Silicon Diodes

DT-470 and DT-471 Features and Description

DT-470 Features

- Advanced, hermetic ceramic and sapphire packaging with the lowest self-heating errors
- Monotonic temperature response over its useful range from 1.4 K to 475 K
- All sensors follow a standard temperature response curve (Curve 10)
- Available in five tolerance bands to a standard curve (Curve 10)
- Repeatability at 4.2 K typically ±10 mK over repeated thermal cycling
- High sensitivity for critical low temperature measurements
- Accommodates a variety of mounting adapters and probe assemblies
- Useful above 60 K in magnetic fields up to 5 tesla
- SoftCal™ calibration available

DT-471 Features

- Temperature range: 10 K to 475 K
- Follows Curve 10 from 10 K to 475 K
- Accuracy: ±1.5 K or ±1.5% of temperature reading, whichever is greater
- Shares other benefits with the DT-470
  - Repeatability
  - Sensitivity
  - Mounting
  - B dependence
- SoftCal™ calibration available

Interchangeable – The DT-470/471 Silicon Diode temperature sensors incorporate remarkably uniform sensing elements that exhibit precise, repeatable, monotonic temperature response over a wide range. The elements are mounted into rugged, hermetically-sealed packages that have been specifically designed for proper thermal behavior in a cryogenic environment. The result is a family of sensors with temperature characteristics so predictable, tightly grouped and stable, that the sensors in most applications can be routinely interchanged with one another.

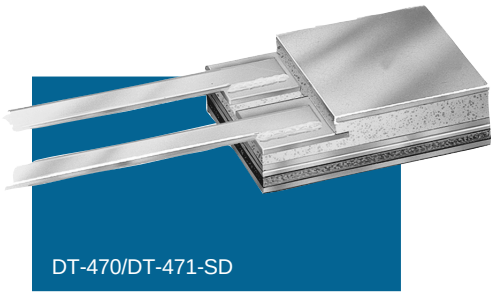
Repeatable – The small silicon chip in each sensor has a temperature characteristic that is well known and stable. The SD sensor package is designed to withstand repeated cycling to low temperatures without mechanical failure. Repeatability at 4.2 K over repeated thermal cycling from room temperature to helium temperature is typically ±10 mK or better. Repeatability from 1.4 K to 330 K is typically better than ±20 mK. For long term stability, see the specifications.

Accurate – All DT-470/471 Silicon Diodes follow a standard temperature response curve, Curve 10 (See the Reference Section). For the DT-470 diodes, five tolerance bands are offered to allow sensor selection that will meet both technical and economic requirements. Within these five bands, low temperature accuracies of ±0.25 K, ±0.5 K and ±1 K are available. For the DT-471 diodes, accuracy is ±1.5 K or ±1.5% of temperature reading, whichever is greater, from 10 K to 475 K. For more demanding requirements, DT-470/DT-471 diodes can be used with SoftCal™, or these sensors can be calibrated to accuracies of ±50 mK or better.

Note

The DT-471 Silicon Diode sensors offer an inexpensive alternative for situations in which temperature measurement below 10 K is not necessary and a tolerance band wider than Band 13 is acceptable. The upper operating temperature is 475 K for the Model DT-471-SD, and it's available with (CO) mounting adapter to 475 K. Because the DT-471 package/mounting adapter configurations are identical to those for the DT-470 diodes, installation and operation procedures are identical.

1987 COMPETITION WINNER 25th YEAR IR100 Cited by Research & Development magazine for developing one of the 100 most-significant technical products of the year



DT-470/DT-471-SD

Typical Magnetic Field-Dependent Temperature Errors(1) ΔT/T (%) at B (magnetic induction) for Silicon Diodes

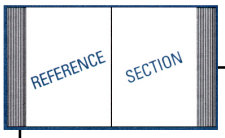
Package Base Parallel to Field

T(K)	B (tesla) 1	2	3	4	5
4.2	-200	-300	-350	-400	-500
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

Package Base Perpendicular to Field

T(K)	B (tesla) 1	2	3	4	5
4.2	-8	-9	-11	-15	-20
20	-4	-5	-5	-5	-10
40	-1.5	-3	-4	-5	-5.5
60	-0.5	-0.7	-0.8	-1	-1.1
80	-0.1	-0.3	-0.5	-0.6	-0.7
300	<0.1	0.2	0.5	0.6	0.6

(1) As can be seen from the table above, magnetic field-induced temperature errors are strongly orientation dependent. To minimize this effect, the sensor should be oriented so that the package base is perpendicular to the magnetic field flux lines; this results in the diode current being parallel to the magnetic field.



What is SoftCal™ ?

SoftCal™ is a 2-point or 3-point calibration which offers improved accuracy without the cost of a full calibration. SoftCal™ is available for Silicon Diodes and platinum sensors.

For detailed information on SoftCal™, CalCurve™ and Curve 10, see the Reference Section.

DT-414, DT-420 Series Features and Description

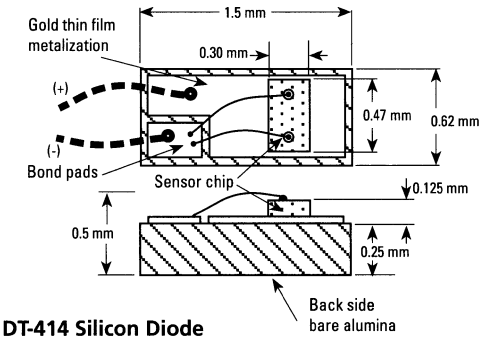
DT-414 Features

- Temperature range: 1.4 K to 375 K (Calibration not available above 325 K)
- Small mass for rapid thermal response
- Incorporates non-magnetic materials

DT-414 Unencapsulated Silicon Diodes

The Model DT-414 uses the Silicon Diode chip used in the DT-470s. It is mounted on a flat substrate. This chip-level sensor offers minimal thermal mass and minimal physical size. Die attachment is with silver epoxy. The chip is unencapsulated, leaving the fragile gold wires exposed.

The DT-414 is supplied in a Gel-Pak™ with 0.5" to 1" long, 50 µm diameter gold leads. If it is desired to wirebond the chip into a circuit using the user's wire, the gold ball bonds can be removed using a sharp blade. This will leave more room for attachment of new gold or aluminum wire. The leads (as supplied) can also be thermo-compression bonded or soldered at their free ends.



DT-414 Silicon Diode
Not to scale.

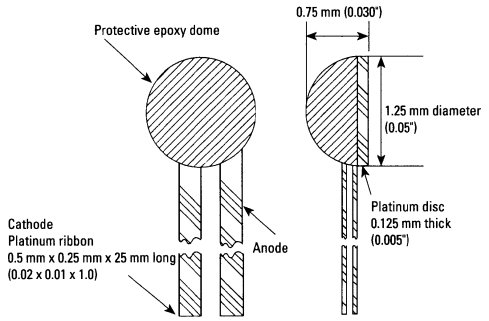
Exposed wires are fragile.

DT-420 Features

- Temperature range: 1.4 K to 325 K
- Repeatability (at 4.2 K) typically ±50 mK over repeated thermal cycling
- Exposed flat substrate for surface mounting
- Incorporates non-magnetic materials
- Small mass for rapid thermal response

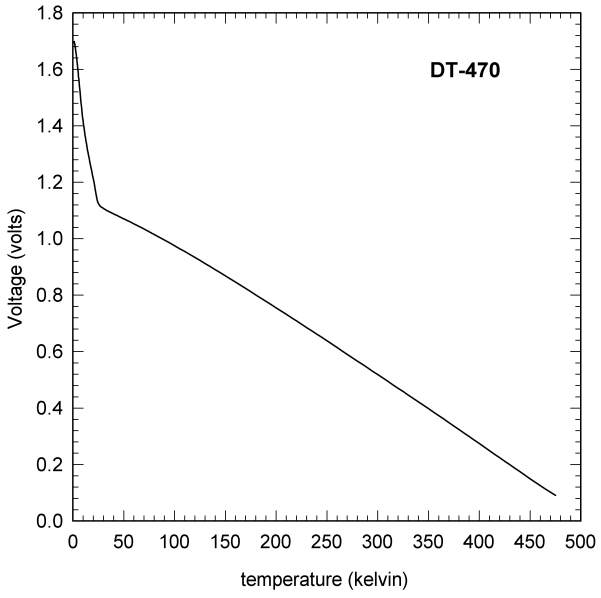
DT-420 Miniature Silicon Diode

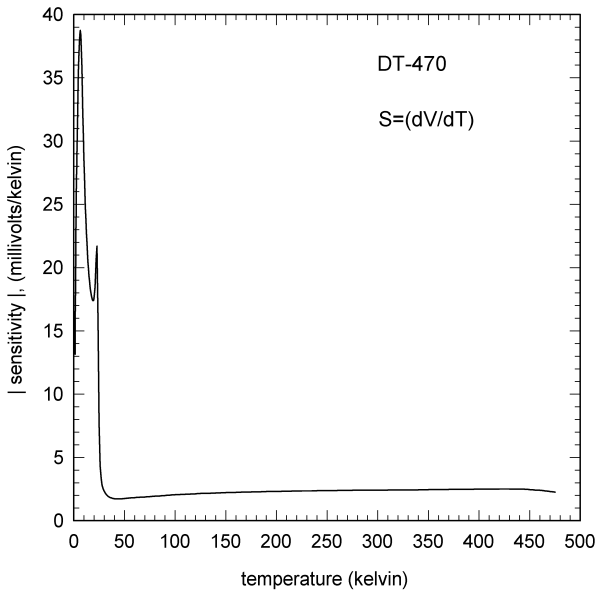
The DT-420 subminiature Silicon Diode temperature sensor is configured for installation on flat surfaces. The DT-420 sensor package exhibits precise, monotonic temperature response over its useful range and is designed to withstand repeated cycling to low temperatures without mechanical failure. The sensor chip is in direct contact with the epoxy dome which causes increased voltage at 4.2 K and prevents full range conformity to the Curve 10. The anode lead is electrically connected to the platinum base and should be isolated by the user for installation on metallic surfaces (see Reference Section). Also see the Accuracy specification for the difference between the DT-421 and DT-422.



DT-420 Silicon Diode
Not to scale.

Typical Voltage and Sensitivity Values for Silicon Diodes





Specifications

	DT-470-SD and DT-471-SD	DT-414
Temperature		
Useful range		
Minimum	1.4 K (10 K for the DT-471)	1.4 K
Maximum	475 K	375 K
Maximum storage temperature	305 K	305 K
Standard curve	Curve 10 (5 tolerance bands for DT-470)	Curve 10
Voltage (typical)	1.626 V at 4.2 K; 1.020 V at 77 K; 0.507 V at 305 K (both models)	
Sensitivity (typical)	-33.6 mV/K at 4.2 K (DT-470 only); -1.91 mV/K at 77 K; -2.41 mV/K at 305 K	-33.6 mV/K at 4.2 K; -1.91 mV/K at 77 K; -2.41 mV/K at 305 K
Repeatability (typically)	±10 mK or better at 4.2 K; ±20 mK (1.4 K to 330 K)	±10 mK or better at 4.2 K; ±20 mK (1.4 K to 330 K)
Accuracy (interchangeability)	DT-470: Curve 10 (Band 11 to Band 13 DT-471: ±1.5 K or ±1.5% whichever is greater(10 K to 475 K)	±1.5 K or ±1.5% whichever is greater
Accuracy (SoftCal™)		
2 point (77 K and 305 K)	±0.25 K (30 K to 60 K) ±0.15 K (60 K to 345 K) ±0.25 K (345 K to 375 K) ±1.0 K (375 K to 475 K)	Not applicable
3 point (DT-470 only) (4.2 K, 77 K and 305 K)	±0.5 K (2 K to 30 K) ±0.25 K (30 K to 60 K) ±0.15 K (60 K to 345 K) ± 0.25 K (345 K to 375 K) ±1.0 K (375 K to 475 K)	Not applicable
Accuracy (calibrated)	±20 mK < 10 K; ±50 mK (10 K to 330 K); ±55 mK (330 K to 475 K) (all models)	
Stability		
Short-term	±20 mK or better (1.4 K to 330 K) ±10 mK or better at 4.2 K	±20 mK or better (1.4 K to 330 K)
Long-term (per year)	±10 mK/year at 4.2 K ±40 mK/year at 77 K ±25 mK/year at 300 K	±10 mK/year at 4.2 K ±40 mK/year at 77 K ±25 mK/year at 300 K
Thermal response time (SD package)	Typical < 10 milliseconds at 4.2 K; 100 milliseconds at 77 K; 200 milliseconds at 305 K (all models)	
Recommended recalibration schedule	Annual	Annual
Excitation		
Recommended	10 μA ±0.05%	10 μA ±0.05%
Maximum reverse voltage (diode)	40 VDC	40 VDC
Maximum forward current (diode)	500 μA continuous or 5 mA in < 100 microsecond pulses (all models)	
Maximum current before damage	1 mA continuous	1 mA continuous
Dissipation at rated excitation	17 μW at 4.2 K; 10 μW at 77 K; 5 μW at 300 K	17 μW at 4.2 K; 10 μW at 77 K; 5 μW at 300 K
Units range	0 to 2 volts	0 to 2 volts
Lead wire configuration (polarity)	Positive lead on right with package lid up and leads towards user.	Positive lead on left with chip up and leads towards user.
Physical Specifications		
Materials in the sensor/construction	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. Silicon chip with aluminum metallization.	Alumina base, with metallization 0.1 mm of molybdenum, 0.2 mm gold
Size	1 mm high x 1.9 mm wide x 3.2 mm long	0.5 mm high x 0.63 mm wide x 1.52 mm dia.
Mass	37 milligrams	3 milligrams
Leads		
Size	0.38 mm x 0.1 mm thick x 12.7 mm long	50 μm diameter x 2.54 mm long
Number	Two (2)	Two (2)
Material	Nickel and gold plated Kovar	Gold
Insulation	None	None
Internal atmosphere	Package hermetically sealed	Not applicable
Environmental		
Radiation effects	See Reference Section	See Reference Section
Magnetic fields	Not recommended for use in magnetic field applications below 60 K. Low magnetic field dependence when used in fields up to 5 tesla above 60 K (all three models).	
Vacuum vs. liquid differences at -4.2 K	Typically 5 mK to 35 mK depending on configuration. See application note “Self-heating Temperature Errors in Silicon Diode Temperature Sensors” in the Reference Section (both models).	
ESD sensitivity	Better than 3000 static volts	3000 static volts
Noise sensitivity	Can be significant(1)	Can be significant(1)

(1) See the application note titled "Measurement system induced errors in diode thermometry," **Rev. Sci. Instrum. 57 (4),** April 1986. Lake Shore order number 1420. Also see the Reference Section.

Specifications

	DT-421/422
Temperature	
Useful range	
Minimum	1.4 K (must be calibrated for use below 10 K)
Maximum	325 K
Maximum storage temperature	305 K
Standard curve	DT-421 follows Curve 10 to a tolerance of 2.0 K or 1.5% of temperature from 10 K to 325 K, whichever is greater. DT-422 follows Curve 10 to a tolerance of 1.0 K or 1.0% of temperature from 40 K to 325 K, whichever is greater.
Voltage (typical)	1.789 V at 4.2 K; 1.020 V at 77 K; 0.507 V at 305 K
Sensitivity (typical)	-36 mV/K at 4.2 K; -2 mV/K at 100 K; -2.4 mV/K at 305 K
Repeatability	Repeatability at 4.2 K is required to be better than ±50 mK over three thermal cycles for device acceptance. Repeatability is typically better than ±10 mK.
Accuracy (interchangeability)	DT-421: ±2 K or ±1.5% temperature from 10 K to 325 K, whichever is greater DT-422: ±2 K from 10 K to 40 K; Band 13; from 40 K to 325 K, whichever is greater
Accuracy (SoftCal™)	2 point: ±0.25 K (30 K to 60 K) ±0.15 K (60 K to 325 K)
Accuracy (calibrated)	±50 mK or better
Stability	
Short-term	±25 mK at 4.2 K
Long-term (per year)	±10 mK/year at 4.2 K ±40 mK/year at 77 K ±25 mK/year at 300 K
Thermal response time	< 10 milliseconds at 4.2 K; 100 milliseconds at 77 K; 200 milliseconds at 305 K (both models)
Recommended recalibration schedule	Annual
Excitation	
Recommended	10 μA ±0.05%
Maximum reverse voltage (diode)	40 VDC
Maximum forward current (diode)	500 μA continuous or 5 mA in < 100 microsecond pulses
Maximum power before damage	2 mW continuous
Dissipation at rated excitation	17 μW at 4.2 K; 10 μW at 77 K, 5 μW at 300 K
Units range	0 to 2 volts
Lead wire configuration (polarity)	Positive lead is right-hand ribbon with the platinum disk down and the leads towards the user.
Physical Specifications	
Materials in the sensor/construction	The sensing element is mounted to a platinum disk and covered with a dome of Stycast® epoxy.
Size in millimeters	< 1 mm high x 1.25 mm diameter
Mass	23 milligrams
Leads	
Size	0.5 mm x 0.25 mm x 25 mm long
Number	Two (2)
Material	Platinum ribbon with ends tinned with 60/40 PbSn solder.
Insulation	None
Environmental	
Radiation effects	See Reference Section
Magnetic fields	Not recommended for use in magnetic field applications below 60 K. Low magnetic field dependence when used in fields up to 5 tesla above 60 K.
Vacuum vs. liquid differences	< 100 mK at 4.2 K typical greased to copper block in vacuum
ESD sensitivity	3000 static volts or better
Noise sensitivity	Can be significant(1)

(1) See the application note titled "Measurement system induced errors in diode thermometry," **Rev. Sci. Instrum. 57 (4),** April 1986. Lake Shore order number 1420. Also see the Reference Section.

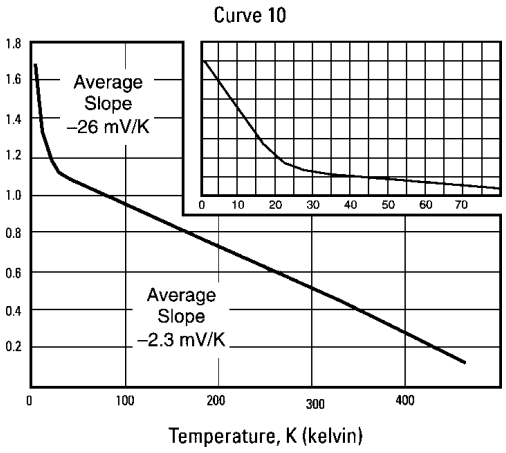
For information on Packages for Sensor Installation, see pages 1-40 to 1-42.

Adding lead length to sensors - see page 1-43.

Curve 10

Measurement Current = 10 microamperes, ±0.05%

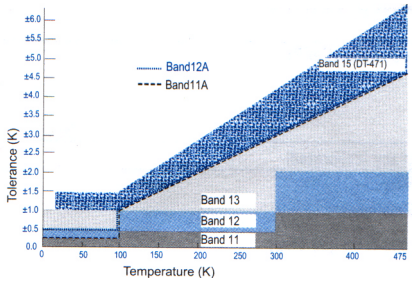
All DT-470, DT-471, DT-421*, DT-422* and DT-414 Silicon Diode temperature sensors follow the same standard temperature response curve, Curve 10 (table below). Consequently, Lake Shore's Silicon Diodes can be interchanged with one another routinely in any application utilizing this response curve. Curve 10 is programmed into all Lake Shore temperature controllers, digital thermometers and cryopump monitors.



Shaded portion highlights truncated portion of Curve 10 corresponding to the reduced temperature range of DT-471 diode sensors. Note that packaging may limit the allowable temperature range, especially at the high end.

Tolerance Bands for DT-470 Silicon Diodes

Standard Curve 10 Tolerance Bands			
Band	2 K - 100 K	100 K - 305 K	305 K - 475 K
11	± 0.25 K	± 0.5 K	± 1.0 K
11A	± 0.25 K	± 1% of temp.	± 1% of temp.
12	± 0.5 K	± 1.0 K	± 2.0 K
12A	± 0.5 K	± 1% of temp.	± 1% of temp.
13	± 1.0 K	± 1% of temperature	



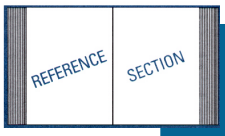
* Partial conformances

T (K)	Voltage (V)	dV/dT (mV/K)	T (K)	Voltage (V)	dV/dT (mV/K)	T (K)	Voltage (V)	dV/dT (mV/K)
1.40	1.69812	-13.1	16.5	1.27607	-18.2	100.0	0.97550	-2.04
1.60	1.69521	-15.9	17.0	1.26702	-18.0	110.0	0.95487	-2.08
1.80	1.69177	-18.4	17.5	1.25810	-17.7	120.0	0.93383	-2.12
2.00	1.68786	-20.7	18.0	1.24928	-17.6	130.0	0.91243	-2.16
2.20	1.68352	-22.7	18.5	1.24053	-17.4	140.0	0.89072	-2.19
2.40	1.67880	-24.4	19.0	1.23184	-17.4	150.0	0.86873	-2.21
2.60	1.67376	-25.9	19.5	1.22314	-17.4	160.0	0.84650	-2.24
2.80	1.66845	-27.1	20.0	1.21440	-17.6	170.0	0.82404	-2.26
3.00	1.66292	-28.1	21.0	1.19645	-18.5	180.0	0.80138	-2.28
3.20	1.65721	-29.0	22.0	1.17705	-20.6	190.0	0.77855	-2.29
3.40	1.65134	-29.8	23.0	1.15558	-21.7	200.0	0.75554	-2.31
3.60	1.64529	-30.7	24.0	1.13598	-15.9	210.0	0.73238	-2.32
3.80	1.63905	-31.6	25.0	1.12463	-7.72	220.0	0.70908	-2.34
4.00	1.63263	-32.7	26.0	1.11896	-4.34	230.0	0.68564	-2.35
4.20	1.62602	-33.6	27.0	1.11517	-3.34	240.0	0.66208	-2.36
4.40	1.61920	-34.6	28.0	1.11212	-2.82	250.0	0.63841	-2.37
4.60	1.61220	-35.4	29.0	1.10945	-2.53	260.0	0.61465	-2.38
4.80	1.60506	-36.0	30.0	1.10702	-2.34	270.0	0.59080	-2.39
5.00	1.59782	-36.5	32.0	1.10263	-2.08	273.15	0.58327	-2.39
5.50	1.57928	-37.6	34.0	1.09864	-1.92	280.0	0.56690	-2.39
6.00	1.56027	-38.4	36.0	1.09490	-1.83	290.0	0.54294	-2.40
6.50	1.54097	-38.7	38.0	1.09131	-1.77	300.0	0.51892	-2.40
7.00	1.52166	-38.4	40.0	1.08781	-1.74	305.0	0.50688	-2.41
7.50	1.50272	-37.3	42.0	1.08436	-1.72	310.0	0.49484	-2.41
8.00	1.48443	-35.8	44.0	1.08093	-1.72	320.0	0.47069	-2.42
8.50	1.46700	-34.0	46.0	1.07748	-1.73	330.0	0.44647	-2.42
9.00	1.45048	-32.1	48.0	1.07402	-1.74	340.0	0.42221	-2.43
9.50	1.43488	-30.3	50.0	1.07053	-1.75	350.0	0.39783	-2.44
10.0	1.42013	-28.7	52.0	1.06700	-1.77	360.0	0.37337	-2.45
10.5	1.40615	-27.2	54.0	1.06346	-1.78	370.0	0.34881	-2.46
11.0	1.39287	-25.9	56.0	1.05988	-1.79	380.0	0.32416	-2.47
11.5	1.38021	-24.8	58.0	1.05629	-1.80	390.0	0.29941	-2.48
12.0	1.36809	-23.7	60.0	1.05267	-1.81	400.0	0.27456	-2.49
12.5	1.35647	-22.8	65.0	1.04353	-1.84	410.0	0.24963	-2.50
13.0	1.34530	-21.9	70.0	1.03425	-1.87	420.0	0.22463	-2.50
13.5	1.33453	-21.2	75.0	1.02482	-1.91	430.0	0.19961	-2.50
14.0	1.32412	-20.5	77.35	1.02032	-1.92	440.0	0.17464	-2.49
14.5	1.31403	-19.9	80.0	1.01525	-1.93	450.0	0.14985	-2.46
15.0	1.30422	-19.4	85.0	1.00552	-1.96	460.0	0.12547	-2.41
15.5	1.29464	-18.9	90.0	0.99565	-1.99	470.0	0.10191	-2.30
16.0	1.28527	-18.6	95.0	0.98564	-2.02	475.0	0.09062	-2.22

Ordering Information

Uncalibrated sensor
Specify the Model number in the left column only, for example DT-470-BO-11.

Calibrated sensor
Add Calibration Range Suffix Code to the end of the Model number, for exampe DT-470-BO-13-1.4L.



See the Reference Section for a detailed description of
- Installation
- Uncalibrated sensors
- SoftCal™
- Calibrated sensors
- CalCurve™
- Sensor packages

Accessories suggested for installation (see Section 3):
- Stycast® Epoxy
- Apiezon® Grease
- IMI-7031 Varnish
- Indium Solder
- 90% Pb, 10% Sn Solder
- Phosphor-Bronze Wire
- Manganin Wire
- CryoCable™

DT-470	Calibration Range Suffix Codes Numeric figure is the low end of the calibration. SoftCal™ Letters represent the high end: D = 100 K, L = 325 K, H = 475 K.											
Model number	2S	3S	1.4D	1.4L	1.4H	4D	4L	4H	10L	10H	70L	70H
DT-470-BO-11												
DT-470-BO-11A												
DT-470-BO-12												
DT-470-BO-12A												
DT-470-BO-13	✓	✓	✓	✓		✓	✓				✓	
DT-470-BR-11												
DT-470-BR-11A												
DT-470-BR-12												
DT-470-BR-12A												
DT-470-BR-13	✓	✓	✓	✓		✓	✓				✓	
DT-470-CO/ET/LR/MT-11												
DT-470-CO/ET/LR/MT-11A												
DT-470-CO/ET/LR/MT-12												
DT-470-CO/ET/LR/MT-12A												
DT-470-CO-13	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓
DT-470-CU-11												
DT-470-CU-11A												
DT-470-CU-12												
DT-470-CU-12A												
DT-470-CU-13	✓	✓	✓	✓		✓	✓				✓	
DT-470-CY-12												
DT-470-CY-12A												
DT-470-CY-13	✓	✓	✓	✓		✓	✓				✓	
DT-470-DI-13												
DT-470-ET-13	✓	✓	✓	✓		✓	✓				✓	
DT-470-LR-13	✓	✓	✓	✓		✓	✓				✓	
DT-470-MT-13	✓	✓	✓	✓		✓	✓				✓	
DT-470-SD-11												
DT-470-SD-11A												
DT-470-SD-12												
DT-470-SD-12A												
DT-470-SD-13	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓
DT-471-BO	✓								✓		✓	
DT-471-BR	✓								✓		✓	
DT-471-CO	✓								✓	✓	✓	✓
DT-471-CU	✓								✓		✓	
DT-471-CY	✓								✓		✓	
DT-471-DI												
DT-471-ET/LR/MT	✓								✓		✓	
DT-471-SD	✓								✓	✓	✓	✓
DT-414-UN						✓	✓					
DT-421-HR	✓		✓	✓		✓	✓					
DT-422-HR	✓		✓	✓		✓	✓					
Model number	2S	3S	1.4D	1.4L	1.4H	4D	4L	4H	10L	10H	70L	70H

Other packaging available through special order. Please consult Lake Shore.

The DT-414 is extremely fragile and difficult to handle because of its small size and exposed fine wires. Lake Shore recommends that an SD package be used unless there is a size restriction that requires the smaller sensor.

Lake Shore does not warrant mechanical damage to the DT-414.

Handling
1. Fragile assembly, must not be turned over on gold wire bond side. Handle by edges of substrate or by 50 µm diameter gold leads.
2. Unencapsulated device must not be exposed to moisture or corrosive atmosphere.

Accessories available for sensors

ECRIT	Expanded interpolation table
SCR	Special calibration report
8000	Calibration report on floppy disk
COC-SEN	Certificate of conformance

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