6 key Differences Between RTD's and Thermocouples - that Might Change your Preferences

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What is the difference between a Resistance Temperature Detector (RTD) and a thermocouple (TC)? Both RTD's and thermocouples are temperature sensors that can be used in a broad range of applications - their design and versatility, however, are completely different.

This often raises the question: how do I choose between RTD's and thermocouples? Each technology has its own advantages and disadvantages, which either makes them suitable or unsuitable for certain processes and applications.

This paper highlights the 6 most important differences between RTD's and thermocouples by delving into the technology-based advantages and disadvantages of each type of sensor. The various considerations that must be taken into account before deciding on which type of sensor is right for your application will be explained and concluded.

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RTD Sensors

The measuring principle of a Resistance Temperature Detector, or RTD, can be described as follows:

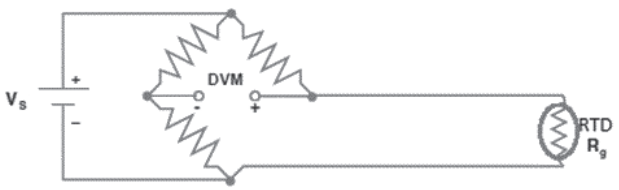
- The electrical resistance of metals rise as heat increases and the metals become hotter
- The electrical resistance of metals fall as heat decreases and the metals become colder

RTD's are therefore temperature sensors that use the change in electrical resistance of metals to measure the change in local temperature.

All RTD sensor elements either consist of a fine coiled platinum (Pt) wire wrapped around a ceramic core – or a thin film of platinum in an element substrate. The element is typically relatively fragile, so it is typically installed inside a sheath in order to protect it.

RTD sensor elements are constructed from pure materials that have their resistance at various temperatures documented. In other words, the material has a predictable change in resistance as the temperature varies. It is this change that is used to determine the actual temperature.

RTD's are generally considered to be among the most accurate temperature sensors available. In addition to offering a very high accuracy, they provide excellent short- and long-term stability as well as repeatability.



RTD principle (source: Electrical4you.com)

RTD Highlights and Limitations

Highlights

- Very high accuracy
- Outstanding sensitivity
- Excellent stability and repeatability (low drift)

Limitations

- Narrow temperature range
- High Cost

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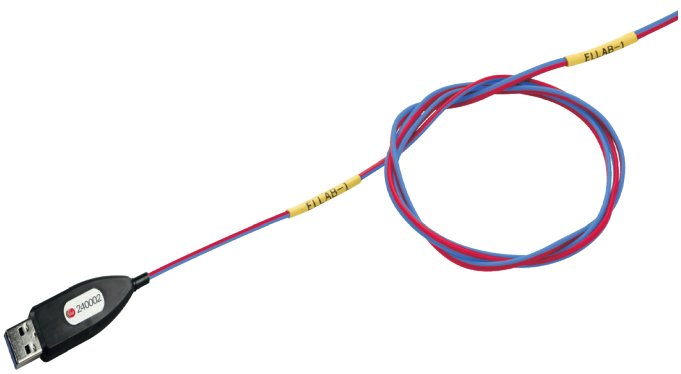
Thermocouple Sensors

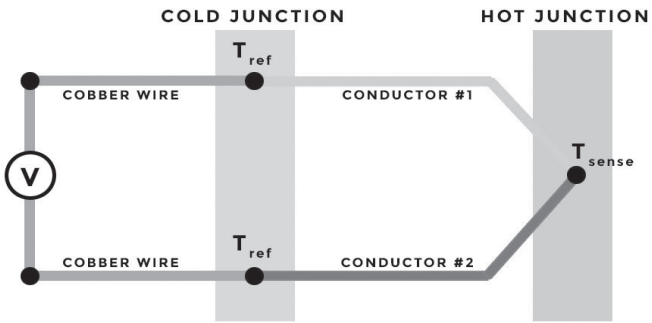
A thermocouple, or TC, consists of two dissimilar metals welded together at one end. When the junction of the two metals is cooled or heated, a difference in voltage is produced that can be correlated directly back to the temperature, but only when the necessary cold junction compensation has been considered.

Thermocouples are manufactured in different combinations of metals and/or calibration ranges. The most common types are J, K, T and E, whereas high temperature thermocouples include R, S and C. Each type has a different temperature range and environmental performance. While the type defines the temperature range, the diameter of the thermocouple wire is also a factor.

Since thermocouples measure wide temperature ranges and are relatively rugged, they can be used for industrial and process applications in which a high accuracy may be a less important factor.



Type	Junction	Temperature Range °C
B	Platinum/Rhodium	50 to 1800
E	Chromel/Constantan	-200 to 850
J	Iron/Constantan	-200 to 850
K	Chromel/Alumel	-200 to 1100
R	Platinum/Rhodium	0 to 1400
S	Platinum/Rhodium	0 to 1400
T	Copper/Constantan	-250 to 400



Thermocouple principle (source: PLC Academy.com)

Thermocouple Highlights and Limitations

Highlights

- High measuring range
- Low cost

Limitations

- Lowered accuracy
- Less sensitive
- Relatively high drift-over-time

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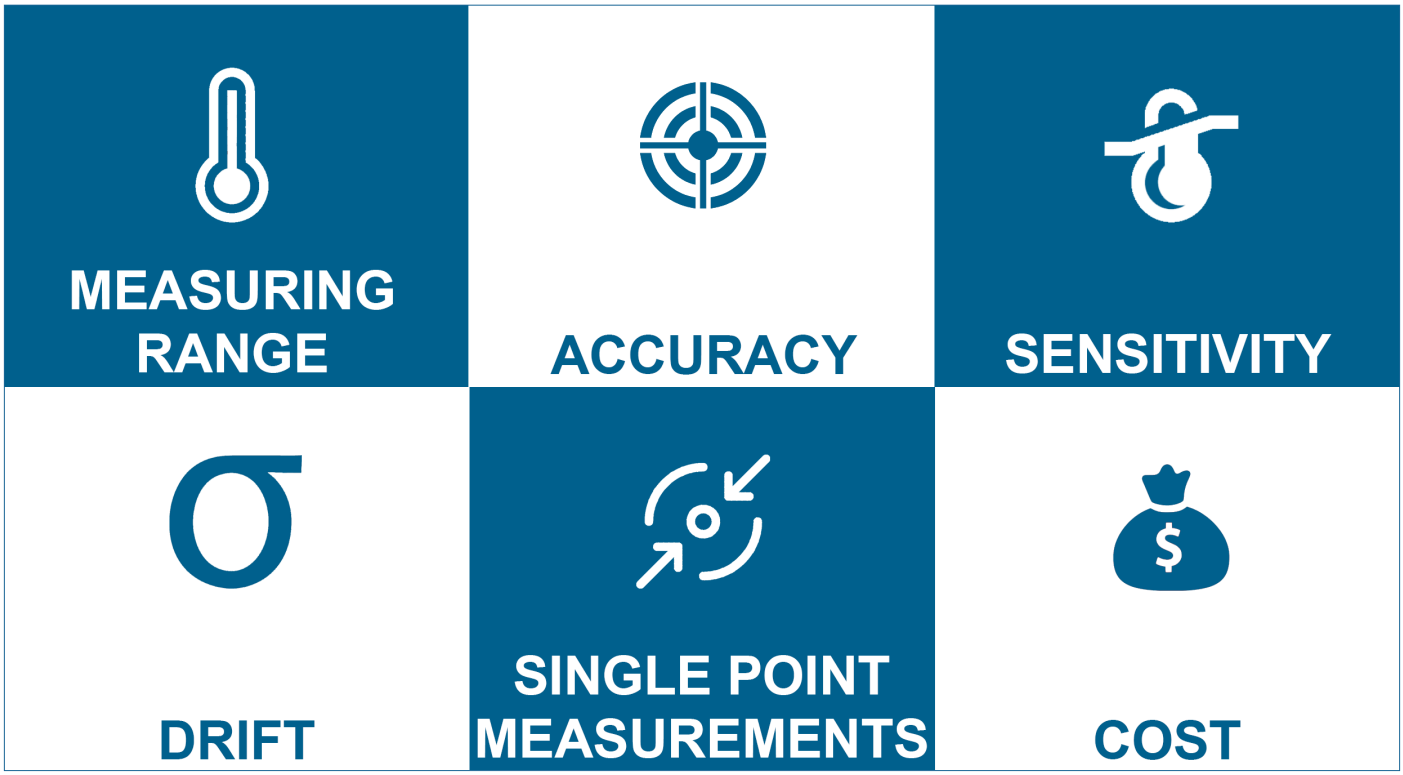
6 key Differences Between RTD's and Thermocouples

Because RTD's and thermocouples are designed differently, having specific characteristics for each makes it impossible to conclude whether RTD's or thermocouples are the superior choice for a specific application.

Instead, it is far more useful to compare the performance of RTD's and thermocouples by using other qualities, such as their measuring range, accuracy, sensitivity, drift and cost in order to facilitate an appropriate decision based on the specific needs.



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1. Measuring Range

The main advantage of thermocouples is their range. Most RTD sensors are limited to temperatures of up to 400-500 °C, and in some cases higher, whereas certain thermocouples can be used to measure above the 1400 to 1800 °C range, which makes them suitable for a large range of applications.

2. Accuracy

RTD's provide the highest accuracy and may be the preferred solution when a temperature measurement accuracy is required to be around ± 0.05 to ± 0.1 °C.
Thermocouples in comparison, have a lowered accuracy around ± 0.2 to ± 0.5 °C.

3. Sensitivity

Although a thermocouple sensor system usually has a faster response time due to the changing temperature at its point of contact, it generally takes longer to reach thermal equilibrium. This is largely due to the presence of the cold junction compensation, which does not respond to the change in temperature as quickly as the hot junction located at the tip of the sensor does. In comparison an RTD sensor is designed to be more durable and react faster to temperature changes (naked tip).

4. Drift

The RTD sensors drift is small due to their design, which makes them produce stable readings for longer durations than thermocouples can. Unlike RTD sensors, a thermocouple has a relative high drift-over-time, which is typically caused by inhomogeneity of the conductor wires resulting from heat- and chemical exposure or mechanical damage, such as having been bent, tugged or squeezed during use. Due to this, frequent calibrations and adjustments are mandatory for thermocouples.

5. Single Point Measurements

Due to the design of a thermocouple, it is possible to narrow the measuring point down to the exact spot where the two metals are welded together. This point can then be defined very accurately when operating thermocouples with "naked tips". For RTD sensors however, measurements are calculated by taking the average value along the entire surface of the PT (platinum) element itself. This is mainly a disadvantage for large elements like PT100, whereas smaller elements like the PT1000 rarely have this issue, as some leading suppliers can provide PT1000 elements as small as 1x1.5 mm.

6. Cost

When it comes to cost, thermocouples are generally less expensive than RTD sensors, as most thermocouples cost between half to one third of an RTD. As mentioned however, thermocouples require regular adjustments and calibration, which in addition to the longer installation and setup times, adds to the long-term costs of the product.

Sensor Comparison

Parameter	RTD	Thermocouple
Typical Measuring Range	-240 to +650 °C	-270 to +2,320 °C
Long-term Stability	Excellent	Poor to Fair
Accuracy	Excellent	Good to Medium
Repeatability	Excellent	Poor to Fair
Response Time	Good	Medium to Excellent
Linearity	Good	Fair
Undesirable Self-Heating	Medium to Excellent	Excellent
Tip Sensitivity	Fair	Excellent

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Conclusion

The conclusion is based exclusively on the advantages and disadvantages of the sensor types, and does not consider the features and benefits of the measuring equipment.

For applications that require a high accuracy and operate at temperatures below 500 °C, the RTD temperature sensors are often the right choice. Thermocouples, on the other hand, are ideal for simply constructed processes that require a wider temperature range, faster response time and the ability to measure highly specific points of interest.

Looking at the 6 key differences, the RTD sensor is more accurate, stable and repeatable. They also drift far less. RTD's also offer a more robust output signal, resulting in an increased sensitivity and linearity. However, they have a narrower operating range, lower maximum operating temperature and are generally more expensive.

Thermocouples are less expensive, are more durable and can measure a wider range of temperatures. However, they have a lowered accuracy and a high drift-over-time, making frequent calibrations mandatory, adding to overall costs.

The conclusion is that RTD's and thermocouples each have their own advantages and disadvantages. When choosing between the two types of temperature sensors, all 6 key differences should be taken into consideration and be held against the important factors of the process. Finally, size is also an important factor to consider, as RTD sensors remain relatively large by comparison to thermocouples.

What Ellab Offers

Ellab offers complete validation solutions, in which the sensors themselves only consist as a small part of the overall measuring equipment. This means that there are additional considerations before making a final choice.

Several studies have shown that purchasing wired cable systems, may initially be cheaper from an investment point of view. But when it comes to operating the two different systems (TrackSense and E-Val Pro), one big factor stands out – it is generally a lot faster to install and operate RTD's via wireless data loggers, making the initial purchase price considerably less important when compared to the total running costs.

In other words, time is money and working with a wireless system generally saves operators a highly considerable amount of time.

Ellab has also developed a highly unique hybrid solution, in which a thermocouple sensor is attached to one of our TrackSense Pro wireless data loggers. This solution enables a wide range of alternatives for applications like Lyophilization and UHT/HTST pasteurization.

If you wish to learn more about Ellab, we recommend that you take a closer look at the various thermocouple and RTD based validation systems available at ellab.com