INSTRUMENTS

Temperature Measurement for Everyone

Several years ago, I received a call from a friend saying, “My computer is going crazy. When I press a key on the keyboard, I get the wrong character, and I have a paper due in a few hours. I’ll have to stop using the computer and type my final draft with a typewriter.” And so she did. Later that day, I found the problem. Books blocked the computer’s cooling vent. Keeping the vent clear solved the problem.

Electronic circuits generate heat. A temperature change can cause resistors to drift or cause transistors operating in their linear range to saturate. You also can use temperature measurements to get an indication of how much power a component consumes. For example, you might want to measure the temperature on both sides of a power transistor’s electrical insulator.

Probes and Meters
To measure temperature, you typically need a probe and a meter. For the probe, you can use a thermocouple, a resistance temperature detector (RTD), or a thermistor. You also can use an IC sensor as part of a temperature-measuring circuit. Finally, you can use an infrared thermometer to make a nonintrusive measurement. Table 1 highlights typical temperature ranges for each type of sensor.

<table>
<thead>
<tr>
<th>Table 1. Temperature Sensor Ranges</th>
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</thead>
<tbody>
<tr>
<td>Sensor</td>
</tr>
<tr>
<td>Type K thermocouple</td>
</tr>
<tr>
<td>Type J thermocouple</td>
</tr>
<tr>
<td>Type T thermocouple</td>
</tr>
<tr>
<td>Type E thermocouple</td>
</tr>
<tr>
<td>Pt 100 RTD (α=0.00385)</td>
</tr>
<tr>
<td>Thermistor</td>
</tr>
<tr>
<td>IC sensor</td>
</tr>
<tr>
<td>Infrared thermometer</td>
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</tbody>
</table>

Source: Omega Engineering

Therefore, you may have to measure the temperature of individual circuit components during a design evaluation test or during a field failure test. You may also have to measure the temperature in an enclosure to verify that the product’s cooling vents and fans work properly. When you assemble a rack of instruments, you should measure the temperature inside it (with the doors closed) and, if necessary, provide an escape for the hot air.

When you measure the effectiveness of your cooling vents and fans, you often need to measure at least two temperatures. The difference between the vent’s input and output temperatures tells you how well the electronics are being cooled.

Thermocouples, RTDs, and thermistors are available as just the sensor element with short lead wires or with the sensor mounted in a protective sheath. If you’re measuring the temperature of an IC, then you should use a sensor without a sheath. (A sheath may be too big to fit into a small area, and it may not make sufficient contact to get good thermal transfer.) Attach the sensor to your IC with tape or use an adhesive that conducts heat.

For measuring the temperature inside an enclosure or rack, use a probe with a sheath. Some sheaths come with mounting hardware attached. These probes might have plates with screw holes for mounting to flat surfaces or clamps for attaching to pipes.

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Thermocouples are the most popular temperature probes. They’re the least expensive and easiest to use, and they have an accuracy of between 1°C and 2°C. You can mount the sensor several hundred feet from the electronics that measure its output. Thermocouples come in different types depending on their composition. The most popular thermocouple today is called a “type K.” If you have a DMM that can measure temperature, it probably works with type-K thermocouples. Your meter may also accept other thermocouple types such as type J or type T, and it may accept RTDs.

The simplest thermocouple assembly consists of two thermocouple wires crimped or welded together at one end.

The opposite ends of the wires should be at the same temperature as each other so you have identical temperature differences along the lengths of both wires. Most thermocouple meters have a heat-conducting block to minimize any temperature difference between the wires at the meter.

While using just unsheathed wires is certainly easy and inexpensive, the thermocouple is prone to damage unless you permanently mount it. And because the wires may not be shielded, they are susceptible to EMI from computers, machinery, electrical lines, and so forth. Thermocouples generate a low-level voltage. At 100°C, a type-K thermocouple generates about 4 mV, so EMI can interfere with your measurements.

When you use a thermocouple to measure temperature on metal surfaces, check for possible ground loops or shorts. If the metal surface is grounded, contact with the sensor may ground the sensor, too. If you use a thermocouple enclosed in a sheath, verify if the sheath or the thermocouple wire is grounded. You might short out the sensor or introduce interference.

RTDs offer better accuracy (less than 1°C) and better long-term stability than thermocouples. Their temperature range isn’t as wide as most thermocouples, but it well exceeds the range you need for measurements on electronic circuits or even on vehicle engines. RTDs are less susceptible to EMI than are thermocouples.

Instead of generating a voltage like thermocouples do, RTDs change resistance with temperature. The most popular RTD, known as a Pt 100 sensor, consists of a platinum wire that has a nominal resistance of 100 Ω at 0°C. The resistance-temperature curve for a Pt 100, which your meter will linearize, is based on a polynomial equation in which the most significant constants, α, is 0.00385 Ω/°C (also called the European curve).

You can get better than 1°C accuracy with RTDs, but the resolution you get depends on your measurement instrument. RTDs typically change resistance by less than 0.4 Ω/°C. With 1 mA of excitation current, that translates into 0.4 mV/°C. So, your instrument needs to resolve better than 0.4 mV for 1°C resolution.

Most industrial RTDs use three wires. One wire carries excitation current, typically 1 mA. Another wire carries the sense signals from the element. The third is a common wire for both sensing and excitation-current return. In applications that require the best accuracy, you can use a four-wire RTD, which separates the sense return and the current return, thereby eliminating IR losses on one of the wires. Typically, you won’t need four-wire RTDs for everyday measurements; calibration labs typically use four-wire RTDs to calibrate working probes.

Thermistors are also resistance devices, but they’re made of semiconductor material rather than platinum wire. Unlike RTDs, some thermistors have a resistance that decreases with temperature—these are called negative temperature coefficient (NTC) thermistors.

Thermistor resistance-to-temperature curves are also highly nonlinear, but today’s instruments can easily compensate for the nonlinearities. Because of their high sensitivity, thermistors usually require only two-wire connections. To minimize IR losses,
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TEST TIPS & TECHNIQUES

use short wires—no longer than just a
couple of feet—between the sensor and
your measurement instrument.

A thermistor probe is the best
choice when you need the highest res-
olution, that is, when you want to mea-
sure small changes in temperature. If
you’re trying to measure the temperature
coefficient of a component such as
a crystal over a narrow temperature
range, then use a thermistor. Ther-
mistor probes measure temperature
resolution and have higher resolution than other sensors. A

Thermists have a narrow temperature range compared to thermocouples and RTDs.

typical 10-kΩ (at
25°C) thermistor has a
resolution of 438
Ω/°C. That’s more
than a thousand times
increase in resolution
over an RTD.

Thermistors have a narrow temperature range compared to thermocouples and RTDs. Thermistors work best if the

IC temperature sensors contain not
only a temperature sensor but also sig-

IC temperature sensors may re-

An infrared thermometer measures the

The field of view is inversely pro-

A thermistor will display the average tem-

You can use a variety of instru-

FOOTNOTES


2. Zurbuchen, John, “Precision Thermistor

3. Infrared thermometers measure the sur-

4. Hausmann, Werner, “Thermistor and DMM

5. You can contact Martin Rowe at

You will display the average temperature of more than one object, which will give you a false reading. You also have
to be concerned about emissivity—how
temperature relates to radiation.

Thermistors have a narrow temperature range compared to thermocouples and RTDs.

Regardless of which type of probe

+1.5°C/°C to 4°C/°C with
different types of probes

-10°C to +10°C

-20°C to +20°C

-30°C to +30°C

-40°C to +40°C

-50°C to +50°C

-60°C to +60°C

-70°C to +70°C

-80°C to +80°C

-90°C to +90°C

-100°C to +100°C

-110°C to +110°C

-120°C to +120°C

-130°C to +130°C

-140°C to +140°C

-150°C to +150°C

-160°C to +160°C

-170°C to +170°C

-180°C to +180°C

-190°C to +190°C

-200°C to +200°C

-210°C to +210°C

-220°C to +220°C

-230°C to +230°C

-240°C to +240°C

-250°C to +250°C

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