

Automation NOTEBOOK

Your guide to practical products, technologies and applications

From  AUTOMATIONDIRECT.com

Build Better Machines Faster

Process-enabled motion controllers and motion-enabled PLCs give OEMs the flexibility to optimize design and performance.

Student Spotlight: Automating Rocket Science PG. 8

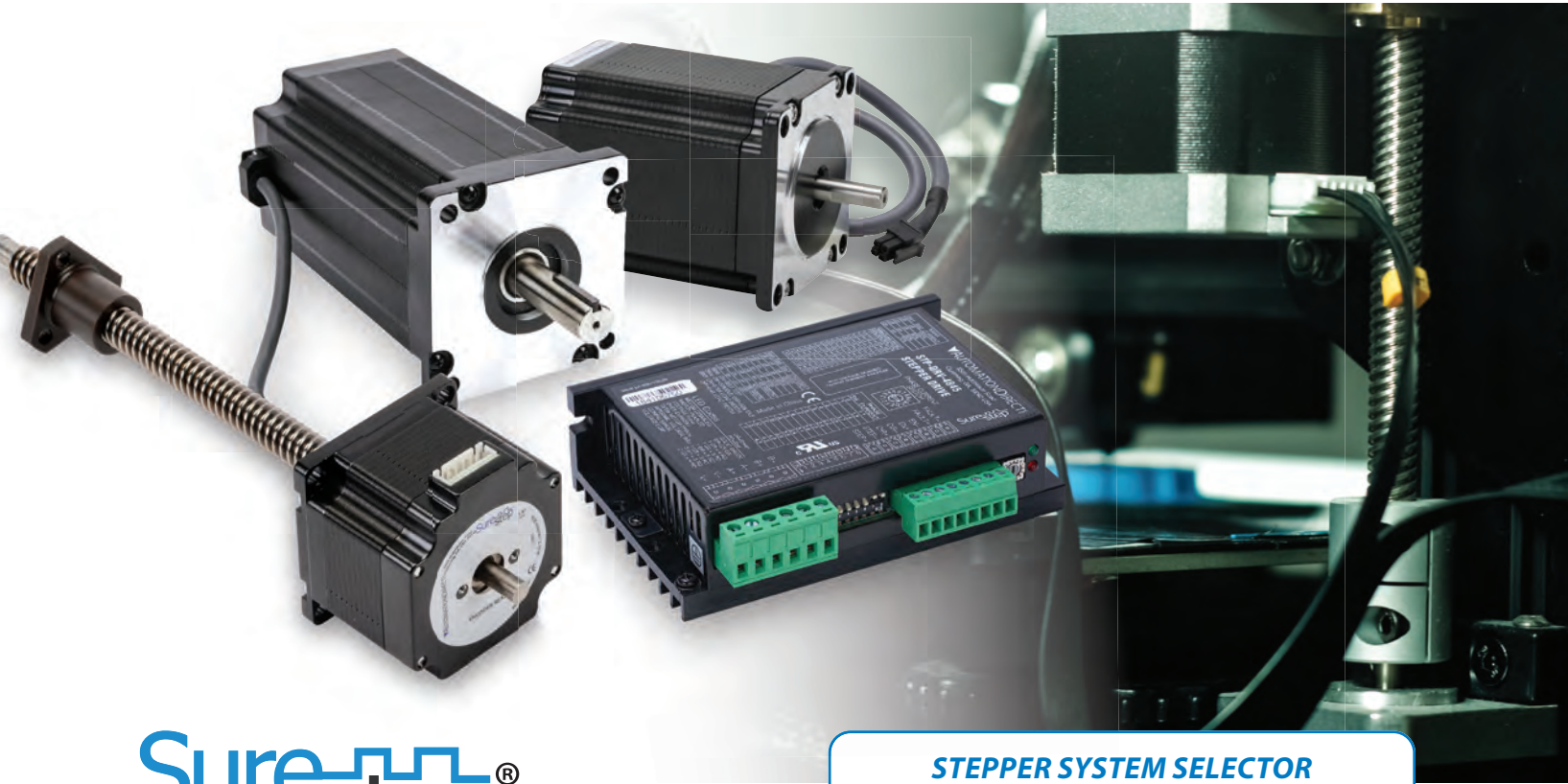
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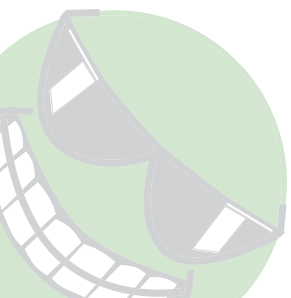
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Making a Difference With Industrial Automation



Stephanie Neil

Stephanie Neil
VP, Editorial Director
sneil@wtwhmedia.com

Welcome to the fall issue of AutomationDirect's **NOTEBOOK**, your guide to practical products, technologies, and applications!

This fall season has been difficult for many of us in the direct path of Hurricanes Helene and Milton. Our thoughts are with everyone personally impacted.

From a business standpoint, AutomationDirect is paying close attention to the supply chain given the disruption to transportation routes in parts of the southeastern U.S. In addition, a looming dockworker strike across 36 ports on the east coast may also affect AutomationDirect's suppliers. Product availability is a top priority for the company's customers. As such, a statement on countermeasures can be found in this magazine.

In this issue of **NOTEBOOK**, we continue to explore the many ways industrial automation products are making a difference.

In our cover story, we dig into the evolution of motion controllers and PLCs looking at how the lines are beginning to blur between the two. Motion controllers are now equipped with multiple I/O points, can support a variety of network protocols, and are capable of handling PID control, making these controllers just as sophisticated as the PLC. Meanwhile, PLCs are going beyond basic machine control and expanding into safety and motion, as well. But the two technologies are not synonymous in every way. On page 10, AutomationDirect's Kevin McClellion and Joe Scoccimaro explain how to choose between the two.

In a technical brief, Joe Kimbrell, Product Manager for motion control products at AutomationDirect, explains the difference between Ethernet communication protocols. Turn to page 22 to learn more. In a separate story on page 24, Joe offers an overview of encoders, providing details on what they are, how they can be configured, and how to choose the right option for your application needs.

We also dig into some examples of how industrial automation can be used outside of the factory floor. In the success story "Automating a Luxury Bus" on page 27, we learn how Mark McHenry, founder of Systems & Controls, has leveraged his systems integrator skillset within the custom coachbuilder industry.

Speaking of system integrators, turn to page 4 to learn more about AutomationDirect's Systems Integrator program that connects end users of all sizes with SIs ready to support their automation needs.

Connecting people is important, especially given the current workforce crisis.

A second feature story shines a spotlight on the growing skills shortage. It's estimated that nearly 350,000 people are retiring from the manufacturing industry annually — and they can't fill those roles fast enough. Even with automation advancements, the industry still needs people. AutomationDirect education specialist Chip McDaniel addresses the issues on page 17.

There is much more to explore in the following pages of **NOTEBOOK**. Please take a read, pass it along to your colleagues, and send us a note if there's something you want us to cover in an upcoming issue! ▼





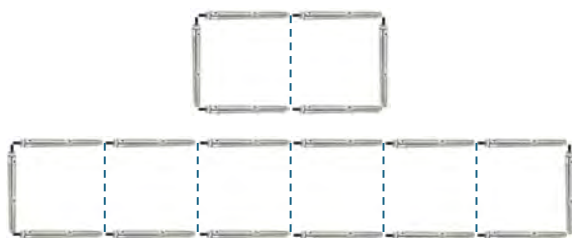
AutomationDirect BRAINTEASERS

Cylinder Splendor

Shown below are 20 pneumatic cylinders, divided into groups of 6 and 14 and forming two enclosed shapes. The area of the larger shape is exactly 3 times larger than the smaller (the dashed line are shown only to help envision the sizes of the enclosures). Can you divide the 20 cylinders into groups of 7 and 13 and accomplish the

same arrangement (i.e. create two closed areas with one area exactly three times larger than the other)?

Did you know that AutomationDirect sells a full line of pneumatic components, including over 800 models of cylinders in seven popular styles: non-repairable, stainless-steel NR, compact, compact extruded, NFPA tie rod, dual guide rod, and ISO 1552. (<https://go2adc.com/pneu>)



Suction Cup Shuffle

Can you place 6 suction cups on a flat surface and then slide them into the exact arrangement shown? (feel free to use identical coins if you don't have six suction cups at hand) The round objects must be positioned exactly, not "by eye", and you may not lift any of them from the surface – or the solution would be trivial. No measuring or marking should be needed, you just need the six objects, and a clever method.

Did you know that Automation Direct offers a line of pneumatic vacuum products, including Schmalz suction cups, end-of-arm tooling components, vacuum ejectors and accessories? (<https://go2adc.com/vacuum>)

And yes – we're aware that suction cups don't slide very easily ;-)



Truffle Kerfuffle

The factory's robotic truffle picker is making gift boxes with a single row of seven unique types of truffles. The assortment includes three white chocolate truffles, while the other four are milk or dark chocolate. The placement of the seven truffles in the row is completely random. What are the odds that a given gift box will have white truffles on both ends?



AI Image | Google Gemini

Find these answers and more @
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Automation NOTEBOOK

EDITORIAL STAFF

VP, Editorial Director
Stephanie Neil
sneil@wtwhmedia.com

COORDINATING EDITORS

Director of Marketing
Joan Welty
AutomationDirect
jwelty@automationdirect.com

Technical Marketer
Bill Dehner
AutomationDirect
bdehner@automationdirect.com

Advertising Manager
Tina Gable
AutomationDirect
tgable@automationdirect.com

Puzzle Master
Chip McDaniel
cmcdaniel@automationdirect.com

CREATIVE SERVICES

VP, Creative Director
Matt Claney
mclaney@wtwhmedia.com

Cover Artist
Erika Kinney
ekinney@automationdirect.com

SALES TEAM

VP, Business Development
Jim Powers
jpowers@wtwhmedia.com

CONTENT STUDIO

VP, Content Studio
Peggy Carouthers
pcarouthers@wtwhmedia.com

Program Manager
Meghan Brown
mbrown@wtwhmedia.com

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AutomationDirect
3505 Hutchinson Road
Cumming, GA 30040
Ph: 800.633.0405 | 770.889.2858
FAX: 770.889.7896

(produced by) **WTWH Media, LLC**
1111 Superior Ave., Suite 2600
Cleveland, OH 44114
Ph: 888.543.2447
FAX: 888.543.2447

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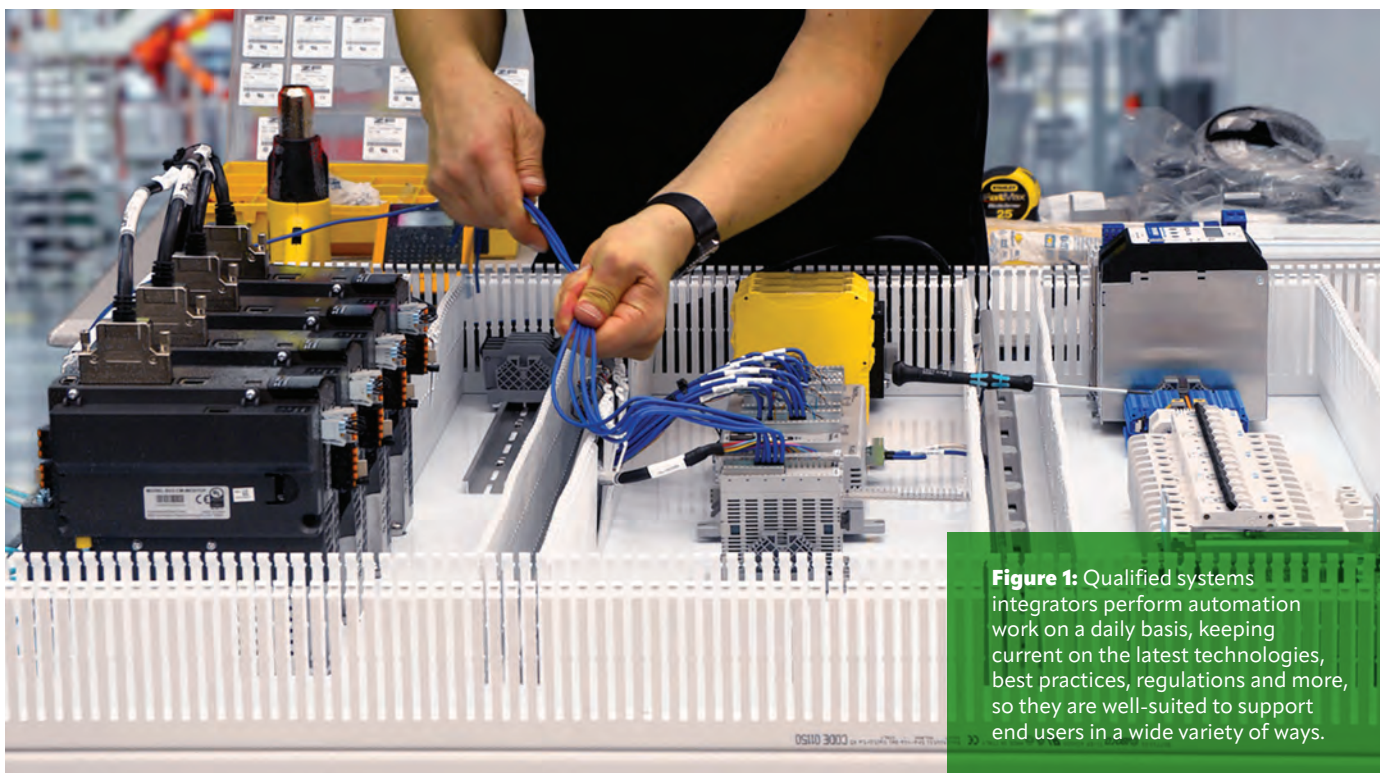


Figure 1: Qualified systems integrators perform automation work on a daily basis, keeping current on the latest technologies, best practices, regulations and more, so they are well-suited to support end users in a wide variety of ways.



SI Direct: AutomationDirect's Systems Integrator Program

BY JEFF PAYNE, AUTOMATIONDIRECT

The SI Direct program connects end users of all sizes with systems integrators ready to support their automation needs, spanning a variety of technologies and processes.

Every manufacturing business must make choices about supporting their machines, production processes and personnel. Careful application of the right automation technologies and skillsets in each of these areas yields the best overall results.

When it comes to the personnel aspect, it was historically common for larger enterprises to cultivate fully-staffed in-house engineering and maintenance groups. There are many benefits to this approach, as these companies could curate internal knowledge of the best ways for designing, installing, supporting and maintaining all aspects of the manufacturing process.

However, it is well understood that hiring, retaining and training experienced technicians and engineers is a challenge,

especially considering evolving automation technologies. In fact, smaller operations simply cannot carry this kind of staff, even though they have the same needs as bigger companies to support and upgrade their production systems. In-house team members require continued education to support the application of newer technologies needed to run the business optimally. This problem is compounded by the number of specialties within the broad field of automation, such as motion control, vision systems and data analytics. The cost of these efforts adds up, but the alternative of building up a large "technical debt" by not keeping up with technology is undesirable for any company.

For these and other reasons, many companies now choose to outsource some or all of their maintenance and engineering,

often by partnering with systems integrator (SI) firms. There are some pitfalls to watch out for, but in many cases outsourcing can provide the most cost- and technically-effective way to keep the facility running in top form, while taking advantage of the most appropriate new technologies.

Outsourcing options

There are clear benefits to supporting all maintenance and engineering efforts internally, especially for larger companies. Chief among these is that one or more team members are readily available to support production. Additionally, the entire team develops specific and intimate knowledge of production machinery and processes, including the best design practices, modification possibilities and maintenance procedures fit for the company, providing a great degree of efficiency.

Smaller businesses and startups tend to run very lean, although they still have plenty of dreams and ideas about how to grow their operations, develop continuous improvements and increase overall efficiencies and profits. In many cases, they can leverage YouTube videos and other internet resources along with easy-to-use AutomationDirect products to conduct a large portion of their own automation work.

However, whether a business is large or small, there are often cases where the automation needs simply require a skillset or team size not available in-house. These companies may fear, rightfully, that outside SI firms and technical specialists brought in “cold” will be unable to proficiently support existing systems or perform new project work without a detailed history of the operation. In spite of this fear, many

“Smaller businesses and startups tend to run very lean, although they still have plenty of dreams and ideas about how to grow their operations, develop continuous improvements and increase overall efficiencies and profits.”

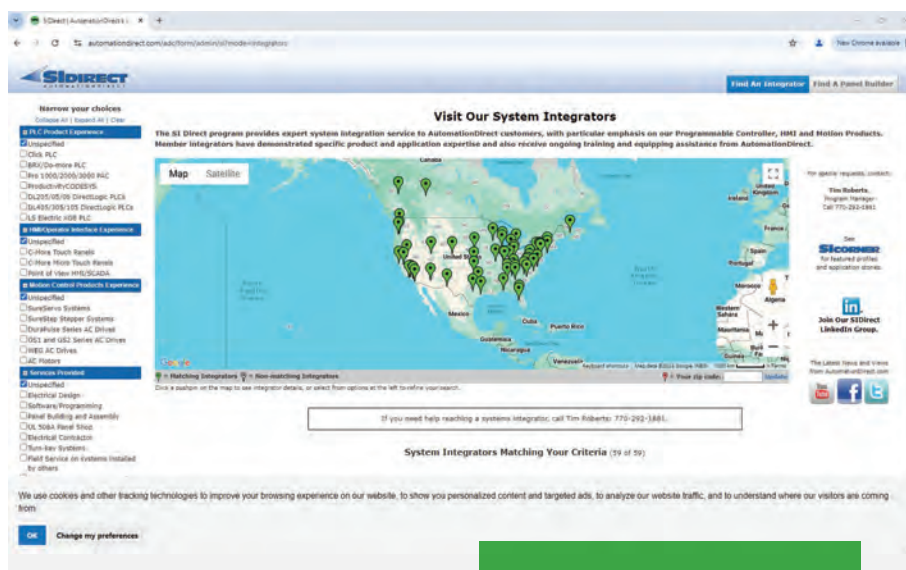


Figure 2: The AutomationDirect website is the home of the SIDirect interface, which helps users search for best-fit systems integrators based on a variety of parameters including technologies and location.

manufacturing organizations already outsource a degree of their automation needs. For example, most of these companies use various original equipment manufacturer (OEM) machinery, which employs specialty automation.

Seeking SI skillsets

When it comes to automation requirements for an overall production facility, or even for the case of retrofitting, troubleshooting, or upgrading portions of the operation, engaging SI services can be a great advantage. These engagements can be arranged in many ways, such as through an ongoing contract, per project or on a time & materials basis.

By definition, SIs specialize in a variety of automation technologies needed to integrate a range of systems. Some SIs focus on specific processes, while others are generalists. The former bring deep and particular experience to a project, while the latter can apply concepts from other industries to provide novel solutions. Because SIs perform automation work on a daily basis, they are current on the latest best practices, products, certifications and regulations (Figure 1).

Some SIs concentrate on just instrumentation, networking, control logic, visualization configuration, databases or analytics, while others span many of these disciplines. Correspondingly, SIs come in many sizes. While some provide plant-wide turnkey installations, others work on a specific type of machine or process, or will jump in to help fill a precise void.

Qualified SIs supply knowledgeable and experienced personnel with great skills and abilities to supplement a manufacturing company's personnel to keep operations running smoothly and optimally.

The AutomationDirect SIDirect program

Recognizing these needs among end users, AutomationDirect created the SIDirect program in 2005. AutomationDirect already maintains a massive portfolio of automation hardware, software and accessories, and many end users order just about everything they need for automation projects directly through the website. However, for end users looking for additional help, the SIDirect program matches you and your needs to qualified experts with a working knowledge of these products.

The SIDirect interface, with a quick overview map display, is a readily available way for end users to identify where best-fit SIs are located, as most companies prefer nearby providers. The faceted search function allows filtering by a specific domain of technological expertise, such as PLCs, HMIs, motion control and more (Figure 2). >>

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SIDIRECT PROGRAM

There is no substitute for experience. Every SI in the SIDirect program is vetted by staff at AutomationDirect to verify the credentials to install and program specified automation hardware and software. These SIs possess the skills and knowhow to design control panels and wiring diagrams that meet industry standards and regulations, including UL 508A and the National Electric Code (NEC) (Figure 3).

Consider motion control, for instance — it is a relatively complex specialty within automation controls programming, but is now more tightly integrated into modern PLCs than ever before. Motion control designers must have a solid understanding of the PLCs, servo motors and drives, motion controllers, encoders, mechanisms and other products needed to implement these systems. These experts must also understand mechanical principles of operation and the relationships between speed, torque, acceleration, deceleration and regenerative energy. Motion can be linear, rotary or a combination of these movements, coordinated independently, relatively or absolutely. Even though modern motion control products substantially streamline the effort required to develop a solution, there are extensive fundamental principles required to stand up these systems reliably.

Today in 2024, over 40 out of the SIDirect program's 59 members across the United States and Canada are experienced in motion control using AutomationDirect hardware. Odds are, if you have a motion control application — or any other

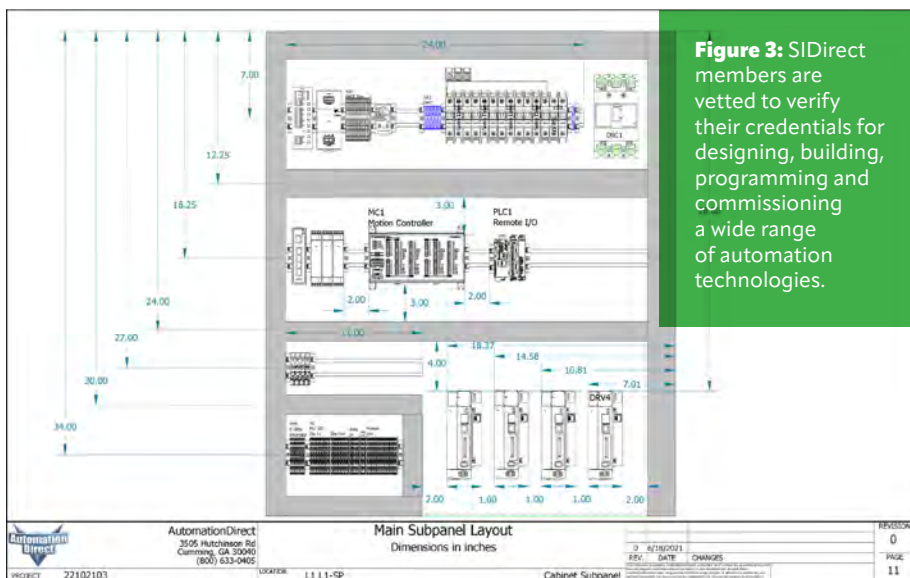
automation specialty for that matter — the SIDirect program can connect you with one or more SIs ready to partner on a solution.

Flexible automation support for the future

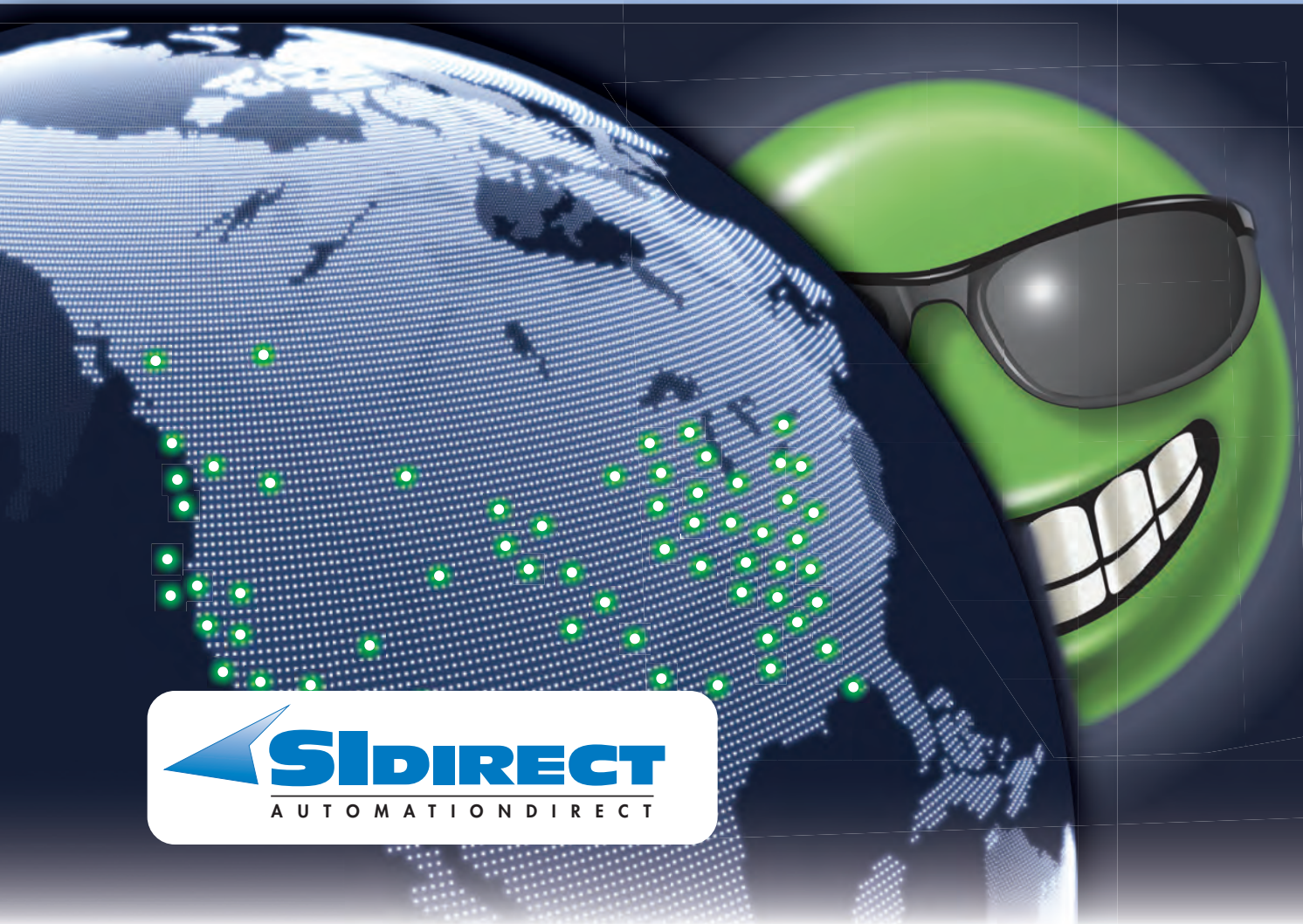
Automation technology has advanced rapidly over the decades, providing amazingly expanded capabilities and performance. Many developments have reduced the implementation costs and simplified support compared with older technologies. However, the field includes many specialties, and it is nearly impossible for any one person or even a team to be adept in them all.

AutomationDirect products, and the SIDirect program, provide a reliable way for end user companies of all sizes to supplement staffing and leverage automation technologies to their fullest. Engaging an SIDirect member significantly improves the speed at which organizations can accomplish projects and tasks of all sizes, whether small upgrades, entire production lines or anything in between. ▼

Jeff Payne is the Director of Business Development at AutomationDirect. Prior to this role, he spent almost 20 years as a product manager for PLCs, motor drives, soft starters and motors. Before joining the company 25 years ago, he managed, designed, programmed, installed, maintained and repaired a wide variety of highly automated equipment. He has been working in the industrial automation field for nearly 35 years and earned a degree in Industrial Systems Technology and Industrial Automation from Lanier Technical College.



With the AutomationDirect SI Direct integrator network, good help is never hard to find.

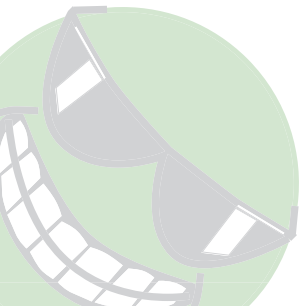


AutomationDirect's SI Direct program provides expert system integration service to AutomationDirect customers, with particular emphasis on programmable controller, HMI, and motion products. These numerous ready-to-hire integrators, across the USA & Canada, have demonstrated specific product and application expertise and also receive ongoing training and equipping assistance from AutomationDirect.

To learn more about the SI Direct program or to find the SI Direct integrator near you, go to: www.automationdirect.com/si-direct

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Industry Supports Rocket Science

Industrial-grade products provide a path for this student organization to develop a space-capable rocket.

BY OLEG KHALIMONOV, SPACE CONCORDIA



Figure 1: The Space Concordia team is developing a truly space-capable rocket system, which is relatively rare in academia. All figures courtesy of Space Concordia

Many are familiar with the phrase “it isn’t rocket science.” But today more than ever, sometimes it is rocket science. SpaceX and other organizations have made rocket launches and space exploration commercially viable and almost commonplace, but there is still a great deal of work to do.

For about 15 years at Concordia University in Montreal, Canada, a student society called Space Concordia has provided an opportunity for students to work on projects in rocketry, spacecraft, robotics and more. The organization equips students with valuable technical experience that employers value. While the university supports Space Concordia, the program is also partly funded by industry sponsorships.

The work is quite sophisticated, as would be expected in a space-grade program, but several aspects are based on very fundamental and practical principles, including the use of proven industrial-grade products and equipment to create a fit-for-purpose solution.

Combustion complexity

For about six years, the team has been developing the Starsailor, a 42-foot, bi-propellant, pressure-fed reusable rocket designed to lift a 143-pound payload straight up and back down for a non-orbital flight (Figure 1). With a 76-mile-high apogee, the rocket will technically reach space, which is relatively rare for launch vehicles

in academia. The team is also developing Trailer Tom, a mobile engine test stand, and Bigger Ben, a 72-foot-tall launch tower.

Because the 8,000-pound force rocket engine is fueled by a combination of liquid oxygen and liquid kerosene there is a significant amount of complexity loading, storing and unloading these materials on both the ground-based and rocket-based systems, and also handling them during flight. Liquid-propelled rockets require careful design, control and monitoring of valves, solenoids, sensors and related systems, and it is rare for student rocket projects to undertake the development cost and learning curve required for success.

Practical specifications

The Space Concordia team faces the same considerations that governments or large companies do for this type of work, including development and approval of procedures, and compliance with environmental, health and safety provisions.

For safe handling of the liquid fuel and oxidizer, the team developed requirements for vessels, valves, lines

and fittings with regards to pressures, flows and temperatures. Many of the valves and other mechanical equipment are operated using nitrogen gas-driven actuators, which are controlled using smaller solenoid valves to provide the necessary operating forces (Figure 2).

Most operations are remotely controlled using hardwired switches or a digital controller, which required significant design, fabrication and installation of control panels (Figure 3).

While massive aerospace corporations can specify custom products and highly-engineered solutions, a student-run organization must be far more cost-conscious. Fortunately, the team has found that a wide variety of commercial off-the-shelf (COTS) components developed for industrial applications work well in the rocketry project (Figure 4).

They were able to specify a wide range of products right out of the AutomationDirect catalog, with a variety of components performing admirably in both the ground support and rocket systems, including:

Figure 2: (BELOW) The same qualities that make many AutomationDirect products suitable for industrial use also situate them ideally for certain aspects of a space-going rocket program.

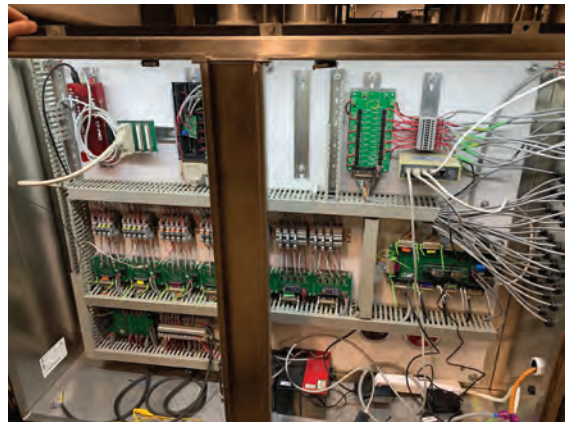
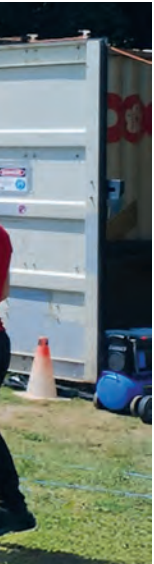


Figure 3: (TWO ABOVE) The ground-based Trailer Tom and Bigger Ben equipment each use a significant quantity of commercial off-the-shelf products, such as those available from AutomationDirect.

- Pneumatic actuators, tubing, fittings and accessories
- Solenoid valves and accessories
- Sensors
- Cables, conductors and associated fittings
- Ethernet networking devices and cables, both for copper and fiber optics
- Buttons, switches, horns, terminal blocks, relays, power supplies and other control panel devices

The AutomationDirect website provides a clear way to investigate a wide variety of products, enabling the team to determine the technical details, cost, availability and options available for each component. In some cases, AutomationDirect worked with Space Concordia team members to identify the best-fit products. The website also hosts a complete range of helpful materials, including data sheets and support videos.

Factory fundamentals can serve in space

While only a select few automation projects qualify as actual rocket science, every automation project deserves

to be outfitted with top-quality and high-value components. Since 1994, AutomationDirect has been in the business of supplying end users of any scale with the reliable products, support and value they need to create innovative solutions on Earth, and now in space.

Space Concordia has put AutomationDirect products to ample use throughout the Starsailor project, and it will soon complete a 30-second full-power engine test fire. The next steps will include final vehicle tests and preparations to launch from Churchill, Manitoba. You can see the team's previous tests on YouTube here:

- https://youtu.be/ZQ8lm6LtN8I?si=Nqdl_zRdu4ogiS_n
- <https://youtu.be/ivnEfmpdbMw?si=mtp1Tc46I5biySWG>
- <https://youtu.be/p44dx-hXuHs?si=E48kji-WackYmzfL>

The team would like to thank AutomationDirect for all the support throughout this process, and it looks forward to the continued relationship. ▼

Figure 4: Industrial-grade AutomationDirect products, such as solenoids, are in service on board the Starsailor rocket vehicle, which is designed to reach space with an apogee of 76 miles above the Earth's surface.



Oleg Khalimonov is the Starsailor program director for Space Concordia at Concordia University in Montreal, Canada. He supervises a team of about 80 students as the multi-year project progresses

***Build better
machines
faster***
***using today's enhanced
motion controllers and PLCs***

Process-enabled motion controllers and motion-enabled PLCs give OEMs the flexibility to optimize design and performance.

BY KEVIN MCCLELION AND JOE SCOCCIMARO
AUTOMATIONDIRECT

Introduction

There was a time when designing machines that included motion control followed a standard architecture. The PLC handled basic machine control and a dedicated motion controller managed the motion axes. Today, the trend toward smart automation components with increased onboard processing power and memory has blurred those lines. PLCs can now manage multiple axes of coordinated position control, while motion controllers can support a variety of machine communications protocols and I/O points.

This flexibility is a game changer for OEMs and integrators building new platforms. After all, if there is one truism in engineering, it's that there is no one right solution, just the best solution for the application at hand. Modern PLCs and motion controllers streamline design and integration while enabling machine builders to offer customers solutions with higher performance, lower cost and reduced maintenance.

The evolution of motion controllers

Motion controllers have come a long way from the early days of industrial automation. Motion controllers initially targeted computationally intensive

applications like CNC machine control and robot kinematics, or machines with very high axis counts. Due to limitations in computer processing power and memory, many controllers had to be custom designed with hardware for individual applications in order to meet the performance required. Many were PC circuit-board based. These controllers had limited communications capabilities and no ability to add I/O points.

Today's motion controllers support OPC UA, the IoT-focused lightweight protocol MQTT, and a variety of industrial Ethernet protocols, including EtherCAT, EtherNet/IP and ProfiNET. They also have greater I/O capabilities than ever before (see Figure 1). In addition to embedded I/O, motion controllers can now use communications protocols like EtherCAT

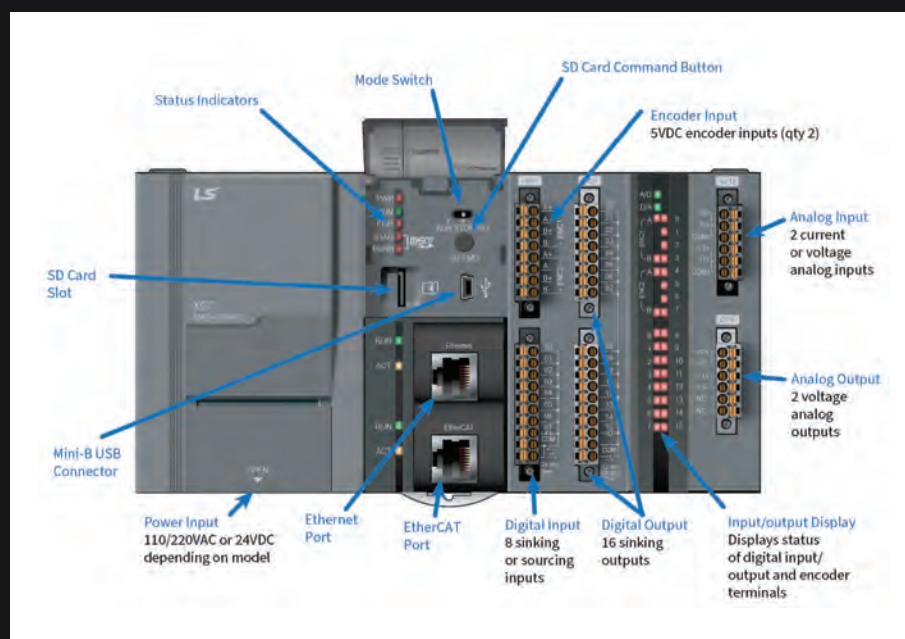
to connect to as many field I/O points as the CPU can handle. These enhanced capabilities enable motion controllers to perform machine control tasks formerly handled by PLCs, such as PID control of a temperature loop within a motion application.

What are the process control capabilities of modern motion controllers?

High-end motion controllers with augmented capabilities can perform many tasks formerly associated with PLCs, including:

- Process control
- PID control
- Data logging
- Communication messaging
- IEC 61131-3 programming languages >>

Figure 1: The LS Electric XMC programmable motion controller combines high-performance motion control with eight embedded inputs and 16 embedded outputs. The XMC can act as an EtherCAT master to control any EtherCAT device. This allows the XMC controller to seamlessly communicate with EtherCAT I/O, encoders, AC drives, etc. A built-in SD card slot also supports data logging.



Why motion controller-based machine control?

Performing machine control with a motion controller can eliminate the need for a PLC. This reduces costs, integration time, wiring, points of failure and need for maintenance. For centralized architectures, it also leaves more space in the cabinet.

Tips for motion-controller-based machine control

Tip #1: Take advantage of remote I/O
PLCs allow I/O to be added directly to the unit, while some motion controllers may not. There is an easy fix, however. Use high-speed deterministic protocols like EtherCAT to connect the motion controller to remote devices, enabling synchronous I/O control. Remote I/O via industrial Ethernet enables I/O points to be distributed throughout the machine, reducing wiring runs.

Tip #2: Balance demand on the CPU of the motion controller
Even a powerful CPU has its limitations when managing the demanding processes of motion control, network communications and process control. It is important to ensure that the most critical application

— typically, the motion control — gets the appropriate amount of CPU time. Managing the cycle rate of the motion network and task scan times of the logic program and network control can make a huge difference in optimizing the CPU. Use the slowest cycle time possible for motion operations

and network communications that allows adequate resolution of the application.

The evolution of PLCs
PLCs started out as machine controllers dedicated to tasks like timing, counting and managing I/O. As time went on, they gained the ability to control simple motion operations such as uncoupled Y-axis or X-axis movement. Anything more complex, like drawing a circle, required a dedicated motion controller.

Modern PLCs have vastly expanded functionality. It starts with more advanced communications protocols, including most versions of industrial Ethernet, as well as alternatives like ModbusTCP, MQTT, and OPC UA. An increasing number of PLCs are IEC 61131-3 compliant, making them programmable in ladder logic, function block, instruction list, sequential function chart and structured text.

Additional capabilities include functional safety. This can be implemented either with a dedicated safety PLC in addition to the main machine controller or by using the same PLC for machine control and safety.

From a design perspective, however, one of the key advances is the ability of modern PLCs to manage advanced motion control.

What are the motion capabilities of modern PLCs?
The motion capabilities of modern PLCs include (see Figure 2):



Figure 2: The LS Electric XGB line of motion-capable PLCs features CPU modules with two to six axes of built-in motion control (left). Users can add control of up to 16 additional servo drives using EtherCAT expansion modules (right).

TABLE: FEATURE COMPARISON OF MOTION-ENABLED PLC VS PROCESS-ENABLED MOTION CONTROLLER.

COMPARES	XGB PLC + PN04/08B	XMC MOTION CONTROLLER
Physical design	Compact modular	Block
On board I/O	Up to 16 in / 16 out	8 in/16 out, 2 AI/2 AO, encoder
I/O modules expansion	Yes	No (remote I/O only)
Pulse direction motion	Yes	No
EtherCAT motion axes	Yes (option card), up to 16	Embedded, 8 or 16
EtherCAT master	Stepper motor or servo motor only*	Full master
Programming:		
Main programming	XG5000	XG5000
Motion configuration programming	XG-PM	XG5000
EtherNET/IP comms configuration	Table based	None
Modbus TCP comms configuration	Table based	Table (server), FB (client)
Additional features:		
G Code/M Code CNC programming	No	Yes
Robot controls	No	Cartesian, Delta3, Delta3R and Linear Delta

- Pulse direction control mode
- Fieldbus-based motion control
- Linear, circular, helical interpolations
- Homing
- Camming

Support for fieldbus-based motion (e.g., EtherCAT, EtherNet/IP, ProfiNET, Modbus, etc.), in particular, brings significant advantages over pulse direction control, including simpler wiring, easier system set up and troubleshooting and better diagnostics.

Why PLC-based motion control?

Performing motion control with a PLC eliminates the need for a dedicated motion controller. That once again lowers cost, integration time, wiring, failure points and maintenance requirements, as well as cabinet space.

Other benefits are intangible but no less important. Application permitting, some teams are more at home working

with PLCs. Motion-capable PLCs let them stay in their comfort zones, where they can operate most efficiently.

Tips for PLC-based motion control

Although the capabilities mentioned above are powerful, the results are only as good as the implementation.

Tip #1: Make trade-offs between motion and machine control

The PLC has a single processor that has to be shared among multiple tasks. Meanwhile, sophisticated motion profiles and high-speed operation require fast cycle times – and lots of CPU cycles. The PLC may be able to accommodate these commands, but the trade-off may be slowing down general communication rates and program code.

Analyze the PLC program processing time and make trade-offs based on what the application requires. If you can slow down the communication rate during motion-intensive parts of the cycle without

negatively impacting your process, you can avoid overloading the PLC.

Tip #2: Be sure to properly size the PLC for the application

PLCs are available with different processing powers. Check the datasheet for the total number of communication nodes, motion axes, and refresh rates and ensure that the application operates within them. If the capabilities of the PLC are insufficient and trade-offs aren't possible, consider upsizing the PLC to accommodate faster processing speeds.

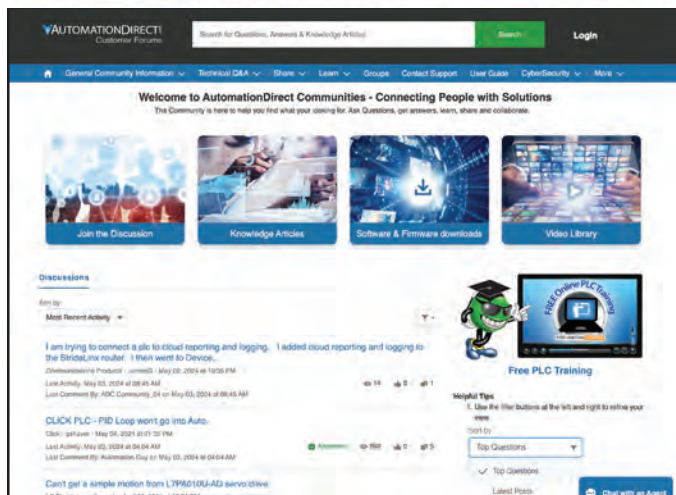
Making the choice

The two technologies are not fully interchangeable. Start by comparing the capabilities of a motion-enabled PLC with those of a process-enabled motion controller (see table). Next, consider the operational requirements placed on the machine by the application and use that to determine the optimal solution. >>

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When to choose motion controllers

For a machine primarily focused on motion control, with limited focus on communications and machine process control, a process-enabled motion controller might be an ideal fit. Motion controllers use high-performance field-bus protocols specifically designed for real-time communication and deterministic data exchange, making them very effective for applications like robotics, CNC machines, assembly lines and packaging machines. These applications may require faster cycle times or larger axis counts that make them best suited to a motion controller.

Application spotlight for process-enabled motion controllers: horizontal flow wrapper

This horizontal flow wrapper encloses items in a preprinted plastic film, sealing each end with a fin seal. An XMC motion controller controls the entire machine, both motion axes and non-motion tasks, using the EtherCAT protocol with a 500 µs cycle time.

The machine consists of three modules: an infeed module, a film module that wraps and seals the product in the plastic film, and an outfeed module (see Figure 3). The film module includes heaters that form a 2X wide seal between individual items. A rotary knife between the film module and outfeed conveyor cuts that seal in half to separate the product into discrete items, and a second pair of heaters seals the side of the packet before it is released to the outfeed conveyor.

Non-motion components include an eye-mark sensor to synchronize the film feed with conveyor speed, and a “no cut” sensor to prevent cutting if an item shifts or line shafts lose synchronization.

The XMC manages four axes of motion: a servo axis to run the rotary knife, a servo axis to run the infeed conveyor, a servo axis to feed the plastic film into the machine and a VFD with AC motor for the outfeed conveyor. In addition, the motion controller monitors and controls the heaters and uses input from the sensors to adjust motion operations.

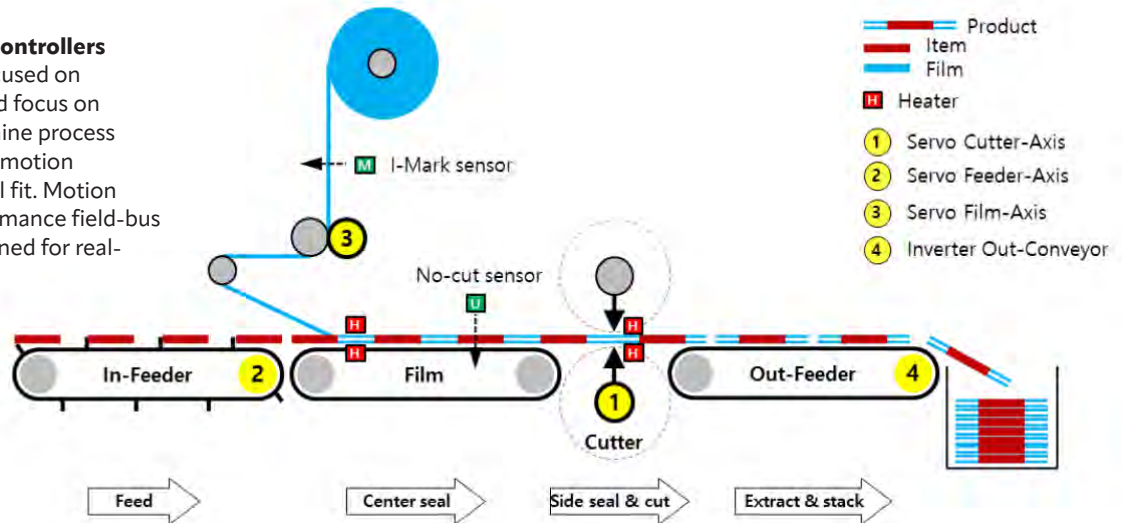


Figure 3: (ABOVE) In a horizontal flow wrapper, an XMC motion controller manages I/O for heaters and sensors, as well as for axes of motion.
Courtesy of LS Electric.

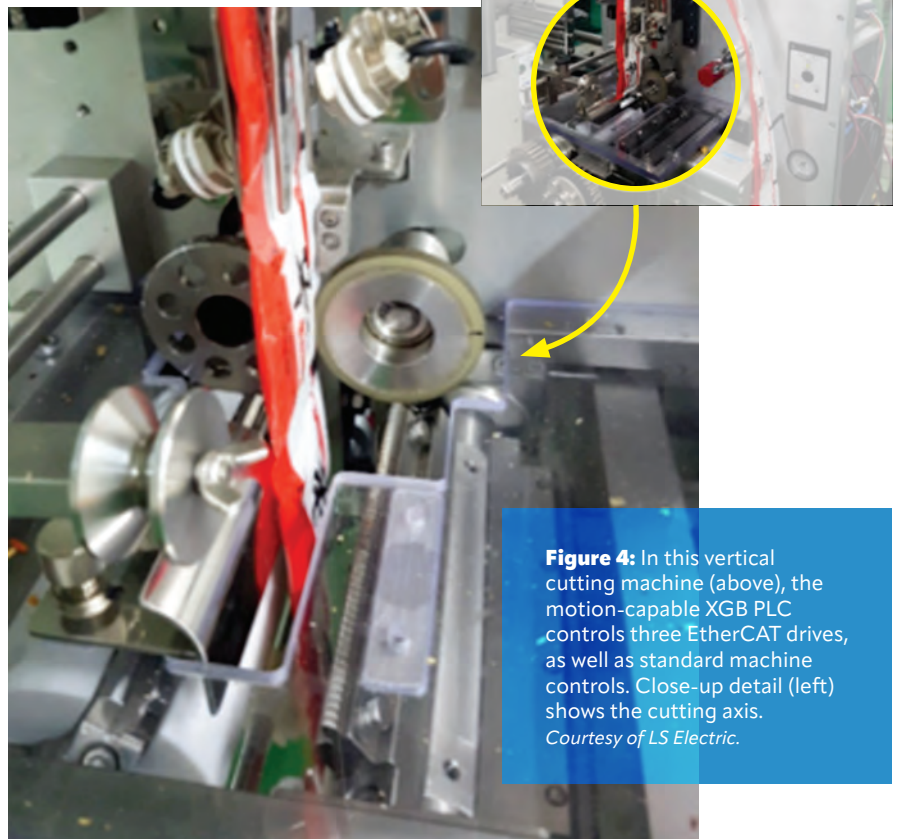


Figure 4: In this vertical cutting machine (above), the motion-capable XGB PLC controls three EtherCAT drives, as well as standard machine controls. Close-up detail (left) shows the cutting axis.
Courtesy of LS Electric.

SPOTLIGHT ON ETHERCAT

High-speed communications buses like EtherCAT are the foundation of many of these advances. Moving away from hardwired pulse communications to a fieldbus streamlines commissioning and reconfiguration, adds flexibility and simplifies maintenance. EtherCAT is a high-performance protocol specifically designed for real-time communication and deterministic data exchange, making it ideal for motion control and I/O expansion. Because of this well-defined standard, integrating different types of components from many different manufacturers is seamless. Designers now have many options when it comes to sourcing parts.

—K.M. and J.S.

When to choose PLCs

If the application primarily requires PID control with only limited motion, then a motion-enabled PLC is the best choice. Look for applications that don't require extremely fast cycle times, such as flying cutoff saws, rotary tables or small rotary drill machines.

Application spotlight for motion-enabled PLCs: vertical cutting machine

A vertical cutting machine divides a web of Ramen noodle flavoring packets into individual sachets. The XGB PLC controls not just machine operation but three axes of highly coordinated motion in the form of EtherCAT drives operating with cycle times of 1 ms.

The machine can be separated into three modules: an infeed module, a cutter module and an outfeed module. Axis 1 powers the infeed conveyor. Axis 2 powers the rotary knife that cuts through the sealed sections to separate the sachets (see Figure 4). It must match the speed of the web in order to ensure that it cuts the web at the center of the seals. Axis 3 is the master encoder axis, which is used to phase the feeder axis to correct any slippage in the material.

Conclusion

Integrating machine control, motion and communications into one controller can save in cost and system complexity. Modern motion control provides multiple ways to achieve this goal. Even standard PLCs have very advanced motion control capabilities. Today's motion controllers have added capabilities previously reserved for PLCs, such as communications, I/O points, and data logging. OEMs and integrators have the flexibility to choose the solution that best fits their application and their project. ▼

Need help identifying the right controller for your latest project? Reach out to the AutomationDirect team at kmcclelion@automationdirect.com or jscoccimaro@automationdirect.com.

Kevin McClellion and Joe Scoccimaro are Product Engineers at AutomationDirect.

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HOW INDUSTRIAL ENTERPRISES CAN ADDRESS THE “GREY TSUNAMI”

BEHIND TODAY’S GROWING SKILLS SHORTAGE

BY CHIP MCDANIEL,
AUTOMATION EXPERT
& EDUCATION
SPECIALIST,
AUTOMATIONDIRECT

Human resources departments call the phenomenon the “grey tsunami.” They’re referencing a historic U.S. retirement surge of 4.1 million Americans a year. Manufacturing, in particular, is taking a big hit as industrial engineers, equipment operators, maintenance and repair technicians, plant managers, and others in supporting roles join those retirement ranks. With the sector accounting for about 8.5% of all U.S. employment, that implies nearly 350,000 people are retiring from manufacturing annually.

Meanwhile, reshoring manufacturing driven by the global, post-pandemic supply chain shortages as well as government initiatives such as the Inflation Reduction Act and the CHIPS Act are creating new manufacturing jobs faster than they can be filled. The Boston Consulting Group estimates that more than 90% of North American manufacturers have moved back at least

some of their production or supply chain in the last five years, with even more planned in the next five years.

Even with the help of advanced automation to shore up the loss of their skills and experience, the industry still needs trained people at every level — from the shop floor to the top floor, as the saying goes — and lots of them. In fact, the U.S. Census Bureau estimates that by 2030 about 2.1 million manufacturing jobs will go unfilled across the nation.

Understanding the Manufacturing Skills Gap

Today’s manufacturing skills deficit is growing for several reasons. First, not enough young people are training to replace those retiring. Many seem to have little interest in working in factories due largely to misconceptions about the grime or danger associated with such jobs many decades before they were born.

Next, there seems to be a mismatch between what schools teach students regarding qualifications necessary for modern positions within the manufacturing industry vis-a-vis actual demands placed on these workers by their employers today. That’s especially true considering breakthroughs made possible through automation and artificial intelligence (AI).

At AutomationDirect, we believe technologies such as these, along with data analytics, 3D digital twins, 3D printing, the Industrial Internet of Things (IIoT), and others, can make manufacturing careers much more interesting and rewarding. But as these technologies have found their way into manufacturing over the past decade, the gap between required knowledge areas in large-scale production processes has widened significantly. These days, companies also need individuals with traditional engineering abilities who are also proficient in data analysis or high-level >>

programming languages such as C++, Python, Java, and others.

Such an elevation and expansion of needed skills is due to advancements in computerized systems, which have become integral to production, relying on specialized software embedded in hardware such as computer vision, robotic arm controllers, web servers, sensors, actuators, motors, pumps, and valves. Augmented reality (AR) and virtual reality (VR) are also finding their way into plant environments, paving the way, along with robotics, to so-called cyber-physical systems.

At the same time, older technologies including pneumatics, hydraulics, electronics, electrical systems, control engineering, and power transmission remain essential and need engineers, operators, and technicians who know how to design, run, and maintain and repair such systems.

Close the Gap: What Manufacturers Can Do

Manufacturers are responding to skills shortages in several ways. One, of course, is using more automation or AI to handle tasks that previously needed human interaction and oversight. While this approach can handle many repetitive manual tasks much faster and with fewer errors, it won't replace workers altogether. Instead, it serves a complementary function by freeing up staff time for more strategic thinking around innovating processes and solving problems.

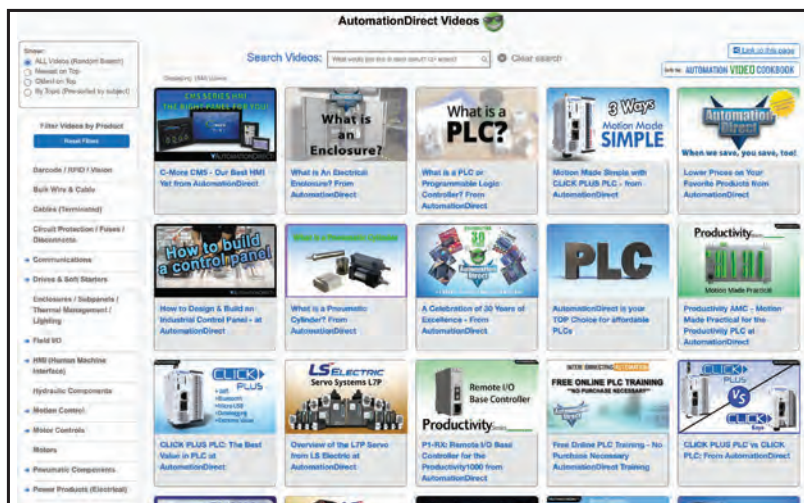
Still, to enact this model successfully, employee skills must change to become compatible with these new ways of working. It's why many manufacturers have started investing heavily in retraining and upskilling existing staff members who may find themselves using such tools in their jobs more and more.

• Enrich Engineering and Other Plant Roles with Automation

For decades, automation has been associated with manufacturing job losses. But, at the same time, it has also opened new opportunities for engineers, machine operators, technicians, and other plant staff to enrich their jobs — an outcome that will continue — and to work more collaboratively than ever with greater operational visibility.

For example, engineers will always be needed to optimize process and discrete production models in terms of quality, efficiency, costs, and safety. While programmable logic controllers (PLCs) will remain a core technology in factory automation, next-level production optimization will increasingly involve big data analytics, algorithm development and machine learning, digital twins, AR and VR, to name a few of the technologies that are revolutionizing manufacturing.

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They'll also be using sophisticated tools and engineering methodologies such as computational fluid dynamics, kinematics modeling, and "cobots" among many others. Cybersecurity will also remain a high-level priority, not only because production shutdowns are disruptive and costly, but also because they can threaten life safety inside plants as well as outside them.

Climate change is another area where engineers can use automation, for example, to support decarbonization efforts. Sustainable production practices that reduce energy usage and material waste will also demand sharp process engineering skills oriented toward innovation and supported by creative, out-of-the-box thinking.

- **Make the Most of Current Workforces**

An important strategy that manufacturers are using to close the skills gap is workforce retention as well as upskilling and reskilling their current plant staff. Skills required in manufacturing — engineering, operations, maintenance, and management — are continuously evolving as automation becomes more extensive alongside the other advanced technologies mentioned.

Upskilling. This refers to enhancing the existing value-adding capacities of plant employees so they can meet these evolving demands, especially as a plant adopts new technologies. Training courses aimed at improving digital literacy skills, data analysis abilities and automated system management competencies can help achieve this objective.

Reskilling. This involves training an employee on entirely different job skills after their existing skills have become redundant or not needed any longer within the same company or elsewhere due to the introduction of fresh approaches and systems into operations.

For example, a worker whose job requires manual "clipboard data gathering" could learn how to monitor and optimize automated systems. Or plant technicians who are accustomed to scheduled machine maintenance during planned shutdowns and break-fix repair models can study and help to implement AI-enabled condition monitoring of

machine health that supports more proactive and efficient predictive maintenance models.

Retention. Of course, both upskilling and reskilling require personnel who are willing to learn new ways of doing their

make hundreds of their PLC training videos available for free. ICA offers both training equipment and certificate programs through which trainees can be hands-on with a "PLC trainer" following the video instructions and completing tests at set milestones to earn the certificates.



work. Plant management should work with their HR partners to assess each employee and, working with each one, develop continuous learning plans that can help advance their careers in meaningful ways, such as more responsibility and compensation. The results will be greater job satisfaction and retention, the latter protecting the often-substantial investment a company has already made in an employee's working tenure.

To these ends, AutomationDirect offers manufacturers a vast online collection of free training materials, such as our Learning Library, plus video tutorials and a YouTube channel to help engineers and technicians learn new skills. The latter provides specific solutions and how-to steps to complete complex tasks. Our free PLC Handbook is available for download to users who want a thorough introduction to this core manufacturing technology.

What's more, we have partnered with InterConnecting Automation (ICA) to

Attract New Engineering Talent

Across the manufacturing sector, young engineers are invaluable to closing the industry's skills gaps not just today but in the future. However, getting them involved can be a challenge and keeping their talents onboard once they're hired can also prove hard. Competition for them will rise alongside growing demand for their increasingly sophisticated skills.

That's why more and more manufacturers are creating new recruitment strategies to attract well-qualified candidates. Often social media platforms such as Twitter, Facebook, and Instagram are used where career opportunities can be shared widely among potential candidates who may not have seen them elsewhere.

Virtual career fairs have also emerged as an effective recruitment tactic that allows employers to interact directly with students from different universities, thereby increasing the chances of finding suitable recruits for their various job openings. >>

Another retention strategy would be through mentorship programs connecting experienced professionals in different fields/industries with upcoming talents, providing guidance and support networks through which they meet other people doing similar things, thus gaining additional insights into what is done best.

• **Encourage Aspiring Engineers in Higher-Ed — and Even Earlier**

AutomationDirect supports numerous educational programs at the university level as well as at post-secondary technical schools and vocational high schools. We can provide instructors with product donations and generous product discounts so they can competently and confidently teach the many advanced technologies the manufacturing sector is increasingly using.

Available products include selections from our four PLC families, human-machine interfaces (HMIs), variable frequency drives (VFDs), servo and stepper systems, plus networking and fieldbus products. We also offer free software so instructors don't have to deal with licensing restrictions or determining which of their school's PCs will run certain copies of a particular software package. They can simply install the software at will.

In addition, AutomationDirect supports competitive robotics programs from the elementary grade level up to high school and college programs. Starting with sponsorship of a single high-school team in 2005, this program has grown to include over 200 teams in practically every school in AutomationDirect's home of Forsyth County, a northern suburb of Atlanta with 42 schools serving over 55,000 students. And, earlier this year, we announced the winners of the FIRST Robotics Competition 2024 Digital Animation Award, which we have sponsored for many years.

We also support the state and national organizations which coordinate these types of competitions. Such programs excite students and give them a glimpse into the worlds of engineering, automation, and manufacturing. It's an open secret that "building a robot" is a hands-on way to teach math, science, physics and other STEM (Science, Technology, Engineering and Math) disciplines in an extracurricular activity.

Students are flocking to these challenges. While we don't expect them all to enter the field of robotics, any interest generated in scientific and related endeavors, such as STEM-related fields, is a plus. And many of the robotics teams are run like a business with marketing

be formed very easily. Companies can support competitive robotics in many ways; cash sponsorships are always welcome. Some companies may be able to donate robotics and automation parts.

Perhaps most important are the mentors, coaches, and parents who assist the teams. Does your company have engineers who can mentor a few hours a week? Can your company allow mentors to be onsite at the school or at the offsite "build space" to coach and assist the students? Does your company have some extra office or warehouse space where the team could meet and build?

These are concrete, tangible ways to get involved today, and their positive impacts on workforce development can be nearly immediate. At AutomationDirect, we employ many interns (both summer and afterschool) who are team members of these local robotics teams and have hired several after their college graduation. Programs such as these can also engage students who might not aspire to be degreed engineers, but they can certainly lend a hand on many engineering projects. We invite readers to join us in supporting workforce development across manufacturing to make the most of today's talent and to cultivate the talent needed tomorrow. ▼

"AutomationDirect would like to challenge readers of this article and their companies to get involved with these programs. Existing teams throughout the country can use your help and new teams can be formed very easily."

But even more valuable, the students are welcome to install the software on their personal PCs, which can untether them from the lab to work on their projects whenever and wherever they want. They can then return to their school's lab to test their code with actual hardware. Here are just a few of the free software packages available:

- CLICK PLC Software
- Do-more PLC Software
- Productivity PLC Software
- LS XG5000 PLC Software
- CODESYS Development System

operations, accounting specialists, and fundraisers, plus the mechanical and electrical teams who actually design and build the 'bots. So, there are many opportunities for students to learn valuable business skills in many other areas as well.

Conclusion: Creating Future-Proof Workforces

AutomationDirect would like to challenge readers of this article and their companies to get involved with these programs. Existing teams throughout the country can use your help and new teams can



Chip McDaniel works in technical marketing for AutomationDirect and is a graduate of Georgia Tech. His decades of experience in the industrial automation field include designing, building and commissioning multi-axis servo systems, as well as the marketing of a wide range of automation products.

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EtherCAT

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XMC for Xtensive automation - Not only can XMC controllers handle numerous EtherCAT devices, they also support G-code, M-code, and programming specific to robot control including Delta3, Delta3R, Linear Delta, and more.



XMC for blazing fast Xecution - The XMC controllers offer extremely fast processing capabilities, with a scan time of 6.25 ns for basic commands, 5ns for motion commands, and 30ns for arithmetic commands. EtherCAT-based high-speed communication cycle times are also 0.5/1/2/4ms.



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Enhancing Automation System Performance with the EtherCAT Protocol

BY JOE KIMBRELL,
AUTOMATIONDIRECT

The EtherCAT protocol is a high-performance and cost-effective Ethernet networking technology, providing a versatile solution when EtherNet/IP and PROFINET simply aren't fast enough.

Ethernet rapidly expanded into and throughout commercial information technology (IT) networking connectivity environments beginning in the 1980s, and it has experienced rapid performance advancements and adoption since then in the IT realm. Once the speed and responsiveness improved sufficiently, and robust form factors were developed to withstand operational technology (OT) environments, Ethernet was ready for industrial applications.

However, Ethernet as a media must also be applied in conjunction with one or more industrial communications protocols suitable for the application. There are several protocol options, some of them general-purpose, and others

specialized for certain applications. A top choice for high-speed input/output (I/O) signaling and motion control applications is Ethernet for Control Automation Technology (EtherCAT).

The right Ethernet protocol for the right job

Some estimates (Reference 1) indicate that for the industrial network market, Ethernet protocols as a group hold almost 70% of the share and growing, with traditional fieldbuses at around 25% and shrinking, and wireless making up the remainder and growing. The two most deployed general-purpose protocols are EtherNet/IP and PROFINET, and there are several other

protocols holding much smaller market shares, including Modbus TCP. But a solid third place is occupied by the EtherCAT protocol.

The EtherCAT protocol was originally developed by Beckhoff Automation in the early 2000s, and they then donated the rights so the protocol could be standardized under IEC 61158. The EtherCAT protocol works over normal Ethernet media much more efficiently than other general-purpose industrial protocols. A key feature of EtherCAT is the ability for communication among devices to maintain very rapid data transfer with accurate synchronization and deterministic cycle times.

EtherCAT details

This high level of performance is possible because specific master and slave devices are used. A single master device initiates a data telegram (potentially containing multiple datagrams), which is then sequentially passed through slave devices (network nodes). This avoids the type of data collisions which may occur with other protocols. Each device rapidly receives and then sends the telegram to the next node in a cyclical fashion. Data can be inserted in the telegram as it passes through a node, but processing data received at the node only happens "on the fly" when possible after the frame is read, so there are no delays in transmitting the frame (Figure 1).

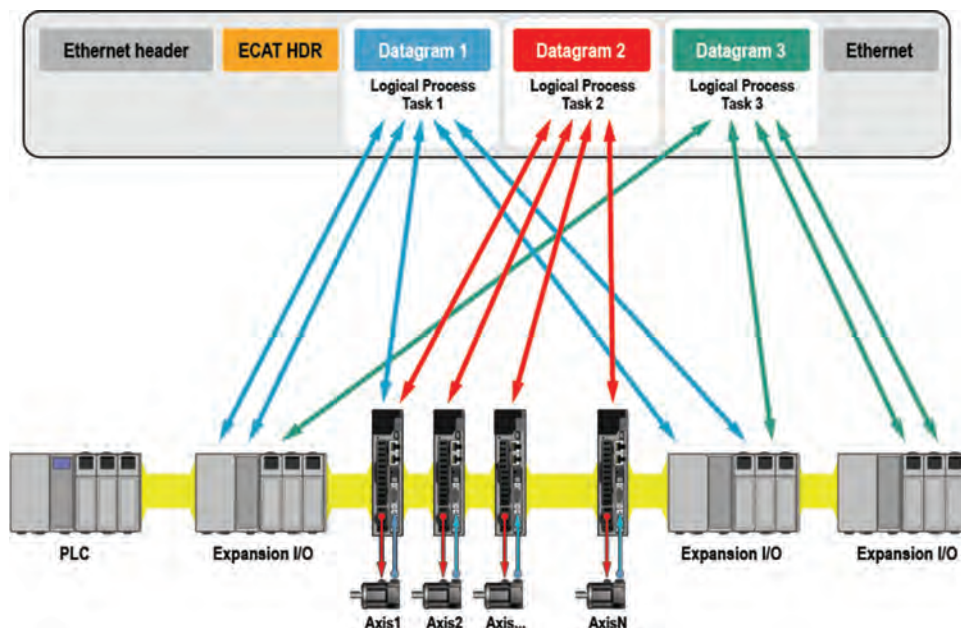


Figure 1: Each EtherCAT data telegram contains I/O and motion control commands from the EtherCAT master, and optional feedback information inserted from the EtherCAT slave devices. All figures courtesy of AutomationDirect

Therefore, the EtherCAT protocol is:

- **Deterministic:** Provides short deterministic cycle times of less than 100 μ s, with a minimal communication jitter of less than 1 μ s.
- **Scalable:** As an open standard that works with many makes and models of controllers and devices, it can handle a large number of devices on a single cable, making it a convenient architecture for complex multi-axis motion control systems.
- **Cost-effective:** Although master and slave devices are specialized hardware, the architecture uses standard Ethernet installation media and the reduced installation complexity of a linear topology (although other topologies are possible), which is very economical and provides favorable overall hardware costs compared with older technologies.

EtherCAT in motion

Many applications are well-served with general-purpose industrial protocols and network architectures, but motion control is a notable exception which benefits from the performance possible with the EtherCAT protocol (Figure 2).

The EtherCAT protocol, when implemented between a programmable logic controller (PLC) or dedicated motion controller, and one or more associated servo drive/controller slaves, simplifies installation and enables functionality to be fully orchestrated in the PLC (Figure 3). It also permits extensive data communication between the controller and drives, which is not possible using traditional hardwired control.

For high-performance industrial I/O and motion control applications, the EtherCAT protocol offers a powerful and versatile solution. Its combination of features supports the speed, accuracy, scalability and cost-effectiveness needed to make it a preferred choice for these applications. ▼

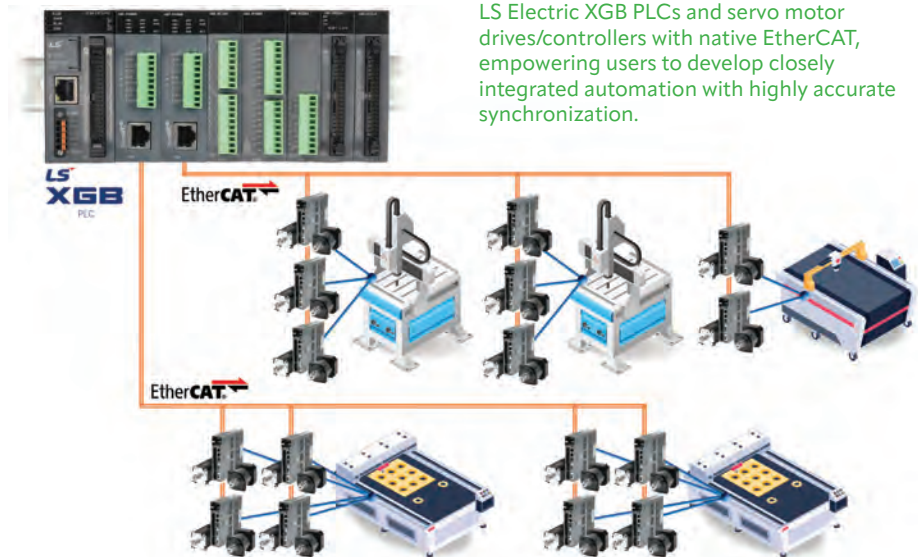


Figure 2: For demanding motion control applications, AutomationDirect offers LS Electric XGB PLCs and servo motor drives/controllers with native EtherCAT, empowering users to develop closely integrated automation with highly accurate synchronization.

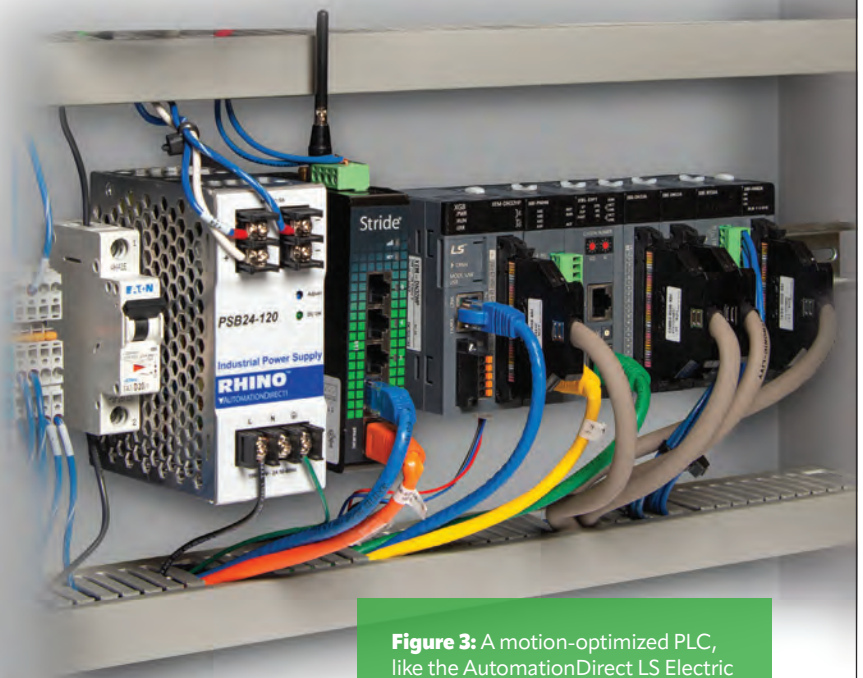


Figure 3: A motion-optimized PLC, like the AutomationDirect LS Electric XGB shown installed here, combines proven automation control and data connectivity with multi-axis servo controllers in a compact platform.



Joe Kimbrell is the Product Manager for Motion Control Products at AutomationDirect. He has over 25 years' experience with automation, motors, drives, motion control and servos, and has worked as engineering manager at a packaging OEM and at a multi-axis motion control integration firm. Joe holds a BSEE degree from Georgia Tech.

References Reference 1: <https://www.hms-networks.com/news/news-details/21-05-2023-industrial-network-market-shares-2023>

What is an Encoder?

BY JOE KIMBRELL, AUTOMATIONDIRECT

For determining the precise motion of industrial machinery and equipment elements, or servo motors, encoders provide a high-performance solution — but only if they are specified properly.

Mechanical movement generated on automated machinery and equipment almost always needs to be monitored by sensors to provide a robust motion control solution. This is especially the case for servo motor controls in motion control systems, but accurate motion detection is used for other types of applications as well. Sensing devices called encoders are one of the most common devices applied to provide this functionality for industrial applications.

Encoder basics

Accurately determining the position, velocity and direction of rotary or linear motion is fundamental for precise, rapid and sophisticated motion control. Whether the equipment in question is for assembly, packaging, pick-and-place, a rotary table, robotics or many other applications, the ability to accurately detect motion is crucial. These sensors need to work with high-speed digital controllers, such as specialized motion controllers, variable frequency drives (VFDs) or industrial programmable logic controllers (PLCs) rated for this capability.

A basic limit switch can identify a single equipment position, and some other technologies such as lasers can detect a range of positions. But to provide comprehensive feedback to a controller, especially on rapidly moving equipment, a much more capable choice is an encoder. An encoder does this by providing high-speed precision electrical signals (pulses or communication) to the controller (Figure 1).

Encoder geometry and resolution

Encoders are available in rotary or linear configurations, and the rotary style is often applicable even for linear motion systems because driveshafts, gearboxes and other rotary elements may form part of the mechanism. Encoders are available in light-, medium-, and heavy-duty versions to withstand various amounts of force and environmental conditions.

This article focuses primarily on rotary encoders (Figure 2), but many of the concepts are applicable for linear encoders.

- **Rotary Encoders:** A coded target disc and sensing head internal to the encoder measures rotational motion. The resolution is typically expressed in pulses per revolution (PPR) or lines per revolution (LPR). The term LPR comes from the fact that optical encoders use high-speed optoelectronics to read light through apertures on a disc (Figure 3).
- **Linear Encoders:** A scale or coded target strip, similar to a tape measure, is read by a sensing head to determine motion along a straight path, with a resolution expressed in pulses per distance, such as pulses per inch (PPI).

More pulses per an amount of motion provide greater resolution.

One-channel encoders

For a one-channel (one physical output) encoder rated for 100 PPR, the output will pulse 100 times for one revolution of the shaft, but does not indicate direction.

Two-channel (quadrature) encoders

A two-channel encoder — also called quadrature, “times 4”, or “x4” — uses two output channels, oriented 90 degrees

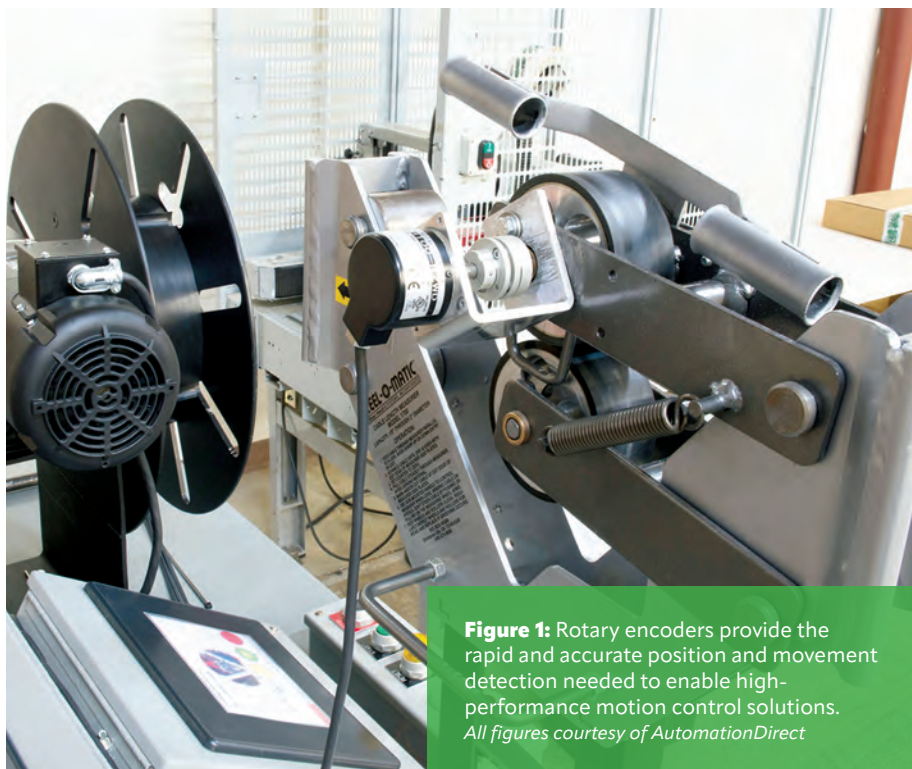
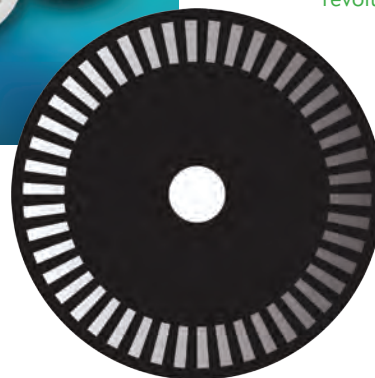


Figure 1: Rotary encoders provide the rapid and accurate position and movement detection needed to enable high-performance motion control solutions. All figures courtesy of AutomationDirect



Figure 2: (LEFT) Rotary encoders, such as the Koyo TRD series offered by AutomationDirect, are a high-performance way to accurately detect position, velocity and direction of moving equipment.

Figure 3: (BOTTOM) Optical rotary encoders use high-speed optoelectronics to read light through apertures on a disc, with the resolution defined as pulses per revolution or lines per revolution.



apart from each other (Figure 4). Since there are multiple transitions of high and low pulses, the device reading these two-channel encoders can actually determine four times the number of positions of a one-channel encoder. Therefore, a two-channel encoder rated at 100 PPR would have a rating of 400 counts per revolution (CPR). Another great advantage of quadrature encoders is that a digital controller can determine the direction the encoder is turning based on which pulse (A or B) goes high first.

Digital communication capable (serial) encoders

The previous examples refer to incremental encoders providing basic hardwired discrete outputs as feedback. Today, there are many encoders that can transmit their information using various digital interfaces such as:

- Synchronous serial interface (SSI)
- Bidirectional/serial/synchronous (BiSS)
- Modbus TCP
- EtherNet/IP
- CANOpen
- Ethernet for Control Automation Technology (EtherCAT)

Communication-based encoders typically offer very high resolutions compared to quadrature encoders. Communication-based encoders (also known as “serial encoders”) are normally classified by how many bits of data they use for storing and transmitting position. A 19-bit EtherNet/IP encoder would be able to determine $2^{19} = 524,288$ positions per revolution.

Some versions of these devices—absolute encoders discussed more below—also store how many complete revolutions they have turned. This feature of an absolute encoder allows motion systems to home one time and theoretically not have to be homed/calibrated again (provided the encoder battery is changed every couple of years).

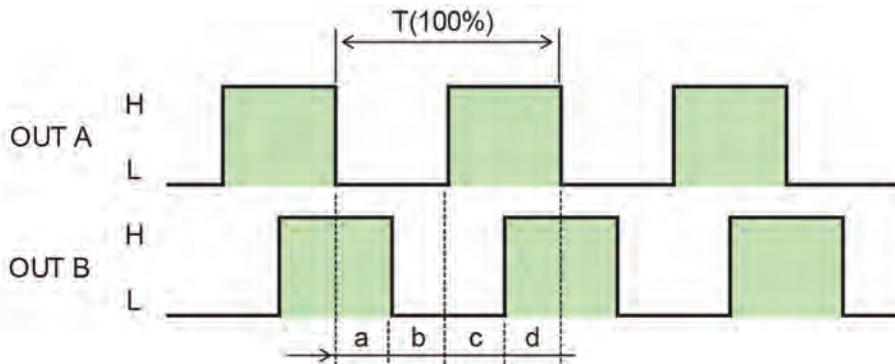
Encoder sensing technology

Encoders can be classified based on their pulse sensing technology:

- Optical Encoders: Use light as the detection method. They are capable of high accuracy and resolution but are susceptible to dust, vibration and contaminants — so must be carefully protected. Optical encoders should be specified with an environmental rating of IP50 (dustproof) or higher.

- Magnetic Encoders: Use a magnetic pickup, which is less accurate compared with optical encoders, but they are more durable and suited for harsh environments, although they can be susceptible to magnetic interference.
- Capacitive Encoders: Use capacitive technology, a relative newcomer compared with magnetic types, and perform similarly to magnetic encoders, but are slightly more susceptible to dust and moisture. >>

Figure 4: Two-channel, or quadrature, encoders use two channels to provide four times the resolution of one-channel versions and also determine the direction the encoder is turning.



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TECHNICAL BRIEFS

Other encoder terms

It is important to select the right encoder options to meet the application needs; following are some common terms:

- **Incremental Encoders:** These track relative motion by counting pulses, but they only show how far the shaft has travelled, and they do not retain position data when powered off. If the starting position is important, then the automation system must be programmed to start counting when the equipment is at a known "home" point.
- **Single-Turn Absolute Encoders:** These are absolute encoders that know what angle they are at upon power up, but don't know how many turns they have accomplished. If that information is important, then the signal needs to be homed, or a multi-turn encoder should be used.
- **Multi-Turn Absolute Encoders:** These encoders provide the same basic functionality to provide PPR while the encoder is turning, and they also use a battery or super-capacitor (or recently, Weigand technology) to maintain a persistent count of how many total revolutions have been made by the encoder shaft. Multi-turn absolute encoders have two ratings: PPR (pulses per one revolution) and "turns" (how many turns the encoder can count before rolling over).
- **Z-Pulse or Index Channel:** Some incremental encoders generate an additional pulse output when the disc crosses a fixed zero position. This signal can be used to reset a revolution counter or provide precise homing.
- **Gray Code:** This is an alternate scheme, as compared to standard binary code, which ensures only one signal line changes at a time, so that a controller is less likely to decode erroneous data.
- **Electrical Output:** Absolute encoders with discrete outputs (Gray Code, binary, etc.) can work with general-purpose controller inputs, but discrete incremental encoders produce high-speed pulse streams and generally must be wired into high-speed controller inputs of the appropriate type. Some types of high-speed signaling are line driver, NPN open collector, push-pull (totem pole), HTL and TTL.

- **Speed Limitations:** Encoders are subject to both mechanical speed limits (the actual max physical speed the encoder can be turned) and electrical speed limits (the speed that discrete outputs can transition), so designers must ensure the application remains below both these limits by an acceptable margin.

High-performance position/velocity/direction detection

When used with a typical PLC, servo motor controller or other controller, an encoder is often the best way to precisely determine the position, velocity and direction of equipment motion. Selecting the appropriate encoder requires consideration of various factors as listed above, plus others in some cases. Users also need to understand how these elements work together to ensure the encoder meets the specific needs of the application by providing accurate and reliable motion feedback.

The AutomationDirect website features a wide range of encoders, accessories and other sensing technologies, along with informational resources such as specifications, documents/drawings and videos. AutomationDirect's free and award-winning technical support staff are ready to help you find the right application solutions to deliver maximum value and performance. ▼



Joe Kimbrell is the Product Manager for Motion Control Products at AutomationDirect. He has over 25 years' experience with automation, motors, drives, motion control and servos, and has worked as engineering manager at a packaging OEM and at a multi-axis motion control integration firm. Joe holds a BSEE degree from Georgia Tech.



Automating a Luxury Bus

BY MARK MCHENRY, SYSTEMS & CONTROLS

Industrial automation products are useful for much more than traditional applications, as PLCs and HMIs can be used in all sorts of unique commercial markets.

Other than being large and generally rectangular-shaped, a modern custom bus — the type frequented by touring music stars, mobile multi-millionaires and campaigning politicians — bears little resemblance to the utilitarian school buses many remember. Sometimes called luxury coaches, motorcoaches, motorhomes or recreational vehicles (RVs), these conveyances are bespoke creations built-to-order.

Their interiors are typically appointed with premium materials and carefully thought-out design features. This extends to the electrical and electronic systems, where LED lighting and digital controls and displays provide efficient and sophisticated functionality. But because they build far fewer units than a massive auto manufacturer, these custom coachbuilders have a problem. They have less of an opportunity to benefit from economies of scale, so many of the digital components they use must be specially developed for changing and unique applications.

The industrial automation sector already faces challenges like this, and designers and systems integrators (SIs) address these needs by applying commercial off-the-shelf (COTS) digital control products to make them suitable for the demanding applications. Mark McHenry founded Systems & Controls (S&C) in Lenoir City, TN in 1999 to service industrial customers, but over the years he has found success leveraging his company's SI skillset to support the custom coachbuilder industry.

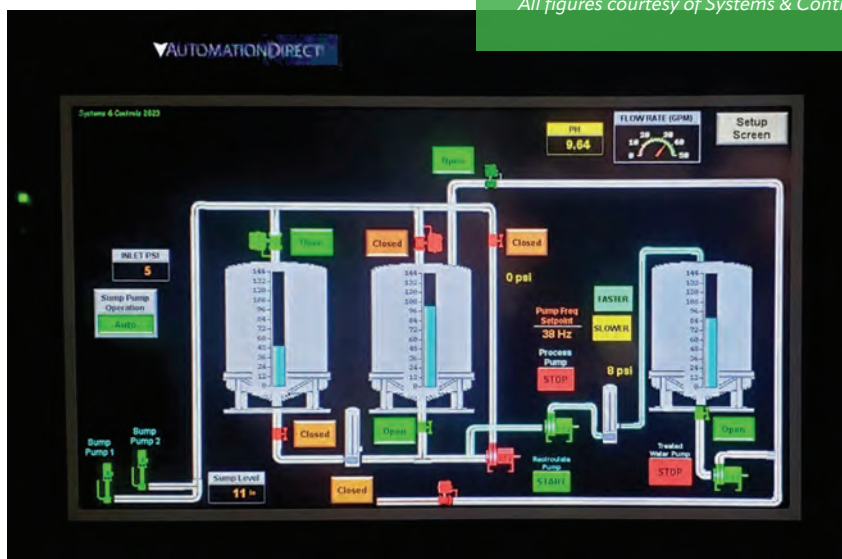
A concrete beginning

Working with scales, loadcells, flowmeters and associated equipment was an early specialty of S&C. The company rapidly expanded their capabilities to include custom automated storage, transfer, filling, batching and blending systems for dry and wet materials. A typical client would be a concrete batching plant, where various raw materials were scaled and metered according to a recipe to make the desired product.

One of the most effective ways to automate industrial systems like this is to use COTS digital devices, such as

human-machine interfaces (HMIs) and programmable logic controllers (PLCs) to monitor and operate field-located sensors, along with other equipment such as valves and motors. S&C refined the control logic and best visualization practices for automating systems using proven HMI and PLC devices (Figure 1). >>

Figure 1: S&C works with many makes and models of automation devices, but it favors AutomationDirect HMIs and PLCs for the majority of their projects based on the ease of use and favorable price/performance ratio. All figures courtesy of Systems & Controls



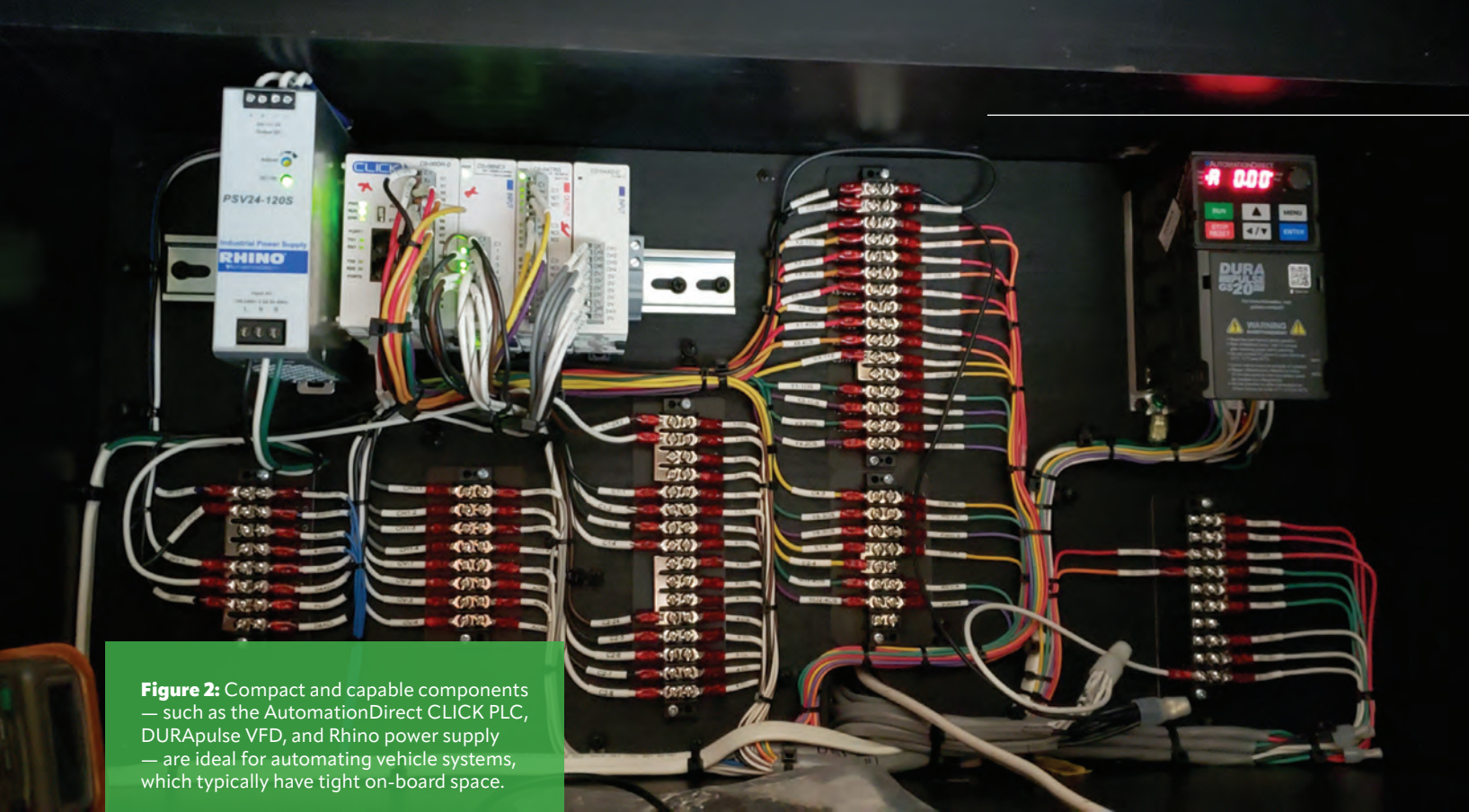


Figure 2: Compact and capable components — such as the AutomationDirect CLICK PLC, DURApulse VFD, and Rhino power supply — are ideal for automating vehicle systems, which typically have tight on-board space.

Of course, PLCs and HMIs can be used to automate almost anything. When S&C's owner heard about an opportunity to work with a custom coachbuilder, he knew they had the right product knowledge and skillset to help.

Opening the door to new markets

Custom coachbuilders are typically strongest at selecting a chassis, and then outfitting the rig with the hardware and components to create a personalized product for their clients. There are some integration technology suppliers offering smart switches and touchscreen devices suitable for use on board RVs, boats and similar mobile transportation. However, these are mostly suitable for remotely viewing some status points, or for allowing users to remotely turn things on and off, with limited automation functions.

One coachbuilder engaged S&C to help with controlling an automatic motor-drive sliding pocket door. For the chosen mechanism, they needed a way to carefully control a small three-phase motor which transmitted motion using a cogged belt to open and close the door based on user button presses. The door would need to operate quietly, and smoothly run into each stop as it reached fully opened or closed. Most importantly, it would need to detect any blockage while moving, such as a person, pet or other

obstacle. If obstructed while closing, the door needed to stop and then reverse; if somehow obstructed while opening, the door needed to stop until another command was received. In addition, it must be possible to move the door by hand if a failure occurs.

Most vehicle systems operate at 12VDC. However, large custom coaches typically incorporate a full-time 120VAC distribution system — supporting multiple air conditioners, appliances and other large loads — using an on-board generator or plug-in connection to "shore power," depending on whether the vehicle is moving or parked. Three-phase power is typically not available, but S&C solved this issue by using an AutomationDirect DURApulse GS20 variable frequency drive (VFD), which has the capability to accept common single-phase 120VAC and output three-phase 240VAC. An AutomationDirect CLICK stackable micro brick PLC, and other compact components such as a Rhino power supply, ensured that S&C could create a design suitable for installation in the limited on-board space (Figure 2).

The design took a bit of iteration, and S&C along with one of the coach builders made a test jig so they could prove out the function in the convenience of their shop. The first idea was to run the VFD on a time basis, but this was not very accurate and

resulted in the door bumping into each end-of-travel, and sometimes slipping the belt. However, by incorporating limit switches and monitoring the current draw, they could provide fine control of the door movement and stop it immediately as it snugged into each end point. Current monitoring was also essential as a safety function because any blockage due to a person, pet or other item in the way of the door would be detected as the motor was forced to work a little harder, and movement would be commanded to stop.

Initially, the design was for operating just one pocket door. Since that time, adding additional I/O to the PLC has allowed it to control up to four pocket doors per installation. Just one PLC program was created to control up to four doors, and unused inputs are ignored if there are fewer. One issue discovered was that multiple switch activations or pressing open/close buttons while the door was moving could cause unintended operation, so the PLC was programmed to ignore switch activations in a way to prevent this problem.

Interfacing with on-board systems

The PLC was easily interfaced with the coach's smart switch system or discrete switches so users could interact with the door using the interface available to them for all other on-board functions (Figure 3).

Using a PLC in this type of application is also beneficial because the input/output (I/O) module count is easily expandable, and there is plenty of programming memory available, so that one PLC can control multiple things. Another custom coach application is coordinating air conditioners. Some coaches have up to five 120VAC air conditioners. If more than one happens to start at the same moment, there is the potential of tripping a circuit breaker. To avoid this, S&C has configured a PLC to monitor the air conditioner run command from each thermostat, and it then performs logic to stagger the starting of each unit and prevent an overcurrent trip.

Automation is for more than just industry

Industrial automation products are widely used for all types of machinery, equipment and manufacturing processes, but they also provide an ideal way to monitor and operate almost any type of system. S&C has recognized this, and it has expanded their client base over the years to perform many types of projects over and above their typical core work.

Part of the S&C success story is attributable to the selection of the right automation supplier. Key characteristics needed to facilitate the work of an SI are an extremely wide range of products, a favorable price performance ratio, and support by a comprehensive ordering and documentation website. Free software, online/phone support and training/example videos make it easy for users to learn and work with the products. S&C is sticking with their preferred supplier based on all these reasons, and because they have a large installed base of reliable installations. ▼

Mark McHenry graduated Tennessee Institute of Electronics with an Associate degree in electronic technology in 1980. After working for almost 19 years in the electronics industry as a technician, he started Systems & Controls in 1999 and will be celebrating 25 years in business this fall. With almost 70 years combined experience, Mark and his team at Systems & Controls enjoy the challenges of one off and custom system integration.

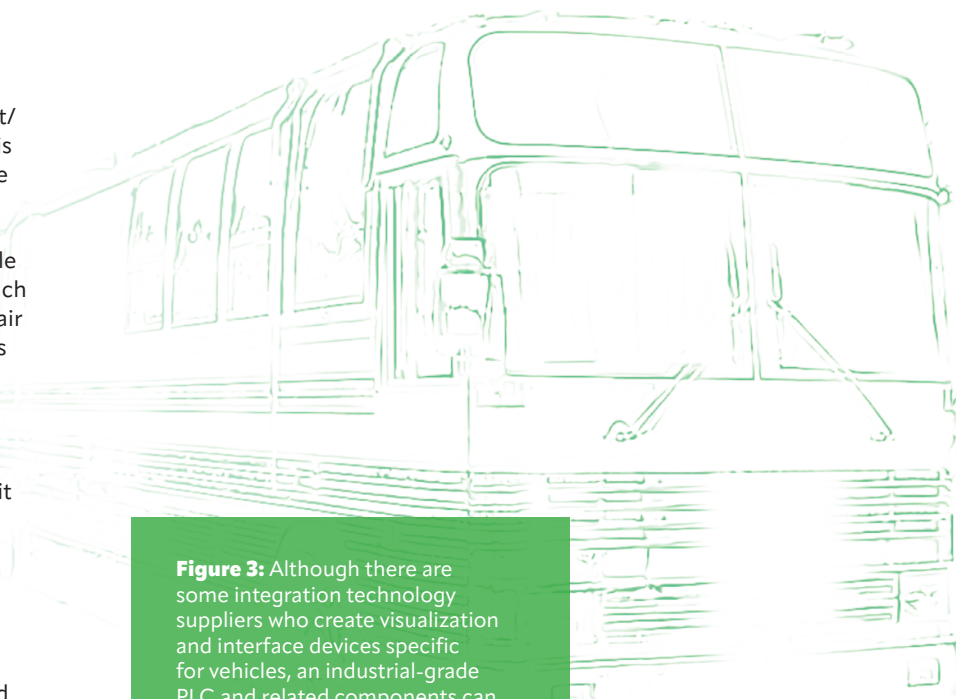


Figure 3: Although there are some integration technology suppliers who create visualization and interface devices specific for vehicles, an industrial-grade PLC and related components can be the best way to achieve more sophisticated and robust equipment control for vehicle systems.





C-more CM5 Headless HMI

AutomationDirect has added the CM5-RHMI headless HMI which has all the powerful functionality of the C-more CM5 touch panel HMIs but without display size restrictions. This HDMI-enabled device works with televisions, monitors, projectors and most any other HDMI display device of any size to display real-time operational data or messages. Or skip the local display entirely and use the remote access feature which supports any windows PC (web browser) or Apple iOS and Android smartphones and tablets with the C-more Remote HMI mobile app.

The CM5-RHMI supports numerous screen resolutions including VGA 640x480, SD 720x480, XGA 1024x768, HD 1280x720 and FHD 1920x1080, provides an SD card slot for log files, project memory or graphic media and offers 90MB of user memory. The four integrated USB ports allow connections to industrial touch screen monitor displays that support the USB interface or can be used for USB mouse operations. The two serial ports and two 10/100 Base-T Ethernet ports provide support for all the major protocols and enable easy connections to multiple devices simultaneously.

All CM5 HMIs utilize our FREE powerful configuration software that features C-more's legendary ease of use. The software has a built-in time-saving project simulator, a convenient Event Manager, flexible recipes, a huge array of screen objects, trend graphs, PID faceplates, true historical data logging, converts EA9 projects to CM5 and much, much more.

The new CM5-RHMI headless HMI is priced at \$599.00 and comes with a 2-year warranty.

Learn more by visiting: <https://www.automationdirect.com/headless-hmi>



LS Electric XMC EtherCAT® Motion Controllers and EtherCAT Bus Coupler

AutomationDirect has added the powerful LS Electric XMC motion controller to provide full EtherCAT master motion control. With a blindingly fast processor (scan times as low as 5ns) and built-in support for 8 or 16 axes of EtherCAT-based motion control (depending on the model), the XMC controller can handle virtually any motion control application. These brick-style controllers feature 8 discrete inputs, 16 discrete outputs, 2 analog inputs and 2 analog outputs. Utilize the new EtherCAT bus coupler with the diverse LS XGB PLC I/O modules to expand the XMC controller I/O capability.

The controllers also have two embedded quadrature encoder inputs to support full-closed-loop control. If further I/O expansion is required, the controllers support the addition of up to 32 racks of EtherCAT remote I/O (depending on the model).

The new EtherCAT bus coupler (XEL-BSSCT) supports LS Electric XGB I/O modules (already offered by AutomationDirect) with over 30 I/O modules available, including discrete, analog, relay, temperature, high-speed counter and load cell models. With the XEL-BSSCT bus coupler, these economical EtherCAT I/O racks are compatible with any EtherCAT master controller.

XMC controllers utilize the powerful XG5000 software to configure and program all the control logic for advanced motion and basic PLC applications. XG5000 has a comprehensive set of motion function blocks (in ladder or structured text) to handle any application. These function blocks meet the standards of PLCopen to ensure interoperability, efficiency and easier code development for motion applications.

The new EtherCAT XMC motion controllers start at \$779.00, and the EtherCAT bus coupler is \$199.00.

Learn more by visiting: <https://www.automationdirect.com/ethercat-motion-plc>



LS Electric DC Servo Systems (EtherCAT®, Pulse and Indexing Control)

AutomationDirect has added LS Electric PHOX servo systems that operate with 24-80 VDC input power and accept a wide variety of control inputs. These flexible systems are suitable for both single-axis use and for advanced multi-axis motion control systems.

With output power from 100W to 300W, these four matched sets of servo motors, drives, cables and accessories are perfect for mobile applications or situations where DC power sharing between servo axes is advantageous. An integral holding brake is optional on each motor.

Possible control options include pulse train, velocity or torque control (with analog inputs or predefined setpoints), a built-in indexer, and the use of external encoder feedback (full closed-loop control). The systems can also be controlled by any CANopen over EtherCAT (CoE) compatible PLC/host controller. The drives are fully digital with a 1kHz velocity loop response and offer Safe Torque Off (STO), eliminating the need for large external e-stop contactors.

Network motion control options include Cyclic Mode where all drives are updated every EtherCAT cycle (~1 millisecond) with position, velocity, or torque setpoints, and Profile Mode with drives receiving target setpoints for each move over EtherCAT.

All motion parameters can be stored, loaded and triggered from an EtherCAT-compatible PLC, simplifying your control scheme. Networked motion control capabilities include storage of up to 400 position setpoints (per axis) in the PLC, electronic camming, registration, flying shear, advanced torque control and more.

The new DC powered EtherCAT-compatible servo drives start at \$434.00 and the matching servo motors start at \$267.00.

Learn more by visiting: <https://automationdirect.com/PHOX-servo>



DURApulse GS30 AC Drives

AutomationDirect has added new DURApulse GS30 drives. These high-performance drives support several control modes including sensorless vector control, closed-loop flux vector control and torque control modes in a compact package. The GS30 series expands the DURApulse family by adding internal tension control loop expanded parameter sets for greater versatility, as well as optional EtherCAT and single- or dual-port EtherNet/IP communication cards.

GS30 drives support up to four (4) independent induction motor (IM) parameter sets or control of a single AC permanent magnet (PM) motor. They are available in sizes up to 3hp for a 230VAC single-phase input, 50hp for a 230VAC three-phase input, and 100hp for a 460VAC three-phase input. Their compact design allows for a zero-stack installation to save even more space. This series offers PID control, built-in PLC functionality and STO capability typically found with more expensive high-performance AC drives.

The new DURApulse GS30 AC Drives start at \$239 and have CE, TUV and cUL approvals. All new DURApulse GS30 AC drives and accessories come with a two-year warranty.

Learn more by visiting: <https://www.automationdirect.com/high-performance-vfd>



Bucher Hydraulics HPUs, Heat Exchangers and Solenoid Valves

AutomationDirect has added hydraulic power units (HPUs), heat exchangers for HPUs and hydraulic solenoid valves from Bucher Hydraulics, a well-respected name in the industry.

Hydraulic power units contain a reservoir, pump/motor, filter and all necessary controls to power a hydraulic system. They are offered in the single-phase powered M-series and three-phase powered T-series models. A T-series dual-flow, dual-pressure model is also available.

Heat exchangers for hydraulic power units extend the life of a hydraulic system by maintaining a lower fluid temperature. Hydraulic solenoid valves are available in both NFPA D03 and D05 patterns and are 4-port, 4-way, 3-position valves with tandem, closed, open and float center options.

The new Bucher hydraulic power supplies, heat exchangers, solenoid valves and accessories have a 1-year warranty. Hydraulic Power Units start at \$171.00.

Learn more by visiting: <https://www.automationdirect.com/hydraulic-power-units>



M.G.M. Electric IEC Motors and Brake Motors

AutomationDirect has added M.G.M. Electric IEC standard and brake motors that are manufactured in Italy using state-of-the-art, high-quality processes and are rated for general-purpose and inverter duty. IEC motors provide the same power output as NEMA motors but have a smaller footprint and feature a lightweight aluminum construction.

IEC standard motors offer outputs rated up to 5hp at 1800rpm and up to 1hp at 3600rpm. M.G.M. brake motors are available with outputs rated up to 5hp at 1800rpm and feature brakes that are direct 3-phase AC coils (no DC rectifier required). This results in faster response time and higher holding torque. Replacement brakes are also available.

The new M.G.M. IEC and brake motors are extremely cost-effective, starting at only \$144.00 and all motors come with an 18-month warranty.

Learn more by visiting: <https://www.automationdirect.com/ac-motors>



More Reer MOSAIC Safety Controller Options

AutomationDirect has added more options to the Reer MOSAIC safety controller family. The MOSAIC-M1S-USBC has all the features of the enhanced MOSAIC-M1S master controller module, including embedded digital inputs, OSSD outputs and expansion capabilities, but also offers a USB-C programming port.

The new Reer MOSAIC MZERO controllers are simple standalone safety controllers that have plenty of fixed I/O but do not support expansion I/O. They are ideal for small systems with fewer safety devices. Also available is a proprietary memory card for use with these controllers.

All Reer safety controllers come with a standard 1-year warranty and start at \$463.00.

Learn more by visiting: <https://www.automationdirect.com/safety-controller>



IN CLOSING...

Flexibility Gives OEMs and Integrators What They Need to Succeed

Automation technologies have advanced significantly over the last several decades, and continue to realize rapid growth in use and capabilities throughout multiple industries. Among the biggest trends we're seeing is improved flexibility built into products, making them easier to use in a variety of applications and driving workforce adoption of new technologies.

As a leader in industrial controls, AutomationDirect is ideally positioned to actively support OEMs, systems integrators (SIs) and product designers/developers with the parts and education they need to succeed.

COTS Over Custom

Fully custom automation designs and products are required for some applications, but in most cases it is more efficient for users to apply commercial off-the-shelf (COTS) products with capable features to create automation solutions. AutomationDirect understands this and has built an entire product portfolio and organization around the specific needs of OEMs, SIs and end users.

Industrial Machines to Luxury Buses to Rocketry

PLCs, HMIs, motion controllers, and other COTS automation products aren't just for factories anymore. These automation technologies are being used in applications ranging from industrial machinery to bespoke luxury buses, to rocketry and more.

Automation of industrial machinery and manufacturing processes are still some of the primary applications of

PLCs and HMIs, and are used by both OEMs and integrators. But these technologies can be used for monitoring and operating any kind of system.

As we saw in this month's stories, AutomationDirect offers the parts and support needed by a range of industries and end users for systems large and small — from fuel-handling systems developed by the students of the Space Concordia team, to automatic control of a sliding pocket door in a luxury coach bus.

Maximize Your Workforce with Automation

Employee training and retention is vital to a successful business. Flexible, accessible, and easy-to-use automation technologies help maximize your current workforce and address the manufacturing skills gap. These technological solutions, in concert with the support of SIs and training programs, support the upskilling, reskilling and retention of current workers, as well as inspiring the next generation through educational initiatives at the university and vocational school level, and even earlier through programs such as FIRST Robotics. Whether it's providing software support or parts and products for classroom use, AutomationDirect is encouraging the up-and-coming technological workforce.

AutomationDirect services all these needs, between the online catalogue available 24/7/365, resources and software supporting the use and application of many available products, and training and educational materials on everything from PLC programming to workforce development. ▼

Meghan Brown
Program Manager
WTWH Media

AC drives that won't drive up your cost

Get affordable VFDs for any application from AutomationDirect!

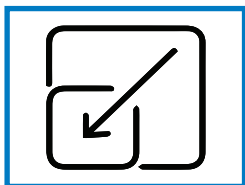


AutomationDirect carries a full line of AC drives, from basic micro drives to full-featured high-performance drives boasting flux vector control and built-in PLCs. So no matter the application or environment, AutomationDirect has an affordable drive solution for you!

Micro VFDs

Starting at \$119.00

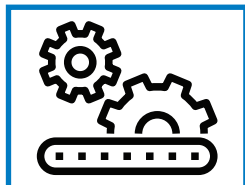
With sizes as small as 55mm wide, these drives provide the needed motor speed control without taking up large amounts of panel space.



General Purpose VFDs

Starting at \$147.00

General purpose drives offer great value for a wide variety of applications including conveyors, pumps, fans, HVAC systems, and elevators.



High Performance VFDs

Starting at \$232.00

High-performance AC drives are top-of-the-line drives that are usually specified when a high degree of precision in speed control is required or when full torque is needed at very low or zero speeds.



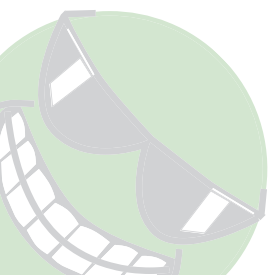
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A close-up photograph of a technician's hands working on a complex industrial control system. The technician is using blue-handled wire cutters to trim a blue wire. The system consists of several grey metal racks filled with electronic modules, including a 'PILZ' safety relay and an 'OMRON' relay. Numerous colored wires (blue, green, black, red) are connected to the modules and organized into a grey wire management tray. The background shows a wooden workbench and other industrial components.

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