We get technical

DigiKey




contents

Editor's note

Programmable Logic Controllers (PLCs) have become indispensable in the world of industrial automation and control systems. Their robustness and versatility allow for complex operations to be managed with precision and reliability, catering extensively to the needs of engineers who require efficient and flexible control solutions.

PLCs are essentially industrial digital computers that have been ruggedized to operate within harsh manufacturing environments. They are used to automate various processes by receiving inputs from devices such as sensors and switches, processing the data, and then outputting commands to machinery and other systems. This allows for precise control over manufacturing processes, leading to improved productivity and safety.

One of the key strengths of PLCs is their programmability. Originally designed to replace hard-wired relay systems, PLCs can be reprogrammed without changing any physical wiring. Engineers use various programming languages, such as Ladder Logic, Functional Block Diagrams, and Structured Text, which are defined by the international standard IEC 61131-3. This versatility enables PLCs to be adapted quickly to different operations and makes them a valuable asset in industries that require frequent changes in manufacturing processes.

As technology evolves, the integration of PLCs with the Internet, Cloud computing, and other modern industrial technologies such as the Internet of Things (IoT) enhances their capabilities. This integration allows for real-time data acquisition, analysis, and remote process management, further extending the functionality and application scope of PLCs in modern industrial environments.

For engineers, understanding the capabilities and programming of PLCs is fundamental. Their ability to streamline complex processes and adapt to various industrial needs makes them a pivotal part of modern automation and control systems.

For more information,
please check out our website at
www.digikey.com/automation.

Address industrial automation challenges with a new generation of PLC hardware

Written by:
Steven Keeping,
Contributing Author, DigiKey

Automation founded on the Industrial Internet of Things (IIoT) promises faster time-to-market, improved productivity, greater safety, lower costs, and higher quality. That said, there are still obstacles. Legacy systems that are difficult to upgrade, overly conservative engineering departments, closed systems, and a lack of specialist knowledge are some of the problems that are holding back the Industry 4.0 revolution.

While suitable standards-based technologies provide the backbone of the connected factory, many legacy, or 'workhorse', programmable logic controller (PLC) hardware and software have limited capabilities. This makes it challenging for engineers to quickly implement the factory-wide upgrades that are needed to take full advantage of the IIoT. Further complicating matters, engineers risk basing expensive factory upgrades on technology that could become outdated or unsupported as new technologies are introduced.

Lessons can be learned from other parts of the IoT, such as the smart home, where open systems, collaborative platforms, and accessible software make it easier to implement future-proof intelligent solutions. Industrial automation manufacturers are embracing this experience and knowledge.

This article briefly discusses the challenge of deploying IIoT technology and explains how advances in open systems and factory automation hardware offer solutions. The article introduces an example implementation of next-generation PLC hardware and software from Phoenix Contact and shows how it simplifies gathering data and sending it to the Cloud for analysis and automated decision making.

The importance of the PLC

The mainstay of the factory is the PLC, a digital device invented in the late 1960s to replace earlier relay logic systems. PLCs are designed to work in difficult environments without fail for many years. The key to this reliability is a focus on

Figure 1: Rugged and reliable, PLCs are the backbone of factory automation.
Image source: Phoenix Contact

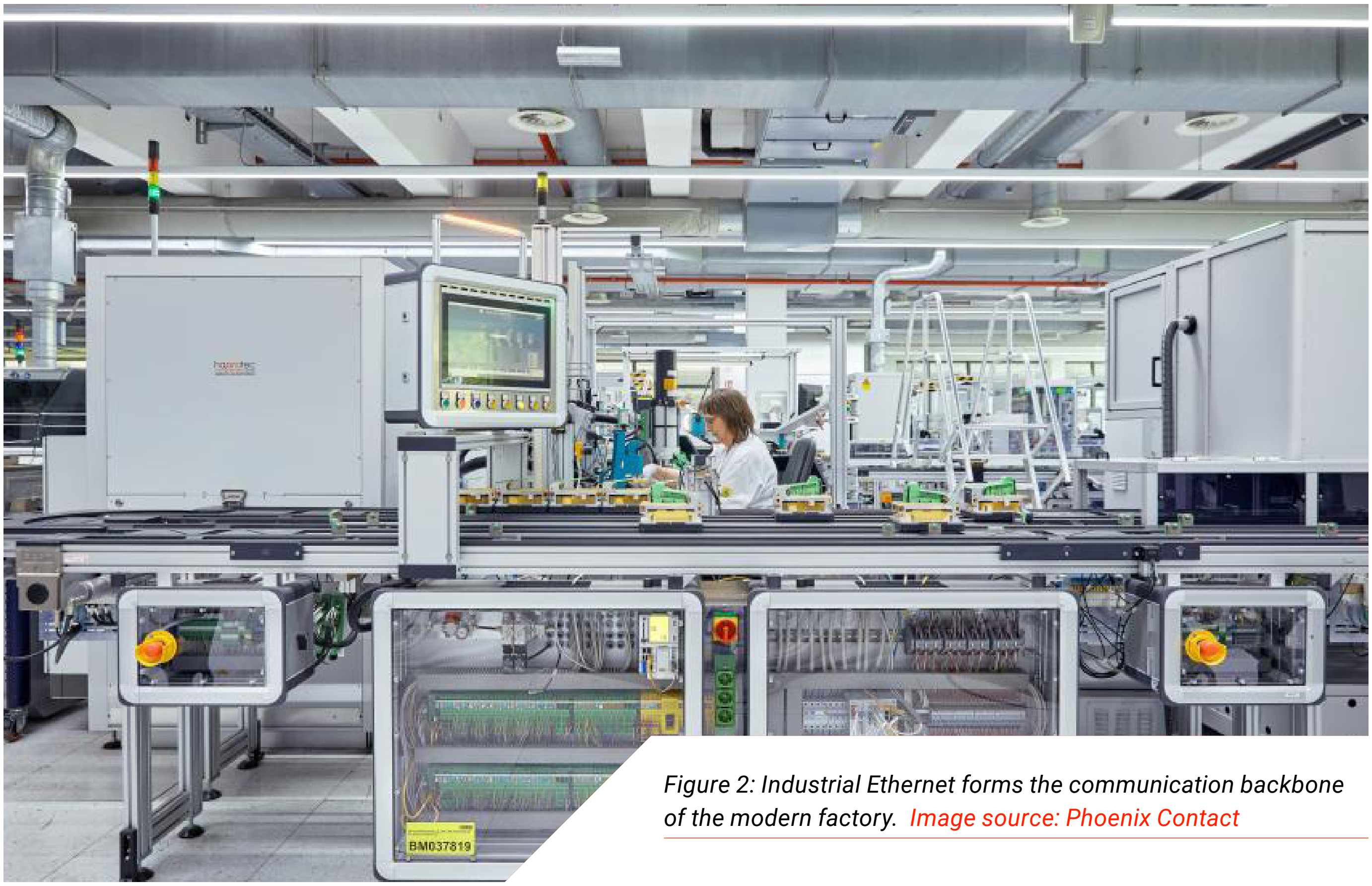


Figure 2: Industrial Ethernet forms the communication backbone of the modern factory. Image source: Phoenix Contact

simplicity. In the rare event that something does fail, PLCs are designed to troubleshoot and fix issues so that volume production can resume quickly.

The units comprise an input module (receiving data from digital and analog input devices such as keyboards, switches, relays, and sensors), a power supply, a programmable CPU with associated memory, and an output module to send information to connected devices (Figure 1).

Conventional PLCs are programmed using one of five languages defined by IEC 61131-3. These include Instruction List (IL), Symbolic Flowchart (SFC), Ladder Diagram (LD), Function Block Diagram (FBD), and Structured Text (ST). The most popular is LD, or ladder logic, which uses symbols to represent functions like relays, shift registers, counters, timers, and math operations. The symbols are arranged according to the desired sequence of events.

PLC makers are rapidly adapting to the progress in factory automation that has been made through the implementation of Industrial Ethernet. Industrial Ethernet is IP interoperable, is the most widely used wired networking option, and has extensive vendor support. Industrial Ethernet is characterized by rugged hardware and industrial standard software, and it is a proven and mature technology for factory automation (Figure 2). The hardware is complemented by Industrial Ethernet protocols, including Ethernet/IP, Modbus TCP, and PROFINET. Each is designed to ensure a high level of determinism for industrial automation applications. (See 'Design for Rugged IoT Applications Using Industrial Ethernet-Based Power and Data Networks'.)

Many of today's PLCs offer built-in Ethernet connectivity. For legacy devices featuring non-Ethernet interfaces, the divide between the Ethernet infrastructure and the

PLC is bridged by gateways. (See, '[How to Connect Legacy Factory Automation Systems to Industry 4.0 without Disruption]'.)

The next generation of PLCs

A factory that uses a mix of modern and legacy systems can make it difficult for engineers to leverage the full benefits promised by Industry 4.0. However, lessons from other parts of the IoT, such as the smart home and logistics sectors, reveal that open systems, collaborative platforms, and accessible standards-based software make it easier to implement future-proof intelligent solutions.

The knowledge gained from these other sectors encourages manufacturers of PLCs and associated systems to introduce a new generation of products that operate like traditional PLCs without being constrained by the limitations of legacy hardware and software. An example of this new generation is Phoenix Contact's PLCnext Control technology.

From a software perspective, a product such as the Phoenix Contact 1069208 PLCnext controller represents a significant move toward the open solutions that are starting to dominate other areas of the IoT. For example, PLCnext is compatible with a wide range of software, so innovative factory automation apps can be easily downloaded from the Internet and installed on the PLC, like apps on a smartphone.

PLCnext uses the Linux operating system (OS). It can still be programmed using the languages defined under IEC 61131-3, but Linux makes it easy for engineers to program the PLC using the higher-level languages C++, C#, Java, Python, and Simulink. These simple-to-use languages make modern factory automation accessible to a much wider cohort of engineers. In addition, PLCnext features task handling that enables program routines from different sources to run as legacy PLC code, with high-level language programs automatically becoming deterministic (Figure 3).

Figure 4: PLCnext PLCs use the Linux operating system and support legacy languages defined under IEC 61131-3, plus higher-level languages.
Image source: Phoenix Contact

Connectivity is through Industrial Ethernet hardware; the control system runs under the IP-interoperable PROFINET protocol and uses the PROFICLOUD IoT platform for Cloud computing support. The PLC also supports other open-standard protocols such as http, https, FTP, SNTP, SNMP, SMTP, SQL, MySQL, and DCP.

The hardware is based on an Intel Atom microprocessor running

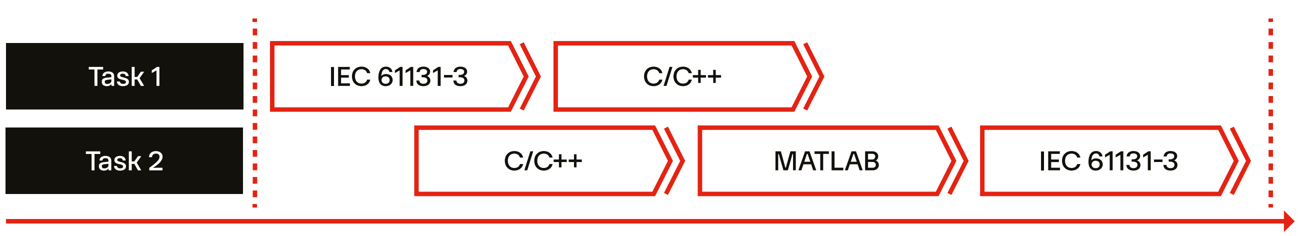


Figure 3: PLCnext features task handling that enables program routines from different sources to run as legacy PLC code. Image source: Phoenix Contact

The IIoT promises to transform the factory. However, while engineers are installing Industrial Ethernet, the full potential of factory automation is being held back by traditional PLCs that offer limited connectivity and dated software.

at 1.3 gigahertz (GHz). The PLC features 1 gigabyte (Gbyte) of flash memory and 2,048 megabytes (Mbytes) of RAM. The IEC 61131 runtime system has 12 Mbytes of program memory and 32 Mbytes of program data storage. The unit can support up to 63 local bus devices and requires a 24 volt supply with a maximum current draw of 504 milliamps (mA) (Figure 4).

Phoenix Contact's PLCnext range includes PLCs and other critical elements of an industrial automation system, such as communications modules and managed switches. Specific examples are the 2403115 communications module and the 2702981 managed network address translation (NAT) switch. The communications module adds an extra gigabit-capable Industrial Ethernet interface to the PLC. The module has an independent MAC address, offers PROFINET support, and includes electrical isolation between the Ethernet interface and the logic.

The managed switch is used for storing and forwarding Ethernet-transported information and features four Ethernet RJ45 ports, two small form-factor pluggable (SFP) ports, and two combination ports (RJ45/SFP). The switch is a PROFINET Conformance Class B product.

Improving decision making in the factory

Optimization of factory production is essential because manufacturing demands precision and repeatability. The key to ensuring high levels of precision and repeatability is process control. In the modern factory, IIoT sensors and cameras can monitor machines and measure finished components to pick up any minor deviations in the product and correct the process accordingly. Other sensors keep track of the health of machines to predict maintenance requirements before a worn machine starts to fail. Even more sensors keep track of the factory's temperature, humidity, and air quality.

A key feature of PLCnext Control is that, unlike traditional PLCs, it can tap into this factory data. According to Phoenix Contact, it is sufficient to connect the PLC to just 3 to 5% of the system's analog and digital inputs and outputs (I/Os) for it to be able to map the manufacturing

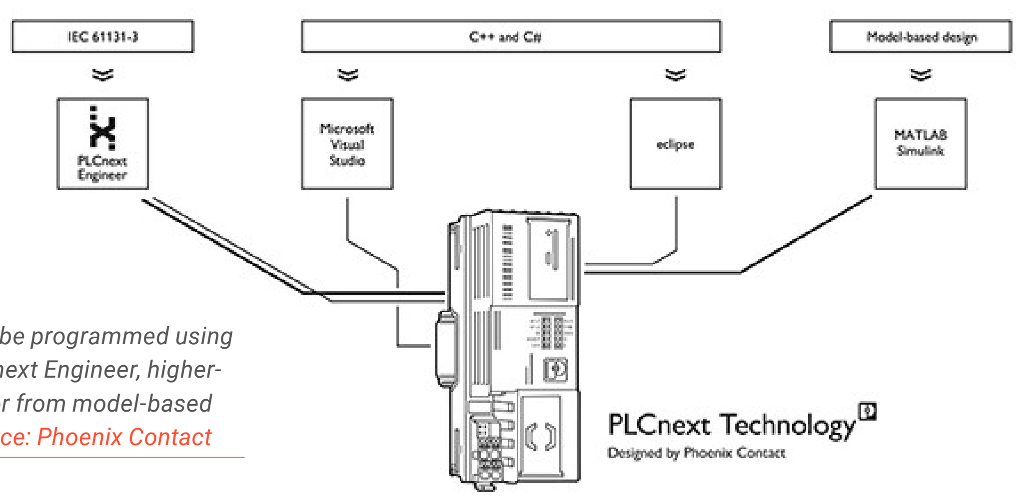


Figure 5: PLCnext PLCs can be programmed using legacy languages from PLCnext Engineer, higher-level languages from IDEs, or from model-based design systems. Image source: Phoenix Contact

processes comprehensively and without significant intervention.

PLCnext Control can then connect to any Cloud service, including Phoenix Contact’s Proficloud.io, Amazon’s AWS, or Microsoft’s Azure. As a result, the factory system gains access to powerful computing resources to ensure that the operations management and maintenance processes run as efficiently as possible. The result is higher productivity, better product quality, and lower costs.

Getting started with PLCnext

Working with PLCnext controllers and related units is relatively straightforward. To assist in starting a PLC programming project, Phoenix Contact has introduced the 1188165 PLCnext Technology Starter Kit. The kit comprises a 2404267 PLCnext control module (PLC), a module carrier, and a choice of analog or digital modules.

To use the starter kit, the PLC and analog/digital module units must first be connected to the 24 volt DC (VDC) supply. Next, an Ethernet cable is connected between the PLC and PC and the PC’s IP address is set. Then, the IP address of the PLC is typed into a browser window on the PC. The PLC becomes operational after users log in with their username and password. Further instructions are supplied from the web-based management system. Programming of the PLC is done using the PLCnext Engineer software. The software allows an engineer to configure, diagnose, and visualize an entire automation solution.

PLCnext Engineer enables programming and configuration using the legacy languages defined under IEC 61131-3. It is also simple to program in higher-level languages such as C++ and C#. In addition to PLCnext Engineer, code can be built in other popular Integrated Development Environments (IDEs) such as Eclipse or Microsoft Visual Studio. The software can then be imported into PLCnext Engineer as a library for use with any compatible PLC (Figure 5).

A key advantage of PLCnext technology is that it allows several developers to work independently and in parallel on a single PLC program, even if they are using different programming languages. This enables fast development of complex applications and allows developers with legacy language skills and those with higher-level language skills to combine their talents.

Conclusion

The IIoT promises to transform the factory. However, while engineers are installing Industrial Ethernet, the full potential of factory automation is being held back by traditional PLCs that offer limited connectivity and dated software. PLCnext technology from Phoenix Contact is based on open systems, collaborative platforms, and accessible software. It can combine routines coded in legacy languages with those written in higher-level languages to open industrial automation to future-proof solutions with enhanced productivity, higher yields, better product quality, and lower costs.

Programming PLCs: A technical summary with Siemens examples

Written by:
Lisa Eitel, Contributing Author, DigiKey

Programmable logic controllers (PLCs) are ruggedized microprocessor-based electronics essential to all modern automation, including:

- The process-heavy industries of oil and gas, nuclear, steelmaking, and wastewater treatment
- Industries with an emphasis on control of discrete tasks — including general factory automation, automated warehousing, packaging, food and beverage, and medical-device manufacture

In these installations, PLCs are traditionally found on DIN-rail mounted or control-cabinet rack systems with slots to accept PLC modules (having CPUs to run logic and dispatch commands) and complementary power supply modules, application-specific function modules, and digital as well as analog I/O modules.

Of course, PLCs aren't the only option for automation control. Relay-based systems maintain their indispensability in a vast array of applications, and programmable automation controllers (PACs) or industrial PCs (IPCs), as well as panel PCs (HMIs with control electronics), are other alternatives for many machine designs and systems needing varying degrees of distributed control. PACs and IPCs running industrial-grade Microsoft Windows OSs especially offer top design flexibility.

Each of these control systems is configured and programmed with software of diverse sophistication to render all types of control design more advanced and user-friendly than ever. This in turn allows OEM machine builders and plant engineers to quickly institute system builds, upgrades, and migrations with maximal efficiency, productivity, and IIoT connectivity.

The tools to program controls — including PLCs

Nearly all PLCs today are configured and programmed through PC-based software. Large vendors with broad programmable motion control, sensing, actuation, and machine-interface component offerings (in addition to general automation and PLC products) typically allow programming of all these components in their own proprietary unified programming environments — PC-based Windows-compatible software with design, configuration, programming, and even operating and management modules. That's especially true where vendor lineups include pre-integrated offerings — such as smart motors or HMIs having PLC functionality, for example.

While potentially daunting to learn, unified programming environments (once mastered) dramatically speed machine design.

One benefit of such software environments is how they provide error-free, editable, and universally applicable databases of symbol, variable, or tag names. These are human-readable alphanumeric names assigned to the addresses of components (including PLCs) and improving upon the direct use of complicated register addresses — which was once standard practice. Complementing these sortable and searchable device tags are informative machine and workcell tags as well as those for common machine functions such as Auto, Manual, MotorOn, Fault, or Reset.

Consider Siemens STEP 7 Totally Integrated Automation (TIA Portal) software, which includes various use-specific packages and is accessible through the Siemens SIMATIC (Siemens Automatic) software-management environment. STEP 7 software is convenient for illustrating the most common approaches to PLC programming, as it's the most widely used software in the world for industrial automation — with copious verification of functionality and reliability. By most estimates, Siemens PLCs are employed in nearly one-third of all PLC installations worldwide.

With this software, engineers can create process control, discrete automation, energy management, HMI visualization, or simulation and digital-twin programming related to the functions of PLCs and other industrial controllers. For PLCs, Siemens' STEP 7 (TIA Portal) engineering software evolved from legacy SIMATIC STEP 7 software to support the programming of S7-1200, S7-1500, and S7-1500 controllers — as well as ET 200SP I/O CPUs and legacy S7-300 CPUs (an enduring industry staple) along with S7-400 and SIMATIC WinAC controllers. Professional-grade and specially licensed copies of STEP 7 include additional functions, logic editors, and integration of traditional engineering software.

Though beyond the scope of this article, it's worth noting that industrial control alternatives to multi-function PLCs are configurable and programmable through complementary software. The vast ecosystem of Siemens controls provides copious examples.

1. LOGO! logic modules satisfy small and modest automation applications to bridge the gap between relays and microprocessor-based industrial controllers. They're programmed via Siemens LOGO! software with Soft Comfort engineering software, a LOGO! Access Tool, and a LOGO! Web Editor for simple configuration and design operation

2. Process control systems employ Siemens SIMATIC PCS 7 controller products programmable through SIMATIC PCS 7 system software

3. Rack (rail), panel, and box industrial PC (IPC) products

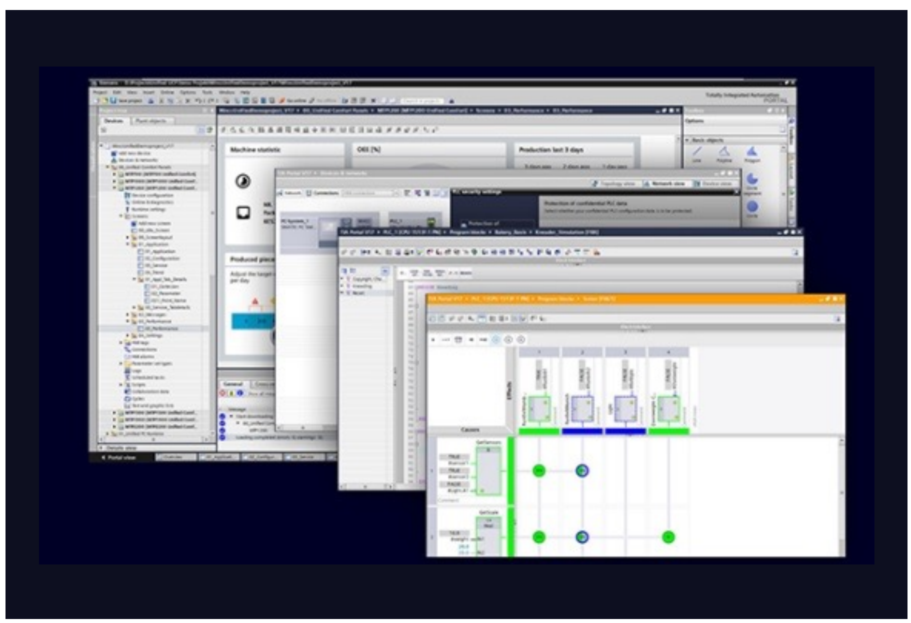


Figure 1: PLCs offer all the strengths of purpose-built hardware — including reliability. In contrast, PACs offer top flexibility. Some suppliers allow engineers to program both control types in the same unified software environment.
Image source: Siemens

for distributed controls and machines needing IIoT connectivity rely on Siemens SIMATIC IPC software modules, including an IPC Image and Partition Creator; IPC DiagMonitor; IPC Remote Manager; IPC FirmwareManager; and the SIMATIC Industrial OS

4. 4. HMIs serving as panel PCs for on-machine controls employ SIMATIC WinCC Unified (TIA Portal) software as well as SIMATIC WinCC (TIA Portal), WinCC flexible, WinCC V7, WinCC OA, ProAgent process diagnostics software, notification software for mobile devices, and more

Choosing between SIMATIC PLCs and other machine controls is simplified with still more software — in the form of an online Cloud-based Selection Tool (or the offline variation) that asks engineers about a given design's physical arrangement (whether necessitating a control cabinet or distributed control) and:

- The number of anticipated I/Os including sensors, switches, and actuators
- The programming language to be used, whether ladder diagram (LD), structured control language (SCL), or Function Block Diagram (FBD); more advanced structured text (ST), graph-based sequential function chart (SFC), and continuous function chart (CFC); or more advanced languages
- The level of motion control required (where applicable) — from simple speed and position control to electronic camming and advanced kinematic controls
- The hardware preference and whether a software PLC program running on an IPC might be most suitable

PLC program projects

- PLC programming written in PLC supplier software is often contained in projects. These are associated with focused application-specific operations such as:
- Heating, mixing, filling, metering, and irrigating
- Moving, steering, cycling, positioning, and braking
- Gripping, cutting, punching, and slicing
- Welding, gluing, marking, and dispensing
- Sensing, tracking, sequencing, and indicating

The most advanced options support digital planning and integrated engineering as well as transparent operation that's easily accessible through HMIs with user-specific screens one in operation. In other words, such PLC software can allow for the presentation of pertinent PLC information on different displays to serve the divergent informational needs of machine operators, technicians, plant managers, or even business managers.

Simulation tools within PLC supplier software environments also can speed time to market for a given product — and boost throughput of finished product. Completing the suite of software-based improvements are energy-management functions and diagnostics.

Verifying and loading PLCs with programs written in software

Core to optimal PLC functionality is the quality of its programming. All code should satisfy software-development industry standards and best practices. Beyond that, verification processes (both manual and automated) can reveal everything from critical errors to code inefficiencies. Reconsider the programming of SIMATIC S7 products. Within the Siemens ecosystem, a TIA Portal Project Check application can automatically compare certain code against rules defined by a programming style guide for these specific PLCs. Then engineers can export comparison results to an XML or Excel file. User-defined rule sets (even complex types) can also be added via a Project Check software development kit (or SDK) in C# or Visual Basic (.NET). This SDK primarily proofs a program's style.

After a project destined for a PLC is fully written and verified, it must

Figure 2: Siemens SIMATIC PLC and automation systems were first introduced in the 1950s. Today, SIMATIC S7 products (including the SIMATIC S7-1500 PLC components shown here) have evolved to support various industrial automation applications. Image source: Siemens

be loaded onto that PLC. In many cases, a PC (often a laptop) is temporarily connected to the PLC via an Ethernet cable or a specialty PC USB to PLC COMM adapter — to load that programming onto PLC microelectronics. The PLC then connects to controlled components via I/O modules. After additional verification upon startup, the PLC executes its programs by commanding networked actuators (via various signal types) and making real-time adjustments in response to returned feedback from field devices.

Occasionally, a machine or automated workcell will require adjustment, troubleshooting, or repair — and (through some type of programming PC connection to the PLC) the overriding of PLC default responses to feedback with forcing. This 'tricks' the PLC into operating as if certain feedback is at some value when it isn't — a tactic employed when the stations downstream of a malfunctioning actuator must be cleared, for example. Other times, a machine or workcell might require in-field adjustment of an installed PLC's parameters via modifying. Such adjustments must reference suitable triggers, variable values or tables, counters, and timers.

Conclusion

Working with the vast array of Siemens automation and industrial-controls offerings can provide design engineers with a deeper understanding of today's control options — including PLCs and other hardware types. That's true no matter the brand or hardware subtype ultimately chosen for an automated installation.

Programming Aspect	Goal	Quality	Realization • Tool
Style	Comprehensibility	Empirical	Code review • Style check
Technique	Conformity	Pragmatic	Static code analysis • Lint
Technique	Efficiency	Pragmatic	Dynamic code analysis • Profiling
Test cases	Functionality	Syntactic	Function test • Unit/ integration test
Mathematical model	Correctness • completeness	Semantic	Formal verification • Model check

Table 1: Verification of PLC programming can leverage manual and automated approaches — with the latter especially useful for verifying style and technique. Chart source: Siemens

Making use of IO-Link in industrial applications

Written by:
Etiido Uko, Mechanical Engineer & Technical Writer + Lisa Eitel, Contributing Editor, DigiKey

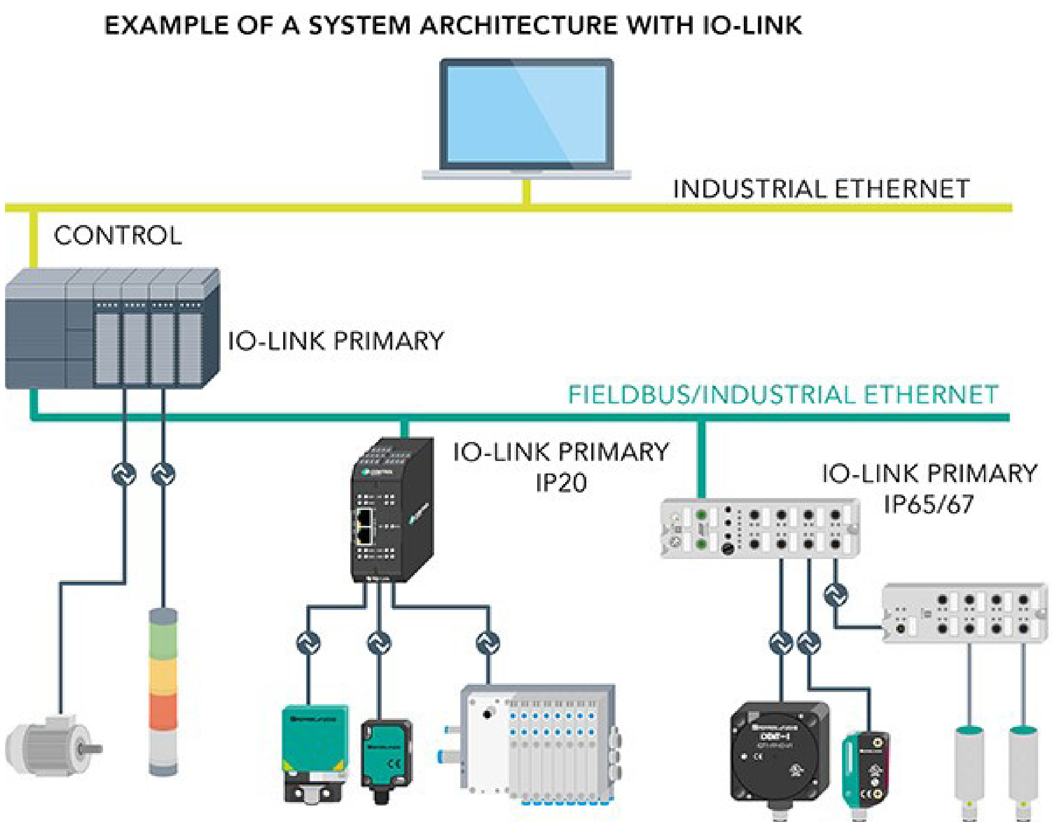
With the advent of the fourth industrial revolution and Industry 4.0, comprehensive and intelligent automation came to be defined by advanced controls, monitoring, and diagnostics. Such capabilities are only possible through industrial connectivity — through which controls and machine devices are unified on some platform (such as IO-Link) for continual data exchange.

The key enabling technologies underpinning industrial connectivity are standardized networks and devices with onboard communications features. Protocols abound for these functions. However, not all industrial protocols satisfy the data-exchange and intelligence requirements required by today's automation. IO-Link was created to satisfy a wide array of these modern applications.

As [covered in a previous digikey.com article](), IO-Link is a wired point-to-point communication protocol that facilitates smart bidirectional data communication between devices. Typically, IO-Link primaries (local controllers) have several IO-Link ports (channels) into which various IO-Link devices independently plug. These node-to-node endpoint connections are what render IO-Link a point-to-point communication protocol.

Launched in 2009 by a consortium of 41 members that is now hundreds of members strong, IO-Link is has become a widely accepted communication protocol to harness data crucial for:

Figure 1: IO-Link complements existing network protocols by easily integrating into fieldbus or Ethernet networks via the IO-Link primary. The connection between an IO-Link primary and its IO-Link devices is through unshielded and unscreened three or five-wire cable also capable of supplying power to the IO-Link devices. Here, power from the primary is 24-Vdc. Image source: Pepperl+Fuchs



- Optimizing operations
- Reducing downtime and streamlining maintenance
- Trimming raw material costs and making strategic operational decisions.

The harmonized IO-Link interface is defined by the IEC 61131-9 standard and supported by Siemens, Omron Corp., ifm Efector, Balluff, Cinch Connectivity, Banner Engineering, Rockwell Automation, SICK, Pepperl+Fuchs, and dozens of other component and system manufacturers. No wonder IO-Link connectivity is widely leveraged in operations involving assembly automation, machine tools, and intralogistics. Its three main uses in these and other industrial settings include status communications, machine control, and rendering devices intelligent.

IO-Link controller modes correlate to uses

Recall from previous digikey.com articles that the IO-Link communication protocol renders each connector port on an IO-Link high-level primary (controller) capable of four communication modes. These include a fully deactivated mode as well as IO-Link, digital input (DI), and digital output (DQ) operating modes. The modes loosely correlate to the three main IO-Link uses listed above.

The IO-Link operating mode supports bidirectional data communications with field devices and is typically used during data collection for monitoring, testing, and diagnostics. A primary's port in DI mode accepts digital inputs and works when the port is connected to sensors — in this context, acting as input devices. In contrast, a port in DQ mode acts as a digital output, typically when the port is connected to an actuator (in this context, effectively an output device) or when a system PLC is set up to directly send instructions to another IO-Link device.

Figure 2: The type of connector used with the connecting cable depends on the type of port. IO-Link class-A primary ports accept M8 or M12 (like the AL1120 from ifm efector shown here) connectors with up to four pins, while class-B counterparts accept connections with devices having five-pin M12 connectors (for bidirectional data communication).
Image source: ifm Efector

Though beyond the scope of this article, it's worth noting that the ports on an IO-Link primary can readily switch between modes. For example, a primary's port connected to a sensor can run in DI mode — and then switch to IO-Link communication mode when diagnostics and monitoring data from the sensor is requested by the primary.

IO-Link application 1 of 3: actionable status communications

Machine monitoring is possible with IO-Link devices set up to report status that can, in turn, inform the system of necessary adjustments and corrections. Consider one use in the machine-tool industry — that of IO-Link pressure sensors which verify workpieces are clamped with a pressure appropriate for damage-free yet secure holding during material-removal operations. Here, IO-Link sensors essentially support the optimization of machine tasks for fewer rejected workpieces.

IO-Link devices can also make actionable status communications to support enhanced maintenance routines for minimized downtime. For example, IO-Link position sensors on an assembly machine might continually report the locations of end effectors to ensure none are out of range or alignment.

By analyzing diagnostics data

Figure 3: IO-Link facilitates the creation of highly advanced control and automation systems. The machine-tool industry makes copious use of IO-Link sensors to verify appropriate workpiece clamping and milling end-tool pressures and positions.
Image source: Getty Images

provided by IO-Link devices, a plant's machine technicians can predict and correct errors and potential breakdowns before they happen. Technicians can also identify weak links in a machine or plant — to inform enterprise-level operational changes, purchasing decisions, and captive machine designs in the future.

IO-Link application 2 of 3: advanced control and automation

Control and automation are other application functions supported by IO-Link. Where an IO-Link installation supports functions that run sans intervention of personnel, the IO-Link primary often connects to a host system or higher-level PLC that processes received data and then directly or indirectly commands actuators in the design to the appropriate coordinated responses. Such automated control requires that the IO-Link system connect to a higher-level controller via standardized fieldbus or Ethernet protocols and cabling. In fact, most IO-Link primaries have fieldbus or Ethernet ports for such connections.

Devices in advanced control applications involving IO-Link systems integrate in one of three ways:

- They directly connect to the host computer or PLC
- They connect to an IO-Link primary and communicate via the IO-Link protocol
- They use IO-Link compatible communications and connect to an IO-Link primary via an IO-Link hub

The latter essentially acts as an intermediary to connect non-IO-Link devices to the primary.

An added benefit of IO-Link

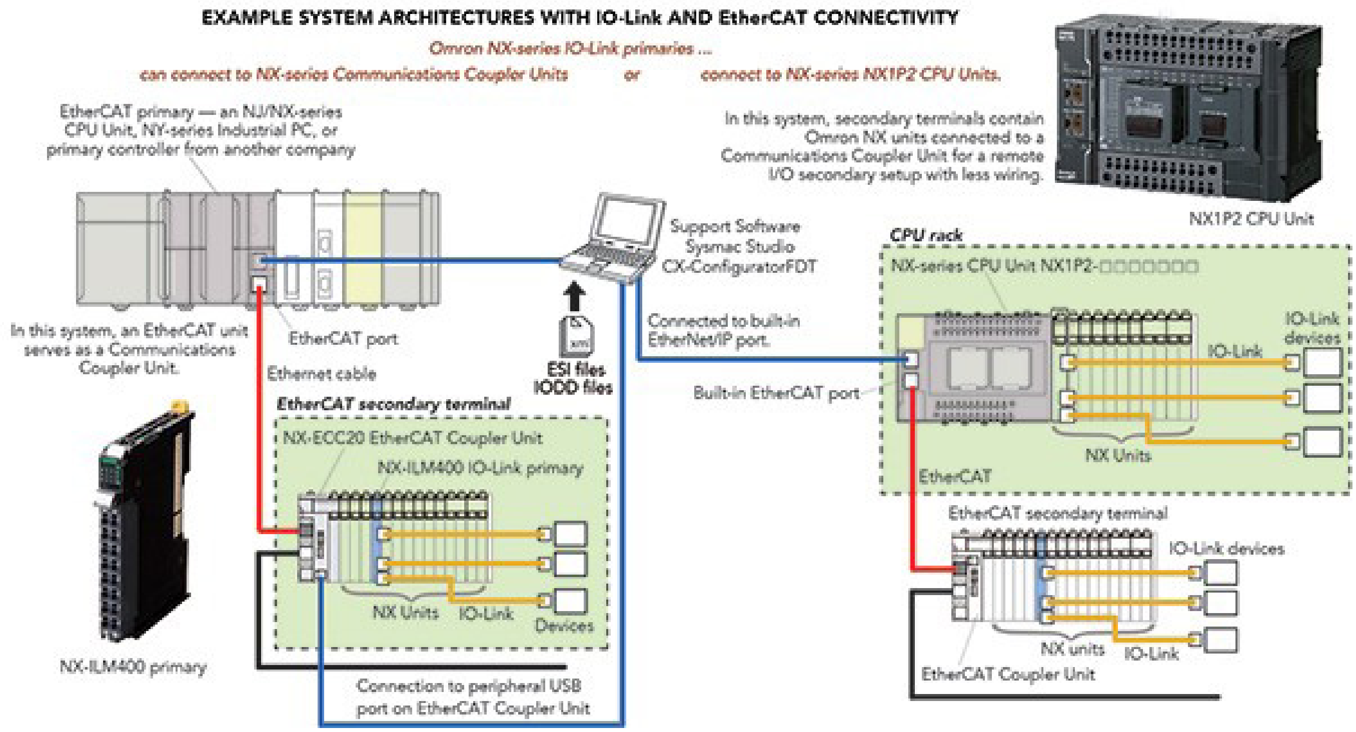


Figure 4: An IO-Link system involved in advanced controls includes an IO-Link primary (controller), like the Omron NX-ILM400 shown here, and various IO-Link-enabled sensors, power supplies, and mechatronic devices connected to that primary. IO-Link systems for such applications typically yoke the IO-Link primary and devices to a PLC or other automation system. Image source: Omron

systems having fieldbus and Ethernet-communications connectivity is that long-distance connections are allowable — which in turn lets installers locate IO-Link primaries in a control cabinet or at the outermost machine reaches if that makes the most sense for a given application.

Consider how IO-Link primaries benefit advanced assembly applications by serving as low-level controllers capable of processing both digital and analog signals. Here, primaries might:

- Accept the data generated by IO-Link linear encoders on the axes of an XY stage
- Process that data as a gateway
- Submit that processed IO-Link field-device data to the PLC or other system controller

IO-Link application 3 of 3: device intelligence

The third application of IO-Link is to render devices smart. Especially common in sensor designs that resemble legacy sensor options with no (or more modest) programming, these IO-Link-enabled devices can receive instructions, monitor, and execute self-testing routines — and generate data. Because IO-Link also lets devices provide more than basic two-value (yes-no or pass-fail) data, the reporting of precise values is also possible. For example, process-automation tasks benefit from IO-Link temperature

Figure 5: The IO-Link connection interface is very small and can fit on most compact field devices. Shown here is a Balluff BUS004Z proximity sensor with IO-Link connectivity. Image source: Balluff

Input devices such as pushbutton switches from RAFI can leverage IO-Link functions to support smart-device features — including color-coded indicator lights.

sensors that go beyond reporting high or low temperature status by continually reporting the exact temperature value of a monitored zone or volume.

Another benefit of IO-Link for smart field devices is the way in which its physical connections are compact. That's in contrast with the physical connections of fieldbus and Ethernet interfaces, which can sometimes be too big to fit on field microdevices.

IO-Link smart components can also be precisely controlled. For example, instead of basic off-and-on controls, an actuator can be commanded to turn off once a scenario satisfies a set of conditions.

Input devices such as pushbutton switches from RAFI can leverage IO-Link functions to support smart-device features — including color-coded indicator lights.

There are some caveats to the use of IO-Link for smart-device applications. Though there is a wireless form of IO-Link under development, it's still a wired communication protocol — so it is still subject to all the limitations of hard wiring. To maintain data integrity, IO-Link primary-to-device cabling mustn't exceed 20m. Plus, because the IO-Link protocol can only transmit up to 32 bytes of data per cycle, it's insufficient for use with field devices such as cameras, which can generate many MB of data per minute.

Conclusion

Uses for IO-Link systems abound to complement existing protocols underpinning virtually limitless controls and data-collection systems. Spurring adoption has been the simplicity of IO-Link systems — comprising only an IO-Link primary and its devices and their connectorized three or five-wire cables. Plug-and-play installation and cost-effectiveness are other IO-Link benefits.

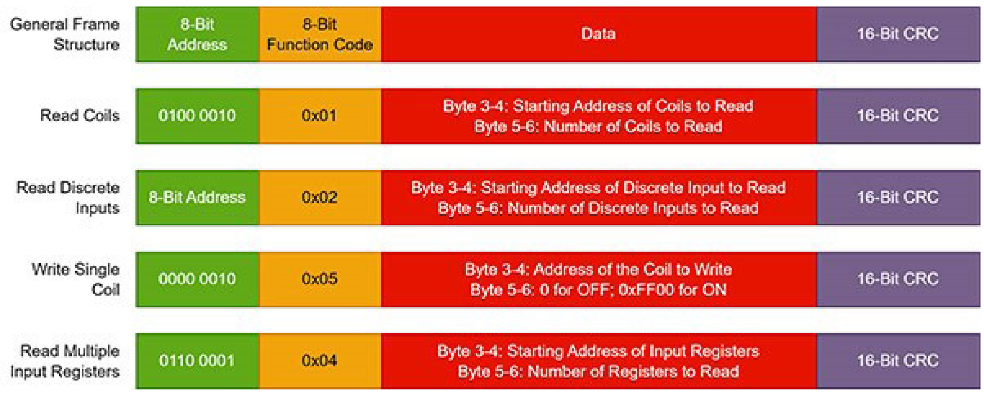
Efforts by the IO-Link consortium of member companies have ensured wide compatibility between controllers, devices, and actuators from various manufacturers, which has given design engineers the widest selection of equipment for their specific use cases.

What is the Modbus protocol?

Written by:
Maker.io Staff

Similar to CAN, Modbus is an older yet widely used industrial communication protocol allowing data exchange between devices in a network. Read on to learn more about the protocol, its functionality, and how you can apply Modbus to your day-to-day projects.

Figure 1: shows the general composition of request frames in Modbus RTU.



A high-level view on the Modbus protocol

Modbus is a serial communication protocol that primarily focuses on describing the message format, encoding, and addressing on a high level without dictating the underlying implementation on the physical layer. Each network comprises precisely one Modbus client and can accommodate anywhere from one to 247 Modbus servers. Each device on the bus has a unique address.

In Modbus RTU (Remote Terminal Unit), the client is the only device capable of actively requesting data on the network. Conversely, the servers can supply data via their internal registers when instructed by the server. Each server has a unique address in the network, and the client uses the server's internal register addresses to retrieve data from a device.

Modbus is commonly used to transmit signals from instrumentation and control devices to a centralized controller. One example of this configuration could involve a system consisting of sensors measuring the temperature and vibrations of an electric motor in a factory crane. The collected data is then submitted to a computer for anomaly detection and to trigger safety measures when necessary. For such purposes, several versions of the Modbus standard exist to support common physical communication standards, such as RS-232, RS-485, and Ethernet.

Modbus object types and function codes

The server devices store information and the client can either request register values or write values to registers. However, as Modbus is an older standard originally intended for use with industrial PLCs (Programmable Logic Controllers), the data tables defined by the protocol reflect this

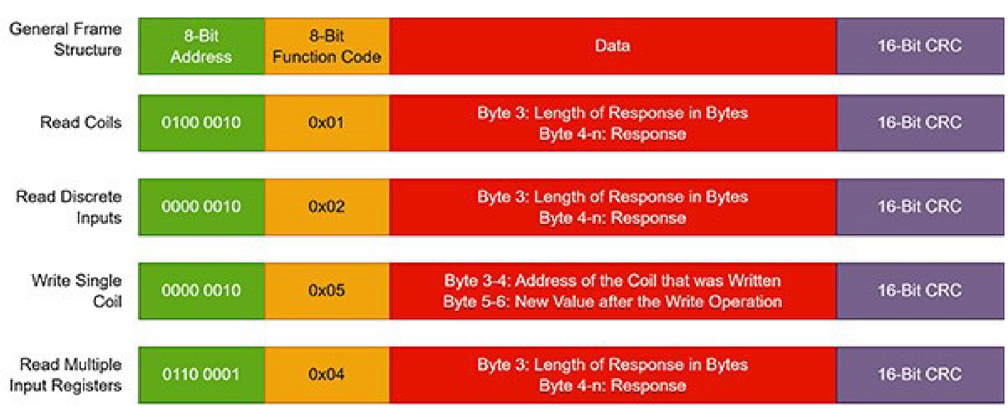


Figure 2: shows the general composition of some example responses in Modbus RTU.

original design decision.

The binary coil object type represents discrete outputs and is typically used for controlling devices. Discrete inputs are the counterpart to the coils. These binary variables represent the state of binary inputs. Input registers are 16-bit read-only registers that hold analog data such as temperature readings or other sensor values. Furthermore, holding registers are 16-bit registers that the client can read from and write to, used for transmitting general data.

Finally, function codes enable the server to know what operation a client wants to perform. In Modbus RTU, function code 01 represents a read from multiple coils operation, 05 corresponds to writing a value to a single coil, 02 initiates a read from a discrete input, 04 lets the client read an input register, and function codes 03 and 06 let a client read and write holding register values.

Modbus RTU frames

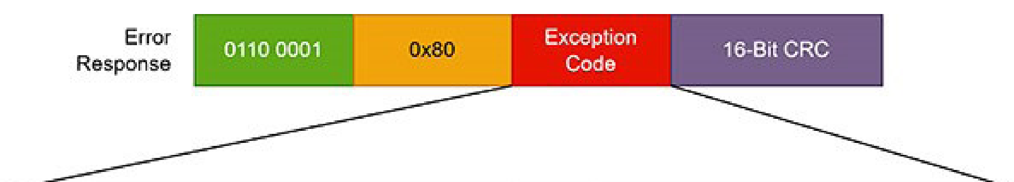
Each request frame in Modbus RTU begins with 28 bits of silence to begin the transmission. Next, the server sends the eight-bit address of the client it wants to communicate with, followed by the eight-bit function code. Following is the data field, whose field length, contents, and meaning depend on the function code. The frame concludes with a 16-bit CRC error-correcting code followed by the end condition, which consists of 28 bits of silence on the data line.

While all frames adhere to the same overall structure, the data field varies widely depending on the specific operation being performed and the quantity of coils or registers involved to read or write. Figure 1 shows a few examples of requests in Modbus RTU.

Across the requests, the data

field typically follows the same structure, where the first two bytes define the starting address and the next two contain either a value to write or the number of registers/ coils to read. The figure 2 shows examples of responses to these requests.

Note how the address and function code remain equal in the request and matching response. Read-request responses commonly adhere to a similar structure as well, where the first data byte denotes the number of bytes in



0x01	Illegal Function	0x06	Server Device Busy
0x02	Illegal Data Address	0x07	Negative Acknowledge (Server can't process the request)
0x03	Illegal Data Value	0x08	Memory Parity Error
0x04	Server Device Failure	0x0A	Gateway Path Unavailable
0x05	Acknowledge (Server requires some time processing the request)	0x0B	Gateway Target Device Failed to Respond

Figure 3: shows the general composition of a Modbus RTU error frame with some common exception codes.

Similar to CAN, Modbus is an older yet widely used industrial communication protocol allowing data exchange between devices in a network. Read on to learn more about the protocol, its functionality, and how you can apply Modbus to your day-to-day projects.

the response, and the subsequent bytes contain the requested values. However, when writing a value, the first two bytes contain the address of the modified coil, and the last two bytes in the data block contain the newly written value that must match the one found in the request.

Aside from the normal response, the server can also reply with an error frame. In the normal frame, the response always repeats the function code in the request. In an error frame, the server replies with a function code of 0x80, and the response only contains a single data byte describing the error:

Figure 3 shows the general composition of a Modbus RTU error frame with some common exception codes.

Summary

Modbus is a relatively old industrial communication standard that describes the composition and structure of messages and data types without restricting the underlying physical implementation. Common standard options for implementing Modbus include RS-232 and Ethernet. This article focused on Modbus RTU on RS-232.

In Modbus RTU, the client is the only device that requests data on the network. Servers can supply data via their internal registers. Each server has a unique address in the network, and the client uses the server's internal register addresses to read data.

Modbus RTU data frames generally consist of an eight-bit address field, an eight-bit function code, several bytes of data, and a 16-bit CRC field for error correction. Normal response frames copy the address and function code values from the response and supply the answer via the data field, which typically varies in length. Response frames also end with a CRC field. In addition to normal responses, clients can send an error frame that replaces the function code with the hexadecimal value 0x80. The error frame's data field can contain an error code to describe what went wrong.

EtherNet/IP versus PROFINET

Written by:
Lisa Eitel, Contributing Editor,
DigiKey

Adoption of industrial Ethernet continues to outpace other options as companies become digitally connected. That's especially true where Internet of Things (IoT) functionality is employed in automation and industrial control systems to boost data accessibility and usability. EtherNet/IP and PROFINET are the top options here.

Structure of EtherNet/IP and expanding EtherNet/IP applicability

EtherNet/IP is an industrial network protocol that employs the Common Industrial Protocol (CIP) to standard Ethernet. It works on a network application layer — which (in the two conceptual models of networks) is at the 'topmost' device and user-facing layer to allow communication between controls and input-output (I/O) devices. More specifically, EtherNet/IP is the top layer of the Open Systems Interconnection (OSI) and transmission control protocol/ internet protocol (TCP/IP) models.

EtherNet/IP employs:

- The application layer just mentioned
- An Internet Protocol networking layer
- The standard Ethernet link layer

Note that the IP in EtherNet/IP is short for industrial protocol and refers to network protocols originally developed to allow communication over serial connections such as RS-232 and RS-485 — both standards for industrial data transmission. Many such connections now operate over Ethernet using protocols such as TCP/IP, so common for Internet communications. EtherNet/IP communications and its very standardized hardware (including hubs, switches, routers, Ethernet cables, and Ethernet network cards) is defined by the IEEE 802.3 Transmission Control Protocol and the Internet Protocol.

Developed in 2009, EtherNet/IP arose from collaboration between the Open DeviceNet Vendors Association (ODVA) and ControlNet International (CI) under the auspices of ODVA and its members. ODVA itself was founded in 1995 as a consortium of automation companies (including Rockwell Automation, Cisco, Schneider Electric, Omron, and Bosch Rexroth) to advance open and interoperable communications for industrial automation. According to ODVA, EtherNet/IP leads industrial-Ethernet adoption — representing 25% share of market in 2017 and 28% in 2018 with the most nodes of industrial Ethernet networks shipped.

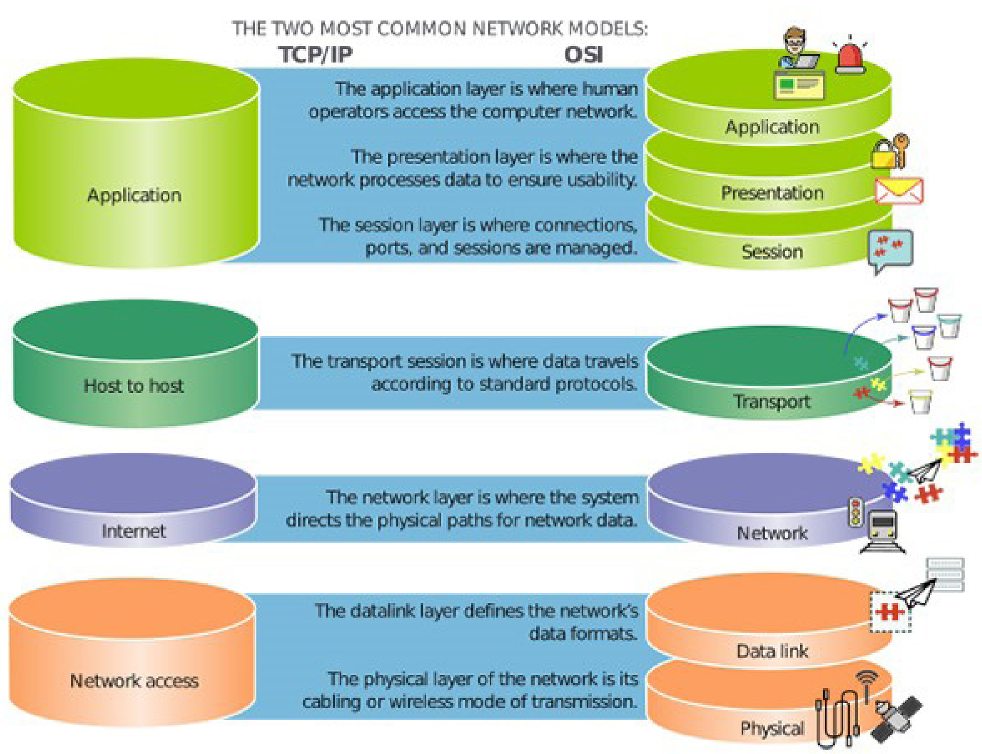


Figure 1: The two most common models used to describe networks are the OSI model and the TCP/IP model. Image source: Design World

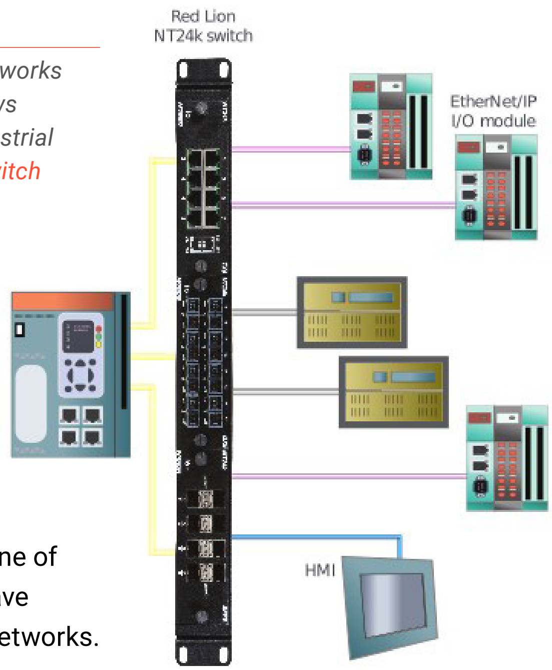


Figure 2: Because EtherNet/IP works on the application layer, it allows communications between industrial controllers and I/Os. NT24k switch image source: Red Lion

At present, EtherNet/IP is one of four ODVA networks that have adopted CIP for industrial networks. The others are DeviceNet, ControlNet, and CompoNet.

CIP is a conduit of organizing and sharing data in industrial devices. More specifically, it uses different types of messages and services to exchange data in industrial automation applications that include process and system control, safety, synchronization, motion, configuration, and information. CIP lets these applications integrate with enterprise-level Ethernet networks and the Internet. It is a unified communication network used for manufacturing and industrial applications and widely adopted by vendors around the world.

For industrial protocols, data is ordered as objects with data elements or attributes. These data objects typically sort into required objects and application objects. The former are found in every CIP.

EtherNet/IP is rather easy to implement, and it's compatible with standard Ethernet switches for industrial automation. However, the basic form of EtherNet/IP is non-deterministic and therefore unsuitable for strict real-time industrial applications. CIP Motion can complement EtherNet/IP to help the latter satisfy demanding requirements for deterministic real-time control (including closed-loop motion control) with unmodified Ethernet in full compliance with IEEE 802.3 and TCP/IP Ethernet standards.

EtherNet/IP complemented with CIP Motion technology delivers multi-axis distributed motion control. It is scalable and offers a common application interface for motion designs.

Data transmission via EtherNet/IP

TCP and the user datagram protocol (UDP) are the underlying communication protocols of the Internet and many private networks as well. EtherNet/IP employs a TCP port for what is called explicit messaging. Such messaging is when the system sends data to a client in response to a specific request for that data. It uses TCP/IP — a connection-oriented protocol that explicitly manages links between clients and servers. Core to TCP/IP networking, TCP helps fragment data packets so that data messages reach their destination. Note that IP deals only with packets; TCP lets two hosts establish connection and exchange data streams. TCP guarantees delivery of data as well as that packets will be delivered in the order in which they were sent.

EtherNet/IP employs a UDP port for implicit messaging — system communications sent from preset memory locations to a controller or other client at some prescheduled interval. Such communications are far faster than explicit messaging, and the one-way data transmission of UDP connections (sans validating receipts) simplifies cyclical system updates.

Figure 3: EtherNet/IP and PROFINET are leading industrial Ethernet protocols. Both are supported by the ODVA. Image source: ODVA Inc.

PROFINET for deterministic communications

PROFINET is another technical standard that defines a mode of data communication via industrial Ethernet. PROFINET modifications to standard Ethernet ensure proper and prompt data transmission even in challenging applications. Its definitions dictate a means of data collection from industrial equipment and systems to satisfy specific and often tight time constraints. PROFINET arose from PROFIBUS — a standard for fieldbus communication to support automation. While PROFIBUS is a classical serial fieldbus based on industrial Ethernet, PROFINET goes further with additional capabilities to allow faster and flexible communications to control automation components.

In fact, PROFINET had 30% of the industrial-network market share as of 2018, making it the world's leading Ethernet-based communication solution for industrial automation. More than five million PROFINET-ready devices come to market every year.

Figure 4: EtherNet/IP is most common in the United States. PROFINET is widely used in Europe.
Image source: PI North America

PROFINET and PROFIBUS communications are deterministic, which allows support of automation systems with precise I/O structure limits and their defined I/O structures allow precise calculation of maximum update times. PROFINET can also provide isochronous real-time (IRT) data exchange. IRT essentially leverages the ultra-precise time clock of PROFINET to prioritize the passage of some types of data traffic and buffer the rest. IRT excels in demanding applications such as motion control and other applications that need more deterministic operation than real-time operation. In a real-time data exchange, bus cycle times are less than 10 msec. In contrast, IRT data exchanges occur within a few dozen µsec to a few msec.

For example, PROFINET in a packaging and labeling operation can support data transmission to ensure bottles are filled to a precise level in less than a second — to within just an msec or so. PROFINET can also detect, quantify, and alert operators of any anomalies in the bottling process and immediately shutdown processes as well.

Side note on PROFINET hardware

Standard Ethernet is only suitable for data transmission in home, office, and select industrial-monitoring settings. In contrast, the industrial Ethernet of PROFINET is suitable for installation in harsh industrial facilities requiring deterministic data communications. PROFINET cables and connectors differ from those employed in standard Ethernet — and includes connectors with heavier lock mechanisms and ruggedized industry cables. PROFINET routers (whether integrated into other hardware or built as standalone elements) function on network layer three (from the network models mentioned earlier) and communicate using IP addresses. These routers connect local area networks (LANs) and form wide area networks (WANs) while employing algorithms to determine the best data-transmission routes between networks. Some PROFINET switches also employ fiber-optic connections. These ultra-fast components integrate PROFINET-capable devices into Ethernet networks (or PROFIBUS) via gateway elements for copper-to-fiber-optic conversions.

PROFINET managed and unmanaged switches

PROFINET switches work on the second data layer of the conceptual network model covered earlier. They function to control the receipt and transmission of data signals through the network.

Unmanaged PROFINET switches send incoming Ethernet data through the proper ports connected to intended device endpoints. Ports may have an LED indicator to show the presence of data flow, but these unmanaged switches usually don't provide much more information about or management of that data flow.

In contrast, managed PROFINET switches are more intelligent and work with different IT protocols — including the simple network management protocol (SNMP) and link layer discovery protocol (LLDP) for PROFINET. Because of their intelligence, managed switches are often used where preventing downtime is a top objective — and where troubleshooting failures is useful. Of course, they're usually costlier than unmanaged switches.

Direct comparison of EtherNet/IP and PROFINET characteristics

Industry-specific adaptations of EtherNet/IP are transforming many industries. For example, the packaging industry employs EtherNet/IP for high-speed communications, determinism, and real-time performance. Industries such as chemical processing, traditional automation, and power generation use EtherNet/IP to continually quantify output. Still other industrial applications involve fully automated processes that necessitate counting and real-time data acquisition for control. Here both EtherNet/IP and PROFINET excel in creating the deterministic networks such applications require.

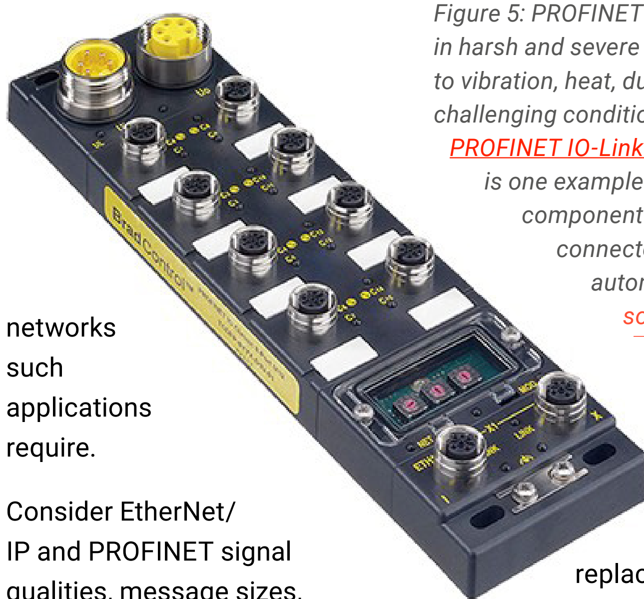


Figure 5: PROFINET hardware excels in harsh and severe conditions subject to vibration, heat, dust, oil, and other challenging conditions. This Brad PROFINET IO-Link HarshIO module is one example of a ruggedized component for PROFINET-connected factory automation. Image source: Molex

Consider EtherNet/IP and PROFINET signal qualities, message sizes, and update rates for details on how the two differ. PROFINET is generally faster than EtherNet/IP and most often deployed with standard hardware, though PROFINET IRT requires specific hardware. EtherNet/IP is more interoperable, as it's based on object-oriented programming and relies on commercial off-the-shelf (CotS) components. In fact, that use of CotS components and hardware not unlike the ubiquitous variations employed in office settings means EtherNet/IP is very cost effective for high-speed industrial connectivity. Economies of scale and the interchangeable nature of much of this hardware help minimize upfront costs the most.

In contrast, PROFINET-ready components can integrate into PROFIBUS-based fieldbuses, effectively capable of supplementing existing systems without necessitating complete replacement. There are cost benefits to the way existing devices can be shared and existing networks accept the addition of supplemental hardware. Even so, upfront costs for PROFINET technologies may be up to 15% more than those based on EtherNet/IP. That cost is partially offset by easier installation, estimated to be about half as complicated (read: expensive) as installation of Ethernet/IP.

Topologies and components supported by EtherNet/IP and PROFINET also differ somewhat. Network topology is the arrangement of the links and nodes of a network. Links are wireless and wired technologies such as coaxial, ribbon, and twist-pair cable as well as fiber-optic cable. In contrast, network nodes are hubs, bridges, switches, routers, modems, and firewall interfaces. Topologies include star, line, ring, daisy chain, and mesh.

EtherNet/IP networks primarily

use a star topology complemented by others: Ring topology connects multiple devices sequentially — though if a cable is cut within the ring, each device maintains its path to control. Tree topology uses devices or switches wired with connections between device groupings; any break prompts an algorithm to determine the next best workable path to solution.

PROFINET's line topology uses minimal cabling and no external switches; connections to any star and tree topologies are via standalone switches. Here if a star or tree switch fails, communications to all nodes are affected — which can be problematic. So, to ensure communications continuity, PROFINET supports topologies with added devices to provide media backup and other elements should a cable or node fail.

Note that EtherNet/IP and PROFINET networks deploy in systems under centralized and decentralized control — and sometimes work in systems that combine both control arrangements. With EtherNet/IP and PROFINET, centralized systems use a client-server setting having a center server connecting one or more client nodes. Client nodes submit requests to the central server rather than process on their own while the server handles all the major processing. In decentralized systems, every node autonomously executes its own logic. The final actions of the system are the sum of all nodes' logic.

Figure 6: This [Anybus Communicator protocol-converting gateway] facilitates the serial connection of non-networked equipment to PROFINET networks. Image source: [HMS Networks]

EtherNet/IP and PROFINET gateways

Gateways (whether standalone pieces of hardware or integrated with router, firewall, or server functions) control the flow of data in and out of a given network and sometimes between disparate systems. That includes some gateways that are specifically designed to communicate I/O between EtherNet/IP and PROFINET networks. For the latter, most gateways function as a PROFINET device and EtherNet/IP adapter for automatic compatibility.

Besides their primary role, gateways can also unburden a system's PLC of signal timing, counting, calculating, comparing, and processing tasks. EtherNet/IP and PROFINET gateways with router functionality let computers send and receive data over the Internet. Today, smart human-machine interfaces (HMIs) connected to networks sometimes do double-duty as gateways between automation systems and controllers as well — for simplified system commissioning and maintenance.

Connecting future industrial automation installations

EtherNet/IP and PROFINET connectivity are enabling innovative new permutations of automation and industrial controls with unprecedented agility and IIoT functionality. As hardware, software, and connectivity technologies leverage EtherNet/IP and PROFINET in new ways, they'll help systems meet evermore-demanding industrial production requirements.

Five-five-five: The story of Interdesign Inc.

Written by: David Ray,
Cyber City Circuits

1960: from Zurich to Boston

Most other stories involving the 555 timer ignore the interesting story about how it was only the beginning for a company named Interdesign Inc.

Born in 1934, young Hans Camenzind was raised in Zurich, Switzerland. Coming to age at the end of WW2, Hans received an Electrical Engineering degree from the Swiss Federal Institute of Technology before immigrating to the United States in 1960. He and his wife, Pia Camenzind, moved to Massachusetts for Hans to attend Northeastern University to receive a degree in electrical engineering.

While a student, he had access to the Massachusetts Institute of Technology's libraries and spent much of his time thumbing through journals, books, magazines, etc. It was here that he first found the concept of a 'phase-locked loop.'

"I went to the MIT library. I had access to this library, and underneath the circular white dome, on the 6th and 7th floor, I spent almost a week looking through old issues of the Proceedings of the IRE (Institute of Radio Engineers). There was no index, no computer search, so I had to go through volume after volume. I came across a concept called a phase-locked loop [PLL]. I had never heard of it before. I looked at it, and it was a very obscure concept; it was used to lock on to some faint signal. I think NASA used this to lock on to signals coming back from the moon for the lunar landing."

He began working for P.R. Mallory and Co. in the research and development department after graduation. While there, he developed new ideas and concepts, sharpening his skills in the new Integrated Circuit technology. The problem was that P.R. Mallory made batteries. Their flagship product was named 'Duracell.' So, they didn't care about his fancy and wasteful ideas. He did make some great relationships while there.

Disenchanted by the life of an IC designer at a battery manufacturer, he turned his eyes west to Signetics. He packed up his wife and four children and headed for Silicon Valley. While working for Signetics for two years, he was responsible for developing the NE565 and NE567, which were the earliest monolithic PLL chips developed for the market. He also designed the NE566 function generator that was used in developing the growing touch-tone phone technology.

1970: the recession and the rise of Interdesign Inc.

In 1970, the nationwide recession was creeping into the components industry, and the bean counters at Signetics downsized the engineering staff by half. Hans was offered a severance package, and he took it. In an interview with Jack Ward of 'The Transistor Museum,' he says that he resigned because he wanted the opportunity to study and write a book. During this time, he spent his evenings

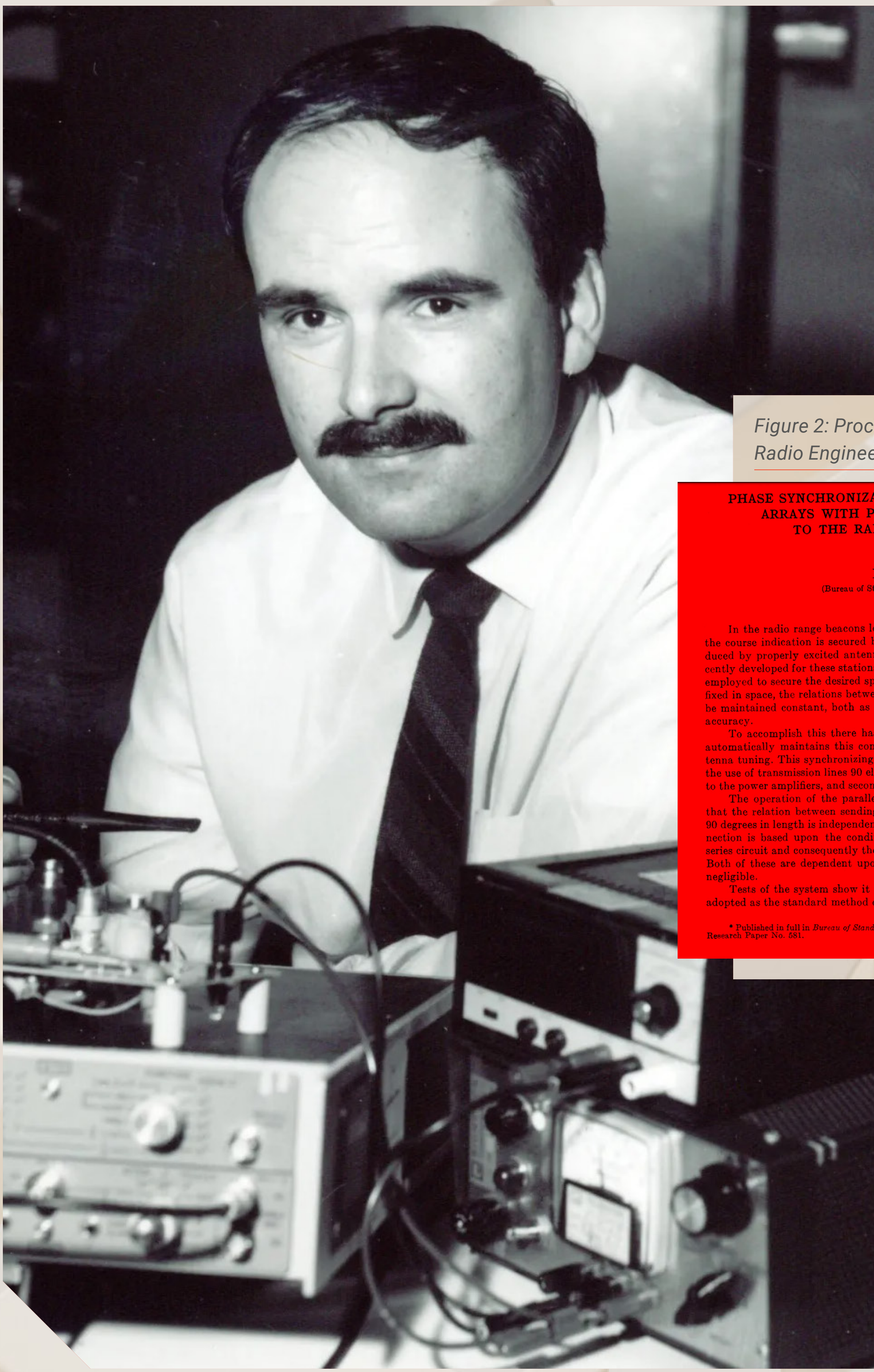
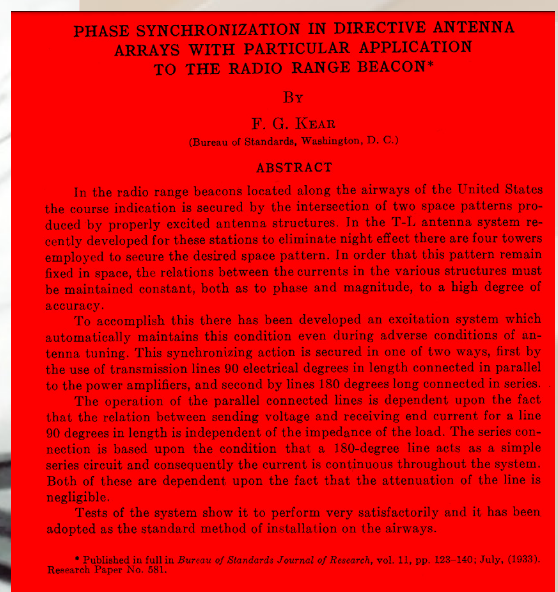


Figure 1: Hans Camenzind

Figure 2: Proceedings of the Institute of Radio Engineers - Jan 1934



PHASE SYNCHRONIZATION IN DIRECTIVE ANTENNA ARRAYS WITH PARTICULAR APPLICATION TO THE RADIO RANGE BEACON*

BY

F. G. KEAR

(Bureau of Standards, Washington, D. C.)

ABSTRACT

In the radio range beacons located along the airways of the United States the course indication is secured by the intersection of two space patterns produced by properly excited antenna structures. In the T-L antenna system recently developed for these stations to eliminate night effect there are four towers employed to secure the desired space pattern. In order that this pattern remain fixed in space, the relations between the currents in the various structures must be maintained constant, both as to phase and magnitude, to a high degree of accuracy.

To accomplish this there has been developed an excitation system which automatically maintains this condition even during adverse conditions of antenna tuning. This synchronizing action is secured in one of two ways, first by the use of transmission lines 90 electrical degrees in length connected in parallel to the power amplifiers, and second by lines 180 degrees long connected in series.

The operation of the parallel connected lines is dependent upon the fact that the relation between sending voltage and receiving end current for a line 90 degrees in length is independent of the impedance of the load. The series connection is based upon the condition that a 180-degree line acts as a simple series circuit and consequently the current is continuous throughout the system. Both of these are dependent upon the fact that the attenuation of the line is negligible.

Tests of the system show it to perform very satisfactorily and it has been adopted as the standard method of installation on the airways.

* Published in full in *Bureau of Standards Journal of Research*, vol. 11, pp. 123–140; July, (1933). Research Paper No. 581.

Figure 3: Electronic Design 21

ICs & SEMICONDUCTORS

Custom bipolar IC design lowers cost and turn-around

Interdesign Corp., 165 S. Murphy Ave., Sunnyvale, Calif. Phone: (408) 732-4171. P&A: see text.

A versatile concept known as the Monochip shortens custom bipolar IC design time from the usual four months to as little as two weeks per circuit and costs about 20% as much as previous approaches.

What makes this possible is a simple idea: each chip contains a large number of standardized components which are processed routinely up to the metal-evaporation stage and then put into inventory.

The only non-standard step is to draw up an interconnection mask which connects the components together, just like wiring up a number of discrete components. This mask is then applied to a waiting wafer. The entire process, from circuit diagram to prototypes, takes about 10 working days. And, since only a single mask has to be cut instead of the normal six or seven, the cost is much lower.

The first Monochip version, called Monochip A, is designed for both digital and linear circuits with an operating voltage up to 20 V. It contains 57 small npn transistors, two high-current (200 mA) npn transistors, 19 lateral pnp transistors, 16 Schottky-barrier diodes and 167 resistors—for a total of 261 components. If the circuit to be integrated is smaller than this, the unused components are ignored.

Although the process used for the A version is optimized as a linear process, the presence of the Schottky diodes provides very short switching times for high-speed digital applications.

The new devices offer great flexibility. Each transistor can be converted into a diode by shorting its collector and base together by using one of the junction diodes. Transistors can also be paralleled for higher-current operation. Any junction can be used as a capacitor, and series or parallel resistor combinations can provide a wide range of values.

A design kit is available which contains a selection of Monochip components for breadboarding, a booklet with their characteristics, design hints and a layout drawing. Since the components are drawn from the Monochip, their performance is identical to those in the finished IC, and all stray effects can be safely simulated. Once the circuit is breadboarded, the engineer interconnects the Monochip components on the drawing according to his circuit diagram and sends it to Interdesign for a mask.

With an initial cost of $2800, one can obtain a Monochip A, in 100-quantity lots, for $1.50 to $10 per circuit, depending on circuit complexity. Each circuit can be obtained in conventional 14 or 16-pin ceramic or plastic DIPs.

CIRCLE NO. 269

Blank Monochip bipolar IC (top) is custom designed and integrated (bottom) in as little as two weeks and at 20% of conventional costs.

can one LATCHING RELAY offer all this?

- High Reliability (100 x 10⁶ operations)
- Inherent Contact Memory
- Bounce-Free Operation
- Self-Healing Contacts
- Operation in Any Mounting Position
- Miniature Size
- No Latching Current
- Virtually No Noise
- Shock and Vibration Resistance
- For Signals from DC to 120 MHz

Yes... if it's a LOGCELL® Mercury Film Relay

Both latching and nonlatching Logcell Relays are available. For more information about Logcell Relays, and Logcell Switches, too, write Fifth Dimension Inc., Box 483, Princeton, New Jersey 08540. Or call (609) 924-5990.

FIFTH DIMENSION INC.

INFORMATION RETRIEVAL NUMBER 64

112

ELECTRONIC DESIGN 21, October 14, 1971

studying for an M.B.A. and teaching electrical engineering classes in the mornings. Not long after, however, Signetics came back, asking him to return. He declined, instead requesting an independent contractor position. The NE555 Timer would be Interdesign Inc.'s very first freelance contract.

Soon Hans would find himself in the same conference room he was in when he worked for Signetics, with the same engineers he worked with. He was here to propose a new design. This new design would be both an oscillator and a timer. In his book, 'Designing Analog Chips,' he says he described it to Signetics as 'an oscillator whose frequency could be set by an external resistor and a capacitor and was not affected by changes in either supply voltage or temperature… modified so it could also be triggered and produce a single cycle only.' Nothing like this had been put to market yet. It could reduce space and cost to produce a study clock signal, but some people were opposed to this concept. His proposal was met with protests that it was a wasted effort and would shoot Signetics in the foot because it would hurt op-amp sales and op-amps were their biggest seller. It took the linear IC marketing manager, Art Fury, to champion the device, which Art would later name the 'NE555 Timer'.

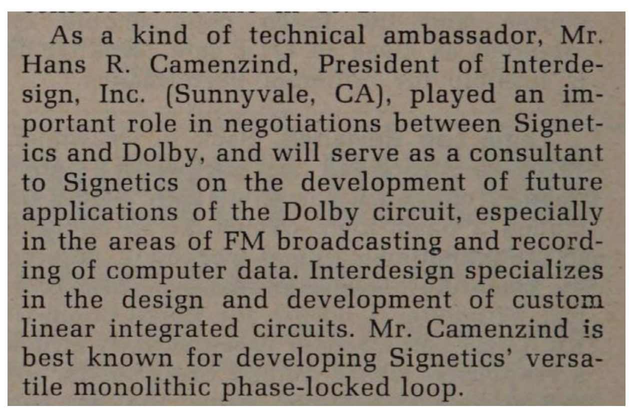
"The reaction of the Signetics engineering group was disappointing. A user can make a timer from a comparator, a flip-flop, and a zener diode, they said; there is no need for another IC. Had it not been for Art Fury, the marketing manager for linear ICs, the project would have died before it started. Art simply had the gut feel that such a circuit would be useful. But even he was surprised by the outcome." – Hans Camenzind

With this new contract, Hans started his own company, Interdesign. Soon after, Hans brought a friend he met in Massachusetts into Interdesign, James Victor Ball [6]. James, himself an Austrian immigrant, became Interdesign's Vice President and Hans' right hand. Hans and James had both gone to Northeastern University for their master's degree in electrical engineering and worked at P.R. Mallory, where they met.

His contract gave him one year to design and test the 555 timer. With his schedule, he claims the breadboard layout alone took six months of his twelve-month contract. In the end, his final design consisted of twenty-three transistors, fifteen resistors, and two diodes.

1972: the five-five-five was the beginning

The 555 timer was first introduced in the Signetics 1972 Full Line Catalog [8]. Being very industrious, he also released his second textbook during this time, 'Electronic Integrated Systems



As a kind of technical ambassador, Mr. Hans R. Camenzind, President of Interdesign, Inc. (Sunnyvale, CA), played an important role in negotiations between Signetics and Dolby, and will serve as a consultant to Signetics on the development of future applications of the Dolby circuit, especially in the areas of FM broadcasting and recording of computer data. Interdesign specializes in the design and development of custom linear integrated circuits. Mr. Camenzind is best known for developing Signetics' versatile monolithic phase-locked loop.

Figure 4: Announcement of Interdesign developing what became the Signetics NE545 Dolby Noise Processor"
Citation: Popular Electronics - Oct 1971 Page 90

People

Cunningham: Instruments can thrive on custom ICs.

James R. Cunningham, who 17 years ago helped found Systron-Donner Corp., Concord, Calif., surprised a lot of people when he resigned earlier this month as general manager of the $44-million instrument company's Computer Systems division. And he surprised even more people when he became president of Interdesign Inc., a small $2.5 million company in Sunnyvale, Calif., which until now specialized in custom integrated circuits.

Responsibility. At Interdesign, Cunningham hopes to be calling more of the shots.

Why did he make the move? The answer is simple. Cunningham was bored and bugged.

"I got into a static slot at Systron-Donner, and I wanted a change," he says. "I wanted to call the shots, to totally run an operation. Interdesign was an opportunity for me to have all operations responsibility, to utilize all my marketing skills."

Instrument maker. Moreover, as president of Interdesign, Cunningham feels that he will also get a chance to return to his first love—instruments—a field Interdesign is just now getting into because of its know-how in custom ICs.

"For years I've been bugged by the inability of most instrument houses to produce relatively sophisticated instruments at truly low prices—say the $50 to $200 range—and to do it profitably," he says. "It can be done, I'm sure. The key is finding a way to produce ICs, especially linear ICs, in low volume and at a low cost. It was a dilemma I thought was insoluble until I came to Interdesign."

Founded in 1970, Interdesign is best known for its monochip, a low-cost IC kit for custom designing circuits. The kit consists of three bipolar chips on which are placed a large number of standardized ICs. By varying only the final metalization layer, the entire prototype cycle from layout to sketch to finished IC takes less than three weeks, compared to at least six months for an ordinary custom IC, says Cunningham. Typical startup costs are less than a twentieth the industry norm, he points out.

"When we assessed the directions the company wanted to go recently, we asked ourselves why should our customers be the only ones to take advantage of this approach," says Cunningham. "It was obvious that in certain areas, such as instrumentation, we had the key to our future growth."

The firm's first instrument is a $150 pulse generator built around the monochip, which Cunningham calls "the poor man's custom IC."

Cunningham has rosy expectations for the near future. Even with the slowdown in the economy, his company will grow, he says, by at least 20% to 30% a year because he believes there will always be a market for the low-cost custom ICs Interdesign can produce.

Bendix's McCormick: billion-dollar man?

Most engineers might pale at being responsible for R&D that's expected to create billions of dollars in sales. But Joseph L. McCormick, recently named engineering director at Bendix Corp.'s Communications division, Towson, Md., says that for him, it's "no problem."

McCormick, who has been with Bendix ever since earning his bachelor's degree in physics from Baltimore's Loyola University in 1957, is

AT YOUR FINGERTIPS
Industry's Best Delivery On Every
Precision/ Power Wire-wound Resistor
In Our Catalog
Call our hotline for prompt service and delivery.
(201) 374-3311
RCL
ELECTRONICS, Inc.
General Sales Office:
700 So. 21st Street
Irvington, N. J. 07111

14 Circle 14 on reader service card

Electronics/October 3, 1974

Figure 5: Electronics - James Cunningham

Design' in 1972.

Interdesign also developed a new concept called 'analog/linear master slice', which was built into a complete family of integrated circuits named 'Monochip'. The Monochip-A was released in late 1971 and made it more accessible for designers to develop 'ASIC' type of designs with off the shelf parts for less money and less time.

During this time, Interdesign also became the centerpiece in a partnership between Signetics and the UK's Dolby Laboratories. According to the October 1971 Issue of Popular Electronics, Interdesign would 'consult' on the development of a microcircuit version of the famous Dolby noise reduction technology for consumer equipment. Two years later, in 1973, Signetics released the NE 545 Dolby noise processing integrated circuit.

Interdesign did this from a small office at 165 S Murphy Ave, which he says was between two Chinese restaurants in downtown Sunnyvale, CA. One of the restaurants, Tao Tao Café, is still open if you're nearby. Soon Interdesign's success allowed Hans and his team to move the company to an office park on the other side of Sunnyvale. The new building was thirty thousand square feet. Hans and James had learned quite a lot and had started fabricating their own integrated circuits in-house. Back then there were two avenues for circuit board development, have an ASIC built, like Signetics would do, or develop standard off the shelf logic parts, the Monochip was right in the middle, providing an assortment of useful logic gates, comparators, timers, etc. all in a single DIP package. Interdesign designed a variety of these chips for the market.

In late 1974, James R. Cunningham, who was the General Manager of a large test equipment company, resigned from his job to come work as president of Interdesign. His plan was to design a whole line of affordable test equipment, built around the Monochip series of chips. It does not look like this effort got off the ground before the company was being courted by interested parties.

"When we assessed the directions the company wanted to go recently, we asked ourselves why should our customers be the only ones to take advantage of this approach, it was obvious that in certain areas, such as instrumentation, we had the key to our future growth." – J.R. Cunningham concerning using Monochip to develop low-cost and high-margin test equipment.

The Monochip line made Interdesign a big name in the industry and, in 1977, he sold Interdesign to the British company Ferranti. Ferranti would continue

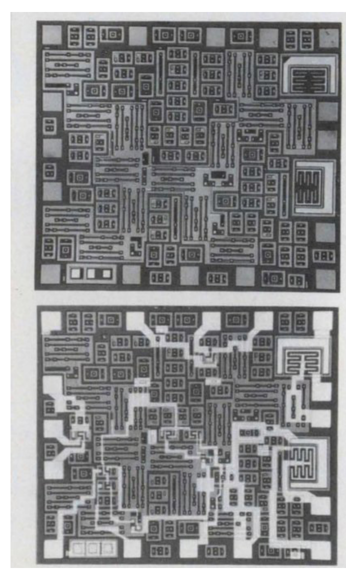


Figure 6: MonoChip-A Dies

Fun fact: the office that Hans Camenzind designed the 555 timer in is now a real estate broker's office

1960
Hans Camenzind immigrates to Massachusetts from Switzerland

1962
Hans Camenzind begins work at P.R. Mallory

1968
Hans Camenzind begins work at Signetics

1970
Resigns from Signetics and starts Interdesign Inc.

1972
Release of Monochip-A

1972
Release of NE555 Timer

1973
Release of NE545 Dolby Noise Processor

1973
Signetics IPO

1977
Ferranti acquires Interdesign

the Monochip line for many years, adding it to their catalog of parts.

The legacy of an IC pioneer

Soon after Ferranti's acquisition of Interdesign, Hans retired from the company and continued to teach at the University of Santa Clara. In the late 1980s, he started another design and consulting company, Array Design. After a well-lived life, Hans Camenzind died in 2012 at the age of 78. In his life, he has designed over 140 integrated circuits.

Following the release of the Dolby NE545, Signetics held a very successful IPO, and Philips, the inventor of the compact cassette tape, licensed the use of the Dolby microcircuit technology. It became very popular with manufacturers of Hi-Fi sound systems, and two years later, Philips purchased Signetics outright, eventually rebranding it to Philips Semiconductor. Today Signetics lives an assumed identity under the name NXP Semiconductors.

Since 1971, the original NE555 design has been cloned and copied time and time again but has not changed. According to Hans Camenzind even modern 555 timers use the same rubylith mask layout that he created in 1971. Many years later, Hans took it upon himself to redesign the 555 timer with CMOS equivalent technology, and it was produced by Zetex with the part number ZSCT1555.

From the 555 timer, the first monolithic Dolby chip, to the Monochip series, Hans Camenzind's rubylith knife has had a lasting impact on today's world.

Suggested reading

1. The 555 Timer IC: An Interview with Hans Camenzind - The Designer of the Most Successful Integrated Circuit Ever Developed. The Transistor Museum.
2. The 555 Timer Was Just The Beginning For Hans Camenzind by Peter Camenzind. ElectronicDesign.com
3. Redesigning the Old 555 by Hans Camenzind. IEEE Spectrum, Sept 1997 (Pages 80-85)
4. Designing Analog Chips by Hans Camenzind. DesigningAnalogChips.com
5. No More Laughing at the Deaf Boy: A Technological Adventure Between Silicon Valley and the Alps. Geoffrey Ball.
6. Homage to a Handmade Chip: The World's Most Popular Integrated Circuit Turns 50. Make: Magazine
7. The 1972 Signetics Full-Line Catalog. Bitsavers.org
8. New Products: Do-it-yourself IC design (The Electronic Engineer, Jan 1972). Archive.org

References

1. J. E. HELMREICH, "The Bombing of Zurich," Aerospace Power Journal, Summer 2000.
2. H. Camenzind, Interviewee, The 555 Timer IC: An Interview with Hans Camenzind - The Designer of the Most Successful Integrated Circuit Ever Developed. June 2004.
3. H. R. Camenzind, Much Ado About Almost Nothing: Man's Encounter With the Electron, Self-Published, 2007.
4. H. R. Camenzind, Designing Analog Chips, Self-Published, 2005.
5. H. R. Camenzind, "Redesigning the Old 555," IEEE Spectrum, 1997.
6. G. Ball, No More Laughing at the Deaf Boy: A Technological Adventure Between Silicon Valley and the Alps, Self Published, 2012.
7. "James Victor Ball: Obituary," Legacy.com, 2019.
8. Signetics Corporation, Signetics Full Line Catalog, 1972.
9. H. R. Camenzind, Electronic Integrated Systems Design, Van Nostrand, 1972.
10. D. Bray, "Analog/Linear Master Slices," in Gate Arrays, Design Techniques and Applications, McGraw Hill, 1985.
11. C. Platt, "Homage to a Handmade Chip: The World's Most Popular Integrated Circuit Turns 50," 9 November 2022.
12. "New Products: Do-it-yourself IC Design," The Electronic Engineer, 1972.
13. "Cunningham: Instruments Can thrive on Custom ICs," Electronics The International Magazine of Electronics Technology, 1974.
14. "The Turnaround of Britain's Ferranti," New York Times, 1982.
15. University of Santa Clara, University of Santa Clara Bulletin, University of Santa Clara, 1975-1976.
16. P. Camenzind, "The 555 Timer Was Just the Beginning For Hans Camenzind," 2012.
17. B. Cole, "The Debt We Owe to Hans Camenzind (1934-2012)," 2012.
18. H. R. Camenzind, Circuit Design For Integrated Circuits, Addison-Wesley Publishing Compay, 1968.
19. J. Penter, Circumstantial Evidence, San Francisco: Faraday Press, 1981.
20. Electronics Magazine.

How to connect legacy factory automation systems to Industry 4.0 without disruption

Written by:
Steven Keeping, Contributing Editor, DigiKey

Factories are transforming as Industry 4.0 and the Industrial Internet of Things (IIoT) gains momentum. Among other large-scale automation functions, Industry 4.0 brings widespread machine-to-machine communication (M2M) to the shop floor. This creates the opportunity for more data gathering and analysis to increase productivity and improve efficiency.

While M2M has been accelerating in recent years, it is not new, having been a part of the digitalization of the factory stretching back decades. Modern wired and wireless M2M technology, such as Industrial Ethernet and Wi-Fi, are streamlined and efficient, but this long history means there are many legacy networks in place. Such networks use older technologies such as programmable logic controllers (PLCs), which transfer data over wired networks employing serial data technologies such as RS-232 and RS-485.

This presents factory managers with a dilemma. Retaining older communication systems means missing out on the productivity benefits brought by Industry 4.0, but upgrading the factory to bring in Industrial Ethernet is expensive and disruptive. Worse, many older machines are typically controlled by a generation of PLCs that are not compatible with newer Industrial Ethernet protocols such as Ethernet/IP and ModbusTCP. Yet those machines could have many years of useful life left. An industrial gateway can provide a cost-effective interim solution by bridging between legacy infrastructure and an Ethernet backbone as it is phased in.

Figure 1: PLCs are the mainstay of factory automation and are inexpensive, reliable, and robust. Image source: Siemens

This article briefly describes the benefits of an Industrial Ethernet network and modern industrial protocols for improving factory productivity and efficiency. It then addresses how an industrial gateway can provide a quick and easy solution for bridging legacy infrastructure and the Ethernet backbone. The article will introduce two industrial gateway examples from Weidmüller and describe how to use them to link a PLC running an RS-232/RS-485 serial data technology to an Ethernet/IP backbone.

A short history of industrial automation

The digitalization of factories really got started with the invention of the PLC in 1969. A PLC is a specialized type of computer that continuously runs a single program. A key advantage of a PLC is its virtually real-time and highly repeatable program execution. They are also relatively inexpensive, reliable, and robust. A good example is the Siemens SIPLUS unit which features an RS-485 serial interface (Figure 1).

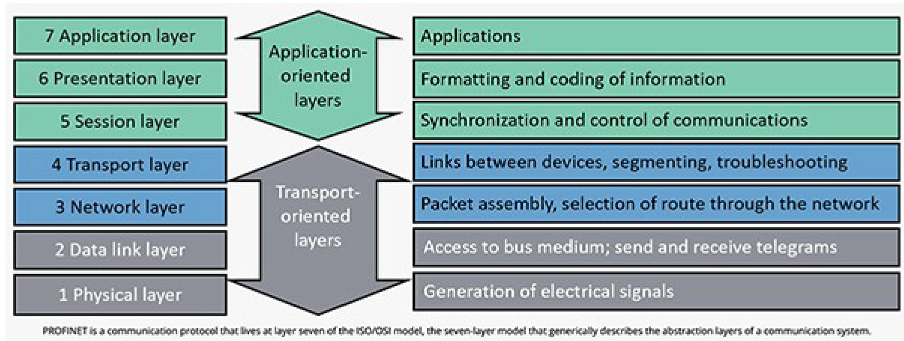


Figure 2: Shown is the Industrial Ethernet software stack. Industrial Ethernet protocols such as PROFINET operate in the application layer.
Image source: PROFINET

In the early days of factory automation, manufacturers linked their PLCs to a central supervisory system using RS-232. This was a wired, serial data link with a maximum throughput of a few hundred kilobits per second (Kbits/s) at best. It used ground voltage to represent digital '0' and ±3 to 15 volts to represent digital '1'. Later, RS-422 and RS-485 took wired communications to a more advanced level using differential signaling over a twisted pair cable. The systems allowed one controller to supervise up to 32 PLCs and offered a data rate of up to 10 megabits per second (Mbits/s) over a distance of up to 1,200 meters (m).

It is important to note that RS-232 and RS-485 are standards that specify the physical layer (PHY); they do not specify the communication protocol. In the industrial automation sector, several protocols have been developed to run on the RS-232 or RS-485 PHY. Examples include Modbus Remote Terminal Unit (RTU), Modbus American Standard Code for Information Interchange (ASCII), DF1-Common Industrial Protocol (CIP), DF1-Programmable Controller Communication Commands (PCCC), Point-to-Point Interface protocol (PPI), DirectNET, Coprocessing Communication Module (CCM), and HostLink. The protocols have been developed and supported by many PLC makers.

PLCs proved to be a robust, reliable, and flexible way to bring automation to the shop floor, and RS-485 and its associated industrial protocols offered an inexpensive and simple-to-install network technology. Today, PLCs are typically used to control entire assembly lines, and most industrial automation uses some type of PLC. Many thousands of factory automation installations are based on venerable RS-232 and RS-485 networks.

Ethernet enters the factory

However, since the turn of the century, Ethernet has provided the most accessible and proven solution for a modern factory network. It is the most widely used wired networking option with extensive vendor support. Ethernet typically uses TCP/IP (part of the Internet Protocol (IP) suite) for routing and transport, ensuring cloud interoperability, a capability that is well beyond RS-232 and RS-485 technology.

'Industrial Ethernet' describes Ethernet systems adapted for factory use. Such systems are characterized by rugged hardware and industrial standard software. Industrial Ethernet is a proven and mature technology for factory automation that allows a remote supervisor to easily access drives, PLCs, and I/O devices on the manufacturing floor. The infrastructure typically uses line or ring topologies because these help to shorten cable runs (mitigating the impact of electromagnetic interference (EMI)), reduce latency, and build in a degree of redundancy.

Standard Ethernet's communication mechanism is prone to disruption and lost packets, which increase latency and make it unsuitable for the near real-time demands of fast-moving

Figure 3: The 7940124933 Industrial Gateway Communication Device bridges the gap between Industrial Ethernet and up to four RS-232/RS-485 serial networks. The 7940124932 version supports two serial ports. Image source: Weidmüller

and synchronized production lines. Such an environment requires a deterministic protocol to ensure machine instructions arrive on time, every time, no matter how high the network load.

To overcome this challenge, Industrial Ethernet hardware is complemented by customized software. There are several proven Industrial Ethernet protocols available, including Ethernet/IP, ModbusTCP, and PROFINET. Each is designed to ensure a high level of determinism for industrial automation applications.

Standard Ethernet comprises the PHY, data link, network, and transport layers (which use either TCP/IP or UDP/IP as the transport) and can be viewed as a communication mechanism that brings efficiency, speed, and versatility. In contrast, Industrial Ethernet protocols, for example, PROFINET, use the application layer of the Industrial Ethernet stack (Figure 2).

For more, see 'Design for Rugged IoT Applications Using Industrial Ethernet-Based Power and Data Networks'.

A gateway to Industry 4.0

Updating legacy RS-232 and RS-485 factory automation systems to Industrial Ethernet is daunting for designers. There could be thousands of PLCs in a large factory and tens of kilometers of wiring. The cost and disruption caused by ripping out old systems for new replacements is not viable for many companies. Yet, without upgrading, a production facility will not be able to take advantage of the productivity gains promised by Industrial Ethernet.

One strategy to limit cost and disruption is to commit to an Industrial Ethernet backbone while retaining legacy serial buses, PLCs, and machines. Then, when machines are replaced or when new machines are added to the factory, they can be specified such that they're interoperable with the Ethernet backbone. This allows the factory to be gradually updated to the latest communications standards without production interruptions or major cashflow issues.

However, such a strategy creates a discontinuity between the RS-232/RS-485 and Industrial Ethernet networks. This discontinuity can be bridged with an Industrial Gateway Communication Device such as the 7940124932 or the 7940124933 (Figure 3) from Weidmüller. Each gateway is a single solution providing a cost-effective way to move data between PLCs and peripheral devices, using different

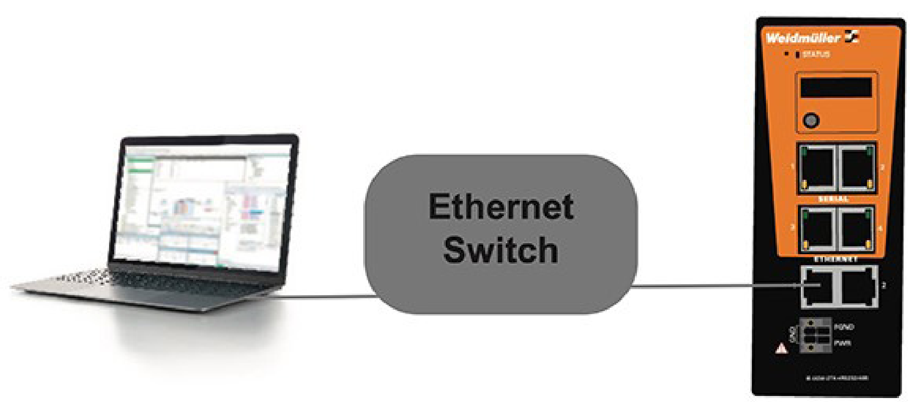


Figure 4: The industrial gateway setup involves connecting the device to an Ethernet switch and a power supply, then connecting a PC to the switch and configuring the gateway via a browser. Image source: Weidmüller

Figure 5: Dialog for programming the Weidmüller gateway with PLC tag properties. The tags are names assigned to variables of any type stored in the PLC memory. Image source: Weidmüller

protocols and without having to add wiring or multiple gateways.

These Weidmüller gateways offer two Ethernet ports and either two (in the 7940124932 model) or four serial ports (7940124933). They support EtherNet/IP, EtherNet/IP-PCCC, ModbusTCP, and S7comm (a Siemens Industrial Ethernet protocol) at up to 10 Mbits/s. The Ethernet ports accept an 8 pin RJ45 connector. On the serial side, the gateways can handle Modbus RTU, Modbus ASCII, DF1-CIP, DF1-PCCC, PPI, DirectNET, CCM, and HostLink serial protocols. Note that while the serial support is for RS-232/RS-485 standards, the serial input to the gateway is via the Ethernet-style 8-pin RJ45 connector rather than the RS-232/RS-485 type. The gateways are interoperable with PLCs from Automation Direct, GE, Rockwell Automation, Schneider, and Siemens. The gateways can be DIN rail mounted, and they operate over a 0 to 55˚C temperature range using a 12-to-24-volt input.

Once configured via a browser, the Weidmüller gateways require no other equipment to transfer serial data formatted for one of the supported RS-232/RS-485 serial protocols into one of the supported Industrial Ethernet protocols, or vice versa. Data can be transferred to and from any port in any combination without the need to edit any PLC code.

Getting started with industrial gateways

Configuring the Weidmüller gateway simply requires connecting the device to an Ethernet switch and then plugging in a PC into the other side of the switch (Figure 4). Once that's done, the gateway can be connected to the 12-to-24-volt supply. The PC can then be used to log in through a browser window where the main gateway dialog appears. Dialogs then simplify the setup of the Industrial Ethernet network, as well as the addition of Ethernet and serial network devices to the gateway. Finally, the gateway serial ports are set to match the serial port configuration of the connected controller.

The key to the gateway's ability to communicate between devices that use different protocols is the use of 'tag' data. The gateway enables the movement of tag data between different connected devices.

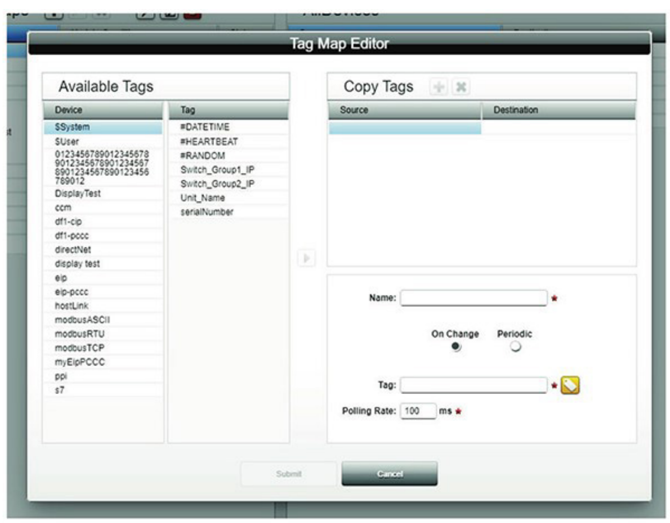


Figure 6: For each connected PLC, the Tag Map Editor enables each tag data source to be mapped to a data destination. The process is repeated for all connected devices. Image source: Weidmüller

Industry 4.0 enhances manufacturing productivity and efficiency. However, it requires new Industrial Ethernet infrastructure, which is expensive and disruptive to install.

Tags are key when programming modern PLCs. They are names assigned to variables of any type stored in the PLC memory. Some examples of tag names are: '#DATETIME', 'HEARTBEAT', and 'Switch_Group1_IP'. The tags are stored in the PLC's memory in a tag database.

In this tag database, all function blocks (for example, relays, timers, and counters) and program variables (for example, a timer value called 'Transmitter_ RF_ Mute_ Timer'), as well as all other objects, are stored as tagged variables with attributes such as initial value, float, string, integer, Boolean (on/off), ASCII text, discrete inputs, and discrete outputs. The tag approach allows for a more efficient approach to more complex programming but does require (as with other structured programming languages) that the developer assigns the variable tags as well as the data type in advance of their use in the program. Data arrays can also be defined in the tag database.

For each PLC connected to the gateway, the developer must specify the tags from which data will be read and the tags to which that data will then be written. This first requires the tags from each PLC connected to the gateway to be programmed into the gateway before it can use them for communication across the network.

This is done from the PC connected to the gateway via the Ethernet switch. By selecting the 'Add Tag' icon in the configuration browser window, a dialog is activated that allows the developer to specify the tag name, data type, address, and other related information if required. It is also possible to speed things up by importing tags from a .csv file (Figure 5).

Once the tags for all the connected devices have been entered, the next step is to create a 'tag map'. The tag map enables the gateway to read the data in the registers of a source PLC and write them to the correct destination device. The data in the registers is effectively the communication payload. The payload is extracted from the source tag using the source PLC protocol, and then delivered to the gateway memory for transmission to the destination tag using the destination device protocol. It's not critical that the source and destination tags have the same data type.

Creating the tag map is again performed from the PC connected to the Ethernet switch via the 'Add Tag Map' icon, which initiates the Tag Map Editor dialog (Figure 6). Each PLC connected to the network will need its own tag map. In the dialog, the target device is selected, and each tag to be used as a data source is 'mapped' to a data destination. The process is then repeated for all connected devices.

The final step in the process is to activate the tag map to initiate communication between the source and destination tags hosted on the network devices. A tag map viewer on the PC allows for a check that the right source data is heading to the right destination.

Conclusion

Industry 4.0 enhances manufacturing productivity and efficiency. However, it requires new Industrial Ethernet infrastructure, which is expensive and disruptive to install. As shown, industrial gateways allow for a staged introduction of Industry 4.0 by bridging the gap between existing RS-232/RS-485 networks and the phasing in of Industrial Ethernet infrastructure. Using these solutions, equipment and networks can be gradually upgraded over months or years with minimal disruption.

Supporting mass customization, high quality, and sustainable operations in Industry 4.0 factories

Written by:
Jeff Shepard, Contributing Editor, DigiKey

DigiKey

Supporting mass customization with high-quality and sustainable production processes can be challenging for designers of Industry 4.0 automated manufacturing systems. Multiple sensing and control devices need to be deployed and connected across various wired and wireless networks, and their state and energy consumption need to be monitored in real-time, all while meeting established sustainability standards.

To accommodate the variety of functions, networks, monitoring, and standards requirements, while also ensuring scalability and flexibility, automation system designers for Industry 4.0 don't have to piece it all together themselves. They can instead, incorporate compact integrated controllers to implement flexible production systems with high levels of quality and sustainability. These controllers have numerous embedded control and energy management functions, digital and analog inputs, and outputs (IOs), and the secure communications capabilities necessary to implement a scalable, flexible, and highly sustainable Industry 4.0 factory.

This article provides a brief overview of typical Industry 4.0 factory automation elements and requirements. It then introduces a family of compact and expandable controllers from Siemens as examples of programmable logic controllers (PLCs), which contain integrated communications interfaces and technology functions. It closes with a review of the International Standards Organization (ISO) 50001 and related standards for operational energy management, including an example of an energy management implementation for sustainability.

Key elements of an Industry 4.0 factory

A typical Industry 4.0 factory application comprises devices like temperature controls, pump and fan controls, conveyor systems, and packaging machines that require flexible integration and precision to ensure high-quality production. In addition, the energy consumption of these devices needs to be continuously monitored and analyzed to support efficient and sustainable operations. Additionally, it all needs to be supported with multiple layers of wired and wireless connectivity, ranging from distributed sensors and controllers to motor drives, energy meters, and machine technicians and operators in real time.

To address these diverse needs while speeding process deployment and reconfiguration, maximizing uptime, and ensuring efficient operation, automation system designers need dedicated process controllers with several key features. Such features include secure communication interfaces, digital and analog IOs, as well as integrated control functions like high-speed counters, pulse width modulation (PWM), pulse sequence outputs, speed control, positioning, condition monitoring, and energy management. In addition, communications interfaces need to be available that support protocols like serial communication, PROFIBUS, IO-Link, actuator sensor interface (AS-Interface), MODBUS real-time unit (RTU), universal serial interface (USI), TCP/IP, and mobile wireless standards.

Industry 4.0 connectivity

To cater to Industry 4.0 connectivity requirements, the SIMATIC S7-1200 family of PLCs from Siemens supports the connection of sensors, actuators, and motors to human-machine interfaces (HMIs) and to the cloud. It uses the OPC Unified Architecture (OPC UA), a machine-to-machine (M2M) communication protocol for industrial automation. OPC UA has a platform independent, service-oriented architecture that simplifies connectivity. It supports the integration of all classes of devices, automation systems, and software applications in an inherently secure environment. It includes field extensions specified by the Field Level Communication (FLC) initiative, based on the OPC UA Framework, and specified in International Electrotechnical Commission (IEC) 62541.

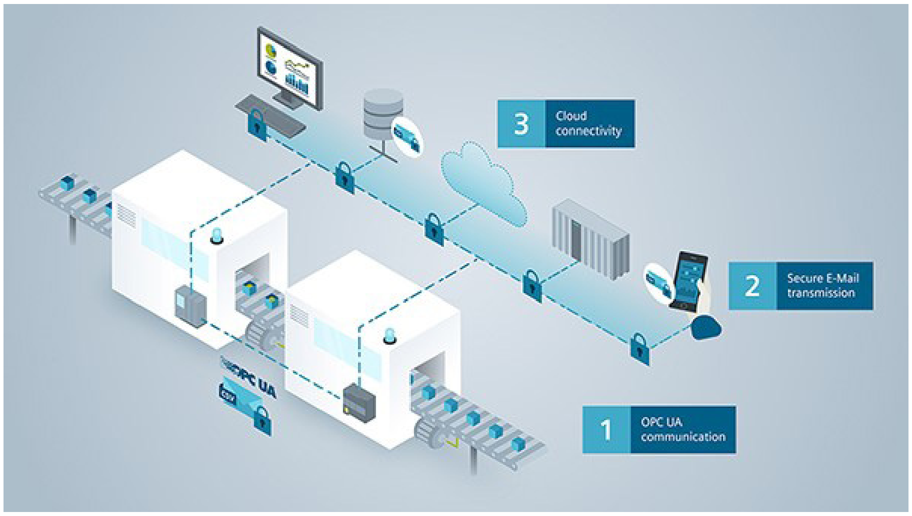


Figure 1: OPC UA is a foundational element of Industry 4.0 factory connectivity. Image source: Siemens

FLC provides equipment suppliers with an independent platform for secure and reliable communications that emphasizes authentication, signing, and data encryption. OPC UA is more than an M2M communications protocol; it's designed to support connections between the factory network and business networks. OPC UA Data Access on Siemens' SIMATIC S7-1200 PLCs provides for standardized horizontal and vertical communication, as well as compliance with industry-specific requirements such as The Organization for Machine Automation and Control Packaging Machine Language (OMAC PackML), an automation standard that makes it easier to transfer consistent machine data, as well as the Weihenstephan Standards (WS), which define a communication interface for the standardized transmission of machine data to higher level IT systems. Key features of OPC UA implementations on S7-1200 PLCs include (Figure 1):

- The ability to efficiently add new processes between PLCs and any higher level, business-oriented software layers
- A simplified implementation of industry-specific companion specifications with Siemens OPC UA Modeling Editor
- Cloud connectivity through a wireless connection to an Ethernet network
- DNS name resolution for simplified addressing with open user communication (OUC), including encryption
- A means to send emails securely, with optional attachments

Scalable controllers

In addition to integrated support for OPC UA communication, S7-1200 controllers like the 6ES72141AG400XB0 (Figure 2) and the 6ES72151BG400XB0 are highly flexible and scalable. The former operates from a 24-volt direct current (VDC) power supply and has 24 VDC inputs and outputs, while the latter operates from a 120 or 230 volt alternating current (VAC) power supply, with 24 VDC inputs and relay outputs.

All S7-1200 controllers have integrated IOs, are modularly expandable, and have several communications options. The Siemens Totally Integrated Automation (TIA) portal provides a simple software environment for developing control programs, and the SIMATIC automation tool can be used in the field for operating and maintaining SIMATIC S7-1200 controllers. Additional features include:

- A PROFINET interface to support scalability and flexibility
- Security features that include comprehensive access, copy, and manipulation protection
- Diagnostics, with messages displayed in simple, plain text in the Siemens TIA Portal, through a web server, on the SIMATIC HMI, and in the SIMATIC Automation Tool with no additional programming
- Safety features in certain models that can execute both standard and safety-related programs for applications up to Safety Integrity Level 3 (SIL3) defined in IEC 61508, and IEC 62061 and Performance Level e (PLe) defined in ISO 13849

Integrated technology functions like high-speed counters, PWM, pulse sequence outputs, speed control, and positioning make these controllers suitable for temperature control, pump and fan control, conveyor technology, and packaging machines. They are optimized for loop control, weighing, energy management, high-speed counting, radio frequency identification (RFID), and condition monitoring.

Flexible communications options

Comprehensive networking options are a hallmark of S7-1200 PLCs. Supported communications protocols include:

PROFINET: An open Industrial Ethernet (IE) standard. The integrated PROFINET interface uses TCP/IP standards and can be used for programming or to communicate with HMI devices and additional controllers.

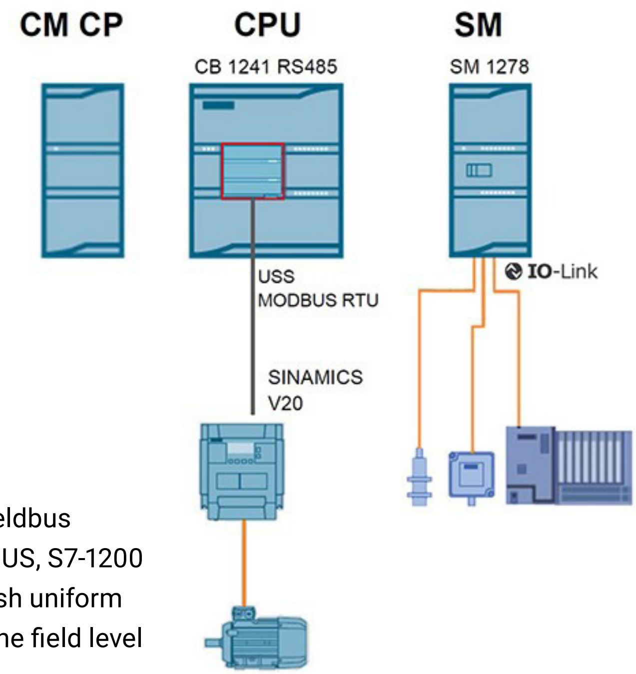


Figure 3: Expandable communications for S7-1200 PLCs are supported by a combination of external (left and right) and internal (red box top center) expansion modules. Image source: Siemens

PROFIBUS: This is a fieldbus standard. With PROFIBUS, S7-1200 controllers can establish uniform communication from the field level to the control level.

AS-Interface: This is a fieldbus standard for actuators and sensors. Up to 62 AS-Interface standard slaves, such as motor starters, position switches, and modules can be connected.

In addition to the integrated communications capabilities, modules are available that support additional protocols such as:

- CANopen
- Modbus RTU
- Modbus TCP
- IO-Link
- General Packet Radio Service (GPRS)/Long Term Evolution (LTE)
- RS-485, RS-422, and RS-232
- USS

Figure 2: Siemens S7-1200 controllers have integrated OPC UA communications support. Image source: Siemens

Achieving mass customization and high quality

Their wide range of functionality and communications capabilities allow the S7-1200 PLCs to accommodate the drive toward mass customization and high quality that's occurring as part of Industry 4.0. While there are numerous ways to achieve those goals, the following example shows the use of communication expansion modules for wireless cellular connectivity, RS-485/USS/Modbus RTU serial connectivity for motor control, and IO-Link for simpler connectivity to sensors and actuators, relative to field buses (Figure 3).

In Figure 3, the 'CM CP' is a GPRS wireless communications module like the 6GK72427KX310XE0 that can be used for Cloud

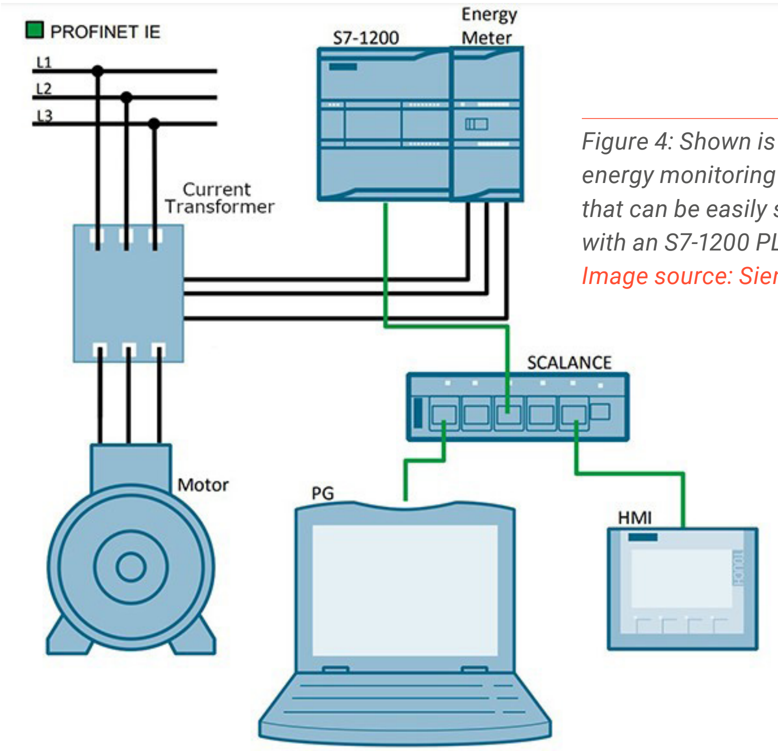


Figure 4: Shown is a typical energy monitoring application that can be easily supported with an S7-1200 PLC.
Image source: Siemens

connectivity. An RS-485 communication board like the 6ES72411CH301XB0 resides inside an S7-1200 PLC ("CPU") and is used to communicate with a motor drive (the SINAMICs V20) through the USS/Modbus RTU interface. The 'SM' on the right comprises an IO-Link master communications module like the 6ES72784BD320XB0. The IO-Link master is connected to two sensors on the left and center, as well as to an IO-Link hub on the right. The hub can connect to additional IO-Link devices.

Sustainable energy management

Improved energy efficiency and sustainability rely on smart energy management, which in turn relies on more granular and real-time energy consumption data. It increasingly begins with the consideration of ISO 50001 standards for operational energy management. This is a foundational standard that provides a framework of requirements, including the development of policies, targets, and objectives for more efficient energy use, and the use of data to measure the results. ISO 50001 is supported by additional standards, including:

- ISO 50003 ensures the effectiveness of energy management systems (EnMS). It encompasses auditing, personnel competence requirements, and the duration of audits and multi-site sampling
- ISO 50004 helps organizations take a systematic approach toward achieving continual improvement in energy management and energy performance
- ISO 50006 expands on how to meet ISO 50001 requirements, including the development and maintenance of energy performance indicators (EnPIs) and energy baselines (EnBs) for ongoing performance monitoring

The EnPIs and EnBs in ISO 50006 enable the effective measurement and management of energy performance, which can help to optimize energy efficiency. In addition to improvements in sustainability, better energy management leads to significant cost savings. The standard defines the starting point (EnBs) and meaningful performance metrics (EnPIs), and it identifies four types of indicators: 'absolute' and 'relative energy performance indicators', along with 'statistical' and 'technical' models.

Siemens' S7-1200 controllers can simplify the implementation of these ISO standards and support highly effective energy management systems. Automation system designers can add an energy meter module to enable measurement, evaluation, and display of energy consumption data in real time. Figure 4 illustrates a typical application:

1. The motor represents a typical load being monitored for energy

consumption
2. The current transformer transforms the energy consumption into a measurable quantity for the energy meter module. The meter also measures numerous other parameters like voltage and power factor
3. Software in the S7-1200 controller evaluates the measurements and saves statistics on the energy consumption in a data log. It's connected to the PG/PC and HMI through a SCALANCE industrial router using PROFINET IE buses
4. The HMI displays the measured values and enables operators to evaluate parameters such as power consumption peaks over time
5. The controller can also send the data log onto the PG/PC in the form of standard web pages

Energy meter module

In an application such as that shown in Figure 4, an SM 1238 energy meter module can be used for data acquisition (Figure 5). It can be used in single and three-phase supply systems up to 480 VAC. These modules can provide S7-1200 controllers with the data needed to support compliance with ISO 50001, 50003, 50004, and 50006 requirements. They can record over 200 electrical measurements and energy values, including:

- Currents
- Voltages
- Phase angles
- Frequencies
- Power factors
- Power consumption
- Minimum and maximum values
- Operating hours
- Energy/electrical work

Conclusion

To simplify and accelerate the deployment of sustainable Industry 4.0 factory networks, automation system designers can use the S7-1200 family of PLCs and expansion modules. These solutions support a wide range of secure communications options, have integrated control functions and digital and analog IOs, and are expandable to support a wide array of applications, including energy management.

Figure 5: The SM 1238 is an energy monitoring module for single and three-phase power systems.
Image source: Siemens

Recommended reading

1. How to Make Smart Factory Actuators More Productive Using IO-Link
2. How to Use Traceability 4.0 Solutions for Improved Product Safety, Compliance, and Tracking
3. Programming PLCs: A Technical Summary with Siemens Examples

Vertical Farming: leveraging KUNBUS' Revolution Pi for enhanced efficiency and productivity

Written by:
Paige West, Managing Editor,
Electronic Specifier

DigiKey

Vertical farming offers a sustainable, efficient approach to growing crops by cultivating plants in vertically-stacked layers within controlled indoor environments using various technologies.

By breaking free from the constraints of traditional outdoor farming, vertical farms have the potential to redefine how we produce food in urban areas where land is scarce and the demand for fresh, locally-grown produce is higher than ever. This article explores the role of automation in vertical farms and explores how KUNBUS' Revolution Pi platform, combined with sensor technology and LED lighting solutions, can be utilized to optimize vertical farming operations.

A sustainable solution for food production

One of the most significant benefits of vertical farming is its space efficiency. Unlike conventional farms that require vast expanses of land, vertical farms can grow a substantial amount of crops in a fraction of the space. By stacking growing beds vertically and utilizing advanced hydroponic or aeroponic systems, these facilities can maximize their yield per square foot, making vertical farming ideal for cities with limited or expensive real estate.

In addition to space efficiency, vertical farms can also improve water conservation. Conventional farming methods rely on extensive irrigation systems that can lead to water waste and runoff, depleting natural resources and contributing to environmental degradation. In contrast, vertical farms employ closed-loop hydroponic or aeroponic systems that recirculate water and nutrients, dramatically reducing water consumption by up to 95% compared to other farming techniques.

Another benefit of vertical farming is its ability to produce crops without using harmful pesticides or herbicides. In outdoor farms, pests and diseases pose a constant threat to crop health and yield, forcing farmers to rely heavily on chemical treatments to protect their harvests. However, the controlled environment of vertical farms minimizes the risk of infestations and the spread of plant diseases, virtually eliminating the need for pesticides and herbicides.

Vertical farming also provides a solution to the problem of food miles – the distance that produce travels from farms to tables. In conventional farms, crops are transported over longer distances, leading to more emissions, higher transportation costs, and reduced freshness. By strategically locating vertical farms near urban centers, the farm-to-table journey can be considerably shorter, cutting down on transportation costs and associated carbon footprints.

Environmental factors to monitor and control in vertical farms

In vertical farming, maintaining an optimal climate is of utmost importance for the health, growth, and productivity of the crops. Four climatic factors that require precise monitoring and control are air temperature, humidity, CO2 levels, and air speed. Each of these parameters is necessary to create an ideal growing environment, and even slight deviations from the optimal range can have a significant impact on plant development and yield.

Air temperature is perhaps the most fundamental climatic factor in vertical farming, as it directly influences plant growth, metabolism, and transpiration. Different crops have varying temperature requirements, and it is vital to maintain the appropriate range for each species to ensure optimal growth and prevent stress. For hydroponics, crops thrive in temperatures from 18°C and 28°C (65°F to 82°F), although some may require slightly cooler or warmer conditions.

Proper humidity levels are necessary for plant transpiration, nutrient uptake, and overall health. Excessive humidity can lead to fungal growth and disease, while too little can cause crops to become stressed and dry out. Most crops require relative humidity levels between 50 and 70%, although some tropical species require higher levels.

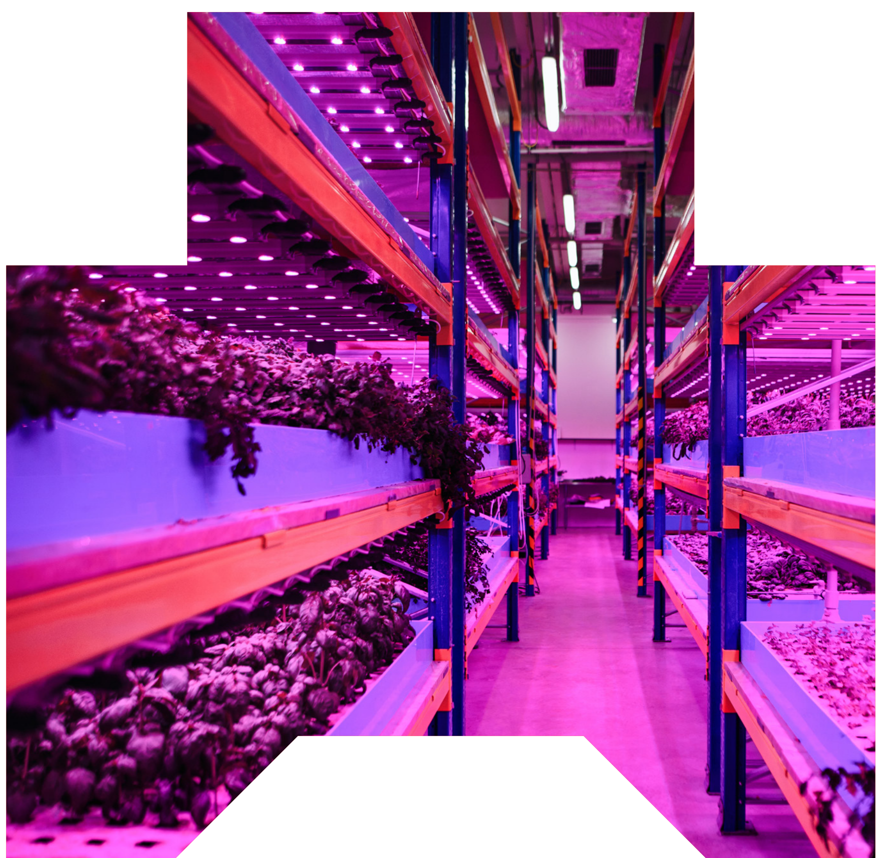
CO_2 levels in growing environments also have a direct impact on plant growth and productivity. As plants photosynthesize, they absorb CO_2 from the air and convert it into the energy needed for growth and development. In the controlled environment of a vertical farm, CO_2 levels can be monitored and adjusted to optimize photosynthesis and boost crop yields. Sensors and injection systems allow growers maintain the ideal concentration for their specific crops, maximizing the efficiency of photosynthesis and accelerating growth rates.

Air speed, or the movement of air within the growing environment, must be carefully controlled in vertical farms. Proper circulation helps to regulate temperature and humidity, prevent stagnation, and ensure even distribution of CO_2 and other nutrients. In addition, gentle airflow can stimulate plant growth by mimicking the natural wind conditions that plants would experience outdoors. Automation controls, such as fans and ventilation systems, can maintain an optimal air speed for crops, promoting healthy growth and minimizing the risk of damage or stress.

Automation controls: optimizing growth conditions and production

The basis of any successful vertical farming operation is the ability to monitor and regulate the environmental factors that affect crop growth and health. Automation controls are the eyes, ears, and hands of the farm, continuously gathering data from a network of sensors and using it to make real-time adjustments to parameters such as temperature, humidity, CO_2 levels, and light intensity. By maintaining ideal horticultural conditions, these systems maintain an environment in which crops can thrive, free from the stresses and fluctuations that can hamper crop growth.

In addition to environmental regulation, automation controls also play a crucial role in the precise management of water and nutrients. Hydroponic and aeroponic growing systems depend on the delivery of carefully balanced nutrients to the plant roots, and slight deviations from the optimal formula can have an outsized impact on crop health and yield. Automated systems ensure that each plant receives exactly the right amount of water and nutrients at the right time, minimizing waste and promoting healthy growth. By monitoring nutrient levels and adjusting delivery rates, these systems offer a balance of resources, optimizing plant uptake



and preventing deficiencies or toxicities that could compromise crop quality.

Automation also reduces labor costs and optimizes the workforce in vertical farming operations. Many of the tasks performed by human workers, such as planting, watering, and harvesting, can now be automated using robotic systems and conveyor belts. This not only reduces the need for manual labor, but also allows vertical farms to operate with a smaller, specialized team focused on monitoring, maintenance, and quality control.

Perhaps most importantly, automation controls enable vertical farms to scale up their operations as demand for produce grows. Automated systems can seamlessly replicate successful growing processes across levels and locations, ensuring that quality and efficiency are maintained, even as operations grow in size and complexity.

Data collection and monitoring

Real-time data collection plays a crucial role in enabling predictive maintenance and preventing equipment failures in vertical farms. By monitoring the performance and health of components like pumps, fans, and sensors, growers can detect early warning signs of potential issues and schedule maintenance or repairs before failures occur. This proactive approach to maintenance can help minimize downtime, reduce repair costs, and ensure that critical equipment is always operating at peak performance.

The following are some key products for data collection and monitoring in vertical farms:

Product highlight: TEKTELIC KIWI agriculture sensor (T0005982)

TEKTELIC KIWI Agriculture Sensor (T0005982).
Image credit: DigiKey

TEKTELIC Communications' KIWI Agriculture Sensor is a powerful, versatile device that offers a comprehensive suite of features for monitoring key environmental parameters in vertical farming operations. Designed specifically for agricultural applications, the KIWI sensor provides real-time data on soil moisture and temperature, ambient humidity and temperature, and light intensity.

T0005982 accurately measures soil moisture levels using advanced capacitance-based sensing technology. By monitoring the moisture content of the growing medium, growers can optimize irrigation schedules and ensure that crops are receiving the right amount of water at the right time. This not only helps conserve water, but promotes healthy root development and minimizes the risk of overwatering or underwatering.

In addition to soil moisture, the KIWI sensor also measures soil temperature, providing growers with valuable information about the thermal environment of the root zone. Soil temperature plays a vital role in many plant processes, including nutrient uptake, root growth, and microbial activity, and can be influenced by factors like air temperature, lighting, and irrigation. The T0005982 also features sensors for measuring ambient humidity and temperature, providing a comprehensive picture of the overall growing environment.

Another key feature of the KIWI sensor is its ability to detect and measure light intensity using advanced photodiode technology. Light is one of the most critical inputs for plant growth, and the intensity, duration, and spectral composition of light impacts crop morphology, yield, and quality. By continuously monitoring light levels and comparing them to optimal ranges for each crop and growth stage, the sensor allows growers to adjust lighting strategies to ensure that crops receive the right amount and type of light for healthy growth and development.

T0005982 is designed for long-term, low-maintenance operation in harsh growing environments. With a battery life of up to 10 years and an IP67-rated enclosure fully protected against dust and water ingress, the KIWI sensor can provide reliable, continuous data collection without the need for frequent battery replacements or maintenance.

Finally, the KIWI sensor is designed for easy integration with existing vertical farming control and automation systems. It communicates via LoRaWAN, which enables long-range, low-power data transmission without the need for complex wiring or infrastructure. This makes it easy to deploy these sensors throughout large-scale vertical farming operations and integrate them with central control systems, data analytics platforms, and other software tools.

Product highlight: Beyond LED technology LED grow lights

Beyond LED Steel Series Grow light Image credit: DigiKey

LED technology is favored as an alternative to sunlight in vertical farming applications, offering a range of benefits including energy efficiency, spectral control, and smart automation capabilities. Beyond LED Technology LED Grow Lights are a prime example of the cutting-edge LED lighting solutions currently transforming the vertical farming industry. One of their primary features is the ability to provide a full-spectrum light output that mimics natural sunlight. This is achieved by using a carefully selected blend of LED chips that emit light across the entire photosynthetically active radiation (PAR) spectrum, from 400 to 700 nm.

The full-spectrum output of Beyond LED grow lights is critical for supporting optimal plant growth and development, as different wavelengths of light are absorbed by different plant pigments and play distinct roles in photosynthesis and other physiological processes. For example, red light (620-750 nm) is primarily absorbed by chlorophyll and is essential for driving photosynthesis and energy production. Blue light (450-495 nm), on the other hand, is absorbed by cryptochrome pigments and plays a role in regulating plant morphology, leaf expansion, and stomatal opening. By providing a balanced mix of red, blue, and other wavelengths, grow lights enable plants to utilize light more efficiently and achieve optimal growth and development.

In addition to full-spectrum output, Beyond LED grow lights also offer high PPFD (photosynthetic photon flux density) output, which measures the amount of PAR light that is actually reaching the plant canopy. The lights are capable of delivering up to 2400 μmol/s of PPFD, which is more than sufficient for most high-light crops like tomatoes, peppers, and cucumbers. This high PPFD output is achieved through the use of high-efficiency LED chips and precision optics that focus the light onto the plant canopy, minimizing wasted light and maximizing the amount of energy that is available for photosynthesis.

Another key feature of the Beyond LED grow lights is their passive cooling design, which helps to extend the lifespan of the LEDs and reduce energy consumption. Unlike conventional HPS or fluorescent lamps, which generate significant heat and require active cooling systems to prevent overheating, Beyond LED grow lights use a fanless design that relies on natural convection and heat sinks to dissipate the heat. This not only minimizes the energy required for cooling but also minimizes the risk of equipment failure and maintenance downtime. These grow lights also offer dimming capabilities, which allow growers to precisely control the intensity of the light output to match the needs of various crops and growth stages. Dimming is achieved through either 0-10V or PWM (pulse-width modulation) control, depending on the specific application.

Finally, the Beyond LED grow lights are designed with smart control capabilities that allow them to be easily integrated into larger vertical farming control systems. The lights can be controlled remotely via central control panels or apps, allowing growers to adjust light intensity, spectrum, and scheduling from any part of the world. They can also be programmed to automatically adjust their output based on data from sensors and other devices in the growing environment, enabling dynamic and responsive lighting control that adapts to changing conditions in real-time.

KUNBUS Revolution Pi platform: a versatile solution for vertical farms

Revolution Pi is an open, modular industrial PC developed by KUNBUS, a leading manufacturer of industrial communication solutions. KUNBUS simplifies industrial communication by providing easy-to-use, flexible, and cost-effective solutions that bridge the gap between different protocols and systems in industrial facilities. Based on the Raspberry Pi Compute Module, Revolution Pi is designed to meet the demands of industrial environments, such as vertical farms. It incorporates the flexibility and affordability of Raspberry Pi with industrial features such as wide temperature range, vibration resistance, and sturdiness.

The KUNBUS Revolution Pi platform. Credit: KUNBUS

The Revolution Pi runs on various operating systems, including Linux and Windows IoT Core, allowing users to develop and deploy custom applications for automation, data acquisition, and remote monitoring. It also supports a broad range of interfaces, including digital inputs/outputs, analog inputs, and serial ports, making it suitable for connecting to sensors, actuators, and other industrial devices. Housed in a compact DIN-rail casing, the platform offers three base modules that can be expanded with I/O modules and fieldbus gateways. The 24V powered modules can be connected via an overhead connector and can be quickly configured using a graphical tool.

Revolution Pi runs on an adapted Raspberry Pi OS with a real-time patch, ensuring compatibility with most Raspberry Pi applications. This flexibility allows vertical farm operators to leverage an already extensive Raspberry Pi ecosystem while benefiting from the robustness and reliability of an industrial-grade platform. Moreover, support for common programming languages like Python and C++ makes it easy for developers to create tailored software applications that meet the unique needs of their vertical farming operations.

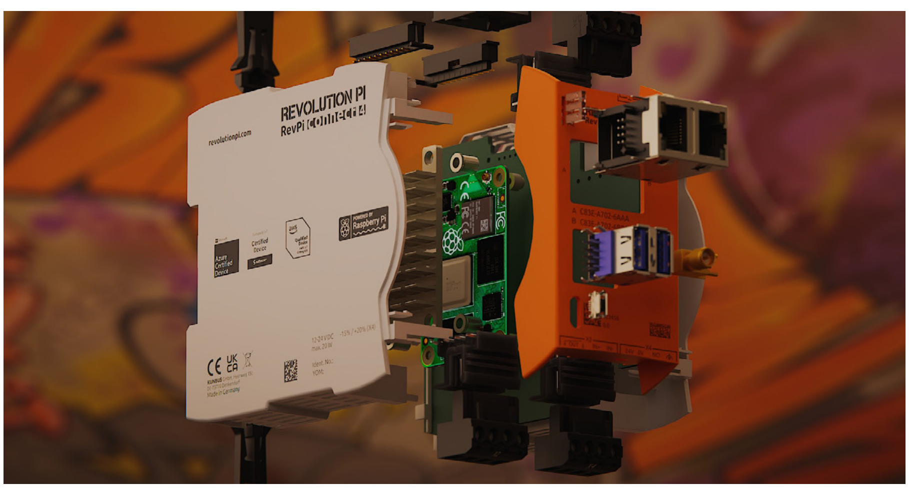
Application with agricultural sensors and LED grow light components

KUNBUS' Revolution Pi platform, combined with agricultural sensors like the TEKTELIC KIWI and LED grow lights from Beyond LED, provides a flexible, scalable solution to drive automation and optimization in vertical farming. By enabling precise monitoring and control of every aspect of the growing environment, this integrated approach helps maximize efficiency, minimize costs, and ensure consistent production of high-quality crops.

Revolution Pi's support for various industrial communication protocols allows users to create scalable control systems to manage every aspect of the vertical farming environment from one centralized interface. At the heart of the platform is the Raspberry Pi Compute Module, which provides the processing power and flexibility needed to handle complex automation tasks. The platform's modular design also allows customers to expand its capabilities by adding various I/O modules and gateways, enabling connectivity with a wide range of sensors, actuators, and other industrial devices.

The KIWI Agriculture Sensor can be integrated with Revolution Pi via LoRaWAN connectivity. This low-power, long-range wireless communication protocol allows the sensor to transmit data wirelessly to a Revolution Pi base module, avoiding complex wiring or infrastructure. The base module can then process sensor data using custom software applications to enable real-time monitoring, data logging, and automated control of various parameters. For example, when the sensor detects that soil moisture levels have fallen below a predefined threshold, Revolution Pi can trigger irrigation systems to deliver water to the affected plants. Similarly, when the sensor detects sub-optimal temperature or humidity, Revolution Pi can activate HVAC systems or adjust the ventilation to maintain ideal growing conditions.

Revolution Pi also provides a powerful platform for integrating and controlling LED grow lights. For instance, it can be programmed to adjust light intensity, spectrum, and photoperiod based on predefined schedules or in response to real-time data from sensors. This dynamic approach to lighting control helps optimize energy usage, minimize waste, and ensure that plants receive the optimal amount and quality of light for healthy growth and development.



The KUNBUS Revolution Pi platform. Credit: KUNBUS

Conclusion

Utilizing automation systems to precisely monitor and control environmental conditions, resource inputs, and crop growth, vertical farm operators are achieving unprecedented levels of precision, consistency, and efficiency in crop production. Automation has enabled these farms to produce higher yields of better-quality crops with fewer resources and less waste than ever before, while also reducing labor costs, improving worker safety, and minimizing the risk of errors. Moreover, vast amounts of data generated from various aspects of the growing process enables growers to learn, adapt, and improve their operations over time. The integration of automation technologies in vertical farming shows how technology can enhance food production and sustainability in the face of growing global challenges.

We've got the new products your ideas deserve

We have over 400,000 new, name-brand products in stock and ready to ship–with more added daily. If you can design it, we can help you build it.

Find what you need at digikey.com/new or call 1.800.344.4539

DigiKey

we get technical

DigiKey is an authorized distributor for all supplier partners. New products added daily. DigiKey and DigiKey Electronics are registered trademarks of DigiKey Electronics in the U.S. and other countries. © 2024 DigiKey Electronics, 701 Brooks Ave. South, Thief River Falls, MN 56701, USA

ECIA MEMBER
Supporting The Authorized Channel