TECHNOLOGY OVERVIEW SERIES

PERFORMANCE WITHOUT COMPROMISE

EtherNet/IP™ combines with CIP Motion™ to deliver high-performance motion control

Executive Summary

Ever increasing performance requirements for equipment that delivers higher quality and more varied product at reduced scrap rates is familiar territory for end-users and OEMs alike. Most of the time, high performance motion control systems are one of the key enablers for fulfilling these requirements. Automation networks for machines with high performance motion control have proven to be a "win-win" for both OEMs and end-users by simplifying the tasks of installation, commissioning, product changeover and maintenance and ultimately have improved return on investment by providing better machines at a lower overall production cost.

Most high performance motion applications combine motion control with other key disciplines such as safety and general machine or process control. To manage this combination of disciplines, a traditional implementation might use multiple dedicated networks or it might hardwire certain portions of the control. For example, motion control often had its own dedicated network while general machine control required a second. Safety, often, was not networked at all, but instead was hardwired into the control system. This disparate approach existed because the network technology was not capable of integrating these controls together – and the automation suppliers and products were typically focused on certain areas of control. Although workable, this "hodge-podge" approach of integration brought a lot of complexities and hidden costs. Multiple people were often required to manage and setup each network; additional costs were required for multiple communications gateways and also for programming the movement of data from each non-interoperable network to the control. Finally, and not least important, this implementation demanded ongoing maintenance costs to troubleshoot and correct problems in the plant on this equipment.

But now there is a simpler and more cost effective approach to equipment design that delivers performance without compromise – EtherNet/IP™ – a single automation network that can combine machine control, safety and high performance motion control capabilities into one, standard Ethernet network that is available on a wide offering of interoperable products from the world's leading automation companies. In addition, EtherNet/IP-enabled equipment provides users with the foundation needed to adopt a converged network architecture throughout their production plants. EtherNet/IP is the only automation network available today that implements the complete range of necessary machine control capabilities on a technology platform using the most widely installed Ethernet standards found today. The overall result can be a multiplicative gain in return on investment from state-of-the art equipment, increased overall enterprise productivity and reduced costs for training and maintenance.

In this paper, ODVA lays out the building blocks for the EtherNet/IP technology that make it unique among industrial networks in solving applications requiring high performance motion control on a standard Ethernet platform, including:

- The network application layer used by EtherNet/IP – CIP™ – that allows it to provide a comprehensive communication framework for industrial applications needing real-time control;
- Ethernet standards that, together with CIP, constitute EtherNet/IP;
- Services, known as CIP Safety™ and CIP Sync™, that allow EtherNet/IP to combine safety and synchronization in a single real-time control network;
- Capabilities in EtherNet/IP, known as CIP Motion™, that allow it to provide motion control for high performance applications; and

- The suppliers and association behind EtherNet/IP that help to ensure long-term availability of a robust ecosystem of interoperable products on this open network standard.

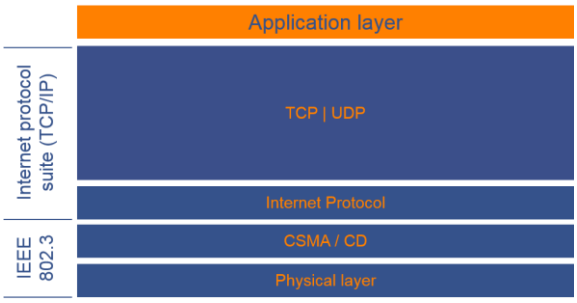
Along the way, end-users and OEMs also share their experiences using EtherNet/IP on equipment for applications requiring high performance motion control. The audience for this paper includes manufacturing executives and specifying engineers at industrial enterprises who are seeking to define their future network architecture for equipment within the plant and for the plant as a whole. The audience also includes product managers at automation suppliers who are developing product roadmaps for their network connected products for OEM applications requiring high performance motion control.

KEY WORDS: Motion, Safety, Real-time, Ethernet, OEM, Machine, Producer-Consumer, COTS, Quality-of-Service, QOS, IEEE 1588, IEEE 802, Internet Protocol, Servo, Encoder, Drive, Feedback, PTP, Precision Time Protocol, Safe Motion

The EtherNet/IP Technology – CIP

CIP, short for the "Common Industrial Protocol," is ODVA's network application layer for real-time, industrial automation applications. CIP uses an object-oriented design to provide services and device profiles needed for real-time control applications and to promote consistent implementation of automation functions across a diverse ecosystem of products. At its core, CIP is media-independent but needs media-dependent transport, network, data link and physical layers on which to reside. CIP was first adapted to DeviceNet™ in the early 1990s and then subsequently to ControlNet™, CompoNet™ and EtherNet/IP. Today it has a proven track record in real-time control with tens of millions of CIP-enabled devices installed in the field. As a media-independent protocol, CIP does not inherently rely upon data rate and packet size to optimize network efficiency. Rather it takes advantage of the communication efficiencies possible with producer-consumer networks. Such networks can provide an efficient solution for applications requiring real-time control, including high-performance motion, by making it possible for one message to be produced one time and then consumed simultaneously by many nodes on the network using a technique called multicast communication. The result is a flexible framework for industrial automation applications that supports many communications relationships such as one-to-one, one-to-many and one-to-all, as well as alternative communication hierarchies including master-to-slave, slave-to-multi-master (i.e., shared inputs), target-to-originator and peer-to-peer.

The EtherNet/IP Technology – Ethernet Standards



While other networks have adopted Ethernet data link and physical layer standards, EtherNet/IP stands alone in using both of the most widely deployed collections of Ethernet standards – the Internet Protocol suite and IEEE 802 project – to define the features and functions for its transport, network, data link and physical layers. This approach gives EtherNet/IP significant advantages over other industrial networks, Ethernet and non-Ethernet alike, and protects the user's investment in the EtherNet/IP technology. One way EtherNet/IP protects this investment is by taking continual advantage of the rapid technical advancements and cost reductions possible with widely deployed, commercial-off-the shelf (COTS) technologies. Another way EtherNet/IP protects this investment is by incorporating key elements of Ethernet's standard capabilities and services into the CIP object model framework. A case in point is the adaptation of the User Datagram Protocol, a core member of the Internet Protocol Suite, to transport I/O messages in CIP. Another case in point is the adaption of the message priority levels found in the IEEE 802 project for Quality-of-Service (QoS) to meaningful priorities in a CIP context. The application of these QoS priority levels throughout the entire connection path is referred to as End-to-End QoS. End-to-End QoS plays an important role in the ability to use EtherNet/IP as a single network solution for industrial applications requiring real-time control. It reduces the variability in the delivery of message packets, known as jitter, and delays in their delivery, known as latency, and allows multiple message types – such as control, safety and motion – to share bandwidth on the same network without compromising performance.

The EtherNet/IP Technology – Distinctive Services for Safety and Synchronization

Safety functions are essential to most equipment, due to concerns for operator safety and regulations requiring their implementation. Although historically hardwired and inflexible, today's safety networks have been developed and accepted by industry and regulators. In recent years, a "black channel" concept has been accepted that permits safety messages to be transmitted independently from the underlying network architecture. As a result, safety systems can be integrated on the same network with control systems. EtherNet/IP, with CIP Safety (CIP services for safety functions), can provide the necessary input/output functions needed for standard safety applications, such as perimeter guarding. Additional safe motion capabilities are also available for control of typical motion safety circuits such as emergency stop.

Synchronization is another essential function for a wide range of applications from registration control to multi-axis transfer systems. Hardwired interrupts and purpose-built motion networks are typical in these applications and often result in solutions that are either complex, inflexible or both. However, EtherNet/IP can simultaneously reduce complexity and increase flexibility with CIP Sync™ (CIP services for synchronization). CIP Sync adapts the IEEE 1558 standard, known as the Precision Time Protocol (PTP), to the CIP object-model framework such that all devices enabled with CIP Sync can operate based on a common time base. These devices can be relied upon to perform actions at precisely commanded times, effectively eliminating network performance variations resulting from latency and jitter. Resulting synchronization between devices can be optimized to meet application requirements with the capability of achieving less than 100 nanoseconds device to device time synchronization if necessary.

The EtherNet/IP Technology – A Better Approach for Applications Requiring High Performance Motion

Applications requiring high performance motion need sub-millisecond registration and sub-millimeter axis-to-axis position coordination. Solving these applications without a network dedicated to motion requires a different approach. EtherNet/IP uses a different and better approach – an approach that aligns with business goals of cutting cost, simplifying machine design and maintenance, and increasing flexibility today and tomorrow.

In EtherNet/IP, the approach to these demanding applications uses all of the fundamental building blocks that make up the EtherNet/IP technology and have been explained in the preceding paragraphs – CIP, Ethernet standards, and CIP Distinctive Services including CIP Safety and CIP Sync – plus one more building block: CIP Motion™. CIP Motion combines the producer-consumer model of CIP and the common time base of CIP Sync with parameters and services needed for the application of drives in high performance motion control applications. The resulting objects and device profiles are scalable from high-end multi-axis systems comprised of servo drives to simple half-axis systems consisting of an incremental encoder.

Enabled with CIP Motion, EtherNet/IP can provide users with a single automation network that can combine machine control, safety and high performance motion control

capabilities that achieves manufacturing performance goals without compromises in costs and flexibility. Motion commands in systems with up to 100 axes can all be updated in one millisecond and motion systems can be integrated with other functions from sensors to IT, or even voice and video. For manufacturers, it enables a converged network architecture for plants where Ethernet and standard Ethernet infrastructure can be deployed throughout, including at the machine level.

The EtherNet/IP Technology – Users Make Paradigm Shift with EtherNet/IP and CIP Motion

EtherNet/IP has been successfully deployed in wide-ranging industrial automation applications around the world. With CIP Motion, this success is now being replicated in applications requiring high performance motion control. The result is a paradigm shift in the network architecture for these applications and in the ability of automation systems to help companies meet their business goals. A sample of representative case studies explains how.

Converting equipment supplier, **Curt G. Joa, Inc.**, produces machinery with very high axis counts custom built to the customer's production requirements. Kevin Zeinemann, Joa's Manager of Electrical Engineering, describes Joa's standardizing on EtherNet/IP with CIP Motion as key to offering customers equipment that is not only modular, but also provides high-quality product and more process data. Zeinemann says customer specifications often change while building the equipment, sometimes even at the last minute. "Joa always needs to have control equipment that is modular from both a hardware and software perspective so that we can continue to modify our design and make upgrades in real-time to meet our customers' evolving requirements," Zeinemann said.

Joa's customers also benefit from the ability to improve product quality with Joa equipment, increasing real-time performance made possible by CIP Sync. With CIP Sync, Joa uses EtherNet/IP-enabled high-speed registration and output cams to identify defects on a product and take corrective action in real-time. Due to the data-rich object model that comes as a part of CIP Motion, Joa's customers can also look at more process information over the long term. No longer limited to a few parameters such as position error, torque and speed, Joa customers can monitor many more parameters in real-time on every drive. "Unlike our previous designs, we don't need to keep switching between parameters to poll because we aren't restricted in how much we can query at any one time," Zeinemann said. "As our customers realize what they can do with the data, they ask us to provide more and more because it helps them make better decisions and they have more information about what is going on with their processes."

> "TODAY CIP MOTION SITS ON ETHERNET/IP WITH EVERYTHING ON CIP INCLUDING DRIVES, I/O, HMI AND CONTROLLERS. EVERYTHING IS INTEROPERABLE BECAUSE OF THE CIP OBJECT MODEL FRAMEWORK. IF A CUSTOMER COMES IN DURING THE COMMISSIONING PROCESS AND NEEDS TO ADD 10 DRIVES FOR ANY REASON, IT'S NOT A PROBLEM FOR US TO COMPLY."
>
> KEVIN ZEINEMANN, CURT G. JOA, INC. CONVERTING OEM AND ETHERNET/IP USER

Packaging machinery supplier, **Aagard Group**, builds custom equipment that typically has 20-30 axes of motion with some applications as high as 50 axes. Daren Myren, control engineer for Aagard, reports that, by standardizing on EtherNet/IP with CIP Motion, Aagard has been able to replace three separate networks – one for machine control, one for motion and one for safety – with one single EtherNet/IP network and also to add some more new functionality. Myren states that "with electrical panels distributed throughout our machines, it doesn't make sense to loop multiple networks through every electrical panel. With EtherNet/IP and CIP Motion, Aagard has been able to combine it all into one network plus achieve better motion control." Aagard needs to synchronize many axes across their machines. For example, Aagard offers a flexible pouching system which operates at speeds up to 200 pouches per minute. This requires that the pouch film travel at lines speeds in excess of 600 millimeters per second. CIP Sync is used to capture registration marks imprinted on the film and trigger precise cuts-on-the-fly.

Aagard's customers also are benefitting from machines that get up and running in less time, save operating costs and improve overall production efficiency. Ease of troubleshooting has been another major benefit of Aagard's single EtherNet/IP-based network architecture. Myren remarks that "previously communication problems could take days to isolate and resolve. But with EtherNet/IP, our customers are able to identify in minutes where and when a device drops out." Aagard now can provide more diagnostics and monitoring by integrating a number of other devices onto the same network – such as barcode scanners, cameras, gluing systems and laser printers – without compromising machine performance. Aagard achieves this by using the QoS features that are common to standard Ethernet and EtherNet/IP, noting that today at least 75% of their customers now require run-time data for use in subsequent business analytics. With EtherNet/IP and CIP Motion, Aagard's customers not only have access to a rich set of drive parameters but also to data regarding machine state, machine mode, case counts and product counts.

The EtherNet/IP Technology – Putting It All Together with a Common Set of Values

EtherNet/IP is supported by an ecosystem of over 300 leading automation suppliers who are members of ODVA, the organization that manages the EtherNet/IP technology on behalf of its contributing members. The values that ODVA and its members embrace have helped to create, and continue to help evolve, the overall EtherNet/IP value proposition for users. Core values shared by this ecosystem are:

- To provide best-in-class industrial automation solutions using the EtherNet/IP technology through a comprehensive specification and a diverse range of products provided by a wide range of suppliers;
- To facilitate consistent user experiences with the EtherNet/IP technology through product compliance with ODVA's implementation specifications and product interoperability in multi-vendor systems, as validated by ODVA's vendor-independent conformance testing practice; and
- To maintain a level playing field for all through ODVA's technology management process that results in an open, vendor-independent implementation specification for EtherNet/IP products and in the ability to make, sell and/or use EtherNet/IP products on reasonable and non-discriminatory terms with zero royalties; and

- To protect industry's overall investment in information and communication technologies by leveraging commercial-off-the-shelf technologies and industry standards wherever possible.

Learn More

ODVA knows that, while high performance motion control applications share many common attributes, every application is different. Thus, readers of this paper who want to learn more are encouraged to visit ODVA's website at **www.odva.org** to read more about the technology and products available today on EtherNet/IP and where one can also find a number of technical papers that provide in-depth explanations of the various building blocks for EtherNet/IP and CIP Motion. One can also find papers by subject matter experts on possible future innovations in ODVA technologies.