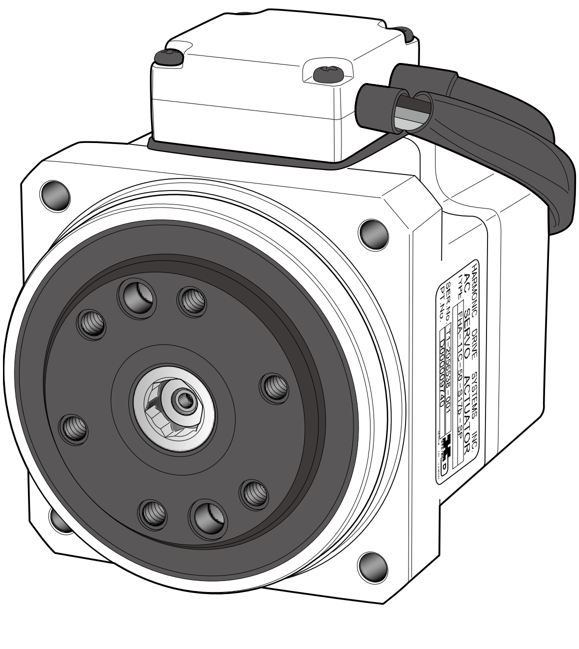
AC Servo Actuator

FHA-C mini Series

+

Panasonic Corporation
AC Servo Amplifier MINAS A6

Manual



Introduction

Thank you very much for your purchasing our FHA-Cmini series servo actuator.
Wrong handling or use of this product may result in unexpected accidents or shorter life of the product. 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 and refer to it whenever necessary in operating or maintaining the units.
The end user of the actuator should have a copy of this manual.

SAFETY GUIDE

To use this actuator 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 actuator.

NOTATION

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

WARNING	Indicates a potentially hazardous situation, which, if not avoided, could result in death or serious personal 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

The equipment listed in this document may not be used for the applications listed below:

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

If the above list includes your intending application for our products, please consult us.

CAUTION

Safety measures are essential to prevent accidents resulting in death, injury or damage of the equipment due to malfunction or faulty operation.

SAFETY NOTE

- **CAUTIONS FOR ACTUATORS AT APPLICATION DESIGNING**

CAUTION

Always use under followings conditions:

The actuator is designed to be used indoors. Observe the following conditions:

- **Ambient temperature: 0 to 40 ℃**
- **Ambient humidity: 20 to 80 %RH (Non-condensation)**
- **Vibration: Max 24.5 m/s^2**
- **Impact: Max 294 m/s^2**
- **No contamination by water, oil**
- **No corrosive or explosive gas**

Follow exactly the instructions in the relating manuals to install the actuator in the equipment.

- **Ensure exact alignment of actuator shaft center and corresponding center in the application.**
- **Failure to observe this caution may lead to vibration, resulting in damage of output elements.**

- **CAUTION FOR ACTUATORS IN OPERATIONS**

WARNING

Never connect cables directly to a power supply socket.

- **Each actuator must be operated with a proper servo amplifier.**
- **Failure to observe this caution may lead to injury, fire or damage of the actuator.**

Do not apply impacts and shocks.

- **Do not use a hammer during installation.**
- **Failure to observe this caution could damage the encoder and may cause uncontrollable operation.**

Avoid handling of actuators by cables.

- **Failure to observe this caution may damage the wiring, causing uncontrollable or faulty operation.**

CAUTION

Keep limited torques of the actuator.

- **Keep limited torques of the actuator.**
- **Be aware, that if arms attached to output element hits by accident an solid, the output element may be uncontrollable.**

ITEMS YOU SHOULD NOTE WHEN USING THE SERVO AMPLIFIER

- **Read the related manuals to ensure safe operation. For details on the related manuals, refer to the [Related manual] (P4).**

- **Before usage, ensure you read the "Safety Guide AC Servo Motor & Amplifier MINAS A6 Series" operation manual.**
  Please download the operation manual from the Panasonic Corporation website.
  http://industrial.panasonic.com/jp/products/motors-compressors/fa-motors

- **OPERATIONAL PRECAUTIONS**

WARNING

Never change any wiring while the power is active.
Make sure that the power is not active before servicing the products. Failure to observe this caution may result in an electric shock or uncontrollable operation.

Do not touch the terminals for at least 15 minutes after turning OFF the power supply.
- Even after the power supply is turned OFF, electric charge remains in the servo amplifier. In order to prevent electric shock, perform inspections 15 minutes or more after the power supply is turned OFF.
- When installing, make sure that the inner electronic components are hard to reach.

DISPOSAL

CAUTION

The actuator and servo amplifier must be disposed of as industrial waste.
When disposing of the actuator or servo amplifier, disassemble it as much as possible, separate parts according to the material description (if indicated), and dispose of them as industrial waste.

Related manual

The related manual is listed below. Use it as a reference as necessary.

Title	Document No.	Description	Obtaining method
Modbus communication and Block operation Specification	No.SX-DSV03033	MINAS A6/A6L Modbus communication specifications and block operation function specifications are explained.	Can be downloaded from the Panasonic Corporation website.
Functional Specification	No.SX-DSV02910	Servo amplifier MINAS A6 series functions are explained.	
Realtime Express（RTEX） Functional Specification	No.SX-DSV03027	Servo amplifier MINAS A6N series functions are explained.	
Realtime Express（RTEX） Communication Specification	No.SX-DSV03028	The specifications of the network interface "Realtime Express" RTEX, which connects the servo amplifier MINAS A6N series to the host device, are explained.	
EtherCAT Functional Specification	No.SX-DSV03215	Servo amplifier MINAS A6B series functions are explained.	
EtherCAT Communication Specification	No.SX-DSV03216	The specifications of the network interface EtherCAT, which connects the servo amplifier MINAS A6B series (slave) to the host device (master), are explained.	

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Chapter 1

Outlines

Outlines of product models, specifications, external drawings, etc., are explained in this chapter.

1-1 Outlines

FHA-C mini series AC Servo Actuators provide high torque and highly accurate rotary operation. These integrated AC Servo Actuators are each composed of a thin type speed reducer HarmonicDrive® for precision control from models No. 8 to No. 14 and a flat AC servo motor.
Can now be controlled by Modbus, RTEX, or EtherCAT when combined with the Panasonic AC servo amplifier MINAS A6 series.
FHA-C mini series actuators play an important role in driving various factory automation (FA) equipment, such as robot joints, alignment mechanisms for semi-conductor LCD devices, etc.

Slim line body

Combines an ultra-thin speed reducer HarmonicDrive® for precision control with an ultra-flat AC servo motor for an ultra-slim design. The compact size allows much smaller machines and devices to be designed.

Lightweight, compact and high-output torque

The thin type speed reducer HarmonicDrive® for precision control allows the FHA-C mini series actuator to have a much higher output torque per external drawing than direct drive motors.

High positional accuracy

Achieves unidirectional positional accuracy within 150 seconds.

* Varies by model No. and speed ratio. For details, refer to [1-7 Uni-directional positional accuracy] (P1-8).

1-2 Model

Model names for the FHA-C mini series and how to read the symbols are explained below.

FHA-8 C-30-14S17b G-C-A6

- **FHA**: Model: AC Servo Actuator
  FHA-C mini series
- **8**: Model No.: 8, 11, 14
- **C**: Version symbol
- **30**: Reduction ratio of the HarmonicDrive®
  30 : 1/30
  50 : 1/50
  100 : 1/100
- **14S17b**: Encoder type and resolution

14S17b	Absolute encoder (Conforming to MINAS format)	131072 p/rev (17bit)

- **G**: Input power supply
  G: 200 VAC specification
- **C**: With connector (standard specification)
- **A6**: Combined amplifier symbol
  A6: MINAS A6 series

1-3 Combinations with servo amplifier and extension cables

The combinations of FHA-C mini series actuators, MINAS A6 servo amplifiers, and extension cables are as follows:

Actuator model	Model No.	FHA-8C			FHA-11C			FHA-14C		
	Speed ratio	30	50	100	30	50	100	30	50	100
Servo amplifier model	MADL☐05■	○	○	○	○	○	○		○	○
	MADL☐15■							○		
Extension cables (option)	Motor wire	EWD-MB**-A06-TN-P								
	Encoder wire	MFECA0**-0EAE (With battery box)								

"☐" and "■" in the servo amplifier model are the function classifications for safety functions and interface specifications. See below for details.

Symbol	Symbol	Specification
☐	N	Without safety function
	T	With safety function

Symbol	Symbol	Interface specification	Function classification
■	SE	Analog/Pulse	Position control type
	SG		General purpose communication type
	SF		Multi-function type
	NE	RTEX	Standard type
	NF		Multi-function type
	BN	EtherCAT	Standard type
	BF		Multi-function type

For details on servo amplifiers and encoder extension cables, contact Panasonic Corporation customer support.

1-4 Specifications

The specifications for the FHA-C mini series actuators are as follows.

Item	Unit	FHA-8C 30	FHA-8C 50	FHA-8C 100	FHA-11C 30	FHA-11C 50	FHA-11C 100	FHA-14C 30	FHA-14C 50	FHA-14C 100
Maximum torque *1	N·m	1.8	3.3	4.8	4.5	8.3	11	9.0	18	28
	kgf·m	0.18	0.34	0.49	0.46	0.85	1.1	0.92	1.8	2.9
Allowable continuous torque *1*2	N·m	0.75	1.5	2	1.8	2.9	4.2	3.5	4.7	6.8
Max. rotational speed	r/min	200	120	60	200	120	60	200	120	60
Allowable continuous rotation speed *2	r/min	116.7	70	35	116.7	70	35	100	60	30
Torque constant	N·m/A	3.9	6.7	14	3.8	6.6	13	4.2	7.2	15
	kgf·m/A	0.40	0.68	1.4	0.39	0.67	1.4	0.43	0.74	1.5
Max. current *1	A	0.61	0.64	0.48	1.5	1.6	1.1	2.9	3.2	2.4
Allowable continuous current *1*2	A	0.31	0.34	0.26	0.74	0.69	0.54	1.27	1.06	0.85
Input power supply (servo amplifier)	V	AC200								
EMF constant (interphase)	V/(r/min)	0.48	0.80	1.6	0.48	0.80	1.6	0.52	0.86	1.70
Phase resistance (20 °C)	Ω	14			3.7			1.4		
Phase inductance	mH	5.7			3.2			1.8		
Inertia moment ($GD^2/4$)	$kg\cdot m^2$	0.0026	0.0073	0.029	0.0062	0.017	0.069	0.019	0.054	0.215
Inertia moment (J)	$kgf\cdot cm\cdot s^2$	0.0270	0.0747	0.298	0.0630	0.176	0.705	0.197	0.547	2.189
Reduction ratio		30	50	100	30	50	100	30	50	100
Permissible moment load	N·m	15			40			75		
	kgf·m	1.5			4.1			7.7		
Moment stiffness	N·m/rad	2×10^4			4×10^4			8×10^4		
	kgf·m/rad	0.2×10^4			0.4×10^4			0.8×10^4		
Encoder type		Absolute encoder								
Encoder resolution	Single-turn detector	2^{17} (131072)								
	Multi-turn detector	2^{16} (65536)								
Output shaft resolution	Pulse/rev	3932160	6553600	13107200	3932160	6553600	13107200	3932160	6553600	13107200
Uni-directional positional accuracy	Sec.	150	120	120	120	90	90	120	90	90
Mass	kg	0.50			0.75			1.3		
Protection structure		Totally enclosed self-cooled type								
Environmental conditions		Operating temperature: 0 to 40 °C /Storage temperature: -20 to 60 °C Operating humidity/storage humidity: 20 to 80 % RH (no condensation) Resistance to vibration: 24.5 m/s^2 (frequency 10 to 400 Hz) *3 Shock resistance: 294 m/s^2 *3 No dust, metal powder, corrosive gas, inflammable gas, or oil mist. To be used indoors, no direct sunlight. Altitude: less than 1000 m above sea level Magnetic noise resistance: 0.01 tesla								
Motor insulation		Insulation resistance: 100 MΩ or more (by 500 VDC insulation tester) Dielectric strength: 1500 VAC/1 min Insulation class: B								
Safety standard compliance		CE marking								
Mounting direction		Can be installed in any direction.								

The table shows the output shaft values of the actuators.
*1: The typical value when combined with a MINAS A6 servo amplifier.
*2: Values after the temperature has risen and saturated when installed on the following aluminum radiation plates.
8C, 11C: 150×150×6 [mm]
14C : 200×200×6 [mm]
*3: For testing conditions, refer to [1-11 Shock resistance] (p.1-13) and [1-12 Resistance to vibration] (p.1-14).

1

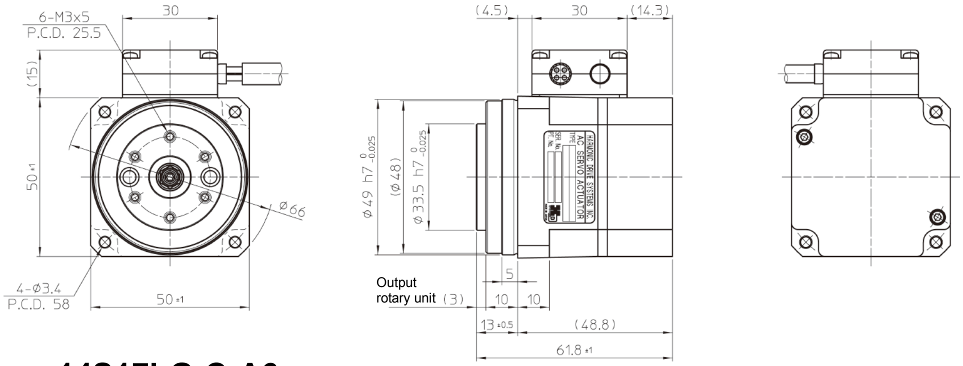
Outlines

1-5 External drawing

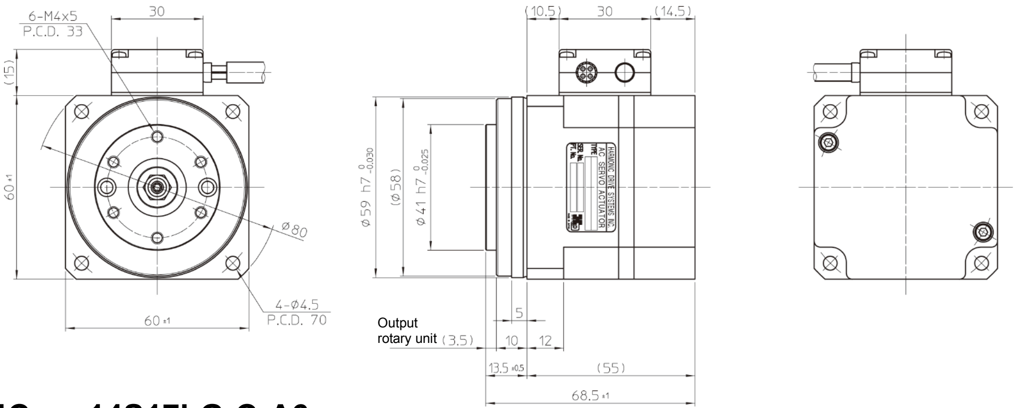
The external drawings of FHA-C mini series are shown below.
Use the included accessory encoder connector converter cable to connect the encoder.

FHA-8C-xx-14S17bG-C-A6

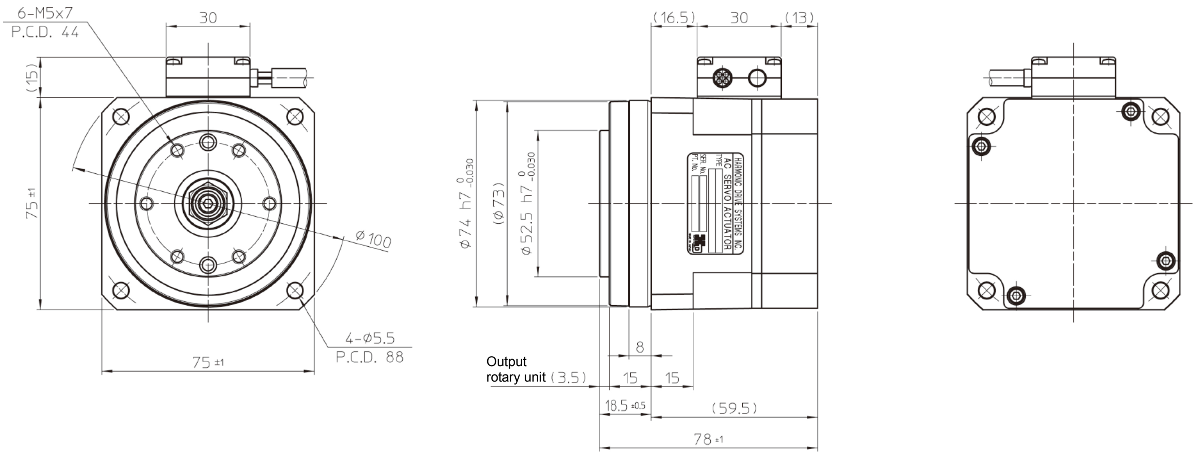
Unit [mm] (third angle projection)



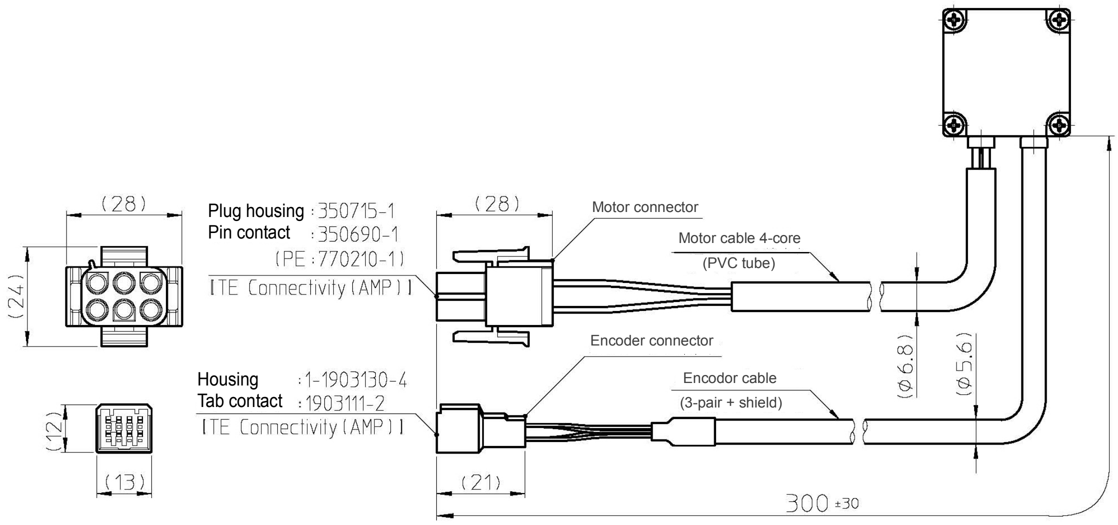
FHA-11C-xx-14S17bG-C-A6



FHA-14C-xx-14S17bG-C-A6

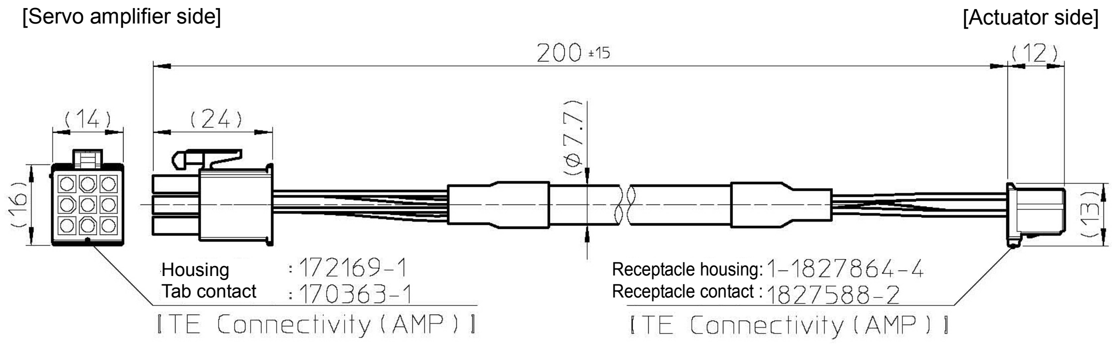


Cable pullout (common specification)



Note: Tolerances may vary due to product manufacturing method (foundry piece, machine-finished good). Please contact us for the tolerance when it is not indicated in the dimensions.

Encoder connector converter cable



Note: For details on the connector, refer to [1-14 Cable specifications] (P1-18).

1-6 Mechanical accuracy

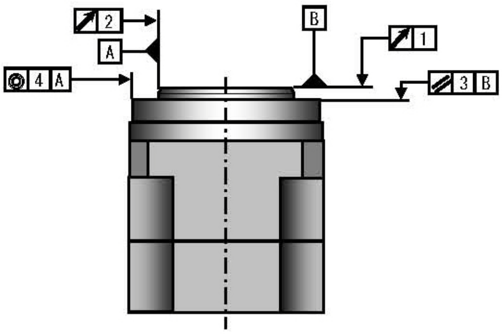
The mechanical accuracies of the output shaft and mounting flange are shown below for FHA-C mini series actuators.

Mechanical accuracy

Unit [mm]

Accuracy items	FHA-8C	FHA-11C	FHA-14C
1. Output shaft surface runout	0.010		
2. Deflection of output shaft	0.010		
3. Parallelism between the output shaft end mounted surface	0.040		
4. Concentricity between the output shaft and fitting part	0.040		

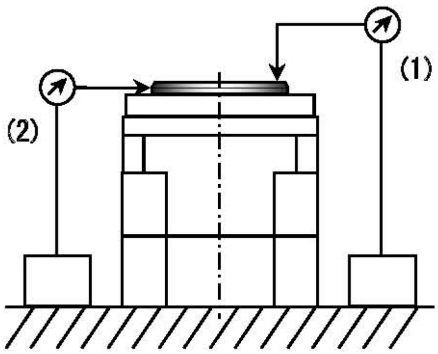
Note: All values are T.I.R. (Total Indicator Reading).



The measuring for the values are as follows:

1 Output shaft surface runout

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

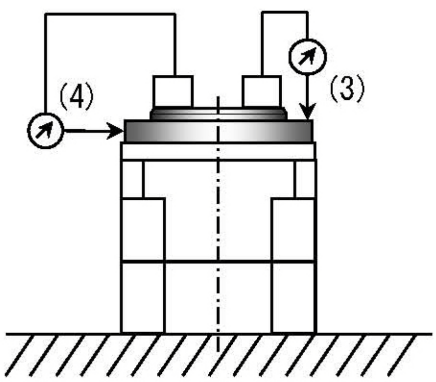


2 Deflection of output shaft

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

3 Parallelism between the output shaft end mounted surface

The dial gauge on the output rotary unit measures the axial runout (maximum runout width) of the outermost periphery of the mounting surface (both on the output shaft side and opposite side) of the output rotary unit per revolution.

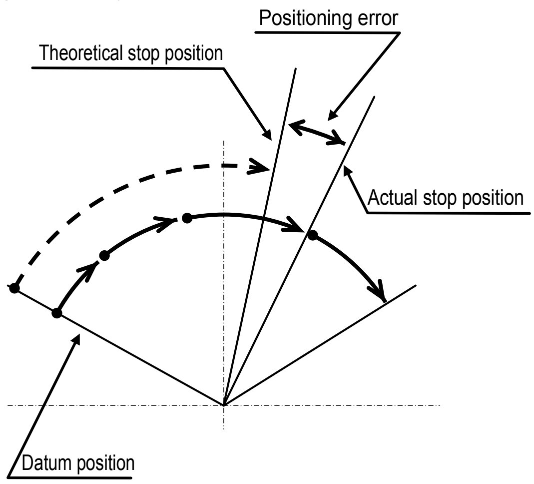


4 Concentricity between the output shaft and fitting part

The dial gauge 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 means the maximum positional difference between the actual rotated angle from the datum position and its theoretical rotational angle in 1 revolution when series of positionings are performed in the same rotation direction.
(refer to JIS B-6201-1987.)
FHA-C mini series actuators house speed reducer HarmonicDrive® for precision control, so the positioning error of the motor shaft is compressed to 1/30, 1/50 or 1/100 by the gearing. The actual angle transmission error of the speed reducer determines the uni-directional positional accuracy. Therefore, the measurement value of the angle transmission error of the speed reducer is expressed as the uni-directional positioning accuracy of the FHA-C mini series.



The uni-directional positional accuracy is shown in the table below:

Item \ Model		FHA-8C			FHA-11C			FHA-14C		
		30	50	100	30	50	100	30	50	100
Uni-directional positional accuracy	**Sec.**	150	120	120	120	90	90	120	90	90

1-8 Output shaft resolution

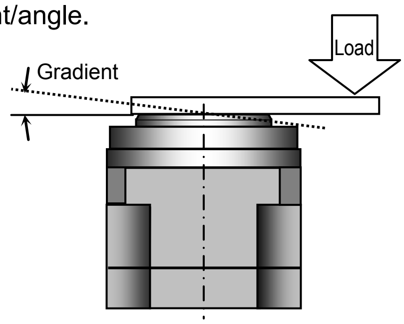
The motors of the FHA-C mini series actuators are equipped with an absolute encoder of 131072 pulses per revolution. The function reduces the motor output to 1/30, 1/50 and 1/100 by using a speed reducer HarmonicDrive® for precision control. The output shaft resolution per revolution is 30, 50 or 100 times.

Item \ Speed ratio		30	50	100
Encoder resolution		2^{17} (131072 pulse/rev)		
Reduction ratio		30	50	100
Output shaft resolution	Pulse/rev	3932160	6553600	13107200
Resolvable angle per pulse	Sec.	Approx. 0.33	Approx. 0.2	Approx. 0.1

1-9 Rigidity

Moment stiffness

The moment stiffness refers to the torsional stiffness when a moment load is applied to the output shaft of the actuator (shown below).
For example, when a load is applied to the end of an arm attached on the actuator output shaft, the face of the output shaft tilts in proportion to the moment load (shown below). The moment stiffness is expressed as the tensional moment/angle.

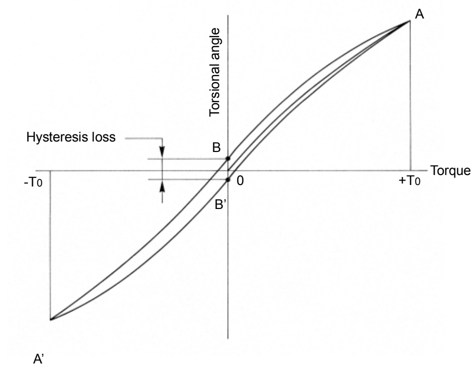


Item \ Model		FHA-8C	FHA-11C	FHA-14C
Moment stiffness	N·m/rad	2 x 10^4	4 x 10^4	8 x 10^4
	kgf·m/rad	0.2 x 10^4	0.4 x 10^4	0.8 x 10^4
	kgf·m/arc-min	0.59	1.2	2.4

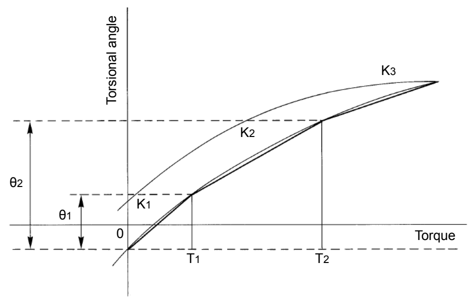
Rotation direction torsional stiffness

If a torque is applied to the output shaft of the actuator with the servo locked, the output shaft generates a torsional stress roughly in proportion to the torque.

The upper right figure shows the torsional angle of the output shaft when a torque starting from zero and increased to positive side [+T_0] and negative side [–T_0] is applied to the output shaft. This is called [torque vs. torsional angle] diagram, which typically follows a loop 0→A→B→A'→B'→A. The torsional rigidity of the FHA-C mini series actuator is expressed by the slope of this [torque vs. torsional angle] diagram representing a spring constant (unit: [N·m/rad]).



As shown by lower right figure, this [torque vs. torsional angle] diagram is divided into 3 regions and the spring constants in these regions are expressed by K_1, K_2, and K_3, respectively.
K_1: Spring constant for torque region 0 to T_1
K_2: Spring constant for torque region T_1 to T_2
K_3: Spring constant for torque region over T_2



The torsional angle for each region is expressed as follows:

*φ : Torsional angle

- Range where torque T is T1 or below: $\varphi = \frac{T}{K_1}$
- Range where torque T is T1 to T2: $\varphi = \theta_1 + \frac{T - T_1}{K_2}$
- Range where torque T is T_2 or above: $\varphi = \theta_2 + \frac{T - T_2}{K_3}$

The table below shows the average value of each actuator.

Item	Model	FHA-8C			FHA-11C			FHA-14C		
		30	50	100	30	50	100	30	50	100
T_1	N·m	0.29	0.29	0.29	0.80	0.80	0.80	2.0	2.0	2.0
	kgf·m	0.030	0.030	0.030	0.082	0.082	0.082	0.20	0.20	0.2
K_1	x10^4 N·m/rad	0.034	0.044	0.091	0.084	0.22	0.27	0.19	0.34	0.47
	kgf·m/arc-min	0.010	0.013	0.027	0.025	0.066	0.080	0.056	0.10	0.14
θ_1	x10^{-4} rad	8.5	6.6	3.2	9.5	3.6	3.0	10.5	5.8	4.1
	arc-min	3.0	2.3	1.1	3.3	1.2	1.0	3.6	2.0	1.4
T_2	N·m	0.75	0.75	0.75	2.0	2.0	2.0	6.9	6.9	6.9
	kgf·m	0.077	0.077	0.077	0.20	0.20	0.20	0.70	0.70	0.7
K_2	x10^4 N·m/rad	0.044	0.067	0.10	0.13	0.30	0.34	0.24	0.47	0.61
	kgf·m/arc-min	0.013	0.020	0.031	0.037	0.090	0.10	0.07	0.14	0.18
θ_2	x10^{-4} rad	19	13	8	19	8	6	31	16	12
	arc-min	6.6	4.7	2.6	6.5	2.6	2.2	10.7	5.6	4.2
K_3	x10^4 N·m/rad	0.054	0.084	0.12	0.16	0.32	0.44	0.34	0.57	0.71
	kgf·m/arc-min	0.016	0.025	0.036	0.047	0.096	0.13	0.10	0.17	0.21

The table below shows reference torque values calculated for different torsional angles. Unit [N·m]

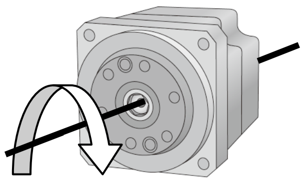
Torsional angle (arc-min) / Model	FHA-8C			FHA-11C			FHA-14C		
	30	50	100	30	50	100	30	50	100
2	0.20	0.25	0.56	0.49	1.3	1.8	1.1	2.0	3.0
4	0.42	0.63	1.2	1.1	3.3	4.2	2.3	4.7	6.5
6	0.68	1.1	1.9	1.8	5.2	6.8	3.6	7.6	11

1-10 Rotation direction

With the factory settings, the rotation direction is defined as clockwise (CW) as viewed from the output shaft when a forward command is applied to the MINAS A6 servo amplifier.
This rotation direction can be changed with the MINAS A6 servo amplifier parameter Pr 0.00.

Setting of [Pr 0.00: Rotation direction setting]

Set value	Actuator rotation direction		Setting
	When forward command is input	When reverse command is input	
0	CCW (counterclockwise) direction	CW (clockwise) direction	
1	CW (clockwise) direction	CCW (counterclockwise) direction	Default



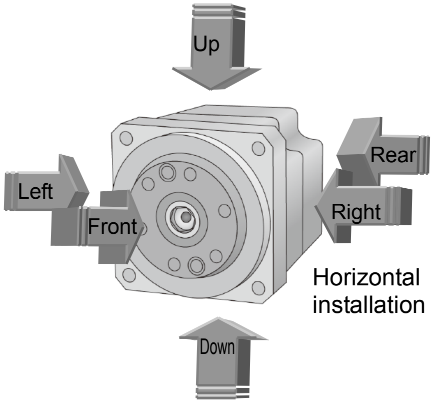
FWD rotation: Clockwise direction

1-11 Shock resistance

The shock acceleration when applying a impact in the up/down and left/right directions with the center shaft of the actuator installed horizontally is as follows.

Shock acceleration: 294 m/s^2
Direction: top/bottom, right/left, front/back
Repeating times: three each

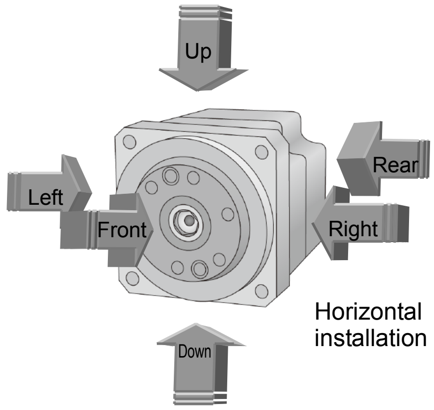
However, never apply a direct impact to the output shaft.



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: 24.5 m/s^2 (frequency: 10 to 400 Hz)
This specification does not have a warranty period and terms against fletting wear of mechanical parts due to micro-vibration.



Resistance to vibration test

1-13 Operable range

The graphs below show the operable range when a FHA-C mini series actuator and a MINAS A6 servo amplifier combination is selected. Refer to [Chapter 2 Selection guidelines] for the most efficient use of FHA-C mini series actuators' output.

1. Continuous motion range

The range allows continuous operation for the actuator.

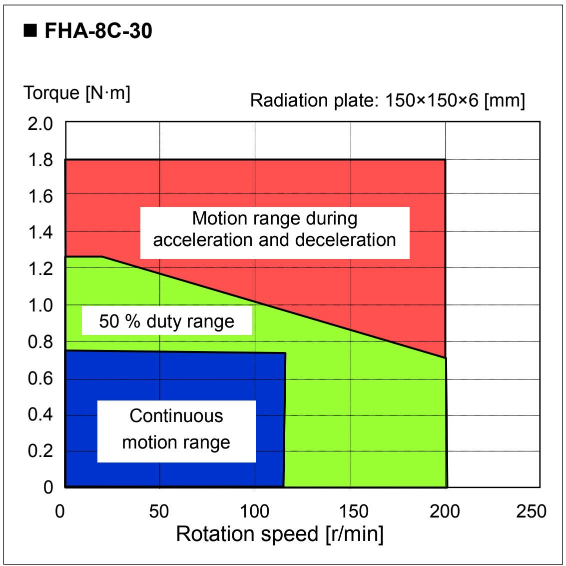
2. 50 % duty motion range

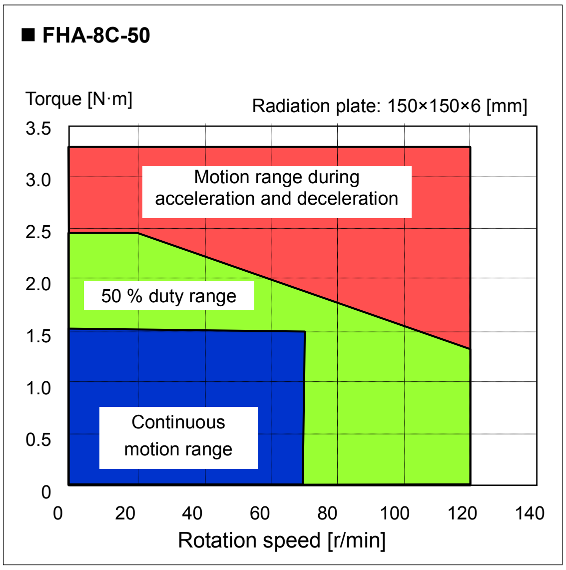
This range indicates the torque rotation speed which is operable in the 50 % duty operation (the ratio of operating time and delay time is 50:50).

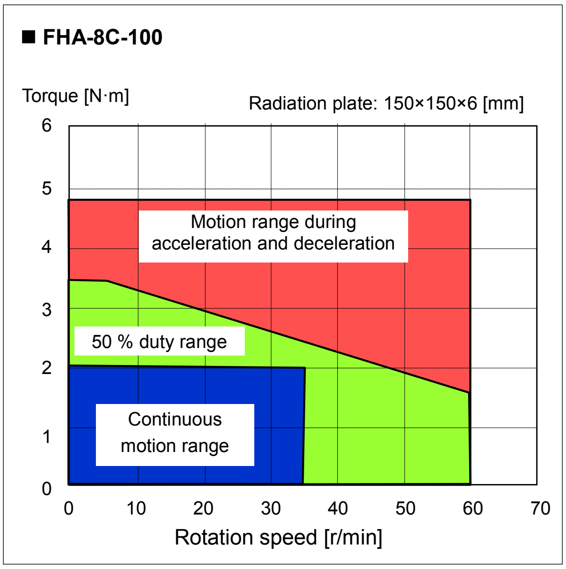
3. Motion range during acceleration and deceleration

This range indicates the torque rotation speed which is operable momentarily. The range allows instantaneous operation like acceleration and deceleration, usually.

The continuous and 50 % duty motion ranges shown on each graph are measured on the condition where the radiation plate specified in the graph is installed.

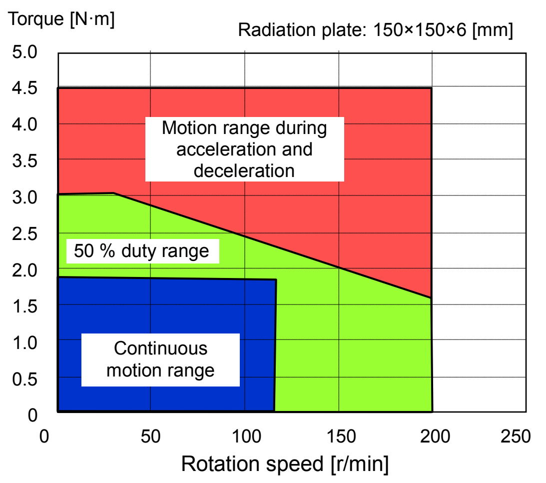




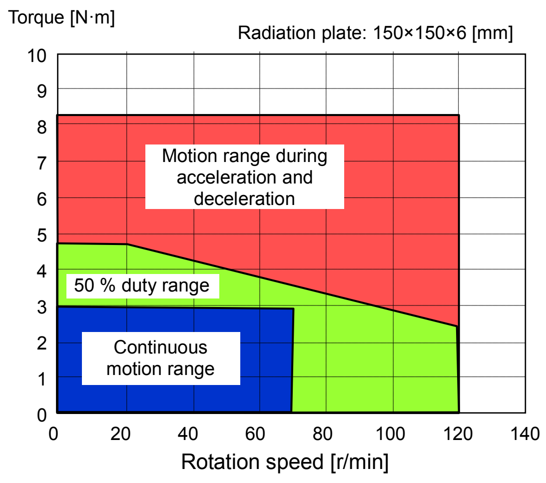


Note1 : If you are continuously using a single direction for the continuous motion range, please consult us.
Note2 : The graph shows typical values of 3-phase 200 VAC.

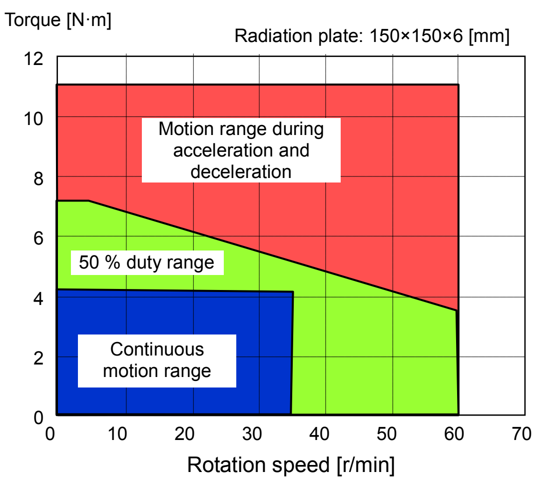
■ **FHA-11C-30**



■ **FHA-11C-50**

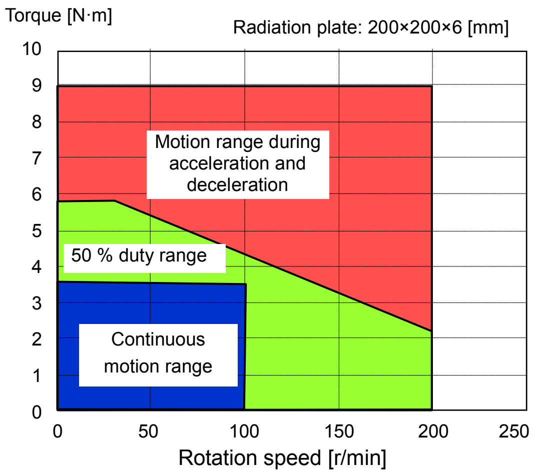


■ **FHA-11C-100**

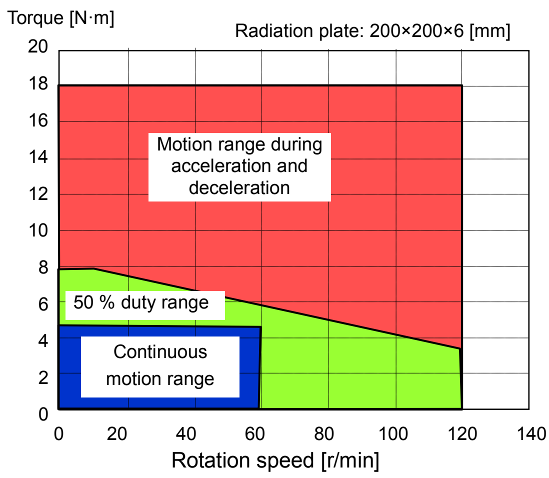


Note1 : If you are continuously using a single direction for the continuous motion range, please consult us.
Note2 : The graph shows typical values of 3-phase 200 VAC.

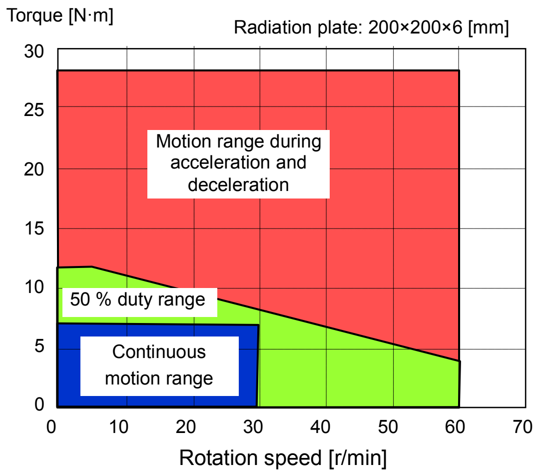
■ FHA-14C-30



■ FHA-14C-50



■ FHA-14C-100



Note1 : If you are continuously using a single direction for the continuous motion range, please consult us.
Note2 : The graph shows typical values of 3-phase 200 VAC.

1-14 Cable specifications

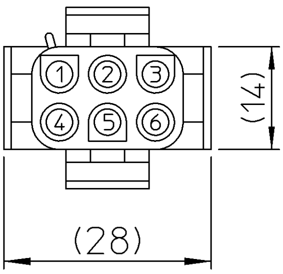
The following tables show specifications of the motor and encoder cables of the FHA-C mini series actuators.

Motor power cable

- **Pin layout**

Pin No.	Color	Motor cable
1	Red	Motor phase-U
2	White	Motor phase-V
3	Black	Motor phase-W
4	Green/Yellow	PE
5	—	—
6	—	—

- **Pin position**



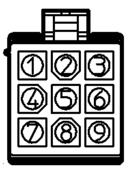
Connector model: 350715-1
Pin model : 350690-1 (PE: 770210-1)
TE Connectivity (AMP product family)

Encoder connector converter cable (servo amplifier side)

- **Pin layout**

Pin No.	Color	Signal name	Remarks
1	Orange	BAT+	Battery +
2	Gray	BAT-	Battery - (GND)
3	Shield	FG	
4	Yellow	PS	Serial signal differential output (+)
5	Blue	$\overline{PS}$	Serial signal differential output (-)
6	—	No connection	
7	Red	E5 V	Power supply input +5 V
8	Black	E0 V	Power supply input 0 V (GND)
9	—	No connection	

- **Connector pin layout**



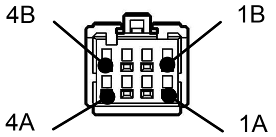
Connector model: 172169-1
Pin model : 170363-1
TE Connectivity (AMP product family)

Encoder connector converter cable (actuator side)

- **Pin layout**

Pin No.	Color	Signal name	Remarks
1A	Red	E5 V	Power supply input +5 V
1B	Black	E0 V	Power supply input 0 V (GND)
2A	Yellow	PS	Serial signal differential output (+)
2B	Blue	$\overline{PS}$	Serial signal differential output (-)
3A	—	No connection	—
3B	Shield	FG	
4A	Orange	BAT+	Battery +
4B	Gray	BAT-	Battery - (GND)

- **Connector pin layout**



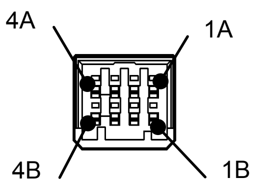
Connector model: 350715-1
Pin model: 350690-1（PE：770210-1）
TE Connectivity (AMP product family)

Encoder connector (actuator side)

- **Pin layout**

Pin No.	Color	Signal name	Remarks
1A	White	E5 V	Power supply input +5 V
1B	Black	E0 V	Power supply input 0 V (GND)
2A	Blue	PS	Serial signal differential output (+)
2B	Purple	$\overline{PS}$	Serial signal differential output (-)
3A	—	No connection	—
3B	Shield	FG	
4A	Orange	BAT+	Battery +
4B	Brown	BAT-	Battery - (GND)

- **Connector pin layout**



Connector model: 1-1903130-4
Pin model: 1903111-2, 1903116-2, or 1903117-2
TE Connectivity (AMP product family)

Chapter 2

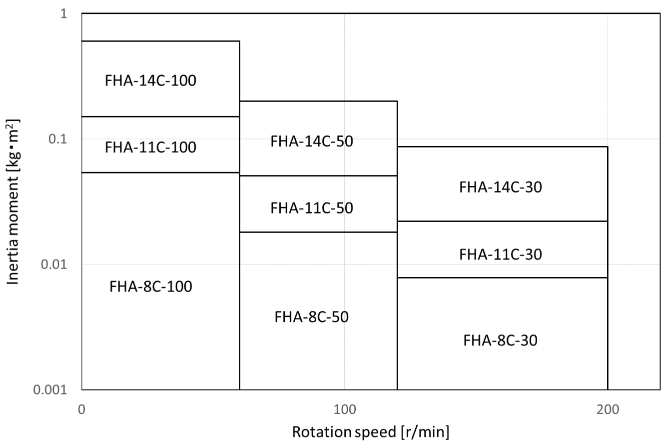
Selection guidelines

The following explains the guidelines for selecting actuators.

2-1 FHA-C mini series selection

Allowable load inertia moment

To achieve high accuracy and performance, select a FHA-C mini series actuator where the allowable load inertia moment (reference value) specified for the applicable model No. is not exceeded.
For the calculation of inertia moment, refer to [Apx-2 Calculating inertia moment] (PApx-3).



When temporarily selecting an actuator, make certain that the inertia moment and rotation speed do not exceed the allowable values shown in the table below.

Actuator model			FHA-8C			FHA-11C			FHA-14C		
			30	50	100	30	50	100	30	50	100
Reduction ratio			30	50	100	30	50	100	30	50	100
Max. rotational speed		r/min	200	120	60	200	120	60	200	120	60
Inertia moment	($GD^2/4$)	$kg \cdot m^2$	0.0026	0.0073	0.029	0.0062	0.017	0.069	0.019	0.054	0.215
	(J)	$kgf \cdot cm \cdot s^2$	0.027	0.0747	0.298	0.063	0.176	0.705	0.197	0.547	2.189
Allowable load inertia moment		$kg \cdot m^2$	0.0078	0.022	0.087	0.018	0.051	0.20	0.054	0.15	0.60
		$kgf \cdot cm \cdot s^2$	0.081	0.23	0.90	0.18	0.51	2.0	0.54	1.5	6.0

2-2 Change in moment of inertia of load

FHA-C mini series actuators include HarmonicDrive® gearing that has a high reduction ratio. Because of this, the effects of change in load inertia moment on the servo performance are minimal. In comparison to direct servo drive mechanisms, therefore, this benefit allows the load to be driven with a better servo response.

For example, assume that the load inertia moment increases to N-times. The total inertia moment converted to motor shaft which has an effect on servo response is as follows:

The symbols in the formulas are:

J_S: Total inertia moment converted to motor shaft
J_M: Motor inertia moment
R: Reduction ratio of FHA-C mini series actuators
L: Ratio of load inertia moment to inertia moment of motor
N: Rate of change in load inertia moment

- Direct drive

Before: $Js = J_M(1+L)$ After: $Js' = J_M(1+NL)$ Ratio: $Js'/Js = \frac{1+NL}{1+L}$

- Driven by FHA-C mini series

Before: $Js = J_M\left(1+\frac{L}{R^2}\right)$ After: $Js' = J_M\left(1+\frac{NL}{R^2}\right)$ Ratio: $Js'/Js = \frac{1+NL/R^2}{1+L/R^2}$

With the FHA-C mini series, the value of R increases to 30, 50 or 100, which means that the value of R^2 increases substantially to 900, 2500 or 10000. Then the ratio is $Js'/Js \fallingdotseq 1$. This means that FHA-C mini series are hardly affected by the load variation. Therefore, it is not necessary to take change in load inertia moment into consideration when selecting a FHA-C mini series actuator.

2-3 Verifying and examining load weights

The FHA-C mini series actuator incorporates a precise cross roller bearing for directly supporting an external load (output flange). To demonstrate the full ability of the actuator, verify the maximum load weight as well as the life and static safety coefficient of the cross roller bearing.

Checking procedure

- **Checking the maximum load weight (M*max*, Fr*max*, Fa*max*)**
  Calculate the maximum load weight (M*max*, Fr*max*, Fa*max*)
  ↓
  Check the maximum load weight (M*max*, Fr*max*, Fa*max*) is less than or equal to the permissible loads (Mc, Fr, Fa)
- **Checking the life of the cross roller bearing**
  Calculate the average radial load (Fr*av*) and average axial load (Fa*av*).
  ↓
  Calculate the radial load coefficient (X) and the axial load coefficient (Y).
  ↓
  Calculate the life of the bearing and verify the life is allowable.
- **Verifying the static safety coefficient**
  Calculate the static equivalent radial load (Po).
  ↓
  Verify the static safety coefficient (fs).

Specifications of the main roller bearing

The following table shows the specifications of the main roller bearings built in FHA-C mini series actuators.

Table 1

Item / Model	Pitch circle diameter of a roller (dp)	Offset amount (R)	Basic dynamic rated load (C)	Basic static rated load (Co)	Permissible axial load (Fa)	Permissible moment capacity (Mc)
	mm	mm	N	N	N	N·m
FHA-8C	35	12.9	5800	8000	200	15
FHA-11C	42.5	14	6500	9900	300	40
FHA-14C	54	14	7400	12800	500	75

Maximum load weight

The table below shows how to calculate the maximum load weight (M*max*, Fr*max*, Fa*max*).
Confirm that each maximum load weight is less than or equal to each permissible load.

◆ **Formula (1)**

$$M\,max = \frac{Fr\,max \cdot (Lr + R) + Fa\,max \cdot La}{1000}$$

Symbols used in the formulas

M*max*	Max. moment capacity	N·m	
Fr*max*	Max. radial load	N	See Fig.1.
Fa*max*	Max. axial load	N	See Fig.1.
Lr ,La	————	mm	See Fig.1.
R	Offset amount	mm	See Fig.1 and Table 1.

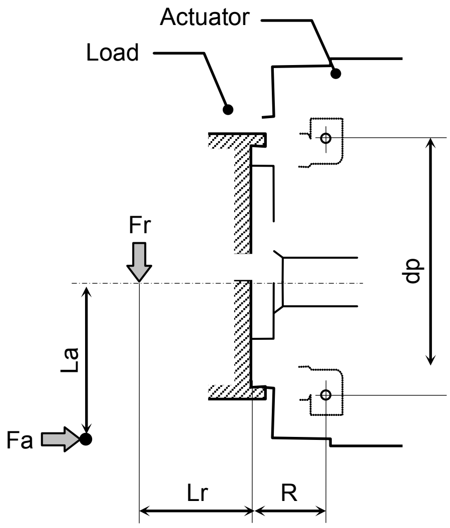


Fig. 1: External load action diagram

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

When the radial and/or axial loads vary during motion, calculate and verify the life of the cross roller bearing converting the loads to their average values.

◆ **Formula (2): Average radial load (Frav)**

$$Fr_{av} = \sqrt[10/3]{\frac{n_1t_1|Fr_1|^{10/3} + n_2t_2|Fr_2|^{10/3} \cdots n_nt_n|Fr_n|^{10/3}}{n_1t_1 + n_2t_2 + \cdots + n_nt_n}}$$

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 (Faav)**

$$Fa_{av} = \sqrt[10/3]{\frac{n_1t_1|Fa_1|^{10/3} + n_2t_2|Fa_2|^{10/3} \cdots n_nt_n|Fa_n|^{10/3}}{n_1t_1 + n_2t_2 + \cdots + n_nt_n}}$$

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 (Nav)**

$$N_{av} = \frac{n_1t_1 + n_2t_2 + \cdots + n_nt_n}{t_1 + t_2 + \cdots + t_n}$$

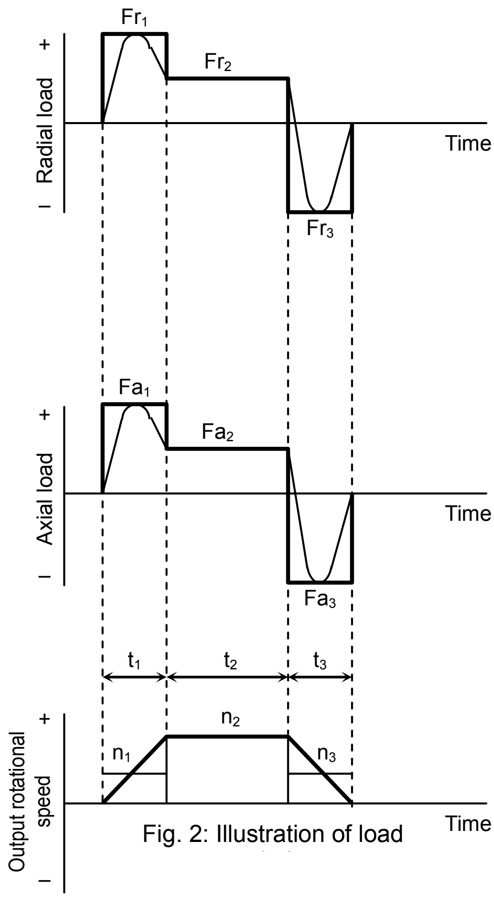


Fig. 2: Illustration of load

Radial load coefficient and axial load coefficient

Table 2: Radial load coefficient (X), axial load coefficient (Y)

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

Symbols used in the formulas

Fr*av*	Average radial load	N	Refer to the average load.
Fa*av*	Average axial load	N	Refer to the average load.
Lr ,La	————	mm	See Fig.1.
R	Offset amount	mm	See Fig.1 and Table 1.
dp	Pitch circle diameter of a roller	mm	See Fig.1 and Table 1.

2

Selection guidelines

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 formulas

Pc	Dynamic equivalent radial load	N	
Fr*av*	Average radial load	N	Obtained by formula (2).
Fa*av*	Average axial load	N	Obtained by formula (3).
dp	Pitch circle diameter of a roller	mm	See Table 1.
X	Radial load coefficient	—	See Table 2.
Y	Axial load coefficient	—	See Table 2.
Lr, La	—	mm	See Fig.1.
R	Offset amount	mm	See Fig.1 and Table 1.

Life of cross roller bearing

Calculate the life of cross roller bearing with the formula (7) below:

◆ **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 formulas

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

Table 3 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 cross roller bearing life 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 formulas

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

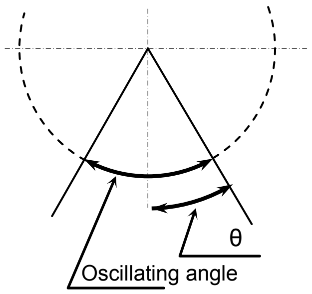


Fig. 3: Oscillating movement

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.

Static equivalent radial load

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

$$Po = Fr\mathit{max} + \frac{2M\mathit{max}}{dp \times 10^{-3}} + 0.44Fa\mathit{max}$$

Symbols used in the formulas

Fr*max*	Max. radial load	N	See Fig.1.
Fa*max*	Max. axial load	N	See Fig.1.
M*max*	Max. moment load	N·m	Refer to the maximum load weight calculation methods.
dp	Pitch circle diameter of a roller	mm	See 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, calculate the static safety coefficient (fs) by formula (10).

Table 4 shows general values representing using conditions. Calculate the static equivalent radial load (Po) by formula (9).

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

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

Symbols used in the formulas

fs	Static safety coefficient	—	See Table 4.
Co	Basic static rated load	N	See Table 1.
Po	Static equivalent radial load	N	Obtained by formula (9).

Table 4 Static safety coefficient

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

2

Selection guidelines

2-4 Examining operating status

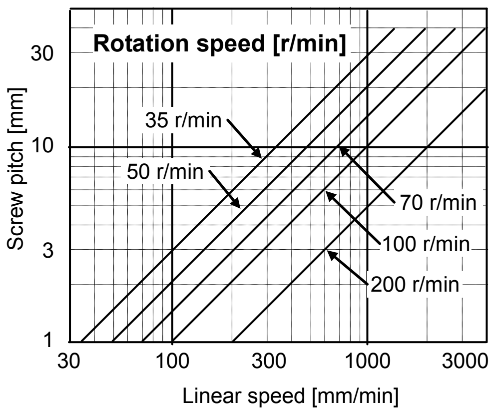
The actuator generates heat if started/stopped repeatedly or operated continuously at high speed. Accordingly, examine whether or not the generated heat can be accommodated.
The study is as follows:

Examining actuator rotation speed

Calculate the actuator rotation speed [r/min] of the load driven by the FHA-C mini series.
For linear operation, use the rotation 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 the 30, 50 or 100 series so that the calculated actuator rotation speed does not exceed the maximum rotational speed of the FHA-C mini series actuator.



Calculating and examining load inertia moment

Calculate the inertia moment of the load driven by the FHA-C mini series actuator.
Refer to [Apx-2 Calculating inertia moment] (PApx-3) for the calculation.
Based on the calculated result, tentatively select a FHA-C mini series actuator by referring to [Allowable load inertia moment] (P2-1).

Load torque calculation

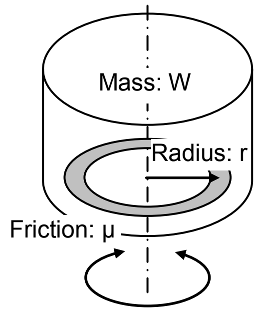
Calculate the load torque as follows:

Rotary motion

The rotary torque for the rotating mass W on the ring of 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]

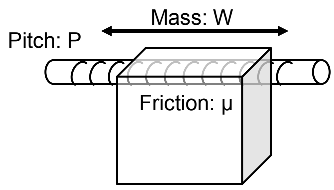


Linear operation (horizontal operation)

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

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

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

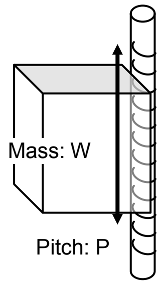


Linear operation (vertical operation)

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

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

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

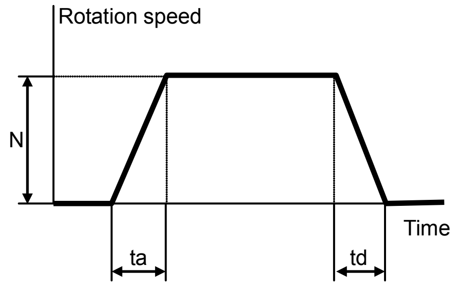


Acceleration time and deceleration time

Calculate acceleration and deceleration times for the selected actuator.

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

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



t_a	: Acceleration time	[s]
t_d	: Deceleration time	[s]
J_A	: Actuator inertia moment	[kg·m²]
J_L	: Load inertia moment	[kg·m²]
N	: Actuator rotation speed	[r/min]
T_M	: Maximum actuator torque	[N·m]
T_F	: Actuator friction torque	[N·m]

$T_F = K_T$ x $I_M - T_M$

K_T: Torque constant [N·m/A]

I_M : Max. current [A]

T_L : Load torque [N·m]

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

Example 1

Select an actuator that best suits the following operating conditions:

- Rotation speed: 100 [r/min]
- Load inertia moment: 0.04 [kg·m²]
- Since the load mechanism is mainly inertia, the load torque is negligibly small.

(1) According to the conditions above, tentatively select FHA-11C-50 from the table in section 2-1.

(2) From the rating table in section 1-4, the following values are obtained:

J_A = 0.017 [kg·m²]

T_M = 8.3 [N·m]

K_T = 6.6 [N·m/A]

I_M = 1.6 [A]

(3) Based on the above formula, the actuator's friction torque T_F is calculated as

6.6 × 1.6 - 8.3 = 2.26 [N·m].

(4) The acceleration time and deceleration time can be obtained as follows from the above formulas:

t_a = (0.017 + 0.04) × 2 × π / 60 × 100 / 8.3 ≒ 0.072 [s]

t_d = (0.017 + 0.04) × 2 × π / 60 × 100 / (8.3 + 2 × 2.26) ≒ 0.047 [s]

(5) If the calculated acceleration/deceleration times are too long, correct the situation by:

・Reducing the inertia moment of load

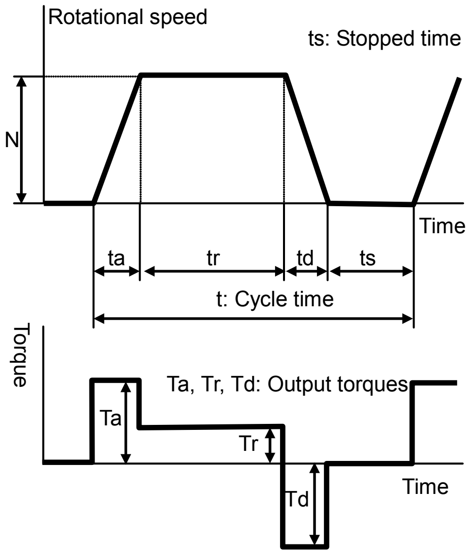
・Selecting a actuator with a larger frame size

Examining effective torque and average rotation 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] (1-15).
Using the following formula, calculate the effective torque Tm and average rotational speed N_{av} when the actuator is operated repeatedly in the drive pattern shown to the right.

$$T_m = \sqrt{\frac{T_a^2 \times t_a + T_r^2 \times t_r + T_d^2 \times t_d}{t}}$$

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



ta	: Acceleration time from speed 0 to N	[s]
td	: Deceleration time from speed N to 0	[s]
tr	: Operation time at constant speed N	[s]
t	: Cycle time	[s]
Tm	: Effective torque	[N･m]
Ta	: Torque during acceleration	[N･m]
Tr	: Torque at constant speed	[N･m]
Td	: Torque during deceleration	[N･m]
Nav	: Average rotational speed	[r/min]
N	: Rotational speed at constant speed	[r/min]

- **Calculation example 2**

The calculation method is explained below using FHA-11C-50 as an example.
Operating conditions: Accelerate an inertia load and then let it move at a constant speed, followed by deceleration, based on conditions similar to those used in calculation example 1. The travel angle per cycle is 120° and the cycle time is 0.8 seconds.

(1) The travel angle is calculated from the area of the rotational speed vs. time diagram shown above. In other words, the travel angle θ is calculated as follows:

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

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

When θ = 120° and
ta = 0.072 [s]
td = 0.047 [s]
N = 100 [r/min]
in calculation example 1, are applied to this formula, tr is calculated as 0.069 seconds.

(2) Next, calculate the torque during acceleration and torque during deceleration. 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:

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

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

When the values in calculation example 1 are applied to this formula,
T_a = 2.30 [N･m] and
T_d = 2.53 [N･m]
are obtained.

(3) Calculate the effective torque. Apply the values in (1) and (2), T_r = 0 N･m, and t = 0.8 seconds to the above formulas.

$$T_M = \sqrt{\frac{8.3^2 \times 0.072 + 0^2 \times 0.141 + 2.53^2 \times 0.047}{0.8}} = 3.19\,[N \cdot m]$$

2

Selection guidelines

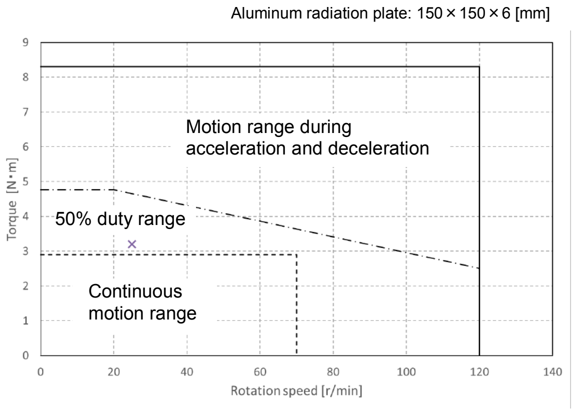
(4) Calculate the average rotational speed. Apply the values in (1), N = 100 r/min, and t = 0.8 seconds to the above formulas.

$$N_{av} = \frac{100/2 \times 0.072 + 100 \times 0.141 + 100/2 \times 0.047}{0.8} = 25.0\ [r/min]$$

(5) The figure on the right shows the points of operation determined by the effective torque and average rotational speed calculated above, plotted on the graph of operable range of FHA-11C-50, exceeding the continuous motion range. The conclusion is that this actuator cannot be operated continuously under these conditions. Accordingly,

◆the operation pattern
◆load (possible reduction)
◆actuator model No.

etc., must be reevaluated.



Operable range of FHA-11C-50

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

$$t = \frac{T_a^2 \times t_a + T_r^2 \times t_r + T_d^2 \times t_d}{T_m^2}$$

Apply the following:

T_a = 8.3 [N・m]
T_r = 0 [N・m]
T_d = 8.3 [N・m]
T_m = 2.9 [N・m]
t_a = 0.072 [s]
T_r = 0.141 [s]
T_d = 0.047 [s]

Then, the following equation is obtained:

$t = (8.3^2 \times 0.072 + 0^2 \times 0.141 + 8.3^2 \times 0.047) / 2.9^2 = 0.97$ [s]

Based on the result, setting the cycle time to 1.0 seconds or more to provide a longer stop time gives T_m = 2.9 [N・m] or less, thereby permitting continuous operation within the allowable continuous torque.

Caution

- The aforementioned continuous motion range represents an allowable range where the actuator 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

Installation

This chapter explains the procedure for installing the FHA-C mini series actuator.

3-1 Receiving inspection

Check the following items after unpacking the package.

Verification steps

1 Check the items thoroughly for damage sustained during transportation.

If any item is damaged, immediately contact the dealer.

2 Check if the actuator is what you ordered.

The nameplate is found on the rear end face of FHA-C mini 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.
Refer to the section [1-2 Model] (P1-2) in this manual for the detail of the model codes.

3 Check if the servo amplifier combinations are correct.

Check that this is the model combination given in this document in [1-3 Combinations with servo amplifier and extension cables] (P1-3).

4 Check if the input voltage being input are correct.

The value of the power voltage input is shown in the servo amplifier nameplate “INPUT” column. If the voltage to be supplied is different from the label voltage, immediately contact the dealer it was purchased from.

Do not combine with an actuator other than the one given in this document.
The characteristics of the servo amplifier have been adjusted according to the actuator. A wrong combination of “servo amplifier” and “actuator” may cause inadequate torque or overcurrent that may cause burn damage to the actuator, injury or fire.

Do not connect a supply voltage other than the voltage specified on the servo amplifier’s nameplate.
Connecting a power supply not matching the input voltage specified on the nameplate may result in damage to the servo amplifier, injury or fire.

3-2 Notices on handling

Handle the FHA-C mini series actuator carefully by observing the notices specified below.

WARNING

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

CAUTION

(1) Do not apply any excessive force or impact, especially to the actuator's output shaft.
(2) Do not put the FHA-C mini series actuator on a table, shelf, etc., where the actuator could easily fall.
(3) The allowable storage temperature is -20 to +60 °C. Do not expose the actuator to direct sunlight for long periods of time or store it in areas in low or high temperature.
(4) The allowable relative storage humidity is 80 % or less. In particular, do not store the actuator in a very humid place or in areas where temperatures are likely to fluctuate greatly during day and night.
(5) Do not use or store the actuator in locations subject to corrosive gases or dust particles.

3-3 Installation location and installation

Environment of installation location

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

- Operating temperature: 0 to 40 °C
  The temperature in the cabinet may be higher than the atmosphere depending on the power loss of housed devices and size of the cabinet. Plan the cabinet size, cooling system, and device locations so the ambient temperature of the actuator is kept 40°C or below.
- Operating humidity: humidity 20 to 80 %. Make sure without condensation.
  Take note that condensation is likely to occur in a place where there is a large temperature change between day and night or when the actuator is started/stopped frequently.

- Vibration: 24.5 m/s^2 (2.5 G) (10 to 400 Hz) or less
- Impact: 294 m/s^2 (30 G) or less
- Free from dust, dirt, condensation, metal powder, corrosive gases, water, water droplets, oil mist, etc.
- Protection class: Standard products are structurally designed to meet the IP-44 requirements.

  The protection class against contact and entry of foreign matter is as follows:
  4: Protected against large solid objects (up to 1 mm)

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

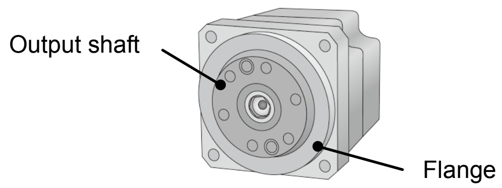
  However, rotating and sliding areas (oil seal areas) and connectors are not IP-44-compliant.
- Locate the actuator indoors or within an enclosure, and do not expose it to sunlight.
- Altitude: lower than 1000 m above sea level

Installation

The FHA-C mini series actuator drives mechanical load system at high accuracy.
When installing the actuator, pay attention to precision and do not tap the actuator output part with a hammer, etc. As an encoder is incorporated in the actuator, excessive impact may damage the encoder.

Installation procedure

1 Align the axis of rotation of the actuator and the load mechanism precisely.



Caution

- Perform this 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.
- Do not apply shock or impact during installation.

2 Fasten the flange of the actuator on the load machine with flat washers and high-tension bolts.

When tightening, use a torque wrench to control the tightening torque.
The tightening torques are shown in the table below:

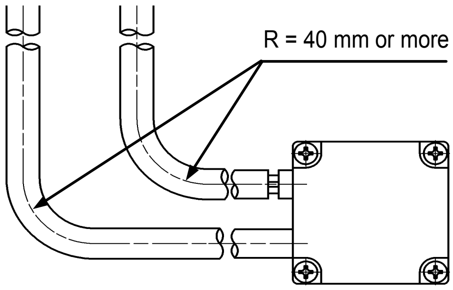
Item \ Model		FHA-8C		FHA-11C		FHA-14C	
		Output shaft	Flange	Output shaft	Flange	Output shaft	Flange
Tightening torque	Screw, hole depth	6-M3 Depth 5	4-M3	6-M4 Depth 5	4-M4	6-M5 Depth 7	4-M5
	N·m	2	1.2	4.5	2.7	9.0	5.4
	kgf·cm	20	12	46	28	92	55

3 Connect the servo amplifier and wiring.

An extension cable is provided. Use it when wiring the servo amplifier. For details on wiring, refer to [1-14 Cable specifications] (P1-18) and the manual of your MINAS A6 servo amplifier.

4 Wire the motor cable and encoder cable.

Do not pull the cables with a strong force. The connection points may be damaged. Install the cable wiring with slack so that no tension is applied to the actuator. Provide a sufficient bending radius (R = 40 mm or more), especially when the cable flexes.



CAUTION

Do not disassemble/reassemble the actuator.
The actuator uses many precision parts. We cannot guarantee if assembly or disassembly by the customer will cause lower precision and performance.

Appendix

This chapter explains the default settings, etc.

Apx-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	Degree	Min.	Sec.
Factor	57.3	3.44×10^3	2.06×10^5

Unit	Degree	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 x 10^3

Unit	deg/s²	deg/min²
Factor	0.01755	2.93 x 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	7.06x10^{-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 x 10^3	8.85	5.47 x 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 x 10^{-4}	0.113	1.829x10^{-5}	7.06 x 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 x 10^{-5}	1.78 x 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 x 10^4	562	77.6	6.47
↓					
SI system	N·m/rad				

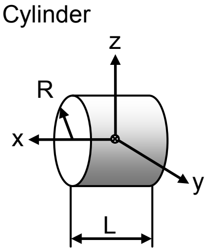
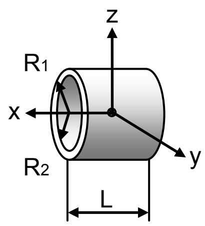
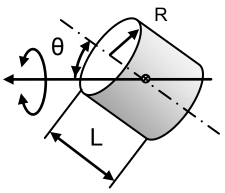
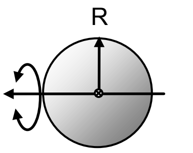
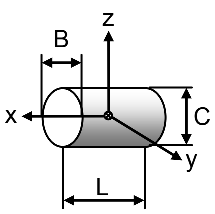
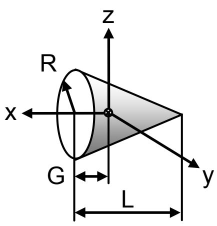
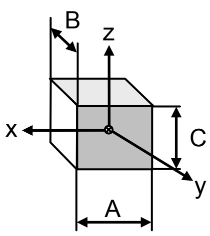
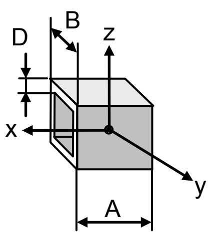
Apx-2 Calculating inertia moment

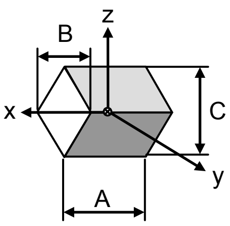
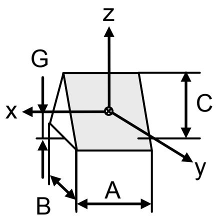
Formula of mass and inertia moment

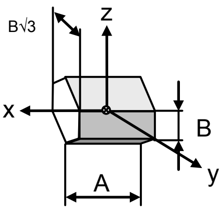
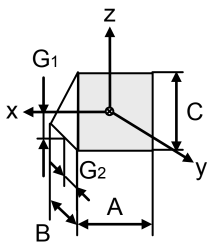
(1) Both centerlines of rotation and gravity are the same:

The following table includes formulas to calculate mass and inertia moment.
m: mass [kg]; Ix, Iy, Iz: inertia moments which rotate around x-, y-, z-axes respectively [kg·m^2]
G: distance from end face of gravity center [m]
ρ: specific gravity [×10^{3}kg / m^3]

Unit Inertia moment [kg·m^2]

Object form	Mass, inertia, gravity center	Object form	Mass, inertia, gravity center
Cylinder 	$m = \pi R^2 L \rho \times 10^3$ $Ix = \frac{1}{2} m R^2$ $Iy = \frac{1}{4} m \left(R^2 + \frac{L^2}{3} \right)$ $Iz = \frac{1}{4} m \left(R^2 + \frac{L^2}{3} \right)$	Circular pipe  R_1: outer diameter, R_2: inner diameter	$m = \pi \left(R_1^2 - R_2^2 \right) L \rho \times 10^3$ $Ix = \frac{1}{2} m \left(R_1^2 + R_2^2 \right)$ $Iy = \frac{1}{4} m \left\{ \left(R_1^2 + R_2^2 \right) + \frac{L^2}{3} \right\}$ $Iz = \frac{1}{4} m \left\{ \left(R_1^2 + R_2^2 \right) + \frac{L^2}{3} \right\}$
Slanted cylinder 	$m = \pi R^2 L \rho \times 10^3$ $I_\theta = \frac{1}{12} m$ $\times \left\{ 3R^2 \left(1 + \cos^2\theta \right) + L^2 \sin^2\theta \right\}$	Ball 	$m = \frac{4}{3} \pi R^3 \rho \times 10^3$ $I = \frac{2}{5} m R^2$
Ellipsoidal cylinder 	$m = \frac{1}{4} B C L \rho \times 10^3$ $Ix = \frac{1}{16} m \left(B^2 + C^2 \right)$ $Iy = \frac{1}{4} m \left(\frac{C^2}{4} + \frac{L^2}{3} \right)$ $Iz = \frac{1}{4} m \left(\frac{B^2}{4} + \frac{L^2}{3} \right)$	Cone 	$m = \frac{1}{3} \pi R^2 L \rho \times 10^3$ $Ix = \frac{3}{10} m R^2$ $Iy = \frac{3}{80} m \left(4R^2 + L^2 \right)$ $Iz = \frac{3}{80} m \left(4R^2 + L^2 \right)$ $G = \frac{L}{4}$
Rectangular pillar 	$m = A B C \rho \times 10^3$ $Ix = \frac{1}{12} m \left(B^2 + C^2 \right)$ $Iy = \frac{1}{12} m \left(C^2 + A^2 \right)$ $Iz = \frac{1}{12} m \left(A^2 + B^2 \right)$	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
Rhombus pillar 	$m=\frac{1}{2}ABC\rho$ $Ix=\frac{1}{24}m\left(B^2+C^2\right)$ $Iy=\frac{1}{24}m\left(C^2+2A^2\right)$ $Iz=\frac{1}{24}m\left(B^2+2A^2\right)$
Isosceles triangle pillar 	$m=\frac{1}{2}ABC\rho$ $Ix=\frac{1}{12}m\left(\frac{B^2}{2}+\frac{2}{3}C^2\right)$ $Iy=\frac{1}{12}m\left(A^2+\frac{2}{3}C^2\right)$ $Iz=\frac{1}{12}m\left(A^2+\frac{B^2}{2}\right)$ $G=\frac{C}{3}$

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

Example of specific gravity

The following tables show reference values for specific gravity. Confirm the specific gravity for the material of the drive load.

Material	Specific gravity [×10^3kg / m^3]
SUS304	7.93
S45C	7.86
SS400	7.85
Cast iron	7.19
Copper	8.92
Brass	8.50

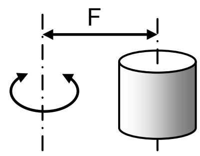
Material	Specific gravity [×10^3kg / m^3]
Aluminum	2.70
Duralumin	2.80
Silicon	2.30
Quartz glass	2.20
Teflon	2.20
Fluorocarbon resin	2.20

Material	Specific gravity [×10^3kg / 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 motion objects

The inertia moment, converted to FHA-C actuator axis, 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 motion object converted to actuator axis [kg·m^2]

m : Mass [kg]

P : Linear travel per actuator revolution [m/rev]

Apx

Appendix

Index

Warranty period and terms

The warranty period of the FHA-Cmini series and warranty terms are explained below.

■ Warranty period

Under the condition that it is used properly according to each item specified in the manuals and operation manuals, this product is warranted for the period of 1 year after delivery or 2,000 hours of operation (this product), whichever ends first.

■ Warranty terms

If the product fails due to any defect in workmanship or material during the warranty period specified above, the defective product will be repaired or replaced free of charge.
This limited 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 other than by Harmonic Drive Systems, Inc.;
(3) Failure not attributable to this product; or
(4) Natural disaster or any other event beyond the control of Harmonic Drive Systems, Inc.

The warranty covers only the above-named product purchased from Harmonic Drive Systems, Inc.
Harmonic Drive Systems, Inc. shall not be liable for any consequential damages of other equipment caused by the defective product, or expenses and labor costs for removing and installing the defective product from/to your system.

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All specifications and dimensions in this manual subject to change without notice.
This manual is correct as of July 2021.

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