Engineering Data
Servo Actuators PMA

Harmonic Drive SE

Contents

1. General

About this documentation
This document contains safety instructions, technical data and operation rules for servo actuators and servo motors of Harmonic Drive SE.
The documentation is aimed at planners, project engineers, commissioning engineers and machine manufacturers, offering support during selection and calculation of the servo actuators, servo motors and accessories.

Rules for storage
Please keep this document for the entire life of the product, up to its disposal. Please hand over the documentation when re-selling the product.

Additional documentation
For the configuration of drive systems using the products of Harmonic Drive SE, you may require additional documents. Documentation is provided for all products offered by Harmonic Drive SE and can be found in pdf format on the website.

www.harmonicdrive.de

Third-party systems
Documentation for parts supplied by third party suppliers, associated with Harmonic Drive® components, is not included in our standard documentation and should be requested directly from the manufacturers.

Before commissioning servo actuators and servo motors from Harmonic Drive SE with servo drives, we advise you to obtain the relevant documents for each device.

Your feedback
Your experiences are important to us. Please send suggestions and comments about the products and documentation to:

Harmonic Drive SE
Marketing and Communications
Hoenbergstraße 14
65555 Limburg / Lahn
Germany
E-Mail: info@harmonicdrive.de

1.1 Description of Safety Alert Symbols

Symbol	Meaning
DANGER	Indicates an imminent hazardous situation. If this is not avoided, death or serious injury could occur.
WARNING	Indicates a possible hazard. Care should be taken or death or serious injury may result.
ATTENTION	Indicates a possible hazard. Care should be taken or slight or minor injury may result.
ADVICE	Describes a possibly harmful situation. Care should be taken to avoid damage to the system and surroundings.
INFORMATION	This is not a safety symbol. This symbol indicates important information.
	Warning of a general hazard. The type of hazard is determined by the specific warning text.
	Warning of dangerous electrical voltage and its effects.
	Beware of hot surfaces.
	Beware of suspended loads.
	Precautions when handling electrostatic sensitive components.

1.2 Disclaimer and Copyright

2. Safety and Installation Instructions

Please take note of the information and instructions in this document. Specialy designed models may differ in technical detail. If in doubt, we strong recommend that you contact the manufacturer, giving the type designation and serial number for clarification.

2.1 Hazards

⚠ DANGER

Electric servo actuators and motors have dangerous live and rotating parts. All work during connection, operation, repair and disposal must be carried out by qualified personnel as described in the standards EN50110-1 and IEC 60364! Before starting any work, and especially before opening covers, the actuator must be properly isolated. In addition to the main circuits, the user also has to pay attention to any auxilliary circuits.

Observing the five safety rules:
- Disconnect mains
- Prevent reconnection
- Test for absence of harmful voltages
- Ground and short circuit
- Cover or close off nearby live parts

The measures taken above must only be withdrawn when the work has been completed and the device is fully assembled. Improper handling can cause damage to persons and property. The respective national, local and factory specific regulations must be adhered to.

⚠ ATTENTION

The surface temperature of gears, motors and actuators can exceed 55 degrees Celsius. The hot surfaces should not be touched.

ADVICE

Cables must not come into direct contact with hot surfaces.

DANGER

Electric, magnetic and electromagnetic fields are dangerous, in particular for persons with pacemakers, implants or similiar. Vulnerable groups must not be in the immediate vicinity of the products themselves.

DANGER

Built-in holding brakes alone are not functional safe. Particularly with unsupported vertical axes, the functional safety and security can only be achieved with additional, external mechanical brakes.

WARNING

The successful and safe operation of gears, servo actuators and motors requires proper transport, storage and assembly as well as correct operation and maintenance.

ADVICE

Use suitable lifting equipment to move and lift gears, servo actuators and motors with a weight > 20 kg.

INFORMATION

Special versions of products may differ in the specification from the standard. Further applicable data from data sheets, catalogues and offers of the special version have to be considered.

2.2 Intended Purpose

The Harmonic Drive® servo actuators and motors are intended for industrial or commercial applications. They comply with the relevant parts of the harmonised EN 60034 standards series.

Typical areas of application are robotics and handling, machine tools, packaging and food machines and similar machines.

The servo actuators and motors may only be operated within the operating ranges and environmental conditions shown in the documentation (altitude, degree of protection, temperature range etc).
Before plant and machinery which have Harmonic Drive® servo actuators and motors built into them are commissioned, the compliance must be established with the Machinery Directive, Low Voltage Directive and EMC guidelines.

Plant and machinery with inverter driven motors must satisfy the protection requirements in the EMC guidelines. It is the responsibility of the installer to ensure that installation is undertaken correctly.
Signal and power lines must be shielded. The EMC instructions from the inverter manufacturer must be observed in order that installation meets the EMC regulations.

2.3 Non Intended Purpose

The use of servo actuators and motors outside the areas of application mentioned above or, inter alia, other than in the operating areas or environmental conditions described in the documentation is considered as non-intended purpose.

ADVICE

Direct operating from the mains supply is not allowed.

The following areas of application are, inter alia, those considered as non-intended purpose:

- Aerospace
- Areas at risk of explosion
- Machines specially constructed or used for a nuclear purpose whose breakdown might lead to the emission of radio-activity
- Vacuum
- Machines for domestic use
- Medical equipment which comes into direct contact with the human body
- Machines or equipment for transporting or lifting people
- Special devices for use in annual markets or leisure parks

2.4 Declaration of Conformity

PMA series DC servo actuators are considered as components in terms of the Machinery Directive and are thus not in its scope.
As the actuators are designed for voltages below 75 VDC, they are not in the scope of the Low Voltage Directive alike.
Commissioning is prohibited until the final product conforms to the Machinery Directive.

Mini servo actuator with DC motor

PMA Series Servo Actuators combine a highly dynamic DC motor with encoder and PMG Gearbox to create a dynamic compact servo actuator.

Available in four sizes with gear ratios of 50 and 100:1, the actuators can provide a maximum torque from 0.39 to 20 Nm. The accurate positioning of the actuator ensures stable machine characteristics and short cycle times.

Compatible with many common servo controllers on the market, PMA Mini Servo Actuators enable easy setup of compact servo axes – especially for small quantities.

3.2 Ordering Code

Table 9.1

Series	Size	Ratio		Motor winding	Motor feedback system	Special design
PMA	5A	50	100	01	E256ML	According to customer requirements
	8A	50	100		E500ML	
	11A	50	100			
	14A	50	100			

Ordering code

PMA	**-**	**8A**	**-**	**100**	**-**	**01**	**-**	**E500ML**	**-**	**SP**

Table 9.2

Motor winding		
Size	**Ordering code**	**Maximum DC bus voltage**
5A	01	18 VDC
8A		48 VDC
11A		36 VDC
14A		42 VDC

Table 9.3

Motor feedback system		
Ordering code	**Type**	**Protocol**
E256ML	Incremental	–
E500ML		

Explanation of the technical data can be found in the Glossary.

Combinations

Table 10.1

Size		5A	8A	11A	14A
Ratio	30	–	–	–	–
	50	●	●	●	●
	80		–	–	–
	100	●	●	●	●
	120	–	–	–	–
	160	–	–	–	–
Motor winding	01	●	●	●	●
Motor feedback system	E256ML	●	–	–	–
	E500ML	–	●	●	●

● available on request – not available

3.3 Technical Data

3.3.1 General Technical Data

Table 11.1

Lubrication		Harmonic Drive SK-2
Degree of protection (EN 60034-5)		IP40
Ambient operating temperature	°C	0 ... 40
Ambient storage temperature	°C	-20 ... 60
Altitude (a. s. l.)	m	< 1000
Relative humidity (without condensation)	%	35 ... 80
Vibration resistance (DIN IEC 68 Part 2-6, 5 ... 400 Hz)	g	5
Shock resistance (DIN IEC 68 Part 2-27, 18 ms)	g	30

The continuous operating characteristics specified in the following refer to a temperature rise of the motor winding of 100 K at an ambient temperature of 40 degrees Celsius. The continuous operating characteristic curve applies to actuators mounted on an aluminium plate with the follwing dimensions.

Table 11.2

Series	Size	Unit	Dimensions
PMA	5A	[mm]	100 x 100 x 3
	8A	[mm]	150 x 150 x 6
	11A	[mm]	150 x 150 x 6
	14A	[mm]	150 x 150 x 6

3.3.2 Actuator Data

Table 12.1

	Symbol [Unit]	PMA-5A	
Ratio	i [ ]	**50**	**100**
Maximum output torque	T_{max} [Nm]	0.39	0.69
Maximum output speed	n_{max} [rpm]	180	90
Maximum current	I_{max} [A_{rms}]	0.85	0.78
Continuous stall torque	T_0 [Nm]	0.20	0.45
Continuous stall current	I_0 [A_{rms}]	0.44	0.44
Maximum DC bus voltage	U_{DCmax} [V_{DC}]	18	
Electrical time constant (20° C)	t_e [ms]	0.04	
Mechanical time constant (20° C)	t_m [ms]	6.0	
No load current	I_{NLS} [A_{rms}]	0.08	0.05
No load running current constant (30° C)	K_{INL} [x10^{-3} A_{rms}/rpm]	1.4	2.8
No load running current constant (80° C)	K_{INL} [x10^{-3} A_{rms}/rpm]	0.4	0.8
Torque constant (at output)	k_{Tout} [Nm/A_{rms}]	0.56	1.14
Torque constant (at motor)	k_{TM} [Nm/A_{rms}]	0.013	
Voltage constant motor	k_{EM} [V_{rms}/1000 rpm]	1.35	
Motor terminal voltage	U_M [V]	18	
Maximum motor speed	n_{max} [rpm]	9000	
Rated motor speed	n_N [rpm]	4500	
Armature Resistance	R [Ω]	7.4	
Armature Inductance	L [mH]	0.3	
Weight without brake	m [kg]	0.1	

Moment of Inertia

Table 12.2

	Symbol [Unit]	PMA-5A	
Ratio	i [ ]	**50**	**100**
Moment of inertia at outputside			
Moment of inertia without brake	J_{out} [x10^{-4} kgm²]	3.68	14.70
Moment of inertia at motor			
Moment of inertia at motor without brake	J [x10^{-4} kgm²]	0.0002	

Performance Characteristics

The performance curves shown below are valid for the specified ambient operating temperature if the motor terminal voltage is higher or equal to the values given in the ratings table.

Illustration 13.1 PMA-5A-50

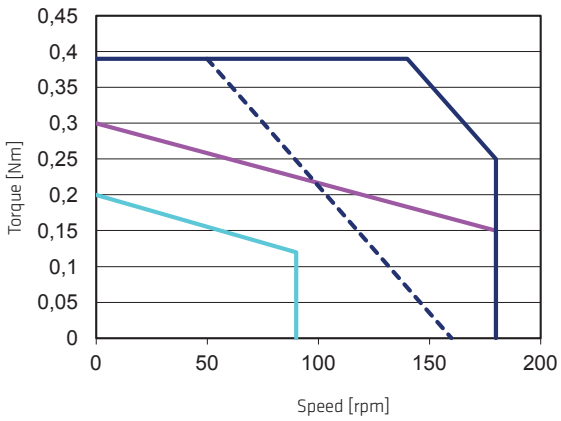
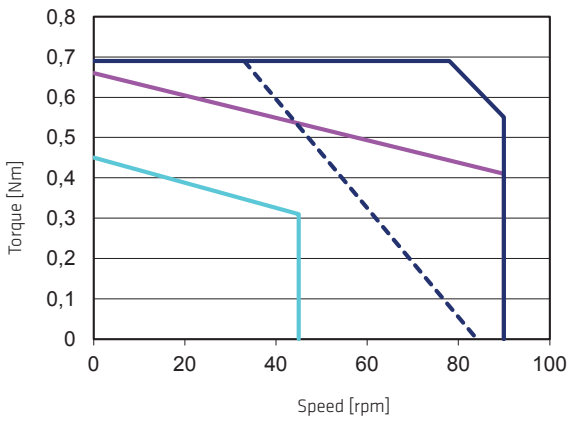


Illustration 13.2 PMA-5A-100



Legend

Intermittent duty — 24 VDC — S3-ED 50% (1 min)
Continuous duty — (PMA-5A: 12 VDC)

Table 14.1

	Symbol [Unit]	PMA-8A	
Ratio	i [ ]	**50**	**100**
Maximum output torque	T_{max} [Nm]	3	4
Maximum output speed	n_{max} [rpm]	120	60
Maximum current	I_{max} [A_{rms}]	1.57	1.03
Continuous stall torque	T_0 [Nm]	0.96	2.06
Continuous stall current	I_0 [A_{rms}]	0.6	0.6
Maximum DC bus voltage	U_{DCmax} [V_{DC}]	48	
Electrical time constant (20° C)	t_e [ms]	0.1	
Mechanical time constant (20° C)	t_m [ms]	4.0	
No load current	I_{NLS} [A_{rms}]	0.09	0.05
No load running current constant (30° C)	K_{INL} [x10^{-3} A_{rms}/rpm]	1.5	3.0
No load running current constant (80° C)	K_{INL} [x10^{-3} A_{rms}/rpm]	0.4	0.9
Torque constant (at output)	k_{Tout} [Nm/A_{rms}]	1.88	3.75
Torque constant (at motor)	k_{TM} [Nm/A_{rms}]	0.044	
Voltage constant motor	k_{EM} [V_{rms}/1000 rpm]	4.59	
Motor terminal voltage	U_M [V]	48	
Maximum motor speed	n_{max} [rpm]	6000	
Rated motor speed	n_N [rpm]	3500	
Armature Resistance	R [Ω]	7.96	
Armature Inductance	L [mH]	0.8	
Weight without brake	m [kg]	0.25	

Moment of Inertia

Table 14.2

	Symbol [Unit]	PMA-8A	
Ratio	i [ ]	**50**	**100**
Moment of inertia at outputside			
Moment of inertia without brake	J_{out} [x10^{-4} kgm²]	32.8	131.0
Moment of inertia at motor			
Moment of inertia at motor without brake	J [x10^{-4} kgm²]	0.013	

Performance Characteristics

The performance curves shown below are valid for the specified ambient operating temperature if the motor terminal voltage is higher or equal to the values given in the ratings table.

Illustration 15.1 PMA-8A-50

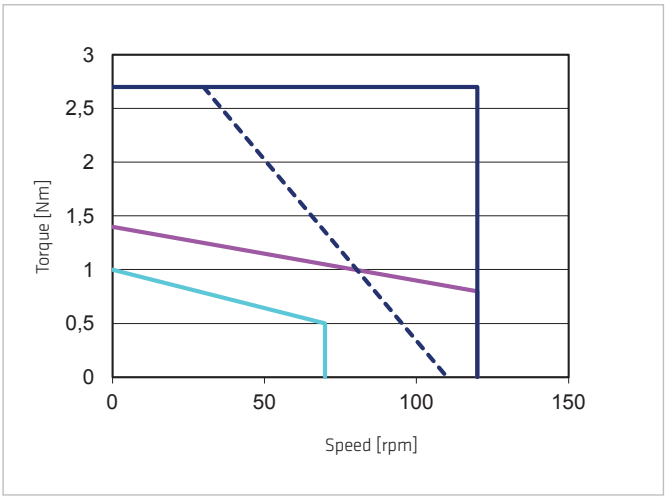
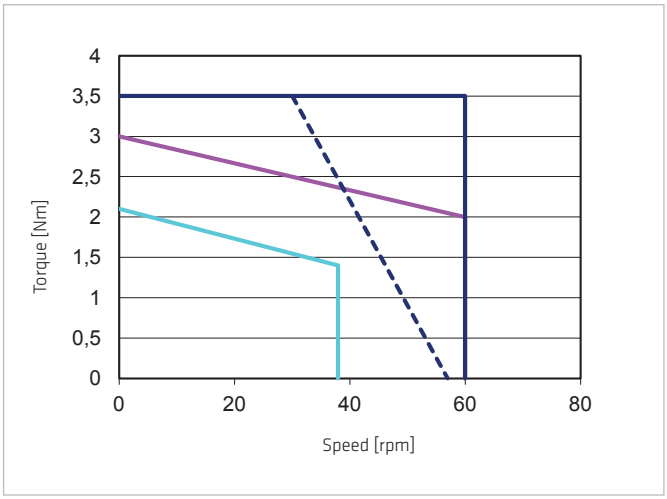


Illustration 15.2 PMA-8A-100



Legend

Intermittent duty — 24 VDC — S3-ED 50% (1 min)
Continuous duty — (PMA-5A: 12 VDC)

Table 16.1

	Symbol [Unit]	PMA-11A	
Ratio	i [ ]	**50**	**100**
Maximum output torque	T_{max} [Nm]	5.0	7.9
Maximum output speed	n_{max} [rpm]	100	50
Maximum current	I_{max} [A_{rms}]	3.35	2.50
Continuous stall torque	T_0 [Nm]	2.8	5.9
Continuous stall current	I_0 [A_{rms}]	1.8	1.8
Maximum DC bus voltage	U_{DCmax} [V_{DC}]	36	
Electrical time constant (20° C)	t_e [ms]	0.18	
Mechanical time constant (20° C)	t_m [ms]	3.0	
No load current	I_{NLS} [A_{rms}]	0.18	0.10
No load running current constant (30° C)	K_{INL} [x10^{-3} A_{rms}/rpm]	4.5	9.0
No load running current constant (80° C)	K_{INL} [x10^{-3} A_{rms}/rpm]	1.3	2.6
Torque constant (at output)	k_{Tout} [Nm/A_{rms}]	1.73	3.47
Torque constant (at motor)	k_{TM} [Nm/A_{rms}]	0.0398	
Voltage constant motor	k_{EM} [V_{rms}/1000 rpm]	4	
Motor terminal voltage	U_M [V]	36	
Maximum motor speed	n_{max} [rpm]	5000	
Rated motor speed	n_N [rpm]	3500	
Armature Resistance	R [Ω]	1.58	
Armature Inductance	L [mH]	0.29	
Weight without brake	m [kg]	0.5	

Moment of Inertia

Table 16.2

	Symbol [Unit]	PMA-11A	
Ratio	i [ ]	**50**	**100**
Moment of inertia at outputside			
Moment of inertia without brake	J_{out} [x10^{-4} kgm²]	109	437
Moment of inertia at motor			
Moment of inertia at motor without brake	J [x10^{-4} kgm²]	0.044	

Performance Characteristics

The performance curves shown below are valid for the specified ambient operating temperature if the motor terminal voltage is higher or equal to the values given in the ratings table.

Illustration 17.1 PMA-11A-50

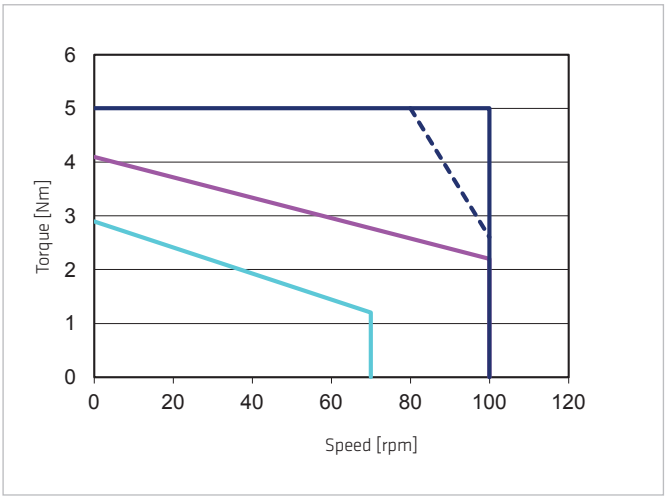
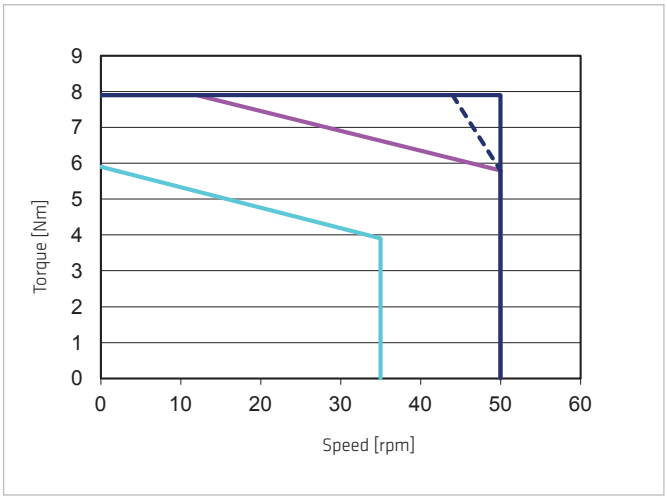


Illustration 17.2 PMA-11A-100



Legend

Intermittent duty — 24 VDC — S3-ED 50% (1 min)
Continuous duty — (PMA-5A: 12 VDC)

Table 18.1

	Symbol [Unit]	PMA-14A	
Ratio	i [ ]	**50**	**100**
Maximum output torque	T_{max} [Nm]	14	20
Maximum output speed	n_{max} [rpm]	100	50
Maximum current	I_{max} [A_{rms}]	6.5	4.8
Continuous stall torque	T_0 [Nm]	4	9
Continuous stall current	I_0 [A_{rms}]	2.4	2.2
Maximum DC bus voltage	U_{DCmax} [V_{DC}]	42	
Electrical time constant (20° C)	t_e [ms]	0.3	
Mechanical time constant (20° C)	t_m [ms]	5.0	
No load current	I_{NLS} [A_{rms}]	0.27	0.16
No load running current constant (30° C)	K_{INL} [x10^{-3} A_{rms}/rpm]	7	14
No load running current constant (80° C)	K_{INL} [x10^{-3} A_{rms}/rpm]	2	4
Torque constant (at output)	k_{Tout} [Nm/A_{rms}]	2.07	4.56
Torque constant (at motor)	k_{TM} [Nm/A_{rms}]	0.053	
Voltage constant motor	k_{EM} [V_{rms}/1000 rpm]	6	
Motor terminal voltage	U_M [V]	42	
Maximum motor speed	n_{max} [rpm]	5000	
Rated motor speed	n_N [rpm]	3500	
Armature Resistance	R [Ω]	2.1	
Armature Inductance	L [mH]	0.6	
Weight without brake	m [kg]	0.76	

Moment of Inertia

Table 18.2

	Symbol [Unit]	PMA-14A	
Ratio	i [ ]	**50**	**100**
Moment of inertia at outputside			
Moment of inertia without brake	J_{out} [x10^{-4} kgm²]	257	1026
Moment of inertia at motor			
Moment of inertia at motor without brake	J [x10^{-4} kgm²]	0.103	

Performance Characteristics

The performance curves shown below are valid for the specified ambient operating temperature if the motor terminal voltage is higher or equal to the values given in the ratings table.

Illustration 19.1 PMA-14A-50

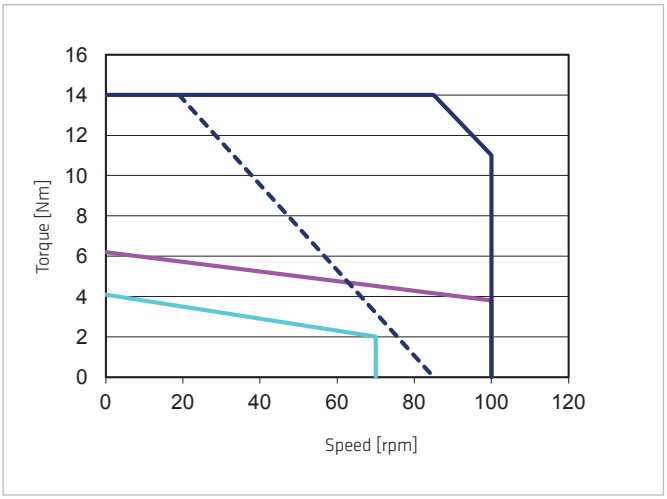
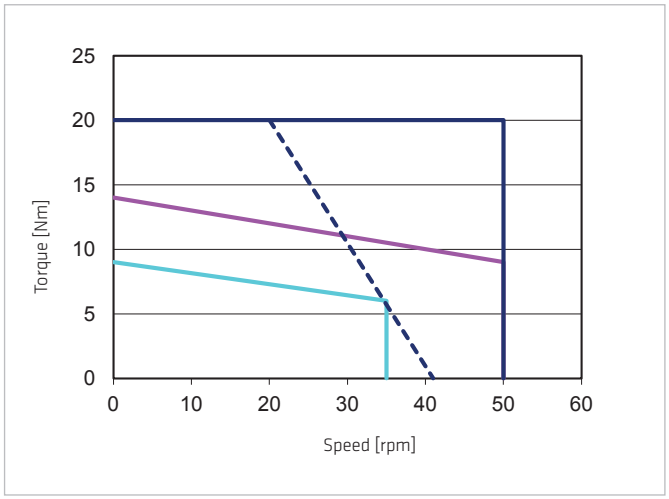


Illustration 19.2 PMA-14A-100



Legend

Intermittent duty — 24 VDC — S3-ED 50% (1 min)
Continuous duty — (PMA-5A: 12 VDC)

3.3.3 Dimensions

Illustration 20.1 PMA-5A [mm]

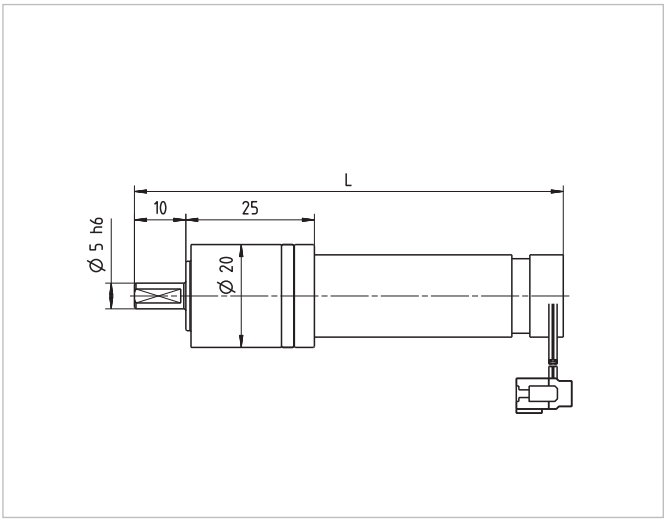


Illustration 20.2 PMA-8A [mm]

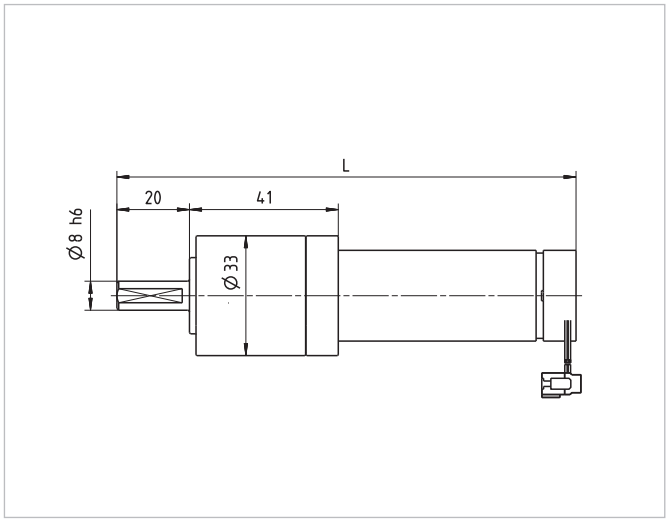


Table 20.3

	Symbol [Unit]	PMA-5A	PMA-8A
Motor feedback system		E256ML	E500ML
Length (without brake)	L [mm]	84	127

Illustration 20.4 PMA-11A [mm]

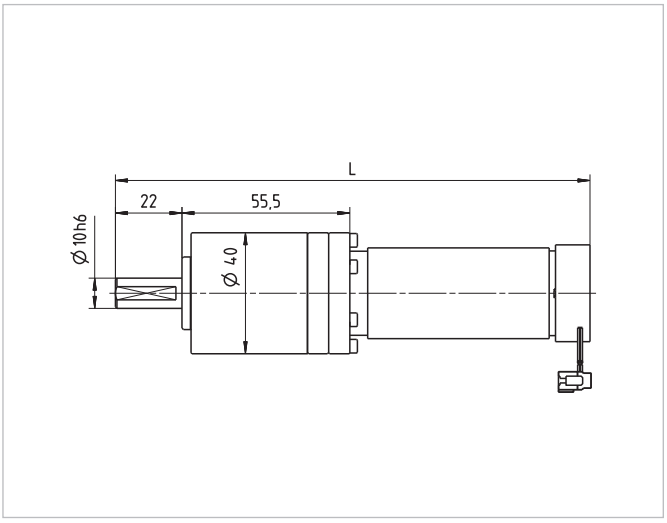


Illustration 20.5 PMA-14A [mm]

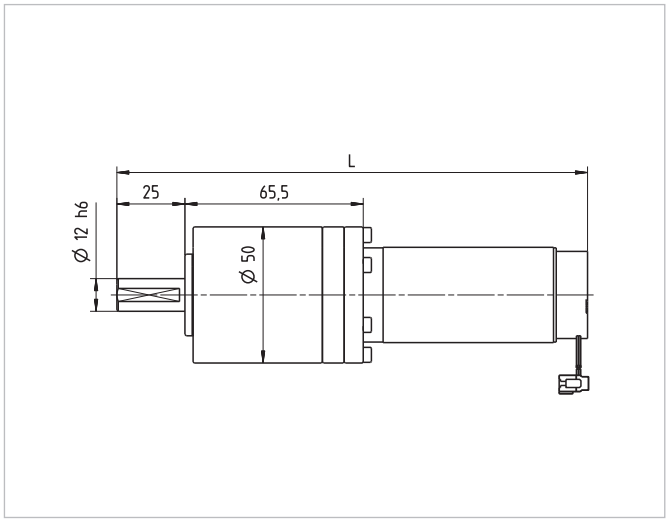


Table 20.6

	Symbol [Unit]	PMA-11A	PMA-14A
Motor feedback system		E500ML	E500ML
Length (without brake)	L [mm]	157	173

3.3.4 Accuracy

Table 21.1

	Symbol [Unit]	PMA-5A	PMA-8A
Transmission accuracy	[arcmin]	< 4,5	< 2,5
Repeatability	[arcmin]	< ± 1,5	< ± 1
Lost Motion	[arcmin]	< 4	< 3

Table 21.2

	Symbol [Unit]	PMA-11A	PMA-14A
Transmission accuracy	[arcmin]	< 2	< 2
Repeatability	[arcmin]	< ± 1	< ± 1
Lost Motion	[arcmin]	< 3	< 3

3.3.5 Torsional Stiffness

Table 21.3

	Symbol [Unit]	PMA-5A		PMA-8A	
T1	[Nm]	0.05		3.9	
T2	[Nm]	0.19		12	
Ratio	i [ ]	50	>50	50	>50
K3	[Nm/rad]	n. v.	100	n. v.	690
K2	[Nm/rad]	55	60	389	500
K1	[Nm/rad]	24	30	246	380

Table 21.4

	Symbol [Unit]	PMA-11A		PMA-14A	
T1	[Nm]	7		29	
T2	[Nm]	25		108	
Ratio	i [ ]	50	>50	50	>50
K3	[Nm/rad]	n. v.	1400	n. v.	4270
K2	[Nm/rad]	1160	1320	2250	3300
K1	[Nm/rad]	622	770	1320	1710

3.3.6 Output Bearing

The output shaft of the PMA servo actuators is supported by two paired and pre-loaded ball bearings. Due to the controlled pre-load, an improvement of the output shaft run-out is achieved. The bearing of the output shaft supports axial as well as radial forces.

The bearing avoids the inclination of the gear, thus a long service life and constant accuracy is reached. For the user, the integration of the output bearing can mean a reduction of design and manufacturing cost as he might not need external bearings.

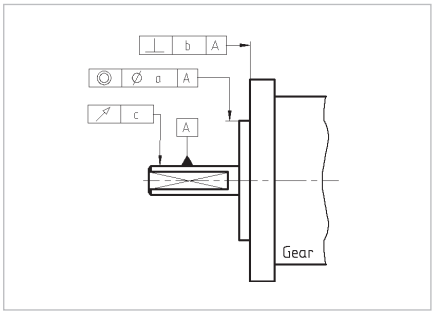
Technical Data

Table 22.1

	Symbol [Unit]	PMA-5A	PMA-8A	PMA-11A	PMA-14A
Maximum radial load [1]	$F_{R\,(max)}$ [N]	59	196	245	392
Maximum axial load	$F_{A\,(max)}$ [N]	29	98	196	392

1) The maximum radial load refers to the middle of the output shaft

Illustration 22.2



Tolerances

Table 22.3

	Symbol [Unit]	PMA-5A	PMA-8A	PMA-11A	PMA-14A
a	[mm]	0.040	0.040	0.040	0.040
b	[mm]	0.040	0.040	0.040	0.040
c	[mm]	0.020	0.020	0.020	0.020

3.3.7 Motor Feedback Systems

Design and Operation

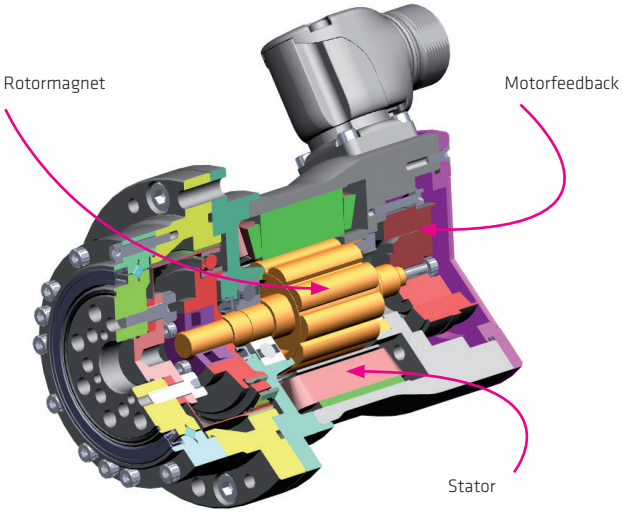
For accurate position setting, the servo motor and its control device are fitted with a measuring device (feedback), which determines the current position (e.g. the angle of rotation set for a starting position) of the motor.

This measurement is effected via a rotary encoder, e.g. a resolver, an incremental encoder or an absolute encoder. The position controller compares the signal from this encoder with the pre-set position value. If there is any deviation, then the motor is turned in the direction which represents a shorter path to the set value which leads to the deviation being reduced. The procedure repeats itself until the value lies incrementally or approximately within the tolerance limits. Alternatively, the motor position can also be digitally recorded and compared by computer to a set value.

Servo motors and actuators from Harmonic Drive SE use various motor feedback systems which are used as position transducers to fulfil several requirements.

Actual Speed

The actual speed is obtained in the servo controller suing the feedback signal, from the cyclical change in position information.



Actual Position

The actual signal value needed for setting the position is formed by adding up the incremental position changes. Where incremental encoders have square wave signals, definition of the edge evaluation can be quadrupled (quad counting).

Resolution

In conjunction with the Harmonic Drive SE high precision gears, the output side position can be recorded via the motor feedback system without any additional angle encoders having to be used. The resolution of the motor feedback system can also be multiplied by gear ratio.

E256ML

Incremental motor feedback with two track signals (A and B) and a reference signal (I) (RS422 Standard)

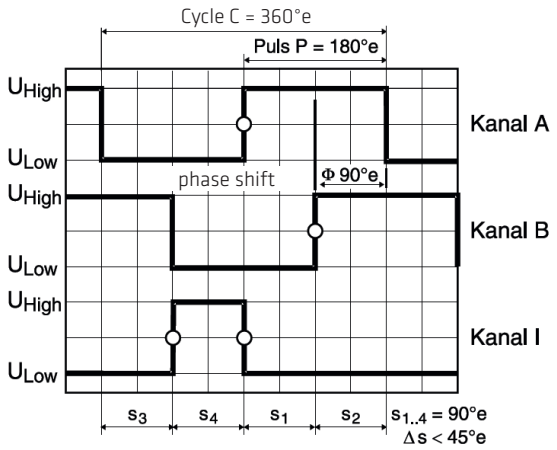
Table 24.1

Ordering code	Symbol [Unit]	E256ML	
Manufacturer's designation		MR 256IMP 3K	
Power supply [1]	U_b [VDC]	5 ± 5%	
Current consumption [1]	I [mA]	15	
Incremental signals		RS422	
Signal form		rectangular	
Number of pulses	n_1 [A / B]	256	
Commutation signals		- / -	
Signal form		- / -	
Number of pulses	n_2 [U / V / W]	- / -	
Reference signal	n_3 [I]	1	
Accuracy [1]	[arcsec]	- / -	
Resolution incremental (motor side) [2]	[qc]	1024	
Resolution (output side) [2]		Gear Ratio PMA	
	i [ ]	50	100
	[arcsec]	25.4	12.7

[1] Source: Manufacturer
[2] with quadcounting

Signal wave form

Illustration 24.2



Valid for direction of rotation
- CW at the motor shaft (when viewed from the front face of the motor)
- CCW at output shaft of PMA

E500ML

Incremental motor feedback with two track signals (A and B) and a reference signal (I) (RS422 Standard)

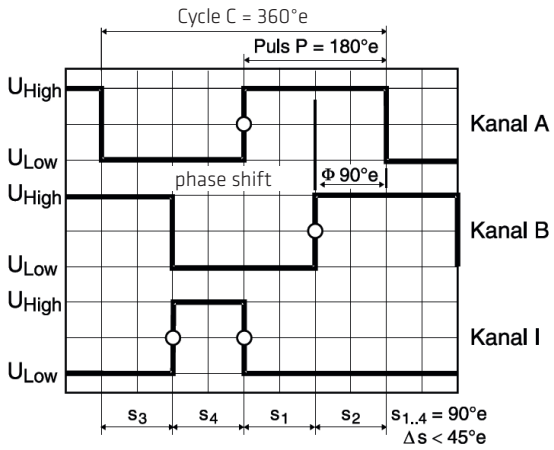
Table 25.1

Ordering code	Symbol [Unit]	E500ML	
Manufacturer's designation		MR 500IMP 3K	
Power supply [1]	U_b [VDC]	5 ± 5%	
Current consumption [1]	I [mA]	15	
Incremental signals		RS422	
Signal form		rectangular	
Number of pulses	n_1 [A / B]	500	
Commutation signals		- / -	
Signal form		- / -	
Number of pulses	n_2 [U / V / W]	- / -	
Reference signal	n_3 [I]	1	
Accuracy [1]	[arcsec]	- / -	
Resolution incremental (motor side) [2]	[qc]	2000	
Resolution (output side) [2]		Gear Ratio PMA	
	i [ ]	50	100
	[arcsec]	13.0	6.5

[1] Source: Manufacturer
[2] with quadcounting

Signal wave form

Illustration 25.2



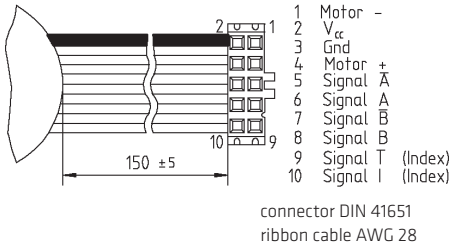
Valid for direction of rotation
- CW at the motor shaft (when viewed from the front face of the motor)
- CCW at output shaft of PMA

3.3.8 Electrical Connections

PMA-5A-xx-01-E256ML

Motor und Encoder

Illustration 26.1

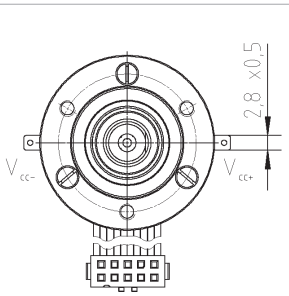


Direction of rotation for output shaft:
CW (when viewed from the front face of the motor)
with positive voltage between motor + versus motor -

PMA-8A (11A, 14A)-xx-01-E500ML

Motor

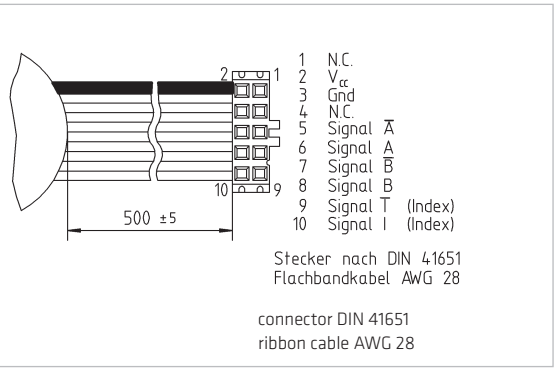
Illustration 26.2



Direction of rotation for output shaft:
CW (when viewed from the front face of the motor)
with positive voltage between motor + versus motor -

Encoder

Illustration 26.3



3.3.9 Materials Used

Housing:	Cast iron, chemically nickel plated and aluminium anodised
Adapter flange:	Aluminium anodised
Screws:	Corrosion protected (Delta-tone) or stainless steel
Shafts:	Stainless steel

4. Actuator Selection Procedure

4.1. Selection Procedure and Calculation Example

ADVICE

We will be pleased to make a gear calculation and selection on your behalf. Please contact our application engineers.

Flowchart for actuator selection

Equation 27.1

$$T_1 = T_L + \frac{2\pi}{60} \cdot \frac{(J_{out} + J_L) \cdot n_2}{t_1}$$

Equation 27.2

$$T_2 = T_L$$

$$T_3 = T_L \cdot (T_1 - T_L)$$

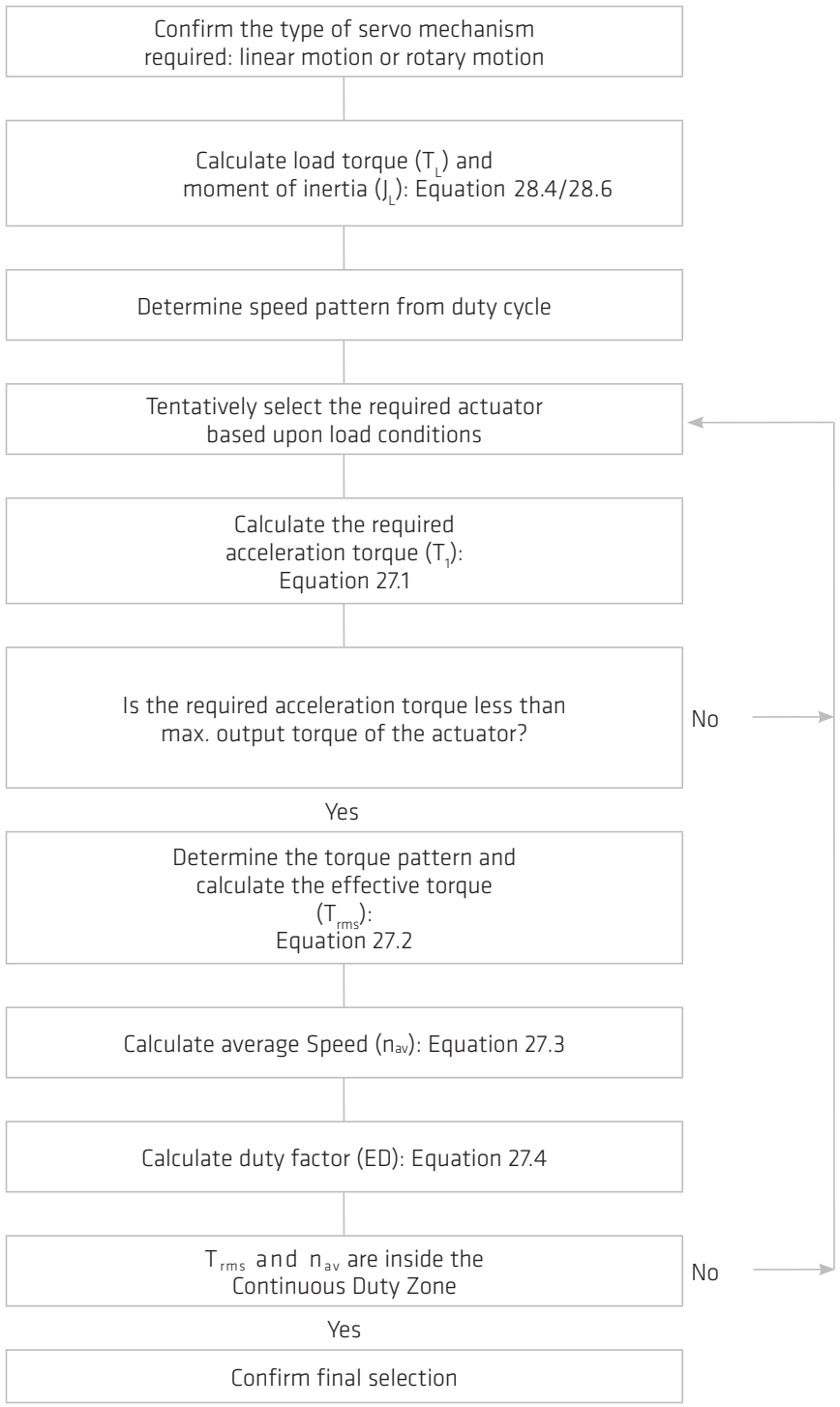
$$T_{rms} = \sqrt{\frac{T_1^2 \cdot t_1 + T_2^2 \cdot t_2 + T_3^2 \cdot t_3}{t_1 + t_2 + t_3 + t_p}}$$

Equation 27.3

$$n_{av} = \frac{\frac{n_2}{2} \cdot t_1 + n_2 \cdot t_2 + \frac{n_2}{2} \cdot t_3}{t_1 + t_2 + t_3 + t_p}$$

Equation 27.4

$$ED = \frac{t_1 + t_2 + t_3}{t_1 + t_2 + t_3 + t_p} \cdot 100\ \%$$



Pre selection conditions

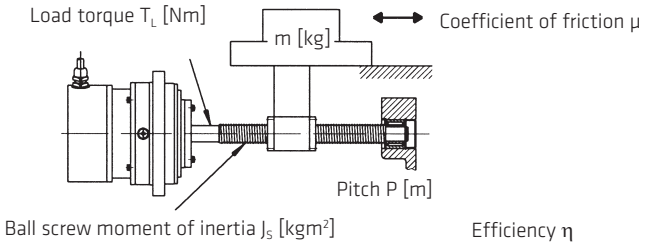
Table 28.1

Load	Confirmation	Catalogue value	Unit
Load max. rotation speed (n_2)	≤ n_{max}	Max. output speed	[rpm]
Load moment of inertia (J_L)	≤ $3J_{Out}$ [1)]	Moment of inertia	[kgm²]

[1)] $J_L \leq 3 \cdot J_{Out}$ is recommended for highly dynamic applications (high responsiveness and accuracy).

Linear horizontal motion

Illustration 28.2



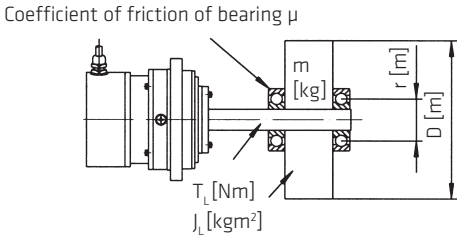
Equation 28.3

$$J_L = J_S + m \left(\frac{P}{2\pi}\right)^2 \text{ [kgm²]}$$

$$T_L = \frac{\mu \cdot m \cdot P \cdot g}{2\pi \cdot \eta} \text{ [Nm]}$$

Rotary motion

Illustration 28.4

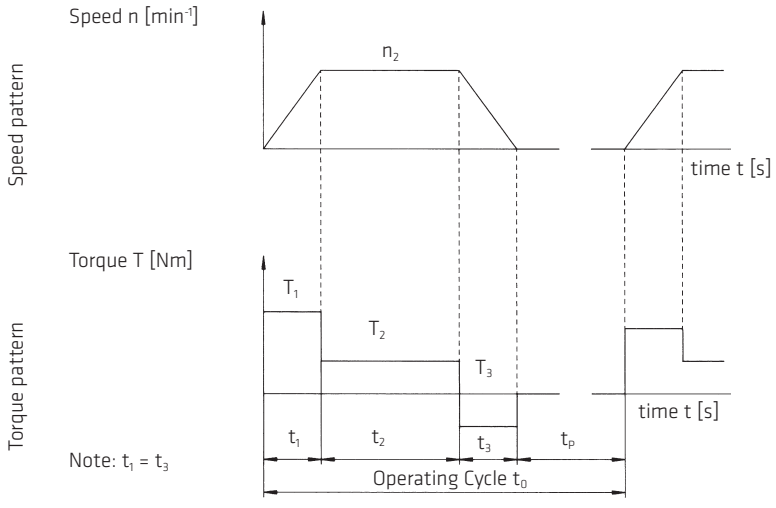


Equation 28.5

$$J_L = \frac{m}{8} \cdot D^2 \text{ [kgm²]}$$

$T_L = \mu \cdot m \cdot g \cdot r$ [Nm] g = 9.81 [m/s²]

Illustration 28.6



Example of actuator selection

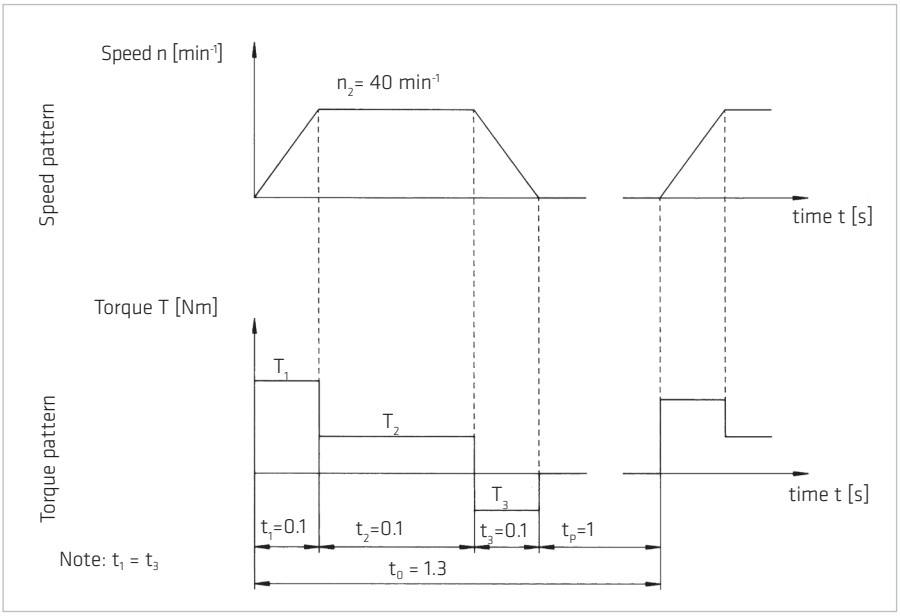
Load Conditions
Assume servo mechanism is used to cyclically position a mass with a horizontal axis of rotation.

Table 29.1

Load rotation speed	n_2 = 40 [min^{-1}]
Load torque (e. g. friction)	T_L = 5 [Nm]
Load inertia	J_L = 1.3 [kgm^2]
Speed pattern	
Acceleration; Deceleration	$t_1 = t_3$ = 0.1 [s]
Operate with rated speed	t_2 = 0.1 [s]
Stand still	t_p = 1 [s]
Total cycle time	t_0 = 1.3 [s]

Please note: Each characteristic value should be converted to the value at the output shaft of the actuator.

Illustration 29.2



Actuator data FHA-25C-50-L

Table 29.3

Max. Torque	T_{max} = 151 [Nm]
Max. output speed	n_{max} = 90 [min^{-1}]
Moment of inertia	J_{Out} = 0.86 [kgm^2]

Actuator selection

Tentatively select a required actuator based upon load conditions. FHA-25C-50 meets the tentative selection requirements from catalogue value (see rating table)

$n_2 = 40\ min^{-1} < n_{max} = 90\ min^{-1}$
$J_L = 1.3\ kgm^2 < 3J_{out} = 2.58\ kgm^2$

Calculate required acceleration torque (T_1)

$$T_1 = 5 + \frac{2\pi}{60} \cdot \frac{(1.3 + 0.86) \cdot 40}{0.1} = 95\ Nm$$

Confirm: Is the required acceleration torque less than the maximum output torque of the actuator?

$T_1 = 95\ Nm < T_{max} = 151\ Nm$

No

Yes

Calculate effective torque (T_{rms})

$T_1 = 95\ Nm$
$T_2 = T_L = 5\ Nm$
$T_3 = T_L - (T_1 - T_L) = -85\ Nm$

$$T_{rms} = \sqrt{\frac{95^2 \cdot 0.1 + 5^2 \cdot 0.1 + (-85)^2 \cdot 0.1}{1.3}} = 35\ Nm$$

Calculation of the average speed

$$n_{av} = \frac{\frac{40}{2} \cdot 0.1 + 40 \cdot 0.1 + \frac{40}{2} \cdot 0.1}{1.3}$$

$n_{av} = 6\ min^{-1}$

Calculation of the duty factor

$$ED = \frac{0.1 + 0.1 + 0.1}{1.3} \cdot 100\%$$

$ED = 23\,\%$

$T_{rms} = 35\ Nm$
$n_{av} = 6\ min^{-1}$

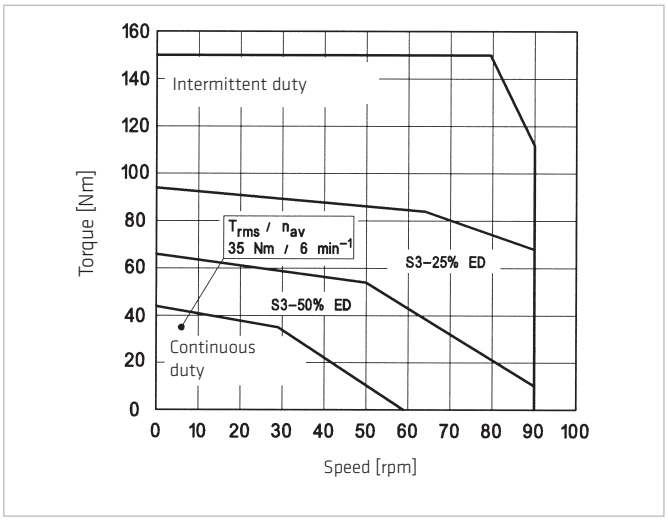
Check according to the performance characteristics

T_{rms} and n_{av} are inside the continuous duty zone

Confirm final selection

Illustration 30.1

FHA-25C-50L



$min^{-1} \triangleq rpm$

ED = 1 min.

ADVICE

We will be pleased to make a gear calculation and selection on your behalf. Please contact our application engineers.

4.2 Calculation of the Torsion Angle

Equation 31.1

$$T \leq T_1$$

$$\varphi = \frac{T}{K_1}$$

Equation 31.2

$$T_1 < T \leq T_2$$

$$\varphi = \frac{T_1}{K_1} + \frac{T - T_1}{K_2}$$

Equation 31.3

$$T > T_2$$

$$\varphi = \frac{T_1}{K_1} + \frac{T_2 - T_1}{K_2} + \frac{T - T_2}{K_3}$$

φ = Angle [rad]
T_1 = Limit torque 1 from Section 3.3.5 [Nm]
T_2 = Limit torque 2 from Section 3.3.5 [Nm]
K_1 = Torsional stiffness up to the limit torque T_1 from Section 3.3.5 [Nm/rad]
K_2 = Torsional stiffness up to the limit torque T_2 from Section 3.3.5 [Nm/rad]
K_3 = Torsional stiffness above the limit torque T_2 from Section 3.3.5 [Nm/rad]

Example

$T = 60$ Nm $\quad K_1 = 6.7 \cdot 10^4$ Nm/rad

$T_1 = 29$ Nm $\quad K_2 = 1.1 \cdot 10^5$ Nm/rad

$T_2 = 108$ Nm $\quad K_3 = 1.2 \cdot 10^5$ Nm/rad

$$\varphi = \frac{29 \text{ Nm}}{6.7 \cdot 10^4 \text{ Nm/rad}} + \frac{60 \text{ Nm} - 29 \text{ Nm}}{11 \cdot 10^4 \text{ Nm/rad}}$$

$$\varphi = 7.15 \cdot 10^{-4} \text{ rad}$$

$$\varphi = 2.5 \text{ arc min}$$

Equation 31.4

$$\varphi \text{ [arc min]} = \varphi \text{ [rad]} \cdot \frac{180 \cdot 60}{\pi}$$

4.3 Output Bearing

4.3.1 Lifetime calculation

For oscillating motion

The operating life at oscillating motion can be calculated using equation 32.1.

Equation 32.1

$$L_{OC} = \frac{10^6}{60 \cdot n_1} \cdot \frac{180}{\varphi} \cdot \left(\frac{C}{f_w \cdot P_C} \right)^B$$

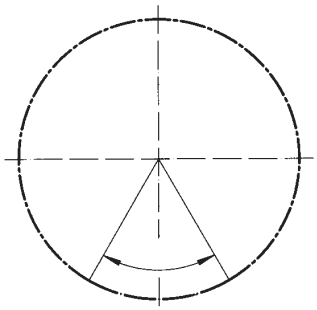
with:

L_{OC} [h]	=	Operating life for oscillating motion
n_1 [cpm]	=	Number of oscillations/minute*
C [N]	=	Dynamic load rating, see table "Output Bearing" in the appropriate product chapter
P_C [N]	=	Dynamic equivalent load
φ [Degree]	=	Oscillating angle
f_W	=	Operating factor (Table 32.3)

* one oscillation means 2φ

Illustration 32.2

Oscillating angle



At oscillating angles < 5° fretting corrosion may occur due to insufficient lubrication. In this case please contact our sales engineer for counter-measures.

Bearing type of selected products see "Output Bearing Ratings" in the appropriate product chapter.

Table 32.3

Bearing type	B
Cross roller bearing	10/3
Four point bearing	3

For continuous operation

The operating life of the output bearing can be calculated using equation 32.3.

Equation 32.4

$$L_{10} = \frac{10^6}{60 \cdot n_{av}} \cdot \left(\frac{C}{f_w \cdot P_C} \right)^B$$

where:

L_{10} [h]	=	Operating life
n_{av} [min^{-1}]	=	Average output speed
C [N]	=	Dynamic load rating, see table "Output Bearing Ratings"
P_C [N]	=	Dynamic equivalent load
f_W	=	Operating factor

Average output speed

$$n_{av} = \frac{|n_1| t_1 + |n_2| t_2 + \ldots + |n_n| t_n}{t_1 + t_2 + \ldots + t_n + t_p}$$

Table 32.5

Load conditions	f_W
No impact loads or vibrations	1 ...1.2
Normal rotating, normal loads	1.2 ... 1.5
Impact loads and/or vibrations	1.5 ... 3

Dynamic equivalent load

Equation 33.1

$$P_C = x \cdot \left(F_{rav} + \frac{2M}{dp} \right) + y \cdot F_{aav}$$

Equation 33.2

$$F_{rav} = \left(\frac{|n_1| \cdot t_1 \cdot (|F_{r1}|)^B + |n_2| \cdot t_2 \cdot (|F_{r2}|)^B + \ldots + |n_n| \cdot t_n \cdot (|F_{rn}|)^B}{|n_1| \cdot t_1 + |n_2| \cdot t_2 + \ldots + |n_n| \cdot t_n} \right)^{1/B}$$

Equation 33.3

$$F_{aav} = \left(\frac{|n_1| \cdot t_1 \cdot (|F_{a1}|)^B + |n_2| \cdot t_2 \cdot (|F_{a2}|)^B + \ldots + |n_n| \cdot t_n \cdot (|F_{an}|)^B}{|n_1| \cdot t_1 + |n_2| \cdot t_2 + \ldots + |n_n| \cdot t_n} \right)^{1/B}$$

where:

F_{rav} [N]	=	Radial force
F_{aav} [N]	=	Axial force
d_p [m]	=	Pitch circle
x	=	Radial load factor (Table 33.4)
y	=	Axial load factor (Table 33.4)
M	=	Tilting moment

Table 33.4

Load factors	x	y
$\frac{F_{aav}}{F_{rav} + 2 \cdot M / dp} \leq 1.5$	1	0.45
$\frac{F_{aav}}{F_{rav} + 2 \cdot M / dp} > 1.5$	0.67	0.67

Illustration 33.5

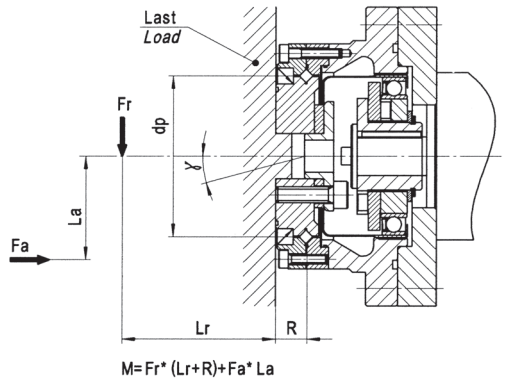
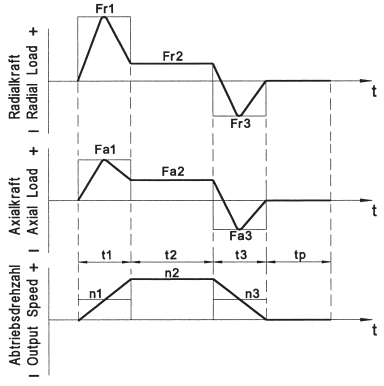


Illustration 33.6



Please note:
F_{rx} represents the maximum radial force.
F_{ax} represents the maximum axial force.
t_p represents the pause time between cycles.

4.3.2 Angle of Inclination

The angle of inclination of the output flange, as a function of the tilting moment acting on the output bearing, can be calculated by means of equation 34.1:

Equation 34.1

$$\gamma = \frac{M}{K_B}$$

with:

γ [arcmin]	=	Angle of inclination of the output flange
M [Nm]	=	Tilting moment acting on the output bearing
K_B [Nm/arcmin]	=	Moment stiffness of the output bearing

5. Installation and Operation

5.1 Transport and Storage

The transportation of the servo actuators and motors should always be in the original packaging. If the servo actuators and motors are not put into operation immediately after delivery, they should be stored in a dry, dust and vibration-free environment. Storage should be for no longer than 2 years at room temperatures (between +5° C ... +40° C) so that the grease life is preserved.

INFORMATION

Tensile forces in the connecting cable must be avoided.

5.2 Installation

Check the performance and protection and check the suitability of the conditions at the installation site. Take suitable constructive measures to ensure that no liquid (water, drilling emulsion, coolant) can penetrate the output bearing or encoder housing.

ADVICE

The installation must be protected against impact and pressure on the gear.

The mounting must be such that heat loss can be adequately dissipated.

No radial forces and axial forces may act to the protection sleeve of the hollow shaft actuator.

During installation, the actuator must be fitted ensuring the machine housing can be rotated without terminals. Already low terminals may affect the accuracy of the gear and, should this be the case, the installation of the machine housing should be checked.

5.3 Mechanical Installation

The data necessary for mounting the actuator and for connecting to the load are given in table 35.1.

Table 35.1

	Symbol [Unit]	PMA-5A	PMA-8A	PMA-11A	PMA-14A
Housing assembly					
Number of screws		3	3	4	4
Screw size		M2	M3	M4	M5
Screw quality		8.8	8.8	8.8	8.8
Pitch circle diameter	[mm]	16.4	26	34	40
Screw tightening torque	[Nm]	0.38	1.34	3.0	5.9

ADVICE

All values valid for completely degreased connection surfaces only (friction coefficient μk = 0,15).

Tightening torque valid for mounting flange made of high-tensile aluminium (F47) or steel only.
Minimum clamping length of 1 x d required.

Protect screws against loosening.

For securing screws, LOCTITE 243 is recommended.

5.4 Electrical Installation

All work should be carried out with power off.

DANGER

Electric servo actuators and motors have dangerous live and rotating parts. All work during connection, operation, repair and disposal must be carried out only by qualified personnel as described in the standards EN50110-1 and IEC 60364! Before starting any work, and especially before opening covers, the actuator must be properly isolated. In addition to the main circuits, the user also has to pay attention to any auxilliary circuits.

Observing the five safety rules:
- Disconnect mains
- Prevent reconnection
- Test for absence of harmful voltages
- Ground and short circuit
- Cover or close off nearby live parts

The measures taken above must only be withdrawn when the work has been completed and the device is fully assembled. Improper handling can cause damage to persons and property. The respective national, local and factory specific regulations must be adhered to.

DANGER

Due to the fact that the motor contains permanent magnets, a voltage is generated at the motor terminals when the rotor is turned.

ADVICE

- The connecting leads should be suitable for the type of use, as well as the voltages and amperages concerned.
- The protective earth must be connected to the terminal marked PE.
- All cables used should be provided with a shield and in addition, the encoder cable should feature twisted pair leads.
- The power supply is switched off before connecting and disconnecting the power connection and signal connections.

ADVICE

Encoders and sensors contain electrostatically sensitive components, observe the ESD measures!

5.5 Commissioning

NOTE

Commissioning must be executed in accordance with the documentation of Harmonic Drive SE.

Before commissioning, please check that:
- The actuator is properly mounted,
- All electrical connections and mechanical connections are designed according to requirements,
- The protective earth is properly connected,
- All attachments (brakes, etc) are operational,
- Appropriate measures have been taken to prevent contact with moving and live parts,
- The maximum speed nmax is specified and cannot be exceeded,
- The set up of the drive parameters has been executed,
- The commutation is adjusted correctly.

⚠ ATTENTION

Check the direction of rotation of the load uncoupled.

In the event of changes in the normal operating behaviour, such as increased temperature, noise or vibration, switch the actuator off. Determine the cause of the problem and contact the manufacturer if necessary. Even if the actuator is only on test, do not put safety equipment out of operation.

This list may not be complete. Other checks may also be necessary.

ADVICE

Due to heat generation from the actuator itself, tests outside the final mounting position should be limited to 5 minutes of continuous running at a motor speed of less than 1000 rpm.

These values should not be exceeded in order to avoid thermal damage to the actuator.

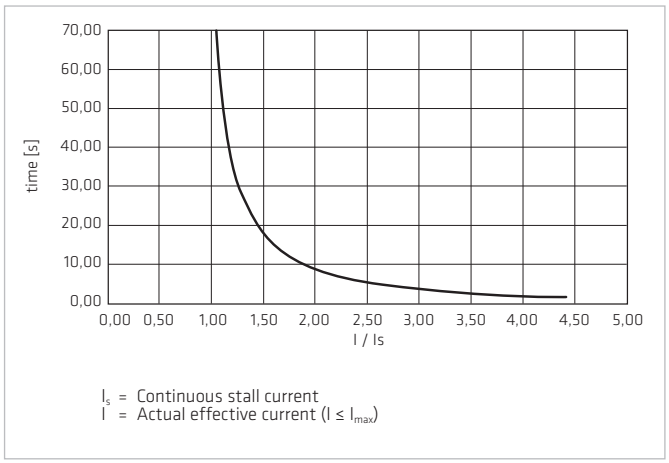
5.6 Overload Protection

Temperature sensors are integrated into the servo actuators and motors to protect them from.

To protect the servo actuators and motors from temperature overload sensors are integrated into the motor windings. The temperature sensors alone do not guarantee motor protection. Protection against overload of the motor winding is only possible only with an input speed > 0. For special applications (eg load at standstill or very low speed) is an additional overload protection by limiting the overload period.

The built specification of the integrated temperature sensors can be found in the technical data.

Illustration 37.1 Over load characteristic



In addition, it is recommended to protect the motor winding against overload by the use of I^2t monitoring integrated in the controller. The graph shows an example of the overload characteristic for the I^2t monitoring. The overload factor is the ratio between the actual RMS current and continuous stall current.

5.7 Protection against Corrosion and Penetration of Liquids and Debris

The product achieves the degree of protection according to the table Technical Data with assembled and plugged connectors, provided that the connectors are suitable for this degree of protection and no corrosion is caused on the running surfaces of the oil seal by the environmental conditions (liquids, gases, dew formation). Special designs can vary from this degree of protection.

Contact between sharp edged or abrasive objects (cutting chips, splinters, metallic or minerals dusts etc) and the output shaft seal must be prevented. Permanent contact between the output shaft seal and a permanent liquid covering should also be prevented.
A change in the operating temperature of a completely sealed actuator can lead to a pressure differential between the outside and the inside temperature of the actuator. This can cause any liquid covering the output shaft seal to be drawn into the housing which could cause corrosive damage.

As a countermeasure, we recommend the use of an additional shaft seal (to be provided by the user) or the maintenance of a constant pressure inside the actuator. Please contact Harmonic Drive SE for further information.

ADVICE

Specification sealing air: constant pressure in the actuator as described above; the supplied air must be dry and filtered with pressure at not more than 10^4 Pa.

5.8 Shutdown and Maintenance

In case of malfunctions or maintenance measures, or to shutdown the motors, proceed as follows:

1. Follow the instructions in the machine documentation.
2. Bring the actuator on the machine to a controlled standstill.
3. Turn off the power and the control voltage on the controller.
4. For motors with a fan unit; turn off the motor protection switch for the fan unit.
5. Turn off the mains switch of the machine.
6. Secure the machine against accidental movement and against unauthorised operation.
7. Wait for the discharge of electrical systems then disconnect all the electrical connections.
8. Secure the motor, and possibly the fan unit, before disassembly against falling or movement then pay attention to the mechanical connections.

⚠ DANGER

Risk of death by electric voltages. Work in the area of live parts is extremely dangerous.

- Work on the electrical system may only be performed by qualified electricians. The use of a power tool is absolutely necessary.

Observing the five safety rules:
- Disconnect mains
- Prevent reconnection
- Test for absence of harmful voltages
- Ground and short circuit
- Cover or close off nearby live parts

The measures taken above must only be withdrawn when the work has been completed and the device is fully assembled. Improper handling can cause damage to persons and property. The respective national, local and factory specific regulations must be adhered to.

⚠ ATTENTION

Burns from hot surfaces with temperatures of over 100° C

Let the motors cool down before starting work. Cooling times of up to 140 minutes may be necessary.
Wear protective gloves.
Do not work on hot surfaces!

⚠ WARNING

Persons and property during maintenance and operation

Never perform maintenance work on running machinery. Secure the system during maintenance against re-starting and unauthorised operation.

Cleaning

Excessive dirt, dust or chips may adversely affect the operation of the device and can, in extreme cases, lead to failure. At regular intervals you should therefore, clean the device to ensure a sufficient dissipation of the surface heat. Insufficient heat emissions can have undesirable consequences. The lifetime of the device is reduced if temperature overloads occures. Overtemperature can lead to the shutdown of the device.

Checking of electric connections

⚠ DANGER

Lethal electric shock by touching live parts!

In any case of defects of the cable sheath the system must be shut down immediately and the damaged cable should be replaced. Do not make any temporary repairs on the connection cables.

- Connection cord should be periodically checked for damage and replaced if necessary.
- Check optionally installed power chains (power chains) for defects.
- Protective conductor connections should be in a good condition and tightness checked at regular intervals. Replace if necessary.

Control of mechanical fasteners

The fastening screws and the load of the housing must be checked regularly.

6. Decommissioning and Disposal

The gears, servo actuators and motors from Harmonic Drive SE contain lubricants for bearings and gears as well as electronic components and printed circuit boards. Since lubricants (greases and oils) are considered hazardous substances in accordance with health and safety regulations, it is necessary to dispose of the products correctly. Please ask for safety data sheet where necessary.

7. Glossary

7.1 Technical Data

AC Voltage constant k_{EM} [V_{rms} / 1000 rpm]

Effective value of the induced motor voltage measured at the motor terminals at a speed of 1000 rpm and an operating temperature of 20° C.

Ambient operating temperature [° C]

The intended operating temperature for the operation of the drive.

Average input speed (grease lubrication) $n_{av\ (max)}$ [rpm]

Maximum permissible average gear input speed for grease lubrication.

Average input speed (oil lubrication) $n_{av\ (max)}$ [rpm]

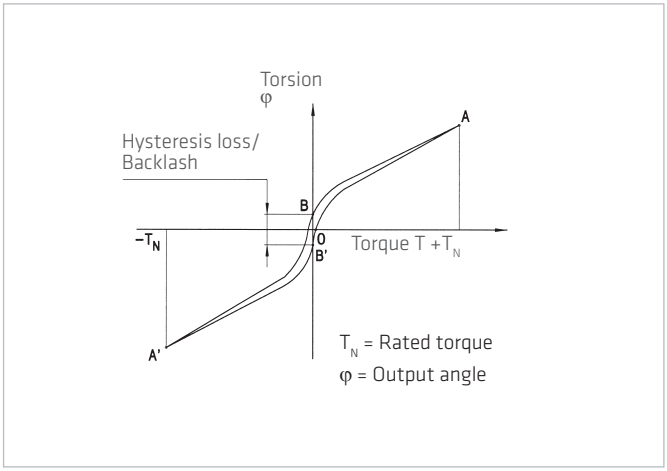
Maximum permissible average gear input speed for oil lubrication.

Average torque T_A [Nm]

When a variable load is applied to the gear, an average torque should be calculated for the complete operating cycle. This value should not exceed the specified T_A limit.

Backlash (Harmonic Planetary gears) [arcmin]

When subjected to the rated torque, Harmonic Planetary gears display characteristics shown in the hysteresis curve. When a torque is applied to the output shaft of the gear with the input shaft locked, the torque-torsion relationship can be measured at the output. Starting from point 0 the graph follows successive points A-B-A'-B'-A where the value B-B' is defined as the backlash or hysteresis.



Brake closing time t_C [ms]

Delay time to close the brake.

Brake current to hold I_{HBr} [A_{DC}]

Current for applying the brake.

Brake current to open I_{OBr} [A_{DC}]

Current required to open the brake.

Brake holding torque T_{Br} [Nm]

Torque the actuator can withstand when the brake is applied, with respect to the output.

Brake opening time t_O [ms]

Delay time for opening the brake.

Brake voltage U_{Br} [VDC]

Terminal voltage of the holding brake.

Continuous stall current I_0 [A_{rms}]

Effective value of the motor phase current to produce the stall torque.

Continuous stall torque T_0 [Nm]

Allowable actuator stall torque.

Demagnetisation current I_E [A_{rms}]

Current at which rotor magnets start to demagnetise.

Dynamic axial load $F_{A\ dyn\ (max)}$ [N]

With the bearing rotating, this is the maximum allowable axial load with no additional radial forces or tilting moments applied.

Dynamic load rating C [N]

Maximum dynamic load that can be absorbed by the output bearing before permanent damage may occur.

Dynamic radial load $F_{R\ dyn\ (max)}$ [N]

With the bearing rotating, this is the maximum allowable radial load with no additional axial forces or tilting moments applied.

Dynamic tilting moment $M_{dyn\ (max)}$ [Nm]

With the bearing rotating, this is the maximum allowable tilting moment with no additional axial forces or radial forces applied.

Electrical time constant τ_e [s]

The electrical time constant is the time required for the current to reach 63% of its final value.

Hollow shaft diameter d_H [mm]

Free inner diameter of the continuous axial hollow shaft.

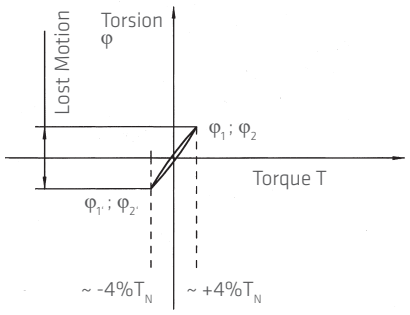
Inductance (L-L) $L_{L\text{-}L}$ [mH]

Terminal inductance calculated without taking into account the magnetic saturation of the active motor parts.

Lost Motion (Harmonic Drive® Gearing) [arcmin]

Harmonic Drive® Gearing exhibits zero backlash in the teeth. Lost motion is the term used to characterise the torsional stiffness in the low torque region.

The illustration shows the angle of rotation φ measured against the applied output torque as a hysteresis curve with the Wave Generator locked. The lost motion measurement of the gear is taken with an output torque of about ± 4% of the rated torque.



Maximum current I_{max} [A]

The maximum current is the maximum current that can be applied for a short period.

Maximum DC bus voltage $U_{DC\ (max)}$ [VDC]

The maximum DC bus power supply for the correct operation of the actuator. This value may only be exceeded for a short period during the braking or deceleration phase.

Maximum hollow shaft diameter $d_{H\ (max)}$ [mm]

For gears with a hollow shaft, this value is the maximum possible diameter of the axial hollow shaft.

Maximum input speed (grease lubrication) $n_{in\ (max)}$ [rpm]

Maximum allowable input speed with grease lubrication.

Maximum input speed (oil lubrication) $n_{in\ (max)}$ [rpm]

Maximum allowable input speed for gearing with oil lubrication.

Maximum motor speed n_{max} [rpm]

The maximum allowable motor speed.

Maximum output speed n_{max} [rpm]

The maximum output speed. Due to heating issues, this may only be momentarily applied during the operating cycle. The maximum output speed can occur any number of times as long as the calculated average speed is within the permissible continuous operation duty cycle.

Maximum output torque T_{max} [Nm]

Specifies the maximum allowable acceleration and deceleration torques. For highly dynamic processes, this is the maximum torque available for a short period. The maximum torque can be parameterised by the control unit where the maximum current can be limited. The maximum torque can be applied as often as desired, as long as the calculated average torque is within the permissible continuous operation duty cycle.

Maximum power P_{max} [W]

Maximum power output.

Mechanical time constant τ_m [s]

The mechanical time constant is the time required to reach 63% of its maximum rated speed in a no-load condition.

Momentary peak torque T_M [Nm]

In the event of an emergency stop or collision, the Harmonic Drive® Gearing may be subjected to a brief collision torque. The magnitude and frequency of this collision torque should be kept to a minimum and under no circumstances should the collision torque occur during the normal operating cycle.

Moment of inertia J [kgm^2]

Mass moment of inertia at motor side.

Moment of inertia J_{in} [kgm^2]

Mass moment of inertia of the gearing with respect to the input.

Moment of inertia J_{out} [kgm^2]

Mass moment of inertia with respect to the output.

Motor terminal voltage (Fundamental wave only) U_M [V_{rms}]

Required fundamental wave voltage to achieve the specified performance. Additional power losses can lead to restriction of the maximum achievable speed.

Number of pole pairs p

Number of magnetic pole pairs on the rotor of the motor.

Offset R [mm]

Distance between output bearing and contact point of the load.

Pitch circle diameter d_p [mm]

Pitch circle diameter of the output bearing rolling elements.

Protection IP

The degree of protection according to EN 60034-5 provides suitability for various environmental conditions.

Rated current I_N [A]

RMS value of the sinusoidal current when driven at rated torque and rated speed.

Rated motor speed n_N [rpm]

The motor speed which can be continuously maintained when driven at rated torque T_N, when mounted on a suitably dimensioned heat sink.

Rated power P_N [W]

Output power at rated speed and rated torque.

Rated speed n_N [rpm], Mechanical

The rated speed is a reference speed for the calculation of the gear life. When loaded with the rated torque and running at rated speed the gear will reach the expected operating life L_{50}. The speed n_N is not used for dimensioning the gear.

[rpm]

Product series	**n_N**
CobaltLine®, HFUC, HFUS, CSF, CSG, CSD, SHG, SHD	2000
PMG size 5	4500
PMG size 8 to 14	3500
HPG, HPGP, HPN	3000

Rated torque T_N [Nm], Servo

The output torque which can be continuously transmitted when driven at rated input speed, when mounted on a suitably dimensioned heat sink.

Rated torque T_N [Nm], Mechanical

The rated torque is a reference torque for the calculation of the gear life. When loaded with the rated torque and running at rated speed the gear will reach the average life L_{50}. The rated torque T_N is not used for the dimensioning of the gear.

Rated voltage U_N [V_{rms}]

Supply voltage for operation with rated torque and rated speed.

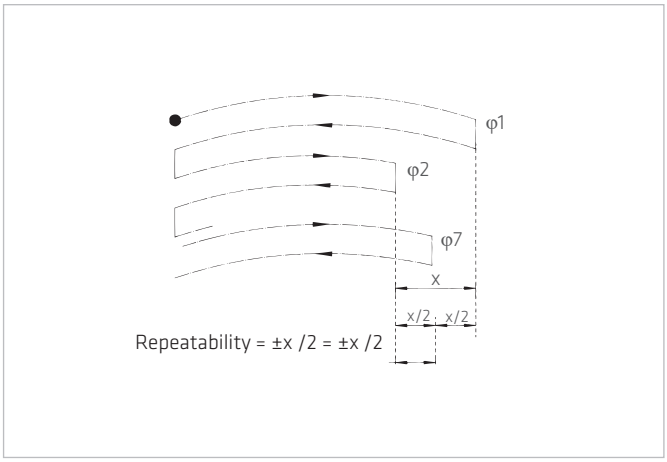
Ratio i [ ]

The ratio is the reduction of input speed to the output speed.

Note for Harmonic Drive® Gears: The standard version has the Wave Generator as the input element, the Flexspline as the output element and the Circular Spline is fixed to the housing. Since the direction of rotation of the input (Wave Generator) is opposite to the output (Flexspline), a negative ratio should be used for calculations in which the direction of rotation is to be considered.

Repeatability [arcmin]

The repeatability of the gear describes the position difference measured during repeated movement to the same desired position from the same direction. The repeatability is defined as half the value of the maximum difference measured, preceded by a ± sign.



Repeatable peak torque T_R [Nm]

Specifies the maximum allowable acceleration and braking torques. During the normal operating cycle the repeatable peak torque T_R should be not be exceeded.

Resistance (L-L, 20° C) R_{L-L} [Ω]

Winding resistance measured between two conductors at a winding temperature of 20° C.

Size

1) Actuators / Gears with Harmonic Drive® gears or Harmonic Planetary gears
The frame size is derived from the pitch circle diameter of the gear teeth in inches multiplied by 10.

2) CHM Servo motor series
The size of the CHM servo motors is derived from the stall torque in Ncm.

3) Direct drives from the TorkDrive® series
The size of the TorkDrive® series is the outer diameter of the iron core of the stator.

Static load rating C_0 [N]

Maximum static load that can be absorbed by the output bearing before permanent damage may occur.

Static tilting moment M_0 [Nm]

With the bearing stationary, this is the maximum allowable radial load with no additional axial forces or tilting moments applied.

Tilting moment stiffness K_B [Nm/arcmin]

Describes the relationship between the tilting angle of the output bearing and an applied moment load.

Torque constant (motor) k_{TM} [Nm/A_{rms}]

Quotient of stall torque and stall current.

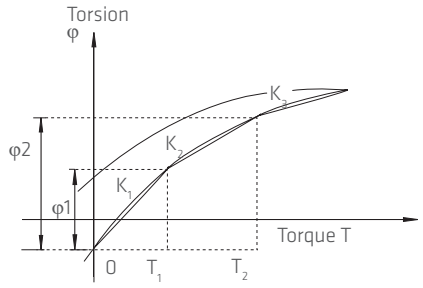
Torque constant (output) k_{Tout} [Nm/A_{rms}]

Quotient of stall torque and stall current, taking into account the transmission losses.

Torsional stiffness (Harmonic Drive® Gears) K_3 [Nm/rad]

The amount of elastic rotation at the output for a given torque with the Wave Generator blocked. The torsional stiffness K_3 describes the stiffness above a defined reference torque where the stiffness is almost linear.

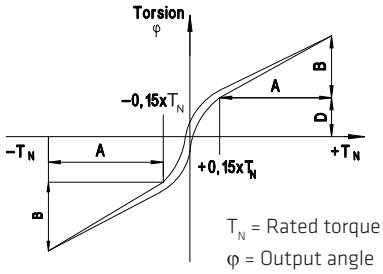
The value given for the torsional stiffness K_3 is an average that has been determined during numerous tests. The limit torques T_1 and T_2 and calculation example for the total torsional angle can be found in sections 3 and 4 of this documentation.



K_1, K_2, K_3 = Torsional stiffness, w = Output angle
φ1 = Torsion angle, with output torque T_1
φ2 = Torsion angle, with output torque T_2

Torsional stiffness (Harmonic Planetary gears) K [Nm/rad]

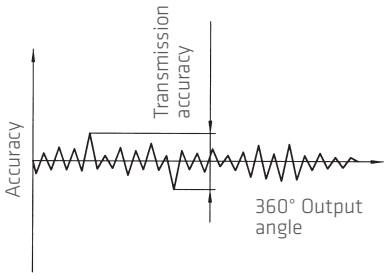
The amount of elastic rotation at the output for a given torque and blocked input shaft. The torsional rigidity of the Harmonic Planetary gear describes the rotation of the gear above a reference torque of 15% of the rated torque. In this area the torsional stiffness is almost linear.



T_N = Rated torque
φ = Output angle

Transmission accuracy [arcmin]

The transmission accuracy of the gear represents the linearity error between input and output angle. The transmission accuracy is measured for one complete output revolution using a high resolution measurement system. The measurements are carried out without direction reversal. The transmission accuracy is defined as the sum of the maximum positive and negative differences between the theoretical and actual output rotation angles.



Weight m [kg]

The weight specified in the catalog is the net weight without packing and only applies to standard versions.

7.2 Labelling, Guidelines and Regulations

CE-Marking

With the CE marking, the manufacturer or EU importer declares in accordance with EU regulation, that by affixing the CE mark the product meets the applicable requirements in the harmonization legislation established the Community.

REACH Regulation

REACH is a European Community Regulation on chemicals. REACH stands for Registration, Evaluation, Authorization and Restriction of Chemicals.

RoHS EU Directive

The RoHS EU Directive on the restriction of the use of certain hazardous substances in electrical and electronic equipment.

PASSION GENERATES THE HIGHEST QUALITY.

Harmonic Drive SE
Hoenbergstraße 14
65555 Limburg/Lahn
Germany

T +49 6431 5008-0
info@harmonicdrive.co.uk
www.harmonicdrive.co.uk

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