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Comparing Three Types Of Temperature Sensors

RTDs vs. THERMOCOUPLES vs. THERMISTORS

RTDs

Resistance Temperature Detectors (RTDs) are temperature sensing devices consisting of a wire coil or deposited film of pure metal, usually platinum. The element's resistance increases with temperature in a known and repeatable manner. RTDs exhibit excellent accuracy over a wide temperature range, –200 to 650°C (–328 to 1202°F).

— RTDs offer —

Stability and repeatability: The platinum RTD is the primary interpolation instrument used by the National Institute of Standards and Technology from –260 degrees Celsius to 630 degrees Celsius. Precision RTDs can be manufactured with a stability of 0.0025 degrees Celsius per year. However, most industrial models drift less than 0.1 degrees Celsius per year.

Linearity: The platinum RTD produces a more linear curve than thermocouples or thermistors. The RTD's non-linearities can be corrected through proper design of resistive bridge networks.

Sensitivity: The voltage drop across an RTD provides a much larger output than a thermocouple. Since thermistors have a higher resistance than RTDs, the measuring current through them may be so low as to limit self-heating, making their voltage drop less than that of an RTD.

Standardization: RTDs are manufactured to industry standard curves, usually 100 ohm platinum to IEC 751, which makes them very interchangeable.

System Cost: RTDs usually offer a lower system cost than do thermocouples as they use ordinary copper extension leads and require no cold junction compensation.

Thermocouples

A thermocouple consists of two wires of dissimilar metals welded together into a junction. At the other end of the signal wires, usually as part of the input instrument, is another junction called the reference junction. Heating the sensing junction generates a thermoelectric potential (emf) proportional to the temperature difference between the two junctions. This millivolt-level emf, when compensated for the known temperature of the reference junction, indicates the temperature at the sensing tip. Published millivolt tables assume the reference junction is at 0 degrees Celsius.

Thermocouples are simple and familiar. Designing them into systems, however, is complicated by the need for special extension wires and reference junction compensation.

—Thermocouple advantages include—

Extremely high temperature capability: Thermocouples with a noble metal junction may be rated as high as 1700°C (3100°F).

Ruggedness: The inherent simplicity of thermocouples makes them resistant to shock and vibration.

Small size/fast response: A fine-wire thermocouple junction takes up little space and has low mass, making it suitable for point sensing and fast response.

Thermistors

Thermistors are resistive devices usually made of metal oxides formed into a bead and encapsulated in epoxy or glass. Thermistors show a large negative temperature coefficient. Their resistance drops dramatically and non-linearly with a temperature increase. A thermistor's sensitivity is many times that of an RTD, but its useful temperature range is limited.

Because of wide variations of performance and cost among thermistors, generalized advantages and disadvantages may not always apply.

— Typical benefits are —

Lower Sensor Cost: Basic thermistors are less costly than RTDs and thermocouples, but when assembled in protective sheaths or wells the price difference narrows. Thermistors with tighter interchangeability or extended temperature ranges often cost more than RTDs.

High Sensitivity: Resistance may be several thousand ohms, which provides a larger output than RTDs with the same measuring current, offsetting lead wire resistance problems. Caution must be taken to limit measuring current because thermistors are more susceptible to self-heating than are RTDs.

Point Sensing: A thermistor bead may be the size of a pinhead, allowing for small area sensing.

TEMPCO'S ACCU-OHM™ RTD

All of Tempco's Accu-Ohm RTDs comply with the following specifications:

IEC publication 751 issued by the International Electrotechnical Commission (dated 1983).

This is the widest international scope of any RTD standard. This publication sets the tolerance for platinum RTDs with a value of 100 ohms at 0°C with a temperature coefficient of resistance (TCR) of 0.00385 ohms/ohm/°C in one of two classes:

Class A: Plus or minus 0.06% at 0°C

Class B: Plus or minus 0.12% at 0°C

All Tempco RTDs meet class B; class A is optional.

DIN 43760 issued by Deutsches Institute fur Normung (Germany), dated 1987. The platinum resistance curves are now covered under DIN IEC 751.

JIS 1604-1989 issued by the Japanese Standards Association (dated 1989).

The Platinum resistance curves are in accordance with IEC 751 but there is also a provision for TCR 0.003916 ohms/ohm/°C which can be supplied in most of Tempco's standard designs on special request.

BS 1904-1984 issued by the British Standard Institute (dated 1984). This specification is identical to IEC 751.

What is Temperature Coefficient of Resistance (TCR)?

Temperature coefficient differentiates between resistance/temperature curves of RTDs. It is also called ALPHA and may be specified in various ways by different manufacturers. Here TCR is the RTDs resistance change from 0 to 100°C, divided by the resistance at 0°C, divided by 100°C:

$$\text{TCR } (\Omega/\Omega/°\text{C}) = \frac{\text{R } 100°\text{C} - \text{R } 0°\text{C}}{\text{R } 0°\text{C} \times 100°\text{C}}$$

Example: A platinum RTD measuring 100 Ω's at 0°C and 138.5 Ω's at 100°C has TCR 0.00385 Ω/Ω/°C

$$\text{TCR} = \frac{138.5\,\Omega - 100\,\Omega}{100\,\Omega \times 100°\text{C}} = 0.00385\ \Omega/\Omega/°\text{C}$$

Stated another way, TCR is the average resistance increase per degree of a hypothetical RTD measuring 1 ohm at 0°C.

The most common use of TCR is to distinguish between curves for platinum, which is available with TCRs ranging from 0.00375 to 0.003927. The highest TCR indicates the highest purity platinum, and is mandated by ITS-90 for standard platinum thermometers.

There are no technical advantages of one TCR versus another in practical industrial applications. 0.00385 platinum is the most popular worldwide standard and is available in both wire-wound and thin-film elements.

In most cases, all you need to know about TCR is that it must be properly matched when replacing RTDs or connecting them to instruments.

Interchangeability and Repeatability

Interchangeability and accuracy are commonly cited as the RTDs most distinguishing attributes. Because of the tight tolerances of the Class A and Class B, RTDs are quite interchangeable. Their accuracy is also very good because of the RTD's repeatability over the standard temperature scale from −260°C to 630°C. Ordinary industrial RTDs tend to show a drift of less than 0.1°C per year in normal use.

Because RTDs are exactly what the name implies (Resistance Temperature Detectors), a resistance type sensor, any resistance introduced by the addition of extension wires between the RTD and the control or measuring instrument will add to the readings. This added resistance is not constant since the extension wires, usually copper, change their resistance values with changing ambient temperature. Extension wire errors can be significant, particularly with small gauge wires or elements with low sensitivity. Fortunately most of these errors may be nearly canceled by using a three wire system.

The majority of RTDs in today's industry are 3- or 4-wire systems; the 2-wire lead system is the least efficient unless the leads are heavy gauge, very short, or both.

In 3- or 4-wire circuits, common leads, connected to the same end of the RTD element, are the same color.

Tolerances for 100Ω RTDs

Temperature (°C)	Tolerance Class A (± °C)	Class A (± Ω)	Class B (± °C)	Class B (± Ω)
–200	0.55	0.24	1.3	0.56
–100	0.35	0.14	0.8	0.32
0	0.15	0.06	0.3	0.12
100	0.35	0.13	0.8	0.30
200	0.55	0.20	1.3	0.48
300	0.75	0.27	1.8	0.64
400	0.95	0.33	2.3	0.79
500	1.15	0.38	2.8	0.93
600	1.35	0.43	3.3	1.06
650	1.45	0.46	3.6	1.13
700	—	—	3.8	1.17
800	—	—	4.3	1.28
850	—	—	4.6	1.34

Tolerance Values as a Function of Temperature for 100Ω RTDs