Keywords: programmable logic controller, PLC, Industry 4.0, Micro PLC

APPLICATION NOTE 6159

MEETING THE INTEGRATION CHALLENGE IN PROGRAMMABLE LOGIC CONTROLLERS

Abstract: Industrial manufacturing is deploying the latest sensor technologies, adopting new control architectures, and starting to discover the potential of "big data" and analytics in a transition called Industry 4.0. Manufacturing is increasing the number of sensors used to track environmental and process variables. This is, in turn, accelerating the transition to a distributed-control architecture, where plant operators reduce bottlenecks and shorten control loops by moving programmable logic controllers (PLCs) closer to the processes that they control. In this app note we discuss how the promise of improved operational efficiencies and yields will lead to the largest overhaul of plant operations since the invention of the PLC, and to the need for much more analog integration in PLCs and Micro PLCs.

Introduction

In today's highly competitive global economy, small improvements in manufacturing processes can yield huge competitive advantages.

This mindset is driving fundamental transformations across the factory floor. Manufacturers are deploying the latest sensor technologies, adopting new control architectures, and starting to discover the potential of "big data" and analytics. Often called Industry 4.0, what's happening in manufacturing is nothing short of a revolution (**Figure 1**).

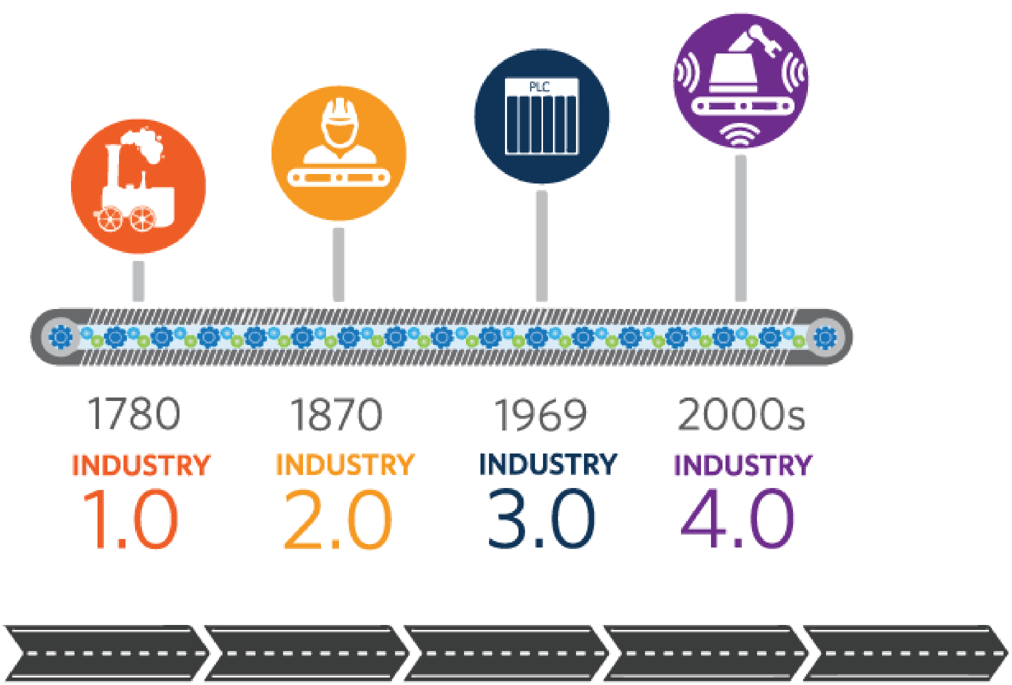


Figure 1. Once again, technology advances are transforming the production environment. Contemporary technology is offering significant advantages to manufacturers who invest in the latest control and automation equipment.

For equipment OEMs, this represents a massive opportunity. The number of sensors used to track environmental and process variables continues to increase. This is accelerating the transition to a distributed-control architecture, where plant operators reduce bottlenecks and shorten control loops by moving programmable logic controllers (PLCs) closer to the processes that they control. Ultimately, the promise of improved operational efficiencies and yields will lead to the largest overhaul of plant operations since the invention of the PLC.

This poses a considerable challenge for PLC engineers. To win in this market, system designers need to pack more I/Os and more functionality into enclosures that keep shrinking. The problem is that there is relatively little space to be gained from digital scaling of the microprocessor. In today's advanced PLC modules, analog and passive components consume approximately 85% of board space.

Engineers can no longer afford to ignore the obvious problem on their boards. Many of the analog and discrete components that have worked so well in previous systems are simply too big for Micro PLCs and embedded controllers. The promise of Industry 4.0 will only be realized through greater levels of integration, across the PLC system design.

The Next Industrial Revolution Has Arrived

PLCs have been at the nexus of industrial transformation ever since the introduction of the Modicon 084 in 1969. Thanks to the digital revolution, they have become progressively more powerful over the years, capable of handling more inputs, larger words, and more complex instruction sets.

Today, innovations in analog and sensor technology are helping manufacturers take full advantage of the massive compute resources available, both within the factory and in the cloud. Industry 4.0 represents a vision for what's possible when you combine this intelligence with pervasive sensing, distributed control, and robust, seamless connectivity.

Once again, the PLC finds itself at the center of a revolution. This is creating new business opportunities for PLC OEMs, as manufacturers increase capital expenditures to take advantage of these technologies. However, it also raises a variety of challenges for system designers.

Realizing the Promise of Big Data

Thanks to the steady march of Moore's Law, we now have massive amounts of processing power at our disposal (**Figure 2**). This processing power enables enterprises to crunch terabytes or even petabytes of data to enhance decision making, generate new insights, and optimize processes.

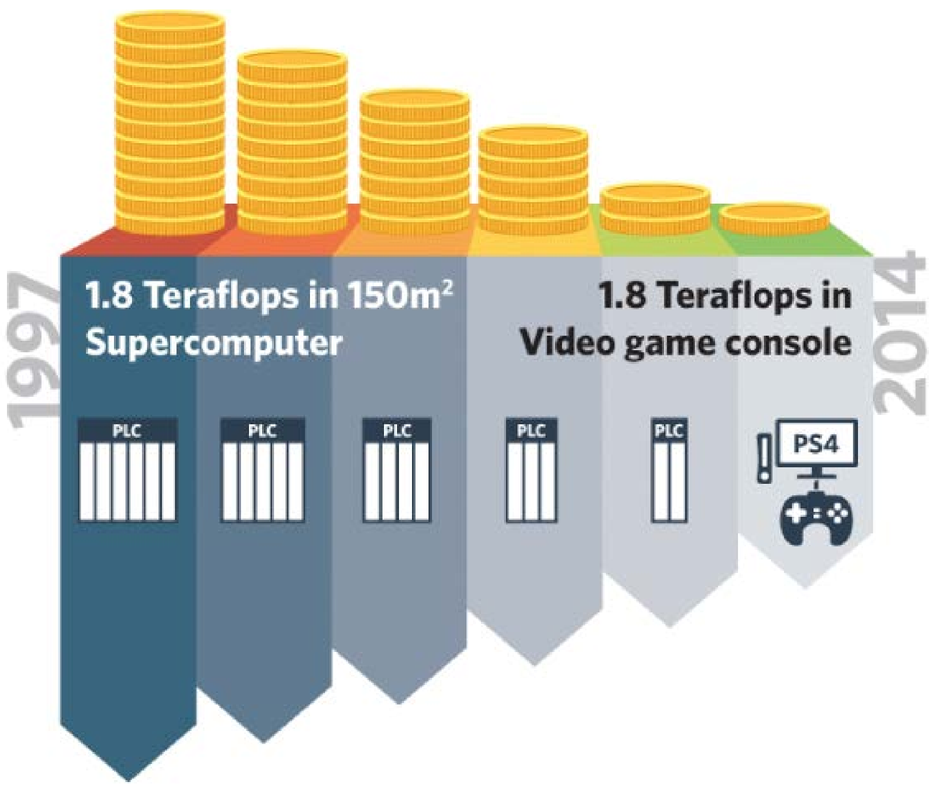


Figure 2. In 1997, a state-of-the-art supercomputer offered 1.8 TeraFLOPS of processing power in 150m^2; today, you can get that in a video game console.

For manufacturers, the biggest challenge is collecting and acting on this data. Three technology trends have emerged to address this problem:

- Pervasive sensing: The cost of sensors and their interfaces continues to decline, enabling manufacturers to track more variables and types of data.
- Distributed control: Moving process controllers closer to the machines that they control eliminates bottlenecks and improves manufacturing throughput and flexibility.
- Seamless connectivity: Manufacturers are connecting the factory floor to the enterprise network to unlock the potential of big data and analytics. This brings numerous benefits, but it also raises many security issues at the system level.

Addressing the New Integration Problem

The biggest problem in PLCs is the one that no one sees. A recent market study revealed that most engineers still believe that digital technology offers the best opportunity for space savings. Yet, digital chips consume just 15% to 20% of the board space in PLC modules.

The real problem is the amount of PCB devoted to analog and discrete components. These devices consume as much as 85% of available board space in PLC modules (**Figure 3**), but they do not scale like digital chips. So PLCs now need greater levels of integration to conserve PCB space while delivering the required functionality.

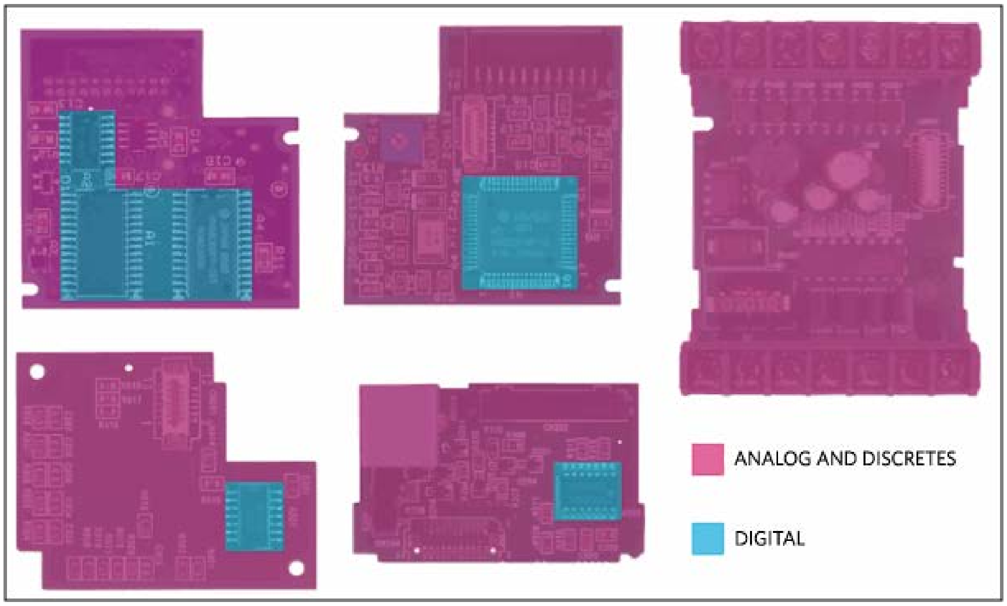


Figure 3. In this typical Micro PLC, analog and discrete components take up more than 80% of the board space.

Solving this PCB space problem requires a new approach to analog design. Gone are the days when system designers could just select catalog parts with adequate specs and then perform heroic feats in layout to make them fit the PLC enclosure. Today's market requires a step-function improvement in space and energy efficiency. To be successful, designers need to systematically look for opportunities to streamline analog circuitry and reduce power dissipation.

Fortunately, Maxim Integrated is developing solutions to capitalize on their integration capabilities as the industrial market evolves. Combining multiple discrete analog functions in a single IC can provide system designers with significant advantages in size, power consumption, and cost.

Maxim's Micro-PLC Technology Demonstration Platform shows how analog integration can enable a 10x smaller PLC footprint, 50% cooler operation, and 70x faster throughput for digital I/O (**Figure 4**). These achievements are realized using Maxim's Smart Integration approach to product development and its proprietary process technology.

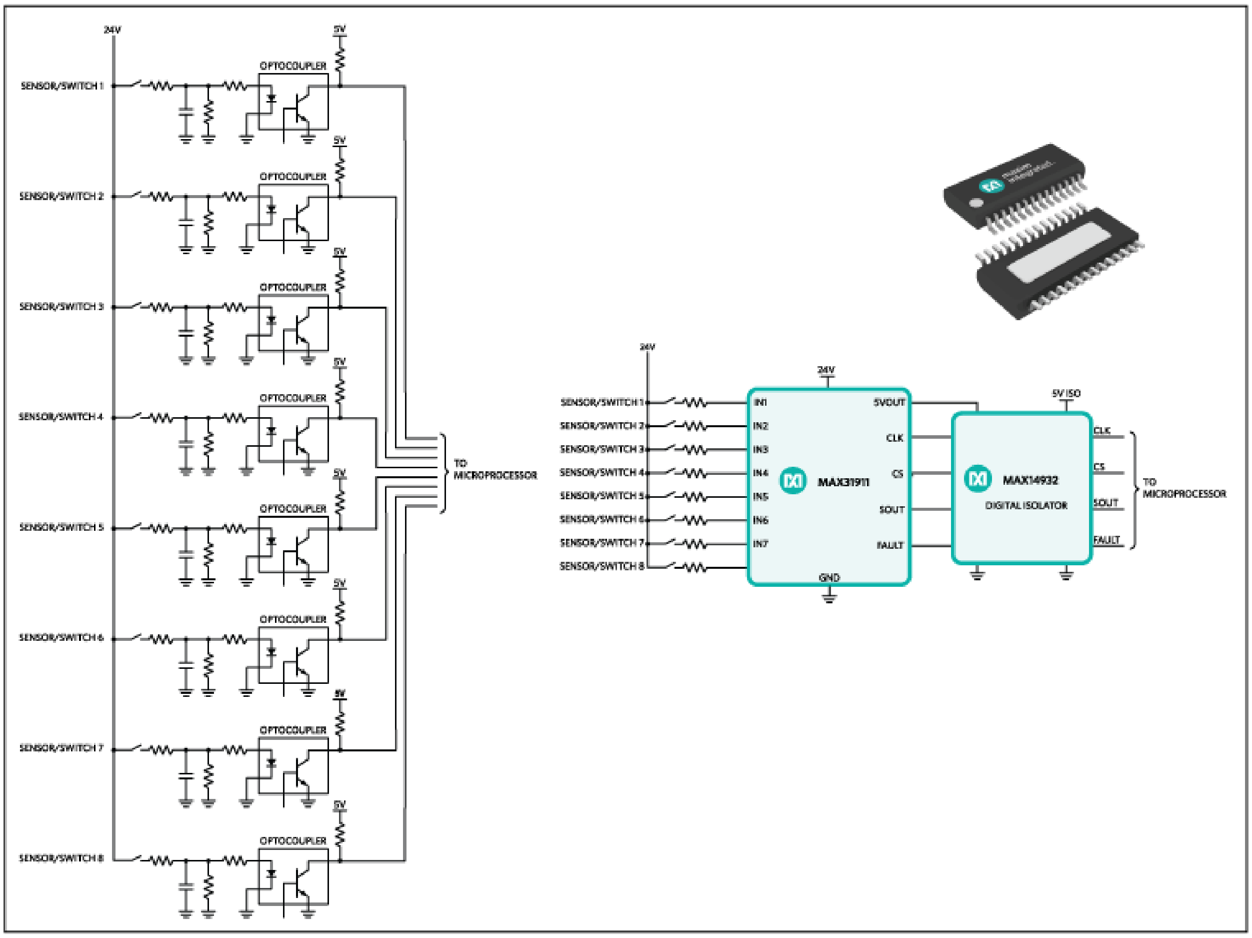
Figure 4. Maxim's Micro PLC Reference Design shows how much space can be saved when engineers take advantage of the latest advances in analog integration.

Increasing I/O Density in Micro PLCs

I/Os are the essential link between PLCs and the countless sensors and actuators required by Industry 4.0. As manufacturers add more sensors across factory floors, equipment designers must push channel density ever higher, even as available space in the PLC continues to shrink.

The I/O isolation architecture offers an opportunity for significant space savings. The traditional approach is to use one optocoupler per channel, and connect each optocoupler output to a digital input on the microcontroller. This approach is costly in parts count, board space, and use of digital I/O pins.

Today, multichannel serializers like the MAX31911 can translate, condition, and serialize the 24V digital outputs of sensors and switches to the 5V, CMOS-compatible levels required by PLC microcontrollers. This approach reduces the necessary number of isolated channels to just three (**Figure 5**).



More detailed image.

Figure 5. The MAX31911 greatly reduces the number of optocouplers for digital-input designs.

The MAX31911, for example, is an 8-channel industrial interface that supports SPI daisy chaining; larger numbers of inputs from multiple serializers can share the same three isolated signals. **Figure 6** shows the dramatic savings in power dissipation, parts count, overall PCB real-estate footprint, optocouplers, and cost for a 32-channel implementation. Compare this with the nonserialized approach.

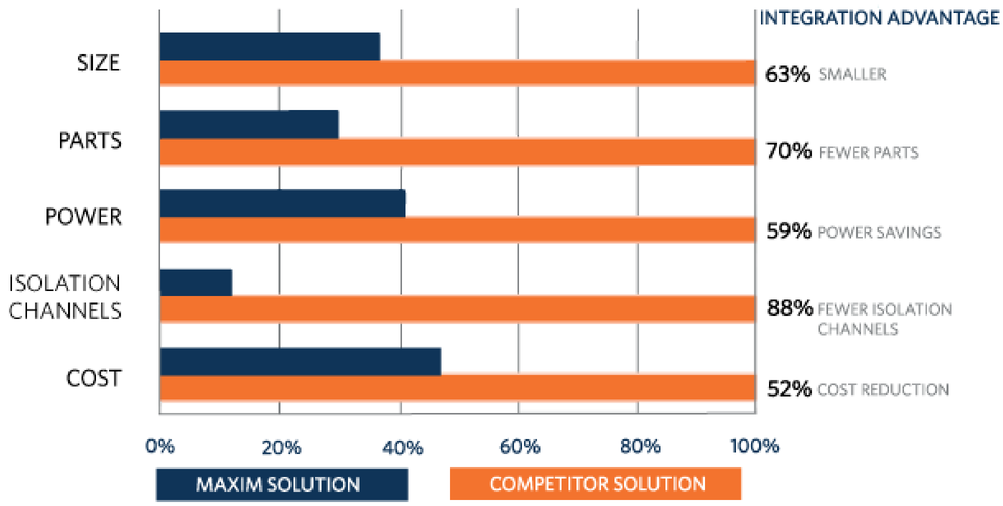


Figure 6. The streamlined isolation architecture offered by the MAX31911 provides numerous benefits to system designers.

Lowering Heat Dissipation in Power Designs

Higher I/O density and smaller form factors also add to the design challenge in another basic way, a consequence of the inevitable power dissipation. The system must be more power efficient than ever to keep the PLC from overheating, especially in an application where fans and vents are generally not acceptable. An often-overlooked source of heat in PLCs is I^2R losses in the DC power-distribution feeds. Frequently, 24V is used for PLC backplanes, while 12V is used for on-board distribution. A better approach is to use 48V across the board, as this reduces currents by a factor of 4 and, correspondingly, PCB copper losses by a factor of 16.

Using high-voltage point-of-load (POL) DC-DC converters like the MAX17503 eliminates the need for an intermediate DC-DC conversion stage. These converters operate directly with up to 60V inputs to enable single-stage conversion for digital, analog, and mixed-signal loads at low voltage. The converters free valuable board space while avoiding the cost and energy losses of the interstitial stage. Additionally, they minimize copper losses, reduce connector contact current ratings, increase reliability, and maintain cool operation (typically 50% cooler) due to their synchronous switch architecture (**Figure 7**).

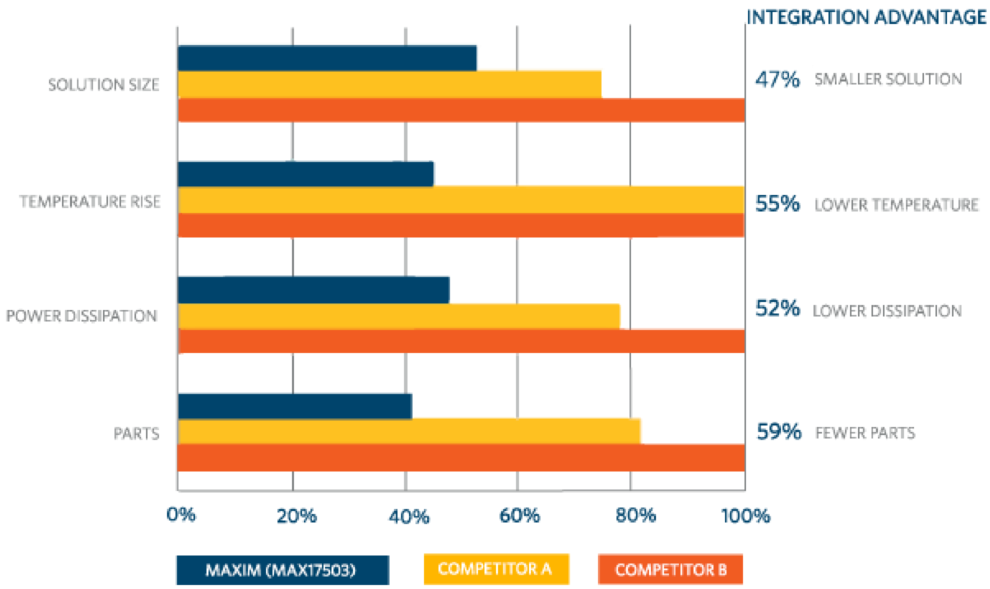


Figure 7. Maxim's 60V synchronously rectified DC-DCs like the MAX17503 greatly reduce heat, size, and component count.

Reducing the Complexity of Power Subsystems

Today's signal-conditioning, processing, and communication circuits require a diverse set of power rails, often differing by a few volts or only fractions of a volt. This exacerbates an already complex electrical environment. 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.

Maxim's Beyond the Rails™ products simplify the signal chain, enabling a design (**Figure 8**) that allows ±10V bipolar inputs to be multiplexed, amplified, filtered, and digitized, all with a single 5V supply. This approach eliminates the need for additional ±15V power supplies; thus, reducing component count, system cost, power dissipation, and footprint.

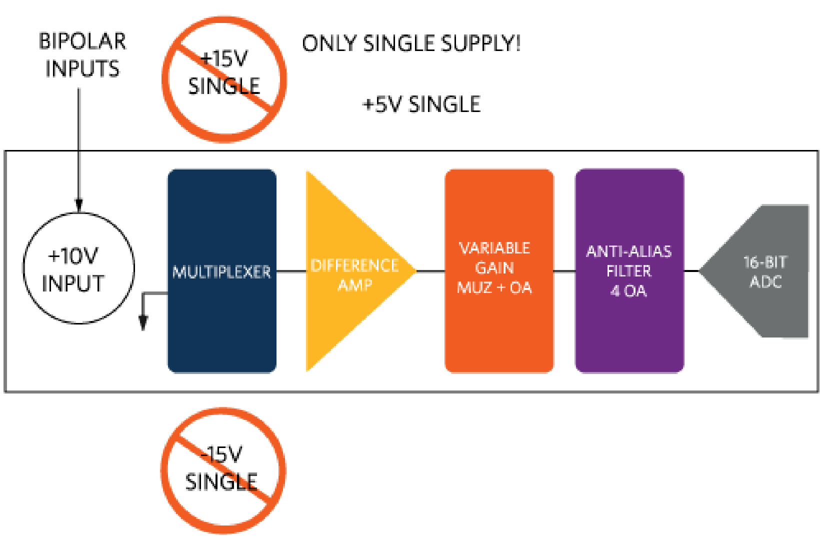


Figure 8. Beyond the Rails products implify power subsystem designs by supporting rails up to ±10V from a single +5V supply.

Integrating Safeguards Against New Security Threats

When factory networks were closed to the outside, IT security issues usually involved rogue employees and internal data theft. Those "good old days" are gone and not coming back. Today's Internet-connected PLCs must be protected against multiple threats, including hackers, malware, and viruses.

System-level software provides an initial level of protection, but in many cases this is not enough. Hardware-based security is needed to protect against:

- **Cloned or counterfeit components:** Counterfeit field sensors and I/O modules pose a real threat to your bottom line. But there is a bigger danger: counterfeit field sensors could be used to execute an attack on the industrial environment. Using a secure authentication IC is the only way to guarantee that you can trust the sensors' readings sent from critical components to the PLC.
- **Malware injection:** Stuxnet was a wake-up call to industry. System operators must ensure that all equipment upon which a supervisory control and data acquisition (SCADA) or distributed control (DCS) system is built runs genuine software. Secure boot and secure update management are the best ways to protect a device from malware injection. A secure co-processor can be used to implement an encryption design that fully addresses these issues with minimal design-in effort.
- **Eavesdropping:** As concern over industrial espionage increases, manufacturers must ensure that unauthorized users cannot steal trade secrets off industrial networks. Encryption and authentication ICs can protect against such eavesdropping, and go further with active tamper detection to prevent brute-force attacks on the hardware components.

Maxim has a rich history in hardware security implementation for ATMs, point-of-sale (POS) systems, and consumables such as printer cartridges. The security product portfolio ranges from simple authentication engines to complex, secure microcontrollers that implement advanced standards-based encryption algorithms.

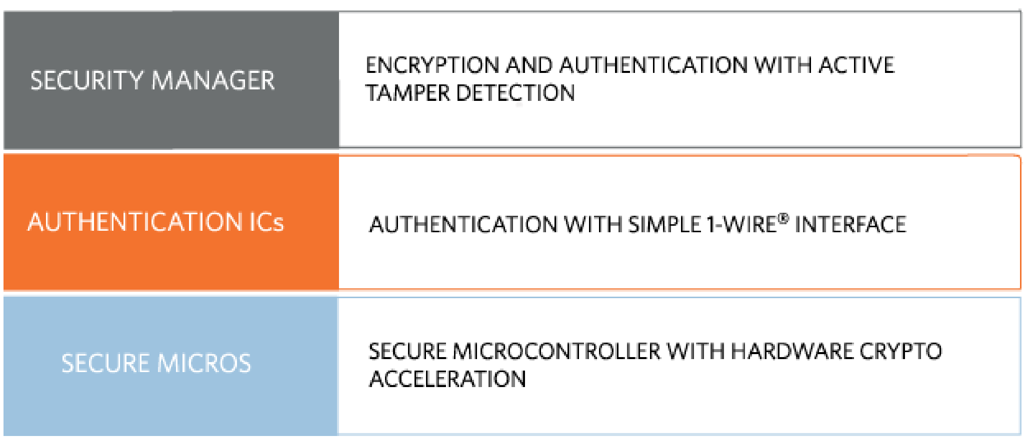


Figure 9. Maxim provides a complete portfolio of hardware security products to address the full range of security needs and price points.

Seize the Integration Advantage in PLCs

Industry 4.0 is fundamentally transforming what it takes to win in the PLC market. Success today demands new strategies for managing competing demands for more functions in less space–smaller form factors, higher I/O density, and advanced capabilities.

This problem cannot be solved by Moore's law. The large amount of analog content in these systems means that PLC engineers can no longer ignore the integration problem in front of them–not when success depends on how much functionality you can pack into every centimeter of space. Engineers who systematically seek higher levels of component integration will be well positioned as manufacturers pursue the benefits promised by Industry 4.0.

An article similar to this application note was published in Embedded-Know-How.com, November 2015.

Related Parts		
MAX14932	4-Channel, 2.75kV$_{RMS}$ and 3.75kV$_{RMS}$ Digital Isolators	Free Samples
MAX17503	4.5V-60V, 2.5A, High-Efficiency, Synchronous Step-Down DC-DC Converter with Internal Compensation	Free Samples
MAX31911	Industrial, Octal, Digital Input Translator/Serializer	Free Samples

More Information
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