Motion Control

When, Where and Why to Use Pneumatics or Servos.

Emerson.com

EMERSON™

All types of machinery rely on motion control to perform their functions, whether it is initiated manually by operators or automatically by more advanced control platforms. Original equipment manufacturing (OEM) designers must evaluate several technical and commercial requirements to strike the right balance when selecting these motion control solutions.

Two popular technologies for accomplishing OEM equipment motion functionality are servo motors and drives and pneumatics. In very general terms, pneumatic components are often seen as a cost-effective solution with less precision, while servo motors and controls are considered more suitable for high-performance applications with high precision requirements. However, each technology features various benefits, and there are applications where either or both may be suitable.

The numerous motion offerings can lead to confusion regarding how to select the right solutions, and end users often need guidance during the decision-making process to address unique concerns like:

- Machine design effort and learning curves for new technologies
- Initial, operating, and maintenance costs
- Integration of motion products with other devices
- Ability to connect, collect data and analyze device health
- Performance, flexibility, and accuracy requirements of the application

OEMs should become familiar with the range of technologies, benefits, and best-fit applications so they can follow a balanced approach in their designs. This white paper provides a knowledge base comparing the use of pneumatics and electric servos motion control to help OEMs choose the best options for their systems.

Motion Control Overview

Modern approaches to motion control involve several options for motion paths and geometries:

- Linear motion, such as to move a product pusher
- Rotary motion, such as to operate a conveyor
- Positional motion, where equipment must be accurately moved to various location

Each degree of motion is known as an axis. A simple linear pusher is one axis, while a complex robot may use four or more axes.

Two types of primary motion drivers are pneumatic actuators and electric servo motors. These drivers may be connected directly to the driven equipment, or indirectly via a gearbox or mechanisms such as belts, ball screws or tables. Mechanisms and gearboxes are used to change the geometry, speed and/or applied force of operation.

Designers must address the following requirements for any motion application:

- Motion type (linear, rotary, other)
- Fixed or varying speed
- Acceleration (linear or variable)
- Positioning, distance, and force requirements
- Accuracy
- Duty cycle (how often the motion occurs)
- Reliability and durability
- Available energy sources.
- Initial, operating, and maintenance costs.

Before exploring selection details, following are some general explanations of each technology.

Pneumatic Motion Basics

The essence of pneumatic motion is using a compressed gas, usually air but possibly other gasses such as nitrogen, to physically act on a mechanism to produce the required motion. Pneumatic motion is a relatively straightforward and readily understood technology. Pneumatic motion solutions provide robust operation with low overall capital expenditure costs for hardware, design, and installation. Some estimates indicate pneumatic motion solutions cost 20% less per axis compared to servo motion solutions. Furthermore, upgrading pneumatic solutions often comes at a lower cost because there are less components to change or replace.

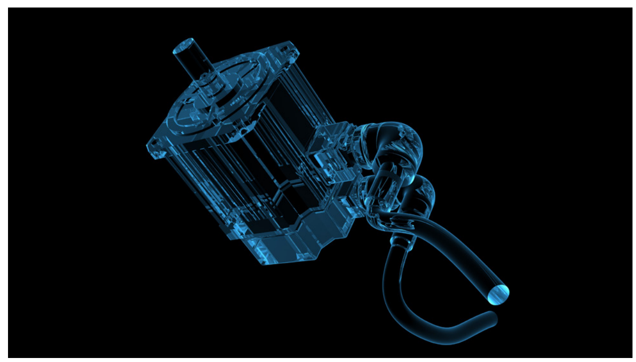
The most common pneumatics example is a cylinder with an internal piston. When compressed gas is applied to one side of the piston and vented on the opposite side, a linear force is developed which creates motion. The cylinder is mechanically arranged to move the target load. If compressed air is either blocked or vented on both sides of the piston, then the cylinder can be locked in place or freed.

Other arrangements are possible, such as pneumatic quarter-turn actuators, or air motors able to produce continuous rotational motion. There are also many possible accessories such as sensors and flow controls to monitor and optimize operation.

Electronic position control for pneumatics can be initiated with operator-controlled buttons and switches, or by a programmable logic controller (PLC) or loop controller. Initiated and sometimes monitored by discrete (on/off) or analog (modulating) input signals, these devices usually operate relatively small electro-pneumatic on/off solenoid valves or modulating positioning valves, which in turn pressurize the pneumatic equipment. Optional position switches or sensors on the driven equipment provide a closed-loop feedback signal to the controller so air flow and pressure can be applied to achieve the desired position.

Pneumatics are often considered to be a discrete motion technology, such as for just fully extending or retracting a mechanism. However, with differential pressure control it is possible to achieve continuous pneumatic positioning by applying controlled pressure against a constant back pressure.

Servo Motion Basics



Servo motors are a high-precision form of electric motor, converting electricity into motion. The motion is most commonly rotational, but linear motors are also available. Servo motion requires more complex components, design practices, and installation methods than pneumatic motion solutions. However, servos are usually the best choice when fast speed, pinpoint accuracy, and high efficiency are critical design targets.

Servo motors are a closed loop system, with the following typical elements (which are sometimes combined into fewer devices):

- Motion controller
- Servo drive
- Motor
- Feedback sensor

Each servo motor is associated with one drive that follows commanded signals to create the desired motor operation. While some other motor designs simply spin at a commanded speed, servos are specialized to deliver accurate positioning, precise angular velocities, and variable acceleration profiles.

PLCs and other controllers can accomplish advanced motion control and synchronization when they are connected with servo motion systems. This provides driven energy for even the most complex applications like machining, robotics, and manufacturing equipment. Following are some specialized servo motion functions:

- Positioning: Highly accurate, with sub-micron repeatability.
  - Jogging: Controlled movement along an axis.
  - Homing: Moving an axis to a predefined 'zero' position.
  - Indexing: Moving an axis to a predefined angle or spacing.
  - Roll feed: Continuous product feeding with cutting to specific lengths.
- Electronic Camming: Controlling a secondary axis in synchronization with a primary axis according to a predefined cam table.
  - Absolute camming: Each cam table point is an absolute distance from some starting point.
  - Relative camming: Each cam table is a relative distance from the previous point.
- Electronic gearing: Controlling a secondary axis incrementally and proportionally with a primary axis position or speed.
  - Absolute gearing: The secondary axis follows the primary axis reference using an absolute relation.
  - Relative gearing: The secondary axis follows the rate of the primary axis based on time, velocity, or other characteristic, with advanced applications usually incorporating mathematic relations.

Most servos are rotational devices, although some linear versions are available, so a gearbox or other mechanism may be needed to provide linear motion paths. Servo systems can be configured to deliver positional motion control for applications such as a robot arm joint, or to operate continuously rotating equipment like conveyors.

Analytics

The topic of analytics is worth reviewing in more detail. Today's end users are familiar with many types of consumer goods which offer digital automation and detailed user interfaces. They are coming to expect the same types of rich information from industrial systems.

Pneumatics are beginning to make this information available, and servo drives have long offered this information via comprehensive connectivity. Once users begin installing systems with IIoT capabilities, they can connect the produced data to higher level analytical systems and begin analyzing production performance, energy usage, and reliability. Turning raw field data into useful information then empowers a process of continuous improvement whereby users can improve their machine operations and ultimately their production.

Comparing Pneumatic Motion with Servo Motion

Designers working to select the right motion control technologies for their applications must assess many criteria (Figure 3).

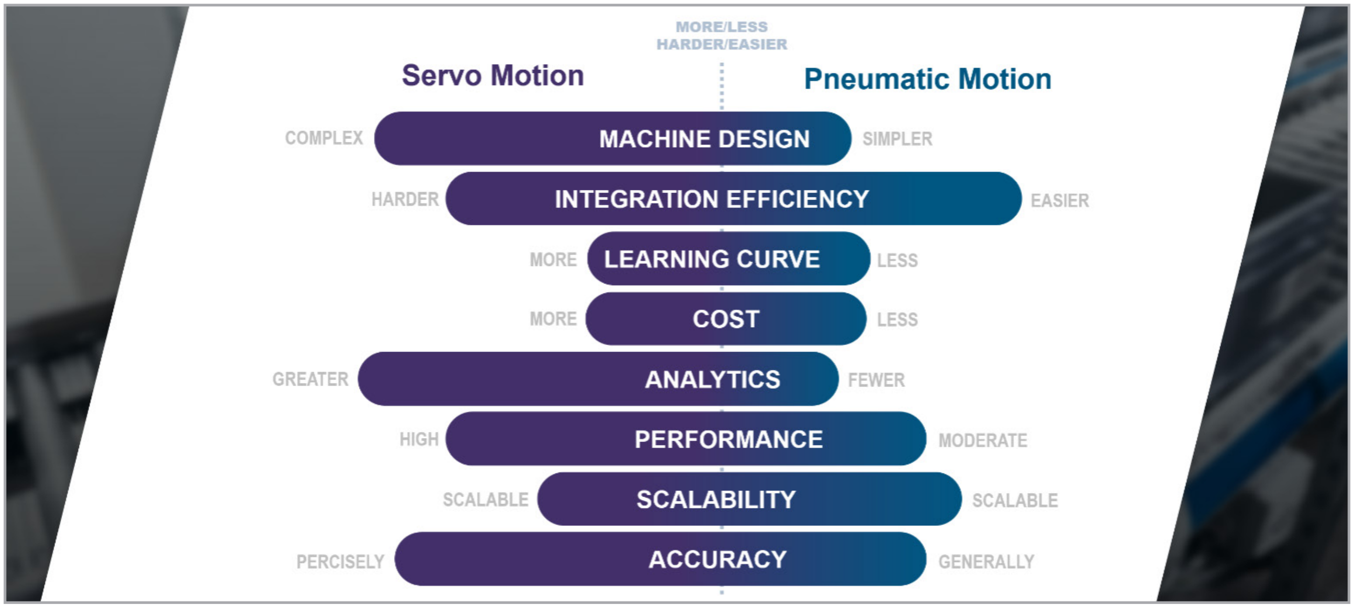


Figure 3: This chart graphically compares many aspects of pneumatic and servo motion.

Some general attributes of pneumatic motion control are:

- Strengths
  - o Can deliver linear and rotational motion, as well as other configurations like airbags for expansion force, air jets for cleaning parts, and grippers for holding parts.
  - o Possible to include provisions for fail-safe operation.
  - o Can generate large forces.
  - o Relatively inexpensive and simple to design, install, and maintain.
- Weaknesses
  - o Not as accurate or repeatable as a servo.
  - o Operating expense (OpEx) energy costs are higher than for servos.
  - o Can generate excessive noise.
  - o Pneumatics are gaining intelligence, but additional software is usually needed for analytics.

Some general attributes of servo motion control are:

- Strengths
  - o Can operate at high speeds and produce strong forces.
  - o Superior accuracy and repeatability due to closed loop feedback between the controller and the motor.
  - o OpEx energy costs are lower than for pneumatics.
  - o Because servo drives and controllers are microprocessor devices, they have a high level of on-board functionality and can support many local and remote diagnostic and data logging features.
- Weaknesses
  - o Relatively complicated to design, program, install, and maintain.
  - o Some installations require cooling.
  - o The normal failure mode is to fail-in-position, which may not be desirable.

o As with all electrical devices, servos and drives are vulnerable to washdown conditions and require protection provisions.

Applications

Sometimes an application will clearly be best served by either pneumatic or servo technology. However, in many cases there are a spectrum of choices and needs. End users will find that when they work with trusted suppliers offering a complete portfolio of technologies and sizing options, it is easier to select the right solutions, put them into service, and support them over the long haul.

Every motion solution must technically meet the application needs, and sometimes the choice is clear. For a simple mechanism to push boxes off a conveyor, a pneumatic cylinder is most likely the right choice. On the other hand, if a small conveyor must move a container into a location, stop it without tumbling, and then transport it out after filling, a servo motor would provide the required precise conveyor control.

It is quite common for manufacturing facilities to rely on many types of OEM equipment arranged in a production line, with transport and accumulation conveyors moving product between the machines. Such an application has many opportunities for incorporating both pneumatic and servo motion. An electro-pneumatic solution developed from a portfolio of motion products helps users apply the best technologies for each specific action.

A generic arrangement is shown in Figure 4, which incorporates the following functions in order:

- Stretch blow molding a container.
- Fill and cap containers.
- Convey and accumulate (surge).
- Label containers.
- Inspect fill and label.
- Pack containers into cases.
- Palletize cases and shrink wrap.

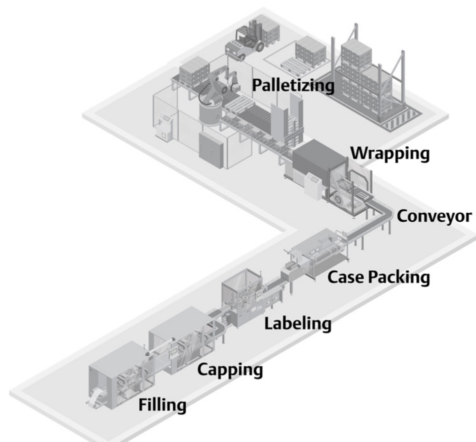


Figure 4: Typical manufacturing production lines incorporate many types of OEM equipment and take advantage of various pneumatic and servo motion elements.

Following are some of the ways pneumatic and servo motion solutions can play a role in each of these functions.

- Stretch blow molding relies heavily on pressure provided by pneumatics.
- Simple transport conveyors may be driven by basic electrical motors operated in an on/off fashion or by a variable frequency drive (VFD), and the associated product stops and gates are good candidates for pneumatic actuation.
- Precision conveying and positioning of bottles within the filler and labelling equipment is best provided by a servo solution. Servos coordinated with photo eyes and vision systems can detect print marks, operate label cutting knives, maintain constant product gaps, and position bottles precisely for filling.
- Packaging equipment used to fold boxes and apply glue is less exacting than labelling, so pneumatic control is more prevalent for these applications.
- Palletizing systems may use both forms of motion. Pneumatics work well for handling bulk cases, while servo motion provides a substantial degree of interpolation and fine position adjustments.

Conclusion

Designers and OEM equipment manufacturers rely on dependable motion control solutions. Pneumatically- and servo-driven elements are two popular options.

- Pneumatic motion is simple, economical, robust, and maintainable—but can lack sufficient operating precision.
- Servo motion is intelligent, precise, and fast—but can be expensive and complicated to design and implement.

For modern systems, pneumatics has been gaining IIoT functionality. However, for data-intensive applications and deeper analytical capabilities, servo controls are the better choice.

Once designers have a good understanding of the benefits of each technology, they can review the physical, automation, installation, and operation performance requirements and costs to arrive at the best solution for each application.

United States Office
Emerson Automation Solutions
Intelligent Platforms, LLC
2500 Austin Dr
Charlottesville, VA
T: +49 821 50340

Italy Office
Emerson Srl
Via D'Annunzio 295,
I-41123 Modena, Italy
T: +39 059 451060

Germany Office
Emerson Automation Solutions
ICC Intelligent Platforms
GmbH
Memminger Straße 14
Augsburg, Germany 86159
T: +49 821 50340

China Office
Emerson Automation Solutions Intelligent
Platforms (Shanghai) Co., Ltd
No.1277, Xin Jin Qiao Road, Pudong,
Shanghai, China, 201206
F: +86 21 28929001
T: +86 21 28929000

Brazil Office
Emerson Automation Solutions
Rua Irmã Gabriela, 51 – Cidade Monções
São Paulo – SP, 04571-130
T: +55 11 3797-6342 ; +55 11 3797-6340 ;
+55 (11) 96386-1647
E: mas.latam.customercare@emerson.com

Singapore Office
Emerson Automation Solutions Intelligent
Platforms Asia Pacific Pte. Ltd.
1 Pandan Crescent,
Singapore, 128461
F: +65 67708056
T: +65 97937472

India Office
Emerson Automation Solutions
Intelligent Platforms Pvt. Ltd.,
Building No.8, Ground Floor Velankani
Tech Park, No.43
Electronics City Phase I, Hosur Road
Bangalore-560100
T: +91-80-42515300