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Measuring Temperature with an RTD or Thermistor

Visión General

This tutorial is part of the National Instruments Measurement Fundamentals Series. Each tutorial in this series, will teach you a specific topic of common measurement applications, by explaining the theory and giving practical examples. This tutorial introduces and explains the concepts and techniques of measuring temperature with an RTD or Thermistor.

For more in-depth guidance on making a temperature measurement, visit the how-to guides for thermistor measurements and RTD measurements.

You can also view an on demand webcast on strain gauge measurements.

To find more information on the Measurement Fundamentals series, return to the Measurement Fundamentals Main Page.

Contenido

What Is Temperature?

Qualitatively, the temperature of an object determines the sensation of warmth or coldness felt by touching it. More specifically, temperature is a measure of the average kinetic energy of the particles in a sample of matter, expressed in units of degrees on a standard scale.

RTDs and Thermistors

RTDs

Resistance temperature detectors (RTDs) operate on the principle of changes in electrical resistance of pure metals and are characterized by a linear positive change in resistance with temperature. Typical elements used for RTDs include nickel (Ni) and copper (Cu), but platinum (Pt) is by far the most common because of its wide temperature range, accuracy, and stability.

RTDs are constructed by one of two different manufacturing configurations. Wire-wound RTDs are constructed by winding a thin wire into a coil. A more common configuration is the thin-film element, which consists of a very thin layer of metal laid out on a plastic or ceramic substrate. Thin-film elements are cheaper and more widely available because they can achieve higher nominal resistances with less platinum. To protect the RTD, a metal sheath encloses the RTD element and the lead wires connected to it.

RTDs are popular because of their excellent stability, and exhibit the most linear signal with respect to temperature of any electronic temperature sensor. They are generally more expensive than alternatives, however, because of the careful construction and use of platinum. RTDs are also characterized by a slow response time and low sensitivity; and because they require current excitation, they can be prone to self-heating.

RTDs are commonly categorized by their nominal resistance at 0 °C. Typical nominal resistance values for platinum thin-film RTDs include 100 Ω and 1000 Ω. The relationship between resistance and temperature is very nearly linear and follows the equation

For <0 °C $R_T = R_0 [1 + aT + bT^2 + cT^3 (T - 100)]$ *(Equation 1)*

For >0 °C $R_T = R_0 [1 + aT + bT^2]$

Where R_T = resistance at temperature T
R_0 = nominal resistance
a, b, and c are constants used to scale the RTD

The resistance/temperature curve for a 100 W platinum RTD, commonly referred to as Pt100, is shown below:

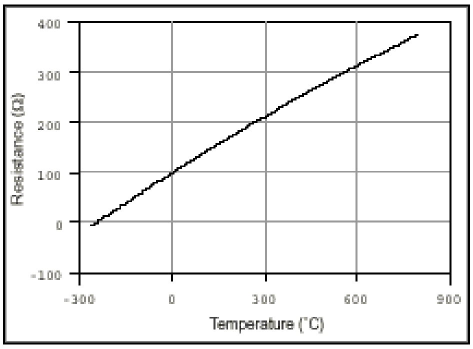

Figure 1. Resistance-Temperature Curve for a 100 Ω Platinum RTD, a = 0.00385

The most common RTD is the platinum thin-film with an a of 0.385%/°C and is specified per DIN EN 60751. The a value depends on the grade of platinum used, and also commonly include 0.3911%/°C and 0.3926%/°C. The a value defines the sensitivity of the metallic element, but is normally used to distinguish between resistance/temperature curves of various RTDs.

Table 1. Callendar-Van Dusen Coefficients Corresponding to Common RTDs

Standard	Temperature Coefficient (a)	A	B	C
DIN 43760	0.003850	3.9080×10^{-3}	-5.8019×10^{-7}	-4.2735×10^{-12}
American	0.003911	3.9692×10^{-3}	-5.8495×10^{-7}	-4.2325×10^{-12}
ITS-90	0.003926	3.9848×10^{-3}	-5.870×10^{-7}	-4.0000×10^{-12}

* For temperatures below 0 °C only; C = 0.0 for temperatures above 0 °C.

Thermistors

Thermistors (thermally sensitive resistors) are similar to RTDs in that they are electrical resistors whose resistance changes with temperature. Thermistors are manufactured from metal oxide semiconductor material which is encapsulated in a glass or epoxy bead.

Thermistors have a very high sensitivity, making them extremely responsive to changes in temperature. For example, a 2252 W thermistor has a sensitivity of -100 W/°C at room temperature. In comparison, a 100 W RTD has a sensitivity of 0.4 W/°C. Thermistors also have a low thermal mass that results in fast response times, but are limited by a small temperature range.

Thermistors have either a negative temperature coefficient (NTC) or a positive temperature coefficient (PTC). The first has a resistance which decreases with increasing temperature and the latter exhibits increased resistance with increasing temperature. Figure 2 shows a typical thermistor temperature curve compared to a typical 100 W RTD temperature curve:

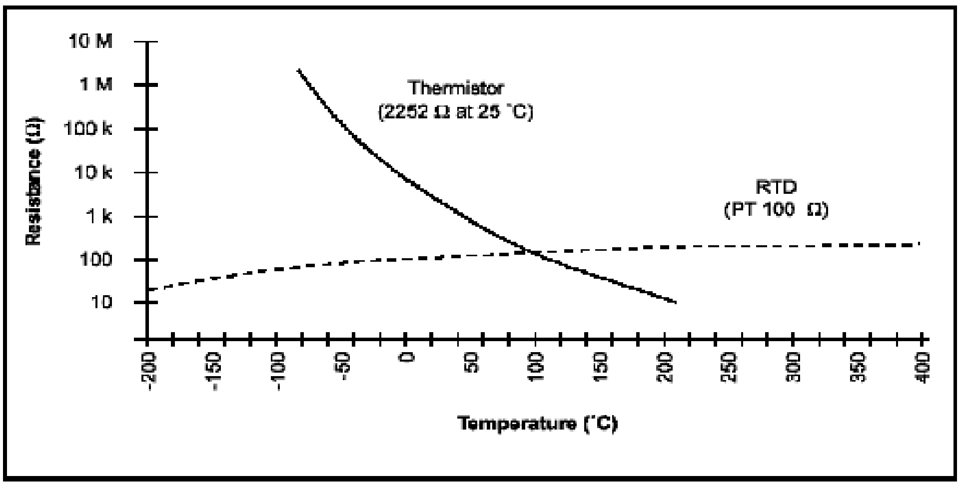

Figure 2. Resistance versus Temperature for a Typical Thermistor and RTD

RTD and Thermistor Measurement and Signal Conditioning

Because RTDs and thermistors are resistive devices, you must supply them with an excitation current and then read the voltage across their terminals. If extra heat cannot be dissipated, I^2R heating caused by the excitation current can raise the temperature of the sensing element above that of the ambient temperature. Self-heating will actually change the resistance of the RTD or thermistor, causing error in the measurement. The effects of self-heating can be minimized by supplying lower excitation current.

The easiest way to connect an RTD or thermistor to a measurement device is with a 2-wire connection.

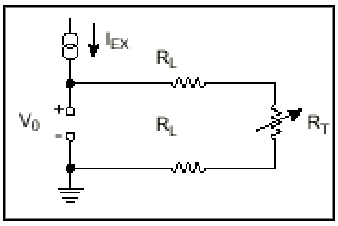

Figure 3. Making a 2-Wire RTD/Thermistor Measurement

With this method, the two wires that provide the RTD or thermistor with its excitation current are also used to measure the voltage across the sensor. Because of the low nominal resistance of RTDs, measurement accuracy can be drastically affected by lead wire resistance. For example, lead wires with a resistance of 1 W connected to a 100 W platinum RTD cause a 1% measurement error.

A 3-wire or 4-wire connection method can eliminate the effects of lead wire resistance. The connection places leads on a high impedance path through the measurement device, effectively eliminating error caused by lead wire resistance. It is not necessary to use a 3 or 4-wire connection method for thermistors because they typically have much higher nominal resistance values than RTDs. A diagram of a 4-wire connection is shown below.

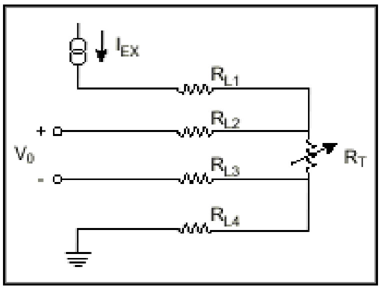

Figure 4. Making a 4-Wire RTD Measurement

RTD and thermistor output signals are typically in the millivolt range, making them susceptible to noise. Lowpass filters are commonly used in RTD and thermistor data acquisition systems to effectively eliminate high frequency noise in RTD and thermistor measurements. For instance, lowpass filters are useful for removing the 60 Hz power line noise that is prevalent in most laboratory and plant settings.

DAQ Systems for Measuring Temperature with RTDs and Thermistors

Using SCXI with RTDs and Thermistors

National Instruments SCXI is a signal conditioning system for PC-based data acquisition systems. An SCXI system consists of a shielded chassis that houses a combination of signal conditioning input and output modules, which perform a variety of signal conditioning functions. You can connect many different types of sensors, including RTDs and thermistors, directly to SCXI modules. The SCXI system can operate as a front-end signal conditioning system for PC plug-in data acquisition (DAQ) devices (PCI and PCMCIA) or PXI DAQ modules.

Figure 5. SCXI Signal Conditioning System

SCXI offers a variety of analog and digital signal conditioning modules for various types of signals, including RTDs and thermistors. Table 1 includes the features of SCXI modules that can be used for RTD and thermistor measurements. See Table 2. to select a data acquisition system by application.

Table 1. SCXI Signal Conditioning Modules for RTDs and Thermistors

	SCXI-1121	SCXI-1122	SCXI-1102 w/ SCXI 1581
Number of inputs	4	16 (devices in series) 8 (4-wire scanning mode)	32
Amplifier gains	1 to 2000 – jumper selectable	1 to 2000 – jumper selectable	1 or 100 – software selectable per channel
Filtering options	4 Hz or 10 kHz	4 Hz or 4 kHz – software programmable	2 Hz
Isolation	250 V_{rms}	480 V_{rms}	N/A
Excitation Values	3.33 V, 10 V 0.15 mA, 0.45 mA	3.33 V 1 mA	100 µA
Recommended terminal block for RTDs/Thermistors	SCXI-1320 or SCXI-1322	SCXI-1322	SCXI-1300 or SCXI-1303

Table 2. Recommended DAQ Systems

RTD		
Application	**Channel Count**	**Features**
High-Channel Count	16-1500+	Modular and expandable
Isolated	Up to 48 per system	250 Vrms Isolation per channel
Ethernet	Up to 32 per network node	Rugged, industrial platform

Return to Sensor Fundamentals or the Measurement Fundamentals Main Page for information on other sensor and measurement types.
Return to NI Temperature Measurement Solutions for more information on temperature measurement hardware.

Comentarios del Lector | Enviar un comentario »

"lead wires with a resistance of 1 W connected to a 100 W platinum RTD cause a 1% measurement error." I think you mean "Ohm" and not "W" in the above statement.

- 06-oct-2008

wire diagram
Nice and short explanation. But a bit to short. I would like some wiring examples with your products, like SSC RTD01.
- 14-feb-2008

Good website. Simple and straight. In terms of adding material, I would recommend an equation which models Thermistor behavior.
- 02-nov-2006