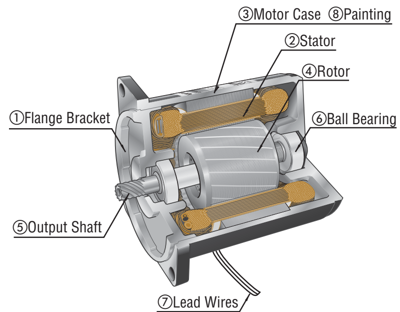
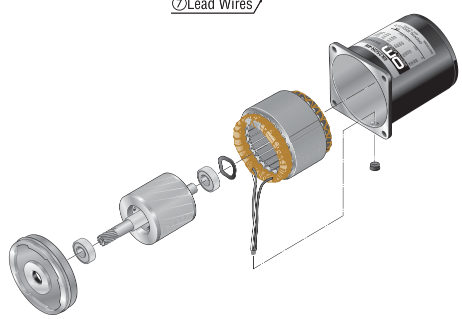
Standard AC Motors

Structure of Standard AC Motors

The following figure shows the structure of a standard AC motor.





① Flange Bracket
Die cast aluminum bracket with a machined finish, press-fitted into the motor case

② Stator
Comprised of a stator core made from electromagnetic steel plates, a polyester-coated copper coil and insulation film

③ Motor case
Die cast aluminum with a machined finish inside

④ Rotor
Electromagnetic steel plates with die cast aluminum

⑤ Output shaft
Available in round shaft type and pinion shaft type.
The metal used in the shaft is S45C. Round shaft type has a shaft flat (output power of 25 W 1/30 HP or more), while pinion shaft type undergoes precision gear finishing.

⑥ Ball bearing

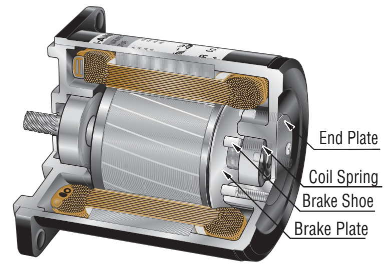
⑦ Lead wires
Lead wires with heat-resistant polyethylene coating

⑧ Painting
Baked finish of acrylic resin or melamine resin

Brake Mechanism of Reversible Motors

A reversible motor has a built-in friction brake mechanism (friction brake) at its rear. This mechanism is provided for the following purposes:

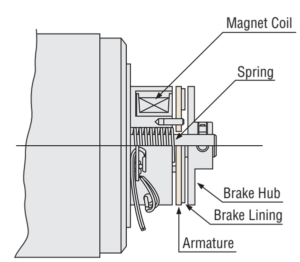
- To improve the instant reversing characteristics by adding a friction load
- To reduce overrun



The brake mechanism is constructed as shown in the figure above. The coil spring applies constant pressure to allow the brake shoe to slide toward the brake plate.
This mechanism provides a certain degree of holding brake force, but the force is limited due to the mechanism's structure, as described above. The brake force produced by the brake mechanism of an Oriental Motor's reversible motor is approximately 10% of the motor's output torque.

Structure of an Electromagnetic Brake

An electromagnetic brake motor is equipped with a power off activated type electromagnetic brake.
As shown in the figure, when voltage is applied to the magnet coil, the armature is attracted to the electromagnet against the force of the spring, thereby releasing the brake and allowing the motor shaft to rotate freely.
When no voltage is applied, the spring works to press the armature onto the brake hub and hold the motor's shaft in place, thereby actuating the brake.

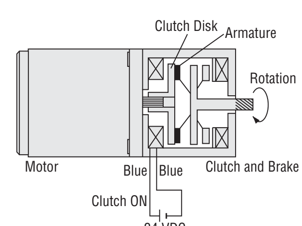


Structure and Operation of **C·B** Motor

The illustration to the right shows the structure of the **C·B** motor. When 24 VDC is not applied to either the clutch coil or brake coil, the output shaft can be rotated freely.

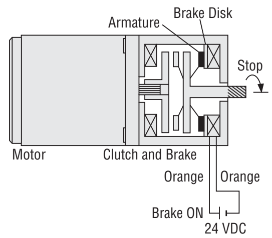
●Operation

When 24 VDC is applied to the clutch coil, the armature of the clutch coil is drawn against the clutch disk, transmitting motor rotation to the output shaft. The motor continues to rotate.

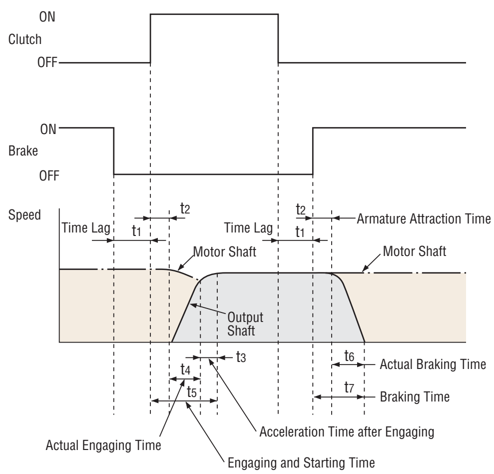


Stopping and Load Holding

By removing the clutch coil excitation, after a certain time lag, applying 24 VDC to the brake coil will cause the armature on the brake to come into contact with the brake disk, which will cause the output shaft to come to a stop. During braking, the output shaft is released from the motor, so the inertia from the motor has no effect. The motor is constantly rotating.



The figure below shows the relationship between the action of the motor shaft and output shaft and the state of excitation of the clutch and brake coils.



Operation

When operation is shifted from holding the load to moving the load, a time lag of 20 ms or more is required after releasing the brake and before applying voltage to the clutch. (This is to prevent the clutch and brake from engaging at the same time.)
The time required for the clutch/brake output shaft to reach a constant speed after applying voltage to the clutch is referred to as the engaging and starting time (t_5) and is calculated by adding up the following time elements:

① Armature Attraction Time t_2
The time required for the armature to come into contact with the clutch after voltage application to the clutch.

② Actual Engaging Time t_4
The time required for the clutch/brake output shaft, which is accelerated by dynamic friction torque, to engage completely with the motor shaft after the armature comes in contact with the clutch.

③ Acceleration Time after Engaging t_3
The time needed to accelerate to the required speed when load is suddenly applied to the motor during actual engaging time described in ②, causing a temporary drop in speed.

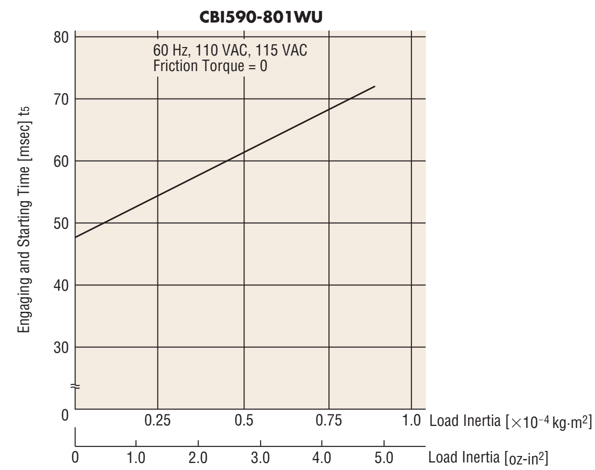
Braking

When operation is shifted from rotation to stopping or holding a load, a time lag of 20 ms or more is required after releasing the clutch and before applying voltage to the brake. The time required for the clutch/brake output shaft to come to a stop after applying voltage to the brake is referred to as the braking time (t_7) and is calculated by adding up the following time elements:

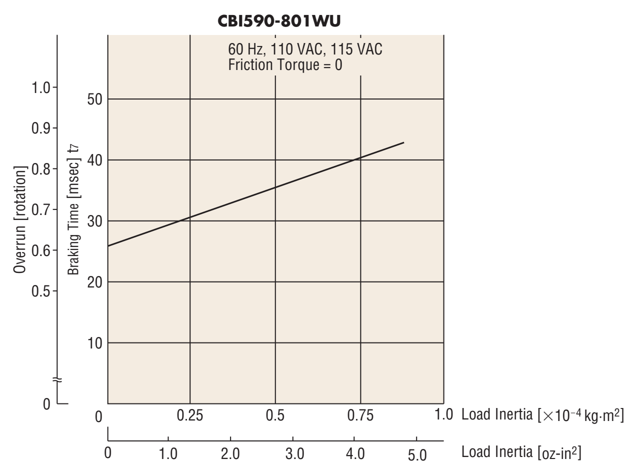
① Armature Attraction Time t_2
The time required for the armature to contact with the brake plate after voltage application to the brake.

② Actual Braking Time t_6
The time required for rotation of the clutch/brake output shaft to come to a stop after the armature comes into contact with the brake plate.

Engaging and Starting Characteristics (Reference value)

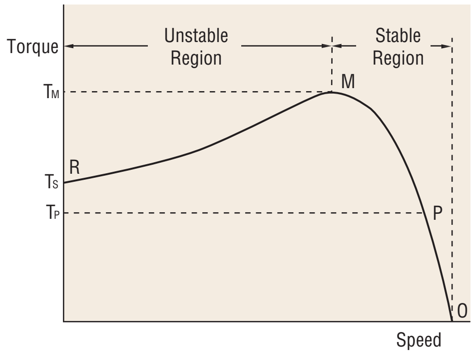


Braking Characteristics (Reference value)



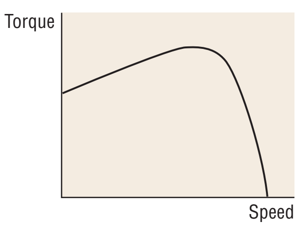
Speed – Torque Characteristics of Induction Motors

The figure below shows the speed – torque characteristics of induction motors.

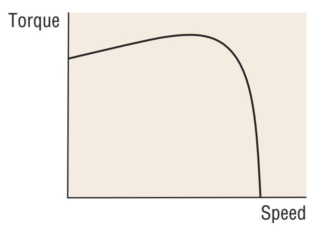


Under no load, the motor rotates at a speed close to synchronous speed. As the load increases, the motor's speed drops to a level (P) where a balance is achieved between load and motor torque (T_P).
If the load is further increased and reaches point M, the motor can generate no greater torque and stops at point R.
In other words, the motor can be operated in a stable range between M and O, while the range between R and M is subject to instability.

Induction motors are available in two types: single-phase (capacitor run) and three-phase induction motors. With the single-phase motor, the starting torque is generally smaller than the operating torque, while the three-phase motor features a relatively greater starting torque.



Single-Phase Induction Motors

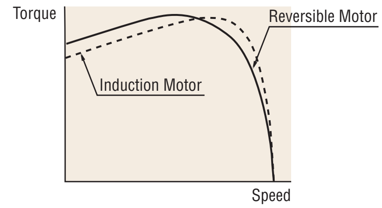


Three-Phase Induction Motors

The torque the motor produces changes proportionally to roughly twice the power supply voltage.
For example, if 110 V is applied to a motor whose rated voltage is 100 V, the torque produced by the motor increases to approximately 120%. In this case, the motor temperature will rise and may exceed the permissible range.
If 90 V is applied to the same motor, the torque produced by the motor decreases to approximately 80%. In this case, the motor may not be able to operate the automated equipment as expected.
For the above reasons, the power supply voltage should be kept within ±10% of the rated voltage. Otherwise, when the power supply voltage fluctuates beyond the aforementioned range, the motor temperature may rise beyond the permissible range or the motor torque may drop and thereby make the equipment operation unstable.

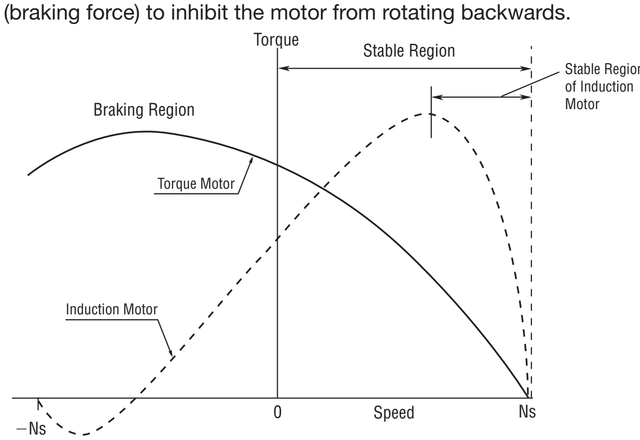
Speed – Torque Characteristics of Reversible Motors

The reversible motor is a capacitor run, single-phase induction motor that features the same speed – torque characteristics as an induction motor, as described above. However, the reversible motor features a higher starting torque than an induction motor in order to improve the instant reversing characteristics.



Speed – Torque Characteristics of Torque Motors

The figure below shows the speed – torque characteristics of torque motors.
The speed – torque characteristics of torque motors differ from those of induction motors or reversible motors. As the graph shows, they have sloping characteristics (torque is highest at zero speed and decreases steadily with increasing speed), enabling stable operation over a wide speed range, from starting to no load speed. The torque generated during reversal of the motor is a large positive torque in the same direction as the rotational magnetic field. When the motor which rotates uni-directionally is locked by the load and the motor is rotated opposite the desired direction, this torque acts as a force (braking force) to inhibit the motor from rotating backwards.



Temperature Rise in Standard AC Motors

●Temperature Rise in Motors

When a motor is operating, all energy loss (copper loss, iron loss, etc.) of the motor is transformed into heat, causing the motor's temperature to rise.

- Induction motors (continuous rating) reach the saturation point of temperature rise after two or three hours of operation, whereupon its temperature stabilizes.
- Reversible motors (30 minutes rating) reach their limit for temperature rise after 30 minutes of operation. The temperature will increase further if operation continues.

●Measuring the Temperature Rise

The following is a description of the methods Oriental Motor uses for temperature measurement and for the determination of a motor's maximum permissible temperature rise.

◇Thermometer Method

The temperature at which the temperature rise during motor operation becomes saturated is measured using a thermometer or thermocouple attached to the center of the motor case. The temperature rise is defined as the difference between the ambient temperature and measured temperature.

◇Resistance Change Method

In the resistance change method, the winding temperature is measured according to the change in resistance value. A resistance meter and thermostat is used to measure the motor's winding resistance and ambient temperature before and after operation, from which the temperature rise in the motor windings is obtained.

■Operating Time and Temperature Rise of Reversible Motors

Reversible motors have a "30 minute rating." However, the operating time varies according to the operating conditions, even with intermittent operation for short times. When using a reversible motor intermittently for a short period of time, a large current flows, which causes the generation of a large amount of heat when starting or reversing. However, as the natural cooling effect of the motor is high when the motor is left stopped for a longer period of time, you can curb rises in temperature.

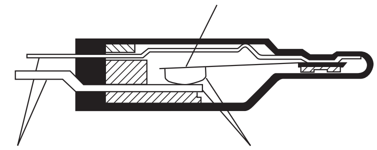
The motor case temperature equals the rise in motor temperature plus the ambient temperature. Generally, if the case temperature of the motor is 90˚C (194˚F) or less, continuous motor operation is possible with the same operating conditions, considering the insulation class of motor winding. However, the lower the motor temperature is, the longer the bearing grease life is.
The motor temperature varies according to conditions such as the load, the operating cycle, the mounting method of the motor and the ambient temperature.

■Overheat Protection Device

If a motor operating in run mode locks due to overload, ambient temperature rises rapidly, or the input current increases for some reason, the motor's temperature rises abruptly. If the motor is left in this state, the performance of the insulation within the motor may deteriorate, reducing its life and, in extreme cases, scorching the winding and causing a fire. In order to protect the motor from such thermal abnormalities, our motors recognized by UL and CSA Standards and conform to EN and IEC Standards are equipped with the following overheat protection device.

●Thermally Protected Motors

Motors with a frame size of 70 mm (2.76 in.) sq., 80 mm (3.15 in.) sq., 90 mm (3.54 in.) sq., or 104 mm (4.09 in.) sq. contain a built-in automatic return type thermal protector. The structure of a thermal protector is shown in the figure below.



Structure of Thermal Protector

The thermal protectors employ bimetal contacts, with solid silver used in the contacts. Solid silver has the lowest electrical resistance of all materials, along with a thermal conductivity second only to copper.

◇Operating Temperature of Thermal Protector

Open···130±5˚C (266±9˚F)
[the operating temperature varies depending on the model, e.g., **BH** Series: 150±5˚C (302±9˚F)]
Close···82±15˚C (179.6±27˚F)
[the operating temperature varies depending on the model, e.g., **BH** Series: 96±15˚C (204.8±27˚F)]

The motor winding temperature, where the thermal protector is activated, is slightly higher than the operating temperature listed above.

●Impedance Protected Motors

Motors with a frame size of 60 mm (2.36 in.) sq. or less are equipped with impedance protection.
Impedance protected motors are designed with higher impedance in the motor windings so that even if the motor locks, the increase in current (input) will be minimized and temperature will not rise above a certain level.

■Capacitor

Oriental Motor's single-phase AC motors are all permanent split capacitor types. Permanent split capacitor motors contain an auxiliary winding offset by 90 electrical degrees from the main winding. The capacitor is connected in series with the auxiliary winding, causing the advance of current phase in the auxiliary winding.
Motors employ vapor-deposition electrode capacitors recognized by UL. This type of capacitor, which uses a metallized paper or plastic film as an element, is also known as a "self-healing (SH) capacitor" because of the self-healing property of the capacitor element.
Although most of the previous capacitors used paper elements, the plastic film capacitor has become a mainstream model in recent years due to the growing demand for compact design.

●Capacitance

The use of a capacitor with a different capacitance may cause excessive motor vibration and heat generation or may result in torque drops and unstable operation. Be sure to use the capacitor included with the motor. The capacitor's capacitance is expressed in microfarads (μF).

●Rated Voltage

Using a capacitor exceeding the rated voltage may cause damage and then smoke or ignite. Be sure to use the capacitor included with the motor. The rated voltage of the capacitor is expressed in volts (V). The capacitor’s rated voltage is indicated on the surface of the capacitor case. Take proper precautions, since the capacitor’s rated voltage is different from that of the motor.

●Rated Conduction Time
The rated conduction time is the minimum design life of the capacitor when operated at the rated load, rated voltage, rated temperature and rated frequency. The standard life expectancy is 25000 hours. A capacitor that breaks at the end of its life expectancy may smoke or ignite. We recommend that the capacitor be replaced after the rated conduction time. Consider providing a separate protection measure to prevent the equipment from being negatively influenced in the event of capacitor failure.

●Safety Feature of Capacitor
Some capacitors are equipped with a safety feature that allows for safe and complete removal of the capacitor from circuits to prevent smoke and/or fire in the event of a dielectric breakdown. Oriental Motor products use capacitors with UL recognized safety features that have passed the UL 810 requirement of the 10000 A fault current test.

■Glossary

●Ratings

◇Ratings
Motor rating represents the operation limit certified the motor on dynamic characteristics such as temperature, mechanical strength, vibration and efficiency, and there are two categories: continuous rating and limited duty rating. Operation limit on output power, as well as voltage, frequency and speed are established. These are known as rated output power, rated voltage, rated frequency and rated speed, respectively.

◇Continuous and Limited Duty Ratings
The time during which output can continue without abnormality is called a time rating. When continuous operation at rated output is possible, it is known as a continuous rating. When operation at rated output is possible only for a limited time, it is known as the limited duty rating.

●Output Power

◇Output Power
The amount of work that can be performed in a given period of time is determined by the motor's speed and torque. Each motor specification indicates the value of rated output power. Output power is expressed in watts or in horsepower.

Output Power [Watts] $= 1.047 \times 10^{-1} \times T \times N$

1 HP $= 746$ Watts

where: 1.047×10^{-1} : Constant

T [N·m] : Torque

N [r/min] : Speed

◇Rated Output Power
This term refers to output power generated continuously when the optimal characteristics are achieved at the rated voltage and frequency in continuous operation. The speed and torque that produce the rated output power are called the rated speed and rated torque. Generally, the term "output power" refers to rated output power.

●Torque

◇Starting Torque
This is the torque generated instantly when the motor starts. If the motor is subjected to a friction load greater than this torque, it will not operate. See ① in the figure on the right.

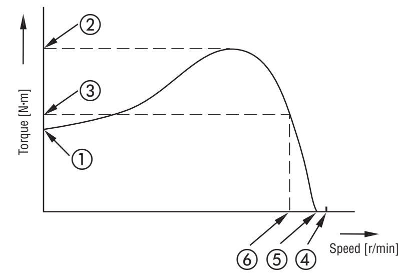
◇Stall Torque
This is the maximum torque under which the motor will operate at a given voltage and frequency. If a load greater than this torque is applied to the motor, it will stall. See ② in the figure below.

◇Rated Torque
This is the torque generated when the motor is continuously producing rated output power at the rated voltage and frequency. It is the torque at rated speed. See ③ in the figure below.

◇Static Friction Torque
Static friction torque is the torque output required to hold a load when the motor is stopped by an electromagnetic brake or similar device.

◇Permissible Torque
The permissible torque is the maximum torque that can be used when the motor is running. It is limited by the motor's rated torque, temperature rise and the strength of the gearhead combined with the motor.

Speed – Torque Characteristics
①: Starting torque
②: Stall torque
③: Rated torque
④: Synchronous speed
⑤: No load speed
⑥: Rated speed



●Speed

◇Synchronous Speed
This is an intrinsic factor determined by line frequency and the number of poles.
It is indicated as the speed per minute.

$$Ns = \frac{120f}{P} \text{ [r/min]}$$

Ns : Synchronous speed [r/min]
f : Frequency [Hz]
P : Number of poles
120 : Constant

For example, for a four-pole motor with a line frequency of 60 Hz, the synchronous speed will be:

$$Ns = \frac{120 \times 60}{4} = 1800 \text{ [r/min]}$$

See ④ in the figure above.

◇No Load Speed
This is the speed under no load conditions.
The speed of induction or reversible motors under no load conditions is lower than synchronous speed by a few percent (approximately 20 to 60 r/min). See ⑤ in the figure above.

◇Rated Speed
This is the appropriate speed of the motor at rated output power.
From the standpoint of utility, it is the most desirable speed.
See ⑥ in the figure above.

◇Slip

The following formula is one method of expressing speed:

$$S = \frac{Ns - N}{Ns} \quad \text{or} \quad N = Ns\,(1 - S)$$

Ns: Synchronous speed [r/min]

N : Speed under a given load [r/min]

In the case of a four-pole, 60 Hz induction motor operated with a slip of S = 0.1, the speed under a given load will be:

$$N = \frac{120 \times 60}{4}\,(1 - 0.1) = 1800\,(1 - 0.1) = 1620 \text{ [r/min]}$$

●Overrun

◇Overrun

This is the number of excess rotations the motor makes from the instant the power is cut off to the time that it actually stops. It is normally indicated either by angle or by rotations.

●Gearhead

◇Gear Ratio

The gear ratio is the ratio by which the gearhead reduces the motor speed. The speed at the gearhead's output shaft is $\frac{1}{\text{Gear Ratio}}$ times the motor speed.

◇Maximum Permissible Torque

This is the maximum load torque that can be applied to the gearhead.
It is dependent upon such mechanical strength factors as the materials of gearheads and bearings, and size. Therefore, it varies according to the gearhead type and gear ratio.

◇Service Factor

This is a coefficient used to estimate the gearhead life.
These values are determined in accordance with the results of life tests under various loads and conditions of use.

◇Transmission Efficiency

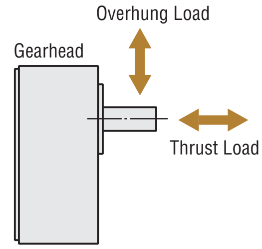
This is the efficiency when the torque is transmitted with the gearhead combined.
It is expressed as a percentage (%) and is determined by the friction in the gears and bearings used in the gearhead and the resistance of the lubrication grease.
Transmission efficiency is, when using a **GN** gearhead, usually 90% for one stage of reduction gears, and is 81% for two stage gearheads. As the gear ratio increases, the number of reduction gear stages increases, with a consequent reduction in the gear efficiency to 73% and 66% for each gear stage added.

◇Overhung Load

This is a load on the gearhead output shaft in the vertical direction.
The maximum overhung load on a gearhead shaft is called the permissible overhung load, and it varies with the gearhead type and distance from the shaft end.
This is equivalent to tension under belt drive.

◇Thrust Load

This is the load that is placed in the direction of the gearhead output shaft.
The maximum thrust load on the gearhead is called the permissible thrust load, which varies with the gearhead type.



●Others

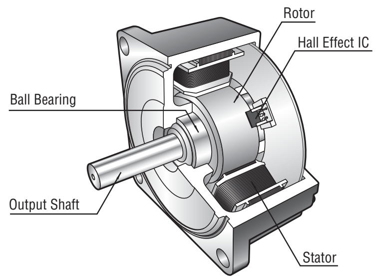
◇CW, CCW

These show the direction of motor rotation.
CW is clockwise as seen from the output shaft, while CCW is counterclockwise.

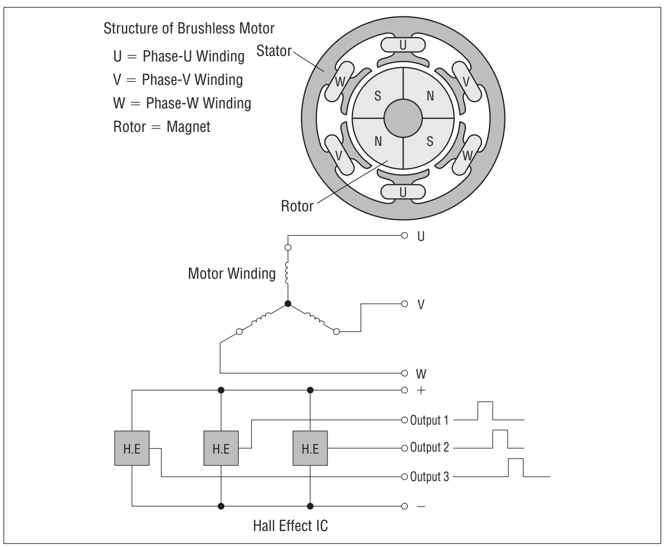
Speed Control Systems

Brushless Motor Structure and Principle of Operation

Structure of Brushless Motor



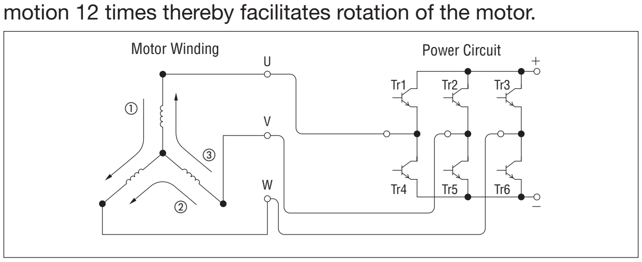
The brushless motor has a built-in magnetic element or optical encoder for the detection of rotor position. The position sensors send signals to the drive circuit. The brushless motor uses three-phase windings in a "star" connection. A permanent magnet is used in the rotor.



A Hall effect IC is used for the sensor's magnetic element. Three Hall effect ICs are placed within the stator, and send digital signals as the motor rotates.

Drive Method of Brushless Motors

The motor windings are connected to switching transistors, six of which make up the inverter. The top and bottom transistors turn on and off, according to a predetermined sequence, to change the direction of current flow in the windings. The mechanism of brushless motor rotation can be described as follows:
In step 1 of the transistor's switching sequence, as shown in the following figure, transistors Tr1 and Tr6 are in the "ON" state.
At this time the winding current flows from phase U to phase W, and phases U and W are excited so that they become N and S poles, respectively, thus causing the rotor to turn 30˚. Repeating such a motion 12 times thereby facilitates rotation of the motor.



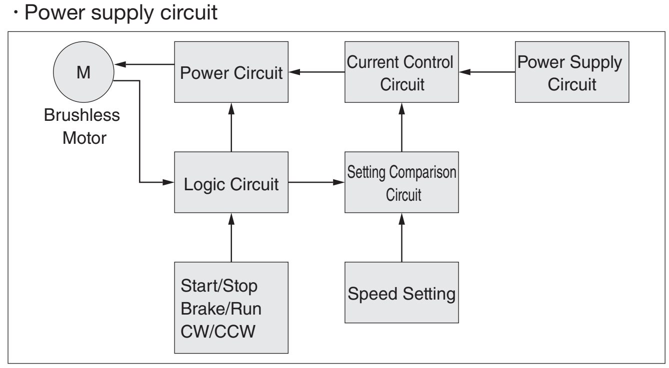
Switching Sequences of Individual Transistors

Transistor \ Step	①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪	⑫	⑬
Tr1	ON					ON	ON					ON	ON
Tr2		ON	ON					ON	ON				
Tr3				ON	ON					ON	ON		
Tr4			ON	ON					ON	ON			
Tr5					ON	ON					ON	ON	
Tr6	ON	ON					ON	ON					ON
Phase-U	N	–	S	S	–	N	N	–	S	S	–	N	N
Phase-V	–	N	N	–	S	S	–	N	N	–	S	S	–
Phase-W	S	S	–	N	N	–	S	S	–	N	N	–	S

Control Method of Brushless Motors

The drive circuit of the brushless motor is connected in the configuration shown in the figure below, and is comprised of five main blocks.

- Power circuit
- Current control circuit
- Logic circuit
- Setting comparison circuit
- Power supply circuit



◇Power Circuit

This circuit uses six transistors to control the current flow in the motor windings.
The transistors provided at the top and bottom turn on and off repeatedly according to a predetermined sequence, thereby controlling the current flow to the motor windings.

◇Current Control Circuit

The current flow to the motor varies according to the load. It is constantly detected and controlled so that the speed will not deviate from the set speed.

◇Logic Circuit

The logic circuit detects the rotor position by receiving feedback signals from the motor's Hall effect IC and determines the excitation sequence of motor windings. The circuit signal is connected to each transistor base in the power circuit, driving the transistors according to a predetermined sequence. It also detects the motor's speed.
The logic circuit is also used to control commands to the motor, including start/stop, brake/run and CW/CCW.

◇Setting Comparison Circuit

This circuit compares the motor speed signal against the speed setting signal in order to determine whether the motor speed is higher or lower than the set speed. The input to the motor is lowered if the motor speed is higher than the set speed, but the input is raised if it is lower than the set speed. In this manner, the speed that has varied is returned to the set speed.

◇Power Supply Circuit

This circuit converts a commercial power supply into the voltage necessary to drive the motor and control circuits.

Speed Control Methods of AC Motor Systems

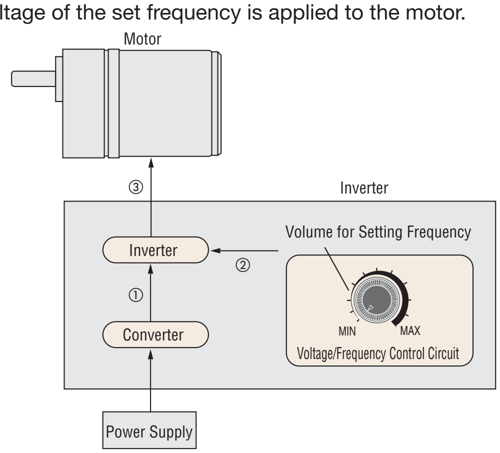
The basic block diagrams and outline of the control methods are shown below. AC speed control motors employ a closed-loop control system, while inverters employ an open-loop control system.

●Inverters

◇**BHF** Series, **FE100/FE200**

Control Method

① Input from the AC power supply is rectified, and output as DC voltage.
② A voltage signal led by the frequency set with the volume for setting frequency is output.
③ Voltage of the set frequency is applied to the motor.

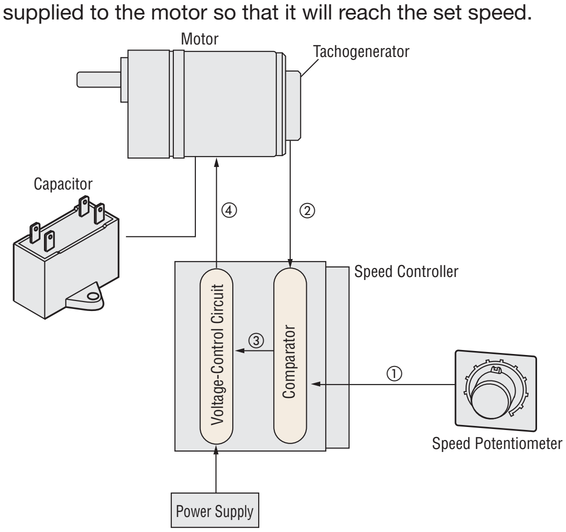


●AC Speed Control Motors

◇**ES01/ES02**, **US** Series

Control Method

① The speed setting voltage is supplied via a speed potentiometer.
② The motor speed is detected and the speed signal voltage is supplied.
③ The difference between the speed setting voltage and speed signal voltage is output.
④ A voltage determined by the output from the comparator is supplied to the motor so that it will reach the set speed.

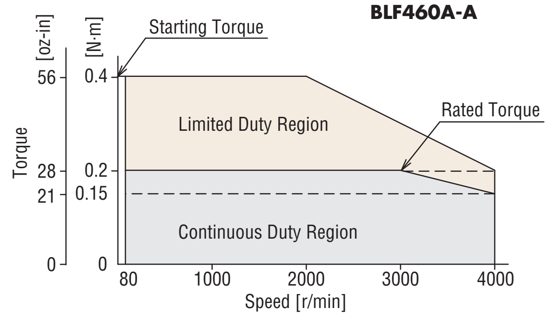


Speed – Torque Characteristics of Speed Control Systems

●Brushless Motor Systems

The figure below illustrates the characteristics example of a **BLF** Series motor. The **BX** Series, **BLU** Series and **BLH** Series motors also have similar characteristics, although their speed control ranges are different.
Brushless motors generate constant rated torque from 80 to 4000 r/min, with the same starting torque as rated torque. (With the **BLF** Series and **BLH** Series, the output torque at the maximum speed is less than rated torque.) Unlike AC speed control motors, torque in a brushless motor will not drop at low speeds, so brushless motors can be used at rated torque from high to low speeds.
In addition to continuous duty region, brushless motors also have limited duty region. The torque generated in the limited duty region, which is 1.2 times the rated torque (2 times for the **BX** Series and **BLF** Series), is effective for starting inertial load. If operated for more than approximately five seconds in the limited duty region, the overload protective function of the driver may engage and the motor will coast to a stop.

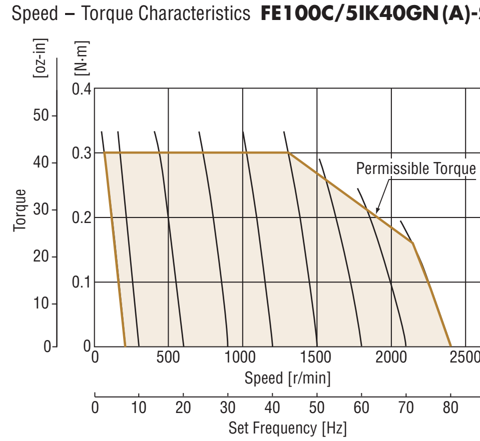
Speed – Torque Characteristics **BLF460A-□**
BLF460A-□FR
BLF460A-A



●Inverters

The speed – torque characteristics shown in the figure below is typical for all inverters.
The speed of an inverter varies depend on the frequency of the voltage applied to the motor. Accordingly, the speed also changes due to the load torque, which is equal to the induction motor.

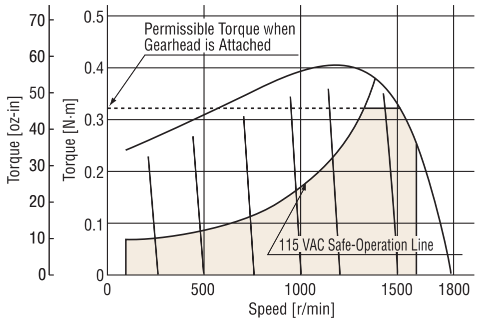
Speed – Torque Characteristics **FE100C/5IK40GN(A)-SW2**



●AC Speed Control Motors

The speed – torque characteristics shown in the figure below is typical for all AC speed control motors.

Speed – Torque Characteristics **ES01/5IK40RGN(A)-AW2U**



●Safe-Operation Line and Permissible Torque When Gearhead is Attached

Input power to the speed control motor varies with the load and speed. The greater the load, and the lower the speed, the greater an increase in motor temperature.
In the speed – torque characteristics of AC speed control motor and inverter, there is the safe-operation line, while the area below the line is called the continuous duty region.
The safe-operation line, measured by motor's temperature, indicates its limit for continuous operation (30 minutes operation for a reversible motor) with the temperature level below the permissible maximum.
Whether the motor can be operated at a specific load and speed is determined by measuring the temperature of the motor case. In general, when the motor case temperature is 90˚C (194˚F) or less, continuous operation is possible, considering the insulation class of motor winding. It is recommended that the motor be used under conditions that keep the motor temperature low, since the motor life is extended with lower motor temperature.
When using a gearhead, be aware that it is necessary to operate below the torque in the "gearmotor – torque table." If the actual torque required exceeds this torque, it may damage the gearhead and shorten its life.

●Variable Speed Range (Speed ratio) and Load Factor

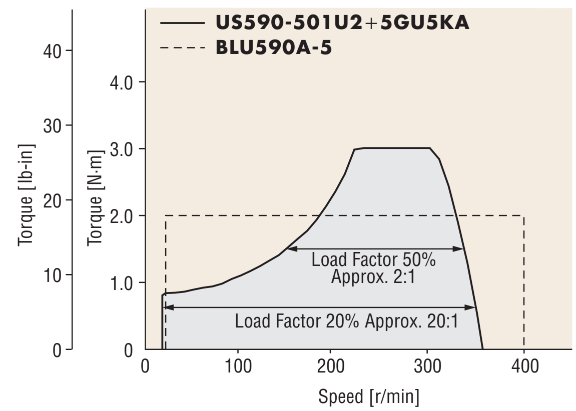
When the ratio of minimum speed and maximum speed of an AC speed control motor is given as the motor's speed ratio, the speed ratio increases to as much as 20:1 in a range where the load factor (ratio of load torque to starting torque) is small (Refer to the 20% load factor range in the diagram to the right). This widens the motor's range of operation.
If the load factor is high, the speed ratio becomes low.

◇Load Factor and Speed Ratio

The following explains the relationship of load factor and speed ratio. Usually, a motor is often used in combination with a gearhead. The following assumes such a configuration.

The following table shows the continuous duty region and speed ratio of the **US** Series at load factors of 20% and 50%, as read from the diagram.
Although the speed ratio is large when the load factor is 20%, it decreases when the load factor is 50%. As shown, generally AC speed control motors do not have a wide speed range. To operate your motor over a wide speed range, choose a type that offers high starting torque (a motor with the next larger frame size).
With a brushless motor, the operation speed range remains wide regardless of the load factor, as indicated by the dotted line.

Speed – Torque Characteristics
US590-501U2/5GU5KA

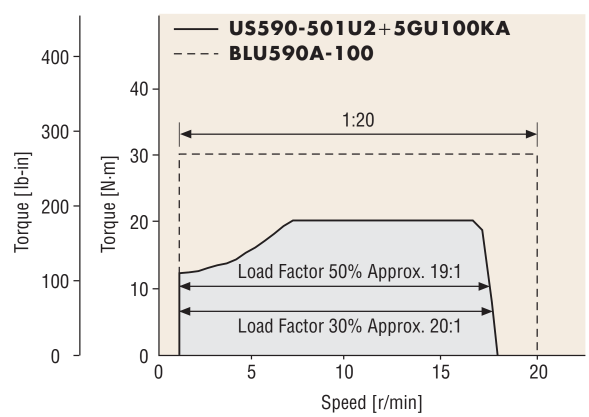


Load Factor [%]	Continuous Duty Region		Speed Ratio
	Min. Speed [r/min]	Max. Speed [r/min]	
20	17	348	Approx. 20:1
50	148	337	Approx. 2:1

◇Speed Ratio When a High Ratio Gearhead is Used

Since the starting torque is also limited by the maximum permissible torque of the gearhead, the load factor of a gearhead with a high gear ratio is determined by the load torque with respect to the maximum permissible torque of the gearhead.
In the previous example, a gearhead with a gear ratio of 5:1 was used. The diagram below shows when a gearhead with a gear ratio of 100:1 is used.

Speed – Torque Characteristics with a High Gear Ratio



The maximum permissible torque of the **5GU100KA**, which has a gear ratio of 100:1, is 20 N·m (177 lb-in). The speed ratios at load factors of 30% and 50% are shown in the table below:

Load Factor [%]	Continuous Duty Region		Speed Ratio
	Min. Speed [r/min]	Max. Speed [r/min]	
30	0.9	17.6	Approx. 20:1
50	0.9	17.4	Approx. 19:1

The table above demonstrates that high speed ratios can be obtained by combining a motor with a gearhead having a high gear ratio, in which case the load factor is one of minor concern.

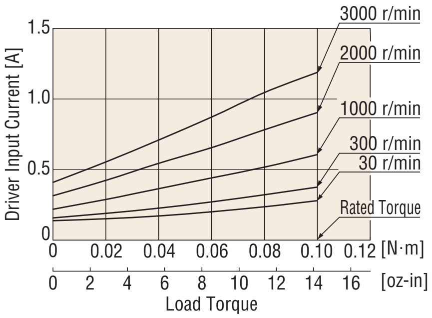
■Load Torque – Driver Input Current Characteristics of Brushless Motors (Reference values)

The driver input current for brushless motors varies with the load torque. Load torque is roughly proportional to the driver input current. These characteristics may be used to estimate load torque from the driver input current. However, this is valid only when the motor is rotating at a steady speed. Starting and bi-directional rotation requires greater current input, so the characteristics do not apply to such operations.

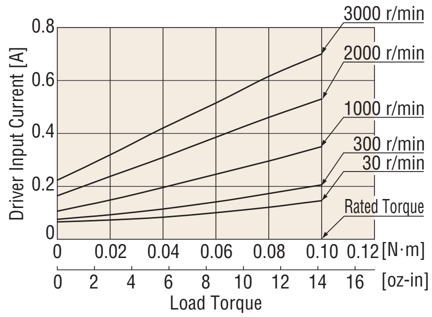
●Data for combination types models and geared motors apply to the motor only.

◇BX Series

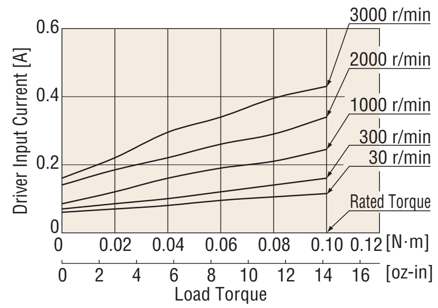
BX230A-□S, **BX230AM-□S**
BX230A-□FR, **BX230AM-□FR**
BX230A-A, **BX230AM-A**



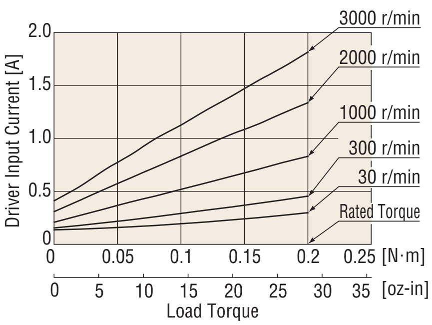
BX230C-□S, **BX230CM-□S** (Single-phase 200-230 VAC)
BX230C-□FR, **BX230CM-□FR** (Single-phase 200-230 VAC)
BX230C-A, **BX230CM-A** (Single-phase 200-230 VAC)



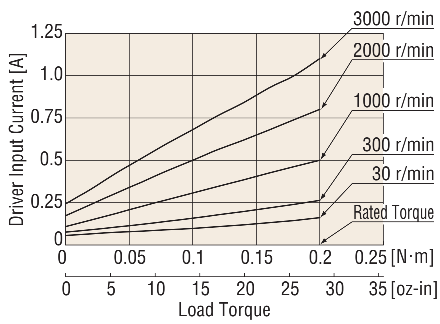
BX230C-□S, **BX230CM-□S** (Three-phase 200-230 VAC)
BX230C-□FR, **BX230CM-□FR** (Three-phase 200-230 VAC)
BX230C-A, **BX230CM-A** (Three-phase 200-230 VAC)



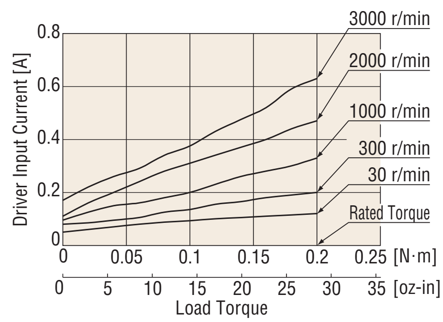
BX460A-□S, **BX460AM-□S**
BX460A-□FR, **BX460AM-□FR**
BX460A-A, **BX460AM-A**



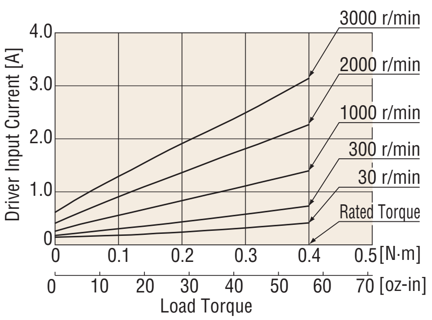
BX460C-□S, **BX460CM-□S** (Single-phase 200-230 VAC)
BX460C-□FR, **BX460CM-□FR** (Single-phase 200-230 VAC)
BX460C-A, **BX460CM-A** (Single-phase 200-230 VAC)



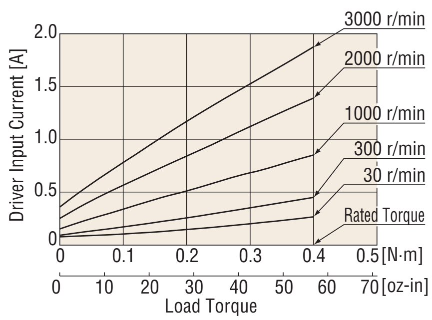
BX460C-□S, **BX460CM-□S** (Three-phase 200-230 VAC)
BX460C-□FR, **BX460CM-□FR** (Three-phase 200-230 VAC)
BX460C-A, **BX460CM-A** (Three-phase 200-230 VAC)



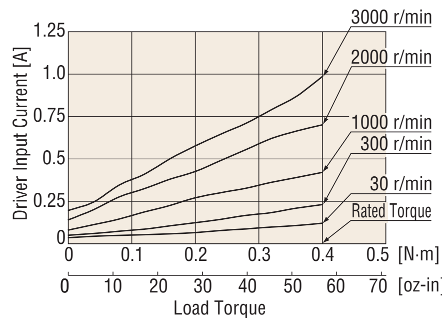
BX5120A-□S, **BX5120AM-□S**
BX5120A-□FR, **BX5120AM-□FR**
BX5120A-A, **BX5120AM-A**



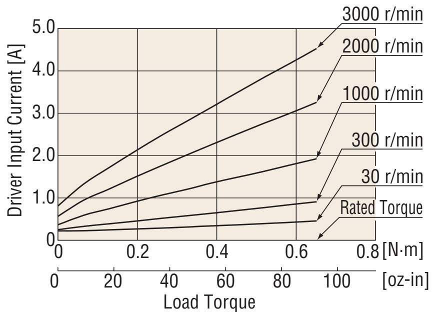
BX5120C-□S, **BX5120CM-□S** (Single-phase 200-230 VAC)
BX5120C-□FR, **BX5120CM-□FR** (Single-phase 200-230 VAC)
BX5120C-A, **BX5120CM-A** (Single-phase 200-230 VAC)



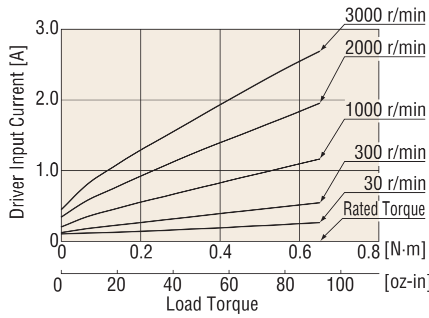
BX5120C-□S, **BX5120CM-□S** (Three-phase 200-230 VAC)
BX5120C-□FR, **BX5120CM-□FR** (Three-phase 200-230 VAC)
BX5120C-A, **BX5120CM-A** (Three-phase 200-230 VAC)



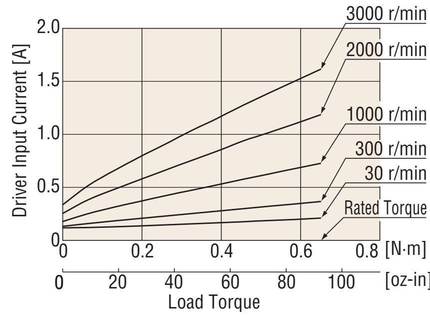
BX6200A-□S, BX6200AM-□S
BX6200A-A, BX6200AM-A



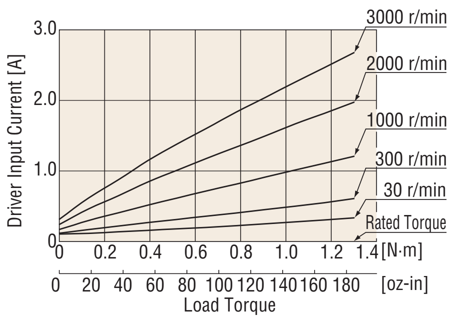
BX6200C-□S, BX6200CM-□S (Single-phase 200-230 VAC)
BX6200C-A, BX6200CM-A (Single-phase 200-230 VAC)



BX6200C-□S, BX6200CM-□S (Three-phase 200-230 VAC)
BX6200C-A, BX6200CM-A (Three-phase 200-230 VAC)

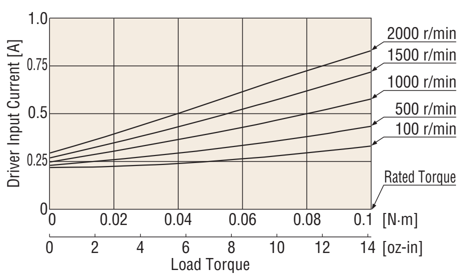


BX6400S-□S, BX6400SM-□S
BX6400S-A, BX6400SM-A

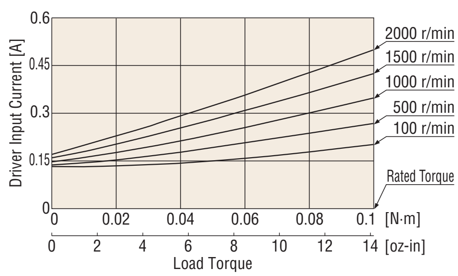


◇**BLU** Series

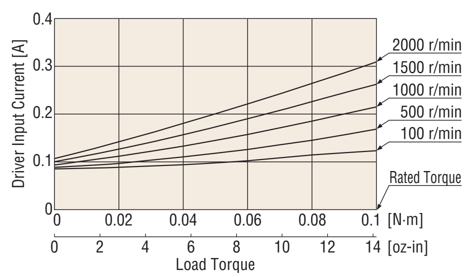
BLU220A-□, BLU220A-□FR
BLU220A-A



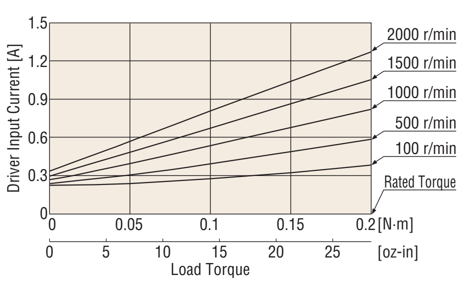
BLU220C-□, BLU220C-□FR
BLU220C-A



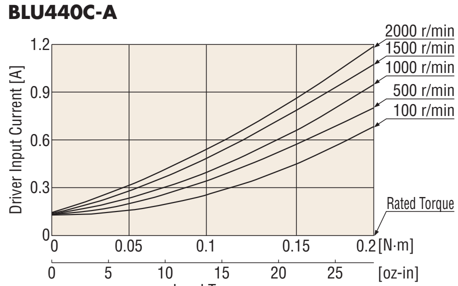
BLU220S-□, BLU220S-□FR
BLU220S-A



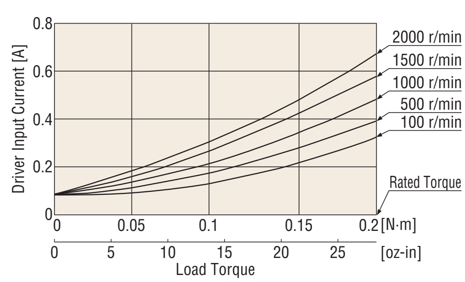
BLU440A-□, BLU440A-□FR
BLU440A-A



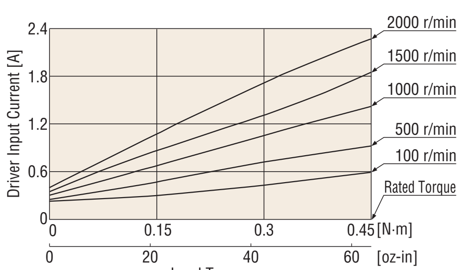
BLU440C-□, BLU440C-□FR
BLU440C-A



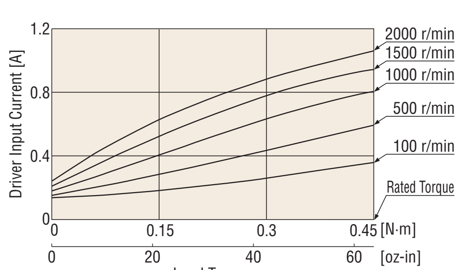
BLU440S-□, BLU440S-□FR
BLU440S-A



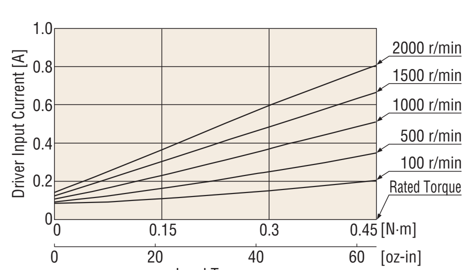
BLU590A-□, BLU590A-□FR
BLU590A-A



BLU590C-□, BLU590C-□FR
BLU590C-A

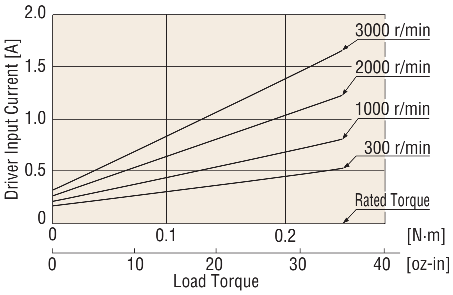


BLU590S-□, BLU590S-□FR
BLU590S-A

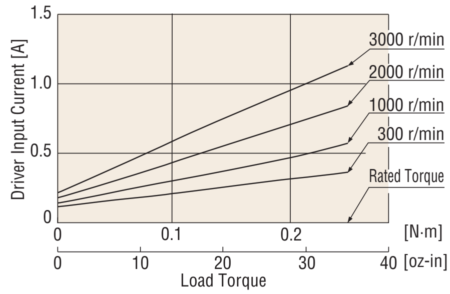


◇FBLⅡ Series

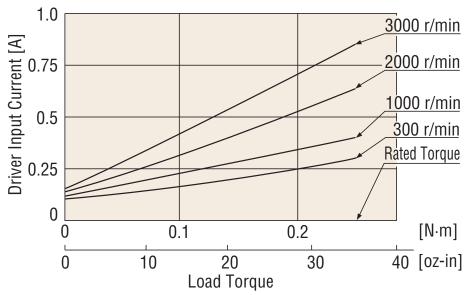
FBL575AW-□
FBL575AW-A



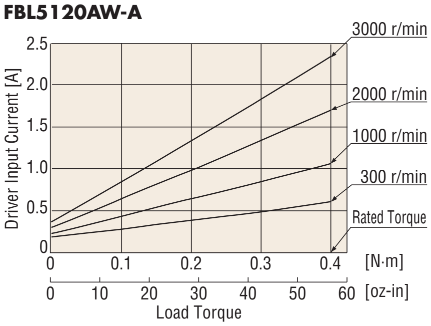
FBL575CW-□
FBL575CW-A



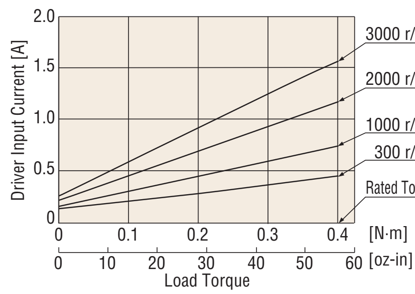
FBL575SW-□
FBL575SW-A



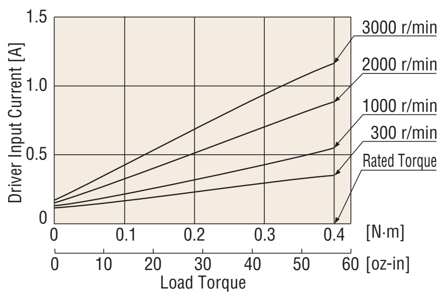
FBL5120AW-□
FBL5120AW-A



FBL5120CW-□
FBL5120CW-A

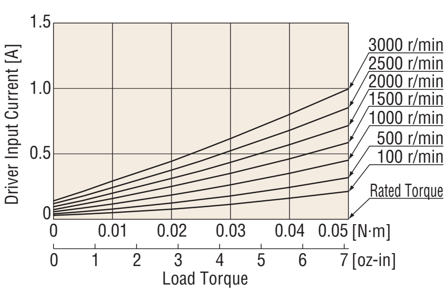


FBL5120SW-□
FBL5120SW-A

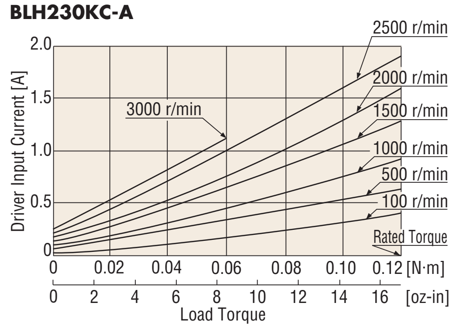


◇BLH Series

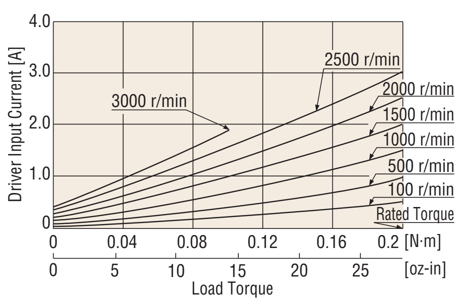
BLH015K-□
BLH015K-A



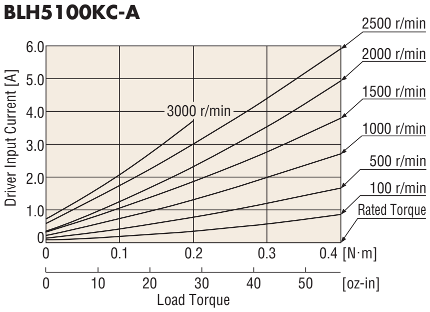
BLH230KC-□, BLH230KC-□FR
BLH230KC-A



BLH450KC-□, BLH450KC-□FR
BLH450KC-A



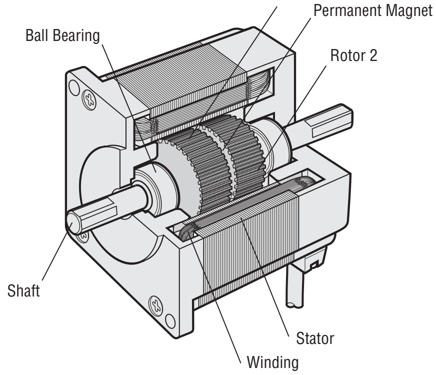
BLH5100KC-□, BLH5100KC-□FR
BLH5100KC-A



Stepping Motors

Structure of Stepping Motors

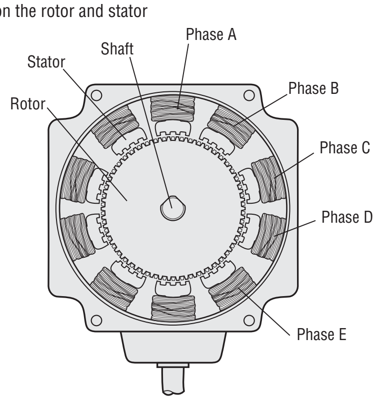
The figures below show two cross-sections of a 5-phase stepping motor.
The stepping motor consists primarily of two parts: a stator and rotor.
The rotor is made up of three components: rotor 1, rotor 2 and a permanent magnet. The rotor is magnetized in the axial direction so that, for example, if rotor 1 is polarized north, rotor 2 will be polarized south.



Motor Structural Diagram: Cross-Section Parallel to Shaft

The stator has ten magnetic poles with small teeth, each pole being provided with a winding.
Each winding is connected to the winding of the opposite pole so that both poles are magnetized in the same polarity when current is sent through the pair of windings. (Running a current through a given winding magnetizes the opposing pair of poles in the same polarity, i.e., north or south.)
The opposing pair of poles constitutes one phase. Since there are five phases, A through E, the motor is called a "5-phase stepping motor."
There are 50 small teeth on the outer perimeter of each rotor, with the small teeth of rotor 1 and rotor 2 being mechanically offset from each other by half a tooth pitch.

Excitation: To send current through a motor winding
Magnetic pole: A projected part of the stator, magnetized by excitation
Small teeth: The teeth on the rotor and stator



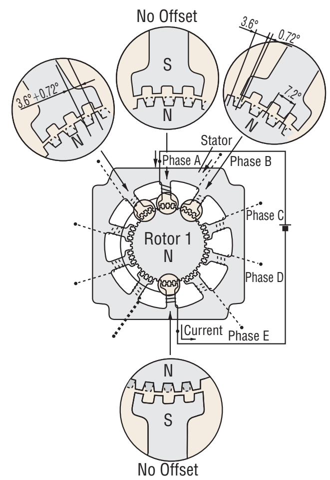
Motor Structural Diagram: Cross-Section Perpendicular to Shaft

Stepping Motor's Principle of Operation

Following is an explanation of the relationship between the magnetized stator small teeth and rotor small teeth.

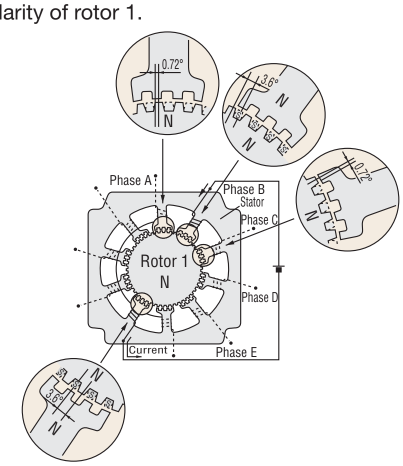
●When Phase "A" is Excited

When phase A is excited, its poles are polarized south. This attracts the teeth of rotor 1, which are polarized north, while repelling the teeth of rotor 2, which are polarized south. Therefore, the forces on the entire unit in equilibrium hold the rotor stationary. At this time, the teeth of the phase B poles, which are not excited, are misaligned with the south-polarized teeth of rotor 2 so that they are offset 0.72˚. This summarizes the relationship between the stator teeth and rotor teeth with phase A excited.



●When Phase "B" is Excited

When excitation switches from phase A to B, the phase B poles are polarized north, attracting the south polarity of rotor 2 and repelling the north polarity of rotor 1.

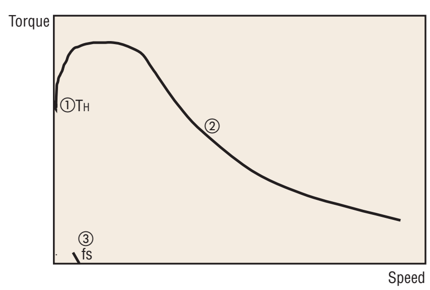


In other words, when excitation switches from phase A to B, the rotor rotates by 0.72˚. As excitation shifts from phase A, to phases B, C, D and E, then back around to phase A, the stepping motor rotates precisely in 0.72˚ steps. To rotate in reverse, reverse the excitation sequence to phase A, E, D, C, B, then back around to phase A.
High resolution of 0.72˚ is inherent in the mechanical offset between the stator and rotor, accounting for the achievement of precise positioning without the use of an encoder or other sensors. High stopping accuracy of ±3 arc minutes (with no load) is obtained, since the only factors affecting stopping accuracy are variations in the machining precision of the stator and rotor, assembly precision and DC resistance of windings. The driver performs the role of phase switching, and its timing is controlled by a pulse-signal input to the driver. The example above shows the excitation advancing one phase at a time, but in an actual stepping motor an effective use of the windings is made by exciting four or five phases simultaneously.

Basic Characteristics of Stepping Motors

An important point to consider in the application of stepping motors is whether the motor characteristics are suitable to the operating conditions.
The following sections describe the characteristics to be considered in the application of stepping motors.
The two main characteristics of stepping motor performance are:

- **Dynamic Characteristics:**
  These are the starting and rotational characteristics of a stepping motor, mainly affecting the machinery's movement and cycling time.
- **Static Characteristics:**
  These are the characteristics relating to the changes in angle that take place when the stepping motor is in standstill mode, affecting the machinery's level of precision.



Speed - Torque Characteristics

●Dynamic Characteristics

◇Speed – Torque Characteristics

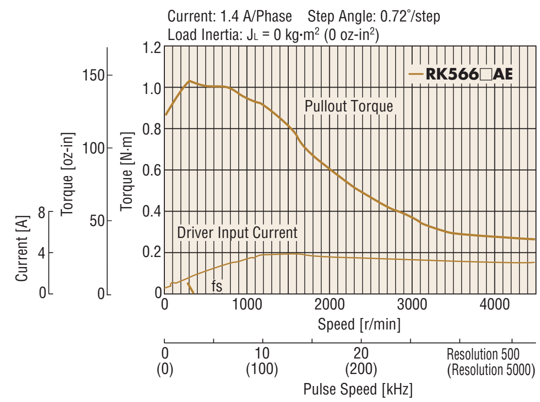
The figure above is a characteristics graph showing the relationship between the speed and torque of a driven stepping motor.
These characteristics are always referred to in the selection of a stepping motor. The horizontal axis represents the speed at the motor output shaft, and the vertical axis represents the torque.
The speed – torque characteristics are determined by the motor and driver, and are greatly affected by the type of driver being used.

① Maximum holding torque (T_H)
The maximum holding torque is the stepping motor's maximum holding power (torque) when power is supplied (at rated current) when the motor is not rotating.

② Pullout torque
The pullout torque is the maximum torque that can be output at a given speed.
When selecting a motor, be sure the required torque falls within this curve.

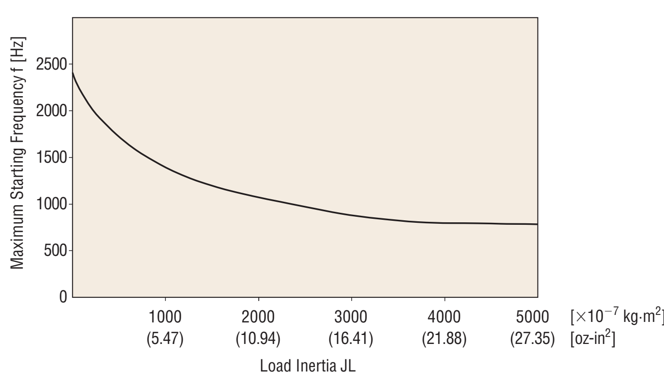
③ Maximum starting frequency (f_S)
This is the maximum pulse speed at which the motor can start or stop instantly (without an acceleration/deceleration time) when the stepping motor's friction load and inertial load are 0.
Driving the motor at a pulse speed in excess of this rate will require a gradual acceleration or deceleration. This frequency will decrease when an inertial load is added to the motor.
Refer to the inertial load – starting frequency characteristics below.

Maximum response frequency (f_r)
This is the maximum pulse speed at which the motor can be operated through gradual acceleration or deceleration when the stepping motor's friction load and inertial load are 0.
The figure below shows the speed – torque characteristics of a 5-phase stepping motor and driver package.



◇Inertial Load – Starting Frequency Characteristics

These characteristics show the changes in the starting frequency caused by the load inertia.
Since the stepping motor's rotor and load have their own moment of inertia, lags and advances occur on the motor axis during instantaneous starting and stopping. These values change with the pulse speed, but the motor cannot follow the pulse speed beyond a certain point, so that missteps result.
The pulse speed immediately before the occurrence of a misstep is called the starting frequency.



Inertial Load – Starting Frequency Characteristics

Changes in maximum starting frequency with the inertial load may be approximated via the following formula:

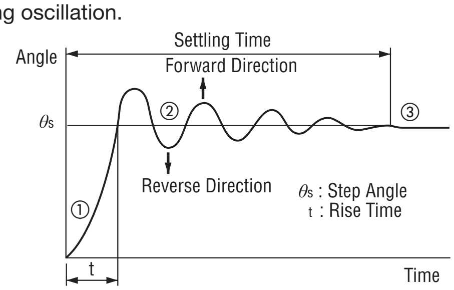
$$f = \frac{f_S}{\sqrt{1 + \frac{J_L}{J_0}}} \text{ [Hz]}$$

f_S : Maximum starting frequency of motor [Hz]
f : Maximum starting frequency where inertial load is present [Hz]
J_0 : Moment of inertia of rotor [kg·m^2 (oz-in^2)]
J_L : Moment of inertia of load [kg·m^2 (oz-in^2)]

◇Vibration Characteristics

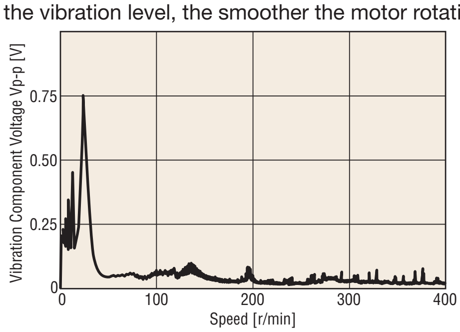
The stepping motor rotates through a series of stepping movements. A stepping movement may be described as a 1-step response, as shown below:

① A single pulse input to a stepping motor at a standstill accelerates the motor toward the next stop position.
② The accelerated motor rotates through the stop position, overshoots a certain angle, and is pulled back in reverse.
③ The motor settles to a stop at the set stop position following a damping oscillation.



1-Step Response

Vibration at low speeds is caused by a step-like movement that produces this type of damping oscillation.
The vibration characteristics graph below represents the magnitude of vibration of a motor in rotation.
The lower the vibration level, the smoother the motor rotation will be.

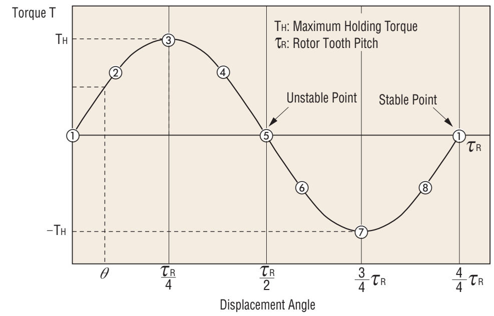


Vibration Characteristics

●Static Characteristics

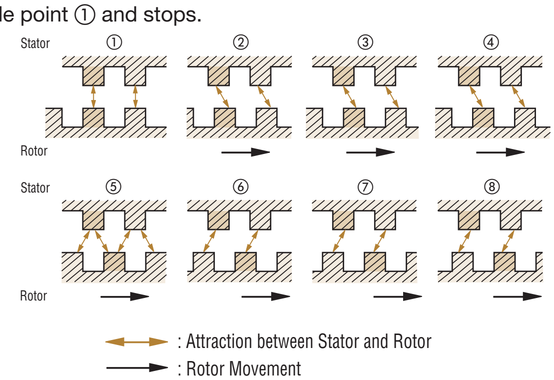
◇Angle – Torque Characteristics

The angle – torque characteristics show the relationship between the angular displacement of the rotor and the torque externally applied to the motor shaft while the motor is excited at the rated current. The curve for these characteristics is shown below:



Angle – Torque Characteristics

The following illustrations show the positional relationship between the rotor teeth and stator teeth at the numbered points in the diagram above.
When held stable at point ① the external application of a force to the motor shaft will produce torque T (+) in the left direction, trying to return the shaft to stable point ①. The shaft will stop when the external force equals this torque at point ②.
If additional external force is applied, there is an angle at which the torque produced will reach its maximum at point ③. This torque is called the maximum holding torque TH.
Application of external force in excess of this value will drive the rotor to an unstable point ⑤ and beyond, producing torque T (−) in the same direction as the external force, so that it moves to the next stable point ① and stops.



Stable Points:
Points where the rotor stops, with the stator teeth and rotor teeth are exactly aligned. These points are extremely stable, and the rotor will always stop there if no external force is applied.

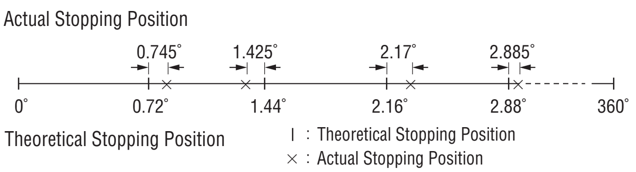
Unstable Points:
Points where the stator teeth and rotor teeth are half a pitch out of alignment. A rotor at these points will move to the next stable point to the left or right, even under the slightest external force.

◇Angle Accuracy

Under no load conditions, a stepping motor has an angle accuracy within ±3 arc minutes (±0.05°). The small error arises from the difference in mechanical precision of the stator and rotor and a small variance in the DC resistance of the stator winding.
Generally, the angle accuracy of the stepping motor is expressed in terms of the stop position accuracy, as described on the right.

Stop Position Accuracy:

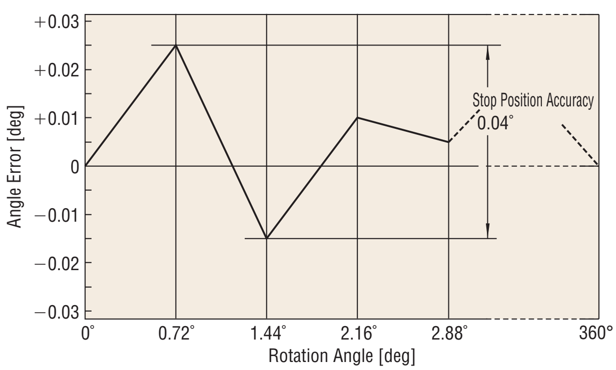
The stop position accuracy is the difference between the rotor's theoretical stopping position and its actual stopping position. A given rotor stopping point is taken as the starting point, then the stop position accuracy is the difference between the maximum (+) value and maximum (–) value in the set of measurements taken for each step of a full rotation.



The stop position accuracy is within ±3 arc minutes (±0.05°), but only under no load conditions. In actual applications there is always the same amount of friction load.

The angle accuracy in such cases is produced by the angular displacement caused by the angle – torque characteristics based upon the friction load. If the friction load is constant, the displacement angle will be constant for uni-directional operation. However, in bi-directional operation, double the displacement angle is produced over a round trip.

When high stopping accuracy is required, always position in the same direction.



Excitation Sequence of Stepping Motor and Driver Packages

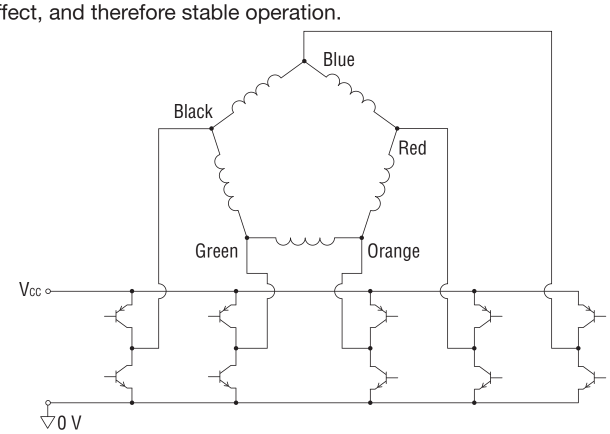
Every 5-phase motor and driver package listed in our catalog consists of a New Pentagon, five-lead wire motor and a driver incorporating a special excitation sequence. This combination, which is proprietary to Oriental Motor, offers the following benefits:

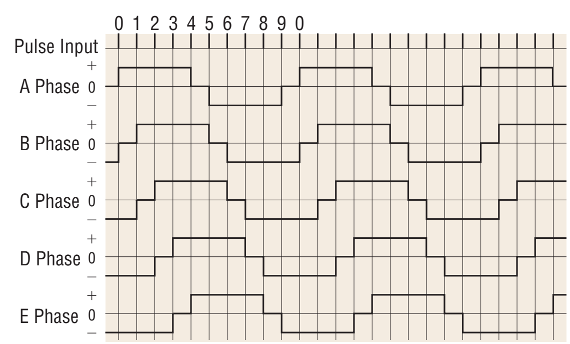
- Simple connections for five leads
- Low vibration

The following sections describe the wiring and excitation sequence.

●New Pentagon, 4-Phase Excitation: Full Step System (0.72°/step)

This is a system unique to the 5-phase motor, in which four phases are excited. The step angle is 0.72° (0.36°). It offers a great damping effect, and therefore stable operation.

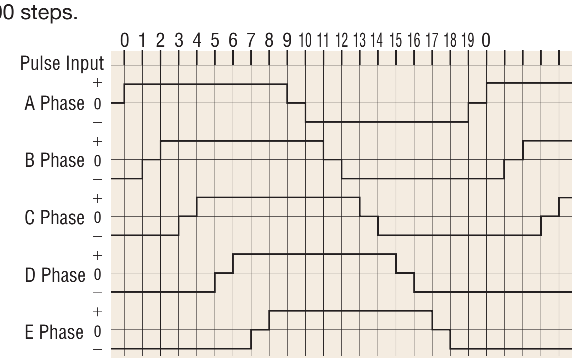




New Pentagon, 4-Phase Excitation Sequence

●New Pentagon, 4-5-Phase Excitation: Half-Step System (0.36°/step)

A step sequence of alternating the 4-phase and 5-phase excitation produces rotation at 0.36° per step. One rotation may be divided into 1000 steps.



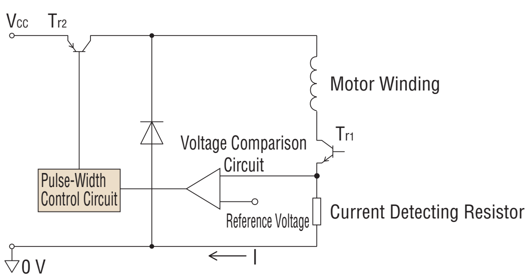
New Pentagon, 4-5-Phase Excitation Sequence

■Stepping Motor Drivers

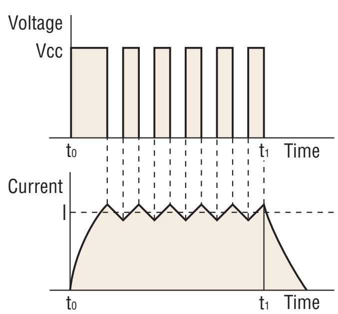
There are two common systems of driving a stepping motor: constant current drive and constant voltage drive.
The circuitry for the constant voltage drive is simpler, but it's relatively more difficult to achieve torque performance at high speeds.
The constant current drive, on the other hand, is now the most commonly used drive method, since it offers excellent torque performance at high speeds. All Oriental Motor's drivers use the constant current drive system.

●Overview of the Constant Current Drive System

The stepping motor rotates through the sequential switching of current flowing through the windings. When the speed increases, the switching rate also becomes faster and the current rise falls behind, resulting in lost torque.
The chopping of a DC voltage that is far higher than the motor's rated voltage will ensure the rated current reaches the motor, even at higher speeds.



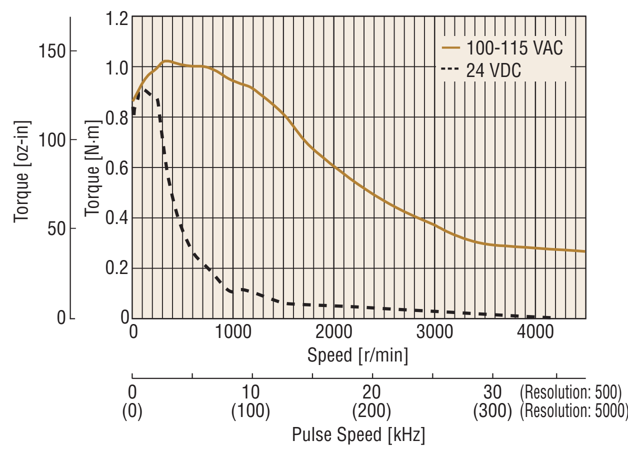
The current flowing to the motor windings, detected as a voltage through a current detecting resistor, is compared to the reference voltage. Current control is accomplished by holding the switching transistor Tr_2 ON when the voltage across the detecting resistor is lower than the reference voltage (when it hasn't reached the rated current), or turning Tr_2 OFF when the value is higher than the reference voltage (when it exceeds the rated current), thereby providing a constant flow of rated current.



Voltage – Current Relationship in Constant Current Chopper Drive

●Differences between AC Input and DC Input Characteristics

A stepping motor is driven by a DC voltage applied through a driver. In Oriental Motor's 24 VDC input motor and driver packages, 24 VDC is applied to the motor. In the 100-115 VAC motor and driver packages the input is rectified to DC and then approximately 140 VDC is applied to the motor. (Certain products are exceptions to this.)
This difference in voltages applied to the motors appears as a difference in torque characteristics at high speeds. This is due to the fact that the higher the applied voltage is, the faster the current rise through the motor windings will be, facilitating the application of rated current at higher speeds. Thus, the AC input motor and driver package has superior torque characteristics over a wide speed range, from low to high speeds, offering a large speed ratio.
It is recommended that AC input motor and driver packages, which are compatible with a wider range of operating conditions, be considered for your applications.



●Microstep Drive Technology

Microstep drive technology is used to divide the basic step angle (0.72˚) of the 5-phase stepping motor into smaller steps (up to a maximum of 250 divisions) without the use of a speed reduction mechanism.

◇Microstep Drive Technology

The stepping motor moves and stops in increments of the step angle determined by the rotor and stator's salient pole structure, easily achieving a high degree of precision in positioning. The stepping motor, on the other hand, causes the rotor speed to vary because the motor rotates in step angle increments, resulting in resonance or greater vibration at a given speed.
Microstepping is a technology that achieves low resonance, low noise operation at extremely low speeds by controlling the flow of electric current fed to the motor coil and thereby dividing the motor's basic step angle into smaller steps.

- The motor's basic step angle (0.72˚/full step) can be divided into smaller steps ranging from 1/1 to 1/250. Microstepping thus ensures smooth operation.
- With the technology for smoothly varying the motor drive current, motor vibration can be minimized for low noise operation.

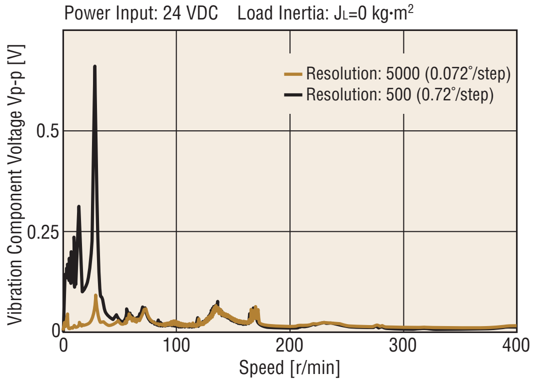
◇Up to 250 Microsteps

Thanks to the microstep driver, different step angles (16 steps up to 250 divisions) can be set to two step angle setting switches. By controlling the input signal for step angle switching via an external source, it is possible to switch the step angle between the levels set for the respective switches.

Features of Microstep Drive

- **Low Vibration**

Microstep drive technology electronically divides the step angle into smaller steps, ensuring smooth incremental motion at low speeds and significantly reducing vibration.
While a damper or similar device is generally used to reduce vibration, the low vibration design employed for the motor itself — along with the microstep drive technology — minimizes vibration more effectively.
Anti-vibration measures can be dramatically simplified, so it's ideal for most vibration sensitive applications and equipment.



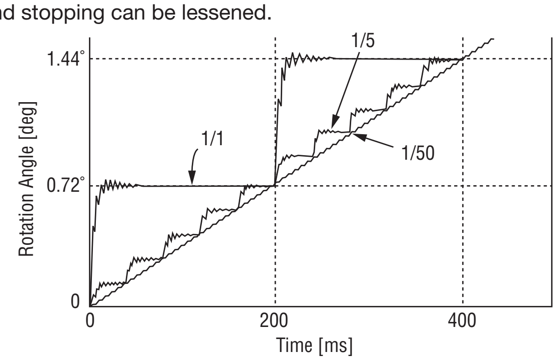
Vibration Characteristics

- **Low Noise**

Microstep drive technology effectively reduces the vibration related noise level at low speeds, achieving low noise performance.
The motor demonstrates outstanding performance in even the most noise sensitive environment.

- **Improved Controllability**

The New Pentagon microstep driver, with its superior damping performance, minimizes overshoot and undershoot in response to step changes, accurately following the pulse pattern and ensuring improved linearity.
In addition, shock normally resulting from the motions of starting and stopping can be lessened.



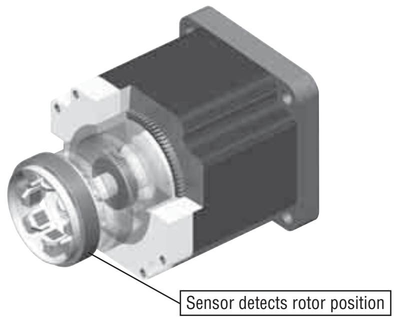
Step-Response Variation

Stepping Motor and Driver Package αSTEP

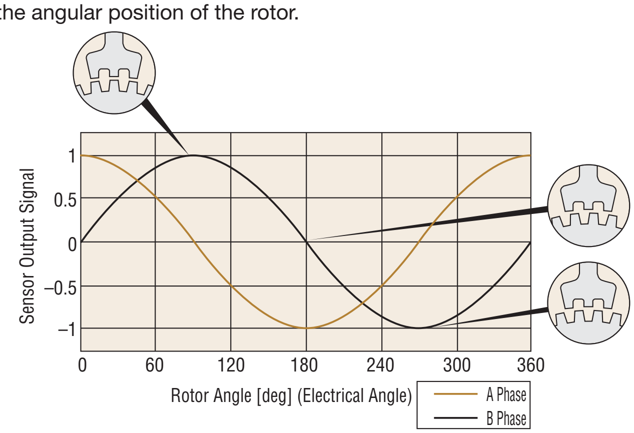
Overview of the Control System

◇The Sensor to Detect Rotor's Position

A rotor position detection sensor is built into the counter end of the motor output shaft.



The sensor winding detects changes in magnetic reluctance due to the angular position of the rotor.

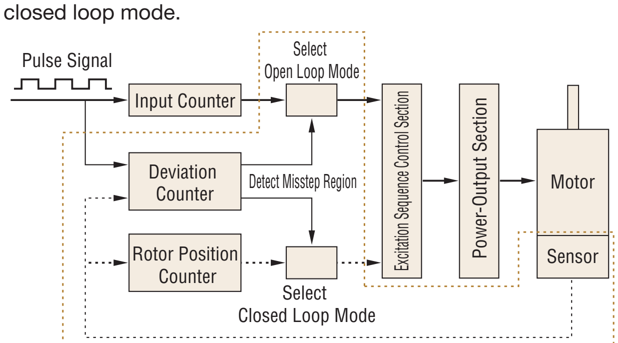


Output Signal of Rotor Position Detection Sensor

◇Featuring Innovative Closed Loop Control

The deviation counter calculates the deviation (lag/advance) of the rotor's actual angular position with regard to the position command by the pulse signal.
The calculation result is used to detect a "misstep region" and operate the motor by switching between open loop and closed loop modes.

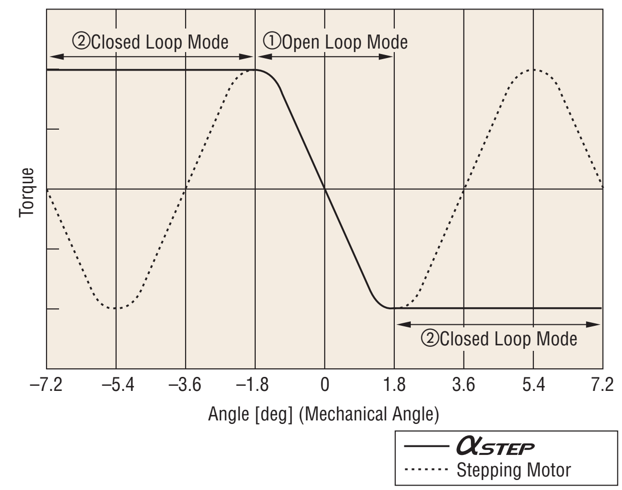
- If the positioning deviation is less than ±1.8˚, the motor runs in the open loop mode.
- If the positioning deviation is ±1.8˚ or more, the motor runs in closed loop mode.



: Unique Control Section of αSTEP
Rotor Position Counter: Specifies an excitation sequence that would develop maximum torque for a given rotor position.

αSTEP Control Diagram

In the closed loop mode, motor-winding excitation is controlled so that maximum torque is developed for the given angular position of the rotor.
This control method eliminates unstable points (misstep region) in the angle – torque characteristics.



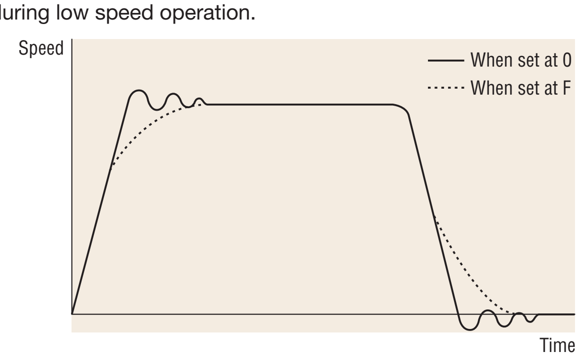
Angle – Torque Characteristics

Features of αSTEP

◇Improved Stepping Motor Performance

- At high speeds αSTEP will not "misstep." Therefore, unlike conventional stepping motors, the αSTEP operation will be free of the following restrictions:
  - Restrictions on acceleration/deceleration rates and inertia ratio stemming from the pulse profile of the controller.
  - Restrictions on starting pulse speed caused by "misstep."

- Use the velocity filter to adjust responsiveness while starting/stopping
  The responsiveness of starting/stopping can be adjusted with 16 settings without changing the controller data (starting pulse, acceleration/deceleration rates).
  This feature is intended to reduce shock to the work and vibration during low speed operation.

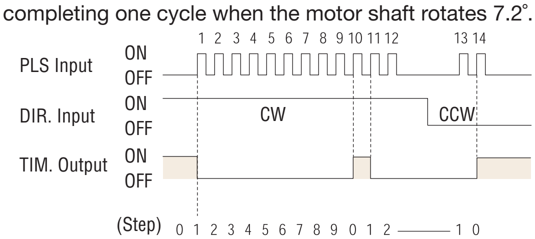


Effect of Velocity Filter

Return to Mechanical Home Operation Using Excitation Timing Signal

Excitation Timing Signal

The excitation timing (TIM.) signal is output when the driver is initially exciting the stepping motor (step "0").
Oriental Motor's 5-phase stepping motor and driver packages perform initial excitation when the power is turned on, and advance the excitation sequence each time a pulse signal is input, completing one cycle when the motor shaft rotates 7.2˚.

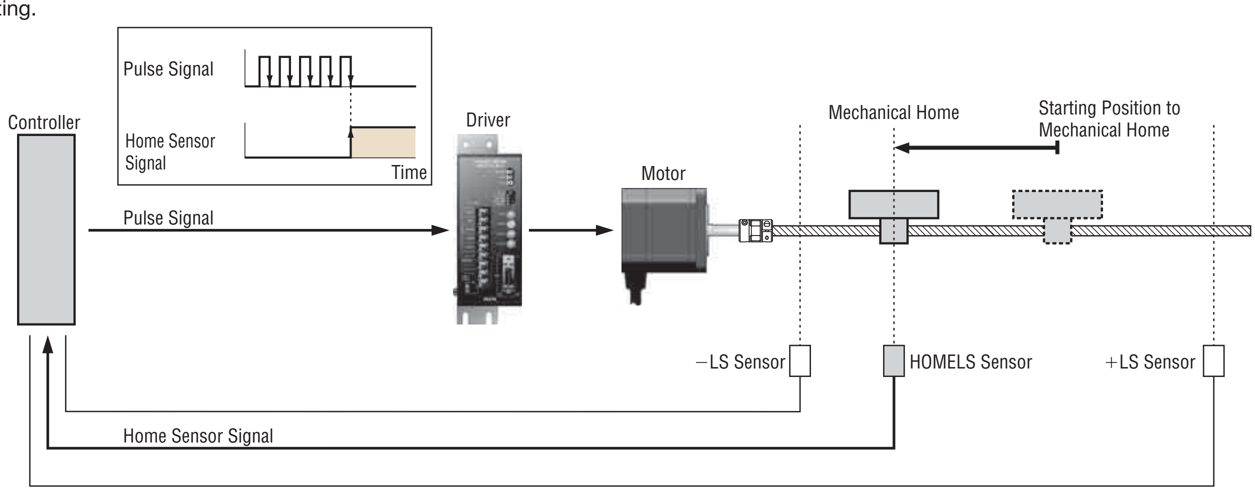


Relationship between the Excitation Sequence and Excitation Timing Signal (5-phase stepping motor and driver package)

Use these timing signals when it is necessary to perform highly reproducible return to mechanical home operation.
The following sections describe stepping motor return to mechanical home operation and the use of timing signals.

Return to Mechanical Home Operation for Stepping Motors

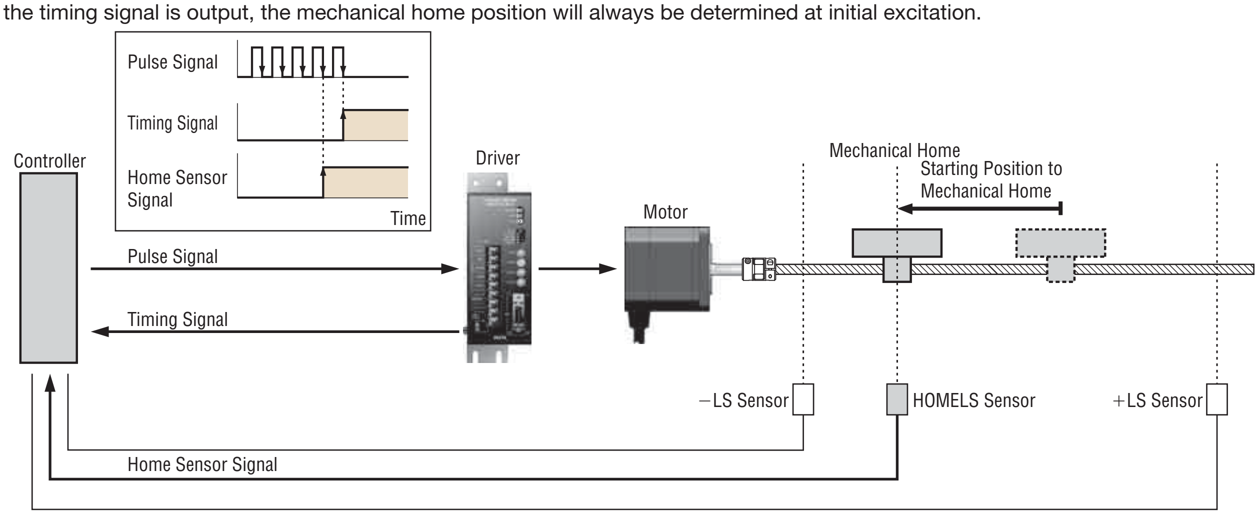
When turning on the power to start automated equipment or restarting the equipment after a power failure, it is necessary to return stepping motors to their standard position. This operation is called the "return to mechanical home operation."
The return to mechanical home operation for stepping motors uses home sensors to detect the mechanical component used for the positioning operation. When the detected signals are confirmed, the controller stops the pulse signal, and the stepping motor is stopped.
The accuracy of the home position in such a return to mechanical home operation depends on the detection performance of the home sensors. As the detection performance of the home sensors varies according to factors such as the ambient temperature and approach speed of the mechanism detection area, it's necessary to reduce these factors for applications that require a highly reproducible mechanical home position detecting.



Return to Mechanical Home Operation Using Sensors (3-sensor mode: HOME, CW LS, CCW LS)

Improved Reproducibility Using Excitation Timing Signal

A method of ensuring that the mechanical home position does not vary due to variations in the detection performance of the home sensors, is to stop the pulse signal by logically multiplying with the timing signal. As the timing signal is output at initial excitation, if the pulse signal is stopped when the timing signal is output, the mechanical home position will always be determined at initial excitation.



Relationship between Cable Length and Transmission Frequency

As the pulse line cable becomes longer, the maximum transmission frequency decreases. Specifically, the resistive component and stray capacitance of the cable cause the formation of a CR circuit, thereby delaying the pulse rise and fall times.
Stray capacitance in a cable occurs between electrical wires and ground planes. However, it is difficult to provide distinct numerical data, because conditions vary according to the cable type, layout, routing and other factors.

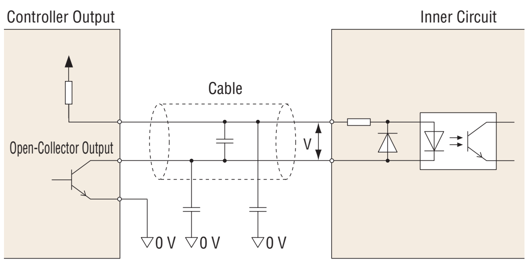


Image Diagram of Stray Capacitance in a Cable

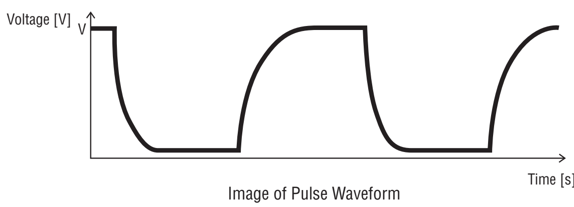


Image of Pulse Waveform

The transmission frequency when operated in combination with our products (actual-measurement reference values) are shown below:

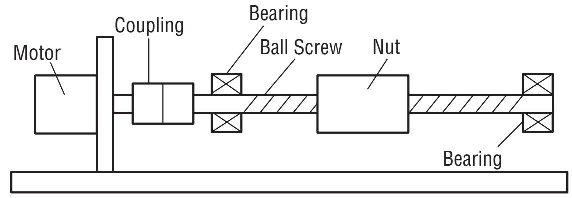
Maximum Transmission Frequency (Reference value)

Driver	Controller	Cable	Maximum Transmission Frequency
RK Series	**EMP400** Series	**CC01EMP5** [1 m (3.3 ft.)]	170 KHz
		CC02EMP5 [2 m (6.6 ft.)]	140 KHz
AS Series		**CC01EMP4** [1 m (3.3 ft.)]	150 KHz
		CC02EMP4 [2 m (6.6 ft.)]	120 KHz

Effect of Coupling Rigidity on Equipment

The specifications that indicate coupling performance include permissible load, permissible speed, torsional spring constant, backlash (play) in the coupling, and permissible misalignment. In practice, when selecting couplings for equipment that requires high positioning performance or low vibration, the primary selection criteria would be "rigid, with no backlash."
However, in some cases coupling rigidity has only a slight effect on the equipment's overall rigidity.
This section provides an example by comparing the overall rigidity of equipment consisting of a ball screw drive in two applications where a jaw coupling such as an **MCS** and a bellows coupling offering higher rigidity are used. (Data is taken from KTR's technical document, for which reason the coupling dimensions differ from the products offered by Oriental Motor.)

● Overview of Test Equipment



Equipment with Ball Screw Drive

● Specifications of Parts

Torsional spring constant of jaw coupling
$C_j = 21000$ [N·m/rad]
Torsional spring constant of bellows coupling
$C_b = 116000$ [N·m/rad]
Servo motor rigidity
$C_m = 90000$ [N·m/rad]
Ball screw lead
$h = 10$ [mm]
Ball screw root circle diameter
$d = 28.5$ [mm]
Ball screw length
$L = 800$ [mm]
Bearing rigidity in axial direction
$R_{brg} = 750$ [N/μm]
Rigidity in axial direction of ball screw nut
$R_n = 1060$ [N/μm]
Modulus of elasticity of ball screw
$R_f = 165000$ [N/mm²]

① Obtain the torsional rigidity of the ball screw, bearing and nut.
The rigidity in the axial direction of the ball screw R_s is calculated as follows:

$$R_s = (R_f \times d^2)/L$$
$$= (165000 \times 28.5^2)/800$$
$$= 167526 \text{ [N/mm]}$$
$$= 167.5 \text{ [N/μm]}$$

Therefore, the total rigidity in the axial direction of the ball screw, bearing and nut R_t is calculated as follows:

$$\frac{1}{R_t} = \frac{1}{2R_{brg}} + \frac{1}{R_s} + \frac{1}{R_n}$$
$$= \frac{1}{2 \times 750} + \frac{1}{167.5} + \frac{1}{1060}$$
$$= 0.00758$$
$$\therefore R_t = 131.9 \text{ [N/μm]}$$

This rigidity in the axial direction is applied as torsional rigidity C_t.

$$C_t = R_t\left(\frac{h}{2\pi}\right)^2$$
$$= 131.9 \times 10^6 \times \left(\frac{10 \times 10^{-3}}{2\pi}\right)^2$$
$$= 334.1 \text{ [N·m/rad]}$$

② Obtain the overall equipment rigidity C when a jaw coupling is used.

$$\frac{1}{C} = \frac{1}{C_m} + \frac{1}{C_j} + \frac{1}{C_t}$$
$$= \frac{1}{90000} + \frac{1}{21000} + \frac{1}{334.1}$$
$$= 0.003052$$
$$\therefore C = 327.7 \text{ [N·m/rad]}$$

③ Obtain the overall equipment rigidity C when a bellows coupling is used.

$$\frac{1}{C}=\frac{1}{C_m}+\frac{1}{C_b}+\frac{1}{C_t}$$
$$=\frac{1}{90000}+\frac{1}{116000}+\frac{1}{334.1}$$
$$=0.0030128$$
$$\therefore C=331.9\ [\mathrm{N{\cdot}m/rad}]$$

④ Calculation results

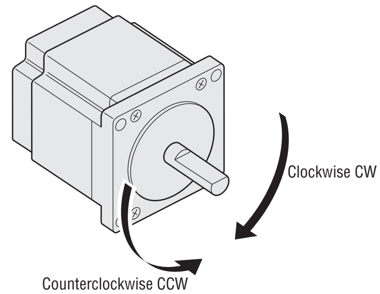
	Coupling Rigidity [N·m/rad]	Overall Equipment Rigidity [N·m/rad]
Jaw Coupling	21000	327.7
Bellows Coupling	116000	331.9

The rigidity of the jaw coupling is one-fifth the rigidity of the bellows coupling, but the difference in overall equipment rigidity is 1.2%.

Glossary

●CW, CCW

The rotation direction of motor is expressed as CW (clockwise) or CCW (counterclockwise). These directions are as seen from the output shaft.



●Overhung Load

The load on the motor shaft in the vertical direction. The value varies with the model.

●Angle Accuracy

The difference between the actual rotation angle and the theoretical rotation angle. Although there are several expressions according to how the criteria are set, generally, the angle accuracy of the stepping motor is expressed in terms of the stop position accuracy.

●Angular Transmission Error

Angular transmission error is the difference between the theoretical rotation angle of the output shaft, as calculated from the input pulse number, and the actual rotation angle. It is generally observed when a reduction mechanism is provided. Angular transmission error is used to represent the accuracy of a reduction mechanism. Oriental Motor's planetary (**PN**) gear is designed to minimize the angular transmission error to a maximum of only six arc minutes, and may be effectively used in high accuracy positioning and indexing applications.

●Inertial Load (Moment of Load Inertia)

This is the degree of force possessed by a physical object to maintain its current level of kinetic energy. Every physical object has an inherent inertial load. Greater torque is required to accelerate and decelerate an object having a larger inertial load. The degree of such torque is proportional to the degree of inertial load and the acceleration that is obtained from the operating speed and acceleration time.

●Automatic Current Cutback Function

This is a function used for the automatic reduction of motor current by approximately 50% when the pulse signal is not input, in order to minimize the heating of the motor and driver.
(Approximately 40% in **CMK** Series and **UMK** Series stepping motors)
This function automatically reduces the motor current at motor standstill, and does so within approximately 0.1 second after the pulse signal stops.

$$\text{Holding torque [N·m (oz-in)]}=\frac{\text{Maximum holding torque [N·m (oz-in)]}\times\text{Current at motor standstill [A]}}{\text{Rated motor current [A]}}$$

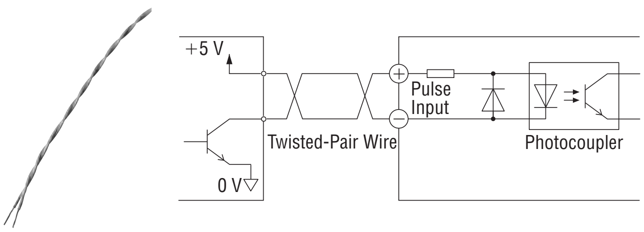
●Resonance

This refers to the phenomenon in which vibration becomes larger at specific speeds. Resonance is a result of the characteristic vibration frequency and operating vibration of a motor or other mechanism. For 2-phase stepping motors, there are resonance areas between 100 Hz and 200 Hz; 5-phase stepping motors have lower levels of resonance.

●Thrust Load
The thrust load is the load in the direction of the motor output shaft. The value varies with the model.

●Misstep
Stepping motors are synchronized by pulse signals. They can lose their synchronization when speed changes rapidly or an overload occurs. Misstep is the term for losing synchronization with the input pulse. The correctly selected and normally operated motor doesn’t suffer a sudden misstep. Essentially, misstep is a condition in which an overload alarm occurs with a servo motor.

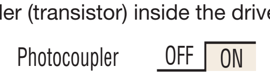
●Twisted-Pair Wire
Twisted-pair wires entwine two wires as shown in the figure below. They are used to reduce noise in signal wires. Because the wires face in opposite directions from each other and carry the same current, noise from the ambient surroundings is cancelled out and noise effects reduced.



●Backlash
Backlash is a term used to describe the play in a gear or coupling. Since the range of backlash angle cannot be controlled, minimizing the backlash will help improve the accuracy of positioning. Oriental Motor provides the non-backlash harmonic and **PN** geared type as well as the **TH** geared type offering low backlash.

●Pulse Input Mode
The pulse mode used when the CW/CCW rotation direction is controlled by the pulse command. The pulse input configuration may be 1-pulse (1P) input mode or 2-pulse (2P) input mode. The 1-pulse input mode uses the pulse signal and rotation direction signal, while the 2-pulse input mode uses the CW pulse input for the CW direction and the CCW pulse input for the CCW direction.

●Photocoupler "ON" "OFF"
Photocouplers are electronic components that relay electrical signals as light. They are electronically insulated on the input and output sides, so noise has little effect on them. Input (output) "ON" indicates that the current is sent into the photocoupler (transistor) inside the driver. Input (output) "OFF" indicates that the current is not sent into the photocoupler (transistor) inside the driver.



●Microstep
Microstepping is a technology used to achieve higher resolution by controlling the flow of current to the motor’s coil and dividing the step angle into smaller steps. Extremely small steps help eliminate vibrations caused by the stepping drive, thus achieving low vibration and low noise operation.

●Gravitational Operation
Gravitational operation refers to the downward movement of a lifted load. Since the motor is operating by gravity, the servo motor used in this application generates electricity. To prevent damage to the driver as a result of the electricity thus generated, a regeneration circuit is required. The operation of stepping motors, including our αSTEP, is synchronized with pulses, enabling speed control even during gravitational operation.

●Excitation Home Position
Condition in which the excitation sequence is in its initial condition. In the 5-phase stepping motor, the sequence returns to the initial condition at 7.2° intervals.

●Excitation Sequence
The stepping motor rotates by sending current to the motor coils according to a preset combination and order. The excitation sequence is the order in which current is sent to the motor coils. It varies with the types of motor and excitation system.

Gearheads

Role of the Gearhead

The role of a gearhead is closely related to motor development. Originally, when the AC motor was a simple rotating device, the gearhead was mainly used to change the motor speed and as a torque amplifier. With the introduction of motors incorporating speed control functions, the primary role of the gearhead was to amplify torque. But with the wide acceptance of stepping motors to meet the requirements for control of speed and position, gearheads found new purposes, including the amplification of torque, improvement in permissible inertia and reduction of motor vibration. Furthermore, the accurate positioning capability of motors has created a demand for high-precision, backlash-free gearheads, unlike the conventional gearheads for AC motors.
Oriental Motor, keeping up with these trends, has been developing specific gearheads having optimal characteristics needed to preserve the characteristics of the motor with which it is used. Gearheads for AC motors are designed with emphasis on high permissible torque, long life, low noise and a wide range of gear ratios to use continuously for power source. By contrast, gearheads for stepping motors are designed for high accuracy positioning, where a high accuracy, high permissible torque and high speed operation are important. The following sections describe these gearheads in detail.

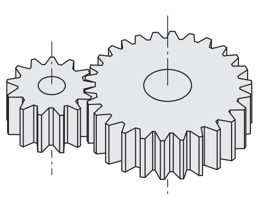
Gearheads for AC Motors

Standard AC motors have a long history, as do the gearheads used with these motors. During the course of that history, AC motors and gearheads have found a wide spectrum of applications and user needs including low noise level, high power, long life, wide range of gear ratios and resistance to environmental conditions. Oriental Motor has therefore been developing products in order to accommodate various needs.
Following is a description of the major mechanical categories applying to gearheads.

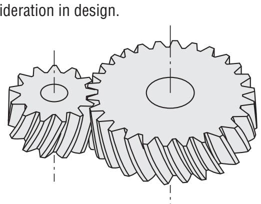
●Parallel Shaft Gearheads

Parallel shaft gearheads are the most commonly used gear systems today. Our parallel shaft gearheads employ spur gears and helical gears. Particularly, helical gears are used for low noise, high strength performance.

●Spur Gear
The spur gear is a cylindrical gear on which the teeth are cut parallel to the shaft.

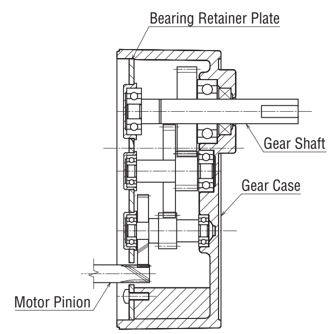


●Helical Gear
The helical gear is a cylindrical gear having teeth cut in a helical curve. Its high rate of contact, as compared to the spur gear, has the advantages of low noise and higher strength, but its axial load calls for careful consideration in design.



In both types of gearheads, the helical configuration is employed for the motor pinion and its mating gear. This contributes significantly to noise reduction because of their high contact speeds, thereby achieving lower noise output.
The long life, low noise **GN-S** gearhead and **GV** gearhead is illustrated in the following as examples.
The **GN-S** gearhead generates less noise than the conventional gearhead. Thanks to the gear case made more rigid and gears with a special shape and surface machining assembled with the use of advanced technology.
The **GN-S** gearhead and **GE-S** gearhead achieve a rated life of 10000 hours by adopting a large, specially designed bearing and reinforced gears.

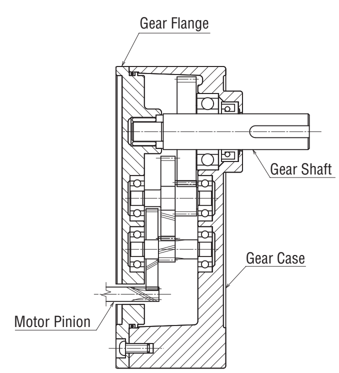
GN-S Gearhead



GN-S Gearhead

The **GV** gearhead achieves noise reduction through improving gear case rigidity, further improvement of gear machining technology, and higher accuracy in assembly technology. The **GV** gear head, with their hardened gears by carburizing and quenching and the larger bearings, also achieves permissible torque of two to three times that of conventional products, as well as a rated life of 10000 hours. Moreover, the **GV** gearhead will survive 20000 hours of operation when used under the same torque commonly expected of conventional gear heads. Indeed, the **GV** gearhead provides a great way to extend maintenance intervals and save energy and resources.

GV Gearhead

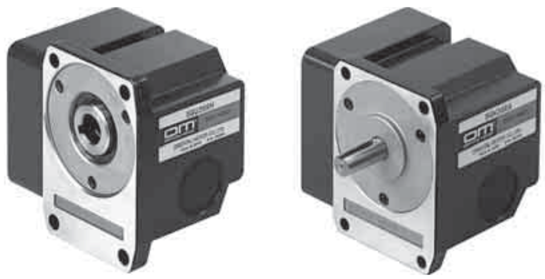


GV Gearhead

For use with standard AC motors, many of which are constant speed motors, the availability of various gear ratios suits a wide range of desired speeds. We support these motors with 20 different gear ratios, ranging from 3:1 to 180:1.

●Right-Angle Gearheads (Solid shaft and hollow shaft)

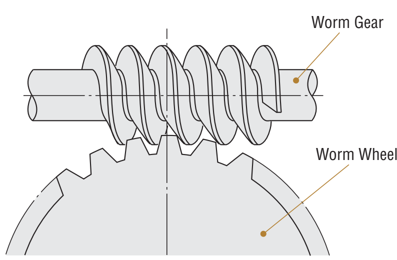
The right-angle gearhead is designed to facilitate the efficient use of limited mounting space and the elimination of couplings and other power-transmission components (in the case of the hollow shaft gearhead). Oriental Motor's gearhead consists of right-angle, hollow shaft gearheads and right-angle, solid shaft gearheads (**RH**, **RA**), which have worm gears, screw gears or hypoid gears [□104 mm (4.09 in.)]. Both right-angle gearheads incorporate right-angle gearing at the final stage, leaving the input end identical to that of the parallel shaft gearheads (**GN-S**, **GE-S**, **GU**). This facilitates the conversion from the parallel shaft gearhead to a right-angle gearhead without changing the motor.



◇Worm Gears

The worm gear transmits power from a single or multiple threaded worm to a mating worm wheel. The worm gear have a long history as the spur gear, but its application has been limited due to its relatively low efficiency and difficulty of manufacturing. Oriental Motor has successfully incorporated the worm gear based on its right-angle property and capacity for large gear ratios, and has improved its efficiency over conventional types by increasing the lead.

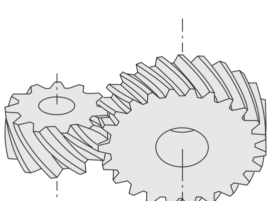
●Worm Gear
The worm gear transmits power from a single or multiple threaded worm to a mating worm wheel.

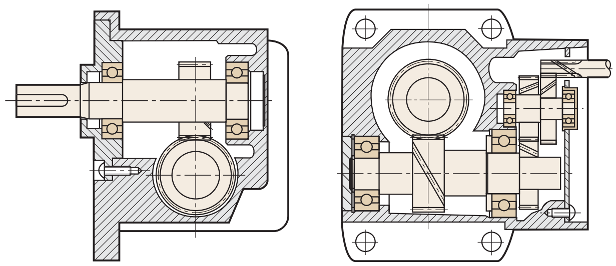


◇Screw Gears

A single screw gear appears to be another regular helical gear. While the mating helical gears in the parallel shaft configuration have equal helix angles and contact with the helixes running in opposite directions, the screw gears are designed to contact their shafts crossing at right angles. Due to their point-to-point contact configuration, they're mainly used under relatively small loads, such as at low gear ratios with our right-angle gearheads.

●Screw Gear
The screw gear is helical gear used on offset shafts (neither perpendicular nor parallel to each other)





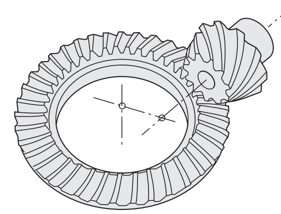
Structure of the Screw Gear in the Right-Angle Gearhead

◇Hypoid Gears

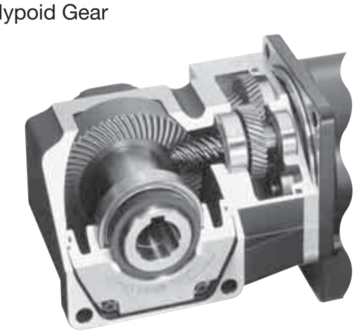
Generally, the differential gears for automotive use have been hypoid gears. Being something of a midpoint between the 0 offset bevel gear and maximum-offset worm gear, the hypoid gear achieves a combination of high strength and efficiency. The offset placement of the pinion gear of hypoid gear allows the suppression of vibration and helps obtain higher gear ratios, as compared to the bevel gear. The hypoid gears in Oriental Motor's gearheads are incorporated at the final stage, facilitating the disassembly of the gears from the motor.

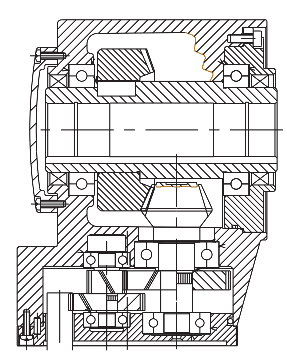
● Offset: In hypoid gears the two shafts do not cross but are in displaced planes, separated from each other at right angle. The displacement is called the offset.

●Hypoid Gear
The hypoid gear is conical gear with curved teeth for transmitting power between two offset shafts.



BH Series, Hypoid Gear





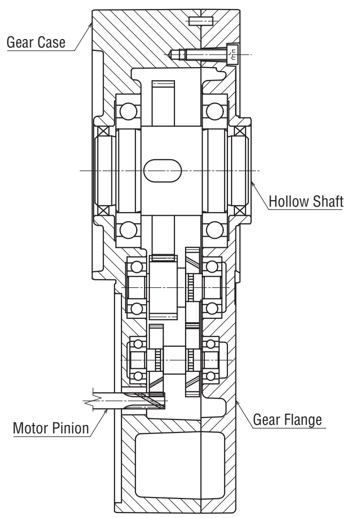
Structure of the Hypoid Gear

Gearheads for Brushless Motor

Brushless motors used for speed control have a high maximum speed in a range of 3000 to 4000 r/min. Accordingly, gearheads to be combined with these motors must keep the noise level low even at high speeds, while also ensuring high permissible torque and long life to fully utilize the characteristics of the high output motors.
Oriental Motor's gearheads for brushless motor provide parallel shaft gearheads having the same structure as AC motor gearheads, and hollow shaft flat gearheads achieving a hollow shaft specification with the parallel shaft structure.

●Hollow Shaft Flat Gearheads

Hollow shaft flat gearheads need few connection parts such as couplings, and also prevent saturation of permissible torque even at high gear ratios. Accordingly, these products are ideal for applications where high permissible torque is required.
Combination of hollow shaft flat gearhead and compact brushless motor realizes a compact installation without a right-angle shaft mechanism.
Hollow shaft flat gearheads are structured to increase the space volume beyond the levels achieved with conventional parallel shaft gearheads by extending the gear shaft layout in the longitudinal direction. At the same time, the gear case has been made more rigid while the gear and bearing outer diameters have been increased. These features make it possible to provide a hollow output shaft with the parallel shaft structure, which helps increase the permissible torque and life of the product.
In addition, the parallel shaft structure ensures higher gear transmission efficiency compared to conventional right-angle shaft mechanisms.
Our brushless motors offer as combination type with motor and gearhead pre-assembled. This enables easy mounting to the machinery and also allows the gearhead to be replaced to change the gear ratio.



Structure of the Hollow Shaft Flat Gearhead

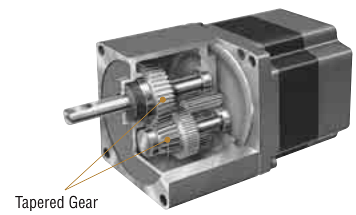
Stepping Motor Gears

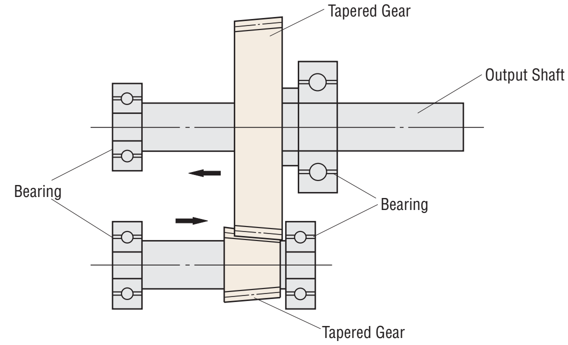
Since stepping motors and other control motors are designed to allow accurate positioning, the gearheads used for these motors must provide the same level of accuracy. Accordingly, Oriental Motor has developed a mechanism to minimize backlash in gears used with stepping motors in order to ensure low backlash properties.
Generally speaking, a stepping motor features greater output torque than an AC motor of the same frame size. Therefore, the stepping motor is designed to accommodate high torque and high speed so as not to diminish the motor's characteristics.
The basic principles and structures of typical control motor gears are explained below.

●**TH** (Taper Hobbed) Gears

◇Principle and Structure

Tapered gears are used for the final stage of the spur gear's speed-reduction mechanism and the meshing gear. The tapered gear is produced through a continuous profile shifting toward the shaft. The tapered gears are adjusted in the direction of the arrows, as shown in the figure below, to reduce backlash.



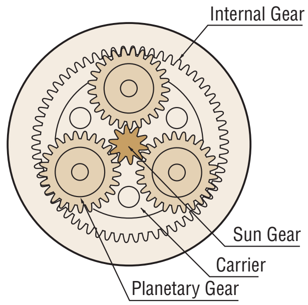


Structure of **TH** Gear's Final Stage

●Planetary (**PN**) Gears

◇Principle and Structure

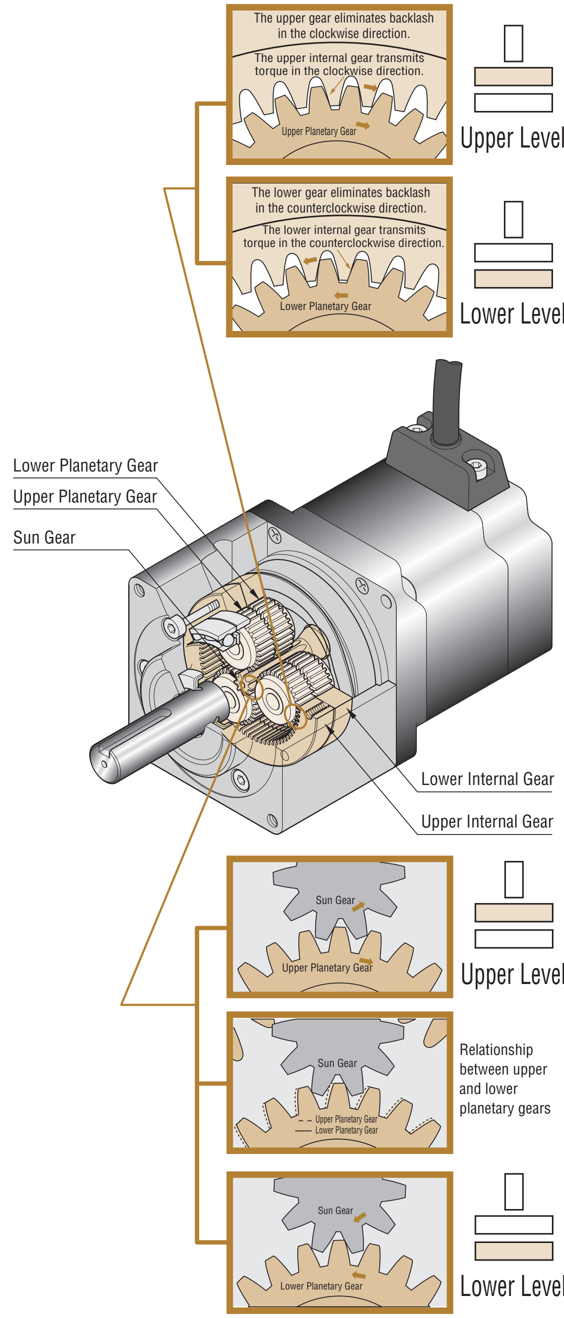
The planetary gear mechanism is comprised mainly of a sun gear, planetary gears and an internal tooth gear. The sun gear is installed on the central axis (in a single stage type, this is the motor shaft) surrounded by planetary gears enclosed in an internal tooth gear centered on the central axis. The revolution of planetary gears is translated into rotation of the output shaft via carriers.



Cross Section of a **PN** Gear

Sun Gear:	A gear located in the center, functioning as an input shaft.
Planetary Gears:	Several external gears revolving around the sun gear. Each planetary gear is attached to the carrier, onto which the gear's output shaft is securely fixed.
Internal Gear:	A cylindrical gear affixed to the gearbox, having teeth on its inside diameter.

The **PN** gear employs the planetary gear speed-reduction mechanism. The **PN** gear achieves the specified backlash of three arc minutes through the improved accuracy of its components and the backlash-elimination mechanism. That mechanism is comprised of two sets of internal and planetary gears on the upper and lower levels with the internal gear teeth twisted in the circumferential direction. The upper internal gears and planetary gears reduce clockwise backlash; the lower internal gears and planetary gears reduce counterclockwise backlash.



◇High Permissible Torque

In conventional spur-gear speed reduction mechanisms, gears mesh one to one, so the amount of torque is limited by the strength of each single gear. On the other hand, in the planetary gear speed reduction mechanism, a greater amount of torque can be transmitted, since torque is distributed through dispersion via several planetary gears.

The torque applied to each gear in the planetary gear speed reduction mechanism is obtained through the following formula:

$$T = k\frac{T'}{n}$$

T: Torque applied to each planetary gear [N·m (oz-in)]

T': Total torque transference [N·m (oz-in)]

n: Number of planetary gears

k: Dispersion coefficient

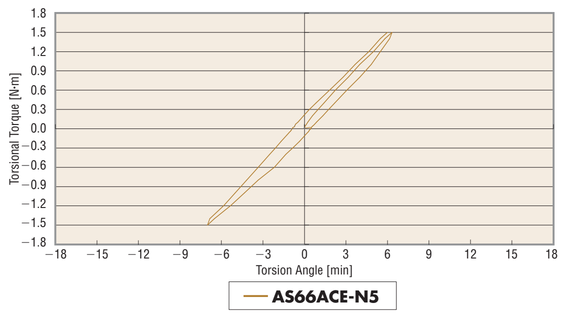
The dispersion coefficient indicates how evenly the torque is dispersed among the individual planetary gears. The smaller the coefficient, the more evenly the torque is dispersed and the greater the amount of torque that can be transferred. To evenly distribute the transferred torque, each component must be accurately positioned.

◇Gear Characteristics

Torsional rigidity

When a load is applied to the **PN** gear's output shaft, displacement (torsion) occurs by the spring characteristics of gear. The graph below shows data for torsion angles measured by gradually increasing and decreasing the load on the output shaft in the forward and backward directions. Since the **PN** gear's backlash is maintained at or below three arc minutes, the torsional torque will not result in an abrupt increase in torsion angle.

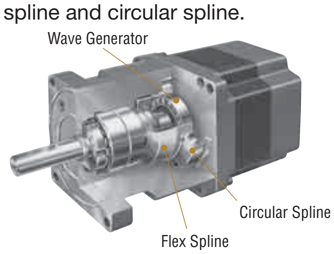
Torsional Rigidity of **PN** Geared Types



●Harmonic Gears

◇Principle and Structure

The harmonic gear offers unparalleled precision in positioning and features a simple structure utilizing the metal's elastodynamics property. It is comprised of three basic components: a wave generator, flex spline and circular spline.



• Wave Generator

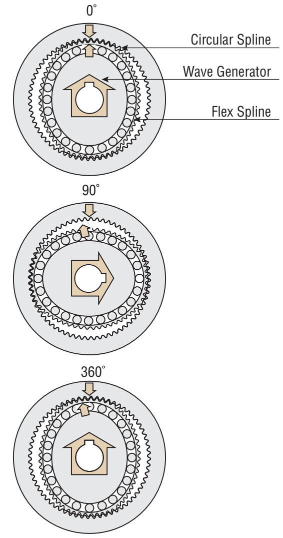
The wave generator is an oval-shaped component with a thin ball bearing placed around the outer circumference of the oval cam. The bearing's inner ring is attached to the oval cam, while the outer ring is subjected to elastic deformation via the balls. The wave generator is mounted onto the motor shaft.

• 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 gear's output shaft is attached to 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 two more teeth than the flex spline. The circular spline is attached to the gearbox along its outer circumference.



Combines three basic parts. The flex spline is bent into an oval shape by the wave generator. The teeth at the long axis of the oval mesh with the circular spline, while the teeth at 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.

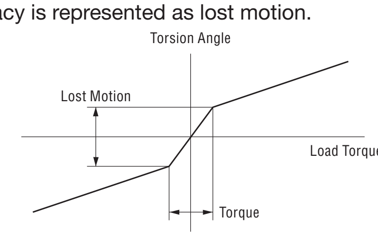
When the wave generator completes one revolution, the flex spline has rotated two fewer teeth than the circular spline has, resulting in the movement of flex spline for the difference in the tooth count (two teeth) in the opposite direction of the wave generator's rotation (i.e., counterclockwise). This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

◇Precision

Unlike conventional spur gears, the harmonic gear is capable of averaging the effects of tooth pitch errors and accumulated pitch errors to the rotational accuracy, thus achieving highly accurate, non-backlash performance. However, the gear's own torsion may become the cause of a problem when performing ultra-high accuracy positioning of two arc minutes or less. When using a harmonic gear for ultra-high accuracy positioning, remember the following three points.

• Lost Motion

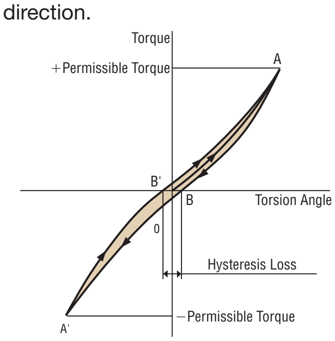
Lost motion is the total value of the displacement produced when about 5% of permissible torque is applied to the gear's output shaft. Since harmonic gears have no backlash, the measure indicating the gear's accuracy is represented as lost motion.



• Hysteresis Loss

When torsion torque is gradually applied to the gear output shaft until it reaches the permissible torque in the clockwise or counterclockwise direction, the torsion angle will become smaller as the torque is reduced. However, the torsion angle never reaches 0, even when fully returned to its initial level. This is referred to as "hysteresis loss," as shown by B-B' in the figure.

Harmonic gears are designed to have a hysteresis loss of less than two minutes. When positioning in the clockwise or counterclockwise direction, this hysteresis loss occurs even with a friction coefficient of 0. When positioning to two minutes or less, positioning must be done in a single direction.



Torsion Angle – Torque Characteristics

● Torque – Torsion Characteristics

Displacement (torsion) is produced by the gear's spring constant when a load is applied to the output shaft of the harmonic gear. The amount of this displacement, which is caused when the gear is driven under a friction load, is the same as the value when the motor shaft is held fixed and torsion torque is applied to the gear's output shaft.
The amount of displacement (torsion angle) can be estimated through use of a formula, as shown below.

The harmonic gear's torsion angle – torque characteristics curve is not linear, and the characteristics can be expressed in one of the following three formulas depending on the load torque:

1. Load torque T_L is T_1 or less.

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

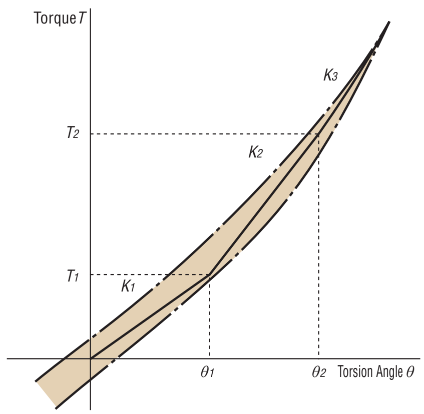
2. Load torque T_L is greater than T_1 but not larger than T_2.

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

3. Load torque T_L is greater than T_2.

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

Torsion angles obtained by these formulas are for individual harmonic gears.



Torsion Angle – Torque Characteristics

Values for Determining Torsion Angle

Model \ Item	Gear Ratio	T_1 N·m (lb-in)	K_1 N·m/min (lb-in/min)	θ_1 min	T_2 N·m (lb-in)	K_2 N·m/min (lb-in/min)	θ_2 min	K_3 N·m/min (lb-in/min)
CRK513P-H50	50	0.075 (0.66)	0.03 (0.26)	2.3	0.22 (1.94)	0.04 (0.35)	5.9	0.05 (0.44)
CRK513P-H100	100	0.075 (0.66)	0.04 (0.35)	1.7	0.22 (1.94)	0.05 (0.44)	4.5	0.06 (0.53)
ASC34-H50	50	0.29 (2.5)	0.08 (0.7)	3.7	–	0.12 (1.06)	–	–
ASC34-H100	100	0.29 (2.5)	0.1 (0.88)	2.9	1.5 (13.2)	0.15 (1.32)	11	0.21 (1.85)
ASC46-H50 **CRK543-H50**	50	0.8 (7)	0.64 (5.6)	1.25	2 (17.7)	0.87 (7.6)	2.6	0.93 (8.2)
ASC46-H100 **CRK543-H100**	100	0.8 (7)	0.79 (6.9)	1.02	2 (17.7)	0.99 (8.7)	2.2	1.28 (11.3)
AS66-H50 **ASC66-H50** **RK564-H50** **CRK564-H50**	50	2 (17.7)	0.99 (8.7)	2	6.9 (61)	1.37 (12.1)	5.6	1.66 (14.6)
AS66-H100 **ASC66-H100** **RK564-H100** **CRK564-H100**	100	2 (17.7)	1.37 (12.1)	1.46	6.9 (61)	1.77 (15)	4.2	2.1 (18.5)
AS98-H50 **RK596-H50**	50	7 (61)	3.8 (33)	1.85	25 (220)	5.2 (46)	5.3	6.7 (59)
AS98-H100 **RK596-H100**	100	7 (61)	4.7 (41)	1.5	25 (220)	7.3 (64)	4	8.4 (74)

Advantages of Geared Stepping Motors

Geared stepping motors are designed mainly for speed reduction, higher torque and high resolution as well as the following purposes:

- Downsizing (smaller frame size and lower mass)
- High rigidity (making the motor less prone to the effects of fluctuation in friction load)
- Shorter positioning time and improved safety margin for inertial loads
- Low vibration

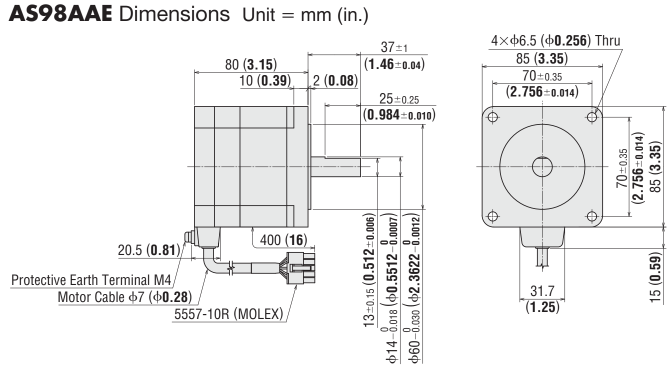
To further explain these four purposes using examples, comparisons will be made below between a standard type motor and a geared motor, both of which have similar output torque and permissible torque. If no problem exists in terms of speed, the standard type motor may be replaced by the geared motor.

● Downsizing (smaller frame size and lower mass)

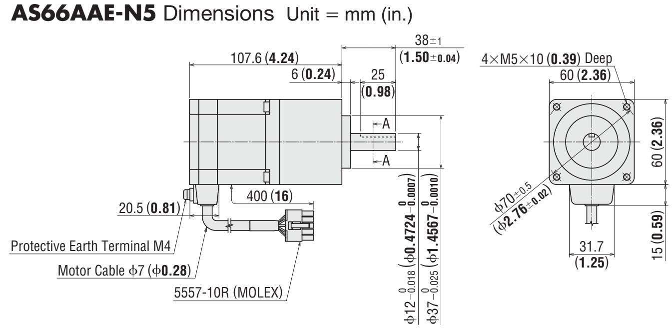
A standard type motor may be switched to a smaller geared motor as long as both motors operate at equivalent torque. For example, a standard type motor with a frame size of □85 mm (□3.35 in.) can be replaced by the geared motor with a frame size of □60 mm (□2.36 in.), thereby reducing the mass from 1.8 kg (4.0 lb.) to 1.5 kg (3.3 lb.) (comparison between **AS98AAE** and **AS66AAE-N5**).

Item \ Product Name	Standard Type	Geared Motor	
	AS98AAE	**AS66AAE-T7.2**	**AS66AAE-N5**
Motor Frame Size [mm (in.)]	□85 (□3.35)	□60 (□2.36)	□60 (□2.36)
Gear Ratio	—	7.2: 1	5: 1
Maximum Holding Torque Permissible Torque [N·m (lb-in)]	2 (17.7)	2.5 (22)	3.5 (30)
Backlash [minute]	—	15	2
Speed [r/min]	0~4000	0~250	0~600

AS98AAE Dimensions Unit = mm (in.)



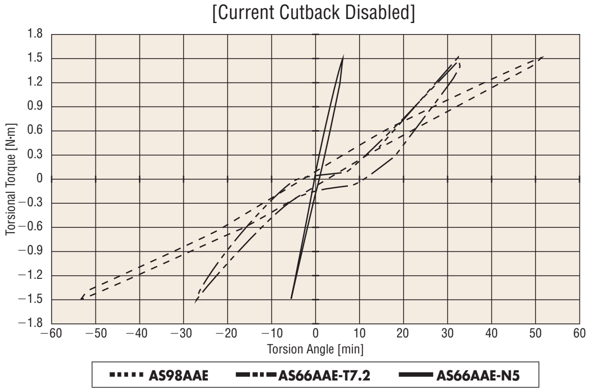
AS66AAE-N5 Dimensions Unit = mm (in.)



●High Rigidity (making the motor less prone to the effects of fluctuation in friction load)

With the motor's power on, the output shaft is subjected to torsion applied externally to measure the amount of displacement (torsion angle) for comparison of rigidity. At a given torque, the smaller displacement (torsion angle) means higher rigidity. For example, the **AS66AAE-T7.2** geared motor receives backlash effects at a light load of 0.1 N·m torsional torque, but becomes less prone to twisting than the **AS98AAE** as the torsion increases. The **AS66AAE-N5** motor receives little in the way of backlash effects at a light load, and maintains high rigidity throughout the entire torque range.

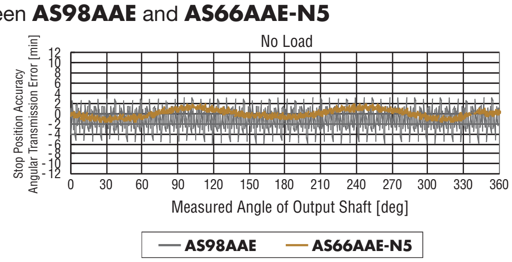
Comparison of Torsional Rigidity between Standard Type Motor and Geared Motor
[Current Cutback Disabled]

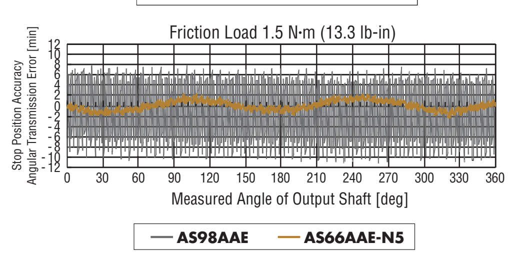


Positioning accuracy against the fluctuating friction load is an important determinant of motor rigidity. Positioning accuracy can be measured by the stop position accuracy (angular transmission error for the geared motor). The stop position accuracy (angular transmission error) refers to the difference between the theoretical rotation angle (this is the rotation angle calculated from the number of input pulses) and the actual output shaft's rotation angle. The error closer to 0 represents higher rigidity.

The standard type **AS98AAE** motor and **AS66AAE-N5** geared motor are compared by measuring the stop position accuracy (angular transmission error) under no load and a friction load, at 0.36° intervals for a rotation. The results of comparison show that standard type motor's stop position accuracy significantly increases when the load is applied while the geared motor's angular transmission error barely changes, even when the load is applied. In other words, the geared motor is more resistant to fluctuations in friction load, thus achieving more stable positioning. This feature applies to any type of geared motor. Therefore, geared motors are more effective for positioning operation for vertical drive and other applications in which friction load fluctuates due to the varying quantity and weight of the load.

Comparison of Stop Position Accuracy (Angular transmission error) between **AS98AAE** and **AS66AAE-N5**



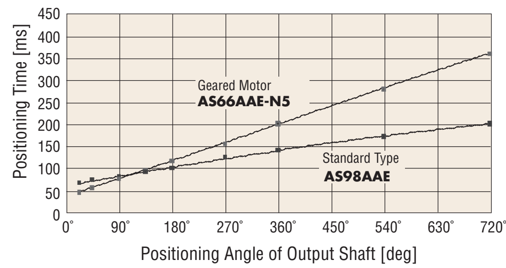


●Shorter Positioning Time and Improved Safety Margin for Inertial Loads

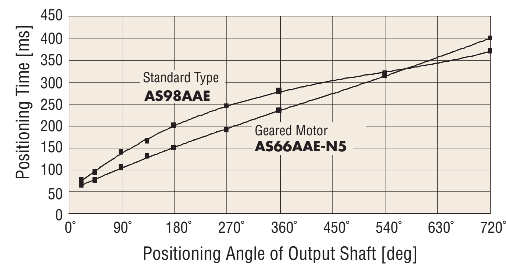
To drive a large inertial load within a short period of time, the use of a geared motor will achieve a shorter positioning time than a standard type motor.

Assume that the standard type **AS98AAE** motor is connected to inertial loads that are 5 and 30 times the rotor inertia, and that each of these inertial loads is connected to the geared type **AS66AAE-N5** motor. The shortest positioning time for each rotation angle is measured as shown in the graphs below.

$J_L=7000\times10^{-7}$ kg·m² (38 oz-in²)
(Equivalent to 5 times the rotor inertia of standard type **AS98AAE** motor)



$J_L=42000\times10^{-7}$ kg·m² (230 oz-in²)
(Equivalent to 30 times the rotor inertia of standard type **AS98AAE** motor)



The geared motor is more effective in reducing the positioning time for a smaller positioning angle and a larger inertial load. The geared motor tends to achieve shorter positioning time in a wider range of positioning angles with a larger inertial load.

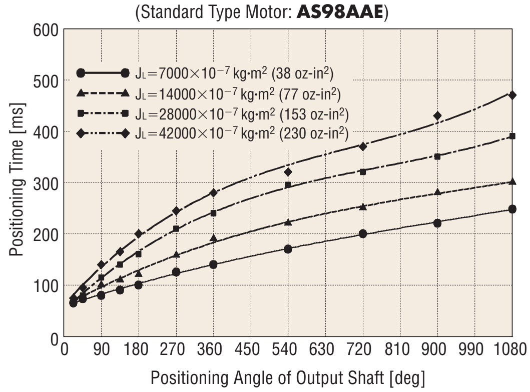
The geared motor reduces positioning time for the following reasons:

・Inertial load to the motor shaft can be reduced through the use of gears, thereby ensuring quick acceleration and deceleration starting.

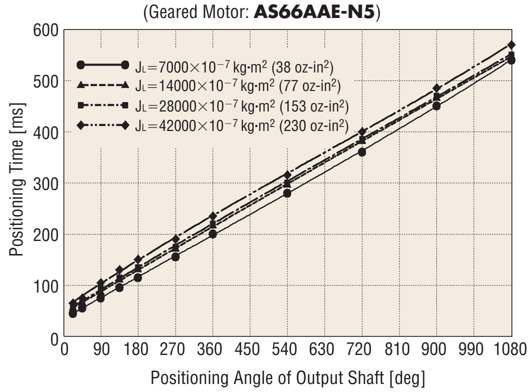
cf.) $J_M \text{ (Motor shaft inertia)} = \dfrac{J_G \text{ (Gear shaft inertia)}}{I^2 \text{ (Gear ratio)}}$

Another advantage of the geared motor is its ability to maintain a consistent positioning time regardless of changes in inertial load. The graphs below show changes in the shortest positioning time of the standard type motor and geared motor when each motor is subjected to variations in inertial load.

Changes in Positioning Time due to Variations in Load Inertia
(Standard Type Motor: **AS98AAE**)

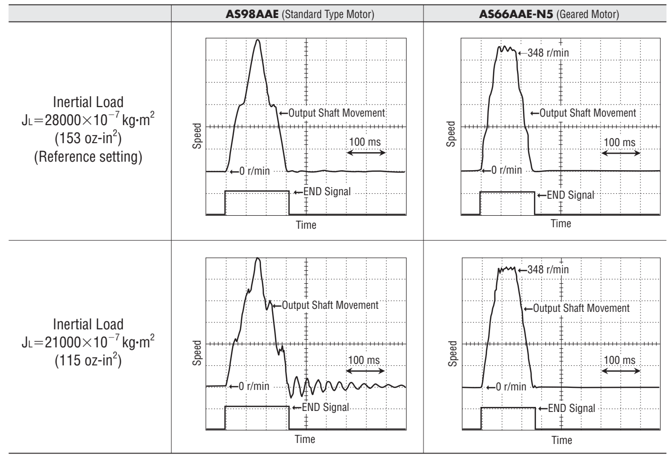


Changes in Positioning Time due to Variations in Load Inertia
(Geared Motor: **AS66AAE-N5**)



While the shortest positioning time of the standard type motor changes significantly with the increase in inertial load, that of the geared motor shows little change. In other words, the geared motor is capable of driving a larger inertial load within the most consistent, shortest positioning time.

No matter how quickly a motor can perform positioning, the failure to achieve stable operation against inertial load fluctuations may result in a problem. Therefore, it is also important to study how the operation waveform is shaped according to fluctuations in inertial load.
Connect the same inertial load to both the standard type motor and geared motor, under the operating conditions that allow for the shortest positioning. Then switch the inertial load to a smaller inertial load without changing the operating conditions. The operation waveform for each of these cases is shown in the graphs below.

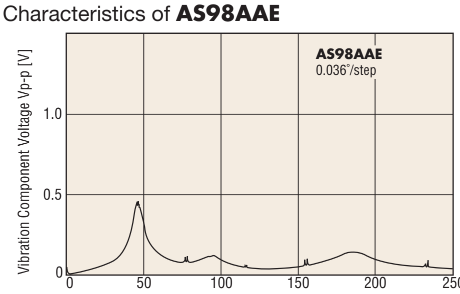


Even under the operating conditions that are optimized to reduce damping with a given inertial load, the damping characteristics of the standard type motor will deteriorate with fluctuations in inertial load. For the motor it is therefore necessary to reset the operating conditions for optimal performance each time the inertial load fluctuates. On the other hand, the geared motor's damping characteristics change little with fluctuations in inertial load, thereby ensuring steady operation.

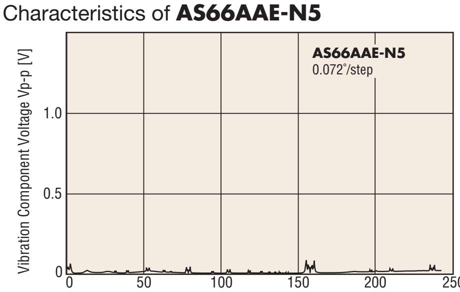
●Low Vibration

Vibration characteristics are represented in voltage, into which the vibration width of the output shaft in rotation is converted. Vibration of the geared motor can be reduced for the following reasons:
・The motor's own vibration can be reduced in accordance with the gear ratio.
・The low speed vibration range can be avoided, since the motor rotates at higher speeds.

Vibration Characteristics of **AS98AAE**



Vibration Characteristics of **AS66AAE-N5**



Linear Heads

Characteristics of Linear Heads

The three major characteristics of linear heads are rack speed, maximum transportable mass and holding force.

●Rack Speed

The rack speed of the **LS** linear head is shown in the specifications table for each product. Rack speed is expressed as "basic speed." The basic speed is calculated on the basis of the motor's synchronous speed (1800 r/min at 60 Hz). The actual rack speed varies with the load.

If the **LS** linear head is combined with a speed control motor, the rack speed can be calculated from the motor speed by using the formula below:

$$V = N_S \times \frac{1}{60} \times \frac{1}{i} \times \pi D_P$$

V : Traveling speed of rack [mm/s (inch/sec.)]
N_S : Speed of the applicable motor [r/min]
i : Gear ratio of the linear head's reduction unit
➜ Refer to table to the right.
D_P : Pitch circle diameter of pinion [mm (in.)]
➜ Refer to table to the right.

●Maximum Transportable Mass

The maximum transportable mass of the **LS** linear head is shown in the specifications table for each product.
When combining a motor and linear head not shown in the specifications table, you can use the following formula to calculate the thrust force from the torque generated by the motor.
However, in the case of a high gear ratio or use in a horizontal direction, the solution obtained by the formula will indicate a thrust force sufficient to drive the load mass in excess of the gearhead's mechanical strength. Make sure the load mass of linear head is at or below its maximum transportable mass, regardless of the traveling direction of rack.

$$F = T_m \times i \times \eta_1 \times \frac{2}{D_P} \times \eta_2$$

$$W = F/9.807$$

T_m : Motor torque [mN·m]*
F : Thrust force [N]
W : Transportable mass [kg]
i : Gear ratio of the linear head's reduction unit
➜ Refer to table to the right.
η_1 : Transmission efficiency as determined by gear ratio
➜ Refer to table to the right.
D_P: Pitch circle diameter of pinion [mm]
➜ Refer to table to the right.
η_2 : Transmission efficiency of rack and pinion [= 0.9]
*Use the starting torque or rated torque, whichever is smaller, in the calculation.

Any maximum transportable mass listed in the specifications table or any calculated thrust force is the value for horizontal operation of rack. The maximum load mass that can be driven when operating the rack vertically is the value in the specifications table less the rack mass (refer to dimensions) or the force calculated by multiplying rack mass by 9.807.

◇LS Linear Heads

Model	Gear Ratio i	Transmission Efficiency η_1	Pitch Circle Diameter of Pinion D_P [mm (in.)]
2LSF (B) 45-□	17.68	0.73	10.7 (0.42)
2LSF (B) 20-□	35.36	0.66	
2LSF (B) 10-□	86.91	0.59	
4LSF (B) 45-□	36	0.73	21.25 (0.84)
4LSF (B) 20-□	75	0.66	
4LSF (B) 10-□	150	0.66	

●Holding Force

The following formula is used to calculate the holding force of the **LS** linear head using the holding force of an applicable motor.

$$F_B = T_B \times i \times \frac{2}{D_P}$$

F_B : Holding force [N]
T_B : Holding torque of motor [mN·m]
i : Gear ratio of the linear head's reduction unit
➜ Refer to table above.
D_P : Pitch circle diameter of pinion [mm]
➜ Refer to table above.

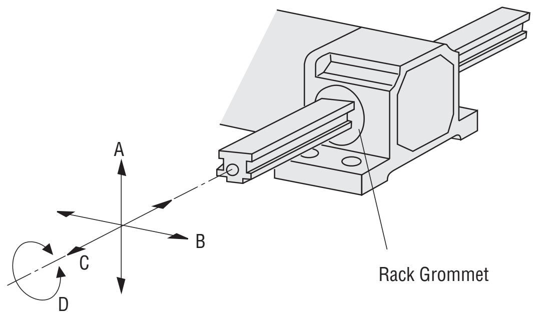
Any holding force listed in the specifications table or any calculated holding force is the value for horizontal installation of rack. The holding force that can be installed vertically is the value in the specifications table less the force calculated by multiplying rack mass by 9.807 (refer to dimensions).

●Rack Play (Initial values)

◇LS Linear Heads

The rack is supported at two rack grommets in the rack case. Because the rack passes through the inside of the grommets, a slight gap has been left between the grommets and the rack. Therefore, the rack is subject to play, as shown in the figure below.

Direction A or B	2 mm (0.079 in.) max.
Direction C (Backlash)	0.5 mm (0.020 in.) max.
Direction D	0.5° max.



● Play in directions A and B has been measured at a point 500 mm (20 in.) from the case surface.
● The rack play will increase during operation. If the rack play becomes a problem, install an external guide.

●Overrun (Reference value)

◇LS Linear Heads

2L Type

Unit = mm (in.)

Motor \ Linear Head	**2LSF(B)10-□**	**2LSF(B)20-□**	**2LSF(B)45-□**
2RK6GN-AW2U **2RK6GN-CW2E**	2.3 (0.091)	5.7 (0.22)	11 (0.43)
2RK6GN-AW2U **2RK6GN-CW2E** +Brake Pack **SB50W**	0.6 (0.024)	1.4 (0.055)	2.9 (0.11)
2RK6GN-AW2MU **2RK6GN-CW2ME**	1.2 (0.047)	2.9 (0.11)	5.7 (0.22)
2RK6GN-AW2MU **2RK6GN-CW2ME** +Brake Pack **SB50W**	0.6 (0.024)	1.4 (0.055)	2.9 (0.11)

●The above overrun values are reference values measured under no load condition.

4L Type

Unit = mm (in.)

Motor \ Linear Head	**4LSF(B)10-□**	**4LSF(B)20-□**	**4LSF(B)45-□**
4RK25GN-AW2U **4RK25GN-CW2E**	2.7 (0.11)	5.3 (0.21)	11 (0.43)
4RK25GN-AW2U **4RK25GN-CW2E** +Brake Pack **SB50W**	0.7 (0.028)	1.3 (0.051)	2.8 (0.11)
4RK25GN-AW2MU **4RK25GN-CW2ME**	1.3 (0.051)	2.7 (0.11)	5.6 (0.22)
4RK25GN-AW2MU **4RK25GN-CW2ME** +Brake Pack **SB50W**	0.7 (0.028)	1.3 (0.051)	2.8 (0.11)

●The above overrun values are reference values measured under no load condition.

Linear and Rotary Actuators

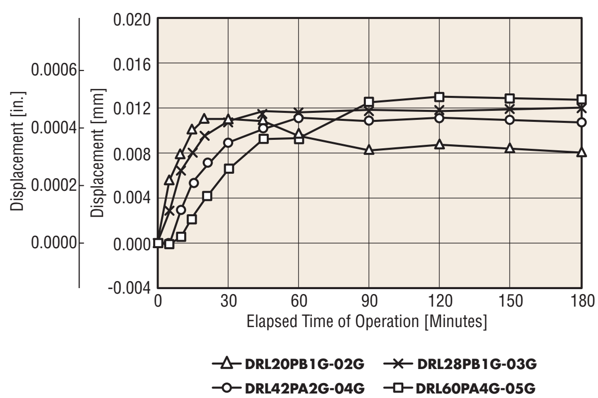
Repetitive Positioning Accuracy of Compact Linear Actuators DRL Series

Take proper precautions in order to ensure observance of the repetitive positioning accuracy requirements provided in the specifications.

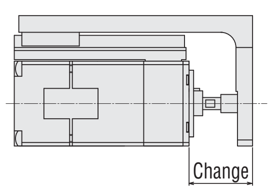
① Sufficient rigidity for peripheral equipment
- The linear-guide and other mechanical components to be used with the actuator should have rigidity sufficient to withstand the load mass and external forces. Insufficient rigidity may cause deflection, which will prevent the actuator from meeting the requirements defined in the specifications.
- The mounting brackets used for installation of the actuator and the work attachment brackets should also have rigidity sufficient to withstand the load mass and external forces. Insufficient rigidity may cause deflection, which will prevent the actuator from meeting the requirements defined in the specifications.

② Sensor
- Use a high accuracy home sensor (photo micro sensor etc.). Home positioning accuracy is not included as part of the repetitive positioning accuracy.

③ Temperature rise in actuator
- The actuator may generate a significant amount of heat, depending on the drive conditions. The heat thus generated will cause the internal ball screw to elongate, resulting in displacement as shown in the following figure (reference value). To minimize the temperature dependent effects on the repetitive positioning accuracy, control the input current to the actuator and provide a design that allows for adequate heat ventilation in peripheral equipment.

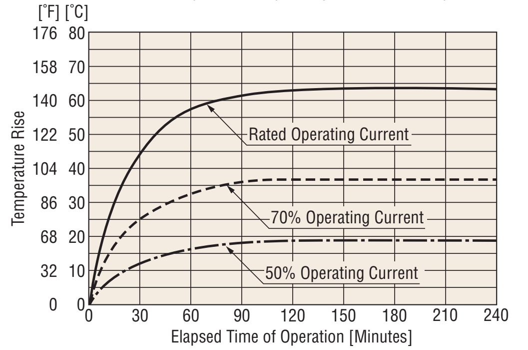


Conditions
Current cutback : OFF
Running duty : 80%
Measurement method : Using a laser displacement meter



[Reference]
The temperature rise in actuator changes when the actuator's input current is adjusted. This method is effective when there is an ample allowance in starting characteristics and holding force.

DRL42 Relationship between Operating Current and Temperature Rise



In addition to the factors mentioned above, changing the running duty also affects the temperature rise. (The above graph assumes a running duty of 75%.)

Relationship between Cable Length and Transmission Frequency

As the pulse line cable becomes longer, maximum transmission frequency decreases. Specifically, the resistive component and stray capacitance of the cable cause the formation of a CR circuit, thereby delaying the pulse rise and fall times.
Stray capacitance in a cable occurs between electrical wires and ground planes. However, it is difficult to provide distinct numerical data, because conditions vary according to the cable type, layout, routing and other factors.

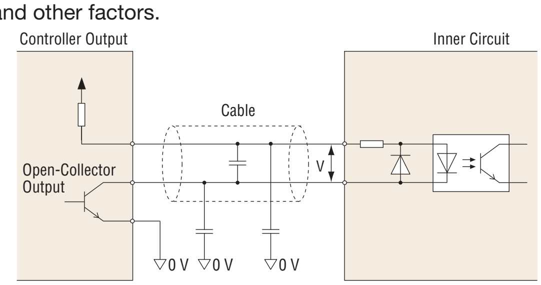


Image Diagram of Stray Capacitance in a Cable

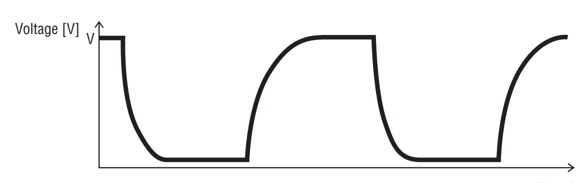


Image of Pulse Waveform

The transmission frequency when operated in combination with our products (actual-measurement reference values) are shown below:

Maximum Transmission Frequency (Reference value)

Driver	Controller	Cable	Maximum Transmission Frequency
DG Series	**EMP400** Series	**CC01EMP4** [1 m (3.3 ft.)]	150 KHz
		CC02EMP4 [2 m (6.6 ft.)]	120 KHz

Cooling Fans

Structure of Cooling Fans

The following explains the structure of axial flow fans, centrifugal blowers and cross flow fans as well as how these fans blow air.

●Axial Flow Fans

The propellers (fan blades) located in the circular flow path between the cylindrical hub and casing are used to force-feed air in order to generate air flow in the direction of the axis of rotation.
Since air flows along the axis of rotation, the structure is kept compact. Capable of generating a large air flow, axial flow fans are suited for applications requiring ventilation cooling where the entire space inside the equipment must be cooled.

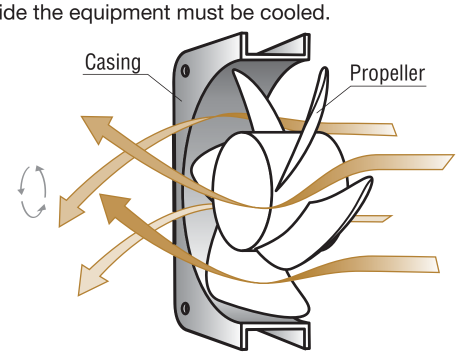


Fig. 1 Structure and Air Flow Mechanism of Axial Flow Fans

●Centrifugal Blowers

The centrifugal force of the cylindrically positioned runner (forward-facing blades) generates rotational flows roughly perpendicular to the axis of rotation. The generated rotational flows are aligned in a uni-direction through scroll action, and the pressure rises accordingly.
Since the exhaust outlet is reduced to focus air in a specified direction, these blowers are used for spot cooling. The static pressure is also high, which makes them a suitable choice when cooling equipment through which air cannot flow easily or when blowing air using a duct.

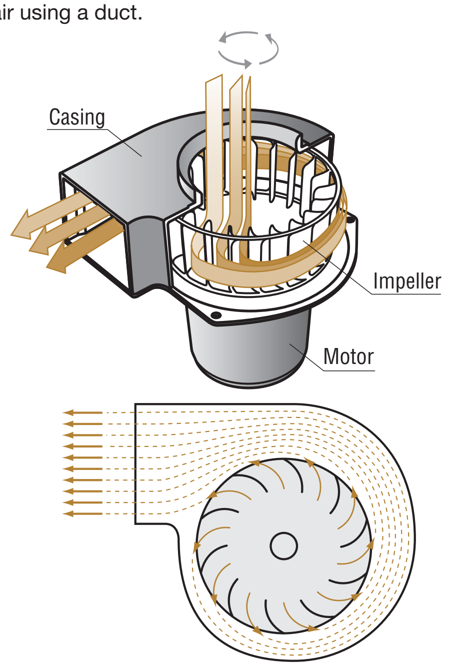


Fig. 2 Structure and Air Flow Mechanism of Centrifugal Blowers

●Cross Flow Fans

A cross flow fan has an impeller similar to that of a centrifugal blower, but both sides of the fan are covered with side panels and thus no air enters from the axial direction. As a result, air flows that pass through the impeller are generated. Cross flow fans utilize these air flows. Since a long cylindrical impeller is used to blow air, air travels over a wide width. Also, uniform air can be achieved because air is exhausted sideways along the circumference of the impeller.

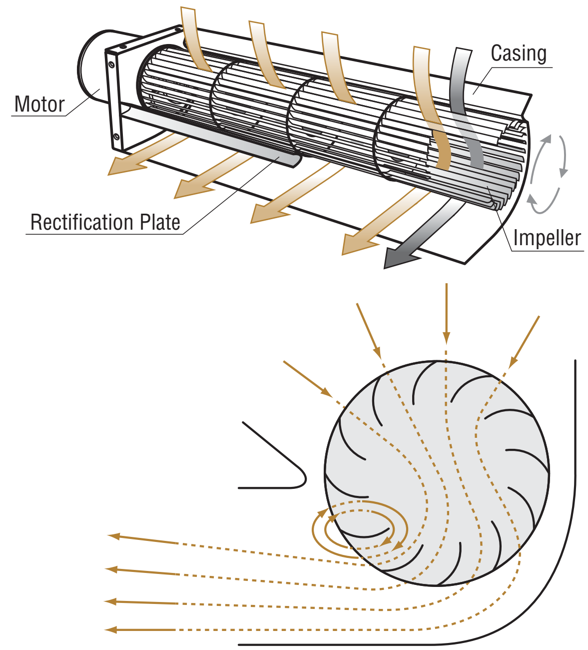


Fig. 3 Structure and Air Flow Mechanism of Cross Flow Fans

Air Flow – Static Pressure Characteristics

●Pressure Loss

When air flows along a certain path, air flow resistance is produced by anything in the path that inhibits the flow.
Comparing the cases illustrated in Fig. 4 and Fig. 5, we see that the device shown in Fig. 4 is almost empty, so there is almost no air flow resistance in the device and little decline in the air flow. By contrast, there are many obstructions of the air flow in the device shown in Fig. 5, which increases air flow resistance and decreases air flow.
This situation is very similar to the role of impedance in the flow of electrical current: when impedance is low, the current flow is large, and when impedance is high, the current flow is low. The air flow resistance becomes the pressure energy that increases the static pressure within the device. This is called pressure loss. Pressure loss is determined using the following formula:

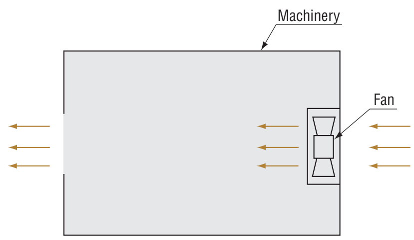


Fig. 4 Flow Path with Low Air Flow Resistance

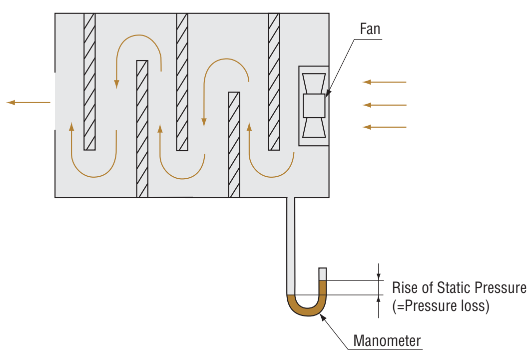


Fig. 5 Flow Path with High Air Flow Resistance

Pressure Loss $P = \frac{1}{2}\xi V^2 \rho$

$$= \frac{1}{2}\xi\left(\frac{Q}{A}\right)^2 \cdot \rho$$

V : Flow speed [m/s]
ρ : Air density [kg/m^3]
ξ : Resistance coefficient specific to flow path
A : Cross-sectional area of flow path [m^2]
Q : Air flow [m^3/s]

In terms of the fan, this formula says that to achieve a certain air flow (Q), the fan must be able to supply static pressure sufficient to increase the pressure inside the device by $P = \frac{1}{2}\xi\left(\frac{Q}{A}\right)^2 \cdot \rho$.

●Air Flow – Static Pressure Characteristics

Fan characteristics are generally expressed in terms of the relationship between air flow and the static pressure required to generate such air flow, given as air flow – static pressure characteristics. As an example, assume the air flow required is Q_1 and the accompanying pressure loss of the device is P_1. When the fan characteristics are as shown in Fig. 6, the fan is capable of a static pressure of P_2 at an air flow of Q_1. This is more than sufficient for the required air flow, since it exceeds the required static pressure value of P_1.

Since pressure loss is proportional to the square of the air flow, if the air flow needs to be doubled, then the fan chosen must be capable of providing not only twice the air flow but four times the static pressure, as well.

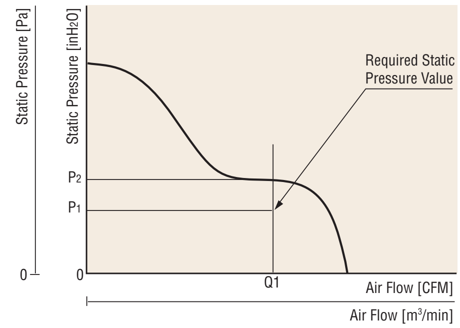


Fig. 6 Air Flow – Static Pressure Characteristics

●How to Measure the Air Flow – Static Pressure Characteristics

Two methods are available for measuring the air flow – static pressure characteristics: the air-duct measurement method via the pitot tube, and the double chamber measurement method.
Oriental Motor employs the double chamber method, which offers higher accuracy than the air-duct method and is used worldwide. Moreover, Oriental Motor uses measuring equipment conforming to AMCA (Air Moving and Conditioning Association) standard 210, a fan measurement standard that is recognized worldwide. In the double chamber method, air flow – static pressure characteristics of fan to be measured are obtained by measuring the pre- and post-nozzle differential pressure (ΔP) and the pressure within the chamber (Ps), as shown in Fig. 7.
(AMCA: The Air Moving and Conditioning Association)

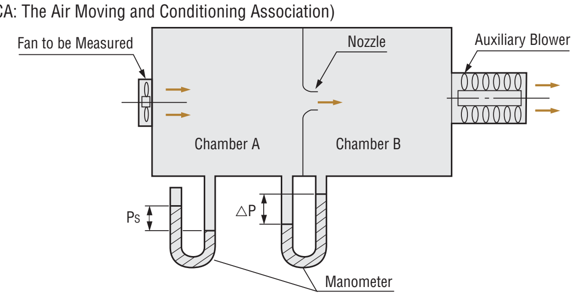


Fig. 7 Double Chamber Measuring Device

Oriental Motor's double chamber equipment is a measuring device with the highest level of general utility that may be used regardless of whether the fan is equipped with an intake or outlet tube.
Since this method allows the speed of the fluid flowing through the nozzle to be determined from the pressure differential between chambers A and B, the air flow (Q) can be expressed as a product of the flow speed (V) through the nozzle, the nozzle area (A), and the flow coefficient (C), as shown below.

$$Q = 60CA\bar{V}$$

$$= 60CA\sqrt{\frac{2\Delta P}{\rho}} \text{ [m}^3\text{/min]}$$

A : Cross-sectional area of nozzle [m^2]
C : Flow coefficient
$\bar{V}$: Average flow speed at the nozzle [m/sec]
ρ : Air density [kg/m^3] (ρ = 1.2 [kg/m^3] at 20˚C [68˚F] and 1 atm.)
ΔP : Differential pressure [Pa]

The measurement of air flow – static pressure characteristics uses an auxiliary blower to control the pressure in chamber B, altering the pressure in chamber A. Thus, each point on the characteristics curve can be measured. Oriental Motor's measuring equipment is connected to a computer, providing extremely precise measurements in a short period of time.

●Changes in Air Flow – Static Pressure Characteristics Using Two Fans

By using two fans featuring the same characteristics together, you can change the characteristics of the fans.

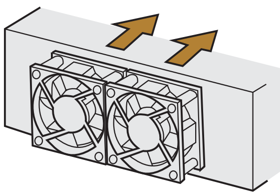


Fig. 8 When Using Two Fans

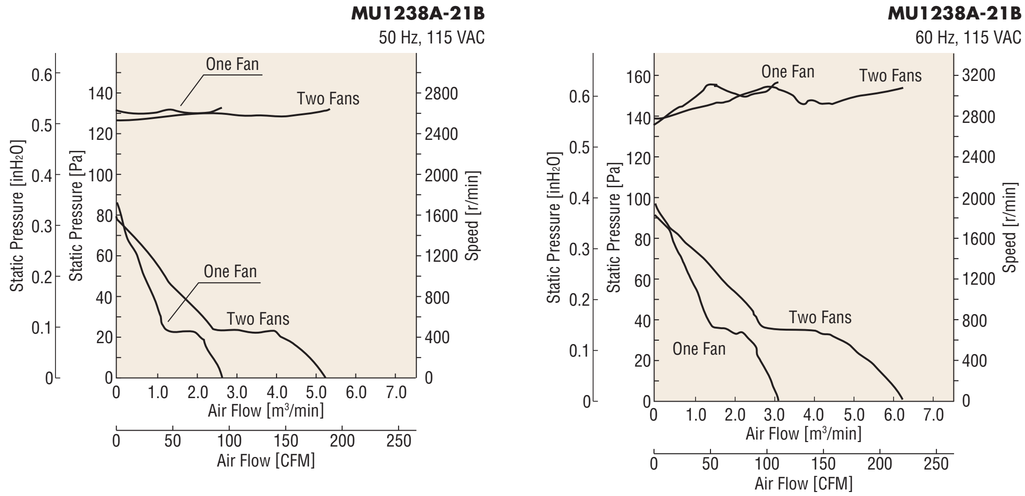


Fig. 9 Changes in Air Flow – Static Pressure Characteristics Using Two Fans

As shown in Fig. 9, the maximum air flow is approximately twice as large using two fans.

●Changes in the Air Flow – Static Pressure Characteristics with Installation of Accessories

When installing a fan in equipment, the safety and reliability of the overall apparatus can be significantly improved by attaching accessories such as finger guards and filters. However, these parts produce air flow resistance, affecting fan characteristics and fan noise. This should be taken into account when selecting fans and accessories.

The graph in Fig. 10 shows data regarding pressure loss caused by its accessories for a frame size 119 mm (4.69 in.) sq. fan. The filter causes the most significant pressure loss, while the finger guard causes little loss.

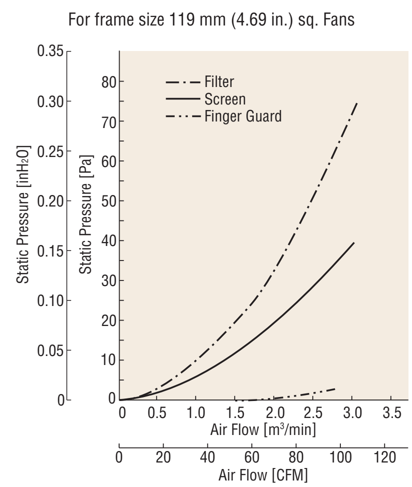


Fig. 10 Pressure Loss Caused by Accessories

The graphs in Fig. 11 show how characteristics may change with installation of accessories, using the **MU1225S-21** as an example.

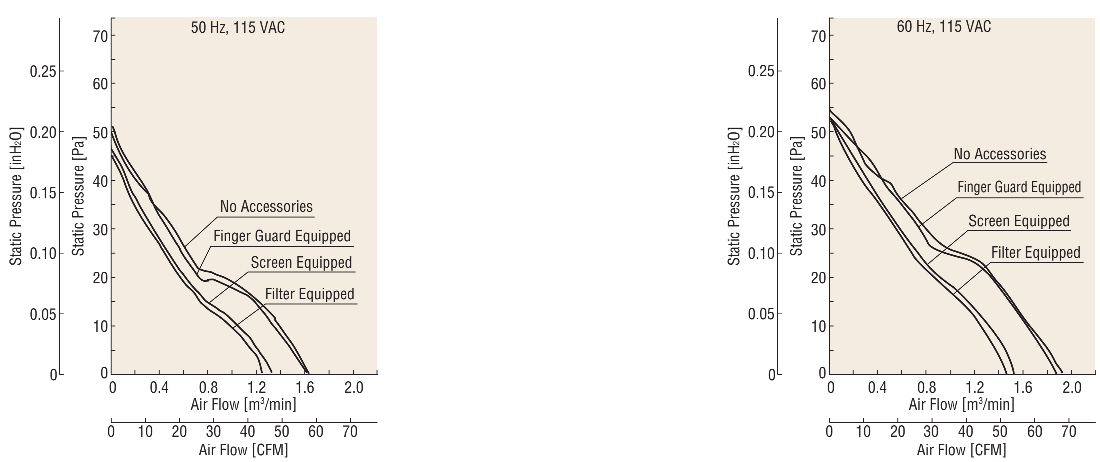


Fig. 11 Changes in Characteristics with Accessories Equipped to the **MU1225S-21**

As the Fig. 11 shows, the greater the pressure loss caused by accessories, the greater the reduction in air flow – static pressure characteristics.

Noise

What is Noise?

We generally refer to sounds that are unpleasant to us as "noise." In the case of fans, the rotation of the fan blades causes air pressure fluctuation and generates noise. The greater the change in air pressure, the louder the resulting noise will be.

Measurement of Noise

The noise level of Oriental Motor fans is measured in the A-weighted sound pressure level at a distance of 1 m (3.3 ft.) from the intake side (at a point above the center line of the intake side).

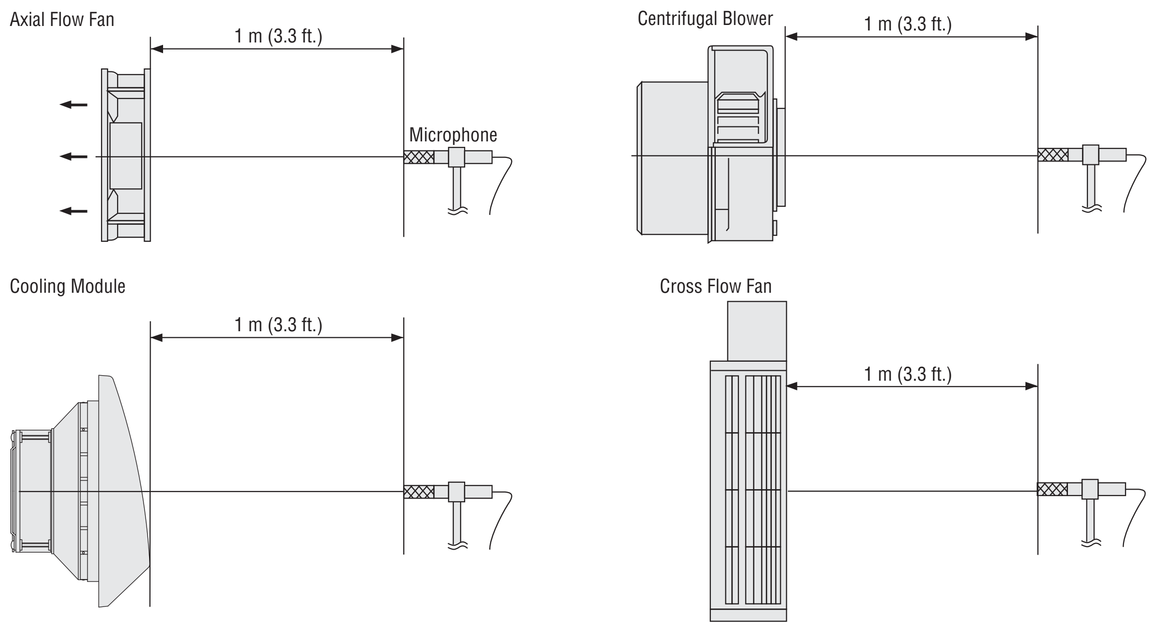


Fig. 12 How to Measure Noise

Composition of Noise

This section explains the noise level when using two fans, each of which produces 40 dB of noise.
Noise is expressed in decibel units, and noise cannot be determined simply by adding individual noise levels. The value that expresses this combined noise is found by determining the energy of the noise and then using it to calculate the increase in sound pressure.

The relationship between sound energy (J) and sound pressure (P) is expressed in the following formula: $J = \frac{P^2}{\rho c}$ where, ρ = Air density, c = Speed of sound propagation.
Using the above formula, the noise level can be expressed in decibel unit as follows:

$$\text{Noise level} = 20 \log P/P_0 = 10 \log J/J_0$$

P: Actual sound pressure
J: Measured noise energy
P_0, J_0: Minimum noise energy audible to the human ear

In this formula the noise level is expressed in decibels based on the reference energy of J_0. As the noise energy for n fans is n times that of a single fan, the sound pressure obtained by this formula will be:

$$\text{Noise level} = 10 \log n \cdot J/J_0 = 10 \log J/J_0 + 10 \log n$$

In other words, when n fans are operated simultaneously, the increase in noise is equal to 10 log n [dB].
In this example, if two 40 dB fans ($n = 2$) are operated simultaneously, the increase in noise level is equal to 10 log 2 or 3 dB, and the combined noise level is 43 dB.

The following explains the combined noise level when a 40 dB fan and a 50 dB fan are operated simultaneously. Again, the combined noise level is not given by a simple arithmetic sum but is obtained as follows:

Take the difference between the two noise levels. 50 dB − 40 dB ➜ 10 dB

↓

At the 10 dB point on the horizontal axis of the graph, find the corresponding point on the curve and read the vertical axis value. ➜ 0.4 dB

↓

Add 0.4 to the larger of the two noise levels, 50 dB.

↓

The combined noise level when operating the two fans simultaneously is 50.4 dB.

If 40 dB of noise is combined with 50 dB, the resulting increase in noise level is only 0.4 dB. In other words, the noise level is always controlled by the larger of noise values, so it is important to suppress the noise of the fan producing greater noise.

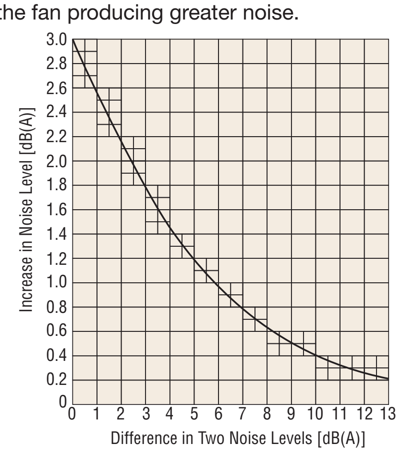


Fig. 13 Difference in Two Noise Levels and Increase in Noise Level

●Distance and Noise

The noise level decreases as the distance from sound source increases.
The decrease in noise level due to distance is given by the following formula:

$$SPL_2 = SPL_1 - 20 \log r_2/r_1$$

SPL_2: Noise level at distance r_2
SPL_1: Noise level at distance r_1

In the following example the noise level at a distance of 2 m (6.6 ft.) from the intake side of fan, whose noise level is 40 dB at a distance of 1 m (3.3 ft.) from the intake side of fan, is calculated.
Since $r_2 = 2$ m (6.6 ft.), $r_1 = 1$ m (3.3 ft.), and $SPL_1 = 40$ dB, substituting in the formula gives:

$$SPL_2 = 40 - 20 \log 2/1 = 34 \text{ [dB]}$$

Thus, at a distance of 2 m (6.6 ft.), the noise level decreases by 6 dB.
The value 20 log r_2/r_1 in the above formula represents the ratio between two distances. Thus, if the values used above were 3 m (9.8 ft.) and 6 m (19.7 ft.), the result would have been the same.
Therefore, if the noise level at a certain distance is known, the noise level at another distance can be estimated.

Capacitor

Permanent split capacitor motors contain an auxiliary winding offset by 90 electrical degrees from the main winding. The capacitor is connected in series with the auxiliary winding, causing the advance of current phase in the auxiliary winding.
Motors employ vapor-deposition electrode capacitors recognized by UL. This type of capacitor, which uses a metallized paper or plastic film as an element, is also known as a "self-healing (SH) capacitor" because of the self-healing property of the capacitor element.
Although most of the previous capacitors used paper elements, the plastic film capacitor has become a mainstream model in recent years due to the growing demand for compact design.

●Capacitance

The use of a capacitor with a different capacitance may cause excessive motor vibration and heat generation or may result in torque drops and unstable operation. Be sure to use the capacitor included with the fan. The capacitor's capacitance is expressed in microfarads (μF).

●Rated Voltage

Using a capacitor exceeding the rated voltage may cause damage and then smoke or ignite. Be sure to use the capacitor included with the fan. The rated voltage of the capacitor is expressed in volts (V).
The capacitor's rated voltage is indicated on the surface of the capacitor case. Take proper precautions, since the capacitor's rated voltage is different from that of the fan.

●Rated Conduction Time

The rated conduction time is the minimum design life of the capacitor when operated at the rated load, rated voltage, rated temperature and rated frequency. The standard life expectancy is 25000 hours. A capacitor that breaks at the end of its life expectancy may smoke or ignite. We recommend that the capacitor be replaced after the rated conduction time.
Consider providing a separate protection measure to prevent the equipment from being negatively influenced in the event of capacitor failure.

Overheat Protection Device

If a fan in run mode locks due to overload, ambient temperature rises rapidly, or the input current increases for some reason, the fan's temperature rises abruptly. If the fan is left in this state, the performance of the insulation within the fan may deteriorate, reducing its life and, in extreme cases, scorching the winding and causing a fire. In order to protect the fan from such thermal abnormalities, our fans recognized by UL and CSA Standards and conform to EN and IEC Standards are equipped with the following overheat protection device.

●Thermal Protector

The **MRS** Series, **MB** Series (impeller diameter ϕ80 mm (3.15 in.) or more) and **MF** Series fans contain a built-in automatic return type thermal protector. The structure of a thermal protector is shown in the figure below.

The thermal protectors employ bimetal contacts, with solid silver used in the contacts. Solid silver has the lowest electrical resistance of all materials, along with a thermal conductivity second only to copper.

●Operating Temperature of Thermal Protector

open 120±5˚C (248±9˚F)
close 77±15˚C (170.6±27˚F)

(The fan winding temperature, where the thermal protector is activated, is slightly higher than the operating temperature listed above.)

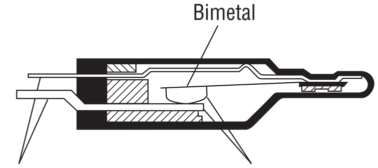


Fig. 14 Structure of Thermal Protector

●Impedance Protected

The **MU** and **MB** Series (**MB520** and **MB630** type) fans are equipped with impedance protection.
Impedance protected fans are designed with higher impedance in the fan windings so that even if the fan locks, the increase in current (input) will be minimized and the temperature will not rise above a certain level.

Glossary

Decibels (dB)

Noise level is expressed in decibel units (dB).
When the noise level is expressed based on the linear scale, with the minimum level of noise audible to the human ear being 1, the maximum level of noise the human ear can withstand is expressed in such a substantial figure as 5 million. In contrast, if noise (sound pressure level) is expressed in decibels, then

Sound pressure level $= 20 \log P/P_0$
P: Actual sound pressure
P_0: Minimum sound pressure audible to the human ear

Therefore, the range of sound pressure audible to the human ear can be conveniently expressed as 0 to 130 dB.

A-Weighted Sound Pressure Level

It is generally said that the audible range of the human ear is between 20 Hz and 20 kHz. Moreover, low frequency and extremely high frequency sounds are not disturbingly loud to the human ear. For this reason, an accurate indication of loudness as perceived by the human ear cannot be achieved simply by measuring sound pressure without taking frequency into account. Therefore, measurements of the sound pressure level must be corrected according to frequency in order to accurately reflect the human perception of loudness. This corrected level is called the A-weighted sound pressure level.
The graph below compares the corrected measured values (A-weighted sound pressure level) with the uncorrected measured values (C-weighted sound pressure level).

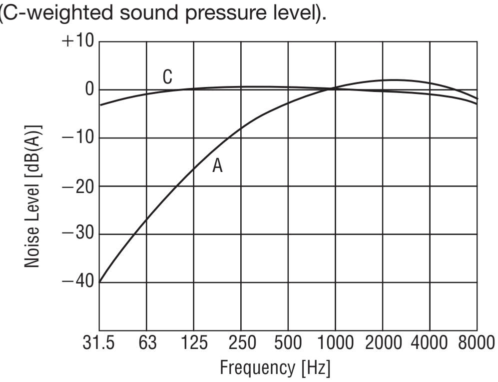


Fig. 17 Comparison of Sound Pressure Level

Flammability Grade

The flammability grade represents the degree of fire retardancy for plastic materials used in equipment parts. The generally accepted standards for flammability grade are the UL Standards (UL94, STANDARD FOR TESTS FOR FLAMMABILITY OF PLASTIC MATERIALS FOR PARTS IN DEVICES AND APPLIANCES). The UL Standards provide the flammability of plastic materials based on the burning rate, duration of burning from the onset of fire, fire ignited by a dripping substance and other items.
Flammability grade is rated in four different grades, as shown in the table below.

Grade	Flammability Grade
V-0	High
V-1	↑
V-2	
HB	Low

● Cooling fans use blades and frames with materials that receive the highest grade in this classification, V-0.