

Integrated Motion Control in Packaging Machines Delivers Value



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Introduction

Over the past few years, packaging has become a source of competitive differentiation for many companies, offering everything from food products, office products, and consumer products, which all require packaging. Packages have developed from being merely ways to deliver a product to being part of the product itself. Ideas such as the “Fridge-Door-Fit” ketchup bottles to milk cartons that stack better for decreased shipping costs have changed the way we view packaging.

The explosion of new products and increasing customer expectations requires OEMs to provide better flexibility, openness, and performance for their manufacturing and production customers. Maximizing machine productivity and performance is imperative to success and is driving OEMs to adopt and invest in the latest technologies that can meet their customers’ challenges.

At the forefront of these performance-driven technologies is an integrated control system, called a programmable automation controller (PAC), and latest generation motion solutions. PACs provide easy integration for multi-domain functionality such as motion control, process control, logic control and HMI—enabling the operational excellence that allows companies to become more productive and more efficient. PACs with integrated motion control can especially benefit applications in the packaging industry that require high-performance multi-axis motion control.

This white paper discusses the background and recent trends that have led to the need for integrated motion control in packaging machines and how they deliver value in their applications.

The packaging industry drives innovation in automation

Consumer desire can be a fickle target to satisfy, so companies rely on an endless variety of new product introductions of manufactured goods and multiple line extensions to fuel interest. Strolling through a typical supermarket reflects this reality, for example, with six different versions of the same brand of cheese on the shelf: 1 kilo block, ½ kilo block, shredded, cubed, and a two-flavor mix.

Likewise, there may be five different sizes for the same flavor of pretzels: school snack pack, 100-calorie pack, 20 ounce, 32 ounce, and family size packaging. Shelf life is much shorter as products come in and out of vogue, and stores are continually restocking their shelves to meet consumers’ demands for new offerings. This explosion of SKUs requires packaging machinery manufacturers to have more flexibility, speed, and innovation in their machines to keep up.

OEMs and end users are driving a major shift in automation solutions to adapt to these trends. In the past, end users would choose to standardize on a given automation platform and specify to OEMs what control platform they should use, even if it did not allow the level of performance, openness and flexibility to maximize productivity. The primary reason was to reduce the learning curve for their engineers and to leverage their existing expertise and intellectual property on a particular system.

However, to keep pace with the growing demand for increased productivity and product variability, more end users are allowing OEMs to select a control platform that maximizes productivity by leveraging the highest degree of innovation and latest technology. To maximize asset utilization, end users must have the ability to run more products on the same line and at increasing production speeds. This flexibility to handle frequent line changes and increase machine or line throughput is raising the bar on performance for new machine designs.

Packaging machines represent the largest application of general motion control systems; greater than 20% of general motion control systems go into some sort of packaging application with form/fill/seal equipment most widely used, and labeling and coding machines recording the highest growth in recent years. OEMs of packaging equipment are leading with performance-driven solutions that enable a higher level of flexibility, accuracy and speed. They are seeking to deliver automation systems that can handle faster product turnover, greater variability, and shorter production runs while delivering increased product quality—driving much of the innovation in automation for all industries.

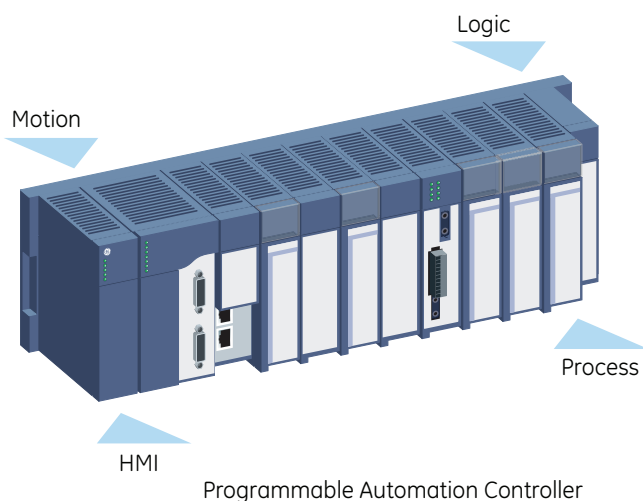
The marketplace shift toward PACs and integrated motion control

As productivity and time-to-market have become more critical to end users, integrating disparate plant floor packaging and production equipment, and networking them to operations and enterprise-level systems as a way to improve productivity has led to greater demand for integrated control systems such as PACs and ever-increasing motion control performance and flexibility. Furthermore, the integration of systems such as HMI/SCADA, process data collection, and overall enterprise data connectivity is all becoming critical for end users in our information-driven world.

While a PAC's form factor can be similar to that of a traditional PLC, a PAC's capabilities are far more comprehensive. PACs are multi-functional controller platforms that encompass various technologies and products that users can implement as needed. It can include motion control, process control, logic control, and HMI—enabling true convergence. Since their introduction in 2003, PACs have become attractive to end users because they can greatly reduce the total cost of ownership.

Key PAC features include:

- A single integrated, multi-discipline development environment
- Common tag names and a single tag database for access by all functions
- An open architecture for interoperability with other suppliers' solutions based on interface standards such as TCP/IP, OPC and XML, and open communication standards such as Ethernet/IP, Profibus and CAN



Easy integration of multi-domain functionality in one controller

Motion control can be easily integrated into the overall PAC package. The latest generation of motion control tightly coupled with a PAC controller, such as GE Intelligent Platforms' PACMotion* and PACSystems* RX3i, can provide significant customer benefits, including:

- Improved machine productivity
- Increased engineering efficiency
- Enhanced machine flexibility and modularity

Improved machine productivity

In a recent study done by DDR Communications of Chicago, Illinois, the single greatest decision criteria for end users purchasing packaging machines was high productivity—which they were willing to pay an up-charge for—followed by greater throughput. There are three major ways to increase productivity:

- Increase throughput
- Improve production yield (reduce scrap)
- Increase machine availability

Increasing throughput in the control systems of a machine comes down to being able to process the many inputs and outputs more efficiently. PACs integrated with motion controllers can use a very high speed backplane and real-time data exchange techniques to provide tighter synchronization of multi-axis motion and between motion and logic events. GE's PACMotion, for example, employs a demand-driven data exchange model with the PAC CPU, which reduces scan time impact and ensures the most recent motion data is readily available to the application program.

While in traditional architectures that include a PLC and a standalone motion unit, you have to pass motion data (for example, axis actual position) at specific times within each CPU scan, an integrated motion control module in a backplane passes instance data to the program motion function blocks asynchronously as soon as new data is available—allowing access to the motion data without waiting for the next CPU scan. This level of data synchronization is critical for accurate control of high-speed machines such as labelers, as a scan delay can cause phase errors to occur because the data may be stale by the next CPU scan.

Improving production yield also increases machine productivity, as more good parts are made using the same amount of resources. In some products using a non-integrated architecture, or even using an integrated architecture that is not optimized, the main host controller CPU is also used to execute motion path planning for each axis. Motion path planning is computationally intensive and because of this additional processor load, the time between position loop updates must increase as more axes are added.

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In some cases, the servo position loop for each axis is also closed by the main CPU, resulting in even further reduction in motion update rates. This means that the motor's actual position and commanded position are compared less frequently—resulting in larger position errors. The reduced update rate may force a reduction of machine cycle rate (throughput), and larger position errors can have a direct impact on product quality.

For example, imagine a home that is trying to maintain a set temperature (the command). If the thermostat checks the temperature once every hour (the feedback), there can be large swings in the actual temperature over that hour (the error). On the next update cycle, the temperature is checked against the set point, and the thermostat detects the temperature error and turns on the air conditioner to attempt to bring the temperature back to the desired level. However, the A/C system can quickly cool the house and over the next one-hour cycle of the thermostat, the temperature drops well below the desired temperature set point, again resulting in significant error in the desired temperature. The same thermostat, if checked once every five minutes would keep a much more constant temperature in the house.

Servo position loops work in much the same way; the more frequently they are checked, the more accurately they will control axis motion on the machine. A fast position loop update keeps position deviation small when torque disturbances are encountered, which can arise from machine binding, excessive friction, impact loads, etc. The faster the servo can recognize the disturbance, the more quickly corrective action can be initiated.

A rotary cut/seal machine cuts and heat-seals a continuously moving web of material at defined lengths; there is a high cycle rate on the knife axis for productivity and high-speed registration inputs to detect printed registration cut marks. The knife speed must match material speed during the cut to prevent tearing or bunching, as well as size accuracy with the material being cut. If the machine encounters a phase error due to asynchronous position updates or long servo updated loop times, it could, for example, introduce a 1 ms phase error. If the machine is moving product through at 1 meter/second, a variation in cut length up to 1 mm could occur, causing scrap or rework.

Increasing machine availability in packaging equipment has become more important as product life cycles have drastically shrunk; long gone are the days of putting one product on one line and letting it run for days. Manufacturing today requires rapid line change overs to be able to run different products, and virtually no downtime during those change overs. Companies are adopting new tactics to achieve these goals by increasing the automation of their machines, most of which have gone from a mechanical line shaft to an electronic line shaft and have increased the adoption of servos.

When evaluating integrated motion control systems, OEMs are realizing that the reliability of all of the system components is critical, as it only takes one part of the system to make the entire machine go down. The servo systems that run these parts undergo more physical stress than any other part of the system, and the application programs that run them tend to be some of the most complex programs running on the system.

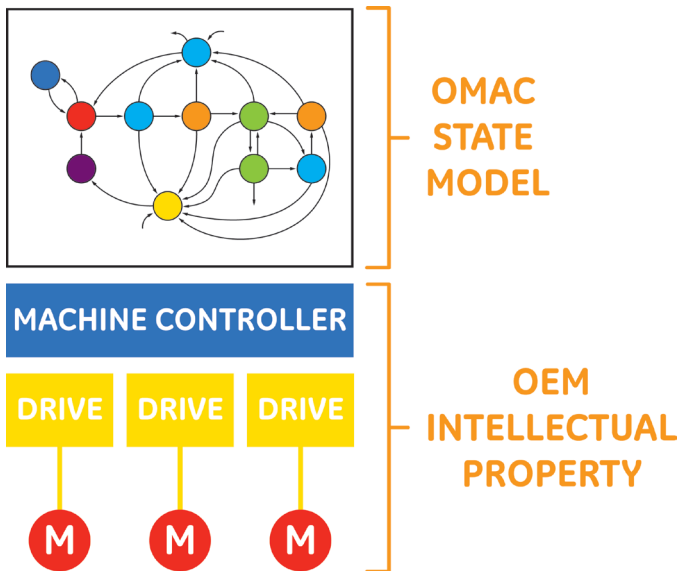
Therefore, the evaluation criteria of a motion control system for reliability should include low mean time to repair (MTTR) for fast recovery and reduced downtime. Manufacturers should publish mean time to failure based on historical information, which can help you gauge component reliability in real-world applications. For example, GE's PACMotion controller uses the highly reliable FANUC servos, which have a mean time before failure (MTBF) measured in decades. The FANUC amplifiers have no stored configuration or tuning parameters that must be loaded when replaced so they are easily swapped in the rare case of failure. This type of design in any motion control system can directly impact the reliability of the entire machine.

Increased engineering efficiency

As time-to-market is critical for success in today's competitive packaging marketplace, integrating motion into one common environment with HMI, logic and process control substantially increases engineering efficiency. With a common open standard programming language, tag database and function blocks, engineers can spend less time and effort learning new programming environments and synchronizing different programs. The result is faster program development, quicker time to market, and faster machine commissioning.

Machine builders that have used standalone motion products have had the added burden of having to use and learn different programming software environments for the host controller, motion and servo configuration. Each piece of the system requires its own individual application program(s), and the additional programming required to synchronize the main machine control (logic) program and the motion program(s) can be significant. As a result, system performance can be limited because of the processor burden to run additional synchronization logic, the timing constraints for asynchronous handshaking between programs, and even the bandwidth of the motion interface.

The coordination of passing information between the multiple programs forces tradeoffs between quantity of data and speed, and also introduces another layer of complexity where errors and bugs may occur. This added program complexity can also impact timely commissioning of new machine designs, leading to longer development cycles.



Would an integrated control system benefit your business?

Switching your automation or motion control platform requires careful consideration. Ultimately, the decision may come down to risk management—whether the benefits of a PAC controller with integrated, high performance motion control outweigh any potential risks. Some questions to assess the potential benefits of an integrated control system include:

- Are your customers getting the machine throughput they desire with current motion controls? What is the bottleneck in your current machine?
- Does adding more axes to your system degrade system performance?
- Is the throughput of your machine limited by the slow servo update rates, the ability to respond to motion events quickly enough, or long program scan time resulting from sharing a single processor for motion and logic control?
- Does your motion control solution allow you to make changes to end position, velocity acceleration, or jerk to active motion profiles at any point along the profile?
- Are you able to synchronize the position loop of all axes in the system to eliminate position phase errors?
- Are you able to instantly reconfigure your machine or line to handle different products? Can you programmatically change master/slave axis assignments and scaling, electronic gear ratios, cam profiles, or engineering units (e.g. English to metric) on the fly?
- Could your solution benefit from the reduced wiring and improved noise immunity and reliability provided by distributing servo amplifiers and motion centric machine I/O via a fiber optic link?
- Does your solution include multiple programming software packages and/or different programs for logic, motion, and operator interface control that must be synchronized? Would an integrated programming environment reduce risk or improve engineering efficiency?
- Would your engineering resources benefit from an integrated environment?

However, the integrated programming environment of a PAC should not be confused with a “simple” programming environment, as most integrated control programming packages allow users to program in many of the standard IEC languages such as structured text, ladder logic, ‘C’, and others. For example, GE’s PACSystems features a control engine that is portable to multiple platforms and allows users to choose the hardware and programming language that best suits each particular application. When integrating motion control, the system provides a universal engineering development environment for rapid development, implementation, and migration.

A noteworthy trend affecting engineering efficiency is a shift toward open standards, which reduce engineering development effort. The Organization for Machine Automation (OMAC) provides many packaging industry standards such as PackTags and PackML, and adoption of OMAC standards can lower multi-machine integration and coordination costs, standardize program structure, increase machine features, and reduce the cost of maintenance and training. A library of re-usable OMAC standard machine application code greatly reduces the development cycle.

Motion-specific programming has also followed this paradigm shift—away from proprietary languages toward open (PLCopen) standards. PLCopen has developed a well-received open standard motion language that integrates with IEC languages. Open standard programming significantly increases programmer productivity and protects investment in intellectual property by providing portability to different hardware platforms.

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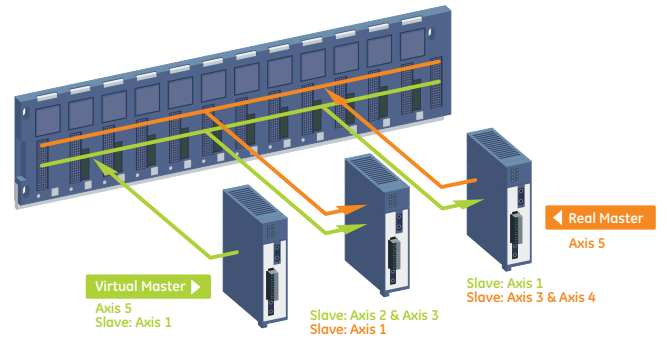
Products such as GE's PACMotion supports over 50 motion functions in both structured text and ladder diagram function block, and its programming has been developed in compliance with PLCopen standards. Any quality vendor of integrated machine control should provide standards-based programming to reduce engineering development effort.

Enhanced machine flexibility and modularity

Because production runs are routinely turned over multiple times per day, today's production lines require an incredible level of flexibility. In addition to providing the scalability to handle machines with varying levels of performance and different numbers of axes, automation and motion control solutions must also facilitate instant line reconfiguration at the push of a button. A single line might fill 16 ounce, 20 ounce, and 2-liter bottles in successive daily production runs.

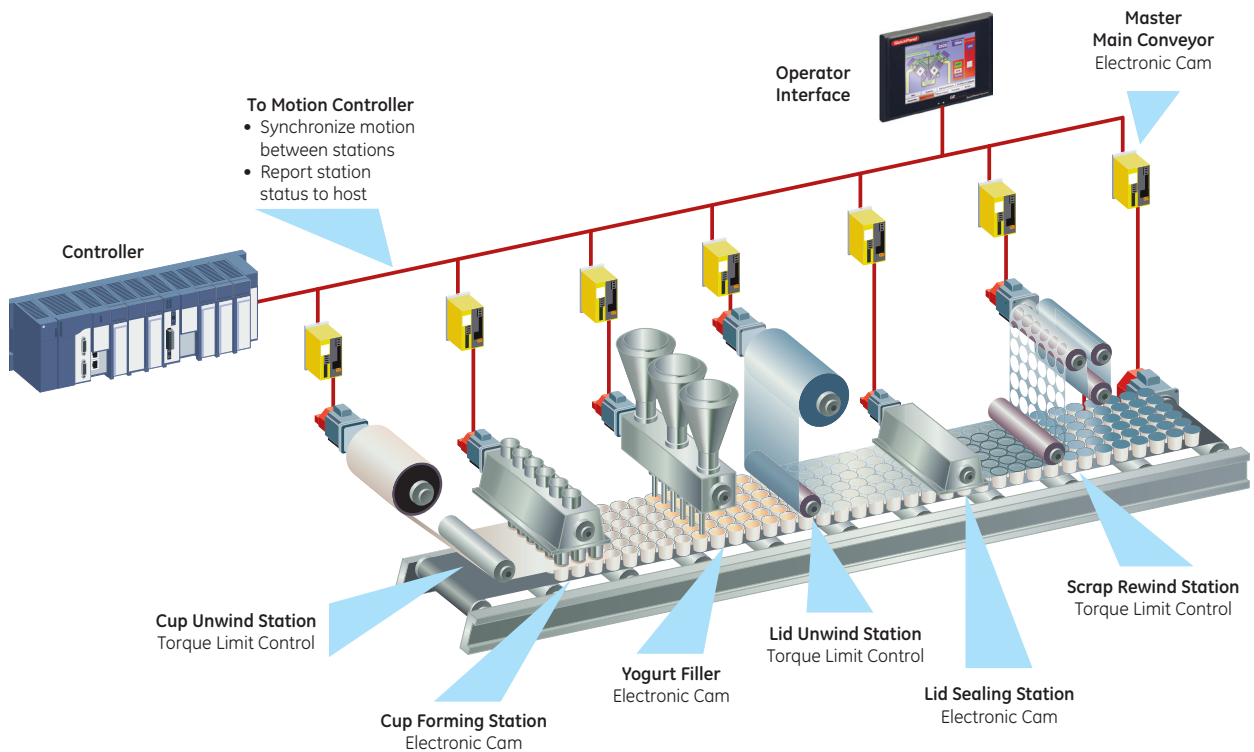
To realize this capability, current generation machines utilize electronic line shafts (ELS) to synchronize all axes of motion on a machine or line. An electronic line shaft synchronized system uses independent axis control at each station, which is then synchronized to a master source—either an encoder or time-based profile (virtual master).

Typically, a single master axis acts as the pacer for all other axes (slaves); this master can be a real axis (motor), an external encoder mounted on the machine, or a time-based virtual



master. For example, each PACMotion Motion Module includes a master axis that can be configured as a real master tied to an encoder or as a virtual master with full motion programming support. Being integrated right into the PAC provides the flexibility to tightly synchronize all axes in the system by passing master axes over the backplane, and any axis can be a master or a slave to any other axis in the system without any additional wiring. More importantly, these master/slave relationships can be redefined "on the fly" by the application program.

This electronic synchronization not only simplifies the wiring and reduces I/O, but enables instant line conversion at any time. For example, in a line used to manufacture, fill, and seal plastic yogurt cups, each operation must be synchronized to



the main conveyor that is moving products through the line. The cup forming press, filling, and sealing stations use electronic cam profiles that can be changed or scaled “on the fly” to adapt for different cup sizes or shapes.

The wind/unwind stations use torque control to control tension in the plastic film, which is used to make the cups and the foil used to form the lid. These torque limits can quickly and easily be changed to conform to the requirements of different materials used across the range of yogurt cups made on this line.

Furthermore, tight integration with the PAC controller leverages flexible system configuration, whereby both centralized and hybrid distributed architectures are supported. Hybrid solutions merge the benefits of centralized programming and control with the reduced wiring by distributing the amplifiers and motors. Distributing the amplifiers and motors also facilitates modular machine designs such as wrapping, cartoning, and case-packing machine with multiple stations.

Advanced features in motion control with PACs

The sweet spot for PACs integrated with motion may be in the more complex packaging applications that require higher cycle rates and tight coordination of multiple axes. Many of these complex applications can benefit from advanced motion features available in high-performance PACs such as variable jerk control and blending of jerk limited profiles.

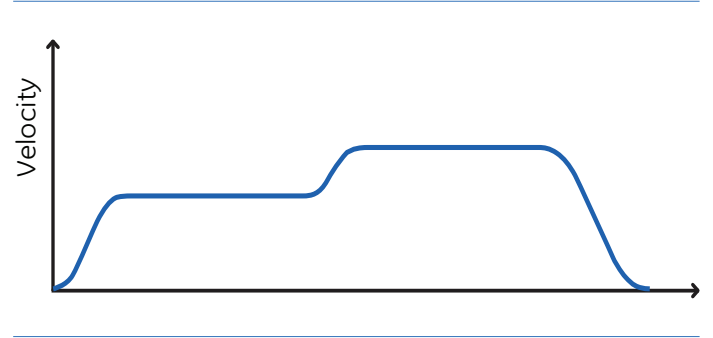
Jerk control can be advantageous in certain applications such as transporting liquids without spilling, tearing, or stretching when pulling paper or plastic film, or preventing boxes from toppling or slipping on a conveyor belt. Additionally, proper application of variable jerk control can minimize machine wear while optimizing servo motor sizing. The trade off of using jerk control is that it requires greater torque (acceleration) capability from the motor.

As shown in the diagram to the left, full (100%) jerk control requires exactly twice the acceleration torque from the motor compared to linear acceleration in the same amount of time. Variable jerk control can tap the motor reserve torque to mini-

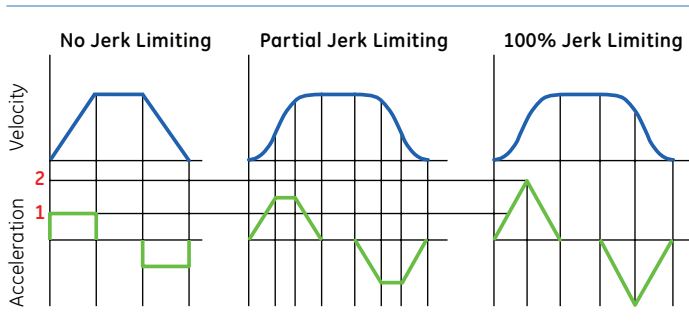
mize machine wear without increasing motor size and cost. Minimizing jerk reduces the repetitive impact loads on mechanical components such as lead screws, gearboxes, and couplings that can cause them to fail prematurely. However, some motion path planners only support linear and/or full (100%) jerk control, so select a motion control solution that will meet all of your application requirements while reducing maintenance cost and maximizing machine life.

The blending of jerk limited profiles can provide much tighter control in applications where velocity changes are required during the move. For example, a packaging line transfer conveyor (also called a smart belt or random infeed) equalizes the random spacing of products coming off an infeed conveyor as they are transferred to an outfeed conveyor for wrapping or packaging.

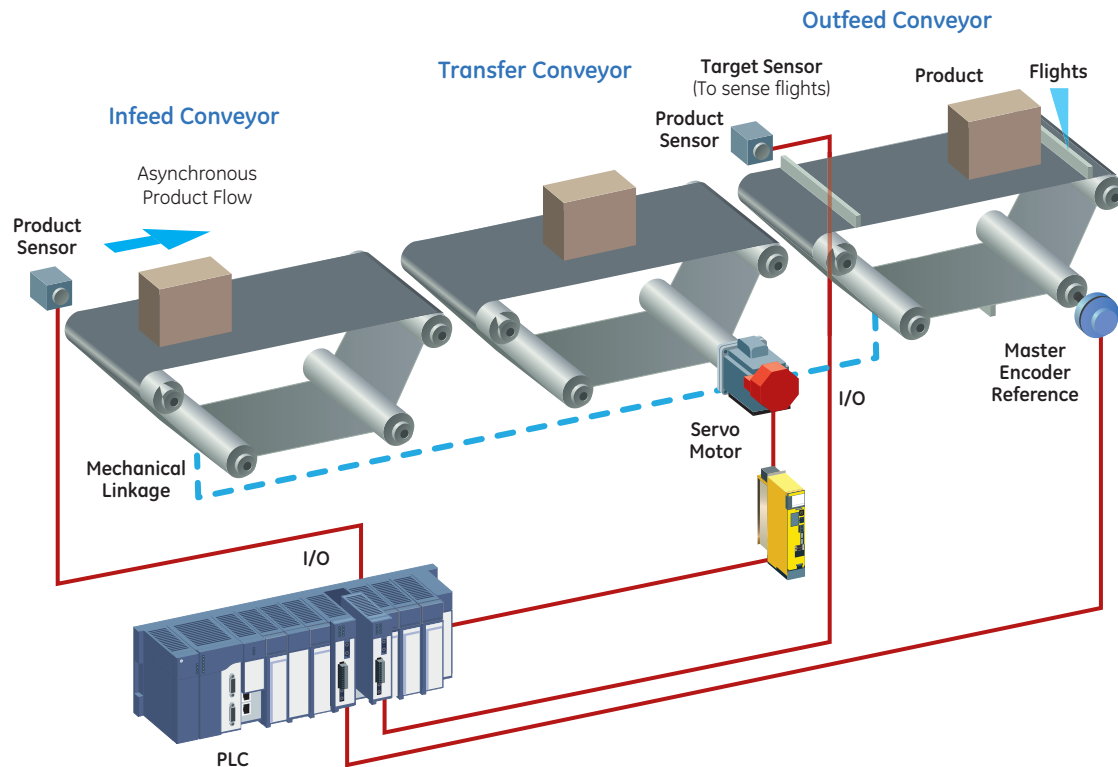
As the product is transferred from the infeed conveyor to the transfer conveyor, the speed of the two belts must be equal. Once the transfer is complete, the transfer conveyor will accelerate or decelerate based on sensor inputs to equalize the spacing as it is transferred to the outfeed conveyor. During the transfer conveyor’s speed changes, it is critical that the product does not slip on the belt, else the product spacing will be incorrect. In this case, it is important to blend two jerk limited profiles.



The same concept of blending jerk limited profiles at non-zero velocity can be used to change the speed of a moving web without tearing or stretching the material, resulting in higher product quality and reduced downtime.



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Summary

The packaging machinery industry continues to evolve and adapt to demanding customer needs through the use of more complex automation. As OEMs increasingly adopt and invest in the latest technologies to meet their customers' challenges, integrated motion with a programmable automation controller provides value by maximizing machine productivity, increasing engineering productivity, and increasing machine flexibility.

Selecting an integrated motion control solution with the performance, flexibility, and reliability to keep pace with the ever-increasing demand for productivity becomes a critical success factor for packaging machine OEMs. Companies in high-performance packaging that require multi-axis motion control for mid- to high-end applications may especially benefit from integrated control systems such as GE's PACSystems and PACMotion as they help maximize machine productivity for a sustainable competitive advantage.

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www.ge-ip.com

