measurement matters

Leading questions

Lead resistances have a large impact on the accuracy of resistance temperature detectors (RTDs). With typical 100 ohm platinum RTDs, lead-wires cause an error of about 2.5 degrees Celsius for every ohm of lead resistance, and for large installations errors of several degrees are common. Since platinum RTDs are preferred for applications such as food and chemical processing where accuracies in the range 0.1 to 1.0 degree Celsius are required, this is a serious problem.

Figure 1 shows a two-wire measurement of a 100 Ω platinum RTD. In this measurement, the resistance of the leadwires is indistinguishable from the resistance of the sensor, causes the error.

Figure 2 shows the ideal solution, a four-wire resistance measurement. Resistance measurement has two aspects:

(i) a known current is passed through the resistor; and
(ii) the voltage across the resistor is measured.

The resistance is the given by the ratio of the voltage to the current (R = V/I). In the four-wire measurement these two aspects are separated. The sensing current is passed through one pair of leads, and the voltage across the sensor is measured using the other pair of leads. The lead effects in good four-wire measurements are practically zero. For this reason all laboratory thermometers and reference thermometers use four-wire systems.

Figure 3 shows a three-wire measurement; a common compromise solution offering a saving in cable costs for large installations.

This technique has evolved from older Wheatstone-bridge based instrumentation where four-wire measurements are difficult to implement. With modern instruments, four-wire measurements are simple. The three-wire technique exploits the fact that the voltage error caused by one of the lead resistances can be measured, and subtracted from the voltage across the sensor. This works well so long as the lead resistances are identical.

In practice there are small differences in the lead resistances and the connections to the instrument, which cause errors of perhaps several tenths of an ohm (up to one degree Celsius).

Industrial temperature controllers and indicators are readily available with all of these options, as are RTD assemblies.

To work out which of the systems you should use, you need to know the accuracy you require and the sensitivity of the sensor. The product of the two figures gives the permissible lead resistance. For example, if we require an accuracy of two degrees Celsius from a 100 Ω RTD with a sensitivity of 0.4 Ω/°C, then we can tolerate up to 2×0.4 = 0.8 Ω of lead resistance.

The principles outlined here also apply to other resistive sensors such as strain gauges, light meters, and a variety of chemical transducers. These often have a higher resistance than RTDs, so lead effects are less of a problem.

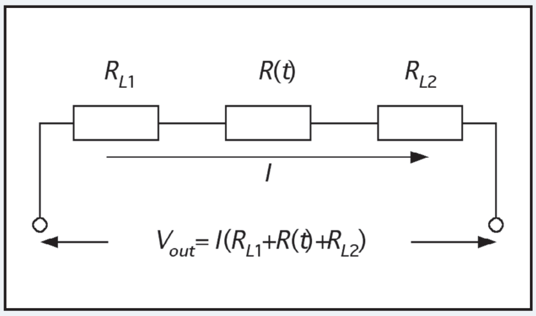

Figure 1: A two-wire resistance measurement

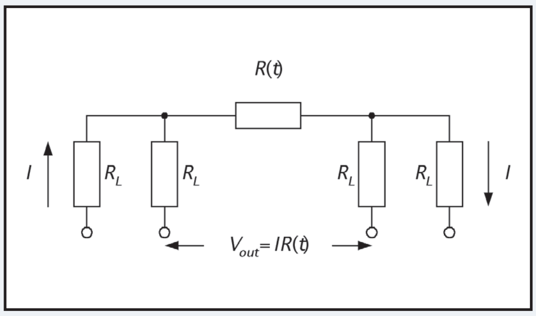

Figure 2: A four-wire resistance measurement

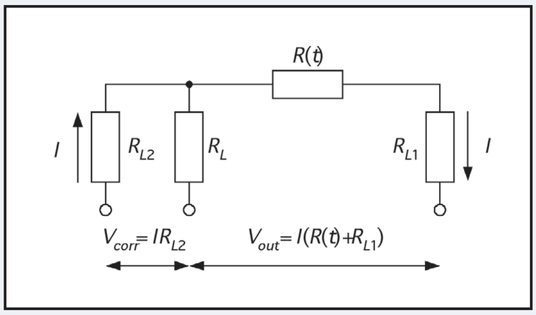

Figure 3: A three-wire resistance measurement

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