Geared Linear Actuators
Technical Information

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General information

The FAULHABER **L** series linear actuators with gearhead are designed to provide high performances in compact dimensions. These actuators can support high input speeds, deliver high output forces and are suited for a wide range of applications like robotics, industrial machines and laboratory equipment.

A large number of reduction ratios, uniformly distributed, are available, thereby allowing one to select the most appropriate configuration for various force or speed operating points as required by the application.

With a large selection of different screw sizes and types, this new family offers a high level of flexibility. Moreover, numerous options are available to cover the demands of different ambient conditions and make the mechanical integration in applications faster and smoother through various flange and nut configurations.

The main advantages of the new FAULHABER **L** series linear actuators with gearhead are:

- High performance
- Very robust design
- Large and modifiable selection of screw and nut types
- Full reduction ratio range
- Wide portfolio of combinable motors

Service life
The operational lifetime of combinations of linear actuator with gearhead and motor is determined by:

- Screw[1] and nut type and material
- Axial load and linear speed, resulting in output power
- Operating temperature of the motor
- Operating mode and duty cycle
- Operating conditions (ambient conditions, temperature, dust, etc.)
- Operating environment and integration into other systems

Because numerous parameters must be taken into consideration in every application, it is nearly impossible to state the actual lifetime that can be expected from a specific type of screw or motor-gearhead combination. Our sales teams can help you to find the best solution for your particular needs.

Screw type (lead screws vs. ball screws)

The new **L** series offers various screw solutions. Each type has its own characteristics that should be taken into account when determining the best match for your specific needs.

The basic difference between ball and lead screws is the rolling movement of the ball screw nut, which eliminates the sliding friction typical for lead screws, thereby resulting in a very high efficiency.

There are applications in which lead screws are better suited to your application than ball screws and vice versa. The following table gives you an initial comparison of their main characteristics:

Characteristics	Lead screw	Ball screw (22L and 32L only)
High load rating	● ●	● ● ● ● ●
Efficiency	● ● ●	● ● ● ● ●
Self-heating	● ● ●	● ● ● ● ●
High accuracy	● ● ●	● ● ● ● ●
Reliability and long life service	● ● ●	● ● ● ● ●
Customizable	● ● ● ● ●	● ● ●
Material selection	● ● ● ● ●	●
Ambient condition resistance	● ● ● ●	● ● ●
Low maintenance	● ● ● ● ●	● ● ● ●
Low noise	● ● ● ●	● ●
Cost effective	● ● ● ● ●	● ● ●
Self-locking	y	n

Motor combinations
The **L** series linear actuators with gearhead can be combined with a wide range of DC motors, 4-pole and 2-pole brushless motors and stepper motors. These linear actuators are optimized to best utilize the torque and speed range of the different FAULHABER motor families.

[1] For a ball screw, a theoretical service life can be calculated on the basis of standard ISO 3408. This value refers only to the ball screw and does not include other combination elements such as coupler and motor.

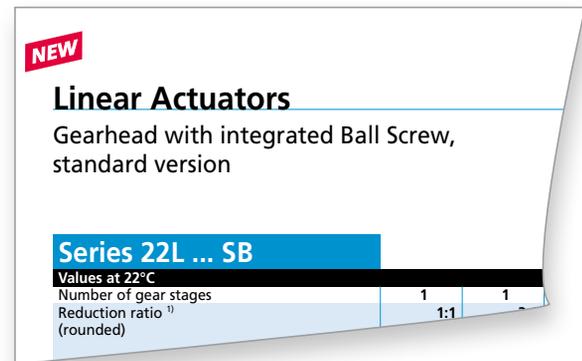# Geared Linear Actuators

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Modifications and standard options

The FAULHABER **L** series linear actuators with gearhead are available with a wide range of standard options and modifications. Some of these options serve to meet particular requirements related to certain applications with specific ambient conditions, others are made to ease the product integration in the application system or to enhance particular performance parameters for specific needs.

Product options can refer to the coupler, to the screw or both, for example:

- Screw type and length
- Nut type and length;
- Ambient conditions such as a particular temperature range or specific ambient conditions, e.g., vacuum
- Different orientation of motor cables or terminals when integrating the device combination in the application

Note that most options are modifications of the basic product. Thus, the associated characteristics will differ from the performance of the standard version. This should be considered when selecting an option. Contact your local sales representative with any questions.

NEW

Linear Actuators
Gearhead with integrated Ball Screw, standard version

Series 22L ... SB

Values at 22°C		
Number of gear stages	1	1
Reduction ratio [1] (rounded)	1:1	

Notes on the data sheets

Unspecified tolerances

If not specified, the tolerances are in accordance to ISO 2768-m (medium), i.e.:

- up to 6 mm: ±0,1 mm
- over 6 mm up to 30 mm: ±0,2 mm
- over 30 mm up to 120 mm: ±0,3 mm
- over 120 mm up to 400 mm: ±0,5 mm
- over 400 mm up to 1000 mm: ±0,8 mm

Reduction ratio, *i*

The listed ratios are nominal values only; the exact ratio for each reduction gearhead can be calculated using the stage ratio applicable for each type[2].

Continuous output speed, max $v_{c\,max}$ [mm/s]

Designates the maximum permissible continuous linear speed. This results from the product of the maximum recommended continuous rotational speed and the screw lead.

$$v_{c\,max} \;=\; \frac{p \cdot n_{c\,max}}{60 \cdot i}$$

$v_{c\,max}$ = Continuous output speed
$n_{c\,max}$ = Gearhead continuous input speed, max
i = Reduction ratio
p = Screw lead

[2] Document "Linear actuator, reduction ratios" includes the complete list of nominal reduction ratio versus absolute value.

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Peak output speed, max $v_{p\ max}$ [mm/s]

Designates the maximum permissible peak linear speed. This results from the product of the maximum permissible peak rotational speed and the screw lead.

$$v_{p\ max} = \frac{p \cdot n_{p\ max}}{60 \cdot i}$$

$v_{p\ max}$ = Peak output speed
$n_{p\ max}$ = Gearhead peak input speed, max
i = Reduction ratio
p = Screw lead

Continuous input speed, max $n_{c\ max}$ [min⁻¹]

The recommended maximum rotational input speed for continuous operation serves as a guideline. The linear actuator with gearhead can also be operated at higher rotational speeds.

To achieve an optimum service life in applications that require continuous operation and long life, however, the recommended speed should be observed.

Peak input speed, max $n_{p\ max}$ [min⁻¹]

The peak input linear speed value may be applied for a short period. It should only be used for brief intervals and not exceed 20% of the continuous duty cycle. Operating the linear actuator with gearhead at linear speeds higher than peak maximum value is not recommend as it will significantly reduce the service life and, in some cases, could lead to premature damage with sudden stop.

Continuous axial force, avg. $F_{m\ max}$ [N]

Designates the maximum recommended average axial output force during continuous operation. The linear actuator with gearhead can also be operated at higher average axial output force. This level should not be exceeded in any operation phase to obtain optimum life performance.

Peak axial force, dynamic max. $F_{p\ max}$ [N]

Designates the maximum recommended peak axial output force during operation. This level should not be exceeded in any operation phase to obtain optimum life performance.

Please note that system inertia is also to be taken into account when calculating the applied forces. This parameter has particular relevance in cases of highly dynamic movements.

Peak axial force, static max. $F_{stat\ max}$ [N]

Maximum permissible static axial force of the screw. To avoid permanent damage to the system, this level must not be reached either during any phase of operation or during standstill. To prevent exceeding the permissible loading, the motor current must be limited if necessary.

Output power max. $P_{out\ max}$ [N]

Designates the maximum recommended output power during operation. This level should not be exceeded in any operation phase to obtain optimum life performance.

Efficiency of gearhead/coupler, max. $\eta_{g\ max}$ [%]

The maximum efficiency refers to the continuous operation mode. This value varies depending on the number of stages and may also depend on the reduction ratio. The gearhead/coupler efficiency is dependent on the operating point.

Screw efficiency, max. $\eta_{s\ max}$ [%]

Describes the ratio between the power input and power output of the screw at axial load $F_{m\ max}$.

Please note the dependence of the efficiency on the axial load. This should be given special consideration in cases with small axial loads when selecting the drive; working points with high efficiency are to be given preference.
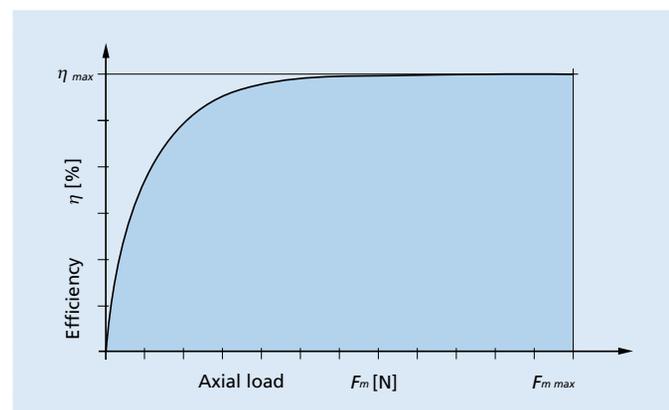
Mass inertia incl. screw, max. J [gmm²]

The maximum input inertia can be used to determine the torque required to ensure a particular acceleration of the system, typically for highly dynamic positioning applications. This inertia value refers to the linear actuator input at the motor output shaft including the motor pinion. This value is dependent on the gearhead configuration (e.g., number of planetary gears), the number of stages and the

selected screw. The specified value is the maximum value taking into consideration the various possible configurations of the gearhead, whereby the screw was considered at a standard length.

Accuracy, screw standard length, max. σ_a [µm]

Designates the maximum mechanical positioning accuracy of the linear actuator with gearhead and standard screw. This results from the screw accuracy, the nut axial play and coupler/gearhead backlash.

Radial load, max. (15 mm from flange) [N]

The maximum screw load represents the maximum dynamic load (when the screw is rotating) that can be applied radially at a particular distance from the output flange and that the ball bearing system can support without impacting the service life. If the radial load is applied at a different distance, this value should be extrapolated appropriately.

Gearhead backlash, at no load, typical [°]

Backlash represent the angular play that arises when rotating the gearhead/coupler output shaft with no load while the gearhead input is fixed. This angular play takes into account the angle between the two end positions of the output shaft in the clockwise and counterclockwise directions, without applying torque.

Radial play screw, 10 mm from flange [mm]

The radial play is the maximum amount that the screw can move radially when measured at a specific distance from the front flange, excluding the elastic deformation of the system.

The measurement of the radial play is dependent on the measurement position along the screw and on the force used for the measurement.

Screw axial play [mm]

The axial play of the screw is the maximum distance that the screw travels in the axial direction if pushed or pulled against the inner/outer side of the gearhead/coupler. The value of the axial play is dependent on the ball bearing system and the given preloading. For the axial play, it is assumed that the maximum static peak axial force specified in the data sheet is not exceeded. The elastic deformation of the system has not been taken into consideration.

Please note that the concentricity specified in the drawing was measured without the radial play.

Nut axial play [mm]

Maximum axial displacement of the screw nut relative to the screw if they are not turned against each other.

Screw length from flange, standard [mm]

Designates the length of the screw between the front of the housing and the end of the screw.

The maximum stroke can be calculated from the screw length considering the length of its threaded part and subtracting the length of the nut.
As example for a 22L ML 150 KWS1, the thread is:
150 - 6,9 - 5 = 138,1 mm. Therefore the maximum stroke is:
138,1 - 20 = 118,1 mm; excl. tollerances.
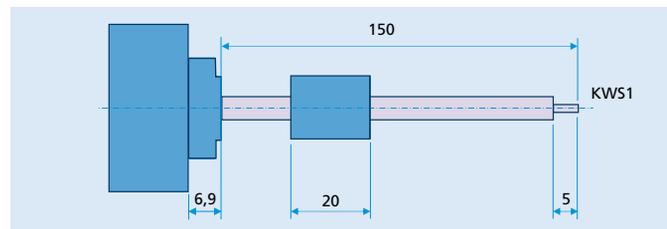
Note: The nut of the ball screw must not run beyond the threaded part or be removed from the screw, remounting will be impossible.

Screw length from flange, max. [mm]

A different screw length can be ordered in 5 mm increments up to the specified maximum value.

Note that changing the screw length affects several parameters, such as the critical speed and the buckling load.

Mass [g]

The average mass of the linear actuator with gearhead including standard length screw.

Screw type

■ **Diameter (Ø) [mm]**
   Nominal diameter used for designation.

■ **Lead *p* [mm]**
   Axial displacement when rotating the ball screw by 360° relative to the ball screw nut. Note that for a single-start screw, the lead is equivalent to the pitch, i.e., the distance between screw threads.

■ **Screw accuracy (ball screw only)**
   Accuracy class according to ISO 3408-3.

The following international standards apply:

■ Ball screws (SB/PB): DIN ISO 3408.

■ Lead screws: metric thread (ML), DIN 13.
   Trapezoidal thread (TL), DIN 103.

Screw material

The screw material and the surface protection of the standard configuration.

Nut material
The nut material of the standard configuration; other materials available as an option.

Gearhead housing material
The housing material and the surface protection of the standard configuration.

Gear material
The gear material of the standard configuration.

Bearings on output flange
The bearing system on the output flange.

Operating temperature range [°C]
Standard range as specified on the data sheet.

Critical speed [mm/s]
The critical speed is reached when the rotational frequency of the screw equals its first natural frequency, thereby causing resonant vibrations.

The critical speed is dependent on the screw geometry and the type of bearing according to the formula below, whereby a safety factor is also incorporated to take into account other influencing factors, such as the alignment in the final mounting.

To avoid any risk of damaging the system, the critical speed must not be reached in any operating phase.

$$n_{cr} = k \cdot 10^6 \cdot \frac{d_r}{l_{max}^2} \cdot S$$

$$v_{cr} = \frac{p \cdot n_{s\_crit}}{60}$$
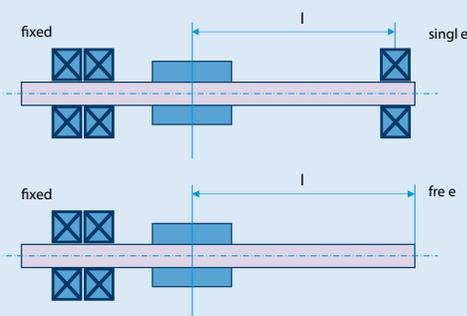
n_{cr} = Critical rotational speed of screw
k = Bearing conf. constant (fixed – single = 190; fixed – free = 43)
d_r = Diameter of screw root
l_{max}^2 = Max. stroke length
S = Safety factor (typ. 0,8)
p = Screw lead

Buckling force [N]
When subject to an axial compressive force, the screw can permanently deform and eventually break (buckling). The maximum compressive force is dependent on the screw geometry and type of bearing according to the formula below.

As buckling is an irreversible event, a safety factor is also taken into account.

$$F_b = k_b \cdot \frac{(d_r)^4}{l_{max}^2} \cdot S \cdot 10^3$$
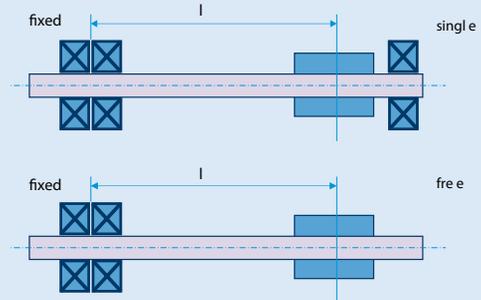
F_b = Maximal permissible force for avoiding buckling
k_b = Constant dep. on bearing type (fixed – single = 200; fixed – free = 25)
d_r = Diameter of screw root
l_{max}^2 = Max. stroke length
S = Safety factor (typ. 0,5)

Length without motor L2 [mm]
The length L2 without motor specified in the data sheet is the length of the standalone gearhead/coupler excluding adapter flange and screw.

Length with motor L1 [mm]
The length L1 with motor is the total length of the combination including the motor, excluding any adapter flange and screw.

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How to select a linear actuator with gearhead

Our online Faulhaber Drive Selection will help you find the right solution according to your specific application and needs.

This section provides a basic procedure for selecting a linear actuator for an application under constant ambient conditions.

Application Data:

Screw type	Ball screw / Lead screw	
Hub length	l	[mm]
Screw supported	yes/no	
Max. diameter	Ø	[mm]
Max. drive length	L1	[mm]
Required forces	$F_1 … F_n$	[N]
Required speeds	$v_1 … v_n$	[mm/s]
Cycle	$t_1 … t_n$	[s]

The assumed application data for the selected example are:

Screw type	Ball screw	
Hub length	150	[mm]
Screw supported	yes	
Max. diameter	22	[mm]
Max. drive length	any	[mm]
Required forces	100 – 0 – 30	[N]
Required speeds	50 – 0 – 50	[mm/s]
Cycle	3 – 1 – 3	[s]

Note that this example is based on standard application parameters. Other constraints could also be relevant, such as the system accuracy, the temperature range and the used materials.

Preselection

1. Mechanical requirements

Depending on the requirements of the application, you can first filter the available products by checking screw type and available space.

The example above refers to a linear actuator with gearhead and ball screw and max. diameter of 22 mm. The **22L SB xx:1 6x2 150** was therefore selected.

2. Linear speed

The second step is to check that the required forces and speeds can be achieved by all available screws.

a) Critical speed above required max speed.

In the data sheet diagram, check the actual critical screw speed (v_{cr_std}) according to the screw bearing system (fixed – free or fixed – single).

If the stroke length differs from the standard, the actual v_{cr} can be obtained using the following formula:

$$v_{cr\_l} \; = \; v_{cr\_std} \; \frac{l_{std}^2}{l_s^2}$$

In our example, we consider bearing version **22L SB xx:1 6x2 150**, supported (fixed – single):

$$v_{cr\_l} \; = \; v_{cr\_std} \; = \; 690 \text{ mm/s}$$

Make certain that the critical speed is above maximum cycle speed, i.e., no resonance problem will occur:

$$v_{cr\_l} \; > \; v_{max}$$

In our example, the requirement is satisfied, since:

$$v_{cr\_l} \; = \; 690 \text{ mm/s} \; > \; v_{max} \; = \; 50 \text{ mm/s}$$

b) Peak output speed max. $v_{p\;max}$ above the required maximum speed.

For each available reduction ratio, check whether the maximum required speed is below the given limit[3]:

$$v_{p\;max} \; \geq \; v_{max}$$

In our example for version **22L SB xx:1 6x2 150**, all ratios > 6.6:1 are to be excluded.

c) Continuous output speed max. $v_{c\;max}$ above the required average speed.

The average output speed can be calculated according to the formula:

$$v_m \; = \; \sum_1^n \; v_j \; \cdot \; \frac{t_j}{t_{tot}}$$

In our example, the cycle input data are taken into account:

$$v_m \; = \; \frac{(\,50 \cdot 3 + 0 \cdot 1 + 50 \cdot 3\,)}{7} \; = \; 42{,}9 \text{ mm/s}$$

[3] For each actuator stage, the max. output speed and max. continuous force range can be found in the data sheet. The complete list of speed and force versus reduction ratio is also available in document "Linear actuator, reduction ratios".

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For each available reduction ratio, check whether the required average speed is below the given limit[3]:

$$v_{c\,max} \; > \; v_m$$

In our example for version 22L SB, all ratios > 6.6:1 are to be excluded (already performed in point b).

3. Axial force

The next step is to check whether the remaining linear actuator configurations can support the required forces.

a) Buckling force above the required maximum force.

In the data sheet diagram, check the actual buckling force of the screw (F_{b_std}) according to the screw bearing system (fixed – free or fixed – single). If the stroke length is different from standard, calculate the actual F_b using formula:

$$F_{b\_l} \; = \; F_{b\_std} \cdot \frac{l_{std}^2}{l_s^2}$$

In our example, bearing version 22L SB (fixed – single) is considered:

$$F_{b\_l} \; = \; F_{b\_std} \; = \; 2562 \text{ N}$$

Make certain that the buckling force is above maximum cycle force, i.e., that no buckling problems will occur:

$$F_{b\_l} \; > \; F_{max}$$

In our example, the requirement is satisfied, since:

$$F_{b\_l} \; = \; 2562 \text{ N} \; > \; F_{max} \; = \; 100 \text{ N}$$

b) Peak axial force max. $F_{p\,max}$ above the required maximum force.

For each available reduction ratio, check whether the maximum required axial force is below the given limit[3]:

$$F_{p\,max} \; \geq \; F_{max}$$

In our example, the requirement is satisfied for all ratios.

c) Continuous axial force max. $F_{m\,max}$ above the required average force

The average output force can be calculated using formula:

$$F_m \; = \; \sqrt[3]{\sum_1^n \frac{F_j^3 \cdot n_j \cdot \dfrac{t_1}{t_{tot}}}{n_m}}$$

In our example, the cycle input data are taken into account:

$$F = \sqrt[3]{\frac{100^3 \cdot \dfrac{50 \cdot 60}{2} \cdot \dfrac{3}{7} + 0 + 30^3 \cdot \dfrac{50 \cdot 60}{2} \cdot \dfrac{3}{7}}{\dfrac{42,9 \cdot 60}{2}}} = 80.1 \text{ N}$$

For each available reduction ratio, check whether the required average force is below the specified limit[3]:

$$F_{m\,max} \; \geq \; F_m$$

In our example, the requirement is satisfied for all ratios.

Note that it is possible to operate the linear actuator with gearhead with a higher average axial force. To achieve an optimum service life, however, the recommended value should be considered.

4. Power

The last step is to check whether the linear actuator can provide the required output power.

a) Output power, max. P_{max} above the maximum required mechanical power.

For each cycle step, the mechanical power can be calculated using formula:

$$P_j \; = \; \frac{v_j \cdot F_j}{1000}$$

For each linear actuator stage, the maximum value must be below the specified limit:

$$P_{out\_max} \; \geq \; P_m$$

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[3] For each actuator stage, the max. output speed and max. continuous force range can be found in the data sheet. The complete list of speed and force versus reduction ratio is also available in document "Linear actuator, reduction ratios".

In our example, the maximum power is

$$P_m = \frac{50 \cdot 100}{1000} = 5 \text{ W}$$

Therefore, configurations with 4 stages must be excluded.

A subset of possible configurations can be selected on the basis of the above preselection.

In the example above, the following configurations satisfy the requirements of the application:

- 22L SB 1:1 6x2 150
- 22L SB 3:1 6x2 150
- 22L SB 3,6:1 6x2 150
- 22L SB 4,5:1 6x2 150
- 22L SB 6,6 6x2 150

Input data calculation: rotational speed and torque

For each of the available solutions, the input rotational speed and torque must be calculated using the following formulas:

$$M_{in\_j} = \frac{F_j \cdot p \cdot 100}{2\pi \eta_{screw}} \cdot \frac{100}{i \cdot \eta_{coupler}} \quad \text{[mNm]}$$

F_j	= Required force at step "j" of the cycle [N]
η_{screw}	= Screw efficiency [%]
$\eta_{coupler}$	= Coupler efficiency [%]
p	= Screw lead [mm]

$$n_{in\_j} = \frac{60 \cdot i \cdot v_j}{p} \quad \text{[min}^{-1}\text{]}$$

v_j	= Required screw output speed at step "j" of the cycle [mm/s]
i	= Reduction ratio
p	= Screw lead [mm]

In our example, the torque and speed at the input of **22L SB 1:1 6x2 150** have the following values during the cycle:

Required torque	37,2 – 0 – 11,2	[mNm]
Required speed	1500 – 0 – 1500	[min^{-1}]
Cycle	3 – 1 – 3	[s]

The motor can then be selected according to the relevant technical information of each motor family.

Note that the calculation provided is intended only for quickly estimating possible solutions. Other motor parameters may be relevant for the correct drive selection, such as:

- System inertia, which may be relevant for highly dynamic applications
- Linear movement direction; in the case of a non-horizontal movement, the gravitational force must be taken into account
- Torque in the case of a preloaded nut

In addition, a sufficiently powerful motor should be selected to avoid operating the motor at an excessively high constant temperature. At such high temperatures, extra heat would be transferred to the linear actuator with gearhead, prematurely degrading the lubricant and shortening the service life of the combination unit.
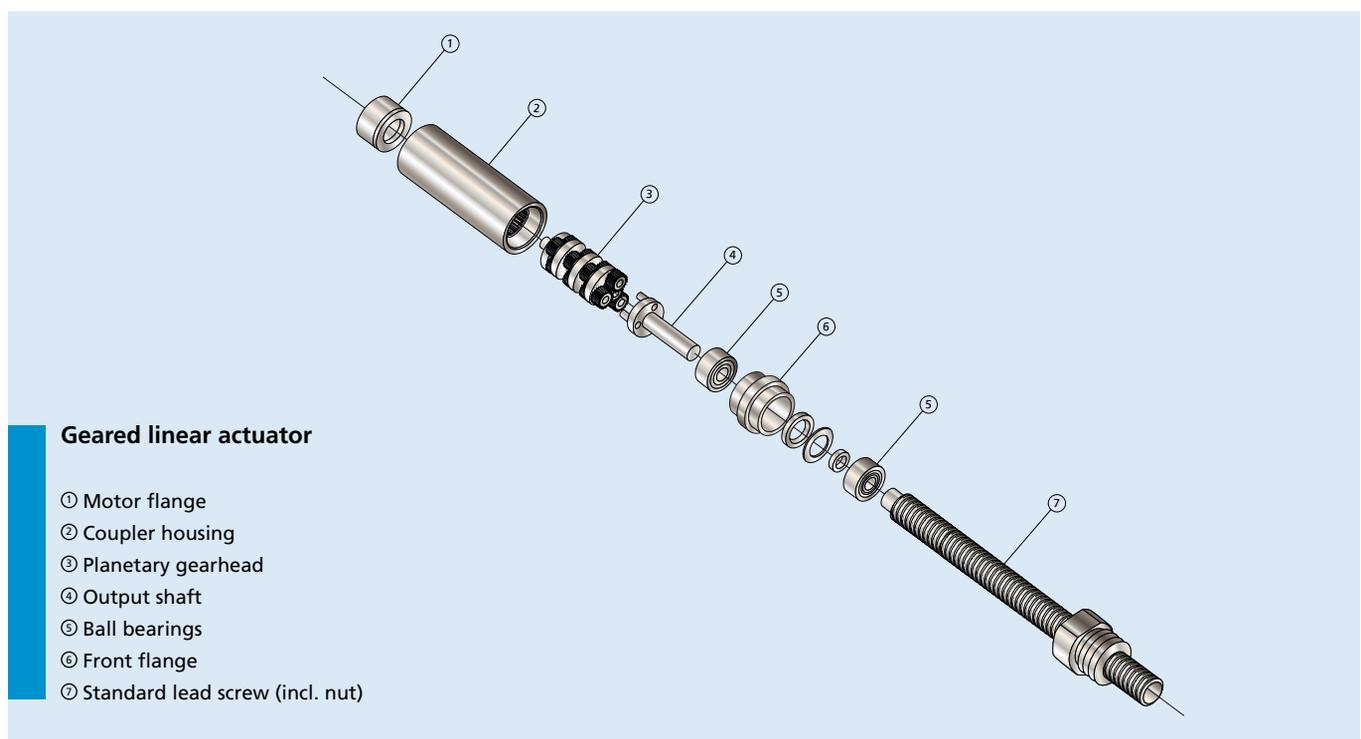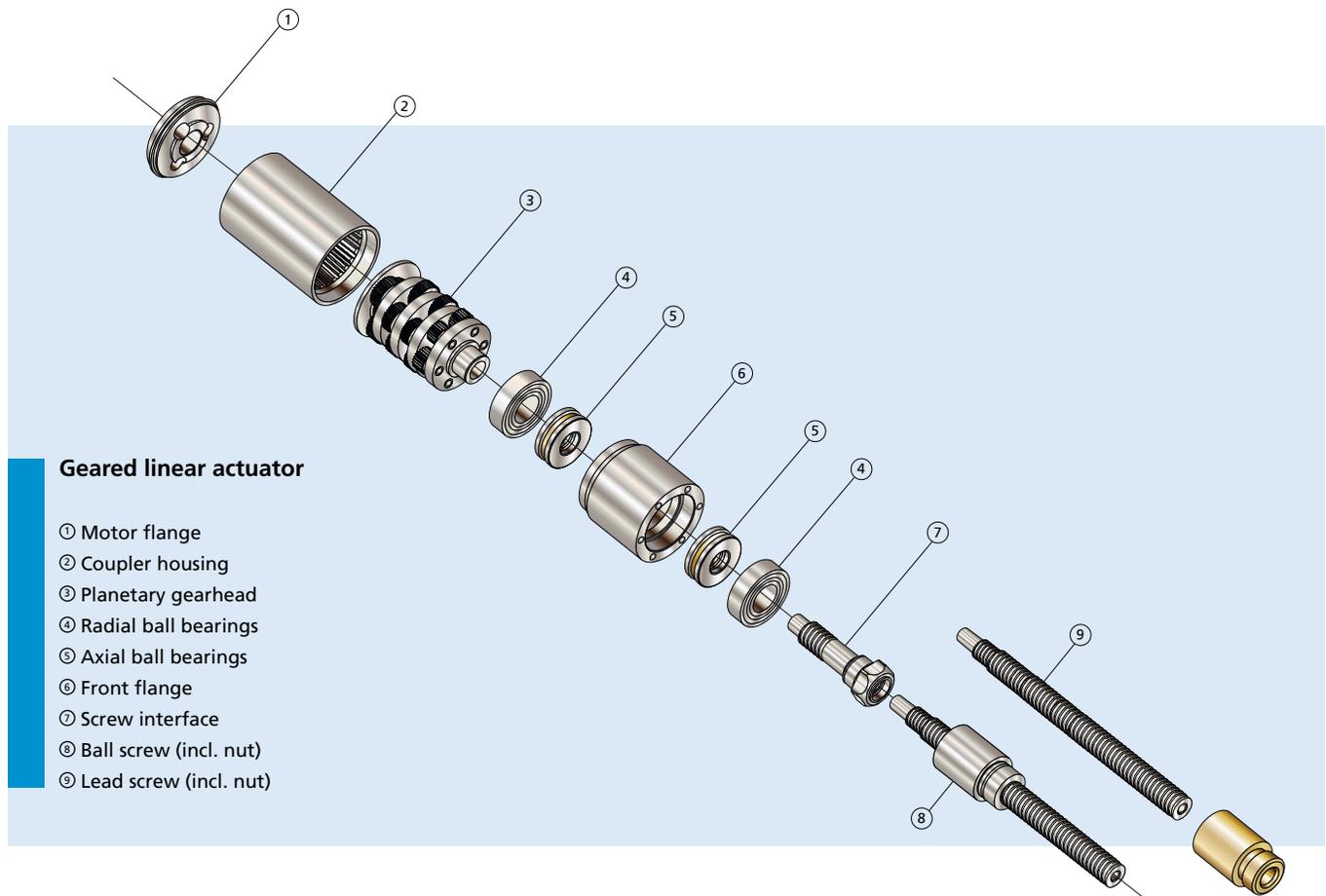
To achieve a long service life, the motor should, in general, not exceed a temperature of 60 °C to 70 °C in continuous operation. At these motor temperatures, premature degradation of the lubricant is prevented.

The results can also be compared with the suggestions from our online FAULHABER Drive Selection Tool.

Our sales engineers will be happy to help you confirm your selection or find the right solution for your application, taking into account special requirements such as specific ambient conditions, mechanical constraints, etc.

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Basic structure

Geared linear actuator

① Motor flange
② Coupler housing
③ Planetary gearhead
④ Radial ball bearings
⑤ Axial ball bearings
⑥ Front flange
⑦ Screw interface
⑧ Ball screw (incl. nut)
⑨ Lead screw (incl. nut)

Geared linear actuator

① Motor flange
② Coupler housing
③ Planetary gearhead
④ Output shaft
⑤ Ball bearings
⑥ Front flange
⑦ Standard lead screw (incl. nut)

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