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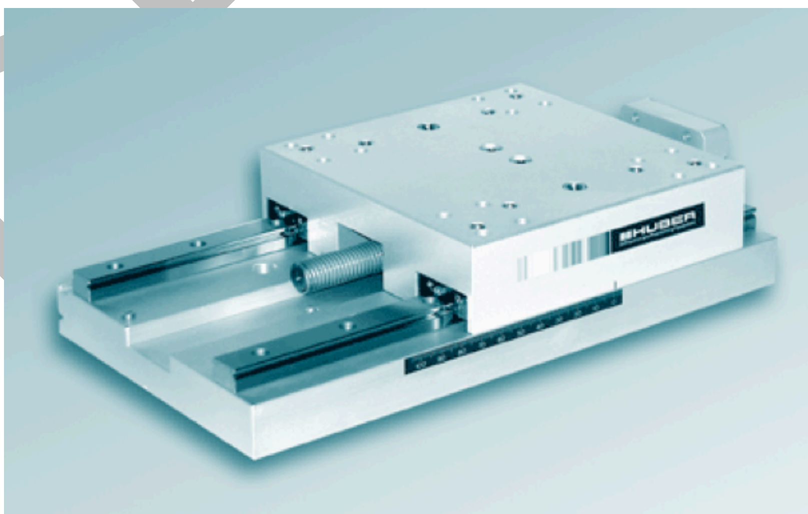
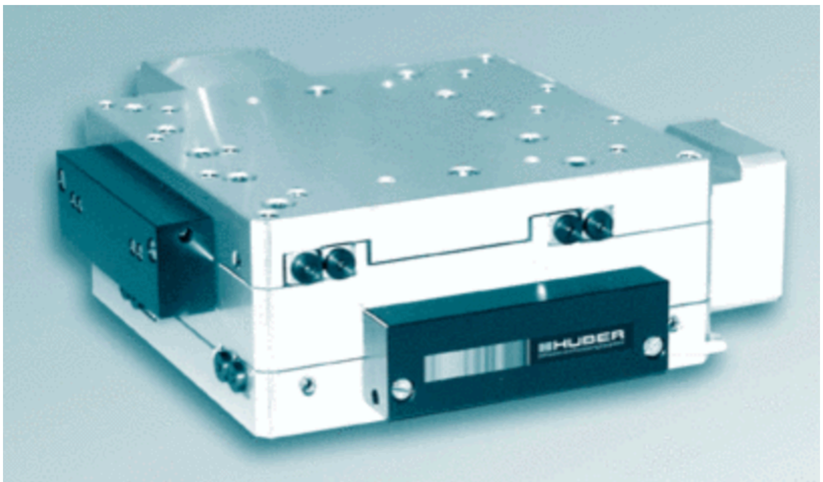
Motion Control Components

Linear actuators





European Spallation Source ESS AB
Visiting address: ESS, Tunavägen 24
P.O. Box 176
SE-221 00 Lund
SWEDEN

www.esss.se

DOCUMENT REVISION HISTORY

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List of Authors	List of Reviewers	List of Approvers
Johannes Schmidt (v1) Kristina Jurisic (v2)		

SUMMARY

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Appendix A:

LIST OF ABBREVIATIONS

Abbreviation	Definition
ESS	European Spallation Source
MCAG	Motion Control + Automation Group
ICS	Integrated Controls Systems Division
DMSC	Data Management & Software Centre
NSS	Neutron Scattering Systems
EPICS	Experimental Physics and Industrial Control System

1. INTRODUCTION

Motivated by the fact that certain applications at ESS need to provide straight motion in a preferable direction, linear actuators are inalienable, when it comes to translational sample- or object manipulation on scientific instruments. In contrast to the complexity of a robot movement, linear actuators show their advantages providing user-friendly easy handling without defining intricate trajectories, furthermore, high static and dynamic load capacity and actuating forces, maximized precision and low maintenance costs as well as compactness. Combining several linear stages allows also manipulating in each direction of an x-y-z coordinate system.

This document should serve as a guideline, facilitating the choice of a linear actuator, if needed for a certain application. Thereby, not merely comparable attitudes of thorough selected linear actuators are quoted, but rather basics about functionality of the mechanics and essential technical terms belonging linear actuators are elucidated as well.

The content of this document depicts the result of a market survey.

2. SCOPE

2.1 Introduction

Linear actuator is an actuator that creates motion in a straight line, in contrast to the circular motion of a conventional electric motor. They are used in machine tools and industrial machinery, in computer peripherals like disk drives and printers, in valves and dampers, and in many other places where linear motion is required.

The following mechanisms are used to generate linear motion from rotating motor:

- Mechanical
- Hydraulic
- Pneumatic
- Piezoelectric
- Electro-mechanical
- Linear motor

2.2 Linear actuators

A common linear actuator consists basically of a track rail (bed) as basis, a certain drive mechanic (e.g. lead screw, ball screw, timing belt, linear motor), a slide table, some kind of motor attachment as well as other mechanical links and last but not least a motor (e.g. stepper, servo) as drive for the unit. Additionally, most of the linear actuator vendors supply sensors (e.g. mechanical, inductive), to be used as limit switches or reference points and encoders (absolute, incremental) for getting positioning feedback. Fig. 1 shows a typical example of a ball screw driven linear actuator with the features even described.

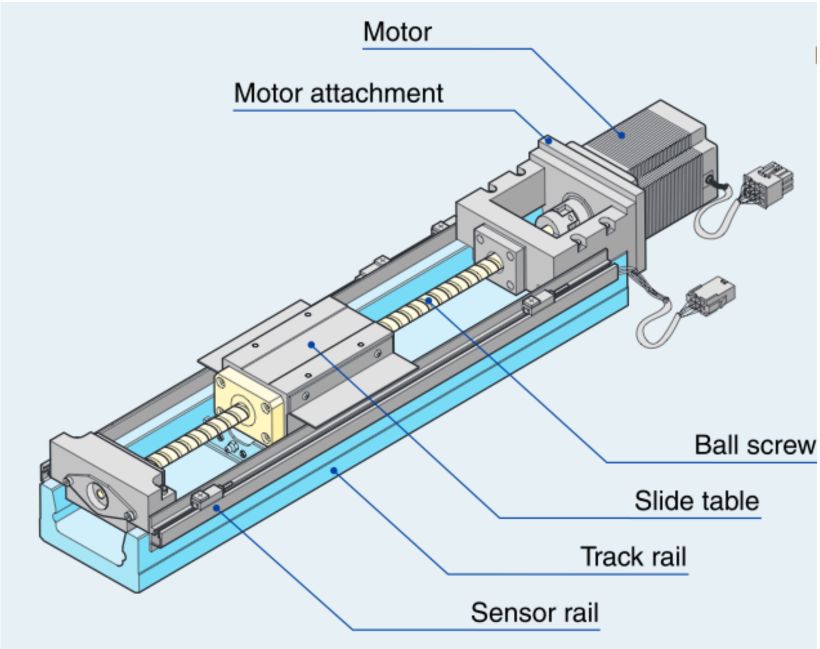


Figure 1 - typical example for a ball screw driven linear actuator []

The track rail is predominantly made of aluminum or steel and serves as carrier for the other parts of the unit. Related guide rails act as bearings for the slide table. In terms of a ball screw or lead screw drive a manufacturer-specific nut connects the drive mechanic and the slide table together, whereas a belt driven unit has accordingly clamp plates between slide table and belt instead of a nut. When it comes to a linear motor driven unit, slide table and drive are acting more or less “contactless”. It is important to distinguish between bearings connecting the slide table to the guide rails and the mechanism connecting the drive mechanics with the slide table. Sometimes it could be confusing or ambiguous, whether a criterion like “recirculating balls”, mentioned in the datasheet of a certain vendor, describes the (passive) bearings of the guide rails or the (active) drive mechanism of a slide table.

The motor (except linear motors) connected to a linear actuator converts electrical energy into torque (rotational movement). Depending on the drive mechanism, this torque is used to perform linear motion. Basically, “an electric motor mechanically connected turns a lead screw. A threaded lead or ball nut with corresponding threads that match those of the screw is prevented from rotating with the screw. When the screw rotates, the nut gets driven along the threads. The direction the nut moves depends on which direction the screw rotates and also returns the actuator to its original position.” [3]

Linear motors on a linear actuator on the contrary are a special kind of drive mechanism. They operate based on the principle of interaction between a permanent magnet assembly (see Fig. 2 – moving magnet) and a coil assembly (see Fig. 2 – stator coil). Controlling the current flowing through the coils, results in the built up/slope (changing) of magnetic fields, which produces attracting and repelling forces on the moving permanent magnet. Accordingly, the sample stage, connected to this magnet, performs the linear movement in forward- or backward direction. More detailed information about the functionality of a linear motor driven actuator is provided in chapter 2.3.3.

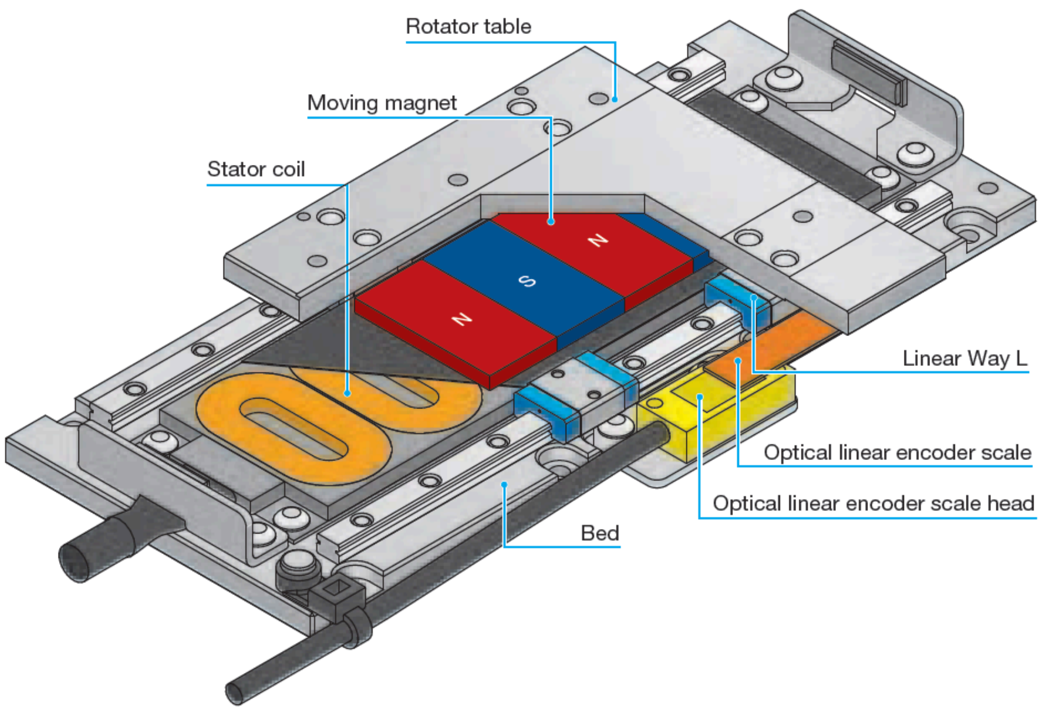
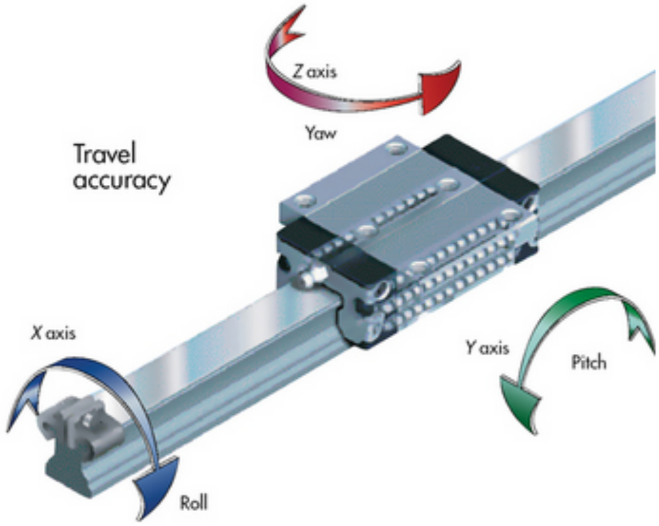


Figure 2 - typical example for a motor driven linear actuator []

2.3 Linear mechanics and parameters

2.3.1 TRAVEL ACCURACY

Travel accuracy measures pitching (up and down), yawing (side to side), and rolling (around the axis). Minimizing these motions depends on the quality of the travel guidance system and the surface it mounts on. Linear-motion systems typically conform to their mounting surfaces, so travel accuracy varies with machine surface alignment, preparation, and tolerances.



Travel accuracy measures pitching, yawing, and rolling. Minimizing these motions depends on the quality of the linear guide and the surface on which it mounts.

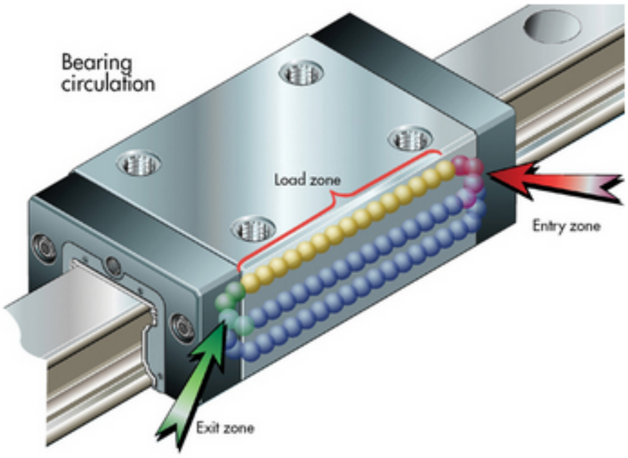
High-quality travel-guidance systems follow industry standard tolerances for height, width, and parallelism. As the tolerance band decreases, component costs increase. Spending more on components and not addressing the structural elements' flatness and straightness wastes money and diminishes travel accuracy for the axis and machine.

Also, bearings circulating inside a linear guide can cause precision-reducing vibration as the bearings transition from "load-bearing" to "nonload-bearing" conditions. Some manufacturers optimize the bearings' transition-point geometry with specialized high-precision runner blocks to minimize vibrations. For example, Bosch Rexroth's High-Precision ball rail uses a steel insert with relief zones that dampen ball-entry forces at the ends of the raceway. The result is consistent, extremely smooth motion as balls circulate in the bearing raceways.

2.3.2 POSITIONING ACCURACY

Positioning accuracy depends on the capabilities and tolerances of the drive, such as an electromechanical ball screw, hydraulic or pneumatic cylinder, electric linear motor, or rack and pinion, among others.

Ball screws can have significant lead error or lead deviation within the ball screw or ball nut — the element typically connected to and driving the load. The degree of error often depends on the manufacturing method used to generate the screw threads. Grinding can introduce lead error from the inherent machine inaccuracies, tool wear, or heating of the ball-screw shaft during the grinding process. Forming threads via rolling can introduce lead error primarily through the postprocess heat treatment.



Bearing circulation can cause precision-reducing vibration during the transition from load-bearing to nonload bearing zones in the runner block. High-precision runner blocks are designed to provide extremely smooth motion as the balls circulate in the bearing raceways.

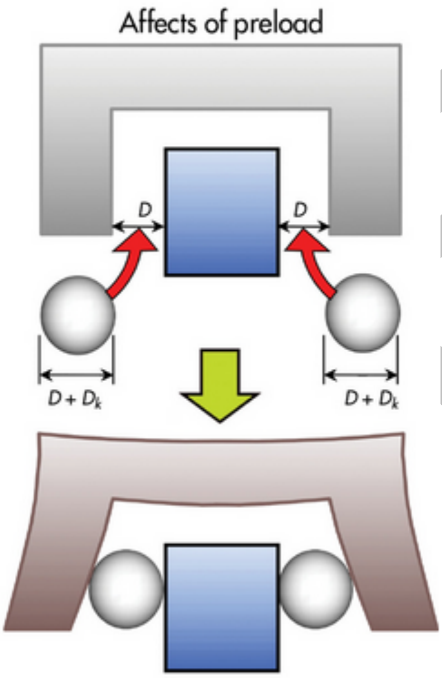
Grinding has traditionally been recognized as more accurate than rolling, but the gap is narrowing. Some Rexroth rolled screws deliver Class 5 or even Class 3 precision for travel (lead) deviation, with a maximum deviation of ±12 µm across 300 mm of travel. Electronic correction techniques, which compensate for small lead errors across standard travel runs, can further improve accuracy. The "Correction in the Control" graphic shows a corrected lead deviation of up to 13 µm across 700 mm of travel.

Adding external feedback to the machine axis can also improve positioning accuracy. This can be done indirectly using a rotary encoder or directly using a linear scale.

2.3.3 SYSTEM STIFFNES

This is an area where mechanical factors often reduce the efficiency of the finest controls. The machine's frame and base rigidity, thickness, material (for instance, aluminum versus steel), and frame construction (solid or tubular) can all have an impact on precision. Mechanical-drive-based factors such as preload, axis length, types of antifriction elements and bearing support, as well as the fasteners connecting the linear-motion system to the frame can all indirectly influence machine precision.

System stiffness is critical because any force or load applied to the motion components — downward, upward, or sideways — can cause deflection, an enemy of repeatability. Greater force produces more deflection. To combat this, designers often improve the overall rigidity or stiffness of the linear-guide block by introducing preload with oversized antifriction elements. The "Affects of Preload" graphic shows a typical preload, using oversized rolling elements (D_k) in the guide-rail gap (diameter D). Linear-guide manufacturers typically offer widely varying levels of preload to minimize deflection.



One way to correct for elastic deflection is to preload linear guides with oversized antifriction components.

The drive can contribute to total system rigidity through the stiffness of its support bearings, ball-nut unit, and the ball screw itself. The biggest factor affecting the stiffness of the screw drive is its length: the longer the screw, the harder it is to compensate for deflection. Compensation techniques include extra preload or selecting a stiffer ball nut.

2.3.4 SPEED

Demanding, high-throughput applications present tough challenges because short cycle times sometimes have speed requirements that tax the limits of linear-guide and ball-screw speed and acceleration capabilities.

The first limit is the ball-screw shaft's critical speed — the speed at which the screw vibrates or oscillates excessively (known as screw whip). This speed depends largely on the shaft length and bearing supports. The ability of designers to alter critical speed is limited mainly to the choice of end-bearing supports. Fixed-fixed mountings (where bearing are constrained at both ends of the screw) allow the highest critical speeds, and fixed-free systems, the lowest.

With a fixed mounting, the bearing arrangement is truly fixed on the screw and has a bearing set designed to support axial loading. Floating mountings may be chosen because they introduce less friction, allowing better thermal performance, but they have a lower critical speed than fixed mountings. Floating mountings typically use just a radial bearing to support the radial load or weight of the screw out in space. This arrangement gets its floating name as the bearing is allowed to float or move in the pillow-block housing as the screw spindle expands and contracts due to temperature changes.

The second limitation is the bearing system's characteristic speed, based on the circulation of antifriction elements. In the case of a ball screw, the ball nut represents the bearing system.

Temperature, vibration, and inertia of the balls all play a role. The characteristic speed is often called the Dn factor, calculated by:

$d_0 \times n \leq D_n$

where d_0 = ball-screw nominal diameter (mm) and n = speed in rpm.

The lower of the two speeds is most critical for precise motion control. Characteristic speed is independent of shaft length, but critical speed declines as length increases. When a system reaches critical speed, vibration increases, accuracy drops, and performance (for example, machining surface-finish quality in a machine tool) will diminish. In addition, the ball-screw assembly will fatigue much faster.

More on:

http://machinedesign.com/motion-control/six-keys-more-precise-linear-motion

2.4 Transmission

2.4.1 GENERAL PRINCIPLE

Most electromechanical linear actuators incorporate a lead screw and lead nut, while some use a ball screw and ball nut. In either case, the screw may be connected to a motors or manual control knob either directly or through a series of gears.

Gears are typically used to allow smaller, weaker motor, rotating at a higher RPM to be geared down to provide the torque necessary to rotate the screw under a heavier load than the motor would otherwise be capable of driving directly. Generally speaking, this approach effectively sacrifices linear actuator speed in favour of increased actuator thrust. In some applications, the use of a worm gear is common, as this approach allows a smaller built in dimension, while allowing for greater travel length.

The following provides summarized basics on different drive mechanics. For more detailed information on how to specify, configure and calculate certain parameters of drives, the reference hereby is made to the remarks concerning [4].

2.4.2 BALL SCREWS

"Ball-screw-driven actuators use a ball screw and a train of recirculating ball bearings contained in a nut to convert rotary motion to linear motion (or vice versa). Bearing balls travel in opposed, hardened ball tracks located in an axially translating ball nut and on a stainless-steel rod. The rod track or groove is cut at a particular helix angle and the matching helical grooves, and balls, which roll between these grooves providing the only contact between the nut and the screw.

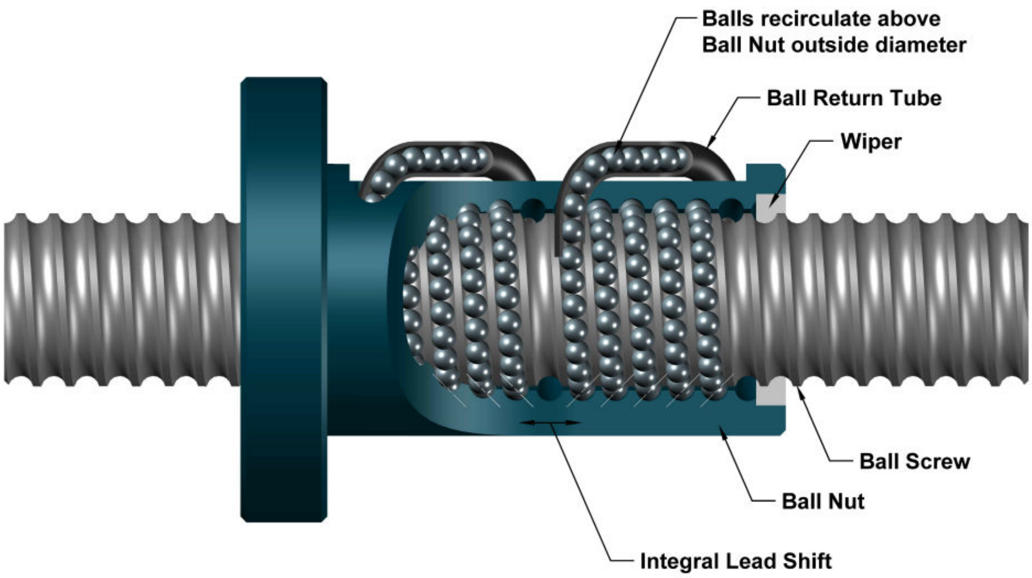
Screw pitch scales with the rod helix angle and is defined as the distance between adjacent screw threads. The lead — defined as the pitch of the screw multiplied by the number of threads — specifies the linear travel of the ball nut per revolution of the screw. Screws with greater pitches axially move a nut faster for a given screw rpm. Smaller-lead screws lower the amount of drive torque needed to move an object and therefore produce greater linear force (thrust).

Either an internal reversing system or a series of external return tubes circulate the balls. Balls are in compression when riding in the ball track, and unloaded in the return system. They are preloaded to eliminate axial play between the nut and screw. Actuator manufacturers typically use oversized ball bearings to adjust preload.

Ball-screw actuators tend to be rigid, highly accurate and precise, because bearing balls have little compressibility, and the actuators themselves are held to tighter manufacturing tolerances. A low rolling friction of the recirculating balls means drive mechanisms are typically over 90% efficient, which lowers energy consumption and wear.

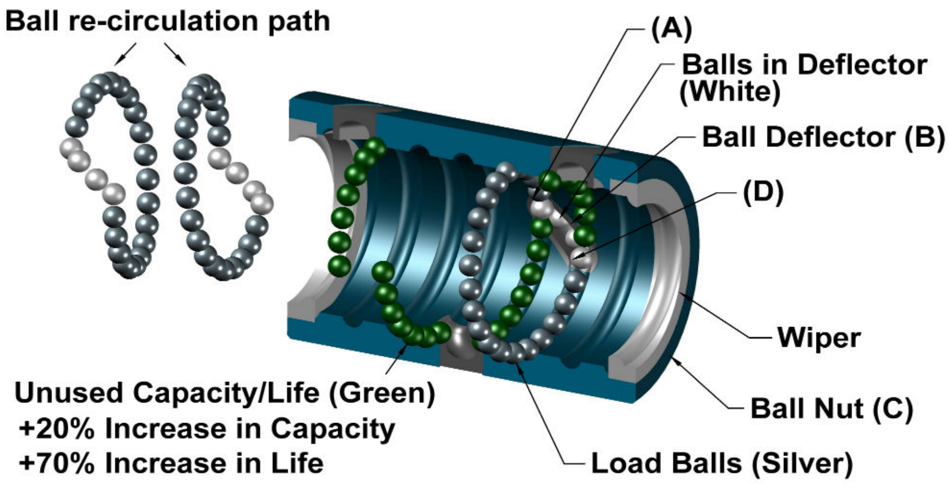
Ball-screw actuators can have lifetimes exceeding 5,000 km when operated at low speeds and loads. Higher loads and speeds approaching 1 to 1.5 m/sec shorten lifetimes to about 3,000 km. Ball-screw actuators are length limited by the critical speed of the screw. Critical speed scales with screw diameter and is inversely proportional to the square of (unsupported) screw length. In other words, smaller-diameter screws for a given unsupported length have a lower critical speed than larger-diameter screws. In addition, manufacturers employ different methods of supporting the screw to increase critical speed." [1]

The ball nut determines the load and life of the ball screw assembly. The ratio of the number of threads in the ball nut circuit to the number of threads on the ball screw determines how much sooner the ball nut will reach fatigue failure (wear out) than the ball screw will. [2]



External Ball Return System

In this type of return system, the ball is returned to the opposite end of the circuit through a ball return tube, which protrudes above the outside diameter of the ball nut. [2]

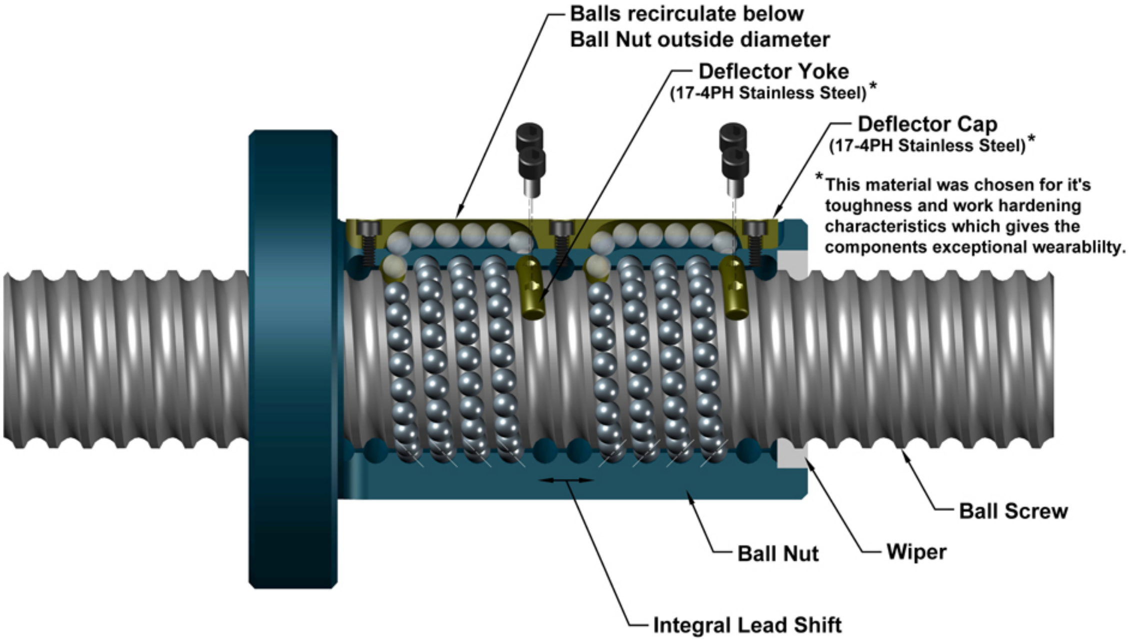


Internal Ball Deflector Type Return System

The ball is returned through or along the nut wall, but below the outside diameter. (There are several variations of this type of return system)

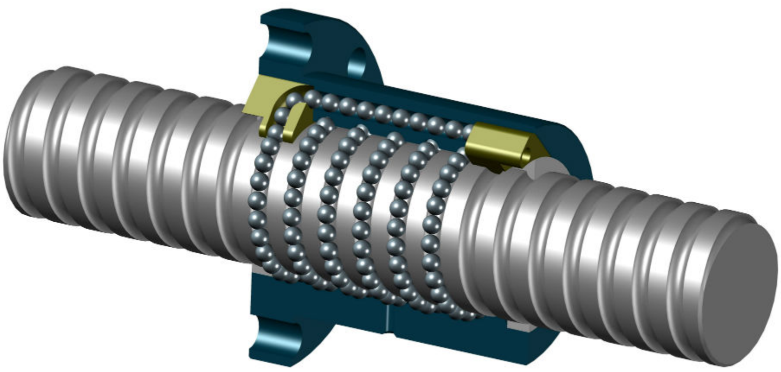
Example (1): Some manufacturers have one-revolution circuits where the balls are forced to climb over the crest of the thread on the screw by the return system. This is known as a crossover deflector type internal return system. In the cross-over deflector type of ball nuts, the balls make only one revolution of the shaft and the circuit is closed by a ball deflector (B) in the nut (C) allowing the ball to cross over between adjacent grooves at points (A) and (D). [2]

Example (2): The Internal Ball Return System. In this type of return system, the ball is returned to the opposite end of the circuit through or along the nut wall, but below the outside diameter through a "V" cap. [2]



Internal Ball Return System

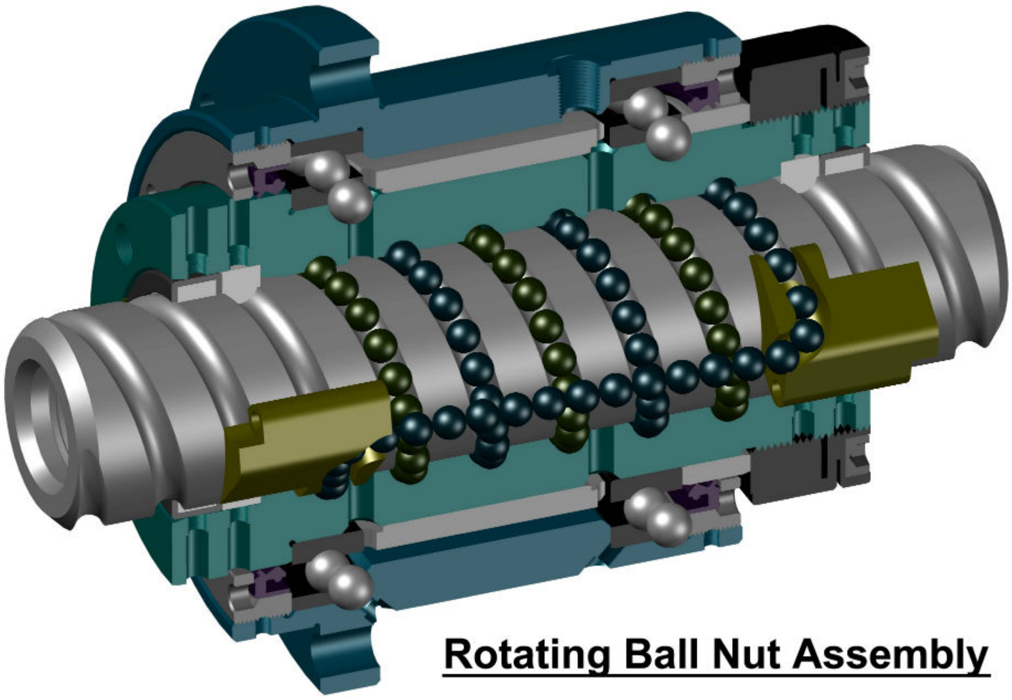
Example (3): The Tangential Internal Ball Return System. For high speed or high load applications a tangential ball return system is used. This provides a very smooth flow of balls at any speed in a limited amount of space. This is a very durable ball return system and is also used on high load carrying applications. [2]



Rotating Ba

Tangential Ball Return System

When a long ball screw rotates at high speed it can begin to vibrate once the slenderness ratio reaches the natural harmonics for that shaft size. This is called the critical speed and can be very detrimental to the life of a ball screw. The safe operating speed should not exceed 80% of the critical speed for the screw. [2]



Still some applications require longer shaft lengths and high speeds. This is where a rotating ball nut design is needed. [2]

2.4.3 ROLLER SCREWS

Roller screw, also known as a planetary roller screw or satellite roller screw, is a low friction precision type actuator, a mechanical device for converting rotational motion to linear motion or vice versa. Planetary roller screws are used as the actuating mechanism in many electro-mechanical linear actuators. Because of its complexity the roller screw is a relatively expensive actuator (as much as an order of magnitude more expensive than ball screws) but may be suitable for high precision, heavy load, long life and heavy use applications.

Roller screws mechanisms are commonly incorporated into motion/positioning systems in a variety of industries such as manufacturing and aerospace.

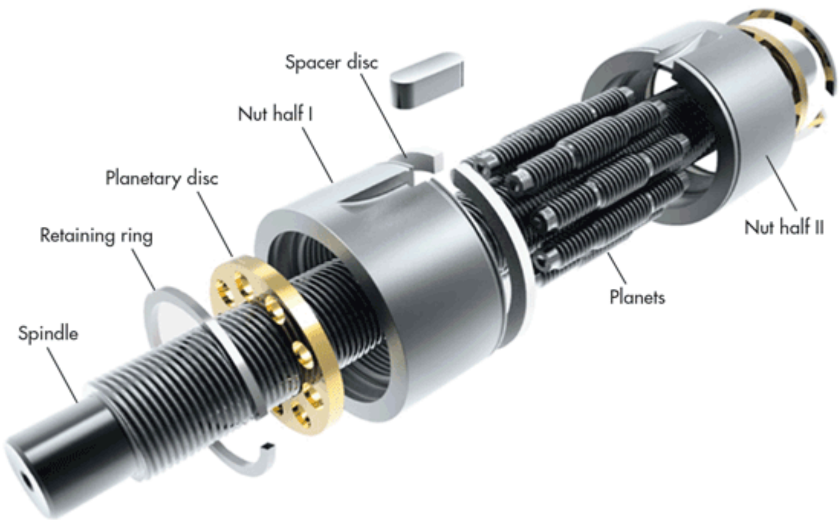
Principle of operation

A roller screw is a mechanical actuator similar to a ball screw that uses rollers as the load transfer elements between nut and screw instead of balls. The rollers are typically threaded but may also be grooved depending on roller screw type. Providing more bearing points than ball screws within a given volume, roller screws can be more compact for a given load capacity while providing similar efficiency (75%-90%) at low to moderate speeds, and maintain relatively high efficiency at high speeds.

Roller screws can surpass ball screws in regard to:

- positioning precision
- load rating
- rigidity
- speed
- acceleration
- lifetime

The three main elements of a typical planetary roller screw are the crew shaft, nut and planetary roller, the screw, a shaft with a multi-start V-shaped thread, provides a helical raceway for multiple rollers radially arrayed around the screw and encapsulated by a threaded nut. The thread of the screw is typically identical to the internal thread of the nut. The rollers spin in contact with, and serve as low-friction transmission elements between screw and the nut. The rollers typically have a single start thread with convex flanks that limit friction at the rollers contacts with screw and nut. The rollers typically orbit the screw as they spin (in the manner of planet gears to the sun gear) and are known as planetary or satellite rollers. As with a lead screw or ball screw, rotation of the nut results in screw travel, and rotation of the screw results in nut travel.



Comparison Roller vs Ball screw

Roller vs Ball Screw Performance – Comparisons:

Loads and Stiffness: Due to design factors, the number of contact points in a ball screw is limited by the ball size. Exlar's planetary roller screw designs provide many more contact points than possible on comparably sized ball screws. Because this number of contact points is greater, roller screws have higher load carrying capacities, plus improved stiffness. In practical terms, this means that typically an Exlar roller screw actuator takes up much less space to meet the designer's specified load rating.

Travel Life: As you would expect, with their higher load capacities, roller screws deliver major advantages in working life Usually measured in "Inches of Travel," the relative travel lives for roller and ball screws are displayed on the graph on page 3. As you can see there, in a 2,000 lb. average load application applied to a 1.2 inch (approximate) screw diameter with a 0.2 inch (approximate) lead, you can predict that the roller screw will have an expected service life that is **15 Times Greater.**

Speeds: Typical ball screw speeds are limited to 2000 rpm and less, due to the interaction of the balls colliding with each other as the race rotates. In contrast, the rollers in a roller screw are fixed in planetary fashion by journals at the ends of the nut and therefore do not have this limitation. Hence, roller screws can work at 5000 rpm and higher – producing comparably higher linear travel rates.

Figure 3 - http://www.consultolsen.com/roller_screw_linear_actuators.html

2.4.4 BELT DRIVES

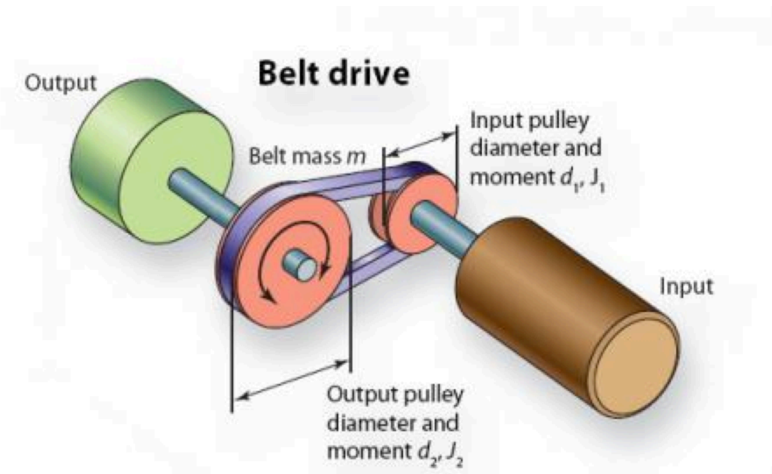


Figure 4 - http://machinedesign.com/archive/basics-configuring-drives

Overview

Belt-driven actuators, in contrast, are optimized for high speeds. They are limited in length only by the actuator profile itself, or about 3 that of equivalent ball-screw actuators.

Belt driven actuators are an excellent choice if a design requires speed and force. Using a grooved belt instead of a lead screw, these mechanisms are ideal for horizontal applications with the need for speed and longer strokes. With a toothed timing belt that runs between geared pulleys, the motor's driving torque is converted into a tangential linear force; gear heads are sometimes used to increase the force output and load capabilities of belt drive systems.

Mechanics

Belt-driven actuators use a synchronous, toothed timing belt to run two geared pulleys mounted at each end of an actuator profile. One pulley acts as the driving gear, and the other as the driven gear. A motor coupled to the drive pulley converts rotary torque to tangential force. Actuator thrust scales with pulley diameter. Linear speeds and accelerations are mostly limited by the guiding mechanism, not by the belt or pulleys.

Belt-driven actuators typically employ either a recirculating ball-bearing guide or a roller guide. Recirculating guides combine high dynamic load capability with high speeds. Roller guides excel in light-duty, extremely high-speed applications.

Belts made of a synthetic rubber, such as polychloroprene, surrounding a core of either metallic or fiberglass strands are lightweight, flexible, and have an extremely high tensile strength. Belt teeth come in different shapes, the most common of which are a rounded tooth or a trapezoidal-shaped tooth. Trapezoidal teeth can transmit more power, while rounded teeth, or self-tracking circular teeth, reduce noise and vibration. Regardless of design, teeth are covered with a nylon fabric for low friction and wear resistance. Belt drives require little maintenance except for the belt itself, which generally lasts about 2,500 to 5,000 km (up to 15 km in some cases).

Environments

Belt drives are usually a source of noise. The frequency of the noise level increases proportionally with the belt speed. The higher the initial belt tension, the greater the noise level. The belt teeth entering the pulleys at high speed act as a compressor and this creates noise.

Belt drives are inherently efficient. It can be assumed that the efficiency of a synchronous belt drive is greater than 95%.

Typically belt driven actuators are not utilized in vertical systems without a motor brake, as there is a risk of sending the load into free fall if there was a loss of power. Belt driven actuators are ideally suited for horizontal loads and make for the better choice for mechanisms require long strokes and high speeds.

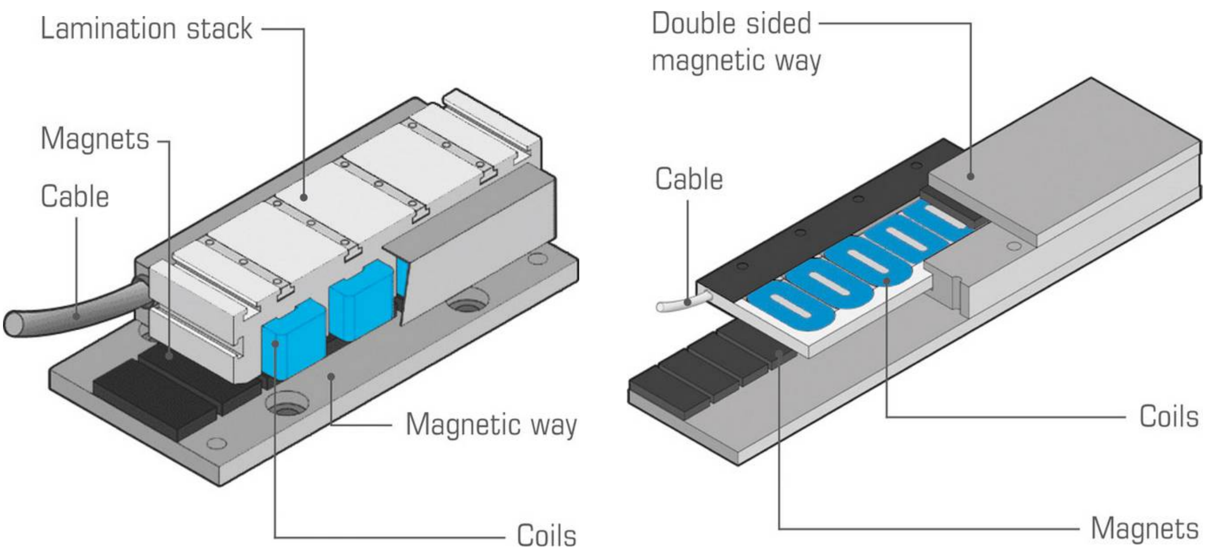
Steven Buffamonte - Product Management Specialist
Festo Corp.

http://www.orientalmotor.com/technology/articles/ezsII-glossary-linear-slide-terms.html

http://www.myostat.ca/ball-screw-versus-belt-driven-actuators

http://file.lasersaur.com/docs-thirdparty/The_World_of_Timing_Belts.pdf

2.4.5 LINEAR MOTOR DRIVES



Linear motors are a special class of synchronous brushless servomotors. They work like torque motors, but are opened up and rolled out flat. Through the electromagnetic interaction between a coil assembly (primary part) and a permanent magnet assembly (secondary part), the electrical energy is converted to linear mechanical energy with a high level of efficiency. Other common names for the primary component are motor, moving part, slider or glider, while the secondary part is also called magnetic way or magnet track.

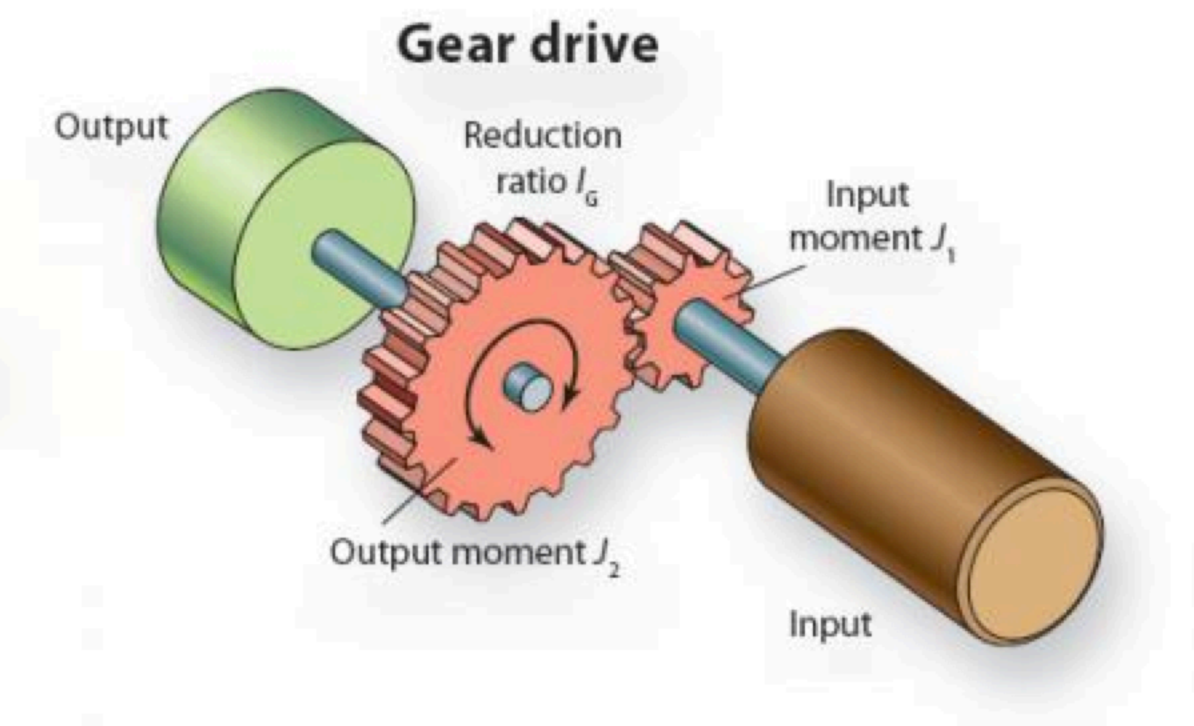
Since linear motors are designed to produce high force at low speeds or even when stationary, the sizing is not based on power but purely on force, contrary to traditional drives.

The moving part of a linear motor is directly coupled to the machine load, saving space, simplifying machine design, eliminating backlash, and removing potential failure sources such as ball screw systems, couplings, belts, or other mechanical transmissions. Finally, the bandwidth and the stiffness of the motion system are much higher, giving better positional repeatability and accuracy over unlimited travel at higher speeds.

Given that frameless linear motors do not include a housing, bearings, or feedback device, the machine builder is free to select these additional components in order to best fit the application requirements.

http://www.etel.ch/linear-motors/principle/

2.4.6 GEAR DRIVES



These drives are used to provide a variable output speed from a constant-speed power source (as in a machine tool driven by a constant-speed ac motor) or to provide torque increase for a variable-speed power source (as in an automobile). Variable mechanical drives are less costly than competing electrical variable-speed drives and their control is much simpler. But mechanical drives often are not as durable and cannot be controlled as precisely as electrical drives. And except for gear drives, the mechanical type generally cannot transmit as much power as electrical drives when variable speed is essential.

http://machinedesign.com/archive/straight-talk-linear-actuators

http://machinedesign.com/bearings/three-life-changing-environments-bearings

http://machinedesign.com/basics-design/gear-drives

2.4.7 RACK AND PINION

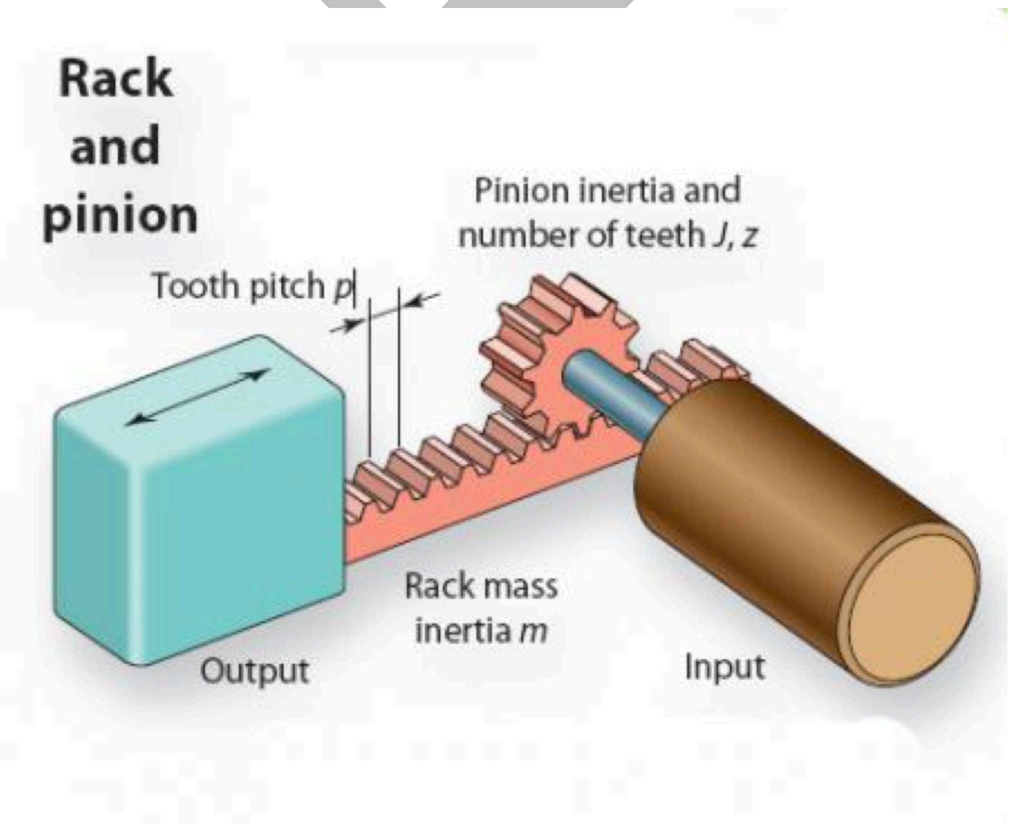


Figure 5 - http://machinedesign.com/archive/basics-configuring-drives

http://www.wittenstein-rack-pinion.com/site/en/The-Linear-System/Systems/Pages/Precision-System.aspx

2.5 Motor

There are many types of motors that can be used in a linear actuator system. These include DC brush, DC brushless, stepper, or in some cases, even induction motors. It all depends on the application requirements and the loads the actuator is designed to move. For example, a linear actuator using an integral horsepower AC induction motor driving a lead screw can be used to operate a large valve in a refinery. In this case, accuracy and high movement resolution aren't needed, but high force and speed are. For electromechanical linear actuators used in laboratory instrumentation robotics, optical and laser equipment, or X-Y tables, fine resolution in the micron range and high accuracy may require the use of a fractional horsepower stepper motor linear actuator with a fine pitch lead screw. There are many variations in the electromechanical linear actuator system. It is critical to understand the design requirements and application constraints to know which one would be best.

Selecting the motor for linear actuator:

http://blog.tolomatic.com/bid/77398/stepper-or-servo-selecting-the-best-motor-for-your-linear-actuator

2.6 Encoder

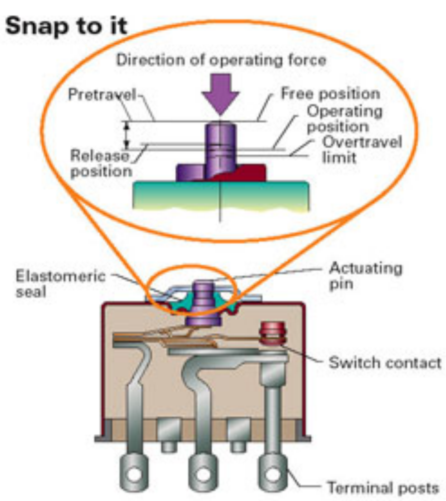
http://www.anaheimautomation.com/manuals/forms/encoder-guide.php#sthash.51xBrOZG.dpbs

2.7 Limit switches

Linear limit switches are frequently used to limit the motion of linear actuators.
Linear limit switches may use mechanical or solid state means to detect an object and switch a load.

Electromechanical switches

Electromechanical limit switches use arms, levers, knobs, plungers, or other actuators that make physical contact with another object. When the object contacts the actuator, the switch's contacts either make or break a connection depending on the switch's contact orientation.



Because of the physical nature of operation, mechanical limit switches are subject to wear but are often manufactured as extremely rugged devices to compensate. Other advantages include high current switching capability (typically up to 10 A), excellent environmental resilience, and low cost. However, mechanical limit switches may be limited by the need to make physical contact with an object.

Solid state switches

Solid state limit switches contain no moving parts. They detect objects using an optical sensor or other electronic device, and switch using solid state components such as resistors, capacitors, and transistors. While solid state devices usually have longer operating lives than electromechanical types, they are also more expensive.

More on:

http://www.globalspec.com/learnmore/electrical_electronic_components/switches/linear_limit_switches

3. GLOSSARY OF TERMS AND DEFINITIONS

Motion Control Coordinate System

Any positioning stage is considered to have six degrees of freedom: three linear, along the x, y, and z-axes and three rotational about those same axes (see Figure 1). All motions described here follow the right-hand coordinate system convention. The cross product of the +X and +Y axes (second and third fingers) is the +Z axis (thumb). Also, if the thumb of the right hand points in the positive direction of an axis, the fingers will wrap around the axis in the direction of positive rotation about that axis. All movements are composed of translations along and/or rotations about the coordinate axes. Generally, the X and Y axes are on the horizontal plane, the direction of travel of the first or bottom stage being aligned with the X axis, and the Z-axis as vertical.

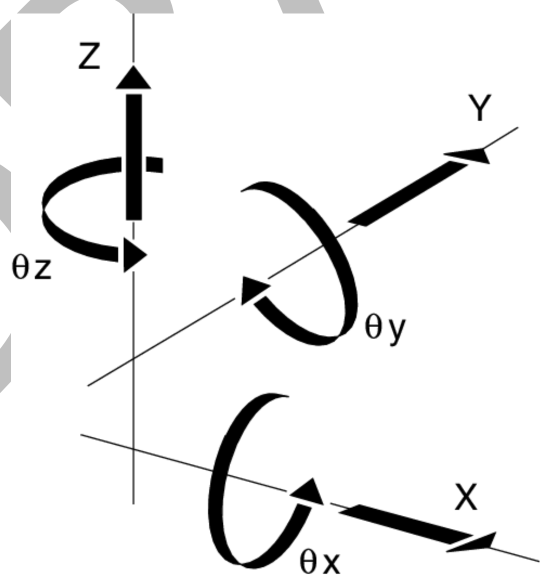


Figure 6 - Right-hand coordinate system showing six degrees of freedom

Accuracy

Accuracy is a measure of the degree to which a given displacement, linear or rotary, conforms to an agreed upon standard. The accuracy of a motion system can be highly influenced by the test set up, environmental conditions, and the procedure used to measure displacement. In the micron and submicron world, thermal expansion can have a profound impact upon accuracy, particularly when temperatures are not constant or well controlled. Other common parameters that adversely affect accuracy include cosine error and Abbe error. Additionally, undesired motion in any of the six degrees of freedom will produce added uncertainty. For multi-axis systems, the influence of a combination of stages must be considered.
Accuracy is sometimes confused with incremental motion. For example, consider a screw-driven stage. If the drive screw has a pitch of 1 mm and is directly driven by a 200 step-per-revolution stepper motor, this does not necessarily mean the stage has an accuracy of 0.005 mm (proportional to one motor step). Variations in screw pitch and motor step angle must be included in accuracy analysis. Likewise, a stage utilizing a glass scale encoder has its own

accuracy considerations that must be taken into account. The latter includes scale accuracy, alignment of the scale to the stage axis of motion (cosine error), alignment between read head and scale, and interpolation of the encoder signal.
Newport's accuracy and other performance measurements are conducted in a well-controlled environment (20 degrees Celsius with corrections made for atmospheric pressure and humidity). Tests are conducted in accordance with a written procedure that governs the set up, method, equipment and data analysis. Recognized national and international standards, including ISO-230 and ASME B5.57, guided the establishment of our procedure. All pertinent equipment is carefully maintained, regularly calibrated in accordance with accepted procedures and traceable to recognized national standards.

Absolute Accuracy

Absolute Accuracy is the actual output of a system versus the commanded or ideal input. It is more intuitively called inaccuracy. For example, when a motion system is commanded to move 10 mm and actually moves 9.99 mm, as measured by a perfect ruler and a test procedure that conforms to suitable standards, the deviation from the commanded position is 0.01 mm. Accuracy may be expressed per unit distance of travel or over the full travel of the stage. For example, a 200 mm travel stage may be specified as having an accuracy of 5 micrometers per 100 mm of travel or possibly 8 micrometers over its full travel.

On-Axis Accuracy

On-Axis Accuracy with Linear Error Compensation is the deviation from absolute accuracy along the defined axis of travel after compensation of linear error sources have been accounted for. Linear or monotonically increasing errors include cosine error, inaccuracy of the lead screw pitch, angular deviation at the measuring point (Abbe error), and thermal expansion effects. Graphically, these errors can be approximated by the slope of a best fit, straight line on a plot of position versus deviation (Figure 7). Knowing the slope of this line (error/travel), we can approximate absolute accuracy as:

Absolute Accuracy = On-Axis Accuracy + (Slope x Travel)

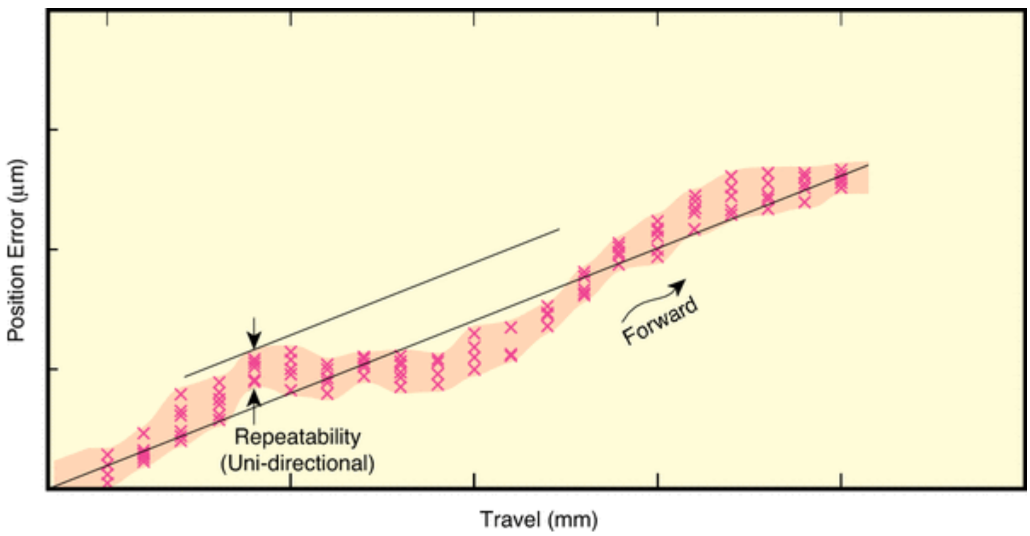


Figure 7 - Slope of straight line fit for linear deviation compensation

Repeatability

There are two types of repeatability: unidirectional and bidirectional. They are not the same as accuracy. Thus, a system may be very repeatable yet lack in accuracy. Figure 4 graphically depicts the difference between accuracy and repeatability.

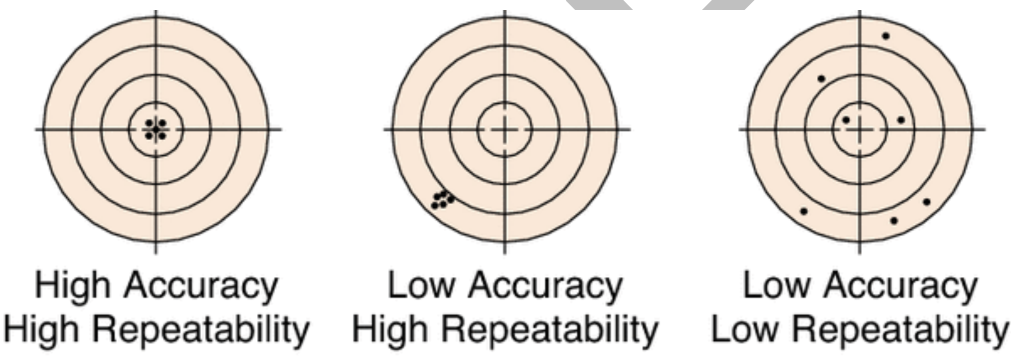


Figure 8 - http://www.newport.com/Motion-Basics-and-Standards/140230/1033/content.aspx

Unidirectional repeatability

Unidirectional repeatability is a measure of the ability of a system to achieve a commanded position over many attempts when approached from the same direction. Each position must be approached from a distance greater than the reversal value to achieve an accurate representation of repeatability. Figure 5 graphically represents unidirectional performance data. All positions are approached five times from the same direction. The dots represent the spread of the data at each position. (Note: Overlapping dots may give the appearance of fewer than five values at some positions.)

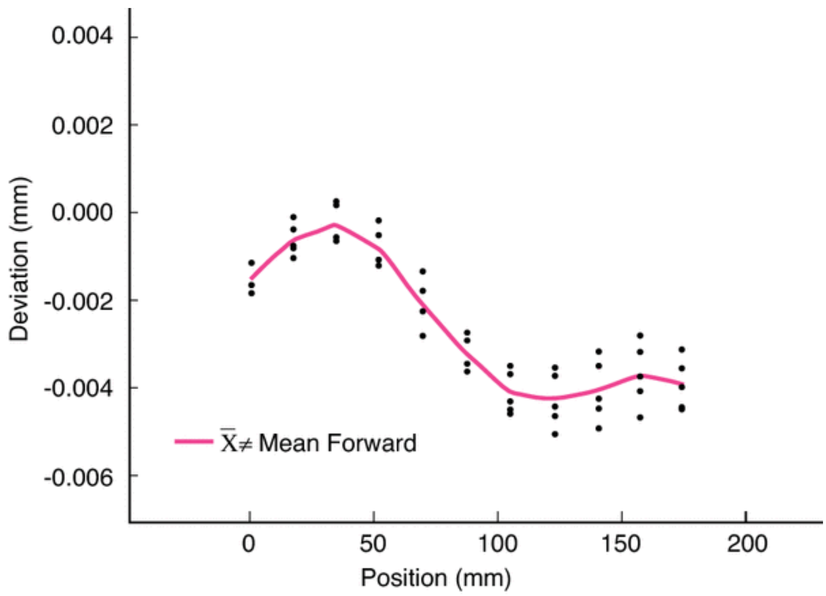


Figure 9 - Unidirectional test data obtained from a linear stage showing the deviation at each position of measurement

Bidirectional repeatability

Bidirectional repeatability is a measure of the ability of a system to achieve a commanded position over many attempts when approached from either direction. Each position must be approached from a distance greater than the reversal value to achieve an accurate representation of repeatability. Figure 6 graphically represents bi-directional performance data. Vertical separation of the forward and reverse data is caused by the reversal value. Ten values are presented at each position: Five in the forward and 5 in the reverse directions. Like the unidirectional example, the dots represent the spread of the values at each position. All positions are approached from a distance that is greater than the reversal value. (Note: Overlapping dots give the appearance of fewer than five values at some positions.)
Figures 5 and 6 illustrate data that may be used to assess the accuracy and repeatability of a stage.

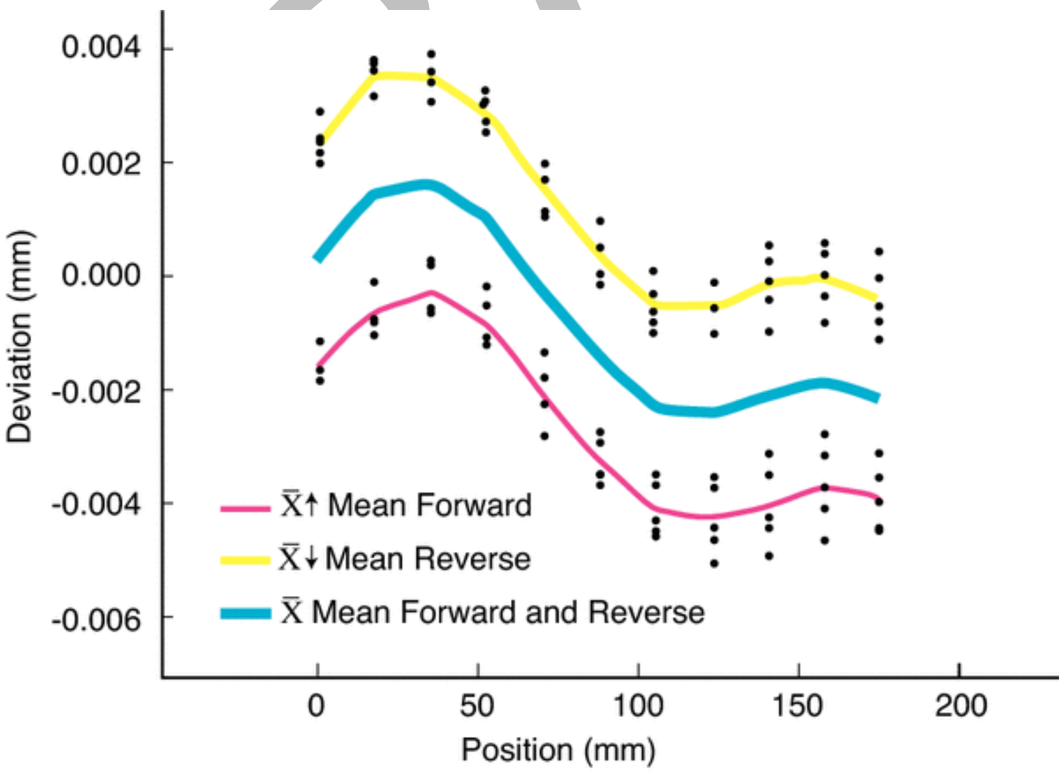


Figure 10 - Bidirectional test data obtained from a linear stage showing the deviation at each position in the forward and reverse direction. The vertical offset between the forward and reverse directions is due to the reversal value.

Reversal Value

Reversal Value is the difference between the positional values obtained for a given position when approached from the two opposite directions of travel. This value is a combination of backlash and hysteresis. In motion systems made up of several interacting components, it is difficult to completely isolate backlash and hysteresis. Figure 2 is a graphical representation of Backlash and Hysteresis.

Backlash

Backlash is a component of the reversal value. It is the result of relative movement between interacting mechanical parts of a drive system that does not produce output motion. Contributing factors include clearance between mechanical parts such as gear teeth and mechanical deformation. Although not all systems have backlash, backlash affects bi-directional repeatability and accuracy. However, backlash is usually quite repeatable and can thus be compensated for by all Newport controllers in many applications. Backlash also affects precision alignment and tracking applications as it provides a discontinuity between commanded motion and output motion when reversing direction. Hence, 100% compensation for backlash is not recommended for these applications which may lead to undesirable results.

http://www.aerotech.com/media/247131/section%202_linear%20stage%20terminology.pdf

http://www.parkermotion.com/engineeringcorner/linearmechanics.html

Hysteresis

Hysteresis is a component of the reversal value that is dependent on the recent history of the system. It is observed when the forces acting on a system reverse direction and is the result of elastic forces in the various components. It affects both bi-directional repeatability and accuracy. Hysteresis can also affect precision alignment and tracking applications, as the output motion is not linear to the input motion when reversing the direction of motion. Different than backlash, hysteresis is present in all mechanical systems even if its value might be low.

Resolution

Resolution, also referred to as display or encoder resolution, is the smallest increment that a motion system can be commanded to move and/or detect. It is not the same as the Minimum Incremental Motion. A system may or may not be able to consistently make incremental moves equal to the resolution. Factors that can affect a move include friction, load, external forces, system dynamics, controller, vibrations, and inertia. (See also the discussion about Minimum Incremental Motion.)

Minimum Incremental Motion

Minimum Incremental Motion (MIM) is the smallest increment of motion a device is capable of consistently and reliably delivering. It should not be confused with resolution, which is typically based on the smallest controller display value or smallest encoder increment. Resolution can be significantly smaller than the smallest actual motion output, a key distinction, but unfortunately very rarely disclosed. Newport specifies the minimum incremental motion with most of its products. Others refer to it as "practical resolution". Two different test methods are used depending on the capabilities of the stage.

With stages where the minimum incremental motion is limited by friction in the drive train, a high number of small incremental motion is commanded in the forward and then in the reverse direction. The actual displacement with each step is measured with an external tool like a laser interferometer or an autocollimator. It is important to use an external tool for this measurement as the encoder position might indicate an accurate display, but the actual motion of the stage carriage does not match this encoder displacement. As a rule of thumb, Newport specifies as Minimum Incremental Motion, the smallest step size where 3X the standard deviation of the actual displacements is smaller than the commanded step size. This ensures that an individual step will result in a real displacement within a certain tolerance. Figure 2 shows the results of such a measurement for an MFA-CC linear stage. In the graphical representation, the distribution of the actual displacements is shown, resulting in an MIM of 0.1µm. This test method allows a detailed analysis of the stage's backlash (no output motion when reversing direction of motion) and hysteresis (non-linear output motion when reversing direction of motion due to elastic forces in the drive train) of the stage at the same time.

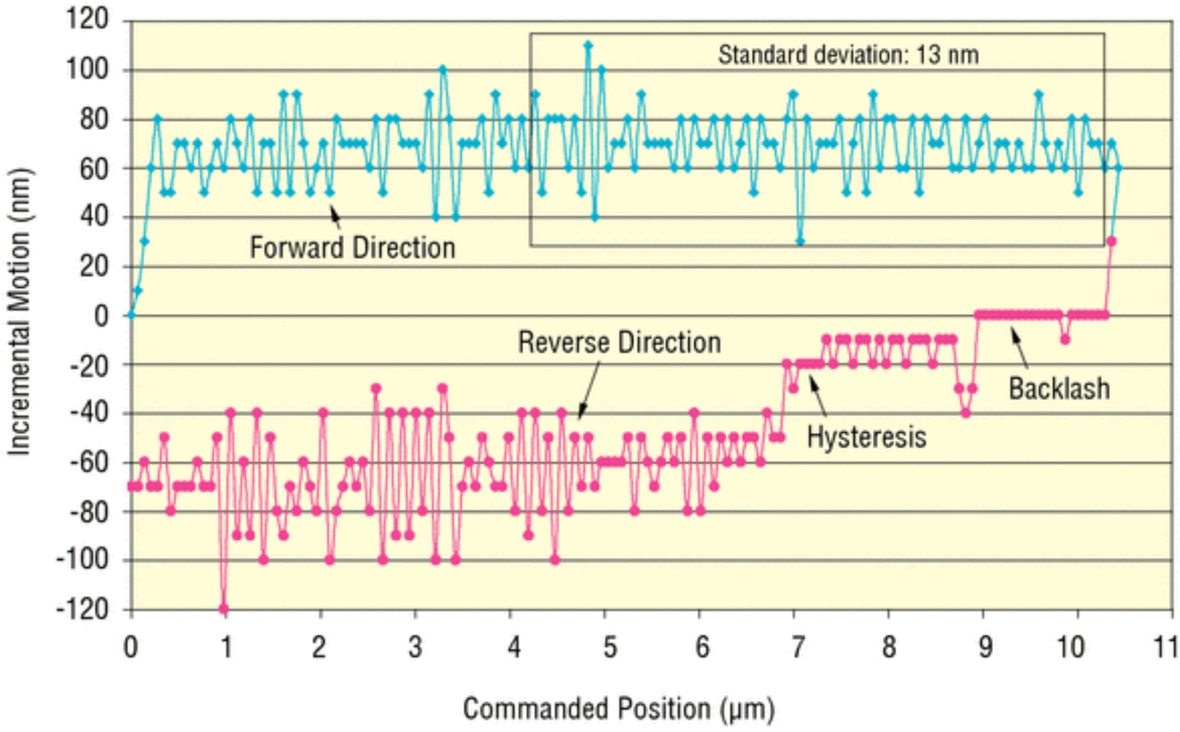


Figure 11 - Minimum incremental motion of an MFA-CC linear stage

For stages where the MIM is limited only by noise, an alternative test method is used. A smaller number of incremental motion is commanded in the forward and then in the reverse direction and the actual position is recorded at a high frequency. Again, the actual position is measured with an external tool, which can be quite different from the encoder position. The high temporal measurement allows a precise analysis of the temporal response of the stage and an exact determination of the position noise. As a rule of thumb, MIM is specified as 2X the peak-to peak position noise, in this case 0.02µm. Figure 3 shows such a measurement for the IMS-LM linear stages.

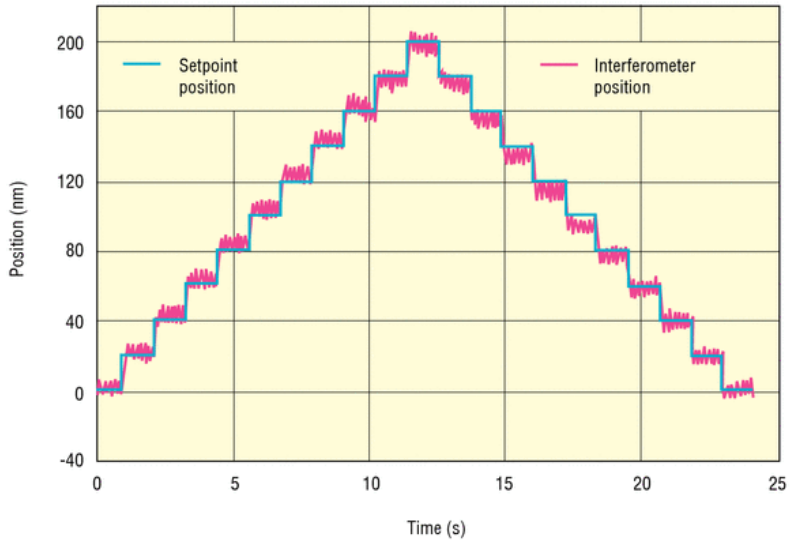


Figure 12 - Minimum incremental motion of an IMS-LM linear stage.

Runout of a Linear Stage

Runout of a Linear Stage is the linear (versus angular) portion of off-axis error. It is the departure from desired, ideal straight-line motion and consists of two orthogonal components. In ISO-230 and ASME B5.57 standards, runout is referred to as straightness or the lack thereof. However, in the motion industry it is common to refer to flatness and straightness as defined below.

Flatness

In Figure 8, ideal straight line motion is depicted as being confined to the x-axis. Flatness deviation is displacement along the z-axis.

Straightness

In Figure 8, ideal straight line motion is depicted as being along the x-axis. Straightness deviation is displacement along the y-axis.

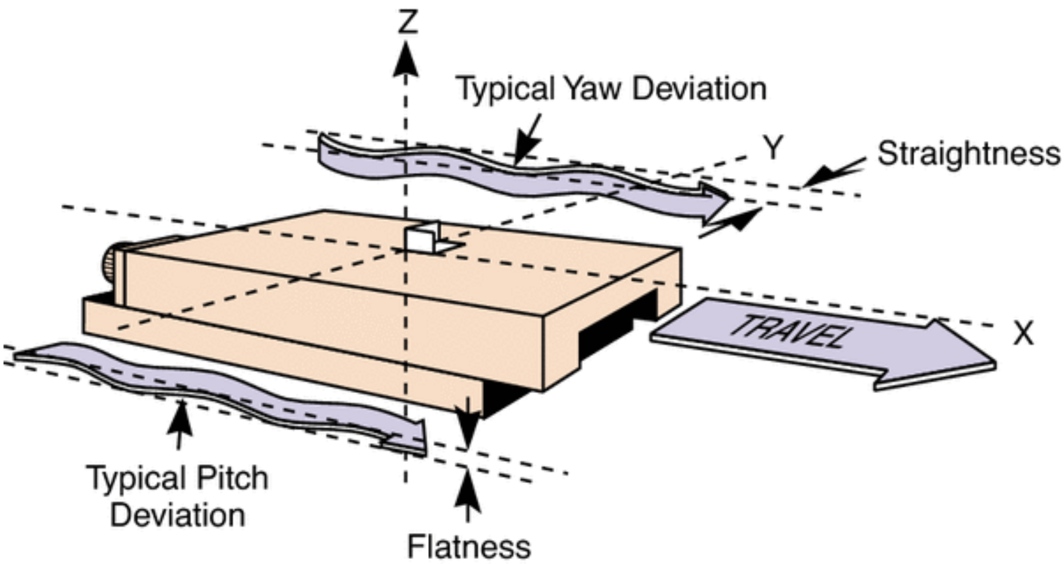


Figure 13 - Flatness and straightness runout of a linear stage

Position Stability

Position Stability is the ability to maintain a position within a specified position range over a specified time. Deviation from a stable position may also be called drift. Contributors include worn parts, vibration, migration of lubricant, and thermal variations.

Load Capacity

Load Capacity is the maximum allowable force that can be applied to a stage, in a specified direction, while meeting stage specifications. This maximum force includes static (mass * gravity) and dynamic forces (mass * acceleration). Dynamic forces must include any external forces, such as vibrations, acting upon the stage. The amount of acceleration a stage can impart to a mass is limited to the accelerating force it can produce without exceeding a load capacity. For rotary stages, torque (the product of angular acceleration and rotational moment of inertia) is the analogue of force. Rotational torques on linear stages can also be a significant factor when cantilevered loads are accelerated. Unless otherwise specified, catalogue load capacities refer to a centred, normal load (Figure 13).

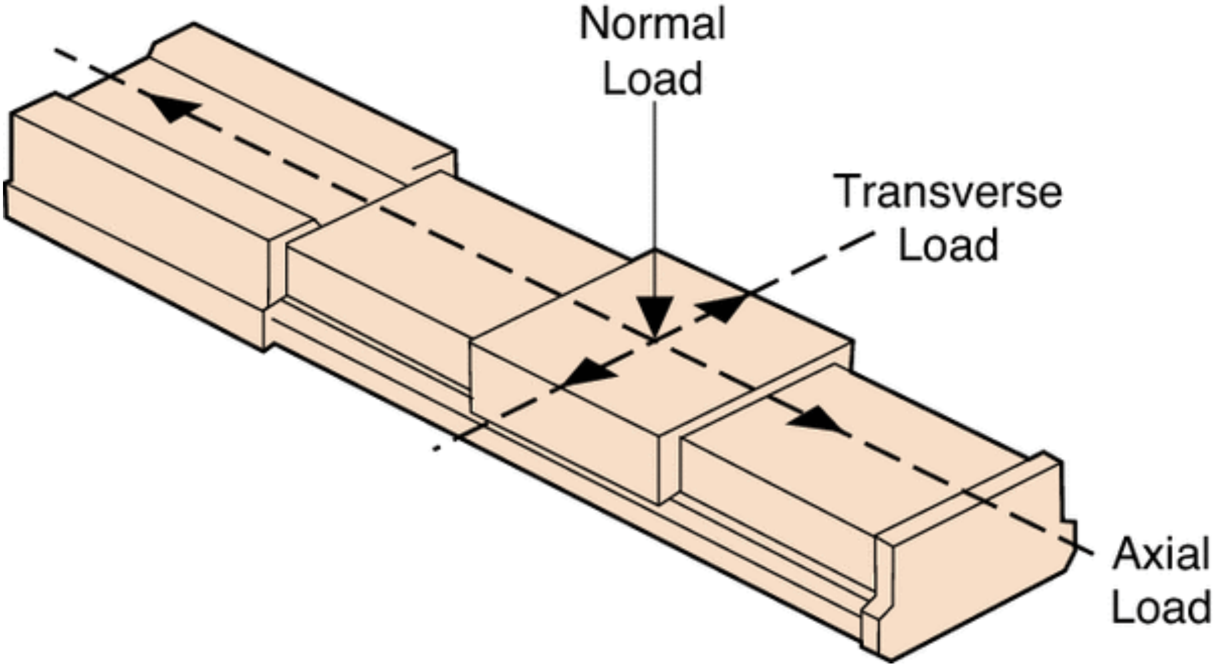


Figure 14 - Capacity specifications refer to loads that are centered and perpendicular

Centered Normal Load Capacity

For linear stages, this is the maximum load that can be applied to a stage, with the load center of mass at the center of the carriage, in a direction perpendicular to the axis of motion and the carriage surface (Figure 13). For rotary stages, it is the maximum load along the axis of rotation. In addition, the rotational moment of inertia must be within limits for rotary stages.

Transverse Load Capacity

Also called side load capacity, it is the maximum load that can be applied perpendicular to the axis of motion and along the carriage surface (Figure 13). This is typically smaller than the normal load capacity.

Axial Load Capacity

Axial Load Capacity is the maximum load along the direction of the drive train (Figure 13). For linear stages mounted vertically, the specified vertical load capacity is usually limited by the axial load capacity. However, cantilevered loading must also be considered when a stage is mounted vertically.

Off-Center Load Capacity Derating

Please note the equation and parameter values for individual stages in the specifications part of the catalog. The maximum load capacity is derated when the load is not centered. In case of high loads, users should review their application with a Newport Applications Engineer.

Inertia

Inertia is the measure of a load's resistance to change in velocity. The larger the inertia, the greater the force required accelerating or decelerating the load. Inertia is a function of a load's mass and shape and additionally location for rotational inertia. If there is a constraint on the amount of force available, then the allowable acceleration and deceleration must be adjusted to an acceptable value.

Speed (Velocity)

Speed (Velocity) is the change in distance per unit time. Specifications for maximum speed are stated at the normal load capacity of the stage. Higher speeds may be possible with lower loads. Minimum stated speeds are highly dependent on a motion system's speed stability. In this catalogue, velocity (a vector) and speed (a scalar) are used interchangeably.

Speed Stability

Speed Stability is a measure of the ability of a motion system to maintain, within specified limits, a constant speed. It is usually specified as a percent of the desired speed. Also specified as velocity regulation, this parameter depends upon the stage's mechanical design, its feedback mechanism, the motion controller, control algorithm, the magnitude of the speed, and the application.

Mean Time Before Failure

Mean Time Between Failure, MTBF, is a prediction of the reliability of a product. Tests and statistical analysis of parts and components are performed to predict the rate at which a product will fail. It is one of the most common forms of reliability prediction and is usually based on an established analysis model. Many analytical models exist, and choosing one over another must be based on a broad array of factors specific to a product and its application. In general, MTBF is specified with a duty cycle parameter.

4. CONSIDERATIONS FOR THE CHOICE OF LINEAR ACTUATORS

4.1 Advantages and Disadvantages of linear actuators

A linear actuator moves a load (sample), which can be an assembly, components, or a finished product, in a straight line. It converts energy into a motion or force and can be powered by pressurized fluid or air, as well as electricity. [3]

Here is a breakdown of common electric linear actuators, their advantages and their disadvantages. [3]

Advantages

• Electrical actuators offer the highest precision-control positioning regarding accuracy and repeatability. Their setups are scalable for any purpose or force requirement, and are quiet, smooth, and repeatable.

• Electric actuators can be networked and reprogrammed quickly. They offer immediate feedback for diagnostics and maintenance.

• They provide complete control of motion profiles and can include encoders to control velocity, position, torque, and applied force.

• In terms of noise, they are quieter than pneumatic and hydraulic actuators

• Because there are no fluids leaks, environmental hazards are eliminated.

Disadvantages

• The initial unit cost of an electrical actuator is higher than that of pneumatic and hydraulic actuators.

• Electrical actuators are not suited for all environments, unlike pneumatic actuators, which are safe in hazardous and flammable areas

• A continuously running motor will overheat, increasing wear and tear on the reduction gear. The motor can also be large and create installation problems.

• The motor chosen locks in the actuator’s force, thrust, and speed limits to a fixed setting. If a different set of values for force, thrust, and speed are desired, the motor must be changed.

4.2 How to Select a Linear Actuator for a Specific Application

"Linear actuator" is a broad term covering many different types of devices. The process of selecting the best device for a specific application is dependent upon the user's diligent research and development practices. It is not easy when comparing the specifications between linear actuator manufacturers, as there is very little standardization within the industry. Each type of each linear actuator fulfills a different set of design requirements. Because there are many variations in the electromechanical linear actuator system, it is critical to understand all design requirements and application constraints for the proper selection.

Linear actuators are used in a variety of applications across numerous industries, including medical equipment, agriculture machinery, high-voltage switch gears, train and bus doors, and factory processes and assembly machinery. Typical end uses include medical beds, patient lifters, wheelchairs, adjustable tables and workstations, diagnostics, to name a few. Each linear actuator application has unique requirements.

Manufacturers throughout the world that offer innumerable models of linear actuators in a wide variety of stroke sizes, speeds, voltage and types. With the availability of so many manufacturers, models and options, selecting the right linear actuator for an application can be a daunting task. When contacting a manufacturer for application assistance for a linear actuator, it's important be able to provide as much of the application requirements as possible, including the environment in which you plan to use the linear actuator. Most linear actuators are built either for high speed, high force, or a compromise between the two.

Starting the Process

Step One: The Basics
Describe and discuss the application in as much detail as possible with a knowledgeable and experienced supplier. At this stage, focus on basic specifications for load, actuator, and power and control) in the selection process. When considering a linear actuator for a specific application, the most important specifications are: travel distance, speed, force, accuracy and lifetime requirements. Other aspects of the linear actuator application will help determine which products to choose. The following questions must be answered before the selection process can start:

- **What type of energy source will you use? Air, fluid, electricity?** Answering this question will eliminate many manufacturers and linear actuator types.

- **Determine the amount of force required.** This may be the weight of an object you are lifting or friction that needs to be overcome. How much force (in newtons or pounds-force) and in what directions (push, pull, vertical, and/or horizontal) will the actuator need to move? (Force is a function of maximum and average dynamic loads.) Rule out any linear actuators that are not capable of producing enough force.

- **Speed:** How fast (millimeters/second or inches/second) will the actuator need to move?
  Decide how fast you need to move; you can rule out any linear actuators that are too fast or too slow. Determining the speed combined with the force from step one will give you the mechanical power required and how powerful the motor must be.

- **Distance:** Define how far your actuator needs to travel, also known as the stroke length. Whenever possible select the standard catalog options. How far will the actuator need to move? This will factor in both the stroke and retracted lengths and is usually expressed in millimeters. Special requirements are generally costlier. **IMPORTANT:** Keep in mind that the longer the stroke, the longer the linear actuator will be when fully retracted. This is especially important if you need to fit into an existing space.

- **Duty Cycle:** How often will the actuator operate, and how much time will elapse between operations? (This refers to the "duty cycle," which will be based on the number of expected repetitions per unit of time in hours/day, minutes/hour, and/or strokes/minute.) Check the duty cycle rating of your remaining choices. Except for high-end servo units, most linear actuators may not operate continuously without overheating.

- **Options to consider:** What are the power supply options (motor vs. battery)? A battery-powered application will probably require a DC motor rated the same as the battery voltage. However, an AC powered application does not necessarily need an AC motor because AC is fairly easily converted to any DC voltage. Be flexible when choosing options such as built-in limit switches and position feedback devices such as potentiometers and encoders. Consider that limit switches, for example, can often be incorporated into part of your mechanism rather that being part of the actuator itself.

- **Environmental Considerations:** Will environmental factors (temperature variations, moisture, vibration, or end-product shock) pose a challenge to operation? Most linear actuators can operate well in an indoor environment, but harsh outdoor conditions, extreme temperatures or submersion will drastically limit your product choices. Sometimes it is easier to provide some external protection to the unit rather than find one with the proper ingress protection rating that meets all your other requirements.

Step Two: Beyond the Basics – Options to Consider
When a system is tailored for an application, the specific requirements will influence both the design and the manufacturing processes. Regardless of end use, an actuation system is designed by first identifying basic needs, and then evaluating certain key parameters that ultimately affect the overall system operation.

Electromechanical linear actuators are designed to provide precision, efficiency, accuracy, and repeatability in effecting and controlling linear movement. These devices serve as practical, efficient, and relatively maintenance-free alternatives to their hydraulic or pneumatic actuator counterparts. Depending on type and manufacturer, today's electromechanical linear actuators can handle loads up to 3,000 pounds (13 kilonewtons) and deliver speeds up to 6 inches/second (150 millimeters/second), with strokes ranging from 2 inches (50 millimeters) to 60 inches (1,500 millimeters). Actuators can be self-contained in aluminum, zinc, or polymer housings and ready to mount for easy plug-in operation (using either AC or DC power supplies).

What's more, actuators featuring both modular design and open architecture enable interchangeable internal and external components, according to specifications. Please note that standard components, including the types of drive screws, motors, front and rear attachments, controls, and limit switches used, will allow for desired customization without the costs typically associated with special modifications.

Note: The specific parameters that play a crucial role in every electromechanical actuator application is the: electrical power in, duty cycle, and actuator efficiency. Answering the following questions will help you to define the linear actuator further:

1. What is the desired lifetime for the end product? (Those answers will impact virtually every component within a linear actuator system.)
2. How will the actuator be mounted? Will front and/or back mounts require special configurations?
3. Does the application suggest particular safety mechanisms (e.g., "manual operators" for use in case of emergency)?
4. Is space limited? (If so, the actuator will have to be designed to fit in a specific footprint.
5. If a motor is utilized, what are its type (AC, DC, or special) and voltage?
6. Is feedback required for speed and/or position? (This will indicate a need for add-on components, such as encoders.)

Step Three: The Power Factor

A linear actuator is a device that produces linear motion by utilizing some external energy source. As far as the source of energy used is concerned, it can be piezoelectric, pneumatic, hydraulic, mechanical, electro-mechanical, etc. A linear actuator system draws principles from both electrical and mechanical engineering disciplines. Consequently, power (defined in watts) is usually the first requirement to be calculated. In order to get mechanical power out of an electric linear actuator, it's necessary to put electrical power into the system. Mechanical power out is usually the easier of the two to define because all that's needed for its calculation is the force, or the load that will be moved, and the speed required.

If the parameters are in metric (SI) units, multiply the force (in newtons) by the speed (in millimeters/second) to obtain watts. (To convert pounds to newtons, multiply by 4.448; to convert inches to millimeters, multiply by 25.4.)

Mechanical power out (Po):

$$Po = F \times v$$

F = Force (N)

v = Velocity (meters/sec)

Information regarding electrical power can be ascertained through performance graphs and charts from suppliers' specification sheets. Suppliers chart this information differently, but more often than not, there are graphs for force vs. speed and force vs. current draw at a specified voltage. This data is often presented in two graphs or combined in one. The current draw may also be presented in tabular form. In addition, factors will be given based on a duty-cycle curve. *The relevant formula is as follows:*

Electrical power in (Pi):

Pi = E x I

E = Voltage (V)

I = Current (A)

Step Four: Calculating Duty Cycle
Users will want to establish the duty-cycle factor (sometimes called the "derating factor"). Duty cycle is important. Sometimes the preliminary actuator selection may not meet all of an application's operating requirements. The duty cycle indicates both how often an actuator will operate and how much time there is between operations. Because the power lost to inefficiency dissipates as heat, the actuator component with the lowest allowable temperature (usually this is the motor) establishes the duty-cycle limit for the complete linear actuator system. Please note: There are some heat losses from friction in a gearbox, and via ball-screw and acme-screw drive systems.

To demonstrate how the duty cycle is calculated, assume an actuator runs for 10 seconds cumulative, up and down, and then doesn't run for another 40 seconds. The duty cycle is 10/(40+10), or 20%. If duty cycle is increased, either load or speed must be reduced. Conversely, if either load or speed decreases, duty cycle can increase. The duty cycle is relatively easy to determine if a linear actuator is used on a machine or production device. In other, less predictable applications or those where the linear actuator will be used infrequently, it's advisable to estimate the worst-case scenario in order to assign a meaningful duty-cycle calculation. It is not advisable to operate on the edge of the manufacturer's power curves because this might cause the linear actuator and other components to run too hot. However, in some applications where the duty cycle is 10% or less, the actuator can run to the limit of its power curves.

Step Five: Ascertaining 'Efficiency' and Expected Life
A system's "efficiency" is usually missing from most manufacturers' literature, but it can tell the user how hot the actuator may get during operation; whether holding brakes should be specified in the system if the actuator uses a ball screw; and how long batteries may last in battery-powered systems, among other pertinent data. Calculating efficiency from performance curves is simple: Divide mechanical power out by electrical power in. This yields the efficiency percentage.

While these factors are being calculated and decision making is moving toward final selection, one additional parameter should be addressed: the application's expected lifetime. Although linear actuator components (e.g., the motor or screw) can be replaced, most actuators can't be easily repaired. In addition, it's important to cover application life expectancy because suppliers will sometimes indicate acme or ball screw life at a certain load, or include mathematical formulae to calculate life based on application parameters. A good design practice is to strive to have the screw and motor life expectancies match as closely as possible.

In those cases where an existing linear actuator must be replaced, ensure that the application engineer has all the necessary information to ensure a good fit. Whenever a linear actuator is subject to replacement, it is recommended to review the application as if it were new.

Other Selection Considerations: Budget and Experience
Having a clear picture of a linear actuator system budget in your mind will help in selecting the best product at an affordable price. Advance budget planning can definitely save the user a lot of time in the selection process by eliminating some types that are too expensive for the application. As mentioned earlier, there are many companies providing linear actuators to the customers based on their requirements. It is important to choose a reliable company for the best results in terms of the actuator features and price.

- See more at: http://www.anaheimautomation.com/manuals/forms/linear-actuator-guide.php#sthash.N3XbXRPB.dpuf

Quick Selection Guide	
Application	**Linear Actuator Type**
Slow movement of very heavy loads.	Hydraulic
Short stroke fast movement.	Pneumatic
Very accurate positioning.	Ball screw
Lower cost less accurate positioning.	Acme screw
Long travel with high speed.	Timing Belt
High speed very accurate repeatable positioning.	Linear motor
Short stroke, moderate to heavy load, repeatable positioning.	Rod-type cylinder
Very small movements, generally very light load.	Piezoelectric

4.3 Technology Comparison

Roller Screw vs. Other Linear Motion Technologies (Used in electronic positioning applications)

	EXLAR ROLLER SCREWS	ACME SCREWS	BALL SCREWS	HYDRAULIC CYLINDERS	PNEUMATIC CYLINDERS
Load ratings	Very High	High	High	Very High	High
Lifetime	Very long, many times greater than ball screw	Very low, due to high friction & wear	Moderate	Can be long with proper maintenance	Can be long with proper maintenance
Speed	Very high	Low	Moderate	Moderate	Very high
Acceleration	Very high	Low	Moderate	Very high	Very high
Electronic Positioning	Easy	Moderate	Easy	Difficult	Very Difficult
Stiffness	Very high	Very high	Moderate	Very high	Very low
Shock Loads	Very high	Very high	Moderate	Very high	High
Relative Space Requirements	Minimum	Moderate	Moderate	High	High
Friction	Low	High	Low	High	Moderate
Efficiency	>90%	approx 40%	>90%	<50%	<50%
Installation	Compatible with standard servo electronic controls	User may have to engineer a motion/actuator interface	Compatible with standard servo electronic controls	Complex, requires servo-valves, high pressure plumbing, filtering, pumps linear positioning & sensing	Very complex requires servo-valves, plumbing, filtering, compressors linear positioning & sensing
Maintenance	Very low	High, due to poor wear characteristics	Moderate	Very high	High
Environmental	Minimum	Minimum	Minimum	Hydraulic fluid leaks & disposal	High noise levels

http://www.consultolsen.com/roller_screw_linear_actuators.html

5. OVERVIEW – LINEAR STAGE MANUFACTURERS ON THE MARKET

Length of travel	Possible stroke of the sledge movement.
Load capacity F_z	Maximum allowable force that can be applied on the linear actuator in Z-direction
Travel force F_x	Maximum allowable force that canbe applied on the linear actuator in X-direction.
Min.Torque	Least inertia necessary to perform movement with the linear actuator.
Max. Speed	Highest achievable velocity of the linear actuator.
Accuracy	Measurement of the difference between expected position and actual position.
Repetability	Mean value of the deviation of position for the same predefined movement.
Backlash	Deviation due to the mechanics of a linear actuator when it is changing direction.
Gear ratio	Movement transferred to the linear actuator for each revolution of the motor. Depending on e.g. spindle pitch.
Weight	Total mass of the unit.
Mechanics	
Material	Solids the unit consist of.
Motor	Type of source which imparts motion.
Encoder	Kind of position feedback (available if the kind is not specified with the manufacturer).
Position Switches	Specification of reference positions.
Producer	Manufacturer of the unit.
Comments/Options	Each of the following datasheets provides additional information about special features and functionally variations.
Webpage	Source of information
Price	?

5.1 Ball screw drive

5.1.1 Festo – EGC-XX-XX

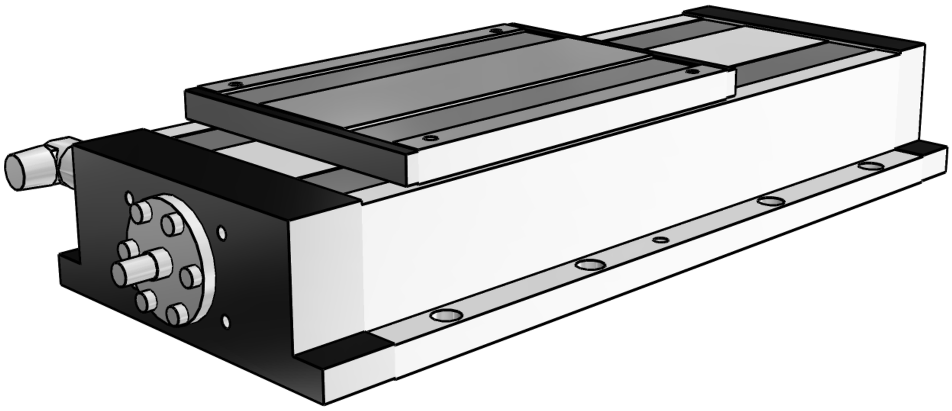
<table>
<tr><td colspan="2">Length [mm]: variable *)</td><td colspan="2">Height [mm]: 64 … 172.5</td><td colspan="2">Width [mm]: 70 … 185</td></tr>
<tr><td>Length of travel [mm]:</td><td colspan="2">50 … 1000 **)</td><td>Accuracy [µm]:</td><td colspan="2">(+/-) ?</td></tr>
<tr><td>Load capacity F_z [N]:</td><td colspan="2">1850 … 15200</td><td>Repeatability [µm]:</td><td colspan="2">(+/-) 20</td></tr>
<tr><td>Travel force F_x [N]:</td><td colspan="2">300 … 3000</td><td>Backlash [µm]:</td><td colspan="2">(+/-) ?</td></tr>
<tr><td>Min. Torque [Nm]:</td><td colspan="2">0.2 … 4.3</td><td>Gear ratio [mm/°]:</td><td colspan="2">10 … 40/360</td></tr>
<tr><td>Max. Speed [m/s]:</td><td colspan="2">0.5 … 2</td><td>Weight [kg]:</td><td colspan="2">1.5 … 34.5</td></tr>
<tr><td colspan="3">Mechanics
Spindle: Diameter 12 - 40
Guide system: ?</td><td colspan="3">Material
Spindle: Steel
Guide system: Steel/Aluminium
Base/sledge: Anodized Aluminium</td></tr>
<tr><td colspan="3">Motor:
Stepper motor
Servo motor</td><td colspan="3">Encoder:
?</td></tr>
<tr><td colspan="3">Position switches:
Limit +, Limit -</td><td colspan="3">Producer:
Festo</td></tr>
<tr><td colspan="6">Comments:
*) depending on width
**) for narrowest, wider can be ordered longer (up to 3000)
Options:
Heavy duty version available

Belt drive version available</td></tr>
<tr><td colspan="3">Webpage: http://www.festo.com/cat/..</td><td colspan="3">Price [EUR]: ?</td></tr>
</table>

5.1.2 Festo – EGSK+EGSP

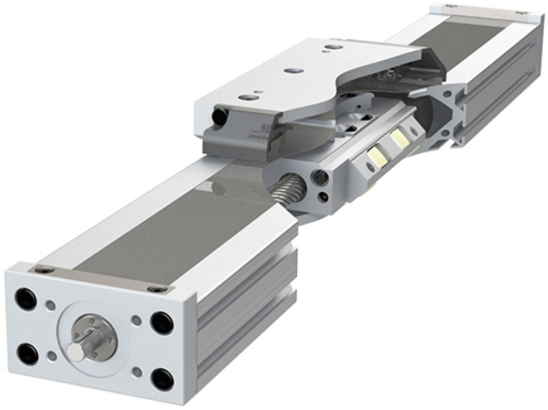

Length [mm]: variable *)	**Height [mm]:** 30 … 86	**Width [mm]:** 15 … 46	
Length of travel [mm]:	variable *)	**Accuracy [µm]:**	(+/-) ?
Load capacity F_z [N]:	747 … 3904	**Repeatability [µm]:**	(+/-) 1.5 … 5
Travel force F_x [N]:	300 … 3000	**Backlash [µm]:**	(+/-) ?
Min. Torque [Nm]:	?	**Gear ratio [mm/°]:**	1 … 20/360
Max. Speed [m/s]:	2	**Weight [kg]:**	?
Mechanics Spindle: ? Guide system: ?		**Material** Spindle: Steel Guide system: ? Base/sledge: Steel	
Motor: Stepper motor Servo motor		**Encoder:** ?	
Position switches: Limit +, Limit -		**Producer:** Festo	
Comments: *) depending on width **Options:**			
Webpage: http://www.festo.com/cat/..		**Price [EUR]:**	?

5.1.3 Franke – FTB06X



Length [mm]: 365 … 1880	**Height [mm]:** 70	**Width [mm]:** 155	
Length of travel [mm]:	100 … 1500	**Accuracy [µm]:**	(+/-) 25 *)
Load capacity F_z [N]:	15000, 30000	**Repeatability [µm]:**	≤10
Travel force F_x [N]:	1500	**Backlash [µm]:**	(+/-) ?
Min. Torque [Nm]:	0.3, 0.4	**Gear ratio [mm/°]:**	16/360
Max. Speed [m/s]:	0.1 … 0.2	**Weight [kg]:**	6.4 … 22.9
Mechanics Spindle: ? Guide system: roller guide		**Material** Spindle: ? Guide system: Aluminium Base/sledge: Anodized Aluminium	
Motor: ?		**Encoder:** ?	
Position switches: Limit +, Limit - **)		**Producer:** Franke	
Comments: *) per 300 mm travel **) magnetic (open/close), PNP, NPN (close) **Options:**			
Webpage: http://www.franke-gmbh.com/..		**Price [EUR]:**	?

5.1.4 HepcoMotion – PSD



Length [mm]:	400 … 1500	**Height [mm]:**	81.5	**Width [mm]:**	120

Length of travel [mm]:	length - 247	**Accuracy [µm]:**	(+/-) ?
Load capacity F_z [N]:	700	**Repeatability [µm]:**	(+/-) ?
Travel force F_x [N]:	?	**Backlash [µm]:**	(+/-) ?
Min. Torque [Nm]:	?	**Gear ratio [mm/°]:**	5 … 32/360
Max. Speed [m/s]:	0 … 8	**Weight [kg]:**	3.25 *)
Mechanics Spindle: Guide system:	 166mm diameter ?	**Material** Spindle: Guide system: Base/sledge:	 Polymer drive nut Steel cover Aluminium
Motor: Stepper motor AC motor Servo motor		**Encoder:** ?	
Position switches: Limit +, Limit - **)		**Producer:** HepcoMotion	
Comments: *) + 0.008 x length **) mechanical inductive **Options:** Smaller version (PSD80) is available with lead screw; Special length and pitch are available on req.			
Webpage: http://www.hepcomotion.com/..		**Price [EUR]:**	?

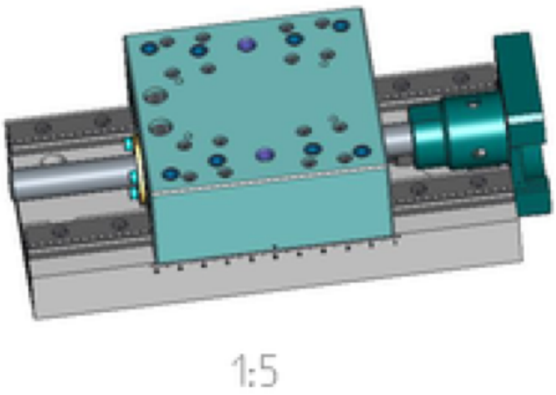
5.1.5 Hiwin – SK

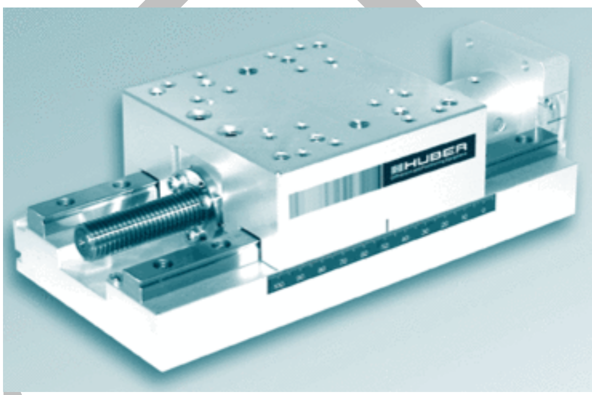
Length [mm]: 220 … 1040	**Height [mm]:** 48, 68	**Width [mm]:** 60 … 86	
Length of travel [mm]:	150 … 940	**Accuracy [µm]:**	(+/-) 10 … 20 *)
Load capacity F_z [N]:	?	**Repeatability [µm]:**	(+/-) 1, 3
Travel force F_x [N]:	?	**Backlash [µm]:**	(+/-) ?
Min. Torque [Nm]:	?	**Gear ratio [mm/°]:**	5 … 20/360
Max. Speed [m/s]:	0.39 … 1.48	**Weight [kg]:**	1.5 … 12.4
Mechanics Spindle: ? Guide system: ?		**Material** Spindle: ? Guide system: ? Base/sledge: ?	
Motor: 2 phase/ 5 phase stepper motor Servo motor		**Encoder:** ?	
Position switches: ?		**Producer:** Hiwin	
Comments: *) only valid for precision version, depending on width and length of travel **Options:** 2 different types of sledge available 2 sledge version available Precision version available			
Webpage: http://www.hiwin.com/..		**Price [EUR]:**	?

5.1.6 Hiwin – KA

Length [mm]: 460 … 1410	**Height [mm]:** 71	**Width [mm]:**	100 … 200
Length of travel [mm]:	length - 360	**Accuracy [µm]:**	(+/-) ?
Load capacity F_z [N]:	210 … 3150	**Repeatability [µm]:**	(+/-) 20
Travel force F_x [N]:	40 … 900	**Backlash [µm]:**	(+/-) ?
Min. Torque [Nm]:	?	**Gear ratio [mm/°]:**	5 … 25/360
Max. Speed [m/s]:	0.25 … 1.25	**Weight [kg]:**	?
Mechanics Spindle: ? Guide system: ?		**Material** Spindle: ? Guide system: ? Base/sledge: ?	
Motor: 3 phase/ 5 phase stepper motor Servo motor		**Encoder:** ?	
Position switches: Limit +, Limit -		**Producer:** Hiwin	
Comments: *) only valid for precision version, depending on width and length of travel **Options:** 2 different types of sledge available 2 sledge version available Precision version available			
Webpage: http://www.hiwin.com/..		**Price [EUR]:**	?

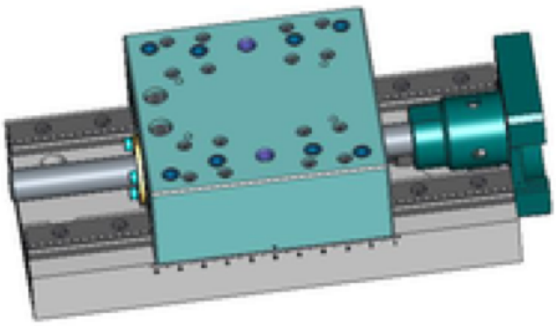
5.1.7 Huber – 5101.20 X2



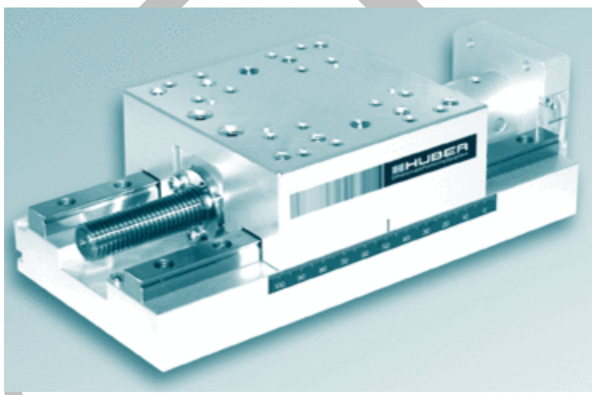


Length [mm]: 219	**Height [mm]:** 62	**Width [mm]:** 102	
Length of travel [mm]:	100	**Accuracy [µm]:**	(+/-) 4
Load capacity F_z [N]:	1000	**Repeatability [µm]:**	(+/-) 2
Travel force F_x [N]:	250	**Backlash [µm]:**	4
Min. Torque [Nm]:	0.6	**Gear ratio [mm/°]:**	2/360
Max. Speed [m/s]:	?	**Weight [kg]:**	2.8
Mechanics Spindle: Guide system:	 free of play low friction	**Material** Spindle: Guide system: Base/sledge:	 Bronze ? Aluminium
Motor: 2-/3-/5 phase stepper motor DC servo motor		**Encoder:** ?	
Position switches: Limit +, Limit - *)		**Producer:** Huber	
Comments: *) mechanical **Options:** extended or shortened travel range adjustable limit switches			
Webpage: http://www.xhuber.de/..		**Price [EUR]:**	?

5.1.8 Huber – 5101.20 XE



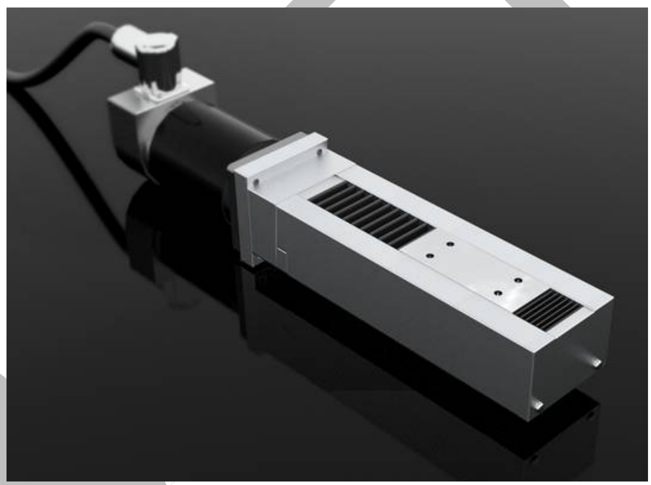
1:5



Length [mm]:	219	**Height [mm]:**	62	**Width [mm]:**	102

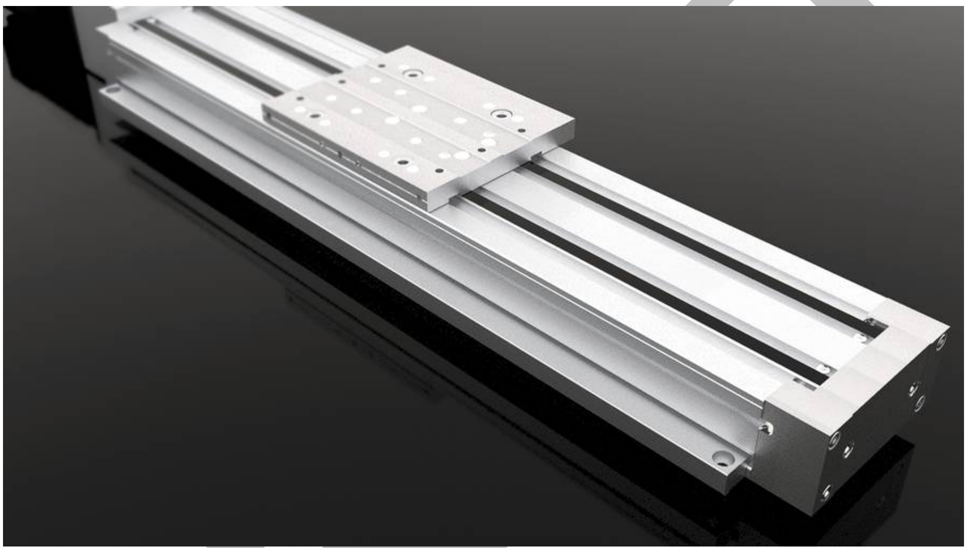
Length of travel [mm]:	100	**Accuracy [µm]:**	(+/-) 0.1
Load capacity F_z [N]:	1000	**Repeatability [µm]:**	(+/-) 0.1
Travel force F_x [N]:	250	**Backlash [µm]:**	0.1
Min. Torque [Nm]:	0.6	**Gear ratio [mm/°]:**	2/360
Max. Speed [m/s]:	?	**Weight [kg]:**	2.8
Mechanics Spindle: Guide system:	 free of play low friction	**Material** Spindle: Guide system: Base/sledge:	 Bronze ? Aluminium
Motor: 2-/3-/5 phase stepper motor DC servo motor		**Encoder:** incremental, absolute	
Position switches: Limit +, Limit - *)		**Producer:** Huber	
Comments: *) mechanical **Options:** extended or shortened travel range adjustable limit switches			
Webpage: http://www.xhuber.de/..		**Price [EUR]:**	?

5.1.9 IEF – MS 60



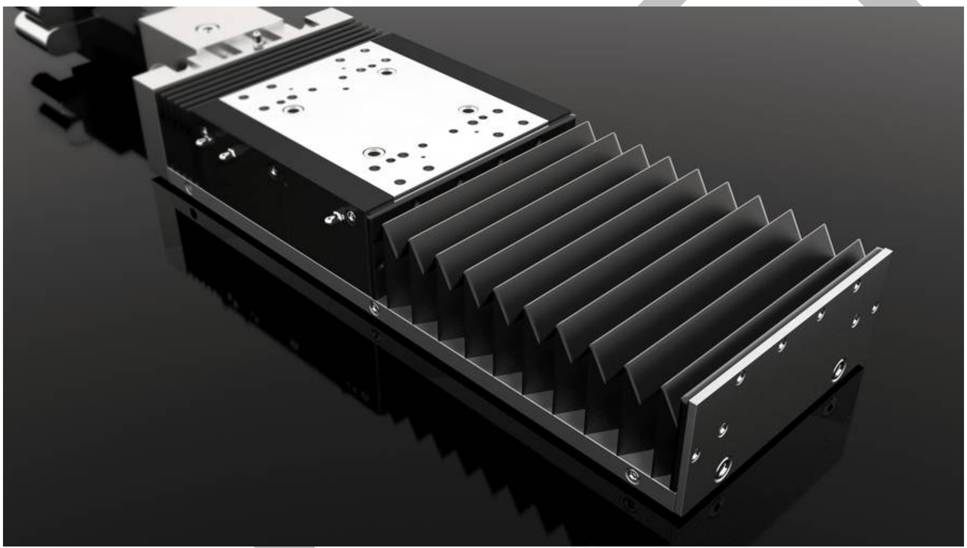
Length [mm]:	176 … 251	**Height [mm]:** 43	**Width [mm]:** 60.3
Length of travel [mm]:	25 … 100	**Accuracy [µm]:**	(+/-) 10
Load capacity F_z [N]:	665 … 1330	**Repeatability [µm]:**	(+/-) 2 **)
Travel force F_x [N]:	?	**Backlash [µm]:**	(+/-) 1 **)
Min. Torque [Nm]:	?	**Gear ratio [mm/°]:**	1 … 5/360
Max. Speed [m/s]:	?	**Weight [kg]:**	1.7 … 2.3
Mechanics Spindle: ? Guide system: ?		**Material** Spindle: ? Guide system: Steel Base/sledge: ?	
Motor: ?		**Encoder:** ?	
Position switches: Limit +, Limit - *)		**Producer:** Huber	
Comments: *) integrated **) accuracy and repeatability only with spindle pitch 1mm **Options:**			
Webpage: http://www.ief-werner.de/..		**Price [EUR]:**	?

5.1.10 IEF – profiLine 115



Length [mm]: 315 … 1455	**Height [mm]:** 52.5	**Width [mm]:** 115	
Length of travel [mm]:	60 … 1200 *)	**Accuracy [μm]:**	(+/-) ?
Load capacity F_z [N]:	3000	**Repeatability [μm]:**	(+/-) 2
Travel force F_x [N]:	2000	**Backlash [μm]:**	(+/-) ?
Min. Torque [Nm]:	?	**Gear ratio [mm/°]:**	5 … 16/360
Max. Speed [m/s]:	?	**Weight [kg]:**	6.2 **)
Mechanics Spindle: ? Guide system: ?		**Material** Spindle: ? Guide system: Aluminium Base/sledge: ?	
Motor: ***)		**Encoder:** ?	
Position switches: ?		**Producer:** IEF	
Comments: *) Length and travel increments of 30mm **) weight increase of 0.63 kg per 60 mm stroke ***) assembly variant has to be chosen **Options:**			
Webpage: http://www.ief-werner.de/..		**Price [EUR]:**	?

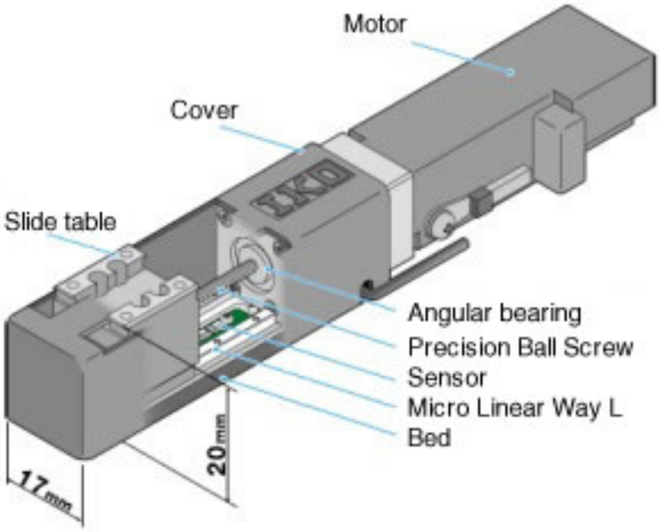
5.1.11 IEF – Line 200 GG



Length [mm]: 549, 749	**Height [mm]:** 85	**Width [mm]:** 200

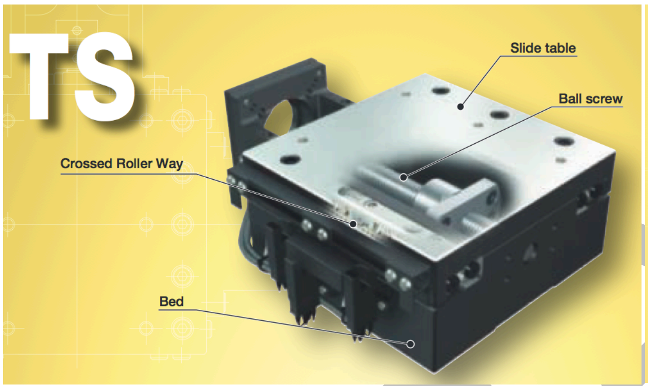
Length of travel [mm]:	190, 350	**Accuracy [µm]:**	(+/-) ?
Load capacity F_z [N]:	3000	**Repeatability [µm]:**	(+/-) 3
Travel force F_x [N]:	3000	**Backlash [µm]:**	(+/-) ?
Min. Torque [Nm]:	?	**Gear ratio [mm/°]:**	5/360
Max. Speed [m/s]:	?	**Weight [kg]:**	32, 40
Mechanics Spindle: ? Guide system: ?		**Material** Spindle: ? Guide system: Iron Base/sledge: ?	
Motor: ?		**Encoder:** ?	
Position switches: ?		**Producer:** IEF	
Comments: **Options:** with bellow			
Webpage: http://www.ief-werner.de/..		**Price [EUR]:**	?

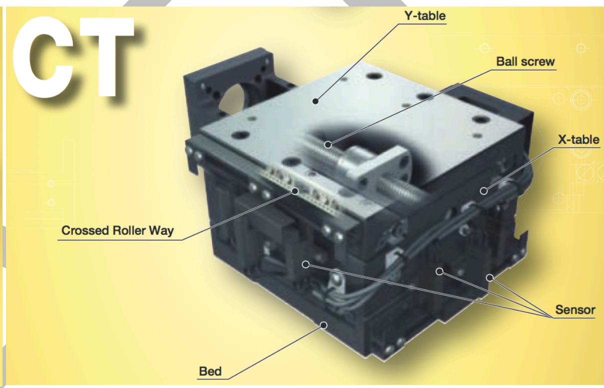
5.1.12 IKO – TM



Length [mm]: 116, 162	**Height [mm]:** 20	**Width [mm]:** 17	
Length of travel [mm]:	10 … 60	**Accuracy [µm]:**	15
Load capacity F_z [N]:	7 … 15	**Repeatability [µm]:**	(+/-) 1, 2
Travel force F_x [N]:	5	**Backlash [µm]:**	(+/-) ?
Min. Torque [Nm]:	?	**Gear ratio [mm/°]:**	0.5 … 1.5/360
Max. Speed [m/s]:	0.015 … 0.150	**Weight [kg]:**	0.15 … 0.21
Mechanics Spindle: Guide system:	 ? linear way (ball type)	**Material** Spindle: Guide system: Base/sledge:	 ? Steel Steel
Motor: 2-/5-phase stepper AC servo motor		**Encoder:** resolver	
Position switches: Limit +, Limit -, Origin, Pre-origin		**Producer:** IKO	
Comments: **Options:**			
Webpage: http://www.ikont.com/..		**Price [EUR]:**	?

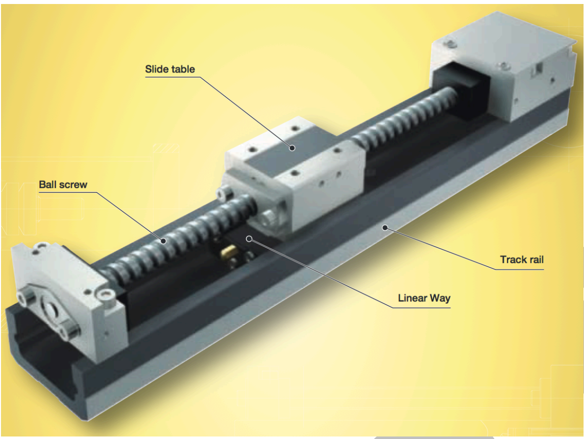
5.1.13 IKO – TS/CT

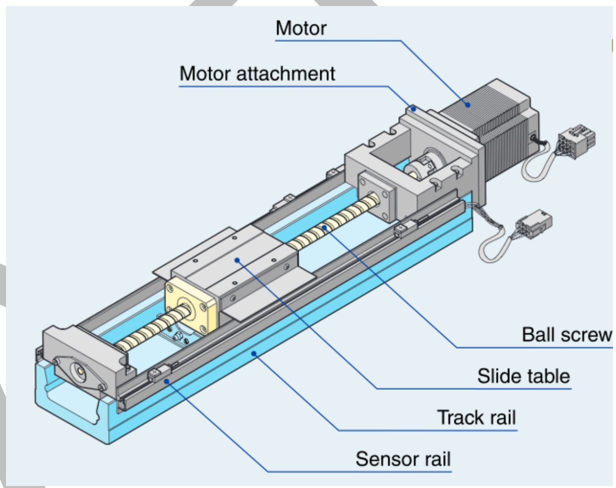




Length [mm]: 55 ... 350	**Height [mm]:** 35.5 ... 150	**Width [mm]:** 55 ... 350	
Length of travel [mm]:	15 ... 250	**Accuracy [µm]:**	5 ... 25
Load capacity F_z [N]:	43 ... 3100	**Repeatability [µm]:**	(+/-) 2, 3
Travel force F_x [N]:	15 ... 290	**Backlash [µm]:**	(+/-) ?
Min. Torque [Nm]:	?	**Gear ratio [mm/°]:**	1 ... 5/360
Max. Speed [m/s]:	0.030 ... 0.250	**Weight [kg]:**	7.5 ... 77
Mechanics Spindle: ? Guide system: crossed roller way		**Material** Spindle: ? Guide system: Iron Base/sledge: Iron	
Motor: 2-/5-phase stepper AC servo motor		**Encoder:** available	
Position switches: Limit +, Limit -, Origin, Pre-origin		**Producer:** IKO	
Comments: **Options:** units combinable			
Webpage: http://www.ikont.com/..		**Price [EUR]:**	?

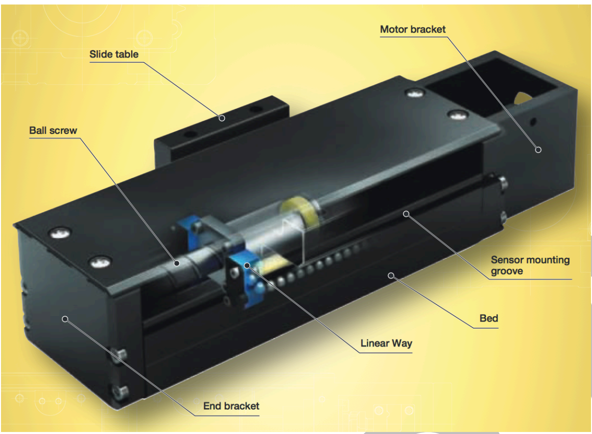
5.1.14 IKO – TU

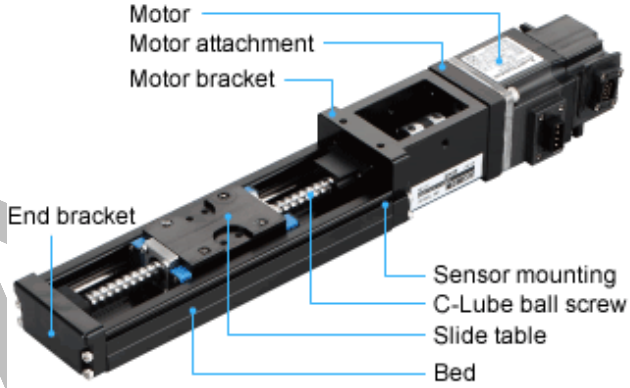




Length [mm]:	146 ... 1572	**Height [mm]:**	20 ... 107.5	**Width [mm]:**	25 ... 106
Length of travel [mm]:	30 ... 1300	**Accuracy [µm]:**	50		
Load capacity F_z [N]:	110 ... 1530	**Repeatability [µm]:**	(+/-) 40		
Travel force F_x [N]:	48 ... 340	**Backlash [µm]:**	50		
Min. Torque [Nm]:	?	**Gear ratio [mm/°]:**	2 ... 25/360		
Max. Speed [m/s]:	0.1 ... 1.1	**Weight [kg]:**	?		
Mechanics Spindle: ? Guide system: ?		**Material** Spindle: ? Guide system: ? Base/sledge: high carbon steel			
Motor: Stepper motor AC servo motor		**Encoder:** ?			
Position switches: Limit +, Limit -, Origin, Pre-origin		**Producer:** IKO			
Comments: **Options:** Ground screw and roller screw available					
Webpage: http://www.ikont.com/..		**Price [EUR]:**	?		

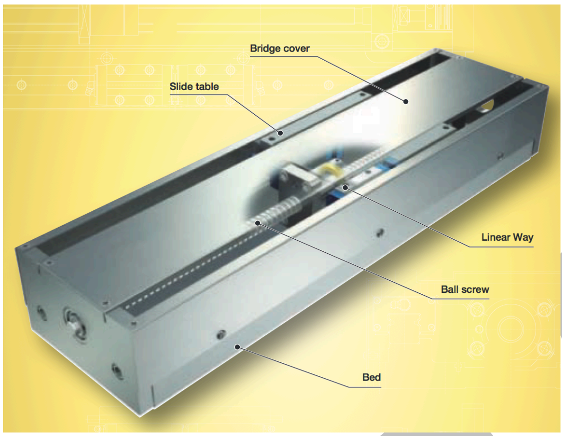
5.1.15 IKO – TE

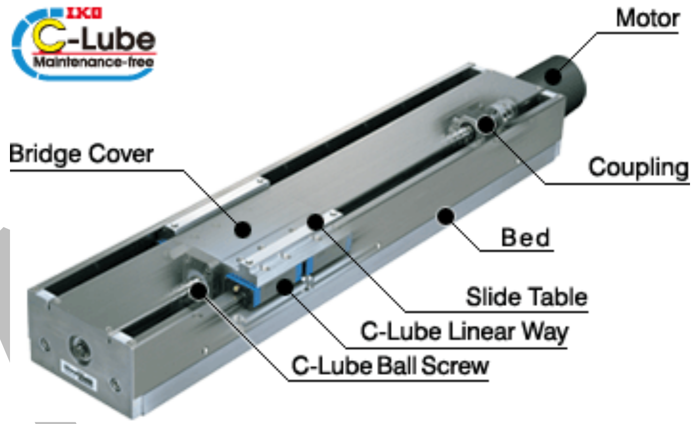




Length [mm]:	218 ... 1023	**Height [mm]:** 52 ... 78	**Width [mm]:** 50 ... 86
Length of travel [mm]:	50 ... 800	**Accuracy [µm]:**	35 ... 65
Load capacity F_z [N]:	120 ... 360	**Repeatability [µm]:**	(+/-) 2
Travel force F_x [N]:	70 ... 180	**Backlash [µm]:**	5
Min. Torque [Nm]:	?	**Gear ratio [mm/°]:**	4 ... 20/360
Max. Speed [m/s]:	0.12 ... 1.86	**Weight [kg]:**	0.52 ... 1.1 *)
Mechanics Spindle: ? Guide system: ?		**Material** Spindle: ? Guide system: ? Base/sledge: Aluminium alloy	
Motor: Stepper motor AC servo motor		**Encoder:** ?	
Position switches: Limit +, Limit -, Origin, Pre-origin		**Producer:** IKO	
Comments: *) basic weight with 60mm stroke **Options:**			
Webpage: http://www.ikont.com/..		**Price [EUR]:**	?

5.1.16 IKO – TSL

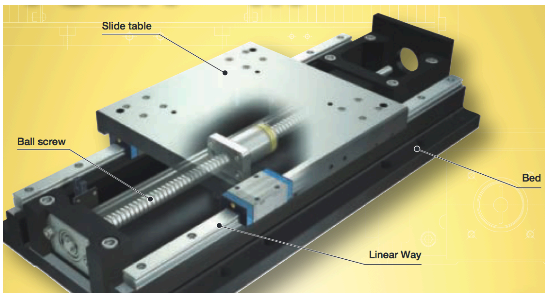


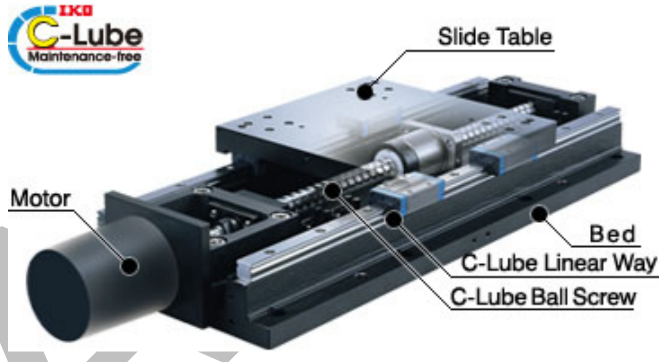


Length [mm]:	179 ... 1245	**Height [mm]:**	65 ... 90	**Width [mm]:**	90 ... 220

Length of travel [mm]:	50 ... 1000	**Accuracy [µm]:**	15 ... 60
Load capacity F_z [N]:	460 ... 2260	**Repeatability [µm]:**	(+/-) 20 ... 70
Travel force F_x [N]:	70 ... 210	**Backlash [µm]:**	3
Min. Torque [Nm]:	?	**Gear ratio [mm/°]:**	5, 10/360
Max. Speed [m/s]:	0.15 ... 0.5	**Weight [kg]:**	3.2 ... 6.6 *)
Mechanics Spindle: ? Guide system: ?		**Material** Spindle: ? Guide system: ? Base/sledge: Aluminium alloy	
Motor: Stepper motor AC servo motor		**Encoder:** ?	
Position switches: Limit +, Limit -, Origin, Pre-origin		**Producer:** IKO	
Comments: *) basic weight with 100mm stroke **Options:**			
Webpage: http://www.ikont.com/..		**Price [EUR]:**	?

5.1.17 IKO – TSLH

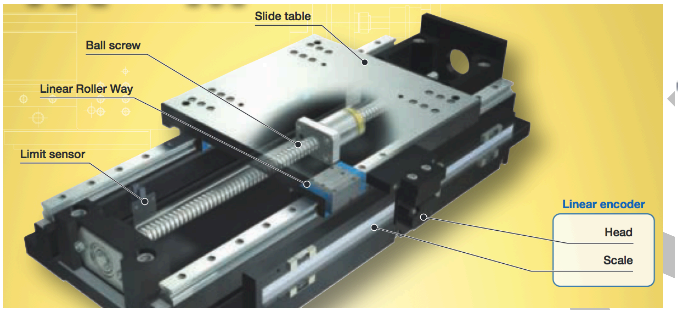


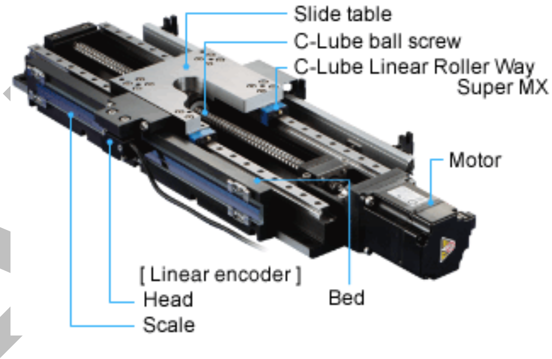


Length [mm]:	256 ... 1216	**Height [mm]:**	65 ... 140	**Width [mm]:**	120 ... 420

Length of travel [mm]:	100 ... 800	**Accuracy [µm]:**	10 ... 35
Load capacity F_z [N]:	1350 ... 5190	**Repeatability [µm]:**	(+/-) 2
Travel force F_x [N]:	80 ... 300	**Backlash [µm]:**	1
Min. Torque [Nm]:	?	**Gear ratio [mm/°]:**	5, 10/360
Max. Speed [m/s]:	0.15 ... 0.5	**Weight [kg]:**	14 ... 100 *)
Mechanics Spindle: Guide system:	 ? ?	**Material** Spindle: Guide system: Base/sledge:	 ? ? Iron
Motor: Stepper motor AC servo motor		**Encoder:** ?	
Position switches: Limit +, Limit -, Origin, Pre-origin		**Producer:** IKO	
Comments: *) basic weight with 300mm stroke **Options:** Bellows available Crossed version available (2 units combined, movable in xy-plane)			
Webpage: http://www.ikont.com/..		**Price [EUR]:**	?

5.1.18 IKO – TX

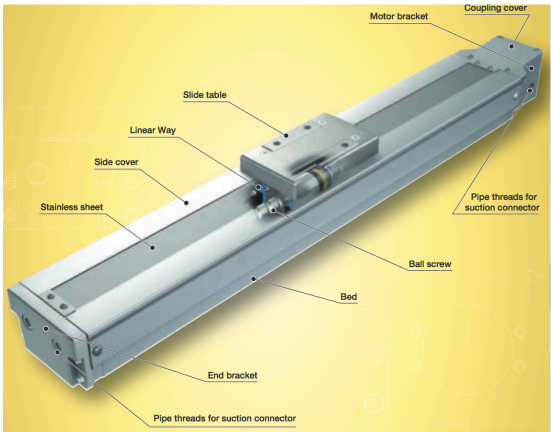


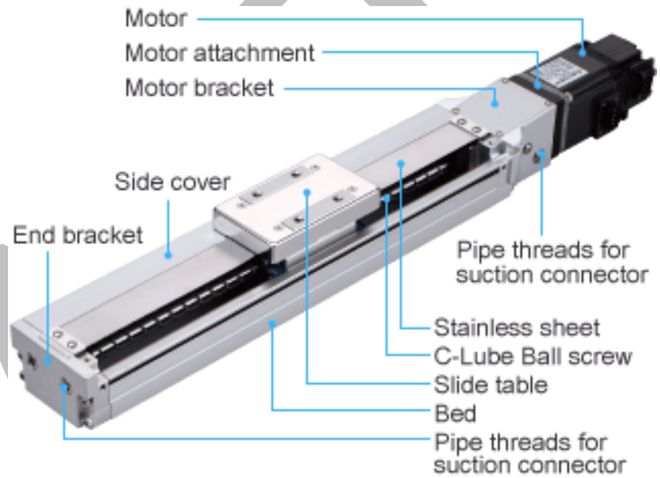


Length [mm]:	275 ... 1250	**Height [mm]:**	65 ... 140	**Width [mm]:**	120 ... 420

Length of travel [mm]:	100 ... 800	**Accuracy [µm]:**	3 ... 8 *)
Load capacity F_z [N]:	1540 ... 5360	**Repeatability [µm]:**	(+/-) 0.5 *)
Travel force F_x [N]:	80 ... 300	**Backlash [µm]:**	?
Min. Torque [Nm]:	?	**Gear ratio [mm/°]:**	5, 10/360
Max. Speed [m/s]:	0.15 ... 0.5	**Weight [kg]:**	17 ... 104 **)
Mechanics Spindle: ? Guide system: ?		**Material** Spindle: ? Guide system: ? Base/sledge: Iron	
Motor: Stepper motor AC servo motor		**Encoder:** linear	
Position switches: Limit +, Limit -, Origin, Pre-origin		**Producer:** IKO	
Comments: *) values with linear encoder **) basic weight with 300mm stroke **Options:** Crossed version available (2 units combined, movable in xy-plane)			
Webpage: http://www.ikont.com/..		**Price [EUR]:**	?

5.1.19 IKO – TC

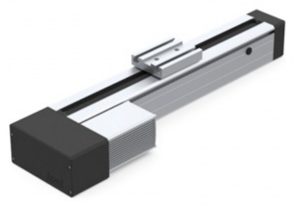




Length [mm]:	226 ... 1030	**Height [mm]:**	42 ... 62	**Width [mm]:**	72 ... 108

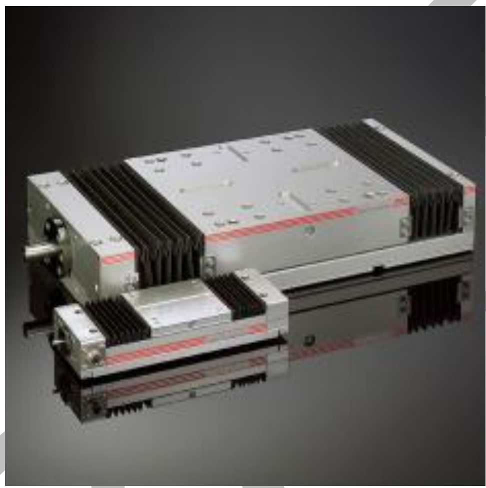
Length of travel [mm]:	50 ... 800	**Accuracy [µm]:**	35 ... 65
Load capacity F_z [N]:	120 ... 360	**Repeatability [µm]:**	(+/-) 2
Travel force F_x [N]:	70 ... 180	**Backlash [µm]:**	5
Min. Torque [Nm]:	?	**Gear ratio [mm/°]:**	4 ... 20/360
Max. Speed [m/s]:	0.2 ... 1	**Weight [kg]:**	0.9 ... 1.1 *)
Mechanics Spindle: ? Guide system: ?		**Material** Spindle: ? Guide system: ? Base/sledge: Aluminium alloy	
Motor: Stepper motor AC servo motor		**Encoder:** linear	
Position switches: Limit +, Limit -, Origin, Pre-origin		**Producer:** IKO	
Comments: *) basic weight with 50mm stroke **Options:** Crossed version available (2 units combined, movable in xy-plane)			
Webpage: http://www.ikont.com/..		**Price [EUR]:**	?

5.1.20 ISEL - LESX



<table>
<tr><td>Length [mm]: ?</td><td colspan="2">Height [mm]: ?</td><td>Width [mm]: ?</td></tr>
<tr><td colspan="2">Length of travel [mm]: ?</td><td colspan="2">Accuracy [µm]: ?</td></tr>
<tr><td colspan="2">Load capacity F_z [N]: ?</td><td colspan="2">Repeatability [µm]: (+/-) 20</td></tr>
<tr><td colspan="2">Travel force F_x [N]: ?</td><td colspan="2">Backlash [µm]: ?</td></tr>
<tr><td colspan="2">Min. Torque [Nm]: ?</td><td colspan="2">Gear ratio [mm/°]: 2.5 ... 20/360</td></tr>
<tr><td colspan="2">Max. Speed [m/s]: ?</td><td colspan="2">Weight [kg]: ?</td></tr>
<tr><td colspan="2">Mechanics
Spindle: ?
Guide system: ?</td><td colspan="2">Material
Spindle: Steel
Guide system: Aluminium/Steel
Base/sledge: Aluminium</td></tr>
<tr><td colspan="2">Motor:
Stepper motor
AC servo motor</td><td colspan="2">Encoder:
linear</td></tr>
<tr><td colspan="2">Position switches:
Limit +, Limit - *)</td><td colspan="2">Producer:
ISEL</td></tr>
<tr><td colspan="4">Comments:
*) position free of choice
Options:
belt drive version available
bellows gaiter cover</td></tr>
<tr><td colspan="2">Webpage: https://www.isel.com/..</td><td colspan="2">Price [EUR]: ?</td></tr>
</table>

5.1.21 Line Tech - LM x.x.xxxx x x



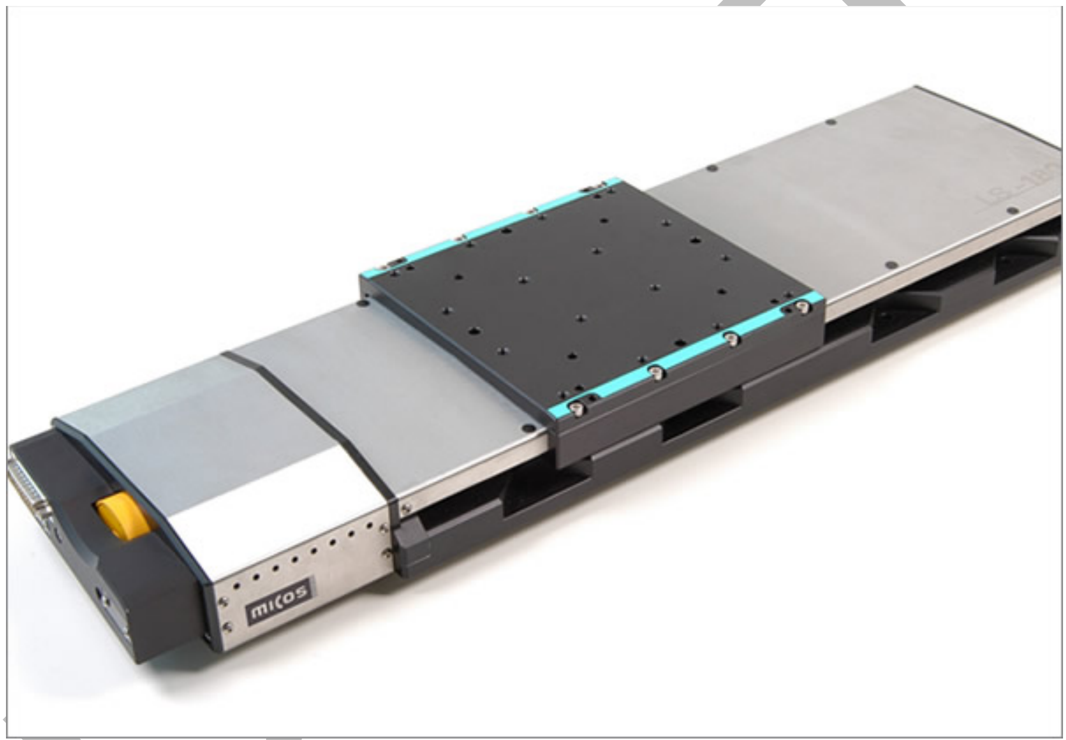
Length [mm]:	0... 2360 *)	**Height [mm]:** 85 ... 129	**Width [mm]:** 65 ... 110
Length of travel [mm]:	length - 360 **)	**Accuracy [µm]:**	130 *****)
Load capacity F_z [N]:	16700 ***)	**Repeatability [µm]:**	(+/-) 10 ******)
Travel force F_x [N]:	?	**Backlash [µm]:**	?
Min. Torque [Nm]:	?	**Gear ratio [mm/°]:**	2.5 ... 20/360
Max. Speed [m/s]:	****)	**Weight [kg]:**	4.5 ... 16.8*******)
Mechanics Spindle: ? Guide system: ?		**Material** Spindle: Steel Guide system: Aluminium/Steel Base/sledge: Aluminium	
Motor: Stepper motor AC/DC servo motor		**Encoder:** ?	
Position switches: Limit +, Limit - ********)		**Producer:** Line Tech	
Comments: *) wider screws may have a longer stroke **) for smallest version, largest version length – 475 ***) recommended to apply max. 20% of max. load capacity ****) depends on gear ratio, rpm and length *****) per 300mm, higher accuracy available, speedy version has even lower accuracy ******) 50 for speedy version *******) basic weight without stroke ********) PNP, NPN / mechanical **Options:**			
Webpage: http://www.linetech.ch/..		**Price [EUR]:**	?

5.1.22 Micos – LS-270

Length [mm]:	550... 1400	**Height [mm]:**	100	**Width [mm]:**	250

Length of travel [mm]:	155 ... 1016	**Accuracy [µm]:**	on request
Load capacity F_z [N]:	1500	**Repeatability [µm]:**	0.05 ... 0.5
Travel force F_x [N]:	1200	**Backlash [µm]:**	(+/-) 0.1, 2.5
Min. Torque [Nm]:	?	**Gear ratio [mm/°]:**	?
Max. Speed [m/s]:	0.050 ... 0.150	**Weight [kg]:**	25 ... 50
Mechanics Spindle: ? Guide system: cross-roller bearings		**Material** Spindle: ? Guide system: ? Base/sledge: Aluminium anodized	
Motor: 2-phase stepper motor DC servo motor		**Encoder:** available	
Position switches: Limit +, Limit -		**Producer:** Micos	
Comments: **Options:**			
Webpage: http://www.pimicos.com/..		**Price [EUR]:**	?

5.1.23 Micos – LS-180



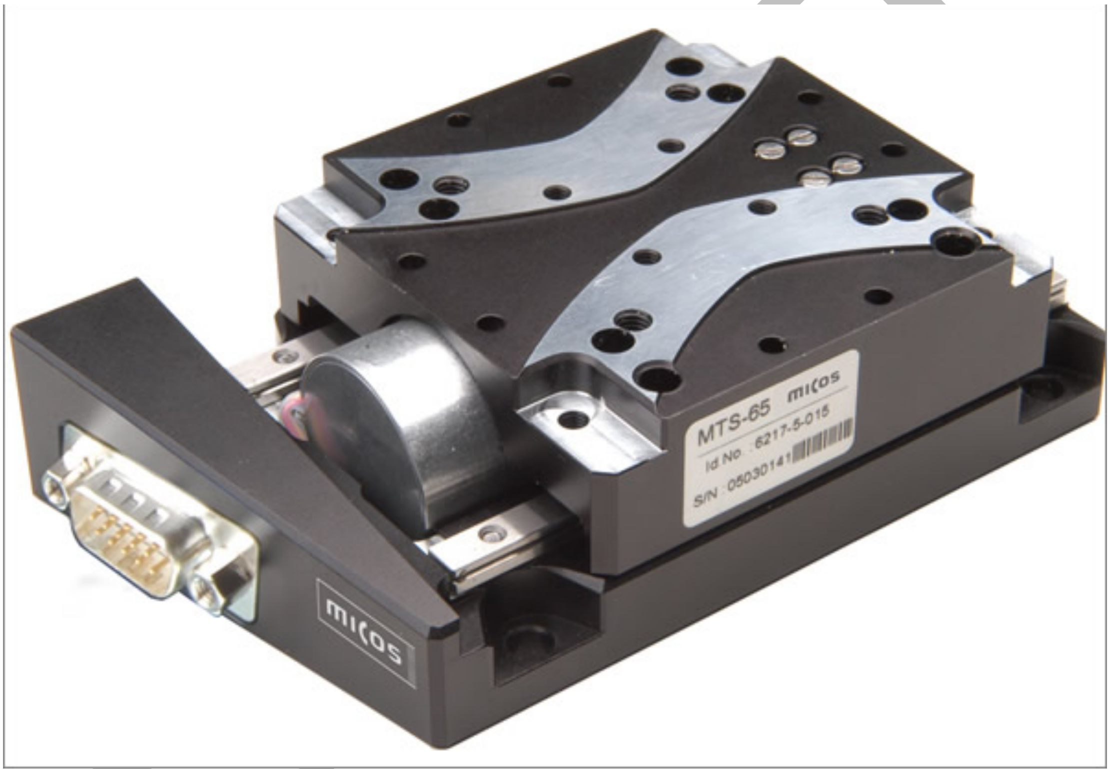
Length [mm]:	470... 820	**Height [mm]:**	55	**Width [mm]:**	150

Length of travel [mm]:	155 ... 508	**Accuracy [µm]:**	on request
Load capacity F_z [N]:	1000	**Repeatability [µm]:**	0.05, 0.5
Travel force F_x [N]:	500	**Backlash [µm]:**	(+/-) 0.1, 0.5
Min. Torque [Nm]:	?	**Gear ratio [mm/°]:**	5/360
Max. Speed [m/s]:	0.075 ... 0.200	**Weight [kg]:**	8.4 ... 10.8
Mechanics Spindle: Guide system:	 ? re-circulating ball guides	**Material** Spindle: Guide system: Base/sledge:	 ? ? ?
Motor: 2-phase stepper motor DC servo motor		**Encoder:** available	
Position switches: Limit +, Limit -		**Producer:** Micos	
Comments: **Options:**			
Webpage: http://www.pimicos.com/..		**Price [EUR]:**	?

5.1.24 Micos – LS-40

Length [mm]: 63 ... 102 *)	**Height [mm]:** 26	**Width [mm]:** 40	
Length of travel [mm]:	13 ... 52	**Accuracy [µm]:**	on request
Load capacity F_z [N]:	30	**Repeatability [µm]:**	(+/-) 3
Travel force F_x [N]:	20	**Backlash [µm]:**	?
Min. Torque [Nm]:	?	**Gear ratio [mm/°]:**	0.5 ... 1/360
Max. Speed [m/s]:	0.0004 ...0.0015	**Weight [kg]:**	0.18 ... 0.25
Mechanics Spindle: ? Guide system: re-circulating ball guides		**Material** Spindle: ? Guide system: ? Base/sledge: Aluminium anodized	
Motor: 2-phase stepper motor DC servo motor		**Encoder:** available	
Position switches: Limit +, Limit -		**Producer:** Micos	
Comments: *) motor excluded **Options:**			
Webpage: http://www.pimicos.com/..		**Price [EUR]:**	?

5.1.25 Micos – MTS-65



Length [mm]: 100 ... 148 *)	**Height [mm]:** 31	**Width [mm]:** 80.4	
Length of travel [mm]:	13 ... 52	**Accuracy [µm]:**	on request
Load capacity F_z [N]:	20	**Repeatability [µm]:**	(+/-) 0.2 ... 5
Travel force F_x [N]:	10	**Backlash [µm]:**	?
Min. Torque [Nm]:	?	**Gear ratio [mm/°]:**	?
Max. Speed [m/s]:	0.008	**Weight [kg]:**	0.4 ... 0.8
Mechanics Spindle: Guide system:	 ? re-circulating ball bearing	**Material** Spindle: Guide system: Base/sledge:	 ? ? Aluminium anodized
Motor: 2-phase stepper motor		**Encoder:** available	
Position switches: Limit +, Limit -		**Producer:** Micos	
Comments: *) motor excluded **Options:** repeatability and accuracy down to 0.1 µm offered with linear scale			
Webpage: http://www.pimicos.com/..		**Price [EUR]:**	?

5.1.26 Micos – PLS-85

Length [mm]:	119 ... 258 *)	**Height [mm]:** 35	**Width [mm]:** 84
Length of travel [mm]:	26 ... 155	**Accuracy [µm]:**	on request
Load capacity F_z [N]:	100	**Repeatability [µm]:**	(+/-) 0.1 ... 1
Travel force F_x [N]:	60	**Backlash [µm]:**	?
Min. Torque [Nm]:	?	**Gear ratio [mm/°]:**	1/360
Max. Speed [m/s]:	0.005	**Weight [kg]:**	0.9 ... 1.8
Mechanics Spindle: Guide system:	 ? cross-roller bearings	**Material** Spindle: Guide system: Base/sledge:	 ? ? Aluminium anodized
Motor: 2-phase stepper motor DC servo motor		**Encoder:** available	
Position switches: Limit +, Limit -		**Producer:** Micos	
Comments: *) motor excluded **Options:** linear scale for higher precission			
Webpage: http://www.pimicos.com/..		**Price [EUR]:**	?

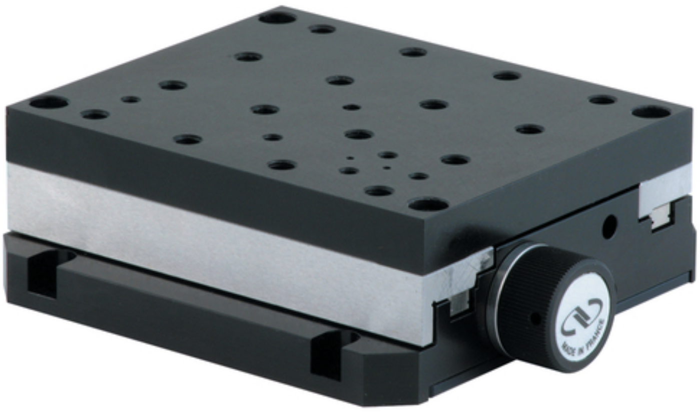
5.1.27 Micos – LS-110

Length [mm]: 225 ... 480 *)	**Height [mm]:** 45	**Width [mm]:** 110	
Length of travel [mm]:	26 ... 305	**Accuracy [µm]:**	on request
Load capacity F_z [N]:	100	**Repeatability [µm]:**	(+/-) 0.1 ... 1
Travel force F_x [N]:	50	**Backlash [µm]:**	?
Min. Torque [Nm]:	?	**Gear ratio [mm/°]:**	2/360
Max. Speed [m/s]:	0.045 ... 0.09	**Weight [kg]:**	2.6 ... 3.7
Mechanics Spindle: ? Guide system: re-circulating linear ball bearings		**Material** Spindle: ? Guide system: ? Base/sledge: Aluminium anodized	
Motor: 2-phase stepper motor DC servo motor		**Encoder:** available	
Position switches: Limit +, Limit -		**Producer:** Micos	
Comments: *) motor excluded **Options:** linear scale for higher precission			
Webpage: http://www.pimicos.com/..		**Price [EUR]:**	?

5.1.28 Micos – HPS-170

Length [mm]: 261 ... 556	**Height [mm]:** 50	**Width [mm]:** 170	
Length of travel [mm]:	55 ... 305	**Accuracy [μm]:**	on request
Load capacity F_z [N]:	350	**Repeatability [μm]:**	0.05, 0,2
Travel force F_x [N]:	150	**Backlash [μm]:**	(+/-) 0.05, 1
Min. Torque [Nm]:	?	**Gear ratio [mm/°]:**	?
Max. Speed [m/s]:	0.0359	**Weight [kg]:**	5 ... 7
Mechanics Spindle: Guide system:	 ? high-quality cross-roller bearings	**Material** Spindle: Guide system: Base/sledge:	 ? ? Aluminium anodized
Motor: 2-phase stepper motor DC servo motor		**Encoder:** available	
Position switches: Limit +, Limit -		**Producer:** Micos	
Comments: **Options:**			
Webpage: http://www.pimicos.com/..		**Price [EUR]:**	?

5.1.29 Newport – VP25 XX



Length [mm]:	110	**Height [mm]:** 39	**Width [mm]:** 110
Length of travel [mm]:	25	**Accuracy [µm]:**	(+/-) 1
Load capacity F_z [N]:	60	**Repeatability [µm]:**	0.07 ... 0.15
Travel force F_x [N]:	40	**Backlash [µm]:**	0.14, 0.2
Min. Torque [Nm]:	?	**Gear ratio [mm/°]:**	1/360
Max. Speed [m/s]:	0.000025	**Weight [kg]:**	1.5
Mechanics Spindle: Guide system:	 ? recirculating ball bearings	**Material** Spindle: Guide system: Base/sledge:	 ? ? Aluminium
Motor: DC servo motor		**Encoder:** available *)	
Position switches: Limit +, Limit - **)		**Producer:** Newport	
Comments: *) existing output, standard or analogue encoder interface **) optical **Options:** Backlash-free ball screw			
Webpage: http://www.newport.com/..		**Price [EUR]:**	?

5.1.30 Newport – GTS

Length [mm]:	150, 225	**Height [mm]:**	50	**Width [mm]:**	125

Length of travel [mm]:	70, 150	**Accuracy [µm]:**	(+/-) 1
Load capacity F_z [N]:	100	**Repeatability [µm]:**	0.15
Travel force F_x [N]:	20, 25	**Backlash [µm]:**	0.2
Min. Torque [Nm]:	?	**Gear ratio [mm/°]:**	2/360
Max. Speed [m/s]:	0.05	**Weight [kg]:**	2.7, 3.6
Mechanics Spindle: Guide system:	 8 mm diameter Anti-creep crossed roller bearings	**Material** Spindle: Guide system: Base/sledge:	 ? ? Aluminium
Motor: DC servo motor		**Encoder:** available *)	
Position switches: Limit +, Limit -		**Producer:** Newport	
Comments: *) integrated linear encoder with 50 nm resolution **) optical **Options:** Backlash-free ground ball screw			
Webpage: http://www.newport.com/..		**Price [EUR]:**	?

5.1.31 Newport – ILS

Length [mm]:	358 ... 594	**Height [mm]:** 60	**Width [mm]:** 115
Length of travel [mm]:	50 ... 250	**Accuracy [µm]:**	(+/-) 1.5 ... 5
Load capacity F_z [N]:	250	**Repeatability [µm]:**	0.4, 1
Travel force F_x [N]:	<40	**Backlash [µm]:**	0.7, 2
Min. Torque [Nm]:	?	**Gear ratio [mm/°]:**	2/360
Max. Speed [m/s]:	0.05 ... 0.1	**Weight [kg]:**	4.2 ... 5.4
Mechanics Spindle: ? Guide system: double-row recirculating ball bearing		**Material** Spindle: ? Guide system: ? Base/sledge: Aluminium	
Motor: Stepper motor DC servo motor		**Encoder:** available *)	
Position switches: Limit +, Limit - **)		**Producer:** Newport	
Comments: *) Screw mounted rotary encoder for some versions **) optical **Options:** Backlash-free ball screw			
Webpage: http://www.newport.com/..		**Price [EUR]:**	?

5.1.32 Rose + Krieger – PLS

Length [mm]:	142 ... 252 *)	**Height [mm]:**	50 ... 118	**Width [mm]:**	90 ... 200

Length of travel [mm]:	830 ... 3000	**Accuracy [µm]:**	(+/-) 100 **)
Load capacity F_z [N]:	790 ... 2550	**Repeatability [µm]:**	?
Travel force F_x [N]:	340 ... 3050	**Backlash [µm]:**	?
Min. Torque [Nm]:	0.1 ... 0.4	**Gear ratio [mm/°]:**	3 ... 10/360
Max. Speed [m/s]:	?	**Weight [kg]:**	1 ... 16.66 ***)
Mechanics Spindle: lead or ball screw Guide system: ?		**Material** Spindle: Aluminium Guide system: Aluminium Base/sledge: Aluminium	
Motor: 3 phase stepper motor DC servo motor		**Encoder:** ?	
Position switches: Limit +, Limit -		**Producer:** Rose + Krieger	
Comments: *) basic length **) per 300 mm travel ***) weight for basic length, additional weight per 100mm travel has to be added **Options:**			
Webpage: http://www.rk-rose-krieger.com/		**Price [EUR]:**	?

5.1.33 Rose + Krieger – RK Compact, RK DuoLine S

Length [mm]:	58 ... 502 *)	**Height [mm]:**	28 ... 160	**Width [mm]:**	17 ... 100

Length of travel [mm]:	10 ... 2890	**Accuracy [µm]:**	(+/-) 50 **)
Load capacity F_z [N]:	160 ... 8900	**Repeatability [µm]:**	(+/-) 40 ... 100
Travel force F_x [N]:	50 ... 8000	**Backlash [µm]:**	?
Min. Torque [Nm]:	0.2	**Gear ratio [mm/°]:**	1 ... 50/360
Max. Speed [m/s]:	0.02 ... 2.4	**Weight [kg]:**	0.06 ... 11.7 ***)
Mechanics Spindle: ? Guide system: ?		**Material** Spindle: ? Guide system: ? Base/sledge: ?	
Motor: 3 phase stepper motor DC servo motor hand wheel		**Encoder:** available ***)	
Position switches: Limit +, Limit -		**Producer:** Rose + Krieger	
Comments: *) basic length with 0mm stroke **) per 300 mm travel ***) only duoLine **Options:** higher accuracy for duoLine with linear encoder longer strokes available on request			
Webpage: http://www.rk-rose-krieger.com/		**Price [EUR]:**	?

5.1.34 Schaeffler – MKUSE

Length [mm]: ?	**Height [mm]:** 125		**Width [mm]:** 110
Length of travel [mm]:	any?	**Accuracy [µm]:**	?
Load capacity F_z [N]:	45500?	**Repeatability [µm]:**	?
Travel force F_x [N]:	?	**Backlash [µm]:**	?
Min. Torque [Nm]:	?	**Gear ratio [mm/°]:**	5 ... 40/360
Max. Speed [m/s]:	?	**Weight [kg]:**	17.5 *)
Mechanics Spindle: ? Guide system: ?		**Material** Spindle: ? Guide system: ? Base/sledge: ?	
Motor: Servo motor		**Encoder:** ?	
Position switches: ?		**Producer:** Schaeffler	
Comments: *) basic weight, no stroke **Options:**			
Webpage: http://medias.schaeffler.com/..		**Price [EUR]:**	?

5.1.35 Steinmeyer – PLT240-xx

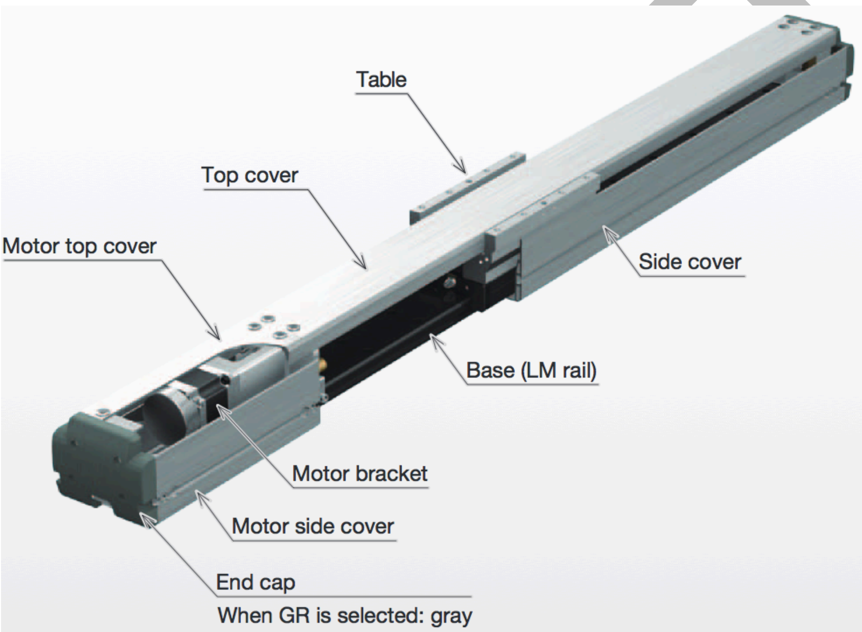
Length [mm]: ?	**Height [mm]:** ?	**Width [mm]:** 240	
Length of travel [mm]:	100 ... 850	**Accuracy [µm]:**	2 ... 25
Load capacity F_z [N]:	872	**Repeatability [µm]:**	(+/-) 0.5 ... 1
Travel force F_x [N]:	180 ... 826	**Backlash [µm]:**	?
Min. Torque [Nm]:	?	**Gear ratio [mm/°]:**	5/360
Max. Speed [m/s]:	0.25	**Weight [kg]:**	22 ... 25 *)
Mechanics Spindle: ? Guide system: ?		**Material** Spindle: ? Guide system: ? Base/sledge: ?	
Motor: Stepper motor DC servo Linear motor		**Encoder:** linear, rotary	
Position switches: ?		**Producer:** Steinmeyer	
Comments: *) with 100mm stroke **Options:**			
Webpage: http://mechatronik.steinmeyer.com/..		**Price [EUR]:**	?

5.1.36 Steinmeyer – PA30-DC

Length [mm]:	329.5 *)	**Height [mm]:**	40	**Width [mm]:**	30

Length of travel [mm]:	25 ... 150	**Accuracy [µm]:**	10
Load capacity F_z [N]:	204.4	**Repeatability [µm]:**	(+/-) 1
Travel force F_x [N]:	44.4	**Backlash [µm]:**	1.5
Min. Torque [Nm]:	?	**Gear ratio [mm/°]:**	1/360
Max. Speed [m/s]:	0.1	**Weight [kg]:**	?
Mechanics Spindle: ? Guide system: ?		**Material** Spindle: ? Guide system: anodized surface Base/sledge: stainless bearings	
Motor: Stepper motor DC servo		**Encoder:** rotary	
Position switches: Limit +, Limit - **)		**Producer:** Steinmeyer	
Comments: *) with 100mm stroke **) integrated hall-switches **Options:** options: stepper motor clean room preparation vacuum preparation			
Webpage: http://mechatronik.steinmeyer.com/..		**Price [EUR]:**	?

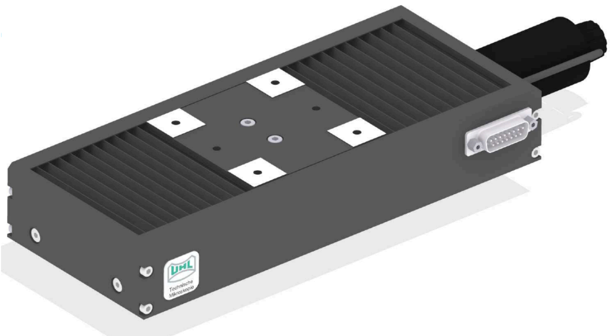
5.1.37 THK – US



Length [mm]:	400 ... 540 *)	**Height [mm]:**	70 ... 86	**Width [mm]:**	65 ... 124

Length of travel [mm]:	100 ... 1700	**Accuracy [μm]:**	?
Load capacity F_z [N]:	?	**Repeatability [μm]:**	(+/-) 20
Travel force F_x [N]:	210	**Backlash [μm]:**	50
Min. Torque [Nm]:	?	**Gear ratio [mm/°]:**	5 ... 40/360
Max. Speed [m/s]:	0.12 ... 2.2 **)	**Weight [kg]:**	3 ... 22.6 ***)
Mechanics Spindle: ? Guide system: ?		**Material** Spindle: ? Guide system: ? Base/sledge: ?	
Motor: ?		**Encoder:** available	
Position switches: Limit +, Limit - ****)		**Producer:** THK	
Comments: *) basic length with 100mm stroke **) depending on stroke ***) with 100mm stroke ****) photo sensor PNP **Options:** many different versions available			
Webpage: http://abh30.com/thk/..		**Price [EUR]:**	?

5.1.38 Walter Uhl - LT



Length [mm]: ?	**Height [mm]:** 40	**Width [mm]:** 100 ... 210

Length of travel [mm]: ?	**Accuracy [µm]:** ?
Load capacity F_z [N]: ?	**Repeatability [µm]:** ?
Travel force F_x [N]: ?	**Backlash [µm]:** ?
Min. Torque [Nm]: ?	**Gear ratio [mm/°]:** 5/360
Max. Speed [m/s]: ?	**Weight [kg]:** 3 ... 22.6 ***)
Mechanics Spindle: ballscrew *) Guide system: backlash-free preloaded cross roller guides	**Material** Spindle: ? Guide system: ? Base/sledge: Aluminium anodized
Motor: Stepper DC servo	**Encoder:** linear, rotary
Position switches: ?	**Producer:** Walter Uhl
Comments: *) backlash-free preloaded **Options:** custom motors encoder TTL	
Webpage: http://www.walteruhl.com/	**Price [EUR]:** ?

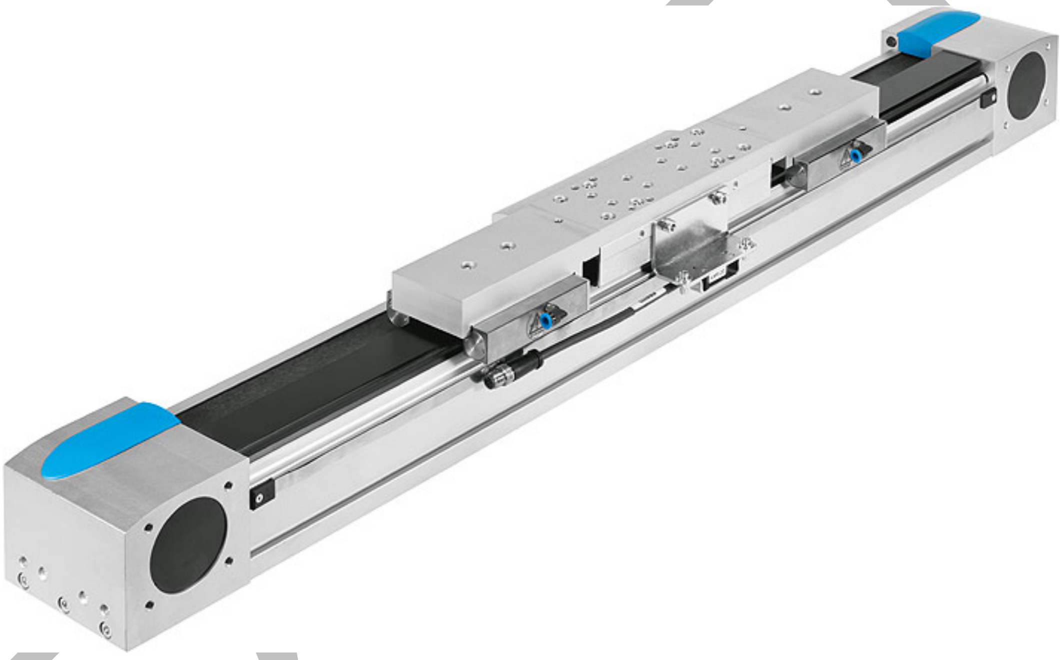
5.2 Belt-drive

5.2.1 Festo - DGE



Length [mm]: ?	**Height [mm]:** ?	**Width [mm]:**	8 ... 63
Length of travel [mm]:	1 ... 5000 *)	**Accuracy [µm]:**	?
Load capacity F_z [N]:	38 ... 14050 *)	**Repeatability [µm]:**	(+/-) 80 ... 100
Travel force F_x [N]:	?	**Backlash [µm]:**	?
Min. Torque [Nm]:	?	**Gear ratio [mm/°]:**	?
Max. Speed [m/s]:	1 ... 10 *)	**Weight [kg]:**	variable
Mechanics Spindle: ? Guide system: ?		**Material** Spindle: Guide system: Base/sledge:	 Polychloropene Glascord and nylon Aluminium anodized
Motor: Stepper DC servo		**Encoder:** ?	
Position switches: ?		**Producer:** Festo	
Comments: *) depending on model and width **Options:** special length on request			
Webpage: http://www.festo.com/..		**Price [EUR]:**	?

5.2.2 Festo - EGC



Length [mm]:	155 ... 612	**Height [mm]:**	43 ... 173	**Width [mm]:**	50 ... 185

Length of travel [mm]:	50 ... 1900 *)	**Accuracy [µm]:**	?
Load capacity F_z [N]:	38 ... 14050 *)	**Repeatability [µm]:**	(+/-) 80 ... 100
Travel force F_x [N]:	2395 ... 55997	**Backlash [µm]:**	?
Min. Torque [Nm]:	?	**Gear ratio [mm/°]:**	?
Max. Speed [m/s]:	3.5	**Weight [kg]:**	0.62 ... 32.6 **)
Mechanics Spindle: Guide system:	 10 ... 50.5 mm width ?	**Material** Spindle: Guide system: Base/sledge:	 Polychloropene Glascord and nylon Aluminium anodized
Motor: Stepper DC servo		**Encoder:** available	
Position switches: available		**Producer:** Festo	
Comments: *) with most narrow version, longer strokes available for wider versions **) basic weight with 0 mm stroke **Options:** special length on request			
Webpage: http://www.festo.com/..		**Price [EUR]:**	?

5.2.3 Festo - ELGR

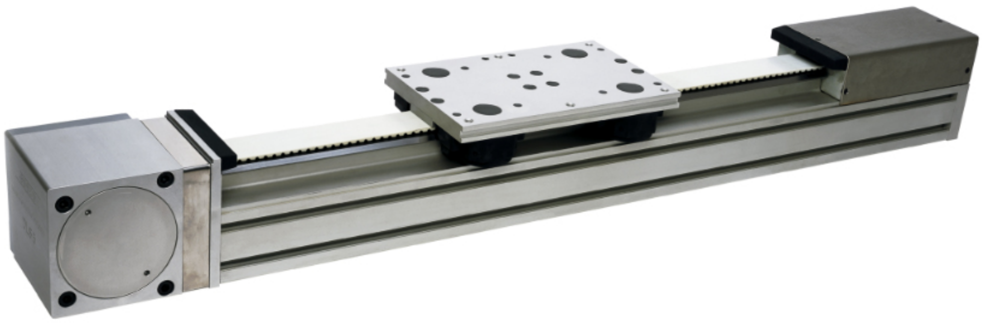
Length [mm]:	178 ... 243 *)	**Height [mm]:**	78 ... 135	**Width [mm]:**	35 ... 55

Length of travel [mm]:	50 ... 1500	**Accuracy [µm]:**	?
Load capacity F_z [N]:	38 ... 300 **)	**Repeatability [µm]:**	(+/-) 80
Travel force F_x [N]:	50 ... 350 **)	**Backlash [µm]:**	?
Min. Torque [Nm]:	0.1 ... 0.4	**Gear ratio [mm/°]:**	2 ... 3/360
Max. Speed [m/s]:	3	**Weight [kg]:**	1.5 ... 5.4 ***)
Mechanics Spindle: Guide system:	 ? recirculating ball bearing ****)	**Material** Spindle: Guide system: Base/sledge:	 Polychloropene Glascord, nylon, steel Aluminium anodized
Motor: Stepper DC servo		**Encoder:** supported	
Position switches: Limit+, Limit - *****)		**Producer:** Festo	
Comments: *) with 0 mm stroke **) depending on weight ***) basic weight with 0mm stroke ****) option: plain bearing guide *****) NPN, PNP **Options:** optimum price/performance ratio option: 2 slide version (ELGG) long slide available			
Webpage: http://www.festo.com/..		**Price [EUR]:**	?

5.2.4 Franke - FTC

Length [mm]: 260 ... 274 *)	**Height [mm]:** 74 ... 88	**Width [mm]:** 73 ... 117	
Length of travel [mm]:	100 ... 3400	**Accuracy [µm]:**	?
Load capacity F_z [N]:	?	**Repeatability [µm]:**	?
Travel force F_x [N]:	?	**Backlash [µm]:**	?
Min. Torque [Nm]:	0.2 ... 0.6	**Gear ratio [mm/°]:**	?
Max. Speed [m/s]:	2 ... 5	**Weight [kg]:**	0.75 ... 13.2
Mechanics Spindle: ? Guide system: Aluminium roller guide		**Material** Spindle: ? Guide system: ? Base/sledge: ?	
Motor: ?		**Encoder:** ?	
Position switches: Limit+, Limit - *****)		**Producer:** Franke	
Comments: *) + stroke **Options:** spindle version available			
Webpage: http://www.franke-gmbh.com/..		**Price [EUR]:**	?

5.2.5 HepcoMotion - DLS



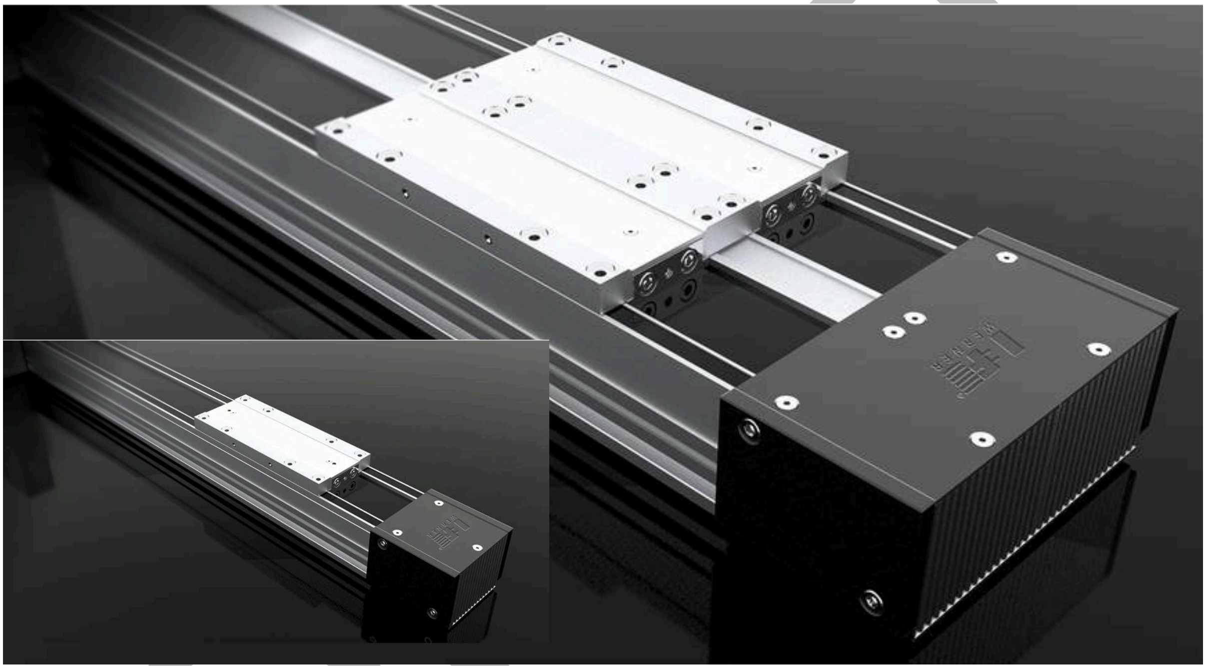
Length [mm]:	0 ... 6000 *)	**Height [mm]:** 100, 130	**Width [mm]:** 90, 116
Length of travel [mm]:	length - 558	**Accuracy [µm]:**	100 **)
Load capacity F_z [N]:	1600, 3500	**Repeatability [µm]:**	<500
Travel force F_x [N]:	560, 125	**Backlash [µm]:**	?
Min. Torque [Nm]:	?	**Gear ratio [mm/°]:**	0.135 ... 0.2/360
Max. Speed [m/s]:	0.5 ... 5 *)	**Weight [kg]:**	34 ***)
Mechanics Spindle: ? Guide system: ?		**Material** Spindle: ? Guide system: ? Base/sledge: Aluminium	
Motor: Stepper motor AC/DC servo		**Encoder:** no feedback	
Position switches: Limit+, Limit - ****)		**Producer:** Franke	
Comments: *) depending on motor and gear box **) depending on motor and controller ***) with 1000mm stroke, 17.5 kg for each additional 1000 mm stroke ****) mechanical, inductive **Options:** HDLS version with similar attitudes available			
Webpage: http://www.hepcomotion.com/		**Price [EUR]:**	?

5.2.6 Hiwin - KA

Length [mm]:	492 ... 3292	**Height [mm]:**	71 ... 116	**Width [mm]:**	100 ...170

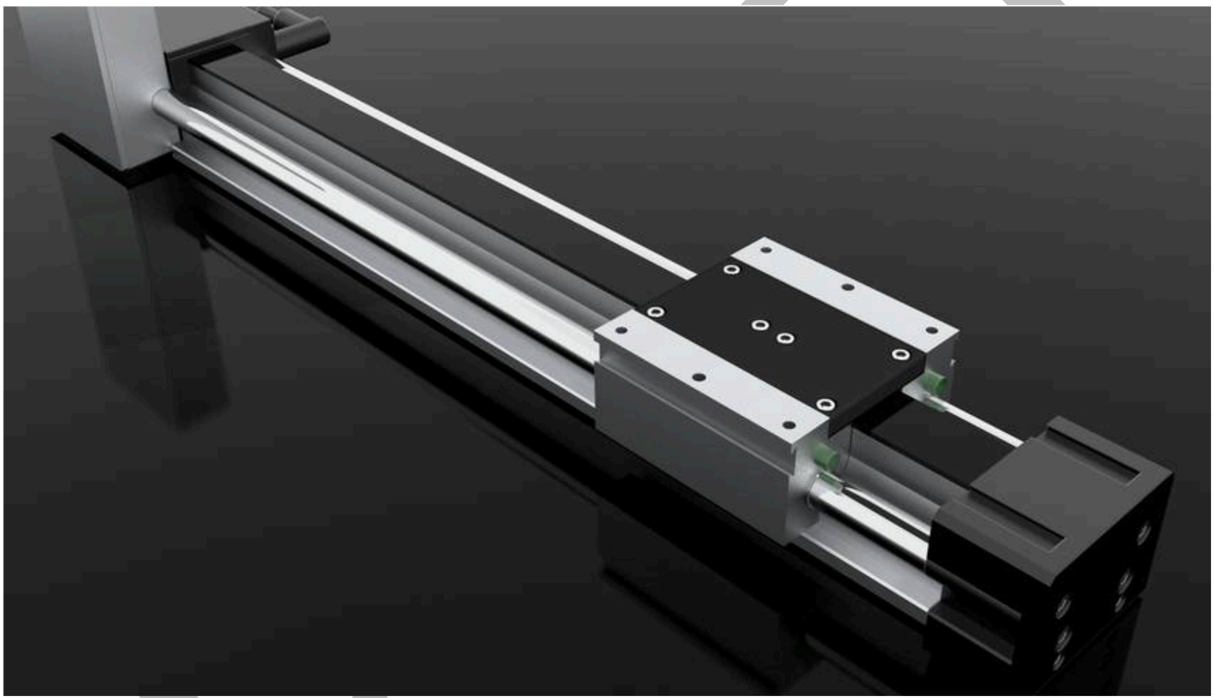
Length of travel [mm]:	length - 292	**Accuracy [μm]:**	?
Load capacity F_z [N]:	100 ... 390	**Repeatability [μm]:**	20 ... 100
Travel force F_x [N]:	?	**Backlash [μm]:**	?
Min. Torque [Nm]:	?	**Gear ratio [mm/°]:**	?
Max. Speed [m/s]:	1.8 *)	**Weight [kg]:**	4.86 ... 29.5
Mechanics Spindle: ? Guide system: ?		**Material** Spindle: ? Guide system: ? Base/sledge: Aluminium	
Motor: 3-/5-phase stepper motor servo motor		**Encoder:** ?	
Position switches: Limit+, Limit -		**Producer:** Franke	
Comments: *) depending on model, other versions might be lower **Options:** If the product is to be used in a vertical implementation, contact the manufacturer			
Webpage: http://www.hiwin.com/..		**Price [EUR]:**	?

5.2.7 IEF - Module 65/15, 80/15, 115/42, 160/15



Length [mm]: 524 ... 5924	**Height [mm]:** 82	**Width [mm]:** 100 ... 195	
Length of travel [mm]:	100 ... 5500	**Accuracy [μm]:**	?
Load capacity F_z [N]:	500 ... 2000	**Repeatability [μm]:**	40 ... 50
Travel force F_x [N]:	?	**Backlash [μm]:**	?
Min. Torque [Nm]:	?	**Gear ratio [mm/°]:**	46.667 ... 140/360
Max. Speed [m/s]:	5	**Weight [kg]:**	6 ... 10.4 *)
Mechanics Spindle: ? Guide system: ?		**Material** Spindle: ? Guide system: ? Base/sledge: ?	
Motor: no motor supplied		**Encoder:** ?	
Position switches: Limit+, Limit -		**Producer:** IEF	
Comments: *) basic weight for 100mm stroke **Options:**			
Webpage:		**Price [EUR]:**	?

5.2.8 IEF – easyLine



Length [mm]: 390 ... 5790	**Height [mm]:** 65		**Width [mm]:** 105	
Length of travel [mm]:	100 ... 5500		**Accuracy [µm]:**	?
Load capacity F_z [N]:	1000		**Repeatability [µm]:**	(+/-) 40
Travel force F_x [N]:	?		**Backlash [µm]:**	?
Min. Torque [Nm]:	?		**Gear ratio [mm/°]:**	46.667 ... 140/360
Max. Speed [m/s]:	2.5		**Weight [kg]:**	4.4 *)
Mechanics Spindle: ? Guide system: ?			**Material** Spindle: ? Guide system: ? Base/sledge: ?	
Motor: no motor supplied			**Encoder:** ?	
Position switches: Limit+, Limit -			**Producer:** IEF	
Comments: *) basic weight for 100mm stroke **Options:**				
Webpage:			**Price [EUR]:**	?

5.2.9 IEF – Module 105, 142

Length [mm]:	379 ... 5850	**Height [mm]:**	68 ... 75	**Width [mm]:**	140 ... 190
Length of travel [mm]:	100 ... 5500	**Accuracy [μm]:**	?		
Load capacity F_z [N]:	1500 ... 3800	**Repeatability [μm]:**	(+/-) 40		
Travel force F_x [N]:	?	**Backlash [μm]:**	?		
Min. Torque [Nm]:	?	**Gear ratio [mm/°]:**	?		
Max. Speed [m/s]:	2	**Weight [kg]:**	8.2 ... 11.2 *)		
Mechanics Spindle: ? Guide system: ?		**Material** Spindle: ? Guide system: ? Base/sledge: ?			
Motor: no motor supplied		**Encoder:** ?			
Position switches: Limit+, Limit -		**Producer:** IEF			
Comments: *) basic weight for 100mm stroke **Options:**					
Webpage:		**Price [EUR]:**	?		

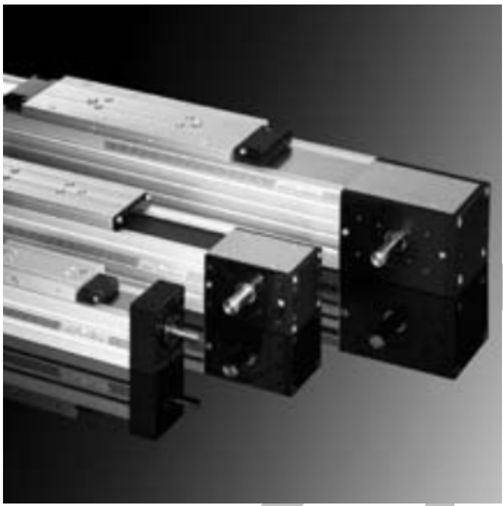
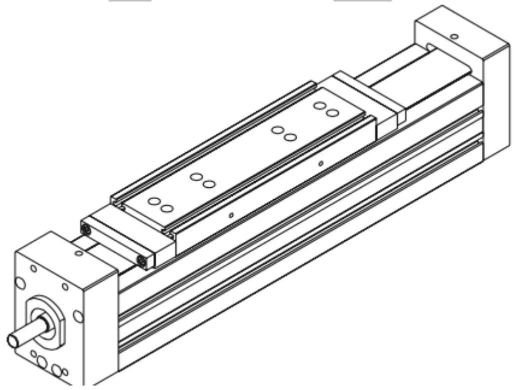
5.2.10 ISEL – LEZ



Length [mm]:	298…2998	**Height [mm]:**	44…95	**Width [mm]:**	30…130

Length of travel [mm]:	<2050… 6000	**Accuracy [µm]:**	(+/-) ?
Load capacity F_z [N]:	?	**Repeatability [µm]:**	(+/-) 0.2
Travel force F_x [N]:	?	**Backlash [µm]:**	(+/-) ?
Min. Torque [Nm]:	?	**Gear ratio [mm/°]:**	?
Max. Speed [m/s]:	1.5 … 5	**Weight [kg]:**	3.43… 12 *)
Mechanics Spindle: Guide system:		**Material** Spindle: Guide system: Base/sledge:	 Aluminium
Motor: Stepper/ servo		**Encoder:** ?	
Position switches: ?		**Producer:** ISEL	
Comments: *) Without drive module, 1000mm **Options:** Covered version available			

5.2.11 Line Tech - LM

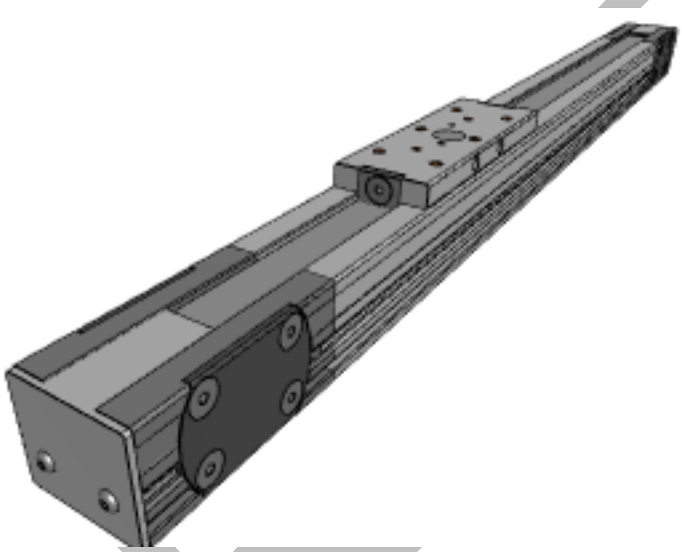
Length [mm]:	475…8375	**Height [mm]:**	85…129	**Width [mm]:**	65…110

Length of travel [mm]:	<7900	**Accuracy [µm]:**	(+/-) 200/1000mm
Load capacity F_z [N]:	1560…5280	**Repeatability [µm]:**	(+/-) 100
Travel force F_x [N]:	?	**Backlash [µm]:**	(+/-) 0
Min. Torque [Nm]:	?	**Gear ratio [mm/°]:**	?
Max. Speed [m/s]:	1.6	**Weight [kg]:**	4.5…19.5*)
Mechanics Spindle: Guide system:	 Linear guide	**Material** Spindle: Guide system: Base/sledge:	
Motor: AC/ DC/ stepper		**Encoder:** ?	
Position switches: PNP, NPN/ mechanical		**Producer:** Line Tech	
Comments: *) with 0mm stroke **Options:** Roller guide available			
Webpage: http://www.kml.at/downl...		**Price [EUR]:**	?

5.2.12 Rose Krieger – PLZ, SQZ, LMZ

Length [mm]: 142…640*)	**Height [mm]:** 50…198	**Width [mm]:** 90…200	
Length of travel [mm]:	<4590…5898	**Accuracy [μm]:**	(+/-) ?
Load capacity F_z [N]:	790…7000	**Repeatability [μm]:**	(+/-) 50
Travel force F_x [N]:	140…3400	**Backlash [μm]:**	(+/-) ?
Min. Torque [Nm]:	0.25…1.2	**Gear ratio [mm/°]:**	3…8/360
Max. Speed [m/s]:	0.5…10	**Weight [kg]:**	1…22.8*)
Mechanics Spindle: Guide system:		**Material** Spindle: Guide system: Base/sledge:	 Aluminium Aluminium Aluminium
Motor: AC servo/ 3-ph stepper		**Encoder:** ?	
Position switches: Limit+, Limit- (inductive, mechanical)		**Producer:** Rose Krieger	
Comments: *) with 0mm stroke **Options:**			
Webpage: http://www.rk-rose-krieg...		**Price [EUR]:**	?

5.2.13 Schaeffler – MLFI



Length [mm]: ?	**Height [mm]:** 45…110	**Width [mm]:** 38…86

Length of travel [mm]: <2000	**Accuracy [µm]:** (+/-) ?
Load capacity F_z [N]: ?	**Repeatability [µm]:** (+/-) ?
Travel force F_x [N]: ?	**Backlash [µm]:** (+/-) ?
Min. Torque [Nm]: ?	**Gear ratio [mm/°]:** ?
Max. Speed [m/s]: ?	**Weight [kg]:** 1.1…8*)
Mechanics Spindle: Guide system: Internally guided	**Material** Spindle: Guide system: Base/sledge:
Motor: AC/ DC/ stepper	**Encoder:** ?
Position switches: ?	**Producer:** Schaeffler
Comments: *) with 0mm stroke **Options:** Longer travel lengths on request, available with 3 sets of toothed belts.	
Webpage: https://www.festo.com/net/fi_...	**Price [EUR]:** ?

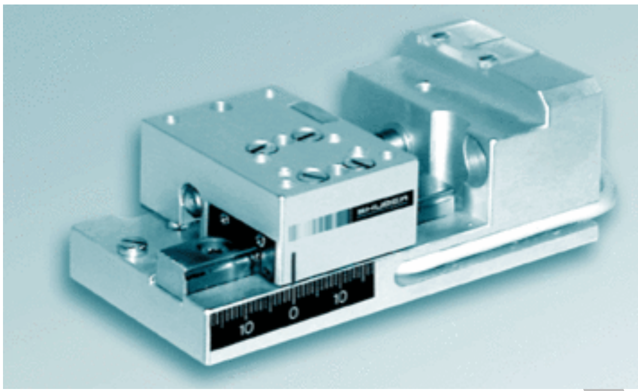
5.3 Lead screw drive

5.3.1 Festo - DMES

Length [mm]:	178…328 *)	**Height [mm]:**	57…145	**Width [mm]:**	45…142

Length of travel [mm]:	50…1800	**Accuracy [µm]:**	(+/-) ?
Load capacity F_z [N]:	36…14050	**Repeatability [µm]:**	(+/-) 50…70
Travel force F_x [N]:	240…3000	**Backlash [µm]:**	(+/-) <100
Min. Torque [Nm]:	0.07…1.1	**Gear ratio [mm/°]:**	1.5…6/360
Max. Speed [m/s]:	0.05	**Weight [kg]:**	0.55…27.14*)
Mechanics Spindle: Guide system:	 Recirculating ball bearings	**Material** Spindle: Guide system: Base/sledge:	 Steel Hardened steel Wrought Al alloy, anodised
Motor: DC/ servo/ stepper		**Encoder:** Available	
Position switches: Available		**Producer:** Festo	
Comments: *) With 0mm stroke **Options:** with/ without guide. Protected version available.			
Webpage: https://www.festo.com/net/fi...		**Price [EUR]:**	?

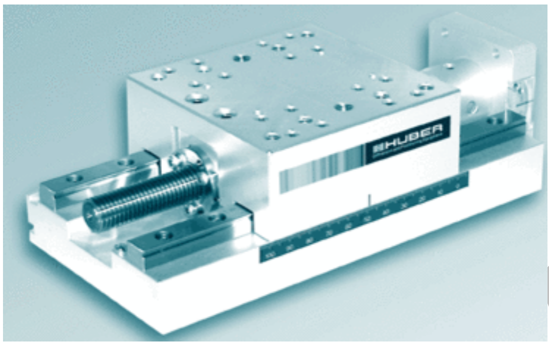
5.3.2 Huber 5101.05



Length [mm]: 88	**Height [mm]:** 29	**Width [mm]:** 43

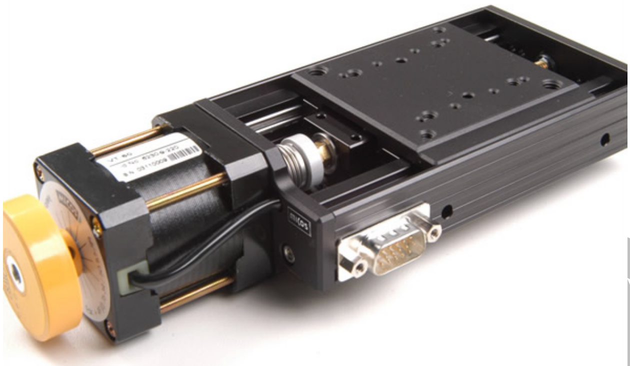
Length of travel [mm]:	30 *)	**Accuracy [µm]:**	(+/-) ?
Load capacity F_z [N]:	50	**Repeatability [µm]:**	(+/-) ?
Travel force F_x [N]:	50	**Backlash [µm]:**	(+/-) ?
Min. Torque [Nm]:	0.02	**Gear ratio [mm/°]:**	1/360
Max. Speed [m/s]:	?	**Weight [kg]:**	0.25
Mechanics Spindle: Guide system:	 Self-locking	**Material** Spindle: Guide system: Base/sledge:	 Bronze Aluminium
Motor: 2-/5-ph servo/ DC		**Encoder:** Incremental	
Position switches: Mechanical		**Producer:** Huber	
Comments: *) can be extended or shortened **Options:** Extended or shortened travel range, adjustable limit switches.			
Webpage: http://www.xhuber.de/en/pr...		**Price [EUR]:**	?

5.3.3 Huber – 5101.20 X1



Length [mm]: 219	**Height [mm]:** 62	**Width [mm]:** 102	
Length of travel [mm]:	100 *)	**Accuracy [µm]:**	(+/-) 10
Load capacity F_z [N]:	1000	**Repeatability [µm]:**	(+/-) 3
Travel force F_x [N]:	250	**Backlash [µm]:**	6
Min. Torque [Nm]:	0.6	**Gear ratio [mm/°]:**	2/360
Max. Speed [m/s]:	?	**Weight [kg]:**	2.8
Mechanics Spindle: Free of play Guide system: Low friction		**Material** Spindle: Bronze Guide system: Base/sledge: Aluminium	
Motor: 2-/3-/5-ph servo/ DC		**Encoder:** ?	
Position switches: Mechanical		**Producer:** Huber	
Comments: *) can be extended or shortened **Options:** Extended or shortened travel range, adjustable limit switches.			
Webpage: http://www.xhuber.de/en...		**Price [EUR]:**	?

5.3.4 Micos – VT-80



Length [mm]:	100…375*)	**Height [mm]:** 25	**Width [mm]:** 72.5
Length of travel [mm]:	25…300	**Accuracy [µm]:**	(+/-) on req.
Load capacity F_z [N]:	50	**Repeatability [µm]:**	(+/-) 10 **)
Travel force F_x [N]:	40	**Backlash [µm]:**	?
Min. Torque [Nm]:	?	**Gear ratio [mm/°]:**	1/360
Max. Speed [m/s]:	0.013…0.020	**Weight [kg]:**	0.55…1.25
Mechanics Spindle: Guide system:	 Recirculating ball bearing	**Material** Spindle: Guide system: Base/sledge:	 Al, black anodised
Motor: 2-ph stepper/DC servo		**Encoder:** Available	
Position switches: Limit+, Limit-		**Producer:** Micos	
Comments: *) motor excluded **) bidirectional **Options:** vacuum prepared			
Webpage: http://www.pimicos.com/w...		**Price [EUR]:**	?

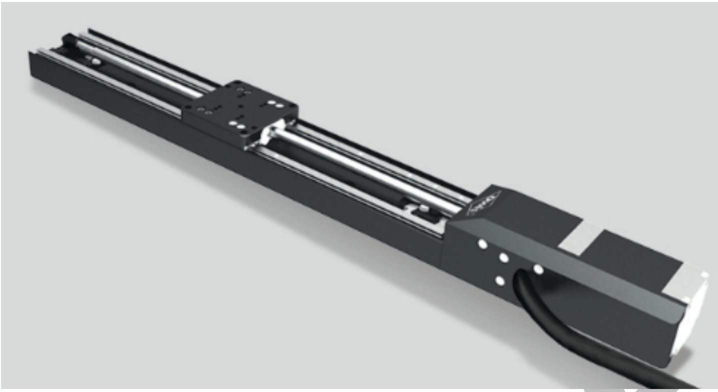
5.3.5 Micos – LS-65

Length [mm]: 93…171*)	**Height [mm]:** 30	**Width [mm]:** 75	
Length of travel [mm]:	26…102	**Accuracy [µm]:**	(+/-) on req.
Load capacity F_z [N]:	60	**Repeatability [µm]:**	(+/-) 5**)
Travel force F_x [N]:	50	**Backlash [µm]:**	?
Min. Torque [Nm]:	?	**Gear ratio [mm/°]:**	0.4…1/360
Max. Speed [m/s]:	0.02	**Weight [kg]:**	0.6…0.9
Mechanics Spindle: Guide system:	 Recirculating ball guides	**Material** Spindle: Guide system: Base/sledge:	 Al, black anodised
Motor: 2-ph stepper/DC servo		**Encoder:** Available	
Position switches: Limit+, Limit-		**Producer:** Micos	
Comments: *) motor excluded **) bidirectional **Options:** vacuum prepared			
Webpage: http://www.pimicos.com/we...		**Price [EUR]:**	?

5.3.6 Newport - UTS

Length [mm]: 180…280	**Height [mm]:** 42.3	**Width [mm]:** 105	
Length of travel [mm]:	50…150	**Accuracy [µm]:**	(+/-) 2.25…4
Load capacity F_z [N]:	200	**Repeatability [µm]:**	(+/-) 1
Travel force F_x [N]:	50	**Backlash [µm]:**	3.5…6
Min. Torque [Nm]:	?	**Gear ratio [mm/°]:**	2/360
Max. Speed [m/s]:	0.02…0.04	**Weight [kg]:**	2.8…3.8
Mechanics Spindle: Guide system:	 Linear ball bearing	**Material** Spindle: Guide system: Base/sledge:	 Steel
Motor: Micro stepper/DC servo		**Encoder:** Rotary encoder (not all versions)	
Position switches: optical		**Producer:** Newport	
Comments: Precision ground backlash-compensated; Leadscrew with decoupling nut **Options:**			
Webpage: http://www.newport.com/UTS...		**Price [EUR]:**	?

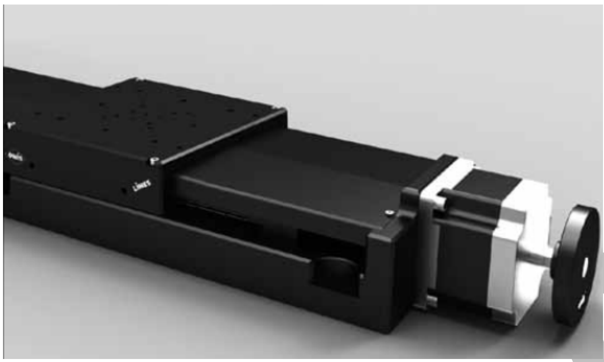
5.3.7 Owis - LPTM



Length [mm]:	160…260	**Height [mm]:**	22	**Width [mm]:**	30

Length of travel [mm]:	50…150	**Accuracy [µm]:**	(+/-) <35
Load capacity F_z [N]:	60	**Repeatability [µm]:**	(+/-) <9*)
Travel force F_x [N]:	20	**Backlash [µm]:**	?
Min. Torque [Nm]:	?	**Gear ratio [mm/°]:**	0.5/360
Max. Speed [m/s]:	?	**Weight [kg]:**	?
Mechanics Spindle: Guide system:	 Stainless recirculating ball bearings	**Material** Spindle: Guide system: Base/sledge:	 Reflection poor black anodised Al
Motor: 2-ph stepper/ DC servo		**Encoder:** Available	
Position switches: Available		**Producer:** Owis	
Comments: *) Bidirectional **Options:**			
Webpage: http://www.owis.eu/fileadm...		**Price [EUR]:**	?

5.3.8 Owis - LIMES




Length [mm]:	265…1870	**Height [mm]:**	38…80	**Width [mm]:**	45…170

Length of travel [mm]:	85…1500	**Accuracy [µm]:**	(+/-) <10/100mm
Load capacity F_z [N]:	70…1500	**Repeatability [µm]:**	(+/-) <3 *)
Travel force F_x [N]:	20…400	**Backlash [µm]:**	?
Min. Torque [Nm]:	?	**Gear ratio [mm/°]:**	1…5/360
Max. Speed [m/s]:	0.005…0.15	**Weight [kg]:**	?
Mechanics Spindle: Guide system:	 Stainless recirculating ball bearings	**Material** Spindle: Guide system: Base/sledge:	 Reflection poor black anodised Al
Motor: 2-ph stepper/ DC servo		**Encoder:** Available	
Position switches: Available		**Producer:** Owis	

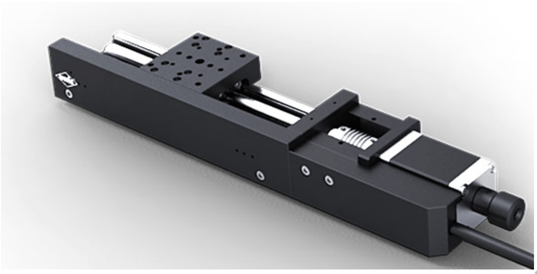
Comments: *) Bidirectional

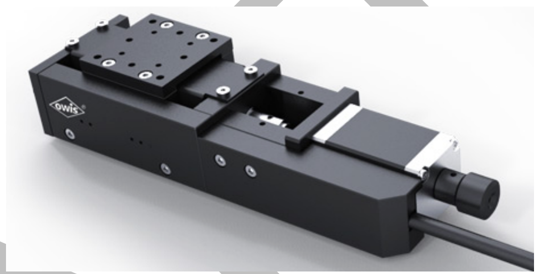
Several different models available some including bellows (60, 80, 122 mm width) rest with metal covering.

Options: Brake, linear measuring system, mechanical limit switches, vacuum prepared. (all options are not available for all models)

Webpage:	http://www.owis.eu/en/pro...	**Price [EUR]:**	?

5.3.9 Owis - LTM





Length [mm]:	285…535	**Height [mm]:**	32.5…50	**Width [mm]:**	55.3…135

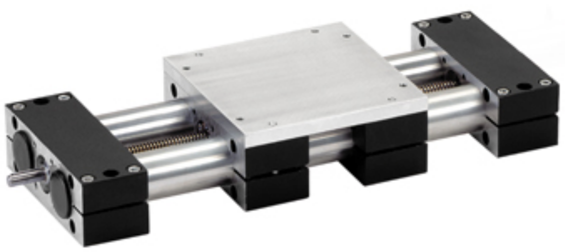
Length of travel [mm]:	25…390	**Accuracy [µm]:**	(+/-) <(25…35)
Load capacity F_z [N]:	70…150	**Repeatability [µm]:**	(+/-) ?
Travel force F_x [N]:	20…60	**Backlash [µm]:**	<15
Min. Torque [Nm]:	?	**Gear ratio [mm/°]:**	1/360
Max. Speed [m/s]:	0.005…0.010	**Weight [kg]:**	?
Mechanics Spindle: Guide system:		**Material** Spindle: Guide system: Base/sledge:	 Aluminium
Motor: 2-ph stepper/ DC servo		**Encoder:** Available	
Position switches: Hall-effect, mechanical		**Producer:** Owis	
Comments: **Options:** Metal covering; Bellows; parallel mounted motor			
Webpage: http://www.owis.eu/pro...		**Price [EUR]:**	?

5.3.10 Rose Krieger - quad

Length [mm]:	96…354*)	**Height [mm]:**	30…80**)	**Width [mm]:**	30…80**)

Length of travel [mm]:	<1375…3006	**Accuracy [µm]:**	(+/-) 150/300mm
Load capacity F_z [N]:	33…6000	**Repeatability [µm]:**	(+/-) ?
Travel force F_x [N]:	800…2500	**Backlash [µm]:**	?
Min. Torque [Nm]:	0.3…0.9	**Gear ratio [mm/°]:**	3…5/360
Max. Speed [m/s]:	?	**Weight [kg]:**	0.3…4.66*)
Mechanics Spindle: Guide system:		**Material** Spindle: Guide system: Base/sledge:	
Motor: No motor supplied (hand wheel)		**Encoder:** No encoder	
Position switches: Limit+, Limit-		**Producer:** Rose Krieger	
Comments: *) with 0mm stroke **) Only guide dimensions **Options:**			
Webpage: http://www.rk-rose-krie...		**Price [EUR]:**	?

5.3.11 Rose Krieger – EP(X), COPAS, PLM




Length [mm]:	104…360*)	**Height [mm]:**	29…143	**Width [mm]:**	82…360

Length of travel [mm]:	380…2915	**Accuracy [µm]:**	(+/-) 100…200***)
Load capacity F_z [N]:	70…9100	**Repeatability [µm]:**	(+/-) 100
Travel force F_x [N]:	400…4500	**Backlash [µm]:**	?
Min. Torque [Nm]:	0.3…1.4	**Gear ratio [mm/°]:**	1…6/360
Max. Speed [m/s]:	2.7…8 mm/s **)	**Weight [kg]:**	0.09…36.01 *)
Mechanics Spindle: Guide system:		**Material** Spindle: Guide system: Base/sledge:	 Anodised Al****)
Motor: Servo / 3-ph motor/ hand wheel		**Encoder:** No encoder	
Position switches: Limit+, Limit-		**Producer:** Rose Krieger	

Comments: *) with 0mm stroke
**) EP(X) with ball bearings allows speeds up to 20mm/s

***) per 300mm travel

****) Copas only

Options: corrosion protected units, bellows, second free-running carriage. Longer strokes available on req.

Webpage: http://www.rk-rose-krieg...	**Price [EUR]:** ?

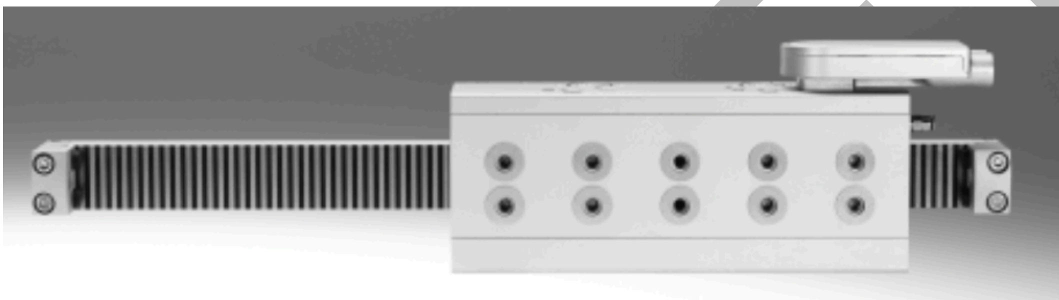
5.3.12 Thorlabs – 220mm

Length [mm]: 195…800	**Height [mm]:** 35…80	**Width [mm]:** 57…130

Length of travel [mm]: 100…600	**Accuracy [µm]:** (+/-) 12
Load capacity F_z [N]: 9…100	**Repeatability [µm]:** (+/-) 0.25…1.5
Travel force F_x [N]: ?	**Backlash [µm]:** ?
Min. Torque [Nm]: ?	**Gear ratio [mm/°]:** ?
Max. Speed [m/s]: 0.4…0.5	**Weight [kg]:** 0.72…9.1
Mechanics Spindle: Guide system: Linear bearings	**Material** Spindle: Guide system: Base/sledge:
Motor: DC servo	**Encoder:** Available
Position switches: ?	**Producer:** Rose Krieger
Comments: not recommended for vertical use. Possible to use the short-stroke units as dual axis configurations. **Options:**	
Webpage: https://www.thorlabs.de/...	**Price [EUR]:** ?

5.4 Linear Motor drive

5.4.1 Festo - ELGL



Length [mm]:	360…550*)	**Height [mm]:** 58…60	**Width [mm]:** 84…174
Length of travel [mm]:	1…1550	**Accuracy [µm]:**	(+/-) ?
Load capacity F_z [N]:	160…2500	**Repeatability [µm]:**	(+/-) 10
Travel force F_x [N]:	44…450	**Backlash [µm]:**	(+/-) ?
Min. Torque [Nm]:	?	**Gear ratio [mm/°]:**	?
Max. Speed [m/s]:	2…4	**Weight [kg]:**	7.7 … 35.8
Mechanics Spindle: Guide system:	 Air bearing	**Material** Spindle: Guide system: Base/sledge:	 Steel Wrought Al alloy, anodised
Motor: Linear AC servo motor		**Encoder:** Incremental, magnetic	
Position switches: ?		**Producer:** Festo	
Comments: *) with 100mm stroke **Options:**			
Webpage: http://www.festo.com/cat/en...		**Price [EUR]:**	?

5.4.2 Franke - FTH

Length [mm]:	506…3872	**Height [mm]:**	65…96	**Width [mm]:**	170…275

Length of travel [mm]:	170…3625	**Accuracy [µm]:**	(+/-) 20
Load capacity F_z [N]:	7500…29900	**Repeatability [µm]:**	(+/-) 20
Travel force F_x [N]:	61…560*)	**Backlash [µm]:**	(+/-) ?
Min. Torque [Nm]:	?	**Gear ratio [mm/°]:**	?
Max. Speed [m/s]:	6	**Weight [kg]:**	3…16**)
Mechanics Spindle: Guide system:	 Roller guide	**Material** Spindle: Guide system: Base/sledge:	 Aluminium
Motor: Linear Motor		**Encoder:** Absolute?	
Position switches: PNP (open/close) 2+1 reference		**Producer:** Franke	
Comments: *) maximum values 162 … 1300 **)with 0mm stroke **Options:**			
Webpage: http://www.franke-gmbh.com/...		**Price [EUR]:**	?

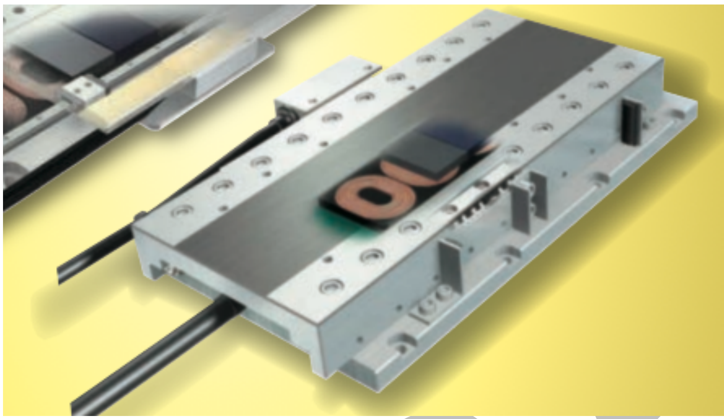
5.4.3 IEF – euroLINE 120 standard slide

To be discussed Several can be combined

Length [mm]:	329…3929	**Height [mm]:**	71	**Width [mm]:**	140.5

Length of travel [mm]:	114…3714	**Accuracy [µm]:**	(+/-) ?
Load capacity F_z [N]:	?	**Repeatability [µm]:**	(+/-) 5
Travel force F_x [N]:	210	**Backlash [µm]:**	(+/-) ?
Min. Torque [Nm]:	?	**Gear ratio [mm/°]:**	?
Max. Speed [m/s]:	5	**Weight [kg]:**	5.75*)
Mechanics Spindle: Guide system:		**Material** Spindle: Guide system: Base/sledge:	
Motor: Linear motor		**Encoder:** ?	
Position switches: ?		**Producer:** ?	
Comments: *) with 0mm stroke **Options:**			
Webpage:		**Price [EUR]:**	?

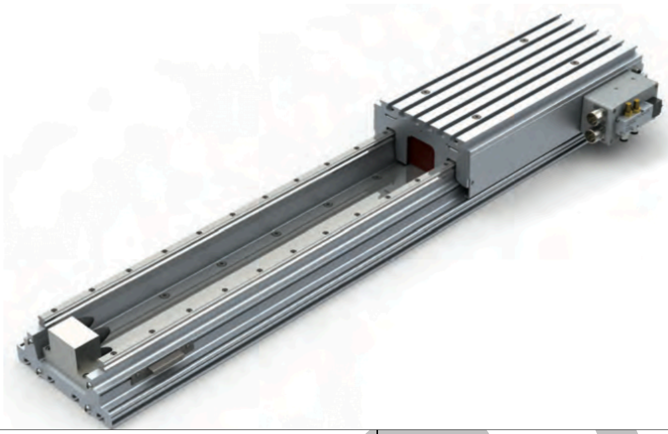
5.4.4 IKO – NT…V



Length [mm]:	62…280	**Height [mm]:**	11…16	**Width [mm]:**	38…88

Length of travel [mm]:	10…120	**Accuracy [µm]:**	(+/-) 1
Load capacity F_z [N]:	50	**Repeatability [µm]:**	(+/-) 0.1…0.5
Travel force F_x [N]:	0.6…8	**Backlash [µm]:**	(+/-) ?
Min. Torque [Nm]:	?	**Gear ratio [mm/°]:**	?
Max. Speed [m/s]:	0.09…1.3	**Weight [kg]:**	1.6…2
Mechanics Spindle: Guide system:	 Linear way (ball type guide system) crossed roller way	**Material** Spindle: Guide system: Base/sledge:	 High carbon steel
Motor: Linear motor		**Encoder:** optical	
Position switches: Limit+, Limit-, pre-origin, origin		**Producer:** IKO	
Comments: *) with 0mm stroke Axis combination possible. **Options:**			
Webpage: http://www.ikont.com/positi...		**Price [EUR]:**	?

5.4.5 ISEL – iLD 50-6



Length [mm]:	691…3513	**Height [mm]:**	?	**Width [mm]:**	?

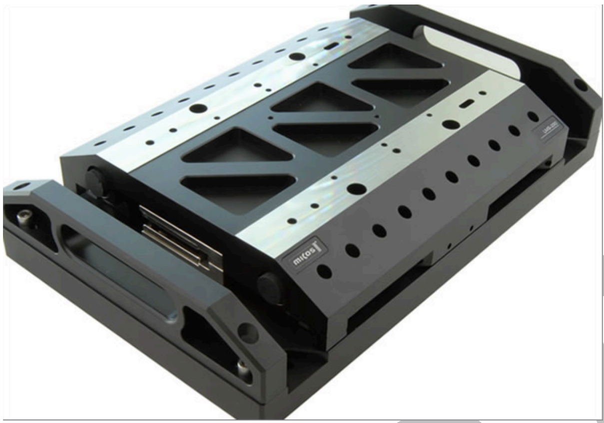
Length of travel [mm]:	181…3003*)	**Accuracy [µm]:**	(+/-) ?
Load capacity F_z [N]:	?	**Repeatability [µm]:**	(+/-) <10
Travel force F_x [N]:	?	**Backlash [µm]:**	(+/-) ?
Min. Torque [Nm]:	?	**Gear ratio [mm/°]:**	?
Max. Speed [m/s]:	4.5	**Weight [kg]:**	?
Mechanics Spindle: Guide system:		**Material** Spindle: Guide system: Base/sledge:	
Motor: Linear motor		**Encoder:** Incremental	
Position switches: Inductive		**Producer:** ISEL (former ISEG)	
Comments: *) possible to expand up to 15m iron core linear motor with magnetic rails, with or without audio signal **Options:**			
Webpage: https://www.isel.com/usa/...		**Price [EUR]:**	?

5.4.6 Micos – UPS-150

Length [mm]:	198 … 454	**Height [mm]:**	55	**Width [mm]:**	155

Length of travel [mm]:	52…305	**Accuracy [µm]:**	(+/-) on req.
Load capacity F_z [N]:	150	**Repeatability [µm]:**	(+/-) 0.015…0.025
Travel force F_x [N]:	75	**Backlash [µm]:**	(+/-) 0.025…0.035
Min. Torque [Nm]:	?	**Gear ratio [mm/°]:**	?
Max. Speed [m/s]:	0.6	**Weight [kg]:**	4.7 … 8.7
Mechanics Spindle: Guide system:	 High quality cross-roller bearings	**Material** Spindle: Guide system: Base/sledge:	 Aluminium, black anodised
Motor: Linear motor		**Encoder:** Available	
Position switches: Limit+, Limit-		**Producer:** Micos	
Comments: **Options:**			
Webpage: http://www.pimicos.com/we...		**Price [EUR]:**	?

5.4.7 Micos – LMS-230



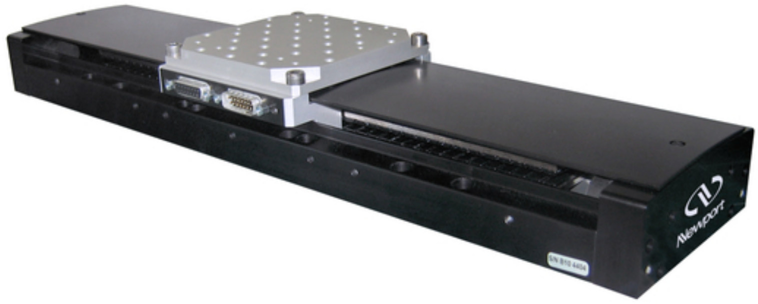
Length [mm]: 375	**Height [mm]:** 72	**Width [mm]:** 230	
Length of travel [mm]:	52	**Accuracy [µm]:**	(+/-) on req.
Load capacity F_z [N]:	88	**Repeatability [µm]:**	(+/-) 0.01
Travel force F_x [N]:	75	**Backlash [µm]:**	(+/-) 0.02
Min. Torque [Nm]:	?	**Gear ratio [mm/°]:**	?
Max. Speed [m/s]:	0.4	**Weight [kg]:**	13.5
Mechanics Spindle: Guide system:	 High quality cross-roller bearings	**Material** Spindle: Guide system: Base/sledge:	 Al, black anodised
Motor: Linear motor		**Encoder:** Available	
Position switches: Limit+, Limit-		**Producer:** Micos	
Comments: **Options:**			
Webpage: http://www.pimicos.com/we...		**Price [EUR]:**	?

5.4.8 Micos – LMS-180

Length [mm]:	470…820	**Height [mm]:**	55	**Width [mm]:**	180

Length of travel [mm]:	155…508	**Accuracy [μm]:**	(+/-) on req.
Load capacity F_z [N]:	450	**Repeatability [μm]:**	(+/-) 0.05
Travel force F_x [N]:	450	**Backlash [μm]:**	(+/-) 0.1
Min. Torque [Nm]:	?	**Gear ratio [mm/°]:**	?
Max. Speed [m/s]:	0.5	**Weight [kg]:**	10.2 … 14.2
Mechanics Spindle: Guide system:		**Material** Spindle: Guide system: Base/sledge:	
Motor: Linear motor		**Encoder:** Available	
Position switches: Limit+, Limit-		**Producer:** Micos	
Comments: **Options:**			
Webpage: http://www.pimicos.com/we...		**Price [EUR]:**	?

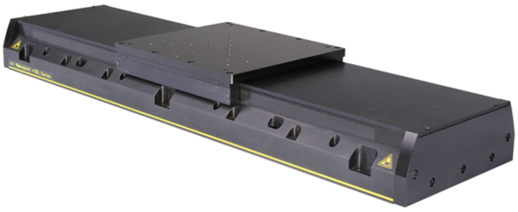
5.4.9 Newport – ILS-LM



Length [mm]: 285…485	**Height [mm]:** 60	**Width [mm]:** 115

Length of travel [mm]:	100…300	**Accuracy [µm]:**	(+/-) 1.5…2.5
Load capacity F_z [N]:	250	**Repeatability [µm]:**	(+/-) 0.4
Travel force F_x [N]:	15*)	**Backlash [µm]:**	(+/-) 0.6
Min. Torque [Nm]:	?	**Gear ratio [mm/°]:**	?
Max. Speed [m/s]:	0.5	**Weight [kg]:**	?
Mechanics Spindle: Guide system:	 Recirculating bearings	**Material** Spindle: Guide system: Base/sledge:	 Steel Aluminium
Motor: Linear motor		**Encoder:** Available	
Position switches: 3 ph synchronous linear motor.		**Producer:** Newport	
Comments: *) Peak travel force: 30. **) necessary as feedback for XPS controller **Options:**			
Webpage: http://www.newport.com/ILS...		**Price [EUR]:**	?

5.4.10 Newport – IDL

<table>
<tr><td colspan="2">Length [mm]: 686…1031</td><td colspan="2">Height [mm]: 100…120</td><td colspan="2">Width [mm]: 225…560</td></tr>
<tr><td colspan="3">Length of travel [mm]: 200…1000</td><td colspan="3">Accuracy [µm]: (+/-) 1.5…2.5</td></tr>
<tr><td colspan="3">Load capacity F_z [N]: 1000…2000</td><td colspan="3">Repeatability [µm]: (+/-) ?</td></tr>
<tr><td colspan="3">Travel force F_x [N]: 113…391</td><td colspan="3">Backlash [µm]: (+/-) 0.75</td></tr>
<tr><td colspan="3">Min. Torque [Nm]: ?</td><td colspan="3">Gear ratio [mm/°]: ?</td></tr>
<tr><td colspan="3">Max. Speed [m/s]: 2</td><td colspan="3">Weight [kg]: ?</td></tr>
<tr><td colspan="3">Mechanics
Spindle:
Guide system: Recirculating caged ball bearings</td><td colspan="3">Material
Spindle:
Guide system:
Base/sledge: Aluminium</td></tr>
<tr><td colspan="3">Motor:
Ironless linear motor</td><td colspan="3">Encoder:
?</td></tr>
<tr><td colspan="3">Position switches:
Optical</td><td colspan="3">Producer:
Newport</td></tr>
<tr><td colspan="6">Comments:
Options:</td></tr>
<tr><td colspan="3">Webpage: http://www.newport.com/IDL...</td><td colspan="3">Price [EUR]: ?</td></tr>
</table>

5.4.11 Owis – HPL 120

Length [mm]:	628…764	**Height [mm]:**	116	**Width [mm]:**	180

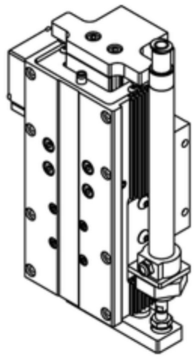
Length of travel [mm]:	240…360	**Accuracy [µm]:**	(+/-) <16 /100mm
Load capacity F_z [N]:	150	**Repeatability [µm]:**	(+/-) <0.4*)
Travel force F_x [N]:	40	**Backlash [µm]:**	(+/-)
Min. Torque [Nm]:	?	**Gear ratio [mm/°]:**	?
Max. Speed [m/s]:	0.4	**Weight [kg]:**	?
Mechanics Spindle: Guide system:	 Stainless recirculating ball bearing	**Material** Spindle: Guide system: Base/sledge:	 Reflector poor black anodised Al.
Motor: Ironless linear motor		**Encoder:** Available	
Position switches: Available		**Producer:** Owis	
Comments: *) bidirectional **Options:**			
Webpage: http://www.owis.eu/filead...		**Price [EUR]:**	?

5.4.12 Steinmeyer – PMT160-EDLM

<table>
<tr><td colspan="2">Length [mm]: 275*)</td><td colspan="2">Height [mm]: 40</td><td colspan="2">Width [mm]: 213</td></tr>
<tr><td colspan="3">Length of travel [mm]: 50…260</td><td colspan="3">Accuracy [µm]: (+/-) 1.5…3</td></tr>
<tr><td colspan="3">Load capacity F_z [N]: 248</td><td colspan="3">Repeatability [µm]: (+/-) 0.3 **)</td></tr>
<tr><td colspan="3">Travel force F_x [N]: 44</td><td colspan="3">Backlash [µm]: (+/-) ?</td></tr>
<tr><td colspan="3">Min. Torque [Nm]: ?</td><td colspan="3">Gear ratio [mm/°]: ?</td></tr>
<tr><td colspan="3">Max. Speed [m/s]: 0.5</td><td colspan="3">Weight [kg]: 6.1*)</td></tr>
<tr><td colspan="3">Mechanics
Spindle:
Guide system:</td><td colspan="3">Material
Spindle:
Guide system:
Base/sledge: Low distortion Al alloy, black anodised</td></tr>
<tr><td colspan="3">Motor:
3-ph linear motor</td><td colspan="3">Encoder:
Incremental</td></tr>
<tr><td colspan="3">Position switches:
Limit+, limit-</td><td colspan="3">Producer:
Steinmeyer</td></tr>
<tr><td colspan="6">Comments: *) with 50mm stroke
**) unidirectional
with bellows
Options:</td></tr>
<tr><td colspan="3">Webpage: http://mechatronik.steinm...</td><td colspan="3">Price [EUR]: ?</td></tr>
</table>

5.5 Special drives

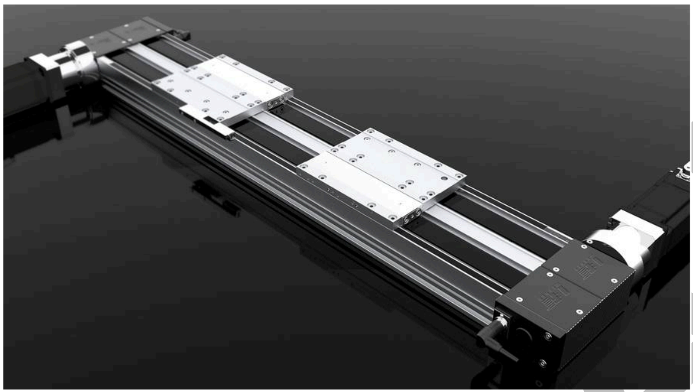
5.5.1 IEF – euroLINE 32 KLA-Z

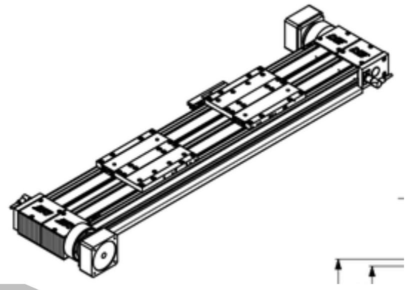



Length [mm]:	162 … 327	**Height [mm]:**	57	**Width [mm]:**	86

Length of travel [mm]:	167 .. 189	**Accuracy [µm]:**	(+/-) ?
Load capacity F_z [N]:	?	**Repeatability [µm]:**	(+/-) 3
Travel force F_x [N]:	22 … 44	**Backlash [µm]:**	(+/-) ?
Min. Torque [Nm]:	?	**Gear ratio [mm/°]:**	?
Max. Speed [m/s]:	5	**Weight [kg]:**	0.71 … 1.05
Mechanics Linear Motor Spindle: ? Guide system: ?		**Material** Spindle: Guide system: Base/sledge:	
Motor: Linear		**Encoder:** ?	
Position switches: ?		**Producer:** IEF	
Comments: Raises in Z-direction **Options:**			
Webpage: http://www.ief-werner.de/...		**Price [EUR]:**	?

5.5.2 IEF – Module 160/15 G



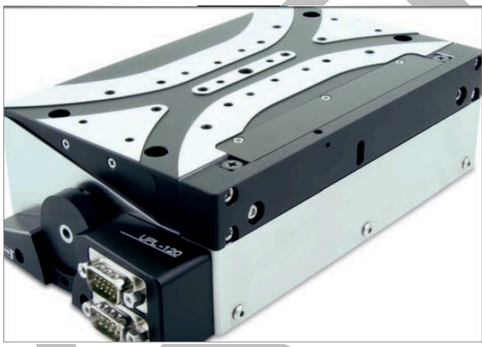


Length [mm]: 740 … 5940	**Height [mm]:** 82	**Width [mm]:** 195
Length of travel [mm]: 100 … 5300	**Accuracy [μm]:** (+/-) ?	
Load capacity F_z [N]: 2000	**Repeatability [μm]:** (+/-) 50	
Travel force F_x [N]: ?	**Backlash [μm]:** (+/-) ?	
Min. Torque [Nm]: ?	**Gear ratio [mm/°]:** ?	
Max. Speed [m/s]: 5	**Weight [kg]:** 12.6 *)	
Mechanics Belt drive Spindle: Guide system:	**Material** ? Spindle: Guide system: Base/sledge:	
Motor: ?	**Encoder:** ?	
Position switches: Stroke lim, End pos switch.	**Producer:** IEF	
Comments: *) basic weight with 100mm stroke. **) stroke increments 100 mm. two movable slides. **Options:**		
Webpage: http://www.ief-werner.de/...	**Price [EUR]:** ?	

5.5.3 Line Tech – PE series

Length [mm]: ? / **Height [mm]:** 50 ... 105	**Width [mm]:** 110 ... 310
Length of travel [mm]: <500... 10000	**Accuracy [µm]:** (+/-)
Load capacity F_z [N]: 9KN...184KN* *)	**Repeatability [µm]:** (+/-) 10 ***)
Travel force F_x [N]: ?	**Backlash [µm]:** (+/-)
Min. Torque [Nm]: ?	**Gear ratio [mm/°]:**
Max. Speed [m/s]: 1.6 ... 5	**Weight [kg]:** 3...45
Mechanics Spindle: Guide system: linear guide	**Material** Spindle: Guide system: Base/sledge:
Motor: DC/AC/stepper	**Encoder:** ?
Position switches: Limit, reference switch available	**Producer:** IEF
Comments: *) Most of the optional drive types can have longer strokes. **) Recommended not to load more than 20% of maximum. ***) (+/-) 5 for satellite ball screw. **Options:** Different drive types available: ball screw, satellite ball screw, high helix lead screw, belt drive, and 'rack and pinion'. Bellows available.	
Webpage: http://www.kml.at/downl...	**Price [EUR]:** ?

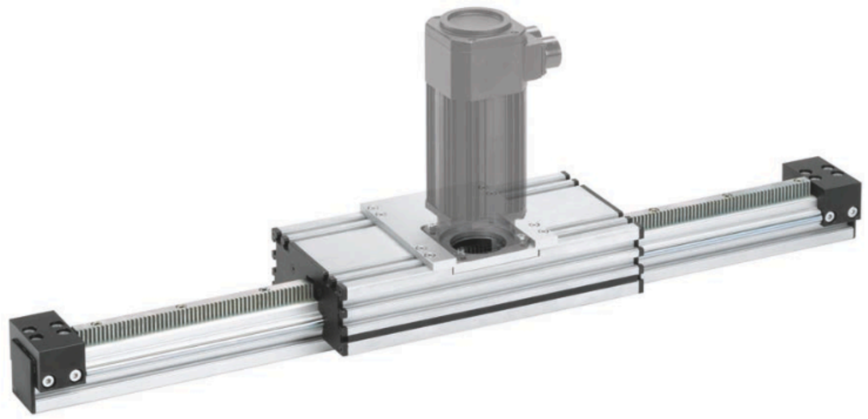
5.5.4 Micos – NPE-200, UPL-120, ES-100

Length [mm]:	140…238	**Height [mm]:**	55+…105	**Width [mm]:**	100…200

Length of travel [mm]:	13…26	**Accuracy [µm]:**	(+/-) on req.
Load capacity F_z [N]:	30…300	**Repeatability [µm]:**	(+/-) 0.04…0.5
Travel force F_x [N]:	100…200	**Backlash [µm]:**	(+/-) 0.04 … 1.5
Min. Torque [Nm]:	?	**Gear ratio [mm/°]:**	2/360
Max. Speed [m/s]:	Line	**Weight [kg]:**	2.1 … 9.2
Mechanics Spindle: Guide system:	Ball screw	**Material** Spindle: Guide system: Base/sledge:	 Aluminium
Motor: 2 phase stepper / DC servo		**Encoder:** ?	
Position switches:		**Producer:** Micos	
Comments: Elevating stages. **Options:**			
Webpage: http://www.pimicos.com/we...		**Price [EUR]:**	?

5.5.5 Rose Krieger – SQ-ZST



Length [mm]:	470*)	**Height [mm]:**	98…198**)	**Width [mm]:**	180…200**)

Length of travel [mm]:	Up to 30m	**Accuracy [µm]:**	(+/-) ?
Load capacity F_z [N]:	2550	**Repeatability [µm]:**	(+/-) ?
Travel force F_x [N]:	1132	**Backlash [µm]:**	(+/-) ?
Min. Torque [Nm]:	?	**Gear ratio [mm/°]:**	?
Max. Speed [m/s]:	5	**Weight [kg]:**	11.77 … 14.28 *)
Mechanics Spindle: Guide system:	Rack and pinion	**Material** Spindle: Guide system: Base/sledge:	 Aluminium
Motor: AC / (3 ph stepper?)		**Encoder:** ?	
Position switches: Mechanical/ inductive limit switches		**Producer:** Rose Krieger	

Comments: *) with 0mm stroke
**) Without motor
Options: Second non-driven carriage. Longer stroke length, additional independently driven carriages.

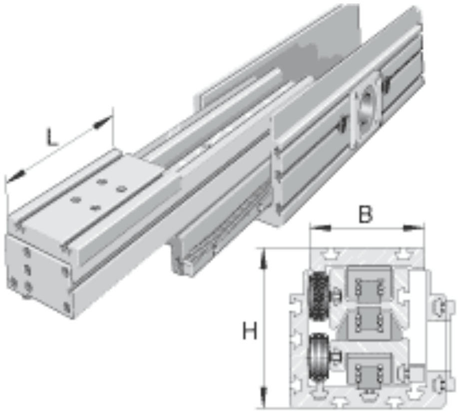
Webpage: http://www.rk-rose-krieg...	**Price [EUR]:** ?

5.5.6 Rose Krieger – RK, E

Length [mm]:	80… 520 *)	**Height [mm]:**	18…80	**Width [mm]:**	18…80

Length of travel [mm]:	220…2740	**Accuracy [μm]:**	(+/-) 200…300 **)
Load capacity F_z [N]:	8…5650	**Repeatability [μm]:**	(+/-) ?
Travel force F_x [N]:	300…4500	**Backlash [μm]:**	(+/-) ?
Min. Torque [Nm]:	0.2…1.20	**Gear ratio [mm/°]:**	2…6/360
Max. Speed [m/s]:	0.003…0.021	**Weight [kg]:**	0.225…10 *)
Mechanics Spindle: Guide system:	Single tube actuator Self locking Slide guide	**Material** Spindle: Guide system: Base/sledge:	 Aluminium Aluminium Aluminium
Motor: No motor supplied (hand wheel)		**Encoder:** No encoder	
Position switches: Limit+, Limit-		**Producer:** Rose Krieger	
Comments: *) with 0mm stroke **) per 300mm travel **Options:** Spindle with ball bearing or slide bearing. Optional carriage with slide bearings available			
Webpage: http://www.rk-rose-krieg...		**Price [EUR]:**	?

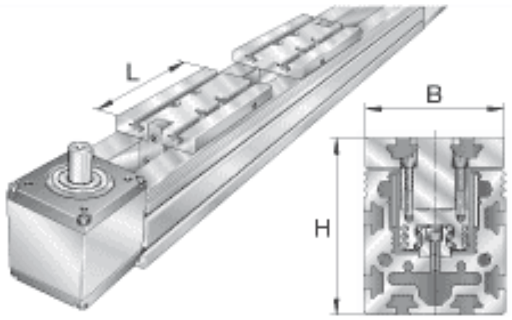
5.5.7 Schaeffler – MTKUSE



Length [mm]: 200	**Height [mm]:** 175	**Width [mm]:** 125

Length of travel [mm]: ?	**Accuracy [µm]:** (+/-) ?
Load capacity F_z [N]: ?	**Repeatability [µm]:** (+/-) ?
Travel force F_x [N]: ?	**Backlash [µm]:** (+/-) ?
Min. Torque [Nm]: ?	**Gear ratio [mm/°]:** ?
Max. Speed [m/s]: ?	**Weight [kg]:** 7.9 … 8.6*)
Mechanics Spindle: Guide system:	**Material** Spindle: Guide system: Base/sledge:
Motor: ?	**Encoder:** ?
Position switches: ?	**Producer:** Schaeffler
Comments: *) with 0mm stroke Sledge with 6 rows of balls. **Options:**	
Webpage: http://medias.schaeffler.d...	**Price [EUR]:** ?

5.5.8 Schaeffler – MKKUSE



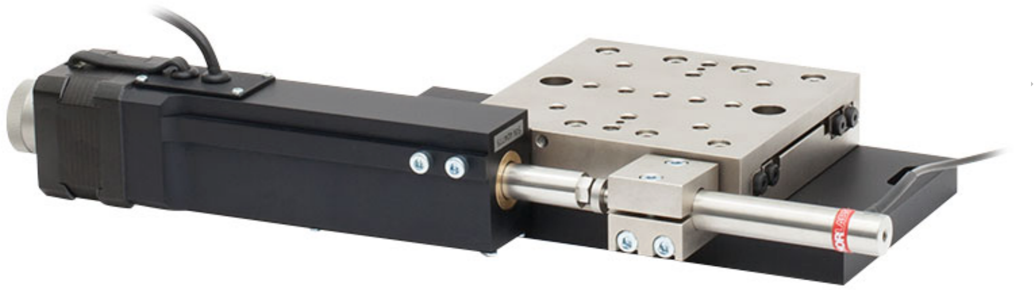
Length [mm]: ?	**Height [mm]:** 110	**Width [mm]:** 86

Length of travel [mm]: <4000*)	**Accuracy [µm]:** (+/-) ?
Load capacity F_z [N]: ?	**Repeatability [µm]:** (+/-) ?
Travel force F_x [N]: ?	**Backlash [µm]:** (+/-) ?
Min. Torque [Nm]: ?	**Gear ratio [mm/°]:** ?
Max. Speed [m/s]: ?	**Weight [kg]:** 7.5**)
Mechanics Belt drive Spindle: Guide system:	**Material** Spindle: Guide system: Base/sledge:
Motor: DC/ AC/ stepper	**Encoder:** ?
Position switches: ?	**Producer:** Schaeffler
Comments: Two carriages moving in opposite direction. *) Longer on request. **) with 0mm stroke. **Options:**	
Webpage: http://medias.schaeffler.c...	**Price [EUR]:** ?

5.5.9 Steinmeyer – PMT160-NM

Length [mm]: 275*)	**Height [mm]:** 40	**Width [mm]:** 187	
Length of travel [mm]:	50…250	**Accuracy [µm]:**	(+/-) 1.5…3
Load capacity F_z [N]:	248	**Repeatability [µm]:**	(+/-) 0.3
Travel force F_x [N]:	44	**Backlash [µm]:**	(+/-) ?
Min. Torque [Nm]:	?	**Gear ratio [mm/°]:**	?
Max. Speed [m/s]:	0.25	**Weight [kg]:**	3.6*)
Mechanics Spindle: Guide system:	Piezo motor	**Material** Spindle: Guide system: Base/sledge:	 Low dist Al. alloy, Black anodised.
Motor: Piezo linear motor		**Encoder:** Incremental	
Position switches: 2 non contact limit switches		**Producer:** Steinmeyer	
Comments: *) with 50mm stroke **Options:** High res lin. Encoder; glass scale for higher accuracy; customized connectors; additional homing sensor; vacuum preparation; cleanroom preparation;			
Webpage: http://mechatronik.steinmeye...		**Price [EUR]:**	?

5.5.10 Thorlabs – 50mm travelMax



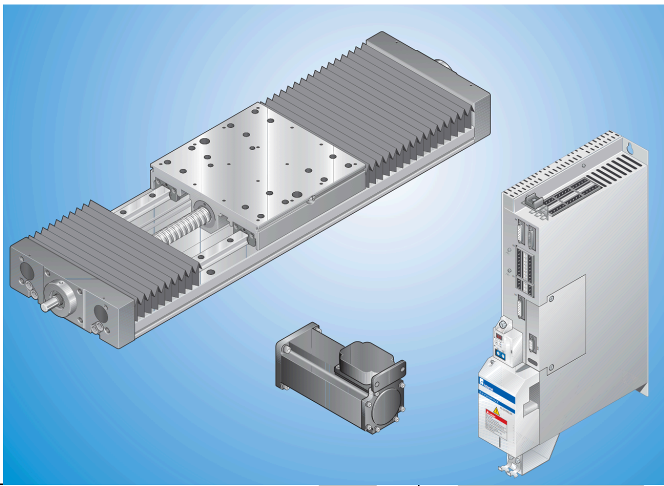
Length [mm]: 292.1	**Height [mm]:** 47.9	**Width [mm]:** 100	
Length of travel [mm]:	50	**Accuracy [µm]:**	(+/-) 0.05
Load capacity F_z [N]:	30	**Repeatability [µm]:**	(+/-) 0.3…0.5
Travel force F_x [N]:	10	**Backlash [µm]:**	(+/-) <6
Min. Torque [Nm]:	?	**Gear ratio [mm/°]:**	?
Max. Speed [m/s]:	0.02	**Weight [kg]:**	2.82
Mechanics Spindle: Guide system:	Stepper+piezo with Heavy-Duty Crossed Roller Bearings	**Material**	Rugged thermally matched steel construction
Motor: Stepper+piezo combined		**Encoder:** Linear optical	
Position switches: ?		**Producer:** Steinmeyer	
Comments: Trapezoidal Lead Screw Stepper Motor for Cleaner, More Wear-Resistant Operation. **Options:** Can be combined with a piezo actuator with travel range of 20 or 100 microns, gives resolutions down to 5nm.			
Webpage: https://www.thorlabs.de/ne...		**Price [EUR]:**	?

5.5.11 Thorlabs – 25mm standard

Length [mm]: 251.2	**Height [mm]:** 20.3	**Width [mm]:** 76.2	
Length of travel [mm]:	25	**Accuracy [µm]:**	(+/-) <130
Load capacity F_z [N]:	90	**Repeatability [µm]:**	(+/-) <1.5
Travel force F_x [N]:	45	**Backlash [µm]:**	(+/-) <8
Min. Torque [Nm]:	?	**Gear ratio [mm/°]:**	?
Max. Speed [m/s]:	2.6	**Weight [kg]:**	?
Mechanics Spindle: Guide system:		**Material** Spindle: Guide system: Base/sledge:	
Motor: 2-phase stepper motor DC servo motor		**Encoder:** Hall effect encoder	
Position switches: Limit+, Limit-		**Producer:** Thorlabs	
Comments: **Options:**			
Webpage: https://www.thorlabs.de/newg...		**Price [EUR]:**	726

5.6 Bosch Rexroth

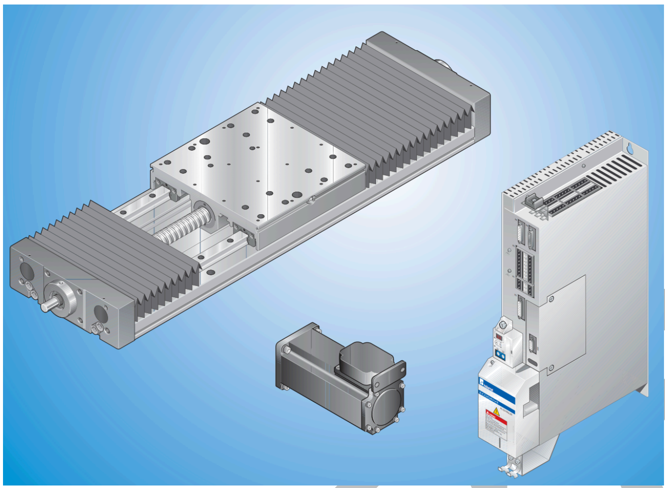
5.6.1 Rexroth-ball rail table TKK 15-155 Al



Length [mm]: *)	**Height [mm]:** 60	**Width [mm]:** 115

Length of travel [mm]: **)	**Accuracy [µm]:** (+/-)
Load capacity F_z [N]: 24000	**Repeatability [µm]:** (+/-)
Travel force F_x [N]: 6000	**Backlash [µm]:** ?
Min. Torque [Nm]:	**Gear ratio [mm/°]:**
Max. Speed [m/s]: 1.25 ***)	**Weight [kg]:**
Mechanics: Spindle: Guide system:	**Material:** Spindle: Guide system: Base/sledge: Aluminum
Motor: 3-phase step motor	**Encoder:** Optical, absolute
Position switches: Inductive, mechanical, external	**Options:** With or without bellows
Producer: Bosch Rexroth	**Comments:** *) Extremely variable (220 .. 2860) **) Extremely variable (60.. 2700) ***) Manufacturer recommends maximum 20% of max load capacity for continuous use. ****) Velocity up to 5m/s is possible but decreases the expected life time.
Webpage: https://www13.boschrexroth-u...	**Price [EUR]:**

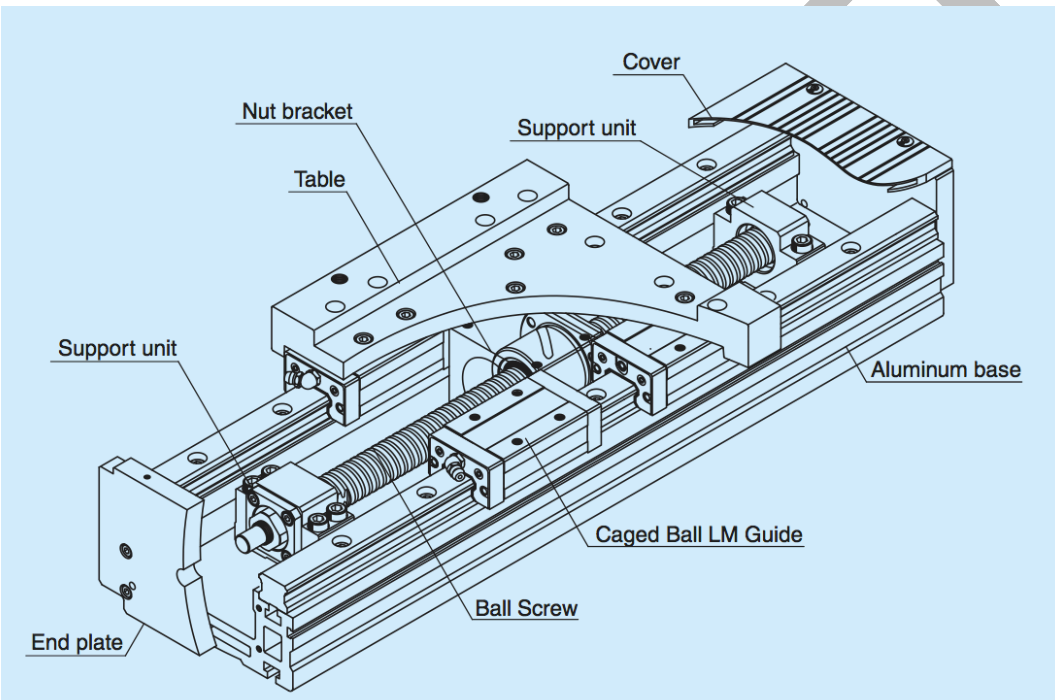
5.6.3 Rexroth-ball rail table TKK 20-225 Al



Length [mm]: 645(520) *)	**Height [mm]:** 75	**Width [mm]:** 225

Length of travel [mm]: 226	**Accuracy [µm]:** (+/-) 9
Load capacity F_z [N]: 79200 **)	**Repeatability [µm]:** (+/-) 5
Travel force F_x [N]: 19800 **)	**Backlash [µm]:** ?
Min. Torque [Nm]:	**Gear ratio [mm/°]:**
Max. Speed [m/s]: 1.25 ***)	**Weight [kg]:** 21.3 ****)
Mechanics: Spindle: Guide system:	**Material:** Spindle: Guide system: Base/sledge: Aluminum
Motor: 3-phase step motor	**Encoder:** Optical, absolute
Position switches: Inductive, mechanical, external	**Options:** Steel version available
Producer: Bosch Rexroth	**Comments:** *) With motor (without motor) **) Manufacturer recommends maximum 20% of max load capacity for continuous use. ***) Velocity up to 5m/s is possible but decreases the expected life time. ****) Weight without motor and switches
Webpage: https://www13.boschrexroth-u...	**Price [EUR]:**

5.7 THK – LM actuator GL20N



Length [mm]: 484(460)	**Height [mm]:** 90	**Width [mm]:** 180
Length of travel [mm]: 238	**Accuracy [µm]:** ?	
Load capacity F_z [N]: 4500	**Repeatability [µm]:** (+/-) 20	
Travel force F_x [N]: *)	**Backlash [µm]:** ?	
Min. Torque [Nm]: *)	**Gear ratio [mm/°]:** 120/360	
Max. Speed [m/s]: 1	**Weight [kg]:** 9.9	
Mechanics: Spindle: Guide system:	**Material:** Spindle: Guide system: Base/sledge: Aluminum	
Motor: 5-phase step motor, AC-servo	**Encoder:** ?	
Position switches: Optical, inductive	**Options:**	
Producer: THK	**Comments:** *) Depending on type of motor	
Webpage: http://www.thk.com/sites/de...	**Price [EUR]:**	

6. REFERENCES

[1] http://machinedesign.com/archive/straight-talk-linear-actuators

[2] http://www.barnesballscrew.com/how-a-ball-screw-works/

[3] http://machinedesign.com/linear-motion/what-s-difference-between-pneumatic-hydraulic-and-electrical-actuators

[4] http://machinedesign.com/archive/basics-configuring-drives

[5]

7. APPENDIX A: XXX