Silicon Temp Sensors Measure by Degrees

Jon Titus, Senior Technical Editor

People measure temperature more than any other physical characteristic. As a result, semiconductor vendors offer a large variety of silicon-based temperature sensors that usually operate in a range from -40°C to 125°C, although vendors sometimes tailor sensor spans for specific applications. Sensors used in PCs and servers, for example, may measure in a narrower range — about 75°C to 110°C. Depending on your application and budget, you can purchase inexpensive sensors with an accuracy of ±1°C to ±2°C. ZMD America, though, uses a proprietary band-gap reference that lets its sensors resolve temperatures to tenths of a degree. And, engineers can choose from a variety of plastic, ceramic and metal sensor packages.

Analog sensors produce a voltage or current proportional to temperature. Digital sensors create a frequency or pulse-width signal or communicate a direct temperature value. Sensors typically produce information proportional to Celsius degrees, but you can adjust some circuits to yield degrees Fahrenheit.

Proper sensor placement helps ensure accurate measurements. If you run an analog signal from a sensor past “noisy” power, control or bus signals, the noise may couple to sensor lines. So, separate a sensor and other signals to keep sensor signal paths short. Some ICs from SMSC use an external 2N3904 transistor as a sensor, measuring the base-emitter voltage to obtain a temperature. “Designers must keep the sensor leads away from DC/DC converters and from switch-mode power supplies,” stressed Mitch Polonsky, product-line manager at SMSC. “The PCB traces can act like antennas, and the 2N3904 can rectify or ‘detect’ spurious signals which affect accuracy.”

Kumen Blake, a staff applications engineer at Microchip Technology, explained that good measurements also depend on the accuracy of the reference used in the equipment’s ADC, whether external or internal to a microcontroller (MCU). Microchip matches its MCP9700 (10 mV/°) and MCP9701 (19.5 mV/°) analog sensors with the ADC reference in its MCUs.

“A 12-bit ADC with a 4.1V reference gives you one mV per LSB,” explained Ezana Haile, a senior applications engineer at Microchip. “So a sensor with a 10 mV per degree C output lets the MCU theoretically resolve 0.1°C. Use the 19.5 mV per degree C sensor — the 9701 — with an eight-bit ADC and a 5V reference and you get 1°C per LSB.” That match-up simplifies the use of ADC values in calculations.

According to Susan Pratt, a senior applications engineer at Analog Devices, engineers specify digital sensors most of the time. “They can read a temperature value from a register and leave the responsibility for a reference, linearization and calibration to the silicon vendor. And overall, digital sensors provide higher accuracy than silicon analog sensors.” Pratt noted that engineers particularly like digital sensors with I2C, SPI and pulse-width modulation (PWM) interfaces. When an application requires a remote sensor, digital communications offer the best bet. You do not want to send low-level analog signals over long distances.

Frank Cooper, president of ZMD America, cautioned engineers about the errors induced by interpolation from analog to digital and then vice-versa. “It makes no sense to convert an analog output to a digital value, send the digital value to equipment, convert it back to an analog signal and then measure it. But we do see people do that once in a while.”

Physical characteristics also can spell the difference between good and bad measurements. “If you want to measure temperature, how does the heat get to a sensor?” asked Pratt of Analog Devices. “To measure heat on a PCB, you can connect the ground pin to a large area of copper to conduct heat to and from the sensor chip. If you want an ambient air temperature, use a metal-can package, elevate the sensor above the board and shield it from nearby heat sources.”

Microchip’s Blake has first-hand experience with heat conduction. He and colleagues prototyped an MCU-based sensor board, and he got an unexpected result: thermal conduction on the PCB traces caused a 6°C temperature rise in the sensor chip. “At first we didn’t think about the MCU as a heat source,” said Blake. “But in hindsight it seems obvious.” A PCB redesign should mitigate the heat transfer in three ways: First, 1k-W resistors on conductors between the MCU and the sensor chip will increase thermal resistance. Second, Blake and his colleagues added a “gap” of about 0.20 on the PCB that lacks a ground plane and contains only essential signals so the PCB material can act like a thermal isolator. Third, added metal layers in the sensor location create a large thermal island that should remain at a constant un-elevated temperature.

Not all sensors report temperatures; some simply act on them. In addition to using external transistors as sensors, the SMSC interface devices can use substrate diodes within graphics and CPU chips to measure temperatures and then turn fans on or off to control heat. SMSC’s EMC1001 temperature sensor, for example, includes two interrupt outputs that designers can program with temperature limits.

For Further Reading

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Links:
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