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Technical Information

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WE CREATE MOTION

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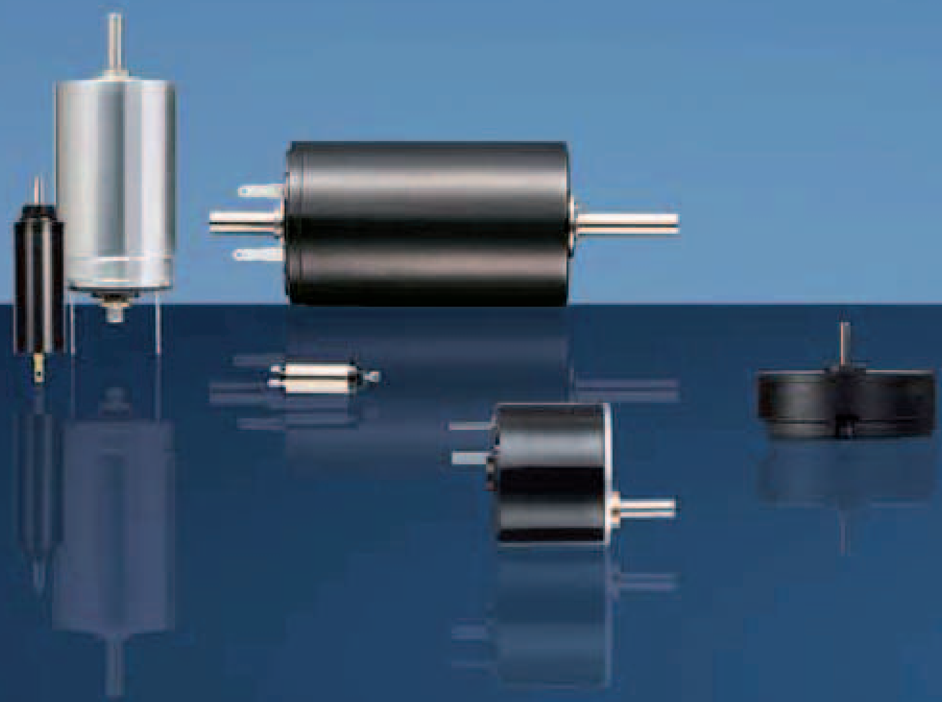


WE CREATE MOTION

DC-Micromotors

Technical Information

General information

The lifetime, depending on the application type, may exceed the 10 000 hours. Higher speeds cause accelerated mechanical wear, resulting in reduced lifetime.
Also excessively high current and temperature shortens the lifetime. On the average, lifetime of up to 1 000 hours for metal brushes, and more than 3 000 hours for graphite brushes can be expected when the motors are operated within recommended values indicated on the data sheet. These values do not influence each other. It is advisable that the current under load in continuous operation should not be higher than one third of the stall current. In motors with graphite brushes the relationship between stall current and current under load depends on the delivered power and frame size. The motors should not be operated at the stall torque M_H, otherwise after a short period of time, the commutation or the windings could be damaged.

The motor develops its maximum power $P_{2\,max.}$ at exactly half the stall torque M_H which also corresponds to half the speed. For reasons of life performance, this working point should only be selected for intermittent periods.
For exceptional long life performance, brushless DC-Motors are available.

Unspecified tolerances:

Tolerances in accordance with ISO 2768 medium.

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

Motors with tighter tolerances and tolerances of values not specified are given on request.

Bearing options:

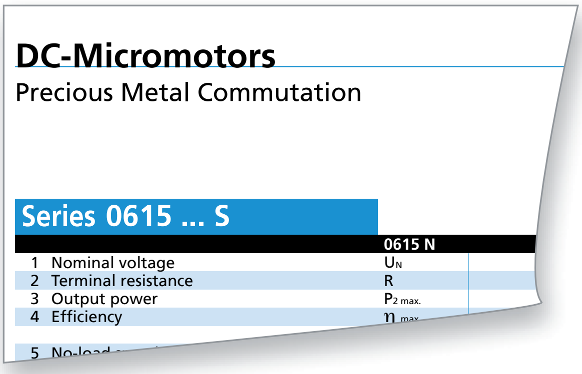
– Standard:	Unless otherwise stated, vacuum impregnated sintered bearings are used
– Optional:	Shielded ball bearings

Motor shaft:

All dimensions with shaft pushed against motor.

Motor choice:

The listed motor types represent standardised executions. However, a variety of further coil possibilities are available.


DC-Micromotors
Precious Metal Commutation
Series 0615 ... S

		0615 N
1	Nominal voltage	U_N
2	Terminal resistance	R
3	Output power	$P_{2\,max.}$
4	Efficiency	$\eta_{max.}$
5	No-load ...	

Notes on technical data

All values at 22 °C.
All values at nominal voltage, motor only, without load.

Nominal voltage U_N [Volt]
The nominal voltage at which all other characteristics indicated are measured.

Terminal resistance R [Ω] ±12%
The resistance measured across the motor terminals. The value is directly affected by the coil temperature (temperature coefficient: α_{22} = 0,004 K^{-1}).

Output power $P_{2\,max.}$ [W]
The maximum obtainable mechanical power achieved at the nominal voltage.

$$P_{2\,max.} = \frac{R}{4} \cdot \left(\frac{U_N}{R} - I_o\right)^2$$

Efficiency $\eta_{max.}$ [%]
The max. ratio between the absorbed electrical power and the obtained mechanical power of the motor.
It does not always correspond to the optimum working point of the motor.

$$\eta_{max.} = \left(1 - \sqrt{\frac{I_o \cdot R}{U_N}}\right)^2 \cdot 100$$

No-load speed n_o [rpm] ±12%
Describes the maximum speed under no-load conditions at steady state and 22 °C ambient temperature. If not otherwise defined the tolerance for the no-load speed is assumed to be ±12%.

$$n_o = (U_N - I_o \cdot R) \cdot k_n$$

No-load current I_o [A] ±50%
Describes the current consumption of the motor without load at an ambient temperature of 22°C after reaching a steady state condition. The tolerance is given at +/-50%.

The no-load current is speed and temperature dependent. Changes in ambient temperature or cooling conditions will influence the value. In addition, modifications to the shaft, bearing, lubrication, and commutation system or combinations with other components such as gearheads or encoders will all result in a change to the no-load current of the motor.

Stall torque M_H [mNm]
The torque developed by the motor at zero speed and nominal voltage. This value is greatly influenced by temperature.

$$M_H = k_M \cdot \left(\frac{U_N}{R} - I_o\right)$$

Friction torque M_R [mNm]
Torque losses caused by the friction of brushes, bearings and commutators. This value is influenced by temperature.

$$M_R = k_M \cdot I_o$$

Speed constant k_n [rpm/V]
The speed variation per Volt applied to the motor terminals at constant load.

$$k_n = \frac{n_o}{U_N - I_o \cdot R} = \frac{1\,000}{k_E}$$

Back-EMF constant k_E [mV/rpm]
The constant corresponding to the relationship between the induced voltage in the rotor at the speed of rotation.

$$k_E = \frac{2\pi \cdot k_M}{60}$$

Torque constant k_M [mNm/A]
The constant corresponding to the relationship between the torque developed by the motor and the current drawn.

Current constant k_I [A/mNm]
The constant between the current in the motor and the torque developed.

$$k_I = \frac{1}{k_M}$$

Slope of n-M curve $\Delta n/\Delta M$ [rpm/mNm]
The ratio of the speed variation to the torque variation. The smaller the value, the more powerful the motor.

$$\frac{\Delta n}{\Delta M} = \frac{30\,000}{\pi} \cdot \frac{R}{k_M^2}$$

Rotor inductance L [µH]
The inductance measured on the motor terminals at 1 kHz.

Mechanical time constant τ_m [ms]
The time required for the motor to reach a speed of 63% of its final no-load speed, from standstill.

$$\tau_m = \frac{100 \cdot R \cdot J}{k_M^2}$$

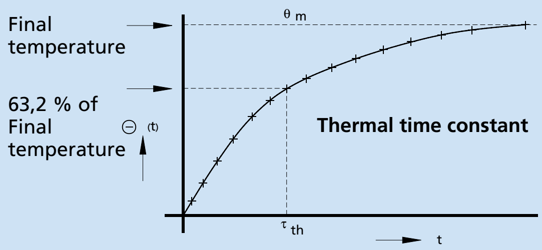
Rotor inertia J [gcm²]
Rotor's mass dynamic inertia moment.

Angular acceleration $\alpha_{max.}$ [$\cdot 10^3$ rad/s²]
The acceleration obtained from standstill under no-load-conditions and at nominal voltage.

$$\alpha_{max.} = \frac{M_H \cdot 10}{J}$$

Thermal resistance R_{th1}/R_{th2} [K/W]
R_{th1} corresponds to the value between the rotor and housing. R_{th2} corresponds to the value between the housing and the ambient air.
R_{th2} can be reduced by enabling exchange of heat between the motor and the ambient air (for example using a heat sink or forced air cooling).

Thermal time constant τ_{w1}/τ_{w2} [s]
The thermal time constant specifies the time needed for the rotor and housing to reach a temperature equal to 63% of final value.



Operating temperature range [°C]
Indicates the min. and max. motor operating temperature, as well as the maximum permitted rotor temperature.

Shaft bearings
The bearings used for the DC-Micromotors.

Shaft load max. [N]
The output shaft load at a specified shaft diameter for the primary output shaft. For motors with ball bearings the load and lifetime are in accordance with the values given by the bearing manufacturers. This value does not apply to second, or rear shaft ends.

Shaft play [mm]
The shaft play on the bearings, measured at the bearing exit.

Housing material
The housing material and the surface protection.

Weight [g]
The average weight of the basic motor type.

DC-Micromotors

Technical Information

Direction of rotation

The direction of rotation is viewed from the front face. Positive voltage to the + terminal gives clockwise rotation of the motor shaft. All motors are designed for clockwise (CW) and counterclockwise (CCW) operation; the direction of rotation is reversible.

Recommended values

The maximum recommended values for continuous operation to obtain optimum life performance are listed below. The values are independent of each other.
The values will be reduced with thermal insulation and elevated temperature but can be increased with forced cooling.

Speed $n_{e\,max.}$ [rpm]
The maximum recommended operating speed.

Torque $M_{e\,max.}$ [mNm]
The maximum recommended torque rating.

Current $I_{e\,max.}$ [A]
The maximum allowable current, based on the thermal limits of the max. permissible standard rotor temperature at 22 °C ambient.

How to select a DC-Micromotor

This section reviews a step-by-step procedure on how to select a DC-Micromotor. The procedure allows calcula-tion of the parameters in order to produce a graph of the characteristics and per-mitting the definition of the motor's behaviour. To simplify the calculation, in this example continuous operation and optimum life perform-ance are assumed and the influence of temperature and tolerances has been omitted.

Application data:
The basic data required for any given application are:

Required torque	M	[mNm]
Required speed	n	[rpm]
Duty cycle	δ	[%]
Available supply voltage, max.	U	[V DC]
Available current source, max.	I	[A]
Available space, max.	diameter/length	[mm]
Shaft load	radial/axial	[N]

The assumed application data for the selected example are:

Output torque		M	= 3	mNm
Speed		n	= 5 500	rpm
Duty cycle		δ	= 100	%
Supply voltage		U	= 20	V DC
Current source, max.		I	= 0,5	A
Space max.		diameter	= 25	mm
		length	= 50	mm
Shaft load		radial	= 1,0	N
		axial	= 0,2	N

Preselection
The first step is to calculate the power the motor is expected to deliver:

$$P_2 = M \cdot n \, \frac{\pi}{30 \cdot 1\,000} \qquad [W]$$

$$P_2 = 3 \cdot 5\,500 \, \frac{\pi}{30 \cdot 1\,000} \qquad = 1,73 \quad W$$

A motor is then selected from the catalogue which will give at least 1,5 to 2 times the output power [$P_{2\,max.}$] than the one obtained by calculation, and where the nominal voltage is equal to or higher than the one required in the application data.
The physical dimensions (diameter and length) of the motor selected from the data sheets should not exceed the available space in the application.

$$P_{2\,max.} \geq P_2 \qquad U_N \geq U$$

The motor selected from the catalogue for this particular application, is **series 2233 T 024 S** with the following characteristics:

Nominal voltage		U_N	= 24	V DC
Output power, max.		$P_{2\,max.}$	= 2,47	W
Frame size:	diameter	Ø	= 22	mm
	length	L	= 33	mm
Shaft load, max.:		radial	= 1,2	N
		axial	= 0,2	N
No-load current		I_o	= 0,005	A
No-load speed		n_o	= 8 800	rpm
Stall torque		M_H	= 10,70	mNm

Caution:
Should the available supply voltage be lower than the nominal voltage of the selected DC-Micromotor, it will be necessary to calculate [$P_{2\,max.}$] with the following equation:

$$P_{2\,max.} = \frac{R}{4} \cdot \left(\frac{U_N}{R} - I_o\right)^2 \qquad [W]$$

$$P_{2\,max.}\,(20\,V) = \frac{57}{4} \cdot \left(\frac{20}{57} - 0,005\right)^2 \qquad = 1,70 \quad W$$

Optimizing the preselection

To optimize the motor's operation and life performance, the required speed [n] has to be higher than half the no-load speed [n_o] at nominal voltage, and the load torque [M] has to be less than half the stall torque [M_H].

$$n \geq \frac{n_o}{2} \qquad M \leq \frac{M_H}{2}$$

From the data sheet for the DC-Micromotor, **2233 T 024 S** the parameters meet the above requirements.

$$n\ (5\,500\ \text{rpm}) \geq \frac{n_o}{2} \quad \text{is greater than} \quad \frac{8\,800}{2} = 4\,400 \quad \text{rpm}$$

$$M\ (3\ \text{mNm}) \leq \frac{M_H}{2} \quad \text{is less than} \quad \frac{10{,}70}{2} = 5{,}35 \quad \text{mNm}$$

This DC-Micromotor will be a good first choice to test in this application. Should the required speed [n] be less than half the no-load speed [n_o], and the load torque [M] be less than half the stall torque [M_H], try the next voltage motor up.

Should the required torque [M] be compliant but the required speed [n] be less than half the no-load speed [n_o], try a lower supply voltage or another smaller frame size motor.

Should the required speed be well below half the no-load speed and or the load torque [M] be more than half the stall torque [M_H], a gearhead or a larger frame size motor has to be selected.

Performance characteristics at nominal voltage (24 V DC)

A graphic presentation of the motor's characteristics can be obtained by calculating the stall current [I] and the torque [M] at its point of max. efficiency [$M_{opt.}$]. All other parameters are taken directly from the data sheet of the selected motor.

Stall current

$$I = \frac{U_N}{R} \qquad [A]$$

$$I = \frac{24}{57} = 0{,}421 \quad A$$

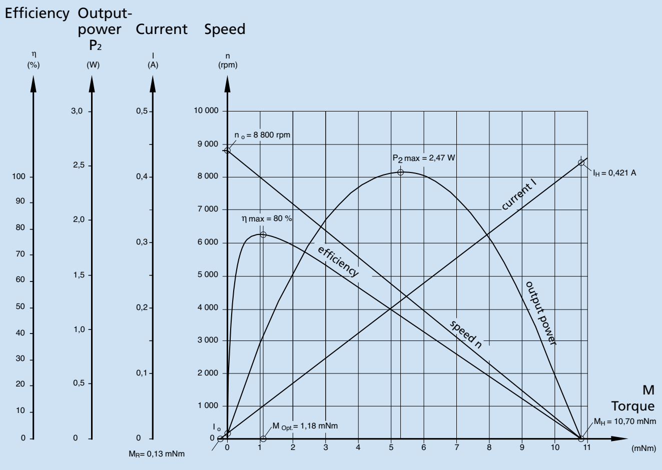
Torque at max. efficiency

$$M_{opt.} = \sqrt{M_H \cdot M_R} \qquad [mNm]$$

$$M_{opt.} = \sqrt{10{,}70 \cdot 0{,}13} = 1{,}18 \quad mNm$$

It is now possible to make a graphic presentation and draw the motor diagram (see graph 1).

Graph 1



Calculation of the main parameters

In this application the available supply voltage is lower than the nominal voltage of the selected motor.
The calculation under load therefore is made at 20 V DC.

No-load speed n_o at 20 V DC

$$n_o = \frac{U - (I_o \cdot R)}{k_E} \cdot 1\,000 \qquad [rpm]$$

inserting the values

Supply voltage	U	= 20	V DC
Terminal resistance	R	= 57	Ω
No-load current	I_o	= 0,005	A
Back-EMF constant	k_E	= 2,690	mV/rpm

$$n_o = \frac{20 - (0{,}005 \cdot 57)}{2{,}690} \cdot 1\,000$$

= 7 315 rpm

Stall current I_H

$$I_H = \frac{U}{R}$$

$$I_H = \frac{20}{57} \qquad [A]$$

= 0,351 A

Stall torque M_H

$$M_H = k_M (I_H - I_o)$$

inserting the value

Torque constant	k_M	= 25,70	[mNm] mNm/A

M_H = 25,70 (0,351 – 0,005) = 8,91 mNm

DC-Micromotors

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Output power, max. $P_{2\,max.}$

$$P_{2\,max.} = \frac{R}{4} \cdot \left(\frac{U_N}{R} - I_o\right)^2 \qquad [W]$$

$$P_{2\,max.}(20\,V) = \frac{57}{4} \cdot \left(\frac{20}{57} - 0{,}005\right)^2 \qquad = 1{,}70 \quad W$$

Efficiency, max. $\eta_{max.}$

$$\eta_{max.} = \left(1 - \sqrt{\frac{I_o}{I_H}}\right)^2 \cdot 100 \qquad [\%]$$

$$\eta_{max.} = \left(1 - \sqrt{\frac{0{,}005}{0{,}351}}\right)^2 \cdot 100 \qquad = 77{,}6 \quad \%$$

At the point of max. efficiency, the torque delivered is:

$$M_{opt.} = \sqrt{M_H \cdot M_R} \qquad [mNm]$$

inserting the values

Friction torque	M_R	=	0,13	mNm
and				
Stall torque at 20 V DC	M_H	=	8,91	mNm

$$M_{opt.} = \sqrt{8{,}91 \cdot 0{,}13} \qquad = 1{,}08 \quad mNm$$

Calculation of the operating point at 20 V DC

When the torque (M = 3 mNm) at the working point is taken into consideration I, n, P_2 and η can be calculated:

Current at the operating point

$$I = \frac{M + M_R}{k_M} \qquad [A]$$

$$I = \frac{3 + 0{,}13}{25{,}70} \qquad = 0{,}122 \quad A$$

Speed at the operating point

$$n = \frac{U - R \cdot I}{k_E} \cdot 1\,000 \qquad [rpm]$$

$$n = \frac{20 - 57 \cdot 0{,}122}{2{,}690} \cdot 1\,000 \qquad = 4\,841 \quad rpm$$

Output power at the operating point

$$P_2 = M \cdot n \cdot \frac{\pi}{30 \cdot 1\,000} \qquad [W]$$

$$P_2 = 3 \cdot 4\,841 \cdot \frac{\pi}{30 \cdot 1\,000} \qquad = 1{,}52 \quad W$$

Efficiency at the operating point

$$\eta = \frac{P_2}{U \cdot I} \cdot 100 \qquad [\%]$$

$$\eta = \frac{1{,}52}{20 \cdot 0{,}122} \cdot 100 \qquad = 62{,}3 \quad \%$$

In this example the calculated speed at the working point is different to the required speed, therefore the supply voltage has to be changed and the calculation repeated.

Supply voltage at the operating point

The exact supply voltage at the operating point can now be obtained with the following equation:

$$U = R \cdot I + k_E \cdot n \cdot 10^{-3}$$

$$U = 57 \cdot 0{,}122 + 2{,}695 \cdot 5\,500 \cdot 10^{-3} \qquad = 21{,}78 \text{ V DC}$$

In this calculated example, the parameters at the operating point are summarized as follows:

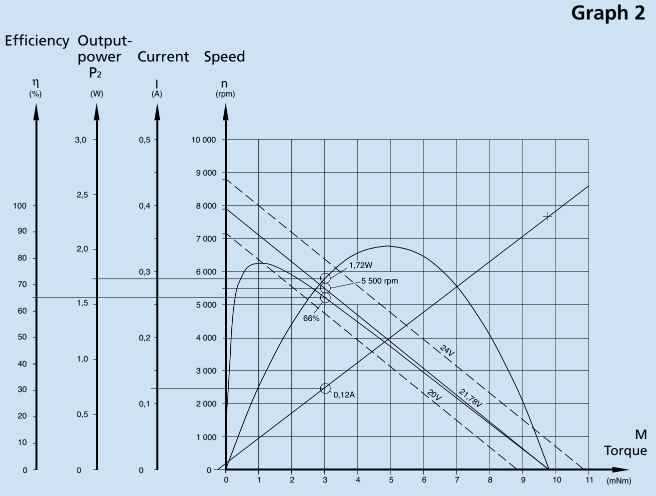
Supply voltage	U	= 21,78	V DC
Speed	n	= 5 500	rpm
Output torque	M_N	= 3	mNm
Current	I	= 0,12	A
Output power	P_2	= 1,72	W
Efficiency	η	= 66	%

Motor characteristic curves

For a specific torque, the various parameters can be read on graph 2.

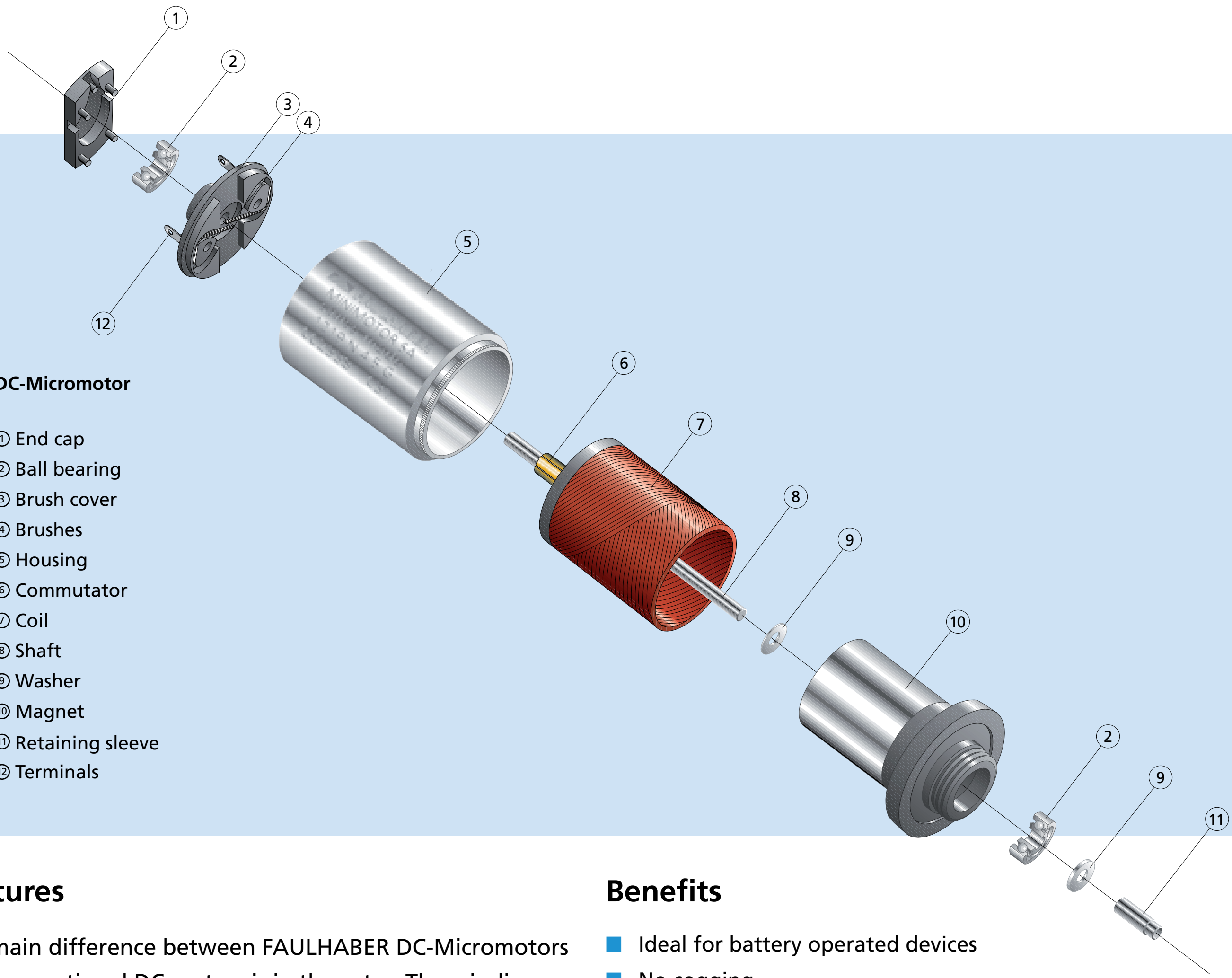
To simplify the calculation, the influence of temperature and tolerances has deliberately been omitted.
In certain cases the influence of temperature should, however, be taken into consideration.

Graph 2



DC-Micromotors

Precious Metal Commutation



DC-Micromotor

① End cap
② Ball bearing
③ Brush cover
④ Brushes
⑤ Housing
⑥ Commutator
⑦ Coil
⑧ Shaft
⑨ Washer
⑩ Magnet
⑪ Retaining sleeve
⑫ Terminals

Features

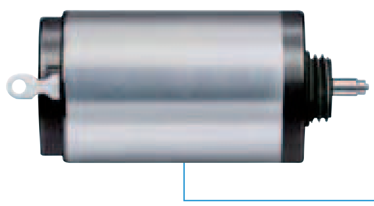
The main difference between FAULHABER DC-Micromotors and conventional DC motors is in the rotor. The winding does not have an iron core but consists of a self-supporting skew-wound copper coil. This featherweight rotor has an extremely low moment of inertia, and it rotates without cogging. The result is the outstanding dynamics of FAULHABER motors. For low power motors, commutation systems using precious metals are the optimum solution because of their low contact resistance.

FAULHABER precious metal commutated motors range in size from just 6 mm to 22 mm in diameter. FAULHABER completes the drive system by providing a variety of additional hightech standard components including high resolution encoders, precision gearheads, and drive electronics. FAULHABER specializes in the modification of their drive systems to fit the customer's particular application requirements. Common modifications include vaccuum compatibility, extreme temperature compatibility, modified shaft geometry, additional voltage types, custom motor leads and connectors, and much more.

Benefits

- Ideal for battery operated devices
- No cogging
- Extremely low current consumption – low starting voltage
- Highly dynamic performance due to a low inertia, low inductance coil
- Light and compact
- Precise speed control
- Simple to control due to the linear performance characteristics

Product Code

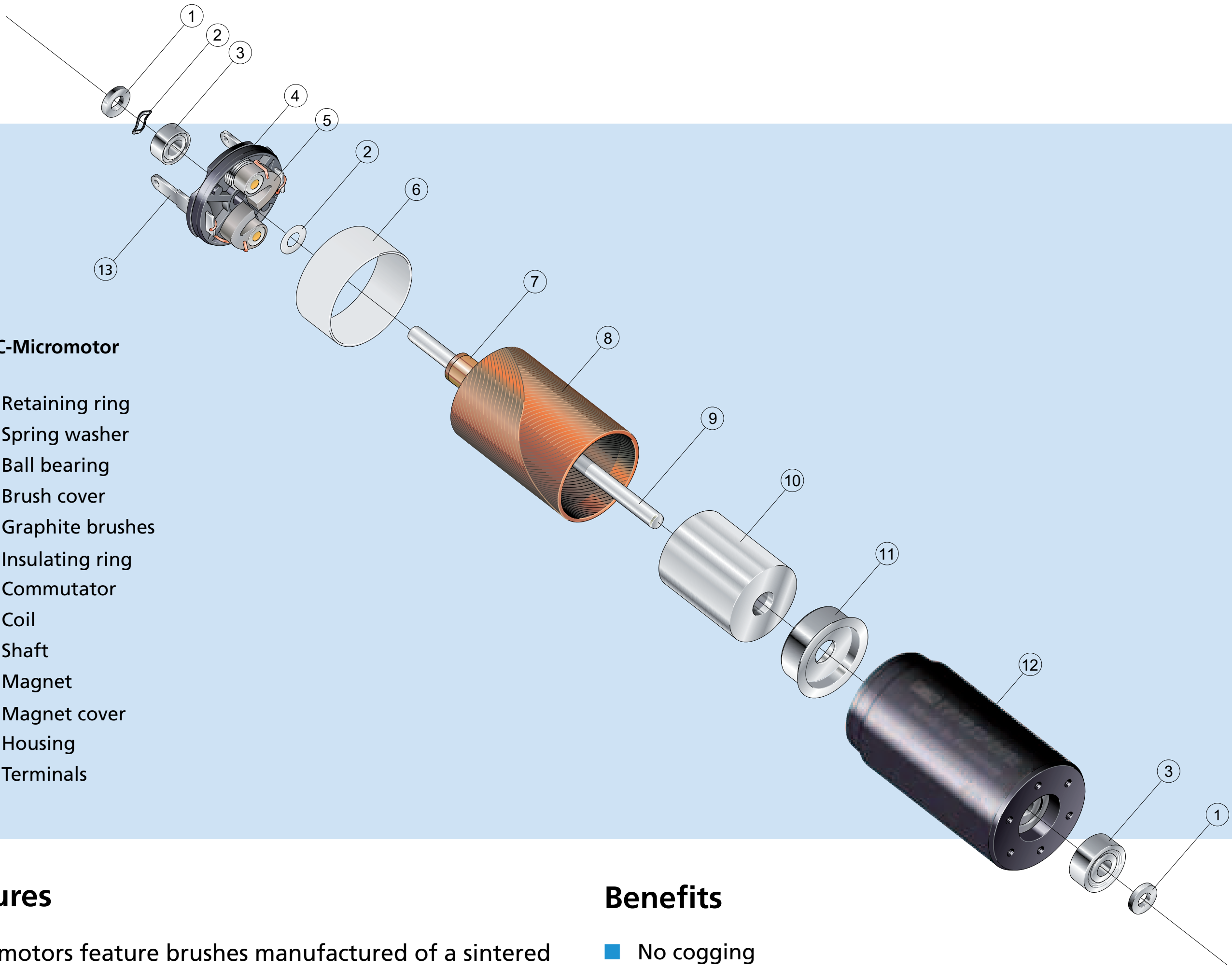


1219 N 012 G

12	Motor diameter
19	Motor length [mm]
N	Shaft type
012	Nominal voltage [V]
G	Type of commutation (precious metal)

DC-Micromotors

Graphite Commutation



DC-Micromotor

① Retaining ring
② Spring washer
③ Ball bearing
④ Brush cover
⑤ Graphite brushes
⑥ Insulating ring
⑦ Commutator
⑧ Coil
⑨ Shaft
⑩ Magnet
⑪ Magnet cover
⑫ Housing
⑬ Terminals

Features

These motors feature brushes manufactured of a sintered metal graphite material and a copper commutator.
This ensures that the commutation system can withstand more power and still deliver exceptionally long operational lifetimes.

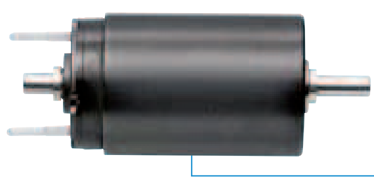
A multitude of adaptations for customer specific requirements and special executions are available.

FAULHABER motors with graphite brushes range in size from just 13 mm to 38 mm in diameter.
FAULHABER completes the drive system by providing a variety of additional high-tech standard components including high resolution encoders, precision gearheads, drive electronics, brakes and other servo componets.
FAULHABER specializes in the modification of their drive systems to fit the customer's particular application requirements. Common modifications include vaccuum compatibility, extreme temperature compatibility, modified shaft geometry, additional voltage types, custom motor leads and connectors, and much more.

Benefits

- No cogging
- High power density
- Highly dynamic performance due to a low inertia, low inductance coil
- Light and compact
- Precise speed control
- Simple to control due to the linear performance characteristics

Product Code

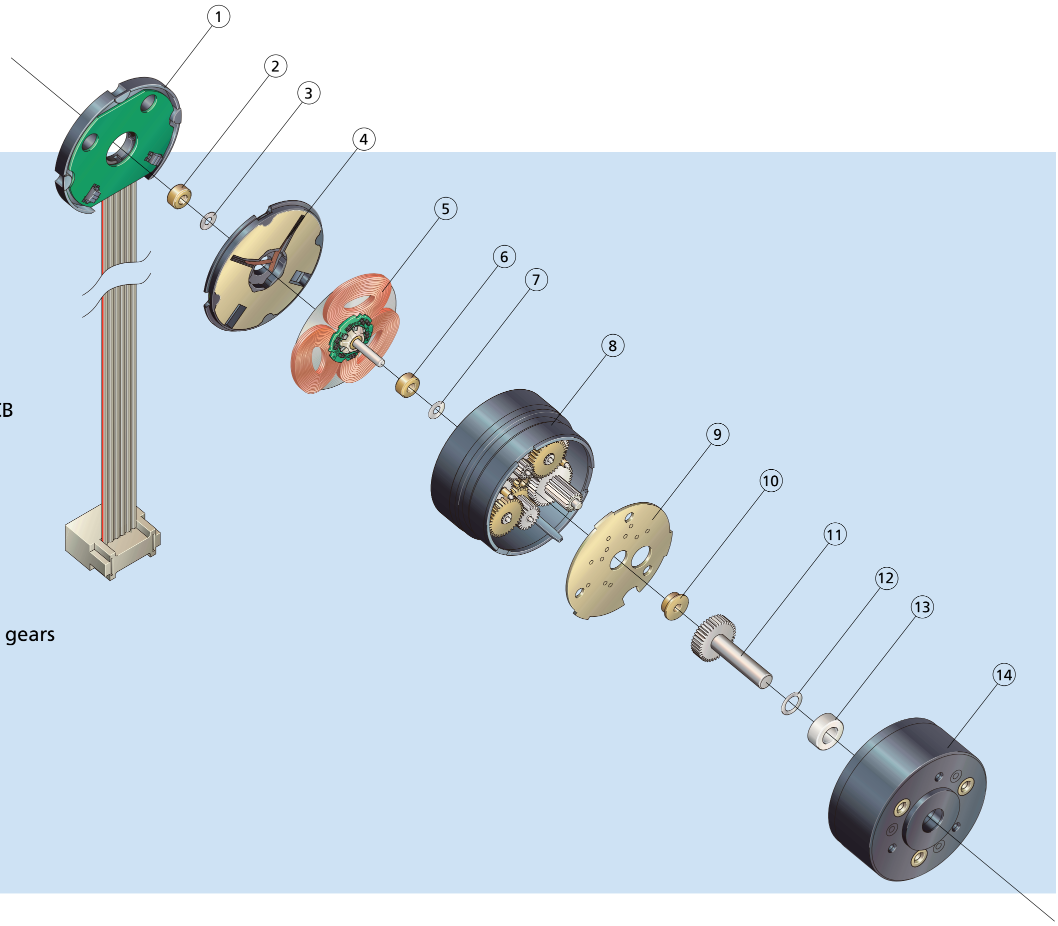


2342 S 024 CR

23	Motor diameter [mm]
42	Motor length [mm]
S	Shaft type
024	Nominal voltage [V]
C	Type of commutation (Graphite)
R	Version (rare earth magnet)

Flat DC-Micromotors

Precious Metal Commutation



DC-Gearmotor with integrated encoder

① End cap with encoder PCB
② Sintered bearing
③ Washer
④ Brush cover
⑤ Coils and collector
⑥ Sintered bearing
⑦ Washer
⑧ Housing with integrated gears
⑨ Intermediate plate
⑩ Sintered bearing
⑪ Output shaft
⑫ Washer
⑬ Sleeve bearing
⑭ Front cover

Features

The heart of these Flat DC-Micromotors is the ironless rotor made up of three flat self supporting coils.
The rotor coil has exceptionally low inertia and inductance and rotates in an axial magnetic field.

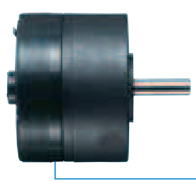
Motor torque can be increased by the addition of an integrated reduction gearhead. This also reduces the speed to fit the specifications in the application.

FAULHABER specializes in the modification of their drive systems to fit the customer's particular application requirements. Common modifications include vaccuum compatibility, extreme temperature compatability, modified shaft geometry, additional voltage types, custom motor leads and connectors, and much more.

Benefits

- No cogging
- Extremely low current consumption – low starting voltage
- Highly dynamic performance due to a low inertia, low inductance coil
- Light and compact
- Precise speed control
- Simple to control due to the linear performance characteristics

Product Code

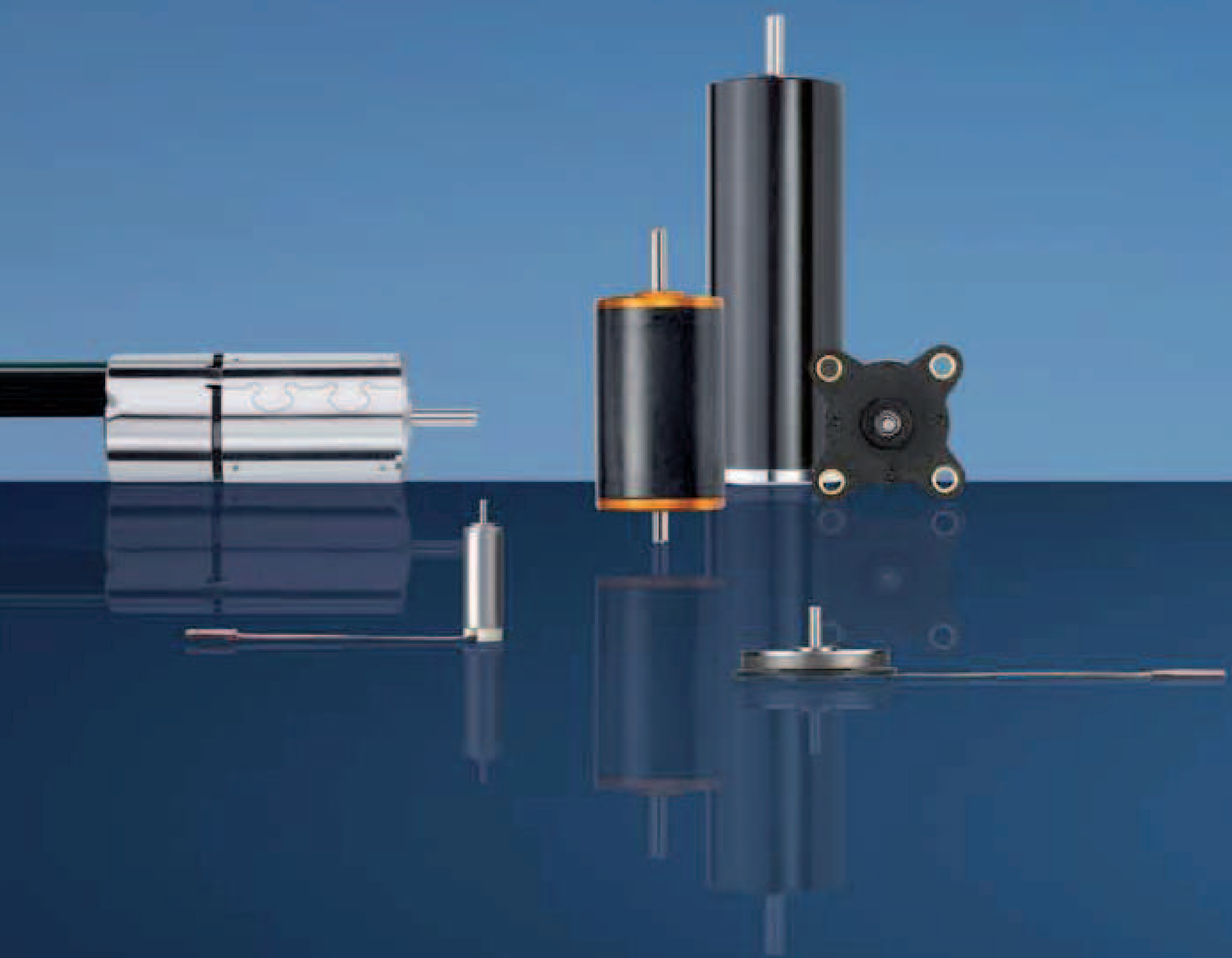


2619 S 012 SR

26	Motor diameter [mm]
19	Motor length [mm]
S	Shaft type
012	Nominal voltage [V]
S	Type of commutation (precious metal)
R	Version (rare earth magnet)

FAULHABER

Brushless DC-Motors



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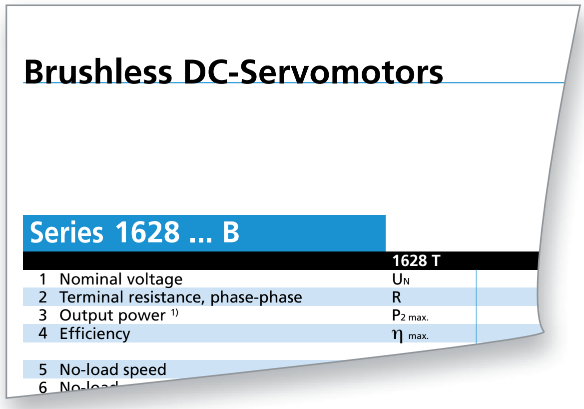
Brushless DC-Servomotors

Technical Information


Brushless DC-Servomotors

Series 1628 ... B

		1628 T
1	Nominal voltage	U_N
2	Terminal resistance, phase-phase	R
3	Output power [1]	$P_{2\ max.}$
4	Efficiency	$\eta_{max.}$
5	No-load speed	
6	No-load	

Notes on technical data

The perfomance lifetime of Brushless DC-Servomotors is mainly influenced by the ball bearings service life and the electronic components used. On average, the lifetime may exceed 10 000 hours if the motors are operated within the recommended values indicated on the data sheet.

All values at 22 °C.
All values at nominal voltage, motor only, without load.

Nominal voltage U_N [Volt]
The direct voltage applied on the motor phases correspond to a bipolar supply with a 120° square-wave commutation logic. Definition of motor parameters η, n_o and I_o are directly related to it. A higher or lower voltage may be applied according to the application requirement.

Terminal resistance, phase to phase R [Ω] ±12 %
The resistance measured between two motor phases. The value is directly affected by the coil temperature (temperature coefficient: $\alpha_{22} = 0{,}004\ K^{-1}$).

Output power $P_{2\ max.}$ [W]
The maximum obtainable mechanical power achieved by the motor at continuous operation and at the thermal limit. This power can only be obtained at high speeds.

$$P_{2\ max.} = \frac{\pi}{30\,000} \cdot n \cdot (k_m \cdot I_{e\ max.} - C_o - C_v \cdot n)$$

Efficiency $\eta_{max.}$ [%]
The max. ratio between the absorbed electrical power and the obtained mechanical power of the motor.
It does not always correspond to the optimum working point of the motor.

No-load speed n_o [rpm] ±12 %
The maximum speed the motor attains under no-load conditions at the nominal voltage. This value varies according to the voltage applied to the motor.

$$n_o = (U_n - I_o \cdot R) \cdot \frac{1\,000}{k_E}$$

No-load current I_o [A] ± 50 %
The current consumption of the motor at nominal voltage and under no-load conditions. This value varies proportionally to speed and is influenced by temperature.

$$I_o = \frac{C_o + C_v \cdot n_o}{k_M}$$

Stall torque M_H [mNm]
The torque developed by the motor at zero speed and nominal voltage.

$$M_H = k_M \cdot \frac{U_N}{R} - C_o$$

Friction torque C_o [mNm]
The sum of torque losses not depending from speed. This torque is caused by static mechanical friction of the ball bearings and magnetic hysteresis of the stator.

Viscous damping factor C_v [$\cdot 10^{-5}$ mNm/rpm]
The multiplier factor defining the torque losses proportional to speed. This torque is due to the viscous friction of the ball bearings as well as to the Foucault currents in the stator, originated by the rotating magnetic field of the magnet.

Speed constant k_n [rpm/V]
The speed variation per Volt applied to the motor phases at constant load.

$$k_n = \frac{n_o}{U_N - I_o \cdot R} = \frac{1\,000}{k_E}$$

Back-EMF constant k_E [mV/rpm]
The constant corresponding to the relationship between the induced voltage in the motor phases and the rotation speed.

$$k_E = \frac{2\pi \cdot k_M}{60}$$

Torque constant k_M [mNm/A]
The constant corresponding to the relationship between the torque developed and the current drawn.

Current constant k_I [A/mNm]
The constant corresponding to the relationship between the current drawn and torque developed.

$$k_I = \frac{1}{k_M}$$

Slope of n-M curve $\Delta n/\Delta M$ [rpm/mNm]
The ratio of the speed to torque variations. The smaller this value, the more powerful the motor.

$$\frac{\Delta n}{\Delta M} = \frac{30\,000}{\pi} \cdot \frac{R}{k_M^2}$$

Terminal inductance, phase to phase L [μH]
The inductance measured between two phases at 1 kHz.

Mechanical time constant τ_m [ms]
The time required by the motor to reach a speed of 63% of its final no-load speed, from standstill.

$$\tau_m = \frac{100 \cdot R \cdot J}{k_M^2}$$

Rotor intertia J [gcm²]
Rotor's mass. dynamic inertia moment.

Angular acceleration $\alpha_{max.}$ [$\cdot 10^3$ rad/s²]
No-load rotor acceleration, from standstill and at nominal voltage.

$$\alpha_{max.} = \frac{(U_N/R) \cdot k_M - C_o}{J} \cdot 10$$

Thermal resistance $R_{th\,1}$ / $R_{th\,2}$ [K/W]
$R_{th\,1}$ corresponds to the value between the coil and housing.
$R_{th\,2}$ corresponds to the value between the housing and the ambient air.
$R_{th\,2}$ can be reduced by enabling exchange of heat between the motor and the ambient air (for example using a heat sink or forced air cooling).
All parameters calculated at thermal limit are given with a $R_{th\,2}$ value reduced by 55%.

Thermal time constant τ_{w1} / τ_{w2} [s]
The thermal time constant specifies the time needed for the rotor and housing to reach a temperature equal to 63% of final value.

Operating temperature range [°C]
The min. and max. permissible operating temperature of the motor.

Shaft bearings
The standard bearings used for the Brushless DC-Servomotor.

Shaft load max. [N]
The max. load values allow a motor lifetime of 20 000 hours. This is in accordance with the values given by the bearing manufacturer. The radial load is defined for a force applied at the center of the standard shaft length.

Shaft play [mm]
The shaft play on the bearings, measured at the bearing exit.

Housing material
The housing material and the surface protection.

Weight [g]
The average weight of the basic motor type.

Direction of rotation
The direction of rotation is given by the external servo amplifier. All motors are designed for clockwise (CW) and counter-clockwise (CCW) operation; the direction of rotation is reversible.

Recommended values

The maximum recommended values for continuous operation to obtain optimum life performance are listed below.

These values are independent each other.

The recommended torque ($M_{e\,max.}$) and current ($I_{e\,max.}$) are given with the $R_{th\,2}$ value reduced by 55%.

Speed $n_{e\,max.}$ [rpm]
The max. operation speed limited by Foucault currents is generated by the rotation of the magnet and the magnetic field in the stator. The values are calculated at 2/3 of the max. permissible motor temperature, rounded off.

$$n_{e\,max.} = \sqrt{\frac{C_o^2}{4 \cdot C_v^2} + \frac{30\,000 \cdot (T_{83} - T_{22})}{\pi \cdot 0{,}45 \cdot R_{th\,2} \cdot C_v}} - \frac{C_o}{2 \cdot C_v}$$

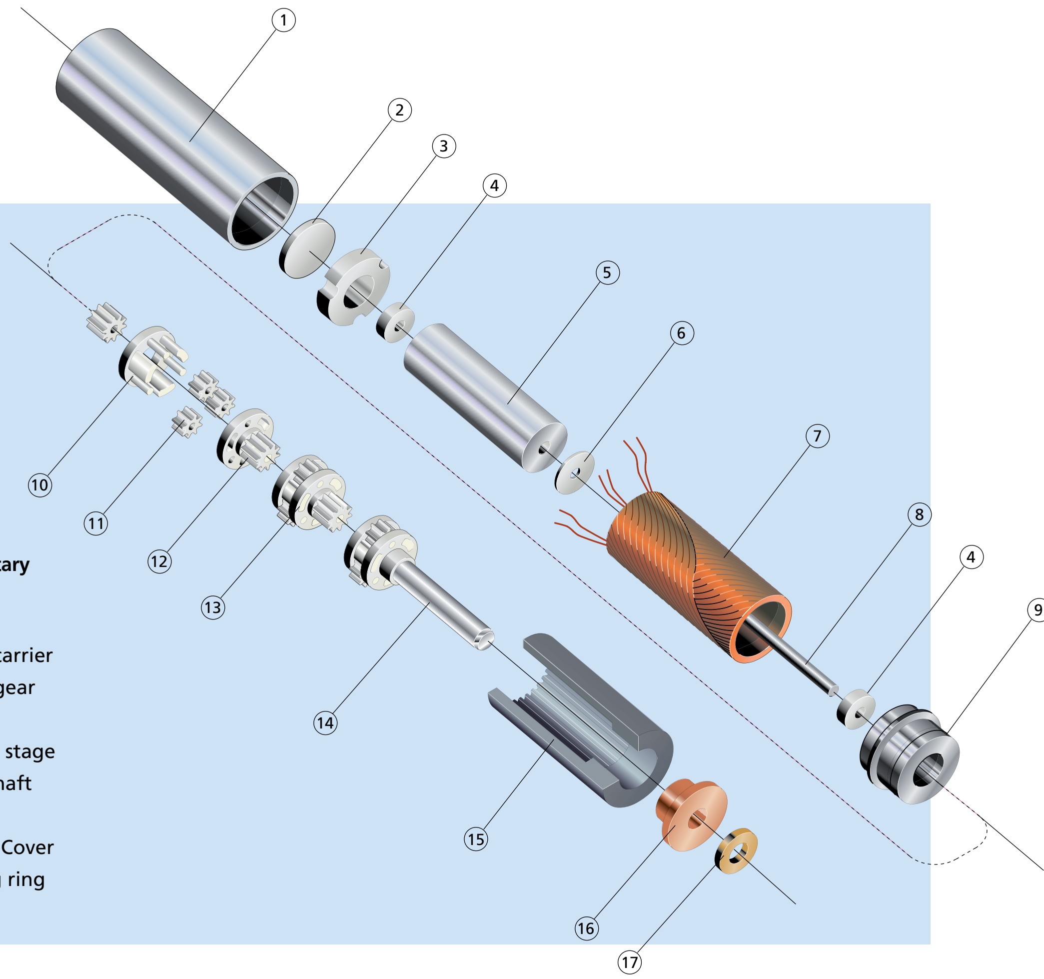
Torque $M_{e\,max.}$ [mNm]
The calculated torque for a motor at the thermal limit.

$$M_{e\,max.} = k_M \cdot I_{e\,max.} - C_o - C_v \cdot n$$

Current $I_{e\,max.}$ [A]
The calculated current for a motor at the thermal limit.

$$I_{e\,max.} = \sqrt{\frac{T_{125} - T_{22} - \frac{\pi}{30\,000} \cdot n \cdot 0{,}45 \cdot R_{th\,2} \cdot (C_o + C_v \cdot n)}{R \cdot (1 + \alpha_{22} \cdot (T_{125} - T_{22})) \cdot (R_{th\,1} + 0{,}45 \cdot R_{th\,2})}}$$

Brushless DC-Micromotors



Brushless DC-Micromotor

① Housing
② Rear cover
③ Bearing support
④ Bearing
⑤ Magnet
⑥ Washer
⑦ Coil
⑧ Shaft
⑨ Cover / Bearing support

Micro Planetary Gearhead

⑩ Satellite carrier
⑪ Satellite gear
⑫ Sun gear
⑬ Planetary stage
⑭ Output shaft
⑮ Housing
⑯ Bearing / Cover
⑰ Retaining ring

Features

This smallest, brushless DC-Micromotor is based on the System FAULHABER® skew wound coil technology.
It is essentially comprised of a three phase coil, a stator housing, and a two-pole NdFeB magnet on the ouput shaft as the rotor.

A Micro Planetary Gearhead of conventional design was likewise developed for combination with the brushless DC-Micromotor. The production employs LIGA-technology, a method combining lithography, electroforming and mold-copying. Special involute toothing with a module of 55 µm and a reduction ratio of 3,6 : 1 per gear stage is used, providing the three stage gear motor combination with 150 µNm torque. The microdrive is produced in series under cleanroom conditions.

Brushless DC-Micromotors require an external electronic controller. FAULHABER offers a wide variety of speed control solutions for operation of the microdrive.

Benefits

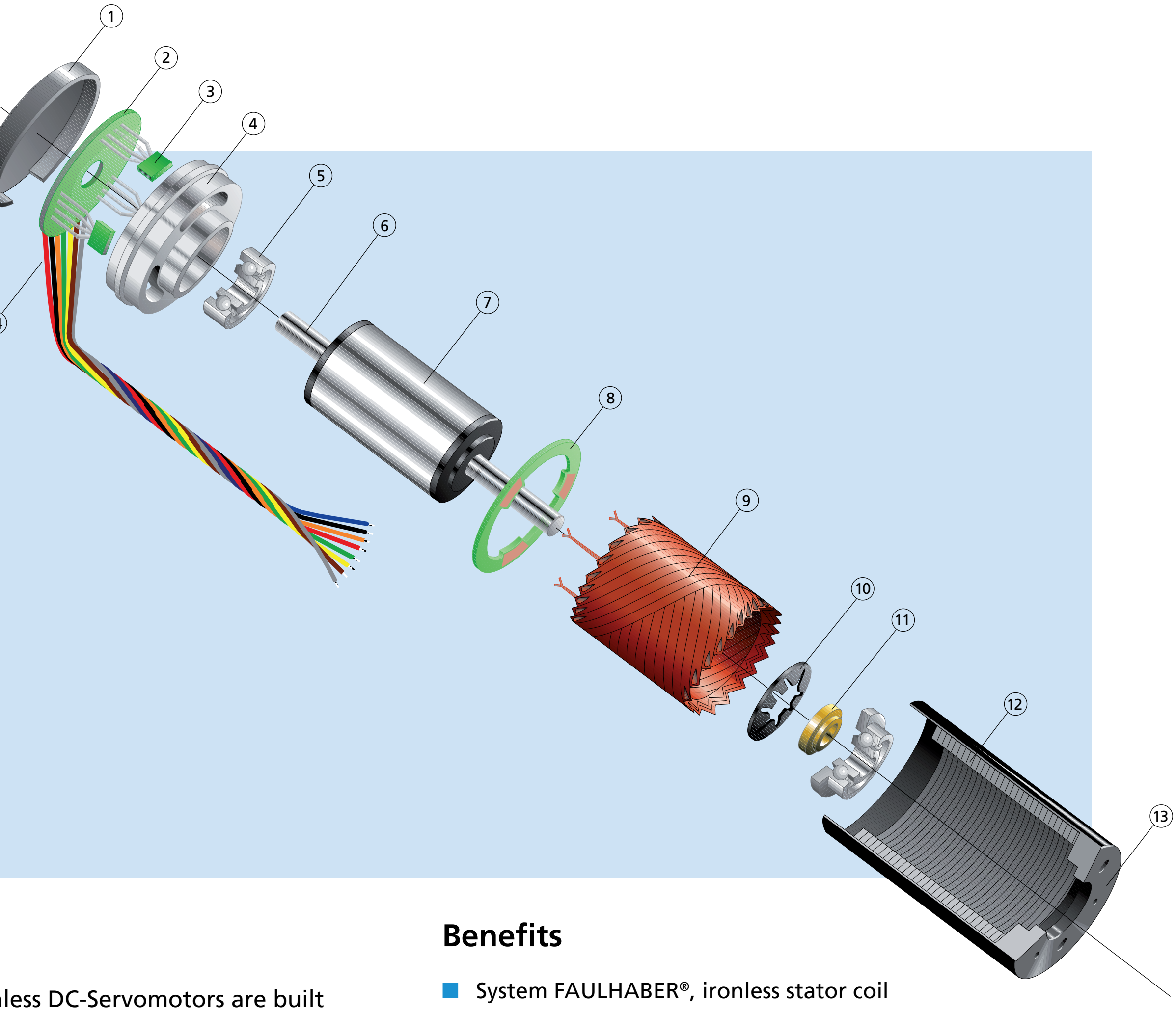
- Extremely light and compact
- Exceptional power to volume ratio
- Brushless commutation for long life
- Low operating voltage
- For combination with micro planetary gearheads

Product Code

0206 H 001 B

02	Motor diameter [mm]
06	Motor length [mm]
H	Shaft type
001	Nominal voltage [V]
B	Type of commutation (brushless)

Brushless DC-Servomotors



Brushless DC-Servomotor

① Rear cover
② PCB
③ Hall sensors
④ Bearing support
⑤ Ball bearing
⑥ Shaft
⑦ Magnet
⑧ PCB
⑨ Coil
⑩ Spring washer
⑪ Spacer
⑫ Stator laminations
⑬ Housing
⑭ Lead wires

Features

The FAULHABER Brushless DC-Servomotors are built for extreme operating conditions. They are precise, have extreme long lifetimes and are highly reliable. Exceptional qualities such as smooth running and especially low noise level are of particular note. The rare-earth magnet as rotor, and FAULHABER skew winding technology ensure that these motors deliver top performance dynamics within minimum overall dimensions.

This series is also available in an autoclavable version and is ideally suited for application in laboratory and medical equipment.

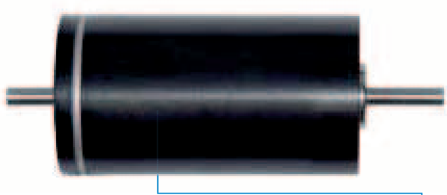
Sterilizing conditions

- Temperature 134 °C ± 2 °C
- Water vapour pressure 2,1 bar
- Relative humidity 100 %
- Duration of cycle 20 min.
- Rated for a minimum of 100 cycles

Benefits

- System FAULHABER®, ironless stator coil
- High reliability and operational lifetime
- Wide range of linear torque / speed performance
- No sparking
- No cogging
- Dynamically balanced rotor
- Simple design
- Standard with digital hall sensors with optional analog hall sensors

Product Code

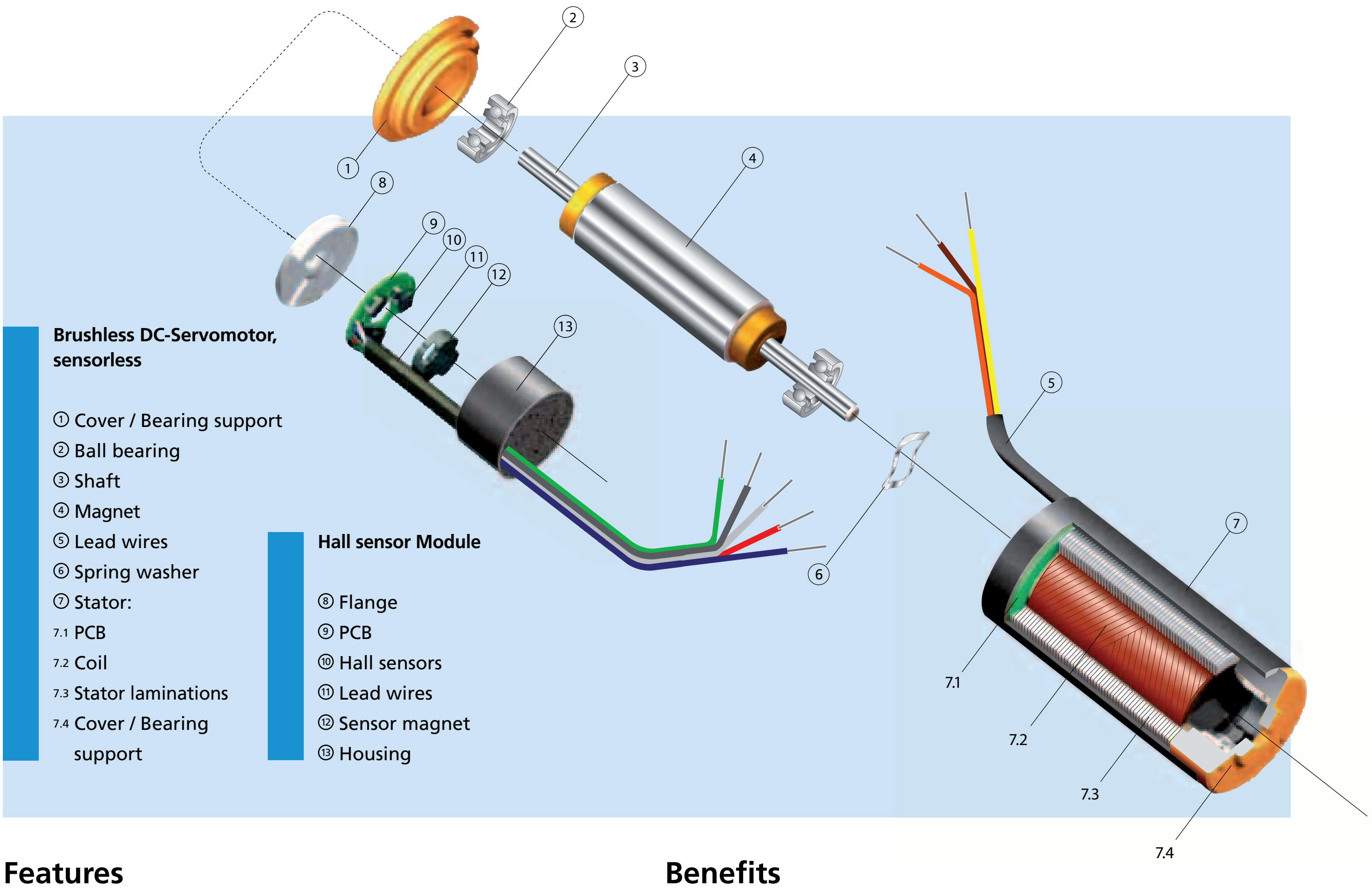


2444 S 024 B

24	Motor diameter [mm]
44	Motor length [mm]
S	Shaft type
024	Nominal voltage [V]
B	Type of commutation (brushless)

Brushless DC-Servomotors

Sensorless, SMARTSHELL® Technology



Features

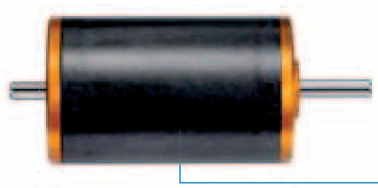
The skew-wound self-supporting coil, System FAULHABER®, the printed circuit board, the laminated stack and the front-end bearing cover are all encapsulated and meshed together with a mould-injected LCP (Liquid Crystal Polymer), exhibiting outstanding mechanical and thermal features.

The modular design concept of the SMARTSHELL® motors offers two Hall sensor modules for precise speed and position control. With these modules assembled to the rear end of the motors, the BDS (Brushless Digital Sensors) and BAS (Brushless Analog Sensors) options are available for use with the appropriate drive electronics.

Benefits

- System FAULHABER®, ironless stator coil
- High reliability and operational lifetime
- Wide range of linear torque / speed performance
- No sparking
- No cogging
- Dynamically balanced rotor
- Simple design
- Available with optional digital or analog hall sensors

Product Code

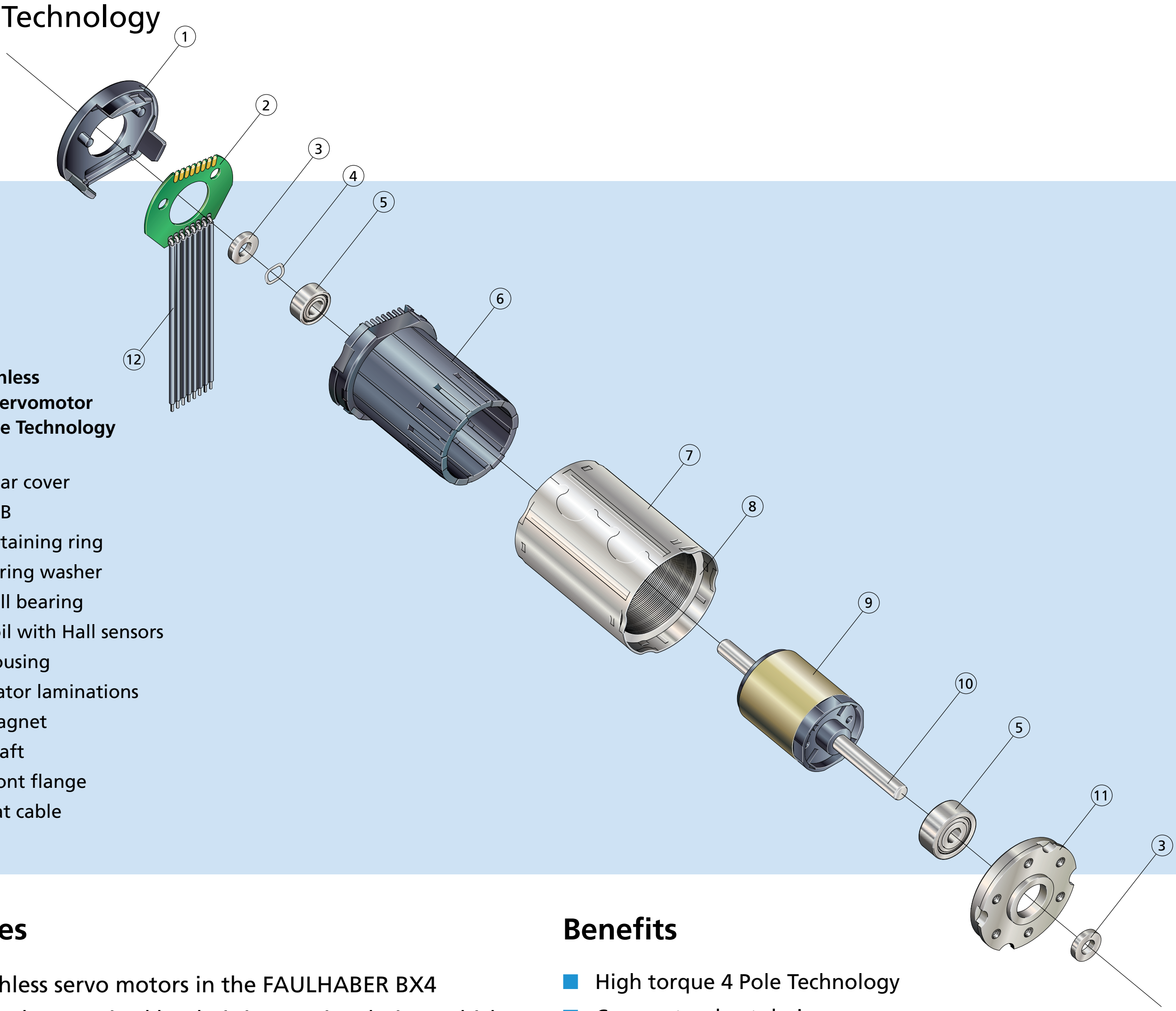


22	Motor diameter [mm]
32	Motor length [mm]
S	Shaft type
048	Nominal voltage [V]
B	Type of commutation (brushless)
SL	Version (sensorless)

2232 S 048 BSL

Brushless DC-Servomotors

4 Pole Technology



Brushless
DC-Servomotor
4 Pole Technology

① Rear cover
② PCB
③ Retaining ring
④ Spring washer
⑤ Ball bearing
⑥ Coil with Hall sensors
⑦ Housing
⑧ Stator laminations
⑨ Magnet
⑩ Shaft
⑪ Front flange
⑫ Flat cable

Features

The brushless servo motors in the FAULHABER BX4 series are characterised by their innovative design, which comprises just a few individual components.

Despite their compact dimensions, the 4 pole magnet technology gives these drives a high continuous torque with smooth running characteristics and a particularly low noise level. The modular rotor system makes it possible to tune the performance of the motor to the higher torque or higher speed needs of the application.

Thanks to the electronic commutation of the drives, the lifetime is much longer in comparison with mechanically commutated motors. Alongside the basic version in which the commutation is provided by an external control, the highly flexible BX4 series also includes advanced specifications with integrated speed controller or integrated encoder.

The motors come standard with digital Hall sensors.

Benefits

- High torque 4 Pole Technology
- Compact, robust design
- Modular concept
- Available with integrated encoders and speed controllers
- High reliability and operational lifetime
- No sparking
- No cogging
- Dynamically balanced rotor
- Simple design

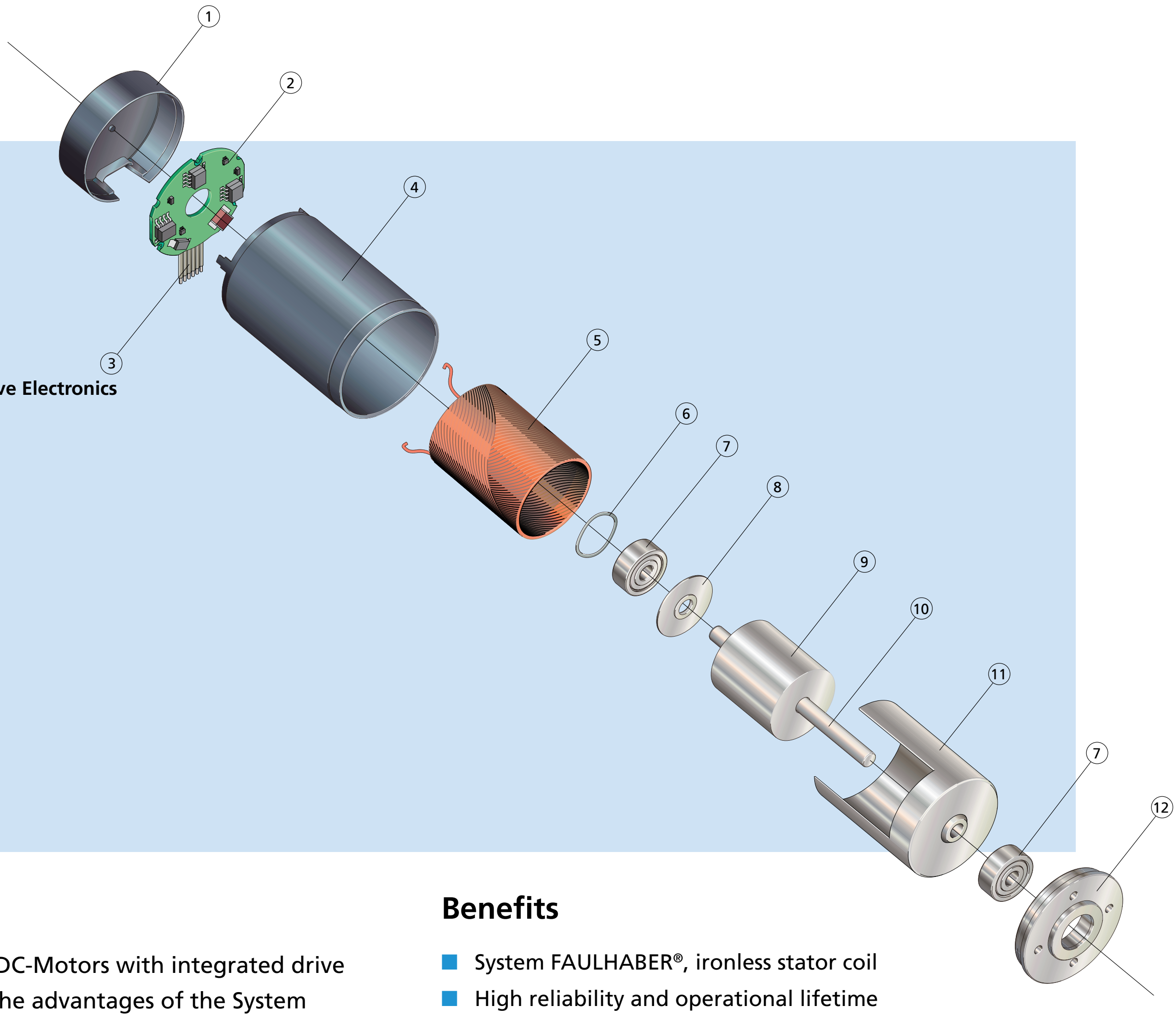
Product Code

2232 S 012 BX4

22	Motor diameter [mm]
32	Motor length [mm]
S	Shaft type
012	Nominal voltage [V]
BX4	Type of commutation (brushless), 4 Pole Technology

Brushless DC-Motors

with integrated Drive Electronics



Brushless DC-Motor
with integrated Drive Electronics

① Rear cover
② Drive Electronics
③ Flat cable
④ Housing
⑤ Coil
⑥ Spring washer
⑦ Ball bearing
⑧ Washer
⑨ Magnet
⑩ Shaft
⑪ Rotor back-iron
⑫ Front flange

Features

These new brushless DC-Motors with integrated drive electronics combine the advantages of the System FAULHABER® skew wound coil technology with the lifetime benefits of electronic commutation. The motors are based on a three-phase ironless coil, a bipolar rare-earth permanent magnet and sensorless electronic commutation.

To define the position of the rotor in relation to the rotating field of the coil, the back-EMF is measured and processed. The position detection of the rotor is sensorless. The design features the basic linear characteristics over a wide speed range and the absence of cogging torque just like the traditional brush commutated DC-Motors in the FAULHABER program. The rotating magnet and iron flux path avoid iron losses and results in higher efficiency.

Benefits

- System FAULHABER®, ironless stator coil
- High reliability and operational lifetime
- Wide range of linear torque / speed performance
- Programmable motor characteristics
- No sparking
- No cogging
- Dynamically balanced rotor
- Integrated electronics
- Simple design
- Available with optional digital or analog Hall sensors

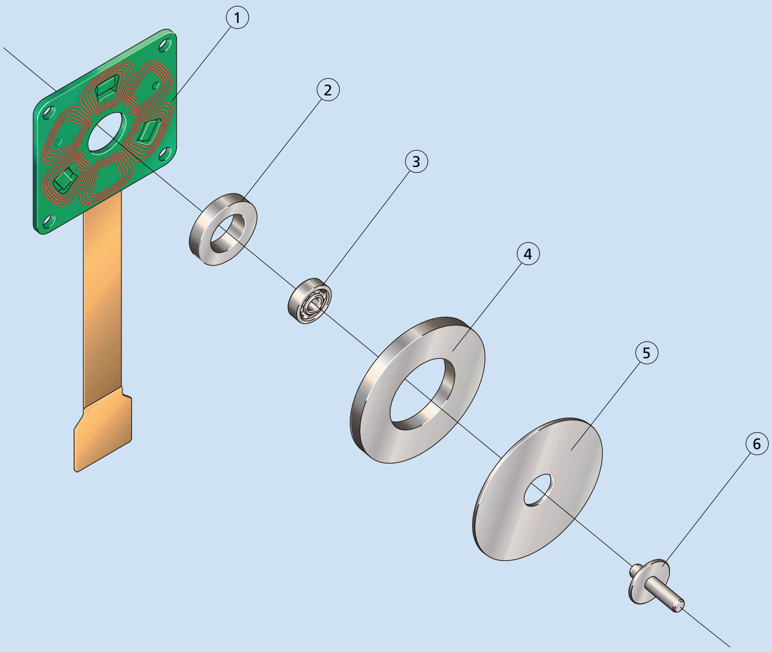
Product Code

3153 K 012 BRC

31	Motor diameter [mm]
53	Motor length [mm]
K	Shaft type
012	Nominal voltage [V]
BRC	Type of commutation (brushless), with integrated electronics

Brushless Flat DC-Micromotors

penny-motor® Technology



Brushless Flat DC-Micromotor

① PCB with coil
② Bearing support
③ Ball bearing
④ Magnet
⑤ Rotor disc
⑥ Shaft

Features

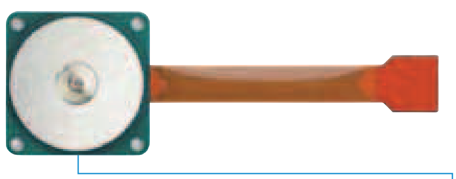
The extremely flat design of the brushless penny-motor® is made possible by innovative coil design. Instead of being mechanically wound, it is fabricated by means of photo-lithographic processes. High power neodymium magnets (NdFeB) and a precise bearing system complete the motors for exceptional torque and smooth performance despite their extremely flat dimensions.

Motors with integrated spur gears are available with coaxial or eccentric shafts for higher torque in a compact form. The motors are electronically commutated for extremely long operational lifetime. They are particularly suited for applications where precise speed control and continuous duty operation are a must; for example in high precision optical filters, choppers or scanning devices.

Benefits

- Ultra flat design
- No cogging and precise speed control
- Exceptional power to volume ratio
- Very low current consumption
- High operational lifetime

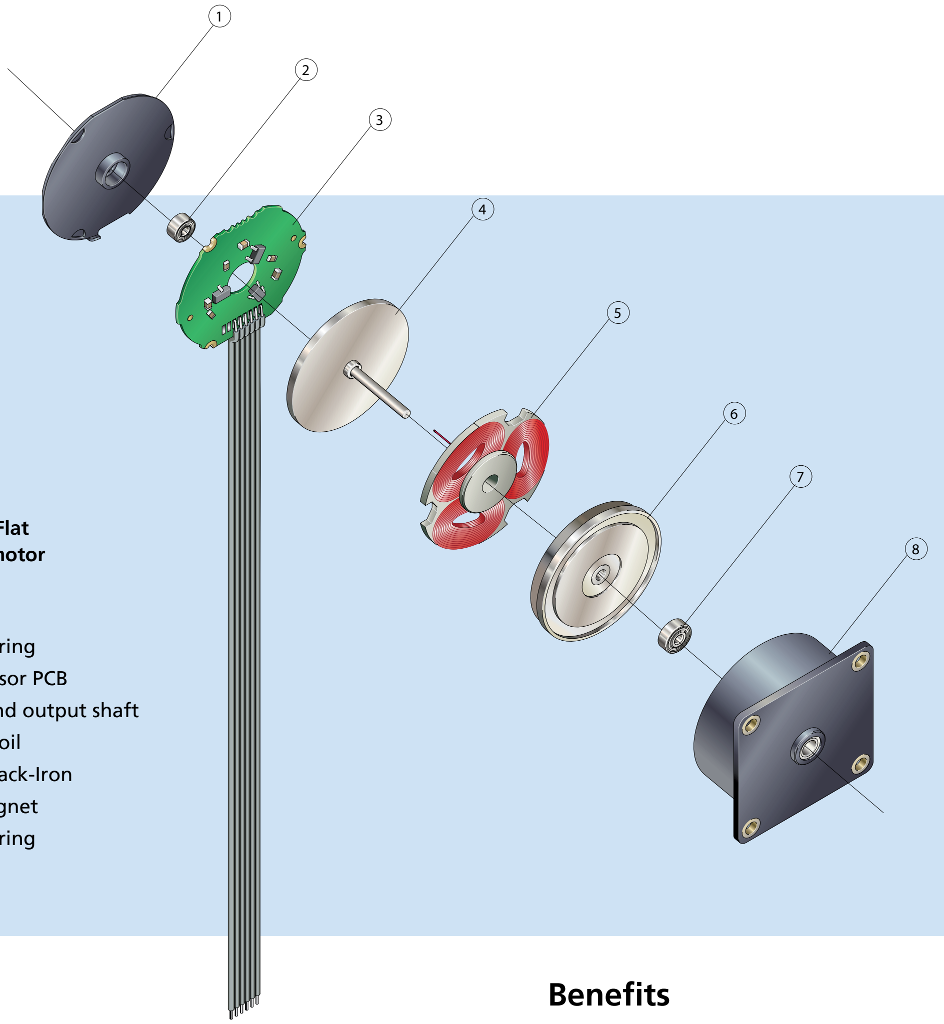
Product Code



1202 H 004 BH

12	Motor diameter [mm]
02	Motor height [mm]
H	Shaft type
004	Nominal voltage [V]
B	Type of commutation (brushless)
H	Hall sensors

Brushless Flat DC-Micromotors



Brushless Flat DC-Micromotor

① End cap
② Ball bearing
③ Hall Sensor PCB
④ Rotor and output shaft
⑤ Stator Coil
⑥ Rotor, Back-Iron and Magnet
⑦ Ball bearing
⑧ Housing

Features

The heart of each brushless flat DC motor consists of the flat stator coils. The rotor is constructed of a high power rare earth magnet and two rotating discs which provide the back iron for an optimal use of the magnetic flux. The rotating back iron also serves to eliminate any cogging, or so-called detent torque which improves the inherent speed control properties of the motor drastically.

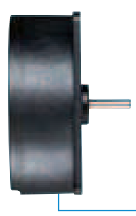
Thanks to the brushless commutation the motors can reach much higher operational lifetimes than conventional mechanically commutated DC motors.

Motor torque can be increased and motor speed reduced by the addition of an integrated reduction gearhead. The revolutionary integrated design provides for a wide variety of reduction ratios while maintaining a very flat profile.

Benefits

- No cogging torque
- Electronic commutation using three digital hall sensors
- Precise speed control
- Flat, light, and very compact

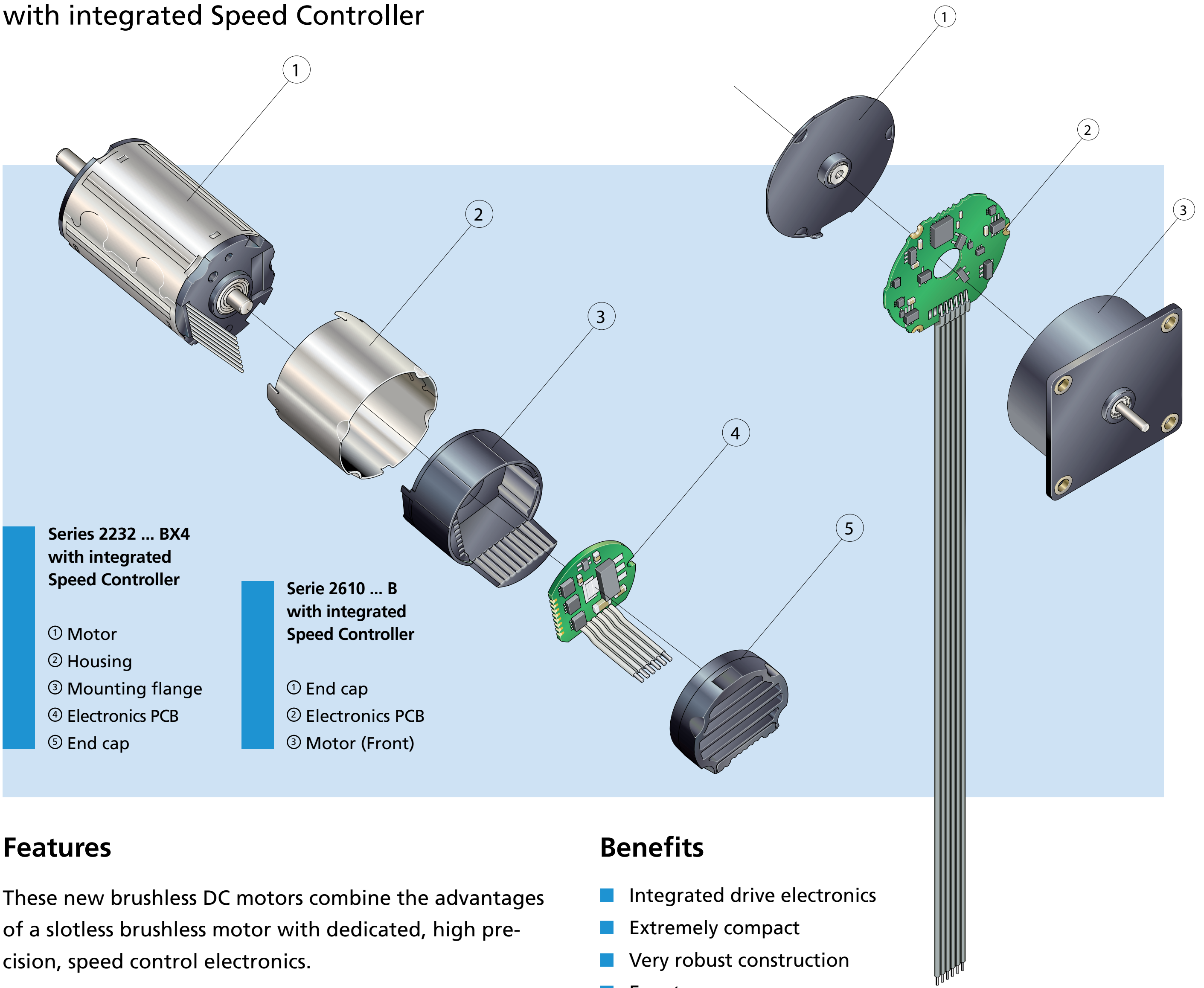
Product Code



26 10 T 012 B

26	Motor diameter [mm]
10	Motor length [mm]
T	Shaft type
012	Nominal voltage [V]
B	Type of commutation (electronic)

Brushless DC-Motors
with integrated Speed Controller



Features

These new brushless DC motors combine the advantages of a slotless brushless motor with dedicated, high precision, speed control electronics.

Speed control is achieved using the on board PI controller with an external command voltage. The drives are protected from overload with the integrated current limiting.

The control parameters of the drive electronics can be modified to fit the application using our optional programming adapter and the easy to use FAULHABER Motion Manager software.

Many drives are also available in a simple 2 wire configuration for ease of integration or replacement of standard DC motors in some applications.

Benefits

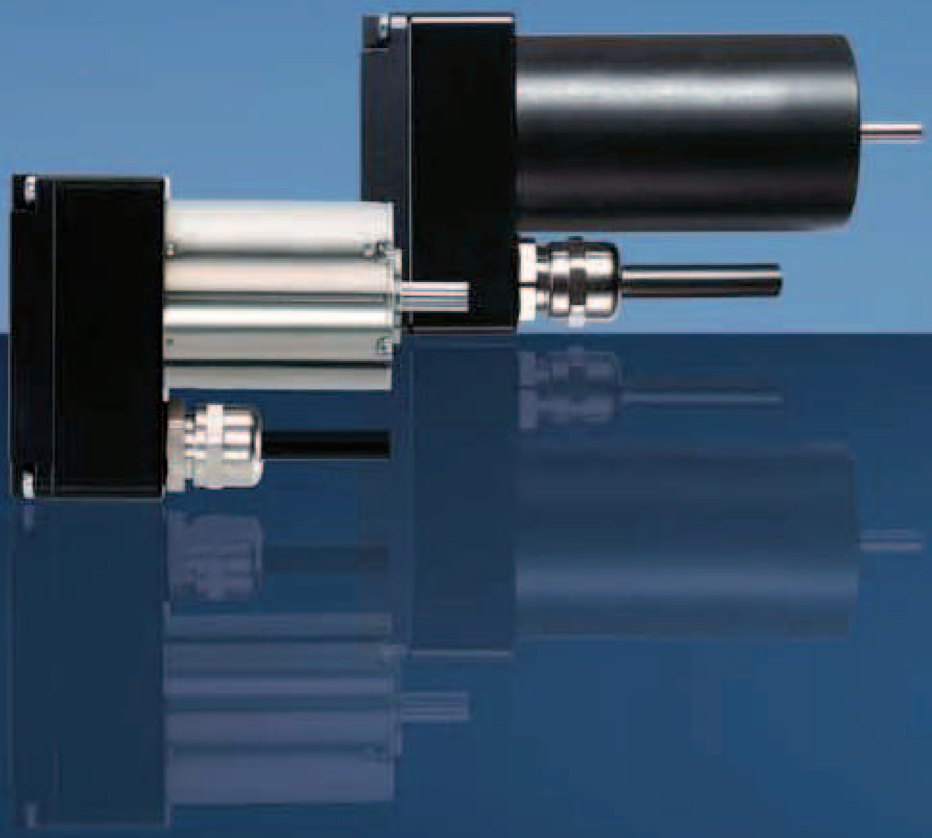
- Integrated drive electronics
- Extremely compact
- Very robust construction
- Easy to use
- Integrated current limiting
- Control parameters can be tuned to the application

Product Code

32 68 G 024 BX4 SC

32	Motor diameter [mm]
68	Motor length [mm]
G	Shaft type
024	Nominal Voltage [V]
BX4	Type of commutation (electronic)
SC	Integrated Speed Controller

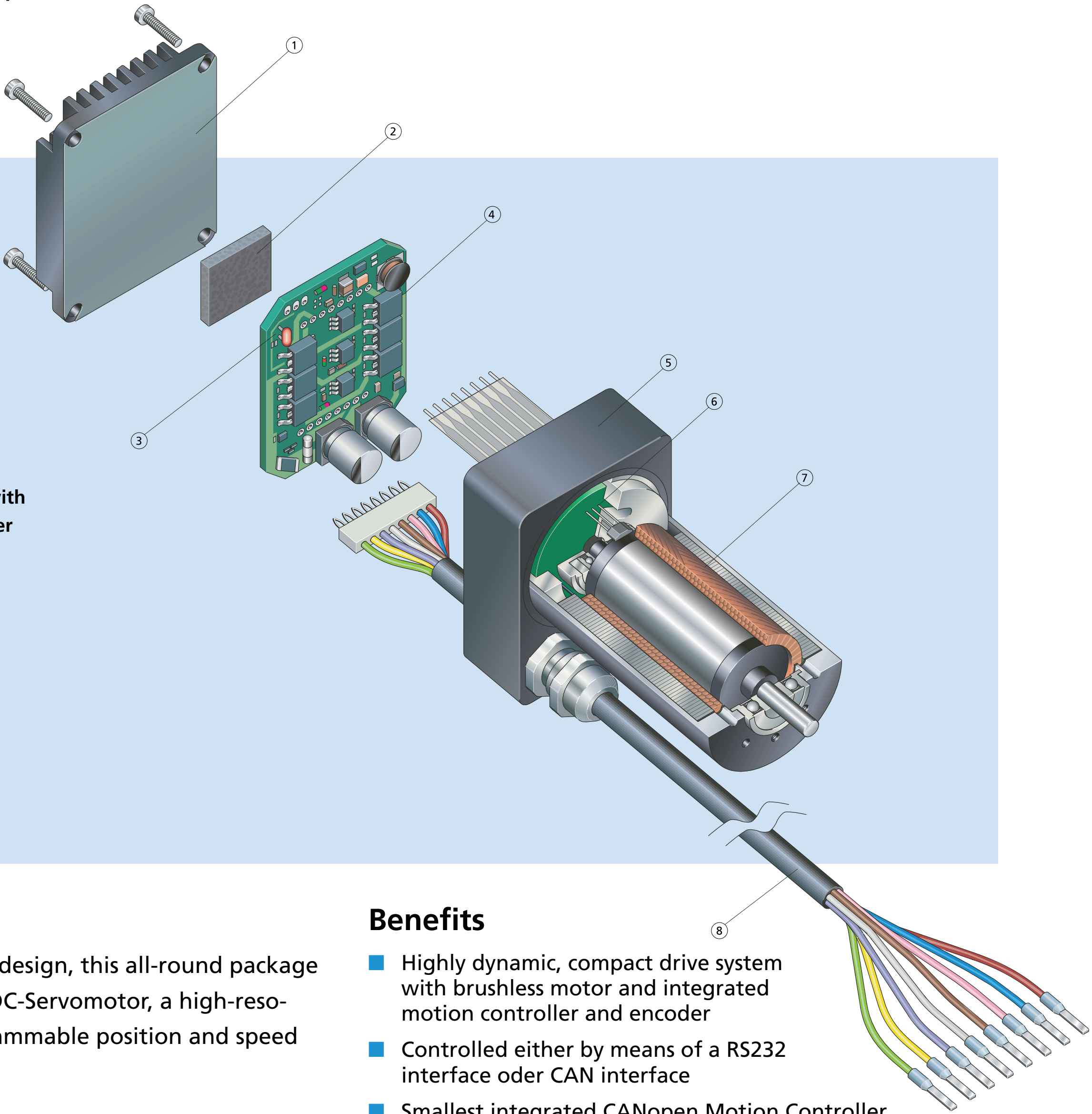
Motion Control Systems



WE CREATE MOTION

Motion Control Systems

Technical Information



Brushless DC-Servomotor with integrated Motion Controller

① Heat sink/cover
② Thermal conduction pad
③ Thermal protection
④ Motion Controller
⑤ Housing
⑥ Analog Hall sensors
⑦ Brushless DC-Servomotor
⑧ Interface cable

Features

With its incredibly compact design, this all-round package units a powerful brushless DC-Servomotor, a high-resolution encoder and a programmable position and speed regulator.

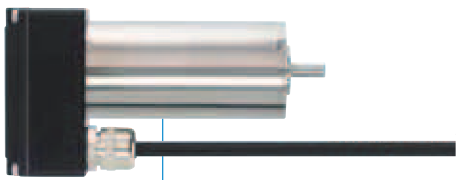
Because of its brushless commutation, the service life of these powerful complete systems is only limited by the servicelife of the bearings and the electronic components used. As well as the familiar RS232 interface, the system is now available for the first time with a CAN interface and CANopen protocol. This means that up to 127 can be linked and controlled with ease.

The powerful motion controller, together with the valuator, permits a whole host of positioning tasks and speed regulations with a resolution of 1/3000 revolutions.
The integrated self-protection against overheating and overvoltage ensures reliable operation. The use of the latest DSP technology enables very high regular sensing rates and PWM frequencies that make the dynamic power pack score extremely well in terms of regulation and effectiveness.

Benefits

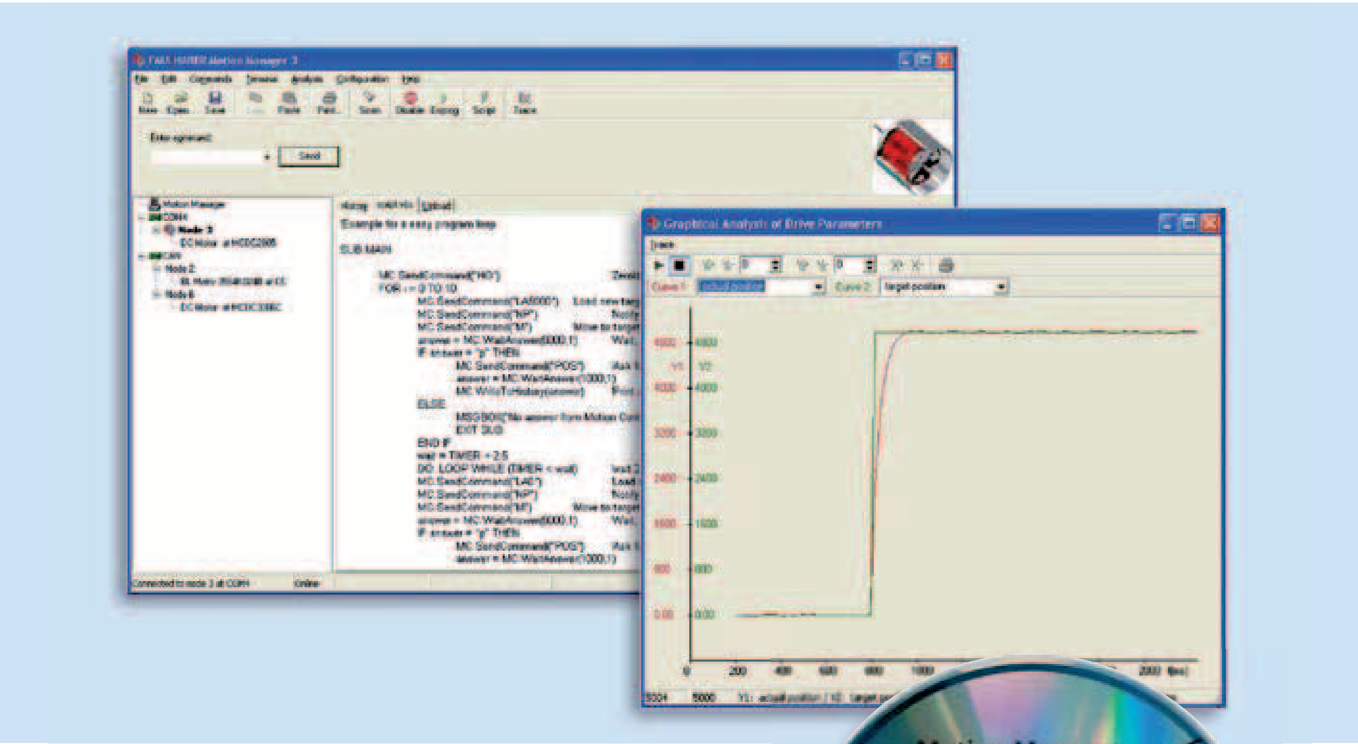
- Highly dynamic, compact drive system with brushless motor and integrated motion controller and encoder
- Controlled either by means of a RS232 interface oder CAN interface
- Smallest integrated CANopen Motion Controller with CiA DS301 V4/ DSP402 V2 standard protocols
- Exact torque regulation through improved power monitoring
- Very flexible motion control functionality
- Digital inputs for TTL and PLC can be configured compatibly

Product Code



3268	Motor series
G	Shaft type
024	Nominal voltage [V]
BX4	Type of commutation (brushless, integrated electronics)
CS	Type of interface

3268 G 024 BX4 CS



Motion Manager

The high-performance “Motion Manager” software from FAULHABER enables users to control and configure drive systems with motion controllers.

The graphic user interface and commands use the same menus and functions regardless if the CAN or RS232 interface is in use. This can dramatically simplify the first steps into CAN applications.

Motion Manager for all Windows™ versions can be downloaded free of charge in German or English from www.faulhaber.com.

Startup and configuration

Motion Manager automatically searches for connected drive nodes and displays these in the “Node Explorer”. Transparent configuration dialogs and dynamic regulating parameter setting, make entry easy.

Graphical online analysis of drive behavior (e.g. as step responses) and possibility to change the regulating parameter continuious, provide invaluable help during to enter commands. The program also supports the creation, transmission and administration of sequential programs and parameter files.

The program is rounded off with an online help and the integrated Visual Basic Script language.

Motion Control Systems

Programming

Version with RS 232 Interface
A complete ASCII command set is available for operation and configuration of the drive.

Motion programs can be created in the Motion Manager or other available terminal programs and then transmitted to the drive where they are stored in the on-board memory. The easy to use motion command library provides all the necessary commands for programming.

Version with CAN Interface
In addition to the standard CANopen profiles as defined in the CiA DSP402 such as profile position mode and profile velocity mode, the drive supports a special FAULHABER Mode. With the help of the CAN command interpreter implemented in the FAULHABER Motion Manager software this mode allows the user to operate and configure the drive with the same easy to use command set as with the RS232 version.

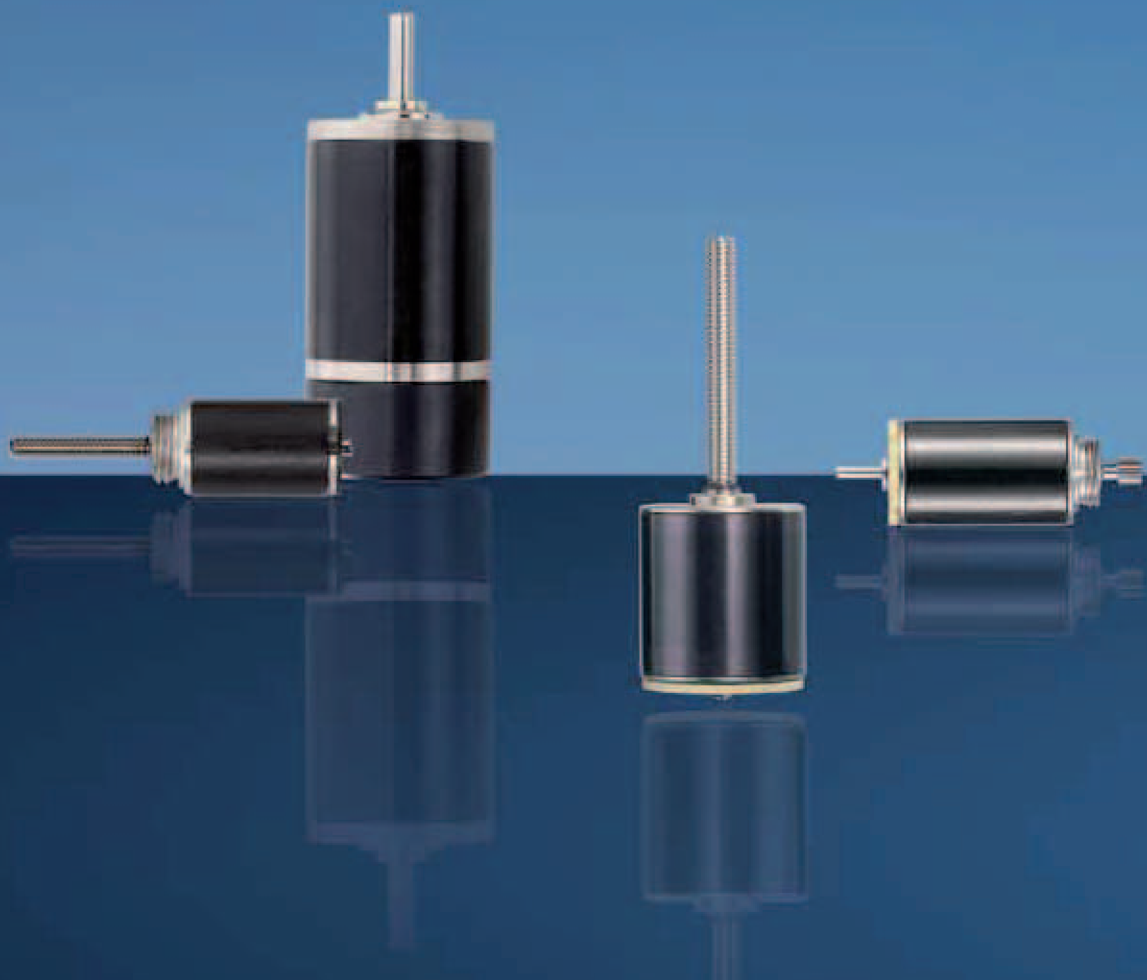
The FAULHABER CANopen motion controller supports the standard CiA DS301 / DSP402 / DSP305 protocols. The CAN interface offers a wide range of functions. You will find details of how to use and configure the controller in the user's manual (available at www.faulhaber.com) Alternatively, you can contact your local support engineer.

Integration in higher level control systems
The ASCII commands and CAN telegrams make it possible to integrate the drive into a higher level control system as well as field bus based control environments.
Visual Basic Script can be written and tested directly in the Motion Manager.

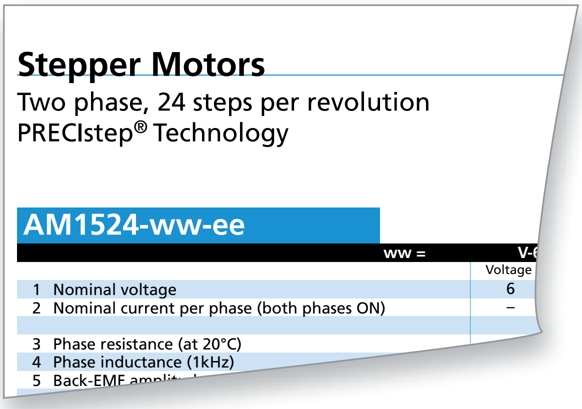
Furthermore, any high level language (Basic, C/C++, Delphi, LabView...) can be used to develop applications on the PC which send commands via RS232 directly to the drive mechanism or to read messages sent from there. Commands can also be used within a PLC program for data exchange with the drive unit.

FAULHABER

Stepper Motors



WE CREATE MOTION



Notes on technical data

Nominal voltage [Volts]
Is the voltage applied to both phase windings that will not overheat the motor. The motor develops nominal holding torque using this voltage.

Nominal current per phase (both phases ON) [A]
Is the current level supplied to both phase windings that will not overheat the motor. The motor develops the nominal holding torque when energized this way.

Phase resistance 1) [Ω]
Phase winding resistance at 20 °C; tolerance is ±12%.

Phase inductance [mH]
Inductance of the phase windings, measured at 1 kHz.

Back-EMF 1) [V/k 1000step/s]
Amplitude of the back-EMF at 1000 steps/s. It is one of the factors which reduce the provided torque at higher speed.

Holding torque, at nominal current [mNm]
Is the amplitude of the torque the motor generates with both phases energized in voltage or current mode.

Holding torque, at 2 x nominal current [mNm]
Is the amplitude of the torque the motor generates with both phases energized with 2 x nominal current.

There is no risk of motor damage due to their magnetic design. However, to limit heat development the boost current should be applied only for short periods during critical sections of the motion cycle.

Step angle [degr.]
Number of angular degrees the motor moves per full-step.

Step angle accuracy [%]
Percentage of a full step by which the unloaded motor with identical currents in both phases will be off from any calculated fullstep position. This error does not cumulate.

Residual torque 1) [mNm]
Torque needed to rotate rotor by outside torque when no phase winding is energized. Residual torque is useful to hold a position without any current to save battery life or to reduce heat.

Rotor inertia [kgm²]
This value represents the inertia of the complete rotor.

Resonance frequency (at no load) [Hz]
Is the step rate at which the unload motor will show rotor resonance. It is recommended to start with a frequency above this frequency or to use half-, micro-step to operate outside this frequency. The resonance frequency changes with the addition of inertial loads.

Electrical time constant [ms]
Is the time needed to establish 67% of the max. possible phase current under a given operation point. It is one of the factors which reduce the provided torque at higher speed.

Ambient temperature range [°C]
Temperatures at which the motor can operate.

Winding temperature tolerated max. [°C]
Maximum temperature supported by the winding and the magnets.

Thermal resistance winding-ambient air [°C/W]
The gradient at which the motor winding temperature increases per Watt of power losses generated in the motor. Additional cooling surface is reducing it.

Thermal time constant [s]
Time needed to reach 67% of the final winding temperature. Adding cooling surfaces reduces the thermal resistance but will increase the thermal time constant.

Shaft bearings
Offered are either self lubricating sintered bronze bearings or 2 preloaded ball bearings. The ball bearing preload is assured by a spring washer assembled at the rear bearing.

Shaft load, max. radial [N]
The figure is representing for all bearing types the recommended maximally supported radial load.

Shaft load, max. axial [N]
The figure is representing for all bearing types the recommended maximally supported axial load. The load handling capability of ball-bearings is higher than the set preload. The rotor can be pulled without risk of damage to the motor by about 0,2 mm.

Shaft play max., radial [μm]
The clearance between shaft and bearing tested with the indicated force to move the shaft.

Shaft play max., axial [μm]
Represents the axial play tested with the indicated force.

Isolation test voltage [1)] [VDC]
Is the test voltage for isolation test between housing and phase windings.

Motor dimensions [mm]
The values provide a rapid view about the motor housing diameter and length as well as the standard shaft diameter.

Weight [g]
Is the motor weight in grams.

[1)] these parameters are measured during final inspection on 100 % of the products delivered.

Stepper Motor Selection

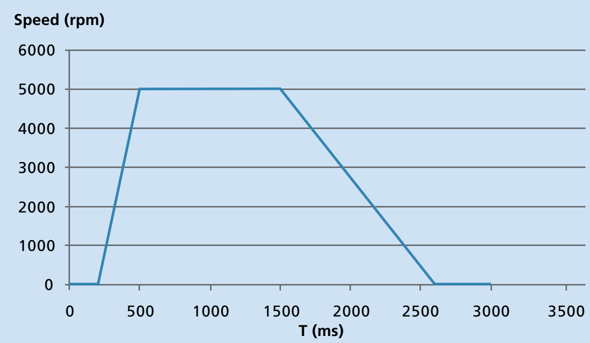
The selection of a stepper motor requires the use of published torque speed curves based on the load parameters.

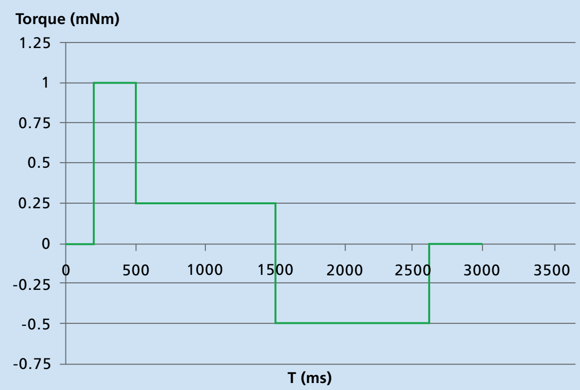
It is not possible to verify the motor selection mathematically without the use of the curves.

To select a motor the following parameters must be known:

- Motion profile
- Load friction and inertia
- Required resolution
- Available space
- Available power supply voltage

1. Definition of the load parameters at the motor shaft
The target of this step is to determine a motion profile needed to move the motion angle in the given time frame and to calculate the motor torque over the entire cycle using the application load parameters such as friction and load inertia.
The motion and torque profiles of the movement used in this example are shown below:





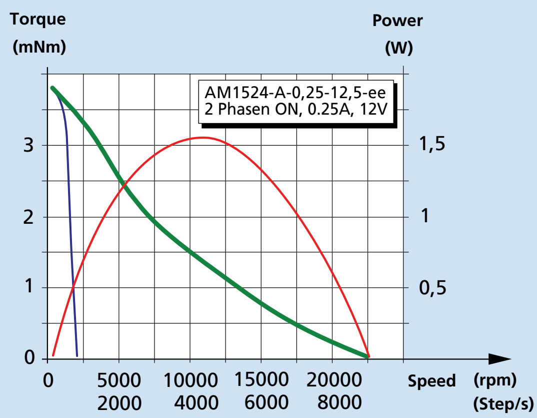
Depending on the motor size suitable for the application it is required to recompute the torque parameters with the motor inertia as well.

In the present case it is assumed that a motor with an outside diameter of maximum 15 mm is suitable and the data has been computed with the inertia of the AM1524.

2. Verification of the motor operation.
The highest torque/speed point for this application is found at the end of the acceleration phase. The top speed is then n = 5000 rpm, the torque is M = 1 mNm.

Using these parameters you can transfer the point into the torque speed curves of the motor as shown here with the AM1524 curves for a current mode drive.

It is not possible to use the full torque of the motor: a safety factor of 30% is requested. The shown example assures that the motor will correctly fulfil the requested application conditions.



In case that no solution is found, it is possible to adapt the load parameters seen by the motor by the use of a reduction gearhead.

The demonstrated method does not specify the differences between the two published torque speed curves, one for voltage mode and one for current mode (which was used as the solution for the application example).

The difference is mainly linked to the performance one may get from the motor. Whereas the voltage mode is offering good performance at low speed the torque will decrease rapidly, the current mode allows higher speed performance as the constant current mode drive (the current is controlled by a chip related control loop) which allows to apply a higher voltage to the motor phases.

Voltage mode is the best choice for application with supply voltage below 10 V mainly due to the availability of suitable driver chips. In voltage mode, the motor winding must have a nominal voltage equal to the power supply to get the best performances.

The moment the voltage is higher than 10 V a current mode driver will be the better choice. It is recommended to apply a supply voltage at least U = 5 x R x I of the selected motor winding.

3. Verification of the resolution
It is assumed that the application requires a resolution of 9° angular.

The selected motor AM1524 has a step angle of 15° which means that the motor is not suitable directly. It can be operated either in half-step, which reduces the step angle to 7,5°, or in micro stepping. With micro stepping, the resolution can be increased even higher whereas the precision is reduced because the error angle without load of the motor (expressed in % of a full-step) remains the same independently from the number of micro-steps the motor is operated.

For that reason the most common solution for adapting the motor resolution to the application requirements is the use of a gearhead or a lead-screw where linear motion is required.

General application notes

In principle each stepper motor can be operated in three modes: full step (one or two phases on), half step or microstep.

Holding torque is the same for each mode as long as dissipated power (I^2R losses) is the same. The theory is best presented on a basic motor model with two phases and one pair of poles where mechanical and electrical angle are equal.

- In full step mode (1 phase on) the phases are successively energised in the following way:
  1. A+   2. B+   3. A–   4. B–.
- Half step mode is obtained by alternating between 1-phase-on and 2-phases-on, resulting in 8 half steps per electrical cycle: 1. A+   2. A+B+   3. B+   4. A–B+   5. A–   6. A–B–   7. B–   8. A+B–.
- If every half step should generate the same holding torque, the current per phase is multiplied by √2 each time only 1 phase is energised.

The two major advantages provided by microstep operation are lower running noise and higher resolution, both depending on the number of microsteps per full step which can in fact be any number but is limited by the system cost.

As explained above, one electrical cycle or revolution of the field vector (4 full steps) requires the driver to provide a number of distinct current values proportional to the number of microsteps per full step.

For example, 8 microsteps require 8 different values which in phase A would drop from full current to zero following the cosine function from 0° to 90°, and in phase B would rise from zero to full following the sine function.

These values are stored and called up by the program controlling the chopper driver. The rotor target position is determined by the vector sum of the torques generated in phase A and B:

$$M_A = k \cdot I_A = k \cdot I_o \cdot \cos \varphi$$

$$M_B = k \cdot I_B = k \cdot I_o \cdot \sin \varphi$$

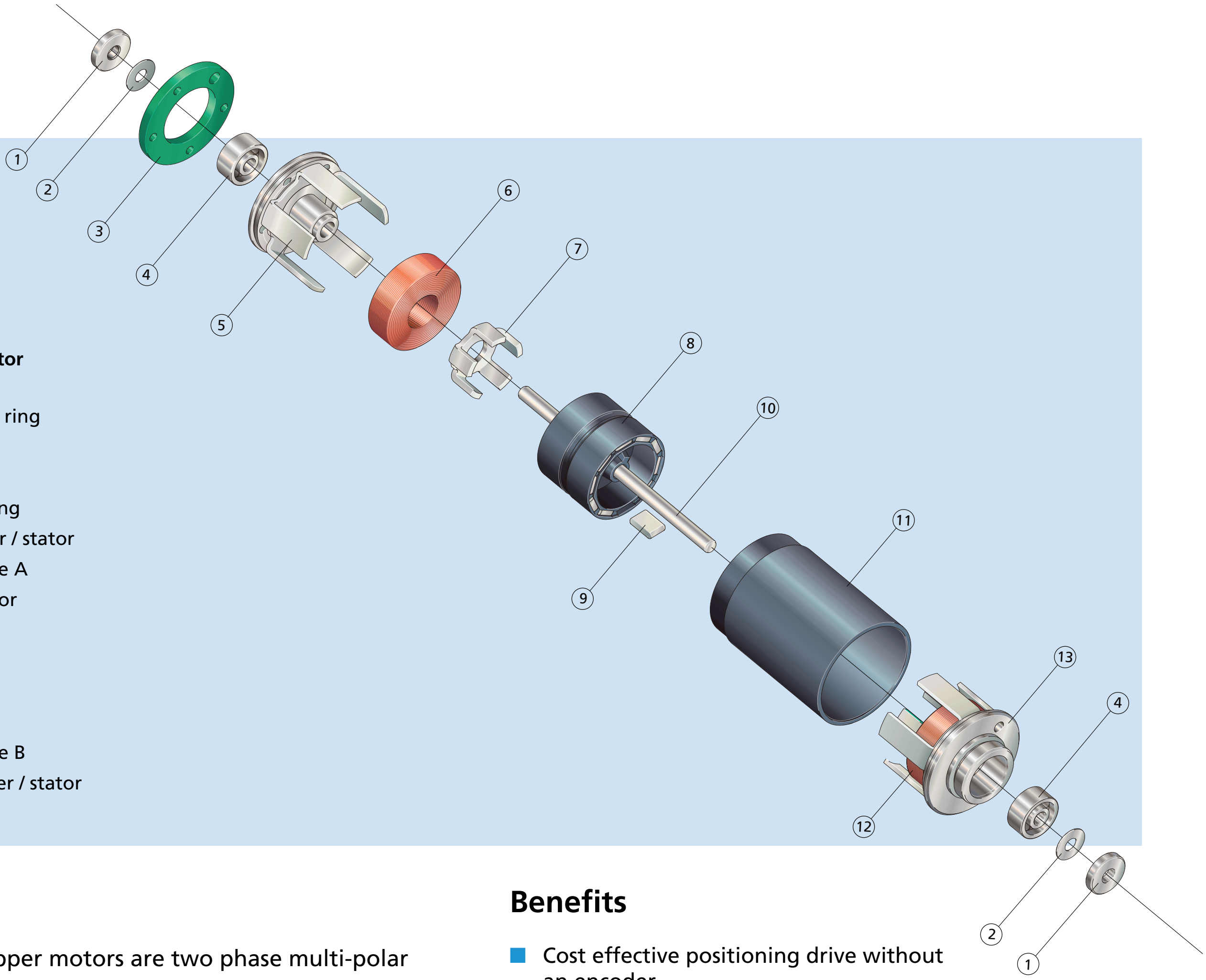
where M is the motor torque, k is the torque constant and Io the nominal phase current.

For the motor without load the position error is the same in full, half or microstep mode and depends on distortions of the sinusoidal motor torque function due to detent torque, saturation or construction details (hence on the actual rotor position), as well as on the accuracy of the phase current values.

4. Verification in the application
Any layout based on such considerations has to be verified in the final application under real conditions.
Please make sure that all load parameters are taken into account during this test.

Stepper Motors

Two phase



Stepper Motor

① Retaining ring
② Washer
③ PCB
④ Ball bearing
⑤ Rear cover / stator
⑥ Coil, Phase A
⑦ Inner stator
⑧ Rotor
⑨ Magnets
⑩ Shaft
⑪ Housing
⑫ Coil, Phase B
⑬ Front cover / stator

Features

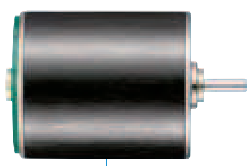
PRECIstep® stepper motors are two phase multi-polar motors with permanent magnets. The use of rare-earth magnets provides an exceptionally high power to volume ratio. Precise, open-loop, speed control can be achieved with the application of full step, half step, or micro-stepping electronics.

The rotor consists of an injection moulded plastic support and magnets which are assembled in a 10 or 12 pole configuration depending on the motor type. The large magnet volume helps to achieve a very high torque density. The use of high power rare-earth magnets also enhances the available temperature range of the motors from extremely low temperatures up to 180 °C as a special configuration. The stator consists of two discrete phase coils which are positioned on either side of the rotor. The inner and outer stator assemblies provide the necessary radial magnetic field.

Benefits

- Cost effective positioning drive without an encoder
- High power density
- Long operational lifetimes
- Wide operational temperature range
- Speed range up to 16 000 rpm using a current mode chopper driver
- Possibility of full step, half step and microstep operation

Product Code

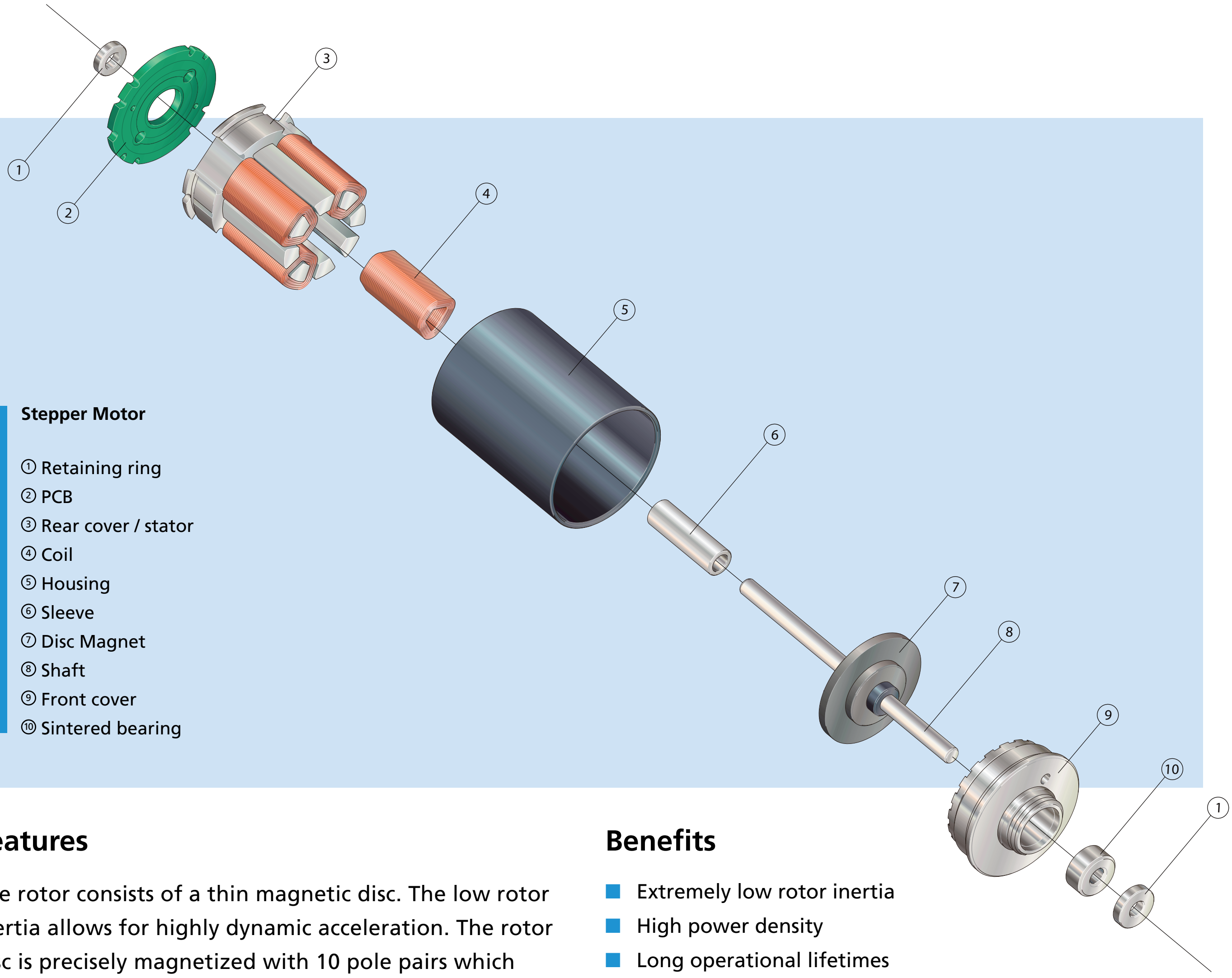


AM1524-2R-V-12-150-57

AM1524	Motor series
2R	Bearing type
V-12-150	Coil type
57	Motor version

Stepper Motors

Two phase with Disc Magnet



Stepper Motor

① Retaining ring
② PCB
③ Rear cover / stator
④ Coil
⑤ Housing
⑥ Sleeve
⑦ Disc Magnet
⑧ Shaft
⑨ Front cover
⑩ Sintered bearing

Features

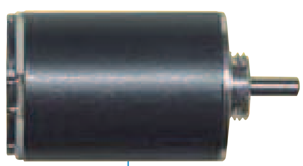
The rotor consists of a thin magnetic disc. The low rotor inertia allows for highly dynamic acceleration. The rotor disc is precisely magnetized with 10 pole pairs which helps the motor achieve a very high angular accuracy. The stator consists of four coils, two per phase, which are located on one side of the rotor disc and provide the axial magnetic field.

Special executions with additional rotating back-iron are available for exceptionally precise micro-stepping performance.

Benefits

- Extremely low rotor inertia
- High power density
- Long operational lifetimes
- Wide operational temperature range
- Ideally suited for micro-stepping applications

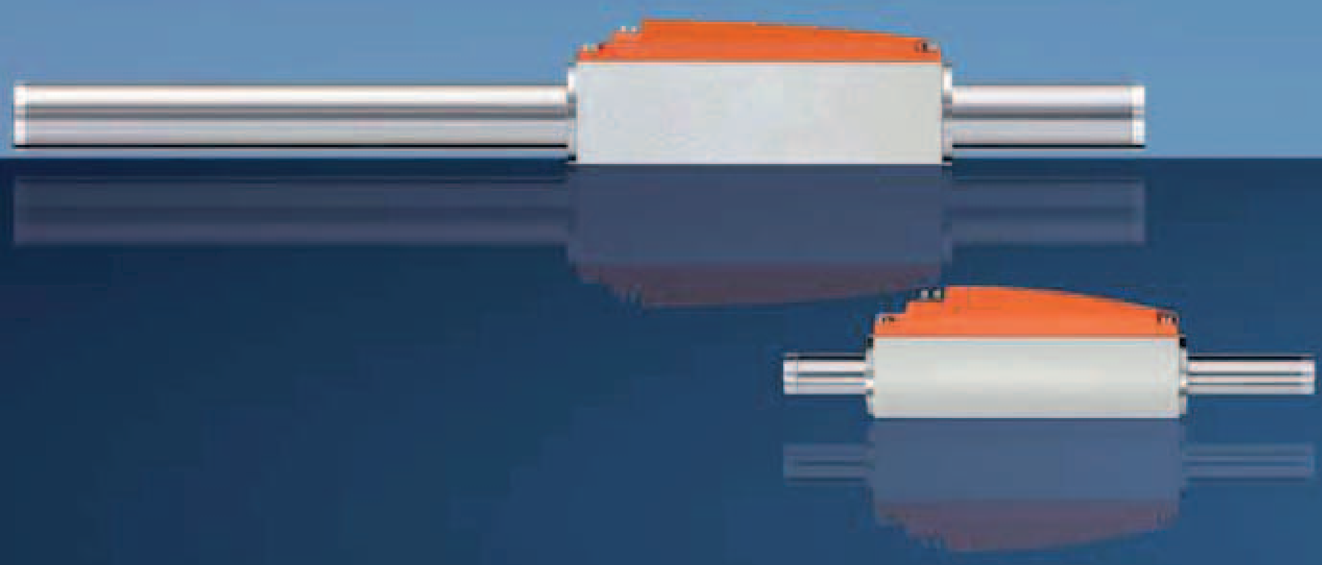
Product Code



ADM1220-2R-V2-01

ADM1220	Motor series
2R	Bearing type
V2	Coil type
01	Motor version

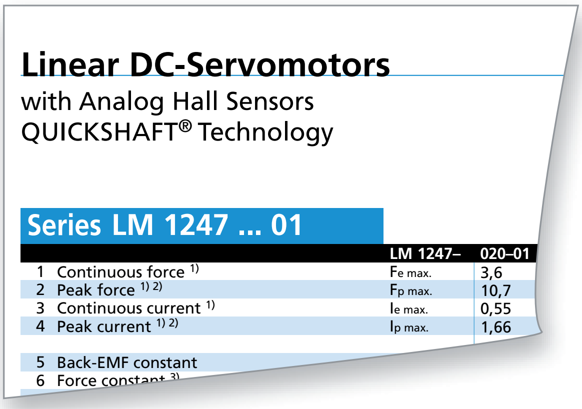
Linear DC-Servomotors



WE CREATE MOTION

Linear DC-Servomotors

Technical Information



Linear DC-Servomotors

with Analog Hall Sensors
QUICKSHAFT® Technology

Series LM 1247 ... 01

		LM 1247–	020–01
1	Continuous force [1]	$F_{e\ max.}$	3,6
2	Peak force [1) 2)]	$F_{p\ max.}$	10,7
3	Continuous current [1]	$I_{e\ max.}$	0,55
4	Peak current [1) 2)]	$I_{p\ max.}$	1,66
5	Back-EMF constant		
6	Force constant [3]		

Notes on technical data

All values at 22 °C.

Continuous force $F_{e\ max.}$ [N]
The maximum force delivered by the motor at the thermal limit in continuous duty operation.

$$F_{e\ max.} = k_F \cdot I_{e\ max.}$$

Peak force $F_{p\ max.}$ [N]
The maximum force delivered by the motor at the thermal limit in intermittent duty operation (max. 1 s, 20% duty cycle).

$$F_{p\ max.} = k_F \cdot I_{p\ max.}$$

Continuous current $I_{e\ max.}$ [A]
The maximum motor current consumption at the thermal limit in continuous duty operation.

$$I_{e\ max.} = \sqrt{\frac{T_{125} - T_{22}}{R \cdot (1 + \alpha_{22} \cdot (T_{125} - T_{22})) \cdot (R_{th\,1} + 0{,}45 \cdot R_{th\,2})}} \cdot \frac{\sqrt{2}}{\sqrt{3}}$$

Peak current $I_{p\ max.}$ [A]
The maximum motor current consumption at the thermal limit in intermittent duty operation (max. 1 s, 20% duty cycle).

Back-EMF constant k_E [V/m/s]
The constant corresponding to the relationship between the induced voltage in the motor phases and the linear motion speed.

$$k_E = \frac{2 \cdot k_F}{\sqrt{6}}$$

Force constant k_F [N/A]
The constant corresponding to the relationship between the motor force delivered and current consumption.

Terminal resistance, phase-phase R [Ω] ±12%
The resistance measured between two motor phases. This value is directly influenced by the coil temperature (temperature coefficient: α_{22} = 0,004 K^{-1}).

Terminal inductance, phase-phase L [µH]
The inductance measured between two phases at 1 kHz.

Stroke length $s_{max.}$ [mm]
The maximum stroke length of the moving cylinder rod.

Repeatability [µm]
The maximum measured difference when repeating several times the same movement under the same conditions.

Precision [µm]
The maximum positioning error. This value corresponds to the maximum difference between the set position and the exact measured position of the system.

Acceleration $a_{e\ max.}$ [m/s²]
The maximum no-load acceleration from standstill.

$$a_{e\ max.} = \frac{F_{e\ max.}}{m_m}$$

Speed $v_{e\ max.}$ [m/s]
The maximum no-load speed from standstill, considering a triangular speed profile and maximum stroke length.

$$v_{e\ max.} = \sqrt{a_{e\ max.} \cdot s_{max.}}$$

Thermal resistance $R_{th\,1}$ / $R_{th\,2}$ [K/W]
R_{th1} corresponds to the value between coil and housing.
R_{th2} corresponds to the value between housing and ambient air.
The listed values refer to a motor totally surrounded by air.
R_{th2} can be reduced with a heat sink and/or forced air cooling.

Thermal time constant τ_{w1} / τ_{w2} [s]
The thermal time constant of the coil and housing, respectively.

Operating temperature range [°C]
The minimum and maximum permissible operating temperature values of the motors.

Rod weight m_m [g]
The weight of the rod (cylinder with magnets).

Total weight m_t [g]
The total weight of the linear DC-Servomotor.

Linear DC-Servomotors

Technical Information

Magnetic pitch τ_m [mm]
The distance between two equal poles.

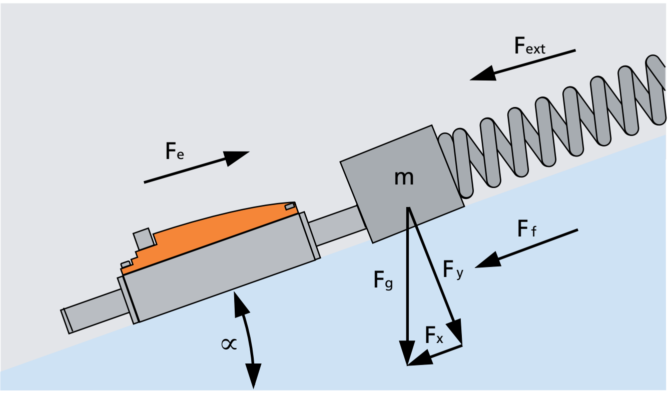
Rod bearings
The material and type of bearings.

Housing material
The material of the motor housing.

Direction of movement
The direction of movement is reversible, determined by the control electronics.

Force calculation

To move a mass on a slope, the motor needs to deliver a force to accelerate the load and overcome all forces opposing the movement.



The sum of forces shown in above figure has to be equal to:

$\sum F = m \cdot a$	[N]

Entering the various forces in this equation it follows that:

$F_e - F_{ext} - F_f - F_x = m \cdot a$	[N]

where:

F_e :	Continuous force delivered by motor	[N]
F_{ext} :	External force	[N]
F_f :	Friction force $F_f = m \cdot g \cdot \mu \cdot \cos(\propto)$	[N]
F_x :	Parallel force $F_x = m \cdot g \cdot \sin(\propto)$	[N]
m :	Total mass	[kg]
g :	Gravity acceleration	[m/s²]
a :	Acceleration	[m/s²]

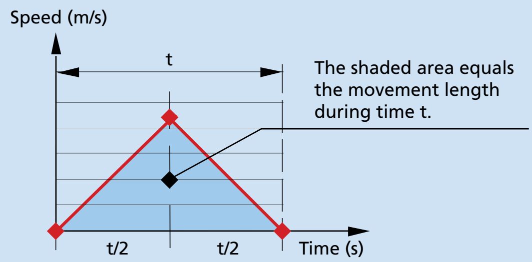
Speed profiles

Shifting any load from point A to point B is subject to the laws of kinematics.

Equations of a uniform straight-line movement and uniformly accelerated movement allow definition of the various speed vs. time profiles.

Prior to calculating the continuous duty force delivered by the motor, a speed profile representing the various load movements needs to be defined.

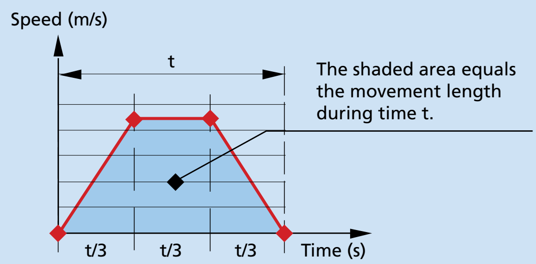
Triangular speed profile
The triangular speed profile simply consists of an acceleration and a deceleration time.



Displacement:	$s = \frac{1}{2} \cdot v \cdot t = \frac{1}{4} \cdot a \cdot t^2 = \frac{v^2}{a}$	[m]
Speed:	$v = 2 \cdot \frac{s}{t} = \frac{a \cdot t}{2} = \sqrt{a \cdot s}$	[m/s]
Acceleration:	$a = 4 \cdot \frac{s}{t^2} = 2 \cdot \frac{v}{t} = \frac{v^2}{s}$	[m/s²]

Trapezoidal speed profile

The trapezoidal speed profile, acceleration, speed and deceleration, allow simple calculation and represent typical real application cases.



Displacement:	$s = \frac{2}{3} \cdot v \cdot t = \frac{1}{4,5} \cdot a \cdot t^2 = 2 \cdot \frac{v^2}{a}$	[m]
Speed:	$v = 1,5 \cdot \frac{s}{t} = \frac{a \cdot t}{3} = \sqrt{\frac{a \cdot s}{2}}$	[m/s]
Acceleration:	$a = 4,5 \cdot \frac{s}{t^2} = 3 \cdot \frac{v}{t} = 2 \cdot \frac{v^2}{s}$	[m/s²]

How to select a linear DC-Servomotor

This section describes a step-by-step procedure to select a linear DC-Servomotor.

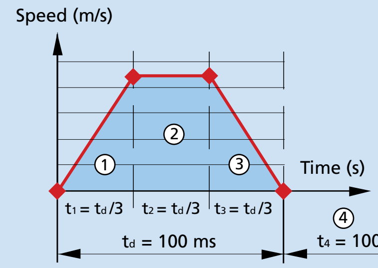
Speed profile definition

To start, it is necessary to define the speed profile of the load movements.

Movement characteristics are the first issues to be considered. Which is the maximum speed? How fast should the mass be accelerated? Which is the length of movement the mass needs to achieve? How long is the rest time?

Should the movement parameters not be clearly defined, it is recommended to use a triangular or trapezoidal profile.

Lets assume a load of 500 g that needs to be moved 20 mm in 100 ms on a slope having a rising angle of 20° considering a trapezoidal speed profile.



	Unit	1	2	3	4
s (displacement)	m	0,005	0,01	0,005	0
v (speed)	m/s	0 ... 0,3	0,3	0,3 ... 0	0
a (acceleration)	m/s²	9,0	0	–9,0	0
t (time)	s	0,033	0,033	0,033	0,100

Calculation example

Speed and acceleration of part 1

$$v_{max.} = 1,5 \cdot \frac{s}{t} = 1,5 \cdot \frac{20 \cdot 10^{-3}}{100 \cdot 10^{-3}} = 0,3 \text{ m/s}$$

$$a = 4,5 \cdot \frac{s}{t^2} = 4,5 \cdot \frac{20 \cdot 10^{-3}}{(100 \cdot 10^{-3})^2} = 9 \text{ m/s}^2$$

Force definition

Assuming a load of 500 g and a friction coefficient of 0,2, the following forces result:

			Forward				Backward			
Force	Unit	Symbol	1	2	3	4	1	2	3	4
Friction	N	F_f	0,94	0,94	0,94	-0,94	0,94	0,94	0,94	0,94
Parallel	N	F_x	1,71	1,71	1,71	1,71	-1,71	-1,71	-1,71	-1,71
Acceleration	N	F_a	4,5	0	-4,5	0	4,5	0	-4,5	0
Total	N	F_t	7,15	2,65	-1,85	0,77	3,73	-0,77	-5,27	-0,77

Calculation example

Friction and acceleration forces of part 1

$$F_f = m \cdot g \cdot \mu \cdot \cos(\alpha) = 0,5 \cdot 10 \cdot 0,2 \cdot \cos(20°) = 0,94 \text{ N}$$

$$F_a = m \cdot a = 0,5 \cdot 9 = 4,5 \text{ N} \qquad = 4,5 \text{ N}$$

Motor selection

Now that the forces of the three parts of the profile are known, requested peak and continuous forces can be calculated in function of the time of each part.

The peak force is the highest one achieved during the motion cycle.

$$F_p = \max.\,(|\mathbf{7,15}|, |2,65|, |-1,85|, |0,77|, |3,73|, |-0,77|, |-5,27|, |-0,77|) = 7,15 \text{ N}$$

Linear DC-Servomotors

Technical Information

The continuous force is represented by the expression:

$$F_e = \sqrt{\frac{\sum (t \cdot F_t^2)}{2 \cdot \sum t}} = \ldots$$

$$F_e = \sqrt{\frac{0{,}033 \cdot 7{,}15^2 + 0{,}033 \cdot 2{,}65^2 + 0{,}033 \cdot (-1{,}85)^2 + 0{,}1 \cdot 0{,}77^2 + 0{,}033 \cdot 3{,}73^2 + 0{,}033 \cdot (-0{,}77)^2 + 0{,}033 \cdot (-5{,}27)^2 + 0{,}1 \cdot (-0{,}77)^2}{2 \cdot (0{,}033 + 0{,}033 + 0{,}033 + 0{,}1)}} = 2{,}98 \text{ N}$$

With these two values it is now possible to select the suitable motor for the application.

Linearer DC-Servomotor **LM 1247–020–01**

$s_{max.}$ = 20 mm ; $F_{e\,max}$ = 3,09 N ; $F_{p\,max.}$ = 9,26 N

Coil winding temperature calculation

To obtain the coil winding temperature, the continuous motor current needs to be calculated.
For this example, considering a force constant k_F equal to 6,43 N/A, gives the result:

$$I_e = \frac{F_e}{k_f} = \frac{2{,}98}{6{,}43} = 0{,}46 \text{ A}$$

With an electrical resistance of 13,17 Ω, a total thermal resistance of 26,2 °C/W (R_{th1} + R_{th2}) and a reduced thermal resistance Rth2 by 55% (0,45 · R_{th2}), the resulting coil temperature is:

$$T_c\,(I) = \frac{R \cdot (R_{th1} + 0{,}45 \cdot R_{th2}) \cdot (I_e \cdot \frac{\sqrt{3}}{\sqrt{2}})^2 \cdot (1 - \alpha_{22} \cdot T_{22}) + T_{22}}{1 - \alpha_{22} \cdot R \cdot (R_{th1} + 0{,}45 \cdot R_{th2}) \cdot (I_e \cdot \frac{\sqrt{3}}{\sqrt{2}})^2} = \ldots$$

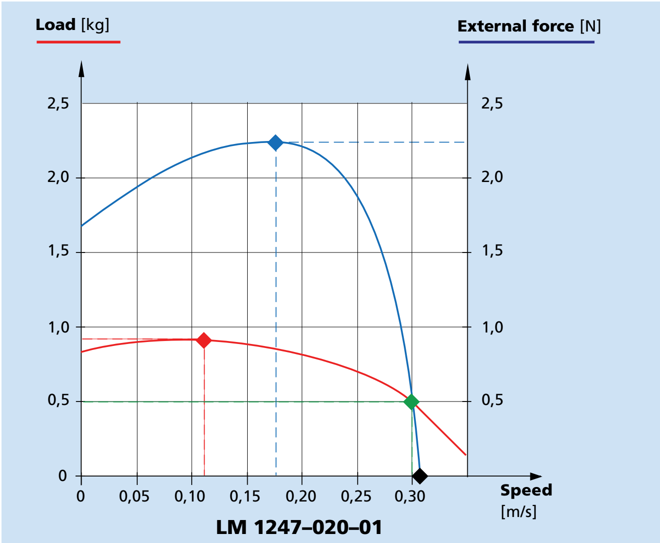
$$T_c\,(I) = \frac{13{,}17 \cdot (8{,}1 + 0{,}45 \cdot 18{,}1) \cdot (0{,}46 \cdot \frac{\sqrt{3}}{\sqrt{2}})^2 \cdot (1 - 0{,}0038 \cdot 22) + 22}{1 - 0{,}0038 \cdot 13{,}17\,(8{,}1 + 0{,}45 \cdot 18{,}1) \cdot (0{,}46 \cdot \frac{\sqrt{3}}{\sqrt{2}})^2} = 113{,}5\ °\text{C}$$

Motor characteristic curves

Motion profile:
Trapezoidal (t1 = t2 = t3), back and forth

Motor characteristic curves of the linear DC-Servomotor with the following parameters:

Displacement distance:	20 mm
Friction coefficient:	0,2
Slope angle:	20°
Rest time:	0,1 s



Load curve

Allows knowing the maximum applicable load for a given speed with 0 N external force.

The graph shows that a maximum load (◆) of 0,87 kg can be applied at a speed of 0,11 m/s.

External force curve

Allows knowing the maximum applicable external force for a given speed with a load of 0,5 kg.

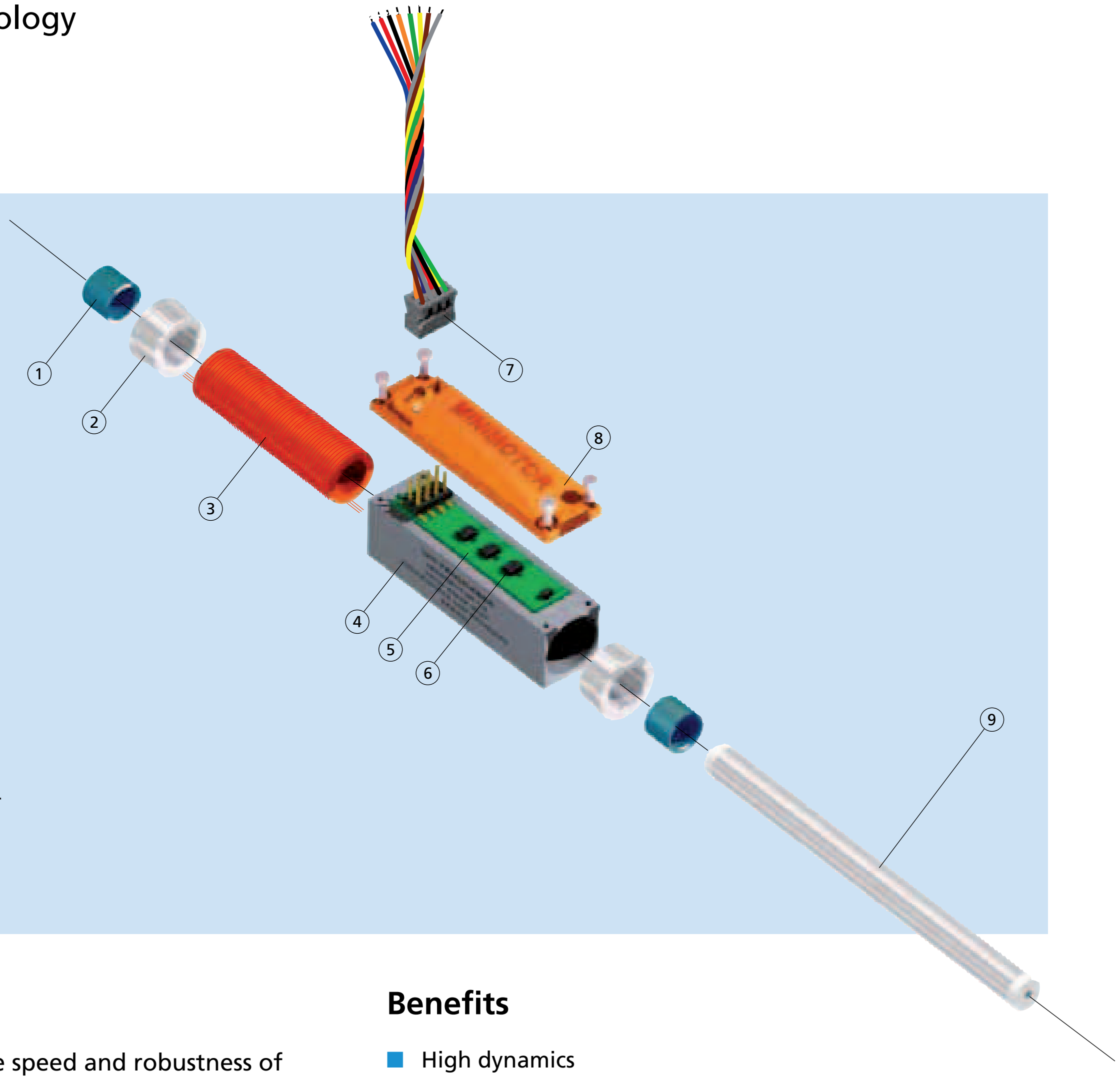
The graph shows that the max. achievable speed (◆) without external forces, but with a load of 0,5 kg is 0,31 m/s.

Therefore, the maximum applicable external force (◆) at a speed of 0,3 m/s is 0,5 N.

The external peak force (◆) is achieved at a speed of 0,17 m/s, corresponding to a maximum applicable external force of 2,27 N.

Linear DC-Servomotors

QUICKSHAFT© Technology



Linear DC-Servomotor

① Sleeve bearings
② Bearing support
③ Coil
④ Housing
⑤ PCB
⑥ Hall sensors
⑦ Lead wires and connector
⑧ Cover
⑨ Forcer rod

Features

QUICKSHAFT® combines the speed and robustness of a pneumatic system with the flexibility and reliability features of an electro-mechanical linear motor.
The innovative design with a 3-phase self-supporting coil and non-magnetic steel housing offers outstanding performance.

The absence of residual static force and the excellent relationship between the linear force and current make these motors ideal for use in micro-positioning applications. Position control of the QUICKSHAFT® Linear DC-Servomotor is made possible by the built-in Hall sensors.

Performance lifetime of the QUICKSHAFT® Linear DC-Servomotors is mainly influenced by the wear of the sleeve bearings, which depends on operating speed and applied load of the cylinder rod.

Benefits

- High dynamics
- Excellent force to volume ratio
- No residual force present
- Non-magnetic steel housing
- Compact and robust construction
- No lubrication required
- Simple installation and configuration

Product Code

LM1247–020–01

LM	Linear Motor
12	Motor width □ [mm]
47	Motor length [mm]
020	Stroke length [mm]
01	Sensors type: linear

FAULHABER

Precision Gearheads

WE CREATE MOTION

FAULHABER

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 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 data

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 reduction 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	[rpm]
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 rpm
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	≤ 5 000 rpm
– Shaft load, max.	radial	≤ 30 N
	axial	≤ 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.

Precision Gearheads

Technical Information

Calculation of the input speed n_{input}

$n_{input} = n \cdot i$	[rpm]
$n_{input} = 30 \cdot 159 = 4\,770$	rpm

Calculation of the input torque M_{input}

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

The efficiency of this gearhead is 60%, consequently:

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

The values of

Input speed	n_{input}	= 4 770	rpm
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.

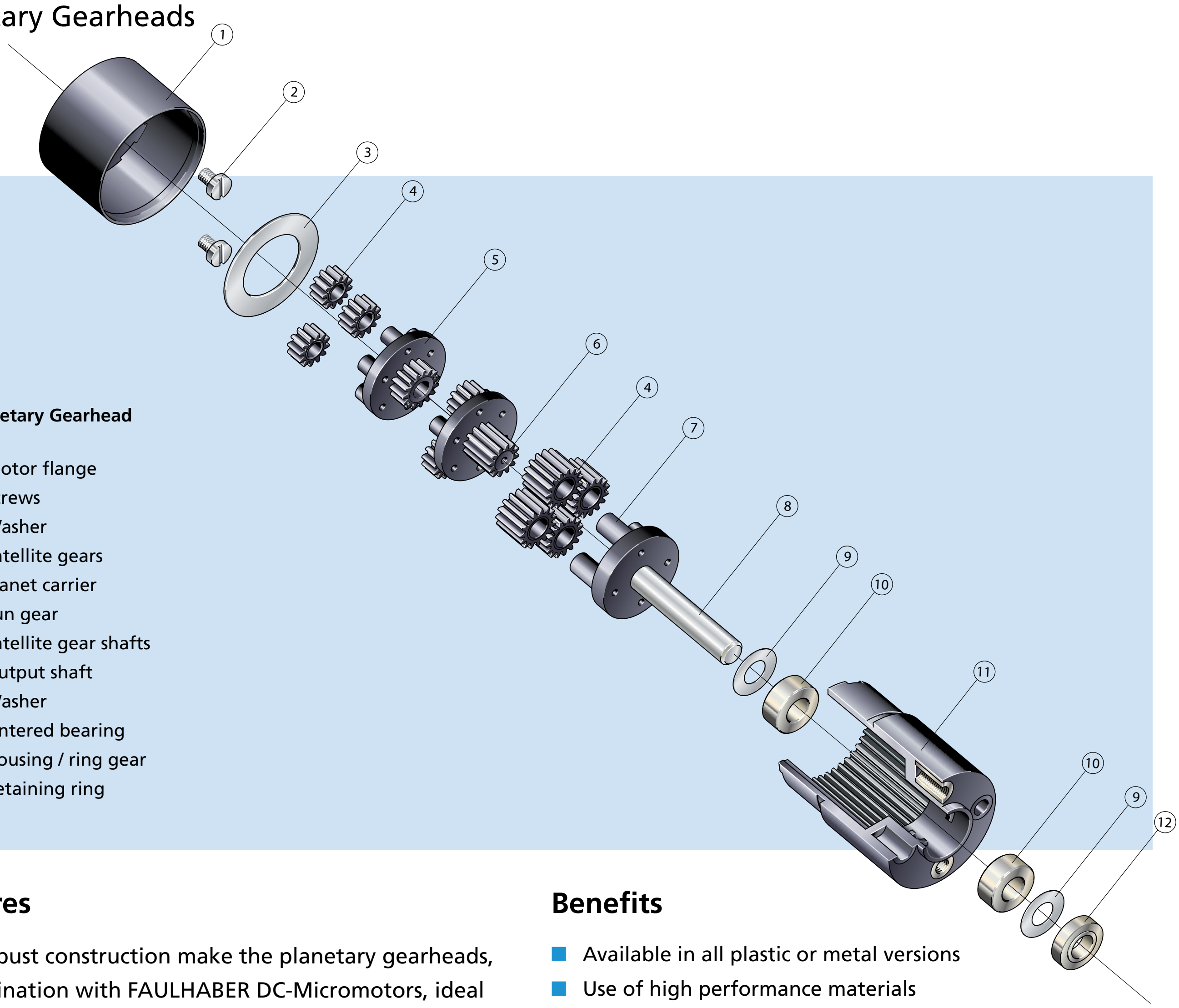
It is recommended to select suitable components based on a first estimation, and then test the units in the application by varying the supply voltage until the required speed and torque are obtained.
Recording the applied voltage and current at the point of operation, along with the type numbers of the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

FAULHABER

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 RPM's. 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 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

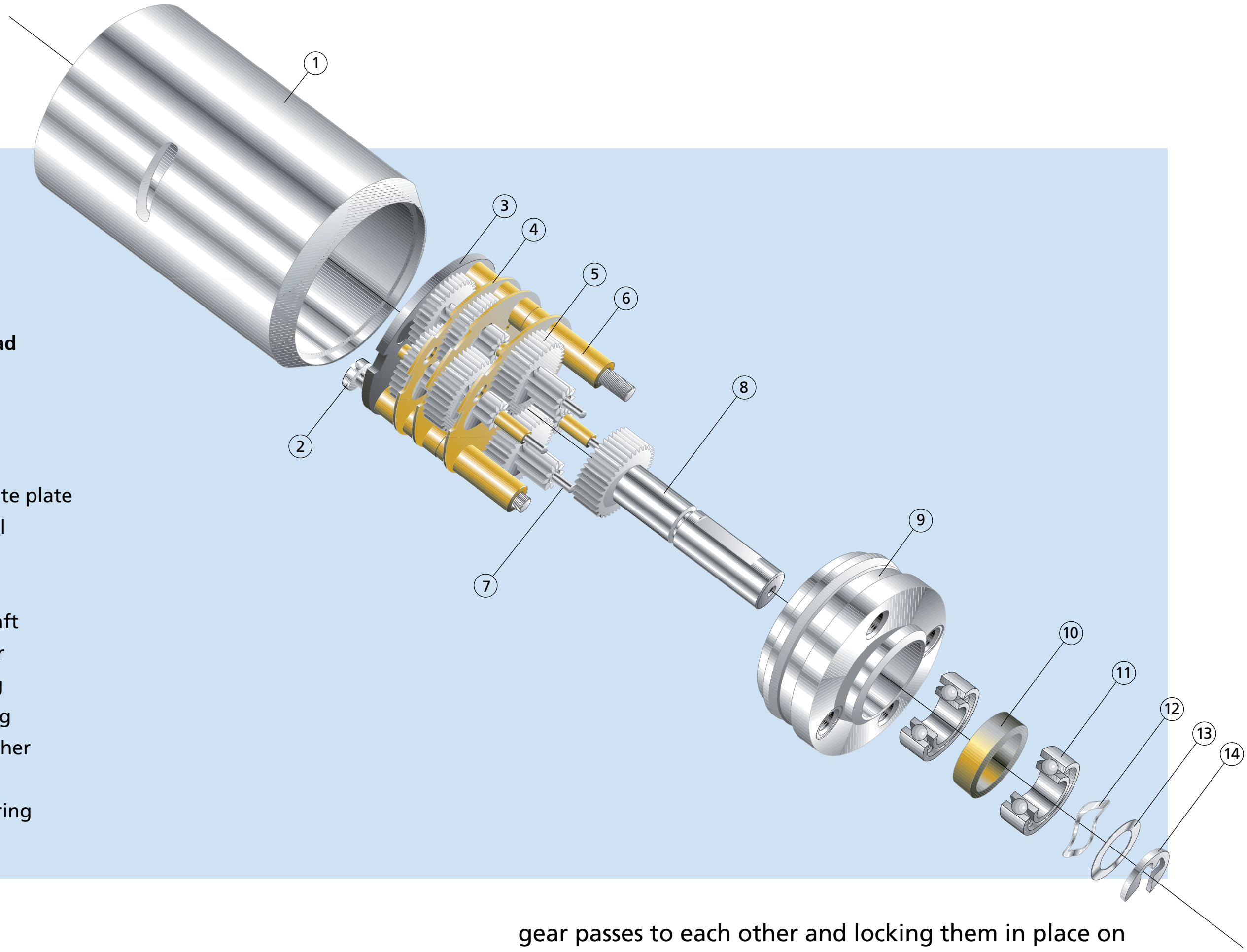
26A 64:1

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

All metal planetary gearhead series 12/4

Precision Gearheads

Spur Gearheads

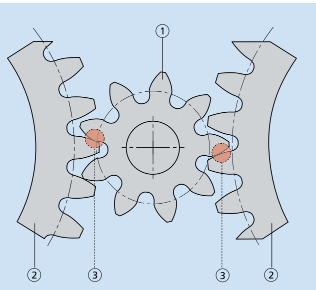


Spur Gearhead

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

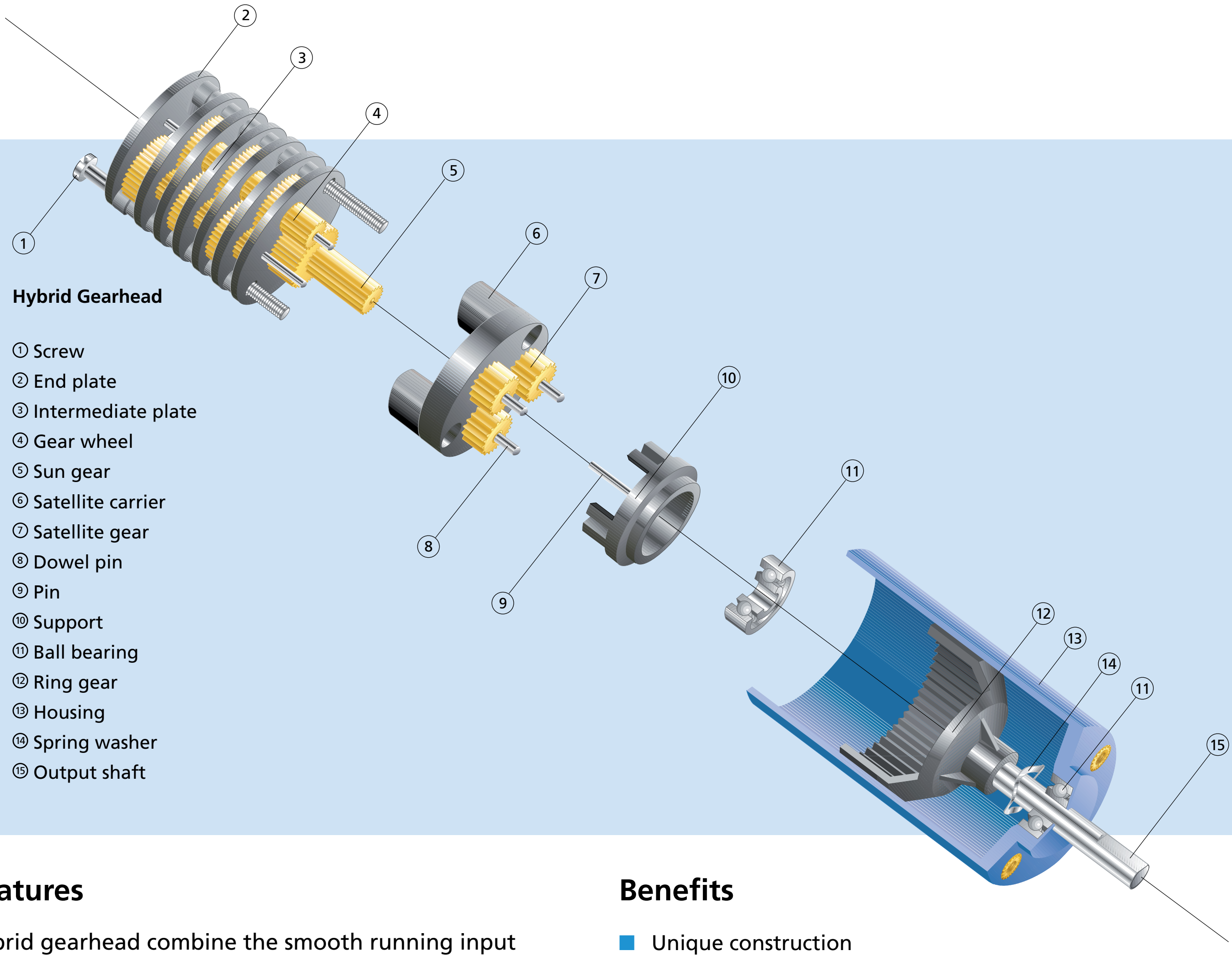
Product Code

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

22/5 377:1

Precision Gearheads

Hybrid Gearheads



Hybrid Gearhead

① Screw
② End plate
③ Intermediate plate
④ Gear wheel
⑤ Sun gear
⑥ Satellite carrier
⑦ Satellite gear
⑧ Dowel pin
⑨ Pin
⑩ Support
⑪ Ball bearing
⑫ Ring gear
⑬ Housing
⑭ Spring washer
⑮ Output shaft

Features

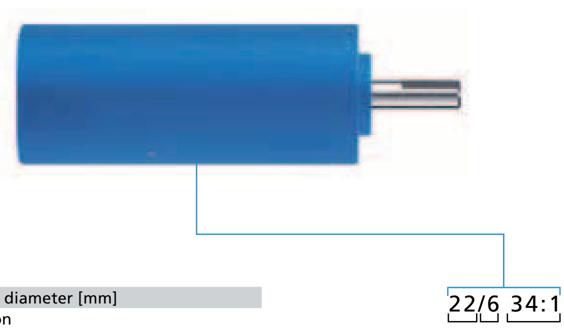
Hybrid gearhead combine the smooth running input stages of a spur gearhead with the power of a planetary output stage. For added power, the output shaft and planet carrier are one single piece. The geartrain is metal but the casing is plastic thereby reducing the overall weight of the gearhead without compromising its performance.

The motor is assembled with a slip fit in the gearhead housing for a seamless concentric fit.

Benefits

- Unique construction
- Combines the advantages of spur and planetary gearhead technology in one unit

Product Code



22	Outer diameter [mm]
/6	Version
34:1	Reduction ratio

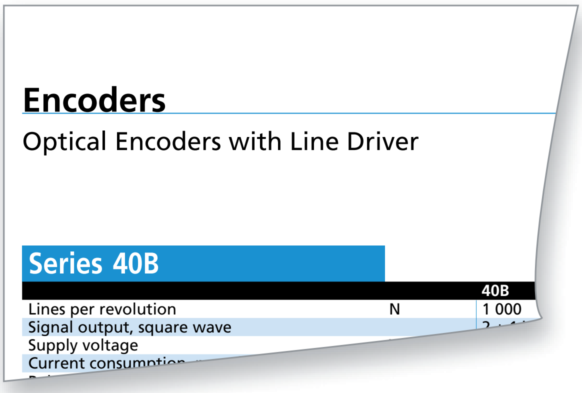
FAULHABER

Encoders

WE CREATE MOTION

Encoders

Technical Information


Encoders

Optical Encoders with Line Driver

Series 40B

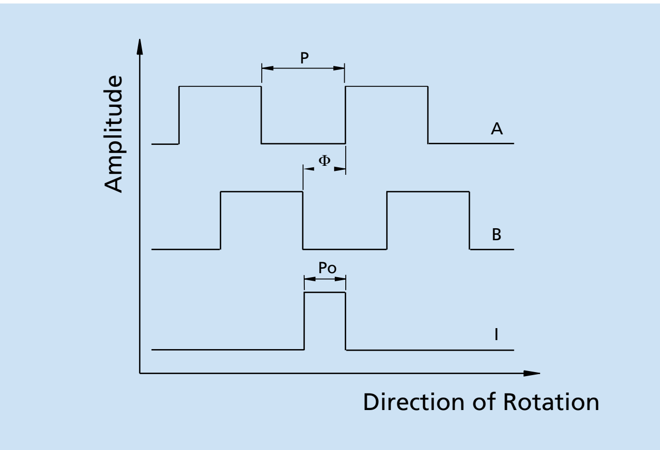
		40B
Lines per revolution	N	1 000
Signal output, square wave		
Supply voltage		
Current consumption		

Notes on technical data

Lines per revolution (N)
The number of incremental encoder pulses per revolution per channel.

The output signal is a quadrature signal which means that both the leading and following edge, or flank, can be evaluated. For example, an encoder with two channels and 256 lines per revolution has 1024 edges, or flanks per revolution.

Output signal
The number of output channels. For example, the IE3 encoders offer 2 channels, A and B, plus an 1 additional index channel.



Supply Voltage (U_{DD})
Defines the range of supply voltage necessary for the encoder to function properly.

Current consumption, typical (I_{DD})
Indicates the typical current consumption of the encoder at the given supply voltage.

Output current, max. (I_{OUT})
Indicates the maximum allowable load current at the signal outputs.

Puls width (P)
Width of the output signal in electrical degrees (°e) of the channels A and B. The value corresponds to one full period, or 360°e at channel A or B.

Index pulse width (P_0)
Indicates the width of the index pulse signal in electrical degrees.

Tolerance ΔP_0:

$$\Delta P_0 = \left| 90° - \frac{P_0}{P} * 180° \right|$$

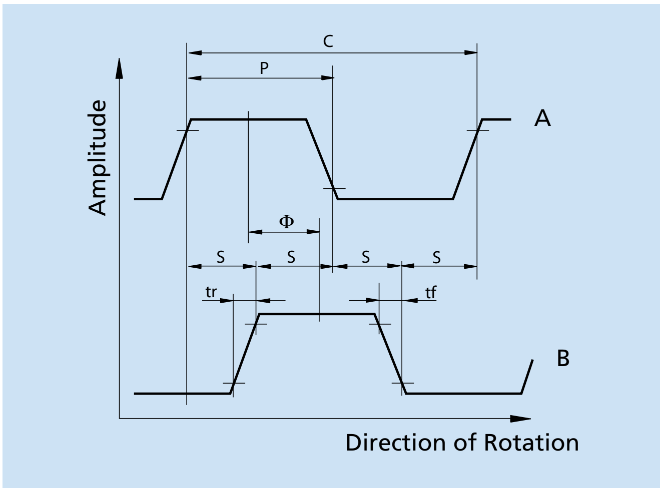
Phase shift, channel A to B (Φ)
The phase shift in electrical degrees between the following edge of output channel A and the leading edge of output channel B.

Phase shift tolerance ($\Delta\Phi$)
Indicates the allowable position error, in electrical degrees, between the following edge of channel A to the leading edge of channel B.

$$\Delta\Phi = \left| 90° - \frac{\Phi}{P} * 180° \right|$$

Signal period (C)
The total period, measured in electrical degrees of one pulse on channel A or B.

Typically one period is 360 °e.



Logic state width (S)
The distance measured in electrical degrees (°e) between two neighbouring signal edges, for example the leading edge of signal A to the leading edge of signal B.

Typically this has a value of 90 °e.

Signal rise/fall time, typical (tr/tf)
Corresponds to the slope of the rising and falling signal edges.

Frequency range (f)
Indicates the maximum encoder frequency. The maximum achievable motor speed can be derived using the following formula.

$$n = \frac{60 \cdot f}{N}$$

Inertia of the code disc (J)
Indicates the additional inertial load due on the motor due to the code wheel.

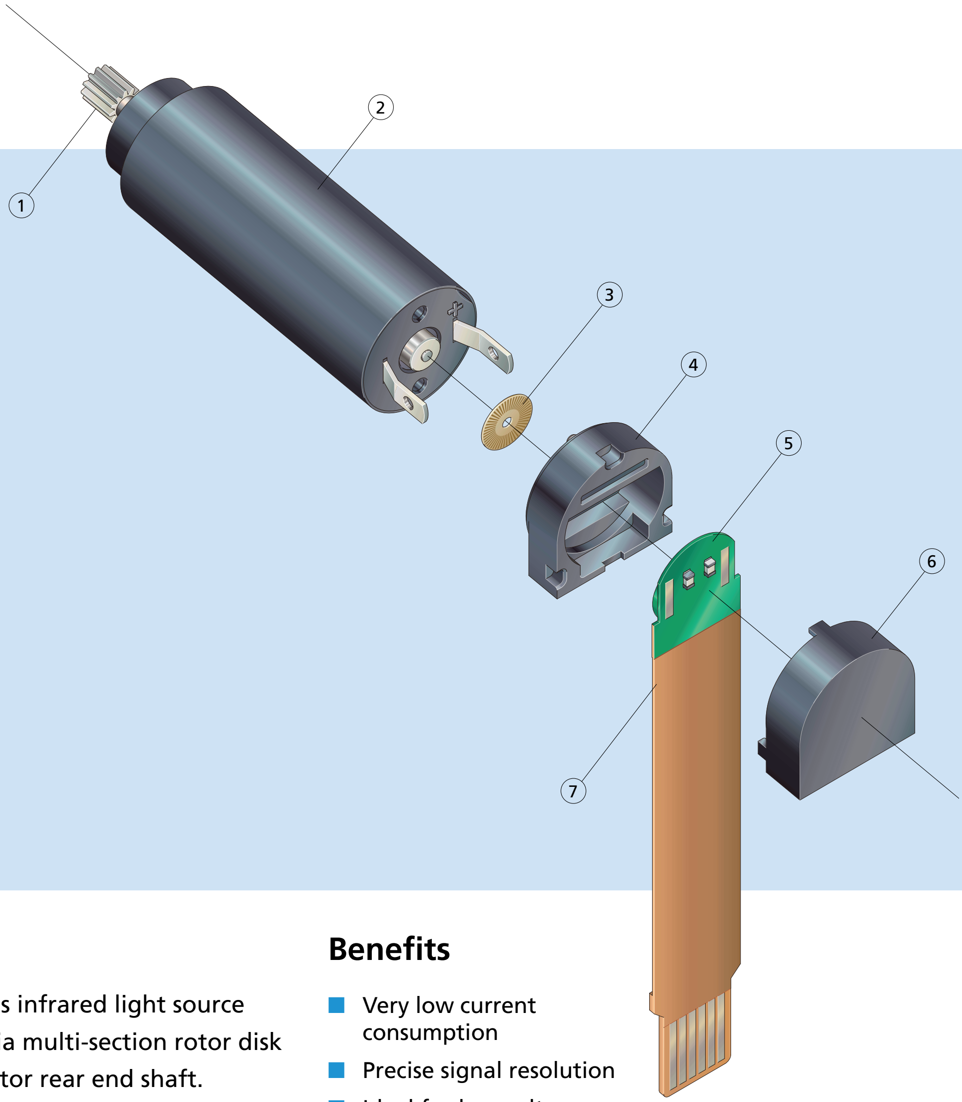
Operating temperature range
Indicates the minimum and maximum allowable temperature range for encoder operation.

Test speed
The speed at which the encoder specifications were measured.

Line Driver
This is an integrated signal amplifier in the encoder that makes it possible to send the encoder signals through much longer connection cables. It is a differential signal with complementary signals to all channels which eliminates sensitivity to ambient electrical noise.

Optical Encoders

Technical Information



Optical Encoder

① Output shaft
② Motor
③ Code wheel
④ Adapter flange
⑤ Encoder PCB
⑥ End cap
⑦ Flex cable

Features

Optical encoders use a continuous infrared light source transmitting through a low-inertia multi-section rotor disk which is fitted directly on the motor rear end shaft. The unit thus generates two output signals with a 90° phase shift.

In optoreflective encoders, the light source is sent and reflected back or alternately absorbed to create the necessary phase shifted pulse.

Benefits

- Very low current consumption
- Precise signal resolution
- Ideal for low voltage battery operation
- Insensitive to magnetic interference
- Extremely light and compact

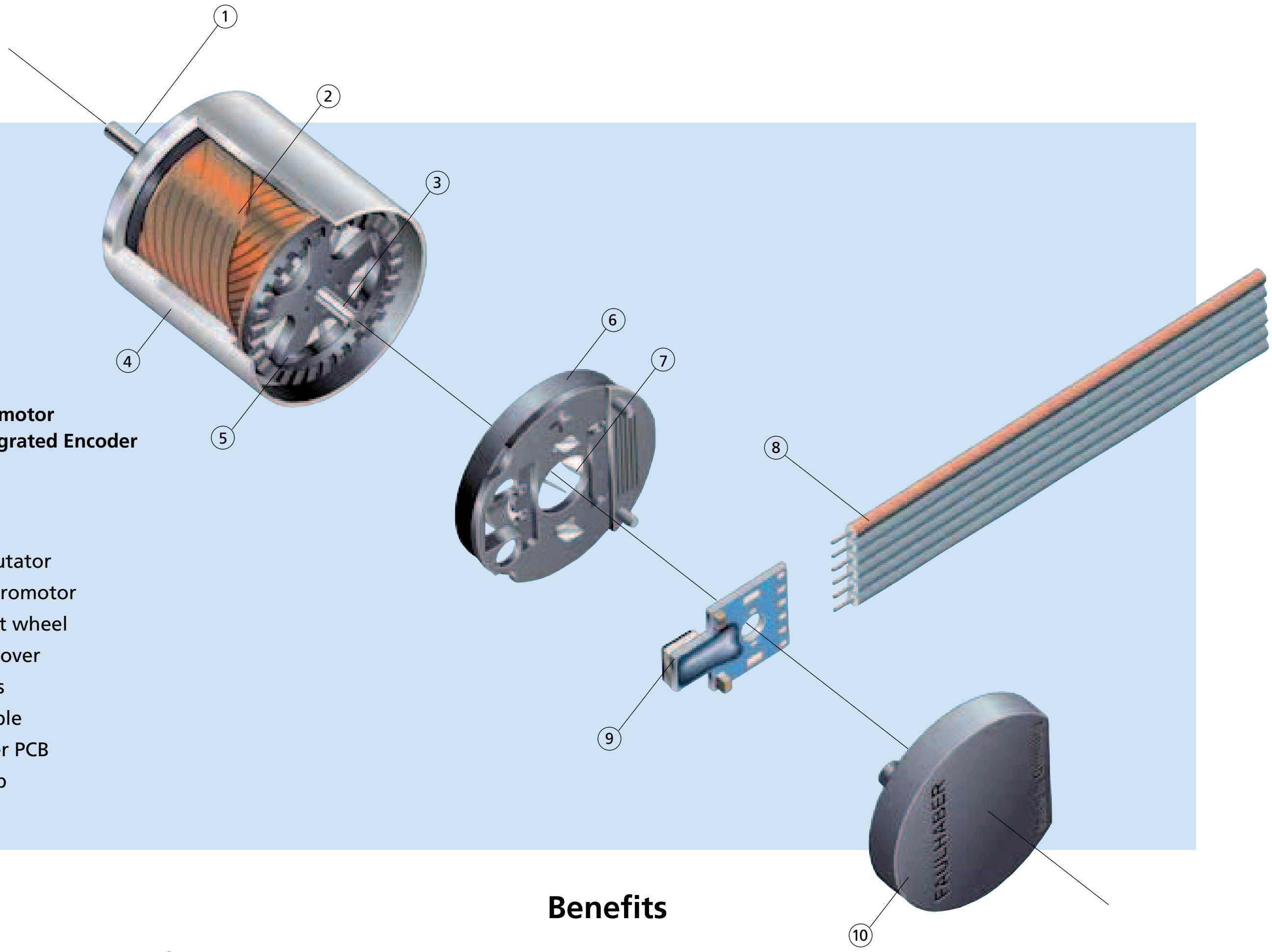
Product Code

PA2 - 50

PA	Encoder series
2	Number of Channels
50	Resolution

Integrated Encoders

Technical Information



DC-Micromotor with integrated Encoder

① Shaft
② Coil
③ Commutator
④ DC-Micromotor
⑤ Magnet wheel
⑥ Brush cover
⑦ Brushes
⑧ Flat cable
⑨ Encoder PCB
⑩ End cap

Features

Series IE2 encoders consist of a rotormounted magnetic toothed ring and a special hybrid circuit.
The magnetic field differences between the tip and base of each tooth are converted into electrical signals by a sensor integrated into the circuit.

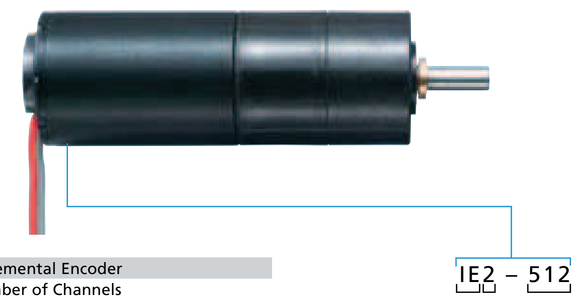
This signal is then processed by a proprietary circuit.
The output consists of two 90°-offset square-wave signals with up to 512 pulses.

The encoder is integrated into the SR-Series motors, increasing its length by a mere 1,4 mm and as built-on option for DC-Micromotors and brushless DC-Servomotors.

Benefits

- Highly compact design
- High resolution up to 2 048 steps per revolution (corresponding to an angular resolution of 0,18°)
- No pull-up resistors across outputs because no open-collector outputs
- Symmetrical pulse edges, CMOS- and TTL -compatible
- Low power consumption
- Available in many combinations

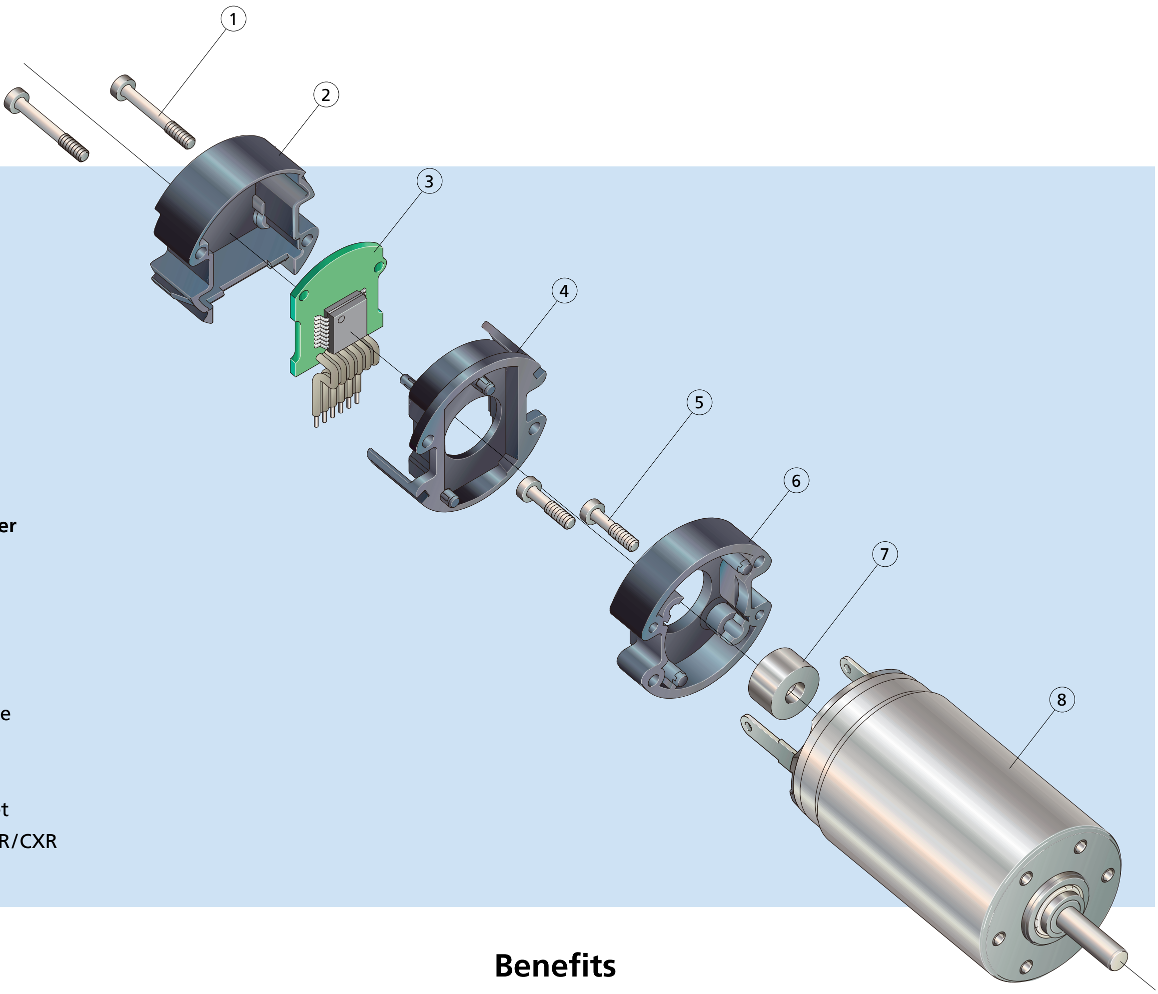
Product Code



IE	Incremental Encoder
2	Number of Channels
512	Resolution

Magnetic Encoders

Single Chip



Magnetic Encoder
Single Chip

① Screws
② Rear cover
③ Encoder PCB
④ Encoder flange
⑤ Screws
⑥ Motor flange
⑦ Sensor magnet
⑧ Motor Serie CR/CXR

Features

FAULHABER IE3 encoders are designed with a diametrically magnetized code wheel which is pressed onto the motor shaft and provides the axial magnetic field to the encoder electronics. The electronics contain all the necessary functions of an encoder including Hall sensors, interpolation, and driver. The Hall sensors sensed the rotational position of the sensor magnet and the signal is interpolated to provide a high resolution position signal.

The encoder signal is a two channel quadrature output with a 90 °e phase shift between channels.
A third channel provides a single index pulse per revolution. These encoders are available as attachable kits or preassembled to FAULHABER DC-Motors with graphite commutation, or as integrated assemblies for many FAULHABER Brushless DC-Servomotors.

Benefits

- Compact modular system
- A wide range of resolutions are available
- Index channel
- Line Drivers are available
- Standardized encoder outuputs
- Ideal for combination with FAULHABER Motion Controllers and Speed Controllers
- Custom modifications including custom resolution, index position and index pulse width are possible

Product Code

IE3 – 256 L

IE	Incremental Encoder
3	Number of Channels
256	Resolution
L	with integrated Line Driver

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