

Make the Right Choice When Selecting Multiplexing ADCs

This article explores the advantages of modern multiplexed ADC architectures and provides practical guidance for selecting and deploying them across a range of industrial process-control scenarios.

As industrial automation evolves toward tighter integration, higher channel counts, and more data-centric operation, it's led to a shift in the role of data acquisition. [Analog-to-digital converters \(ADCs\)](#), once simple sampling components, are now complex subsystems that must interface with distributed sensors, withstand harsh environments, and [deliver reliable measurements](#) in real-time.

Modern multiplexed ADCs — devices that integrate channel-selection multiplexers, programmable gain amplifiers, filtering blocks, and increasingly sophisticated diagnostics — have emerged as a key technology for process control, enabling scalable, cost-effective, and high-density signal acquisition.

What's the Role of Multiplexed ADCs in Process Control?

Industrial processes, from chemical and petrochemical plants to water treatment systems, power generation, mining, and discrete manufacturing, depend on large numbers of analog measurements. These include temperatures (resistance temperature detectors [RTDs], thermocouples), pressures (bridge sensors, piezoresistive elements), flows (differential pressure, Coriolis sensors), levels (ultrasonic, capacitive, radar analog readout), and both voltages and currents (transmitters, inductive sensors).

In legacy systems, each sensor often required an ADC, a conditioning chain, and a channel interface. This meant high cost, large footprint, and limited flexibility.

Modern multiplexed ADCs can service tens of sensors using a shared converter core, dramatically reducing board space, power consumption, per-channel cost, and calibration overhead. And because process control increasingly requires digitization closer to the field, multiplexed ADCs

make it easier to embed multichannel measurement in smart transmitters, distributed I/O nodes, and edge-control units.

Technical Advantages of Modern Multiplexed ADCs

For starters, high integration reduces system complexity. Today's multiplexed ADCs integrate input multiplexers (8 to 128 channels), low-noise [programmable gain amplifiers](#) (PGAs), digital and analog filters, sensor excitation circuitry, open-wire detection, lead-break and short-circuit detection, and even built-in calibration engines.

This consolidation reduces BOM size and ensures that channel switching, scaling, and error handling behave consistently across the entire measurement chain.

ADCs also feature lower power for high channel density. Manufacturers have optimized converter cores for lower power per conversion step, enabling the use of battery-powered or energy-harvesting field devices, compact distributed I/O modules (without requiring aggressive cooling), and per-channel power scaling, depending on sampling requirements.

Many modern converters also use "burst mode" acquisition, doing rapid conversions and entering sleep states — ideal for slow-changing process variables.

Modern multiplexed ADCs also offer improved accuracy and better noise performance. They typically leverage $\Sigma\Delta$ ([sigma-delta conversion](#), [chopper-stabilized](#)) PGAs, low-drift reference buffers, and oversampling filters.

This provides higher effective resolution — often 18 to 24 bits — without requiring external signal conditioning for many sensor types. With well-designed anti-aliasing filters and careful PCB layout, multiplexed ADCs can rival multi-converter systems.

Older ADC multiplexers suffered from long settling times after channel switching. New designs provide programma-

ble digital filter windows optimized for channel sequencing, fast-settle modes for step inputs, and per-channel filter tuning for mixed-speed inputs

This enables mixed workloads, such as fast sampling on vibration or motor-current channels or slow sampling on temperature or pressure channels — all on a single device.

Modern devices typically offer a flexible sensor interface that may include hardware and firmware support for RTDs (2-, 3-, 4-wire configurations), thermocouples (cold-junction compensation support), bridge sensors (strain, pressure), 4- to 20-mA transmitters (with internal shunt integration), and general voltage and current measurements. This versatility enables a single multiplexer/ADC solution to handle entire process skids or modular I/O blocks.

Finally, modern ADCs typically provide built-in diagnostics and safety features. For process industries — especially in chemical, oil & gas, and power systems — diagnostics are crucial for safety integrity levels (SILs). Typical offerings include per-channel fault detection, sensor-open and sensor-shorted detection, CRC protection on data output, [watchdog timers](#), reference-monitoring, and internal temperature sensors.

These capabilities support IEC 61508/SIL2+ architectures when paired with appropriate microcontroller diagnostics.

How Do You Choose the Right Multiplexed ADC?

Several key engineering considerations are involved in selecting a multiplexed ADC, covering topics like expandability and conversion architecture.

1. Number of Channels and Expandability

Consider an ADC family that scales with system growth.

Ask:

- Does the manufacturer offer pin-compatible devices with more channels?
- Is daisy-chaining or channel stacking supported? (In large distributed I/O racks, daisy-chainable Σ - Δ devices reduce wiring congestion and simplify board routing.)

2. Conversion Architecture: Σ - Δ vs SAR

Σ - Δ (*sigma-delta*)

- High resolution (18 to 24 bits)
- Excellent for slow-moving variables (temperature, pressure)
- Strong noise rejection (poor for fast transient measurement)

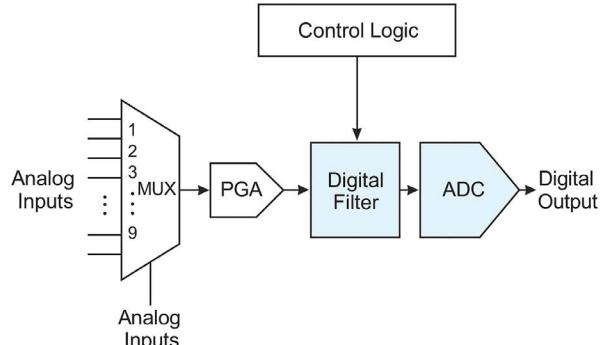
SAR (*successive approximation*)

- Fast (up to multi-MSPS per channel)
- Good for vibration, current control, and fast loops (typically lower resolution, 12 to 18 bits)

Hybrid systems

- Many plants use Σ - Δ ADCs for slow process variables and SAR for fast control loops.

3. Multiplexer Settling Time



A multiplexer uses a single ADC to convert multiple analog signals by rapidly switching between them, routing one signal at a time for digitization. The programmable gain amplifier (PGA) conditions the analog signal from each input channel so that it makes the best use of the ADC's available measurement range.

Critical for applications where multiple channels must be sampled quickly. Evaluate:

- Internal switching transients
- Programmable gain amplifier (PGA) response after channel changes
- Required acquisition time per channel
- Worst-case settling during full-scale transitions

Consider devices with fast, predictable settling behavior under the expected sensor characteristics.

4. Input Impedance and Sensor Compatibility

Bridge sensors and thermocouples prefer high input impedance to minimize loading error. 4- to 20-mA loops require:

- Precision shunt resistors
- Isolation from high common-mode voltages
- Robust transient protection

Check whether the ADC tolerates:

- \pm Common mode
- High-EMI environments
- Induced surge and ESD events

5. Digital Interface Considerations

Serial peripheral interface (SPI) is most common, but newer devices support:

- I₂C for low-speed simplicity
- High-speed SPI for multichannel throughput
- LVDS or JESD204-style interfaces for long cable runs or noisy environments

Look for:

- CRC-protected data streams
- Clocking schemes compatible with noisy industrial backplanes
- Support for galvanic isolation

6. Robustness, Compliance, and Environmental Ratings

In process plants, ADCs face temperature drift, vibration,

humidity, dust, and electrical noise. Select devices rated for:

- -40 to +125°C operation
- IEC 61000-4 surge/ESD/EMI immunity
- ISO/IEC intrinsic safety requirements (if in hazardous zones)
- Predictable drift over long lifetimes

Deployment Tips for Process-Control Applications

1. Sensor Excitation and Grounding

RTDs and strain gauges require stable excitation. Best practices:

- Use ADCs with built-in current sources.
- Place excitation-return sense lines near the ADC.
- Avoid ground loops by using star grounding or isolated front ends.

For thermocouples, ensure:

- Cold-junction compensation (CJC) is accurate and thermally stable.
- Thermal gradients across PCB layers are minimized.

2. Anti-Aliasing, Filtering, and Oversampling

Process environments deal with EMI from pumps, VFDs, motors, and welders.

Design rules should always include implementing a passive anti-aliasing filter per channel, tuning digital filtering for each sensor, using oversampling to improve SNR without changing hardware, and spreading out switching events across sequences to reduce crosstalk.

3. PCB Layout for Multiplexed ADCs

Multiplexing increases channel coupling risks.

Layout recommendations include isolating analog and digital grounds, keeping analog traces short, (differential where possible), guarding critical nodes around high-impedance inputs, physically separating high-voltage I/O from low-level sensor traces, and using solid ground references and low-impedance return paths.

4. Calibration and Self-Test

Multiplexed ADCs benefit from per-channel offset/gain calibration, system-level calibration during commissioning, periodic online calibration using internal references, and leveraging built-in diagnostics to spot drift or wiring faults.

Many manufacturers also include automated calibration engines and use them to reduce downtime.

5. Isolation and Safety Integration

For distributed process-control modules, aim to isolate analog front ends when sensors operate at high common-mode potentials, use digital isolators for serial peripheral interface (SPI) links to the host CPU, and pair ADC diagnostics with PLC/RTU logic for SIL compliance.

Isolation not only improves safety, but it reduces noise-induced measurement errors.

6. Vendor Ecosystem and Firmware Support

Choosing a manufacturer isn't just about the sili-

con. Also consider the availability of development kits; sample firmware; long-term availability roadmaps; accuracy of datasheets, especially for drift parameters; online support and application notes; and ease of integrating into an industrial automation stack.

Leading vendors for multiplexed ADCs include Analog Devices, Maxim Integrated (Analog Devices), Microchip, Renesas, and Texas Instruments.

Wrapping Up

Modern multiplexed ADCs are essential building blocks for high-density, high-reliability process control. Their integration of analog front ends, diagnostics, filtering, and flexible channel sequencing enables engineers to reduce system complexity while improving measurement accuracy and robustness. Selecting the right device requires a careful evaluation of signal types, accuracy requirements, channel count, environmental conditions, communication bandwidth, and diagnostic needs.

References

[Measuring multiple RTDs with a multiplexed ADC & intro to conversion latency](#)

[Enhancing Cybersecurity Visibility in Industrial Control Systems \(ICS\)](#)