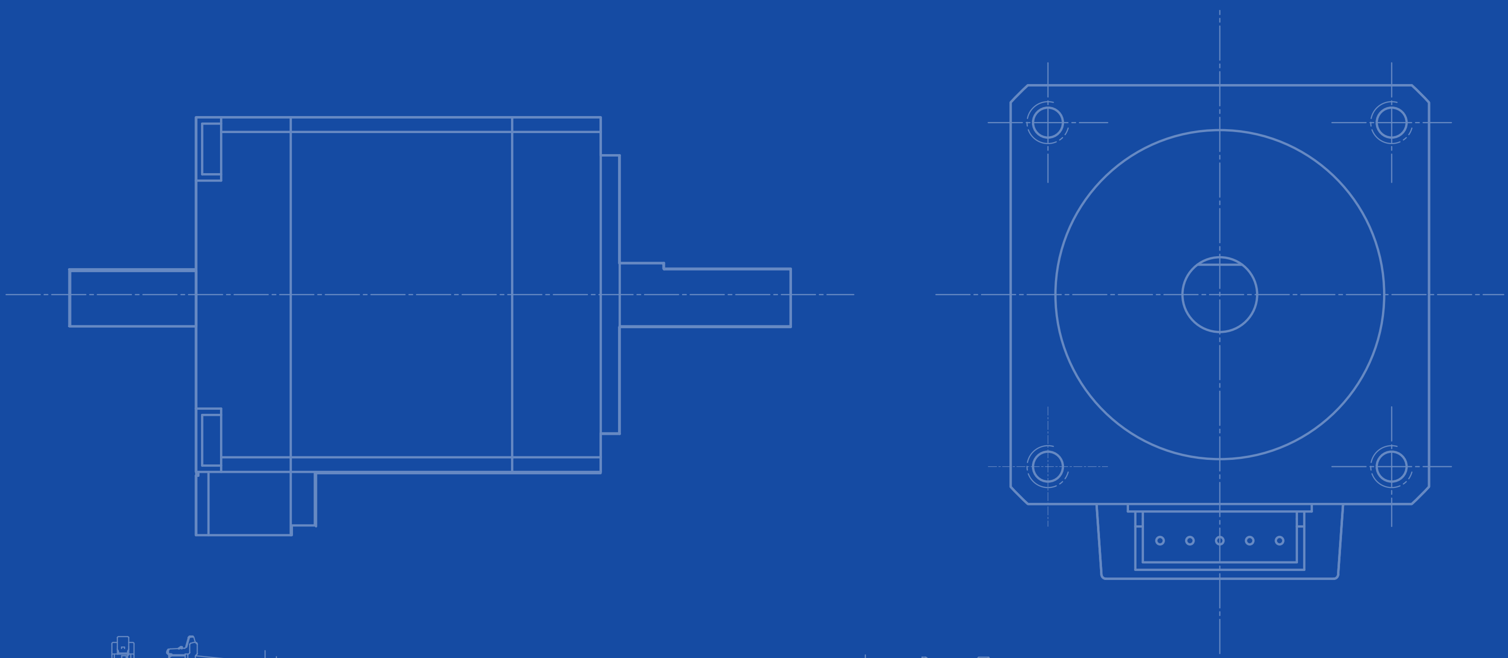
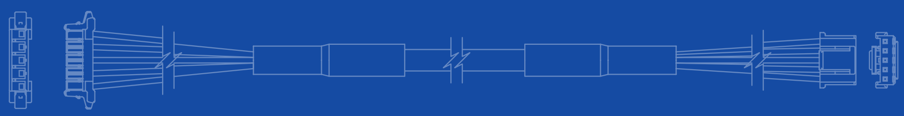
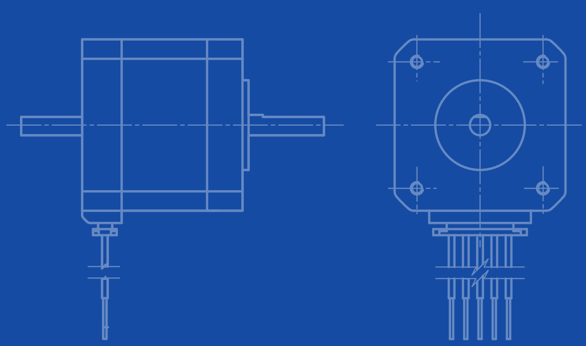
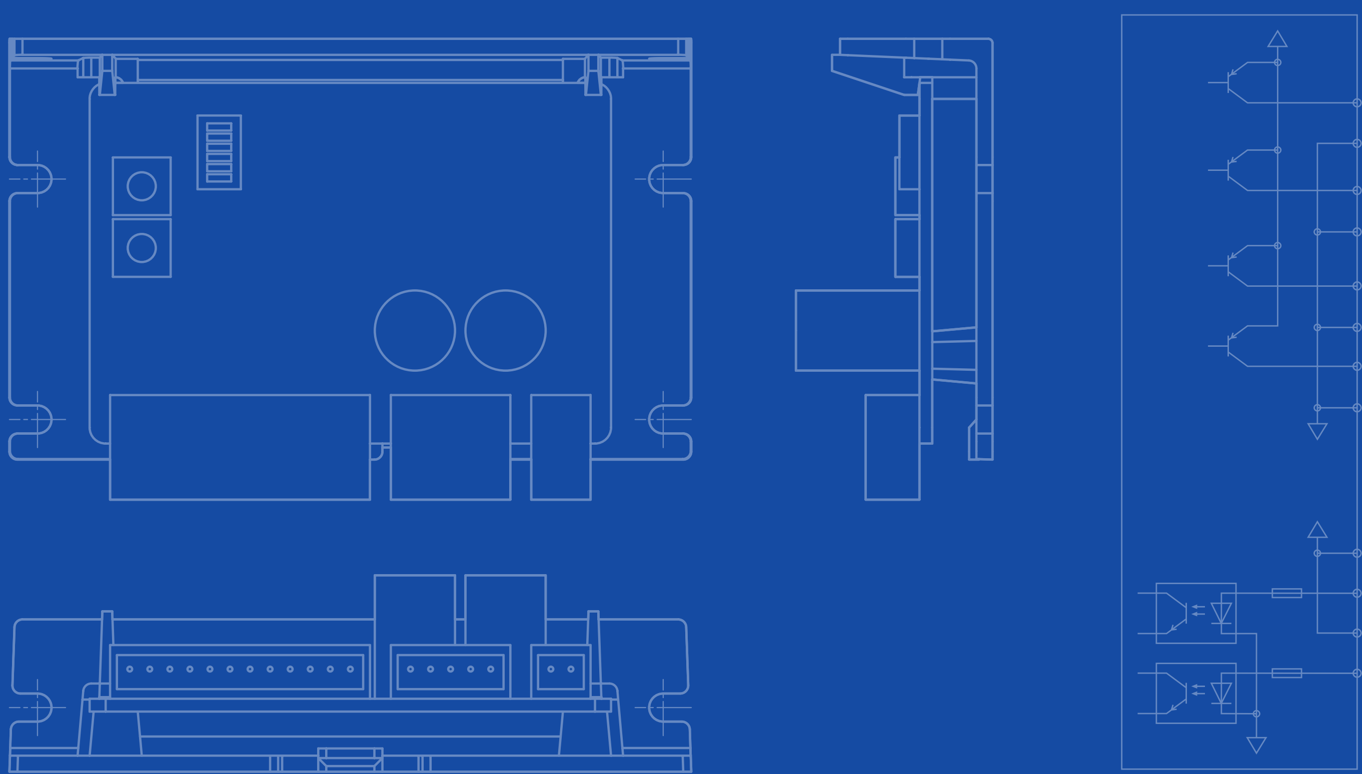
Orientalmotor







STEPPER MOTOR Handbook



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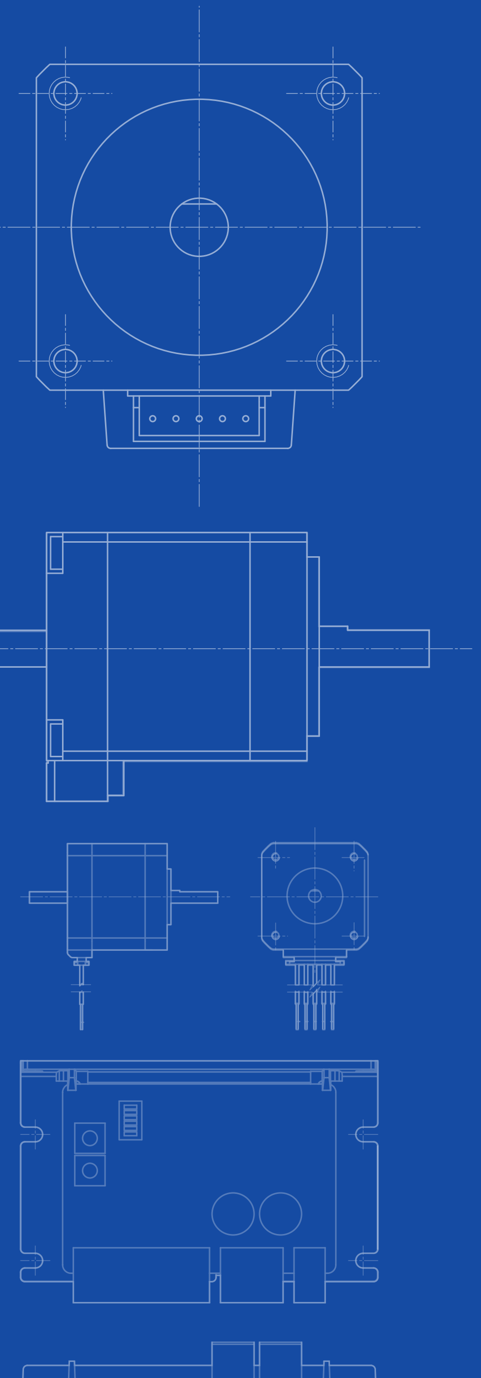
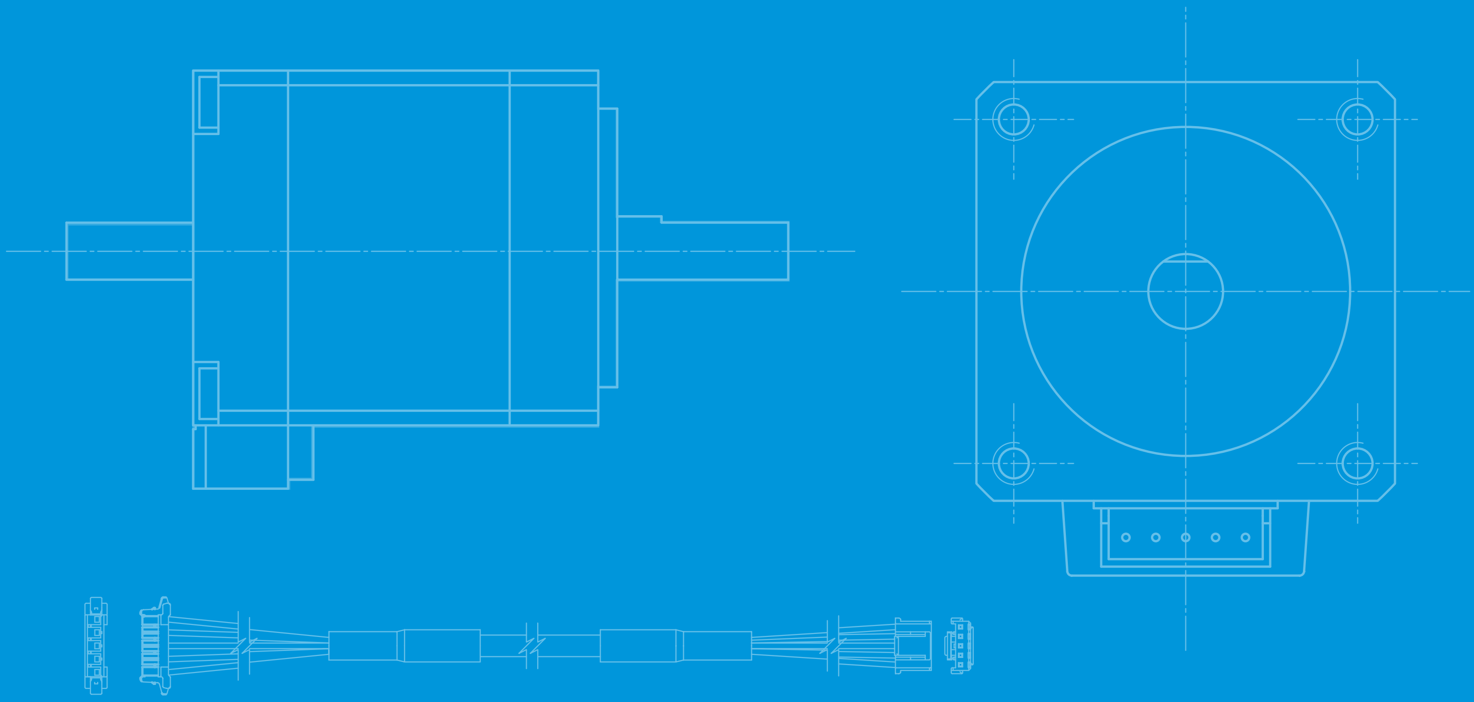
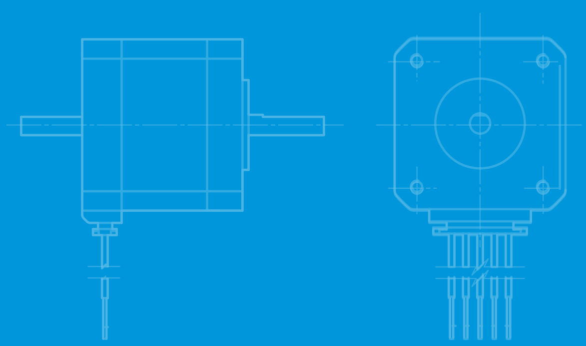
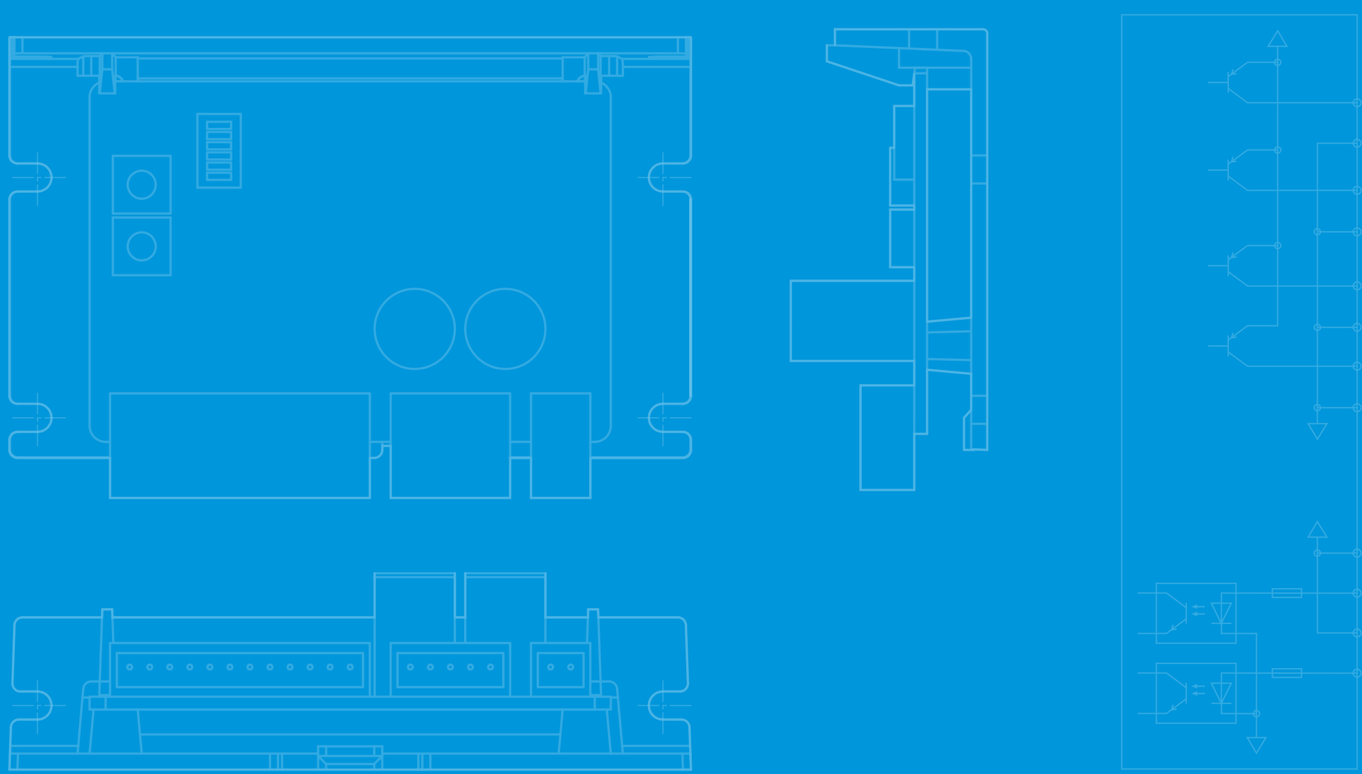






Product Line

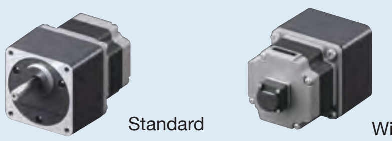


Stepper Motors

[2-Phase] **PKP** Series

High Torque | Low Vibration | Oriental Motor 2-Phase Stepper Motors PKP Search

● Bipolar (4 lead wires) and unipolar (5 or 6 lead wires) wiring types are available.

Motor Type	Motor Frame Size	Additional Function		
		Standard	With Encoder	With Electromagnetic Brake
Standard Type (Basic Step Angle: 1.8°/step) Flat Connector High Strength  Mini-Connector Type / Connector Type (Standard) / With Encoder / With Electromagnetic Brake	□ 20 mm	●	●	–
	□ 28 mm	●	●	●
	□ 35 mm	●	●	●
	□ 42 mm✻1	● (red)	●	●
	□ 56.4 mm	● (red)	●	●
	□ 60 mm✻	●	–	–
	□ 85 mm	●	–	–
High-Resolution Type (Basic Step Angle: 0.9°/step) Flat Connector High Strength  Mini-Connector Type / Connector Type (Standard) / With Encoder / With Electromagnetic Brake	□ 28 mm	●	●	–
	□ 42 mm	● (red)	●	●
	□ 56.4 mm	● (red)	●	●
Flat Type (Basic Step Angle: 0.018° to 1.8°/step)  Standard / With Harmonic Gearhead	□ 42 mm	●	–	–
	□ 60 mm	●	–	–
	□ 51 mm	With Harmonic Gearhead		
	□ 61 mm	With Harmonic Gearhead		
SH Geared Type (Basic Step Angle: 0.05° to 0.5°/step)  Standard / With Encoder	□ 28 mm	●	NEW	–
	□ 42 mm	●	●	–
	□ 60 mm	●	●	–
	□ 90 mm✻	●	–	–
CS Geared Type (Basic Step Angle: 0.09 to 0.36°/step)  Standard	□ 28 mm	●	–	–
	□ 42 mm	●	–	–
	□ 60 mm	●	–	–

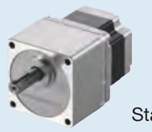
●(red): 2 types are available—the "Mini-Connector Type" and the "Connector Type."

✻ This is the conventional **PK** Series.

✻1 High torque, high efficiency types are available in the **PK** Series, and they contribute to reduction of power consumption and reduction of heat generation.

[5-Phase] **PKP** Series High Accuracy Low Vibration

Oriental Motor 5-phase Stepper Motors PKP Search

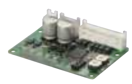
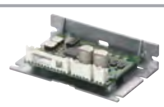
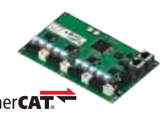
Motor Type	Motor Frame Size	Additional Function		
		Standard	With Encoder	With Electromagnetic Brake
Standard Type (Basic Step Angle: 0.72°/step) Flat Connector High Strength  Mini-Connector Type  Connector Type (Standard)  With Encoder	□20 mm*	●	●	–
	□28 mm	●	NEW	–
	□42 mm	● (red)	●	–
	□56.4 mm	●	●	–
	□60 mm	●	●	–
	□85 mm*	●	–	–
High-Resolution Type (Basic Step Angle: 0.36°/step)  Standard	□28 mm	●	NEW	–
	□42 mm	●	NEW	–
	□60 mm	●	NEW	–
TS Geared Type (Basic Step Angle: 0.024 to 0.2°/step)  Standard	□42 mm	●	–	–
	□60 mm	●	–	–

●(red): 2 types are available—the "Mini-Connector Type" and the "Connector Type."
* This is the conventional **PK** Series.

Stepper Motor Drivers

[2-Phase] [5-Phase] **CVD** Series Compact Low Vibration

Oriental Motor CVD Series Search
Oriental Motor CVD Series S Type Search

Bipolar Driver for 2-Phase Stepper Motors Driver for 5-Phase Stepper Motors **CVD** Series—Pulse Input Type	 Right Angle with Mounting Plate  With Mounting Plate  Without Mounting Plate
Bipolar Driver for 2-Phase Stepper Motors Driver for 5-Phase Stepper Motors **CVD** Series RS-485 Communication Type	 Right Angle with Mounting Plate  With Mounting Plate
Driver for 5-Phase Stepper Motors **CVD** Series **SC** Type	 Right Angle with Mounting Plate  With Mounting Plate
CVD Series Fully Closed-Loop Control Type NEW 	**CVD** Series Multi-axis Type EtherCAT-compatible NEW  EtherCAT

Electric Actuator

DRLⅡ Series Compact Electric Cylinders

This product features a stepper motor integrated with a ball screw to generate linear motion. The reduction of mechanical parts, such as couplings, reduces equipment size and improves performance with high precession positioning.

■Guide Type


DRLM20G

DRLM28G

DRLM42G

DRLM60G

Oriental Motor DRL II Series Search

	Frame Size Dimension [mm]	Ball Screw Product Line	Accuracy: Repetitive Positioning Accuracy [mm]	Accuracy: Lost Motion [mm]	Lead [mm]	Stroke [mm]	Speed [mm/s] (10 20 30 40 … 100 110 120)	Thrust [N] (50 100 150 200 250 300)	Transportable Mass [kg]: Horizontal	Transportable Mass [kg]: Vertical	Dynamic Permissible Moment [N·m]: M_P	M_Y	M_R
DRLM20G	□20	Precise	±0.003 [±0.01]*	0.02 max.	1	25	~20	~15	0.5	1	0.1	0.05	0.15
DRLM28G	□28	Rolled	±0.01	0.05 max.	1	30	~40*	~30	1	1.5	0.13	0.07	0.3
		Precision	±0.003 [±0.01]*	0.02 max.									
DRLM42G	□42	Rolled	±0.01	0.05 max.	2	40	~30*	~100	2	5	0.5	0.25	0.8
		Precision	±0.003 [±0.01]*	0.02 max.									
		Rolled	±0.01	0.05 max.	8	40	~120	~30	2	3			
DRLM60G	□60	Rolled	±0.01	0.05 max.	4	50	~40*	~300	3	15	0.6	0.35	2.2
		Precise	±0.003 [±0.01]*	0.02 max.									

*Specifications vary according to conditions. For details, check the specifications for each product.

■Type without a Guide


DRLM20

DRLM28

DRLM42

DRLM60

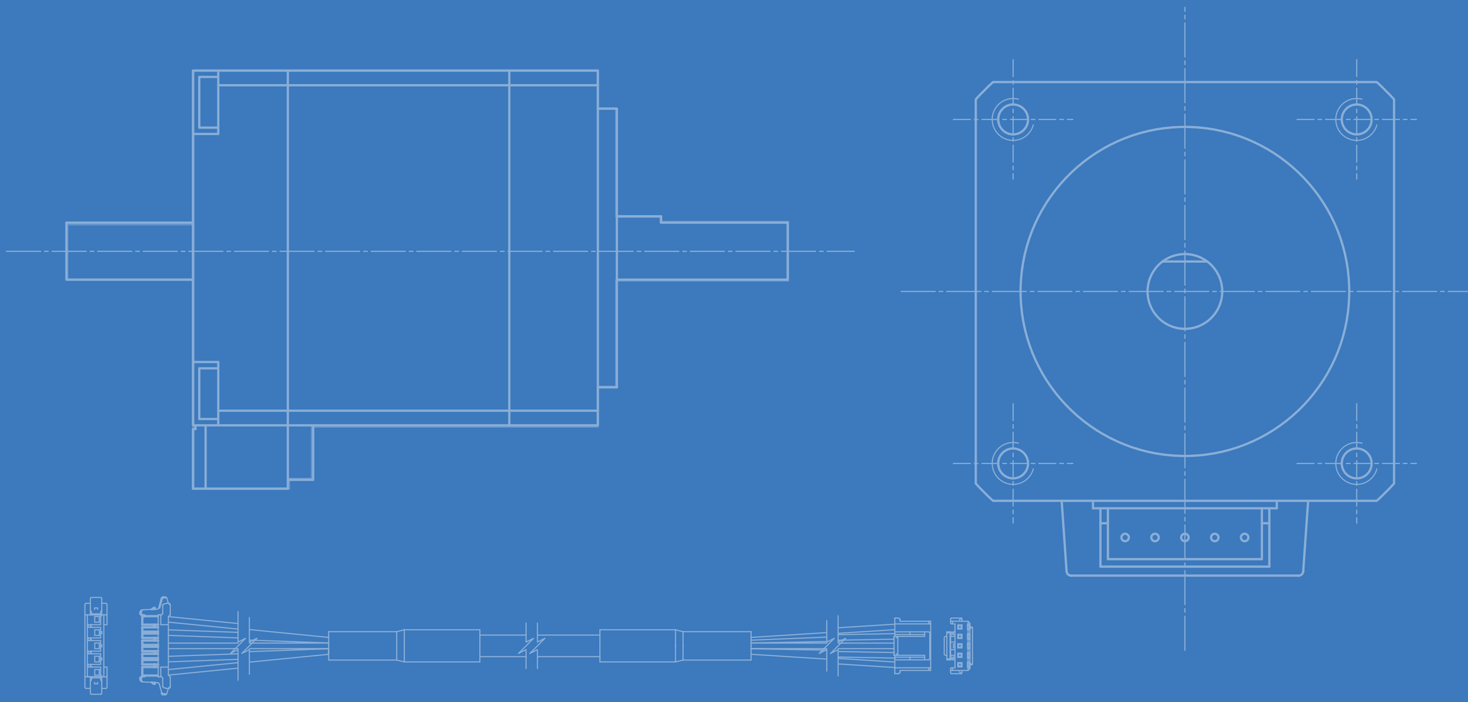
	Frame Size [mm]	Ball Screw Product Line	Accuracy: Repetitive Positioning Accuracy [mm]	Accuracy: Lost Motion [mm]	Lead [mm]	Stroke [mm]	Speed [mm/s] (10 20 30 40 … 100 110 120)	Thrust Force [N] (50 100 150 200 250 300)	Transportable Mass [kg]: Horizontal	Transportable Mass [kg]: Vertical
DRLM20	□20	Precision	±0.003	0.02 max.	1	25	~20	~15	–	1.5
DRLM28	□28	Rolled	±0.01	0.05 max.	1	30, 60	~40*	~30	–	3
		Precision	±0.003	0.02 max.						
DRLM42	□42	Rolled	±0.01	0.05 max.	2	40, 100	~30*	~100	–	10
		Precision	±0.003	0.02 max.						
		Rolled	±0.01	0.05 max.	8	40, 100	~120	~30	–	3
DRLM60	□60	Rolled	±0.01	0.05 max.	4	50, 100	~40*	~300	–	30
		Precision	±0.003	0.02 max.						

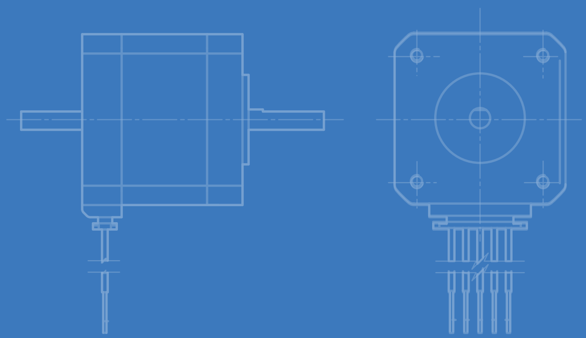
*Specifications vary according to conditions. For details, check the specifications for each product.

DH Series Hollow Rotary Actuators

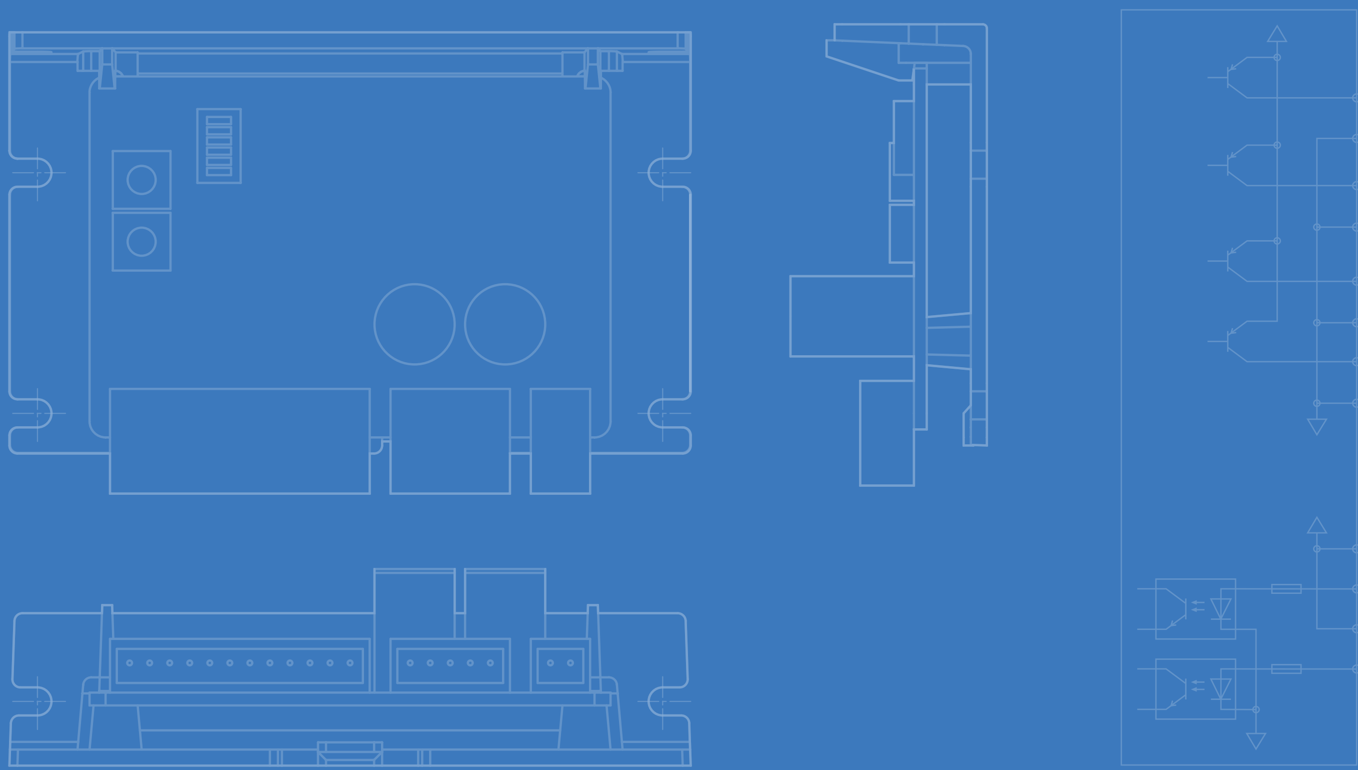
Oriental Motor DH Series Search

This actuator is a 5-phase stepper motor with a hollow flange. Air piping and electrical wiring can be passed through the hollow section, helping to make equipment simpler and more compact to save space.



Explanation of Motors



The Advantages of Using Oriental Motor Stepper Motors

PKP Series Product Line

Oriental Motor PKP Series/CVD Series Search

The **PKP** Series products are high-torque, low vibration stepper motors. A wide variety of products are available for selecting the optimal motor that meets your equipment design specifications.

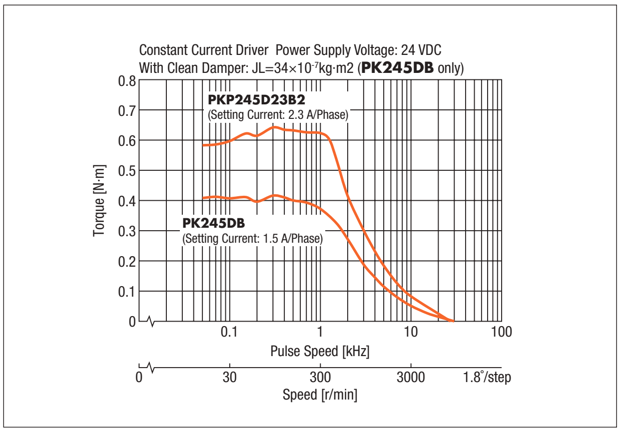
- Motor Frame Size: 20 mm to 85 mm
- Standard Type: 200 steps per revolution (Basic step angle: 1.8°/step)
- High-Resolution Type: Resolution of 400 steps per revolution (Basic step angle: 0.9°/step)
- Flat Type: Thinnest 2-phase stepper motor (Compared to other Oriental Motor products)
- **SH** Geared Type: High Torque, High Resolution
- Wiring Type: Bipolar (4 lead wires) Unipolar (5 or 6 lead wires)
- With Encoder
- With Electromagnetic Brake
- Motor Current Specifications: Supports wide range from low current to high current

What is the **PKP** Series?

Features

◆ Increased Torque Over the Entire Speed Range from Low to High

After revising the magnetic design and structure design of the **PKP** Series, it produces much more torque than standard **PK** Series motors of the same size. In addition, torque can be increased in the high-speed range by using high current motors.



High current is possible due to the revised motor winding design and the highly efficient design of the drive circuit that can be combined. Increased torque over the entire speed range from low to high is achieved.

Fig. 1 Comparison of Speed – Torque Characteristics of the Same Size Motors

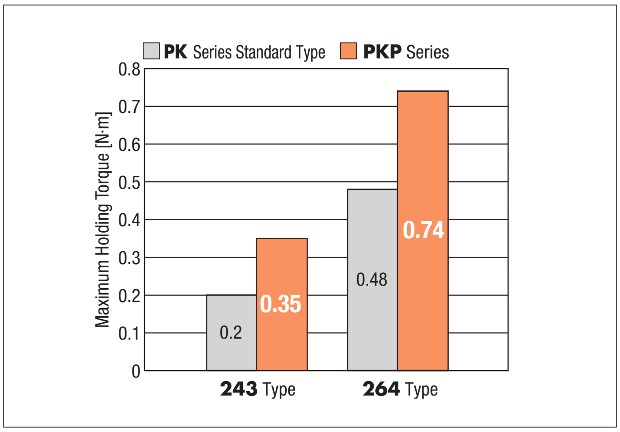


Fig. 2 Comparison of Maximum Holding Torque

◆ Conservation of Energy and Electrical Power

By lowering the operating current supplied to the motor, it is possible to achieve the same torque as conventional products, while reducing power consumption and CO2 emissions.

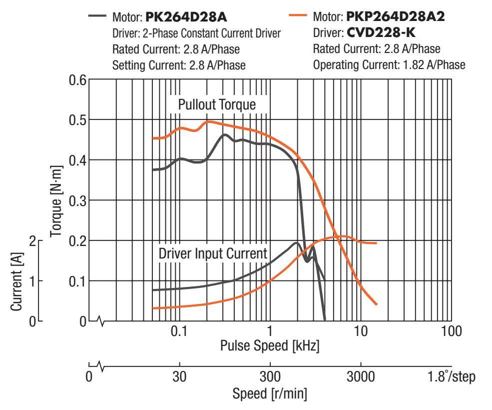


Fig. 3 Reduced Operating Current with the **PKP** Series

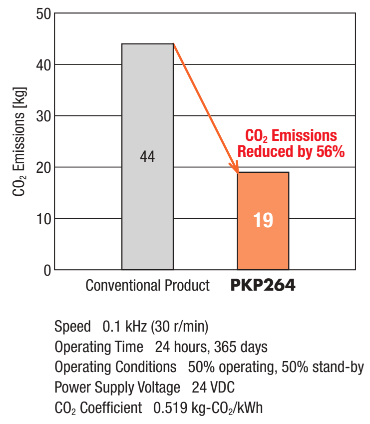


Fig. 4 Reduced Power Consumption and CO2 Emissions

PKP Series Mini-Connector Type

The **PKP** Series Mini-Connector type has the following product features.

- Easy placement of lead wiring thanks to the use of connectors
- The design is optimized for microstep drive
- Improved permissible load*

✻ For information about permissible load, refer to "Radial and Axial Loads".

As equipment continues to become smaller and more complex, this series retains the compact motor size of previous products, while also offering simple lead wiring placement. These motors match well with the microstep drive that has become mainstream in recent years, as equipment with increased precision and lower vibration is demanded more frequently. Not only is permissible load improved, but tension is easier to adjust with a the belt and pulley mechanism.

PK Series　　**PKP** Series Connector Type　　**PKP** Series Mini-Connector Type

Fig. 5: Transition from Lead Wire Type to Connector Type

Advantages of the Connector Type

In the past, stepper motors were usually lead wire type. When wiring a motor and driver, relay terminal blocks and connectors were used, and it was usually necessary to customize each one to match the equipment. This customization created higher costs and delivery times for equipment production due to the increased work time to process the individual lead wires, and the need for specialized parts and overall increase in parts count. This made the wiring and the motor itself special orders.

With the connector type, as long as connection cables have been procured, the motor and driver can be connected directly (Fig. 6). This is superior is terms of connection, parts purchasing, replacement work and management of replacement parts (Fig. 7).

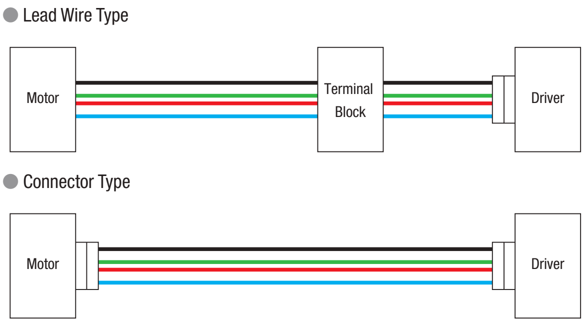


Fig. 6 **Motor and Driver Connection**

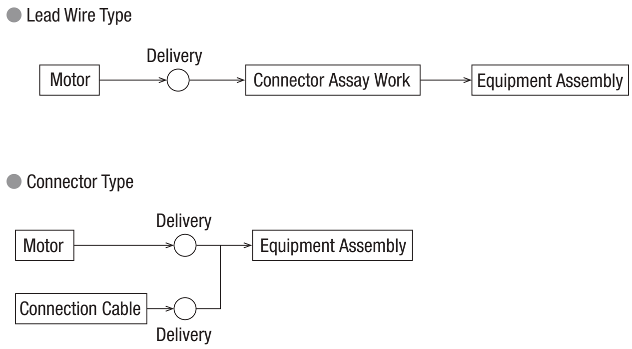


Fig. 7 **Purchasing Motor and Connection Cables**

Structure and Characteristics of the Mini-Connector Type

In recent years, as the applications for stepper motors have expanded, the demand for higher torque in the high-speed rotation range has also increased, which means that connectors that can handle higher motor current are needed. The mini-connector type was developed jointly with a connector manufacturer to achieve both a smaller connector size combined with high current capability.

Based on the structure of conventional products, motors with the new connectors incorporated will have a longer overall length. By using thin-wall molding of the bracket to maintain space for the coil windings and combining it with a lower profile connector, an overall length of the motor similar to the conventional product has been achieved (Fig. 9). The connection method used between the circuit board and the windings has been improved to accommodate higher currents.

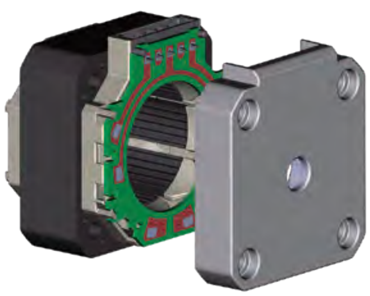


Fig. 8 **Connector Structure**

Fig. 9 **Overall Motor Length**

Microstep Drive Optimized Design

The **PKP** Series Mini-Connector type is designed and magnetically optimized for microstep drive. Compared to conventional products, torque linearity with respect to motor input current is improved. As a result, the torque increase was achieved over the entire speed range as shown in Fig. 11. Fig. 11 shows the speed – torque characteristics when combined with a **CVD** Series driver that performs microstep driving over the full speed range.

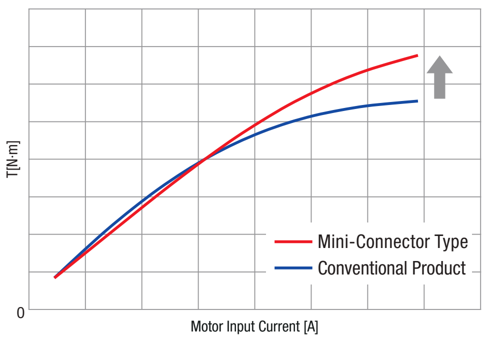


Fig. 10 Input Current–1-Phase Excitation Torque Characteristic Comparison

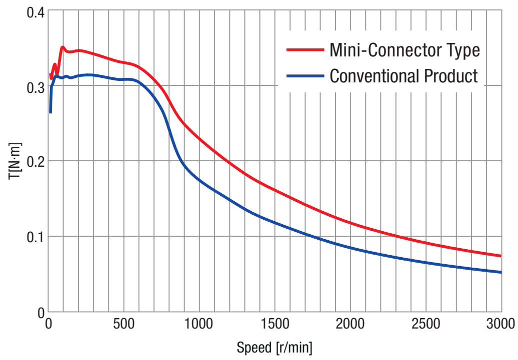


Fig. 11 Speed – Torque Characteristics (Pullout Torque) Comparison

Variations in Pullout Torque by Drive System

Here, half-step drive (0.9° step drive using microstep) is used as an example. In half-step drive, 1-phase excitation and 2-phase excitation are repeated, and the torque is equalized during rotation by reducing the amount of torque saturation during one-phase excitation, which leads to a decrease in the torque.

Stepper motors rotate by switching the winding excitation. The step movement and torque generated by the drive system can be explained using the angle – torque characteristics (θ– T characteristics).

2-phase stepper motors are generally driven using 2-phase excitation. The θ– T characteristics for 2-phase excitation are shown in Fig. 12. The maximum value of this characteristic is called the maximum holding torque. Current flow in Phase A and Phase B is called AB, while current flow in Phase A, is called A. If the excitation is switched to AB during AB excitation, the rotor moves as if it is pulled into the stabilization point of the excited phase. Switching the excitation shifts the stabilization point by 1.8°. This drive is called full step drive, and by repeating this operation, the rotor rotates continuously. When a load is applied, the intersection of the load torque and the θ– T characteristic is the operating point. It can withstand load torque up to the intersection point of the AB and AB θ– T characteristics. This intersection point is the maximum torque that can be generated during rotation and is called the pullout torque. The pullout torque for 2-phase motor during full step drive is approximately 70% of the maximum holding torque.

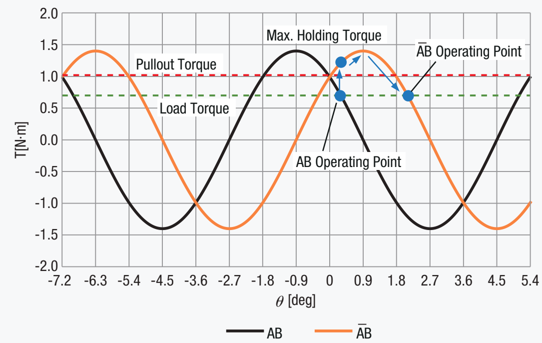


Fig. 12 2-Phase Excitation (Full Step Drive) θ–T Characteristics

1–2 phase excitation with alternating 1-phase and 2-phase excitation is called half-step drive, and rotates in 0.9° increments (expressed as 0.9°/step). The θ– T characteristics for this are shown in Fig. 13. The pullout torque in half-step drive is the maximum holding torque for 1-phase excitation.

Based on the above, it can be seen that full-step and half-step drives have equal pullout torque.

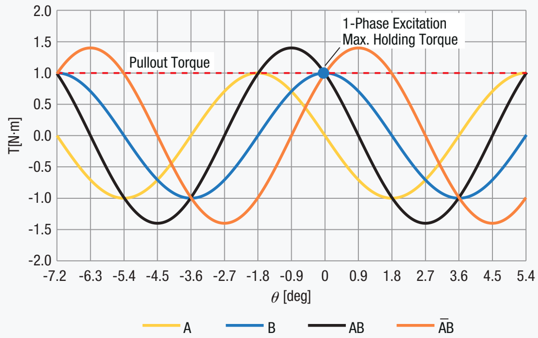


Fig. 13 1-2-Phase Excitation (Half Step Drive) θ–T Characteristics

The input power of the motor is determined by the temperature rise due to winding losses (copper loss). Since copper loss is proportional to the square of the current, the current for 1-phase excitation can be increased by a factor of √2 times so that the copper loss for 2-phase and 1-phase excitation is equal. Fig. 14 shows the θ– T characteristics when the current for 1-phase excitation is multiplied by √2. Driving in this manner results in higher pullout torque.

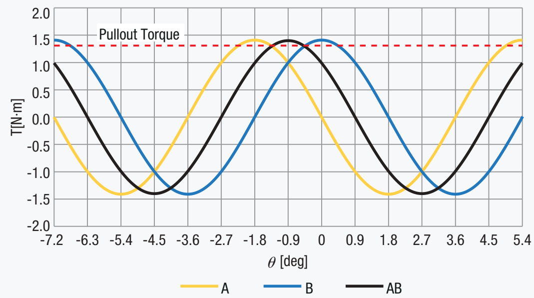


Fig. 14 Microstep (0.9°/step) Drive θ–T Characteristics

Furthermore, microstep drive is a type of drive with higher resolution (finer step angle). By providing an intermediate level at the current switching point, the step angle is subdivided into finer gradations while changing the current value.

Fig. 15 shows the θ–T characteristics when the step angle is subdivided into 0.45° units. As the resolution is increased, the pullout torque increases along with the resolution, approaching the maximum holding torque for 2-phase excitation. Because the current approaches a sine wave, it is sometimes called a sine wave drive.

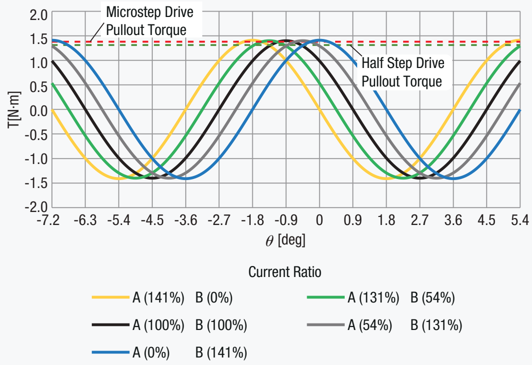


Fig. 15 Microstep (0.45°/step) Drive θ–T Characteristics

Improving Torque Characteristics

In principle, torque is proportional to the motor's input current and is expressed by Formula (1).

$$T = k_t \cdot I \quad \cdots\cdots (1)$$

T : Torque [N·m]
I : Motor Input Current [A]
k_t : Constant

In reality, however, as shown in Fig. 16, current and torque do not have a proportional relationship, and there is a tendency for torque to saturate. This is due to the magnetic properties of the magnetic steel sheets used in the stator and rotor cores. As a result, when the current in the 1-phase excitation state is increased for microstep drive, the torque of the 1-phase excitation is lower than that of the 2-phase excitation, and therefore, the torque is not actually √2 times higher even if the current is √2 times higher.

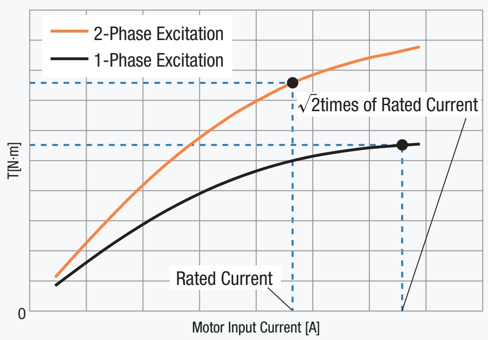


Fig. 16 Input Current – Torque

Based on this, in conventional products, the torque saturation of the 1-phase excitation is higher than the 2-phase excitation, and the torque of the 1-phase excitation is lower than the torque of the 2-phase excitation. Fig. 17 shows the θ–T characteristics considering torque saturation. The pullout torque is the maximum holding torque for 1-phase excitation.

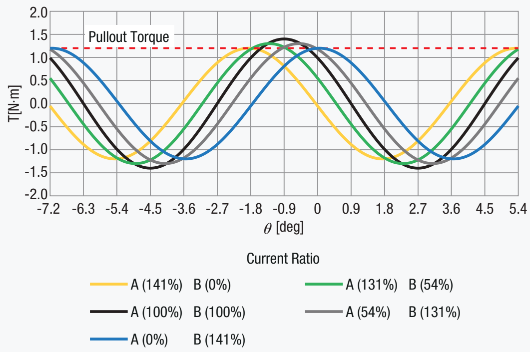


Fig. 17 1-Phase Excitation Torque Saturation θ–T Characteristics

As described in "Microstep Drive Optimized Design", the **PKP** Series Mini-Connector type has higher torque for the 1-phase excitation. Therefore, it has excellent speed–torque characteristics even when microstep driving is performed

Reduction of Vibration Due to Resonance

In general, as torque fluctuation increases, stepper motors tend to vibrate more. Vibration can cause missteps and noise. In principle, the microstep drive has equally spaced θ-T intervals for each excitation state. The interval between the stabilization points is the step angle. Because the microstep drive changes the current in phase A and phase B gradually, the stabilization point is determined by the balance between the torque of phase A and phase B. In conventional products, due to magnetic saturation, the combined torque of phases A and B does not follow the principle, and the spacing of the stability points is not equally spaced (Fig. 18).

Differences in the interval of the stabilization points means that the traveling speed of the stabilization points fluctuates. When the stabilization point traveling speed fluctuates, torque fluctuation occurs, and when the frequency of the torque fluctuation matches the natural frequency of the motor, the shaft speed fluctuation increases rapidly. This phenomenon is called resonance. Fig. 19 shows the vibration characteristics of the conventional product and the mini-connector type. Large vibration around 80 r/min is due to resonance. The mini-connector type has improved linearity of the current–torque characteristic, resulting in reduced torque fluctuation and reduced vibration.

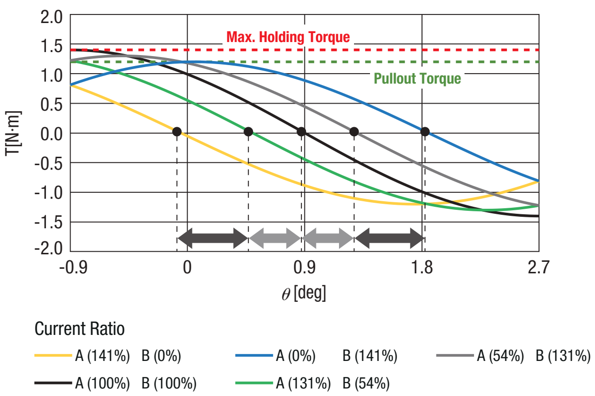


Fig. 18 Stabilization Point Interval When Torque Saturation is High

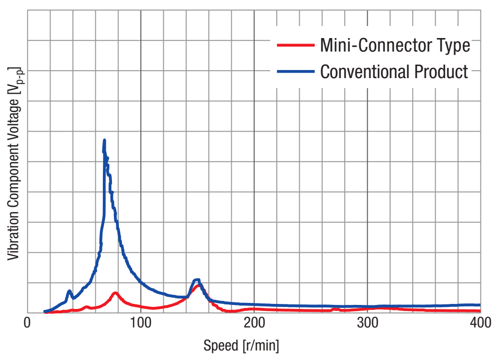


Fig. 19 Vibration Characteristics Comparison

Improved Output Shaft Permissible Load

The **PKP** Series Mini-Connector specification have a higher permissible radial load than conventional products.

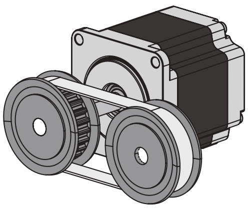
Equipment can have a higher safety factor on the belt and pulleys, which has the advantage of making tension adjustment easier.

Table 1 Comparison of Mini-Connector Type and Conventional Product (for 2-phase)

Type		Mini-Connector Type 		Conventional Product 
Permissible Radial Load (Max. Value)	□42 mm	85 N	63% Increase	52 N
	□56.4 mm	270 N	68% Increase	160 N
Permissible Axial Load	□42 mm	15 N	50% Increase	10 N
	□56.4 mm	30 N		20 N

◇Applications

Belt and Pulley Mechanism



◇Advantages

· The components for supporting the radial load on the shaft are no longer needed, with the result that the equipment can be more compact than before.

· Because the belt tension safety factor is higher, adjustment of the belt tension is easier.

Technology to Support Increased Permissible Loads

In the Mini-Connector type, the shaft diameter of the ball bearing component is enlarged to increase the permissible radial load, and a ball bearing with a larger basic dynamic rated load is used to improve the permissible axial load. The shaft fastener has the same output shaft diameter as the conventional product for compatibility with conventional products.

However, simply increasing the shaft diameter will reduce the volume of the rotor's permanent magnet, resulting in lower torque. In the Mini-Connector type, the magnetic design is based on the assumption of a larger shaft diameter.

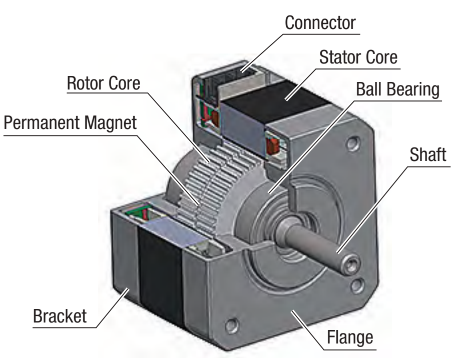


Fig. 1 Motor Structure

What are Radial Load and Axial Load

Radial Load

This is the load applied perpendicular to the output shaft. The maximum radial load that can be applied to the output shaft is called the permissible radial load, and this depends on the type of motor and the distance from the shaft end. This includes the tension in the belt drive.

Axial Load

This is the load applied to the output shaft in the axial direction. The maximum axial load that can be applied to the output shaft is called the permissible axial load, and this depends on the type of motor.

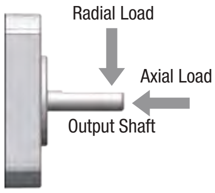


Fig. 2 Radial Load and Axial Load

Exceeding the permissible radial load or permissible axial load may cause bearing fatigue wear inside the motor, affecting its service life and possibly resulting in damage.

Calculating Radial Load Using a Conveyor as an Example

Radial load (W) is calculated using the formula below:

Radial Load $$W = \frac{K \times T \times f}{\gamma}$$

W : Radial load [N]
K : Load coefficient by drive method
T : Transmission power at gear head output shaft [N·m]
f : Service factor
γ : Effective radius of gear, pulley, etc. [m]

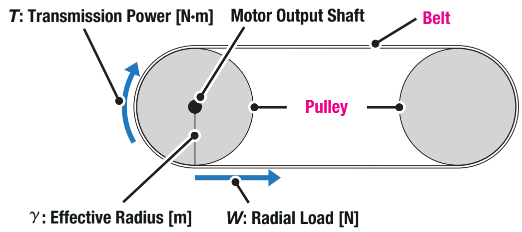


Fig. 3 Radial Load of Conveyor

Table 2 Load Coefficient (K) by Drive Method

Drive Method	K
Chain/Toothed Belt	1
Gear	1.25
V Belt	1.5
Flat Belt	2.5

Table 3 Service Factor (f)

Load Type	Example	Factor f
Uniform Load	• Unidirectional continuous operation • For driving belt conveyors and film reels that are subject to minimal load fluctuation	1.0
Slight Impact	• Frequent starting and stopping • Cam drive and inertial load positioning control via stepper motor	1.5
Medium Impact	• Frequent instantaneous bi-directional operation, starting and stopping of reversible motors • Frequent instantaneous stopping by brake pack of AC motors • Frequent instantaneous starting and stopping of brushless motors and servo motors	2.0

Products Optimized for Axial Loads and Radial Loads

Products other than the standard type are available to responding to more in-depth issues in making equipment smaller and overall space-saving. Geared type and **DH** Series equipment contribute to the simplification of equipment structures.

Products Optimized for Axial Loads

The hollow rotary actuator **DH** Series allows the load to be directly installed on the flange, contributing to a reduction in the number of moving peripheral parts. Also, the hollow space can be utilized for wiring.

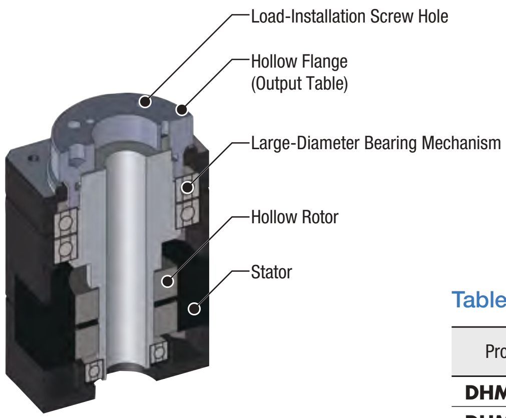


Fig. 4 **DH** Series Structure

Table 4 **DH** Series Specification

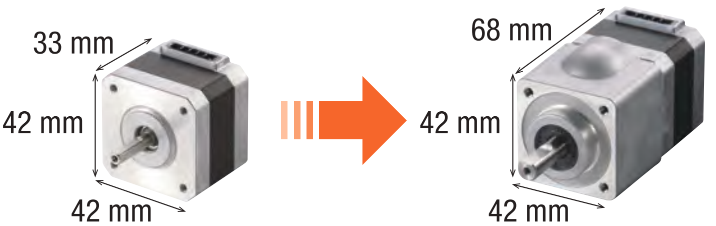
Product Name	Frame Size	Permissible Axial Load	Diameter of Hollow Section	Mass
DHM28PAK2	28 mm	40 N	ϕ5.2 mm	0.17 kg
DHM42PAK	42 mm	150 N	ϕ10 mm	0.47 kg

Products Optimized for Radial Loads

The **PKP** Series offers a variety of geared motors. The use of geared motors allows for large radial loads and contributes to reducing the size of the mechanism.

◆ Achieves Increased Torque with the Same Motor Frame Size

Switching to a geared type motor increases torque without changing the motor frame size. This is effective when installation is not possible because the motor installation space is limited.



Standard Type	Motor Type	**CS** Geared Type
PKP243D15A2	Product Name	**PKP243D15A2-CS20**
0.35 N·m	Max. Holding Torque	2 N·m
35 N	Radial Load*	59 N

✻ Value when distance from shaft end is 0 mm

Fig. 5 Comparison of Standard Type and **CS** Geared Type

◆ Geared Motors Optimized for High Radial Loads

CS Geared

TS Geared

Use of High-Resolution Type

Resolution is Doubled (Compared to Standard Type)

The number of rotor teeth has doubled to 100, compared to 50 with the standard type. As a result, the basic step angle is 0.9°/step, half of normal.

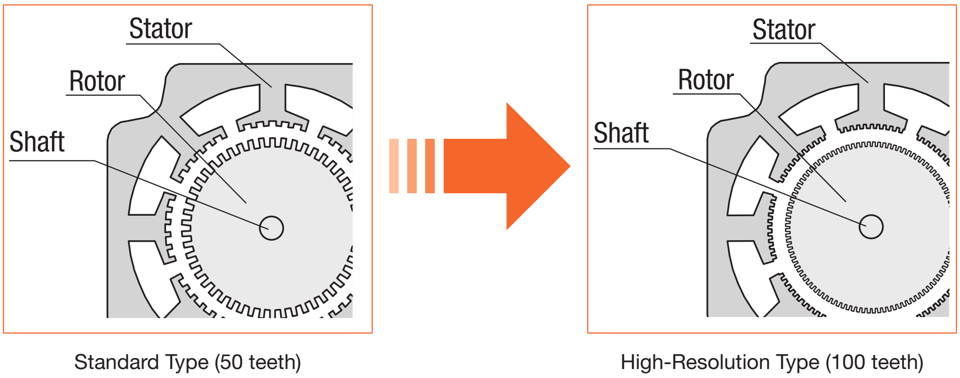


Fig. 1 Difference Between High-Resolution Type and Standard Type

◆ Avoidance of Resonance Regions

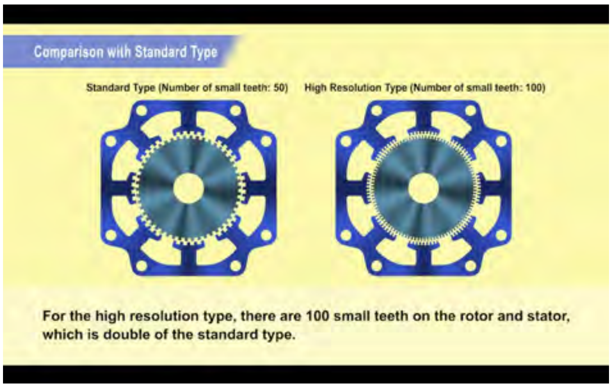
If the pulse speed is within a resonance region, vibration may increase.
Resonance regions can be avoided by switching to a high-resolution type.

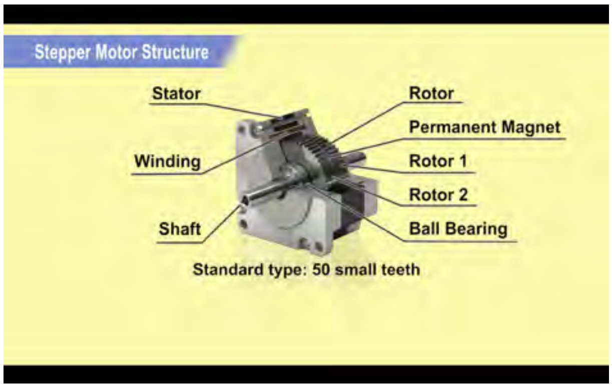
◆ Improved Stopping Accuracy

The displacement angle for the frictional load applied to the motor is decreased. As a result, stopping accuracy is improved.

◆ Reference Video

Videos showing the structure and benefits are available in the Oriental Motor video library.
https://www.youtube.com/watch?v=yT18jMiGKZc





Explanation of Motors

Improved Stopping Accuracy

Stopping Accuracy

Positioning accuracy of stepper motors is related to the stop position accuracy and displacement angle due to load. Positioning accuracy is the combination of both of these.

[Positioning accuracy] = [Stop position accuracy] + [Displacement angle due to load]

◆ Stop Position Accuracy

Indicates the positioning accuracy of the motor alone. Mainly, as the number of teeth increases, the error decreases. It may also vary due to the effect of the drive circuit.

◆ Displacement Angles Due to Load

If a frictional load or external force is applied to a stepper motor when it has stopped, it will stop offset from the theoretical stopping position in proportion to the load torque.

Stop Position Accuracy Measurement Method

The figure below shows the configuration for Oriental Motor's measurement of stop position accuracy.

A computer is used to send commands to the pulse generator to determine the theoretical stopping position, and an encoder counter is used to measure the actual stopping position to determine the stop position accuracy.

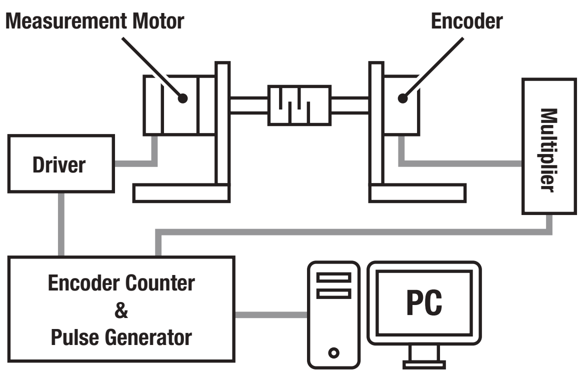


Fig. 2 Stop Position Accuracy Measurement System

Factors in Stop Position Accuracy

There are two main factors that contribute to stop position accuracy.

One is the imbalance of torque in each phase due to variations in the motor's windings. Stepper motors are controlled so that the same current flows for each phase, but there can be a slight deviations. As the current changes, the generated torque also changes, which also affects the stopping position.

In addition, slight dimensional variations in the small teeth located on the rotor and stator also affect the stop position accuracy.

These electrical factors and mechanical factors are the cause of deviations in stop position accuracy.

① Imbalance of torque in each phase due to variations in motor windings

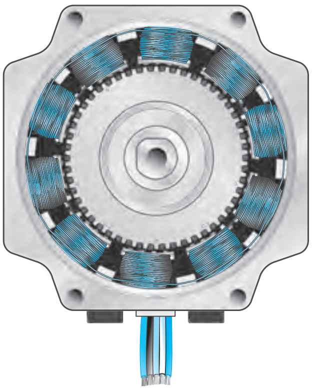


Fig. 3 Structure of 5-Phase Stepper Motor (Cross Section)

② Misalignment of the stator's magnetic poles and the small teeth on the rotor due to mechanical precision

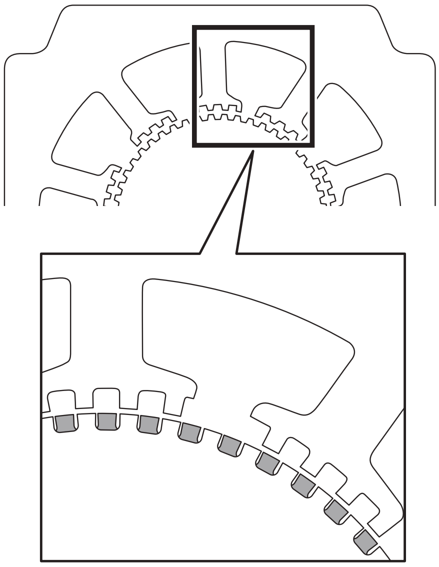


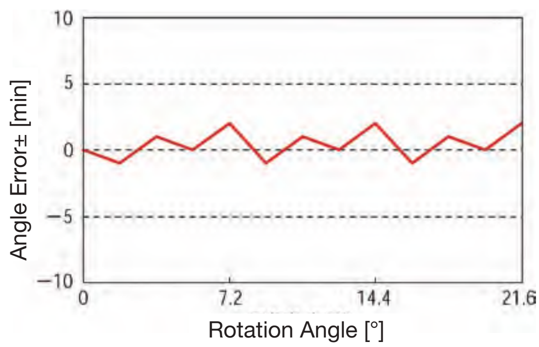
Fig. 4 Arrangement of Small Teeth on the Stator and Rotor of a 5-Phase Stepper Motor

2-Phase Stop Position Accuracy

A comparison of the stop position accuracy using the same motor and same driver is shown below. The change in stopping accuracy with microstep drive is quite obvious. Note that the driver that was used was a general driver IC.

Full Step (1.8°/step)

±1.9 min (0.032°)



Microstep (0.1125°/step)

±7.2 min (0.12°)

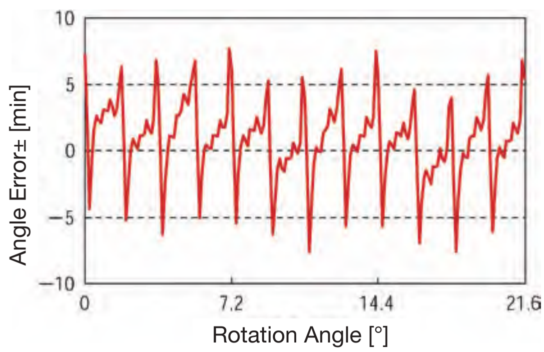


Fig. 5 Comparison of Stop Position Accuracy for a 2-Phase Stepper Motor

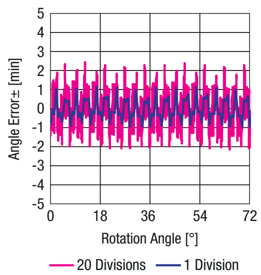
5-Phase Stop Position Accuracy

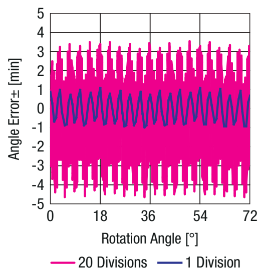
The stop position accuracy when equivalent motor and driver products are used in shown below.

Differences in drivers have an impact on stopping accuracy. We can see that there is a small change in stop position accuracy even when the 5-phase stepper motor is driven in microstep.

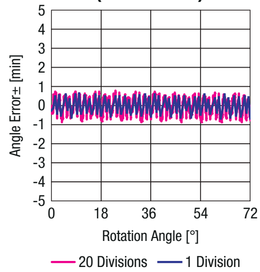
Table 1 Comparison of Stop Position Accuracy for Microstep Drive

Step Angle	2-Phase General Purpose Driver IC A	2-Phase General Purpose Driver IC B	**RKⅡ** Series
1 Step (0.72°/step)	±1.1 min	±1.1 min	±0.8 min
20 Steps (0.036°/step)	±2.3 min	±4.2 min	±0.9 min





5-Phase Stepper Motor (RK II Series)

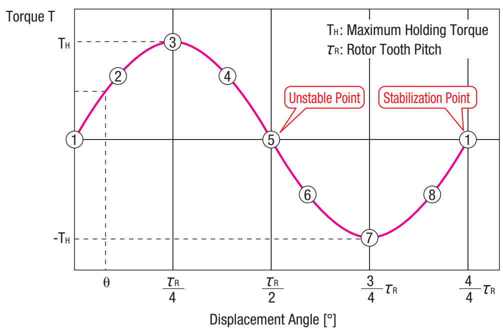


Impact of Load on Stopping Accuracy

Actual positioning accuracy is affected by the displacement angle due to load in addition to the motor's stop position accuracy.

> [Stop position accuracy] = [Static stop position accuracy deviation] + [Displacement angle due to load]
>
> ↑ Motor Performance
>
> ↑ θ_L Load Applied to Motor Output Shaft

When a motor is excited at the rated current and torque is applied externally to the motor shaft to change the angle of the rotor, the relationship between the angle and torque is called the angle–torque (θ–T) characteristic, which is shown in the figure below.



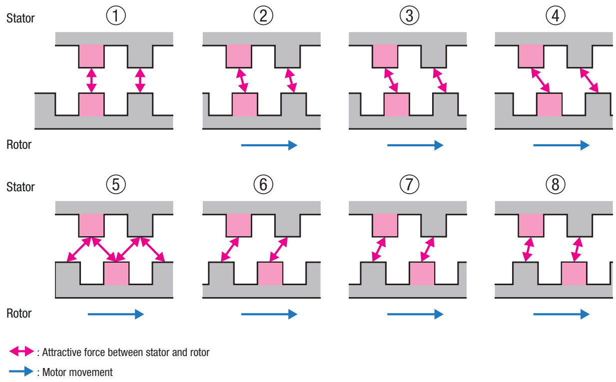
Angle – Torque Characteristics

The figure on the next page shows the positional relationship between the small teeth of the stator and rotor at each of the points shown in the characteristic diagram above.

When the motor stops balanced at stabilization point ①, applying an external force to the motor shaft generates torque T (+) in the left side to pull it back to the stabilization point ①, and it stops at an angle balanced with the external force.

② There is an angle at which the torque generated reaches its maximum when an external force is further applied. The torque generated at that time is the maximum holding torque T_H.

③ When an external force exceeding the above is applied, it passes through the unstable point ⑤, generates torque T (-) in the same direction as the external force, moves to the next stabilization point ①, and stops.



Stabilization Point: The place where the small teeth of the stator and rotor stop in a completely relative position. This is very stable and always stops at this point when the external force is set to 0.

Unstable Point: The place where the small teeth of the stator and rotor are misaligned by 1/2 pitch. This is a very unstable state, and if any external force is applied, it will move to the right or left stabilization point.

Method for Reducing Displacement Angle Due to Load

Two ways to reduce "Displacement Angle Due to Load" are shown below.

◆ Increase Torque

As shown in the figure below, as the motor torque increases, the slope of the θ–T characteristic increases.
If the load is the same, the displacement angle due to load is approximately halved when the torque is doubled.

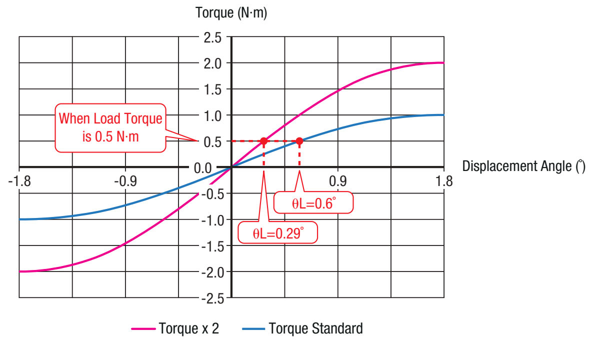
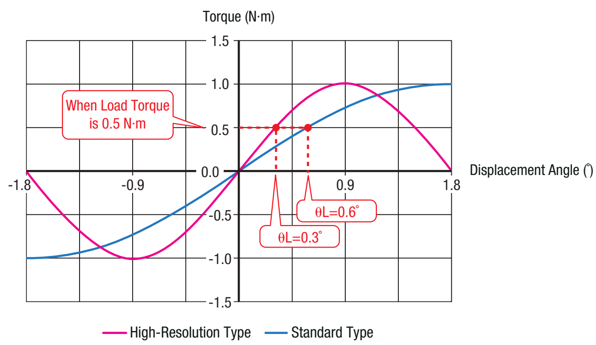


Fig. 6 Comparison of Displacement Angle

◆ Use of High-Resolution Type

For the high-resolution type, the period of the θ–T characteristics is reduced by 1/2.* If the load is the same, the displacement angle due to load becomes approximately 1/2.



✻ The period of the θ–T characteristic is determined by the number of small teeth.
For standard type with 50 small teeth, the period is 360° ÷ 50 teeth = 7.2°.
For high-resolution type with double the small teeth (100), the θ–T characteristics period is half.

Fig. 7 Comparison of Displacement Angle

With Encoder

Stepper Motors and Encoders

The structure of a stepper motor enables their high-precision positioning. This allows open-loop speed and position control and eliminates the need for an encoder for basic operations. However, even greater reliability can be achieved when an encoder is combined with the stepper motor.

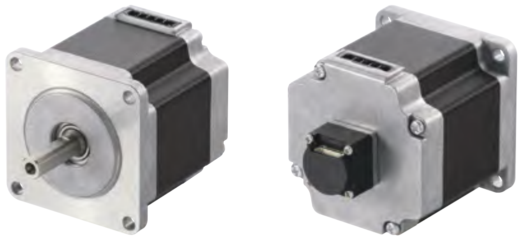


Fig. 1 Standard Type with Encoder

Table 1 **PKP** Series Encoder-Equipped Product Line

Number of Phases	Type	Frame Size [mm]	Encoder Resolution	Output Signals	Encoder Output Circuit Type
2-Phase	Standard Type	□20 ~ □56.4	200 P/R, 400 P/R, 1000 P/R*	A-phase, B-phase, Z-phase (3ch)	Voltage Output Line Driver Output
	High-Resolution Type	□28 ~ □56.4	400 P/R	A-phase, B-phase, Z-phase (3ch)	Voltage Output Line Driver Output
	SH Geared Type	□28 ~ □60	400 P/R	A-phase, B-phase, Z-phase (3ch)	Voltage Output Line Driver Output
5-Phase	Standard Type	□20 ~ □60	500 P/R, 1000 P/R*	A-phase, B-phase, Z-phase (3ch)	Voltage Output Line Driver Output

*Frame Size 42 mm and 56.4 mm only

Improved Reliability and Space Saving of the Equipment

Monitoring the current position and detecting positional errors is possible. By comparing the current position with the command position, the normal operation of the motor can be visualized, contributing to early detection of malfunctions and improvement of equipment reliability. In addition, motors with encoders can be installed in smaller spaces than when encoders are attached to the side of the equipment mechanism, helping to reduce the number of components.

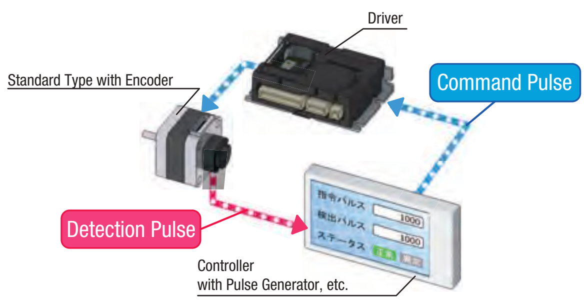


Fig. 2 System Configuration Example

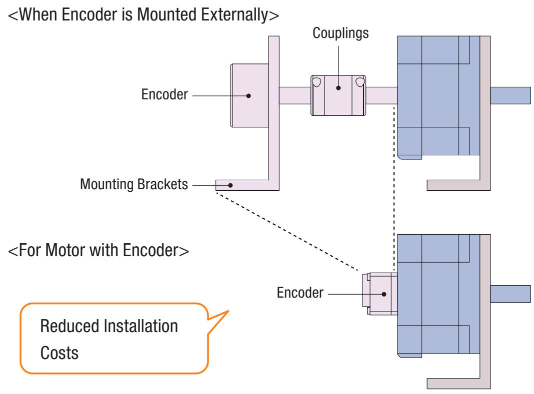


Fig. 3 Space Saving by using Motor with Encoder

Advantages of High Resolution Encoders (1000 P/R)

Capable of Highly Accurate Position Detection

Models with a high-resolution (1000 P/R) magnetic encoder are available. The angular accuracy is ±0.36° (guaranteed value) with the motor in an assayed state. This allows for more accurate position detection compared to the existing motor with encoder.

Table 2 Comparison of Encoder Resolution and Angular Accuracy

	High Resolution Magnetic Encoder	Existing Product Optical Encoder
Resolution	1000 P/R	500 P/R
Angular Accuracy	±0.36°	–

What is Angular Accuracy

Angular accuracy is the error between the actual rotation angle and the angle output by the encoder. A motor with a 1000 P/R resolution encoder guarantees angular accuracy of ±0.36°.

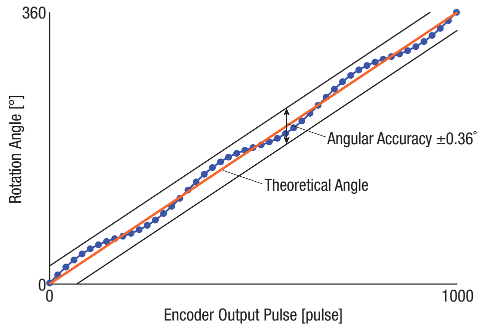
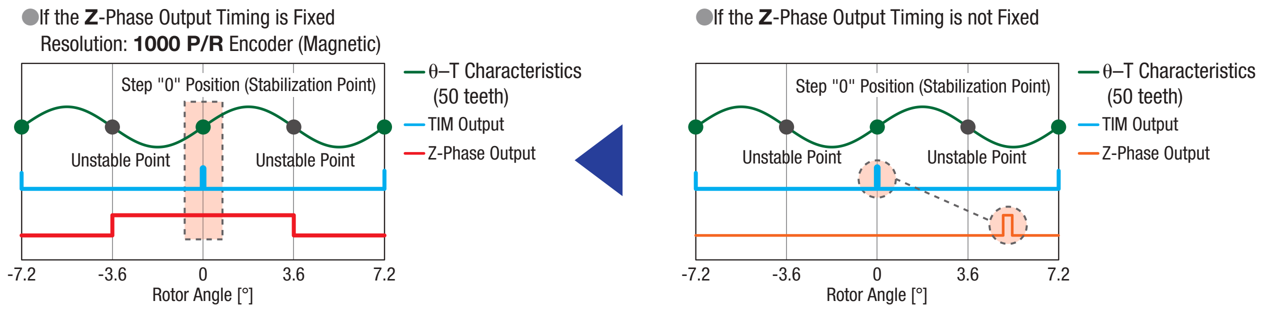


Fig. 4 Angular Accuracy of 1000 P/R Resolution Encoder.

Capable of Highly Repeatable Return-to-Home

The Z-phase signal is output using the step "0" position (stabilization point), so the home sensor (the sensor that detects the home within one rotation, attached to the motor shaft) can be used instead. It is also easier for the Z-phase output signal and TIM output signal* to be used together, increasing the repeatability of return-to-home.

* The signal output by the driver every time the motor output shaft rotates 7.2° from home.



The Z-phase signal outputs with a width of ±3.6°, centered on the step "0" position (stabilization point).

The Z-phase signal output timing is unstable, making it difficult to use it as a home sensor substitute, and also making it difficult to use it in combination with the TIM signal.

Fig. 5 Step "0" Position and Z-Phase Signal Relationship

Geared Type

About Geared Type

Geared type products are a gear head assembled to the motor.
They have the following features.

- The motor and gear frame size are the same.
- Guaranteed specifications as a geared motor. No need to consider gear and motor specifications separately.
- Variations are available to consider for various aspects such as size, torque and backlash

Advantages of Geared Type

- High Torque, Large Inertia

  More torque can be provided and larger inertial loads can be driven.

- Compact

  Compared to standard motors with similar maximum holding torque, the frame size of geared motors is smaller, which can reduce equipment volume. They are effective when reducing equipment size and weight is needed.

- Reduced Components Count

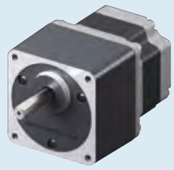
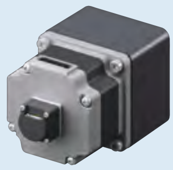
  The number of parts can be reduced because belts, pulleys, and external reduction mechanisms are no longer needed.

- Low Vibration

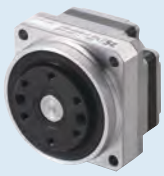
  The vibration of the assembled motor output shaft is reduced through the gearhead. This helps reduce overall vibration.

Geared Type Product Lineup

The product line features the permissible torque and stopping accuracy (backlash) that our customers require.

Type	Frame Size [mm]	Gear Ratio	Permissible Torque\ Max. Instantaneous Torque [N·m]	Backlash [arcmin]	Basic Step Angle [°/step]	Speed Range Upper Limit [r/min]
SH Geared  Standard  With Encoder*1	28	7.2	0.3 \	90	0.25	416
		9			0.2	333
		10			0.18	300
		18	0.4 \		0.1	166
		36	0.4 \		0.05	83
	42	3.6	0.2 \	90	0.5	833
		7.2	0.4 \	60	0.25	416
		9	0.5 \		0.2	333
		10	0.56 \		0.18	300
		18	0.8 \		0.1	166
		36	0.8 \		0.05	83
	60	3.6	1 \	70	0.5	833
		7.2	2 \	45	0.25	416
		9	2.5 \		0.2	333
		10	2.7 \		0.18	300
		18	3 \		0.1	166
		36	4 \		0.05	83
	90	3.6	2.5 \	(Approx. 60 - 120)*2	0.5	500
		7.2	5 \		0.25	250
		9	6.3 \		0.2	200
		10	7 \		0.18	180
		18	9 \		0.1	100
		36	12 \		0.05	50
CS Geared 	28	10	0.4 \	90	0.18	600
		15	0.6 \		0.12	400
		20	0.8 \		0.09	300
	42	5	0.5 \	(90)*3	0.36	600
		10	1 \	(60)*4	0.18	300
		15	1.5 \		0.12	200
		20	2 \		0.09	150
	60	5	1.3 \	70	0.36	600
		10	2.7 \	45	0.18	300
		15	4 \		0.12	200
		20	4.5 \		0.09	150

*1: Products with Encoder Include 2 types: □42 mm and □60 mm Frame Sizes *2: Approx. 1~2° (Reference value) *3: 1.5° (Reference value) *4: 1° (Reference value)

Type	Frame Size [mm]	Gear Ratio	Permissible Torque\ Max. Instantaneous Torque [N·m]	Backlash [arcmin]	Basic Step Angle [°/step]	Speed Range Upper Limit [r/min]
TS Geared 	42	3.6	0.65 \ 0.85	45	0.2	833
		7.2	1.2 \ 1.6	25	0.1	416
		10	1.7 \ 2		0.072	300
		20	2 \ 3	15	0.036	150
		30	2.3 \ 3		0.024	100
	60	3.6	1.8 \ 2.5	35	0.2	833
		7.2	3 \ 4.5	15	0.1	416
		10	4 \ 6		0.072	300
		20	5 \ 8	10	0.036	150
		30	6 \ 10		0.024	100
Thin Harmonic Geared 	51	50	1.8 \ 3.3	0	0.036	70
		100	2.4 \ 4.8	0	0.018	35
	61	50	3.5 \	0	0.036	70
		100	5 \	0	0.018	35

Principle and Structure for the Various Gear Types

CS Gear

◆ Principle and Structure

The **CS** gear is a parallel shaft gear reduction mechanism with the output shaft positioned at the center of the frame size.

One side of the gear case has a convex portion, provides space for the gears to be positioned, enabling flexible installation of the center shaft. The gear and bearing diameters have been enlarged by optimizing the design using this convex portion. This allows for the product to provide increased permissible torque, permissible radial load and permissible axial load.

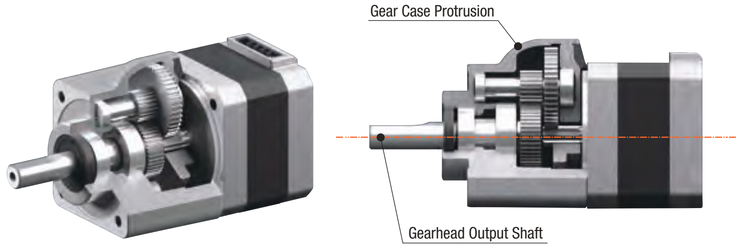


Fig. 1 Structure of the **CS** Gear

TS Gear

◆ Principle and Structure

TS gears are machined with high accuracy gear processing and heat treatment to reduce dimensional variation to reduce their effects on backlash. In addition, because the gear on the output shaft undergoes a high accuracy finishing process after the heat treatment, there are no dimensional variation effects from the heat treatment.

Because of this, **TS** gears allow for simple structures that do not require a special adjustment mechanism.

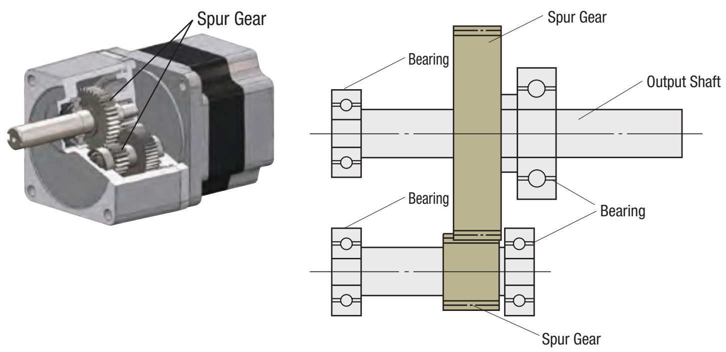


Fig. 2 Structure of the **TS** Gear's Final Deceleration Stage

Harmonic Gears

Principle and Structure

The harmonic gear offers excellent positioning accuracy for a gear and features a simple construction that utilizes the metal's elastodynamic property. It is comprised of 3 basic components: a wave generator, a flex spline and a circular spline.

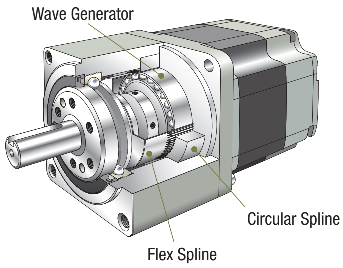


Fig. 3 Structure of the Harmonic Gear

Wave Generator

The wave generator is an oval-shaped component with a thin ball bearing placed around the outer circumference of the oval cam. The bearing's inner ring is fixed to the oval cam, while the outer ring is subjected to elastic deformation via the balls. The wave generator is installed onto the motor shaft.

Flex Spline

The flex spline is a thin, cup-shaped component made of elastic metal, with teeth formed along the outer circumference of the cup's opening. The gearhead output shaft is attached at the bottom of the flex spline.

Circular Spline

The circular spline is a rigid internal gear with teeth formed along its inner circumference. These teeth are the same size as those of the flex spline, but the circular spline has 2 more teeth than the flex spline. The circular spline is fixed to the gear case along its outer circumference.

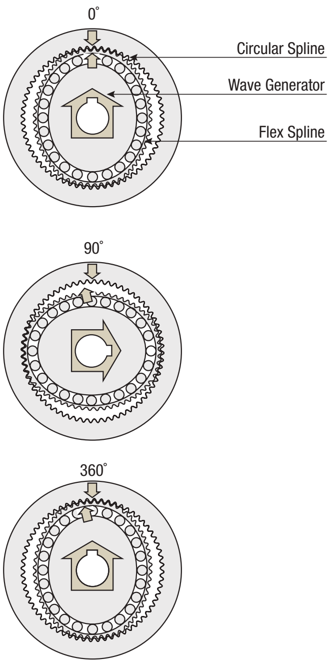


Fig. 4 Drive Principle

The flex spline is bent into an oval shape by the wave generator. The teeth on the long axis of the oval mesh with the circular spline, while the teeth on the short axis of the oval are completely separate from it.

Rotating the wave generator (input) clockwise while keeping the circular spline fixed in position will subject the flex spline to elastic deformation, causing a gradual shift in the point of engagement between the circular spline and flex spline.

When the wave generator completes a revolution, the flex spline has rotated 2 fewer teeth than the circular spline has, resulting in the movement of flex spline for the difference in the number of teeth (2 teeth) in the opposite direction of the wave generator's rotation (i.e., counterclockwise). This movement translates into output, thereby decelerating the speed.

◆ Accuracy

Unlike the conventional spur gear gearhead, the harmonic gear has no backlash. The harmonic gear has many teeth in simultaneous meshing engagement, and is designed to average out the effects of tooth pitch error and cumulative pitch error on rotation accuracy to ensure high positioning accuracy. Also, harmonic gears have high gear ratio, so that the torsion when the load torque is applied to the output shaft is much smaller than a single motor and other geared motor, and the rigidity is high. High rigidity is less subject to load fluctuation and enables stable positioning. When the high positioning accuracy and rigidity are required, refer to the following characteristics.

◆ Angular Transmission Accuracy

Angular transmission error is the difference between the theoretical rotation angle of the output shaft, as calculated from the input pulse count, and actual rotation angle. Represented as the difference between the min. value and max. value in the set of measurements taken for a single rotation of the output shaft, starting from an arbitrary position.

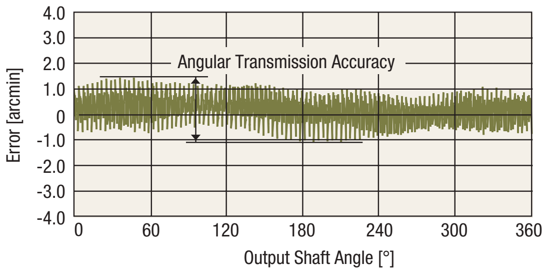


Fig. 5 Angular Transmission Accuracy

Product Name	Angular Transmission Accuracy [arcmin]
PKP242-H□	2 (0.034°)
PKP262-H□S	1.5 (0.025°)

These are the values under no load conditions (gear reference value). In actual applications, there is always frictional load, and displacement is produced as a result of this frictional load. If the frictional load is constant, the displacement will be constant for unidirectional operation. However, in bidirectional operation, double the displacement is produced over a round trip. This displacement can be estimated from the following torque – torsion characteristics.

Torque – Torsion Characteristics

The torque – torsion characteristics in the graph measure displacement (torsion) when the motor shaft is fixed and the load (torque) is gradually increased and decreased in the forward and reverse directions of the output shaft. When a load is applied to the output shaft in this way, displacement occurs due to the gear's spring constant.

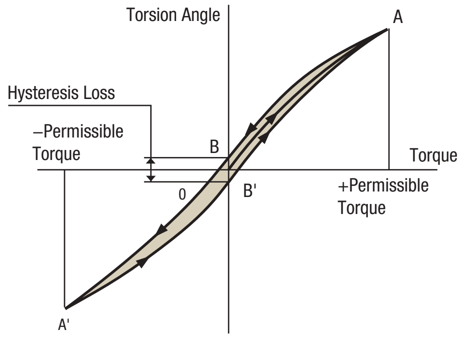


Fig. 6 Torsion Angle – Torque Characteristics

This displacement occurs when an external force is applied as the gear is stopped, or when the gear is driven under a frictional load. The slope can be approximated with the spring constant in the following 3 classes, depending on the size of the load torque, and can be estimated through calculation.

1. Load torque T_L is less than T_1

$$\theta = \frac{T_L}{K_1} \text{[min]}$$

2. Load torque T_L exceeds T_1 and is less than T_2

$$\theta = \theta_1 + \frac{T_L - T_1}{K_2} \text{[min]}$$

3. Load torque T_L exceeds T_2

$$\theta = \theta_2 + \frac{T_L - T_2}{K_3} \text{[min]}$$

The torsion angle of the harmonic gear alone is calculated according to the size of the load torque.

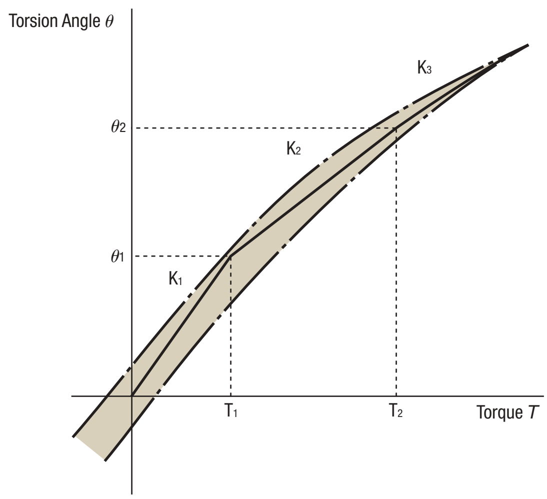


Fig. 7 Torsion Angle – Torque Characteristics

Values for Determining Torsion Angle

Product Name\ Item	Gear Ratio	T 1 N·m	K 1 N·m/min	θ 1 min	T 2 N·m	K 2 N·m/min	θ 2 min	K 3 N·m/min
PKP242-H50	50	0.29	0.13	2.3	0.75	0.19	4.5	0.24
PKP242-H100	100	0.29	0.26	1.1	0.75	0.29	2.8	0.35
PKP262-H50S	50	0.8	0.64	1.2	2	0.87	2.8	0.93
PKP262-H100S	100	0.8	0.79	1	2	0.99	2.1	1.28

Hysteresis Loss

As shown in the torque–torsion characteristics, the torsion angle will not become 0 and a slight torsion remains even when the torque is removed after applying up to the permissible torque bidirectionally. (Fig. 6 B-B')

This is referred to as a hysteresis loss. The harmonic gear is designed to have a hysteresis loss of 2 arc minutes or less.

When the external force is applied during stopping, or when the acceleration/deceleration torque is applied in the inertial drive, or when the frictional load is applied while driving, etc., a slight torsion remains because of the hysteresis loss, even if there is no load.

Lost Motion

Since the harmonic gear has no backlash, lost motion is used as a reference for gear accuracy.

Lost motion represents the total displacement that occurs when a torque corresponding to approximately 5% of the permissible torque is applied to the gearhead output shaft.

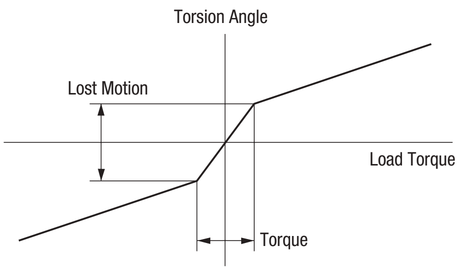


Fig. 8 Lost Motion

The Technology and Advantages of the **CS** Gears

Oriental Motor offers parallel gears, planetary gears and harmonic gears. Conventional parallel shaft gears generally have a structure in which the gearhead output shaft is offset from the center of the frame size. In contrast, the **CS** gear is a parallel shaft mechanism with the gearhead output shaft positioned at the center of the frame.

Fig. 9 **PKP** Series **CS** Geared Type

Generally, conventional parallel shaft gears are designed so that the gear outline fits within the projected plane of the motor's frame size. When trying to balance this design constraint with a concentric structure, the distance between the motor shaft and the shaft of the large initial stage gear is restricted, which shortens the distance between the shafts of each gear pair, ultimately resulting in a smaller diameter for the large final stage gear. This makes it difficult to design for gear ratios of more than 10 or to transmit large torques.

To overcome this problem, the distance between the shafts of the gear pairs must be increased and the large final stage gear diameter must be larger (Fig. 10). In the **CS** gear products, the pitch of the mounting holes is maintained and a portion of the gear case shape is bulged out, which allows the initial stage gear to be placed in the space that this creates, thereby securing distance between the shafts (Fig. 11). This allows the large final stage gear to have a larger diameter and a gear ratio of up to 20, allowing transmission of a larger amount of torque.

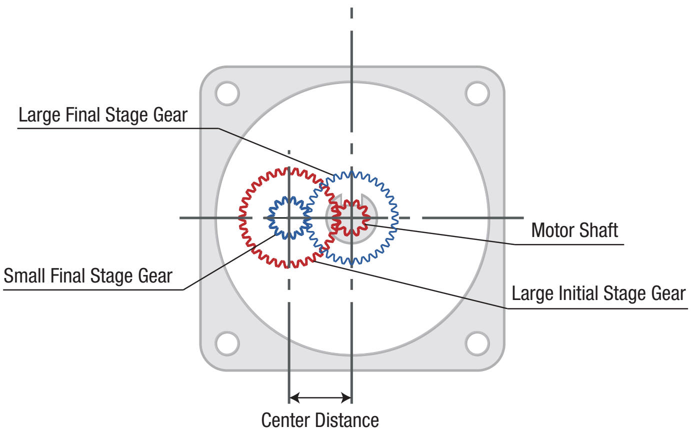


Fig. 10 Concentric Structure of Conventional Parallel Shaft Gear Design (Front)

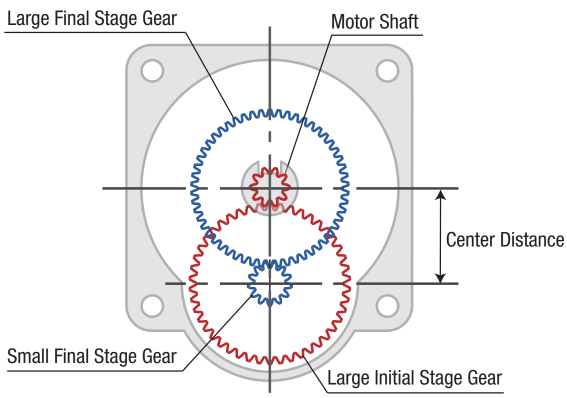


Fig. 11 Concentric Structure of **CS** Gear (Front)

Planetary gears feature concentric shafts and also have high permissible torque, which means that the equipment may be over-specced, depending on the application. The **CS** gears are parallel shaft gear that also provide concentric shafts, which not only reduces costs, but also simplifies layout design for the equipment.

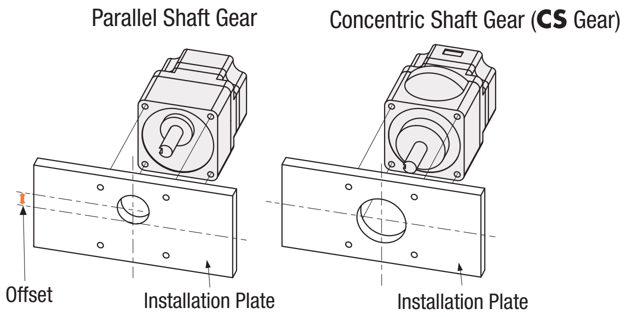


Fig. 12 Installation to Equipment

CS gears also provide improvements to permissible torque and radial load. In addition to increased size of the initial and final stage gears, the gears are heat-treated, resulting in a permissible torque approximately twice as much as that of **SH** gears (Fig. 13). The longer distance between gear shafts also allows for larger bearings, and the permissible radial load is up to four times higher compared to **SH** gears. Proper tension control can be performed when a belt is required to transmit a high load.

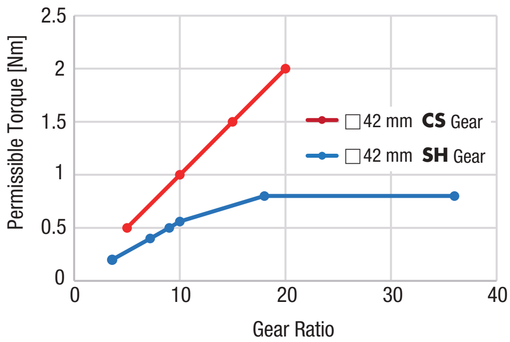


Fig. 13 Permissible Torque Comparison

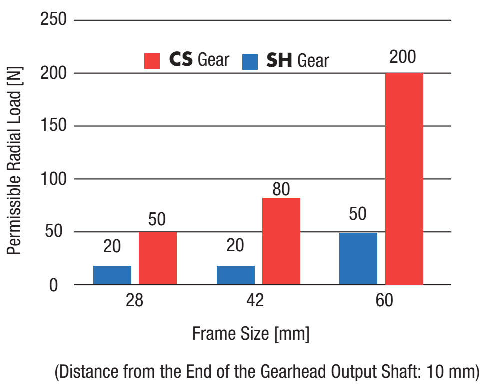
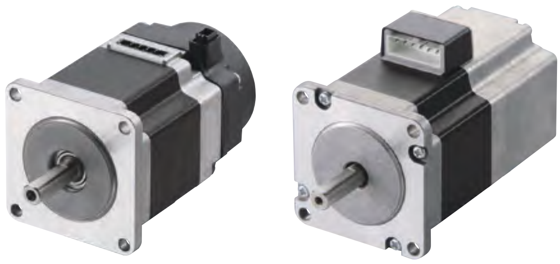


Fig. 14 Radial Load Comparison (Gear Ratio 10)

With Electromagnetic Brake

The Features of Electromagnetic Brake Type

These stepper motors include a power off activated electromagnetic brake.



Advantages of Using Electromagnetic Brake Type Products

◆ Safety Even for Unexpected Events

The electromagnetic brake holds the load in position to prevent it from dropping or moving if a power failure or other unexpected event occurs. This prevents large loads from dropping.

◆ Guaranteed Holding Power

The specifications including the electromagnetic brake's holding force are clearly indicated.

◆ Contributes to Reduced Power Consumption and Reduced Temperature

When a stepper motor without an electromagnetic brake is holding a position, holding current is necessary. By using an electromagnetic brake, holding current is no longer necessary. When the holding period is long, this contributes to reduced power consumption and reduces motor temperature.

●Without Electromagnetic Brake　　●With Electromagnetic Brake

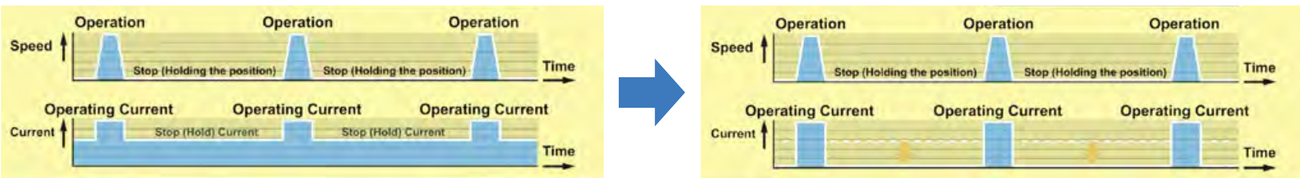
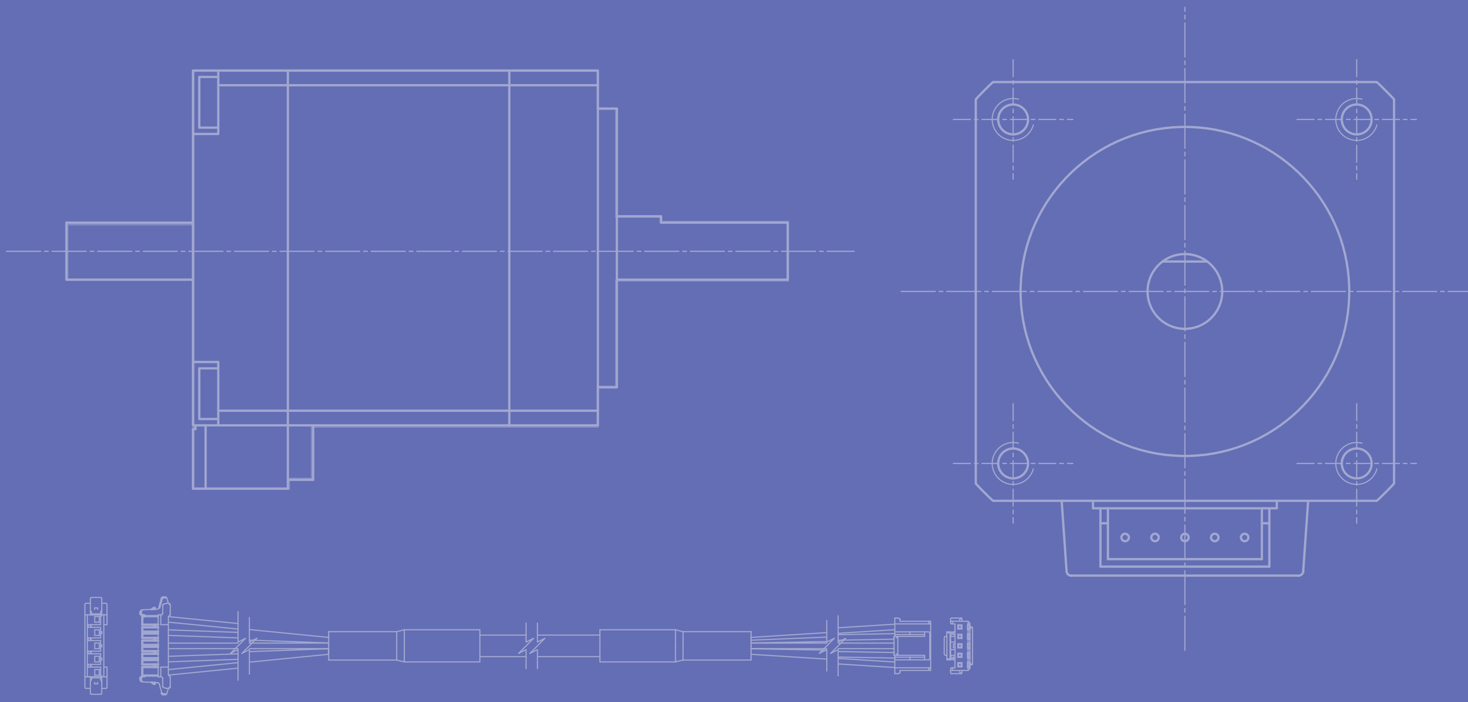
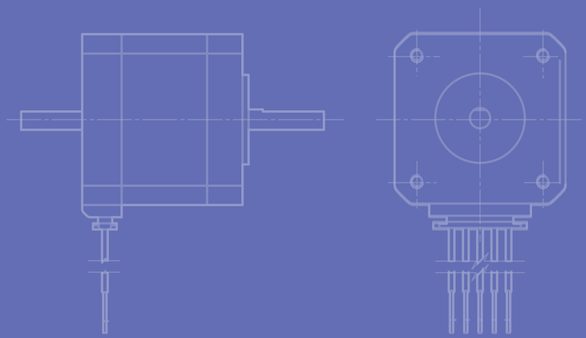
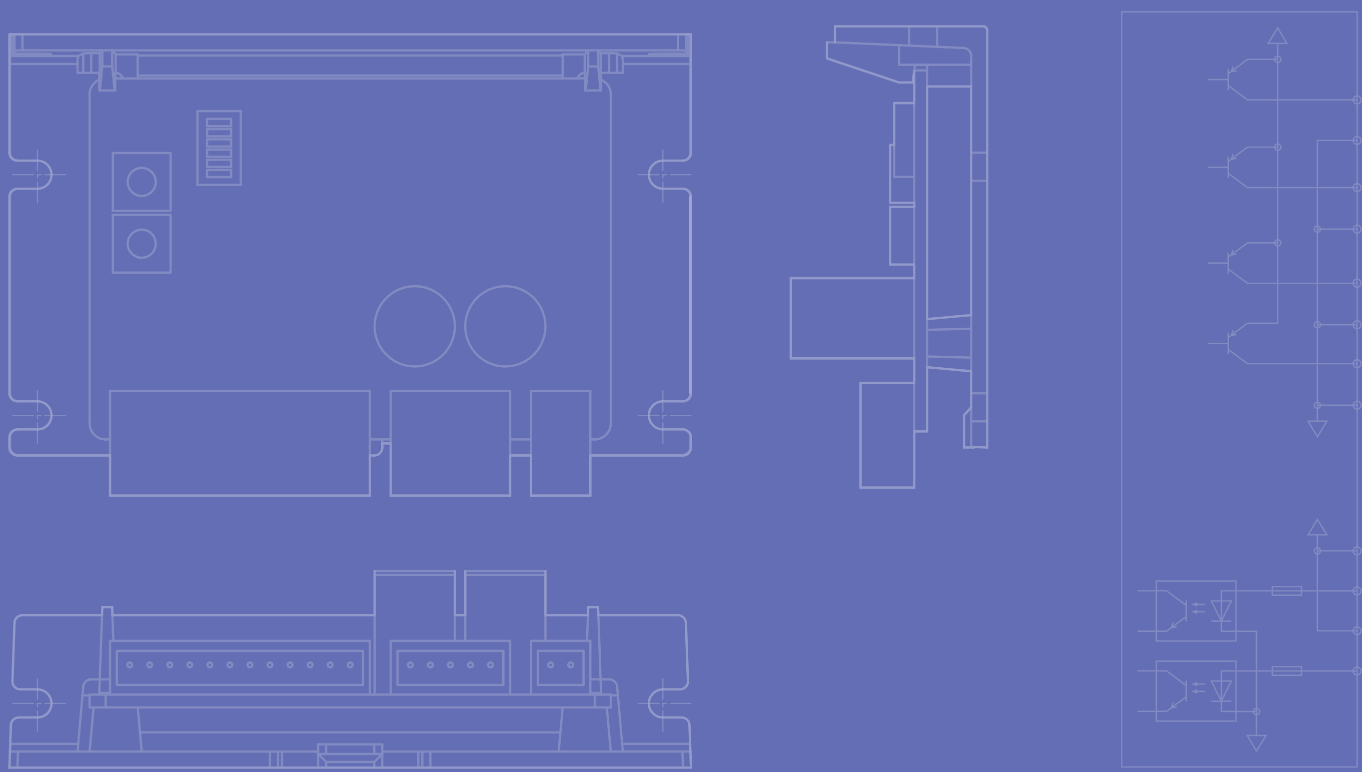


Fig. 1 Advantages of Electromagnetic Brake Products





Explanation of Drivers



The Advantages of Oriental Motor Drivers

The Features of Oriental Motor Drivers

By using Oriental Motor drivers, regardless of whether the motor is 2-phase or 5-phase, torque and vibration that cannot be achieved with general driver ICs can be obtained.

The Technology and Advantages of the **CVD** Series

Oriental Motor CVD Series Search

Low Vibration

Full-time microstep drive with full-digital control significantly improves vibration levels, resulting in low vibration over the entire speed range.

Significantly Improved Vibration Characteristics at All Speeds

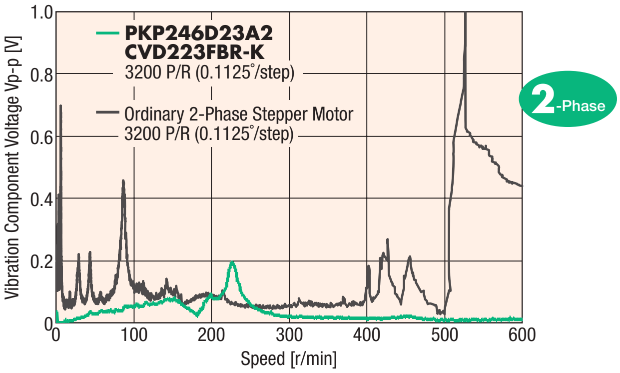


Fig. 1 Speed – Vibration Component Voltage Characteristics

5-Phase Motor has Even Lower Vibration

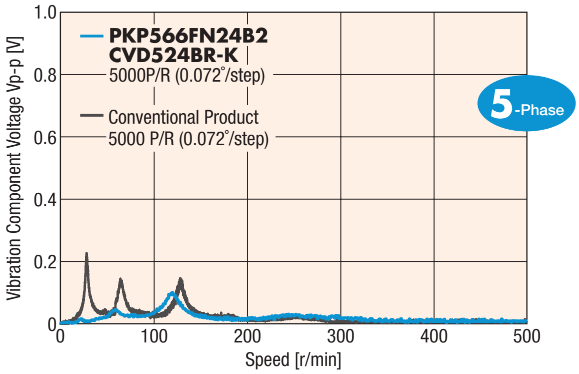


Fig. 2 Speed – Vibration Component Voltage Characteristics

Noise Reduction

The general perception is that stepper motors are noisy when they are driven. The **CVD** Series has a low drive noise level of approximately 35 dB at low speed (60 rpm) (approximately 30 dB at motor standstill).

The drive noise for 2-phase stepper motor with general driver IC, 2-phase stepper motor with **CVD** Series, 5-phase stepper motor and **CVD** Series were compared. You can watch and hear the actual differences in the sounds in the Oriental Motor video library.

Technology Supporting Low Vibration

If the rotational vibration of the motor is large, it can resonate with the equipment and become a source of noise, or cause the material to be conveyed to shift due to the vibration. The **CVD** Series reduces rotational vibration using the following three methods.

· Improved current controllability using detection of each phase current
· Implementation of microstep drive at all speeds
· Current compensation using magnetic circuit characteristics

As a result, vibration is significantly reduced for both 2-phase and 5-phase models compared to conventional products.

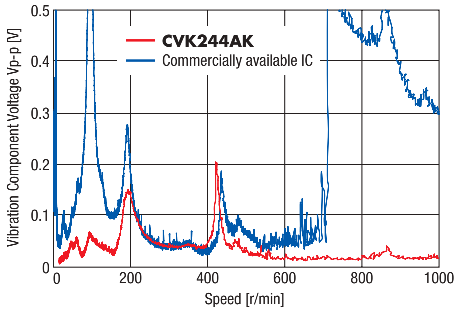


Fig. 3 Vibration Characteristics of 2-phase **CVD** Series and Commercial Stepping Motor Driver ICs

Improved Current Controllability Using Detection of Each Phase Current

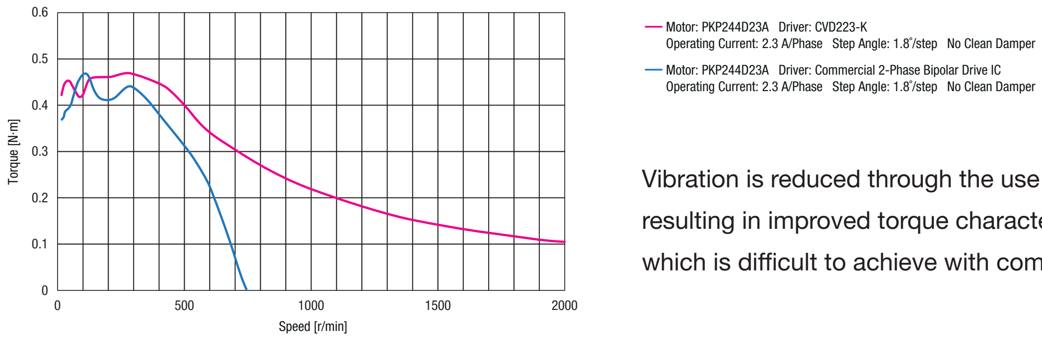
The motor is controlled by the current flowing through the motor windings. If the current flowing through the motor windings can be properly controlled, the motor will run more smoothly. The key point is the method for detecting the current in the motor winding.

For 5-phase stepper motors, conventional products use a method that detects the current for all phases at once using this current in 5 cables connected to the motor. While this method has the advantage of a simple circuit with only one detection circuit, current control is unstable because currents that do not pass through the detection circuit but are returned cannot be detected, so some ingenuity was required to reduce vibration.

In contrast, the **CVD** Series uses a phase current detection method that detects each of the 5 currents individually. Although this requires 5 individual detection circuits, the recent improvement in microcontroller performance has made this detection a reality.

Implementation of Microstep Drive at All Speeds

Stepper motors rotate and stop at each step angle, so one of their features is high-precision position control. However, when rotated by a single basic step angle, the rotor undergoes a large change in speed, which may cause vibration and noise. Microstep drive is used to reduce this vibration. Microstep drive is a drive system that electrically subdivides the step angle. Smaller step angles allow for smaller velocity changes during single step travel, resulting in lower vibration. The **CVD** Series uses microstep drive over the entire speed range to minimize vibration caused by step movement over the entire speed range.



Vibration is reduced through the use of full microstep, resulting in improved torque characteristics at high speeds, which is difficult to achieve with commercial ICs.

Fig. 4 Torque Characteristics of 2-Phase **CVD** Series and Commercial Stepper Motor Driver ICs

Current Compensation Using Magnetic Circuit Characteristics

In the low winding current region, the motor output torque is proportional to the current. As the current increases, the relationship between current and torque gradually deviates from proportionality due to the magnetic saturation phenomenon caused by the armature reaction magnetic flux (Fig. 5). In order to increase the motor's output torque, the region that has moved out of out of proportion must also be effectively utilized.

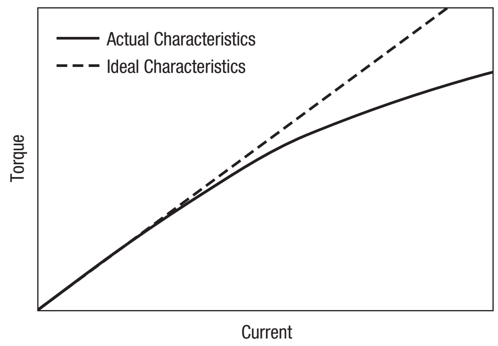


Fig. 5 **Example of Current – Torque Characteristic Distortion**

The variation in output torque when the excitation phase is changed is called torque ripple. By making the magnitude of the torque generated in each phase a sine wave, in theory no torque ripple will occur. If the relationship between motor current and torque generated is linear, by making the current in each phase into a sine wave, torque ripple will not occur, but in reality, the relationship between motor current and torque generated is not linear (Fig. 5 above).

If the current value flowing in each phase is a sine wave, torque distortion occurs at points where the current value increases, causing vibration. Therefore, changes must be made for the control to achieve both high output torque and low vibration. In the **CVD** Series, the phase of the sine wave-shaped current flowing to the motor is corrected to compensate for the distortion of the current–torque characteristics, resulting in both low vibration and high output torque. Fig. 6 shows how much the rotational vibration characteristics are improved by this phase correction process. With the correction process enabled, the peak vibration values are greatly improved. In addition, an improvement in the stop position accuracy is also possible.

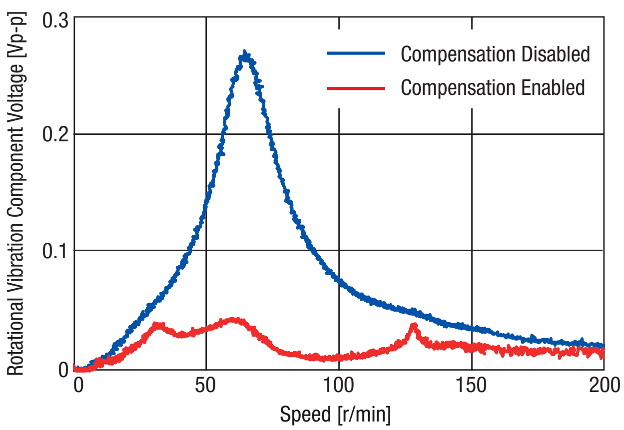


Fig. 6 **Example of Improvement of Rotational Vibration by Phase Correction Process**

The optimal value of the phase compensation depends on the magnetic characteristics of the motor. Therefore, the optimal compensation amount is set for each driver and motor combination.

High performance is achieved by performing current control that accounts for the magnetic characteristics of the motor. This is a strength unique to Oriental Motor, because we develop both the motors and the drivers.

Technology Supporting High Torque

Higher motor torque can increase transportable weight and shorten takt time. In the **CVD** Series, the output current value is increased in order to achieve higher torque. The method is introduced below.

2-Phase Motors Increased Torque at Low Speed

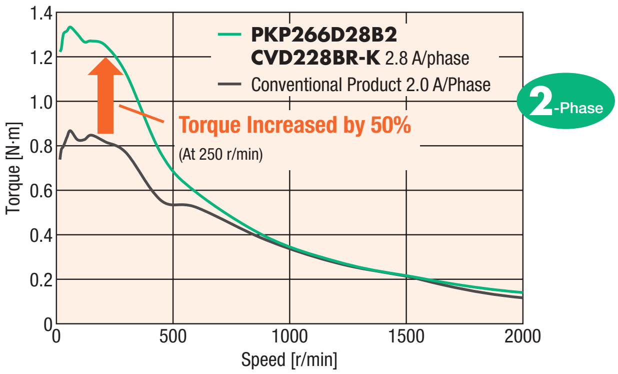


Fig. 7 Speed – Torque Characteristics

5-Phase Motors Increased Torque at All Speeds

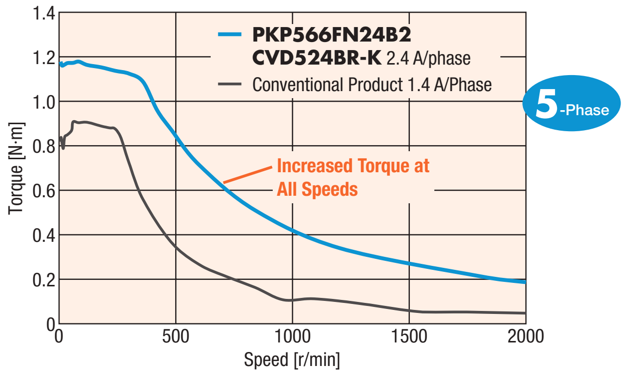


Fig. 8 Speed – Torque Characteristics

Adoption of Low-Loss Switch Components

The switching component (NchMOS-FET) that controls the motor current is one of the electronic components in the driver that generates a large amount of heat. The main cause of heat generation in FETs is conduction losses, which increase in proportion to the magnitude of the on-resistance when current is applied to the device. The **CVD** Series uses low-loss FETs with on-resistance reduced to 1/20 of that of conventional products. This reduces the amount of heat generated.

Fig. 9 shows a graph comparing driver losses when the motor is operated with no load. The difference in loss is up to 75%, supporting the data that the driver generates less heat

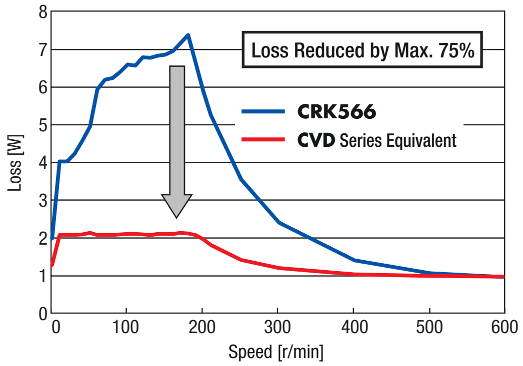


Fig. 9 Comparison of Driver Loss with No Load

Explanation of Drivers

Pattern Design that Considers Heat Radiation to the Circuit Board

To ensure FET reliability, it is important that the FET temperature remains low. The conventional thermal countermeasure for drivers has been to dissipate the heat generated by the FET into an external aluminum heat radiation plate to limit the temperature rise to a specified level.

With the **CVD** Series, the printed circuit board itself functions as a heat sink, eliminating the need for an external aluminum heat radiation plate. For a printed circuit board to work effectively as a heat sink, the thermal resistance of the board must be lowered. The printed circuit board was designed with the following in mind:

1) Secure the largest possible area of copper foil as possible
2) Through-hole parallel connections

In addition, a FET in a package that can efficiently transfer the heat generated inside the components to the printed circuit board is used. Fig. 10 shows a cross-sectional schematic diagram of the **CVD** Series printed circuit board. The heat generated in the FET is dissipated by transferring it through the copper foil of the circuit board.

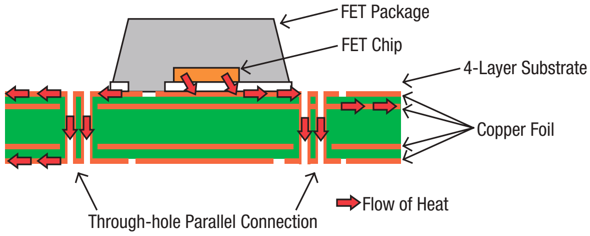


Fig. 10 **Cross-sectional schematic diagram of FET and printed circuit board**

The reduction of the amount of heat generated and the heat radiation structure on the circuit board allow the output current value to be increased without the need for an external aluminum heat radiation plate.

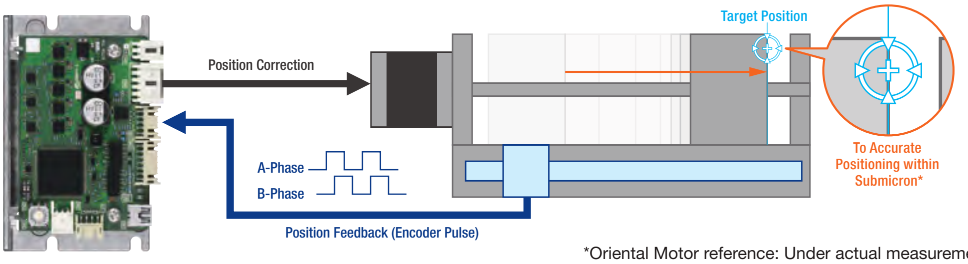
CVD Series Fully Closed-Loop Control Type

The **CVD** Series Fully Closed-Loop Control Type allows for high-precision positioning operation in combination with an external sensor, while maintaining the ease of use of a stepper motor.

	Product Name
With Mounting Plate	**CVD5B-KF**
Right-Angle with Mounting Plate	**CVD5BR-KF**

Enables High Precision Positioning

The use of fully closed-loop control, which provides direct feedback for the mechanism position, allows for the correction of any deviations between the command position and the feedback position.

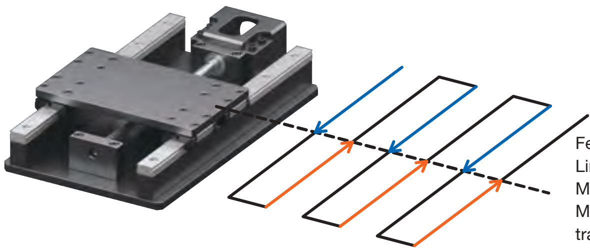


*Oriental Motor reference: Under actual measurement data conditions

Reference: Actual Measurement Data

Actual measured data of lost motion (positioning of motor from CW and CCW directions with respect to the target position, and the error with respect to the target position at that time).

Open Loop Control	Fully Closed-Loop Control
0.726 µm	0.014 µm



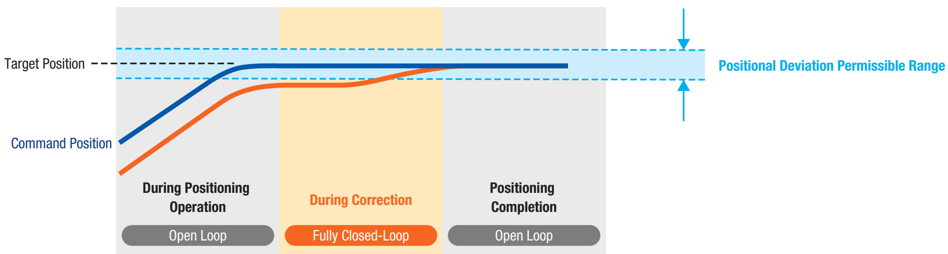
Feed screw lead 1 mm
Linear scale resolution 0.1 µm
Measurement using laser
Measurement error of ±0.2 ppm for traveling amount

Fully Closed-Loop Stepper Motor Control

The **CVD** Series fully closed-loop control type uses open loop control at the start of positioning to take advantage of the high response of the stepper motor.

After the positioning command has been completed, it transitions to fully closed-loop control using feedback from external sensors to correct the position.

CVD Series Fully Closed-Loop Control



CVD Series Multi-Axis Type EtherCAT-Compatible

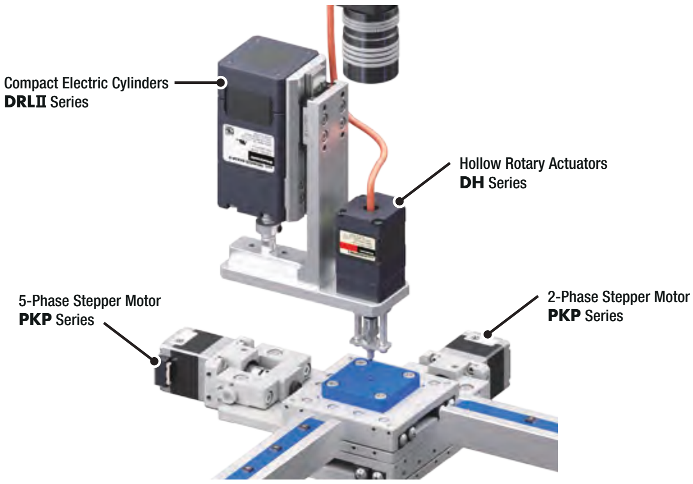
This is a **CVD** Series multi-axis type EtherCAT-compatible open loop control driver.

	Product Name	List Price
Straight Type	**CVD4A-KED**	
Right-Angle Type	**CVD4AR-KED**	

Mixed 2-Phase/5-Phase 4-Axis Driver

Four axes can be controlled from a single driver. Motors, geared motors and actuators can be driven by setting current values via EtherCAT communication, and both 2-phase and 5-phase can be controlled by a single driver.

The rated currents that can be driven by the **CVD** Series multi-axis drivers are 2-phase: 2.8 A max. and 5-phase: 2.4 A max.



Various Combinations to Utilize the Wide Variety of Products

Various product combinations are available, including standard type, with encoder, geared type, hollow rotary actuator, and compact electric cylinder.

Stepper Motors
PKP Series

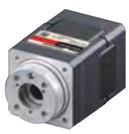
High Speed Drive

Stepper Motors
PKP Series
with Encoder

Monitor

PKP Series
Flat Type with
Harmonic Gears

Large Inertia

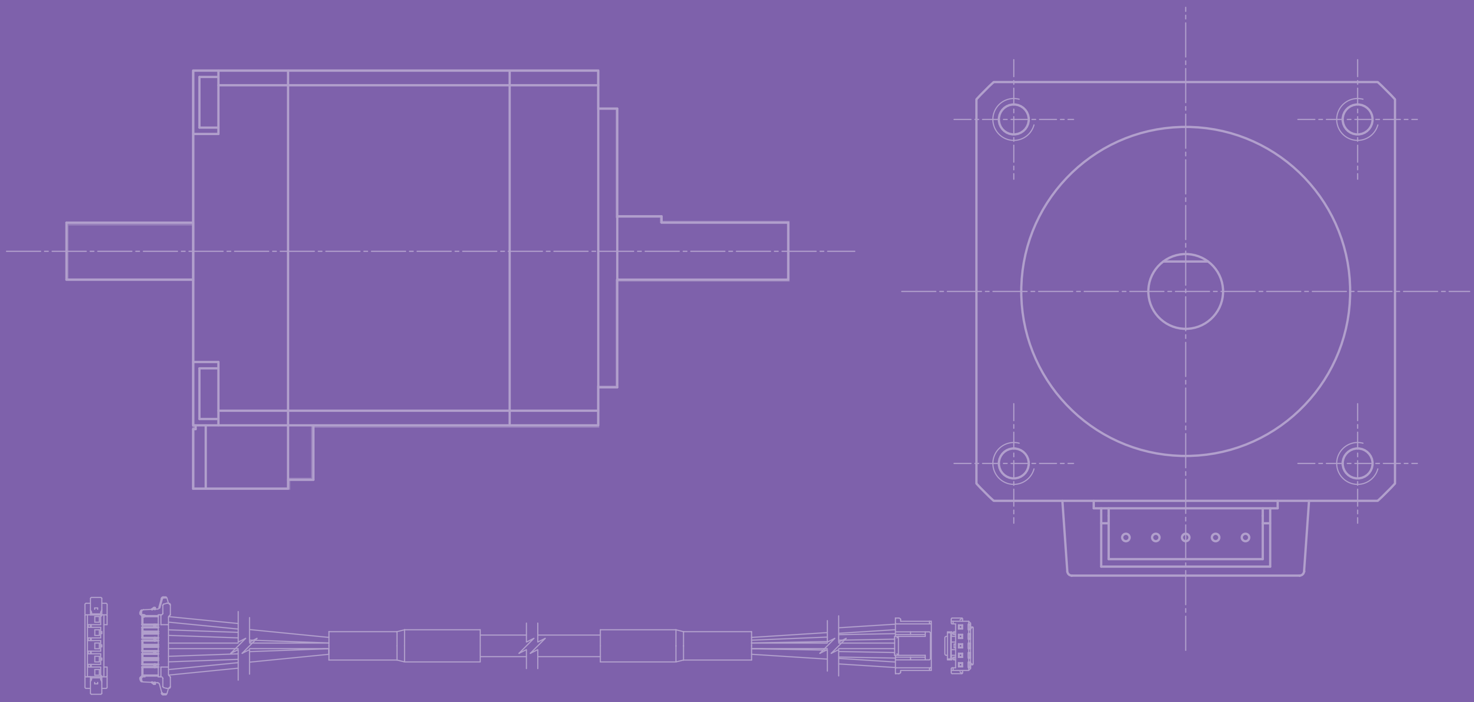


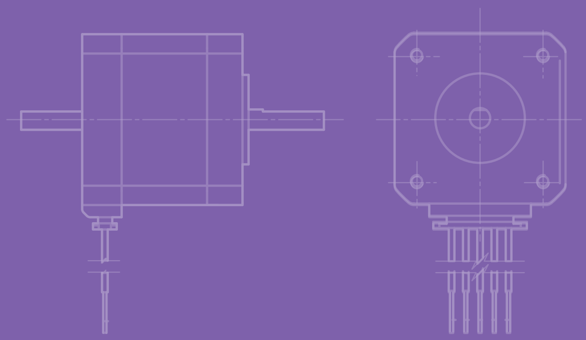
Hollow Rotary Actuators
DH Series

Hollow/Simple Wiring

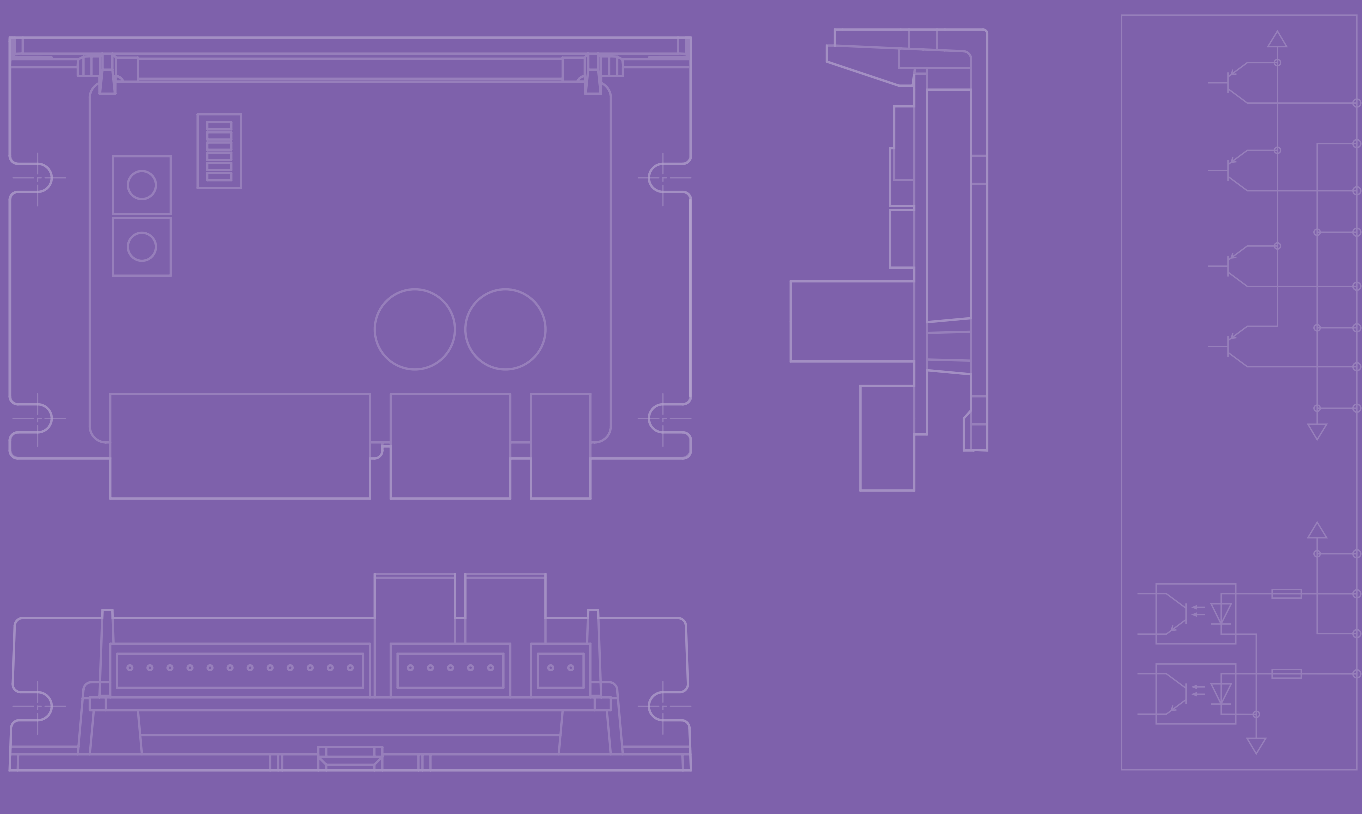
Compact Electric
Cylinders
DRLII Series

Linear Drive





Technical Information



2-Phase and 5-Phase

About 2-Phase and 5-Phase Products

Stepper motors are widely used not only for factory automation but also for equipment sold as devices because of their ability to provide high precision positioning and speed control through the use of open loop control. Among these, 2-phase stepper motors are used in large numbers, partly because it is easy to create custom circuits.

In addition to 2-phase, stepper motors are also available in 3-phase, 4-phase and 5-phase. Although 2-phase motors are most commonly used in the market, motors with a large number of phases, such as 5-phase motors, are used by many customers because they can provide characteristics that cannot be achieved with 2-phase motors.

5-phase stepper motors have the following features.

- Low vibration
- Stopping accuracy is high Stopping accuracy does not get worse with microstep drive.

These kinds of advantages can be achieved by reducing torque fluctuations during excitation switching, thanks to the large number of phases of the motor.

Number of Phases and Motor Characteristics

For motors of the same size, the maximum holding torque remains almost the same even when the number of phases is changed.

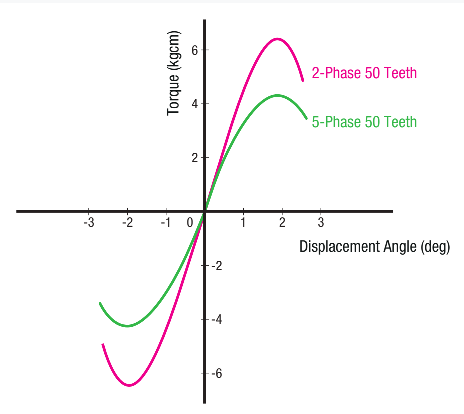


Fig. 1 Angle – Torque Characteristics

However, because the traveling amount per step is π/n for the electromagnetic angle, the ripple of the composite torque during operation varies greatly, as shown in Figs. 2 and 3. Then, if the value of the valley of this ripple is T_g, this is the maximum torque that can be applied during low speed operation.

The angle – torque characteristic can be approximated by a sine wave, in which case the following equation holds between the maximum holding torque: T_H and the value of the ripple trough: T_g.

$$T_g = T_H \cos\frac{\pi}{2n} = \gamma \cdot T_H$$

(However, $= \cos\frac{\pi}{2n}$)

The maximum effective operating torque: T_e is defined by the following equation using the average torque while the rotor moves one step: θ_S.

$$T_e = \frac{2n}{\pi} \cdot T_H \sin\frac{\pi}{2n} = k \cdot T_H$$

$$(\text{However, } k = \frac{2n}{\pi}\sin\frac{\pi}{2n})$$

Table 1 shows the values of γ and k for different number of phases: n. Based on this, the larger the number of phases: n, the closer both the ripple trough torque: T_g and the maximum effective operating torque: T_e are to the maximum holding torque: T_H, and the higher the efficiency of torque generation. However, when considering the case of 6-phase instead of 5-phase, the number of switching components required is proportional to the number of phases, even though the change in the values of γ and k is negligible. In addition, winding workability becomes poor, so the improvement of motor characteristics based on the number of phases is considered to be maximized at 5 phases.

Table 1 Number of Phases: Values of γ and k for n

Number of Phases: n	Γ ($T_g=\gamma \cdot T_H$)	K ($T_e=k \cdot T_H$)
2	0.71	0.90
3	0.87	0.95
4	0.92	0.97
5	0.95	0.98
6	0.97	0.99

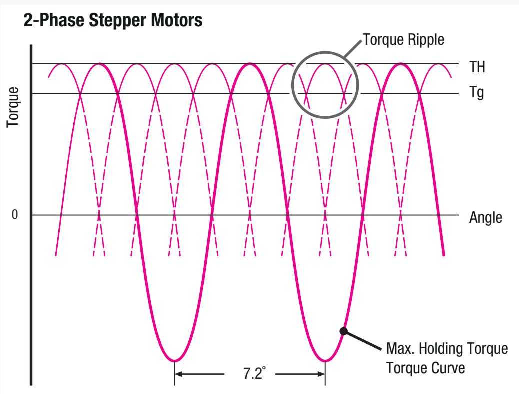


Fig. 2 Angle – Torque Characteristics Ripple (1.8°/step)

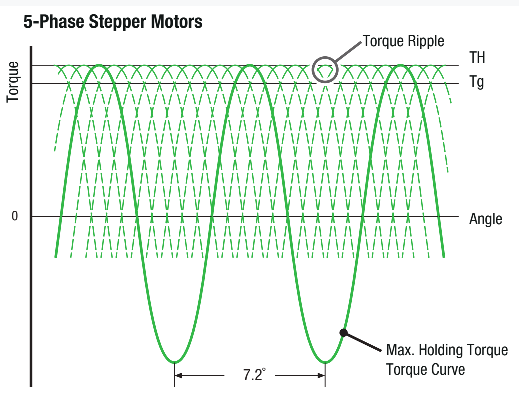


Fig. 3 Angle – Torque Characteristics Ripple (0.72°/step)

Another feature of motor characteristics when increasing the number of phases: n is that torque fluctuations can be reduced when half step drive is used. Table 2 shows the maximum holding torque T_n and T_{n-1} and their ratio T_{n-1}/T_n for 1-phase excitation.

Table 2 Maximum Holding Torque

Number of Phases	T_n	T_{n-1}	T_{n-1}/T_n
2	1.41	1.00	0.71
3	2.00	1.73	0.87
4	2.61	2.41	0.92
5	3.24	3.08	0.95
6	3.86	3.73	0.97

As can be seen, the torque fluctuation during half step drive for a 2-phase stepper motors has been reduced from 29% to 8% with a 4-phase motor and 5% with a 5-phase motor.

Figs. 4 and 5 show the $\theta-T$ characteristics of 2-, 4-, and 5-phase stepper motors with n-phase excitation and n-1 phase excitation.

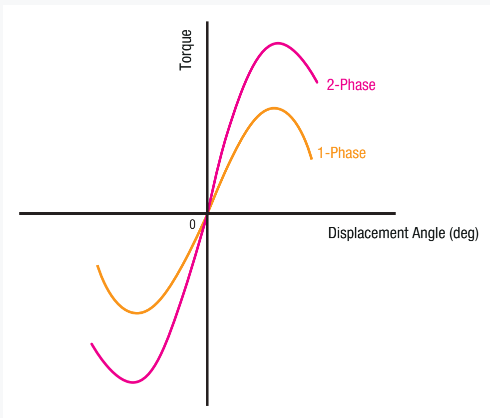


Fig. 4 2-Phase Stepper Motors

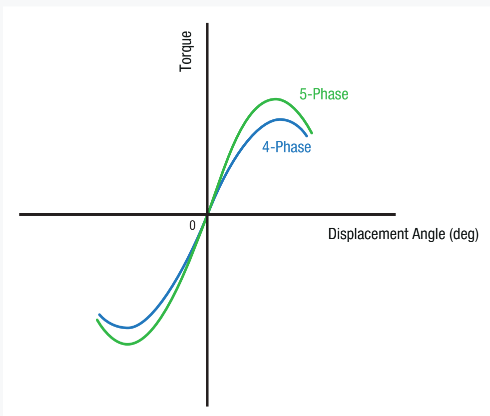


Fig. 5 5-Phase Stepper Motors

In the case of 4-phase and 5-phase stepper motors, torque fluctuation is small and angle fluctuation per step is also small when a load is applied. Thus, the difference in the number of phases of the motor manifests itself as a difference in torque ripple and torque (angle) fluctuation during half step drive, which in practical use results in differences in vibration, operating torque, and standstill accuracy.

In other words, by using a motor with a higher phase count, a smaller size motor can be used for driving, thus reducing the size of the set. At the same time, it also enables improvements in vibration reduction and increased precision.

However, as mentioned above, increasing the number of phases does face restrictions in terms of machining, and the rate of characteristics improvement is also smaller.

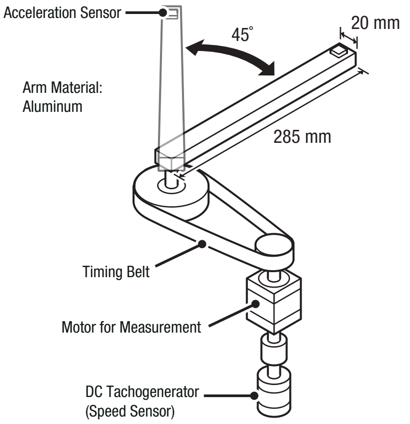
For these reasons, 5-phase is considered optimal for the number of motor phases.

Differences in Positioning Time (Reference Case)

When driving a load, not only the theoretical positioning time but also the time required for residual vibration in the mechanism to subside may be considered. Examples of actual measurements with a 2-phase stepper motor and a 5-phase stepper motor are shown below.

◆ Measurement Mechanism Specifications

Using the arm mechanism as an example, the positioning times under different conditions and with different motors were compared.



Mechanisms Used

Large Pulled Diameter: ϕ60 mm
Small Pulled Diameter: ϕ20 mm
Thickness 11 mm
Material: Aluminum
Gear Ratio: 3:1

Fig. 6 Mechanism for Measurement

◆ Motors Used

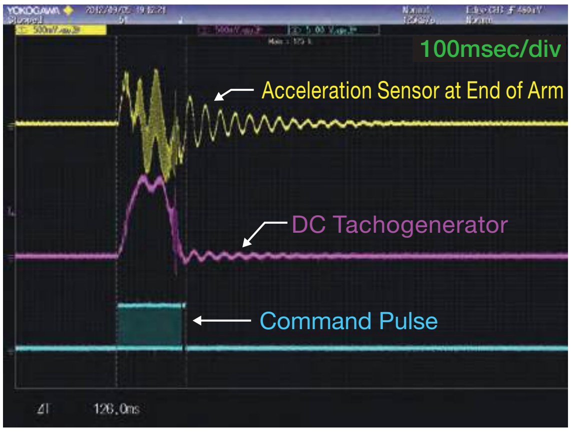
① 2-Phase Stepper Motor
- Frame Size: 42 mm
- Basic Step Angle: 1.8°
- Series Bipolar Wiring
- 24 VDC, 0.84 A/Phase
- Step Angle: 0.1125°
- No Damper
- Inertia Ratio: 13 times

② 5-Phase Stepper Motor
- Frame Size: 42 mm
- Basic Step Angle: 0.72°
- 24 VDC, 0.75 A/Phase
- Step Angle: 0.036°
- No Damper
- Inertia Ratio: 12.5 times

③ 5-Phase Stepper Motor
- Frame Size: 42 mm
- Basic Step Angle: 0.36°
- 24 VDC, 0.75 A/Phase
- Step Angle: 0.036°
- No Damper
- Inertia Ratio: 12 times

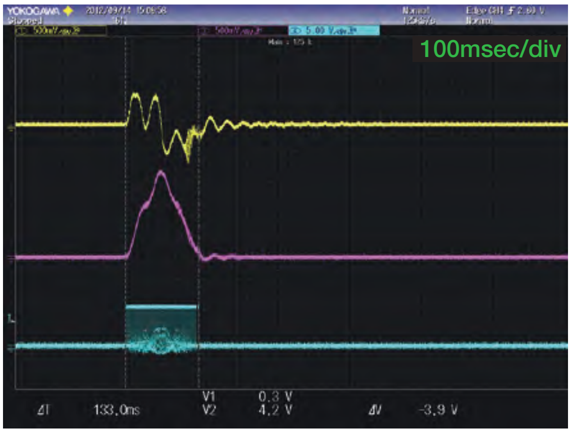
Measurement Results

①2-Phase Stepper Motor



· Positioning Time: 126ms
· Positioning Time including Residual Vibration: Approx. 500 ms

②5-Phase Stepper Motor Basic Step Angle: 0.72°



· Positioning Time: 133ms
· Positioning Time including Residual Vibration: Approx. 250 ms

③5-Phase Stepper Motor Basic Step Angle: 0.36°

· Positioning Time: 127ms
· Positioning Time including Residual Vibration: Approx. 150 ms

Fig. 7 Differences in Positioning Time (Measured Value) including Residual Vibration

Wiring – Unipolar and Bipolar

Drive System and Wiring Method

Oriental Motor offers stepper motors with bipolar wiring and unipolar wiring. Changing the wiring of a stepper motor will change the torque characteristics of the motor. By using a 6-lead wire stepper motor and differentiating between half-coil wiring when torque is desired in the high-speed range and series wiring when torque is desired in the low-speed range, the number of individual motor inventory types can be reduced.

Oriental Motor also offers a wide product line of standard stepper motor products. Compared to custom-order products, the standard products offer superior delivery timing and cost. Therefore, it is desirable that the motors used in equipment be standard products.

However, if the torque characteristics of standard products do not meet the equipment requirements, custom-order products are also available.

Unipolar and Bipolar

The differences in torque characteristics due to differences in the drive system and wiring method (assuming the stepper motors have the same frame size and L dimension) are shown below.

Details of the features, advantages and disadvantages of each method are explained in the following sections.

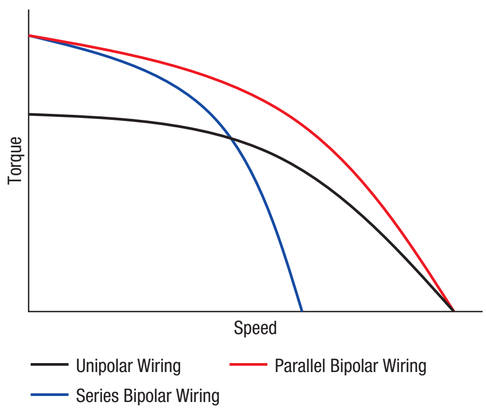


Fig. 1 Differences in Torque Characteristics Based on Wiring

Unipolar Drive

Features

This is commonly used because the direction of the excitation current is unidirectional and the circuit configuration is simple.

Advantages: Circuit configuration is easy

Disadvantages: For the two-phase excitation mode, only half of the motor windings are used, which does not achieve the motor's full characteristics.

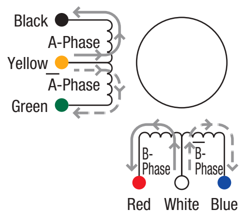


Fig. 2 Inner Wiring Diagram

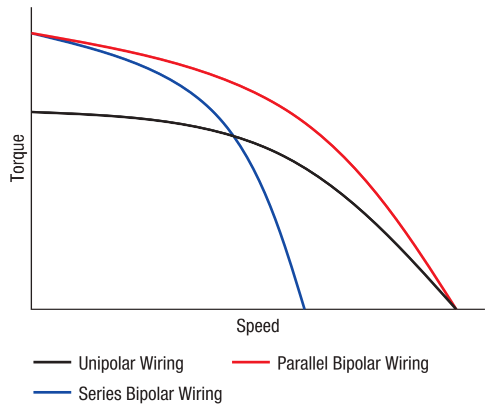


Fig. 3 Differences in Torque Characteristics Based on Wiring

Wiring

In unipolar drive, only half of the current flows through the motor windings.

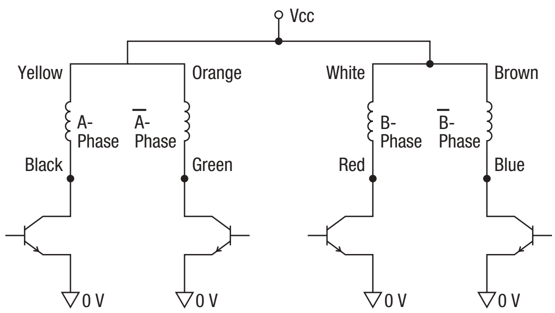


Fig. 4 Wiring

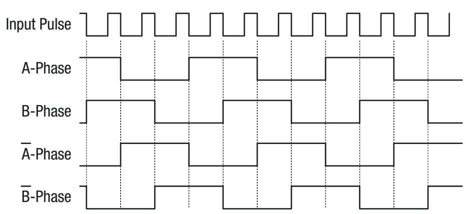


Fig. 5 Sequence Example

Bipolar Drive

● Features

The direction of the excitation current is bidirectional, positive and negative, and the motor windings are effectively used to output greater torque at lower speeds than unipolar drives.

Advantages: Compared to unipolar drive a large amount of torque is output at low speeds.
Since the number of winding phases is half that of unipolar drive, angle errors caused by winding variations are small.

Disadvantages: The doubling of the windings increases the time constant, resulting in lower torque at high speeds.
Because 4 switching components are needed for each phase, the drivers are expensive.

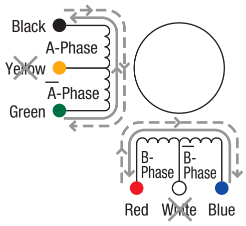


Fig. 6 Inner Wiring Diagram

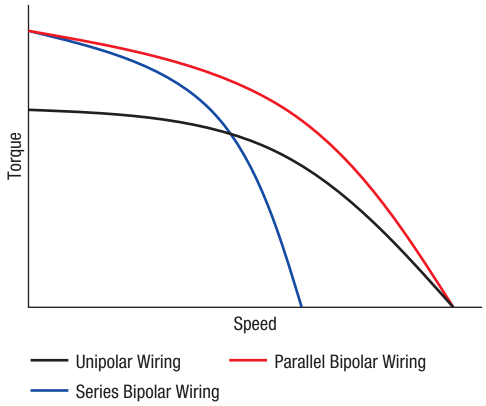


Fig. 7 Differences in Torque Characteristics Based on Wiring

● Bipolar Drive Wiring

① Bipolar, Parallel Wiring (Parallel Bipolar Wiring)

Resistance value is 1/2 compared to unipolar drive and the number of turns in the windings is the same.

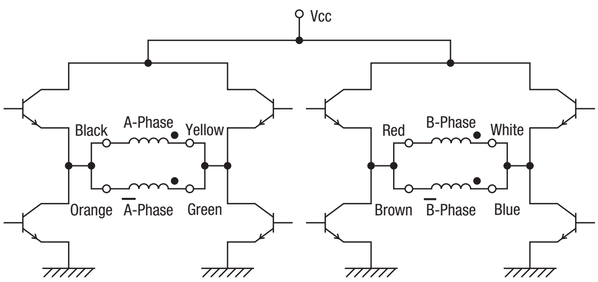


Fig. 8 Wiring

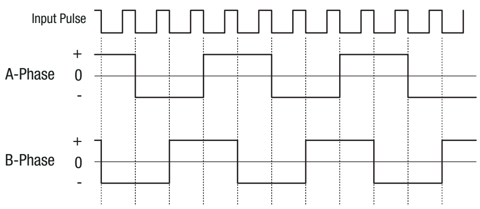


Fig. 9 Sequence Example

② Bipolar, Serial Wiring (Series Bipolar Wiring)

Resistance value is twice as large compared to unipolar drive and the number of turns in the windings is also doubled.

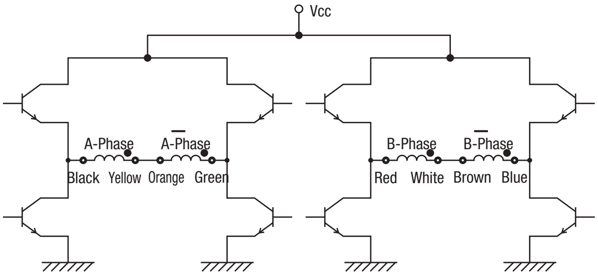


Fig. 10 Wiring

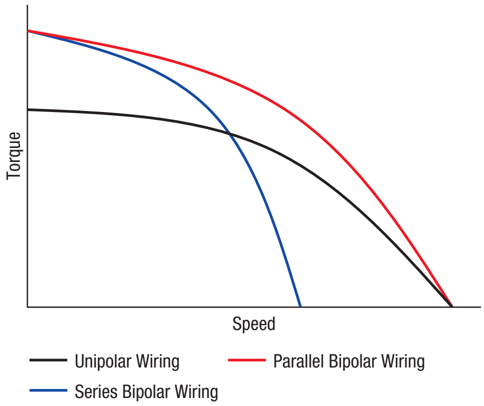


Fig. 11 Differences in Torque Characteristics Based on Wiring

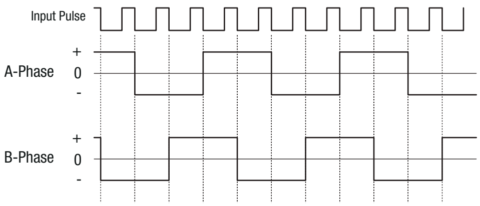


Fig. 12 Sequence Example

③ Bipolar, Half Wiring (Half Coil Bipolar Wiring)

Resistance value and number of turns on the windings is the same as unipolar drive.

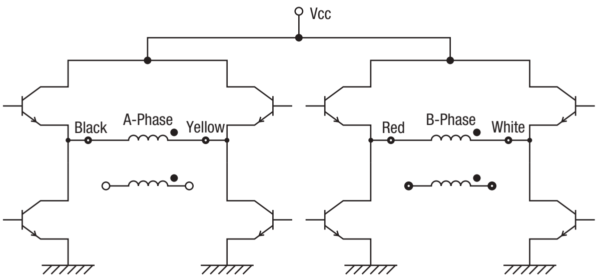


Fig. 13 Wiring

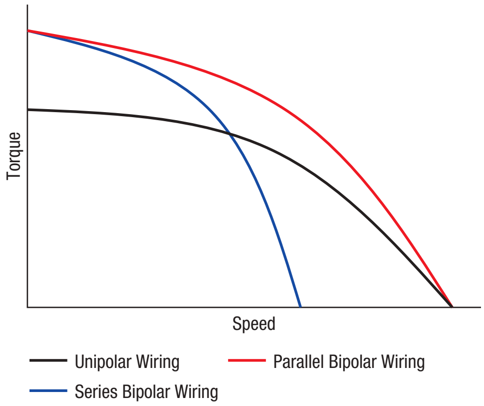


Fig. 14 Differences in Torque Characteristics Based on Wiring

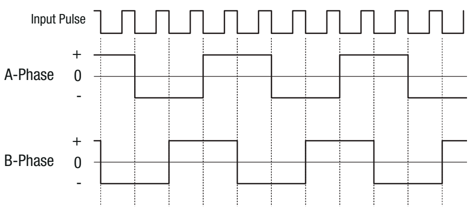


Fig. 15 Sequence Example

Relationship between Torque and Windings

Motor torque is proportional to the current and the number of turns of the windings. This is explained below.

◆ Relationship between Motor Drive Current and Torque

$T \propto I \cdot t$	T : Motor Torque I : Drive Current (A) t : Number of turns of the windings

The higher the motor drive current, the higher the torque. In reality, however, drive current and torque do not have a proportional relationship, and torque tends to saturate (Fig. 17). This is due to the magnetic properties of the magnetic steel sheets. As the drive current increases, the increase in torque becomes smaller. Note that the drive current should not exceed the rated current, since a larger drive current will cause the motor to generate more heat.

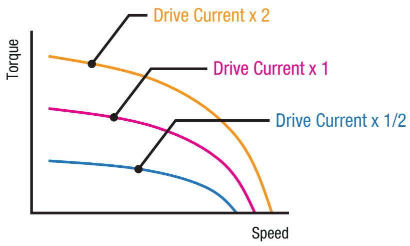


Fig. 16 Relationship between Drive Current and Torque Characteristics

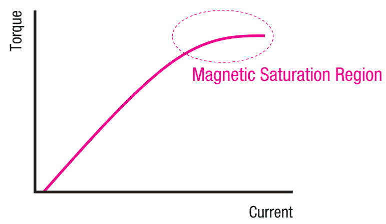


Fig. 17 Relationship between Drive Current and Maximum Holding Torque

◆ Relationship between Number of Winding Turns and Torque

As the number of winding turns increases, the higher the torque at startup, but the lower the torque at high speed. The lower the number of turns, the lower the starting torque, but the higher the torque at high speed.

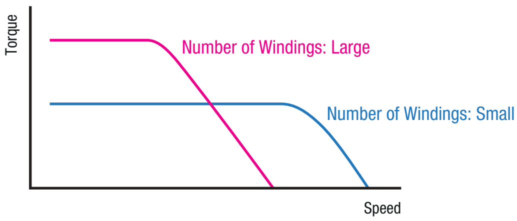


Fig. 18 Difference in Torque Characteristics Due to Different Number of Winding Turns

Difference in Characteristics Due to Winding Specifications

Oriental Motor includes a number indicating the rated current in the motor product name. Even when the motor size is the same, if the rated current is different, the torque characteristics will also differ.

In this example, the number of windings is adjusted so that the ampere-turns are the same, although the rated currents are different. Therefore the maximum holding torque is the same for both.

Table 1 For **PKP266** Type

	Motor Winding Specifications			Power Consumption (I^2R)	Motor Winding Specifications		Ampere-Turn A×T	Maximum Holding Torque
	Voltage [V]	Resistance [Ω/Phase]	Rated Current [A/Phase]		Wire Diameter	Number of Windings (Tentative)		
PKP266U10A	8.1	8.1	1	8.1	Fine	30	30	1.1 N·m
PKP266U20A	4	2	2	8	Middle	15	30	1.1 N·m
PKP266U30A	2.76	0.92	3	8.28	Thick	10	30	1.1 N·m

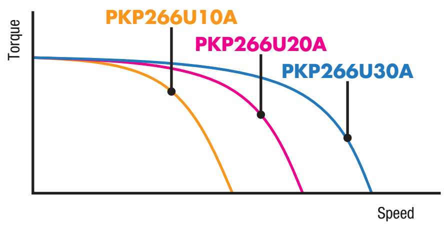


Fig. 19 **PKP266** Torque Characteristics Comparison (Illustration)

The characteristics diagram for overcurrent and for reduced number of winding turns is shown below (for reference).

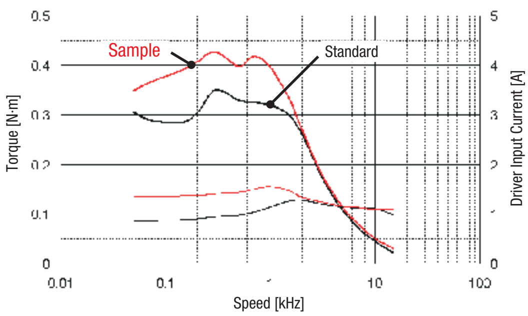


Fig. 20 Torque Characteristics When Overcurrent is Input

Example: When overcurrent is input

Standard	Sample
PKP244	**PKP244**
1.2 A/Phase specification	1.2 A/Phase specification
With damper	With damper
1.2 A/Phase input	1.55 A/Phase input

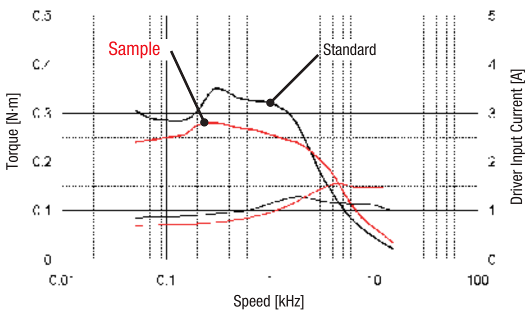


Fig. 21 Torque Characteristics When Number of Windings is Decreased

Example: When number of winding turns is decreased

Standard	Sample
PKP244	**PKP244**
1.2 A/Phase specification	1.55 A/Phase specification
With damper	With damper
1.2 A/Phase input	1.2 A/Phase input

Relationship between Voltage and Torque Characteristics

The following is an example of the difference in torque characteristics due to different voltages.

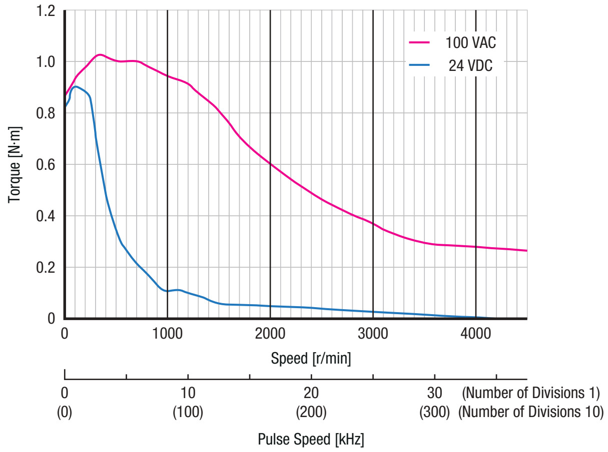
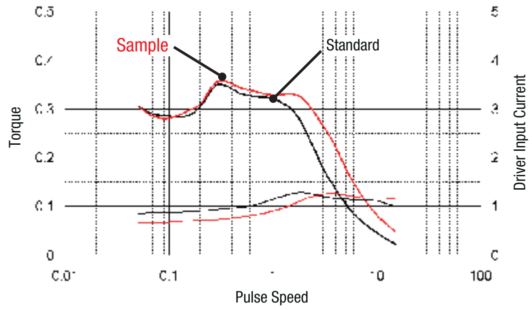


Fig. 22 Comparison of Torque Characteristics between AC Power Supply Input Type and DC Power Supply Input Type



Example: When overvoltage is applied

Standard	Sample
PKP244	**PKP244**
1.2 A/Phase specification	1.2 A/Phase specification
With damper	With damper
24 VDC Input	36 VDC Input

Fig. 23 Torque Characteristics When Overvoltage is Applied

Constant Voltage Drive and Constant Current Drive

There is a difference in torque at high speeds between constant voltage drive and constant current drive. Even for the same motor, if the drive system is different, the torque characteristics will also be different.

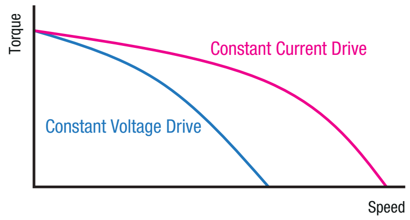


Fig. 24 **Difference in Torque Characteristics Due to Different Drive Systems**

When attempting to rotate a stepper motor at high speed, the torque will be reduced. This is because the drive current decreases as the winding impedance increases. Therefore, the constant voltage drive system provides low torque at high speed rotation.

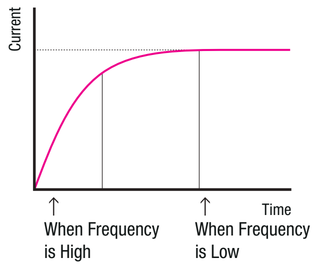


Fig. 25 **Relationship between Drive Current and Command Frequency**

On the other hand, the constant current drive system supplies a voltage higher than the rating of the stepper motor to the windings so that the drive current does not decrease and remains constant. This results in high torque even at high speeds.

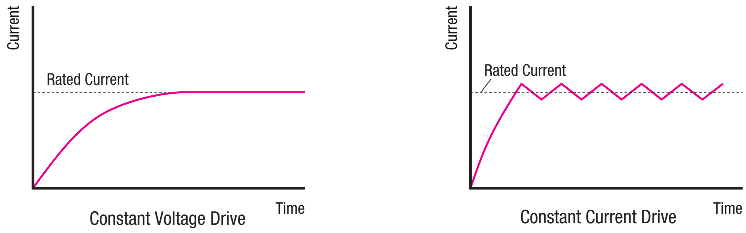


Fig. 26 **Difference in Current Rise Due to Different Drive Systems**

The higher the chopping voltage of the constant current drive, the faster the current rises, resulting in higher torque even at high speeds.

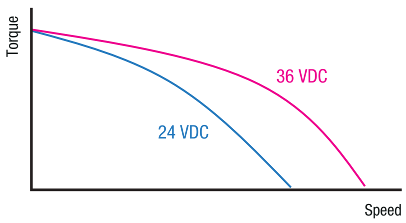


Fig. 27 **Difference in Torque Characteristics Due to Different Chopping Voltages**

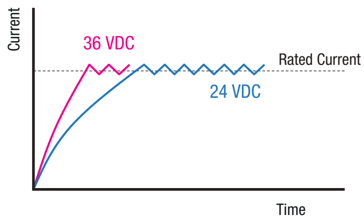


Fig. 28 **Difference in Current Rise Due to Different Chopping Voltages**

Motor Vibration Countermeasures

Motor Vibration

Stepping motors use small teeth arranged on the rotor and stator to achieve high precision positioning and speed control. On the other hand, there are cases where this mechanical structure creates vibration which requires countermeasures.

Step Response Characteristics

Many cases of vibration problems in stepper motors are caused by rotor inertia.
This factor can be seen in the single-step response characteristic.

The single-step response characteristic represents the angular displacement when the motor moves one step.
This characteristic indicates that when the stepper motor moves one step, it does not stop immediately, but rather repeatedly overshoots and undershoots.

The strength of the vibration varies according to the speed.

Low Speed Operation	Single-step response characteristics are continuous
Resonance Frequency	Large vibration due to continuous large overshoot/undershoot
High Speed Operation	Before overshoot/undershoot occur, it moves to the next step, making vibration less noticeable.

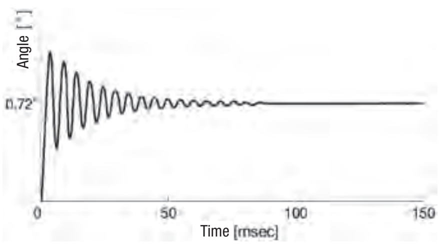


Fig. 1 Single-Step Response Characteristics
(For basic step angle 0.72°)

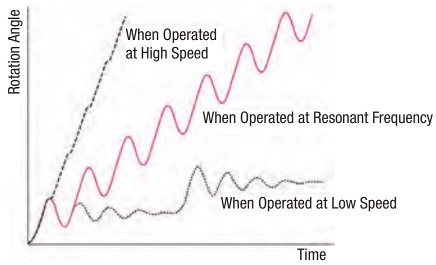


Fig. 2 Continuous Step Response Characteristics

Resonance Frequency

Vibration is greatest in stepper motors when it is amplified by resonance. The resonance frequency of a stepper motor can be calculated by the following equation.

$$f_{res} \doteqdot \frac{1}{2\pi}\sqrt{\frac{T_H Z_R}{J}}$$

T_H : Maximum holding torque
Z_R : Number of small teeth on rotor
J : Inertia

Resonance occurs at integer multiples of the resonance frequency or at integer fractions of the frequency. The magnitude of the resonance frequency is highly dependent on the torque fluctuations due to the step angle of the motor and the number of excitations between steps.

As an example, here is how to avoid resonance frequencies without changing the motor.

· Change the speed
· Change the inertia

Vibration Countermeasures Methods

In the previous section, it was explained that vibration problems can be avoided by attaching a large inertia body based on the formula for the resonance frequency. From a practical perspective, there are multiple options, including solutions that use the space inside and outside the equipment and the driver.

① Make the step angle finer
② Change from 2-phase to 5-phase motor
③ Use of geared motor
④ Reduction of drive current
⑤ Increase load inertia
⑥ Increase frictional load
⑦ Attach a damper

◆ ① Make the step angle finer

By making the step angle finer, the angular displacement (amplitude of vibration) per step is reduced.

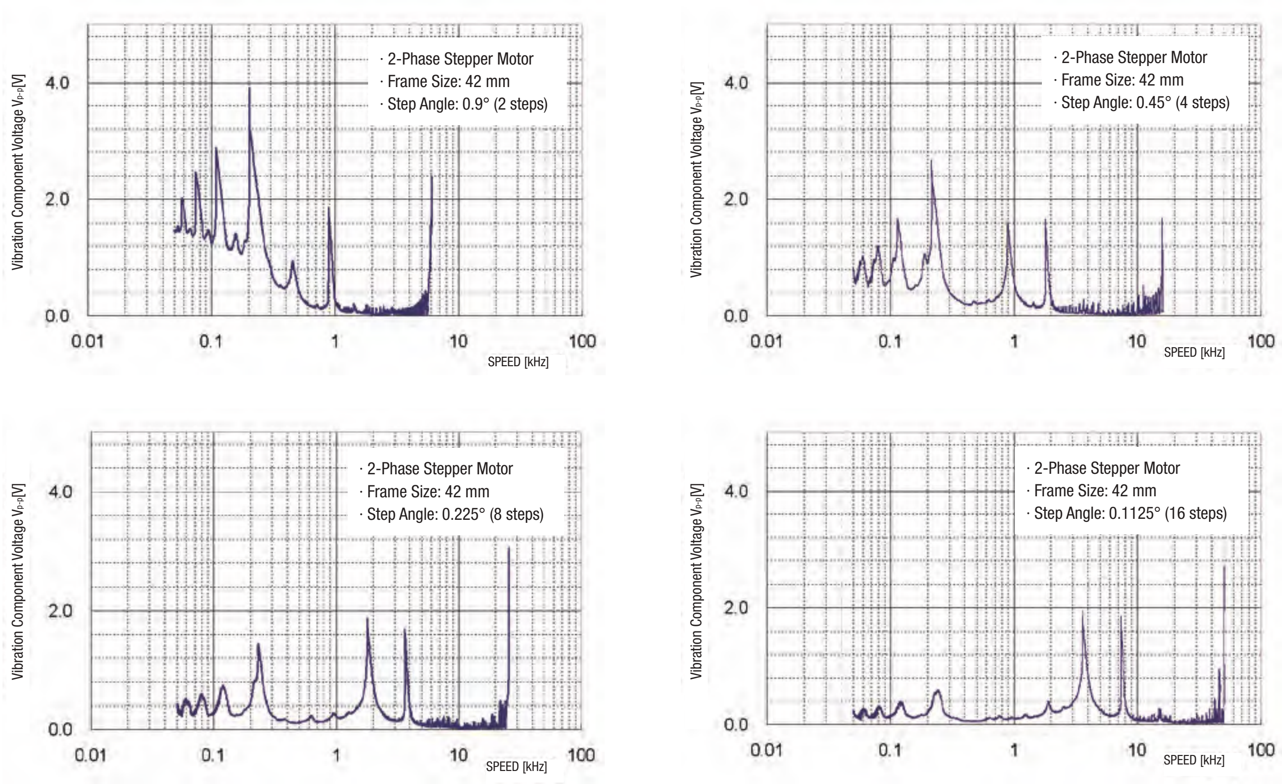


Fig. 3 Step Angle and Vibration Characteristics

◆ ② Change from 2-phase to 5-phase motor

5-phase stepper motors have a finer basic step angle than 2-phase motors, resulting in a smaller amount of vibration.

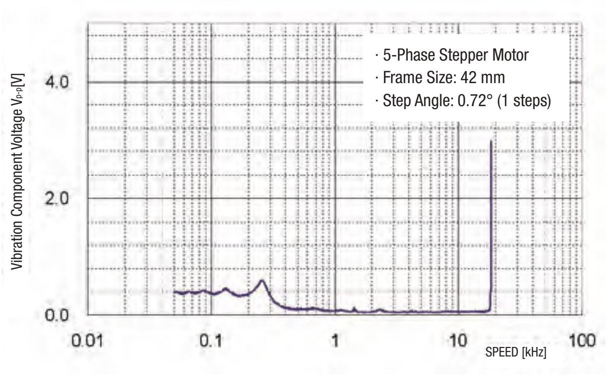


Fig. 4 5-Phase Motor Vibration Characteristics

◆ ③ Use of geared motor

Geared motors have lower vibration because the gearhead reduces the vibration of the output shaft of the assembled motor.

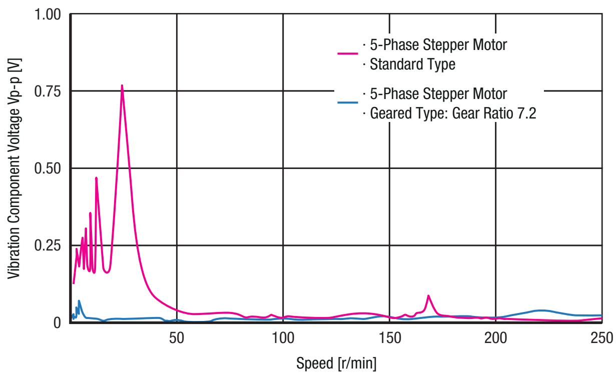


Fig. 5 Vibration When Using Geared Motors

◆ ④ Reduction of drive current

If the torque margin of the motor is too large, it may cause vibration.

✻Torque margins must be reconfirmed.

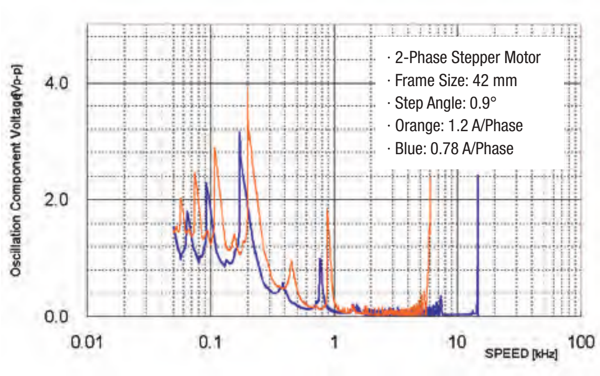


Fig. 6 Drive Current and Vibration Characteristics

◆ ⑤ Increase load inertia

Changing the inertia applied to the motor changes the resonance frequency.

✻Reconfirmation of torque margin is required due to changing load conditions.

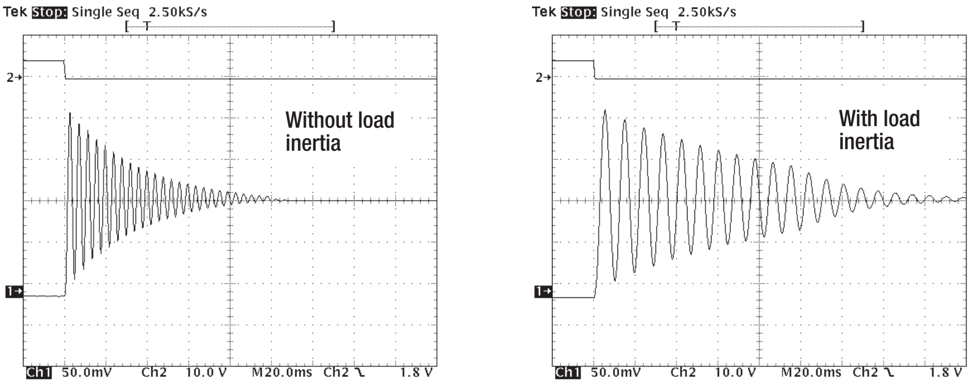


Fig. 7 Single-Step Response Characteristics When Load Inertia is Applied

◆ ⑥ Increase frictional load

Adding frictional load can speed up vibration damping.

✻Reconfirmation of torque margin is required due to increased load torque.

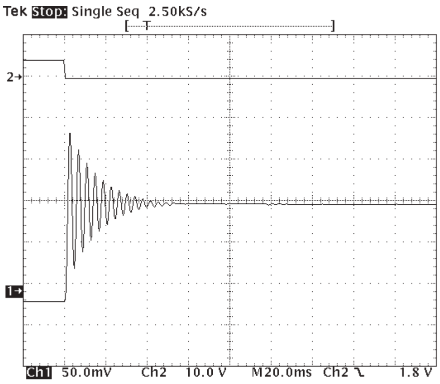


Fig. 8 Single-Step Response Characteristics When Frictional Load is Applied

2-Phase and 5-Phase
Wiring - Unipolar and Bipolar
Motor Vibration Countermeasures
Motor Heat Generation Countermeasures
Detent Torque
Torque Characteristics and Operating Pattern

◆ ⑦ Attach a damper

Even if a stepper motor is controlled by the constant current method, as the rotation speed increases, sufficient voltage cannot be applied to the motor due to the reverse voltage of the motor. This makes the constant current control unstable and the motor prone to vibration. By using a clean damper, this vibration can be reduced. Vibration reduction can also be achieved in the low-speed range.

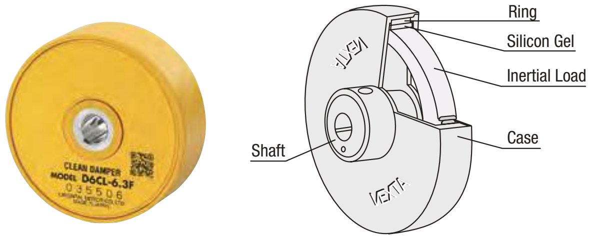


Fig. 9 View and Structure of Clean Damper

● Damper Effects

- Can reduce vibration
- Torque characteristics are improved (mainly in the mid- to high-speed range) because missteps caused by vibration can be avoided.

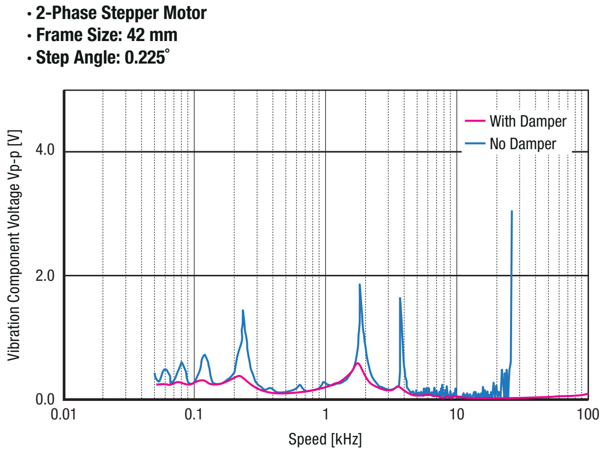


Fig. 10 Vibration Characteristics Comparison

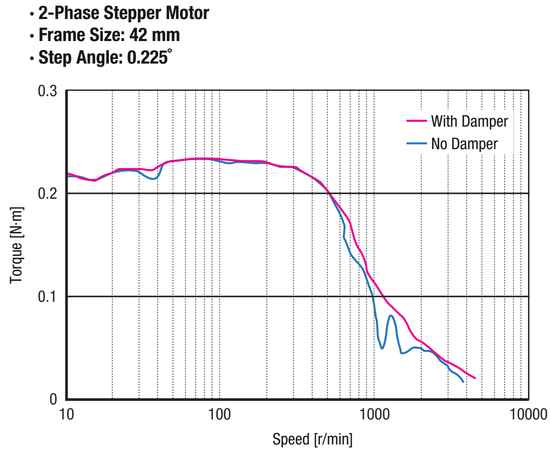


Fig. 11 Torque Characteristics Comparison

● Damper Features

- Superior Vibration Absorbing Effect
  The internal inertia body absorbs vibration energy.

- Clean Response
  Abrasion debris and dust is not created, making it safe to use in environments where cleanliness is required.

- Applicable to Double Shaft Types
  Can be used on double shaft type stepper motors.

When Vibration Noise is a Problem

If the motor is installed on a large mounting plate, for example, the mounting plate may reverberate the vibration sound like a speaker. In this case, vibration noise may be reduced by inserting anti-vibration rubber between the motor and the mounting plate.

Motor Heat Generation Countermeasures

Temperature Rise

Stepper motors can have a large temperature rise depending on the frequency of starting and stopping and the conditions of the operating cycle (rotation speed, operating time, and stopping time). To prevent degradation of the insulation on the motor windings, the surface temperature of the motor case must be kept below 100°C.

● Saturation Temperature Rise

If the motor continues to run in a constant operating pattern, the temperature rise stops and a constant temperature is reached. The difference between the windings temperature and ambient temperature at this time is called the saturation temperature rise.

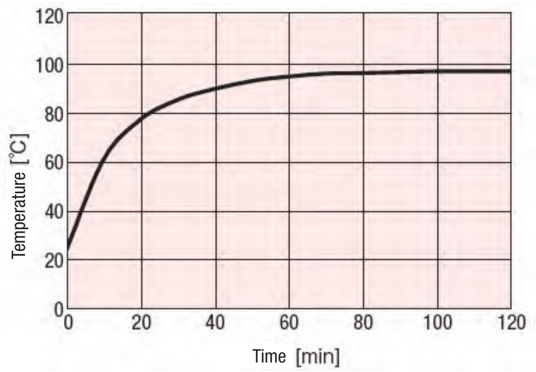


Fig. 1 Temperature Rise Characteristics

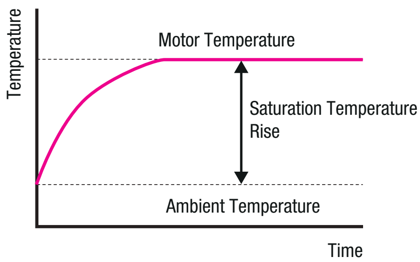


Fig. 2 Saturation Temperature Rise

Temperature Rise Countermeasures

This section describes methods to reduce the temperature rise of stepper motors.

- Adjustment of operating current and current at motor standstill
- Increase motor size
- Use high torque motor
- Adjustment of operating duty
- Re-examine heat sinks
- Use powerful cooling fans
- Use electromagnetic brake motor

Adjustment of Operating Current and Current at Motor Standstill

Lowering the current flowing through the motor during operation (operating current) reduces the temperature rise.

- Reducing the operating current helps provide energy-saving effects.
- Motor torque decreases when the operating current is decreased.
  Make adjustments after confirming the required torque. Because the holding force is also decreased when the current at motor standstill is decreased, this must also be checked.

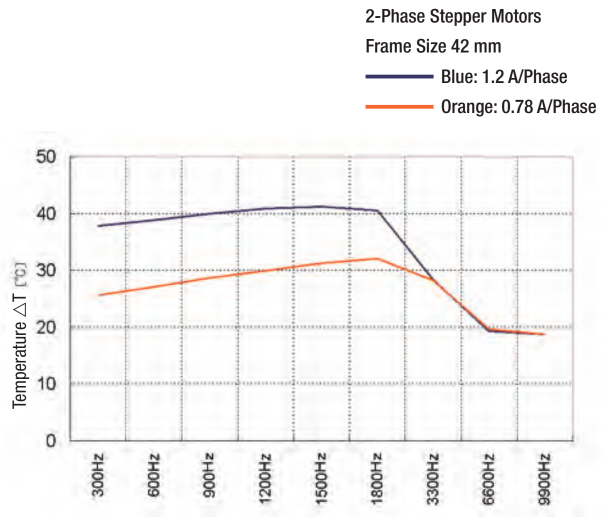


Fig. 3 Change in Motor Temperature Due to Adjustment of Operating Current

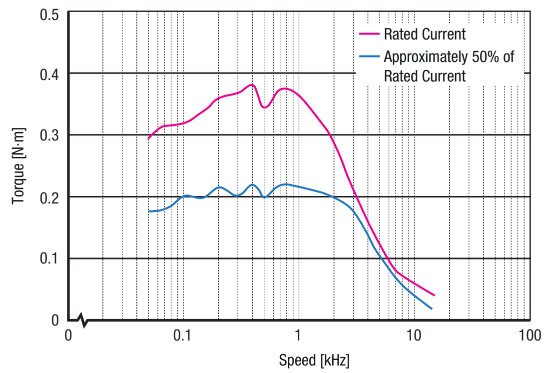
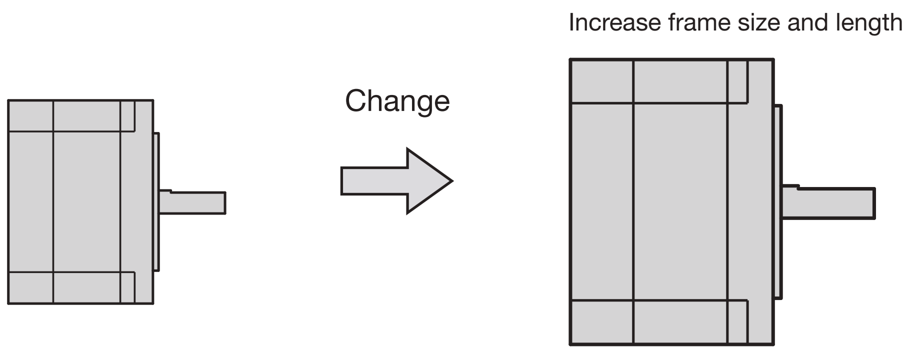


Fig. 4 Relationship between Operating Current and Torque Characteristics

Increase Motor Size

Temperature rise can be reduced by operating at a lower current than the rated current.

- Reducing the operating current helps provide energy-saving effects.



Rated Current: 1 A/phase
Rated Torque: 0.5 N·m
Operating Current: 1 A/phase (100% of rating)
Generated Torque: 0.5 N·m

Rated Current: 1 A/phase
Rated Torque: 10 N·m
Operating Current: 0.5 A/phase (50% of rating)
Generated Torque: 0.5 N·m

Fig. 5 Change of Motor Size

Use High Torque Motor

The **PKP** Series uses the latest design technology to achieve high torque by optimizing the iron plate design, increasing the occupancy ratio of the windings, and employing high flux magnets. By changing from a conventional motor, torque can be increased.

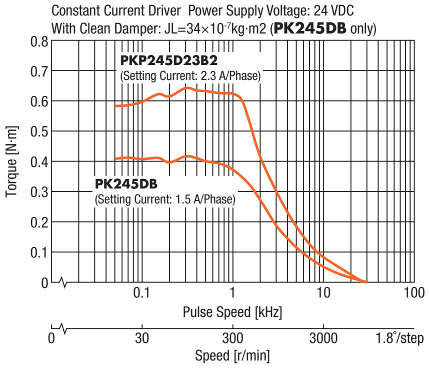


Fig. 6 Comparison of Speed – Torque Characteristics of the Same Size Motors

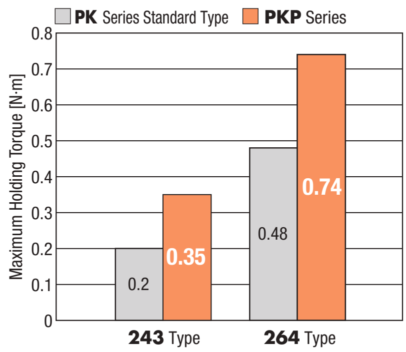
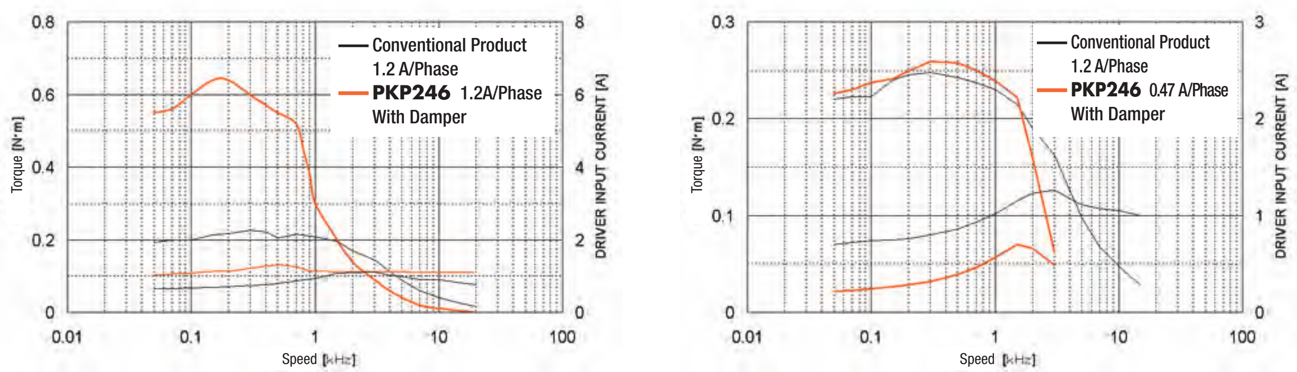


Fig. 7 Comparison of Maximum Holding Torque

Even with motors of the same frame size, the maximum torque that can be generated varies depending on the length of the motor. Temperature rise can be reduced by using a motor with extra maximum torque and reducing the operating current so that the torque is the same as that of the motor currently used.



Torque Characteristics at Rated Current Setting

Torque Characteristics When Operating Current is Reduced

Fig. 8 Change in Torque Due to Adjustment of Operating Current

It has been shown that operating the same motor with the same frame size (42 mm) at the same torque leads to a reduction in temperature rise of approximately 20°C (Fig. 10).

- Lower temperatures will prolong the life of the motor bearings.

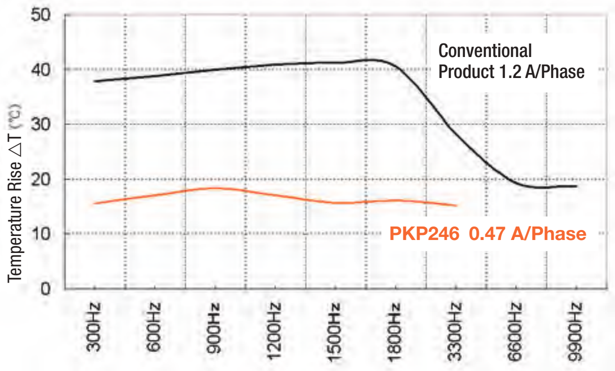
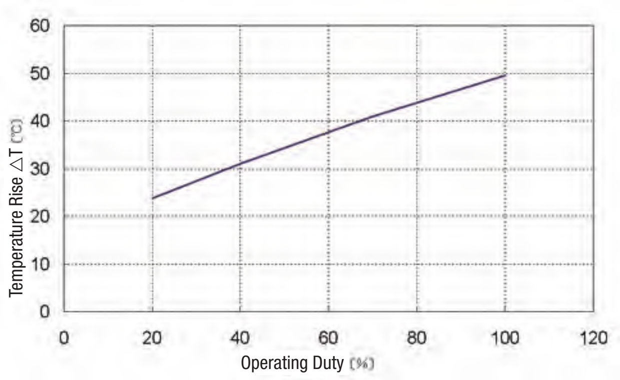


Fig. 9 Change in Temperature Due to Adjustment of Operating Current

Adjustment of Operating Duty

Longer stopping times can reduce temperature rise.

$$[\text{Operating duty}] = \frac{[\text{Running time}]}{[\text{Running time}] + [\text{Stopping time}]} [\%]$$



· 2-Phase Stepper Motor Frame Size 42 mm
· Heat Sink Size: 115 mm × 115 mm × 5 mm thick
· Operating Current 1.2 A/Phase
· Stop Current 0.48 A/Phase

Fig. 10 Operating Duty – Temperature Rise Characteristics

Re-Examine Heat Sinks

Generally, the mounting portion of the device acts as a heat sink. The following three items are the key points for improving heat dissipation.

- Increase the volume (increase the thickness of the heat sink)
- Expand surface area (make it uneven and increase the area in contact with the air)
- Change heat sink materials

Use Powerful Cooling Fans

Motor heat can be exhausted by the use of fans.

Use Electromagnetic Brake Motor

A power off activated type electromagnetic brake is equipped. Therefore, the load can be held without supplying current at standstill. This is effective when the interval between motor movements is large, such as when a load is inspected or machined for long periods of time.

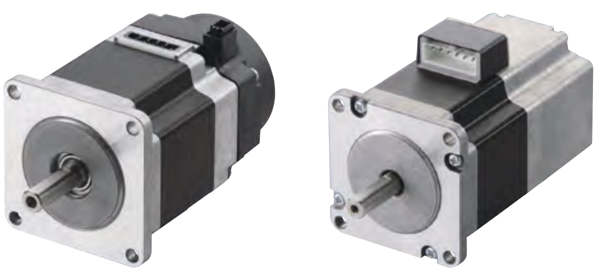


Fig. 11 **PKP** Series Type with Electromagnetic Brake

Detent Torque

What is Detent Torque

Detent torque is the torque that is generated even when zero current is flowing due to the action of the magnet in the rotor. If the shaft is moved by hand while the motor is not excited, it will not rotate smoothly and there is a reactive force. Detent torque may be utilized as a holding force.

Example of θ-T Characteristic Measurement and Detent Torque

Fig. 1 shows the θ-T characteristics measured for the excitation of a 2-phase stepper motor at several different current levels. Because torque is roughly proportional to current, curves with different amplitudes are displayed superimposed. The red line shows the characteristics for 2-phase excitation and the blue line shows the characteristics for 1-phase excitation. The black line shows the detent torque. The maximum torque for 2-phase excitation is the holding torque (T_H).

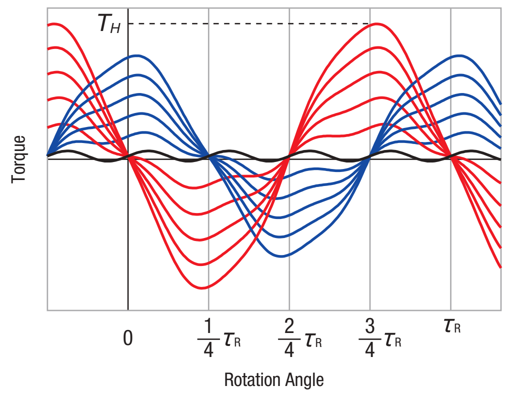


Fig. 1 θ-T Characteristics When Current is Changed

Fig. 2 shows only detent torque measured for 1 rotation. The roughly constant offset is the result of losses occurring in the motor, mainly due to hysteresis losses in the iron core. The fine fluctuations are due to slight imbalances in the suction force of the small teeth.

The demands for detent torque are two-fold: when it is used as a simple brake, larger is better, but because it can also be regarded as a loss, smaller is also better. For example, if a geared motor is used, or if the speed reduction ratio on the mechanism side is large, the detent torque will be large. In such cases, they may be used as simple brakes.

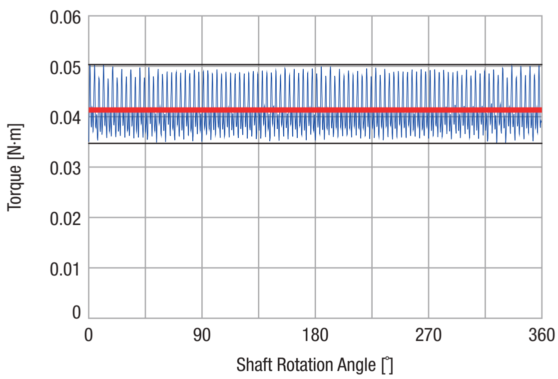


Fig. 2 Detent Torque Example

Torque Characteristics and Operating Pattern

Speed – Torque Characteristics

Pull-in Torque and Pullout Torque

There are two types of torque characteristics of stepper motors: pull-in torque (start/stop region) and pullout torque (slew region). To operate a stepper motor in the slew region, it must initially start in the start/stop region and then gradually increase its rotational speed. This is called acceleration/deceleration operation (trapezoidal operation). On the other hand, in the start/stop region, no acceleration/deceleration time is required, so it can start and stop instantly. This is called self-start operation (rectangular operation).

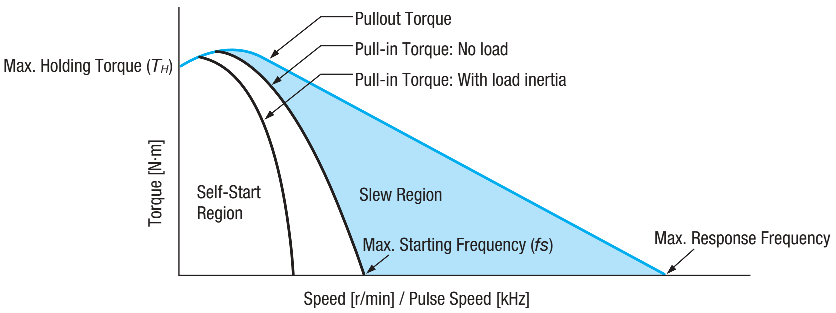


Fig. 1 Speed – Torque Characteristics

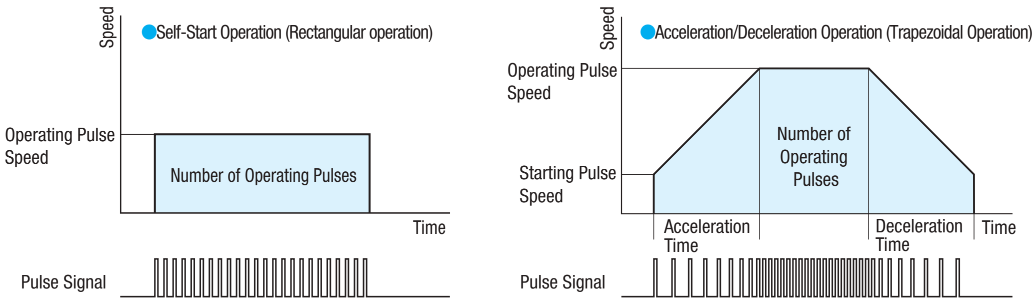


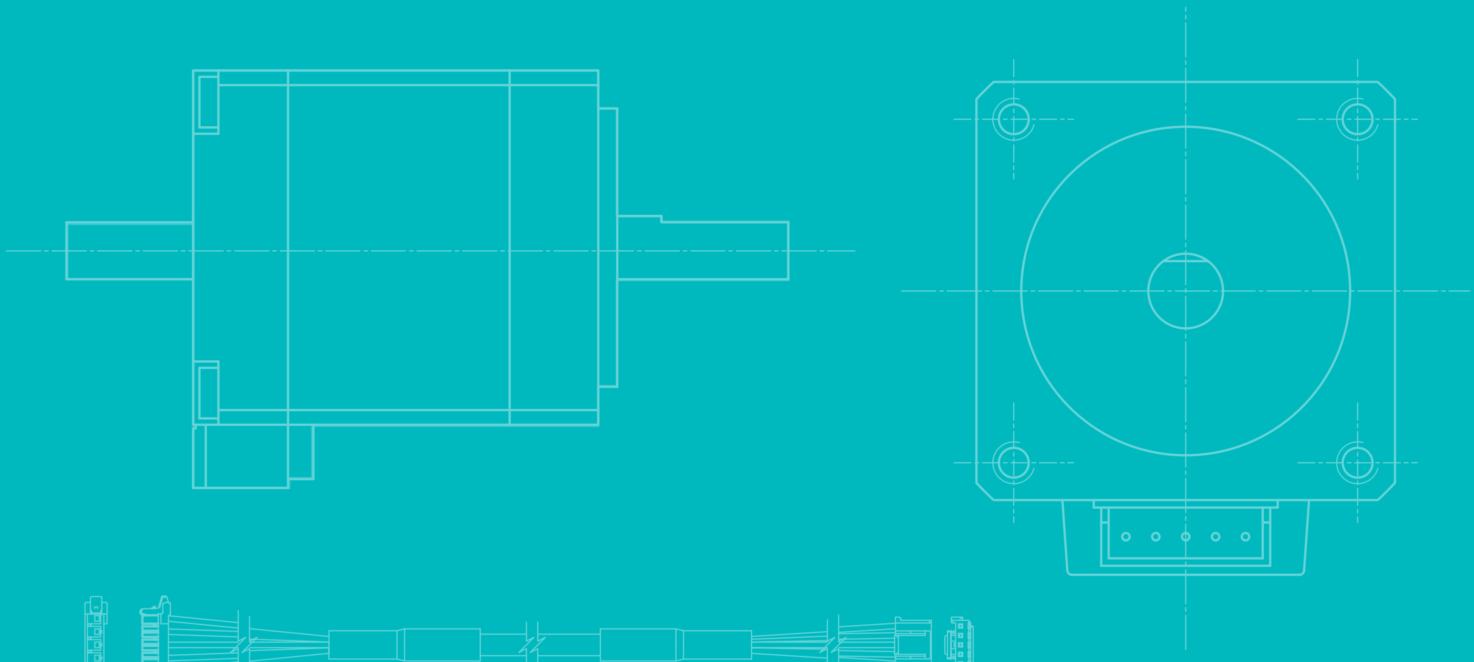
Fig. 2 Self-Start Operation (Rectangular Operation) and Acceleration/Deceleration Operation

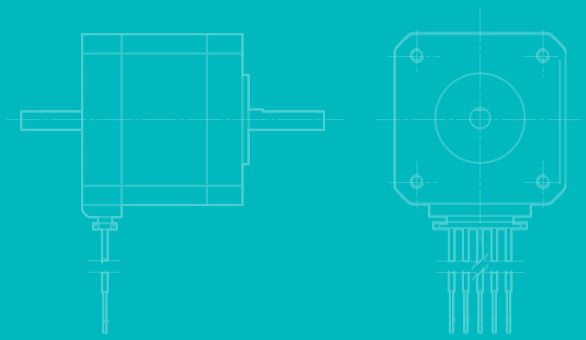
About Self-Start Operation (Rectangular Operation)

The maximum speed possible for a start at no load is indicated in the torque characteristics of the product as the “maximum starting frequency (f_s)”. As the load moment of inertia increases, the maximum starting frequency decreases, thus narrowing the starting region. The maximum starting frequency can be approximated by the following equation.

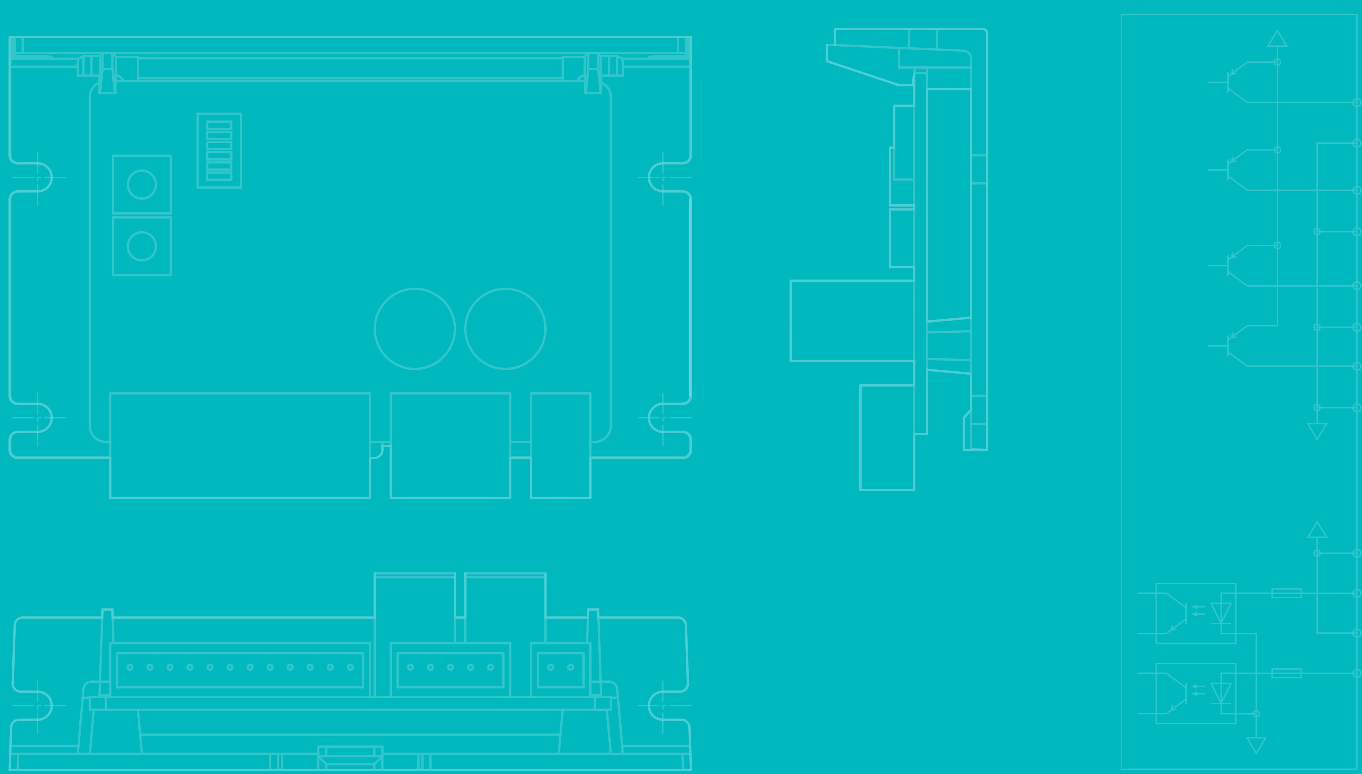
$$f = \frac{fs}{\sqrt{1 + \frac{J_L}{J_0}}} \text{ [Hz]}$$

F: Max. starting frequency with load inertia [Hz]
fs: Max. starting frequency for motor alone [Hz]
J_L: Load inertia [kgm2]
J_0: Rotor inertia [kgm2]





Information



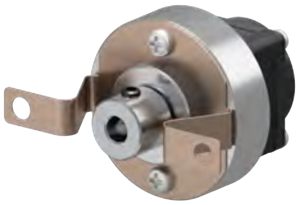
Accessory

Rotary Encoder

Oriental Motor Rotary Encoder Search

Output circuit types include both a voltage output type and a line driver output type.

Round Shaft Type



Hollow Shaft Type

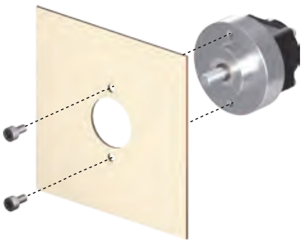
◆ Small, Thin, and Lightweight High-Resolution Incremental Encoder

Because these are small, thin and lightweight, with an outer diameter of ϕ30 mm, depth of 22 mm, and mass of 33 g (round shaft type) / 38 g (hollow shaft type), they can be installed even in tight spaces.

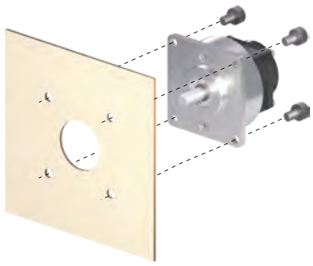
It is also a high resolution (1000 P/R or 2000 P/R) incremental type.

◆ Can Be Installed to Suit the Mechanism

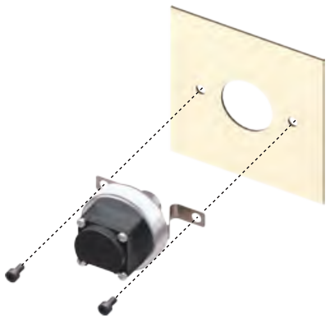
Round Shaft Type



Round Shaft Type + Mounting Bracket (Sold separately)



Hollow Shaft Type



Regeneration Unit

Oriental Motor Regeneration Unit Search

This is a regeneration unit specificially for DC input products.

By using this regeneration unit the voltage rise inside the driver and the rise of the power supply voltage can be suppressed using motor regeneration.

Applicable Products: **AZ** Series mini driver, **CVD** Sereies pulse input type, **CVD** Sereies **SC** type

Oriental Motor's support website

On this website you will find information and service offers on the subject of technical support.

Oriental Motor's support website

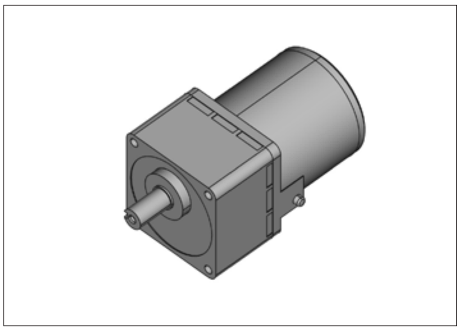
[Data]

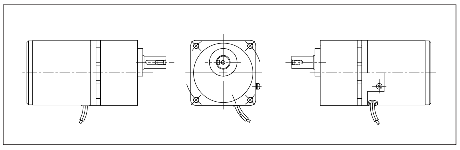
Catalogs

You can download catalogs and request materials (request postal mail materials).

CAD Data

Search and download 2D CAD data, 3D CAD data.
Search by product name or CAD file number.

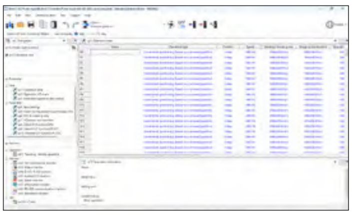




[Software]

Support Software MEXE02

This is support software that allows customers to set up and edit various types of data on their own computer. The status of the product, can be checked, through waveform monitoring and alarm monitoring.



Programming Software MRC Studio

MRC Studio is software that supports the robot controller MRC01 from start-up to maintenance.
In addition to creating operation programs and setting and editing various parameters, teaching and various conditions can be monitored.

Oriental Motor Downloads Search

Orientalmotor

These products are manufactured at plants certified with the international standards **ISO 9001** (for quality assurance) and **ISO 14001** for systems of environmental management).

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