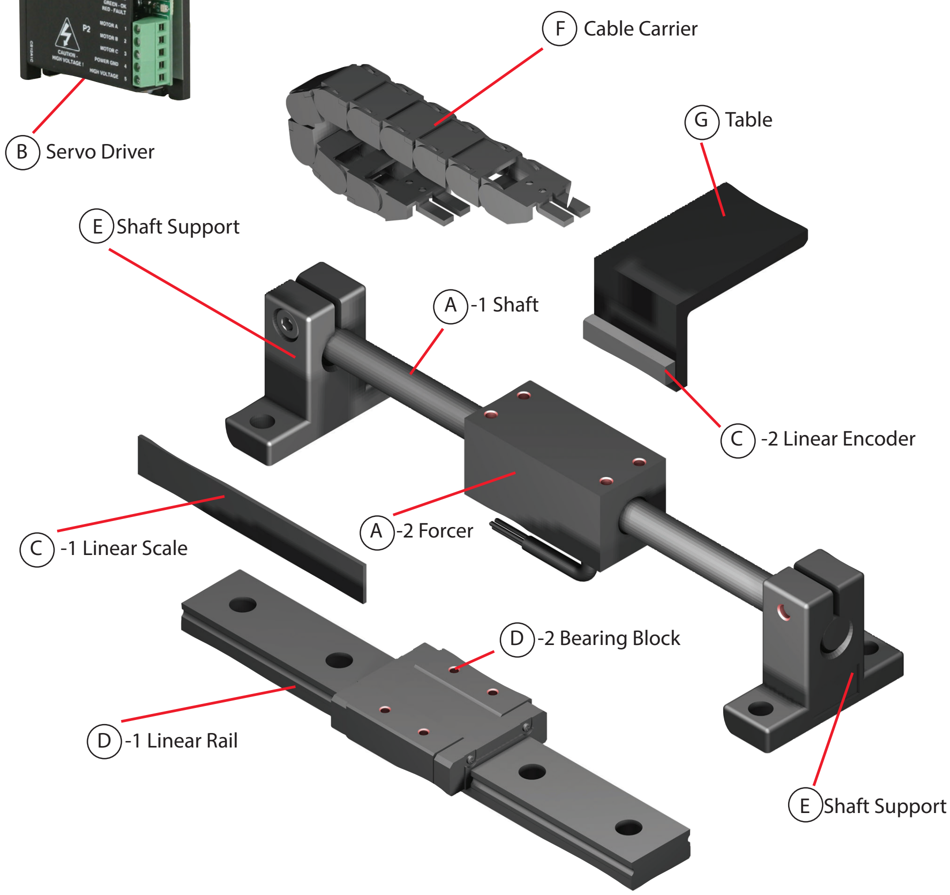
Linear Shaft Motor

System Configuration

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. There are various design considerations that are different from traditional servo system practices. The following are the main components needed to make a Linear Shaft Motor system, as well as factors to consider when designing a system.



Configuring 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 consideration must be given to the application, demand specifications, environmental conditions, and whether the forcer or the shaft will be moving.

The other items, E through G, are optional and will depend on the application.

Putting Together a Linear Shaft Motor System

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

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Choose the shaft supports based on design and motor specifications.

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

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Choose the linear encoder to achieve the required position resolution.

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

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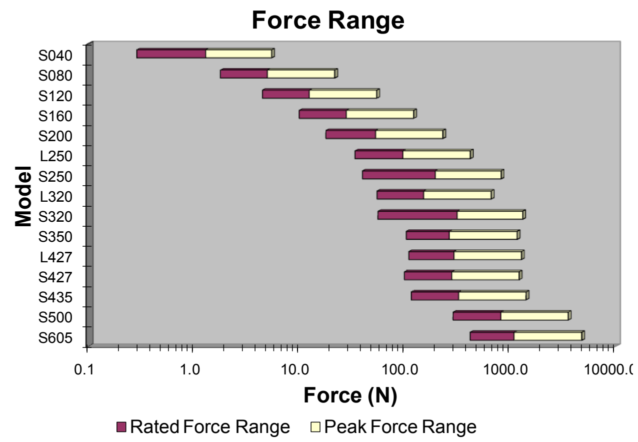
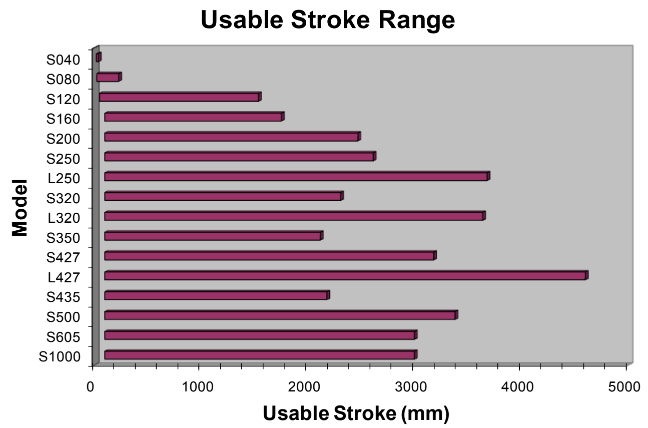
Choose the Over Temperature Limit, switches and other components, and assemble the Linear Shaft Motor system.

Choose the Linear Shaft Motor Based on Force and Stroke Requirements

For assistance in selecting the correct Linear Shaft Motor, check out Nippon Pulse's "SMART" tool (Linear Shaft Motor Application Resource Tool) which can be found at nipponpulse.com. The Linear Shaft Motor should be mounted as closely as possible to the center of gravity of the moving load, and to the working point of the machine.

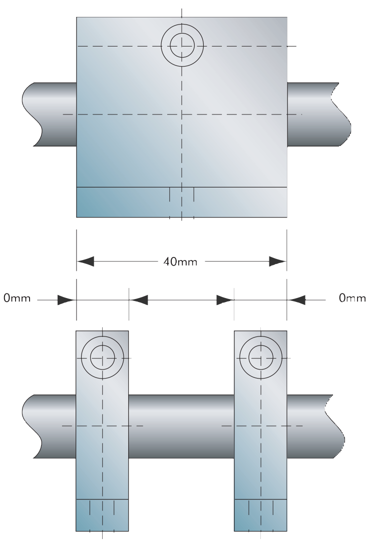
If the motor and feedback are far apart, the machine structure and linear guide (bearings) must be of sufficient mechanical stiffness to minimize dynamic deflections of the structure. Be sure to allow clearance for ventilation and access for cleaning, repair, service and inspections. Ventilation is extremely important. Be sure the area for ventilation is not obstructed, as motors may get warm, and 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, another option is to space two smaller shaft supports for the specified support length. The drawing to the right illustrates these two different options.



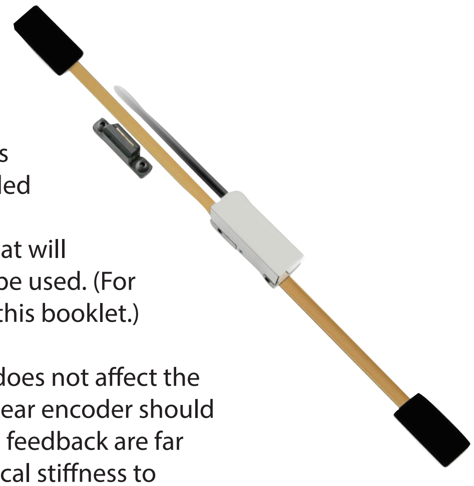
Choose the Linear Guide (Bearings) Based on Smoothness (Performance) Constraints

The linear guide (bearings) must be selected to support the moving load. Often, the linear guide 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 Motor 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 below. Air bearings are most desirable from the standpoint of smoothness, while mechanical slide rails are desirable due to portability.

	Slide Rails	Cam Follower	Crossed Roller	Recirculating 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 1µm 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 10 times your required resolution. Either an optical or a magnetic encoder can be used. (For more information about selecting your encoder, see Engineering Notes at the back of this booklet.)

In the case of a magnetic linear encoder, take care it is installed so 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 Amplifier/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. (For help selecting the correct servo driver, check out our SMART tool at nipponpulse.com, or see the Engineering Notes at the back of this booklet.) 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 (DC) units for voltage and current ratings, while most servomotors (like the Linear Shaft Motor) use RMS (AC) 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.

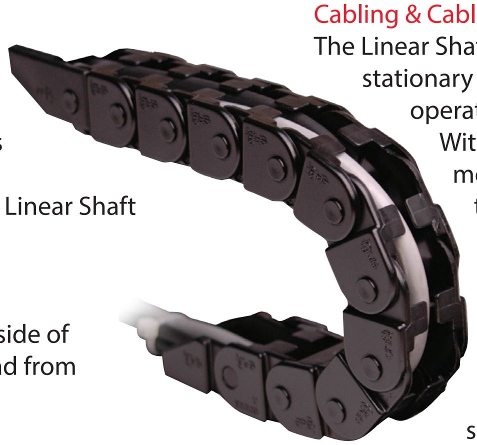
Choose the OTL, Limit Switches and Other Components, and Assemble the Linear Shaft Motor System

Temperature Sensor

A temperature sensor OTL (Over Temperature Limit) will cut power to the motor should it get too hot due to overload. This 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

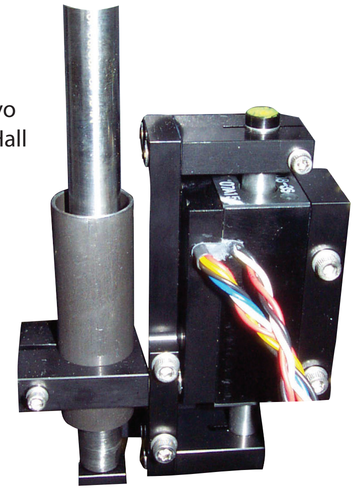
Limit switches can be added on either side of the load on the shaft to prevent the load from overshooting.



Cabling & Cable Carrier

The Linear Shaft Motor is typically operated with a stationary shaft and a moving forcer (it can be operated with a stationary forcer and moving shaft). 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 will 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 radio frequency interference.

Hall Effect Sensors



Hall effect sensors are devices able to 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 is 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.

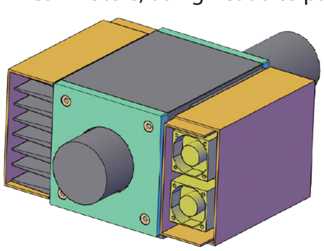
Because of the size of Hall effect sensors, they are not available on our 4mm Linear Shaft Motor. On the 8-20mm motors, the dimensions of your project must be expanded to include the sensors, which must be connected externally to the motor. On the 25mm series and above, the sensors fit inside the motor and no additional space is needed in your design.

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.

Cooling Methods

Although the Linear Shaft Motor inherently runs cooler than other linear motors, using heat dissipation can improve the ratings of the LSM by 30 to 40 percent. Cooling methods include, but are not limited to: heat routing, heat fins (see left side of image, left), heat fans (see right side of image, left), forced air, and water cooling.



Attached to a S080D, a 200mm x 100mm x 12mm heat sink improved the rated current by 75 percent. The same heat sink improved the rated current of a S160D by 30 percent.

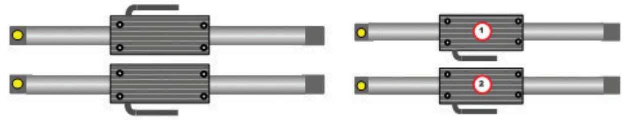
Nippon Pulse sales engineers can suggest a variety of cooling methods, if cooling is necessary for your application.

At right is an example of a water-cooled S500D Linear Shaft Motor.

Linear Shaft Motor in Parallel Systems

Parallel drive systems are any application that has two or more linear motors in parallel. In parallel applications, the wires extend from the shaft on opposite sides, whereas in non-parallel applications, other motor locations are not accounted for in the wiring.

Parallel Linear Shaft Motor Design



Advantages of Using Linear Shaft Motor in a Parallel Alignment

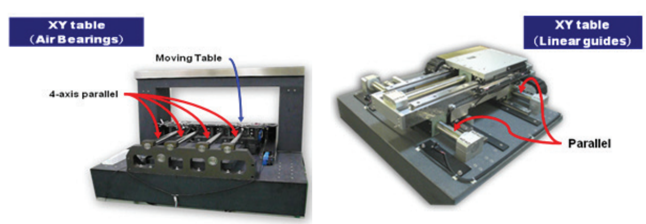
In high-precision, single-axis robot applications, truly accurate positioning is only possible when the feedback is directly in the center of mass of the work point. You also want your force generation from the motor directly in the center of mass of the work point as well; however, it is impossible to have the motor and feedback in the exact same location.

By putting an encoder in the center of mass, and using parallel Linear Shaft Motors equally spaced off the center of mass, you, in effect, are getting the desired feedback and force generation in the center of mass. You also are able to remove the heat source from the center of mass in high precision applications. This is impossible for other types of parallel drive systems, which require two sets of encoders and servo drives to provide this parallel drive functionality.

Multiple Motors, One Encoder, One Amplifier

In the past, systems may have had two different motors driving separate ball-screws, using two different controllers electronically connected together. Now that same system can be accomplished with two shaft motors, one encoder and one amplifier, as long as the stiffness in the system itself is sufficiently high.

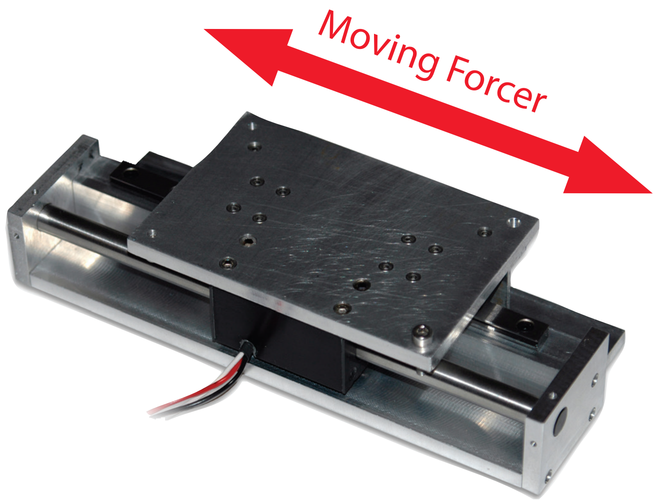
Examples of Parallel Systems

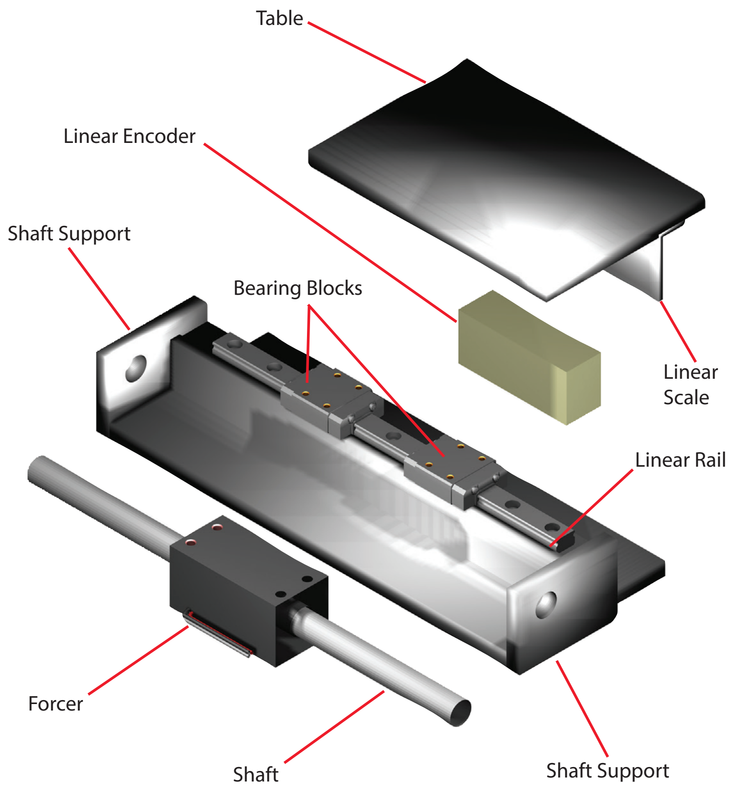


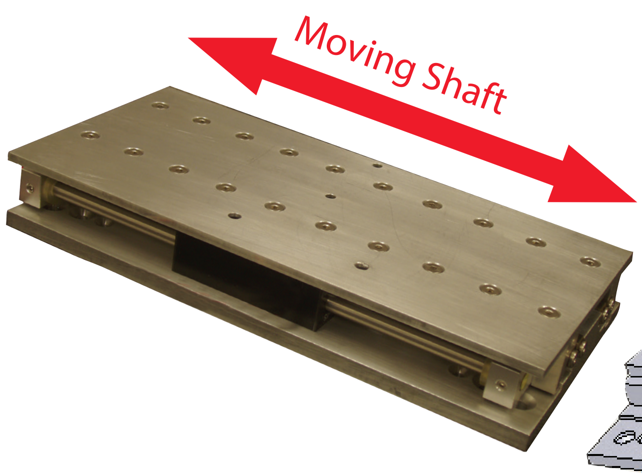
Unlimited Linear Shaft Motors Connected Together

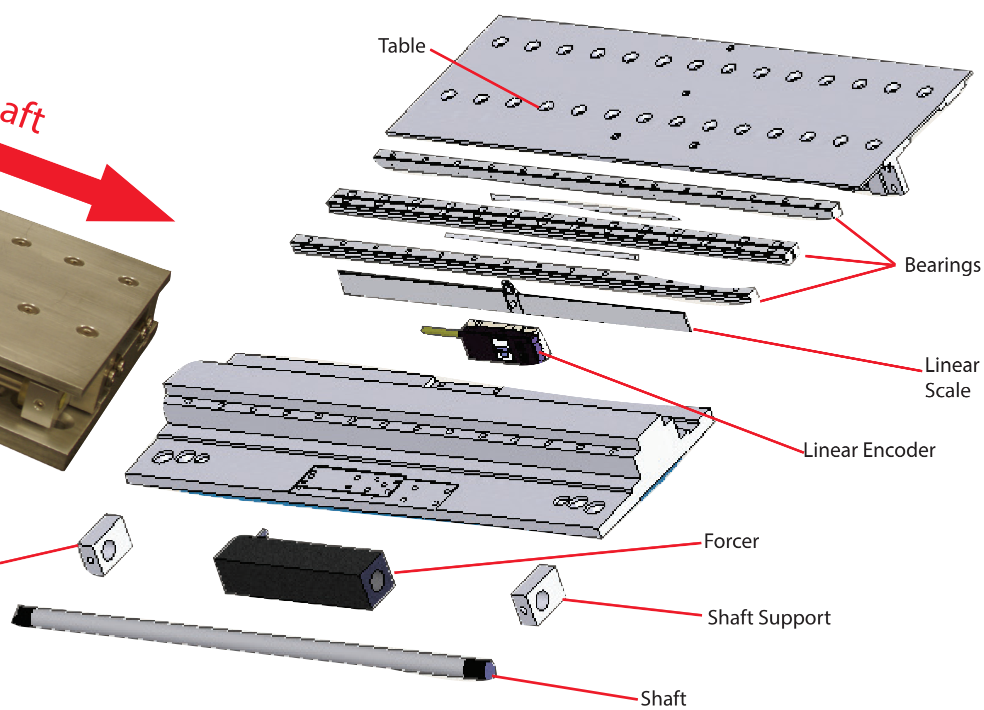
This is also is an advantage for applications where extremely high amounts of force are needed. It is possible to connect any number of Linear Shaft Motors together, thus allowing their forces to be combined.

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.