

Feed-to-length

Applications in which a continuous web, strip, or strand of material is being indexed to length, most often with pinch rolls or some sort of gripping arrangement. The index stops and some process occurs (cutting, stamping, punching, labeling, etc.).

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X/Y Point-to-point

Applications that deal with parts handling mechanisms that sort, route, or divert the flow of parts.

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Metering/Dispensing

Applications where controlling displacement and/or velocity are required to meter or dispense a precise amount of material.

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Indexing/Conveyor

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Contouring

Applications where multiple axes of motion are used to create a controlled path, (e.g., linear or circular interpolation).

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Tool Feed

Applications where motion control is used to feed a cutting or grinding tool to the proper depth.

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Winding

Controlling the process of winding material around a spindle or some other object.

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Following

Applications that require the coordination of motion to be in conjunction with an external speed or position sensor.

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Injection Molding

Applications where raw material is fed by gravity from a hopper into a pressure chamber (die or mold). The mold is filled rapidly and considerable pressure is applied to produce a molded product.

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Flying Cutoff

Applications where a web of material is cut while the material is moving. Typically, the cutting device travels at an angle to the web and with a speed proportional to the web.

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1. BBQ Grill-Making Machine

Application Type: Feed-to-Length

Motion: Linear

Application Description: A manufacturer was using a servo motor to feed material into a machine to create barbeque grills, shopping carts, etc. The process involves cutting steel rods and welding the rods in various configurations. However, feed-length was inconsistent because slippage between the drive roller and the material was too frequent. Knurled nip-rolls could not be used because they would damage the material. The machine builder needed a more accurate method of cutting the material at uniform lengths. The customer used a load-mounted encoder to provide feedback of the actual amount of material fed into the cutting head.

Machine Objectives:

- Compensate for material slippage
- Interface with customer's operator panel
- Smooth repeatable operation
- Variable length indexes
- High reliability

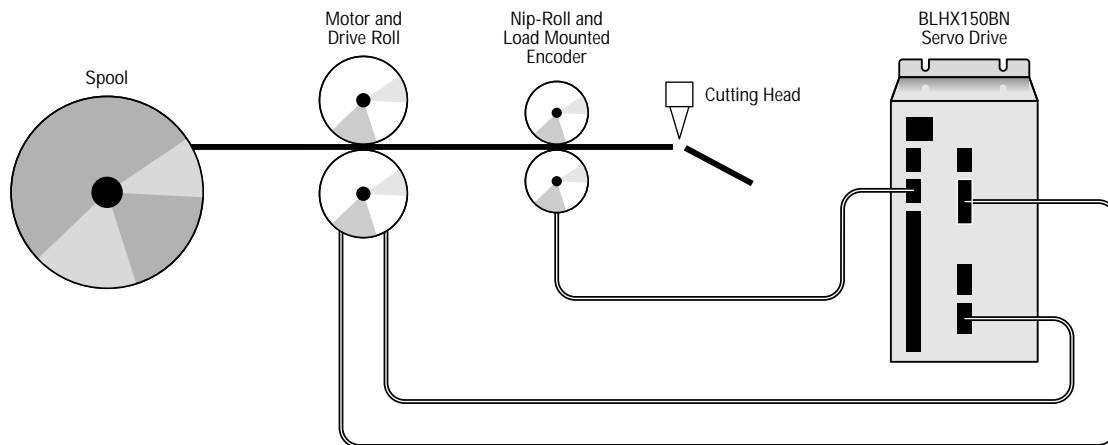
Motion Control Requirements:

- Accurate position control
- Load-mounted encoder feedback
- High-speed indexing
- XCode language

Application Solution: By using the global position feedback capability of the BLHX drive, the machine builder was able to close the position loop with the load-mounted encoder, while the velocity feedback was provided by the motor-mounted encoder and signal processing. The two-encoder system provides improved stability and higher performance than a single load-mounted encoder providing both position and velocity feedback. The load-mounted encoder was coupled to friction drive nip-rollers close to the cut head.

Product Solutions:

Controller/Drive	Motor
BLHX75BN	ML3450B-10



2. Film Advance

Application Type: Feed-to-Length
Motion: Linear

Tangential drives consist of a pulley or pinion which, when rotated, exerts a force on a belt or racks to move a linear load. Common tangential drives include pulleys and cables, gears and toothed belts, and racks and pinions.

Tangential drives permit a lot of flexibility in the design of drive mechanics, and can be very accurate with little backlash. Metal chains should be avoided since they provide little or no motor damping.

Application Description: A movie camera is being modified to expose each frame under computer control for the purpose of generating special effects. A motor will be installed in the camera connected to a 1/2-inch diameter, 2-inch long steel film drive sprocket and must index one frame in 200 milliseconds. The frame spacing is 38 mm (1.5").

Machine Requirements:

- Index one frame within 200 milliseconds
- Indexer must be compatible with BCD interface
- Fast rewind and frame indexing

Motion Control Requirements:

- Little to no vibration at rest—∴ Stepper
- Minimum settling time
- Preset and slew moves

Application Solution:

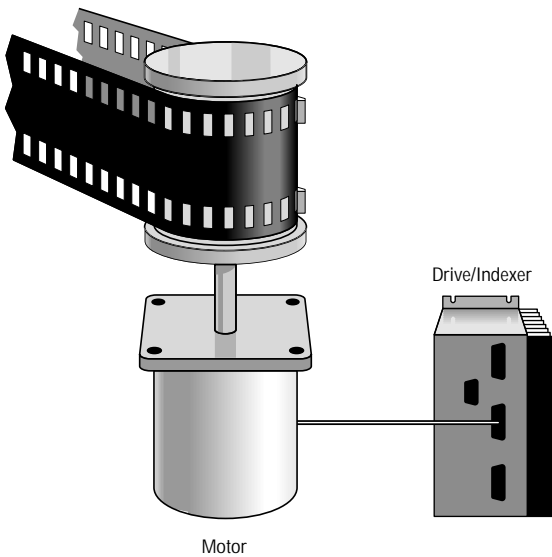
In this application, the move distance and time are known, but the required acceleration is not known. The acceleration may be derived by observing that, for a trapezoidal move profile with equal acceleration, slew and deceleration times, 1/3 of the move time is spent accelerating and 1/3 of the total distance is travelled in that time (a trapezoidal move).

It is determined that the acceleration required is 107.4 rps² at a velocity of 7.166 rps. Assume that the film weighs 1 oz. and total film friction is 10 oz-in. The rotor, sprocket, and film inertia is calculated to be 0.545 oz-in/sec². Solving the torque formula indicates that the motor for this application must provide 11.9 oz-in to drive the film and pulley (refer to Direct Drive Formulas on p. A63).

An indexer is selected to be connected to a BCD interface in the camera electronics. Preset and Slew modes on the indexer are then controlled by the camera electronics to provide fast rewind and frame indexing.

Product Solutions:

Drive/Indexer	Motor
SX	S57-51-MO



3. On-the-Fly Welder

Application Type: Feed-to-Length

Motion: Linear

Description: In a sheet metal fabrication process, an unfastened part rides on a conveyor belt moving continuously at an unpredictable velocity. Two spot-welds are to be performed on each part, 4 inches apart, with the first weld 2 inches from the leading edge of the part. A weld takes one second.

Machine Objectives

- Standalone operation
- Position welder according to position and velocity of each individual part
- Welding and positioning performed without stopping the conveyor
- Welding process must take 1 second to complete

Motion Control Requirements

- Programmable I/O; sequence storage
- Following
- Motion profiling; complex following
- High linear acceleration and speed

Application Solution:

This application requires a controller that can perform following or motion profiling based on a primary encoder position. In this application, the controller will receive velocity and position data from an incremental encoder mounted to a roller on the conveyor belt carrying the unfastened parts. The conveyor is considered the primary drive system. The secondary motor/drive system receives instructions from the controller, based on a ratio of the velocity and position information supplied by the primary system encoder. The linear motor forcer carries the weld head and is mounted on an overhead platform in line with the conveyor.

Linear motor technology was chosen to carry the weld head because of the length of travel. The linear step motor is not subject to the same linear velocity and acceleration limitations inherent in systems converting rotary to linear motion. For

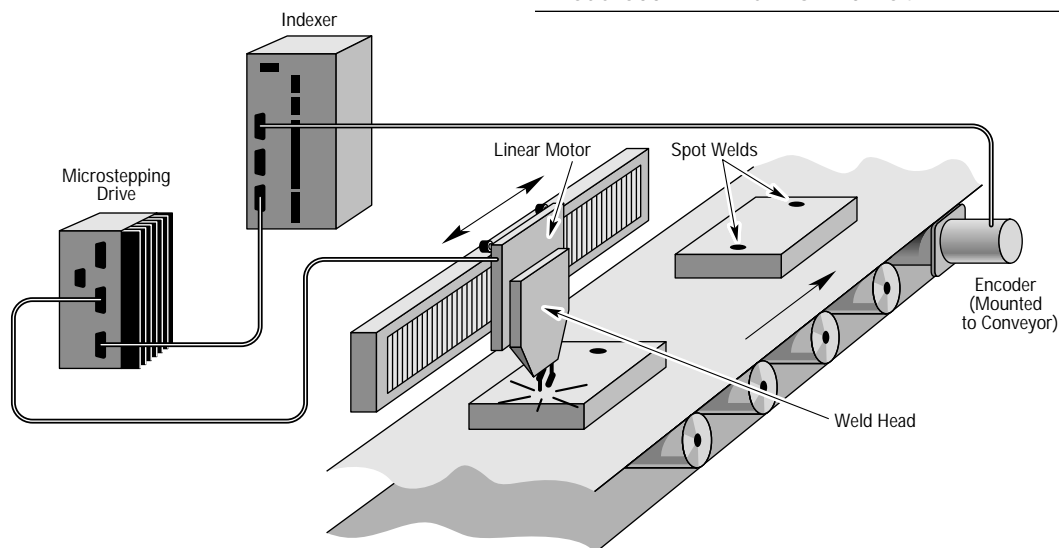
example, in a leadscrew system, the inertia of the leadscrew frequently exceeds the inertia of the load and as the length of the screw increases, so does the inertia. With linear motors, all the force generated by the motor is efficiently applied directly to the load; thus, length has no effect on system inertia. This application requires a 54-inch platen to enable following of conveyor speeds over 20 in/sec.

Application Process

1. A sensor mounted on the weld head detects the leading edge of a moving part and sends a trigger pulse to the controller.
2. The controller receives the trigger signal and commands the linear motor/drive to ramp up to twice the speed of the conveyor. This provides an acceleration such that 2 inches of the part passes by the weld head by the time the weld head reaches 100% of the conveyor velocity.
3. The controller changes the speed ratio to 1:1, so the weld head maintains the speed of the conveyor for the first weld. The weld takes 1 second.
4. The following ratio is set to zero, and the welder decelerates to zero velocity over 2 inches.
5. The controller commands the linear forcer to repeat the same acceleration ramp as in step 1 above. This causes the weld head to position itself, at an equal velocity with the conveyor, 4 inches behind the first weld.
6. Step 3 is repeated to make the second weld.
7. Once the second weld is finished, the controller commands the linear forcer to return the weld head to the starting position to wait for the next part to arrive.

Product Solutions:

Indexer	Drive	Motor	Encoder
Model 500	L Drive	PO-L20-P54	-E



4. Optical Scanner

Application Type: X-Y Point-to-Point
Motion: Rotary

Application Description: A dye laser designer needs to precisely rotate a diffraction grating under computer control to tune the frequency of the laser. The grating must be positioned to an angular accuracy of 0.05°. The high resolution of the microstepping motor and its freedom from “hunting” or other unwanted motion when stopped make it ideal.

Machine Requirements:

- System must precisely rotate a diffraction grating to tune the frequency of the laser
- PC-compatible system control
- Angular accuracy of 0.05°
- IEEE-488 interface is required

Motion Control Requirements:

- High resolution—∴ Microstepper
- Little to no vibration at rest—∴ Stepper
- No “hunting” at the end of move—∴ Stepper
- Limited space is available for motor—∴ small motor is required

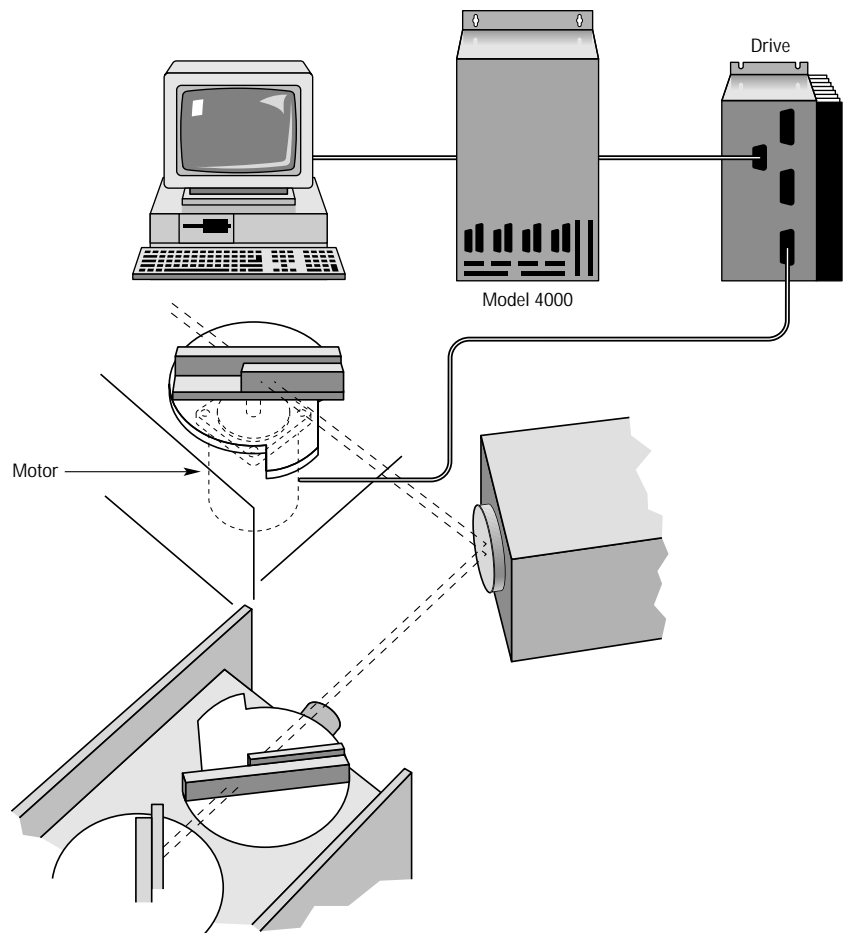
Application Solution:

The inertia of the grating is equal to 2% of the proposed motor’s rotor inertia and is therefore ignored. Space is at a premium in the cavity and a small motor is a must. A microstepping motor, which provides ample torque for this application, is selected.

The laser’s instrumentation is controlled by a computer with an IEEE-488 interface. An indexer with an IEEE-488 interface is selected. It is mounted in the rack with the computer and is controlled with a simple program written in BASIC that instructs the indexer to interrupt the computer at the completion of each index.

Product Solutions:

Indexer	Drive	Motor
Model 4000	LN Drive	LN57-51



5. Circuit Board Scanning

Application Type: X-Y Point-to-Point

Motion: Linear

Application Description: An Original Equipment Manufacturer (OEM) manufactures X-Ray Scanning equipment used in the quality control of printed circuit boards and wafer chips.

The OEM wants to replace the DC motors, mechanics and analog controls with an automated PC-based system to increase throughput and eliminate operator error. The host computer will interact with the motion control card using a "C" language program. The operator will have the option to manually override the system using a joystick.

This machine operates in an environment where PWM (pulse width modulation) related EMI emission is an issue.

Machine Requirements:

- 2-Axis analog joystick
- Joystick button
- Travel limits
- Encoder feedback on both axes

Display Requirements:

- X and Y position coordinates

Operator Adjustable Parameters:

- Dimensions of sample under test
- (0,0) position—starting point

Motion Control Requirements:

- AT-based motion controller card
- Replace velocity control system (DC motors) and mechanics with more accurate and automated positioning scheme
- Manual Joystick control
- Continuous display of X & Y axis position
- User-friendly teach mode operations
- Low EMI amplifiers (drives)

Application Solution:

The solution of this application uses the existing PC by providing a PC-based motion controller and

the AT6400 to control both axes. A microstepping drive is used because its linear amplifier technology produces little EMI. The PC monitor is the operator interface.

A "C" language program controls the machine.

Machine operation begins with a display to the operator of a main menu. This main menu lets the operator select between three modes: Automated Test, Joystick Position and Teach New Automated Test.

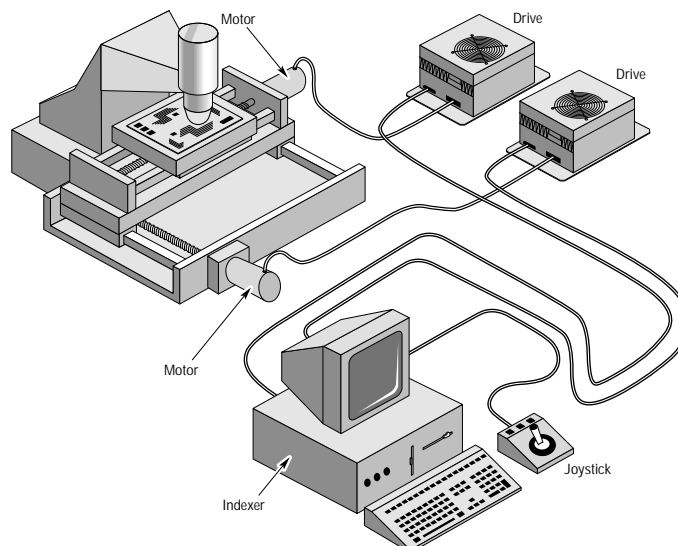
In Automated Test mode, the PC displays a menu of preprogrammed test routines. Each of these programs has stored positions for the different test locations. This data is downloaded to the controller when a test program is selected. The controller controls the axes to a home position, moves to each scan position, and waits for scan completion before moving to the next position.

In Joystick Position mode, the controller enables the joystick allowing the operator to move in both X and Y directions using the joystick. The AT6400 waits for a signal from the PC to indicate that the joystick session is over.

When Teach mode is selected, the PC downloads a teach program to the controller (written by the user). After the axes are homed, the controller enables the joystick and a "position select" joystick button. The operator then jogs axes to a position and presses the "position select" button. Each time the operator presses this "position select" button, the motion controller reads this position into a variable and sends this data to the PC for memory storage. These new position coordinates can now be stored and recalled in Automated Test mode.

Product Solutions:

Controller	Drive	Motor	Accessories
AT6400-AUX1	LN Drive	LN57-83-MO	-E Daedal X-Y Table Joystick



6. Telescope Drive

Application Type: Metering/Dispensing
Motion: Rotary

Traditional gear drives are more commonly used with step motors. The fine resolution of a microstepping motor can make gearing unnecessary in many applications. Gears generally have undesirable efficiency, wear characteristics, backlash, and can be noisy.

Gears are useful, however, when very large inertias must be moved because the inertia of the load reflected back to the motor through the gearing is divided by the square of the gear ratio.

In this manner large inertial loads can be moved while maintaining a good load inertia-to-rotor inertia ratio (less than 10:1).

Application Description: An astronomer building a telescope needs to track celestial events at a slow speed (15°/hour) and also slew quickly (15° in 1 second).

Machine Requirements:

- Smooth, slow speed is required—∴ microstepper
- High data-intensive application—∴ bus-based indexer
- Future capabilities to control at least 2 axes of motion
- Visual C++ interface

Motion Control Requirements:

- High resolution
- Very slow speed (1.25 revolutions per hour)—microstepping
- AT bus-based motion controller card
- Dynamic Link Library (DDL) device driver must be provided with indexer. This helps Windows™ programmers create Windows-based applications (i.e., Visual C++) to interface with the indexer

Application Solution:

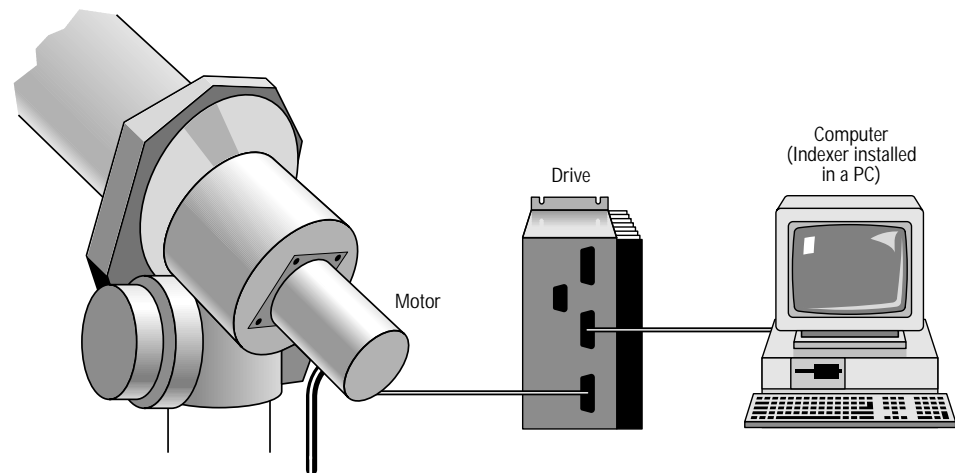
A 30:1 gearbox is selected so that 30 revolutions of the motor result in 1 revolution (360°) of the telescope. A tracking velocity of 15°/hour corresponds to a motor speed of 1.25 revs/hour or about 9 steps/sec. on a 25,000 steps/rev. Moving 15° (1.25 revolutions) in 1 second requires a velocity of 1.25 rps.

The inverse square law causes the motor to see 1/ 900 of the telescope's rotary inertia. The equations are solved and the torque required to accelerate the telescope is 455 oz-in. The step pulses required to drive the motor are obtained from a laboratory oscillator under the operator's control.

Product Solutions:

Indexer	Drive	Motor
AT6200-AUX1*	S Drive	S106-178

* To control up to four axes, refer to the AT6400.



7. Engine Test Stand

Application Type: Metering/Dispensing

Motion: Rotary

Application Description: A jet engine manufacturer is building a test facility for making operational measurements on a jet engine. The throttle and three other fuel flow controls need to be set remotely. While the application only calls for a rotary resolution of 1 degree (1/360 rev.), the smoothness and stiffness of a microstepping system is required.

Motor speeds are to be low and the inertias of the valves connected to the motors are insignificant. The main torque requirement is to overcome valve friction.

Machine Requirements:

- Low wear
- Remote operation
- High reliability

Motion Control Requirements:

- Motor velocity is low
- High stiffness at standstill
- Slow-speed smoothness
- Four axes of control
- Homing function

Application Solution:

Each valve is measured with a torque wrench. Two valves measure at 60 oz-in and the other two measure at 200 oz-in. Two high-power and two low-power microstepping motor/drives systems are selected. These choices provide approximately 100% torque margin and result in a conservative design.

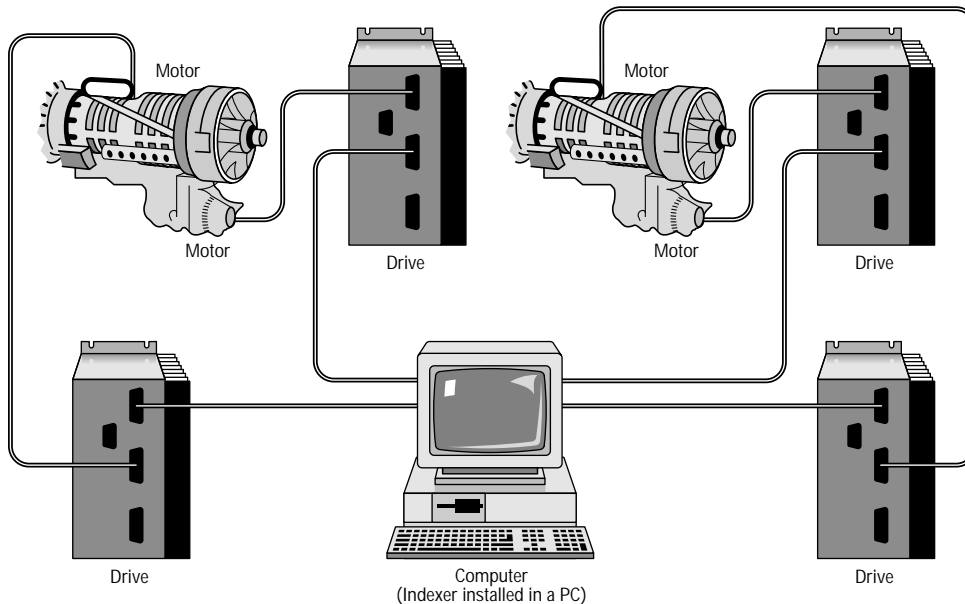
The operator would like to specify each valve position as an angle between 0° and 350°.

Home position switches are mounted on the test rig and connected to each indexer to allow for power-on home reference using the indexer's homing feature.

Product Solutions:

Indexer	Drive	Motor
AT6400*	S Drive	S57-102

* A standalone indexer could also be used (instead of a bus-based indexer), refer to the Model 4000.



8. Capsule Filling Machine

Application Type: Metering/Dispensing
Motion: Linear

Application Description: The design requires a machine to dispense radioactive fluid into capsules. After the fluid is dispensed, it is inspected and the data is stored on a PC. There is a requirement to increase throughput without introducing spillage.

Machine Requirements:

- Increase throughput
- No spilling of radioactive fluid
- Automate two axes
- PC compatible system control
- Low-cost solution
- Smooth, repeatable motion

Motion Control Requirements:

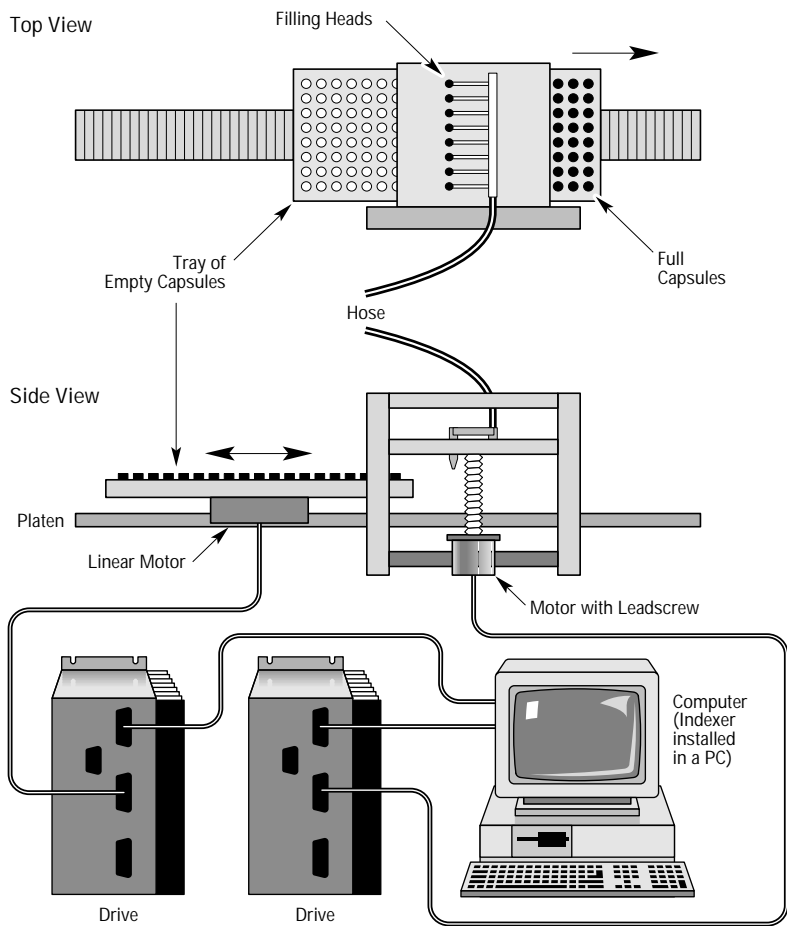
- Quick, accurate moves
- Multi-axis controller
- PC bus-based motion control card
- Open-loop stepper if possible
- High-resolution motor/drive (microstepping)

Application Solution:

The multi-axis indexer is selected to control and synchronize both axes of motion on one card residing in the IBM PC computer. An additional feature is the integral I/O capability that's necessary to activate the filling process. The horizontal axis carrying the tray of capsules is driven by a linear motor. The simple mechanical construction of the motor makes it easy to apply, and guarantees a long maintenance-free life. The vertical axis raises and lowers the filling head and is driven by a microstepping motor and a leadscrew assembly. A linear motor was also considered for this axis, but the fill head would have dropped onto the tray with a loss of power to the motor. Leadscrew friction and the residual torque of the step motor prevents this occurrence.

Product Solutions:

Indexer	Drive	Motor
AT6200	Axis 1: ZETA Drive Axis 2: ZETA Drive	S57-51 PO-L20-P18



9. Indexing Table

Application Type: Indexing/Conveyor

Motion: Linear

Application Description: A system is required to plot the response of a sensitive detector that must receive equally from all directions. It is mounted on a rotary table that needs to be indexed in 3.6° steps, completing each index within one second. For set-up purposes, the table can be positioned manually at 5 rpm. The table incorporates a 90:1 worm drive.

Machine Requirements:

- Low-EMI system
- Repeatable indexing
- Remote operation
- Table speed of 5 rpm

Motion Control Requirements:

- Jogging capability
- Sequence select functionality
- Capable of remote drive shutdown

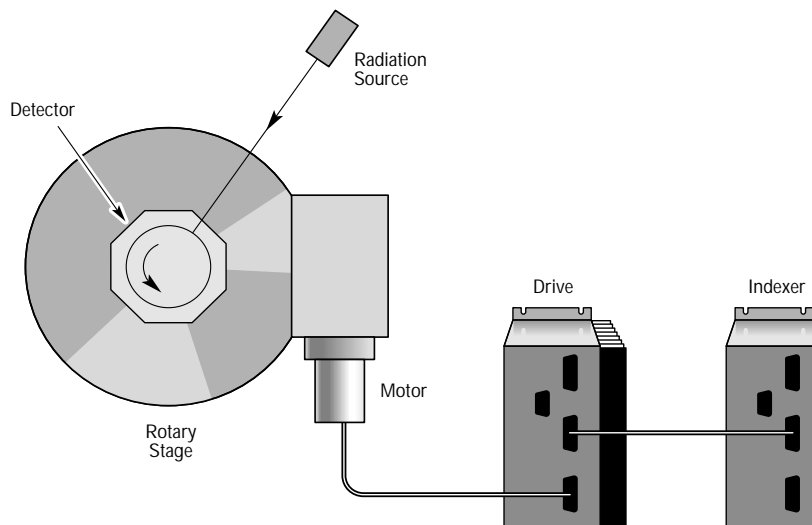
Application Solution:

The maximum required shaft speed (450 rpm) is well within the capability of a stepper, which is an ideal choice in simple indexing applications. Operating at a motor resolution of 400 steps/rev, the resolution at the table is a convenient 36,000 step/rev. In this application, it is important that electrical noise is minimized to avoid interference with the detector. Two possible solutions are to use a low-EMI linear drive or to shut down the drive after each index (with a stepper driving a 90:1 worm gear there is no risk of position loss during shutdown periods).

Product Solutions:

Indexer	Drive	Motor
Model 500	LN Drive	LN57-102

* The SX drive/indexer and PK2 drive are other products that have been used in these types of applications.



10. Rotary Indexer

Application Type: Indexing Conveyor
Motion: Rotary

Application Description: An engineer for a pharmaceutical company is designing a machine to fill vials and wants to replace an old style Geneva mechanism. A microstepping motor will provide smooth motion and will prevent spillage.

The indexing wheel is aluminum and is 0.250-inch thick and 7.5" in diameter. Solving the equation for the inertia of a solid cylinder indicates that the wheel has 119.3 oz-in². The holes in the indexing wheel reduce the inertia to 94 oz-in². The vials have negligible mass and may be ignored for the purposes of motor sizing. The table holds 12 vials (30° apart) that must index in 0.5 seconds and dwell for one second. Acceleration torque is calculated to be 8.2 oz-in at 1.33 rps². A triangular move profile will result in a maximum velocity of 0.33 rps. The actual torque requirement is less than 100 oz-in. However, a low load-to-rotor inertia ratio was necessary to gently move the vials and fill them.

- Machine Requirements:
- Smooth motion
 - PLC control
 - Variable index lengths
- Motion Control Requirements:
- Smooth motion
 - Sequence select capability
 - I/O for sequence select
 - Programmable acceleration and deceleration

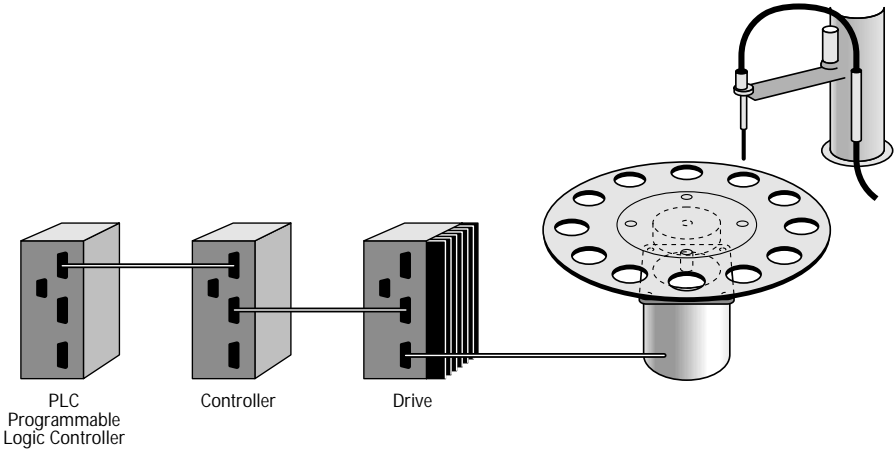
Application Solution:

The index distance may be changed by the engineer who is controlling the machine with a programmable controller. Move parameters will be changing and can therefore be set via BCD inputs. The indexer can be “buried” in the machine and activated with a remote START input.

Product Solutions:

Drive Indexer	Motor
SX Drive Indexer*	S83-135

* The 6200, AT6200, and Model 500 are other indexer products that have been used in these types of applications.



11. Conveyor

Application Type: Indexing/Conveyor

Motion: Linear

Tangential drives consist of a pulley or pinion which, when rotated, exerts a force on a belt or racks to move a linear load. Common tangential drives include pulleys and cables, gears and toothed belts, and racks and pinions.

Tangential drives permit a lot of flexibility in the design of drive mechanics, and can be very accurate with little backlash. Metal chains should be avoided since they provide little or no motor damping.

Application Description: A machine vision system is being developed to automatically inspect small parts for defects. The parts are located on a small conveyor and pass through the camera's field of view. The conveyor is started and stopped under computer control and the engineer wants to use a system to drive the conveyor because it is necessary for the part to pass by the camera at a constant velocity.

It is desired to accelerate the conveyor to a speed of 20 inches/sec. in 100 milliseconds. A flat timing belt weighing 20 ozs. is driven by a 2-inch diameter aluminum pulley 4 inches wide (this requires a motor velocity of 3.2 rps). The maximum weight of the parts on the pulley at any given time is 1 lb. and the load is estimated to have an inertia of 2 oz-in². Static friction of all mechanical components is 30 oz-in. The required motor torque was determined to be 50.9 oz-ins (refer to Direct Drive Formulas on p. A63).

Machine Requirements:

- Computer-controlled system
- High accuracy
- Low backlash

Motion Control Requirements:

- Accurate velocity control
- Linear motion
- High resolution
- AT bus-based motion control card

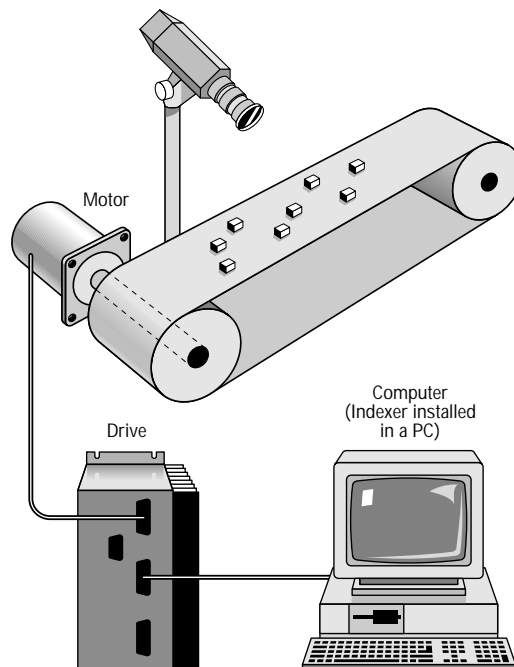
Application Solution:

A computer controls the entire inspection machine. A bus-based compatible indexer card was selected. A microstepping motor/drive system that supplied 100 oz-in of static torque was also chosen to complete the application.

Product Solutions:

Indexer	Drive	Motor
PC21*	S Drive	S57-83

* The AT6200 and AT6400 are other PC-based indexer products that are often used in these types of applications.



12. Engraving Machine

Application Type: Contouring
Motion: Linear

Application Description: An existing engraving machine requires an upgrade for accuracy beyond 0.008 inches, capability and operating environment. Using a personal computer as the host processor is desirable.

Machine Requirements:

- Positional accuracy to 0.001 inches
- Easy-to-use, open-loop control
- CNC machining capability
- Interface-to-digitizer pad
- Compatibility with CAD systems

Motion Control Requirements:

- High resolution
- Microstepping
- G-Code compatibility
- IBM PC compatible controller

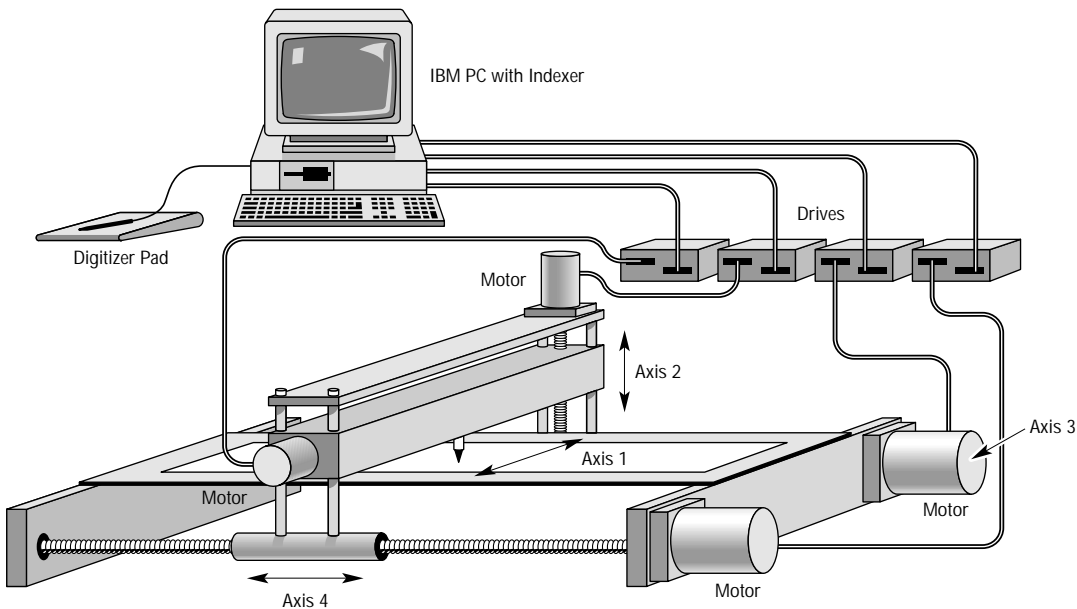
Application Solution:

A four-axis motion controller resides on the bus of an IBM compatible computer, allowing full integrated control of four axes of motion. Axes 3 and 4 are synchronized to prevent table skew. CompuCAM's G-Code package allows the user to program in industry-standard machine tool language (RS274 G-Code) or to import CAD files with CompuCAM-DXF. Open-loop microstepping drives with precision leadscrews give positional accuracies better than the desired ± 0.001 inch. This simple retrofit to the existing hardware greatly improved system performance.

Product Solutions:

Indexer	Drives	Motor
AT6400*	S Drives	S83-135

* The Model 4000 (standalone) and AT6450 are servo controller products that have also been used in these types of applications.



13. Fluted-Bit Cutting Machine

Application Type: Contouring

Motion: Linear

Application Description: The customer manufactures a machine that cuts a metal cylinder into fluted cutting bits for milling machines. The machine operation employed a mechanical cam follower to tie the bit's rotation speed to the traverse motion of the bit relative to the cutting tool. The cut depth was manually adjusted using a hand crank.

This arrangement was acceptable when the company had a bit for the cam they wanted to grind. Unfortunately, custom prototype bits made of titanium or other high-tech metals required that they make a cam before they could machine the bit, or do those parts on a \$10,000 CNC screw machine. Both of these alternatives were too expensive for this customer.

Machine Requirements:

- Machine must be capable of making low-volume custom bits as well as high-volume standard bits—an be economical for both processes.

- Quick set-up routine
- Operator interface for part entry

Motion Control Requirements:

- Smooth motion
- Four axes of coordinated motion
- 2 axes of linear interpolation
- Math capabilities

Application Solution:

Controlled by a multi-axis step and direction controller, microstepping motors and drives are attached to four axes for smooth, programmable motion at all speeds.

- Axis 1: Alignment
- Axis 2: Chamfer (cutting depth)
- Axis 3: Traverse
- Axis 4: Rotation

To allow for the flexibility required to cut a bit at a desired pitch, the traverse and rotation axes (axes 3 and 4) are synchronized along a straight line. The controller's linear interpolation allows this functionality. Both the alignment and chamfer axes (axes 1 and 2) remain stationary during the cutting process.

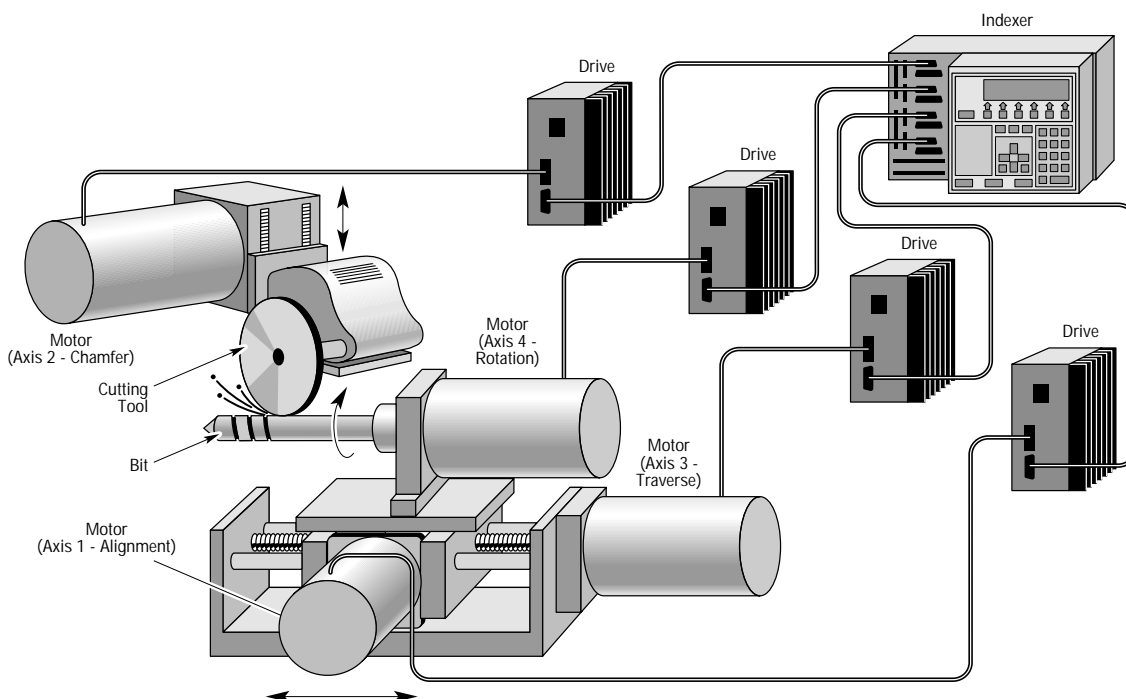
The controller's operator input panel and math capabilities allow the operator to enter the bit diameter, desired pitch, depth, and angle. Using these part specifications, the controller generates all motion profiles and stores them in nonvolatile battery-backed RAM. Programming is accomplished with the controller's menu-driven language. The typical process is as follows:

1. Axis 1 aligns the center line of the bit to the cutting tool.
2. Axis 2 lowers the cutting tool to the desired cutting depth (chamfer).
3. Axis 3 traverses the bit along the cutting tool.
4. While axis 3 traverses, axis 4 rotates the bit to create the desired pitch.

Product Solutions:

Indexer	Drives	Motor
Model 4000*	S Drives	S83-135

* The Model AT6400 and AT6450 are other controllers that have been used in these types of applications.



14. Surface Grinding Machine

Application Type: Tool Feed
Motion: Linear

Application Description: A specialty machine shop is improving the efficiency of its surface grinding process. The existing machine is sound mechanically, but manually operated. Automating the machine will free the operator for other tasks, which will increase overall throughput of the machine shop.

Machine Requirements:

- Allow flexibility to machine various parts
- Easy set up for new parts
- Automate all three axes
- Keep operator informed as to progress
- Low-cost solution
- High-resolution grinding

Motion Control Requirements:

- Nonvolatile memory for program storage
- Teach mode
- Multi-axis controller
- Interactive user configurable display
- Open-loop stepper if possible
- High resolution motor/drive (microstepping)

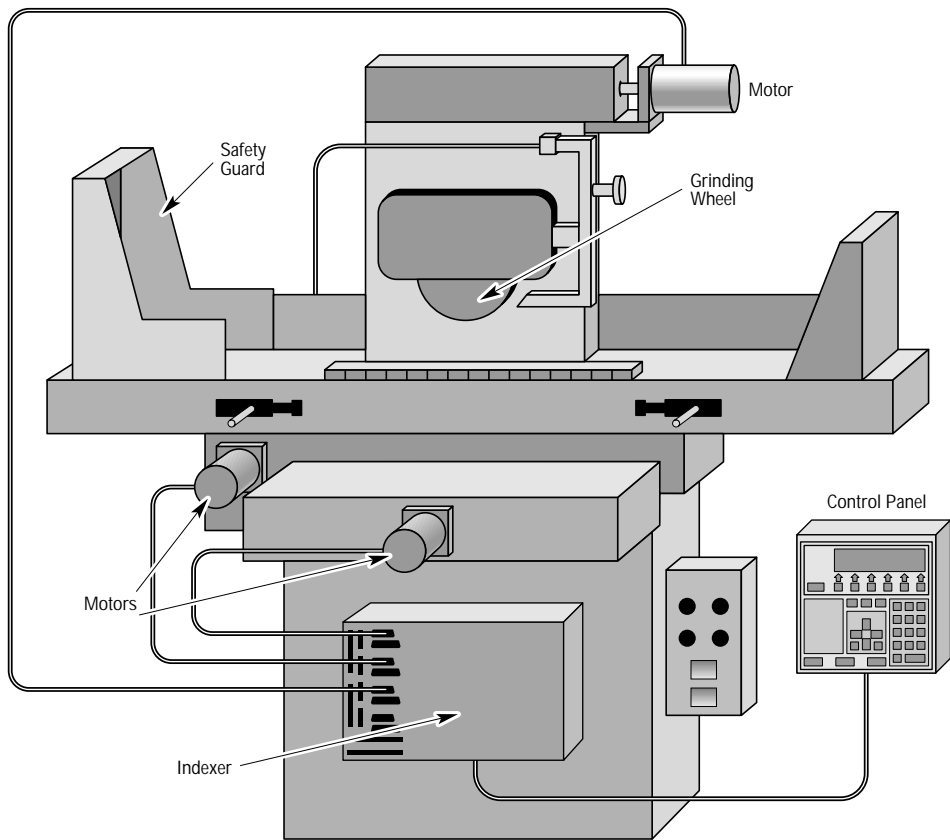
Application Solution:

A four-axis motion controller with a user-configurable front panel is required for this application. An indexer with a sealed, backlit display would be ideal for the application's industrial environment (machine shop). The controller's Teach mode and sizable nonvolatile memory allows for easy entry and storage of new part programs. Microstepping drives, which plenty of power, resolution, and accuracy are selected instead of more expensive closed-loop servo systems. The operator utilizes the controller's jog function to position the grinding head at the proper "spark off" height. From this point, the controller takes over and finishes the part while the operator works on other critical tasks. Increasing the parts repeatability and throughput of the process justified the cost of automating the machine.

Product Solutions:

Indexer	Drive	Motor
Model 4000*	S Drive	S83-93

* The AT6400 PC-based indexer has also been used to solve similar applications.



15. Transfer Machine

Application Type: Tool Feed

Motion: Linear

Application Description: A stage of a transfer machine is required to drill several holes in a casting using a multi-head drill. The motor has to drive the drill head at high speed to within 0.1" of the workpiece and then proceed at cutting speed to the required depth. The drill is then withdrawn at an intermediate speed until clear of the work, then fast-retracted and set for the next cycle. The complete drilling cycle takes 2.2 seconds with a 0.6-second delay before the next cycle.

Due to the proximity of other equipment, the length in the direction of travel is very restricted. An additional requirement is to monitor the machine for drill wear and breakage.

Machine Requirements:

- Limited length of travel
- Limited maintenance
- Monitor and minimize drill damage
- High-speed drilling

Motion Control Requirements:

- Packaged drive controller
- Complex motion profile
- High speed
- High duty cycle

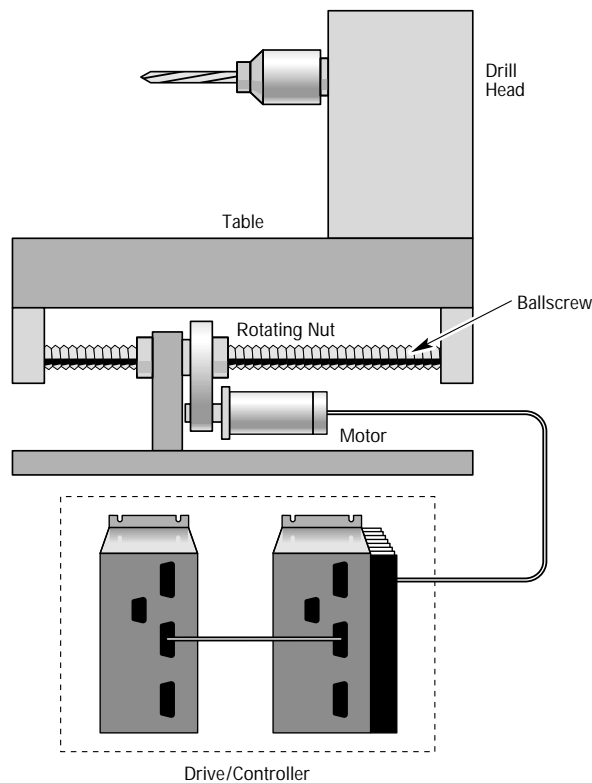
Application Solution:

The combined requirements of high speed, high duty cycle and monitoring the drill wear all point to the use of a servo motor. By checking the torque load on the motor (achieved by monitoring drive current), the drilling phase can be monitored (an increased load during this phase indicates that the drill is broken).

This type of application will require a ballscrew drive to achieve high stiffness together with high speed. One way of minimizing the length of the mechanism is to attach the ballscrew to the moving stage and then rotate the nut, allowing the motor to be buried underneath the table. Since access for maintenance will then be difficult, a brushless motor should be selected.

Product Solutions:

Drive/Controller	Motor
APEX6152	606 Motor



16. Flute Grinder

Application Type: Tool Feed
Motion: Linear

Application Description: A low-cost machine for grinding the flutes in twist drills requires two axes of movement—one moves the drill forwards underneath the grinding wheel, the other rotates the drill to produce the helical flute. At the end of the cut, the rotary axis has to index the drill round by 180° to be ready to grind the second flute. The linear speed of the workpiece does not exceed 0.5 inches/sec.

Machine Requirements:

- Two-axis control
- Low cost
- Easy set-up and change over of part programs
- Smooth, accurate cutting motion

Motion Control Requirements:

- Two-axis indexer
- Linear interpolation between axes
- Nonvolatile program storage
- Flexible data pad input
- Moderate speeds
- Programmable I/O

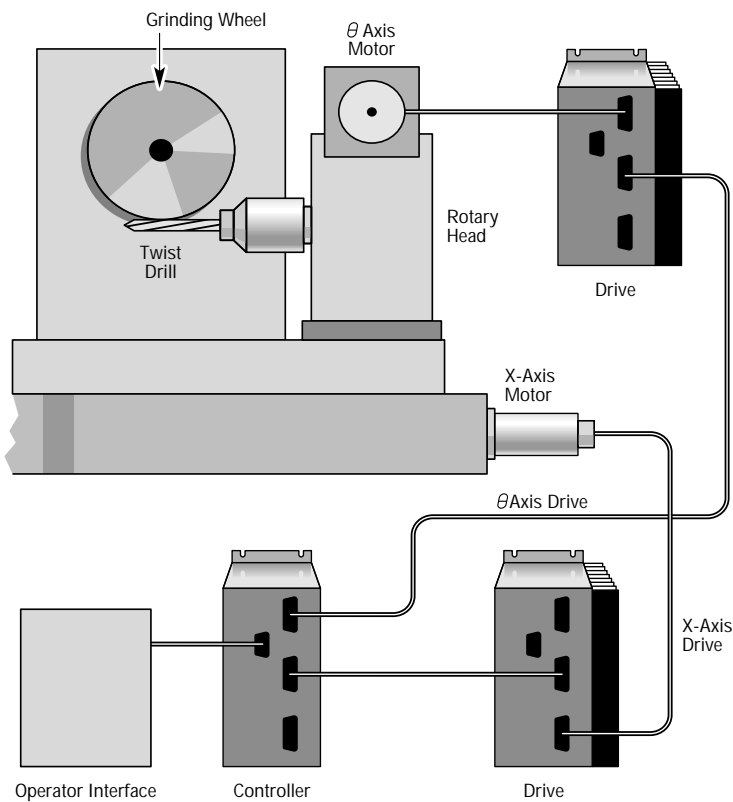
Application Solution:

This is a natural application for stepper motors, since the speeds are moderate and the solution must be minimum-cost. The grinding process requires that the two axes move at accurately related speed, so the controller must be capable of performing linear interpolation. The small dynamic position error of the stepper system ensures that the two axes will track accurately at all speeds.

Product Solutions:

Controller	Drive	Motor	Operator Interface
6200*	S Drive	S83-135	RP240

* The Model 4000-FP has also been used to solve similar applications.



17. Disc Burnisher

Application Type: Tool Feed

Motion: Rotary

Application Description: Rigid computer discs need to be burnished so that they are flat to within tight tolerances. A sensor and a burnishing head move together radially across the disc. When a high spot is sensed, both heads stop while the burnishing head removes the raised material. The surface speed of the disc relative to the heads must remain constant, and at the smallest diameter, the required disc speed is 2400 rpm. The machine operates in a clean environment, and takes approximately one minute to scan an unblemished disk.

Machine Requirements:

- High-speed burnishing
- Surface speed of disc relative to the heads must remain constant
- Clean environment—∴ no brushed servo motors

Motion Control Requirements:

- Variable storage, conditional branching and math capabilities
- Linear interpolation between the head axes (axes #1 and #2)
- Change velocity on-the-fly
- Programmable inputs

Application Solution:

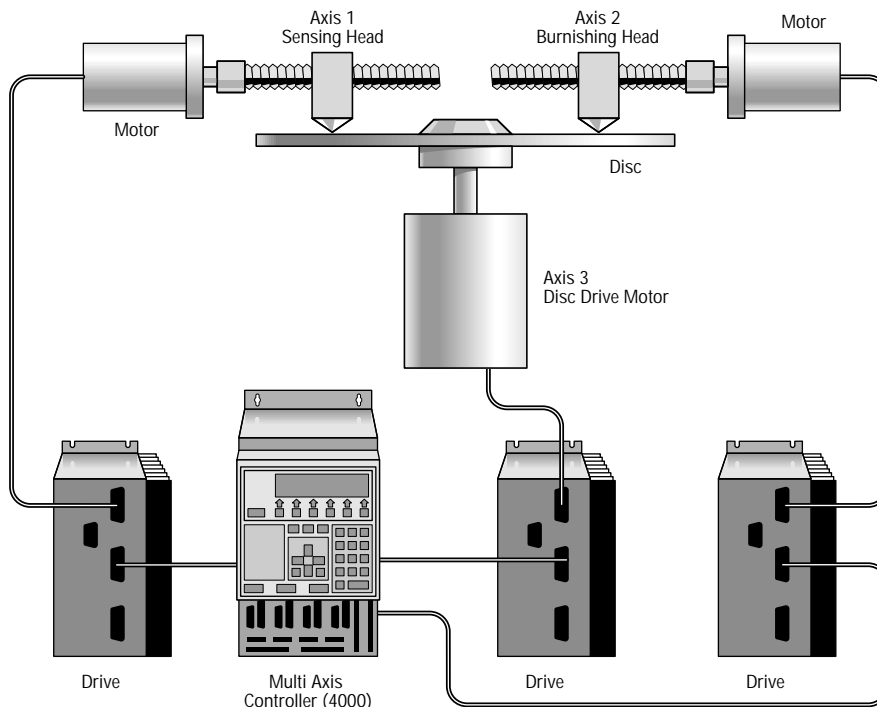
The drive for the disc requires continuous operation at high speed, and a brushless solution is desirable to help maintain clean conditions. The natural choice is a brushless servo system. The speed of this axis depends on head position and will need to increase as the heads scan from the outside to the center. To successfully solve this application, the multi-axis indexer requires variable storage, the ability to perform math functions, and the flexibility to change velocity on-the-fly.

The sense and burnishing heads traverse at low speed and can be driven by stepper motors. Stepper motors—since the sense and burnishing heads need to start and step at the same time, linear interpolation is required.

Product Solutions:

Controller	Drive #1	Drive #2	Drive #3
Model 4000*	S Drive	S Drive	Z Drive
Motor #1	Motor #2	Motor #3	
S83-93	S83-93	Z60	

* The AT6400 PC-based indexer has also been used in these types of applications.



18. Monofilament Winder

Application Type: Winding
Motion: Rotary

Application Description: Monofilament nylon is produced by an extrusion process that results in an output of filament at a constant rate. The product is wound onto a bobbin that rotates at a maximum speed of 2000 rpm. The tension in the filament must be held between 0.2 lbs. and 0.6 lbs to ensure that it is not stretched. The winding diameter varies between 2" and 4".

The filament is laid onto the bobbin by a ballscrew-driven arm, which oscillates back and forth at constant speed. The arm must reverse rapidly at the end of the move. The required ballscrew speed is 60 rpm.

Machine Requirements:

- Controlled tension on monofilament
- Simple operator interface
- High throughput

Motion Control Requirements:

- 2 axes of coordinated motion
- Linear interpolation
- Constant torque from motor

Application Solution:

The prime requirement of the bobbin drive is to provide a controlled tension, which means operating in Torque mode rather than Velocity mode. If the motor produces a constant torque, the tension in the filament will be inversely proportional to the winding diameter. Since the winding diameter varies by 2:1, the tension will fall by 50% from start to finish. A 3:1 variation in tension is adequate, so constant-torque operation is acceptable. (To maintain constant tension, torque must be increased in proportion to winding diameter.)

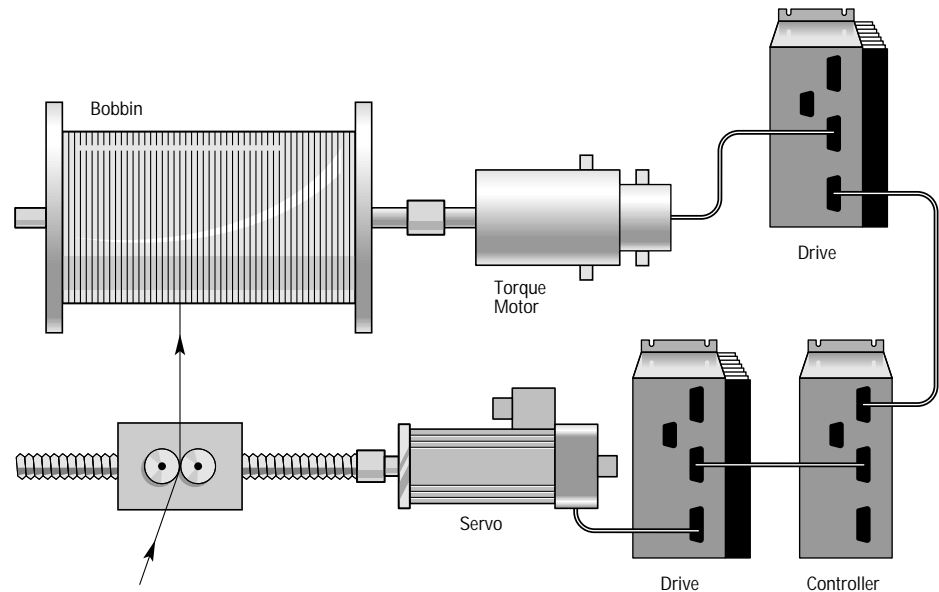
This requirement leads to the use of a servo operating in torque mode (the need for constant-speed operation at 2000 rpm also makes a stepper unsuitable). In practice, a servo in Velocity mode might be recommended, but with an overriding torque limit, the programmed velocity would be a little more than 2000 rpm. In this way, the servo will normally operate as a constant-torque drive. However, if the filament breaks, the velocity would be limited to the programmed value.

The traversing arm can be adequately driven by a smaller servo.

Product Solutions:

Indexer	Drive	Motor
6250*	BL30	ML2340

* The AT6450 PC-based servo controller and the APEX20/APEX40 servo controllers have also been used in this type of application.



19. Capacitor Winder

Application Type: Winding

Motion: Linear

Application Description: The customer winds aluminum electrolytic capacitors. Six reels, two with foil (anode and cathode) and four with paper, are all wound together to form the capacitor. After winding the material a designated number of turns, the process is stopped and anode and cathode tabs are placed on the paper and foil. The tabs must be placed so that when the capacitor is wound, the tabs end up $90^\circ (\pm 0.1^\circ)$ from each other. This process is repeated until the required number of tabs are placed and the capacitor reaches its appropriate diameter.

The previous system used a PLC, conventional DC drives, and counters to initiate all machine functions. DIP switches were used to change and select capacitor lengths. Lengthy set-up and calibration procedures were required for proper operation. In addition, material breakage was common, resulting in extensive downtime. An operator had to monitor the machine at all times to constantly adjust the distances for accurate tab placement.

Machine Requirements:

- Constantly monitor the linear feed length of the paper and foil and calculate the constantly changing capacitor circumference as a function of that length
- A complete motion control package is required to eliminate the need for a PLC and separate motion cards
- Reduce time and complexity of set-up (too much wiring in previous system)
- Reduce machine downtime caused by material breakage

Motion Control Requirements:

- Following
- Two axes of coordinated motion
- Math capability
- AT-based control card

Application Solution:

Precise motion control of the material feed axes demands closed-loop servo commands. Actuation of external cylinders and solenoids requires both analog and digital I/O. A flexible operator interface is needed for diagnostics and other alterations of machine function. Motion, I/O, and an operator interface should be provided with a machine controller.

The first motorized axis (mandril) pulls all six materials together and feeds an appropriate distance. An encoder is placed on this motor as well as on the materials as they are fed into the mandril. The controller constantly compares the two encoders to get an exact measurement of linear distance, and compensates for material stretching.

When the linear distance is achieved, the first motor comes to an abrupt stop while a second axis places a tab. The controller then initiates a cold weld (pressure weld) of the tab onto the paper and foil.

To avoid material breakage, constant tension is applied to each of the six reels via air cylinders. Sensors are installed on all axes so that if a break occurs, the controller can stop the process.

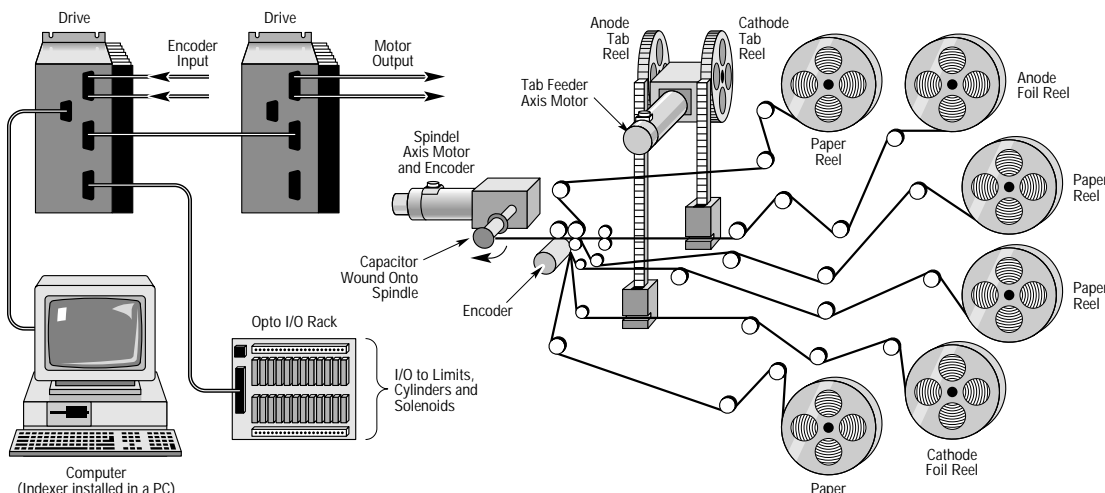
A computer makes this process easy to use and set up. PC/AT-based support software allows the user to build his controller command program.

The operator sets the diameter of the appropriate capacitor, the operating speed and the number of capacitors (all via the keyboard). After this process, the machine runs until a malfunction occurs or it has completed the job.

Product Solutions:

Controller	Drive	Motor	Accessories
AT6250*	BL30	ML2340	-E Encoder

* The 6250 standalone 2-axis servo controller and APEX20/APEX40 servo drives have also been used in these types of applications.



20. Labelling Machine

Application Type: Following
Motion: Linear

Application Description: Bottles on a conveyor run through a labelling mechanism that applies a label to the bottle. The spacing of the bottles on the conveyor is not regulated and the conveyor can slow down, speed up, or stop at any time.

Machine Requirements:

- Accurately apply labels to bottles in motion
- Allow for variable conveyor speed
- Allow for inconsistent distance between bottles
- Pull label web through dispenser
- Smooth, consistent labelling at all speeds

Motion Control Requirements:

- Synchronization to conveyor axis
- Electronic gearbox function
- Registration control
- High torque to overcome high friction
- High resolution
- Open-loop stepper if possible

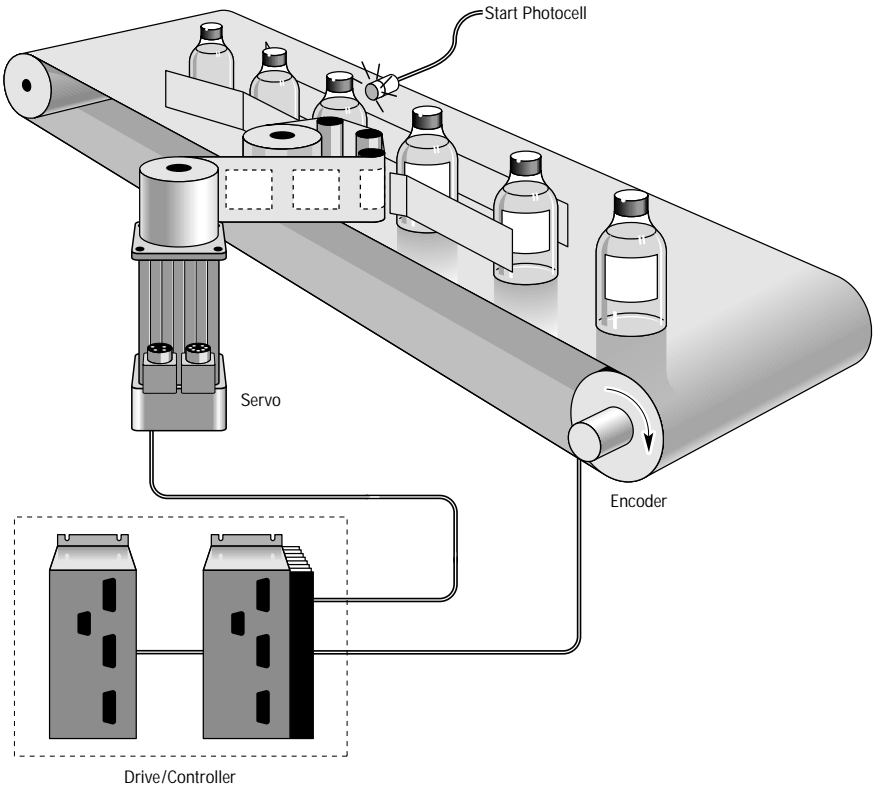
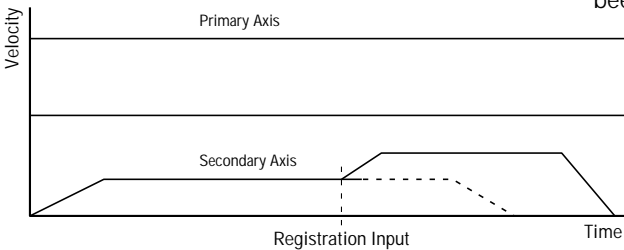
Application Solution:

A motion controller that can accept input from an encoder mounted to the conveyor and reference all of the speeds and distances of the label roll to the encoder is required for this application. A servo system is also required to provide the torque and speed to overcome the friction of the dispensing head and the inertia of the large roll of labels. A photosensor connected to a programmable input on the controller monitors the bottles' positions on the conveyor. The controller commands the label motor to accelerate to line speed by the time the first edge of the label contacts the bottle. The label motor moves at line speed until the complete label is applied, and then decelerates to a stop and waits for the next bottle.

Product Solutions:

Controller	Motor
APEX6152*	APEX604

* The ZXF single-axis servo controller has also been used in these types of applications.



21. Window Blind Gluing

Application Type: Following

Motion: Linear

Application Description: A window blind manufacturer uses an adhesive to form a seam along the edge of the material. It is critical that the glue be applied evenly to avoid flaws; however, the speed that the material passes beneath the dispensing head is not constant. The glue needs to be dispensed at a rate proportional to the varying speed of the material.

Machine Requirements:

- Allow for varying material speed
- Dispense glue evenly
- Allow for multiple blind lengths

Motion Control Requirements:

- Synchronization to material speed
- Velocity following capabilities
- Sequence storage

Application Solution:

A step and direction indexer/follower and a microstepping motor/drive are used to power a displacement pump. The indexer/follower is programmed to run the motor/drive at a velocity proportional to the primary velocity of the material, based on input from a rotary incremental encoder. This assures a constant amount of glue along the length of the material.

When the start button is depressed, the glue will begin dispensing and can be discontinued with the stop button. If a new speed ratio is desired, FOR can be changed with either the front panel pushbutton, thumbwheels, or with the RS-232C serial link.

Program

Two following commands are used.

FOR Sets the ratio between the secondary motor resolution and the primary encoder resolution

FOL Sets the ratio of the speed between the primary and secondary motor

One input will be configured to start motion, a second input will be used to stop motion. The motor has 10000 steps/revolution. The encoder that is placed on the motor pulling the material has 4000 pulses/revolution. It is desired to have the motor dispensing the glue turning twice as fast as the encoder sensing the material.

FOR2.5 Set the motor to encoder ratio

FOL200 The following speed ratio is 200% or twice as fast

A10 Set acceleration to 10 rps²

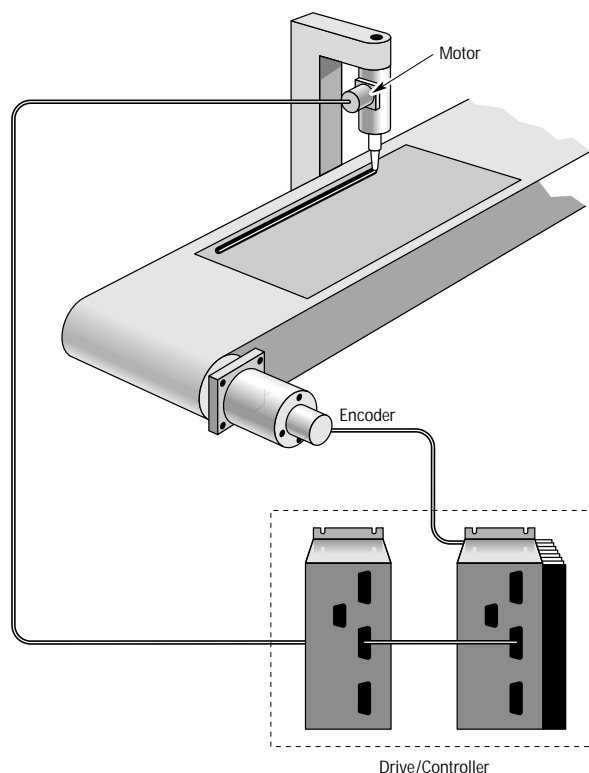
AD10 Set deceleration to 10 rps²

MC The controller is placed in Continuous mode

Product Solutions:

Drive/Controller	Motor
SXF Drive/Controller*	S57-102

* The Model 500 single-axis controller and the S Drive have also been used in these types of applications.



22. Moving Positioning System

Application Type: Following
Motion: Linear

Application Description: In a packaging application, a single conveyor of boxes rides between 2 conveyors of product. The product must be accurately placed in the boxes from alternate product conveyors without stopping the center conveyor of boxes. The line speed of the boxes may vary. When the product is ready, the controller must decide which box the product can be placed into and then move the product into alignment with the moving box. The product must be moving along side of the box in time for the product to be pushed into the box.

Machine Requirements:

- Reliable product packaging on the fly
- Standalone operation
- Multiple product infeeds
- Continuous operation without stopping the box conveyor

Motion Control Requirements:

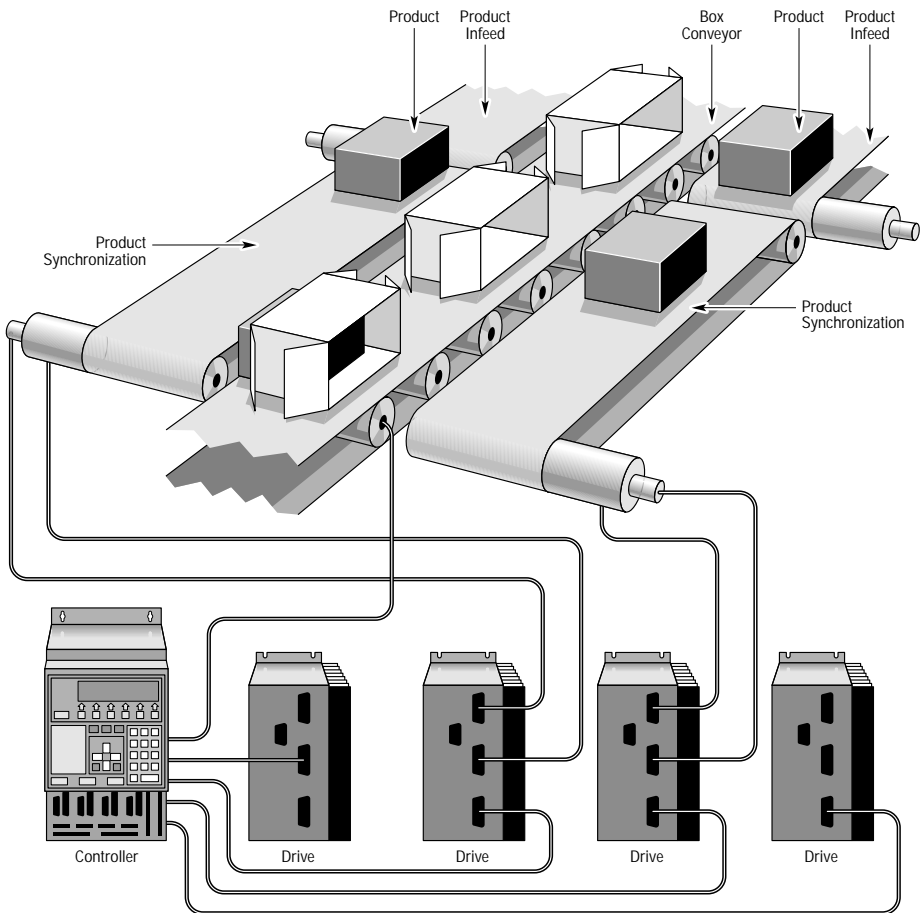
- Programmable I/O
- Sequence storage
- Complex following capabilities
- Moving positioning system functionality
- Multitasking

Application Solution:

A standalone multiple-axis controller provides the control for this application. The controller can perform motion profiling based on an external encoder that is mounted on the center conveyor of boxes. The two product conveyors are driven by servo motors for high speeds and accelerations. The controller looks for a product ready signal from a sensor mounted on the product infeed conveyor and then makes a move based on the status of the boxes on the box conveyor and the status of the product on the other product conveyor. The controller is multitasking the control of the two product conveyors and the external encoder input, as well as a sensor input to monitor the status of the boxes. Thus the controller can instantaneously decide into which box the product should be placed and where that box is located. The controller then accelerates the product into alignment with the appropriate box in time for the product to be completely placed in the box, and continues to monitor the other rest of the product and box positions.

Product Solutions:

Controller	Drive	Motor	Encoder
Model 500	L Drive	L20	-E Encoder



23. Plastic Injection Molding

Application Type: Injection Molding

Motion: Linear

Application Description: A manufacturer of injection molding machines wants a system that will close a molding chamber, apply pressure to the molding chamber for 5 seconds and then open the mold. This action needs to be synchronized with other machine events. When the molding chamber is open the motor must be 'parked' at a designated position to allow clearance to remove the molded part. The manufacturer would like an electronic solution (this is the only hydraulic axis on the current machine).

Machine Requirements:

- Electronic solution
- Computer-controlled solution
- 4000N (900lbs.) force

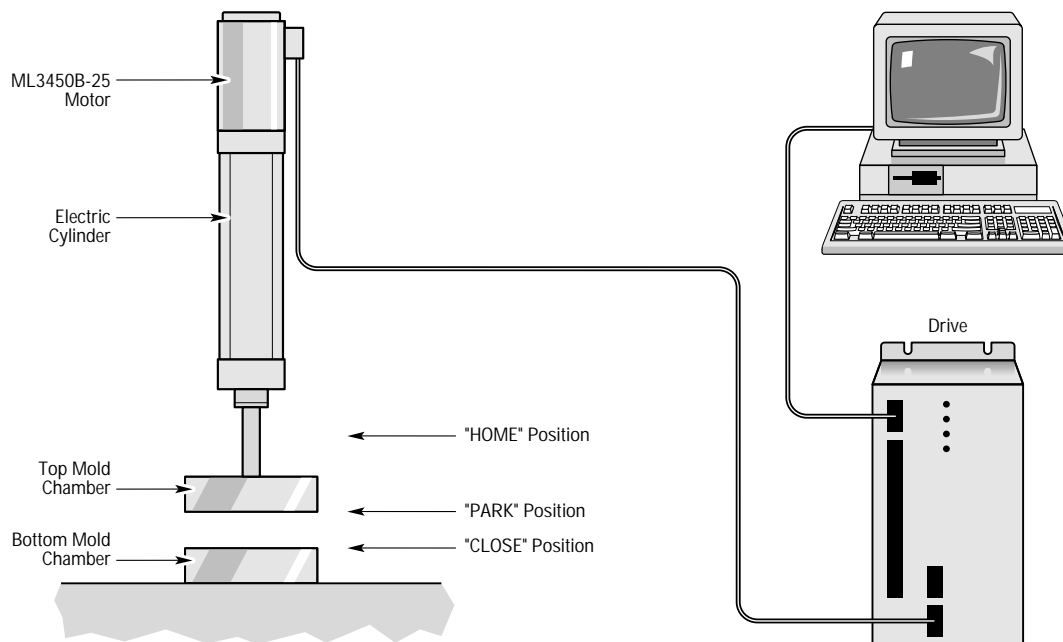
Motion Control Requirements:

- Position and torque control
- Serial link to computer and other drives
- Ability to change pressure and dwell

Application Solution: A BLHX75BP brushless servo drive with an ML345OB-25 motor and an ETS80-BO4LA Electro-Thrust Electric Cylinder were used. The motor drives the rod inside the cylinder and extends/retracts the top molding chamber. During this portion of the machine cycle, the servo drive must control the position of the motor. When the top molding chamber closes on the bottom molding chamber, a pressure must be applied. While pressure is being applied to the mold the position of the motor is not important. However, the motor must control the pressure on the molding chamber by applying a torque from the motor. A regular positioning servo can only apply torque by generating a position error—trying to control torque through position is not very accurate and can create instabilities. The BLHX servo was chosen because it can switch between position control and torque control on-the-fly without instability or saturation and then, while in torque control mode, directly controls motor torque.

Product Solutions:

Controller/Drive	Motor	Actuator
BLHX75BN	ML3450B-10	-ET580-BO4LA



24. Rotating Tube Cutter

Application Type: Flying Cutoff
Motion: Linear

Application Description: Metal tubing feeds off of a spool and needs to be cut into predetermined lengths. A rotating blade mechanism is used to cut the tube, and the blade mechanism must spin around the tube many times in order to complete the cut. The throughput of this machine must be maximized, so the tubing cannot be stopped while this cut is being made. Therefore, to make a clean cut on the tube, the blade must move along with the tube while the cut is being performed.

Machine Requirements:

- Standalone operation
- Move cutting mechanism with the tubing to make the cut without stopping
- Simple user interface to set different tube lengths
- High accuracy on cut

Motion Control Requirements:

- Programmable I/O
- Program storage
- Position following
- High acceleration and speed

Application Solution:

A single-axis servo controller/drive was chosen to solve this application. An external encoder monitors the tube output and sends this information back to the servo system. The servo system tracks the length of the tube that is being fed past the cutting blade. Once the appropriate amount of material has been fed past the blade, the servo accelerates the cutting device up to the speed of the tube, sends an output to start the cutter, and then follows the tube speed exactly.

Product Solutions:

Drive/Controller	Motor
APEX6152	APEX610

