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The freedom of the absolute

Let the application guide your encoder choice

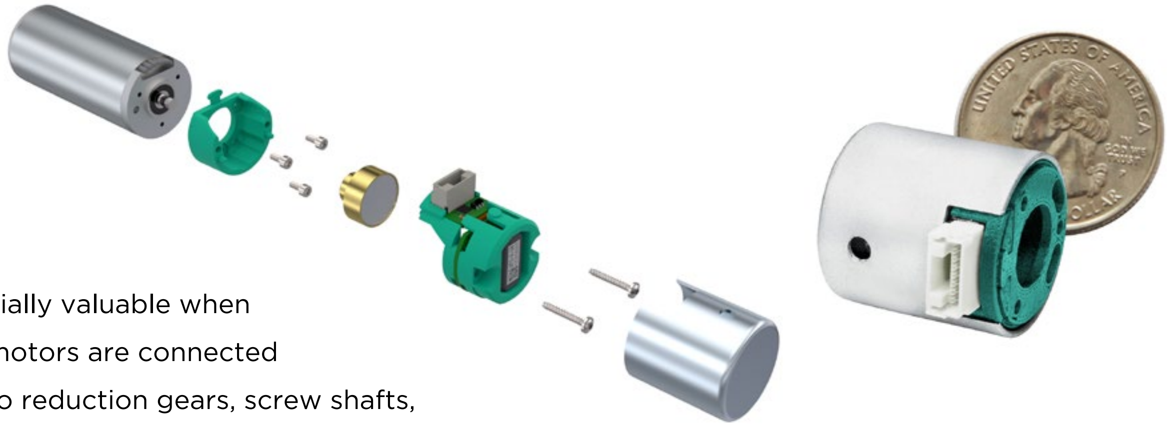
By Anna Townshend, managing editor

Machine builders have many choices for measuring position, count, speed or direction of a mechanism. In choosing an encoder, the specific application should guide the design. Determining what accuracy is needed, what conditions the encoders will operate in and other mechanical restrictions will help to guide selection. Two manufacturers, Posital-Fraba (www.posital.com) and Balluff (www.balluff.com) offer some encoder options for measuring rotation in small servo and stepper motors and linear measurement via a magnetic absolute encoder.

Where incremental encoders indicate movement from one position to the next, not a specific position, absolute encoders will indicate when position has changed and the location of that position relative to shaft rotation. Absolute encoders are the best choice when exact position needs to be known.

SMALL, LIGHT PACKAGE

To provide position feedback for small servo or stepper motors, Posital-Fraba offers the 22-mm absolute rotary kit encoder. This is smaller and lighter than Posital's other modular encoders. The kit is built into a package that is 22-mm diameter (vs. 36-mm) and 35 g (vs. 45 g). "The small diameter makes it a great fit for the compact 22-mm dc motors sold by many manufacturers," says Christian Fell, head of Posital operations in North America and vice president for technology development. "The multi-turn measurement range is espe-



cially valuable when motors are connected to reduction gears, screw shafts, spools or other mechanisms where position changes involve multiple motor rotations."

Unique to this kit encoder is its self-powered multi-turn rotation counter system, which is energized by Posital's Wiegand energy-harvesting technology. "The complete rotation history is accurately recorded, even when rotations take place while system power in unavailable," Fell says. "As the counter system generates its own power, there is no need for installing, testing and replacing backup batteries."

Fell says the system is ideal for position-control tasks in manufacturing equipment, mobile machinery, medical equipment and many other tasks. "Absolute encoders are instruments that measure the rotation angle of a mechanism and report it to the control system as a digital message," Fell says.

The encoder's self-powered multi-turn measurement range supplies a complete picture to the controller of the absolute position of the mechanism driven by the motor. "There is no need to re-home equipment and re-initialize the rotation count in the event of a system restart. This is unlike incremental encoders, which send out a signal each time the shaft rotates by a specific amount, leaving the controller with the task of continuously updating the rotary position," Fell says.

The Posital absolute encoder kit uses magnetic-measurement technology based on multiple Hall-Effect sensors and signal-processing algorithms. The Hall-Effect-based sensor system is designed to determine the angular position of the shaft according to the direction of a permanent magnet's magnetic field. The permanent magnet is attached to the shaft, and its magnetic field penetrates the Hall sensor.

The Hall-Effect based sensor system is the single-turn stage of the absolute encoders. However, it doesn't enable the encoder to count revolutions if the external power supply is disconnected. Posital solves this problem by means of an energy-harvesting system based on the Wiegand effect, which requires no batteries or gears.

END OF TRAVEL

For applications where position accuracy is necessary and end of travel is required, the Balluff absolute magnetic linear encoders with Siemens Drive-Cliq interface offer plug-and-play installation and high accuracy.

"The BML absolute rotary magnetic encoder systems from Balluff ensure absolute positional feedback in every position," says Scott Rosenberger, after-sales technical support engineer for Balluff. "They can be used immediately, without a reference run." The encoders are tested and certified by Siemens and integrate into Siemens motion-control environments.

"It's a way for us to make it easier for customers already using Siemens to incorporate Balluff products into Siemens architecture," Rosenberger says. Siemens is a major player, especially in Europe, where this product was developed, he explains.

"Plug-and-play installation makes incorporating them into the drive system easy," says Rosenberger. The encoders are designed to integrate with Siemens motion controller environments.

"The controller automatically detects the sensor and its basic settings," Rosenberger says. "It's automatic status monitoring continuously checks the measurement quality, detecting any mechanical position shift during operation."

The accuracy of the sensor is affected by the measurement quality, Rosenberger says. "The magnetic tape is coded with the absolute positional information," he explains. "The encoder head reads that position information from the tape and puts out a signal in a serial data format that a control system can read."

In general, the sensor must be in close proximity to the tape to be effective. "When we talk about measurement quality, we're talking about factors that can affect that, such as the sensor head not being aligned with the tape or too far away, or the tape is physically damaged," Rosenberger says. "In the case of this product, it can transmit, and, if it starts to sense that it's not optimally seeing the tape, it can inform the controller that measurement quality is less than optimal and action is needed by the user."

Balluff offers two Siemens certified encoder versions—BML085L and BML08MH—pro-

Absolute encoders are the best choice when exact position needs to be known.

viding 1 µm position resolution and a stroke length of up to 48 m. “Equally impressive is the system of accuracy of +/- 12 µm and high read distance of. 1.3 mm,” Rosenberger says. Additionally, the BML08MH version has an input for a temperature sensor. That data is rolled into the position information and integrated all from one source.

The encoder is made for applications that require accurate x and y axis position data, such as industrial cutting systems or a large industrial printer for billboard panels or large-scale graphics. Rosenberger says the sensor is also well-suited for demanding applications because the magnetic tape and the sensor don’t touch each other. “There is no mechanical wear, nor are they affected by dirt or dust or grim,” Rosenberger says.

The BML larger portfolio of magnetic encoder systems is designed for linear or rotary motion, position or angle measurement, format changes or short- or long-distance measurement. Balluff magnetic encoders provide absolute measurement by traveling above a magnetically coded strip that can be up to 8 m long, with a read distance of 1.3 mm.

The encoders meet IO-Link’s smart sponsor profile 2.0 specifications, adding four switching signal channels to the process data, says Rosenberger. “Each channel uses IO-Link to program an on and off point for the encoder, which allows measurements to be limited to set ranges or windows,” he explains.

To support the switching signal channels, the encoders send 2 additional bytes of processing data. “Without this, you would need to use additional sensors to set these limits,” Rosenberger says. Using IO-Link, the encoders send digital measurement data to the network or provide an optional analog real-time sine-cosine signal for control applications. To report signal quality, the line’s enhanced version adds condition-monitoring functions.

Do you speak linear translation?

How to convert rotary motion into linear motion

By Rick Rice

Automation has always involved knowing where an object is at a particular moment in the process. Simple movement can be determined by sensing the location of the device at the beginning and end of its intended path. Rotary motion can be determined by the use of an encoder to decode angular movement and translating that into degrees or radians. Rotary motion can be converted into linear motion by applying a gearbox and some pulleys to the rotary shaft. Some math will give you a relationship between rotation and linear travel. Let's dive deeper into how to measure linear motion.

As with any detailed examination of trends in automation, it is good to go back to the beginning. The beginning, in this case, starts with a linear actuator—pneumatic or hydraulic cylinder—and digital sensors—proximity switches, usually—to indicate start and end points of motion. Sensors can be any of the typical types. A limit switch, proximity switch, reed switch or photoelectric switch is the one of the more common types. Always remember that it is better to detect the position of the driven object, rather than the driver. The reason for this is fairly simple, a clevis might come apart or a guide jams up and the driver— the actuator—might make it to the fully extended or fully retracted position but the driven object might not.

Sensing other positions along a linear plane of travel can also be done using digital switches. While not as practical for full-stroke devices, intermediate sensors might be of value for proportional valves where multiple-stop positions can be sensed and maintained.

Beyond the techniques discussed thus far, the real desire with linear movement is to know the exact position along a linear path at any given moment. For this to happen, we have to resort to analog signals or encoded position feedback.

The definition of linear measurement is the distance between two given points or objects. For example, one might measure the length of a table by using a yardstick and start at one end of the table and note the point at which the yardstick meets the opposite end of the table. In a controls environment, we don't have the ability to extend a measuring stick across a span and get a value in return, but we do have something more practical. We have at our disposal a variety of means by which to convert a distance into an analog value.

An early method of linear measurement evolved from the need to measure length travel over a longer distance. Called a draw wire, the concept is rather simple. Pull a string out with the movement of the object and pull the string back in as the object retracts. The string or rope is wound around a spool, and a potentiometer is attached to the spindle of the spool. The voltage output via the potentiometer represents the amount of string played out. While creative, the accuracy was only good if a single layer of string is displaced. As one can imagine, multiple layers means a different circumference with respect to a turn of the potentiometer. To be most accurate, the entire length of the string would have to be contained in a single turn of the spool.

Another example of a linear sensor would be a photoelectric switch with analog feedback. Light is transmitted by the photo-sensor, bounced off the object in motion and received back at the receiver of the sensor. By means of triangulation, the sensor can detect the distance of the object from the light transmitter. Earlier versions of this sensor would have used diffused light, while newer versions rely on the much more finite beam of a laser to make use of this multi-pixel technology (MPT).

A newer, more accurate version of this methodology employs pulsed light to determine distance. The speed of light is a constant, so the time between the sent pulse and the received pulse can be directly related to the distance the pulse of light travels to and from the object. Dividing this result by two gives us the distance. This technology is referred to by one vendor as pulse ranging technology (PRT).

A technology that has been around for years is linear variable differential transformer (LVDT). The basic principle is to put a pair of coils around a ferromagnetic core. The first (primary) coil is in the middle, and the opposite (secondary) coil is split to be upstream and downstream of the first coil. An alternating current drives the primary coil and induces a voltage in the secondary coil that is proportional to the length of the core linking to the secondary. If the core is exactly in the middle between the secondary coils, then the voltage output is equal and, therefore, negating. Moving the core from one end of the travel to the other will produce a positive net voltage through a zero net voltage to a negative net voltage. This voltage is directly proportional to the distance traveled by the object connected to the core. The great thing about an LVDT is the output is absolute. If the power is shut off, then the same relationship exists between the primary and secondary coils when power is restored, so it will give the same result representing position. Another great thing about an LVDT is that the use of a magnetic core and an induced voltage means that the core "floats" in the tube and, as such, has no friction to impede the accuracy of the device.

Linear measurement techniques continue to use these three principles. As with any technology however, improvements are constantly being made.

Many vendors offer variations of linear encoders. In one such application, an encoder is calibrated to represent the full travel of the linear device. Photoelectrical scanning is at the base of this method. A sensor reads fine grooves etched into a substrate material—usually glass, steel or steel strips—and interpolates that into position feedback. The grooves are applied in a lithographic manner and graduations from 40 µm to 1 µm are possible, providing a high degree of accuracy.

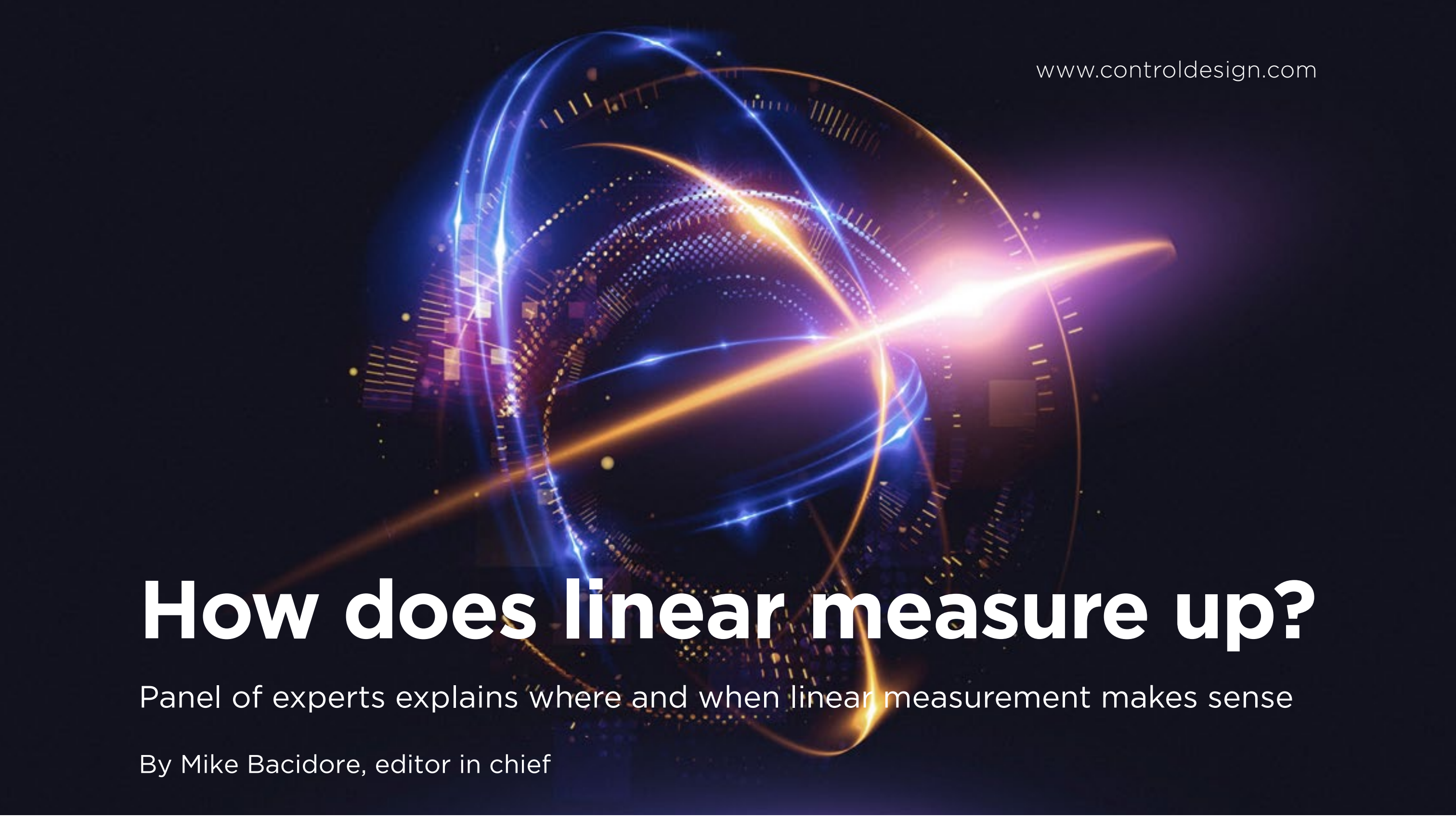
Another variation, called an exposed linear encoder, uses the laser Doppler principle in a new and innovative manner. A camera-based barcode reader determines position based on a barcoded tape. Resolution as small as 0.1 mm and precise positioning up to 10 m are possible. The use of a camera means it is wear- and maintenance-free. Speeds up to 10 m/s are attainable. These devices, available with a variety of communications protocols, makes them a great way to accurately determine length, and the use of barcode technology means linear measurement can be accurately reported regardless of straight or curved travel.

Highly accurate measurement techniques are essential to precision movement applications such as CNC machining and micro-machining used in the production of semiconductor products. The need to move with an accuracy of +/- 1 mm requires a different degree of position feedback than the requirement to repeatedly execute a movement of microns on the substrate of a semiconductor used in electronics.

As with many parts of life, the more things change, the more they stay the same. In

The great thing about an LVDT is the output is absolute.

the field of controls design, just because something was invented a long time ago, it doesn't mean it can't be improved upon. Innovations in technology often provide a means by which to breathe new life into a solid concept. Linear measurement has come a long way from the days when a series of independent sensors were used to provide feedback on travel in a straight line. Today, even a curve can be resolved into a series of straight lines with a great degree of accuracy and repeatability. Technology will continue to move forward with every increasing resolution. Greater things in smaller packages always stimulate the creative process.



How does linear measure up?

Panel of experts explains where and when linear measurement makes sense

By Mike Bacidore, editor in chief

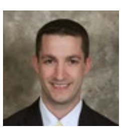
Opportunities to include linear measurement are all around. Some applications are better than others. Our panel of experts explains where and when linear measurement makes sense.

Several manufacturing processes can include positioning a crane, inserting a part to a defined depth or checking material thickness. These might need more than limit switches, hard stops and manual checks. How could linear measurement devices be used?

Greg Cameron, VP manufacturing quality systems, RedViking (www.redviking.com), Control System Integrators Association (CSIA, www.controlsys.org) member, Linear displacement transducers can be calibrated to a known position, and any deviation from the space could be recorded to define overhead crane placement. In addition, linear-displacement devices can be used as gaging instruments to precisely measure part variation relative to the mean or master dimensions.

Sixto Moralez, regional motion engineer, Yaskawa America (www.yaskawa.com), Linear-measurement devices can be used within several manufacturing processes to give precise positioning at the load. A linear-measurement device offers the ability to fully close the loop on a given mechanism because it is directly laid on the mechanism itself. A fully closed loop system allows the Servopack to compensate for mechanical inaccuracies in the drive train.

Patrick Maxwell, applications engineer, Posital Fraba (www.fraba.com), Linear-measurement devices like draw wires can be used to provide linear distance measurements on a continuous basis or to control the length of a repeated stroke. These sensors can provide precise measurements in harsh environments, such as sluice gates for water/waste water, overhead port cranes for heavy-duty material handling, as well as for more precise tasks like the positioning or leveling of medical tables.



Jeremy Miller, product manager—linear mechanics, Parker Hannifin (www.parkermotion.com), The application itself is really the key determining factor for what type of linear-measurement device or positioning capability is required. As highlighted, elements like limit sensors and hard stops can be used if the application only requires positioning between two points. If, however the application demands more incremental positioning, the next question is to what accuracy and/or repeatability is required. In the example of a crane or gantry-type system, the application may only require coarse positional accuracy, in the neighborhood of tenths of a millimeter or even multiple millimeters. A good example of this might be a palletizing machine. This level of precision is typically achievable through positional control via a servo or stepper motor, and often does not require additional linear measurement devices. A rotary encoder embedded on the back of a rotary servo motor to control a belt- or screw-driven actuator often has sufficient resolution to achieve application demands, even when including the inherent inaccuracy of the drive train and mechanical linkages.

On the other hand, examples like metrology applications such as precision measurement of material thickness or optical inspection, often require much higher precision motion. In this case linear-encoder technology is often implemented in combination with linear positioning stages. By affixing the point of measurement—encoder read head—directly to the load—point of interest—we can remove effects of inaccuracies due to mechanical linkages and drive-train elements. These elements can significantly impact the system accuracy when using a rotary encoder on the motor to position, as per the example above. With the use of a linear encoder, we are now able to achieve submicron level repeatability specifications.

Adrian Johnson, managing director, Contrinex USA (www.contrinex.com), Control System Integrators Association (CSIA, www.controlsys.org) member, Analog inductive sensors provide precise linear output signals and are ideal for applications that require precise part positioning, material differentiation and measurement of size, distance and thickness. Typically used for distances up to 40 mm, these sensors provide a high-resolution analog signal that is proportional to the distance of the metal target from the sensor face.

Kyle Horsman, sensors product specialist, Turck (www.turck.com), Having continuous measurement allows for a more defined, real-time execution of feedback and process control. This helps customers to have more information and make better decisions based upon precision rather than guesswork.

Andrew Skidmore, senior project engineer, Thomson Industries (www.thomsonlinear.com), When we talk about measurements with slides and actuators, we're usually talking about how far the component has moved, rather than a more traditional inspection type of measurement. Our actuator is usually just one link in the mechanism, and it's the total movement of the mechanism that's really important. While speed and force are also important, the accuracy and precision of the actuator are critical for achieving the required machine accuracy. So, the first thing is to correlate the actuator motion to the desired machine motion, while taking into account other lost motion in the mechanism. Calculating this stack-up will yield the required actuator precision and accuracy.

Within the actuator or slide itself there are a couple ways to measure movement. Since all of the slides and actuators convert a rotary motion to a linear movement in a fixed ratio, a reliable way of determining linear position is to track the rotary motion of the motor. This is the typical approach for slide tables and gives users access to a wide variety of signal types. In most cases slides are ready to accept a customer-supplied motor. This allows the user to install a motor with the type of feedback she or he needs to integrate into the rest of the system, such as encoders or resolvers. The linear actuators take a similar approach but measure the rotary position of the drive screw rather than the motor. This allows use of a precision multi-turn potentiometer that yields an easy to read voltage signal that is easily scaled to the stroke length of the actuator.

In either case, the accuracy of the drive screw, or lead error, and the backlash, preloaded or not, are both important. Variation in the lead of the screw degrades the accuracy of the measurement, as does backlash. Similarly belt stretch in long systems will have lower accuracy. The precision of the measurement is more a matter of the resolution of the installed encoder or the controller reading the potentiometer.

How does linear measurement compare to motion control, encoders, vision systems and laser measurement?

Michael Miller, regional motion engineer, Yaskawa America (www.yaskawa.com), Linear measurement complements motion control by giving feedback of the actual load to position precisely. Linear measurement is another avenue from the traditional rotary encoder but gives the same type of feedback. Vision systems give coordinates of a snapshot or area where objects are located given a workspace. Lastly, laser measurement is used to give depth measurement where a physical linear device cannot be installed. Typically, this is for carton depths or object detection.

Greg Cameron, VP manufacturing quality systems, RedViking (www.redviking.com), Control System Integrators Association (CSIA, www.controlsys.org) member, Linear-measurement devices are typically more accurate and repeatable compared to motion control, encoders, vision systems and laser measurement. Linear displacement provides specified, precise axis-point measurements whereas vision and laser measurements allow you to see a contour of a part or a wider view with multiple measurement output.

The most beneficial methods include various measurement types because environmental conditions, product type, sampling rates and many other factors may vary the method you choose. Measurement throughput, repeatability, accuracy, cost, process control, part quality and ease of documentation are all at stake and must be considered. With vision systems, environments should be completely free of debris, so when measuring in a manufacturing environment, vision may not be your best choice. If you're measuring very small parts, with many features and high sampling rates, vision or laser measurement would be your best choice.

Patrick Maxwell, applications engineer, Posital Fraba (www.fraba.com), Draw wires are a versatile and cost-effective way of measuring linear displacements for motion control. They consist of a rotary encoder coupled to a robust draw-wire mechanism, or spool. As the wire extends or retracts, the rotation of the wire spool is measured by the encoder and reported to the control system. This simple mechanism has proven to be reliable in challenging indoor or outdoor environments and is not affected by the moisture or dust that can fog lenses in optical or laser-based measurement systems. The linear range is up to 15 meters, or 49 ft.

Like the encoders that they are based on, linear sensors are available with a variety of interfaces, from analog to Ethernet. This makes them readily adaptable to a wide range or linear motion control applications.

Adrian Johnson, managing director, Contrinex USA (www.contrinex.com), Control System Integrators Association (CSIA, www.controlsys.org) member, The popularity of inductive linear sensors has to do with their robust design for harsh environments, insensitivity to dirt/dust/heat, accuracy on reflective metals, simple setup to PLC and hence cost-effectiveness.

Kyle Horsman, sensors product specialist, Turck (www.turck.com), Choosing the best measurement solution is about fitting the product to the application. Comparing linear and rotary devices is a good example. The same theory applies to a linear device as with something that is rotary. There is a defined measuring range and a corresponding output type, which can then be interpreted by the control system, and further processes are defined based upon application requirements. When dealing with linear motion, rotary products can be used but there are typically additional computations that need to occur in order to get a corresponding output.

Andrew Skidmore, senior project engineer, Thomson Industries (www.thomsonlinear.com), Linear measurement within slides is just part of motion control. Encoders, resolvers, potentiometers and similar direct measurement devices will monitor the position of the slide or actuator so the user can calculate the motion of the machine. Other systems such as vision or laser systems are often useful for verifying or fine-tuning the final position of the machine.

Can you offer any linear-measurement application examples or best practices that demonstrate how best to utilize it?

Greg Cameron, VP manufacturing quality systems, RedViking (www.redviking.com), Control System Integrators Association (CSIA, www.controlsys.org) member, Linear-measurement devices are used in gaging applications to locate a pallet or a tooling position within an assembly process. When it comes to deciding whether to use linear measurement devices or vision/laser measurement devices, weigh the cost of quality to the product. Does the additional information rendered by measuring multiple data points through laser or vision systems provide a higher quality product or do I only need two or three data points to get the same result? In this case, linear measurements may be best.

Karl Knutson, senior applications engineer, Curtiss-Wright (www.curtisswright.com), They are effective in applications requiring extremely high accuracy. Instead of using the encoder on the motor for position measurement, the linear feedback device attached to the load takes the actuator out of the equation. Actuators are not perfectly rigid, and temperature fluctuations change the length of the components in the actuator. Both of those would influence accuracy when using the feedback device on the motor and would be eliminated using a linear device at the load.

Jeremy Miller, product manager-linear mechanics, Parker Hannifin (www.parkermotion.com),

Often, linear-positioning stages are limited from a precision standpoint due to the inherent inaccuracies of mechanical elements such as guidance systems, drive train elements, mechanical chassis and linkages to the motor—rotary or linear. These inaccuracies are cumulative so, as length/travel increases, so in turn will the overall positional inaccuracy of the stage. One way to address this inaccuracy is through the use of laser interferometry to map errors of the stage over its usable travel and then set a correction factor that can dramatically improve the overall accuracy of the stage. The principle here is that by taking precise positional measurements at multiple locations throughout the travel of a stage, you can chart out the difference between the commanded position—the position that the motion controller thinks the stage is at—and the actual position, through reading from the laser interferometer. From here a linear correction factor can be introduced into the motion controller to significantly improve the overall system accuracy.

The concept of system repeatability vs. positional accuracy is an area where there is often confusion. It is critical to understand the difference between these two attributes when specifying linear-motion equipment, as specifying a high positional accuracy specification, when in reality repeatability is all that is truly needed, can often overburden the project with unneeded precision and thus cost. Repeatability comes into play when one attempts to move to the same commanded position continually. The repeatability of the system is the total range of the error moving to the same point repeatedly. Accuracy is the difference between a predicted move location and the actual achieved position. Many motion-control applications require motion between a finite set of positions within an addressable space. Think for example of a liquid handling/dispensing application where a multi-axis system might be dispensing samples into wells on a microtiter plate. These locations are all known in advance, and therefore, during programming of the controller, we can establish the exact coordinates with which to position to each time. In this case repeatability is the critical attribute, as we need to be able to repeatedly position to the same location each time. If, however, the specification is derived in terms of positional accuracy, it may require a higher precision stage to accomplish. The reason for this is that, as with the error mapping example, positional accuracy must account for inaccuracies within the system such as drive train or guidance, whereas taught positions limit the determining factors to attributes like backlash, as compounded inaccuracies of drive-train elements can be accounted for and essentially ignored. For this reason, linear stages are often able to achieve much greater levels of repeatability than that of positional accuracy.

Kyle Horsman, sensors product specialist, Turck (www.turck.com), The number of real applications is endless. Turck sees a number of opportunities with part position and vertical/horizontal equipment location. Speed control is another example. Speed control works by using a distance vs. time relationship. When placing a part, a carriage rides in a linear motion along the face of the sensor. The output corresponds to that linear position and the next step in the process can occur. The output continuously adjusts as the position moves and then a simple calculation can occur within the controller to determine the speed at which the equipment is travelling.

Sixto Moralez, regional motion engineer, Yaskawa America (www.yaskawa.com), A typical example would include a ball-screw application but could include a belt drive or rack-and-pinion system. The ball screw is coupled to a servo motor that has an encoder embedded within the servo-motor housing. This servo motor is then connected to a Servopack for control. The Servopack has the ability to send pulses to the servo motor to control the load by using the encoder feedback device to position the load. However, this isn't a fully closed option because it does not account for any mechanical compliance in the system. Thus, the use of a linear-measurement device would give another layer of feedback to the Servopack to know exactly where the load is in relation to the servo motor and correct for any position error.

Adrian Johnson, managing director, Contrinex USA (www.contrinex.com), Control System Integrators Association (CSIA, www.controlsys.org) member, Some of the more unique applications include monitoring vibration of a propeller shaft of a ship; setting multiple switch points on/off with one sensor; and hidden cam and valve measurement often found in process manufacturing.

Andrew Skidmore, senior project engineer, Thomson Industries (www.thomsonlinear.com), Consider a slide using a precision ground ballscrew with a preloaded ballnut to eliminate backlash. For this example, we'll consider a slide with a 600-mm stroke and using a 5-mm lead and a servo motor with a 2,048-line-per-revolution encoder. The screw has an accuracy of 23 µm/300 mm, and the slide as a whole has a repeatability of +/- .005 mm. So, if the slide is homed to the motor end and the encoder count is 0 at that position, then moves to an encoder count of 85,452, we can calculate the slide's position and positional tolerance. Calculating the expected position is easy:

Expected position = encoder count x lead / encoder lines per revolution = 85,452 counts x 5 mm per revolution / 2,048 lines per revolution = 208.623 mm.

And the tolerance is a stack-up of the lead error and the repeatability. At this length, the lead error = screw length x accuracy
209 mm x .023 mm / 300 mm = .016 mm

And we use the root-mean-squared method of combining the tolerances:

Total tolerance = square root (lead error^2 + accuracy^2) = square root (.016^2 + .005^2) mm = .0168 mm.

So, we would say the position of the slide is 208.623mm +/- .0168mm.