Screws

Ball and roller screws are key components to build electric actuators. They transfer rotary movements of the motor into linear movements. Their efficiency and their load and speed capabilities have a very big influence on the performance of electric actuators.

Emerson builds AVENTICS electric actuators with precision screw solutions that fulfill the most demanding applications in terms of efficiency, precision, durability and value. All screws are made of high-strength materials with specific heat-treatment.

Lead Screw

These screws transmit torque into linear motion through direct sliding friction.
A typical assembly consists of a steel screw and plastic nut. Some of the electric actuators are equipped with lead screws with a relatively high friction coefficient that makes them well suited for self-locking application.
Lead screw actuators accommodate high static force, withstand excessive vibration, operate quietly, and represent cost-effective solutions.

Precision Rolled Ball Screws

Ball screw assemblies provide high performance solutions suitable for a wide range of applications where high loads, precision driving, durability and value are prerequisites.
Standard lead precision is G9, according to ISO 286-2:1988. Production meets G7 lead precision for screw shaft nominal diameter starting from 20 mm. On request, Emerson can deliver ball screws with G5 lead precision, according to ISO 3408-3:2006, defined for positioning screws, and matching the lead precision of G5 ground ball screws.

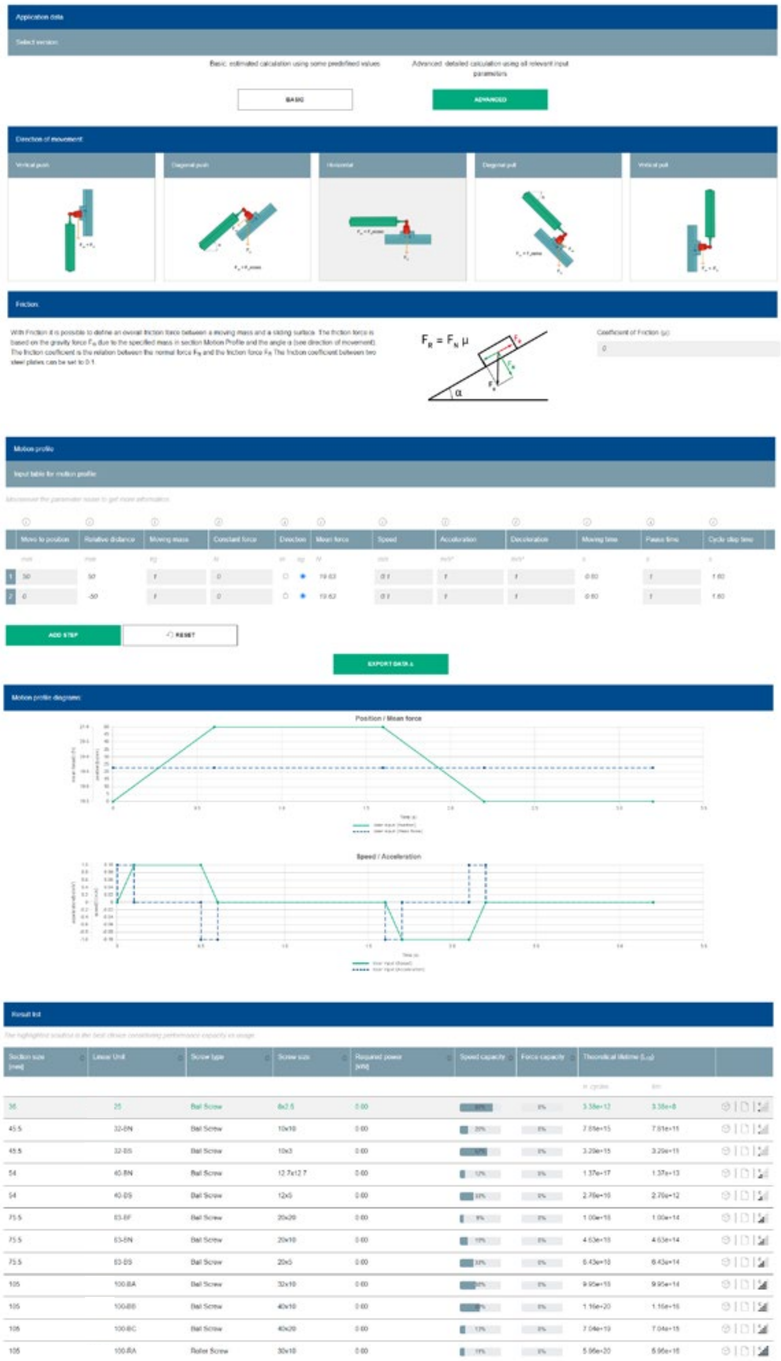
Roller Screws

Roller screws offer a performance level far beyond the capabilities of ball screws. Planetary roller screws are well suited for heavy loads, high duty, high rotational speed, high linear speed, high acceleration and rigidity, and for operation in harsh environments.

For very high precision applications, recirculating roller screws with a very fine lead of thread allow high positioning accuracy, repeatability and exceptional rigidity.

Catalog Pages

To select a series SPRA actuator, click **here** or scan the QR code below to get to the catalog pages.



The AVENTICS MotionFinder is a free online actuator and accessory selection tool. This calculation tool will give recommendations to select components of a linear servo axis (motor, linear unit and accessories) based on the application data. Based on the requirements and operating conditions of the user, the program will transform them into performance requirements.

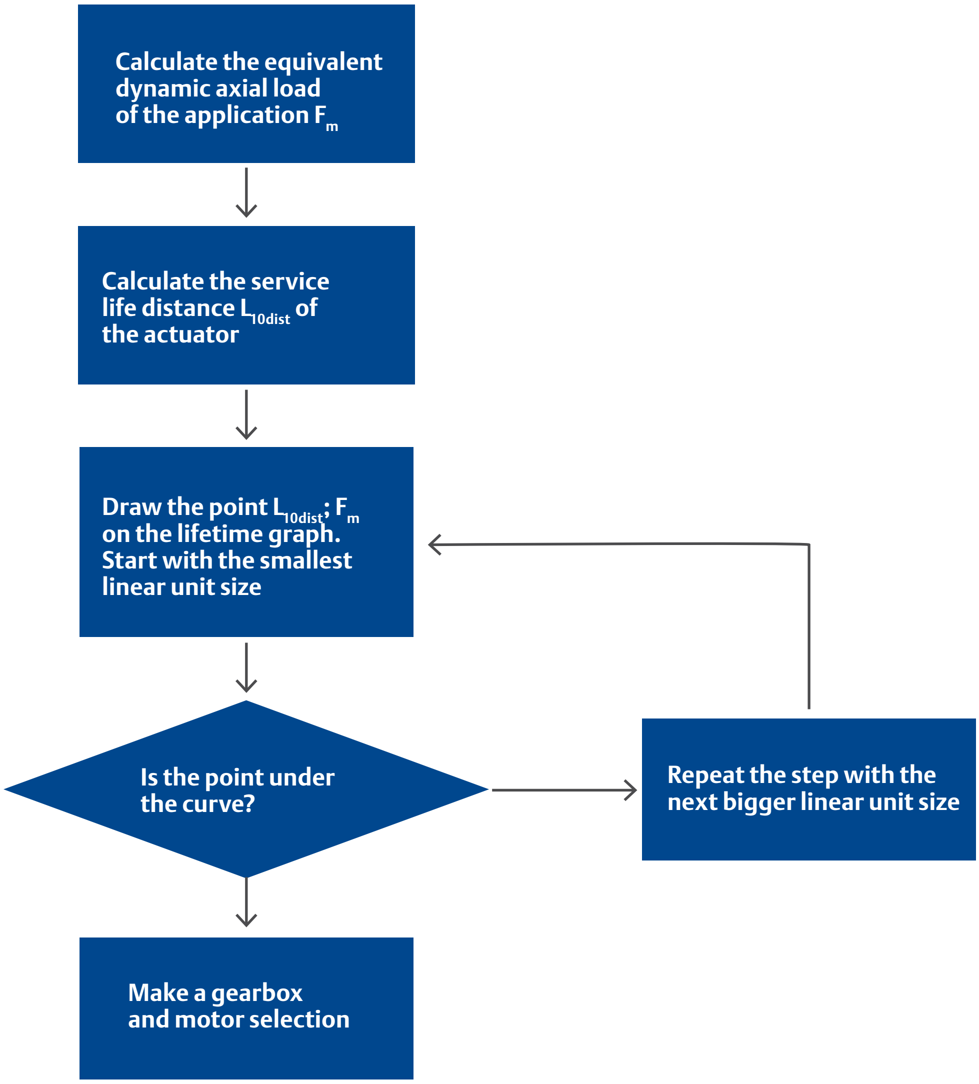
The user can insert the main information about the working cycle, describing each step as absolute movement, weight and inertia of the mass to be moved. Based on that, the program will provide simple graphs that show the required position, speed and acceleration over time.

Consequently, the program suggests a list of possible solutions that fulfill the user needs in terms of perfomance and lifetime. For each solution, the graphs are updated to show the requirements vs. the real performance of the selection.

By following the described flow (diagram 1), the user can select the right linear unit and motor that fulfill the application needs. Each of these steps is described in the following pages, with the related calculation formulas to be used and a real example. The main factors to be considered from the application are the equivalent dynamic axial load, acting on the actuator, the travel distance to be achieved and the desired speed during the working cycles.

From these values, user can then define the right actuator size and the required motor performances, in terms of torque and rotating speed. Finally, it's then possible to define the desired type of motor adapters, to match the possible dimensional constrains or to get a reduction ratio between the motor and the linear unit. If further assistance is needed, please contact Emerson to get complete technical support.

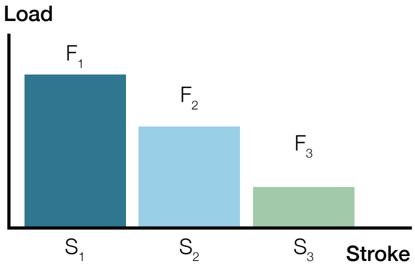
Diagram 1



How to Calculate the Equivalent Dynamic Axial Load F_m of the Application.

In most of the applications, the magnitude of the load fluctuates over the travelling distance. The service life of the linear unit depends on the load acting on it. To simplify the calculation we calculate the equivalent dynamic axial load over a full motion cycle F_m which has the same influence on the linear unit's service life as the actual fluctuating load.

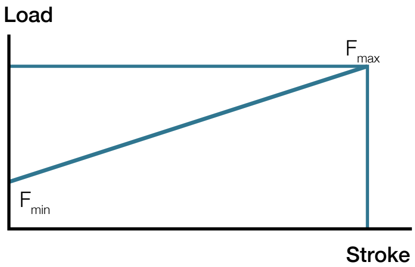
$$F_m = \sqrt[3]{\frac{F_1^3 \text{ x } s_1 + F_2^3 \text{ x } s_2 + F_3^3 \text{ x } s_3 + \ldots}{s_1 + s_2 + s_3}} = 570 \text{ N}$$



or

$$F_m = \frac{F_{min} + 2F_{max}}{3}$$

where:



F_m:	Equivalent dynamic axial load in N
F_1, F_2… F_n:	Load exerted over a segment of travelled distance sn
S_1, S_2… S_n:	Travelling distance over which the load F_n is exerted

Example to calculate the equivalent dynamic axial load

F_1 = 700 N, s_1 = 200 mm
F_2 = 500 N, s_2 = 0 mm
F_3 = 300 N, s_3 = 200 mm

$$F_m = \sqrt[3]{\frac{700^3 \text{ x } 200 + 500^3 \text{ x } 0 + 300^3 \text{ x } 200}{200 + 0 + 200}} = 570 \text{ N}$$

or

$$F_m = \frac{300 + 1\,400}{3} = 566 \text{ N}$$

How to Calculate the Lifetime Distance L_{10dist}

The service life distance L_{10dist} is defined as the life in km that 90% of a sufficiently large group of apparently identical actuators can be expected to attain or exceed.

$$L_{10dist} = \frac{S_{cycle}\, t_L \times 3{,}6}{t_{cycle}}$$

$$L_{10dist} = s_{cycle}\, n_{cycles}$$

where:

- L_{10dist}: Lifetime distance in km
- S_{cycle}: Distance travelled per motion cycle in m (both directions)
- t_{cycle}: Time per motion cycle in s (from one motion cycle to the next)
- t_L: Required lifetime in hours
- n_{cycles}: Number of cycles (in 1000)

Example to select a linear unit

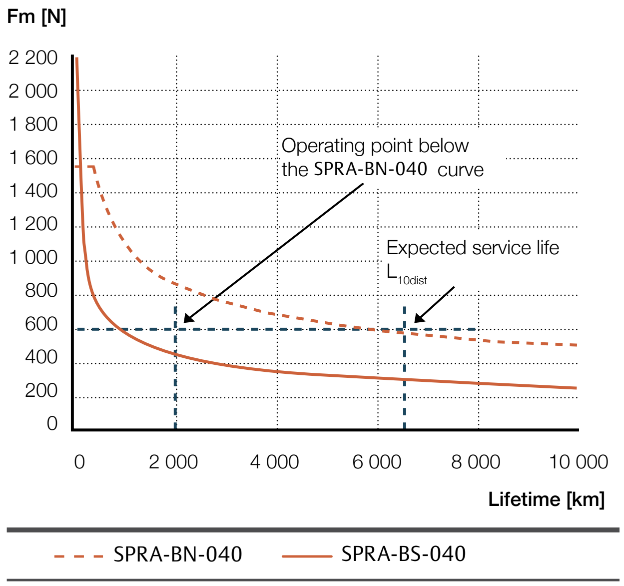
Total distance travelled per motion cycle: s_{cycle} = 0,4 m
Total time per motion cycle: t_{cycle} = 20 s
Required lifetime: t_L = 5 years × 230 days/year × 24 hours/day = 27600 hours
n_{cycles} = 3 cycles/minute × 60 minutes × 24 hours × 230 days × 5 years / 1000 = 4968 k_{cycles}

$$L_{10dist} = \frac{0{,}4 \times 27\,000 \times 3{,}6}{20} = 1\,987 \text{ km}$$

L_{10dist} = 0,4 × 4968 = 1987 km

Select the linear unit

Equivalent dynamic axial load F_m = 570 N
Lifetime distance L_{10dist} = 1987 km



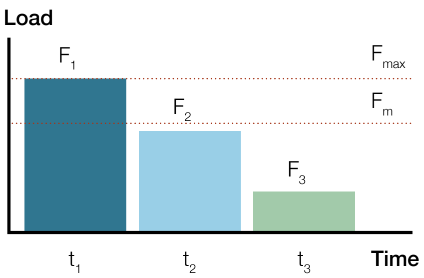
The operating point is below the SPRA-BN-040 curve. It is the smallest linear unit which fulfills the requirements. The expected service life is almost 6500 km.

How to Calculate the Thermal Load of the Motor F_{th}

To calculate the mean motor torque, we first need to calculate the thermal load F_{th} over the motor running time. Please note that the use of a motor brake during pause time will reduce the needed power of the motor.

$$F_{th} = \sqrt[2]{\frac{F_1^2 \times t_1 + F_2^2 \times t_2 + F_3^2 \times t_3}{t_1 + t_2 + t_3}}$$

F_{th}:	Equivalent thermal load of the application
$F_1, F_2 \ldots F_n$:	Load exerted over a time (percentage of full motion cycle time t_{cycle})
$t_1, t_2 \ldots t_n$:	Time over which the load F_n is exerted



Example

F_1 = 700 N, t_1 = 2 s
F_2 = 500 N, t_2 = 15 s (No travelling distance, but to hold a load of 500 N in position)
F_3 = 300 N, t_3 = 3 s

If no brake is engaged

$$F_{th} = \sqrt[2]{\frac{700^2 \times 2 + 500^2 \times 15 + 300^2 \times 3}{1 + 15 + 3}} = 500\ \text{N}$$

If a brake is engaged during the period t_2 to hold the load (F_2 = 0 for the motor)

$$F_{th} = \sqrt[2]{\frac{700^2 \times 2 + (0^2 \times 15) + 300^2 \times 3}{1 + 15 + 3}} = 250\ \text{N}$$

How to Select a Motor

If using a motor of your choice, the force capabilities of the linear units have to be converted into motor torque specifications for the motor. The minimum required continuous torque and the maximum torque of the motor need to be calculated. This could either be done by considering screw leads and friction or by a simplified calculation using information about the linear unit's maximum input torque to get the maximum force.

Calculation of the required continuous torque of the motor

$$M_{Ac} = \frac{M_{max} F_{th}}{F_{max}}$$

where

M_{Ac}: Required continuous torque of the motor in Nm
M_{max}: Maximum input torque of the linear unit in Nm
F_{th}: Equivalent thermal load of the application in N
F_{max}: Maximum dynamic axial force of the linear unit in N

Example (if using the brake)

$$M_{Ac} = \frac{3{,}64 \text{ x } 250}{1550} = 0{,}59 \text{ Nm}$$

Calculation of the maximum required torque of the motor

$$M_{Amax} = \frac{T_{Umax} F_{Amax}}{F_{Umax}}$$

where

M_{Amax}: Required maximum torque of the motor in Nm
T_{Umax}: Maximum input torque of the linear unit in Nm
F_{Amax}: Maximum dynamic axial load of the application in N
F_{Umax}: Maximum dynamic axial force of the linear unit in N

$$M_{Amax} = \frac{3{,}64 \text{ x } 700}{1550} = 1{,}64 \text{ Nm}$$

In our example, the continuous torque of the motor should be higher than 0,59 Nm (if using the brake) while the maximum torque must exceed 1,64 Nm to move the load of 700 N.

This calculation is valid for inline adapters and parallel adapters with a belt, where the gear ratio equals 1 and the efficiency is close to 100%.

The rotational speed is directly linked to the linear speed. Divide the linear speed by the screw lead to obtain the rotational speed. The relation of torque and force is a constant factor: To get the torque, take the force * M_{max} / F_{max}

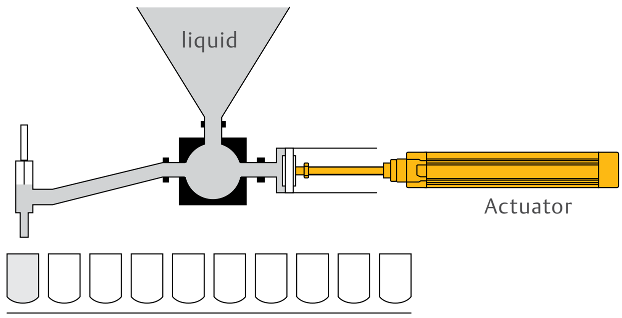
Please Note

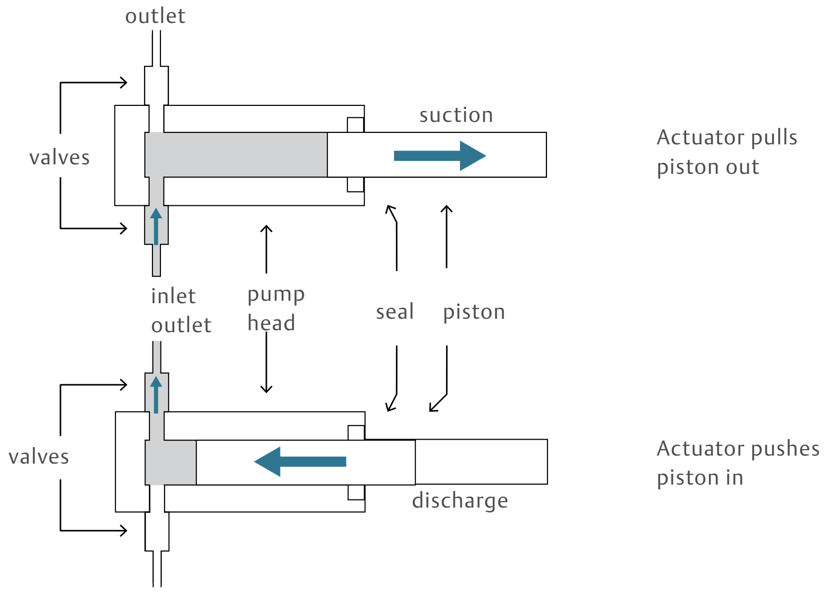
The dynamic torque of the motor may vary with the speed. Please make sure that your motor is able to reach the needed speed, acceleration and max. torque for your application.

Dosage of Liquids with SPRA Electric Actuators

Technical Requirements

Stroke:	s = 100 mm
Mounting position:	horizontal
Push force:	F_1 = 250 N
Pull force:	F_2 = 50 N
Cycles:	90 cycles per minute
Working time:	16 hours per day
Lifetime:	2 years (520 days)



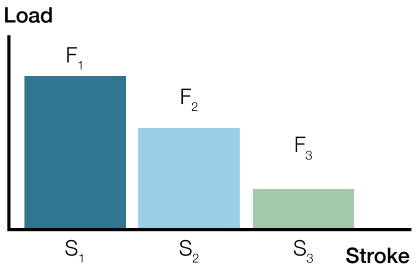


Selection of the Linear Unit

Calculate the equivalent dynamic axial load F_m of the application

$$F_m = \sqrt[3]{\frac{F_1^3 s_1 + F_2^3 s_2 + F_3^3 s_3 + \ldots}{s_1 + s_2 + s_3}}$$

where



F_m = Equivalent dynamic axial load in N

$F_1, F_2 \ldots F_n$ = Load exerted over a segment of travelled distance s_n

$s_1, s_2 \ldots s_n$ = Travelling distance over which the load F_n is exerted

$$F_m = \sqrt[3]{\frac{250^3 \times 100 + 50^3 \times 100}{100 + 100}} = 199\ \text{N}$$

Calculate the service life distance L_{10dist}

$L_{10dist} = s_{cycles} \times n_{cycles}$

where:

L_{10dist} = Lifetime distance in km

S_{cycle} = Distance travelled per motion cycle in m (both directions)

n_{cycles} = Number of cycles (in 1000 cycles)

Distance travelled per motion cycle:

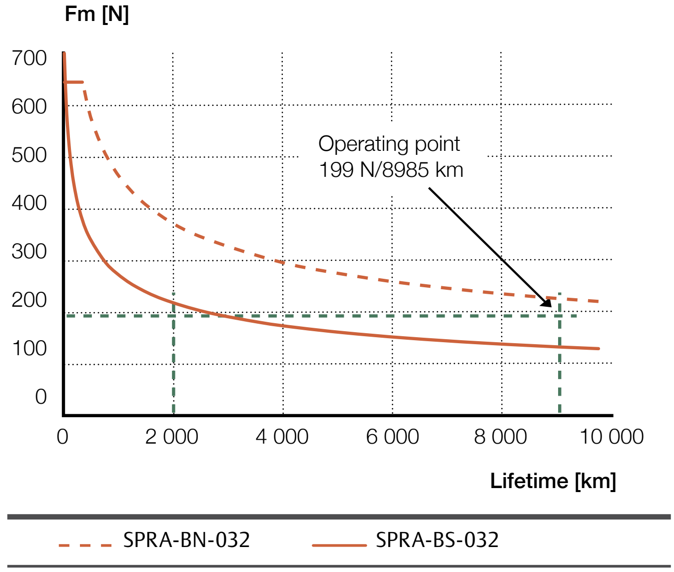
s_{cycle} = extend 100 mm + retract 100 mm = 0,2 m

Number of cycles n_{cycles} = 90 cycles × 60 minutes × 16 hours × 520 days = 44928 k_{cycles}

L_{10dist} = 0,2 × 44928 = 8 985,6 km

Select the linear unit

Equivalent dynamic axial load F_m = 199 N
Lifetime distance L_{10dist} = 8985,6 km



The operating point is below the dashed line. The SPRA-BN-032 is the smallest linear unit for this application which fulfills the requirements.

Selected linear unit: SPRA-BN-032 with 100 mm stroke.
The expected service life is > 10000 km

Speed check

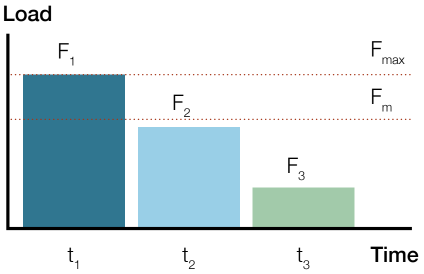
To move 200 mm within 0,667 seconds (90 cycles per minute), we need a speed of at least 200 mm/0,667 s = 300 mm/s.

The SPRA-BN-032 can do 500 mm/s.

Selection of the Motor

Calculation of the thermal load of the motor F_{th}

$$F_{th} = \sqrt[2]{\frac{F_1^2 t_1 + F_2^2 t_2 + F_3^2 t_3 + \dots}{t_1 + t_2 + t_3}}$$



where:

F_{th}:	Equivalent thermal load of the application
$F_1, F_2 \dots F_n$:	Load exerted over a time (percentage of full motion cycle time t_{cycle})
$t_1, t_2 \dots t_n$:	Time over which the load F_n is exerted

$$F_{th} = \sqrt[2]{\frac{250^2 \text{ x } 0{,}333 + 50^2 \text{ x } 0{,}333}{0{,}333 + 0{,}333}} = 180 \text{ N}$$

What if we would move with maximum speed and engage the brake during the pause time? The maximum speed is 500 mm/s. We could do the 100 mm stroke within 0,2 seconds (acceleration and deceleration disregarded).

$$F_{th} = \sqrt[2]{\frac{250^2 \text{ x } 0{,}2 + 50^2 \text{ x } 0{,}2 + 0^2 \text{ x } 0{,}267}{0{,}2 + 0{,}2 + 0{,}267}} = 140 \text{ N}$$

In some cases, a smaller (cheaper) motor can be used if we are using a brake.

To realize all the advantages of electromechanical actuators, the approach to system redesign must be different from the commonly adopted one. As pneumatic, hydraulic and electromechanical cylinders have unique features, there needs to be a change in thinking when it's time to replace one with the other.

In fact, it's important to understand the different mechanical and electrical specifications along with the required budget, as there are always multiple ways to replace one application. This requires more time to analyze and study but it's the only way to make an effective product selection that can save a lot of money at the end.

There are some common mistakes that designers can make when replacing a fluid powered cylinder with a electromechanical one that may lead to oversized systems. To avoid them, it's important to consider the following:

Define the real force requirement

In many applications, the real work load and related required push and pull forces are not known, as it's quite easy with fluid power to oversize the system by using higher pressures or bigger cylinder diameters. This can lead to an oversize of the actuator screw and motor that significantly increases the cost. Instead, by calculating the real force in the application, it's possible to select an optimized solution that delivers the required performance at the right price.

Evaluate the duty cycle in operation

While duty cycle can have a minor impact on fluid powered systems, in actuators it can determine the type of technology required and therefore the related system complexity and cost. If the application is done from time to time (e.g. 1 minute operating – 4 minutes standing still), it's possible to use lead screw that can deliver the required power much cheaper than equivalent ball screws.

Analyze the mechanical layout

Hydraulics can deliver more power in a smaller package than electromechanical actuators. In case of leveraged connections (e.g. scissor mechanism), it's quite common to have an unfavorable situation where the high forces are exerted over a very short stroke. By slightly revising the mechanical layout, it may be possible to have more favorable leverages that spread the load over a longer stroke, requiring less peak output power and then a smaller actuator.

Define the required motion accuracy

Depending on the application, it may be needed to perform a simple motion from one position to another and back or to have fine control of the speed and acceleration in multiple positions. With electromechanical actuators, the simple DC and asynchronous AC motors can perform basic movements in an ON/OFF control mode while with a servo motor, it's possible to achieve complete control in operation with the use of a motion controller. Moreover, depending on the positioning accuracy required, it's possible to select a simple trapezoidal screw with axial play or a recirculating pre-loaded roller screw for the ultimate positioning precision and repeatability, down to microns. The cost and control complexity rises linearly allowing a direct selection tailored to real application needs.

Emerson has extensive expertise in sizing electromechanical solutions for different types of industries and applications. A dedicated team of Application Engineers are available to support customers in defining the right solution, and advising on the best choice based on theoretical calculation and field expertise.

Visit Emerson.com/AVENTICS to easily select and size your actuator and to get in contact with our experts.

A	
Absolute movement	A move referenced from a fixed absolute zero position.
Acceleration	The change in velocity as a function of time, going from a lower speed to a higher speed.
Accuracy	An absolute measurement defining the difference between expected and actual position.
Actuator	An actuator is a device that is responsible for moving or controlling a mechanism or system also known as cylinder, electromechanical cylinder or linear actuator.
Ambient temperature	The temperature of the cooling medium, usually air, immediately surrounding the actuator or another device.
Angular contact ball bearing	Angular contact ball bearings have raceways in the inner and outer rings that are displaced relative to each other in the direction of the bearing axis. This means that they are designed to accommodate combined loads, i.e. simultaneously acting radial and axial loads.
Anodized	Protective treatment for aluminium that involves subjecting the metal to electrolytic action in a chemical bath, to create a protective film of aluminium oxide with a very smooth finish.
Axial load	Load where the force is acting along the axis of actuator (bearing) in any direction.
B	
Backlash	also known as axial play, is the distance that the push tube can travel while changing the force direction, when the actuator body attachment is fixed and the input shaft is not rotating. It's calculated by summing the backlash of the different components of the kinematic chain as screw, bearings and anti-rotation (for the linear unit), plus coupling and gearbox (for the complete actuator). This value is valid for new actuators.
Ball bearing	A support device which allows a smooth low friction motion between two surfaces loaded against each other with balls as rolling elements.
Ball screw	A screw assembly which uses a ball nut which contains one or more circuits of recirculating steel balls which roll between the nut and the screw.
Bearing	A support device which allows a smooth low friction motion between two surfaces loaded against each other.
Brushless DC motor	Synchronous motor type that are powered by a DC electric supply through an inverter that produce an AC signal to drive the motor.
Bushing	A cylindrical sleeve inserted into a machine part to reduce friction between moving parts.
C	
Configurator (product)	Name given to the software that uses the configuration string to build-up a specific actuator from an existing list of components and options.
Continuous torque	Is the torque that the motor is able to provide continuously with no limitation in time.
Current	The flow of charge through a conductor.
Cycle	A complete motion of an actuator from the start position via intermediate positions and back to the start position
Cycle time	Time for one complete motion cycle, from the start of the cycle until the start of the next cycle
Cylinder	A mechanical device which produces a linear force to achieve a reciprocating linear motion. There three common types: pneumatic, hydraulic and electromechanical (or electric). The first two use the power of compressed media (gas or liquid) while the latter uses a mechanical device (screw) to transform the rotational input movement of a motor into a linear one.

D	
Deceleration	The change in velocity as a function of time, going from a higher speed to a lower speed.
Duty cycle	The ratio of motor on time and total cycle time within a given cycle of operation (considered under normal ambient working conditions).
Dynamic load rating	Constant that is used to calculate the service life of a screw drive. The value for the dynamic load rating represents the load under which 90% of a sufficient large number of identical screw drives can achieve a service life of one million revolutions.
E	
Efficiency	Ratio of output power versus input power.
Electric actuator	A self-contained system which converts rotary motion (from a motor) to linear motion.
Electromechanical cylinder	A self-contained system which converts rotary motion (from a motor) to linear motion.
Electrode	The part of a resistance welding gun that facilitates the high voltage current path to the parts being welded.
Equivalent dynamic axial load	Load of constant magnitude over a full motion cycle which has the same influence on the linear unit's service life as the actual fluctuating load.
F	
Foot mount	Mounting plates, attached to front and end of a cylinder, to mount the cylinder in parallel to a flat surface.
Force	The action of one body on another which tends to change the state of motion of that body. Typically described in terms of magnitude, direction and point of application.
Friction	The resistance to motion of two surfaces that are in direct contact.
G	
Gear ratio	This relates to the transmission and conversion of movements, linear and rotary speeds, forces and torques in a geared mechanism. The gear ratio (also known as reduction ratio) is the ratio between the input and output variable, e.g. the ratio of input speed to output speed.
H	
Hall effect sensor	A magnetically controlled transistor switch controlling DC power. It has no moving parts and theoretically unlimited contact life.
Holding force	Maximum external force that can be applied to a stopped actuator, without causing any linear movement. It is usually given by the holding torque of an electromechanical brake applied on the motor.
Humidity (relative)	A ratio that indicates the amount of water vapor in the air. It is usually expressed as a percentage. At any temperature, it is the amount of water vapor in the air, divided by the amount that would be present at saturation.
I	
Inertia	Property of an object that resists a change in motion. It is dependent on the mass and shape of the object. The greater an object's mass, the greater its inertia and the more force is necessary to accelerate and decelerate it.
K	
Keyway	An axially-located groove in the length of a shaft along which a key may be located.
L	
Lead	Describes the axial distance a nut is moving on a screw at one full rotation of either the screw or the nut.
Lead screw	A screw which uses a threaded screw design (e.g. with trapezoidal shaped thread) with sliding surfaces between the screw and nut.
Lifetime	Service life in km that 90% of a sufficiently large group of apparently identical cylinders can be expected to reach or exceed.
Limit switch	A switch that is actuated by some part of motion of a machine or equipment to alter the electrical circuit associated with it.
Linear speed	The linear speed is the change in position as a function of time.
Max. linear speed	Maximum linear speed, a linear unit or a cylinder can reach without damaging the mechanical system. Limiting factors can be the recirculating system of the balls or rollers, or the heat dissipation when using lead screws, or others. If the motor of the cylinder could turn faster, it needs to be limited.
Load	A mass or weight of an application acting on the in axial direction on the push tube.

M	
Mass	The quantity of matter that an object contains.
Moment	Rotational forces applied to a linear axis, typically expressed as yaw, pitch and roll.
Motion profile	A method of describing a move operation in terms of time, position and velocity. Typically, velocity is characterized as a function of time or distance which results in a triangular or trapezoidal profile.
Motor	A device which converts electrical energy into mechanical energy.
O	
O-ring	A ring of synthetic rubber with a circular cross-section, used as a gasket or seal.
Overheating	The heat in a system is mostly dissipated into the surrounding air. Dissipation can be accelerated by various forms of ventilation. In case the dissipation level is lower than the heat generation, overheating takes place.
P	
Peak force	The peak force is the maximum force an actuator can push or pull for a short time (peak), without being mechanically damaged or overheating.
Peak torque	The peak force is the maximum torque a motor can provide for pull for a short time (peak), without being mechanically damaged or overheating.
PLC (programmable logic controller)	An industrial digital computer that is used to control machines and processes by continuously monitoring analog and digital inputs and making decisions based on customer programs.
Positioning accuracy	Is the maximum deviation between the actual position and the target position, as defined in VDI/DGQ 3441 norms.
Power	How much work is done in a specific amount of time.
Proximity sensor	A device for sensing a position of an actuator or application. Proximity sensors supply either a sourcing or sinking signal to a device such as a programmable logic controller.
R	
Radial load	Load where the force is acting perpendicular to the axis of the actuator.
Repeatability	The ability of a positioning system to return to an exact location during operation (from the same direction with the same load and speed).
Resolver	A feedback device consisting of a stator and rotor that provides position and velocity information to the drive for motor commutation.
RMS	The root mean square is the square root of a mean square value.
Rod cylinder	A cylinder using a rod attached to its piston to transmit force.
Roller screw	A screw assembly which uses a roller nut which contains guided steel rollers which are rotating around their own axis and around the screw (planetary rollers).
S	
Screw assembly	Device which converts rotary motion into linear motion.
Service life	The nominal life is expressed by the number of revolutions (or number of operating hours at constant rotary speed) that will be attained or exceeded by 90% of a sufficiently large number of identical screw drives before the firsts signs of material fatigue become evident.
Servomotor	A motor which is used in closed loop systems where feedback is used to control motor velocity, position or torque.
Spur gear	Is a gear or a system of gearing having radial teeth parallel to the axle.
Static axial force	Maximum axial force which can be applied on a linear unit only if it is not moving.
Stiffness	Is the rigidity of an object, representing its resistance to deformation from an applied force.
Stroke length	The linear distance that the push tube of a cylinder can extend or retract.

T	
Thermal load	The thermal load describes the force which the actuator can permanently move without overheating. The thermal load is calculated by a formula in respect of changing load conditions over different time phases of a full motion cycle.
Torque	A measure of angular force which produces rotational motion.
U	
Units (metric)	A decimal system of weights and measures based on the kilogram and meter.
V	
Volt	Difference in electrical potential between two points.
W	
Watt	A unit of power or a rate of doing work. The power dissipated by a one-ohm resistor with one ampere of current is one watt.
Weight	Force of gravity acting on a body. Determined by multiplying the mass of the object by the acceleration due to gravity.

		A	
a	m/s²	**Acceleration**	The change in velocity as a function of time, going from a lower speed to a higher speed.
a_{max}	m/s²	**Max. acceleration**	The maximum allowed change in velocity as a function of time from a lower speed to a higher speed. Exceeding this value can cause damages.
		C	
C	kN	**Dynamic load capacity**	Constant that is used to calculate the service life of a ball or roller screw. The value for the dynamic load rating represents the load under which 90% of a sufficient large number of identical screws can achieve a service life of one million revolutions.
		D	
D	%	**Duty cycle of the cylinder**	The ratio of active time at full load and total cycle time within a given cycle of operation.
D_{unit}	%	**Duty cycle of the linear unit**	The ratio of active time and total cycle time within a given cycle of operation.
d_{screw}	mm	**Screw diameter**	Describes the outer diameter of the screw shaft.
		E	
η	%	**Efficiency**	Ratio of output power versus input power.
η_{lu}	%	**Efficiency of the linear unit**	Ratio of output power versus input power of the linear unit.
		F	
F	N	**Force (cylinder) or load (application)**	The action of one body on another which tends to change the state of motion of that body. Typically described in terms of magnitude, direction and point of application. The force is related to the capability of the cylinder while the load is related to the mass or weight of an application acting on the axial direction on the push tube.
F_{Amax}	N	**Maximum dynamic axial load of the application**	Maximum axial push or pull load which is needed to fulfill the specifications of the application.
F_c	N	**Continuous force at max speed**	The continuous force at max speed describes the force the cylinder can permanently move at maximum allowed linear speed, without overheating.
F_{c0}	N	**Continuous force at zero speed**	The continuous force at zero speed describes the force the cylinder can permanently hold without overheating and without using a brake.
F_{cont}		**Continuous force curve**	A curve that represents the continuous force an actuator can permanently move at maximum allowed linear speed, without overheating.
F_{Hold}	kN	**Holding force of the brake**	Describes the maximum axial load the engaged brake (optional motor brake) can hold if the motor is disabled. This value must not exceed the maximum axial force of the cylinder.
F_m	N	**Equivalent dynamic axial load**	Load of constant magnitude over a full motion cycle which has the same influence on the linear unit's service life as the actual fluctuating load.
F_{max}	N	**Maximum dynamic axial force**	The maximum dynamic axial force describes the maximum force an electric actuator can deliver during movements without damaging parts. The acceleration/ deceleration of masses need to be considered.
F_{maxL10}	N	**Maximum dynamic axial force**	Maximum dynamic axial force usable to apply the theoretical lifetime calculation (L10).
F_{max0}	N	**Max. static axial force**	Maximum axial force which can be applied on a linear unit only if it is not moving.
F_p	N	**Peak force**	The peak force describes the maximum force the cylinder can push or pull for a short time, without being mechanically destroyed or by overheating. The length of the peak is depending on the temperature of the system when the peak is initiated.
F_{p0}	N	**Peak force at zero speed**	The peak force at zero speed is the maximum force the cylinder can hold for a short time without using a brake.
F_{peak}		**Peak force curve**	A curve that represents the continuous force an actuator can push or pull for a short time, without being mechanically destroyed or by overheating. The length of the peak is depending on the temperature of the system when the peak is initiated.

I			
i	#	**Gear reduction**	Describes the factor between the number of revolutions of the input of the gear divided by the number of revolutions of the output of the gear. A gear reduction 2 means that the output of the gear (linear unit side) is turning with half speed compared to the input of the gear (motor side). Using a gear reduction enables for using smaller motors with less torque to bring higher force but with lower speed.
I	A	**Nominal current**	Is the nominal current consumption of the motor.
I_{peak}	A	**Peak current**	Is the maximum current consumption of the motor for a short period of time.
IP		**Degree of protection**	International protection (also ingress protection) describes the protection of a product with two digits. The first digit describes the protection against dust, the second against water. The higher the value the better the protection.
J			
J	10^{-4} kgm^2	**Inertia**	Property of an object that resists a change in motion. It is dependent on the mass and shape of the object. The greater an object's mass, the greater its inertia and the more force is necessary to accelerate and decelerate. As an electric actuator is available in different lengths, the inertia is typically given for stroke 0, followed by an inertia indication ΔJ for each additional 100 mm.
J_{brake}	10^{-4} kgm^2	**Inertia of the brake**	Property of an object that resists a change in motion. It is dependent on the mass and shape of the object. The greater an object's mass, the greater its inertia and the more force is necessary to accelerate and decelerate. As the brake is typically an option, this value has to be added to the Inertia of the electric actuator .
J_{lu}	10^{-4} kgm^2	**Inertia of the linear unit**	Property of an object that resists a change in motion. It is dependent on the mass and shape of the object. The greater an object's mass, the greater its inertia and the more force is necessary to accelerate and decelerate. As the linear unit is available in different lengths, the inertia is typically given for stroke 0, followed by an inertia indication ΔJ for each additional 100 mm.
L			
$L_{10\,dist}$	km	**Lifetime distance**	Service life in km that 90% of a sufficiently large group of apparently identical cylinders can be expected to reach or exceed.
M			
m	kg	**Weight**	Force of gravity acting on a body. Determined by multiplying the mass of the object by the acceleration due to gravity.
Δm	kg	**Weight difference**	As electric actuators are available in different lengths, the weight is typically given for stroke 0, followed by a weight indication Δm for each additional 100 mm.
m_{arot0}	kg	**Weight of the antirotation device**	The weight of the optional anti-rotation device has to be added to the weight of the cylinder.
m_{brake}	kg	**Weight of the brake**	The weight of the optional brake has to be added to the weight of the cylinder.
m_{lu}	kg	**Weight of the linear unit**	As the linear unit is available in different lengths, the weight is typically given for stroke 0, followed by a weight indication Δm for each additional 100 mm.
M	Nm	**Torque**	A measure of angular force applied to a linear axis to produce rotational motion.
M_{Ac}	Nm	**Required continuous torque**	A measure of continuous angular force (torque) a motor has to deliver without overheating.
M_{Amax}	Nm	**Required maximum torque of the motor**	Maximum angular force (torque) of a motor which is required that the cylinder is able to push or pull the maximum load of the application.
M_{max}	Nm	**Maximum torque**	The maximum torque is the upper limitation of the torque. Exceeding this value can cause damages of related parts.

N			
n_{cycles}	#	**Number of cycles**	The number of motion cycles a cylinder has to have without damage during the expected life of the application.
n_{max}	1/min	**Max. rotational speed**	Describes the maximum allowed number of full rotations of an axis. Exceeding this value can cause damages.
P			
P	W	**Nominal power**	Nominal power of the motor, given by multiplying the nominal voltage and the nominal current.
p_{screw}	mm	**Screw lead**	Describes the axial distance a nut is moving on a screw at one full rotation of either the screw or the nut.
R			
R	Ω	**Resistance**	The opposition to the flow of charge through a conductor.
S			
s	mm	**Stroke**	The linear distance that the push tube of a cylinder can extend or retract.
s_0	mm	**Internal over stroke**	Additional stroke which is not part of the specified stroke length of the cylinder. It is used to prevent the screw nut touching the mechanical end stops when moving over the full specified stroke.
$s_{backlash}$	mm	**Backlash**	Axial play that the cylinder push tube has without turning the screw. It's equivalent with the mechanical axial play of the inner parts of the cylinder.
s_{cycle}	m	**Distance travelled per motion cycle**	Travelled distance of a push tube for a full motion cycle, from the start to the next start in both directions.
s_{max}	mm	**Maximum stroke**	The maximum stroke describes the mechanical limitation which a cylinder can extend or retract. Limiting factors are side loads (buckling), speed (wobbling of the screw inside), limitations in the manufacturing process and others.
T			
t	s	**Time**	Time in seconds which is needed for a certain activity.
t_{cycle}	s	**Cycle time**	Time for one complete motion cycle, from the start of the cycle until the start of the next cycle.
t_L	h	**Required lifetime in hours**	The lifetime of a cylinder in hours which is required to serve an application without damage during the expected life of the application.
T	Nm	**Torque**	A measure of angular force applied to a linear axis to produce rotational motion.
$T_{ambient}$	°C	**Ambient temperature**	Temperature of the environment around the object.
U			
U	V	**Nominal voltage**	Is the supply voltage required by the electric motor.
V			
v	mm/s	**Linear speed**	The linear speed is the change in position as a function of time.
v_{max}	mm/s	**Max. linear speed**	Maximum linear speed, a linear unit or a cylinder can reach without damaging the mechanical system. Limiting factors can be the recirculating system of the balls or rollers, or the heat dissipation when using lead screws, or others. If the motor of the cylinder could turn faster, it needs to be limited.