Highly Accurate Data Acquisition System for Supporting Sensors with Different Output Signals

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Today's data acquisition systems are a central element to more than just industrial applications. They are usually used for sensor-based measurements of temperature, flow, fill level, pressure, and other physical quantities, which are then converted to high resolution digital information and communicated further for processing via software. These systems require increasingly more precision. Thus, developers often have to struggle to unite properties that have negative impacts to the system, such as signal noise and drift with requirements for high conversion and transmission rates. High input impedances are typically required to directly connect different sensor types with correspondingly different analog signal outputs. In addition, the inputs should be able to buffer, amplify, and adjust levels of input signals or also generate differential signals to cover the complete voltage range of the analog-to-digital converter (ADC) inputs and simultaneously meet their common-mode voltage requirements. However, the original measurement signal should remain as undistorted as possible. The input stage is, thus, one of the decisive factors for determining the overall accuracy of data acquisition systems. Programmable gain instrumentation amplifiers (PGIAs) are typically used for this purpose, which is how gain is usually adjusted via external resistors and the outputs are directly coupled to the inputs of a downstream ADC. PGIAs are commonly equipped with single-ended outputs and hence cannot be used to drive fully differential successive approximation register (SAR) ADCs directly. Therefore, an additional signal conditioning or driver stage is needed. However, the additional driver stage affects the performance of the overall data acquisition system because further error components can be introduced through it. Good performance can be achieved with the right selection of components, as can be seen in the circuit described in Figure 1.

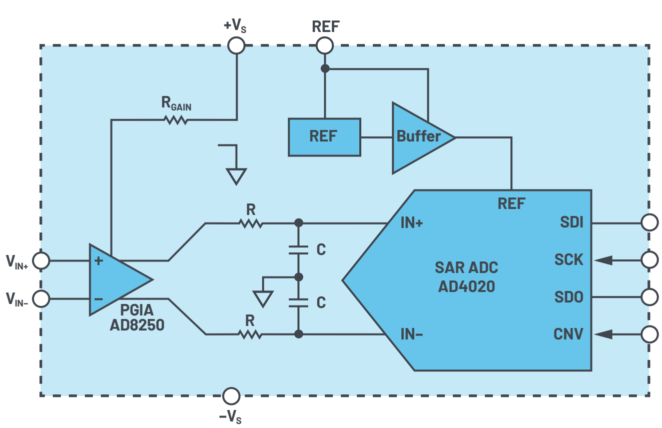

Figure 1. A simplified block diagram of a precise data acquisition system.

Figure 1 shows a simplified circuit for a data acquisition system that contains a reference voltage source and a reference buffer with integrated power supply, as well as a PGIA and an AD4020 SAR ADC. The differential outputs of the PGIA consist of discrete standard components for digitally programmable gain. It features an input impedance in the GΩ range, a common-mode rejection ratio of over 92 dB, low output noise, and low distortion. This makes it suitable for direct control of the SAR ADC without loss of performance. The PGIA drives the AD4020, a precision, 20-bit, 1.8 MSPS, low power SAR ADC. The AD4020 offers a host of other functions that can be used for reducing the complexity of the complete signal chain and increasing channel density without detracting from performance in any way. Additional functions include, for example, a high impedance mode for reducing nonlinear input currents coupled with a long detection phase for direct connection of the PGIA with a simple RC filter in between. The high sampling rate of the AD4020 enables precise acquisition of high frequency signals up to several hundred kilohertz. It also allows decimation so that the dynamic range can be expanded for the precise detection of low voltage signals. Moreover, the demands on the antialiasing filter can be reduced.

The SPI interface, which is compatible with different logic levels (1.8 V, 2.5 V, 3 V, and 5 V), can be programmed in many ways and offers both read and write functions.

With the components used in Figure 1, the circuit shown offers a good linearity (INL) of typically ±2 ppm, low offset and gain drifts (±3.5 ppm/°C and ±6 ppm/°C, respectively), and a good noise power of over –115 dB, all at the full conversion rate and over the entire gain range. The circuit enables both bipolar and unipolar single-ended or fully differential input signals up to ±10 V for gains of 1 to 10. An overview of the input voltage range as a function of gain is given in Table 1.

Table 1. Input Voltage Range as a Function of Gain

Input Signal (V)	Gain
Differential	
±1	G = 5
±2.5	G = 2
±5	G = 1
Single-Ended	
±1	G = 10
±2	G = 5
±5	G = 2
±10	G = 1

The circuit shown also offers calibration options for use of larger PGIA ranges. This function offers precise ratiometric performance and simplifies the system design by already containing options for signal buffering, amplification and attenuation, common-mode level shifting, and various other functions for overcoming the challenges in analog signal processing. With the high impedance input and the programmable gain, a wide variety of sensors with unipolar, bipolar, differential, and single-ended outputs can be connected. Also drift, offset, linearity, SNR, and common-mode rejection requirements can be met. Through this, a high precision data acquisition system for applications with extremely high accuracy requirements can easily be realized.

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 Analog Devices. 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. He can be reached at *thomas.brand@analog.com*.

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