APPLIED SENSOR TECHNOLOGIES
A Division of UNITED ELECTRIC CONTROLS

Overview of temperature sensor types

Applied Sensor Technologies offers four basic types of temperature sensor:

- Thermocouples
- RTD's
- Thermistors
- Integrated circuit (IC)

Thermocouples

At its most basic, a thermocouple is two wires of dissimilar metals, joined at one end. Changes in the temperature at the "hot junction" (measuring end) induce a change in electromotive force (emf) at the "cold junction", where it can be input into a controller or indicator. As the temperature increases, this output emf also rises, though not completely linearly. Thermocouples can measure temperatures over wide ranges, fairly inexpensively. They are very rugged, but they are somewhat less accurate vs. RTDs and thermistors.

Here is a summary of some of the advantages and disadvantages of thermocouples:

Advantages	Disadvantages
Self powered	Non linear
Simple	Low voltage
Rugged	Reference required
Inexpensive	Least stable
Wide variety	Least sensitive output vs. temperature change
Wide temperature range	

Thermocouple Types ("Calibrations")

There are many different types of thermocouples, made of different types of wire and having very different properties. This sometimes makes one type better for a specific application than another. Below are descriptions of the types of thermocouples that Applied Sensor Technologies manufactures:

Type J The most widely used thermocouple; it is versatile and has widespread usage throughout industry. It is recommended for reducing atmospheres. The operating range for this alloy combination is from 0° to 750°C (32° to 1380° F) for the largest wire sizes. Smaller size wire should operate in correspondingly lower temperatures.

Type K Often used at high temperatures, it is recommended for use in clean oxidizing atmospheres. The operating range for this alloy is from 0° to 1250° C (32° to 2280° F) for the largest wire sizes. Smaller size wire should operate in correspondingly lower temperatures.

Type E With the highest emf of all standard thermocouples, it is recommended for use in oxidizing, inert or dry reducing atmospheres or for short periods of time in a vacuum. These elements must be protected from sulfurous and marginally oxidizing atmospheres. Type E thermocouples can be used for temperatures from 0° to 900° C (32° to 1650° F).

Thermocouple Types ("Calibrations"), Continued

Type T Type T is recommended for use in mildly oxidizing and reducing atmospheres at temperatures from 0° to 350° C (32° to 660 °F). It is suitable for applications where moisture is present. This alloy is recommended for low temperature work since the homogeneity of the component wires can be maintained better than with other base metal wires. Therefore, errors due to material variation within wires in zones of temperature gradients are greatly reduced.

Types R, S & B Made from platinum and platinum alloy wires, these thermocouples are designed for high temperature applications, such as vacuum furnaces and a variety of process applications. Because of the chance for contamination, they should be protected by a suitable protection tube, preferably of high-purity alumina (99% or better). Mullite is not recommended for use with Types R&S due to the chance of silica contamination, and the thermocouple should never be inserted directly into a metal tube..

Thermocouple Constructions

Applied Sensor Technologies offers three thermocouple constructions depending on the application:
GP - General Purpose thermocouples that are comprised of a pair of thermocouple wires inside a metal tube. This inexpensive method can typically be used to measure temperatures of 260° C (500° F) or less.
MI - For higher temperature applications, magnesium oxide powder is compacted around the wires inside the sheath. This Mineral Insulated construction is very rugged, can be bent and is used to measure temperatures of throughout the thermocouple's temperature range (depending on sheath material).
BTC - Beaded thermocouples are constructed of bare wire, separated by ceramic "beads." This simple yet effective construction is used for high temperature applications such as furnaces and many applications in the metals industry.

Thermocouple Ranges and Accuracy

Thermocouple conductors are specified with either 'standard" or "special" limits of error. The chart below shows the usable range of each sensor calibration, along with their accuracies. Accuracy is based on the larger of the two values given, for temperatures above 0°C..

Calibration	Insulation color-code (North America)	Range	Accuracy	
			(Standard Limits)	(Special Limits)
J	White (+) Red (-)	32° to 1380°F 0° to 750°C	2.2°C or 0.75%	1.1°C or 0.4%
K	Yellow (+) Red (-)	-325° to 2280°F -200° to 1250°C	2.2°C or 0.75%	1.1°C or 0.4%
E	Purple (+) Red (-)	-325° to 1650°F -200° to 900°C	1.7°C or 0.5%	1.0°C or 0.4%
T	Blue (+) Red (-)	-420° to 660°F -250° to 350°C	1.0°C or 0.75%	0.5°C or 0.4%
R & S	Black (+) Red (-)	32° to 2730°F 0° to 1500°C	1.5°C or 0.25%	0.6°C or 0.1%
B	Gray (+) Red (-)	32° to 3100°F 0° to 1700°C	0.5% over 800°C	N/A

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RTD's or Resistance Temperature Detectors

An RTD capitalizes on the fact that the electrical resistance of a material changes as its temperature changes. Most RTD’s use a thin film of a conductor (platinum, nickel iron or copper) deposited on a ceramic substrate. However, some special applications require the older method of wrapping a length of thin conductor around an insulator. RTD's are stable and have a fairly wide temperature range, and in many cases are similarly priced to thermocouples. Because they must be isolated from the environment, they are less responsive to changes compared to grounded or exposed junction thermocouples. Since they require an electric current source to make measurements, RTD's can be subject to small inaccuracies from self-heating. RTD's can be used to measure temperatures from -200° to 800° C (-325° to 1475° F)

Here is a summary of some of the advantages and disadvantages of RTDs:

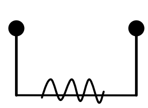
Advantages	Disadvantages
Stable	More expensive than a thermocouple
Accurate	Current source required
More linear than thermocouple	Small change in resistance
	Low absolute resistance
	Self heating
	Less rugged that thermocouples

RTD Types

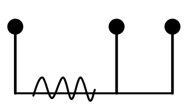
The most common type of RTD (and Applied Sensor Technologies’ standard) is platinum, with characteristics that have been standardized under the European IEC 751 standard. It has a temperature coefficient (α) of 0.00385 and its reference resistance is 100Ω. There are also variations of the platinum that have 500Ω and 1000Ω references, and a similar RTD with an α = 00.392 (called the “American” curve, it has different levels of purity to the platinum and is much less common). In addition, there are RTD’s made from copper and nickel-iron. Applied Sensor Technologies can offer any of these as options if required.

RTD Wiring Configurations

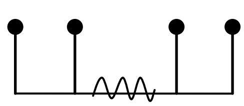
Because the absolute resistance of the RTD element is relatively small in most cases (roughly 100Ω), the leadwire length between the sensor and the measuring equipment becomes a potential area of significant error. In order to compensate for this error, RTDs may be constructed with extra leads so that the wire resistance can be measured and negated. Applied Sensor Technologies manufactures 2-wire, 3-wire and 4-wire configurations to handle every requirement.



2-Wire. Common in many types of OEM equipment (such as lab, medical and appliance) where the short lead lengths do not impart significant resistance and the designer is looking to keep cost to a minimum (the leadwire itself is inexpensive, but connectors and connector real estate on a PC-board can be expensive).



3-Wire. The most common configuration in industrial applications. The third leadwire allows for the measurement of the resistance of one leg, and the resistance of the other is then inferred. In most applications, this provides an acceptable level of accuracy.



4-Wire. This configuration is used in applications where the highest level of accuracy is required. It allows for the resistance of each leg to be measured separately, and then eliminated.

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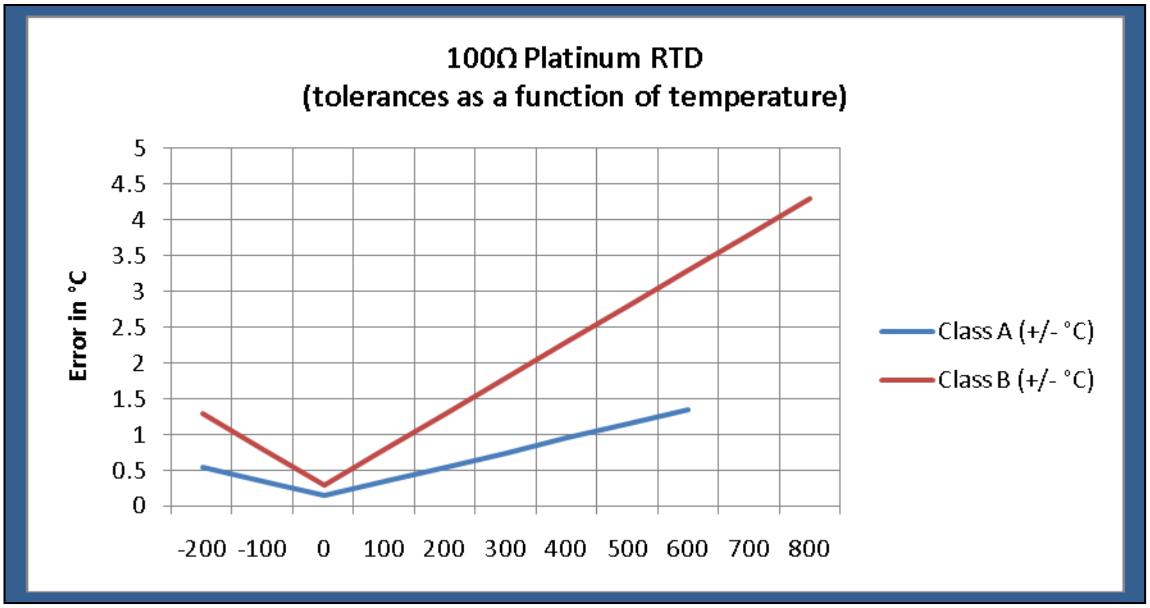
RTD Tolerances

Platinum RTDs are categorized by their tolerances, with Class B considered the most common in industrial applications. There are also Class A, 1/3 DIN and 1/10 DIN also available, with progressively tighter tolerances. The chart and graph below illustrate the tolerances for Class A and B (based on the IEC 751 standard). Actual accuracy of the instrument however may be dependent on the leadwire used, the manufacture of the RTD assembly, stresses incurred in the application and many other factors.

Temperature (°C)	Tolerance	
	Class A (+/- °C)	Class B (+/- °C)
-200	0.55	1.3
-100	0.35	0.8
0	0.15	0.3
100	0.35	0.8
200	0.55	1.3
300	0.75	1.8
400	0.95	2.3
500	1.15	2.8
600	1.35	3.3
700		3.6
800		4.3



Thermistors

A thermistor's output is based on the resistance change in a metal-oxide semiconductor material as its temperature changes. Thermistors can be either NTC (Negative Temperature Coefficient), where the resistance drops non-linearly with a temperature rise, or PTC (Positive Temperature Coefficient), where the resistance increases as the temperature rises. Thermistors can be a low cost solution to temperature measurement. They tend to have large signal outputs and their small size permits fast response to temperature changes. Thermistors may be more accurate than thermocouples, but they have a much more limited temperature range because of their marked non-linearity. Thermistors are typically used to measure temperatures from -45° to 260° C (-50° to 500° F).

Here is a summary of some of the advantages and disadvantages of thermistors:

Advantages	Disadvantages
High output	Non linear
Fast response time	Limited temperature range
Low cost	Current source required
Accurate over small ranges	Self-heating

IC Sensors

The newest type of temperature sensor to be developed is the integrated circuit (IC) temperature transducer. IC sensors can be designed to produce either voltage or current output and are extremely linear. IC sensors are a very effective way to produce an analog voltage proportional to temperature. They have a limited temperature range and are used to measure temperatures from -45° to 150° C (-50° to 300° F). Typically, these are used on OEM equipment, where their linearity is an advantage to the design engineer.

Here is a summary of some of the advantages and disadvantages of IC sensors:

Advantages	Disadvantages
Most linear	Temperatures limited to 150 degrees C
Highest output	Power supply required
Inexpensive	Slow response time
	Self-heating
	Larger in size than other types of sensor
	Limited configurations