TEMPERATURE SENSORS

Temperature sensors are manufactured in-house mainly catering to customers who are major electrical machinery manufacturers and to some process based application where the main sensors are RESISTANACE TEMPERTURE DEETECTORS (RTD"S), THERMOCOUPLES NTC's and PTC's

RAVIRAJ Process Controls, A-677, Khairne MIDC, TTC Industrial Estate, Khopar Khairne, NAVI MUMBAI -400709

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CATALOUGE ON TEMEPRATURE SENSORS, MANUFACTURED AT RAVIRAJ PROCESS CONTROLS

RAVIRAJ
PROCESS CONTROLS

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RAVIRAJ PROCESS CONTROLS HAS BEEN SUPPORTING CUSTOMERS IN THE DEVELOPMENT AND MANUFACTURE OF TEMPEREATURE SENSORS

THEY ARE APPROVED FOR USE IN SPECIAL ENVIRONMENTS WITH APPROVALS FROM

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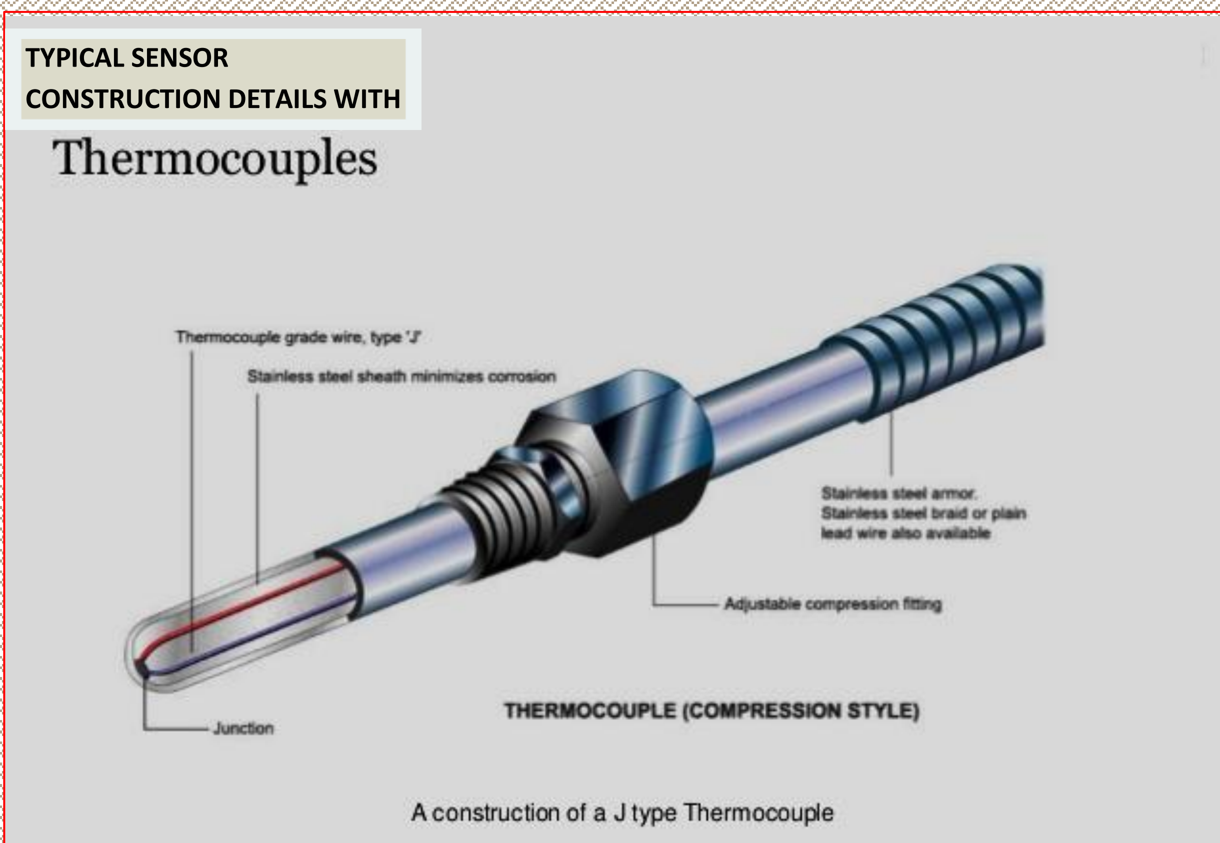
TEMPERATURE SENSORS

TEMPERATURE IS AN IMPORTANT PARAMETER HENCE MEASUREMENT IS EQUALLY OF IMPORTANTANCE SINCE THIS IS A MEASURE OF THERMAL HEAT ENERGY, WHICH IS CRITICAL FOR THE PERFORMANCE OF MACHINES, PROCESS REACTIONS, A MEASURE OF THE EFFICIENCT USE/WASTAGE OF THERMAL ENERGY, IN ADDITION THE DAMAGING EFECT - EXCESS HEAT WILL CULMINATE IN HIGHER TEMPERATURES LEADIND TO DAMAGES TO EQUIPMENT, EVENTUALLY LEADING TO FIRE.

This leads us to the fact that the sensors used for measurement has to be capable of detecting the temperature condition with accuracy, quick in response, capable of operating in the temperature range being measured and compatible for use in the environment in which it has to operate, having features built into it for proper installation. Today the most popular temperature measurement sensors employed in the industry are, either an RTD (Resistance Temperature Detector) element or Thermocouple (different types of metals) as a sensor.

Typical construction features of these sensors are shown for a better understanding

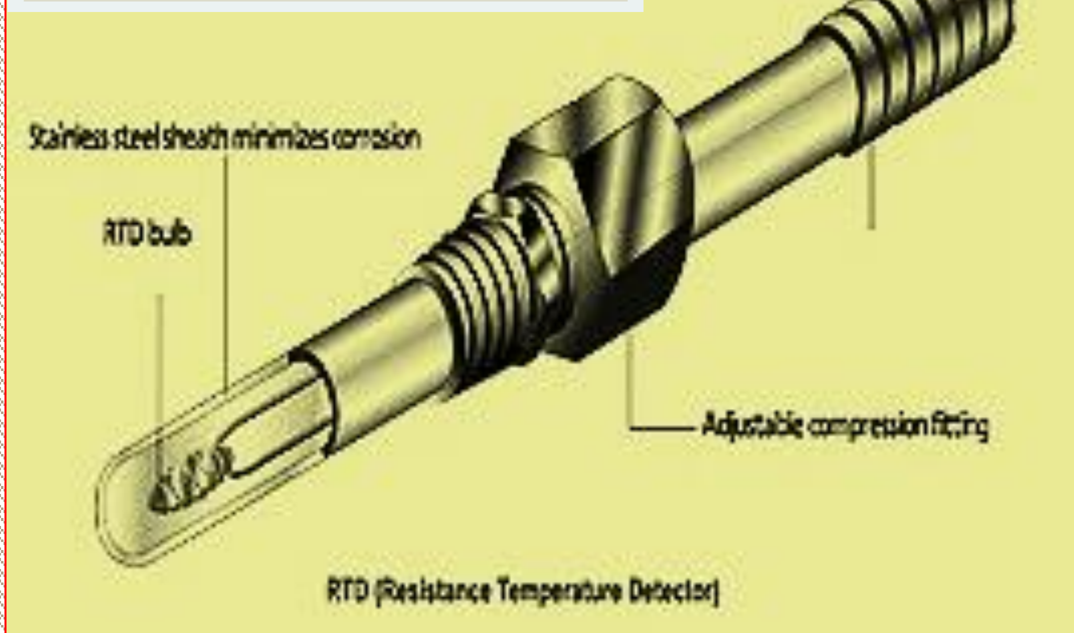


A construction of a J type Thermocouple

Typical THERMOCOUPLE sensor construction details

TYPICAL SENSOR CONSTRUCTION DETAILS

RESITANCE TEMPERATURE DETECTOR



Typical RTD sensor construction details

THE IMPORTANTANT COMPONENTS AS SEEN FOR THE SENSOR CONSTRUCTION CAN BE CLASSIFIED INTO

1. **THERMOCOUPLE**
   A. THE THERMOCOUPLE, DISSIMILAR METAL WIRE JUNCTION, THE SENSOR
   B. THE APPROPRIATE METAL SHEATH FOR THE SENSOR PROTECTION
   C. THE SPECIFIED LEADS WIRE OF REQUIRED SPECIFICATION FOR SIGNAL CONNECTIVITY
   D. ADJUSTABLE COMPRESSION FITTING FOR PROCESS CONNECTION

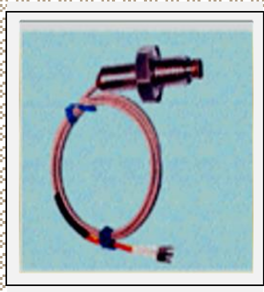
2. **RESISTAANCE TEMPERATURE DETECTOR (RTD)**
   A. THE RTD SENSOR BULB
   B. THE APPROPRIATE METAL SHEATH FOR THE SENSOR PROTECTION
   C. THE SPECIFIED LEADS WIRE OF REQUIRED SPECIFICATION FOR SIGNAL CONNECTIVITY
   D. ADJUSTABLE COMPRESSION FITTING FOR PROCESS CONNECTION

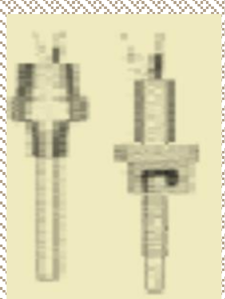
SENSOR TYPES MANUFACTURED

SPECIAL DESIGNS OF SENSORS FOR

1. BEARING TEMPERATURE MEASUREMENT

Bearing temperature is a critical parameter for any rotating machine. The life of a machine depends on the operating temperature of its bearings.
The Bearing Temperature Detectors (BTD's) are encapsulated in Brass, Aluminum or Stainless Steel (grade 304 / 316) bulbs which are constructed as per the specifications of the customer.


The BTD's are available in Simplex as well as in Duplex Combination

Simplex 2wire, 3wire and 4wire construction

Duplex 4wire, 6wire and 8wire construction.

PTFE cables of different types and lengths provided as per requirements of the customer.
The measuring elements are **Pt100 thin film sensors** complying with **DIN EN60751** confirming to class A. Sensors confirming to Class B can be made as per requirement.

BTD's are available in insulated as well as non-insulated variants.

The BTD's can be extended for process industry applications for Temperature sensing.

RTD accuracy – Class A, Class B, 1/3 DIN, 1/10 DIN

ACTUAL	RTD ACCURACY +/- °C PT100 Ω ALPHA 0.003850 to DIN 43760 IEC751 DIN EN 60 751			
	B CLASS	A CLASS	BAND 3 (1/3 DIN)	BAND 5 (1/10 DIN)
-200 °C	1.30 °C	0.55 °C	0.39 °C	0.38 °C
-150 °C	1.05 °C	0.45 °C	0.23 °C	0.21 °C
-100 °C	0.80 °C	0.35 °C	0.15 °C	0.12 °C
-90 °C	0.75 °C	0.33 °C	0.14 °C	0.10 °C
-80 °C	0.70 °C	0.31 °C	0.13 °C	0.09 °C
-70 °C	0.65 °C	0.29 °C	0.12 °C	0.08 °C
-60 °C	0.60 °C	0.27 °C	0.11 °C	0.07 °C
-50 °C	0.55 °C	0.25 °C	0.10 °C	0.06 °C
-40 °C	0.50 °C	0.23 °C	0.10 °C	0.06 °C
-30 °C	0.45 °C	0.21 °C	0.09 °C	0.05 °C
-20 °C	0.40 °C	0.19 °C	0.09 °C	0.04 °C
-10 °C	0.37 °C	0.17 °C	0.08 °C	0.03 °C
0 °C	0.30 °C	0.15 °C	0.08 °C	0.03 °C
10 °C	0.35 °C	0.17 °C	0.09 °C	0.04 °C
20 °C	0.40 °C	0.19 °C	0.10 °C	0.04 °C
30 °C	0.45 °C	0.21 °C	0.11 °C	0.05 °C
40 °C	0.50 °C	0.23 °C	0.12 °C	0.06 °C

RTD accuracy – Class A, Class B, 1/3 DIN, 1/10 DIN

Actual	B CLASS	A CLASS	BAND 3 (1/3 DIN)	BAND 5 (1/10 DIN)
50 °C	0.55 °C	0.25 °C	0.13 °C	0.07 °C
60 °C	0.60 °C	0.27 °C	0.14 °C	0.08 °C
70 °C	0.65 °C	0.29 °C	0.16 °C	0.09 °C
80 °C	0.70 °C	0.31 °C	0.17 °C	0.10 °C
90 °C	0.75 °C	0.33 °C	0.18 °C	0.11 °C
100 °C	0.80 °C	0.35 °C	0.19 °C	0.12 °C
110 °C	0.85 °C	0.37 °C	0.20 °C	0.13 °C
120 °C	0.90 °C	0.39 °C	0.21 °C	0.14 °C
130 °C	0.95 °C	0.41 °C	0.22 °C	0.15 °C
140 °C	1.00 °C	0.43 °C	0.24 °C	0.15 °C
150 °C	1.05 °C	0.45 °C	0.25 °C	0.16 °C
160 °C	1.10 °C	0.47 °C	0.26 °C	0.17 °C
170 °C	1.15 °C	0.49 °C	0.27 °C	0.18 °C
180 °C	1.20 °C	0.51 °C	0.29 °C	0.19 °C
190 °C	1.25 °C	0.53 °C	0.30 °C	0.21 °C
200 °C	1.30 °C	0.55 °C	0.31 °C	0.22 °C

PROCESS SENSORS

For Process temperature measurement applications for the entire operating range of the process similar construction followed using RTD, or Thermocouples sensors except that the material of the sheath will depend on the compatibility with the process fluid, the end fitting designed to suit the requirement (typical examples, flanged or, compression or, tri-clover fitting etc.), the finished product having lengths as per requirement, which could be a few millimeters to meters. Flame proof and transmitter mounted sensors available as per specification.

Material test certificates are available for the sheath material, including all test reports.

Revised Standard IEC 60751

General requirements

Tolerance classes

Temperature range of validity

The temperature ranges of validity of tolerance classes for resistors given in Table 2 are based on the working experience with film and wire resistors showing that in these ranges most resistors can maintain their tolerances and other performance characteristics. The value of –196 °C was chosen as being close to the boiling point of liquid nitrogen.

Resistors

The tolerance values of resistors are classified in Table 2. These tolerances apply for resistors of any value of R_0. Where the specified temperature range of a particular resistor is smaller than in this table, this shall be stated.

Table 1 – Tolerance classes for resistors

For wire wound resistors		For film resistors Tolerance		Tolerance value °C
Tolerance class	**Temperature range of validity °C**	**Tolerance class**	**Temperature range of validity °C**	
W 0.1	–100 to +350	F0.1	0 to +150	± (0.1 + 0.0017 ∣ t ∣)
W 0.15	–100 to +450	F 0.15	–30 to +300	± (0.15 + 0.002 ∣ t ∣)
W 0.3	–196 to +660	F 0.3	–50 to +500	± (0.3 + 0.005 ∣ t ∣)
W 0.6	–196 to +660	F 0.6	–50 to +600	± (0.6 + 0.01 ∣ t ∣)
a ∣ t ∣ = modulus of temperature in °C without regard to sign.				

Thermometers

The tolerance values of resistance thermometers are classified in Table 3. These tolerances apply for thermometers of any value of R_0. Where the specified temperature range of a particular thermometer is smaller than in this table, this shall be stated.

Table 2 – Tolerance classes for thermometers

Temperature range of validity	Tolerance class °C		Tolerance values °C
	Wire wound resistors	**Film resistors**	
AA	**–50 to +250**	**0 to +150**	**± (0.1 + 0.0017 ∣ t ∣)**
A	**–100 to +450**	**–30 to +300**	**± (0.15 + 0.002 ∣ t ∣)**
B	**–196 to +600**	**–50 to +500**	**± (0.3 + 0.005 ∣ t ∣)**
C	**–196 to +600**	**–50 to +600**	**± (0.6 + 0.01 ∣ t ∣)**
∣ t ∣ = modulus of temperature in °C without regard to sign.			

Special tolerance classes and special temperature ranges of validity

Tolerances and ranges of validity which differ from values given in Table 1 and Table 2shall be agreed between manufacturer and user.
Recommended special tolerance classes are constructed as multiples or fractions of class B tolerance values. A special tolerance class without specification of the temperature range of validity is not permissible. It is left to the manufacturers and users to establish tolerances for their thermometers or resistors at temperatures outside the ranges in Table 1 and Table 2.
Special tolerance classes may also be defined for restricted or extended temperature ranges, e.g. for the ranges –196 °C to 850 °C or - 200 °C to 660 °C.

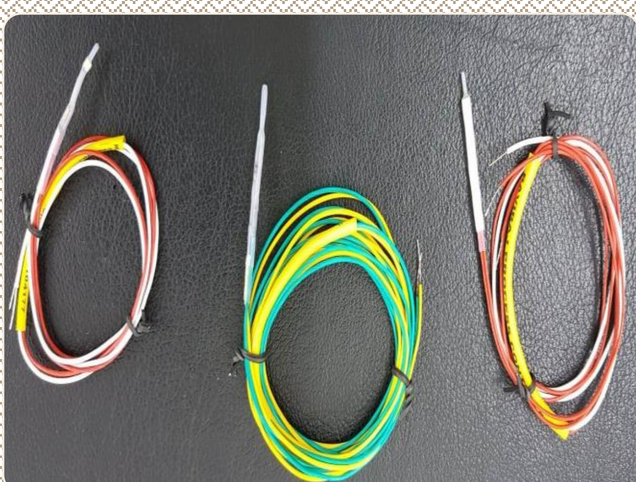
Measuring current
The measuring current to the resistor shall be limited to a value at which the self-heating of the thermometer under conditions as specified in Self-heating does not exceed 25 % of the tolerance value of the declared tolerance class. The measuring current is usually not more than 1 mA for a 100 Ω wire wound resistor.

Electrical supply
Resistors and thermometers shall be constructed so that they are suitable for use in measuring systems using direct current or alternating current at frequencies up to 100 Hz. Some measuring systems may require operation at higher frequencies.

Self-heating
The self-heating coefficient expressed in °C/mW shall be evaluated at a temperature between 0 °C and 30 °C in flowing air with a velocity of (3 ± 0.3) m/s and/or in flowing water with a velocity >0.2 m/s. The self-heating under the above mentioned conditions shall not exceed 25 % of the tolerance value of the declared tolerance class at the declared maximum measuring current.

CATALOUGE

RESISTANCE TEMPERATURE DETECTOR



BEARING RTD/PROCESS RTD SENSORS

SPECIFICATION

TYPE	PT 100 / PT 1000 / PT 10
ELEMENT	SIMPLEX / DUPLEX
SHEATH MATERIAL	SS304 / SS316 / PTFE
SHEATH DIMENSION	AS PER CUSTOMER SPECIFICATION
TEMPERATURE RANGE	-50°C TO 200°C
CALIBRAITON STANDARD	IEC 60751 ά= 0.003850
ACCURACY CLASS	CLASS - A CLASS - B
SENSING CURRENT	10 mA (MAX.)
DIELECTRIC STRENGTH	1.0 KV ; 1.5KV ; 2.0 KV ; 2.5 KV FOR 60 SEC.
INSULATION RESISTANCE	>550 MΩ @ 500 VDC
CONSTRUCTIONAL TYPE	1. HEAD MOUNTED RTD 2. WITHOUT HEAD
LEAD WIRE CONFIGURATION	2 WIRE / 3 WIRE / 4 WIRE /6 WIRE/ 8 WIRE
HEAD	ALUMINUM DIE-CAST HEAD STEEL HEAD BRASS HEAD
LEAD WIRE CONSTRUCTION	SILVER PLATED COPPER WIRE WITH PTFE OR SILICON INSULATION WITH FOLLOWING CONFIGURATION – ➢ TWISTED CABLE ➢ SINGLE CORE CABLE ➢ PTFE /PTFE ➢ PTFE /PTFE/ SS BRAID ➢ PTFE /PTFE/SPC BRAID / PTFE

2. RESISTANCE TEMPERATURE DETECTORS FOR WINDINGS.

The winding is the heart of any electrical machines. In order to maintain the winding and its insulation in a healthy condition, its temperature needs to be monitored and controlled on a continuous basis.

Bulb type winding overhang RTD's for LT motors:

Temperature detectors for measurement of winding temperatures of wire wound stators are encapsulated and sealed in cylindrical Teflon sleeves and overall protected with heat shrinkable Teflon sleeve. These RTD's are available in Simplex as well as in Duplex Combination with 2wire, 3wire and 4wire construction for Simplex and 4wire, 6wire and 8wire construction for Duplex.

Glass Epoxy embedded slot RTD's:

The Winding Temperature Detectors (RTDs) are encapsulated in high temperature class H glass epoxy material.

The sensing elements are either ***Pt100 thin film sensors*** *or* ***Pt100 Platinum wire wound*** *with* ***sensing length from 20 mm to 600 mm long, having thickness of 1.6 mm to 3.0 mm and width above 6.0 mm*** *or as required by the customer.*

RTD's available in ***Simplex*** *having* ***2wire, 3wire*** *and* ***4wire*** *construction and in* ***Duplex 4wire, 6wire and 8wire*** *construction for Duplex.*

The RTD's can be provided with ***high temperature heat shrinkable insulating sleeve*** *on request.*

PTFE cables of various types and lengths *are provided as per the requirements of the customer.*

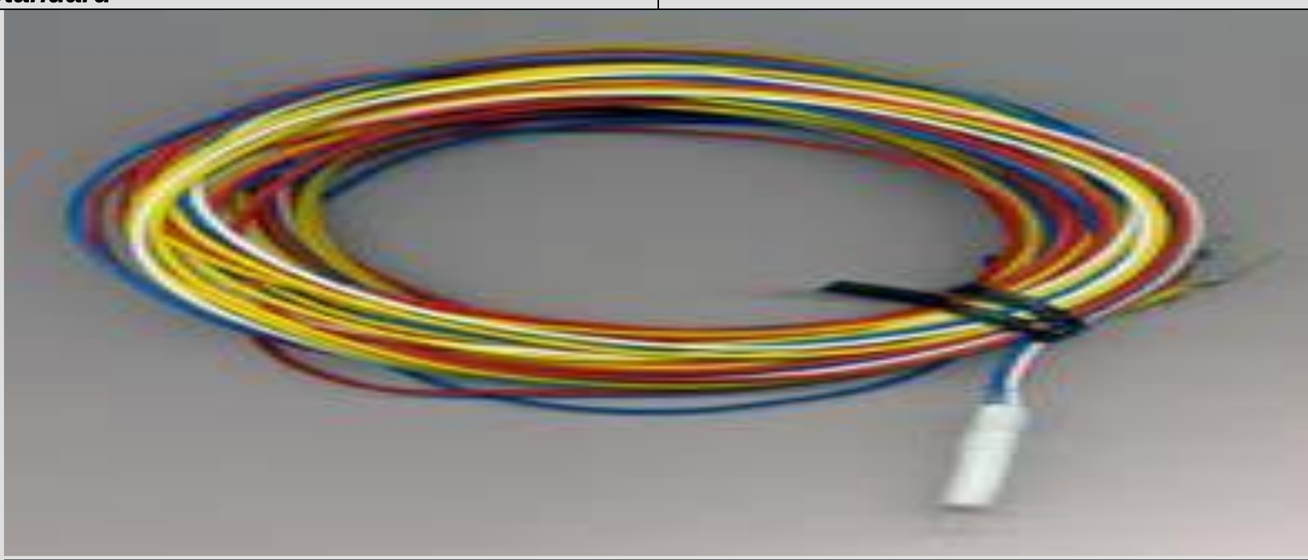
These sensors confirm to DIN EN60751 Standard

Glass Epoxy embedded slot RTD's with shielding:

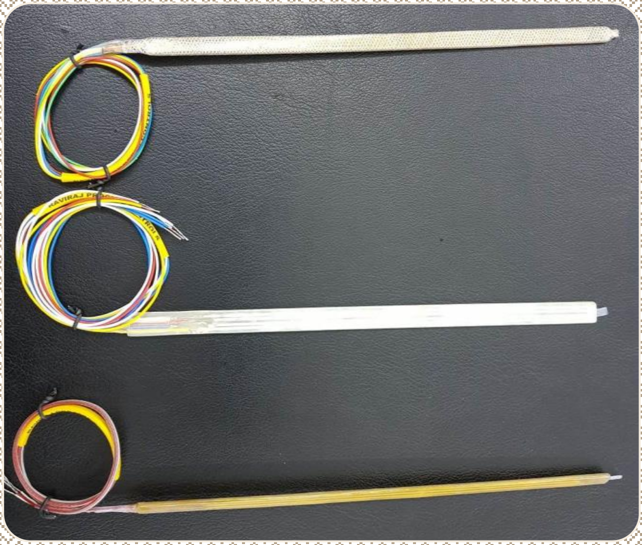
For special applications, ***glass epoxy RTD's*** *are* ***provided with silver plated copper wire shielding over the entire length of the sensing element****. The shielding is connected to an earth lead wire.*

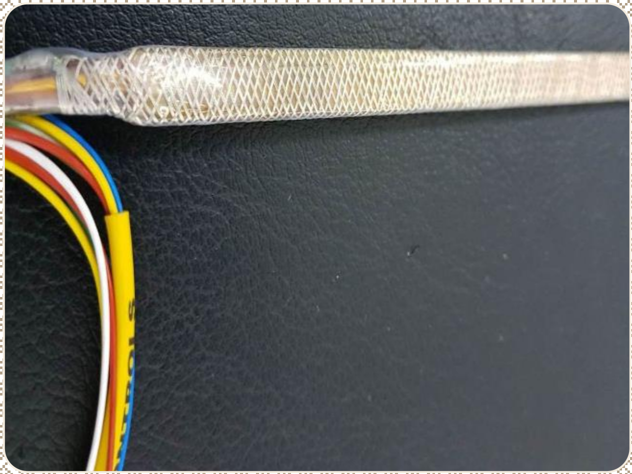
High temperature heat shrink PTFE sleeve *is provided over the shielding for overall protection.*

Temperature detectors for measurement of winding temperatures of wire wound stators are encapsulated and sealed in cylindrical Teflon sleeves and overall protected with heat shrinkable Teflon sleeve. These RTD's are available in ***Simplex with 2wire, 3wire and 4wire construction*** *as well as in* ***Duplex*** *Combination* ***with 4wire, 6wire and 8wire construction****.*



RESISTANCE TEMPERATURE DETECTOR





SLOT RTD

SPECIFICATION

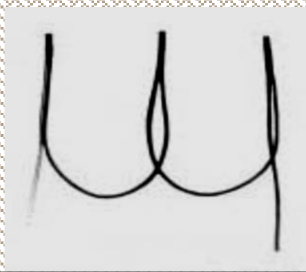
TYPE	PT 100 / PT 1000 / PT 10
ELEMENT	SIMPLEX / DUPLEX
SHEATH	FIBREGLASS SHEET
SHEATH DIMENSION	LENGTH (L) – 20 TO 500 MM WIDTH (W) – 6 TO 20 MM THICKNESS (T) – 0.7 TO 8.0 MM OTHER RANGES OF DIMENSIONS ARE AVAILABLE AS PER CUSTOMER SPECIFICATION
TEMPERATURE RANGE	-50°C TO 180°C
CALIBRAITON STANDARD	IEC 60751 **ά = 0.003850** & **α – 0.003916 (on request as special case for winding RTD element)**
ACCURACY CLASS	CLASS - A CLASS - B
SENSING CURRENT	10 mA (Max.)
DIELECTRIC STRENGTH	1.0 kV ; 1.5kV ; 2.0 kV for 60 Sec. (Optional 5.0 kV)
INSULATION RESISTANCE	>550 MΩ @ 500 VDC
LEAD WIRE CONFIGURATION	2 WIRE / 3 WIRE / 4 WIRE /6 WIRE/ 8 WIRE
LEAD WIRE CONSTRUCTION	SILVER PLATED COPPER WIRE WITH PTFE OR SILICON INSULATION – ➢ TWISTED CABLE ➢ SINGLE CORE CABLE ➢ PTFE /PTFE ➢ PTFE /PTFE/ SS BRAID ➢ PTFE /PTFE/SPC BRAID / PTFE

3. THERMISTORS SINGLE ELEMENT AND TRIPLE ELEMENTS IN SERIES

POSITIVE TEMPERATURE CO-EFFICIENT (PTC)

PTC Thermistors:

Temperature rating	Lead 1	Lead 2
80°C	White	White
90°C	Green	Green
100°C	Red	Red
110°C	Brown	Brown
120°C	Grey	Grey
130°C	Blue	Blue
140°C	Blue	White
145°C	White	Black
150°C	Black	Black
155°C	Blue	Black
160°C	Blue	Red
170°C	White	Green



Three elements in series

Single element

Lug type

Lead colour codes for PTC Thermistor:

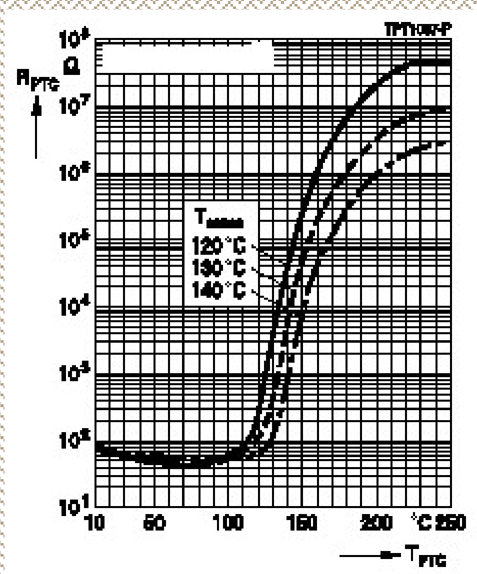
Thermal protection of windings for medium and large rating rotating machines is generally done by using RTD's. For thermal protection of FHP and small rating rotating machines PTC Thermistors are used as switches for switching off the power circuits in case of overshooting of winding temperatures.
The PTC Thermistor features, pellets with insulating encapsulation for high temperature grade. The PTC's have a low resistance, steep R/T curve thereby ensuring its correct response to the operating temperature. These PTC's are provided with silver plated copper conductors with Teflon coating for better electrical insulation good thermal properties. Due to its compact size, the PTC's have fast response time. The temperature characteristics and the colour coding of wires confirm to DIN 44081. For motor protection application, the PTC's are available in single element and triple (series) element combination. The PTC's are available in temperature grade of 80ºC ~ 180ºC and are provided with a standard wire length of 0.5 meters. Different wire lengths can be provided as per customer requirement.

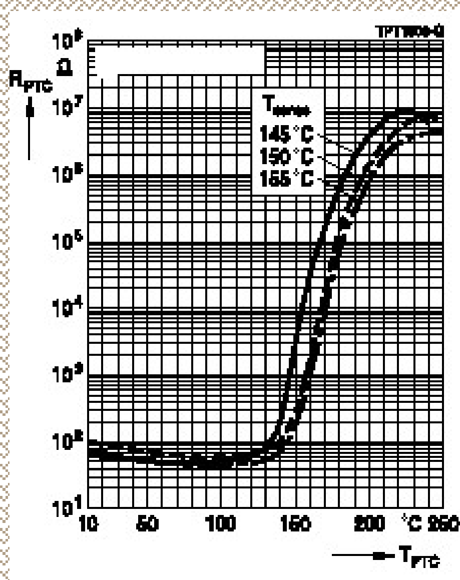
PTC Thermistor resistance values at different operating temperatures:

Temp rating	Ambient	ROT–5°C	ROT (Typical)	ROT+5°C	ROT+15°C
Single element PTC Thermistor					
80 ~180°C	< 250 Ω	< 550 Ω	1000 Ω	> 1330 Ω	> 4000 Ω
Triple element PTC Thermistor					
Temp rating	Ambient	ROT –5°C	ROT (Typical)	ROT +5°C	ROT +15°C
80 ~180°C	< 750 Ω	< 1550 Ω	3000 Ω	> 3990 Ω	> 12000 Ω

Note: ROT = Rated Operating Temperature of the PTC thermistor

Temperature characteristics for PTC thermistors



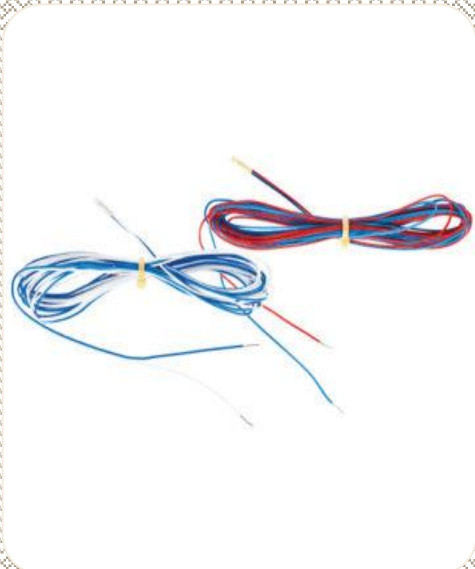


PTC sensors, the short form for POSITIVE TEMPERATURE CO-EFFICIENT sensors, are used extensively for the positive interlock of circuits where temperature rise detection and cut off are critical to avoid exigencies.

The very nature of the sensor ensures at its breakdown temperature range the resistance of the element changes by a substantial value that will ensure positive detection thus eliminate any errors of operation where the signal (resistance) magnification is of sufficient magnitude. Hence it finds wide application in the electrical industry in the detection of temperature of windings, of motors, generators, etc., where the critical temperature limit can be defined based on the class of winding and its tolerance limits.

CATALOUGE

PTC (Positive Temperature Co-efficient) sensors



PTC

SPECIFICATION

ELEMENT	SIMPLEX / TRIPLEX		
SENSOR DIAMETER	1.8 – 2.5 mm		
TEMPERATURE RANGE	PTC 80°C	PTC 130°C	PTC 155°C
	PTC 100°C	PTC 140°C	PTC 160°C
	PTC 110°C	PTC 145°C	PTC 170°C
	PTC 120°C	PTC 150°C	PTC 180°C
DIELECTRIC STRENGTH	2 kV ; 2.5kV		
Resistance @ Room Temperature	< 250 Ω for Single Element < 750 Ω for Triple Element		
Resistance @ (ROT-5)°C	< 550 Ω for Single Element < 1650 Ω for Triple Element		
Resistance @ (ROT)°C	1000 Ω typical for Single Element 3000 Ω typical for Triple Element		
Resistance @ (ROT+5)°C	> 1330 Ω for Single Element > 3990 Ω for Triple Element		
Resistance @ (ROT+15)°C	> 4000 Ω for Single Element > 12000 Ω for Triple Element		
INSULATION RESISTANCE	>550 MΩ @ 500 VDC		
LEAD WIRE SIZE	AWG 24/7/32 ; AWG 26/7/34		
LEAD WIRE CONSTRUCTION	PTFE Insulation over Silver Plated Copper Conductor		

PTC	80	100	110	120	130	140	145	150	155	160	170	180
Lead Wire Colour	White	Red	Brown	Gray	Blue	White	White	Black	Blue	Blue	White	Red
	White	Red	Brown	Gray	Blue	Blue	Black	Black	Black	Red	Green	White

4. THERMISTORS SINGLE ELEMENT AND TRIPLE ELEMENTS IN SERIES

NEGATIVE TEMPERATURE CO-EFFICIENT (NTC)

Negative temperature co-efficient sensors has the resistance decreasing with increasing temeparture, such devices are called negative temperature coefficient (NTC) thermistors. Resistors that are not thermistors are designed to have as close to zero as possible variation in their resistance value over a wide temperature range.

The major applications for NTC's include temperature measurement, compensation, and control. NTC probes are used as resistance thermometers. They are extremely versatile and accurate, also has a good resolution which makes them ideal for a wide variety of applications that measure temperature.

Negative Temperature Coefficient Thermistor

Negative temperature coefficient of resistance thermistors, or *NTC thermistors* for short, reduce or decrease their resistive value as the operating temperature around them increases. Generally, NTC thermistors are the most commonly used type of temperature sensors as they can be used in virtually any type of equipment where temperature plays a role.

NTC temperature thermistors have a negative electrical resistance versus temperature (R/T) relationship. The relatively large negative response of an NTC thermistor means that even small changes in temperature can cause significant changes in its electrical resistance. This makes them ideal for accurate temperature measurement and control.

A thermistor is an electronic component whose resistance is highly dependent on temperature so if we send a constant current through the thermistor and then measure the voltage drop across it, we can thus determine its resistance and temperature.

NTC thermistors reduce in resistance with an increase in temperature and are available in a variety of base resistances and curves. They are usually characterised by their base resistance at room temperature, that is 25°C, (77°F) as this provides a convenient reference point. So for example, 2kΩ at 25°C, 10kΩ at 25°C or 47kΩ at 25°C, etc.

Another important characteristic is the "B" value. The B value is a material constant which is determined by the ceramic material from which it is made and describes the gradient of the resistive (R/T) curve over a particular temperature range between two temperature points. Each thermistor material will have a different material constant and therefore a different resistance versus temperature curve.

Then the B value will define the thermistors resistive value at the first temperature or base point, (which is usually 25°C), called T1, and the thermistors resistive value at a second temperature point, for example 100°C, called T2. Therefore the B value will define the thermistors material constant between the range of T1 and T2. That is BT1/T2 or B25/100 with typical NTC thermistor B values given anywhere between about 3000 and about 5000.

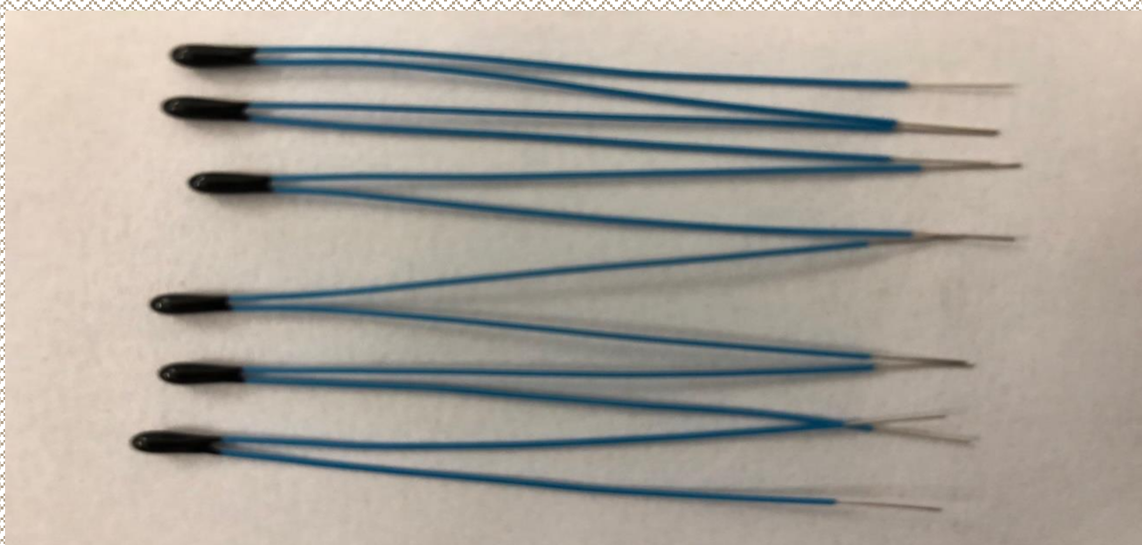
Note however, that both the temperature points of T1 and T2 are calculated in the temperature units of Kelvin where 0°C = 273.15 Kelvin. Thus a value of 25°C is equal to 25°C + 273.15 = 298.15K, and 100°C is equal to 100°C + 273.15 = 373.15K, etc.

So by knowing the B value of a particular thermistor (obtained from manufacturers datasheet), it is possible to produce a table of temperature versus resistance to construct a suitable graph using the following normalised equation:

Thermistor Equation

$$B_{(T1/T2)} = \frac{T_2 \times T_1}{T_2 - T_1} \times \ln\left(\frac{R_1}{R_2}\right)$$

- Where:
- T1 is the first temperature point in Kelvin
- T2 is the second temperature point in Kelvin
- R1 is the thermistors resistance at temperature T1 in Ohms
- R2 is the thermistors resistance at temperature T2 in Ohms



Thermistor Example No1

A 10kΩ NTC thermistor has a B value of 3455 between the temperature range of 25°C to 100°C. Calculate its resistive value at 25°C and at 100°C.

Data given: B = 3455, R1 = 10kΩ at 25°C. In order to convert the temperature scale from degrees Celsius, °C to degrees Kelvin add the mathematical constant 273.15

The value of R1 is already given as its 10kΩ base resistance, thus the value of R2 at 100°C is calculated as:

$$B_{(25/100)} = \frac{(100+273.15)\times(25+273.15)}{(100+273.15)-(25+273.15)} \times \ln\left(\frac{10000}{R_X}\right)$$

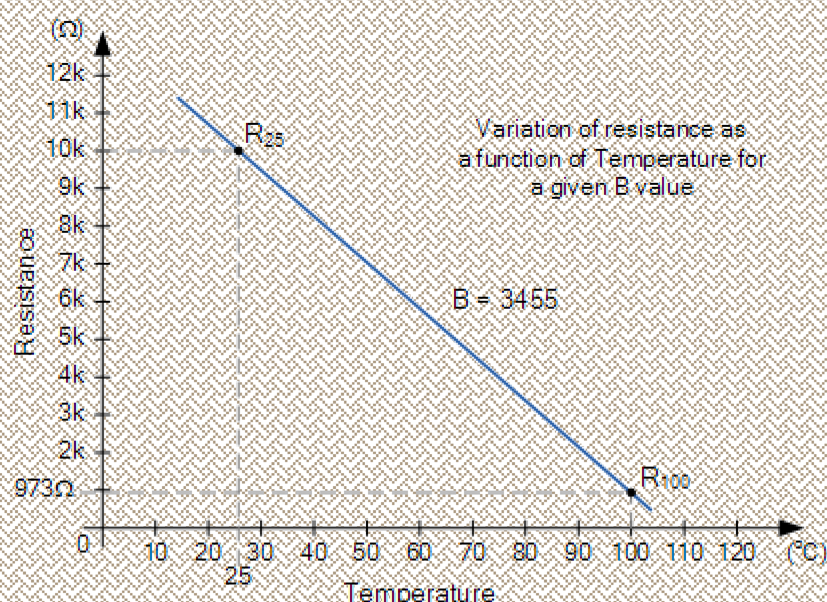
$$3455 = \frac{111254.6725}{75} \times \ln\left(\frac{10000}{R_X}\right)$$

$$3455 = 1483.4 \times \ln\left(\frac{10000}{R_X}\right)$$

$$e^{\left[\frac{3455}{1483.4}\right]} = \frac{10000}{R_X}$$

$$\therefore R_X = \frac{10000}{e^{2.33}} = 973\Omega$$

Giving the following two point characteristics graph of:

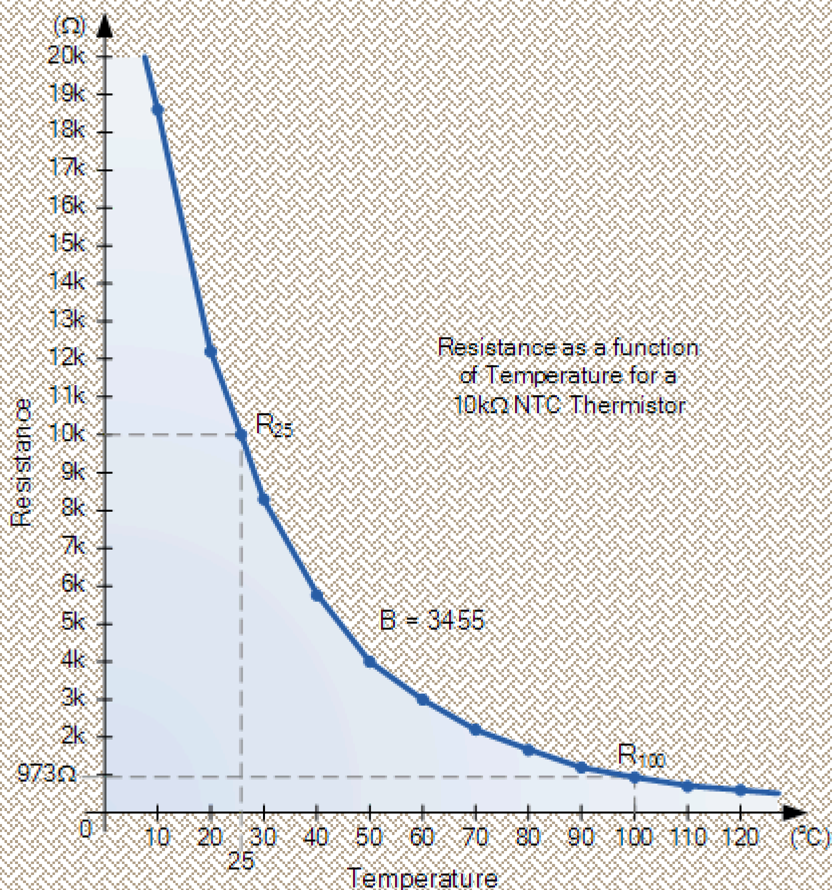


Note that in this simple example, only two points were found, but generally thermistors change their resistance exponentially with changes in temperature so their characteristic curve is nonlinear, therefore the more temperature points are calculated the more accurate will be the curve.

Temperature (°C)	10	20	25	30	40	50	60	70	80	90	100	110	120
Resistance (Ω)	18476	12185	10000	8260	5740	4080	2960	2188	1645	1257	973	765	608

and these points can be plotted as shown to give a more accurate characteristics curve for the 10kΩ NTC Thermistor which has a B-value of 3455.

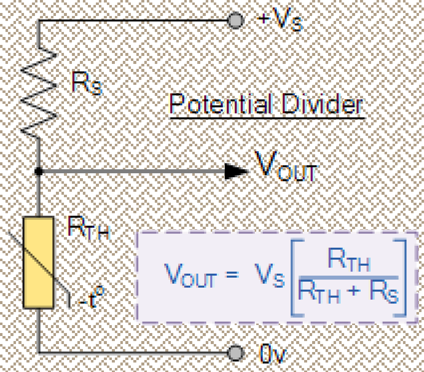
NTC Thermistor Characteristics Curve



Notice that it has a negative temperature coefficient (NTC), that is its resistance decreases with increasing temperatures.

Using a Thermistor to Measure Temperature.

So how can we use a thermistor to measure temperature. Hopefully by now we know that a thermistor is a resistive device and therefore according to Ohms law, if we pass a current through it, a voltage drop will be produced across it. As a thermistor is an active type of a sensor, that is, it requires an excitation signal for its operation, any changes in its resistance as a result of changes in temperature can be converted into a voltage change.



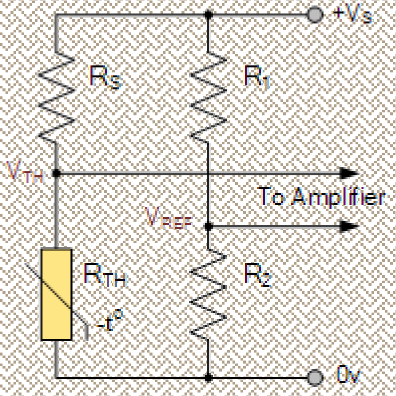
The simplest way of doing this is to use the thermistor as part of a potential divider circuit as shown. A constant voltage is applied across the resistor and thermistor series circuit with the output voltage measured across the thermistor.

If for example we use a 10kΩ thermistor with a series resistor of 10kΩ, then the output voltage at the base temperature of 25°C will be half the supply voltage.

When the resistance of the thermistor changes due to changes in temperature, the fraction of the supply voltage across the thermistor also changes producing an output voltage that is proportional to the fraction of the total series resistance between the output terminals.

Thus the potential divider circuit is an example of a simple resistance to voltage converter where the resistance of the thermistor is controlled by temperature with the output voltage produced being proportional to the temperature. So the hotter the thermistor gets, the lower the voltage.

If we reversed the positions of the series resistor, RS and the thermistor, RTH, then the output voltage will change in the opposite direction, that is the hotter the thermistor gets, the higher the output voltage.



We can use ntc thermistors as part of a basic temperature sensing configuration using a bridge circuit as shown. The relationship between resistors R1 and R2 sets the reference voltage, VREF to the value required. For example, if both R1and R2 are of the same resistive value, the reference voltage will be equal to half of the supply voltage. That is Vs/2.

As the temperature and therefore the resistance of the thermistor changes, the voltage at VTH also changes either higher or lower than that at VREF producing a positive or negative output signal to the connected amplifier.

The amplifier circuit used for this basic temperature sensing bridge circuit could act as a differential amplifier for high sensitivity and amplification, or a simple Schmitt-trigger circuit for ON-OFF switching.

The problem with passing a current through a thermistor in this way, is that thermistors experience what is called self-heating effects, that is the I2.R power dissipation could be high enough to create more heat than can be dissipated by the thermistor affecting its resistive value producing false results.

Thus it is possible that if the current through the thermistor is too high it would result in increased power dissipation and as the temperature increases, its resistance decreases causing more current to flow, which increases the temperature further resulting in what is known as *Thermal Runaway*. In other words, we want the thermistor to be hot due to the external temperature being measured and not by itself heating up.

Then the value for the series resistor, RS above should be chosen to provide a reasonably wide response over the range of temperatures for which the thermistor is likely to be used while at the same time limiting the current to a safe value at the highest temperature.

One way of improving on this and having a more accurate conversion of resistance against temperature (R/T) is by driving the thermistor with a constant current source. The change in resistance can be measured by using a small and measured direct current, or DC, passed through the thermistor in order to measure the voltage drop produced.

5. THERMOCOUPLE TEMPERATURE SENSORS

Thermocouples work on the principle of generation of a voltage based on the temperature difference across a hot junction and a cold junction, the junction formed out of dissimilar metals of a particular combination of metals as described below. It works on the principle of Seebeck effect.

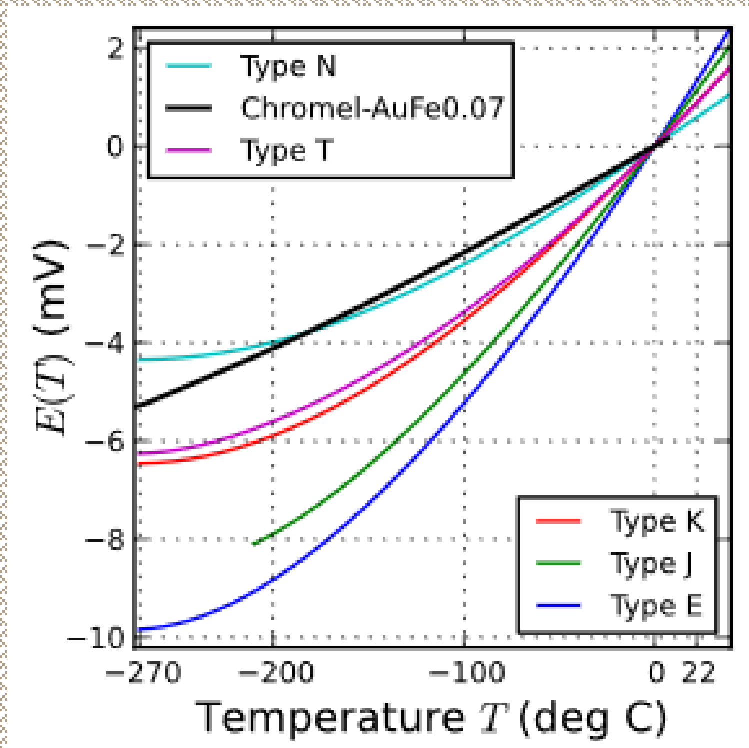
Thermocouples consist of two wire legs made from different metals. The wires are welded together at one end creating a junction. This junction is where the temperature is measured. When the junction experiences a change in temperature, a voltage is generated. This voltage is then interpreted as temperature based on the nature of the metals using the reference table.

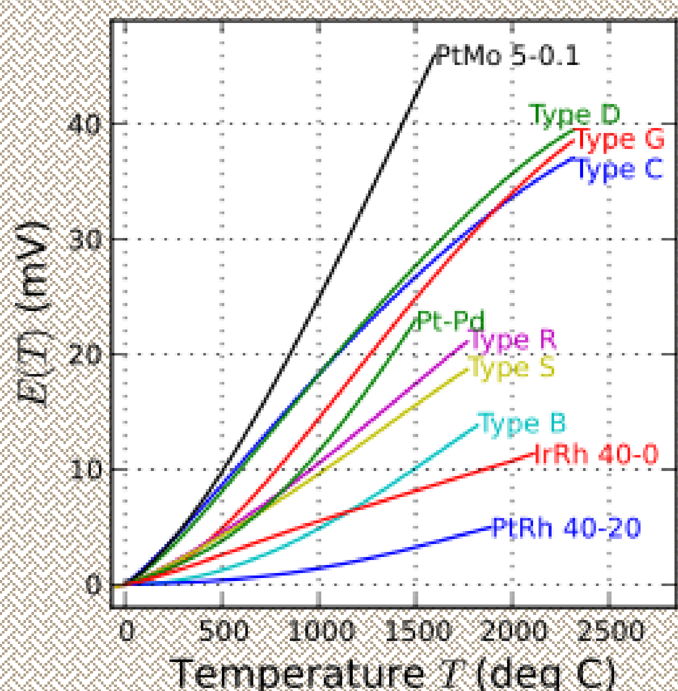
Type J,K, T, &E are the base metal thermocouples that are most commonly employed types, whereas Type R,S and B are thermocouples made from Noble Metals which are for very high temperature applications. These are widely employed in process industries for temperature measurement.

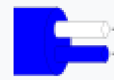
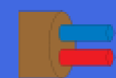
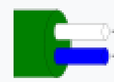
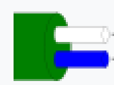
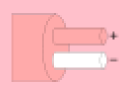
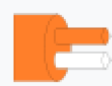
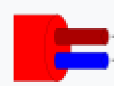
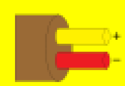
Types of Thermocouples:

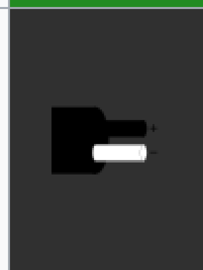
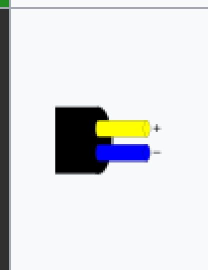
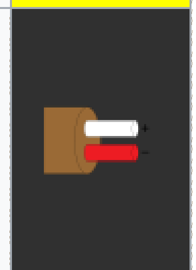
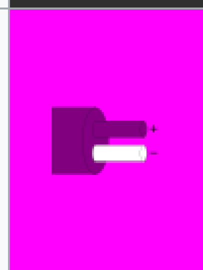
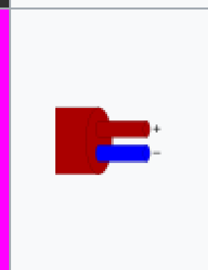
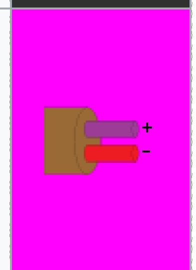
Type K Thermocouple	• (Nickel-Chromium / Nickel-Alumel):
Type J Thermocouple	• (Iron/Constantan):
Type E Thermocouple	• (Nickel-Chromium/Constantan):
Type T Thermocouple	• (Copper/Constantanl):
Type N Thermocouple	• (Nicrosil / Nisil):
Type R Thermocouple	• (Platinum Rhodium -13% / Platinum):
Type S Thermocouple	• (Platinum Rhodium - 10% / Platinuml):
Type B Thermocouple	• (Platinum Rhodium - 30% / Platinum Rhodium 6%):

CHARACTERISTIC CURVE OF THEERMOCOUPLE - TEMPERTAURE VS MILLI VOLT GENERTAED W.R.T ZERO REFERENCE JUNCTION TEMEPERATURE





Type	Temperature range (°C)				Tolerance class (°C)		Color code		
	Continuous		Short-term		One	Two	IEC	BS	ANSI
	Low	High	Low	High					
T	−185	+300	−250	+400	−40 – 125: ±0.5 125 – 350: ±0.004×T	−40 – 133: ±1.0 133 – 350: ±0.0075×T			
S	0	+1600	−50	+1750	0 – 1100: ±1.0 1100 – 1600: ±0.003×(T − 767)	0 – 600: ±1.5 600 – 1600: ±0.0025×T			Not defined
R	0	+1600	−50	+1700	0 – 1100: ±1.0 1100 – 1600: ±0.003×(T − 767)	0 – 600: ±1.5 600 – 1600: ±0.0025×T			Not defined
N	0	+1100	−270	+1300	−40 – 375: ±1.5 375 – 1000: ±0.004×T	−40 – 333: ±2.5 333 – 1200: ±0.0075×T			
K	0	+1100	−180	+1300	−40 – 375: ±1.5 375 – 1000:	−40 – 333: ±2.5 333 –			

Type	Temperature range (°C)				Tolerance class (°C)		Color code		
	Continuous		Short-term		One	Two	IEC	BS	ANSI
	Low	High	Low	High					
					±0.004×*T*	1200: ±0.0075×*T*			
J	0	+750	−180	+800	−40 – 375: ±1.5 375 – 750: ±0.004×*T*	−40 – 333: ±2.5 333 – 750: ±0.0075×*T*			
E	0	+800	−40	+900	−40 – 375: ±1.5 375 – 800: ±0.004×*T*	−40 – 333: ±2.5 333 – 900: ±0.0075×*T*			
Chromel/AuFe	−272	+300	N/A	N/A	Reproducibility 0.2% of the voltage. Each sensor needs individual calibration.				
B	+200	+1700	0	+1820	Not available	600 – 1700: ±0.0025×*T*	No standard	No standard	Not defined

Type K Thermocouple • (Nickel - Chromiun/ Nickel - Alumel):

The type K is the most common type of thermocouple. It's inexpensive, accurate, reliable, and has a wide temperature range.

TemperatureRange:

- Thermocouple grade wire, –454°F to 2,300°F (–270°C to 1260°C)
- Extension wire, 32°C to 392°F (0 to 200°C)

Accuracy (whichever is greater):

- Standard: +/- 2.2°C or +/- .75%
- Special Limits of Error: +/- 1.1°C or 0.4%

Type J Thermocouple • (Iron/Constantan):

The type J is also very common. It has a smaller temperature range and a shorter lifespan at higher temperatures than the Type K. It is equivalent to the Type K in terms of expense and reliability.

Temperature Range:

- Thermocouple grade wire, -346 to 1,400°F (-210 to 760C)
- Extension wire, 32 to 392°F (0 to 200°C)

Accuracy (whichever is greater):

- Standard: +/- 2.2°C or +/- .75%
- Special Limits of Error: +/- 1.1°C or 0.4%

Type T Thermocouple

- (Copper/Constantan):

The Type T is a very stable thermocouple and is often used in extremely low temperature applications such as cryogenics or ultra low freezers.

Temperature Range:

- ❖ Thermocouple grade wire, -454 to 700°F (-270 to 370°C)
- ❖ Extension wire, 32 to 392°F (0 to 200°C)

Accuracy (whichever is greater):

- ❖ Standard: +/- 1.0°C or +/- .75%
- ❖ Special Limits of Error: +/- 0.5°C or 0.4%

Type E Thermocouple

- (Nickel-Chromium/Constantan):

The Type E has a stronger signal & higher accuracy than the Type K or Type J at moderate temperature ranges of 1,000F and lower. See temperature chart (linked) for details.

Temperature Range:

- ❖ Thermocouple grade wire, -454 to 1600°F (-270 to 870°C)
- ❖ Extension wire, 32 to 392°F (0 to 200°C)

Accuracy (whichever is greater):

- ❖ Standard: +/- 1.7°C or +/- 0.5%
- ❖ Special Limits of Error: +/- 1.0°C or 0.4%

Type N Thermocouple

- (Nickel/Nisil):

The Type N shares the same accuracy and temperature limits as the Type K. The type N is slightly more expensive.

Temperature Range:

- Thermocouple grade wire, -454 to 2300°F (-270 to 392°C)
- Extension wire, 32 to 392°F (0 to 200°C)

Accuracy (whichever is greater):

- Standard: +/- 2.2°C or +/- .75%
- Special Limits of Error: +/- 1.1°C or 0.4%

NOBLE METAL THERMOCOUPLES (Type S, R, & B):

Noble Metal Thermocouples are selected for their ability to withstand extremely high temperatures while maintaining their accuracy and lifespan. They are considerably more expensive than Base Metal Thermocouples.

Type S Thermocouple

- **(Plantinum Rhodium - 10% / Platinum):**

The Type S is used in very high temperature applications. It is commonly found in the BioTech and Pharmaceutical industries. It is sometimes used in lower temperature applications because of its high accuracy and stability.

Temperature Range

- Thermocouple grade wire, -58 to 2700°F (-50 to 1480°C)
- Extension wire, 32 to 392°F (0 to 200°C)

Accuracy (whichever is greater):

- Standard: +/- 1.5°C or +/- .25%
- Special Limits of Error: +/- 0.6°C or 0.1%

Type R Thermocouple
- (Platinum Rhodium - 13%/ Platinum):

The Type R is used in very high temperature applications. It has a higher percentage of Rhodium than the Type S, which makes it more expensive. The Type R is very similar to the Type S in terms of performance. It is sometimes used in lower temperature applications because of its high accuracy and stability.

Temperature Range:
- Thermocouple grade wire, -58 to 2700°F (-50 to 1480°C)
- Extension wire, 32 to 392F (0 to 200°C)

Accuracy (whichever is greater):
- Standard: +/- 1.5C or +/- .25%
- Special Limits of Error: +/- 0.6C or 0.1%

Type B Thermocouple
- (Platinum Rhodium - 30%/ Platinum Rhodium - 6%):

The Type B thermocouple is used in extremely high temperature applications. It has the highest temperature limit of all of the thermocouples listed above. It maintains a high level of accuracy and stability at very high temperatures.

Temperature Range:
- Thermocouple grade wire, 32 to 3100°F (0 to 1700°C)
- Extension wire, 32 to 212°F (0 to 100°C)

Accuracy (whichever is greater):
- Standard: +/- 0.5%
- Special Limits of Error: +/- 0

CATALOUGE

THERMOCOUPLES

APPLICATION RANGE

Type	ames of Materials	Application Range
K	Chromel (+) Alumel (-)	-200 to 1200ºC
J	Iron (+) Constantan (-)	-40 to 750ºC
T	Copper (+) Constantan (-)	-200 to 350ºC
E	Chromel (+) Constant (-)	-200 to 900ºC
N	Nicorsil (+) Nisil (-)	-200 to 1200ºC

THERMOCOUPLE

SPECIFICATION

THERMOCOUPLE TYPE

e Thermocouple
e Thermocouple
e Thermocouple
e Thermocouple
e Thermocouple

INSULATION TYPE

- Mineral Insulated (MI)
- Ceramic Beds
- PTFE Insulated Elements (Upto 200ºC)

SHEATH MATERIAL

SS321, SS316, SS310, INCONEL 600, INCONEL 800

ELEMENT SIZE

MI Type - 3, 4.5, 6, 8, 10 (mm) Other Sizes on request

NON MI Type - 3, 4.5, 6, 8, 10,15 (mm) Other Sizes on request

JUNCTION TYPE

- Ungrounded
- Grounded

HEAD & CONNECTOR

HEAD :

Die Casted Aluminum Head - Dual Entry , Single Entry

CONNECTOR :

Miniature & Standard Size Connector With Polarity Marking

THERMOCOUPLE JUNCTION

- **Grounded Thermocouples:** This is the most common junction style. A thermocouple is grounded when both thermocouple wires and the sheath are all welded together to form one junction at the probe tip. Grounded thermocouples have a very good response time because the thermocouple is making direct contact with the sheath, allowing heat to transfer easily. A drawback of the grounded thermocouple is that the thermocouple is more susceptible to electrical interference. This is because the sheath often comes into contact with the surrounding area, providing a path for interference.

- **Ungrounded Thermocouples (Or Ungrounded Common Thermocouples):** A thermocouple is ungrounded when the thermocouple wires are welded together but they are insulated from the sheath. The wires are often separated by mineral insulation.

- **Exposed Thermocouples (or "bare wire thermocouples"):** A thermocouple is exposed when the thermocouple wires are welded together and directly inserted into the process. The response time is very quick, but exposed thermocouple wires are more prone to corrosion and degradation. Unless your application requires exposed junctions, this style is not recommended.
- **Ungrounded Uncommon:** An ungrounded uncommon thermocouple consists of a dual thermocouple that is insulated from the sheath and each of the elements are insulated from one other.

- **Exposed Thermocouples (or "bare wire thermocouples"):** A thermocouple is exposed when the thermocouple wires are welded together and directly inserted into the process. The response time is very quick, but exposed thermocouple wires are more prone to corrosion and degradation. Unless your application requires exposed junctions, this style is not recommended.

- **Ungrounded Uncommon:** An ungrounded uncommon thermocouple consists of a dual thermocouple that is insulated from the sheath and each of the elements are insulated from one other.

Thermocouple Sheath Comparison:
- **316SS (stainless steel) & 316L SS:** This is the most common sheath material. It is relatively corrosion resistant and is cost effective.
- **304SS:** This sheath is not as corrosion resistant as 316SS. The cost difference between 316SS and 304SS is nominal.
- **Inconel (registered trademark) 600:** This material is recommended for highly corrosive environments.

Special Limits of Errors (SLE)

- **Special Limits of Error:** These thermocouples are made with a higher grade of thermocouple wire, which increases their accuracy. They are more expensive than standard thermocouples.

  Standard Limits of Error: These thermocouples use standard “thermocouple grade” wire. They are less expensive and more common.

M.I. Cable

- M.I. (Mineral Insulated) cable is used to insulate thermocouple wires from one another and from the metal sheath that surrounds them. MI Cable has two (or four when duplex) thermocouple wires running down the middle of the tube. The tube is then filled with magnesium oxide powder and compacted to ensure the wires are properly insulated and separated. MI cable helps to protect the thermocouple wire from corrosion and electrical interference.

System Error?

- System error is calculated by adding the accuracy of the temperature sensor (thermocouple) and the accuracy of the meter used to read the voltage signal together. For example, a Type K thermocouple has an accuracy of +/- 2.2C above 0C. Let’s say the meter has an accuracy of +/- 1C. That means the total system error is +/- 3.3C above 0C.

Thermocouple vs. RTD

- Temperature range:
First, consider the difference in temperature ranges. Noble Metal Thermocouples can reach 3,100° F (1700° C), while standard RTDs have a limit of 600° F (315° C) and extended range RTDs have a limit of 1,100° F (600° C).

- Cost:
A plain stem thermocouple is 2 to 3 times less expensive than a plain stem RTD. A thermocouple head assembly is roughly 50% less expensive than an equivalent RTD head assembly.

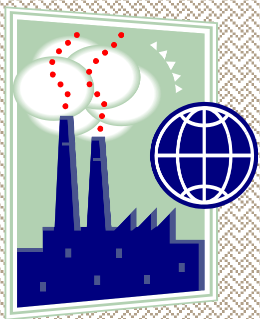
- Accuracy, Linearity, & Stability:
As a general rule, RTDs are more accurate than thermocouples. This is especially true at lower temperature ranges. RTDs are also more stable and have better linearity than thermocouples. If accuracy, linearity, and stability are your primary concerns and your application is within an RTD's temperature limits, go with the RTD.

- Durability:
In the sensors industry, RTDs are widely regarded as a less durable sensor when compared to thermocouples. However, developed manufacturing techniques that have greatly improved the durability of our RTD sensors. These techniques make RTDs nearly equivalent to thermocouples in terms of durability.

- Response Time:
RTDs cannot be grounded. For this reason, they have a slower response time than grounded thermocouples. Also, thermocouples can be placed inside a smaller diameter sheath than RTDs. A smaller sheath diameter will increase response time. For example, a grounded thermocouple inside a 1/16" dia. sheath will have a faster response time than a RTD inside a ¼" dia. sheath.

Notes:

RAVIRAJ
PROCESS CONTROLS



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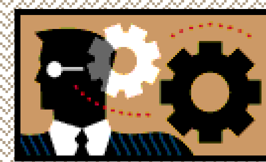

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