NTC Thermistor

Product Guide

Expect THE BEST

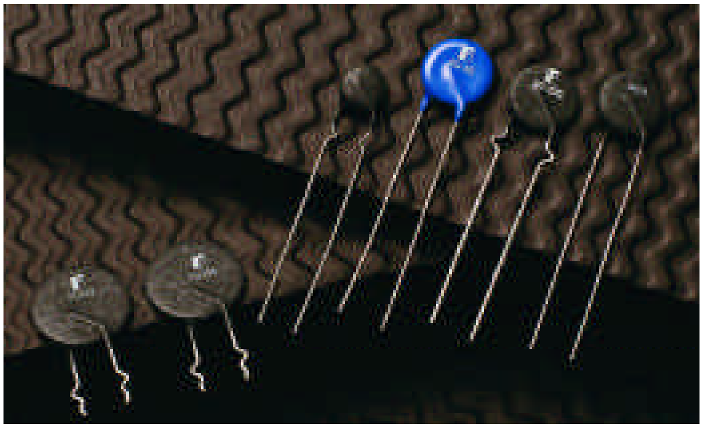
RTI Electronics, Inc.

Table Of Contents

Commitment To Excellence

The Company - RTI Electronics, Inc. designs, manufactures and sells thermistor products to a diverse international marketplace. The company has developed lasting customer relationships by providing reliable, industry standard thermistor products, just-in-time service and competitive prices. As the recognized leader in the supply of inrush current limiting devices, used in power supplies, the company's **SURGE-GARD™** product line enjoys a unique position in the world marketplace. The company has earned a reputation for meeting the most exacting specifications as well as demanding global delivery schedules. The company is staffed by experienced, innovative professionals, uniquely qualified to assist design and production engineers in the application of thermistor products.

Quality - Quality principles are firmly established in the company's operating methodology. Our vision is to use TQM principles as the foundation of our business and have employees who are empowered to create and maintain an environment that fosters excellence...where creativity and teamwork combine to do the job right the first time, every time.



SURGE-GARD™

Circuit Protection Devices

NTC Thermistors

NTC Thermistors

SURGE-GARD™ Features

- **Lowers rectifier cost by reducing required peak forward surge current rating**
- **Reduces Noise**
- **Reduces Fuse Failures**
- **High Current Capability**

Negative Temperature Coefficient (NTC) thermistors are thermally sensitive semiconductor resistors which exhibit a decrease in resistance as absolute temperature increases. Change in the resistance of the NTC thermistor can be brought about either by a change in the ambient temperature or internally by self-heating resulting from current flowing through the device. Most of the practical applications of NTC thermistors are based on these material characteristics.

Inrush Current Limiting Devices

RTI manufactures **SURGE-GARD™** inrush current limiting devices using specially formulated metal oxide ceramic materials. These devices are capable of suppressing high inrush current surges. They are especially useful in power supplies where the low impedance of the charging capacitor exposes the diode bridge rectifier to an excessively high current surge at turn-on.

Thermistor Terminology for Inrush Current Limiting Devices

- **I_{MAX} -** The maximum steady state RMS AC or DC current.
- **I_{OP} -** The actual operating current.
- **RI_{MAX} -** The approximate resistance under maximum steady state current conditions.
- **MAX Operating Temperature -** RTI's recommended maximum ambient temperature is 65°C without de-rating. (Ref. Fig. C on page 5 for de-rating information)
- **Recovery Time - SURGE-GARD™** devices require time to return to their ambient resistance state in order to provide adequate inrush current limiting at each power turn-on. This time varies with each device, the mounting configuration and the ambient operating temperature. RTI recommends a minimum of 60 seconds. The selection of a capacitor bleeder resistor can reduce the required cool down time requirement.

Applications

RTI's **SURGE-GARDs™** are used in many applications today that require limiting inrush current when power is applied to a system. The most popular application is the inrush protection of the AC current in switching power supplies (SPS). The primary reason for having surge current suppression in a SPS is to protect the diode bridge rectifier as the input or charging capacitor is initially charged. This capacitor draws significant current during the first half AC cycle and can subject the components in line with the capacitor to excessive current. The inherent equivalent series resistance (ESR) of the capacitor provides very little protection for the diode bridge rectifier. Use of the proper **SURGE-GARD™** will provide maximum current protection when the power supply is turned on and allow the design engineer to select lower peak current rated diode bridge rectifiers for use in their SPS.

SURGE-GARD™
Selection Procedure

- **Calculate I_{MAX}**
- **CALCULATE R@25°C**
- **Select SURGE-GARD™ specified to handle the input energy & maximum current with a R@25°C value capable of limiting the inrush current**
- **Evaluate Joules Rating**
- **Calculate the SURGE-GARD™ resistance at I_{OP} using the 'M' curve in Figure B**
- **Check Figure C if de-rating is required for high ambient operating temperature**

If the resistance of one **SURGE-GARD™** does not provide sufficient inrush current limiting for an existing application, two or more may be used in series or in separate legs of the power supply circuit. **SURGE-GARDs™** should not be used in parallel since one unit will tend to conduct nearly all the current available. **SURGE-GARDs™** may be used in the AC input side or in the circuit on the DC line between the charging capacitors and the diode bridge rectifier circuit. (Reference Figure A on page 5)

Selection Considerations for SURGE-GARDs™

- **I_{MAX} -** The first critical consideration in the selection of a **SURGE-GARD™** is the maximum steady state current (AC or DC) of the power supply. **SURGE-GARDs™** are rated for maximum continuous current. The input power (Pin) is calculated as Pin = Pout/efficiency. In the case of a 75 Watt SPS with 0.70 efficiency, 100% load is calculated to be 107.14 Watts. The maximum input current is at the minimum input voltage. The effective input current (I_e) is equal to the maximum load divided by the minimum input voltage. In this case, a 75 Watt SPS, $I_e = P_{in}/V_{in}^{(low)}$ = 107.14 Watts/90 Volts = 1.2 Amps. Therefore, the **SURGE-GARD™** must have an I_{MAX} rating of at least 1.2 Amps.

- **R@25°C. -** The second step is to determine the minimum R value of the **SURGE-GARD™** to be selected that will limit the one cycle maximum current rating of the diode bridge rectifier to 50% of its rating to ensure adequate surge protection. Several additional calculations must be made to determine the estimated resistance value required at the point in time of the maximum current surge. RTI provides for a maximum AC voltage rating of 265V RMS on most **SURGE-GARDs™**. (Reference the **Specifications** located on page 6.) If the desired maximum inrush current is less than 100 Amps (50% of the diode bridge with a peak current rating of 200 Amps), then solving for R would produce a value of 2.65 Ω. If the **MAX Operating Temperature** is other than 25°C then the zero power resistance value must be calculated using the **NTC Resistance/Temperature Conversion Tables** located on page 7.

Selection Considerations for SURGE-GARDs™ (Cont.)

As an example, if the **MAX Operating Temp.** is 50°C, and the **SURGE-GARD™** selected has an **R-T Curve A,** the **R_T/R_{25}** factor is **0.464.** This indicates in order for the **SURGE-GARD™** to have the same effective current limiting characteristic at the elevated temperature, it must have a higher resistance than the **R@25°C** value previously determined. To simplify our selection of the minimum R value divide the initial **R@25°C** value by the **R_T/R_{25}** factor. In this case, the **Minimum R@25°C value** = 2.65 Ω/0.464 = **5.71Ω.**

- **Select a SURGE-GARD™ -** The third requirement is to select a **SURGE-GARD™** from the **Specifications** located on page 6. First find the column labeled R@25°C. The resistance values are listed in ascending order. If the exact R value calculated is not listed round up to the next highest R value. In this example that would be a 6Ω, 5 Amp part, number SG418. Notice that the current rating is higher than required. This current rating is mass dependent therefore the part would be larger in size than the circuit requires. Continue down the column until the closest current rating is located. In this case it would be a 10Ω, 3 Amp rated part, number SG220. This would be the selected **SURGE-GARD™** of choice.

- **Evaluate Joules Rating -** The fourth step is to review the amount of energy that can be absorbed or dissipated by a **SURGE-GARD™** before a failure may occur. The **SURGE-GARD™** devices are rated in **Joules.** In order to calculate the Joules rating the input capacitor value must be specified. Assume that the input capacitor is 220µfd. The instantaneous energy is equal to one half times the capacitance of the capacitor plus its tolerance times the peak voltage squared. In this example, Ei = 0.5 (220 (+/-Tol))$^{10-6}$ *(265*1.414)^{2} = **15.44 J** (nominal). The Joules rating for the SG220 selected is 17J.
  (Please note that other criteria such as hold up time, ripple current, capacitor discharge time, and the efficiency of the power supply design may affect the SURGE-GARD™ selection process. Consult RTI's application engineering personnel for additional information.)

- **Calculate I_{OP}/I_{MAX} Ratio -** Next, estimate the actual operating current, **I_{OP}**, and calculate the **I_{OP}/I_{MAX}** ratio. The nominal resistance of a **SURGE-GARD™** when operated at its **I_{MAX}** rating is specified in the **Specifications** located on page 6 under the **RI_{MAX}** heading. The device's resistance when it is operated at a current less than its **I_{MAX}** rating can be estimated by multiplying its **RI_{MAX}** rating by the factor, **M**. As an example, a **SURGE-GARD™** with an **I_{MAX}** of 3.0 Amps and an **RI_{MAX}** of 0.20 Ω that is operated at 1.2 Amps, the **I_{OP}/I_{MAX}** current ratio is 1.2 Amps/3.0 Amps = 0.40. The corresponding **M** factor can be determined from the graph shown in Figure C to be 3.2. Therefore the device's estimated resistance at 1.2 Amps can be calculated to be **R** = 3.2 * 0.20 Ω = 0.64 Ω. If two different **SURGE-GARDs™** have similar **I_{MAX}** ratings but different R@25°C values and they meet the circuit requirements, then select the one with the lowest **RI_{MAX}** nominal value.

- Lastly, if the **MAX Operating Temp.** range is >65°C or <0°C, refer to the **SURGE-GARD™ Recommended I_{MAX} De-rating Curve**, Figure C on Page 5.

SURGE-GARD™ Installation Options

- **Thru-hole Leads**
- **Insulated/ Uninsulated**
- **Standoffs**
- **Preformed Leads**
- **See Figure D on page 5**

SURGE-GARD™ Installations

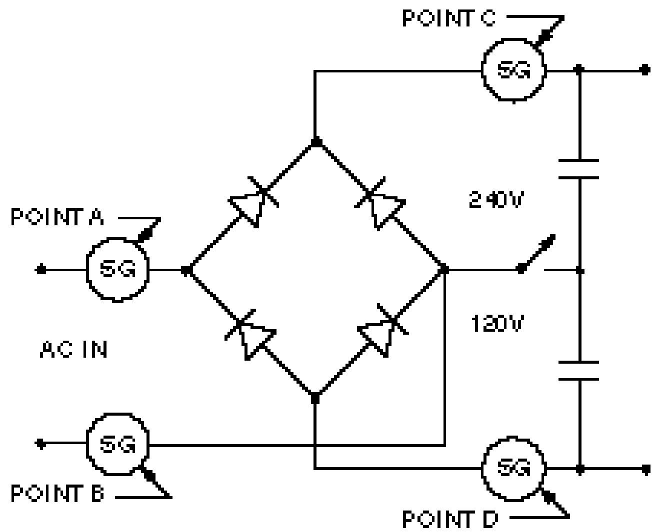


Figure A

SURGE-GARD™ Resistance Curve

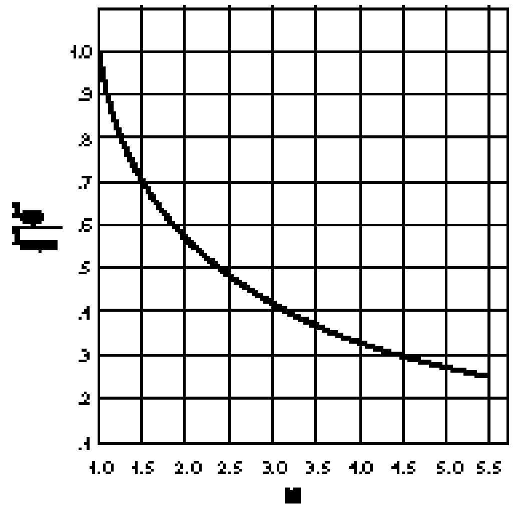


Figure B

SURGE-GARD™ Recommended Imax Derating Curve

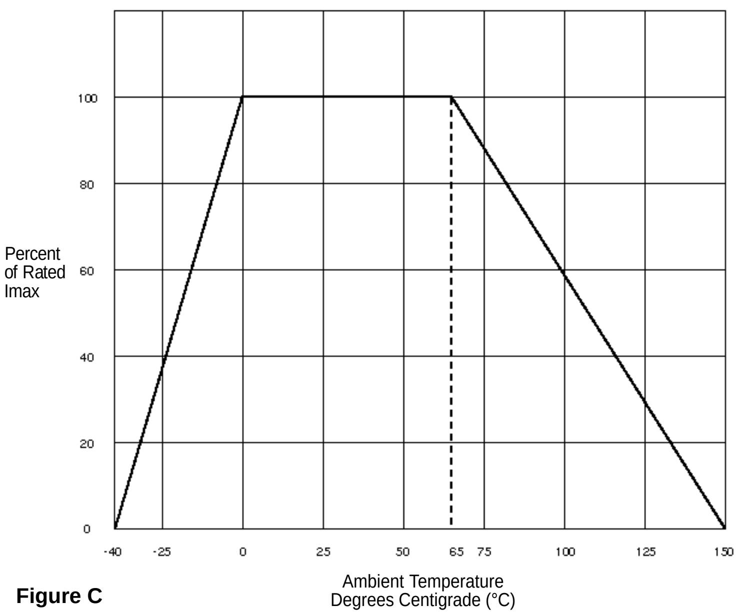


Figure C

The recommended Imax current versus the ambient temperature is shown in Figure C.

If the ambient temperature is between 0°C and 65°C, the percent of Imax is 100%.

If the ambient temperature is between 65°C and 150°C, the percent of Imax = $100\left[1-\frac{T-65°C}{85°C}\right]$

T = ambient temperatures between 65°C and 150°C

If the ambient temperature is between 0°C and -40°C, the percent of Imax = $100\left[1-\frac{T-0°C}{-40°C}\right]$

T = ambient temperatures between 0°C and -40°C

Lead Style Configurations

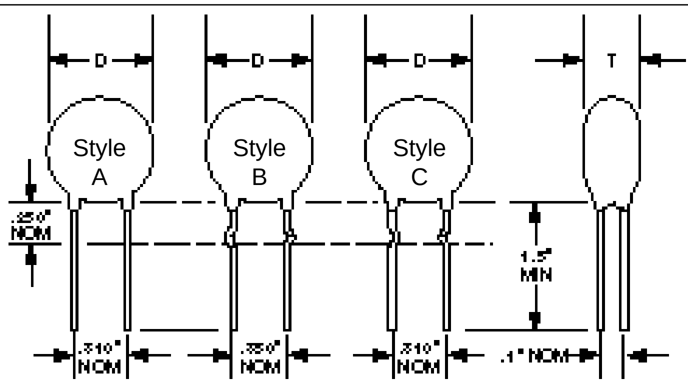


Figure D

SURGE-GARD™ Specifications

Part Number			R@25°C	R Tolerance	Imax	RImax	Max. D	Max. T	Lead Dia.	NTC	Surge Rating
Style A	Style B	Style C	(Ohms)	(±%)	(AMPS)	(Ohms)	(Inches)	(Inches)	(Inches)	Curve	(Joules)
SG260	SG326		.5	20	30.00	.010	1.250	.200	.040	A	31*
SG415	SG327		.7	25	12.00	.030	.740	.200	.040	A	45
SG100	SG301		1.0	15	20.00	.015	.900	.300	.040	A	48*
SG405	SG328		1.0	25	30.00	.015	1.250	.250	.040	A	157
SG416	SG329		1.3	25	8.00	.050	.525	.200	.040	A	40
SG110	SG302		2.0	15	18.00	.030	.900	.350	.040	A	80
SG420	SG355		2.0	25	23.00	.025	1.250	.300	.040	A	250
SG120		SG303	2.5	15	3.00	.150	.600	.250	.032	A	27
SG130		SG304	2.5	15	7.00	.050	.600	.250	.032	A	27
SG140		SG305	2.5	15	9.00	.040	.600	.250	.032	A	27
SG150	SG306		2.5	15	10.00	.040	.900	.300	.040	A	87
SG160	SG307		2.5	15	15.00	.030	.900	.300	.040	A	87
SG170	SG308		4.0	15	8.00	.070	.600	.250	.040	A	27
SG32	SG330		4.0	20	14.00	.050	.900	.350	.040	A	100
SG180		SG309	5.0	15	2.00	.400	.600	.250	.032	A	36
SG413			5.0	25	2.80	.250	.530	.200	.025	A	23
SG190		SG310	5.0	15	4.00	.150	.600	.250	.032	A	36
SG450		SG373	5.0	15	6.00	.100	.600	.250	.032	A	30
SG200		SG311	5.0	15	7.00	.070	.600	.250	.032	A	40
SG44	SG332		5.0	20	8.00	.050	.600	.250	.040	A	40
SG26	SG333		5.0	15	12.00	.060	.900	.275	.040	A	100
SG418		SG334	6.0	15	5.00	.150	.600	.270	.032	A	40
SG210	SG312		7.0	15	4.00	.200	.600	.300	.040	A	50
SG85	SG335		7.0	25	5.00	.150	.600	.300	.040	A	45
SG64	SG336		7.0	15	10.00	.080	.950	.275	.040	J	100
SG13		SG337	10.0	15	2.00	.300	.500	.250	.040	A	17
SG220		SG313	10.0	15	3.00	.200	.450	.300	.032	A	17
SG42	SG338		10.0	15	5.00	.200	.600	.350	.040	A	44
SG27	SG314		10.0	15	6.00	.150	.500	.350	.040	A	40
SG40	SG72		10.0	20	8.00	.100	.900	.350	.040	J	50
SG451	SG374		12.0	15	4.00	.220	.500	.350	.040	A	40
SG452		SG375	15.0	15	2.50	.330	.550	.300	.032	A	40
SG86			16.0	25	1.70	.600	.530	.300	.025	A	45
SG414			16.0	25	2.70	.400	.530	.300	.025	A	45
SG63	SG320		16.0	25	4.00	.250	.750	.250	.040	J	50
SG230		SG315	20.0	15	1.75	.600	.500	.300	.032	A	31
SG411		SG341	25.0	25	1.70	.600	.500	.300	.032	A	30
SG412		SG342	25.0	25	2.40	.400	.500	.300	.032	A	30
SG38	SG343		30.0	15	3.00	.400	.600	.250	.040	B	25
SG240		SG316	40.0	15	2.00	.600	.625	.250	.032	B	20
SG52	SG344		47.0	25	3.00	.500	.770	.240	.040	B	55
SG453		SG376	60.0	15	1.50	1.000	.600	.250	.032	B	50
SG250	SG317		120.0	15	3.00	.900	.925	.250	.040	C	36
SG31	SG346		220.0	20	1.30	1.900	.600	.300	.040	C	25

For applications requiring ratings not shown, contact RTI Electronics, Inc. applications engineering.
Maximum operating voltage is 265V RMS.
*Maximum operating voltage is 120V RMS.

NTC Resistance/Temperature Conversion Tables

Temperature °C	R-T Curve A R_T/R_{25}	Curve A DEV	R-T Curve B R_T/R_{25}	Curve B DEV	R-T Curve C R_T/R_{25}	Curve C DEV	R-T Curve J R_T/R_{25}	Curve J DEV
-60	43.0		75.0	6.6	140.5	6.6	52.5	
-55	31.9		54.1	6.1	96.4	6.1	39.0	
-50	24.3		39.7	5.6	67.0	5.6	29.2	18.5
-45	18.6		29.2	5.2	47.2	5.2	22.1	17.0
-40	14.4	7.6	21.7	4.7	33.7	4.7	16.9	15.4
-35	11.3	6.9	16.4	4.3	24.3	4.3	13.0	14.0
-30	8.93	6.2	12.5	3.8	17.7	3.8	10.1	12.5
-25	7.10	5.6	9.58	3.4	13.0	3.4	7.90	11.2
-20	5.69	5.0	7.42	3.0	9.71	3.0	6.24	9.9
-15	4.56	4.4	5.75	2.6	7.30	2.6	4.96	8.7
-10	3.68	3.7	4.50	2.2	5.53	2.2	3.97	7.4
-5	2.99	3.1	3.55	1.9	4.23	1.9	3.20	6.2
0	2.45	2.5	2.82	1.5	3.27	1.5	2.60	5.0
5	2.02	2.0	2.26	1.2	2.54	1.2	2.12	3.9
10	1.68	1.6	1.83	0.8	1.99	0.8	1.74	2.7
15	1.42	1.1	1.48	0.5	1.57	0.5	1.44	1.6
20	1.18	0.6	1.22	0.2	1.25	0.2	1.20	0.5
25	1.00	0.0	1.00	0.0	1.00	0.0	1.00	0.0
30	.854	0.6	.828	0.4	.806	0.4	.841	1.4
35	.732	1.1	.689	0.7	.653	0.7	.710	2.3
40	.628	1.6	.576	1.0	.533	1.0	.602	3.2
45	.537	2.0	.482	1.3	.437	1.3	.513	4.3
50	.464	2.5	.406	1.5	.360	1.5	.439	5.0
55	.403	3.0	.343	1.8	.299	1.8	.377	5.9
60	.350	3.4	.292	2.0	.249	2.0	.326	6.7
65	.305	3.8	.247	2.3	.208	2.3	.282	7.5
70	.267	4.2	.212	2.5	.175	2.5	.245	8.2
75	.236	4.6	.182	2.8	.148	2.8	.214	9.0
80	.208	4.9	.157	3.0	.126	3.0	.188	9.8
85	.183	5.3	.137	3.2	.107	3.2	.165	10.5
90	.163	5.6	.120	3.4	.0916	3.4	.146	11.2
95	.145	6.0	.105	3.6	.0787	3.6	.129	11.9
100	.130	6.3	.0920	3.8	.0679	3.8	.114	12.6
105	.117	6.7	.0812	4.0	.0588	4.0	.102	13.3
110	.105	7.0	.0723	4.2	.0511	4.2	.0908	13.9
115	.0943	7.3	.0641	4.4	.0445	4.4	.0813	14.4
120	.0852	7.6	.0569	4.6	.0389	4.6	.0730	14.9
125	.0771	7.9	.0508	4.8	.0342	4.8	.0657	15.6
130	.0700	8.2	.0455	4.9	.0301	4.9	.0593	16.3
135	.0636	8.4	.0408	5.1	.0265	5.1	.0536	17.0
140	.0579	8.6	.0368	5.3	.0235	5.3	.0486	17.6
145	.0529	9.0	.0332	5.4	.0208	5.4	.0442	18.0
150	.0483	9.3	.0300	5.5	.0185	5.5	.0402	18.4

NTC Resistance/Temperature Curve Characteristics

R-T Curve	A	B	C	J
Temperature Coefficient α @ 25°C	-3.3%/°C	-3.9%/°C	-4.4%/°C	-3.5%/°C
Beta, β	3000°K	3530°K	3965°K	3200°K

Temperature Measurement and Control Devices DISC and CHIP Style

NTC Thermistors

NTC Thermistors

DISC & CHIP STYLE Features

- **Wide Ohmic Value Range**
- **Accurate & Stable**
- **Fast Thermal Response Time**
- **Tight Tolerances**
- **High Sensitivity**

Negative Temperature Coefficient (NTC) thermistors are thermally sensitive semiconductor resistors which exhibit a decrease in resistance as absolute temperature increases. Change in the resistance of NTC thermistor can be brought about either by a change in the ambient temperature or internally by self-heating resulting from current flowing through the device. Most of the practical applications of NTC thermistors are based on these material characteristics.

NTC DISC & CHIP Style Devices

RTI manufactures **DISC & CHIP** style thermistors in resistance values ranging from 1.0 ohm to 500,000 ohms. These devices are suitable for a range of resistance values and temperature coefficients from relatively low resistance and temperature coefficients to very high values. Precision resistance tolerances are available to 1%. Standard resistance tolerances are from 5% to 20%. All tolerances are specified at 25°C or may be specified at any temperature within the operating temperature range of the thermistor.

Thermistor Terminology for Temperature Measurement & Control Devices

- **D.C. -** The dissipation constant is the ratio, normally expressed in milliwatts per degree C (mw/°C), at a specified ambient temperature, of a change in power dissipated in a thermistor to the resultant change in body temperature.

- **T.C. -** The thermal time constant is the time required for a thermistor to change 63.2% of the total difference between its initial and final body temperature when subjected to a step function change in temperature under zero-power conditions and is normally expressed in seconds (S).

- **Alpha (α) or Temperature Coefficient or Resistance -** The temperature coefficient of resistance is the ratio at a specified temperature, T, of the rate of change of zero-power resistance with temperature to the zero-power resistance of the thermistor. The temperature coefficient is commonly expressed in percent per degree C (%/°C).

  $\alpha_T = \Delta R_T / \Delta T$

Applications

Time and temperature are two of the most frequently measured variables. There are numerous ways of the measuring temperature electronically, most commonly by thermocouples and negative temperature coefficient (NTC) thermistors. For general purpose temperature measurement, NTC temperature sensors can operate over a wide temperature range (-55 to +300°C). They are stable throughout a long lifetime, and are small and comparatively inexpensive. Typically, they have negative temperature coefficients between -3.3 and -4.9%/°C at 25°C. This is more than ten (10) times the sensitivity of a platinum resistance thermometer of the same nominal resistance. RTI's **DISC & CHIP** style thermistors are used in many applications that require a high degree of accuracy and reliability.

NTC DISC & CHIP Selection Considerations

- **Select Req'd. Resistance Value & Temperature Coefficient**
- **Determine Accuracy Req'd.**
- **Review Power Dissipation**
- **Determine Operating Temperature Range**
- **Review Thermal Time Constant**

Some of the most popular applications of NTC thermistors include:

- Temperature Compensation
- Temperature Measurement & Control
- Fan Motor Control
- Fluid Level & Temperature Sensors

Selection considerations for NTC DISC & CHIP Devices

Power dissipation is a common problem in the use of thermistors as they can only dissipate a certain amount of power. If the power dissipated exceeds the dissipation constant (D.C.) rating of the sensor it is likely that it will exhibit self heating. Most thermistors dissipate from 1 to 25 mW/°C nominal. This means that the resistance changes by an equivalent of 1°C for each D.C. rating (mW/°C) for the selected device. To maintain a higher degree of accuracy, temperature error caused by self-heating should be an order of magnitude less than the required sensor accuracy. For many applications, this degree of accuracy is not required and a less stringent de-rating may be adequate. Several options to reduce the thermistor power are to increase the thermistor resistance, lower the source voltage and/or increase the series resistor in the divider circuit.

As an example, if the D.C. of the thermistor selected is 5 mW/°C and the power dissipated by the device is 20 mW/°C, then a 4°C error is induced due to the effect of self-heating. To minimize this effect, a factor can be derived simply by taking the DC rating times 10^{-1} (one order of magnitude lower) and use it in the power equation to produce a good approximation of the maximum allowable power. For instance, if the desired accuracy is 1°C, and the rated D.C. of the device selected is 5 mW/°C, adjusting the specified D.C. rating in the power equation to 0.5 mW/°C compensates for self-heating error and effectively predicts the maximum power the device can dissipate without significantly affecting the desired accuracy. The resulting maximum power that should be applied would be calculated as **1°C*0.5mW/°C = 0.5mW.**

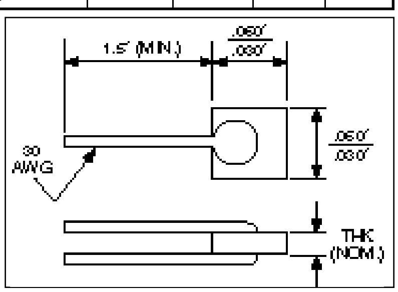
NTC DISC & CHIP Selection Process

- **Select R Value**
- **Determine R @ T**
- **Calculate DEV for R @ T**
- **Evaluate Power Rating (D.C.)**
- **Review T.C. Requirements**

NTC Standard Chip Thermistor Specifications

Part Number	Resistance @25°C (Ohms) ±10%	R-T Curve	THK (in.)	D.C.	T.C.
05CA101K	100	A	.020	2	2
05CA151K	150	A	.025	2	2
05CA201K	200	A	.030	2	2
05CA251K	250	A	.040	2	2
05CA301K	300	A	.050	2	3
05CA401K	400	A	.070	2	3
05CA501K	500	A	.080	2	3
05CB102K	1,000	B	.020	2	2
05CB152K	1,500	B	.025	2	2
05CB202K	2,000	B	.030	2	2
05CB302K	3,000	B	.050	2	3
05CB402K	4,000	B	.070	2	3
05CB502K	5,000	B	.080	2	3
05CC802K	8,000	C	.020	2	2
05CC103K	10,000	C	.025	2	2
05CC153K	15,000	C	.035	2	2
05CC203K	20,000	C	.050	2	3
05CC253K	25,000	C	.060	2	3
05CC303K	30,000	C	.075	2	3
05CE104K	100,000	E	.030	2	2
05CE154K	150,000	E	.045	2	2
05CE204K	200,000	E	.060	2	2
05CE304K	300,000	E	.090	2	3
05CE404K	400,000	E	.120	2	3
05CE504K	500,000	E	.150	2	3

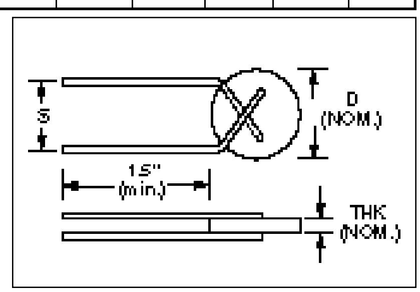
Maximum temperature rating: 150°C



NTC Standard Disc Thermistor Specifications

Part Number	Resis. @25°C (Ohms) ±10%	R-T Curve	D (in.)	THK (in.)	D.C.	T.C.	Leads AWG#	S (in.)
5DA4R0K	4	A	.50	.065	14	60	22	.330
5DA5R0K	5	A	.50	.080	15	70	22	.330
2DA100K	10	A	.20	.025	7	18	24	.100
3DA100K	10	A	.30	.060	8	48	24	.100
5DA100K	10	A	.50	.150	17	120	22	.330
3DA150K	15	A	.30	.090	8	55	24	.100
2DA200K	20	A	.20	.050	7	20	24	.100
1DA300K	30	A	.10	.020	3	5	28	.070
2DA300K	30	A	.20	.075	7	25	24	.100
1DA500K	50	A	.10	.030	3	6	28	.070
2DA500K	50	A	.20	.120	7	30	24	.100
3DB500K	50	B	.30	.025	8	35	24	.100
4DB500K	50	B	.40	.045	9	50	22	.330
1DA101K	100	A	.10	.060	3	10	28	.070
2DB101K	100	B	.20	.025	7	18	24	.100
2DB151K	150	B	.20	.035	7	19	24	.100
2DB201K	200	B	.20	.050	7	20	24	.100
2DB301K	300	B	.20	.070	7	25	24	.100
3DB301K	300	B	.30	.150	9	75	24	.100
1DB501K	500	B	.10	.030	3	6	28	.070
2DB501K	500	B	.20	.120	7	30	24	.100
4DC501K	500	C	.40	.070	9	65	22	.330
1DB102K	1,000	B	.10	.060	3	10	28	.070
2DC102K	1,000	C	.20	.035	7	18	24	.100
3DC102K	1,000	C	.30	.080	8	48	24	.100
1DB202K	2,000	B	.10	.120	4	14	28	.070
2DC202K	2,000	C	.20	.070	7	25	24	.100
2DC302K	3,000	C	.20	.100	7	30	24	.100
3DC302K	3,000	C	.30	.210	10	90	24	.100
2DC402K	4,000	C	.20	.125	7	32	24	.100
1DC502K	5,000	C	.10	.040	3	8	28	.070
2DC502K	5,000	C	.20	.160	8	36	24	.100
1DC103K	10,000	C	.10	.080	4	12	28	.070
2DE103K	10,000	E	.20	.040	7	17	24	.100
3DE103K	10,000	E	.30	.085	8	48	24	.100
2DE203K	20,000	E	.20	.075	7	20	24	.100
2DE303K	30,000	E	.20	.115	7	25	24	.100
1DE503K	50,000	E	.10	.050	3	6	28	.070
2DE503K	50,000	E	.20	.190	7	30	24	.100
1DE104K	100,000	E	.10	.095	3	9	28	.070

Maximum temperature rating: 150°C
Standard resistance tolerances:
J=5%, K=10%, L=15%, M=20%
Other resistance tolerances available.



NTC Resistance/Temperature Conversion Tables

Temp.	R-T Curve A		R-T Curve B		R-T Curve C		R-T Curve E	
°C	R_T/R_{25}	DEV	R_T/R_{25}	DEV	R_T/R_{25}	DEV	R_T/R_{25}	DEV
-60	43.0		75.0	6.6	140.5	6.6		
-55	31.9		54.1	6.1	96.4	6.1	131.0	
-50	24.3		39.7	5.6	67.0	5.6	97.5	
-45	18.6		29.2	5.2	47.2	5.2	66.6	
-40	14.4	7.6	21.7	4.7	33.7	4.7	45.5	7.6
-35	11.3	6.9	16.4	4.3	24.3	4.3	32.3	6.9
-30	8.93	6.2	12.5	3.8	17.7	3.8	23.0	6.2
-25	7.10	5.6	9.58	3.4	13.0	3.4	16.5	5.6
-20	5.69	5.0	7.42	3.0	9.71	3.0	12.0	5.0
-15	4.56	4.4	5.75	2.6	7.30	2.6	8.79	4.4
-10	3.68	3.7	4.50	2.2	5.53	2.2	6.51	3.7
-5	2.99	3.1	3.55	1.9	4.23	1.9	4.86	3.1
0	2.45	2.5	2.82	1.5	3.27	1.5	3.71	2.5
5	2.02	2.0	2.26	1.2	2.54	1.2	2.79	2.0
10	1.68	1.6	1.83	0.8	1.99	0.8	2.13	1.6
15	1.42	1.1	1.48	0.5	1.57	0.5	1.65	1.1
20	1.18	0.6	1.22	0.2	1.25	0.2	1.28	0.6
25	1.00	0.0	1.00	0.0	1.00	0.0	1.00	0.0
30	.854	0.6	.828	0.4	.806	0.4	.794	0.6
35	.732	1.1	.689	0.7	.653	0.7	.623	1.1
40	.628	1.6	.576	1.0	.533	1.0	.496	1.6
45	.537	2.0	.482	1.3	.437	1.3	.398	2.0
50	.464	2.5	.406	1.5	.360	1.5	.320	2.5
55	.403	3.0	.343	1.8	.299	1.8	.259	3.0
60	.350	3.4	.292	2.0	.249	2.0	.211	3.4
65	.305	3.8	.247	2.3	.208	2.3	.172	3.6
70	.267	4.2	.212	2.5	.175	2.5	.141	4.2
75	.236	4.6	.182	2.8	.148	2.8	.114	4.6
80	.208	4.9	.157	3.0	.126	3.0	.0962	4.9
85	.183	5.3	.137	3.2	.107	3.2	.0799	5.3
90	.163	5.6	.120	3.4	.0916	3.4	.0666	5.6
95	.145	6.0	.105	3.6	.0787	3.6	.0558	6.0
100	.130	6.3	.0920	3.8	.0679	3.8	.0468	6.3
105	.117	6.7	.0812	4.0	.0588	4.0	.0395	6.7
110	.105	7.0	.0723	4.2	.0511	4.2	.0333	7.0
115	.0943	7.3	.0641	4.4	.0445	4.4	.0283	7.3
120	.0852	7.6	.0569	4.6	.0389	4.6	.0241	7.6
125	.0771	7.9	.0508	4.8	.0342	4.8	.0205	7.9
130	.0700	8.2	.0455	4.9	.0301	4.9	.0176	8.2
135	.0636	8.4	.0408	5.1	.0265	5.1	.0151	8.4
140	.0579	8.6	.0368	5.3	.0235	5.3	.0130	8.6
145	.0529	9.0	.0332	5.4	.0208	5.4	.0112	9.0
150	.0483	9.3	.0300	5.5	.0185	5.5	.0101	9.3

NTC DISC & CHIP Configuration Options

DISC

- **Leaded**
  Insulated/
  Non-insulated
- **Without Leads**
- **Pre-formed Leads**

CHIP

- **Standard size 0.050" x 0.050" x "T"**
- **Leaded**
- **Epoxy Coated**
- **Un-coated**

NTC Resistance/Temperature Curve Characteristics

R-T Curve	A	B	C	E
Temperature Coefficient (α @ 25°C)	-3.3%/°C	-3.9%/°C	-4.4%/°C	-4.9%/°C
Beta, β	3000°K	3530°K	3965°K	4500°K
R@0°C/R@50°C	5.3±5%	6.9±3%	9.1±3%	11.6±5%
R@25°C/R@125°C	13.0	19.8	29.4	48.7

Resistance at Temperature:
To determine the nominal resistance value of a thermistor at a specified temperature, multiply its R_T/R_{25} value for the desired temperature and R-T curve from the table above by its nominal resistance value at 25°C.

For instance, the nominal resistance value at 80°C for a thermistor with part number 1DC103K is 10,000 times 0.126, the R_T/R_{25} value in R-T Curve C table above, or 1,260 ohms.

Resistance Tolerances:
The standard resistance tolerance at 25°C for RTI's NTC thermistors is ±10% and is indicated in its part number by the addition of the suffix K. However, RTI's thermistors may also be supplied with other resistance tolerances.

To determine a thermistor's resistance tolerance at a temperature other than 25°C, add the appropriate DEV value from the R-T Curve table above to its resistance tolerance at 25°C.

For instance, the resistance tolerance at 80°C for a thermistor with part number 1DC103K is ±10% ±3.0%, the DEV value from the R-T Curve C table above or ±13%.

Precision Temperature Measurement and Control Devices

Interchangeables

NTC Thermistors

NTC Thermistors

ACCU-CURVE™ Features

- **Wide Ohmic Value Range**
- **Accurate & Stable**
- **D.C. 1mW/°C**
- **Fast Thermal Response Time**
- **T.C. 10 Sec. in Air**
- **Compact Epoxy Package Style**
- **High Sensitivity**

Negative Temperature Coefficient (NTC) thermistors are thermally sensitive semiconductor resistors which exhibit a decrease in resistance as absolute temperature increases. Change in the resistance of the NTC thermistor can be brought about either by a change in the ambient temperature or internally by self-heating resulting from current flowing through the device. Most of the practical applications of NTC thermistors are based on these material characteristics.

Interchangeable Thermistors

RTI manufactures precision resistance-temperature matched **ACCU-CURVE™** thermistors. These devices offer interchangeability over a broad temperature range and eliminate the need to individually calibrate or provide circuit compensation for part variability. Accurate temperature measurement to ±0.2°C is available over the 0°C to 70°C temperature range. Standard ohmic values at 25°C range from 2,252 to 100,000 ohms.

Thermistor Terminology for Temperature Measurement & Control Devices

- **D.C. -** The dissipation constant is the ratio, normally expressed in milliwatts per degree C (mw/°C), at a specified ambient temperature, of a change in power dissipated in a thermistor to the resultant change in body temperature.

- **T.C. -** The thermal time constant is the time required for a thermistor to change 63.2% of the total difference between its initial and final body temperature when subjected to a step function change in temperature under zero-power conditions and is normally expressed in seconds (S).

- **Alpha (α) or Temperature Coefficient of Resistance -** The temperature coefficient of resistance is the ratio at a specified temperature, T, of the rate of change of zero-power resistance with temperature to the zero-power resistance of the thermistor. The temperature coefficient is commonly expressed in percent per degree C (%/°C).

$$\alpha_T = \Delta R_T / \Delta T$$

Applications

There are numerous ways of measuring temperature electronically. Improvements in thermistor technology, coupled with the introduction of integrated circuitry, have made precision temperature measurement systems very cost effective. Microprocessors, A/D converters, interface electronics and displays are readily available. Circuit designs with built-in thermistor resistance-temperature algorithms have gained wide spread acceptance in precision temperature metrology. RTI's **ACCU-CURVE™** style thermistors are used in many applications that require a high degree of accuracy and reliability.

Some of the most popular applications of NTC **ACCU-CURVE™** thermistors include:

- Temperature Measurement & Control
- Temperature Sensors

ACCU-CURVE™
Selection Considerations

- **Determine Resistance Value & Temperature Coefficient**
- **Determine Accuracy Req'd.**
- **Review Power Dissipation**
- **Select Temperature Range**
- **Review Thermal Time Constant**

Selection Considerations for NTC ACCU-CURVE™ Devices

Interchangeable **ACCU-CURVE™** NTC thermistors are usually selected when a high degree of measurement accuracy is required over a wide temperature range. By modifying the **Alpha** equation the resistance and temperature tolerances can be calculated for various temperature intervals. ($\Delta T = \Delta R/(\alpha * R)$ and $\Delta R = \alpha * R * \Delta T$) Because thermistors are non-linear with respect to their resistance-temperature characteristics, **Alpha** therefore is non-linear across their resistance-temperature range. As an example, a thermistor material curve with an **Alpha** of -4.4%/°C @ 25°C will have an **Alpha** of -3.8%/°C @ 50°C. For practical applications we recommend that the standardized R/T curves (see page 14) be used.

RTI **ACCU-CURVE™** thermistors can dissipate 1mW/°C. As a result, the possibility of error induced by excessive current flow, which would defeat the level of accuracy these devices are capable of representing, may exist in some circuits. To prevent this type of error, RTI recommends that circuit design engineers select the highest R value their circuit will tolerate for applications > 5 Volts to minimize any self-heating of the thermistor device. Refer to the **ACCU-CURVE™ Specifications** table (located on page 14) for resistance values and temperature tolerances.

RTI offers two standard R/T curves, "C" & "W", with temperature coefficients of resistance (α) of -4.4%/°C and -4.7%/°C, and Beta (β) values of 3965°K and 4250°K. To determine the nominal resistance value of a thermistor at a specified temperature, multiply its resistance at 25°C value by the corresponding R_T/R_{25} value for the desired temperature and applicable R-T curve from the **ACCU-CURVE™ Resistance/Temperature Conversion Table** (located on page 15).

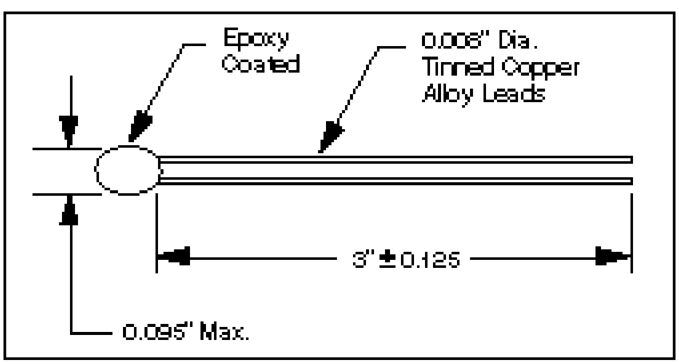
ACCU-CURVE™ Specifications

Resistance @ 25° C (Ω)	Temperature Tolerance from 0° C to 70° C			Color Code
	±0.2° C	±0.5° C	±1.0° C	
	Part Number	Part Number	Part Number	
2,252	ACC-001	ACC-011	ACC-021	Brown
3,000	ACC-002	ACC-012	ACC-022	Red
5,000	ACC-003	ACC-013	ACC-023	Orange
10,000	ACC-004	ACC-014	ACC-024	Yellow
30,000	ACW-005	ACW-015	ACW-025	Green
50,000	ACW-006	ACW-016	ACW-026	Blue
100,000	ACW-007	ACW-017	ACW-027	Violet

ACCU-CURVE™ Resistance/Temperature Table

RESISTANCE (Ω)

TEMP	"C" CURVES				"W" CURVES		
(°C)	2,252Ω @ 25°C	3,000Ω @ 25°C	5,000Ω @ 25°C	10,000Ω @ 25°C	30,000Ω @ 25°C	50,000Ω @ 25°C	100,000Ω @ 25°C
-40	75,780	100,950	168,250	336,500	1,204,600	2,007,700	4,015,500
-30	39,860	53,100	88,500	177,000	619,200	1,032,000	2,064,000
-20	21,860	29,121	48,535	97,070	331,030	551,720	1,103,400
-10	12,460	16,599	27,665	55,330	183,560	305,940	611,870
0	7,352.8	9,795.0	16,325	32,650	105,310	175,510	351,020
10	4,481.5	5,970.0	9,950.0	19,900	62,354	103,920	207,850
20	2,812.8	3,747.0	6,245.0	12,490	38,022	63,370	126,740
25	2,252.0	3,000.0	5,000.0	10,000	30,000	50,000	100,000
30	1,814.4	2,417.1	4,028.5	8,057.0	23,827	39,711	79,422
40	1,199.6	1,598.1	2,663.3	5,327.0	15,314	25,524	51,048
50	811.40	1,080.9	1,801.5	3,603.0	10,077	16,795	33,591
60	560.30	746.40	1,244.0	2,488.0	6,777.1	11,295	22,590
70	394.55	525.60	876.00	1,752.0	4,650.5	7,750.9	15,502
80	282.63	376.50	627.50	1,255.0	3,251.2	5,418.7	10,837
90	206.13	274.59	457.65	915.30	2,312.3	3,853.9	7,707.7
100	152.75	203.49	339.15	678.30	1,670.8	2,784.6	5,569.3
110	114.92	153.09	255.15	510.30	1,224.9	2,041.5	4,082.9
120	87.671	116.79	194.65	389.30	909.99	1,516.7	3,033.3
130	67.770	90.279	150.47	300.93	684.31	1,140.5	2,281.0
140	52.983	70.581	117.64	235.27	520.30	867.16	1,734.3
150	41.881	55.791	92.985	185.97	399.56	665.94	1,331.9



The **ACCU-CURVE™** device can also be supplied with 30 AWG solid Teflon insulated leads of 3, 6, 9 and 12 inches in length. contact RTI applications engineering for additional information.

WARNING: USE HEAT SINKS WHEN SOLDERING TO THERMISTOR LEADS.

ACC-0XX “C” CURVE

TEMP. °C	R_T/R_{25}	TEMP. °C	R_T/R_{25}
0	3.2650	36	0.6267
1	3.1030	37	0.6017
2	2.9500	38	0.5777
3	2.8050	39	0.5547
4	2.6690	40	0.5327
5	2.5390	41	0.5117
6	2.4170	42	0.4917
7	2.3010	43	0.4727
8	2.1920	44	0.4543
9	2.0880	45	0.4370
10	1.9900	46	0.4200
11	1.8970	47	0.4040
12	1.8090	48	0.3890
13	1.7250	49	0.3743
14	1.6460	50	0.3603
15	1.5710	51	0.3467
16	1.5000	52	0.3340
17	1.4320	53	0.3217
18	1.3680	54	0.3099
19	1.3070	55	0.2986
20	1.2490	56	0.2878
21	1.1940	57	0.2774
22	1.1420	58	0.2675
23	1.0920	59	0.2579
24	1.0450	60	0.2488
25	1.0000	61	0.2400
26	0.9573	62	0.2316
27	0.9167	63	0.2235
28	0.8777	64	0.2157
29	0.8407	65	0.2083
30	0.8057	66	0.2011
31	0.7723	67	0.1942
32	0.7403	68	0.1876
33	0.7097	69	0.1813
34	0.6807	70	0.1752
35	0.6530		

ACW-0XX “W” CURVE

TEMP. °C	R_T/R_{25}	TEMP. °C	R_T/R_{25}
0	3.5102	36	0.6074
1	3.3264	37	0.5814
2	3.1532	38	0.5566
3	2.9899	39	0.5330
4	2.8360	40	0.5105
5	2.6908	41	0.4891
6	2.5539	42	0.4686
7	2.4246	43	0.4492
8	2.3026	44	0.4306
9	2.1873	45	0.4129
10	2.0785	46	0.3961
11	1.9756	47	0.3800
12	1.8784	48	0.3646
13	1.7865	49	0.3499
14	1.6995	50	0.3359
15	1.6173	51	0.3225
16	1.5395	52	0.3098
17	1.4658	53	0.2976
18	1.3961	54	0.2859
19	1.3300	55	0.2748
20	1.2674	56	0.2641
21	1.2081	57	0.2539
22	1.1519	58	0.2442
23	1.0985	59	0.2348
24	1.0480	60	0.2259
25	1.0000	61	0.2174
26	0.9545	62	0.2092
27	0.9113	63	0.2014
28	0.8702	64	0.1939
29	0.8313	65	0.1867
30	0.7942	66	0.1798
31	0.7590	67	0.1732
32	0.7256	68	0.1669
33	0.6938	69	0.1608
34	0.6636	70	0.1550
35	0.6348		

To determine the nominal resistance value of a thermistor at a specified temperature, multiply its R_T/R_{25} value for the desired temperature and R-T curve from the table above by its nominal resistance at 25°C.

Temperature Compensation Devices

Surface Mount

NTC Thermistors

NTC Thermistors

SMD

(CHIP STYLE)

Features

- **Wide Ohmic Value Range**
- **Accurate & Stable**
- **Fast Thermal Response Time**
- **Standard Sizes**
- **High Sensitivity**

Negative Temperature Coefficient (NTC) thermistors are thermally sensitive semiconductor resistors which exhibit a decrease in resistance as absolute temperature increases. Change in the resistance of the NTC thermistor can be brought about either by a change in the ambient temperature or internally by self-heating resulting from current flowing through the device. Most of the practical applications of NTC thermistors are based on these material characteristics.

Surface Mount Thermistors

RTI manufactures precision resistance-temperature **SMD** thermistors. Standard values from 250 ohms to 150,000 ohms are available. As with RTI's disc and chip thermistors, **SMD** thermistors are suitable for temperature sensing applications over a wide range of resistance values and temperature coefficients. **SMD's** operating temperature range is from -55°C to +150°C. Dissipation constant is 2mW/°C, with a maximum power rating of 250mW @ 25°C.

Thermistor Terminology for SMD Temperature Measurement

- **D.C. -** The dissipation constant is the ratio, normally expressed in milliwatts per degree C (mw/°C), at a specified ambient temperature, of a change in power dissipated in a thermistor to the resultant change in body temperature.

- **T.C. -** The thermal time constant is the time required for a thermistor to change 63.2% of the total difference between its initial and final body temperature when subjected to a step function change in temperature under zero-power conditions and is normally expressed in seconds (S).

- **Alpha (α) or Temperature Coefficient of Resistance -** The temperature coefficient of resistance is the ratio at a specified temperature, T, of the rate of change of zero-power resistance with temperature to the zero-power resistance of the thermistor. The temperature coefficient is commonly expressed in percent per degree C (%/°C).

$$\alpha_T = \Delta R_T / \Delta T$$

Applications

Most semiconductors and the circuits comprised of them exhibit a positive temperature coefficient. NTC thermistors are well suited for compensating these responses to temperature changes. It is important to match the temperature of the compensating NTC thermistor to that of the component responsible for the temperature response.

RTI's **SMD** temperature measurement NTC sensors can operate over a wide temperature range (-55 to +150°C). They are stable throughout a long lifetime, and are small and comparatively inexpensive. Typically, they have negative temperature coefficients between -3.3 and -4.7%/°C at 25°C. RTI's **SMD** style thermistors are used in many applications that require a high degree of accuracy and reliability.

SMD
Selection Considerations

- **Select Req'd. Resistance Value & Temperature Coefficient**
- **Calculate DEV for R @ T**
- **Determine Accuracy Req'd.**
- **Review Power Dissipation**
- **Review Thermal Time Constant**

Some of the most popular applications of NTC thermistors include:

- Temperature Compensation
- LCD Controls
- Temperature Measurement & Control
- Power Transistor Stabilization

Selection Considerations for SMD NTC Devices

To determine the nominal resistance value of a thermistor at a specified temperature, multiply its R_T/R_{25} value for the desired temperature and R-T curve from the table on page 19 by its nominal resistance value at 25°C. As an example, the nominal resistance value at 80°C for a thermistor with the part number KR0805B103K is 10,000 times 0.157, the R_T/R_{25} value in the R-T Curve "B" in the table on page 19.

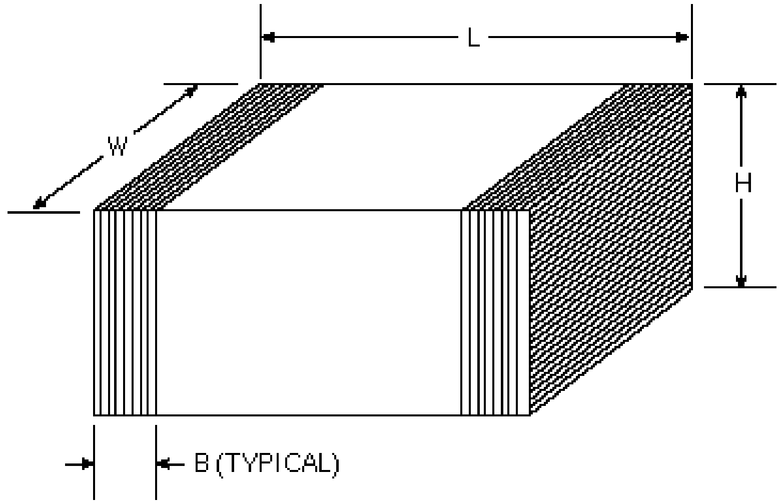
Standard resistance tolerances at 25°C for RTI's **SMD** thermistors is ±10% and is indicated in its part number by the addition of the suffix K. To determine the resistance value at other than 25°C, add the appropriate DEV value from the conversion table on page 19 to its resistance tolerance at 25°C. For example, the resistance tolerance at 80°C for a thermistor with part number KR0805B103K is ±10% ±3.0%, the DEV value from the R-T Curve "B" Table.

Although standard sizes, resistance values and tolerances are listed on page 18, custom sizes, resistance values and tolerances are available depending on the application and volume requirements.

SMD

Configuration Option

- **Standard EIA Sizes Available**
- **Bulk or Tape and Reel Packaging**
- **Two Sided & Wrap Around Termination's**
- **Silver Palladium Termination's**



Size

Size	0805		1206	
Units	Inches	Millimeters	Inches	Millimeters
W	0.049 ±0.008	1.240 ±0.200	0.063 ±0.008	1.600 ±0.200
H	0.051 Maximum	1.300 Maximum	0.059 Maximum	1.500 Maximum
L	0.079 ±0.008	2.000 ±0.200	0.126 ±0.008	3.200 ±0.200
B	0.008 Minimum	0.200 Minimum	0.008 Minimum	0.200 Minimum

Nonstandard values and sizes available upon request.

Standard Products

Part Number Size 0805	Part Number Size 1206	Resistance @ 25°C ±10%	Temperature Coefficient (α@25°C)
KR0805A251K	KR1206A251K	250 Ω	-3.3%/°C
KR0805A501K	KR1206A501K	500 Ω	-3.3%/°C
KR0805J102K	KR1206J102K	1.0K Ω	-3.5%/°C
KR0805J252K	KR1206J252K	2.5K Ω	-3.5%/°C
KR0805B502K	KR1206B502K	5.0K Ω	-3.9%/°C
KR0805B103K	KR1206B103K	10K Ω	-3.9%/°C
KR0805C203K	KR1206C203K	20K Ω	-4.4%/°C
KR0805C253K	KR1206C253K	25K Ω	-4.4%/°C
KR0805C503K	KR1206C503K	50K Ω	-4.4%/°C
KR0805W104K	KR1206W104K	100K Ω	-4.7%/°C
KR0805W154K	KR1206W154K	150K Ω	-4.7%/°C

Ordering Information

KR	0805	A	251	K	X
Model	Size	R-T Curve	Resistance*	Tolerance**	Termination***

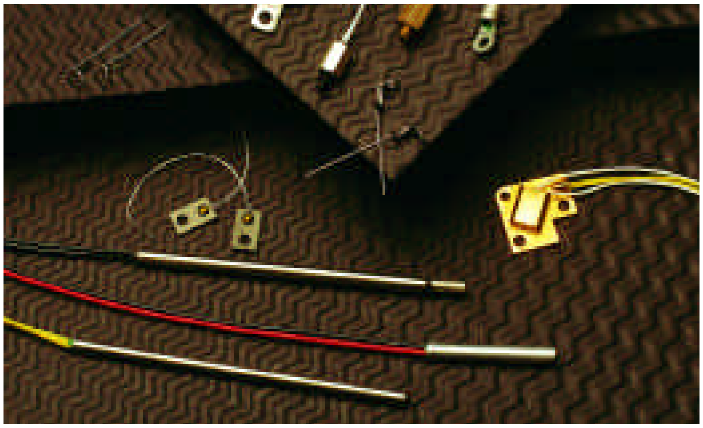
* Resistance value: First two digits are resistance value, third is the number of zeroes. Example: 251 = 250Ω.
** Tolerances available: K = ±10% and J= ±5%.
***Terminations: No letter = Palladium Silver (Consult factory for optional terminations)

NTC Resistance/Temperature Conversion Tables

Temperature °C	R-T Curve A R_T/R_{25}	DEV	R-T Curve B R_T/R_{25}	DEV	R-T Curve C R_T/R_{25}	DEV	R-T Curve J R_T/R_{25}	DEV	R-T Curve W R_T/R_{25}	DEV
-60	43.0		75.0	6.6	140.5	6.6	52.5			
-55	31.9		54.1	6.1	96.4	6.1	39.0			
-50	24.3		39.7	5.6	67.0	5.6	29.2	18.5		
-45	18.6		29.2	5.2	47.2	5.2	22.1	17.0		
-40	14.4	7.6	21.7	4.7	33.7	4.7	16.9	15.4	40.2	7.6
-35	11.3	6.9	16.4	4.3	24.3	4.3	13.0	14.0	28.6	6.9
-30	8.93	6.2	12.5	3.8	17.7	3.8	10.1	12.5	20.6	6.2
-25	7.10	5.6	9.58	3.4	13.0	3.4	7.90	11.2	15.0	5.6
-20	5.69	5.0	7.42	3.0	9.71	3.0	6.24	9.9	11.0	5.0
-15	4.56	4.4	5.75	2.6	7.30	2.6	4.96	8.7	8.18	4.4
-10	3.68	3.7	4.50	2.2	5.53	2.2	3.97	7.4	6.12	3.7
-5	2.99	3.1	3.55	1.9	4.23	1.9	3.20	6.2	4.62	3.1
0	2.45	2.5	2.82	1.5	3.27	1.5	2.60	5.0	3.51	2.5
5	2.02	2.0	2.26	1.2	2.54	1.2	2.12	3.9	2.69	2.0
10	1.68	1.6	1.83	0.8	1.99	0.8	1.74	2.7	2.08	1.6
15	1.42	1.1	1.48	0.5	1.57	0.5	1.44	1.6	1.62	1.1
20	1.18	0.6	1.22	0.2	1.25	0.2	1.20	0.5	1.27	0.6
25	1.00	0.0	1.00	0.0	1.00	0.0	1.00	0.0	1.00	0.0
30	.854	0.6	.828	0.4	.806	0.4	.841	1.4	.794	0.6
35	.732	1.1	.689	0.7	.653	0.7	.710	2.3	.635	1.1
40	.628	1.6	.576	1.0	.533	1.0	.602	3.2	.510	1.6
45	.537	2.0	.482	1.3	.437	1.3	.513	4.3	.413	2.0
50	.464	2.5	.406	1.5	.360	1.5	.439	5.0	.336	2.5
55	.403	3.0	.343	1.8	.299	1.8	.377	5.9	.275	3.0
60	.350	3.4	.292	2.0	.249	2.0	.326	6.7	.226	3.4
65	.305	3.8	.247	2.3	.208	2.3	.282	7.5	.187	3.8
70	.267	4.2	.212	2.5	.175	2.5	.245	8.2	.155	4.2
75	.236	4.6	.182	2.8	.148	2.8	.214	9.0	.129	4.6
80	.208	4.9	.157	3.0	.126	3.0	.188	9.8	.108	4.9
85	.183	5.3	.137	3.2	.107	3.2	.165	10.5	.0912	5.3
90	.163	5.6	.120	3.4	.0916	3.4	.146	11.2	.0771	5.6
95	.145	6.0	.105	3.6	.0787	3.6	.129	11.9	.0654	6.0
100	.130	6.3	.0920	3.8	.0679	3.8	.114	12.6	.0557	6.3
105	.117	6.7	.0812	4.0	.0588	4.0	.102	13.3	.0476	6.7
110	.105	7.0	.0723	4.2	.0511	4.2	.0908	13.9	.0408	7.0
115	.0943	7.3	.0641	4.4	.0445	4.4	.0813	14.4	.0351	7.3
120	.0852	7.6	.0569	4.6	.0389	4.6	.0730	14.9	.0303	7.6
125	.0771	7.9	.0508	4.8	.0342	4.8	.0657	15.6	.0263	7.9
130	.0700	8.2	.0455	4.9	.0301	4.9	.0593	16.3	.0228	8.2
135	.0636	8.4	.0408	5.1	.0265	5.1	.0536	17.0	.0199	8.4
140	.0579	8.6	.0368	5.3	.0235	5.3	.0486	17.6	.0173	8.6
145	.0529	9.0	.0332	5.4	.0208	5.4	.0442	18.0	.0152	9.0
150	.0483	9.3	.0300	5.5	.0185	5.5	.0402	18.4	.0133	9.3

NTC Resistance/Temperature Curve Characteristics

R-T Curve	A	B	C	J	W
Temperature Coefficient α @ 25°C	-3.3%/°C	-3.9%/°C	-4.4%/°C	-3.5%/°C	-4.7%/°C
Beta, β	3000°K	3530°K	3965°K	3200°K	4250°K
R_0°C/R_{50}°C	5.3±5%	6.9±3%	9.1±3%	5.9±5%	10.45±5%
R_{25}°C/R_{125}°C	13.0	19.8	29.4	15.2	38.0



Special Applications

Thermistors Probes & Assemblies

Probes & Assemblies

RTI Electronics has extensive experience in designing thermistors to suit the specific needs of users for a wide range of applications. RTI has produced components from simple consumer sensors to hybrid substrates for critical satellite applications.

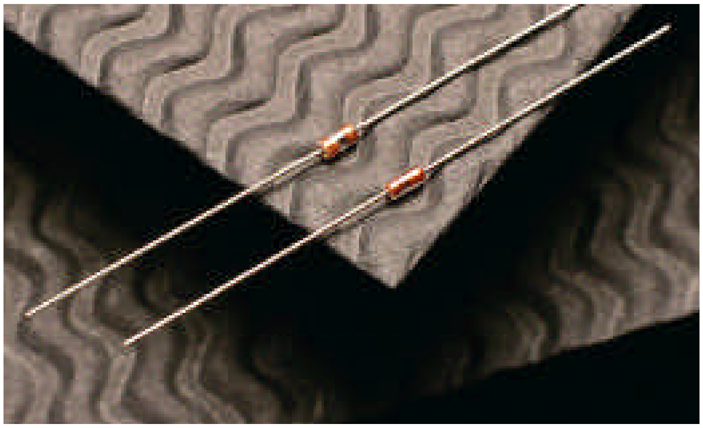
RTI's application engineers are available to work with customers in order to provide custom designs with the proper resistance properties, response times, sizes and others application specific requirements.

Customized thermistor products are subject to the same exacting quality controls as are standard products, assuring high reliability, stability and precision designed into each product.

RTI's thermistors can be supplied in networks of two or more units to accomplish specific application tasks. They can be connected in series or in parallel, depending on the requirements of the specific application.

RTI has also designed and produced a variety of probes and assemblies for a broad range of temperature measurement and control applications. These probes can be ultra miniature chip probes or large units with thermowells, special leads and cable assemblies or standard screw mount fixtures.

For difficult environments, such as liquid submersion, chemical media, et. al. consult RTI's engineering staff for recommendations on thermistor housings and critical physical properties.

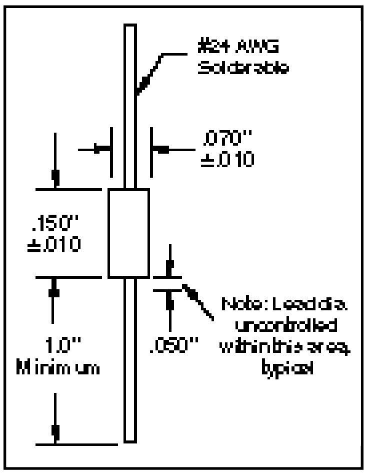


Special Applications

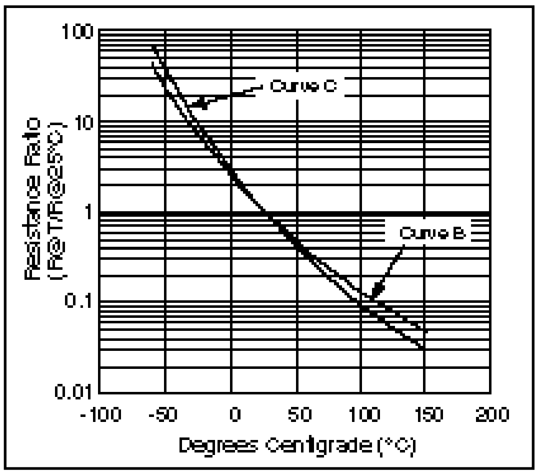
Hermetically Sealed, Glass Encapsulated Style Thermistors

RTI **MINI-SENSOR™** thermistors are small, rugged, hermetically sealed, glass encapsulated (DO-35) devices which are especially useful in applications where extreme temperatures and severe environmental conditions are encountered. They are supplied with Negative Temperature Coefficient characteristics and are available in a broad range of resistance values.
Their high sensitivity makes them especially useful in applications such as temperature measurement, temperature control, liquid level indication, flow measurement and temperature compensation. These low cost devices exhibit excellent long term stability and repeatability.

Dimensions



Resistance/Temperature Chart



MINI-SENSOR™ Specifications

part Number	Resistance* @ 25°C OHMS ±10%	Temp.Coeff. %/°C @ 25°C	Resist. Ratio R@25°C / R@125°C	Resistance Temp Characteristics (See Table)	D.C.** MW/°C	T.C.*** sec.	Max Temp. °C
MSB202K	2,000	-3.9	19.7	B	2	8	204
MSB502K	5,000	-3.9	19.7	B	2	8	204
MSB103K	10,000	-3.9	19.7	B	2	8	204
MSC103K	10,000	-4.4	29.25	C	2	8	204
MSB153K	15,000	-3.9	19.7	B	2	8	204
MSC203K	20,000	-4.4	29.25	C	2	8	204
MSC253K	25,000	-4.4	29.25	C	2	8	204
MSC503K	50,000	-4.4	29.25	C	2	8	204
MSC753K	75,000	-4.4	29.25	C	2	8	204
MSC104K	100,000	-4.4	29.25	C	2	8	204
MSC154K	150,000	-4.4	29.25	C	2	8	204

* Other resistance tolerances available.
** Dissipation Constant.
*** Time Constant.

Resistance/Temperature Tables

To determine resistance at any specified temperature, multiply resistance factor by thermistor resistance at 25°C

Table B

Specified Temp.	Resistance Factor
-60	75.0
-50	39.7
-40	21.7
-30	12.5
-20	7.42
-10	4.50
0	2.82
+10	1.83
+20	1.22
+25	1.00
+30	.828
+40	.576
+50	.406
+60	.292
+70	.212
+75	.182
+80	.157
+90	.120
+100	.0920
+110	.0723
+120	.0569
+125	.0508
+130	.0455
+140	.0368
+150	.0300
+160	.0297
+170	.0206
+180	.0174
+190	.0148
+200	.0128

Table C

Specified Temp.	Resistance Factor
-60	140.5
-50	67.0
-40	33.7
-30	17.7
-20	9.71
-10	5.53
0	3.27
+10	1.99
+20	1.25
+25	1.00
+30	.806
+40	.533
+50	.360
+60	.249
+70	.175
+75	.148
+80	.126
+90	.0916
+100	.0679
+110	.0511
+120	.0389
+125	.0342
+130	.0301
+140	.0236
+150	.0185
+160	.0147
+170	.0120
+180	.0098
+190	.0081
+200	.0066

Resistance Ratios

Composition B: $\frac{R@\ 25°C}{R\ @\ 125°C}$ = 19.7 ± 10%

Composition C: $\frac{R@\ 25°C}{R\ @\ 125°C}$ = 29.25 ± 10%

Thermistor Glossary

Accu-Curve™: Accu-Curve™ is the trademark name for RTI's NTC precision interchangeable thermistors.

Alpha (α): See Temperature coefficient of resistance (alpha, α).

Beta (β): See Material constant (Beta, β).

Curie point: See Switch temperature (Ts).

Current-time characteristic: The current-time characteristic is the relationship at a specified ambient temperature between the current through a thermistor and time, upon the application or interruption of voltage to it.

D.C.: See Dissipation constant (D.C. or delta, δ).

Delta (δ): See Dissipation constant (D.C.) or delta, δ).

Dissipation constant (D.C. or delta δ): The dissipation constant is the ratio, normally expressed in milliwatts per degree C (mw/°C), at a specified ambient temperature, of a change in power dissipation in a thermistor to the resultant body temperature change.

Heat capacity (H_c): The heat capacity of a thermistor is the amount of heat required to increase the body temperature of it by one degree centigrade (1°C). Heat capacity is a common rating of standard PTC thermistors and is expressed in watt-second per cubic inch per degree C (watt-sec/in^3/°C). The heat capacity per unit volume relationship of standard PTC thermistors is approximately 50 watt-sec/in^3/°C.

H_c: See Heat capacity (H_c)

I_{cc}: See Maximum continuous current (I_{cc}).

I_{max}: See Maximum steady-state current (I_{max}).

Inrush current: Inrush current is the initial surge of current that results when power is first applied to a load having a low starting impedance, such as a discharged capacitor, a cold lamp filament, or a stopped motor's winding.

Inrush current limiter: Specially designed and constructed NTC thermistors may be used as inrush current limiters. RTI Surge-Gard™ inrush current limiters are available in a wide range of current handling and zero-power resistance value combinations.

I_s: See Minimum switching current (I_s).

Material constant (Beta , β): The material constant of a NTC thermistor is a measure of its resistance at one temperature compared to its resistance at a different temperature. Its value may be calculated by the formula shown below and is expressed in degrees kelvin (°K). The reference temperatures used in this formula for determining material constant ratings of RTI thermistors are 298.15°K and 348.15°K.

$$\beta = \ln (R @ T2/R @ T1) / (T2^{-1} - T1^{-1})$$

Maximum continuous current (I_{cc}): The maximum continuous current is the amount of current, normally expressed in amperes (A), that a standard PTC thermistor must be capable of conducting without switching into its high resistance state.

Maximum operating temperature: The maximum operating temperature is the maximum body temperature at which a thermistor will operate for a extended period of time with acceptable stability of its characteristics. This temperature is the result of internal or external heating, or both, and should not exceed the maximum value specified.

Maximum power rating: The maximum power rating of a thermistor is the maximum power, expressed in watts or milliwatts (W or mW), which a thermistor will dissipate for an extended period of time with acceptable stability of its characteristics.

Maximum steady-state current (Imax): The maximum steady-state current is the rating of the maximum current, normally expressed in amperes (A), allowable to be conducted by an inrush limiting NTC thermistor for an extended period of time.

Maximum surge current: The maximum surge current is the maximum permissible surge current in a circuit and, in conjunction with the maximum peak voltage, determines the minimum required zero-power resistance of the Surge-Gard™ thermistor required to limit it adequately. See inrush current.

Maximum operating voltage (V_{max}): The maximum operating voltage is the maximum rated voltage, either direct current or 60 Hz RMS alternating current, expressed in volts (VDC or VAC), that a standard PTC thermistor will continuous withstand for an extended period without affecting its normal characteristics.

MIL-T-23648: MIL-T-23648 is the U.S. military's general specification for thermistors.

Minimum switching current (I_s): The minimum switching current is the minimum amount of current, normally expressed in amperes (A), that, when conducted by a standard PTC thermistor, is required to cause it to switch to its high resistance state.

Mini-Sensor™: Mini-Sensor™ is the trademark name for RTI miniature glass encapsulated thermistors.

Negative temperature coefficient (NTC): A NTC thermistor is one whose zero-power resistance decreases with an increase in temperature.

NTC: See Negative temperature coefficient (NTC).

Positive temperature coefficient (PTC): A PTC thermistor is one whose zero-power resistance increases with an increase in temperature.

PTC: See Positive temperature coefficient (PTC)

Recovery time: The recovery time of a thermistor is the approximate time required for it to cool sufficiently after power is removed and allow it to provide the characteristics required when power is reapplied.

Resistance at maximum current (RI_{max}) The resistance at maximum current is the approximate resistance of an inrush current limiting thermistor, expressed in ohms (Ω), when it is conducting its rated maximum steady-state current.

Resistance ratio characteristic: The resistance ratio characteristic identifies the ratio of the zero-power resistance of a thermistor measured at one temperature to that resistance measured at a different temperature. The resistance ratio characteristic specified in military specification MIL-T-23648 is the resistance measured at 25°C divided by the resistance measured at 125°C.

Resistance-temperature characteristic: The resistance temperature characteristic is the relationship between the zero-power resistance of a thermistor and its body temperature.

RI_{max}: See Resistance at maximum current (RI_{max}).

R_t: See Zero-power resistance (R_t or R_o).

R_o: See Zero-power resistance (R_t or R_o).

Silicon PTC thermistor: A silicon PTC thermistor is a type PTC thermistor that has an approximately linear resistance-temperature characteristic and a temperature coefficient of resistance of approximately +0.7%/°C. Silicon PTC thermistors are distinguished from standard PTC thermistors.

Stability: The stability of a thermistor is the ability of it to retain specified characteristics after being subjected to designated environmental or electrical test conditions.

Standard PTC thermistor: A standard PTC thermistor is a type of PTC thermistor that has a switch temperature. Standard PTC thermistors are distinguished from silicon PTC thermistors.

Standard reference temperature: The standard reference temperature is the thermistor body temperature at which nominal zero-power resistance is specified and is usually 25°C.

Static voltage-current curve: The static voltage-current (V/I) curve defines the relationship between voltage and current at any point of equilibrium for a standard PTC thermistor.

Surge-Gard™: Surge-Gard™ is the trademark name for RTI inrush current limiting thermistors.

Switch temperature (T_S): The switch temperature is the temperature of a standard PTC thermistor at which its resistance begins to increase very rapidly. The typical specification for RTI standard PTC thermistors rates their resistance at their switch temperature as two times their zero-power resistance at 25°C. Switch temperature is sometimes also identified as transition temperature or Curie point.

Tau (τ): See Thermal time constant (T.C. or tau, τ).

T.C.: See Thermal time constant (T.C. or tau, τ).

Temperature coefficient of resistance (alpha, α): The temperature coefficient of resistance is the ratio at a specified temperature, T, of the rate of change of zero-power resistance with temperature to the zero-power resistance of the thermistor. The temperature coefficient is commonly expressed in percent per degree C (%/°C).

$$\alpha T = \frac{(dR_T)}{(d_T)}$$

T_s: See Switch temperature (T_S).

Temperature-wattage characteristic: The temperature-wattage characteristic of a thermistor is the relationship at a specified ambient temperature between the thermistor temperature and the applied steady-state wattage.

Thermal time constant (T.C. or tau, τ): The thermal time constant is the time required for a thermistor to change 63.2 percent of the total difference between its initial and final body temperature when subjected to a step function change in temperature under zero-power conditions and is normally expressed in seconds.

Thermistor: A thermistor is a thermally sensitive resistor whose primary function is to exhibit a change in electrical resistance with a change in body temperature.

Transition temperature: See Switch temperature (T_S).

V_{max}: See Maximum operating voltage (V_{max}).

Zero-power resistance (R_t or R_o): The zero-power resistance is the direct current resistance value of a thermistor measured at a specified temperature, T, with a power dissipation by the thermistor low enough that any further decrease in power will result in not more than 0.1 percent (or 1/10 of the specified measurement tolerance, whichever is smaller) change in resistance.

Standard NTC Thermistor Applications

GENERALNOTES

Thermistors are temperature sensitive passive semiconductors which exhibit a large change in electrical resistance when subjected to a relatively minute change in body temperature. Negative Temperature Coefficient (NTC) thermistors decrease in resistance when subjected to an increase in body temperature. Their extreme sensitivity to minute temperature changes enables them to perform many unique functions heretofore impossible with standard electronic components.

NTC Resistance Temperature Characteristic Formula:

The resistance of a thermistor is solely a function of its absolute body temperature. When testing for resistance accuracy it is essential that the surrounding environmental temperature is held at a constant, and power dissipated in the thermistor is low enough to insure no "self-heating". Formula for determining resistance of RTI composition A, B, C and E NTC thermistors at any temperature within the operating limits:

$$R_\circ (T) = R_\circ (T_\circ) \left[e^{Y\left(\frac{1}{T} - \frac{1}{T_\circ}\right)} \right]$$

Where:

$R_\circ$ (T)	is the resistance at Temperature T
$R_\circ$ ($T_\circ$)	is the resistance at 25°C
e	is 2.718
T	is the Temperature at which R is unknown expressed in °Kelvin. (273.15 + °C)
$T_\circ$	is 298.15°K (25°C)
Y	is $(a + bT + cT^2)$

	Comp. A	Comp. B	Comp. C	Comp. E
a =	2641.67	2183.03	2923.94	3197.35
b =	1.0643	6.6190	4.8657	4.2865
c =	-.0001571	-.008048	-.005363	-.001836

The temperature coefficient of resistance (α) is expressed mathematically as follows:

$$\alpha = \frac{1}{R_\circ} \frac{dR_\circ}{dT} \quad \text{Ohms/Ohms/°C}$$

which is approximately equal to $\frac{\beta}{T^2}$

NTC APPLICATIONS

Temperature Measurement:
When a very small amount of power is dissipated in a thermistor, its temperature will be dependent upon the surrounding ambient. Therefore, its electrical resistance becomes a function of the ambient temperature, and may be used to measure temperature variations. Because of the very high temperature coefficient of the thermistor, accurate temperature measurements can be made with a simple measuring device. Figure 1 shows a simple circuit using a microammeter in series with a thermistor connected to a potential source. The meter can be calibrated in terms of temperature.

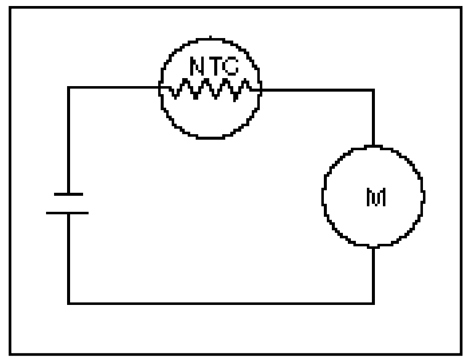


Figure 1

A more sensitive method would be as shown in Figure 2 using a bridge circuit with a thermistor in one leg. Caution must be taken to insure that the power dissipated in the thermistor is held at a minimum and current flow is insufficient to cause "self- heating''.

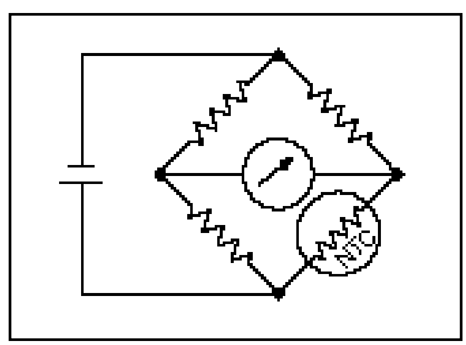


Figure 2

Temperature Differential:

By placing matched thermistors in two legs of a bridge circuit as seen in Figure 3, temperature differentials as close as .001°C can be readily detected.

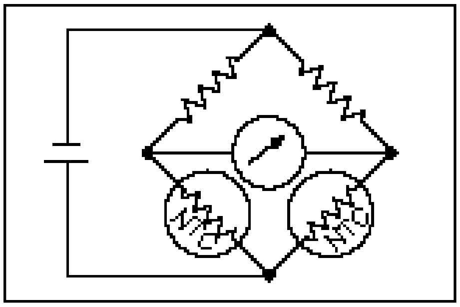


Figure 3

Temperature Control

By placing a thermistor in series with a relay coil and potentiometer as shown in Fig.4, a simple temperature controller is obtained. The potentiometer will control the switching temperature.

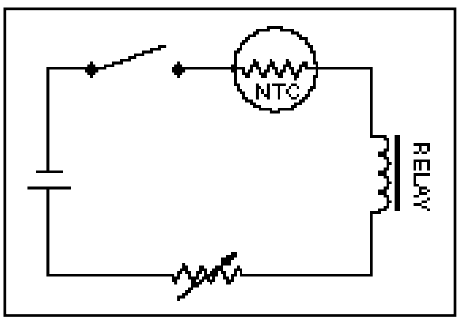


Figure 4

A more sensitive controller can be obtained by feeding the output of a thermistor bridge as shown in Figure 3 into a high gain amplifier. Sensitivity of .005°C can be sensed easily with this method.

Temperature Compensation:

Since all metals used for coil windings, etc., have a positive temperature coefficient of resistance, NTC thermistors are especially useful for compensating resistance changes in devices subjected to temperature variations. Where a copper meter coil would change 50% in resistance over a commonly used temperature range, a thermistor shunted by a resistor in series with the unit as shown in Figure 5 allows the total impedance of a circuit to be held uniform over the entire operating range. Due to the high temperature coefficient of the thermistor as opposed to the low temperature coefficient of the copper, full compensation can be achieved by using a thermistor- resistor network. This network adds less than 15% to the total impedance of the circuit. Compensation of transistor amplifiers, crystal oscillators, etc. can be achieved by using similar methods. RTI's application engineering staff is always anxious to help you solve your temperature compensation problems.

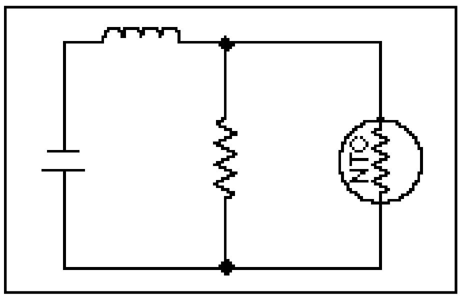


Figure 5

Time Delay

By placing a thermistor in series with a relay, a potentiometer, and a battery as shown in Figure 4, a simple time delay circuit is obtained. A relatively high potential is applied to the circuit. The thermistor begins to "self-heat," lowering its resistance and allowing more current to flow. The increased current further heats the thermistor, allowing still more current to flow, which in turn actuates the relay. The time required for the relay to actuate after voltage is applied can be controlled by adjusting the potentiometer.

Surge Suppression

By placing a thermistor in series with a filament string as shown in Figure 6, current surge can be eliminated. The resistance of the thermistor is higher than the total resistance of the filaments when the circuit is turned on. As current begins flowing, the thermistor "self-heats." Its resistance is reduced to a minimum and becomes insignificant to the total resistance of a circuit.

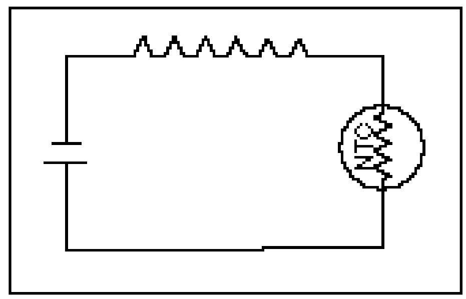


Figure 6

Current surges in electric motors can be held to minimum using the same concept. Figure 7 shows a typical DC motor's turn-on surge before and after the application of a RTI thermistor to the circuit.

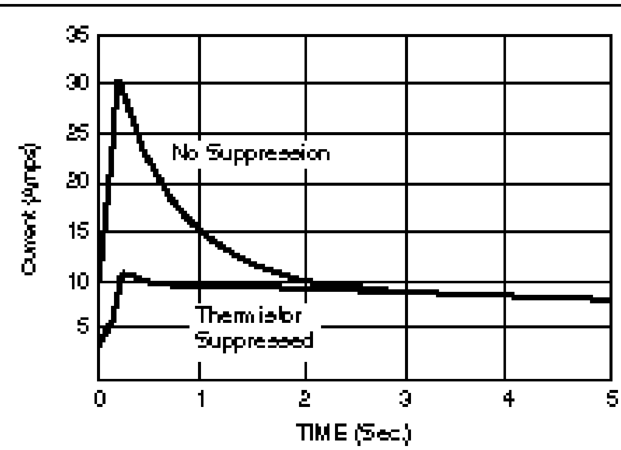


Figure 7

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