

## REDUCING PACKAGING PLANNED DOWNTIME THROUGH EFFECTIVE SENSOR APPLICATION

**White Paper**

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### White Paper

**Sensor technology is constantly evolving, giving OEM packaging machine designers new ways to reduce the cost of their machine designs while decreasing planned downtime during machine changeovers.**

Reducing downtime is one of the most effective ways packaging end-users can achieve profitability in today's highly competitive marketplace. For OEMs to help end-users minimize downtime, they must develop equipment that has the operational flexibility and technical attributes able to:

- minimize planned downtime
- reduce or eliminate unplanned downtime
- be competitive in the market place

The easiest way OEMs can accomplish this is to turn away from obsolescent methods and expensive technology such as servo motors. New, more economical sensor and encoder technology will make their packing products more changeover-friendly, more repeatable, more sustainable, and less costly over their production life.

Product changeovers are the most common type of planned downtime in the packing industry. While reducing planned downtime is a core goal of lean manufacturing, there becomes a time when procedure and process is not enough. Yes, we can pre-stage change parts, or continue a changeover through a break or lunch to get production up sooner, but when we have optimized all we can, we must turn to the latest technology to further limit planned downtime. Today, that means using sensors to help shorten changeover downtime while increasing machine repeatability and flexibility at a cost the end-user will pay.

### What is a Changeover?

The industry defines a changeover as running at a known level of efficiency on one product to running at a planned level of efficiency on a new product. The downtime involved includes the machine tuning time necessary to achieve a specified level of performance.

Of course, the time a changeover takes equals lost production revenue.

### The Changeover Process

Let's assume a changeover is about to begin. In an optimized lean plant, the change parts will be positioned on a cart of one color and an empty cart of another color will be positioned as well to hold removed parts. As the changeover begins, we know the package size we are currently running, and we know what size we want to go to. The mechanical and electrical changing process continues with parts being removed and replaced as fast as possible. Once this is done, we must complete the rest of the changeover by eye, turning cranks and looking at linear scales, and then eyeballing the proper position.

Once we have completed this process, we run the machine and tune it for actual operation and optimization. Tuning is essential to a successful manual changeover, but the less tuning is involved, the more repeatable the changeover is.

### Linear Position Sensors Enable Low-Cost Automatic Size Changing

To automate previously manual size-changing operations, the challenge has been to overcome the inaccuracy and delay inherent with human interpretation of mechanical measuring scales, without resorting to high-cost servomotor technology. While servos provide the necessary level of accuracy, their high cost per axis eliminates them from consideration for automatic size changing. Too, their performance envelope far exceeds the requirements for size changing – they're simply overkill for the application.

Yet servos remain compelling to designers because they provide both motion and control. Other prime mover technologies, such as DC motors or pneumatic cylinders, provide motion but lack appropriate control. This is where low-cost yet accurate and reliable linear position sensors can help. By providing the missing continuous position feedback signal, the linear position sensor suddenly allows a low-cost DC motor or pneumatic cylinder to emerge as a cost-competitive functional alternative to a servo system for automatic size changing. It's even possible to consider leaving the human operator as the prime mover, yet employ a linear position sensor and an appropriate HMI interface to automatically indicate to the operator when the mechanism has reached the proper position according to the current control recipe. Linear position sensing enables full control of the resizing sequence with complete repeatability, based upon low-cost prime mover technologies.

Of course, taking full advantage of the economic benefits of this new approach is most effectively accomplished during the OEM design process, not on the factory floor. The key person in this process is not the electrical engineer, but the mechanical engineer who designs the motion technology into the OEM machine to begin with. Without proper forethought applied to the integration of the sensors into the machine design, sensor technology will never be applied to maximum effect. This is why the trend towards mechatronics is so important. Mechatronics is the combined application of mechanical, electronic, and software engineering to produce an effective machinery control system. The emergent trend is that the machine's mechanical designer is a sensor expert and a control code writer as well, so that the complete vision of the machine's mechanical design and functional capabilities rests with one highly capable person.

## A New Approach to Reducing Planned Downtime

Recipe-driven size changing is not a new idea, but the approach of using sensors to validate the repeatability of the process is — and as a plus, the sensors to do this are much more affordable compared to servo technology. As for keeping track of change parts, we can use an RFID tag with a scanner to verify only correct parts are applied to the machine. With respect to other changeover steps, a recipe-driven process built into the operator interface allows the changeover to be made in the proper sequence — including prompts to hand-change mechanical parts in the middle of the automatic changeover process.

As we reconfigure the machine, we verify the change through the feedback loop from our sensors regardless if the prime mover is a motor, air cylinder, or a person. If the prime mover is something other than a person, the size changing prime mover stops automatically once the planned position is achieved. If it is a person, we can provide an audible sound or visual indication that the position has been reached. Once the changeover is accomplished, a simple check list can be used to confirm that the correct parts have been installed and the machine is positioned properly. As the machine continues to run, and minor changes are required to adapt to packing material variations, we can save and store the final settings before going to the next new size. This allows maintenance people the opportunity to decide if the recipe for a specific package size should be permanently altered for changeovers in the future.

## Looking at the Technologies Available

### Linear Positioning

Affordable linear positioning is fast gaining ground as a preferred technology to speed machine size changing, and is available in several form factors to fit most machine applications. While it is an effective method of monitoring machine position during a changeover, it is also cost effective because it can replace expensive servo motor controls without negative impact on changeover repeatability.

Linear positioning technology comes in absolute analog or digital versions, each with the ability to directly or indirectly measure machine positioning. These sensors take an open ended prime mover such as a motor or air cylinder and make it a closed loop device at an affordable price (Figure 1).

The advantages of this technology are its accuracy, repeatability, and low installed cost. For less than \$200 per twelve inch stroke measurement, linear positioning provides an infinite number of stop locations along its measured axis.

While the skill level of operating personnel continues to grow, the demand for more flexible equipment grows even faster. Lines that were once base-loaded for only one size just a few years ago are now required to be changed over two or three times a day to meet daily manufacturing needs. Not only is the frequency of changeover increasing but the number of sizes may be different from year to year.

## Changeover Evolution: Reducing Planned Downtime

A typical changeover application is moving the entire side of a cartoner or case packer. Today, we do this with a crank, a bunch of chains, and some position counters or linear scales. There are several ways to reduce the cost of this planned downtime, improve the technology of the machine, and execute changeover faster with more repeatability (Figure 2).

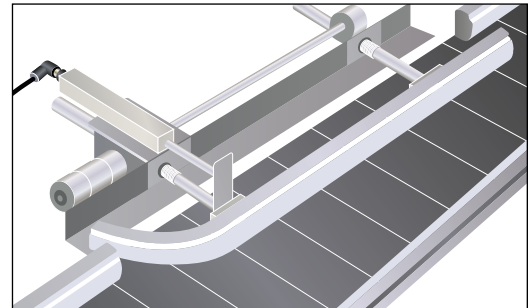


Figure 1: Linear positioning technology provides recipe-driven exact placement capability.

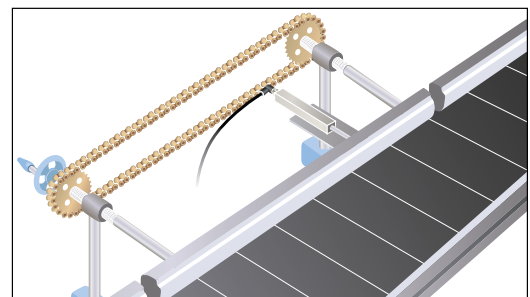


Figure 2: Traditional hand turned chain and sprocket methodology depends on the skill of the operator.

Take the example of the hand crank and chains. We can put a linear sensor on the machine to monitor its movement and give an audible signal to the person operating the crank as to when to stop (Figure 2a). This becomes an effective retrofit for existing machines. The next step is to replace the crank with a motor and gear box and continue to use the linear sensor as a feedback loop (Figure 2b).

However, the best solution is to replace the chains, cranks and all of the supporting mechanism and use a couple of rod-lock style air cylinders together with a linear sensor and have a complete recipe driven automatic changeover system (Figure 2c).

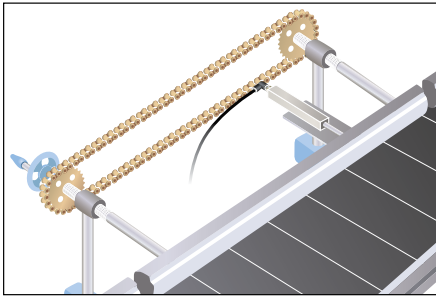


Figure 2a: Adding a transducer can provide higher position accuracy.

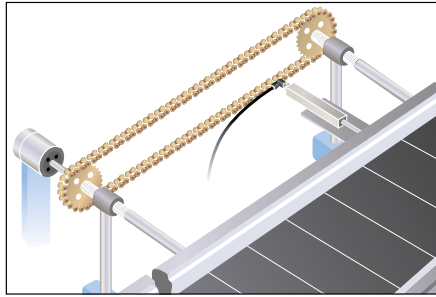


Figure 2b: A simple motor used with a linear feedback device closes the feedback loop.

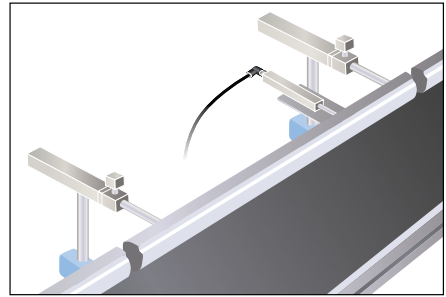


Figure 2c: Air cylinders and transducer provides accuracy, precision, at less cost.

## Linear Motion Evolution: Increasing Flexibility While Lowering Cost

Let's take the example of an air cylinder or mechanical system that is pushing a collated group of cartons into a container to make a case of product.

In the original air cylinder-based solution, the collated product is pushed in front of the loading ram, and then pushed a known distance into a container. Let's say we must push a second load into the container as well. Typically, we would have pushed at the same stroke distance and depended on the second load to push the first load all the way into the container (Figure 3).

Then came the servo motor; that allowed us to have two stroke distances and push the load into the container at a purchase cost of about \$3,500. This was a step improvement over the air cylinder. With the servo motor, we could make the acceleration and deceleration momentum of the load more gentle.

The next step was a sensor driven solution at a much reduced price. Proximity sensors can provide discrete position information. In (Figure 3a), four sensors provide the positioning information to allow a two position box loading operation.

Today, using a linear transducer coupled with an air cylinder, we can obtain the same machine function for one third the cost of a servo motor — an excellent example of sustainability and total delivered cost reduction (Figure 3b).

### Adding More Flexibility

Often machines designed for specific package sizes now must handle new packages within its size capability. The answer is to convert Binary control to Linear control. This means using more flexible sensor technology — in other words, converting proximity switches (Figure 3a) to linear positioning technology (Figure 3b) for increased machine flexibility.

The good news is that linear technology is inherently less expensive than using conventional sensors. Let's assume we have planned four different package sizes and we are adjusting a machine component to a known position by using proximity switches. The total delivered cost of each proximity switch is about \$175. The proximity switch may cost \$20, the bracket \$40, the cable is another \$35, the PLC input will cost \$30 and the labor to install the device is \$50 including mechanical and electrical. The cost of four devices is \$700. If we substituted a linear positioning device, the total cost for a more flexible and efficient machine would be about \$350.

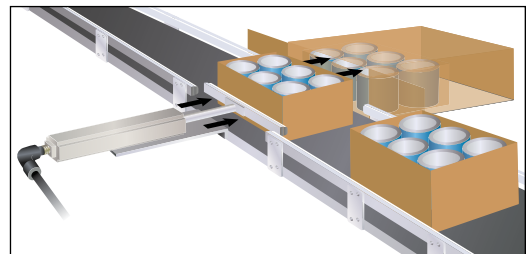


Figure 3: Air cylinder technology alone can only push to one distance.

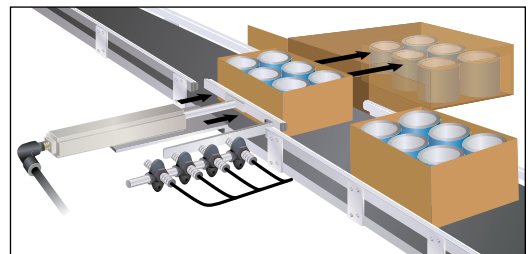


Figure 3a: Inductive sensor arrays give multiple discrete distance positioning capability.

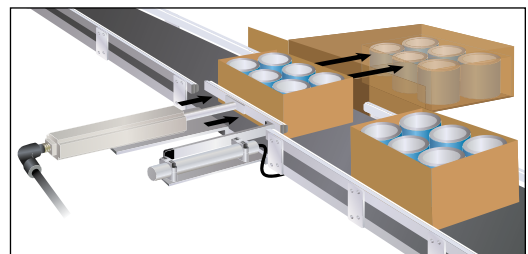


Figure 3b: Analog linear technology can provide infinite distance positioning capability.

## Power Remote Wireless Connectivity: Subassembly Flexibility the Easy Way

Another form of changeover is to replace an entire assembly on a machine with another subassembly. This normally involves disconnecting and reconnecting control circuits, which opens us up to a range of undesirable problems such as misconnection, connector fatigue, and unnecessary downtime. The answer is a power remote system. Power remotes transmit power to sensors and other components across an air gap of about 2mm from one subassembly to another. At the same time, control information is also transmitted back and forth across this air gap, to and from sensors and the PLC is using a remote communicator for sensors, actuators or motors themselves. By removing entire assemblies from a machine including the sensors and putting another sub assembly in place we can have a changeover time of seconds (Figure 4).

Power remotes come in a range of sizes and power capacities. Some are as small as a 30mm proximity switch, and handle up to 8 inputs. Larger versions handle more sensors and pass over 6 amps of current across the air gap to run a motor. Power Remotes also solve the problem of twisted, shorted out wiring and unreliable wiper-based contact technology in rotating assembly platforms, all without introducing conventional wireless complexity.

### Rotary Shaft Encoders

Magnetic linear technology has combined with rotary technology to make an incremental shaft encoder. This product has the ability to convert 46,000 magnetic segments per revolution into 360 degrees of rotation to convert rotary motion into exact linear measurement of the conveyor. It can be used to keep track of position for a rotating table to degrees of rotation of a machine. Its advantage is its magnet. It does not have a glass disk and it will run in almost any environment. It can even run in a wash down environment with proper protection. Mounted in a hollow shaft configuration at a cost of under \$250, it reduces the cost of the encoder and improves the machine's accuracy. Typically today, we measure machine position indirectly. We do this by installing a sprocket on the main drive and connect the encoder mounted separately through a chain (Figure 5).

This assembly costs about \$700, with \$300 for the encoder, two sprockets, chain and a custom bracket, plus the cost to mount and wire the device. We must also worry about over tensioning the chain, ruining the bearings in the encoder, while hoping we don't drop a wrench on the encoder and break it. In contrast, a magnetic hollow shaft encoder mounts directly on the main drive shaft, has no additional parts for mounting, and reads the machine position directly without chain slop (Figure 5a).

The setup for the rotary magnetic encoder is simple. We feed the quadrature input into a high speed counting card, or standard PLC input for slow applications, and convert the 46,000 pulses into 360 degrees of machine position. From here we can have an infinite number of cams in the machine – some cams for machine internal decisions and some to control actual machine function. For example, establishing a point for the machine to cycle stop.

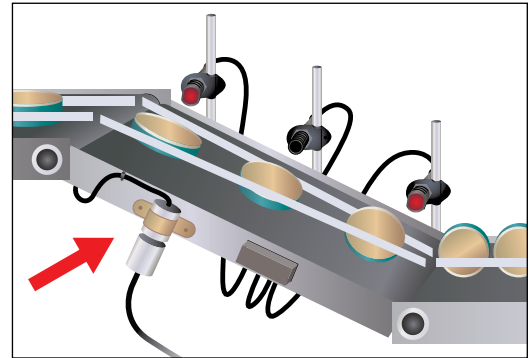


Figure 4: Power Remotes provide wireless modular connections anywhere on the line.

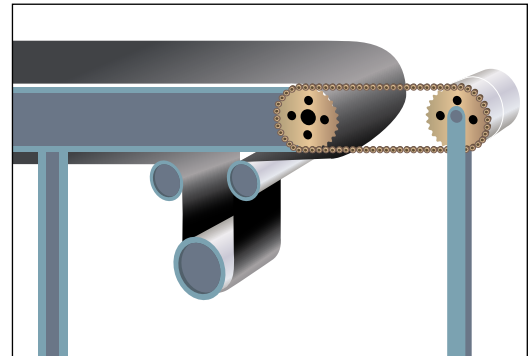


Figure 5: Traditional chain and encoder positioning.

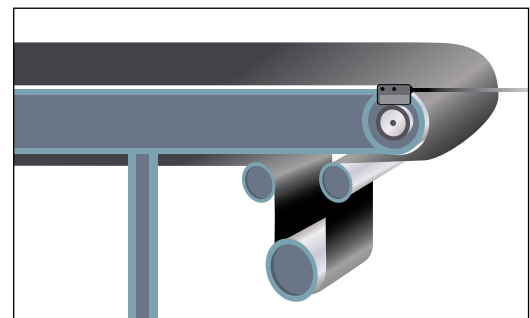


Figure 5a: Rotary encoder positioning provides for scores of control functions on the line.

## Distributed Detection with Single Station Rejection

Because the pulses from the rotary encoder come in a stream to the PLC, we can use rotary encoders for tasks such as tracking the position of a part, and rejecting it down stream from a quality check. Let's say we are using this device to track degrees of rotation for a labeling machine. The PLC can use the same pulses that it is converting into degrees of rotation and convert them to linear distance to track the product to the reject station.

This feature also works for multiple detection devices and one reject station. A recipe-driven application can determine which detection devices are for the specified product, using the same reject station for all detection stations. When the recipe for the change-over is selected, it will determine which error proofing sensors to activate and send rejects from them to the same reject point. This is another example of reducing total delivered cost (TDC). It also helps sustainability because we have fewer components to fail within the system (Figure 6).

## Color Detection

Advanced color sensors can be programmed to either look for a single color, or look for several colors to error proof different products. Again, the goal is reduced planned downtime. Color sensors can be programmed by simply selecting the new product recipe when the color sensor is set up for a new product. This way of reducing planned downtime includes full color detection of parts and avoids re-teaching of sensors to recognize new color parameters.

Today's advanced full color sensors are capable of being programmed with multiple outputs, each corresponding to the correct color (or colors) of the product batch being run down the line. This error-proofing detection step fits into the recipe-driven change-over scheme by allowing the code writer to assign specific inputs (or colors) for each recipe. In turn, the control system will look for the correct color as targets are presented and will automatically reject a "bad" or incorrect color product, thus keeping the line running continuously. Some full color sensors feature multiple outputs which are easy to program and operate at speeds sufficient to keep up with today's fast moving applications (Figure 7).

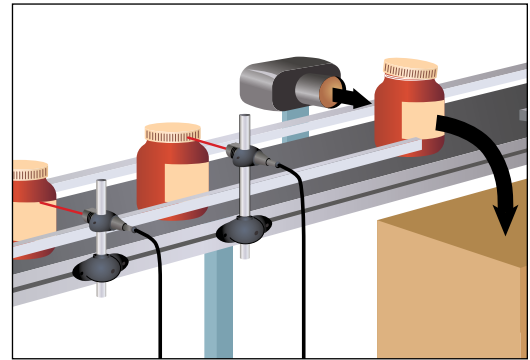


Figure 6: Rotary encoders allow multiple sensor error proofing with single station rejection. Here a misapplied cap is rejected.

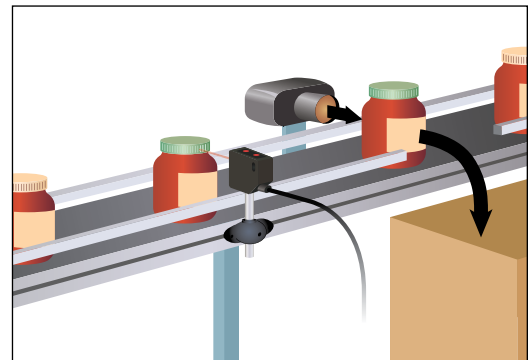


Figure 7: Color sensors add an added dimension of error proofing capability.

## Optical Sensors

New vision-based optical sensors use simplified vision technology to bridge the gap between vision systems and sensor technologies. They provide a simple, practical, and cost effective way to error proof production by simultaneously checking several aspects of the product with a single device. Using a simple configuration interface that can be learned and used quickly by in-house staff, new optical sensors provide more information than a single function “smart camera” or a group of standard discrete sensors. At the same time, they avoid the traps of complex vision systems in cost, complexity, and high operator expertise (Figure 8).

Optical sensors operate more like a smart sensor than a vision system. Just like a sensor, they are configured to look for certain attributes of a part or product to make sure those aspects of the product are present, the part is configured correctly, and positioning is verified. And like a vision system, they can error proof parts or configurations presented to them in different positions (Figures 8a & 8b).

The result is a perfect solution for advanced error proofing. With the combination of both technologies and the simplified “sensor like” approach to configuration and usage, the user can apply higher level sensing at a lower cost point, allowing these new optical sensors to be applied more readily in a true error-proofing scheme. The optical sensor provides an inexpensive new capability that was not available before for reducing planned down time, easier line changeovers, and accommodation of flexible or “build to suit” manufacturing.

## The Bottom Line

The goal in all of these applications is a lower total delivered cost, lower cost of ownership, and a more flexible machine with superior sustainability. Modern sensor technology combined with seasoned application expertise gets you there.

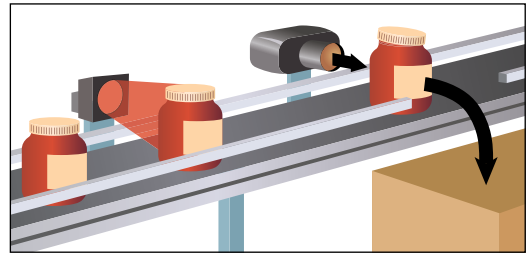
Combining machine positioning — both linear and rotary — along with programmable sensors for different machine setups, plus RFID technology to confirm the use of the proper change parts, allows entire sub assemblies to be removed from a machine. This provides more run time to make more product in the same manufacturing time.

OEM designers need to incorporate new sensor and linear positioning technologies into their packing machines to achieve evolving industry-driven performance/cost ratios. The resulting equipment will be less costly, more flexible, more sustainable, and provide lower cost of overall operation. This allows OEMs to commit to higher throughputs to reduce machine cost per manufactured case.

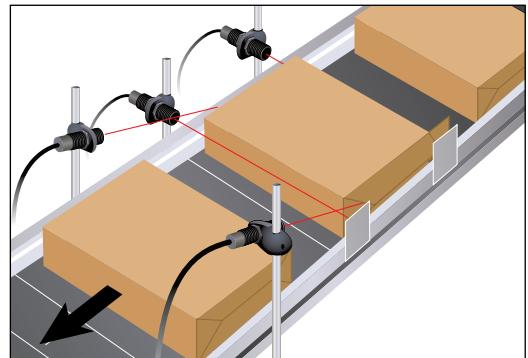
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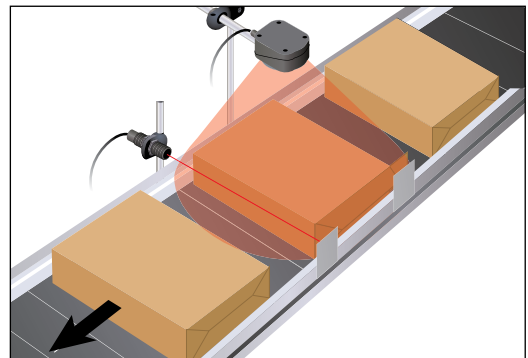
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**Figure 8: Instead of multiple sensors, as in Fig. 6, optical sensors can reduce the number of sensors needed for error proofing.**



**Figure 8a: Traditional sensor driven trailing open flap error proofing uses at least four sensors.**



**Figure 8b: One optical sensor and one keying sensor can simplify the process.**

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