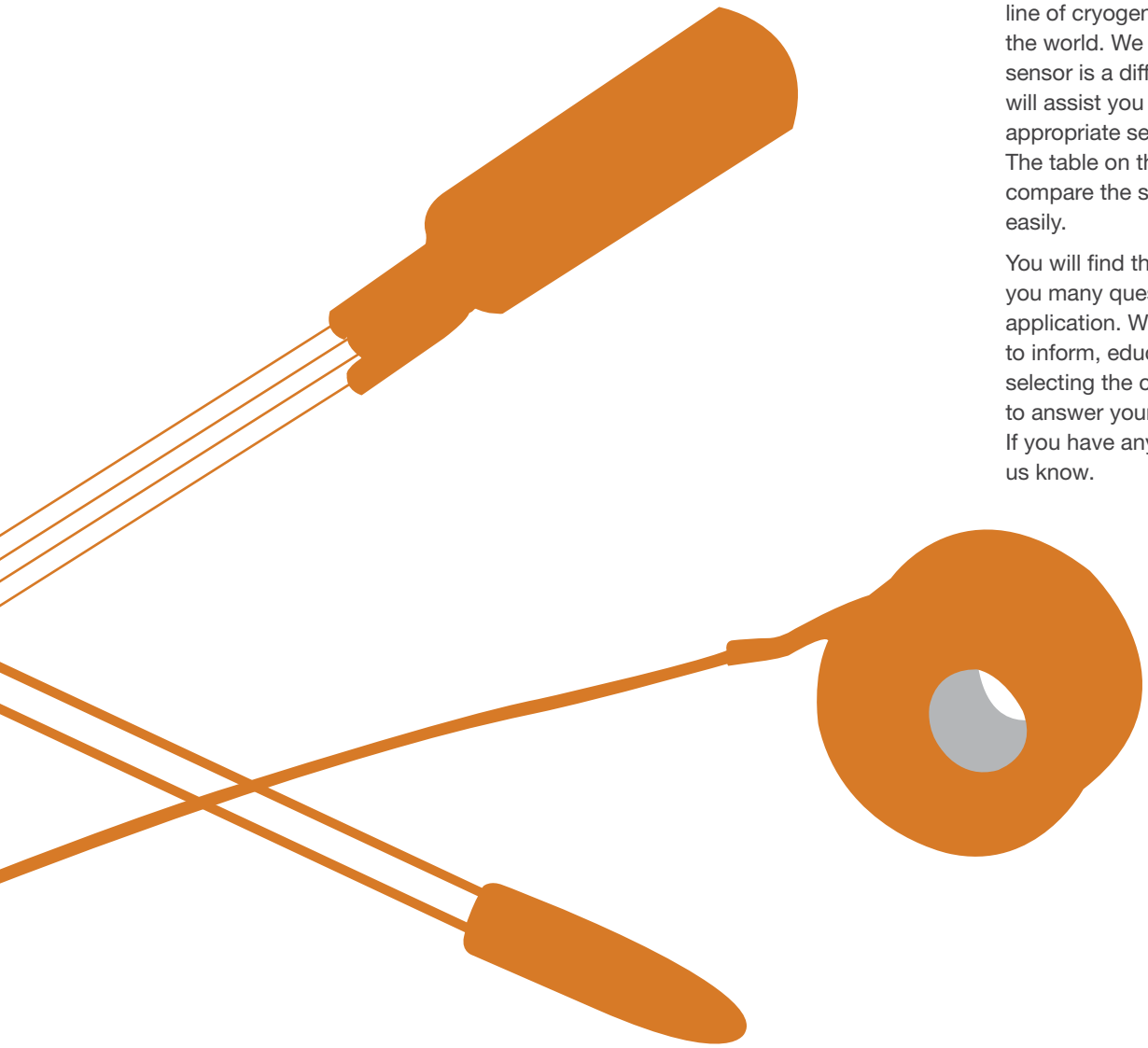
Sensor Selection Guide



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.

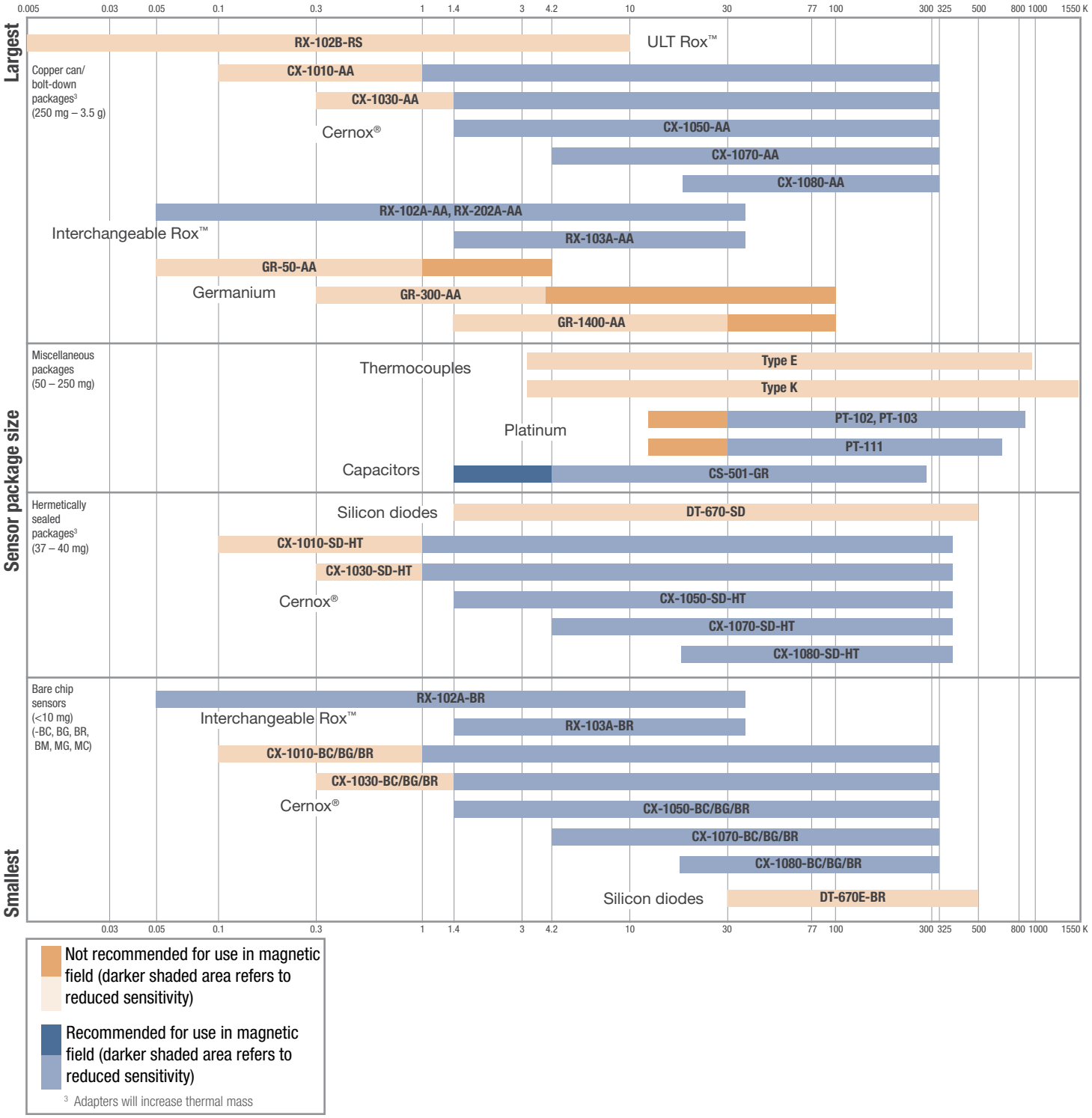
Sensor Characteristics

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



Not recommended for use in magnetic field (darker shaded area refers to reduced sensitivity)

Recommended for use in magnetic field (darker shaded area refers to reduced sensitivity)

[3] Adapters will increase thermal mass

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)

	T(K)	Magnetic flux density B 2.5 T	8 T	14 T	19 T	Notes
Cernox® 1050 (CX series)	2	1.3	3.1	3.9	5	Best sensor for use in magnetic field (T > 1 K)
	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 range. Consistent behavior between devices in magnetic fields.
	3	-1.5	-7	-14	-18	
	4	-0.56	-6.7	-14	-18	
	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. Predictable behavior.
	3	0.44	1.1	1.7	2.0	
	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 range. Consistent behavior between devices in magnetic fields.
	3	0.18	-0.68	-2.7	-3.7	
	4	0.77	0.046	-1.8	-3.2	
	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 (PT series)	20	20	100	250	—	Recommended for use when T ≥ 40 K.
	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 ΔT/T(%) <0.05 at 77 K and 305 K and 18.7 tesla				Recommended for control purposes. Monotonic in C vs. T to nearly room temperature.
Germanium resistors (GR series)	2.0	-8	-60	—	—	Not recommended except at low B owing to large, orientation-dependent temperature effect.
	4.2	-5 to -20	-30 to -55	-60 to -75	—	
	10	-4 to -15	-25 to -60	-60 to -75	—	
	20	-3 to -20	-15 to -35	-50 to -80	—	
Type E thermocouples (chromel-constantan)	10	1	3	7	—	Useful when T ≥ 10 K. Refer to notes for Chromel-AuFe (0.07%).
	20	<1	2	4	—	
	455	<1	<1	2	—	

	T(K)	1 T	2 T	3 T	4 T	5 T	Notes
Silicon diodes Junction parallel to field (DT series)	4.2	-200	-300	-350	-400	-500	Strongly orientation dependent.
	20	-10	-20	-25	-30	-40	
	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 Junction perpendicular to field (DT series)	4.2	-8	-9	-11	-15	-20	Strongly orientation dependent.
	20	-4	-5	-5	-5	-10	
	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	—	—	—

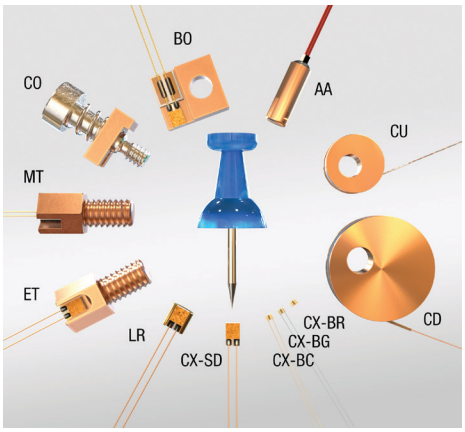
[12]All accuracies are: 2 σ figures; $[(\text{calibration uncertainty})^2 + (\text{reproducibility})^2]^{0.5}$; for additional information, please see Appendix D.

Sensor Packages and Mounting Adapters

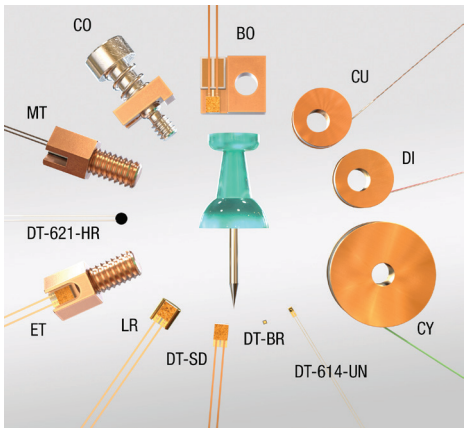
Temperature sensors are available in a variety of packages to facilitate mounting. Included are adapters that allow the sensor to be soldered in place, screwed on, bolted down, inserted into a hole, or inserted through a pressure seal in the form of a thermowell. Gold-plated copper bobbins are available 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

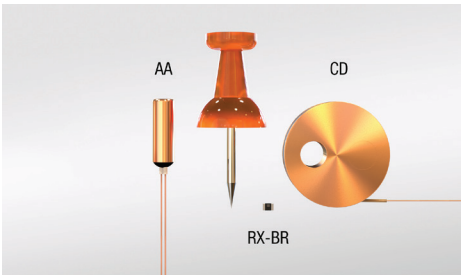
Packages



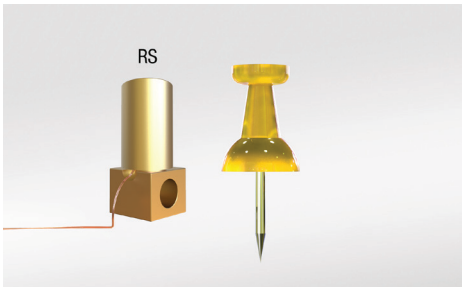
Cernox® packages



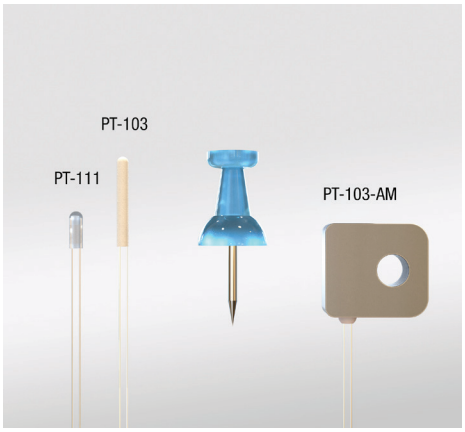
Silicon diode packages



Interchangeable Rox™ packages



Ultra low temperature Rox™ package



Platinum packages

Capacitance package

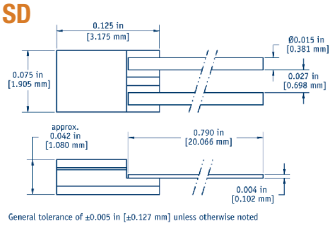
Unique packages

see individual sensor pages

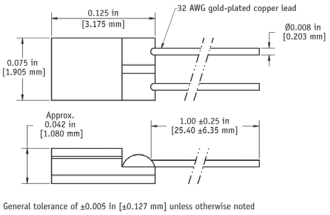
PT-103	CX-10XX-BC
PT-111	CX-10XX-BG
	CX-10XX-BR
	RX-102B-RS

The Lake Shore Hermetically Sealed SD Package

SD



SD (Cernox®)

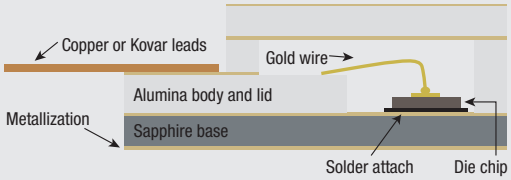


- Small package designed primarily for bonding or clamping to a flat surface
- Indium, silver epoxy, 2850 Stycast® epoxy, or a CO clamp may be used for mounting

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 60/40 SnPb
Mass:	0.03 g
Limitation:	The useful upper temperature limit of this configuration is 500 K

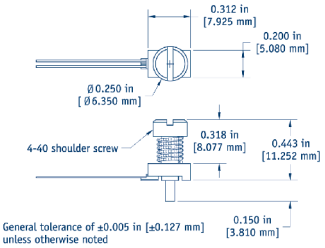
The Lake Shore SD package—the most rugged, versatile package in the industry

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

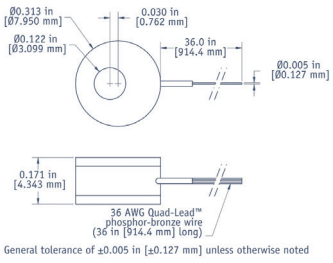
CO



- 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

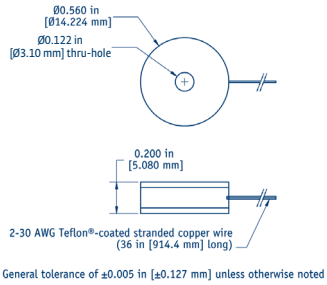
- SD packaged sensor indium-soldered into a flat copper bobbin with the leads thermally anchored to that same bobbin
- HT (high temperature) version is soldered using high temperature (90% Pb, 10% Sn) solder
- Can be mounted to any flat surface with a 4-40 screw

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)

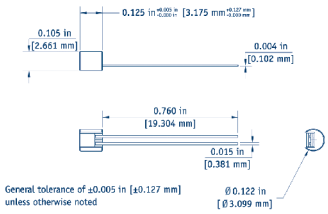
CY



- 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

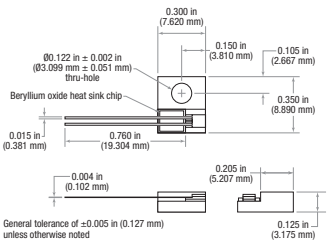
LR



- 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

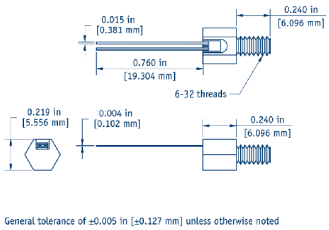
BO



- 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

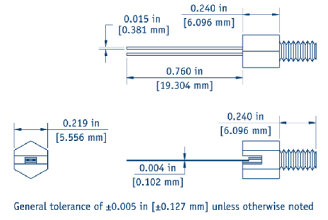
ET



- 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

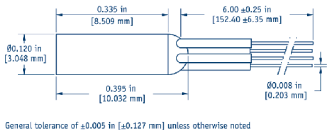


- The MT package is similar to the ET version except the SD package is mounted in a slot in the center of the hexagonal head and the stud is a 3 mm × 0.5 metric thread

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

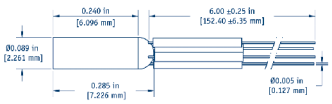
AA



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

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

B



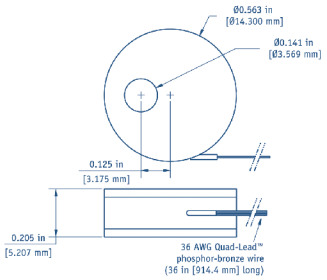
General tolerance of ±0.005 in [±0.127 mm] unless otherwise noted

- 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



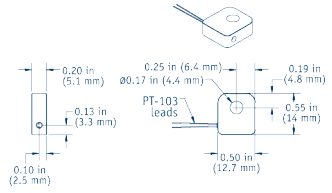
General tolerance of ±0.005 in [±0.127 mm] unless otherwise noted

- 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.