DECLARATION OF CONFORMITY

in relation to

DIRECTIVE 2002/95/EC OF THE EUROPEAN PARLIAMENT
AND OF THE COUNCIL
OF 27 JANUARY 2003
ON THE RESTRICTION OF THE
USE OF CERTAIN HAZARDOUS SUBSTANCES (RoHS) IN
ELECTRICAL AND ELECTRONIC EQUIPMENT

Temperature Sensors

Silicon Diodes, GaAlAs, Diodes, Platinum RTDs, Rhodium-Iron RTDs, Cernox RTDs, Germanium RTDs, Carbon Glass RTDs, Ruthenium Oxide, Thermocouples, and capacitance sensors are primarily used by researchers and scientists studying the physical properties of materials at very low temperatures. The sensors operate from < 50 mK to 1505 K and are available in a variety of packages and designs to accommodate various mounting methods and environmental conditions. Applications include but are not limited to, cryo-coolers, dilution refrigerators, ultra-low temperature physics, condensed matter physics, general laboratory cryogenics, cryo-gas products, metrology, and space flight.

The equipment detailed above falls outside the scope of the Directive 2002/96/EC on Waste Electrical and Electronic Equipment (WEEE) and Directive 2002/95/EC on the Restriction of the use of certain Hazardous Substances (RoHS) as they constitute a 'component' element, which is not discernable electrical and electronic equipment (EEE) or finished goods. As such, it may legitimately contain substances restricted by Article 4.1 of Directive 2002/95/EC within each homogeneous element above the maximum concentration values defined within Commission Decision 2005/618/EC.

On behalf of Lake Shore: Karen E Lint
Karen E. Lint, COO

Date: 5/23/2006

LakeShore®

Lake Shore Cryotronics Inc. • 575 McCorkle Boulevard • Westerville, OH 43082
Sales: (614) 891-2244 • Fax: (614) 891-1392 • sales@lakeshore.com • www.lakeshore.com

Standard Curve 10

Standard Curve 10: Measurement Current = 10 μA ±0.05%

T (K)	Voltage	dV/dT (mV/K)	T (K)	Voltage	dV/dT (mV/K)	T (K)	Voltage	dV/dT (mV/K)
1.40	1.69812	–13.1	16.0	1.28527	–18.6	95.0	0.98564	–2.02
1.60	1.69521	–15.9	16.5	1.27607	–18.2	100.0	0.97550	–2.04
1.80	1.69177	–18.4	17.0	1.26702	–18.0	110.0	0.95487	–2.08
2.00	1.68786	–20.7	17.5	1.25810	–17.7	120.0	0.93383	–2.12
2.20	1.68352	–22.7	18.0	1.24928	–17.6	130.0	0.91243	–2.16
2.40	1.67880	–24.4	18.5	1.24053	–17.4	140.0	0.89072	–2.19
2.60	1.67376	–25.9	19.0	1.23184	–17.4	150.0	0.86873	–2.21
2.80	1.66845	–27.1	19.5	1.22314	–17.4	160.0	0.84650	–2.24
3.00	1.66292	–28.1	20.0	1.21440	–17.6	170.0	0.82404	–2.26
3.20	1.65721	–29.0	21.0	1.19645	–18.5	180.0	0.80138	–2.28
3.40	1.65134	–29.8	22.0	1.17705	–20.6	190.0	0.77855	–2.29
3.60	1.64529	–30.7	23.0	1.15558	–21.7	200.0	0.75554	–2.31
3.80	1.63905	–31.6	24.0	1.13598	–15.9	210.0	0.73238	–2.32
4.00	1.63263	–32.7	25.0	1.12463	–7.72	220.0	0.70908	–2.34
4.20	1.62602	–33.6	26.0	1.11896	–4.34	230.0	0.68564	–2.35
4.40	1.61920	–34.6	27.0	1.11517	–3.34	240.0	0.66208	–2.36
4.60	1.61220	–35.4	28.0	1.11212	–2.82	250.0	0.63841	–2.37
4.80	1.60506	–36.0	29.0	1.10945	–2.53	260.0	0.61465	–2.38
5.00	1.59782	–36.5	30.0	1.10702	–2.34	270.0	0.59080	–2.39
5.50	1.57928	–37.6	32.0	1.10263	–2.08	280.0	0.56690	–2.39
6.00	1.56027	–38.4	34.0	1.09864	–1.92	290.0	0.54294	–2.40
6.50	1.54097	–38.7	36.0	1.09490	–1.83	300.0	0.51892	–2.40
7.00	1.52166	–38.4	38.0	1.09131	–1.77	310.0	0.49484	–2.41
7.50	1.50272	–37.3	40.0	1.08781	–1.74	320.0	0.47069	–2.42
8.00	1.48443	–35.8	42.0	1.08436	–1.72	330.0	0.44647	–2.42
8.50	1.46700	–34.0	44.0	1.08093	–1.72	340.0	0.42221	–2.43
9.00	1.45048	–32.1	46.0	1.07748	–1.73	350.0	0.39783	–2.44
9.50	1.43488	–30.3	48.0	1.07402	–1.74	360.0	0.37337	–2.45
10.0	1.42013	–28.7	50.0	1.07053	–1.75	370.0	0.34881	–2.46
10.5	1.40615	–27.2	52.0	1.06700	–1.77	380.0	0.32416	–2.47
11.0	1.39287	–25.9	54.0	1.06346	–1.78	390.0	0.29941	–2.48
11.5	1.38021	–24.8	56.0	1.05988	–1.79	400.0	0.27456	–2.49
12.0	1.36809	–23.7	58.0	1.05629	–1.80	410.0	0.24963	–2.50
12.5	1.35647	–22.8	60.0	1.05267	–1.81	420.0	0.22463	–2.50
13.0	1.34530	–21.9	65.0	1.04353	–1.84	430.0	0.19961	–2.50
13.5	1.33453	–21.2	70.0	1.03425	–1.87	440.0	0.17464	–2.49
14.0	1.32412	–20.5	75.0	1.02482	–1.91	450.0	0.14985	–2.46
14.5	1.31403	–19.9	80.0	1.01525	–1.93	460.0	0.12547	–2.41
15.0	1.30422	–19.4	85.0	1.00552	–1.96	470.0	0.10191	–2.30
15.5	1.29464	–18.9	90.0	0.99565	–1.99	475.0	0.09062	–2.22

Lighter numbers indicate truncated portion of Standard Curve 10 corresponding to the reduced temperature range of DT-471 diode sensors. The 1.4–325 K portion of Curve 10 is applicable to the DT-450 miniature silicon diode sensor.

POLYNOMIAL REPRESENTATION

Curve 10 can be expressed by a polynomial equation based on the Chebychev polynomials. Four separate ranges are required to accurately describe the curve. Table 1 lists the parameters for these ranges. The polynomials represent Curve 10 on the preceding page with RMS deviations of 10 mK. The Chebychev equation is:

$$T(x)=\sum_{i=0}^{n} a_i t_i(x) \qquad (1)$$

where T(x) = temperature in kelvin, $t_i(x)$ = a Chebychev polynomial, and a_i = the Chebychev coefficient. The parameter x is a normalized variable given by:

$$x=\frac{(Z-ZL)-(ZU-Z)}{(ZU-ZL)} \qquad (2)$$

where Z = voltage and ZL and ZU = lower and upper limit of the voltage over the fit range. The Chebychev polynomials can be generated from the recursion relation:

$$t_{i+1}(x)=2xt_i(x)-t_{i-1}(x)$$
$$t_0(x)=1, t_1(x)=x \qquad (3)$$

Alternately, these polynomials are given by:

$$t_i(x)=\cos[i\times\arccos(x)] \qquad (4)$$

The use of Chebychev polynomials is no more complicated than the use of the regular power series and they offer significant advantages in the actual fitting process. The first step is to transform the measured voltage into the normalized variable using Equation 2. Equation 1 is then used in combination with equations 3 and 4 to calculate the temperature. Programs 1 and 2 provide sample BASIC subroutines which will take the voltage and return the temperature T calculated from Chebychev fits. The subroutines assume the values ZL and ZU have been input along with the degree of the fit. The Chebychev coefficients are also assumed to be in any array A(0), A(1),..., A(i_{degree}).

An interesting property of the Chebychev fits is evident in the form of the Chebychev polynomial given in Equation 4. No term in Equation 1 will be greater than the absolute value of the coefficient. This property makes it easy to determine the contribution of each term to the temperature calculation and where to truncate the series if full accuracy is not required.

```
FUNCTION Chebychev (Z as double)as double
REM Evaluation of Chebychev series
   X=((Z-ZL)-(ZU-Z))/(ZU-ZL)
   Tc(0)=1
   Tc(1)=X
   T=A(0)+A(1)*X
   FOR I=2 to Ubound(A())
      Tc(I)=2*X*Tc(I-1)-Tc(I-2)
      T=T+A(I)*Tc(I)
   NEXT I
   Chebychev=T
END FUNCTION
```

Program 1. BASIC subroutine for evaluating the temperature *T* from the Chebychev series using Equations (1) and (3). An array T_c (i_{degree}) should be dimensioned. See text for details.

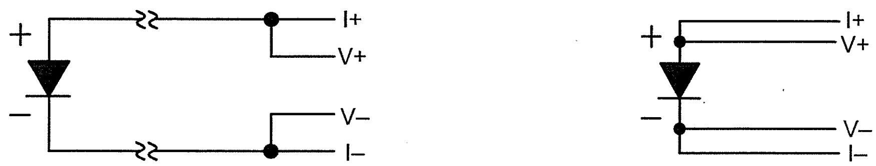
```
FUNCTION Chebychev (Z as double)as double
REM Evaluation of Chebychev series
    X=((Z-ZL)-(ZU-Z))/(ZU-ZL)
    T=0
    FOR I=0 to Ubound(A())
       T=T+A(I)*COS(I*ARCCOS(X))
    NEXT I
    Chebychev=T
END FUNCTION
```

NOTE: $\arccos(X)=\frac{\pi}{2}-\arctan\left[\frac{X}{\sqrt{1-X^2}}\right]$

Program 2. BASIC subroutine for evaluating the temperature *T* from the Chebychev series using Equations (1) and (4). Double precision calculations are recommended.

Table 1. Chebychev Fit Coefficients

2.0 K to 12.0 K		12.0 K to 24.5 K		24.5 K to 100.0 K		100 K to 475 K	
ZL =	1.32412	ZL =	1.11732	ZL =	0.923174	ZL =	0.079767
ZU =	1.69812	ZU =	1.42013	ZU =	1.13935	ZU =	0.999614
A(0) =	7.556358	A(0) =	17.304227	A(0) =	71.818025	A(0) =	287.756797
A(1) =	–5.917261	A(1) =	–7.894688	A(1) =	–53.799888	A(1) =	–194.144823
A(2) =	0.237238	A(2) =	0.453442	A(2) =	1.669931	A(2) =	–3.837903
A(3) =	–0.334636	A(3) =	0.002243	A(3) =	2.314228	A(3) =	–1.318325
A(4) =	–0.058642	A(4) =	0.158036	A(4) =	1.566635	A(4) =	–0.109120
A(5) =	–0.019929	A(5) =	–0.193093	A(5) =	0.723026	A(5) =	–0.393265
A(6) =	–0.020715	A(6) =	0.155717	A(6) =	–0.149503	A(6) =	0.146911
A(7) =	–0.014814	A(7) =	–0.085185	A(7) =	0.046876	A(7) =	–0.111192
A(8) =	–0.008789	A(8) =	0.078550	A(8) =	–0.388555	A(8) =	0.028877
A(9) =	–0.008554	A(9) =	–0.018312	A(9) =	0.056889	A(9) =	–0.029286
		A(10) =	0.039255	A(10) =	–0.116823	A(10) =	0.015619
				A(11) =	0.058580		



A. Two-Lead Measurement Scheme

B. Four-Lead Measurement Scheme

Figure 1. Two-Lead Versus Four-Lead Measurements

4. Prepare the connecting wire ends with a RMA (rosin mildly active) soldering flux, tin them with a minimal amount of 60% Sn 40% Pb solder. Use a low wattage soldering iron which will not exceed 200 °C.
5. Clean off residual flux with rosin residue remover. The sensor leads can be prepared in an identical manner.
6. Join one sensor lead with two of the connector wires. Apply the soldering iron to the connector wire above the joint area until the solders melt, then remove the iron. Repeat for the other set of connector wires and the other sensor lead. Heat sinking the SD sensor with a flat jaw alligator clip is good practice to eliminate heat build up at the sensor element.
7. Avoid putting stress on the device leads and leave enough slack to allow for the thermal contractions that occur during cooling which could fracture a solder joint or lead. Some epoxies and shrink tubing can put enough stress on lead wires to break them.

HEAT SINKING/THERMAL ANCHORING

1. Since the area being measured is read through the base of the sensor, heat flow through the connecting leads can create an offset between the sensor chip and the true sample temperature. Thermal anchoring of the connecting wires is necessary to assure that the sensor and the leads are at the same temperature as the sample.
2. Connecting wires should be thermally anchored at several temperatures between room temperature and cryogenic temperatures to guarantee that heat is not being conducted through the leads to the sensing element. Two different size copper bobbins are available from Lake Shore for heat sinking connecting leads: P/N 9007-900 and 9007-901.
3. If connecting wires have a thin insulation such as Formvar™ or Polyimide, a simple thermal anchor can be made by winding the wires around a copper post, bobbin, or other thermal mass. A minimum of five wraps around the thermal mass should provide sufficient thermal anchoring. However, if space permits, additional wraps are recommended for good measure. To maintain good electrical isolation over many thermal cycles, it is good practice to first varnish a single layer of cigarette paper to the anchored area then wrap the wire around the paper and bond in place with a thin layer of IMI 7031 Varnish. Formvar wiring insulation has a tendency to craze with the application of IMI varnish. If used, the wires cannot be disturbed until the varnish is fully cured and all solvents have evaporated (typically 12–24 hours).
4. A final thermal anchor at the sample itself is good practice to ensure thermal equilibrium between the sample and temperature sensor.

CRYOGENIC ACCESSORIES – Recommended for proper installation and use of DT-470/471/670 SD sensors:

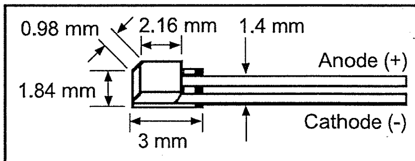
Stycast® Epoxy 2850FT (P/N 9003-020, 9003-021): Permanent attachment, excellent low temperature properties, poor electrical conductor, low cure shrinkage.
Apiezon® N Grease (P/N 9004-020): Low viscosity, easy to use, solidifies at cryogenic temperatures, excellent lubricant.
IMI 7031 Varnish (P/N 9009-002): Nonpermanent attachment, excellent thermal conductor, easy to apply and remove.
Indium Solder (P/N 9007-002-05): 99.99% pure, excellent electroplating material, foil form.
90% Pb 10% Sn Solder (P/N 9008-001): Greater lead content, for higher temperature applications no greater than 200 °C.
RMA Soldering Flux (P/N 9008): Variety of types, refer to Lake Shore Product Catalog for details.
Phosphor-Bronze Wire (P/N 9001-00X): Available in single, duo, and quad strands, no magnetic attraction, low thermal conduction.
Manganin Wire (P/N 9001-00X): Low thermal conductivity, high resistivity, no magnetic attraction.
Heat Sink Bobbin (P/N 9007-900 Large, 9007-901 Small): Gold-plated oxygen-free high-conductivity (OFHC) copper bobbins.
Instruments: Lake Shore sells a complete line of instrumentation used with the DT-470/471/670 Sensors, such as: Current Sources, Cryopump Monitors, Temperature Controllers, Monitors and Thermometers, Temperature Scanners and Transmitters.

For complete product description and detailed specifications on the above accessories and instruments, consult the Lake Shore Temperature Measurement and Control Catalog, call at (614) 891-2243, or e-mail at sales@lakeshore.com.

Installation Instructions
Silicon Diode Temperature Sensor
DT-470/471/670 SD Package

There are three aspects of using a cryogenic temperature sensor which are critical to its optimum performance. The first involves the proper mounting of the sensor package, the second relates the proper joining of sensor lead wires and connecting wires. The final concern is the thermal anchoring of the lead wires. Although the sequence in which these areas should be addressed is not fixed, all elements covered under each aspect should be adhered to for maximum operating capabilities of the sensor.

SENSOR MOUNTING



Leads (mm): 0.38 W × 0.10 T × ≈19 L
Sensor Mass: 0.03 gram

1. Mounting area should be prepared and cleaned with a solvent such as Acetone followed by an Isopropyl Alcohol rinse. Allow time for the solvents to evaporate before sensor mounting.

2. The list below provides brief instructions on mounting a sensor using a number of different methods. The constraints of your application should dictate the most appropriate mounting method to follow.

   Mechanical – The preferred method for mechanically mounting an SD sensor is using the Lake Shore spring loaded clamp. This clamp should be ordered at the time the sensor is ordered (P/N DT-670-CO, DT-470-CO, etc.). The clamp holds the SD sensor in contact with the surface and also allows the sensor to be easily changed or replaced. A thin layer of Apiezon® N Grease (≤0.055 mm) or a flat 100% indium preform should be used between the sensor and mounting surface to enhance thermal contact. The spring prevents crushing the sensor.

   Indium Solder (100% In) – A low wattage heat source should be used and the sensor must never exceed 200 °C. The mounting surface and sensor should be tinned with a rosin flux (type RMA is recommended) prior to mounting the sensor. A thin, uniform layer of indium solder should be the goal. Clean both the sensor and mounting surface of residual flux using rosin residue remover. Once the surface area is dry, reheat the mounting surface to the melting point of the solder (156 °C). Press the sensor into position and allow it to warm to the melting point of the solder. Remove heat source and allow sufficient time for the solder to solidify (typically 2–3 seconds) before removing it.

   Apiezon® N Grease – Is best used as a thermal conductor when the sensor is mounted in a hole or recess and when the sensor is intended to be removed. The sensor should be surrounded with thermal grease and placed into the mounting position. When the temperature is lowered the thermal grease will harden, giving good support and thermal contact.

   IMI 7031 Varnish – Prepare varnish and apply a thin layer on the mounting surface. Press the sensor firmly against the varnish during curing to ensure a thin bond layer and good thermal contact. Varnish will air dry in 5–10 minutes. Sufficient time must be allowed for the solvents in the varnish to evaporate. There is a small probability of ionic shunting across the sensor during the full cure period of the varnish (typically 12–24 hours).

   Stycast® 2850FT Epoxy – Prepare epoxy and apply a thin layer on the mounting surface. Press the sensor firmly into the epoxy during curing to assure a thin bond layer and good thermal contact. Epoxy will cure in 12 hours at 25 °C or in 2 hours at 66 °C.

   NOTE: If using an electrically conductive adhesive or solder, it is important that the excess does not "creep-up" the edges of the sensor or come in contact with the sensor leads. There is a thin braze joint around the sides of the SD package that is electrically connected to the sensing element. Contact to the sides with any electrically conductive material will cause a short.

3. Follow manufacturers instructions for adhesive curing schedule. Never heat the sensor above 200 °C.

LEAD ATTACHMENT

1. Although the DT-470/471/670 SD sensor package is a two-lead device, measurements should be preferably made using a four-wire configuration to avoid uncertainties associated with lead resistance.

   Two-lead measurement scheme – The leads used to measure the voltage are also the current carrying leads. The resultant voltage measured at the instrument is the sum of the temperature sensor voltage and the voltage drop across the two leads. See Figure 1A.

   Four-lead measurement scheme – The current is confined to one pair of current leads with the sensor voltage measured across the voltage leads. See Figure 1B.

2. Lead Polarity: When viewed with the base down (the base is the largest flat surface) and the leads towards the observer, the positive lead (anode) is on the right and the negative (cathode) is on the left.

3. Strip the insulation from the connecting wires by delicately scraping with a razor blade, fine sand paper, or steel wool. Phosphor-bronze or Manganin wire, in sizes 32 or 36 AWG, is commonly used as the connecting lead wire. These wires have low thermal conductivity and high resistivity which help minimize the heat flow through the leads. Typical wire insulation is Polyvinal Formal (Formvar™) or Polyimide (ML). Formvar™ insulation has better mechanical properties such as abrasion resistance and flexibility. Polyimide insulation has better resistance to chemical solvents and burnout.

Lake Shore Cryotronics, 575 McCorkle Blvd. Westerville, OH 43082-8888. Visit Our Website: www.lakeshore.com.
(614) 891-2243 – Phone, (614) 891-1362 – Fax, E-Mail: sales@lakeshore.com, service@lakeshore.com.