Lake Shore CRYOTRONICS

Certificate Of Calibration

Report Number: D6167361576680403

Sensor Model:	DT-670-CU-HT-1.4L	Serial Number:	D6167361
Sensor Type:	Silicon Diode	Calibration Date:	4/3/2024
Sensor Excitation:	see *As-Measured Data* page	Calibration Due:	
Temperature Range:	1.4 K to 325 K		

Traceability and Calibration Method

This temperature sensor has been calibrated to the International Temperature Scale of 1990 (ITS-90) or the Provisional Low Temperature Scale (PLTS-2000) as appropriate. The calibrations are traceable to the National Institute of Standards and Technology (NIST, United States), the National Physical Laboratory (NPL, United Kingdom), the Physikalisch-Technische Bundesanstalt (PTB, Germany), or natural physical constants.

Lake Shore Cryotronics maintains ITS-90 and PLTS-2000 on standard platinum (SPRT), rhodium iron (RIRT), and germanium (GRT) resistance thermometers that have been calibrated directly by an internationally recognized national metrology institute (NIST, NPL, PTB) for T < 330 K or an ISO 17025 accredited metrology laboratory for 330 K < T < 800 K. A nuclear orientation thermometer is also used for temperatures less than 50 mK. These standards are routinely intercompared to verify consistency and accuracy of the temperature scale.

The sensor calibrations are performed by comparison to laboratory standard resistance thermometers and tested in accordance with Lake Shore Cryotronics, Inc. Quality Assurance Manual. The quality system of Lake Shore Cryotronics is registered to ISO 9001.

Procedures used: Q00277, Q00754, Q00765, Q00826

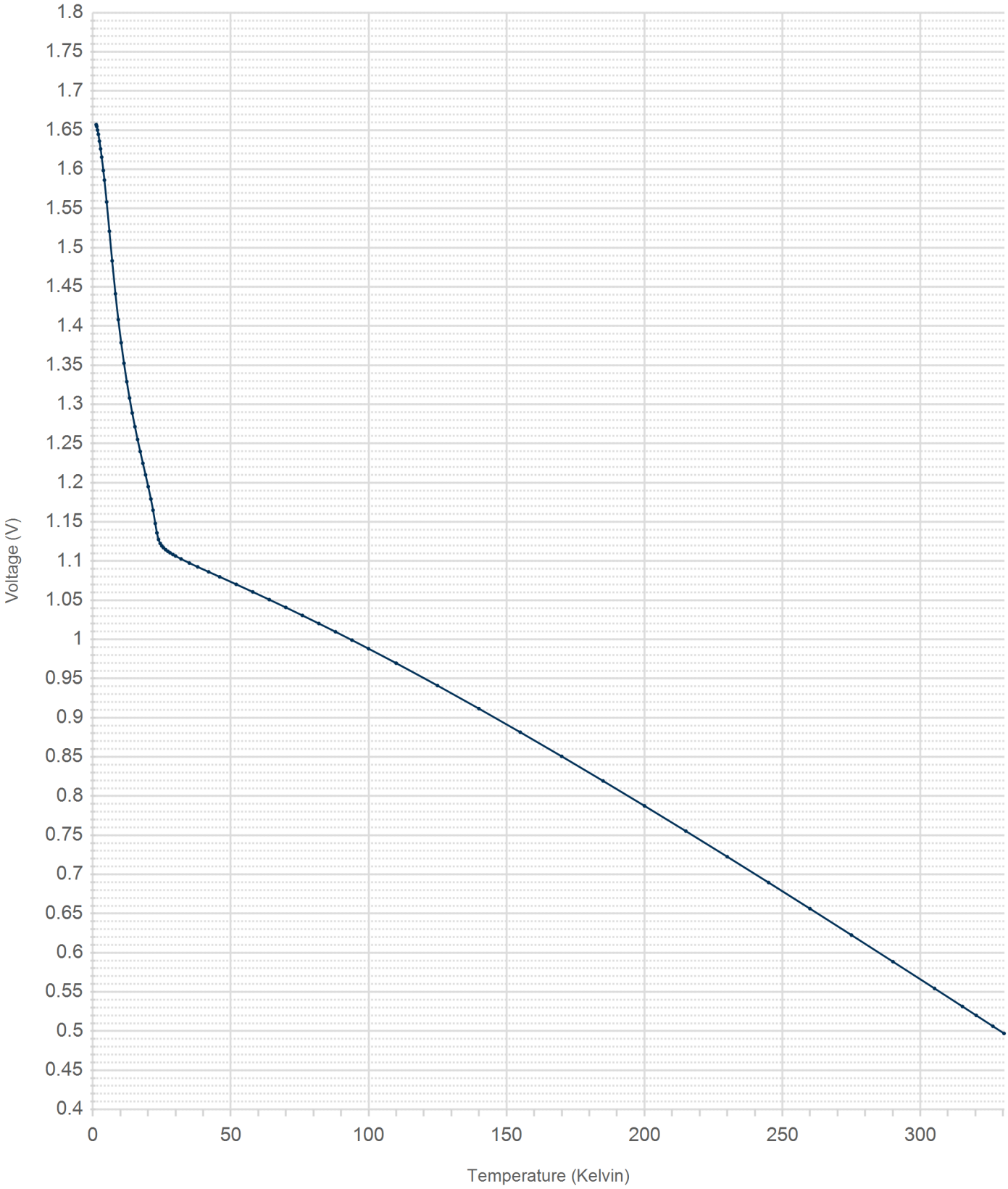
In Accordance with ISO 17025:

The calibration results in this report apply only to the specific sensor specified above. This report shall not be reproduced, except in full, without written approval from Lake Shore Cryotronics, Inc. Unless stated otherwise, the uncertainties in this report are based on an approximate 95% confidence level with a coverage factor k=2.

Approved By: Romerero Prince
Metrology

Please visit www.lakeshore.com/resources/sensor for a detailed description of this report, its contents, and calibration procedures.

As-Measured Data Plot



As-Measured Data

Acquired Data Points: 71

Temp. (K)	Voltage (V)	Excitation	Temp. (K)	Voltage (V)	Excitation
1.20308	1.65722	10µA ± 0.1%	31.9900	1.10272	10µA ± 0.1%
1.30591	1.65603	10µA ± 0.1%	34.9879	1.09751	10µA ± 0.1%
1.41134	1.65467	10µA ± 0.1%	37.9809	1.09259	10µA ± 0.1%
1.70334	1.65018	10µA ± 0.1%	41.9787	1.08623	10µA ± 0.1%
1.99412	1.64478	10µA ± 0.1%	45.9852	1.07988	10µA ± 0.1%
2.39552	1.63605	10µA ± 0.1%	51.9793	1.07030	10µA ± 0.1%
2.80096	1.62615	10µA ± 0.1%	57.9869	1.06059	10µA ± 0.1%
3.20019	1.61568	10µA ± 0.1%	63.9656	1.05078	10µA ± 0.1%
3.79891	1.59861	10µA ± 0.1%	69.9625	1.04079	10µA ± 0.1%
4.19171	1.58629	10µA ± 0.1%	75.9602	1.03063	10µA ± 0.1%
4.99853	1.55841	10µA ± 0.1%	81.9547	1.02028	10µA ± 0.1%
5.99790	1.52110	10µA ± 0.1%	87.9533	1.00975	10µA ± 0.1%
6.99824	1.48325	10µA ± 0.1%	93.9564	0.99904	10µA ± 0.1%
8.18579	1.44114	10µA ± 0.1%	99.9536	0.98816	10µA ± 0.1%
9.22532	1.40814	10µA ± 0.1%	109.959	0.96964	10µA ± 0.1%
10.2654	1.37870	10µA ± 0.1%	124.955	0.94108	10µA ± 0.1%
11.2915	1.35255	10µA ± 0.1%	139.960	0.91165	10µA ± 0.1%
12.3023	1.32914	10µA ± 0.1%	154.961	0.88150	10µA ± 0.1%
13.2970	1.30810	10µA ± 0.1%	169.978	0.85069	10µA ± 0.1%
14.2806	1.28901	10µA ± 0.1%	184.977	0.81937	10µA ± 0.1%
15.2517	1.27155	10µA ± 0.1%	199.989	0.78753	10µA ± 0.1%
16.2180	1.25525	10µA ± 0.1%	215.001	0.75526	10µA ± 0.1%
17.1780	1.23979	10µA ± 0.1%	230.003	0.72261	10µA ± 0.1%
18.1399	1.22483	10µA ± 0.1%	244.998	0.68962	10µA ± 0.1%
19.1023	1.21006	10µA ± 0.1%	260.001	0.65628	10µA ± 0.1%
20.0710	1.19504	10µA ± 0.1%	275.029	0.62258	10µA ± 0.1%
21.0433	1.17916	10µA ± 0.1%	290.078	0.58861	10µA ± 0.1%
21.8243	1.16494	10µA ± 0.1%	305.176	0.55439	10µA ± 0.1%
22.6279	1.14800	10µA ± 0.1%	315.269	0.53142	10µA ± 0.1%
23.2235	1.13597	10µA ± 0.1%	320.297	0.51996	10µA ± 0.1%
23.8224	1.12751	10µA ± 0.1%	326.313	0.50619	10µA ± 0.1%
24.4235	1.12251	10µA ± 0.1%	330.353	0.49700	10µA ± 0.1%
25.0141	1.11936	10µA ± 0.1%			
25.6046	1.11702	10µA ± 0.1%			
26.3963	1.11453	10µA ± 0.1%			
27.1962	1.11242	10µA ± 0.1%			
27.9914	1.11056	10µA ± 0.1%			
28.9912	1.10843	10µA ± 0.1%			
29.9889	1.10644	10µA ± 0.1%			

Uncertainty Analysis

Calibration Data Uncertainty

The uncertainties of the measured calibration data for Lake Shore's sensors are summarized in the table below. The values given are the combined uncertainty of the temperature measurement and the voltage measurement expressed as an equivalent temperature uncertainty in millikelvin (mK). Note that the values are the calibration uncertainty only and do not include the stability of the temperature sensor. The uncertainty analysis has followed the guidelines for determining measurement uncertainty as outlined in the ISO Guide to the Expression of Uncertainty in Measurement and NIST Technical Note 1297. Since the uncertainty varies with temperature due to the variation of the sensor sensitivity and excitation, the table gives typical values at several different temperatures throughout the range of the calibration. The uncertainty is based on an approximate 95% confidence level with a coverage factor k = 2.

Diode										
Temperature (K)	1.4	4.2	10	20	30	50	100	300	400	500
Uncertainty (± mK)	7	5	6	9	31	37	32	35	39	54

Polynomial Fit Uncertainty

When a sensor is used to measure temperature, a polynomial fit to the measured calibration data is often used to convert the voltage (V) to a temperature (T). How well the polynomial represents the sensor calibration data is another source of uncertainty when using the sensor. The typical uncertainty contribution from the fit is significantly smaller than the system measurement uncertainty. See www.lakeshore.com/resources/sensors for further details on determining the additional uncertainty for a specific fitted/interpolated data set.

A note on uncertainty and resolution of data provided:

The full resolution of the calibration data provided in this report may be orders of magnitude higher than the uncertainty. This level of resolution is provided because practical usage of a cryogenic temperature sensor involves use of interpolation and a host of curve-fitting methods where the calculated output is likely to be highly sensitive to rounding errors. Additionally, usage can depend on temperature differentials as well as absolute temperature which has the same effect of potentially introducing rounding errors through even simple calculations.

The resolution of the data presented in this report is therefore provided in full to allow for the highest level of accuracy of calculations performed. It should not be considered as representative of the accuracy of the calibration system itself. Only the stated uncertainty values are to be used as such.

Polynomial Equation

Polynomial Type: Chebychev

Useful Range of Fit:

1.400 K to 13.297 K

1.308 V to 1.655 V

Lower and Upper limits of Voltage used in computing Chebychev coefficients:

ZL: 1.271549315 ZU: 1.657223339

Order	Coefficient	Std. Deviation of Coefficient	Ratio (Coeff. / Std Dev.)
0	7.967609	9.01798E-004	8835.25
1	-6.537992	1.33686E-003	-4890.57
2	0.384796	1.37742E-003	279.36
3	-0.418994	1.28428E-003	-326.25
4	-0.079499	1.21816E-003	-65.26
5	-0.036040	1.16259E-003	-31.00
6	-0.017960	1.15570E-003	-15.54
7	-0.015142	1.10648E-003	-13.69
8	-0.011263	1.16062E-003	-9.70
9	-0.007970	1.19129E-003	-6.69
10	-0.008680	1.23543E-003	-7.03
11	-0.005597	1.30130E-003	-4.30
12	-0.005160	1.31481E-003	-3.92

Z = Voltage

k = ((Z-ZL)-(ZU-Z))/(ZU-ZL)

Temp. (K) = ΣA_i* COS(i * ARCCOS(k)), where 0 <= i <= 8 and the A_i's are the coefficients in the table above.

Polynomial Equation

Polynomial Type: Chebychev

Temp. (K) vs. Voltage

	Meas. (V)	T Meas. (K)	T Eq. (K)	T diff. (mK)
1	1.657223	1.20308	1.20811	-5.03
2	1.656029	1.30591	1.30410	1.81
3	1.654667	1.41134	1.40659	4.75
4	1.650181	1.70334	1.70203	1.31
5	1.644782	1.99412	1.99705	-2.92
6	1.636054	2.39552	2.39741	-1.89
7	1.626152	2.80096	2.79981	1.16
8	1.615677	3.20019	3.19813	2.06
9	1.598610	3.79891	3.79898	-0.08
10	1.586290	4.19171	4.19391	-2.20
11	1.558407	4.99853	4.99734	1.19
12	1.521105	5.99790	5.99752	0.38
13	1.483251	6.99824	6.99975	-1.51
14	1.441142	8.18579	8.18335	2.43
15	1.408137	9.22532	9.22785	-2.52
16	1.378702	10.26536	10.26447	0.89
17	1.352554	11.29145	11.29013	1.32
18	1.329136	12.30225	12.30455	-2.30
19	1.308101	13.29699	13.29535	1.64
20	1.289009	14.28057	14.28117	-0.60
21	1.271549	15.25167	15.25158	0.09

Order of Fit = 12 RMS error of Fit = 2.21 mK

Largest absolute error = 5.03 mK at data point no. 1

Polynomial Equation

Polynomial Type: Chebychev

Useful Range of Fit:

13.297 K to 25.014 K

1.119 V to 1.308 V

Lower and Upper limits of Voltage used in computing Chebychev coefficients:

ZL: 1.114527721 ZU: 1.352553833

Order	Coefficient	Std. Deviation of Coefficient	Ratio (Coeff. / Std Dev.)
0	17.904716	8.43827E-003	2121.85
1	-7.035724	1.58684E-002	-443.38
2	0.450235	1.32980E-002	33.86
3	-0.040253	9.36208E-003	-4.30
4	0.258332	4.91579E-003	52.55
5	-0.265598	2.72153E-003	-97.59
6	0.178211	6.30265E-003	28.28
7	-0.133843	9.46841E-003	-14.14
8	0.048011	1.12656E-002	4.26
9	-0.057003	1.05041E-002	-5.43
10	0.005992	8.36014E-003	0.72
11	-0.021632	5.23318E-003	-4.13

Z = Voltage

k = ((Z-ZL)-(ZU-Z))/(ZU-ZL)

Temp. (K) = ΣA_i* COS(i * ARCCOS(k)), where 0 <= i <= 8 and the A_i's are the coefficients in the table above.

Polynomial Equation

Polynomial Type: Chebychev

Temp. (K) vs. Voltage

	Meas. (V)	T Meas. (K)	T Eq. (K)	T diff. (mK)
1	1.352554	11.29145	11.29144	0.01
2	1.329136	12.30225	12.30236	-0.11
3	1.308101	13.29699	13.29628	0.71
4	1.289009	14.28057	14.28285	-2.28
5	1.271549	15.25167	15.24801	3.66
6	1.255254	16.21798	16.21970	-1.72
7	1.239786	17.17796	17.18098	-3.01
8	1.224825	18.13991	18.13616	3.76
9	1.210056	19.10230	19.10075	1.55
10	1.195041	20.07101	20.07567	-4.66
11	1.179157	21.04328	21.04289	0.38
12	1.164938	21.82430	21.81877	5.53
13	1.148001	22.62786	22.63650	-8.64
14	1.135971	23.22347	23.21678	6.69
15	1.127510	23.82236	23.81932	3.04
16	1.122513	24.42351	24.43253	-9.01
17	1.119359	25.01411	25.01557	-1.46
18	1.117019	25.60459	25.59572	8.87
19	1.114528	26.39625	26.39955	-3.29

Order of Fit = 11 RMS error of Fit = 4.60 mK

Largest absolute error = 9.01 mK at data point no. 16

Polynomial Equation

Polynomial Type: Chebychev

Useful Range of Fit:

25.014 K to 87.953 K
1.010 V to 1.119 V

Lower and Upper limits of Voltage used in computing Chebychev coefficients:

ZL: 0.9881606442 ZU: 1.127509679

Order	Coefficient	Std. Deviation of Coefficient	Ratio (Coeff. / Std Dev.)
0	60.015281	7.84754E-003	7647.66
1	-39.837958	1.38934E-002	-2867.41
2	1.066970	1.31402E-002	81.20
3	1.482595	9.45663E-003	156.78
4	0.838459	6.85586E-003	122.30
5	0.336512	3.17581E-003	105.96
6	0.072038	3.57713E-003	20.14
7	-0.023859	6.65659E-003	-3.58
8	-0.060133	9.40953E-003	-6.39
9	-0.021958	1.02082E-002	-2.15
10	-0.030305	1.04549E-002	-2.90
11	-0.001342	8.20193E-003	-0.16
12	-0.014717	5.76683E-003	-2.55

Z = Voltage

k = ((Z-ZL)-(ZU-Z))/(ZU-ZL)

Temp. (K) = ΣA_i* COS(i * ARCCOS(k)), where 0 <= i <= 8 and the A_i's are the coefficients in the table above.

Polynomial Equation

Polynomial Type: Chebychev

Temp. (K) vs. Voltage

	Meas. (V)	T Meas. (K)	T Eq. (K)	T diff. (mK)
1	1.127510	23.82236	23.82158	0.78
2	1.122513	24.42351	24.43124	-7.72
3	1.119359	25.01411	25.00198	12.13
4	1.117019	25.60459	25.59962	4.97
5	1.114528	26.39625	26.40256	-6.30
6	1.112418	27.19615	27.20632	-10.17
7	1.110563	27.99140	27.99639	-4.99
8	1.108429	28.99122	28.98850	2.72
9	1.106441	29.98894	29.98059	8.36
10	1.102716	31.99000	31.98128	8.72
11	1.097513	34.98792	34.99442	-6.50
12	1.092594	37.98091	37.98971	-8.80
13	1.086227	41.97868	41.97259	6.08
14	1.079876	45.98522	45.98023	4.99
15	1.070295	51.97932	51.98632	-7.01
16	1.060586	57.98691	57.98445	2.45
17	1.050785	63.96555	63.96340	2.16
18	1.040793	69.96255	69.96606	-3.52
19	1.030625	75.96018	75.95775	2.43
20	1.020282	81.95469	81.95572	-1.03
21	1.009753	87.95331	87.95304	0.27
22	0.999039	93.95636	93.95640	-0.04
23	0.988161	99.95361	99.95360	0.00

Order of Fit = 12 RMS error of Fit = 5.95 mK

Largest absolute error = 12.13 mK at data point no. 3

Polynomial Equation

Polynomial Type: Chebychev

Useful Range of Fit:

87.953 K to 325.000 K

0.509 V to 1.010 V

Lower and Upper limits of Voltage used in computing Chebychev coefficients:

ZL: 0.4969960998 ZU: 1.030625219

Order	Coefficient	Std. Deviation of Coefficient	Ratio (Coeff. / Std Dev.)
0	207.313253	1.03662E-003	199990.55
1	-126.180277	1.49194E-003	-84574.52
2	-3.928505	1.46758E-003	-2676.85
3	-0.942699	1.51600E-003	-621.83
4	-0.215084	1.50293E-003	-143.11
5	-0.074933	1.44094E-003	-52.00
6	-0.016769	1.39345E-003	-12.03

Z = Voltage

k = ((Z-ZL)-(ZU-Z))/(ZU-ZL)

Temp. (K) = ΣA_i* COS(i * ARCCOS(k)), where 0 <= i <= 8 and the A_i's are the coefficients in the table above.

Polynomial Equation

Polynomial Type: Chebychev

Temp. (K) vs. Voltage

	Meas. (V)	T Meas. (K)	T Eq. (K)	T diff. (mK)
1	1.030625	75.96018	75.95499	5.19
2	1.020282	81.95469	81.95707	-2.38
3	1.009753	87.95331	87.95756	-4.24
4	0.999039	93.95636	93.95896	-2.60
5	0.988161	99.95361	99.95413	-0.53
6	0.969640	109.95949	109.95726	2.23
7	0.941083	124.95475	124.95091	3.84
8	0.911653	139.96046	139.95850	1.97
9	0.881501	154.96135	154.96215	-0.81
10	0.850689	169.97813	169.97986	-1.74
11	0.819367	184.97722	184.97929	-2.06
12	0.787531	199.98949	199.99153	-2.04
13	0.755260	215.00114	215.00184	-0.71
14	0.722615	230.00331	230.00121	2.10
15	0.689624	244.99762	244.99264	4.97
16	0.656277	260.00124	259.99823	3.01
17	0.622582	275.02870	275.03315	-4.45
18	0.588614	290.07808	290.08609	-8.02
19	0.554387	305.17625	305.17340	2.84
20	0.531422	315.26882	315.26332	5.51
21	0.519959	320.29712	320.29164	5.48
22	0.506195	326.31336	326.32326	-9.90
23	0.496996	330.35313	330.35080	2.33

Order of Fit = 6 RMS error of Fit = 4.11 mK

Largest absolute error = 9.90 mK at data point no. 22

Interpolation Table

Temp. (K)	Meas. (V)	dV/dT (mV/K)	Temp. (K)	Meas. (V)	dV/dT (mV/K)
1.400	1.65482	-13.4394	8.500	1.43077	-32.4633
1.500	1.65341	-14.6935	9.000	1.41497	-30.7247
1.600	1.65188	-15.8837	9.500	1.40004	-29.0387
1.700	1.65024	-17.0095	10.00	1.38591	-27.5163
1.800	1.64848	-18.0795	10.50	1.37249	-26.1649
1.900	1.64662	-19.1035	11.00	1.35972	-24.9310
2.000	1.64466	-20.0816	11.50	1.34754	-23.8000
2.100	1.64261	-20.9971	12.00	1.33591	-22.7305
2.200	1.64047	-21.8370	12.50	1.32480	-21.7144
2.300	1.63824	-22.6012	13.00	1.31419	-20.7616
2.400	1.63595	-23.2897	13.50	1.30403	-19.8756
2.500	1.63359	-23.9111	14.00	1.29430	-19.0647
2.600	1.63117	-24.4724	14.50	1.28495	-18.3304
2.700	1.62870	-24.9737	15.00	1.27596	-17.6671
2.800	1.62618	-25.4150	15.50	1.26727	-17.0803
2.900	1.62361	-25.8259	16.00	1.25886	-16.6103
3.000	1.62101	-26.2372	16.50	1.25064	-16.2465
3.100	1.61837	-26.6489	17.00	1.24261	-15.9075
3.200	1.61568	-27.0611	17.50	1.23473	-15.6056
3.300	1.61295	-27.4910	18.00	1.22698	-15.4207
3.400	1.61018	-27.9559	18.50	1.21929	-15.3447
3.500	1.60736	-28.4559	19.00	1.21162	-15.3366
3.600	1.60449	-28.9909	19.50	1.20394	-15.4339
3.700	1.60156	-29.5610	20.00	1.19616	-15.7200
3.800	1.59858	-30.1662	21.00	1.17989	-16.9820
3.900	1.59553	-30.7848	22.00	1.16139	-20.5828
4.000	1.59242	-31.3960	23.00	1.14019	-19.9459
4.200	1.58602	-32.5963	24.00	1.12574	-9.13901
4.400	1.57939	-33.7070	25.00	1.11942	-4.52517
4.600	1.57255	-34.6772	26.00	1.11571	-3.12839
4.800	1.56553	-35.5068	27.00	1.11291	-2.53812
5.000	1.55835	-36.1958	28.00	1.11054	-2.22599
5.200	1.55106	-36.7650	29.00	1.10841	-2.05222
5.400	1.54365	-37.2346	30.00	1.10642	-1.93774
5.600	1.53617	-37.6047	31.00	1.10452	-1.85760
5.800	1.52862	-37.8753	32.00	1.10270	-1.79851
6.000	1.52102	-38.0463	33.00	1.10092	-1.75296
6.500	1.50199	-37.9668	34.00	1.09919	-1.71371
7.000	1.48319	-37.1235	35.00	1.09749	-1.68078
7.500	1.46495	-35.7843	36.00	1.09583	-1.65338
8.000	1.44744	-34.2137	37.00	1.09418	-1.63078

Interpolation Table

Temp. (K)	Meas. (V)	dV/dT (mV/K)	Temp. (K)	Meas. (V)	dV/dT (mV/K)
38.00	1.09256	-1.61299	200.0	0.78751	-2.13568
39.00	1.09096	-1.59954	205.0	0.77681	-2.14516
40.00	1.08936	-1.58998	210.0	0.76606	-2.15436
42.00	1.08619	-1.58257	215.0	0.75526	-2.16327
44.00	1.08303	-1.58441	220.0	0.74442	-2.17192
46.00	1.07985	-1.58941	225.0	0.73354	-2.18032
48.00	1.07667	-1.59571	230.0	0.72262	-2.18845
50.00	1.07347	-1.60154	235.0	0.71166	-2.19639
52.00	1.07026	-1.60690	240.0	0.70066	-2.20416
54.00	1.06704	-1.61255	245.0	0.68962	-2.21177
56.00	1.06381	-1.61922	250.0	0.67854	-2.21914
58.00	1.06057	-1.62691	255.0	0.66743	-2.22622
60.00	1.05730	-1.63522	260.0	0.65628	-2.23300
65.00	1.04907	-1.65693	265.0	0.64510	-2.23938
70.00	1.04073	-1.68060	270.0	0.63389	-2.24527
75.00	1.03227	-1.70552	273.15	0.62681	-2.24872
77.35	1.02824	-1.71732	275.0	0.62265	-2.25066
80.00	1.02367	-1.73062	280.0	0.61138	-2.25538
85.00	1.01496	-1.75557	285.0	0.60009	-2.25922
90.00	1.00612	-1.78008	290.0	0.58879	-2.26219
95.00	0.99716	-1.80451	295.0	0.57747	-2.26499
100.0	0.98808	-1.82837	300.0	0.56614	-2.26837
105.0	0.97888	-1.85135	305.0	0.55479	-2.27233
110.0	0.96956	-1.87345	310.0	0.54342	-2.27569
115.0	0.96014	-1.89465	315.0	0.53203	-2.27708
120.0	0.95062	-1.91495	320.0	0.52064	-2.28382
125.0	0.94100	-1.93434	325.0	0.50920	-2.28805
130.0	0.93128	-1.95283			
135.0	0.92147	-1.97040			
140.0	0.91157	-1.98706			
145.0	0.90160	-2.00286			
150.0	0.89155	-2.01785			
155.0	0.88142	-2.03204			
160.0	0.87123	-2.04554			
165.0	0.86097	-2.05849			
170.0	0.85064	-2.07088			
175.0	0.84026	-2.08276			
180.0	0.82982	-2.09418			
185.0	0.81932	-2.10515			
190.0	0.80877	-2.11570			
195.0	0.79816	-2.12588			

Breakpoints Description

Calibration Report:	D6167361576680403		
Sensor Model:	DT-670-CU-HT-1.4L	Serial Number:	D6167361
Sensor Type:	Silicon Diode	Temperature Range:	1.4 K to 325 K

The data presented in this calibration report may be used with Lake Shore Cryotronics instrumentation or with customer provided equipment (e.g. voltmeter, current source, computer).

If using Lake Shore instrumentation, then the provided Breakpoint tables provide a seamless solution for measuring temperature sensors and converting the measurement into temperature units. See Sensor Calibration Accuracies: Breakpoint Table for details on using this data with Lake Shore Cryotronics Instrumentation.

If the sensor is used with customer provided equipment (e.g., voltmeter, current source, and computer) then the Chebychev curve fit in the section labelled "Polynomial Equation" should be used. When using customer provided equipment to perform the sensor measurement, please refer to www.lakeshore.com/sensors for information regarding appropriate operating parameters.