The Joy of Precision Analog: True System-on-Chip Performance

By Aaron GL Podbelski, senior product marketing engineer, Cypress Semiconductor Corp.

As systems increase in complexity, engineers have a need to incorporate more components, both analog and digital, into a single device while maintaining the integrity of the design. New mixed-signal microcontrollers are emerging which integrate more precision analog components than previous generations. Utilizing these next generation mixed-signal microcontrollers allow for designs which reduce BOM costs, save board space, protect IP, and provide more flexibility for change throughout the design process. Now mixed-signal microcontrollers have ADCs with a precision upwards of 20-bits, amplifiers with lower offset voltages, and 0.1% voltage references.

Previous generations of mixed-signal microcontrollers allowed for an increased level of integration in a design, but often those featured analog components did not have enough precision for many designs. Low-end analog designs benefited from the integration, but mid- and high-end designs still required external analog components. Newer generations of mixed-signal microcontrollers have improved their analog components, and therefore are allowing mid- and some high-end designs to take advantage of the benefits of a device incorporating both digital and analog signals.

The more capable the mixed-signal microcontroller is, the more likely the design can be a true system-on-a-chip. By incorporating ADCs, DACs, comparators, mixers, amplifiers, filters, and voltage references a single mixed-signal microcontroller can be the complete analog front end of a design and the control system. A design could have the input of two sensors, amplify and condition the signals, then quantify them to be displayed on an LCD that is directly driven by the device. An example of this would be a temperature compensated gas meter, a design which would be a complete system-on-a-chip.

One of the main benefits of using a mixed-signal microcontroller is analog IP protection. A complex analog design which uses individual components can be reverse-engineered by competitors. The list of components used can easily be determined, and the signals can be read by an oscilloscope effectively turning the analog front end into a reference design. If the design effectively uses a mixed-signal microcontroller to condition the analog signal then it renders that design into a black box situation. A competitor trying to determine how an analog signal is being handled only sees the input into the device and has no insight into the components used, how they are interconnected, or their settings. Good designs utilize novel methods to solve a problem; smart designs employ novel means to protect their IP.

Another benefit of certain mixed-signal microcontrollers, such as Cypress' PSoC 3 and PSoC 5 devices, is that they solve worries on routing signals. When laying out traces on a PCB, designers need to take careful consideration of noise-inducing signals and properly shield sensitive ones. The software tools used to program these devices automatically route all the internal signals to provide the optimal integrity for analog signals, so a system designer has more time to focus on other portions of the project.

In general mixed-signal microcontrollers allow for cost savings in a design. The integration of ADCs, DACs, comparators, amplifiers, mixers, voltage references, analog MUXs, etc., provide a BOM reduction. As a device incorporates more commonly used analog components, then the external components are obviously not needed and money is saved. In the same respect, as these components are no longer on the board, the PCB can be reduced in size to save more money. Additionally, with fewer components on the board, routing is simplified, allowing a designer to worry less about noise issues with traces and spend less design time. As mixed-signal microcontrollers start to increase the precision and accuracy of the included analog components, more designs can utilize the money-savings from using these devices as systems-on-chips.

A digital cooking thermometer is a good example of how new high-precision mixed-signal microcontrollers can provide a concise solution over previous generations. In this example, a type K thermocouple will be used for the temperature probe, which provides an output of ~40μV/ºC. Since the output is small for the range needed, a very precise reference is required to accurately capture the signal. The thermocouple output is an absolute measurement, so a cold junction reading is required as well, which is performed by a thermistor (as a thermistor provides a ratiometric measurement).

Previous generations of mixed-signal microcontrollers required the use of some external components to properly measure a thermocouple. Because the internal voltage reference inside of older mixed-signal microcontrollers is accurate to 3% on average, an external precision reference is required. A 0.1% accurate voltage reference is commonly used for this purpose. The voltage reference is used as a scale reference point and is fed into the controller's ADC as well as into the thermocouple input. The ADC then alternates between reading the thermocouple and the voltage reference in order to provide a proper

[+] Feedback

reading. Because the thermocouple's output is small, an amplifier may be used to increase the signal depending on the resolution of the ADC. The output of the thermistor is read as a thermal reference and the output of the thermocouple is added to this measurement. Figure 1 shows this setup.
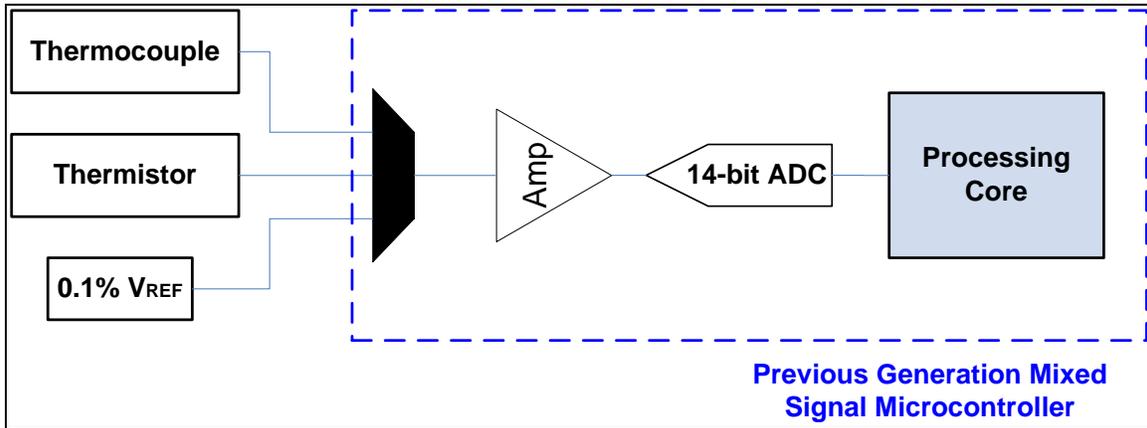

Figure 1: Block diagram of a thermocouple reading based on less precise mixed-signal microcontrollers.

For the new mixed-signal microcontrollers the setup for measuring a thermocouple's output is far simpler. Some of these mixed-signal microcontrollers have a highly accurate voltage reference, such as Cypress' PSoC 3, which has a 0.1% voltage reference. In this case, the external reference is not needed. The ADC can use the internal reference for measurement so the designer does not need to worry about accounting for the additional setup to accurately read a thermocouple, which is shown in Figure 2. If the device being used also has a high-resolution ADC, then the amplification stage can be removed since the conversion will provide enough granularity of the signal. The Cypress PSoC 3 device has a 20-bit Delta-Sigma ADC which can measure a 1.0V range signal down to 1µV. The use of a high-precision mixed-signal microcontroller allows designers to spend less time on the design, as it is less complicated. This in turn saves board space and money.
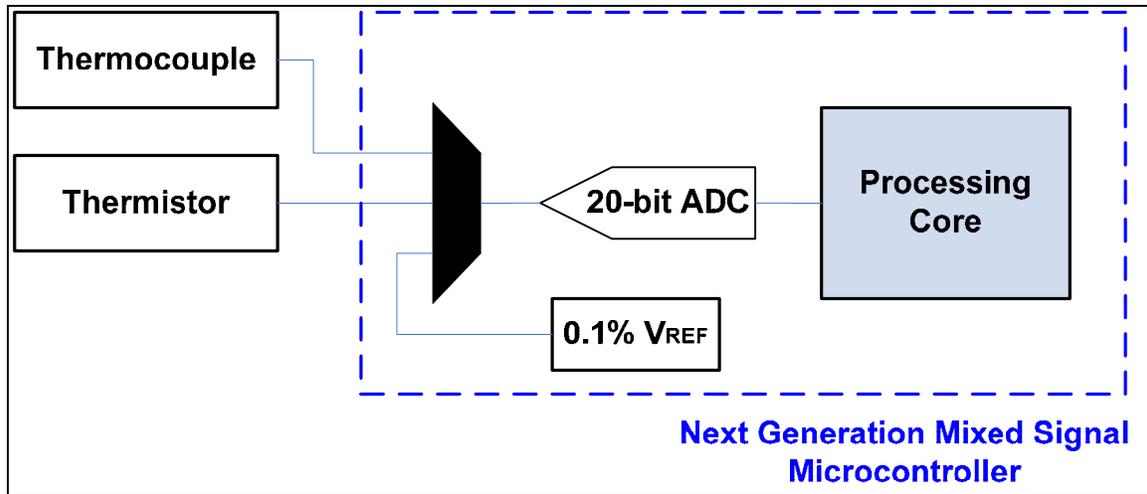
Figure 2: Block diagram of a thermocouple reading base on new high precision mixed-signal microcontrollers.

[+] Feedback

Overall, new generations of mixed-signal microcontrollers allow designers to simplify their designs, protect their IP, reduce the need for external components, and increase the amount of value they are receiving from a device. The increased quality of the analog components in these devices provides designers with more choices in how a design can be accomplished and allows for unique methods to solve a problem. The thermocouple example discussed shows how various levels of mixed-signal microcontrollers can solve an issue, and how the newer generations allow an even more simplified design. Mixed-signal microcontrollers are becoming more prevalent in a wide variety of designs, and the latest generation of these devices, with their increased analog performance, validates this growth.

[+] Feedback