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APPLICATION NOTE 5758

Analog Integration Drives Factory Integration

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Abstract: Analog integration is driving the integrated factory. Advances in analog and mixed-signal ICs contribute greatly to factory productivity, efficiency, quality, safety, and security. These all lead to increased uptime and reduced maintenance costs. This integration enables robust machine to machine (M2M) communications and ultimately the internet of things (IoT). Distributed intelligence, smart machines, smart sensors, and the integration of factory data with business-management systems (information technology or IT) allows optimization of not only the factory process, but also material handling, machine utilization, scheduling, reporting, and throughput.

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Introduction

Advances in analog and mixed-signal ICs have contributed greatly to unprecedented combinations of factory productivity, efficiency, quality, and safety. These ICs enable higher system performance, increasingly accurate measurements, robust communication, lower power, and higher levels of security. They are central to factory systems that act rapidly on large numbers of sensor-based measurements that precisely control material handling, processing steps, power and temperature, and operational safety.

When computational resources are integrated into these analog and mixed-signal ICs, the factory can deploy a distributed intelligence model. Factory data can now interface more readily with business-management systems. This *integrated factory* model, comprising many of the techniques and technologies described below, makes factory information available worldwide in real time to supply chain, sales, logistics, and senior management.

Distributed Intelligence

Integrated factories exploit distributed intelligence, pushing computational resources and decision making out of the control room and into widely dispersed process machinery. This shift in system architecture delivers data to management personnel in almost real time. It eliminates data-processing bottlenecks. It allows management to deploy more measurement and control nodes, and to act on significantly larger sets of process data.

The benefits of distributed intelligence to the factory floor can actually be summarized in a single concept: uptime. Factories will reduce measurement-to-control feedback latencies; experience better reporting of process efficiency, throughput, WIP (work-in-progress) status, and machine utilization; and lower maintenance costs.

Benefits to the company, however, extend far beyond the factory floor. Integrated-factory systems provide up-to-the-minute workflow data, which, when combined with supply-chain intelligence, allow operations to optimize their scheduling and inventory management. Worldwide sales and distribution management can act on precise and timely factory productivity data. Management can better optimize production-line balancing and capacity utilization.

These many benefits clearly depend on sophisticated software tools for optimal operation at the highest level of abstraction. But

the software systems cannot deliver these results without accurate, efficient, and robust electronics to implement the sensor-based measurements, control functions, and energy-management tasks.

Integrated ICs Enhance Sensor Measurements

Mixed-signal ICs bring signal conditioning and digitizing functions closer to the points of measurement which are often widely distributed. Digitizing at a sensor node increases control-data quality by reducing noise susceptibility. Temperature measurements are among the most common process-control inputs. The temperatures of feedstocks and other raw materials, of processing environments such as ovens and tanks, and of machinery such as drive motors and molding machines, all impact manufacturing quality and system reliability.

Temperature measurement channels must provide open-load detection so that the system can force a safe control state when a temperature sensor or one of its connections is broken. A signal conditioner like the MAX31855, for example, reads a thermocouple that is, in turn, monitoring a processing oven's temperature. In the event of any detected sensor fault, the signal conditioner reports an error code in the digital data stream so that the system can respond quickly and cut power to the oven and report a fault to the supervisory level system monitors.

There is, however, a challenge. Temperature sensors such as thermocouples and resistance temperature devices (RTDs) output voltage changes on the order of only 10s of microvolts per degree C. So, signal conditioners must accurately resolve small voltages corresponding to temperature measurements. If the signal conditioners are measuring RTDs, they must also provide an accurate *excitation* signal in the form of a low-noise current source. The RTD transduces the excitation current to a voltage that is proportional to its temperature. The excitation current is limited to relatively small values to prevent self-heating in the sensor due to I^2R dissipation.

Integrating the sensor excitation, signal conditioning, digitizer, fault detection, and protection circuits in a single monolithic device greatly simplifies the design of measurement channels or channel clusters. Essentially forming single-chip measurement subsystems, mixed-signal ICs like the MAX31855 provide specified parametric performance from sensor to digital controller; they eliminate PCB layout complexity, reduce susceptibility to sources of electrical noise, and significantly improve functional density (**Figure 1**). In sum, analog integration improves system performance and process quality.

Figure 1. A complete thermocouple-to-digital converter includes cold-junction compensation and fault detection.

For Your Reference

In cases where no single IC addresses a set of design requirements, tested reference designs speed the process of selecting components that work together to best meet end-equipment design goals, shrink time to market, and reduce design risk.

Reference designs include schematics, BOMs (bills of materials), and, in most cases, are available with sample boards, layout files, and supporting software. Reference designs can implement power-management functions in addition to signal processing and galvanic isolation. They may also integrate an on-board microcontroller and provide software to support sequential processing and control interfaces and secure the application. Reference designs are very beneficial in reducing the time often spent debugging schematic or software errors, and layout issues that can degrade precision analog performance.

For example, the integrated Santa Fe reference design implements a four-input analog front-end (AFE) for voltage or current-loop inputs (**Figure 2**). The design provides galvanic isolation for power and the output data.

You can also combine reference designs. For example, the Monterey current/voltage output conditioner subsystem and Santa Fe can form a complete loop-powered temperature transmitter and analog front-end/receiver with high accuracy.
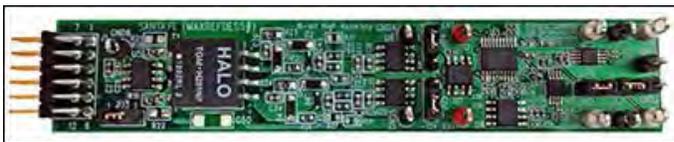
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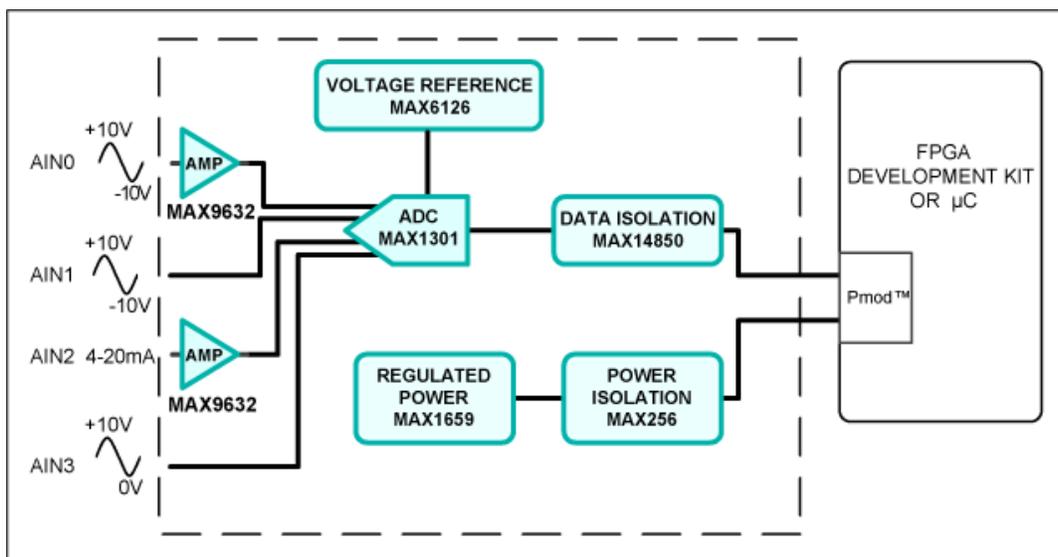
Figure 2. The Santa Fe reference design (top) implements a four-channel AFE with 16-bit resolution and on-board galvanic isolation as shown in the block diagram (bottom).

Drive Safety

Automation-system outputs control valves, actuators, solenoids, motors, and more. System designs must ensure that these electromechanical devices operate in a safe manner, even under fault conditions. Consider a robotic arm in motion when a power-quality event forces its microcontroller to reboot. The system cannot allow the arm's motion to continue with a break in its control loop, so the driving circuits must detect the fault and assume a safe state. Motor drives must transition to safe torque states. Valves must close or open depending on the situation. In general, all actuators must assume a state that is safe for the materials in the production line, for the production equipment, and most importantly, for the human operators on the factory floor.

Analog and digital output devices designed for industrial applications ease controller hardware designs when they support these safety requirements. For example, a multichannel DAC (digital-to-analog converter) like the MAX5725 has an integrated

programmable watchdog timer that resets when the DAC receives a valid command. If the watchdog times out due to a communication failure, channels for which the watchdog is active revert to a predetermined, programmable-output potential. This feature ensures that, should the host processor hang up or the communications link fail, the actuators, valves, servos, or other hardware under DAC control assume a safe state.

Found in Translation

 A challenge in many industrial applications is translating 24V binary signals from sensors and switches to low-level logic-compatible levels that dissipate little energy. The system costs of level translating and galvanically isolating each signal can be high. Serializing the inputs and isolating the serial stream for monitoring with an on-board microcontroller greatly simplify the interface design, but require the process to tolerate a high input voltage. These designs must also significantly reduce power consumption, when compared to traditional approaches; they must be integrated if they are to shrink the design into a single, space-saving IC as well.

Today there are industrial, multichannel, digital-input translator/serializers like the MAX31911 that translate, condition, and serialize multiple high-voltage input channels to logic-compatible signals for the microcontrollers in programmable-logic controllers (PLCs) and related equipment. Compared to discrete resistor-divider methods, these translator/serializer ICs reduce power dissipation by 60%.

Many applications require galvanic isolation, and serializers can reduce the necessary number of isolated channels to three. The new MAX31913 translator/serializer, for example, provides SPI daisy chaining, so larger numbers of inputs from multiple serializers can share the same three isolated signals. To assure data integrity in the translation from parallel to serial, the translator/serializer ICs integrate cyclic redundancy checking (CRC) (**Figure 3**).
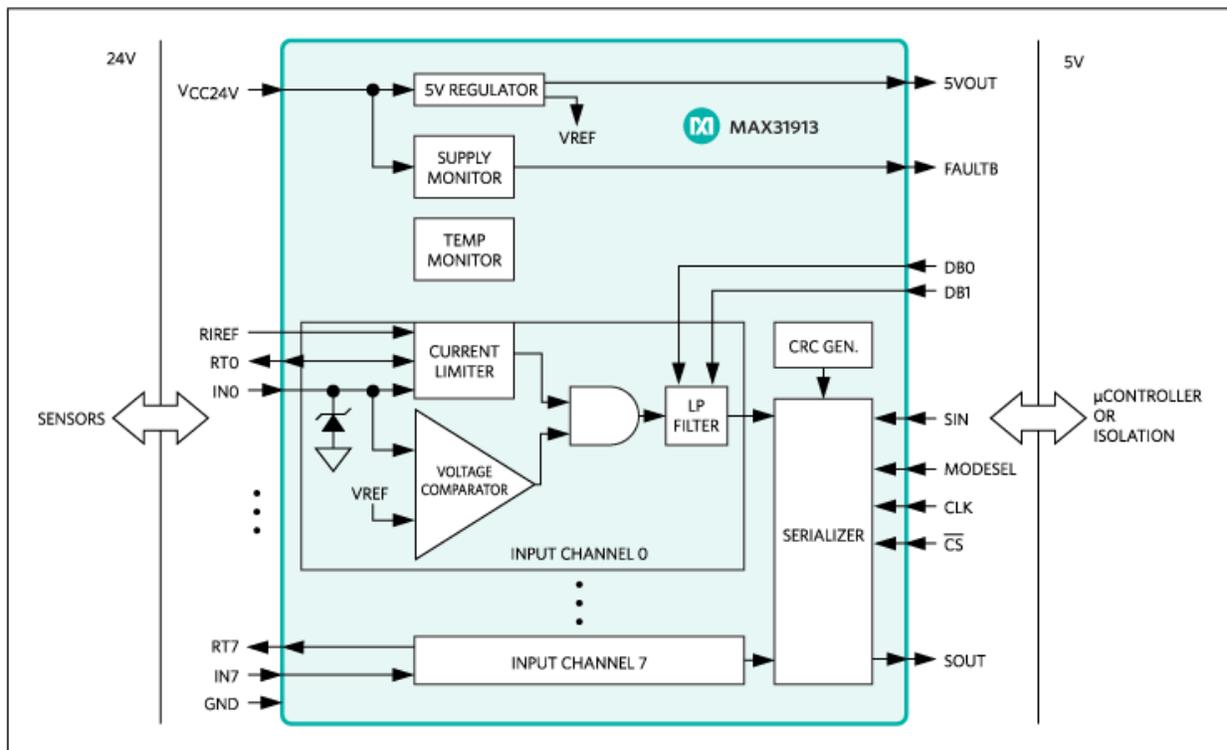

Figure 3. A MAX31913 industrial, octal, digital-input translator/serializer allows 24V signals from sensors and switches to interface directly with low-level CMOS logic.

To the Rails…and Beyond

 Supplying power to industrial electronics has become an increasingly challenging part of system designs. The number of

voltage rails that signal conditioning and data processing blocks require exacerbates an already complex electrical environment; the rails require galvanic isolation between nodes or clusters of nodes and the control system. Add to this the increasingly sophisticated methods of energy savings through various power-control methods, and the cost and complexity of power subsystems only increase further.

Given the industrial signal levels, the need for higher voltage rails such as ±25V, or more, is quite common. This high-voltage requirement is specifically for front-end and back-end circuits that interface with the outside industrial world. In contrast, the other power-supply rails serving processors and other digital electronics operate at much lower voltages.

The proven Beyond-the-Rails technology integrated in the MAX14778 eliminates some of these higher voltage rails by extending the signal range of analog and mixed-signal functions beyond the positive and negative supply potentials. A single unipolar supply, therefore, is the only requirement for many functions that would otherwise require two or even three supply rails (**Figure 4**).

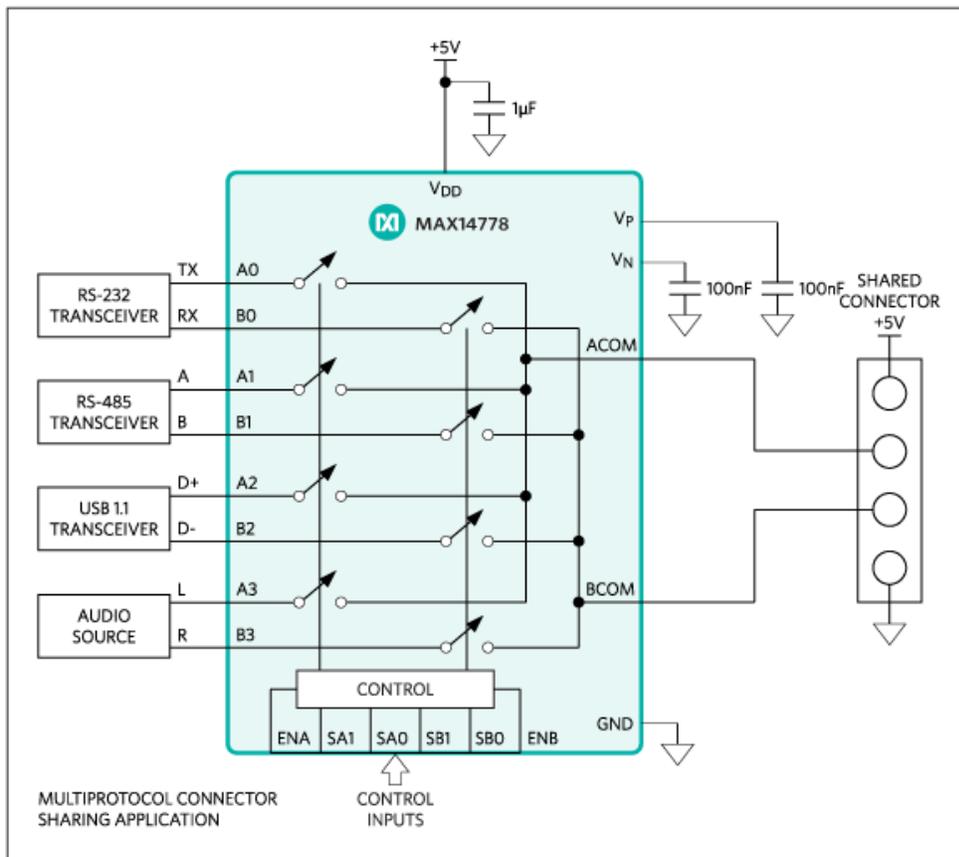*Figure 4. On-chip charge pumps allow the MAX14778 to implement multiprotocol sharing, amongst other functions, with signals as large as ±25V while operating on a single 3.0V to 5.5V supply.*

Low-Loss Power Distribution

Industrial customers and system manufacturers have become increasingly mindful of the need to minimize energy losses in large distributed systems. One area, I^2R losses in DC power-distribution feeds, is being addressed by high-voltage point-of-load DC-DC converters like the MAX17503. These converters operate directly with up to 60V inputs and provide single-stage conversion for digital, analog, and mixed-signal loads at low voltage.

Today 24V is commonly used for PLC backplanes and 12V is used for on-board distribution. If 48V were to be used across the board, when compared to 12V, this could reduce currents by a factor of four and, correspondingly, PCB copper losses by a

factor of 16. Furthermore, by removing an intermediate DC-DC conversion stage, these high-input voltage converters free valuable board space and eliminate the cost and energy losses of the interstitial stage. They can reduce copper losses, reduce connector contact current ratings, and increase reliability while maintaining cool operation (typically 50% cooler) due to their synchronous switch architecture.

Securing the Factory

Systems designed with distributed intelligence exploit common low-cost communication hardware interfaces and data-transfer methods such as Ethernet and the Internet protocol. The trend today is away from proprietary communication schemes and toward an Internet of Things (IoT). The IoT promises a low-cost means for machine-to-machine (M2M) communication both within an industrial site and among sites worldwide.

These advances, however, expose system vulnerabilities to cyber attack. The most effective protection builds in hardware-based security at each node and at each interface, thus embedding the security functions throughout the system to protect against the vulnerabilities. This is often a key part of the total solution for widely dispersed, exposed systems. In this way each piece of equipment has built-in security, each communications interface is secured, and the communications between them and the cloud are protected.

Today there are proven hardware-level security technologies that protect against cyber attack, malicious tampering, IP theft, and the use of unauthorized or cloned equipment. A DS28E35 DeepCover® secure authenticator,[1] for example, provides a highly secure means for a host controller to authenticate peripherals with industry-standard cryptographic methods.

Summary

Integrated factories and distributed intelligence. Integrated security and the IoT. This is the future of secure, successful, productive factories. New electronic systems for industrial applications must address four critical aspects of system performance: accurate measurement of very low signals while controlling very high power levels; robust communication among sensors and systems distributed widely; low-power, high-density and low-latency control systems; and state-of-the-art embedded security. This application note has discussed how industry-leading analog and mixed-signal integration meets these stringent industrial demands. It has shown how analog integration drives today's integrated factories and anticipates tomorrow's demands.

References

1. Information about the DS28E35 is available at www.maximintegrated.com/DS28E35. See also Linke, Bernhard, "The Fundamentals of a SHA-256 Master/Slave Authentication System," EE Times online, June 19, 2013, at www.eetimes.com/document.asp?doc_id=1280942.

Beyond-the-Rails is a trademark of Maxim Integrated Products, Inc.
DeepCover is a registered trademark of Maxim Integrated Products, Inc.

Related Parts		
DS28E35	DeepCover Secure Authenticator with 1-Wire ECDSA and 1Kb User EEPROM	Free Samples
MAX14778	Dual ±25V Above- and Below-the-Rails 4:1 Analog Multiplexer	Free Samples
MAX17503	4.5V-60V, 2.5A, High-Efficiency, Synchronous Step-Down DC-DC Converter with Internal Compensation	Free Samples
MAX31855	Cold-Junction Compensated Thermocouple-to-Digital Converter	Free Samples
MAX31911	Industrial, Octal, Digital Input Translator/Serializer	Free Samples

| MAX31913 | Industrial, Octal, Digital Input Translator/Serializer | Free Samples |
| MAX5725 | Ultra-Small, Octal-Channel, 8-/10-/12-Bit Buffered Output DACs with Internal Reference and SPI Interface | Free Samples |

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