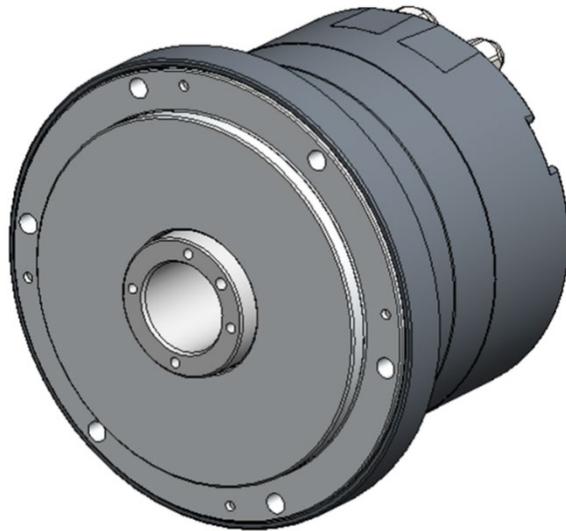


Harmonic Drive[®]

MECHATRONICS

Flat Hollow Shaft AC Servo Motors
compatible with Mitsubishi Electric
MELSERVO-J4 series

MMA series manual



Introduction

Thank you for purchasing our MMA series AC servo motor.

Incorrect handling or improper use of this product may result in unexpected accidents or a shorter product life. Read this manual carefully and use the product correctly so that the product can be used safely for many years.

The information contained in this manual is subject to change without notice.

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 product.

The end user of the product should have a copy of this manual.

SAFETY GUIDE

To use this product safely and correctly, be sure to read the 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 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
- Machines 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 intended application for our products, please consult us.



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 when the output control is disabled due to damage.

SAFETY NOTE

ITEMS YOU SHOULD NOTE WHEN USING THE MOTOR

● CAUTIONS RELATED TO THE DESIGN



Always use the motor under the specified conditions:

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

- Ambient temperature: 0 to 40 °C
- Ambient humidity: 20 to 80 % RH (no condensation)
- Vibration: Max. 25 m/s²
- No contamination by water or oil
- No corrosive or explosive gas

Always follow the instructions in the related manuals to install the motor in the equipment.

- Follow the instructions in the manual to ensure that the center of the motor is aligned with the center of the paired unit.
- Improper alignment may cause vibration or damage to the output shaft.

● OPERATIONAL PRECAUTIONS



Do not exceed the allowable torque.

- Do not apply a 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 cables directly to a power supply socket.

- Motors must be connected to the proper servo amplifier to operate.
- Do not connect a commercial power supply directly to the motor. Failure to observe this caution may damage the motor, possibly resulting in a fire.

Do not apply impacts and shocks to the motor.

- Do not tap the motor with a hammer or other tool because an encoder is connected directly to the motor.
- If the encoder is damaged, the motor may become uncontrollable.

Do not pull the cables.

- Pulling the cables can damage connectors, causing the motor to become 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] (P6).
- Be sure to read the “MELSERVO-J4 SERIES AC SERVO SAFETY GUIDE”, which comes together with the servo amplifier, before using this product.
- OPERATIONAL PRECAUTIONS

**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 5 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 5 minutes or more after the power supply is turned OFF.
- When installing, make sure that the inner electronic components are hard to reach.

DISPOSAL**The motor and servo amplifier must be disposed of as industrial waste.**

When disposing of the motor 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.

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Related manual

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

Title	Document No.	Description	Obtaining method
MR-J4- B_(-RJ) SERVO AMPLIFIER INSTRUCTION MANUAL	SH-030098	The information on how to use the "MR-J4-□B-S033" servo amplifier in combination with the MMA series is provided.	Can be downloaded from the Mitsubishi Electric website.
MR-J4-□B-S033 PRODUCT SPECIFICATIONS	BCN-B72000-090	The precautions for combining the "MR-J4-□B-S033" servo amplifier with the MMA series are provided.	Obtain by giving the manual number to the supplier or store where you purchased your servo amplifier.

Conformance to overseas standards

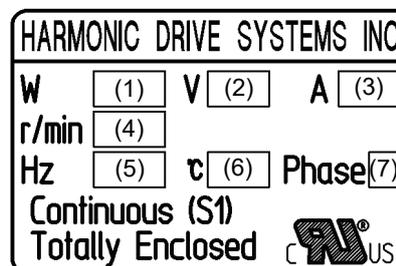
The MMA series motors are compliant with the following overseas standards.

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

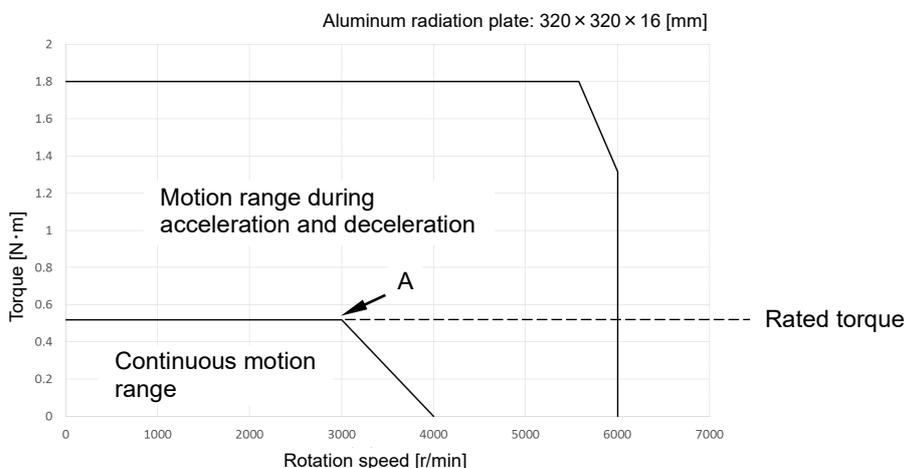
UL nameplate sticker

According to the UL1004-1, UL1004-6 (File No. E243316) standards, the following specifications are indicated on the MMA series motors.

Nameplate field	Description
(1)	Output [W] at point A on the graph below
(2)	Voltage [V] between motor wires at point A on the graph below
(3)	Allowable continuous current [A]
(4)	Rotational speed at point A on the graph below [r/min]
(5)	Current fundamental frequency [Hz] at point A on the graph below
(6)	Allowable ambient temperature [°C]
(7)	Number of phases



UL nameplate sticker



The values displayed on the name plate for each model are shown below.

Model		MMAB09
Item		
(1) Output at point A	W	251
(2) Voltage at point A	V	136
(3) Allowable continuous current	A	2.5
(4) Speed at point A	r/min	3000
(5) Frequency at point A	Hz	250
(6) Allowable ambient temperature	°C	40
(7) Number of phases	-	3

Model		MMAB12
Item		
(1) Output at point A	W	406
(2) Voltage at point A	V	129
(3) Allowable continuous current	A	4.2
(4) Speed at point A	r/min	2500
(5) Frequency at point A	Hz	208
(6) Allowable ambient temperature	°C	40
(7) Number of phases	-	3

Model		MMAB15
Item		
(1) Output at point A	W	754
(2) Voltage at point A	V	125
(3) Allowable continuous current	A	7.8
(4) Speed at point A	r/min	2000
(5) Frequency at point A	Hz	167
(6) Allowable ambient temperature	°C	40
(7) Number of phases	-	3

Model		MMAA21A
Item		
(1) Output at point A	W	1320
(2) Voltage at point A	V	100
(3) Allowable continuous current	A	20.0
(4) Speed at point A	r/min	1000
(5) Frequency at point A	Hz	133
(6) Allowable ambient temperature	°C	40
(7) Number of phases	-	3

Chapter 1

Outlines

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

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1-1 Outlines

All MMA series AC servo motor models feature a hollow bore structure and compact design and they can be controlled with the SSCNETIII/H when combined with the Mitsubishi Electric AC servo amplifier MELSERVO-J4 series. Wires, pipes, ball screws, or laser beams go through the hollow bore depending on the mechanism design required for your applications.

MMA series AC servo motors play an important role in driving various factory automation (FA) equipment, such as robot joints, alignment mechanisms for semi-conductors and LCD devices, ATC of metal-cutting machines, printing machine roller drives, etc.

◆ Comes standard with a 17-bit magnetic absolute encoder

The MMA series AC servo motors are equipped with a highly reliable 17-bit magnetic absolute encoder* with safety function. The serial communication requires fewer cables.

The encoder also constantly compares two sets of detected angles. If any abnormality is found, the encoder's built-in failsafe function outputs a signal to the host system. This helps you build a safe system.

◆ Supporting a combination with MELSERVO-J4 amplifiers

Combination with Mitsubishi Electric MELSERVO-J4 amplifiers is now available. It can be controlled using the SSCNETIII/H high-speed motion network.

1-2 Combinations with servo amplifier and extension cables

The combinations of MMA motors, MR-J4-_B-S033 servo amplifiers, and extension cables are as follows:

		MMAB09	MMAB12	MMAB15	MMAA21A
SSCNETIII/H type		MR-J4-60B-S033	MR-J4-100B-S033	MR-J4-200B-S033	MR-J4-500B-S033
Extension cables (option)	Motor wire	EWD-MB**-A06-TMC-M			EWD-MB**-D09-TMC-M2
	Encoder wire Note 1	MR-EKCBL□M-H (Long flex life product) or MR-EKCBL□M-L (Standard product)			

** and □ in the extension cable model indicates the cable length. See below for details.

Motor wire : 02 = 2 m, 05 = 5 m, 10 = 10 m

Encoder wire: 2 = 2 m, 5 = 5 m, 10 = 10 m

For details on encoder wires, contact Mitsubishi Electric customer support.

Note 1: When connecting the encoder wires MR-EKCBL□M-* and MMAA21A, please use the encoder connector converter cable that comes with the motor.

The MR-J4-_B-S033 servo amplifier parameters (PA17: Motor series, PA18: Motor type) are set for the above combination. For parameters not covered in this section, refer to [Related manual] (P6).

No.	Abbreviation (Note)	Name and function	Default value (units)	Setting range																
PA17	*MSR	<p>Servo motor series setting When driving MMA motor, select the motor type with [Pr.PA17] and [Pr.PA18]. Set at the same time as [Pr.PA18]. For the setting values, refer to the following table.</p> <table border="1" style="margin-left: 20px;"> <thead> <tr> <th rowspan="2">Motor series</th> <th colspan="2">Parameters</th> </tr> <tr> <th colspan="2">[Pr.PA17] set value</th> </tr> </thead> <tbody> <tr> <td>MMAB09</td> <td colspan="2" rowspan="4" style="text-align: center; vertical-align: middle;">00E1</td> </tr> <tr> <td>MMAB12</td> </tr> <tr> <td>MMAB15</td> </tr> <tr> <td>MMAA21A</td> </tr> </tbody> </table>	Motor series	Parameters		[Pr.PA17] set value		MMAB09	00E1		MMAB12	MMAB15	MMAA21A	0000h	0000h to FFFFh					
Motor series	Parameters																			
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PA18	*MTY	<p>Motor type setting When driving MMA motor, select the motor type with [Pr.PA17] and [Pr.PA18]. Set at the same time as [Pr.PA17]. For the setting values, refer to the following table.</p> <table border="1" style="margin-left: 20px;"> <thead> <tr> <th rowspan="2">Motor series</th> <th rowspan="2">Combined servo amplifier</th> <th>Parameters</th> </tr> <tr> <th>[Pr.PA18] set value</th> </tr> </thead> <tbody> <tr> <td>MMAB09</td> <td>MR-J4-60B-S033</td> <td>09C9</td> </tr> <tr> <td>MMAB12</td> <td>MR-J4-100B-S033</td> <td>0CC9</td> </tr> <tr> <td>MMAB15</td> <td>MR-J4-200B-S033</td> <td>0FC9</td> </tr> <tr> <td>MMAA21A</td> <td>MR-J4-500B-S033</td> <td>15C9</td> </tr> </tbody> </table>	Motor series	Combined servo amplifier	Parameters	[Pr.PA18] set value	MMAB09	MR-J4-60B-S033	09C9	MMAB12	MR-J4-100B-S033	0CC9	MMAB15	MR-J4-200B-S033	0FC9	MMAA21A	MR-J4-500B-S033	15C9	0000h	0000h to FFFFh
Motor series	Combined servo amplifier	Parameters																		
		[Pr.PA18] set value																		
MMAB09	MR-J4-60B-S033	09C9																		
MMAB12	MR-J4-100B-S033	0CC9																		
MMAB15	MR-J4-200B-S033	0FC9																		
MMAA21A	MR-J4-500B-S033	15C9																		

Note: * The set values become effective when the servo amplifier power supply is connected.

1-3 Model

The model names for the MMA series motors and how to read the symbols are explained below.

Model example:

MMA	B	09	A	200	-	36	S	17b	A	-	C	Y	-	SP
(1)	(2)	(3)	(4)	(5)	-	(6)	(7)	(8)	(9)	-	(10)	(11)	-	(12)

(1) Model: MMA series AC servo motor

(2) Motor version symbol

A	Model No. 21A
B	Model Nos. 09, 12, 15

(3) Model Nos.: 09, 12, 15, 21A

(4) Brake

A	Without brake
B	With brake

(5) Applicable servo amplifier input voltage

200	200 V
-----	-------

(6) Encoder format

36	Conforming to Mitsubishi format, transmission rate: 2.5 Mbps, 1-on-1 connection, without backup capacitor
----	---

(7) Encoder type

S	Multi-turn absolute type
---	--------------------------

(8) Encoder resolution

17b	17 bit (131072 pulses/revolution)
-----	-----------------------------------

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

A	0 degree
---	----------

(10) Connector specification

C	With standard connector
N	Without connector

(11) Option symbol

Y	Cable taken out from the side
---	-------------------------------

(It is not available for model No. 21A.)

(12) Special specification

No description	Standard product
SP	Special specification product

1-4 Specifications

The specifications of the MMA series motors are shown below.

Item		Model	MMAB09	MMAB12	MMAB15	MMAA21A
Compatible servo amplifier			MR-J4-60B-S033	MR-J4-100B-S033	MR-J4-200B-S033	MR-J4-500B-S033
Input power supply	V		200	200	200	200
Rated output	W		251	406	754	1320
Maximum momentary torque ^{*1}	N·m		3.0	6.6	13	45
	kgf·m		0.31	0.67	1.33	4.59
Rated torque ^{*1,2}	N·m		0.80	1.55	3.60	12.6
	kgf·m		0.082	0.158	0.367	1.29
Max. rotational speed ^{*1}	r/min		5600	4800	4000	3000
Rated rotational speed	r/min		3000	2500	2000	1000
Instantaneous max. current ^{*1}	A		8.9	18	29	75
Rated current ^{*1,2}	A		2.5	4.2	7.8	20.0
Torque constant ^{*1}	N·m/A		0.41	0.44	0.54	0.72
	kgf·m/A		0.042	0.045	0.055	0.073
EMF constant ^{*3}	V/(r/min)		0.043	0.046	0.057	0.075
Phase resistance (20 °C)	Ω		1.2	0.33	0.19	0.028
Phase inductance	mH		3.0	1.4	1.2	0.29
Inertia moment Values in parentheses are for models with a brake.	GD ² /4	×10 ⁻⁴ kg·m ²	1.78 (2.16)	6.45 (6.83)	15.8 (19.8)	125 (141)
	J	×10 ⁻⁴ kgf·cm·s ²	18.2 (22.1)	65.8 (69.7)	161 (202)	1280 (1444)
Allowable radial load (when stationary)	N		800	1200	2400	4500
	kgf		81.6	122	245	459
Allowable axial load (when stationary)	N		2400	3600	5000	14000
	kgf		245	367	510	1429
Rated radial load (at rated rotational speed)	N		185	233	530	1040
	kgf		18.9	23.8	54.1	106.1
Rated axial load (at rated rotational speed)	N		105	130	180	880
	kgf		10.7	13.3	18.4	89.8
Encoder type			Absolute encoder			
Encoder resolution	Single-turn detector		2 ¹⁷ (131072)			
	Multi-turn detector ^{*4}		2 ¹⁶ (65536)			
Mass Values in parentheses are for models with a brake.	kg		2.0 (2.1)	3.4 (3.8)	5.5 (6.2)	17.5 (19.7)

Environmental conditions ^{*6}	Operating temperature: 0 to 40 °C/Storage temperature: -20 to 60 °C Service/storage humidity: 20 to 80 % RH (no condensation) Resistance to vibration: 25 m/s ² (frequency: 10 to 400 Hz) Resistance to impact: 300 m/s ² ^{*5} 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
Motor insulation	Insulation resistance: 100 MΩ or more (500 VDC insulation tester) Dielectric strength: 1500 VAC/1 min Insulation class: A
Mounting direction	Can be installed in any direction.
Protection structure	Totally enclosed self-cooled type (IP54)

The table above shows the typical values.

*1: This displays representative characteristics for when combined with a dedicated amplifier (driven using an ideal sine wave).

*2: Values after the temperature has risen and saturated when installed on the following aluminum radiation plates.

MMAB09 : 350×350×18 [mm]

MMAB12 : 400×400×20 [mm]

MMAB15 : 500×500×25 [mm]

MMAA21A : 650×650×30 [mm]

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

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

*5: For testing conditions, refer to [1-10 Shock resistance] (P1-15) and [1-11 Resistance to vibration] (P1-16).

Motor operation is not guaranteed in applications where vibrations and impacts are continuously applied for a long period of time.

*6: For details, refer to [3-3 Location and installation] (P3-5).

1-5 Holding brake

The brakes equipped on MMA series motors are used to hold the motor shaft in place when the power is cut off. With some models (MMAB09, 12), the motor's built-in circuit controls the voltage supplied to the brake in order to reduce the power consumption while the brake is actuated.

Always use a DC power supply that has a proper brake excitation voltage and is capable of outputting enough current during suction.

Specifications

Item	Model	MMAB09	MMAB12	MMAB15	MMAA21A
Type		Dry non-excitation actuation type			
Power-saving control		Yes		No	
Brake excitation voltage	V	24 VDC ± 10 % (no polarity) *1			
Current consumption during suction	A	0.8*2	0.8*2	0.7	0.9
Current consumption during holding	A	0.3	0.3	0.7	0.9
Holding torque	N·m	1.0	2.0	4.0	15
	kgf·m	0.102	0.204	0.408	1.53
Allowable number of normal brakings*3		100000 times			
Allowable number of emergency stops*4		200 times			

*1: The power supply for the brake is not included in the product. Use a power supply that is capable of outputting enough current during brake suction.

*2: The duration the current is supplied during suction is 0.5 second or less for the power supply of 24 VDC ± 10 %.

*3: When the brake is activated at the rotational speed of 150 r/min or less.

*4: When the brake is activated at the rotational speed of 3000 r/min, provided that the inertia moment of load is 3 times or less than that of the motor.

*5: Motor with holding brake may generate mechanical noise from the brake rotating body during acceleration/stopping/low speed driving, but it does not affect the performance or functionality.



The holding brake cannot be used for deceleration.

Do not use the holding brake more than the allowable number of normal brakings (100000 times at the rotational speed of 150 r/min or less) or allowable number of emergency stops (200 times at the rotational speed of 3000 r/min, provided that the inertia moment of load is 3 times or less than that of the motor).

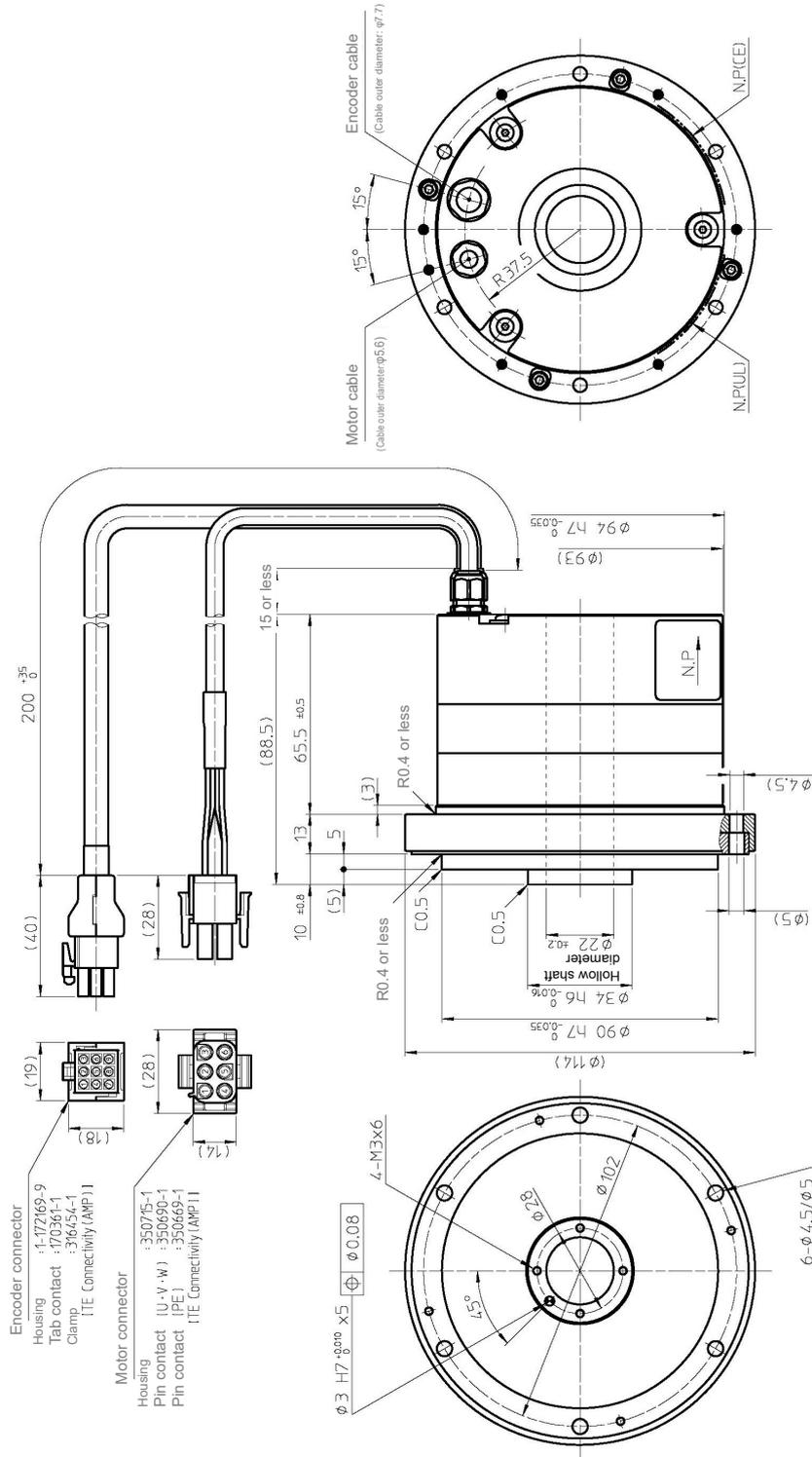
Exceeding the allowable number of normal brakings and allowable number of emergency stops may cause the holding torque to decrease and consequently become unusable as a brake.

1-6 External dimensions

The external dimensions of the MMA series motors are shown below.

- MMAB09 (with/without brake)

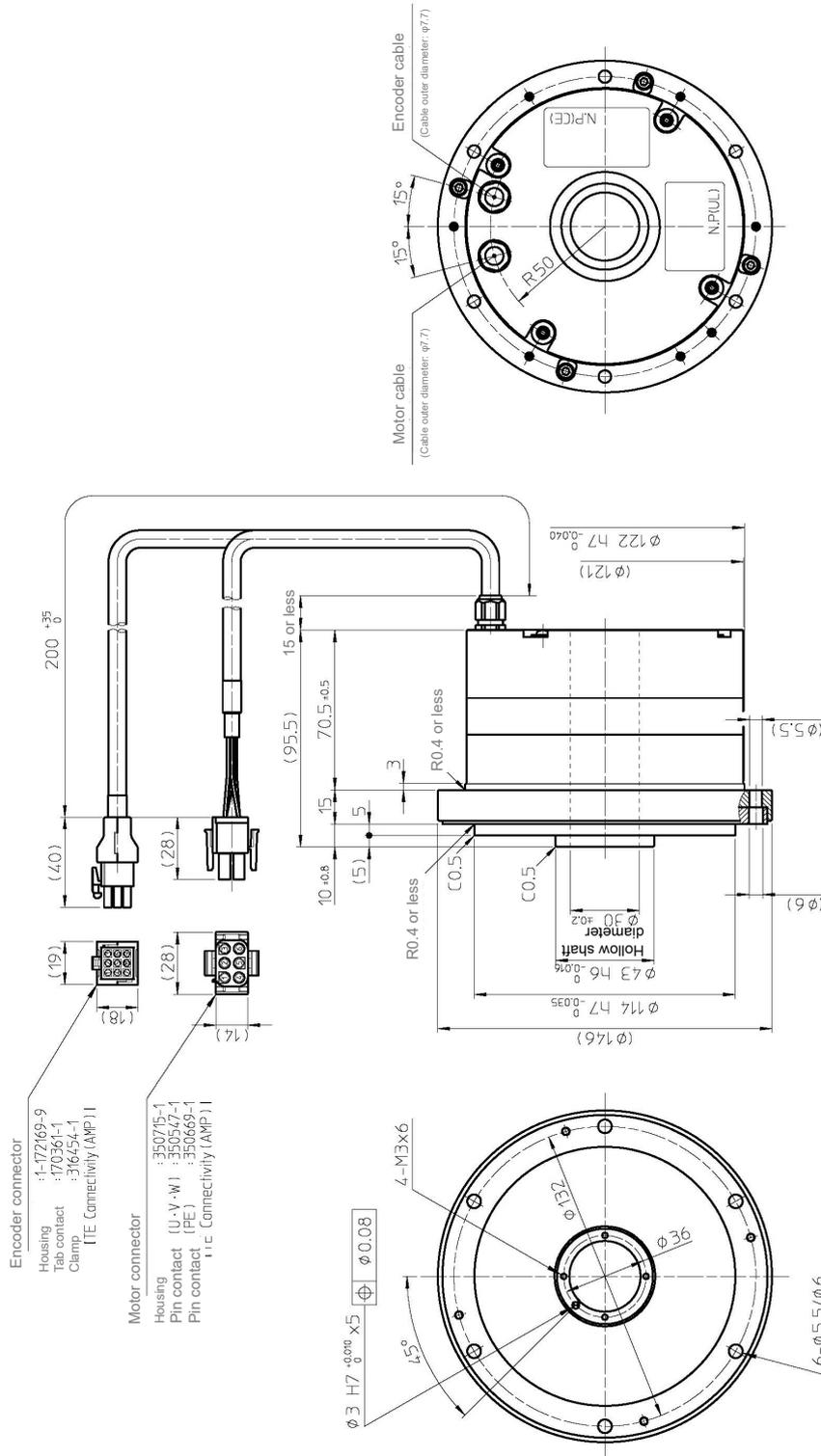
Unit [mm] (third angle projection)



Note: For details on external dimensions, see our illustrated specifications. Tolerances may vary with the product manufacturing method (foundry piece, machine-finished good). Contact us for the differential range of the size that is not described.

● MMAB12 (with/without brake)

Unit [mm] (third angle projection)



Note: For details on external dimensions, see our illustrated specifications. Tolerances may vary with the product manufacturing method (foundry piece, machine-finished good). Contact us for the differential range of the size that is not described.

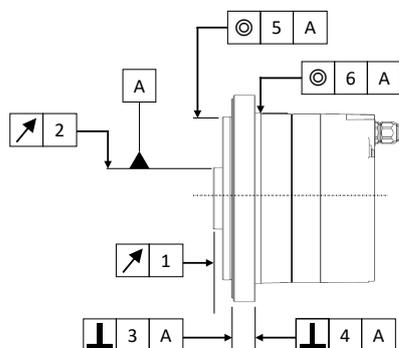
1-7 Mechanical accuracy

The mechanical accuracies of the output shaft and mounting flange for MMA series motors are shown below:

Unit [mm]

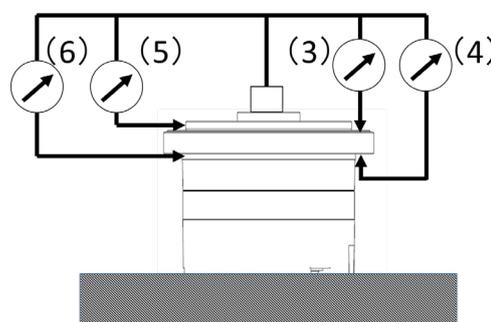
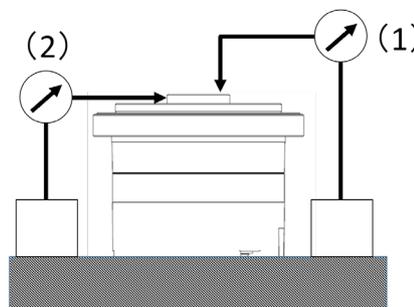
Accuracy items	MMAB09	MMAB12	MMAB15	MMAA21A
1. Output shaft surface runout	0.020	0.020	0.040	0.040
2. Deflection of output shaft	0.020	0.020	0.040	0.040
3. Squareness of the mounting surface to the output shaft	0.080	0.080	0.090	0.100
4. Squareness of the mounting surface to the output shaft	0.065	0.065	0.085	0.090
5. Concentricity of the mounting surface to the output shaft	0.050	0.050	0.050	0.060
6. Concentricity of the mounting surface to the output shaft	0.045	0.045	0.055	0.065

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



The methods for measurement are as follows:

- 1 Output shaft surface runout**
The indicator on the fixed part measures the axial runout (maximum runout width) of the end surface of the output shaft per revolution.
- 2 Deflection of output shaft**
The indicator on the fixed part measures the radial runout (maximum runout width) of the output shaft of the output shaft unit per revolution.
- 3,4 Squareness of the mounting surface to the output shaft**
The indicator on the output shaft reference position measures the axial runout (maximum runout width) of the outermost circumference of the mounting surface (both on the output shaft side and opposite side) per revolution.
- 5,6 Concentricity of the mounting surface to the output shaft**
The indicator on the output shaft reference position measures the radial runout (maximum runout width) of the fitting part (both on the output shaft side and opposite side) per revolution.



1-8 Detector specifications (Absolute encoder)

Absolute encoders installed in the MMA series are multi-turn absolute encoders. The encoder consists of a single-turn detector for detecting the motor shaft position, and a multi-turn detector for detecting the number of revolutions.

The encoder constantly detects the absolute position of the machine and stores it by means of the battery backup, regardless of whether the servo amplifier or external controller power is turned ON or OFF. Accordingly, 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.

The single-turn absolute position detector and the accumulation counter that detects the number of revolutions are both made dual-redundant, where data is constantly checked between two identical devices while the power is ON to ensure a highly reliable design that allows self-detection of encoder errors should they occur.

It is recommended that you replace the battery while the servo amplifier is receiving power. If the battery is replaced with the control circuit power ON, the absolute position data is not lost.

Specifications

Type		Magnetic sensor/electronic battery backup type
Resolution	Single-turn detector	2^{17} : 131072 pulses
	Multi-turn detector	2^{16} : 65536 (-32768 to 32767)
Maximum allowable rotational speed		7000 r/min ^{*1}
Safety/redundancy		<ul style="list-style-type: none"> • Check method in which two identical single-turn detectors are compared • Check method in which two identical cumulative revolution counters that detect the number of revolutions are compared
Backup time by external battery		Approx. 14000 hours ^{*2} (when power is not supplied, ambient temperature of 20 °C)

*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 axis stopped. Frequent movement of the axis with no power supply would cause the external battery to drain quickly.

1-9 Rotation direction

With the factory settings, the rotation direction is defined as counter-clockwise (CCW) as viewed from the output shaft when a pulse train is applied from the MELSERVO-J4 servo amplifier in the direction of rising position addresses.

This rotation direction can be switched with the MELSERVO-J4 servo amplifier "Basic setting parameters ('Pr.PA_')" -> "PA14: Rotation direction selection".



CCW (counterclockwise) rotation direction

"PA14: Rotation direction selection" setting

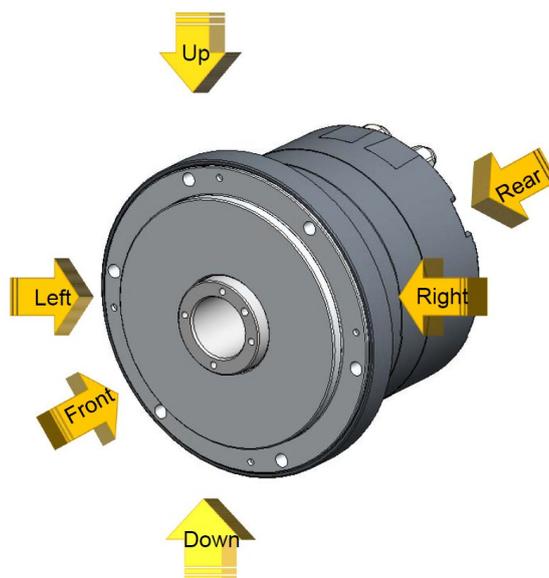
Set value	Motor rotation direction		Setting
	Increases the positioning address	Decreases the positioning address	
0	CCW (counterclockwise) direction	CW (clockwise) direction	Default
1	CW (clockwise) direction	CCW (counterclockwise) direction	

1-10 Shock resistance

The shock resistance of the motor is as follows, and this value is the same in up/down, left/right and front/rear directions:

Shock acceleration: 300 m/s^2

In our shock resistance test, the motor is tested three times in each direction. Motor operation is not guaranteed in applications where impacts exceeding the above value are constantly applied.

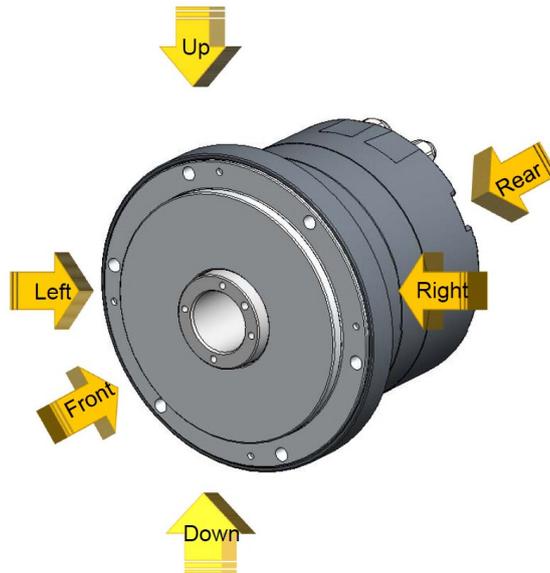


1-11 Resistance to vibration

The resistance to vibration of the motor 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)

In our test, the motor is tested for 2 hours in each direction at a vibration frequency sweep period of 10 minutes.



1-12 Operable range

The graphs below indicate the operable ranges of MMA series motors when combined with a MELSERVO-J4 servo amplifier. For details, refer to [2-1 MMA series selection].

1. Continuous motion range

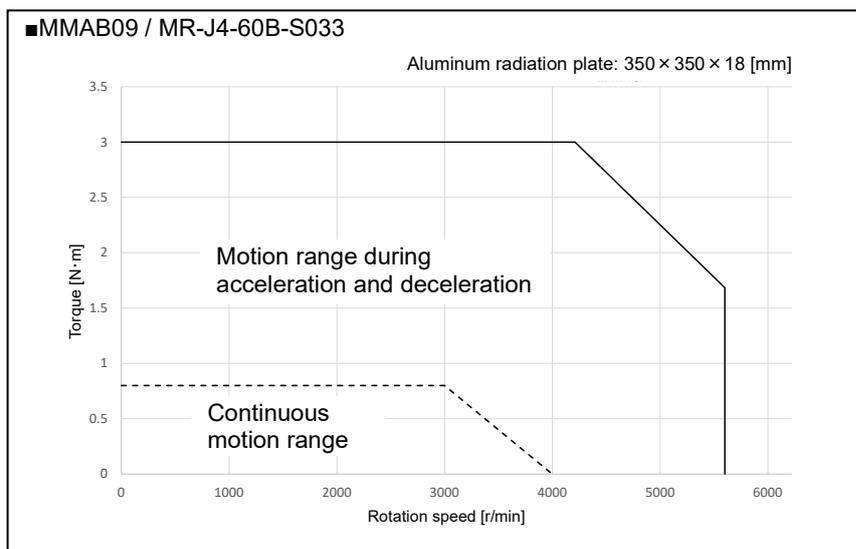
This indicates a range in which the motor can be operated continuously as shown by the relationship between the torque and rotational speed. Note that values are measured with the radiation plate listed on the graphs installed.

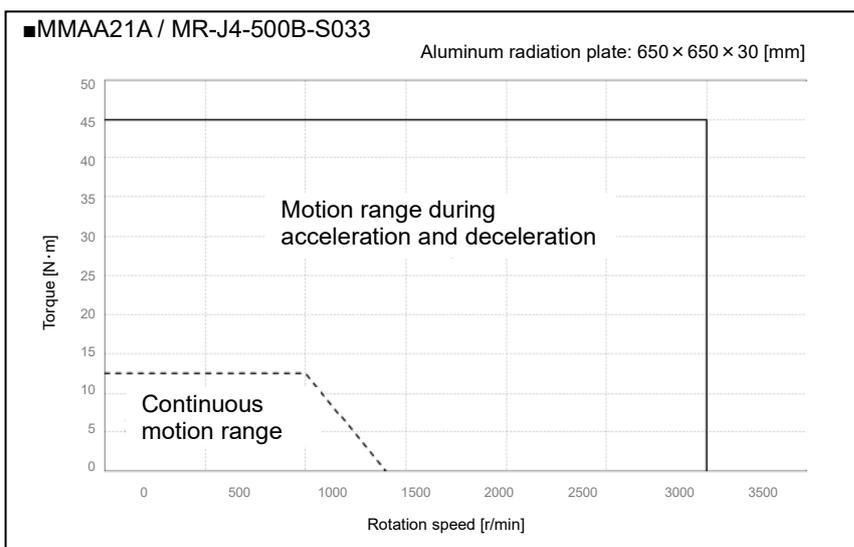
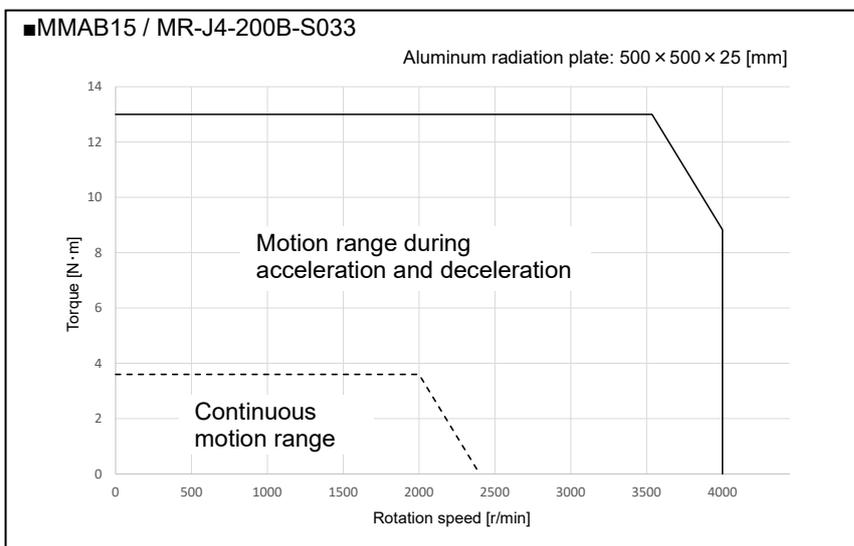
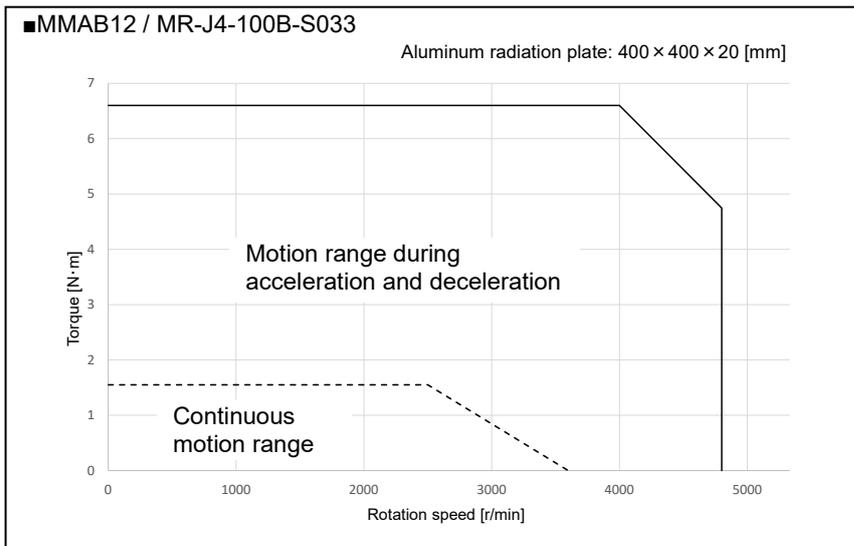
2. Motion range during acceleration and deceleration

This indicates a range in which the motor can be operated instantaneously as shown by the relationship between the torque and rotational speed. This range is normally used for acceleration or deceleration.

Caution

- The continuous motion range represents an allowable range where the motor 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 motor's ambient temperature to 40 K or less as a guide.





1-13 Cable specifications

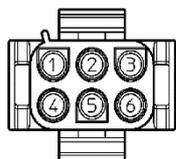
The following tables show the specifications of the motor and encoder cables for the MMA series motors.

Motor cable specifications

- Model Nos. 09, 12, 15

Pin No.	Color	Name	
		Without brake	With brake
1	Red	Motor phase-U	Motor phase-U
2	White	Motor phase-V	Motor phase-V
3	Black	Motor phase-W	Motor phase-W
4	Green/Yellow	PE	PE
5	Blue	No connection	Brake
6	Yellow	No connection	Brake

- Connector pin layout



Connector model: 350715-1

Pin model:

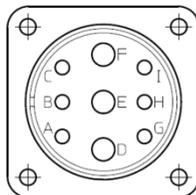
	Model No. 09	Model Nos. 12, 15
Motor UVW	350690-1	350547-1
Brake	350690-1	350690-1
Motor PE	350669-1	350669-1

TE Connectivity (by AMP)

- Model No. 21A

Pin No.	Color (extension cable)	Name	
		Without brake	With brake
A	Blue	No connection	Brake
B	Yellow	No connection	Brake
C	-	No connection	No connection
D	Red	Motor phase-U	Motor phase-U
E	White	Motor phase-V	Motor phase-V
F	Black	Motor phase-W	Motor phase-W
G	Green/Yellow	PE	PE
H	-	PE	PE
I	-	No connection	No connection

- Connector pin layout



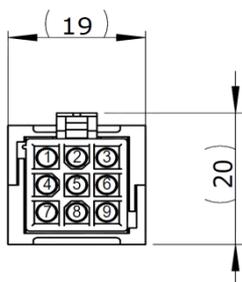
Connector model: CE05-2A24-11PGHS-D (by DDK)

Encoder cable specifications

- Model Nos. 09, 12, 15

Pin number	Color	Signal name	Remarks
1	Yellow	MR	Serial signal differential output (+)
2	Blue	MRR	Serial signal differential output (-)
3	Orange	BAT	Battery +
4	—	No connection	
5	—	No connection	
6	—	No connection	
7	Red	P5	Power supply input +5 V
8	Black	LG	Power supply input 0 V (GND)
9	Shield	SD	

- Connector pin layout

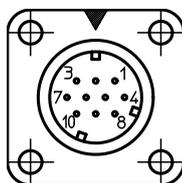


Connector model: 1-172169-9
 Clamp model: 316454-1
 Pin model: 170361-1
 (by AMP)

- Model No. 21A

Pin number	Signal name	Remarks
1	Vbat	Battery +
2	GND (bat)	Battery - (GND)
3	No connection	
4	Vcc	Power supply input +5 V
5	GND (Vcc)	Power supply input 0 V (GND)
6	No connection	
7	No connection	
8	SD+	Serial signal differential output (+)
9	SD-	Serial signal differential output (-)
10	FG	

- Connector pin layout



Connector model: CM10-R10P (D3)-01 (by DDK)

For Model Number 21A, connecting the encoder connector converter cable that comes with the model gives the same connector pin layout as for Model Numbers 09, 12, and 15.

Chapter 2

Selection guidelines

This chapter explains how to select a proper MMA series motor.

2-1 MMA series selection	2-1
2-2 Verifying and examining load weights	2-2
2-3 Examining the operating status	2-3

2-1 MMA series selection

2

Allowable load inertia moment

To maximize the performance of the MMA series, make a tentative selection of a motor so that the rotational speed and load inertia moment ratio are equal to or lower than the allowable values shown in the table below.

The allowable load inertia moment ratios in the table below are reference values for the following cases:

- (1) Controllable range: where the motor is accelerated/decelerated gradually or high responsiveness is not required.
- (2) Stable control range: where higher responsiveness is required to shorten the transient vibration period during positioning or stable operation at a constant speed is required.

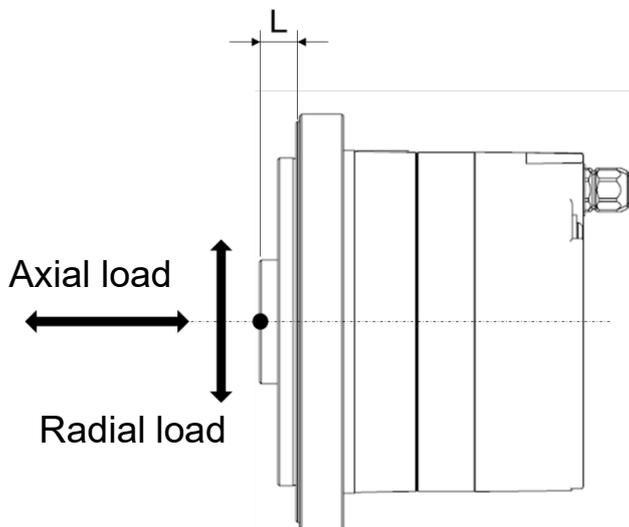
Model		MMAB09	MMAB12	MMAB15	MMAA21A
Allowable rotational speed	r/min	5600	4800	4000	3000
Inertia moment (without brake)	$\times 10^{-4} \text{ kg} \cdot \text{m}^2$	1.78	6.45	15.8	125
	$\times 10^{-4} \text{ kgf} \cdot \text{cm} \cdot \text{s}^2$	18.2	65.8	161	1280
Inertia moment (with brake)	$\times 10^{-4} \text{ kg} \cdot \text{m}^2$	2.16	6.83	19.8	141
	$\times 10^{-4} \text{ kgf} \cdot \text{cm} \cdot \text{s}^2$	22.1	69.7	202	1444
Allowable load inertia moment ratio	(1) Controllable range	10 times or less than inertia moment			
	(2) Stable control range	3 times or less than inertia moment			

Refer to [A-2 Calculating inertia moment] (P5-3) for the calculation of inertia moment.

When a load with a large inertia moment is operated frequently, a greater regenerative energy is produced during braking. If the produced regenerative energy exceeds the absorption capacity of the built-in regenerative resistor of the servo amplifier, an additional regenerative resistor must be connected externally to the servo amplifier. For details, refer to [Related manual] (P6).

2-2 Verifying and examining load weights

For MMA series motors, ensure that the load applied to the center of rotation and the end of the output shaft does not exceed the permissible load in the table below. Values shown in the table are permissible loads when applied individually.



Permissible output shaft load

Item Model	L mm	When operated at the rated speed		When stationary	
		Radial load	Axial load	Radial load	Axial load
		N	N	N	N
MMAB09	10	185	105	800	2400
MMAB12	10	233	130	1200	3600
MMAB15	11	530	180	2400	5000
MMAA21A	16	1040	880	4500	14000

2-3 Examining the operating status

2

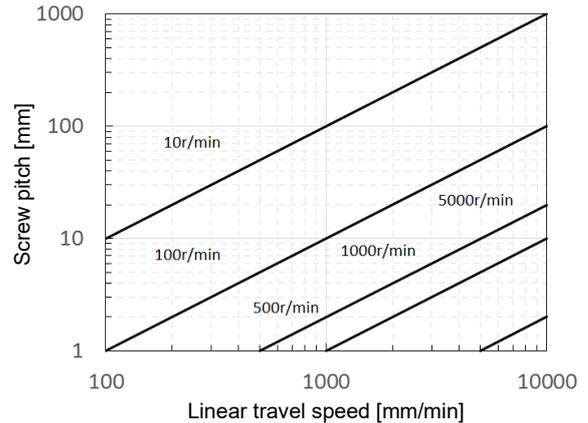
Selection guidelines

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

Examining motor rotational speed

Calculate the motor rotational speed r/min of the load driven by an MMA series motor. For linear operation, use the rotational speed conversion formula below:

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



Check that this motor rotational speed is less than the max. rotational speed of the MMA series motor.

Calculating and examining load inertia moment

Calculate the inertia moment of the load driven by an MMA series motor.

Refer to [A-2 Calculating inertia moment] (P5-3) for the calculation.

Based on the calculation result, make a tentative selection of an MMA series motor referring to [2-1 MMA series selection] (P2-1).

Load torque calculation

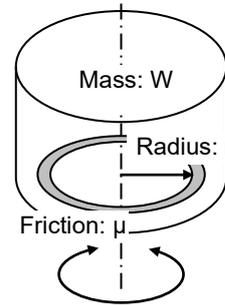
Calculate the load torque as follows:

- Rotary motion

The rotary torque for 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]

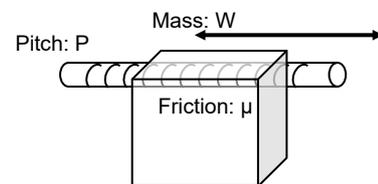


- Linear operation (horizontal operation)

The rotary torque for when 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]

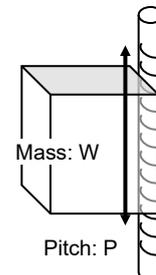


- Linear operation (vertical operation)

The rotary torque for when 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 the acceleration and deceleration times for the motor tentatively selected using the following formula.

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

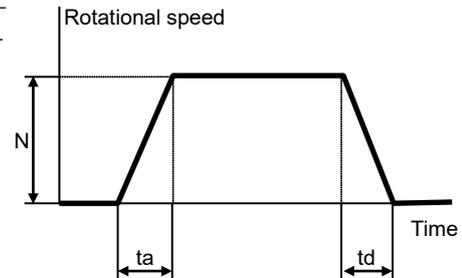
$$\text{Deceleration time: } t_d = k \times (J_M + J_L) \times \frac{2 \times \pi}{60} \times \frac{N}{T_M + 2 \times T_F + T_L}$$

t_a : Acceleration time [s]
 t_d : Deceleration time [s]
 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_M : Inertia moment of motor [kg·m²]
 J_L : Inertia moment of load [kg·m²]
 N : Rotational speed of motor [r/min]
 T_M : Maximum momentary torque [N·m]
 T_F : Motor friction torque [N·m]

$T_F = K_T \times I_R - T_R$
 K_T : Torque constant [N·m/A]
 T_R : Rated torque [N·m]
 I_R : Rated 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.

● Calculation example 1

Select a motor that best suits the following operating conditions:

- Rotational speed: 4000 [r/min]
- Inertia moment of load: 3.0×10^{-4} [kg·m²]
- Since the load mechanism is mainly inertia, the load torque is negligibly small.

(1) According to the conditions above, tentatively select MMAB09 from the table in section 2-1.

(2) From the rating table, the following values are obtained:

$$J_M = 1.78 \times 10^{-4} \text{ [kg·m}^2\text{]}, T_M = 3.0 \text{ [N·m]}, T_R = 0.80 \text{ [N·m]}, K_T = 0.41 \text{ [N·m/A]}, I_R = 2.5 \text{ A}$$

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

$$0.41 \times 2.5 - 0.80 = 0.225 \text{ [N·m]}.$$

(4) If $k = 1.3$, the acceleration time and deceleration time can be obtained as follows from the above formulas:

$$t_a = 1.3 \times (1.78 + 3.0) \times 10^{-4} \times 2 \times \pi / 60 \times 4000 / 3.0 \approx 0.087 \text{ [s]}$$

$$t_d = 1.3 \times (1.78 + 3.0) \times 10^{-4} \times 2 \times \pi / 60 \times 4000 / (3.0 + 2 \times 0.225) \approx 0.075 \text{ [s]}$$

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

- Reducing the inertia moment of load
- Selecting a motor with a larger frame size

Evaluating effective torque and average rotational speed

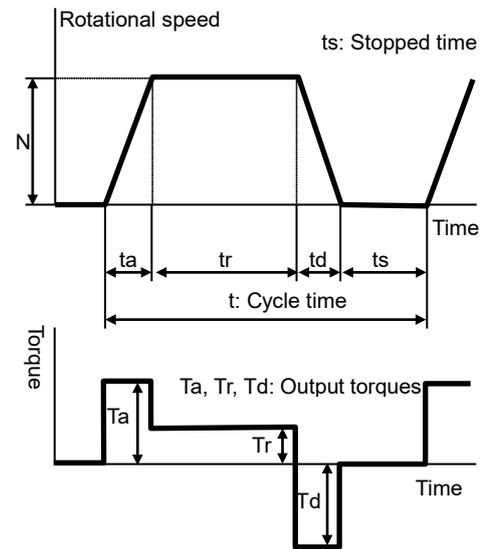
One way to check if the heat generated from the motor during operation would present a problem is to determine if the point of operation, determined by the effective torque and average rotational speed, is inside the continuous motion range explained in [1-12 Operable range].

Using the following formula, calculate the effective torque T_m and average rotational speed N_{av} when the motor is operated repeatedly in the drive pattern shown to the right.

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

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

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]



● Calculation example 2

The calculation method is explained below using MMAB09 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 3600° 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:

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

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

When $\theta = 3600^\circ$ and $t_a = 0.087$ [s], $t_d = 0.075$ [s], $N = 4000$ [r/min] in calculation example 1, are applied to this formula, t_r 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:

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

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

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.

$$T_m = \sqrt{\frac{2.30^2 \times 0.087 + 0^2 \times 0.069 + 2.53^2 \times 0.075}{0.8}} = 1.08 \text{ [N·m]}$$

(4) Calculate the average rotational speed. Apply the values in (1), $N = 4000$ r/min, and $t = 0.8$ seconds to the above formulas.

$$N_{av} = \frac{4000/2 \times 0.087 + 4000 \times 0.069 + 4000/2 \times 0.075}{0.8} = 750 \text{ [r/min]}$$

(5) The * mark in 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 MMAB09, exceeding the continuous motion range. The conclusion is that this motor cannot be operated continuously under these conditions. Accordingly,

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

etc., must be reevaluated.

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.

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

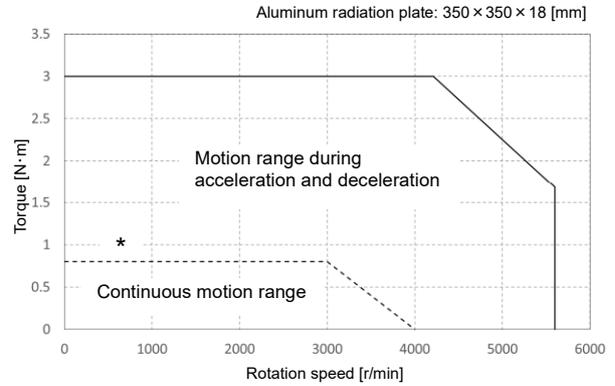
Apply the following:

- $T_a = 2.30$ [N·m]
- $T_r = 0$ [N·m]
- $T_d = 2.53$ [N·m]
- $T_m = 0.80$ [N·m]
- $t_a = 0.087$ [s]
- $t_r = 0.069$ [s]
- $t_d = 0.075$ [s]

Then, the following equation is obtained:

$$t = (2.30^2 \times 0.087 + 2.53^2 \times 0.075) / 0.80^2 = 1.46 \text{ [s]}$$

Based on the result, setting the cycle time to 1.5 seconds or more to provide a longer stop time gives $T_m = 0.80$ [N·m] or less, thereby permitting continuous operation within the rated torque.



Operable range of MMAB09

Caution

- The aforementioned continuous motion range represents an allowable range where the motor 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 motor's ambient temperature to 40 K or less as a guide.

Chapter 3

Installing the motor

This chapter explains how to install the motor.

3-1 Receiving inspection	3-1
3-2 Notices on handling	3-2
3-3 Location and installation	3-5

3-1 Receiving inspection

Check the following items after unpacking the box.

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 motor is what you ordered.

The nameplate is found on the end face or the side of the MMA series motor. Check the TYPE field on the nameplate to confirm that it is the model you have ordered. If any item is different from what you ordered, immediately contact the dealer.

Refer to section [1-3 Model] (P1-4) in this manual for details 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 Chapter 1 Section 2 "Combinations with servo amplifier and extension cables" column.

4 Check if the power voltages being input are correct.

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



Do not combine the servo amplifier with a motor that is not specified on the name plate.

The characteristics of the servo amplifier have been adjusted according to the motor. Wrong combinations of servo amplifiers and motors may cause insufficient torque or overcurrent that may cause motor burnout, injury or fire.

Do not connect a power supply with a voltage that is not specified on the servo amplifier's nameplate.

Connecting a power supply with an input voltage that is not specified on the nameplate may result in damage to the servo amplifier, injury or fire.

3-2 Notices on handling

Practice caution and observe the following notices when handling MMA series motors.

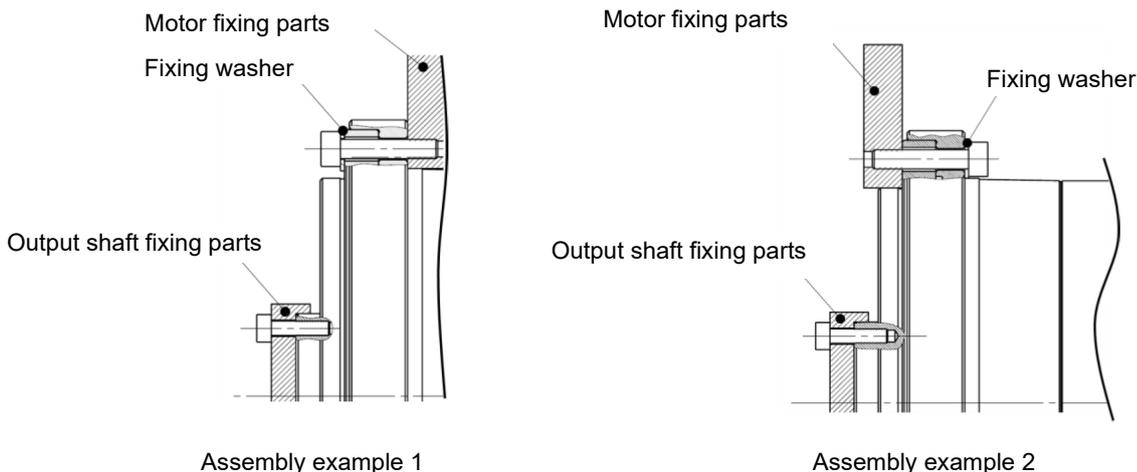


- (1) Do not apply any excessive force or impact, especially to the motor's output shaft.
- (2) Do not place MMA series motors on a table, shelf, etc., where the motor could easily fall.
- (3) Do not connect the motor terminals directly to the power supply. The motor may burn out and cause a fire or electric shock.
- (4) The allowable storage temperature is -20 to $+60$ °C. Do not expose the motor to direct sunlight for long periods of time or store it in areas at low or high temperatures.
- (5) The allowable relative storage humidity is 80 % or less. In particular, do not store the motor in a very humid place or in areas where there are large temperature changes between day and night.
- (6) Do not use or store the motor in locations subject to flammable or corrosive gases or dust particles.
- (7) The large model (MMAA21A) is heavy. Handling these models may cause lower back pain, or injury if the motor drops or topples and you are pinned underneath. Handle your motor with due care by wearing safety shoes, take other proper precautions, and also use supporting jigs.

Installation and transmission torque

Examples of motor assembly are shown below. 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 motor flange is made of aluminum.

Motor assembly example



- Recommended tightening torque and transmission torque

Item \ Model		MMAB09		MMAB12	
		Output shaft	motor	Output shaft	motor
Number of bolts, size		4-M3	6-M4	4-M3	6-M5
Bolt installation P.C.D.	mm	28	102	36	132
Tightening torque	N·m	2.0	4.5	2.0	9.0
	kgf·m	0.20	0.46	0.20	0.92
Transmission torque	N·m	23	215	30	446
	kgf·m	2.4	22.0	3.1	45.5

Item \ Model		MMAB15		MMAA21A	
		Output shaft	Motor	Output shaft	Motor
Number of bolts, size		4-M4	6-M6	4-M5	8-M8
Bolt installation P.C.D.	mm	50	158	74	226
Tightening torque	N·m	4.5	15.3	9.0	37.0
	kgf·m	0.46	1.56	0.92	3.8
Transmission torque	N·m	70	755	167	2630
	kgf·m	7.2	77.1	17.0	268.2

Note 1: The female thread material is assumed to withstand the bolt tightening torque.

2: Recommended bolt: Hexagonal bolt per JIS B 1176 Strength category: JIS B 1051 12.9 or higher

3: Calculation conditions Torque efficiency: 0.2 Tightening efficiency: 1.4 Tightening friction coefficient: 0.15

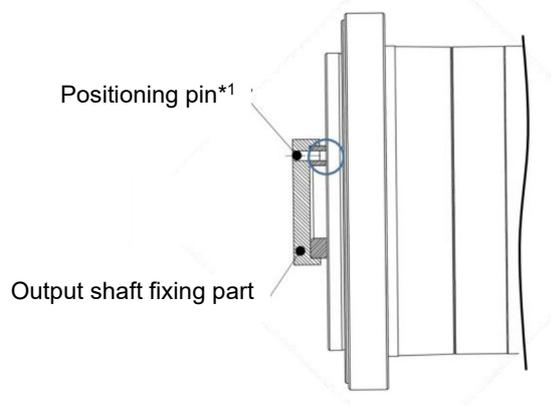
Precautions on installation

When designing the assembly, note that application of any abnormal or excessive force that causes deformation of the installation surface may result in performance drop. To deliver optimal performance of the MMA series motors, pay attention to the following points:

- Warping and deformation on the mounting surface
- Blockage caused by foreign matter
- Burrs, rising and abnormal position accuracy around tapped mounting holes
- Insufficient chamfering of mounting faucet joint
- Abnormal circularity of mounting faucet joint

Use of positioning pins

The MMA series motors have positioning pin holes in the output shaft. Use these pin holes as necessary. For details, refer to [1-6 External dimensions] (P1-8) or the illustrated specifications.



Example of use of positioning pins

*1. Do not drive in positioning pins, but keep proper fitting clearances to the motor shaft. Failure to do so may result in damage to the motor, deformation of the motor shaft, or decreased pin positional accuracy.

Motor material

The MMA series motors use the following materials, however, they are not completely rust-proof.

Location	Material
Housing	Aluminum material is exposed (no treatment)
Hollow shaft (output shaft)	SUS 420J2
Bolt	SCM435 (black oxide coating treatment)

3-3 Location and installation

Environment of location

The environmental conditions of the installation location for MMA series motors are as follows. Always observe these conditions to determine an appropriate installation location.

- ◆ 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 motor is kept 40 °C or below.
- ◆ Operating humidity: Relative humidity of 20 to 80 %. Make sure no condensation occurs. 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 motor is started/stopped frequently.
- ◆ Vibration: 25 m/s² (10 to 400 Hz) or less (Refer to [1-11 Resistance to vibration] (P1-16))
- ◆ Impact: 300 m/s² or less (Refer to [1-10 Shock resistance] (P1-15))
- ◆ Use environment: Free from condensation, metal powder, corrosive gases, water, oil mist, flammable gases, etc.
- ◆ Protection class: Standard products are structurally designed to meet the 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 of foreign matter caused by incomplete protection must not affect the operation of the system.

However, rotating and sliding areas (oil seal areas, all models) and connectors (MMAB09, MMAB12, MMAB15) are not IP-54-compliant. Also, when an MMAA21A encoder connector converter cable is used, the motor side is warranted as installed, but this does not apply to the connector on the servo amplifier side. Connectors of MMAA21A motor are warranted as installed.

- ◆ Use the motor indoors or within an enclosure. Do not expose it to direct sunlight.
- ◆ Altitude: less than 1000 m above sea level

Installation

When installing an MMA series motor, ensure that it is installed accurately and do not tap with a hammer, etc. The motor houses an encoder. Excessive impact may damage the encoder.

Installation procedure

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

Note 1: Perform this alignment carefully, especially when a rigid coupling is used. Even slight misalignment may cause the allowable load of the motor to be exceeded, resulting in damage to the output shaft.



2 Connect the servo amplifier and wiring.

An extension cable is provided. Use it when wiring the servo amplifier. For details on wiring, refer to [1-13 Cable specifications] (P1-19) and [Related manual] (P6)

3 Wire the motor cable and encoder cable.

Do not pull the cables with a strong force. Doing so may damage the connectors. Install the cable with slack and do not to apply any tension to the motor. Provide a sufficient bending radius (at least six times the cable diameter), especially when the cable flexes.

Caution

- Do not bring strong magnetic bodies (magnet chucks, permanent magnets, etc.) near the rear cover of the motor. Encoder abnormality may result.
- This encoder requires an external battery to retain absolute positions.



Do not disassemble/reassemble the motor.

The motor uses many precision parts. If the motor is disassembled/reassembled by the customer, it may cause motor burnout or uncontrollable operation, resulting in a fire or injury.

3

Installing the motor

Chapter 4

Options

This chapter provides information on the options.

4-1 Options	4-1
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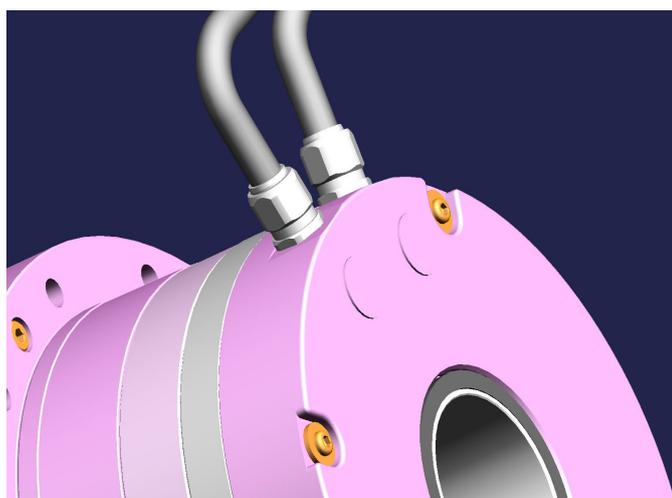
4-1 Options

Cable taken out from side face (option code: Y)

The cables (motor and encoder wires) are taken out from the side face of the motor. Use this option if the motor is housed in a system and there is not enough space at the rear of the housing.

This option is not available for model No. 21A.

For details on the option where cables can be taken out from the side, contact our sales office.



Extension cables

These extension cables are used to connect MMA series motors and MELSERVO-J4 servo amplifiers. Two types of extension cables are available for motor (including brake wire) and encoder. **You must use an extension cable to connect your MMA series motor and MELSERVO-J4 servo amplifier.**

Motor extension cable:

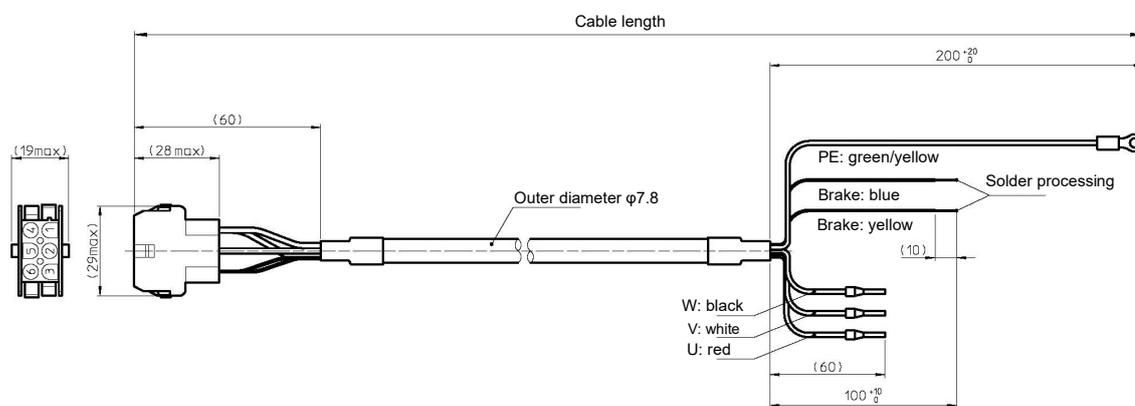
- Motor model Nos. 09, 12, 15

EWD-MB**-A06-TMC-M

** in the model code indicates the cable length (02 = 2m, 05 = 5m, 10 = 10m).

[Motor side]

[Servo amplifier side]

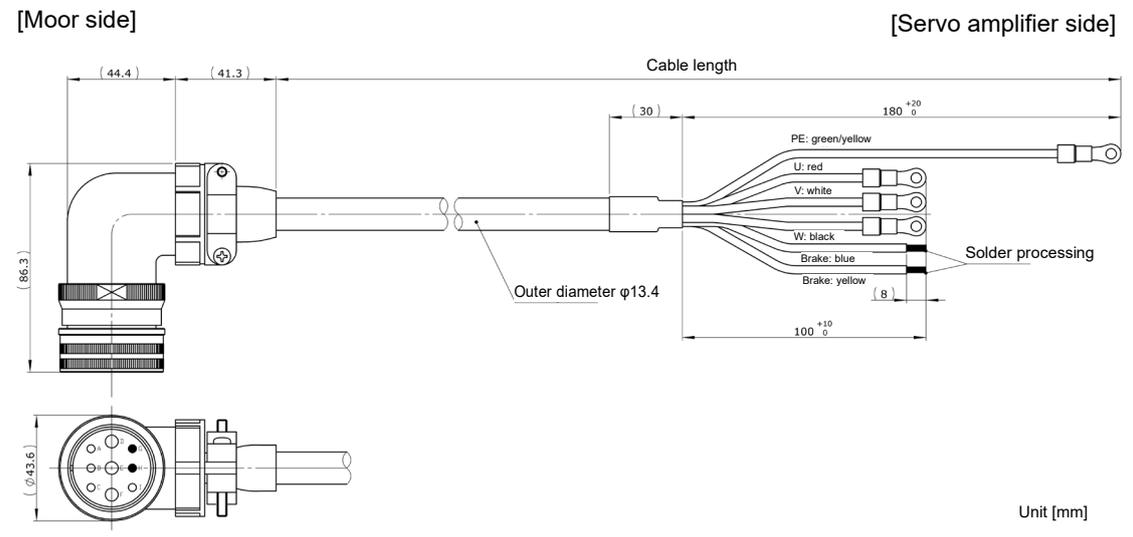


Unit [mm]

● **Motor model No. 21A**

EWD-MB**D09-TMC-M2

** in the model code indicates the cable length (02 = 2m, 05 = 5m, 10 = 10m).



Encoder extension cable:

● **Motor model Nos. 09, 12, 15, 21A**

MR-EKCBL□M-H (Long flex life product)

MR-EKCDL□M-L (Standard product)

□ in the model code indicates the cable length (02 = 2m, 05 = 5m, 10 = 10m).

For details on encoder extension cable, contact Mitsubishi Electric customer support.

Appendix

A-1	Unit conversion	5-1
A-2	Calculating inertia moment	5-3

A-1 Unit conversion

This manual employs the 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

(2) Linear speed

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

(3) Linear acceleration

SI system	m/s ²			
Unit	m/min ²	ft./min ²	ft./s ²	in/s ²
Factor	3600	1.18x10 ⁴	3.281	39.37

(4) Force

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

(5) Mass

SI system	kg	
Unit	lb.	oz.
Factor	2.205	35.27

(6) Angle

SI system	rad		
Unit	Degree	Minute	Sec.
Factor	57.3	3.44 x 10 ³	2.06 x 10 ⁵

(7) Angular speed

SI system	rad/s			
Unit	deg/s	deg/min	r/s	r/min
Factor	57.3	3.44x10 ³	0.1592	9.55

Unit	ft.	in.
Factor	0.3048	0.0254
SI system	m	

Unit	m/min	ft./min	ft./s	in/s
Factor	0.0167	5.08x10 ⁻³	0.3048	0.0254
SI system	m/s			

Unit	m/min ²	ft./min ²	ft./s ²	in/s ²
Factor	2.78x10 ⁻⁴	8.47x10 ⁻⁵	0.3048	0.0254
SI system	m/s ²			

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

Unit	lb.	oz.
Factor	0.4535	0.02835
SI system	kg	

Unit	Degree	Minute	Sec.
Factor	0.01755	2.93 x 10 ⁻⁴	4.88 x 10 ⁻⁶
SI system	rad		

Unit	deg/s	deg/min	r/s	r/min
Factor	0.01755	2.93 x 10 ⁻⁴	6.28	0.1047
SI system	rad/s			

(8) Angular acceleration

SI system	rad/s ²	
	↓	
Unit	deg/s ²	deg/min ²
Factor	57.3	3.44 x 10 ³

Unit	deg/s ²	deg/min ²
Factor	0.01755	2.93 x 10 ⁻⁴

SI system	rad/s ²
-----------	--------------------

(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 x 10 ⁻³

SI system	N·m
-----------	-----

(10) Inertia moment

SI system	kg·m ²							
	↓							
Unit	kgf·m·s ²	kgf·cm·s ²	lb·ft ²	lb·ft·s ²	lb·in ²	lb·in·s ²	oz·in ²	oz·in·s ²
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·s ²	kgf·cm·s ²	lb·ft ²	lb·ft·s ²	lb·in ²	lb·in·s ²	oz·in ²	oz·in·s ²
Factor	9.81	0.0981	0.0421	1.356	2.93 x 10 ⁻⁴	0.113	1.829 x 10 ⁻⁵	7.06 x 10 ⁻³

SI system	kg·m ²							
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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.

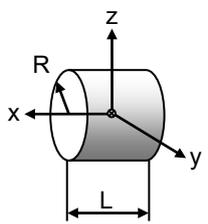
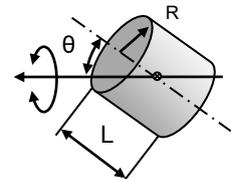
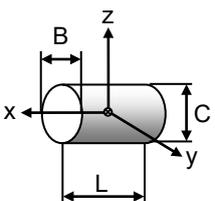
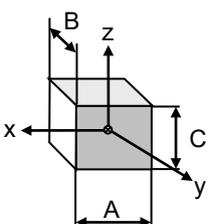
m: Mass [kg], I_x, I_y, I_z : inertia moments which rotate around x-, y-, z-axes respectively [kg·m²]

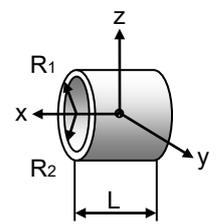
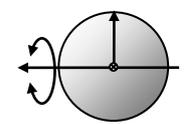
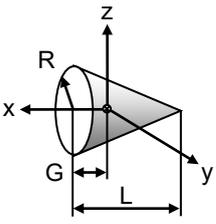
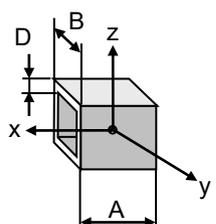
G: Distance from the end face to the center of gravity [m]

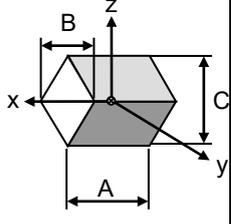
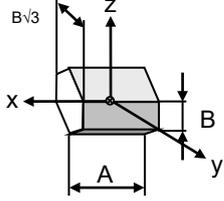
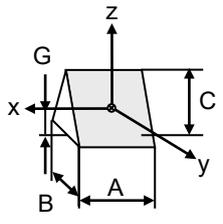
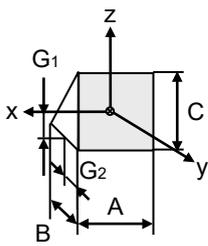
ρ : Specific gravity [$\times 10^3$ kg / m³]

Units Length [m], Mass [kg], Inertia moment [kg·m²]

Appendix

Object form	Mass, inertia, gravity center
	$m = \pi R^2 L \rho \times 10^3$ $I_x = \frac{1}{2} m R^2$ $I_y = \frac{1}{4} m \left(R^2 + \frac{L^2}{3} \right)$ $I_z = \frac{1}{4} m \left(R^2 + \frac{L^2}{3} \right)$
	$m = \pi R^2 L \rho \times 10^3$ $I_\theta = \frac{1}{12} m \times \left\{ 3R^2(1 + \cos^2\theta) + L^2 \sin^2\theta \right\}$
	$m = \frac{1}{4} BCL \rho \times 10^3$ $I_x = \frac{1}{16} m (B^2 + C^2)$ $I_y = \frac{1}{4} m \left(\frac{C^2}{4} + \frac{L^2}{3} \right)$ $I_z = \frac{1}{4} m \left(\frac{B^2}{4} + \frac{L^2}{3} \right)$
	$m = ABC \rho \times 10^3$ $I_x = \frac{1}{12} m (B^2 + C^2)$ $I_y = \frac{1}{12} m (C^2 + A^2)$ $I_z = \frac{1}{12} m (A^2 + B^2)$

Object form	Mass, inertia, gravity center
 <p>R₁: Outer diameter R₂: Inner diameter</p>	$m = \pi (R_1^2 - R_2^2) L \rho \times 10^3$ $I_x = \frac{1}{2} m (R_1^2 + R_2^2)$ $I_y = \frac{1}{4} m \left\{ (R_1^2 + R_2^2) + \frac{L^2}{3} \right\}$ $I_z = \frac{1}{4} m \left\{ (R_1^2 + R_2^2) + \frac{L^2}{3} \right\}$
	$m = \frac{4}{3} \pi R^3 \rho \times 10^3$ $I = \frac{2}{5} m R^2$
	$m = \frac{1}{3} \pi R^2 L \rho \times 10^3$ $I_x = \frac{3}{10} m R^2$ $I_y = \frac{3}{80} m (4R^2 + L^2)$ $I_z = \frac{3}{80} m (4R^2 + L^2)$ $G = \frac{L}{4}$
	$m = 4AD(B - D) \rho \times 10^3$ $I_x = \frac{1}{3} m \left\{ (B \cdot D)^2 + D^2 \right\}$ $I_y = \frac{1}{6} m \left\{ \frac{A^2}{2} + (B \cdot D)^2 + D^2 \right\}$ $I_z = \frac{1}{6} m \left\{ \frac{A^2}{2} + (B \cdot D)^2 + D^2 \right\}$

Object form	Mass, inertia, gravity center	Object form	Mass, inertia, gravity center
<p>Rhombus pillar</p> 	$m = \frac{1}{2} ABC\rho \times 10^3$ $I_x = \frac{1}{24} m(B^2 + C^2)$ $I_y = \frac{1}{24} m(C^2 + 2A^2)$ $I_z = \frac{1}{24} m(B^2 + 2A^2)$	<p>Hexagonal pillar</p> 	$m = \frac{3\sqrt{3}}{2} AB^2\rho \times 10^3$ $I_x = \frac{5}{12} mB^2$ $I_y = \frac{1}{12} m\left(A^2 + \frac{5}{2}B^2\right)$ $I_z = \frac{1}{12} m\left(A^2 + \frac{5}{2}B^2\right)$
<p>Isosceles triangle pillar</p> 	$m = \frac{1}{2} ABC\rho \times 10^3$ $I_x = \frac{1}{12} m\left(\frac{B^2}{2} + \frac{2}{3}C^2\right)$ $I_y = \frac{1}{12} m\left(A^2 + \frac{2}{3}C^2\right)$ $I_z = \frac{1}{12} m\left(A^2 + \frac{B^2}{2}\right)$ $G = \frac{C}{3}$	<p>Right triangle pillar</p> 	$m = \frac{1}{2} ABC\rho \times 10^3$ $I_x = \frac{1}{36} m(B^2 + C^2)$ $I_y = \frac{1}{12} m\left(A^2 + \frac{2}{3}C^2\right)$ $I_z = \frac{1}{12} m\left(A^2 + \frac{2}{3}B^2\right)$ $G_1 = \frac{C}{3} \quad G_2 = \frac{B}{3}$

● Example of specific gravity

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

Material	Specific gravity [$\times 10^3 \text{kg} / \text{m}^3$]	Material	Specific gravity [$\times 10^3 \text{kg} / \text{m}^3$]	Material	Specific gravity [$\times 10^3 \text{kg} / \text{m}^3$]
SUS304	7.93	Aluminum	2.70	Epoxy resin	1.90
S45C	7.86	Duralumin	2.80	ABS	1.10
SS400	7.85	Silicon	2.30	Silicon resin	1.80
Cast iron	7.19	Quartz glass	2.20	Polyurethane rubber	1.25
Copper	8.92	Teflon	2.20		
Brass	8.50	Fluorocarbon resin	2.20		

(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.

$$I = I_g + mF^2$$

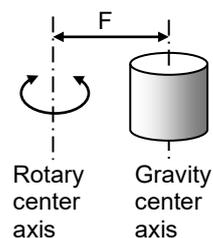
I : Inertia moment when the gravity center axis does not match the rotational axis [$\text{kg} \cdot \text{m}^2$]

I_g : Inertia moment when the gravity center axis matches the rotational axis [$\text{kg} \cdot \text{m}^2$]

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.

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

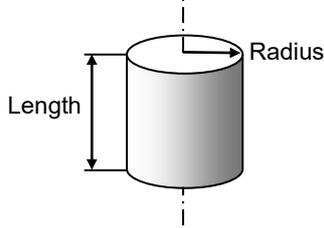
I : Inertia moment of a linear operation object converted to motor axis [$\text{kg} \cdot \text{m}^2$]

m : mass [kg]

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

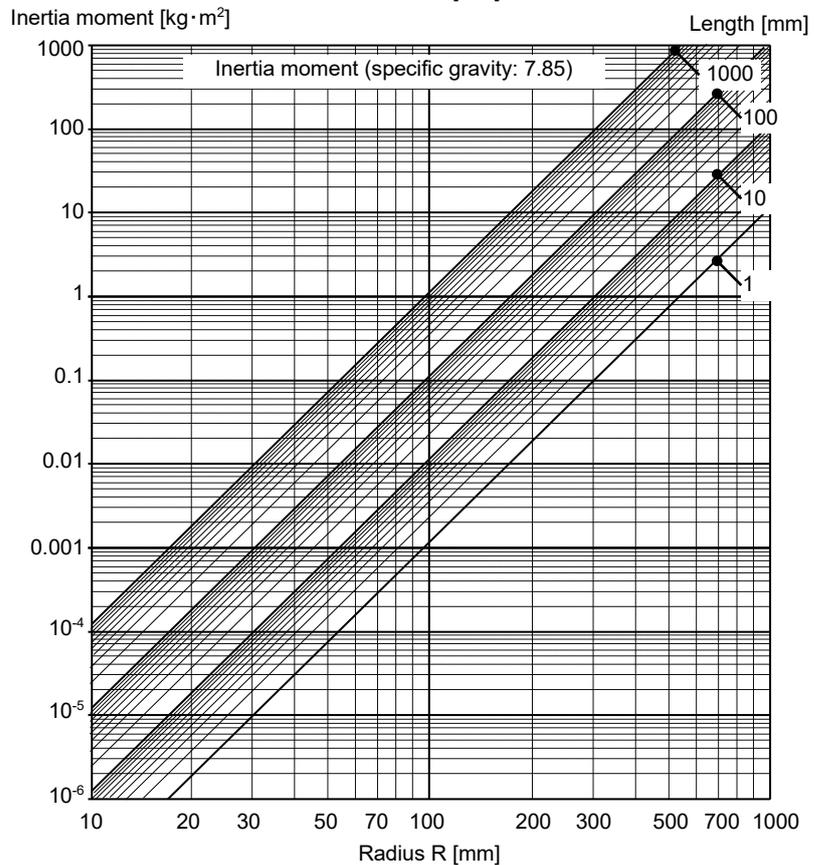
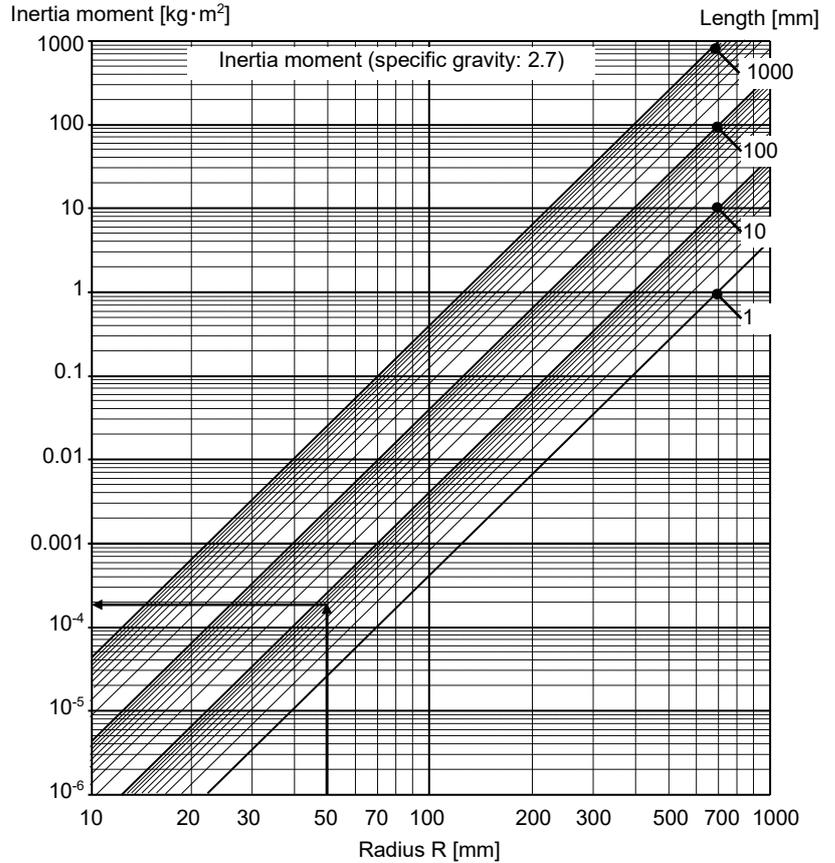
Inertia moment of cylinder

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} [$\text{kg} \cdot \text{m}^2$] (by the graph on the right)
 (Calculated value: 0.000186 m^2)



Appendix

Warranty Period and Terms

The equipment listed in this document is warranted as follows:

■ Warranty period

Under the condition that the motor is handled, used and maintained properly followed each item of the documents and the manuals, all the applicable products are warranted against defects in workmanship and materials for the shorter period of either one year after delivery or 2,000 hours of operation time.

■ Warranty terms

All the applicable products are warranted against defects in workmanship and materials for the warranted period. This limited warranty does not apply to any product that has been subject to:

- (1) user's misapplication, improper installation, inadequate maintenance, or misuse.
- (2) disassembling, modification or repair by others than Harmonic Drive Systems, Inc.
- (3) imperfection caused by a non-applicable product.
- (4) disaster or others that does not belong to the responsibility of Harmonic Drive Systems, Inc.

Our liability shall be limited exclusively to repairing or replacing the product only found by Harmonic Drive Systems, Inc. to be defective. Harmonic Drive Systems, Inc. shall not be liable for consequential damages of other equipment caused by the defective products, and shall not be liable for the incidental and consequential expenses and the labor costs for detaching and installing to the driven equipment.

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