Technical Article

How High Performance, Robust ADCs Are Solving Design Challenges of Modern Industrial Applications

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This article explains how a new generation of multiplexed analog-to-digital converters (ADCs) simplifies complex system design by offering higher channel counts, deeper signal chain integration, flexibility, and robustness to support modern automation and process controls in advanced factories and production plants.

Introduction

In modern production plants, a proper analog front end (AFE) is paramount to enabling robust, precise, and accurate analog-to-digital conversion. Due to variances across different systems and machines, typically, a programmable logic controller (PLC) can be used to control the many complex parameters. To achieve this task, and through analog input modules, different sensors and signals are utilized. Many sensors like pressure, flow, temperature, and weight have analog outputs representing the measured quantities. Therefore, many precise and accurate analog signal inputs are required to generate digital outputs. However, analog-to-digital conversion is just one part of the task. The connectivity between nodes, sensors, analog input modules, and PLCs takes place in the production plant, an environment that is notorious for electrical noise and other disturbance elements, like EMI. Thus, robust ADCs are critical for effectively operating in such harsh conditions.

New Multiplexed ADCs Offer High Integration, High Precision, High Flexibility, and Robustness

PLCs contain many analog voltage inputs to monitor their system, meaning high number of channels.

High channel count can be achieved, for example, with an ADC that has eleven single-ended, or six differential inputs with buffers. The single-ended or differential nature of the inputs provides easy interfacing with different sensors. Furthermore, allocating some of these channels to lower input ranges is useful for current measurements with an external sense resistor. In modern multiplexed ADCs, like some of the AD411x family, such sense resistors are incorporated into the component.

AFEs integrated with critical passive components, like accurate low drift matched 1 MΩ and 10 MΩ voltage dividers with Analog Devices' *i*Passives® technology, eliminate the need for costly external components. This enables higher density and at the same time, more spatially optimized solutions by minimizing the solution footprint, weight, and board space.

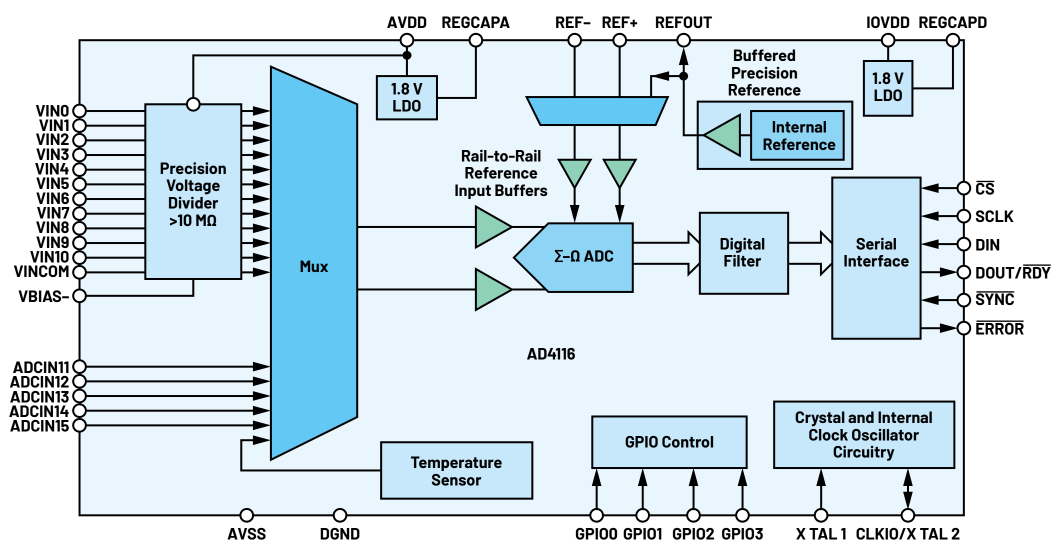

Figure 1. The internal structure of a new-generation multiplexed ADC.

The newest multiplexed ADCs, like the AD4116, have a low power, low noise, 24-bit, sigma-delta (Σ-Δ) ADC that integrates a very high impedance AFE. Figure 1 shows the internal structure of the part. For utmost flexibility, the inputs can be configured independently. Each setup allows the user to enable or disable the buffer, correct the gain and offset, select the filter type, select the output data rate (ODR), and select the reference source.

The flexibility in selecting different voltage reference sources makes the design task easier. These multiplexed ADCs have versatile reference source options, like an internal low drift 2.5 V source, an external reference via differential Ref+ and Ref- pins or using analog power supply (AVDD-AVSS). For an external reference, such ADCs have true rail-to-rail, integrated precision unity gain buffers on both reference inputs. These buffers with high input impedance allow high impedance external sources to be directly connected to these inputs.

Similarly, the user of modern ADCs can select the clock source from an internal oscillator, an external crystal, or an external clock; a flexibility that eases the design process.

On the analog side, the input is a crucial part that determines the robustness of a multiplexed ADC, as it receives external voltages from peripherals. With a single 5 V supply, a modern multiplexed ADC like the AD4116 can achieve input ranges up to ±20 V. This ADC can even accommodate input voltages beyond these voltages, due to ±65 V absolute maximum ratings, without incurring damage to the device. However, in this input range, there may be trade-offs in accuracy. An external protection device like a TVS, shown in Figure 2, can protect the ADCs beyond the absolute maximum ratings. On the digital side, a CRC checksum reinforces the robustness of the interface.

The RC low-pass filter at the inputs of the ADC, as shown in the Figure 2, assists with antialiasing and noise filtering. An important point is that the filter resistor is placed in series with the input impedance of the ADC. This resistor will affect the internal voltage divider ratio resulting in a gain error. Nevertheless, with very high input impedance like 10 MΩ of the ADC, the voltage division error will be very small. For example, if 180 Ω is used, the error will be only around 0.0018%. Moreover, this error can be removed by a system calibration or adjustment of the gain settings. The former can be completed by utilizing the calibration mode offered by the newest multiplexed ADCs. These modern ADCs have four subcalibration modes: internal zero-scale, internal full-scale, system zero-scale, and system full-scale.

In addition to calibration mode, for normal operation, other options include continuous conversion mode, continuous read mode, or single conversion mode. To save power in systems with constricted power budget, the user can also activate standby or power-down modes.

Extra Integrated Functions

The high integration of the newest multiplexed ADCs allows for greater flexibility especially in typical automation applications. For example, there are four integrated general-purpose input output (GPIO) pins, two of which can be configured as digital inputs or outputs, while two others can be configured solely as digital outputs (GPO). These GPIO or GPO pins can be used for controlling an extra external multiplexer. With an external multiplexer, one can increase the channel count even further. Another integrated feature is a programmable delay block that can be enabled before the ADC begins to take samples. This delay allows an external multiplexer or amplifier to settle. The latest ADCs generate, by default, 24-bit conversions. However, the width of the conversions can be reduced to 16 bits via a control bit for easier data processing in some microcontrollers.

An integrated temperature sensor can help monitor the ambient temperature at which the device is operating. It may also be used for diagnostic purposes, or as an indicator of when the application circuit must do a calibration routine due to possible shifts in operating temperature.

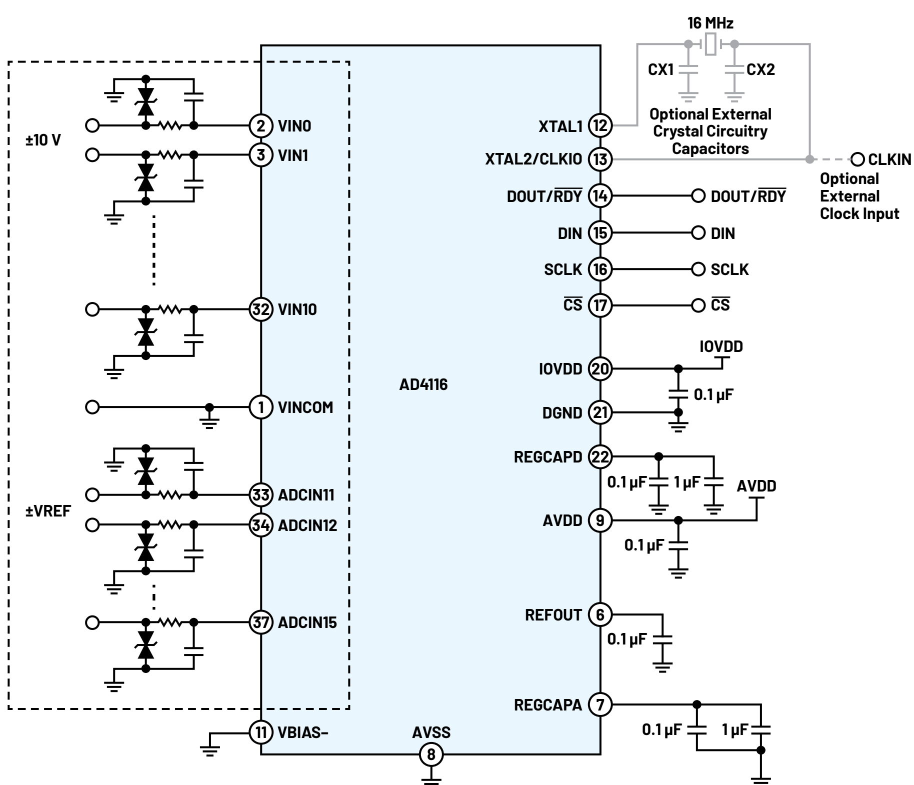

Figure 2. A typical connection diagram.

Conclusion

The latest multiplexed ADCs are highly accurate and can be easily integrated, meeting the increasing need for performance and robustness in modern production plants and industrial applications. At the same time, designers gain greater flexibility and meet system performance requirements more quickly and easily.

About the Author

Hakan Uenlue is a senior field applications engineer at Analog Devices. He has an M.Sc. degree in electrical and electronics engineering from the University of Stuttgart. After previously working as a hardware developer and field applications engineer, he joined ADI in 2015.

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