High-Resolution Temperature Measurement

By Moshe Gerstenhaber and Michael O'Sullivan

The AD8494 thermocouple amplifier includes an on-chip temperature sensor, normally used for cold-junction compensation, allowing the device to be used as a standalone Celsius thermometer by grounding the thermocouple inputs. In this configuration, the amplifier produces a 5-mV/°C output voltage between the output and (the normally grounded) reference pins of the on-chip instrumentation amplifier. One drawback of this approach is the poor system resolution achieved when measuring narrow temperature ranges. Consider this: a 10-bit ADC running on a single 5-V supply has 4.88-mV/LSB resolution. This means that the system shown in Figure 1 has a resolution of about 1°C/LSB. If the temperature range of interest is narrow, say 20°C, the output varies by 100 mV, utilizing only 1/50 of the ADC's available dynamic range.

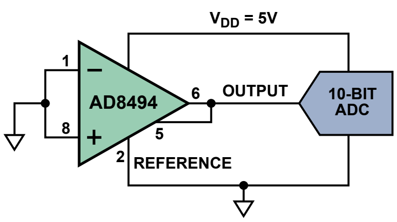

Figure 1. Simple thermometer.

The circuit shown in Figure 2 solves this problem. As before, the amplifier produces a 5 mV/°C voltage between the output and reference pins of the instrumentation amplifier. Now, however, the reference pin is driven by the AD8538 operational amplifier (configured as a unity-gain follower), so the 5-mV/°C voltage appears across R1. The current flowing through R1 also flows through R2, generating a temperature-sensitive voltage across the series combination that is $(R1 + R2)/R1$ times the voltage across R1. With the values shown, the output voltage varies at 20 × 5 mV/°C = 100 mV/°C, so a 20°C temperature change produces a 2-V output voltage change. The new 0.05°C/LSB system resolution is a 20:1 improvement over the original circuit. The AD8538 buffers the resistor network, driving the reference pin with a low impedance in order to maintain good common-mode rejection and gain accuracy.

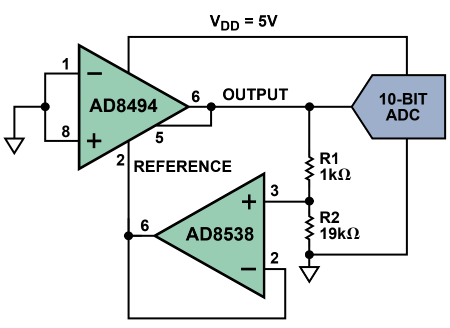

Figure 2. High-resolution temperature measurement.

Care must be taken to match the system sensitivity to the desired temperature range. For example, the output voltage is 2.5 V at 25°C, so the system can accurately measure from 5°C to 45°C as the output voltage varies from 0.5 V to 4.5 V.

A circuit such as the one shown in Figure 3 offers higher sensitivity and customizable temperature ranges. The resistance divider formed by R3 and R4 simulates the thermocouple voltage required to offset the amplifier, zeroing its output voltage at the desired level. If V_{DD} is noisy, a precision voltage reference and divider circuit could be used to provide a quieter, more accurate offset adjustment. As shown, the circuit has an output voltage of about 0.05 V at 25°C, 100 mV/°C sensitivity (0.05°C/LSB resolution), and an operational range of approximately 25°C to 75°C.

The AD8494 has an initial offset error of ±1°C to ±3°C, so the user must include an offset calibration to improve absolute accuracy.

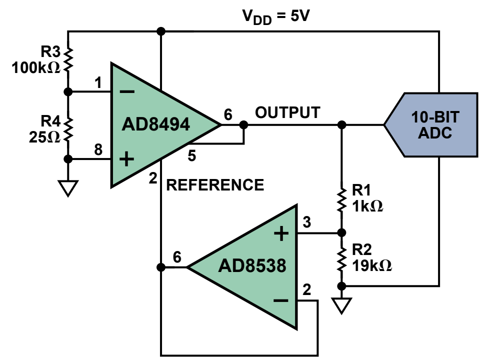

Figure 3. Higher resolution temperature measurement with offset adjustment.

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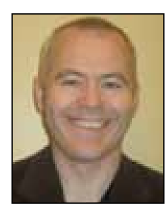

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