

8-bit Microcontroller Drives Battery-Powered Thermostat

By Jim Panfil

Microcontrollers provide many benefits to our lives, including the ability to make many of the products we use more energy efficient. Central heating and air conditioning units is one area where microcontrollers are used to make motors run more efficiently or to provide higher quality regulation and more enhanced user interfaces on thermostats. When building a microcontroller-based thermostat, some of the important goals include small size, low power, low cost, high reliability, and easy manufacturability. One of the ways to reach these goals is to use a highly-integrated microcontroller that supports features directly applicable to building a thermostat.

This AVR-based microcontroller also includes a 10-bit analog-to-digital converter with differential channels, an internal analog reference, 16kbytes flash memory, 512 bytes EEPROM, 1kbyte SRAM, plus other features as shown in Figure 1. This high level of integration allows the system footprint to fit within a 2.5 X 6 cm space, the desired size of the LCD display and hit the \$5 mark for the total system cost.

Writing Power-Aware Applications

When optimizing a design for battery-powered applications or other applications where minimum power consumption is an important goal, there are many factors to consider. Since power increases with V_{cc} ($I = V^2f$; where I is current and f is frequency), you can reduce power consumption without limiting the maximum operating frequency by minimizing the voltage of the device. For example, running at 4.5V instead of 5.0V for a 16MHz device, drops power by almost 20% without compromising the device's performance.

As evidenced by the power equation, reducing clock frequency also plays an important role in power savings. If you can optimize your code to run at 10MHz instead of 16MHz, current consumption is reduced by 30%-40%. Furthermore, if you manage to get down to 8MHz, you can change to a low voltage device and reduce V_{cc} to 3V — the resulting power consumption will be 75% lower than what you started with at 16MHz!

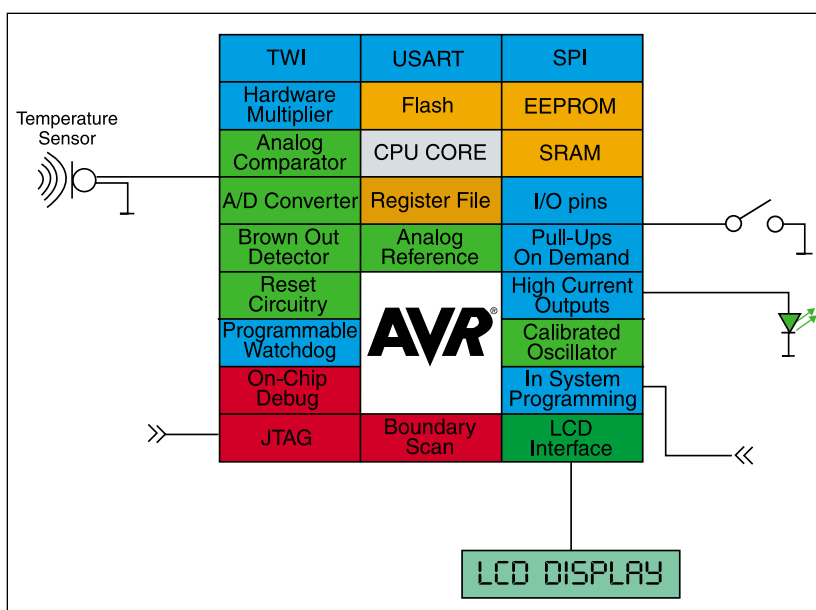


Figure 1. The high integration level of the Mega 169 simplifies system design, helps to lower power consumption, and significantly reduces board space.

Many microcontroller solutions may have some of the right features integrated, but will typically rely on discrete components such as analog-to-digital converters, LCD driver, power management circuitry, temperature sensor, and crystal oscillator. The resulting thermostat will end up with a bill of materials cost greater than \$8.00. Furthermore, with discrete components it is more difficult to control system power and thermostat battery life is typically limited to five years or less.

Atmel's AVR-based Mega 169 is the first member of a low power family designed for metering and other battery-powered applications requiring an integrated LCD controller. One of the features included in the Mega 169 is a 100-segment LCD controller with Automatic Contrast Control. In applications where the power supply voltage can vary, such as in battery-powered systems, maintaining a constant contrast on the LCD display is desirable. Factors such as the type of bias and voltage levels can affect LCD contrast. Automatic Contrast Control requires the matching of different voltage and temperature combinations and then automatically generates the correct voltage ranging from 2.6-3.35V without the need for external circuitry.

For extremely low power applications, such as the thermostat where two AA batteries have to last 10 years, very low frequencies between 32kHz and 1MHz are often used. Many maintenance tasks, such as the sampling of a temperature sensor, can be accomplished at these low frequency levels. Alternatively, these same tasks can be handled at higher frequency levels, taking advantage of AVR sleep modes during idle cycles. In other words, it would be appropriate to run the AVR at high speed for a short period of time and then put it back in the very low power consumption sleep mode for the bulk of the time. This may yield an average power consumption that is much lower than the low frequency operation in active mode would give. The optimum frequency and duty cycle must be determined for each part of your application.

Hardware Considerations for Low Power Applications

Beyond writing more optimized application code, a brute force method of conserving battery life is to completely turn off the microcontroller. However, the disadvantages of using this method outweigh the benefits. For example, now the system must include some sort of external interrupt mechanism to reactivate the power supply that drives the microcontroller.

Another disadvantage when the power is first turned on, the supply voltage will not rise to V_{CC} immediately (Figure 2). The amount of time required to reach V_{CC} will depend on factors such as the charging of the decoupling capacitors. As long as V_{CC} is below the minimum operating voltage, the AVR must be held in reset to avoid incorrect code execution. This reset delay can be set up as either a fixed startup delay or the BOD can be used to measure when V_{CC} is high enough.

For most circumstances, the AVR's programmable sleep mode avoids the need to remove the microcontroller's input voltage. Furthermore, the peripherals

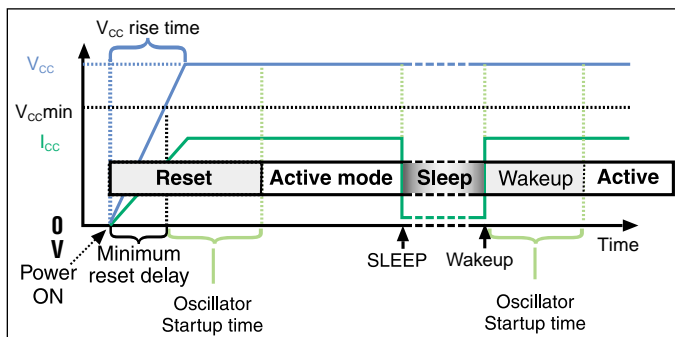


Figure 2. You must hold the microcontroller in reset mode until V_{CC} has ramped past the minimum operating voltage.

integrated into the Mega 169, making up the majority of the thermostat's electronic system, can be individually powered down when not in use. In the power down mode, all peripherals, with the exception of external interrupts, are turned off. This will drop power consumption to 500 NanoAmps. This capability is much more difficult when dealing with discrete components.

When the AVR microcontroller is coming out of power-down mode (or after a hardware reset), the oscillator needs a startup time. This startup time depends on the type of oscillator used. If the Mega 169's active period is relatively short, an oscillator with short startup time will help to save a lot of power. The tradeoff is a slightly less accurate oscillator, however, this is also balanced with a lower cost. For example, if the accuracy of a crystal is not required, an inexpensive RC oscillator or a ceramic resonator will give shorter startup times. Regardless of your preference for oscillators, the reset delay, oscillator type, and oscillator startup time, is selected by fuse settings on the AVR.

The performance of the Mega 169, along with its variety of peripherals allows designers to build one thermostat to serve multiple markets. The microcontroller's in-system Flash program memory enables simplified inventory management, just-in-time delivery, and the ability to program different codes at the end of the line.

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