Application Report

SNIA002A–May 2004–Revised April 2013

# AN-1256 Tiny Temperature Sensors for Portable Systems

## ABSTRACT

The last year has seen the introduction of silicon temperature sensors in revolutionary small packages, ideal for portable systems. This application report discusses trade-offs in accuracy, as well as how to choose between thermistors and analog output IC temperature sensors.

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# 1 Tiny Temperature Sensors for Portable Systems

Figure 1 shows the output voltage transfer function of various analog output temperature sensors. These sensors are available in tiny packages like the SC70 and the 4-bump micro SMD. The LM20 is the smallest, lowest power (10 µA max) analog output temperature sensor Texas Instruments has released and is available in the SC70 and micro SMD packages. The LM70 and LM74 are MICROWIRE/SPI compatible digital temperature sensors and are available in the LLP and 8-bump micro SMD packages, respectively. The LM70 and LM74 have resolutions of 0.125°C and 0.0625°C, respectively. The LM74 is the most accurate of the two, with an accuracy of better than ±1.25°C.

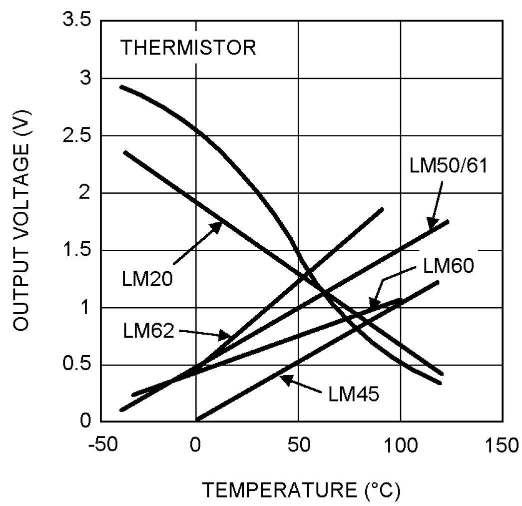


**Figure 1. Comparison of Analog Temperature Sensors to Thermistors**

The curves shown in Figure 1 compare the temperature-to-voltage transfer functions of silicon temperature sensors with that of an NTC thermistor.

Thermistors come in a variety of packages ranging from probes to beads. However, ICs have surface mount packaging equivalent to thermistors, as in the LM20 micro SMD.

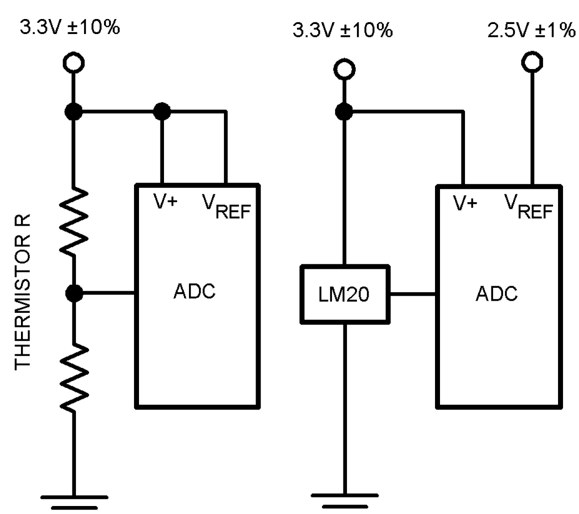


**Figure 2. Connecting a Thermistor or an LM20 to an Analog-to-Digital Converter (ADC)**

Thermistors, when biased ratiometrically (as shown in Figure 2), have the advantage of not requiring an accurate or stable voltage reference in the system. In ratiometric operation, the error introduced by the reference is cancelled out. If ratiometric operation is not possible, for instance when the ADC reference voltage is in an ASIC and is not pinned out, using ICs like the LM20 result in better total system accuracy. The LM20 draws only 10 µA of current while the current drawn by the thermistor circuit depend on the value of R.

A specific thermistor was analyzed: the Murata NTH5G10P/16P33B103F. This thermistor has an accuracy of 1% at 25°C. The evaluation used ADCs with various resolutions to examine the overall system accuracy that depends on the resolution of the ADC, the ADC's errors (gain, offset and nonlinearity or TUE, total unadjusted error) and the resolution of the compensation table.

Figure 3 shows the voltage applied at the ADC input for the thermistor circuit shown in Figure 2. Note that the ADC input voltage decreases logarithmically with increasing temperature. The 97.6k resistor optimizes the power dissipation (30 µA) in the thermistor. It allows the thermistor to operate at a power level not exceeding its maximum power rating while maintaining specified accuracy.

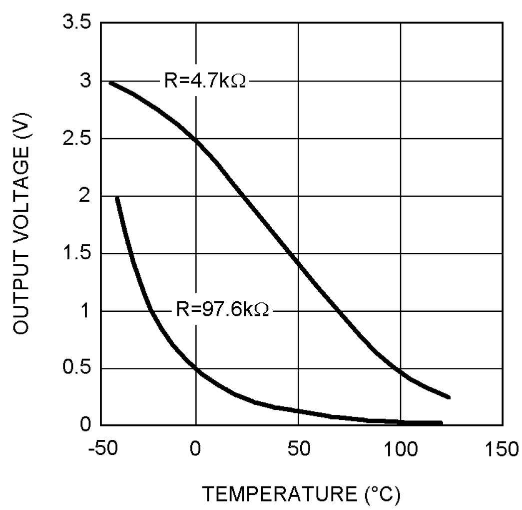


**Figure 3. Thermistor Output Voltage Versus Temperature for Different Values of R**

Lowering the value of R increases the temperature range over which the thermistor's transfer function is linear. With a 4.7k bias resistor, the slope at higher temperatures increases, providing more resolution, at the cost of greater power consumption (600 µA)

Figure 4 compares the overall system accuracy when using a thermistor with an 8-bit ADC and R=100k, a thermistor with a 10-bit ADC and R=33k, or an LM20 with an 8-bit ADC. The quantization error and ADC total unadjusted error (a combination of offset, gain and linearity errors) was considered to determine the overall system accuracy. The black lines show the min/max system performance of the LM20 superimposed over the blue min/max performance of the thermistor. The overall system accuracy for the LM20 remains constant over temperature. At temperatures above 60°C, the LM20 wins big when compared to the performance of the thermistor and 8-bit ADC.

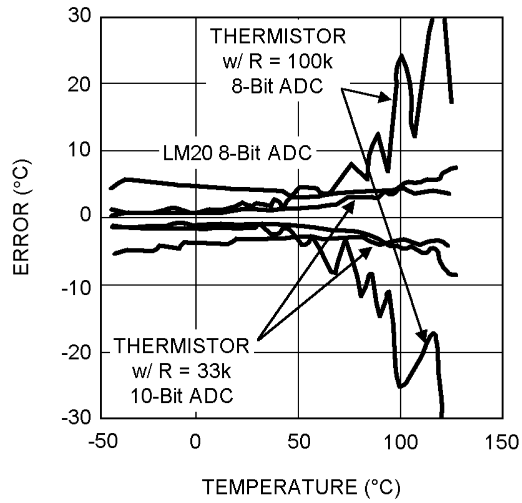


**Figure 4. Comparison of Thermistor to LM20 System Performance**

Increasing the ADC resolution and decreasing the value of R in the thermistor circuit decreases the overall system error. Improving the accuracy of the voltage reference brings the LM20 system accuracy closer to that of the specifications found on the LM20 data sheet of ±2.5°C at +130°C and −55°C, and ±1.5°C at +30°C. Since the output slope of the LM20 is negative, the gain error introduced by the reference voltage plays less of a role in the overall accuracy as the temperature increases, thus the slight negative slope of the LM20 performance.

Designers have numerous options for sensing temperature. Most common are thermistors, RTDs, thermocouples, and active silicon sensors. IC sensors have major advantages when the temperatures to be measured fall within the normal operating temperature range of silicon ICs. Among these advantages are low system cost, small size, and fast design time (because external signal conditioning circuitry is either minimal or not required). ICs can include extensive additional functions, such as built-in trip-point comparators or digital I/O. Since they include on-chip linearity correction when needed, there is no need for lookup tables to correct linearity errors.

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