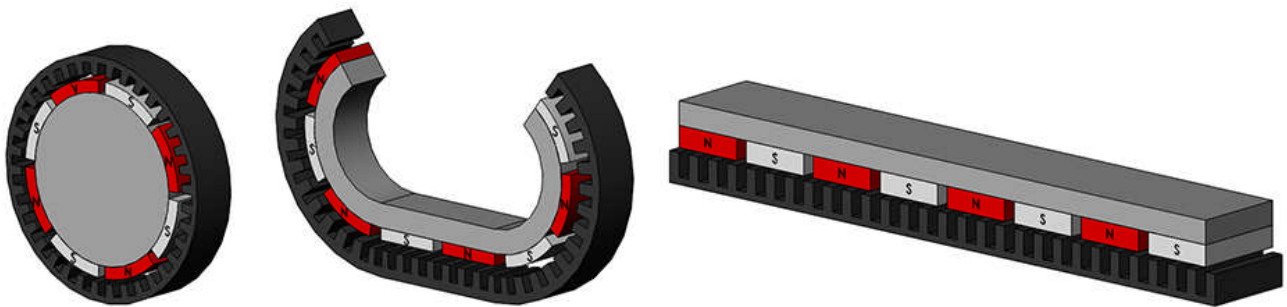


Linear Motors: How Do They Work?

What is a Linear Motor?

A linear motor should be thought of as rotary electric motor that has been cut along a radial plane and unrolled. The resultant motor is a direct drive linear electric motor that can produce linear motion without the need of pneumatic, hydraulic cylinders, or translation of rotary to linear motion with the use of belts or screws. Rotary motors produce torque whereas linear motors produce linear force.












Bridging Terminology

Rotary	Linear
Torque (lb-in) or [N-m]	Force (lbs) or [N]
Velocity (rpm)	Velocity (in/sec) or [m/sec]
Acceleration (rad/s ²)	Acceleration (in/sec ²) or [m/sec ²]
Duty Cycle (%)	Duty Cycle (%)

Basic Types of Linear Motors

As there are various types of AC and DC rotary type motors, there are also different types of linear motors, which include AC, DC, and Stepper:

Image	Positioning Type	Force @ 100% Duty	Force @ 10% Duty	Max Stroke	Max Velocity*	Max Accel.*	Amplifier or Drive Type	Bearing Type	Options
	Closed Loop	1-200 lbs [5-900 N]	3-600 lbs [15-2700 N]	Unlimited	240 ips [6 m/s]	12 g's	3 Phase Brushless Servo, Trapezoidal or Sinusoidal	Customer Supplied	Air, Water Cooling
	Closed Loop	15-1200 lbs [60-2500 N]	45-3600 lbs [180-7500 N]	Unlimited	240 ips [6 m/s]	12 g's	3 Phase Brushless Servo, Trapezoidal or Sinusoidal	Customer Supplied	Air, Water Cooling

Brush		Closed Loop	4-60 lbs [15-275 N]	12-180 lbs [45-825 N]	96 in [2450 mm]	100 ips [2.5 m/s]	6 g's	Brush Type PWM Servo	Customer Supplied	Stationary Cables, Water Cooling
Voice Coil (Moving Coil)		Open & Closed Loop	0.05-600 lbs [0.2-4500 N]	0.15- 1800 lbs [0.6- 13500 N]	4 in [100 mm]	50 ips [1.27 m/s]	20 g's	Linear/PWM Servo	Customer Supplied, Linear Bushing	Mounting, Windings, Transducers
Voice Coil (Moving Magnet)		Open & Closed Loop	0.05-600 lbs [0.2-4500 N]	0.15- 1800 lbs [0.6- 13500 N]	4 in [100 mm]	50 ips [1.27 m/s]	20 g's	Linear/PWM Servo	Customer Supplied, Linear Bushing	Mounting, Windings, Transducers
Single Axis Stepper		Open & Closed Loop	2-50 lbs [9-225 N]	2-50 lbs [9-225 N]	144 in [3.6 m]	80 ips [2 m/s]	1 g	Microstepping	Air, Roller	Mounting, Cables, 2 and 4 Phase
Dual Axis Stepper		Open & Closed Loop	1.5-30 lbs [6-140 N]	1.5-30 lbs [6-140 N]	20 x 20 in [0.5 x 0.5 m]	80 ips [2 m/s]	1 g	Microstepping	Air	Mounting, Cables, 2 and 4 Phase
Linear Induction		Open Loop	1-80 lbs [4-360 N]	5.5-440 lbs [22-1980 N]	Unlimited	1800 ips [45 m/s]	2 g's	AC Line Voltage, Variable Frequency, Vector Drive	Customer Supplied	Air Cooling
Polynoid		Open Loop	1-9 lbs [4-40 N]	5.5-49.5 lbs [22-220 N]	120 in [3 m]	270 ips [6 m/s]	2 g's	AC Line Voltage, Variable Frequency, Vector Drive	Customer Supplied	Air Cooling

* = Max values depend on motor size and bus voltage available. Please contact factory to discuss application requirements.

Brushless

DC brushless linear motors provide non-contact operation for maintenance-free operation. Available in both ironless (cog-free) and iron core versions. They are capable of high speed and high acceleration motion profiles. They can be driven using standard 3 phase brushless servo amplifiers. Brushless linear motors can achieve an acceleration of up to 12 g's, and speeds in excess of 200+ inches per second [5+ m/s].

Brush

DC brush linear motors are ideal for long stroke, open or closed loop servo, linear motion applications. They can be used at speeds up to 100 in/sec [2.5 m/sec] and as low as 1 in/sec [25 mm/sec]. They are capable of very precise position, velocity, and acceleration control when coupled with a linear encoder.

Voice Coil

DC voice coil actuators are ideal for short stroke (typically less than 2 inches) closed loop servo applications. Their compact size allows them to fit into small spaces. They have very low electrical and mechanical time constants. The low moving mass allows for high accelerations of light payloads. They are available in both moving coil and moving magnet versions.

Linear Stepper

Linear stepper motors are used in both open loop and closed loop positioning applications. Since the positioning is built into the forcer and platen, no additional feedback devices are required which reduces the overall cost of a system. For open loop operation, no servo tuning is necessary. Multiple forcers can operate on a single platen. With linear steppers, acceleration of 1 g and speeds up to 100 in/sec [2.5 m/s] are typical. They are available in both single-axis and dual-axis versions.

Linear Induction

The flat AC linear induction motor (LIM) is typically run directly off of 3 phase line voltage, with an adjustable frequency, or vector drive if speed control is required. Accelerations of up to 1 g with speeds in excess of 1800 inches per second [45 m/s] are possible with LIMs. They are ideal for high speed, long travel applications moving heavy payloads.

Polynoid

The tubular AC linear induction motor (polynoid) is typically run directly off of single or 3 phase line voltage. Accelerations greater than 1 g are possible with polynoids. They are ideal for short stroke, low duty cycle applications. They can be used to replace air cylinders when compressed air is not available.

Force Multipliers Based on Duty Cycle

Basic Types of Linear Motors	Continuous Force/ Motor Area	Peak Force/ Motor Area
	lbs/in ² [N/m ²]	lbs/in ² [N/m ²]
AC Linear Motors	0.2	1
DC Linear Motors	2.5	7.5
Linear Stepper Motors	2.5	7.5

Linear Motor Force

As explained, linear motors produce force (measured in pounds or newtons) along a straight line axis to move its payload. Each motor type provides different force levels.

Force depends upon duty cycle. Duty cycle is specified a percentage:

$$Duty\ cycle = \frac{\text{on time}}{\text{on time} + \text{off time}} \times 100\%$$

Linear Motor Advantages

Faster Acceleration: From 1 to 10 g's; this leads to shortened cycle times and improved productivity for the customer.

High Speeds: Speeds to 1800 inches per second [45 m/sec].

Highly Accurate: Accuracy to 0.00004 in/ft [1 μm/305 mm].

Very Repeatable: Repeatability to 0.00004 inch [1 μm].

No Backlash: A direct drive approach has no backlash such as obtained in leadscrews, gears, belt drives, and pinions.

High Stiffness: Direct drive linear motors provide higher stiffness than ball screw / lead screw systems.

Very Smooth Operation: Linear packages provide smooth operation due to the elimination of mechanical linkages.

Non-Contact Parts: This reduces component friction and wear, thus reducing the customer's maintenance.

Long Life: Indefinite life expectancy under normal operating conditions can be expected due to the simplicity and part reduction

Low Maintenance: This helps to reduce the customer's overall costs.

Unlimited Stroke: Stroke lengths are not limited as with ball screws. It is easy to extend the stroke by simply adding another section.

About H2W Technologies - H2W Technologies, Inc. is dedicated to the design and manufacture of linear and rotary motion products that are used in the motion control industry. The complete line of linear electric motors includes: Single and dual axis linear steppers, DC brush and brushless linear motors, voice coil actuators, and AC induction motors. Also offered is a complete line of ball screw, lead screw and belt driven positioning stages. Other motion control products include: Limited angle torque motors for compact, limited angular excursion rotary servo applications, 3 phase brushless rotary servo motors with matching digital servo amplifiers and permanent magnet linear brakes for fail-safe, zero power braking for baggage handling and people moving applications as well as amusement park rides.

With over 75 years combined experience in the linear and rotary motion field, the H2W Technologies team of engineers offers the optimal solution to the most demanding motion control, requirements.

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