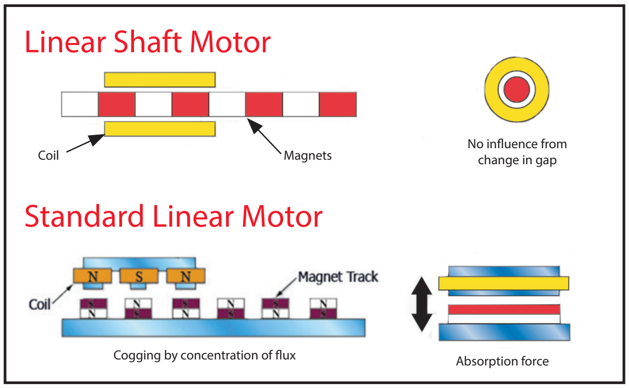
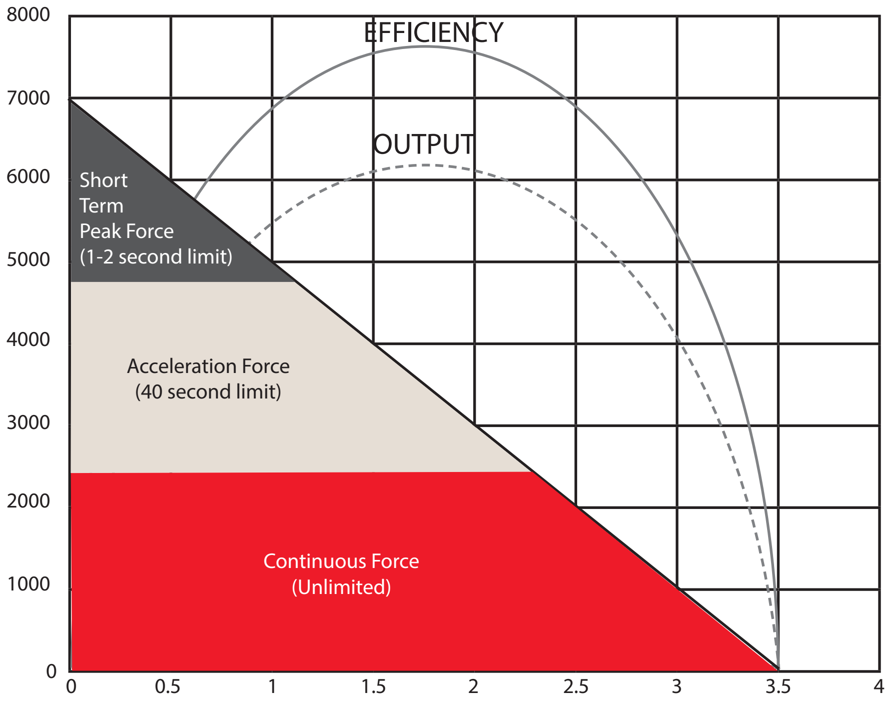
Linear Shaft Motor

Traditionally, linear electric motors have been designed by "opening out flat" their rotary counterparts. For every rotary motor there is a linear motion counterpart, although the opposite of this statement may not always be true. Thus, corresponding to the DC motor and AC induction, stepper and synchronous motor, we have the Linear DC Motor (DCLM), Linear Induction Motor (LIM), Linear Pulse Motor (LPM), and Linear Synchronous Motor (LSM), respectively. Although this does provide a solution, a number of inherent disadvantages arise.



Like the voice coil motor, the force velocity (FV) curve of the Linear Shaft Motor is a straight line from peak velocity to peak force. The Linear Shaft Motor's FV curves are split into three regions. The first is what we call Continuous Force. It is the region in which the motor can operate indefinitely without the need for any external cooling, including heat sinks. The second is Acceleration Force, which is the amount of force that can be delivered by the motor for 40 seconds without the need for any external cooling. The third region, the Peak Force, is limited only by the power which can be supplied and the duty cycle. It is limited to 1 to 2 seconds. Your local Nippon Pulse application engineer can help you map this for your particular application.

The Linear Shaft Motor is a very simple design that consists of a coil assembly (forcer), which encircles a patented round magnetic shaft. This design offers a number of advantages when compared to other types of linear motion systems:



Note: graph may not be not to scale.

No Need for Precision Air Gap

Unlike other types of linear motor technologies, the cylindrical design of the Linear Shaft Motor contains a very large (0.5 to 5.0mm) non-critical air gap. This allows for a constant linear force, which is not affected by the alignment or misalignment of the forcer (coil) to the shaft (magnets). This allows for quick and simple assembly into the final product without the need for extensive machining and alignment time.

High Efficiency

The patented shaft design and resulting magnetic field allow for an unparalleled magnetic field strength. This allows a small amount of current to produce large amounts of force. The cylindrical design allows for 100 percent of the copper, current, and magnetic field to produce force in the direction of travel.

Coreless Design with Ultra-High Stiffness

Platen-style linear motors boast high levels of stiffness due to iron cores. This iron also results in the creation of Eddy currents, which generate large amounts of heat while allowing moderate amounts of heat dissipation. The iron core also introduces large amounts of absorption forces between the stator and armature, and cogging into the linear motion. U-shaped linear motors, on the other hand, have cores of epoxy, which does not create Eddy currents or any absorption force. This type of motor has a stiffness that is, at best, 1/125 that of a similar iron-cored motor. The sandwiching of the coil between the magnetic track and the very low thermal conductivity of epoxy produces a very thermally limited motor. The Linear Shaft Motor is designed to have a motor stiffness 100 times better than that of the U-shaped motor, while dissipating heat at a rate of four times that of similar sized Platen-style linear motors.

Linear Shaft Motor Advantages

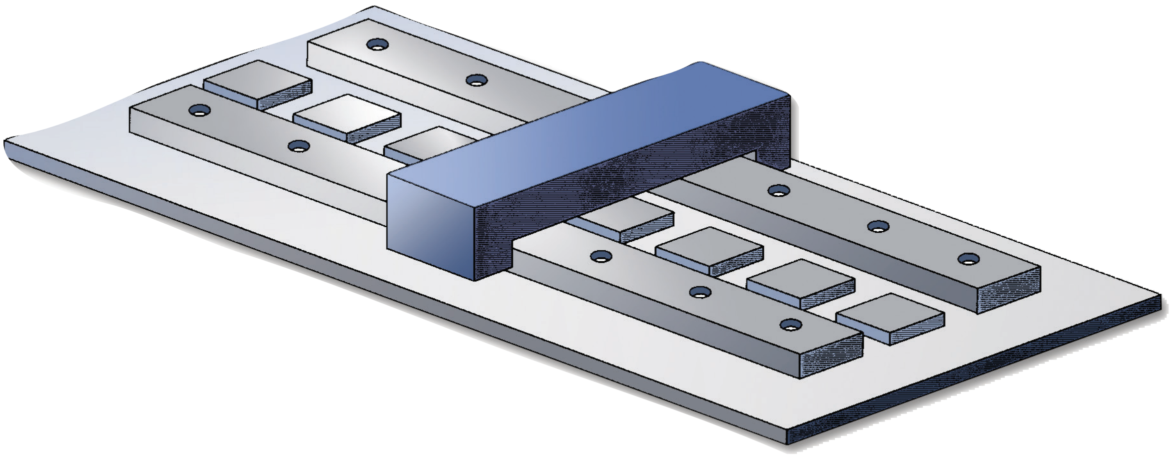
- Compact & Lightweight: Lower weight when compared to traditional type of linear motors
- Zero Cogging: The coreless, ironless design results in no magnetic cogging
- Large Air Gap: The non-critical 0.5 to 5.0mm nominal annular air gap allows for easy installation and alignment
- Highly Efficient: Some of the highest efficiencies of any linear motor[1]
- Enclosed Magnets: Easy integration into a number of environments
- Efficient Use of Magnetic Flux: Forcer encircles the magnets, allowing full use of the magnetic flux

[1] An independent study by the University of Virginia (Oct. 2010) shows, when all factors are equal, the Linear Shaft Motor is at least 50 percent more efficient than U-shaped linear motors.

Linear Stepping Motors
- Open loop or low servo stiffness
- Limited force/speed

Platen-Style Linear Motors
- Precision air gap required
- Large force between stator and armature
- Exposed magnet track

Piezo Motors
- Side loading
- Constant contact results in wear
- Audible noise generated
- Custom electronics needed

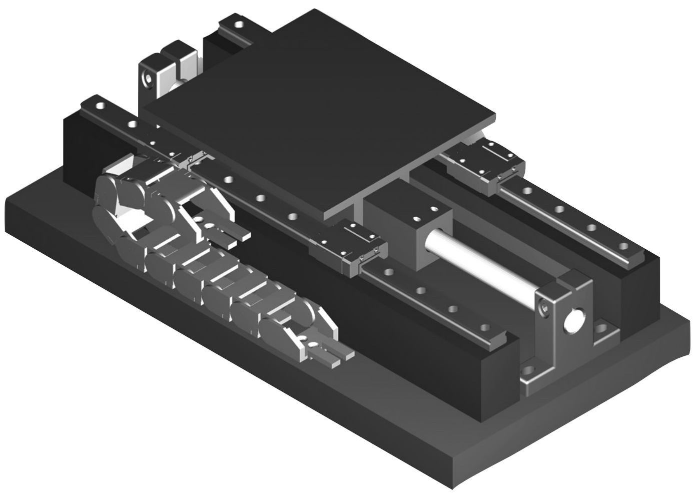


Linear Induction Motors
- Large physical size
- High power consumption
- Complex cooling typically required
- Large force between stator/armature

U-shaped Linear Motors
- Restricted heat dissipation from sandwiched armature coils
- Partial use of magnetic flux in design
- Limited mechanical stiffness

Linear Shaft Motor vs. Rotary-to-Linear Technologies

Linear Shaft Motors provide direct thrust for the positioning of the payload.
They eliminate the need for a rotary-to-linear conversion mechanism.
Examples: ball-screw, rack and pinion, toothed belt.



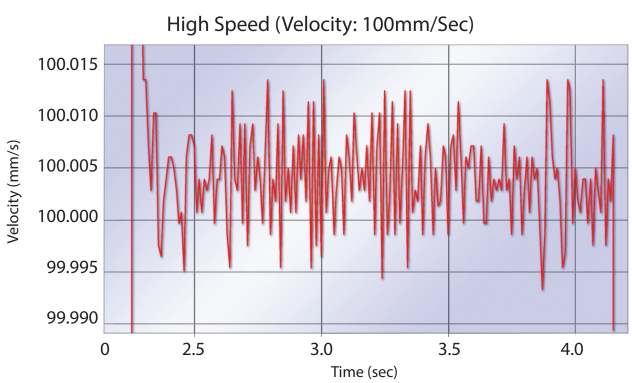
No Lubrication or Adjustment Maintenance Necessary

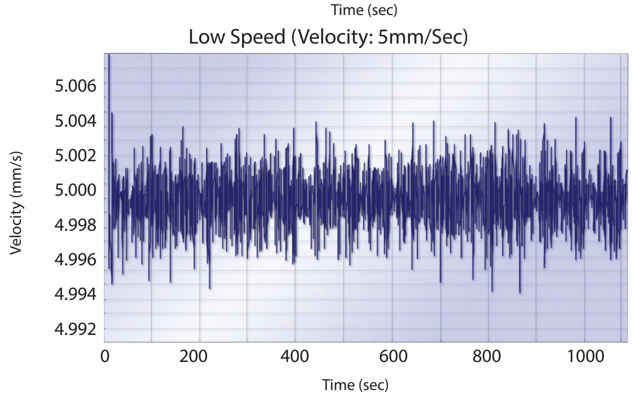
The Linear Shaft Motor requires no greasing, and has no performance degradation because of wear or aging, as with ball-screw and belt drive systems. Because the Linear Shaft Motor is maintenance-free, there is significant cost reduction throughout its lifespan. The air gap between the shaft and the forcer eliminates the need for adjustments such as positioning of the guide or concentric adjustment, which are all required for ball-screw systems.

No Noise and No Dust Operation

Dust and noise, inevitable in ball-screw and pneumatic systems, do not exist in the non-contact Linear Shaft Motor. This is not only applicable for clean room environments; it also greatly improves the work environment by reducing noise and dust.

Speed Fluctuation

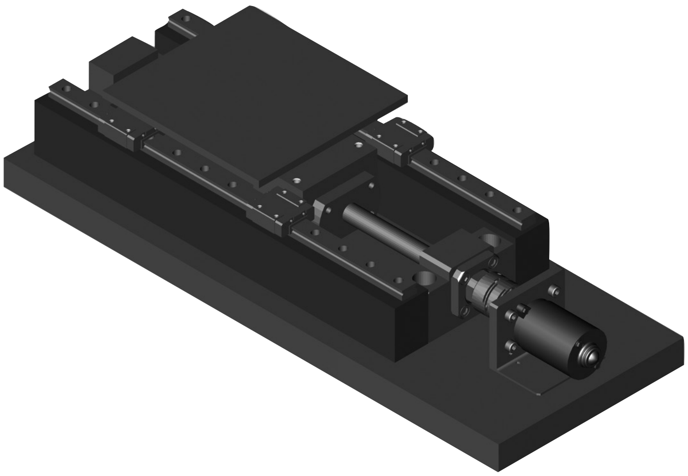




The Linear Shaft Motor is coreless and, as a result, is able to provide uniformity of speed.

Advantages of Linear Shaft Motors

• Simple mechanical arrangement	Minimal number of moving parts
• Direct thrust motor	No backlash, no wear
• Wide speed range	8µm/sec to >10m/sec
• Smooth	Virtually no speed fluctuation
• Quiet	Virtually silent motion
• Maintenance-free motor	No internal moving parts
• Lower inertia	Less mass to move
• Lower power requirements	Direct drive systems are more efficient than coupled systems



Extremely High Precision[1], Low Speed Uniformity and High Repeatability

The Linear Shaft Motor enables a level of precision not achievable in ball-screws, and allows you to drastically improve the yield of high precision processes, which are limited by other linear mechanisms.

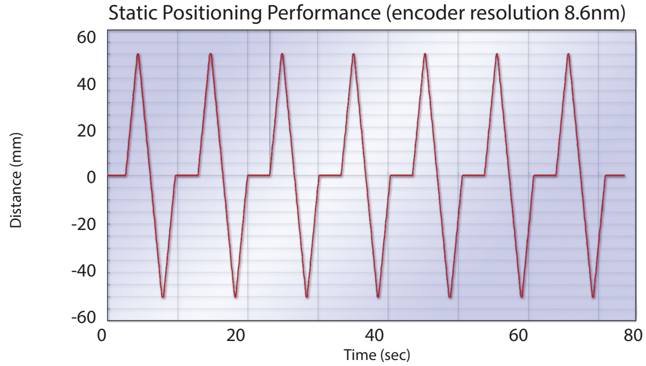
Realizes High Speed Motions while Retaining High Precision

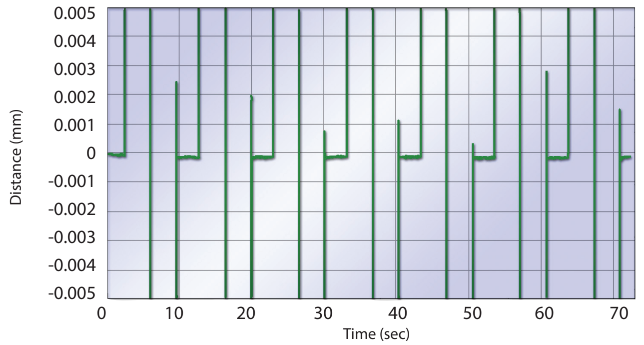
The Linear Shaft Motor's accuracy in high-speed operation shortens the travel time required by ball-screws.

Resistance Against Environmental Change

For precision operation, other linear mechanisms require strict control of work environment, including temperature control. The Linear Shaft Motor, which operates without direct contact, allows constant precision unaffected by environmental changes. This facilitates a large reduction in climate-control cost.

Precision





This is the center section of the top graph displayed at 10,000X magnification.

Using Linear Shaft Motors Can:

- Reduce the number of parts
- Save space
- Eliminate the need to adjust with locating guides and concentrics
- Reduce base machining costs and time
- Lower design costs and time

[1] The accuracy of repetitive positioning is dependent on the resolution of the linear encoder. It is necessary to have sufficient machine rigidity. Absolute positioning precision is fundamentally dependent on the linear encoder. It is not dependent on the expansion or contraction caused by the heat of the Linear Shaft Motor.