DESIGN SOLUTIONS
ANALOG

Guard Your Portable Device While It Sleeps

Introduction

Finding ways to extend battery life is a key challenge facing designers of portable electronic equipment, such as the wristband fitness monitor illustrated in Figure 1. The most common way to meet this challenge is to place a device in a low-power standby mode of operation whenever it is not being used. However, even in standby mode, there are supervisory functions that are critical to ensure the safe functioning of the device.

One of these vital functions is temperature monitoring. A malfunctioning battery can raise the temperature of a portable device beyond specified levels. Such a temperature rise may cause it to malfunction, be irreparably damaged, or in a worst-case scenario, it could even pose a fire hazard to the user. In this design solution, we review how temperature is typically monitored in a portable electronic device and introduce a simple yet innovative way for portable device manufacturers to monitor temperature with little overhead in terms of power, size, or cost.

Figure 1. Portable Fitness Monitor

Microcontroller Temperature Monitoring

Most portable electronic systems consist of a microcontroller to process inputs and deliver outputs to the user. For example, a smartwatch may monitor the pulse rate of the wearer and display the results on an LCD display or store the information in on-board flash memory for later analysis. During normal operation, a simple temperature detection circuit constructed using a thermistor (Figure 2) sends an analog signal proportional to the measured temperature to the microcontroller (µC).

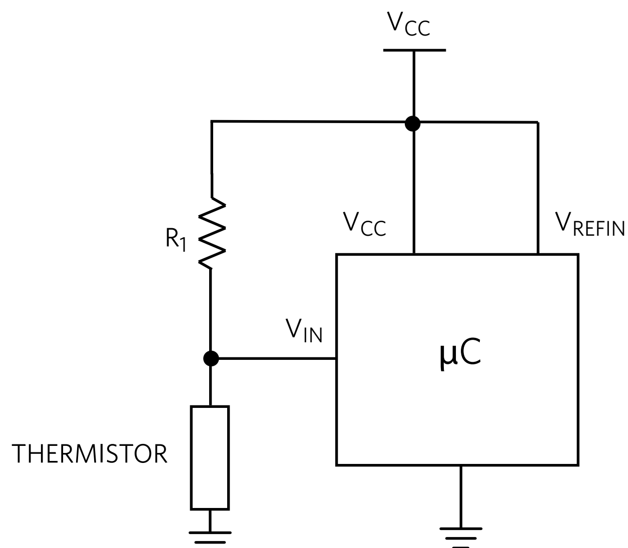

Figure 2. Temperature Monitoring Circuit Using a Thermistor

An analog-to-digital converter (ADC) within the microcontroller then produces a digital representation of the temperature. Depending on the measured value, the microcontroller will take appropriate action. For example, if the temperature is determined to be outside the specified range of operation, the controller may decide to shut down certain blocks of circuitry or activate a thermal-setting fuse until the normal temperature range has been restored, thereby preventing possible damage due to overheating. However, to minimize power consumption in sleep mode, the analog input from the thermistor may not be regularly monitored by the microcontroller (or possibly not at all). If the battery in the device begins to overheat, the sleeping microcontroller may not be aware of the temperature rise and be unable to take corrective action. Clearly there is a trade-off to be made between choosing to allocate the resources of the microcontroller in sleep mode (and increasing power consumption) with the potential for a catastrophic temperature rise left unmonitored.

Alternative Solution

A simple alternative would be to use a small-footprint, low-power comparator circuit (Figure 3) calibrated to detect when a pre-set temperature has been exceeded.

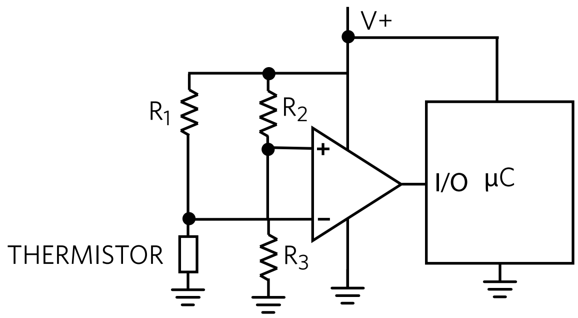

Figure 3. Temperature Monitoring Using a Comparator

A thermistor behaves like a resistor with a negative temperature coefficient (its resistance decreases as temperature increases). The Resistance-Temperature (R/T) curves for nine common thermistor types are shown in Figure 4. Thermistors are named according to their nominal resistance at 25°C. As highlighted, the 10K thermistor has a resistance of 10kΩ at 25°C. Below this temperature, it has a higher resistance, while above this temperature it has a lower resistance. To construct the circuit in Figure 3 above so that it detects when the temperature of a device exceeds 25°C, you would simply need to select a 10kΩ thermistor and use 10kΩ resistors for R1, R2, and R3.

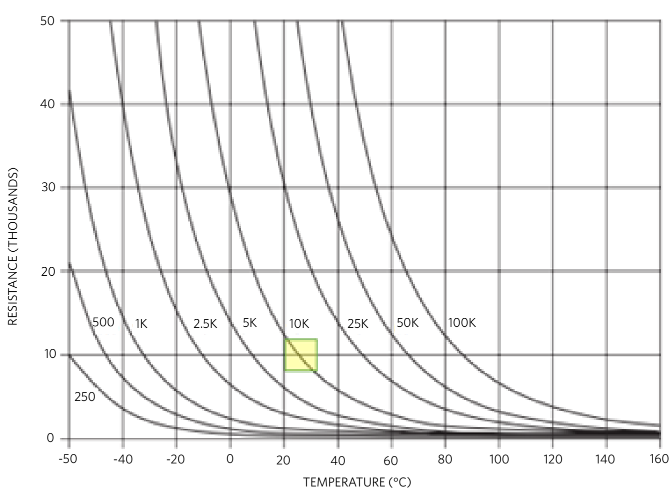

Figure 4. Resistance-Temperature Curves for Nine Common Thermistors

If the temperature of the device is below 25°C, the voltage at the negative terminal of the comparator will exceed the voltage at the positive terminal. However, once the temperature of the device exceeds 25°C, the reduced resistance of the thermistor will cause the voltage at the negative terminal to fall below that of the positive terminal. This will cause the comparator to toggle, sending a flag to the sleeping microcontroller which then wakes and takes appropriate action.

If smaller resistors are desired, then it is merely a case of selecting a thermistor with the same resistance at 25°C. To detect that a different temperature has been exceeded, then a thermistor resistance value corresponding to that temperature (and a set of resistors of the same value) should be selected. Note that while the R-T curve of a thermistor is nonlinear, this is not a problem as the circuit is designed to toggle at one defined temperature.

Although this is a simple solution, system designers may be reluctant to include such an implementation for several reasons, including power consumption, real estate, and cost. An alternative option which minimizes these concerns includes the use of Maxim Integrated's MAX4000x family of comparators.

Features of the MAX4000x Family

The MAX4000x family of parts are tiny, single, ultra-low power comparators with a typical power consumption of 500nA.

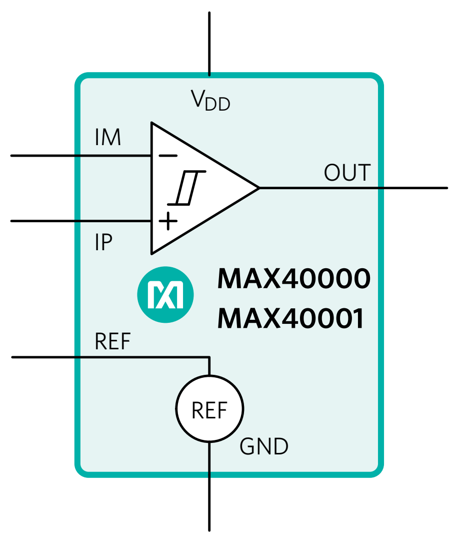

Figure 5. MAX40000/MAX40001 Functional Diagram

The MAX40000/MAX40001 comparators are available in a 6-bump wafer level package (WLP) with a tiny area of 1.11mm × 0.76mm. MAX40002/MAX40003/MAX40004/MAX40005 parts have an even smaller footprint of 0.73mm × 0.73mm in a choice of 4-bump WLP and 5-pin SOT23 packages. These small footprints allow the temperature detector circuit to be located very close to (or within) the battery pack of a portable device. The devices offer a 1.7V to 5.5V supply voltage range and feature internal filtering to provide high RF immunity, important in many portable applications. The MAX40000/MAX40001 (Figure 4) devices also have a high-precision integrated external reference voltage that is factory-trimmed to an initial accuracy of 1% and better than 2.5% over the entire specified operating temperature range. Reference voltage options include 1.252V, 1.66V, 1.94V, and 2.22V depending on the device chosen. The MAX40002–MAX40005 devices do not have an external reference but come with a pre-set internal reference with voltage options of 0.2V, 0.5V, or 1.222V.

The MAX40000 has a push-pull output and the MAX40001 has an open-drain output. The MAX40002–MAX40003 have open-drain outputs, while the MAX40004–MAX40005 feature push-pull outputs. The MAX40002/MAX40004 have noninverting inputs, while the MAX40003/MAX40005 have inverting inputs.

Conclusion

Designers of portable electronic devices may attempt to preserve battery life and save space by choosing not to monitor device temperature changes while in sleep mode. However, this could have potentially catastrophic consequences for the device and the end-user. The MAX4000x range of comparators provide a robust solution for implementing a tiny, extremely low-power (500nA) temperature detection circuit. With the device temperature continuously monitored, the system microcontroller will have the required information to react to temperature changes outside specified levels. The MAX4000x series of comparators can also be used to monitor supply voltages or other system critical signals in a wide variety of portable electronics applications such as cell phones, portable instruments, and notebooks that have extremely tight board space and power constraints.

Glossary Terms

ADC: Analog-to-digital converter

WLP: Wafer level package. Wafer-level packaging (WLP) allows an integrated circuit (IC) to be attached to a printed-circuit board (PCB) face-down, with the chip's pads connected to the PCB pads through individual solder balls.

SOT: Small outline transistor. This is a small-footprint, discrete, surface-mount package commonly used in consumer electronics.

Thermistor: A temperature-dependent resistor with a high temperature coefficient, usually composed of sintered semiconductor material.

Learn more:

MAX40000 1.7V, nanoPower Comparator with Built-in Reference

MAX40001 1.7V, nanoPower Comparator with Built-in Reference

MAX40000EVKIT Evaluation Kit for the MAX40000/MAX40001

MAX40002 nanoPower 4-Bump Comparator in Ultra-Tiny 0.73mm x 0.73mm WLP/SOT23 Packages

MAX40003 nanoPower 4-Bump Comparator in Ultra-Tiny 0.73mm x 0.73mm WLP/SOT23 Packages

MAX40004 nanoPower 4-Bump Comparator in Ultra-Tiny 0.73mm x 0.73mm WLP/SOT23 Packages

MAX40005 nanoPower 4-Bump Comparator in Ultra-Tiny 0.73mm x 0.73mm WLP/SOT23 Packages

MAX40002EVKIT Evaluation Kit for the MAX40002/MAX40003/MAX40004/MAX40005

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