How to Save Space and Development Time When Designing Precision Data Acquisition Systems

Whitepaper

How to Save Space and Development Time When Designing Precision Data Acquisition Systems

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Contributed By Digi-Key's North American Editors

Designers of systems for industrial automation and healthcare are increasingly employing advanced sense, detect, and image and video capture technology for digitization and analysis. However, the analysis is only as good as the input data, the acquisition of which relies upon high-performance, high-dynamic range, precise and stable signal conditioning, and conversion blocks. The design of these blocks using discrete circuit methods requires considerable design resources, board space, and time, all of which add to overall cost.

At the same time, designers need to ensure their end systems remain competitive, which means lowering cost and time to market as much as possible, while ensuring outstanding performance.

This article briefly describes a typical data acquisition system and its core elements. It then introduces a data acquisition (DAQ) module from **Analog Devices Inc.** that integrates many of those critical elements to provide stable, 18-bit, 2 megasample per second (MS/s) performance. An evaluation board is also introduced to help designers get familiar with the module and how to use it.

Elements of a DAQ system

A typical data acquisition system is shown in Figure 1. The signal of interest is picked up by a sensor which outputs an electrical signal in response to some physical phenomena. The sensor's outputs may be single-ended or differential, and may require some signal conditioning such as filtering. In order to obtain the maximum possible dynamic range from the analog-to-digital converter (ADC), the signal must be amplified to match the ADC's input voltage range. The amplifier gain and offset are generally controlled by precision resistors which must be carefully matched for dynamic and temperature drift considerations. Temperature dependencies usually require that components are in close physical proximity. Dynamic conditions include noise and distortion levels which must be minimized.

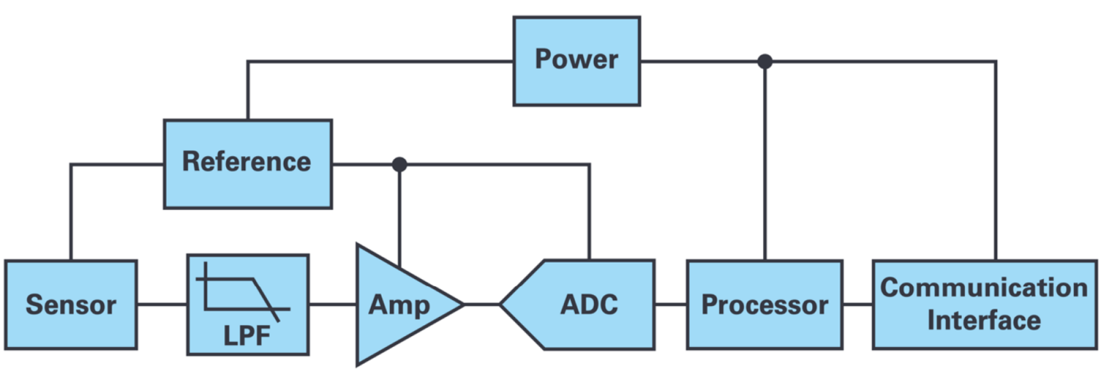

Figure 1: A typical DAQ system acquires data from a sensor, conditions it, optimizes the signal amplitude applied to the ADC, and communicates the digital data to the system processor. (Image source: Analog Devices)

The successive approximation register (SAR) ADC must have sufficient dynamic range, indicated by the number of bits of resolution. It also requires a buffered, stable, and clean voltage reference.

Finally, acquired data has to be accessible via a communications interface. Implementing such a data acquisition system using discrete components requires more physical space and often results in much poorer performance than that obtained from an integrated device. As an example, consider that the performance requirements of a differential amplifier to drive an ADC are such that it must have the input and feedback resistors on both legs of the amplifier input closely matched, as any imbalance will decrease the common mode rejection ratio (CMRR). Likewise, the input resistors must be precisely matched to the feedback resistors to set the gain of the stage. These resistors must also track over temperature as well, requiring that they be located close together. Additionally, overall circuit layout is critical in preserving signal integrity and minimizing parasitic response.

The integrated DAQ module saves time and space

To meet performance requirements while reducing size and design time, designers can use the Analog Devices **ADAQ4003BBCZ** μModule system in package (SIP) as an alternative to discrete implementations (Figure 2). Measuring 7 x 7 millimeters (mm), the ADAQ4003 focuses on integrating the most common sections of a signal chain, including signal conditioning and digitization, to provide a more complete signal chain solution with advanced performance. In doing so, it fills the gap between standard discrete components and highly integrated customer specific ICs to solve data acquisition needs.

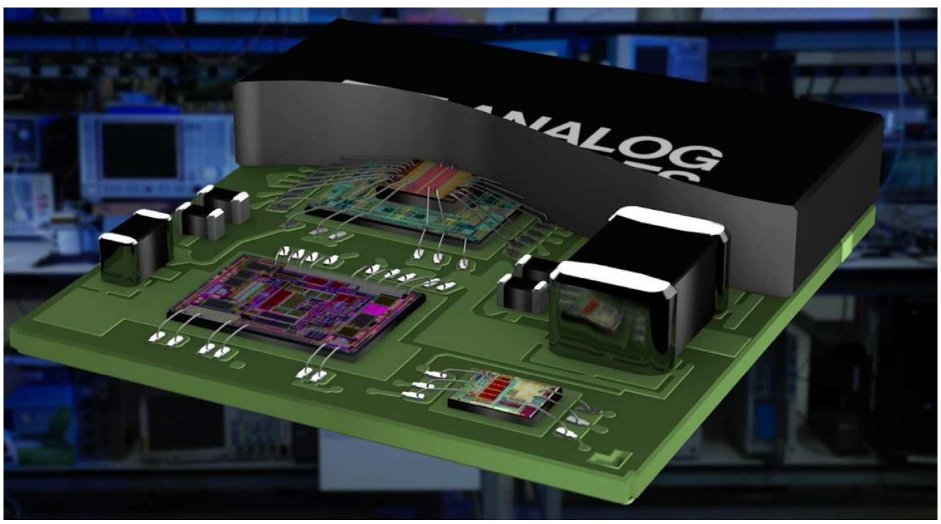

Figure 2: A cutaway view of a μModule SIP which combines multiple common signal processing blocks into a single device measuring only 7 mm on a side. (Image source: Analog Devices)

The ADAQ4003 combines a high-resolution 18-bit, SAR ADC running at up to 2 MS/s, a low-noise, fully differential ADC driver amplifier (FDA), a stable voltage reference buffer, and all of the required critical passive devices. Its small, 49-contact ball grid array (BGA) package meets compact form factor requirements.

The ADAQ4003 offers better than a four times (4x) reduction in pc board area compared to a discrete layout as show in Figure 3.

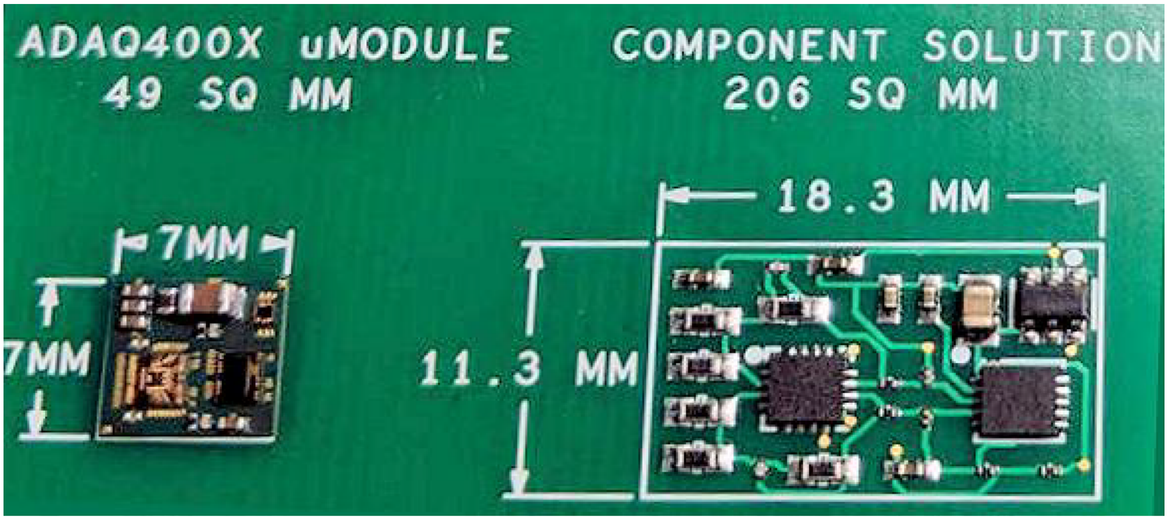

Figure 3: The ADAQ4003 (left) with its cover removed compared to an identical circuit implemented with discrete components takes less than one fourth the surface area. (Image source: Analog Devices)

The advantages of the μModule compared to the discrete implementation are many. Smaller footprint, components are physically close for better temperature tracking, as well as reduced parasitic effects due to lead inductance and stray capacitance.

The functional block diagram of the ADAQ4033 shows the four key components found in every data acquisition system (Figure 4).

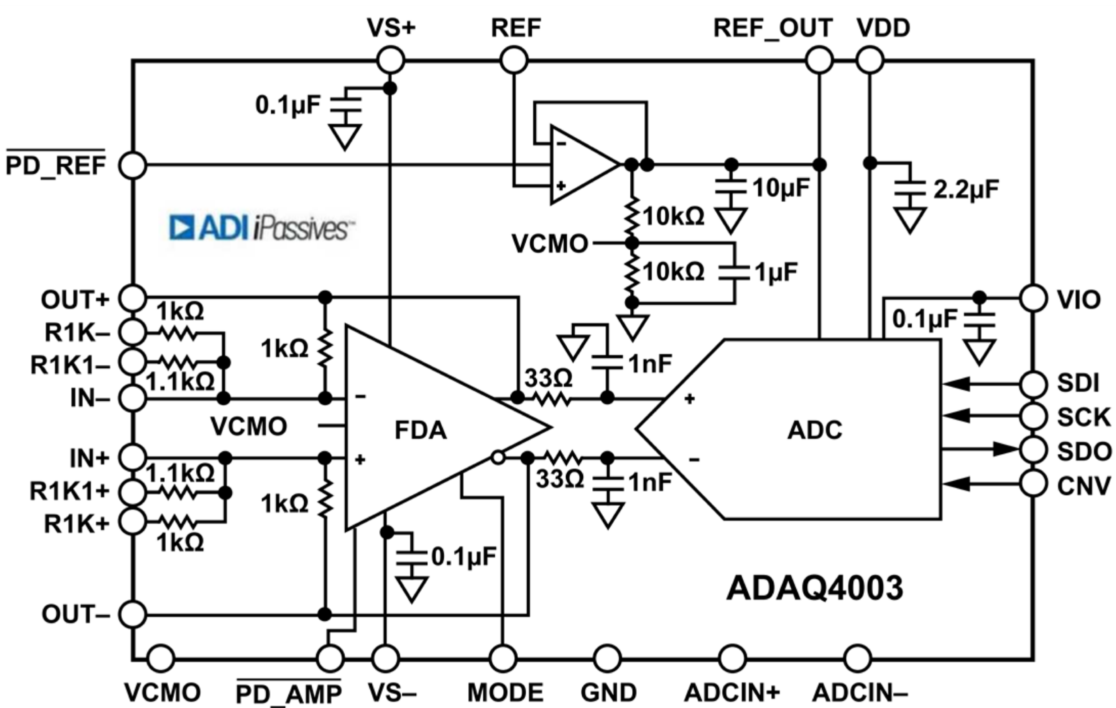

Figure 4: The functional block diagram of the ADAQ4003 shows how much it packs into its 7 x7 mm, 49-contact BGA package. (Image source: Analog Devices)

Despite its small physical size, the ADAQ4003 incorporates the critical passive components by using Analog Devices' iPassives technology. Integrated passives are fabricated on substrates where multiple passive networks are produced at the same time. The manufacturing process produces these parts with great precision. For example, the resistor array components are matched to within 0.005%. Adjacent components, spaced very closely, are well matched in initial value, certainly much better than discrete passives. Implemented on a common substrate, the component values will also track better over temperature, mechanical stress, and lifetime aging due to the component's integrated structure.

As mentioned, the SAR 18-bit ADC can be clocked at up to 2 MS/s, yet operates with no missing code states. The precise value and matching of the passive components assure excellent performance from the ADC. It has a typical signal to noise and distortion (SINAD) ratio of 99 decibels (dB) at a gain setting of 0.454. Its integral non-linearity is typically 3 parts per million (ppm). The input resistor array can be pin strapped, allowing gain settings of 0.454, 0.909, 1.0, or 1.9 to match the input to the full-scale range of the ADC, thus maximizing its dynamic range. The matching of the critical components results in a gain error drift of ± 0.5 ppm/C° and an offset error drift of 0.7 ppm/C° on the 0.454 gain range.

The ADC block is preceded by the FDA driver with a CMRR of 90 dB on all gain ranges in the differential configuration. The amplifier has a very wide common mode input range which depends on specific circuit configurations and gain settings. The FDA can be used as a differential amplifier, but can also perform single-ended to differential conversion for single-ended inputs.

There is a single-pole RC filter, implemented differentially using internal components between the FDA driver and the ADC. This is designed to limit the noise at the ADC inputs and reduce the effect of voltage kickbacks coming from the capacitive digital-to-analog converter (DAC) input of a SAR ADC.

The ADAQ4003 also houses a reference buffer configured at unity gain to optimally drive the dynamic input impedance of the SAR ADC reference node. All the necessary decoupling capacitors for the voltage reference node and power supplies are also included. These decoupling capacitors feature low equivalent series resistance (ESR) and low equivalent series inductance (ESL). The fact that they are internal to the ADAQ4003 further simplifies the bill of materials (BOM).

The digital interface for the ADAQ4003 uses a serial peripheral interface (SPI) that is compatible with DSP, MICROWIRE, and QSPI. Using a separate VIO supply, the output interface is compatible with 1.8 volt, 2.5 volt, 3 volt, or 5 volt logic.

The ADAQ4003 operates with low total power dissipation—only 51.5 milliwatts (mW) at the maximum clock rate of 2 MS/s—and with lower power dissipation at lower clocking rates.

The physical layout of the ADAQ4003 aids designers in maintaining signal integrity and performance by separating the analog and digital signals. The pinout has analog signals on the left and digital signals on the right, allowing designers to isolate sensitive analog and digital sections to minimize any crossover.

Circuit models

Analog Devices makes simulation models available, providing a model for the ADAQ4003 in its free LTspice simulator. It also makes an IBIS model available for other commercial circuit simulators. LTspice includes a basic reference circuit using the ADAQ4003, shown in Figure 5.

The device is used in a differential input configuration, and the input resistors are strapped to set the FDA gain to 0.454 by putting the 1.0 and 1.1 kilohm (kΩ) input resistors in series. The model reference voltage setting is 5 volts, and it uses a 2 MS/s conversion clock.

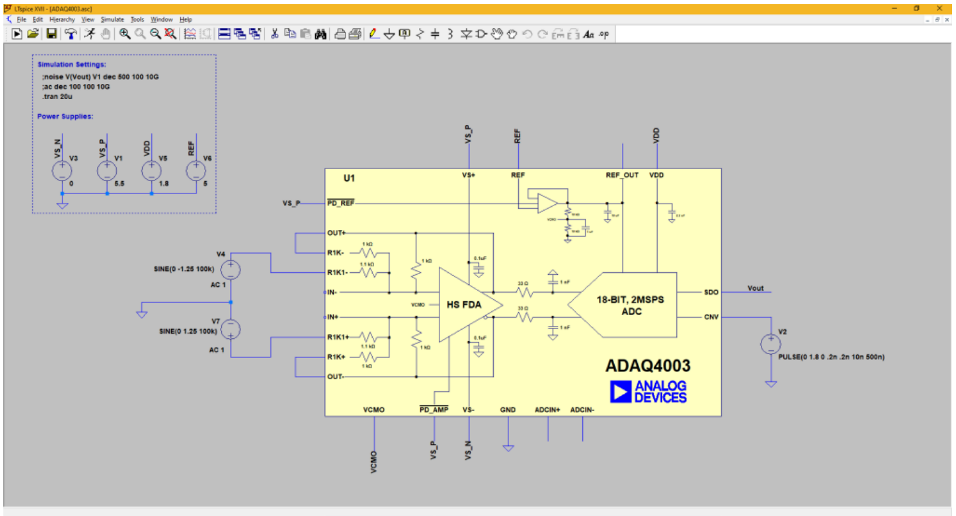

Figure 5: ADI makes available LTspice simulation models for the ADAQ4003 using a differential input configuration. (Image source: Art Pini)

The LTspice model is a starting point for any design which can be further verified using an evaluation board.

Evaluation boards

When considering the ADAQ4003, it's wise to run it through its paces using the **EVAL-ADAQ4003FMCZ** evaluation board. This multi-board set includes the evaluation board and a field programmable array mezzanine card. These work with the Analog Devices **EVAL-SDP-CH1Z** system demonstration platform. ADI also supplies **Analysis/Control/Evaluation (ACE)** demo software with product-specific plugins, allowing the user to perform detailed product testing including harmonic analysis, and integral and differential nonlinearity measurements.

Conclusion

For designers tasked with quickly developing high-performance DAQ systems while keeping size and cost to a minimum, the ADAQ4003 µModule is a good option. The device reduces the development cycle of a precision measurement system by removing the signal chain design challenges of discrete component selection, optimization, and layout. The ADAQ4003 further simplifies the design process by providing a single component with an optimized, space-efficient data acquisition solution as the basis for a custom design.

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