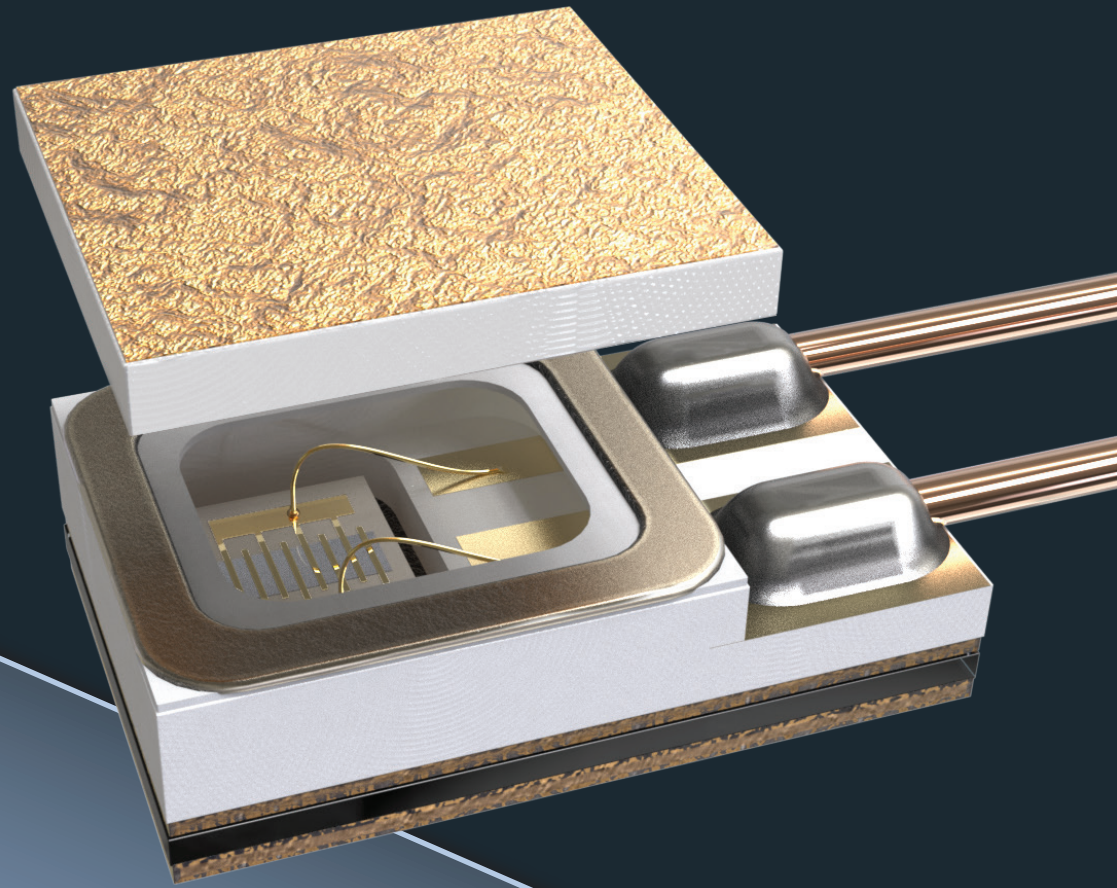
Temperature Sensor
SELECTION GUIDE



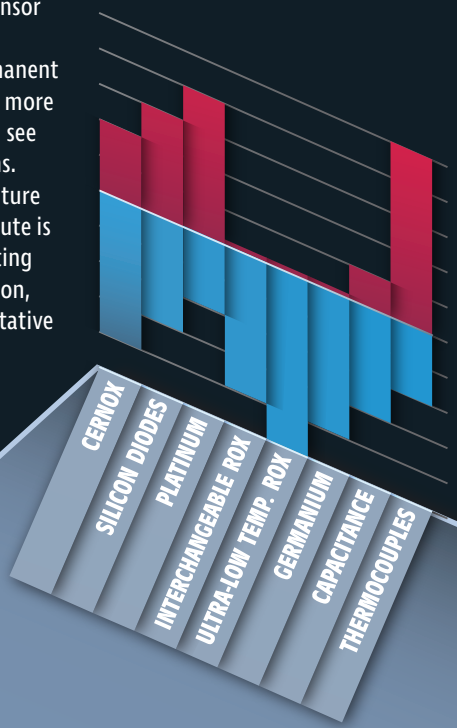
Lake Shore
CRYOTRONICS
a **DwyerOmega** brand

SENSOR ATTRIBUTE SUMMARIES

Each sensor has been given a rating for six attributes or characteristics. These ratings give a general idea of how a sensor will perform and aid in the early decision making process, but are not a substitute for detailed specifications. Sensor summaries begin on page 5.

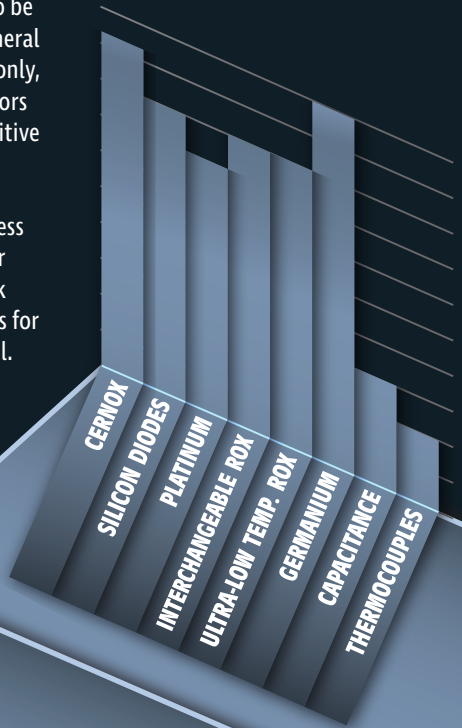
TEMPERATURE RANGE

It is important to select sensors that suit the temperature range of the intended system. The low-end temperature rating generally indicates where the sensor type starts to perform poorly, whereas the upper rating is the point where the sensor will begin to sustain permanent damage. For more information, see specifications. The Temperature Range attribute is a relative rating for comparison, not a quantitative measure.



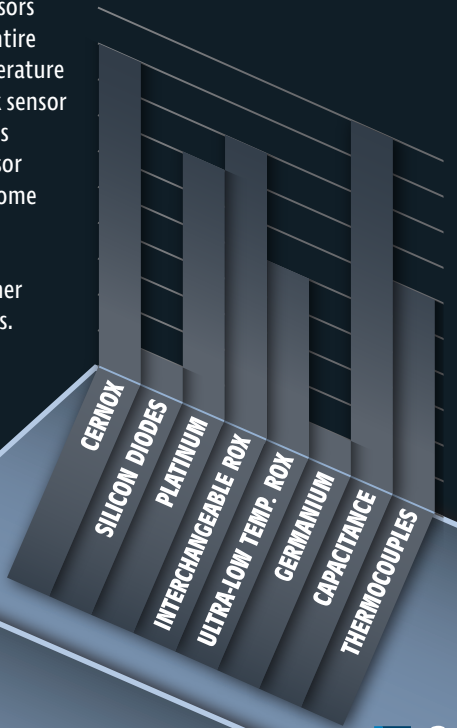
ACCURACY AND RESOLUTION

The Accuracy and Resolution rating for each sensor type takes into account the amount of uncertainty in the measurement by the sensor with respect to an absolute standard, as well as sensitivity over the temperature range of interest. These ratings are to be used as a general comparison only, as some sensors are very sensitive over narrow temperature ranges, but less sensitive over others. Check specifications for greater detail.



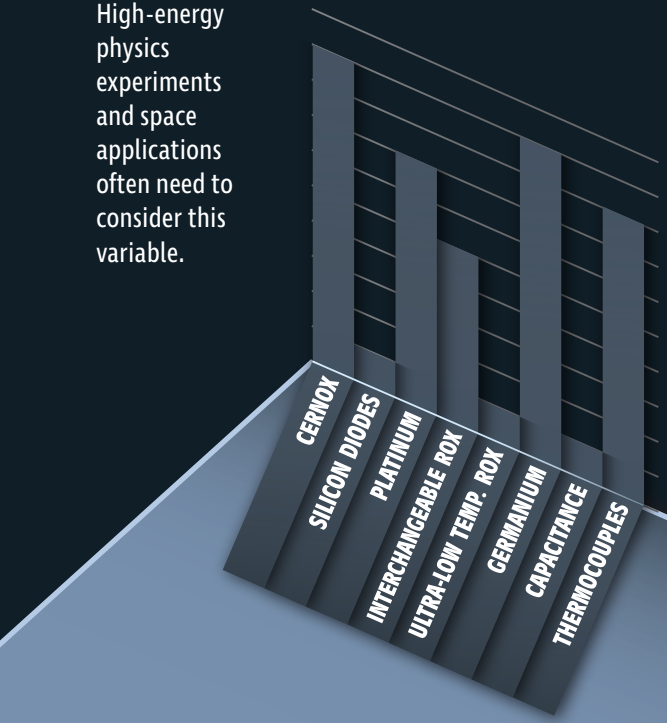
MAGNETIC RESILIENCE

The Magnetic Resilience rating for each sensor type is a comparative rating of the sensor's accuracy in magnetic field. The higher the rating, the less the sensor shifts when exposed to magnetic field. This is a general comparison between sensors across the entire sensor temperature range. Check sensor specifications for each sensor as many become resilient to magnetic fields at higher temperatures.



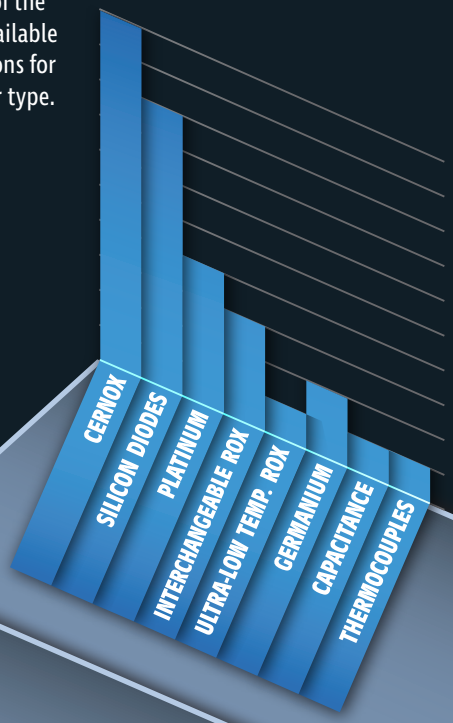
RADIATION RESILIENCE

The Radiation Resilience rating is a measure of a sensor's ability to withstand exposure to ionizing radiation. Sensors with a high rating will have a greater ability to stay within calibration after exposure. High-energy physics experiments and space applications often need to consider this variable.



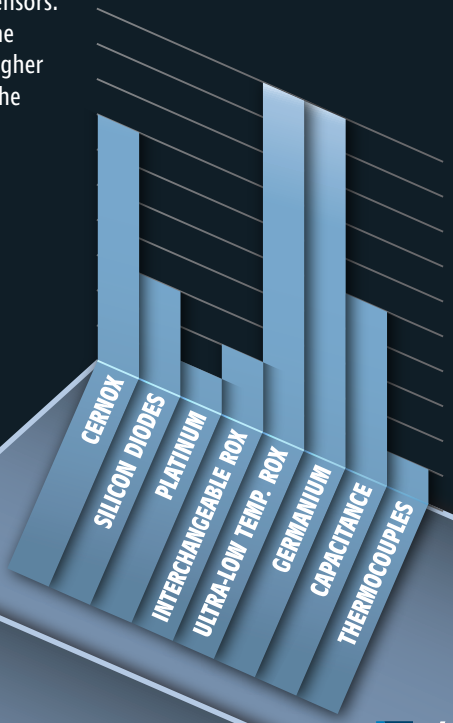
PACKAGE OPTIONS

Good thermal contact is vital when making cryogenic temperature measurements. Having a wide range of packaging options will make it easier to find a solution that is optimal for a given system. The Package Options rating is a measure of the number of available package options for a given sensor type.



PRICE

Each sensor type has been given a rating for price. This rating takes into account the total price of the sensor type without the addition of package options, and should only be used as a tool to compare Lake Shore sensors. The higher the rating, the higher the price of the sensor.



SENSOR TYPES

Lake Shore offers an extensive range of cryogenic temperature sensors. The following sensor summaries compare the performance and features of these sensors.

CERNOX®

Specifically designed by Lake Shore for the demanding requirements of cryogenic applications, Cernox thin film RTD sensors offer extremely consistent high-resolution measurements over a wide temperature range. Due to the materials used and the physical structure of the chip, Cernox sensors are inherently resistant to magnetic-field induced offsets and damage by ionizing radiation. This makes Cernox the first choice for any traditional cryostat system.

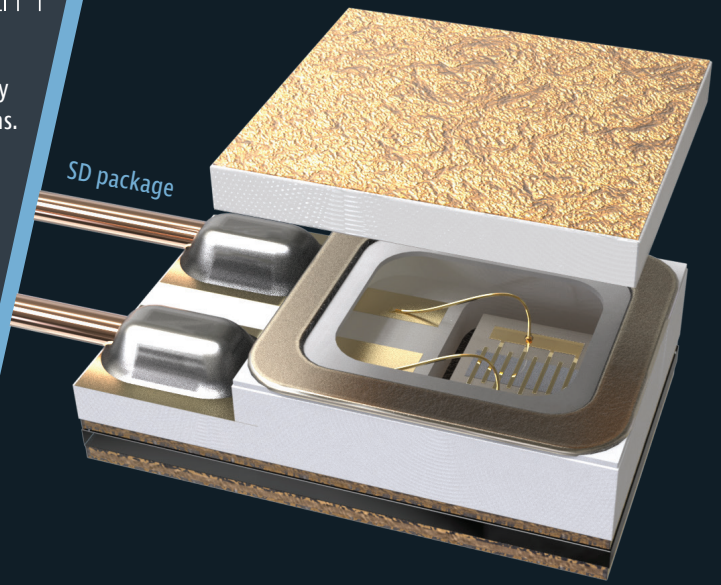


HR SERIES HIGH RELIABILITY

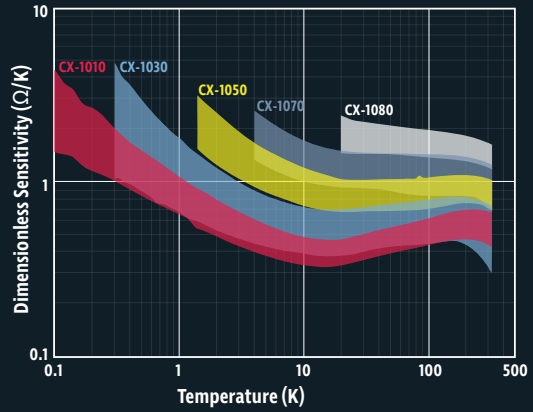
Cernox sensors are also available as a high-reliability variant for space applications.

KEY FEATURES

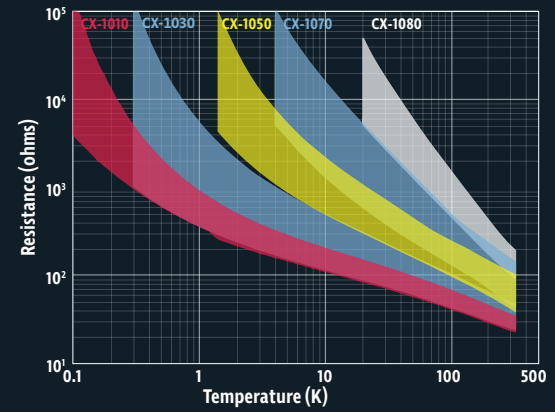
- Very tolerant to ionizing radiation
- Excellent performance in magnetic field
- Extremely consistent, wide temperature range



TYPICAL CERNOX® DIMENSIONLESS SENSITIVITY



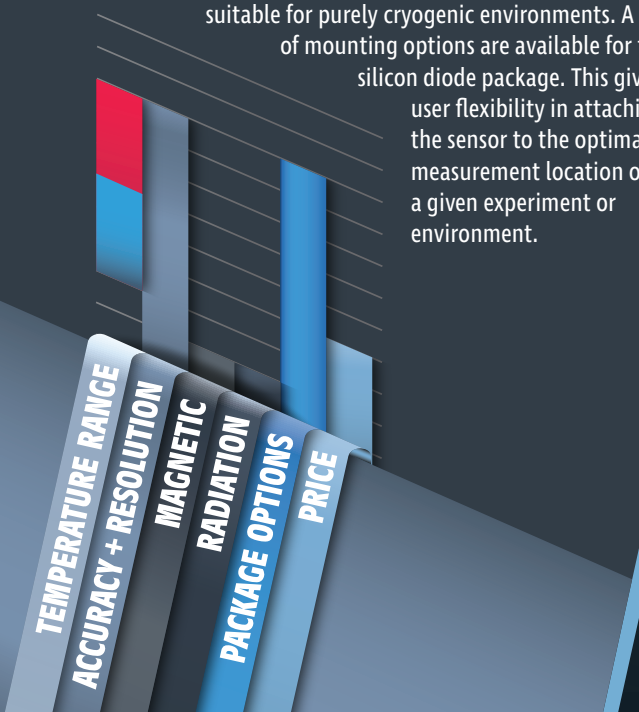
TYPICAL CERNOX® RESISTANCE



SILICON DIODES

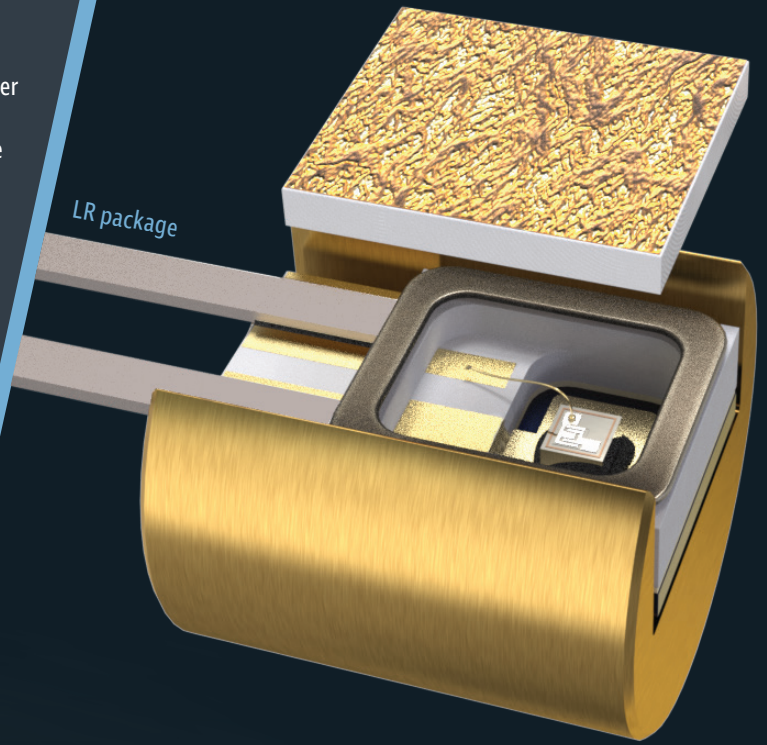
Silicon diodes are an excellent general purpose sensor with a wide operating temperature range, from 1.4 K to 500 K. With their adherence to a standard curve, silicon diodes are interchangeable. This makes them less complicated to operate and maintain. Silicon diodes have excellent accuracy and resolution below 30 K, making them an outstanding choice below these temperatures. Above 30 K their sensitivity is reduced.

Due to orientation dependent magnetic offsets and a high susceptibility to ionizing radiation, silicon diodes are only suitable for purely cryogenic environments. A number of mounting options are available for the silicon diode package. This gives the user flexibility in attaching the sensor to the optimal measurement location of a given experiment or environment.

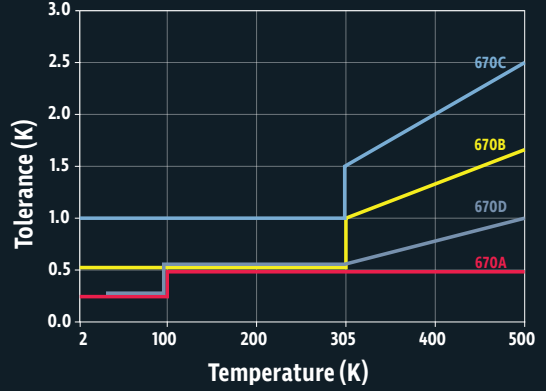


KEY FEATURES

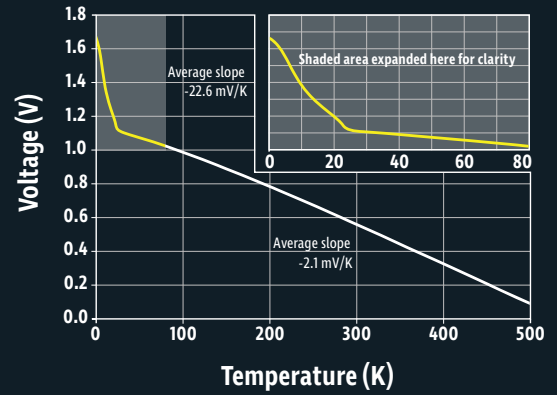
- Useful temperature range from 1.4 K to 500 K
- Interchangeable using a standard curve



CURVE DT-670 TOLERANCE BANDS



CURVE DT-670 TOLERANCE BANDS

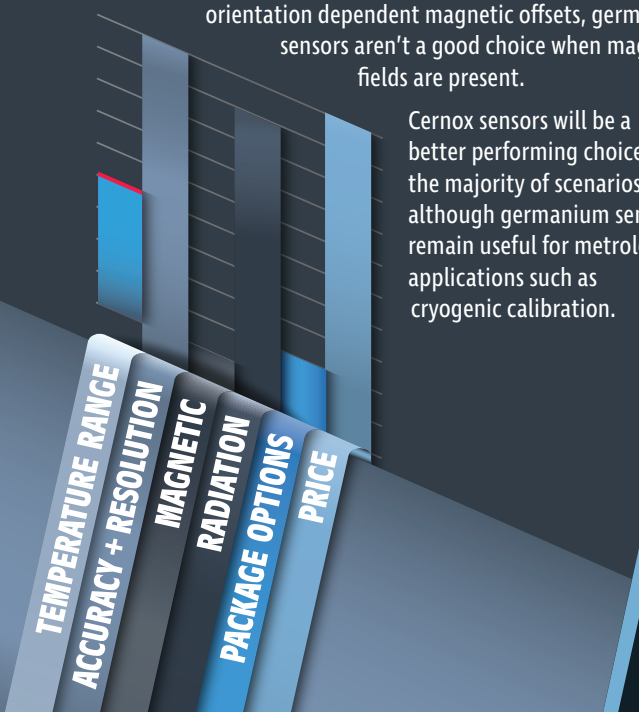


GERMANIUM

Lake Shore germanium resistance temperature sensors are recognized as Secondary Standard Thermometers due to their excellent long-term stability, however, this advantage comes at a cost. Germanium sensing elements must be mounted without strain inside the package, leaving AA and CD packages the only choices available. These sensors are not useful above 30 K due to reduced sensitivity, but are highly accurate and precise from 1 K down to 0.05 K.

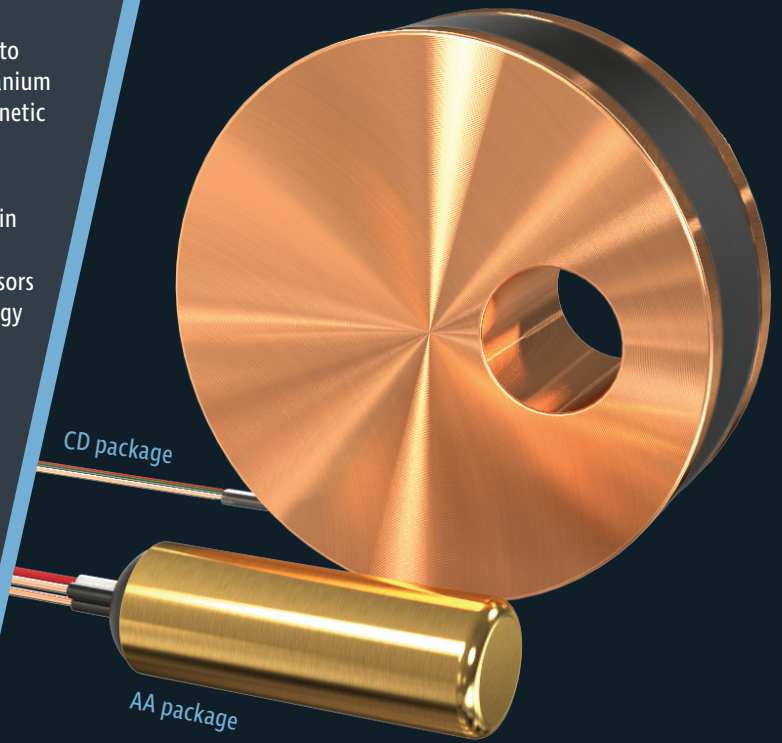
Because the germanium sensing element is susceptible to orientation dependent magnetic offsets, germanium sensors aren't a good choice when magnetic fields are present.

Cernox sensors will be a better performing choice in the majority of scenarios, although germanium sensors remain useful for metrology applications such as cryogenic calibration.

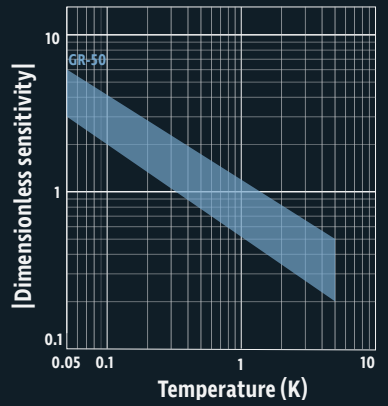


KEY FEATURES

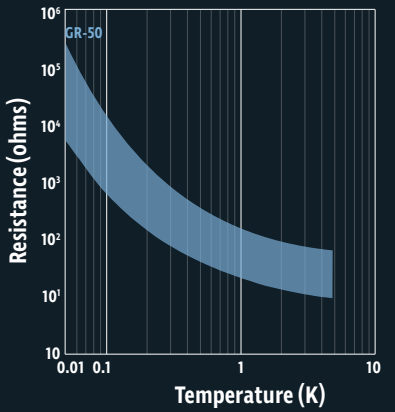
- Highly stable and accurate



GERMANIUM DIMENSIONLESS SENSITIVITY



TYPICAL GERMANIUM RESISTANCE

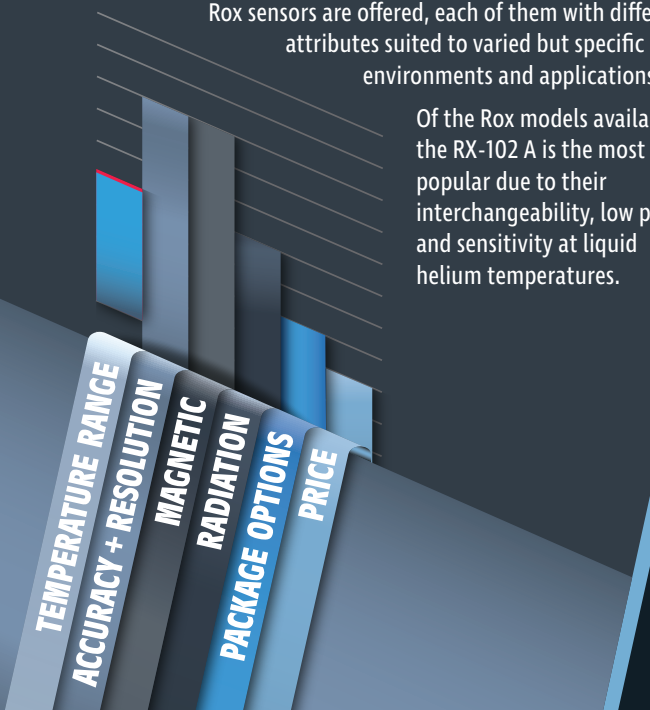


INTERCHANGEABLE ROX™

The Rox family are all ruthenium-oxide RTDs, but have quite different characteristics. In general, these are low-temperature sensors with useful maximum temperatures of 40 K or less. Most Rox™ sensors are consistent enough to be considered interchangeable, with two accuracy bands available with each sensor model.

Rox sensors are not suited for environments with ionizing radiation and also experience measurement shifts when exposed to magnetic fields, though these shifts can be compensated for. Four different Rox sensors are offered, each of them with different attributes suited to varied but specific environments and applications.

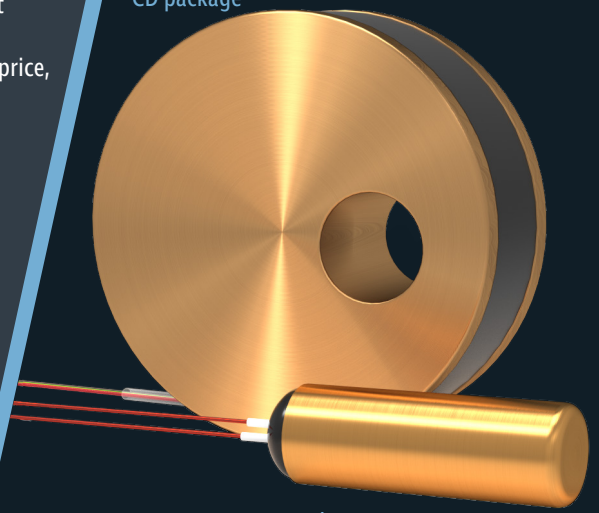
Of the Rox models available, the RX-102 A is the most popular due to their interchangeability, low price, and sensitivity at liquid helium temperatures.



ROX™ 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

CD package



AA package

RX-102A

- Interchangeable
- Useful range of operation from 50 mK to 10 K

RX-202A

- Interchangeable
- Useful range of operation from 50 mK to 300 K

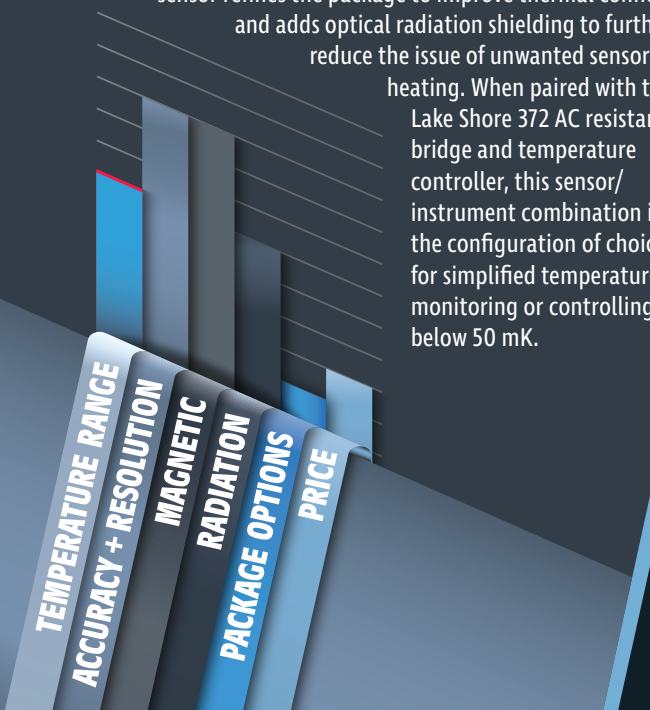
RX-103A

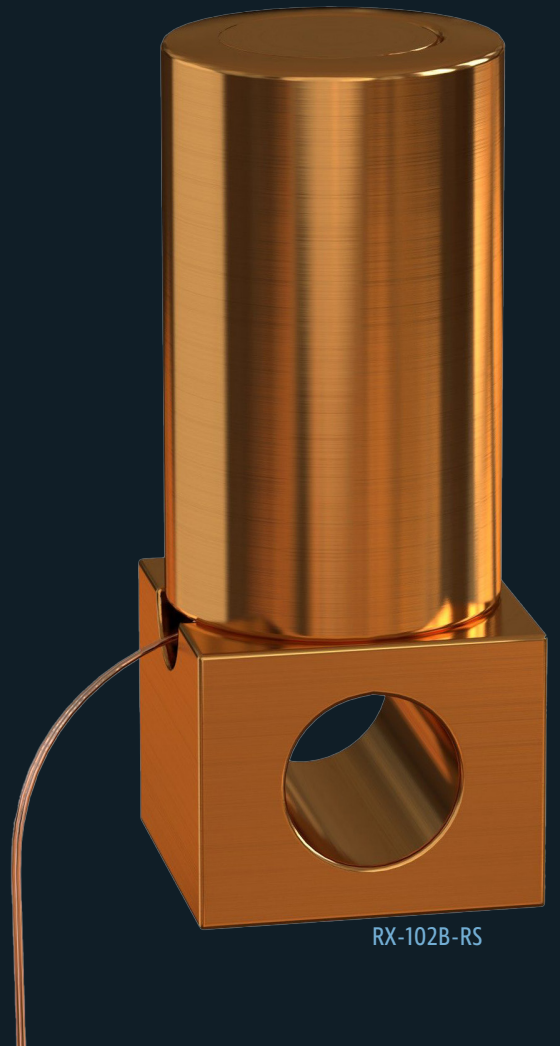
- Interchangeable
- Useful range of operation from 1.4 K to 40 K

ULTRA-LOW TEMPERATURE ROX™

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.



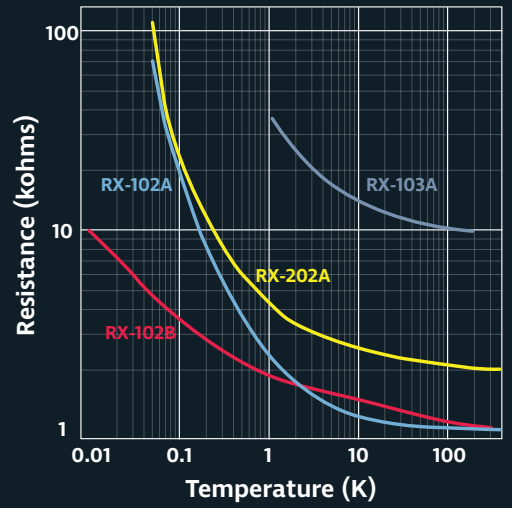


RX-102B-RS

RX-102B-RS

- Ultra-low temperature sensing down to 20 mK
- Only sensor option capable of measuring below 50 mK

TYPICAL ROX™ RESISTANCE

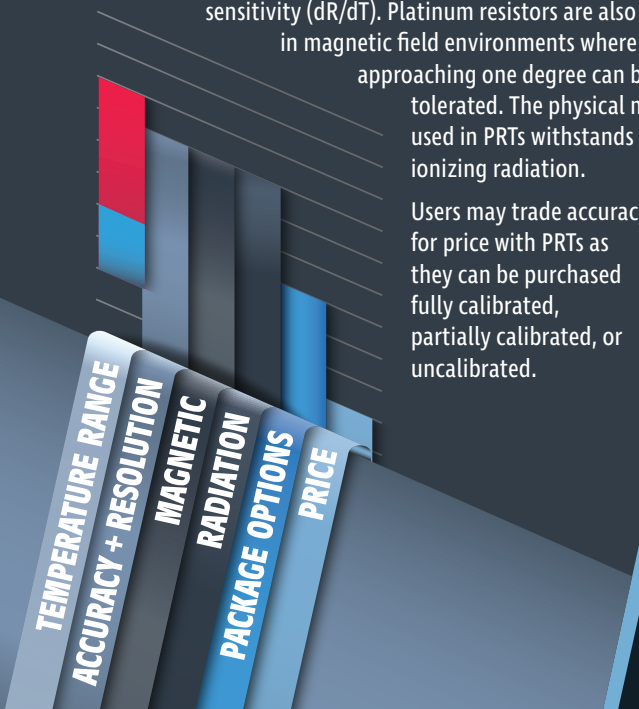


PLATINUM

Platinum resistance thermometers (PRTs) are very popular due to their low price and are useful in higher temperature systems with operating ranges from liquid nitrogen temperatures (77.35 K) to many hundreds of degrees Celsius, the only sensor capable of reading higher being thermocouples. Lake Shore's 100 Ω PRTs adhere to the ISO standard temperature curve but have also been characterized for viable operation down to 14 K, making them the lowest temperature PRTs available.

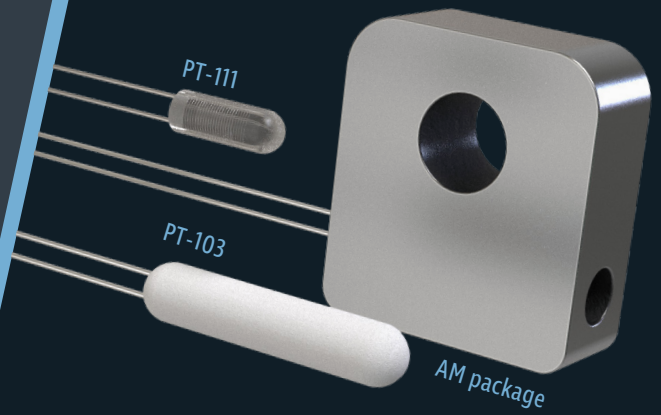
Above 70 K, PRTs offer high repeatability and nearly constant sensitivity (dR/dT). Platinum resistors are also useful in magnetic field environments where errors approaching one degree can be tolerated. The physical material used in PRTs withstands ionizing radiation.

Users may trade accuracy for price with PRTs as they can be purchased fully calibrated, partially calibrated, or uncalibrated.

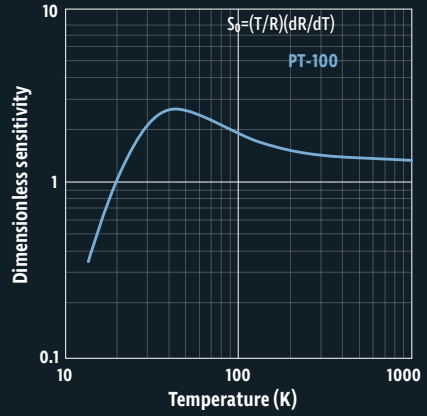


KEY FEATURES

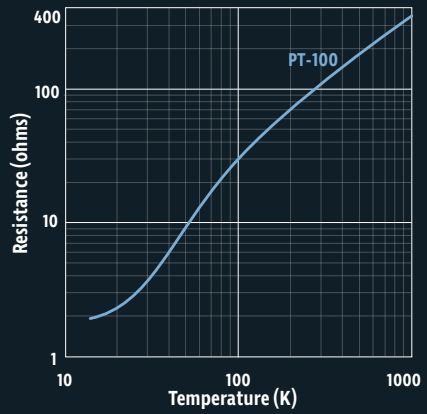
- Useful upper temperature limit of 873 K
- Interchangeable
- Low cost



TYPICAL PLATINUM DIMENSIONLESS SENSITIVITY



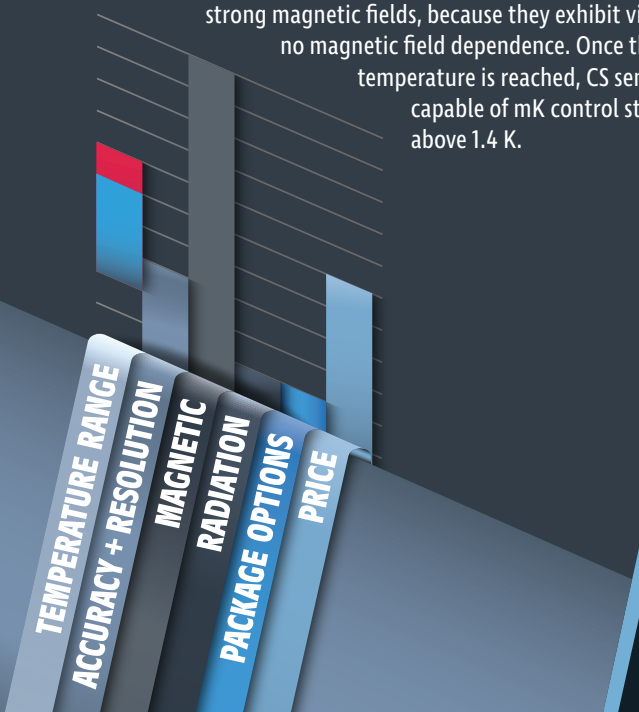
TYPICAL PLATINUM RESISTANCE



CAPACITANCE

CS capacitance sensors are highly specialized sensors for the sole purpose of controlling the temperature of cryogenic systems under the influence of very strong magnetic fields. These sensors require partner sensors, such as Cernox, to perform other temperature monitoring tasks and also require special measurement hardware, like the 3061 capacitance option card for the Lake Shore Model 335 or 336 temperature controller.

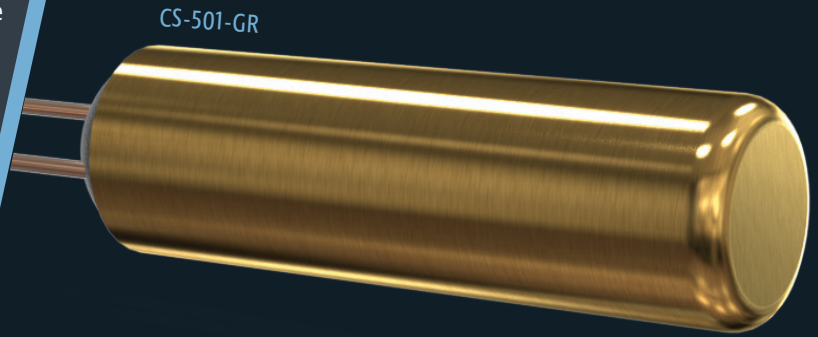
Despite this added complexity, capacitance sensors are vital if the system temperature must be held extremely stable when under strong magnetic fields, because they exhibit virtually no magnetic field dependence. Once the target temperature is reached, CS sensors are capable of mK control stability above 1.4 K.

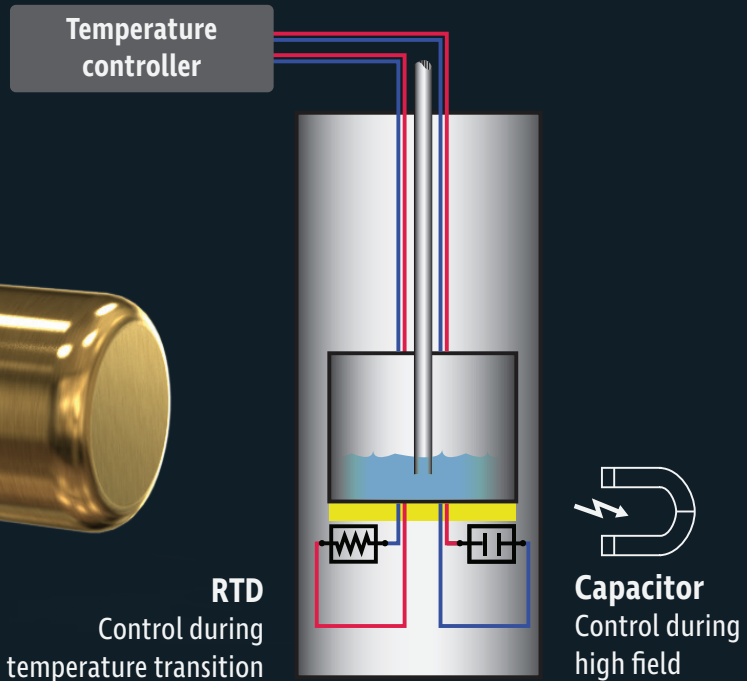


KEY FEATURES

- Lowest possible offset in magnetic environment
- Requires an accompanying sensor for absolute accuracy, and specific measurement equipment capable of capacitance temperature control

It is recommended that temperature in zero field be measured with another sensor and that the capacitance sensor be employed as a control element only.





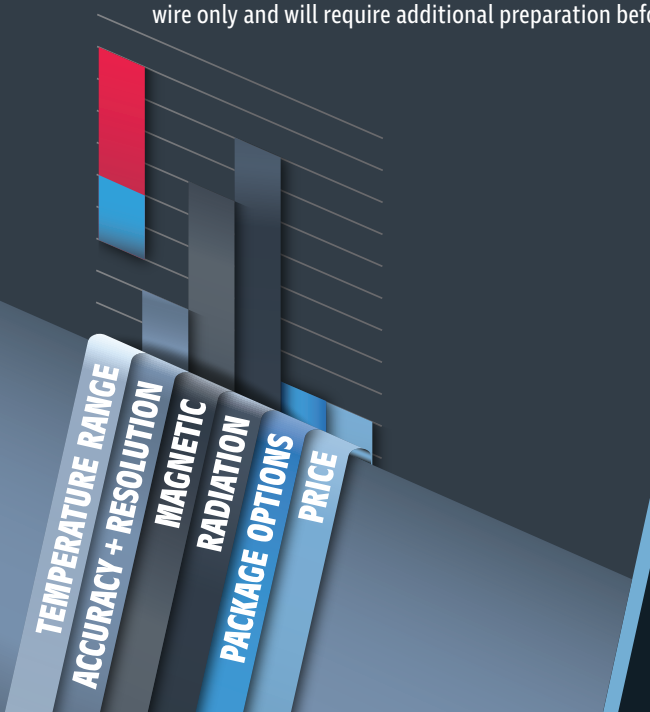
RTD
Control during temperature transition

Capacitor
Control during high field

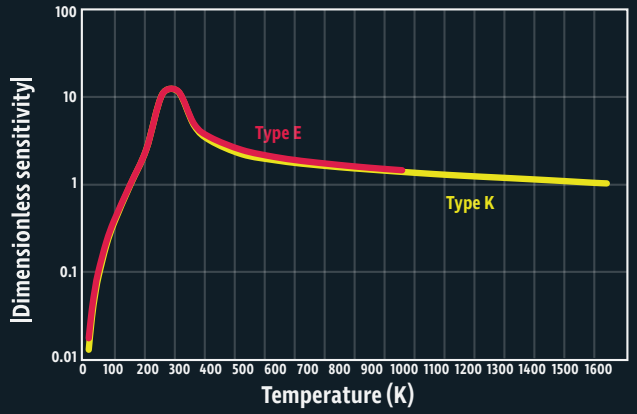
THERMOCOUPLES

With the widest available temperature range of any sensor type, thermocouple wire is useful for basic temperature measurement on a budget. The downside of using this sensor type comes with the care required to mount, thermally anchor, and run the wire to the measurement apparatus, along with a lack in measurement accuracy.

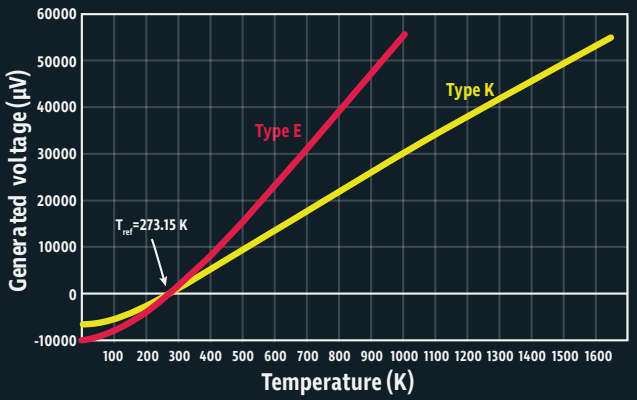
Unless operating temperatures exceed that of platinum sensors, most users select other sensor types to avoid the added challenges that come with working with thermocouples. Thermocouples are sold as wire only and will require additional preparation before use.

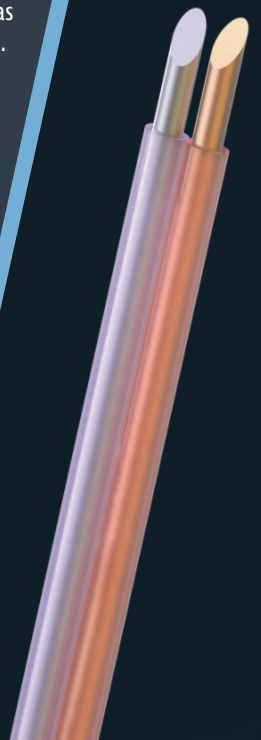


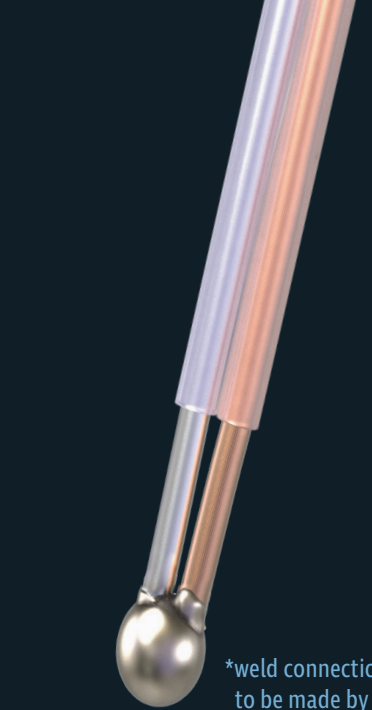
TYPE E AND K THERMOCOUPLE
DIMENSIONLESS SENSITIVITY (T_{REF}=273.15 K)



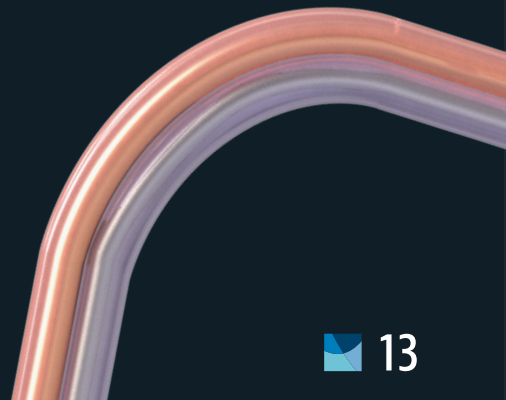
TYPE E AND K THERMOCOUPLE
TEMPERATURE RESPONSE CURVES (T_{REF}=273.15 K)







*weld connection to be made by user



SENSOR PACKAGES

Lake Shore offers the widest range of sensor packaging options to suit any application. The following summaries allow easy comparison by scoring various characteristics important to the package selection process.

SD PACKAGE

The most popular cryogenic package. Specifically designed to be rugged and compact with excellent thermal contact to the outside environment.

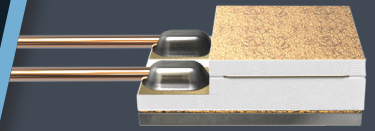
- Easy to bond or clamp to flat surfaces
- Package mass is kept low, ensuring fast thermal response times
- Sapphire base for excellent thermal conductivity and electrical isolation
- Alumina body and lid
- Hermetically sealed with an inert argon internal atmosphere
- Gold plated to reduce effect of optical radiation

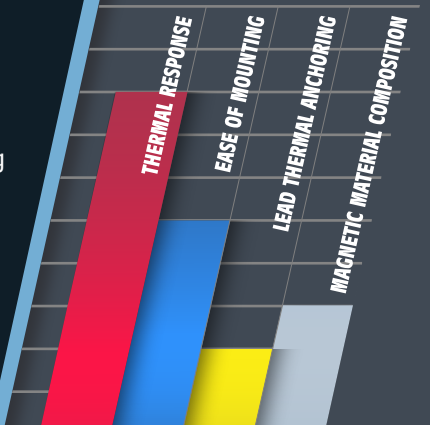
Methods for surface attachment:

- Indium solder
- Stycast® 2850 Epoxy
- IMI 7031 varnish
- CO clamp with Apiezon® N grease or Indium preform. This is a spring loaded clamp that screws into a 4-40 screw hole

CERNOX® (SD)

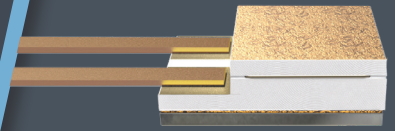
- SD package with 32 AWG gold-plated copper leads approximately 3 cm long
- Leads soldered to package using eutectic lead/tin solder
- Package will have a slight magnetic signature due to a thin nickel underplating

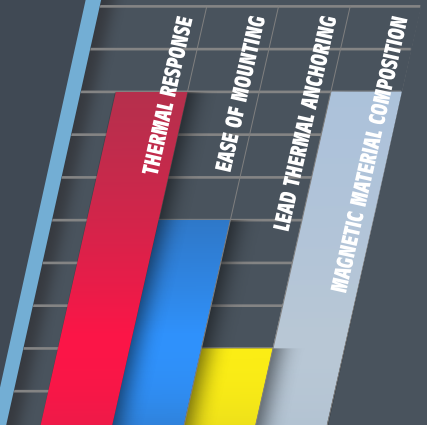




SILICON DIODES (SD)

- SD package with two Kovar® leads approximately 2 cm long
- Leads brazed to package for increased temperature rating.
- Package is quite magnetic due to Kovar® leads and is not recommended for use in magnetic fields.





Sensor mounting accessories

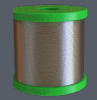
CO clamp

Mechanically holds sensor providing strong thermal contact



Solder

Permanently bonds sensor with excellent thermal transfer, though difficult to remove



Stycast epoxy

Permanent. Strong, stable and cryogenically compatible



Varnish

Removeable adhesive with good thermal contact. Ideal for low-temperatures



Apiezon grease

Non-permanent coupling with decent thermal conductivity. Easy to clean.



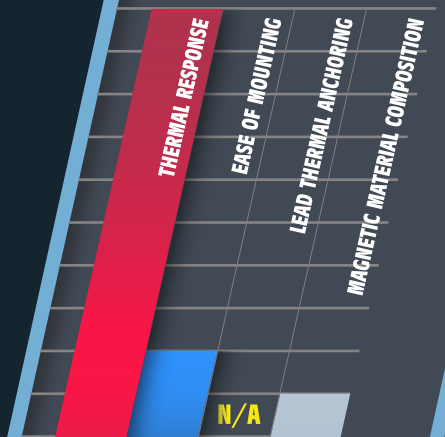
BARE CHIPS

When the smallest possible size and thermal mass is required, bare chip sensors are the package of choice. This option will require more advanced mounting steps than any other package option.

CERNOX® (BR)

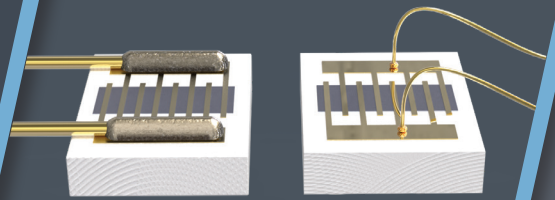
- Sapphire chip with electrical contacts and sensor element on one side
- Best option if you can make your own wire bonds
- Backside metalized

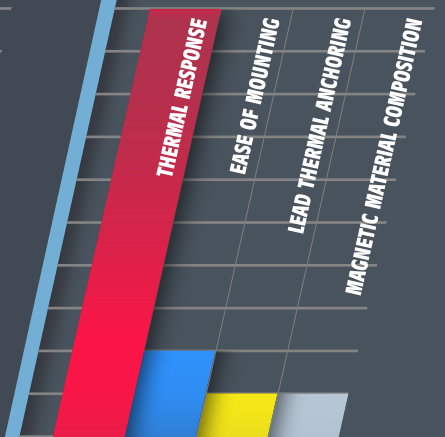




CERNOX® with LEADS (BG/BC)

- BG: Approximately 25 mm of 2 mil (44 AWG) gold wire bonded to both contact pads of the sensor
- BC: Approximately 25 mm of 2.5 mil (42 AWG) bare copper bonded to both contact pads of the sensor using silver-loaded epoxy.
- Gold leads are the best option for maintaining lowest possible sensor mass
- Copper leads are a little more robust than gold and do not dissolve as fast in solder

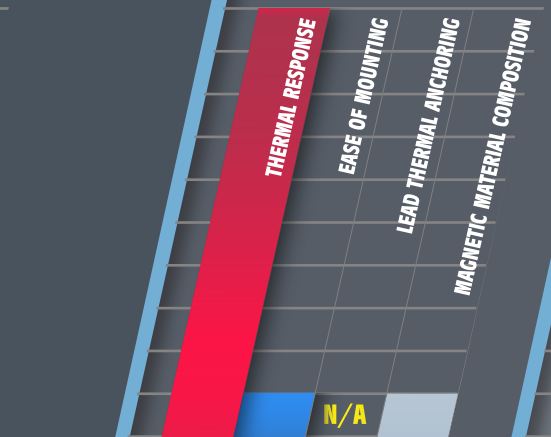




SILICON DIODE (BR)

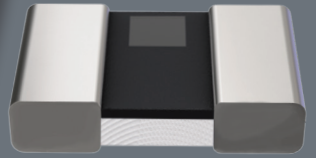
- Difficult to work with due to extremely small size and electrical contacts on both sides of the chip
- Requires die attach and wire bonding equipment
- Lowest thermal mass sensor available from Lake Shore

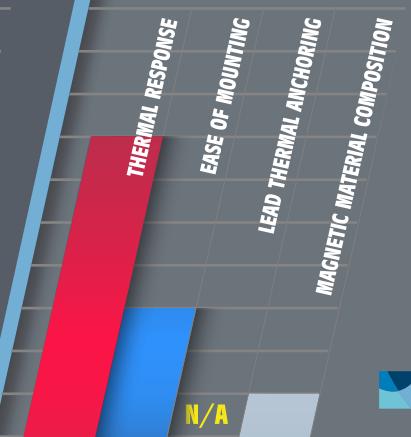




ROX™ (BR)

- Surface-mount resistor package
- Metal contacts must be electrically isolated





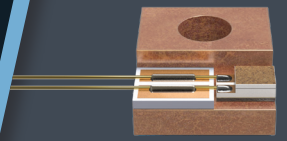
BOLT-DOWN PACKAGES

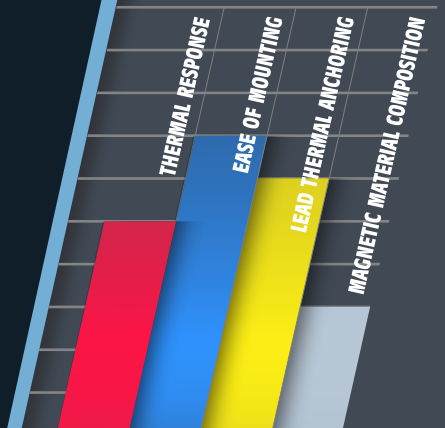
Bolting sensors down provides a convenient semi-permanent method for attaching sensors to an apparatus. The trade-off for this convenience is an increase in the thermal mass of the sensor, resulting in a decrease in thermal response.

BO

Available sensor types
Cernox®, Silicon Diodes, GaAlAs Diodes

- Lowest mass bolt-down package option
- Leads thermally anchored with BeO heat sink chip
- Standard two gold-coated copper leads of the SD package

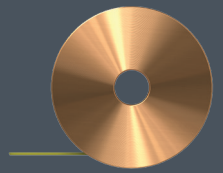


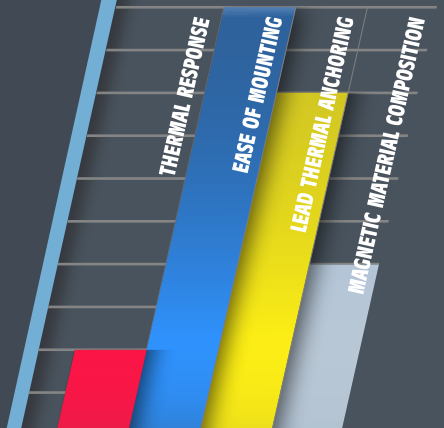


CY

Available sensor types
Silicon Diodes

- Most rugged package available, targeting industrial applications
- Rugged multi-strand Teflon®-coated wire makes this suitable for less extreme cryogenic temperatures due to heat leak and difficulty in thermal anchoring
- 2-lead connection makes this package suitable for diodes only

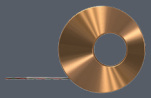


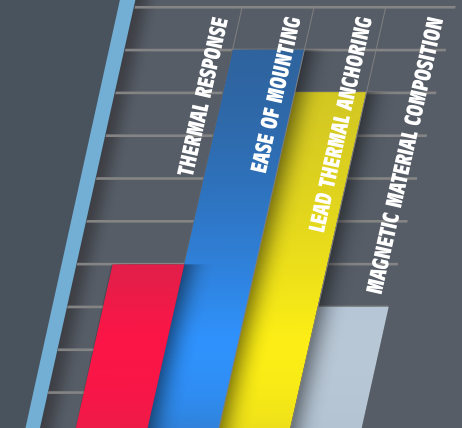


CU

Available sensor types
Cernox®, Silicon Diodes, GaAlAs Diodes

- Lowest mass bolt-down package with insulated leads
- Insulated leads thermally anchored to copper bobbin
- 4-lead connection allows easy modification of lead length without altering calibrations



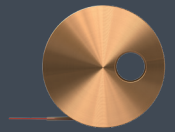


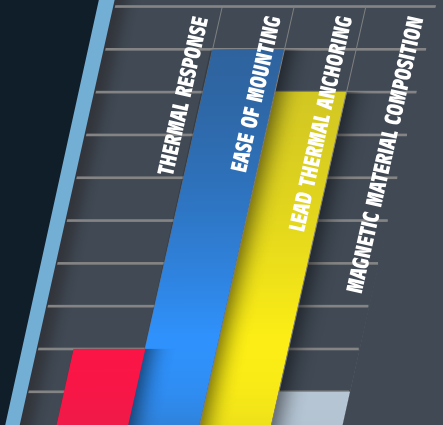
BOLT-DOWN PACKAGES (CONTINUED)

CD

Available sensor types
Cernox®, Rox™, Germanium

- Lowest magnetic signature bolt-down package for many sensors
- Comparatively large thermal mass
- 4-lead connection allows modification of lead length without altering calibrations

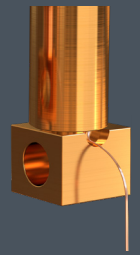


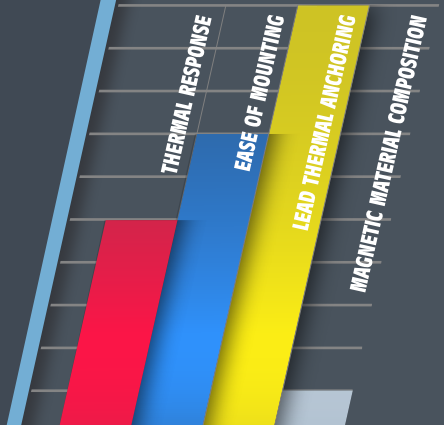


RS

Available sensor types
Rox™

- Rox package specifically designed for sub-50 mK operation
- Free from magnetic material

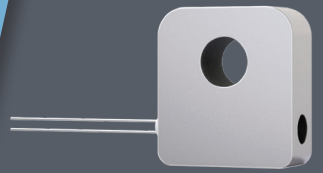


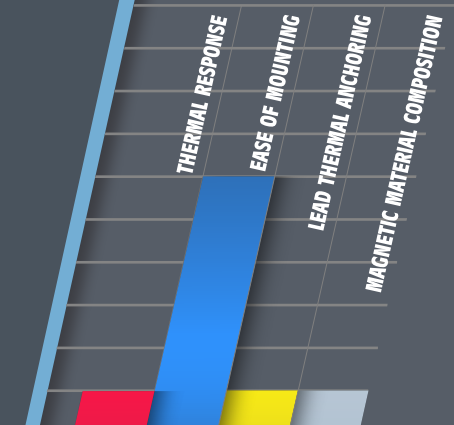


AM

Available sensor types
Platinum

- Improves the ease of mounting for Lake Shore PT-103 platinum sensors
- Platinum leads remain exposed and must be handled with care
- Aluminum alloy limits maximum temperature to 800 K





EMBEDDED PACKAGES

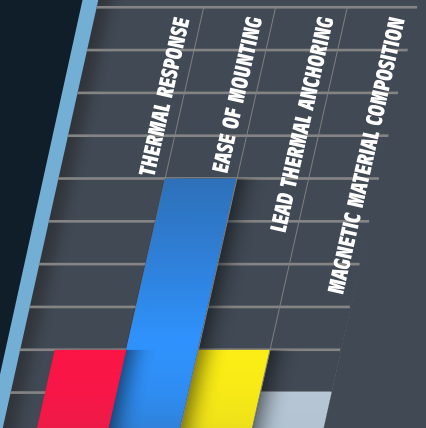
Several package options are available that can be recessed into a mounting hole. This solution results in a smaller sensor footprint, but makes replacing the sensors more difficult than other options.

AA

Available sensor types
Cernox®, Rox™, Germanium

- Free from magnetic material
- Reduced thermal conductivity compared to SD or bolt-mounted packages
- 4-lead insulated sensor for Cernox and germanium
- 2-lead insulated connection for Rox

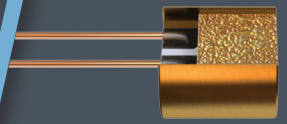


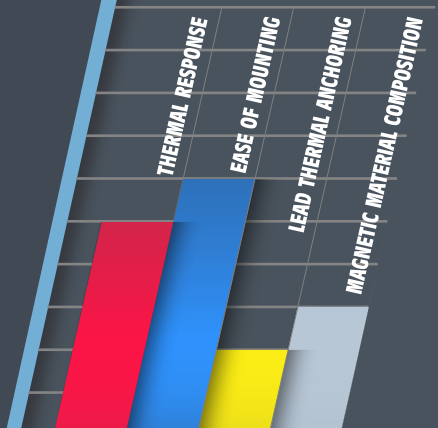


LR

Available sensor types
Cernox®, Silicon Diodes

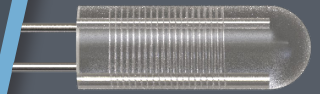
- Cylindrical copper adapter mounted to SD package using indium solder
- Better thermal conduction path than other hole-mounted packages
- Uninsulated leads require handling care so they don't short to the mounting surface

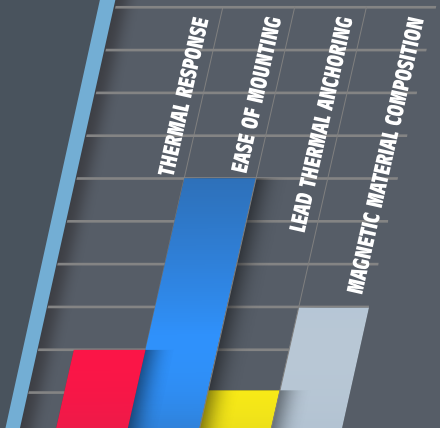




Platinum

- Various sized packages depending on sensor type
- Uninsulated leads require insulation and handling
- Care must be exercised when handling fragile leads





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