MOTION CONTROL TECHNOLOGY

Understanding PLC Based Stepper Motion Control

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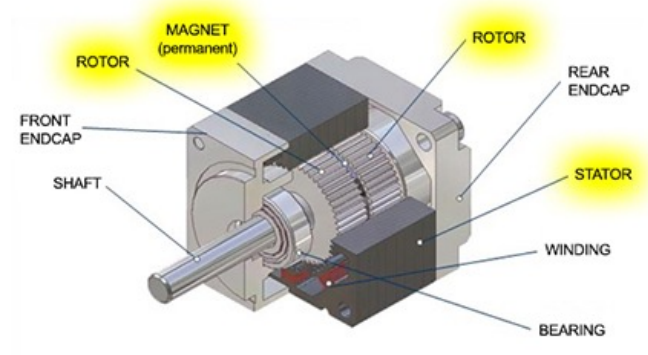
INTRODUCTION

Choosing the right motor for your application is critical for the efficiency of your motion control applications. It can be difficult to choose between servo motors and stepper motors as there are so many considerations: Cost, Torque, Efficiency, Speed, Circuitry, and More.

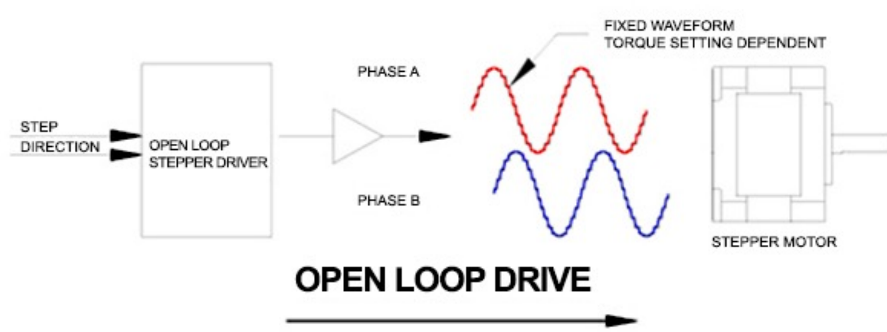
It is helpful to first understand the basics of these motors as well as what differentiates them from one another. By aligning the capabilities of the motor with the needs of your application, you explore all options for integrating stepper motion into a plc control system. Both motors are broadly used in industry, yet neither is a universal solution. When properly applied, both stepper and servo motors can provide efficient, reliable power for a highly successful system.

MOTOR BASICS: HOW A STEPPER MOTOR WORKS

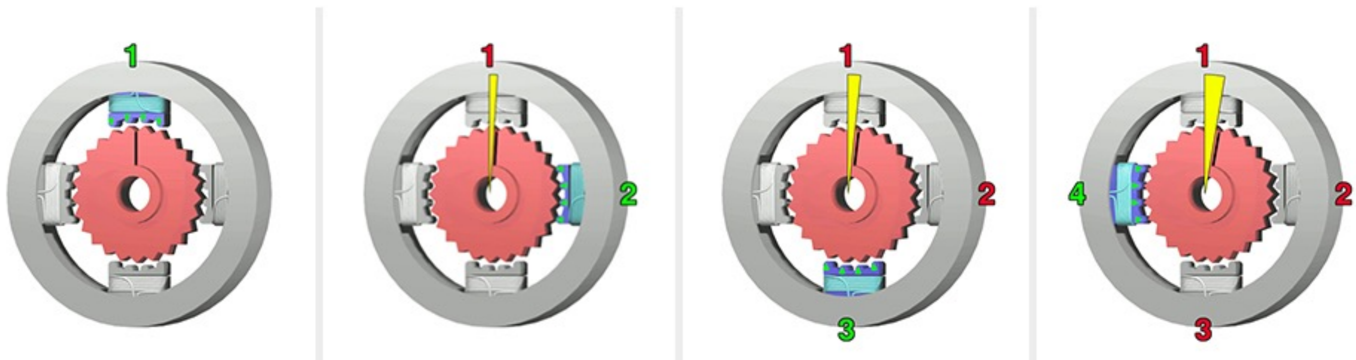
Stepper Motor Construction
Most industrial stepper motors are hybrid stepper motors that consist of a permanent magnet rotor and a wound electromagnetic stator. The switching of the motor current changes the magnetic field within the stator, causing the rotor to rotate.



Stepper Motor Current
A stepper system is a constant current system. DC current is used to energize the magnetic coils of the stepper motor at all times, even at rest.



The current supplied from the drive creates a magnetic field that is used to rotate the shaft of the motor. Below is a basic representation of how this process works.



1. The upper electromagnet is activated and the teeth of the central cog line up accordingly.
2. The upper electromagnet is deactivated and the right one turned on. The closest cog teeth then jump to line up with this. This causes a step (e.g. 1.8˚ turn).
3. The right electromagnet is deactivated and the lower one is turned on. The cog teeth then jump to line up with the bottom electromagnet. This causes another step.
4. The bottom electromagnet is deactivated and the left-most one turned on. The cog teeth then jump to line up with this. This causes another step. On a motor which has a step angle of 1.8˚, 200 steps are required for a full rotation.

OTHER THINGS TO KNOW

1. Microstepping increases the number of steps/turn.
2. Increasing the current increases motor torque.
3. The higher the step frequency the higher the motor speed.
4. As motor speed increases, back EMF can reduce motor torque.
5. Because they generate incremental motion, they are generally run open loop, eliminating the cost and complexity of an encoder or resolver.

STEPPER BASICS SUMMARY

DC current generates a magnetic field. It is an open loop, constant current system. Current is maintained while motor is at rest.

Advantages

- Simple design/control
- No feedback required
- Excellent low speed torque
- Excellent low speed smoothness
- Lower overall system cost

Disadvantages

- Torque decreases as speed increases
- Constant current regardless of torque requirements
- Cannot react to changes in load
- No method to overcome position loss

WHAT MAKES UP A STEPPER MOTION SYSTEM

Every Stepper motion system consists of 3 components.

The first component is the CONTROLLER. It generates the control signals, typically digital pulses, that interface to the drive. Commands sent to the controller from the PLC allow it to regulate the speed, distance, direction, and acceleration and deceleration of the motor. More sophisticated controllers have dedicated inputs for motion specific functions such as homing and registration.

The second component is the DRIVE. The drive is essentially an amplifier. It receives the commands from the control, and amplifies the low level DC signals and outputs current to the motor. A drive can be either AC powered or DC powered.

And our third component is the MOTOR. The current supplied by the drive generates a magnetic field within the motor stator. The resulting magnetic field rotates the rotor, thus the shaft of the motor.

Different by design, PLC based stepper systems are made up of three components and are designed to:

1. Integrate with PLC controllers (in-chassis)
2. Program via the PLC's software (nothing new to learn)
3. Take advantage of the PLC's onboard I/O and processing power.

A classic PLC system integrates a PLC plug-in module for the stepper controller. The plug-in provides seamless integration into the plc logic, taking advantage of the existing PLC software. No third party software is required.
Stepper control modules are available for a range of Rockwell Automation PLC's.

- 1734 Point I/O
- 1746 SLC 500
- 1762 MicroLogix
- 1769 CompactLogix
- 1756 ControlLogix

For applications where a PLC slot is not available or a plug in slot is not practical, network connected stepper controllers are an alternative to a PLC plug-in card. The network connection provides the same programming structure with the PLC as a plug-in module, while offering flexibility in the number of axis and encoder feedback options. In multi axis applications, the network stepper controller can provide efficiency and design over a single axis plug in module. Network stepper controllers are available in most industrial networks, including but not limited to Ethernet I/P, Profinet, and EtherCAT.

Continuous design improvements have led to the development of integrated stepper motion products. Integrated motion products combine two or more of the basic components into one device. The combination can be a stepper driving motor, a stepper drive and controller, or all three. Integrated components save money at the component level and reduce labor costs. With AMCI Integrated Products, efficiency and design is gained without sacrificing functionality or the ease of programming.

INTEGRATED STEPPER MOTOR +DRIVE

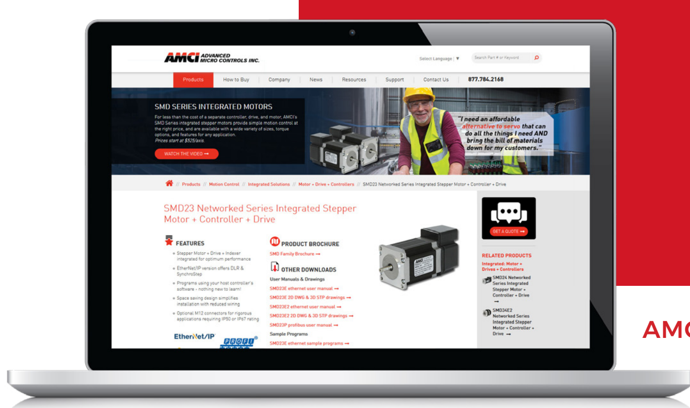
The Integrated stepper motor saves time, saves space, and saves money. Cost-sensitive and/or high-volume applications such as hand crank automation and conveyor controls, benefit from stepper component integration. Combining the stepper motor and drive simplifies the motion control design without reducing performance. Benefits are lower package cost and guaranteed compatibility. All motors are industry standard NEMA frame sizes. By locating the drive with the motor on the machine, panel space has been reduced.

INTEGRATED STEPPER CONTROLLER + DRIVE

The stepper drive controller. It combines the sophistication of a plc plug-in module with the power of a high-end stepper drive. One obvious benefit is the elimination of wiring between the stepper drive and motor.
The integrated drive receives commands directly from the plc through the ethernet communication port. This allows for seamless integration to the plc program, without the need for third party programming software or a secondary user's interface for the motion controller, and wiring couldn't be easier.
Industry standard connections let you take advantage of off the shelf network cables and optional input connection.

INTEGRATED STEPPER DRIVE + MOTOR + CONTROLLER

The all in one motion controller drives the motor drive and control into one compact but powerful package. The three in one package eliminates wiring between the motor and drive and the drive to controller, saving money on initial cost and installation. Like other integrated products, the all in one design takes advantage of the standard industrial networks to communicate directly to the PLC. The network connection provides a direct path to the PLC, allowing the user to program in a language and software environment that is familiar and understood. The all in one package uses industry standard motors and cables for a quick and easy installation. And as the number of industrial networks expands, the available connectivity of the all-in-one motion controller expands as well, offering a wide range of communication options for most industrial PLC's and PAC's.



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APPLICATIONS

CONVEYOR

The popularity of stepper motion control for PLC-based automation keeps growing, because so many applications benefit from the control architecture that steppers provide. Conveyors are used throughout factories for transporting materials and automating production lines. PLC Stepper motion control is a popular technology for these applications due to its ease of integration, price, reliability and low maintenance. Stepper motion is used on uni-directional and bi-directional conveyors, transfer stations, vertical conveyors, material elevators, and many more.

LINEAR MOTION

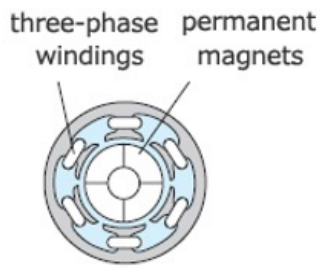
Stepper motion has a large presence with linear applications in a variety of processes including semiconductor, food processing, material handling and packaging. PLC stepper control is a great choice for linear motion applications due to its repeatability, high torque, and low maintenance. Linear stepper motion applications include XY Tables, and XY Staging, linear guide adjustment and vertical actuation.

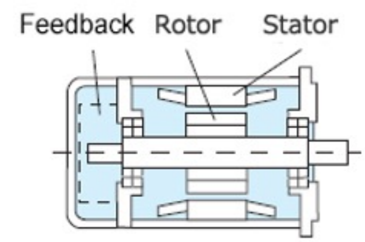
ROTARY MOTION

Rotary stepper motion control can be found in a variety of simple, repetitive automation applications, including packaging, labeling, filling and positioning. PLC stepper motion control is ideal for these applications due to its versatile yet standard mounting options, repeatable performance, and high reliability. Rotary stepper motion applications include indexing tables often found on assembly machines, material feeding such as cut to length applications and labelers, and simple repeatable motion.

MOTOR BASICS: HOW A SERVO MOTOR WORKS

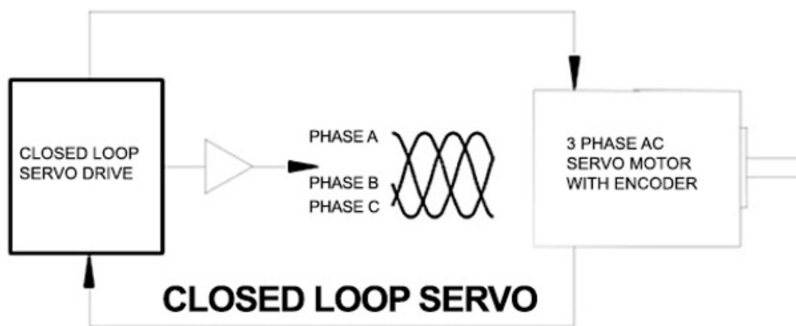
Servo Motor Construction
An AC servo consists of a three phase stator and a permanent magnet rotor. In addition motor feedback such as a resolver or encoder is needed for proper current control.

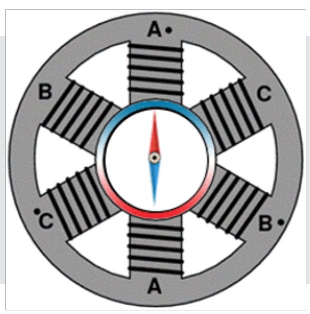




Servo Motor Current
3 phase AC current is used to energize the magnetic coils of the servo motor.

As the current in the stator changes, the magnetic field of the three phases change; causing the permanent magnets of the rotor to align with the respective phase.





OTHER THINGS TO KNOW

1. Increasing the current increases motor torque.
2. The higher the current frequency, the faster the motor will rotate.
3. Servos monitor and regulate the motor current for more precise torque control.
4. Motor feedback is required for proper current control.

SERVO BASICS

SERVO BASICS SUMMARY

Three phase AC current generates a magnetic field. It is a closed loop system that continuously monitors position relative to commanded position and adjusts current accordingly. A motor brake is required for zero speed holding torque.

Advantages

- Closed loop control
- Higher torque at higher speed
- Lower motor heating
- Better choice for variable load systems

Disadvantages

- More complex control – tuning required
- Position feedback required
- Higher overall system cost

STEPPER OR SERVO? CHOOSING A MOTOR

Selecting the Right Motor
When you start a motion application, do you select the motor based on design criteria or habit? Do you select a servo because it is what you always use? Do you select a stepper only for simple applications?

This section will help you understand the questions you should ask to find the best motor for the application.

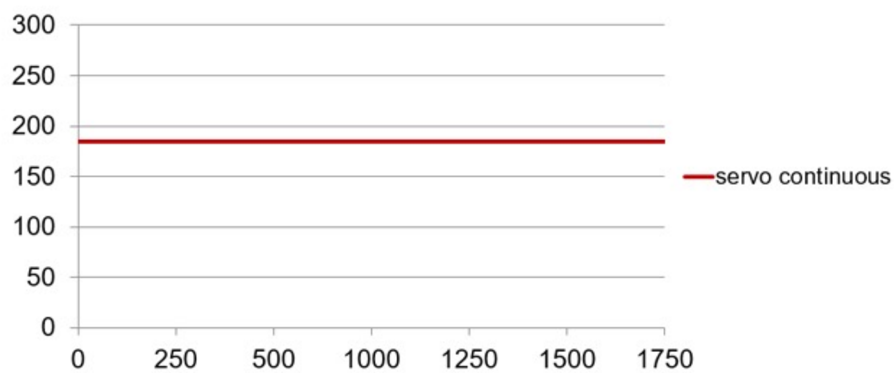
QUESTIONS TO ASK

1. What is the load I need to move?
2. What are the speeds I need to run at?
3. Does my load vary throughout the move?
4. Are there any special functions I need such as holding torque or torque limiting?
5. What is my budget?
6. Which motor is best for my application?

1.

WHAT IS THE LOAD I NEED TO MOVE? (TORQUE)

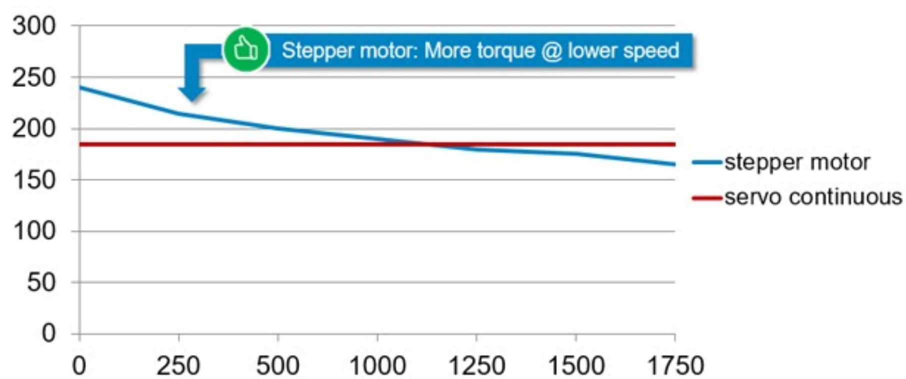
When we select a motor for an application we need to know how much torque the motor can supply. For this we use a motor torque curve. Here is a typical servo motor torque curve.



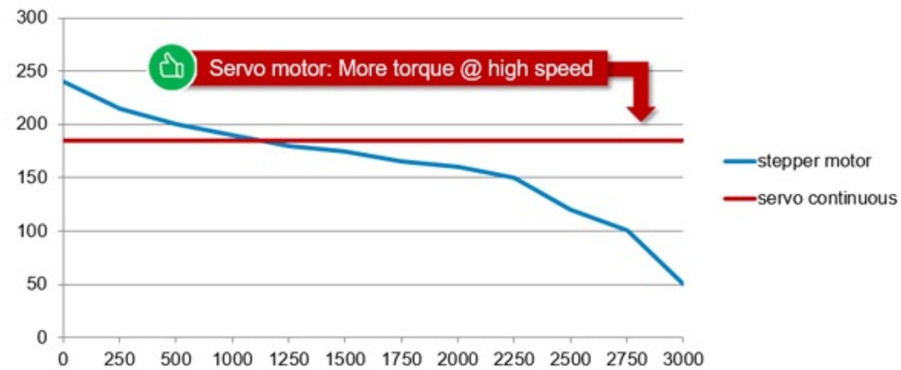
2.

WHAT ARE THE SPEEDS I NEED TO RUN AT? (TORQUE + SPEED)

It's often assumed servo motors outperform steppers of equivalent size. But this often not the case. Here is an equivalent sized stepper motor torque curve compared to the servo torque curve.



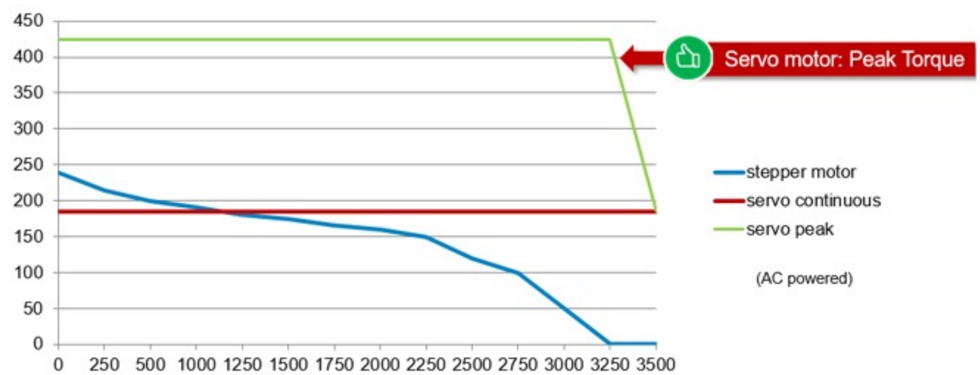
At high speeds the stepper motor torque approaches zero while the servo motor provides consistent torque throughout the entire speed range.



3.

DOES MY LOAD VARY THROUGHOUT THE MOVE?

Servo motors have the additional ability to provide peak torque for brief moments to overcome variations in load and higher motor acceleration.



4.

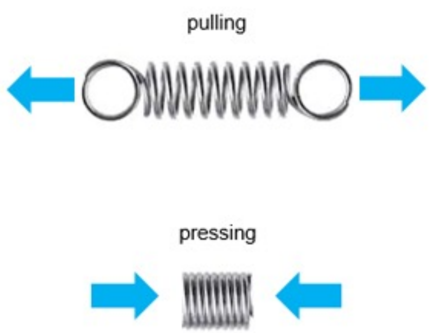
SPECIAL FUNCTIONS: HOLDING TORQUE

Stepper motors can provide full torque at standstill while the windings are energized, holding a load against an external force when the rotor is not rotating - holding torque. This feature make stepper motors a good choice for cases where a load needs to be held in place.

5.

SPECIAL FUNCTIONS: TORQUE LIMITING

Servo motors can control motor torque through precise monitoring of the current provided to the motor, and limits it so a specific torque value cannot be exceeded – torque limiting. With the advantages of torque control, many applications that require precise force control for pressing, pulling and twisting motions can be accomplished.



6.

WHAT IS MY BUDGET: STEPPER MOTOR COSTS

Stepper motors typically don't require feedback, use less expensive magnets, and rarely incorporate gearboxes. Because of the high pole count and their ability to generate holding torque, they consume less power at zero speed. As a result, a stepper motor is generally less expensive than a comparable servo motor.

7.

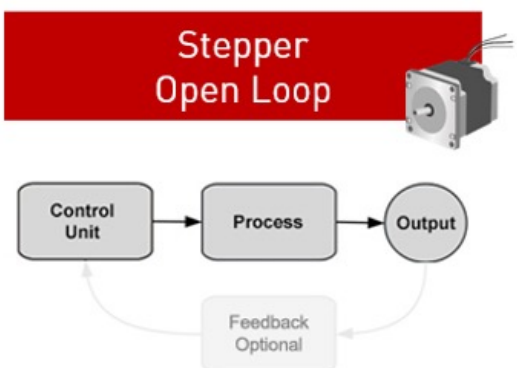
WHAT IS MY BUDGET: SERVO MOTOR COSTS

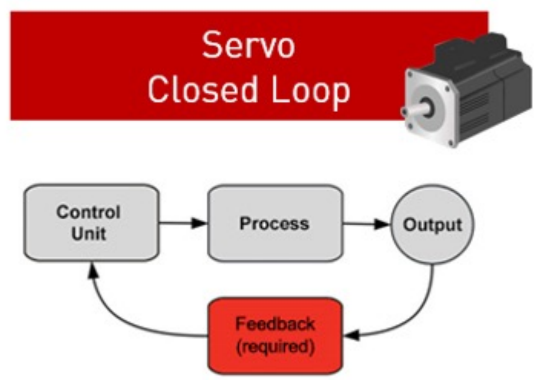
Servo motors require feedback, use more expensive magnets, and often incorporate gearboxes. They also consume more power at zero speed. As a result, a servo motor is generally more expensive than a comparable stepper motor.

8.

WHICH MOTOR IS BEST FOR MY APPLICATION?

How the motors are controlled is quite different when comparing a stepper to a servo. A stepper is an open-loop system while a servo is a closed loop system. Review your application needs to determine if one control method provides features that set it apart from the other.





When considering application requirements, there are several parameters that need to be considered, and the chart below provides a good starting point to help guide the designer to the more appropriate technology.

Application Requirements	Servo	Stepper
Position Feedback	Required	Optional
Holding Torque	No	Yes
Torque Control	Yes	No
Tuning Required	Yes	No
Support Dynamic Loads	Yes	No
Low speed smoothness	Good	Excellent


9.

WHICH MOTOR IS BEST FOR MY APPLICATION?

How the motors are controlled is quite different when comparing a stepper to a servo. A stepper is an open-loop system while a servo is a closed loop system. Review your application needs to determine if one control method provides features that set it apart from the other.

WHEN TO CHOOSE A STEPPER SOLUTION

Consider using a stepper when your application meets any of these requirements.

- High torque, low speed
- Short, rapid, repetitive moves
- Simple control is desired
- Low speed, high accuracy

Benefits of Stepper

- Rugged construction
- High reliability means no maintenance
- No system tuning is required
- Low system cost

Application Requirements	Stepper
Position Feedback	Optional
Holding Torque	Yes
Torque Control	No
Tuning Required	No
Support Dynamic Loads	No
Low speed smoothness	Excellent
Cost	$$

WHEN TO CHOOSE A SERVO SOLUTION

Consider using a servo when your application meets any of these requirements.

- High speed is required
- Dynamic motion profiles
- Control the applied force

Benefits of Stepper

- Torque control
- Can execute complex motion commands
- Can adjust to changes in load
- Lower power consumption

Application Requirements	Servo
Position Feedback	Required
Holding Torque	No
Torque Control	Yes
Tuning Required	Yes
Support Dynamic Loads	Yes
Low speed smoothness	Good
Cost	$$$

APPLICATION EXAMPLES

STEPPER APPLICATION: SET-UP AXES
Automated Roller Adjustment

Specifics: Manufacturer looking to automate roller setup.

The Goal: To reduce changeover time and increase repeatability between various production set ups.

Application Requirements:

- Integrate into existing PLC Control
- Cycle time of under 1 minute
- Make micro adjustments on demand
- Monitor position
- Need to hold position at rest

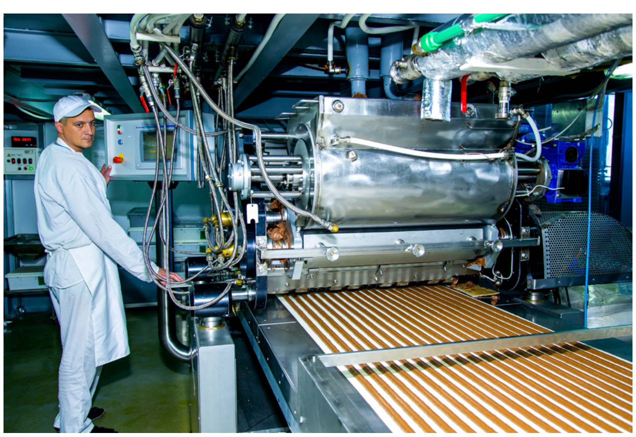
The Solution
The stepper's better low speed smoothness and holding torque at rest make the stepper the better choice.

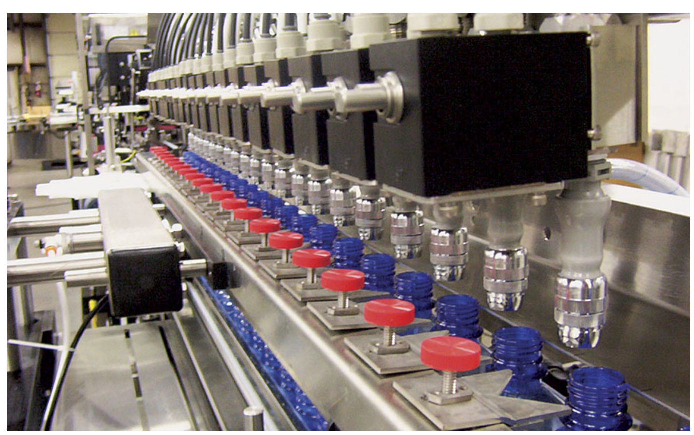
Application Requirements	Servo	Stepper
Precise positioning	Excellent	Very Good
PLC control	Yes	Yes
Torque Monitoring	Yes	No
Maximum speed	5 in/sec	2 in/sec
Cost	$$$	$$

CASE STUDIES

1. A global manufacturer of art supplies needed to redesign a paint filling line. The current pneumatic solution was producing inconsistent fills resulting in wasted product and lost profits. A more precise motion control solution was needed. One of the application requirements was easy PLC Integration. The design team already selected a linear actuator so the proposed solution had to work with existing stepper motors. The filling station had six colors. Multi-axis control was a must. The ultimate goal was to reduce downtime, streamline setup and eliminate improper bottle filling, all of this at an affordable price. The best solution for the application is the AMCI ANG1E DC powered Integrated Drive Controller. The ANG1E solution delivered precise repeatable motion control that eliminated wasteful paint spills at the factory. The product's ethernet interface replaced the need for multiple control modules in the PLC. It's integrated design also cut installation and wiring time in half. Plus, it programs using the PLC software, which makes setup and changeover easy, convenient, and familiar.

2. A confections manufacturer that needed to update a flow wrapper from a mechanical system to a more modern automated system with a PLC based control. Because of varying line speeds and product sizes, timing between the film and sealer was critical. The requirements of the design were PLC integration, coordination motion between two axes, high productivity, high torque requirement at lower motor speeds. For this application the solution was the AC powered integrated drive controller with a size 34 motor with encoder. The 6.3 AMP AC Powered Stepper Drive provided the power and control necessary for the application. The driver and motor combination met the high speed and torque requirements and simplified the motion coordination between the two axes. The programmable inputs of the SD1760E2 allow the second axis to follow the first axis, utilizing the encoder signal from the master axis and electronic gearing feature standard on the SD1760E2. PLC Integration permitted the system to make line speed and gearing adjustments as required.





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