



The evolution of PLCs driving Industry 4.0 forward

How robust and secure semiconductor solutions are providing the brains and the brawn in Next-Generation PLCs, enabling smart factories to meet increasing system requirements

Marlene Würcher
Global Distribution Marketing Manager at Infineon Technologies

www.infineon.com





Figure 1: Industrial automation is becoming increasingly prevalent in modern manufacturing processes.

Executive summary

When the PLC was first conceived there was no Internet, just a desire to increase the level of automation in an industrial environment. Today, the IIoT is driving change but the basic premise of the PLC still holds fast. As vertical sectors

strive to be more competitive across global marketplaces, the connected factory will deliver small but crucial advantages. Achieving that goal will require a new approach to an old solution, as this white paper explores.

Introduction

It is no exaggeration to say that the development of the Programmable Logic Controller (PLC) in 1968 radically changed the modern manufacturing and industrial environment. Before the PLC, giant networks of physical relays controlled production plants by switching machines on and off and opening and closing valves.

Every input and output was hardwired into the system and the more complicated the control requirements, the more wiring and relays would be needed. In some cases, the system would become too cumbersome to manage and almost impossible to troubleshoot.

The development of PLCs

The invention of PLCs moved control logic from a hard-wired relay system to a software configuration executed by a microcontroller. Inputs and outputs were now wired into the PLC input and output boards, while engineers programmed the control logic directly into the CPU. The result of the move from hardware to software-based solutions brought about a radical shift in flexibility and reliability of control systems. The flexibility came from the ability to make changes to the program in the CPU instead of rewiring an existing installation of relays. The reliability came from a substantial reduction in field hardware. Every relay used introduced the possibility of a dirty contact or coil failure; removing literally hundreds of relays and replacing them with a single CPU had a dramatic improvement on the robustness of the plant and equipment downtime. The PLC

has thus rightly become known as the brains of the manufacturing plant. Early models of the PLC used a programming principle called ladder logic. The program effectively mimicked an electrical wiring diagram so that plant engineers could easily transition from the hard-wired relays to the software solution. However, the software became more sophisticated over time allowing for more complex control algorithms and higher levels of automation. Different companies each developed their own product range and protocols, making it necessary to introduce common standards for the industry. For example, the International Electrotechnical Commission issued the IEC 61131-3 standard, which defines programming language constructs and rules for PLCs. These developments led to PLC systems becoming more open therefore increasing their interoperability.

The acceptance of PLCs

During the 1980s and 1990s, PLCs developed to such an extent that they became standard installations for industrial and manufacturing facilities. Improvements in microprocessor capacity enabled a wider range of automation design. At the same time signal processing improved significantly, enabling PLCs to function in the harsh factory environments where they are subject to electromagnetic interference. The requirements of the industrial environment are much more stringent than a typical personal computer system. PLC installations are expected to last up to 20 years. Their electronic design must also cater for isolation from plant disturbances. Industrial users were looking for robust and reliable automation systems and PLCs met those requirements.

Industry 4.0 was never considered at the time PLCs were initially developed. However, in retrospect, they occupy a critical position in control systems architecture to enable Industry 4.0. As the brains of manufacturing and industrial plants, they are the collection point for all plant data. They are also the implementer of instructions. They drive setpoints, operate motors and valves and change product models or types based on external inputs. Industry 4.0 enables these instructions to come from cloud-based applications based on data analysis, potentially without any human intervention.



Figure 2: The smart factory is heavily reliant on programmable logic controllers, which control the movement of assembly lines and robots.

Enabling Industry 4.0

Industry 4.0 offers significant benefits to manufacturers by enabling them to optimize their production systems. Access to data across enterprise and logistics systems makes it possible to adjust production plans in real time based on customer needs or bottlenecks. Plant information can also

be used to assess equipment problems and plan repairs before failures occur. It is access to information and powerful applications that take automation to another level; this is the foundation and the promise of Industry 4.0.

The benefits of Industry 4.0

Industry 4.0 requires the collection of much more data than industrial control systems used to collect previously. A single machine could literally have hundreds of sensors, continuously capturing information on its health and performance. Smart devices connect to PLCs using network architecture, each device sending potentially large volumes of data. Equipment data can be analyzed in the cloud to identify problems before they arise, for example a pump bearing running hot could automatically initiate a maintenance request. Industry 4.0 therefore advances the maintenance activity so that repairs are executed before the bearing fails completely. Human intervention in terms of monitoring pump performance and investigating poten-

tial problems are completely bypassed as long as sensors produce accurate information and software models diagnose problems correctly.

The output side of PLCs is also affected by Industry 4.0. Cloud-based applications develop new production plans based on customer needs and other external factors. Changing the plan on a production line consisting of multiple robots requires detailed instructions and updates to each unit on the line, which must happen in real time to facilitate uninterrupted production. PLCs have the power to control the whole production line as a single unit due to their processing and I/O capacity.

The challenges of Industry 4.0

The benefits of Industry 4.0, in the form of optimization and equipment analysis, can only be achieved using the data collection and automation facilities offered by PLCs. Nevertheless, Industry 4.0 also creates some challenges for the manufacturing and industrial environment.

Safety is one area of universal concern. Industrial and manufacturing sites are highly regulated with an onus placed on the employer to keep workers safe and prevent incidents that could affect neighbouring communities. The introduction of internet-based technology that integrates with the physical plant raises cyber security concerns. It would be catastrophic for external parties to gain control of live operating plants with the aim of sabotaging the facility. Prior to Industry 4.0 the entire industrial automation system ran on a proprietary architecture that was isolated from the internet. With the benefits of Industry 4.0 come risks that

weren't there before, which must be adequately managed in order for Industry 4.0 to gain a wider acceptance.

Robustness is also a perceived challenge in terms of implementing Industry 4.0. The ability of PLCs to handle the harsh environment of industrial settings has been critical to their acceptance and success to date. They have built-in barriers that limit the impact of electromagnetic disturbances to the integrity of sensor data and output accuracy. However, the increase in data throughput and the use of ethernet based networks for smart devices can cause industrial users to question the robustness of Industry 4.0 systems.

Industrial and manufacturing companies are caught in the tension between the clear benefits of Industry 4.0 and their concerns about cyber security and robustness.

The evolution of the PLC for industrial robots

The international market for industrial robots is growing at a rate of more than 14 percent per year. This growth is driven by a reduction in the costs of manufacturing robots as the technology becomes more widely used, as well as a higher level of control over robot functionality that has opened up new applications. Robot movement can now be controlled in up to 22 axes using individual motors. Multiple sensors capture the status of the robot including position, speed and even external influences. Cobots, or cooperative robots, which work together with humans in

the same workspace are equipped with arrays of safety sensors that pick up human movement in their danger zone. Sophisticated algorithms determine the safety risk based on position and movement. Motion control systems slow the robot and even stop it before a safety incident occurs. All these features require very fine control of robot movement, as well as high quality sensor information in real time. An industrial robot may have magnetic, pressure, radar and current sensors as well as torque, position and various safety sensors.

The openness and robustness of PLCs

Development in PLC technology has helped facilitate advances in robotic control. Their robustness is particularly important in industrial settings using robots. Motors and electrical switching devices create large electromagnetic disturbances that can influence sensor signals. PLCs must take measures such as built-in barriers to prevent the sensitive control side from being impacted by disturbances from the I/O environment.

While early robotic systems were very vendor dependent and proprietary, current trends are towards more open systems and architectures. Converting a control algorithm from one proprietary vendor system to another was time consuming and expensive; interoperability problems that were resolved with open PLC systems. They make it possible to copy one robotic control system to another even when different vendors are involved, speeding up commissioning of new facilities.

PLCs for motion control

Industrial robots line the floors of production lines in factories around the world. Their motion controllers instruct the motors that control their speed and position to pinpoint accuracy. This can only be achieved using high levels of signal processing, with barriers to protect against electromagnetic disturbances. PLCs can deliver this level of input and output processing directly without relying on another

layer of motion control. The advantages of using PLCs for motion control includes the ability to manage the entire production line using one master control algorithm. This is important for Industry 4.0 using cloud-based applications, which may require changes to the entire production line based on customer or logistics information.

How PLCs enable Industry 4.0 for industrial robots

As an example, a logistics bottleneck at a distribution warehouse may require switching the production line to a different model. This change could make the difference between continuing to run at full capacity and a complete production line shutdown. Cloud-based applications monitoring enterprise systems and factory information can identify problems and implement solutions using PLCs.

Another key advantage of using PLCs for robotic control in Industry 4.0 applications is the collection of comparative information for analysis. Similar robots in similar service can be compared for performance and maintenance criteria. Thus, lessons learned from a robot failure in Germany can be applied to a robot in service in China. As the database of information grows from multiple sources all over the world, cloud-based applications get better at predicting failure. Industry 4.0 systems can initiate planned repairs resulting in a reduction of unplanned outages.

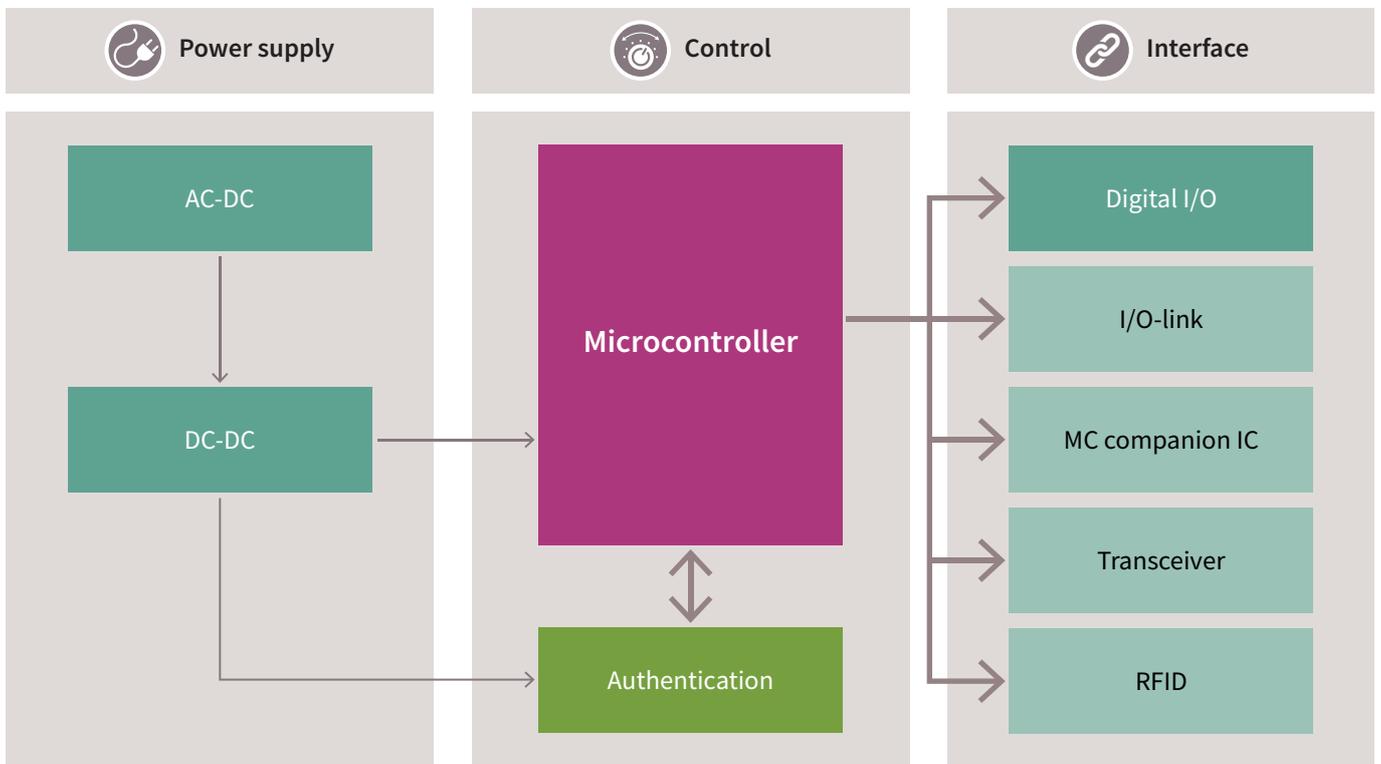


The changing face of PLCs

As industry embraces Industry 4.0 it is becoming clear that the number of potential applications for PLCs is also increasing. This is giving rise to new solutions that conform more closely to the end-application's requirements, but must still demonstrate the same levels of robustness, security and interoperability that have been established over decades of use. The technologies to enable this new breed of PLC are coming from reliable semiconductor manufacturers like Infineon, who understand the demands and requirements involved.

Developing a PLC relies on access to components designed to meet the task. As PLC formats become more flexible it will be necessary to secure access to components that can fit those formats. Figure 3 shows a block diagram of a typical Micro PLC; a solution that is pared down to only the most essential components. At the heart of any PLC of any size is the microcontroller and, here, Infineon offers class-leading solutions. The XMC family of industrial microcontrollers is based on the ARM® Cortex®-M4 core with floating-point unit and built-in DSP instruction set. This positions the family squarely in the application space now being addressed by connected PLCs in the Industry 4.0.

Figure 3: A conceptual system-level diagram of a Micro PLC



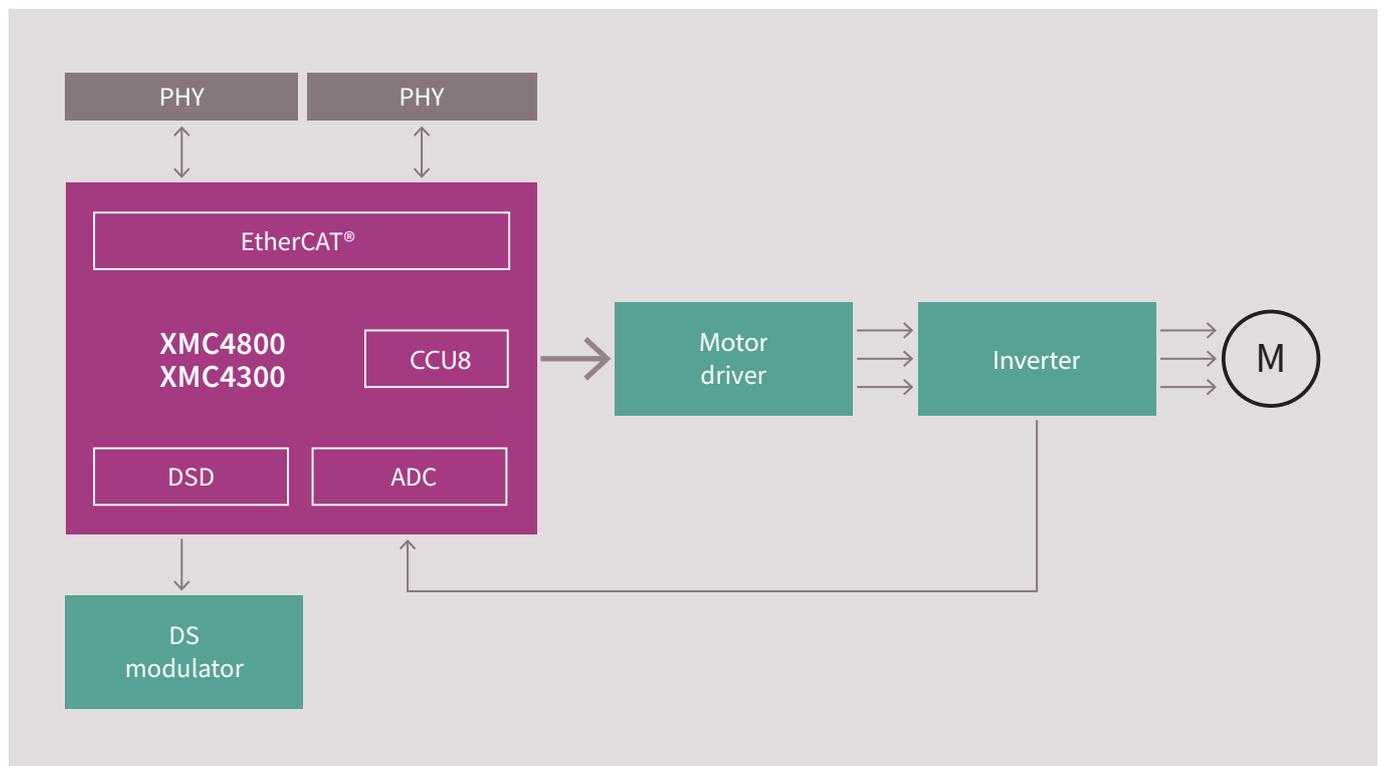
Any microcontroller targeting industrial applications must include real-time performance with enhanced connectivity that can support multiple communication protocols, as well as a range of peripherals optimized for driving industrial loads, Hall sensors, encoders and resolvers. High levels of integration minimize the need for external components, ensuring a more reliable solution. An extended operating temperature range is also essential.

The main features of the XMC4000 family include the core itself, which can run at up to 144 MHz, with as much as 2 MB of fast (access time of just 22 ns) on-chip flash memory and 352 kB of RAM. In addition there are a wide range of peripherals that are standard across the family, including 8 or 12 channel DMA, multi-function serial ports (up to 6), multiple 12 Msamples/s ADCs, up to 6 CAN bus interfaces, bus interfaces to support external memory or an LCD, as

well as touch and LED matrix support. Two members of the family, the XMC43000 ad XMC4800, also integrate dedicated EtherCAT® nodes and are guaranteed to be available until at least 2031.

EtherCAT® is the ‘engineers’ choice’ for connectivity in real-time systems, as it offers nanosecond accuracy, while minimising the load on the host processor. The network topology removes the need for hubs and switches, which removes the restrictions that other industrial Ethernet solutions may have, while actually easing the network’s administration. For these reasons, EtherCAT® is now being used in a wide range of industrial applications, including robotics, automated assembly, welding machines and various control systems, as well as power plants and substations. figure 4 shows a typical application for the XMC4300/ XMC4800 as a servo driver and port expander.

Figure 4: The XMC4300/XMC4800 in a typical application



The changing face of PLCs

As the first industrial microcontrollers based on the ARM® Cortex®-M4 core to feature fully integrated EtherCAT®, the XMC4300 and XMC4800 are already being used in a large number of industrial applications. To help developers, Infineon has also produced the XMC4300 Relax EtherCAT® Kit (figure 5), which includes ESD and

reverse-current protection, and is compatible with the Arduino platform. The board includes an on-board debugger and is powered through a USB connection and also features a standard EtherCAT® plug and optional PHY to PHY connection. A block diagram of the XMC4300 is shown in figure 6.

Figure 5: The XMC4300 Relax EtherCAT® Kit

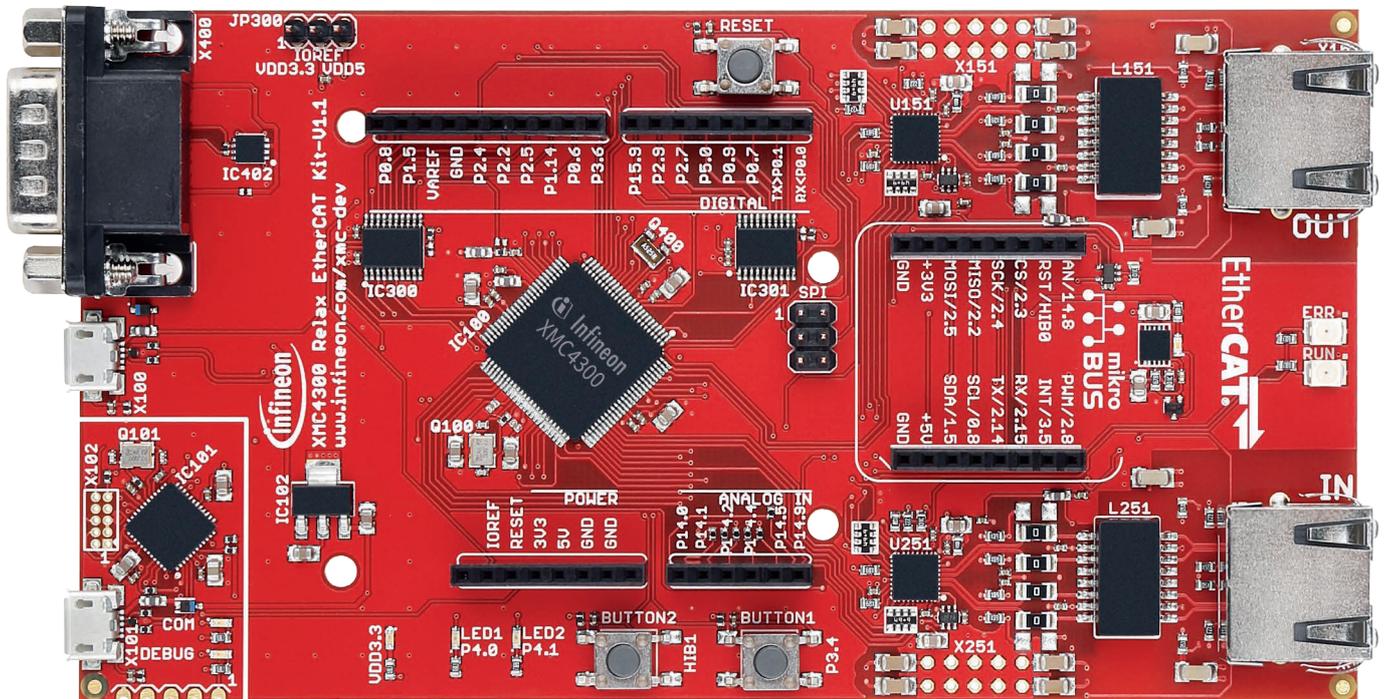
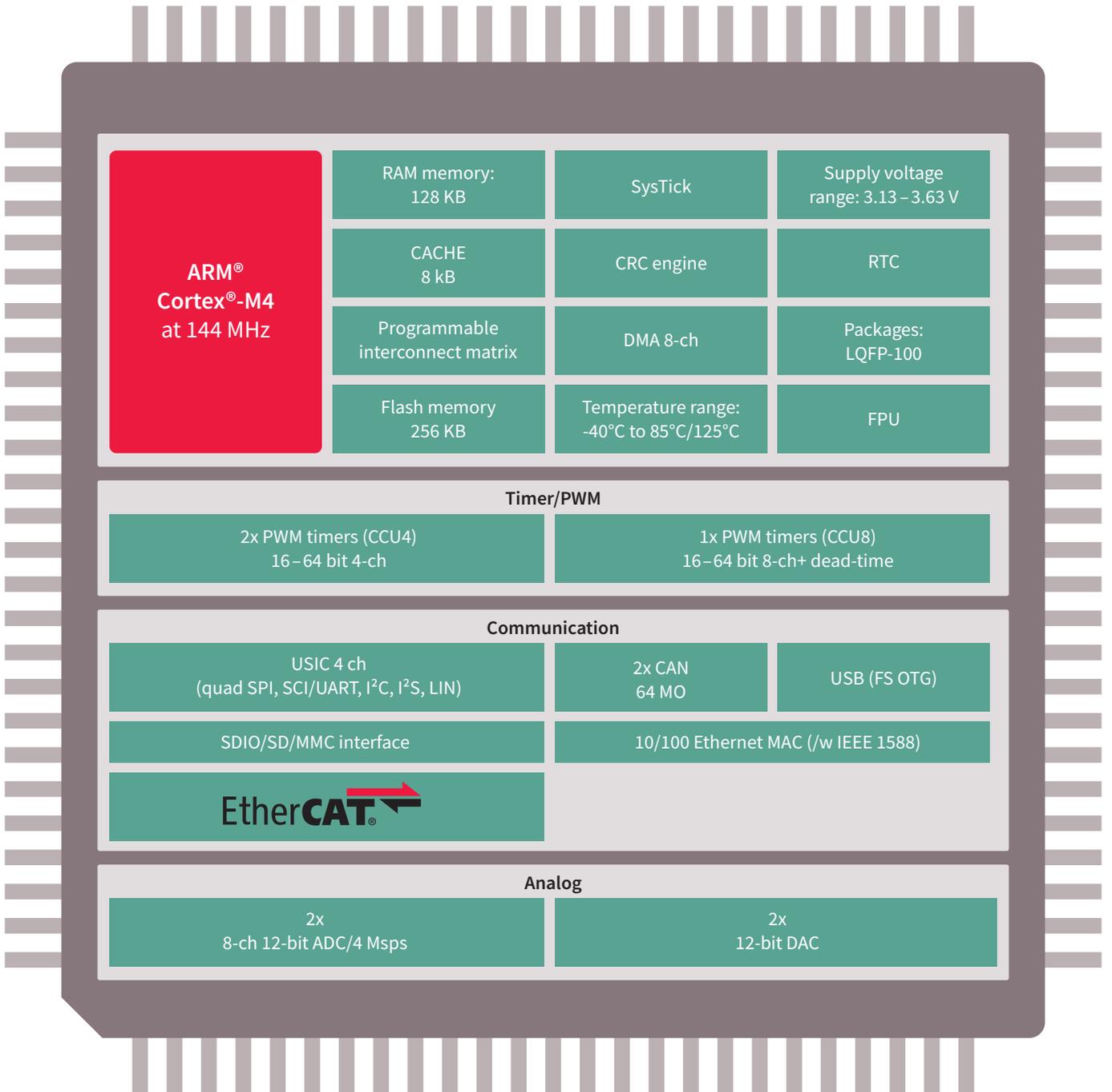


Figure 6: Block diagram of the XMC4300



Protected switching

In addition to the microcontroller being the processing powerhouse of any PLC, it needs a safe, reliable and efficient way of actually controlling the large voltages and currents used in industrial control. Infineon's solution to this is the PROFET™ series, or PROTECTED FET. As background, an FET is a Field Effect Transistor, an electronically controlled switch. The PROFET™ series adds a number of features designed specifically for demanding applica-

tions that raises the simple FET to something much more (figure 7). As figure 8 shows, the PROFET™ series developed for the industrial market are high-side switches with integrated protection and optional diagnostic features. The range covers load currents from less than 0.5 A up to 7 A, with 1-, 2-, 4- and 8-channel variants. An example is shown in figure 9, a 2-channel PROFET™ that is available in a TSON-10 package measuring just 3.3 mm by 3.3 mm.

Figure 7: The PROFET™ series raises FETs to a new level

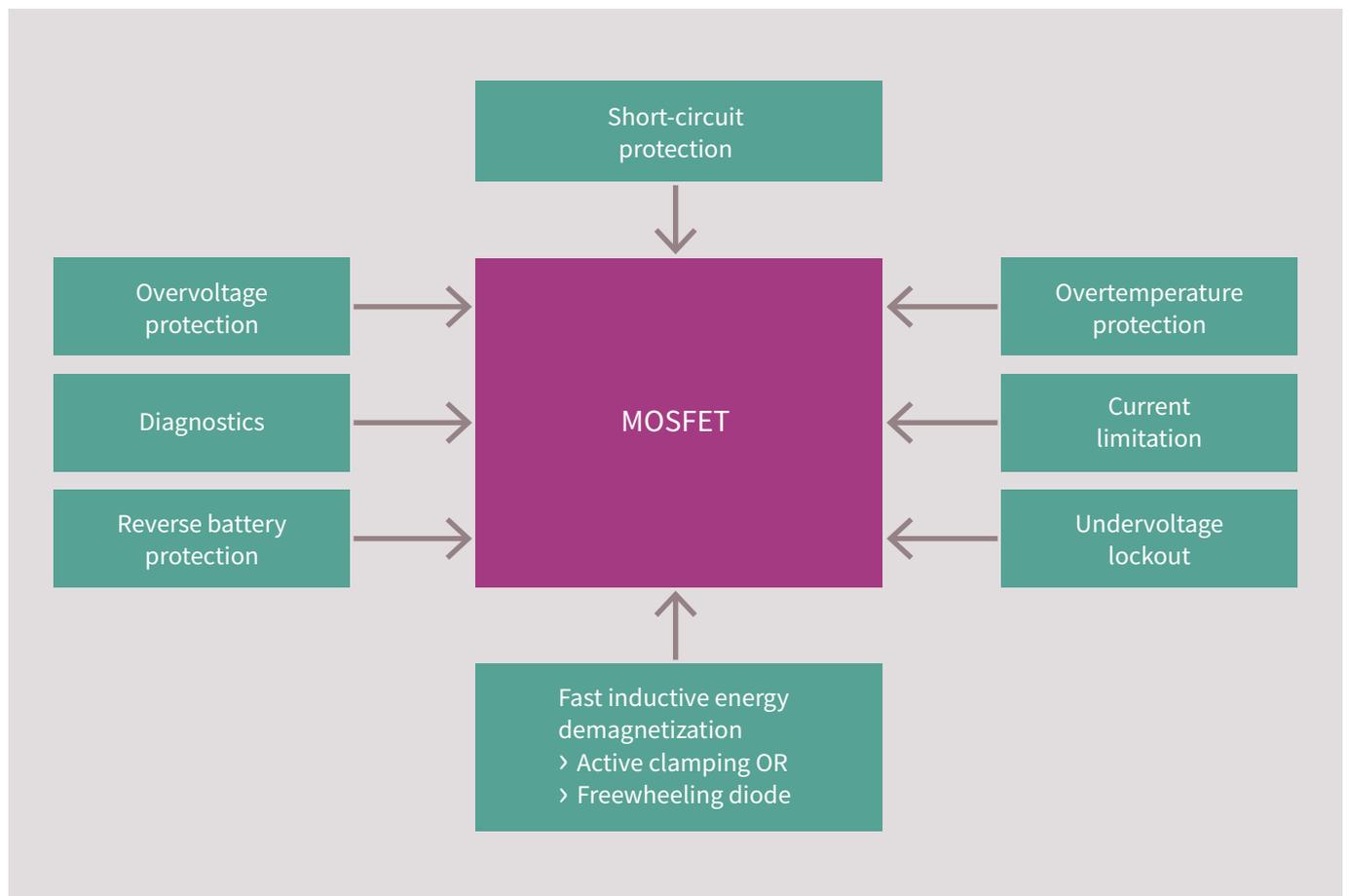
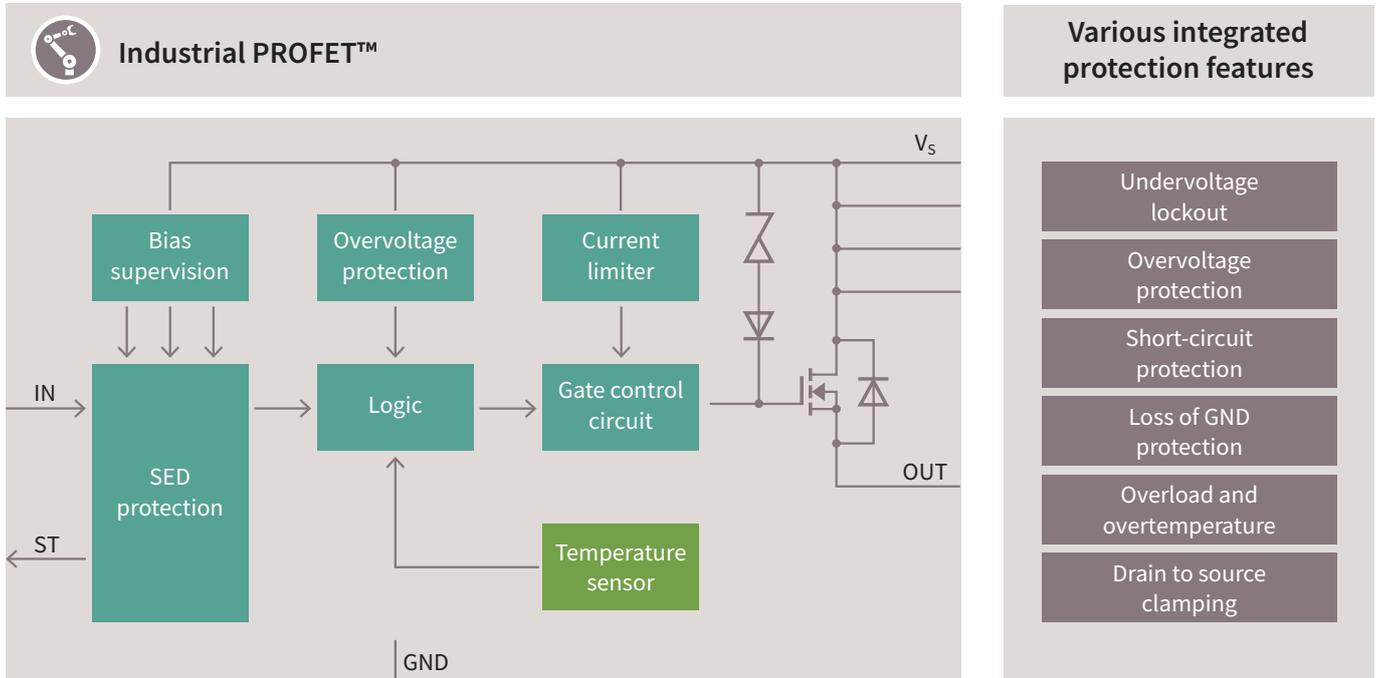


Figure 8: PROFET™ devices integrate high-side power switching with advanced logic



These intelligent power switches combine DMOS and CMOS technology to integrate both power and logic, respectively, and they are applicable for any kind of rugged load, be they resistive, capacitive or inductive. This includes bulbs, motors, heaters and relays (figure 9). The integration allows

a number of ‘smart’ features to be built-into the devices, along with protection. This includes the ability to detect their status in terms of temperature, as well as the size of the load being switched, and the current drawn by the load. These features help eliminate the need for additional circuitry, which lowers the overall cost and increases the reliability of the end-application.

Figure 9: The Infineon industrial PROFET™ can be used to control a range of loads

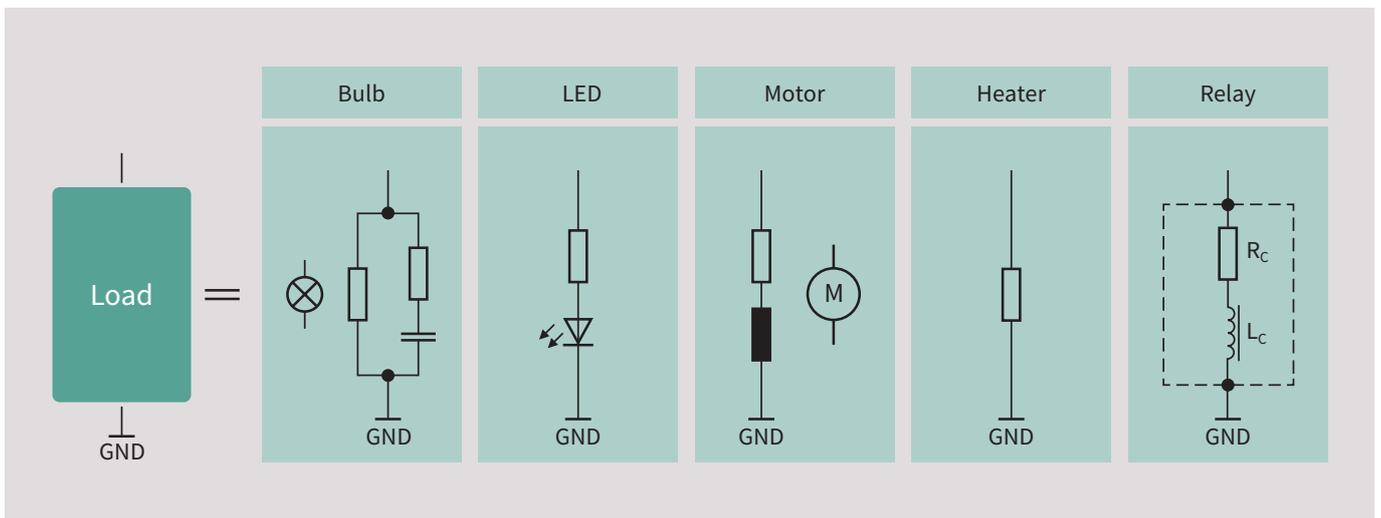


Figure 10: An example of factory automation using PROFET™ devices

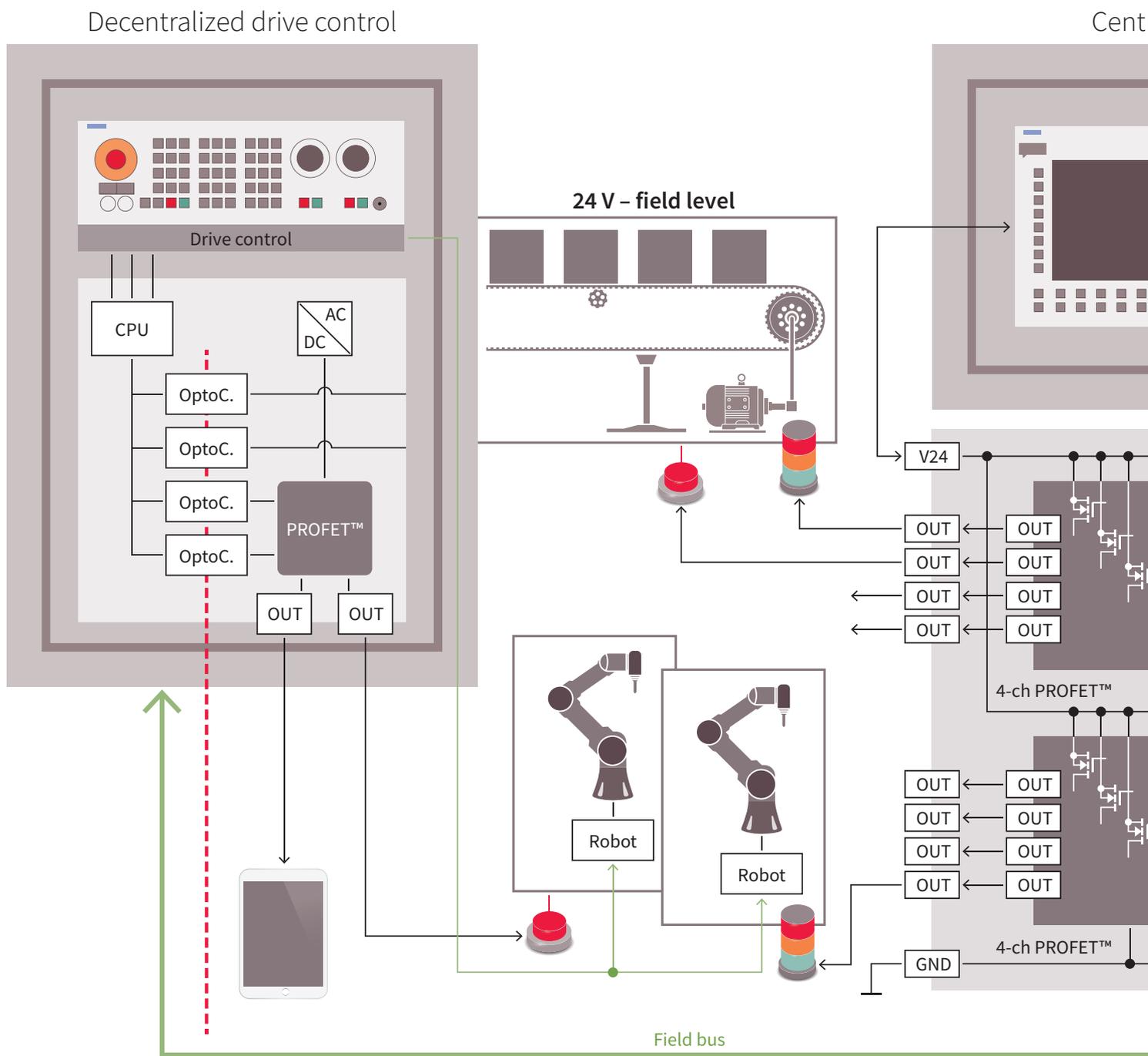


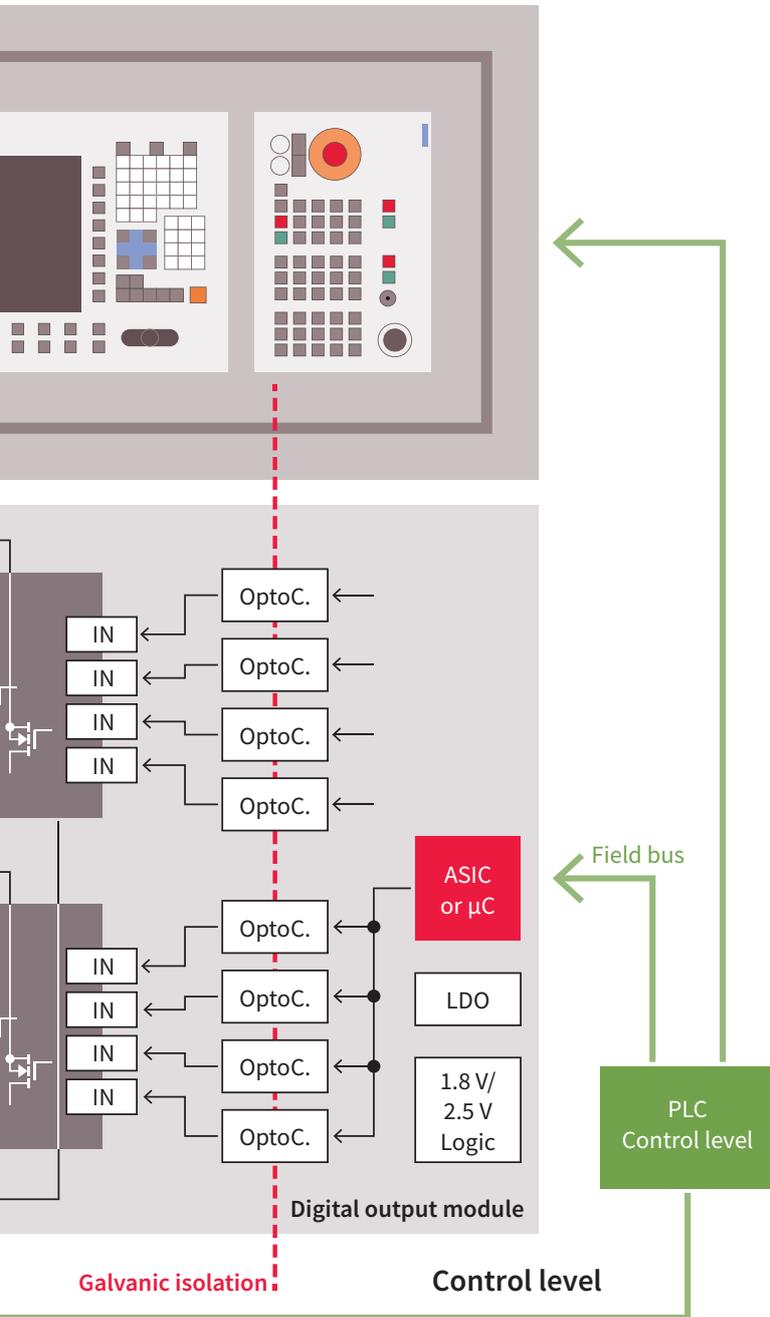
Figure 10 demonstrates how PROFET™ devices would be used in a factory automation application.

Conclusion

PLCs continue to define the smart factory and improve the efficiency, safety and reliability of industrial automation. Without higher levels of automation the advancements society has come to expect and rely on will slow down and, eventually, stall.

Industry 4.0 is heavily dependent on the evolution of PLCs, as they need to be more connected, more competent and increasingly more secure. The move to software-defined functionality and control was the first step towards achieving that, but many industries are now dependent on that evolution continuing and, if possible, accelerating. With robust and secure solutions to meet this demand, Infineon is well placed to provide the technologies needed to realize the promise of Industry 4.0.

Centralized control cabinet



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