

# IN MFG

INNOVATIONS • SOLUTIONS • TRENDS

## Instrumentation/Control

FIRST OF A TWO-PART SERIES

# Sensor Selection 101

Your First Step to Achieving Accurate Temperature Measurement

By Cal Swanson, Senior Principle Engineer, Single Iteration (a Div. of Watlow Electric Mfg. Co.)

There's no simple solution to achieving accurate temperature measurement. It's a combination of knowing the inherent accuracy of particular sensor types, but also how environmental factors can create further measurement uncertainty and the sensor calibration techniques available to reduce this uncertainty — topics for next month's installment (Part II).

### Thermocouples

Thermocouples are the smallest, fastest and most durable temperature measurement solution. They can withstand very high temperatures, harsh mechanical punishment and are simple to operate. Their size allows for rapid temperature response times and the sensing junction can often be placed very close to the desired point of measurement. The durability and simplicity of this sensor type makes them ideal for embedding into other devices.

However, the thermocouple is most at risk from accuracy, noise and precision error (Type E and T thermocouples, particularly). When extreme accuracy and precision is required, many of these shortcomings can be compensated for — simply by using short runs of insulated and shielded



**RTDs are suitable when extremely stable and precise measurements are required. Thermistors operate well in temperatures less than 300 deg. C.**

thermocouple wires with balanced, low-pass filtered differential amplifiers (to avoid common-mode voltage offsets), as well as through relatively complex calibration procedures.

Lack of alloy homogeneity presents additional challenges. Deviations in metal purity and alloy homogeneity result in thermocouple temperature profiles deviating from the National Institute of Standards and Technology (NIST) standards, which becomes particularly problematic when long runs are required. When high accuracy is required without calibration, a

thermocouple type that consists of a minimum number of elements like a type T, J or G should be used.

### Thermistors

Thermistors are ideal for measuring applications that require high accuracy sensitivity over a relatively narrow range of temperatures (less than 300 deg. C). However, they cannot endure high temperatures or mechanical stresses like thermocouples, which makes them difficult to use in applications and assembly operations where these influences are not well controlled. To compensate for this limitation, the sensor can be encased in a protective metal enclosure — but this will be at the cost of thermal responsiveness.

Despite being less subject to different types of error, local signal conditioning is still recommended for thermistors (though it is much simpler than that required for thermocouples) because thermistors tend to be larger than thermocouples, which results in slower response times, and may also be subject to additional location and heat transfer error than equivalently placed thermocouples.

Near their maximum sensitivity point, small changes in temperature produce relatively high changes in resistance. However, away from the maximum sensitivity point, thermistors are less



**Thermocouples can withstand very high temperatures and are simple to operate.**

able to resolve changes in temperature. The use of padding resistors, through a voltage divider circuit, can obtain a more linear response.

Thermistors are capable of being made relatively uniformly in batches, but batch-to-batch variations can still create problems when high precision accuracy is required. In this scenario, special version thermistors that are capable of working to temperatures of 1000 deg. C should be used. Additionally, there are no NIST standards for thermistors, which can also result in large batch-to-batch or manufacturer-to-manufacturer response variations. Strategies for

minimizing this particular effect include forming arrays from a single manufacturing batch.

### RTDs

RTDs are suitable when extremely stable and precise measurements are required, or when accuracy over a prolonged time is the most important factor (the accuracy and precision of an RTD often exceeds that of both a thermistor and thermocouple). RTDs follow Deutsche Industrie Normen (DIN) and/or Joint Information Systems Committee (JISC) national standards and with good tolerance specifications, off-the-shelf RTDs are very consistent regardless of their batch number.

RTDs are very delicate, and while the melting temperature of an RTD element is sufficiently high enough to survive many high-temperature manufacturing operations, they do not tend to survive aggressive mechanical operations (such as compaction), which results in them being difficult to embed into custom mechanical devices. This limitation can be reduced through the use of metal-sheathed assemblies that remove the fragility, but this is at the cost of response time. Additionally, their larger size typically results in slower response times than comparable thermocouples.

For a typical 100 ohm RTD, wire and termination resistance associated with long lead lengths and multiple connections can become a significant source of error. To achieve the highest

accuracy, three or four-wire RTDs are often used. The electronics can be constructed to dynamically remove error associated with lead resistance, but there is also a trade-off in terms of cost and the number of wires required to perform the measurement.

Noise from external sources can create additional measurement problems, but can be mitigated in much the same way as thermocouples — by using differential, ungrounded and shielded elements. These effects can also be limited through optional electronics that perform 10% duty cycle measurements to limit self-heating power without reducing signal strength. However, the trade-off for utilizing low-level signals (power) to drive an RTD is that even further measures may then be required to minimize the effect of external noise.

### Sensor considerations

When building your knowledge base on sensor types, be sure to consider inherent accuracy in terms of durability, range of operation and susceptibility to external noise influences. Also examine how the sensor will be used in terms of temperature range, the required level of accuracy and repeatability, handling/installation endurance, whether it will be calibrated/grounded, and the type of environment it will be used in. **Single Iteration 866-449-6846**

**Use InfoLINK 125-50801-116 or  
Call 800-441-6180**