INSTALLATION AND USER'S GUIDE

THE NEXT-GENERATION ULTRA-PRECISION BRUSHLESS LINEAR MOTOR

● SIMPLE ● HIGH-PRECISION ● NON-CONTACT

LINEAR SHAFT MOTOR

NPM Nippon Pulse America, Inc.
a subsidiary of Nippon Pulse Motor Co., Ltd.

Linear Shaft Motor
Installation and Users Guide
October 2008
Revision C
Item Number 24135

DISCLAIMER
Nippon Pulse America (NPA) makes no guarantees of any kind with regard to this manual. NPA shall not be liable for errors contained herein or for consequential or incidental damages incurred because of acting on information contained in the manual.

CUSTOMER CARE
For inquiries relating to the operation and use of the Linear Shaft Motor described in this manual please, contact your local NPA representative.

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Important:

This instruction manual is not intended to include a comprehensive listing of all details for all procedures required for installation, operation, and maintenance. This manual describes general guidelines that apply to most of the linear motor products shipped by NPA. If you have any questions about a procedure or are uncertain about any detail, do not proceed. Please contact your local NPA representative for more information or clarification.

Warranty

NPA guarantees its products are free from faulty components and defects in material or workmanship for one (1) year from the date of delivery. NPA shall not be liable for any special, incidental, indirect, or consequential damages. Additional information regarding NPA's warranties can be found in our Terms and Conditions of Sale, which are available upon request. All requests for repair and replacement should be directed to NPA's Inside Sales Department. The serial number of the equipment should be quoted in any communications. NPA reserves the right to alter specifications and pricing at any time.

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GENERAL INFORMATION

This instruction manual contains general procedures that apply to NPA Linear Shaft Motor products. Be sure to read and understand the Safety Notice statements in this manual. For your protection, do not install, operate, or attempt to perform maintenance procedures until you understand the Warning and Caution statements.

A Warning statement indicates a condition that can cause harm to personnel. A Caution statement indicates a condition that can cause damage to equipment.

Warnings

Heart Pacemakers. Linear Shaft Motors contain powerful permanent magnets. Anyone with a pacemaker or A.I.C.D. should maintain a minimum distance of 12 inches from the magnets.

Strong magnets. The magnetic attraction between the magnet shaft and other magnetic or ferrous materials is extremely high. Keep fingers and other body parts away from these objects to avoid injury by this magnetic attraction.

Electric shock. Do not touch electrical connections until you ensure that power has been disconnected. Electrical shock can cause serious or fatal injury.

Hot surface. Surface temperatures of up to 80°C (144°F) can be present during the commissioning and servicing of this equipment. Allow the forcer and shaft to cool before working on the equipment.

Heavy object. Use proper care and safety procedures during handling, lifting, installing, operating, and maintaining operations. Improper methods may cause muscle strain or other harm.

Crush hazard. The forcer may move unexpectedly. Always isolate all sources of electrical supply before working on the equipment.

General hazard. Follow the advice given.

WARNING: **Be sure the system is properly grounded before applying power. DO NOT apply AC power before you ensure that all grounding instructions have been followed. Electrical shock can cause serious or fatal injury. National Electrical Code and local codes must be carefully followed.**

CAUTION: **Be careful when sliding the motor from its shipping container. Slide the motor from the box onto a level, flat surface to prevent bending. Bending can damage the forcer and shaft.**

Receiving

Each Linear Shaft Motor is thoroughly tested at the factory and carefully packaged for shipment. When you receive your motor, there are several things you should do immediately.

1. Observe the condition of the shipping container and report any damage immediately to the commercial carrier that delivered your motor.
2. Verify that the part number of the motor you received is the same as the part number listed on your purchase order.

Storage

If the parts are not put into service immediately, store them in a clean, dry, and warm location. If the storage location is damp or humid, the exposed metal surface of the motors and windings must be protected from moisture. If the ambient temperature decreases suddenly, condensation may form. Protect all parts from moisture.

Unpacking

Each Linear Shaft Motor is packaged for ease of handling and to prevent entry of contaminants. To avoid condensation, do not unpack until the motor has reached room temperature of the room in which it will be installed. The packing provides insulation from temperature changes during transportation. When the motor has reached room temperature, remove all protective wrapping material from the forcer. It is recommended that the protective wrapping material be left on the shaft during installation. Unpack the magnet shaft and place it on a clean non-magnetic surface away from other magnet devices and any other ferrous material.

Always keep the magnet shaft at a safe distance from magnetic or ferrous material. If the magnet shaft is to be left unattended for any period of time, precautions should be taken to prevent accidents due to the strength of the magnets (it is best to leave them in their packing material to prevent injury due to magnetic attraction). Anyone who will come in contact with this assembly while receiving, transporting, storing, installing, disassembling, or at any other time, must be made aware of this danger.

Handling

Be extremely careful. Keep in mind:

The magnetic attraction between the magnet shaft and other magnetic or ferrous materials is extremely high. Keep fingers and other body parts away from these objects to avoid injury.

Use proper care and procedures that are safe during handling, lifting, installing, operating, and maintaining operations. Improper methods may cause muscle strain or other harm.

Repairs

NPA will not share any responsibility for damage caused by customer attempt to repair or modify a motor. Any repairs or modifications attempted by the customer without first consulting NPA will void any warranties, both implied and stated. Consult NPA before performing any service or modification to the motor(s).

OVERVIEW

Nippon Pulse America's (NPA) family of Linear Shaft Motors are the next generation linear brushless motor. When reliability, zero maintenance, zero cogging, and precision are paramount, the Linear Shaft Motors from NPA are an ideal component choice, offering the user uncompromised performance, ease of use, compact package size, and high value.

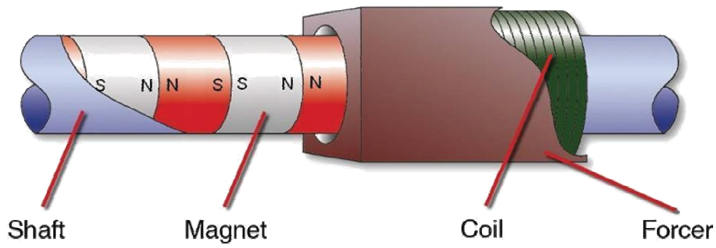


Figure 1

What is a Linear Shaft Motor?

The Linear Shaft Motor is simply a high precision direct drive linear servomotor that consists of a shaft of Rare Earth-Iron-Boron-Permanent (NIB) Magnets and a "forcer" of cylindrically wound coils which can be supplied with optional Hall Effect devices. The shaft supplies the magnetic field which the forcer acts upon. The forcer assembly, combined with the amplifier and control electronics, produces the force for the motor. The Hall Effect devices can be supplied, if they are required by your selected servo driver for proper commutation of a brushless linear motor and are integrated into the forcer assembly.

Shaft Construction

The magnetic structure of the Shaft is built in such a manner that there is no space between each magnet and is fully supported within itself. The magnetic structure is then inserted into a protective stainless steel tube. This is shown in **Figure 1**. This is a patented process which is protected by numerous patents throughout the world. Thus the patented process used by the Linear Shaft Motor produces a very strong magnetic field which is twice that of other linear motors. An actual measured magnetic field is shown in **Figure 2.**

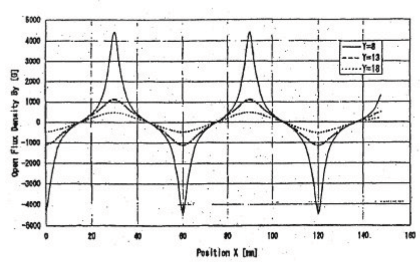


Figure 2

Forcer Construction

The coils of the Linear Shaft Motor are of a cylindrical design, thus providing a number of key advantages over other linear motors.

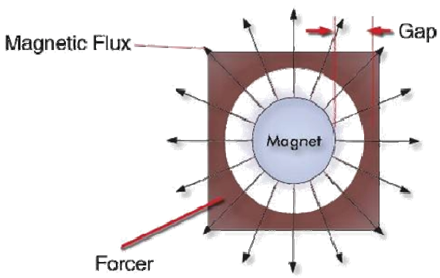


Figure 3

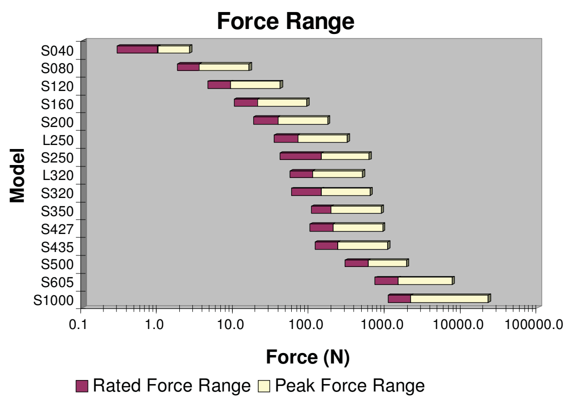
- The cylindrical design of the coils makes the coil assembly very stiff without the use of external stiffening materials, such as the iron used by platen style linear motors.
- The coils surround the magnets allowing for the optimal use of all the magnetic flux. (**Figure 3)** This makes the air gap non-critical. As long as the forcer does not com in contact with the shaft there is no variation in the linear force.
- The magnetic flux cuts motor windings at right angles for max efficiency.
- All sides of the coil are positioned to allow for maximum dissipation of heat.

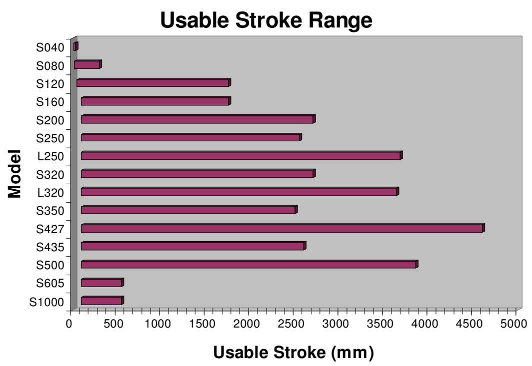
Thus the Linear Shaft Motors requires less current and less mass, to produce a similar force, and is more efficient than any other linear motor on the market.

The Linear Shaft Motor products described herein are protected by a number of granted, maintained patents worldwide.

Advantages of Linear Shaft Motors

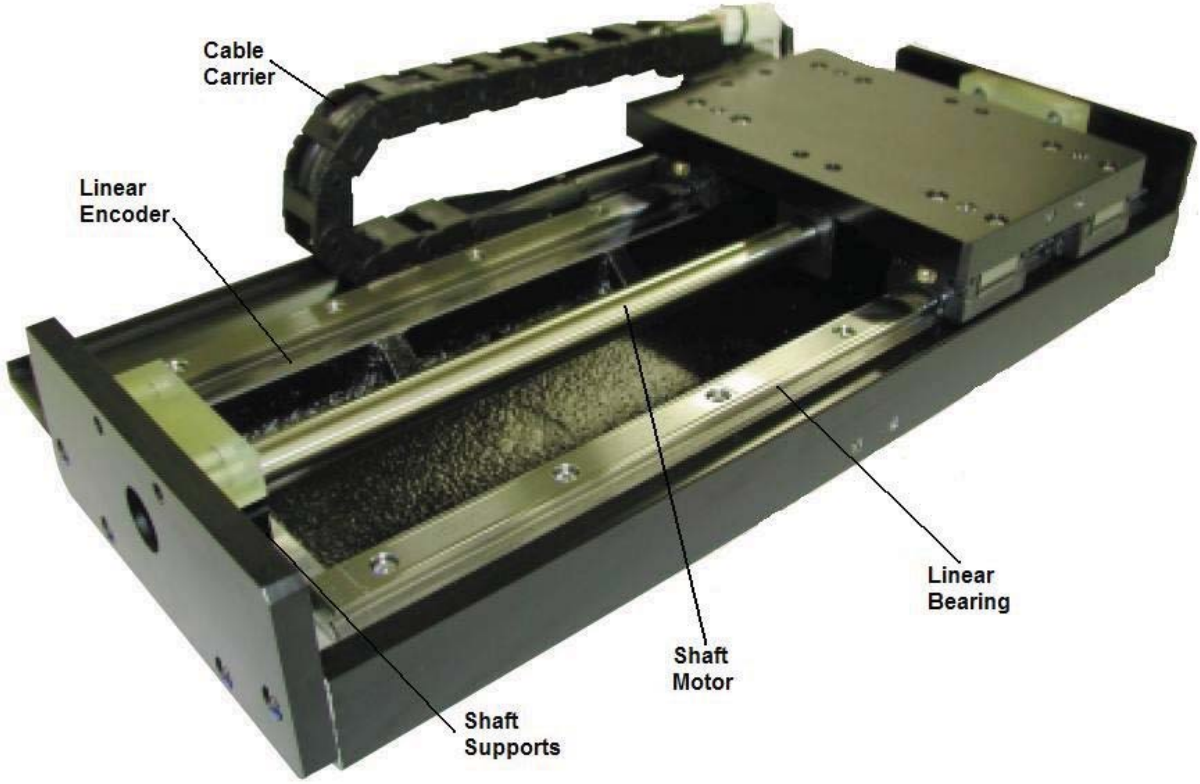
- **Very simple construction.** The Linear Shaft Motor itself consists of only two parts: the shaft (with magnets) and the forcer (to which the load is attached). There is an air gap, and no physical contact, between the shaft and the forcer.
- **Direct drive.** Unlike lead screws with gearheads, the Linear Shaft Motor offers high thrust (up to 20000 Newtons 4500 pounds) without any gearheads, or backlash.
- **Precision linear position control.** Linear movement resolution as small as 0.07 nanometers is achievable.
- **Precise speed control.** High speeds (up to 6.5 meters/second) and low speeds (down to 8 micrometers per second) are achievable with virtually no speed fluctuations (+/- 0.006% at 100 micrometers/second).
- **Durable construction.** Capable of operating in a clean room environment, in a vacuum, or under water.
- **Quiet Operation.** The absence of friction makes the system extremely quiet. The only mechanical contact section is the linear guide.
- **Compact and lightweight.** Lightweight 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 0.5 mm to 2.5 mm nominal annular air gap allows for easy installation and alignment.
- **Wide capability.** Thrust forces less than 0.5 Newtons and peak thrust forces up to 20000 Newtons are available. Usable strokes from 20 mm up to 4.6 meters can be chosen from a number of available models.





- **Simple drive.** The Linear Shaft Motors have built-in flexibility to cater to most servo amplifiers. They can be driven by traditional three phase brushless DC servo (also called AC servo) drives. Several units can be networked to achieve a cluster of Linear Shaft Motors that can be synchronized with a network controller or a PC.
- **Power Efficiency.** The Linear Shaft Motors extremely strong magnetic flux, cylindrical design and small moving mass provide for a very efficient linear motion. >50% more efficient then non-direct drive systems (Belt drive, ball/lead screw, etc.) and >30% more efficient then other direct drive systems (Linear motor etc.)

The Linear Shaft Motor System



The following components go into making a Linear Shaft Motor system:

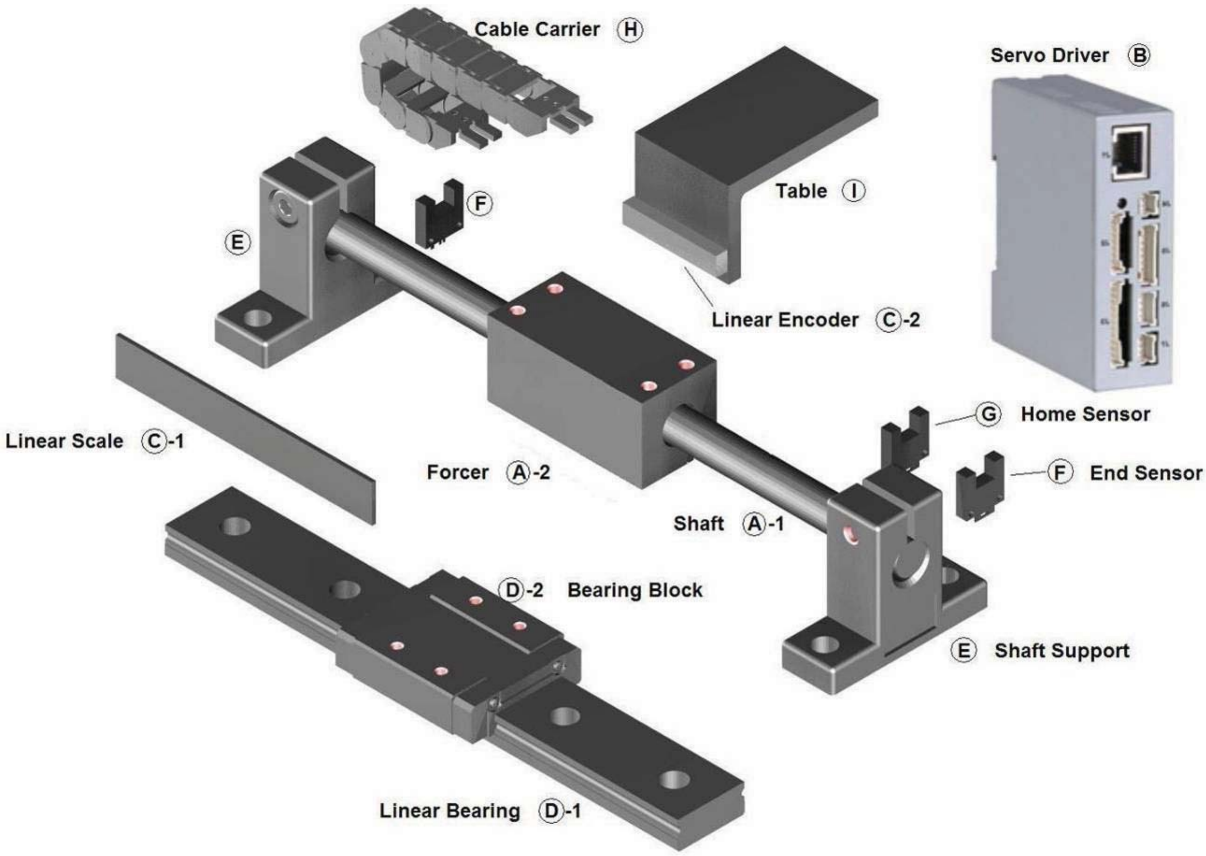
- ***The Linear Shaft Motor itself.*** There are eleven models available. The correct model needs to be chosen for the application, depending on the stroke length and thrust required.
- ***Shaft supports.*** Two supports, one at each end, are required. In most applications the shaft is stationary while the forcer moves and is attached to the load.
- ***Linear guide or linear rail.*** These are used to guide the forcer as it moves linearly. This is the only contacting part. For totally no-contact applications, air bearings can be used.
- ***Linear Encoder.*** This is placed along the linear guide, or rail, and provides precise linear position feedback to the servo system.
- ***Servo driver.*** This is a standard three phase brushless DC (sometimes referred to as AC servo) driver.
- ***Motion controller.*** This can be a PC or a dedicated programmable single (or multiple axes) motion controller. This is sometimes integrated into the Servo Driver
- ***Cable Carrier.*** Cable tracks will help guide and prevent damage to the motor cable, encoder cable, and any ancillary cables or hoses attached to the forcer.

The next section "Design Considerations" will help in making the right choice regarding the components required to put together a system.

Notes:

DESIGN CONSIDERATIONS

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

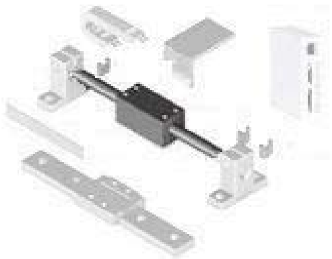


To configure a system using the Linear Shaft Motor, the following peripheral devices are required:

A. Linear Shaft Motor
B. Servo Driver

Items C, D, and E are necessary parts of a system, but much consideration must be given to your application, demand specifications, environmental conditions, and which will be moving — the forcer or the shaft. The other items, F through I, are optional and will need to be selected depending on your application.

Linear Shaft Motor



With the Linear Shaft Motor there are two ways to achieve linear motion. The shaft can be held stationary while the forcer moves or the forcer can be held stationary while the shaft moves. There is no restriction on the angle or orientation at which the system can be mounted. This provides the user with a high degree of flexibility.

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 this is not possible, then two Linear Shaft Motors can be used and should be spaced evenly from the working point.

In the majority of applications, the shaft will be fixed and the forcer will be the moving element. In this case, the forcer has been designed for the payload to be mounted via the supplied mounting holes. It is recommended that you use an adapter plate if the holes must be customized for mounting bearings, the encoder system and other specific mounting needs. The forcer comes with standard surface mounting holes that can be used to attach it to the load. Refer to the Data Sheet for your Linear Shaft Motor in the detailed information on the mounting dimensions for your Linear Shaft Motor.

If the application requires a moving shaft, then the surface to which the stationary forcer is mounted should have a minimum flatness of 0.01mm, and parallelism of 0.03mm. In this case the payload would need to be fixed to the shaft support system.

In either case, here are some principles to help you maximize motor efficiency and minimize any damage to your Linear Shaft Motor.

Shaft

The magnetic field emanating from the shaft is very strong; always use extreme caution when handling.

Since the shaft contains strong magnets, its proximity to ferrous parts, or parts sensitive to magnetic fields, should be carefully considered.

The shaft must be mounted so that it maintains concentricity with the central bore of the forcer. When the forcer and shaft are aligned correctly there is a nominal radial air gap of between 0.5 to 2.5mm depending on the series of Linear Shaft Motor you are using; where practical this should be maintained along the whole length of travel. This ‘large’ air gap is non critical, but the forcer should not rub on the shaft. If this occurs there is a large increase of friction.

NOTE: The shaft is not a load-bearing member.
Do not us it as a bearing surface.

There are no mounting holes provided in the shaft, nor is it advisable for the customer to drill any. The shaft must therefore be clamped in position. As the forcer encircles the shaft and travels along its length, it is only possible to clamp the shaft at its ends. In order to propel the forcer only, the shaft must be prevented from moving longitudinally. (For applications where the shaft is to move, the forcer must be prevented from moving). The shaft contains magnetic components whose performance can be impaired if subjected to temperatures above 160℃. Therefore, avoid mounting the shaft close to any direct heat source. Consideration should also be given to the continuous operating current at the applicable ambient temperature.

To operators unfamiliar with cylindrical linear motors, the shaft appears as a solid metal bar and is often used as a handle. This may cause damage to the system, and should be avoided. Furthermore, operators are often caught unaware by the magnetic nature of these parts. Use warning labels to clearly identify the potential hazard, and when possible use a suitable physical guard or cover.

The north end of the shaft is marked with a yellow dot. It is most critical when designing systems with parallel Linear Shaft Motors driven with one servo driver that the north ends of both shafts are in the same direction.

Forcer

For applications where the duty cycle is high, ensure that a good flow of air over the forcer and shaft is available.

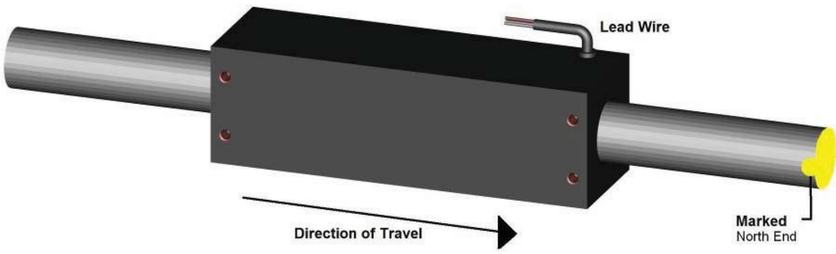
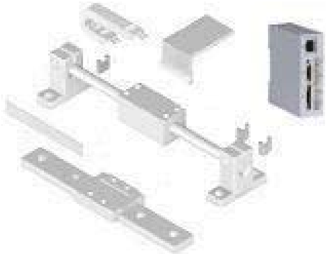


Figure 4

The end of the Linear Shaft Motor forcer with the lead wire coming out should be toward the North end of the shaft marked with a yellow dot. (**Figure 4**) This is most critical when designing systems with tandem and parallel Linear Shaft Motors driven with one servo driver. The linear encoder should also be installed to count up in this direction of travel. If it does not, the A and B encoder signals should be exchanged.

Note that the forcer is electrically earth grounded through the forcer case, for CE type forcers the earth ground is also available through the motor cable.

Servo Driver



Any three phase brushless DC servomotor driver can be used to drive the Linear Shaft Motor[1]. In order to control the position of the Linear Shaft Motor, it is necessary to employ a servo controller and amplifier combination. There are many different makes and models of amplifiers available, but they tend to fall into one of three possible categories:

1. Intelligent amplifiers that have built in servo controllers
2. Velocity amplifiers capable of controlling only the velocity of the motor
3. Current/Torque amplifiers that control only the force of a linear motor (torque in a rotary motor)

Commutation

Different servo amplifiers have different commutation arrangements. The Linear Shaft Motors have built-in flexibility to cater to most servo amplifiers. The two most common methods of Commutation are trapezoidal and sinusoidal. Commutation is usually started in one of three ways.

1. Digital Hall Effects are used where trapezoidal commutation is required, or where sinusoidal commutation is achieved through encoder feedback and the Hall Effects are used to read, on power-up, the location of the forcer in relation to the magnetic fields of the shaft.

If the servo amplifier you are using does not look at the hall signals on power up it most likely only uses sinusoidal commutation, it starts commutation in one of two ways.

2. The driver will apply power to move the servo motor a few counts before initiating commutation. Usually called a motionless start.
3. The other method will cause your motor to jump when power is applied to the system as the commutation sequence is typically initiated by energizing one of the motor phases.

Encoder

When sinusoidal encoder commutation is used, the electrical cycle of the motor is a required setting within the amplifier. The electrical cycle is normally defined in terms of encoder counts per pole pair (the distance between consecutive like poles).

Hall Effect

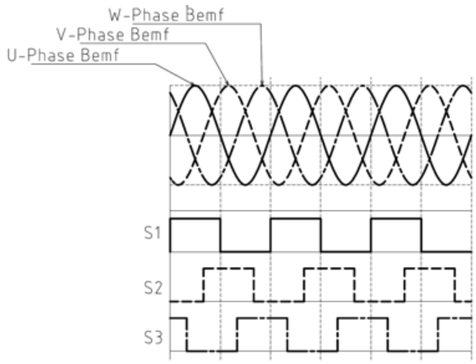
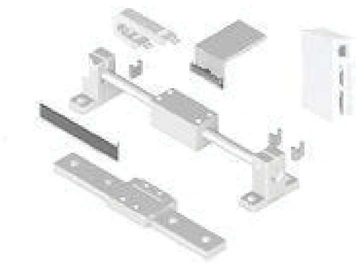


Figure 5

Effect sensors are devices that can sense position magnetically and provide this information to the driver. Hall sensors are quite small and can be, depending on the model of Shaft Motor, mounted outside or inside the forcer to sense the magnetic field of the shaft assembly. The sensors are operated only as switches, that are "ON" or "OFF" to sense the changing field direction as alternate north-south poles pass by when the forcer moves. The Hall sensors are mounted 120 electrical degrees apart. Each 60° segment has a unique set of Hall sensor outputs so that the forcer position can be resolved to any six segments over the 360 electrical degrees. (**Figure 5**) The Hall Effect sensors used in the Linear Shaft Motors employ an open collector output. 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 driver.

[1] For a list of Servo Drivers which have been tested to work with the Linear Shaft Motor see Appendix C.

Linear Encoder



One of the advantages of the Linear Shaft Motor is that there is no inherent backlash in the motor. It is therefore possible to produce systems that can be moved to the same position from either direction without errors due to mechanical backlash. It is always desirable to use encoder systems that do not suffer from backlash. (i.e. The use of rotary encoders with conversion systems is not advisable) Basically, any type of system that can produce a measurable signal based upon distance moved can be used. The actual choice is often dependant on a number of variables, such as repeatability required, operating environment, and signal type. The most commonly used linear encoders available consist of an encoded strip (attached to a surface parallel to the motor), and a sensor read head mounted to the moving part (motor). These are normally either optical, magnetic, or inductance based systems. For very high accuracy systems it is also possible to use a laser interferometer.

Resolution

The positioning resolution, repeatability, and smoothness of operation depend on the resolution of the encoder. The application usually determines the required resolution. In addition, the maximum response speed of the encoder may limit the maximum system speed. It is also imperative that you insure the controller is capable of counting the frequency of encoder pulses produced at your application's maximum speed. It is always important to ensure that the encoder type selected is compatible with the controller that you are intending to use. When sinusoidal encoder commutation is used, the electrical cycle of the motor is divided by the encoder resolution within the amplifier. For this reason, the smoothness of operation depend on the resolution of the encoder, it is recommended you use an encoder with a resolution that is at least equal to or finer than the north to south magnetic distance divided by 1000. See **Table 1**.

Error Signal

It is recommended that a magnetic or optical encoder, which has an Error Signal, be used when using a servo drive utilizing hall commutation. Using the encoder's error signal will allow the servo controller to detect when the system is missing pulses (drifting) or when the encoder signal is lost. Many servo drives using hall commutation may try to apply full power to the motor when the encoder signal is lost, which will cause a highly undesirable system condition. To prevent this, the servo drive should be disabled by the servo controller or commanded to stop in a controlled manner when the encoder signal is lost.

In general, encoder errors are normally due to either:

- Incorrect sensor read head alignment with the encoder scale
- Incorrect gap between sensor read head and the encoder scale
- Damaged or dirty encoder scale, particularly optical scales
- Damaged signal wires
- Noise on the encoder signals

Sinusoidal Commutation Course Encoder

Coil	N-S	Resolution
S040	9 mm	9 um
S080	15 mm	15 um
S120	24 mm	24 um
S160	30 mm	30 um
S200	36 mm	36 um
S250 L250	45 mm	45 um
S320 L320 S350	60mm	60 um
S427 S435 S500	90mm	90 um
S1000	135mm	135 um

Table 1

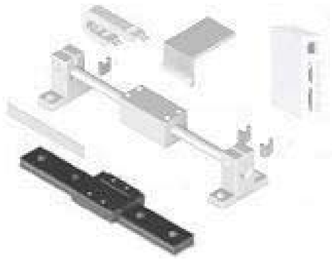
Magnetic Encoder

In the case of a magnetic linear encoder, take care that it is installed so that the magnetic shaft does not affect the encoder. Magnetic encoder strips can be affected by the high magnetic fields produced by the shaft. It is possible for the magnetic field of the shaft to interfere with the field of the strip, or affect the read head directly; it is therefore necessary to ensure that there is sufficient distance between the components to ensure that this does not occur. It is advisable that the two be separated by a distance equal to or greater than the north to north magnetic distance.

Mounting Location

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 bearings must be of sufficient stiffness to minimize dynamic deflections of the structure

Bearing System



NOTE: The shaft is not a load-bearing member.
Do not us it as a bearing surface.

Like a ball screw carriage, the forcer must be supported by a linear bearing system. The linear bearing system must be capable of supporting the load/heatsink and the forcer. Often, the linear bearing is the only moving contact type component in the system. Therefore, this component requires special attention. If the motor and feedback are far apart, the machine structure and bearings must be of sufficient stiffness to minimize dynamic deflections of the structure. Desirable bearing characteristics include high 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 **Table 2**.

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*					

Table 2

Shaft Support

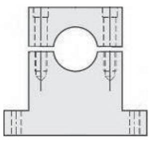
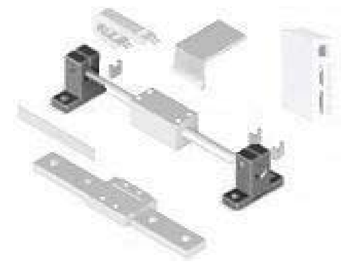


Figure 6



The shaft support along with the patented shaft design 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 the shaft support can be designed into the basic system structure of your machine, a typical shaft hanger such as the one shown in **Figure 6** can also be used. However, a few points to note are as follows:

1. It is recommended that the shaft be supported for the support length listed on the Linear Shaft Motor data sheet for your motor.
2. 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. If using two shaft supports at each end of the shaft, confirm that the shaft supports are spaced according to the specified support length as outlined in the data sheet. See **Figure 7**.
3. There should be the capability to adjust the position of the shaft to align it with the central bore of the force.

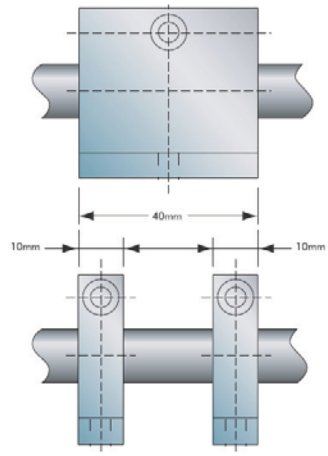


Figure 7

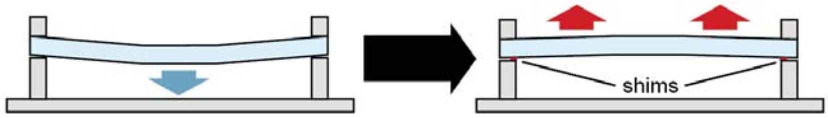
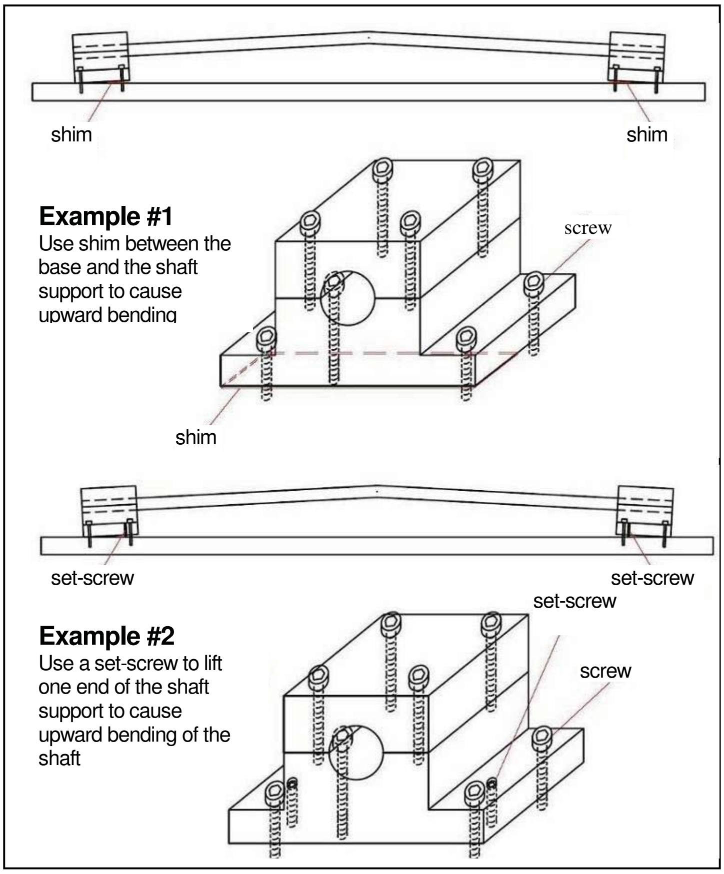
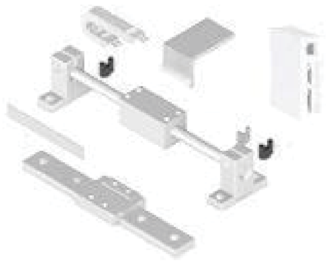


Figure 8

4. Due to the simply supported nature of the shaft, on longer systems the shaft will have a tendency to bow in the middle due to gravity. This can be overcome, to some extent, by inducing an upward bow into the shaft. **(Figure 8)** Two common methods of doing this include; using shims to angle the end clamps (**Example 1**) or providing screw adjustment to angle the end clamps. (**Example 2**) Verify that the shaft does not exceed the maximum bending as shown in the Data Sheet for your Linear Shaft Motor.



End Sensors



End Sensors also called Limit (end of travel) switches

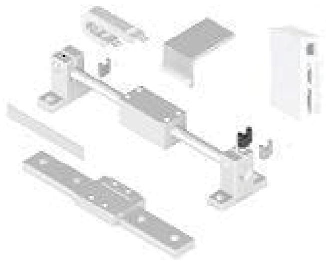
In the event that the system starts losing counts (if the encoder stops producing them correctly or the controller counts them incorrectly) the physical position of the motor will change for the same count values. The limit switches can be used to ensure that if the motor passes a defined maximum physical position it can be disabled or even stopped, thus minimizing damage potential.

This may be very useful when the system is initializing, during commissioning, and when unforeseen errors occur during normal operation. They can also be used as part of the homing sequence if required. There is normally one switch at either end of travel. Many quality linear encoders include limit switches.

When debugging a system, a common error (that may result in motor damage) is to leave the motor applying force against an end stop. If the limit signals are used to disable the amplifier, or to allow motion only in the direction away from the end stop, then this type of damage can be avoided. Limit switches are also helpful when the commanded positions are larger than the travel available.

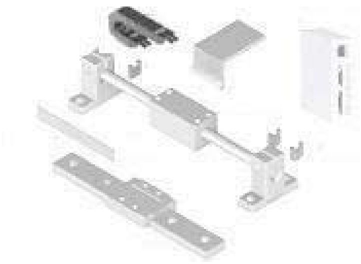
It also advised to incorporate end of travel safety bumpers in to your system to absorb and stop motion of the travel in case of over travel.

Home Sensor



If an incremental encoder is used it is not possible for the controller to know the absolute position of the motor when the system is initially powered up. In order to establish a known position, it is necessary to perform a search for a home or index mark; this is often referred to as the homing sequence. For linear encoders with only one index mark it is only necessary to search for the index mark from the encoder. However, many linear encoders have index marks at regular intervals along the length of travel. In this case it is advisable to use a home sensor for the homing sequence.

Cable Carrier



It is recommended that when the Linear Shaft Motor is used with a moving forcer, a cable carrier be used. The cable carrier will help guide and prevent damage to the motor cable, encoder cable, and any ancillary cables or hoses attached to the forcer.

The forcer provides some strain relief for the cable, but when the forcer is moving it should not be relied upon as the only means of cable strain relief. Cable carriers also provide a means to strain relieve the motor and encoder cables

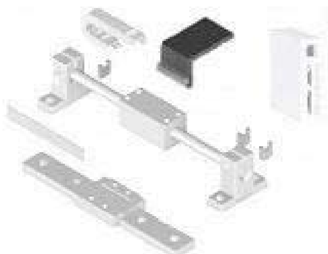
For short stroke systems it may not be necessary to use a cable carrier. In order to achieve the rated flex-life of the motor and encoder cables, special attention should be given to the cable suppliers' recommended cable bend radius.

The cable that exits the forcer is not a high-flex type; therefore it must terminate before entering the cable carrier.

It is strongly suggested that a high-flex cable be mounted with a connector to your Linear Shaft Motor before it enters the cable carrier. This allows maintainability of the high-flex cable without having to removing the forcer. To assist with this every Linear Shaft Motor is shipped with a connector which you can install. A good shield connection on all cabling is required for proper operation. Cables should be made in a twisted pair configuration, shielded, and grounded properly to the machine base, servo amplifier, and motor in order to reduce RFI

Note that the forcer is electrically earth grounded through the forcer case, for CE type forcers the earth ground is also available through the motor cable.

Other System Components



Each component in your system must have the highest stiffness to increase resonant frequencies higher than the required servo bandwidth. All moving parts should also be of the lowest possible mass, permitting higher accelerations and velocities, and reducing thermal losses. Hollowed and ribbed components or honeycomb structures, along with special materials, are often utilized to achieve this. Obtaining the highest 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.

Environmental Considerations

Temperature considerations are critical when using the Linear Shaft Motor. For this reason ventilation is extremely important. Be sure to allow clearance for ventilation and access for cleaning, repair, service, and inspections. Be sure the area for ventilation is not obstructed. Obstructions limit the free passage of air. The Linear Shaft Motors get warm and the heat must be dissipated to prevent damage. The amount of force produced by any linear motor is dependent on the coil temperature rise above ambient. The design of the Linear Shaft Motor allows for the maximum amount of heat dissipation of any linear motor. The thermal characteristics of the windings determine the operating force as a function of temperature. 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 is typically 135°C. The standard temperature difference between the coil and the forcer surface is as shown in **Table 3.**

Standard temperature difference between the coil and the forcer surface

Type	Standard temperature difference (°C)
S040D/T/Q	10
S080D/T/Q	10
S120D/T/Q	15
S160D/T/Q	15
S200D/T/Q	20
S250D/T/Q/X L250D/T/Q/X	20
S320D/T/Q/X L320D/T/Q/X	25
S427D/T/Q	30
S435D/T/Q	30
S500D/T/Q	40
S605D/T/Q	40
S1000D/T/Q	40

Table 3

Vertical Applications

If the Linear Shaft Motor is to be operated in a vertical orientation, it is recommended that a counter-balance be used. If the load is not counter-balanced, the Linear Shaft Motor must always work against gravity, even when it is not moving. This should be taken into consideration when sizing the Linear Shaft Motor. The counter-balance should be designed to balance the gravitational force acting on the system, which is the weight of the forcer and the payload. If a system is properly counter-balanced, even when no power is applied to the forcer, it should remain stationary. Typical counterbalance techniques include a pneumatic cylinder, springs, or a counterweight.

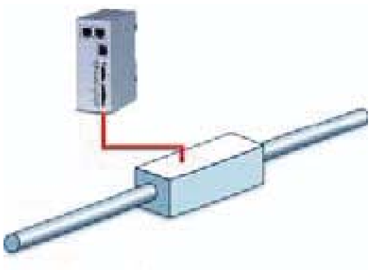
If a counter-balance mechanism is not possible a brake should be used to prevent the load from dropping in the event of a power interruption.

Clean Room

Stages prepared for Class 10, 100 and 10,000 clean room requirements can be built using standard Linear Shaft Motors. The customer must consider the bearing and other moving parts selected to confirm that they are materials suitable for the specified environment. It is recommended that air bearings be used in stages for clean rooms. Linear Shaft Motors can be provided as clean room prepped if requested. The customer must perform the final cleaning.

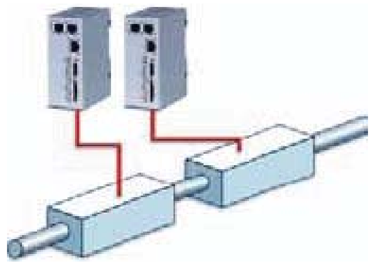
Multi-Axis Systems

The unique functionality of the Linear Shaft Motor allows for various multi-axis configurations. These range from a single axis with two or more motors on the same shaft and bearing system, to X-Y-Z gantry systems. These can be mixed and matched to achieve the desired load thrust and the complexity of the application. Typical systems can be configured in the following formats.



Single Drive System:

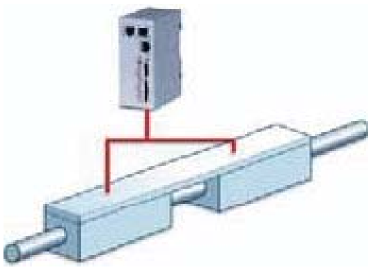
This is a basic drive system. The X and Y shafts can be used to create an X-Y stage.



Multi Forcer

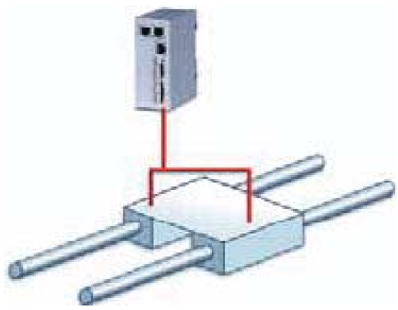
Multiple forcers on the same axis share the same bearing rail and shaft and can be synchronized, or act independently. This is a unique feature of linear motor systems and is impossible in a ball screw system. This capability allows for greater flexibility in automated assembly applications, or test machines and provides a very cost effective, and space efficient solution.

Tandem Drive System:



Multiple forcers on the same axis share the same bearing, rail, shaft, and servo driver can be used to multiply the force. Locate the Dual forcer information on the data sheet. Please note the forcer spacing and also note if the second forcer is to be flipped. If the second forcer is to be flipped, it will need to be installed on the shaft reversed from the first forcer. Lead wires from both forcers will be towards each other. The U and V leads from the second forcer will also need to be swapped.

This capability allows for greater flexibility in automated assembly applications, or test machines and provides a very cost effective method of increasing force.



Parallel Drive System:

Linear Shaft Motor's can be used in parallel (two or more sliders and two shafts connected to the same load), to achieve large thrusts for moving heavy objects. This is a unique feature of the Linear Shaft Motor and due to its non-critical air gap it is very simple to implement. The Parallel Linear Shaft Motors will be perfectly synced (within 1.2 counts of encoder resolution) when using one servo driver and one encoder. This allows the best method for providing force evenly across the load.

Notes:

INSTALLATION



UNPACKING

- Check packaging for signs of damage.
- Metal surfaces may be hot or below 0°C following prolonged storage.
- Remove packaging. Do not discard. In the event that items need to be returned to NPA, it is recommended that the original packaging be used.
- Ensure that the delivery note correctly reflects your order and the items delivered.
- Check equipment for signs of damage. Never use the equipment if it appears damaged in any way.
- Read and understand this Installation Guide before installing and using this equipment.

PRECAUTIONS

- Since the shaft has a strong magnetic force (5000 ~ 7000G), it is recommended that you use non-magnetic material for the system structure when possible.
- If magnetic material is required, please arrange it at such a distance that it will not be affected by the magnetic attraction of the shaft.
- The magnetic force will cause bending in longer shafts. Thus, take special care when the shaft is longer then 500mm.
- The Linear Shaft Motor assembly has no directivity, but the forcer coil does have an operating directivity when related to the shaft. The lead wires should be carefully arranged with this aspect in mind to keep the leads from being tangled.
- Although contact between the shaft and forcer does not cause any problems in operation, their contact does cause added intermittent friction, thereby making the setup and adjustment of the system troublesome. Physical contact between the shaft and the forcer should be avoided.
- During continuous operation, the forcer will heat up. Heat radiation and insulation should be considered. Proper ventilation needs to be provided to remove the heat generated in the forcer.

Please locate the Data Sheet for your Linear Shaft Motor before continuing.

Installation should conform to the National Electrical Code as well as local codes and practices. When other devices are coupled to the motor, be sure to install protective devices to prevent accidents. Machinery that is accessible to personnel should provide protection in the form of guardrails, screening, warning signs etc.

Mechanical Basic

The installation of your Linear Shaft Motor is very simple. Installation should be possible after reviewing these few key points.

Shaft

When using hand tools around the shaft keep in mind, the magnetic field emanating from the shaft is very strong; always use extreme caution.

Since the shaft contains strong magnets, its proximity to ferrous parts, or parts sensitive to magnetic fields, should be carefully considered.

Alignment

It is a good practice for the shaft to be mounted so that it maintains concentricity with the central bore of the forcer. When the forcer and shaft are aligned correctly there is a nominal radial air gap of between 0.5 to 2.5mm depending on the series of Linear Shaft Motor you are using; where practical this should be maintained along the whole length of travel. On longer strokes the shaft will not stay concentric along the whole length of travel, but as long as the shaft does not touch the central bore of the forcer the system will run correctly.

This 'large' air gap is non critical, but the forcer should not rub on the shaft. While contact between the shaft and forcer does not cause any problems in operation, their contact causes added intermittent friction, thereby making the setup and adjustment of the system troublesome.

Due to the simply supported nature of the shaft, on longer systems the shaft will have a tendency to bow in the middle due to gravity. This can be overcome, to some extent, by inducing an upward bow into the shaft. **(Figure 9)** Two common methods of doing this include; using shims to angle the end clamps or providing screw adjustment to angle the end clamps. Verify that the shaft does not exceed the maximum bending as shown in the Data Sheets for your Linear Shaft Motor.

NOTE: The shaft is not a load-bearing member.
Do not us it as a bearing surface.

The shaft is not intended to withstand side loading. It is advised that an external linear bearing always be used.

Forcer

It is good a practice for the forcer to be electrically earth grounded through the forcer case, for CE type forcers the earth ground is also available through the motor cable.

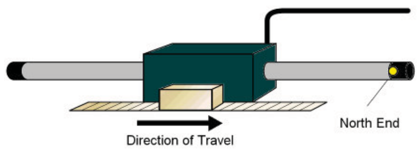


Figure 9

The end of the Linear Shaft Motor forcer with the lead wire coming out should be toward the North end of the shaft marked with a yellow dot. (**Figure 10)** This is most critical when designing systems with tandem and parallel Linear Shaft Motors driven with one servo driver. The linear encoder should also be installed to count up in this direction of travel. If it does not, the A and B encoder signals should be exchanged.

When using Two shafts in parallel confirm that both shafts are installed the same direction and that they are parallel to each other.

If you need more explanation the procedures outlined in the "Advanced" section can serve as a general guideline to your Linear Shaft Motor installation and alignment.

Figure 10

Mechanical Advanced

The procedures outlined in the advanced section can serve as a general guideline to your Linear Shaft Motor installation and alignment. This is not, and was not intended to be, a step by step installation guide since your system components will be very dependent on your design and may be very different from what is described here; however our hope is that these guidelines should be helpful. The guidelines assume that the system has been mounted in a horizontal plane. Systems that have been mounted vertically, sideways, or upside down, will require a slightly modified procedure.

Note: Before carrying out these procedures, ensure that there are non-ferrous (cardboard, wood, aluminum, etc.) packing pieces available to insert between the shaft and bearing rail. These packing pieces must be non-ferrous due to the magnetic nature of the shaft. The use of these packing pieces is essential, as the shaft is attracted to the bearing rail; the force with which they will 'snap' together is great. This situation may cause personal injury, and is likely to cause irreparable damage to the shaft or other structures.

Shaft Support

It is recommended that one shaft support, the width of the recommended support length on the Linear Shaft Motor data, sheet be used. If using two shaft supports at each end of the shaft, confirm that the shaft supports are spaced according to the specified support length as outlined in the data sheet**. (Figure 11).**

The shaft support system should allow for the ability, so the shaft may be aligned with the central bore of the forcer.

Due to the simply supported nature of the shaft, on longer systems the shaft will have a tendency to bow in the middle due to gravity. The shaft support system should allow for the ability to adjust for this. Some of the common methods of doing this include using shims or providing screw adjustment to angle the end clamps. This is discussed in more detail in the "Shaft Alignment" section.

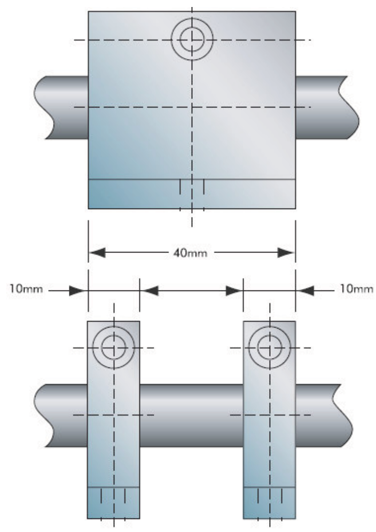


Figure 11

Shaft / Forcer Installation

The end of the Linear Shaft Motor forcer with the lead wire coming out should be toward the direction of the marked end of the shaft. See **Figure 11**. The linear encoder should also be installed to count up in this direction of travel. If it does not, the A and B encoder signals should be exchanged

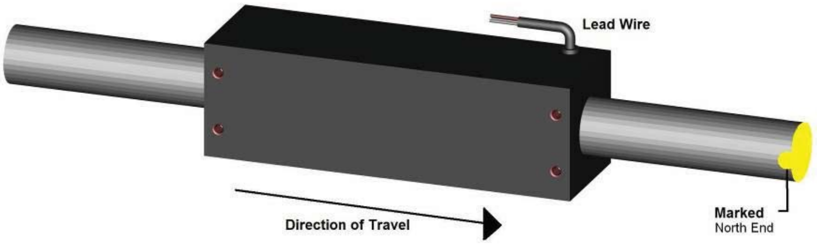


Figure 12

Tandem Forcer

Locate the Tandem forcer information on the data sheet. Please note the forcer spacing and if the second forcer is to be flipped. If the second forcer is to be flipped, it will need to be installed on the shaft in a direction reversed from the first forcer. (**Figure 13**) The U and V leads from the second forcer will also need to be swapped. The second forcer should be the one with the lead wire and Serial Number away from the marked end of the shaft.

Second forcer flipped

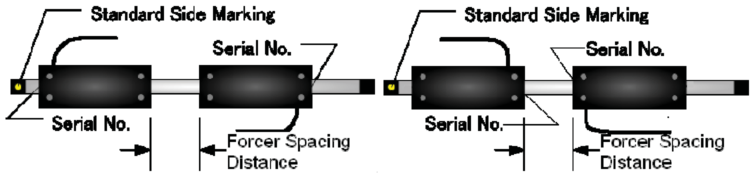


Figure 13

Second forcer not flipped

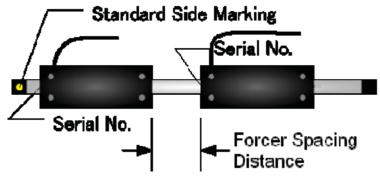


Figure 14

Shaft Alignment

Short Strokes

When installing the Linear Shaft Motor it will be necessary to adjust the position of the shaft in relation to the central bore of the forcer.

An example of a procedure that has been used is shown to the right[2]:

After both supports have been adjusted, remove the packing pieces and move the forcer, by hand, along the whole length of travel, visually checking the alignment of the shaft in relation to the central bore of the forcer.

On systems of over 1m, there may be some deviation from concentricity, but as long as the shaft does not touch the central bore of the forcer, over the whole length of travel, the system will run correctly. If the shaft touches the central bore of the forcer, this may be evident by an increase in resistance to the movement of the forcer.

Sample short stroke forcer/shaft alignment[2]:

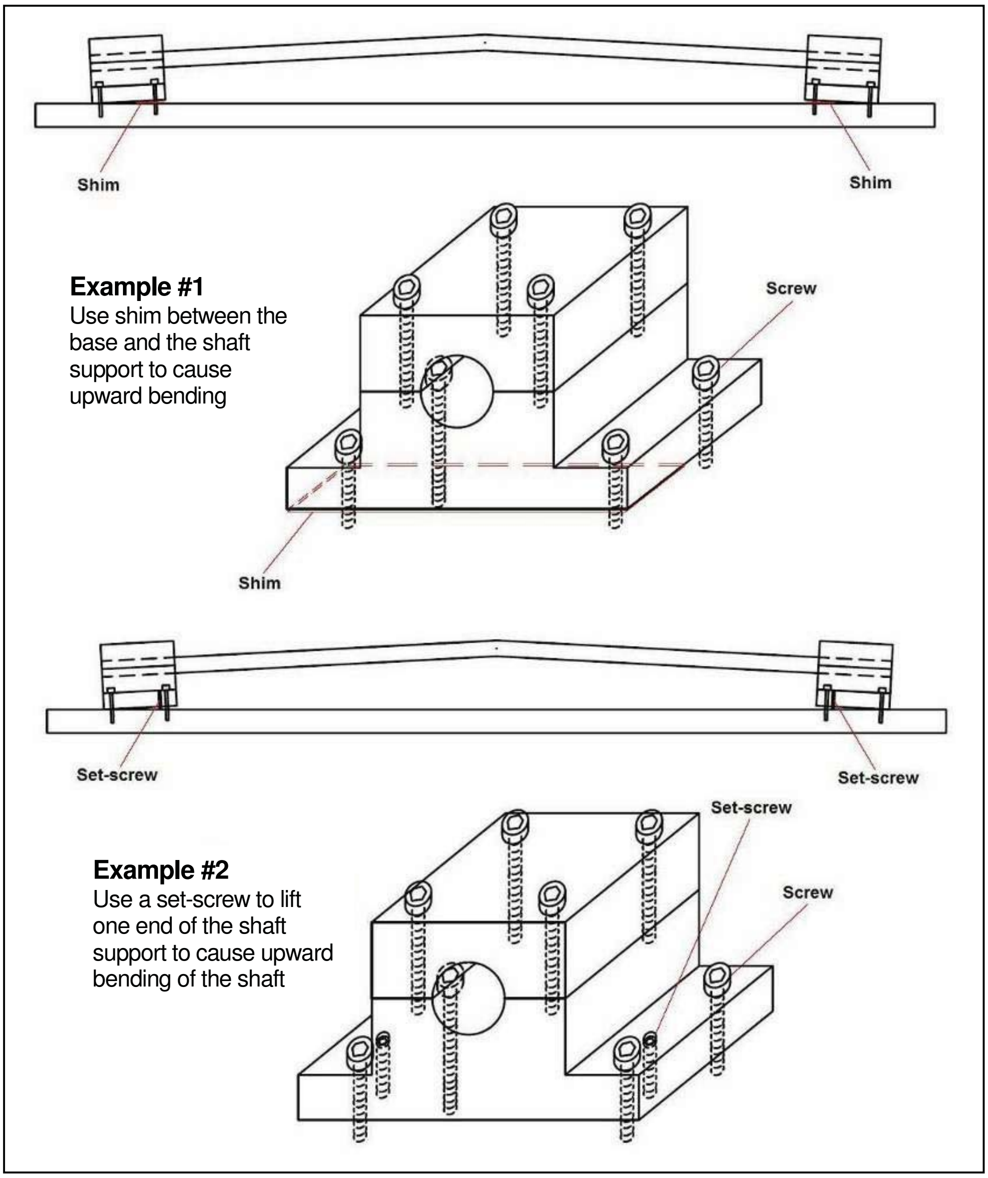
1. First, ensure that packing pieces are inserted between the shaft and bearing rail. These pieces do not need to be a tight fit but should be spaced no greater than 500mm apart.
2. Temporarily tighten one of the supports; loosely tightening the base bolts and fully tightening the shaft clamp bolt.
3. Slide the forcer to approximately 50mm from this support; removing and replacing the packing pieces as required.
4. Adjust the position of the support so that the shaft is aligned concentrically with the central bore of the forcer. The correct position can be determined by eye alone.
5. Tighten the base bolts, ensuring that the position of the support does not change while doing so.
6. Repeat the procedure for the other shaft support.

[2] This procedure can serve as a general guideline to your Linear Shaft Motor installation and alignment. This is not, and was not intended to be, a step by step installation guide since your system components will be very dependent on your design and may be very different from what is described here; however our hope is that these guidelines should be helpful. The guidelines assume that the system has been mounted in a horizontal plane. Systems that have been mounted vertically, sideways, or upside down, will require a slightly modified procedure.

Long Strokes

Due to the simply supported nature of the shaft, on longer systems the shaft will have a tendency to bow in the middle due to gravity on longer stroke systems. This can be overcome, to some extent, by inducing an upward bow into the shaft. Two common methods of doing this include; using shims (**Example #1**) to angle the end clamps or providing screw adjustment (**Example #2**) to angle the end clamps. Verify that the shaft does not exceed the maximum bending as shown in the Data Sheets for your Linear Shaft Motor.

Both of these alignment methods of the shaft requires the 'simultaneous' adjustment of both of the shaft supports. On the next page is an example of an adjustment using shims.[3]



[3] This procedure can serve as a general guideline to your Linear Shaft Motor installation and alignment. This is not, and was not intended to be, a step by step installation guide since your system components will be very dependent on your design and may be very different from what is described here; however our hope is that these guidelines should be helpful. The guidelines assume that the system has been mounted in a horizontal plane. Systems that have been mounted vertically, sideways, or upside down, will require a slightly modified procedure.

Sample long stroke forcer/shaft alignment[4]

Stage 1: When installing the shaft supports and Linear Shaft Motor, we will start with the use of a temporary shim. The size of the final shim will vary depending on the length of system, and therefore how much bow needs to be induced into the shaft to overcome the natural sag due to gravity. The shim size will normally be between 0.3mm and 1.0mm (A 0.8mm shim is therefore a good starting point).

Insert a shim below both of the inner bolts, on each of the supports, between the support and the bottom plate. Please see the illustration with example #1 for clarification. Tighten the bolts, on each support, enough to hold the shims in place and force the support against the bottom plate. Tighten the top bolts both to hold the shaft rigidly in the supports.

Stage 2: Position the whole shaft support.

1. First, ensure that packing pieces are inserted between the shaft and bearing rail. These pieces do not need to be a tight fit but should be spaced no greater than 500mm apart.
2. Temporarily tighten one of the supports; loosely tightening the base bolts and fully tightening the shaft clamp bolt.
3. Slide the forcer to approximately 50mm from this support; removing and replacing the packing pieces as required.
4. Adjust the position of the support so that the shaft is aligned concentrically with the central bore of the forcer. The correct position can be determined by eye alone.
5. Tighten the base bolts, ensuring that the position of the support does not change while doing so.
6. Repeat the procedure for the other shaft support.

Stage 3: After both supports have been adjusted, move the forcer to the middle of travel, and remove the packing pieces. (The forcer is moved to the middle of travel, to stop the shaft from ‘snapping’ down onto the bearing rail, in the event of an error being made during the shaft support adjustment). Move the forcer, by hand, along the whole length of travel, visually checking the position of the shaft in relation to the central bore of the forcer. The shaft will not stay concentric along the whole length of travel, but as long as the shaft does not touch the central bore of the forcer the system will run correctly. The shaft will look similar to the one shown in **Figure 15**.

If the shaft touches the central bore of the forcer, it may be evident by an increase in resistance to the movement of the forcer. If this occurs, the shaft will need to be realigned. Minor adjustments can be made by repositioning of the whole support; larger adjustments will require different size shims to be used in stage 1 of the adjustment. Rubbing in the center will require larger shims, while rubbing at 1/3 from ends will require smaller shims. Always remember, that before undoing any of the shaft support bolts, packing pieces should be inserted between the shaft and the bearing rail.

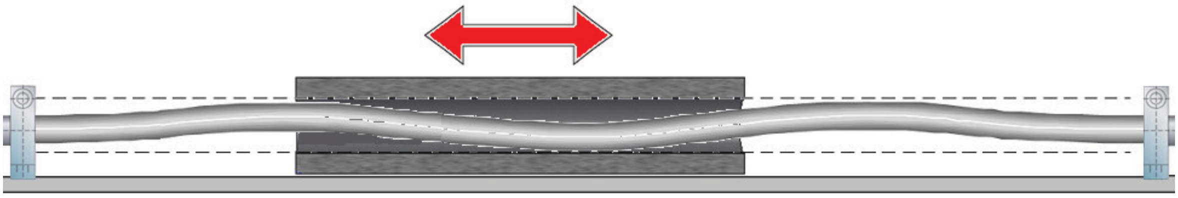


Figure 15

[4] This procedure can serve as a general guideline to your Linear Shaft Motor installation and alignment. This is not, and was not intended to be, a step by step installation guide since your system components will be very dependent on your design and may be very different from what is described here; however our hope is that these guidelines should be helpful. The guidelines assume that the system has been mounted in a horizontal plane. Systems that have been mounted vertically, sideways, or upside down, will require a slightly modified procedure.

Encoder Installation

Encoders should be installed according to the encoder manufacturer's installation information, attention should be given to the proximity of the encoder to the shaft, due to the shaft's strong magnetic field. This is particularly important when using magnetic type encoders.

The direction of count of a two channel (Quadrature decoded) incremental encoder is defined such that a signal denoted as channel A should lead channel B when the motor is moving in the forward direction. It is sometimes not possible to mount the encoder systems so that the counts will conform to this convention. Under these circumstances, it becomes necessary to reverse the direction of count as seen by the controller. There are two possible methods of reversing the direction of the count from an incremental encoder which are described below.

- If a channel is inverted (i.e. A wired to A- and vice versa) then the signal from channel A will then lag behind channel B. This will cause the controller to reverse the count as perceived from the encoder.
- If the signals from channel A and channel B are swapped completely with one another (i.e. A+ wired to B+, A- wired to B-, and vice versa), this will result in channel B leading channel A, and reverses the count.

Magnetic encoders

If the rod and strip come into contact, or are in very close proximity with one another, then the magnetic profile in the strip will be permanently damaged.

Cable Carrier

It is recommended that when the Linear Shaft Motor is used with a moving forcer, a cable carrier is used. The cable carrier will help guide and prevent damage to the motor cable, encoder cable, and any ancillary cables or hoses attached to the forcer.

For short stroke systems it may not be necessary to use a cable carrier.

The cable that exits the forcer is not a high-flex type; therefore it must terminate before entering the cable carrier. Cable undergoing dynamic movement should be protected and have a method of strain relief, ideally cable should be protected within a cable carrier. It is important to lay any cables, or conduit, neatly within the cable carrier to prevent damage to them, and to minimize the friction of the system due to the cable carrier binding. All static cables should be routed in such a way that they are protected from being damaged by parts of the machine or secondary moving parts.

Operation Considerations

The motor must always be operated within the specified operating parameter limits. Exceeding those limits will permanently damage the motor. The following steps must be completed to ensure safe and proper operation.

Verify that all electrical wiring and cables are properly connected. Refer to the manual provided with the driver for this information.

1. Adjust the servo driver current to match the motor's current specification. See the data sheet.
2. Refer to the motor specifications for operating parameters. Adjust the control parameters to the motor data specifications as necessary.
3. Adjust the control for the proper P.I.D. loop tuning. Begin at a low gain setting and increase the gain as necessary.
4. Strain relieve the wires prior to operating.

The cable that exits the forcer is not a high-flex type; therefore it must terminate before entering the cable carrier. Cable undergoing dynamic movement should be protected and have a method of strain relief, ideally cable should be protected within a cable carrier. It is important to lay any cables, or conduit, neatly within the

cable carrier to prevent damage to them, and to minimize the friction of the system due to the cable carrier binding. All static cables should be routed in such a way that they are protected from being damaged by parts of the machine or secondary moving parts.

Using the supplied connector provided with the Linear Shaft Motor, connect cables before entering the cable carrier. This connector attaches to the high-flex cable in the cable carrier. This allows maintainability of the high-flex cable without have to removing the forcer. Required for proper operation, is a good shield connection on all cabling. Cables should be made in a twisted pair configuration, shielded, and grounded properly to the machine base, servo amplifier, and motor in order to reduce RFI

Note that the forcer is electrically earth grounded through the forcer case, for CE type forcers the earth ground is also available through the motor cable.

MOUNTING ORIENTATION

There is no restriction on the angle or orientation at which the system can be mounted. If the system is to be mounted in a vertical orientation, it is recommended that a counter-balance be used. If the load is not counter-balanced, the motor must always work against gravity, even when it is not moving. This should be taken into consideration when sizing the motor. The counter-balance should be designed to balance the gravitational force acting on the system, which is the weight of the forcer and the payload. If a system is properly counter-balanced, when no power is applied to the forcer it should remain stationary.

Electrical Installation

⚠ (**Note**: The lead wire supplied with the Linear Shaft Motor is not intended for use in a cable carrier. It is suggested that you use the supplied connectors for connection to a suitable cable for continuous operation.)

All connections to the motor are made through the flying leads exiting on the side of the motor. High voltages can be present. Ensure that all power is removed from the motor before connecting or disconnecting the motor.

Power and Control Connections

All the power and control connections are made through the Linear Shaft Motor's forcer assembly. For an example of an integrated configuration using the Linear Shaft Motor and amplifier / controllers, refer to **Figure 16**.

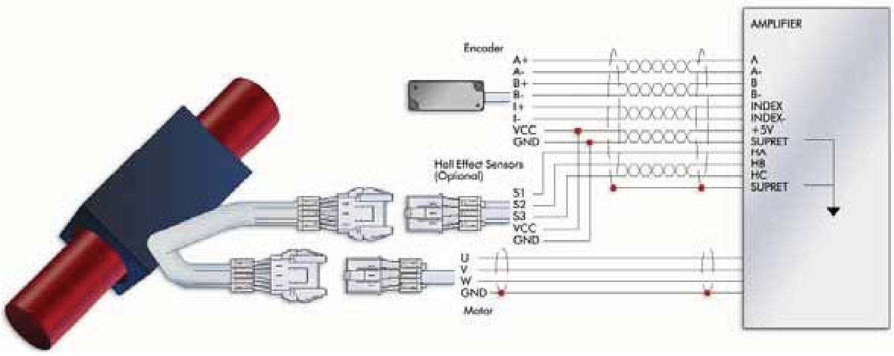


Figure 16

The data sheet for your Linear Shaft Motor identifies the color, function, and length of the wire in the forcer assembly. Connect the three wire (U, V and W) flying leads exiting on the side of the motor to the Servo amplifier. For correct operation, the flying leads on the end of your motor cable should be connected as detailed in your servo amplifier instructions. These wiring connections may be indicated on your servo drive connector as; U, V, and W; or R, S and T; or M1, M2, and M3, or A, B and C; or simply 1, 2 and 3.

Hall Effects

If your Linear Shaft Motor has the hall effect option, connect S1, S2, S3, GND, and VCC connection for the hall effects to the respected input terminals of the driver. Suitable cable should be selected for use between the Linear Shaft Motor and the driver. Consideration should be given to shielding and bending radius cable when used in a cable carrier.

The Linear Shaft Motor uses EW500 Hall Sensor. The circuit is shown in **Figure 17**.

As shown in **Figure 18**: S1 – U, S2 – V, S3 – W

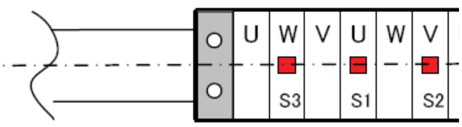
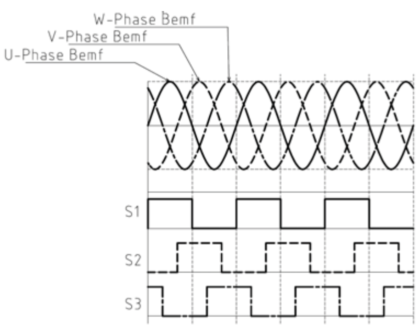


Figure 18



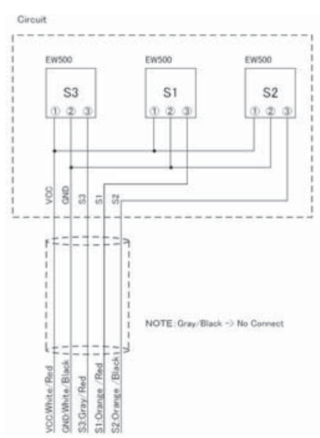


Figure 17

Tandem Forcers

If your system makes use of Tandem forcers, locate the tandem forcer information on the data sheet, and **Table 4**. Please note the forcer spacing and if the second forcer is to be flipped. If the second forcer is to be flipped, it will need to be installed on the shaft reversed from the first forcer. **(Table 4)** The U and V leads from the second forcer will also need to be swapped.

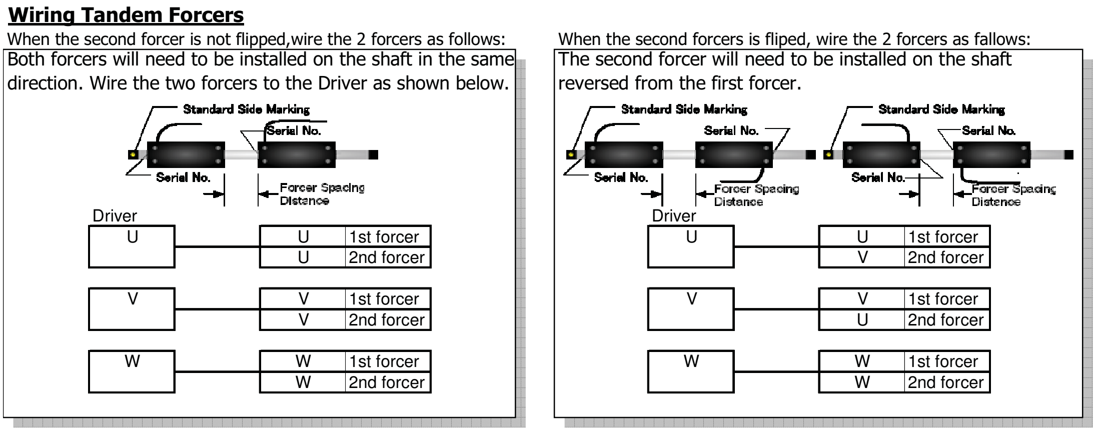


Table 4

Encoder and other Sensors

Connect the encoder and other sensors -- OTL (Over Temperature Limit), Limit Switches, and Air Sensors-- to the driver. Please refer to the instruction manual of the driver and device being connected to confirm correct connection.

Grounding

The motor ground must be connected at both the servo amplifier's earth ground terminal and the body of the forcer. When using a CE type motor, the motor ground is available through a ground screw. Always keep the connection between motor and the earth point as short as possible. For best results, use a heavy gauge, multi-strand earth strap.

Electromagnetic Compatibility (EMC)

The ultimate responsibility for ensuring the Electromagnetic Compatibility of a system lies with the OEM. However, to make the task easier, IDC has designed in a number of features to help meet the requirements of Directive 89/336/EEC.

Motor

All the motor windings are contained within the, aluminum housing of the forcer. This housing provides very effective screening from the noise radiated by the high switching currents associated with a pulse width modulated amplifier, and is also very effective at preventing external sources of noise from affecting the electronics contained in the termination pocket.

Hall Effect Devices

Digital Hall Effect devices have the built in noise immunity that comes from using digital electronics.

General Precautions

Although the motor's EMC performance is very good, it is still advisable to take precautions to minimize the risk of any Electromagnetic Interference (EMI) in your application. These precautions include:

- Keep all cable routing as short and direct as possible
- Avoid routing signal cables alongside power cables or close to "noisy" components such as mechanical relays.
- Where shielded cables are provided, ensure that the shield termination is as short and direct as possible. Do not use "pig tails" to terminate shields.

Servo Driver

The following information can serve as a general guideline to your servo driver installation and alignment. This is not, and was not intended to be, a step by step installation guide since your system components will be very dependent on your design and may be very different from what is described here; however our hope is that these guidelines should be helpful.

Basic PID(F) Servo Controller Setup

PID(F) controllers use the error between the desired position of the motor and its current position to control the force that the motor will produce. PID refers to proportional, integral and derivative terms applied to this error (referred to as the following error) that are used in this type of control system. Many of these controllers will also have feed-forward terms (F) to help reduce the response times of the system. In order for the controller to move the system to the desired position it is necessary to set values to these terms. The process of selecting the value to which these parameters should be set is called tuning. In order to tune a system it is necessary to understand the effect of each of the terms. Refer to your servo tuning guide for detailed information.

Proportional gain.

The proportional gain in a system causes the motor to produce a force directly proportional to the following error. So, the further away from the desired position the motor , the greater the following error, and the greater the amount of correcting force produced. As this value is increased the position error is reduced. It is possible to use too large a value of proportional gain, as the system can become unstable. This parameter also provides stiffness when in position.

Derivative/Velocity feedback gain.

One method of stabilizing a system requiring a high proportional gain is to introduce a velocity feedback factor into the loop. This parameter reduces the force that is available to the motor as the speed of the motor increases. Although this allows higher gains to be used, there is still a limit to the maximum value, as the system will still become unstable if very large values of velocity feedback are used.

Integral gain.

When the above two terms have been set there may still be an unacceptable following error in the system. This integral term is combined with the following error in a continuously incrementing accumulation to produce a force to drive the motor. Because of the time dependency of this term, it tends to have a much slower response rate when compared to the above two terms. For most systems, a quick response is required, and so a high value for this gain is tried. Unfortunately, even at fairly low values this term can cause the system to become unstable. For linear systems this term is generally very small, or set to zero.

Feed-forward gains.

There are several different types of feed-forward gains that can be available, depending on the controller type. Velocity, acceleration, deceleration and friction feed-forward compensation are a few of the more common ones. During a move, feed-forward terms allow the controller to produce a force based upon the commanded move rather than on the following error. An example would be to consider the acceleration feed-forward term. Using Newton's law of motion, F = MA, it is possible to assume that if an acceleration is required, then a certain current needs to flow in the motor windings (force is directly proportional to current). An acceleration feed-forward term would produce a command signal that could be expected to achieve this acceleration. This does, however, mean that the feed-forward terms are open-loop in nature. Just as with all the other gains, if any feed-forward terms are too large the system will be unstable. In general, the feed-forward terms are used to minimize following errors and improve system response time. Unfortunately, there is no universal method of tuning, or predetermined gain values, that can be used on all servo controllers available commercially. Each servo controller has its own control algorithms and scaling.

Notes:

MAINTENANCE AND SERVICE

When correctly installed, the Linear Shaft Motor system requires little maintenance. The Linear Shaft Motor systems contain no parts undergoing frictional contact. When incorporating a Linear Shaft Motor system, care should be taken to allow access for routine maintenance of the bearing and encoder systems and any other ancillary equipment. The Linear Shaft Motor itself is entirely *maintenance free*. It does not have any parts that can wear out.

NPA does recommend that you periodically perform minimal inspection.

Periodically:

- Check that the forcer can move freely over the entire stroke.
- Clean any accumulated debris from the shaft surface (ferrous material in particular can be attracted to the shaft.)
- Check the bending of the shaft.
- Check that all parts are tight and secure.
- Check all flexing cables for signs of wear or damage.

The forcer contains the stator coils; these are potted into the aluminum housing with an epoxy resin. The aluminum housing and the coils are therefore, in effect, a single piece and there is no maintenance needed. If, however, wear has been noted on the shaft, then the central bore (internal diameter of the coils) should be inspected for wear, or excessive ingress of foreign matter. The shaft will need to be removed from the bore of the forcer to do this.

The shaft is NOT a bearing surface, and should NOT be oiled or greased. When correctly set up there should be no maintenance requirements for the shaft. However, on long systems where the possibility of the shaft rubbing on the central bore of the forcer is greater, regular checks should be made for correct alignment.

The only contact and source of friction is in the external linear bearing. The external linear bearing must be lubricated from time to time according to the slide manufacturer's specifications. Please consult the bearing manufacturer for recommendations on lubrication types and lubrication intervals.

If a roller bearing or an air bearing system is used to guide the load, there may not be any maintenance at all.

Service

The Linear Shaft Motor is not designed to be serviced in the field. In the rare event that there is a malfunction, please contact NPA for return authorization.

4 Corporate Drive, Radford, VA 24141, USA

Phone: 1-540-633-1677

E-mail: info@linearshaftmotor.com

Web: http://www.linearshaftmotor.com

Notes:

TROUBLESHOOTING GUIDE

This section covers symptoms, probable causes and solutions related to the Linear Shaft Motor. It lists the most common symptoms of irregular operation, and the possible causes and solutions for these faults. Most problems encountered during installation can be traced to a few basic mechanical alignment problems, or incorrect/noisy wiring.

A logical and methodical approach to trouble-shooting is essential to isolating and resolving these problems.

Common problems include:

- Mechanical alignment of the shaft
- Incorrect tuning of the servo controller and/or drive
- Motor power and hall effect devices incorrectly wired
- Encoder feedback failure
- Motor over-temperature

The magnetic attraction between the magnet shaft and other magnetic or ferrous materials is extremely high. Keep fingers and other body parts away from these objects to avoid injury.

Before performing the tests described in this section, be aware that lethal voltages may exist on the motor connections. A qualified service technician or electrician should perform these tests.

Symptom	Probable cause	Corrective Action
The Linear Shaft Motor does not move freely by hand when power is not applied to the system	Forcer rubbing on shaft	Realign forcer so that its bore is concentric with the forcer per the instructions the Installation Section
Encoder counts when motor is not moving	Encoder shield not connected	Connect encoder shield
	Amplifier/motor noise	Check shields and earth grounds (See Section Installation page 32)
		Route encoder cables away from motor cable at controller
Encoder feedback failure or intermittent feedback	Encoder not set up correctly	Adjust encoder per encoder manual
	Encoder scale dirty	Clean scale
	Encoder strip scratched (Optical)	Replace encoder strip
	Encoder strip damaged (magnetic)	
	Encoder read head failed	Replace Encoder Sensor

Symptom	Probable cause	Corrective Action
The Linear Shaft Motor Runs Away (Positive Feedback)	Polarity of control signal and encoder count direction are opposite	Ensure that a positive force or velocity command from the servo controller yields an increase in the reported encoder position (See Section Installation page 26)
The Linear Shaft Motor runs unevenly	Incorrect number of encoder counts per pole pitch for commutation	Recalculate counts per pole pitch (See Engineering Notes page 23)
	Servo gains set incorrectly	Re-tune system
	Current offsets in drive amplifier	Contact drive supplier
	Shaft damaged due to excessive heat	Replace shaft (Contact NPA)
	Earth ground/shields not connected correctly	Check connections (See Section Installation page 31, 32)
The Linear Shaft Motor stalls on power up	Hall Effects not connected correctly	Check Hall Effects connections (See Section Installation page 31)
	Motor power not connected correctly	Check motor connections
Amplifier fails to enable	Faulty Wiring	Check and correct wiring
	Limit switches active	Move motor away from limits, or disable limits at controller
Linear Shaft Motor Drifting	Exceeding encoder frequency specifications of amplifier	Reduce linear motor speed
	Electrical noise affecting read head	Check for grounding loops
The Shaft is discolored	Motor exceeded rated temperature	Check continuous current setting
		Measure motor phase resistances
The Linear Shaft Motor fails to phase align on power-up	Motor/encoder/halls not wired correctly	Check connections (See Chapter Installation page 31)
	Insufficient travel available to complete phase sequencing	Clear obstruction
		Replace shaft with longer shaft (Contact NPA)
	Insufficient phase search current	Check amplifier setting
Forcer locks into certain positions on the shaft	Hall Effect signal missing	Check connections
	Motor phase not connected	
The Linear Shaft Motor feels coggy	Ferrous materials used in stage	Replace ferrous parts with no ferrous materials.
Shaft pitted or scarred	Forcer rubbing on shaft	Realign forcer so that its bore is concentric with the forcer per the instructions in Installation Section
RMS Over-current Fault	Move regimen too strenuous for payload being carried, and the motor's capabilities	Reduce commanded accelerations and or velocity
		Reduce payload
	Incorrect drive settings for motor	Correct drive settings
Following Error	System can not follow commanded move velocity and/or acceleration.	Reduce commanded speed and/or acceleration
	Encoder signal failure, or intermittent encoder signal	Check encoder signal with drive disabled
	Following Error Window set too tight	Increase following error window
	System not tuned properly	Adjust tuning parameters per your servo control's instructions
System is not repeatable	Servo system is not tuned properly for application	Adjust tuning parameters
	Settling time is not sufficient to meet settling window requirements	Increase allowable settling time
System vibrates when servo loop closed	Servo controller gains set too high, or incorrectly	Reduce gains and retune system

Symptom	Probable cause	Corrective Action
The Linear Shaft Motor moves the wrong direction	Polarity of control signal and encoder count direction are opposite	Ensure that a positive force or velocity command from the servo controller yields an increase in the reported encoder position (See Section Installation page 26)
	Control's direction sense is not set correctly for your application	Switch direction sense
Linear Shaft Motor does not move and produces no force	Drive not powered	Check all connections to make sure they are tight and secure, and that the power is turned on.
	Linear Shaft Motor phase is not connected to drive	Check phase connections to the drive
	Over-temperature sensor setup but not connected	Check settings and connection of over-temperature sensor and the drive
	Linear Shaft Motor is over-temperature	Allow forcer to cool
Linear Shaft Motor does not move but does produce force	One or more of the motor phase connections are missing or connected improperly	Check phase connections to the drive make sure they are tight and secure.
	One or more of the position sensor connections are missing or connected improperly	Check position sensor connections to the drive make sure they are tight and secure
	The Linear Shaft Motor is mechanically blocked	Check to see that the Linear Shaft Motor is free to move
Linear Shaft Motor gets too hot	The Linear Shaft Motor is being driven beyond its designed load carrying capacity	Turn off the machine and call NPA to double check the proper sizing
Linear Shaft Motor moves but has a jerky motion that produces excessive noise	Incorrect pole pitch set up or phase offset between position sensor and forcer back EMF	Check drive or controller set up
Linear Shaft Motor moves but in the wrong direction	One or more of the position sensor connections are connected improperly	Check position sensor connections to the drive.
	The position sensor is set up improperly in the drive or controller	Check drive or controller set up
The Linear Shaft Motor moves but the commanded position is not what it is supposed to be	There is improper reading of position from the encoder by the driver	Align the encoder's linear scale properly so that it is exactly parallel to the rail guide, linear bearing, or air bearing being used

Notes: