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What is Commutation and Why is it Applied to Linear Motors?

Commutation is the process of switching current in the phases of a motor in order to generate motion. Most linear motor designs today use a 3-phase brushless design. In brushed motors, commutation is easy to understand as brushes contact a commutator and switch the current as the motor moves. Brushless technology has no moving contacting parts and therefore is more reliable. However, the electronics required to control the current in the motor is a little more complex.

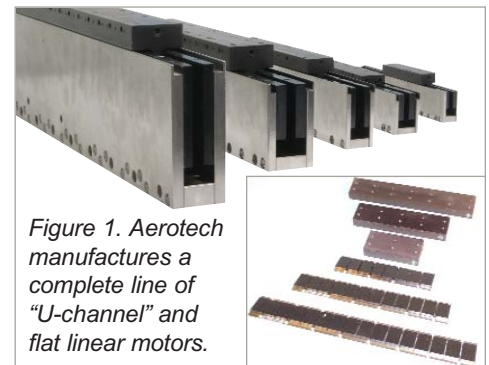


Figure 1. Aerotech manufactures a complete line of "U-channel" and flat linear motors.

The method of commutation entirely depends on the application that the motor will be used for, but it is important to understand how the motor can be commutated and the disadvantages of some methods. To start, let's consider the brushed motor. When current is applied to the motor, the correct winding is energized by virtue of the brushes being in contact with the commutator at the point where the winding terminates. As the motor moves, the next coil in the sequence will be energized. In brushless motors, because there is no fixed reference, the first thing a control or amplifier must determine is which phase needs to be energized. There are a number of ways that this can be achieved, but by far the most popular is by using Hall effect devices. There are three of these devices, one for each phase, and they output a signal that represents the magnetic fields generated by the magnet track. By analyzing these fields, it is possible to determine which part of the magnet track theforcer is in and ,therefore, energize the correct phase sequence.

There are three different types of commutation currently available on the market: trapezoidal, modified six step, and sinusoidal. Trapezoidal commutation is the simplest form of commutation and requires that digital

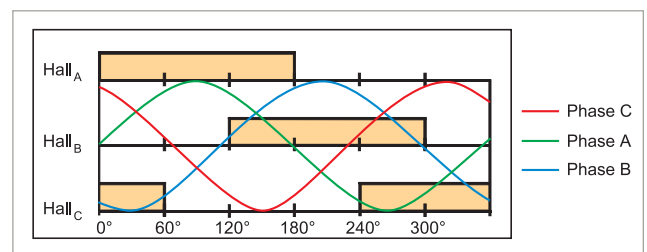


Figure 2. Hall sequence for brushless motor and phase current.

Hall devices are aligned 30° electrically from the zero crossing point of the phase. At each point that a Hall signal transition takes place, the phase current magnitude is varied and commutation of the motor occurs. This is the cheapest form of commutation and the motor phase current looks like the diagram shown in Figure 2.

Modified six step commutation is very similar to trapezoidal commutation. The digital Hall devices are aligned with the zero crossing point of the phase

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as per Figure 2. Again, at each point that the Hall signal translation is seen, the phase current is switched. However, with this method two current sensors are used and it provides a current waveform that is closer to the ideal sinusoidal phase current. This method is slightly more costly than trapezoidal commutation due to sensing two current levels. Both of these Hall-based methods will cause disturbance forces resulting in higher running temperature and motion which is not smooth.

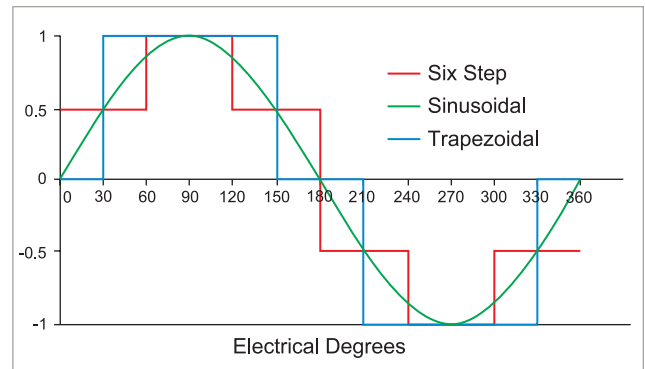


Figure 3. Commutation waveforms.

The ideal means to drive any sinusoidally wound brushless motor is by sinusoidal commutation, and this is the method Aerotech employs. There are two ways that this is commonly achieved. Analog Hall effect devices generate a sinusoidal signal as the motor passes over the magnetic poles of the magnet track. The signals, which are correct for motor commutation, are then combined with the demand signal to correctly commute the motor. This method is the lower cost of the two methods, but noise can easily be picked up on the Hall devices and this can affect commutation.

Another more popular method of sinusoidal commutation is by using the encoder. When a change of state is detected in the digital Hall signal, the incremental encoder signals can then be used to digitally determine the position of the motor in the commutation cycle. Commutation is done by generating a $\sin(\theta)$ phase A command signal and a $\sin(\theta + 120^\circ)$ phase B command signal and multiplying this by the current command.

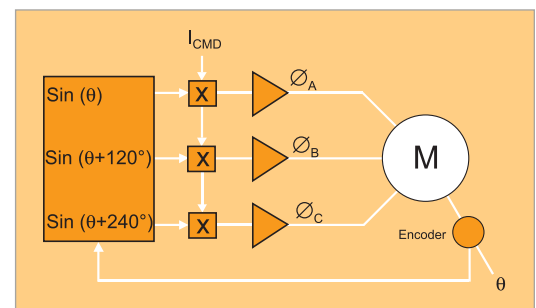


Figure 4. Sinusoidal commutation with an encoder.

This method of commutation gives the best results due to the same processor being used to control current, velocity, and position, and yields faster settling time and tighter servo loops. Also, the noise on the digital Halls is much easier to filter out, creating a more reliable system. When sinusoidal commutation is used with linear motors, the motion is smooth and the motor is driven more efficiently, causing less heating.

For more information on commutation of motors:

Contact an Aerotech [Application Engineer](#)

Download our [Linear Motors Application Guide](#)

View [Aerotech linear motors](#) including specifications, 2D and 3D CADs, etc.

View [Aerotech rotary motors](#) including specifications, 2D and 3D CADs, etc.

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Software	Version	Description
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U600 HMI	Version 6.00.136	Windows® HMI
U600 SDK	Version 6.00.136	U600 Software Developers Kit
U600 LIB	Version 6.00.136	Windows® Help File, U600 Libraries and Utilities
U500 PC-Bus-Based Controller	Version 5.22	Windows® HMI and Windows® Help File
U511 Stand-Alone Controller	Version 5.22	Interface Software and Windows® Help File
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Motion Control and Positioning Library

This resource provides a short summary and a link to articles, tutorials, white papers, and other materials that discuss problems and solutions involving motion control and positioning equipment and systems.

Articles

Precise Triggering of External Events Based on Axis Position

An axis-based trigger in the controller can significantly improve part quality, reduce cycle time, and eliminate processing problems. This article discusses Aerotech's unique PSO (Position Synchronized Output) option, and how any application that requires precise data acquisition or process action linked to axis position can benefit from it. Read the full article [HERE](#).

Laser Machining for Medical Applications

High performance laser machining centers benefit from advances in motion control and positioning technology. Read the full article [HERE](#).

Linear Motors Application Guide

A tutorial guide to the history, design, and application of linear motors. Get the PDF [HERE](#).

Air Bearings Aid Assembly of Flat Panel Displays

Many manufacturing processes for flat panel displays (FPDs) require precision motion control for feature generation and inspection. Aerostatic bearings are an excellent choice for many of these processes because they allow precise, repeatable motion; are clean-room compatible; and are maintenance-free. Read the full article [HERE](#).

Kinematics and Precision Stages Drive Laser Welding

Real-time kinematics coupled with direct-drive positioning systems provide the highest performance solution for laser seam-welding applications. The higher throughput, lower maintenance, and improved part quality available with this approach result in a system with the lowest total cost of ownership. Read the full article [HERE](#).

Applications Dictate Gimbal Selection

The choice between [direct-drive](#) and [gear-driven](#) gimbals and optical mounts presents an opportunity for a comparison of the pros and cons for each. Read the full article [HERE](#).

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