Four-wire Pt100 sensors are always more accurate than two-wire Pt1000 sensors

In traditional industrial processes Pt100 detectors are a well-known concept perceived to represent accurate temperature measurement. In recent years Pt1000 resistors have become increasingly common in quasi-industrial fields, often as replacements for thermistors.

The sensitivity of a platinum resistor is measured in ohms per degree (see Figure 1). Theoretically, the signal from a Pt1000 resistor is ten times greater than that from a Pt100 given the equivalent test current, but the available supply voltage, for instance, can limit the test current and thereby the sensitivity.

Tolerances

IEC 60751:2008 standardises platinum resistors according to the resistor's type: wire wound or thin film patterned. Another distinction is made between stand-alone resistors and resistors built into protective tubes. Error sources arise during the production of temperature sensors. For technical and financial reasons Pt1000 resistors are only used in industrial contexts as thin-film resistors.

Measured in degrees Celsius, the tolerances for the Pt100 and the Pt1000 are the same. However, in terms of resistance, the Pt1000 values are ten times greater. Figure 2 shows that according to the standard, Class A film resistors cannot normally be used at temperatures greater than 300 °C. Otherwise the sensor will deviate outside tolerance class A. [Ref 1] However, special versions are available for which the manufacturer and customer may have agreed on different properties.

Self heating

In practice, the self heating in the Pt100 and Pt1000 is about the same. The greater resistance in the Pt1000 is often countered by the fact that the test current can be reduced somewhat and this reduction has a quadratic effect. Unfortunately, the film resistor's small size means that the heat transfer to the surroundings is worsened compared with that of wire-wound resistors, which tend to heat up far less. On small surfaces, the Pt1000 resistance must increase the length/area ratio on the platinum pattern, which thereby risks heating up even more.

Four-conductor connection most reliable

Four-conductor technology is the most reliable way to measure resistance (see Figure 3a). Normally two wires are used for the constant current source and two more for the voltmeter loop. The voltmeter circuit itself is now at least 10 megohms and with sensor wires of a few ohms the voltage division is so small that its effect is not visible on instruments with a 0.01 °C resolution. Three-conductor technology works well in theory but in unsuitable environments it can lead to large contact resistances, which cause measurement error because in practice the technology requires equal resistance in all three conductors. [Ref 2]

Consider a two-conductor system with a fixed area and length as in Figure 3b. Theoretically, with a Pt100 we would get a 4 °C measurement error, with a Pt1000 we would get a 0.4 °C error and with a thermistor of 10 kilohms we would get an approximate error of 0.04 °C because the thermistor's sensitivity is about ten times greater than that of a Pt1000. Here we can see a dubious reason why Pt1000s are used. The measurement error in the two-conductor system, which saves on cabling, could be reduced by a factor of ten compared with the industry-standard Pt100. In practice, the two-conductor system's resistance is extremely sensitive to changes of length and area in the conductors as well as to time and environment at the connection points. As a result, the two-conductor system is actually extremely unreliable. We can avoid such problems by using a four-conductor connection (see 3a).

Save on cabling/installation

An alternative way to save on both the amount of cable used and the work to install it is to use Pentronic's digital miniature transmitters, which are integrated with the detector and are available in both analog and digital versions. Another benefit of doing this is additional accuracy, down to ±0.05 °C including an appropriately designed detector installation. Pentronic's transmitter system is currently used mainly by machinery manufacturers.

Figure 1

Temperature\Resistor	Pt100	Pt1000	Thermistor
0 °C	100 Ω	1000 Ω	10 kΩ at 25 °C
100 °C	138,5 Ω	1385 Ω	
Sensitivity, (alpha)	0,385 Ω/°C	3,850 Ω/°C	Approx. 40 Ω/°C

Figure 2

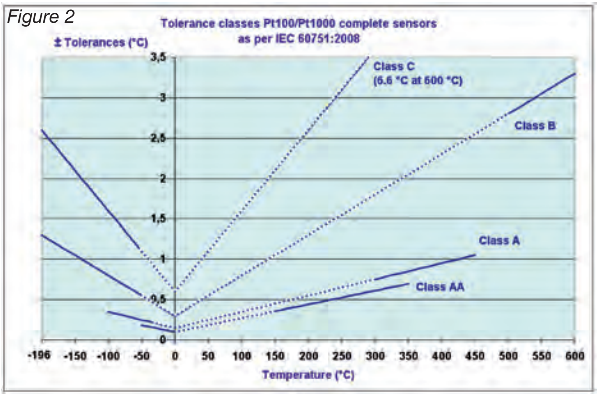

Figure 3a

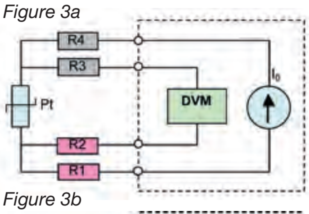

Figure 3b

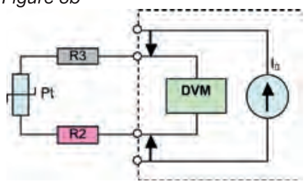

Figure 1. Typical data for the Pt100 and Pt1000 respectively.

Figure 2. The dotted lines apply to sensors with film resistors in accordance with IEC 60751:2008. The solid lines show the extended measurement ranges of wire-wound resistors.

Figure 3a. A four-conductor connection is by far the best for sensors with platinum resistors. R1 to R4 are typically 1 ohm each whilst R(DVM) is at least 10 megohms. The generator maintains the constant current I0 through the platinum resistor. Only a tiny amount of current takes the path through DVM and the voltage drop across R2+R3 is minimal. That is why the small error may only be visible when DVM shows readings equivalent to thousandths of a degree.

Figure 3b. A two-conductor connection is risky when measuring resistance. The measuring current must be reconnected (see the arrows) and will pass through the R2+R3 line resistances in addition to the platinum resistance. The reading will be the sum of the three resistances.

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