Celsius-to-digital thermometer works with remote sensor

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You can use a single-supply system to precisely measure the temperature at a remote location with less than 1°C error over a 0 to 100°C range (Figure 1). The circuit includes \( T_1 \), a low-cost AD590 temperature sensor; IC\(_1\), an AD8541 rail-to-rail amplifier; four resistors; a trimming potentiometer; and an ADC. You can omit the ADC if you need an analog output. You could replace the trimming potentiometer with an AD8400 or AD5273 digital potentiometer for easier calibration. The feedback resistor, \( R_F \), should be a precision resistor to minimize the scale-factor error, but the accuracy of the remaining resistors is not critical. You can choose the grade of the AD590 sensor to achieve the required accuracy.

The AD590 provides an output current proportional to absolute temperature (1 \( \mu \)A/K). In this application, the circuit offsets and scales the output to provide a full-scale range of 0 to 5V with a scale factor of 50 mV/°C over the chosen temperature range of 0°C—the freezing point of water—to 100°C, the boiling point of water. The AD8541 is a low-cost, low-power, rail-to-rail operational amplifier. It has a high common-mode voltage range and extremely low bias currents. You can calibrate out its 1-mV typical offset, the resistor, and AD590 errors. The output swing of the amplifier is 25 mV to 4.965V with a single 5V power supply, limiting the output by about 0.5°C on either end.

This circuit can derive its power from a single 5V power supply. The output of the AD590 varies from 273.15 to 373.15 \( \mu \)A as the temperature varies from 0 to 100°C. The positive input of the AD8541 has an offset of 4V to provide sufficient headroom for the AD590. The series combination of \( R_1 \) and \( R_2 \) develops a 1V drop, and you adjust \( R_2 \) to provide a nominal current of 353.15 \( \mu \)A. Thus, the current through the feedback resistor, \( R_F \), varies from -80 to +20 \( \mu \)A as the temperature varies from 0 to 100°C. The voltage across this resistor varies from -4 to +1V. The 4V offset causes the output voltage of the amplifier to vary from 0 to 5V.

To guarantee the accuracy of 1°C throughout the range, you need to perform a calibration procedure. At a known temperature, such as 25°C, adjust trimming potentiometer \( R_2 \) to obtain the desired voltage at the output of the amplifier, 1.250V, or the desired code at the output of the ADC, 400H. Once you perform the calibration, you can calculate the temperature in Celsius at any measured point inside the range by multiplying the output voltage by 20. Because the sensor has a current output, it is immune to voltage-noise pickup and voltage drops in the signal leads; you can thus use it at a remote location. You should use a twisted-pair or shielded cable.

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