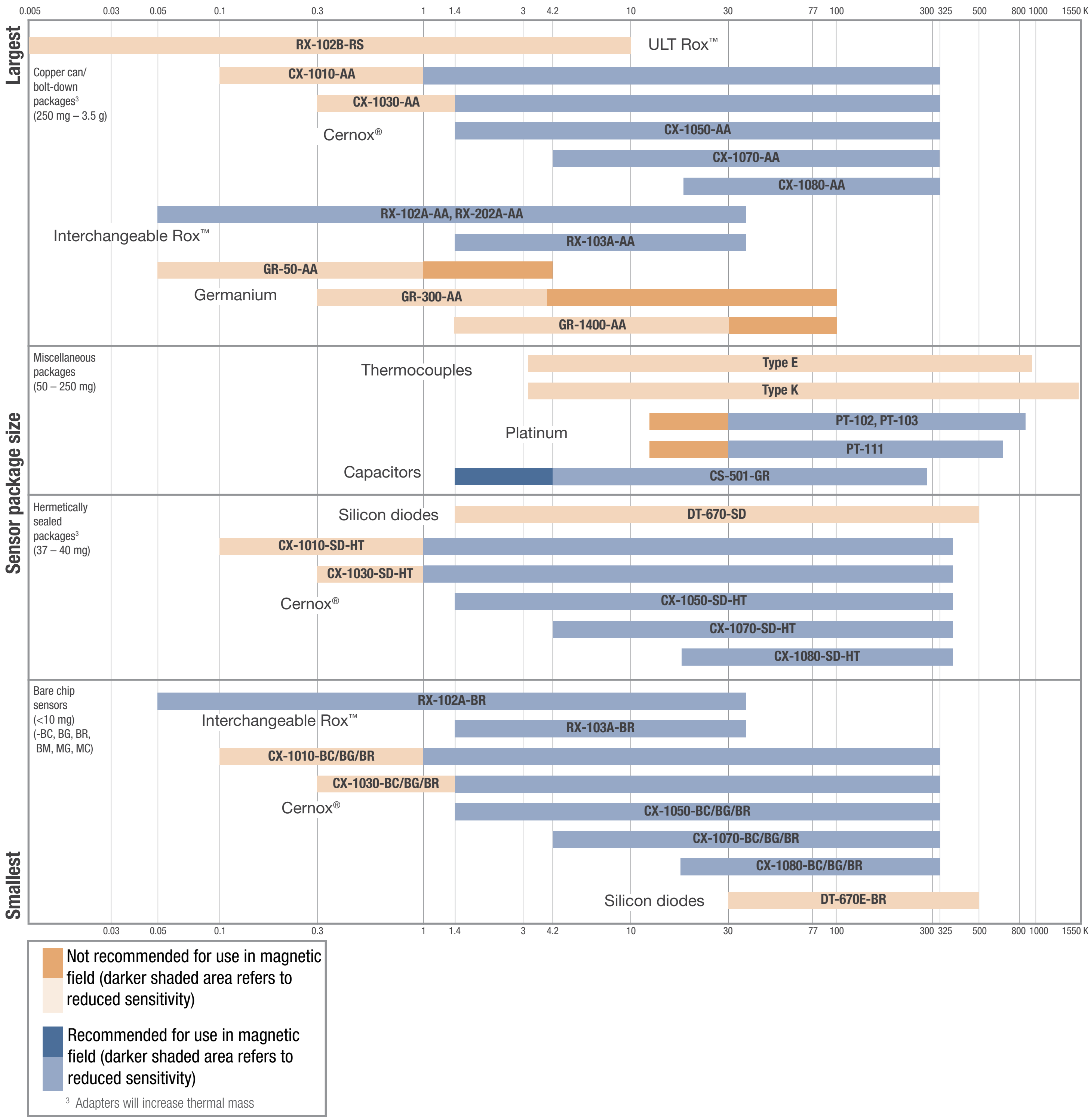
Sensor Characteristics

Sensor packages and characteristics

	Sensor type/ packages	Temperature range		Physical size[1]	Mass	Typical dimensionless sensitivity S_D					
		low	high			1.4 K	4.2 K	20 K	77.4 K	295 K	475 K
Silicon diodes	DT-670-SD	1.4 K	500 K	1.08 mm high × 1.905 mm wide × 3.175 mm long	37 mg	-0.01	-0.08	-0.26	-0.13	-1.19	-7.5
	DT-670E-BR	30 K	500 K	0.178 mm × 0.432 mm × 0.406 mm	72.7 µg	-0.01	-0.08	-0.26	-0.13	-1.19	—
Cernox®	CX-1010-BC	0.1 K	325 K	3.175 mm × 8.89 mm × 7.620 mm	3.0 mg	-0.68	-0.49	-0.44	-0.56	-0.65	—
	CX-1010-SD	0.1 K	325 K	1.08 mm high × 1.905 mm wide × 3.175 mm long	40 mg	—	—	—	—	—	—
	CX-1010-AA	0.1 K	325 K	3.048 mm dia. × 8.509 mm long	400 mg	—	—	—	—	—	—
	CX-1030-BC	0.30 K	325 K	3.175 mm × 8.89 mm × 7.620 mm	3.0 mg	-1.15	-0.71	-0.56	-0.63	-0.64	—
	CX-1030-SD-HT	0.30 K	420 K	1.08 mm high × 1.905 mm wide × 3.175 mm long	40 mg	—	—	—	—	—	—
	CX-1030-AA	0.30 K	325 K	3.048 mm dia. × 8.509 mm long	400 mg	—	—	—	—	—	—
	CX-1050-BC	1.4 K	325 K	3.175 mm × 8.89 mm × 7.620 mm	3.0 mg	-2.5	-1.3	-0.9	-0.91	-0.87	—
	CX-1050-SD-HT	1.4 K	420 K	1.08 mm high × 1.905 mm wide × 3.175 mm long	40 mg	—	—	—	—	—	—
	CX-1050-AA	1.4 K	325 K	3.048 mm dia. × 8.509 mm long	400 mg	—	—	—	—	—	—
	CX-1070-BC	4.2 K	325 K	3.175 mm × 8.89 mm × 7.620 mm	3.0 mg	—	-1.5	-1	-1	-0.9	—
	CX-1070-SD-HT	4.2 K	420 K	1.08 mm high × 1.905 mm wide × 3.175 mm long	40 mg	—	—	—	—	—	—
	CX-1070-AA	4.2 K	325 K	3.048 mm dia. × 8.509 mm long	400 mg	—	—	—	—	—	—
	CX-1080-BC	20 K	325 K	3.175 mm × 8.89 mm × 7.620 mm	3.0 mg	—	—	-1.5	-1.4	-1.2	—
	CX-1080-SD-HT	20 K	420 K	1.08 mm high × 1.905 mm wide × 3.175 mm long	40 mg	—	—	—	—	—	—
	CX-1080-AA	20 K	325 K	3.048 mm dia. × 8.509 mm long	400 mg	—	—	—	—	—	—
Germanium	GR-50-AA	0.05 K	5 K	3.048 mm dia. × 8.509 mm long	355 mg	-0.74	-0.32	—	—	—	—
	GR-300-AA	0.3 K	100 K	3.048 mm dia. × 8.509 mm long	355 mg	-1.8	-1.2	-0.93	-1.1	—	—
	GR-1400-AA	1.4 K	100 K	3.048 mm dia. × 8.509 mm long	355 mg	-3.7	-2.1	-2.4	-1.1	—	—
ULT Rox™	RX-102B-RS	0.005 K	40 K	17.30 mm high × 7.21 mm wide × 7.21 mm long	3.5 g	-0.16	-0.11	-0.12	—	—	—
Interchangeable Rox™	RX-102A-BR	0.05 K	40 K	1.45 mm × 1.27 mm × 0.65 mm thick	2.8 mg	-0.47	-0.25	-0.07	—	—	—
	RX-102A-AA	0.05 K	40 K	3.048 mm dia. × 8.509 mm long	350 mg	-0.47	-0.25	-0.07	—	—	—
	RX-202A-AA	0.05 K	40 K	3.048 mm dia. × 8.509 mm long	350 mg	-0.34	-0.17	-0.10	—	—	—
	RX-103A-BR	1.4 K	40 K	1.40 mm × 1.23 mm × 0.41 mm thick	3.7 mg	-0.62	-0.36	-0.17	—	—	—
	RX-103A-AA	1.4 K	40 K	3.048 mm dia. × 8.509 mm long	350 mg	-0.62	-0.36	-0.17	—	—	—
Platinum	PT-102	14 K	873 K	2.007 mm dia. × 20.995 mm long	250 mg	—	—	+0.74	+1.6	+1.1	+1.0
	PT-103	14 K	873 K	1.6 mm dia. × 12.192 mm long	120 mg	—	—	+0.74	+1.6	+1.1	+1.0
	PT-111	14 K	673 K	1.8 mm dia. × 5 mm long	52 mg	—	—	+0.74	+1.6	+1.1	+1.0
Capacitance	CS-501-GR	1.4 K	290 K	3.048 mm dia. × 8. 484 mm long	260 mg	+0.01	+0.02	+0.11	+0.46	-4.4	—
Thermocouples	Type K	3.2 K	1543 K	30 AWG (0.254 mm) and 36 AWG (0.127 mm)	NA						
	Type E	3.2 K	953 K	30 AWG (0.254 mm) and 36 AWG (0.127 mm)							

[1] Adapters will increase thermal response times—see individual sensor specifications for thermal response times

Sensor package size versus temperature sensor characteristics



Short and long term sensor characteristics

	Interchangeability	Typical reproducibility at 4.2 K	Typical long-term stability	
			Use to 305 K[4]	Use to 500 K[5]
Silicon diode	Yes—see page 18	±10 mK	4.2 K: ±10 mK/yr 77 K: ±40 mK/yr 305 K: ±25 mK/yr	4.2 K: ±40 mK/yr 77 K: ±100 mK/yr 305 K: ±50 mK/yr 500 K: ±150 mK/yr
Cernox®	No	±3 mK	1 K to 100 K: ±25 mK/yr 100 K to 300 K: 0.05% of T	
Germanium	No	±0.5 mK	4.2 K: ±1 mK/yr 77 K: ±10 mK/yr	
ULT Rox™	No	±15 mK	4.2 K: ±30 mK/yr	
Interchangeable Rox™	Yes	±15 mK	4.2 K: ±15 to 50 mK/yr (model dependent)	
Platinum	Yes—see page 18	±5 mK[6]	77 K to 273 K: ±10 mK/yr	
Capacitance	No	±0.01 K after cooling and stabilizing	±1.0 K/yr	
Thermocouples				
Type K	Yes—see ASTM standard	NA	NA	
Type E	Yes—see ASTM standard	NA	NA	

[4] Long-term stability data is obtained by subjecting sensor to 200 thermal shocks from 305 K to 77 K
[5] Based on 670 h of baking at 500 K
[6] Platinum reproducibility tested at 77 K

Sensor characteristics in various environments

	Use in vacuum			Use in radiation[7]	Use in magnetic fields[7]
	High 10^{-1} to 10^{-4} Pa	Very high 10^{-4} to 10^{-7} Pa	Ultra high 10^{-7} to 10^{-10} Pa		
Silicon diode	DT-621	—	DT-670-SD	Not recommended	Not recommended for T<60 K, or for B>5 tesla above 60 K SD package has magnetic leads
Cernox®[8]	AA can	—	Bare chip SD	Recommended	Excellent for use in magnetic fields 1 K and up SD package with non-magnetic leads
Germanium[8]	AA can	—	Bare chip	Recommended	Not recommended for use except at low B due to large orientation-dependent magnetic field effect
ULT Rox™	RS	RS	—	Recommended	Not recommended for use in magnetic fields
Interchangeable Rox™	AA can	—	Bare chip	Recommended	Excellent for use in magnetic fields
Platinum	PT-103	PT-111	—	Recommended	Moderately orientation dependent—suggested use only T ≥ 30 K
Capacitance	CS-501	—	—	Not available	Recommended for control purposes
Thermocouples	Insulated wire	—	—	Recommended	Useful when T ≥ 10 K

[7] See additional information in Appendix A: Overview of Thermometry

Typical magnetic field-dependent temperature errors, ΔT/T (%), at B (magnetic induction)

		Magnetic flux density B				
	T(K)	2.5 T	8 T	14 T	19 T	Notes
Cernox® 1050	2	1.3	3.1	3.9	5	Best sensor for use in magnetic field (T > 1 K)
(CX series)	4.2	0.1	-0.15	-0.85	-0.8	
	10	0.04	-0.4	-1.1	-1.5	
	20	0.04	0.02	-0.16	-0.2	
	30	0.01	0.04	0.06	0.11	
	77	0.002	0.022	0.062	0.11	
	300	0.003	0.004	0.004	0.006	
Rox™ 102A	2	-1.4	-7.9	-13	-17	Recommended for use over the 0.05 K to 40 K temperature
	3	-1.5	-7	-14	-18	range. Consistent behavior between devices in magnetic
	4	-0.56	-6.7	-14	-18	fields.
	8	-1.3	-6.1	-13	-21	
	16	-0.40	-3.4	-9.6	-16	
	23	-0.31	-2.2	-6.2	-11	
Rox™ 102B	2	3.29	13.82	22.53	27.95	
	3	3.96	14.68	23.12	29.12	
	4	3.53	13.92	22.57	28.20	
	8	1.53	7.53	13.50	17.86	
	16	0.27	2.14	4.66	6.58	
	23	0.06	0.79	2.01	3.11	
Rox™ 103A	2	0.58	1.5	2.2	2.6	Excellent for use in magnetic fields from 1.4 K to 40 K.
	3	0.44	1.1	1.7	2.0	Predictable behavior.
	4	0.27	0.95	1.4	1.7	
	8	0.11	0.49	0.71	0.80	
	16	0.018	0.076	0.089	0.040	
	23	0.0051	0.0058	-0.0060	-.0.095	
Rox™ 202A	2	-0.13	-2.2	-3.9	-5.2	Recommended for use over the 0.05 K to 40 K temperature
	3	0.18	-0.68	-2.7	-3.7	range. Consistent behavior between devices in magnetic
	4	0.77	0.046	-1.8	-3.2	fields.
	8	-0.023	0.16	-0.65	-3.0	
	16	0.03	0.16	-0.48	-1.5	
	23	-0.05	-0.08	-0.39	-0.92	
Platinum resistors	20	20	100	250	—	Recommended for use when T ≥ 40 K.
(PT series)	40	0.5	3	6	8.8	
	87	0 .04	0.4	1	1.7	
	300	<0.01	0.02	0.07	0.13	
Capacitance CS-501-GR series		ΔT/T(%) < 0.015 at 4.2 K and 18.7 tesla				Recommended for control purposes.
		ΔT/T(%) <0.05 at 77 K and 305 K and 18.7 tesla				Monotonic in C vs. T to nearly room temperature.
Germanium resistors	2.0	-8	-60	—	—	Not recommended except at low B owing to large,
(GR series)	4.2	-5 to -20	-30 to -55	-60 to -75	—	orientation-dependent temperature effect.
	10	-4 to -15	-25 to -60	-60 to -75	—	
	20	-3 to -20	-15 to -35	-50 to -80	—	
Type E thermocouples	10	1	3	7	—	Useful when T ≥ 10 K.
(chromel-constantan)	20	<1	2	4	—	Refer to notes for Chromel-AuFe (0.07%).
	455	<1	<1	2	—	

	T(K)	1 T	2 T	3 T	4 T	5 T	Notes
Silicon diodes	4.2	-200	-300	-350	-400	-500	Strongly orientation dependent.
Junction parallel to field	20	-10	-20	-25	-30	-40	
(DT series)	40	-4	-6	-8	-10	-12	
	60	-0.5	-1	-2	-3	-3.5	
	80	<0.1	-0.5	-0.8	-1.1	-1.5	
	300	<0.1	<-0.1	<-0.1	<-0.1	<-0.1	
Silicon diodes	4.2	-8	-9	-11	-15	-20	Strongly orientation dependent.
Junction perpendicular to field	20	-4	-5	-5	-5	-10	
(DT series)	40	-1.5	-3	-4	-5	-5.5	
	60	-0.5	-1	-2	-3	-3.5	
	80	-0.1	-0.3	-0.5	-0.6	-0.7	
	300	<0.1	0.2	0.5	0.6	0.6	

Typical accuracy* (interchangeability): uncalibrated sensors

	0.05 K	0.5 K	1.4 K	2 K	4.2 K	10 K	20 K	25 K	40 K	70 K	100 K	305 K	400 K	500 K	670 K
Silicon diode															
DT-670-SD, Band A	—	—	—	±0.25 K	±0.25 K	±0.25 K	±0.25 K	±0.25 K	±0.25 K	±0.25 K	±0.25 K	±0.5 K	±0.5 K	±0.5 K	—
DT-670-SD, Band B	—	—	—	±0.5 K	±0.5 K	±0.5 K	±0.5 K	±0.5 K	±0.5 K	±0.5 K	±0.5 K	±0.5 K	±0.33% of temp	±0.33% of temp	—
DT-670-SD, Band C	—	—	—	±1.0 K	±1.0 K	±1.0 K	±1.0 K	±1.0 K	±1.0 K	±1.0 K	±1.0 K	±1.0 K	±0.5% of temp	±0.5% of temp	—
DT-670-SD, Band D	—	—	—	—	—	—	—	±0.25 K	±0.25 K	±0.25 K	±0.25 K	±0.50 K	±0.2% of temp	±0.2% of temp	—
DT-670-SD, Band E	—	—	—	—	—	—	—	±0.25 K	±0.25 K	±0.25 K	±0.25 K	±0.25% of temp	±0.25% of temp	±0.25% of temp	—
Platinum															
PT-102	—	—	—	—	—	—	—	—	—	±1.3 K	±1.2 K	±0.5 K	±0.9 K	±1.4 K	±2.3 K
PT-103	—	—	—	—	—	—	—	—	—	±1.3 K	±1.2 K	±0.5 K	±0.9 K	±1.4 K	±2.3 K
PT-111	—	—	—	—	—	—	—	—	—	±1.3 K	±1.2 K	±0.5 K	±0.9 K	±1.4 K	±2.3 K
Rox™															
RX-102A-AA	±10 mK	±25 mK	±50 mK	±75 mK	±125 mK	±300 mK	±1.25 K	±1.5 K	±4.0 K	—	—	—	—	—	—
RX-102A-AA-M	±5 mK	±20 mK	±25 mK	±40 mK	±75 mK	±200 mK	±500 mK	±750 mK	±1.5 K	—	—	—	—	—	—
RX-202A-AA	±15 mK	±30 mK	±100 mK	±125 mK	±250 mK	±1 K	±2.5 K	±3 K	±5.0 K	—	—	—	—	—	—
RX-202A-AA-M	±10 mK	±25 mK	±50 mK	±75 mK	±150 mK	±500 mK	±1.0 K	±1.5 K	±2.0 K	—	—	—	—	—	—
RX-103A-AA	—	—	±150 mK	±180 mK	±400 mK	±1 K	±2.0 K	±2.5 K	±4.0 K	—	—	—	—	—	—
RX-103A-AA-M	—	—	±50 mK	±75 mK	±100 mK	±300 mK	±700 mK	±1 K	±1.5 K	—	—	—	—	—	—

Typical accuracy*: SoftCal™ (2-point and 3-point soft calibration sensors)

	2 K	4.2 K	10 K	30 K	70 K	305 K	400 K	475 K	500 K	670 K
Platinum										
PT-102-2S[9]	—	—	—	—	±0.25 K	±0.25 K	±0.9 K	±1.3 K	±1.4 K	±2.3 K
PT-103-2S[9]	—	—	—	—	±0.25 K	±0.25 K	±0.9 K	±1.3 K	±1.4 K	±2.3 K
PT-111-2S[9]	—	—	—	—	±0.25 K	±0.25 K	±0.9 K	±1.3 K	±1.4 K	±2.3 K
PT-102-3S[10]	—	—	—	—	±0.25 K	±0.25 K	±0.25 K	±0.25 K	±1.4 K	±2.3 K
PT-103-3S[10]	—	—	—	—	±0.25 K	±0.25 K	±0.25 K	±0.25 K	±1.4 K	±2.3 K
PT-111-3S[10]	—	—	—	—	±0.25 K	±0.25 K	±0.25 K	±0.25 K	±1.4 K	±2.3 K

[9]2S (2-point at 77 K and 305 K)
[10]3S (3-point at 77 K, 305 K, and 480 K)

**The use of the terms accuracy and uncertainty throughout this catalog are used in the more general and conventional sense as opposed to following the strict metrological definitions. For more information, see Appendix B: Accuracy versus Uncertainty, page 158.*

Typical accuracy*: calibrated sensors (in mK)[12]

	Temperature												
	0.05 K	0.1 K	0.3 K	0.5 K	1 K	1.4 K	4.2 K	10 K	20 K	77 K	300 K	400 K	500 K
Silicon diode													
DT-670	—	—	—	—	—	±21 mK	±12 mK	±12 mK	±14 mK	±34 mK	±35 mK	±50 mK	±54 mK
Cernox®													
CX-1010	—	±4 mK	±4 mK	±4 mK	±5 mK	±5 mK	±5 mK	±6 mK	±11 mK	±25 mK	±79 mK	±125 mK	—
CX-1030	—	—	±4 mK	±4 mK	±5 mK	±5 mK	±5 mK	±6 mK	±9 mK	±25 mK	±75 mK	±96 mK	—
CX-1050	—	—	—	—	—	±5 mK	±5 mK	±6 mK	±9 mK	±16 mK	±49 mK	±77 mK	—
CX-1070	—	—	—	—	—	—	±5 mK	±6 mK	±9 mK	±16 mK	±48 mK	±75 mK	—
CX-1080	—	—	—	—	—	—	—	—	±9 mK	±16 mK	±40 mK	±65 mK	—
Rox™													
RX-102A/103A/202A	±4 mK	±4 mK	±4 mK	±4 mK	±5 mK	±5 mK	±17 mK	±22 mK	±38 mK	—	—	—	—
Platinum													
PT-103/111	—	—	—	—	—	—	—	—	±10 mK	±12 mK	±26 mK	±48 mK	±58 mK
Germanium													
GR-50/300/1400	±5 mK	±5 mK	±5 mK	±5 mK	±6 mK	±6 mK	±6 mK	±4 mK	±8 mK	±25 mK	—	—	—

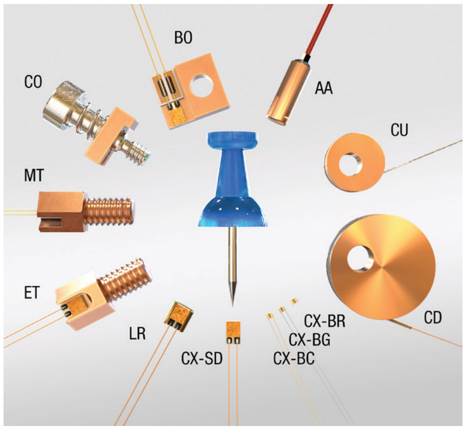
[12]All accuracies are: 2 σ figures; $[(\text{calibration uncertainty})^2 + (\text{reproducibility})^2]^{0.5}$; for additional information, please see Appendix D.

Sensor Packages and Mounting Adapters

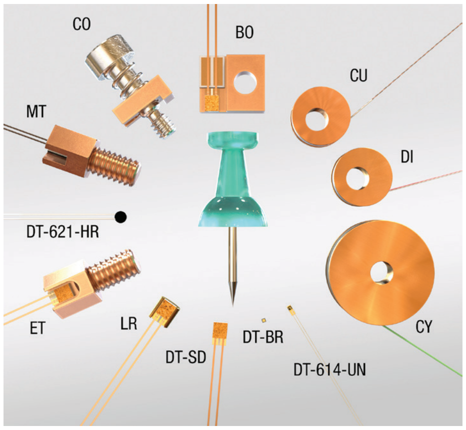
Temperature sensors are available in a variety of packages to facilitate mounting. Included are adapters that allow the sensor to be soldered in place, screwed on, bolted down, inserted into a hole, or inserted through a pressure seal in the form of a thermowell. Gold-plated copper bobbins are available for both diodes and resistors in order to heat sink leads. The chart below summarizes the standard Lake Shore sensor and packaging configurations. Appendix C: Sensor Packaging and Installation discusses techniques for the correct installation of temperature sensors. More specific installation notes are included for the bare chip sensors, the SD package, and the CU, DI, CY, and CD adapters. Special packaging is also available—consult Lake Shore for custom orders.

Packaging *(see individual sensor pages for additional details)*		Silicon diode	Cernox®	Germanium	Interchangeable Rox™	PT-103	PT-111	Installation instructions
Common								
Bare chip sensors								
BC	Bare chip with 2 copper leads (42 AWG)		■					Appendix C
BG	Bare chip with 2 or 4 gold leads		■					Appendix C
BR	Bare chip, no leads		■		■			Appendix C
Hermetically sealed package								
SD		■	■					Appendix C
Mounting adapters for SD								
CO	Clamp	■	■					Appendix C
ET	Screw-in	■	■					Order from Lake Shore
MT	Screw-in (metric)	■	■					Order from Lake Shore
CU	Copper bobbin (small, 4-lead)	■	■					Appendix C
DI	Copper bobbin (small, 2-lead)	■						Appendix C
CY	Copper bobbin (large, 2-lead)	■						Appendix C
LR	Half-rounded cylinder	■	■					Order from Lake Shore
BO	Beryllium oxide heat sink block	■	■					Order from Lake Shore
Platinum mounting adapter								
AM						■		Order from Lake Shore
Copper canister package								
AA			■	■	■			Appendix C
CD	Copper bobbin		■	■	■			Appendix C
Unique packages								
See individual sensor specifications					■	■	■	Order from Lake Shore

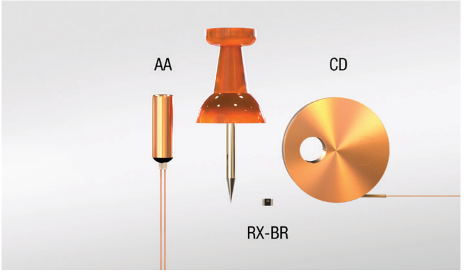
Packages



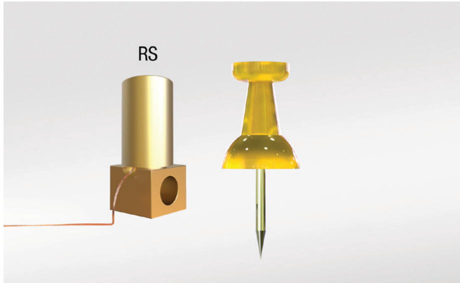
Cernox® packages



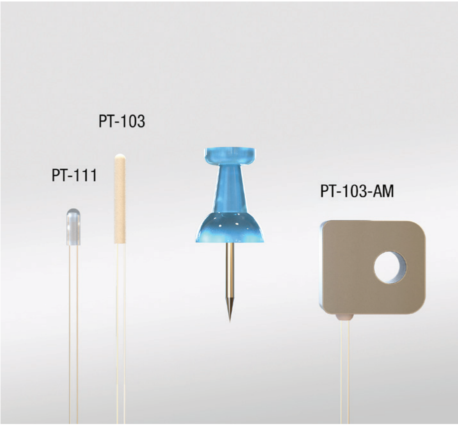
Silicon diode packages



Interchangeable Rox™ packages



Ultra low temperature Rox™ package



Platinum packages

Capacitance package

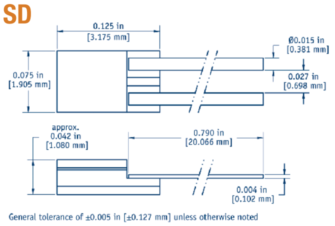
Unique packages

see individual sensor pages

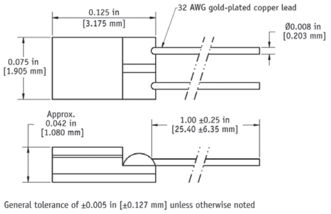
PT-103	CX-10XX-BC
PT-111	CX-10XX-BG
	CX-10XX-BR
	RX-102B-RS

The Lake Shore Hermetically Sealed SD Package

SD



SD (Cernox®)

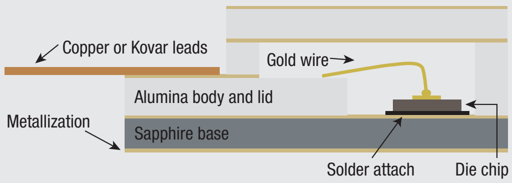


- Small package designed primarily for bonding or clamping to a flat surface
- Indium, silver epoxy, 2850 Stycast® epoxy, or a CO clamp may be used for mounting

Package material:	Sapphire base with alumina body and lid. Molybdenum/manganese metallization on base and lid top with nickel and gold plating. Gold tin solder as hermetic lid seal.
Leads:	2
Lead material:	Silicon diode: brazed Kovar Cernox®: gold-plated copper soldered with 63/37 SnPb
Mass:	0.03 g
Limitation:	The useful upper temperature limit of this configuration is 500 K

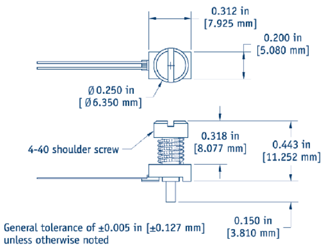
The Lake Shore SD package—the most rugged, versatile package in the industry

The SD package, with its sapphire base, direct sensor-to-sapphire mounting, hermetic sealing, and brazed Kovar leads provides the industry's most rugged, versatile sensors with the best thermal connection between the sample and sensor chip. In addition, this package is designed so heat coming down the leads bypasses the sensor chip. It can survive several thousand hours at 500 K and is compatible with most ultra high vacuum applications, and can be indium soldered to samples. The Lake Shore SD package is now available with Cernox® resistors as well as silicon diodes. For Cernox resistors the Kovar leads are replaced with nonmagnetic leads.



Mounting adapters for SD package—CO, CU, DI, CY, LR, BO, ET, MT

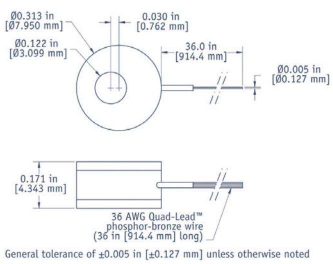
CO



- Spring-loaded clamp holds standard SD sensor in contact with the surface of the sample and allows the sensor to be easily changed or replaced
- Extra clamps are available for frequent relocation of the sensor
- 4-40 stainless steel screw has a formed shoulder, thus applying correct pressure to the clamp

Package material:	See SD package
Adapter material:	Gold-plated copper (nickel strike); spring is ASTM A313 302 Austenitic steel
Leads:	See SD package
Lead material:	See SD package
Mass:	1.8 g (including SD package and clamp)
Limitation:	The useful upper temperature limit of this configuration is 500 K

CU/CU-HT & DI



CU

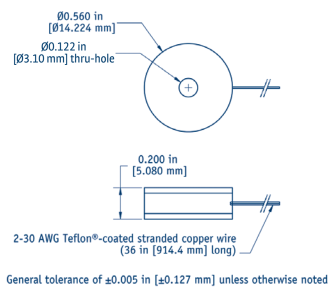
- SD packaged sensor indium-soldered into a flat copper bobbin with the leads thermally anchored to that same bobbin
- HT (high temperature) version is soldered using high temperature (90% Pb, 10% Sn) solder
- Can be mounted to any flat surface with a 4-40 screw

DI

- 2-lead version of the CU

Package material:	See SD package
Adapter material:	Gold-plated copper bobbin (SD indium-soldered to adapter and wrapped in Stycast® epoxy); high temperature CU uses high temperature (90% Pb, 10% Sn) solder
CU leads:	Four 0.91 m (36 in), 36 AWG, color-coded Quad-Lead™
DI leads:	0.91 m (36 in), 36 AWG, color-coded, 2-lead ribbon cable
Lead material:	Phosphor bronze alloy
Mass:	1.1 g (including SD package and bobbin, excluding leads)
Limitation:	The epoxy limits the upper useful temperature of this configuration to 378 K (high temperature CU-HT upper temperature limit is 420 K with Cernox® and 500 K with silicon diodes)

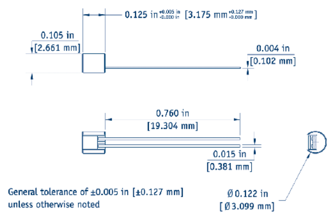
CY



- Similar to the DI package, except the bobbin is larger in diameter with a centered mounting hole
- Relatively large-sized, robust

Package material:	See SD package
Adapter material:	Gold-plated copper bobbin (SD indium-soldered to adapter and wrapped in Stycast® epoxy)
Leads:	Two 0.91 m (36 in), 30 AWG Teflon®-coated leads
Lead material:	Stranded copper
Mass:	4.3 g (Including SD package and bobbin, excluding leads)
Limitation:	The epoxy limits the upper useful temperature of this configuration to 400 K

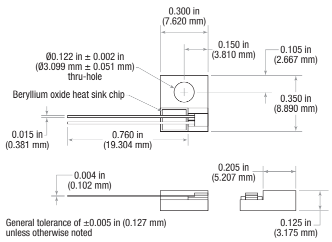
LR



- With an SD packaged sensor mounted on a slightly-more-than half-rounded cylinder, this package is designed to be inserted into a 3.2 mm (1/8 in) diameter hole

Package material:	See SD package
Adapter material:	Gold-plated flat cylindrical copper disk (SD indium-soldered to adapter)
Leads:	See SD package
Lead material:	See SD package
Mass:	0.2 g (Including SD package and disk)
Limitation:	Indium solder limits the upper useful temperature of this configuration to 420 K

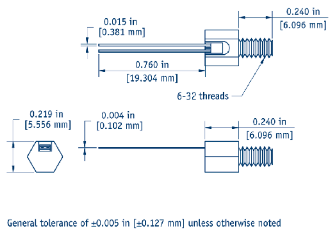
BO



- SD package is soldered to a mounting block and the leads are thermally anchored (without epoxy) to the block via a beryllium oxide insert
- Since leads can be a significant heat path to the sensing element and can lead to measurement errors when incorrectly anchored, this configuration helps maintain the leads at the same temperature as the sensor

Package material:	See SD package
Adapter material:	Gold-plated bolt-on copper block with leads thermally anchored to block (SD indium-soldered to adapter)
Leads:	See SD package
Lead material:	See SD package
Mass:	1.5 g (including SD package and mounting block)
Limitation:	Indium solder limits the upper useful temperature of this configuration to 420 K

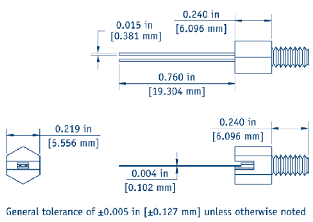
ET



- Convenient screw-in package formed by indium-soldering a basic SD configuration into a recess in one flat of a hexagonal screw head
- The head terminates in a standard SAE 6-32 threaded stud allowing the sensor to be threaded into a mounting hole in the sample

Package material:	See SD package
Adapter material:	ET: gold-plated copper SAE-threaded screw head #6-32 MT: gold-plated copper metric threaded screw head 3 mm × 0.5 metric
Leads:	See SD package
Lead material:	See SD package
Mass:	1.5 g (including SD package and screw head)
Limitation:	Indium solder limits the upper useful temperature of this configuration to 420 K

MT

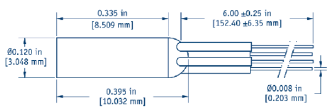


- The MT package is similar to the ET version except the SD package is mounted in a slot in the center of the hexagonal head and the stud is a 3 mm × 0.5 metric thread

Note: *A light coating of vacuum grease on the threads further enhances the thermal contact between the sensor package and the sample.*

Copper canister packages

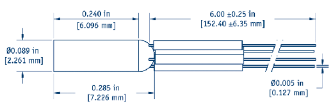
AA



General tolerance of ±0.005 in [±0.127 mm] unless otherwise noted

- Used with Cernox®, germanium, and Rox™ sensors

B



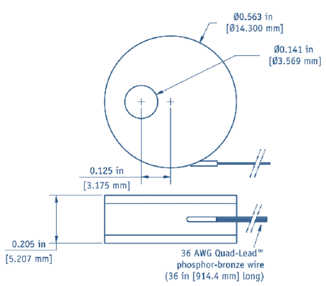
General tolerance of ±0.005 in [±0.127 mm] unless otherwise noted

- Used only with germanium sensors

Adapter material:	Gold-plated cylindrical copper canister, BeO header, Stycast® epoxy
Leads:	Four 32 AWG × 152 mm (6 in) long (Rox™: Two 32 AWG × 152 mm [6 in] long)
Lead material:	Phosphor bronze insulated with polyimide (Rox™: copper insulated with Formvar®)
Mass:	AA canister (empty): 0.091 g B canister (empty): 0.080 g Once sensors are installed, total mass increases to 0.197 g to 0.416 g. Refer to individual sensor specifications.
Limitation:	The epoxy limits the upper useful temperature of this configuration to 400 K

Mounting adapter for AA canister package

CD



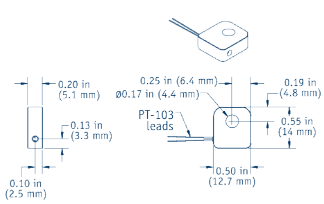
General tolerance of ±0.005 in [±0.127 mm] unless otherwise noted

- AA canister sensor soldered into a flat, copper bobbin with the sensor leads thermally anchored to the bobbin
- Can be mounted to any flat surface with a 6-40 screw (not supplied)
- Used with Cernox®, Germanium, and Rox™ sensors

Adapter material:	Copper bobbin, gold-plated (AA canister epoxied to bobbin with Stycast® epoxy)
Leads:	0.91 m (36 in), 36 AWG, color-coded, Quad-Lead™
Lead material:	Phosphor bronze Grade A alloy
Limitation:	The epoxy limits the upper useful temperature of this configuration to 378 K

Mounting adapter for platinum RTDs

PT-103-AM



General tolerance of ±0.010 in (±0.254 mm) unless otherwise noted

- PT-103 mounted into a flat aluminum block
- Can be mounted to any flat surface with a 6-32 or M3 screw (not included) and Inconel® Belleville washer (included)

Adapter material:	6061 Al block (PT mounted to adapter using Cotronics Durabond® 950 Al-based adhesive)
Leads:	Two 0.010-inch diameter; 15.240 ±1.270 mm (0.600 ±0.050 in) long
Lead material:	Platinum
Mass:	2.1 g
Limitation:	The aluminum alloy limits the upper useful temperature of these configurations to 800 K

Lead Extensions

(formerly SMODs)

Adding extra wire to your sensor leads can be cumbersome and time consuming. Lake Shore offers this service for you at the time of order, allowing numerous options to best suit your application.

There are various options available when selecting a lead extension:

Number of wires

4-wire: For accurate sensor measurements, 4-lead connections are by far the superior option when adding a lead extension to both diodes and resistive temperature sensors. See Appendix C and Appendix E for additional information.

2-wire: This option is useful if the number of electrical connections inside a system must be kept to a minimum. However, 2-lead connections add measureable resistance to sensor measurements as described in Appendix E. This additional resistance will cause a significant (but repeatable) shift on all sensors except diodes.

Wire type

Phosphor bronze: This all-purpose cryogenic wire has a great balance of features.

- Low thermal conductivity minimizes heat leak (lower is generally better)
- Moderate electrical resistance (lower is generally better)
- Non-ferromagnetic and very low magnetoresistance, making this wire the best choice for applications where magnetic fields are present
- Available in several convenient configurations in addition to single strand, such as Quad-Lead™ and Quad-Twist™

Manganin: This wire has several interesting characteristics that make it useful in certain situations.

- Coefficient of thermal expansion very close to that of pure copper
- Very low thermal conductivity minimizes heat leak (lower is generally better)
- Somewhat high electrical resistance (lower is generally better)
- Heavy Formvar® insulation limits upper temperature of wire to 378 K
- Non-ferromagnetic
- Available as single strand wire only

Wire gauge

Wire gauge (AWG)	Wire diameter (in)	Wire diameter (mm)
30	0.01	0.255
32	0.00795	0.202
36	0.0055	0.127
42	0.0025	0.0635

Various wire thicknesses are available, depending on the wire type selected. The wire gauge selection process usually involves a compromise between thermal conductivity and ease-of-use, with thinner wire being preferred to reduce thermal conductivity and thicker wire being easier to handle and work with. Lake Shore uses American wire gauge (AWG) for its wire. This conversion table is provided for your convenience.

32 AWG and 36 AWG are our preferred wire gauges to use with cryogenic sensors. By far they provide the best balance between reduced thermal conductivity and ease-of-use.

Manganin is the only wire type available in 30 AWG as the extremely low thermal conductivity of the wire helps compensate for the “large” cross-sectional area associated with 30 AWG.

Phosphor bronze is the only wire type available in 42 AWG. This wire thickness reduces thermal conductivity substantially to the levels possible with manganin, with the same low magentoresistance of phosphor bronze. Unfortunately, this wire is extremely delicate and can break easily. Lake Shore suggests this wire be ordered only by users with extensive experience with system wiring.

Wire length

Standard lengths of 2 m and 5 m are offered with all wire types and gauges. These lengths have been selected to suit a wide range of applications, most commonly wiring from a temperature sensor through the various stages of a cryostat, up to and terminating at an electrical feedthrough. Additional wire may be trimmed from both of these wire lengths if necessary. However, if a custom length is required, please contact Lake Shore to discuss custom wire lengths.

Component temperature limits

The lead extention components have different maximum temperatures. Use this chart to ensure the lead extensions you order are appropriate for your given application.

Lead extension component	Maximum temperature
Formvar	378 K (105 °C)
Bond Coat 999	433 K (160 °C)
Polyimide	500 K (227 °C)
63/37 Solder	450 K (177 °C)
90/10 Solder	548 K (275 °C)

Recommended standard lead extensions
Lake Shore recommends selecting from one of these two configurations — our most popular configurations due to the wide range of applications they cover.

-QL
Quad-Lead™ phosphor bronze, 32 AWG, 2 m
For situations where ease-of-use and ruggedness is important.

- 32 AWG wire is easier to prepare and solder to that thinner gauges
- Quad-lead™ wire is easy to heat-sink around copper bobbins due to its ribbon structure
- Polyimide insulation is strong and is resistant to solvents, and also has a high temperature rating that protects it from heating that might be applied to help soften the bonding agent used to join the wires to one another

-QT
Quad-Twist™ phosphor bronze, 36 AWG, 2 m
For noisy environments where signal integrity must be protected.

- Quad-twist™ wire helps reject electromagnetic interference that may be present inside the measurement space
- 32 AWG wire is easier to prepare and solder to that thinner gauges
- Quad-twist™ can be slightly more difficult to heat-sink, but the 36 AWG wire reduces thermal conductivity and therefore reduces heat-leak naturally
- Formvar® insulation has excellent mechanical properties such as abrasion resistance and flexibility, which is important when using 36 AWG wire. However, care should be taken as Formvar® can craze when exposed to solvents.

There are certain scenarios where these standard offerings are not adequate and alternative solutions should be selected. One such example is higher-temperature applications above 450 K where both Quad-Lead™ wire and Formvar® insulation become inappropriate. This application would require Quad-Twist, 32 AWG. In this scenario, please use the full part configurations to define the lead extension.

-XXYY-Z

XX = Wire type

YY = Wire gauge (AWG)

Z = Length in meters

Method of ordering
When ordering a lead extension on the website, add the sensor to the shopping cart first, and then come to this page to add a lead extension.

If placing a purchase order, please append the lead extension part number to the sensor that requires the extension. Examples:

CX-1050-SD-HD-4L-**QL**	Quad-Lead™, 32 AWG, 2 m
DT-670-CU-HT-1.4L-**QT**	Quad-Twist™, 36 AWG, 2 m attached to 0.91 m of Quad-Twist™, 36 AWG wire that comes standard with the diode CU-HT package.
PT-102-14L-QT32-**5**	Quad-Twist™, 32 AWG, 5 m
DT-670C-SD-DT32-**2**	Duo-Twist™, 32 AWG, 2 m

Lead extensions are not available on devices with gold or no leads

For more information please visit www.lakeshore.com.

Temperature Probes

Temperature probe features

- Stainless steel-encased probes that provide highly reliable sensor performance in a thermowell or direct cryogen contact
- Highly customizable to suit your particular application
- May be configured with many sensor types, including Cernox® for superior temperature performance from room temperature down to 4 K (-269.15 °C) and below
- Thin-walled probe tubing reduces thermal lag and heat leak from outside the measurement space
- Ideal for temperature measurements in fluid containers and tanks
- Full 3-year standard warranty

Lake Shore offers a variety of temperature sensors in packages that enable mounting in very tight areas. But for some applications (especially if the sensors have to be immersed in liquid) you need to do more to protect the sensor circuitry. For these applications, a cryogenic temperature probe is the optimum choice. Encased in one of these stainless steel thermowell fixtures, the sensor can perform as designed, unaffected by high pressure and sealed to keep electrical components and wiring protected from fluids and other elements.

Typical applications

Lake Shore temperature probes are ideal for thermometry applications where you need to measure inside:

- fluid containers, tanks, and pipes
- cryostats and cryogenic liquid flow meters
- other liquid storage systems.

Highly customizable

Lake Shore temperature probes are made-to-order with a wide range of configuration options available. These include:

- Multiple sensor types including our extremely popular Cernox® RTDs and DT-670 diodes
- Either 1/8 in or 1/4 in stem diameter in lengths up to 0.71 m (28 in) are standard
- Various mounting adapters suited for either positive or negative pressures, if required
- Numerous connectivity options including wire types and lengths as well as various terminating connectors for direct connection to Lake Shore temperature instruments or third party equipment

If you do not see an option available as part of our standard offerings, please contact Lake Shore to discuss further customization options.

Specifications

Note: *These probes are not designed to be intrinsically safe. It is the responsibility of the user to operate these probes safely in explosive environments.*

Probe construction

Stem

Material: 316 stainless steel (non-magnetic)[1]

	Wall thickness	Maximum length
1/4 in stem	0.028 in ±0.003 in	28 in*
1/8 in stem	0.010 in ±0.001 in	20 in

[2]*Not suitable for direct immersion in liquid oxygen or hydrogen environments.*

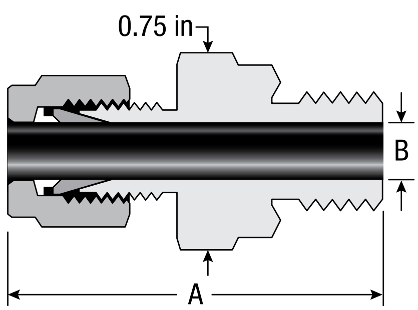
[2]*Longer lengths may be possible depending on the overall configuration. Please contact Lake Shore to discuss.*

Internal components

Internal atmosphere: Air
Internal atmosphere pressure: 98 kPa (14.2 psia)
Internal sensor wire: Quad-Twist™ 4-lead 36 AWG phosphor bronze wire with polyimide insulation

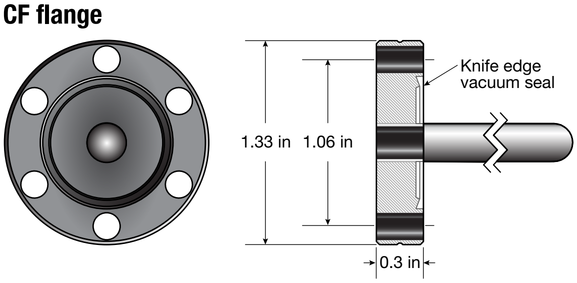
Probe mount

Swagelok® fittings



	1/4 in probe	1/8 in probe
Swagelok® part number:	SS-400-1-4BT	SS-200-1-2BT
Material	316 stainless steel	
Thread	0.25 in NPT male	0.125 in NPT male
A	1.59 in	1.5 in
B	0.25 in	0.125 in

CF flange



Material: 304L stainless steel
Flange size: 1⅓ in (DN16)
Vacuum rating: 1×10^{-13} torr (<1.3×10^{-13} mbar)*

**Requires the use of appropriate bolts, gasket and mating surface.*

Connectors

BNC connector

Standard male BNC connector. When ordering with 4-lead wire, two separate BNC connectors will be provided to maintain the 4-lead measurement.

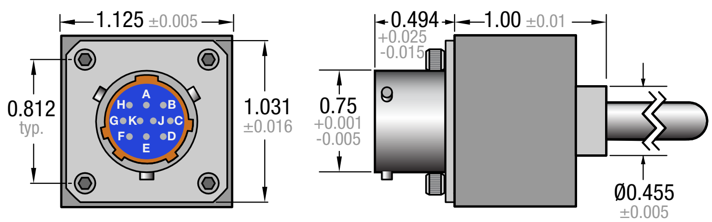
Configuration:

	BNC 1		BNC 2	
	Center pin	Shield	Center pin	Shield
2-lead cable	I/V+ (anode)	I/V- (cathode)	—	—
4-lead cable	I+	I-	V+	V-

10-pin Detoronics® connector

The Detoronics connector is o-ring sealed to the temperature probe.

Note: This connector is mounted directly to the probe, meaning that no external cable can be selected with this option. It also eliminates the CF flange probe mount option.



General specifications
Air leakage: 1×10^{-6} cm³/s at 15 psi
Insulation resistance: 5,000 MΩ at 500 VDC
Operating temperature: -55 °C to +125 °C (-67 °F to +257 °F)
Finish is tin-plated shell and pins.
Materials
Shell, bayonet and flange: Carbon steel
Pins: 52 nickel alloy
Insulator: Glass

25-pin D-sub connector

The 25-pin D-sub is required to connect directly to particular Lake Shore temperature monitors.

Supported instruments:
- Model 211
- Model 218

6-pin DIN connector

The 6-pin DIN is required to connect directly to particular Lake Shore temperature controllers and monitors.

Supported current instruments:
- Model 350
- Model 336
- Model 335
- Model 224

Supported discontinued instruments:
- Model 340
- Model 331/332
- Model 330 (diodes only)
- Model 321 (silicon diodes only)

Connector configurations

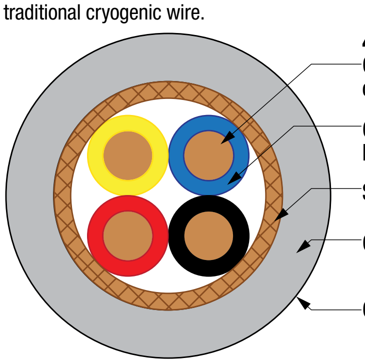
Connector type	I+	V+	I-	V-	Shield*
2-lead BNC (1 connector)	Center pin		Outer cup (shield)		Not connected
4-lead BNC (2 connectors)	Center pin of 'I' BNC	Center pin of 'V' BNC	Outer cup of 'I' BNC	Outer cup of 'V' BNC	Not connected
10-pin probe-mounted Detoronics connector®	Pin A	Pin C	Pin B	Pin D	NA
6-pin DIN	Pin 5	Pin 4	Pin 1	Pin 2	Pin 6
25-pin D-sub	Pin 3	Pin 4	Pin 15	Pin 16	Pin 2

**Shield connection is only used in conjunction with external cable choices that include a braided shield (Cryocable™ and instrument cable)*

Wire

Instrument cable

Robust 4-lead cable best for wiring to instrument where both the wire and instrument are at room temperature. The 30 AWG signal wires make these wires easier to work with than traditional cryogenic wire.



Rated temperature: -20 °C to 80 °C
Thermal conductivity (300 K): 400 W/(m·K)
Resistance (300 K): 0.32 Ω/m
Supported sensor types: Cernox® RTD, silicon diode, GaAlAs diode, platinum RTD
Maximum rated temperature: 378 K

Cryogenic wire

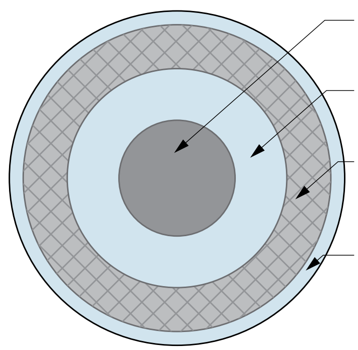
Phosphor-bronze wire combinations that limit heat transfer into the temperature probe and are themselves rated for use in cryogenic environments.

	Quad-Twist™ 36 AWG*	Quad-Twist™ 32 AWG	Quad-Lead™ 32 AWG	Duo-Twist™ 32 AWG
Configuration	4-lead			2-lead
Wire	Phosphor bronze			
Gauge	36 AWG	32 AWG		
Insulation	Formvar	Polyimide		
Structure	Two twisted pairs		Four wires formed into a ribbon using Bond Coat 999 bonding film	One twisted pair
Thermal conductivity (300 K)	48 W/(m·K)			
Resistance (300 K)	10.3 Ω/m	4.02 Ω/m		
Supported sensors	Cernox® RTD, silicon diode, GaAlAs diode, platinum RTD			Diodes only

**Also used for internal probe wiring. Ordering this cable will result in a continuous length of wire from the sensor through to the outside environment.*

SS (stainless steel) coaxial cable

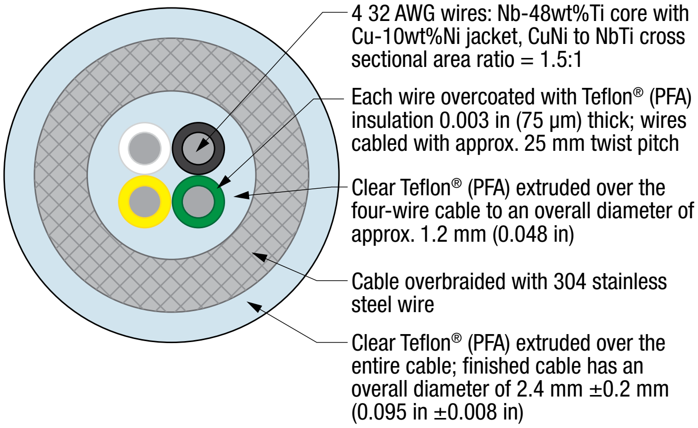
2-lead cabling solution that is extremely robust and limits heat transfer into the probe. Due to the 2-lead configuration, this cable is only compatible with diode sensors and will cause a predictable (potentially insignificant) offset in any temperature readings.



Electrical properties
Resistance—center conductor at 295 K (22 °C): 23.62 Ω/m (7.2 Ω/ft)
Resistance—shield at 295 K (22 °C): 3.61 Ω/m (1.1 Ω/ft)
Insulation temperature range: 10 mK to 473 K
Supported sensor types: Silicon diode, GaAlAs diode, platinum RTD

Cryocable™

A robust, 4-wire cable for use in cryogenic environments to room temperature for the ultimate in thermal isolation from external heat sources. This cable is designed around 32 AWG (203 µm) diameter superconductive wires consisting of a NbTi core (128 µm diameter) and a Cu-10% Ni jacket. The wire is LTS, requiring very low temperatures for it to become superconducting.



Minimum bend radius: 15 mm (0.6 in)
Superconducting critical temperature: 9.8 K
Superconducting critical magnetic field: 10 T
Supported sensor types: Cernox® RTD, silicon diode, GaAlAs diode, platinum RTD

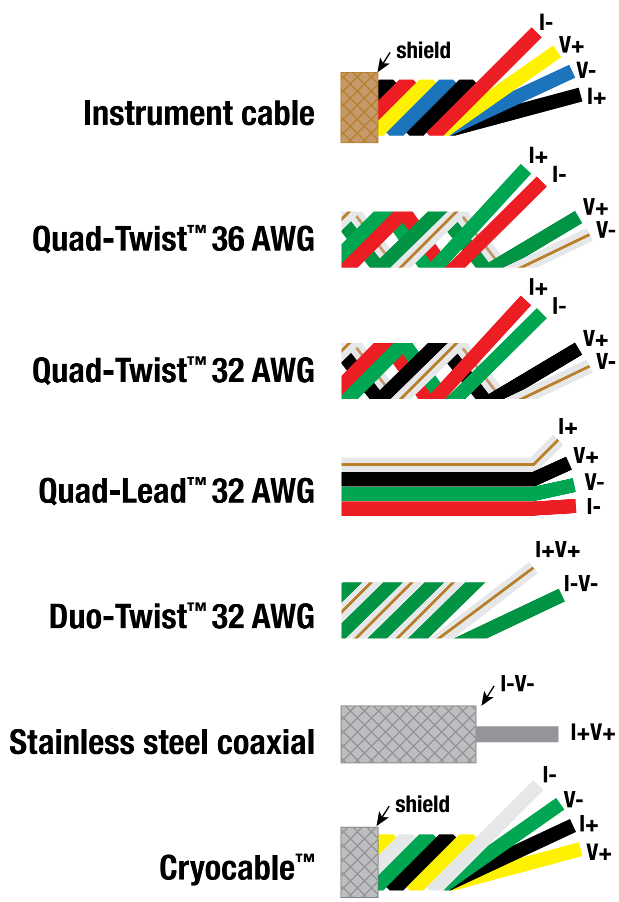
Magnetic field	Critical current (per wire)
3 T	35 A
5 T	25 A
7 T	15 A
9 T	6 A

	Temperature (K)		
	295	77	4.2
Wire resistance (Ω/m)	9.2	8.4	0*
Overbraid resistance (Ω/m)	0.90	0.64	0.62
Thermal conductivity—entire cable assembly (W/(m·K))	7.6	2.8	0.17

**Superconducting*

Wire configurations

Wire type	I+	V+	I-	V-	Shield
Instrument cable	Black	Yellow	Red	Blue	Copper braid
Quad-Twist™ 36 AWG	Green (from red/green pair)	Green (from clear/green pair)	Red	Clear	None
Quad-Twist™ 32 AWG	Red	Black	Green	Clear	None
Quad-Lead™ 32 AWG	Clear	Black	Red	Green	None
Duo-Twist™ 32 AWG	Clear		Green		None
Stainless steel coaxial	Center conductor		Shield		None
Cryocable™	Black	Yellow	White	Green	Stainless steel braid



Temperature sensors

See the individual Cernox, DT-670, and platinum sensor pages for specifications:

Sensor type	Installed sensor package
Cernox®	SD
DT-670	SD
Platinum	Standard PT-100 Series packages

All temperature sensor calibrations are performed before the device is installed into the probe. At this time, Lake Shore does not perform recalibrations on finished probes.

Temperature probe ordering information

The easiest way to request a quote for a temperature probe is to use the online configurator at www.lakeshore.com. Otherwise contact our Sales department at sales@lakeshore.com and we can assist you.

Specify TP-a-bcd-e-f-g, where:

a = probe length in inches—offered in whole inch increments from 1 to 28 inches

b = tube diameter[1]

2	1/8 in
4	1/4 in

[1] Probes over 20 inches long are only available in 1/4-inch diameter

c = probe mount

N	no probe mount adapter
S	Swagelok® fitting[2]
F	CF™ flange mount[3]

[2] For 1/8 in diameter probe, Swagelok® fitting uses a 1/8 in NPT male thread; for 1/4 in diameter probe, Swagelok® fitting uses a 1/4 in NPT male thread
[3] The CF™ flange is welded to the probe

d = external cable/wire type[4]

N	no external cable (usually used with Detoronics connector)
S	S1 coaxial cable (2-lead)
I	30 AWG instrument cable (4-lead)
T	DT-32 (twisted pair of 32 AWG phosphor bronze wire)
F	QT-32 (two twisted pairs of 32 AWG phosphor bronze wire)
Q	QT-36 (two twisted pairs of 36 AWG phosphor bronze wire)
L	QL-32 (four 32 AWG wires in a ribbon configuration)
C	CryoCable™ (4-lead cryogenic coaxial cable)

[4] Lake Shore strongly recommends that all RTD temperature sensors use a 4-lead cable/wire type

e = terminator

N	no connector (leads stripped and tinned)
B	BNC connector
D	10-pin Detoronics connector[5]
Y	25-pin D-shell connector for temperature monitors
R	connector wired for temperature instruments (6-pin round)

[5] Selecting a Detoronics connector limits the following selections: d = N and f = 0; the Detoronics connector is o-ring sealed to the probe

f = external cable length—offered in whole meter increments from 1 to 10 m (enter ‘0’ for no external cable)

g = temperature sensor type[6]—specify sensor model number with calibration range, if applicable

[6] Due to indium solder use, all SD sensors have an upper temperature usage limit of 400 K

Ordering example

TP- 06 - 2FS - B - 03 - S27

(6 in probe, 1/8 in diameter, flange, S1 coaxial cable, BNC connector, 3 m cable length, DT-670-SD calibrated 1.4 K to 325 K)

Calibration range suffix codes

Numeric figure is the low end of the calibration Letters represent the high end: B = 40 K, D = 100 K, L = 325 K, H = 500 K

Cernox® RTDs

Uncalibrated	**C01**	CX-1010-SD
	C02	CX-1030-SD
	C03	CX-1050-SD
	C04	CX-1070-SD
	C05	CX-1080-SD
Calibrated	**C07**	CX-1010-SD-0.1L
	C16	CX-1030-SD-0.3L
	C25	CX-1050-SD-1.4L
	C31	CX-1070-SD-4L
	C32	CX-1080-SD-20L
	C13	CX-1010-SD-1.4L

Platinum RTDs

Uncalibrated	**P01**	PT-102
	P02	PT-103
	P03	PT-111
Calibrated	**P04**	PT-102-2S
	P05	PT-102-3S
	P07	PT-102-14L
	P08	PT-102-14H
	P11	PT-103-2S
	P12	PT-103-3S
	P14	PT-103-14L
	P15	PT-103-14H
	P18	PT-111-2S
	P19	PT-111-3S
	P21	PT-111-14L
	P22	PT-111-14H

Silicon diodes

Uncalibrated	**S07**	DT-670A-SD
	S08	DT-670B-SD
	S09	DT-670C-SD
	S10	DT-670D-SD
	S0A	DT-670A1-SD
	S0B	DT-670B1-SD
Calibrated	**S27**	DT-670-SD-1.4L
	S28	DT-670-SD-1.4H
	S32	DT-670-SD-70L
	S33	DT-670-SD-70H

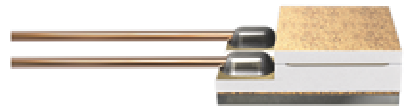
Cernox® RTDs

Cernox® features

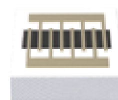
- Low magnetic field-induced errors
- Temperature range of 100 mK to 420 K (model dependent)
- High sensitivity at low temperatures and good sensitivity over a broad range
- Excellent resistance to ionizing radiation
- Bare die sensor with fast characteristic thermal response times: 1.5 ms at 4.2 K, 50 ms at 77 K
- Broad selection of models to meet your thermometry needs
- Excellent stability
- Variety of packaging options

Cernox® thin film resistance temperature sensors offer significant advantages over comparable bulk or thick film resistance sensors. The smaller package size of these thin film sensors makes them useful in a broader range of experimental mounting schemes, and they are also available in a chip form. They are easily mounted in packages designed for excellent heat transfer, yielding a characteristic thermal response time much faster than possible with bulk devices requiring strain-free mounting. Additionally, they have been proven very stable over repeated thermal cycling and under extended exposure to ionizing radiation.

CX-SD



CX-BR



Packaging options

AA, BC, BG, BO, BR, CD, CO, CU, ET, LR, MT, SD

CAUTION: These sensors are sensitive to electrostatic discharge (ESD). Use ESD precautionary procedures when handling, or making mechanical or electrical connections to these devices in order to avoid performance degradation or loss of functionality.

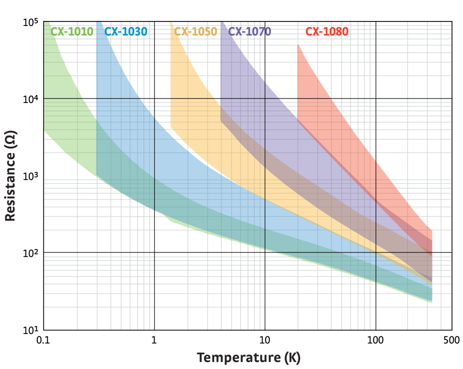
CX-1010—the ideal replacement for germanium RTDs

The CX-1010 is the first Cernox® designed to operate down to 100 mK, making it an ideal replacement for Germanium RTDs. Unlike Germanium, all Cernox models have the added advantage of being able to be used to room temperature. In addition, Cernox is offered in the incredibly robust Lake Shore SD package, giving researchers more flexibility in sensor mounting.

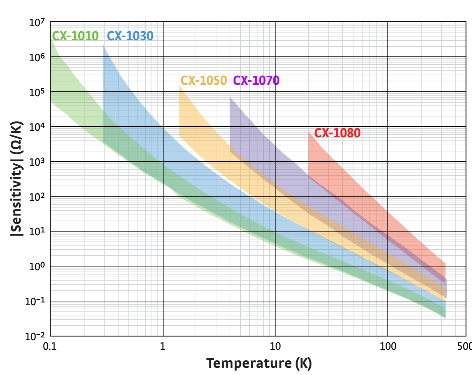
The Lake Shore SD package — the most rugged, versatile package in the industry

The SD package, with direct sensor-to-sapphire base mounting, hermetic seal, and brazed Kovar leads, provides the industry's most rugged, versatile sensors with the best sample to chip connection. Designed so heat coming down the leads bypasses the chip, it can survive several thousand hours at 500 K (depending on model) and is compatible with most ultra high vacuum applications. It can be indium soldered to samples without shift in sensor calibration. If desired, the SD package is also available without Kovar leads.

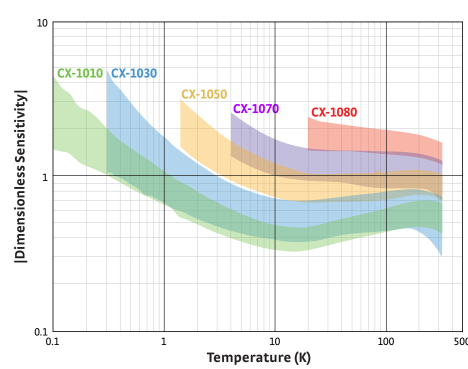
Typical Cernox® resistance



Typical Cernox® sensitivity



Typical Cernox® dimensionless sensitivity



Specifications

Standard curve Not applicable

Recommended excitation[1] 20 µV (0.1 K to 0.5 K); 63 µV (0.5 K to 1 K); 10 mV or less for T > 1.2 K

Dissipation at recommended excitation Typical 10^{-5} W at 300 K, 10^{-7} W at 4.2 K, 10^{-13} W at 0.3 K (model and temperature dependent)

Thermal response time BC, BR, BG: 1.5 ms at 4.2 K, 50 ms at 77 K, 135 ms at 273 K; SD: 15 ms at 4.2 K, 0.25 s at 77 K, 0.8 s at 273 K; AA: 0.4 s at 4.2 K, 2 s at 77 K, 1.0 s at 273 K

Use in radiation Recommended for use in radiation environments—see Appendix B

Use in magnetic field Recommended for use in magnetic fields at low temperatures. The magnetoresistance is typically negligibly small above 30 K and not significantly affected by orientation relative to the magnetic field—see Appendix B

Reproducibility[2] ±3 mK at 4.2 K

Soldering standard J-STD-001 Class 2

1 Recommended excitation for T < 1 K based on Lake Shore calibration procedures using an AC resistance bridge—for more information refer to Appendix D and Appendix E

2 Short-term reproducibility data is obtained by subjecting sensor to repeated thermal shocks from 305 K to 4.2 K

Range of use

	Minimum limit	Maximum limit
Cernox®	0.10 K[3]	420 K

3 Model dependent

Calibrated accuracy[4]

	Typical sensor accuracy[5]	Long-term stability[6]
1.4 K	±5 mK	±3 mK
4.2 K	±5 mK	±3 mK
10 K	±6 mK	±6 mK
20 K	±9 mK	±12 mK
30 K	±10 mK	±18 mK
50 K	±13 mK	±30 mK
77 K	±16 mK	±46 mK
300 K	±60 mK	±180 mK
400 K	±65 mK	—

4 Bare chip sensors can only be calibrated after attaching gold wire leads—the user must remove the ball bonded leads if they are not desired (the bond pads are large enough for additional bonds)

5 $[(\text{Calibration uncertainty})^2 + (\text{reproducibility})^2]^{0.5}$ for more information see Appendices B, D, and E

6 Long-term stability data is obtained by subjecting sensor to 200 thermal shocks from 305 K to 77 K

Typical magnetic field-dependent temperature errors[7] ΔT/T (%) at B (magnetic induction)

	Cernox® 1050			
	2.5 T	8 T	14 T	19 T
2 K	1.3	3.1	3.9	5
4.2 K	0.1	-0.15	-0.85	-0.8
10 K	0.04	-0.4	-1.1	-1.5
20 K	0.04	0.02	-0.16	-0.2
30 K	0.01	0.04	0.06	0.11
77 K	0.002	0.022	0.062	0.11
300 K	0.003	0.004	0.004	0.006

7 Excellent for use in magnetic fields, depending on temperature range (>2 K)

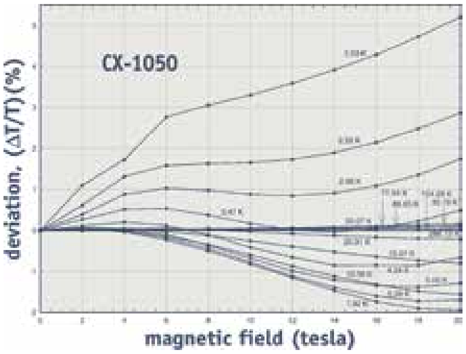
Temperature response data table (typical)

	CX-1010			CX-1030			CX-1050			CX-1070			CX-1080		
	R[8](Ω)	dR/dT (Ω/K)	(T/R)·(dR/dT)	R[8] (Ω)	dR/dT (Ω/K)	(T/R)·(dR/dT)	R[8] (Ω)	dR/dT (Ω/K)	(T/R)·(dR/dT)	R[8] (Ω)	dR/dT (Ω/K)	(T/R)·(dR/dT)	R[8] (Ω)	dR/dT (Ω/K)	(T/R)·(dR/dT)
4.2	277.32	-32.209	-0.49	574.20	-97.344	-0.71	3507.2	-1120.8	-1.34	5979.4	-2225.3	-1.56	—	—	—
10	187.11	-8.063	-0.43	331.67	-19.042	-0.57	1313.5	-128.58	-0.98	1927.2	-214.11	-1.11	—	—	—
20	138.79	-3.057	-0.44	225.19	-6.258	-0.56	692.81	-30.871	-0.89	938.93	-46.553	-0.99	6157.5	-480.08	-1.56
30	115.38	-1.819	-0.47	179.12	-3.453	-0.58	482.88	-14.373	-0.89	629.90	-20.613	-0.98	3319.7	-165.61	-1.50
77.35	70.837	-0.510	-0.56	101.16	-0.820	-0.63	205.67	-2.412	-0.91	248.66	-3.150	-0.98	836.52	-15.398	-1.42
300	30.392	-0.065	-0.65	41.420	-0.088	-0.64	59.467	-0.173	-0.87	66.441	-0.201	-0.91	129.39	-0.545	-1.26
400 (HT)	—	—	—	34.779	-0.050	-0.57	46.782	-0.093	-0.79	51.815	-0.106	-0.81	91.463	-0.261	-1.14
420 (HT)	—	—	—	33.839	-0.045	-0.55	45.030	-0.089	-0.77	49.819	-0.094	-0.80	86.550	-0.231	-1.12

7 See Appendix G for expanded response table

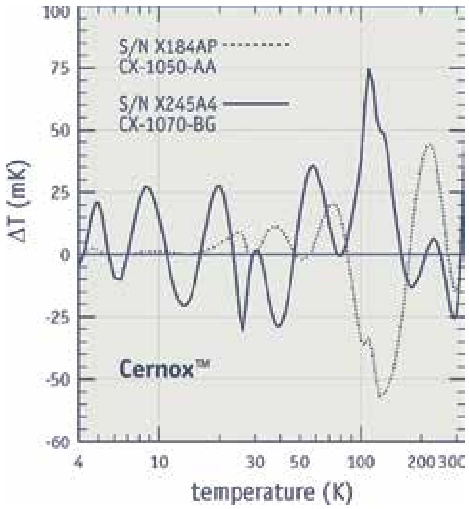
8 Cernox sensors do not follow a standard response curve — the listed resistance ranges are typical, but can vary widely; consult Lake Shore to choose a specific range

Magnetic field dependence data for sample CX RTDs

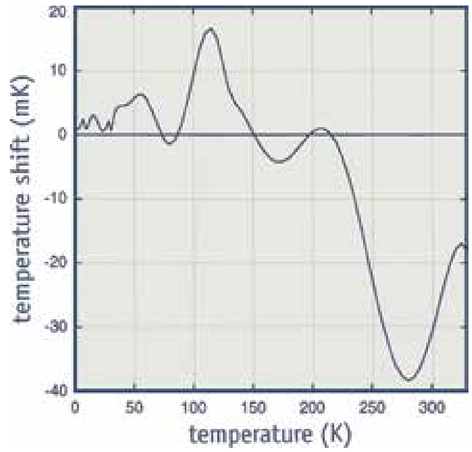


Typical temperature reading errors for operation of CX-1050 sensors in magnetic fields at temperatures from 2.03 K to 286 K. "Low temperature thermometry in high magnetic fields VII. Cernox® sensors to 32 T," B. L. Brandt, D. W. Liu and L. G. Rubin; Rev. Sci. Instrum., Vol. 70, No. 1, 1999, pp 104-110.

Neutrons and gamma rays

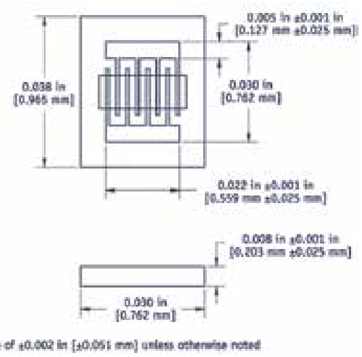


Typical calibration shifts

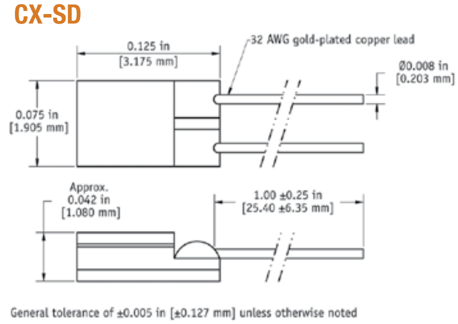


Typical calibration shift after 200 thermal shocks from 305 K to 77 K for a Model CX-1030 temperature sensor (ΔT = 1 mK at 4.2 K and 10 mK at 100 K).

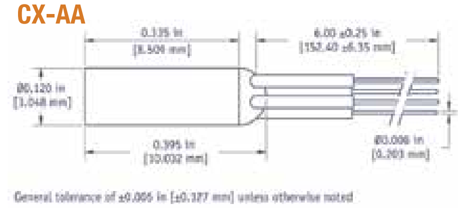
CX-BR



CX-SD



CX-AA

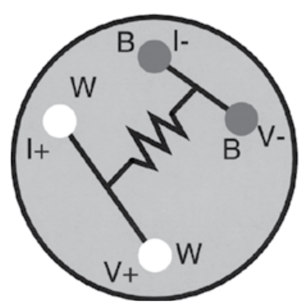


Physical specifications

	Mass	Lead type	Internal atmosphere	Sensor materials used
Bare chip (BC), (BG), (BR)	≤ 3.0 mg	BR: none BG: two 2 mil (44 AWG) bare gold 25 mm long wires BC: two 2.5 mil (42 AWG) bare copper 25 mm long wires	NA	Ceramic oxynitride, gold pads and sapphire substrate with Au Pt Mo back (chip in all models)
Hermetic ceramic package (SD)	≈ 40 mg	2 gold-plated copper	Vacuum	Chip mounted on sapphire base with alumina body and lid, Mo/Mn with nickel and gold plating on base and lid, gold-tin solder as hermetic lid seal, 63/37 SnPb solder used to attach leads
Copper canister package (AA)	≈ 390 mg	4 phosphor bronze with HML heavy build insulation attached with epoxy strain relief at sensor	Helium 4 (^{4}He) is standard	Chip mounted in a gold plated cylindrical copper can

AA package

Wires with the same color code are connected to the same side of the sensor (looking at epoxy seal with leads toward user)



Ordering information

Uncalibrated sensor—Specify the model number in the left column only, for example CX-1050-CD.
Calibrated sensor—Add the calibration range suffix code to the end of the model number, for example CX-1050-CD-1.4L.

Cernox® RTD	Calibration range suffix codes Numeric figure is the low end of the calibration Letters represent the high end: L=325 K, M=420 K										
	Uncal	0.1L	0.1M	0.3L	0.3M	1.4L	1.4M	4L	4M	20L	20M
CX-1010-AA, -BC, -BO, -CD, -ET, -LR, -MT	■	■				■					
CX-1010-BG-HT, -BR-HT	■										
CX-1010-CO-HT, -CU-HT, SD-HT	■	■	■			■	■				
CX-1030-AA, -BC, -BO, -CD, -ET, -LR, -MT	■			■		■					
CX-1030-BG-HT, -BR-HT	■										
CX-1030-CO-HT, -CU-HT, -SD-HT	■			■	■	■	■				
CX-1050-AA, -BC, -BO, -CD, -ET, -LR, -MT	■					■					
CX-1050-BG-HT, -BR-HT	■										
CX-1050-CO-HT, -CU-HT, -SD-HT	■					■	■				
CX-1070-AA, -BC, -BO, -CD, -ET, -LR, -MT	■							■			
CX-1070-BG-HT, -BR-HT	■										
CX-1070-CO-HT, -CU-HT, -SD-HT	■							■	■		
CX-1080-AA, -BC, -BO, -CD, -ET, -LR, -MT	■									■	
CX-1080-BG-HT, -BR-HT	■										
CX-1080-CO-HT, -CU-HT, -SD-HT	■									■	■

ADD -P Add spot-welded platinum leads to the SD package for Cernox® sensors only

Accessories available for sensors

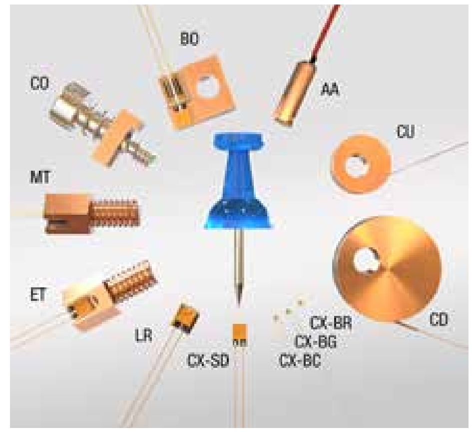
SN-CO-C1	SD package sensor clamp, qty 1
SN-CO-C10	SD package sensor clamp, qty 10
8000-CD	Calibration report on CD-ROM
8000-USB	Calibration report on USB
COC-SEN	Certificate of conformance

Accessories suggested for installation—see Accessories section for full descriptions

Stycast® epoxy	VGE-7031 varnish
Apiezon® grease	Phosphor bronze wire
90% Pb, 10% Sn solder	Manganin wire
Indium solder	CryoCable™

Packaging options

For more information on sensor packages and mounting adapters, see page 20.



CO adapter — spring loaded clamp for easy sensor interchangeability

See the appendices for a detailed description of:
Installation
Uncalibrated sensors
SoftCal™
Calibrated sensors
CalCurve™
Sensor packages

To add length to sensor leads, see page 25.

DT-670 Silicon Diodes

DT-670-SD features

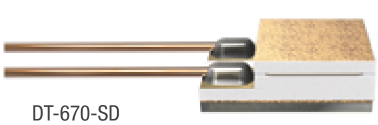
- Best accuracy across the widest useful temperature range—1.4 K to 500 K—of any silicon diode in the industry
- Tightest tolerances for 30 K to 500 K applications of any silicon diode to date
- Rugged, reliable Lake Shore SD package designed to withstand repeated thermal cycling and minimize sensor self-heating
- Conformance to standard DT-670 temperature response curve
- Variety of packaging options

DT-670E-BR features

- Temperature range: 1.4 K to 500 K
- Bare die sensors with the smallest size and fastest thermal response time of any silicon diode on the market today
- Non-magnetic sensor

DT-621-HR features

- Temperature range: 1.4 K to 325 K (uncalibrated down to 20 K)
- Non-magnetic package
- Exposed flat substrate for surface mounting



DT-670-SD

DT-670 Series silicon diodes offer better accuracy over a wider temperature range than any previously marketed silicon diodes. Conforming to the Curve DT-670 standard voltage versus temperature response curve, sensors within the DT-670 series are interchangeable, and for many applications do not require individual calibration. DT-670 sensors in the SD package are available in four tolerance bands—three for general cryogenic use across the 1.4 K to 500 K temperature range, and one that offers superior accuracy for applications from 30 K to room temperature.

DT-670-SD diodes are available with calibration across the full 1.4 K to 500 K temperature range.

The bare die sensor, the DT-670E-BR, provides the smallest physical size and fastest thermal response time of any silicon diode on the market today. This is an important advantage for applications where size and thermal response time are critical, including focal plane arrays and high temperature superconducting filters for cellular communication.

Packaging options

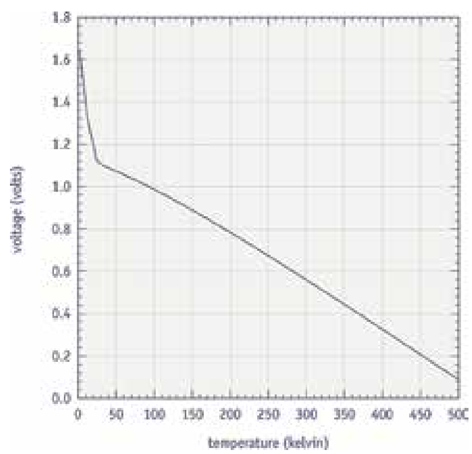
BO, BR, CO, CU, CY, DI, ET, LR, MT

CAUTION: These sensors are sensitive to electrostatic discharge (ESD). Use ESD precautionary procedures when handling, or making mechanical or electrical connections to these devices in order to avoid performance degradation or loss of functionality.

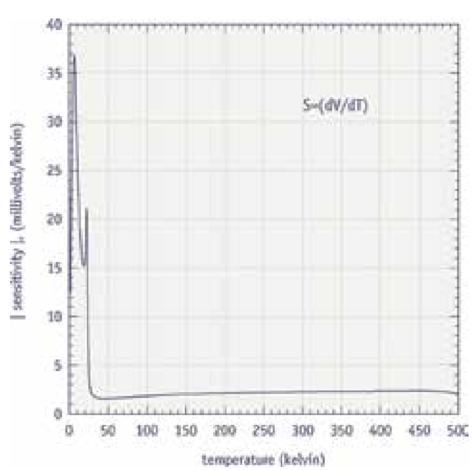
The Lake Shore SD package — the most rugged, versatile package in the industry

The SD package, with direct sensor-to-sapphire base mounting, hermetic seal, and brazed Kovar leads, provides the industry's most rugged, versatile sensors with the best sample to chip connection. Designed so heat coming down the leads bypasses the chip, it can survive several thousand hours at 500 K (depending on model) and is compatible with most ultra high vacuum applications. It can be indium soldered to samples without shift in sensor calibration. If desired, the SD package is also available without Kovar leads.

Typical DT-670 diode voltage



Typical DT-670 diode sensitivity



Specifications

Standard curve Curve DT-670—see next page

Recommended excitation 10 µA ±0.1%

Max reverse voltage 40 V

Max current before damage 1 mA continuous or 100 mA pulsed

Dissipation at recommended excitation
16 µW at 4.2 K; 10 µW at 77 K; 5 µW at 300 K

Thermal response time SD: typical <10 ms at 4.2 K, 100 ms at 77 K, 200 ms at 305 K; BR: 1 ms at 4.2 K, 13 ms at 77 K, 20 ms at 305 K

Use in radiation Recommended for use only in low level radiation—see Appendix B

Use in magnetic field Not recommended for use in magnetic field applications below 60 K. Low magnetic field dependence when used in fields up to 5 tesla above 60 K—see Appendix B

Reproducibility[1] ±10 mK at 4.2 K

Soldering standard J-STD-001 Class 2

[1] Short-term reproducibility data is obtained by subjecting sensor to repeated thermal shocks from 305 K to 4.2 K

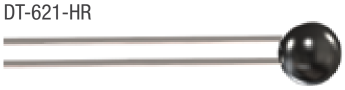
Range of use

Package	Minimum limit	Maximum limit
SD, CU-HT, BR	1.4 K	500 K
CU, LR, CY, ET, MT, BO, HR	1.4 K	420 K

DT-621-HR miniature silicon diode

The DT-621 miniature silicon diode temperature sensor is configured for installation on flat surfaces. Due to the absence of magnetic materials in its construction, this package is suited for applications where minimal interaction between the diode and sample space magnetic field is desired. The DT- 621 sensor package exhibits precise, monotonic temperature response over its useful range. The sensor chip is in direct contact with the epoxy dome, which causes increased voltage below 20 K and prevents full range Curve DT-670 conformity. For use below 20 K, calibration is required.

DT-621-HR



Calibrated accuracy

	Typical sensor accuracy[2]
1.4 K	±12 mK
4.2 K	±12 mK
10 K	±12 mK
77 K	±22 mK
300 K	±32 mK
500 K	±50 mK

[2] [(Calibration uncertainty)^2 +(reproducibility)2]$^{0.5}$ for more information see Appendices B, D, and E

Temperature response data table (typical)

	DT-670		DT-621-HR	
	V (volts)	dV/dT (mV/K)	V (volts)	dV/dT (mV/K)
1.4 K	1.64	-12.5	—	—
4.2 K	1.58	-31.6	1.678	-35
10 K	1.38	-26.8	—	—
77 K	1.03	-1.73	1.03	1.73
305 K	0.560	-2.30	0.560	-2.3

See Appendix G for expanded response table

Long-term stability

	Use to 305 K[3]	Use to 500 K[4]
4.2 K	±10 mK	±40 mK
77 K	±40 mK	±100 mK
305 K	±25 mK	±50 mK
500 K	—	±150 mK

[3] Long-term stability data is obtained by subjecting sensor to 200 thermal shocks from 305 K to 77 K
[4] Based on 670 h of baking at 500 K

Standard curve DT-670 tolerance bands

	2 K to 100 K	100 K to 305 K	305 K to 500 K
Band A	±0.25 K	±0.5 K	±0.5 K
Band A1	±0.25 K	±1.5% of temp	±1.5% of temp
Band B	±0.5 K	±0.5 K	±0.33% of temp
Band B1	±0.5 K	±1.5% of temp	±1.5% of temp
Band C	±1 K	±1 K	±0.50% of temp

	30 K to 100 K	100 K to 305 K	305 K to 500 K
Band D[5]	±0.25 K	±0.50 K	±0.20% of temp

[5] For T < 30 K ±1.5 K

	2 K to 100 K	100 K to 500 K
DT-670E-BR	±1.5 K typical	±1.5% of temp typical

	20 K to 325 K
DT-621-HR	±2.5 K or ±1.5% of temperature, whichever is greater

Physical specifications

	Mass	Lead type	Lead polarity	Sensor materials used
DT-670-SD	37 mg	2—nickel and gold plated Kovar	Positive lead on right with package lid up and leads towards user	Sapphire base with alumina body & lid. Molybdenum/manganese metallization on base and lid top with nickel and gold plating. Gold tin solder as hermetic seal.
DT-670E-BR (bare die)	72.7 µg	None	Positive connection made through bottom of chip; negative connection made on base pad on top of chip	Silicon chip with aluminum metallization on chip contacts.
DT-621-HR	23 mg	2—platinum ribbon with tinned 60/40 SnPb solder	Positive lead is right-hand ribbon with platinum disk down and leads towards user	Sensing element is mounted to a platinum disk and covered with a dome of Stycast® 2850 epoxy

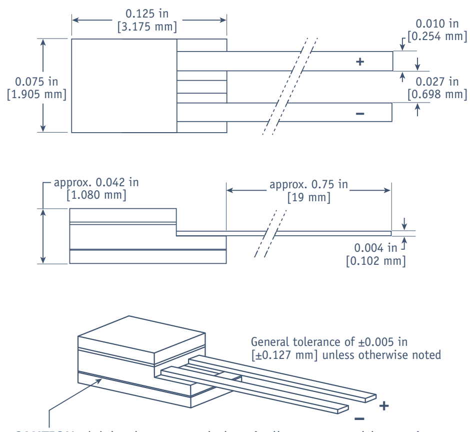
Typical magnetic field-dependent temperature errors[6] ΔT/T (%) at B (magnetic induction)

Package base parallel to field B					
	1 T	2 T	3 T	4 T	5 T
4.2 K	-200	-300	-350	-400	-500
20 K	-10	-20	-25	-30	-40
40 K	-4	-6	-8	-10	-12
60 K	-0.5	-1	-2	-3	-3.5
80 K	< 0.1	-0.5	-0.8	-1.1	-1.5
300 K	<-0.1	<-0.1	<-0.1	<-0.1	<-0.1

Package base perpendicular to field B					
	1 T	2 T	3 T	4 T	5 T
4.2 K	-8	-9	-11	-15	-20
20 K	-4	-5	-5	-5	-10
40 K	-1.5	-3	-4	-5	-5.5
60 K	-0.5	-0.7	-0.8	-1	-1.1
80 K	-0.1	-0.3	-0.5	-0.6	-0.7
300 K	<0.1	0.2	0.5	0.6	0.6

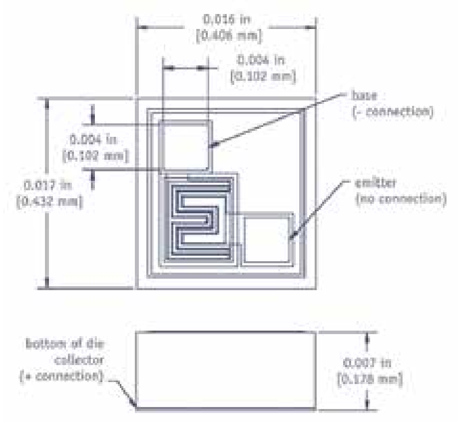
[6] To minimize magnetic field-induced temperature errors, the sensor should be oriented so that the package base is perpendicular to the magnetic field flux lines—this results in the diode current being parallel to the magnetic field

DT-670-SD

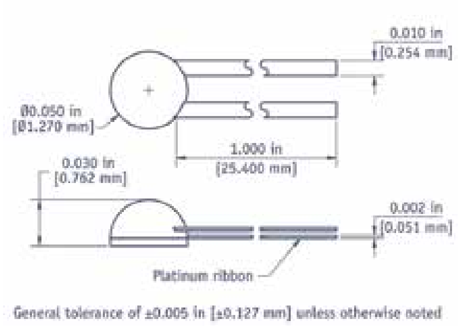


CAUTION: (+) lead connected electrically to external braze ring—take care not to cause a short

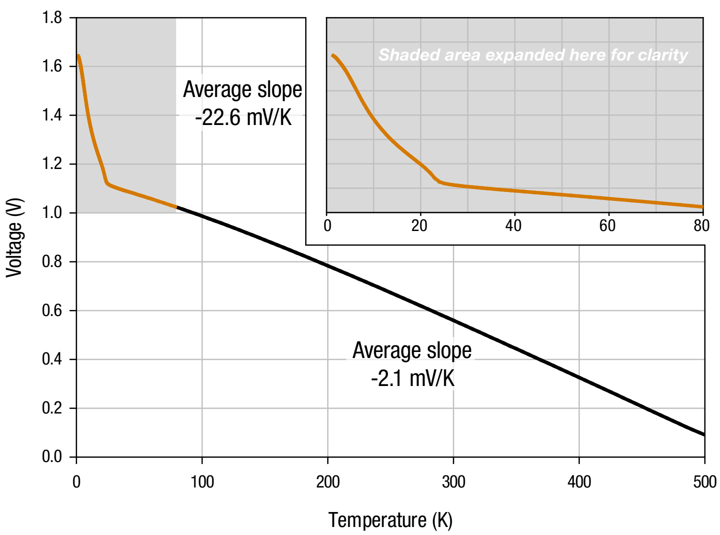
DT-670E-BR



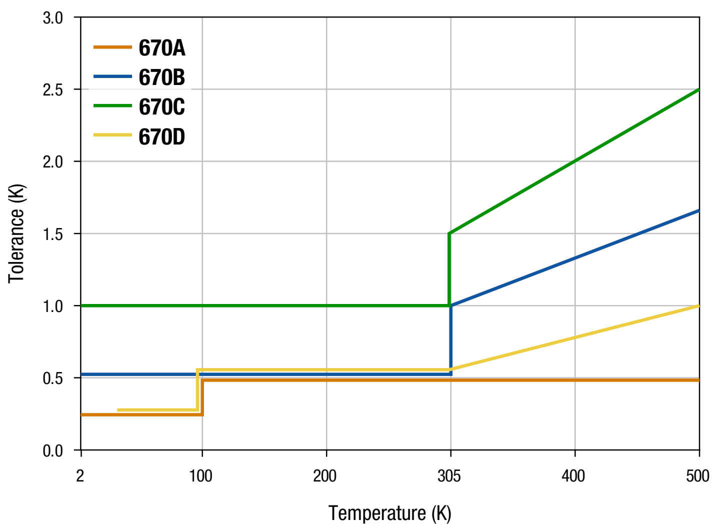
DT-621-HR



DT-670 temperature response curve



Curve DT-670 tolerance bands



DT-670 Series expanded temperature response data table

T (K)	Voltage (V)	dV/dT (mV/K)	T (K)	Voltage (V)	dV/dT (mV/K)	T (K)	Voltage (V)	dV/dT (mV/K)	T (K)	Voltage (V)	dV/dT (mV/K)
1.4	1.644290	-12.5	**6.0**	1.51541	-36.7	**28.0**	1.110421	-2.25	**160.0**	0.868518	-2.07
1.5	1.642990	-13.6	**6.5**	1.49698	-36.9	**29.0**	1.108261	-2.08	**170.0**	0.847659	-2.10
1.6	1.641570	-14.8	**7.0**	1.47868	-36.2	**30.0**	1.106244	-1.96	**180.0**	0.826560	-2.12
1.7	1.640030	-16.0	**7.5**	1.46086	-35.0	**31.0**	1.104324	-1.88	**190.0**	0.805242	-2.14
1.8	1.638370	-17.1	**8.0**	1.44374	-33.4	**32.0**	1.102476	-1.82	**200.0**	0.783720	-2.16
1.9	1.636600	-18.3	**8.5**	1.42747	-31.7	**33.0**	1.100681	-1.77	**210.0**	0.762007	-2.18
2.0	1.634720	-19.3	**9.0**	1.41207	-29.9	**34.0**	1.098930	-1.73	**220.0**	0.740115	-2.20
2.1	1.632740	-20.3	**9.5**	1.39751	-28.3	**35.0**	1.097216	-1.70	**230.0**	0.718054	-2.21
2.2	1.630670	-21.1	**10.0**	1.38373	-26.8	**36.0**	1.095534	-1.69	**240.0**	0.695834	-2.23
2.3	1.628520	-21.9	**10.5**	1.37065	-25.5	**37.0**	1.093878	-1.64	**250.0**	0.673462	-2.24
2.4	1.626290	-22.6	**11.0**	1.35820	-24.3	**38.0**	1.092244	-1.62	**260.0**	0.650949	-2.26
2.5	1.624000	-23.2	**11.5**	1.34632	-23.2	**39.0**	1.090627	-1.61	**270.0**	0.628302	-2.27
2.6	1.621660	-23.6	**12.0**	1.33499	-22.1	**40.0**	1.089024	-1.60	**273.0**	0.621141	-2.28
2.7	1.619280	-24.0	**12.5**	1.32416	-21.2	**42.0**	1.085842	-1.59	**280.0**	0.605528	-2.28
2.8	1.616870	-24.2	**13.0**	1.31381	-20.3	**44.0**	1.082669	-1.59	**290.0**	0.582637	-2.29
2.9	1.614450	-24.4	**13.5**	1.30390	-19.4	**46.0**	1.079492	-1.59	**300.0**	0.559639	-2.30
3.0	1.612000	-24.7	**14.0**	1.29439	-18.6	**48.0**	1.076303	-1.60	**310.0**	0.536542	-2.31
3.1	1.609510	-25.1	**14.5**	1.28526	-17.9	**50.0**	1.073099	-1.61	**320.0**	0.513361	-2.32
3.2	1.606970	-25.6	**15.0**	1.27645	-17.3	**52.0**	1.069881	-1.61	**330.0**	0.490106	-2.33
3.3	1.604380	-26.2	**15.5**	1.26794	-16.8	**54.0**	1.066650	-1.62	**340.0**	0.466760	-2.34
3.4	1.601730	-26.8	**16.0**	1.25967	-16.3	**56.0**	1.063403	-1.63	**350.0**	0.443371	-2.34
3.5	1.599020	-27.4	**16.5**	1.25161	-15.9	**58.0**	1.060141	-1.64	**360.0**	0.419960	-2.34
3.6	1.596260	-27.9	**17.0**	1.24372	-15.6	**60.0**	1.056862	-1.64	**370.0**	0.396503	-2.35
3.7	1.59344	-28.4	**17.5**	1.23596	-15.4	**65.0**	1.048584	-1.67	**380.0**	0.373002	-2.35
3.8	1.59057	-29.0	**18.0**	1.22830	-15.3	**70.0**	1.040183	-1.69	**390.0**	0.349453	-2.36
3.9	1.58764	-29.6	**18.5**	1.22070	-15.2	**75.0**	1.031651	-1.72	**400.0**	0.325839	-2.36
4.0	1.58465	-30.2	**19.0**	1.21311	-15.2	**77.35**	1.027594	-1.73	**410.0**	0.302161	-2.37
4.2	1.57848	-31.6	**19.5**	1.20548	-15.3	**80.0**	1.022984	-1.75	**420.0**	0.278416	-2.38
4.4	1.57202	-32.9	**20.0**	1.197748	-15.6	**85.0**	1.014181	-1.77	**430.0**	0.254592	-2.39
4.6	1.56533	-34.0	**21.0**	1.181548	-17.0	**90.0**	1.005244	-1.80	**440.0**	0.230697	-2.39
4.8	1.55845	-34.7	**22.0**	1.162797	-21.1	**100.0**	0.986974	-1.85	**450.0**	0.206758	-2.39
5.0	1.55145	-35.2	**23.0**	1.140817	-20.8	**110.0**	0.968209	-1.90	**460.0**	0.182832	-2.39
5.2	1.54436	-35.6	**24.0**	1.125923	-9.42	**120.0**	0.949000	-1.94	**470.0**	0.159010	-2.37
5.4	1.53721	-35.9	**25.0**	1.119448	-4.60	**130.0**	0.929390	-1.98	**480.0**	0.135480	-2.33
5.6	1.53000	-36.2	**26.0**	1.115658	-3.19	**140.0**	0.909416	-2.01	**490.0**	0.112553	-2.25
5.8	1.52273	-36.5	**27.0**	1.112810	-2.58	**150.0**	0.889114	-2.05	**500.0**	0.090681	-2.12

Ordering information

Uncalibrated sensor
Step 1: Choose diode series, for example DT-670.
Step 2: Choose tolerance band (if applicable), for example DT-670A.
Step 3: Choose package or mounting adapter—if ordering adapter, substitute the adapter suffix for the SD suffix, for example DT-670A-CU.

Calibrated sensor
Step 1: Choose diode series, for example DT-670.
Step 2: Choose package or mounting adapter—if ordering adapter, substitute the adapter suffix for the SD suffix, for example DT-670-CU.
Step 3: Specify the calibration range suffix code after the model number and package suffix, for example DT-670-CU-1.4L.

DT-670	Calibration range suffix codes Numeric figure is the low end of the calibration Letters represent the high end: L=325 K, H=500 K				
Model number	Uncal	1.4L	1.4H	70L	70H
DT-621-HR	■	■		■	
DT-670A-SD	■				
DT-670A1-SD	■				
DT-670B-SD	■				
DT-670B1-SD	■				
DT-670C-SD	■				
DT-670D-SD	■				
DT-670-SD		■	■	■	■
Mounting adapters are available for use with the SD package—replace SD suffix with mounting adapter suffix					
CO	■	■	■	■	■
CU, LR, CY, ET, BO, MT	■	■		■	
CU-HT	■	■	■	■	■
DI	■				
DT-670E-BR-10	■	bare chip silicon diode sensor, quantity 10			

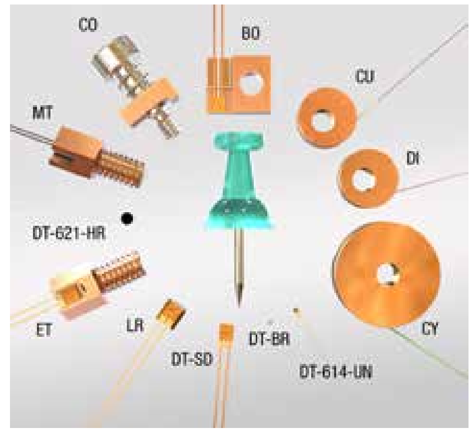
Note: upper temperature limit package dependent—see Sensor Packages section
Other packaging available by special order—please consult Lake Shore

Accessories available for sensors
SN-CO-C1 SD package sensor clamp, qty 1
SN-CO-C10 SD package sensor clamp, qty 10
8000-CD Calibration report on CD-ROM
8000-USB Calibration report on USB
COC-SEN Certificate of conformance

Accessories suggested for installation—see Accessories section for full descriptions
Stycast® epoxy
Apiezon® grease
90% Pb, 10% Sn solder
Indium solder
VGE-7031 varnish
Phosphor bronze wire
Manganin wire

Packaging options

For more information on sensor packages and mounting adapters, see page 20.




CO adapter — spring loaded clamp for easy sensor interchangeability

Upgrade conversion chart

	From:	To:
Sensor	DT-470	DT-670
Band	11	A
	11A	A1
	12	B
	12A	B1
	13	C

See the appendices for a detailed description of:
Installation
Uncalibrated sensors
SoftCal™
Calibrated sensors
CalCurve™
Sensor packages

To add length to sensor leads, see page 25.

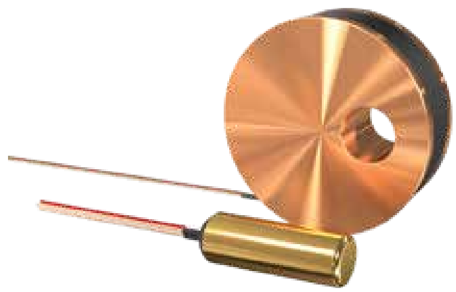
Germanium RTDs

Germanium features

- Recognized as a “Secondary Standard Thermometer”
- High sensitivity provides submillikelvin control at 4.2 K and below
- Excellent reproducibility better than ±0.5 mK at 4.2 K
- Various models for use from 0.05 K to 100 K
- Excellent resistance to ionizing radiation

Lake Shore germanium resistance temperature sensors are recognized as “Secondary Standard Thermometers” and have been employed in the measurement of temperature from 0.05 K to 30 K for more than 40 years.

Germanium sensors have a useful temperature range of about two orders of magnitude. The exact range depends upon the doping of the germanium element. Sensors with ranges from below 0.05 K to 100 K are available. Between 100 K and 300 K, dR/dT changes sign and dR/dT above 100 K is very small for all models. Sensor resistance varies from several ohms at its upper useful temperature to several tens of kilohms at its lower temperature. Because device sensitivity increases rapidly with decreasing temperature, a high degree of resolution is achieved at lower temperatures, making these resistors very useful for submillikelvin control at 4.2 K and below.

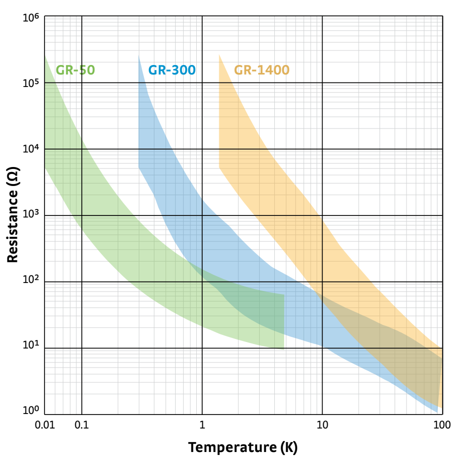


The sensors offer excellent stability, and ±0.5 mK reproducibility at 4.2 K. The germanium resistor is usually the best choice for high-accuracy work below 30 K. Use in a magnetic field is not recommended.

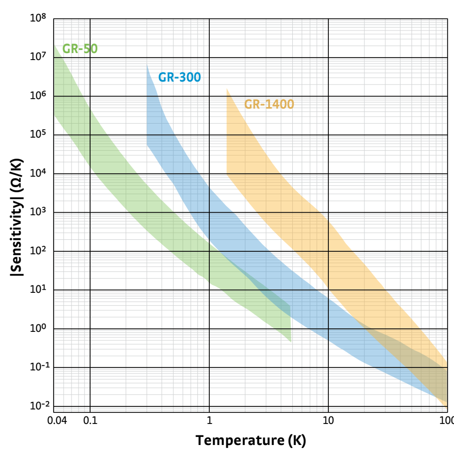
Packaging options

AA,CD

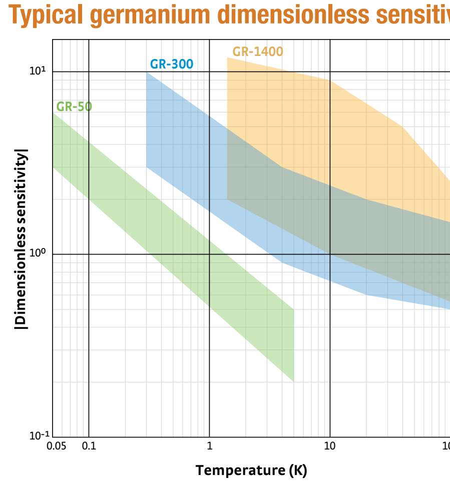
Typical germanium resistance



Typical germanium sensitivity



Typical germanium dimensionless sensitivity



Specifications

Standard curve Not applicable

Recommended excitation[1] 20 µV (0.05 K to 0.1 K); 63 µV (0.1 K to 1 K); 10 mV or less for T > 1 K

Dissipation at recommended excitation 10^{-13} W at 0.05 K, 10^{-7} W at 4.2 K (temperature and model dependent)

Thermal response time 200 ms at 4.2 K, 3 s at 77 K

Use in radiation Recommended for use in ionizing radiation environments—see Appendix B

Use in magnetic field Because of their strong magnetoresistance and associated orientation effect, germanium sensors are of very limited use in magnetic fields—see Appendix B

Soldering standard J-STD-001 Class 2

Reproducibility

	Short term[2]	Long term[3]
4.2 K	±0.5 mK	±1 mK/yr
77 K	—	±10 mK/yr

[1] Recommended excitation for T < 1 K based on Lake Shore calibration procedures using an AC resistance bridge—for more information refer to Appendix D and Appendix E

[2] Short-term reproducibility data is obtained by subjecting sensor to repeated thermal shocks from 305 K to 4.2 K

[3] Long-term stability data is obtained by subjecting sensor to 200 thermal shocks from 305 K to 77 K

Range of use

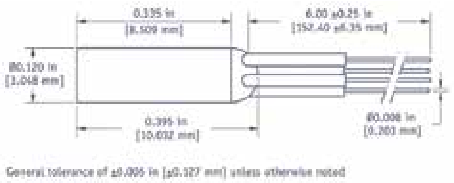
	Minimum limit	Maximum limit
GR-50-AA	<0.05 K	5 K
GR-300-AA	0.3 K	100 K
GR-1400-AA	1.4 K	100 K

Calibrated accuracy[4]

	Typical sensor accuracy[4]		
	GR-50	GR-300	GR-1400
0.05 K	±5 mK	—	—
0.3 K	±5 mK	±4 mK	—
0.5 K	±5 mK	±4 mK	—
1.4 K	±6 mK	±4 mK	±4 mK
4.2 K	±6 mK	±4 mK	±4 mK
77 K	—	±25 mK	±15 mK
100 K	—	±32 mK	±18 mK

[4] [(Calibration uncertainty)2 + (reproducibility)2]0.5 for more information see Appendices B, D, and E

AA package



Typical magnetic field-dependent temperature errors[5] ΔT/T (%) at B (magnetic induction)

	Germanium		
	2.5 T	8 T	14 T
2.0 K	-8	-60	—
4.2 K	-5 to -20	-30 to -55	-60 to -75
10 K	-4 to -15	-25 to -60	-60 to -75
20 K	-3 to -20	-15 to -35	-50 to -80

[5] Long axis of thermometer parallel to applied field

Typical resistance values

GR-AA	Typical resistance at 4.2 K	Typical resistance range at 4.2 K
50	30 Ω	9 Ω to 65 Ω
300	95 Ω	15 Ω to 155 Ω
1400	1750 Ω	350 Ω to 6500 Ω

Temperature response data table (typical)—see Appendix G for expanded response table

	GR-50-AA			GR-300-AA			GR-1400-AA		
	R[8] (Ω)	dR/dT (Ω/K)	(T/R)·(dR/dT)	R[8] (Ω)	dR/dT (Ω/K)	(T/R)·(dR/dT)	R[8] (Ω)	dR/dT (Ω/K)	(T/R)·(dR/dT)
0.05 K	35000	-3642000	-5.2	—	—	—	—	—	—
0.1 K	2320	-71860	-3.1	—	—	—	—	—	—
0.2 K	364.6	-4043	-2.2	—	—	—	—	—	—
0.3 K	164.0	-964.0	-1.8	35180	-512200	-4.4	—	—	—
0.5 K	73.75	-202.9	-1.4	5443	-34800	-3.2	—	—	—
1.0 K	33.55	-31.33	-0.93	875.7	-1901	-2.2	—	—	—
1.4 K	24.73	-13.15	-0.74	448.6	-581.3	-1.8	35890	-94790	-3.7
2.0 K	19.32	-6.167	-0.64	248.8	-187.4	-1.5	11040	-16670	-3.0
4.2 K	13.66	-1.036	-0.32	94.46	-26.56	-1.2	1689	-861.9	-2.1
10 K	—	—	—	33.20	-3.97	-1.2	252.8	-61.95	-2.5
40 K	—	—	—	7.79	-0.235	-1.2	9.57	-0.449	-1.9
77.4 K	—	—	—	3.50	-0.050	-1.1	3.55	-0.050	-1.1
100 K	—	—	—	2.72	-0.024	-0.88	2.80	-0.021	-0.74

Proper selection of germanium sensors for use below 1 K

Germanium resistance thermometers are often classified according to their 4.2 K resistance value. However, for devices to be used below 1 K, there is no close correlation between the 4.2 K resistance and the suitability of the device as a thermometer. As a result, the Lake Shore low resistance germanium sensors (GR-50-AA and GR-300-AA) are classified according to their lowest useful temperatures, not their 4.2 K resistance values.

The resistance vs. temperature behavior for these devices is typical of all the germanium sensors. As the temperature is lowered, both the resistance and sensitivity (dR/dT) increase logarithmically. The lowest useful temperature is generally limited by the rapidly increasing resistance and the difficulties encountered in measuring high resistance values.

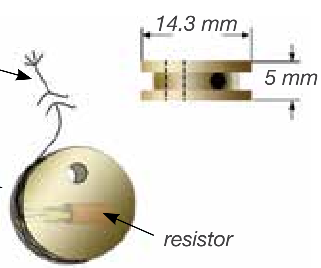
The following recommendations are made concerning the optimum temperature range for using these devices:

GR-50-AA	0.05 K to 1.0 K
GR-300-AA	0.3 K to 100 K

Increasingly better temperature resolution is achievable at lower temperatures.

In general, it is recommended you do not purchase a device which has a lower temperature limit than required, since some sensitivity (dR/dT) will be sacrificed at the higher temperatures. For example, a GR-300-AA will have more sensitivity at 1 K than a GR-50-AA.

CD package

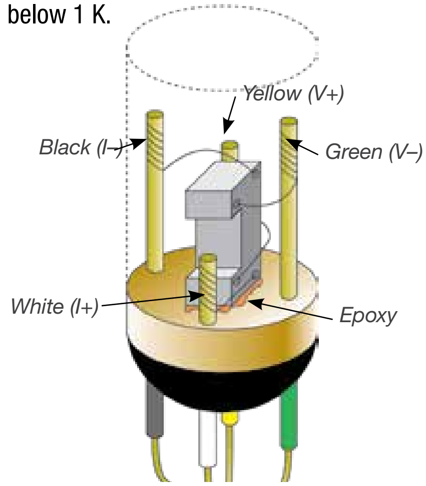


Physical specifications

	Mass	Lead type	Internal atmosphere	Sensor materials used
GR-50-AA GR-300-AA GR-1400-AA	395 mg	4 color coded phosphor bronze with heavy build polyimide, attached with epoxy strain relief at sensor	Helium 4 (4He) at ≥500 Ω, air at <500 Ω	Doped germanium chip mounted strain-free in a gold plated cylindrical copper can

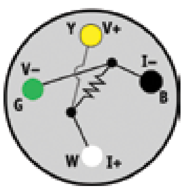
Germanium series construction detail

The epoxy holding the chip to the header is omitted for germanium devices designed for use below 1 K.



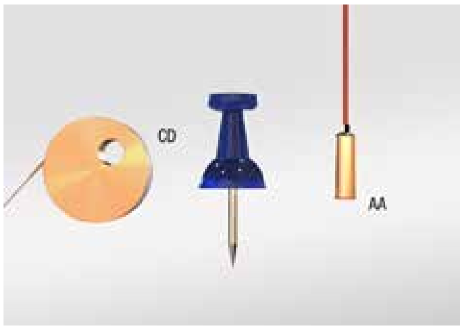
Looking at the wiring end with leads toward user

	Key	Lead Color
W	*I+*	*White*
G	*V-*	*Green*
Y	*V+*	*Yellow*
B	*I-*	*Black*



Packaging options

For more information on sensor packages and mounting adapters, see page 20.



See the appendices for a detailed description of:
Installation
Uncalibrated sensors
SoftCal™
Calibrated sensors
CalCurve™
Sensor packages

To add length to sensor leads, see page 25.

Ordering information

Uncalibrated sensor—Specify the model number in the left column only, for example GR-50-AA.

Calibrated sensor—Add the calibration range suffix code to the end of the model number, for example GR-50-AA-0.05A.

Germanium RTD	Calibration range suffix codes Numeric figure is the low end of the calibration Letters represent the high end: A=5 K, D=100 K			
Part number	Uncal	0.05A	0.3D	1.4D
GR-50-AA	■	■		
GR-300-AA	■		■	■
GR-1400-AA	■			■
GR-50-CD	■	■		
GR-300-CD	■		■	■
GR-1400-CD	■			■

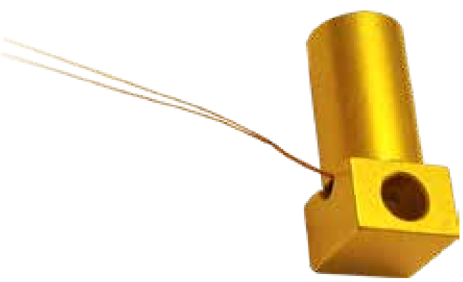
**NOTE: The GR-50-AA calibration is not useful above 5 K*
Other packaging available through special order—consult Lake Shore

Accessories available for sensors
COC-SEN Certificate of conformance

Ultra-low temperature Rox™

RX-102B-RS features

- Useful below 10 mK; calibrations down to 10 mK available
- Include additional extrapolated points to 5 mK
- Optical shielding reduces unwanted sensor heating



Temperature measurement for the world's greatest dilution refrigerators

With the amazing progress made by dilution refrigerator manufacturers to push base temperatures well below 10 mK, the need for accurate, simplified temperature measurements continues to grow. The RX-102B-RS meets this need as a resistive temperature device (RTD) that maintains sensitivity well below 10 mK.

Building on the success of the previous generation RX-102B, this sensor refines the package to improve thermal connection and adds optical radiation shielding to further reduce the issue of unwanted sensor heating.

When paired with the Lake Shore 372 AC resistance bridge and temperature controller, this sensor/instrument combination is the configuration of choice for simplified temperature monitoring or controlling below 50 mK.

Boundary-pushing calibrations

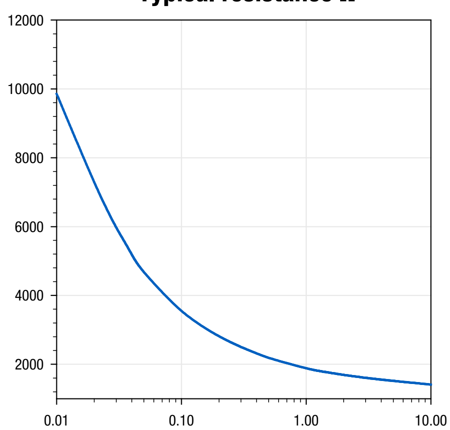
Going beyond the 20 mK calibration offered for many years, Lake Shore is pushing the boundary of world-class metrology by extending calibrations down to 10 mK for these sensors.

As a bonus for those pushing below 10 mK, 0.01B and 0.01C calibrated sensors will include additional extrapolated points to 5 mK to provide an easier method for determining temperature in this region with reasonable accuracy.

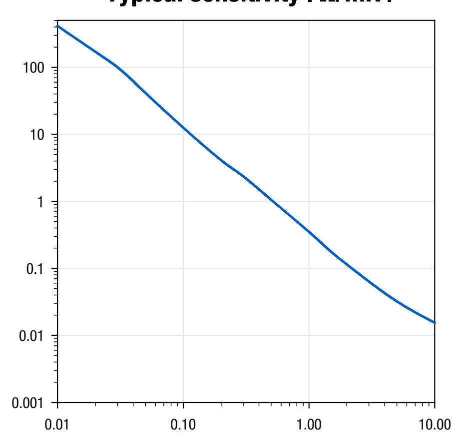
Packaging options

RS

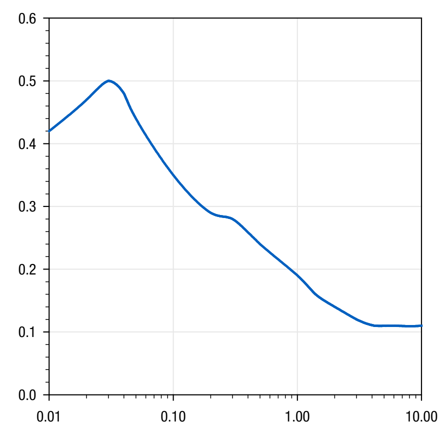
Typical resistance Ω



Typical sensitivity | Ω/mK |



Typical dimensionless sensitivity | S_d |



Specifications

Recommended excitation[1] 20 μV (0.05 K to 0.1 K); 63 μV (0.1 K to 1.2 K); 10 mV or less for T > 1 K

Dissipation at recommended excitation 7.5 × 10^{-8} W at 4.2 K

Thermal response time 0.5 s at 4.2 K, 2.5 s at 77 K

Radiation effects Recommended—see Appendix B

Magnetic field Not recommended

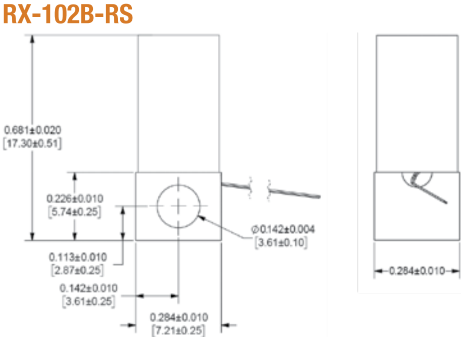
Reproducibility[2] ±15 mK at 4.2 K

Soldering standard J-STD-001 Class 2

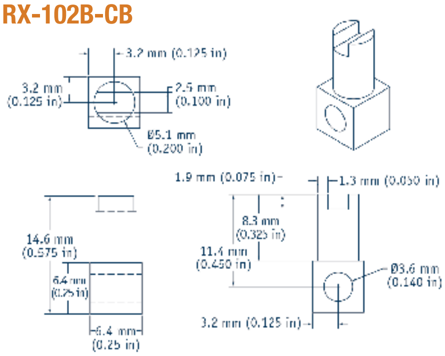
[1] Recommended excitation for T < 1 K based on Lake Shore calibration procedures using an AC resistance bridge—for more information refer to Appendix D and Appendix E

[2] Short-term reproducibility data is obtained by subjecting sensor to repeated thermal shocks from 305 K to 4.2 K

RX-102B-RS



RX-102B-CB



General tolerance of ±0.127 mm (0.005 in) on X.XXX and ±0.254 mm (0.01 in) on X.XX unless otherwise noted

Mount using a #6 or M3 screw

Range of use

	Minimum limit	Maximum limit
RX-102B-RS	0.005 K[3]	40 K
RX-102B-CB (discontinued)	0.01 K[4]	40 K

[3] Calibrations down to 10 mK available

[4] Calibrations down to 20 mK available

Calibrated accuracy[5]

	RX-102B-RS	RX-102B-CB (discontinued)
5 mK	±1.2 mK[6]	—
7 mK	±0.8 mK[6]	—
10 mK	±1 mK	±1 mK[6]
20 mK	±2 mK	±2 mK
50 mK	±4 mK	±4 mK
1.4 K	±16 mK	±16 mK
4.2 K	±16 mK	±16 mK
10 K	±30 mK	±30 mK

[5] $[(\text{Calibration uncertainty})^2 + (\text{reproducibility})^2]^{0.5}$ for more information see Appendices B, D, and E

[6] Extrapolated accuracy values are anticipated

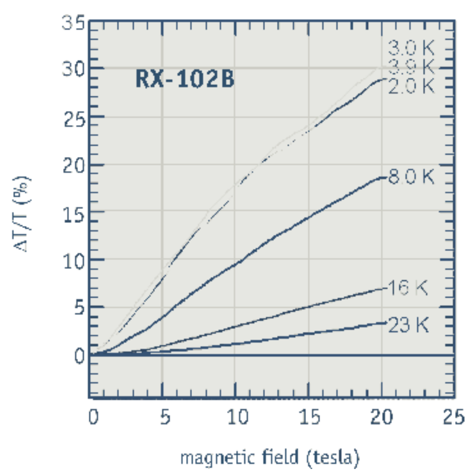
Long-term stability

	RX-102B-RS	RX-102B-CB (discontinued)
4.2 K	±30 mK	±30 mK

Typical magnetic field-dependent temperature errors ΔT/T (%) at B (magnetic induction)

	Rox™ 102B			
	2.5 T	8 T	14 T	19 T
2 K	3.29	13.82	22.53	27.95
3 K	3.96	14.68	23.12	29.12
4 K	3.53	13.92	22.57	28.20
8 K	1.53	7.53	13.50	17.86
16 K	0.27	2.14	4.66	6.58
23 K	0.06	0.79	2.01	3.11

Magnetic field dependance data for sample Rox™ RTDs



Physical specifications

	Mass	Lead type	Mounting hole diameter	Materials used
RX-102B-RS	3.5 g	Two 36 AWG copper leads with heavy build polyimide insulation, 15 cm length, lead ends tinned with 63/37 SnPb solder	Accommodates a #6-32 or M3 screw	Thick ruthenium dioxide and bismuth ruthenate films on aluminum dioxide substrate with palladium silver contacts; epoxy attachment to OFHC adapter; copper leads indium soldered to chip and heat sunk to copper adapter using varnish, covered with copper radiation shield
RX-102B-CB	3.5 g	Two 6 in 36 AWG copper leads with heavy build polyimide insulation	Accommodates a #6-32 or M3 screw	Thick ruthenium dioxide and bismuth ruthenate films on aluminum dioxide substrate with palladium silver contacts; epoxy attachment to OFHC adapter; copper leads indium soldered to chip and heat sunk to copper adapter using varnish

Packaging options

For more information on sensor packages and mounting adapters, see page 20.

See the appendices for a detailed description of:
Installation
Uncalibrated sensors
SoftCal™
Calibrated sensors
CalCurve™
Sensor packages

To add length to sensor leads see page 25.

Ordering information

ULT Rox™ RTD	**Calibration range suffix codes** **Numeric figure is the low end of the calibration** **Letters represent the high end: C=1 K, B=40 K** *(calibration of matched sensors is available—consult Lake Shore)*				
Part number	Uncal	0.01B	0.01C	0.02B	0.02C
RX-102B-RS	■	■	■	■	■

Note: the RX-102B-RS is not interchangeable to a standard curve and is not available as matched.
Other packaging available through special order—consult Lake Shore

Accessories available for sensors

8000-CD	Calibration report on CD-ROM
8000-USB	Calibration report on USB
COC-SEN	Certificate of conformance

Accessories suggested for installation—see Accessories section for full descriptions
Stycast® epoxy
Apiezon® grease
90% Pb, 10% Sn solder
Indium solder
VGE-7031 varnish
Phosphor bronze wire
Manganin wire

Interchangeable Rox™

RX-102A features

- Standard curve interchangeable
- Good radiation resistance
- Useful down to 50 mK
- Low magnetic field-induced errors

RX-202A features

- Standard curve interchangeable
- Good radiation resistance
- Monotonic from 50 mK to 300 K
- 4× improvement in magnetic field-induced errors over other ruthenium oxides

RX-103A features

- Standard curve interchangeable
- Good radiation resistance
- Best choice for interchangeability from 1.4 K to 40 K
- Low magnetic field-induced errors

Ruthenium oxide temperature sensors are thick-film resistors used in applications involving magnetic fields. These composite sensors consist of bismuth ruthenate, ruthenium oxides, binders, and other compounds that allow them to obtain the necessary temperature and resistance characteristics. Each interchangeable Lake Shore Rox™ model adheres to a single resistance versus temperature curve.

RX-102A

The RX-102A (1000 Ω at room temperature) is useful down to 50 mK and has better interchangeability than the RX-202A as well as low magnetic field-induced errors below 1 K.

RX-202A

The RX-202A (2000 Ω at room temperature) has a 4× improvement in magnetic field-induced errors over other commercially available ruthenium oxide temperature sensors with similar resistances and sensitivities. Most ruthenium oxide sensors have a maximum useful temperature limit well below room temperature, where the sensitivity changes from negative to positive. The RX-202A however, is designed to have a monotonic response from 0.05 K up to 300 K.

RX-103A

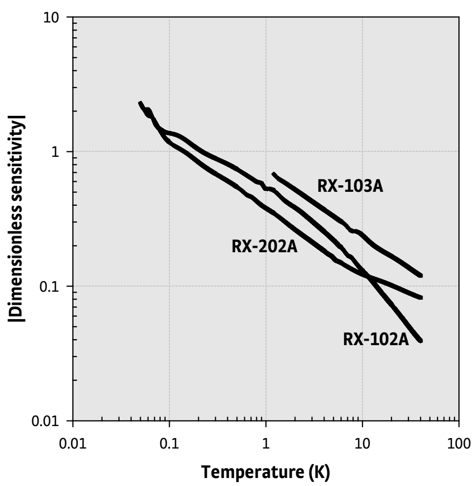
The RX-103A (10,000 Ω at room temperature) has a unique resistance and temperature response curve combined with low magnetic field-induced errors, and is the best choice for interchangeability from 1.4 K to 40 K.

Packaging options

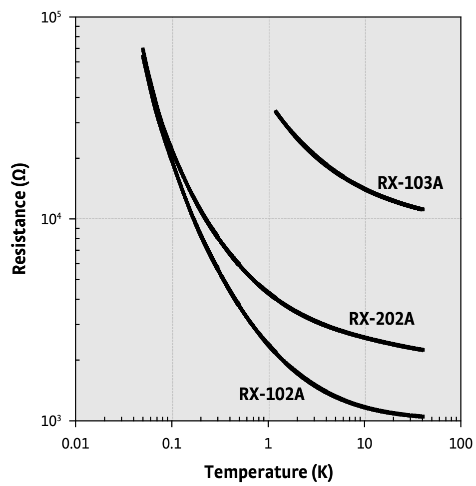
AA, BR

RX-AA

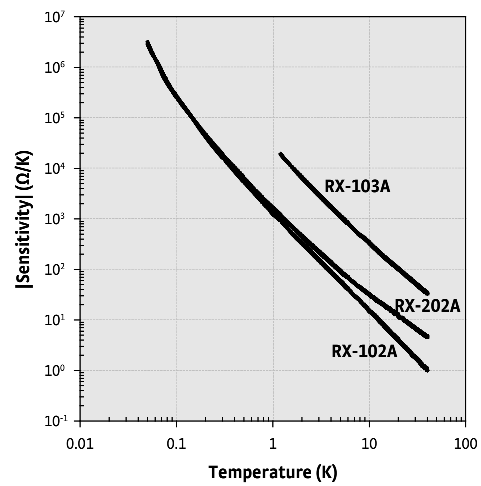
Typical interchangeable Rox™ resistance



Typical interchangeable Rox™ sensitivity



Typical interchangeable Rox™ dimensionless sensitivity



Specifications

Standard curve[1] 102 and 202: 0.05 K to 40 K; 103: 1.4 K to 40 K

Recommended excitation[2] RX-102 and RX-202: 20 µV (0.05 K to 0.1 K); 63 µV (0.1 K to 1.2 K); 10 mV or less for T > 1 K. RX-103: 10 mV or less for T > 1 K

Dissipation at recommended excitation 102 and 202: 7.5×10^{-8} W at 4.2 K; 103: 3.2×10^{-9} W at 1.4 K, 5.5×10^{-9} W at 4.2 K, 9.6×10^{-9} W at 77 K

Thermal response time 0.5 s at 4.2 K, 2.5 s at 77 K

Use in radiation Recommended—see Appendix B

Use in magnetic field[3] Recommended—see Appendix B

Reproducibility[4] ±15 mK

Soldering standard J-STD-001 Class 2

1 102B does not follow a standard curve

2 Recommended excitation for T < 1 K based on Lake Shore calibration procedures using an AC resistance bridge—for more information refer to Appendix D and Appendix E

3 102B not recommended for use in magnetic fields

4 Short-term reproducibility data is obtained by subjecting sensor to repeated thermal shocks from 305 K to 4.2 K

Range of use

	Minimum limit	Maximum limit
RX-102A-AA	0.05 K	40 K
RX-202A-AA	0.05 K	40 K
RX-103A-AA	1.4 K	40 K

Long-term stability

	RX-102A-AA	RX-202A-AA	RX-103A-AA
4.2 K	±30 mK	±50 mK	±15 mK

Calibrated accuracy[5]

	RX-102A-AA	RX-202A-AA	RX-103A-AA
20 mK	—	—	—
50 mK	—	—	—
1.4 K	±16 mK	±16 mK	±16 mK
4.2 K	±16 mK	±16 mK	±17 mK
10 K	±18 mK	±18 mK	±22 mK

5 $[(\text{Calibration uncertainty})^2 + (\text{reproducibility})^2]^{0.5}$ for more information see Appendices B, D, and E

Accuracy: interchangeability

	RX-102A-AA-M matched	RX-102A-AA unmatched	RX-202A-AA-M matched	RX-202A-AA unmatched	RX-103A-AA-M matched	RX-103A-AA unmatched
0.05 K	±5 mK	±10 mK	±10 mK	±15 mK	—	—
0.3 K	±15 mK	±20 mK	±20 mK	±25 mK	—	—
0.5 K	±20 mK	±25 mK	±25 mK	±30 mK	—	—
1.4 K	±25 mK	±50 mK	±50 mK	±100 mK	±50 mK	±150 mK
4.2 K	±75 mK	±125 mK	±150 mK	±250 mK	±100 mK	±400 mK
20 K	±500 mK	±1.25 K	±1 K	±2.5 K	±700 mK	±2 K
40 K	±1.5 K	±4 K	±2 K	±5 K	±1.5 K	±4 K

Temperature response data table (typical)—See Appendix G for expanded response table

	102A			202A			103A		
	R (Ω)	dR/dT (Ω/K)	(T/R)·(dR/dT)	R (Ω)	dR/dT (Ω/K)	(T/R)·(dR/dT)	R (Ω)	dR/dT (Ω/K)	(T/R)·(dR/dT)
0.05 K	63765	-2888654	-2.27	69191	-3186379	-2.3	—	—	—
0.1 K	19400	-266199	-1.37	21927	-256913	-1.17	—	—	—
0.3 K	5615	-16647	-0.89	8079	-18420	-0.68	—	—	—
1.4 K	2005	-667	-0.47	3820	-879	-0.32	30745	-13571	-0.62
4.2 K	1370	-80.4	-0.25	2929	-124	-0.18	18149	-1559	-0.36
10 K	1167	-15.2	-0.13	2582	-31.6	-0.12	14083	-337	-0.24
20 K	1089	-3.96	-0.07	2389	-12.1	-0.1	12289	-102	-0.17
40 K	1049	-1.03	-0.04	2243	-4.6	-0.08	11137	-33	-0.12
40 K	1049	-1.06	-0.04	2244	-4.58	-0.08	11150	-21.7	-0.08

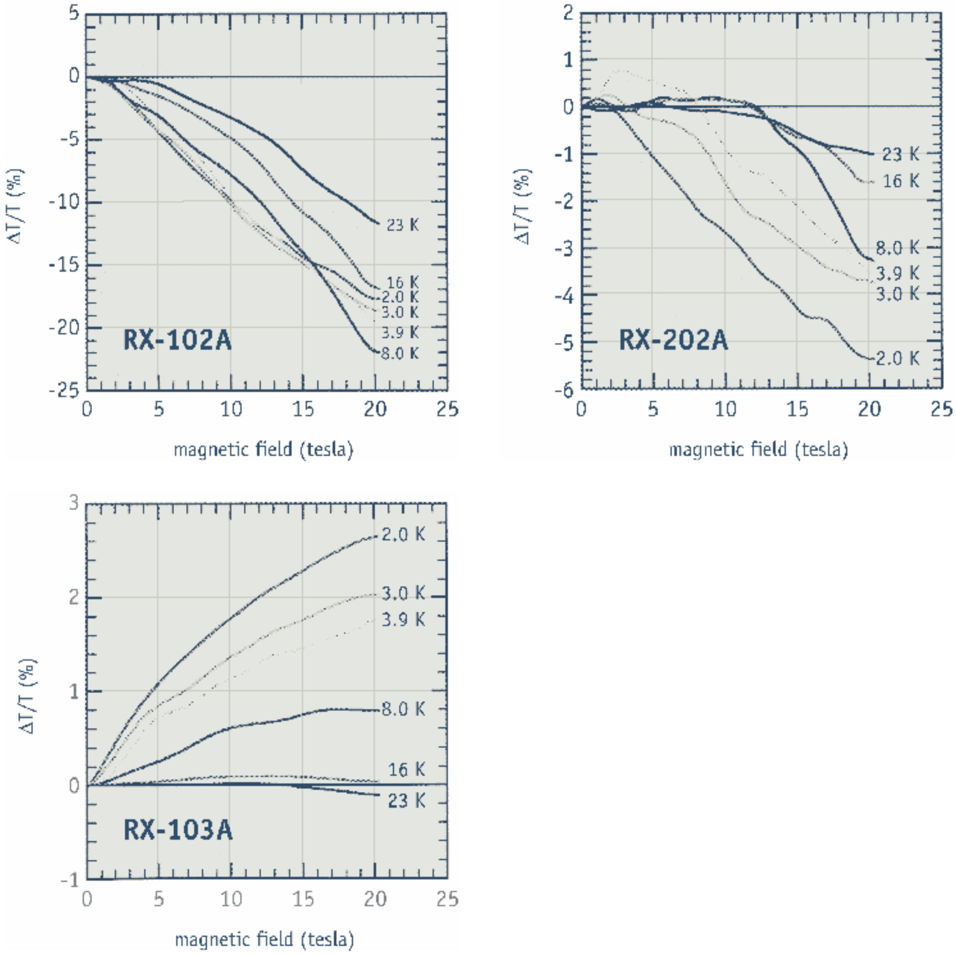
Typical magnetic field-dependent temperature errors ΔT/T (%) at B (magnetic induction)

Rox™ 102A	2.5 T	8 T	14 T	19 T
2 K	-1.4	-7.9	-13	-17
3 K	-1.5	-7	-14	-18
4 K	-0.56	-6.7	-14	-18
8 K	-1.3	-6.1	-13	-21
16 K	-0.40	-3.4	-9.6	-16
23 K	-0.31	-2.2	-6.2	-11

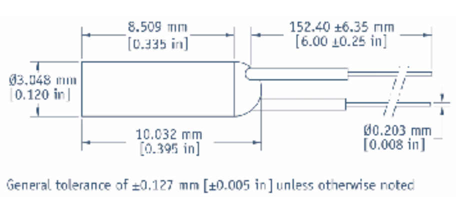
Rox™ 202A	2.5 T	8 T	14 T	19 T
2 K	-0.13	-2.2	-3.9	-5.2
3 K	0.18	-0.68	-2.7	-3.7
4 K	0.77	0.046	-1.8	-3.2
8 K	-0.023	0.16	-0.65	-3.0
16 K	0.03	0.16	-0.48	-1.5
23 K	-0.05	-0.08	-0.39	-0.92

Rox™ 103A	2.5 T	8 T	14 T	19 T
2 K	0.58	1.5	2.2	2.6
3 K	0.44	1.1	1.7	2.0
4 K	0.27	0.95	1.4	1.7
8 K	0.11	0.49	0.71	0.80
16 K	0.018	0.076	0.089	0.040
23 K	0.0051	0.0058	-0.0060	-0.095

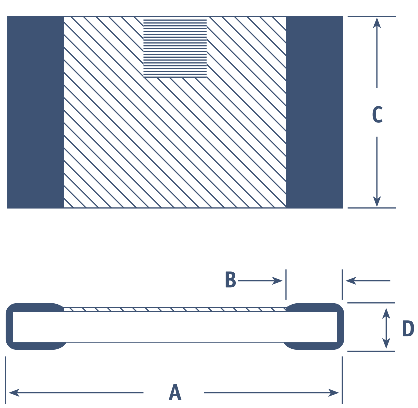
Magnetic field dependance data for sample interchangeable Rox™



RX-AA

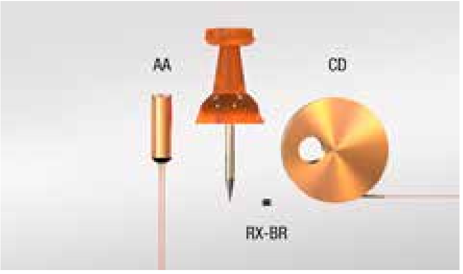


Bare chip (see table on 50)



Packaging options

For more information on sensor packages and mounting adapters, see page 20.



See the appendices for a detailed description of:
Installation
Uncalibrated sensors
SoftCal™
Calibrated sensors
CalCurve™
Sensor packages

To add length to sensor leads see page 25.

Packaging

The Rox™ 202A, 102A, and 103A sensors are available in the Lake Shore standard copper AA canister. Two are available as bare chips for applications requiring a smaller sensor or a faster thermal response time. The RX-102A-BR is a bare chip version of RX-102A. This bare chip features wrap-around noble metal contacts that can be soldered to using standard lead/tin solder. The RX-103A-BR is a bare chip version of the RX-103A. This bare chip has wrap-around pretinned contacts that can be soldered to using standard lead/tin solder. The pretinned contacts increase the sensor thickness from 0.25 mm to 0.41 mm. Leads are not attached to these models, so they are not available as matched or calibrated.

See the Physical Specifications for details and individual dimensions.

Physical specifications

	Mass	Lead type	Internal atmosphere	Materials used
RX-102A-AA	3.3 g	Two 6 in 32 AWG copper leads with heavy build Formvar® attached with epoxy strain relief at sensor–user should branch to 4 (no polarity)	Air	Thick ruthenium dioxide and bismuth ruthenate films with palladium silver contacts, indium solder, aluminum oxide substrate, sapphire header and copper canister with epoxy seal
RX-202A-AA	3.28 g			
RX-103A-AA	3.36 g			

Bare chip	A (chip length)	B (pad width)	C (chip width)	D (thickness)	Materials used
RX-102A-BR	1.45 mm (0.057 in)	0.30 mm (0.012 in)	1.27 mm (0.050 in)	0.65 mm (0.022 in)	Thick ruthenium dioxide and bismuth ruthenate films with palladium silver contacts
RX-103A-BR	1.40 mm (0.070 in)	0.21 mm (0.010 in)	1.23 mm (0.060 in)	0.41 mm (0.016 in)	

Ordering information

Rox™ RTD	Calibration range suffix codes Numeric figure is the low end of the calibration Letters represent the high end: B=40 K, M = matched *(calibration of matched sensors is available—consult Lake Shore)*			
Part number	Uncal	0.05B	0.3B	1.4B
RX-202A-AA, CD	■	■	■	■
RX-202A-AA-M	■			
RX-102A-AA, CD	■	■	■	■
RX-102A-AA-M	■			
RX-102A-BR	■			
RX-103A-AA, CD	■			■
RX-103A-AA-M	■			
RX-103A-BR	■			

Accessories available for sensors

8000-CD	Calibration report on CD-ROM
8000-USB	Calibration report on USB
COC-SEN	Certificate of conformance

Accessories suggested for installation—see Accessories section for full descriptions

Stycast® epoxy
Apiezon® grease
90% Pb, 10% Sn solder
Indium solder
VGE-7031 varnish
Phosphor bronze wire
Manganin wire

PT-100 Series Platinum RTDs

PT-100 Series features

- Temperature range: 14 K to 873 K (model dependant)
- Conforms to IEC 751 standards down to 70 K
- High reproducibility: ±5 mK at 77 K
- Low magnetic field dependence above 40 K
- Excellent for use in ionizing radiation
- SoftCal™ calibration available
- Non-magnetic packages available (PT-103 variants)

Matching

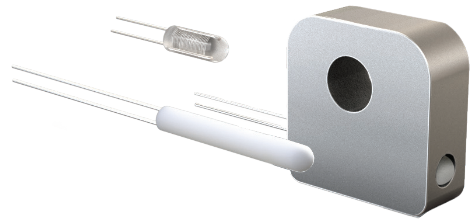
If your application requires more than one platinum resistor, up to five platinum resistors can be matched to one another to within ±0.1 K at liquid nitrogen temperature with the purchase of only one calibration.

PT-100 platinum resistance thermometers (PRTs) are an excellent choice for use as cryogenic temperature sensing and control elements in the range from 30 K to 873 K (-243 °C to 600 °C). Over this temperature span, PRTs offer high repeatability and nearly constant sensitivity (dR/dT). Platinum resistors are also useful as control elements in magnetic field environments where errors approaching one degree can be tolerated. PRTs are interchangeable above 70 K. The use of controlled-purity platinum assures uniformity from one device to another.

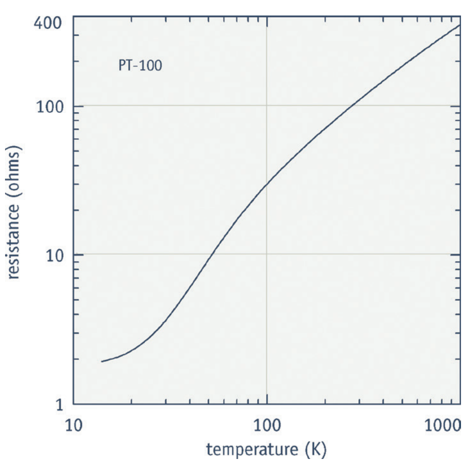
PRTs experience rapidly decreasing sensitivity below approximately 30 K. They should be calibrated in order to achieve maximum accuracy for use below 100 K. The plot illustrates platinum sensor conformance to the IEC 751 curve.

Packaging options

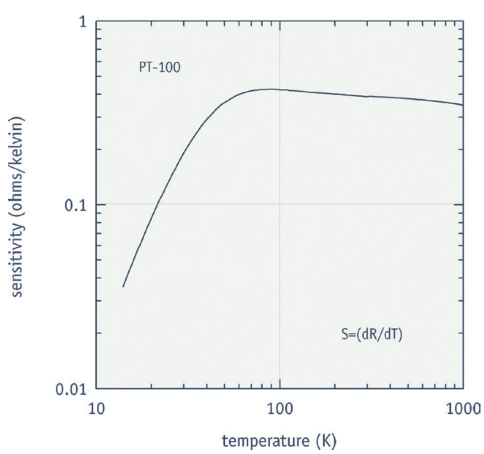
AL, AM



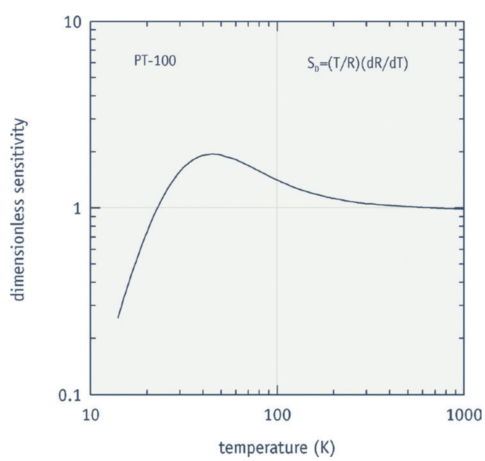
Typical platinum resistance



Typical platinum sensitivity



Typical platinum dimensionless sensitivity



Specifications

Standard curve IEC 751

Recommended excitation 1 mA

Dissipation at recommended excitation 100 µW at 273 K

Thermal response time PT-103: 1.75 s at 77 K, 12.5 s at 273 K; PT-111: 2.5 s at 77 K, 20 s at 273 K

Use in radiation Recommended for use in ionizing radiation environments—see Appendix B

Use in magnetic field Because of their relatively low magnetic field dependence above 30 K, platinum sensors are useful as control elements in magnetic field applications when some error can be tolerated—see Appendix B

Reproducibility[1] ±5 mK at 77 K

Soldering standard J-STD-001 Class 2

[1] Short-term reproducibility data is obtained by subjecting sensor to repeated thermal shocks from 305 K to 77 K

Range of use

	Minimum limit	Maximum limit
PT-103	14 K	873 K
PT-111	14 K	673 K

SoftCal™ accuracy

	30 K to 305 K	305 K to 400 K	400 K to 475 K	475 K to 500 K	500 K to 670 K
2S	±0.25 K	±0.9 K	±1.3 K	±1.4 K	±2.3 K
3S	±0.25 K	±0.25 K	±0.25 K	±1.4 K	±2.3 K

2S: 77 K and 305 K
3S: 77 K, 305 K and 480 K

Calibrated accuracy

	Typical sensor accuracy[2] Calibrations to 800 K	Typical sensor accuracy[2] All other calibrations	Long-term stability[3]
30 K	±10 mK	±10 mK	—
77 K	±12 mK	±12 mK	±10 mK
305 K	±23 mK	±23 mK	—
400 K	±210 mK	±41 mK	—
500 K	±210 mK	±46 mK	—
800 K	±310 mK	—	—

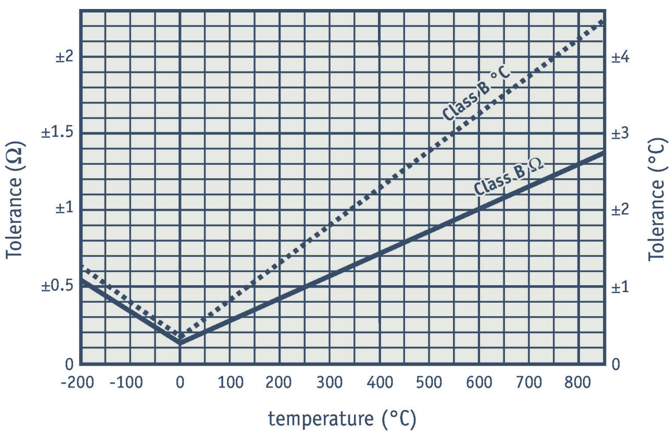
[2] $[(\text{Calibration uncertainty})^2 + (\text{reproducibility})^2]^{0.5}$ for more information see Appendices B, D, and E
[3] If not heated above 475 K—long-term stability data is obtained by subjecting sensor to 200 thermal shocks from 305 K to 77 K

Typical magnetic field-dependent temperature errors[4] ΔT/T (%) at B (magnetic field)

	Package parallel to field B 2.5 T	5 T	8 T	14 T	19 T
20 K	20	—	100	250	—
40 K	0.5	1.5	3	6	8.8
87 K	0.04	0.14	0.4	1	1.7
300 K	0.01	0.001	0.02	0.07	0.13

[4] Recommended for use when T ≥ 30 K

PT-100 Series interchangeability



Temperature response data table (typical)

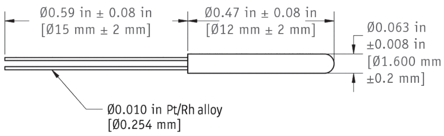
See Appendix G for expanded response table

	PT-100 R (Ω)	S (Ω/K)	(T/R)(dR/dT)
20 K	2.2913	0.085	0.74
50 K	9.3865	0.360	1.90
77 K	20.380	0.423	1.60
150 K	50.788	0.409	1.20
300 K	110.354	0.387	1.10
600 K	221.535	0.372	1.00
800 K	289.789	0.360	1.00

Physical specifications

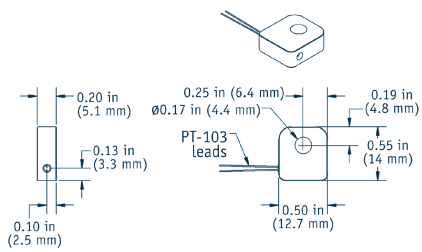
	Mass	Lead type	Internal atmosphere	Materials used	Maximum vacuum	Non-magnetic package
PT-103	120 mg	2, platinum	Fully filled powder	Platinum winding fully supported by a high temperature alumina powder inside a ceramic tube, platinum/rhodium lead wires	1×10^{-4} Pa	Yes
PT-111	52 mg	2, platinum-coated nickel	Solid glass	One platinum band wound onto a glass tube which is protected from the environment by a layer of glaze, platinum coated nickel lead wires	1×10^{-7} Pa	No

PT-103



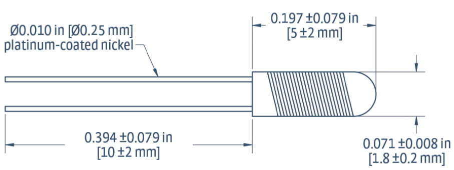
General tolerance of ±0.010 in [±0.254 mm] unless noted otherwise

PT-103-AM



General tolerance of ±0.010 in (±0.254 mm) unless noted otherwise

PT-111



Ordering information

Uncalibrated sensor—Specify the model number in the left column only, for example PT-103.
Calibrated sensor—Add the calibration range suffix code to the end of the model number, for example PT-103-14L.

Platinum RTD	Calibration range suffix codes Numeric figure is the low end of the calibration Letters represent the high end: S=SoftCal™, L=325 K, H = 500 K, J = 800 K					
Part number	Uncal	2S	3S	14L	14H	14J
PT-103	■	■	■	■	■	■
PT-103-AM	■	■	■	■	■	■
PT-111	■	■	■	■	■	

ADD -LN* Matching PT sensors to ±0.1 K at 77 K
**MUST be purchased with all matching sensors, as well as with the sensor to be matched*

Notes:
1. Upper temperature of AL and AM packages is limited to 800 K.
2. If your application requires more than one platinum resistor, up to five platinum resistors can be matched with one another to within ±0.1 K at liquid nitrogen temperature with the purchase of only one calibration. If absolute accuracy is required, one of these matched RTDs can be calibrated. For larger quantities, or for different requirements, consult Lake Shore. At the time of order, add -LN to the model number.
   Example: PT-103-14L-LN is a PT-103-LN RTD with a calibration range of 14 K to 325 K that is matched with at least one other uncalibrated PT-103 to within ±0.1 K at liquid nitrogen temperature.
3. For metrological applications below 30 K, use a germanium RTD. PT-100 sensors are not useful below 14 K for metrology and are of limited use below 30 K for temperature control, due to rapid decline in sensitivity.
4. For use above 500 K, anneal at T_{max} +10 °C for 4 h.

Accessories available for sensors
8000-CD Calibration report on CD-ROM
8000-USB Calibration report on USB
COC-SEN Certificate of conformance

USD VISA MasterCard AMERICAN EXPRESS PayPal

Accessories suggested for installation—see Accessories section for full descriptions

Stycast® epoxy	VGE-7031 varnish
Apiezon® grease	Phosphor bronze wire
90% Pb, 10% Sn solder	Manganin wire
Indium solder	CryoCable™

Packaging options

For more information on sensor packages and mounting adapters, see page 20.

See the appendices for a detailed description of:
Installation
Uncalibrated sensors
SoftCal™
Calibrated sensors
CalCurve™
Sensor packages

To add length to sensor leads see page 25.

Capacitance Temperature Sensors*

Capacitance features

- Virtually no magnetic field-induced errors
- Capable of mK control stability in the presence of strong magnetic fields
- Monotonic in C versus T to nearly room temperature

Patent #3,649,891, exclusively assigned to Lake Shore Cryotronics, Inc.

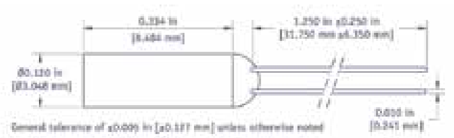
Temperature reproducibility

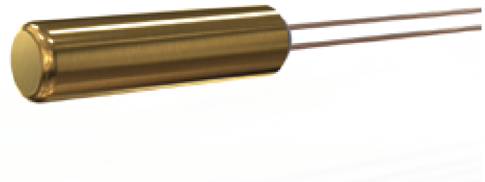
Over a period of days, thermal cycling of capacitance sensors can provide variations in their capacitance/temperature values equivalent to several tenths of a degree at 4.2 K, 77 K, and room temperature. Over longer periods of time, variations can reach one degree or more. However, any reduced capacitance, C(T)/C(4.2 K), is generally stable to within ±0.5 K. These variations, or shifts, in the temperature response curve have no effect on the sensor's stability when operating at a given temperature and, therefore, do not impair the sensor's primary function as a control element.

Capacitance sensors (CS) are ideally suited for use as temperature control sensors in strong magnetic fields because they exhibit virtually no magnetic field dependence. Displacement current is not affected by magnetic fields. Consequently, temperature control fluctuations are kept to a minimum when sweeping magnetic field or when changing field values under constant temperature operation.

Because small variations in the capacitance/temperature curves occur upon thermal cycling, calibrations must be transferred to the capacitor from another sensor after cooling for the best accuracy. It is recommended that temperature in zero field be measured with another temperature sensor and that the capacitance sensor be employed as a control element only.

CS-501GR





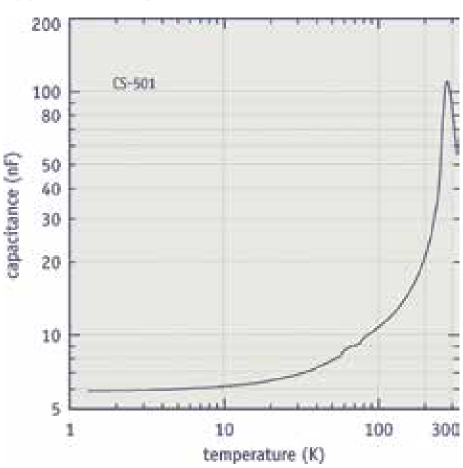
Temperature stability/ temperature transfer accuracy

Capacitance sensors will provide very stable control conditions for long periods of time at operating temperature, but because an operational "aging" phenomenon exists, care must be taken to account for this occurrence in their use.

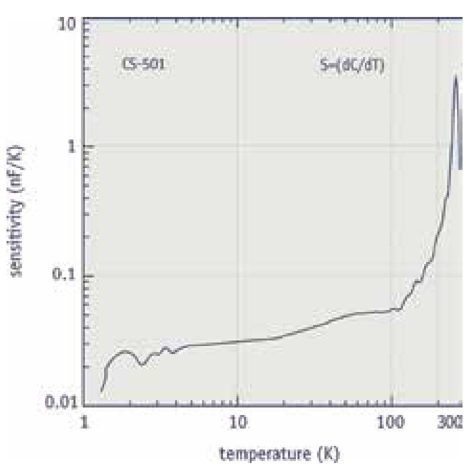
The variation in capacitance/temperature characteristics is likely the result of the time dependence of the dielectric constant and the dielectric loss, or "aging", that all ferroelectric dielectrics exhibit. This time dependence, which occurs as a short term drift (minutes to hours) in capacitance/temperature value, is initiated by disturbing the sensor thermally or by changing the voltage or frequency of excitation. To compensate for this, the sensor should be stabilized for one hour after initial cool-down to desired operating temperature and whenever significant adjustments in control temperature are made.

After the one hour stabilization, this short-term drift is on the order of a few tenths of a millikelvin per minute at 4.2 K, and several millikelvin per minute at 305 K. The drift is always in the direction of decreasing capacitance; consequently, it corresponds to decreasing temperature below 290 K.

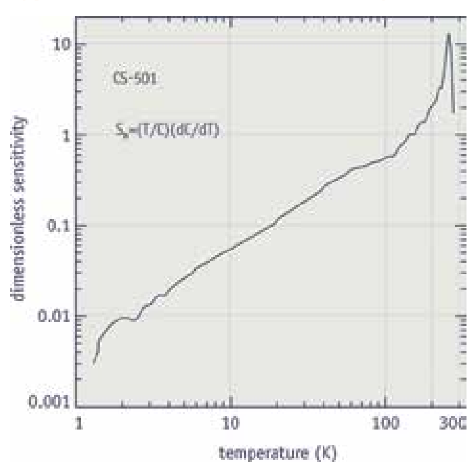
Typical CS capacitance



Typical CS sensitivity



Typical CS dimensionless sensitivity



Specifications

Standard curve Not applicable

Nominal capacitance 6.1 nF

Nominal sensitivity 26 pF/K

Accuracy (interchangeability) Not applicable

Accuracy (calibrated) Calibration should be performed in situ

Recommended excitation 1 to 5 kHz, 0 to 7 V peak to peak or any other acceptable capacitance measuring method

Dissipation at recommended excitation Not applicable

Expected long-term stability ±1.0 K/yr

Thermal response time Minutes, dominated by electronic setting time

Radiation effects Not available

Magnetic fields See table on right

Reproducibility See shaded box on previous page for detailed discussion

Soldering standard J-STD-001 Class 2

Range of use

	Minimum limit	Maximum limit
CS-501GR	1.4 K	290 K

Typical magnetic field-dependent temperature errors[1] ΔT/T (%) at B (magnetic induction)

Package parallel to field B	
	18.7 T
4.2 K	-0.15
77 K	<0.05

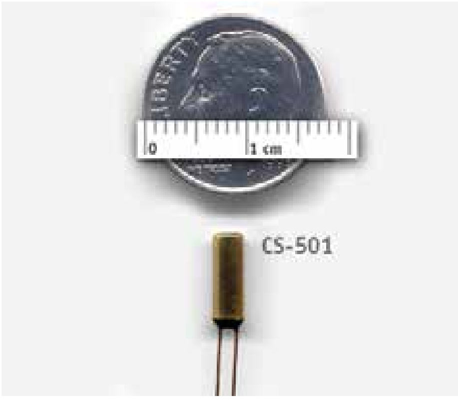
[1] Recommended for control purposes; monotonic in C vs T to nearly room temperature; frequency dependent

Physical specifications

	Size	Mass	Lead Type	Internal atmosphere
CS-501	3.0 mm × 8.5 mm long	260 mg	2 phosphor bronze with heavy build polyimide attached with epoxy strain relief at sensor	Air

Packaging options

For more information on sensor packages and mounting adapters, see page 20.



See the appendices for a detailed description of:
Installation
Uncalibrated sensors
SoftCal™
Calibrated sensors
CalCurve™
Sensor packages

To add length to sensor leads see 25.

Ordering Information

Capacitance sensor	Uncalibrated sensor Specify part number CS-501GR
Part number	Uncal
CS-501GR	■

Accessories suggested for installation—see Accessories section for full descriptions
Stycast® epoxy
Apiezon® grease
90% Pb, 10% Sn solder
Indium solder
VGE-7031 varnish
Phosphor bronze wire
Manganin wire
CryoCable™

USD VISA PayPal

Thermocouple Wire

Thermocouple features

- Type E (chromel-constantan) has the highest sensitivity among the standard thermocouple types typically used at low temperatures. The best choice for temperatures down to 40 K.
- Type K (chromel-alumel) Recommended for continuous use in inert atmospheres. Has a sensitivity of 4.1 mV/K at 20 K (about ½ of Type E).

Thermocouple wire is used in a variety of cryogenic applications, but special techniques must be employed to approach temperature accuracies of 1% of temperature, even without consideration for the effects of high magnetic fields or high radiation fluxes. The problems are further complicated by exposure to variable gradient conditions at cryogenic temperatures.

Many Lake Shore temperature controllers offer inputs that accommodate most common types of cryogenic thermocouple wire in use.

Note:

Heat conduction down the thermocouple wire is the same as with lead wire going to any other sensing device. Refer to Appendix C: Conduction (Lead Attachment) for more detailed information.

See Appendix G for thermocouple curve data.

Typical magnetic field-dependent temperature errors[1] ΔT/T (%) at B (magnetic induction)

	Type E thermocouple[2]		
	2.5 T	8 T	14 T
10 K	1	3	7
20 K	<1	2	4
45 K	<1	<1	2

[2] *Useful when T ≥ 10 K. Refer to comments for chromel-AuFe (0.07%)*

Range of use

	Minimum limit	Maximum limit[3]
Type E	3.15 K	953 K
Type K	3.15 K	1543 K

[3] *Upper limit dependent on wire size; to achieve higher than 473 K, insulation must be removed*

Part number Explanation

TC = Thermocouple
Y = Wire type, E or K
ZZ = Wire diameter excluding insulation
XX = Wire length in meters

	Wire gauge	
	30 AWG	36 AWG
Type E	TC-E-30-XX	TC-E-36-XX
Type K	TC-K-30-XX	TC-K-36-XX

Ordering information

Thermocouple wire	36 AWG = 0.005 in (0.127 mm) diameter wire, excluding insulation 30 AWG = 0.010 in (0.254 mm) diameter wire, excluding insulation All thermocouple wire is Teflon® insulated—76.2 µm wall
Part number	**Description**
TC-Y-ZZ-03	Thermocouple wire — 3 m
TC-Y-ZZ-06	Thermocouple wire — 6 m
TC-Y-ZZ-10	Thermocouple wire — 10 m
TC-Y-ZZ-20	Thermocouple wire — 20 m
TC-Y-ZZ-50	Thermocouple wire — 50 m

USD VISA MasterCard American Express PayPal