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Industry addresses cyber perils

DIGITAL TRANSFORMATION HAS brought greater insights, more efficient production and higher machine uptime to manufacturing facilities. But with great advancements come great perils. Cybersecurity—once a concern harbored by the keepers of the enterprise network—has become a necessity with factory-floor data being shared on-premise and into the cloud. It was one of the topics discussed at the 2023 Control System Integrators Association (CSIA) Executive Conference in New Orleans.

Information technology (IT) and operational technology (OT) are coming together and working together, explained Ken Hackett, director of business development, General Control Systems, a system integrator in Albany, New York, with multiple offices around the United States. "System integrators are avid supporters and trusted advisors to both sides," he said. "There's some type of cybersecurity in every project we quote."

General Control Systems sees itself as trusted advisor on the OT side and is bringing that insight to the IT side, explained Hackett. "The OT side doesn't want their equipment locked down 100%, but IT wants it done in a safe manner," he said. "It's really educating on both sides. On the OT side, the programmable logic controller (PLC) is the easiest place to start making security changes. Human-machine interfaces (HMIs) are another place that you can upgrade. Those are the two easiest ways. In IT, your servers are the easiest."

The attacks brought awareness to the cybersecurity industry.

Hackett also cited the Purdue model for industrial-control-system security as important because of structure. "They can make sure they lock down what needs to be locked down from the IT side," he explained.

"Nobody knows OT systems better than system integrators," explained Keith Mandachit, engineering manager, Huffman Engineering, a system integrator in Lincoln, Nebraska. "The number-one priority is keeping them running. We had a new client, around July 4, 2017, that needed our help because their systems were down. It's the eeriest feeling when you're walking into a manufacturing facility, and it was dead silent. Every machine had a ransomware screen on it. We spent a week there, helping them to get their critical systems back online. Employees were coming in and dropping their laptops in a pile on the conference table. They were a global pharma company, so every site got hit."

The attacks brought awareness to the cybersecurity industry and stressed the importance of analyzing the risk, explained Mandachit. "Application software on the OT side sometimes lags behind what's available and being used on the IT side," he said. cd

Jeremy Pollard
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IEC terminal blocks' impact on panel design

TERMINAL BLOCKS ARE not that exciting to most engineers, I'm sure. They form a major part in any control panel with any type of automation hardware installed in it.

Termination points in any system are required for many reasons, such as the programmable logic controller (PLC) I/O wired to a terminal block in an assembly shop. This allows the engineer to bring the sensors and devices into and out of the control panel when it arrives on site.

When I was working with Allen-Bradley (AB), which is now part of Rockwell Automation, in the 1970s and 1980s, its terminal-block line was the 1492 series. They were an AB design and locally manufactured. They were robust with big screws, and they included all of the things that you would have needed to be successful, such as end blocks and gang strips to connect multiple blocks together—like a jumper for multiple blocks.

> The ability to have power terminal blocks is there with all the same features as control terminations.

Then came Weidmuller and its line of IEC-based terminal blocks. One of the reasons this development caused an uproar in AB terminal-block land was the fact that you could fit three IEC terminations in the physical space of one 1492-CA1 block.

Panel oversizing was going to become a thing of the past due to terminations. I remember being in the panel shop at AB in Cambridge, Ontario, and seeing a double-door 80-inch-high-by-60-inch-wide panel with a 1774 PLC processor and I/O on one side, and the other side completely filled with terminal blocks and wireways.

While I have no idea if IEC-type blocks would have allowed for a smaller panel in this case, the sight of hundreds of blocks in that space was a thing of beauty.

The 1492 lineup of blocks were not competitive with the IEC designs. When they first hit the North American market, I remember a conversation that my district manager had with the vice president of sales for my local distributor. It kind of went like this:

"You will not stock the IEC terminal blocks in any branch. The distributor agreement specifically states that you cannot have any competing product on your shelf, so you have to get rid of all those blocks immediately."

Response: "I have to sell them, so you are saying we can't restock after that?"

Answer: "Yes."

After a short silence, my district manager stated, because he knew that AB would lose projects over terminal blocks: "What you do after I leave is something I don't want to know about."

How's that for a nod-nod-wink-wink moment. And, yes, they kept selling the IEC blocks and we lost about .05% of our business with the distributor.

One of the huge advantages with the IEC blocks was the simple fact that you could remove a center pin to disconnect without having to physically remove the wire. It was simple, but effective.

They were stackable and made from hard material and were much easier to install and keep organized. The amount of options made the decision by distributors understandable.

These days terminal blocks are the bullpen of automation.

The ability to have multiple methods of connectivity via snap-in connections and screw terminals is wild in comparison to 1977.

In fact, the ability to have power terminal blocks is there with all the same features as control terminations.

The first time I had the privilege of working with IEC blocks was about 30 years ago. I couldn't believe the fact that such a small block could be rated as it was.

The panel size was the benefit for sure, but the ability to better tray the cables/wires due to the stacks was crazy in my mind. There was an issue of wire bundles and the flex, but by and large the benefits outweighed the downside.

One of the big advancements with using these smaller blocks was the crimp on pins used to insert into the terminal. The issue of fraying wires was to be no more.

There are so many options for connectivity with push-in technology, tension clamp and snap-in, and the ancient method of screw terminals allows the user to select a favorite one for the job. Cd

JEREMY POLLARD, CET, has been writing about technology and software issues for many years. Pollard has been involved in control system programming and training for more than 25 years.

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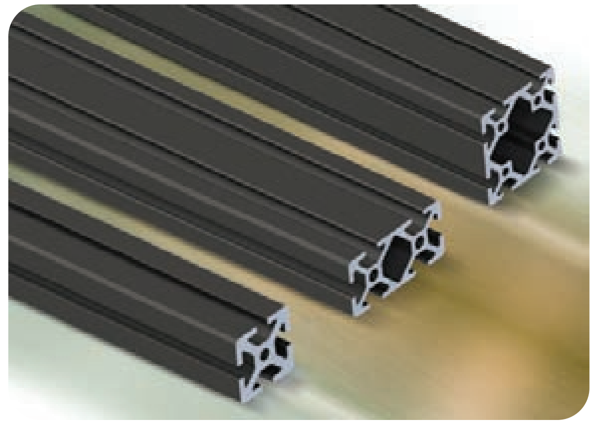

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Rick Rice

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How automation transforms industrial safety

WHEN IT COMES TO automation, safety is the first priority when people need to interact with the equipment.

Over the years, safety devices have changed a lot. In the early days of automation, e-stops and door switches were pretty much all that we had to work with.

In the control cabinet, an electromechanical relay provided the means of interrupting the control voltage to isolate the driven devices from the source of power. The solution was simple but rife with risk of failure.

Safety circuits were a single circuit chain of devices powering a control relay. That control relay would permit power to output devices, as long as the chain was intact.

The manufacturing environment has changed dramatically in just a few short years.

With a single circuit, any one of the devices in the chain could fail, and the circuit was no longer safe. Contacts wear out over time and could fuse in the closed position with the user none the wiser.

The same holds true for the control relay. Over time, the springs in the relay get weaker and could allow the contacts on the relay to remain closed after the power is removed from the coil.

Safety has changed a lot, and the technology behind that is driving how we approach automation. Dedicated safety relays with dual-redundant circuits are the standard by which we design our circuits.

Built-in to the safety relay are monitoring algorithms that watch for small variations in the twin circuits to capture when a device, or subcomponent of that device, is failing and annunciate accordingly.

Devices used in a safety circuit have advanced with the technology, and all the major manufacturers offer a wide variety of components to cover pretty much anything you might want to protect.

It is the availability of such a broad spectrum of safety devices that has dictated the type of automation that can be deployed safely.

The manufacturing environment has changed dramatically in just a few short years, and the proliferation of collaborative robots has made the interaction between people and machine into a close-quarters dance with increased risk but for the use of sophisticated safety systems and devices.

The choice of components breaks down into categories based on three questions:

- How do we sense the danger?
- How do we stop the action?
- What makes that decision?

Sensing a risk starts with assuming that a human is going to be present in close proximity to the operational envelope of the machine. The goal is to determine how close the person is and alter the behavior of the machine based on the real or perceived risk at that distance.

For example, a collaborative robot (cobot) is deemed collaborative because it can operate in close proximity to a person without the need for a physical barrier to isolate one from the other.

Some of the main considerations in determining whether it's collaborative are the size, speed and mass of the robot.

A small robot, not much bigger than a person, with a payload of 2 kg or 5 kg, can't move very far or very fast and, with given limitations, can work in close proximity to a person.

To limit the risk of working in close proximity with this small robot, some safety features are employed. The joints in the robot include technology to sense the resistance to movement.

If the robot bumps into something, like a person, the opposition to the intended movement is detected and corrective action is taken. Depending on the opposing force, it could slow down the action or actually stop and move in the opposite direction before coming to a stop.

Another safety feature is pressure-sensitive safety skin. This technology senses the state of the "skin" of the robot when in an untouched state and then looks for a change due to a foreign object pressing on the skin.

Yet another safety feature is a loosely fit guard on the end of arm tool that is easily knocked off with little pressure applied. A safety switch on the guard is active as long as the guard is in place and immediately cuts off the safety circuit if the guard is displaced.

While these techniques are effective for a small, slower-moving robot, the risks are greatly raised if the robot is larger and faster with a larger payload capacity. For these applications, additional features must be added. It is no longer enough to just sense the bumping of a person with the robot.

The approach to automation is to split the function into collaborative and non-collaborative mode.

A combination of light curtains and area scanners are deployed to extend the operating envelope outward to reach a point where higher-speed motion can happen in a non-collaborative mode.

If a person or object is detected to breach that larger area, the robot automatically slows down to a collaborative behavior where all the other sensing methods can be safely employed.

In this way, an industrial robot can be employed in a less-than-fully-enclosed envelope with the additional safeguards in place to prevent high-speed motion when necessary.

The preceding scenarios elaborated on methods employed to sense a risk. The control system must then utilize methods to reduce or stop motion when needed.

A number of safe motion features can be employed in this situation. While not a complete list, here are some of the means by which motion can be affected in a safety-triggered event.

Safe torque off (STO) is the base motion safety function whereby the drive is rendered to a no-torque state. This means, regardless of a potential command, the output stage of the drive is completely disabled electrically.

Safe stop and safe stop emergency describe two other reactions to a safety situation. In a safe-stop function, the motor is ramped down to zero speed in a controlled manner before the STO is enacted.

For a safe stop emergency, the system can either deploy a safe stop—ramp to zero—or a safe torque off, depending on the device being controlled.

Other safety motion methods include a safety limited speed (SLS), which forces motion to a specific slow speed, and safety maximum speed (SMS), where the motion is limited to speed less than full speed but not a specific slow speed.

The safe torque off feature has revolutionized machine design because it can be used to safely isolate high-voltage presence on a machine during an e-stop condition.

With the output stage of the drive disabled, power to a control system can remain on, rather than a complete power-down lockout of the mains to a control cabinet.

Since the means of power isolation is built-in to the drive, there is no need for individual safety contactors for each drive.

Sensing a risk and bringing the motion to a safe condition must be done in a way that is proven, reliable and repeatable. While a safety relay might be employed to make these decisions, more complicated machines might dictate the employment of a dedicated safety processor to make the critical responses.

The primary difference between a safety relay and a safety processor is the ability to add logic to create groups of safety devices and associated safety outputs.

A safety relay would simply monitor one or more safety channels and apply or remove control power collectively to the safety outputs of the relay. Each safety channel could be one or more safety devices in series with each other.

There is no way to individually detect or monitor devices by means of the safety relay. Each safety input device would have to have a third contact that is wired to a programmable controller to provide a status that can be displayed on an operator station.

With a safety controller, each safety input is connected to its own input on the controller.

Status of the dual channels of each device is monitored by the controller, and the status of that device can be provided to the programmable controller operating the machine to provide status to the operator station without the need to provide physical wiring to an input card on the programmable logic controller (PLC).

Additionally, a safety controller can have multiple outputs that can be used individually or in groups, depending on the user application in the safety controller.

Safety controllers tend to be programmed pictorially using gate logic and with built-in features that can be selected by telling the safety controller what type of device is connected to each input on the controller.

Since the safety controller is independent of the controller that runs the rest of the machine, it is making decisions on a fixed number of control points and is not impacted by the scan time of the main machine-control algorithm.

The type and availability of safety devices has opened up the types of automation that can be deployed in manufacturing and reduced the traditional operating footprint that hard-guarding dictated.

Systems are safer with a higher degree of confidence, so humans and machines can interact in an ever smaller envelope. cd

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PID-control applications, tuning and limits

PROPORTIONAL-INTEGRAL-DERIVATIVE (PID) control stands as a fundamental technique in the field of controls engineering. It plays a crucial role in regulating systems and maintaining desired outputs.

The PID control algorithm is widely used in manufacturing processes. The proportional, integral and derivative components of the control loop are present. The output of the proportional component is inversely correlated to the difference in precision between the desired and actual values. To get rid of steady-state errors, the integral component integrates the error over time. The derivative component predicts future errors based on the rate of change of the error. By combining these components, PID control achieves a balance between responsiveness, stability and accuracy, ensuring efficient control of various systems.

> A higher integral gain can lead to faster error correction but may also introduce overshooting.

Proportional control (P): The proportional control component plays a crucial role in adjusting the system's output based on the error between the desired setpoint and the actual process variable. The output is directly proportional to this error, with a gain factor determining the magnitude of the response.

The gain, or proportional gain, influences the system's sensitivity to error. A higher gain results in a more aggressive response, reducing the error faster but increasing the risk of overshooting and instability. Conversely, a lower gain leads to a more conservative response, providing stability but potentially slower error correction. Balancing the gain is essential to achieving optimal performance in the control system.

Integral control (I): The integral control component in a PID system is essential for eliminating steady-state errors. It addresses the accumulated error over time by continuously integrating the error and generating an output proportional to this accumulated error. By doing so, it effectively eliminates any persistent deviation between the desired setpoint and the actual process variable. However, it is crucial to carefully tune the integral gain to maintain system stability.

A higher integral gain can lead to faster error correction but may also introduce overshooting and instability. Conversely, a lower integral gain provides stability but may result in slower error correction. Striking the right balance is key to achieving optimal system response.

Derivative control (D): The derivative control element of a PID system, which responds to the rate of change of the error signal, is crucial. It computes the rate of change of the mistake and generates an output that counteracts unforeseen changes in the process variable. This increases the responsiveness and stability of the system. However, derivative control can also increase the system's noise, which might lead to instability and irrational behavior.

By reducing noise and guaranteeing a smooth response, filtering techniques can be utilized to solve this issue. The derivative gain needs to be carefully set to strike a compromise between noise reduction and system performance.

PID control finds widespread use in various industries due to its versatility and effectiveness. Speed control in motors, such as those used in robotics and industrial machinery, relies on PID control to maintain consistent and accurate speeds. In HVAC systems, PID control is employed for precise temperature regulation, ensuring optimal comfort and energy efficiency. In chemical processes, PID control plays a vital role in maintaining desired levels of liquid or gas, preventing overflows or shortages. These examples illustrate how PID control is instrumental in achieving stability, accuracy and control in diverse applications.

Proper tuning is important for achieving optimal performance. Various methods can be employed, including manual tuning, the Ziegler-Nichols method and advanced optimization techniques. Manual tuning involves adjusting the PID parameters based on system behavior, while the Ziegler-Nichols method provides a systematic approach to tuning. Advanced optimization techniques utilize algorithms to automatically find optimal PID parameters. Practical tips for tuning include starting with conservative gains, considering system dynamics and iteratively fine-tuning until the desired performance is achieved, resulting in stable and efficient control. cd

Shawn Cox is a licensed master electrician/PLC programmer. He was co-owner/operator of Bobby Cox Electric for 15 years and is currently employed by BMW Manufacturing as an ESA.

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Integrated safety logic finds a way

CHRISTOPHER WOLLER
Safety Product Manager,
Beckhoff Automation

Two decades after its introduction, machine safety technology keeps getting more interesting. Safety in a machine-control context was born in 1996 with the EN 954-1 standard allowing only relay logic or simple electronics. Although process industries have widely used programable safety controllers since the 1980s, it wasn't until 2002 that NFPA 79 finally allowed for programmable safety controllers in machines. Today, integrated safety logic has found its way into a great variety of industrial devices, such as DIN-rail or machine-mounted safety I/Os and servo-drive systems. This proliferation of safety hardware and architectures means machine builders can introduce far more safety functionality in more places to better protect people, equipment and products.

Q: Assuming everyone agrees that integrated safety is here to stay, it may still take many different implementation forms. What are the different architectural possibilities?

A: There are really four different architectures with increasing capability and scalability.

The simplest is stand-alone control, which allows for safety applications without control system integration. One vendor's programmable safety controller can exist alongside any control system or retrofit older equipment with no control system.

Then comes compact architecture. Much like stand-alone control, individual safety controllers operate independently of each other without coordination, but they are networked into a larger control system. Now higher-level systems can monitor individual safety hardware and functions.

Next, centralized control harkens back to the original integrated-safety-over-fieldbus concept of the early 2000s. A single controller governs the entire network of safety devices, enabling larger applications with increased complexity.

The most flexible option is distributed control. In these architectures, a network of safety devices like I/O or drives contain their own safety logic, and they manage local safety functions. This higher level of safety communication allows for passing around larger safety functions like E-stops or coordination among local devices.

Q: What implications do physical and software architectures have on the machine builder from a technical standpoint?

A: It's really about choosing the best architecture for the job. Balancing the flexibility to choose while maintaining existing programming becomes really important. Take a press brake from the 1940s, for example. It will probably employ simple relay logic and basic hydraulic systems. A stand-alone safety controller could be easily added with only small alterations to the original design.

However, maybe the same press brake manufacturer produces a sectional machine line today. In that case, a distributed architecture could break down huge applications with high complexity into bite-size chunks. Those modules can then interact as required.

Every machine builder will end up with all these architectures. So implementing the simplest and most complex safety architectures on a universal platform offers serious engineering efficiency.

Q: How does that translate to commercial impacts?

A: There are huge commercial impacts—for machine builders and end users. It propagates. Very few machine builders build just one machine. They'll leverage several architectures because it really isn't a one-size-fits-all.

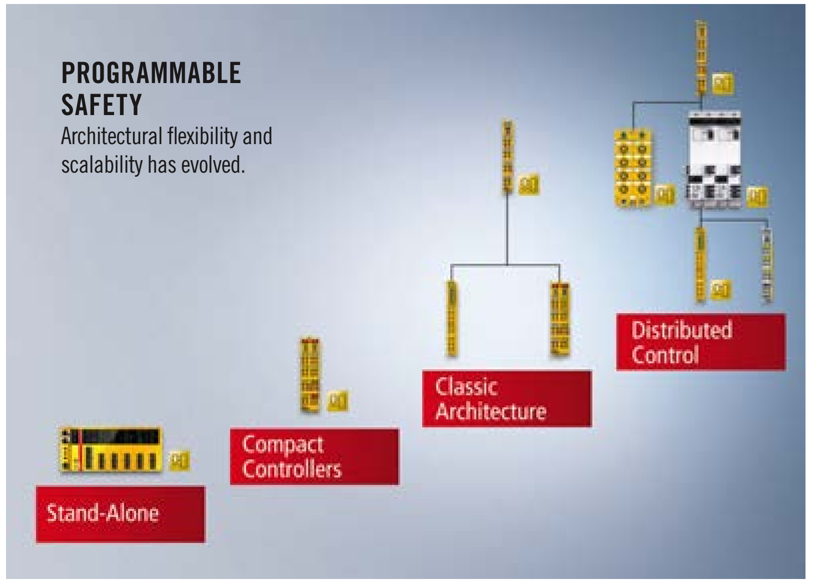
Streamlining really becomes the name of the game. If an OEM uses Manufacturer X for safety, then needs platforms A, B, C and D for the architectural flexibility requirements, that's not efficient.

Even worse, say that same OEM needs three or four different safety manufacturers. That's not efficient either. Multiple platforms get expensive with training, different hardware installation, software maintenance and multi-vendor sourcing.

Distributed logic offers a unique selling proposition for OEMs building modular machines. Distributed logic results in considerably less downtime for the customer when adding modules.

And when it comes to that trickle effect, end users inevitably end up with every architecture mentioned. They need to stay running to make more money, and they can do this by minimizing their safety platforms and resolving issues faster.

Training on fewer platforms ultimately means stocking fewer replacement parts on the shelf. Getting all the flexibility and scalability you need on one platform, under one roof, ultimately means making more money.



Q: What resources can machine builders leverage to enhance their functional-safety design skills?

A: Technology vendors are a great resource for fundamental design information, but there's always bias. A good place to start is with OSHA, the standards themselves, industry organizations and many of the testing labs.

In the U.S., OSHA 1910.212 is the generic regulatory standard that end users are going to be held accountable to regarding the general requirements for their machines. It's not particularly complex, but you should be familiar with it.

The standards themselves—IEC 61508, ISO 12100, ISO 13849, IEC 62061—are generally considered the basis for machine safety. However, U.S. standards like the ANSI B11 series offer further contextual information.

Explanatory information leads to a deeper understanding much faster, and the ANSI B11 standards receive more frequent updates because they're not subject to the EU's Machinery Directive. New technology is explicitly addressed much faster.

One of my favorite organizations is Germany's Institute for Occupational Safety and Health (IFA). They've published incredible resources for both machine builders and end users. Case in point: functional safety of machine controls (IFA Report 2/2017e) and safe drive controls with frequency inverters (IFA Report 4/2018e). These read like how-to books.

The testing labs are also fantastic resources. UL—along with TÜV SÜD, NORD and Rheinland—offers functional safety training. UL even combines functional safety and cybersecurity. Today, one can't really exist without the other, especially in an industrial environment.

Q: What other considerations should OEMs make regarding integrated safety architectures in the equipment they're building?

A: Ask lots of questions during the design phase. Consider the life cycles of the machine, line and plant. How do the machines interact with each other? How are the machines expected to interact with each other tomorrow? Can my machine architecture easily change — to become modular, for example — down the road?

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Improvements and efficiency in motion

Innovations and changes on the horizon for motors and drives

by Mike Bacidore, editor in chief

THREE INDUSTRIAL AUTOMATION veterans discuss how motors and drives have evolved and what's on the horizon.

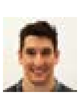
Bruno Chiodi is engineering manager at Moog.

Growing from an applications engineer to project sales engineer, Cody Lorenz is one of Franklin Electric's veteran controls experts. He has nearly 10 years of experience developing and implementing hardware and software improvements for Franklin's starters and drives.

Thiago Mohallem was promoted to general manager of Nidec/U.S. Motors' commercial and industrial motors and drives group, serving many industries, including food and beverage. Mohallem has more than 20 years of leadership experience at multinationals including Procter & Gamble, L'Oreal and BRF. He joined Nidec in 2017 as chief product officer of Embraco brand motors.

What have been the biggest improvements to motor and drives in the past five years?

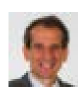
Thiago Mohallem, general manager, commercial and industrial motors and drives, **Nidec/U.S. Motors**: Electronically commutated motors (ECMs) that don't rely on rare earth magnets are making a big difference from an efficiency standpoint. Cost and availability of rare earth magnets would have greatly limited the adoption of integrated motor and drive ECM offerings. The development of motor solutions without rare earth magnets has given manufacturers much more control on the cost and supply chain to meet industry demands.



Cody Lorenz, project sales engineer, **Franklin Electric**: There has been a rise in the popularity of motor designs powered by permanent-magnet (PM) technology, which offer superior energy efficiency and improved handling of rapid system load changes. PM motors have been used regularly in many other industries—automotive and household appliances, to name a few—and are growing in popularity in our industry, and for good reason.

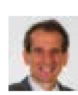
Permanent-magnet motors operate more efficiently using rare-earth magnets that perform with no slip. This translates into lower input power for the same output power, saving on operational costs every time the motor runs. In fact, we've found that motors with a 94% efficiency rating provide an investment payback of less than two years in typical duty-rate applications.

The most significant positive change for drives has been the acceptance to use them over starters, especially soft starters. With the acceptance of drives increasing, more installs are utilizing the unique control features they offer. This has inspired new opportunities for competition in the space to further innovate on the technology—the most prominent of recent developments being Internet and Bluetooth-enabled connectivity.

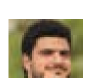


Bruno Chiodi, engineering manager, **Moog**: There's been a push toward a direct integration of motors and drives, which is clearly reshaping the market. These types of decentralized solutions are changing the design of new machines, reducing cabinet sizes and machine footprint. We see and contribute to developments toward seamless incorporation of these decentralized axes into classic multi-axis design.

What's the most innovative or efficient motor/drive application you've ever seen or been involved with?

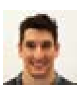


Bruno Chiodi, engineering manager, **Moog**: The electrification of construction and agricultural vehicles (CAVs). This is a field where Moog is active with its platform, and there are innovations taking place. The integration of motor and drive systems that went from an industrial context into these demanding, independent applications, with all the challenges that come with it, is stimulating the ideation and development of innovative solutions.



Thiago Mohallem, general manager, commercial and industrial motors and drives, **Nidec/U.S. Motors**: As a motor manufacturer, we look at this from a solution side. Our new motor applications are focused on providing a solution that is highly efficient across the operational envelope of the equipment, not just focused on motor efficiency, but how can we make the whole system more efficient and reliable?

One example is a belt drive fan driven by an induction motor. We have new technology that can change this to a direct drive solution and then replacing the induction motor with a permanent magnet variable-speed synchronous motor that can vary output according to demand. Adding up the losses that go into the belt, the reduced energy usage during lower demand times, along with increased efficiency across the speed range of the fan, you can see 30-40% efficiency increases in a system.



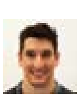
Cody Lorenz, project sales engineer, **Franklin Electric**: Franklin Electric's MagForce high-efficiency motors paired with an engineered drive solution, such as SubDrive Connect Plus or Cerus X-Drive, address projects up to 300 hp. A complete pumping solution can unleash groundbreaking efficiency when pairing a submersible pump with the unparalleled MagForce high-efficiency motor and a compatible variable-frequency drive for an intuitive experience. They are optimized to work together to achieve the highest performance and efficiency possible.

Franklin Electric has also leveraged its submersible-motor manufacturing experience to design an in-house purpose-built permanent-magnet submersible motor.

Permanent-magnet motors are inherently more efficient than their squirrel-cage counterparts. Since the motors were engineered to only be run by a drive, these motors are built with a higher pole count that can take advantage of the higher base frequencies that drives allow.

In addition, we programmed our drive to offer pre-configured settings specific to these motors. This resulted in the package system reaching a motor efficiency rating of 90 to 94%, reducing system energy consumption by 21%.

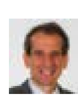
How have motors and drives benefitted from remote monitoring and connectivity?



Cody Lorenz, project sales engineer, **Franklin Electric**: The opportunity to have wireless connectivity is invaluable to drive users, but it's equally important that this connectivity be intuitive to use. As a manufacturer, ease of use has always been critical as we develop and enhance our drive offering.

Figure 1: New applications will continue the need for more integrated packaging of drives and motors.

With any of our connected drives, customers can download all the drive settings and logs via Bluetooth and email them directly to our dedicated technical support team. This connectivity also allows us to help our customers streamline the commissioning process. It can save installers several hours on the jobsite, since they no longer need to manually record each drive's programmed settings during installation and start-up.



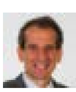
Bruno Chiodi, engineering manager, **Moog**: High-speed fieldbuses and machine-to-machine (M2M) connections are changing the game for industrial products. Internet-of-Things (IoT) capability opens new possibilities for remote monitoring and predictive maintenance; and more data about motor and drive working conditions must be measured and processed.

Thiago Mohallem, general manager, commercial and industrial motors and drives, **Nidec/U.S. Motors**: Users have more control of the process and application by utilizing the tools and information the drive is providing, so, by understanding their application, they can tailor the system output and optimize their energy usage.

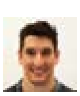
Can you explain how software development has changed motor and drive design and production?

Thiago Mohallem, general manager, commercial and industrial motors and drives, **Nidec/U.S. Motors**: Modeling tools, such as Ansys, have allowed the development process to accelerate. Our teams have used dynamic models and feedback loops to assist in the design and development process. The iterative process with typical prototype development would have taken too much time and resources to efficiently develop the new technology we're seeing. Utilizing software tools allows us to have working prototypes after only a couple of design iterations.

There are many design tools that allow engineers to optimize designs as a digital offering before a physical part is ever created. Electronics, computational fluid dynamics (CFD), motor electrical design and 3D computer-aided design (CAD) are examples.



Bruno Chiodi, engineering manager, **Moog**: From a design point of view, engineers can predict and solve mechanical, electrical and thermal issues using simulation software. Application problems and drive-tuning can also be simulated to reduce commissioning time in the field. On the production side, automatic test and data collection reduce the time to manufacture products and improve quality. These improvements stem from the wide availability of design and production software and the integration of software with the product firmware; that's an added value of the product.

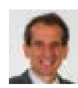


Cody Lorenz, project sales engineer, **Franklin Electric**: Apart from the connectivity side of the drive, most of the changes to drive design and production have paralleled other software-heavy markets.

Several decades ago, drives were using bulky hardware-based logic. Today, they use streamlined assembly language and embedded software designs that is more compact and easier for the average person to program and operate.

The advanced nature of the units also allows them to have more computing power while drawing less electrical current and occupying a smaller physical space: what's known as power density. The microcontrollers have become more powerful, allowing more features to fit into the drive without increasing the cost. Drives have enough computing power to remain generalized products while utilizing integrated PLCs, multiple motor control methods and a wide breadth of I/O. Increasing power density also allows owners and operators to benefit from more streamlined units that are easier to ship and install without sacrificing performance or reliability.

How do motors and drives figure into digital-twin platform models being used by manufacturers?

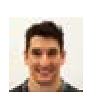


Bruno Chiodi, engineering manager, **Moog**: With the availability of reliable mathematical models of drives and motors, machine builders can access the information necessary to create the machine digital twin. From a component point of view, this means that providing an ever-increasing wealth of data becomes an integral part of developing the product. Without reliable data sets on a component level, accurate modeling is impossible.

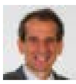
Thiago Mohallem, general manager, commercial and industrial motors and drives, **Nidec/U.S. Motors**: Digital-twin simulations are critical in the development of new drive and motor technologies and greatly help reduce the development cost while accelerating the development time.

Equipment manufacturers are using digital twins to simulate entire installations and applications in a similar way to how we're using these tools for motor and drive development.

When will motors and drives become IT-friendly enough that engineers are no longer required for installation and operation?



Cody Lorenz, project sales engineer, **Franklin Electric**: Drives have already started taking several steps to improve accessibility—a common one is an application parameter that auto-adjusts the rest of the parameters to suit it—and, more recently, the connectivity of drives. Adding connectivity allows a customer to quickly loop in another person with deep knowledge of the product. Future steps could be a connected product grabbing motor information from a product database to set up and configure the motor parameters itself, or even direct communications between the motor and drive to exchange this information.

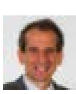


Bruno Chiodi, engineering manager, **Moog**: We are getting close to this situation. In simple applications with advanced graphical user interface (GUI), it's possible to configure a system in a few steps without a deep knowledge of drives or electric motors. It's less necessary to possess in-depth engineering know-how; smart systems can handle themselves with less human input and focus on design and model-based preemptive troubleshooting, anticipating issues and implementing solutions within the system before it is even installed.

Thiago Mohallem, general manager, commercial and industrial motors and drives, **Nidec/U.S. Motors**: Motors and drives are converting significant amounts of electrical power into mechanical power. Development will make integration of ECMs easier, but there will always be inherent electrical and mechanical risks in these types of installations. Professionals with experience in optimizing the application safely, as well as following installation codes and safety procedures, will always be necessary.

What future innovations will impact the use of motors and drives in discrete-manufacturing operations?

Thiago Mohallem, general manager, commercial and industrial motors and drives, **Nidec/U.S. Motors**: Innovation in drives will continue to improve packaging size and processing capability allowing simpler integration into the overall system.

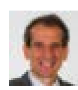


Bruno Chiodi, engineering manager, **Moog**: Integrated and decentralized drive products enable engineers to provide a modular design for a customer's machine, which facilitates implementing discrete-manufacturing systems. The expansion of this decentralized approach to machine design will lead to innovations that impact how teams conceptualize discrete manufacturing.

Cody Lorenz, project sales engineer, **Franklin Electric**: Fundamentally, I do not think drives will change much. Yes, there will be reductions in size and increases in efficiency, but I do not believe there will be a significant innovation that changes drives for some time. More likely, we will see a few things:

- First, we will see a general decrease in cost per power, which may show up as an increase in power density. This will cause drives to expand into more applications as it becomes cost-effective to do so.
- Second, we will see more integrated packaging of drives and motors, likely for these new applications that have developed.
- Third, we will see an expansion of secondary features that boost ease of use and adoption, similar to the recent addition of wireless connectivity.
- And last, we will see more various power components packaged inside the drive instead of in a panel, driven by an increase in electric emission standards or the desire for a self-contained unit.

Tell us about your company's state-of-the-art motor or drive.



Bruno Chiodi, engineering manager, **Moog**: We have a product portfolio that covers all the different industrial applications. For instance, our compact DM2020 with its multi-axis structure improves the energy efficiency of a system, especially when used in conjunction with the Moog DE2020 energy management module.

Thiago Mohallem, general manager, commercial and industrial motors and drives, **Nidec/U.S. Motors**: At Nidec, we're always pushing the envelope and focused on combining the benefits of newer motor technologies with the reliability of trusted products.

A big focus at Nidec is providing integrated motor and drive technology that offers the highest efficiencies. We've introduced several products in the past few years with power drive systems that provide high-efficiency solutions across a large operating range to drive many different systems.

Our newest innovation is the SynRA synchronous motor, which offers the efficiency of permanent magnets but without the need for costly rare earth magnets. SynRA can be paired with a standard drive rather than a special or custom drive and can be dropped into an existing system to yield higher efficiency across the speed range of the equipment. When integrated with our ID300 PerfectSpeed control, it's really a game-changing technology, and we've seen a great deal of interest from customers across different industries.

The Agri-Fusion combined variable speed motor and drive is specifically designed to regulate large ventilation fans with high-torque requirements critical to optimal air circulation. CD

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How to select and communicate with uninterruptible power supplies

KYLE MCLEOD
Product Marketing Manager, UPS SolaHD, Emerson

Uninterruptible power supplies are common devices found in almost every enclosure to protect against outages or disruptions. The uninterruptible power supply (UPS) can vary in input or output ranges, and a fundamental choice between alternating current (ac) and direct current (dc) needs to be made. Emerson's UPS knowledge and offerings span the spectrum from mounting suggestions to communication options.

Q: Can you start by explaining what an uninterruptible power supply is? How does it work, and what is the state-of-the-art technology?

A: An uninterruptible power supply (UPS) is an electrical device designed to provide instantaneous backup power when the primary power source experiences disruptions or failures. It ensures the continuity of critical electronic equipment, preventing data loss, system crashes and downtime during power outages or fluctuations. A UPS functions as an intermediary between the main power source and the connected devices, offering a seamless transition during power disturbances.

A UPS typically consists of three main components: a rectifier/charger, a battery bank and an inverter when an alternating-current output is required. When the main power supply is available, the rectifier converts alternating current (ac) to direct current (dc) to charge the battery. Simultaneously, the inverter converts the dc from the battery back to ac, providing a stable power output to connected devices if necessary. In the event of a power interruption, the stored energy in the battery is immediately released to maintain power to the equipment, offering crucial time for either graceful shutdown or continued operation until the main power is restored.

State-of-the-art UPS technology encompasses several advancements:

- Efficiency: Modern UPS systems incorporate high-efficiency components and advanced power management algorithms to minimize energy losses during ac-dc-ac conversions. This efficiency translates to reduced operational costs and environmental impact.
- Modularity: Modular UPS designs allow for scalability by adding or removing power modules as needed. This approach enhances reliability, as modules can be hot-swapped, ensuring uninterrupted operation during maintenance or upgrades.
- Smart monitoring and management: Advanced UPS systems offer remote monitoring and management capabilities through network interfaces. This enables real-time monitoring of power status, load levels and battery health, facilitating proactive maintenance and troubleshooting.
- Energy storage technologies: Lithium-ion batteries are gaining traction due to their higher energy density, longer lifespans and faster recharge times compared to traditional lead-acid batteries. These batteries enhance UPS efficiency and reduce the physical footprint.

These advancements collectively contribute to UPS systems that offer higher reliability, better energy efficiency and improved management capabilities, making them an essential component in ensuring the seamless operation of critical electronic equipment.

Q: What sort of input and output ranges can be expected from various UPS offerings?

A: Uninterruptible power supplies come in various types, each with distinct input and output voltage ranges tailored to diverse applications. Offline/standby UPS typically offers input ranges around ±15% of nominal voltage (120-220 Vac, 24 Vdc), ensuring power continuity during minor fluctuations. Line-interactive UPS maintains a similar input range, safeguarding against voltage variations. Online/double-conversion UPS provides a wider input range of around ±25% or more, guaranteeing consistent output by continuously converting incoming power.

AC UPS caters to devices reliant on alternating current, while DC UPS serves those requiring direct current. AC UPS devices are more prevalent, offering compatibility and integration advantages. DC UPS devices are crucial for equipment utilizing dc power sources.

The choice between ac and dc UPS hinges on equipment nature, efficiency, battery voltage, redundancy, maintenance and cost considerations. AC UPS is efficient for long-distance distribution, while DC UPS is suitable for direct power transmission. AC UPS is more available and cost-effective due to wider use. Hybrid solutions can convert ac to dc or vice versa based on equipment requirements. To select the right UPS, assess equipment needs, consult experts and balance factors like efficiency, compatibility and budget.

Q: How do I decide to utilize an AC UPS or a DC UPS?

A: Deciding between AC UPS and DC UPS depends on your specific application and power requirements. Choose an AC UPS if your critical equipment primarily operates on ac power, such as computers, servers and appliances. AC UPS systems are widely available and compatible with standard power sources. Opt for a DC UPS if your equipment relies on dc power, commonly seen in industrial machinery and specific electronics. DC UPS systems can avoid unnecessary ac-to-dc conversion, increasing efficiency. Consider AC UPS for its broader support, simplicity and easy integration, while DC UPS suits dc-dependent applications for minimal conversion loss. Ultimately, your choice should align with your equipment's power needs, efficiency goals and compatibility with existing systems.

Q: Data gathering continues to grow in importance. How can UPS data be used by manufacturers?

A: Manufacturers can leverage UPS data for operational optimization and predictive maintenance. Real-time UPS data, including input/output voltages, load levels and battery status, provides insights into power quality and equipment health. Manufacturers can identify voltage irregularities affecting machinery performance and take corrective actions. Load monitoring helps balance energy distribution, optimizing resource allocation. Battery data aids in predicting battery failures and preventing downtime.

UPS data can enhance overall supply-chain efficiency. Manufacturers can track power disruptions and downtime occurrences, enabling proactive communication with customers and suppliers. Analyzing historical UPS data helps identify patterns and trends, guiding strategic decisions for capacity planning and load balancing. Ultimately, utilizing UPS data enables manufacturers to enhance production efficiency, minimize downtime, improve product quality and strengthen customer relationships.

INTERMEDIARY FUNCTION
A UPS is an intermediary between main power and connected devices.

Uninterruptible power supplies can also provide an automated shutdown process for connected equipment including industrial PCs, computers, and programmable logic controllers (PLCs) via their communication connections. This feature helps customers to safely shut down their critical equipment after the line power has failed. This helps to ensure data integrity and improve overall startup functions.

Q: What sort of communication protocols are necessary for connecting uninterruptible power supplies?

A: There are protocols available from suppliers depending on your need and application. The most popular are those that utilize industrial Ethernet such as Ethernet/IP, Modbus TCP, PROFINET and EtherCAT. Many legacy protocols are available as well for communicating over twisted-pair communication networks.

The industrial communication protocol selection is also dependent on the existing network and potential control systems in place. Most control-system platforms have preferred compatible communication networks which allow for seamless integration of devices including uninterruptible power supplies. Users prefer simple integration of the product and common interfaces.

For more information, visit www.emerson.com/en-us/automation/solahd/.

Uncoil the adaptability of PC-BASED CONTROL

George T. Hall and Communications Test Design took advantage of modifiable systems to scale change

One of the biggest benefits of PC-based systems is their flexibility. Software-based applications can be upgraded, modified or replaced.

Two companies took advantage of that flexibility with modular improvements made to systems using PC-based control.

System integrator George T. Hall (GTH) helped a gold mining company in Nevada to upgrade its supervisory control and data acquisition (SCADA), and Communications Test Design (CTDI), a Pennsylvania-based intralogistics company that designs and builds its own equipment, implemented standardized systems to speed up delivery times, adjust to changing customer requirements and scale for peak seasons.

GTH averts risks and enhances operations with strategic SCADA-system upgrades

By Anna Townshend, managing editor

George T. Hall was founded in 1932 and currently employs 53 people, including 10 engineers. Many of the company's integration projects revolve around electric- or gas-fired heating applications for molding, treating or baking products. The system integrator typically handles processes using multiple motors, valve pumps and instruments.

George T. Hall works primarily in the United States for public and private industrial automation customers in core industries, including aerospace, food and beverage, water/wastewater, mining/minerals/metals and pharmaceuticals/life sciences. The company averages about 100 projects per year, varying considerably in product and scope. Typical project timelines from discovery to startup average around one year.

When a food-and-beverage manufacturer wanted a company logo branded on its hamburger buns, George T. Hall developed the controls and heating for the branding machine. Its mushroom-spawn-producer customer wanted a machine to convey and sterilize a substrate in preparation for the inoculation process, which included a 15-ft-tall rotating blender. Data acquisition ensured the proper temperature and pressures throughout the sterilization and inoculation processes.

George T. Hall has completed projects like these over the past couple of years, thanks in part to a focus on mentoring. The development of younger engineers by senior engineers has been inspiring, says Mike Howard, vice president of system integration at GTH. "These partnerships have produced innovative solutions throughout the lifecycle of each project," he adds.

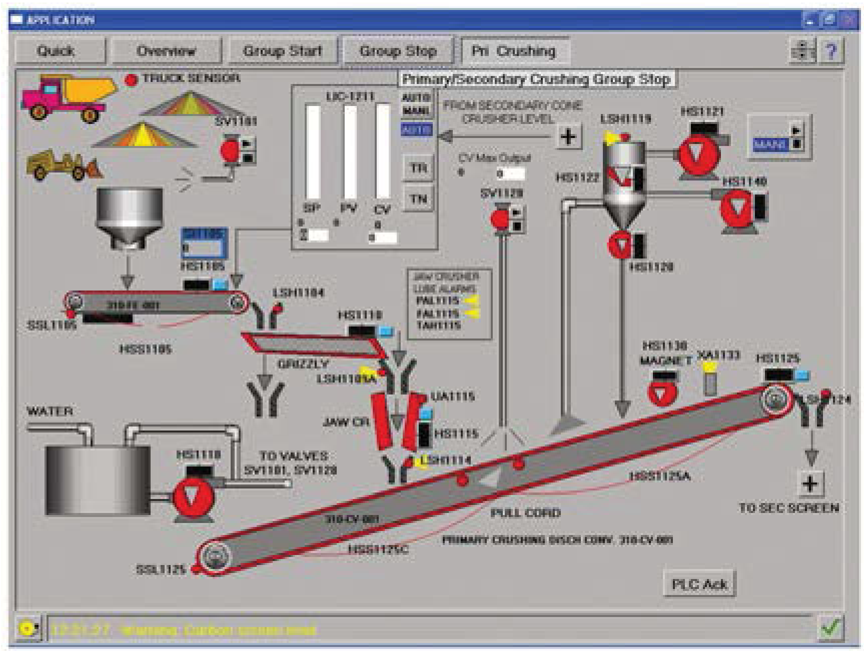


Figure 1: George T. Hall's customer, a gold mining company, needed a SCADA modernization, but had delayed the project for fear of downtime and data loss.

SCADA modernization

A gold mining company in Nevada needed modernization of its SCADA. The system had reached end of life and needed GTH to start an upgrade (Figure 1). The mine had been delaying upgrades because it could not afford unplanned downtime or lose any data in the migration process. The project was challenged with bridging the existing Modbus Plus network over to an Ethernet network. "The systems were run in parallel for a short period until it was proven, and the old system was unplugged from the network," Howard says.

George T. Hall did much of the work from its facility, 250 miles away. The existing Siemens FactoryLink software application was no longer available to analyze off-line, so GTH developed a plan to view the application remotely, and it developed the new application in Aveva InTouch.

"Upon contacting us, we determined that one of the biggest risks this company was facing was that it did not have a backup system in place for its now outdated and unsupported SCADA system. This system consisted of a single old PC running Windows XP; it was programmed

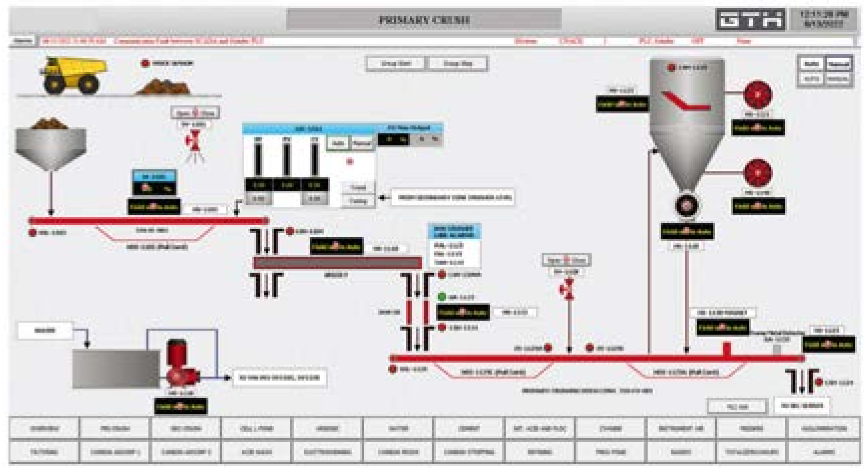


Figure 2: George T. Hall created the new SCADA software to be cleaner, using its experience bridging old technologies with new.

with FactoryLink SCADA software; and it was using Modbus Plus to communicate with field devices," Howard says.

In order to seamlessly move to a new PC running an updated operating system (OS) and modern SCADA software, GTH connected a secure cell model to the old PC. "This allowed us to remotely connect to the SCADA PC, while they continued normal operations," Howard says. "Using this technique, we unobtrusively recreated the SCADA program in Aveva InTouch 2020 from our facility."

For the second phase, GTH developed a plan to upgrade communications to Modbus TCP/IP.

Once the new PC with the modern SCADA software was ready, GTH brought the PC on-site. At this time, GTH used Niobara R&D's Modbus Ethernet Bridge MEB II to convert the Modbus Plus protocol to Modbus TCP. "This way, the customer could have its new and old systems working together with the existing programmable logic controllers (PLCs) in place, allowing us to verify functionality on-site before taking the old system offline," Howard says.

The next phase of the modernization was the PLC migration, and GTH used several tools to accelerate the migration and reduce costs and risks. "First, we took the old Quantum PLC program and ran it through the Unity M580 Application Converter (UMAC) tool to ensure programming compatibility for the new M580 PLCs," Howard says. This greatly reduced time and labor by allowing GTH to reuse about 95% of the existing PLC programming.

During the final modernization plan, GTH updated the existing Quantum Series I/O to X80 I/O using Schneider Electric's swingarm and quick-fit cable assemblies. "Because, like most older systems, this system did not have existing wiring diagrams, it was hard to know exactly what the field wiring was doing, making it risky to make all new connections. By using these assemblies and reusing wiring, we reduced the amount of downtime needed and prevented wiring errors associated with manual I/O module rewiring," Howard says.

George T. Hall's experience with bridging old technologies with new made the difference in this project, he adds. It also took advantage of tools and processes that made it easy to reuse the customer's existing code, hardware and wiring (Figure 2).

This meant the project could transition to the new PLCs in two to four hours, as opposed to programming a new PLC from scratch, which can take weeks. This approach also uses the same logic and language that operators are already familiar with, so operator training time was minimized.

While this SCADA system modernization was relatively small, GTH is also well-versed in modernizations for larger systems with multiple PCs and PLCs. Even with larger systems, old and new can coexist, and the same phased approach can still minimize downtime and other risks.

"We can take advantage of existing planned downtime by developing hybrid systems that allow us to use the allotted time to just replace one part of your system, such as the PLCs. When we take this approach, we ensure the remote I/O can talk to the new PLCs during the transition period and can then replace the remote I/O during the next scheduled downtime period," Howard says.

Risky business?

Updating a SCADA system has its benefits, but it can be risky, especially with critical infrastructure or in industries where downtime is rare because of cost or safety issues.

Likewise, if any part of a facility's critical infrastructure is outdated or obsolete, including the SCADA system, industrial PCs, the operating systems, the control software, human-machine interfaces (HMIs) or programmable logic controllers (PLCs), this poses business and operational risks.

The risks include compatibility issues and cybersecurity threats; plus, maintaining and supporting old systems can be difficult.

System integrator George T. Hall has assisted on many SCADA system upgrades, including a recent project with a gold mining company to reduce risk and downtime during modernization.

George T. Hall identified many of the risks to running an outdated SCADA system:

- Old and new compatibility—An old PC will eventually need to be replaced with a newer PC, and, the older the PC, the more you may experience compatibility issues between old and new. You may be able to create workarounds in your operating system to fix compatibility issues, but your software may still not be able to run as intended.
- Piecemeal system updates—Instead of a full modernization, companies may be inclined to do one-off updates and repairs to the SCADA system as components break one by one. If the legacy industrial PC using older communication ports and protocols goes down, facilities have two options: track down an older PC with the same outdated communication infrastructure or purchase a new computer and adapter and converters to communicate between the outdated hardware and the new computer. It is often more expensive to buy older parts than it is to buy new, if they are available at all; and a cobbled-together system gets complex quickly. Both options may face communication issues between older PCs and the newer SCADA system hardware or newer PCs and older SCADA system hardware.
- Operating system updates/patches—If a facility is running an older operating system (OS), that OS vendor will eventually stop supporting with updates and patches. Without critical security updates, the plant floor or enterprise network can be exposed to cybersecurity risks.
- Changing workforce—As operators, plant engineers and maintenance staff retire, it could become increasingly difficult to find new workers who understand how to operate and maintain an aging SCADA system.

Three more reasons to upgrade outdated SCADA systems include the following:

- Time and cost—An outdated SCADA system will cost more to run: more maintenance issues and more time finding the right resources to address the problem. Vendors may no longer support legacy software or components, or new engineers and maintenance personnel often need to spend time learning old SCADA software. In addition, this can all add to the time it takes to troubleshoot problems.
- Productivity—Old SCADA systems have productivity issues. Older PCs cannot consistently connect to industrial networks, or, if they can, they may be opening the industrial system to many cyber risks. Without a continuous connection, the PC cannot communicate real-time production data. If you want to optimize motor control throughout the plant with variable frequency drives, it may be difficult to do with outdated SCADA systems with older protocols and ports.
- Backups and security issues—Older PCs may have issues performing backups, which can be catastrophic if the system goes down. Legacy SCADA systems may have a hard time communicating with other OT and enterprise systems, or, if they do connect with a SCADA system that includes an unsupported OS, the PC can't receive critical security updates from the vendor. A single outdated PC/OS could expose the entire OT network.

For programmable logic controllers (PLCs) and programmable automation controllers (PACs), system integrator George T. Hall's preferred suppliers are Schneider Electric and Rockwell Automation. "They offer the greatest options and solutions for hardware and software," Howard says. "We also maintain development licenses for platforms, meaning we have access to factory support when needed." The system integrator is less particular about the type of industrial PC it uses but has used Advantech and others that are readily available.

A variety of variable frequency drives (VFDs), including products fromABB, Eaton and Schneider Electric, are used by GTH.

In the past, GTH has not had extensive experience with vision systems, but lately, Howard says, the company is impressed with Elementary Robotics artificial intelligence (AI)-based machine vision system. "We are currently looking for opportunities to partner with them," he notes.

For enclosures, GTH prefers Rittal, which "offers the most flexibility and greatest mounting panel space for a given size," says Howard, but GTH also uses Hoffman and Saginaw Control & Engineering enclosures regularly.

For human-machine interface (HMI), GTH uses a variety of products, including Schneider Electric's Modicon Magelis and Rockwell Automation's PanelView, as well as displays from Phoenix Contact, Inductive Automation and Aveva.

CTDI uses robotics, EtherCAT and PC-based control to more than double hourly throughput

By Mike Bacidore, editor in chief

More than likely, the biggest player in intralogistics you've never heard of is Communications Test Design (CTDI). Based in West Chester, Pennsylvania, CTDI offers reverse and forward logistics for the world's telecommunications carriers, cable service providers and smartphone devices. The family-owned company operates 100 facilities globally with more than 20,000 employees. To remain as technologically advanced as its customers, CTDI has invested heavily in automation in recent years, says CTDI Director Mark Parsons.

CTDI was founded in 1975 by Don and Jerry Parsons and has grown into a global engineering, repair and logistics company. CTDI has a long history of test engineering expertise that has delivered technical services throughout its 47-year history. In 2021, CTDI established a dedicated warehouse automation team that is solely focused on modular automation innovation, which supports CTDI's growing services globally.

To get the group up to speed quickly, Kirk Whittemore joined CTDI as general manager of the Automation Group. For the engineers on Whittemore's team, the company provides research-and-development (R&D) resources as it completes everything from design and programming to wiring and system commissioning in-house. However, the task also requires an understanding of the huge range of company activities, the massive sizes of the facilities, how to avoid scope creep and what to look for in technology partners (Figure 1).

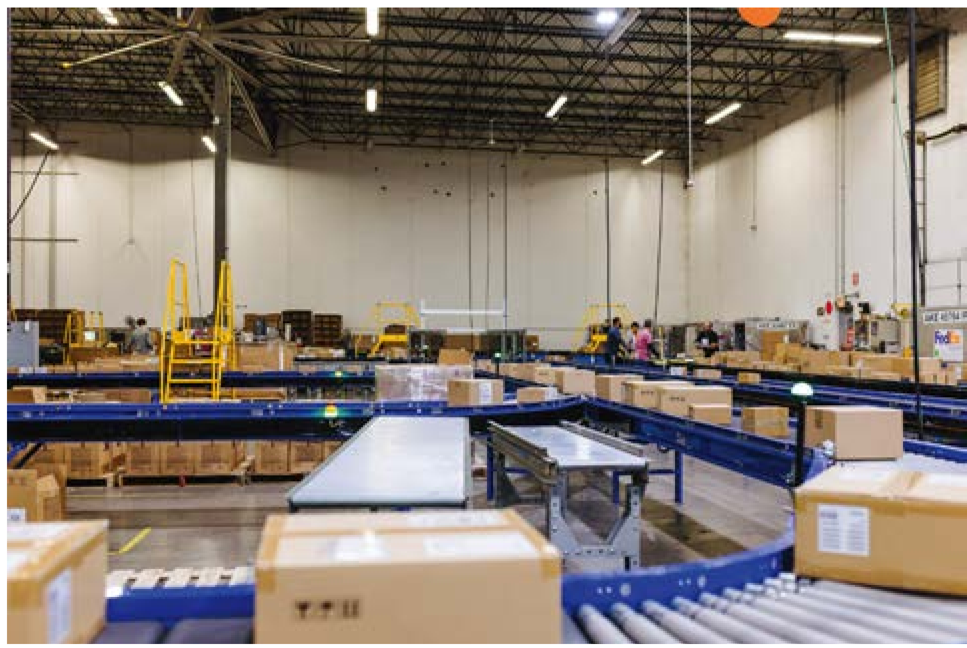


Figure 1: CTDI is increasing warehouse automation capabilities to meet demands, especially at peak times, in its global distribution centers. (SOURCE: FOREWORD LLC, 2022)

"We need to build modularity into our systems and standardize on the right vendors," Whittemore says. "Beckhoff was a clear choice to be our automation technology partner. Their controls and networking technologies enable plug-and-play solutions across all our different automated systems, with extensibility for the future. This helps optimize projects like our fully automated, robotic picking line."

CTDI is just one of the companies that operates as both end user and OEM that is focusing on flexible automation systems in warehouse and fulfillment operations, says Doug Schuchart, global material handling & intralogistics manager at Beckhoff. "More than ever, companies like CTDI must remain nimble to rapidly changing markets and consumer demands," he emphasizes. "This is yet another benefit that Beckhoff users gain with our flexible automation solutions, as well as improved system lifecycle with full protection from system obsolescence, which is another important factor in helping our customers remain competitive."

A custom solution for universal use

As the CTDI warehouse automation team quickly got up to speed, the engineers began to answer their core question: How can CTDI implement standardized systems to speed up delivery times, nimbly adjust to changing customer requirements and scale for peak seasons when each distribution center is so different?

"Our team needed to establish basic principles of how we wanted to approach these projects," Whittemore explains. "First, we decided not to tackle entire buildings, like a warehouse integrator would, but instead solve strategic problems in a modular way. If we can eliminate a pain point for, say, $1 million, then we can implement that at select branches across our network. Globally, flexible systems like our automated picking line provide more value than dedicating massive resources to one multi-million-dollar upgrade that doesn't scale."

The concept for the automated picking line leverages CTDI's standard robotic cell for several tasks (Figure 2). One robot serves as a flexible carton erector to build different sizes of boxes, depending on the type or quantity of product, then places the carton on a conveyor. Next, the cartons are labeled with a unique barcode and weighed. Another robotic cell loads product. Then a final robot adds paperwork or other collateral before the box is weighed, sealed and labeled. At each step, scanners confirm the box and product are correctly matched.

If greater throughput is necessary, the team can deploy additional robot cells for whichever task is the bottleneck (Figure 3). "With this modular approach, we can develop and approve standardized systems that scale across multiple sites," adds Parsons. This approach requires not just standardized robots and conveyor, but also modular controls, as well as networking and programming technologies to make them all work together seamlessly.

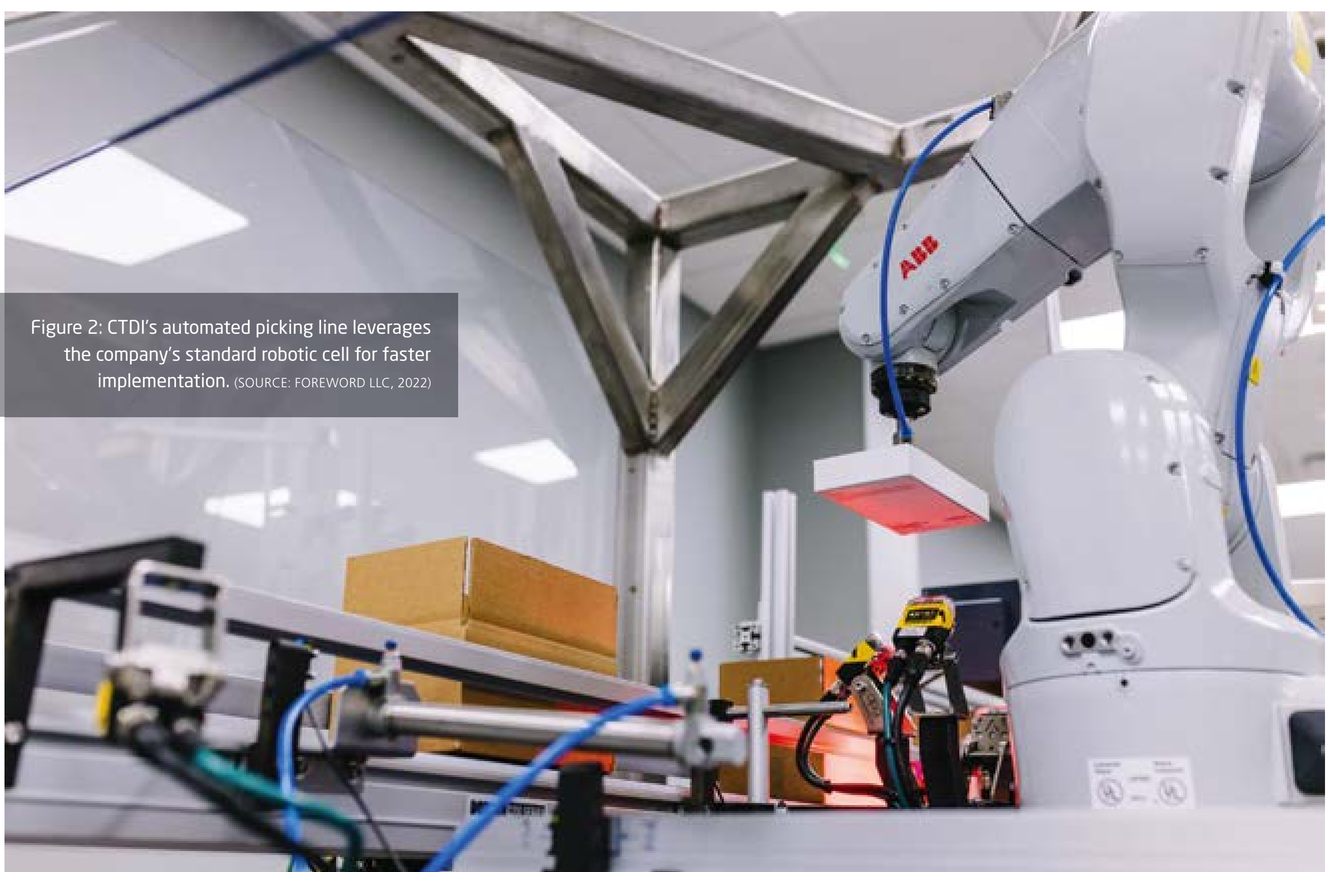


Figure 2: CTDI's automated picking line leverages the company's standard robotic cell for faster implementation. (SOURCE: FOREWORD LLC, 2022)

Automation software, hardware and networking deliver scalability

Automation technology from Beckhoff extends two advantages to CTDI's modular fulfillment systems, says Soham Patwardhan, control systems architect at CTDI. The first is the ability to develop internal libraries in TwinCAT 3 automation software. TwinCAT enables the CTDI warehouse automation team to program in a variety of languages depending on the project, and it also provides a deterministic runtime. The Library Manager in TwinCAT streamlines version control and implementation of standardized code in the field.

"With TwinCAT, we can create code for our standard equipment—for example, a robot, scanner or conveyor—so that it is able to operate in different modes and apply to almost any situation," Patwardhan says. "The code lives on our internal engineering drive, and we simply install it as a library on all the different systems. When we tested this, the standardized approach sped up deployment. This gets us one step closer to plug-and-play capabilities."

The PC-based control philosophy also facilitates communication from warehouse and test automation systems to CTDI's warehouse management software (WMS). "Some of our systems that interact with our WMS also have a global component, such as a test application or middleware, for system communication and other processes. Our standard is Visual Studio with .NET and C# for our code development," Patwardhan explains. Having automation device specification (ADS) protocol in TwinCAT to communicate between the programmable logic controller (PLC) and the .NET has been immensely helpful, adds Patwardhan.

CTDI uses the TwinCAT IoT library to send data between the WMS and the Beckhoff machine controllers. This has reduced additional programming requirements significantly in applications with no test app. "The PLC can directly communicate with a warehouse management system or warehouse execution system (WES), which is much more efficient than our old way of using a C# middle layer," Patwardhan says. "Using tools in the TwinCAT IoT library

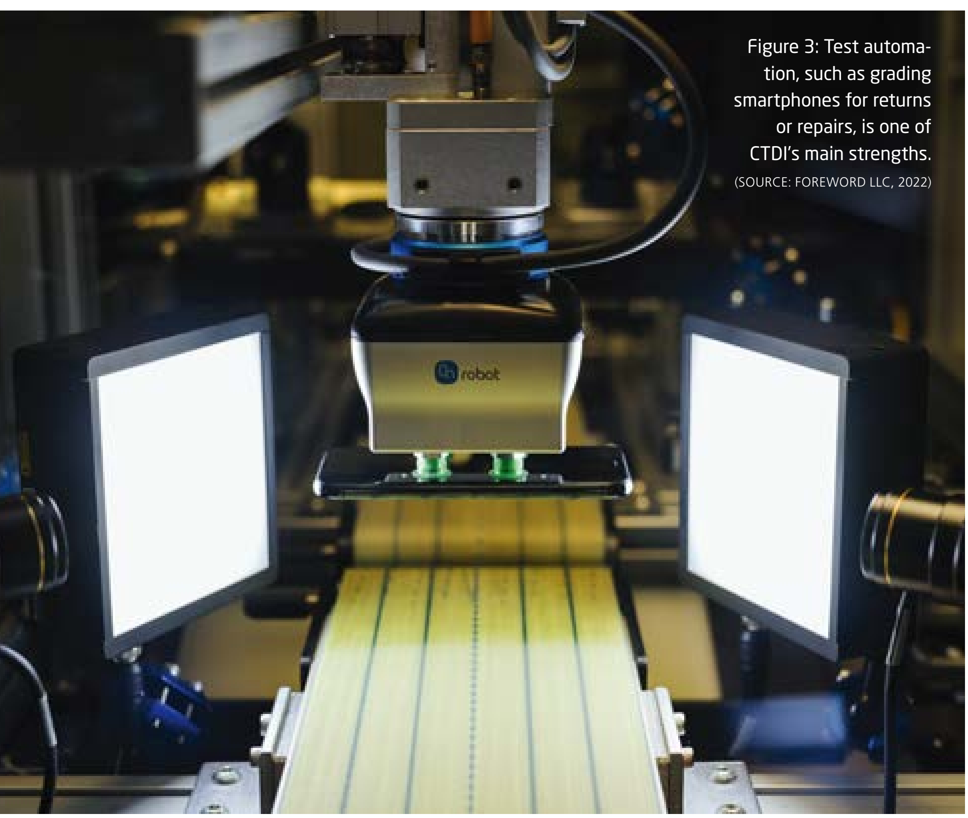


Figure 3: Test automation, such as grading smartphones for returns or repairs, is one of CTDI's main strengths. (SOURCE: FOREWORD LLC, 2022)

Figure 4: CTDI relies on a range of machine controllers, including C69xx series industrial PCs. (SOURCE: FOREWORD LLC, 2022)

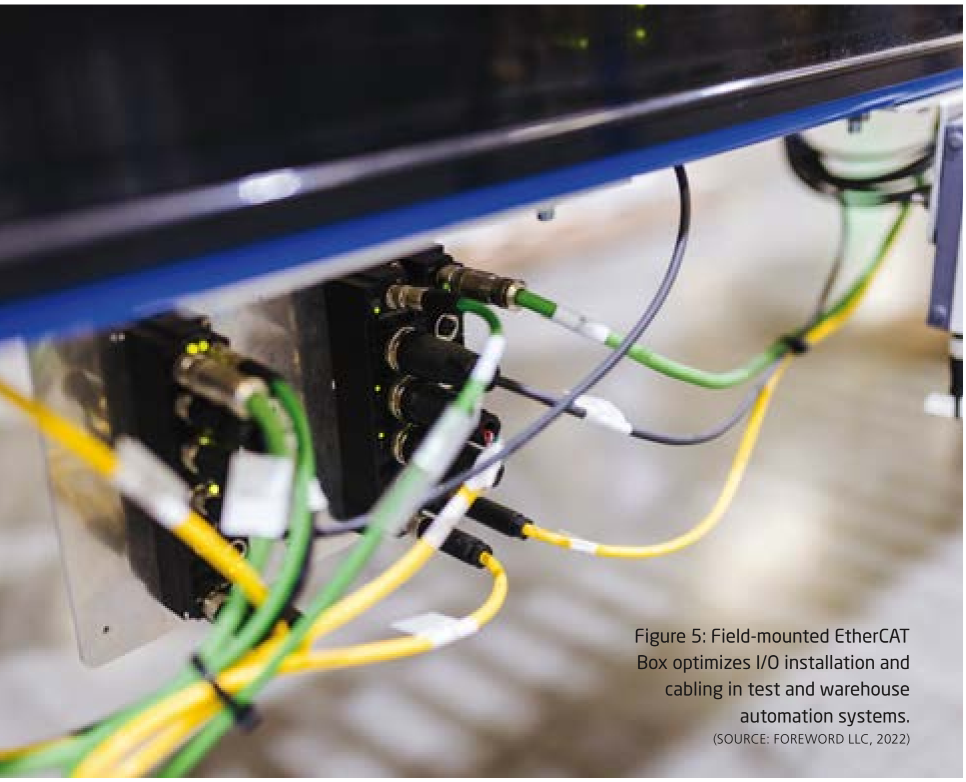


Figure 5: Field-mounted EtherCAT Box optimizes I/O installation and cabling in test and warehouse automation systems.
(SOURCE: FOREWORD LLC, 2022)

Figure 6: TwinSAFE devices leverage the Fail Safe over EtherCAT protocol to send safety data on the standard EtherCAT network using a black-channel approach.
(SOURCE: FOREWORD LLC, 2022)

is also more scalable and stable from a performance standpoint."

The scalable machine control portfolio from Beckhoff also offered an ideal fit for CTDI. The automated picking line leverages a C5210 19-inch rack-mount PC. With Intel Core processors up to eight cores, the C5210 delivers the power needed to control multiple robots and other systems with room to expand. In other applications, CTDI has leveraged control-cabinet industrial PCs (IPCs) in the C69xx series (Figure 4).

"This scalability of Beckhoff's machine control portfolio has proven important to CTDI," Schuchart adds. "When switching controllers to match performance requirements, the engineers do not need to worry about a hardware rip-and-replace scenario or even software changes in TwinCAT. The Beckhoff architecture is fully integrated, which safeguards our customers' control hardware, code base and I/O against obsolescence."

The second critical advantage of working with Beckhoff, says Patwardhan, is the strength of the EtherCAT industrial Ethernet system. "EtherCAT has helped immensely in standardizing designs for our flexible systems," he says. "We do not have network-related maintenance, configurations or any of the issues typical of other networks since EtherCAT automatically scans in connected devices. It's also extremely easy when it comes to network topologies and to the architecture, because you are not confined like switch-based networks." Even on CTDI's largest systems with up to 2,000 linear feet of conveyors, a single EtherCAT network can handle communication without any effects on performance.

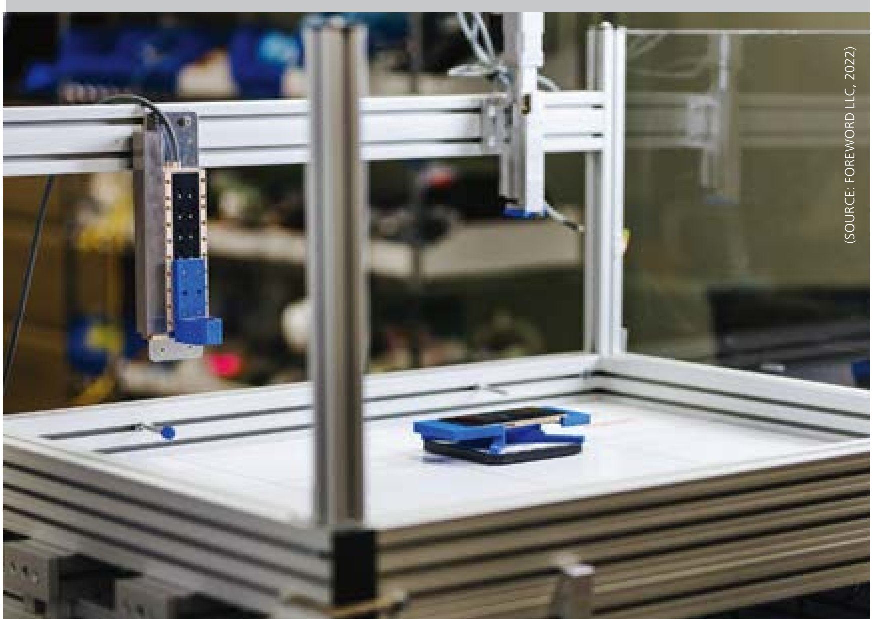
With the broad portfolio of EtherCAT terminals from Beckhoff, CTDI builds standard I/O segments for its robotic cells. This includes IP20-rated terminals for basic input and output, as well as TwinSAFE modules for integrated functional safety. For direct mounting on conveyors, IP67-rated EtherCAT Box and TwinSAFE modules reduce cabling and distribute signal acquisition and safety across the machine (Figure 5). "TwinSAFE devices leverage the Fail Safe over EtherCAT (FSoE) protocol to send safety data on the standard EtherCAT network using a black-channel approach (Figure 6). This reduces costs and engineering effort for hard-wiring safety relays while increasing the amount of data available to analyze machine performance," Schuchart says. "It further supports customers' flexibility initiatives, enabling them to easily add safety devices at any point of the design with little engineering or wiring effort."

The CTDI engineers prefer to use EtherCAT field devices, for example, for check-weighing and other functions. But when needed, they can take advantage of Beckhoff gateway terminals and bus couplers to more than 30 communication protocols. Another option is to communicate via an Ethernet port on the IPC, using TwinCAT to designate that port for EtherNet/IP communication, for example, to robot controllers or other devices.

Investment in innovation

Over nearly five decades, CTDI's philosophy has been to invest in, standardize on and scale with technology. The distribution-and-test-automation company strives to keep pace in its test automation, warehouse automation and warehouse management systems. One way that CTDI accomplishes this is by investing in technologies without requiring them to be tied to specific applications.

At the company's innovation lab in West Chester, the automation teams are evaluating adaptive automation with an XPlanar starter kit. Beckhoff's "flying motion" system with six degrees of freedom in movement offers potential for streamlining forward and reverse logistics processes. CTDI also looks forward to working with the emerging robot solution from Beckhoff—Automation Technology for Robotics (ATRO)—to support CTDI's modular machine concepts.



(SOURCE: FOREWORD LLC, 2022)

Results arrive right on schedule

By building modularity into every system, the CTDI warehouse automation team is able to tackle a project, such as an automated picking line, in six months that would normally take a warehouse integrator a year, says Whittemore. In addition, the engineers in the field make the maintenance technician part of the team during the install so that individual fully understands the equipment.

The automated picking line boosts throughput significantly for picking and shipping orders from 180 per hour in a completely manual process to upwards of 450. This helps CTDI warehouse managers handle fluctuating demands.

EtherCAT and flexible machine control from Beckhoff provide benefits during commissioning and operation (Figure 7).

"As an example, we recently installed a line with 20 EtherCAT I/O Box modules and about the same amount of additional field devices," Patwardhan says. "Using EtherNet/IP or another IP-based protocol, scanning and configuring this system would normally take two hours. With EtherCAT, it takes just five minutes to scan in all devices, so it's a tremendous time savings for us."

What initially attracted CTDI to Beckhoff was the ability to use a Windows environment to run both machine control logic and the company's house-developed testing programs, which grade returned electronics, on the same control hardware. The inherent connectivity of PC-based control technology also boosts commissioning and maintenance (Figure 8). "When I am in the field, it is tremendously valuable to be able to have my team in West Chester log on to the system via our internal network to answer my questions, solve issues or make quick changes," Whittemore explains.

Figure 7: Experts in intralogistics and automation, Matthew Adams (from left), applications engineer at Beckhoff, Mark Parsons, eirector of the ACE Division at CTDI, Kirk Whittemore, general manager of the Automation Group at CTDI, Soham Patwardhan, control systems architect at CTDI, Michael Parsons, executive vice president at CTDI, and Ryan Dusk, northeast regional manager at Beckhoff, gather in West Chester, Pennsylvania. (SOURCE: FOREWORD LLC, 2022)

Figure 8: TwinCAT automation software provides a flexible programming environment for engineers coming from computer-science backgrounds. (SOURCE: FOREWORD LLC, 2022)

> The automated picking line boosts throughput significantly for picking and shipping orders from 180 per hour in a completely manual process to upwards of 450.

This is possible because Beckhoff controllers are architected much like other PLCs, Schuchart adds. "However, our customers can run tasks on separate cores of a multi-core processor and run third-party software," says Schuchart. "We see this often in the intralogistics market with companies running a warehouse management system or warehouse control system (WCS) or other software as does CTDI. Engineers can use Windows or a non-Windows operating system (OS). They can even run the TwinCAT project in a non-Windows environment and run Windows applications in a separate virtual environment on the same hardware. This gives their systems incredible flexibility to meet their customer's requirements."

The Beckhoff architecture also streamlines the collection and transmission of data to the WMS to continue to enhance CTDI's equipment to meet the challenges of forward and reverse logistics. "Reverse logistics is challenging because there's less control over which products are coming in, how they're packaged and what the condition is," Parsons says. "Although forward logistics is more controlled and has fewer unknowns, every single order is a custom order. Our dynamic equipment must communicate between our WMS and our control system in real time, and flexible automation technology is critical to fulfill each order on time every time." cd

DevOps strategies through the lens of automation software development

BRITTANY LANGSTON
Product Manager, B&R Automation

AUTOMATION Studio is the bread and butter of software development at B&R. All B&R hardware is programmed with this integrated development environment. The mechanisms for compiling, creating installation packages, and deploying the software are usable outside of Automation Studio itself (i.e., via the command line). Also, the source files within the Automation Studio project are stored in plain text. This makes for easy integration with DevOps practices.

Q: Can you define DevOps for industrial automation?

A: Generally speaking, DevOps is a set of practices that enables continuous, reliable and swift software delivery to customers. It involves things such as increasing the visibility of tasks and metrics, dividing and planning work into measurable chunks, optimizing team and project architecture, automated testing, automated reporting and so on.

Within industrial automation, our first thought is often related to the hardware side of things, such as the programmable logic controllers (PLCs), drives, motors, input/output (I/O), transport systems and so on. But the application software that supports and ultimately controls this hardware is of equal importance. The software that controls the machine is becoming more of an area where our customers differentiate themselves from competitors. Therefore, modern DevOps practices that are typically observed in pure software companies can and should be extended to the industrial automation space as well.

Q: What is the value proposition of DevOps?

A: DevOps is valuable in many ways. The overarching goal and benefit is to continually, reliably and quickly deliver product to the end customer. More specifically, it enables you to increase the frequency of deployments, increase code quality, reduce the response time for bugfixes, increase productivity and more.

Q: That all sounds very favorable. Why isn't everyone within industrial automation already implementing DevOps wherever possible?

A: DevOps is not simply a software tool or an application that you install. It's more of a mindset and a cultural shift in the way we implement our day-to-day work. There are of course tools that support the strategies, but the implementation itself can vary quite widely. As a result, it takes some time and energy for project managers and software developers to identify how exactly to change their processes in order to incorporate DevOps.

Q: What is B&R doing to increase the adoption of such practices?

A: At B&R, we recognize that the initial effort to change your workflows is a barrier to entry for DevOps. Therefore, we have created what we refer to as the DevOps package. This package includes materials for many topics within DevOps. We provide descriptions of each topic, an explanation of why it's important, directives on how to accomplish the topic within a specific tool and template files wherever applicable. In other words, we have combed through the vast amount of general resources for DevOps strategies and defined them specifically through the lens of software development at B&R. Therefore, we significantly reduce the barrier to entry of incorporating these practices in your daily work by succinctly and clearly defining how to apply the strategies with Automation Studio project development.

CONTINUOUS DEVELOPMENT
DevOps is a set of practices that enables reliable and swift software delivery.

Q: What specific topics are addressed within this DevOps package?

A: At the moment, we provide materials for project management, version control, testing and the build and automation server. For project management, we cover topics such as project planning, issue tracking within Jira and information storage within Confluence. The version control section includes a plethora of information regarding Git, Sourcetree, recommendations on committing and branching, how to resolve merge conflicts and strategies for code reviews. The testing portion goes over in detail how to build a test plan and covers the concept of test-driven development. We also provide a step-by-step guide on how to implement B&R unit testing and provide a template Excel sheet that can be used to keep track of all of your manual and automated tests. Lastly, the automation and build server portion goes over in detail how to use Jenkins in order to automatically build your project, run the unit tests and communicate the results to any interested parties.

> The software that controls the machine is becoming more of an area where our customers differentiate themselves from competitors. DevOps practices that are typically observed in pure software companies can and should be extended to the industrial automation space.

Q: What is the current status of the DevOps package?

A: As of Q2 2023, we are finalizing the first version of our DevOps package materials. We are working on implementing a pilot with a customer in order to further refine the materials so that they are as clear and helpful as possible.

Q: How long before you foresee an implementable version available?

A: We expect to have a finalized version of the package completed by the end of the year. Please reach out to your salesperson for more information and continued updates. And, of course, if anyone is interested in seeing the materials sooner, we'd be happy to share them and get feedback.

How much software is enough?

Adaptable, flexible and modular systems adapt

Control Techniques NFC technology app

The Marshal App by Control Techniques is a mobile app that provides a wireless commissioning, monitoring, diagnostics and support offering and is free for iOS and Android. The app is powered by near-field communication (NFC) technology between the Commander S ac drive and a mobile device. Drives are designed to be commissioned while still in the box without power, as well as drive parameters transferred for repeat builds.

Galco / www.galco.com

Beckhoff TwinCAT 3.1 Build 4026

TwinCAT 3.1 Build 4026 offers a dark mode feature, along with six software products, including OPC UA pub/sub, PLC code Profiler and parallel redundancy protocol (PRP). Other additions include a mediatized setup designed to allow you to run one small installer and select and manage all components from within the package manager. The Visual Studio shell supplied by TwinCAT Engineering (XAE) is available in an updated variant based on the 2022 version from Microsoft. Build 4026 will continue to support the 2017 and 2019 versions of Visual Studio as well. The TE1210 TwinCAT 3 PLC Profiler provides precise analysis of the PLC project's runtime behavior.

Beckhoff / www.beckhoff.com

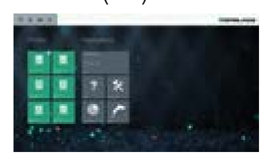
KEB Combivis Studio 6 software

Combivis Studio 6 is an automation and drive configuration software designed to set up, configure and monitor KEB's servo drives, control, I/O and other automation devices. KEB's software is designed to provide real-time visualization, parameter management, diagnostics of complex motion sequences, and compatibility with various communication protocols. Combivis Studio 6 features extensive function block libraries, motion profile editors and simulation tools to simplify complex machine routines and shorten development timelines.

KEB America / www.kebamerica.com

Pepperl+Fuchs VisuNet RM Shell

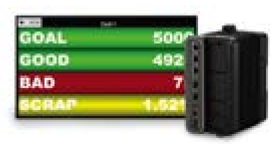
VisuNet RM Shell is a thin client firmware pre-installed on every Pepperl+Fuchs VisuNet Remote Monitor (RM) and box thin client. RM Shell replaces the Windows desktop and reduces the user interface to critical system functions. Predefined user roles are designed to tailor information access to different authorization levels. An app concept is designed to allow integration of third-party remote protocols and applications. Additional features include a universal write filter, USB lockdown and a built-in Ethernet firewall.



Pepperl+Fuchs / www.pepperl-fuchs.com

Red Lion FlexEdge Intelligent Edge Automation platform

FlexEdge Intelligent Edge Automation Platform with HDMI from Red Lion is designed with user-friendly configuration capabilities to develop and deploy customized dashboards. The platform is designed to directly collect data from PLCs, drives, bar code scanners and more and map data to PLCs, PCs and SCADA systems with a no-code drag-and-drop interface, allowing a Siemens PLC to communicate with an Allen Bradley drive in mere seconds. It is designed to sync data to FTP servers, set up alerts for events and link productivity application data to cloud providers.



Red Lion / www.redlion.net

Omron P/N CX-One series software

The P/N CX-One series is a comprehensive software package that integrates PLC software with support software for setting up networks, programmable terminals, servo systems, invert-

ers and temperature controllers. Features include integrated software management for Omron PLCs and components. CPU bus units and special I/O units are designed to be set without concern for memory addresses and without relying on operation manuals and be started from the I/O tables.

Newark Electronics / www.newark.com

Rockwell Automation FactoryTalk Twin Studio

FactoryTalk Twin Studio is an end-to-end automation design software where users can design, program, simulate, emulate and virtually commission in one cloud environment. On-demand digital design software is designed to enable a simpler, more efficient way to work from any web browser with software that is always up to date and flexibly scales users and compute capacity to meet project workload demands. Users can collaborate on projects from anywhere to improve designs and develop projects; build, test and commission machines virtually to confirm that they meet needs before committing to a design; and remotely deploy updates and troubleshoot problems from anywhere using a web browser.

Rockwell Automation / www.rockwellautomation.com

Mitsubishi Electric Melsoft Gemini 3D simulator software

Mitsubishi Electric Automation, Inc. released its Melsoft Gemini 3D simulator software designed to provide visualization, simulation and the streamlining of work processes. Gemini operates using a PC-based 3D digital space and connects directly to factory devices without having to go through an OPC server. Gemini includes a hardware menu that offers selection from approximately 2,500 types of production equipment, including robots, conveyors, processing machines and more. Users can also set parameters to adjust the way the virtual production line operates.

Mitsubishi Electric Automation / us.mitsubishielectric.com

PACEdge industrial edge platform

The PACEdge industrial edge platform is designed to help manufacturers accelerate digital transformation projects by enabling users to create and scale up performance-improving applications quickly. The platform simplifies application development by bringing together open-source tools into a flexible, integrated and secure platform for using machine data and analytics. The release coincides with the launch of the company's PACSystems RXi2-BP edge computer, a small form-factor industrial PC that enables high-performance analytics to be run close to the machine. The platform helps users collect, analyze, store and serve up machine data securely near the source or across enterprise systems.

Emerson / emerson.com

LabView systems engineering software

The LabView programming environment from Emerson simplifies hardware integration. It reduces the complexity of programming, enabling users to focus on engineering problems and visualize solutions with built-in, drag-and-drop engineering user interface creation and integrated data viewers. Developers can create algorithms for data analysis and advanced control with included math and signal processing IP or use their own libraries.

DigiKey / www.digikey.com

TIA Portal V17

Totally Integrated Automation (TIA) is an open system that enables the seamless interaction of automation components, software and higher-level systems and services. This is achieved by consistent data management, worldwide standards and uniform interfaces—from field level to corporate management level. The system offers simulation tools, seamlessly integrated engineering and transparent plant operation, which pair together in TIA Portal for increased flexibility, speed and productivity. The features are built for system integrators and machine builders, as well as plant operators.

Siemens / www.siemens.com CD

Deterministic networks and motion control

A CONTROL DESIGN *reader writes:* How has the acceptance of industrial networks, especially deterministic networks such as EtherCAT, improved motion control?

Answers

EtherCAT advantages from its creator

EtherCAT has been redefining what's possible in motion control since the industrial Ethernet system was released in 2003. It's a high-speed, high-bandwidth, extremely deterministic fieldbus for every aspect of automation—even safe motion functionality. All of this makes it ideal for all things motor- and drive-related, from the most basic precision time protocol (PTP) systems to extremely advanced applications with hundreds of axes, robotics and mechatronics. Because we invented EtherCAT, we've developed our servo, stepper and mechatronics technologies to fully harness the strengths of the protocol.

The functional principle of EtherCAT alone—processing on the fly, distributed clocks, free selection of topology—makes it an ideal motion bus. But I'll work to highlight advantages in three main areas: design, commissioning and operation.

First, design: EtherCAT is an open protocol, and some of the biggest names in servo and stepper technology manufacture EtherCAT devices. The same goes for robot vendors like Denso, Stäubli and Kuka.

But one component you won't have to worry about is managed switches; EtherCAT is a switchless network. EtherCAT devices don't even require IP addresses. This simplifies installation, streamlines architectures, cuts costs, reduces communication delays, which are critical for high-performance motion control, and provides free selection of wiring topology.

How much time do you spend calculating network performance? Stop. Invest that time instead in creating new solutions without limits.

But EtherCAT is also incredibly flexible if you need to incorporate other networks. It can easily connect with other fieldbuses when new equipment is installed in brownfield applications, for example. One EtherCAT network can transmit data from devices with a legacy bus like serial real-time communication system (SeRCoS), CANopen, DeviceNet or Profibus, and it can connect with other industrial Ethernet systems like EtherNet/IP and Profinet.

Next, let's talk commissioning. Unlike those other protocols, one EtherCAT network can connect up to 65,535 nodes, without any special hardware requirements. You can imagine these systems are sometimes spread out, so point-to-point commissioning would be extremely time-consuming. Fortunately, it's not necessary. EtherCAT optimizes commissioning by passing data through a state machine. The state machine allows the configuration to be loaded in stages. You can configure drives over the network via the main controller without disrupting any other devices. It's essentially plug and play.

Even hot-connect capability is perfectly fine while the system is running. The state machine checks the drive parameters, makes sure everything is connected correctly and then ensures the distributed clocks are synchronized.

In this discussion, distributed clocks are a critical feature. This technology enables the EtherCAT protocol to synchronize the time in all local devices within a very narrow tolerance range. EtherCAT devices, from I/O terminals to servo drives, support distributed clock functionality. That means each device on a network contains an internal clock that operates at startup, keeping each axis perfectly in sync with the rest.

Finally, in operation, setpoint generation or path profiles are all deterministically transmitted to the drive. And that's not just one axis, but all of them.

This deterministic data communication enables extremely fast cycle times. One example is the Kinetic Rain moving sculpture at Changi Airport in Singapore, which has 1,200 axes with a 1-millisecond cycle time; or there's the Giant Magellan Telescope in Chile's Atacama Desert, with 3,000 axes on one EtherCAT network.

A little closer to home, we've worked with machine builders, system integrators and end users across all industries

Figure 1: For CMD, EtherCAT simplified the synchronization of a gusset pouch with the continuous material flow. (SOURCE: BECKHOFF)

who discovered EtherCAT's competitive advantages in operation.

Unlike drive-based solutions on other networks that have difficulty adapting, the EtherCAT solution's setpoint generation optimizes path control with smooth adaptation. This is especially true when it comes to functions like camming or logarithmic path profiles.

Another example is ensuring that one axis doesn't cheat ahead of another in a gantry; being able to command them cyclically in the controller is a huge benefit.

The engineers at CMD in Appleton, Wisconsin, noticed these advantages when redesigning their 760-SUP stand-up pouch system. In addition to optimizing a dozen servo axes, the pouch machine had a gusset punch in its continuous-motion section upstream. To synchronize this punch with the continuous material flow using a previous vendor's technology, they needed all sorts of special networking equipment.

With EtherCAT, it just worked (Figure 1). Lead engineer at CMD, Jason Plutz, said it best: This EtherCAT-based solution was "less expensive in our application, but the technology was also a major leap ahead. We made even bigger advances than we had hoped (Figure 2)."

MATT PRELLWITZ

drive technology product manager/ **Beckhoff Automation**

Figure 2: CMD saw measurable increases in performance by using EtherCAT on its redesigned 760-SUP stand-up pouch machine. (SOURCE: BECKHOFF)

One-stop-shop for all business

To put it simply, the acceptance of industrial networks like EtherCAT has facilitated the motion-control process in key areas: improved time and space, simplicity or ease of use, and interoperability and conformity.

While I will use EtherCAT to serve as an example of improving motion control through its use, first think of motion control in the following way before EtherCAT. Imagine you have multiple pieces of business to conduct at the state building. You go in and start in one room, and the associate sends you to another room where you have tasks to complete, followed by another room with additional requirements. You eventually complete this business, not looking forward to this again.

Fast forward, now the EtherCAT office opens up and you go in. In this office, the associate provides you with one form that allows input of all your business. This form then allows for the transport of all your business to the appropriate departments. That is industrial networks like EtherCAT. It allows for freeing up of space for devices like central processing units (CPUs), which means faster and cleaner operations. It creates a simple environment, not convoluted, which allows for seamless operations. It permits multiple device additions and exchanges that follow a certain standard. This enables the installation of new devices that will not be subject to multiple protocol requirements and limitations.

Who doesn't want things to be time-saving, simple to do and easily added or removed? You tell me, but I think I know the answer.

PATRICK TEAGUES

product development analyst / **Misumi USA**

A case for EtherNet/IP and the significance of TSN

Broad market acceptance of industrial Ethernet has improved motion control by allowing for the additional convenience, lower cost and improved diagnostics made possible by using one integrated Ethernet network for different tasks including motion and safety. The additional diagnostics data in particular will grow in importance as machine learning (ML) and artificial intelligence (AI) are applied to more industrial use cases in the future. While many industrial Ethernet networks were introduced in the early 2000s, including EtherNet/IP, Profinet and EtherCAT, it took until 2017 for industrial

Ethernet to overtake fieldbus in new installations. Each industrial Ethernet network approach adds determinism to Ethernet in different ways.

One of the leading industrial networks, EtherNet/IP, enables precise motion control via the common industrial protocol (CIP) Motion extension. CIP Motion relies upon the Institute of Electrical and Electronics Engineers (IEEE) 1588 standard and CIP Sync to enable precision clock synchronization. CIP Motion is unique, in that it removes the requirement for strict determinism from the network infrastructure and entrusts the end devices with the timing information necessary to handle the real-time control needs of the application. Clock synchronization of better than 200 ns can be readily achieved.

Because the clocks in the end devices are tightly synchronized and information in the message is time-stamped, a small amount of jitter in receipt time of the message is unimportant. EtherNet/IP with CIP Motion can thus deliver the high-performance, deterministic control required for closed loop drive operation, using standard, unmodified Ethernet. An important consideration for the future of industrial Ethernet determinism is the impact of increased bandwidth. Adoption of Gigabit and faster cabling and devices combined with separate network zones and conduits with vertically layered switches for both security and safety purposes can significantly lessen the need for time-sensitive solutions.

An additional future option to provide bounded latency and jitter in industrial networks, especially for 100-Mbit/s networks, will be enabled by the International Electrotechnical Commission (IEC)/IEEE 60802 Time Sensitive Networking (TSN) Profile for Industrial Automation standard. 60802 TSN will allow the highest priority traffic, such as motion, safety and I/O,

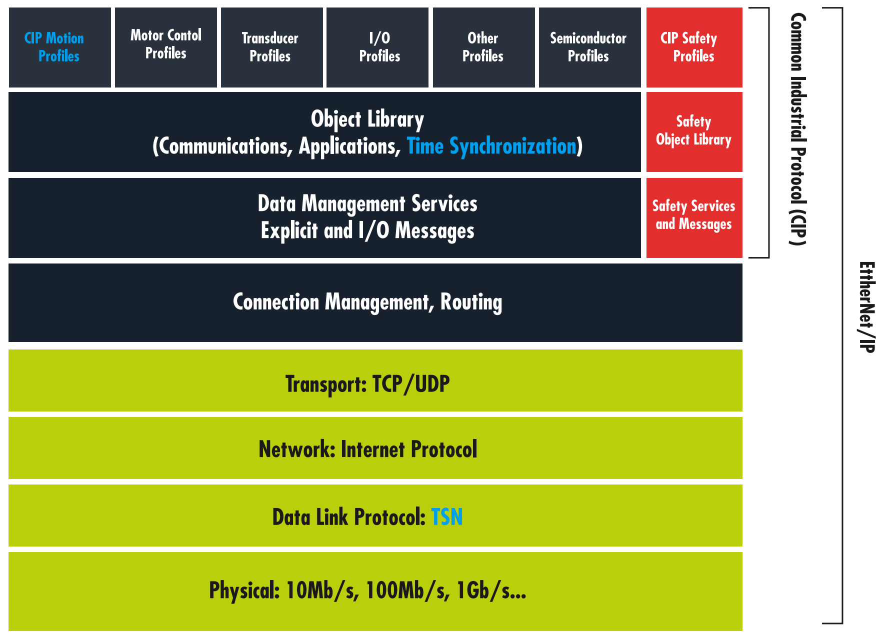


Figure 3: EtherNet/IP network architecture with time-sensitive networking.

while allowing less critical traffic, such as routine diagnostics to wait until additional bandwidth is available. 60802 TSN can significantly reduce the amount of jitter, latency and lost packets due to messages exceeding the available bandwidth.

60802 TSN is able to prioritize critical traffic on an overloaded network via synchronized clocks across the network, critical traffic scheduling, traffic shaping based on relative priority and frame preemption based on packet size. Frame preemption is one of the simplest and most effective methods that 60802 TSN will be able to employ to protect high-priority traffic. 60802 TSN can also take advantage of frame replication and elimination for reliability using virtual paths and ingress policing to identify and remove malicious or misbehaving devices from the network.

EtherNet/IP will be able to adapt CIP Motion to 60802 TSN by aligning the network with the motion-control planner using a common notion of time. Once CIP Motion and 60802 are aligned, network transport can be facilitated using scheduling as necessary to meet the needs of the network and coexist fairly with existing traffic (Figure 3). EtherNet/IP specifications are anticipated to have optional extensions enabling IEC/IEEE 60802 TSN compatible products after the IEC/IEEE 60802 TSN specification is released.

It's important to note that a collaboration between the Avnu Alliance, CC-Link Partner Association, ODVA, OPC Foundation and Profibus and Profinet International will result a single conformance test plan for the IEEE/IEC 60802 Time Sensitive Networking (TSN) Profile for Industrial Automation. This cooperative effort provides end users with confidence that 60802 TSN conformant devices from different manufacturers that support different industrial Ethernet protocols can coexist reliably at the TSN level on shared networks, assuming the usage of a consistent hardware platform.

STEVE FALES

marketing director / **ODVA**

Networking standards increase benefits

Adopting Ethernet has enabled motion control to take advantage of common cabling and connections, as well as increased bandwidth supplied by standard networking technologies, reducing the cost and improving performance of the network for motion control.

EtherCAT and other motion applications and those relying upon them have seen the benefits. The various motion-control applications are at various stages of adopting standards-based, non-proprietary networking models, with more benefits as they adopt more standard models.

The standard networking world is also advancing its time synchronization, resiliency and deterministic networking capabilities even further, as displayed in the IEEE's TSN enhancements, the joint IEEE/IEC 60802 on adopting these enhancements leading to the OPC Foundation's work on new motion-control communication standards using fully standardized networking capabilities.

Bringing motion-control applications on to evermore standard networks with evermore capabilities will enable the full value of Industry 4.0 and digitization to be realized by these applications.

PAUL DIDIER

solution architect manager / **Cisco**

Networks with determinism bring super speed

I always get excited when I think about how much motion control has changed and is still changing. There have been so many advances since the introduction of fieldbuses like Ethernet for control automation technology (EtherCAT) in 2003 and Process Field Network (Profitnet) in 2000. The best way to understand the reasons for their adoption is to look at what they bring to the automation world.

Real-time communication is a strong advantage. You want data transmission to be fast and synchronous. When it comes to complex motion-control applications, EtherCAT is known for its real-time capabilities. It can transmit data at extremely high speeds while maintaining precise synchronization, which can allow for improved motion-control performance. This is not unique to EtherCAT, but it is an important feature of deterministic communication.

Lower latency is a major advantage of industrial networks. Deterministic networks significantly reduce communication and processing latencies, which leads to faster response times in motion-control systems, resulting in improved accuracy and precision.

In my opinion, synchronization is one of the most important advantages of deterministic networks like EtherCAT and Profinet. In motion control, multiple axes often need to be synchronized to work together seamlessly. EtherCAT, for example, features distributed clock synchronization, which allows devices to synchronize across the network. This synchronization enables smooth, coordinated motion along multiple axes, which also results in higher accuracy.

With the requirement to integrate multiple processes into one system, deterministic networks also provide flexibility and scalability for the network topology. EtherCAT and Profinet support various communication configurations, such as daisy-chain, which reduces installation time.

Finally, deterministic networks offer solid diagnostic capabilities for monitoring and troubleshooting. They are able to detect potential issues early and minimize downtime—resulting in higher overall system reliability.

In summary, there are many different fieldbuses on the market that have strengths and weaknesses. The power that networks with determinism bring to motion-control applications is superior speed, which is the real reason for the shift to linear motion control.

PERRY HUDSON

market manager, packaging / **Pepperl+Fuchs**

Sending data between IT and OT

In the early stages of motion control, most of the control was accomplished with analog and digital signals. As implementations grew and machines continued to add axis count, the amount of wiring and relay logic became unbearable to handle. This, along with the prevalence of programmable logic controllers (PLCs), made the transition to a communications bus for drives and other field devices a prominent staple in industrial plants by the new millennium. With the installation of Ethernet networks in our homes and offices, it was only natural this technology would find its way to the plant floor.

These Ethernet protocols are built upon the success of fieldbus protocols with the added vigor of speed, determinism and network switch technology.

In the past decade, capitalizing on being able to receive and send data between the information-technology (IT) and operational-technology (OT) domains has opened up completely new realms of industrial efficiencies, including operational insight, uptime and now artificial intelligence (AI)-led innovations.

CRAIG NELSON

Sinamics, drives product manager / **Siemens Industry**

Industrial network acceptance

The acceptance of industrial networks, particularly EtherCAT, as a deterministic network, is really growing our abilities for industrial motion control. Going back to 2003 with the onset of EtherCAT, there has been a very steady increase in its use and capability.

The ability to process a thousand I/O points in microseconds is a huge advantage in manufacturing. Devices such as drives depend on speed and accuracy, something that EtherCAT can excel at specifically. With data speeds as high as 100 Mbit/s and improving, many manufacturers of drives have adopted EtherCAT as their number-one choice for industrial networks.

ERIC J. HALVORSON
partnership marketing manager II—strategic programs
for automation and control / **DigiKey**

Scalability and convergence

Ethernet-based networks offer scalability, in terms of bandwidth and network size, that is relatively easy to wire but not available in traditional fieldbuses. More importantly, Ethernet technologies bring the possibility of convergence of various functions, including motion, safety and planning. Convergence, in turn, offers the ubiquitous data access that is a cornerstone for the factory of the future.

JORDON WOODS
director and member / **Analog Devices Deterministic Ethernet Technology Group and Avnu Alliance**

Impacts on machine design and maintenance

Industrial networks have had a tremendous impact on how machines are designed and made. These networks have reduced time and cost in manufacturing the machine while also gaining flexibility to the design. Deterministic networks, such as EtherCAT, have had a large impact on motion.

One of the impacts has been in machine design. Machines can now mount devices in more remote locations that are in a closer vicinity to the work they are controlling. The ability to run a communication cable out to devices, such as servo drives, has allowed designers to create this more flexible design. This can save panel space and wiring time and material in machine designs.

Another use for industrial networks is the ability to work on portions of the workflow while the process is still running. Think about cell-based manufacturing where a maintenance person can work on a cell without stopping the complete machine. With a network you can stop communication with devices without faulting out the network and shutting down the entire machine.

We have used this capability to allow tooling in some cells that are not being run at the time, while those cells are shut down and lock-out/tag-out is applied. This can help save machine down time while this maintenance is being done.

The deterministic capabilities of industrial networks can have a large impact on how the machine operates and keep it operating safely and efficiently. One of the things that I have done personally, is use the determinism to write a collision-detection function block based directly on how the machine operates.

We have been able to write a custom routine that monitored command and actual velocity and torque. We then monitored them over a 3-msec period—three points of data—and look at them to watch for a raise in torque and reduction in speed to see that there was a problem based on the motion profile.

Another was collision avoidance when a machine was being moved in a manual manor through a human-machine interface (HMI). We were able to write a function block that monitored position, direction and velocity.

If the two axes were moving toward each other, their speed would be overridden as they got close to each other until they came to a stop. As the axes were commanded to move away from each other, their speed was allowed, and they could separate. This allowed some axes to be manually jogged while others ran in automatic mode without having them collide.

These are just a few functions that we have been able to create by utilizing an industrial network and a couple of examples of how determinism of our industrial network, in this case EtherCAT, can enhance machine performance. Without the benefit of the deterministic network these capabilities would not be accurate enough to work.

GREG DIECK
product manager / **Motion**

Distributed clocks for precise time synchronization

EtherCAT is widely used because of topology flexibility, ease of installation and low cost—no switches. But it's most famous for the performance it offers in motion control. EtherCAT sets the bar high: synchronized, multi-loop, coordinated, centralized motion control. If a fieldbus can do well here, it's certainly capable of less strenuous time-dependent motion requirements.Unbelievably, no special hardware or architecture is required. The functionality is built in to every EtherCAT device.

This widely used functionality for extremely precise time synchronization is called distributed clocks. In an EtherCAT network, the frame is always returned. Each EtherCAT device has a built-in oscillator and can measure the timekeeping (Δt) between a received and returned frame.

You can calculate the timing of the entire system with simple algebra. After that, the EtherCAT network can assign a common system time to every device that delivers high time determinism. Each node has a common system time and can read/write to the drives at exactly the same moment. One can update all the motion devices at the same point in time, removing many tuning complexities.

This was never possible with traditional fieldbuses, including other Ethernet-based systems still used today. EtherCAT uses Ethernet in a very special way, which often takes some getting used to. That doesn't mean it's complicated; it's actually simpler. It's just different than many engineers, especially in the United States, are used to. Sometimes it's hard to unwind your time spent on understanding general Ethernet and deconstruct your preconceived notions. EtherCAT simply takes away the complexity.

EtherCAT sets the bar for user-friendliness extremely high. With EtherCAT, there is nothing special to purchase; high-performance motion control can be accomplished on the same network as everything else. There is no requirement for special network interface controllers (NICs) or devices. Distributed clocks are built into every single EtherCAT device.

Does every motion system require this kind of time synchronization? No. If that functionality is not needed, no problem—just don't enable the functionality. If you need more time precision later, you can enable it. No changes to network architecture or added costs for special devices are needed.

As an open protocol, the EtherCAT Technology Group has more than 7,000 members and more than 3,000 registered device manufacturers worldwide. This includes more than 200 different vendors of EtherCAT drives and thousands of other automation products: controls, sensors, servos, steppers, variable-frequency drives (VFDs), linear motors, mechatronics systems, you name it.

EtherCAT is a winner on every level. Infrastructure costs are minimized. There is well-documented ease of network installation. And it is not difficult for vendors and users to implement.

As a user, you save costs on many levels, not to mention the minimized engineering effort needed to attempt a similar architecture with another Ethernet protocol, which most assuredly will fall short in reality. With EtherCAT, one network does it all.

ROBERT TRASK, P.E.
North American representative /
EtherCAT Technology Group

Open network technology for TSN

When looking at demanding applications, such as motion control, data needs to be transferred with high accuracy and reliability to meet strict cycle times. Ultimately, to be highly synchronized and truly effective, motion-control systems require deterministic network performance.

Up until recently, standard Ethernet did not offer deterministic capabilities, per se. Therefore, determinism in industrial automation could only be achieved in two ways. It could be established by controlling all the devices communicating on a network, essentially closing the network to unknown traffic that can impact determinism. It could also be set by selecting a network technology that could guarantee deterministic performance through key protocols and topologies.

Recently, the introduction of TSN standards has updated the capabilities of industrial Ethernet to make it deterministic, eliminating the need to implement non-standardized strategies. When looking at motion-control applications, open network technologies with TSN functions are helping companies reach new heights in a number of ways.

First, an open network technology that incorporates TSN, such as CC-Link IE TSN, is able to support the need for increasingly shorter cycle times, enabling faster operations while ensuring quality and uptime. Second, it is helping machine developers and users incorporate an unprecedented number of axes within a system and its motion control network, supporting the development of more advanced setups.

This type of open network can also help to enable the digital transformation of business by driving convergence. It can accommodate the coexistence of both deterministic traffic with extreme performance characteristics, such as motion control, and TCP/IP traffic of all kinds for general-purpose communications.

Therefore, a TSN-based technology offers a solid foundation for smart, interconnected factories that leverage data to generate business intelligence, enhancing flexibility and responsiveness and ultimately improving decision-making.

CC-Link IE TSN is leading the market in driving the adoption of TSN in industry. This is the first to leverage gigabit Ethernet and the key TSN standards for time synchronization and traffic shaping. The network technology is widely used, offering a broad development ecosystem for the creation of compatible industrial automation devices and a multitude of products that can be used to futureproof factory operations.

ROY KOK
senior partnerships and alliance specialist /
CC-Link Partner Association (CLPA)

Joey Stubbs
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Safe automation in explosive environments

EXPLOSIVE ENVIRONMENTS POSE unique challenges for any type of automation equipment, but, because most human-machine interfaces (HMIs) have some type of display, there are unique issues for this piece of equipment. The applicable definitions and rules for locating equipment in these areas are regulated by either the National Electrical Code (NEC) in the United States or the Atmosphères Explosibles (AtEx) directives for most of the rest of the world.

Both systems allow for three main approaches to locating any type of control hardware safely in explosive gas or dust areas to prevent fire and explosion:

- limit the power to the devices so ignition cannot occur—intrinsically safe (IS)
- allow combustibles in, but contain any resulting explosion within the control enclosure—explosion proof
- use inert gas purging to prevent explosive gas or particulates from getting into cabinets or devices in the first place.

> Explosion-proof enclosures are effective for using standard components in Class I or Zone 1.

Intrinsically safe is a valid approach to low-power devices, such as sensors, and is used quite effectively every day in many different situations. The power demands of HMIs, however, make this approach a near impossibility for a user display. And, if IS-certified HMIs do exist, I'm sure the cost is nothing short of extraordinary.

Explosion-proof enclosures are effective for using standard components in Class I or Zone 1 environments but very cumbersome, very expensive and very unfriendly to HMI displays. It is and can be done, but, by most accounts, it is not a preferred method for an HMI.

This leaves us with purge and pressurized systems. This approach is quite simple in principle: The enclosure is pressurized with clean air or inert gas, which prevents explosive gas or dust from entering in the first place. It creates a non-explosive mini-environment inside the enclosure.

For the machine designer, this means, depending on the type of purge system and pressure/flow controller used, standard nonhazardous-rated equipment can be used in the enclosure, even up to Class I/Zone 1 for NEC, and Zone 1 for ATEX. Additionally, there are numerous vendors of HMI panels that have purge systems built-in. All the machine designer has to do is supply instrument air and power, and the system has a bona fide purge HMI.

There are two types of purging systems for enclosures—continuous flow (CF) and leakage compensation (LC). Both systems use a flow controller to maintain a minimum pressure or flow to the enclosure, and both have some level of intelligence. It is how they handle and measure the gas flow that is the difference. Both systems require a separate purge phase for expelling any initial explosive gases prior to energizing equipment and then a pressure phase that maintains the protective gas supply during running of the equipment.

Continuous flow is a somewhat simpler method, but only applicable to smaller enclosures less than 17 sq ft. In CF systems, a continuous flow of protective gas is supplied to the enclosure at a rate that maintains a minimum internal pressure, but the flow is the same during the initial purge phase and the normal pressure state. This can result in very long purge times prior to energizing the equipment in the enclosure. Less functionality in the pressure controller is required, so the initial controller cost is lower, but, since the combined purge and running flow is high, this system consumes more air than the LC approach, so long-term costs are higher.

Leakage-compensation systems use a specialized flow controller that gives a higher rate of gas during the purge phase than it does during pressurized running state, so running air flow is lower, and the system consumes less instrument air. The controller is more expensive, but long-term costs are lower as a result of less air usage.

One drawback of purge and pressure systems is the cost and complexity of supplying the required protective gas. Although inert gases, such as nitrogen, can be used at even higher cost, the typical implementation uses instrument-quality air, which is dry, clean air from outside the hazardous location.

Joey Stubbs is a former Navy nuclear technician, holds a BSEE from the University of South Carolina, was a development engineer in the fiber optics industry and is the former head of the EtherCAT Technology group in North America.


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