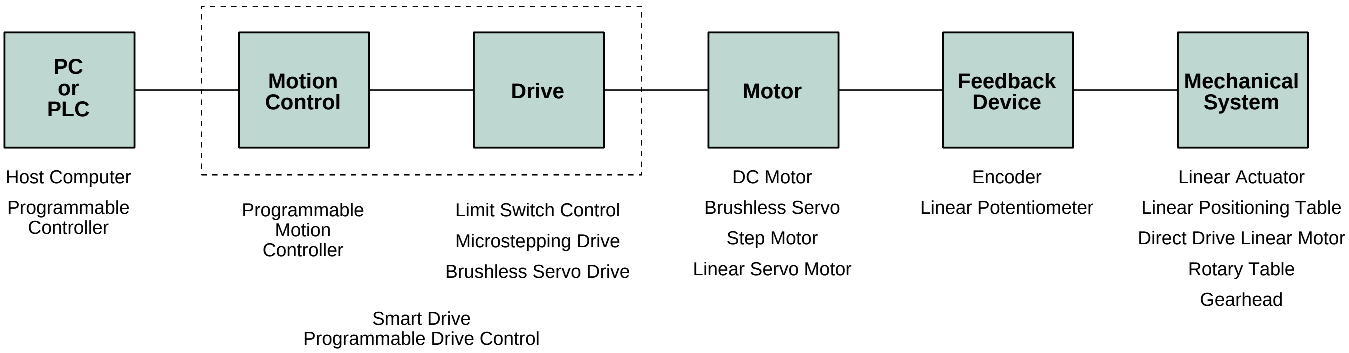
Introduction to Motion Control Technology

Many different components are used in a variety of combinations to create a complete motion control or positioning system. IDC offers the broadest range of products spanning the complete spectrum from mechanical actuators to microstepping and brushless servo drives to programmable motion controllers. A successful application depends on choosing the right combination of actuator, motor, drive, and control technology. More than one technology may meet the requirements of your application. In this case, factors such as performance, cost, flexibility, and simplicity may determine your selection.

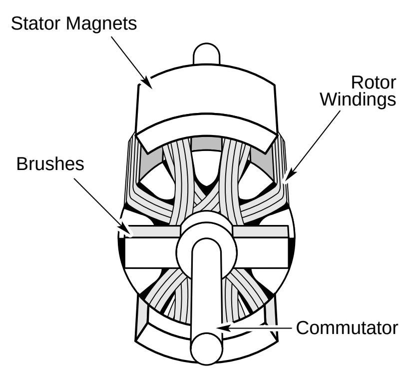


Introduction to Motor Technologies

DC Motor Systems

DC motors are used with IDC's DC motor controls to control velocity and position. With these simple controls, limit switches attached to the actuator or the customer's load provide position feedback. DC motors are also used with analog position controls and a linear potentiometer for position feedback. The result is an absolute positioning system. They can also be used in closed loop servo systems with an incremental encoder for position feedback.

DC motors have windings on the rotor of the motor. To supply current to the rotor, a set of brushes ride on a segmented commutator, which supplies current to the appropriate internal windings depending on the position of the rotor. Brushes may need to be replaced periodically, depending on the load, speed and duty cycle. The commutation method limits the top speed that can be reached before arcing over the commutator segments occurs. The heat generated in the windings must travel across the air gap and the through stator to be dissipated. This long thermal path results in a motor that is less thermally efficient and is therefore larger than a brushless motor with an equivalent power rating. The windings also add inertia to the rotor, which results in lower peak acceleration rates than a similar brushless motor.



Common Applications

- Air cylinder replacement
- Clamping, pressing
- Transfer mechanisms

Advantages

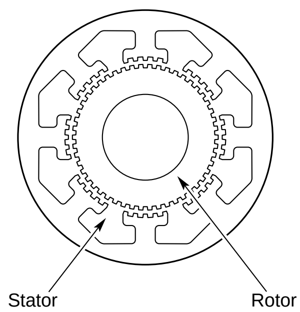
- Lower cost than brushless
- Simple controls

Disadvantages

- High maintenance (brushes).
- Larger motor
- Less responsive

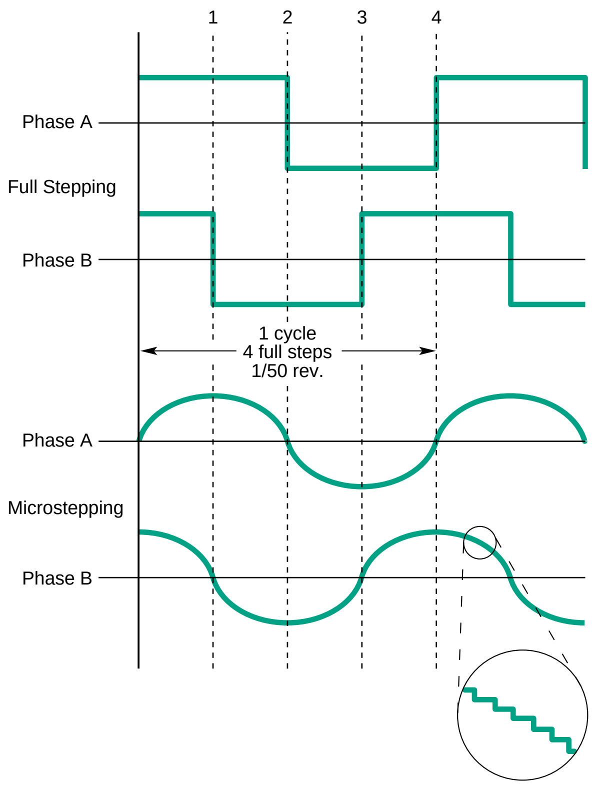
Step Motor Systems

Step motors have the inherent ability to divide a revolution into discrete steps and to hold position at rest without the need for a feedback device. Electromagnets in the stator are energized and cause teeth in the rotor to line up with teeth in the stator. Sequencing the current in the windings causes motion. The rotor will "follow" the stator as if attached by a spring, as long as the available torque from the motor is not exceeded.



A typical "full-step" system will achieve 200 steps per revolution with a 50-tooth hybrid step motor by following a simple four-state sequence of positive and negative winding currents. After each four steps an adjacent rotor tooth will be lined up with a given stator tooth. Fifty cycles through the sequence results in a complete revolution, with the original rotor and stator teeth lined up. The direction you proceed through the sequence determines the motor direction.

Microstepping is a technique that increases resolution by controlling both the direction and amplitude of current in each winding. Instead of a square wave with four steps, we sequence through what looks like a sine and cosine waveform. The cycle is divided into as many as 1000 steps. The result is a positioning resolution of 50,000 steps or more per revolution. Microstepping improves low speed smoothness and minimizes the low speed resonance effects common in full step systems.



IDC microstepping drives employ unique anti-resonance circuitry which damps oscillations and improves performance and throughput.

Step motors can operate open loop in most applications and provide excellent repeatability (±5 arc sec, ± 0.0005" with actuators, submicron with precision tables). An encoder can be used if closed loop operation is desired. This may be important when a jam or stall condition must be detected. An encoder attached directly to the load can improve the overall accuracy of the system as well.

Common Applications

- Short, rapid moves
- Accurate positioning systems

Advantages

- High acceleration, duty cycle
- Excellent repeatability
- No maintenance (brushless)
- High torque at rest, moderate speeds
- Mechanically stiff with no vibration at rest
- Lower cost than brushless servo

Disadvantages

- Inefficient at high speeds
- Excessive loads can stall motor

Introduction to Motion Control Technology

Brushless Servo Systems

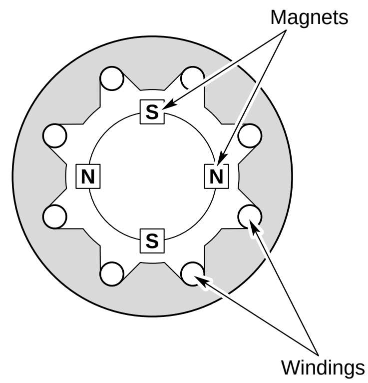
IDC brushless servo systems use a three-phase brushless servo motor with an incremental encoder for position feedback.

Brushless servo motors are constructed with the windings in the stator or outer portion of the motor and have permanent magnets attached to the rotor. The location of the windings next to the finned surface of the motor provides a shorter path for heat generated in the windings to escape. This improved thermal efficiency when compared to a dc motor results in higher power ratings for a similar sized motor. Less rotor inertia and no mechanical commutator limits result in higher speed and acceleration capabilities.

The servo controller and drive use the encoder feedback signal to continuously adjust the motor torque so that the desired position is maintained. This is referred to as a closed loop servo system. The electronics required to operate a brushless motor and "close the loop" are therefore more complex and expensive than microstepping or dc motor controls.

Unlike DC motors, which use a mechanical commutator to deliver current to the appropriate torque producing windings, the brushless motor requires a feedback device to sense the position of the permanent magnet rotor in relation to the motor's windings. The servo drive must maintain the correct relationship between the magnetic vector created by the windings and the rotor position to produce torque.

IDC brushless servo drives employ proprietary vector torque control and advanced servo algorithms to provide unmatched closed loop servo performance (see page K-32 for a more thorough discussion).



Common Applications

- Higher speeds and accelerations
- Changing loads
- Clamping, pressing

Advantages

- Closed loop control
- Highest torque at high speeds
- No maintenance (brushless)
- Efficient operation

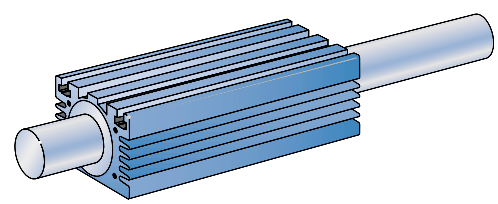
Disadvantages

- Higher cost

Linear Brushless Servo Motors

A special type of brushless servo motor, IDC direct drive linear motors use an innovative design that houses the permanent magnets in a cylindrical thrust rod. The motor's windings reside in the thrust block which surrounds the rod. A linear incremental encoder is used for closed loop position feedback along with hall sensors for commutation.

All of the electromagnetic force is utilized to produce thrust directly, eliminating the need for rotary to linear conversion mechanisms. This eliminates backlash, lead error and other mechanical system innacuracies.



Common Applications

- Highest linear speeds and accelerations
- Repeatable linear positioning

Advantages

- Direct production of thrust
- High reliability
- Efficient operation

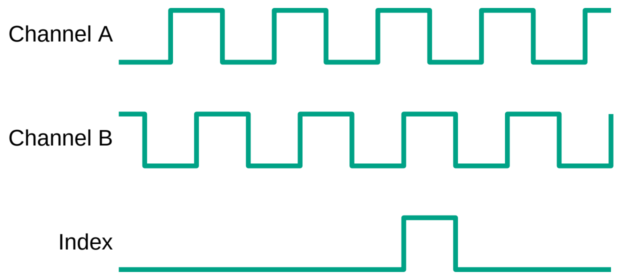
Disadvantages

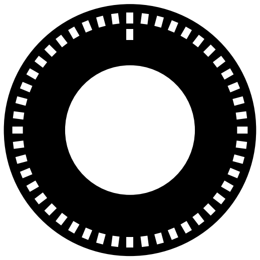
- Higher cost

Introduction to Feedback Devices

Incremental encoder

Optical encoders generate an output signal as the encoder disk rotates. The disk passes between a light source and photo detectors. The number of lines on the disk determines the number of on-off cycles of each output during a revolution. The detectors are arranged such that the two output signals are in "quadrature" (shifted in phase 90°). A once per revolution index channel is usually provided for establishing a home or zero position upon power up.

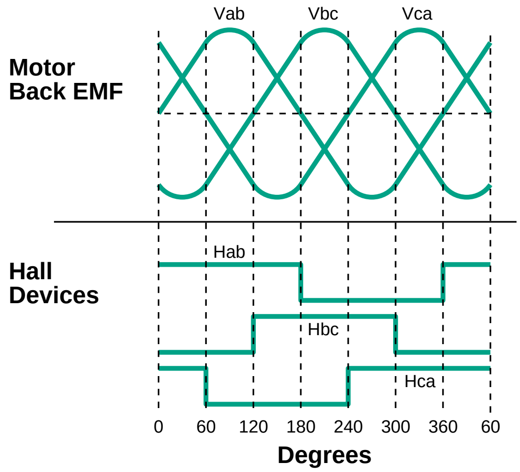


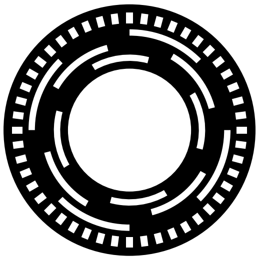


Electronic circuitry in the motion controller counts the pulses from the encoder to determine the position of the motor. The quadrature signal allows the controller to count up when rotating in one direction and down in the other, thus always remembering the absolute position of the system as long as power is applied. There are four unique transitions per cycle and controllers will generally count each transition. The number of counts per revolution is often referred to as the "post quadrature" resolution. For example, an encoder with 1000 lines will generate 4000 counts per revolution "post quadrature".

Incremental encoder with commutation channels

The process of steering current through the appropriate motor windings in order to produce output torque is called commutation. In brush motors, commutation is performed electro-mechanically via brushes and the commutator. In brushless motors, commutation is performed by electronically steering the current to the appropriate winding. To do this, the rotor position must be determined. A circuit board containing the Hall devices is aligned with a magnet on the rotor, so that the relationship shown between the Hall outputs and the motor back EMF can be established.





When a brushless motor is used in a servo application requiring position feedback, room must be made for both the commutation circuit board as well as the encoder. This generally adds both cost and complexity to the motor package. Encoders are now available with integrated commutation outputs equivalent to those produced by Hall devices. The result is a more compact system, reduced alignment time and superior switching accuracy, due to the much lower hysteresis of the encoder when compared to a Hall device. Adding additional data tracks to the encoder disk provides the commutation outputs.