How to Realize Power-Saving Analog-to-Digital Conversion for Highly Accurate Measurements

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This article presents a low power analog-to-digital converter (ADC) solution for high precision measurement applications. A typical application in electrical engineering is the recording of physical quantities by sensors and forwarding of these quantities to a microcontroller for further processing. ADCs are needed to convert the analog sensor output signals into digital signals. In high precision applications, either SAR-ADCs or sigma-delta ADCs are used. With low power applications, every mW that can be saved counts.

Signal Conversion with Sigma-Delta ADCs

Sigma-delta ADCs offer a few advantages over SAR-ADCs. For one, they often have higher resolutions. In addition, they often come integrated with programmable gain amplifiers (PGAs) and general-purpose inputs/outputs (GPIOs). Thus, sigma-delta ADCs are well suited for DC and low frequency high precision signal conditioning and measurement applications. However, due to the high, fixed oversampling rate, a sigma-delta ADC often has a higher power consumption, which translates to a lower lifetime in the case of battery-operated applications.

If the input voltage is small—that is, in the millivolt range—it first has to be amplified so that it can be more easily managed by the ADC. A PGA analog front end (AFE) is required to connect a small voltage with a 10 mV output voltage. For example, to connect small voltages from a bridge circuit to a sigma-delta ADC with a 2.5 V input range, the PGA has to have a gain of 250. This, however, leads to additional noise at the ADC input because the noise voltage is also amplified. The effective resolution of a 24-bit sigma-delta ADC is thereby drastically reduced down to 12-bit. However, in some circumstances, there is no requirement to use all codes in the ADC and at some point, further amplification no longer provides a dynamic range improvement. Another disadvantage of sigma-delta ADCs is the usually higher costs resulting from their internal complexity.

Benefits of Combining a SAR-ADC with an In-Amp

A similarly accurate but more cost effective and more efficient alternative is to utilize a SAR-ADC in combination with an instrumentation amplifier (in-amp), as shown in Figure 1.

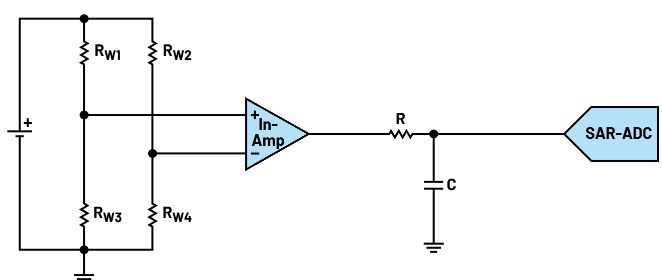

Figure 1. A schematic diagram showing a simplified bridge measurement circuit combined with an in-amp and a SAR-ADC.

The function of a SAR-ADC can be divided into two phases: the data acquisition phase and the conversion phase. Basically, in the data acquisition phase, the current consumption is low. Most SAR-ADCs even power down between conversions. So, the conversion phase draws the most current. The power consumption is dependent on the conversion rate and linearly scales with the sample rate. For power-saving applications for slow-response measurements—that is, measurements in which the measured quantities change slowly (for example, temperature measurements)—a low conversion rate should be used to keep the current draw and thus the losses low. Figure 2 shows the power losses in the AD4003 at various sampling rates as an example. At 1 kSPS, the power loss is approximately 10 μW; at 1 MSPS, it has already risen to 10 mW.

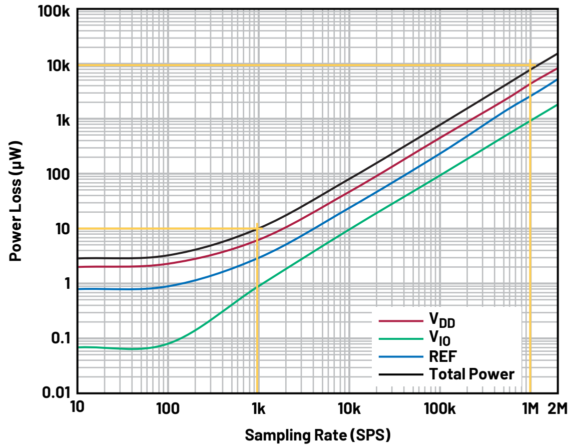

Figure 2. Power loss in the AD4003 as a function of sampling rate.

In contrast to such slow measurements, sigma-delta ADCs have the strengths of oversampling, while using a much higher internal oscillator frequency than the output rate. This allows designers to optimize sampling for higher speeds with worse noise performance or for lower speeds with more filtering, noise shaping (pushing the noise into the frequency band outside the area of measurement interest), and better noise performance. However, that means a lot more power consumption with sigma-delta ADCs compared to SAR-ADCs. The effective resolution and noise-free resolution of many sigma-delta ADCs are mentioned in their data sheets, making it easy to compare the trade-offs.

Conclusion

Both sigma-delta ADCs in combination with PGAs and SAR-ADCs with an in-amp are suitable for signal conversion in high precision measurement applications. The solutions both have a similar accuracy. For power-saving or battery-operated measurement applications, however, the combination of the SAR-ADC and the in-amp is better because it offers a lower power consumption and lower costs compared with the solution consisting of the PGA and the sigma-delta ADC. In addition, a PGA with a high gain often limits the performance because the noise is also amplified. This article just covers one possible solution for a SAR-ADC. There are more integrated solutions available such as a sigma-delta converter like the AD7124-4/AD7124-8 with an integrated PGA.

About the Author

Thomas Brand began his career at Analog Devices in Munich in 2015 as part of his master's thesis. After graduating, he was part of a trainee program at ADI. In 2017, he became a field applications engineer. Thomas supports large industrial customers in Central Europe and also specializes in the field of Industrial Ethernet. He studied electrical engineering at the University of Cooperative Education in Mosbach before completing his postgraduate studies in international sales with a master's degree at the University of Applied Sciences in Constance.

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