Product How-to: Optimizing industrial Data-Acquisition system design

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At the heart of many industrial automation and process-control systems, programmable logic controllers (PLCs) monitor and control complex system variables. Employing multiple sensors and actuators, PLC-based systems measure and control analog process variables such as pressure, temperature, and flow. PLCs are found in diverse applications—such as factories, oil refineries, medical equipment, and aerospace systems—that require high accuracy and robust, long-term operation. In addition, the competitive marketplace demands lower cost and shorter design times. Thus, designers of industrial equipment and critical infrastructure encounter significant challenges in meeting their customers’ stringent accuracy, noise, drift, speed, and safety requirements.

This paper shows how the versatile, low cost, highly integrated ADAS3022 reduces complexity, solving many challenges encountered in the design of multichannel data-acquisition systems by replacing the analog front-end (AFE) stages. Ideally suited for precision industrial, instrumentation, power line, and medical data-acquisition cards with multiple input ranges, this high-performance device reduces cost and time to market while offering a small, easy-to-use footprint and true 16-bit precision at 1 MSPS.

PLC Application Example

Figure 1 shows a simplified signal chain for a PLC used in industrial automation and process-control systems. The PLC typically comprises analog and digital input/output (I/O) modules, a central processing unit (CPU), and power-management circuitry.

In industrial applications, analog input modules acquire and monitor signals from remote sensors located in harsh environments characterized by extreme temperature and humidity, vibration, and explosive chemicals. Typical signals include single-ended or differential voltages with 5 V, 10 V, ±5 V, and ±10 V full-scale ranges, or current loops with 0 mA to 20 mA, 4 mA to 20 mA, and ±20 mA ranges. When long cables with substantial electromagnetic interference (EMI) are encountered, current loops are often used due to their inherently high noise immunity.

Analog output modules typically control actuators, such as relays, solenoids, and valves, to complete the automated-control system. They typically provide output voltages with 5 V, 10 V, ±5 V, and ±10
V full-scale ranges and 4 mA to 20 mA current-loop outputs.

Typical analog I/O modules include 2, 4, 8, or 16 channels. To meet stringent industry standards, these modules require protection against overvoltage, overcurrent, and EMI surges. Most PLCs include digital isolation between the ADC and the CPU and between the CPU and the DAC. High-end PLCs may also incorporate channel-to-channel isolation, as specified by the International Electrotechnical Commission (IEC) standards. Many I/O modules include per-channel software programmable single-ended or differential input ranges, bandwidth, and throughput rate.

In modern PLCs, the CPU performs numerous control tasks in an automated manner, employing real-time access to information to make intelligent decisions. The CPU may embody advanced software and algorithms, and web connectivity for diagnostic error checking and fault detection. Commonly used communication interfaces include RS-232, RS-485, industrial Ethernet, SPI, and UART.

![Figure 1. Typical PLC signal chain.](image1)

The circuit shown in Figure 2 is a highly integrated 16-bit, 1 MSPS, multiplexed 8-channel flexible data acquisition system (DAS) with a programmable gain instrumentation amplifier (PGIA) capable of handling the full range of industrial signal levels. This high level of integration saves board space and lowers the overall parts cost, making the ADAS3022 ideal for space-constrained applications, such as automatic test equipment, power-line monitoring, industrial automation, process control, patient monitoring, and other industrial and instrumentation systems that operate with ±10-V industrial signal levels.

![Figure 2. Simplified schematic of 5 V, Single-Supply, 16-bit, 1MSPS, 8-Channel Data Acquisition Solution](image2)

The ADAS3022 can be configured to measure up to eight single-ended inputs or four differential pairs. Seven bipolar input ranges can handle the full span of industrial signal levels (±640 mV to ±24.576 V), thus allowing direct connection to most sensor interfaces.

A single +5 V supply powers the circuit, and a high efficiency, low ripple boost converter generates the ±15 V that allows processing differential input signals up to ±24.576 V with ±2 LSB INL (maximum), and ±0.5 LSB DNL (typical). For high accuracy applications, this compact and cost-effective circuit offers high precision, as well as low noise. The reference is supplied by the ADR434 low noise reference buffered by a low power AD8031 op amp.

This complete sensor-to-bits solution utilizes only one-third of the board space of discrete
implementations and reduces cost by about 50%, helping engineers to simplify their designs while reducing the size, time to market, and cost of advanced industrial data-acquisition systems. Eliminating the necessity to buffer, level shift, amplify, attenuate, or otherwise condition the input signal, and the concerns regarding common-mode rejection, noise, and settling time, it alleviates many of the challenges associated with designing a precision 16-bit, 1-MSPS data-acquisition system.

The ADP1613 as a SEPIC converter
The ADP1613 is used as the single-ended, primary inductance (SEPIC) Cuk converter, which is an ideal candidate for providing the ADAS3022 with the necessary high voltage ±15 V supplies (at 20 mA) and low output ripple (3 mV maximum) from an external 5 V supply. The switching frequency of the ADP1613 in this application is 1.3 MHz. The ADP1613 satisfies the specification requirements of the ADAS3022 with a minimum of external components, and the efficiency is greater than 86%, as shown in Figure 3. The main advantage of using the low cost ADP1613 in this topology is its excellent tracking between the two supply rails, while creating the ±15 V using off-the-shelf coupled inductors. In addition, it can be quickly and easily designed and built using the ADIsimPower design tool.

![Figure 3. ADP1613 Efficiency (P_{OUT}/P_{IN}) vs. Output Current (I_{OUT})](image)

The circuit shown in Figure 2 was designed using the following inputs within the ADP161x SEPIC-Cuk Downloadable Design Tool, which is available at ADIsimPower. The ADIsimPower design tool allows complete customization of the design and to quickly create the robust dual rails from one controller using an inexpensive SEPIC-Cuk topology.

A functional block diagram of the test setup is shown in Figure 4. The ADP1613 evaluation board is driven with an external +5 V supply to generate the ±15 V required by the ADAS3022 board. A 7 V dc wall wart supplies the EVAL-CED1Z board. The 5 V required by the ADAS3022 board is supplied by regulators on the EVAL-CED1Z board. An Audio Precision SYS-2702 is used to generate a low distortion input signal when running ac tests.

![Figure 4. Test Setup Functional Block Diagram](image)

Figure 5 shows the typical dynamic performance of the ADAS3022 running at 1MSPS with a 20 Vp-p, 20 kHz input signal applied to one of the channels. Experiments were conducted with the ADAS3022 driven from linear ±15 V bench supplies and driven from the ±15 V output of the ADP1613 evaluation board. No difference in ac or dc performance was observed.
Conclusion

The next generation of industrial PLC modules will demand high accuracy, reliable operation, and functional flexibility, all in a small, low-cost form factor. The ADAS3022, with industry-leading integration and performance, supports a wide range of voltage and current inputs to handle a variety of sensors in industrial automation and process control. An ideal fit for PLC analog input modules and other data-acquisition cards, the ADAS3022 will enable industrial manufacturers to differentiate their systems while meeting stringent user requirements.

References


Maithil Pachchigar, Circuit Note CN0201. Complete 5 V, Single-Supply, 8-Channel Multiplexed Data Acquisition System with PGIA for Industrial Signal Levels.