Thermocouple, Thermistor or RTD? - Part 2

As you remember from Part One, temperature is the most common parameter measured by those who use data loggers. I also outlined the basic principles of temperature sensors—detailing the specifics of how thermocouples, thermistors, and RTDs function. In Part Two, I will talk about tips for selecting which temperature sensor is best for your needs, as well as some examples of how these temperature sensors are used in real-world applications.

Selection Criteria

Picking which type of sensor to use for a particular application requires consideration of 3 important factors related to the measurement, along with the cost:

- Temperature Measurement Range
- Required Measurement Accuracy
- Sensor Wire Length, Noise, and Accuracy

One of the most important things is the expected temperature measurement range. Of the three types of sensors, thermocouples have the widest measurement range, from well below -200°C to over 1700°C depending on the thermocouple type. RTDs are more limited spanning -200C to around 500°C although specialized models can go somewhat higher. Thermistors have the most limited measurement range of the 3 types because of both their composition and their non-linear characteristics. Commonly available epoxy-coated thermistors are suitable for use from -50°C to 150°C and glass-coated thermistors can measure above 200°C.

A second consideration is the required accuracy of the temperature measurement. We usually tell customers that of the three types, thermocouples are the least accurate. Standard thermocouple wire is usually specified to have an accuracy of around 1 – 1.5°C based on the wire type and temperature. Small variations in the composition of the metal alloy making up the wire can affect the output voltage.

Some vendors provide thermocouple wire called special limit of error or SLE with a slightly better temperature specification. As mentioned before, thermocouples also require a second reference temperature measurement so any error in this measurement will enter directly into the total error. RTDs have accuracy specified in different classes; class A RTDs have an accuracy of around 0.15°C at 0°C, class B is 0.3°C and class AA or 1/3 DIN is about 0.1°C at the same temperature. So, overall RTDs are 5-10x more accurate than thermocouples. As mentioned before, thermistors exhibit a much greater change in resistance per degree C and so accuracies of 0.1°C are easily achievable.

In any real-world application, the environment where the sensor is installed and the distance between the sensor and the measuring device must be taken into account. I can't tell you how many times we have received questions from customers about noisy thermocouple measurements. As mentioned before, thermocouples only generate a tiny voltage, on the order of millivolts. Any electromagnetic noise in the area where the thermocouple wires run can couple directly into the wire often completely swamping out the signal from the thermocouple. Things like AC power cables, large motors, or radio frequency (RF) equipment can ruin the measurements. In these cases, it becomes necessary to use shielded thermocouple wire or use a signal conditioner module to convert the low-level signal to something like a 4-20mA signal to get decent measurements.

Or, in the case of RTDs, as mentioned before they are typically a relatively low resistance (100 ohms) and an error of 1 ohm can represent an error of >2°C. Considering that 100 feet of standard 18 gauge wire will have a resistance of around 0.6 ohms it becomes apparent that using a 3 or 4 wire connection in combination with a measuring instrument that provides compensations is necessary for accurate measurements. However, there is normally an upper limit on how much lead resistance the measuring device can adjust for. We usually recommend that it's best to keep RTD wire length to less than 50 feet. Thermistors used for temperature measurement are usually much higher in resistance than RTDs, 2252 and 10,000 ohms are common values so the impact of cable length is usually negligible.

Of course, any consideration of which type of sensor to use has to include the cost. Of the 3 types, thermocouples are probably the least expensive. Standard thermocouple wire can be purchased for less than $1.00/foot. Simply stripping the ends and twisting them together can produce a basic functional thermocouple. Also, when looking for probes, thermocouples are widely available in the largest range of styles from simple tubular probes to surface temperature probes to models that can be bolted onto a piece of equipment like a bearing. Both the RTD and thermistor sensing elements themselves can be a bit more expensive upwards of $15-20 for a good quality device. Normally these then need to pack into some type of probe to protect the sensing element so they will typically be a bit more expensive than the same style thermocouple probe.

Typical Examples

Here are a few common applications along with the sensor type that was used:

We have provided data loggers and sensors for several applications for skin temperature measurement. This is an ideal application for a thermistor sensor; the temperature measurement range is small typically only ± a few degrees and right in the sweet spot for thermistors measurements around 30°C and accuracy is very important, a few tenths of a degree can make a big difference. Fortunately, there are a few vendors that provide medically rated thermistor stick-on surface probes just for this application. When combined with one of our Grant Squirrel data loggers which offer built-in software for conversion of standard thermistor resistance to temperature they offer a very accurate and easy-to-use solution.

We offer data loggers for monitoring concrete curing where the temperature vs. time profile of poured concrete can be used as a good predictor of its maturity or strength. For this application, the sensor is embedded in the concrete and normally left in place after the test is complete. An accuracy of ± a degree is enough and while the sensor runs may be relatively long there is usually minimal electrical interference in the environment.

Which sensor type to use? You guessed it, thermocouples are the perfect solution. In this case, we provide a roll of thermocouple wire and the user can simply cut off the length needed, strip the ends, twist the wires together on one end, and attach the other to the data logger. Once the test is complete they cut off any wire sticking out of the concrete and can save it to reuse for the next test.

The last example is one of our biggest applications, monitoring the temperature in a medical refrigerator or freezer, for example, a refrigerator in a clinic used to hold vaccines. As dictated in the guidelines from the CDC for vaccine storage and the Vaccines For Children (VFC) program they recommend a digital data logger (DDL) with an uncertainty of ± 0.5°C (±1.0°F). This is a perfect application for a class A RTD probe which has an accuracy at least 2x better than the recommendation. Normally the logger is placed within 10 feet of the refrigerator so cable length is not an issue. When used with a data logger like our Accsense A2-05 it offers a complete, accurate solution for ensuring that vaccines or other medical supplies or samples have been stored properly.

Summary

Well, there you are. Selecting between thermocouples, RTDs, and thermistors comes down to what temperature you will be measuring, the accuracy that you need, where you will be using the sensor, and how important the cost is vs. the performance. Hope you enjoyed this article and found it informative!