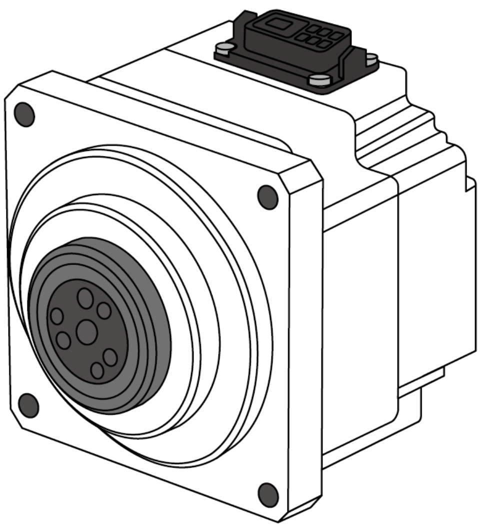
MECHATRONICS

AC servo actuator

FPA Series Manual



Introduction

Thank you for purchasing an HDS FPA series AC Servo Actuator.
Incorrect handling or improper use of this product may result in unexpected accidents or a shorter product life. Read this document carefully and use the product correctly so that the product can be used safely for many years.
Product specifications are subject to change without notice for improvement purposes.
Company names and product names in this document are generally registered trademarks or trademarks of their respective companies.
Keep this manual in a convenient location.
The end user should keep a copy of this document.

SAFETY GUIDE

To use this product safely and correctly, be sure to read SAFETY GUIDE and other parts of this document carefully and fully understand the information provided herein before using the product.

NOTATION

Important safety information you must note is provided herein. Be sure to observe these instructions.

WARNING	Indicates that misuse could result in death or serious injury.
CAUTION	Indicates a potentially hazardous situation, which, if not avoided, may result in minor or moderate personal injury and/or damage to the equipment.
Caution	Indicates what should be performed or avoided to prevent non-operation or malfunction of the product or negative effects on its performance or function.

LIMITATION OF APPLICATIONS

This product may not be used for the applications listed below:

- Space equipment
- Aircraft, aeronautic equipment
- Nuclear equipment
- Household apparatuses
- Vacuum equipment
- Automobile, automotive parts
- Amusement equipment, sport equipment, game machines
- Machines or devices acting directly on the human body
- Instruments or devices to transport or carry people
- Apparatuses or devices used in special environments

If the above list includes your intended application for our products, please consult HDS.

CAUTION

If this product is utilized in any facility in which human life is at stake or that may incur material losses, install safety devices so that accidents do not occur even if output control is disabled due to damage.

SAFETY PRECAUTIONS

Precautions for using actuator

- **Design precautions**

CAUTION

Always use under the following conditions.

The actuator is designed to be used indoors. Be sure to observe the following conditions.

- Ambient temperature: 0 to 40 ℃
- Ambient humidity: 20 to 80 %RH (Non-condensation)
- Vibration: Max. 25 m/s^2
- No exposure to water or oil
- No corrosive or explosive gas

Install using specified methods.

- Ensure exact alignment of the actuator center and the center of the corresponding machine by following the manual.
- Improper alignment may cause vibration or damage to the output shaft.

- **Operational precautions**

WARNING

Do not exceed allowable torque.

- Do not apply torque exceeding the maximum torque.
- Be aware that, if arms directly attached to the output shaft are hit, the output shaft may become uncontrollable.

Never connect directly to a power supply socket.

- Actuators must be connected to the proper driver to operate.
- Never connect directly to a commercial power supply. Doing so may lead to fire or damage to the actuator.

Do not subject the actuator to impact or shock.

- The actuator is directly connected to the encoder. Do not strike it with a hammer or other tool.
- If the encoder is damaged, it may result in uncontrollable operation of the actuator.

Do not pull lead lines.

- Pulling lead lines may damage connections, which may result in uncontrollable operation of the actuator.

Do not touch the actuator during operation.

- The actuator may become hot. Do not touch the actuator or surrounding parts during operation or while cooling, as doing so can result in burns.

Precautions for using driver

- **CAUTIONS RELATED TO THE DESIGN**

CAUTION

Always use under the following conditions.

The driver generates heat. Use under the following conditions while paying careful attention to the heat radiation.

- Use a vertical mounting direction and ensure sufficient space.
- Operating temperature: 0°C to 55°C, Operating humidity: 90%RH or below (no condensation)
- Vibration resistance: 4.9m/s², Shock resistance: 19.6m/s²
- No dust or dirt, no corrosive or explosive gas

Ensure sufficient noise suppression and grounding.

Any noise generated on a signal wire will cause operational errors. Be sure to observe the following conditions.

- Keep signal and power leads separated.
- Keep wiring as short as possible.
- Ground the actuator and driver at a single point using resistance class D grounding or higher.
- Do not use a power line filter in the motor circuit.

Be careful with rotation operations from the load side.

- Operation of the actuator while rotating from the load side may damage the driver. Contact us for information on this type of usage.

Use a ground-fault breaker designed for inverters.

- When using a ground-fault breaker, use one designed for inverters. Do not use a time-delay-type device.

If this product is utilized in any facility in which human life is at stake or that may incur material losses, install safety devices so that accidents do not occur even if output control is disabled due to damage.

- **Operational precautions**

WARNING

Never change wiring while the power is active.

- Make sure to turn the power OFF before detaching wires, or disconnecting or connecting the connectors. Doing otherwise may result in electric shock or uncontrollable operation. The driver may also be damaged.

Do not touch terminals for at least 20 minutes after turning power OFF.

- Even after power is turned OFF, an electric charge will remain in the driver. In order to prevent electric shock, perform inspections at least 20 minutes after the power is turned OFF and confirming the CHARGE lamp turns OFF.
- When installing, make sure that the inner electronic components are hard to reach.

CAUTION

Do not perform a voltage resistance test.

- Do not perform a Megger test or voltage resistance test. Doing so may result in damage to the control circuit of the driver. Contact us for information on this type of test.

Do not operate by switching the power ON/OFF.

- Frequently turning the power ON/OFF may cause deterioration of internal circuit elements.
- Start/stop the actuator using command signals.

Dot not subject to strong impact (dropping, etc.).

- Subjecting the product to strong impact may cause driver damage or breakdown.

Disposal

CAUTION

Dispose of the product as industrial waste.

When disposing this product, disassemble it as much as possible. Separate parts according to the material description (if indicated), and dispose of them as industrial waste.

Contents

Chapter 2 Selection guidelines

Chapter 3 Installing the actuator

Chapter 4 Options

Appendix

Related manuals

The table below lists related manual(s). Check each item as necessary.

Title	Description
AC Servo Driver HA-900 Series Manual	The specifications and characteristics of HA-900 series are explained.

Conformance to overseas standards

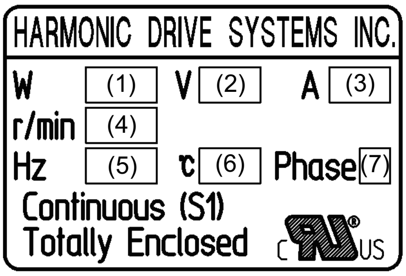
FPA series actuators conform to the following overseas standards.

UL Standards	UL1004-1,UL1004-6（File No. E243316）
CSA Standards	C22.2 No.100
European EC Directive, Low Voltage Directive	EN60034-1, EN60034-5

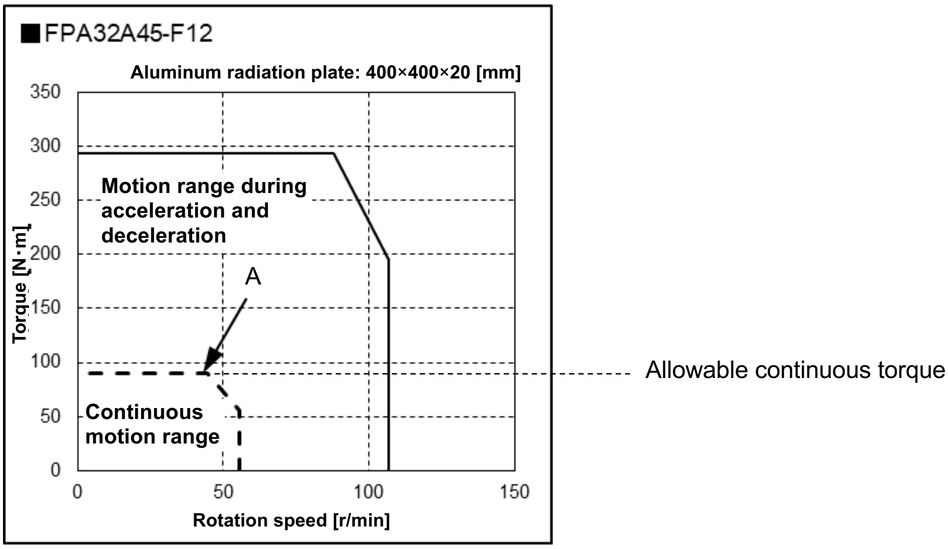
UL nameplate sticker

The following specifications of the FPA series actuators are shown based on the UL1004-1 and UL1004-6 (File No. E243316) standards.

Nameplate field	Explanation
(1)	Output [W] at point A on the graph below
(2)	Power supply voltage [V]
(3)	Allowable continuous current [A]
(4)	Rotational speed [r/min] at point A on the graph below
(5)	Current fundamental frequency [Hz] at point A on the graph below
(6)	Allowable ambient temperature [℃]
(7)	Phases



UL nameplate sticker



The nameplate values of various models are shown below.

Model / Item		FPA11A	FPA14A			FPA20A		FPA32A	
		05	**11**	**15**	**33**	**05**	**11**	**21**	**45**
		F08A200				**F12A200**			
(1) Output at point A	W	145	143	149	95	406	381	399	418
(2) Power supply voltage	V	200							
(3) Allowable continuous current	A	1.8	1.8	1.8	1.2	5.5	5.1	5.3	5.5
(4) Speed at point A	r/min	600	272.7	200	90.9	400	181.8	95.2	44.4
(5) Frequency at point A	Hz	250	250	250	250	167	167	167	167
(6) Allowable ambient temperature	℃	40							
(7) Number of phases	−	3							

Chapter 1

Overview

This chapter explains the features, functions, and specifications of the actuator.

1-1 Overview

FPA series AC Servo Actuators provide high speed, high torque, and highly accurate rotary operation. These AC Servo Actuators consist of a HarmonicPlanetary® precision planetary speed reducer (from model No. 11 to model No. 32) integrated with a flat AC servo motor.
They feature a flat shape. They feature a reduced overall length compared with configurations that combine a servo motor with a right angle speed reducer of the same torque level.
Dedicated HA-900 series drivers are servo drive units for controlling position, speed, and torque. These small multi-functional drivers control the operation of FPA series products with great accuracy and precision.
They play an important role in miniaturizing semiconductor and LCD manufacturing equipment, robots, machine tools, and other factory automation (FA) equipment.

◆ Slim-line body

Consists of a HarmonicPlanetary® precision planetary speed reducer and flat AC servo motor integrated with the coaxial shaft, resulting in a flat shape. It has a shorter total length than even conventional devices consisting of a right angle gear head and AC servo motor, allowing for even smaller machines and equipment to be driven.

◆ High speed and torque

Houses a HarmonicPlanetary® precision planetary speed reducer for a much higher output torque value on external dimensions compared with methods using direct motor drive. Reduction ratios of 1/5 to 1/45 are available. It can be used with a wide range of applications to suit the required speed and torque.

◆ Low backlash

The backlash of the speed reducer is 1 minute or less (3 minutes or less for model No. 11). HarmonicPlanetary® precision planetary speed reducers make use of a "thin flexible internal gear", a proprietary structure that is strong with low backlash. There is hardly any change in backlash during the speed reducer life.

◆ High torsional rigidity

Makes use of the highly rigid HarmonicPlanetary® HPG series products.

◆ 24-bit absolute encoder

Contains a 24-bit absolute encoder compatible with A-format® serial communication. It also provides multi-turn counting functionality required for an actuator with speed reducer, to maintain the absolute position.

◆ One-touch lock connector

Uses lever lock-type connectors for easy wiring. The connectors for the motor drive wire and encoder signal wire are integrated, for one-touch extension cable attachment.

1-2 Model

Model names for the FPA series actuators and how to read the symbols are explained below.

Examples of standard products:

FPA	14	A	11	F0	HG	−	F	08	A	200	−	32	S	24b	A	−	C		
(1)	(2)	(3)	(4)	(5)	(6)	−	(7)	(8)	(9)	(10)	−	(11)	(12)	(13)	(14)	−	(15)	−	(16)

(1) Model: AC Servo Actuator FPA series

(2) Model Nos.: 11, 14, 20, 32

(3) Version symbol

(4) Reduction ratio (indicated by R in 1/R format)

05	1/5	(Model Nos. 11, 20)
11	1/11	(Model Nos. 14, 20)
15	1/15	(Model No. 14)
21	1/21	(Model No. 32)
33	1/33	(Model No. 14)
45	1/45	(Model No. 32)

(5) Output shaft shape code

F0	(Model Nos. 11, 14, 20, 32) Flange output
J20	(Model No. 11) Straight shaft, without key groove
J60	(Model No. 11) Straight shaft, keyed, center tapped
J2	(Model Nos. 14, 20, 32) Straight shaft, without key groove
J6	(Model Nos. 14, 20, 32) Straight shaft, keyed, center tapped

(6) Speed reducer type

HG	HPG series planetary speed reducer

(7) Motor version code: F

(8) Motor size

08	Model Nos. 11, 14
12	Model Nos. 20, 32

(9) Brake

A	Without brake

(10) Applicable servo driver input voltage

200	200 V

(11) Encoder type

32	Conforming to A format, transmission rate: 4 Mbps, 1-on-1 connection

(12) Encoder method

S	Multi-turn absolute (External battery backup type)

(13) Encoder resolution

24b	24-bit (16777216 pulses/revolution)

(14) Encoder phase angle: Phase difference between induced voltage in motor phase U and absolute origin

A	0°

(15) Connector specification

C	With standard connector

(16) Special specification

Blank	Standard product
SP	Special specification product

(Please contact us for special specification products and optional UL compatibility.)

1-3 Combinations with drivers and extension cables

The combinations of FPA series actuators, HA-900 series drivers, and extension cables are as follows:

		FPA11AxxHG-F08	FPA14AxxHG-F08	FPA20AxxHG-F12	FPA32AxxHG-F12
I/O command type		HA-900A-3A-200	HA-900A-3A-200	HA-900A-6A-200	HA-900A-6A-200
Extension cables (option)	Motor wire, Encoder wire	EWE-MBS●●-HR0608■-TN4-MDR14			

Note: ●● in the extension cable model indicates the cable length: 02 = 2 m, 05 = 5 m, 10 = 10 m
■ indicates the cable direction: A = Vertical, B = Rear, C = Front

1-4 Specifications

The specifications of FPA series actuators are as follows:

Item / Model		FPA11A	FPA14A			FPA20A		FPA32A	
		05	11	15	33	05	11	21	45
		F08A200				F12A200			
Combined driver		HA-900A-3A-200				HA-900A-6A-200			
Max. torque[*1]	N·m	7.8	18	23	23	32	71	135	294
Allowable continuous torque[*1*2]	N·m	2.3	5.0	7.1	10	9.7	20	40	90
Max. rotational speed[*1]	r/min	1200	545.4	400	181.8	960	436.3	228.5	106.6
Torque constant[*1]	N·m/A	1.7	3.7	5.0	11.0	2.1	4.6	8.8	18.8
Max. current[*1]	A	5.8	6.1	5.7	2.7	18	18	18	18
Allowable continuous current[*1*2]	A	1.8	1.8	1.8	1.2	5.5	5.1	5.3	5.5
EMF constant[*3]	V/(r/min)	0.19	0.41	0.56	1.2	0.23	0.5	0.95	2.0
Phase resistance (20 ℃)	Ω	1.4				0.33			
Phase inductance	mH	2.5				1.4			
Inertia moment[*4] GD²/4	kg·m²	0.0011	0.0059	0.011	0.052	0.0096	0.045	0.17	0.76
Reduction ratio		1:5	1:11	1:15	1:33	1:5	1:11	1:21	1:45
Permissible moment load	N·m	9.5	32.3			183		452	
Moment stiffness	$\times 10^4$ N·m/rad	0.88	3.0			16.8		42.1	
Uni-directional positional accuracy	Min.	5	4	4	4	5	4	4	4
Encoder type		Absolute encoder							
Encoder resolution	Single-turn detector	2^{24} (16777216)							
	Multi-turn detector[*5]	2^{16} (65536)							
Output shaft resolution	Pulse/rev	83886080	184549376	251658240	553648128	83886080	184549376	352321536	754974720
Mass[*4]	kg	1.6	2.2	2.2	2.2	5.6	5.8	7.4	7.4
Environmental conditions[*6]		Operating temperature: 0 to 40 ℃/Storage temperature: -20 to 60 ℃ Operating/storage humidity: 20 to 80 %RH (no condensation) Resistance to vibration: 25 m/s^2 (frequency: 10 to 400 Hz)/Shock resistance: 300 m/s^2[*7] No dust, metal powder, corrosive gas, inflammable gas, or oil mist. To be used indoors, no direct sunlight Altitude: 1,000 m above sea level or less							
Motor insulation		Insulation resistance: 100 MΩ or more (500 VDC) Dielectric strength voltage: 1500 VAC/1 min Insulation class: A							
Mounting direction		Can be installed in any direction							
Protection structure		Totally enclosed self-cooled type (IP54)							

The values listed above show the typical values of the output shaft.

*1: Typical characteristics when combined (driven by ideal sine wave) with HDS drivers.

*2: Value after temperature rise and saturation when an aluminum radiation plate of the following dimensions is installed.
- FPA11Axx-F08: 320 × 320 × 16 [mm]
- FPA14Axx-F08: 320 × 320 × 16 [mm]
- FPA20Axx-F12: 400 × 400 × 20 [mm]
- FPA32Axx-F12: 400 × 400 × 20 [mm]

*3: Value of phase induced voltage constant multiplied by 3.

*4: Values are for the flange output type. For the straight shaft type, refer to [4-1 Options] (P4-3).

*5: The multi-turn detector range is -32768 to 32767.

*6: For details, refer to [3-3 Location and installation] (P3-4).

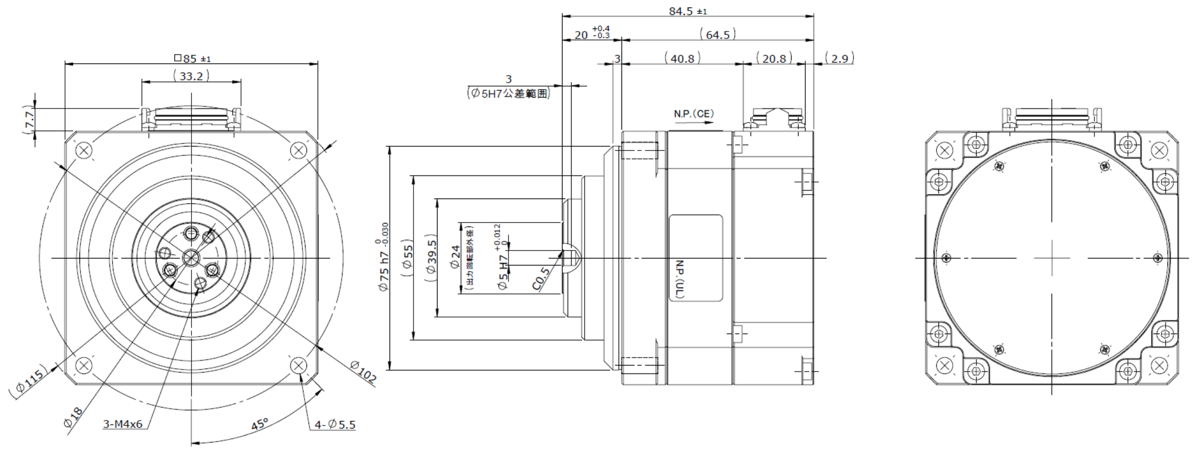
*7: For testing conditions, refer to [1-11 Shock resistance] (P1-13) and [1-12 Resistance to vibration] (P1-14). Motor operation is not guaranteed in applications where vibrations and impacts are continuously applied for a long period of time.

1-5 External dimensions

The external dimensions of FPA series actuators are shown below. The external dimensions of the flange output type are shown. For the dimensions of the straight shaft type output shaft shape, refer to [4-1 Options] (P4-1, P4-2).

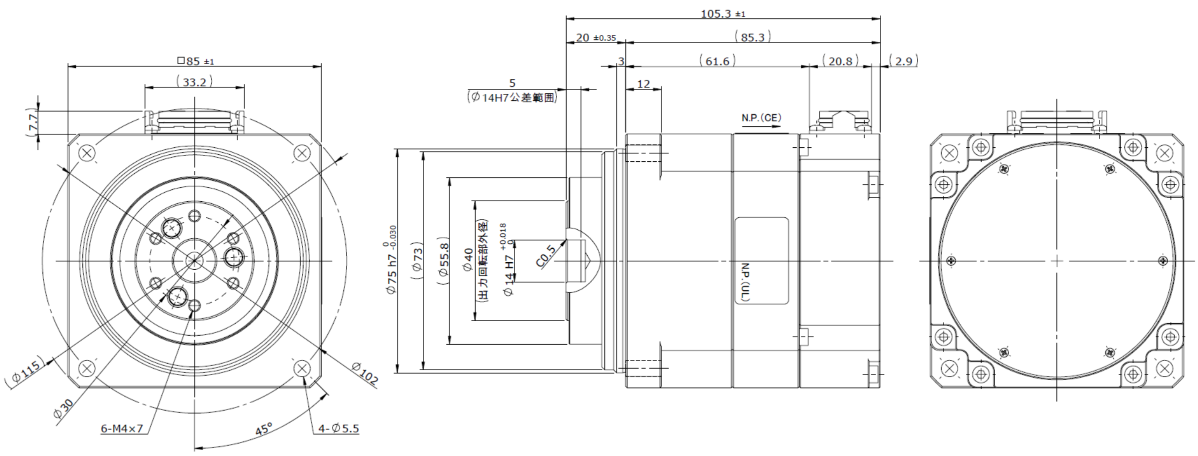
- **FPA11A**

Unit [mm] (third angle projection)



- **FPA14A**

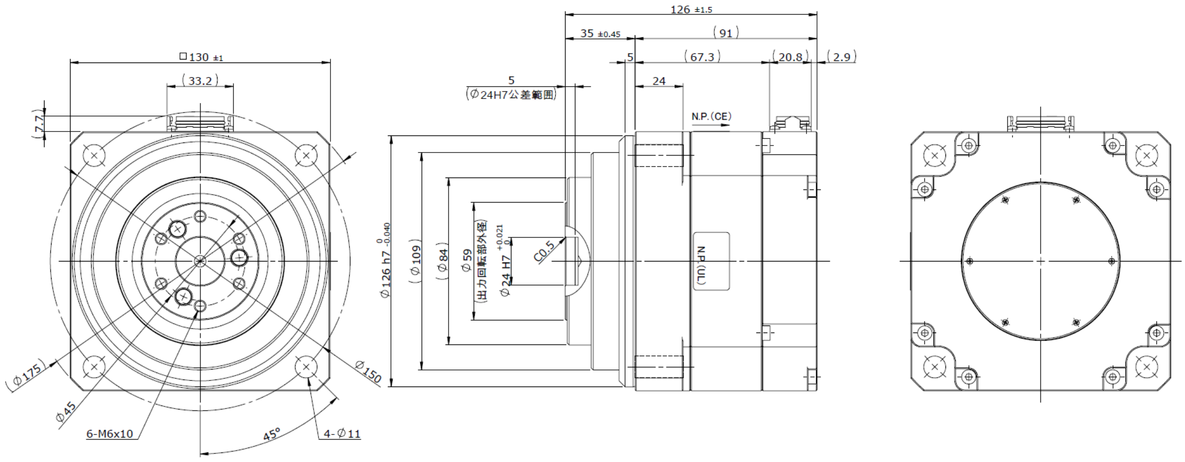
Unit [mm] (third angle projection)



Note: For details on external dimensions, check HDS illustrated specifications.
Tolerances may vary due to product manufacturing method (foundry piece, machine-finished good).
Please contact us for the tolerance if not indicated in the dimensions.

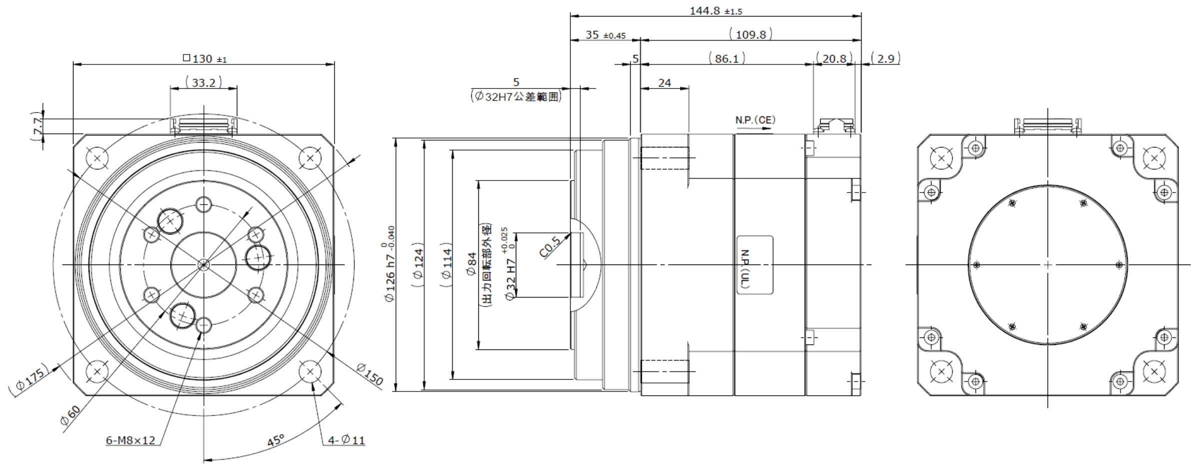
- **FPA20A**

Unit [mm] (third angle projection)



- **FPA32A**

Unit [mm] (third angle projection)



Note: For details on external dimensions, check HDS illustrated specifications.
Tolerances may vary due to product manufacturing method (foundry piece, machine-finished good).
Please contact us for the tolerance if not indicated in the dimensions.

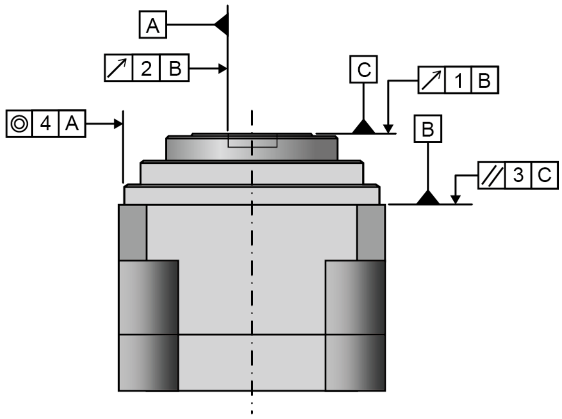
1-6 Mechanical accuracy

The mechanical accuracies of the output shaft and mounting flange are shown below for FPA series actuators: The specifications of the flange output type are shown. For the specifications of the straight shaft type, refer to [4-1 Options] (P4-3).

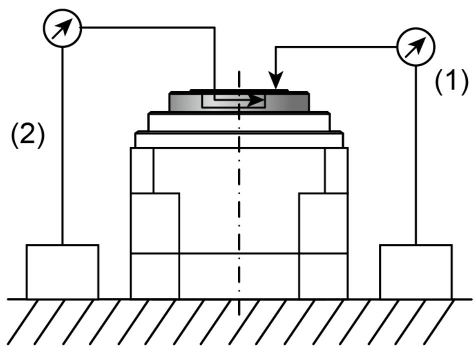
Unit [mm]

Accuracy items	FPA11A	FPA14A	FPA20A	FPA32A
1. Output shaft surface runout	0.020	0.020	0.020	0.020
2. Output shaft runout	0.030	0.040	0.040	0.040
3. Parallelism between the output shaft and mounting surface	0.050	0.060	0.060	0.060
4. Concentricity between the output shaft and fitting part	0.040	0.050	0.050	0.050

Note: All values are T.I.R. (Total Indicator Reading).



The measurement methods are described below.



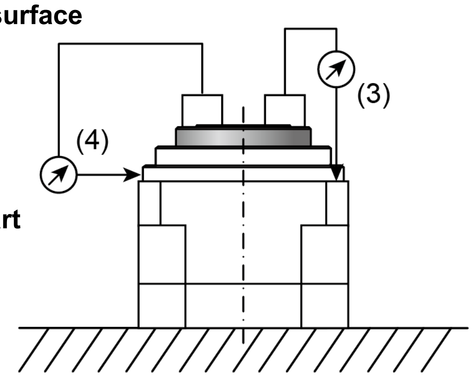
1 Output shaft surface runout

The indicator on the fixed part measures the axial runout (maximum runout width) of the outermost circumference of the output shaft of the output rotary unit per revolution.

2 Output shaft runout

The indicator on the fixed part measures the radial runout (maximum runout width) of the output shaft of the output rotary unit per revolution.

3 Parallelism between the output shaft and mounting surface



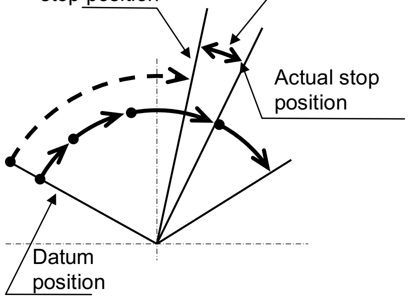
The indicator on the output rotary unit measures the axial runout (maximum runout width) of the outermost circumference of the mounting surface of the output rotary unit per revolution.

4 Concentricity between the output shaft and fitting part

The indicator on the output rotary unit measures the radial runout (maximum runout width) of the fitting part of the output rotary unit per revolution.

1-7 Uni-directional positional accuracy

The uni-directional positional accuracy is the maximum positional difference between the actual rotated angle from the datum position and its theoretical rotational angle in one revolution when a series of positionings are performed in the same rotation direction. (JIS B 6201-1987)
FPA series products incorporate a HarmonicPlanetary® HPG series planetary speed reducer, so the impact of motor shaft positioning error becomes 1/multiple of reduction ratio.



The uni-directional positional accuracy for each model No. is shown in the table below:

Unit [min.]

Model / Reduction ratio	FPA11A	FPA14A	FPA20A	FPA32A
1:5	5	-	5	-
1:11	-	4	4	-
1:15	-	4	-	-
1:21	-	-	-	4
1:33	-	4	-	-
1:45	-	-	-	4

1-8 Detector specifications (absolute encoder)

FPA series products house a multi-turn absolute encoder. It consists of a detector (24-bit) for detecting the position per motor shaft revolution, and a multi-turn detector (16-bit) for detecting the number of revolutions.
This encoder constantly detects the absolute position of the machine and stores it by means of battery backup, regardless of whether the driver or host device power is turned ON/OFF. Once the origin is detected when the machine is installed, originating is not required for subsequent power ON operations. This facilitates the recovery operation after a power failure or breakdown.
There is no backup capacitor in the encoder, so it is recommended to replace the battery while the driver is receiving power.
(The absolute position will be lost when the encoder connector [CN1] of an HA-900 series driver is disconnected.)

Specifications

Type	Optical sensor/external battery backup type (Single-turn and multi-turn optical sensor/external battery backup type)
Single-turn detector	2^{24}: 16777216 pulses
Multi-turn detector	2^{16}: 65536 (-32768 to 32767)
Maximum permissible motor shaft rotational speed	8000 r/min*1
External battery backup time	1 year*2 (when power is not supplied)

*1: This is the rotational speed limit of the encoder and is different from the rotational speed that the motor can drive.
*2: The value is obtained with the motor shaft stopped. Frequent movement of the motor shaft with no power supply will cause the external battery to drain quickly.

Output shaft resolution

Encoder resolution		24-bit (2^{24}: 16777216 pulses)					
Reduction ratio		1:5	1:11	1:15	1:21	1:33	1:45
Output shaft resolution	**Pulse/rev**	83886080	184549376	251658240	352321536	553648128	754974720
Resolvable angle per pulse*	**Sec.**	Approx. 0.015	Approx. 0.007	Approx. 0.0051	Approx. 0.0037	Approx. 0.0023	Approx. 0.0017

*: Calculated values obtained by dividing one output rotation by the resolution (reference values)

Absolute position data

"Absolute position" indicates the absolute position within one motor shaft revolution, while "multi-turn" indicates the number of motor revolutions. The position of the actuator output shaft is obtained by the following formula:
Position of actuator output shaft = (Absolute position + Multi-turn data × Encoder resolution) / Reduction ratio

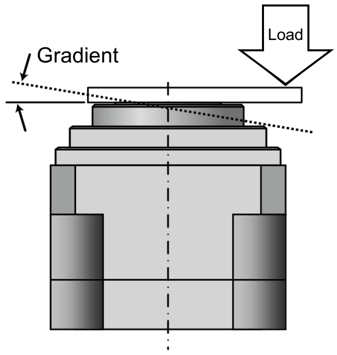
Transfer of encoder data

Data is transferred via bi-directional communication in a normal condition while power is supplied. When the driver control power supply is turned OFF and the driver enters the battery backup mode, communication stops.

1-9 Rigidity

Moment stiffness

"Moment stiffness" refers to the torsional stiffness when a moment load is applied to the face of the output shaft (flange output) of the actuator (shown in the figure).
For example, when a load is applied to the end of a rigid arm attached on the face of the output shaft of the actuator, the face of the output shaft of the actuator tilts in proportion to the moment load. The moment stiffness is expressed as the ratio of the load/gradient angle.



Item \ Model		FPA11A	FPA14A	FPA20A	FPA32A
Moment stiffness	N･m/rad	0.88×10^4	3.0×10^4	16.8×10^4	42.1×10^4

Note: Please contact us for information on the moment stiffness of the straight shaft output shaft shape.

Rotation direction torsional rigidity

If a torque is applied to the output unit with the input and casing of the speed reducer locked, the output unit generates a torsion in proportion to the torque. When the values for torque are gradually changed in sequence from (1) Rated output torque in the positive rotation direction → (2) Zero → (3) Rated output torque in the negative rotation direction → (4) Zero → (5) Rated output torque in the positive rotation direction, the values follow a loop (1)→(2)→(3)→(4)→(5) (returns to (1)) shown in Fig. 1 [Torque vs. torsional angle diagram].
The gradient of the region from "0.15 × Rated output torque of speed reducer" to "Rated output torque of speed reducer" is small, and the torsional rigidity of the speed reducer is the average of this gradient. The gradient of the region from "Zero torque" to "0.15 × Rated output torque of speed reducer" is large. This gradient is caused by semi-partial contact in the meshing region and uneven load distribution from light loads and so forth on the planet gears.

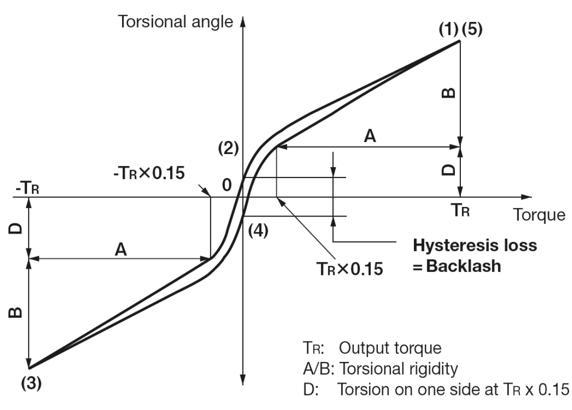
An explanation is provided below on how to calculate the total torsional quantity (average value) on one side from a no-load state after a load has been applied by the speed reducer.

$$\theta = D + \frac{T - TL}{\frac{A}{B}}$$

θ: Total torsional quantity
D: Torsional quantity on one side given by rated output torque × 0.15 torque
T: Load torque
T_R: Rated output torque of speed reducer
TL: Rated output torque × 0.15 torque (= T_R × 0.15)
A/B: Torsional rigidity

The zero torque part widths of (2) and (4) in Fig. 1 [Torque vs. torsional angle diagram] is called the hysteresis loss. For the speed reducer, backlash is defined as hysteresis loss during "rated output torque in the negative rotation direction" from "rated output torque in the positive rotation direction". The backlash of the speed reducer is 1 minute or less (3 minutes or less for FPA11A) with factory settings.

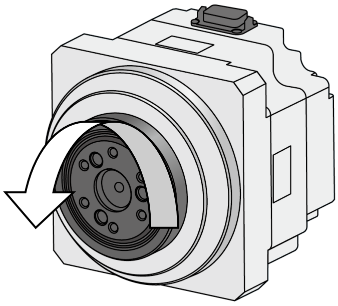
Fig. 1 Torque-torsional angle diagram



Item	Model/speed ratio	FPA11A	FPA14A			FPA20A		FPA32A	
		05	11	15	33	05	11	21	45
Backlash	10^{-4}rad	8.7	2.9	2.9	2.9	2.9	2.9	2.9	2.9
	Min.	3	1	1	1	1	1	1	1
Torsional quantity on one side given by T_R × 0.15 (D)	10^{-4}rad	7.3	7.9	7.9	7.9	4.4	5.8	4.9	4.9
	Min.	2.5	2.7	2.7	2.7	1.5	2.0	1.7	1.7
Torsional rigidity A/B	× 10^2 N・m/rad	22	47	47	47	180	180	740	740

1-10 Rotation direction

By default, the rotation direction is defined as counterclockwise (CCW) rotation as viewed from the output shaft when a FWD command pulse is given from an HA-900 series driver.
This rotation direction can be changed on the HA-900 series driver by selecting the [Pr0.01: Rotation direction setting] parameter.



Counterclockwise rotation direction

Setting of [Pr0.01: Rotation direction setting] driver parameter

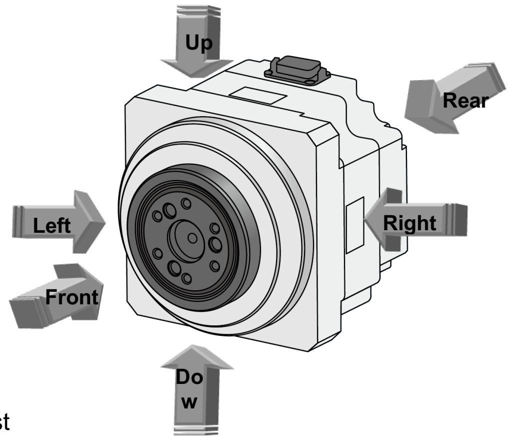
Set value	FWD command pulse	REV command pulse	Setting
0: Do not reverse coordinates	CCW (counterclockwise) direction	CW (clockwise) direction	Default
1: Reverse coordinates	CW (clockwise) direction	CCW (counterclockwise) direction	

1

Overview

1-11 Shock resistance

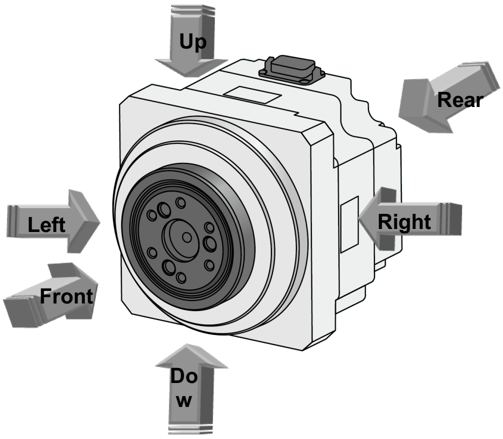
The shock resistance of the actuator is as follows, and this value is the same in up/down, left/right, and front/rear directions:
Impact acceleration: 300 m/s^2
Testing is conducted three times in each direction. This is not guaranteed in applications where impact exceeding the above value is constantly applied.



Shock resistance test

1-12 Resistance to vibration

The resistance to vibration of the actuator is as follows, and this value is the same in up/down, left/right, and front/rear directions:
Vibration acceleration: 25 m/s^2 (frequency: 10 to 400 Hz)
Testing is conducted for 2 hours in each direction at a vibration frequency sweep period of 10 minutes.



Resistance to vibration test

1-13 Operable range

The graph on the next page shows the operable range when an FPA series actuator (combined with an HA-900 series driver) is selected. For details, refer to [Chapter 2 Selection guidelines].

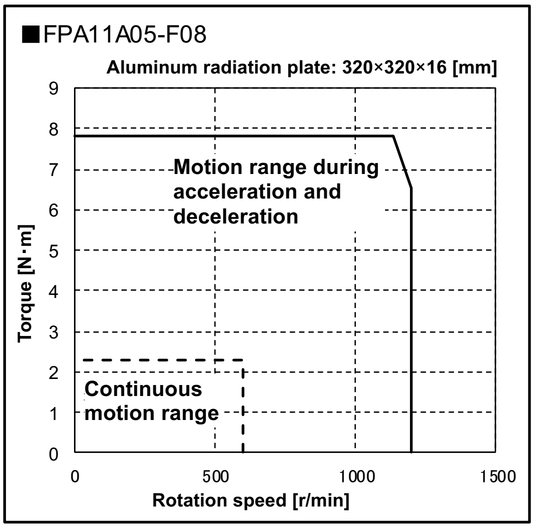
1. Continuous motion range

This indicates the torque and rotational speed range in which continuous operation is possible.
For the continuous motion range, values are measured with an aluminum radiation plate of dimensions specified in the upper right of the graph installed.

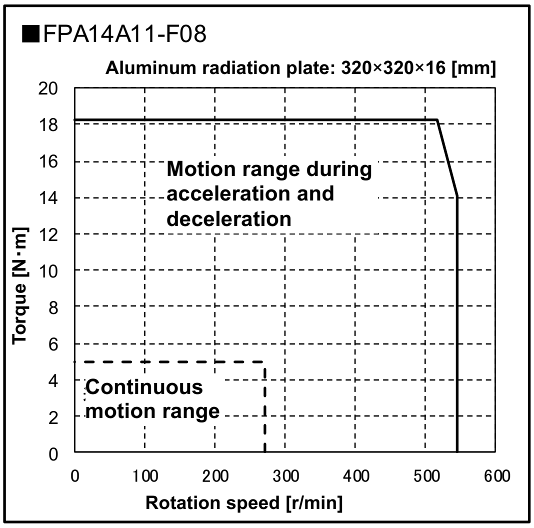
2. Operation range during acceleration and deceleration

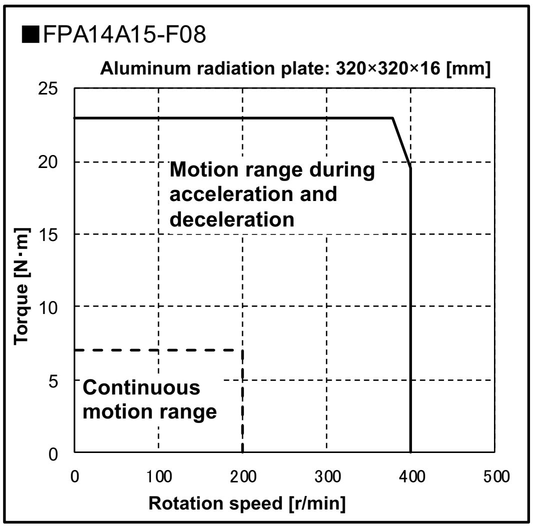
This indicates the torque and rotational speed range in which instantaneous operation is possible. This range is normally used for acceleration or deceleration.

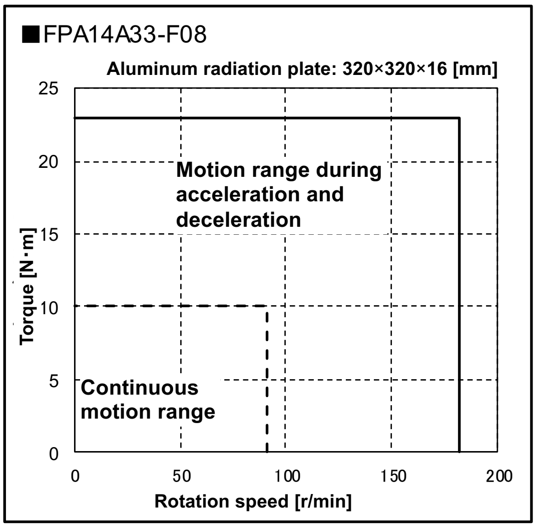
FPA11A



FPA14A

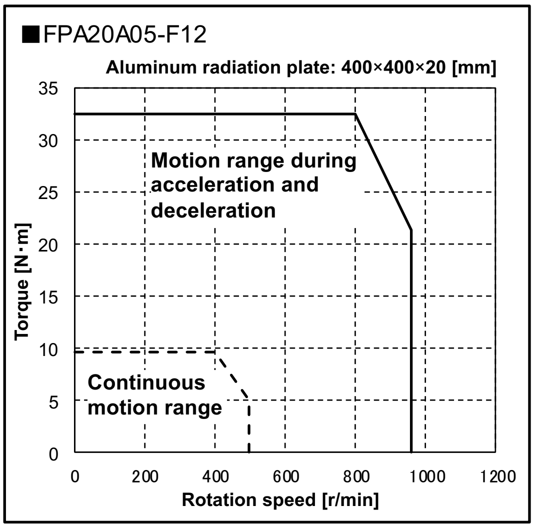


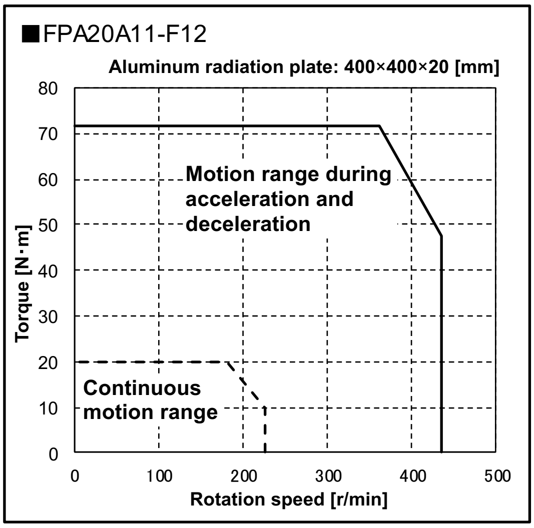




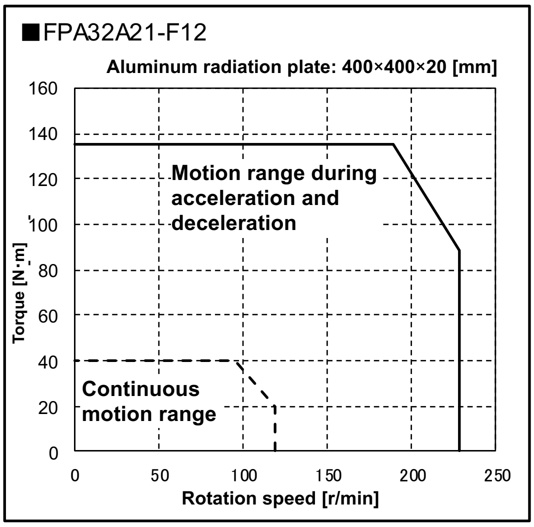
Note 1: For the continuous motion range, values are measured with an aluminum radiation plate of dimensions specified in the upper right of the graph installed.
Note 2: The graphs show typical values of 3-phase 200 VAC.

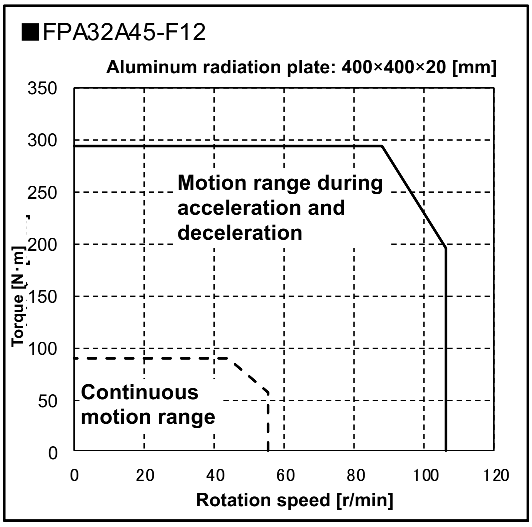
FPA20A





FPA32A





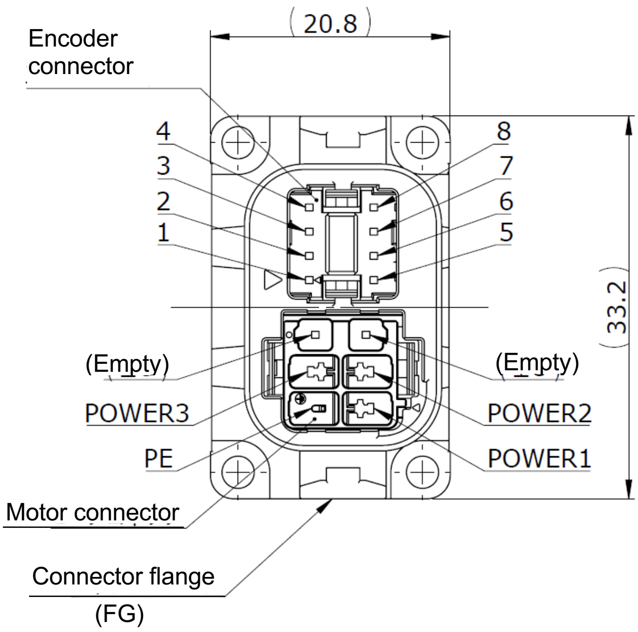
Note 1: For the continuous motion range, values are measured with an aluminum radiation plate of dimensions specified in the upper right of the graph installed.
Note 2: The graphs show typical values of 3-phase 200 VAC.

1-14 Cable specifications

The following tables show connector cable specifications for FPA series actuators.

Connector cable specifications

- Connector pin layout



- Encoder connector cable

Pin No.	Name	Remarks
1	Vbat	Battery +
2	GND(bat)	Battery - (GND)
3	Vcc	Power supply input +5 V
4	GND(Vcc)	Power supply input 0 V (GND)
5	No connection	
6	No connection	
7	SD +	Serial signal differential output (+)
8	SD -	Serial signal differential output (-)
(Connector flange)	FG	FG (connected to extension cable shield)

Connector model: MT50W-8D-C
Pin model: MT50D2-2830PCFA
Hirose Electric

- Motor connector cable

Pin No.	Name
POWER1	Motor phase-U
POWER2	Motor phase-V
POWER3	Motor phase-W
(Empty)	No connection
(Empty)	No connection
PE	PE

Connector model: MT50W-2D3E2-PE-C
Pin model: MT50E2-1820PCFA
Hirose Electric

- Connector flange

  Model: MT50W-8D/2D3E-PE-FL
  Hirose Electric

Chapter 2

Selection guidelines

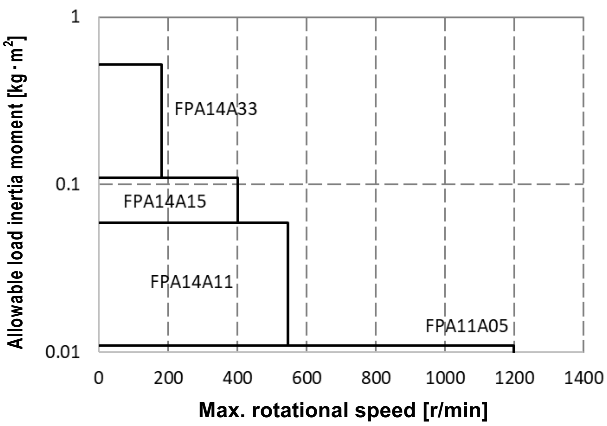
This chapter explains how to select the proper FPA series product.

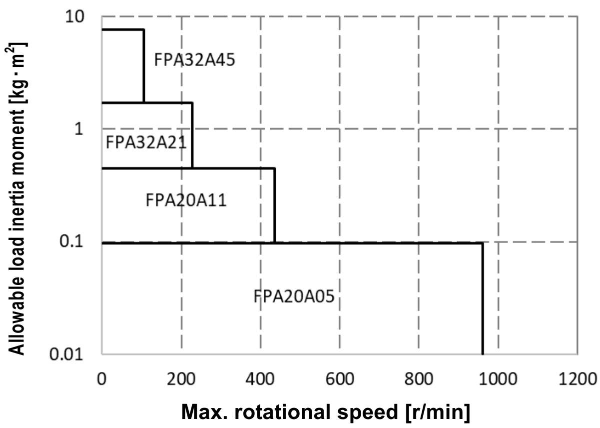
2-1 FPA series selection

Allowable load inertia moment

To achieve high accuracy and performance, select an FPA series actuator where the allowable load inertia moment is not exceeded.
Note that the allowable values in the table below should be referenced if you wish to shorten the transient vibration period during positioning or operate the actuator at a constant speed in a stable manner.
Operation is possible with the allowable value exceeded if the actuator is accelerated/decelerated gradually, commands given from the host device to the servo driver are adjusted, or the servo driver's vibration suppression function is used.

For information on calculating the inertia moment, refer to [AA-2 Calculating inertia moment] (PA-3).





When tentatively selecting an actuator, make certain that the inertia moment and maximum rotational speed do not exceed the allowable values shown in the table below.
When a load generating a large inertia moment is operated frequently, a greater regenerative energy will be produced during braking. If the produced regenerative energy exceeds the absorption capacity of the built-in resistor of the servo driver, an additional regenerative resistor must be connected externally to the driver. For details, refer to the manual of the driver.

Actuator model		FPA11A	FPA14A			FPA20A		FPA32A	
		05	11	15	33	05	11	21	45
		F08A200				F12A200			
Reduction ratio		1:5	1:11	1:15	1:33	1:5	1:11	1:21	1:45
Max. rotational speed	r/min	1200	545.4	400	181.8	960	436.3	228.5	106.6
Actuator inertia moment	$kg \cdot m^2$	0.0011	0.0059	0.011	0.052	0.0096	0.045	0.17	0.76
Allowable load inertia moment (Approximate value for stable operation)	$kg \cdot m^2$	0.011	0.059	0.11	0.52	0.096	0.45	1.7	7.6

2-2 Verifying and examining load weight

FPA series products incorporate a precise cross roller bearing for directly supporting an external load (output flange). To demonstrate the full ability of your FPA series product, verify the maximum load moment load as well as the life and static safety coefficient of the cross roller bearing.

Checking procedure

1 Verify the maximum load moment load (M*max*)

Calculate the maximum load moment load (M*max*)
↓
Verify that the maximum load moment load (M*max*) is less than or equal to the permissible moment load (Mc)

2 Verify life

Calculate the average radial load (Fr*av*) and average axial load (Fa*av*)
↓
Calculate the radial load coefficient (X) and axial load coefficient (Y)
↓
Calculate and verify the life of the part

3 Verify the static safety coefficient

Calculate the static equivalent radial load (Po)
↓
Verify the static safety coefficient (fs)

Main roller bearing specifications

The following table shows the specifications of the main roller bearings.

Table 1: Specifications of the main roller bearings

Model \ Item	Circular pitch of the roller (dp)	Offset amount (R)	Basic dynamic rated load (C)*1	Basic static rated load (Co)*2	Permissible moment load (Mc)*3	Moment stiffness (Km)*4
	mm	mm	N	N	N·m	× 10^4 N·m/rad
FPA11A	27.5	6	3116	4087	9.5	0.88
FPA14A	40.5	11	5110	7060	32.3	3.0
FPA20A	64	11.5	10600	17300	183	16.8
FPA32A	85	14	20500	32800	452	42.1

*1: The basic dynamic rated load is the constant static radial load that results in a bearing basic dynamic rated life of 1 million rotations.
*2: The basic static rated load is the static load that imparts a certain level of contact stress (4 kN/mm^2) in the center of the contact between the rolling element and race under maximum load.
*3: The permissible moment load is the value where operation is possible and basic performance is maintained within the range where the maximum moment load can be sustained by the output shaft bearing.
Verify the bearing life based on the calculations in the following section.
*4: Moment stiffness values are averages.

Table 2: Permissible radial load and permissible axial load

Model No.	Reduction ratio	Permissible radial load*5	Permissible axial load*5
		N	N
11	5	280	430
14	11	600	890
	15	650	980
	33	830	1240
20	5	980	1460
	11	1240	1850
32	21	2920	4360
	45	3670	5480

*5: The permissible radial load and permissible axial load are the permissible values when only a pure radial load or axial load is applied to the bearing (moment load M = 0 [N·m]). (When the radial load is Lr + R = 0 mm or the axial load is La = 0 mm.)
Verify the maximum load moment load and bearing life based on the calculations in the following section.

Maximum load moment load

The formula below shows how to calculate the maximum load moment load (M_{max}).
Verify that the maximum load moment load (M_{max}) is less than or equal to the permissible moment load (Mc).

◆ **Formula (1): Maximum load moment load**

$$M_{max} = \frac{Fr_{max} \cdot (Lr + R) + Fa_{max} \cdot La}{1000}$$

Symbols used in the formula

M_{max}	Maximum load moment load	N·m	
Fr_{max}	Max. radial load	N	Refer to Fig. 1
Fa_{max}	Max. axial load	N	Refer to Fig. 1
Lr ,La	————	mm	Refer to Fig. 1
R	Offset amount	mm	Refer to Fig. 1 and Table 1

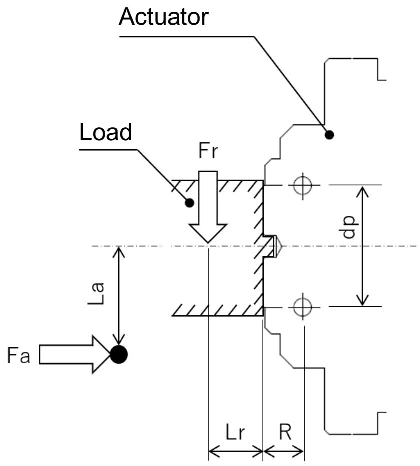


Fig. 1: External load action

Verifying life

Calculating average loads (average radial and axial loads, average output rotational speed)

When the radial load or axial load will change, calculate the average loads of each, and then use these average loads to verify the life of the cross roller bearing.

◆ **Formula (2): Average radial load (Fr_{av})**

$$Fr_{av} = \sqrt[10/3]{\frac{n_1 t_1 |Fr_1|^{10/3} + n_2 t_2 |Fr_2|^{10/3} \cdots n_n t_n |Fr_n|^{10/3}}{n_1 t_1 + n_2 t_2 + \cdots + n_n t_n}}$$

The maximum radial load in section t_1 is given by Fr_1, while the maximum radial load in section t_3 is given by Fr_3.

◆ **Formula (3): Average axial load (Fa_{av})**

$$Fa_{av} = \sqrt[10/3]{\frac{n_1 t_1 |Fa_1|^{10/3} + n_2 t_2 |Fa_2|^{10/3} \cdots n_n t_n |Fa_n|^{10/3}}{n_1 t_1 + n_2 t_2 + \cdots + n_n t_n}}$$

The maximum axial load in section t_1 is given by Fa_1, while the maximum axial load in section t_3 is given by Fa_3.

◆ **Formula (4): Average output rotational speed (N_{av})**

$$N_{av} = \frac{n_1 t_1 + n_2 t_2 + \cdots + n_n t_n}{t_1 + t_2 + \cdots + t_n}$$

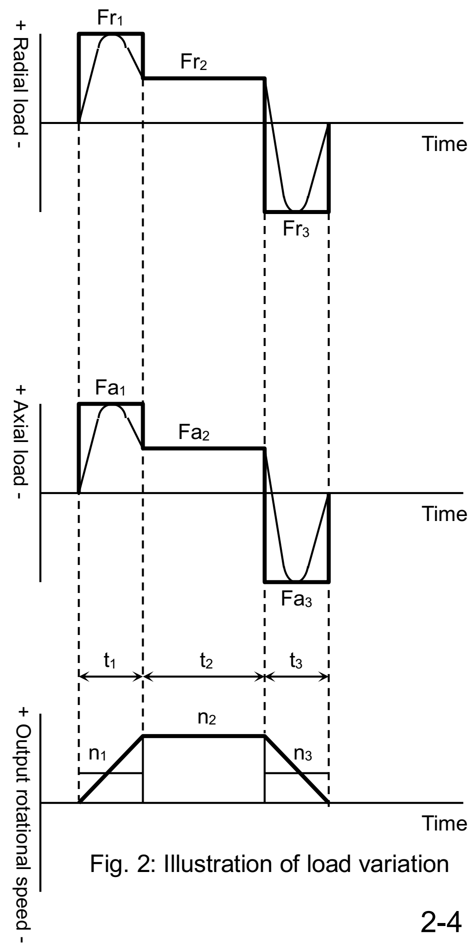


Fig. 2: Illustration of load variation

Radial load coefficient and axial load coefficient

Determine the values of the radial load coefficient (X) and the axial load coefficient (Y) based on conditional judgment according to formula (5).

Table 3: Radial load coefficient (X), axial load coefficient (Y)

◆ **Formula (5)**	X	Y
$\dfrac{Fa_{av}}{Fr_{av}+2(Fr_{av}(Lr+R)+Fa_{av}\cdot La)/dp} \le 1.5$	1	0.45
$\dfrac{Fa_{av}}{Fr_{av}+2(Fr_{av}(Lr+R)+Fa_{av}\cdot La)/dp} > 1.5$	0.67	0.67

Symbols used in the formula

Fr*av*	Average radial load	N	Refer to formula (2)
Fa*av*	Average axial load	N	Refer to formula (3)
Lr ,La	————	mm	Refer to Fig. 1
R	Offset amount	mm	Refer to Fig. 1 and Table 1
dp	Circular pitch of the roller	mm	Refer to Fig. 1 and Table 1

Dynamic equivalent radial load

◆ **Formula (6): Dynamic equivalent radial load**

$$Pc = X\cdot\left(Fr_{av}+\frac{2(Fr_{av}(Lr+R)+Fa_{av}\cdot La)}{dp}\right)+Y\cdot Fa_{av}$$

Symbols used in the formula

Pc	Dynamic equivalent radial load	N	
Frav	Average radial load	N	Refer to formula (2)
Faav	Average axial load	N	Refer to formula (3)
dp	Circular pitch of the roller	mm	Refer to Table 1
X	Radial load coefficient	-	Refer to Table 2
Y	Axial load coefficient	-	Refer to Table 2
Lr, La	−	mm	Refer to Fig. 1
R	Offset amount	mm	Refer to Fig. 1 and Table 1

Life of cross roller bearing

Use formula (7) to calculate the life of the cross roller bearing.

◆ **Formula (7): Cross roller bearing life**

$$L_{B-10} = \frac{10^6}{60\times N_{av}}\times\left(\frac{C}{fw\cdot Pc}\right)^{10/3}$$

Symbols used in the formula

L_{B-10}	Life	hour	—
N*av*	Average output rotational speed	r/min	Refer to formula (4)
C	Basic dynamic rated load	N	Refer to Table 1
Pc	Dynamic equivalent radial load	N	Refer to formula (6)
fw	Load coefficient	-	Refer to Table 3

Table 4: Load coefficient

Loaded state	fw
Smooth operation free from impact/vibration	1 to 1.2
Normal operation	1.2 to 1.5
Operation subject to impact/vibration	1.5 to 3

Cross roller bearing life based on oscillating movement

Use formula (8) to calculate the life of the cross roller bearing against oscillating movement.

◆ **Formula (8): Cross roller bearing life (oscillating)**

$$Loc = \frac{10^6}{60 \times n_1} \times \frac{90}{\theta} \times \left(\frac{C}{fw \cdot Pc}\right)^{10/3}$$

Symbols used in the formula

Loc	Life	hour	—
n_1	Number of reciprocating oscillations per min.	cpm	—
C	Basic dynamic rated load	N	Refer to Table 1
Pc	Dynamic equivalent radial load	N	Refer to formula (6)
fw	Load coefficient	-	Refer to Table 3
θ	Oscillating angle/2	-	Refer to Fig. 3

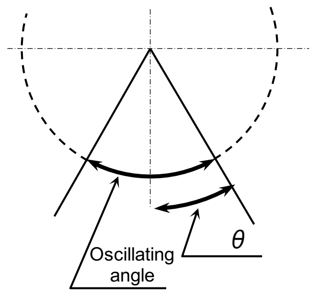


Fig. 3: Oscillating movement

If the oscillating angle is 5° or less, fretting wear may occur because oil film does not form effectively on the contact surface between the race and rolling element of the cross roller bearing. In such cases, consult HDS.
If used over a long period of time when the rotational speed of the output shaft is in the extremely slow operation (0.1 r/min or less) range, there will be insufficient bearing lubrication which may cause bearing deterioration or an increased load. Please contact us if using this product in the extremely slow operation range.

Verifying the static safety coefficient

Static equivalent radial load

◆ **Formula (9): Static equivalent radial load**

$$Po = Fr_{max} + \frac{2M_{max}}{dp} + 0.44Fa_{max}$$

Symbols used in the formula

Fr_{max}	Max. radial load	N	Refer to Fig. 1
Fa_{max}	Max. axial load	N	Refer to Fig. 1
M_{max}	Max. moment load	N·m	Refer to the maximum load weight calculation methods
dp	Circular pitch of the roller	mm	Refer to Table 1

Static safety coefficient

Generally, the static equivalent load is limited by the basic static rated load (Co). However, the specific limit should be calculated according to the using conditions and required conditions. In this case, use formula (10) to calculate the static safety coefficient (fs).
Table 4 shows general values representing using conditions. Use formula (9) to calculate the static equivalent radial load (Po).

◆ **Formula (10): Static safety coefficient**

$$fs = \frac{Co}{Po}$$

Symbols used in the formula

fs	Static safety coefficient	-	Refer to Table 4
Co	Basic static rated load	N	Refer to Table 1
Po	Static equivalent radial load	N	Refer to formula (9)

Table 5: Static safety coefficients

Using conditions	fs
High rotational accuracy is required, etc.	≧3
Operation subject to impact/vibration	≧2
Normal operation	≧1.5

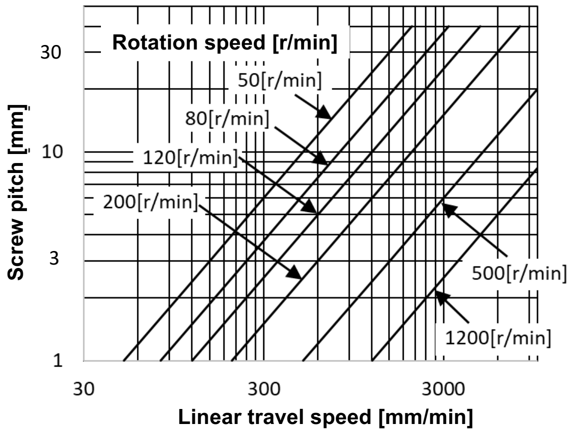
2-3 Examining operating status

The actuator generates heat if started/stopped repeatedly or operated continuously at high speed. Accordingly, examine whether or not the generated heat can be accommodated.
Examine as follows:

Examining rotational speed

Calculate the rotational speed [r/min] of the load driven by the FPA series product.
For linear operation, use the rotational speed conversion formula below:

$$\text{Actuator rotation speed [r/min]} = \frac{\text{Linear travel speed [mm/min]}}{\text{Screw feed pitch [mm]}}$$



Select an appropriate reduction ratio from 5, 11, 15, 21, 33, and 45 so that the rotational speed is the maximum rotational speed of the FPA series actuator or lower.

Calculating and examining load inertia moment

Calculate the inertia moment of the load driven by the FPA series actuator.
Refer to [AA-2 Calculating inertia moment] (PA-3) for the calculation.
Based on the calculated result, tentatively select an FPA series actuator by referring to [Allowable load inertia moment] (P2-1).

Calculating load torque

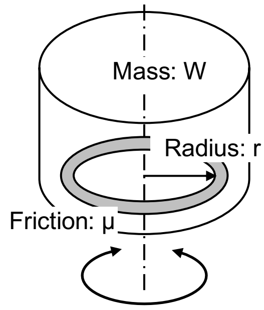
Calculate the load torque as follows:

- Rotary motion

The rotary torque for the rotating mass W on the ring of the radius r from the center of rotation is shown in the figure to the right.

$$T = 9.8 \times \mu \times W \times r$$

T: Rotary torque [N·m]
μ: Friction coefficient
W: Mass (kg)
r: Average radius of friction side [m]

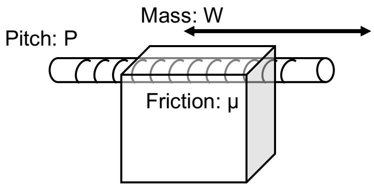


- Linear operation (horizontal operation)

The rotary torque when the mass W moves horizontally due to the screw of the pitch P is shown in the figure to the right.

$$T = 9.8 \times \mu \times W \times \frac{P}{2 \times \pi}$$

T: Rotary torque [N·m]
μ: Friction coefficient
W: Mass (kg)
P: Screw feed pitch [m]

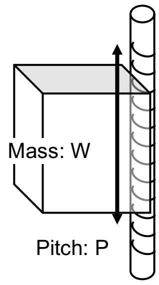


- Linear operation (vertical operation)

The rotary torque when the mass W moves vertically due to the screw of the pitch P is shown in the figure to the right.

$$T = 9.8 \times W \times \frac{P}{2 \times \pi}$$

T: Rotary torque [N·m]
W: Mass [kg]
P: Screw feed pitch [m]



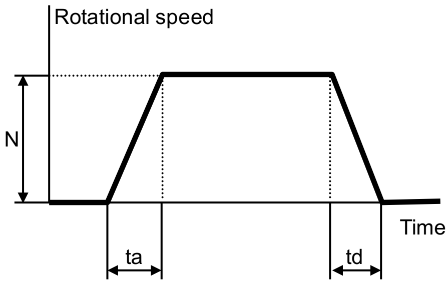
Acceleration time and deceleration time

Using the following formula, calculate the acceleration and deceleration times for the tentatively selected actuator.

Acceleration time: $t_a = k \times (J_A + J_L) \times \frac{2 \times \pi}{60} \times \frac{N}{T_M - T_L}$ ···(1)

Deceleration time: $t_d = k \times (J_A + J_L) \times \frac{2 \times \pi}{60} \times \frac{N}{T_M + 2 \times T_F + T_L}$ ···(2)

Actuator friction torque: $T_F = K_T \times I_R - T_R$ ···(3)



- ta: Acceleration time [s]
- td: Deceleration time [s]
- k: Acceleration reduction coefficient 1 to 1.5
  The total positioning time may become shorter if the acceleration is lowered for the purpose of reducing the settling time after positioning.
- J_A: Actuator inertia moment [kg·m²]
- J_L: Load inertia moment [kg·m²]
- N: Actuator rotational speed [r/min]
- T_M: Maximum actuator torque [N·m]
- T_F: Actuator friction torque [N·m]
- K_T: Torque constant [N·m/A]
- T_R: Allowable continuous torque [N·m]
- I_R: Allowable continuous current [A]
- T_L: Load torque [N·m]

  The polarity is positive (+) when applied in the rotation direction, or negative (-) when it is applied in the opposite direction.

● Calculation example 1

Select an actuator that best suits the following operating conditions:

- Rotational speed: N = 400 [r/min]
- Load inertia moment: J_L = 0.1 [kg·m^2]
- The load mechanism is mainly inertia. The load torque is negligibly small. (T_L = 0 [N·m])

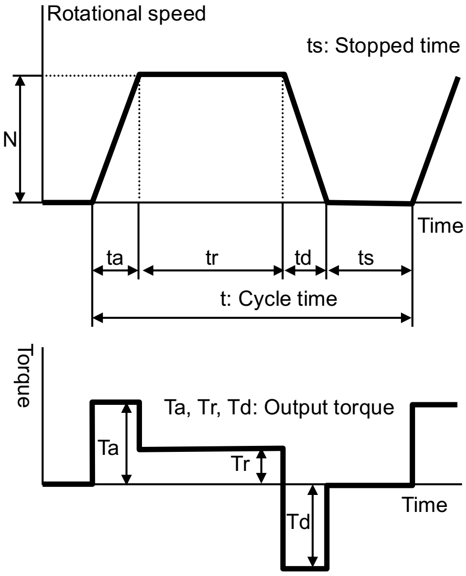
(1) After applying these conditions to the graph in [2-1], FPA14A15F0HG-F08A200-C is tentatively selected.
(2) From the rated table, the following values are obtained:
J_A = 0.011 [kg·m^2]
T_M = 23 [N·m]
T_R = 7.1 [N·m]
K_T = 5.0 [N·m/A]
I_R = 1.8 [A]
(3) Based on formula (3) above, the actuator's friction torque is calculated as T_F = 5.0 × 1.8 - 7.1 = 1.9 [N·m].
(4) If k = 1.3, the acceleration time and deceleration time can be obtained as follows from formulas (1) and (2) above:
t_a = 1.3 × (0.011 + 0.1) × 2 × π / 60 × 400 / (23 - 0) = 0.263 [s]
t_d = 1.3 × (0.011 + 0.1) × 2 × π / 60 × 400 / (23 + 2 × 1.9 ＋ 0) = 0.226 [s]
(5) If the calculated acceleration/deceleration times are too long, correct the situation by:
- Reducing the load inertia moment
- Selecting an actuator with a larger frame size

Examining effective torque and average rotational speed

One way to check if the heat generated from the actuator during operation would present a problem is to determine if the point of operation, determined by the effective torque and average rotational speed, is inside the continuous motion range explained in [1-13 Operable range] (P1-15).
Using the following formula, calculate the effective torque T_m and average rotational speed N_{av} when operating repeatedly in the drive pattern shown in the figure to the right.

$$T_m = \sqrt{\frac{T_a^2 \times t_a + T_r^2 \times t_r + T_d^2 \times t_d}{t}} \quad \cdots(1)$$

$$N_{av} = \frac{N/2 \times t_a + N \times t_r + N/2 \times t_d}{t} \quad \cdots(2)$$



The travel angle is calculated from the area of the [Rotational speed vs. time] figure to the right.

$\theta = (N / 60) \times \{t_r + (t_a + t_d) / 2\} \times 360 \quad \cdots(3)$

Accordingly, $t_r = \theta / (6 \times N) - (t_a + t_d) / 2 \quad \cdots(4)$

Based on the acceleration/deceleration time formulas in the preceding section, the relational expressions for torque during acceleration and torque during deceleration if k = 1 are as follows:

$T_a = (J_A + J_L) \times 2 \times \pi / 60 \times N / t_a + T_L \quad \cdots(5)$

$T_d = (J_A + J_L) \times 2 \times \pi / 60 \times N / t_d - 2 \times T_F - T_L \quad \cdots(6)$

t_a:	Acceleration time from speed 0 to N	[s]
t_d:	Deceleration time from speed N to 0	[s]
t_r:	Operation time at constant speed N	[s]
t:	Cycle time	[s]
T_m:	Effective torque	[N・m]
T_a:	Torque during acceleration	[N・m]
T_r:	Torque at constant speed	[N・m]
T_d:	Torque during deceleration	[N・m]
N_{av}:	Average rotational speed	[r/min]
N:	Rotational speed at constant speed	[r/min]
θ:	Travel angle	[°]
T_R:	Allowable continuous torque	[N・m]

- **Calculation example 2**

The following explanation uses FPA14A15F0HG-F08A200-C as an example.
Operating conditions: Accelerate an inertia load under conditions similar to those used in calculation example 1, allow it to move at a constant speed, and then decelerate it.
The travel angle per cycle is 1080 [°] (3 output shaft rotations) and the cycle time is 1.5 [s].

(1) When θ = 1080 [°], and
t_a = 0.263 [s]
t_d = 0.226 [s]
N = 400 [r/min]
in calculation example 1, are applied to formula (4) above, t_r = 0.206 [s].

(2) Next, calculate the torque during acceleration and torque during deceleration.
When the values in calculation example 1 are applied to formulas (5) and (6) above,
T_a = 17.7 [N・m] and
T_d = 16.8 [N・m]
are obtained.

(3) Calculate the effective torque. Apply the values in (1) and (2), and T_r = 0 [N･m] and t = 1.5 [s] to formula (1) above.

$$T_m=\sqrt{\frac{17.7^2\times0.263+0^2\times0.206+16.8^2\times0.226}{1.5}}=9.9\ [\mathrm{N\cdot m}]$$

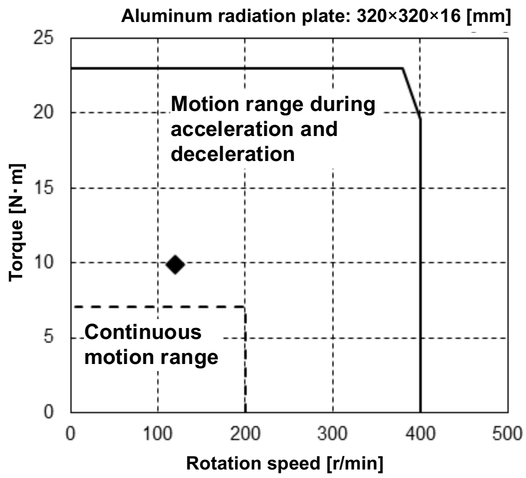
(4) Calculate the average rotational speed. Apply the values in (1), and N = 400 [r/min] and t = 1.5 [s], to formula (2) above.

$$N_{av}=\frac{400/2\times0.263+400\times0.206+400/2\times0.226}{1.5}=120\ [\mathrm{r/min}]$$

(5) When the points of operation determined by the effective torque and average rotational speed calculated above are plotted on the operable range graph of FPA14A15, the continuous motion range is exceeded, as shown in the figure below. The conclusion is that operation is not possible under these conditions. Accordingly,

◆Operation pattern,
◆Load (possible reduction),
◆Actuator model No.

etc. must be reexamined.



Operable range of FPA14A15

The following formula is a modified version of formula (1) for effective torque. By applying the value of allowable continuous torque T_R to T_m in this formula, the allowable cycle time can be calculated.

$$t=\frac{T_a{}^2\times t_a+T_r{}^2\times t_r+T_d{}^2\times t_d}{T_m{}^2}\qquad\cdots(7)$$

Apply the following:

T_a = 17.7 [N･m]
T_r = 0 [N･m]
T_d = 16.8 [N･m]
T_m = 7.1 [N･m]
t_a = 0.263 [s]
t_r = 0.206 [s]
t_d = 0.226 [s]

Then, the following equation is obtained:

$t = (17.7^2 \times 0.263 + 0^2 \times 0.206 + 16.8^2 \times 0.226) / 7.1^2 = 2.9$ [s]

Based on the result, setting the cycle time to 2.9 [s] or more to provide a longer stopped time gives T_m = 7.1 [N･m] or less, thereby permitting continuous operation within the allowable continuous torque.

Caution

- The aforementioned continuous motion range represents the allowable range where the product installed on a specified aluminum radiation plate is operated under natural air cooling. If the radiation area of the mounting member is small or heat conduction of the material is poor, adjust the operating conditions to keep the rise in the actuator's ambient temperature to 40 K or less as a guide.

Chapter 3

Installing the actuator

This chapter explains how to install the actuator.

3-1 Checking items

Check the following items after unpacking the package.

Inspection procedure

1 Check the items thoroughly for damage sustained during transportation.

If any item is damaged, immediately contact the dealer.

2 Check if the product is what was ordered.

The nameplate is found on the rear end face of the FPA series actuator. Check the TYPE field on the nameplate to confirm that it is indeed the model you have ordered. If any item is wrong, immediately contact the dealer.
For details on model codes, refer to [1-2 Model] (P1-2).

3 Check if the driver combination is correct.

The applicable combined FPA series actuator models are shown in the ADJ. field of the nameplate on the HA-900 series driver.

4 Check if the input power supply voltage is correct.

The driver's model code is shown in the TYPE field of the driver's nameplate. The last three digits of this model code indicate the input power supply voltage.

200: 3-phase/single-phase 200 VAC power supply

If this is different from the power supply voltage that will be connected, immediately contact the dealer.

WARNING

Use combined only with the actuator listed on the driver's nameplate.
The characteristics of this driver have been adjusted according to the actuator. Wrong combinations of drivers and actuators may cause low torque problems or overcurrent that may cause burned damage to the actuator, injury, or fire.

Do not connect a power supply with a voltage other than that specified on the driver's nameplate.
Connecting to a power supply with an input power supply voltage different from that listed on the nameplate may damage the driver, which may result in injury or fire.

3-2 Notices on handling

Handle the FPA series actuator carefully by observing the notices specified below.

CAUTION

(1) Do not apply any excessive force or impact exceeding specifications, especially to the actuator's output shaft. If the output shaft stops during rotation due to an impact, it could cause the positions of the output shaft and encoder shaft to become misaligned.

(2) Do not put the FPA series actuator on a table, shelf, etc., where the actuator could easily fall.

(3) Do not connect the actuator terminals directly to the power supply. The actuator may burn and cause fire or electric shock.

(4) The allowable storage temperature is -20 to +60 ℃. Do not expose the product to direct sunlight for long periods of time or store it in areas in low or high temperature.

(5) The allowable relative storage humidity is 80 % or less. Do not store the product in a very humid place or in areas where temperatures are likely to fluctuate greatly during day and night.

(6) Do not use or store the product in locations subject to flammable or corrosive gases or dust particles.

Installation and transmission torque

Use high-tension bolts and tighten them with a torque wrench to control the tightening torque. Use flat washers because the tightening torque is high and the actuator flange is made of aluminum.

- Recommended tightening torque and transmission torque

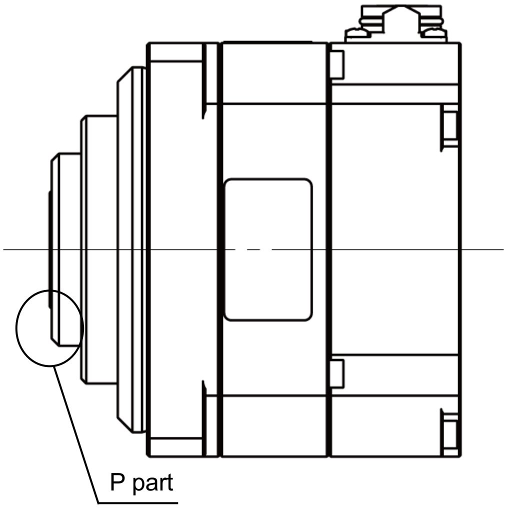
Item \ Model		FPA11AxxHG-F08		FPA14AxxHG-F08		FPA20AxxHG-F12		FPA32AxxHG-F12	
		Output shaft (Flange output)	Actuator	Output shaft (Flange output)	Actuator	Output shaft (Flange output)	Actuator	Output shaft (Flange output)	Actuator
Number of bolts, size, depth		3-M4 Depth 6	4-M5*4	6-M4 Depth 7	4-M5*4	6-M6 Depth 10	4-M10*5	6-M8 Depth 12	4-M10*5
Bolt installation P.C.D.	mm	18	102	30	102	45	150	60	150
Tightening torque	N·m	4.5	5.5	4.5	5.5	15.3	38.0	37.2	38.0
Transmission torque	N·m	19	140	63	140	215	712	524	712

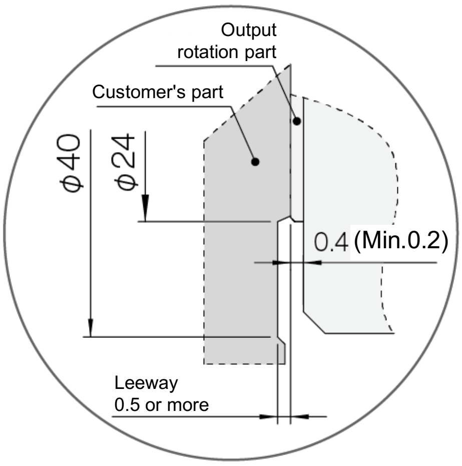
*1: The female thread material is premised to withstand the bolt tightening torque.
*2: Recommended bolt: Hexagonal bolt per JIS B 1176 Intensity category: JIS B 1051 12.9 or higher
*3: Calculation conditions Torque coefficient: 0.2 Tightening coefficient: 1.4 Tightening friction coefficient: 0.15
*4: Use flat washers.
Recommended flat washer: JIS B 1256 normal series, φ5.3 inner diameter, φ10 outer diameter, thickness 1, steel
*5: Use flat washers.
Recommended flat washer: JIS B 1256 small series, φ10.5 inner diameter, φ18 outer diameter, thickness 1.6, steel

Precautions on installation

- FPA11A

  Take note of the following when using the output shaft (flange output) of FPA11A.
  Provide the leeway shown in the figure below on the part provided by the user, because the gap between the output rotary unit and the oil seal of the non-rotating part is small (min. 0.2).





P part detail

Surface treatments

Standard FPA series actuators are given the following surface treatments:

Location	Surface treatments
Housing	No treatment (aluminum material is exposed)
Output shaft bearing (fixed part, rotating part)	Low-temperature black chrome plating
Encoder cover	Zinc plating
Connector flange	Nickel plating
Bolt	Black oxide coating treatment
Small screw	Chromate treatment

The surface treatments given to FPA series actuators do not fully prevent rust.

3-3 Location and installation

Environment of location

The environmental conditions of the installation location for FPA series actuators must be as follows. Determine an appropriate installation location by observing these conditions without fail.

- Operating temperature: 0 to 40 ℃
  If stored in a cabinet, the temperature may be higher than the outside air temperature depending on the power loss of housed devices and the size of the cabinet. Plan the cabinet size, cooling system, and device locations so that the ambient temperature of the actuator is kept at 40 ℃ or below.
- Operating humidity: Relative humidity of 20 to 80 % with no condensation.
  Take note that condensation is likely to occur in a place where there are large temperature changes between day and night or when the product is started/stopped frequently.
- Vibration: 25 m/s^2 (10 to 400 Hz) or less (refer to [1-12 Resistance to vibration] (P1-14).)
- Impact: 300 m/s^2 or less (refer to [1-11 Shock resistance] (P1-13).)
- Use environment: Free from condensation, metal powder, corrosive gases, water, oil mist, flammable gases, etc.
- Protection class: Standard products are structurally designed to meet IP-54 requirements.

  The protection class against water entry is as follows:
  4: Protected against water splashed from all directions.

  The protection class against contact and entry of foreign matter is as follows:
  5: Protected against entry of dust/dirt. Entry caused by incomplete protection must not affect the operation of the system.

  The above protection classes are applicable only when the extension cable connector is connected. However, this does not apply to rotating sliding areas (oil seal areas).
- Use the product indoors. Do not expose it to direct sunlight.
- Altitude: 1,000 m above sea level or less
- The oil seals in rotating and sliding areas do not fully prevent leakage of lubricant. If the product will be used in a clean room, etc., provide additional oil leakage prevention measures.

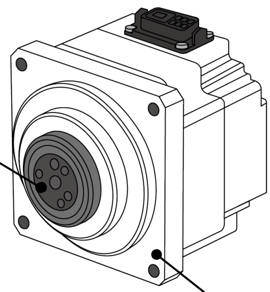
Installation

The FPA series actuator drives a mechanical load system at high accuracy.
When installing it, pay attention to precision and do not tap the actuator output unit with a hammer, etc.
The actuator houses an encoder. Excessive impact may damage the encoder.

Installation procedure

1 Ensure that the center of the actuator shaft is sufficiently aligned with the center of the load system.

Note: Perform alignment carefully, especially when a rigid coupling is used. Even slight misalignment may cause the permissible load of the actuator to be exceeded, resulting in damage to the output shaft.



2 Connect the driver.

An extension cable is provided. Use it when wiring the driver. For details on wiring, refer to [1-14 Cable specifications] (P1-18) and the manual of the HA-900 series driver.

3 Wire the extension cable.

Do not pull the cable with a strong force. The connection points may be damaged. Install the cable with some slack so as not to apply tension to the actuator. Provide a sufficient bending radius (at least six times the cable diameter), especially in cases where the cable will flex.

WARNING

Do not disassemble/reassemble the actuator.
The actuator uses many precision parts. If disassembled/reassembled, it may cause burned damage or uncontrollable operation of the actuator, resulting in fire or injury.

Chapter 4

Options

This chapter provides information on available options.

4

Options

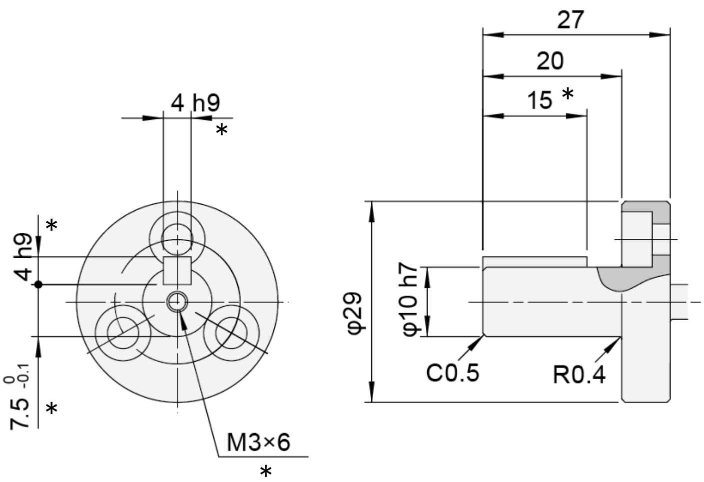
4-1 Options

Straight shaft (output shaft shape codes: J20, J60, J2, J6)

Straight output shafts are available. They are shipped assembled to products.

- For model No. 11

Unit [mm] (third angle projection)

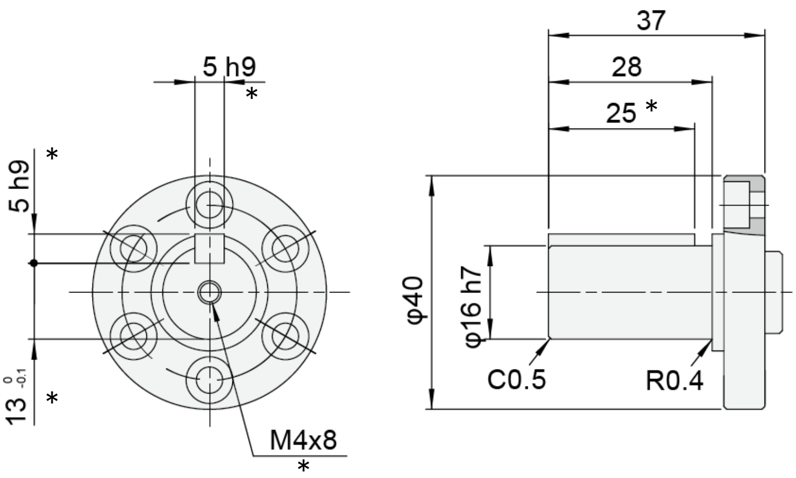


∗Not available for J20 specification

Code	Specifications	Provided with product
J20	Straight shaft, without key groove	-
J60	Straight shaft, keyed, center tapped	Parallel key: 4h9 x 49 x 15L (side tapered)

- For model No. 14

Unit [mm] (third angle projection)

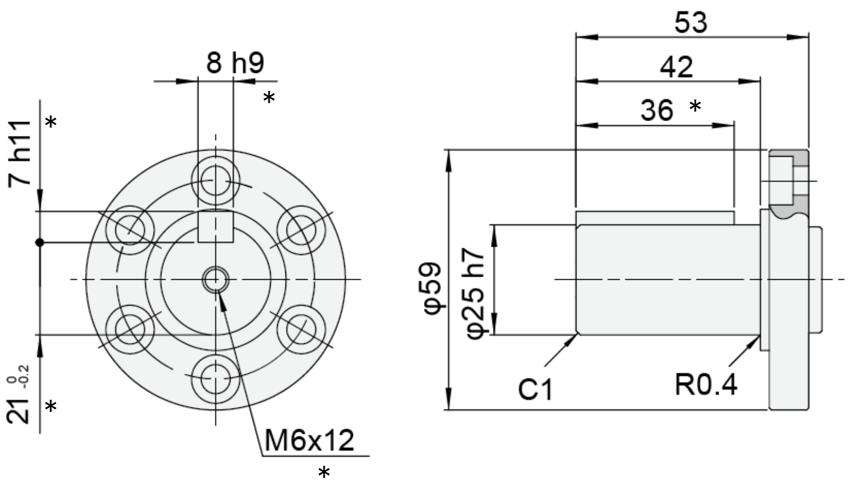


∗Not available for J2 specification

Code	Specifications	Provided with product
J2	Straight shaft, without key groove	-
J6	Straight shaft, keyed, center tapped	Parallel key: 5h9 x 5h9 x 25L (side tapered)

- For model No. 20

Unit [mm] (third angle projection)

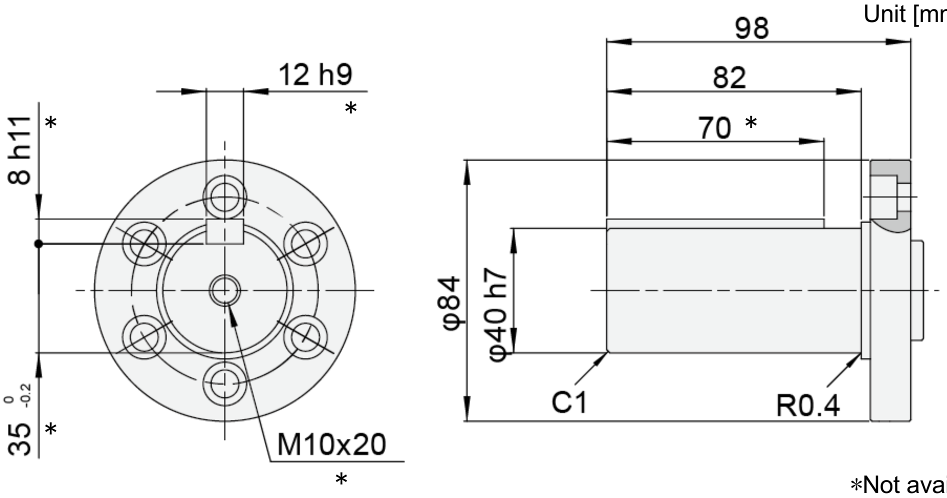


*Not available for J2 specification

Code	Specifications	Provided with product
J2	Straight shaft, without key groove	-
J6	Straight shaft, keyed, center tapped	Parallel key: 8h9 x 7h11 x 36L (side tapered)

- For model No. 32

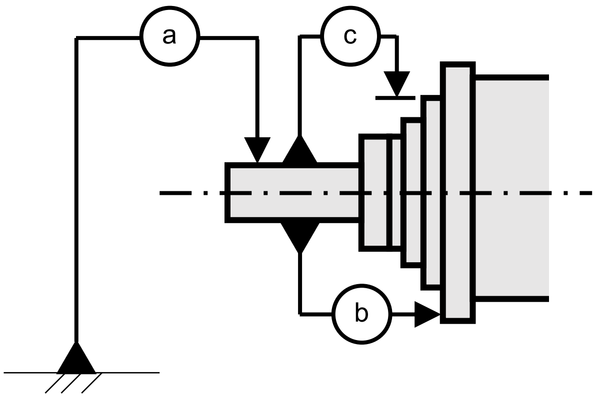
Unit [mm] (third angle projection)



*Not available for J2 specification

Code	Specifications	Provided with product
J2	Straight shaft, without key groove	-
J6	Straight shaft, keyed, center tapped	Parallel key: 12h9 x 8h11 x 70L (side tapered)

- Mechanical accuracy



Unit: mm

Model No.	Output shaft runout [mm] a	Surface runout of mounting surface b	Concentricity between output shaft and fitting part c
11	0.030	0.050	0.040
14	0.040	0.060	0.050
20	0.040	0.060	0.050
32	0.040	0.060	0.050

Note 1: All values are T.I.R. (Total Indicator Reading).
Note 2: For detailed actuator dimensions, refer to the illustrated specifications.
Note 3: The output shaft has not been surface treated.

- Mass, inertia moment

Actuator model		FPA11A	FPA14A			FPA20A		FPA32A	
		05	11	15	33	05	11	21	45
		F08A200				F12A200			
Reduction ratio		1:5	1:11	1:15	1:33	1:5	1:11	1:21	1:45
Actuator mass (Straight shaft)	kg	1.7	2.3	2.3	2.3	6.0	6.2	8.8	8.8
Actuator Inertia moment (Straight shaft)	$kg \cdot m^2$	0.0011	0.0059	0.011	0.052	0.0097	0.045	0.17	0.76

- Surface treatments

The output shaft is not treated (bare steel surface). Anti-rust oil is applied before shipment.

Note: When storing a product for a long period of time, inspect the product for rust every 6 months and reapply anti-rust oil. Please contact us for information on reapplying anti-rust oil.

Extension cables

These extension cables are for connecting FPA series products with HA-900 series drivers.
The actuator has an integrated motor and encoder connector, for one-touch attachment. Three specifications are available, each with a different cable lead-out direction.
You must use an extension cable to connect a FPA series product and HA-900 series driver.

- Model

EWE－MBS●●－HR0608■－TN4－MDR14

Cable direction

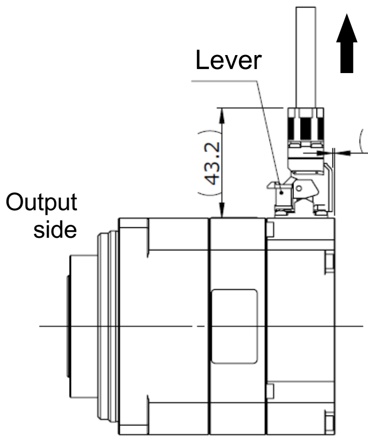
Code	Specifications
A	(All model Nos.) Vertical lead-out
B	(All model Nos.) Rear lead-out
C	(All model Nos.) Front lead-out

Note: Be cautious of the cable bending space for Model No. 11

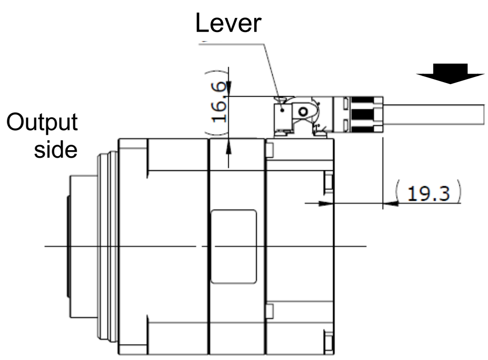
Cable length

Code	Specifications
02	2 m
05	5 m
10	10 m

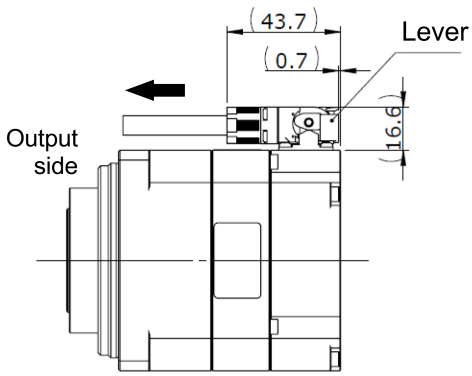
- Installation figures



A: Vertical lead-out



B: Rear lead-out



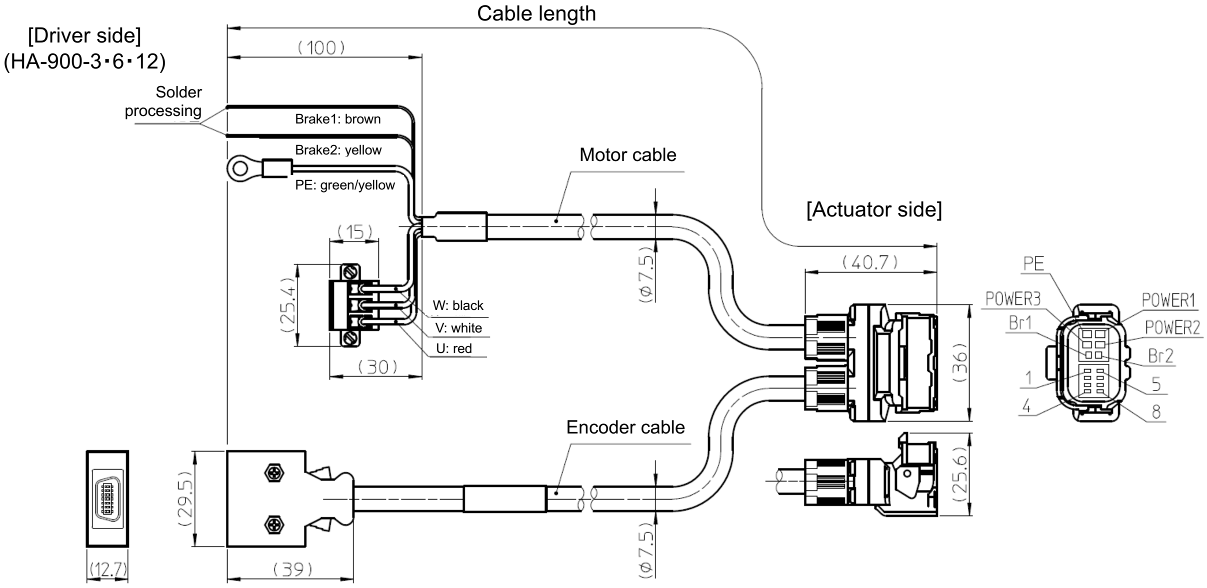
C: Front lead-out

- Design and installation precautions
  - Provide a sufficient bending radius when wiring cables. (Ensure at least four times the cable diameter for fixed parts and at least six times for moving parts.)
  - When using the front lead-out type, take note of the shape of the part that will be attached by the user, in order to ensure sufficient cable wiring space. The mounting surface of model No. 11 is especially close to the cable lead-out position of the connector, so you will need to provide some leeway on the part.
  - When attaching the connector of the extension cable to the actuator, ensure that you feel the lever clicking into place and then confirm the lever position by sight in order to ensure that the lever is locked securely.

- Vertical lead-out type external diagram

EWE－MBS●●－HR0608**A**－TN4－MDR14

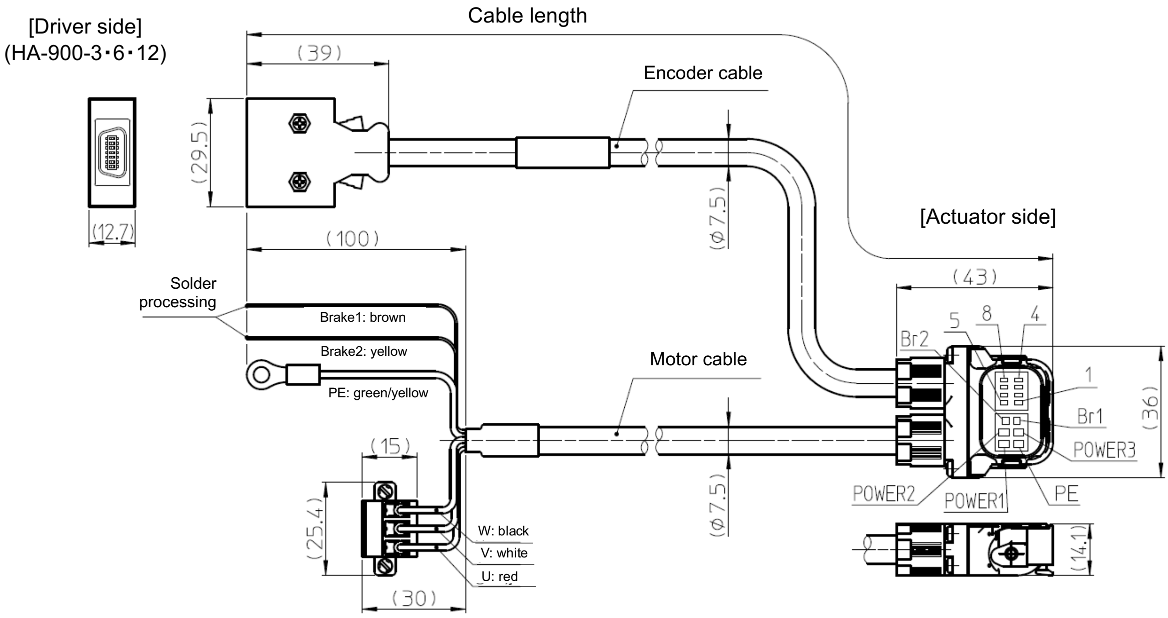
Cable length (02 = 2 m, 05 = 5 m, 10 = 10 m)



- Rear lead-out type external diagram

EWE－MBS●●－HR0608**B**－TN4－MDR14

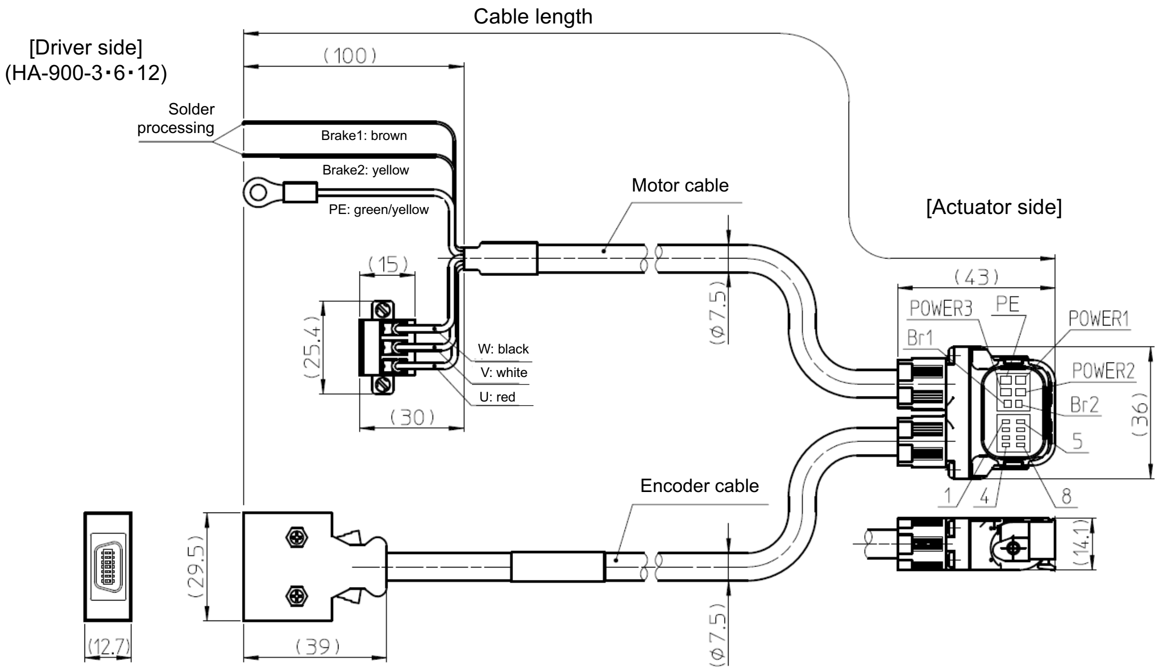
Cable length (02 = 2 m, 05 = 5 m, 10 = 10 m)



- Front lead-out type external diagram

EWE－MBS●●－HR0608**C**－TN4－MDR14

Cable length (02 = 2 m, 05 = 5 m, 10 = 10 m)



Appendix

Apx

Appendix

A-1 Unit conversion

This manual employs SI system for units. Conversion factors between the SI system and other systems are as follows:

(1) Length

SI system	m	
Unit	ft.	in.
Factor	3.281	39.37

Unit	ft.	in.
Factor	0.3048	0.0254
SI system	m	

(2) Linear speed

SI system	m/s			
Unit	m/min	ft./min	ft./s	in/s
Factor	60	196.9	3.281	39.37

Unit	m/min	ft./min	ft./s	in/s
Factor	0.0167	5.08×10^{-3}	0.3048	0.0254
SI system	m/s			

(3) Linear acceleration

SI system	m/s^2			
Unit	m/min^2	$ft./min^2$	$ft./s^2$	in/s^2
Factor	3600	1.18×10^{4}	3.281	39.37

Unit	m/min^2	$ft./min^2$	$ft./s^2$	in/s^2
Factor	2.78×10^{-4}	8.47×10^{-5}	0.3048	0.0254
SI system	m/s^2			

(4) Force

SI system	N		
Unit	kgf	lb (force)	oz (force)
Factor	0.102	0.225	4.386

Unit	kgf	lb (force)	oz (force)
Factor	9.81	4.45	0.278
SI system	N		

(5) Mass

SI system	kg	
Unit	lb.	oz.
Factor	2.205	35.27

Unit	lb.	oz.
Factor	0.4535	0.02835
SI system	kg	

(6) Angle

SI system	rad		
Unit	deg.	min.	sec.
Factor	57.3	3.44×10^{3}	2.06×10^{5}

Unit	deg.	min.	sec.
Factor	0.01755	2.93×10^{-4}	4.88×10^{-6}
SI system	rad		

(7) Angular speed

SI system	rad/s			
Unit	deg/s	deg/min	r/s	r/min
Factor	57.3	3.44×10^{3}	0.1592	9.55

Unit	deg/s	deg/min	r/s	r/min
Factor	0.01755	2.93×10^{-4}	6.28	0.1047
SI system	rad/s			

(8) Angular acceleration

SI system	rad/s²	
Unit	deg/s²	deg/min²
Factor	57.3	3.44×10^{3}

Unit	deg/s²	deg/min²
Factor	0.01755	2.93×10^{-4}
SI system	rad/s²	

(9) Torque

SI system	N·m			
Unit	kgf·m	lb·ft	lb·in	oz·in
Factor	0.102	0.738	8.85	141.6

Unit	kgf·m	lb·ft	lb·in	oz·in
Factor	9.81	1.356	0.1130	7.06×10^{-3}
SI system	N·m			

(10) Inertia moment

SI system	kg·m²							
Unit	kgf·m·s²	kgf·cm·s²	lb·ft²	lb·ft·s²	lb·in²	lb·in·s²	oz·in²	oz·in·s²
Factor	0.102	10.2	23.73	0.7376	3.42×10^{3}	8.85	5.47×10^{4}	141.6

Unit	kgf·m·s²	kgf·cm·s²	lb·ft²	lb·ft·s²	lb·in²	lb·in·s²	oz·in²	oz·in·s²
Factor	9.81	0.0981	0.0421	1.356	2.93×10^{-4}	0.113	1.829×10^{-5}	7.06×10^{-3}
SI system	kg·m²							

(11) Torsional spring constant, moment stiffness

SI system	N·m/rad				
Unit	kgf·m/rad	kgf·m/arc-min	kgf·m/ deg	lb·ft/ deg	lb·in/ deg
Factor	0.102	2.97×10^{-5}	1.78×10^{-3}	0.0129	0.1546

Unit	kgf·m/rad	kgf·m/arc-min	kgf·m/ deg	lb·ft/ deg	lb·in/ deg
Factor	9.81	3.37×10^{4}	562	77.6	6.47
SI system	N·m/rad				

Apx

Appendix

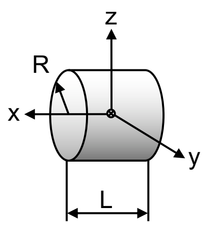
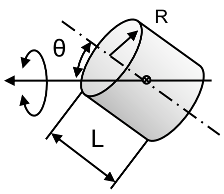
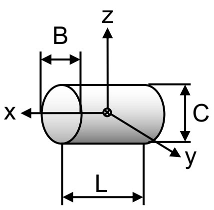
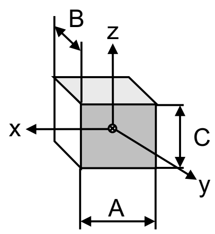
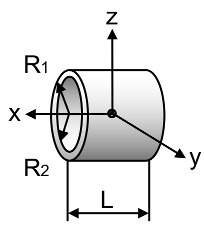
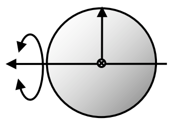
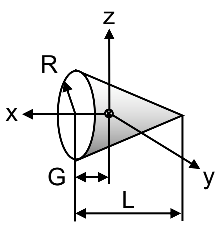
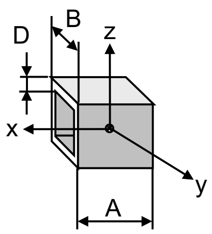
A-2 Calculating inertia moment

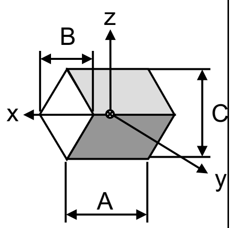
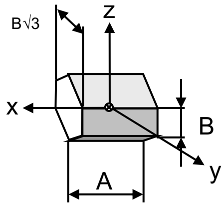
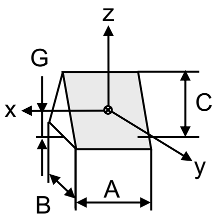
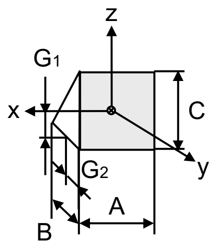
Formulas of mass and inertia moment

(1) The center of rotation matches the centroidal line

The following table includes formulas to calculate mass and inertia moment.
m: Mass [kg], Ix, Iy, Iz: Inertia moments with x-, y-, z-axes as center of rotation [kg·m^2]
G: Distance from the end face to the center of gravity [m]
ρ: Specific gravity [× 10^3kg / m^3]

Unit Inertia moment [kg·m^2]

Object form	Mass, inertia, gravity center
cylinder 	$m = \pi R^2 L \rho \times 10^3$ $Ix = \frac{1}{2} m R^2$ $Iy = \frac{1}{4} m \left(R^2 + \frac{L^2}{3} \right)$ $Iz = \frac{1}{4} m \left(R^2 + \frac{L^2}{3} \right)$
Slanted cylinder 	$m = \pi R^2 L \rho \times 10^3$ $I_\theta = \frac{1}{12} m$ $\times \left\{ 3R^2 \left(1 + \cos^2\theta \right) + L^2 \sin^2\theta \right\}$
Ellipsoidal cylinder 	$m = \frac{1}{4} B C L \rho \times 10^3$ $Ix = \frac{1}{16} m \left(B^2 + C^2 \right)$ $Iy = \frac{1}{4} m \left(\frac{C^2}{4} + \frac{L^2}{3} \right)$ $Iz = \frac{1}{4} m \left(\frac{B^2}{4} + \frac{L^2}{3} \right)$
Rectangular pillar 	$m = A B C \rho \times 10^3$ $Ix = \frac{1}{12} m \left(B^2 + C^2 \right)$ $Iy = \frac{1}{12} m \left(C^2 + A^2 \right)$ $Iz = \frac{1}{12} m \left(A^2 + B^2 \right)$
Circular pipe  R_1:Outer diameter R_2: Inner diameter	$m = \pi \left(R_1{}^2 - R_2{}^2 \right) L \rho \times 10^3$ $Ix = \frac{1}{2} m \left(R_1{}^2 + R_2{}^2 \right)$ $Iy = \frac{1}{4} m \left\{ \left(R_1{}^2 + R_2{}^2 \right) + \frac{L^2}{3} \right\}$ $Iz = \frac{1}{4} m \left\{ \left(R_1{}^2 + R_2{}^2 \right) + \frac{L^2}{3} \right\}$
Ball 	$m = \frac{4}{3} \pi R^3 \rho \times 10^3$ $I = \frac{2}{5} m R^2$
Cone 	$m = \frac{1}{3} \pi R^2 L \rho \times 10^3$ $Ix = \frac{3}{10} m R^2$ $Iy = \frac{3}{80} m \left(4R^2 + L^2 \right)$ $Iz = \frac{3}{80} m \left(4R^2 + L^2 \right)$ $G = \frac{L}{4}$
Square pipe 	$m = 4AD(B - D)\rho \times 10^3$ $Ix = \frac{1}{3} m \left\{ (B - D)^2 + D^2 \right\}$ $Iy = \frac{1}{6} m \left\{ \frac{A^2}{2} + (B - D)^2 + D^2 \right\}$ $Iz = \frac{1}{6} m \left\{ \frac{A^2}{2} + (B - D)^2 + D^2 \right\}$

Object form	Mass, inertia, gravity center	Object form	Mass, inertia, gravity center
Rhombus pillar  	$m=\frac{1}{2}ABC\rho\times10^3$ $Ix=\frac{1}{24}m\left(B^2+C^2\right)$ $Iy=\frac{1}{24}m\left(C^2+2A^2\right)$ $Iz=\frac{1}{24}m\left(B^2+2A^2\right)$	Hexagonal pillar  	$m=\frac{3\sqrt{3}}{2}AB^2\rho\times10^3$ $Ix=\frac{5}{12}mB^2$ $Iy=\frac{1}{12}m\left(A^2+\frac{5}{2}B^2\right)$ $Iz=\frac{1}{12}m\left(A^2+\frac{5}{2}B^2\right)$
Isosceles triangle pillar  	$m=\frac{1}{2}ABC\rho\times10^3$ $Ix=\frac{1}{12}m\left(\frac{B^2}{2}+\frac{2}{3}C^2\right)$ $Iy=\frac{1}{12}m\left(A^2+\frac{2}{3}C^2\right)$ $Iz=\frac{1}{12}m\left(A^2+\frac{B^2}{2}\right)$ $G=\frac{C}{3}$	Right triangle pillar  	$m=\frac{1}{2}ABC\rho\times10^3$ $Ix=\frac{1}{36}m\left(B^2+C^2\right)$ $Iy=\frac{1}{12}m\left(A^2+\frac{2}{3}C^2\right)$ $Iz=\frac{1}{12}m\left(A^2+\frac{2}{3}B^2\right)$ $G_1=\frac{C}{3}$ $G_2=\frac{B}{3}$

- **Example of specific gravity**

The following tables show reference values for specific gravity. Check the specific gravity for each material.

Material	Specific gravity [$\times10^3$kg / m^3]
SUS304	7.93
S45C	7.86
SS400	7.85
Cast iron	7.19
Copper	8.92
Brass	8.50

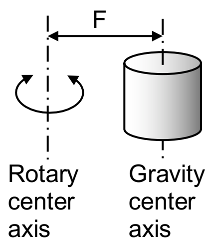
Material	Specific gravity [$\times10^3$kg / m^3]
Aluminum	2.70
Duralumin	2.80
Silicon	2.30
Quartz glass	2.20
Teflon	2.20
Fluorocarbon resin	2.20

Material	Specific gravity [$\times10^3$kg / m^3]
Epoxy resin	1.90
ABS	1.10
Silicon resin	1.80
Polyurethane rubber	1.25

(2) Both centerlines of rotation and gravity are not the same:

The following formula calculates the inertia moment when the rotary center is different from the gravity center.

$$I=Ig+mF^2$$



I : Inertia moment when the gravity center axis does not match the rotational axis [kg･m^2]

I_g : Inertia moment when the gravity center axis matches the rotational axis [kg･m^2]
Calculate according to the shape by using formula (1).

m : Mass [kg]

F : Distance between rotary center and gravity center [m]

(3) Inertia moment of linear operation objects

The inertia moment, converted to output shaft, of a linear motion object driven by a screw, etc., is calculated using the formula below.

$$I=m\left(\frac{P}{2\pi}\right)^2$$

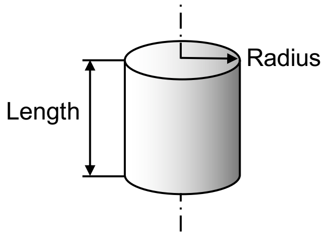
I : Inertia moment of a linear operation object converted to motor axis [kg･m^2]

m : Mass [kg]

P : Linear travel per motor one revolution [m/rev]

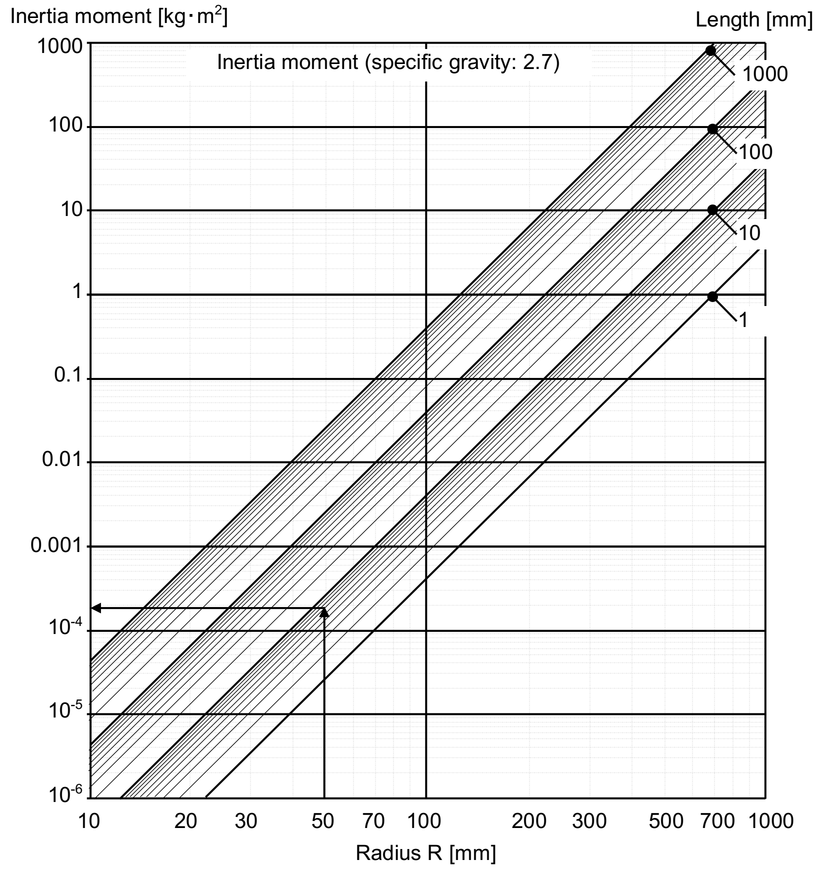
Inertia moment of cylinder

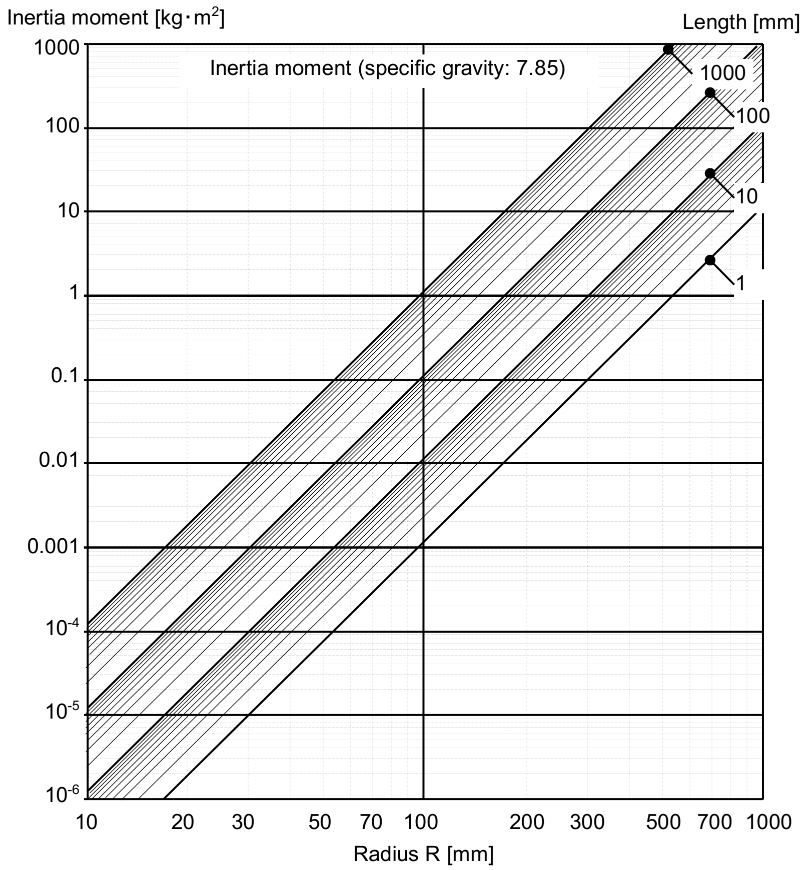
The inertia moment of a cylinder can be obtained from the graphs to the right.



Apply the top graph to aluminum materials (specific gravity: 2.7) and bottom graph to steel materials (specific gravity: 7.85):

(Example)
Material: Aluminum
Outer diameter: 100 [mm]
Length: 7 [mm]
Shape: Column
Outer diameter: 100 [mm]
Inner diameter: 50 [mm]
Inertia moment:
Approx. 1.9×10^{-4} [kg・m^2] (by the graph on the right)





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Appendix

The warranty period of this product and its warranty terms are explained below.

■ Warranty period

Assuming that it is used properly as described in applicable manuals and operating manuals, this product is guaranteed for a period of one year after delivery or 2,000 hours of operation, whichever comes first.

■ Warranty terms

If the product suffers breakdown due to any defect in workmanship or material during the warranty period specified above, the defective product will be repaired or replaced by us.

This warranty does not apply to any product that has been subject to:

(1) Improper handling or use by the customer;
(2) Modification or repair carried out by parties other than Harmonic Drive Systems, Inc.;
(3) Breakdowns not attributable to this product; or
(4) Natural disasters or any other event beyond the control of Harmonic Drive Systems, Inc.

The warranty covers only the applicable product.

Harmonic Drive Systems, Inc. shall not be liable for any consequential damage to other equipment caused by product breakdown, or expenses and labor costs for removing and installing the defective product from/to the system.

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All specifications and dimensions in this manual subject to change without notice. This manual is correct as of July 2026.

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