Embedded Metal Encased and Surface Mount SMD Temperature Sensor Comparison

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Background:

All thermal systems for analytical equipment need some form of control, usually an embedded sensor in a metal heatsink or a Surface Mount Device (SMD). The question of how does one compare to the other is often asked. This white paper will look at the performance difference between the two sensors in relation to temperature changes.

The most common type of sensor used in analytical equipment are NTC (Negative Temperature Coefficient) thermistors and RTD's (Resistance Temperature Detectors). Both type of sensors are available in metal encased versions and SMD versions.

From a temperature accuracy perspective there are several aspects to consider when designing your system and also the sensor you choose. While this paper focuses more on the mounting method, the following performance aspects do need to be considered when determining which temperature sensor is right for your application:

Base Resistance:
Generally the higher the base resistance the less impact lead-wire resistance will have on the temperature accuracy. Thermistors are available in 10K, 25K, 50K and others, where RTD's are typically 100 ohm and 1000 ohm sensors.

Temperature Capability of the Sensor:
RTD's are good for temperatures up to 600C where thermistors are commonly good to 105C.

Resistance Tolerance/Interchangeability:
This refers to how "accurate" one sensor is from another. RTD's are commonly available in class A (±0.06%) and B (±0.12%) and thermistors are available in 1% to 5% tolerance.

Standardization:
RTD's follow an international standard (IEC 751) that covers the Temperature Coefficient of Resistance (TCR) curve. Thermistors vary by manufacturer, each thermistor manufacturer has their own TCR curve.

Drift:
Drift refers to long term stability over many cycles or years. For the best long term stability choose either glass bead thermistors or RTD's.

Lead-Wire Compensation:
Since the resistance of the leads to the sensor add to the base resistance that does need to be compensated for. Lead-wire resistance has the most impact on low resistances and can be compensated for with RTD's by using a 1000 ohm sensor or a 3 wire sensor. Three wire sensors in thermistors are not as common because the effect on the base resistance is often minimal. All Flex can propose for each construction the most economical method of reducing the lead wire effect.

Linearity:
RTD's are generally fairly linear where thermistors are non-liner.

Test Set-Up:

The test system consisted of two 50 watt heaters connected in parallel to produce 100 total watts for the thermal system. Between each heater was an SMT sensor connected to the data logger. Also connected to the data logger was a metal encased sensor. For temperature control, a separate sensor was mounted on the side opposite the heaters and this sensor was connected to a PID controller. The heatsink was 0.25” thick aluminum plate that was 2” by 2”. A cross sectional view of the system is below.

Controller Set-Up:
The controller was previously set to auto-tune to determine the optimum PID, parameters for control of the thermal system. Once established the thermal system was allowed to stabilize at room temperature before conducting the test.

Data Logging Set-Up:
The Embedded sensor and SMT sensor were estimated to be 0.067C on average difference in temperature. This was the off-set used to record data for the following charts.

Sensor Tolerance/Interchangeability:
Both sensors for data logging were 100 ohm Platinum RTD sensors with a tolerance of ±.012% or an acceptable interchangeability of ±0.8C at 100C. The results confirm the results were within this limit.

Mass/Weight Involved:
The heatsink weighs 69.39 grams. There was a cold load applied that weighs 35.15 grams.

Testing:
The thermal system was allowed to stabilize at room temperature, an environmental cover was utilized to limit ambient effects. In the table below lists important events during the test.

Results:

Chart 1:
The embedded sensor reached a maximum overshoot temperature of 105.41C at time 1 min, 44.3 seconds, where the SMT sensor reached a maximum temperature of 104.50C at a time of 1 min, 43.0 seconds. Since both of these sensors are reacting to the heatsink temperature, it is safe to estimate that the SMT sensor responded 1.3 seconds faster.

Chart 2:
The embedded sensor reached a minimum temperature of 100.731 at 13 minutes 12.6 seconds whereas the SMT sensor reached a minimum temperature of 100.30 at 13 minutes 11.8 seconds. During this test of sensitivity to a cold load, it appears that the SMT sensor responded 0.8 seconds faster. By comparing the slopes of the temperature changes, the SMT sensor does respond faster to heatsink temperature changes.

Chart 3:
The embedded sensor reached a maximum temperature of 100.936 at time 22 minutes 45.7 seconds, where the SMT sensor reached a maximum temperature of 100.637 at a time of 22 minutes 44.1 seconds. Since both of these sensors are reacting to the heatsink temperature, it is safe to estimate that the SMT sensor responded 1.6 seconds faster.

Chart 4:
The embedded sensor reached a maximum temperature of 101.449 at time 27 minutes 42.2 seconds, where the SMT sensor reached a maximum temperature of 101.179 at a time of 22 minutes 40.7 seconds. Since both of these sensors are reacting to the heatsink temperature, it is safe to estimate that the SMT sensor responded 1.5 seconds faster.

Conclusion:

There are performance differences between an embedded sensor and a SMT sensor and it appears an SMT sensor, in this test, responds faster to temperature changes in a thermal system compared to a sensor embedded into the heat sink. Each thermal system will have different requirements and a slower responding sensor may be more attractive than a faster sensor.

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