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Linear Shaft Motor

NPM

NIPPON PULSE AMERICA, INC.

A subsidiary of Nippon Pulse Motor Co., Ltd.

Linear Shaft Motor

The next generation brushless motor



Nippon Pulse Motor Co., Ltd. (NPM) was founded in 1952. Since then, we have supplied innovative technology in mechatronics and other related areas. NPM has a track record of being a supplier of products based on a solid foundation of advancing technology and thorough product research.

At NPM, we believe that by bringing products to market which not only meet the customers' requirements, but actually impress them, we contribute to the creation of a plentiful society.

Nippon Pulse America, Inc. (NPA) is a wholly owned subsidiary of Nippon Pulse Motor Co., Ltd. NPA's product line includes: stepping motors

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(tin can and hybrid), drives, controllers (chip level and board level with communication) and Linear Shaft Motors.

NPA is located in Radford, VA to better assist customers in the North and South American markets. NPA has a model shop for quick turnaround. Limited quantities of stock on standard motors and electronics are available to allow faster response to customer needs.

NPA's mission is to faithfully create the new values sought by its customers and to contribute to the development of society from a global viewpoint.

Linear Shaft Motor

Linear Shaft Motor - The Next Generation Actuator

The Linear Shaft Motors offered by Nippon Pulse Motor Co., Ltd. (NPM) are next generation linear brushless motors. When reliability, zero maintenance, zero cogging, and precision are paramount, the Linear Shaft Motors from NPM are an ideal component choice.

What is a Linear Shaft Motor?

A direct drive linear brushless servomotor consisting of a magnetic shaft and a forcer of cylindrically wound coils that are controlled by the flow of current.

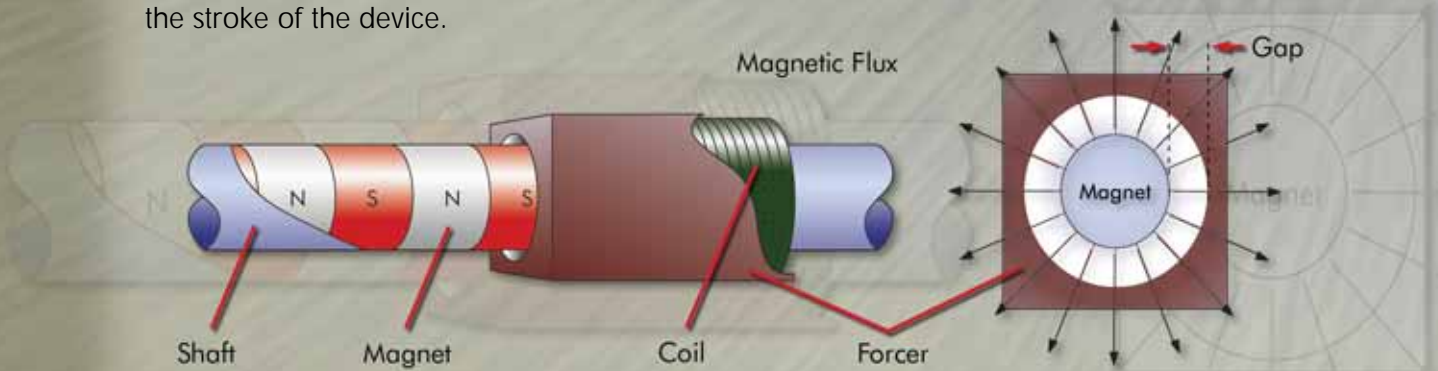
The Linear Shaft Motor was designed with three basic design concepts:

- **Simple** - **High Precision** - **Non Contact** -

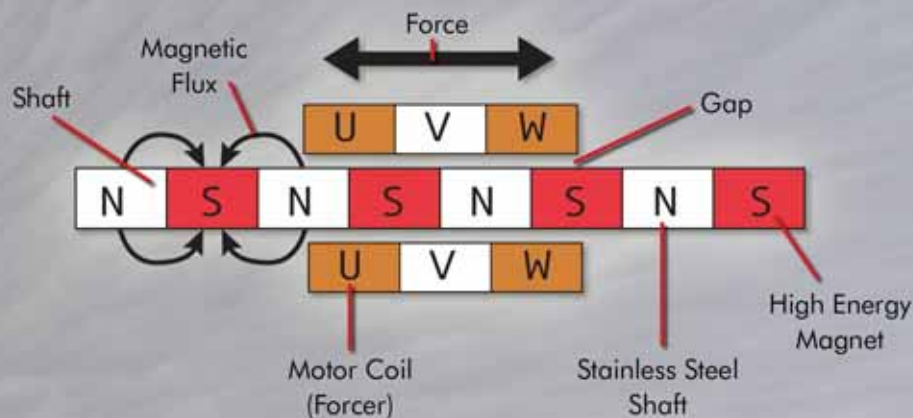
Linear Shaft Motors are **simple**. They consist of only two parts, a magnetic shaft, and a "forcer" of cylindrically wound coils.

Linear Shaft Motors provide ultra **high precision**. They have no iron in the forcer or shaft thus giving you the precision and zero cogging expected in a coreless design. The coils of the Linear Shaft Motor themselves form the core thus giving you the stiffness expected in an iron cored motor.

Linear Shaft Motor is **non-contact**. Since the coil completely wraps around the magnets, all the magnetic flux is efficiently used. This allows for a large (0.3 to 1.75mm) nominal annular air gap. This air gap is non-critical, meaning there is no variation in force as the gap varies over the stroke of the device.



The next generation Linear Motor.



Basic Structure of a Linear Shaft Motor

The basic structure is a combination of a stainless steel shaft with built-in permanent high-energy magnets and a forcer containing the coil. Since the coil completely wraps around the magnet, magnetic flux is efficiently used, enabling a large thrust, and high efficiency not possible in other linear motors. Thanks to its simple structure, the Linear Shaft Motor is capable of high resolution down to 0.14nm^1 . The Linear Shaft Motor features a diverse range of characteristics.

Outstanding Features of Linear Shaft Motors

- Capable of high thrust (2780 N)
- Quiet due to the absence of friction, the only mechanical contact section is the linear guide. (Fully non-contact operation is possible using an air slider.)
- Simplified unit construction allows a stroke of up to 4.6 meters
- High precision (0.14nm^1)
- High speed drive (6.5m/s)
- Low speed drive ($8\mu\text{m/s}$)
- Virtually no speed fluctuations ($\pm 0.006\%$ at 100mm/s)
- Durable construction, capable of operation even underwater or in a vacuum

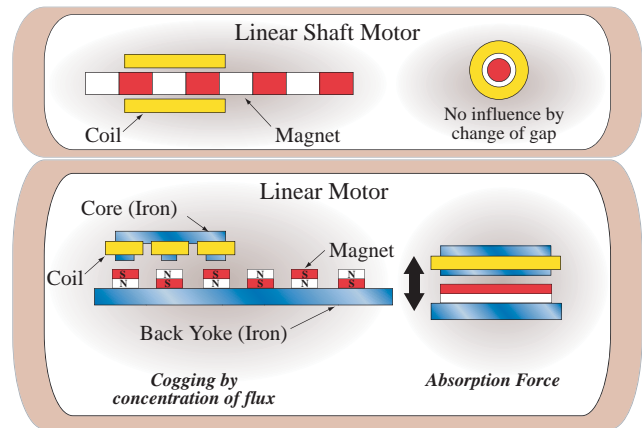
¹ The precision of repetitive positioning is dependent on the resolution of the linear encoder. In addition, it is also necessary to have sufficient machine rigidity. In the same way, the absolute positioning precision is also fundamentally dependent on the linear encoder. It is not dependent on the expansion or contraction caused by the heat of the Linear Shaft Motor.

Linear Shaft Motor

Traditionally, linear electric motors have been designed by “opening out flat” their rotary counterparts. It is literally the same as the imaginary equivalent of cutting through a conventional motor rotary armature and rotary stator, and laying it out flat. Although this does provide a solution, a number of inherent disadvantages arise.

The Linear Shaft Motor was modeled after the ball screw and not a flattened rotary motor as other linear technologies are. The Linear Shaft Motor consists of a moving coil assembly (forcer), which encircles a round magnetic shaft. The magnets in the Shaft assembly are not exposed. With this design, the forcer can make full use of the magnetic flux. Because of this, the air gap is not critical and is typically 0.5-1.75mm (0.02”-0.07”) nominal annular clearance between the forcer and the shaft. The large air gap is provided for ease of alignment.

In addition to the obvious difference between the cylindrical and flat configurations, the other difference is that the magnetic circuits of most motors, including linear motors, are made of magnetic iron while Linear Shaft Motors are not. For this reason, the high-quality Linear Shaft Motor has no core containing iron, thus there is no magnetic attraction between the forcer and the shaft.



Nor is there any adsorption force between the shaft and the forcer (coil), thereby eliminating cogging.

Because the shaft style linear motors make full use of the magnetic flux, they are highly efficient. Linear Shaft Motors do not require any type of cooling for normal operation, thereby eliminating the need to incorporate any type of cooling (heatsink, liquid or forced air-cooling) into the basic design.

Advantages

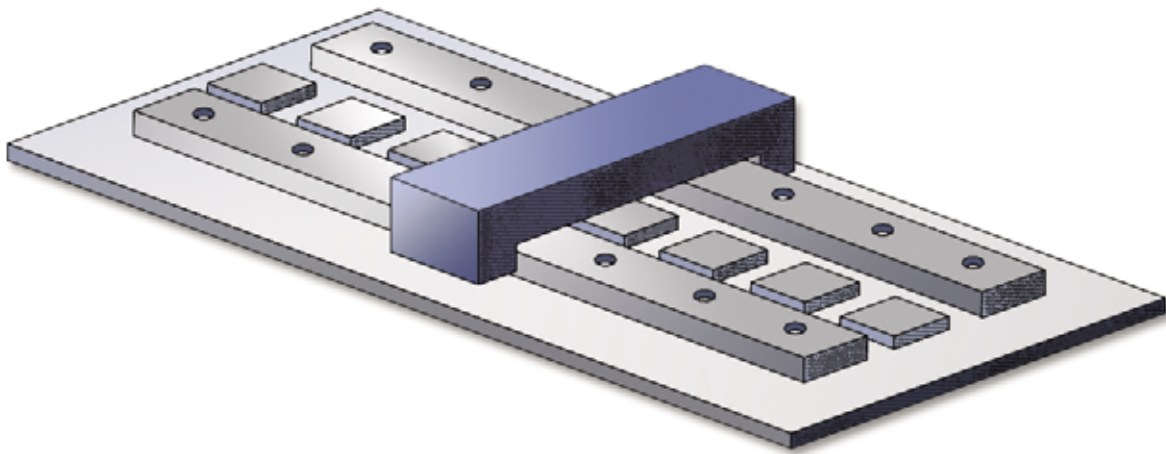
- **Compact & Lightweight** Lower weight when compared to traditional type of linear motors.
- **Zero Cogging** The coreless design results in no magnetic cogging whatsoever.
- **Large Air Gap** The non-critical 0.3mm to 1.75mm nominal annular air gap allows for easy installation and alignment.
- **Highly Efficient** Some of the highest Force Constants of a linear motor.
- **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.

Linear Stepping Motors

- Open loop or low servo stiffness
- Limited force/speed

Platen-Type Linear Motors

- Precision air gap required
- Large force between stator and armature
- Exposed magnet track



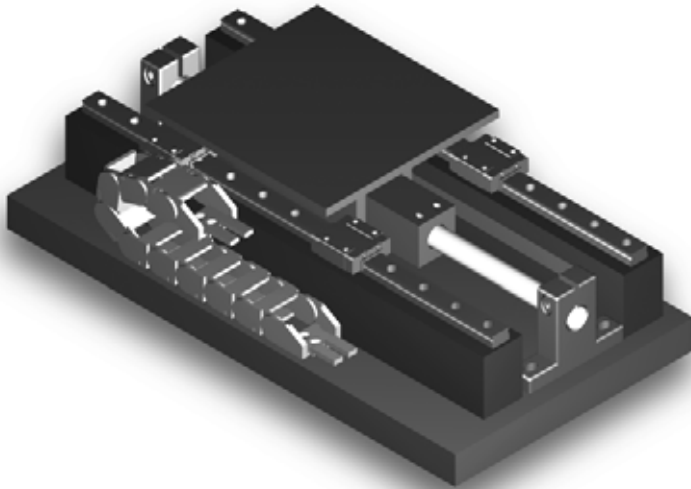
Linear Induction Motors

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

U-Shaped Linear Brushless Motors

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

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



No Lubrication/Adjustment Maintenance Necessary

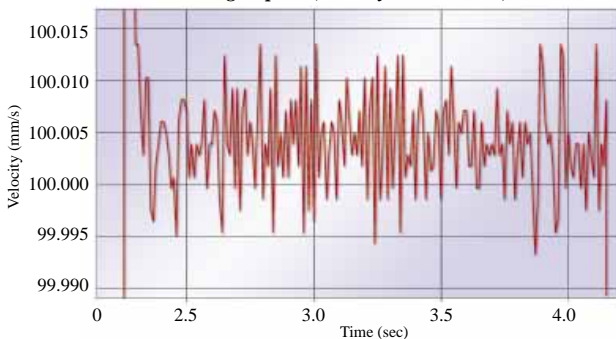
No greasing, as is necessary with a ball screw, and no performance degradation because of wear/aging as with ball screw and belt drive systems. By making it maintenance free and giving it a long lifetime, this contributes to cost reduction through out the life of the product. The clearance between the shaft and the slider eliminates the need for adjustments such as positioning of the guide or concentric adjustment, which are all required for ball screws.

Eco-Friendly - No Noise/No Dust Operation

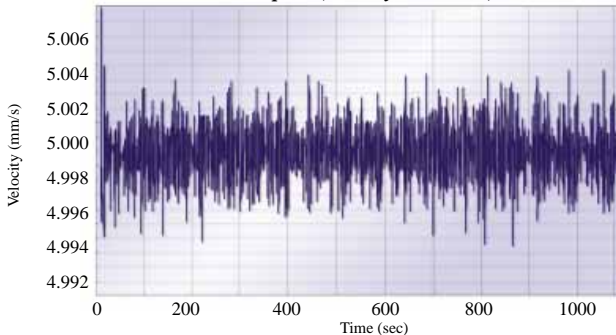
Dust and noise, inevitable in ball screw and pneumatic systems, does not exist in the non-contact Linear Shaft Motor. This is not only very applicable for clean room environments, but it also magnificently improves the work environment by reducing noise and dust.

Speed Fluctuation

High Speed (Velocity: 100mm/Sec)



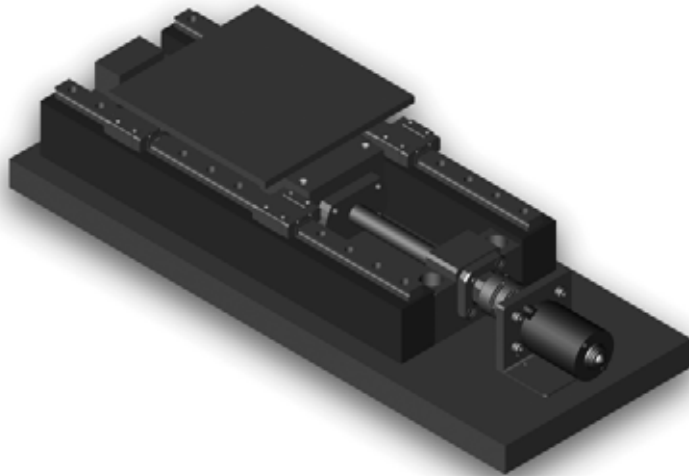
Low Speed (Velocity: 5mm/Sec)



The Linear Shaft Motor is coreless and thus able to provide uniformity of speed over a large range of speeds.

Advantages of Linear Shaft Motors

- Simple mechanical arrangement Minimum number of moving parts
- Direct thrust motor No backlash, no wear
- Wide speed range 8µm/sec to >6.5m/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 Precision¹ / Low Speed
Uniformity / High Repeatability**

The Linear Shaft Motor enables high precision not achievable in ball screws, and allows you to drastically improve the yield of high precision process, which had been limited by other linear mechanisms.

**Realizes High Speed Motions while
Retaining High Precision**

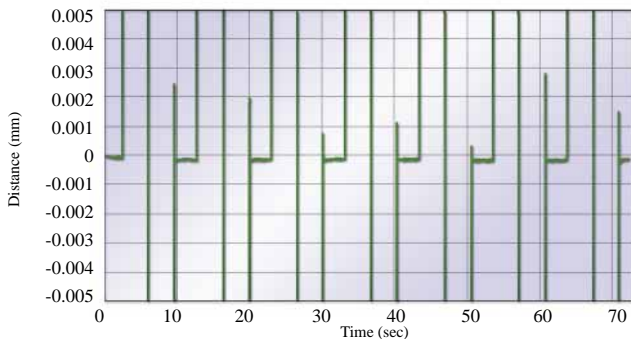
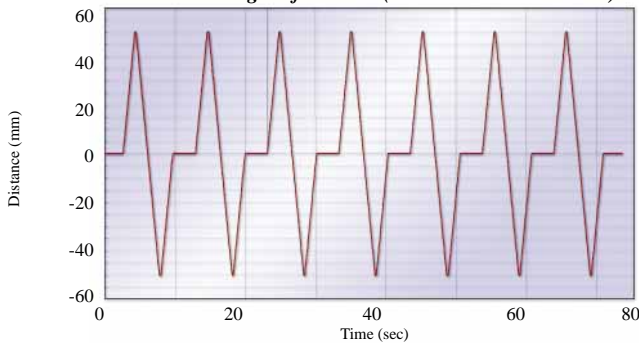
Linear Shaft Motor's high precision in high-speed operation shortens the travel time required by ball screws.

**Good Resistance Against Environmental
Changes such as Temperature**

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

Precision

Static Positioning Performance (encoder resolution 8.6nm)



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

Using Linear Shaft Motors can:

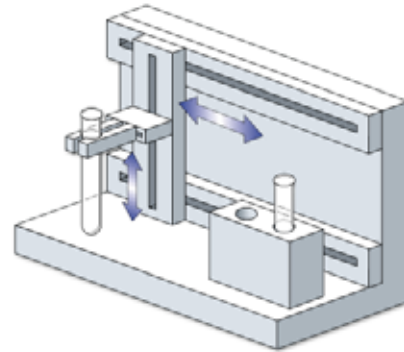
- Reduce the number of parts
- Save space
- Eliminate the need to adjust with locating guides and concentrics

¹ The precision of repetitive positioning is dependent on the resolution of the linear encoder. In addition, it is also necessary to have sufficient machine rigidity. In the same way, the absolute positioning precision is also fundamentally dependent on the linear encoder. It is not dependent on the expansion or contraction caused by the heat of the Linear Shaft Motor.

A wide range of applications is possible by utilizing one or more of the features of the Linear Shaft Motor listed on these two pages.

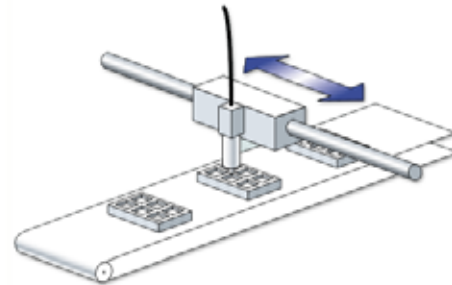
Friction free and quiet.

The Linear Shaft Motor has no contacting moving parts. Thus, all sources of noise and friction are eliminated. Allowing its use in quiet and clean room surroundings, such as test laboratories or medical facilities



Environmental compatibility.

Operates well in production locations where oil or water are used, or in a vacuum.



Large stroke lengths.

Up to 4.6 meters, are ideal for high-precision conveying, such as LCD's over relatively long distances.



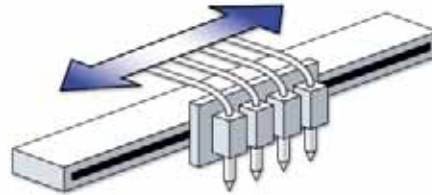
High thrust.

Peak thrust of up to 2780 Newtons is achievable. Can be used for precisely conveying heavy loads such as in clinical equipment or transfer lines on the factory floor.

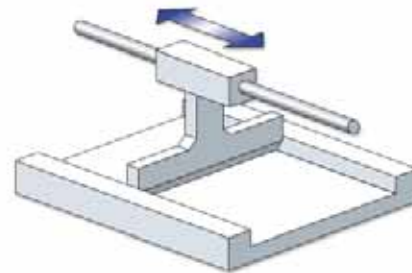


High controllable speed.

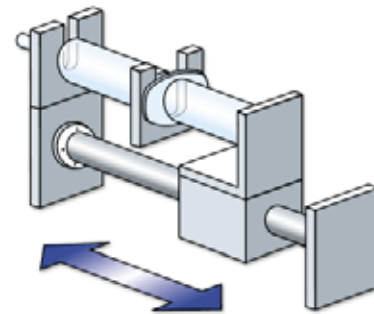
Speeds of up to 6.5 meters/sec have been documented. Ideal for line head drives in high-speed printers.

**Low speed drives.**

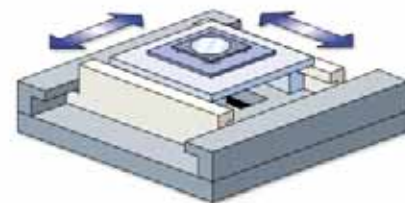
Speeds as low as 8 μ m/sec have been documented. Ideal for equipment, such as in life sciences, which may be difficult to handle with ball screws.

**No speed fluctuation.**

Ideal for constant speed drug dispensing which may be difficult to achieve with lead screws or ball screws.

**High resolution.**

Useful for precise micro positioning required in semiconductor equipment.



Linear Slider

In this application, a single Linear Shaft Motor was used with a servo driver, motion controller, linear encoder, and linear guide (bearing).

- Linear Shaft Motor: S160T
- Stroke: 300 mm
- Thrust: 15 Newtons
- Resolution: 0.082 μ to 5 μ (settable in eight levels within this range).
- Maximum operating speed: 7.2 meters per second.

A Linear Shaft Motor was selected because of its high speed and acceleration along with high precision.



Linear Station

In this application, two Linear Shaft Motors were used in blood testing equipment. A single Linear Shaft Motor with two sliders for two independent movements was used on the X-axis and a single Linear Shaft Motor was used on the Y-axis. A dedicated controller controlled the axes.

- Linear Shaft Motors:

X axis	S160T
Y axis	S200T
- Stroke: X axis 350 mm
Y axis 200 mm
- Thrust: X axis 15 Newtons
Y axis 28 Newtons
- Resolution: 4 micrometers
- Stepping motors were used on the other axes for specimen aspiration/dispensing, aspiration tip disposal, test tube chucking and test tube position control.
- Controller: Motionnet for multi-axis control and cable saving.
- Processing time: One specimen every 35 seconds
- Maximum operating speed: 0.5 meters per second.

The Linear Shaft Motor was selected because of its ability to have two heads running at the same time.

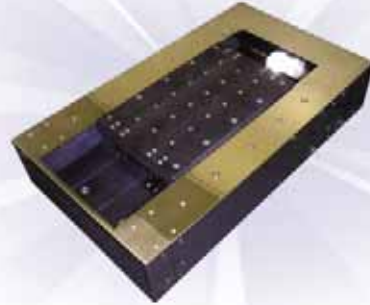


High Precision Stage

In this application, a single Linear Shaft Motor was used for a high precision granite stage.

- Linear Shaft Motor: S320D
- Stroke: 40 mm
- Thrust: 56 Newtons
- Resolution: 0.14 nm
- Controller: UMAC made by Delta-Tau Data Systems, Inc.
- Servo driver: SVDH5-A made by Servoland
- Linear Encoder: Laser scale P/N BS55A made by Sony Manufacturing System (± 0.04 micrometers on 40mm effective length)
- Interpolator: BD95-T12 by Sony Manufacturing System (Resolution is 0.14nm)
- Linear guide: Air slider

The Linear Shaft Motor was selected because of its high motor stiffness and its ability for ultra high precision.



Microscope Stage

In this application, two Linear Shaft Motors were used for micro pinioning or specimen to be analyzed by the microscope.

- Linear Shaft Motors:
 - X axis S080Q
 - Y axis S120Q
- Stroke: 300 mm
- Thrust: X axis 3.5 Newtons
- Y axis 8.9 Newtons
- Resolution: 5 nanometers
- Maximum operating speed: 100 mm per second.

The Linear Shaft Motor was selected because of its wide speed range, and its ability for high precision.



Vertical Slider

In this application, a single Linear Shaft Motor was used for smooth vertical movement and for quiet operation.

- Linear Shaft Motor: S250D
- Stroke: 50 mm
- Thrust: 46 Newtons
- Resolution: 100 μ
- Maximum operating speed: 1.3 m per second

A Linear Shaft Motor was selected because of its totally quiet operation.



Clean Room Pick and Place

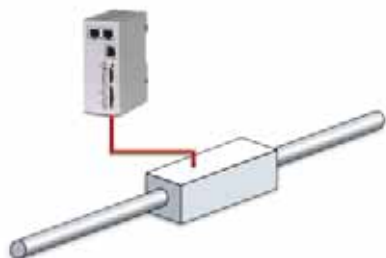
In this application, a single Linear Shaft Motor was used in a non-contact stage suitable for a class 10,000 clean room.

- Linear Shaft Motor: S200T
- Stroke: 500 mm
- Thrust: 28 Newtons
- Maximum operating speed: 1.0 m per second

A Linear Shaft Motor was selected because of its non contact construction, and the fact that it does not require maintenance.

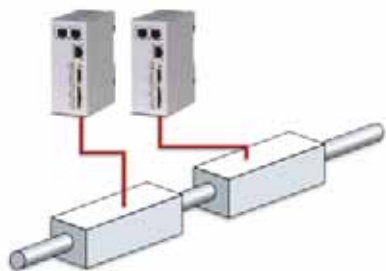


The Linear Shaft Motor can be mixed and matched to achieve the desired load thrust, based upon the complexity of the application.



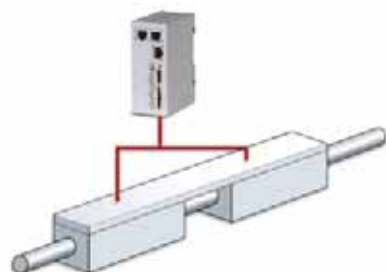
Single Drive System

This is a basic drive system. The X and Y shafts can be used to create an X-Y stage.



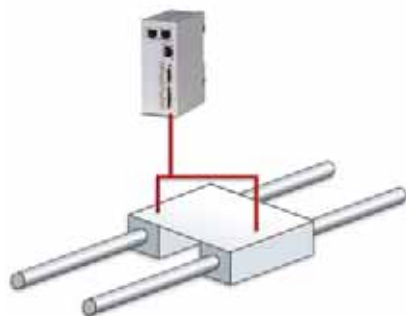
Multi-drive System

Multiple forcers can be used with a single shaft to support complex movements required by of some applications.



Tandem Drive System

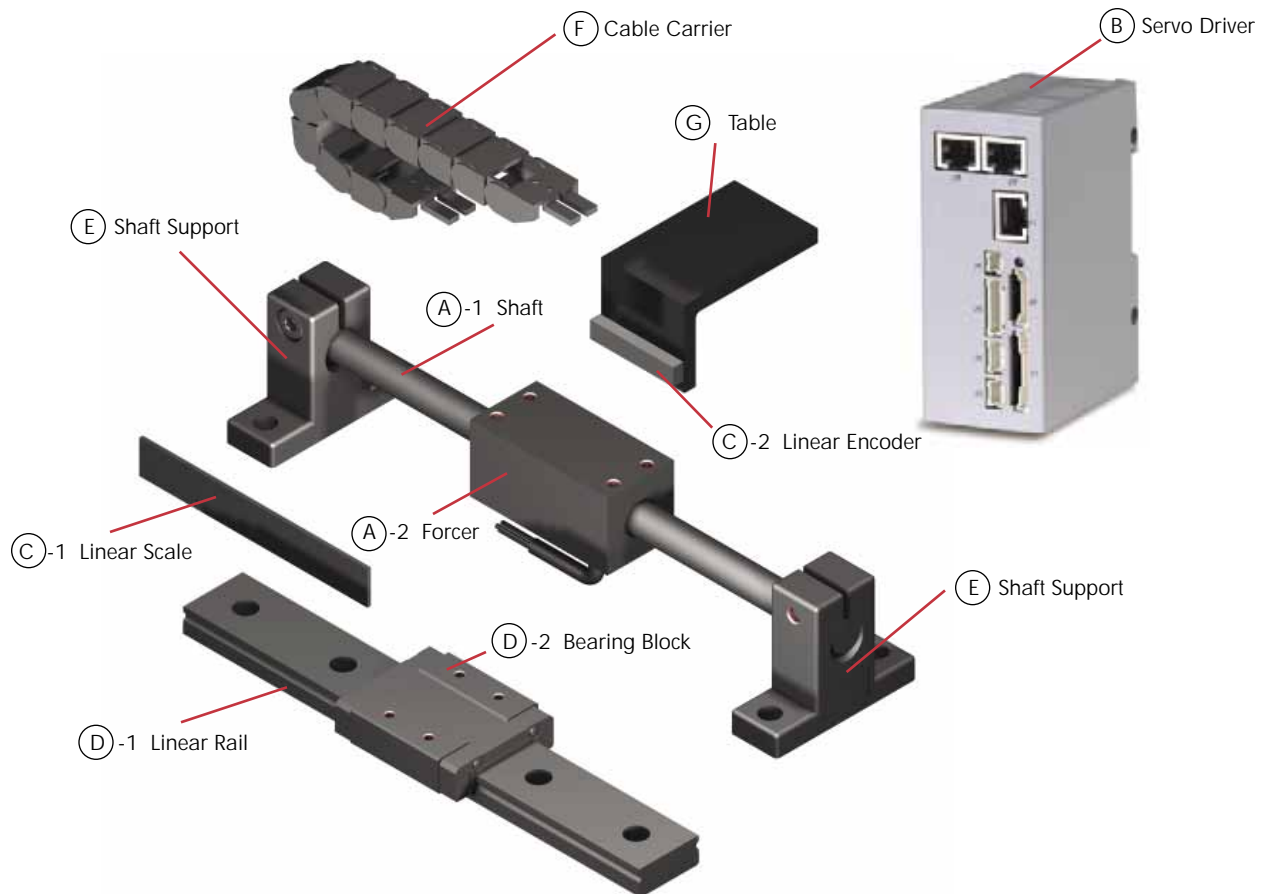
Two or more forcers can be used on the same shaft to multiply the thrust.



Parallel Drive System

Linear Shaft Motors can be used in parallel as shown (two or more forcers and two shafts connected to the same load), to achieve large thrusts for moving heavy objects.

The design of the Linear Shaft Motor allows you to replace the standard ball screw system with the Linear Shaft Motor and achieve higher speed and resolution. However, to achieve the highest performance with the Linear Shaft Motor system, the entire system structure must be optimized. Please be aware that there are various design considerations which are somewhat different from traditional servo system practices. We will discuss the main components needed to make a Linear Shaft Motor system, as well as what to keep in mind when designing a system.



Configure the Linear Shaft Motor

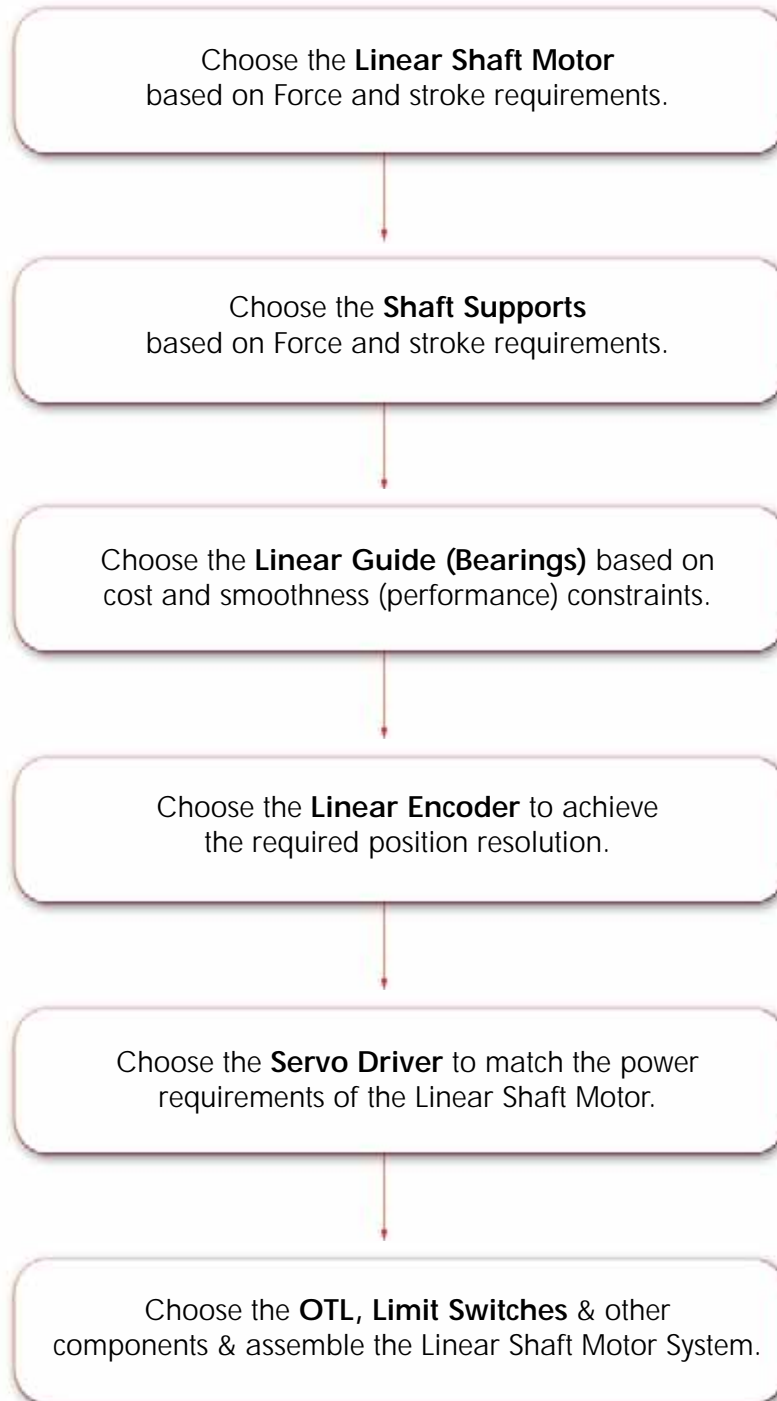
To configure a system using the Linear Shaft Motor, the following peripheral devices are required:

- A. Linear Shaft Motor
- B. Servo Driver
- C. Linear encoder (optical or magnetic)

Item D (Linear Guide) is a necessary part of a system, but much consideration must be given to the application, demand specifications, environmental conditions, and which will be moving, the forcer or the shaft.

The other items, E through G, are optional and will need to be selected depending on the application.

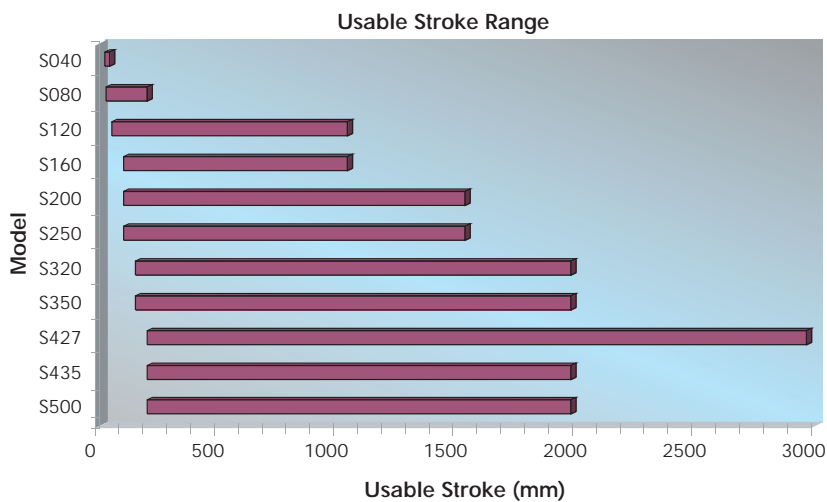
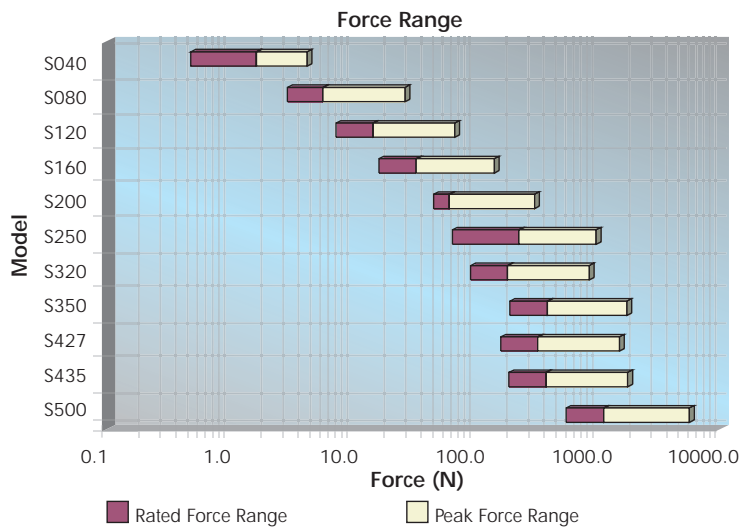
Steps to putting together a Linear Shaft Motor System



Choose the Linear Shaft Motor based on force and stroke requirements.

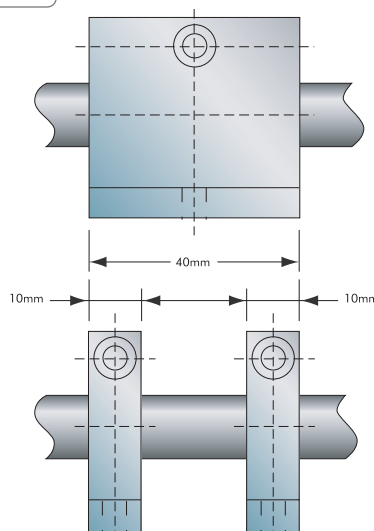
To assist in selecting the correct Linear Shaft Motor, feel free to make use of the Selection Guide in the Engineering Notes section and “SMART” (Linear Shaft Motor Application Resource Tool). The Linear Shaft Motor should be mounted as closely as possible to the center of gravity of the moving load and should be as close as possible to the working point of the machine.

If the motor and feedback are far apart, the machine structure and linear guide (bearings) must be of sufficient mechanical stiffness to minimize dynamic deflections of the structure. Be sure to allow clearance for ventilation and access for cleaning, repair, service, and inspections. Ventilation is extremely important. Be sure the area for ventilation is not obstructed. Obstructions limit the free passage of air. Motors get warm and the heat must be dissipated to prevent damage.



Choose the shaft supports based on force and stroke requirements.

Select a shaft support as outlined in the data sheet of your selected Linear Shaft Motor. The shaft support is what allows longer strokes in a Linear Shaft Motor system without excessive bending of the shaft. The shaft support should not only be able to support the mass of the shaft, but also be in contact with the shaft for the specified support length. While a single shaft support will provide better security and easier alignment, a lower cost option is to space two smaller shaft supports for the specified support length. The drawing to the right illustrates these two different options.



Choose the linear guide (bearings) based on cost and smoothness (performance) constraints.

The linear guide (bearings) must be selected to support the moving load. Often, the linear guide (bearings) is the only moving contact type component in the system. Therefore, this component requires special attention. Desirable bearing characteristics include high mechanical stiffness (for increased natural frequency) and low friction. Because the Linear Shaft Motors can provide high velocities, the speed and acceleration limitations of the bearings need to be considered. Some common bearing choices are compared in the table to the right. Air bearings are most desirable from the standpoint of smoothness, but they are also the most costly. Mechanical slide rails on the other hand are the least expensive, but they are least desirable with respect to load carrying capability.

	Slide Rails	Cam Follower	Crossed Roller	Recalculating Element	Air
Travel	⊙	⊙	●	⊙	⊙
Stiffness	●	●	⊙	⊙	⊙
Speed	●	⊙	⊙	○	⊙
Smoothness	●	⊙	⊙	⊙	○
Precision	●	●	⊙	⊙	○
Load	⊙	●	⊙	⊙	●
Cost	○	○	⊙	⊙	●

Least Desirable ● ○ *Most Desirable*

Choose the linear encoder to achieve the required position resolution.

The linear encoder is one of the most important parts of your Linear Shaft Motor system. A processed signal from the linear encoder is used to precisely measure the actual position of the system. The positioning resolution, repeatability, and smoothness of operation depend on the resolution of the encoder. For this reason, it is recommended you use an encoder with a 1μ resolution or better. In addition, the maximum response speed of the encoder may limit the maximum system speed. Select a linear encoder that will supply ten times your required resolution. To assist in selecting the correct encoder, feel free to make use of the Encoder formula in the Engineering Notes section. Either an optical or a magnetic encoder can be used. In the case of a magnetic linear encoder, take care that it is installed so that the magnetic shaft does not affect the encoder. Ensure your driver supports the output mode of the selected encoder. The linear encoder should be mounted as close as possible to the working point of the machine. If the motor and feedback are far apart, the machine structure and linear guide (bearings) must be of sufficient mechanical stiffness to minimize dynamic deflections of the structure.





Choose the servo driver to match the power requirements of the Linear Shaft Motor.

Select a servo driver that can meet the power requirements of your selected Linear Shaft Motor. To assist in selecting the correct servo driver, feel free to make use of the Driver Sizing Guide in the Engineering Notes section. Any three phase brushless DC servomotor driver can be used to drive the Linear Shaft Motor. In selecting a servo driver, check the method in which the magnetic position is detected.

Since the Linear Shaft Motor does not come with hall effect sensors in its standard configuration, they will need to be added as an option if required by your selected servo driver. If the servo driver does not require the use of hall effect sensors, you may use the Linear Shaft Motor in its standard configuration.

Most servo drivers use peak units for voltage and current ratings while most servomotors (like the Linear Shaft Motor) use RMS units. Please pay attention to the units when selecting a servo driver. The Engineering Notes section has formulas for converting peak values to RMS values.

Choose the OTL, limit switches, and other components and assemble the Linear Shaft Motor System.

Temperature Sensor

A temperature sensor OTL (Over Temperature Limit), which will cut power to the motor should it get too hot due to over load, can be added in series with the main power to the driver. The maximum coil temperature limit of the Linear Shaft Motor is 135°C.

Limit Switches

Limit switches can be added on either side of the load on the shaft to prevent the load from overshooting and causing harm. Many quality linear encoders include limit switches.



Cabling & Cable Carrier

The Linear Shaft Motor is typically operated with a stationary shaft and a moving forcer. With such an arrangement, you will have moving cables. A provision must be provided in the machine to carry the cables. A connector is provided with the Linear Shaft Motor to allow you to connect cables for proper flex life at the designed bend radius in the locations where the cable would move. Cables should be made in a twisted pair configuration, shielded, and grounded properly to the machine base, servo driver, and motor in order to reduce RFI.



Hall Effect Sensor

Hall effect sensors are devices, which can sense position magnetically and provide this information to the servo driver. Some servo drivers require hall sensor feedback for commutation. The hall effect sensors are used by some servo drivers to obtain forcer position information relative to the shaft for commutation. Other servo drivers are able to obtain information for commutation from the linear encoder.

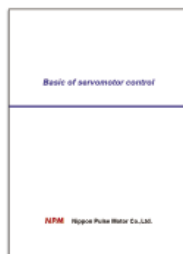
For most horizontal applications using servo drivers, there is no need for digital hall effects. The commutation is based on a commutation table built during the tuning process, and thus derived from the linear encoder. For most vertical applications, it is best to use digital hall effects. The Linear Shaft Motor does not come with hall effect sensors in its standard configuration; they will need to be selected as an option if required by your selected servo driver.

Other Components

Each component must be of the lowest mass and highest mechanical stiffness possible in order to decrease settling times. Hollowed and ribbed components or honeycomb structures, along with special materials, are often utilized to achieve this. Obtaining the highest mechanical stiffness with the lowest mass requires that the linear motor be treated as an integral element to a motion system and not an add-on part.

For more information...

feel free to download the Application Note: "Basic of servomotor control" from our website, www.NipponPulse.com



Motion controller

Cards

NPMC/PPCI series, board-level motion controllers are multi-axes digital servomotor controllers. The boards are available in 4-axes PC/104 bus (NPMC6045A-4104) and 4-axes PCI-bus (PPCI7443).

General features are high pulse rate capability (6.5Mpps), S-curve ramp-up and down, encoder feedback inputs, and circular and linear interpolations. The NPMC/PPCI series is powerful and makes it easy to program your own motion profiles (the software uses Microsoft Windows™ to provide quick setup and testing, and is included along with a C programming library).



Network

The Motionnet System is a communication system that allows for cost and wire savings while supplying high-speed serial communications (20Mbps) and high precision motion control.

The Motionnet System is a modular serial communication product that allows you to create the configuration you need.

There are three devices in the Motionnet System:

Master Device

PCI PPCI-L112
PC/104 NPMC/MNET-I/O104

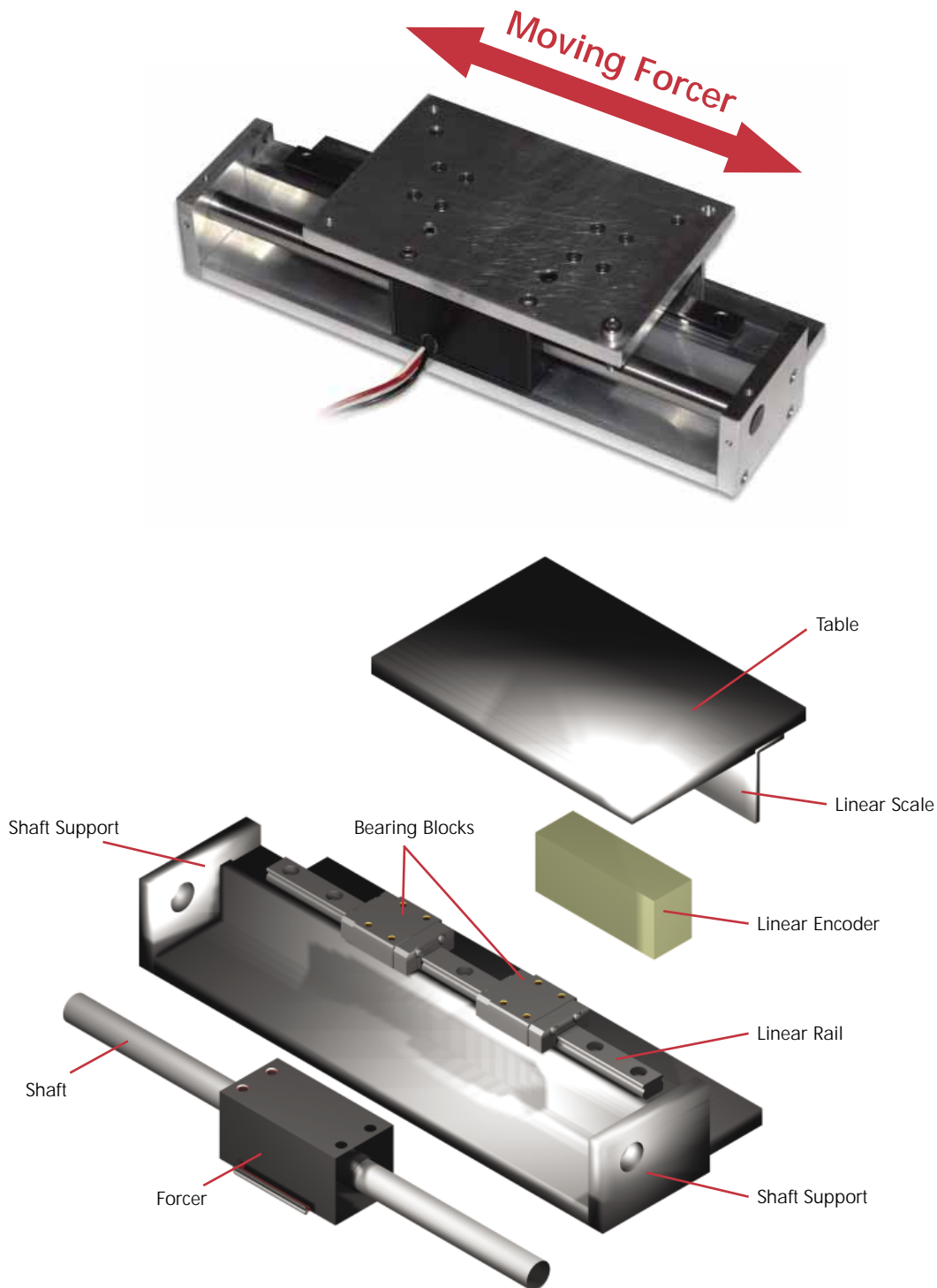
I/O Device

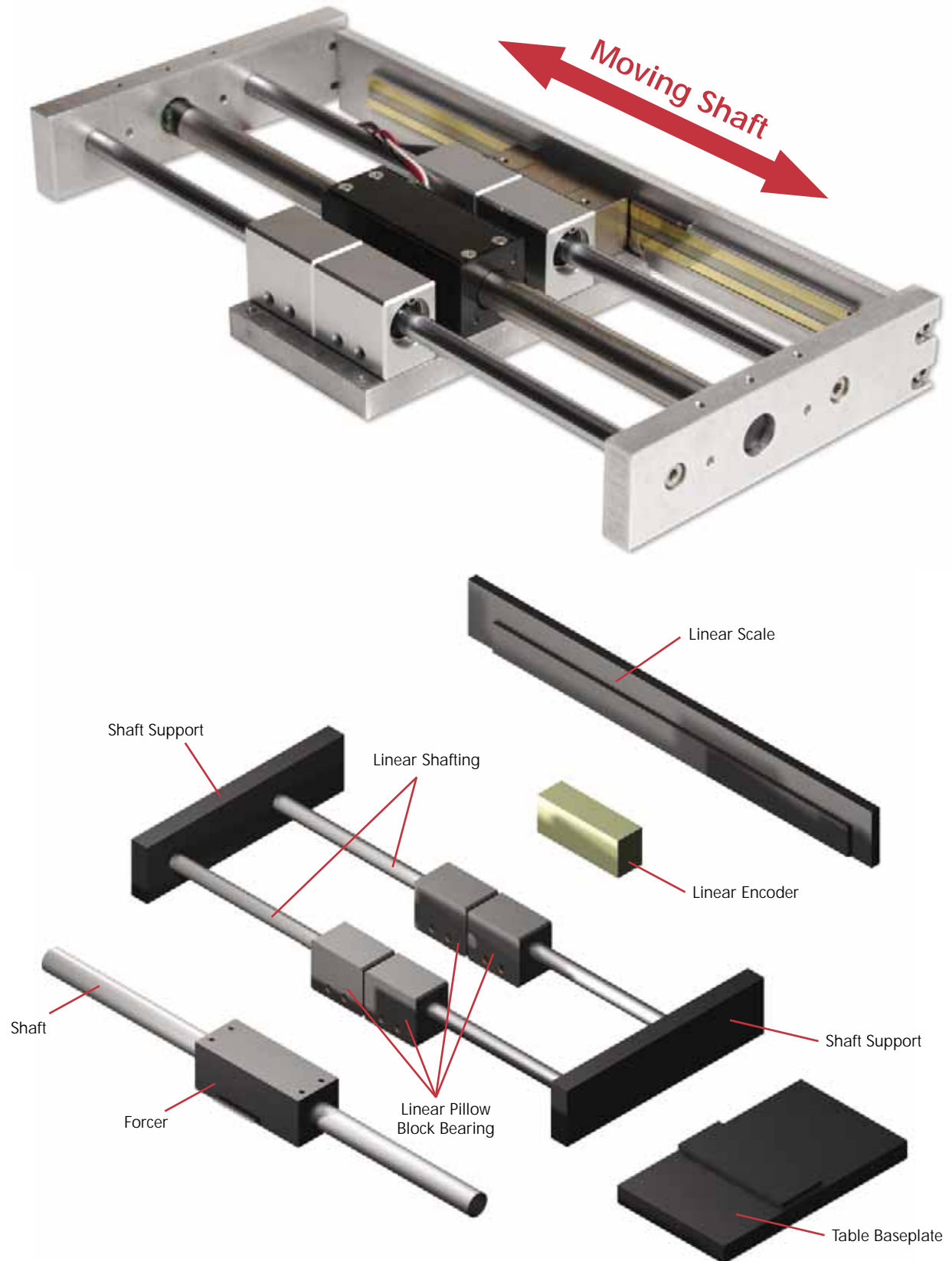
32 – digital input MNET-D340
32 – digital output MNET-D304
16 – digital input & 16 digital output MNET-D322

Motion Control Device

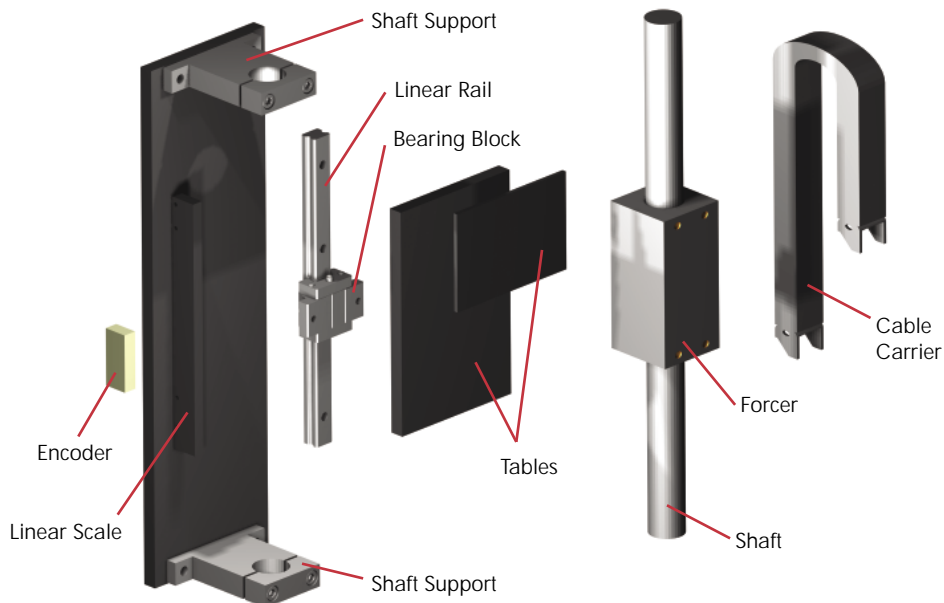
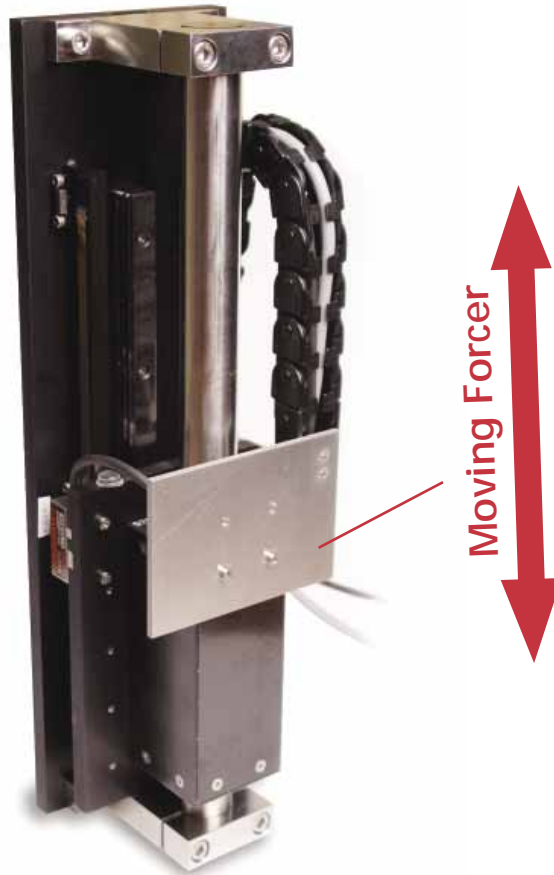
MNET-M101-DUM

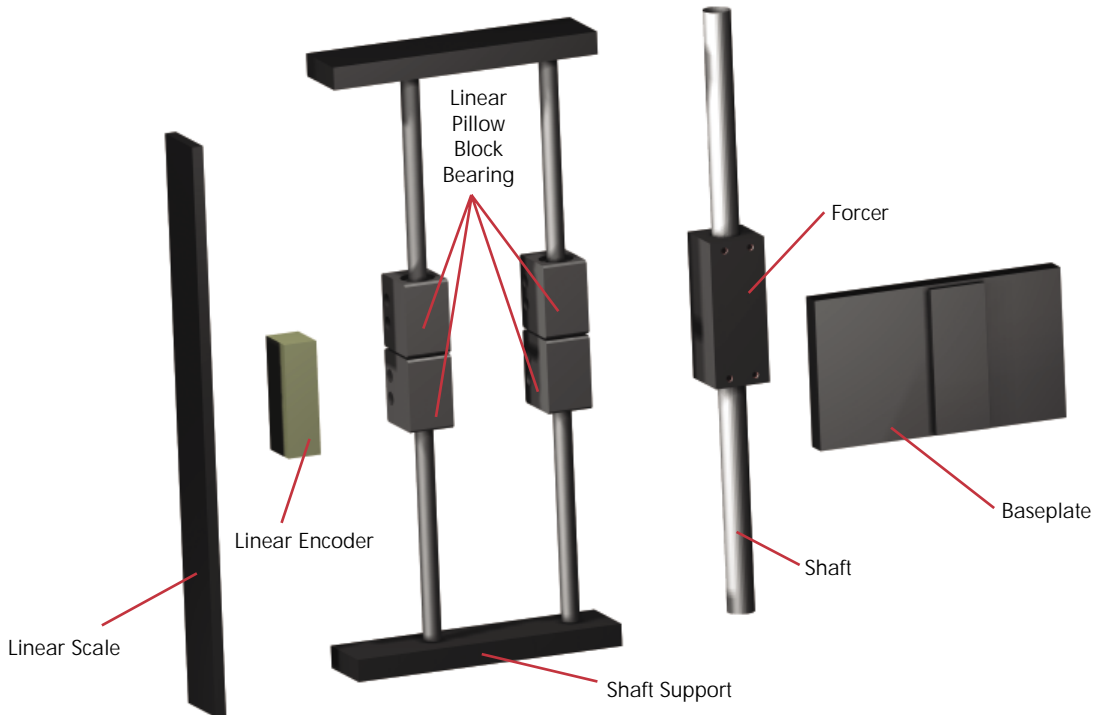
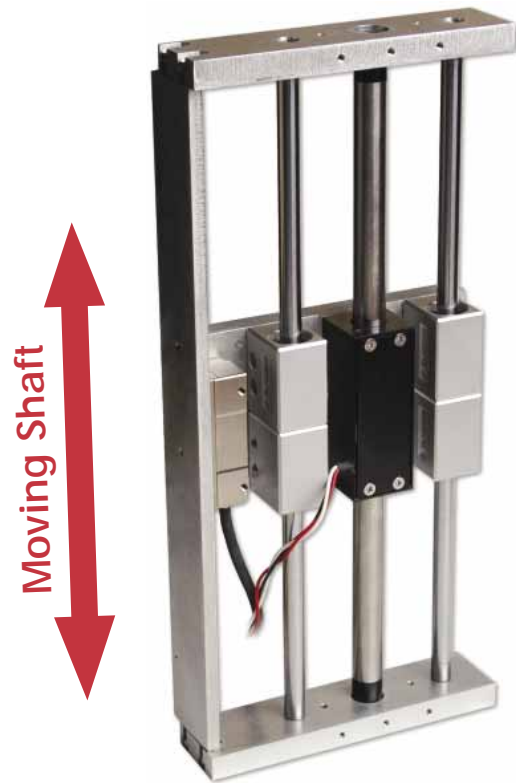
When used in a horizontal application, Linear Shaft Motors typically will have the load attached to the forcer so as to achieve very simple and precise linear movements. In a Linear Shaft Motor system, the shaft is supported at both shaft supports and the load moves along slide rails, linear bearings or air bearings. A linear encoder scale is attached to the guide rails to provide linear position feedback for servo control.



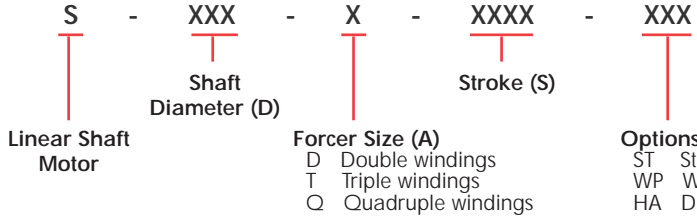


When used in a vertical application, Linear Shaft Motors typically require a counterbalance mechanism, or brake, to prevent the load from dropping in the event of a power interruption. The counter balance can also reduce the net load on the motor by supporting the load against gravity. Typical counterbalance techniques include a pneumatic cylinder, springs, or a counterweight.





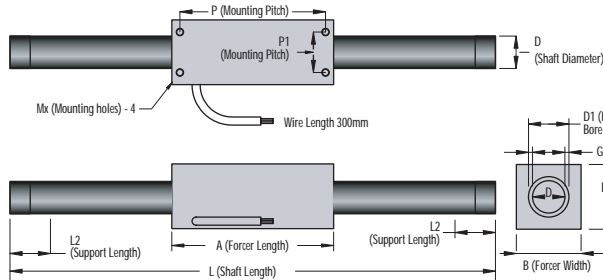
Linear Shaft Motor Part Number



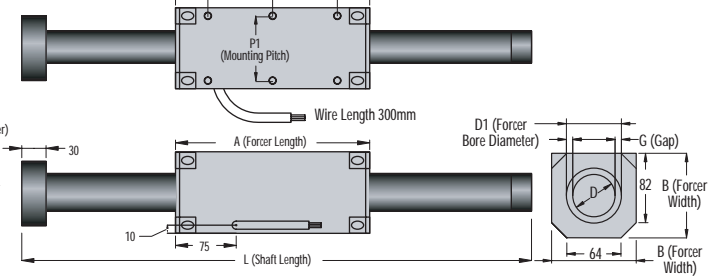
There are 11 basic shaft diameters of the Linear Shaft Motor, which can deliver a continuous force range of 0.4N to 690N and peak force up to 2780N. Numerous stroke lengths are available from 20mm to 4.6M. If you do not see the size you need, ask your local NPA representative.

Linear Shaft Motor	S040D	S040T	S040Q	S080D	S080T	S080Q	S120D	S120T	S120Q	S160D	S160T	S160Q
Specifications												
Continuous Force (*1) N(lbs)	0.29 (0.07)	0.45 (0.1)	0.58 (0.13)	1.8 (0.4)	2.7 (0.61)	3.5 (0.79)	4.5 (1.01)	6.6 (1.48)	8.9 (2.0)	10 (2.25)	15 (3.37)	20 (4.5)
Continuous Current (*1) Arms	0.32	0.32	0.32	0.81	0.81	0.81	0.4	0.4	0.4	0.62	0.62	0.62
Peak Force N(lbs) (*2)	1.2 (0.27)	1.8 (0.4)	2.3 (0.52)	7.5 (1.7)	11 (2.5)	15 (3.4)	19 (4.3)	28 (6.3)	37 (8.3)	39 (8.8)	58 (13 lbs)	78 (17.5)
Peak Current Arms (*2)	1.3	1.3	1.3	3.4	3.4	3.4	1.7	1.7	1.7	2.4	2.4	2.4
Force Constant Kf N/amp (lbs/amp)	0.9 (0.2)	1.4 (0.31)	1.8 (0.4)	2.2 (0.5)	3.3 (0.7)	4.3 (1.0)	11 (2.5)	17 (3.8)	22 (4.9)	16 (3.6)	24 (5.4)	33(7.2)
Back EMF V/m/s (V/in/s)	0.4 (0.01)	0.6 (0.02)	0.7 (0.02)	0.7 (0.02)	1.1 (0.03)	1.4 (0.04)	3.7 (0.09)	5.5 (0.14)	7.4 (0.19)	5.4 (0.14)	8.1 (0.21)	11 (0.28)
Resistance (*3) Ohms	11	17	22	4.7	6.8	9.0	37	54	73	21	33	43
Inductance (*3) mH	0.5	0.7	1.0	0.7	1.0	1.3	12	18	24	8.2	12	16
Thermal Resistance Kq °C/W	50	33	25	35	24	18	19	13	9.4	13	8.7	6.6
Forcer Weight kg (lb)	0.009 (0.02)	0.011(0.024)	0.014(0.031)	0.05 (0.11)	0.06 (0.13)	0.08 (0.18)	0.09 (0.20)	0.12 (0.26)	0.16 (0.35)	0.15 (0.33)	0.20 (0.44)	0.30 (0.66)
Pole(N-N) Distance mm(in)	18 (0.71)	18 (0.71)	18 (0.71)	30 (1.18)	30 (1.18)	30 (1.18)	48 (1.89)	48 (1.89)	48 (1.89)	60 (2.36)	60 (2.36)	60 (2.36)
Stroke (S)	20, 30, 40 mm			50 ~ 200 mm (50mm separation)			50 ~ 1050 (50mm separation)			100 ~ 1050 (50mm separation)		
Linear Shaft Motor	S200T	S200Q	S250D	S250T	S250Q	S250X	S320D	S320T	S320Q	S350D	S350T	S350Q
Specifications												
Continuous Force (*1) N(lbs)	28 (6.29)	38 (8.54)	40 (9.0)	60 (13.5)	75 (16.9)	140 (31.5)	56 (12.6)	85 (19.1)	113 (25.5)	118 (27)	180 (40)	240 (54)
Continuous Current (*1) Arms	0.59	0.59	1.3	1.3	1.3	2.4	1.2	1.2	1.2	1.7	1.7	3.4
Peak Force N(lbs)	120 (27)	160 (36)	150 (33.7)	230 (51.7)	300 (67.4)	560 (126)	240 (54)	350 (78.7)	470 (106)	476 (107)	710 (160)	950 (214)
Peak Current Arms	2.5	2.5	5.2	5.2	5.2	9.6	5.2	5.2	5.2	6.8	6.8	13.6
Force Constant Kf N/amp (lbs/amp)	47 (10.57)	64 (14.39)	28 (6.29)	42 (9.44)	56 (12.59)	56 (12.59)	45 (10.12)	68 (15.29)	91 (20.46)	70 (15.74)	104 (23.38)	70 (15.74)
Back EMF V/m/s (V/in/s)	16 (0.41)	21 (0.53)	9.7 (0.25)	15 (0.38)	19 (0.48)	19 (0.48)	15 (0.38)	23 (0.58)	30 (0.76)	23 (0.58)	35 (0.89)	23 (0.58)
Resistance (*3) Ohms	43	56	7.8	12	15	7.6	11	17	23	14	20	7
Inductance (*3) mH	29	39	9.8	15	19	9.8	17	26	34	22	33	11
Thermal Resistance Kq °C/W	7.4	5.6	8.4	5.7	4.3	2.5	6.3	4.5	3.1	2.8	1.9	1.4
Forcer Weight kg (lb)	0.5 (1.1)	0.7 (1.5)	0.8 (1.8)	1.1 (2.4)	1.5 (3.3)	2.6 (5.7)	1.2 (2.6)	1.7 (3.7)	2.2 (4.9)	1.3 (2.9)	1.9 (4.2)	2.4 (5.3)
Pole(N-N) Distance mm(in)	72 (2.83)	72 (2.83)	90 (3.54)	90 (3.54)	90 (3.54)	90 (3.54)	120 (4.72)	120 (4.72)	120 (4.72)	120 (4.72)	120 (4.72)	120 (4.72)
Stroke (S)	100 ~ 1550 (50mm separation)					150 ~ 2000 (50mm separation)						
Linear Shaft Motor	S427D	S427T	S427Q	S435D	S435T	S435Q	S500D	S500T	S500Q			
Specifications												
Continuous Force (*1) N(lbs)	100 (22.5)	150 (33.7)	200 (45)	116 (26.1)	175 (39.3)	233 (52.4)	340 (76.4)	510 (115)	690 (155)	<i>Notes:</i> (*1) Based on a temp rise of coil surface of 110°K over 23°C ambient temp and no external cooling or heatsinking. (*2) Can be maintained for a maximum of 40 seconds, consult Nippon Pulse America. (*3) All winding parameters listed are measured line-to-line (phase-to-phase). Specifications may change depending on servo driver selected. Consult Nippon Pulse America.		
Continuous Current (*1) Arms	3.0	3.0	3.0	3.0	3.0	3.0	4.7	7.1	9.4			
Peak Force N(lbs)	420 (94)	620 (139)	830 (187)	490 (110)	730 (164)	970 (218)	1360 (306)	2040 (459)	2780 (625)			
Peak Current Arms	12	12	12	12	12	12	19	28	38			
Force Constant Kf N/amp (lbs/amp)	34 (7.64)	50 (11.24)	68 (15.29)	39 (8.77)	59 (13.26)	78 (17.53)	73 (16.41)	73 (16.41)	73 (16.41)			
Back EMF V/m/s (V/in/s)	11 (0.28)	17 (0.43)	23 (0.58)	13 (0.33)	20 (0.51)	26 (0.66)	24 (0.61)	24 (0.61)	24 (0.61)			
Resistance (*3) Ohms	2.7	3.9	5.2	2.7	3.9	5.2	4.5	3	2.3			
Inductance (*3) mH	7.3	11	15	7.3	11	15	27	18	13			
Thermal Resistance °C/W	4.5	3.1	2.4	4.5	3.1	2.4	1.5	1	0.7			
Forcer Weight kg (lb)	3.0 (6.6)	4.2 (9.2)	5.4 (11.9)	3.0 (6.6)	4.2 (9.2)	5.4 (11.9)	8 (17.6)	11 (24.3)	12 (26.5)			
Pole(N-N) Distance mm(in)	180 (7.09)	180 (7.09)	180 (7.09)	180 (7.09)	180 (7.09)	180 (7.09)	180 (7.09)	180 (7.09)	180 (7.09)			
Stroke (S)	200 ~ 3000 (50mm Separation)			200 ~ 2000 (50mm Separation)								

* S040 ~ S435



* S500

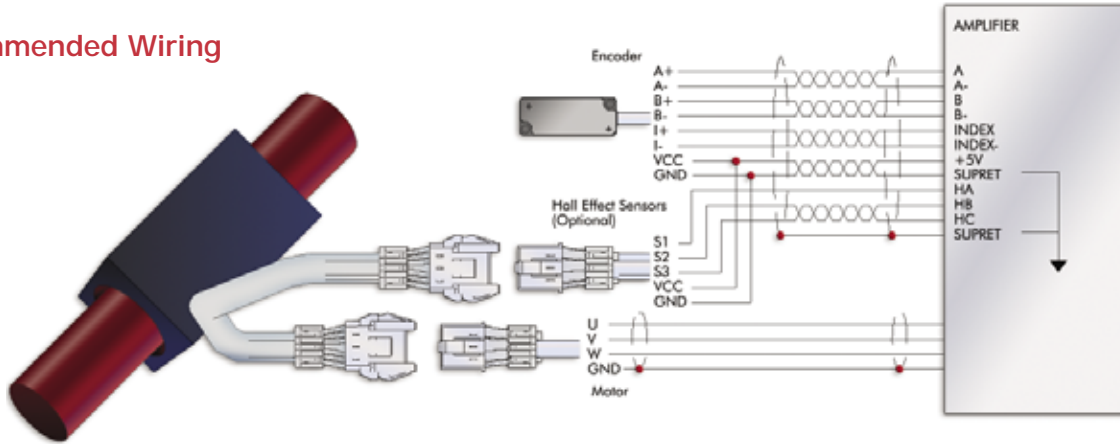


Notes:

- The dimension S (Stroke) should be used for limit switch spacing.
- The total length of the shaft (L) can be calculated using the following formula: L (Total Length) = S (Stroke) + A (Forcer Length) + $2 \times L2$ (Support Length)

Linear Shaft Motor		S040D	S040T	S040Q	S080D	S080T	S080Q	S120D	S120T	S120Q	S160D	S160T	S160Q						
Dimensions																			
Shaft Diameter	mm (in)	D			4 ± 0.1 (0.16)			8 ± 0.1 (0.32)			12 ± 0.1 (0.47)			16 ± 0.1 (0.63)					
Forcer	Length	mm (in)	A		25 (0.98)	34 (1.34)	43 (1.69)	40 (1.57)	55 (2.17)	70 (2.76)	64 (2.52)	88 (3.46)	112 (4.41)	80 (3.15)	110 (4.33)	140 (5.51)			
	Width	mm (in)	B		10 ± 0.3 (0.39)			20 ± 0.3 (0.79)			25 ± 0.3 (0.98)			30 ± 0.3 (1.18)					
	Weight	kg (lb)	0.009 (0.02)	0.011 (0.024)	0.014 (0.031)	0.05 (0.11)	0.06 (0.13)	0.08 (0.18)	0.09 (0.20)	0.12 (0.26)	0.16 (0.35)	0.15 (0.33)	0.20 (0.44)	0.30 (0.66)					
	Mounting Pitch	mm (in)	P		21.5 (0.85)	30.5 (1.2)	39.5 (1.55)	34 (1.34)	49 (1.93)	64 (2.52)	56 (2.2)	80 (3.15)	104 (4.1)	70 (2.76)	100 (3.94)	130 (5.12)			
	Mounting Pitch	mm (in)	P1		4 ± 0.3 (0.15)			10 ± 0.3 (0.39)			12 ± 0.3 (0.47)			16 ± 0.3 (0.63)					
	Mounting Screws	Mx	4-M2x2			4-M3x5			4-M3x5			4-M3x5			4-M3x5				
Bore Diameter	mm (in)	D1		4.6 (0.18)			9 (0.35)			13 (0.51)			17 (0.67)						
Gap	mm (in)	G		0.3 (0.01)			0.5 (0.02)			0.5 (0.02)			0.5 (0.02)						
Linear Shaft Motor		S200T	S200Q	S250D	S250T	S250Q	S250X	S320D	S320T	S320Q	S350D	S350T	S350Q						
Dimensions																			
Shaft Diameter	mm (in)	D			20 ± 0.3 (0.79)			25 ± 0.3 (0.98)			32 ± 0.2 (1.26)			35 ± 0.2 (1.37)					
Forcer	Length	mm (in)	A		130 (5.1 in)	166 (6.5 in)	120 (4.7)	165 (6.5)	210m (8.3)	390 (15.3)	160 (6.3)	220 (8.66)	280 (11)	160 (6.30)	220 (8.66)	280 (11.0)			
	Width	mm (in)	B		40 ± 0.3 (1.57)			50 ± 0.3 (1.96)			60 ± 0.3 (2.36)			60 ± 0.3 (2.36)					
	Weight	kg (lb)	0.50 (1.1)	0.70 (1.5)	0.80 (1.8)	1.1 (2.4)	1.5 (3.3)	2.6 (5.7)	1.2 (2.6)	1.7 (3.7)	2.2 (4.9)	1.3 (2.9)	1.9 (4.2)	2.4 (5.3)					
	Mounting Pitch	mm (in)	P		120 (4.72)	156 (6.14)	105 (4.13)	150 (5.9)	195 (7.68)	375 (14.76)	140 (5.51)	200 (7.87)	260 (10.24)	140 (5.51)	200 (7.87)	260 (10.24)			
	Mounting Pitch	mm (in)	P1		20 ± 0.3 (0.79)			25 ± 0.3 (0.98)			30 ± 0.3 (1.2)			30 ± 0.3 (1.18)					
	Mounting Screws	Mx	4-M4x6			4-M6x9			4-M8x12			4-M8x12			4-M8x12				
Bore Diameter	mm (in)	D1		21.5 (0.85)			26.5 (1.04)			34 (1.34)			37 (1.46)						
Gap	mm (in)	G		0.75 (0.029)			0.75 (0.029)			1.00 (0.039)			1.00 (0.039)						
Linear Shaft Motor		S427D/T/Q			S435D/T/Q			S500D/T/Q											
Dimensions																			
Shaft Diameter	mm (in)	D			42.7 ± 0.2 (1.68)			43.5 ± 0.2 (1.71)			50.0 ± 0.2 (1.96)								
Forcer	Length	mm (in)	A		220 (8.66)	310 (12.2)	400 (15.75)	220 (8.66)	310 (12.2)	400 (15.75)	240 (9.45)	330 (12.99)	420 (16.54)						
	Width	mm (in)	B		80 ± 0.3 (3.15)			80 ± 0.3 (3.15)			100 x 105 ± 0.3 (3.94 x 4.13)								
	Weight	kg (lb)	3.0 (6.6)	4.2 (9.2)	5.4 (11.9)	3.0 (6.6)	4.2 (9.2)	5.4 (11.9)	10 (22)	13 (28.7)	15 (33)								
	Mounting Pitch	mm (in)	P		200 (7.87)	290 (11.4)	380 (15.0)	200 (7.87)	290 (11.4)	380 (15.0)	80 (3.15)	125 (4.92)	170 (6.69)						
	Mounting Pitch	mm (in)	P1		50 ± 0.3 (1.96)			50 ± 0.3 (1.96)			80 ± 0.3 (3.15)								
	Mounting Screws	Mx	4-M8x12			4-M8x12			6-M8x13										
Bore Diameter	mm (in)	D1		46 (1.81)			46 (1.81)			53.5 (2.11)									
Gap	mm (in)	G		1.65 (0.06)			1.25 (0.05)			1.75 (0.07)									
Linear Shaft Motor		S040D/T/Q			S080D/T/Q			S120D/T/Q			S160D/T/Q								
Stroke	mm	S		~ 40			~ 200			~ 350			~ 800		801 ~				
Support Length	mm (in)	L2		5 (0.20)			10 (0.39)			25 (0.98)		40 (1.57)		60 (2.36)					
Linear Shaft Motor		S200T/Q			S250D/T/Q			S250X			S320D/T/Q			S350D/T/Q					
Stroke	mm	S		~ 300	~ 700	~ 701	~ 700	~ 1500	1501 ~	~ 500	~ 1300	1301 ~	~ 750	~ 1500	1501 ~	~ 750	~ 1500	1501 ~	
Support Length	mm (in)	L2		25 (0.98)	40 (1.57)	60 (2.36)	50 (1.96)	70 (2.76)	100 (3.94)	50 (1.96)	70 (2.76)	100 (3.94)	50 (1.96)	70 (2.76)	100 (3.94)	50 (1.96)	70 (2.76)	100 (3.94)	
Linear Shaft Motor		S427D		S427T		S427Q		S435D		S435T		S435Q		S500D		S500T		S500Q	
Stroke	mm	S		~ 550		~ 1000		1001 ~		~ 750		751 ~							
Support Length	mm (in)	L2		60 (2.36)		80 (3.15)		100 (3.94)		80 (3.15)		100 (3.94)							

Recommended Wiring



SMART

(Linear Shaft Motor Application Resource Tool)

Nippon Pulse America has made available the Linear Shaft Motor Application Resource Tool (SMART). It required Microsoft Excel 98 or newer and the use of macros. To request your copy fill free to contact your local NPA Representative.



Data Entry screen



Results Example

Useful Formulas

Amplifier Sizing

- Voltage due to Back EMF $V_{BEMF} = \text{Back EMF} * \text{Velocity}$
- Voltage due to R * I $V_{ri} = 1.225 * \text{Resistance} * \text{Peak Current}$
- Voltage due to Inductance $V_L = \frac{7.695 * \text{Velocity} * \text{Inductance} * \text{Peak Current}}{\text{Magnetic Pitch}}$
- Min. Bus Voltage needed $V_{bus} = 1.15 \sqrt{[(V_{bemf} + V_{ri})^2 + V_L^2]}$
- Peak Current (rms value) $I_{prms} = \text{Peak Current} * 1.2$
- Continuous Current (rms value) $I_{Crms} = \text{Continuous Current} * 1.2$

These formulas add a 20% safety margin for current and a 15% safety margin for voltage.

Encoder Formulas

- Enc. Resolution $E_r = \frac{\text{Scale Pitch}}{(4 * \text{Interpolation})}$
- Enc. Output Freq. (A-B Phase) $E_{OF} = \frac{\text{Velocity} * 10^6}{(4 * \text{Encoder Resolution})}$
- Enc. Output Freq. (Sine-Cosine) $E_{OF} = \frac{\text{Velocity} * 10^6}{(\text{Scale Pitch})}$

Conversions

Units to Convert		Multiply by	Units to Convert		Multiply by
Force			Weight		
Newton	*Pound Force	0.2248	Kilogram	*Pound	2.2046
Newton	*Gram Force	101.97	Kilogram	*Gram	1000
Newton	*Ounce Force	3.5969	Kilogram	*Ounce	35.274
Pound Force	*Newton	4.4482	Pound	*Kilogram	0.4536
Gram Force	*Newton	0.0098	Gram	*Kilogram	0.0010
Ounce Force	*Newton	0.2780	Ounce	*Kilogram	0.0283
Length			Velocity		
mm	*Inch	0.0394	mm/sec	*In/sec	0.0394
mm	*Feet	0.0033	m/sec	*In/sec	39.370
mm	*cm	0.1	in/sec	*mm/sec	25.4
Micron	*Inch	0.00003937	in/sec	*m/sec	0.0254
Nanometer	*Inch	0.0000003937	mm/sec	*m/sec	0.001
Meter	*Feet	3.2808	m/sec	*mm/sec	1000
Inch	*mm	25.4	Acceleration		
Feet	*mm	304.8	G	*m/sec ²	9.8067
cm	*mm	10	G	*mm/sec ²	9806.7
Feet	*Meter	0.3048	G	*in/sec ²	386.09
Inch	*Micron	25400	G	*Foot/sec ²	32.144
Inch	*Nanometer	25400000	m/sec ²	*G	0.1020
Temperature			mm/sec ²	*G	0.0001
°C	*°F	*1.8 then + 32	in/sec ²	*G	0.0026
°F	*°C	-32 then / 1.8	Foot/sec ²	*G	0.0311

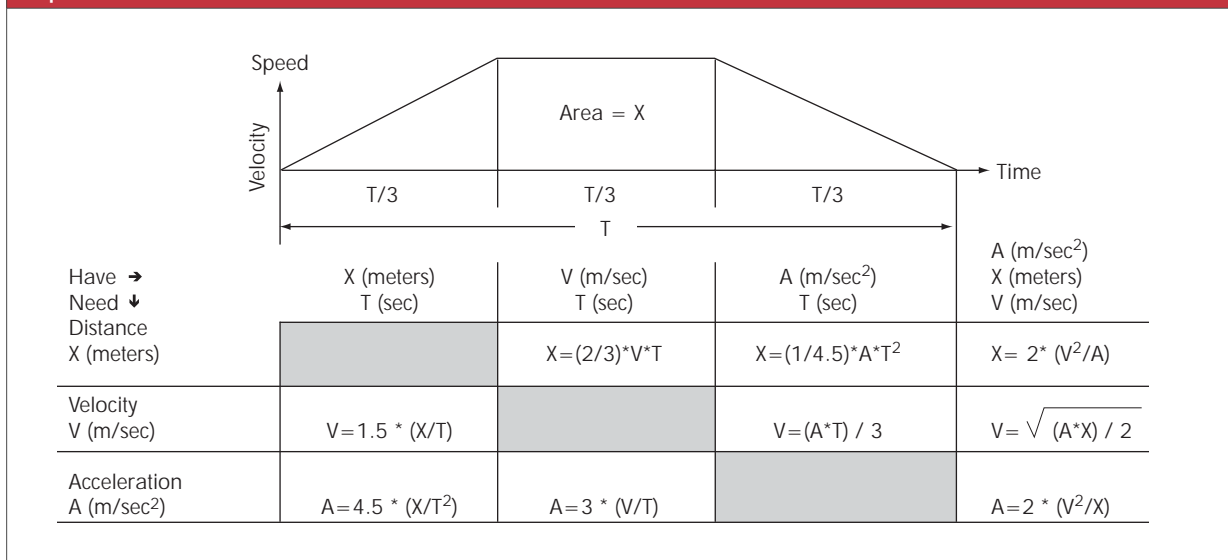
Useful Formulas

$V=I \cdot R$ $I=V/R$ $R=V/I$

Voltage and Current RMS vs. Peak

			Voltage	Resistance	Current
RMS = Peak * 0.707	Example:	RMS Values	5	25	0.2
Peak = RMS * 1.414		Peak Values	3.535	25	0.1414

Trapezoidal Profile



Acceleration g $ACCG = A \text{ (m/sec}^2\text{)} / 9.81$

Gravity $G = 9.81$

Fc = Friction Coefficient Friction Coefficient can be calculated in the following way. The mass of the load to be moved being M1, and the amount of force required to move the mass being M2.
Friction Coefficient = $M2/M1$

Vertical movement

If moving up Dir = 1 Acceleration = $G \cdot (ACCG + Fc + Dir)$

If moving Down Dir = -1 Continues = $G \cdot Fc + G$

Pause = G

Horizontal movement

Acceleration = $G \cdot (Accg + Fc)$

Continues = $G \cdot Fc$

Pause = 0

Acceleration Force = $Acceleration^2 \cdot Acceleration \text{ Time}$

Continues Force = $Continues^2 \cdot Continues \text{ Time}$

Average Force = $\sqrt{\text{Total force} / \text{Total time}}$

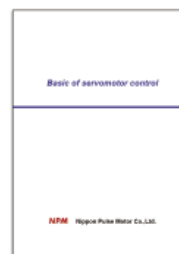
Current = $\text{Average Force} \cdot (\text{mass} + \text{motor mass}) / \text{Force Constant}$

Force = $\text{Current} \cdot \text{Force Constant}$

For Peak current and Force use largest Acceleration Value in place of Average Force.

For more information...

feel free to download the Linear Shaft Motor "Installation and User's Guide" from our website, www.NipponPulse.com



Linear Shaft Motor Selection Guide

This information is provided to assist in your selection of a Linear Shaft Motor. If you have concerns about the temperature rise for your application please make use of the Linear Shaft Motor Application Resource Tool (SMART).

Feel free to contact your local Nippon Pulse America Representative for a copy. Please note that actual temperature rise may vary depending on your cooling method. Always confirm temperature rise in an actual system. In case you have selected a preloaded guide for higher precision, please consult the technical documentation from the guide manufacture to correctly account for the extra friction this guide will introduce.

Please use the following chart to assist in organizing the operation conditions for your system.

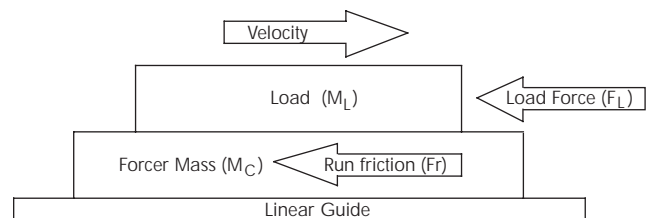
Operation Condition

Item	Symbol	Value	Unit	Notes
Stroke	Sl		mm	
Maximum Load Mass	M_L		Kg	
Load Force	F_L		N	Keep in mind other external forces that disturb the movement. (Example Cable Chain, Preloaded Guide)
Maximum Speed	V_m		m/s	
To the right is a typical velocity and load pattern. Please confirm the following two things: 1. What is the fastest acceleration needed? 2. What is the maximum required thrust?				
Velocity	v		m/s	
Acceleration Time	t_1		s	
Continuous Time	t_2		s	
Deceleration Time	t_3		s	
Settling Time	t_4		s	
Waiting Time	t_5		s	

Selection Flow

1. Calculations for Load Condition

The chart shown here helps to calculate a load force. The frictional load of the linear guide and the resistance force of the cable carrier (FC) are run friction and treated as load force. For your initial calculations, it is suggested that you use 1/10 the load mass, as the value for Forcer mass (MC).



2. Calculations for Required Thrust - You will need to calculate a thrust value for each section of the motion profile. In these equations, "μ" is the coefficient of friction on the guide. "g" is the acceleration of gravity. $g = 9.81 \text{ m/sec}^2$

F1	acceleration thrust	$F1 = Fa + FL + Fr$	accel force + external force
F2	continuous thrust	$F2 = FL + Fr$	load of external force
F3	deceleration thrust	$F3 = Fd + FL + Fr$	decel force + external force
Fa	acceleration force	$Fa = (ML + MC) * V / t1$	
Fd	deceleration force	$Fd = -(ML + MC) * V / t3$	
Fr	run friction	$Fr = \mu \{ (ML + MC) * g + FC \}$	

3. Temporary Selection - The largest thrust value calculated in section 2, must be less than peak thrust of the selected Linear Shaft Motor. It is good practice to add 20 to 50% to the peak thrust as a safety margin. Please note that the peak thrust of the Linear Shaft Motor may vary with operation speed.

4. Confirm that MC (forcer mass) is smaller than the value used in section 1. If it is larger, please return to section 1 to recalculate using the new MC value.

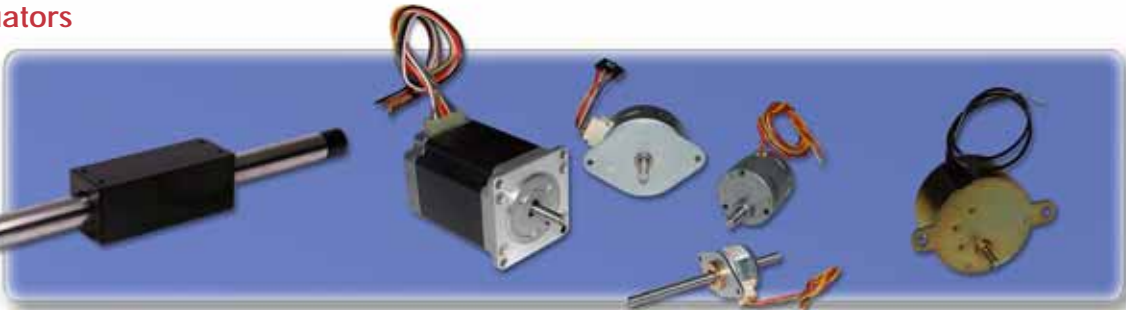
5. Confirm Effective thrust (Feff) - Please confirm that effective force (Feff) is less than the continuous rated force (Frated) of the motor plus a safety factor (SF) of 30% to 50%.

$$F_{\text{eff}} = \sqrt{\frac{(f1^2 * t1) + (F2^2 * t2) + (F3^2 * t3)}{(t1 + t2 + t3 + t4 + t5)}} < SF_{\text{rated}} + SF$$

6. If the effective force (Feff) is larger, please select new motor whose the rated force (Frated) is met in the equation.

Nippon Pulse Product Overview

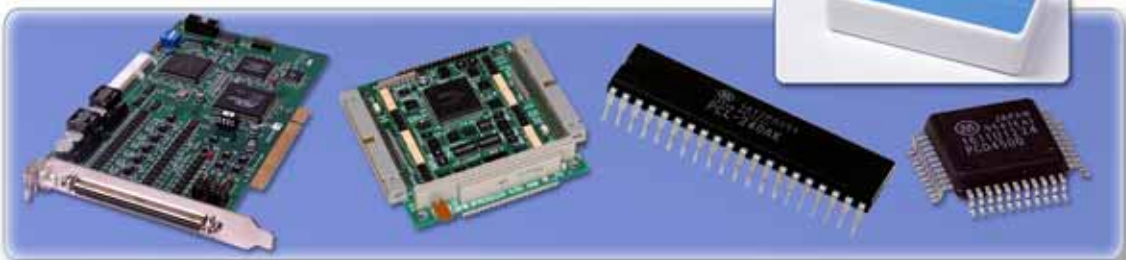
Actuators



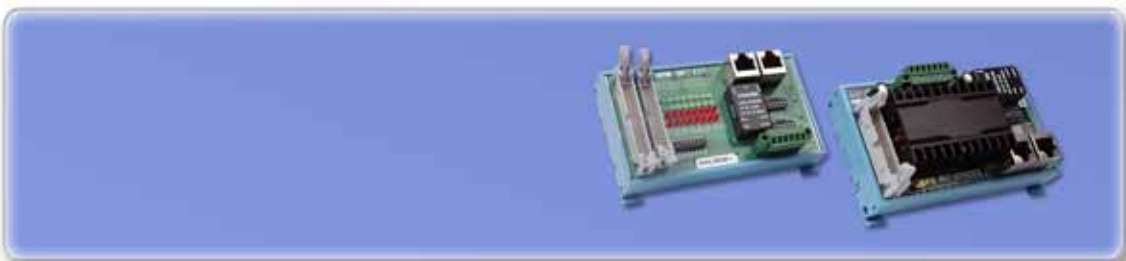
Driver



Controller



Network



NPM

Nippon Pulse America, Inc.

A subsidiary of Nippon Pulse Motor Co., Ltd.

Radford Virginia 24141 USA

Tel: 1-540-633-1677 • Fax: 1-540-633-1674

Web: www.nipponpulse.com • Email: info@nipponpulse.com