Whether performed through hydraulic pumps, electric motors or linear actuators, motion control is a vital function of industrial automation. Increase your understanding of the components and how they operate, including lessons from companies just like yours.
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More than 85% of the global population has a cell phone. This means almost six billion phones need access to a radio link to complete a call, send a text or stream a video. Cellular networks that provide these links are composed of individual cell sites or base stations made up of the requisite antenna and equipment that facilitate cellular communication.

CommScope is a major provider of communications network infrastructure, and addresses the growing need for cellular links by producing base stations for all that cell service. The company also produces the coaxial, or coax, cable for its base stations out of its facilities in Suzhou, China. To bring cable manufacturing to the United States, management needed control system upgrades to consolidate production and testing at its North Carolina facility.

Managers wanted to modernize its production line by moving from an outdated Allen-Bradley® PLC-5® solution to an Allen-Bradley ControlLogix® platform. In the process of upgrading, migration solutions helped CommScope slash shipping costs by $6 million and reduce its equipment footprint and installation and maintenance costs.
CommScope produces the coax cable for its base stations out of its facilities in Suzhou, China. During production, spools of a coated inner copper core are pulled through an extruder that applies a layer of plastic insulation. That cable is moved down the line by payoff wheels until it arrives at a welding table, where it’s surrounded by the outer conductive channel, a sheet of copper tape that’s welded around the core. The cable then moves through a corrugater, then into another extruder where the final polymer jacket is applied.

Once production is complete, CommScope ships its products to Mexico for quality testing. After testing, the wire spools are shipped back to the China factory, where they’re cut into 6-foot lengths and incorporated into cellular base stations that are being installed all over Asia.

Choosing the Technology
In early 2012, CommScope managers realized the company could save upward of $6 million per year in shipping costs associated with product testing if it moved production from Suzhou, China to its facility in Claremont, North Carolina.

To make the move, the company needed to upgrade the automation equipment on the home automation production line at its North Carolina facility that produced several types of coaxial, twisted pair and special-order cables. This line didn’t have the necessary extruding or feeder equipment for the new cable. The new machinery would be shipped from the factory in China.

However, a control-system upgrade was needed to allow all existing and new equipment to communicate reliably, and ensure the line could quickly change over to produce a range of cables.

King Lewis, control engineering supervisor at CommScope’s Claremont, North Carolina, facility, upgraded the Allen-Bradley PLC-5 processor to the ControlLogix PAC and programmed it to communicate with existing Allen-Bradley SLC 500 controllers.

Unified Programming Environment
The existing automation line at the North Carolina facility was controlled by a PLC-5 processor running Rockwell Software® RSLogix5™ software (www.rockwellautomation.com/go/rslogix5) with about 300 points of 1771 I/O. The feeder and extruder coming from the Chinese plant used a different automation system and hardware.
Additionally, the two other feeders on the line were run with Allen-Bradley SLC™ 500 controllers and needed to be integrated into the new line control system.

Lewis first looked at using the existing processor on the extruder from the China system, but quickly realized the difficulty with interfacing that processor with hardware on the existing line. Additionally, he would lose the system design features he and his team had come to appreciate with the Rockwell Automation control system at the North Carolina facility.

“If we switched to a new programming environment, not only would we have to start our coding from scratch, but we’d lose the features that make our current system so easy to use,” Lewis says.

“I couldn’t ask my team to go back to creating I/O map addresses using bit tables. The ability to design and manage address allocation with meaningful tag-based aliases is important. Plus, I never had to take a class to learn how to use programming software. It’s intuitive,” he explains.

Powerful Migration Tools
Committed to keeping his preferred control and design environment, Lewis began working with Rockwell Automation in mid-April 2012 to develop a migration plan. Step one was to document his current system and define the requirements he needed for his new system. The team decided to transition to Allen-Bradley ControlLogix 5571 programmable automation controllers (PACs, www.rockwellautomation.com/go/tjcontrollogix) on EtherNet/IP™ for line control.

From here, the remaining system parts were selected in less than an hour by using the Rockwell Automation Integrated Architecture® Builder (IAB, www.rockwellautomation.com/go/iab). Lewis uploaded an AutoCAD drawing of the existing system into the tool, and it produced a list of all the new part numbers needed to migrate.

The new system included Allen-Bradley Bulletin 1492™ I/O Wiring Conversion System interface modules (www.rockwellautomation.com/go/1492) and cables that connect through prewired cables to existing digital and analog I/O. This allowed Lewis to integrate control, motion and safety functions, and easily communicate with legacy processors and new third-party components. Doing so helps keep costs and risks low by allowing Lewis to use much of his existing I/O investment.

In the next phase of the migration plan, the RSLogix 5000 design and configuration software (www.rockwellautomation.com/go/v20), with its embedded conversion utility, automatically converted about 80% of the programming code. This saved CommScope time and engineering resources, and reduced the risk of human error.

After the code was converted and tested, Lewis upgraded the PLC-5 processor to the ControlLogix PAC and programmed the new PAC to communicate with the three uptakes controlled by the SLC 500 processor.
More than 150 points of 1771 I/O were converted using the 1492 I/O Wiring Conversion System. The existing in-chassis 1771 I/O swing arms fit onto new interface modules directly.

Because the I/O conversion was accomplished without the removal of any field wires from the existing swing arm, risk of wiring errors was greatly reduced. Next, for the distributed I/O, Lewis used the Allen-Bradley FLEX™ I/O adapter module (www.rockwellautomation.com/go/tjflex) to migrate all 32 points of I/O for existing line drives from hard wire to EtherNet/IP.

It took only two hours to exchange the PACs. After two days of verification, the line was up and running. The CommScope plant only endured a few days of planned downtime throughout the whole phased migration process.

The smooth, safe transition also gave Lewis and his team several months to run the upgraded line and make sure everything was in order before new equipment arrived from China.

When the new feeder and extruder equipment arrived in July, Lewis connected the new equipment to the ControlLogix system on EtherNet/IP simply by sliding a fieldbus interface card into the controller chassis.


Production on the new coax cable line started in August — just four months after the migration began.

Reducing Transition Risk

“I didn’t know how long this transition would take when we first started the project, but going from mechanical drawings to product in just four months with only a few days of downtime was faster than I thought it could be done,” Lewis says. “The Rockwell Automation migration tools obviously helped make the process relatively fast and painless.”

To stay competitive, CommScope needs the ability to produce multiple types of cables. This requires precision and flexibility as lines change over frequently. Lewis explains, “Our sister plants and competitors overseas can run single cables for a long period of time at low costs to the customer. We have to keep our plant up to date, so we can push product through more quickly and maintain the best quality.

“This system migration not only allowed us to produce a new cable, saving more than $6 million in shipping costs annually, but it also improves production on the other five to 10 types of cable we make on this same line,” he says.

When Lewis first began working at CommScope, the North Carolina facility was controlled only by Allen-Bradley PLC-5 controllers and 1771 I/O. After the migration, the facility uses ControlLogix PACs, 1756 in chassis IO and FLEX I/O on EtherNet/IP.

“These new products allow us to shrink our equipment footprint, move equipment around and cut installation and maintenance costs,” adds Lewis. “Using EtherNet/IP means we don’t have to deal with gateways and can more easily share information throughout the company. We’ve removed pushbuttons and added functionality. And all the migration support and tools from Rockwell Automation reduced the risk of our transition.”

Rockwell Automation Integrated Architecture
www.rockwellautomation.com/go/tj10ia
Nook Industries provides a complete line of linear motion products, serving a wide range of industries. Paring traditional and proven design with the latest technology, Nook Industries manufactures products that customers value.

Our easily accessible 2D/3D library of fully configured linear motion parts and systems has exceeded customer expectation for more than 20 years. Our valued customers have seen benefits including:

- Quicker design times
- Simple design to quote process
- Form and Fit verification
- Motion simulation capability

Click the video below or click on the links to the right to explore Nook’s 2D/3D capabilities!

Nook Industries' SolidWorks Tutorial
The linear motor has come of age in recent years through a dramatic increase in practical and beneficial industrial applications. It’s often described simply as a rotary motor that has been rolled out flat, and the principles of operation are the same. In this article, we examine a sample application that demonstrates a tubular linear motor as a cost-effective and energy-efficient alternative to a pneumatic cylinder.

Cost of Air
Numerous studies have shown the energy efficiency of pneumatics ranges from 5% to 40%. The wide range can be attributed to this simple fact: The more air lines, fittings and connection points, the more chances to increase inefficiency. Because of the low product cost and the familiarity of many plant personnel with pneumatic components, it’s easy to add air to any

HOW DO TUBULAR LINEAR MOTORS WORK?

We examine a sample scenario to illustrate costs associated with a pneumatic cylinder compared to a tubular linear motor system in a practical application.

By Peter Zafiro, General Manager, LinMot USA, Inc.
operation. Running air components can increase fixed costs in terms of electricity bills, adding thousands of dollars per month, especially in larger plants.

Is there a better way? Often, in many actuator applications, there is.

Let’s consider a simple pick-and-place application (see Figure 1): a 30-lb. load, 16-in. stroke, 30 cycles per minute.

Achieving this cycle rate with a maximum speed of 40 in./sec. requires a piston diameter of 2 in. The pneumatic system requires compressed air throughout the entire motion. In addition, the kinetic energy from braking must be absorbed by the dampers. What is the cost of operating this axis?

Based on the cylinder volume and cycle time, the annual air consumption at 6 bar is 200,000 cubic yards. At $0.025 per cubic yard, air operating costs has an operating cost of about $5,000 per year.

Tubular Linear Motors

A tubular linear motor is a type of linear electric motor with a forcer consisting of a series of tubular coils wrapped around a rod that contains a number of strong cylindrical permanent magnets aligned in alternating and opposing directions. Tubular linear motors are used in applications requiring linear actuators with performance that typically can’t be met by other forms of linear actuators, such as pneumatic cylinders or lead screw linear actuators.

Let’s look at the previous pick-and-place example and how a tubular linear motor system would likely tackle it.

The required acceleration rate of 400 in./sec/sec (this is an acceleration rate that is given in inches/sec/sec) is achievable easily and well below the maximum capacity. The motor does most of its work during the acceleration to achieve the top speed. Motor losses occur in the rest of the cycle only because of any constant friction present. In fact, during the braking portion of the cycle, the kinetic energy from the motor is converted into electrical energy and stored in the servo controller, available for use in the next cycle.
The position of a linear motor is constantly controlled and monitored.

This task can be accomplished with less than 100W of power consumption. The annual energy costs are less than $100 per year to operate this pick-and-place application. Within one year and using just one pick-and-place axis that cycles once every 2 seconds, the plant manager has saved $4,900 in air operating costs.

Flexibility Allows Options

Saving money is one thing, but what about the ability to do much more with a programmable servo system? Unlike pneumatic cylinders in which only two positions are provided, the position of a linear motor is constantly controlled and monitored. This provides complete control of the motion axis at all times, meaning even minor deviations can be corrected when needed.

In addition, the linear motor servo controller can provide time curves. Typically, 100 time curves can be stored with up to 16,000 individual waypoints and a 32-bit resolution. The positions can be a sinusoidal motion, such as to optimize power loss, or they can be special reverse optimized motion profiles.

Set-point streaming can be accomplished over EtherNet/IP™ using up to 32-bit resolution. Command tables can be executed with up to 255 individual motion commands. The ability to close the control loop yields up to 12-bit resolution analog force control (see Figure 2).

It’s good to have the ability to set your move distance from point A to point B. However, providing your plant the flexibility to know where your pick and place axis is, knowing what force is being used to move your load, and optimizing your move profiles lead to a whole new world of possibilities.

LinMot USA, Inc. is a participating Encompass™ Product Partner in the Rockwell Automation PartnerNetwork™. Based in Elkhorn, Wisconsin, LinMot USA is part of the global LinMot/NTI AG family of products. The company manufactures high-performance linear motors and linear motor systems, focusing on the development, production and sale of linear direct drives for industrial use.

LinMot USA, Inc.
www.rockwellautomation.com/go/linmot

Rockwell Automation Encompass Product Partner Program
www.rockwellautomation.com/go/tjencompass

Figure 2. With a linear motor, wet-point streaming can be accomplished over EtherNet/IP using up to 32-bit resolution. The ability to close the control loop yields up to 12-bit resolution analog force control.
A CLOSER LOOK AT LINEAR DISPLACEMENT TRANSUDERS

Learn the basics of how these magnetostrictive sensors work, styles available, and the appropriate design for the application.

By Blake Cawley, Business Development Manager, Factory Automation, AMETEK Automation & Process Technologies

The need for automation is greater today than ever before. Linear Displacement Transducers (LDT) play an important role in factory automation. They provide accurate, reliable, absolute position feedback to help automate sophisticated machinery. Sensors must deliver value, be easy to set up and interface easily into the host controller.

A host of linear automation solutions can provide accurate feedback of continuous position to improve productivity and efficiency. LDTs use advanced magnetostrictive technology to provide precise and absolute non-contact position feedback down to 1 micron resolution. These sensors can be packaged to survive in the most demanding and hostile environments. The position of the magnet on the sensing element is precisely determined by a time-of-flight method.

Magnetostrictive Technology Made Easy

Magnetostrictive technology isn’t new, nor is it rocket science. It’s a rugged technology for accurate and repeatable measurement of linear movement. In fact, the physical principles that make it work are the same principles that make motors and generators run.

Basically, in the head of the LDT, circuitry generates a current pulse that’s sent down a special ferromagnetic (magnetostrictive) wire inside the sensor’s protective tube or extrusion (see Figure 1). On the outside of the tube is a moveable target — a magnet. When the pulse interacts with the magnetic field, it generates a torsional twist that travels along the magnetostrictive wire at a fixed rate of speed.

The movable magnet’s position is determined with precision by measuring the time between the launch of the current pulse and the arrival of the torsional strain pulse. The result is highly accurate noncontact position sensing with no wear on the sensing element.

Serial Synchronous Serial Interface Sensors

Many linear automation solutions can provide accurate feedback of continuous position to improve productivity and efficiency. The traditional, preferred approach typically uses analog signal feedback back into an analog input module or drive. However, analog signals are limited by resolution of both the sensor and input module; signals are prone to degradation over long cable runs; and each axis needs its own dedicated cable.

To overcome the shortcomings of traditional analog sensors, users often turn to Serial Synchronous Serial Interface (SSI) sensors. SSI LDTs can provide a serial-clocked output of binary or Gray code positional data with 1 micron resolution, regardless of stroke length of
the sensor or cable run. The displacement value (position) is encoded into a 24-, 25- or 26-bit format and transmitted at high speeds.

Synchronization in a closed loop system is made easy. A clock-pulse train from a controller is used to shift out sensor data: One bit of position data is transmitted to the controller for one clock pulse received by the sensor. The absolute position data is updated continually by the sensor and converted by the shift register into serial information. SSI LDTs can interface seamlessly with the 1756M02AS or any Rockwell Automation programmable controller that can talk SSI.

A disadvantage of these modules is that they typically can’t take in more than two axis per module. They also require their own cable for each axis.

**Network LDTs**

The latest technology is EtherNet/IP™ network LDTs, which use magnetostrictive technology to provide absolute noncontact feedback and resolution to 1 micron. The network LDT provides maximum flexibility for installation and ease of use in demanding, high-performance, networked industrial applications. This is useful in instances when the desired resolution isn’t achievable using an analog device. Additionally, sometimes the user wants to update analog machinery, particularly when he has other EtherNet/IP devices on his machines, so continuous position, motion and velocity monitoring of equipment can be incorporated into the control system process via the network.

EtherNet/IP is an industrial Ethernet implementation of the Common Industrial Protocol (CIP™), managed by ODVA (www.odva.org). EtherNet/IP is the most developed, proven and complete industrial Ethernet network solution available for manufacturing automation. EtherNet/IP systems require only a single-point network connection for both configuration and control, thus simplifying installation and wiring.
Choosing the Best LDT Style
LDTs typically are available in two package styles: the traditional rod style package that is suitable for installation into hydraulic cylinders, and the profile style package that incorporates similar electronics, but is housed in aluminum extrusion housing for ease of mounting.

Your application or industry will dictate which style is best suited for you. Typical applications include:

- Steel mills.
- Hydraulic and pneumatic cylinders (see Figure 2).
- Lumber mills.
- Hydro power.
- Pulp and paper.
- Tire and rubber.
- Stamping.
- Plastic injection molding.
- Any application in which a machine is moving in a linear motion that requires feedback to automate the machine.

More Intelligent Sensors
Over the past decade, linear sensors have become smarter. Many models now can be field configurable for output type, zero position, counting direction, position and velocity format, and resolution. Some of the more sophisticated sensors can even support wide-ranging power supplies (7VDC to 30VDC), so the same unit can be used in stationary or mobile applications. The wide-ranging power supplies also help make the linear transducers backward-compatible with the older generations, which needed a +/- 15V bipolar supply.

Diagnostic LEDs were added to the linear sensors years ago to help diagnose and aid in troubleshooting. Standardized cables (12 mm Euro Style cordsets) typically are available as an option from all suppliers. This can help to reduce the installed cost and make cables more readily available from a host of suppliers.

Automatic gain, commonly referred to as AGC, was introduced years ago as a means to help compensate for the different-style magnets that can be found in hydraulic cylinders. On power-up, most of these smart sensors can measure the strength of the magnet and automatically adjusts its internal signal lengths to match that of the user’s installed magnet. This is beneficial in hydraulic cylinder applications when the magnet installed in the cylinder might be a different brand (strength) that that of the sensor.

Figure 2. Typical applications for LDTs include steel mills, lumber mills, pulp and paper plants, plastic injection molding and stamping. This LDT is mounted in a protective housing on a large hydraulic cylinder.

AMETEK Automation & Process Technologies, based in Clawson, Michigan, is a participating Encompass™ Product Partner in the Rockwell Automation PartnerNetwork™. The company provides linear, rotary and level measurement technology. AMETEK has more than 120 manufacturing locations around the world, supported by more than 100 sales and service locations across the United States and in 30 other countries.

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Automation solutions require accurate feedback of continuous position regardless of the application environment. Analog position sensing devices can have shortcomings in automation applications, including limited features, resolution and cable lengths. That's why the *ReadyLink* Linear Displacement Transducer is a far better solution. Feature for feature, it lets you do—and measure—so much more.

**Introducing the *ReadyLink*™ Network LDT**

- **What to do when analog won’t do.**
- **Supports Star, Line or DLR topology**
- **Magnetostrictive noncontact technology; resolution to 1 micron**
- **Three standard M12 connectors — 1 power, 2 communications**
- **Set IP address from network PC or the last octet via the RapidRecall DIP switches**
- **Five status LEDs monitor LDT and network status**
- **Status bits warn of position/velocity outside of programmed range**
- **Built-in web pages for easy configuration**
- **Wide input power supply range (7–30V) may reduce external power supply requirements**

Learn more about this smart device technology at ametekfactoryautomation.com.
New Zealand boasts a world class dairy industry with annual exports in excess of NZ$11 billion (USD 9.3 billion). This can be attributed largely to technological advances in both farming practices and manufacturing techniques. The key strengths of New Zealand’s dairy industry include its all-grass farming system, large-scale processing and high levels of research and development. With a reputation for providing clean, safe products that comply with rigorous health and safety standards, the New Zealand dairy industry is projected to benefit from continued growth and productivity for many years.

Cheese production is one of the most complex in the dairy industry, involving a variety of processes to achieve the final product. Recent years have seen a substantial increase in premium, internationally renowned specialty cheese products manufactured in New Zealand. Automating processes in cheese manufacture can improve productivity of the manufacturing plant to help meet increasing demand.

It’s All in the Design
Accurate control and customization of the manufacturing processes is necessary for optimal large-scale, quality cheese production. Designing manufacturing processes to produce consistent product characteristics that meet customer’s expectations depends on the skills of a team of engineers and technologists. Advances in process and motion control technology has allowed processes that were historically manually operated to be automated, thus improving efficiency and safety.

When an international cheese manufacturer decided to automate its cheese slicing processes, its leaders called on machine builder Cheese Solutions New Zealand Ltd (CSL) to design a system. CSL used the design capabilities of long-standing system integration partner Integrated Automation Ltd (IAL) to develop a solution.

Advances in motion control technology allow cheese slicing to be taken to a whole new level. The project requirement was to take an industry-standard block of cheese and slice it to specified dimensions and weight.
When looking for products on the market that could achieve this, Integrated Automation Ltd decided to use the programmable control capabilities of the Allen-Bradley® ControlLogix® from Rockwell Automation.

**Timing is Everything**

The challenge was to provide the customer with a complete natural cheese-slicing production line that could take a 20-kg block of cheese, pass it through a number of machines to break it down into smaller logs, and then slice the logs into the end product — a slice of cheese that is 90 mm by 90 mm by 2.5 mm thick. The crux of the solution lies in providing precise, high-speed synchronized motion control.

An important part of this is having accurate control of the portioning process so the product is cut accurately with minimal waste. “While the rest of this plant utilizes product solutions from Rockwell Automation, this new machine required additional motion control capabilities,” says Stephen Cotter, Solutions Architect – Motion Control, Rockwell Automation.

To deliver precise motion control, this solution used the new ControlLogix L73 processor that has faster processing capabilities and improved motion control. “It’s certainly the processor that will do the job because it’s up to speed to control the motion at the cheese-slicing business side,” Cotter explains.

Precise motion control and timing is critical to the success of this application. The log of cheese has to be indexed precisely because the slicing is performed with a rotating knife. Coordinating cheese movement with the rotating blade is critical. There is a finite period when the blade isn’t present during which the cheese moves forward. The speed at which the cheese must move is dependent on the density, weight and size of slice required.
To achieve this, ControlLogix required sample code with a particular CAM profile that was developed by the Rockwell Automation OEM team in Singapore. ControlLogix provided the single control platform with RSLogix™ 5000 design and configuration software.

**Cheese Slicing Precision**

“In addition to the advanced control capabilities required, building this machine also required a comprehensive mechanical design to ensure the machine’s mechatronic system is reliable enough to carry out the tasks of slicing the product,” says Donovan Ryan, director, IAL. “There was no other choice but to go with the new ControlLogix L73 processor in this high-speed motion application, where every millisecond was critical.”

Safety considerations were paramount in this solution. The mechanical design of the cheese-slicing machine provided that the rotating blade was protected from operator access at all times. The maintenance requirements were found to be minimal because the engineers already were familiar with the Logix technology.

The cheese slicer provided the customer with the flexibility to adjust the thickness of the cheese automatically. By checking the weight, the slice thickness can be adjusted automatically by changing the CAM profile to account for the density of the cheese. “This solution provided the customer with the ability to accurately perform to the required velocity with the ease of integration using RSLogix 5000 motion control commands,” Cotter says.

As consumer demand rises, automation and process technology is being used to increase productivity in the cheese industry. The benefits of automating the cheese manufacturing plant extend beyond the amount of product on the supermarket shelf. Establishing clean, efficient and automated processes minimizes waste of natural resources while providing industry with a way to meet increasing customer demands for quality dairy products.
Machine builders are enjoying a new level of machine design flexibility with a single network for their entire machine, including VFD and servo drives for integrated motion control. That’s because advancements to EtherNet/IP™ enable it to deliver the speed, sophistication and precision that motion control applications demand. This eliminates the need for a dedicated motion network and provides a simplified network solution.

The game changer occurred when ODVA (www.odva.org) extended the CIP™ (Common Industrial Protocol) network specifications to include CIP Motion™ technology. Built on the CIP, EtherNet/IP uses a single version of Ethernet to handle a variety of applications, ultimately helping users manage real-time control and information flow throughout manufacturing and the enterprise.

Unlike some Ethernet-based networks, EtherNet/IP uses the same Ethernet and TCP/IP standards as e-mail, the Internet and many other popular commercial and business protocols, without modification. By using standard Ethernet and TCP/IP, EtherNet/IP users can seamlessly connect machines and their motion applications to their production and business enterprise.

In addition, EtherNet/IP enables machine builders (OEMs) and their customers to take advantage of commercial and business technologies ranging from products such as routers, switches and cameras to capabilities such as voice, video and telephony. Machine builders also can offer manufacturers value-added services by adding secure remote access through their customer’s standard business infrastructure.

Enhanced Connectivity
Over the years, the need for different networks has disappeared as machine builders rapidly expanded Ethernet’s usage to include most, if not all, of the space occupied by traditional fieldbusses. This began with information systems, led to I/O control and safety and now has extended to include integrated motion control. To address motion control, ODVA added CIP Motion and CIP Sync™ technologies to the CIP network specification.

CIP Sync is a time synchronization extension to CIP, based on and fully compliant with the IEEE-1588 Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems. It provides increased control coordination needed for demanding events sequencing, distributed motion control and other highly distributed applications in which absolute time synchronization of devices is vital. Users can achieve synchronization down to 100 ns using unmodified, standard Ethernet hardware.
Meanwhile, CIP Motion provides deterministic, real-time, closed-loop motion control over the standard, unmodified Ethernet of EtherNet/IP. Multiple axes can be coordinated for precise, coordinated motion control applications.

CIP Motion’s use of time-stamped data and its simple timing model eliminates any hard synchronization constraints between the drive and controller. Real-time data values are adjusted at the end device when data is applied, so there’s no need to hard schedule the network traffic. CIP Motion delivers an open, high bandwidth, high performance solution for multi-axis, distributed motion control.

Common Platform and Tighter Integration
In addition to connectivity, using a single EtherNet/IP network creates a common platform for a machine’s configuration, programming, commissioning, diagnostics and maintenance. This helps OEMs to coordinate precisely the control of multiple axes for both VFD and servo drives.

In turn, this provides tighter integration while giving machine builders the simplified architecture needed to streamline design and development. They can meet all of their machine’s control and information needs, connect to the user’s infrastructure and provide secure remote access for value-added monitoring.

No Topology Limitations
Many other networks fall short because of network topology limitations. However, an EtherNet/IP network with EtherNet/IP drive hardware in place allows machine builders to deploy any Ethernet topology. In addition, many EtherNet/IP products include embedded dual-port switch support for implementing a linear (daisy chain), reducing the needs for additional hardware.

DLR delivers the resiliency needed for high-speed, high-performance applications. When a DLR detects a break in the ring, it executes alternate data routing to help recover the network at extremely fast speeds — less than 3 ms for a 50-node DLR. That means the machine continues operating without interruption. In addition, diagnostics information is provided to pinpoint the failure’s location for quick recovery.

Regardless of topology, a standard EtherNet/IP network now allows VFD and servo drives to integrate seamlessly with the rest of the plant’s existing infrastructure, as well as other devices, from distributed I/O and smart actuators to overload relays, and robotic and vision systems.

Integrated Motion Gains Momentum
Bringing servo and VFD drives together on the same network gives integrated motion applications a broader power range, from 0.1 to 2,000 hp, along with a wider range of device options. Machine builders can integrate servo devices with other commonly networked devices such as VFDs, I/O, valve manifolds, weigh scales, temperature controllers, vision, robotics and HMIs. This gives OEMs a common programming, configuration and commissioning environment for all motor control technologies.

In addition to using a single network, integrated motion on EtherNet/IP supports drive configuration,

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**VFD and Servo Drives on a Single Network**

Thanks to motion control advancements to standard networking technology, machine builders now can unite both VFD and servo drive technologies on a standard, unmodified network.

For example, the Allen-Bradley® Kinetix® 6500 servo drive ([www.ab.com/motion/servodrives/kinetix6500.html](http://www.ab.com/motion/servodrives/kinetix6500.html)) and the PowerFlex® 755 AC drive ([www.rockwellautomation.com/go/tjpf755](http://www.rockwellautomation.com/go/tjpf755)) from Rockwell Automation offer integrated motion capabilities on EtherNet/IP.

These products offer high-performance, closed-and open-loop drive control using standard Ethernet and IP technology.

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programming, commissioning, diagnostics and maintenance using a single software package.

To implement an EtherNet/IP-based motion application, machine builders follow familiar steps for both VFD and servo drives. Users start by picking the best hardware and network topology for their application, and then configure, program and commission the drive and application for production.

Convenient Configuration
Integrating motion capabilities on EtherNet/IP streamlines configuration. It’s a simple matter of entering the catalog numbers of the drive, motor and actuator. All of the device configuration parameters are automatically set based on catalog number and mode of operation selections. In most cases, default parameters result in optimal machine operation, and no further actions are required.

However, users can customize configuration parameters using integrated commissioning tools such as auto tune and manual tune. The configuration parameters and firmware revision are downloaded automatically to devices on power-up and anytime a device is replaced.

Advanced Programming Support
One of the major benefits of EtherNet/IP integration of VFD and servo drives is access to a common, extensive range of motion functions. Support for pt-pt moves, multi-axis gearing, position/velocity camming (PCAM), multi-axis interpolation and kinematics is common for both drives.

It’s now easier to program and execute high-level position functions such as PCAMing multiple VFD and servo drives with complex registration-phase correction algorithms to a common virtual machine master. The motion functions are supported in multiple languages like ladder, structure text (ST) and sequential function chart (SFC).

Reusable code objects, called Add-On Instructions (AOIs), are another new, sharable resource. Designed to help ease reuse, reduce project development time and improve consistency, AOIs allow machine builders to encapsulate commonly used logic as sets of reusable instructions.

More Maintainable Machines
Reducing the number of networks helps ease machine maintenance because EtherNet/IP provides more powerful diagnostics and troubleshooting capabilities. For example, if a single drive faults, an EtherNet/IP-based application using a software package such as Studio 5000 from Rockwell Automation can identify the problem drive and gather comprehensive information about the error. It then relays the data to the maintenance team.

Meanwhile, the software program time-stamps and logs detailed alarm, fault and status information, providing precise drive-speed and position regulation. This helps manufacturers better understand the status of a machine’s controllers, motors, actuators and other automation devices.

Smart Machines, More Power
EtherNet/IP also gives machine builders access to other intelligent features. For example, many Ethernet/IP devices and drives offer embedded Web pages to provide high-speed access to critical drive data. Operators can monitor real-time performance, safety and network data, as well as alarm and fault history, lost packets and power peaks.

This real-time information, along with remote access capabilities, helps keep machines running. EtherNet/IP enables machines to relay the condition data back to the machine builder, who can then provide secure, remote diagnostics for a machine.

Bringing commonality to the network architecture helps machine builders cut costs and complexity while taking integration to the next level for higher-performance, more flexible machines.

Rockwell Automation Integrated Motion on EtherNet/IP
www.rockwellautomation.com/go/prmotion

Rockwell Automation Integrated Motion Solutions
www.rockwellautomation.com/go/tjmotion
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video
When designing any electromechanical system, it’s important that all components are properly sized so as not to negatively impact the functionality and the cost of the system. When sizing motors for ball screws and ball screw actuators, problems arise when calculations aren’t accurate. It’s critical to allow for adequate torque that results from drag when using a preloaded ball screw and when ball nut wipers are used, because it can have significant effects on motor and drive size.

Preload in ball screws can increase the accuracy, repeatability and overall stiffness of the mechanical system, while utilization of ball nut wipers can help keep contamination from entering the nut. The benefits of both preload and seals make them ideal for many applications.

Why Improper Sizing Is a Problem
The internal pre-stress of a preloaded ball screw provides a unique situation where, if not properly accounted for, can yield undesirable results. Proper sizing and selection of a motor for equipment is crucial to ensuring equipment performance, reliability and overall cost-efficiency. Too large of a motor and drive can lead to higher cost of ownership, which may not be ideal in today’s sustainability conscious times. Too small of a motor and drive can leave a nonfunctioning motor and a drive that is faulted on current or following error.

Preload drag is a function of screw lead (Ph), ball circle diameter (BCD), Preload force (Fpr = Dynamic Capacity *preload percent), slenderness ratio (S ratio) and allowance for variation per ISO 3408 E12 for screw classification. Seal drag can add an average of two times the calculated preload drag torque.

If the system isn’t fashioned with a preloaded ball screw, but does use ball nut wipers, up to 0.4Nm needs to be added to the calculations.

Using Motion Analyzer software from Rockwell Automation, it’s possible to properly size motors for
ball screws and ball screw actuators. This comprehensive motion-application sizing tool allows for quick sizing, design and validation new machine concepts.

How to Correctly Apply Preload and Drag Torque to Motion Analyzer

In this example of how to correctly size motors, a 40x10 preload ball screw is used where:

- Preload: 5%
- Dynamic Capacity = 56770 N
- External Application Load: 45000 N
- Screw length = 2,300 mm
- Ph = 10mm lead BCD = 40 mm
- Lead Angle $\beta$ = 4.54 degrees
- Preload Drag Torque $T_p = 0.81 Nm$
- S Ratio: $2300/40 = 57.5$, $T_p$ variation = +/- 40%
- $T_p$ variation = 0.4806 Nm to 1.12 Nm

$$T_p = \frac{0.05 \times F_{pr} \times P_h}{\tan \beta \times \frac{2\pi}{\pi \times B.C.D.}} \times 10^{-3}$$

Where $P_h = \tan^{-1} \left( \frac{P_h}{\pi \times B.C.D.} \right)$

Click here for a preload drag torque calculator: [www.nookindustries.com/EngineeringTool/Index#PMBSTorqueCalc](http://www.nookindustries.com/EngineeringTool/Index#PMBSTorqueCalc).

Figure 1. Motion Analyzer software from Rockwell Automation can help select the right motor for a ball screw like the one shown here. Enter combined values for drag from preload and/or from seals into the “Preload” section of the “Mechanism” tab.
Motion Analyzer software can help select the right motor for a ball screw like this. Enter combined values for drag from preload and/or from seals into the “Preload” section of the “Mechanism” tab. Note: Nook industries has teamed with Rockwell Automation to have selectable Nook ball screw products in the newest version of Motion Analyzer. By simply selecting the appropriate Nook ball screw in the mechanism section, the user can bypass the aforementioned hand calculations.

Results With and Without Calculating Total Drag Torque
There’s a significant and potentially costly difference when adding preload drag and seal drag torque to Motion Analyzer. Forgetting to add the total drag torque, Motion Analyzer will give the result that a MPL-A4560F or MPL-A560F servo motor is sufficient for the example given. As discussed, this would be a mistake that results in undersizing the motor and having an underperforming system.

However, when correctly adding preload torque and additional wiper torque and allowing for the required torque variation along the screw, Motion Analyzer would not yield an MPL motor. The recommended motor would be a MPM-A2154C or MPM-A2154E servo motor.

Benefits of Properly Sizing Motors for Ball Screws
The benefits of properly sizing motors for ball screws speak for themselves. Not allowing for adequate torque from drag when preload applies and when ball nut wipers are used can have significant effects on motor and drive size.

It has been said that, “genius is the ability to evade work by doing something right the first time.” In the example, choosing the correct motor results in an up-front cost increase; however, this pales in comparison to the costs of replacing an incorrect motor and drive. Lost project time, shipping costs and return fees can set any project behind and cut into profitability.

By simply remembering to calculate and add in the total drag torque value, costly mistakes that lead to poor system performance and lost time can be avoided easily.

Nook Industries, Inc., is a participating Encompass™ Product Partner in the Rockwell Automation Partner-Network™. Based in Cleveland, Ohio, the company manufactures precision ball screws, actuator systems and linear guidance.

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