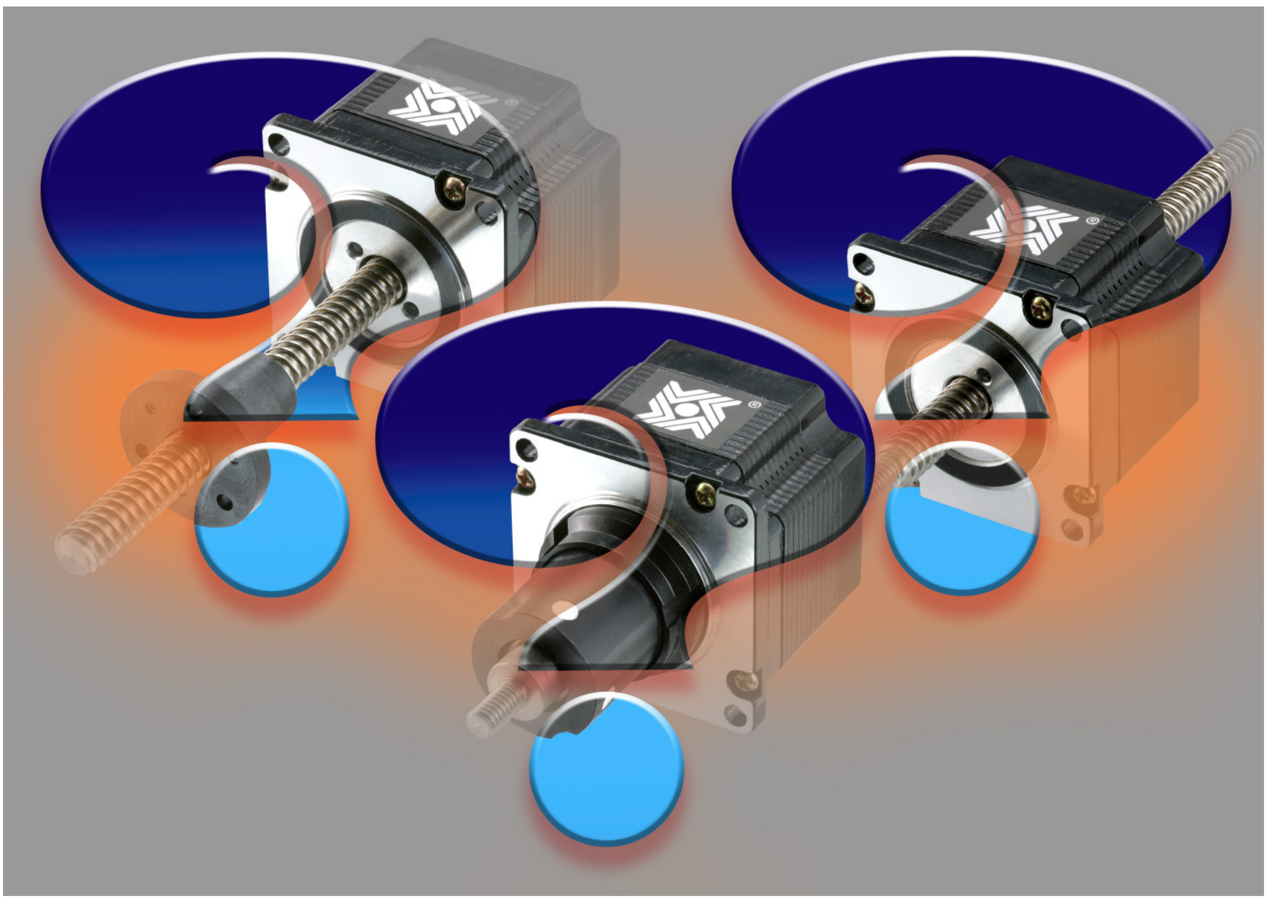
LEAD SCREW LINEAR ACTUATORS:

WHEN TO APPLY EXTERNAL, NON-CAPTIVE AND CAPTIVE STEP MOTOR ACTUATORS



Authored By:
Frank Morton
and Engineering Team Members
Haydon Kerk Motion Solutions

www.HaydonKerk.com
USA: Haydon Kerk Motion Solutions Tel: +1 203 756 7441
France: Tel: +33 2 40 92 87 51
Germany: www.HaydonKerk.de Tel: +49 9123 96 282 12
Asia: Haydon Linear Motors Co., Ltd. Tel: +86 519 85113316

Haydon kerk Motion Solutions®
AMETEK®
PRECISION MOTION CONTROL

WHEN TO APPLY EXTERNAL, NON-CAPTIVE and CAPTIVE STEP MOTOR ACTUATORS

A common way to generate precise linear motion is to use an electric motor (rotary motion) and pair it with a lead screw to generate a linear actuation system. Depending upon what this linear actuator interfaces with it can be constructed in a number of different ways. Here we will discuss several different ways to combine a lead screw and nut with a stepper motor to create a linear actuator system. The stepper motor is frequently used in motion control as it is a cost effective technology that does not require position feedback to operate correctly.

There are three different styles of linear actuators that are commonly used they are the external linear style, non-captive style and captive style. There are many reasons to use a certain style of linear actuator, the three main reasons for selecting one style over another are:

STROKE	What is the amount of linear travel required?
INTERFACE POINT	How will the actuator be mounted and how will the load be attached?
OPTIONS	What other options might be required from the linear actuator?

External Linear Actuator

The simplest way to envision this combination of parts is to simply affix the lead screw onto the shaft of the motor. The nut that rides on the lead screw must be restrained from rotating so that linear motion will be generated. This type of actuator is commonly referred to as an external linear style actuator.

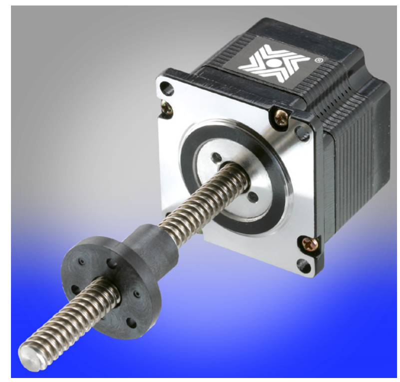


Fig. 1 External linear actuator, Size 23 stepper motor

The stroke is an important consideration, the external linear style actuator is commonly chosen to power linear slide systems in the 60-500mm stroke range. In these cases the linear slides carriage is typically attached to the nut, this provides the anti-rotation for the nut and also supports the load that the nut is moving ensuring that any potential side loading is not transmitted to the screw and nut. Some common type of linear rails are sliding element linear rails and recirculating ball bearing linear rails, below are some pictures to show the different styles:

Fig. 2 Sliding element linear rail – RGS06 with Size 17 stepper motor

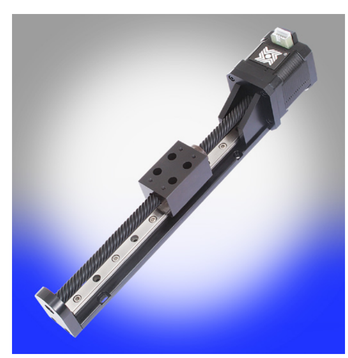


Fig. 3 Recirculating ball linear rail – BGS06 with Size 17 stepper motor

WHEN TO APPLY EXTERNAL, NON-CAPTIVE and CAPTIVE STEP MOTOR ACTUATORS

Long screw lengths do come with some risks, the biggest risk is that at some point along its stroke the actuator and screw will experience a resonance point which most likely will not impact performance but can make audible noise. In some extreme cases the noise/vibration will be enough to cause lost steps which results in loss of position. There are drive techniques that can help to mitigate noise such as micro stepping, acceleration and deceleration and also design techniques to help such as providing a bearing support on the end of the screw.

How the actuator will be mounted in the system and how the load will be attached are also important considerations. If the actuator will be driving a linear stage it is often advantageous to locate the motor to one side of the assembly for ease of wiring and allow the carriage and the nut to traverse the rail, this also allows linear stage height to be kept to a minimum. If a non-captive were used the width of the motor would have to be accommodated on top of the rail and the carriage height would be too large for modern systems that are always looking for ways to reduce package size.

Non-Captive (through screw) Linear Actuator

Another option is to locate the nut inside the motor and allow the screw to move linearly through the actuator. In this case the screw must be prevented from rotating to generate the linear motion. This style of actuator is commonly referred to as a through screw or non-captive linear actuator.

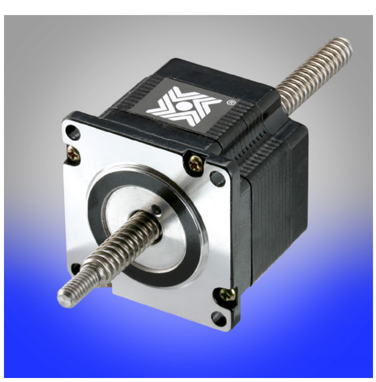


Fig. 4 Non-captive lead screw linear actuator, Size 23 stepper motor

A non-captive (through screw) actuator is common for stroke lengths of 30-200mm, one advantage of the non-captive over the external linear is that this design can tolerate some misalignment. If an external linear screw and nut is not aligned with the linear rail there can be a binding condition created, the nut has some radial clearance but this is often insufficient for an assembly with loose tolerance. These same radial clearances in the non-captive nut allow the screw to exit the actuator at up to a 1° angle; this allows the non-captive to tolerate quite a lot of misalignment.

Another possibility that is unique to the non-captive is one where the linear actuator is used with a linear slide but in this case the motor is attached to the carriage and the screw is fixed in position. One advantage of this is the screw is no longer rotating so critical speed is not a concern. The second advantage of this configuration is it allows multiple linear actuators to be located on the same screw assembly. The actuators cannot 'pass' each other on the screw but their motions can be independent of each other.

As mentioned above non-captives allow for some misalignment in the system not just from loose tolerance assemblies but also some very precise assemblies such as piston pump benefit from this style of actuator. Allowing the screw to find its own center means the screw will follow whatever it is attached to, this allows any misalignment to be accommodated by the actuator and it prevents side loads from being transferred to the piston seals.

Captive Linear Actuator

In instances where the application does not have a mechanism to prevent the rotation of either the nut or the screw a third style exists. This style locates the nut inside the actuator body just like the non-captive actuator above but on the front side a linear spline is attached to the screw, this linear spline engages a front sleeve that is rigidly fixed to the actuator this prevents the rotation of the screw and provides linear output. This style of actuator is referred to as a captive style actuator.

Fig. 5 Captive lead screw linear actuator, Size 23 stepper motor

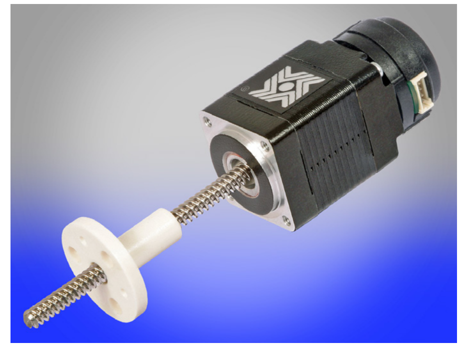
For shorter stroke length, typically less than 50mm and ones where there is no anti rotation feature present a captive style actuator can be used. The advantage here is in the simplicity of the surrounding mechanism as no anti rotation mechanism is required. The anti-rotation feature is a molded spline bushing not meant to handle large side loads but to prevent rotation of the screw relative to the motor body. In cases where severe side loading exists this sliding friction anti rotation assembly can be replaced with a ball spline that uses recirculating ball technology to increase the side load capacity of the captive linear actuator.

Captive actuators typically have the motor body secured to the assembly and the shaft can either be just pushing against the load (not fixed to it) or it can be fixed to the load provided this does not create an over constrained system. If the system is over constrained the possibility of binding would exist.

Options

There are several options that are possible with only certain styles of actuators. It is common for a rotary encoder to be used to verify the actuator has moved the correct amount even if not required for proper operation of the actuator it is a common safety measure. Rotary encoders can be accommodated on all styles of hybrid actuators.

Fig. 6 Linear actuator with encoder, Size 8 external linear stepper motor



In cases where the expense of the encoder isn't justified but one wants to assure the actuator is starting from a known position a home switch can be employed. This switch can be of either a contact (mechanical switch) or non-contact (proximity switch) type. These can be added to captive style actuators because the stroke is known and controlled, for other styles of actuators the position switch would need to be mounted another part of the assembly.

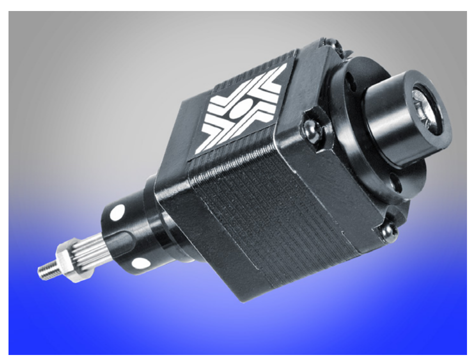


Fig. 7 Linear actuator with proximity sensor, Size 11 captive stepper motor

The lead screw and nut combination works efficiently because it has clearance between the two parts this can however result in lost motion in the system when reversing directions; to reduce this lost motion it is possible to use an anti-backlash nut on the external linear style actuator. There is a large variety of anti-backlash nuts that can be used depending upon what the most important features are. The non-captive and captive actuators only have a simple compression style anti-backlash nut as an option, it can however be applied to either side of the motor body.

WHEN TO APPLY EXTERNAL, NON-CAPTIVE and CAPTIVE STEP MOTOR ACTUATORS

Fig. 8 Anti-backlash nut assemblies, KHD (moderate loads), ZBX (light loads) with Size 8 external linear stepper motor, and ZBX (adjustable drag torque)

An additional benefit of locating the nut outside of the actuator is other nut materials are available to be used. Linear actuators with the nut internal to the motor have to use a reinforced nut material to handle the heat of the motor however this heat is not there on an external linear allowing additional un-reinforced materials to be used.

Some actuators can also be made with the drive electronics integrated into the back of the actuator, the main consideration here is that the drive be able to accommodate a screw thorough its center.

Fig. 9 Linear actuators with software programmable integrated drives, Size 17 non-captive, captive and external linear stepper motors with IDEA™ Drives

Even considering the above factors in selecting the right style of linear actuator doesn't guarantee it will work in the application; other factors may come into play such as the environment the actuator is working in. Temperature or cleanliness of the area where the linear actuator is located can have a detrimental effect on life; an external linear can be configured with a sealing area on the shaft that allows the motor to be protected from the elements and only have the screw and nut be exposed to the extremes. Through the careful selection of screw coatings and nut materials these linear actuators can operate in a variety of environments including under water and in acid fume environments. A captive linear actuator might also be able to work but would likely require a custom sealing bellows to prevent debris from entering the front of the actuator.

The three different styles of linear actuators all have unique features that lend themselves to certain applications. In all cases the linear actuators are designed to provide a linear thrust force and side loading of the screw and shaft should be avoided. Some common applications for each style are listed here:

EXTERNAL LINEAR

- Linear stages
- X-Y stages
- Lens adjustment

NON-CAPTIVE

- Security locks
- Piston pumps
- Guide width adjustment

CAPTIVE

- Hand held pipettes
- Valve control
- Solenoid replacement

These applications are just a small representation of those for which a linear actuator may be ideally suited; consideration of the above variables will help to select the most appropriate type for an application.

This technical presentation was prepared by the engineering team at Haydon Kerk Motion Solutions, a leader in linear motion technologies.

ASK THE EXPERTS
www.HaydonKerk.com

NOW... ASK us the tough motion control questions ONLINE!

http://www.haydonkerk.com/AsktheExperts/tabid/232/Default.aspx

Haydon Kerk Motion Solutions®.
A part of AMETEK® Precision Motion Control.