FAULHABER

Precision Gearheads
Technical Information

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Precision Gearheads

Technical Information

General information

Life performance
The operational lifetime of a reduction gearhead and motor combination is determined by:

- Input speed
- Output torque
- Operating conditions
- Environment and Integration into other systems

Since a multitude of parameters prevail in any application, it is nearly impossible to state the actual lifetime that can be expected from a specific type of gearhead or motor-gearhead combination. A number of options to the standard reduction gearheads are available to increase life performance: ball bearings, all metal gears, reinforced lubrication etc.

Bearings – Lubrication
Gearheads are available with a range of bearings to meet various shaft loading requirements: sintered sleeve bearings, ball bearings and ceramic bearings. Where indicated, ball bearings are preloaded with spring washers of limited force to avoid excessive current consumption.

A higher axial shaft load or shaft pressfit force than specified in the data sheets will neutralise the preload on the ball bearings.

The satellite gears in the 38/1-2 Series Planetary Gearheads are individually supported on sintered sleeve bearings. In the 38A and 44/1 Series, the satellite gears are individually supported on needle or ball bearings.

All bearings are lubricated for life. Relubrication is not necessary and not recommended. The use of non-approved lubricants on or around the gearheads or motors can negatively influence the function and life expectancy.

The standard lubrication of the reduction gears is such as to provide optimum life performance at minimum current consumption at no-load conditions. For extended life performance, all metal gears and heavy duty lubrication are available. Specially lubricated gearheads are available for operation at extended temperature environments and under vacuum.

Notes on technical datasheet

Unspecified tolerances
Tolerances in accordance with ISO 2768 medium.

≤ 6	=	± 0,1 mm
≤ 30	=	± 0,2 mm
≤ 120	=	± 0,3 mm

Input speed
The recommended maximum input speed for continuous operation serves as a guideline. It is possible to operate the gearhead at higher speeds. However, to obtain optimum life performance in applications that require continuous operation and long life, the recommended speed should be considered.

Ball bearings
Ratings on load and lifetime, if not stated, are according to the information from the ball bearing manufacturers.

Operating temperature range
Standard range as listed on the data sheets.
Special executions for extended temperature range available on request.

Reduction ratio
The listed ratios are nominal values only, the exact ratio for each reduction gearhead can be calculated by means of the stage ratio applicable for each type.

Output torque
Continuous operation.
The continuous torque provides the maximum load possible applied to the output shaft; exceeding this value will reduce the service life.

Intermittent operation.
The intermittent torque value may be applied for a short period. It should be for short intervals only and not exceed 5% of the continuous duty cycle.

Direction of rotation, reversible
All gearheads are designed for clockwise and counterclockwise rotation. The indication refers to the direction of rotation as seen from the shaft end, with the motor running in a clockwise direction.

Backlash
Backlash is defined by the amount by which the width of a tooth space exceeds the width of the engaging tooth on the pitch circle. Backlash is not to be confused with elasticity or torsional stiffness of the system.
The general purpose of backlash is to prevent gears from jamming when making contact on both sides of their teeth simultaneously. A small amount of backlash is desirable to provide for lubricant space and differential expansion between gear components. The backlash is measured on the output shaft, at the last geartrain stage.

Zero Backlash Gearheads

The spur gearheads, series 08/3, 12/5, 15/8, 16/8 and 22/5, with dual pass geartrains feature zero backlash when preloaded with a FAULHABER DC-Micromotor.

Preloaded gearheads result in a slight reduction in overall efficiency and load capability.

Due to manufacturing tolerances, the preloaded gearheads could present higher and irregular internal friction torque resulting in higher and variable current consumption in the motor.

However, the unusual design of the FAULHABER zero backlash gearheads offers, with some compromise, an excellent and unique product for many low torque, high precision postioning applications.

The preloading, especially with a small reduction ratios, is very sensitive. This operation is achieved after a defined burn-in in both directions of rotation. For this reason, gearheads with pre-loaded zero backlash are only available when factory assembled to the motor.

The true zero backlash properties are maintained with new gearheads only. Depending on the application, a slight backlash could appear with usage when the gears start wearing. If the wearing is not excessive, a new preload could be considered to return to the original zero backlash properties.

Assembly instructions

It is strongly recommended to have the motors and gearheads factory assembled and tested. This will assure perfect matching and lowest current consumption.

The assembly of spur and hybrid gearheads with motors requires running the motor at very low speed to ensure the correct engagement of the gears without damage.

The planetary gearheads must not be assembled with the motor running. The motor pinion must be matched with the planetary input-stage gears to avoid misalignment before the motor is secured to the gearhead.

When face mounting any gearhead, care must be taken not to exceed the specified screw depth. Driving screws beyond this point will damage the gearhead. Gearheads with metal housing can be mounted using a radial set screw.

How to select a Precision Gearhead

This section gives an example of a step-by-step procedure on how to select a reduction gearhead.

Application data

The basic data required for any given application are:

Required torque	M	[mNm]
Required speed	n	[min^{-1}]
Duty cycle	δ	[%]
Available space, max.	diameter/length	[mm]
Shaft load	radial/axial	[N]

The assumed application data for the selected example are:

Output torque	M	=	120 mNm
Speed	n	=	30 min^{-1}
Duty cycle	δ	=	100%
Space dimensions, max.	diameter	=	18 mm
	length	=	60 mm
Shaft load	radial	=	20 N
	axial	=	4 N

To simplify the calculation in this example, the duty cycle is assumed to be continuous operation.

Preselection

A reduction gearhead which has a continuous output torque larger than the one required in the application is selected from the catalogue.
If the required torque load is for intermittent use, the selection is based on the output torque for intermittent operation.
The shaft load, frame size and overall length with the motor must also meet the minimum requirements.
The product selected for this application is the planetary gearhead, type 16/7.

Output torque, continuous operation	$M_{max.}$	= 300 mNm
Recommended max. input speed for		
– Continuous operation	n	$\leq$ 5 000 min^{-1}
– Shaft load, max.	radial	$\leq$ 30 N
	axial	$\leq$ 5 N

Calculation of the reduction ratio

To calculate the theoretical reduction ratio, the recommended input speed for continuous operation is divided by the required output speed.

$$i_N = \frac{\text{Recommended max. input speed}}{\text{required output speed}}$$

From the gearhead data sheet, a reduction ratio is selected which is equal to or less than the calculated one.

For this example, the reduction ratio selected is 159 : 1.

Calculation of the input speed n_{input}

$$n_{input} = n \cdot i \qquad [min^{-1}]$$

$$n_{input} = 30 \cdot 159 = 4\,770 \qquad min^{-1}$$

Calculation of the input torque M_{input}

$$M_{input} = \frac{M \cdot 100}{i \cdot \eta} \qquad [mNm]$$

The efficiency of this gearhead is 60%, consequently:

$$M_{input} = \frac{120 \cdot 100}{159 \cdot 60} = 1{,}26 \qquad mNm$$

The values of

Input speed	n_{input}	= 4 770	min^{-1}
and			
Input torque	M_{input}	= 1,26	mNm

are related to the motor calculation.

The motor suitable for the gearhead selected must be capable of producing at least two times the input torque needed.

For this example, the DC-Micromotor type 1624 E 024 S supplied with 14 V DC will produce the required speed and torque.

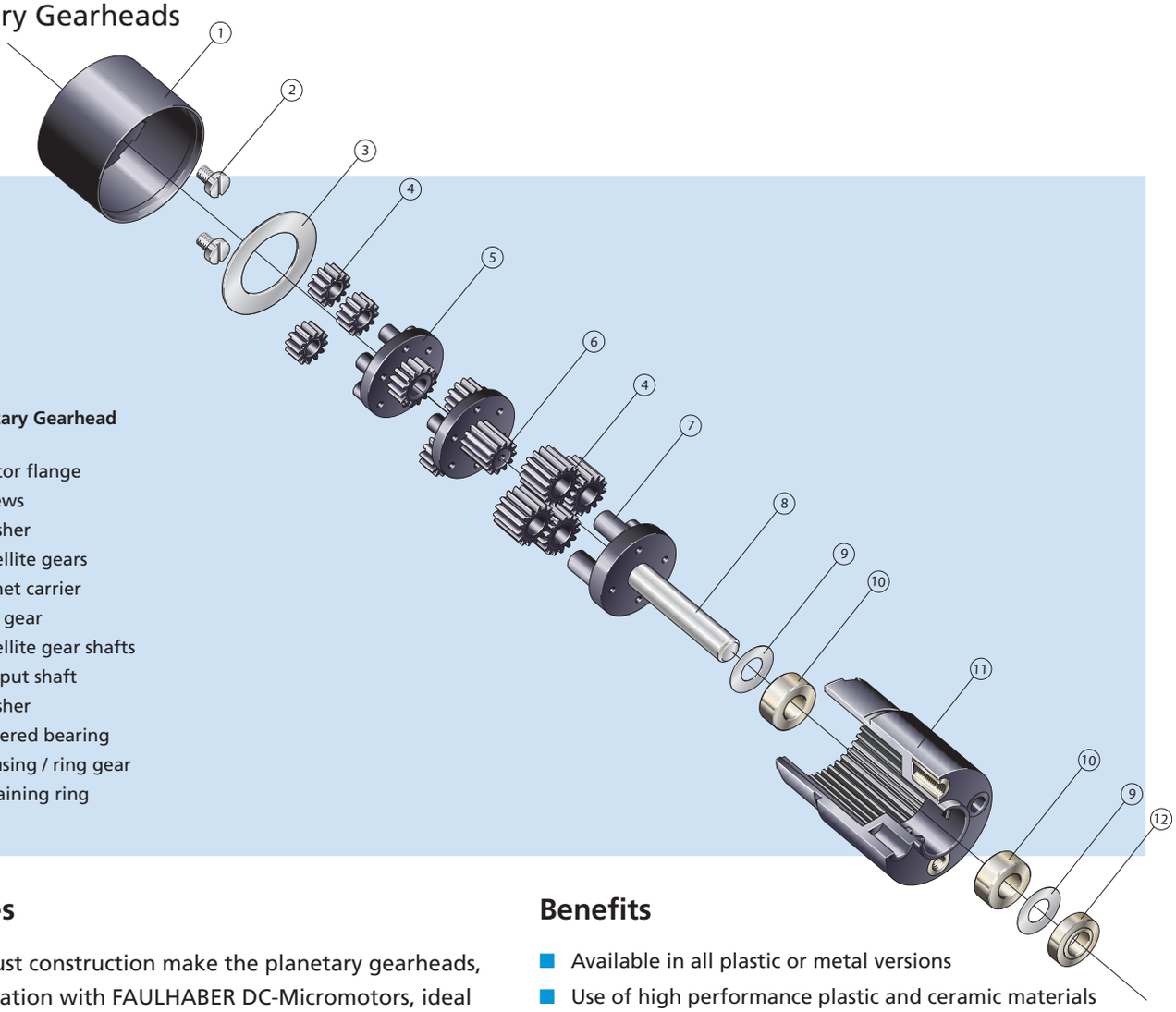
For practical applications, the calculation of the ideal motor-gearhead drive is not always possible.
Detailed values on torque and speed are usually not clearly defined.

It is recommended to select suitable components based on a first estimation, and then test the units in the application by varying the supply voltage until the required speed and torque are obtained.
Recording the applied voltage and current at the point of operation, along with the type numbers of the test assembly, we can help you to select the ideal motor-gearhead.

The success of your product will depend on the best possible selection being made!
For confirmation of your selection and peace of mind, please contact our sales engineers.

Precision Gearheads

Planetary Gearheads



Planetary Gearhead

① Motor flange
② Screws
③ Washer
④ Satellite gears
⑤ Planet carrier
⑥ Sun gear
⑦ Satellite gear shafts
⑧ Output shaft
⑨ Washer
⑩ Sintered bearing
⑪ Housing / ring gear
⑫ Retaining ring

Features

Their robust construction make the planetary gearheads, in combination with FAULHABER DC-Micromotors, ideal for high torque, high performance applications.
In most cases, the geartrain of the input stage is made of plastic to keep noise levels as low as possible at higher speed. All steel input gears as well as a modified lubrication are available for applications requiring very high torque, vacuum, or higher temperature compatability.

For applications requiring medium to high torque FAULHABER offers planetary gearheads constructed of high performance plastics. They are ideal solutions for applications where low weight and high torque density play a decisive role. The gearhead is mounted to the motor with a threaded flange to ensure a solid fit.

Benefits

- Available in all plastic or metal versions
- Use of high performance plastic and ceramic materials
- Available with a variety of shaft bearings including sintered, ceramic, and ball bearings
- Modified versions for extended temperature and special environmental conditions are available
- Custom modifications available

Product code

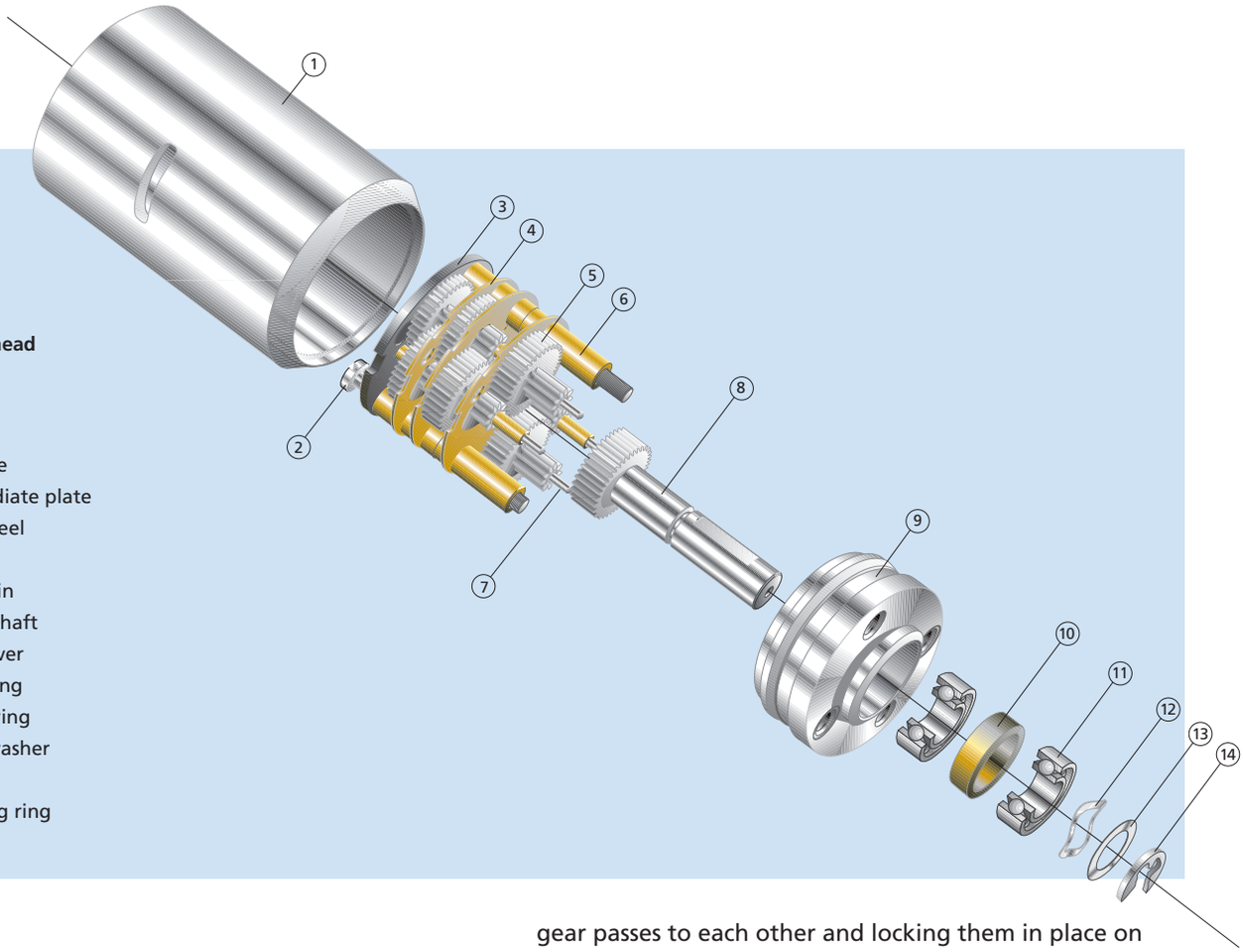
26	Outer diameter [mm]
A	Version
64:1	Reduction ratio

26A 64:1

All metal planetary gearhead series 12/4

Precision Gearheads

Spur Gearheads

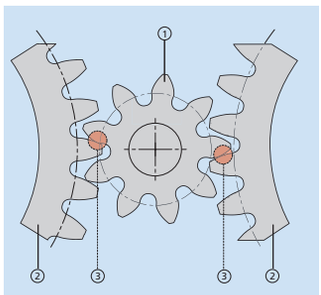


Spur Gearhead

① Housing
② Screws
③ End plate
④ Intermediate plate
⑤ Gear wheel
⑥ Sleeve
⑦ Dowel pin
⑧ Output shaft
⑨ Front cover
⑩ Spacer ring
⑪ Ball bearing
⑫ Spring washer
⑬ Washer
⑭ Retaining ring

Features

A wide range of high quality spur gearheads are available to compliment FAULHABER DC-Micromotors. The all metal or plastic input-stage geartrain assures extremely quiet running. The precise construction of the gearhead causes very low current consumption in the motor, giving greater efficiency. The gearhead is sleeve mounted on the motor, providing a seamless in-line fit. The FAULHABER Spur Gearheads are ideal for high precision, low torque and low noise applications.



Zero Backlash Spur Gearhead

① Motor pinion
② Dual-pass geartrain input stage
③ Zero backlash preloaded engagement

FAULHABER offers a special version of a spur gearhead with zero backlash. These gearheads consist of a dual pass spur geartrain with all metal gears. The backlash is reduced to a minimum by counter-rotating the two individual gear passes to each other and locking them in place on the motor pinion gear. They are ideal for positioning applications with a very high resolution and moderate torque. Zero backlash gearheads can only be delivered preloaded from the factory.

Benefits

- Available in a wide variety of reduction ratios including very high ratios
- Zero backlash versions are available
- Available with a variety of shaft bearings including sintered, ceramic, and ball bearings

Product code

22	Outer diameter [mm]
/5	Version
377:1	Reduction ratio

22/5 377:1

Notes

Planetary Gearheads

The GPT planetary gearheads exhibit high torque and enhanced input speed in compact dimensions. Their improved efficiency and numerous reduction ratios uniformly distributed help to exploit the maximum motor power.

Their geartrain is designed for robustness to sustain intermittent or sudden load changes. Depending on the diameter size, these gearheads can sustain input speed up to 20.000 min^{-1} or output torque up to 25 Nm when operating in intermittent cycles. The GPT product family is also particularly suited for accurate positioning applications granted by a low backlash characteristic.

These gearheads can be combined with an extensive range of DC or brushless motors and they come with various shaft configurations to adapt to many applications. They are ideal for different types of robots – inspection, assembly, rehabilitation or exoskeletons – as well as for production and laboratory automation, for packaging machines, measurement and testing equipment or for semiconductor handling.

Series

22GPT	32GPT
42GPT	

Key Features

Gearhead diameter	22 ... 42 mm
Material	stainless steel
Continuous torque	0,45 ... 18 Nm
Continuous input speed	up to 15.000 min^{-1}
Intermittent torque	0,6 ... 25 Nm
Intermittent input speed	up to 20.000 min^{-1}
Radial load	up to 390 N
Reduction ratio	from 3:1 up to 1294:1

22 GPT 89:1 KS1

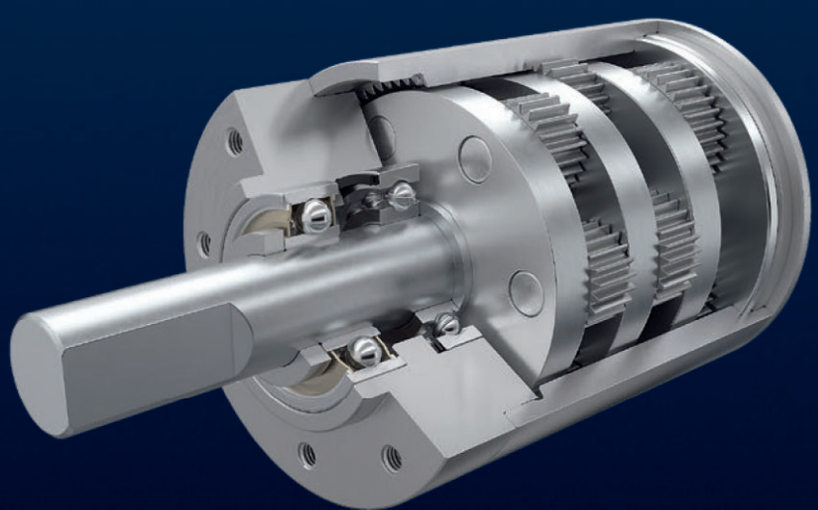
Product Code

22	Gearhead diameter
GPT	Product family
89:1	Reduction ratio
KS1	Standard options

FAULHABER GPT

Advantages of this series at a glance

- Compact length
- High continuous torque
- Very robust for intermittent or impulsive cycles
- High intermittent speed up to 20.000 min^{-1}
- Reduced backlash
- Many reduction ratios
- Large selection of motor combinations
- Many standard options



General information

The FAULHABER GPT metal planetary gearhead series are designed to provide high torque in compact dimensions, they can support large input speeds and are suited for a wide range of applications like robotics, industrial machines and laboratory equipment. The GPT product family is designed to leverage at best the maximum power of FAULHABER DC-Micromotors and Brushless DC-Servomotors. Besides high torque performance, GPT series are also particularly well suited for positioning applications granted by their low backlash characteristics.

On top of optimizing performance for continuous operation, GPT series are also designed to sustain strong torque impulses and large speed variations when used in intermittent cycles. A large number of reduction ratios uniformly distributed are available to select the most appropriate configuration to fit various torque or speed operating points required by the application.

A large selection of options are available to match different ambient conditions and make the mechanical integration inside applications faster and smoother through various shaft configurations.

The main advantages of the GPT series are:

- compactness with short length
- high torque and high inputs speeds
- very robust with high intermittent or impulsive torque
- many reduction ratios
- minimum backlash
- high efficiency
- different shaft configurations
- large selection of motors combinations

Service Life

The operational lifetime of a reduction gearhead and motor combination is determined by:

- input speed and output torque, resulting in output power
- motor operating temperature
- operation mode (continuous, intermittent or impulsive) and duty cycle
- output shaft load (radial or axial load)
- operating conditions like temperature, dust and other ambient conditions
- environment and integration into other systems

Since a multitude of parameters prevail in any application, it is nearly impossible to state the actual lifetime that can be expected from a specific type of gearhead or motor-gearhead combination. A number of options to the standard reduction gearheads are available to increase life performance: ball bearings, different lubrication etc.

Bearings – Lubrication

Gearheads are available with different bearings to meet various requirements. Where indicated, ball bearings are preloaded with spring washers of limited force to avoid excessive current consumption.

A higher axial shaft load than specified in the data sheets will neutralize the preload on the ball bearings.

All bearings are lubricated for life. Relubrication is not necessary and not recommended. The use of non-approved lubricants on or around the gearheads or motors can negatively influence the function and life expectancy.

The standard lubrication of the reduction gears is such as to provide optimum life performance at minimum current consumption at no-load conditions. Special lubricated gearheads are available for operation at extended temperature environments and under vacuum.

Operating limits

In order to avoid short service life or early damage, gearheads are intended to be used within the following limits:

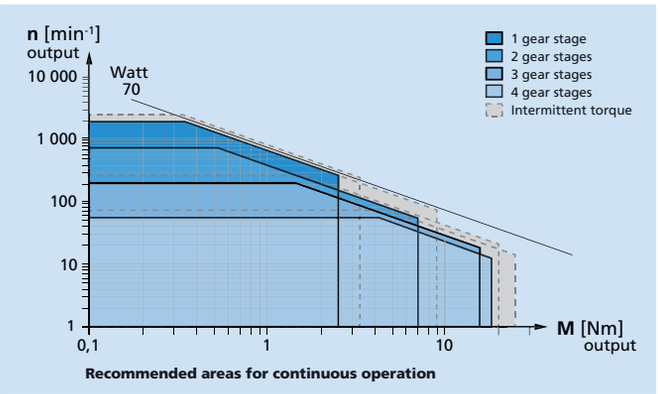
- maximum output torque
- and maximum input speed
- and maximum output power

Values at 22°C				
Number of gear stages		1	2	2
Reduction ratio (rounded)[1]		3:1 3,6:1 4,5:1 6,6:1	9:1	11:1 14:1 16:1 20:1 24:1 30:1 44:1
Continuous torque, max.	Nm	0,45	0,8	0,8
Intermittent torque, max.	Nm	0,6	1,1	1,1
Peak torque	Nm	1	2,5	2,5
Continuous input speed, max.	min^{-1}	9 000	10 000	12 000
Intermittent input speed, max.	min^{-1}	11 000	12 000	15 000
Continuous output power, max.	W	21	12	12
Intermittent output power, max.	W	30	18	18
Efficiency, max.	%	92	84	

An important aspect to consider is that gearhead cannot operate simultaneously at maximum output torque and maximum input speed, such operating condition would result in a power transmission generating excessive heat dissipation and would degrade significantly service life. For such reason, a limitation relative maximum output power is also specified in the datasheet.

These speed, torque and power limits are specified to different values depending on the operating mode, either continuous operation or intermittent operation, for which intermittent operation refers to an operating duty cycle of 20% on-time.

Those limits are represented in a graphical form to illustrate the recommended area of operations for continuous and intermittent operations. Such graph reports the output speed versus output torque on both logarithmic scales.



The limits also vary depending on the number of reduction stages and is also depending on the reduction ratio as expressed in the datasheet through the various columns reporting performance based on reduction ratios.

These limit values are referring to the only gearhead for ambient temperature around 22°C and do not consider any external effects relative to the gearhead. Ambient conditions, influence of integration in the system application and motor behavior like motor temperature are not considered when defining those maximum operating limits.

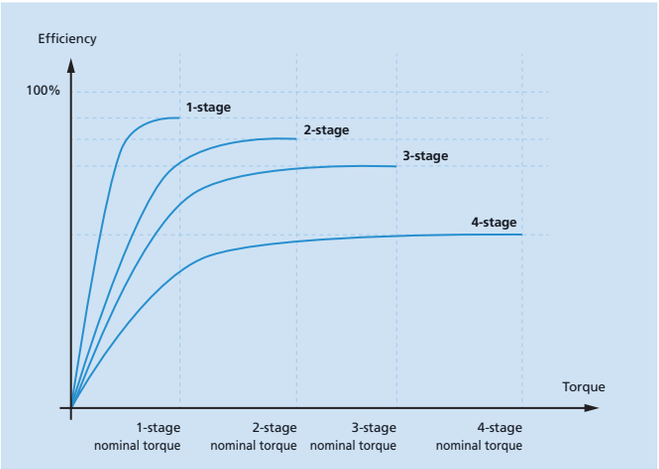
Efficiency

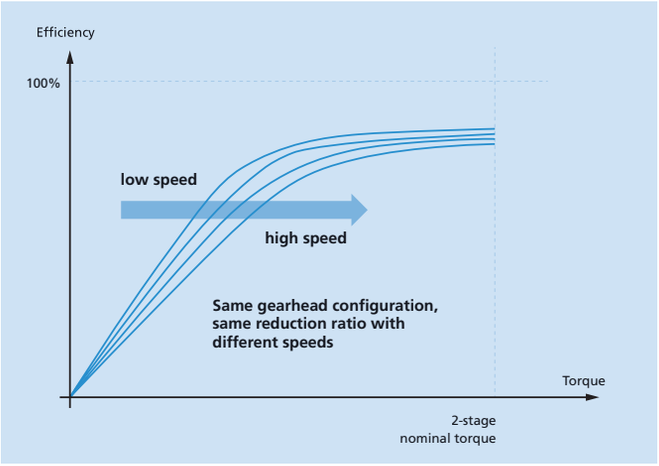
Datasheets report the maximum efficiency of the gearhead based on its configuration as per number of stage and reduction ratio. Such efficiency value refers only to continuous operation mode.

Intermittent output power, max.	W	30	18	18
Efficiency, max.	%	92	84	82

Such maximum efficiency occurs on a specific operating point in terms of speed and torque and it depends also on the gearhead configuration and on the specific reduction ratio.

For each specific configuration, the gearhead efficiency varies with speed and torque. The following graph reports the typical behavior of gearhead efficiency.





In order to achieve a good efficiency the gearhead should ideally be used at torque level above 30% of nominal torque. The primary parameter to ensure good efficiency is torque while speed affect also efficiency but a minor proportion. To provide good efficiency a gearhead should not be used at low torque and high speed.

Besides motor current consumption, the impact of effciency is related to heat dissipation inside the gearhead which also depends on the input power transmitted by the motor. Such heat dissipation is increasing gearhead temperature and contribute to degrade lubricant over time, impacting thus service life.

Motor Combinations
GPT gearhead series can be combined with a wide range of DC motors, 4-pole and 2-pole brushless motors, for smaller diameter size also combination with stepper motors are available. This gearhead series are optimized to leverage at best the torque and speed range of the different FAULHABER motor families.

Combinations with motors come assembled from the factory. Motor-gearhead combination cannot be assembled other than on the factory line.

When combining a motor with GPT gearhead series, the motor should be selected with enough performance capabilities to avoid bringing the motor at a too high steady temperature. Such high temperatures would produce extra heat transfer towards the gearhead and could degrade prematurely the lubricant, thus impacting service life of the combination unit.

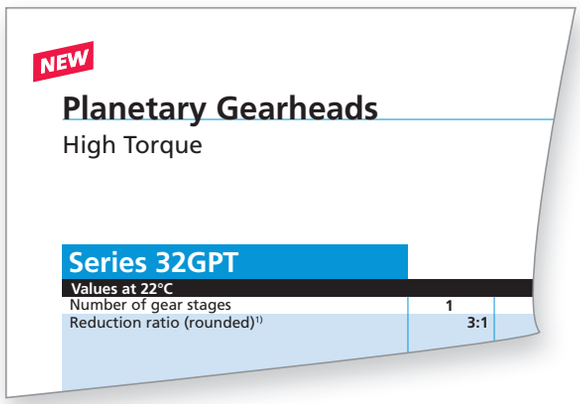
To achieve long service life, a general guideline is to ensure that the motor won't exceed a temperature of 60°C to 70°C at steady state during operation. Such motor temperatures will avoid premature degradation of lubricant inside the gearhead.

Modifications and standard options
GPT gearhead series are available with a big range of standard options and modifications. Some of these options are made available to match particular requirements related to specific applications with special ambient conditions, others are made to ease the product integration inside the application system, others to enhance particular performance parameters for specific needs.

Such product options refers to:

- output shaft shape and dimensions
- ambient conditions like particular temperature range or special environmental conditions as vacuum.
- different motor cable or terminals orientation when integrating the combination unit inside the application
- other requirements related to output load fixed on the output shaft

Most options are modifying the basic product so that characteristics will differ from the performance of the standard version. This latest aspect should be considered when selecting an option and eventual questions should be addressed to your local sales representative.



Notes on technical datasheet

Unspecified tolerances
Tolerances in accordance with ISO 2768 medium.

≤ 6	=	± 0,1 mm
≤ 30	=	± 0,2 mm
≤ 120	=	± 0,3 mm

Reduction ratio
The listed ratios are nominal values only, the exact ratio for each reduction gearhead can be calculated by means of the stage ratio applicable for each type.

Output torque
Continuous operation: The continuous torque provides the maximum possible load applied to the output shaft; exceeding this value will reduce the service life.

Intermittent operation: The intermittent torque value may be applied for a short period. It should be for short intervals only and not exceed 20% of the continuous duty cycle.

Peak torque: This torque limit represents the absolute maximum torque supported by the gearhead for unexpected events generated randomly on the output shaft load. Such peak torque cannot occur in cyclic mode or in a timely repetitive manner. This parameter is not intended to be used as a dimensioning constraints to drive any loads. Gearhead output is able to support such torque value with a non-repetitive scheme few hundreds to few thousand times during its operation without impacting service life.

Input speed
Continuous operation: The recommended maximum input speed for continuous operation serves as a guideline. It is possible to operate the gearhead at higher speeds. However, to obtain optimum life performance in applications that require continuous operation and long life, the recommended speed should be considered.

Intermittent operation: The intermittent input speed value may be applied for a short period. It should be for short intervals only and not exceed 20% of the continuous duty cycle. Operating gearhead at speeds higher than intermittent maximum value is not recommend as it will reduce significantly service life, and in some cases it could generate early damage with abrupt stop.

Output Power
Continuous operation: The recommended maximum output power for continuous operation serves as a guideline. It is possible to operate the gearhead momentarily with higher output power for brief period. However, to obtain optimum life performance in applications that require continuous operation and long life, the recommended continuous output power should be considered.

Intermittent operation: The intermittent output power value may be applied for a short period. It should be for short intervals only and not exceed 20% of the continuous duty cycle. Operating gearhead at higher power than intermittent maximum value is not recommend as it will reduce drastically service life.

Efficiency
The maximum efficiency refers to the continuous operation mode. Such value varies depending on the number of stages and could also depend on the reduction ratio. The gearhead efficiency varies depending on the speed-torque operating point. For low torque value below 30% of nominal torque, efficiency could be significantly reduced. Efficiency varies in minor proportion with speed, at highest speed efficiency is slightly reduced.

Input inertia
Maximum input inertia can be used to determine the necessary torque required to ensure a particular acceleration of the geartrain typically for positioning applications with high dynamics. Such inertia value is referred to the gearhead input at the motor output shaft and including the motor pinion. Such value is depending on the geartrain configuration (e.g.: number of satellite gears), the number of stage and thus on the reduction ratio also. The reported value is the maximum one considering the various possible configuration of the geartrain.

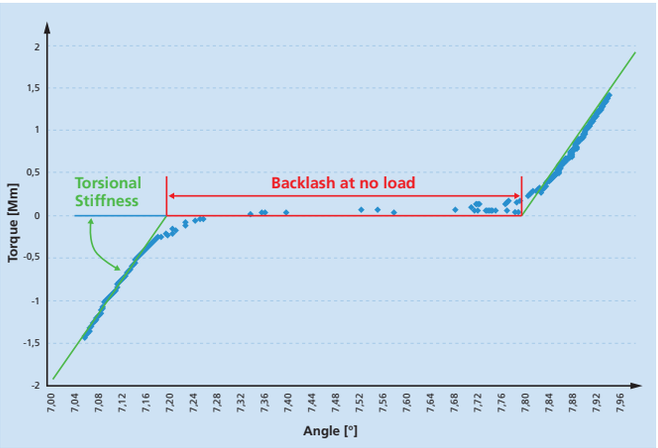
Torsional stiffness
Torsional stiffness represents the angular rigidity of the whole geartrain including the output shaft. This parameter is reporting the output torque necessary to twist the output shaft by one degree when the gearhead input is fixed. This is a typical measured on several samples.

Backlash
Backlash: Backlash is defined by the amount by which the width of a tooth space exceeds the width of the engaging tooth on the pitch circle. Backlash is not to be confused with elasticity or torsional stiffness of the system.

The general purpose of backlash is to prevent gears from jamming when making contact on both sides of their teeth simultaneously. A small amount of backlash is desirable to provide for lubricant space and differential expansion between gear components. The backlash is measured on the output shaft, at the last geartrain stage.

Backlash represent the angular play of the whole geartrain when rotating the gearhead output shaft with no load while the gearhead input is fixed. Such angular play consider the angle between both clockwise and counterclockwise end positions of the output shaft, without applying torque. This reported value is typical measured on several samples.

Backlash under load: The backlash under load between 2 angular positions is depending on the torque load in the CW and CCW directions for those respective positions. Such backlash is the sum of the backlash at no-load and the contribution of the torsional stiffness depending the torque values in these 2 load positions as illustrated the graph below:



Shaft load
Radial load: The maximum output shaft load represents the maximum dynamic load (when output shaft is rotating) that can be applied radially at a particular distance from the output flange and that the gearhead ball bearing system can support without impacting the service life. In case the radial load would be applied at another distance this value should be extrapolated appropriately.

Axial load: The maximum axial load is the maximum dynamic load (when output shaft is rotating) when pressing the shaft towards the inner side of the gearhead without damaging prematurely the bearing system and without impacting service life.

Shaft press fit force
The press fit force is the maximum static force that can be axially applied to gearhead output shaft in order to mount a coupling element, for example a pulley or a pinion. This is a static force while the geartrain is stand-still and not rotating. Please note that this force does not refer to any operating conditions of the gearhead when used inside the application.

Shaft play
Radial Play: The radial play is the maximum clearance that the output shaft can move radially when measured at a specific distance from the front flange. Such radial play measure depends on the position of measurement along the shaft and on the force used for measurement. The radial play value assumes that maximum force reported in the datasheet will not exceed the maximum radial load.

Axial Play: The axial play on the gearhead output shaft is the maximum distance that the output shaft move in the axial direction when pushing the shaft towards the inner side of the gearhead. Such axial play value depends on the ball bearing system and the relative preload design. The axial play assumes that maximum axial load force reported in the datasheet is not exceeded. When pulling the shaft in the direction out from the gearhead, a minimum play is required to avoid ball bearings to jam, such play in pull direction depends on the bearing preload design.

Precision Gearheads

Technical Information

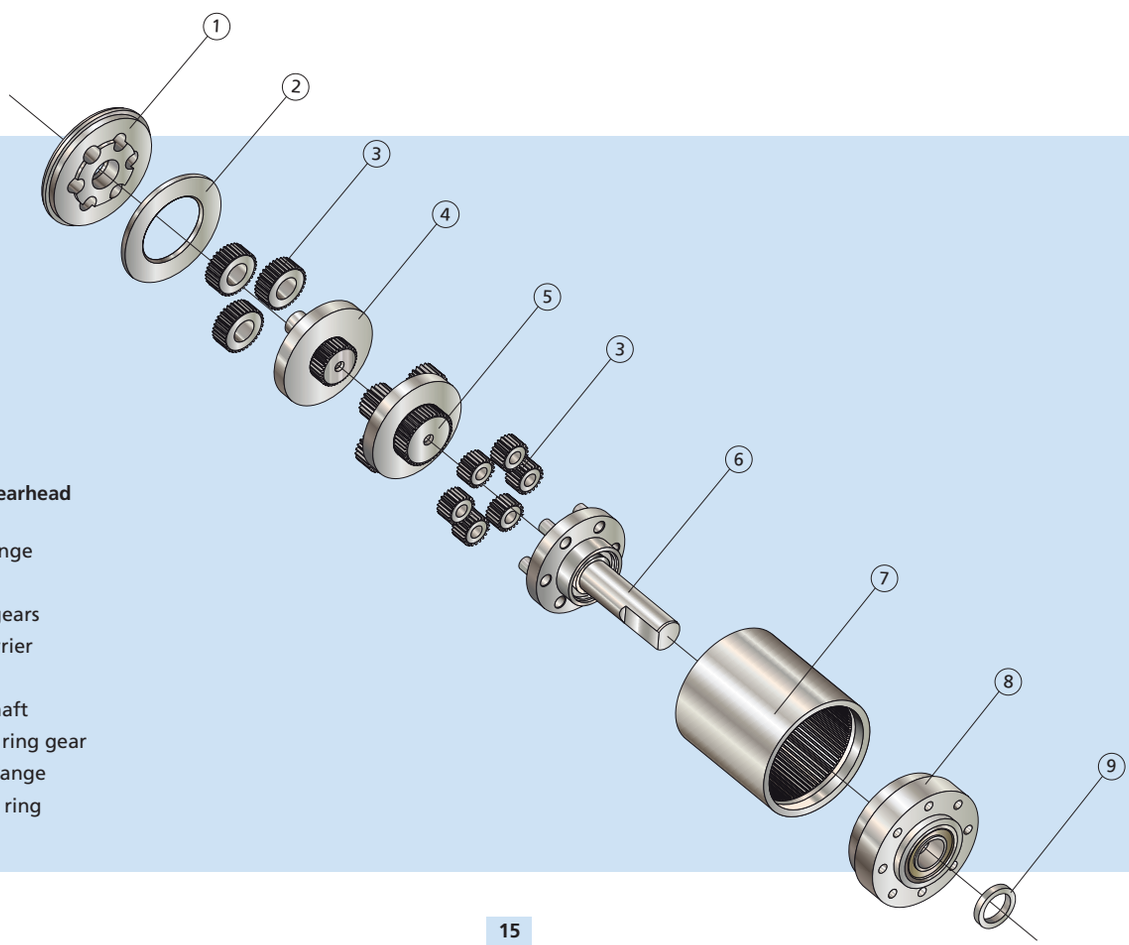
Operating temperature range
Standard range as listed on the data sheets. Service lifetime is also influenced by the operating temperature, especially for high temperature above 70°C.

Special executions for extended temperature range available on request.

Direction of rotation, reversible
All gearheads are designed for clockwise and counterclockwise rotation. The indication refers to the direction of rotation as seen from the shaft end, with the motor running in a clockwise direction.

Ball bearings
Ratings on load and lifetime, if not stated, are according to the information from the ball bearing manufacturers.

Length
The length *L2* without motor reported in the datasheet is the length of the stand-alone gearhead excluding any adaptation flange. The length *L1* with motor is reporting the total length of the combination including the motor, the coupling flange and the gearhead.



Planetary Gearhead

① Motor flange
② Washer
③ Satellite gears
④ Planet carrier
⑤ Sun gear
⑥ Output shaft
⑦ Housing / ring gear
⑧ Bearing flange
⑨ Retaining ring

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As at:
17th edition, 2022

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DFF_TI_04-2022_EN

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