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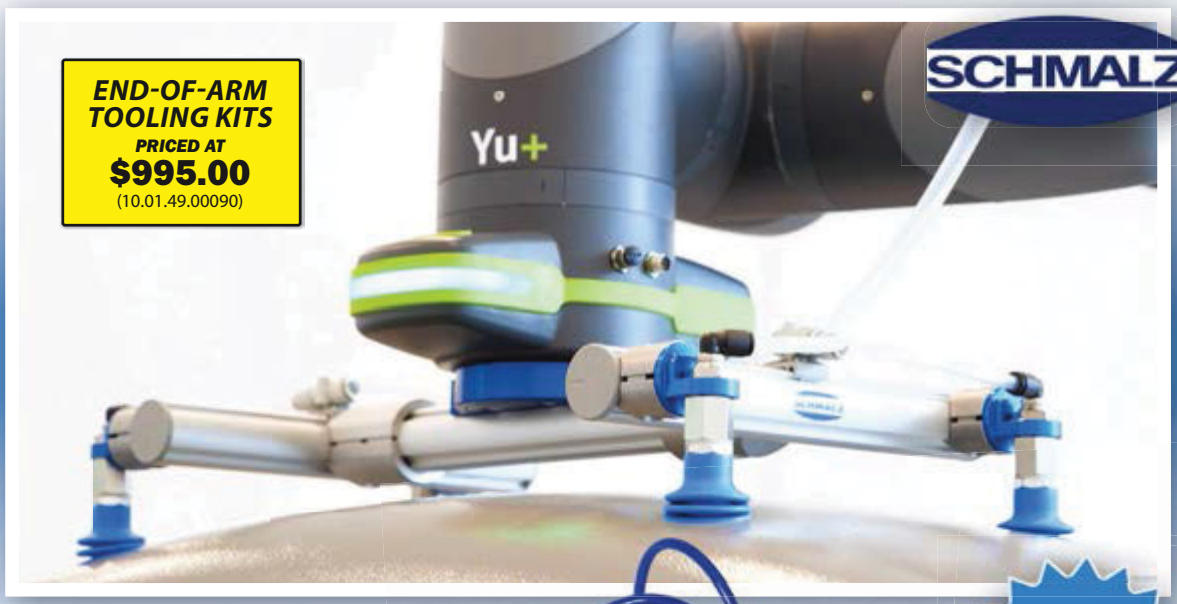

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Robot integration steps ahead

ROBOT APPLICATIONS AND implementations continue to become simpler, despite the explosion of growth. The robot-manufacturer market consists of more than 500 companies, which make conventional industrial robots and cobots; automated guided vehicles (AGVs) for transporting large and small loads in logistics or assembly lines; stationary medical and agricultural applications; and mobile cleaning, construction and underwater activities, according to Boston Consulting Group's "Robotics Outlook 2030: How Intelligence and Mobility Will Shape the Future," released in 2021.

More than half a million robots were installed that same year, according to the International Federation of Robotics' (IFR) World Robotics Report 2022. The bulk of those came from a handful of companies, including ABB, Fanuc, Yaskawa, Kuka, Mitsubishi, Kawasaki, Nachi, Denso, Epson, Stäubli, Comau, Omron, Universal Robots and Foxconn.

Programming and controlling multiple brands and types of robots can be daunting, especially when they need to be integrated into an existing control architecture whose programmers might only be familiar with IEC 61131-3 languages.

Programming and controlling multiple brands and types of robots can be daunting.

Ready Robotics' ForgeOS platform is designed to enable operators to control and program multiple brands of robots from a single user-friendly interface with minimal training. Using Task Canvas, one of many ForgeOS Productivity apps included with the platform, operators can create new automation tasks with a no-code, flowchart-based interface. Rockwell Automation's strategic investment in Ready Robotics, a Rockwell Technology Partner, marks a significant step in the integration path.

"The collaboration between Rockwell and Ready Robotics enables an unprecedented degree of simplification in the application of robots," said Matheus Bulho, vice president and general manager, production automation, at Rockwell. "It not only reduces the need for programming with a low-code approach to the creation of the robot application but also allows system integrators and machine builders to improve productivity with a common approach to programming and management of robot systems from multiple vendors."

Historically, automation has been hampered by software silos between robot vendors, explained Ben Gibbs, CEO and co-founder of Ready Robotics. "Ready's interface alleviates this issue, eases deployment and enables automation where it might have been prohibitive before, especially in high-mix operations," he said.

The collaboration will integrate ForgeOS with Rockwell's line of Logix controllers and design and simulation software. The pace of robot integration is quickening. CD

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What environments require industrial PCs?

IN DICK MORLEY'S BOOK *The Technology Machine: How Manufacturing Will Work in the Year 2020*, he references a 1949 Popular Mechanics article that predicted computers may not weigh more than 1.5 tons in the future. Boy, was that ever right.

Industrial computers are a different breed; they are not personal computers (PCs). When the programmable logic controller (PLC) was first introduced into the wild, we were told to not mention the word computer, which in reality it was. If that word was mentioned, then the plant's IT department had to get involved, which in those days meant IT approval and regulation.

It was new. How could they ever understand how it functioned and what it did? So, it was a controller for industry and the plant floor, owned and operated by the engineering department and maintenance. Whew.

The first industrialized computer—not minicomputers, such as the Digital Equipment Corporation (DEC) PDP-11/12—came into being in the 1980s. It ran on DOS, not Unix, and ushered in a brand-new world. The plant floor had a platform of its own as such. Software for supervisory control and data acquisition (SCADA) and human-machine interface (HMI) began to emerge to run on these machines. PLC programming software also became available, giving the industry a window into it all.

These machines were never going away. DOS was not real-time as such, so operating system add-ons came into being to offer real-time extensions to allow those processes to utilize that feature if they needed to. The age of what was called "PC-based control" was born.

All computers were tagged colloquially as PCs, so the idea of industrialized computers got muddled. Confusion was rampant in the user community because they didn't know why an industrialized computer was twice the cost of a standard Dell or IBM PC.

The dividing line is as blurred now as it ever was. Brick-style PCs with fanless designs, better heat transfer, solid-state drives and switching power supplies with better filtering are commonplace. External power filtering and conditioning is highly recommended in any installation, which makes one wonder: Why pay the extra money for a ruggedized computer?

Arguments vary for an industrial PC vs. a commercial-grade version. The constants, however, are temperature range, vibration specifications and mechanical shock. Cabinets might provide some protection, but temperature and environmental issues, such as dust and airborne stuff, will still exist.

The other main argument is the 24/7 runtime and availability. This is true; the computer has to do this. I had computers running my Visual Studio HMI on 20 computers for more than 10 years. They only rebooted for upgrades in both hardware and software. They just ran. They were commercial-grade PCs since the environment was like your living room.

> The advent of solid-state drives allows for the vibration specification to become less important.

Where vibration, temperature and contaminants are present, then you would be advised to employ a truly ruggedized computer.

Power issues are also of major concern. A standard commercial PC's power supply may protect you once with its minimal surge protection and filtering, but multiple hits will kill it.

The temperature issue is by far the greatest advantage of a ruggedized device. The components used tend to be military specification (Mil-Spec), which allows the computer to operate at higher ambient temperatures. When I checked the specifications on a Dell XPS desktop, it didn't even mention temperature. Zero to 60 °C is the common non-condensing temperature range for industrialized devices. The advent of solid-state drives allows for the vibration specification to become less important. Universal-serial-bus (USB) drives replace floppy-disk, compact-disc (CD) and digital-versatile-disc (DVD) drives, as well. Part of the real problem with the device is the software and drivers that are loaded. One of the biggest problems when we started using PCs, in general, is that the multimedia drivers would crash the device even when you weren't using them.

All we need in a computer in an industrial setting is navigation, motherboard, slots for networking other than Ethernet, if required, and video as a minimum. Additional stuff only adds to the potential for failure and crashes.

Pick your fights. Ruggedized hardware in my opinion is only needed when its needed. Profound, I know. CD

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

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Rick Rice
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How can you proceed safely?

SAFETY IS BONDED to our consciousness. Long gone are the days where a warning label on a piece of equipment is sufficient to make it safe.

Control systems not only have to provide layers of safety, they have to include methods to prevent humans from circumventing the layers of safety. Fortunately, automation manufacturers are not only onboard with the latest safety methods, they have gone out of their way to make the user experience, from a design perspective, practically painless.

Safety systems have come a long way from the early days of master control relays and e-stop buttons. We focus on safety for a number of reasons. Primary to that is to protect the people. Other reasons may include compliance with federal and local regulations, protection of equipment and minimizing liability and fines.

The driving force behind safety can be found in ANSI B11.20-1991, Paragraph 6.13, which indicates the control system shall be designed, constructed and installed such that a single component failure within the system does not prevent stopping action from taking place, but will prevent successive system cycles until the failure has been corrected.

The key elements of this directive are detecting the fault, monitoring the condition of the faulted device and introducing redundancy to ensure that no single device in a faulted condition can prevent the system from stopping or restarting.

The approach is redundancy, and the method is the use of dual safety circuits. Dual-channel devices mean that two circuits have to be made, and broken, to enable function of the controlled system. By monitoring the status of the devices, we detect the failure, or trip, and then watch for the restoration of the device to normal status before allowing the system to be reset and started.

It's important to acknowledge that not all safety designs have dual circuits. A single circuit can be effectively utilized but should include as many means of redundancy as possible.

The degree to which a safety circuit is designed should take into consideration the relative risk to the people interacting with the equipment. Some functions are more risky than others, and every attempt should be made to ensure that everything possible is done to reduce or eliminate that risk.

The list of safety devices ever expands to meet the needs of the application. Examples of safety devices include the e-stop button, light curtain, safety mat, laser scanner, door switch and limit switch. However, the devices themselves are only of limited value without a means to monitor function and status. This is where a safety relay comes into play.

At minimum, a safety relay has one or two safety channels and one or more outputs to drive other devices. Internal design monitors the status of the safety channel and turns off the safety relay output if a fault—broken circuit—occurs on the channel.

> The designed function is to assign one safety device to each input on the controller.

Once broken, the internal logic observes how long the circuit was broken so that even momentary blips will prevent the safety relay from resetting. This helps to identify the device that has failed.

If it is a dual-channel setup, the monitor function will also compare the two channels against each other to detect if one channel stays active while the other one is down. Think of an e-stop button with dual contacts. If one of the contacts breaks without the other, this is a fault condition. If both channels do not reset within a pre-determined time, this is also a fault condition.

Further redundancy can be achieved by using two force-guided relays—these have extra-strong components to guarantee only a make-or-break situation with the associated contacts—on a single output from the safety relay. Wiring the safety-relay reset circuit through normally closed contacts on each of the force-guided relays will identify if one relay doesn't truly turn off at the absence of power to the coil. Both force-guided relays must be off before the safety relay can be reset.

Safety controllers take the function of a safety relay and add the ability to provide additional logic to the safety devices attached to it. Like a regular programmable controller, a safety controller has multiple inputs and outputs for use by the designer.

The designed function is to assign one safety device to each input on the controller. Via the programming interface, additional logic can be added to combine individual inputs into logic groups. Unlike the channels on a safety relay, safety inputs on a safety controller can be combined using standard gate logic to create scenarios where, for instance, two-hand buttons might be combined with a light curtain in an OR function to maintain

a 1 status for the safety channel. Logical gates, from transistor-transistor logic (TTL), offer a variety of functions to determine logic. An OR function of two conditions means one or the other must be true to make the result true—a logic state of 1.

Each input on a safety controller is internally monitored, just like on a safety relay, to detect momentary breaks or connections to identify a component that isn't functioning correctly. A safety controller can also be programmed to group inputs that can be assigned to one of the safety outputs, thereby creating zones of safety within the controlled system.

This functionality saves money in the design of the system because, without a safety controller, one would have to have a separate safety relay for each zone on machine or process. Additionally, because all of the zones are programmed using the same safety controller, inter-zone operability can be achieved.

Another feature introduced recently is the safety I/O network. Based on a structure similar to IO-Link, these networks allow for simple four-wire connections between nodes to which safety devices are connected.

Depending on the node type, the device connected could be a simple e-stop, door switch or even a locking door switch. The network autoconfigures on power-up, and the safety relay to which the network is connected will provide a data table to provide status and commands for each device on the network.

Machine wiring is simplified because the main trunk of the network is a standard M12 cable identical to that used for sensors. Two conductors provide power, and the other two provide communications. A combination of five-wire and eight-wire, both output-signal-switching-devices (OSSD) and mechanical versions, can be combined on a single network.

All of the I/O goes back to the programmable controller via a network interface and appears in the tag database of the controller.

The latest evolution might just be the greatest. Hardware manufacturers have combined the programmable controller with the safety controller, offering a single device that contains both controllers. To maintain the safety aspect, the two controllers are completely independent of each other.

Standard and safety I/O can be placed anywhere in the rack. The great thing about this development is that the interconnection of standard and safety I/O means a user program can look at the status of a safety device in the standard program algorithm and vice versa.

With the evolution of safety hardware come improvements in the design and deployment of the devices making up the system. With safety controllers, regardless of stand-alone or combined with standard controllers, adding devices to the hardware tree brings in a tag structure associated with the type of device.

It might be as basic as input and output words, but if the device is from the same manufacturer as the safety controller, that tag structure might even be specific to that safety device with descriptive tags. The gate logic programming environment permits for building the algorithm using symbols that represent that actual devices.

It would be remiss to talk about all this and not mention that impact that safety relays and controllers have on the equipment downstream of the relay/controller. Since the output from a safety relay/controller includes all of the built-in self-monitoring logic, the resultant output can be used to trigger safety functions in devices such as variable-frequency drives (VFDs) and servo drives.

A safety output can be wired to an input on a drive that operates a safe torque off (STO) feature. This feature renders the output from the drive completely inoperable, regardless of any command it might be receiving via direct wire or network connection. This function eliminates the need to have safety contactors upstream or downstream of the drive.

In days gone by, to make the drive safe, we had to drop the power to it if the safety circuit dropped out. Most drives don't like to have this done to them and, eventually, may even fail.

The same goes for a contactor between the drive and the motor. Most drives don't like to have an open circuit on the output connections and may even generate a fault if the circuit from the drive to the motor is interrupted. A safe-torque-off function prevents unexpected startup of a device during an e-stop condition, fulfilling stop category 0.

There are other safety functions available in some drives, based on the output of the safety relay/controller. These include a safe stop or controlled stop, safe limited speed, safe maximum speed and safe brake control, used for hanging/vertical loads where a brake needs to activate upon dropping power output to the motor.

Safety can be incredibly stressful to the designer. The obligation to protect the people using the equipment or process is paramount and can be somewhat overwhelming. However, with all of the features available to a designer, the safety circuit is much more user-friendly and cost effective to deploy. It is safe to proceed. CD

RICK RICE is a controls engineer at Crest Foods (www.crestfoods.com), a dry-foods manufacturing and packaging company in Ashton, Illinois.

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Pneumatic advances draw more applications

THE ENGINEERING FIELD of pneumatics deals with the use of compressed air or gas to drive mechanical devices. Pneumatic technology has recently advanced, making a wide range of machine applications more common. For applications that call for a balance of speed, power and accuracy, pneumatic systems are the best option because they can provide precise control of motion.

When used in machine applications, pneumatics have many benefits. Pneumatics are excellent for applications that call for high power in a small space due to their high power density. Second, pneumatics are economical because of their reasonably priced parts and the frequently accessible compressed air or gas that powers them. Third, the straightforward design of pneumatics makes them simple to install, use and maintain. Fourth, pneumatics can function in a variety of temperatures and challenging environments. They are also very dependable and long-lasting. Finally, there is no chance of an electrical shock or environmental damage when using pneumatics.

In a wide range of machine applications across numerous industries, pneumatic systems are employed. The best uses of pneumatics include assembly lines, material handling, robotics and automation, packaging and labeling equipment, auto manufacturing, food and beverage processing and medical equipment. The precise motion control, high power density and effective movement of loads provided by pneumatic systems make them the best choice for applications requiring precise and effective movement of goods and components. A preferred option for many industries, pneumatic systems are also secure to use and unlikely to pollute the environment as a result of spills or leaks.

When choosing pneumatics for machine applications, there are several factors to take into account. These considerations include the system's required force and speed, the operating environment, the noise level, energy efficiency, needed maintenance and cost. By carefully considering these factors, it is possible to select a pneumatic system that is best suited to the application's particular requirements while also maximizing performance and reducing operating costs.

For pneumatic systems to work properly in a machine application, several essential components are required: pneumatic actuators, valves, compressors, fittings, tubing and accessories. While valves control the flow of compressed air, pneumatic actuators use compressed air to move parts of a machine. The compressed air required to power the system is produced by compressors, and fittings and tubing link the various parts together. To ensure the system runs as efficiently as possible, accessories such as filters, regulators, lubricators and pressure gauges are used.

> A number of pneumatic grippers engage as the bottles move along the conveyor belt to stabilize them.

To fill and package bottles of different sizes, a bottling plant needs an effective system. A pneumatic system is used to address this need. The system uses a pneumatic cylinder as an actuator to move the bottles along the conveyor belt. To ensure even and steady movement, a pressure control valve controls the flow and pressure of compressed air into the cylinder. A variety of pneumatic fittings and tubing are also included in the system to link the parts together.

A number of pneumatic grippers engage as the bottles move along the conveyor belt to stabilize them while being filled. A system of directional control valves that control the grippers allows for precise positioning and gripping force. The grippers release after the bottles are filled, and they continue to move along the conveyor belt to the packaging station.

In a manufacturing setting, this system offers a reliable and effective method for filling and packaging bottles. The system can run quickly and reliably while also lowering maintenance and operating costs by utilizing pneumatic components. The system's modular construction also makes it simple to upgrade and modify it to suit changing plant requirements.

Pneumatic systems are adaptable and simple to upgrade or modify to meet changing needs. It is possible to guarantee optimum performance and efficiency while reducing operating costs by carefully choosing the right components and designing the system to meet the specific needs of the application. CD

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

Out of the gate

Can thermal-management solutions keep components in the cabinet, or is the momentum insurmountable?

by Mike Bacidore, editor in chief

FOR DECADES, AUTOMATION components were placed in a protective electrical cabinet and wired to the outside machinery. Planning and execution paid dividends, as these critical devices remained safe and secure inside the enclosure, which is still a viable option. Thermal-management solutions continue to evolve, keeping cabinets cool.

But technology marches on, and the need to provide shelter for components is sometimes outweighed by the need to provide processing availability on the machine. Ethernet connectivity and ingress protection (IP) call cadence for the parade of devices that strut their stuff outside the cabinet. IO-Link has allowed components to communicate, but what IP levels are necessary to mount components where they're needed?

Methods Machine Tools looks for an IP rating between IP65 and IP68, depending on the location of the device and the environment, says Kevin Davidson, operators manager at its Detroit Technical Center. "If the device is located outside of our machines, the lower IP rating is sufficient, but, as we get near the coolant areas of the equipment, the IP rating increases," he notes.

"The majority of indoor applications in factory automation require IP65 at a minimum," says Jeremy Andrews, product manager, industrial field connectivity, at Phoenix Contact, "to protect against any spills or splashes of liquid. The industry as a whole has trended toward IP67 as a standard, which really defines more of a worst-case scenario." The test for IP67 takes into account submersion in water for 30 minutes at 1 m in depth, which translates to a much larger issue than just a spill from a conveyor or rain water, explains Andrews.

"Machine-mount device protection considerations are much the same as those for control and electrical cabinets," says Bill Dehner, technical marketing engineer, AutomationDirect. "It depends on the environment and requirement for protection, classified as no protection, finger-safe, dust-tight, water-tight, or high-pressure/high-temperature washdown with cleaning solutions, to name several. For example, the protection needed for devices mounted on a machine outdoors in Tucson, Arizona, will differ from the protection required for a machine headed to Seattle. Ratings of IP68 and NEMA 4X are common for providing good resistance to dust, sand, water and washdown."

Area requirements play a role in determining ingress protection ratings, explains Perry Hudson, key account manager, Pepperl+Fuchs. "I would assume that, at a minimum, you should expect NEMA 12 or IP52," he says. "When considering these ratings, the two numbers refer to two different designations. The first number refers to protection against solid objects, while the second number refers to protection against water. In this case, the 5 indicates that the housing is protected against dust ingress, while the 2 indicates that the housing protects against direct sprays of water up to an angle of 15° from vertical."

A NEMA 12 or IP52 rating is considered the minimum for outdoor protection, Hudson notes. "Most control devices designed for external mounting carry a minimum rating of NEMA 6 or IP67 to accommodate a wide range of installations," he notes, explaining the first digit 6 designates full protection against dust, while the second digit 7 indicates that the housing is protected against the effects of temporary immersion in water between 15 cm and 1 m.

"Most frequently, customers are looking for components rated IP65 or IP67," says Sandro Quintero, business development for electric automation, Festo (Figure 1). "In both cases, the 6 shows solid-particle ingress protection that is dust-tight. The second integer refers to water ingress: 5 indicates protection against water jets, and 7 is temporary immersion in water. IP69K-rated parts are dust-tight and shielded from high temperature, high pressure water and steam ingress. The level of protection selected depends on the environment."

Figure 1: Properly rated valve terminals are capable of resistance to water ingress in a harsh washdown environment. (Source: Festo)

The level of ingress protection is application-dependent, declares Tom Jensen, head of system solutions and technology evangelist at Murr Elektronik. "Most technology companies will make one level of protection in line with their target markets," he explains. "Most providers settle around IP65—dust proof/drip proof, great for logistics, most packaging machines and assembly—and it is only time before subsequent generations of their products will target higher ratings for markets like food and pharma."

Another consideration is environmental ratings for humidity, shock and temperature. "These, along with IP ratings, will let you know if your components can work in cold rooms or move between environments, such as an automated fork truck moving cold products to a warm space," explains Jensen.

Figure 2: Valve terminals can be mounted in the open, close to the process valve actuators for faster response time. (Source: Avery Brewing)

Figure 3: Machine-mounted field devices with the proper environmental ratings can streamline installations, especially for I/O components like the IO-Link device, and they can also provide digital connectivity to many models of PLCs. (Source: AutomationDirect)

Technology-enabled

Ethernet and IO-Link communication protocols on compact modules designed in rugged casings with sufficient IP rating have allowed Methods Machine Tools to mount components on the machine where they're needed, rather than wiring them to the cabinet. "The selection and availability has grown and gives us more options in making the decision whether or not it's a valid choice to mount outside the panel," says Methods' Davidson.

"For decades, we have had fieldbus networks like DeviceNet, CANopen and Profibus," explains Festo's Quintero. "Now we have Ethernet-based fieldbuses, like EtherCAT, EtherNet/IP and Profinet. The Ethernet-based fieldbus networks provide higher speeds, greater data capacity, opportunities for the Industrial Internet of Things (IIoT) and a larger number of components with a wider physical distribution than before on the network." Quintero also agrees that IO-Link is a second important development with machine-mounted I/O designed specifically to control sensors and actuators (Figure 2).

Advancements in device connections allow components that were once confined to a control cabinet to be mounted directly to the machine they are controlling (Figure 3). "No matter how waterproof the body of a device is, it will fail in an outdoor environment if its connections are not sealed properly," warns AutomationDirect's Dehner. "A common solution is the use of M12 connectors, which provide temperature- and chemical-resistant sealed connections and can ensure protection up to IP69K." Machine-mount components are commonly available with connectorized fittings and overall ratings of IP68, NEMA 4X or greater, notes Dehner.

"While NEMA 6 or IP67 is the standard for most external control housings, the use of solid-state components allows for smaller devices that operate with less heat dissipation," explains Pepperl+Fuchs' Hudson. "This has led to the ability to offer higher enclosure protection ratings, and with such expanded where external components can be located on machinery."

Many external control devices are now available with the IP69K rating, which is higher than NEMA 6P, says Hudson. "As with IP67, the first digit means that the enclosures provide complete protection against dust ingress, but in addition, the second rating of 9K means that the housing provides protection against water in the event of direct stream jet cleaning. This level of protection allows the control components to be mounted virtually anywhere on a machine," he notes.

"Combined with advances in remote I/O communication, fieldbus systems, IO-Link and IIoT in general, machine builders and integrators are now able to place controls close to where they are needed, which also results in shorter installation time, easier maintenance and less production downtime," explains Hudson.

"The core technologies driving distributed components are capable fieldbus protocols," says Murr's Jensen. "IP20 cabinet technology for both programmable logic controllers (PLCs) and drives rely on physical backplane model; the drives must be close to their power supply and the I/O needs to be close to the PLC. Capable fieldbus options allow the backplane to be extended beyond the cabinet, and likewise IP65 power supplies allow power to be placed locally allowing I/O and motion components to work where they are needed."

This reopens the fieldbus wars—which fieldbus do I use to get happy customers? To get around this, distributed controllers and PLCs commonly include multiple configurable fieldbus options providing an outward-facing fieldbus to connect to the plant, based on acceptance, and an internal fieldbus that will control distributed components, based on performance,

and these are not mutually exclusive, explains Jensen.

"Another trend that is affecting distributed components is mobile applications and batteries," continues Jensen. "More motion components are being produced to use a 48-Vdc supply because this is commonly found in industrial mobile applications now. There is a huge added benefit in that 48 Vdc is much safer than the +700 Vdc supplies used for IP20-based motion control." IP54 48-Vdc drives and motors have been used in logistic centers for a long time and are finding their ways into the general automation market, he explains.

Figure 4: Electrical cabinets are designed to enclose and protect industrial controls for a variety of environmental challenges including dust and water. (Source: Rittal)

But what about the cabinet?

"Electrical cabinets are designed to enclose and protect industrial controls for a variety of environmental challenges including dust and water," says Troy Miesse, North America product management, Rittal North America (Figure 4). "These same cabinets are also vital for personnel safety in and around the end-use facility and are also a key element in helping to prevent arc-flash hazards. In many industries, the centralizing of industrial controls improves maintainability and can reduce service and system downtime. The cabinets also aid in executing the required lock-out-tag-out procedures required by OSHA."

Even with advancements in technology and processes, the industrial space still comes with some inherent hazards manufacturers must mitigate to help ensure the safety of their personnel, equipment and production facilities. "In many industries, including automotive, one safety hazard of high concern in working with electrically charged equipment like industrial control panels is arc flash," notes Miesse. "An arc-flash event is a major concern for any application that incorporates electrical equipment with a current; risks can be even greater in plants where production takes place on a 24/7 basis or in challenging deployments with extreme environmental conditions."

A large percentage of arc-flash incidents can be attributed to human error, but manufacturers can make some strategic choices in how they build their automation framework to help decrease the likelihood of arc flash, says Miesse. "The best way to avoid exposure to an arc flash is to prevent access," he advises. "Isolating the high-voltage controls equipment from areas where employees are working is key. With unparalleled configuration options and flexibility via interchangeable panels, plus easy mounting plate assembly and installation, modular enclosures allow for fast and simple customization based on space constraints or factory floor layout. This flexibility can help to decrease the potential of an electrical current getting caught between inadequate conductors because it allows manufacturers to house high-voltage and low-voltage equipment within the same enclosure system by utilizing partition walls and individualized compartments. The controls layout can be designed so that power will be isolated to a separate section, which can follow lock-out-tag-out protocols, have proper signage and limit entrance into the hazardous section. To further reduce the possibility of electrical fault, there are modular enclosures that incorporate safety features specifically engineered to help prevent arc flash.

In food-and-beverage processing, it is critical to maintain safety and sanitation standards, particularly following the introduction of the Food Safety Modernization Act (FSMA), which contained the most sweeping food-safety regulations in the past 70 years, says Miesse.

Figure 5: There are so many advantages of machine mounting that the trend of moving components out will continue. (Source: Festo)

"The COVID-19 pandemic also served to heighten consumer attention and focus on hygienic manufacturing processes," he notes. "This is where identifying industrial enclosures engineered specifically for food production environments is key in helping to maintain a safe and sanitary facility where uptime is maximized and the potential for contamination is significantly reduced."

Cabinet-based components still offer a centralized place for marshalling signals and mounting components, explains Phoenix Contact's Andrews. "It can still be a very effective solution for protecting those critical components and controlling access," he says. "Beyond that, it allows a wider selection of products and alternatives if IP ratings or enclosures are not a concern. It really comes down to a case-by-case basis as to whether moving some of the function to de-centralized, machine-mounted makes more sense based on the configuration."

Other than the field wiring involved, it is usually easier and less expensive to mount a system of components—especially traditional form factors, such as PLCs, relays, contactors, disconnects, fuses and fuse blocks, power distribution and terminal blocks, VFDs and communication equipment—into a control enclosure rather than mounting and wiring individually protected units externally, says AutomationDirect's Dehner. "The ability to monitor and control the environment within a control panel is a benefit for preserving the performance and prolonging the life of expensive components that reside inside," he explains.

"Control panels also provide a centralized location for electrical components, enable assembly of the control system separate from the machinery itself and simplify field installation," notes Dehner. "Properly assembled control panels organize wire runs between devices—no need to wire around machine components—provide protection from accidental impacts and can alleviate vibration issues with certain machines. Personnel often find work performed in a control panel, away from the machine, to be safer than working directly on the machine, and enclosures can be locked to provide an extra layer of security and access control to the components inside."

Murr's Jensen says there's only one advantage to keeping components in the cabinet—options. "There are types of products that are new to industrial automation and so have not been ingress-hardened for use outside of the cabinet," he explains. "For example, graphics processing units (GPUs) are now being used to power better vision systems on machines, but they are designed to let open air carry the generated heat away. They also have open connectors to allow the flexibility to be used with all sorts of CPUs and peripherals. Eventually products like these will have their scope narrowed and be defined enough to move them out of the cabinet as well, but for now a tiny cabinet will do."

Sometimes it can be simpler and cleaner to keep the logic in one place, advises Pepperl+Fuchs' Hudson. "With advances in industrial communications and Industry 4.0, IIoT devices allow for smaller control systems and therefore smaller control cabinets," he says. "Having all of the critical logic in one place, with only the remote I/O devices placed externally, can help with troubleshooting and machine updates. This can also help with maintenance and remote servicing, which is becoming more attractive due to labor shortages. In addition, lower-powered devices can cost less and are more readily available when supply chain shortages occur."

There are very minimum advantages in keeping the components in the cabinets, admits Dan Barrera, product manager, ctrlX Automation, Bosch Rexroth. "From the OEM to the end users, the industry is moving toward smaller electrical enclosures and more modular systems," he says, listing some advantages, including:

- reduced wiring and integration labor
- elimination of power losses in the cabinet
- more flexibility and scalability than traditional cabinet solutions
- cost-effectiveness.

Because not every electronic device has an IP rating, environmental protection is a key advantage of keeping components in the cabinet, explains Festo's Quintero. "Components, such as servo drives, may be too large for machine mounting. There are installation and wiring-time benefits of having components close together. OEMs mount PLCs, servo drives, variable frequency drives, power supplies and valve terminals in cabinets. Sometimes we see HMI devices in the cabinets. There are so many advantages of machine mounting that the trend of moving components out will continue (Figure 5). Control cabinets will continue to shrink. I believe it would thrill OEMs and end users to eliminate the control cabinet."

First and foremost, in-cabinet components protect from very harsh environments, agrees Methods' Davidson. "Additionally, covered components ensure high levels of safety and security when you may want to keep unauthorized people away from components that may have hazards or tampering," he explains. "That said, not all components offer the protection needed, and you want to have a central location for servicing the equipment." CD

Enclosures in challenging environments need mechanical and thermal design considerations

What have been the biggest improvements in enclosures over the past five years?

Michael Milam, vice president, industrial automation, **Rittal**: A recent innovation for industrial enclosures within the past year is sustainable, energy-efficient climate control for enclosures. Sustainability is high on the global agenda, alongside digitalization. Companies are faced with growing energy needs and the economic challenge of rising electricity prices. They need to identify and implement workable solutions that fulfill the requirements of political and environmental regulations while supporting their internal energy reduction goals and minimizing energy related costs.

Sustainability is becoming an increasingly important factor in customer purchasing decisions, and they seek companies that follow sustainable practices focused on reducing their carbon footprint.

Innovative climate control that uses active and passive cooling technology helps to achieve an average of 75% energy savings compared with conventional cooling units, which translates into a significantly reduced carbon footprint. This hybrid technology features two parallel cooling circuits that can operate independently or in tandem with each other depending on the temperature fluctuation. These two passive and active cooling circuits continuously adapt perfectly to the ambient conditions and with maximum efficiency. The result is a long service life for the installed components thanks to reduced temperature fluctuations (Figure 1).

Figure 1: Innovative climate control that uses active and passive cooling technology helps to achieve an average of 75% energy savings compared with conventional cooling units, which translates into a significantly reduced carbon footprint.

Steve Jopek, SEC operations manager, **Pepperl+Fuchs**: The design of the cabinets has not changed significantly; however, the changes in manufacturing processes have contributed to higher product quality. The increasing use of robotic or automated welding and machining processes has improved product consistency and allowed for greater customization.

Advanced manufacturing is enabling enhanced modularity in product offerings. Increasingly, more integration is required from

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vendors, as customers move to fewer suppliers offering more services.

Global customers are also using enclosures in applications that must meet a variety of international and country-specific standards, requiring more design and engineering considerations to achieve these certifications. This need has led suppliers to consider additional environmental, thermal and mechanical factors.

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

Steve Jopek, SEC operations manager, **Pepperl+Fuchs**: A few years ago, we had a rather interesting application in a hazardous area. It was a gasification plant with several cascading control enclosures connected to about 20 infrared cameras. The entire system was protected by a purging unit—this included both the main controls and all remote cameras. The cameras were installed in a spiral around the gasification column to continuously monitor temperature. The system architecture essentially consisted of several control cabinets located at ground level and connected to each camera via a 2-inch supply cable. The supply cable contained power and communication lines and allowed air to pass through to each camera for purging, where it was vented locally. Due to the purging requirements, each main cabinet was reinforced in terms of pressure and design to accommodate the large number of camera supply cables.

Michael Milam, vice president, industrial automation, **Rittal**: When it comes to innovative enclosure applications, electric-vehicle (EV) charging stations are a hot topic. The transition to electric vehicles, on the global stage but especially in the United States, has gained significant momentum during the past five years. And while electric-vehicle manufacturers like Tesla have grown beyond niche status, the big three automotive manufacturers in the United States (General Motors, Stellantis and Ford Motor) have not only gotten onboard with EVs, but some of them are actually leading a more mainstream charge toward the adoption of EVs on a mass scale.

For example, General Motors is in the midst of a production plan that will bring 20 EV models to market by 2025 en route to the goal of a complete lineup of EVs in the market by 2035. In addition, Ford Motor doubled down on its efforts in the EV space by splitting its production into two distinct divisions: EV production, Model e; and internal-combustion-engine production, Blue division. This split is designed to place increased emphasis on EV production to achieve Ford's goal of producing more than 2 million EVs annually by 2026.

With the influx of EVs on America's roadways, the automotive industry must also address the infrastructure required to power these vehicles. While the demand for EV charging stations, both current and future, is driven by consumer demand for increased EV production, it's also being advanced by federal initiatives and programs designed to curb the use of fossil fuels and reduce the nation's carbon footprint.

The Biden Administration's American Jobs Plan set the goal of building a robust national network of more than 500,000 EV charging stations to make powering electric vehicles simple, convenient and efficient. In addition, the plan aims to make America the standard bearer for electric powered vehicles by allocating $7.5 billion for EV charging infrastructure and more than $7 billion for the critical materials necessary for batteries, components and recycling; triggering investment commitments of more than $100 billion from private companies to make more EVs and component parts in America, create jobs for our autoworkers and strengthen our domestic supply chains; and providing a host of financial incentives for automakers to ensure that more than 50% of their sales are electric vehicles by 2030.

With these factors in play, EV-charging-station producers are now off to the races to design and engineer EV charging stations in the most efficient way possible. But global factors like supply chain disruption, scarcity of component parts and rising shipping costs have become important challenges for designers and engineers to overcome when specifying the products for station buildouts.

One solution to these challenges is partnering with an enclosure solution provider before you design your charging station, and a second solution is sourcing standardized enclosures and accessories that provide superior flexibility and capacity for customization. Both of these strategies help reduce costs, decrease

lead time and streamline the entire EV charging station design and engineering process (Figure 2).

Manufacturers and their partners that are on the cutting edge are forward-thinking and looking to future-proof their entire process from engineering and sourcing to manufacturing and operations. They have been able to grow their business and thrive, rather than just survive, over the past several challenging years and have set themselves up for success for years to come.

It starts with having the vision for end-to-end transparency and visibility into every step of the design and engineering process to optimize their automation and control manufacturing. With the power of Industry 4.0 and IIoT becoming more realized, original equipment manufacturers (OEMs) are moving to a complete digitalized production model that unifies everything from part procurement to product delivery.

Using powerful digital software programs and computer-aided-engineering (CAE) services for machine, plant and control-cabinet engineering, manufacturers and their partners are paving a simpler path in production and cutting the complexity. Panel builders and machine builders have streamlined workflows for installing controls components, electrical wiring and panel assembly, and system integrators can then reduce downtime and leverage greater degrees of customization.

The synchronization of each individual action along with detailed reporting, real-time updates and data/schematic storage and sharing help manufacturers overcome some of the more common stumbling blocks, such as increasing pricing pressures to be able to provide the right product at the right time within the right budget, especially as competition breeds a race to the bottom line; skilled labor shortages that can result in increases in scrapped materials and revisions/alterations; delivery pressures due to the rapidly changing and real-time

Figure 2: EV-charging-station producers are now off to the races to design and engineer EV charging stations in the most efficient way possible.

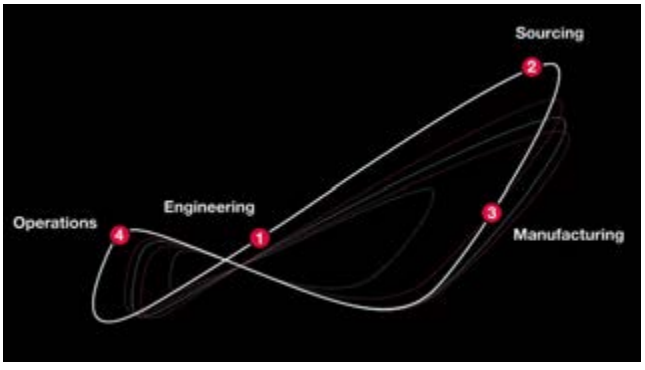


Figure 3: A completely digitalized design environment can simplify and streamline the automation and control manufacturing for any manufacturer and its partners.

demands that manufacturers must respond to; onboarding new employees, which is easier with data-driven, front-end engineering, taking the guesswork out of panel wiring and assembly; and inefficient workflows via antiquated data capture, storage and communication systems.

CAE software gives panel builders, machine builders and system integrators a powerful tool to not only address these challenges but avoid them altogether. In addition, manufacturers and their partners eliminate a host of manual tasks and processes to enhance product quality and precision while also reducing production costs.

With this solution, manufacturers and their partners can wave goodbye to working reactively in variant-rich environments; instead, they're able to work proactively to be more agile and nimble as new markets emerge, as existing markets diversify and change and as demands shift.

So, what truly creates automation in an industrial ecosystem is end-to-end, 360° visibility of everything from the sourcing of component parts to the integration of a finished panel and enclosure into existing production infrastructure. Manufacturers and their partners can have data-driven 3D-modeling capabilities to reduce production-line errors, account for potential variables in production or customization and help to seamlessly integrate workflows and communication of schematics relative to change orders or other real-time fluctuations or modifications based on original specifications.

The bottom line: cutting-edge innovation is a completely digitalized design environment that can simplify and streamline the automation and control manufacturing for any manufacturer and its partners (Figure 3).

Figure 4: In a Midwest automotive plant, model types were reduced from 21 down to nine across 160 units, which provided the potential to lower maintenance costs, repairs and inventory on hand, as well as giving insight into opportunities to reduce up to 80% of annual AC unit energy consumption.

When it comes to energy-efficient enclosure applications, here are two examples that we've seen where plants were able to reduce energy consumption and save cost by having a climate-control analysis of their plants.

In a Wisconsin food-and-beverage plant, the climate-control units were experiencing a 50% or more reduction in useful life. We provided a schedule for repairs and replacements, and it resulted in lowering the energy costs year-over-year, zero air-conditioning (AC) failures for one year, and decreased total costs and downtime.

In a Midwest automotive plant, we provided a plan to scale model types from 21 down to nine types across 160 units. This provided the potential to lower maintenance costs, repairs and inventory on hand; it gave them insight into opportunities to reduce up to 80% of annual AC unit energy consumption from more than 1 million kWh; and it resulted in energy cost savings of more than $500,000 in a 10-year period (Figure 4).

Keeping cabinets properly cool or warm is important. Can you explain the basics of thermal management within enclosures: why is it important, what causes temperature changes, and how is thermal management affected by extreme environments?

Steve Jopek, SEC operations manager, **Pepperl+Fuchs**: In control cabinets, every single electrical component, including cables and some mechanical devices contribute to heat dissipation into the cabinet environment. When planning, it is important to be aware of which devices contribute the most heat to the solution and strategically position these components along with cooling elements.

For small temperature rises, the use of a fan/vent or thermoelectric cooler may be sufficient to maintain the required ambient temperature. For larger heat loads, the use of heat exchangers or air-conditioning units is more suitable. Installing cabinets in hazardous areas limits the available technologies that can be used for cooling, but air conditioners designed for hazardous areas are available, and vortex coolers are also an excellent choice for areas with explosive gases or dust.

In colder environments, the challenge is often to keep electrical equipment at minimum storage temperatures when not in active use. Simple radiant heat-

ers are available in many different footprints and can help moderate cabinet temperatures to avoid extreme temperature fluctuations that can lead to condensation. External factors such as sun exposure, heating from adjacent equipment and the general ambient climate should be considered when selecting the appropriate heating or cooling system.

Michael Milam, vice president, industrial automation, **Rittal**: Heat is the enemy of extending the life of your electronics. Heat attacks your equipment from all sides: on the outside with extreme variations in ambient temperatures and inside with high thermal loads caused by the high density of components within the enclosure. The challenge is to manage temperatures consistently on both ends of the thermal spectrum in any environment. Industrial climate solutions lengthen the life of your components, optimize performance and reduce equipment failure. Time is money, and uptime ensures your operations are profitable.

The trend toward high equipment density in enclosures challenges the heat-removal process. Components, even those rated for high heat use, degrade when the heat load rises. Not only do enclosure temperatures rise from the waste heat generated inside, but also from external environmental factors.

Deployment of mission-critical enclosures into harsh environments increases the level of heat risk to the components inside. Your thermal control system must manage the impact of any factor that inhibits air flow and increases temperature.

Figure 5: Business success that is future-proofed will only be sustainable if it goes hand-in-hand with the complete digital integration of products, processes and the data they generate.

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

Michael Milam, vice president, industrial automation, **Rittal**: Software has evolved into a computer-aided-engineering platform comprised of high-performance solutions where all applications access the same functions and basic data, significantly improving the quality of projects. Eliminating the need for manual data comparisons also makes processes faster, placing the focus back on essential engineering tasks. This enables enclosure assembly to be quicker, easier and reproducible, and it increases accuracy. It is possible to link all enclosure assembly steps to create a highly efficient and digitally seamless automated process.

Panel-building and control-manufacturing cycles are now incredibly tight. Tight timelines and cost efficiency are the new norm, with increasingly complex systems having to be produced in ever shorter timeframes and at lower costs.

The quality of products and services used to be the key success factor, but having the most efficient process is now just as important as a high-quality product in gaining a vital edge over the competition. Control manufacturers that focus on the entire value chain—from planning and designing a product through to the placing of orders, production, delivery and service operations—will increase their throughput, boost their efficiency and achieve crucial competitive advantages. Combining CAE solutions and automation expertise optimizes and industrializes your panel-building and control-manufacturing processes.

Business success that is future-proofed will only be sustainable if it goes hand-in-hand with the complete digital integration of products, processes and the data they generate (Figure 5).

How do enclosures figure into any digital-twin platform being used by manufacturers?

Michael Milam, vice president, industrial automation, **Rittal**: Digitalization, standardization and automation are key success factors to be competitive in manufacturing. They also help prevent errors, boost productivity and save both time and money. The digital twin is at the heart of this workflow and is created during the engineering process to link all downstream process steps—from sourcing and manufacturing through to operations. It is an important basis for production and also for the subsequent maintenance and repair of finished products, ensuring consistent data retention throughout the entire lifecycle of an enclosure.

The digital twin is the basis for enhanced efficiency in the engineering process to plan and design the enclosure, creating the digital twin of the real-life product in the form of a consistent data model. Planning is based on high-quality 3D data that maps the enclosure and its accessories and is complemented by project-specific component and wiring information.

Data from the digital twin is also accessed during commercial processes of the sourcing phase and can be connected to the enterprise-resource-planning (ERP) system. Generated at a single central point, it is then used on a decentralized basis and can also be added to and edited. This makes media discontinuity a thing of the past. If data needs to be modified, this is done just once for the whole system, and the entire process adapts accordingly.

The data from the digital twin enables a great many processes to be automated during the manufacturing phase, too, including panel machining, cable fabrication and the cutting of cable ducts or support rails. This is made possible by using manufacturer-neutral standards for data and data communication, which improves interoperability between the various systems.

Finally, in the operations phase many data enclosures and components such as climate-control units are now equipped with sensors that generate a continuous flow of data. This data is used to offer service and energy-management activities as required during ongoing operation, which improves the availability and efficiency of machinery and equipment (Figure 6).

Figure 6: Many data enclosures and components such as climate-control units are now equipped with sensors that generate a continuous flow of data that is used to offer service and energy-management activities as required during ongoing operation.

What future innovations will impact enclosures in discrete-manufacturing operations?

Michael Milam, vice president, industrial automation, **Rittal**: Future innovations that will impact enclosures in discrete-manufacturing operations include the need to be more energy-efficient, climate-friendly and sustainable.

The harsh elements of outdoor applications create the need for corrosion protection coatings for the improvement of outdoor enclosures. Applications that use harsh chemicals for washdown need hygienic-design solutions for pushbuttons and hygienic-design freestanding enclosures in larger sizes. In industrial applications, processing power needs to be put at the edge—as close to where data is generated and used—to create reduced latency, more analytics and insights, open bandwidth, less storage costs and full support of real-time, data-heavy applications, such as the Internet of Things (IoT), fast network technologies, artificial intelligence and robotics.

Being able to digitally track all machine and plant documentation with a digital-circuit diagram that is always up-to-date and available from any device, anytime and anywhere accelerates processes along the entire value chain, saving time and money.

Enclosures and thermal-management products tend to have a difficult time surviving in harsh, corrosive environments. Which enclosure components are most susceptible to failure, and what can be done to address this, as well as lifetime performance?

Steve Jopek, SEC operations manager, **Pepperl+Fuchs**: : Enclosure design and construction quality are paramount for challenging environments. In most cabinets, the sealing and latching elements are the first points of failure, either due to damage or corrosion. It is important that the cabinet be thoroughly cleaned after construction to remove any residue of foreign materials or chemicals such as acids, solvents or primers. These chemicals can permeate hinges and latches and become noticeable later in the prod-

uct lifetime. For painted cabinets, it is important to properly prepare the surface for painting and then verify the application of the coating through thickness measurements and adhesion tests. For any type of cabinet, a regular inspection and maintenance program is essential, especially in rugged environments. A regular physical inspection of the cabinet allows potential problems to be proactively addressed before they become serious issues that require systems to be shut down.

Michael Milam, vice president, industrial automation, **Rittal**: Generated heat within an enclosure must be removed efficiently, or heat damage will occur. Controlling units and microprocessors age quickly under heat pressure. If left unchecked, small nuisance malfunctions may be the first sign of overheating and lead to a sudden catastrophic failure that can cost thousands in downtime costs and derail your project timeline.

Interior heat consequences include de-rated power performance; trip faults and fluctuations in circuits; mean time between failure (MTBF) decrease; component set point drift; intermittent or catastrophic system failure; voided component warranty; factory downtime; lost revenue; delayed shipments; customer dissatisfaction; and component replacement costs.

External heat factors include ambient temperature range and humidity; factory-equipment heat emissions, level of dust or dirt; exposure to direct or indirect solar radiation; exposure to rain, snow or wind; presence of corrosive or abrasive chemicals and oils; environment requiring high-pressure wash down; and amount of natural ventilation.

Internal heat sources include power supplies; controllers, drives and servos; processors and server racks; ac drives/inverters; microprocessor control gear; variable-frequency-drive (VFD) controllers; soft starters; transformers; programmable-logic-controller (PLC) systems; communication products; human-machine-interface (HMI) systems; and battery back-up systems.

Did you know that you can double the life of your electronics with every 18 °F/10 °C drop in temperature?

Advanced climate-control technology is your defense. A methodical approach ensures the internal temperature is stable and heat-related incidents or costly shutdowns are avoided. Look for high-efficiency climate-control units with an innovative thermal-management system that offers passive and active cooling technology as it can help you save up to 75% on energy costs. This innovative hybrid solution combines a compressor cooling unit with a heat pipe for passive cooling. The compressor only cuts in when passive cooling is no longer sufficient. The patented heat pipe dissipates heat from the enclosure as soon as the ambient temperature drops below the set point. In this way, high heat loads may be dissipated at lower ambient temperatures.

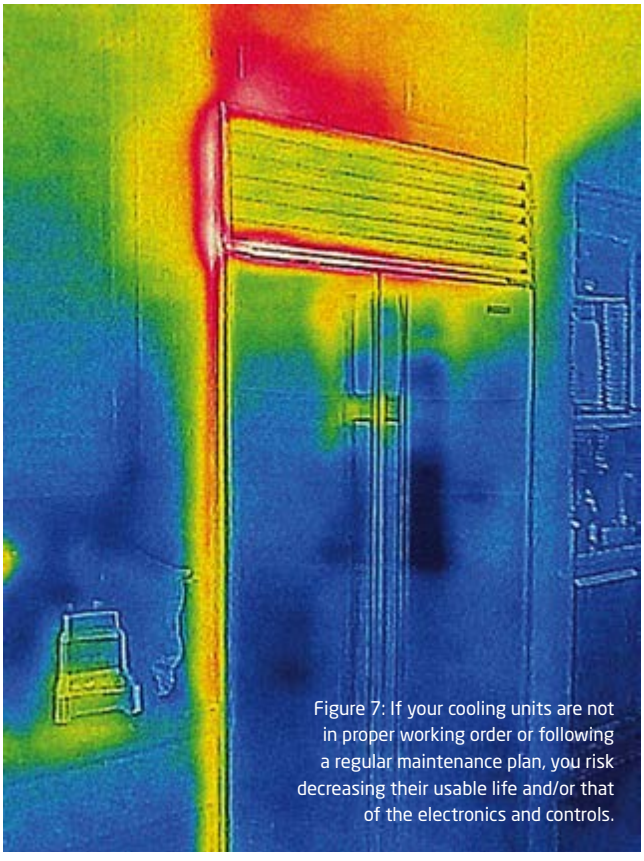


Figure 7: If your cooling units are not in proper working order or following a regular maintenance plan, you risk decreasing their usable life and/or that of the electronics and controls.

To prevent downtime and failures, a proper maintenance program should be top of mind. You need to consider if your system is being maintained regularly, working at optimal levels or driving up energy usage. Having a climate-control analysis done can assess your maintenance and energy needs across your plant. This would include identifying energy consumption and maintenance needs, equipping you to prevent potential risks prior to failure and reduce unplanned downtime or exponential costs. If your cooling units are not in proper working order or following a regular maintenance plan, you risk decreasing their usable life and/or that of the electronics and controls. So, the climate control analysis will help you identify solutions to reduce costs and energy usage and decrease your carbon footprint (Figure 7). CD

A brief history of industrial networks

How a simple cable helped to push the boundaries of what is possible in manufacturing

by Thomas Burke, CLPA

NETWORK TECHNOLOGIES HAVE been evolving and adapting since their inception, addressing the increasingly ambitious needs of the industrial automation landscape with value-adding standards, protocols and innovations. Now that digital manufacturing is becoming a must for companies to maintain and enhance their competitiveness, industrial communications networks are undergoing their latest renaissance.

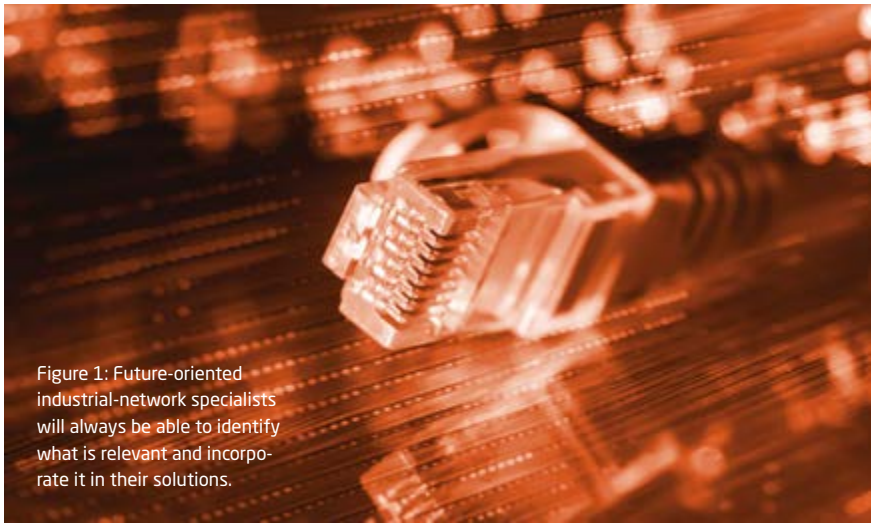


Figure 1: Future-oriented industrial-network specialists will always be able to identify what is relevant and incorporate it in their solutions.

In the late 1950s, the most future-oriented industrial players began to face a pressing and growing issue: how to have shop-floor devices send signals over distance and have them communicate with each other. The development of the first serial data transmission solutions, such as RS-232, in the 1960s gave life to industrial communications.

In effect, less than three decades later, the launch of controller area network (CAN) systems, fieldbus and Ethernet opened the door to more complex and interconnected communications. They enabled a greater number of sensors, controlled devices and other network nodes to share unprecedented volumes of data at high speed. In particular, Ethernet has risen to become the foundational network technology in nearly every industrial application, thanks to its ubiquitous nature.

The evolution of industrial communications technologies doesn't end here. As companies continue to advance their automation systems and shop floors, new needs have emerged. These can be summarized as the ability to add an ever-growing number of devices to the network and reliably handle an increasing volume of data traffic, as well as the opportunity to share data among components from different vendors.

To address these growing demands, capabilities have been added to industrial Ethernet and functionalities have been developed, offering higher speeds and bandwidth to enable more ambitious transmission rates, moving from 10 Mbps to 100 Mbps and, in some cases 1 Gbps. This has allowed automation-device makers to develop more competitive products and users to implement more data-driven operations.

It is possible to identify a clear trend toward open, vendor-neutral network technologies. Interoperable alternatives give system integrators and end users the ability to utilize the automation products that are best suited to address their specific requirements and intended applications. Even equipment vendors have been benefiting from this transition toward more open ecosystems, as they are able to support compatibility with a broader range of devices and, in some instances, establish synergistic collaborations with other industry players.

The drive toward smarter digital manufacturing practices is resulting in further adaptations and advances in what network technologies can and should offer. As companies look at setting up successful Industrial Internet of Things (IIoT) frameworks to improve productivity and efficiency, their primary focus is on reliable network solutions that can support high levels of speed, interconnectivity and flexibility. This can be achieved through enhanced interop-

erability, standardization and responsiveness, as offered by time-sensitive networking (TSN).

This latest extension to the capabilities of Ethernet provides extremely accurate, distributed time synchronization (IEEE 802.1 AS standards) as well as data traffic prioritization, scheduling and queuing functionalities (IEEE 802.1 Qbv standards). As a result, it is possible to meet the exacting requirements of control applications with extremely short cycle times, as well as transfer urgent data traffic first. In practice, these features make network infrastructures able to support even the most demanding motion-control systems, whose communications can be fast-tracked to meet deterministic requirements, while also transferring less urgent, best-effort data.

Ultimately, the use of a TSN-com-

TSN enables the IT-OT convergence

By Roy Kok, Mitsubishi Electric

The idea of creating smart factories is one whose time has come. The vision of the factory of tomorrow is one of machines, production lines, plants and entire supply chains that communicate with each other, in concert with information-technology (IT) systems, to enhance productivity, efficiency and flexibility.

The crucial step on the road to smarter manufacturing is convergence. That means gathering operational-technology (OT) data from machines and production lines and making it available to IT systems to analyze.

This OT-IT convergence allows manufacturers to make smarter decisions about equipment utilization to optimize performance and product quality, to streamline maintenance activities by predicting potential equipment failure ahead of time using condition-based monitoring and to schedule maintenance to minimize downtime.

The industrial Ethernet continues to evolve to support the terabytes of data that can be gathered from the multitude of disparate devices and networks in the OT world. The importance of connectivity and being able to gather data is the foundation for the digital transformation journey.

One of the key technologies for this evolution is time-sensitive networking (TSN), specifically developed to enhance standard Ethernet to provide the key functionality, performance and reliability necessary to achieve this network convergence enabling the digital transformation. The ability to run multiple industrial Ethernet protocols along with IT traffic on the same physical wire can be realized with TSN technology and, more important, allow critical control applications to run in parallel and seamlessly with generic configuration, programming and diagnostic applications.

More precisely, TSN technology addresses network functions at layer 2—the data-link layer—of the open systems interconnection (OSI) model for communications. Hence, it is only responsible for getting data from one place to another in a deterministic manner without looking at what the data is. What needs to be done with the data is typically handled at the higher-level layers that address application requirements. These are managed by specific protocols.

Since most industrial-Ethernet protocols were also created to make Ethernet deterministic, why do we need these and TSN? The answer is convergence. The combination of the required protocols with TSN creates a system that provides all the necessary application flexibility while allowing multiple traffic types to share the same network while being handled in a deterministic way.

Convergence provides the infrastructure to merge different traffic types onto a single network without affecting the determinism of critical control communications. This is fundamental to sharing operational insights and hence increasing process transparency across an enterprise, which can then be used to derive insights to optimize manufacturing facilities and entire organizations. TSN extends standard Ethernet allowing TSN-based devices to coexist with already installed Ethernet devices and networks.

There are four benefits to a converged network.

1. Control devices that have previously been isolated to separated control networks, a past requirement to ensure deterministic performance, can now be addressable and accessible to other applications for use in advanced analytics and digital twins.
2. Devices are becoming smarter and more complex, requiring management, which can now be accomplished over one connection, even while performing their primary functions.
3. Architectures are simplified through the use of one network, improving ease of design and deployment and reducing challenges in troubleshooting.
4. Costs are reduced through the simplification of architectures.

Successful standards are measured by the levels of adoption of their technology. The network of the future will be characterized by enhanced interconnectivity and openness in order to support seamless communications between an ever-expanding range of devices.

Roy Kok is senior partner and alliance specialist, e-F@ctory Alliance, at Mitsubishi Electric.

patible industrial Ethernet technology means that it is possible to create unified IIoT environments where any type of data can be shared, independent of the type or original domain, whether it's IT or OT, to generate business knowledge.

In addition, the latest developments around TSN technology, namely the creation of the TSN Industrial Automation Conformance Collaboration (TIACC), have been driving vendor-neutral, industry-wide conformance. Such initiatives are proactively addressing market demands for the coexistence of differing protocols within the same network, bringing vendors together to validate their TSN-compatible solutions for greater interoperability.

It would be naïve to think that, after these latest developments, industrial networking will reach the end of its evolutionary journey. In fact, we can already see the next generation of ambitions and innovations coming to the fore, such as wireless communications connecting shop floors, enterprises and entire supply chains. Other trends seem to hint at simplified networking requirements, as promoted by single-pair Ethernet (SPE) and power over Ethernet (PoE) advocates.

There is also always room for the unexpected to influence how industrial networking will continue to develop, as new user requirements and applications may not manifest until after the digital transformation of business matures further. Ultimately, which new communications technologies will be released to market and take root will be dictated by what industry players will require to maintain their competitiveness. What we do know for sure though is that experienced, future-oriented industrial network specialists will be able to identify what is relevant and incorporate them into their solutions quickly to benefit automation vendors, machine builders and end users (Figure 1). CD

Thomas Burke is global strategic advisor at the CC-Link Partner Association (CLPA). Contact him at tom.burke@cclinkamerica.org.

How to power AMRs, AGVs in clean rooms

Is inductive charging a silver bullet for meeting requirements?

by Mike Bacidore, editor in chief

THE MARKETS FOR automated guided vehicles (AGVs) and autonomous mobile robots (AMRs) continue to grow. In semiconductor production and pharmaceuticals, for example, robots automate material transport in sensitive production environments, specifically those using clean rooms to control contamination. But that mobile equipment needs to be powered.

The same solution will work for AGVs and AMRs, explains Tommy Hessler, CEO of America in Motion (AIM). "In general, AMRs are smaller and therefore lighter, but it just means that the sizing of the components will need to be a bit different," he notes. "For clean rooms, there are some limits as to what can be done—for example, the wheels and the small amount of dust they generate as they roll or wear can be a problem for higher classifications."

Because of the introduction of particles during mechanical power supply, AGV and AMR systems are typically fitted with inductive charging systems.

The charging connection is a big problem, so inductive charging is the best alternative, suggests Hessler. "It is costly to install the coil wires in the floor, and it makes the free-ranging AGV or AMR not so free as it needs to drive where the inductive coils are for a lot of the time to receive enough charge," he explains. "However, it is contact-free and generates no dust pollution for a clean-room application." The navigation also needs to be looked at, as light detection and ranging (LiDAR) is often used for navigation. "These have a motor in them, and some are not very sealed, so there is a potential for dust to be generated by the rotating laser mirror; however, a good unit should be completely sealed and present no issues," says Hessler, who also spoke with partner publication Machine Design about the Industrial Internet of Things (IIoT) in 2020.

The International Organization for Standardization (ISO) published a revised clean-room standard in 2016. Automotive manufacturing, food production, aerospace and pharmaceuticals utilize controlled and classified clean rooms—zones with highly controlled contaminants that can affect processes and products.

ISO 14644-1:2015, Clean rooms and associated controlled environments—Part 1: Classification of air cleanliness by particle concentration; and ISO 14644-2:2015, Clean rooms and associated controlled environments—Part 2: Monitoring to provide evidence of cleanroom performance related to air cleanliness by particle concentration, are the industry standards used to monitor and classify clean rooms, which enable a large number of high-technology industries.

Recommendations from Dr. Udo Gommel, head of the Ultraclean Technology and Micromanufacturing department at Fraunhofer IPA can help to maintain regulated cleanliness:

- Only materials and components suitable for clean rooms should be used.
- Only low-emission lubricants should be used.
- If possible, tribologically optimized material combinations should be used.
- Surfaces must be easy to clean.
- The surfaces used should have the lowest possible outgassing behavior.
- The undercuts of material combinations/surfaces should be as small as possible.
- Good chemical resistance should be maintained.
- The materials used should have low metabolic capacity.

For energy, AIM's Hessler recommends a sealed battery. "And it needs to be oversized," he suggests. "The depth of discharge (DOD) should not be 100%, but more like 20% to 40%. This means that the battery operates in the range of 60% to 80% full or 40% to 80% full." In general, absorbent-glass-mat (AGM) lead acid batteries that are sealed and have very low internal resistance are good for the 20% DOD, says Hessler, and lithium ion/ferrite-style batteries are good for the 40% DOD setting.

"I am not aware of any issues or special concerns that actually come into play for powering AGVs/AMRs in a clean-room environment," says Alex Bonaire, product manager—robotics, Omron Automation. "The only thing I'd perhaps say is that, if an AMR/AGV is going to have its charger located inside of a clean-room environment, it is possible that a robot that charges with physical electrical contact could create contamination when engaging with the charging paddles so that engagement

Figure 1: Contacts can wear off and need to be replaced after a certain number of docking cycles.
(Source: Wiferion)

would need to be evaluated, although it is likely very low-risk because those charging contacts are located very low to the floor. If the environment is so sensitive that that could be an issue, then it is recommended that the charger for the AMR be located outside of the clean-room environment or a wireless charger is utilized within the clean-room environment."

The worker shortage has impacted manufacturers' needs to automate transport processes, and AGVs and AMRs have seen increased implementations. Transporting resources in clean-room environments requires special considerations as any contamination can lead to downtime. Particles floating in the air that pollute a batch of medicines or damage highly sensitive semiconductor substrates affect the bottom line. For those sensitive environments, components on automated-transport vehicles, including the power supply, should be designed with cleanliness in mind.

Clean-room users of AGVs and AMRs can turn to inductive point charging systems. Transfer of power is contactless, following the principle of magnetic induction. As soon as a vehicle has reached the loading pad of an inductive point charging unit, the charging process starts automatically at full power within a second. Battery fast-charging systems are encapsulated and can operate without mechanical components, minimizing particle generation from charging.

"Clean-room-rated AGVs and AMRs are very niche products, often due to the sensitive nature of the applications and materials handled and the market size," explains David Roach, senior product manager, global products and solutions, mobile and robotic solutions, Dematic. "With that in mind, inductive charging is the best way to charge AGVs and AMRs within the clean-room environment. Inductive charging is wireless, or cordless, charging that is meant to transfer power without the need for mechanical contact using electromagnetic induction. The AGV or AMR only needs to be positioned near a charging point—docking station or inductive pad—without extreme precision for the power transfer to occur. Indifferent from clean-room classification, this method eliminates residue created by physical contactors or electrical arcs produced by a vehicle misalignment or docking using mechanical contact or controls."

In addition, robots' batteries can be charged at machines via in-process charging with the quantity of energy they need for their transport tasks, allowing continuous 24/7 operation.

Charging pads can be installed completely flush with the floor, at the side or like a tile, so as to avoid impeding the flow of work and tripping risk. Charging points can be relocated to reduce the likelihood of broken or dirty contacts.

"In clean-room environments, the benefit of wireless charging is that it is contact-free and therefore doesn't generate any dust and particles from metal friction," explains Matthieu Ebert, vice president of Wiferion North America. "Charging contacts work with two open and exposed metal surfaces, which are mated accordingly to act as an electrical contact and connect the vehicle to a charger. The quality of the electrical connection between those two components depends on the degree of oxidation of the surfaces. If the metal surface is not clean enough or has a too-thick oxide layer, this results in a bad electrical contact, leading to hot spots, and, in the worst case, to meltdown of the connection causing a serious safety risk."

To prevent oxide from building and achieve good electrical contact, one established method is to rub the two contacts about an inch under a contact pressure to achieve self-cleaning, warns Ebert. "This is the part of the process where metal dust is generated," he says. "This metal dust is often a mix of copper and brass and can be very harmful to different types of production processes. Another downside of this self-cleaning approach is that the contacts wear off and need to be replaced after a certain number of docking cycles (Figure 1)."

Ebert sees little difference in charging-technology requirements for AGVs or AMRs. "An AGV is very likely guided optically or with a magnetic band and therefore has a better positioning tolerance than an AMR, which uses free navigation," he explains. "Wireless charging has a way bigger positioning tolerance acceptance than charging contacts and can therefore facilitate deployment and the docking processes." CD

SHARC puts the bite in data connectivity

INDUSTRIAL NECESSITY IS often the mother of development. The need to capture a given data point from a machine with a sensor drove Chris Misztur, founder, and Chris Eudy, product owner, at Mr. IIoT, to create the Simple Hardware Adapter for Remote Communications (SHARC). "We could integrate with the machine, if it was capable, but that became too costly and cumbersome for a large portion of our customers," explains Eudy. "For legacy machines, we would add a sensor and then numerous pieces of hardware and software to capture the data into actionable information. The question we asked ourselves was, 'Why isn't it simpler to just add a sensor and get its data?'"

For more information
Browse to www.mriiot.com.

There was a need, as there still is now, to extract data from processes that might be lacking measurement instrumentation, says Misztur. "As we began instrumenting different processes using off-the-shelf hardware, we found that there is still much complexity and cost involved in wiring up the sensors, installing gateways, powering up the hardware, dealing with multiple protocols and data transformations, and then the need to maintain it all. All of this is just to get the data out of OT and into IT's hands. We thought to ourselves that this will never democratize data access, and our customers won't be able to truly own these solutions."

Misztur and Eudy then identified the recurring themes they saw across the industry:

1. Lack of skills and experience across OT and IT. Internal cross-functional teams that do exist still lack the experience—meaning that mistakes will be made along the way, lessons will be learned, architectures will be thrown away or worse.
2. Missing or misaligned digital strategy across business units within an organization. This leads to tactics and execution that leave IT succumbing to non-standard implementations.
3. Objections to becoming a digital company. This partially goes back to the first two points, where the speed of pilots and momentum suffer as a result.

The next step was to enable anyone, literally anyone, within a company to participate in a digital strategy. And so SHARC was born. "Anyone who can turn a screwdriver has the ability to grab two SHARCs, install them and start collecting data they were always curious about," explains Misztur. "Why two SHARCs? Because that is all it takes to derive everyone's favorite and most-hated overall-equipment-effectiveness (OEE) metric. Quickly the internal conversations become more about which key performance indicators (KPIs) are truly relevant to our business than waiting for dreaded OEE year-long implementations."

SHARC turns any sensor that outputs a discrete (PNP, NPN) signal or analog 0-10 V or 4-20 mA and can run on 24 Vdc into a fountain of information. The beauty of the SHARC lies in its connectivity and user-friendliness. Simply plug power over Ethernet (PoE) 48 Vdc in one end and plug the sensor in the other. Connect to the SHARC over Bluetooth through your computer browser or through the mobile app. You can use the dynamic-host-configuration-protocol (DHCP) address or set it to static. Configure the MQTT broker, reboot the SHARC and subscribe to the MQTT topic.

"The beauty of the SHARC is that you do not have to be an engineer," explains Misztur. "If you have ever used a USB-A to USB-C adapter, then you are qualified to install the SHARC."

The lightweight message-queuing-telemetry-transport (MQTT) protocol and publish/subscribe model accommodate reliable message delivery, making integration between systems seamless and scalable. "MQTT is an effective means to an end for transporting data points from the edge, as well as commanding SHARC's configuration over wired or wireless Ethernet," explains Misztur. CD

Real heavy connections

Industrial networking keeps the data flowing

Modular communication

The Red Lion DA50A automation controller with modular communication is designed to make designing for compatibility with rapidly evolving communications standards as easy as replacing a field-installable sled. With networking capabilities, support for more than 300 industrial drivers and Industrial-Internet-of-Things (IIoT) cloud connectors, the DA50A is designed to communicate with most any brand of PLC or other equipment and securely transmit data to wherever it is required. Automation capabilities include built-in data logging, virtual human-machine interface (HMI) and web server. Powered by Crimson 3.2, it is designed to simplify communications and automation capabilities configurations. With the onboard I/O, you can enable local monitoring and control capabilities, and be notified if the status changes.

RS / us.rs-online.com

Cat. 6a Ethernet Cables

Cat. 6a industrial Ethernet cables from Murrelektronik are shielded cables that include an M12 X-coded connection on one end and an RJ45 connection on the other. The X-coded designation is commonly used with industrial vision systems. These high-flex industrial Ethernet cables are available in lengths up to 5 m with transmission speed capability up to 10 Gbps. These cables have a thermoplastic elastomer (TPE) jacket that is flame-retardant and chemical resistant. The Murrelektronik Cat. 6a Ethernet cables come with a one-year warranty.

AutomationDirect / www.automationdirect.com

Harsh-environment Ethernet switches

Phoenix Contact expanded its line of unmanaged Ethernet switches. The FL Switch 1000 family includes Gigabit fiber variants with an extended temperature range, as well as a 16-port gigabit switch and the 24-port Fast Ethernet switch in a newly developed 65-mm housing. The 1000 series switches support Automation Protocol Prioritization (APP). This feature automatically sends mission-critical data packets from EtherNet/IP, Profinet and other industrial protocols through the network at a higher priority than standard traffic. The robust design has a high immunity to surge and ESD, and the switches can operate in a wide temperature range (-40 to +75 °C).

Phoenix Contact / www.phoenixcontact.com

Dual SIM industrial router

Weidmüller's dual SIM industrial router with integrated VPN technology is designed for secure remote access to components and systems in remote networks. Equipped with WLAN and 4G/LTE modules, two RJ45 Ethernet ports and a serial interface, Weidmüller security routers are designed to ensure maximum connectivity, and their compact dimensions save space in the control cabinet. LTE Cat.4 with up to 150 Mbps downlink and 50 Mbps uplink data rates capability.

Digi-Key Electronics / www.digikey.com

Safety connection

Safety PLC, Safe I/O modules and Safety PLC programming software is part of a full system solution designed by KEB. All safety products are TÜV Rheinland certified to IEC 61508 SIL3 and EN/ISO 13849-1 PL e. KEB's Safety PLC is a Fail Safe over EtherCAT (FSoE) master that is used in tandem with the machine PLC to execute and monitor the safety functions of the machinery. The Safety PLC connects with other FSoE slave modules like Safe I/O and servo drives with Safe Motion functionality. Each FSoE slave device has four safe inputs, two safe outputs and four OSSD outputs. One FSoE master can control up to 65,535 slave devices.

KEB America / www.kebamerica.com

Industrial computer with IEC 62443-4-2 host-device certification

Moxa's industrial Linux 3 (MIL3) platform has enabled a host device to attain ISA/IEC 62442-4-2 certification—the UC-8200 Series computer. IEC 62443-4-2 certification ensures that Moxa UC-8200 computers incorporate a suite of secure-by-design hardware and software features. Built around a Cortex-A7 dual-core processor and offering flexible interfacing options, Moxa UC-8200 Series embedded computers can serve as gateways for data acquisition and processing at field sites, as well as communications platforms for many other large-scale deployments. Powered by an Armv7 Cortex-A7 dual-core 1 GHz processor, it has Dual SIM slots and a microSD socket, two auto-sensing 10/100/1000 Mbps Ethernet ports, one CAN port, and a DIN-rail mountable IP30 metal housing with a temperature range of -40 °C to 85° C. The UC-8200 Series computer incorporates a one-time programmable (OTP) fuse and Trusted Platform Module (TPM) 2.0 technology to establish a hardware-based chain of trust that safeguards the Secure Boot process and software updates.

Moxa / www.moxa.com

IO-Link

ICE2 (EtherNet/IP) and ICE3 (Profinet) series IO-Link masters from Pepperl+Fuchs Comtrol provide versatile industrial IO-Link masters supporting the industry's protocols, including EtherNet/IP, Profinet, and Modbus TCP. The modules come with a full web-based configuration approach with no need for any additional software or a higher-level PLC. Together with an integrated OPC-UA interface, the IO-Link masters can be used for cloud-based and hybrid systems.

Pepperl+Fuchs / www.pepperl-fuchs.com/usa/en/

Gigabit Ethernet switches

N-Tron Series NT5000 Gigabit Managed Layer 2 Ethernet switches are designed to improve network security and reliability for industrial organizations of all sizes and environments. The NT5000 is designed to maximize operating performance and system uptime through seamless integration, advanced management and diagnostic capabilities, network redundancy and layered security. Designed and assembled in the United States, NT5000 switches are available in six-, eight-, 10-, 16- and 18-port configurations in all copper or a mix of copper and fiber options.

Red Lion / www.redlion.net

Touch-panel computer

The Advantech TPC-115W touch-panel computer is equipped with an NXP Cortex-A53 i.MX 8M Mini quad-core processor, TFT LCD display, multi-touch glass sensor, 2 GB of DDR4 RAM, and 16 GB of eMMC storage. To ensure stable operation in harsh industrial environments, it supports a wide operating temperature range (-20 to 60 °C /-4 to 140 °F) and Panel/VESA mounting and features an IP66-rated front panel that protects against water and dust ingress.

Newark / www.newark.com

Terminal blocks

The Dinkle P-LUP 0274/0275 series PCB terminal block is designed to provide tool-free connection for all conductors. The 0274/0275 adapts a tool-free lever to allow the conductors to be installed and released by using the lever. It maintains its conventional push-in connection so any solid conductor or ferruled stranded conductor can be inserted without using the lever. The 0274/0275 is designed to operate within narrow space with 90° and 45° options available. It is stranded-wire compatible and has colors identification.

Dinkle / www.dinkle.com

Managed switches

The Xelity 10 TX IP67 managed switch from Murrelektronik

is designed to offer possibilities for decentralized, cabinet-free data management. With up to 10 Gigabit ports in a robust housing, the Xelity 10 TX IP67 is part of a line of switches designed for heavy traffic. The 10-port switches are available in three models: 10 x 100 Mbit/s, 10 x 1000 Mbit/s, and 2 x 1000 Mbit/s + 8 x 100 Mbit/s. The Xelity 10 TX IP67 is designed to replace classic control cabinet solutions with IP67 components in the field. Its L-coded M12 power connectors (four- or five-pin) ensure fast connections, as well as the ability to daisy-chain several devices as long as the combined power usage does not exceed 16 A. Each model uses the same drilling pattern and power connector connection.

Murrelektronik / www.murrinc.com

Ethernet switches for UL 508A control panels

UL 508A Standard covers industrial control panels intended for general industrial use, operating from a voltage of 1,000 V or less. This equipment is intended for installation in ordinary

locations, in accordance with the National Electrical Code, ANSI/NFPA 70, where the ambient temperature does not exceed 40 °C (104 °F). The EISW series consists of five-, eight- and 16-port 10/100 Mbps Ethernet switches that can be DIN-rail mounted in control panels and powered from a NEC Class 2 limited energy power source. The EISW switches are UL-listed as Information and Communication Technology Equipment under safety standard UL 62368-1 and can be installed in a UL 508A panels without invalidating the control panel listing. The EISW series supports plug-and-play operation and requires no configuration.

Contemporary Control Systems / www.ccontrols.com

Microprocessors

The RZ/Five-RISC-V microprocessor (MPU) from Renesas Electronics expands upon Renesas' Arm CPU core–based MPUs. The RZ/Five a general-purpose MPU based on an Andes AX45MP utilizing a RISC-V CPU instruction set architecture (ISA. The Renesas RZ/Five-RISC-V microprocessor, available from Mouser Electronics, is a single-core, 64-bit processor with a maximum operating frequency of 1 GHz. The MPU has 128 KB of internal SRAM with ECC and 16-bit DDR4-1600 or DDR3L-1333 memory interfaces with in-line ECC supporting up to 4 GB of RAM. Peripheral functions include support for multiple interfaces, including two Gigabit Ethernet MAC channels, two USB 2.0 channels and two serial CAN/CAN-FD interfaces. Additional features of the RZ/Five include a two-channel, 12-bit ADC, thermal sensor, four I2C interfaces, three SPI interfaces and GPIOs. For security support, the MPU also has 1 Kbit of OTP memory, secure boot, a crypto engine and secure JTAG. For additional design flexibility, the peripheral functions and package of the RZ/Five are pin-compatible with those of the Arm core-based RZ/G2UL, allowing for easy reuse of existing and proven designs.

Mouser Electronics / www.mouser.com

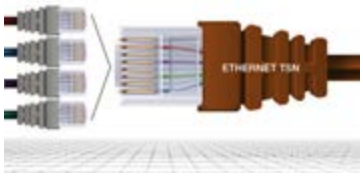
360° distribution box

The icotek Distribution Box is designed to be completely splittable and enable 360° cable entry and cable routing. The 1 to 15 mm diameter cables with and without plugs are routed, sealed and, at the same time, relieved of strain in accordance with DIN EN 62444. Using multiple or single grommets (icotek KT-DT), up to a maximum of 48 cables can be routed. The cables can be distributed 360° from the central point in almost any desired direction. The Distribution Box is designed to fit standard metric cut-outs and is secured with an included lock nut. Thanks to the screwable cover and the use of slotted cable grommets, subsequent retrofitting and service work should be possible at any time without any problems. The 360° cable entry can be combined in many ways with the KT grommet system and the hybrid IMAS-Connect adapter system from icotek. Certifications such as EcoLab, HL3 EN 45542-2 and RoHS have been granted. The rating is IP54, and the permitted temperature range is between -40 °C and +140 °C. The Distribution Box is made of polyamide and is halogen and silicone-free.

Icotek / www.icotek.com

Open industrial network technology

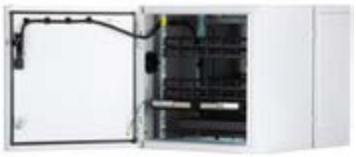
CC-Link IE TSN is an open industrial Ethernet technology that combines gigabit bandwidth and time-sensitive networking (TSN) to support data-driven and convergent smart manufacturing applications. Automation vendors, machine builders and system integrators can connect thousands of devices from the IT and OT domains while delivering highly synchronized cyclic communications with accuracies within ±1 µs. CC-Link IE TSN also supports any topology, as well as an unlimited number of branches. There are hundreds of automation components from multiple vendors that are compatible with the technology and a broad development ecosystem.



CC-Link Partner Association (CLPA) / am.cc-link.org

Pre-configured IDF with G5 access control

The Panduit pre-configured IDF with SmartZone G5 Access Control is designed and engineered to deploy and protect 19-inch rack-mount switches on the factory floor in an industrial network. Consistent design, equipment placement and cable management are designed to minimize engineering and installation time. Access control and power distribution capabilities are designed to protect IT equipment. With UL Type 4/12 and IP55 ratings, the enclosures are designed to provide reliability and performance, as an integral component of the end-to-end solution for industrial networks and allow deployment of cabling subsystem TIA-1005.



Panduit / www.panduit.com

LinkIQ pinpoints industrial Ethernet failures

Fluke Networks' LinkIQ-IE Cable+Network industrial Ethernet tester is designed to troubleshoot network cabling. By combining Fluke Networks' cable measurement technology and basic tests for industrial Ethernet switches, LinkIQ-IE is designed to speed and simplify the discovery of network failures in a touch screen interface. The LinkIQ-IE is based on a single-test approach that provides the appropriate measurements based on what's at the other end of the cable. For an open cable, it shows the length and pairing. If it's terminated with the supplied remote, the test result shows the maximum data rate the cable can support—up to 10 Gb/s. If the cable is connected to a switch port, LinkIQ-IE shows the name of the switch plus the port name, speed and duplex. If PoE is advertised, it will display the power and class (up to 90 W or Class 8) and then load the switch to verify the power can be delivered. The LinkIQ-IE features an RJ45 type connector and includes cabling and adapters simplifying connection to M12-D, M12-X, and M8-D connectors commonly used in industrial applications.

Fluke / www.flukenetworks.com

Ethernet switches

The IDEC SX5E series of Ethernet switches is a compact, five-port 10/100 Mbps unmanaged industrial Ethernet switch. They offer an operating voltage range of 9-60 Vdc and 18-30 Vac with an operating temperature of –40 to +75 °C (–40 to +167 °F). These switches are designed for installation in Class I, Div. 2 hazardous locations and for industrial applications in harsh environmental conditions requiring IP30 rating.

Galco / www.galco.com

Unmanaged switches

Unmanaged switches require no configuration and are nevertheless adaptable. They use basic standardized protocols, such as autonegotiation, autocrossing and flow control, allowing them to adapt automatically to widely varying transmission speeds or connector assignments. All switches support the use of twisted-pair cabling with RJ45 interface or fiberoptic cable based on the interfaces specified in IEEE 802.3. Weidmuller offers different versions with different features. In addition to the unmanaged switches of the EcoLine, BasicLine and ValueLine, Weidmuller offers Power over Ethernet variants within all lines.

Weidmuller / www.weidmuller.com

How linear motion affects machine footprint

A CONTROL DESIGN *reader writes:* Our custom packaging operation has flirted with the implementation of linear-motion technology to help reduce cycle times, but the cost and size always seem out of reach for us. I keep hearing that's changing. Are there affordable choices for smaller applications, specifically for portals and palletizing? Throughput, precision and quality are important. Are there tradeoffs or limits to those gains in cycle times? Where else might we consider implementing linear motion? Are the linear components available with smart capabilities to help us with real-time performance optimization and predictive analytics? We're also concerned about space, which is at a premium in our facility. Will linear-motion applications have any effect on the machinery footprint?

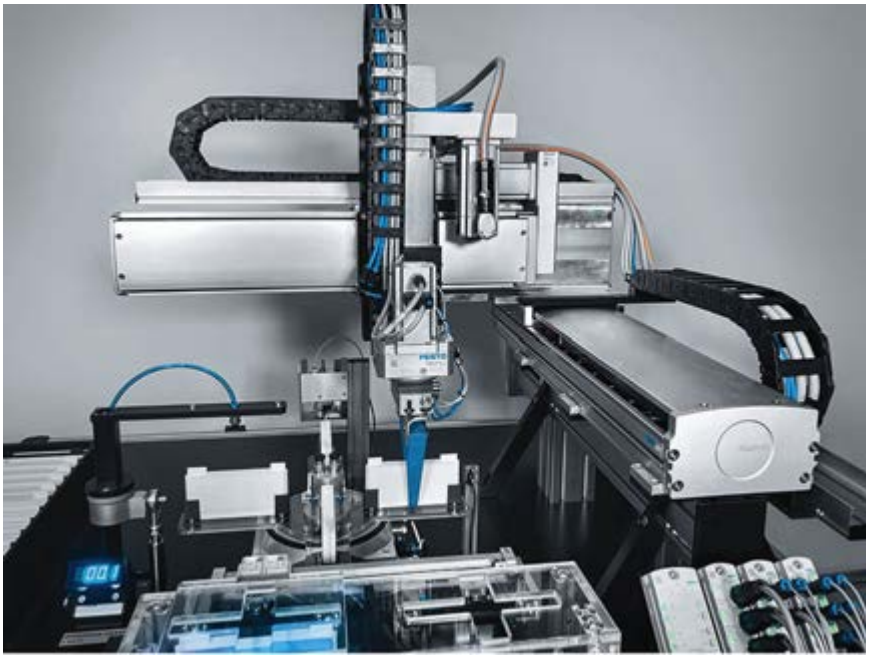


Figure 1: Linear-motion control and Cartesian gantry systems are more affordable because of economies of scale and advancing technology. (SOURCE: FESTO)

Answers

Get in line with the times

I'm thrilled that you inquired about linear systems because electric motion has come so far so fast not everyone knows the ins and outs.

A general definition of linear motion is an electromechanical actuator with a toothed belt or ball-screw drive train connected to a servo or stepper motor with an encoder. This electromechanical system is controlled by a drive and motion controller or programmable logic controller (PLC). Linear-motion control and Cartesian gantry systems are certainly more affordable because of economies of scale and advancing technology (Figure 1). These solutions offer a host of advantages.

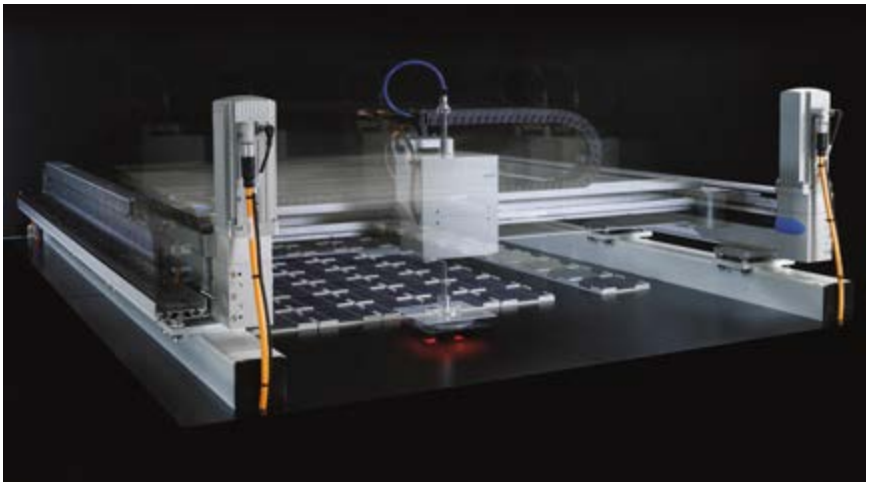


Figure 2: System size depends on such factors as payload, acceleration, speed, torque, throughput and cycle rate. As these factors increase, the size increases and as they become lower, the size decreases. (SOURCE: FESTO)

Figure 3: Beyond palletizing and portal applications, some of the major areas to use linear motion include 90° conveyor transfer, extending nose conveyors, case erecting, major and minor flap closing, overpressure for gluing, picking and placing in top or side load case applications and stretch wrapping. (SOURCE: FESTO)

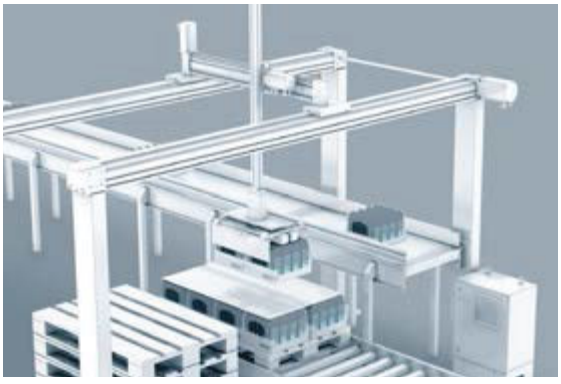


Figure 4: A Cartesian robot offers a compact work envelope is 100% accurate within the work envelope. (SOURCE: FESTO)

If your application will benefit from increased dynamics, throughput, flexibility and fine motion control, then an electromechanical solution may be the optimum one. The most affordable electromechanical solutions use low-voltage steppers and servos paired with linear actuators.

System size depends on such factors as payload, acceleration, speed, torque, throughput and cycle rate. As these factors increase, the size increases and as they become lower, the size decreases (Figure 2).

Throughput can increase by moving to a toothed-belt mechanical actuator rather than a ball screw. Velocity and acceleration are significantly higher with a toothed-belt mechanism. There will be some loss of precision due to play in the system. Determining the tradeoff between throughput, velocity, acceleration, quality and precision in toothed-belt and ball-screw actuators are made clear during the specification phase of the project.

By increasing cycle rates, there is the need for more frequent preventive-maintenance measures, such as replacing a tooth belt or greasing bearings. As throughput increases, service life is derated because moments and forces are higher, leading to increased wear on the mechanical axis. The faster the system moves the payload, the larger the servo motor, drive and mechanical axis needs to be. This raises the cost.

We advise customers to thoroughly understand the key application considerations of force, load, speed, acceleration, throughput, longevity and cycle times and then size appropriately.

Linear motion has come a long way in the past 10 years in terms of mechanics, programming and assembly. Once the engineer has identified the linear system for the application, choosing one over the other—robot or linear motion—becomes clearer.

Beyond palletizing and portal applications, some of the major areas to use linear motion include 90° conveyor transfer, extending nose conveyors, case erecting, major and minor flap closing, overpressure for gluing, picking and placing in top or side load case applications and stretch wrapping (Figure 3).

Interestingly, companies like to apply six-axis robots because of the robot's flexibility. If the application has the need for only three or four axes of motion, a Cartesian robot can be the better option. It's just as flexible within those axes, is less expensive and offers a more compact work envelope. And a Cartesian robot is 100% accurate within the work envelope, where the six-axis and Delta robots lose accuracy on the periphery (Figure 4).

Most linear systems use high-resolution encoders on servo motors, which incorporate capabilities such as position feedback and torque control. Fault and alarm data can be sent to an edge device and analyzed from the cloud for improved process efficiency. Similarly servo drives, which offer accessible parameters and process data, allow the end user to monitor the average speed and cycle rates of defined motion profiles. Out-of-specification profiles show pending problems.

Accessories can be used with linear systems to lower the risk of unplanned shutdowns. For example, linear encoders can indicate when precision and repeatability are trending beyond normal limits. Vibration sensors can pinpoint problems before they become critical, such as a flat facing recirculating ball bearing.

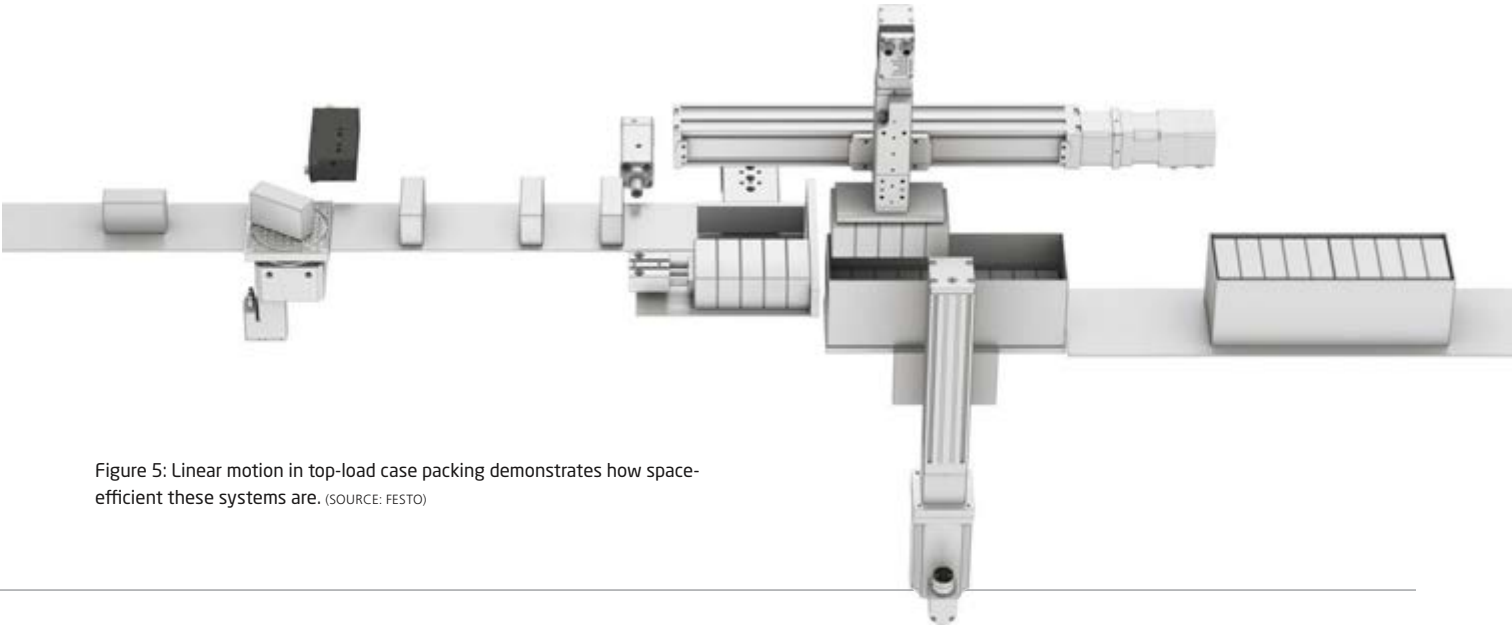


Figure 5: Linear motion in top-load case packing demonstrates how space-efficient these systems are. (SOURCE: FESTO)

Linear motion has a more compact footprint than a robot, which has a large swing radius and requires guarding. Linear gantries easily maximize the pick locations within a rectangular workspace, making them ideal for working over conveyors that move in cardinal directions (Figure 5).

One of the important things about a robot is that it arrives already assembled. Many years ago, multi-axis linear systems had a bad rap because of the assembly time required to bolt the axis together. Suppliers have fixed that issue with axes designed to be compatible for easy assembly. These systems can arrive as kits with all the parts in a box ready to be bolted together. Or they may be assembled and tested prior to shipment and arrive as a drop-in ready subassembly.

ANDY LEWIS

electric automation business driver, food and packaging North America / **Festo**

Match performance and cost parameters

Linear-motion suppliers typically offer several performance and price options to suit the customer's criteria and match the application requirements. The criteria or needs of the application typically coincide with the relative cost of the linear-motion solution. To optimize performance and value, linear-motion providers need to best understand the customer's needs to arrive at an appropriate solution.

Typical questions the user must consider to match performance and cost parameters of the project would include the following lists.

For precision:
- What is more important, accuracy or repeatability?
- What is the accuracy/repeatability requirement?
- Are these values realistic, based upon the desired motion profile?

For orientation:
- How will the system be mounted—normal, on its side, inverted, vertical, at an angle?
- How will this affect the load requirements?

For speed:
- What is the maximum speed and acceleration required?
- What is the maximum jerk allowable?
- What motion profile, or shape, is desired?

For travel:
- What is the required travel, or stroke?
- What is the overall envelope allowed?
- How much over-travel—safety zone—is required?

For loading:
- What is end-of-arm tooling (EOAT), and where is it located?
- What additional forces are seen by the system during use—for example, cutting or pushing forces?
- What do the static and dynamic free body diagrams look like? Have all loads been accounted for?

For duty cycle/life cycle:
- What is the actual duty cycle for the system?
- What is the expected lifetime?

For environmental considerations:
- In what environment will the system be installed?
- Are there any hazards in the environment?
- What is the maintenance schedule, and is the system accessible for maintenance/lubrication?
- Are there contaminants in the environment that can damage the motion system?
- Will the system disburse contaminants into the environment that could damage other equipment or products?

For unknowns:
- What are the known unknowns? What is a reasonable value for these unknowns?
- How will someone misuse this system?
- What could possibly go wrong?
- What else could go wrong? Repeat this question until you can't think of anything else.

For safety:
- Are there any safety standards to which this system needs to conform?
- What could happen if the system fails?
- Are there safeguards that need to be installed for a system failure?
- Could people be injured by this system? If so, how will the system be protected?

DAVE WALDEN

applications engineer / **PBC Linear**

Spacing-saving linear motion

The ability to provide fast, accurate linear motion control for front and end-of-line applications continues to expand. Linear devices can provide greater capacities for heavy loads, but there are also low-profile mini systems for smaller load applications. Typically, low-profile linear systems allow for use in small spaces, operate with loads under 20 lb and can be used economically.

Perhaps at first there can be tradeoffs to gains in cycle times, but with advances in magnet technology and screw actuator sizes, there really are no limits. Direct drive systems tend to operate extremely efficiently. They do not require fluids and are therefore cleaner. They are smaller and require less assembly time. The greatest advantage is in the throughput, precision and quality. Linear systems allow for multiple point positioning via programming changes, they can quickly reverse and turn the product around. They are extremely accurate in their positioning.

Typically, you have a much smaller footprint, but linear motion is also well-suited for retrofitting existing equipment. Things to consider are the typical design questions: load, uptime, ambient operating or communication requirements. It is always best to look at the existing system and determine where it is failing and how it needs to be improved.

Absolutely, components are available with smart capabilities; this is one of their strengths. A linear-motion system consists of four main categories: actuators, linear bearings, motors and control. There are many actuators on the market with intelligent communication capabilities. Linear bearings are maintenance-free. Linear motors are direct drive and are available with smart communication. The controls provide constant feedback with the system and enable machine intelligence and communication beyond the machine.

Again, machinery footprint is where linear motion shines. Think of the traditional approach of driving conveyors with gearboxes and racks, bearings, ball screws, pinions, belts, chains, large motors, large ac drives. Not only is the footprint for the traditional setup larger, it also requires considerable maintenance. Think of a three-shift operation, seven days a week. The machinery needs lubrication. It is messy. The machinery has a high electrical demand. In every instance, linear motion is more efficient. The space savings alone can be 50%.

PERRY HUDSON

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

Repetitive precision and better control

Multiple solutions can be used for portals or palletizing. For portals, some electric actuators can be used and are built in a way where the motor is in parallel, which makes the solution more compact. These solutions are produced for many different applications, which helps reduce their costs as more industries are moving to linear motion, increasing the availability of cost-effective products. They also have the ability of integrating feedback options to help monitoring. All of this, with the benefit of no maintenance, results in less downtime and increased productivity.

For palletizing, a trend we are seeing is the use of collaborative robots together with a vertical lifting solution. These solutions increase process speed and can run continuously resulting in increased productivity; they also help operators, reducing strain and health concerns due to repetitive lifting of the boxes. These linear-

motion solutions offer both precision and repetitiveness, allowing for better control of the movement and optimizing the cycle times.

In general, linear-motion solutions can be implemented wherever there is a push/pull or lift movement. Some actuators have now built in monitoring, and they collect data on force, speed, position feedback and temperature and send it to a controller to be analyzed. All these parameters can give crucial information on how the actuator is behaving, can detect if there is an anomaly—peak force detection—and report it to the PLC or controller. This can help define predictive maintenance more accurately and reduce downtime.

When it comes to concerns about space, the same product can be used for multiple applications. Multiple programs can be written in advance for the different products that might pass on the same line. This can help optimize line usage and can be used for multiple purposes, without having to duplicate lines, therefore reducing machinery footprint.

GRÉGOR CAILLON

sales engineer / **Ewellix USA, distributor for RS**

Your application determines throughput

We have a wide range that customers can pick from. Thinking about portals and palletizing robot solutions might come to mind right away, however, might not always fit the budget. Another smart flexible manufacturing solution for this application is based on linear-motor technology that increases throughput and reduces total cost of ownership. It provides a faster, cleaner and more efficient and productive alternative to pallet conveyor systems. Lastly, if you are looking for an even smaller budget a linear motor and gantry portfolio would be another alternative.

Throughput is determined by your application, but there are various examples that more than doubled the throughput compared with traditional conveyance with a decreased footprint by sometimes half the size. And, lastly, supporting your sustainability targets as you are just consuming energy where your magnet array is positioned, linear motors are naturally the choice for energy efficiency.

The sky is the limit for implementing linear motion. Constantly, we see new applications using this technology, which weren't thought of before. Warehousing, ecommerce, logistics, life sciences, consumer packaged goods, automotive, electrical vehicle battery, semiconductor—limitations are only your own creativity. Built-in motor analytics combined with digital-engineering tools help not only to easily identify and point out where the issue or jam is in the sometimes km-long line, depending on the application, but also help to predict failures before they happen, as well as provide insights into how to further optimize your manufacturing line. Digital engineering, analytics and our devices/components go hand in hand to provide further value not only from maintenance view, but already starting at the machine design—creating your own digital twin of the line, predicting the throughput and allowing simulation with bi-directional integration of the engineering environment using object-oriented programming for further simplification and standardization.

Using linear motor technology requires you to re-think your traditional design. You benefit most, if you truly understand the value and how it can improve your current design.

MICHAELA KAUFMANN

business manager / **Rockwell Automation**

3 common types of actuators

When looking to implement linear motion there are three common types of actuators that will give you linear motion. Ball-screw and belt actuators convert rotary motion to linear motion, while linear motors are motors that move linear inherently.

Converting rotary motion to linear motion is the most cost-effective way of getting linear motion, but you do have a tradeoff for speed, accuracy and force.

Ball-screw actuators are a very good form of linear motion actuators that give very good mechanical advantage when converting rotary to linear motion. By selecting the best pitch screw for the application, you can maintain good speeds, while having good force for the acceleration and deceleration of the load.

Belt actuators allow for higher speeds than ball screws and give good positional accuracy. High acceleration and deceleration are achievable with good force. There are slight inaccuracies mechanically that should be looked at if very high accuracies are needed.

Linear motors have the highest level of capabilities. They have the ability to achieve the highest velocity, acceleration/deceleration and accuracy. They also come with a higher price tag than the other two options.

While all three of these solutions do take up some space, linear motors can have the advantage of being implemented into the machine itself. A linear motor has many components, but the main two are the magnet track and the coil that will travel along that track. Some manufacturers will supply these two items and allow the machine builder to build them into the machine framing to save space. This does take some planning to align the magnet track and coil along the linear rails that the machine builder chooses.

GREG DIECK

product manager, motion / **Omron Automation**

Andy Watkins
contributing editor
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eCAD facilitates manufacturing design

WHEN DESIGNING A product, especially in the prototyping and experimental phases, two great systems help to facilitate success in a more streamlined fashion. We use one of the many types of electronic computer-aided design (eCAD) and a type of part manufacturing known as subtractive or additive manufacturing.

Electronic computer-aided design is the process of designing products using software on a computer. It's used in both subtractive and additive manufacturing processes, but the way it's used is different, depending on a number of factors, such as materials, time and end results needed. Certain types of CAD programs are intended for basic subtractive manufacturing processes only, while others are intended to support both additive and subtractive manufacturing.

> **eCAD is used to create a digital design that can be turned into a physical product.**

The wide ranging options also have a wide range of program costs. Low-cost online options utilize a subscription to give full access to the CAD and design tools, while other options require a substantial investment into the software and maintenance packages.

What was at one time termed "machining" has a new term added to differentiate between the two types of part manufacturing. Subtractive manufacturing is also becoming a major part of industry. Subtractive manufacturing involves starting with a solid block of material and removing parts of it until the desired shape is achieved. Electronic computer-aided design is used to design the product, and the computer generates instructions, such as speed and feeds and toolpaths, for a machine to cut away the excess material. This has been one of the most common ways of manufacturing parts for many decades. At one time this was considered the only way to take a piece of material and to shape it to create all the features of the end product.

We have seen the advent of additive manufacturing, and we are learning of the benefits that it has for manufacturing. Additive manufacturing involves building up a product layer by layer. Electronic computer-aided design is used to design the product, and the computer generates instructions for a machine to add material in specific areas. This can be powder deposition or melted-material deposition depending on the application. The bonding of the material happens in a number of ways, such as laser sintering and adding molten material in a controlled manner.

Unlike a casting, where molten liquid material is added to a predetermined mold or shape, additive manufacturing is able to build on itself layer by layer. Typically there is a good amount of support material designed into the finished product material so that the part is self-supporting during the build process and is made to easily break away after the final build.

In both cases, eCAD is used to create a digital design that can be turned into a physical product through manufacturing. The main difference is whether the process involves removing material—subtractive—or adding material—additive—to achieve the final product. To determine which type of software will work best for your type of product, it takes a solid understanding of the critical success factors for a given operation. Here are some questions to ask:

- Will we be constantly redesigning from prototype to finished product?
- Will the design be controlled by a single individual or by a wide team, and will we need to control iterations of the design?
- Does the design require traceability from the initial design to the finished product?
- Does the software provider also understand post processors and editing of post processors to assist and support the machines, whether additive or subtractive, for the manufacturing build of the part?
- How available are skilled designers and which software package are they most comfortable and familiar with?

Getting a great product starts with the ability to design that product in a way that best suits your manufacturing efforts. It is well worth the extra time and effort to research what type of software is going to work best. The design phase will have a long-lasting effect on the downstream efforts in manufacturing. Investing in eCAD systems prevents downstream failures and helps sucessfully produce products over and over again. CD

Andy Watkins is direct sales manager at Romi Machine Tools in Erlanger, Kentucky. Contact him at andy@andywatkins.com.

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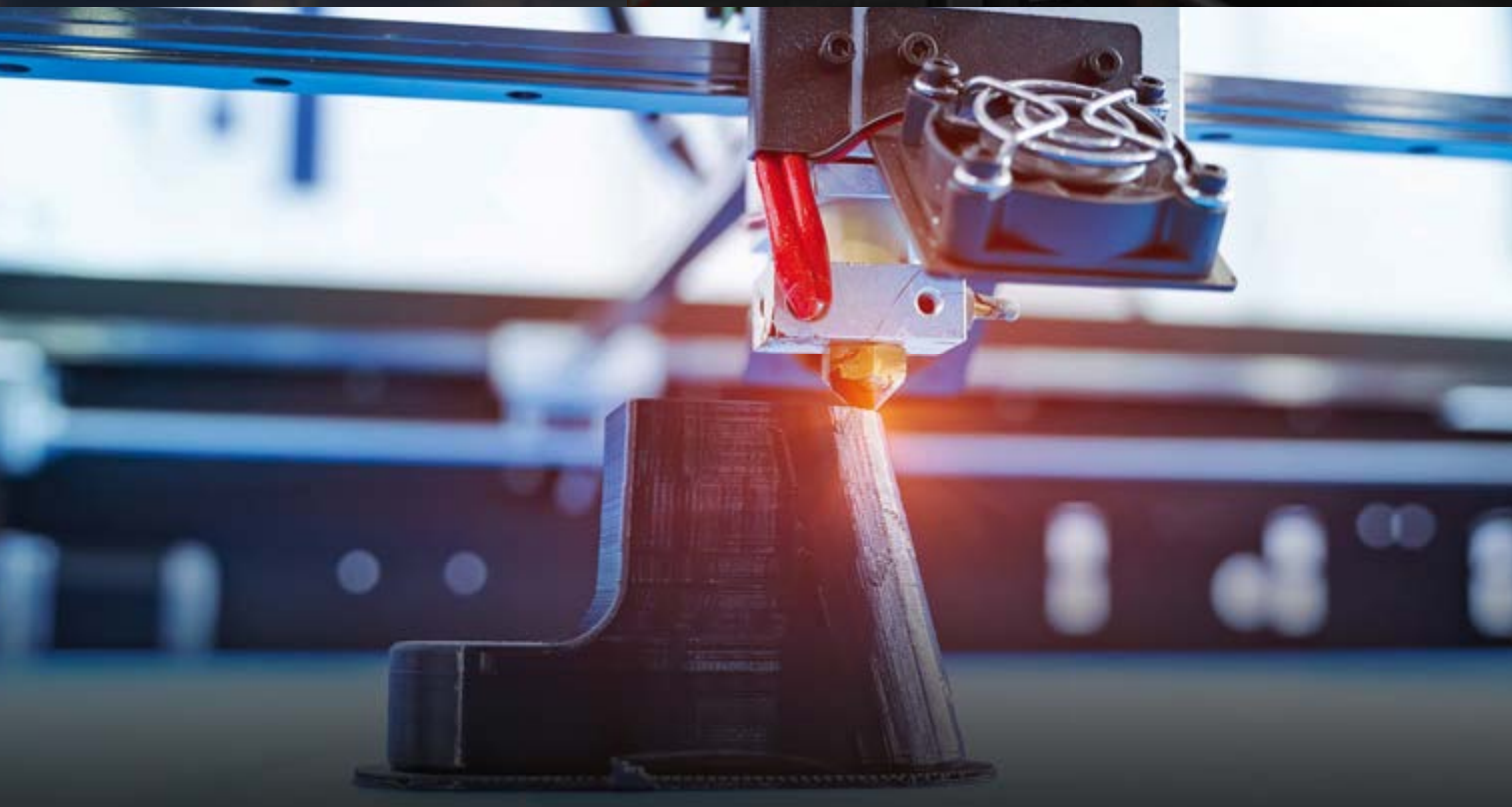
Automation is the future of Electronics Manufacturing



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