Nearly everything that is man-made uses motion control at some point in its life cycle. Either during its manufacturing, packaging, distribution, use or even in its end of life disposal will have been subjected to some form of motion control.

Machine and equipment builders are under pressure to deliver products that provide more actionable information to manufacturers. At the same time, end users are demanding machines help increase throughput and improve application performance.

For machine and equipment builders with discrete and motion capabilities, meeting these challenges has traditionally required two network technologies – one for discrete applications and one for motion control. Today, machine and equipment builders can enable users to effectively manage real-time control and information flow within the machine and manufacturing enterprise using one streamlined network infrastructure.

A unified network offers multiple benefits for both machine and equipment builders and their customers. End users can more easily extract information from a single source, as well as exchange data upstream and downstream. A single network infrastructure offers unprecedented levels of visibility, flexibility and scalability to respond to market opportunities and operational threats.

With a single network architecture, machine and equipment builders eliminate the risks and boundaries associated with proprietary and single-purpose networks. Communication over one wire instead of two means easier plant integration, simplified network management and fewer asset expenses. A network that provides seamless connectivity to the plant while expediting simplified kinematic design and integration of best in class devices results in a better machine.

A network that delivers the performance required of the applications with additional benefits that help the machine and equipment builders design and build a better machine and the end user to produce products quickly, efficiently, and of high quality.

In short, a single network technology provides multiple selling points for machine builders. That is why today, many are turning to CIP™ Motion on EtherNet/IP™. EtherNet/IP is a leading open industrial Ethernet network capable of handling the widest range of applications.

Many machine and equipment builders – in industries ranging from food and beverage to medical devices and printing presses – are already benefiting from the differentiated value CIP Motion offers.
Understanding Your Networks and Protocols: Internet, EtherNet/IP & CIP

The Internet protocol suite, more commonly known as TCP/IP (Transmission Control Protocol and Internet Protocol), is the set of communication protocols used for the internet. It is generally the most popular protocol stack for wide area networks and defines end-to-end connectivity, specifying how data should be formatted, addressed, transmitted, routed and received at the destination. This is what allows users to integrate industrial applications with enterprise-level Ethernet networks and the Internet. It is supported by hundreds of vendors around the world and is media-independent.

EtherNet/IP uses readily available, off-the-shelf media and infrastructure products because it complies with basic Ethernet standards and conventions, such as IEEE 802.3 and TCP/UDP/IP. This helps operations and IT professionals collaborate on the deployment and maintenance of a secure, reliable and robust network infrastructure within the enterprise and throughout the industrial environment. As a result, it is possible to leverage ongoing advancements of standard Ethernet and TCP/IP technology, making EtherNet/IP a scalable, future-ready network architecture.

The Common Industrial Protocol (CIP) is an application protocol that provides industrial networking for safety, time synchronization and motion control through the network extensions CIP Safety™, CIP Sync™ and CIP Motion™. CIP uses the standard network and transport layers deployed in general Ethernet applications. This allows devices to easily interconnect using standard switches, routers and other infrastructure components. In this way, CIP provides unified communication architecture throughout the industrial enterprise. CIP Motion is an extension to CIP providing the functionality of deterministic, real-time, closed loop motion control via standard unmodified Ethernet. Other industrial Ethernet networks require motion-specific networks, differentiating EtherNet/IP technology.

EtherNet/IP serves as a single network solution with no need for a dedicated motion network. Topology independent, motion control can be placed anywhere in the infrastructure without physically isolating the traffic from other forms of traffic on the wire, providing more flexibility in the design phase and less maintenance issues during commissioning and deployment. Also, by using the existing Ethernet infrastructure, motion control can be easily layered into brownfield installations where hardware already exists. This provides for expansion to installed systems and takes full advantage of well-established robust management and diagnostic tools.

Bringing Motion On Board: CIP Motion

The CIP Motion technology was developed with the knowledge that modern drives have more than enough horsepower to extrapolate drive commands given a shared system time. In essence, because instructions are time based, the drive is trusted to do its thing at the required time. Other network technologies require that a master controller perform all of the calculations and then force those pre-calculated answers onto a strict schedule, the approach being: “when you receive this, start doing Y”.

Figure 1. Single Network Architecture for a Machine
The time-based approach, at “X time, be doing Y,” provides great precision regardless of other things occurring in the application. For example, in a time-based system, the part rejection diverter knows precisely when a faulty product will be present and is able to reject that part based on time. As a result, only the faulty part is rejected.

Using application profiles that are designed to allow position, speed and torque loops to be set within a drive, also reducing workload elsewhere in the system. For these reasons, CIP Motion makes logical sense, plus you can couple it with CIP Sync functionality to apply precision clock synchronization to the EtherNet/IP network. This synchronization service provides a distributed time reference to all enabled devices on the network; all CIP Sync devices know what time it is and can act accordingly. Using the shared awareness of the current time and the time of an event such as when an object was in front of the photo eye enables actions to be taken based on the time rather than position. The ability to accelerate or decelerate the application and still reject that one faulty part is due to the distributed knowledge of the time which is at the very core of CIP Motion.

CIP Motion distributes motion control across multiple cells or machine sections at the level in the architecture where the line control functionality is already being accomplished.

EtherNet/IP with CIP Motion is a scalable and complete solution that provides a common application interface and services for general purpose and motion control applications using the same profile. Because it is based on standard Ethernet technology, it is accepted and supported by the corporate IT departments. Even the potential network topologies such as linear, ring and star are accepted by the IT department, making the use of CIP Motion a practical, logical and popular choice.

**Moving Industry Forward**

As technology advances, so will integrated motion on EtherNet/IP. The continued evolution of the programmable automation controller (PAC) provides the ability to perform more applications within a single control platform. The addition of CIP Motion allows for true multi-disciplined control to occur in a single PAC. The same PAC that provides discrete control of the machine can also control the actuators and motors, helping to eliminate the need for a dedicated motion controller. The ControlLogix® and CompactLogix® PACs from Rockwell Automation provide high-performance motion control with advanced kinematic capabilities for a wide scale of applications.

CIP Motion facilitates distributed integrated motion control in applications with just a few axes of motion to applications with more than 150 axes of integrated motion. With modern day PAC scapable of performing motion, discrete machine and process control, there is finally a single environment for industrial control and information.

CIP Motion on EtherNet/IP is a key enabling technology regardless of application size. The following users are finding success with CIP Motion on EtherNet/IP in applications that range from quite small and centralized to those that are very large and highly distributed.
Easier - Using the same Ethernet standard as e-mail, the Internet and other commercial applications, EtherNet/IP (with “IP” referring to Industrial Protocol) is a simple, yet robust communications platform enabling users to effectively manage real-time control and information flow within the machine and manufacturing enterprise.

Seamless - EtherNet/IP is the only industrial protocol that is designed and established to connect from the device level all the way up to the end customer’s IT infrastructure, and across applications, including discrete, safety, motion, process and drive control. This helps machine builders securely connect equipment and machines to up- and downstream operations.

Simplifies - standardizing on EtherNet/IP, machine and equipment builders have one standard network that can lower their total cost to design, develop and deliver machines, while eliminating the risks and boundaries associated with proprietary and dedicated networks.

Best – EtherNet/IP is future-ready technology, allows you to mix commercial and industrial information on one common network infrastructure, is topology independent, has diverse and broad supplier support and is a scalable plant-wide network solution with thousands of nodes installed.

CIP Motion in Action

Beverage Distribution Automated Storage and Retrieval System (ASRS)

In an application that includes conveyance systems moving pallets of product from manufacturing to distribution via an ASRS, one machine builder utilizes 16 pallet cranes capable of movement along three axes while carrying pallets with bottled beverages of varying sizes and shapes in cartons, trays, and/or shrink wrap. Content of the pallet is often stacked five to six feet tall with limited packaging or overwrap restraints. As finished pallets of beverages enter the ASRS, the movement from the conveyance system to pallet rack shelving for storage and retrieval needs to be quick and smooth, so as to not toss or damage bottles. In addition to demanding motion requirements, the accuracy of position of the crane is also critical. The shift from low height (large footprint) storage toward more of a vertical storage practice results in crane heights exceeding 80 feet and rail lengths of over 140 feet.

The motors, AC and servo drives, PACs and HMI are connected via an EtherNet/IP network. Motion instructions, similar to servo drive instructions, helped the machine builder achieve much faster programming. Simplified code is easier to read and troubleshoot resulting in shorter customer acceptance testing/commissioning. The motion instructions allowed for trapezoidal moves including smoothing via camming so contents are not shaken in spite of greater velocity of movement. The resulting smooth yet quick moves provide greater than specified performance in support of the customer’s intent toward operational flow, rather than a traditional storage and retrieval operation. Auto tuning with a dual loop configuration employing a CIP Motion integrated encoder on the elevator motors and a linear encoder on the rails provides position feedback for more accurate pallet placement and retrieval. The accuracy of position is maintained in spite of known wheel slippage issues as cranes are moved along rails with varying load profiles.

CIP Motion on EtherNet/IP also provided a simplified network topology that provides better performance than prior systems using dedicated motion networks. It also meant
the machine builder could quickly and easily integrate third-party motors via a straightforward menu-driven motor spec entry into their programming software. The use of CIP Sync-enabled AC and servo drives provides safe speed functionality needed to satisfy safety standards for human ingress into the ASRS environment.

The machine builder’s CIP Motion “ah hah” moment came when they witnessed the performance of the cranes and the “smoothness of the moves” under varying loads. Their beverage manufacturer customer was sold on the system when the connectivity of the ASRS to the conveyance system on EtherNet/IP resulted in an integrated system that delivered improved flow performance throughout the warehouse. The ASRS produced a smoother flow of product from batching to filling and capping to the store shelf.

**Labeling System**

A new Inline Roller Trunnion Labeler was designed to satisfy demanding requirements for label reconciliation, label assurance and safety zoning, while labeling more than 900 bottles per minute with a placement accuracy of +/- 1/32 of an inch. The inline label application accepts round bottles at random spacing from the filling and capping operation into a roller trunnion. A feed screw is used to space the products to a constant pitch as it enters the labeler. The feed screw then transfers the product to the roller trunnion, which carries it through the remaining labeling process. It then recirculates to capture new bottles for labeling. Labels are dispensed adhesive side out onto a high-speed vacuum drum for application, passing by the reconciler which is able to remove defective labels prior to them reaching the bottle. If the assurance labeling option is selected (a proprietary differentiator), the roller trunnion stops momentarily while the defective label is removed from the vacuum drum. The roller trunnion then resumes normal operation upon confirmation of the next good label. This helps assure that each bottle leaves the machine properly labeled thereby reducing unnecessary rejected good product with no label or with a defective label.

The use of CIP Motion enabled the servo drives to keep the various axis integrated and managed, such that each bottle receives one and only one good label. The connectivity of this machine on EtherNet/IP to the filling and capping processes kept the flow of finished goods from the filling process through labeling at maximum speed. In addition, the use of CIP Motion provides seamless connectivity upstream and downstream allowing for change-over of product and tight integration with labeling such that the products always receive the appropriate label without extended downtime.

**Depositor Machines**

Baker Perkins new generation ServoForm™ Depositor is used for sugar confectionery such as hard and soft candies, lollipops, toffees, fondants, fudges and jellies. Using servo-controlled electric rod actuators to continuously deposit candy syrups at final solids results in end products that are clearer, brighter and higher quality than those from older processes and also offer smoother mouth-feel and better flavor release. The servo technology offers much greater flexibility and control leading to lower labor costs, reduced energy bills and faster payback.

Easier to use, easier to clean, less reliant on the operator’s muscle power during setup, changeover and clean out were the primary requirements described by Baker Perkins with respect to their confectionary depositor machine. The machine pumps candy through depositing nozzles using pistons onto trays that have to be synchronized with the head
as well as the molds. Deployment of a washout tray was a manual effort that could result in extended delays in production and repeatability was completely dependent on the particular operator. Additional complexity was levied in that certain products have higher viscosity which means more power would be needed based on the end product being manufactured.

Baker wanted to know if a linear servo actuator would be a suitable replacement for rotary servos. Baker built a test rig running a glucose solution through the system and performed over 10 million cycles in a 24/7 test mode. Their comment after the tests was that, "it worked flawlessly!" The primary driver for using linear actuator technology was that Baker wanted to automate the washout cycle by revising the machine head design to create space underneath for an integrated discharge tray.

The control system manages the movements of the head, the pistons, and the mold circuit for maximum precision and efficient continuous operation. It also controls the purge and washout system, by stopping the machine, raising the head to create a void, actuating the electric cylinders to position the trays and then operating the pump head using a cleaning solution. In the past this was a two man job, which took considerable physical effort. Now that it is automated, it is repeatable, takes much less time, and results in greater throughput / productivity of the machine. The use of CIP Motion provided tight coordination of the movement of the head, pistons and molds such that the original performance requirements were not only met but exceeded.

**Case Packing**

A machine builder who builds top loading case packers was challenged by its customers to deliver machines that need to be integrated with new, as well as, existing plants. In addition, they were being asked for solutions that would connect their machines to both upstream and downstream operations in the production line. The machine builder solution leveraged CIP Motion on an EtherNet/IP network allowing the machine to be easily integrated into the plant network and the adjacent machine operations. The use of EtherNet/IP eliminated the need for a dedicated motion network simplifying installation, configuration and programming. The end result was a significant reduction in equipment installation and start-up time for the machine builder and faster ramp up to full production capacity of equipment for the end user. The customer also received improved operator safety via the safe off functions and greater awareness of the machine operation through rich data enabled by connecting all equipment with CIP Motion.

**Printing Press**

A newspaper acquired new presses that needed to integrate with existing presses. In order to create maximum efficiency, the existing four towers and two folders and the newly-acquired five towers and one folder – had to be configured into one installation that could function as individually-operating presses, running up to three different print jobs simultaneously. The initial application included the conversion of the presses from a common mechanical driveshaft with a single DC drive to a shaft-less system. The second part of the project was to convert existing AC register motors (with analog feedback potentiometers and black box positioning system) to servo motor control.

The main benefit of the conversion - the printing towers are now mechanically independent of one another, which allow the printer to plate up a press while other towers are printing. Over 150 axes of motion are now fully integrated using CIP Motion on EtherNet/IP. This allows the user to print up to three different products at the same time,
produced out of three folders. The press also runs more quietly than when it was shaft driven. With the extra four towers coupled to the five recently purchased, the printer can now print 32-page products in one run, instead of printing two 16-page sections and then inserting one into the other. “The reduced make-ready time is a big bonus for the printer. In our type of business, we’re deadline driven and can’t afford to be late. The servomotors on CIP Motion result in better register and faster start-up, reducing paper wastage.”

**Medical Equipment**

One of the world’s largest medical-device companies tapped CKC Engineering to design and develop a custom microbore tubing spooler machine for a new extrusion plant. The main goal was to create a system that would operate at an extremely low tension set point, while automatically handling tubing coming in at varying speeds and tensions.

Microbore tubing is an essential tool in modern medicine. As its name implies, the plastic tubing is tiny in diameter. It’s also flexible and durable – qualities that make it indispensable for treating, repairing and even replacing parts of the human body.

Manufacturers produce microbore tubing in a broad range of sizes for different medical purposes. Whatever the size, microbore tubing requires a rigorously precise and consistent production process. One particularly delicate step occurs at the end, when long sections of newly extruded tubing are wound around spools. By carefully aligning layers around a hard core – just as thread is wound on a sewing spool – manufacturers maintain the tubing’s proper shape until it is unwound to make medical products. Tension is a major quality-control issue in the spooling process. If the tubing is too taut, the plastic can stretch; if it’s too loose, it can warp. Either effect can ruin the product.

The application required multi-axis coordinated motion and closed-loop control of the tubing tension by a proportional-integral-derivative (PID) feedback mechanism. Closed-loop control on CIP Motion provided far greater accuracy and repeatability than a manual open-loop system, which depends on the operator’s judgment and intuition about how much to adjust the output on a tensioning device. By coupling the Logix controller with the Kinetix drives on EtherNet/IP, the customer got the high-performance and integrated-motion that was needed in a small footprint. The EtherNet/IP solution also offered a significant cost savings over the prior motion network platform, which had been a preferred platform for coordinated motion.

The machine operates via closed-loop tension control using a high-accuracy tension sensor to ensure the tubing is not stretched or flattened during the spooling process. A traverse axis is electronically (virtually) geared to the operating spool, such that it travels at the correct speed to smoothly lay the tubing, even as the spool speeds up and slows down to maintain the optimal tension. Optical sensors enable the traverse system to detect the edge of the spool and reverse direction – allowing multiple spool sizes to be used interchangeably.

EtherNet/IP provides even more simplicity by easily integrating the HMI, PAC and motion components on the single network, reducing design time and simplifying maintenance. The vice president and controls engineering manager at CKC believes the CIP Motion based control system decreased programming and commissioning time by 25% while also reducing procurement cost by 25%.

CKC’s design met all of the client’s needs. The new tubing spooler accommodates over 100 different extrusions, and enhances the quality and repeatability of the process by accurately controlling the tension.
Paper Converting

Paper Converting Machine Company (PCMC), a leading designer and manufacturer of high-speed printing presses, standardized all of their machines on a common control platform a few years ago. This transition helped the company more efficiently support customers and provide better local support around the globe. PCMC prides itself on providing reliable, high-speed performance machines that are standardized on one platform so customers only need to train their staff on one platform. Their customers are very familiar with the control system, which helps simplify maintenance and lower operating costs. In addition, the engineering and technical service team emphasizes training on that single control platform allowing them to troubleshoot a customer’s machine and carry out preventative maintenance any time, from anywhere with a broader staff and a small inventory of spare parts.

Standardization on a common control platform also allows engineers at PCMC to re-use application code from one type of machine to another, reducing development and troubleshooting time. This common platform has allowed them to share engineering talent across value streams so when one area is particularly busy, engineers from another area can easily be brought in to help. To deliver the new ELS-D printing press, the engineers at PCMC needed to improve its performance, while converting the control platform to better meet specific customer needs in new segments. Namely, customers required a flexible machine that was capable of fast, easy and frequent product changeovers throughout the day. Operators have to be able to input a new recipe quickly and easily without changing machine parts each time.

To do this, the engineers replaced the traditional plate gear drive system with medium inertia servo motors to enable precise motion control and fast product changeovers. The addition of servo motors on the press allows for an infinitely variable repeat so operators can easily command multiple product changeovers throughout the day, each with the touch of a button. The motors also can withstand high-pressure and caustic wash-downs, making them more reliable than the previous gear drives.

The engineers chose to integrate the MP-series servo motors with servo drives to allow easy speed and position adjustment, and deliver motion precision and accuracy. An integrated display computer with HMI software allows users to easily select a specific print-repeat size for each type of package label. The machine also uses a controller that features integrated motion and machine control capability in a single programming environment. This integration provides their customers with fewer spare parts to maintain.

The new system is streamlined and intelligent, allowing operators to more easily operate and maintain the machine than with the previous gear drive system. Now the controls and drives platform is familiar to customers, as well as PCMC engineers and service technicians. Unlike the previous gear drive system, the ELS-D inline printing press can print any print repeat size between minimum and maximum with a simple numeric input on the operator screen. The customer can use the servo-driven printing press for food and beverage product labels as well as pharmaceutical labels. Position control via CIP Motion allowed for greater overall control of the process as there are no tension deviations during acceleration or deceleration; from a manufacturing standpoint their customers are making “good” product from beginning to end with no waste. CIP Motion provided for a shorter start-up as the need to tune the system for inertia compensation was no longer required due to the ability to run in position control. The need to run time based calculations to compute position was also eliminated as the system “knows” where something is. CIP Motion on EtherNet/IP also provided for much longer distances between control cabinets (simplifying installation) without any performance issues.
“Gone are the days when package printers can purchase one machine for each type of product label,” said Mike Jarmuskiewicz, new product development leader, PCMC. “With an increasingly competitive environment on store shelves, manufacturers need to make many different variations of one product type. The ELS-D inline printing press can handle any type of label and quickly change from one label to another multiple times per day.” Equally important is the ability to pre-program different product changeovers. This significantly reduces waste when an operator is setting up each print job as the machine is already programmed for a certain web width and material length. “The operating system also allows the operator to recall a previous print job, which saves time and reduces material waste,” Jarmuskiewicz said. “All in all, the capabilities of this machine have added a new dimension to our business,” said Mark Gillis, global sales director of printing and folding converting, PCMC. “This keeps us in stride with major trends in packaging to help us gain a broader customer base.”

**Tomorrow’s Network Today**

Machine builders and equipment builders are continuously working to stay ahead of the competition. Many have standardized on one network technology thereby lowering their total cost to design, develop and deliver machines. Using CIP Motion servos and linear actuators, they can simplify the kinematics of their machines, resulting in smoother and more productive motion. The use of unique capabilities inherent in high-resolution vision systems, specialty motors and other third-party devices on EtherNet/IP, provide additional opportunities to differentiate the value of their designs over their competition.

By selecting EtherNet/IP, machine and equipment builders are reducing the risks and boundaries associated with proprietary and application specific network technologies. Because EtherNet/IP connectivity provides information and can be easily integrated plant-wide, securely connecting their equipment to up- and downstream operations, these machine and equipment builders are also increasing the value of their equipment to their customers.

EtherNet/IP offers the ability to utilize a single network infrastructure for unprecedented levels of visibility, the flexibility to change quickly as threats and opportunities emerge, and the ability to scale and combine functionality, technology and systems as the situation dictates. Secure, real-time information can be more easily collected and analyzed from machines, systems and enterprises connected via this EtherNet/IP network, helping IT professionals more easily meet business goals. Additionally, the network simplifies network management, reduces network asset costs and optimizes human skill set assets. It is the choice of machine and equipment builders and end users today, and is ready for the changing needs of tomorrow.