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Thermistor Definition

The word thermistor is derived from its description "thermal sensitive resistor" Thermistors are passive semiconductors, which produce resistance values dependent on temperature.

A Negative Temperature Coefficient (NTC) thermistor decreases in resistance as its body temperature increases. In fact, NTC thermistors exhibit two characteristics, which make them extremely useful in a variety of applications. Their change in resistance is predictable and it is relatively large per degree change in temperature.

Manufacturing Process

This is a two-step process of chip manufacturing and thermistor assembly. Manufactured chips are processed by metal oxide powders into ceramic sheets. These sheets are metalized with silver to allow for electrical contact. After metalization, the ceramic sheets are diced into chips. Each chip is tested to meet our superior quality standards.

After a chip has been manufactured and tested, leads are attached. The chip is trimmed to meet the specified tolerance, and then a protective coating is added. Further customizing of the assembly can be done by adding housings, cables, and connectors.

Thermistor quality is assured with in-process inspection and Statistical Process Control (SPC). This process takes place at each manufacturing and assembly step. All finished products are 100% tested both electrically and mechanically to guarantee all specifications are met.

Resistance-Temperature (R/T) Curves and Negative Temperature Coefficient

Nine different materials are made, each with its own unique and predictable resistance-temperature characteristics. These characteristics are called 'curves'. Thermistors are most often specified by their curve and by their resistance value at 25°C.

The NTC (Negative Temperature Coefficient) is the negative percent resistance change per degree C. Our thermistors have NTC values at 25°C ranging from -3.7%/°C to -6.4%/°C. Resistance values at 25°C range from 300 ohms to 1 meg ohms. The tables on pages 26-27 detail this information.

Thermal Time Constant

Time constant, expressed in seconds, is the time required for a thermistor to indicate 63.2% of a newly impressed temperature. The time constant of a thermistor is directly affected by the mass of the thermistor and thermal coupling to the environment. An epoxy or phenolic coated thermistor with a 0.095" O.D., will typically have a time constant of 0.75 seconds in stirred oil and 10 seconds in still air.

Dissipation Constant

Dissipation constant is the power required to raise the temperature of a thermistor 1°C above the surrounding environment. Power is expressed in watts. The dissipation constant of a thermistor with a 0.095" O.D., coated with epoxy or phenolic, is typically 13 mW/°C in stirred oil and 2 mW/°C in still air.

Voltage/Current Requirements

Very low current is required for a thermistor being used in temperature measurement, control or compensation applications. Current levels should typically be less than 100mA for a thermistor to dissipate "zero power". As previously discussed, power dissipation for a thermistor in still air is approximately 2 mW/°C. Therefore, in order to keep the thermal error (self-heat) below 0.1°C, the power dissipation must be less than 0.2 mW.

Self-heating is desirable in applications such as air flow measurement and liquid level control. Standard epoxy or phenolic coated thermistors with a 0.095" O.D., have a maximum power rating of 30 milliwatts at 25°C to 1 milliwatt at 100°C.

Beta

The Beta value of a thermistor is one way to characterize its resistance temperature relationship. Beta is calculated as follows:

$$\beta\ T2/T1 = Ln(R_{T2}/R_{T1})/(1T_2 - 1T/_1)$$

Temperature is in degrees Kelvin; R_{T1} is the resistance at temperature T_1; R_{T2} is the resistance at temperature T_2.

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Steinhart-Hart Equation

The Steinhart-Hart Equation is an empirically developed polynomial which best represents the resistance-temperature relationships of NTC thermistors. The Steinhart-Hart Equation is more accurate than previous methods. Specifically, it is more accurate over wider temperature ranges. To solve temperature when resistance is known, the form of the equation is:

$$1T=a+b(LnR)+c(LnR)^3$$

To solve for resistance when temperature is known, the form of the equation is:

$$R=e(exp)[-a/2+(a^2/4+a^3/27)^{-2})^{-3}+(-a/2-(a^2/4+a^3/27)^2)^3]$$

where alpha = (a-1/T)/c and β = b/c

For both forms of the equation T is temperature expressed in degrees Kelvin; a, b, and c can be solved simultaneously using the following:

$$1/T_1=a+b(LnR_1)+c(LnR_1)^3$$

$$1/T_2=a+b(LnR_2)+c(LnR_2)^3$$

$$1/T3=a+b(LnR_3)+c(LnR_3)^3$$

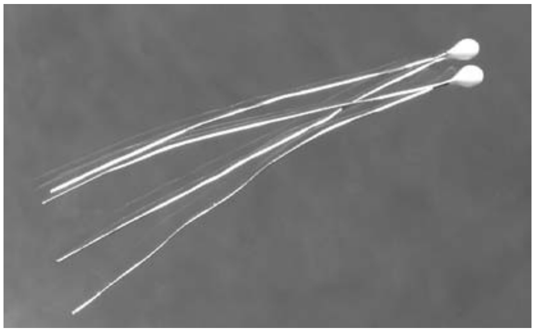
The data calculated by these equations will be accurate to better than ±0.01°C when -40°C is less than or equal to 150°C and |T1-T2| is less than or equal to 50°C and |T2-T3| is less than or equal to 50°C and T1, T2, and T3 are evenly spaced.

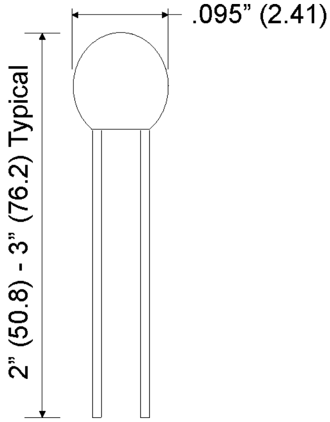
Maximum Temperature Rating/ Recommended Operating Ranges

Our thermistors may be intermittently cycled at temperatures from -50°C to 150°C. Stability is achieved when the thermistors are stored at temperatures less than 50°C and operated continuously at temperatures less than 100°C. For interchangeable thermistors, optimum stability is achieved when the thermistors are operated at temperatures within the specified temperature range.

Stability

Years of experience in thermistor manufacturing, coupled with stringent process controls, ensures that highly stable thermistors are produced. In fact, our thermistors typically exhibit less than 0.02°C thermometric drift per year when stored or operated at temperatures less than 50°C. The stability of a thermistor is greatly dependent on environmental conditions such as humidity, excessive temperatures and thermal shock. These effects should be minimized to guarantee stability.





FEATURES
- RoHS Compliant
- Small size with ease of handling
- High accuracy tolerance to ±0.10°C
- Operating ranges from -50°C to 150°C
- Proprietary processes produce top of the line quality and stability

Interchangeable refers to how accurately thermistors guarantee (R/T) curve over a range of temperatures. This allows every thermistor of the same series specifications to be exchangeable.

SPECIFICATIONS

Temperature rating/ recommended operating ranges	IN Series thermistors may be intermittently cycled at temperatures from -50°C to 150°C. Optimum stability is achieved when they are operated at temperatures within the specified temperature range.	**R/T curves**	IN Series thermistors are available in all R/T curve materials. Detailed curve material information on pages 26-27.
Temperature ranges	-20°C to 50°C 0°C to 50°C 20°C to 45°C 0°C to 70°C 0°C to 100°C	**Dissipation constant**	2m W/°C in still air 13m W/°C in stirred oil
Tolerances	±0.10°C ±0.20°C ±0.50°C ±1.00°C	**Thermal time constant**	Typically 0.75 seconds in stirred oil

ORDERING MAP

IN-_ _ _ _ _ - _ _ _ _ - XX

R/T Curve

A = Curve A
B = Curve B
C = Curve C
D = Curve D
E = Curve E
H = Curve H
J = Curve J
K = Curve K
P = Curve P

Resistance in ohms at 25°C

0300 = 300 ohms
001K = 1K ohms
010K = 10K ohms
100K = 100K ohms
2252 = 2,252 ohms

Tolerance at 25°C

A = ±1.0°C
B = ±0.5°C
C = ±0.2°C
D = ±0.1°C
X = new letter assigned for specials

Temperature Ranges

1 = +20°C to 45°C
2 = -20°C to 50°C
3 = 0°C to 70°C
4 = 0°C to 100°C
5 = +20°C to 90°C
6 = -40°C to 40°C
7 = +50°C to 125°C
8 = 0°C to 50°C
9 = -20°C to 125°
X = new digit assigned for specials

2" Leads

Code	AWG	Lead O.D.	Lead Type	Chip Coating
04	30	0.010"	Tinned Alloy	Uncoated
05	26	0.0169"	Tinned Copper	Epoxy
06	28	0.0126"	Tinned Copper	Epoxy
07	32	0.008"	Tinned Copper	Epoxy
08	30	0.010"	Nickel	Epoxy
09	26	0.0159"	Tinned Alloy 180	Epoxy
10	26	0.0159"	Tinned Copper	Epoxy
11	32	0.008"	Nickel	Epoxy
12	32	0.008"	Tinned Copper	Epoxy
13	30	0.010"	Tinned Alloy 180	Epoxy
14	30	0.010"	Tinned Copper	Epoxy
16	28	0.0126"	Tinned Copper	Epoxy
18	32	0.008"	Tinned Alloy 180	Epoxy
20	28	0.0126"	Nickel	Epoxy

3" Leads

Code	AWG	Lead O.D.	Lead Type	Chip Coating
21	32	0.008"	Nickel	Epoxy
22	32	0.008"	Tinned Copper	Epoxy
24	30	0.010"	Tinned Copper	Epoxy
26	28	0.0126"	Tinned Copper	Epoxy
28	32	0.008"	Tinned Alloy 180	Epoxy
31	30	0.010"	Teflon	Epoxy
41*	30	0.010"	Ag/Cu Twisted Kynar	Epoxy

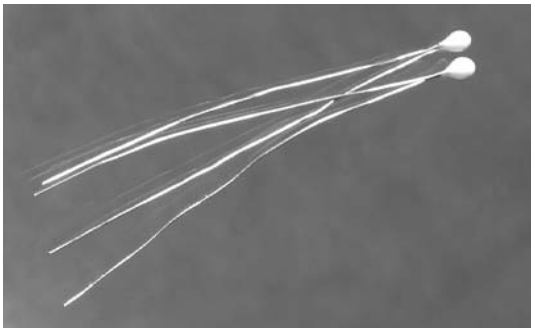
* 6K to 30K only

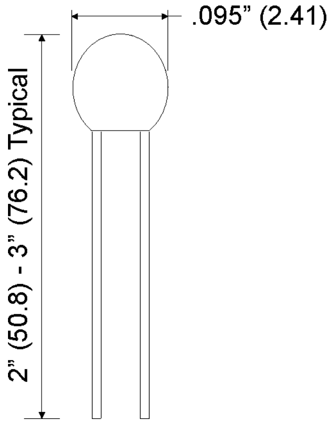
For optional lengths other than 2" or 3" substitute XX with lengths in inches
Example: 4" = 04

Custom designs are available, please fax or e-mail us your requirements

Point Matched NTC Thermistors

PM Series





FEATURES

- RoHS Compliant
- ±1% to ±5% tolerances
- Reduced cost for high volume applications
- Tolerance resistance matched to specific temperature
- Proprietary processes produce top of the line quality and stability

PM Series thermistors are precision tested at a chosen tolerance to a specific temperature. This cost effective thermistor provides an advantage to industries with high volume applications, such as in HVAC, automotive, and industrial markets.

SPECIFICATIONS

Temperature rating/ recommended operating ranges	PM Series thermistors may be intermittently cycled at temperatures from -50°C to 150°C. Optimum stability is achieved when they are stored at temperatures less than 50°C and operated continuously in temperatures less than 100°C.	**Tolerances**	±0.1°C ±0.2°C ±1.0°C ±1% ±2% ±3% ±5%
R/T curves	PM Series thermistors are available in all R/T curve materials. Detailed curve material information on pages 26-27.	**Dissipation constant**	2m W/°C in still air 13m W/°C in stirred oil
Temperature ranges	-20°C 0°C 25°C 37°C 70°C 100°C	**Thermal time constant**	Typically 0.75 seconds in stirred oil
		Maximum power rating	30 mW at 25°C to 1mW at 100°C (used in ‘self-heat’ applications such as liquid level control and air flow sensing).

ORDERING MAP

PM - _ _ _ _ _ - _ _ _ _ - XX

R/T Curve

A = Curve A	F = Curve F
B = Curve B	G = Curve G
C = Curve C	H = Curve H
D = Curve D	K = Curve K
E = Curve E	P = Curve P

Resistance in ohms at 25°C

0300 = 300 ohms
001K = 1K ohms
005K = 5K ohms
006K = 6K ohms
010K = 10K ohms
100K = 100K ohms
2252 = 2,252 ohms
1MEG = 1 million ohms

Tolerance at 25°C

1 = ±1%	0 = ±10%
2 = ±2%	A = ±0.25°C
3 = ±3%	B = ±0.50°C
5 = ±5%	X = letter or digit to be assigned for specials

Temperature Ranges

A = -20°C	D = 37°C
B = 0°C	E = 70°C
C = 25°C	F = 100°C

x = digit to be assigned for specials

2” Leads

Code	AWG	Lead O.D.	Lead Type	Chip Coating
04	30	0.010”	Tinned Alloy	Epoxy
05	26	0.0169”	Tinned Copper	Epoxy
06	28	0.0126”	Tinned Copper	Epoxy
07	32	0.008”	Tinned Copper	Epoxy
08	30	0.010”	Nickel	Epoxy
09	26	0.0159”	Tinned Alloy 180	Epoxy
10	26	0.0159”	Tinned Copper	Epoxy
11	32	0.008”	Nickel	Epoxy
12	32	0.008”	Tinned Copper	Epoxy
13	30	0.010”	Tinned Alloy 180	Epoxy
14	30	0.010”	Tinned Copper	Epoxy
16	28	0.0126”	Tinned Alloy	Epoxy
18	32	0.008”	Tinned Alloy	Epoxy
20	28	0.0126”	Nickel	Epoxy

3” Leads

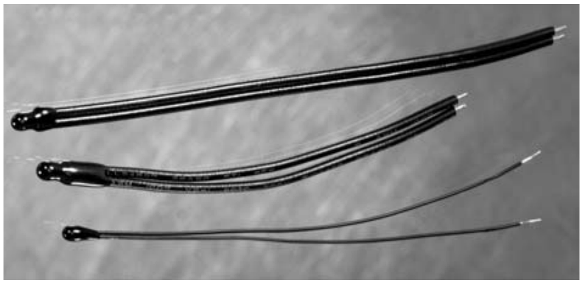
Code	AWG	Lead O.D.	Lead Type	Chip Coating
21	32	0.008”	Nickel	Epoxy
22	32	0.008”	Tinned Copper	Epoxy
24	30	0.010”	Tinned Copper	Epoxy
26	28	0.0126”	Tinned Copper	Epoxy
28	32	0.008”	Tinned Alloy 180	Epoxy
31	30	0.010”	Teflon	Epoxy
41*	30	0.010”	Ag/Cu Twisted Kynar	Epoxy

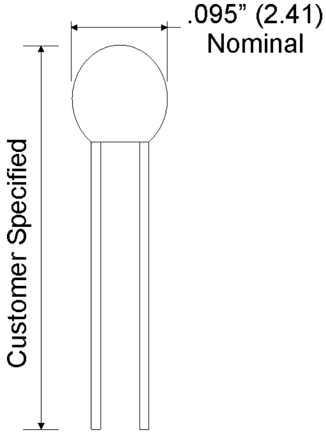
* 6K to 30K only

For optional lengths other than 2” or 3” substitute XX with lengths in inches

Example: 4” = 04

Custom NTC Thermistors
CS Series





FEATURES
- Customer specified
- Various material options
- Modified stock or new custom design
- Available in Point Matched or Interchangeable tolerances

CS Series thermistors are designed to meet your specific application requirements. For "turn-key" solutions, their value-added features can significantly reduce your labor costs. Contact our applications engineering personnel for assistance in designing a standard thermistor into a custom thermistor to match your needs.

SPECIFICATIONS

Temperature rating/ recommended operating ranges	CS Series thermistors may be intermittently cycled at temperatures from -50°C to 150°C. Optimum stability is achieved when they are stored at temperatures less than 50°C and will operate continuously in temperatures less than 100°C. For CS Interchangeable Series thermistors, optimum stability is achieved when they are operated at temperatures within the specified temperature range.	**Dissipation constant**	1m W/°C in still air 8m W/°C in stirred oil
R/T curves	CS Series thermistors are available in **all** R/T curve materials. Detailed curve material information on pages 26-27.	**Thermal time constant**	Time constant varies depending on the configuration of each custom thermistor. Typically 1 second in stirred oil.
Tolerances	±0.10°C ±0.20°C ±0.25°C ±0.50°C ±1.00°C ±1% ±2% ±3% ±5% ±10%	**Maximum power rating**	30 mW at 25°C to 1mW at 100°C (used in 'self-heat' applications such as liquid level control and air flow sensing).
		Custom options	Various lead diameters, material and insulation materials, and lengths.

ORDERING MAP

CS - _ _ _ _ _ - _ _ - X X X X

R/T Curve

A = Curve A	F = Curve F
B = Curve B	G = Curve G
C = Curve C	H = Curve H
D = Curve D	K = Curve K
E = Curve E	P = Curve P

Resistance in Ohms at 25°C

001K = 1K ohms
005K = 5K ohms
006K = 6K ohms
010K = 10K ohms
100K = 100K ohms
2252 = 2,252 ohms
1MEG = 1 million ohms

IN Type Only Tolerance at 25°C

A = ±1.0°C	C = ±0.2°C
B = ±0.5°C	D = ±0.1°C

X = new letter assigned for specials

PM Type Only Tolerance at 25°C

1 = 1%	0 = 10%
2 = 2%	A = 0.25°C
3 = 3%	B = 0.50°C
5 = 5%	X = letter or digit to be assigned for specials

IN Type Only Temperature Ranges

1 = +20°C to 45°C	6 = -40°C to 40°C
2 = -20°C to 50°C	7 = +50°C to 125°C
3 = 0°C to 70°C	8 = 0°C to 50°C
4 = 0°C to 100°C	9 = -20°C to 125°C
5 = +20°C to 90°C	X = new digit assigned for specials

PM Type Only Temperature Ranges

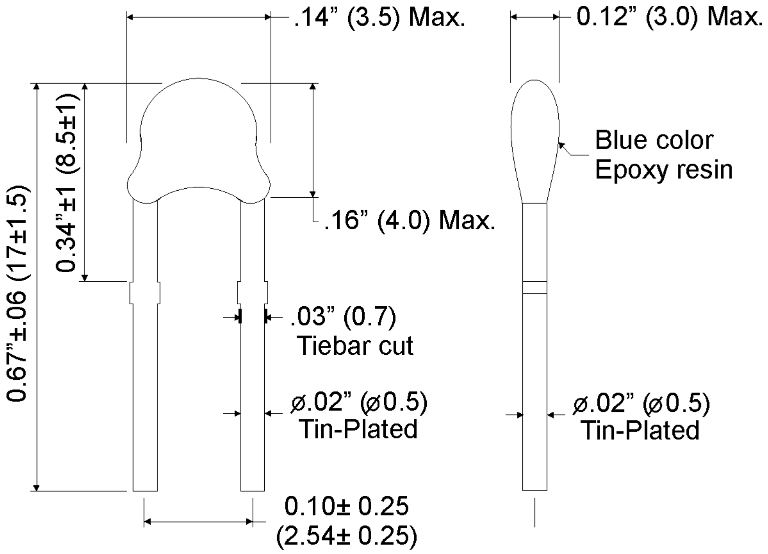
A = -20°C	D = 37°C
B = 0°C	E = 70°C
C = 25°C	F = 100°C

X = digit to be assigned for specials

XXXX = System file number assigned

TO ORDER SPECIFY ALL ITEMS BELOW

- **Lead wire length**
- **Wire gauge size**
- **Solid or stranded wire**
- **Connections if required (Molex, Amp or other)**
- **Blunt or stripped end and length of stripped wire**
- **Insulation material (Isomid, Kynar, Nylon, PVC, Teflon, etc.)**



FEATURES

- RoHS Compliant
- High stability and low cost
- Excellent thermal cycle endurance
- No adjustment between the control circuit and the sensor

The HP thermistor is a high-performance thermal sensing device. They have small B-value tolerance and resistance.

SPECIFICATIONS

Temperature range	-50°C to 110°C	**B value**	3100K - 4665K
R25		**Determined by rated zero-power resistance at 25°C and 85°C**	
Rated Zero-power	1,000 ohms	**R/T curves**	HP Series thermistors are available in all R/T curve materials. Detailed curve material information on pages 26-27.
Resistance value at 25°C	2,000 ohms 5,000 ohms 10,000 ohms 20,000 ohms 47,000 ohms	**Dissipation value**	2 mW/°C
		Thermal time constant	Typically 15 seconds in air
		Maximum power rating	10 - 15 mW (at 25°C)
Tolerances	±1% ±3% ±5%		

ORDERING MAP

HP - _ _ _ _ _ - _

High-Precision Thermistor

R/T Curve

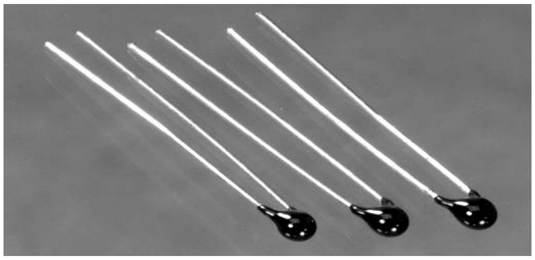
- A = Curve A
- B = Curve B
- C = Curve C
- D = Curve D
- E = Curve E
- F = Curve F
- G = Curve G
- H = Curve H
- J = Curve J
- K = Curve K
- P = Curve P

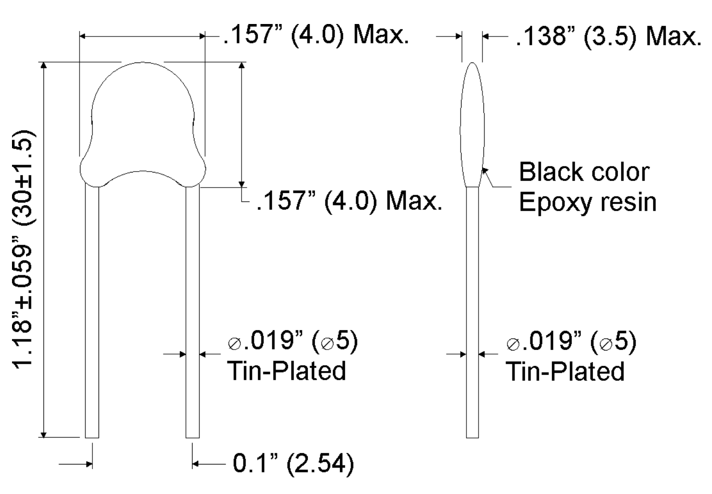
Resistance in Ohms at 25°C

- 001K = 1K ohms
- 002K = 2K ohms
- 005K = 5K ohms
- 010K = 10K ohms
- 020K = 20K ohms
- 047K = 47K ohms
- 100K = 100K ohms

Tolerances

- 1 = ±1%
- 3 = ±3%
- 5 = ±5%





FEATURES

- RoHS Compliant
- High stability and low cost
- Excellent thermal cycle endurance
- No adjust between the control circuit and the sensor

The HT thermistor is a high-performance thermal sensing device. They have small B-value tolerance and resistance.

SPECIFICATIONS

Temperature range	-50°C to 110°C	**B value**	3100K - 4665K
R25		**Determined by rated zero-power resistance at 25°C and 85°C**	
Rated zero-power resistance value at 25°C	1,000 ohms 2,000 ohms 5,000 ohms 10,000 ohms 20,000 ohms 47,000 ohms	**R/T curves**	HT Series thermistors are available in most of the R/T curve materials. Detailed curve material information on pages 26-27.
		Dissipation value	2 mW/°C
		Thermal time constant	Typically 15 seconds in air
Tolerances	±1% ±3% ±5%	**Maximum power rating**	10 - 15 mW (at 25°C)

ORDERING MAP

HT - _ _ _ _ _ - _ - _ _

R/T Curve

A = Curve A
B = Curve B
C = Curve C
D = Curve D
E = Curve E
F = Curve F
G = Curve G
K = Curve K
P = Curve P

Resistance in Ohms at 25°C

001K = 1K ohms
002K = 2K ohms
005K = 5K ohms
010K = 10K ohms
020K = 20K ohms
047K = 47K ohms
100K = 100K ohms

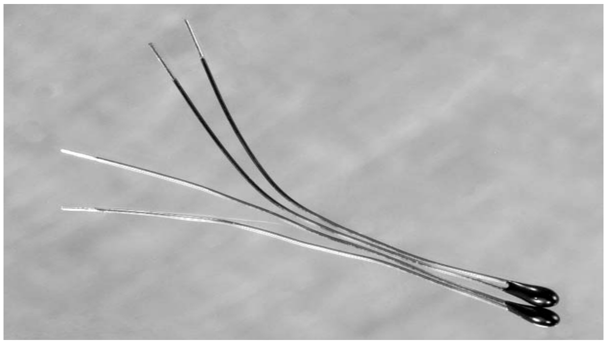
Tolerances

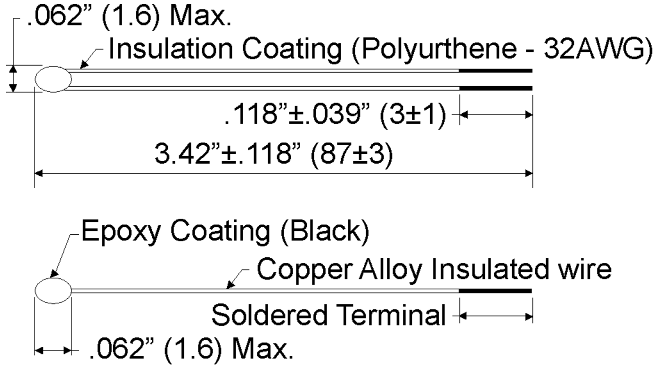
1 = ±1%
3 = ±3%
5 = ±5%

Special Spec

Control # Assigned

Temperature Sensing Thermistors
TS Series





FEATURES
- Fast response
- RoHS available on request
- Lead free available upon request
- Excellent thermal cycle endurance

The TS thermistor is smaller than the HP thermistor. It’s rapid response time and high reliability make it suitable for use in medical equipment and thermometers.

SPECIFICATIONS

Temperature range	-50°C to 110°C	**B value**	3100K - 4274K
R25		**Determined by rated zero-power resistance at 25°C and 85°C**	
Rated Zero-power	4,000 ohms	**R/T curves**	TS Series thermistors are available in most of the R/T curve materials. Detailed curve material information on pages 26-27.
Resistance value at 25°C	10,000 ohms 20,000 ohms 30,000 ohms 40,000 ohms 50,000 ohms 100,000 ohms 230,000 ohms	**Tolerances**	±1%
		Dissipation value	0.7 mW/°C
		Thermal time constant	Typically 15 seconds in air
		Maximum power rating	3.5 mW (at 25°C)
Tolerances	±1% ±3% ±5%		

ORDERING MAP

TS 103 - _ _ _ _ - _

Resistance Value at 25°C
10 x 10^3 ohms

B Value
25°C/85°C

Resistance Tolerance
1 = 1%
3 = 3%
5 = 5%

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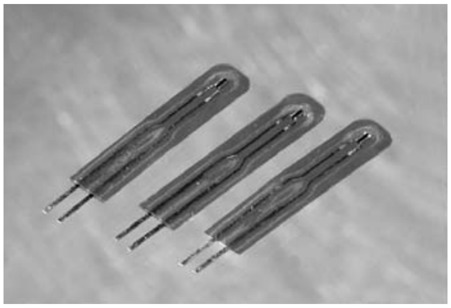
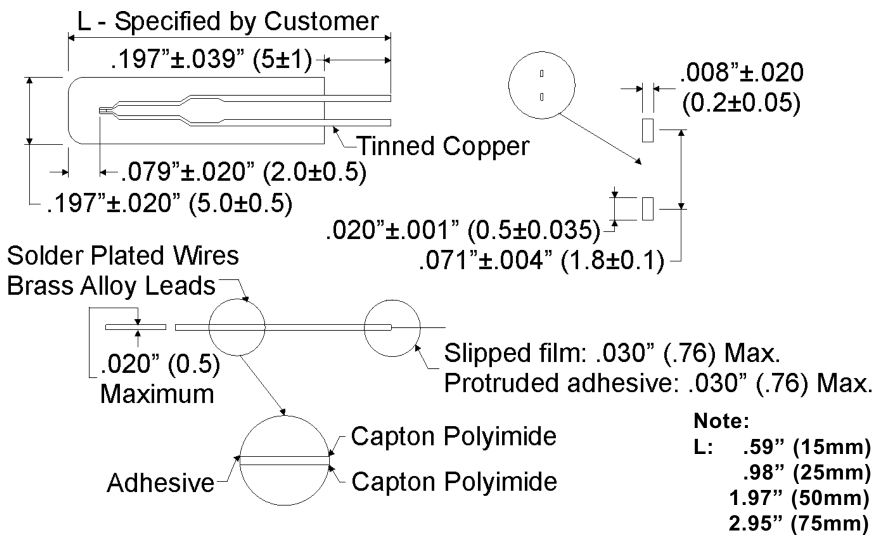
Thin-Film Thermistors
TF Series





FEATURES
- RoHS Compliant
- Rapid response time
- Elastic and solder easily
- Suitable for narrow space

The TF thermistor features ultra thinness of 500 μm and superior electrical insulation. It may safely be used in surroundings that includes contacts with electrodes.

SPECIFICATIONS

Temperature range	-50°C to 90°C	**R/T curves**	A Curve F Curve
R25		**Dissipation value**	0.7 mW/°C in still air
Rated Zero-power	10,000 ohms	**Thermal time constant**	Typically 5 seconds in air
Tolerances	±1% ±3% ±5%	**Maximum power rating**	3.5 mW (at 25°C)
B value	3435K - 3977K		
Determined by rated zero-power resistance at 25°C and 85°C			

ORDERING MAP

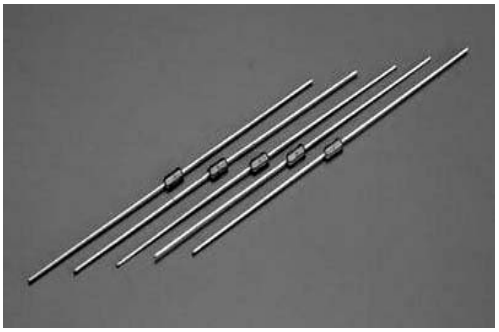
TF - __ 010K - __ - __

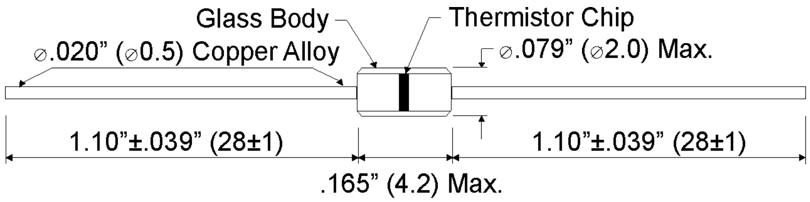
R/T CURVE
A = Curve A
F = Curve F

Tolerances
1 = ±1%
3 = ±3%
5 = ±5%

Length
1 = .59" (15mm)
2 = .98" (25mm)
3 = 1.97" (50mm)
4 = 2.95" (75mm)

Diode Type Thermistors
DT Series





FEATURES

- RoHS Compliant
- High stability and low cost
- Glass sealed body for high reliability
- Excellent thermal cycle endurance

The DT thermistor is a thermal sensor is a DO35 package. The highly reliable thermistor is offered in a wide temperature range of -50°C to 250°C. It can be applied to household appliances and high temperature applications.

SPECIFICATIONS

Temperature range	-50°C to 250°C	**B value**	A Curve = 3970K C Curve = 3695K F Curve = 3435K
R25		**Determined by rated zero-power resistance at 25°C and 85°C**	
Rated Zero-power	10,000 ohms	**Dissipation value**	Minimum 2.4 mW/°C
Resistance value at 25°C	15,000 ohms 30,000 ohms 47,000 ohms 50,000 ohms 100,000 ohms 200,000 ohms	**Thermal time constant**	Typically 15 seconds in still air
		Maximum power rating	250 mW (at 25°C)
Tolerances	±1%, ±3%, ±5%		

ORDERING MAP

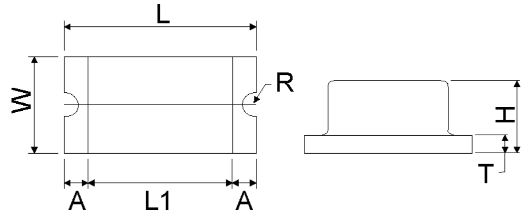
DT - _ _ _ _ _ - _

R/T CURVE
- A = Curve A
- C = Curve C
- F = Curve F

Resistance in Ohms @ 25°C
- 010K = 10K ohms
- 015K = 15K ohms
- 030K = 30K ohms
- 047K = 47K ohms
- 050K = 50K ohms
- 100K = 100K ohms
- 200K = 200K ohms

Tolerances
- 1 = ±1%
- 3 = ±3%
- 5 = ±5%

Surface Mount Chip Thermistors
CT Series



Dim. / Type	L (±0.2)	W (±0.2)	L1	A	R	H (±0.2)	T (±0.05)
1206	.126 (3.2)	.063 (1.6)	.0787 (2.0)	.0236 (0.6)	.0146 (0.37)	.0433 (1.1)	.0197 (0.5)
0805	.0787 (2.0)	0.492 (1.25)	.0551 (1.4)	.0118 (0.3)	.0079 (0.20)	.0433 (1.1)	.0197 (0.5)
0603	.063 (1.6)	.0315 (0.8)	0.472 (1.2)	.0079 (0.2)	.0067 (0.17)	.0315 (0.8)	.0118 (0.3)

FEATURES
- RoHS Compliant
- Surface mount capability
- Ultra small size and low capacitance
- Uniformly sized for pick place assembly

The CT thermistor, a highly reliable thermistor, is characterized by a fast response and standard chip package sizes.

SPECIFICATIONS

Temperature range	-40°C to 125°C
R_{25}	10,000 ohms
Rated Zero-power	47,000 ohms
Resistance value at 25°C	100,000 ohms
Tolerances	±3% ±5%
$B_{25/85}$ value	10,000 ohms - F Curve (3435K) 47,000 ohms - A Curve (3975K) 100,000 ohms - G Curve (4390K)
Dissipation value	0.9 mW/°C in still air
Thermal time constant	Typically 3-8 seconds in still air
Maximum power rating	4-6 mW (at 25°C)

ORDERING MAP

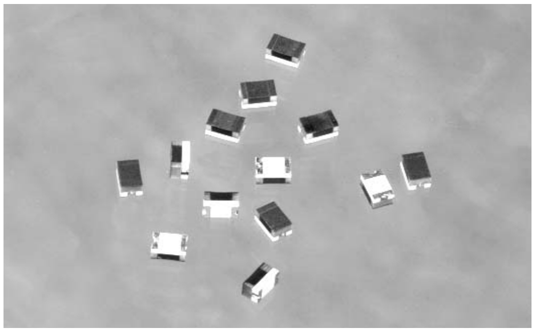
CT _ _ _ _ - _ _ _ _ - _

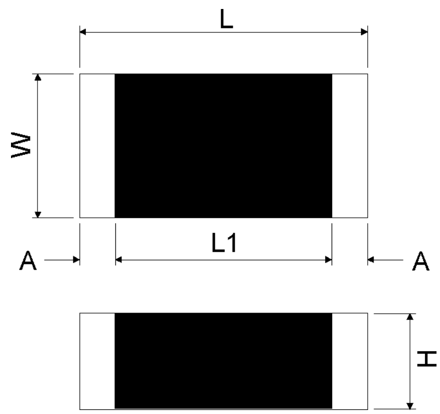
Size Type
1206
0805
0603

Curve/Resistance in ohms @ 25°C
A047K = Curve A 47K ohms
F010K = Curve F 10K ohms
G100K = Curve G 100K ohms

Tolerances @ 25°C
1 = ±1%
3 = ±3%
5 = ±5%

Surface Mount Chip Thermistors
SM Series





FEATURES
- RoHS Compliant
- Surface mount capability
- Ultra small size and low capacitance
- Uniformly sized for pick place assembly

This highly reliable SM thermistor is characterized with a fast response time due to the surface mounting on a PCB. Our manufacturing techniques produce the highest quality surface mount chip thermistors available in today's market.

Type \ Dim.	L (±0.2)	W (±0.2)	L1	A (±0.3)	H (±0.2)
1206	.126 (3.2)	.063 (1.6)	.0787 (2.0)	.0236 0.6	.0433 (1.1)
0805	.0787 (2.0)	0.492 (1.25)	.0551 (1.4)	.0118 (0.3)	.0118 (0.3)
0603	.063 (1.6)	.0315 (0.8)	.0472 (1.2)	.0118 (0.3)	.0118 (0.3)

SPECIFICATIONS

Temperature range	-40°C to 125°C	**$B_{25/85}$ value**	10,000 ohms - F Curve (3435K) 47,000 ohms - A Curve (3977K) 100,000 ohms - G Curve (4390K)
R_{25}	10,000 ohms	**Dissipation value**	3.5 mW/°C in still air
Rated Zero-power	47,000 ohms	**Thermal time constant**	Typically 5-8 seconds in still air
Resistance value at 25°C	100,000 ohms	**Maximum power rating**	350-450 mW (at 25°C)
Tolerances	±1% ±3% ±5%		

ORDERING MAP

SM _ _ _ _ - _ _ _ _ - _

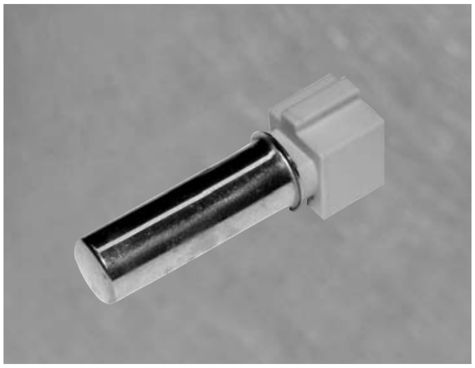
Size Type
1206
0805
0603

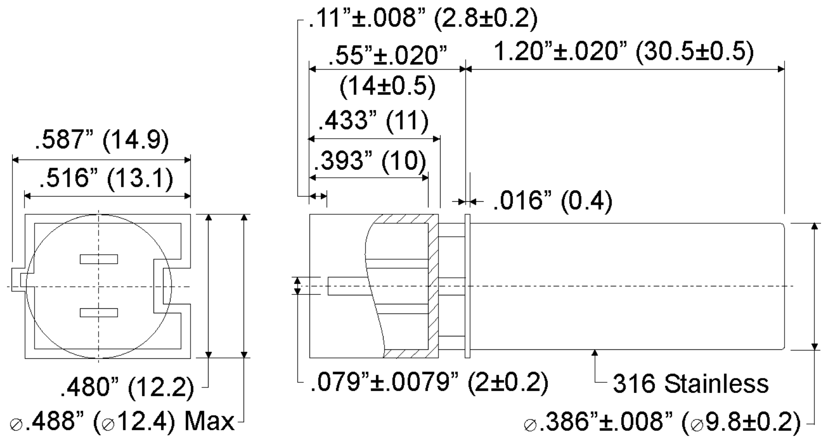
Curve/Resistance in ohms @ 25°C
A047K = Curve A 47K ohms
F010K = Curve F 10K ohms
G100K = Curve G 100K ohms

Tolerances @ 25°C
1 = ±1%
3 = ±3%
5 = ±5%

TR Type Thermistor

TR Series





FEATURES

- RoHS Compliant
- High utility products
- Compact stainless steel case
- Appropriate to use in harsh environmental conditions

The TR thermistors are used widely in household appliances, such as washing machines, dishwashers, tumble-dryers, and water boilers.

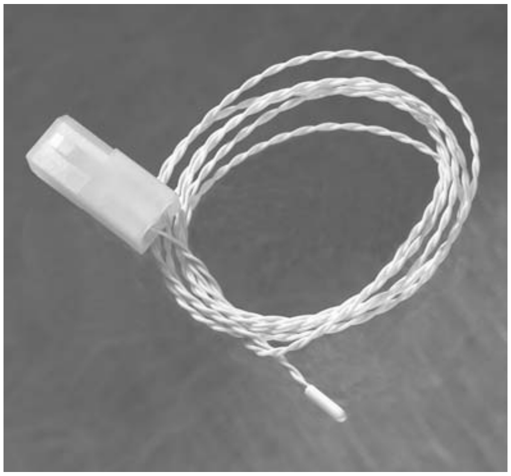
SPECIFICATIONS

Temperature range	-40°C to 125°C	**$B_{25/85}$ value**	10,000 ohms - 3435K 48,150 ohms - 3977K 100,000 ohms - 4150K
R_{25}		**$B_{25/100}$ value**	11,982 ohms - 3760K
Rated Zero-power	10,000 ohms	**Dissipation value**	215 mW/°C in still water
Resistance value at 25°C	11,982 ohms 48,150 ohms 100,000 ohms	**Thermal time constant**	Typically 18 seconds in water
Tolerances	±1% ±3% ±5%	**Maximum power rating**	250~500 mW (at 25°C)

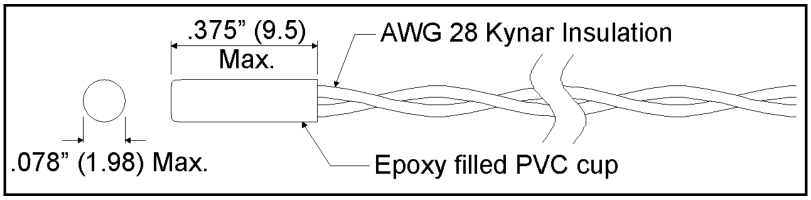
ORDERING MAP

103 - TR - _ _ _ _ - _

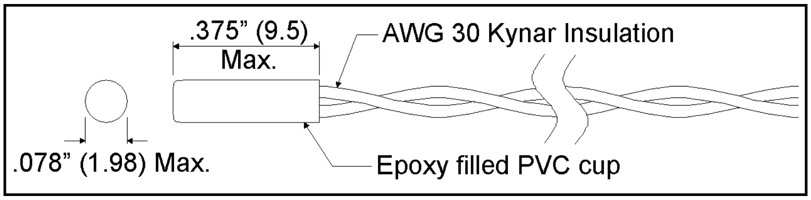
103	TR	_ _ _ _	_
Resistance Value at 25°C 10 x 10^3 ohms	**Transducer Type Thermistor**	**B Value** 25°C/85°C	**Resistance Tolerance** 1 = ±1% 3 = ±3% 5 = ±5%



LS400 Series - 2252 Ohms at 25°C ‘A’ Curve



LS700 Series - 6K/30K Ohms at 25°C ‘A/B’ Curve



Other values and curves available. Detailed values and curve information on pages 26-27.

FEATURES
- High quality construction
- Interchangeable tolerance
- Custom designs at low cost
- Skin and catheter disposable sensor designs
- Compatible with YSI 400 and 700 temperature monitor instruments

These thermistors offer a precision method of life science and patient care temperature sensing. Our disposable sensors meet the necessity of low cost without comprising high quality and precise accuracy.

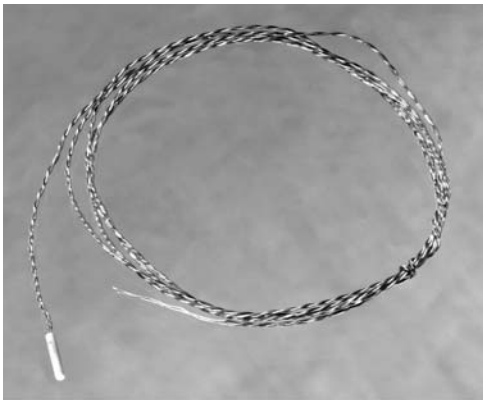
SPECIFICATIONS

Temperature rating/ recommended operating ranges	LS Series thermistors may be intermittently cycled at temperatures from -50°C to 150°C. Optimum stability is achieved when thermistors are operated at temperatures within the specified temperature range.	**Tolerances**	±0.10°C ±0.20°C ±0.50°C ±1.00°C
		Dissipation value	2.5 mW/°C in still air 13 mW/°C in stirred oil
R/T curves	LS Series is manufactured with ‘A’ and ‘B’ R/T curve materials. Detailed curve material information on pages 26-27.	**Thermal time constant**	Typically 1.25 seconds in stirred oil
		Custom options	Various lead materials, terminations and lengths

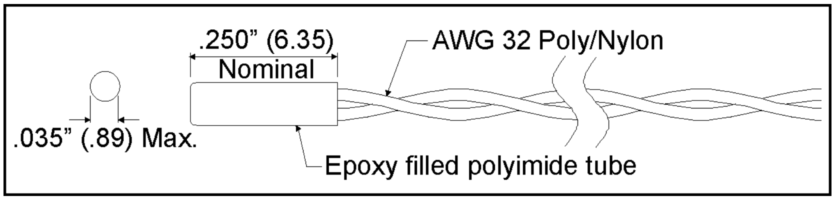
TO ORDER SPECIFY ALL ITEMS BELOW

- **Series: LS400 or LS700**
- **Tolerance**
- **Resistance at 25°C**
- **Curve: A or B**
- **Lead length, gauge, and material**
- **Termination**

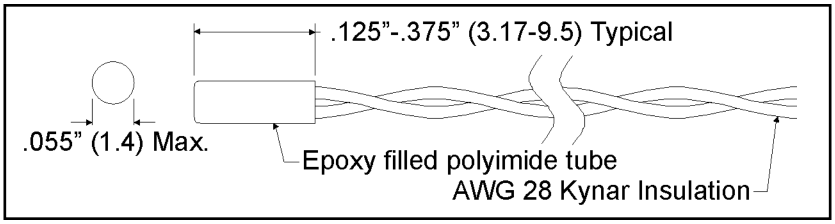
Example: LS400, 0.1°C Tolerance, Curve A, 10” AWG 28 Kynar, Molex part number connector



LSMN 400 or 700 Series
400: 2252 Ohms at 25°C ‘A’ Curve
700: 6K/30K Ohms at 25°C ‘A/B’ Curve



LSMN 400 Series
2252 Ohms at 25°C ‘A’ Curve



Other values and curves available. Detailed values and curve information on pages26-27.

FEATURES
- Custom designs at low cost
- Fast response accuracy to ±0.1°C
- Potted with epoxy in a polyimide tube
- Interchangeable or Point Matched tolerances
- Compatible with YSI 400 and 700 temperature monitor instruments

These tiny thermistors can be used in Life Science applications that require fast response and small size. Since they are available with custom options they can be used in unlimited temperature sensing applications in any industry.

SPECIFICATIONS

Temperature rating/ recommended operating ranges	LSMN Series thermistors may be intermittently cycled at temperatures from -50°C to 150°C. Optimum stability is achieved when thermistors are stored at temperatures less than 100°C. For interchangeable LSMN Mini Series thermistors optimum stability is achieved when they are operated at temperatures within the specified temperature range.	**Tolerances**	±0.10°C ±0.20°C ±0.25°C ±0.50°C ±1.00°C ±1% ±2% ±3% ±5% ±10%
R/T curves	LSMN Mini Series is manufactured with ‘A’ and ‘B’ R/T curve materials. Detailed curve material information on pages 26-27.	**Dissipation value**	1.5 mW/°C in still air 10 mW/°C in stirred oil
		Thermal time constant	Typically 0.4 seconds in stirred oil
		Custom options	Various lead materials, terminations and lengths

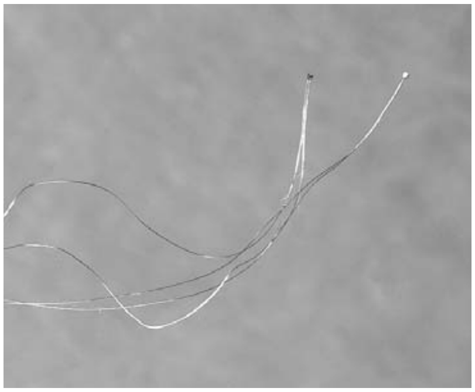
TO ORDER SPECIFY ALL ITEMS BELOW

- **Series: LSMN 400 or LSMN 700**
- **Tolerance**
- **Resistance at 25°C**
- **Curve: A or B**
- **Diameter: .035” or .055”**
- **Lead length, gauge, and material**
- **Termination**

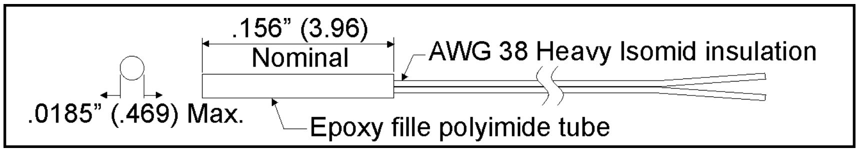
Example: LSMN700, 0.2°C Tolerance, Curve B, 20” AWG 28 Polynylon, Molex part number connector

Life Sciences & Micro Temperature Probes

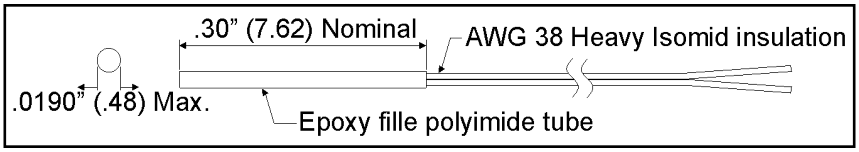
LSMC Micro Series 0.0185” and 0.0190” max. dia. capability to 0.175” dia.



LSMC 10K
10,000 Ohms at 25°C ‘A’ Curve



LSMC 400 Series
2252 Ohms at 25°C ‘A’ Curve



Other values and curves available. Detailed values and curve information on pages26-27.

FEATURES
- Custom designs at low cost
- Fast response accuracy to ±0.1°C
- Potted with epoxy in a polyimide tube
- Interchangeable or Point Matched tolerances
- Compatible with YSI 400 and 700 temperature monitor instruments

These tiny thermistors can be used in many Life Science applications. They are small enough to fit into a hypodermic needle. Since they are available in many custom options they can be used for fast response temperature sensing applications in any industry.

SPECIFICATIONS

Temperature rating/ recommended operating ranges	LSMC Series thermistors may be intermittently cycled at temperatures from -50°C to 150°C. Optimum stability is achieved when thermistors are stored at temperatures less than 50°C. and operated continuously in temperatures less than 100°C. For interchangeable LSMC Series thermistors optimum stability is achieved when they are operated at temperatures within the specified temperature range.	**Tolerances**	±0.10°C ±0.20°C ±0.25°C ±0.50°C ±1.00°C ±1% ±2% ±5% ±10%
		Dissipation value	0.3 mW/°C in still air 2.5 mW/°C in stirred oil
R/T curves	LSMC Series is manufactured with ‘A’ R/T curve material. Detailed curve material information on pages 26-27.	**Thermal time constant**	Typically 0.25 seconds in stirred oil
		Custom options	Lead materials: AWG 38 nickel alloy or copper conductors with heavy isomid insulation, parallel bonded configuration. Parylene coating is available which provides a thin coating resistant to corrosion and humidity.

TO ORDER SPECIFY ALL ITEMS BELOW

- **Series LSMC**
- **Tolerance**
- **Lead length, gauge, and material**

(714) 917-1333 • (800) 257-3526 • FAX (714) 917-1355 • E-mail: sales@selcoproducts.com

Custom Thermistor Probes
CP Series

FEATURES
- Virtually unlimited options
- Customer specification or made from stock materials
- Available in Point Matched or Interchangeable tolerances

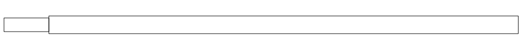
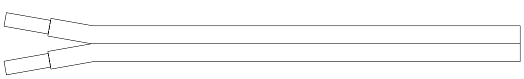
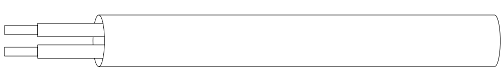
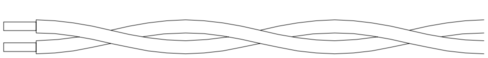
CP Series probes are designed to meet your specific application requirements. Custom probe designs have virtually unlimited options available. Their value-added features significantly reduce your labor costs.

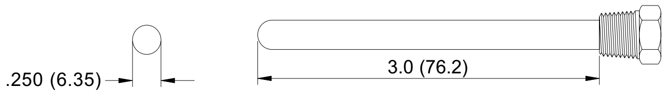
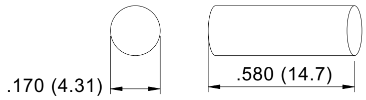
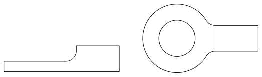
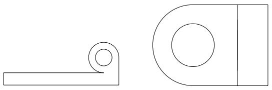
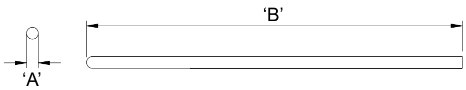
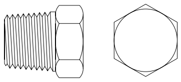
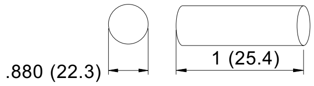
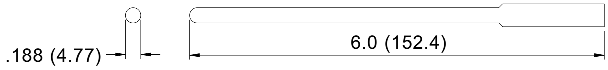
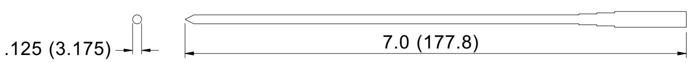
Contact our applications engineering personnel for assistance in designing a probe from the standard components listed on the following pages or from a multitude of other materials.

SPECIFICATIONS

Temperature rating/ recommended operating ranges	CP Series thermistor probes may be intermittently cycled at temperatures from -50 to 105C. Optimum stability is achieved when they are stored at temperatures less than 50°C and operated continuously in temperatures less than 100°C. For interchangeable CP thermistor probes, optimum stability is achieved when they are operated at temperatures within the specified temperature range.	**R/T curves**	CP Series thermistors probes are available in all R/T curve materials. Detailed curve material information on pages 26-27.
		Tolerances	±0.10°C ±0.20°C ±0.25°C ±0.50°C ±1.00°C ±1% ±2% ±5% ±10%

Following are a few examples of the unlimited choices for the combination of wire and probe housings.

Wires	Configuration	Gauge	Insulation
	Single Conductor	18-32	PVC, Etched Teflon
	Zipcord	22-30	PVC
	Jacketed	22-26	PVC
	Twisted	22-24	PVC, Etched Teflon

Housings	Type	Material
	1/8" NPT fitting round, close-end tube	316 Stainless Steel
	End-end cup	PVC
	Flat, closed-end cup	Delrin
	Ring lug terminal, #6	Steel, Copper
	Flat terminal, #6	Steel, Copper
	End-end cup	304 Stainless Steel A = .125" B = 4" 316 Stainless Steel A = .125" B = 3"
	1/8" NPT plug	Aluminum
	Open-end tube	Aluminum, Brass, Stainless Steel
	End-end cup	304 Stainless Steel
	Tapered-end tube	304 Stainless Steel

Custom Thermistor Probes

CP Series - Order Map

ORDERING MAP

CP - _ _ _ _ _ - _ _ - X X X X

R/T Curve

A = Curve A	F = Curve F
B = Curve B	G = Curve G
C = Curve C	H = Curve H
D = Curve D	K = Curve K
E = Curve E	P = Curve P

Resistance in Ohms at 25°C

- 0300 = 300 ohms
- 001K = 1K ohms
- 005K = 5K ohms
- 006K = 6K ohms
- 010K = 10K ohms
- 100K = 100K ohms
- 2252 = 2,252 ohms
- 1MEG = 1 million ohms

IN Type Only Tolerance at 25°C

A = ±1.0°C	C = ±0.2°C
B = ±0.5°C	D = ±0.1°C
X = new letter assigned on special	

PM Type Only Tolerance at 25°C

1 = ±1%	5 = ±5%
2 = ±2%	0 = ±10%
3 = ±3%	X = letter or digit assigned for specials

IN Type Only Temperature Ranges

1 = 20°C to 45°C	6 = -40°C to 40°C
2 = -20°C to 50°C	7 = +50°C to 125°C
3 = 0°C to 70°C	8 = 0°C to 50°C
4 = 0°C to 100°C	9 = -20°C to 125°C
5 = +20°C to 90°C	X = new digit assigned for specials

PM Type Only Temperature Ranges

A = -20°C	D = 37°C
B = 0°C	E = 70°C
C = 25°C	F = 100°C
X = digit to be assigned for specials	

XXXX = System file number assigned

TO ORDER SPECIFY ALL ITEMS BELOW

- **Lead length**
- **Wire gauge size**
- **Solid or stranded wire**
- **Probe type description**
- **Connections if required (Molex, Amp or other)**
- **Blunt or stripped end and length of stripped wire**
- **Insulation material (Isomid, Kynar, Nylon, PVC, Teflon, etc.)**

Resistance - Temperature Table

Ratio is the resistance at temperature divided by the resistance at 25°C. To find the actual resistance value at the temperatures listed in the charts, multiply the R_{25} value by the number listed in the Ratio column next to the corresponding temperature.

As an example, a Curve A thermistor with a temperature tolerance of ±1°C over the temperature range 0° to 70°C would have the following resistance tolerance: 0°C = ±5.1%; 25°C = ±4.4%; 70°C = ±3.4%

NTC (Negative Temperature Coefficient) is the negative percent resistance change per degree C. To determine the resistance tolerance of a precision thermistor at any temperature point multiply the temperature tolerance times the NTC.

	Curve A		Curve B		Curve C		Curve D		Curve E	
β at 25°C/85°C	3975K		3942K		3695K		4262K		4434K	
Temperature °C	Typical R_{25} = 1K to 100K		Typical R_{25} = 10K to 100K		Typical R_{25} = 5K to 20K		Typical R_{25} = 25K to 100K		Typical R_{25} = 1K to 200K	
	R_T/R_{25} RATIO		R_T/R_{25} RATIO		R_T/R_{25} RATIO		R_T/R_{25} RATIO		R_T/R_{25} RATIO	
	RATIO	NTC	RATIO	NTC	RATIO	NTC	RATIO	NTC	RATIO	NTC
-50	67.13	7.1	56.39	6.7	44.13	6.3	82.36	7.4	89.69	7.4
-45	47.26	6.9	40.56	6.5	32.36	6.1	57.30	7.1	62.25	7.2
-40	33.69	6.7	29.48	6.3	23.97	5.9	40.34	6.9	43.69	7.0
-35	24.29	6.4	21.64	6.1	17.92	5.3	28.72	6.7	30.98	6.8
-30	17.71	6.2	16.03	5.9	13.52	5.6	20.67	6.5	22.20	6.6
-25	13.05	6.0	11.99	5.7	10.29	5.4	15.02	6.3	16.06	6.4
-20	9.711	5.8	9.040	5.6	7.891	5.2	11.03	6.1	11.73	6.2
-15	7.297	5.6	6.875	5.4	6.102	5.1	8.174	5.9	8.644	6.0
-10	5.534	5.4	5.270	5.2	4.754	4.9	6.113	5.7	6.425	5.8
-5	4.234	5.3	4.071	5.1	3.731	4.8	4.611	5.6	4.816	5.7
0	3.266	5.1	3.168	4.9	2.949	4.6	3.507	5.4	3.638	5.5
5	2.540	5.0	2.483	4.8	2.346	4.5	2.689	5.2	2.770	5.4
10	1.991	4.8	1.959	4.7	1.879	4.4	2.077	5.1	2.125	5.2
15	1.572	4.7	1.556	4.5	1.514	4.3	1.617	4.9	1.642	5.1
20	1.249	4.5	1.244	4.4	1.227	4.1	1.267	4.8	1.277	5.0
25	1.000	4.4	1.000	4.3	1.000	4.0	1.000	4.7	1.000	4.8
30	0.8056	4.3	0.8088	4.2	0.8196	3.9	0.7943	4.5	0.7881	4.7
35	0.6530	4.1	0.6579	4.1	0.6754	3.8	0.6349	4.4	0.6250	4.6
37	0.6014	4.1	0.6066	4.0	0.6260	3.8	0.5815	4.4	0.5706	4.5
40	0.5325	4.0	0.5380	4.0	0.5594	3.7	0.5106	4.3	0.4986	4.5
45	0.4367	3.9	0.4423	3.9	0.4655	3.6	0.4130	4.2	0.4001	4.3
50	0.3601	3.8	0.3654	3.8	0.3893	3.5	0.3359	4.1	0.3228	4.2
55	0.2985	3.7	0.3034	3.7	0.3270	3.4	0.2747	4.0	0.2619	4.1
60	0.2487	3.6	0.2531	3.6	0.2760	3.4	0.2259	3.9	0.2136	4.0
65	0.2082	3.5	0.2121	3.5	0.2338	3.3	0.1866	3.8	0.1750	3.9
70	0.1752	3.4	0.1785	3.4	0.1990	3.2	0.1549	3.7	0.1441	3.8
75	0.1480	3.3	0.1508	3.3	0.1700	3.1	0.1293	3.6	0.1193	3.7
80	0.1256	3.2	0.1280	3.2	0.1457	3.0	0.1083	3.5	0.09915	3.7
85	0.1071	3.2	0.1091	3.2	0.1254	3.0	0.09115	3.4	0.08278	3.6
90	0.09161	3.1	0.09327	3.1	0.1084	2.9	0.07704	3.3	0.06941	3.5
95	0.07870	3.0	0.08006	3.0	0.09392	2.8	0.06538	3.2	0.05844	3.4
100	0.06786	2.9	0.06897	2.9	0.08168	2.8	0.05570	3.2	0.04940	3.3
105	0.05873	2.9	0.05962	2.9	0.07127	2.7	0.04764	3.1	0.04192	3.2
110	0.05100	2.8	0.05171	2.8	0.06237	2.6	0.04089	3.0	0.03571	3.2
115	0.04444	2.7	0.04500	2.8	0.05476	2.6	0.03522	2.9	0.03053	3.1
120	0.03885	2.7	0.03928	2.7	0.04821	2.5	0.03045	2.9	0.02619	3.0
125	0.03408	2.6	0.03439	2.6	0.04257	2.5	0.02641	2.8	0.02254	3.0
130	0.02997	2.5	0.03020	2.6	0.03769	2.4	0.02298	2.8	0.01947	2.9
135	0.02645	2.5	0.02660	2.5	0.03346	2.4	0.02006	2.7	0.01687	2.8
140	0.02340	2.4	0.02349	2.5	0.02979	2.3	0.01756	2.6	0.01467	2.8
145	0.02076	2.4	0.02080	2.4	0.02658	2.3	0.01542	2.6	0.01279	2.7
150	0.01487	2.3	0.01846	2.4	0.02377	2.2	0.01358	2.5	0.01118	2.7

Resistance - Temperature Table

	Curve F		Curve G		Curve H		Curve K		Curve P	
β at 25°C/85°C	3435K		4390K		4847K		3485K		4144K	
Temperature °C	Typical R_{25} = 10K		Typical R_{25} = 10K		Typical R_{25} = 1MEG		Typical R_{25} = 200 to 2K		Typical R_{25} = 100K	
	R_T/R_{25} RATIO		R_T/R_{25} RATIO		R_T/R_{25} RATIO		R_T/R_{25} RATIO		R_T/R_{25} RATIO	
	RATIO	NTC	RATIO	NTC	RATIO	NTC	RATIO	NTC	RATIO	NTC
-50	32.95	6.2	95.84	8.1			39.18	6.2		
-45	24.77	6.0	65.66	7.8			28.88	6.0		
-40	18.85	5.8	45.72	7.5			21.50	5.8	33.58	6.5
-35	14.41	5.6	32.06	7.2			16.18	5.6	24.41	6.3
-30	11.13	5.4	22.82	7.0			12.28	5.4	17.91	6.3
-25	8.643	5.2	16.37	6.7			9.415	5.2	13.26	5.9
-20	6.777	5.0	11.91	6.5	14.65	6.1	7.278	5.1	9.898	5.8
-15	5.341	4.8	8.727	6.3	10.51	6.6	5.673	4.9	7.452	5.6
-10	4.247	4.7	6.472	6.0	7.607	6.4	4.457	4.7	5.655	5.4
-5	3.39	4.5	4.834	5.8	5.556	6.2	3.528	4.6	4.325	5.3
0	2.728	4.4	3.65	5.7	4.093	6.0	2.813	4.5	3.331	5.1
5	2.205	4.2	2.772	5.5	3.041	5.9	2.259	4.3	2.585	5.0
10	1.796	4.1	2.125	5.3	2.277	5.7	1.826	4.2	2.019	4.9
15	1.469	4.0	1.64	5.1	1.718	5.6	1.485	4.1	1.587	4.7
20	1.209	3.9	1.277	5.0	1.306	5.4	1.215	4.0	1.256	4.6
25	1.000	3.7	1.000	4.8	1.000	5.3	1.000	3.8	1.000	4.5
30	0.8313	3.6	0.7888	4.7	0.7710	5.1	0.8277	3.7	0.8008	4.4
35	0.694	3.5	0.6259	4.5	0.5984	5.0	0.6887	3.6	0.6450	4.3
37					0.5417	5.0	0.6408	3.6	0.5924	4.2
40	0.5827	3.4	0.5003	4.4	0.4675	4.9	0.5760	3.5	0.5224	4.2
45	0.4912	3.3	0.402	4.3	0.3675	4.8	0.4842	3.4	0.4253	4.1
50	0.4161	3.2	0.3251	4.1	0.2907	4.6	0.4089	3.3	0.3480	4.0
55	0.3536	3.1	0.2642	4.0	0.2312	4.5	0.3469	3.2	0.2862	3.9
60	0.302	3.1	0.2161	3.9	0.1580	4.4	0.2956	3.2	0.2365	3.8
65	0.2588	3.0	0.1775	3.8	0.1488	4.3	0.2530	3.1	0.1964	3.4
70	0.2228	2.9	0.1466	3.7	0.1204	4.2	0.2174	3.0	0.1638	3.6
75	0.1924	2.8	0.1215	3.6	0.09784	4.1	0.1875	2.9	0.1372	3.5
80	0.1668	2.7	0.1013	3.5	0.07993	4.0	0.1623	2.8	0.1154	3.4
85	0.1451	2.7	0.08483	3.4	0.06561	3.9	0.1411	2.8	0.09742	3.3
90	0.1266	2.6	0.07135	3.3	0.05411	3.8	0.1230	2.7	0.08260	3.3
95	0.1108	3.0	0.06025	3.3	0.04483	3.7	0.1076	2.6	0.07030	3.2
100	0.09731	2.5	0.05111	3.2	0.03730	3.6	0.09450	2.6	0.06005	3.1
105	0.08572	2.4	0.04351	3.1	0.03117	3.6	0.08322	2.5	0.05148	3.0
110	0.07576	2.4	0.0372	3.0	0.02615	3.5	0.07351	2.5	0.04429	3.0
115			0.0319	2.9	0.02203	3.4	0.06512	2.4	0.03823	2.9
120			0.02746	2.9	0.01863	3.3	0.05786	2.3	0.03310	2.8
125			0.02371	2.8	0.01581	3.2	0.05154	2.3	0.02876	2.8
130					0.01347	3.2			0.02506	2.7
135					0.01152	3.1			0.02190	2.7
140					0.00988	3.0			0.01920	2.6
145					0.00850	3.0			0.0168	2.6
150					0.00734	2.9			0.01487	2.5

NTC Thermistor Applications
Introduction

Our NTC chip thermistors are excellent solutions in applications requiring temperature measurement and compensation from -50° to 150°C.

RTDs, thermocouples and silicon semiconductors cannot compete with the thermistor's sensitive response to temperature. This sensitivity is crucial for accurate temperature measurement.

Unlike RTDs and thermocouples, thermistors are virtually unaffected by lead resistance. This makes NTC thermistors the sensor of choice for remote sensing applications. With their excellent long term stability characteristics, design engineers utilize thermistors in critical applications for the medical, military, aerospace, industrial and scientific industries.

Systems utilizing thermistors are less expensive to produce than other solutions because fewer associated components are required for a high performance system. Chip thermistors can be ordered with tight tolerances to ±0.05°C, eliminating the costly calibration process required by temperature sensors such as silicon semiconductors, RTDs, thermocouples and glass beaded and disk thermistors with loose tolerances.

NTC thermistors provide the design engineer with desirable sensor performance advantages in a variety of applications. The following notes provide a few examples of how to utilize the NTC thermistor.

"Zero Power" Sensing - Dissipation Constant

When utilizing a thermistor for temperature measurement, control, and compensation applications, it is very important not to "self-heat" the thermistor. Power, in the form of heat, is produced when current is passed through the thermistor. Since a thermistor's resistance changes when temperature changes, this "self generated heat" will change the resistance of the thermistor, producing an erroneous reading.

The power dissipation constant is the amount of power required to raise a thermistor's body temperature 1°C. A standard chip thermistor has a power dissipation constant of approximately 2mW/°C in still air. In order to keep the "self-heat" error below 0.1°C power dissipation must be below 0.2mW. Very low current levels are required to obtain such a lower power dissipation factor. This mode of operation is called "zero power" sensing.

Thermistor Linearization - Voltage Mode
Wheatstone Bridge - Voltage Mode

To produce a voltage output that varies linearly with temperature, utilize the NTC thermistor as the active leg in a Wheatstone Bridge. As temperature increases, the voltage output increases. The circuit in **Figure 1** produces an output voltage that is linear with ±0.06°C from 25°C to 45°C. This circuit is designed to produce 1V at 25°C and 200mW at 45°C; this is achieved by the selection of R2 and R3. The value of R1 is selected to best provide linearization of the 10K ohm thermistor over the 25°C to 45°C temperature range.

Figure 2 illustrates the output voltage of the Wheatstone Bridge as a function of temperature.

The circuit in **Figure 3** provides improved output accuracy over a wide temperature range by substituting a 6K/30K ohm thermistor network in place of the single thermistor in the Wheatstone Bridge. This circuit is designed to provide 0V at 0°C and 537mV at 100°C. The maximum linear deviation of this circuit is ±0.234°C from 0°C to 100°C.

Figure 1: Wheatstone Bridge - Voltage Mode

T1 = 10K ohm "A" Curve
R1 = 4980 ohm
R2 = 4980 ohm
R3 = 10K ohm

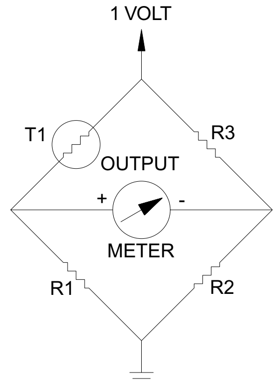


Figure 2: Wheatstone Bridge - Voltage Mode

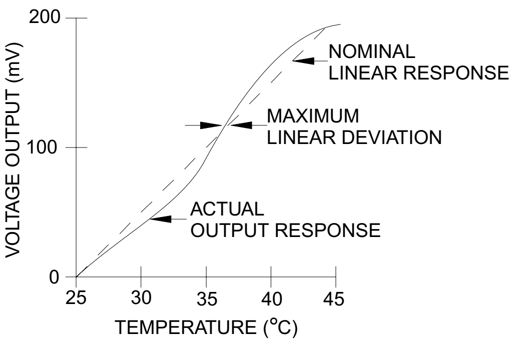
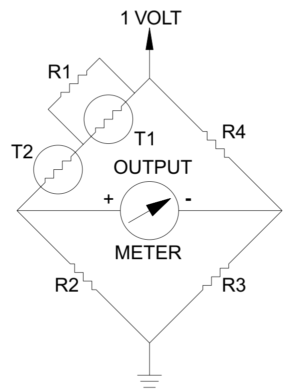


Figure 3: Wheatstone Bridge - Voltage Mode

T1 = 30K ohm "B" Curve
T2 = 6K ohm "A" Curve
R1 = 5420 ohm
R2 = 3970 ohm
R3 = 3970 ohm
R4 = 24720 ohm



Thermistor Linearization
Operational Amplifier - Resistance Mode

A linear voltage output that varies with temperature can also be produced by utilizing an operational amplifier and a linearized thermistor network as illustrated in **Figure 4**. The voltage output decreases linearly as temperature increases. This circuit may be calibrated by adjusting R3 for an output voltage of 200mW at 25°C and 0V at 45°C.

Temperature Measurement and Control
Digital Thermometer

The most common application for the NTC thermistor is temperature measurement. Accurate temperature measurement can easily be accomplished by interfacing a Wheatstone Bridge, 6K/30K ohm thermistor network and a digital voltmeter integrated circuit as illustrated in **Figure 5**. The IC consist of an analog to digital converter with built-in 3-1/2 digit LCD driver providing resolution of 0.1°C. Using the 6K/30K ohm thermistor network makes it possible to achieve an overall system accuracy of ±0.4°C from 0°C to 100°C. This digital thermometer can easily be interfaced with additional circuitry to provide a temperature control circuit with a digital display.

Micro Controller System

The advent of low cost micro controllers used with precision interchangeable NTC thermistors, provides the design engineer with unlimited design possibilities for temperature measurement and control systems. These systems are relatively inexpensive to produce yet offer very high temperature accuracy and various software controlled outputs.

For example, a micro controller system utilizing remote thermistor sensors can monitor and control the temperature in several locations in an office building. For this case, the micro controller is comprised of a built-in microprocessor, analog to digital converter, RAM and several digital inputs/outputs. The complete system **Figure 6** utilizes the micro controller, multiplexer, EPROM, digital display, keypad and display driver.

The micro controller is programmed in assembler language. The temperature measurement is calculated within the micro controller using the resistance versus temperature algorithm and the a, b and c, constants for the specific thermistor resistance and curve material. Refer to the Steinhart Equation on page 5. An alternative method to convert the thermistor resistance to temperature is to program a "look-up" table in EPROM. After programming, the micro controller tells the multiplexer to send back temperature data from a particular zone (room in the office building) and converts the resistance of the thermistor into a temperature reading.

The micro controller can then turn on or off the heating or air conditioning systems in a specific zone.

The thermistor/micro controller system can be used for security, temperature control, monitoring activities and many other applications. The possibilities are endless.

Figure 4: Linearization - Resistance Mode

T1 = 10K ohm "A" Curve
R1 = 4980 ohm
R2 = 5K ohm
R3 = 10K ohm potentiometer

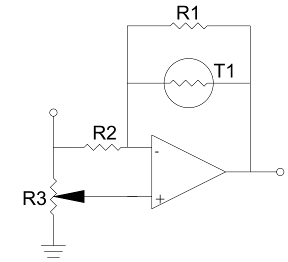


Figure 5: Digital Thermometer

R7 = 1.50K ohm
R8 = 100K ohm
R9 = 470K ohm
R10 = 15K ohm
C1 = 100 pF
C2 = 0.22
C4 = 0.1

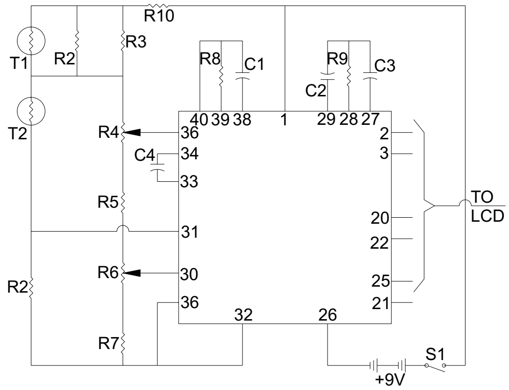
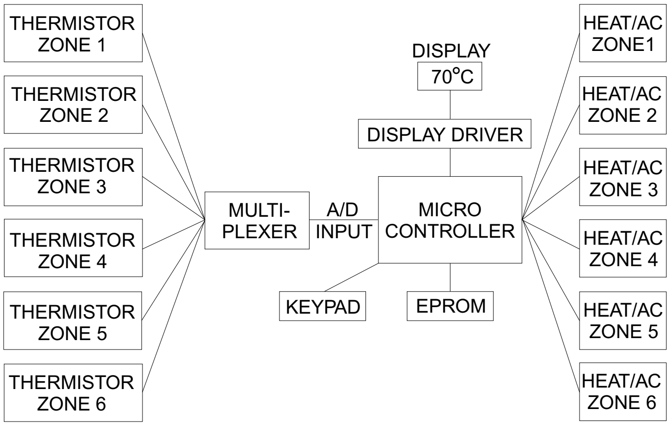


Figure 6: Micro Controller System



Temperature Compensation

NTC thermistors can be used to compensate for the temperature coefficient response of various components such as crystal oscillators, mechanical meters and infrared LEDs. A thermistor/ resistor network **Figure 7** is placed in series with a PTC component requiring compensation. The resistor values are selected to provide the proper NTC slope to offset the PTC component. The net effect is a constant circuit response that is independent of temperature.

"Self-Heat" Sensing Applications

To "self-heat" a thermistor, it must be subjected to power levels that raise the thermistor's body temperature above the environmental surroundings. Self-heat applications include the sensing of liquid and air level and flow rates. This application is dependent on the fact that the environment surrounding a thermistor directly affects the amount of power the thermistor can dissipate. For example, submerged in liquid, a thermistor can typically dissipate 500% to 600% more power than it can air.

Therefore, a thermistor being "self-heated" in air is able to dissipate much more power when transferred to a fluid environment. This increase in power dissipation generates a significant increase in resistance. It is this change in resistance, which makes it possible to sense the fluid level.

A simple liquid level control system can be designed by putting a thermistor in series with a coil **Figure 8**, which operates a valve that releases the liquid in the tank. The thermistor is placed in the tank and operated in a "self-heat" mode.

In air, the thermistor's resistance is low and allows enough current flow to energize the relay coil and keep the relay contact closed. When the fluid level in the tank surrounds the the thermistor, its resistance increases and de-energizes the relay, which opens a valve and releases the fluid. As the fluid is released from the tank, the thermistor's resistance decreases and the relay coil energizes and closes the valve.

Fuel injection in automobiles utilize the thermistor in the "self-heat" mode in order to properly control the air/fuel mixture. Forced air heaters may use the NTC thermistor in the "self-heat" mode in order to maintain proper air flow characteristics. This technology is utilized to monitor the flow rate and level of air and fluids in a variety of applications.

Figure 7: Temperature Compensation

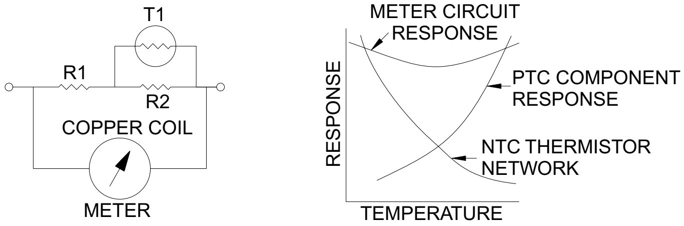


Figure 8: Self-Heat Applications