

**DT-470-SD Features**

- Monotonic temperature response from 1.4 K to 500 K\*
- Conformance to standard Curve 10 temperature response curve
- Useful above 60 K in magnetic fields up to 5 T
- The rugged, reliable Lake Shore SD package designed to withstand repeated thermal cycling and minimize sensor self-heating
- Variety of packaging options

**DT-471-SD Features**

- Lower priced version of DT-470 with a temperature range of 10 K to 500 K\*

**DT-414 Features**

- Temperature range: 1.4 K to 375 K (calibration up to 325 K)
- Small mass for rapid thermal response
- Non-magnetic package

**DT-421 Features**

- Temperature range: 1.4 K to 325 K\*\*
- Non-magnetic package
- Exposed flat substrate for surface mounting

\* Calibrated to 500 K, uncalibrated (Curve 10) to 475 K

\*\* Calibrated down to 1.4 K, uncalibrated (Curve 10) to 20 K



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

# DT-400 Series Silicon Diodes

**DT-470/471 Hermetically Sealed Silicon Diode**

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 are routinely interchangeable with one another.

**PACKAGING OPTIONS** BO, CO, CU, CY, DI, ET, LR, MT



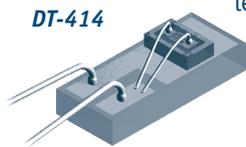
DT-470/471-SD

**The Lake Shore SD Package – The Most Rugged, Versatile Package in the Industry**

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

**DT-414 Unencapsulated Silicon Diodes**

The Model DT-414 uses the DT-400 bare chip Silicon Diode mounted on a flat substrate. This chip-level sensor offers minimal thermal mass and minimal physical size. Die attachment is with silver epoxy, and the chip is unencapsulated, leaving the fragile gold wires exposed.



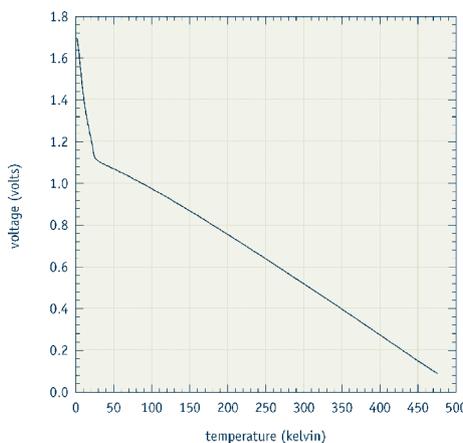
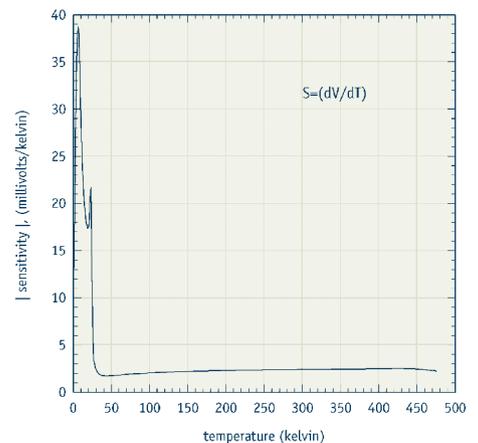
DT-414

**DT-421-HR Miniature Silicon Diode**

The DT-421 miniature Silicon Diode temperature sensor is configured for installation on flat surfaces. The DT-421 sensor package exhibits precise, monotonic temperature response over its useful range. The sensor chip is in direct contact with the epoxy dome, which causes increased voltage at 4.2 K and prevents full range Curve 10 conformity. For use below 20 K, calibration is required.



DT-421-HR

**Typical DT-400 Diode Voltage Values****Typical DT-400 Diode Sensitivity Values**

# Specifications

**Standard curve** Curve 10 (see next page)

**Recommended excitation** 10  $\mu$ A  $\pm$ 0.1%

**Max reverse voltage** 40 V

**Max current before damage** 1 mA continuous or 100 mA pulsed

**Dissipation at recommended excitation**

17  $\mu$ W at 4.2 K; 10  $\mu$ W at 77 K; 5  $\mu$ W at 305 K

**Thermal response time** SD: typical <10 ms at 4.2 K; 100 ms at 77 K; 200 ms at 305 K

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

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

**Reproducibility**<sup>1</sup>  $\pm$ 10 mK at 4.2 K

<sup>1</sup> Short-term reproducibility data is obtained by subjecting sensor to repeated thermal shocks from 305 K to 4.2 K

## Range of Use

	Minimum Limit	Maximum Limit
DT-470-SD	1.4 K	500 K
DT-471-SD	10 K	500 K
DT-414	1.4 K	375 K
DT-421	1.4 K	325 K

## Calibrated Accuracy

	Typical sensor accuracy <sup>2</sup>	Long-term stability <sup>3</sup>
1.4 K	$\pm$ 12 mK	—
4.2 K	$\pm$ 12 mK	10 mK
10 K	$\pm$ 12 mK	—
77 K	$\pm$ 22 mK	40 mK
300 K	$\pm$ 32 mK	25 mK
500 K	$\pm$ 50 mK	—

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

<sup>3</sup> Long-term stability data is obtained by subjecting sensor to 200 thermal shocks from 305 K to 77 K

## Physical Specifications

	Mass	Lead type	Lead polarity	Sensor materials used
<b>DT-470/471-SD</b>	37 mg	2 – gold and nickel plated Kovar	Positive lead on right with package lid up and leads towards user	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 seal. Silicon chip with aluminum metallization.
<b>DT-414</b>	3 mg	2 – gold	Positive lead on left with chip up and leads towards user	DT-414: alumina base with top metallization (0.1 $\mu$ m of molybdenum, 0.2 $\mu$ m gold) DT-414M: metallization on top and bottom
<b>DT-421</b>	23 mg	2 – platinum ribbon with tinned 60/40 SnPb solder	Positive lead is right-hand ribbon with platinum disk down and leads towards user	Sensing element is mounted to a platinum disk and covered with a dome of Stycast® 2850 epoxy

## SoftCal™ Accuracy

	2 K to 30 K	30 K to 60 K	60 K to 345 K	345 K to 375 K	375 K to 475 K
2S <sup>4</sup>	—	$\pm$ 0.25 K	$\pm$ 0.15 K	$\pm$ 0.25 K	$\pm$ 1.0 K
3S	$\pm$ 0.5 K	$\pm$ 0.25 K	$\pm$ 0.15 K	$\pm$ 0.25 K	$\pm$ 1.0 K

2S: 77 K and 305 K (DT-470-SD, DT-471-SD, and DT-421)

3S: 4.2 K, 77 K, and 305 K (DT-470-SD only)

<sup>4</sup> DT-421 SoftCal has a low end temperature limited to 40 K

## Standard Curve 10 Tolerance Bands for DT-400 Series Silicon Diodes

Type 470	2 K to 100 K	100 K to 305 K	305 K to 475 K
Band 11	$\pm$ 0.25 K	$\pm$ 0.5 K	$\pm$ 1.0 K
Band 11A	$\pm$ 0.25 K	$\pm$ 1% of temp	$\pm$ 1% of temp
Band 12	$\pm$ 0.5 K	$\pm$ 1.0 K	$\pm$ 2.0 K
Band 12A	$\pm$ 0.5 K	$\pm$ 1% of temp	$\pm$ 1% of temp
Band 13	$\pm$ 1.0 K	$\pm$ 1% of temp	$\pm$ 1% of temp

Type	1.4 K to 10 K	10 K to 375 K	375 K to 475 K
DT-471	Not recommended	$\pm$ 1.5 K or $\pm$ 1.5% of temp, whichever is greater	
DT-414	$\pm$ 1.5 K or $\pm$ 1.5% of temp, whichever is greater		Not recommended

Type	20 K to 325 K
DT-421	$\pm$ 2.5 K or $\pm$ 1.5% of temp, whichever is greater

## Temperature Response Data Table (typical)

	DT-470/471*/414		DT-421	
	V (volts)	dV/dT (mV/K)	V (volts)	dV/dT (mV/K)
1.4	1.698	-13.1	—	—
4.2	1.626	-33.6	1.789	-36
10	1.42	-28.7	—	—
77	1.0203	-1.75	1.02	2
305	0.507	-2.4	0.507	-2.4

See Appendix G for expanded response table

\* DT-471 useful range: >10 K

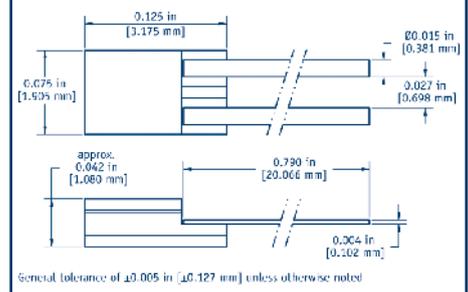
## Typical Magnetic Field-Dependent Temperature Errors<sup>5</sup> $\Delta$ T/T (%) at B (magnetic induction)

T(K)	Package Base Parallel to Field B				
	1 T	2 T	3 T	4 T	5 T
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

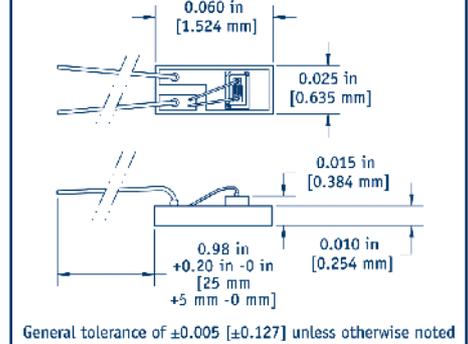
T(K)	Package Base Perpendicular to Field B				
	1 T	2 T	3 T	4 T	5 T
4.2	-8	-9	-11	-15	-20
20	-4	-5	-5	-5	-10
40	-1.5	-3	-4	-5	-5.5
60	-0.5	-0.7	-0.8	-1	-1.1
80	-0.1	-0.3	-0.5	-0.6	-0.7
300	<0.1	0.2	0.5	0.6	0.6

<sup>5</sup> To minimize magnetic field-induced temperature errors, the sensor should be oriented so that the package base is perpendicular to the magnetic field flux lines – this results in the diode current being parallel to the magnetic field

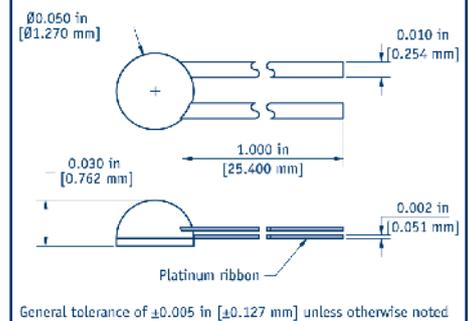
### DT-470/471-SD



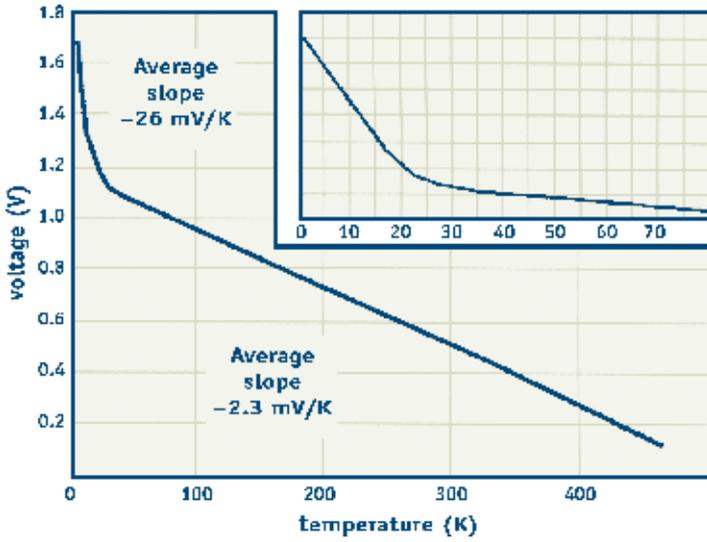
### DT-414



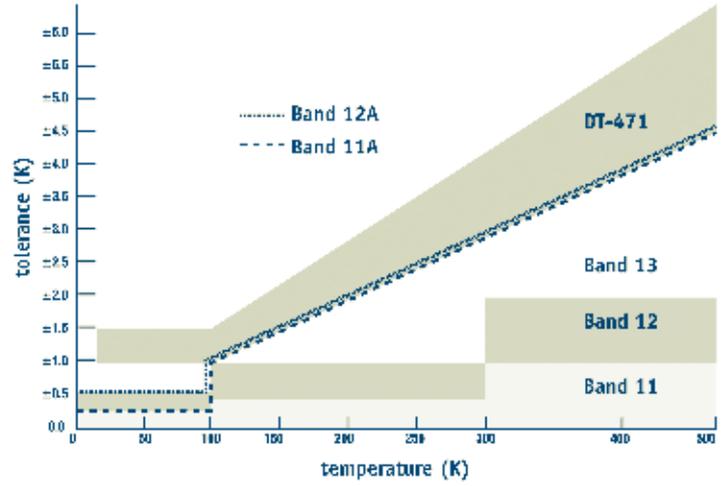
### DT-421



DT-400 Series Curve 10 Temperature Response Curve



Standard Curve 10 Tolerance Bands for DT-470/471 Silicon Diodes



DT-400 Series Expanded Temperature Response Data Table

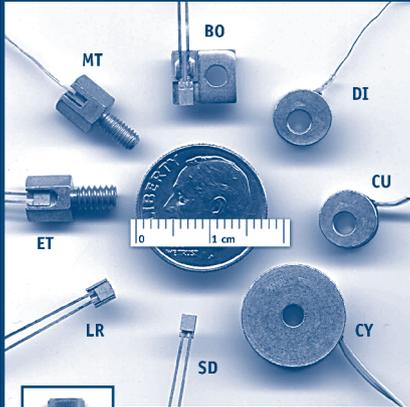
All DT-470, DT-471\*, DT-414\*, and DT-421\* Silicon Diodes follow the same Curve 10 standard temperature response curve, which means they can be interchanged with one another routinely in any application utilizing this response curve.

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

\*Partial conformances

**PACKAGING OPTIONS**

For information on mounting adapters available for use with the SD package, see page 25.



CO adapter – spring loaded clamp for easy sensor interchangeability

To add length to sensor leads (SMOD), see page 28.



See the appendices for a detailed description of:

- Installation
- Uncalibrated sensors
- SoftCal™
- Calibrated sensors
- CalCurve™
- Sensor packages

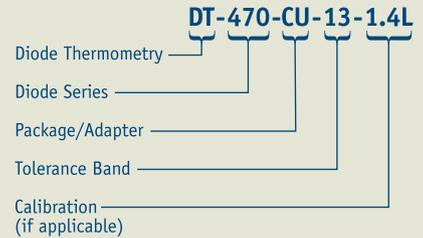
## Ordering Information

### Uncalibrated sensor

- Step 1:** Choose diode series, for example DT-470.
- Step 2:** Choose package or mounting adapter—if ordering adapter, substitute the adapter suffix for the SD suffix, for example DT-470-CU.
- Step 3:** Choose tolerance band (if applicable), for example DT-470-CU-11.

### Calibrated sensor

- Step 1:** Choose diode series, for example DT-470.
  - Step 2:** Choose package or mounting adapter—if ordering adapter, substitute the adapter suffix for the SD suffix, for example DT-470-CU-13.
  - Step 3:** Specify the calibration range suffix code after the model number and package suffix, for example DT-470-CU-13-1.4L.
- Note:** When ordering a DT-470, only Band 13 sensors are calibrated.



DT-400 Series	Calibration Range Suffix Codes						
	Numeric figure is the low end of the calibration						
	Letters represent the high end: L=325 K, H=500 K						

Model number	Uncal	2S	3S	1.4L	1.4H	70L	70H
DT-414-UN*	■			■			
DT-414M-UN*	■			■			
DT-421-HR	■	■		■			
DT-470-SD-11	■						
DT-470-SD-11A	■						
DT-470-SD-12	■						
DT-470-SD-12A	■						
DT-470-SD-13	■	■	■	■	■	■	■

Mounting adapters are available for use with the SD package—replace SD suffix with mounting adapter suffix							
CO	■	■	■	■	■	■	■
CU, LR, CY, ET, BO, MT	■	■	■	■		■	
CU-HT	■	■	■	■	■	■	■
DT-470-DI-13	■						

Model number	Uncal	2S	10L	10 H	70L	70H
DT-471-BO, -CU, -ET, -LR, -MT	■	■	■		■	
DT-471-CO, -CU-HT, -SD	■	■	■	■	■	■
DT-471-DI	■					

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

DT-414 handling: fragile assembly—must not be turned over on gold wire bond side—handle by edges of substrate or by 50 µm diameter gold leads; unencapsulated device must not be exposed to moisture or corrosive atmosphere  
DT-414M-UN substrate is backside metallized

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

### Accessories available for sensors

- SN-CO-C1 CO style sensor clamps for SD package
- ECRIT Expanded interpolation table
- 8000 Calibration report on CD-ROM
- COC-SEN Certificate of conformance

### Accessories suggested for installation—

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

