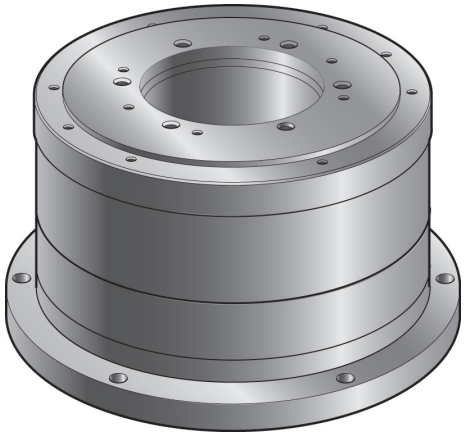
HarmonicDrive®

Direct Drive Motor

KDU Series Manual



ISO14001

ISO9001

Introduction

Thank you very much for purchasing our KDU Series Direct Drive Motor.
Wrong handling or use of this product may result in unexpected accidents or shorter life of the product. Read this manual 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.
Keep this manual in a convenient location and refer to it whenever necessary in operating or maintaining the units.
The end user of the motor 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 driver.

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

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 will not occur even when the output control is disabled due to damage.

SAFETY NOTE

ITEMS YOU SHOULD NOTE WHEN USING THE MOTOR

- **NOTICES ON DESIGN**

Always use them under the followings conditions:

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

- Ambient temperature: 10 to 30℃
- Ambient humidity: 20 to 80%RH (No condensation)
- Under the environment with no vibration or physical shock
- No contamination by water, oil
- No corrosive or explosive gas

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

- Ensure exact alignment of the motor shaft center and corresponding center as per the manual.
- Failure to observe this caution may lead to vibration, resulting in damage of output shafts.

- **OPERATIONAL PRECAUTIONS**

Never connect cables directly to a power supply socket.

- Each motor must be operated with a proper driver.
- Do not directly apply a commercial power supply. Failure to observe this caution may lead to fire or damage to the motor.

Do not apply impacts and shocks.

- Because the motor is directly connected to the encoder with high accuracy, do not apply any impact on it.
- Failure to observe this caution could damage the encoder and may cause uncontrollable operation.

Avoid handling of motor by cables.

- Rough handling of cables may damage connectors, leading to uncontrolled operation of the motor.

Keep limited torques of the motor.

- Keep limited torques of the motor.
- When installing a load on the output shaft, keep the weight well balanced.

ITEMS YOU SHOULD NOTE WHEN USING THE DRIVER

- **NOTICES ON DESIGN**

Always use them under followings conditions:

The driver generates heat. Take extra caution for radiation and use it under the following conditions.

- Mount in a vertical position keeping sufficient distance to other devices to let heat generated by the driver radiate freely.
- 0 to 50℃, 95% RH or below (No condensation)
- No vibration or physical shock
- No corrosive, inflammable or explosive gas

Use sufficient noise suppressing means and safe grounding.

Any noise generated on a signal wire will cause vibration or improper motion. Be sure to observe the following conditions.

- Keep signal and power leads separated.
- Keep leads as short as possible.
- Ground motor and driver at one single point, minimum ground resistance class: D (less than 100 ohms)
- Do not use a power line filter in the motor circuit.

Pay attention to negative torque by inverse load.

- Inverse load may cause damages to the drivers.
- Please consult our sales office, if you intend to make a voltage resistance test.

Use a fast-response type ground-fault detector designed for PWM inverters.

When using a fast-response type ground-fault detector, use one that is designed for PWM inverters. Do not use a time-delay-type ground-fault detector.

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 will not occur even when the output control is disabled due to damage.

- **OPERATIONAL PRECAUTIONS**

Never change wiring while the power is active.

Make sure that power is non-active before servicing the products. Failure to observe this caution may result in electric shock or uncontrollable operation.

Do not touch terminals or inspect products at least 15 minutes after turning OFF power.

- Even after the power supply is turned OFF, electric charge remains in the driver. In order to prevent electric shock, perform inspections 15 minutes after the power supply is turned OFF.
- Make installation of products not easy to touch their inner electric components.

Do not make a voltage resistance test.

- Do not perform a megger test or voltage resistance test. Failure to observe this caution may result in damage to the control circuit of the driver.
- Please consult our sales office, if you intent to make a voltage resistance test.

Do not operate control units by means of power ON/OFF switching.

- Frequent power ON/OFF operations may cause deterioration of circuit elements inside the driver.
- Start/stop operation should be performed via input signals.

DISPOSAL

All products or parts have to be disposed of as industrial waste.

Since the case or the box of drivers have a material indication, classify parts and dispose of them separately.

Structure of this document

Chapter 1	**Overviews**	This chapter explains overviews of motor models, specifications, external dimensions, etc.
Chapter 2	**Installation**	This chapter explains how to install the motor.
Chapter 3	**Option**	This chapter explains options.
Appendix		This chapter explains unit conversion and method of calculating inertia moment.

Contents

Chapter 1

Chapter 2

Chapter 3

Appendix

Memo

Chapter 1

Overviews

Overviews of motor models, specifications, external dimensions, etc., are explained in this chapter.

1-1 Overviews

KDU Series Direct Drive Motor offers high precision positioning with super high resolution.
The KDU Series dedicated HA-770 driver is a servo drive units that can control position by command communication command and pulse command. The small, multi-functional drivers control the operations of KDU Series motors with great accuracy and precision.
The KDU Series plays an important role in ultra-precision measuring devices, driving ultra-precision positioning mechanisms for semi-conductor and semi-conductor LCD devices, and various other factory automation equipment.

Main features

Super high resolution

It achieves ultra-high resolution of 11,840,000 pulse/rev. This makes possible smooth indexing operations and precise indexing positioning for ultra-high accuracy measuring devices, ultra-precise semiconductor manufacturing devices, etc.

High positional accuracy

Achieves absolute positional accuracy of 10 s (with position correction control) and highly accurate repeatability of ±0.5 s.

Large hollow diameter

It has a large hollow structure that has a diameter of 50. A through-hole is provided in the motor, through which energy can be supplied to drive sections of machines and devices and through which signals can be exchanged.

Unique motor structure

The unique motor structure (patent received) achieves superior torque/weight ratios. This delivers more compact and lighter devices.

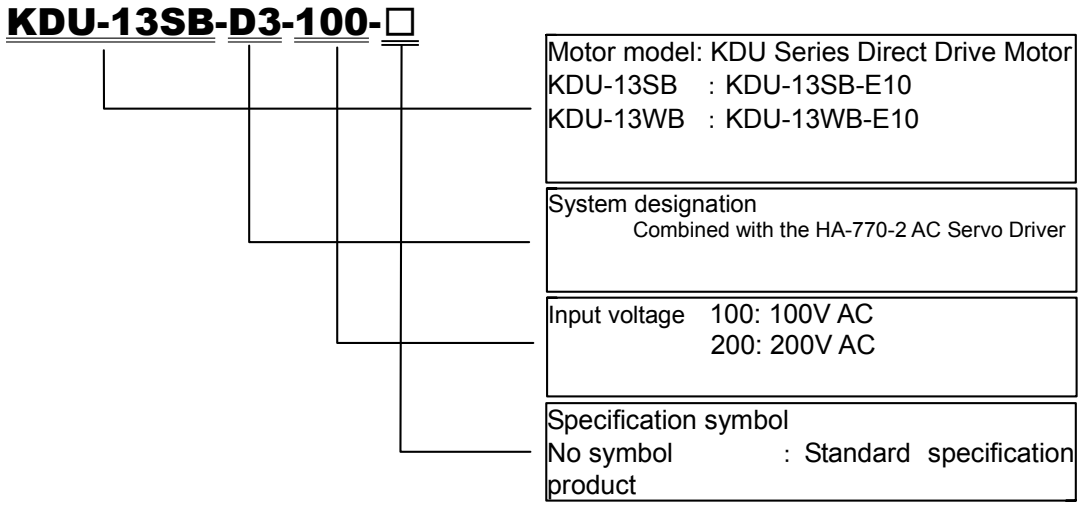
Mechanical accuracy

The high stiffness, high accuracy cross roller bearing configuration achieves an output shaft surface runout accuracy of 2 μm.

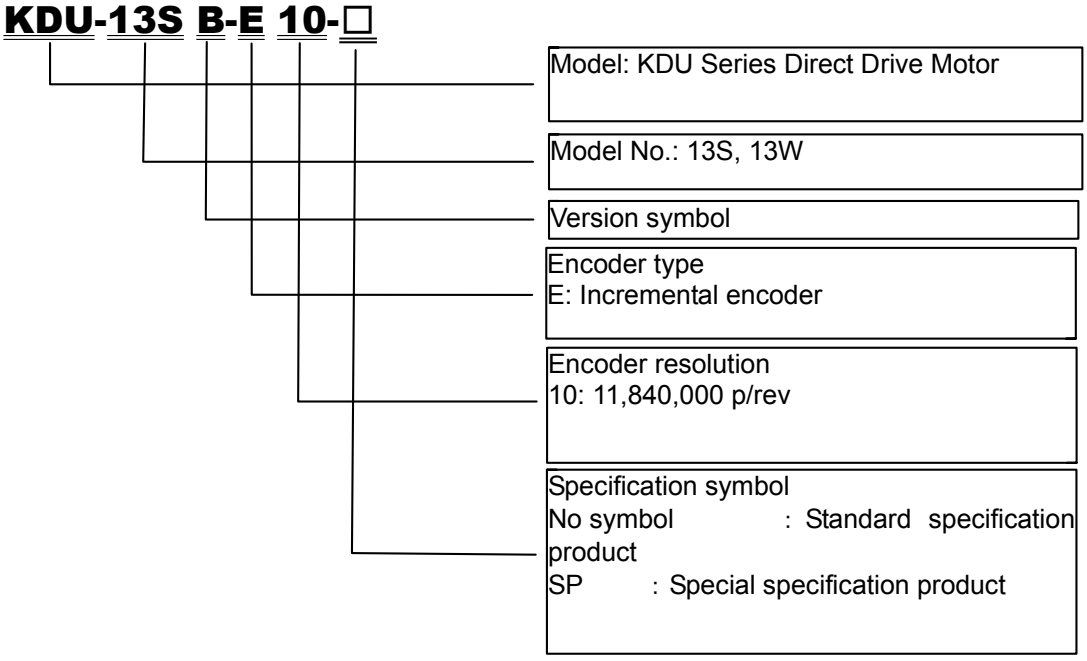
1-2 Model

The KDU Series Direct Drive Motor functions in combination with the HA-770 AC Servo Driver.

The model names for the system and how to read the symbols are explained below.



Model names for the KDU Series Direct Drive Motors and how to read the symbols are explained below.



1-3 Combination with driver

Model names for motors and systems combined with a HA-770 driver are shown below.

Input voltage	System model name	Motor model name	Driver model name
100V	KDU-13SB-D3-100	KDU-13SB-E10	HA-770-2
	KDU-13WB-D3-100	KDU-13WB-E10	
200V	KDU-13SB-D3-200	KDU-13SB-E10	
	KDU-13WB-D3-200	KDU-13WB-E10	

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CAUTION

Use the KDU Series motor combined with a driver as a set.
The KDU Series motor's absolute positional accuracy of 10 seconds is based on correction data from the driver memory. If you use a motor and driver combination that is not shown, the absolute positional accuracy cannot be guaranteed.

1-4 Specifications

Below is the specifications of the KDU Series motors.

Item	Model	KDU	
		-13SB	-13WB
Max. torque Note 2	Nm	7.0	15.0
	kgfm	0.7	1.5
Max. rotational speed	r/min	127	127
Torque constant	N m/A	3.1	6.5
	kgfm/A	0.32	0.66
Input power supply	V	AC100/AC200	
EMF constant	V/(r/min)	0.33	0.68
Line resistance	Ω(20℃)	9.1	14.0
Line inductance	mH	19	35
Inertia moment ($GD^2/4$)	kgm^2	0.0047	0.0065
(J)	$kgfcms^2$	0.048	0.066
Moment stiffness	Nm/rad	2.4×10^5	
	kgfm/rad	0.2×10^4	
Motor position detector	pulse/rev	Incremental encoder Square wave of Phases A and B:11,840,000 Pulse signal of Phase Z	
Repeatability: Note 3	arc sec	±0.5	
Absolute positional accuracy: Note 3	arc sec	10 (angular position correction): Note 4	
Mass	kg	4.0	5.0
Protection structure		Totally enclosed self-cooled type (equivalent to IP40)	
Environmental conditions		Service temperature: 10 to 30℃/Storage temperature: -10 to 60℃ (Note 3) Service/storage humidity: 20 to 80%RH (no condensation) Resistance to vibration while transporting or mounting the motor: 25 m/s2 (frequency: 10 to 400Hz) Resistance to impact while transporting or mounting the motor: 300 m/s2 No dust, metal powder, corrosive gas, inflammable gas, or oil mist. To be used indoors, no direct sunlight. Altitude: less than1,000 m above sea level	
Motor insulation		Insulation resistance: 100MΩ or more (by DC500V insulation tester) Dielectric strength: AC1,500V/1 min Insulation class: B	
Mounting direction		Output shaft facing up	

Note 1: The table above shows the values for the output shaft.

Note 2: The values in the table are obtained when connected to the HA-770 Servo Driver

Note 3: The values for repeatability and absolute positional accuracy are measured with the mounting direction of the output shaft facing up, and in an environment at a temperature of 23±0.3℃, with 50% humidity. Refer to the "Notices for maintaining accuracy" on the next page when you use the motor.

Note 4: These values are after the angular position of the servo driver is corrected.
In order to enable angular position correction, it is always necessary to execute the originating operation by the servo driver.

Caution

Notices for maintaining accuracy

To maintain accuracy, observe the following notices when using the motor.

Use the product in an appropriate environment.

- The environmental conditions for our accuracy measurement are a temperature of 23±0.3℃ and relative humidity of 50%. When using the motor in a device that requires high accuracy positioning control, please take into account the stiffness of the mechanism for temperature change of up to ±3˚C, the coefficient of expansion for each part, external vibration, etc.

Periodically rotate the output shaft at least 90˚.

- In order to prevent uneven wear due to the cross roller bearing grease running out, for devices used in operation environments with fine operations, periodically rotate the output shaft at least 90˚ in order to maintain accuracy.

Mounting direction check

- The mounting condition for our accuracy measurement is to have the output shaft facing up.
  When using the motor with the output shaft not facing up, contact us for more information.

Accuracy cannot be guaranteed in environments subject to vibration and impact.

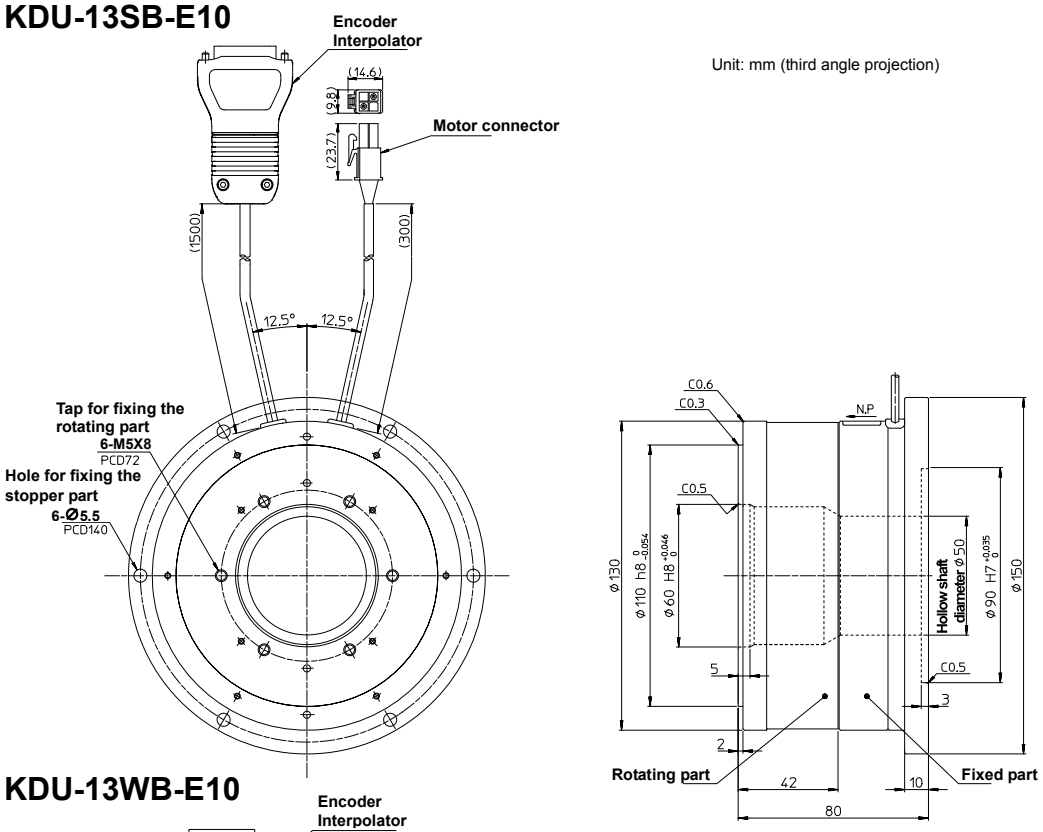
- The resistance to vibration and impact in the specifications table are standard values for the vibration and impact that occur while transporting or mounting the motor. While transporting or mounting the motor, do not subject the motor to any vibration or impact. In order to use the motor with high accuracy, use it in an environment with no impact or vibration.

1-5 External dimensions

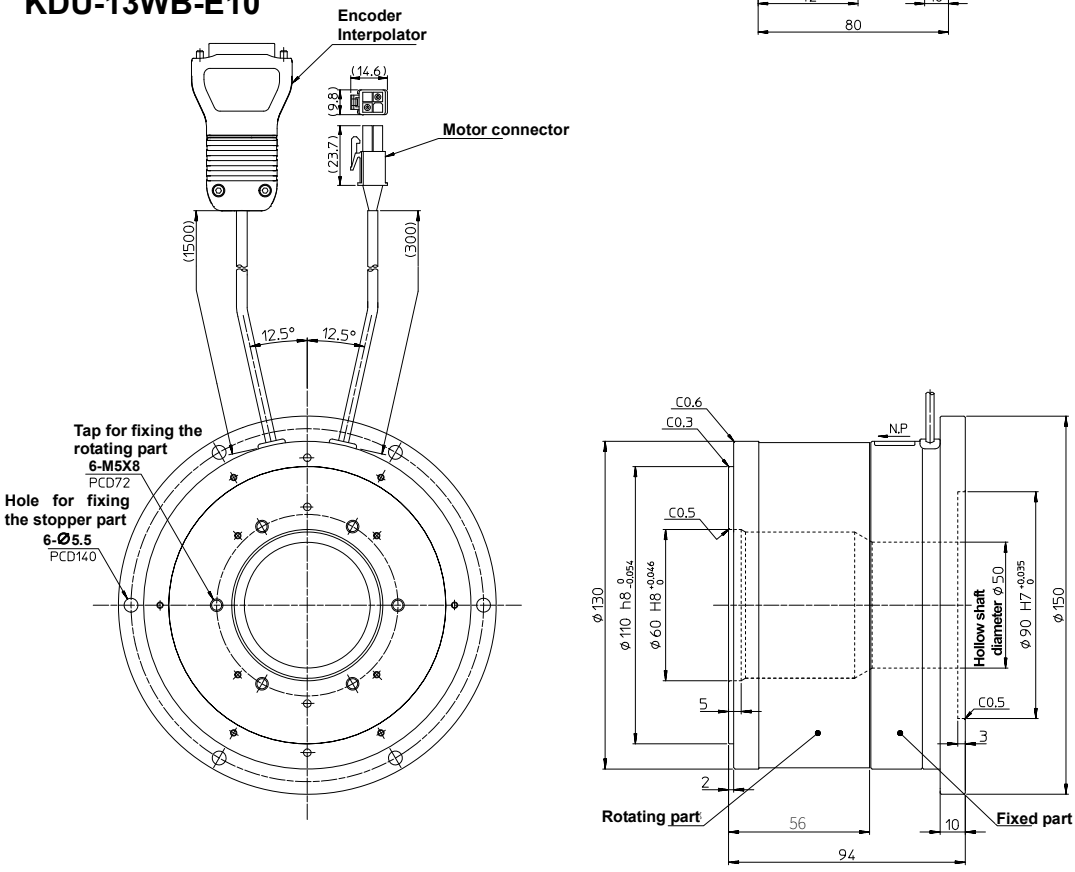
The external dimensions of the KDU Series are shown below.

KDU-13SB-E10

Unit: mm (third angle projection)

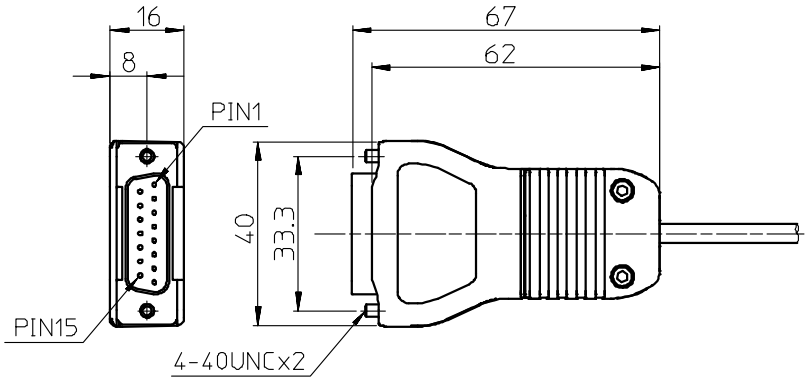


KDU-13WB-E10



Encoder
Interpolator

Unit: mm (third angle projection)



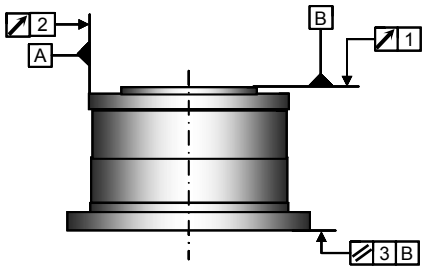
1-6 External drawing

The mechanical accuracies of the output shaft and mounting flange are shown below for the KDU Series motor:

unit: mm

Accuracy items	KDU-13
1. Output shaft surface runout	0.002
2. Deflection of output shaft	0.040
3. Parallelism between the output shaft end mounted surface	0.040

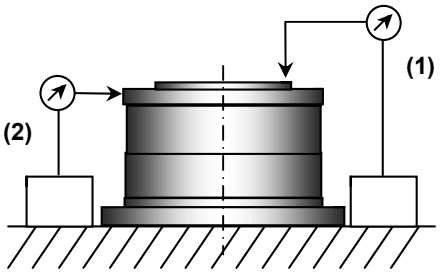
Note: All values are T.I.R. (Total Indicator Reading).



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) Output shaft surface runout

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

Reducing deflection of the output shaft

The specified deflection of output shaft value of 0.040 mm is due to the assembly error of the KDU parts.

The method for reducing deflection of the output shaft is shown below.

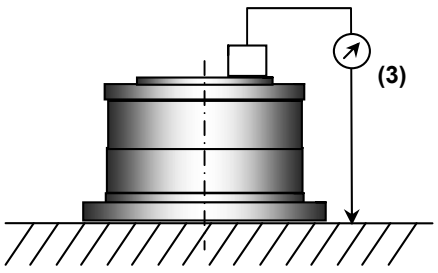
1 When producing the mounted load (disk) at your company, produce it with circularity of 1 µm or less.

2 Temporarily mount the load on the KDU output shaft.

3 Set the dial gauge on the side of the mounted load as in (2).

4 While rotating the motor at low speed, adjust the deflection of the mounted load to lower the reading on the dial gauge.

5 After adjusting the deflection, tighten further to secure the mounted load.

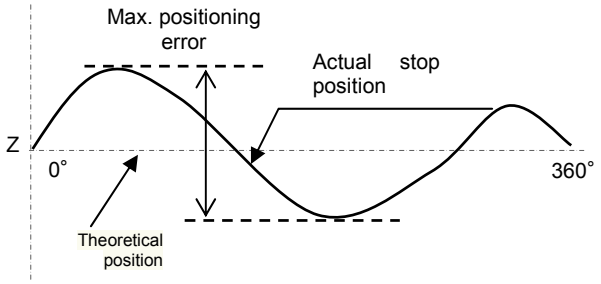


The operations above can secure shaft deflection accuracy of 4 µm or less.

(3) Parallelism between the output shaft and mounted surface

The dial gauge installed 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.

1-7 Absolute positional accuracy



"Absolute positional accuracy"

The accuracy is measured with measurement comparing with a reference encoder. Rotating one revolution with the Z signal as the datum point, the difference between the actual measured value at each positioning point (the position actually moved to from the datum point) and the reference encoder is found, and the value of (maximum – minimum) is shown as the absolute positional accuracy.
[Reference encoder]
Resolution: 57,600,000 pulse/rev
Absolute positional accuracy: 0.26 arc sec

"Absolute position compensation function"

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 one revolution when series of positioning are performed in the same rotation direction.

The "absolute positional accuracy" is shown in the table below:

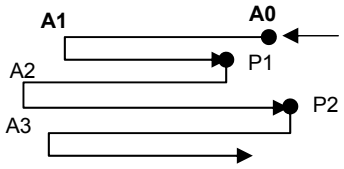
Item \ Model		KDU-13
Absolute positional accuracy (w/position correction function)	arc sec	10

1-8 Repeatability

Repeatability

1 From any A0 point position, move a certain angle.

Make this point the A1 point. Move the same distance in reverse as you moved from the A0 point. Measure the stop position P1 with the measuring instrument.



2 From the P1 point, repeat the same operations as in 1 and measure the P2 point.

3 Repeat the same operations 7 times.

4 Take one half the value of the maximum value minus the minimum value for the measured values P1 through P7 and add the ± sign to give the repeatability.

P3
⋮
P7

$$\text{Repeatability} = \pm \frac{P_{MAX} - P_{MIN}}{2}$$

The "repeatability" is shown in the table below:

Item \ Model		KDU-13
Repeatability	arc sec	±0.5

.

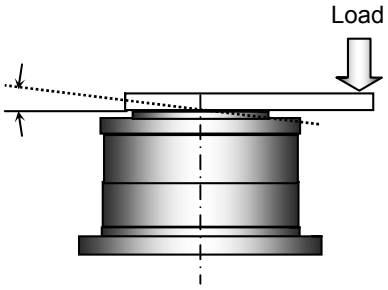
CAUTION

To find the above repeatability, maintain the condition of temperature change no more than ±3˚C.

1-9 Moment stiffness

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

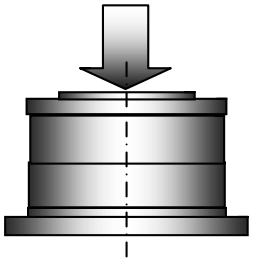
Item \ Model		KDU-13
Moment stiffness	Nm/rad	2.4×10^5
	kgfm/rad	2.4×10^4
	kgfm/arc min	7.12



1-10 Axial load and moment load

For the positional accuracy of the KDU Series motor, the accuracy is checked with an output shaft load of 16 kg or less for an axial load.

Axial load: 16 kg or less

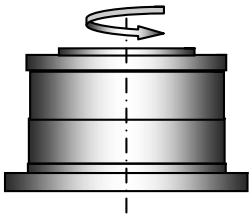


CAUTION

If an axial load larger than 16 kg or a moment load is applied, this affects the positional accuracy. Contact us for more information.

1-11 Rotation direction

Forward rotation direction of the motor is defined as counter-clockwise rotation as viewed from the output shaft when a Forward command is given to a KDU Series motor from a HA-770 driver.



FWD rotation: counter-clockwise as viewed from the output shaft

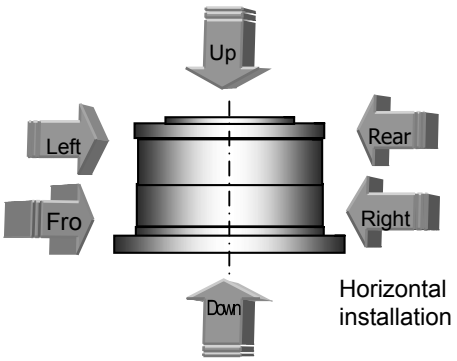
1-12 Resistance to vibration and impact

Subjecting the motor to vibration and impact after installation can make it impossible to maintain stopping stability and positional accuracy.
Use the motor in an environment with no vibration and impact.

Keep in mind the conditions for vibration and impact below when transporting or mounting the motor.

Resistance to vibration

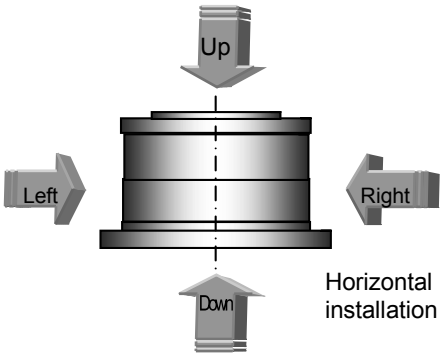
Vibration acceleration: 25 m/s^2 (frequency: 10 to 400Hz)



Resistance to vibration test

Resistance to impact

Shock acceleration: 300 m/s^2
No. of times: 3



Shock resistance test

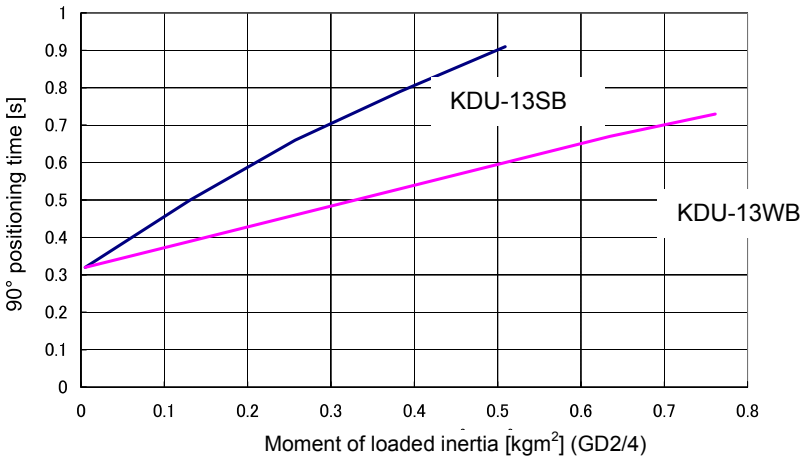
CAUTION

Accuracy cannot be guaranteed in environments subject to vibration and impact.
The resistance to vibration and impact in the specifications table are standard values for the vibration and impact that occur while transporting or mounting the motor. While transporting or mounting the motor, do not subject the motor to any vibration or impact. In order to use KDU Series motor with high accuracy, use it in an environment with no impact or vibration.

1-13 Allowable load inertia moment

The graph below shows the relationship between the KDU-13SB and KDU-13WB load inertia moment and the 90˚ positioning time. To select the load conditions, refer to the load inertia moment in the graph below.
For larger load inertia moments or shorter positioning times than in the graph below, contact us for more information. The values in the graph below are reference values.

- **Load inertia moment and 90˚ positioning time**



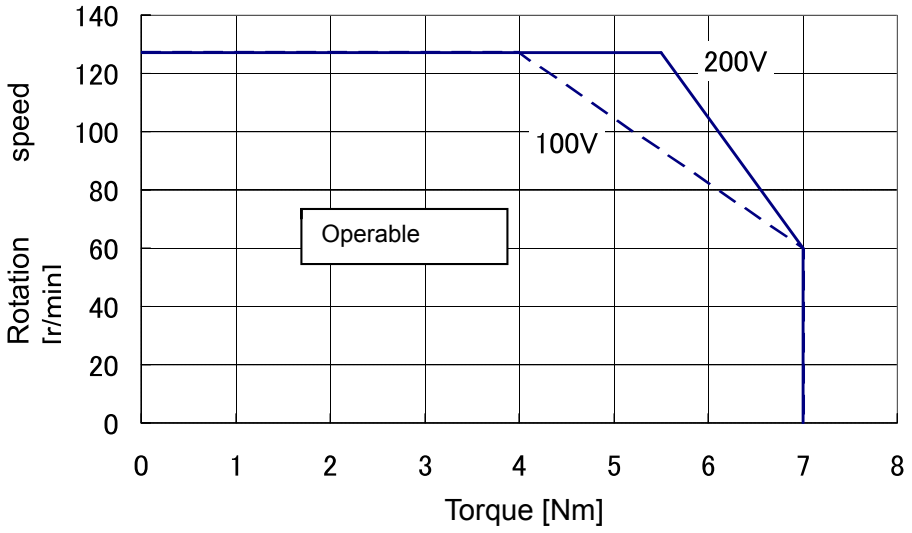
1-14 Operable range

The graph on the next page indicates the operable range when a KDU Series motor (combined with a HA-770 driver) is selected.

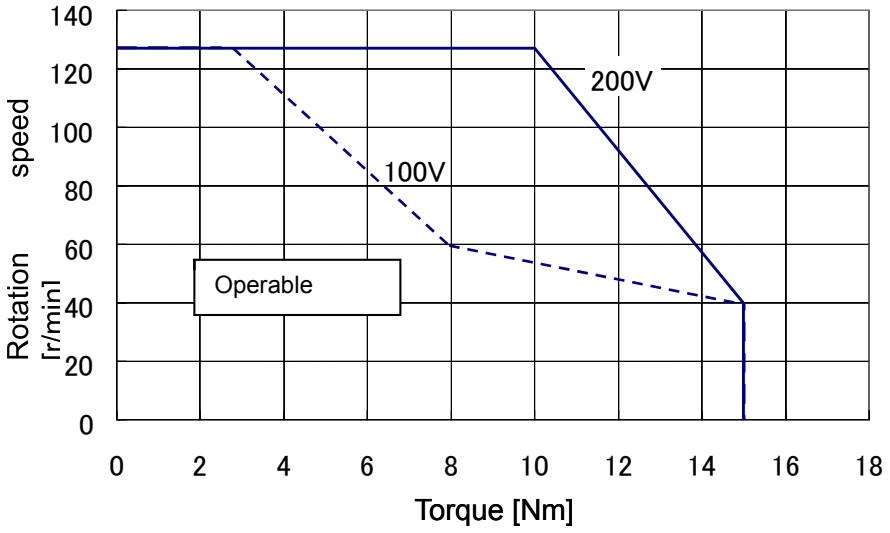
Operable range

For the maximum rotational speed and the maximum torque, the range in which the product can be operated in the instant are shown. For position indexing operations for normal acceleration and deceleration, use the motor within the operable range.

- **KDU-13SB-E10**



- **KDU-13WB-E10**



1-15 Cable specifications

The following tables show specifications of the motor and encoder cables of the KDU Series motors.

Motor drive cable

- **Pin layout**

Pin No.	Color	Signal name	Remarks
1	Red	U	Motor phase-U
2	White	V	Motor phase-V
3	Black	W	Motor phase-W
4	Green	**E**	**Ground**

- **Pin position**

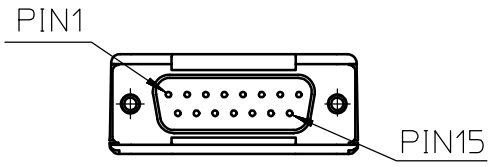
Connector used — Plug : 172167-1(AMP)
Pin : 170364-1
Connector used — Cap : 172159-1(AMP)
Socket : 170366-1

Encoder cable

- **Pin layout**

Pin No.	Signal name	Remarks
1	—	Cannot be connected
2	GND	Power input (GND)
3	—	Cannot be connected
4	Z-	Phase Z- output
5	B-	Phase B- output
6	A-	Phase A- output
7	+5V	Power input
8	+5V	Power input
9	GND	Power input (GND)
10	—	Cannot be connected
11	—	Cannot be connected
12	Z+	Phase Z+ output
13	B+	Phase B+ output
14	A+	Phase A+ output
15	—	Cannot be connected

- **Pin position**



Chapter 2

Installation

This chapter explains how to install the motor.

2-1 Receiving inspection

Check the following items after unpacking the package.

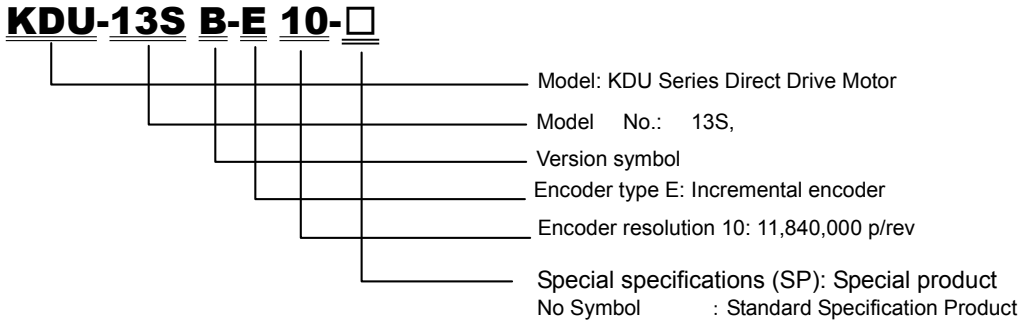
Check procedure

1. Check the items thoroughly for damage sustained during transportation.

If any item is damaged, immediately contact the dealer.

2. The nameplate is found on the side of the KDU Series motor. Check the model on the nameplate to confirm that it is indeed the model you have ordered.

If any item is wrong, immediately contact the dealer.
The model code indicates the following information:



Refer to the Chapter 1 [1-2 Model] (page 1) in this manual for details of the model codes.

3. The serial number of the KDU Series motor that should be combined with the HA-770 is written on the HA-770 driver nameplate.

Make sure your motor is combined with the correct driver.

The motor and driver are combined as a set.
The position correction data for the combination with the KDU Series motor is stored into memory in the HA-770 driver. The same serial number is written at [SER. No] on the motor and driver nameplates. The positional accuracy of the motor cannot be guaranteed for combinations of different numbers.

2-2 Notices on handling

Handle the KDU Series motor carefully by observing the notices specified below.

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

(1) Do not apply any excessive force or impact, especially to the output shaft of the KDU Series motor.

(2) Do not put the KDU Series motor on a table, shelf, etc., where the motor could easily fall.

(3) The allowable storage temperature is -10 to +60 ˚ C. Do not expose the motor 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 motor in a very humid place or in areas where there is a large temperature change between day and night.

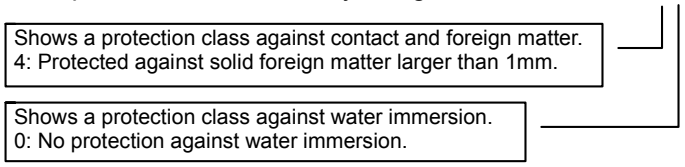
(5) Do not use or store the motor in locations subject to corrosive gases or dust particles.

2-3 Installation location and installation

Environmental conditions of installation location

The environmental conditions of the installation location for KDU Series motor must be as follows. Determine an appropriate installation location by observing these conditions without fail.

- **Operating temperature:** 10 to 30℃ Temperature change environment: less than ±3℃
  The temperature in the cabinet may be higher than the atmosphere depending on the power loss of housed devices and size of the cabinet. Consider the cabinet size, cooling system, and device locations so that the ambient temperature of the motor is kept 30℃ or below.
- **Operating humidity:** 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: In an environment with vibration, it may be impossible to achieve the stopping stability of ±1 pulse.
  Use the motor in an environment where vibration is not transmitted to it.
- Impact: Never subject the motor to impact.
- There must be no dirt, dust, condensation, metal powder, corrosive gas, water, water drops, oil mist, etc.
- **Protection class:** Standard products are structurally designed to meet the IP-40 requirements.



  However, rotating and sliding areas and connectors are not IP-40-compliant.
- Use the motor indoors or within an enclosure. Do not expose it to the sunlight.
- Altitude: lower than 1000m above sea level

Caution

Notices for maintaining accuracy

To maintain accuracy, observe the following notices when using the motor.

Use the product in an appropriate environment.

- The environmental conditions for our accuracy measurement are a temperature of 23±0.3℃ and relative humidity of 50%. When using the motor in a device that requires high accuracy positioning control, please take into account the stiffness of the mechanism for temperature change of up to ±3˚C, the coefficient of expansion for each part, external vibration, etc.

Periodically rotate the output shaft at least 90˚.

- In order to prevent uneven wear due to the cross roller bearing grease running out, for devices used in operation environments with fine operations, periodically rotate the output shaft at least 90˚ in order to maintain accuracy.

Mounting direction check

- The mounting condition for our accuracy measurement is to have the output shaft facing up.
  When using the motor with the output shaft not facing up, contact us for more information.

Accuracy cannot be guaranteed in environments subject to vibration and impact.

- The resistance to vibration and impact in the specifications table are standard values for the vibration and impact that occur while transporting or mounting the motor. While transporting or mounting the motor, do not subject the motor to any vibration or impact. In order to use the motor with high accuracy, use it in an environment with no impact or vibration.

Installation

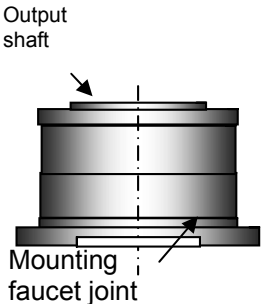
The KDU Series motor drives mechanical load system at high accuracy.
When installing the motor, pay attention to precision and do not tap the output section of KDU Series motor with a hammer, etc. Excessive impact may damage the encoder and make it impossible to guarantee the positional accuracy.

Installation procedure

1. Adequately center the KDU Series mounting spigot and the load position.

Note 1: Perform this alignment carefully, especially when a rigid coupling is used. Even slight misalignment may make it impossible to guarantee the positional accuracy of the KDU Series motor.

Note 2: Avoid all impact during mounting.



2. Fasten the KDU Series motor on the device with high-tension bolts.

Tighten them with a torque wrench to control the tightening torque.
Tightening torques are shown in the table below.

Item \ Model		KDU-13SB		KDU-13WB	
		Output shaft	Flange	Output shaft	Flange
Tightening torque	Screw, hole depth	6-M5 Depth 8	6-M5	6-M5 Depth 8	6-M5
	Nm	7.4	7.4	7.4	7.4
	kgfcm	75	75	75	75

3. Mount the encoder interpolator.

This unit has a function for converting encoder signals into high-resolution digital signals. Fasten securely. It is also necessary to always ground the interpolator and driver. If the grounding is incomplete, positioning may not be performed correctly due to noise.

4. For details on wiring, refer to the HA-770 driver manual, Chapter 6 "Driver Installation".

5. Motor cable and encoder cable

Do not pull the cables with a strong force. The connection points may be damaged. Install the cable with slack and do not to apply any tension to the motor. Provide a sufficient bending radius (R = 40 mm or more), especially when the cable flexes.

CAUTION

Do not disassemble/reassemble the motor.
The motor uses many precision parts. Drops in accuracy and performance due to disassembly and assembly by the customer are not covered by the warranty.

Chapter 3

Option

The following explains the options.

3-1 Extension cable

This extension cable connects the KDU Series direct drive motor and the driver. There are two types of relay cable: for motors and incremental encoder.

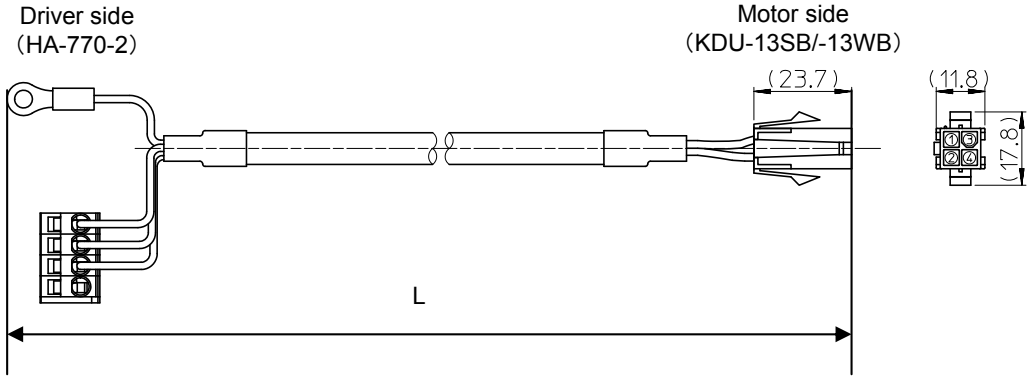
Extension cable model (** indicates the cable length of 3m or 5m.)

- **For motors**

EWA-M**-A04-WG04-01

Cable length

Symbol	L
03	3m
05	5m

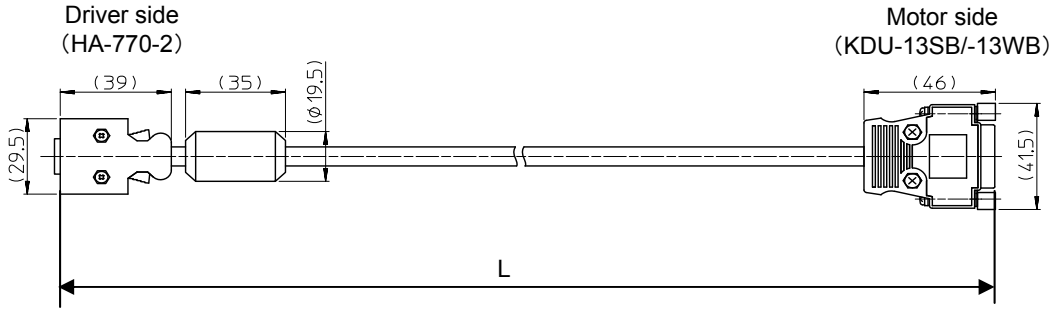


- **Incremental encoder only**

EWA - E** - OM15-3M14

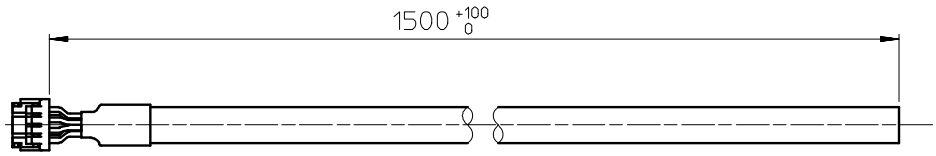
Cable length

Symbol	L
015	1.5m
035	3.5m



3-2 Communication cable

The RS-422/RS-485 cable is used to communicate with the HA-770 driver.
Cable model: HDM-RS422-HA770



- **Connector cable**

Pin No.	Color	Signal cable	
		RS422	RS485
1	Red	TxD	TRX
2	Red/White	NTXD	NTRX
3	Green	RXD	-
4	Green/White	NRXD	-
5	Yellow	RT1	RT1
6	Yellow/White	RT2	RT2
7	Black	GND	GND
8	Shield	FG	FG

3-3 Standard combination

The following are the standard combinations of KDU Series Direct Drive Motor, servo driver, and extension cable.

System model name	Max. Torque	Motor model name	Driver Model name	For incremental encoders Extension cable model name / Motor extension cable model name	Entire length of cable (excluding connector)
KDU-13SB-D3-☐	7.0Nm	KDU-13SB-E10	HA-770-2	EWA-E015-OM15-3M14	Encoder cable: 3 m
				EWA-M03-A04-WG04-01	Motor cable: 3.3 m
				EWA-E035-OM15-3M14	Encoder cable: 5m
				EWA-M05-A04-WG04-01	Motor cable: 5.3m
KDU-13WB-D3-☐	15.0Nm	KDU-13WB-E10		EWA-E015-OM15-3M14	Encoder cable: 3 m
				EWA-M03-A04-WG04-01	Motor cable: 3.3 m
				EWA-E035-OM15-3M14	Encoder cable: 5m
				EWA-M05-A04-WG04-01	Motor cable: 5.3m

Appendix

Appendix -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	Minute	Sec.
Factor	57.3	3.44×10^3	2.06×10^5

Unit	Degree	Minute	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/s^2

↓

Unit	deg/s^2	deg/min^2
Factor	57.3	$3.44x10^3$

Unit	deg/s^2	deg/min^2
Factor	0.01755	$2.93x10^{-4}$

↓

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	$7.06x10^{-3}$

↓

SI system	N·m

(10) Moment of inertia

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	$3.42x10^3$	8.85	$5.47x10^4$	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	$2.93x10^{-4}$	0.113	$1.829x10^{-5}$	$7.06x10^{-3}$

↓

SI system	$kg·m^2$

(11) Torsional spring constant, moment stiffness

SI 単位	N·m/rad

↓

Unit	kgf·m/rad	kgf·m/arc min	kgf·m/deg	lb·ft/deg	lb·in/deg
Factor	0.102	$2.97\ x10^{-5}$	$1.78x10^{-3}$	0.0129	0.1546

Unit	kgf·m/rad	kgf·m/arc min	kgf·m/deg	lb·ft/deg	lb·in/deg
Factor	9.81	$3.37\ x10^4$	562	77.6	6.47

↓

SI system	N·m/rad

Apx

Appendix

Appendix

-2 Inertia moment calculation

1. Formula of mass and inertia moment

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

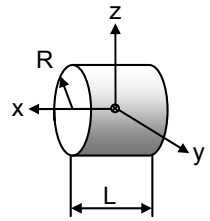
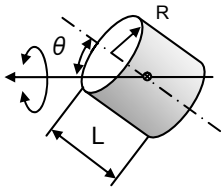
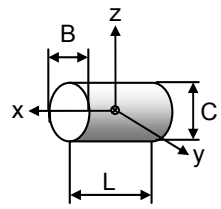
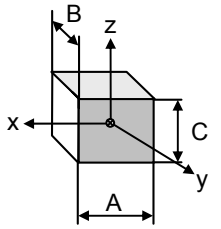
The following table includes formulas to calculate mass and moment of inertia.

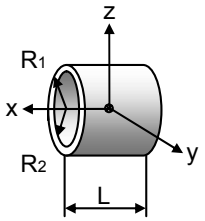
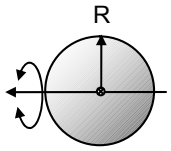
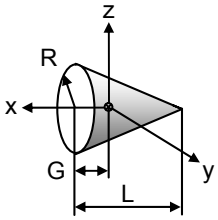
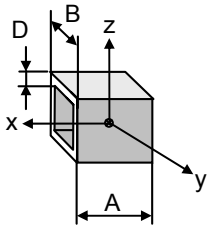
m : mass (kg), Ix, Iy, Iz: inertia moments which rotates around x-, y-, z-axes respectively (kg·m^2)

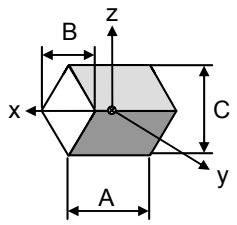
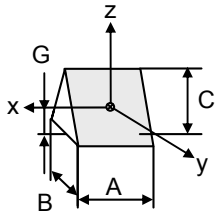
G : distance from end face of gravity center (m)

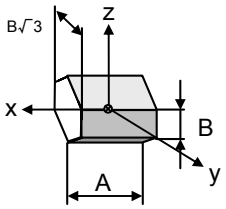
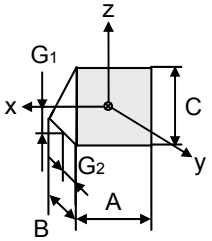
ρ : Specific gravity

Units Length: m, Mass: kg, inertia moment: kg·m^2

Object form	Mass, inertia, gravity center
Cylinder 	$m = \pi R^2 L \rho$ $Ix = \frac{1}{2} m R^2$ $Iy = \frac{1}{4} m \left(R^2 + \frac{L^2}{3} \right)$ $Iz = \frac{1}{4} m \left(R^2 + \frac{L^2}{3} \right)$
Slanted cylinder 	$m = \pi R^2 L \rho$ $I_\theta = \frac{1}{12} m \times \left\{ 3R^2 \left(1 + \cos^2\theta \right) + L^2 \sin^2\theta \right\}$
Ellipsoidal cylinder 	$m = \frac{1}{4} BC\ L\ \rho$ $Ix = \frac{1}{16} m \left(B^2 + C^2 \right)$ $Iy = \frac{1}{4} m \left(\frac{C^2}{4} + \frac{L^2}{3} \right)$ $Iz = \frac{1}{4} m \left(\frac{B^2}{4} + \frac{L^2}{3} \right)$
Rectangular pillar 	$m = A\,BC\rho$ $Ix = \frac{1}{12} m \left(B^2 + C^2 \right)$ $Iy = \frac{1}{12} m \left(C^2 + A^2 \right)$ $Iz = \frac{1}{12} m \left(A^2 + B^2 \right)$

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

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 gravities for the actual materials.

Material	Specific gravity
SUS304	7. 93
S45C	7. 86
SS400	7. 85
Cast iron	7. 19
Copper	8. 92
Brass	8. 50

Material	Specific gravity
Aluminum	2. 70
Duralumin	2. 80
Silicon	2. 30
Quartz glass	2. 20
Teflon	2. 20
Fluorocarbon resin	2. 20

Material	Specific gravity
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 moment of inertia when the rotary center is different from the gravity center.

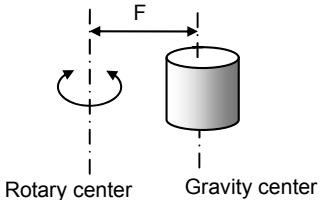
$$I = Ig + mF^2$$

I : Inertia moment when the gravity center axis does not match the rotational axis ($kg \cdot m^2$)

I_g : Inertia moment when the gravity center axis does not match the rotational axis ($kg \cdot m^2$)
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 linearly moving objects

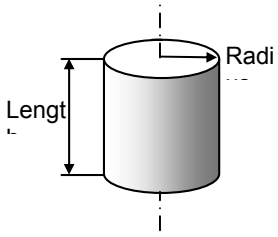
The inertia moment, converted to FHA-C actuator axis, of a linear motion object driven by a screw, etc., is calculated using the formula below:

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

I : Inertia moment of a linear motion object converted to actuator axis ($kg \cdot m^2$)
m : mass (kg)
P : Linear travel per actuator revolution (m/rev)

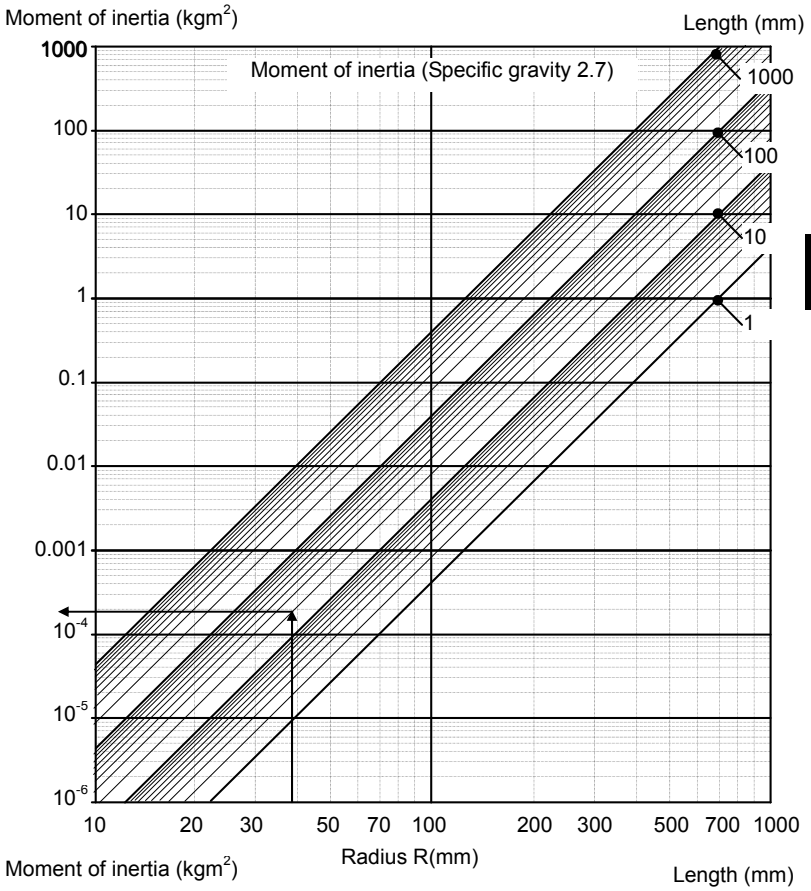
2. Inertia moment of cylinder

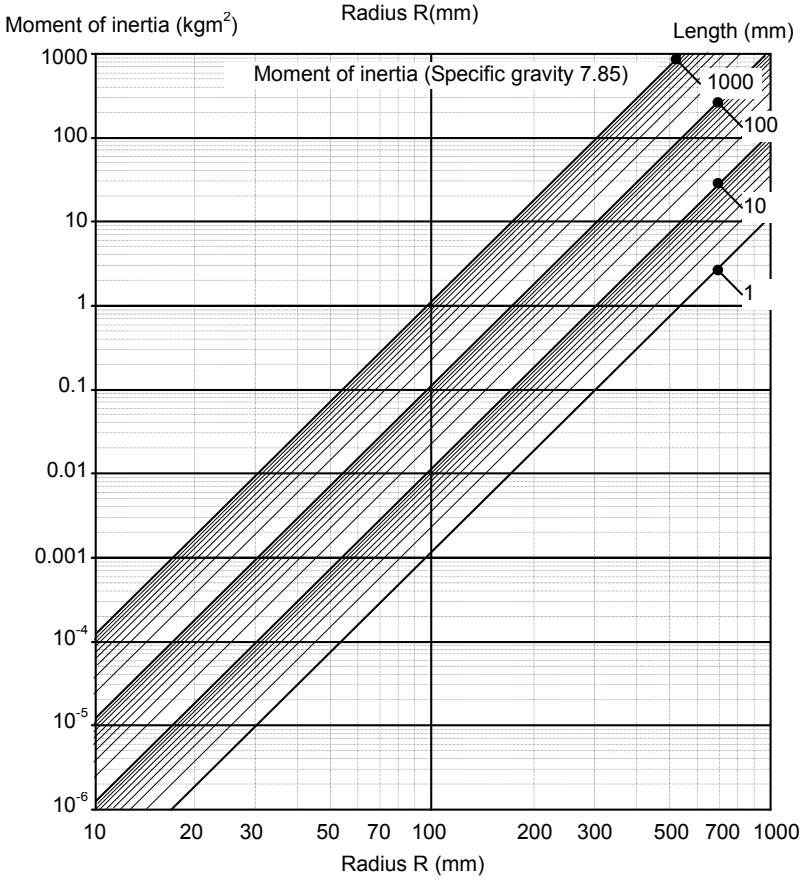
The moment of inertia of a cylinder may be obtained from the graphs to the right.



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: 100mm
Length: 7mm
Shape: Column
Because the outer diameter is 100mm, the radius is 50mm. Therefore, the above graph gives the inertia moment as follows:
Approximately 1.9 x 10^{-4}kg·m^2.
(Calculated value: 0.000186 kg·m^2)





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Warranty Period and Terms

The KDU series servo drivers are warranted as follows:

■ Warranty period

Under the condition that the actuator are handled, used and maintained properly followed each item of the documents and the manuals, all the HA-720 series drivers 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 HA-675 series drivers 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 the other than the KDU series actuator and the HA-720 servo driver.

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

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