THERMISTORS

Contents

NTC THERMISTORS: INTRODUCTION

Continuous Temperature Sensing

Therm-O-Disc NTC Thermistors offer economical, reliable and accurate solutions to those applications requiring more extensive sensing than the one or two temperature points typically offered by a bimetallic thermostat. NTC thermistors provide a change in resistance with temperature that when combined with an electronic circuit provides a means of continuously measuring temperature over a very wide range.

Therm-O-Disc NTC Thermistor Features

- Economical
- Long-term stability
- Accurate
- A wide variety of packaging options available

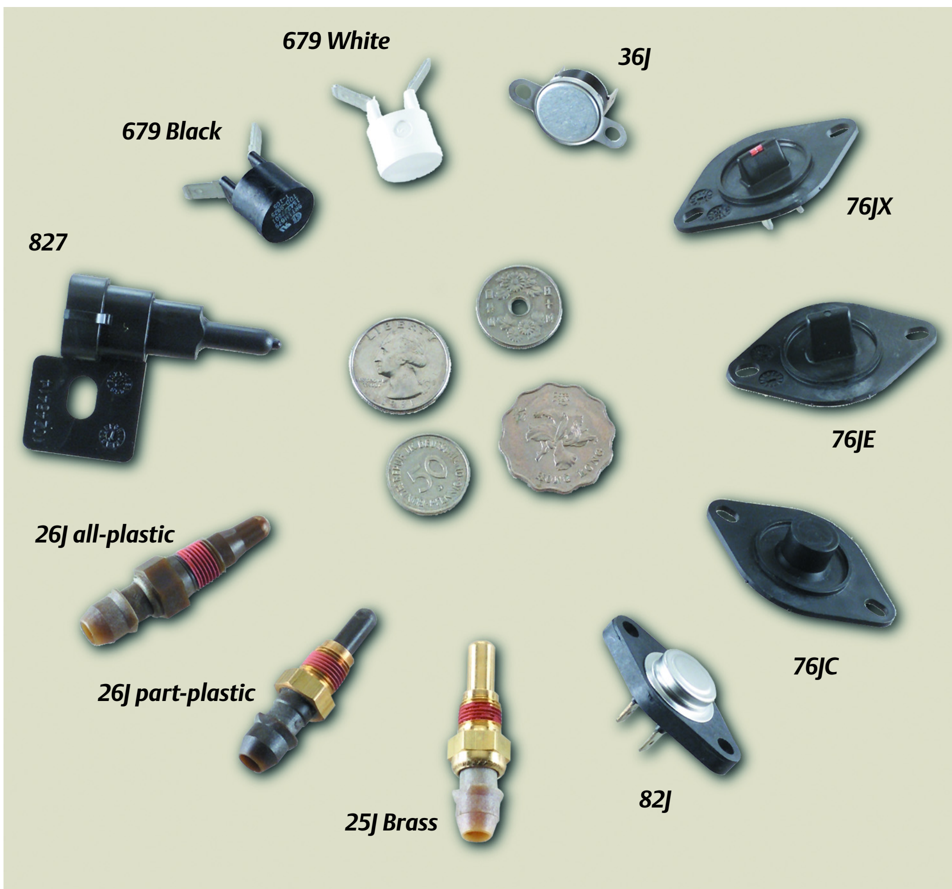
Operating Principle of NTC Thermistors

NTC thermistors are a semiconductor ceramic made with various metal oxides. Their electrical resistance decreases with increasing temperature. This resistance is processed by an electronic circuit to provide temperature measurement. While a bimetallic thermostat provides both temperature sensing and electrical circuit control, the thermistor itself does not provide any control over heating elements, relays, etc. The thermistor is strictly a sensor and any electrical control would need to be implemented by the circuit utilizing the thermistor.

PACKAGED SENSOR SERIES
NTC Thermistor Probes

Rugged Assembly

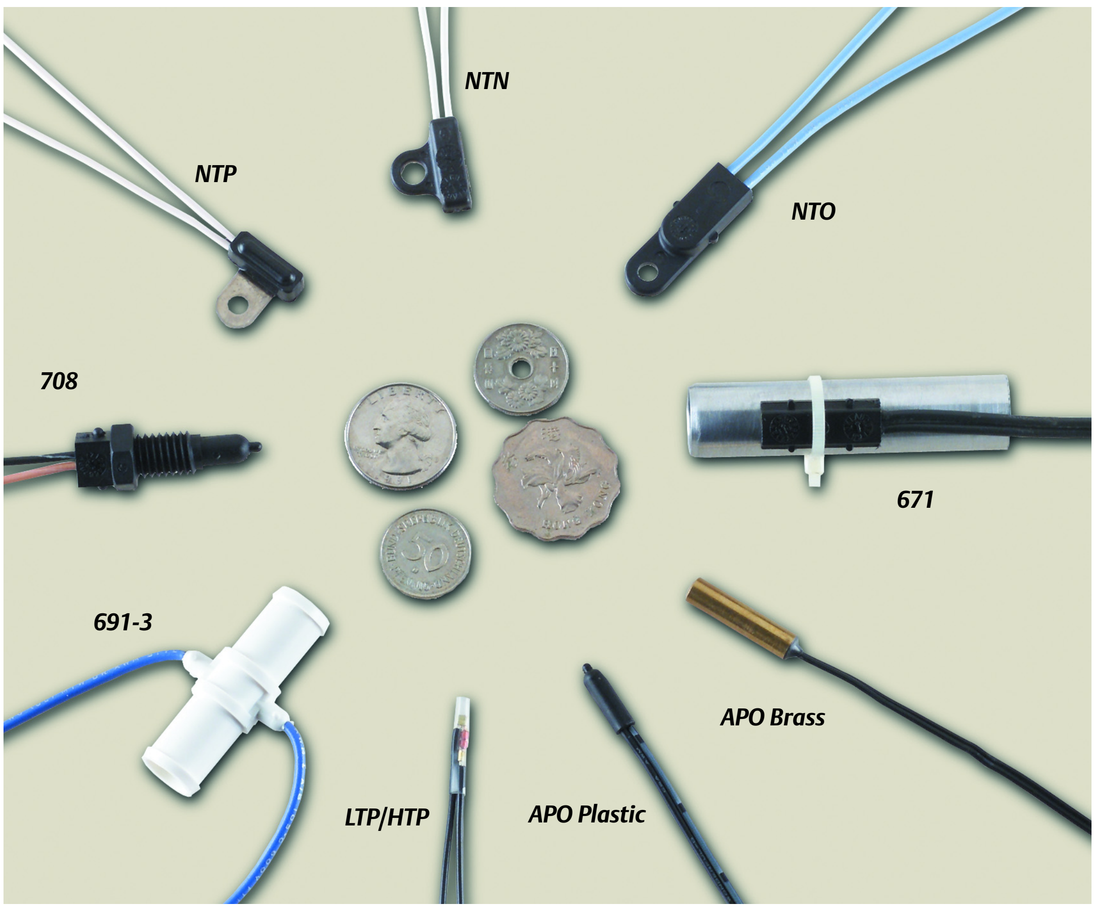
Rugged thermistor probe assemblies from Therm-O-Disc can be depended upon to meet tough application requirements. Select from a wide range of standard body designs already available, or work with experienced application engineers to develop a special design to meet exact application requirements.



Standard Thermistor Probes with Terminals

Terminals or Lead Wires

Terminals or lead wires can be offered as a connection interface to Therm-O-Disc probes. Terminals offer the most cost-effective solution as the extra handling and freight issues add to the material cost of wire.



Standard Thermistor Probes with Lead Wires

Features and Benefits

Therm-O-Disc thermistor probe benefits include:

- Engineered to specific application's exact requirements.
- Thermally responsive.
- Increased performance of the overall system in terms of energy consumption and ease of use.
- Reduced assembly cost and increased reliability.
- Rugged performance and long-term stability.

Therm-O-Disc plastic over-molded sensor features and benefits include:

- Plastic provides a much higher protection against moisture over time.
- Plastic probes can be made into more application-specific shapes.
- Plastic probes can eliminate multiple-part assemblies for customers and reduce their labor and combined material cost.
- Lower weight content than metal probes can benefit transportation costs.
- Piece price is typically lower than metal-based probes.

Sensor Varieties

Therm-O-Disc designed thermistor probes use a variety of sensors to further enhance their use in applications. The most common sensor is the H-Series NTC thermistor which can be supplied with tight tolerances at multiple temperatures. Please refer to the individual H-Series section for general electrical characteristics.

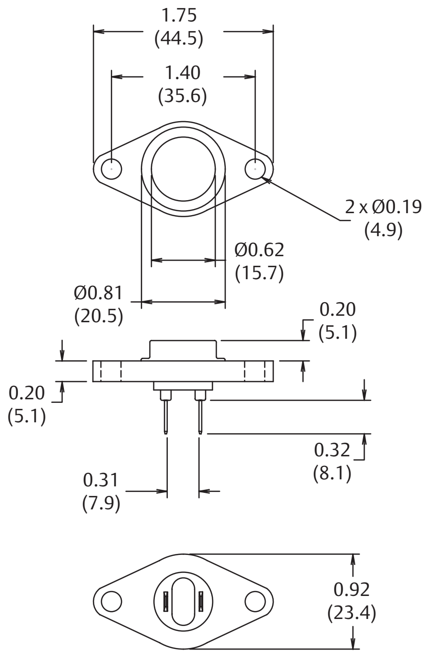
Standard Plastic Materials

Standard plastic materials selection is based on use, probe shape, response time and cost. The most commonly used plastics are General Electric's Valox® and Chevron Phillips Chemical's Ryton®. The advantages of plastic are low cost, design shape flexibility and excellent moisture protection. Other protection methods are epoxy potted-metal housings and shrink tubing. Metal housings are typically brass, stainless steel or aluminum.

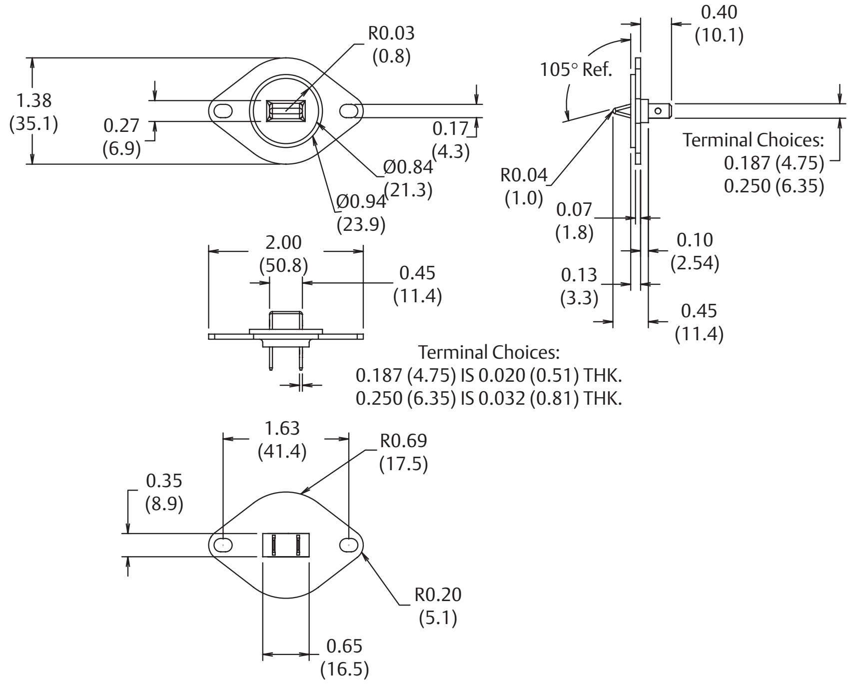
The following are the most commonly used plastics. Customer-specified plastics can also be used.

- Valox – inexpensive, compatible with food products.
- Polypropylene – very inexpensive, low temperature rating.
- Ryton – high temperature rating, good thermal conductivity, relatively expensive, harder but also more brittle than Valox or polypropylene.
- Other plastics used are Noryl and Ultem®.

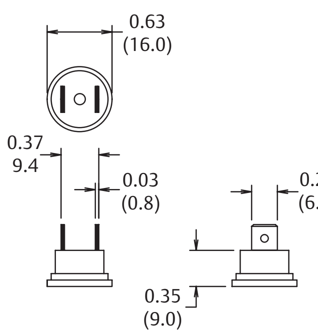
82J



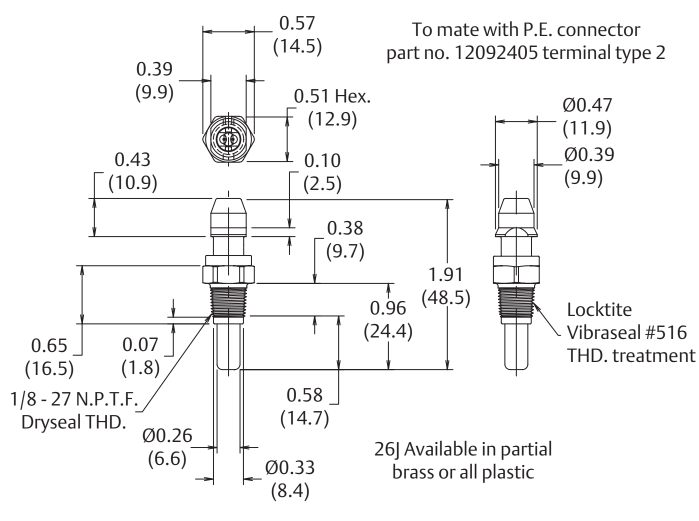
76JX



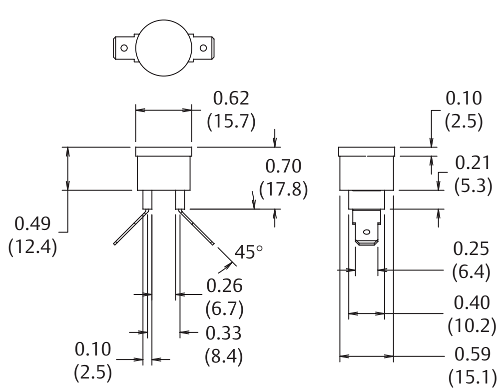
36J



26J



9RT1H679



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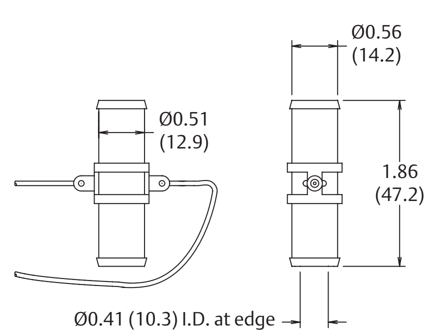
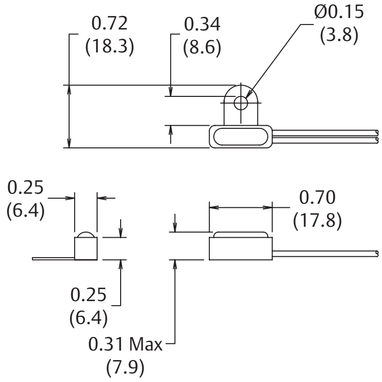
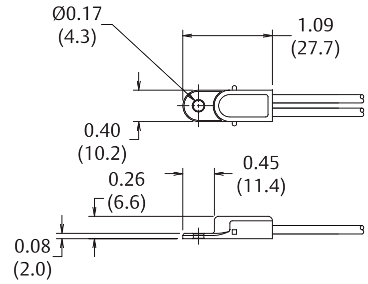


Dimensions are shown in inches and (millimeters).

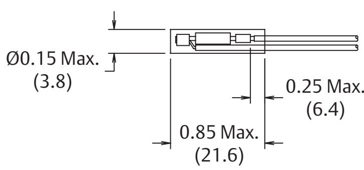
NTP



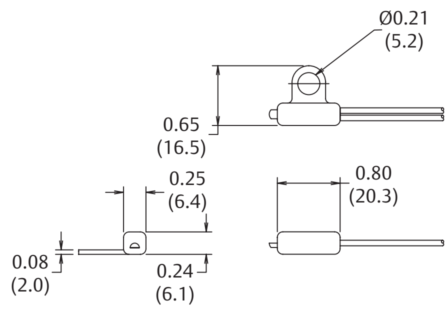
NTO



LTP/HTP



NTN



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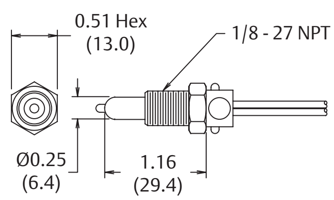
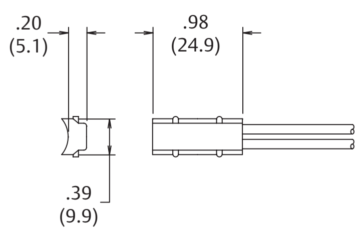


9RT1H671



Dimensions do not include date codes

Dimensions are shown in inches and (millimeters).

Product Information

Product Type	Body Material[1]	Terminal/ Lead wire[2]	Temperature Rating[3]	Marking	Thermal Time Constant[4]	Application	UL File[5]
HTP	Teflon	22 AWG (Ø0.8mm)	392°F (200°C)	None	10 seconds/air	General	None
LTP	PVC	22 AWG (Ø0.8mm)	221°F (105°C)	None	10 seconds/air	General	None
NTP	Valox	22 AWG (Ø0.8mm)	221°F (105°C)	None	—	Surface	None
NTN	Valox	22 AWG (Ø0.8mm)	221°F (105°C)	Date Code Wheels	—	Surface	None
NTO	Valox	22 AWG (Ø0.8mm)	221°F (105°C)	Date Code Wheels	—	Surface	None
APO Plastic	Polypro	24 AWG (Ø0.6mm)	176°F (80°C)	None	15 seconds/liquid	HVAC, Refrigeration	None
APO Brass	Brass	24 AWG (Ø0.6mm)	176°F (80°C)	None	15 seconds/liquid	HVAC, Refrigeration	None
671	Valox	22 AWG (Ø0.6mm)	221°F (105°C)	Date Code Wheels	—	HVAC, Refrigeration	None
708	Valox	20 AWG (Ø0.9mm)	221°F (105°C)	Date Code Wheels	30 seconds/liquid	Marine Engine	None
691-3	Polypro	24 AWG (Ø0.6mm)	221°F (105°C)	Date Code Wheels	10 seconds/liquid	Flow Thru Liquids	None
82J	Ryton	0.187” (4.75mm) Terminals	392°F (200°C)	P/N, Date Code	12 seconds/liquid	Appliance	E81686 (UL/CUL)
76J	Valox	0.25” (6.4mm) or 0 187” (4.75mm) Terminals	221°F (105°C)	Date Code Wheels, Part I.D.	X = 10 seconds/air	Air Flow, Appliance	E19279
679	Valox	0.25” (6.4mm) Terminals	221°F (105°C)	Date Code, Part I.D.	—	Surface, Appliance	E81686 (UL/CSA)
827	Valox	Mates to Packard 12052641	221°F (105°C)	Date Code Wheels	—	Ambient Air, Automotive	None
26J	Ultem/Brass	Mates to Packard 12092405	356°F (180°C)	Date Code	—	Automotive	None
36J	Aluminum	0.25” (6.4mm) or 0.187” (4.75mm) Terminals	302°F (150°C)	TBD	11 seconds/25°C air to 85°C hot plate	Appliance	E179543

NOTE:
1. Most plastics can be substituted with another. Please contact Therm-O-Disc to discuss the possibility.
2. Many times, different wire and terminal sizes can be accommodated with the purchase of a tooling insert.
3. Normally, temperature rating is determined by the lead wire insulation rating. The plastic is generally rated higher than the lead wire insulation.
4. Thermal time constant is defined as the time required for the thermistor to change 63.2% of the temperature difference in a step function change in ambient temperature. Generally, we use 25° and 75°C as the two temperatures.
5. All these probes use UL listed wire, plastics and sensors, even if the entire probe is not UL listed.

How date code wheels work:

One Wheel = Last 2 digits of the year in the center, center arrow points to week.

Two Wheels = One wheel has last 2 digits of the year in the center, center arrow points to month digit. X=10=Oct., Y=11=Nov., Z=12=Dec. Second wheel center arrow points to lot code letter. Letter traceability is logged at Therm-O-Disc.

APPLIANCE/HVAC PROBE SERIES

NTC Thermistor Probes (10JH/11JH)

Applications

- Ambient air temperature sensing
- Condenser coil sensing
- Other remote sensing applications

Lead Wire Specifications

Insulation material: 80°C PVC, 300V Min.
UL2468, 1.6mm pitch twin-lead (two core) seven strand,
0.38mm insulation thickness, 26 AWG (optional 24, 22 AWG)
(Optional UL1015 (11JH only): 600V Min., 105°C PVC)

Operating Temperature Range

-40° to 80°C
(-20° to 105°C with 11JH only optional UL1015 lead wires)

Thermal Time Constant

10 seconds typical (liquid)
25°C/50°C

Dissipation Constant

4mW/°C

10JH

Values Available

R25°C	R-T Curve	Tol@25°C
10KΩ	Grade 1, 5	±1, 2, 3, 4, 5, 10%
15K	5	
20K	1, 5	
30K	1	
50K	1, 5	
100K	1, 5	
200K	4	
500K	4	

11JH

R-T Curve Information

Beta	Grade 1	Grade 4	Grade 5
25/50	3934.4 ref	4422 ref	4060 ref
25/75	3965±1%	4500±2%	4100±2%
25/85	3977 ref	4516 ref	4107 ref

R-T Formula

$1/T = a + b(\ln R) + c(\ln R)^3$

$T = °K + °C + 273.15$

Values for 10K at 25°C:

$a = 1.125498166 \times 10^{-3}$

$b = 2.346771694 \times 10^{-4}$

$c = 8.579674698 \times 10^{-8}$

Values for 15K, Grade 5

$a = 1.110535091 \times 10^{-3}$

$b = 2.256359405 \times 10^{-4}$

$c = 8.301534472 \times 10^{-8}$

Values for 200K, Grade 4

$a = 8.742982059 \times 10^{-4}$

$b = 1.897917438 \times 10^{-4}$

$c = 8.968982871 \times 10^{-8}$

Optional Connector Type

JST Model XHP-2

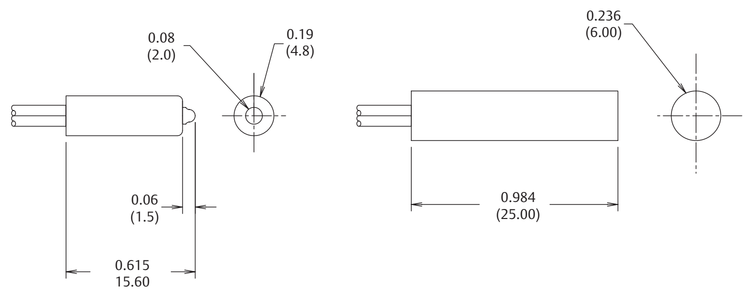
Resistance vs. Temperature

To find the resistance value of a part at any given temperature, multiply the resistance at 25°C by the multiplier value below.

Temp. °C	Grade 1	Grade 4	Grade 5
-40°	33.600	45.5	37.254
-35°	24.270	32.5	26.633
-30°	17.700	23.0	19.258
-25°	13.040	16.7	14.068
-20°	9.7060	12.1	10.382
-15°	7.2940	8.90	7.7426
-10	5.5319	6.60	5.8255
-5°	4.2324	4.90	4.4229
0°	3.2654	3.716	3.3847
5°	2.5396	2.816	2.6125
10°	1.9903	2.150	2.0342
15°	1.5714	1.655	1.5947
20°	1.2493	1.282	1.2594
25°	1.0000	1.0000	1.0000
30°	0.8056	0.7853	0.8008
35°	0.6530	0.6207	0.6448
40°	0.5327	0.4935	0.5223
45°	0.4370	0.3947	0.4256
50°	0.3603	0.3175	0.3487
55°	0.2986	0.2568	0.2872
60°	0.2488	0.2088	0.2379
65°	0.2083	0.1707	0.1980
70°	0.1752	0.1402	0.1655
75°	0.1480	0.1157	0.1389
80°	0.1255	0.0959	0.1174

Reliability Data

High temperature exposure:
1000 hours / 80°C
Typical <1%ΔR
Low temperature exposure:
1000 hours / -20°C
Typical <1%ΔR
Thermal shock testing:
200 cycles. Each cycle consists of:
-20°C for 5 minutes
Room temp water for 30 seconds
80°C water for 5 minutes
Typical <1%ΔR



Dimensions are shown in inches and (millimeters)

Inspection

In-process inspection –
- Resistance at 25°C measured on 100% sensors prior to probe assembly.
- 500V hi-pot 100% final probe for 10JH
- 1000V hi-pot 100% final probe for 11JH

Final inspection –
- Resistance at 25°C.
- Physical dimensions.
- 0.65% AQL, C = 0 Sampling Plan.

Product Numbering System

___ J H ___

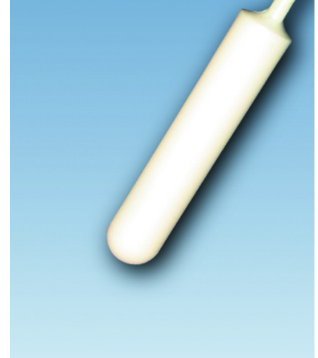
10 – Appliance Probe Series, all-plastic body
11 – Appliance Probe Series, metal body version

Therm-O-Disc H-Series thermistor inside

Sequentially assigned part number

REFRIGERATION PROBE SERIES

NTC Thermistor Probes (12J)



Applications

- Refrigeration systems
- Freezer compartments
- General purpose applications

Lead Wire Specifications

24 AWG, UL2468, 80°C, white standard

Operating Temperature Range

-40° to 80°C

Thermal Time Constant

11 seconds typical

12J probe.

Values Available

R25°C	R-T Curve	Tol@25°C
10KΩ	1	±10, 5, 3, 2, 1%
50K	1	±10, 5, 3, 2, 1%
100K	1	±10, 5, 3, 2, 1%

R-T Curve Information

Beta	Value
25/50	3934.4 ref
25/75	3965±1%
25/85	3977 ref

R-T Formula

$1/T = a + b(\ln R) + c(\ln R)^3$

$T = °K + °C + 273.15$

Values for 10K Part

$a = 1.125190920 \times 10^{-3}$

$b = 2.347363293 \times 10^{-4}$

$c = 8.551343472 \times 10^{-8}$

Values for 50K Part

$a = 7.602330993 \times 10^{-4}$

$b = 2.313331379 \times 10^{-4}$

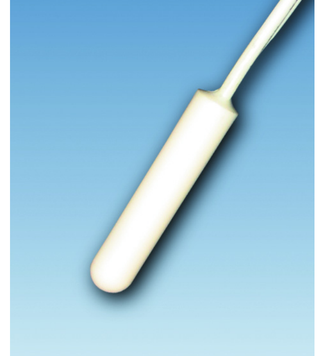
$c = 7.172007260 \times 10^{-8}$

Values for 100K Part

$a = 6.053377486 \times 10^{-4}$

$b = 2.298626288 \times 10^{-4}$

$c = 6.706142562 \times 10^{-8}$



Optional Connector Type

May be specified by the customer

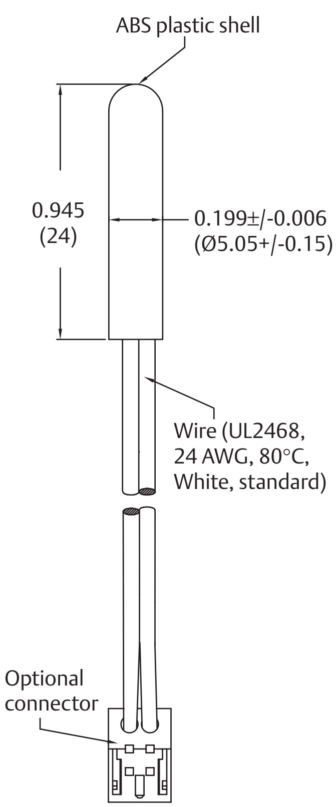
Cap Construction

White ABS plastic, epoxy filled

Insulation Strength

1500VDC/1 second minimum rating

Physical Dimensions

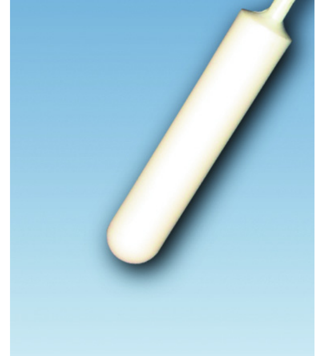


Dimensions are shown in inches and (millimeters).

Resistance vs. Temperature

To find the resistance value of a part at any given temperature, multiply the resistance at 25°C by the multiplier value below.

Temp. °C	Multiplier
-40°	33.600
-35°	24.270
-30°	17.700
-25°	13.040
-20°	9.7060
-15°	7.2940
-10	5.5319
-5°	4.2324
0°	3.2654
5°	2.5396
10°	1.9903
15°	1.5714
20°	1.2493
25°	1.0000
30°	0.8056
35°	0.6530
40°	0.5327
45°	0.4370
50°	0.3603
55°	0.2986
60°	0.2488
65°	0.2083
70°	0.1752
75°	0.1480
80°	0.1255



High temperature exposure:
- 1000 hours / 80°C
- Typical <1%ΔR

Low temperature exposure:
- 1000 hours / -20°C
- Typical <1%ΔR

Thermal shock testing:
- 200 cycles. Each cycle consists of:
- -20°C for 5 minutes
- Room temp water for 30 seconds
- 80°C water for 5 minutes
- Typical <1%ΔR

Inspection

In-process inspection –
- Resistance at 25°C measured on 100% sensors prior to probe assembly.
- Hi-pot 100% final probe.

Final inspection –
- Resistance at 25°C.
- Physical dimensions.
- 0.65% AQL, C = 0 Sampling Plan.

Product Numbering System

12J 1 H ___

- 12J – Package Series
- 1 – Therm-O-Disc R-T curve
- H – Therm-O-Disc H-Series thermistor inside
- ___ – Sequentially assigned part number

APPLIANCE/HVAC PROBE SERIES

NTC Thermistor Probes (36JB)

Applications

- Boiler heating systems
- Fast response applications
- Storage water heaters
- Appliances

Terminal Specifications

0.25” x 0.032” (6.35mm x 0.8mm) or 0.11” x 0.020” (2.8mm x 0.5mm)
Tin-plated brass

Operating Temperature Range

-40° to 180°C (limited exposure to 220°C max)

Thermal Time Constant

3 seconds typical
(25° air to 85°C hot plate)

Values Available

R-T Curve	R25°C	R80°C	R100°C
A	10,000	1256	690
B	10,000	1668	950
C	12,000	1708	952

R-T Curve Information

Curve	Beta	Value
A	25/85	3977±1.5%
B	25/85	3435±1.5%
C	25/85	3740±1.5%

Clip and cup radius sizes

15mm, 18mm and 22mm pipe diameters standard
(other sizes optional)

Construction

Case PPS plastic, black and brown color standard (other colors optional)
Cap is aluminum

Insulation Strength

1500VDC/1 second minimum rating

R-T Formula

$1/T = a + b(\ln R) + c(\ln R)^3$

$T = °K + °C + 273.15$

Values for Part A

$a = 1.068143559 \times 10^{-3}$

$b = 2.449279583 \times 10^{-4}$

$c = 3.840058397 \times 10^{-8}$

Values for Part B

$a = 1.120953374 \times 10^{-3}$

$b = 2.08616283 \times 10^{-4}$

$c = 3.988602001 \times 10^{-7}$

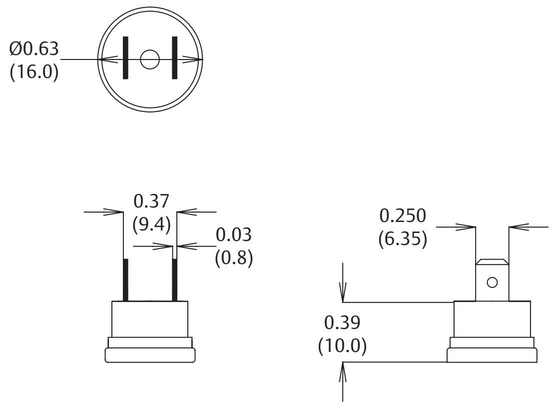
Values for Part C

$a = 9.973534012 \times 10^{-4}$

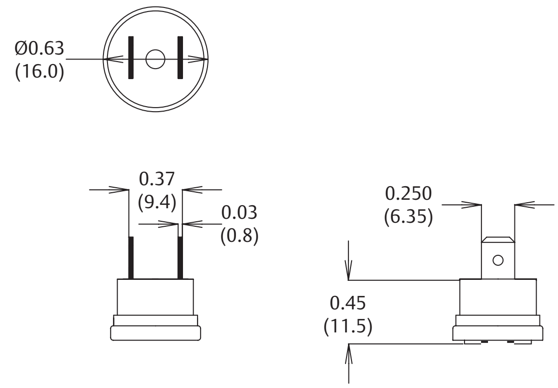
$b = 2.389380822 \times 10^{-4}$

$c = 1.356419659 \times 10^{-7}$

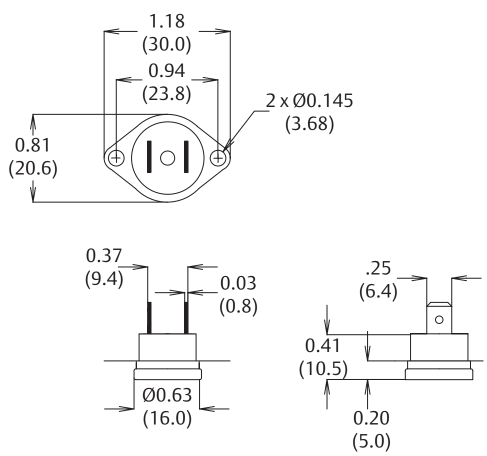
No Mount



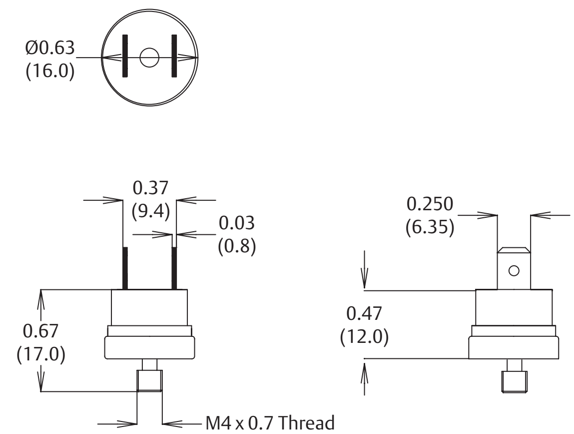
Tube Mount



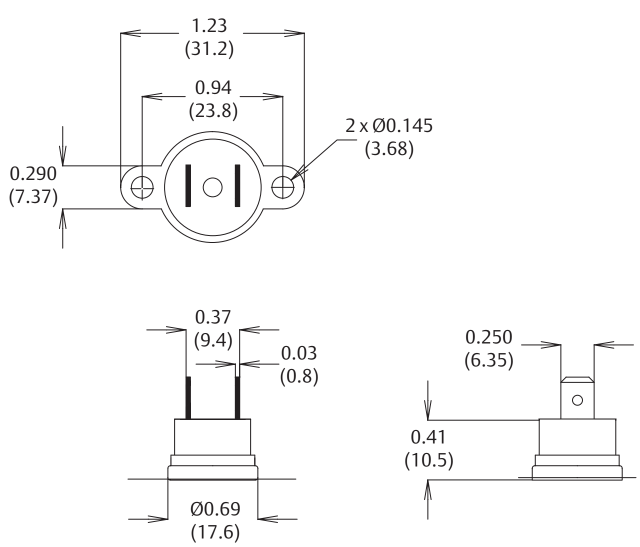
Airstream Mount



Stud Mount



Surface Mount



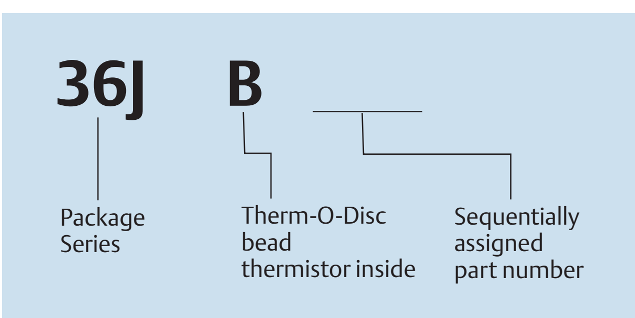
Dimensions are shown in inches and (millimeters).

Resistance vs. Temperature

To find the resistance value of a part at any given temperature, multiply the resistance at 25°C by the multiplier value below.

Temp. °C	Curve A	Curve B	Curve C
-20	9.7060	7.0030	8.2350
-15	7.2940	5.4890	6.3280
-10	5.5319	4.3350	4.9020
-5	4.2324	3.4480	3.8260
0	3.2654	2.7620	3.0080
5	2.5396	2.2270	2.3830
10	1.9903	1.8070	1.8990
15	1.5714	1.4750	1.5240
20	1.2493	1.2110	1.2310
25	1.0000	1.0000	1.0000
30	0.8056	0.8302	0.8171
35	0.6530	0.6928	0.6713
40	0.5327	0.5810	0.5544
45	0.4370	0.4897	0.4603
50	0.3603	0.4145	0.3841
55	0.2986	0.3523	0.3219
60	0.2488	0.3011	0.2711
65	0.2083	0.2582	0.2293
70	0.1752	0.2223	0.1948
75	0.1480	0.1921	0.1662
80	0.1255	0.1668	0.1423
85	0.1070	0.1451	0.1223
90	0.0915	0.1268	0.1055
95	0.0787	0.1112	0.09133
100	0.0680	0.09500	0.07935
105	0.0592	0.08626	0.06917
110	0.0517	0.07634	0.06048
115	0.0450	0.06776	0.05305
120	0.0390	0.06032	0.04668
125	0.0340	0.05384	0.04119

Product Numbering System



APPLIANCE/HVAC PROBE SERIES
NTC Thermistor Probes (36JD)

Applications

- Boiler heating systems
- Fast response applications
- Storage water heaters
- Appliances

Operating Temperature Range

-40° to 125°C

Thermal Time Constant

2 seconds typical
(25° air to 85°C hot plate)

Values Available

R-T Curve	R25°C	R80°C	R100°C
A	10,000	1256	690

R-T Curve Information

Part	Beta	Value
A	25/85	3977±1.5%

Accuracies Available

+/-1°C @ 80°-100°C
+/-2°C @ 80°-100°C
(Custom values also available)

Construction

Case is PPS plastic, black and brown color standard (other colors optional)
Cap is aluminum

Connector

Molex 43045-0412
Mating Connector Molex 43025-0400

Insulation Strength

1500VDC/1 second minimum rating

Resistance vs. Temperature

Temp. °C	Nominal Resistance (ohms)
-20	98960
-15	74200
-10	56140
-5	42860
0	33000
5	25610
10	20030
15	15790
20	12530
25	10000
30	8057
35	6524
40	5315
45	4356
50	3591
55	2976
60	2480
65	2077
70	1748
75	1478
80	1256
85	1072
90	919
95	791
100	690
105	592
110	516
115	451
120	395
125	347

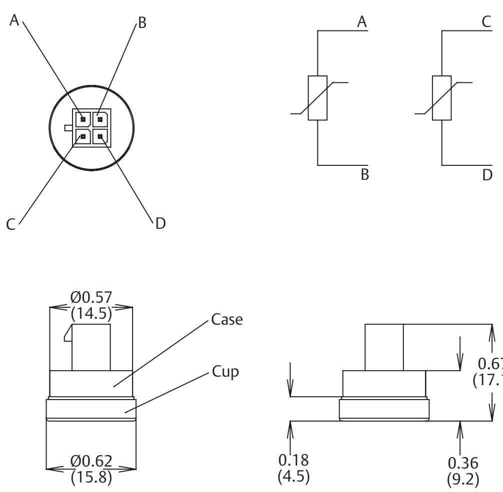
Product Numbering System

36J D ___

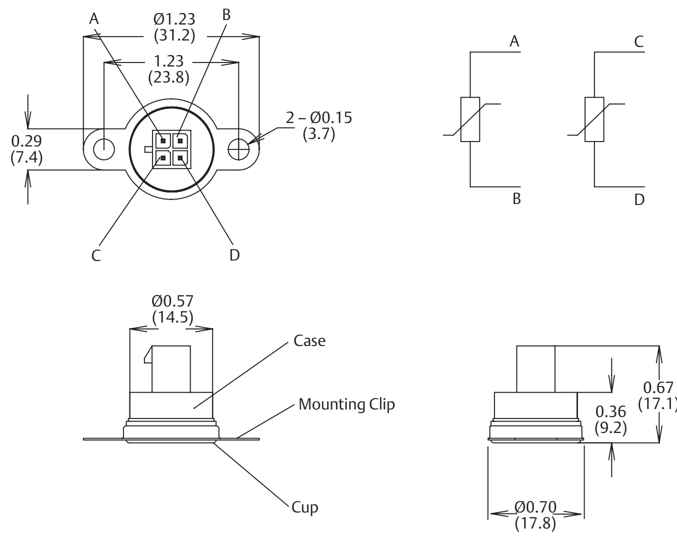
- 36J — Package Series
- D — Two NTC thermistors inside
- ___ — Sequentially assigned part number

Physical Dimensions

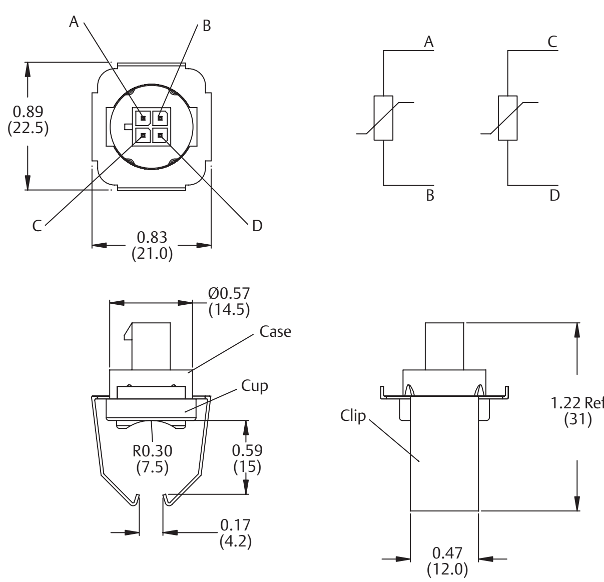
No Mounting Tab Option



Surface Mounting Option



Tube Mounting Option (15, 18, 22mm Ø)



Dimensions are shown in inches and (millimeters).

APPLIANCE/HVAC PROBE SERIES

NTC Thermistor Probes (36JH)

Applications

- Clothes dryers
- Dishwashers
- Coffee makers
- HVAC systems

Terminal Specifications

0.25” x 0.032” (6.35mm x 0.8mm)
Tin-plated brass

Operating Temperature Range

-40° to 180°C

Thermal Time Constant

11 seconds typical with Aluminum Cap
(25° to 85°C hot plate)

Values Available

R25°C	R-T Curve	Tol@25°C
10KΩ	1	±10, 5, 3, 2, 1%
50K	1	±10, 5, 3, 2, 1%
100K	1	±10, 5, 3, 2, 1%

R-T Curve Information

Beta	Value
25/85	3977±1.5%

Clip and cup radius sizes

15mm, 18mm and 22mm pipe diameters standard
(other sizes optional)

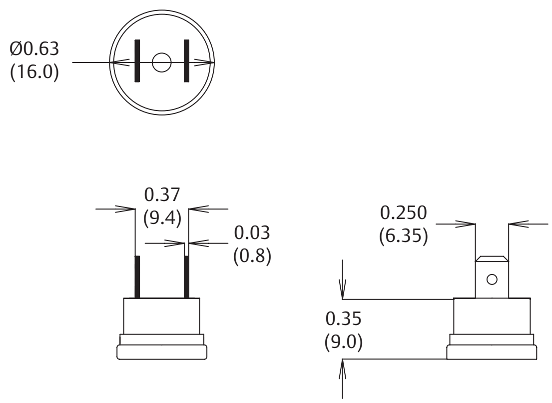
UL/CUL Approved

File E179543 Vol. 2, Sec. 5

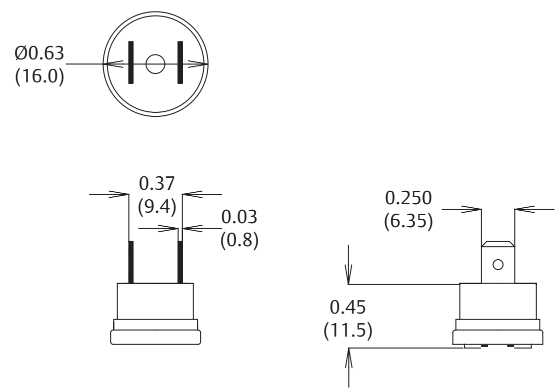
Construction

Case PPS plastic, black and brown color standard (other colors optional)
Cap is aluminum or stainless steel

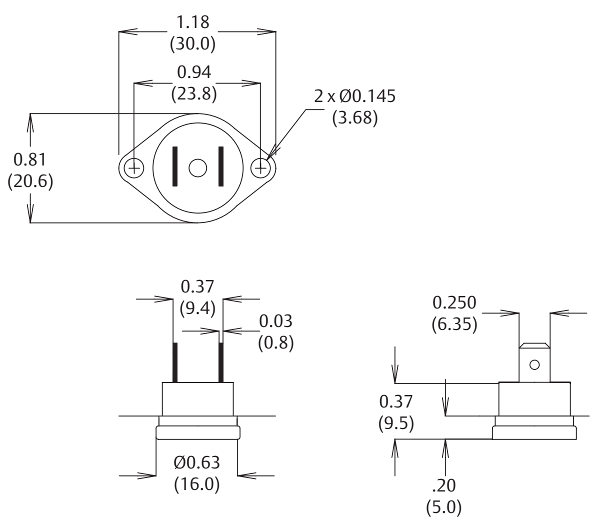
No Mount



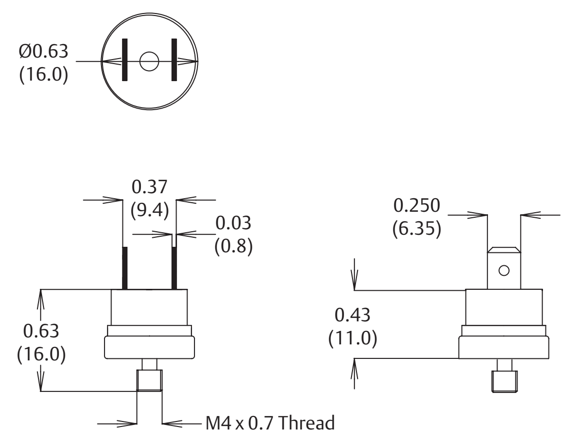
Tube Mount



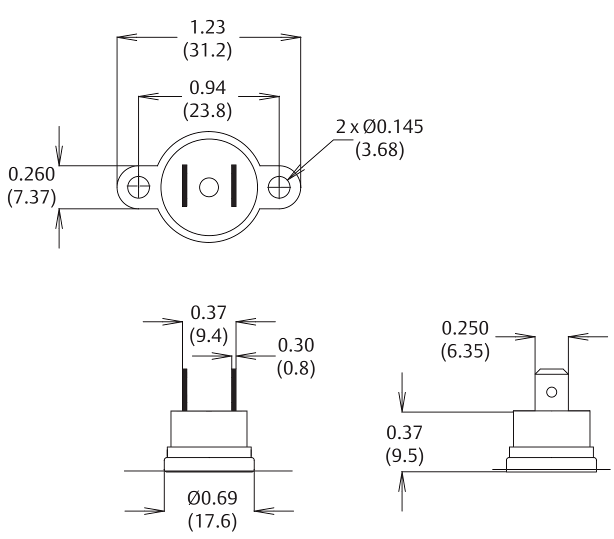
Airstream Mount



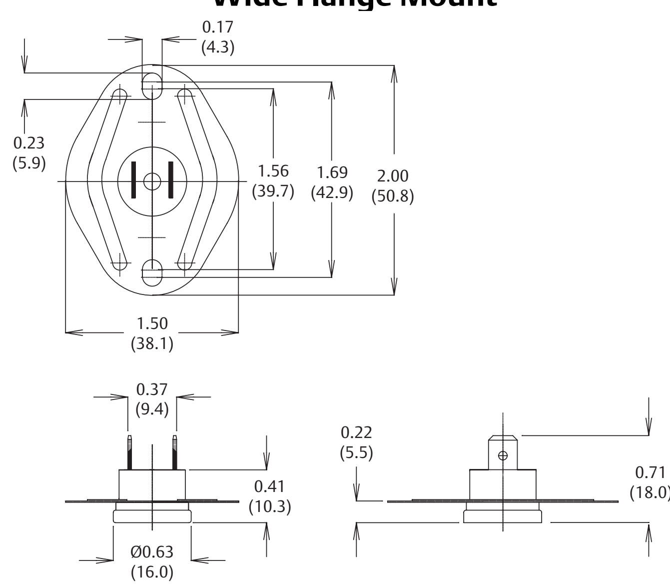
Stud Mount



Surface Mount



Wide Flange Mount



Dimensions are shown in inches and (millimeters).

Insulation Strength

1500VDC/1 second minimum rating

Resistance vs. Temperature

To find the resistance value of a part at any given temperature, multiply the resistance at 25°C by the multiplier value below.

Temp. °C	Multiplier	Temp. °C	Multiplier
-40°	33.600	75°	0.1480
-35°	24.270	80°	0.1255
-30°	17.700	85°	0.1070
-25°	13.040	90°	0.09150
-20°	9.7060	95°	0.07870
-15°	7.2940	100°	0.06800
-10	5.5319	105°	0.05920
-5°	4.2324	110°	0.05170
0°	3.2654	115°	0.04500
5°	2.5396	120°	0.03900
10°	1.9903	125°	0.03400
15°	1.5714	130°	0.03000
20°	1.2493	135°	0.02650
25°	1.0000	140°	0.02350
30°	0.8056	145°	0.02090
35°	0.6530	150°	0.01850
40°	0.5327	155°	0.01620
45°	0.4370	160°	0.01450
50°	0.3603	165°	0.01300
55°	0.2986	170°	0.01180
60°	0.2488	175°	0.01070
65°	0.2083	180°	0.00970
70°	0.1752		

R-T Formula

$1/T = a + b(\ln R) + c(\ln R)^3$

$T = °K + °C + 273.15$

Values for Part A

$a = 1.125190920 \times 10^{-3}$

$b = 2.347363293 \times 10^{-4}$

$c = 8.551343472 \times 10^{-8}$

Values for Part B

$a = 7.602330993 \times 10^{-4}$

$b = 2.313331379 \times 10^{-4}$

$c = 7.172007260 \times 10^{-8}$

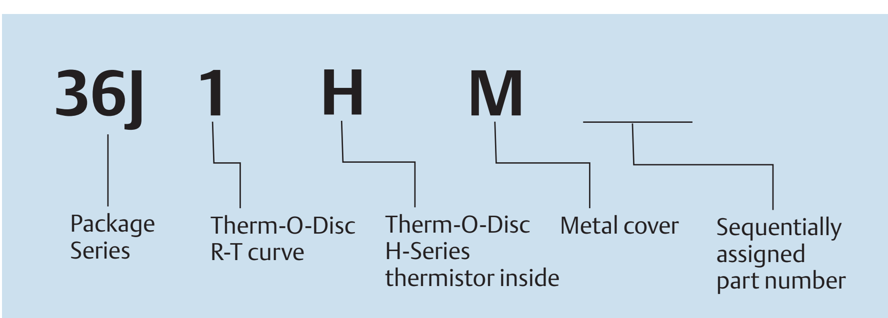
Values for Part C

$a = 6.053377486 \times 10^{-4}$

$b = 2.298626288 \times 10^{-4}$

$c = 6.706142562 \times 10^{-8}$

Product Numbering System



APPLIANCE/HVAC PROBE SERIES

NTC Thermistor Probes (76J1HX)

Applications

- Clothes dryer exhaust
- HVAC air duct sensing

Operating Temperature Range

-40° to 105°C

Thermal Time Constant

13-20 seconds typical
(25° to 100°C air)

Values Available

Any of the Therm-O-Disc H-Series thermistors can be used in this body.

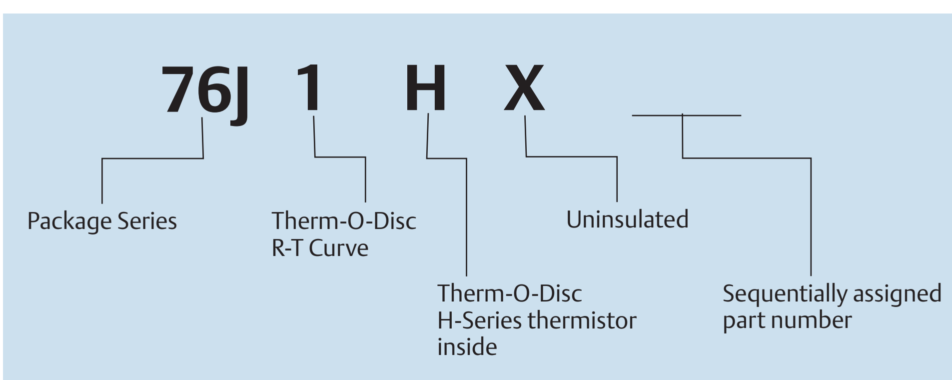
Insulation Strength

UL/CUL rated as uninsulated

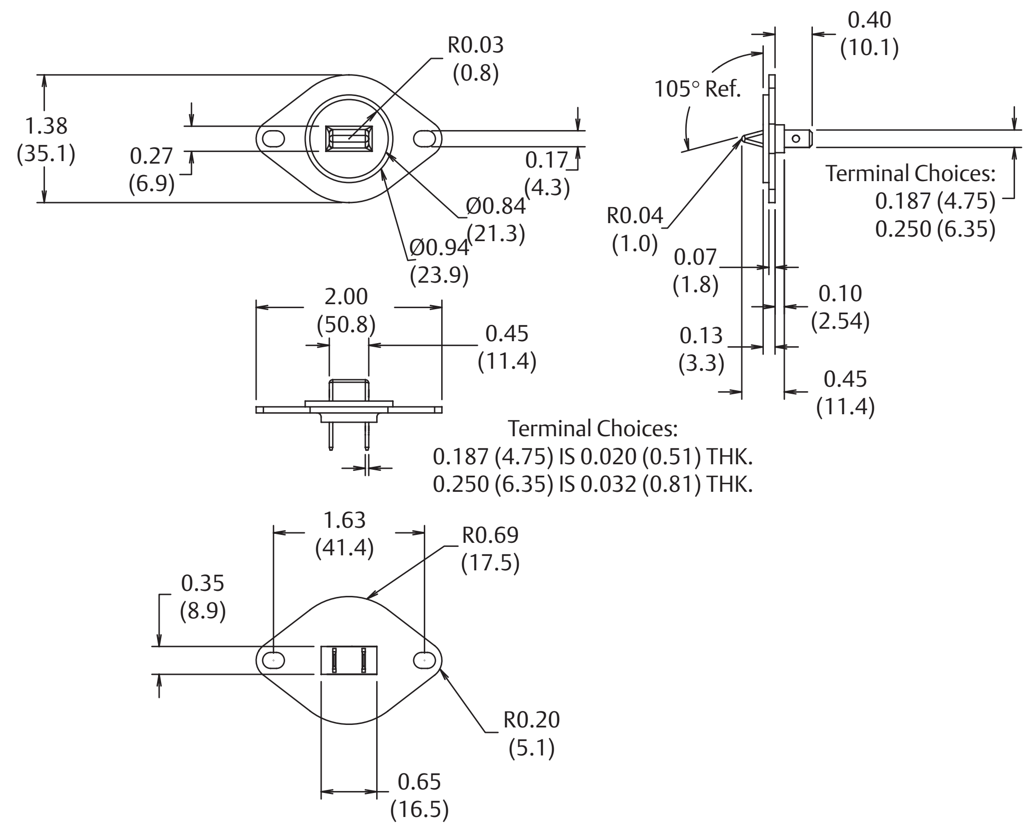
Construction

Valox 745 plastic

Product Numbering System



Physical Dimensions



Dimensions are shown in inches and (millimeters).

APPLIANCE/HVAC PROBE SERIES

NTC Thermistor Probes (93JB)

Applications

- Boiler heating systems
- Fast response in liquid applications
- Showers
- Dryers
- Coffee pots

Operating Temperature Range

-20° to 150°C

Thermal Time Constant

0.2 seconds typical
(25° air to 85°C stirred water)

Values Available

R-T Curve	R25°C	R37°C	R85°C
A	10,000	6006	1072

R-T Curve Information

Part	Beta	Value
A	25/85	3977±1.5%

Accuracies Available

+/-1°C @ 80°-100°C
+/-2°C @ 80°-100°C
(Custom values also available)

Insulation Strength

500VAC/1 second minimum rating

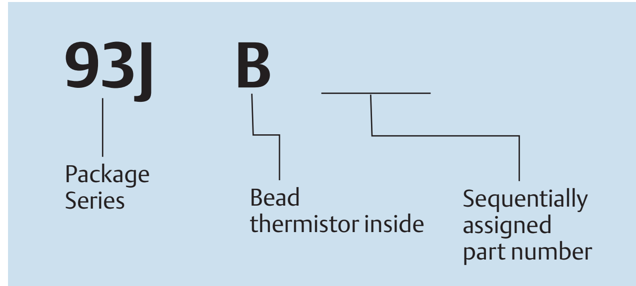
Construction

316L Stainless steel or
Nickel-plated brass body
PPS plastic ring
26AWG 150°C twin lead wire

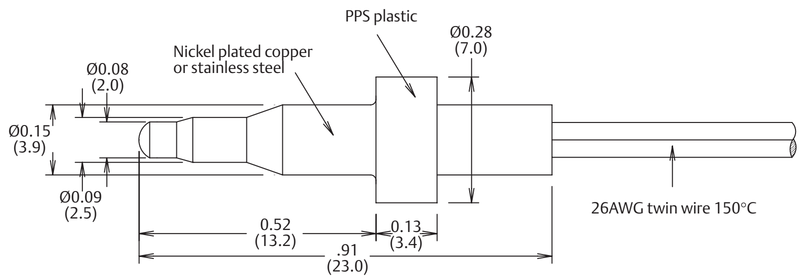
Resistance vs. Temperature

Temp. °C	Nominal Resistance (ohms)
-20	98960
-15	74200
-10	56140
-5	42860
0	33000
5	25610
10	20030
15	15790
20	12530
25	10000
30	8057
35	6524
40	5315
45	4356
50	3591
55	2976
60	2480
65	2077
70	1748
75	1478
80	1256
85	1072
90	919
95	791
100	690
105	592
110	516
115	451
120	395
125	347
130	307
135	271
140	241
145	214
150	191

Product Numbering System



Physical Dimensions



Dimensions are shown in inches and (millimeters).

APPLIANCE/HVAC PROBE SERIES

NTC Thermistor Probes (95JB)

Applications

- Boiler heating systems
- Fast response in liquid applications

Operating Temperature Range

-40° to 125°C

Thermal Time Constant

2.5 seconds typical
(25° air to 85°C stirred water)

Values Available

R-T Curve	R25°C	R80°C	R100°C
A	10,000	1256	690
B	10,000	1668	950
C	12,000	1707.6	952

R-T Curve Information

Curve	Beta	Value
A	25/85	3977±1.5%
B	25/85	3435±1.5%
C	25/85	3740±1.5%

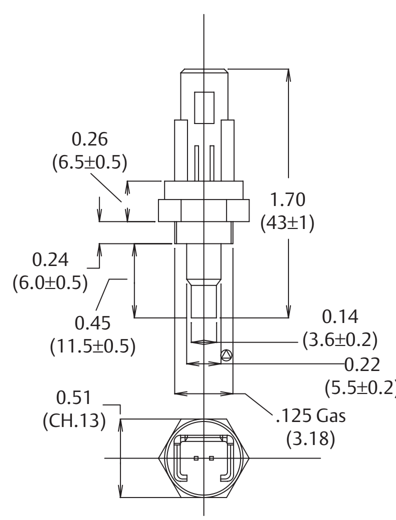
Accuracies Available

+/-1°C @ 80°-100°C
+/-2°C @ 80°-100°C
(custom values also available)

Insulation Strength

1500VDC/1 second minimum rating

Physical Dimensions



Dimensions are shown in inches and (millimeters).

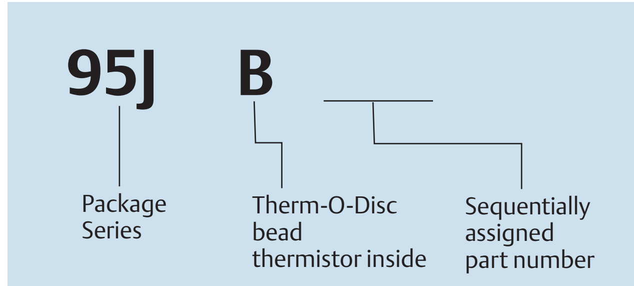
Construction

Black PBT plastic connector – Part A
Blue PBT plastic connector – Part B
Brown PBT plastic connector – Part C
Nickel-plated brass body

Mating Connector

Lumberg connector housing 3114 02
Lumberg contacts: 3111L or 3111G

Product Numbering System



Resistance vs. Temperature

To find the resistance value of a part at any given temperature, multiply the resistance at 25°C by the multiplier value below.

Temp. °C	Curve A	Curve B	Curve C
-20	9.7060	7.0030	8.2350
-15	7.2940	5.4890	6.3280
-10	5.5319	4.3350	4.9020
-5	4.2324	3.4480	3.8260
0	3.2654	2.7620	3.0080
5	2.5396	2.2270	2.3830
10	1.9903	1.8070	1.8990
15	1.5714	1.4750	1.5240
20	1.2493	1.2110	1.2310
25	1.0000	1.0000	1.0000
30	0.8056	0.8302	0.8171
35	0.6530	0.6928	0.6713
40	0.5327	0.5810	0.5544
45	0.4370	0.4897	0.4603
50	0.3603	0.4145	0.3841
55	0.2986	0.3523	0.3219
60	0.2488	0.3011	0.2711
65	0.2083	0.2582	0.2293
70	0.1752	0.2223	0.1948
75	0.1480	0.1921	0.1662
80	0.1255	0.1668	0.1423
85	0.1070	0.1451	0.1223
90	0.0915	0.1268	0.1055
95	0.0787	0.1112	0.09133
100	0.0680	0.09500	0.07935
105	0.0592	0.08626	0.06917
110	0.0517	0.07634	0.06048
115	0.0450	0.06776	0.05305
120	0.0390	0.06032	0.04668
125	0.0340	0.05384	0.04119

R-T Formula

$1/T = a + b(\ln R) + c(\ln R)^3$

$T = °K + °C + 273.15$

Values for Part A

$a = 1.068143559 \times 10^{-3}$

$b = 2.449279583 \times 10^{-4}$

$c = 3.840058397 \times 10^{-8}$

Values for Part B

$a = 1.120953374 \times 10^{-3}$

$b = 2.08616283 \times 10^{-4}$

$c = 3.988602001 \times 10^{-7}$

Values for Part C

$a = 9.973534012 \times 10^{-4}$

$b = 2.389380822 \times 10^{-4}$

$c = 1.356419659 \times 10^{-7}$

APPLIANCE/HVAC PROBE SERIES

NTC Thermistor Probes (95JD)

Applications

- Boiler heating systems
- Fast response in liquid applications

Operating Temperature Range

-40° to 125°C

Thermal Time Constant

5 seconds typical
(25° air to 85°C stirred water)

Values Available

R-T Curve	R25°C	R80°C	R100°C
A	10,000	1256	690

(Inquire about other values.)

R-T Curve Information

Part	Beta	Value
A	25/85	3977±1.5%

Accuracies Available

+/-1°C @ 80°-100°C
+/-2°C @ 80°-100°C
(Custom values also available)

Insulation Strength

1500VDC/1 second minimum rating

Construction

Black PBT plastic connector
Nickel-plated brass body

Resistance vs. Temperature

Temp. °C	Nominal Resistance (ohms)
-20	98960
-15	74200
-10	56140
-5	42860
0	33000
5	25610
10	20030
15	15790
20	12530
25	10000
30	8057
35	6524
40	5315
45	4356
50	3591
55	2976
60	2480
65	2077
70	1748
75	1478
80	1256
85	1072
90	919
95	791
100	690
105	592
110	516
115	451
120	395
125	347

Product Numbering System

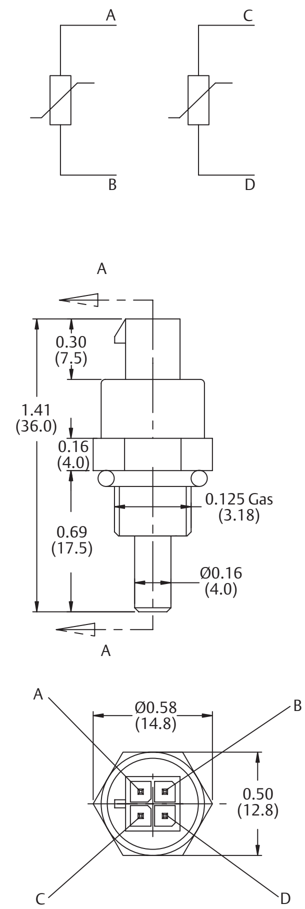
95J **D** ____

Package Series

Two NTC thermistors inside

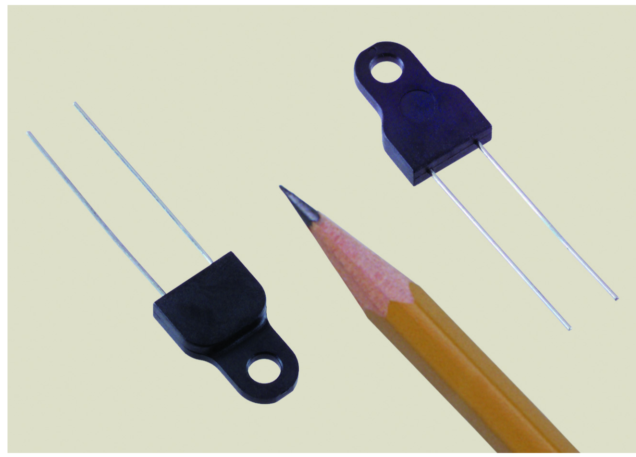
Sequentially assigned part number

Physical Dimensions



Dimensions are shown in inches and (millimeters).

ASN PACKAGE SERIES
NTC Thermistor Probes



Applications

- Heat sink monitoring
- Surface temperature monitoring for power supplies, power amplifiers
- Motor controllers

Operating Temperature Range

-40° to 200°C

Thermal Time Constant

12 seconds typical (oil)
25°C/85°C

Dissipation Constant

2mW/°C

Values Available

R25°C	Tol@25°C
10K, 20K 50K, 100K	± 2, 3, 5, 10%

R-T Curve Information

Beta	
25/75	3965 ± 2%
25/85	3977 ref.

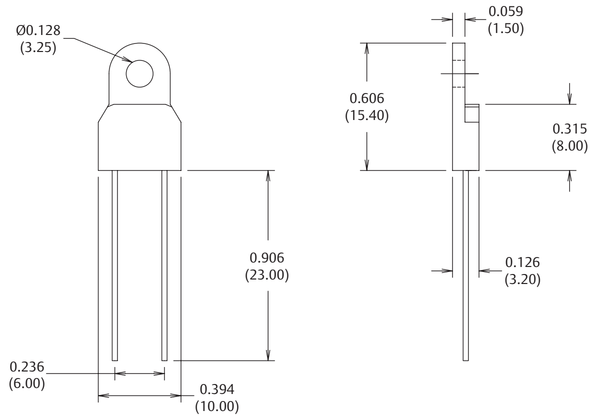
Marking

Resistance value at 25°C

UL Approved

File E179543

Physical Dimensions



Dimensions are shown in inches and (millimeters).

Resistance vs. Temperature Multiplier Values

To use, multiply the resistance at 25°C by the given multiplier at the desired temperature.

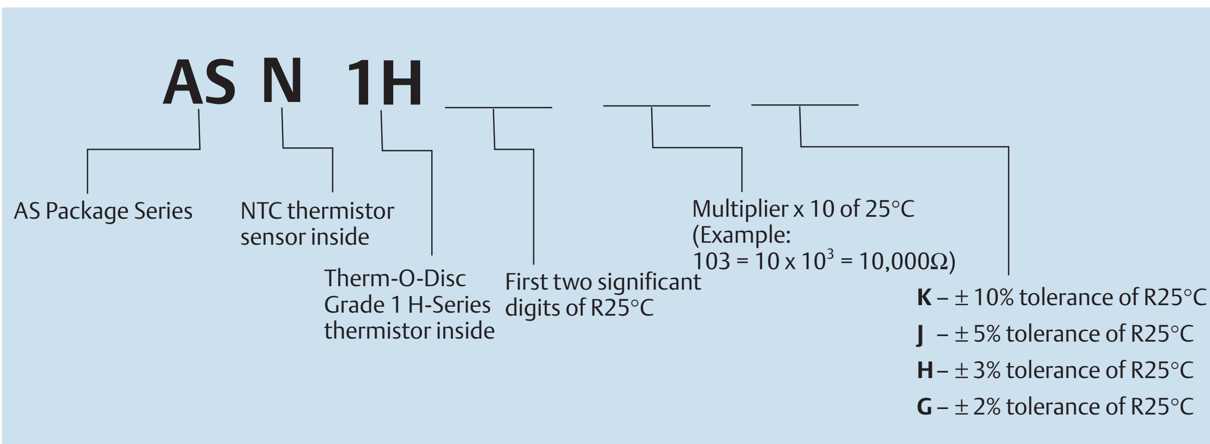
Example – What would be the nominal resistance of an ASN1H103K at 75°C?
Resistance at 25°C is 10,000Ω
Multiplier at 75°C is 0.1480
10,000 x 0.1480 = 1480Ω

Temp. °C	Multiplier	Temp. °C	Multiplier
-40°	33.600	85°	0.1070
-35°	24.270	90°	0.09150
-30°	17.700	95°	0.07870
-25°	13.040	100°	0.06800
-20°	9.7060	105°	0.05920
-15°	7.2940	110°	0.05170
-10	5.5319	115°	0.04500
-5°	4.2324	120°	0.03900
0°	3.2654	125°	0.03400
5°	2.5396	130°	0.03000
10°	1.9903	135°	0.02650
15°	1.5714	140°	0.02350
20°	1.2493	145°	0.02090
25°	1.0000	150°	0.01850
30°	0.8056	155°	0.01620
35°	0.6530	160°	0.01450
40°	0.5327	165°	0.01300
45°	0.4370	170°	0.01180
50°	0.3603	175°	0.01070
55°	0.2986	180°	0.00970
60°	0.2488	185°	0.00870
65°	0.2083	190°	0.00790
70°	0.1752	195°	0.00720
75°	0.1480	200°	0.00650
80°	0.1255		

Tolerance Adder vs. Temperature

(Per MIL-T-23648A) – As temperature deviates from 25°C in either direction, the tolerance increases slightly from the specified tolerance at 25°C by an additional amount.

Product Numbering System



TO-92 PACKAGE TEMPERATURE SENSOR

NTC Thermistor Probes

Applications

- Radial NTC disc replacement
- Probe designs
- PCB temperature monitoring
- Power supply fan control

Operating Temperature Range

-40° to 140°C

Thermal Time Constant

3 Seconds typical (oil); 11 Seconds typical (air)

Dissipation Constant

4.5 mW/°C nominal (as measured per MIL-T-23648A)

UL Approved

File E179543

R-T Curve Information

Beta	Grade A	Grade P
25/75	3965 ± 2%	3727 ± 3%
25/85	3977 ref	3740 ref

Values Available

R25°C	R-T Curve	Tol@25°C
2.2K, 5K, 10KΩ	Grade 'A'	± 5, 10%
12KΩ	Grade 'P'	± 5, 10%

R-T Formula

$1/T = a + b(\ln R) + c(\ln R)^3$

$T = °K + °C + 273.15$

Values for 10K at 25°C

$a = 1.125498166 \times 10^{-3}$

$b = 2.346771694 \times 10^{-4}$

$c = 8.579674698 \times 10^{-8}$

Values for 2.2K at 25°C

$a = 1.475299487 \times 10^{-3}$

$b = 2.379161126 \times 10^{-4}$

$c = 1.043992967 \times 10^{-7}$

Values for 5K at 25°C

$a = 1.28465279 \times 10^{-3}$

$b = 2.361952829 \times 10^{-4}$

$c = 9.323605226 \times 10^{-8}$

Values for 12K at 25°C

$a = 9.922701816 \times 10^{-4}$

$b = 2.398955735 \times 10^{-4}$

$c = 1.308746273 \times 10^{-7}$

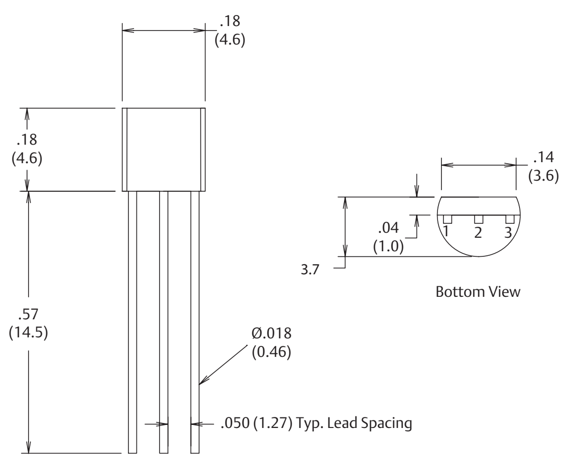
Marking

TOD, R25°C nominal value

Electrical Connections

Pin 1 and Pin 3, Pin 2 no connection (optional lead removal is available)

Physical Dimensions



Dimensions are shown in inches and (millimeters).

Resistance vs. Temperature Multiplier Values

To use, multiply the resistance at 25°C by the given multiplier at the desired temperature.

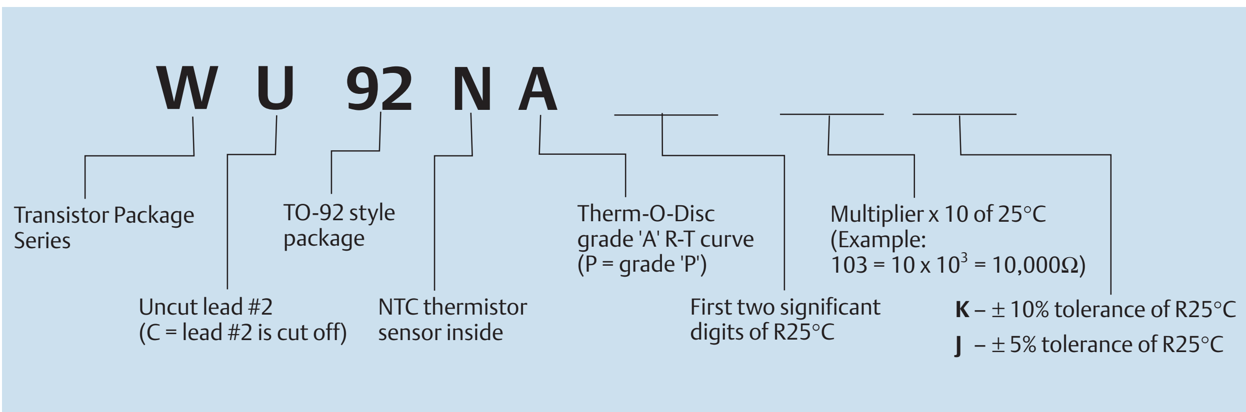
Example – What would be the nominal resistance of a WU92NA-103K at 75°C?
Resistance at 25°C is 10,000Ω
Multiplier at 75°C is 0.1480
10,000 x 0.1480 = 1480Ω

Temp. °C	Grade A	Grade P	Temp. °C	Grade A	Grade P
-40°	33.600	25.792	55°	0.2986	0.3219
-35°	24.270	19.117	60°	0.2488	0.2711
-30°	17.700	14.308	65°	0.2083	0.2293
-25°	13.040	10.808	70°	0.1752	0.1948
-20°	9.7060	8.235	75°	0.1480	0.1662
-15°	7.2940	6.328	80°	0.1255	0.1423
-10	5.5319	4.902	85°	0.1070	0.1223
-5°	4.2324	3.826	90°	0.09150	0.1055
0°	3.2654	3.008	95°	0.07870	0.09133
5°	2.5396	2.383	100°	0.06800	0.07935
10°	1.9903	1.899	105°	0.05920	0.06917
15°	1.5714	1.524	110°	0.05170	0.06048
20°	1.2493	1.231	115°	0.04500	0.05305
25°	1.0000	1.0000	120°	0.03900	0.04668
30°	0.8056	0.8171	125°	0.03400	0.04119
35°	0.6530	0.6713	130°	0.03000	0.03645
40°	0.5327	0.5544	135°	0.02650	0.03234
45°	0.4370	0.4603	140°	0.0235	0.02878
50°	0.3603	0.3841			

Tolerance Adder vs. Temperature

(Per MIL-T-23648A) – As temperature deviates from 25°C in either direction, the tolerance increases slightly from the specified tolerance at 25°C by an additional amount.

Product Numbering System

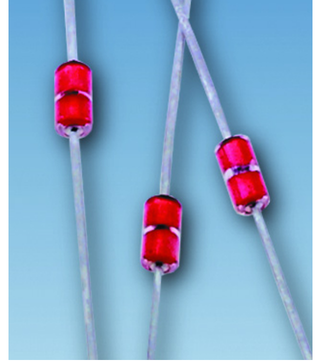


Currently Available P/N's

WU and C92NA-222J and K
WU and C92NA-502J and K
WU and C92NA-103J and K
WU and C92NP-123J and K

H-SERIES AXIAL LEADED

NTC Thermistor Probes



Hermetically Sealed NTC Thermistors

H-series, glass-encapsulated NTC thermistors are small, rugged devices hermetically sealed for long-term stability and electrical isolation. They are recommended for use when fast response times and interchangeability are required.

These thermistors are suitable for applications requiring resistances in the 2KΩ to 1MΩ range. Precision 'Grade 1' thermistors are also available when tighter tolerances and interchangeability are required.

Electrical Properties

The chart shows the specifications for standard H-Series thermistors. This chart can be used as a guide in designing thermistor circuitry for a specific application. The resistance of all thermistors is given at 25°C under zero power.

Standard Values

Base P/N	R25°C (Ω)	Body Style	R-T Grade
2H202T	2000	DO-35	2
1H302T	3000	DO-41	1
1H502T	5000	DO-41	1
2H502T	5000	DO-35	2
1H103T	10,000	DO-35	1
1H203T	20,000	DO-35	1
1H303T	30,000	DO-35	1
1H503T	50,000	DO-35	1
1H104T	100,000	DO-35	1
4H204T	200,000	DO-35	4
4H504T	500,000	DO-35	4
4H105T	1,000,000	DO-35	4

Thermal Characteristics

Body Style	Dissipation Constant	Thermal Time Constant (air)
DO-35	2mW/°C	8 seconds
DO-41	4mW/°C	10 seconds

Dissipation Constant – The amount of power required to raise the temperature of the thermistor, in still air, 1°C over the ambient temperature.

Thermal Time Constant – The amount of time required for a thermistor to change 63.2% of the temperature difference between its initial and final sensing temperature in a step-function change of temperature.

UL Ratings

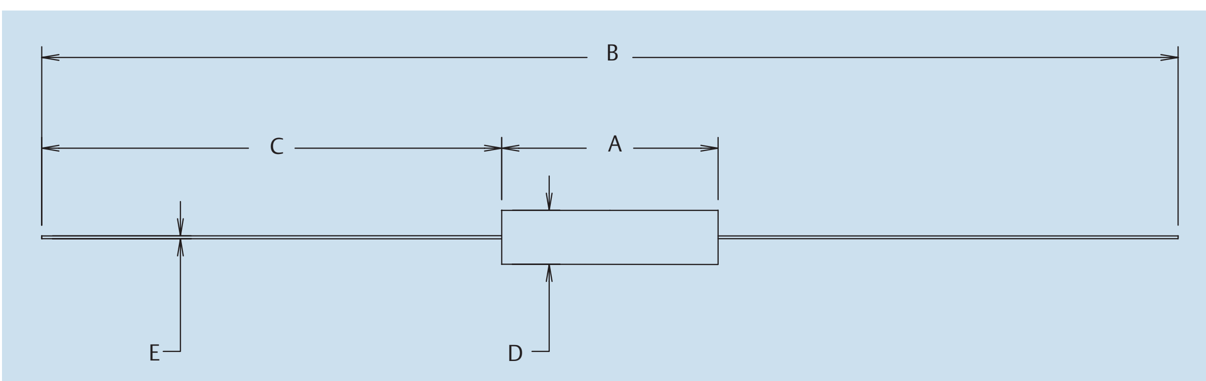
UL File Number: E179543
UL Specification: UL1434
UL Temperature ratings:

‘Grade 1’ parts:	‘Class 1’ -40° to +150°C Limiting	‘Class 2’ -40° to +200°C Limiting
‘Grade 2’ parts:	‘Class 3’ -40° to +150°C Limiting	
‘Grade 4’ parts:	‘Class 1’ -40° to +150°C Limiting	‘Class 3’ -40° to +200°C Regulating
	‘Class 4’ -40° to +200°C Limiting	

Physical Properties

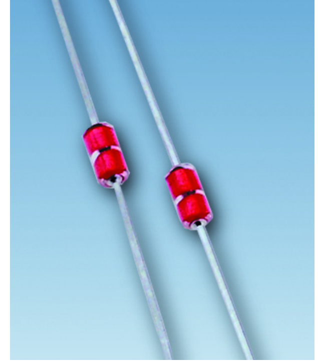
The thermistor material is a ceramic metal oxide. This material is hermetically sealed within a glass capsule. The iron-core, copper-clad leads are tin-plated and can be either welded or soldered into the circuit. Therm-O-Disc will pre-cut and custom-form the leads to any specification. All H-Series NTC thermistors are available on tape and reel for automated insertion.

Axial Leaded Package



Dimensions (millimeters)

Body Style	A	B	C	D	E
DO-35	3.5/4.1	59.1/62.8	27.7/29.4	1.9/2.1	0.48/0.53
DO-41	4.1/4.6	59.1/62.8	27.3/29.0	2.1/2.7	0.73/0.79



Product Numbering System

___ H ___ 07 ___ TR

1 – Grade
2 – Grade
4 – Grade

Package:
H – Glass diode

Resistance @ 25°C:
10,000Ω = 10 x 10^3 = 103
30,000Ω = 30 x 10^3 = 303

Configuration number:
Physical and electrical characteristics
(blank = standard)

T – Tin-plated lead
G – Gold-plated lead

TR – Tape and reel (optional)
Tape and reel spec is EIA-296-E
5K pcs/reel

Standard Tolerances

Base part numbers are +/-10% at 25°C. Other standard tolerances available are: 5, 4, 3, 2 and 1% at 25°C. Tolerances other than those listed and tolerances at temperatures other than 25°C are also available.

Precision H-Series

'Grade 1' 10K, 20K, 30k, 50K and 100KΩ parts are available in a special ±2% version that is tested at multiple temperature points to ensure an accuracy of ±1°C from 0° to 100°C. (Example: P1H103T)

Specifications for Standard H Series Thermistors

To use this chart, multiply the thermistor's resistance at 25°C by the multiplier at the desired temperature. The alpha value is the rate of resistance change with temperature expressed in -%/°C.

Temp. °C (°F)	Grade 1 Multiplier	Grade 1 Alpha	Grade 2 Multiplier	Grade 2 Alpha	Grade 4 Multiplier	Grade 4 Alpha
-40 (-40)	33.600	-6.6%	21.7000	-5.9%	45.5	-7.2%
-35 (-31)	24.270	6.4%	16.3042	5.7%	32.5	7.1%
-30 (-22)	17.700	6.1%	12.3688	5.5%	23.0	7.0%
-25 (-13)	13.040	5.9%	9.46998	5.4%	16.7	6.7%
-20 (-4)	9.706	5.8%	7.31432	5.3%	12.1	6.4%
-15 (5)	7.294	5.6%	5.69676	5.2%	8.9	6.3%
-10 (14)	5.5319	5.4%	4.47247	4.8%	6.6	6.2%
-5 (23)	4.2324	5.3%	3.53814	4.7%	4.9	6.0%
0 (32)	3.2654	5.2%	2.81947	4.6%	3.716	5.9%
5 (41)	2.5396	5.1%	2.26248	4.5%	2.816	5.6%
10 (50)	1.9903	4.8%	1.82766	4.3%	2.150	5.5%
15 (59)	1.5714	4.7%	1.48587	4.2%	1.650	5.3%
20 (68)	1.2493	4.5%	1.21540	4.1%	1.2820	5.2%
25 (77)	1.0000	4.4%	1.000000	4.0%	1.0000	5.0%
30 (86)	0.8056	4.3%	0.827413	3.9%	0.7853	4.9%
35 (95)	0.6530	4.2%	0.688312	3.7%	0.6207	4.8%
40 (104)	0.5327	4.0%	0.575566	3.6%	0.4935	4.6%
45 (113)	0.4370	3.9%	0.483685	3.5%	0.3947	4.5%
50 (122)	0.3603	3.8%	0.408417	3.4%	0.3175	4.4%
55 (131)	0.2986	3.6%	0.346447	3.3%	0.2568	4.2%
60 (140)	0.2488	3.6%	0.295179	3.2%	0.2088	4.1%
65 (149)	0.2083	3.5%	0.252567	3.1%	0.1707	4.0%
70 (158)	0.1752	3.4%	0.216991	3.1%	0.1402	4.0%
75 (167)	0.1480	3.3%	0.187161	3.0%	0.1157	3.9%
80 (176)	0.1255	3.3%	0.162045	2.9%	0.0959	3.8%
85 (185)	0.1070	3.3%	0.140811	2.8%	0.0799	3.7%
90 (194)	0.0915	3.2%	0.132972	2.8%	0.0668	3.6%
95 (203)	0.0787	3.1%	0.107442	2.7%	0.0561	3.5%
100 (212)	0.0680	3.0%	0.0943195	2.6%	0.0473	3.4%
105 (221)	0.0592	2.9%	0.0830615	2.6%	0.0400	3.3%
110 (230)	0.0517	2.8%	0.0733706	2.5%	0.0340	3.2%
115 (239)	0.0450	2.7%	0.0650015	2.5%	0.0290	3.1%
120 (248)	0.0390	2.6%	0.0577511	2.4%	0.0249	3.1%
125 (257)	0.0340	2.6%	0.0514507	2.4%	0.0214	3.0%
130 (266)	0.0300	2.5%	0.0459596	2.3%	0.0184	3.0%

Temp. °C (°F)	Grade 1 Multiplier	Grade 1 Alpha	Grade 2 Multiplier	Grade 2 Alpha	Grade 4 Multiplier	Grade 4 Alpha
135 (275)	0.0265	2.4%	0.4116020	2.2%	0.0159	2.9%
140 (284)	0.0235	2.4%	0.0369537	2.1%	0.0138	2.9%
145 (293)	0.0209	2.3%	0.0332571	2.1%	0.0120	2.8%
150 (302)	0.0185	2.3%	0.0300000	2.0%	0.0105	2.7%
155 (311)	0.0162	2.3%	0.0271230	2.0%	0.00918	2.7%
160 (320)	0.0145	2.2%	0.0245755	1.9%	0.00806	2.6%
165 (329)	0.0130	2.2%	0.0223144	1.9%	0.00709	2.6%
170 (338)	0.0118	2.2%	0.0203030	1.8%	0.00626	2.5%
175 (347)	0.0107	2.2%	0.0185096	1.8%	0.00553	2.4%
180 (356)	0.0097	2.1%	0.0169072	1.7%	0.00491	2.4%
185 (365)	0.0087	2.0%	0.0154724	1.7%	0.00436	2.3%
190 (374)	0.0079	2.0%	0.0141851	1.7%	0.00388	2.3%
195 (383)	0.0072	1.9%	0.0130277	1.6%	0.00346	2.2%
200 (292)	0.0065	1.9%	0.0119853	1.6%	0.00310	2.2%
205 (401)	0.00598	1.9%	—	—	0.00278	2.2%
210 (410)	0.005462	1.8%	—	—	0.00250	2.1%
215 (419)	0.004997	1.8%	—	—	0.00225	2.1%
220 (428)	0.004580	1.8%	—	—	0.00203	2.1%
225 (437)	0.004205	1.8%	—	—	0.00184	2.0%
230 (446)	0.003867	1.7%	—	—	0.00166	1.9%
235 (455)	0.003561	1.7%	—	—	0.00151	1.9%
240 (464)	0.003285	1.6%	—	—	0.00137	1.9%
245 (473)	0.003035	1.6%	—	—	0.00125	1.8%
250 (482)	0.002808	1.5%	—	—	0.00114	1.8%
255 (491)	—	—	—	—	—	—
260 (500)	—	—	—	—	—	—
265 (509)	—	—	—	—	—	—
270 (518)	—	—	—	—	—	—
275 (527)	—	—	—	—	—	—
280 (536)	—	—	—	—	—	—
285 (545)	—	—	—	—	—	—
290 (554)	—	—	—	—	—	—
295 (563)	—	—	—	—	—	—
300 (572)	—	—	—	—	—	—

Beta Values

Beta is an industry term used to describe the steepness of the R-T curve. The greater the beta, the steeper the R-T curve. Please note beta is dependent on the two reference temperatures. Therm-O-Disc uses 25/75 as its standard. The other temperatures are some of the most commonly used.

R-T Grade	25°/75°C	0°/50°C	25°/50°C	25°/85°C
Grade 1	3965	3905	3934.4	3977.5
Grade 2	3530	3400	3450.7	3550
Grade 4	4500	4210	4421	4516

APPLICATION NOTES – DEFINITIONS

NTC Thermistor 101

Thermistors – Thermally sensitive resistors whose primary function is to exhibit a change in electrical resistance with a change in its body temperature. They are passive electronic semiconductors whose electrical resistance varies with temperature and lies between that of conductors and insulators. An important characteristic of thermistors is their extreme sensitivity to relatively minute temperature changes.

While most metals have small positive temperature coefficients of resistance, thermistors exhibit a wide range of negative and positive temperature coefficients. The large coefficients and the non-linear resistance temperature characteristics of thermistors enable them to perform many unique functions.

NTC Thermistors – The resistance of an NTC (Negative Temperature Coefficient) thermistor decreases as its temperature increases. This characteristic gives rise to many uses in electronic design, as a temperature sensor and in applications where temperature can be used to control circuit operation.

NTCs are made from various material grades of manganese, nickel, cobalt and other metallic oxides. After these raw materials are milled and mixed in accurate proportions, suitable binders are added and the units are pressed or extruded to the desired shape. Thermistor elements are then sintered at temperatures above 1000°C under carefully controlled atmospheric and temperature conditions to produce hard ceramic material. Various electrode materials can then be attached and the ceramic can be machined into various geometries.

Alpha (α) – is used to express the slope of the R-T curve at any given point. It is a measure of the rate of change in resistance of the thermistor at a specific temperature. Alpha is expressed in -%/°C. Since the R-T curve is not linear, alpha is greater at lower temperatures than at higher temperatures. For example, the alpha of a typical NTC at -50°C might be as high as –8%/°C whereas its alpha at 150°C might be less than –2%/°C.

Alpha is useful in determining what tolerances are required for a particular application. For example, say the alpha value at 25°C for a particular NTC was –4.4%/°C. If the application requires a temperature accuracy of ±0.5°C, then the tolerance would need to specified as ±2.2%, (4.4%*0.5).

Beta – A constant, expressed in °K, which describes the resistance-temperature characteristics of an NTC thermistor. The beta of a thermistor depends on its physical composition. It is a ratio of resistances at two given temperatures and is defined as:

β = $\ln$(R1/R2)/(1/T1-1/T2) where R1 is the resistance at temperature #1 and R2 is the resistance at temperature #2. Resistance is measured in Ohms and temperature is measured in Kelvin (°K).

This is a somewhat antiquated concept used to describe the resistance vs. temperature slope. The number is dependent on the two temperatures selected. In summary, the higher the Beta, the steeper the resistance vs. temperature slope.

It is important to note that the value for beta is dependent on the two temperatures used to calculate it. This is important to know because there is no industry standard for these two temperatures – every manufacturer uses a different set of numbers. So it may be possible that although the beta values from two manufacturers are different, they may be describing the same R-T characteristics because the two temperatures used to calculate the beta numbers are different.

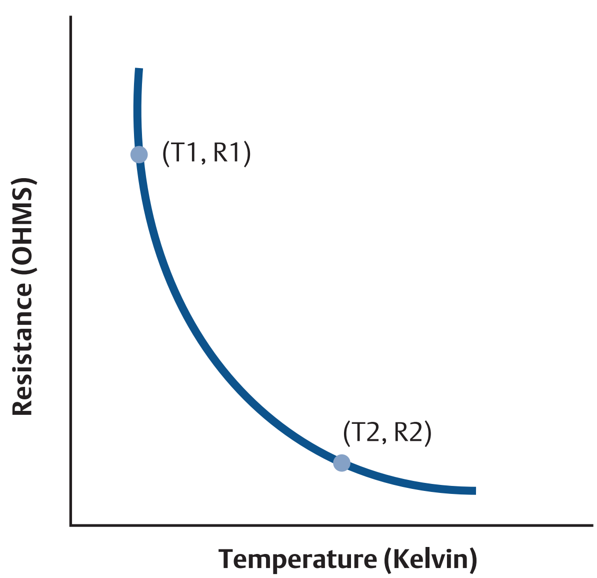
For example, Therm-O-Disc's 'Grade 1' material has a beta value of 3965 for 25/75°C, 3905 for 0/50°C, 3934.4 for 25/50°C and 3977.5 for 25/85°C.

Beta used to be used to calculate R-T characteristics over a relatively narrow band using the following formula:

β = 2076.02 $\ln$(R25°C/R75°C) using a beta based on 25/75°C.

The concept of using beta to calculate R-T values has given way to the Steinhart-Hart equation, which gives very accurate results over a much wider range of temperature.

NTC Thermistor Resistance vs. Temperature Curve



Dissipation Constant – The amount of power required to raise the temperature of the thermistor, in still air, 1°C over the ambient. For example, if a part has a dissipation constant of 4mW/C and the part is dissipating 2mW, then the thermistor's resistance will read 0.5°C above the ambient temperature. The lower the dissipation constant, the more susceptible a part is to self-heating. Similarly, the lower the power dissipated through the thermistor, the closer it will read to the actual ambient temperature.

The amount of heat energy a thermistor dissipates is dependent on its surface area, insulation and ambient medium, among other factors.

Interchangeability – Refers to the ability to substitute a thermistor into an electronic circuit without recalibrating, and then predict the maximum change in temperature measurement. It also means the temperature tolerance of the NTC.

Steinhart-Hart Equation – The basis for much of the terminology is used throughout the industry to describe thermistor characteristics. Every NTC thermistor with a different base resistance and beta value has a unique Resistance vs. Temperature Curve. The curve is best defined as a polynomial equation. The more terms used in the polynomial, the more accuracy is achieved. However, for practical purposes, the Steinhart-Hart equation is extremely accurate for most applications.

$\mathbf{1/T = a + b(\ln R) + c(\ln R)^3}$ – where T is in °K (°C+273.15)

Some of the more popular Therm-O-Disc part number constants:

'Grade 1', 10KΩ (1H103 parts, WC/WU92NA103 parts)
$a = 1.125190920 \times 10^{-3}$
$b = 2.347363293 \times 10^{-4}$
$c = 8.551343472 \times 10^{-8}$

'Grade 1', 50KΩ (1H503 parts)
$a = 7.602330993 \times 10^{-4}$
$b = 2.313331379 \times 10^{-4}$
$c = 7.172007260 \times 10^{-8}$

'Grade 1', 100KΩ (1H104 parts)
$a = 6.053377486 \times 10^{-4}$
$b = 2.298626288 \times 10^{-4}$
$c = 6.706142562 \times 10^{-8}$

Thermal Time Constant – The amount of time required for a thermistor to change 63.2% of the temperature difference between its initial and final sensing temperature in a step-function change of temperature. This value is dependent on the sensing medium – air, oil, etc. The part will respond faster in a liquid ambient compared to an air environment. Also, a part will respond to moving air faster than still air as moving air has the ability to move more heat towards or away from the part.

Tolerance on Resistance – A method of gauging precision in NTC thermistors. Tolerance is the percentage of variation in resistance from nominal that can be expected from a thermistor at a specific temperature. Since the tolerance of a thermistor varies with temperature, tolerance is always stated as a percentage at a specified temperature. The industry standard is to use 25°C as the base temperature, unless another temperature is specified.

In temperature measurement applications, it is generally more appropriate to determine the temperature tolerance than the tolerance on resistance. This is a difficult concept for many electrical engineers who are accustomed only to resistance tolerance for resistive elements. The results are usually an over-specifying of the thermistor's tolerance, which adds unnecessary cost to the thermistor.

Temperature tolerance is calculated using the alpha value as previously mentioned.

Temperature Tolerance = Resistance tolerance/α

Zero-Power Resistance – Refers to the resistance of a thermistor, at a specific temperature, with zero electrical power applied. Thermistor reference resistances are always given at zero-power. In practice, zero-power is not truly possible, as some small amount (albeit very minute) of current must flow through the thermistor to measure the resistance. The trick is to use a current so significantly low (compared to the thermistor's dissipation constant) that it essentially becomes zero-power.

Important Notice

The user must determine the suitability of our products for the application and assumes all risk and liability associated therewith.

APPLICATION NOTES

NTC Thermistor 102

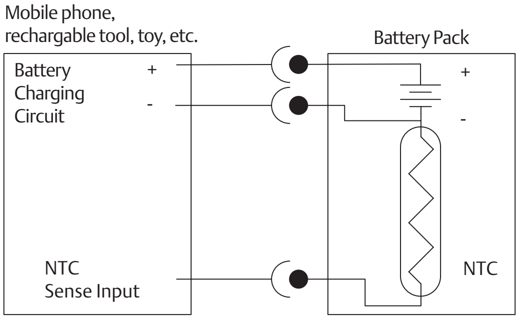
Temperature Measurement

The NTC thermistor offers a practical, low-cost solution to most temperature measurement and control applications. High sensitivity and accuracy can be obtained by placing a thermistor in contact with the material that one wishes to measure the temperature of. Sensing circuitry can use the thermistor as one leg of a Wheatstone bridge for linear voltage outputs, or as a single, simple voltage divider. In the voltage divider, if the resistance of the fixed resistor is chosen to equal the thermistor's resistance at the mid-point of a temperature range, the output voltage is fairly well linearized for temperature ranges under 50°C.

The output of either the Wheatstone bridge or voltage divider can be routed to an A/D pin on any microprocessor equipped for extremely accurate temperature measurement.

In temperature measuring applications, the current through the NTC is limited to a value so that appreciable self-heating does not occur. The device may be calibrated to read directly as a thermometer or used in a control circuit. The high resistance of a thermistor, as compared to the resistance of long runs of wire, makes possible accurate temperature measurements and control from remote locations.

An example of temperature measurement is in battery charging applications. Despite many claims from various silicon semiconductor manufacturers, NTC thermistors remain one of the most economical, simple and reliable methods used to determine termination of the fast-charge cycle for rechargeable batteries.

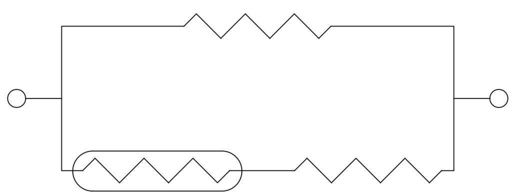


Battery NTC

Temperature Compensation

NTC thermistors are effective in offsetting the effect of temperature on other circuit components. Unlike the NTC thermistor, the resistance of most circuit components increases as the circuit heats up. Thermistor temperature compensation improves the performance of these thermally sensitive circuits and extends their useful operating range. Thermistors can be used to stabilize the gain of a solid state amplifier or to provide temperature compensation in circuits where copper coils are used.

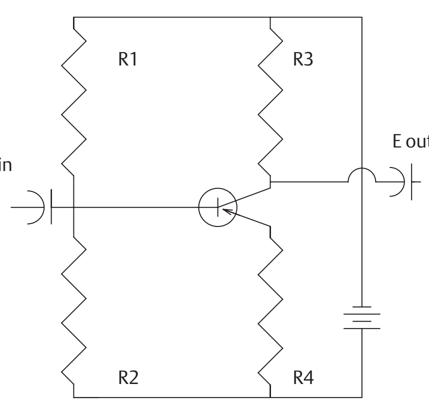
Thermistors used in compensation circuits typically will have fixed resistors used in parallel and series combinations with the NTC. Note that the resulting R-T curve is much shallower and linear than the non-networked NTC.



Rs = (resistor series)
Rp = (resistor parallel)

NTC Net

Thermistors can be used to accomplish temperature compensation of transistor circuits. Use of an NTC thermistor in shunt with R2 in the following circuit is an example of this application.



NTC Compensator

Airflow and Liquid-Level Sensing

The small size and fast response of NTC thermistors make them ideal for liquid and airflow detection circuitry. A thermistor dissipates significantly more heat in a liquid or in an air stream than it does in still air. A liquid-level or airflow circuit can use the difference in the voltage drop across an exposed thermistor. A liquid-level or airflow circuit can use the difference in the voltage drop across an exposed thermistor as input to a comparator or to actuate a signal.

Another design uses a Wheatstone bridge with a thermistor in opposing legs, where the input voltage keeps both thermistors in their self-heating range. The bridge is balanced when both thermistors are in identical environments. When liquid covers the sensing thermistor's housing, or the air begins to flow past it, the bridge becomes unbalanced.

Design Assistance

Temperature Accuracy – Because the resistance of the thermistor changes at a fairly large amount compared to the temperature, it is possible to achieve fairly high temperature accuracy with fairly loose resistance tolerances. For example, the 'Grade 1' NTC sensors change at a rate of approximately -4.4%/C at 25°C. Therefore, a +/-5% part has an accuracy of about +/-1.1°C at 25°C. Similarly, a +/-1% part has an accuracy of about +/-0.2°C at 25°C.

As the rate of resistance change varies with temperature, the tolerance required to achieve a certain accuracy of temperature also varies. For instance, to achieve a +/- 1°C accuracy at 100°C, a resistance tolerance of about +/-2.8% is required, while a +/-5% tolerance at 0°C will also achieve the same precision.

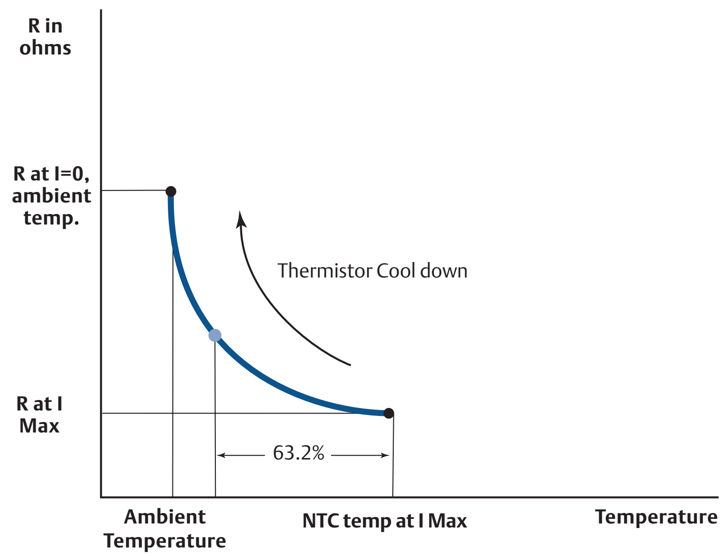
Working Example: Suppose a 10K-ohm part with a +/-1°C accuracy at 50°C is required. Through either the multiplier tables or the R-T formula, we determine the resistances at 49°, 50° and 51°C (50+/- 1°C):
49°C = 3743 ohms nom.
50°C = 3603 ohms nom.
51°C = 3469 ohms nom.

For an accuracy of +/-1°C, we would want a minimum of 3469 ohms and a maximum of 3743 ohms, or 3603 ohms +3.9%/-3.7%.

A deviation of +1.2% is possible on the tolerance at 50°C. If we subtract 1.2% from 3.7%, we find we would need a guard-banded part of at least +/-2.5% at 25°C. The closest standard 10KΩ part would be the 1H10301T, which offers a +/-2% tolerance at 25°C. If a large volume of parts are required and cost is of the essence, it would probably be worthwhile to have a special part number with a +/- 2.5% tolerance not listed here to be selected by a Therm-O-Disc sales engineer.

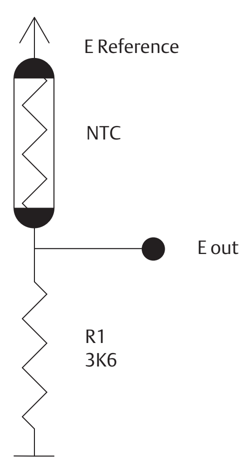
Resistance Tolerance Over Temperature – As the temperature deviates from 25°C, the tolerance increases. If a specific tolerance at a temperature other than 25°C is required, parts can be either "guard band" selected for a tighter tolerance at 25°C that will allow parts to fall within specifications at the desired temperature, or they can be selected by Therm-O-Disc specifically at that temperature.

Explanation of Thermal Time Constant

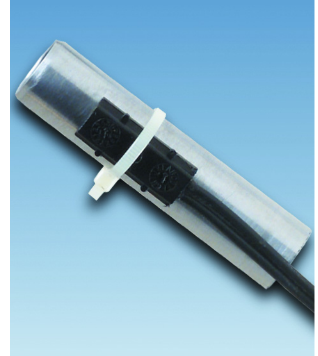


Thermal Time Constant – This is not how fast a thermistor will respond to a change in temperature. It is a method of comparing the relative speeds of thermistors with each other. By definition, the thermal time constant is the amount of time required for a thermistor to change 63.2% of the temperature difference between its initial and final sensing temperatures in a step-function change in temperature. This value is dependent on the sensing medium – still air, moving air, liquid, etc.

Working with Dissipation Constants – For this example, we will use Therm-O-Disc part number 1H103T, which has a published dissipation constant of 2mW/°C. For this example we will use a temperature range of 0° to 100°C and a desired temperature error of 0.1°C. To determine the maximum voltage applied to the circuit, we need to know the minimum resistance of the NTC. For the 1H103T, it would be 680Ω at the upper limit of 100°C. This means the series resistance of the NTC and R1 would be 4280Ω. And since $P=E^2/R$ and $E=\sqrt{PR}$ and if P=0.2mW=0.1°C self-heating, then $E= \sqrt{0.0002*4280}=0.925$volts.



NTC Divider



Interfacing NTC Thermistors – Thermistors require control circuitry to act on a power circuit. To replace a bimetal thermostat, a thermistor requires a few fixed resistors and a transistor/power semiconductor as a minimum. Since thermistors are solid state, they are much less prone to fatigue and can last hundreds of thousands of cycles with minimal change in characteristics, providing very high system reliability.

Comparing NTC Thermistors with other sensors – Thermistors still provide a very versatile and economical means of temperature sensing for electronic circuits. Automotive, appliance, electronic and industrial markets continue to increase their usage of these devices despite the numerous options available for temperature sensing.

A summary of the most popular temperature sensing options:

Sensor Type	Features	Disadvantages
Bimetal Thermostat	Able to sense temperature and provide circuit control	Limited to one or two temperatures
Thermocouple	Capable of high temperatures	Requires special thermocouple wire back to pcboard, low sensitivity
RTD	Capable of high temperatures and high accuracy	Can be expensive, low sensitivity
IC's(special temperature sensing types)	Linear voltage outputs or digital outputs are easy to interface and program	Can be expensive, low sensitivity, limited temperature range,difficult to sense temperatures away from a pcboard
NTC Thermistors	High sensitivity, low cost, wide temperature range, easiest to interface with a pcboard from a remote location	Nonlinear output without using additional components or software correction

The "Wind Chill" Factor – Because many people are concerned with weather, the wind chill index is a very familiar concept. Many engineers using thermistors are concerned that moving air will effect the temperature reading of the thermistors.

The question is: "Does the wind chill factor effect thermistors in sensing the correct ambient temperature?" The answer is no—at least not the way most people would believe.

For a working example, consider a car with a thermistor mounted to the outside to sense temperature outside the car. This is a fairly standard automotive application. Let's say the car has a digital display that converts the thermistor's resistance to read directly in °C. Now pretend this car is in a heated garage where the temperature is 12°C and the temperature outside the garage and surrounding area is 0°C. Inside the garage, the digital display reads 12°C. Now if the car is driven outside the garage and parked in the 0°C ambient, the gauge will slowly change from 12°C to 0°C, as we would expect.

Now consider what would happen if this was repeated except that the car kept moving once outside. This movement creates an artificial wind over the thermistor. This 0°C wind cools the once 12°C thermistor down to 0°C much quicker than still air and the gauge would change from 12°C to 0°C that much faster. In fact, the faster the car was moving, the quicker the 12°C to 0°C transition would take place.

Does the temperature gauge ever go below 0°C? No, because the ambient temperature never goes below 0°C and therefore no ΔT is ever created which is necessary to change the readout. To lower the temperature of the thermistor, a ΔT must be created. Simply moving the same temperature of air across the thermistor does not create the necessary ΔT. The only difference the moving air makes is the rate at which the display changes.

So the wind chill factor is at work in getting the thermistor to its final temperature quicker, but it does not allow a mis-reading of temperature due to it.

Wind chill is the effect of a cooler wind blowing on a heated object such as the human body or a house. Because cooler-moving air is able to move more heat away from a heated object than in still air, it can act in the same manner as colder, yet still air. The key factors are a ΔT between the air and the human body and the fact that the body is heated and warmer to the surrounding air. In the thermistor, the still air has the same temperature as the moving air (no ΔT) and the fact that the thermistor is not heated artificially above the ambient temperature.

Important Notice

The user must determine the suitability of thermistors for the application and assumes all risk and liability associated therewith.

TEMPERATURE MEASUREMENT WITH MICROPROCESSORS

Many individuals designing temperature-measuring circuits are apprehensive to use thermistors because they have a non-linear resistance versus temperature curve. There are three basic methods of temperature measurement using NTC thermistors and microprocessors. Two methods involve software linearization and minimal circuitry (usually a single resistor voltage divider into the ADC). The third method involves hardware linearization and minimal software.

1. **Software linearization using the Steinhart equation NTC Thermistors resistance vs. temperature characteristics track the following equation:** $1/T = a + b(\ln R) + c(\ln R)^3$ where T is in °K (°K = 273.15 + °C) and a, b, c are constants particular to an individual thermistor R-T curve and resistance at 25°C.

The a, b, c constants for most common Therm-O-Disc thermistors

	P1H103T	P1H503T	P1H104T
a =	$1.125190920 \times 10^{-3}$	$7.602330993 \times 10^{-4}$	$6.053377486 \times 10^{-4}$
b =	$2.347363293 \times 10^{-4}$	$2.313331379 \times 10^{-4}$	$2.298626288 \times 10^{-4}$
c =	$8.551343472 \times 10^{-8}$	$7.172007260 \times 10^{-8}$	$6.706142562 \times 10^{-8}$

The user may want to experiment with rounding these constants to less digits. As presented above, the accuracy is approximately less than 0.05°C accurate for 0-100°C.

2. **Software linearization using a look up table.** Rather than calculating temperature, a lookup table can be used to minimize calculation cycle time. This is very simple to program in assembly language, it is the most popular method with our customers and much less demanding on a microprocessor than calculating the Steinhart-Hart equation.

3. Hardware Linearization using a basic bridge circuit *(see figure 1)*.

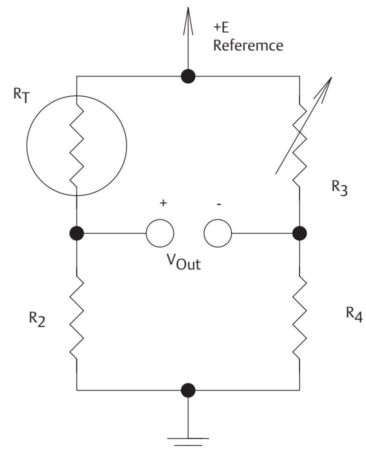


Figure 1

Basic bridge circuit.

R_T is a Therm-O-Disc P1H103T, which has a resistance of 10K ohms ±2% at 25°C and an interchangeability of 1°C. The P1H103T has the following R-T table:

°C	Resistance-ohms
0	32,654
10	19,903
20	12,493
30	8,056
40	5,327
50	3.603
70	1,752
100	680

Voltage into the bridge should be in the area of two volts to keep any self-heating of the thermistor to a minimum.

R_2 and R_4 in the bridge circuit should be of equal value and equal to R_T at its mid-point in the intended temperature range. For a 0° to 50°C range, (32° to 122°F), a 10K ohm resistor is chosen. A circuit reading 0° to 100°C (32° to 212°F), should use 3.6K ohm resistors for R_2 and R_4. Trimmer

R_3 should be set to yield a 0 volt output for 0°C. In both cases, this would be approximately 33K ohms. This can be calibrated with ice water and a thermometer. Care should be taken that the water does not short out the thermistor.

Analog to Digital Conversion

Interfacing this circuit with a microprocessor requires an analog to digital converter. An ADC with an adjustable voltage reference and a differential analog voltage input is preferred. The support circuitry will vary with the microprocessor used. If this type of ADC is not available, the voltage output of the bridge may be fed into a 741-type op-amp as shown *(see figure 2)*.

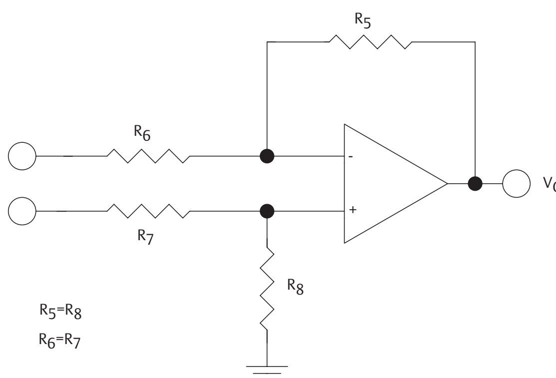


Figure 2

Analog and digital conversion.

A Programming Tip

One may notice the 0°C to 50°C circuit is more linear than the 0°C to 100°C circuit. Likewise, a short segment of 15°C on the 0°C to 50°C circuit is even more linear. Most applications call for reading temperatures between 10°C and 30°C (50°F to 86°F) or a similar interval. Under those conditions, the reading is very linear. Programs over wide ranges that require critical readings should be divided into four or five ranges with a different formula, however slight, to calculate actual temperature. It should be noted that self-heating of the thermistor may also give a false reading 0.1°C higher than the actual ambient temperature.

Another hardware trick to maximize voltage output in all three linearization methods is to pulse a 5V logic signal to the input of the bridge or voltage divider instead of a steady 2V input. With a short pulse, a reading can be made before self heating can effect the thermistor's resistance, thus reducing the amount of signal amplification required.