Technical Reference

F

Motor Sizing Calculations

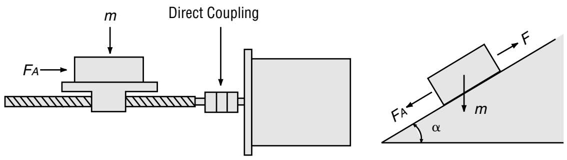
This section describes certain items that must be calculated to find the optimum motor for a particular application.
Selection procedures and examples are given.

Selection Procedure

Determine the drive mechanism component	● First, determine certain features of the design, such as drive mechanism, rough dimensions, distances moved, and positioning period.
▼ Confirm the required specifications	● Confirm the required specifications for the drive system and equipment (stop accuracy, position holding, speed range, operating voltage, resolution, durability, etc.).
▼ Calculate the speed and load	● Calculate the value for load torque, load inertia, speed, etc. at the motor drive shaft of the mechanism. Refer to page 3 for calculating the speed, load torque and load inertia for various mechanisms.
▼ Select motor type	● Select a motor type from AC Motors, Brushless DC Motors or Stepping Motors based on the required specifications.
▼ Check the selected motor	● Make a final determination of the motor after confirming that the specifications of the selected motor/gearhead satisfy all of the requirements (mechanical strength, acceleration time, acceleration torque etc.).

Formulas for Calculating Load Torque

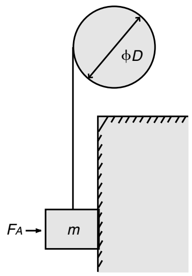
Ball Screw



$$T_L = \left(\frac{FP_B}{2\pi\eta} + \frac{\mu_0 F_0 P_B}{2\pi}\right) \times \frac{1}{i} \text{ [oz-in]} \quad ①$$

$$F = F_A + m(\sin\alpha + \mu\cos\alpha) \text{ [oz.]} \quad ②$$

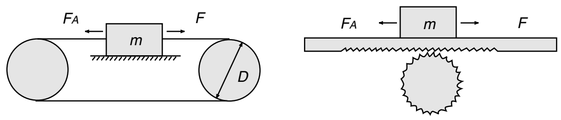
Pulley



$$T_L = \frac{\mu F_A + m}{2\pi} \cdot \frac{\pi D}{i}$$

$$= \frac{(\mu F_A + m)D}{2i} \text{ [oz-in]} \quad ③$$

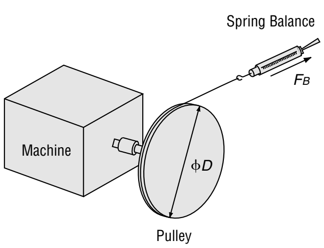
Wire Belt Mechanism, Rack and Pinion Mechanism



$$T_L = \frac{F}{2\pi\eta} \cdot \frac{\pi D}{i} = \frac{FD}{2\eta i} \text{ [oz-in]} \quad ④$$

$$F = F_A + m(\sin\alpha + \mu\cos\alpha) \text{ [oz.]} \quad ⑤$$

By Actual Measurement

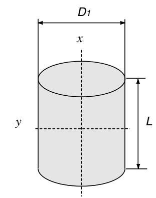


$$T_L = \frac{F_B D}{2} \text{ [oz-in]} \quad ⑥$$

- F = Force of moving direction [oz.]
- F_0 = Pilot pressure weight [oz.] (≒1/3 F)
- μ_0 = Internal friction coefficient of pilot pressure nut (0.1 to 0.3)
- η = Efficiency (0.85 to 0.95)
- i = Gear ratio
- P_B = Ball screw pitch [inch/rev]
- F_A = External force [oz.]
- F_B = Force when main shaft begins to rotate [oz.]
- m = Total weight of work and table [oz.]
- μ = Frictional coefficient of sliding surfaces (0.05)
- α = Angle of inclination [°]
- D = Final pulley diameter [inch]

Formulas for Calculating Moment of Inertia

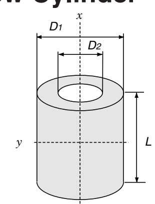
Inertia of a Cylinder



$$J_x = \frac{1}{8} m D_1^2 = \frac{\pi}{32} \rho L D_1^4 \text{ [oz-in}^2\text{]} \quad ⑦$$

$$J_y = \frac{1}{4} m \left(\frac{D_1^2}{4} + \frac{L^2}{3}\right) \text{ [oz-in}^2\text{]} \quad ⑧$$

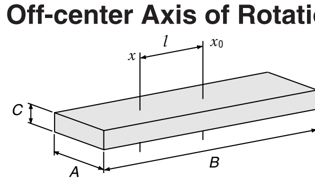
Inertia of a Hollow Cylinder



$$J_x = \frac{1}{8} m (D_1^2 + D_2^2) = \frac{\pi}{32} \rho L (D_1^4 - D_2^4) \text{ [oz-in}^2\text{]} \quad ⑨$$

$$J_y = \frac{1}{4} m \left(\frac{D_1^2 + D_2^2}{4} + \frac{L^2}{3}\right) \text{ [oz-in}^2\text{]} \quad ⑩$$

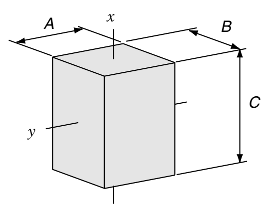
Inertia for Off-center Axis of Rotation



l = Distance between x and x_0 axes [in.]

$$J_x = J_{x0} + m\,l^2 = \frac{1}{12} m (A^2 + B^2 + 12\,l^2) \text{ [oz-in}^2\text{]} \quad ⑪$$

Inertia of a Rectangular Pillar



$$J_x = \frac{1}{12} m (A^2 + B^2) = \frac{1}{12} \rho ABC (A^2 + B^2) \text{ [oz-in}^2\text{]} \quad ⑫$$

$$J_y = \frac{1}{12} m (B^2 + C^2) = \frac{1}{12} \rho ABC (B^2 + C^2) \text{ [oz-in}^2\text{]} \quad ⑬$$

Inertia of an Object in Linear Motion

$$J = m\left(\frac{v}{\omega}\right)^2 = m\left(\frac{A}{2\pi}\right)^2 \text{ [oz-in}^2\text{]} \quad ⑭$$

A = Unit of movement [inch/rev]

- J_x = Inertia on x axis [oz-in^2]
- J_y = Inertia on y axis [oz-in^2]
- J_{x0} = Inertia on x_0 axis [oz-in^2]
- m = Weight [oz.]
- D_1 = External diameter [inch]
- D_2 = Internal diameter [inch]
- ρ = Density [oz/in^3]
- L = Length [inch]

Density

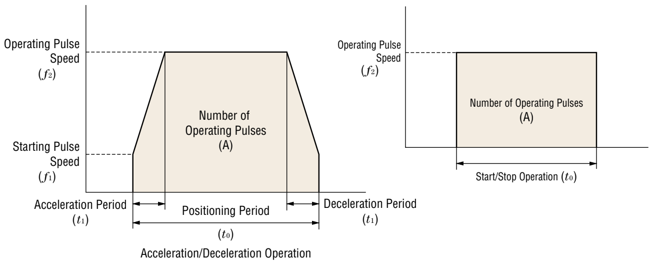
Iron	ρ = 4.64 [oz/in^3]
Aluminum	ρ = 1.65 [oz/in^3]
Bronze	ρ = 5 [oz/in^3]
Nylon	ρ = 0.65 [oz/in^3]

Stepping Motors

This section describes in detail the key concerns in the selection procedure, such as the determination of the motion profile, the calculation of the required torque and the confirmation of the selected motor.

Operating Patterns

There are 2 basic motion profiles.
One is a start/stop operation and the other is an acceleration/deceleration operation.
Acceleration/deceleration operation is the most common.
When load inertia is small, start/stop operation can be used.



Find the Number of Operating Pulses A [pulses]

The number of operating pulses is expressed as the number of pulse signals that adds up to the angle that the motor must move to get the work from point A to point B.

$$\text{Operating Pulse (A) [Pulses]} = \frac{\text{Distance per Movement}}{\text{Distance per Motor Rotation}} \times \text{No. of Pulses Required for 1 Motor Rotation}$$

$$= \frac{l}{lrev} \times \frac{360°}{\theta s} \qquad \theta s\text{: Step Angle}$$

Determine the Operating Pulse Speed f_2 [Hz]

The operating pulse speed can be found from the number of operating pulses, the positioning period and the acceleration/deceleration period.

① For Acceleration/Deceleration Operation

Acceleration/deceleration is a method of operation in which the operating pulses of a motor being used in a medium- or high-speed region are gradually changed. It is found by the equation below. Usually, the acceleration (deceleration) period (t_1) is set at roughly 25% of the positioning periods. For gentle speed changes, the acceleration torque can be kept lower than in start-stop operations.

When a motor is operated under an operating pattern like this, the acceleration/deceleration period needs to be calculated using the positioning period.

Acceleration/Deceleration Period [s] = Positioning Period [s] × 0.25

$$\text{Operating Pulse Speed } f_2 \text{ [Hz]} = \frac{\text{Number of Operating Pulses [Pulses]} - \text{Starting Pulse Speed [Hz]} \times \text{Acceleration (Deceleration) Period [s]}}{\text{Positioning Period [s]} - \text{Acceleration (Deceleration) Period [s]}}$$

$$= \frac{A - f_1 \cdot t_1}{t_0 - t_1}$$

② For Start-Stop Operation

Start-stop is a method of operation in which the operating pulse speed of a motor being used in a low-speed region is suddenly increased without an acceleration period. It is found by the following equation. Since rapid changes in speed are required, the acceleration torque is very large.

$$\text{Operating Pulse Speed } (f_2) \text{ [Hz]} = \frac{\text{Number of Operating Pulses [Pulses]}}{\text{Positioning Period [s]}}$$

$$= \frac{A}{t_0}$$

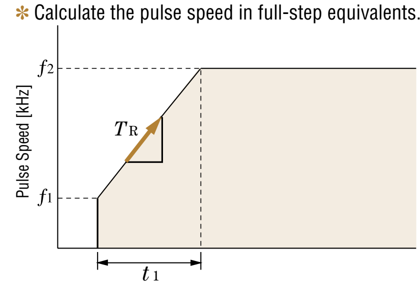
Calculate the Acceleration/Deceleration Rate T_R

Calculate the acceleration/deceleration rate from the following equation.

$$\text{Acceleration/deceleration rate } T_R \text{ [ms/kHz]} = \frac{\text{Acceleration (Deceleration) Period [ms]}}{\text{Operating Pulse Speed [kHz]} - \text{Starting Pulse Speed [kHz]}}$$

$$= \frac{t_1}{f_2 - f_1}$$

✻ Calculate the pulse speed in full-step equivalents.



Calculate the Operating Speed from Operating Pulse speed

$$\text{Operating Speed [r/min]} = \text{Operating Pulse Speed [Hz]} \times \frac{\text{Step Angle}}{360°} \times 60$$

Calculate the Load Torque T_L

(See basic equations on pages F-3)

Calculate the Acceleration Torque Ta

① For Acceleration/Deceleration Operation

Acceleration Torque (Ta) [oz-in]

$$= \left(\text{Inertia of Rotor [oz-in}^2\text{]} + \text{Total Inertia [oz-in}^2\text{]}\right) \times \frac{\pi \times \text{Step Angle [°]}}{180°} \times \frac{\text{Operating Pulse Speed [Hz]} - \text{Starting Pulse Speed [Hz]}}{\text{Acceleration (Deceleration) Period [s]}}$$

$$\times \frac{1}{12 \times \text{Gravitational Acceleration [}ft/s^2\text{]}}$$

$$= (J_0 + J_L) \times \frac{\pi \cdot \theta s}{180} \times \frac{f_2 - f_1}{t_1} \times \frac{1}{g}$$

② For Start-Stop Operation

$$\text{Acceleration Torque } (Ta) \text{ [oz-in]} = \left(\text{Inertia of Rotor [oz-in}^2\text{]} + \text{Total Inertia [oz-in}^2\text{]}\right)$$

$$\times \frac{\pi \times \text{Step Angle [°]} \times (\text{Operating Pulse Speed})^2 \text{ [Hz]}}{180° \times \text{Coefficient}} \times \frac{1}{12 \times \text{Gravitational Acceleration [}ft/s^2\text{]}}$$

$$= (J_0 + J_L) \times \frac{\pi \cdot \theta s \cdot f_2^2}{180° \cdot n} \times \frac{1}{g} \qquad n: 3.6°/\theta s$$

Calculate the Required Torque T_M

Required Torque T_M [oz-in] = (Load Torque [oz-in] + Acceleration Torque [oz-in]) × Safety Factor

$$= (T_L + Ta) \times Sf$$

Choosing Between Standard AC Motors and Stepping Motors

● Selection Considerations

There are differences in characteristics between standard AC motors and stepping motors. Shown below are some of the points you should know when sizing a motor.

◆ Standard AC Motors

① The speed of Induction Motors and Reversible Motors vary with the size of the load torque. So, the selection should be made between the rated speed and the synchronous speed.

② There can be a difference of continuous and short-term ratings, due to the difference in motor specifications, despite the fact that two motors have the same output power. Motor selection should be based on the operating time (operating pattern).

③ Each gearhead has maximum permissible load inertia. When using a dynamic brake, changing direction quickly, or quick starts and stops, the total load inertia must be less than the maximum permissible load inertia.

◆ Stepping Motors

① Checking the Running Duty Cycle

A stepping motor is not intended to be run continuously with rated current. Lower than 50% running duty cycle is recommended.

$$\text{Running Duty Cycle} = \frac{\text{Running Time}}{\text{Running Time} + \text{Stopping Time}} \times 100$$

② Checking the Inertia Ratio

Large inertia ratios cause large overshooting and undershooting during starting and stopping, which can affect start-up times and settling times. Depending on the conditions of usage, operation may be impossible. Calculate the inertia ratio with the following equation and check that the values found are at or below the inertia ratios shown in the table.

$$\text{Inertia Ratio} = \frac{\text{Total Inertia of the Machine [oz-in}^2\text{]}}{\text{Rotor Inertia of the Motor [oz-in}^2\text{]}} = \frac{J_L}{J_0}$$

Inertia Ratio (Reference Values)

Product Series	Inertia Ratio
αSTEP	30
RK Series	10 Maximum

✻ Except geared motor types

When these values are exceeded, we recommend a geared motor. Using a geared motor can increase the drivable inertia load.

$$\text{Inertia Ratio} = \frac{\text{Total Inertia of the Machine [oz-in}^2\text{]}}{\text{Rotor Inertia of the Motor [oz-in}^2\text{]} \times (\text{Gear Ratio})^2} = \frac{J_L}{J_0 \cdot i^2}$$

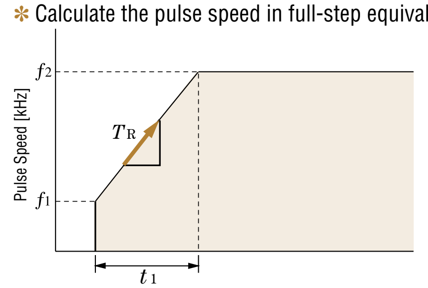
③ Check the Acceleration/Deceleration Rate

Most controllers, when set for acceleration or deceleration, adjust the pulse speed in steps. For that reason, operation may sometimes not be possible, even though it can be calculated.

Calculate the acceleration/deceleration rate from the following equation and check that the value is at or above the acceleration/deceleration rate in the table.

$$\text{Acceleration/Deceleration Rate } T_R \text{ [ms/kHz]} = \frac{\text{Acceleration (Deceleration) Period [ms]}}{\text{Operating Pulse Speed [Hz]} - \text{Starting Pulse Speed [Hz]}} = \frac{t_1}{f_2 - f_1}$$

✻ Calculate the pulse speed in full-step equivalents.



Acceleration Rate (Reference Values with **EMP** Series)

Model	Motor Frame Size inch (mm)	Acceleration/ Deceleration Rate T_R [ms/kHz]
αSTEP	1.10(28), 1.65(42), 2.36(60), 3.35(85)	0.5 Min.
RK Series	1.65(42), 2.36(60)	20 Min.
	3.35(85), 3.54(90)	30 Min.

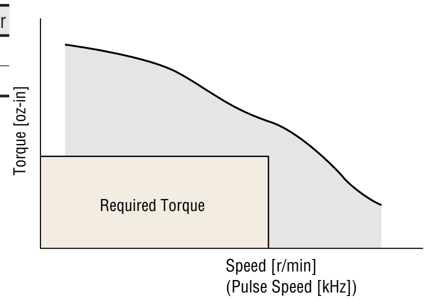
If below the minimum value, change the operating pattern's acceleration (deceleration) period.

④ Checking the Required Torque

Check that the required torque falls within the pull-out torque of the speed-torque characteristics.

Safety Factor: Sf (Reference Value)

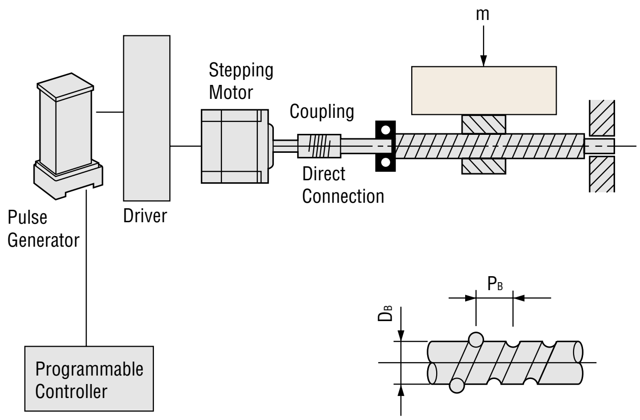
Product Series	Safety Factor
αSTEP	1.5~2
RK Series	2



Sizing Example

Ball Screw

Using Stepping Motors (α_{STEP})



◆ Determine the Drive Mechanism

Total mass of the table and work:	$m = 90$ lb. (40 kg)
Frictional coefficient of sliding surfaces:	$\mu = 0.05$
Ball screw efficiency:	$\eta = 0.9$
Internal frictional coefficient of pilot pressure nut:	$\mu_0 = 0.3$
Ball screw shaft diameter:	$D_B = 0.6$ inch (1.5 cm)
Total length of ball screw:	$L_B = 23.6$ inch (60 cm)
Material of ball screw:	Iron [density $\rho = 4.64$ oz/in^3 (7.9×10^{-3} kg /cm^3)]
Pitch of ball screw:	$P_B = 0.6$ inch (1.5 cm)
Desired Resolution (feed per pulse):	$\Delta l = 0.001$ inch (0.03 mm)/step
Feed:	$l = 7.01$ inch (180 mm)
Positioning period:	$t_0 = 0.8$ sec.

◆ Calculate the Required Resolution

$$\text{Required Resolution } \theta_s = \frac{360° \times \text{Desired Resolution } (\Delta l)}{\text{Ball Screw Pitch } (P_B)}$$

$$= \frac{360° \times 0.001}{15} = 0.72°$$

α_{STEP} can be connected directly to the application.

◆ Determine the Operating Pattern

(see page F-4, see basic equations on pages F-3)

(1) Finding the Number of Operating Pulses (A) [pulses]

$$\text{Operating pulses (A)} = \frac{\text{Feed per Unit } (l)}{\text{Ball Screw Pitch } (P_B)} \times \frac{360°}{\text{Step Angle } (\theta_s)}$$

$$= \frac{7.01}{0.6} \times \frac{360°}{0.72°} = 6000 \text{ pulses}$$

(2) Determine the Acceleration (Deceleration) Period t_1 [sec]

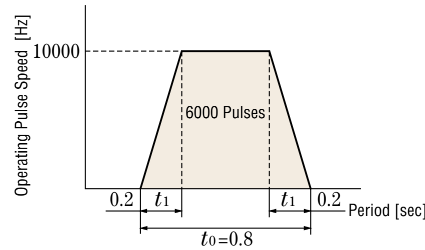
An acceleration (deceleration) period of 25% of the positioning period is appropriate.

Acceleration (deceleration) period (t_1) $= 0.8 \times 0.25 = 0.2$ sec

(3) Determine the Operating Pulse Speed f_2 [Hz]

$$\text{Operating pulse speed } f_2 = \frac{\text{Number of Operating Pulses [A]} - \text{Starting Pulses Speed } [f_1] \times \text{Acceleration (Deceleration) Period } [t_1]}{\text{Positioning Period } [t_0] - \text{Acceleration (Deceleration) Period } [t_1]}$$

$$= \frac{6000 - 0}{0.8 - 0.2} = 10000 \text{ Hz}$$



(4) Calculate the Operating Speed N [r/min]

$$\text{Operating Speed} = f_2 \times \frac{\theta_s}{360} \times 60$$

$$= 10000 \times \frac{0.72}{360} \times 60 = 1200 \text{ [r/min]}$$

◆ Calculate the Required Torque T_M [oz-in]

(see page F-4)

(1) Calculate the Load Torque T_L [oz-in]

$$\text{Load in Shaft Direction } F = F_A + m\,(\sin\alpha + \mu\cos\alpha)$$

$$= 0 + 90\,(\sin 0 + 0.05 \cos 0)$$

$$= 4.5 \text{ lb.}$$

$$\text{Pilot Pressure Load } F_0 = \frac{F}{3} = \frac{4.5}{3} = 1.5 \text{ lb.}$$

$$\text{Load Torque } T_L = \frac{F \cdot P_B}{2\pi\eta} + \frac{\mu_0 \cdot F_0 \cdot P_B}{2\pi}$$

$$= \frac{4.5 \times 0.6}{2\pi \times 0.9} + \frac{0.3 \times 1.5 \times 0.6}{2\pi}$$

$$= 0.52 \text{ lb-in} = 8.3 \text{ oz-in}$$

(2) Calculate the Acceleration Torque T_a [oz-in]

① Calculate the total moment of inertia J_L [oz-in^2]

(See page F-3 for basic equations)

$$\text{Inertia of Ball Screw } J_B = \frac{\pi}{32} \cdot \rho \cdot L_B \cdot D_B^4$$

$$= \frac{\pi}{32} \times 4.64 \times 23.6 \times 0.6^4$$

$$= 1.39 \text{ oz-in}^2$$

$$\text{Inertia of Table and Work } J_T = m\left(\frac{P_B}{2\pi}\right)^2 = 90 \times \left(\frac{0.6}{2\pi}\right)^2$$

$$= 0.82 \text{ lb-in}^2 = 13.1 \text{ oz-in}^2$$

$$\text{Total Inertia } J_L = J_B + J_T = 1.39 + 13.1 = 14.5 \text{ oz-in}^2$$

② Calculate the acceleration torque T_a [oz-in]

$$\text{Acceleration torque } T_a = \frac{J_0 + J_L}{g} \times \frac{\pi \cdot \theta_s}{180°} \times \frac{f_2 - f_1}{t_1}$$

$$= \frac{J_0 + 14.5}{386} \times \frac{\pi \times 0.72}{180} \times \frac{10000 - 0}{0.2}$$

$$= 1.63\,J_0 + 23.6 \text{ oz-in}$$

(3) Calculate the Required Torque T_M [oz-in]

$$\text{Required torque } T_M \text{ [oz-in]} = (T_L + T_a) \times 2$$

$$= \{8.3 + (1.63\,J_0 + 23.6)\} \times 2$$

$$= 3.26\,J_0 + 63.8 \text{ oz-in}$$

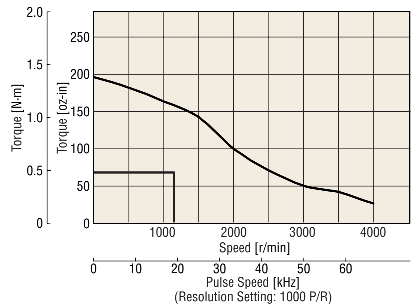
◆ Select a Motor

(1) Provisional Motor Selection

Model	Rotor Inertia [oz-in^2]	Required Torque	
		oz-in	N·m
AS66AA	2.2	71	0.5

(2) Determine the Motor from the Speed-Torque Characteristics

AS66AA



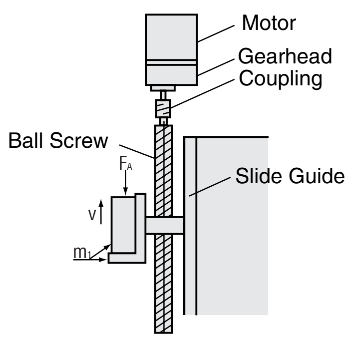
Select a motor for which the required torque falls within the pull-out torque of the speed-torque characteristics.

● Ball Screw

Using Standard AC Motors

This example demonstrates how to select an AC motor with an electromagnetic brake for use on a tabletop moving vertically on a ball screw. In this case, a motor must be selected that meets the following basic specifications.

Required and Structural Specifications



Total weight of table and work ·········· m = 100 lb.
Table speed ·········· $V = 0.6$ in./s±10%
Ball screw pitch ·········· $P_B = 0.197$ in.
Ball screw efficiency ·········· $\eta = 0.9$
Ball screw friction coefficient ·········· $\mu_0 = 0.3$
Friction coefficient of sliding surface (Slide guide) ····· $\mu = 0.05$
Motor power supply ·········· Single-Phase 115 VAC 60 Hz
Ball screw total length ·········· $L_B = 31.5$ in.
Ball screw shaft diameter ·········· $D_B = 0.787$ in.
Ball screw material ·········· Iron (density $\rho = 4.64$ oz/in.^{3})
Distance moved for one rotation of ball screw ···· A = 0.197 in.
External force ·········· $F_A = 0$ lb.
Ball screw tilt angle ·········· $\alpha = 90°$
Movement time ··········5 hours/day
Brake must provide holding torque

◆ Determine the Gear Ratio

Speed at the gearhead output shaft: N_G

$$N_G = \frac{V \cdot 60}{P_B} = \frac{(0.6 \pm 0.06) \times 60}{0.197} = 182 \pm 18 \text{ r/min}$$

Because the rated speed for a 4-pole motor at 60 Hz is 1450~1550 r/min, the gear ratio (i) is calculated as follows:

$$i = \frac{1450\sim1550}{N_G} = \frac{1450\sim1550}{182 \pm 18} = 7.2\sim9.5$$

From within this range a gear ratio of $i = 9$ is selected.

◆ Calculate the Required Torque

F, the load weight in the direction of the ball screw shaft, is obtained as follows:

$$F = F_A + m(\sin\alpha + \mu \times \cos\alpha) = 0 + 100(\sin 90 + 0.05 \times \cos 90)$$
$$= 100 \text{ lb.}$$

Preload weight F_0:

$$F_0 = \frac{F}{3} = 33.3 \text{ lb.}$$

Load torque T_L:

$$T_L = \frac{F \times P_B}{2\pi\eta} + \frac{\mu_0 \times F_0 \times P_B}{2\pi} = \frac{100 \times 0.197}{2\pi \times 0.9} + \frac{0.3 \times 33.3 \times 0.197}{2\pi}$$
$$= 3.8 \text{ lb-in}$$

This value is the load torque at the gearhead drive shaft, and must be converted into load torque at the motor output shaft. The required torque at the motor output shaft (T_M) is given by:

$$T_M = \frac{T_L}{i \cdot \eta_G} = \frac{3.8}{9 \times 0.81} = 0.52 \text{ [lb-in]} = 8.32 \text{ oz-in}$$

(Gearhead transmission efficiency $\eta_G = 0.81$)
Look for a margin of safety of 2 times.

$8.32 \times 2 = 16.64$ oz-in

To find a motor with a start-up torque of 16.64 oz-in or more, select motor **5RK40GN-AWMU**. This motor is equipped with an electromagnetic brake to hold a load. A gearhead with a gear ratio of 9:1 that can be connected to the motor **5RK40GN-AWMU** is **5GN9KA**.
The rated motor torque is greater than the required torque, so the speed under no-load conditions (1740 r/min) is used to confirm that the motor produces the required speed.

◆ Load Inertia Check

Ball Screw Moment of Inertia

$$J_1 = \frac{\pi \times \rho \times L_B \times D_B^4}{32} = \frac{\pi \times 4.64 \times 31.5 \times (0.787)^4}{32}$$
$$= 5.5 \text{ oz-in}^2$$

Table and Work Moment of Inertia

$$J_2 = m\left(\frac{A}{2\pi}\right)^2 = 100 \times 16\left(\frac{0.197}{2\pi}\right)^2$$
$$= 1.57 \text{ oz-in}^2$$

Gearhead shaft total load inertia $J = 5.5 + 1.57 = 7.07$ [oz-in^2]

Here, the **5GN9KA** permitted load inertia is (see page A-12):

$$J_G = J_M \times i^2 = 4 \times 9^2 = 324 \text{ oz-in}^2$$

Therefore, J < J_G, the load inertia is less than the permitted inertia, so there is no problem. There is margin for the torque, so the rotation rate is checked with the no-load rotation rate (about 1750 r/min).

$$V = \frac{N_M \cdot P}{60 \cdot i} = 0.64 \text{ in./s} \quad \text{(where } N_M \text{ is the motor speed)}$$

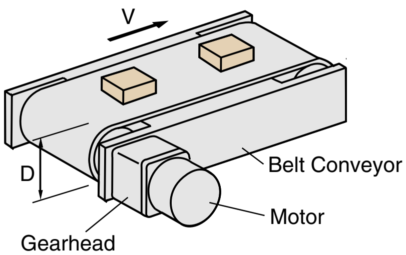
This confirms that the motor meets the specifications.

Belt and Pully

Using Standard AC Motors

Here is an example of how to select an induction motor to drive a belt conveyor.
In this case, a motor must be selected that meets the following basic specifications.

Required Specifications and Structural Specifications



Total weight of belt and work ······························ m_1 = 30 lb.
Friction coefficient of sliding surface ························ μ = 0.3
Drum radius ·· D = 4 inch
Weight of drum ·· m_2 = 35.27 oz.
Belt roller efficiency ··· η = 0.9
Belt speed ··· V = 7 inch/s±10%
Motor power supply ················ Single-Phase 115 VAC 60 Hz

Determine the Gear Ratio

Speed at the gearhead output shaft:

$$N_G = \frac{V \cdot 60}{\pi \cdot D} = \frac{(7 \pm 0.7) \times 60}{\pi \times 4} = 33.4 \pm 3.3 \text{ r/min}$$

Because the rated speed for a 4-pole motor at 60 Hz is 1450~1550 r/min, the gear ratio (i) is calculated as follows:

$$i = \frac{1450 \sim 1550}{N_G} = \frac{1450 \sim 1550}{33.4 \pm 3.3} = 39.5 \sim 51.5$$

From within this range a gear ratio of $i = 50$ is selected.

Calculate the Required Torque

On a belt conveyor, the greatest torque is needed when starting the belt. To calculate the torque needed for start-up, the friction coefficient (F) of the sliding surface is first determined:

$$F = \mu m_1 = 0.3 \times 30 = 9 \text{ lb.} = 144 \text{ oz.}$$

Load torque (T_L) is then calculated by:

$$T_L = \frac{F \cdot D}{2 \cdot \eta} = \frac{144 \times 4}{2 \times 0.9} = 320 \text{ oz-in}$$

The load torque obtained is actually the load torque at the gearhead drive shaft, so this value must be converted into load torque at the motor output shaft. If the required torque at the motor output shaft is T_M, then:

$$T_M = \frac{T_L}{i \cdot \eta_G} = \frac{320}{50 \times 0.66} = 9.7 \text{ oz-in}$$

(Gearhead transmission efficiency $\eta_G = 0.66$)
Look for a margin of safety of 2 times, taking into consideration commercial power voltage fluctuation.

$$9.7 \times 2 = 19.4 \text{ oz-in}$$

The suitable motor is one with a starting torque of 19.4 oz-in or more. Therefore, motor **5IK40GN-AWU** is the best choice. Since a gear ratio of 50:1 is required, select the gearhead **5GN50KA** which may be connected to the **5IK40GN-AWU** motor.

Load Inertia

Roller Moment of Inertia

$$J_1 = \frac{1}{8} \times m_2 \times D^2 \times 2 = \frac{1}{8} \times 35.27 \times 4^2 \times 2 = 141 \text{ oz-in}^2$$

Belt and Work Moment of Inertia

$$J_2 = m_1 \left(\frac{\pi \times D}{2\pi}\right)^2 = 30 \times 16 \times \left(\frac{\pi \times 4}{2\pi}\right)^2 = 1920 \text{ oz-in}^2$$

Gearhead Shaft Load Inertia

$$J = J_1 + J_2 = 141 + 1920 = 2061 \text{ oz-in}^2$$

Here, the **5GN50KA** permitted load inertia is: $J_G = 4 \times 50^2 = 10000 \text{ oz-in}^2$

(See page A-12)
Therefore, $J < J_G$, the load inertia is less than the permitted inertia, so there is no problem.

Since the motor selected has a rated torque of 36.1 oz-in, which is somewhat larger than the actual load torque, the motor will run at a higher speed than the rated speed. Therefore the speed is used under no-load conditions (approximately 1740 r/min) to calculate belt speed, and thus determine whether the selected product meets the required specifications.

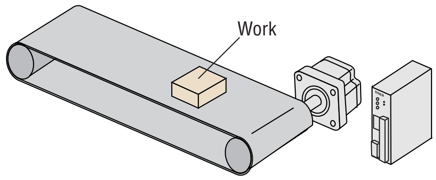
$$V = \frac{N_M \cdot \pi \cdot D}{60 \cdot i} = \frac{1740 \times \pi \times 4}{60 \times 50} = 7.3 \text{ in/s}$$

(Where N_M is the motor speed)
The motor meets the specifications.

Conveyor

Using Brushless DC Motors

Here is an example of how to select a speed control motor to drive a belt conveyor.



- Performance
  Belt speed V_L is 0.6 in./s~40 in./s
- Specifications for belt and work
  Condition: Motor power supply ······ Single-Phase 115 VAC
  Belt conveyor drive
  Roller diameter ································· D = 4 inch
  Mass of roller ································ m_1 = 2.2 lb.
  Total mass of belt and work ············ m_2 = 33 lb.
  Friction coefficient of sliding surface ···· μ = 0.3
  Belt roller efficiency ····························· η = 0.9

Find the Required Speed Range

For the gear ratio, select 15:1 (speed range: 2~200) from the permissible torque table for combination type on page B-14 so that the minimum/maximum speeds fall within the speed range.

$$N_G = \frac{60V_L}{\pi D}$$

N_G: Speed at the gearhead output shaft

Belt Speed

0.6 inch/s ········ $\frac{60\times0.6}{\pi\times4}$ = 2.87 r/min (Minimum Speed)

40 inch/s ········· $\frac{60\times40}{\pi\times4}$ = 191 r/min (Maximum Speed)

Calculate the Load Inertia J_G

Load Inertia of Roller : J_{m1}

$$J_{m1} = \frac{1}{8}\times m_1\times D^2 = \frac{1}{8}\times2.2\times16\times4^2 = 70.4 \text{ oz-in}^2$$

Load inertia of belt and work : J_{m2}

$$J_{m2} = m_2\times\left(\frac{\pi D}{2\pi}\right)^2 = 33\times\left(\frac{\pi\times4}{2\pi}\right)^2 = 132 \text{ oz-in}^2$$

The load inertia J_G is calculated as follows:

$$J_G = J_{m1}\times2 + J_{m2} = 2\times70.4 + 132 = 273 \text{ oz-in}^2$$

From the specifications on page B-15, the permissible load inertia for **BX5120A-15** is 2300 oz-in² (4.2×10⁻² kg·m²)

Calculate the Load Torque T_L

Friction Coefficient of the Sliding Surface: $F = \mu\cdot m_2 = 0.3\times33 = 9.9$ lb.

$$\text{Load Torque } T_L = \frac{F\cdot D}{2\eta} = \frac{9.9\times4}{2\times0.9} = 22 \text{ lb-in}$$

Select **BX5120A-15** from the permissible torque table on page B-14.

Since the permissible torque is 47 lb-in (5.4 N·m), the safety margin is

T_M/T_L=50/22≒2.3

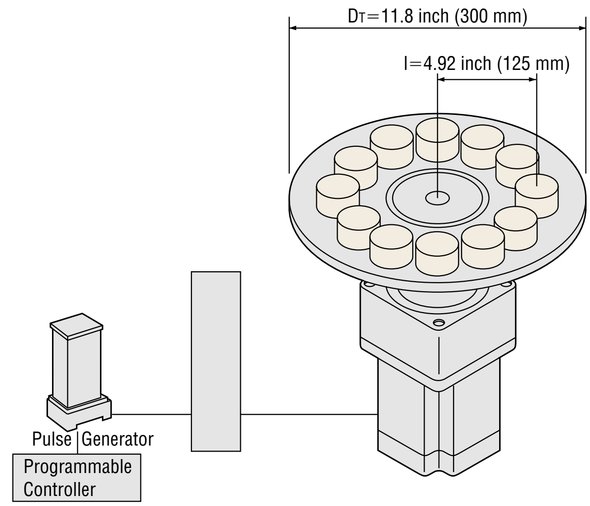
Usually, a motor can operate at the safety margin of 1.5~2 or more.

Index Table

Using Stepping Motors

Geared stepping motors are suitable for systems with high inertia, such as index tables.

Determine the Drive Mechanism



Diameter of index table:	D_T = 11.8 inch (300 mm)
Index table thickness:	L_T = 0.39 inch (10 mm)
Thickness of work:	L_W = 1.18 inch (30 mm)
Diameter of work:	D_W = 1.57 inch (40 mm)
Material of table and load:	Iron [density ρ = 4.64 oz/in³ (7.9×10³ kg /m³)]
Number of loads:	10 (one every 36°)
Distance from center of index table to center of load:	l = 4.92 inch (125 mm)
Positioning angle:	θ=36°
Positioning period:	t_0 = 0.25 [sec]

The αSTEP **PN** geared (gear ratio 10:1) can be used.

Gear Ratio: i = 10

Resolution: θs = 0.036°

Speed Range (Gear Ratio 10:1) is 0~300 r/min

Determine the Operating Pattern

(see page F-4, see basic equations on page F-3)

(1) Find the Number of Operating Pulses (A) [pulses]

$$\text{Operating pulses (A)} = \frac{\text{Angle rotated per movement } (\theta)}{\text{Gear output shaft step angle } (\theta s)} = \frac{36°}{0.036°} = 1000 \text{ Pulses}$$

(2) Determine the Acceleration (Deceleration) Period t_1 [sec]

Generally, an acceleration (deceleration) period should be set approximately 25% or more of the positioning period.

In this example we will set t1=0.1, t1=0.1[s] is provided as the acceleration (deceleration) period.

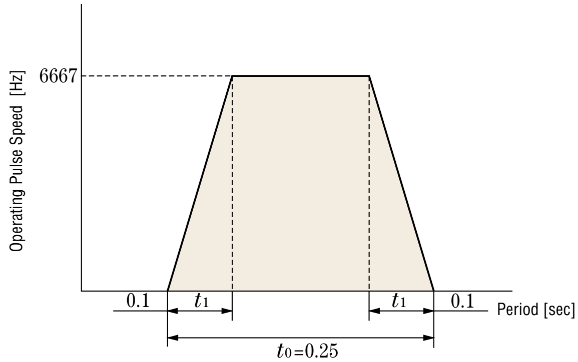
(3) Calculate the Operation Speed

$$\text{Operating N} = \frac{60}{360}\times\frac{\theta}{t_0 - t_1} = \frac{60}{360}\times\frac{36}{0.25-0.1} = 40 \text{ [r/min]}$$

(4) Determine the Operating Pulse Speed f_2 [Hz]

$$\text{Operating Pulse Speed } f_2 = \frac{\text{Number of Operating Pulses [A]} - \text{Starting Pulses Speed } [f_1] \times \text{Acceleration (Deceleration) Period } [t_1]}{\text{Positioning Period } [t_0] - \text{Acceleration (deceleration) Period } [t_1]}$$

$$= \frac{600-0}{0.25-0.1} = 6667 \text{ [Hz]}$$



◆ Calculate the Required Torque T_M [oz-in]

(See page F-4)

(1) Calculate the Load Torque T_L [oz-in]

(See page F-3 for basic equations)

Frictional load is omitted because it is negligible. Load torque is considered 0.

(2) Calculate the Acceleration Torque T_a [oz-in]

① Calculate the Total Inertia J_L [oz-in²]

(See page F-4 for basic equations)

$$\text{Inertia of Table } J_T = \frac{\pi}{32} \cdot \rho \cdot L_T \cdot D_T^4$$

$$= \frac{\pi}{32} \times 4.64 \times 0.39 \times 11.8^4$$

$$= 3400 \text{ oz-in}^2$$

$$\text{Inertia of Work } J_C \text{ (Center of gravity)} = \frac{\pi}{32} \cdot \rho \cdot L_W \cdot D_W^4$$

$$= \frac{\pi}{32} \times 4.64 \times 1.18 \times 1.57^4$$

$$= 3.3 \text{ oz-in}^2$$

$$\text{Weight of Work } m = \pi\left(\frac{D_W}{2}\right)^2 \cdot L_W \cdot \rho$$

$$= \pi\left(\frac{1.57}{2}\right)^2 \times 1.18 \times 4.64$$

$$= 10.6 \text{ oz.}$$

The inertia of the work J_W [oz-in²]relative to the center of rotation can be obtained from distance L [inch] between the center of work and center of rotation, mass of work m [oz], and inertia of work (center of gravity) J_C [oz-in²].

Since the number of work pieces n, is 10 [pcs],

$$\text{Inertia of Work } J_W \text{ (Center of rotation)} = 10 \times (J_C + m \times l^2)$$

$$= 10 \times (3.3 + 10.6 \times 4.92^2)$$

$$= 2600 \text{ [oz-in}^2]$$

$$\text{Total Inertia } J_L = J_T + J_W = 3400 + 2600$$

$$= 6000 \text{ oz-in}^2$$

② Calculating the Acceleration Torque T_a [oz-in]

$$\text{Acceleration Torque } T_a = \frac{(J_0 \cdot i^2 + J_L)}{g} \cdot \frac{1}{12} \cdot \frac{\pi \cdot \theta s}{180} \cdot \frac{f_2 - f_1}{t_1}$$

$$= \frac{(J_0 \times 10 + 6000)}{32.2} \times \frac{1}{12} \times \frac{\pi \times 0.036}{180} \times \frac{6667-0}{0.1}$$

$$= 4.19 J_0 + 650 \text{ [oz-in]}$$

(3) Calculate the Required Torque T_M [oz-in]

Safety Factor Sf=2

$$\text{Required Torque } T_M \text{ [oz-in]} = (T_L + T_a) \times 2$$

$$= \{0 + (4.19 J_0 + 527)\} \times 2$$

$$= 8.38 J_0 + 1300 \text{ [oz-in]}$$

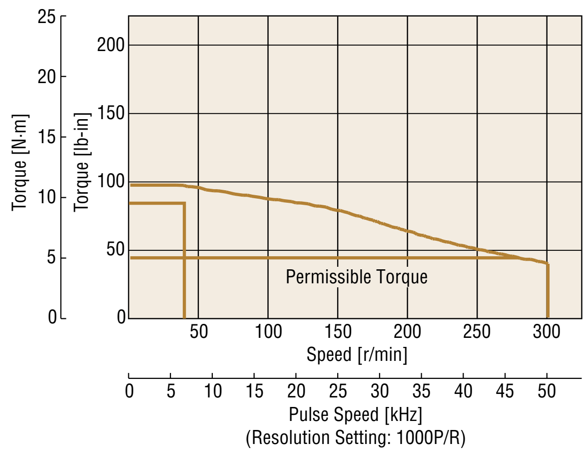
◆ Select a Motor

(1) Provisional Motor Selection

Model	Rotor Inertia oz-in²	Required Torque	
		lb-in	[N·m]
AS66AA-N10	J_0=2.2	84	9.55

(2) Determine the Motor from the Speed-Torque Characteristics

AS66AA-N10



The total torque of the system is the sum of the load torque plus the acceleration torque. The total torque times the safety factor must not exceed the permissible torque.

Fan Sizing Calculations

Selecting a Fan

This section describes basic methods of selecting typical ventilation and cooling products based on their use.

● Device specifications and conditions

Determine the devices required internal temperature.

● Heat generation within the device

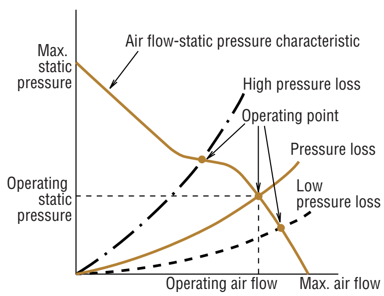
Determine the amount of heat generated internally by the device.

● Calculate required air flow

Once you have determined the amount of heat generated, the number of degrees the temperature must be lowered and what the ambient temperature should be, calculate the air flow required.

● Selecting a fan

Select a fan using the required air flow. The air flow of a mounted fan can be found from the fan's air flow vs. static pressure characteristics and the pressure loss of the object to be cooled. It is difficult to calculate the device's pressure loss, so an estimation for the maximum air flow of 1.3 to 2 times the required air flow may be used.



Air Flow-Static Pressure Characteristic

Fan Selection Flowchart

Determine the device's requirements

Determine how many degrees to lower the internal temperature based on the guaranteed operating temperatures of the device's internal components and elements.

↓

Calculate the amount of heat produced

Calculate the amount of heat produced internally from the device's input/output and efficiency etc.

↓

Calculate the required air flow

Calculate the volume of air required for a set temperature.

↓

Select a fan

Select a fan with a maximum air flow of 1.3 to 2 times the required air volume.

Fan Selection Details

Cabinet Specifications

Item		Letter	Specifications
Installation Conditions		—	Factory Floor
Cabinet	Size	W	Width 0.48 m (19 in.)
		H	Hight 1.44 m (57 in.)
		D	Depth 0.36 m (14 in.)
	Surface area	S	2.42 m²* (3758 in.²)
	Material	—	Steel
	Overrall Heat Transfer Coefficient	U	5 W/ (m²/K)
Target Temperature Rise		ΔT	50˚F (10˚C) Ambient Temperature T_1 25°C (77F°) Max. temperature inside of cabinet T_2 35°C (95F°)
Total Heat Generation		Q	1200 W
Safety Factor		Sf	2
Power Source		—	60 Hz 115 VAC

* Surface of Cabinet = Side Area + Top Area
=1.8 × H × (W+D) + 1.4 × W × D
=2.42 m² (3758 in.²)

① Required Air Flow

◆ Determine Required Air Flow Using Calculations

K: Coefficient 0.05

$V = K \times (Q \div \Delta T\text{-}U \times S) \times Sf$

$= 0.05 \times (1200 \div 10\text{-}5 \times 2.42) \times 2$

$\fallingdotseq 10.8$ [m³/min] (381 [CFM])

◆ Determine Required Air Flow Using a Graph

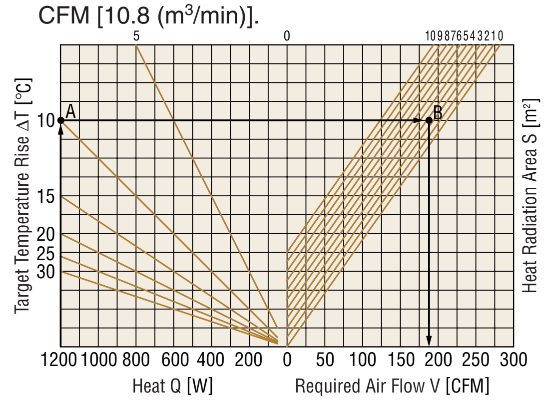
① Search for the cross point A between output of heat Q (1200 W) and target temperature rise ΔT [50˚F (10˚C)].

② Draw a line parallel with the x axis from point A.

③ Search for the cross point B between the parallel line and surface area S [2.42 m² (3758 in.²)] line.

④ Draw a line to the x axis from point B, required airflow is approx. 190 CFM [5.4 (m³/min)].

⑤ Use a safety factor of Sf = 2, Required airflow will be 380 CFM [10.8 (m³/min)].



② Applicable Fans

Based on the air flow requirement, the **MRS18-BTM** is the best match.

MRS18-BTM Specifications

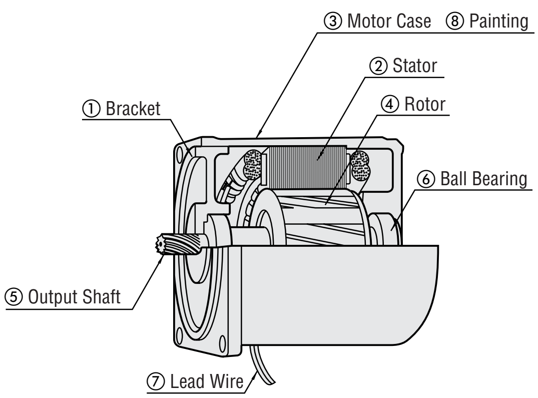
Voltage VAC	Frequency Hz	Input W	Current A	Speed r/min	Max. Air Flow		Max. Static Pressure		Noise dB (A)
					CFM	m³/min	inH₂O	Pa	
115	60	95	1.0	3350	452	12.8	0.98	245	61

Standard AC Motors

Construction of AC Motors

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

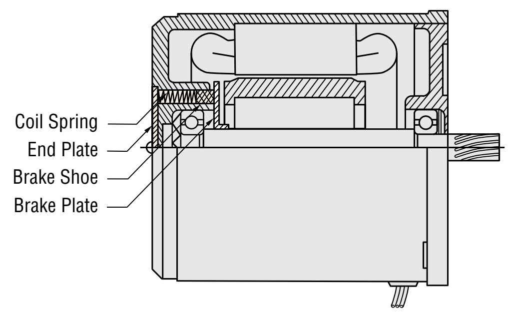
① Bracket: Die-cast aluminum bracket with a machined finish, press-fitted into the motor case.
② Stator: Comprised of a stator core made from laminated silicon/steel plates, a polyester-coated copper coil and insulation film.
③ Motor Case: Die-cast aluminum with a machined finish inside.
④ Rotor: Laminated silicon/steel plates with die-cast aluminum.
⑤ Output Shaft: Available in round shaft and pinion shaft types. The metal used in the shaft is S45C. Round shafts have a shaft flat (output power of 25 W or more), while pinion shafts undergo precision gear finishing.
⑥ Ball Bearing
⑦ Lead Wire: Lead wires with heat-resistant polyethylene coating.
⑧ Painting: Baked finish of acrylic resin or melamine resin.



Brake Mechanism of the Reversible Motor

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

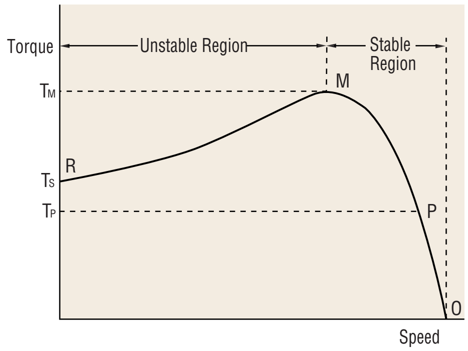
a. To improve the instant reversing characteristics by adding a friction load
b. To reduce overrun



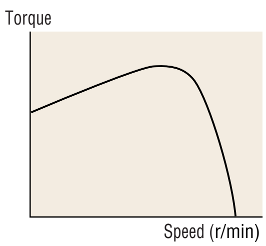
The brake mechanism is constructed as shown in the figure above. The coil spring applies constant pressure to allow the brake shoe to slide toward the brake plate.
This mechanism provides a certain degree of holding brake force, but the force is limited due to the mechanism's structure, as described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

Induction Motor Speed – Torque Characteristics

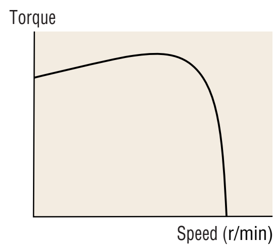
The figure below shows the motor's characteristics of speed and torque.



Under conditions of no load, the motor rotates at a speed close to synchronous rotation (O) . As the load increases, the motor's speed drops to a level (P) where a balance is achieved between load and motor torque (Tp).
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.



Single-Phase motors

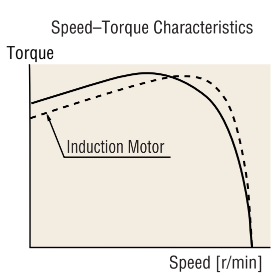


Three-Phase motors

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.

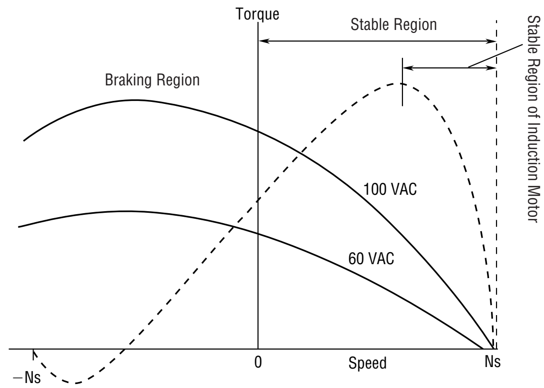
Reversible Motor Speed – Torque Characteristics

The reversible motor is a capacitor-run, single-phase induction motor that features the same 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.



Torque Motor Speed – Torque Characteristics

The figure below shows the torque motor's characteristics of speed and torque. The speed and torque characteristics of torque motors differ from those of induction motors or reversible motors. As the graph shows, they have special torque characteristics (torque is highest at zero speed and decreases steadily with increasing speed), so they can provide stable operation through the entire 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 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.



Service Life of an AC Motor

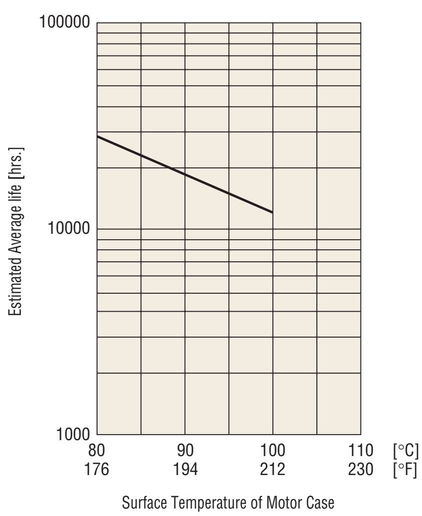
The service life of an AC motor is affected by a number of factors, but in most cases it is determined by the bearings. The useful life of a bearing is represented in terms of ① bearing mechanical life and ② grease life, as described below.

[Bearing Life]

① Mechanical life is affected by rolling fatigue
② Grease life is affected by grease deterioration due to heat

The AC motor's bearing life is estimated based on the grease life, since the bearing life is more affected by grease deterioration due to heat than the load applied to the bearing. Temperature is the primary determinant of grease life, meaning that grease life is significantly affected by temperature. Grease life will be extended at a lower temperature as long as it is within the ambient temperature range specified in the motor's general specifications. Oriental Motor uses bearings that offer an especially high resistance to temperature. The graph below shows the estimated average life characteristic based on actual data measured with regard to the motor case's surface temperature.

According to this graph, the estimated average life is approximately 20,000 hours at 188.6°F (87˚C). And this graph indicate that the useful life doubles when the surface temperature of the motor case is lowered 32.4°F (18˚C).
For the useful life of a gearhead, see page F-45.



Capacitor

Oriental Motor's single-phase AC motors are permanent split capacitor types. Capacitor-run 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 current in the auxiliary winding to lag the current in the main phase.
The motor employs a UL-recognized, metallized electrode capacitor. 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 supplied with the motor. The capacitor's capacitance is expressed in microfarads (μF).

Rated Voltage

Using the capacitor at a voltage level exceeding the rated voltage may significantly reduce the capacitor's service life. Be sure to use the capacitor supplied 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, voltage, temperature and frequency. The standard life expectancy is 25,000 hours. We recommend that the capacitor be replaced after the rated conduction time.

Safety Feature of Capacitor

The UL-recognized capacitors, supplied with the motors, 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 uses capacitors with UL-recognized safety features that have passed the UL810 requirement of the 10,000-A fault current test.

Temperature Rise in Standard Compact AC Motors

When a motor is operating, all energy loss from the motor is transformed into heat, causing the motor's temperature to rise.

- Induction motors: Induction motors, which are rated for continuous duty, reach the saturation point of temperature rise after two or three hours of operation, whereupon its temperature stabilizes.
- Reversible motors: Reversible motors (30 minute 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 allowable 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.

Reversible Motor's Operation Time and Temperature Rise

The reversible motor is rated for 30 minutes. However, when operating the motor intermittently for a short period of time, the operation time may vary in accordance with the operating conditions. Intermittent operation of the reversible motor for a short period of time will result in a considerable flow of electric current when the motor is started or reversed, thus causing greater heat generation. However, the motor's temperature rise can be managed by keeping the motor at rest for a longer period of time, thereby enhancing its natural cooling capability.

Motor case temperature is the sum of the motor's temperature rise and the ambient temperature. In general, if the motor's case temperature is 194°F (90˚C) or below, continuous motor operation under such operating conditions is possible, considering the insulation class of motor winding. The life of the bearing grease is extended according to the lower motor temperature.

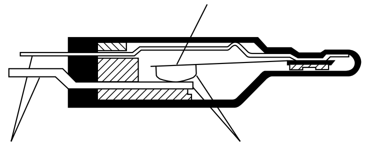
The motor temperature varies depending on load conditions, operating cycle, motor installation, ambient temperature and other factors. Use these factors as rough guidelines, since it is difficult to evaluate everything based solely on data regarding these factors.

Overheating Protection Devices

If a motor operating in run mode locks due to overload or the input current increases, 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 service life and, in extreme cases, scorching the winding and causing a fire. In order to protect the motor from such thermal abnormalities, UL, CSA, EN and IEC standard motors from Oriental Motor are equipped with the following overheating-protection devices.

● Thermally Protected Motors

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



Structure of a Thermal Protector

The thermal protectors employ a bimetal contact with pure silver used in the contacts. Pure silver has the lowest electrical resistance of all materials and has thermal conductivity second only to copper.

♦ Operating temperature of thermal protector

Open···266°F±9°F (130˚C±5˚C) (the operating temperature varies depending on the model, e.g., **BH** Series: 302°F±9°F (150˚C±5˚C)

Close···179.6°F±27°F (82˚C±15˚C) (the operating temperature varies depending on the model, e.g., **BH** Series: 204.8°F±27°F (96˚C±15˚C)

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

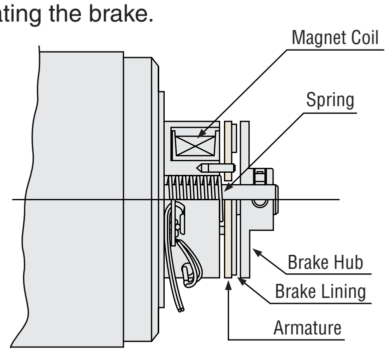
● Impedance Protected Motors

Motors with frame sizes of 2.36 inch sq. (60 mm 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) is minimized and temperature will not rise above a certain level.

Construction of an Electromagnetic Brake

An electromagnetic brake motor is equipped with a power off activated type electromagnetic brake.

As shown in the figure below, 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.

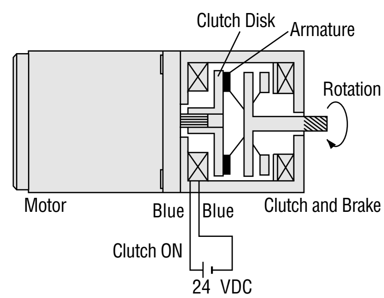


Structure and Operation of a Clutch-Brake Motor

The photograph above shows the structure of the clutch-brake motor. When 24 VDC is not applied to either the clutch coil or brake coil, the output shaft can be rotated by hand.

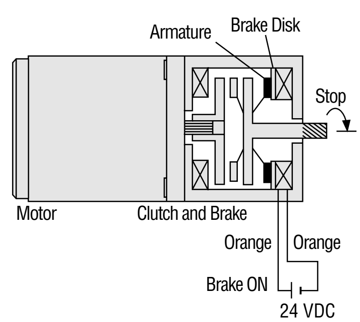
● Run

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

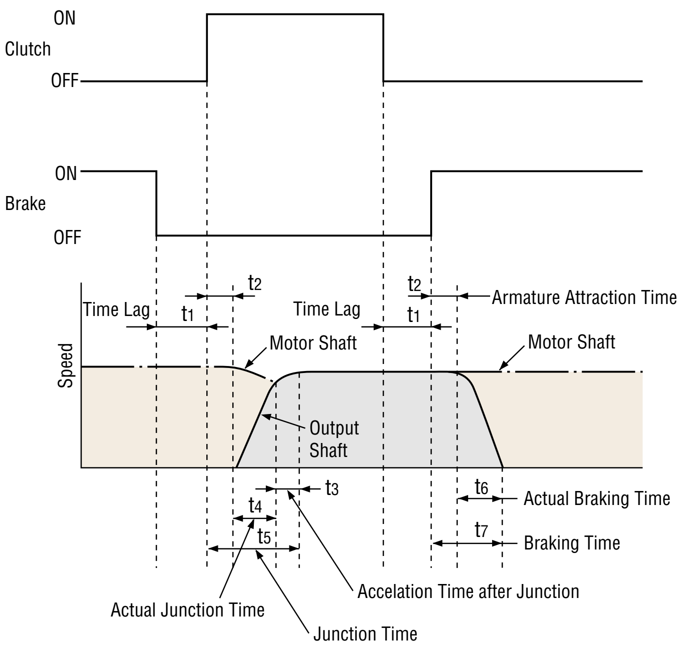


● Stopping and Load Holding

By removing the 24 VDC from the clutch coil and, after a certain time lag, applying 24 VDC to the brake coil, the output shaft will come to a stop. During braking, the output shaft is released from the motor shaft, so the shaft may be stopped without being influenced by motor inertia. The motor continues to rotate.



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, there is a lag of 20 msec. between the time the brake is released and the time voltage is applied to the clutch. This is to prevent the clutch and brake from engaging at the same time, denoted as t_1.

The time required for the clutch/brake output shaft to reach a constant speed after voltage is applied to the clutch is called the junction time (t_5) and is calculated by adding the following elements:

① Armature Attraction Time t_2

The time required from application of voltage to the clutch coil until contact of the armature with the clutch plate.

② Actual Junction Time t_4

The time required after the armature comes in contact with the clutch for the clutch/brake output shaft, accelerated by dynamic friction torque, to engage completely with the motor shaft.

③ Acceleration Time After Junction t_3

The time needed to accelerate back to the required speed if a load is suddenly applied to the motor during the actual junction time, causing a temporary drop in speed.

Braking

When operation is shifted from rotation to stopping or holding a load, a time lag of about 20 msec. is necessary after the clutch is disengaged before voltage is applied to the brake coil denoted as t_1.

The time required after applying voltage to the brake for the clutch/brake output shaft to actually stop is called the braking time (t_7), and is obtained by adding the following elements:

① Armature Attraction Time t_2

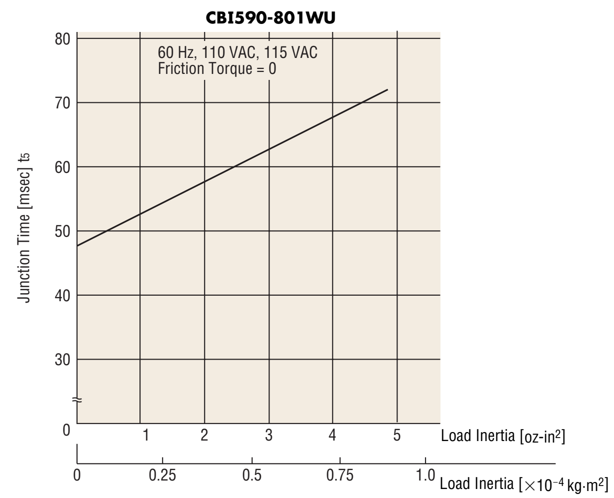
The time from the application of voltage to the clutch coil until contact of the armature with the brake plate.

② Actual Braking Time t_6

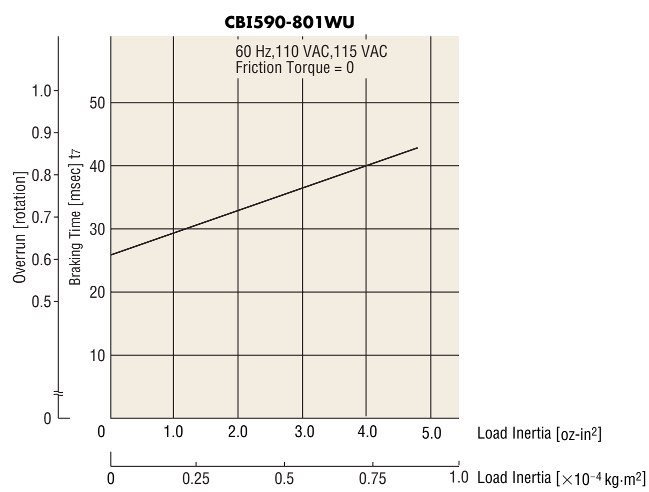
The time required from the moment the armature comes in contact with the brake plate until the moment the output shaft comes to a complete stop.

The following graphs indicate examples of junction and braking characteristics.

Junction Characteristics (Reference value)



Braking Characteristics (Reference value)



Glossary

Ratings

Ratings

Motor rating limitations pertaining to temperature rise are divided into two categories: continuous and short-term ratings. These establish working limitations on output, as well as on voltage, frequency and speed (r/min), and are known as rated output, rated voltage, rated frequency and rated speed (r/min).

Continuous and Limited Duty Ratings

The period during which output can continue without abnormality is called a rating period. 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 period, it is known as the short-term 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 is marked with a rated output value. Output power is expressed in watts and in horsepower.

$$\text{Output Power [watts]} = 1.047\times10^{-1}\times T\times N$$

1 HP=746 watts

where: 1.047×10^{-1} : Constant

T [N·m] : Torque

N [r/min] : Speed

Rated Output Power

When optimal characteristics are achieved at the rated voltage and frequency in continuous operation, the motor is said to be operating at its rated output. The speed and torque that produce the rated output are called the rated speed and rated torque. Generally, the term “output” refers to rated output.

Torque

Starting Torque

This term refers to the torque generated the instant the motor starts. If the motor is subjected to a load greater than this torque, it will not operate. ①

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. ②

Rated Torque

This is the torque created when the motor is continuously producing rated output at the rated voltage and frequency. It is the torque at rated speed. ③

Static Frictional Torque

Static frictional 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 used with the motor.

Speed–Torque Characteristics

①: Starting torque

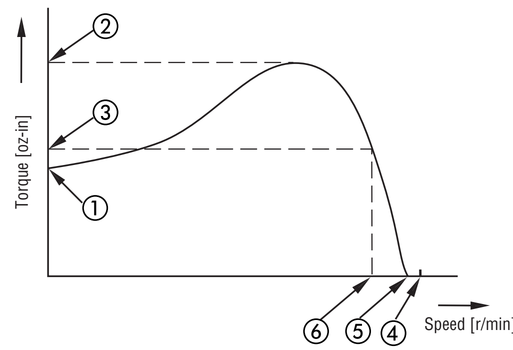
②: Stall torque

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 calculated according to the following formula, and is normally indicated in r/min.

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

N_S: 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 60Hz, the synchronous speed will be:

$$N_S = \frac{120\times60}{4} = 1800 \text{ [r/min]}$$

See ④ in the figure above

No-Load Speed

The speed of induction or reversible motors under no-load conditions is lower than synchronous speed by 2 to 20 percent. See ⑤ in the figure above.

◆ Rated Speed

This is the appropriate speed of the motor at rated output. From the standpoint of utility, it is the most desirable speed. See ⑥ in the figure on the previous page.

◆ 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 an angle or by revolutions.

● Gearhead

◆ Gear Ratio

The gear ratio is the ratio by which the gearhead reduces the motor speed [r/min]. The speed at the gearhead's output shaft is one over the 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 size and construction of the gears and bearings, and thus varies according to the gearhead type and ratio.

◆ Service Factor

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

◆ Transmission Efficiency

This is the efficiency of transmission when the torque is increased with the gearhead attached. 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.

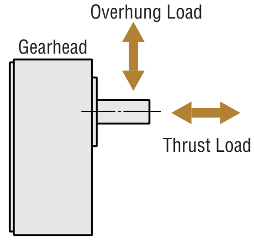
Transmission efficiency is usually 90% for one stage of reduction gears, and is 81% for two-stage gearheads. As the reduction ratio increases, the number of gear stages increases, with a consequent reduction in the gear efficiency to 73% and 66%, respectively, for each gear stage added.

◆ Overhung Load

This is a load on the gearhead's output shaft in the radial 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's output-axis shaft. The maximum thrust load on the gearhead is called the permissible thrust load, which differs by the type of gearhead.



● Others

◆ CW, CCW

This shows the direction of motor rotation.
CW is clockwise as seen from the output shaft side, while CCW is counterclockwise.

Q&A

Q1. I may have to put the motor in an environment below 32°F (0°C) during transport. Will this create a problem?

A1. Extreme changes in temperature may lead to condensation within the motor. Should this occur, parts may rust, greatly shortening the service life. Take measures to prevent condensation.

Q2. Can the motors be shipped through tropical climates?

A2. No. When the humidity and temperature differences within the cargo space of ships and airplanes are severe, the insulation may deteriorate due to condensation. Successful countermeasures are to ship the motors packed in sealed containers or bags containing de-oxygenating material.

Q3. The motor gets extremely hot. Is this all right?

A3. The internal losses generated when the motor converts electrical energy to rotational movement becomes heat, making the motor hot. The motor temperature is expressed as the ambient temperature plus the temperature rise caused by losses within the motor. If internal losses within the motor is 90˚F (50˚C) and the ambient temperature is 85˚F (29˚C), the surface of the motor will be 175˚F (79˚C). This is not abnormal for a small motor.

Q4. Will large fluctuations in power supply voltage affect the motor?

A4. The torque produced by the motor is affected by changes in power supply voltage. The torque the motor produces is proportional to roughly twice the power supply voltage. For example, if the voltage of a motor rated at 115 VAC fluctuates between 103.5 VAC (90%) and 126.5 VAC (110%), the torque produced will vary between 80% and 120%. When using motors under large power voltage fluctuations, remember that the torque produced will vary, so select a motor that provides a sufficient margin.

Q5. Can a reversible motor be used as an induction motor if the brake shoes are removed?

A5. A reversible motor is not simply an induction motor with a simple braking mechanism added. The ratio of coils between the primary coil and the secondary coils in a reversible motor is different from that of an induction motor. Although a simple brake mechanism is added to the rear of the motor, the capacitance is also increased to increase starting torque. This means that if only the brake mechanism is removed, the reversible motor will not be usable at a continuous rating like an induction motor; it will simply lose its holding power and its reversing characteristics will be reduced.

Q6. What does it mean to say that a reversible motor is rated for 30 minutes?

A6. Reversible motors require a larger input power than induction motors to increase the starting torque and improve the instant reversing characteristics. This means that the losses are higher and the temperature rises more during continuous operation. If operated continuously, the motor will burn out. It is designed to provide maximum performance if operated for no more than 30 minutes continuously.

Q7. Can the speed of induction motors and reversible motors be changed?

A7. The speed of single-phase (AC) induction and reversible motors is determined by the power supply frequency. If your application requires changing speed, we recommend AC speed control motors, brushless DC motors.

Q8. Can a single-phase motor be driven using a three-phase power supply?

A8. A single-phase 230 VAC motor can be driven using a three-phase power supply. Use two of the three phases as the source of power supply. The same voltage can be obtained by combining two of the u, v, and w windings in one of the following patterns: U-V, U-W and V-W.
When using a number of motors, be sure to connect them to the power supply so that a balanced supply of power is achieved from each phase.

Q9. Can instant reversal of a reversible motor be implemented using a SSR (solid state relay)?

A9. When instant forward/reverse operation is controlled with an SSR, the SSR characteristics can cause shorts in the circuit. Time must be allowed between switching from the SSR for clockwise rotation to the SSR for counterclockwise rotation.

Q10. The connection diagrams shows that a capacitor must be connected. Why is this necessary?

A10. Most of Oriental Motor standard compact AC motors fall within the broad group of single-phase induction motors are "capacitor-run motors". To run an induction motor, a rotational magnetic field must be created. Capacitors perform the role of creating a power supply with the phase shift that is required for creating such a rotational magnetic field. Three-phase motors, by contrast, always supply power with different phases, so they do not require capacitors.

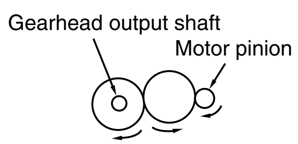
Q11. Can I use a capacitor other than the one that comes with the motor?

A11. The capacitor that comes with the motor has a capacitance that was selected to work optimally with the motor. When another capacitor is used, it should be a motor capacitor with the same capacitance and rated voltage as the capacitor that comes with the motor. Electrolytic capacitors may not be used.

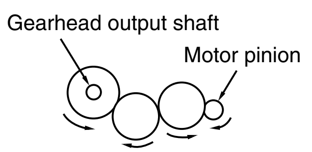
Q12. Why do some gearheads output in the same direction as the motor while others output in the opposite direction?

A12. Gearheads reduce the motor speed by 3:1 to 180:1. They do not, however, reduce the speed with a single gear stage, but with several. The number of gear stages depends on the gear ratio, so the direction of output shaft rotation differs.

●Rotating in motor axis direction

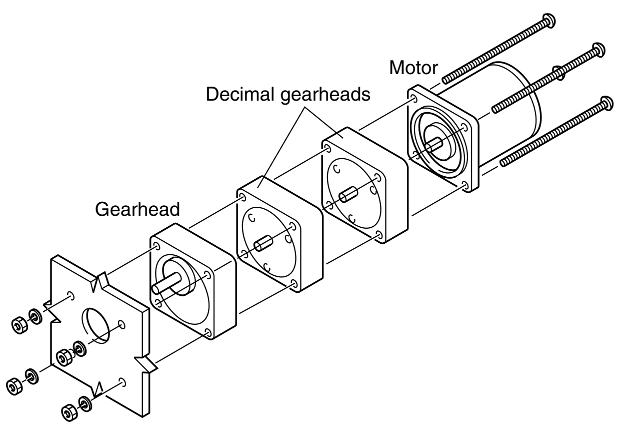


●Rotating opposite of motor axis direction



Q13. Can gearheads be used to reduce the motor speed to 1/18,000?

A13. Yes. A gearhead with a gear ratio of 180:1 must be connected to two decimal gearheads with a gear ratio of 10:1. The permissible torque is the same as if the 180:1 gearhead were used alone. Longer mounting screws must be used.



Q14. Do gearheads require oiling?

A14. Oriental Motor lubricates the surface of gears in gearheads with grease. Oiling is not required.

Q15. We wired the induction motor according to the wiring diagram, but it does not move. When we turned the shaft by hand, it started to move in the direction we turned it. What could be the cause of this?

A15. In order to turn a single-phase induction motor, it is necessary to use a capacitor to create two power supplies with different phases to obtain the rotating magnetic field. The problem described occurs, if the capacitor is not properly connected. Check for a cut line or contact defect near the capacitor section. The way to check is to measure the voltage across the capacitor terminals and check whether or not it is at least 1.5 times the power supply voltage. If not, the capacitor may not be working properly.

Speed Control Systems

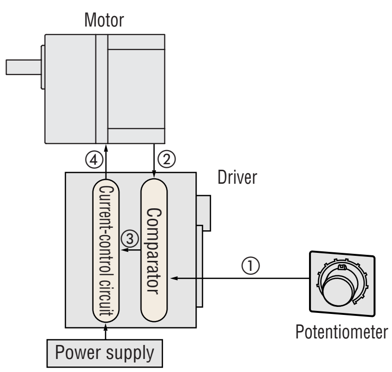
Speed Control Methods of Speed Control Systems

The basic block diagrams and outline of the control methods are shown below. Both brushless DC and AC speed control systems employ a closed-loop control system.

● Brushless DC Motor and Driver System

Control Method

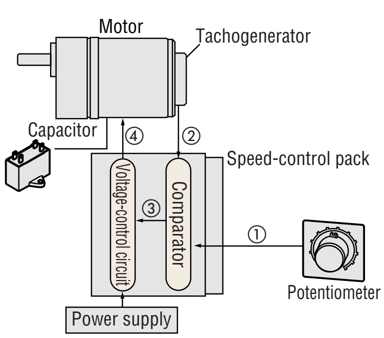
① The speed setting voltage is supplied via a potentiometer.
② The motor speed is sensed and the speed signal voltage is supplied.
③ The difference between the speed setting voltage and speed signal voltage is output.
④ Current determined by the output from the comparator is supplied to the motor so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



● AC Speed Control Motor System

Control Method

① The speed setting voltage is supplied via a potentiometer.
② The motors speed is sensed 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

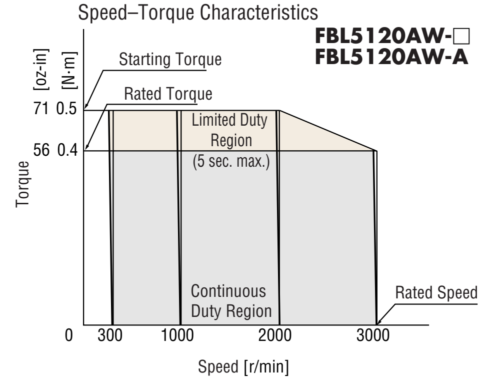
● Brushless DC Motor and Driver System

The figure bellow illustrates the characteristics of an **FBLⅡ** Series motor. The **BX**, **AXU** and the **AXH** Series motors also have similar characteristics, although their speed control ranges are different.

Brushless DC motors operate at rated torque from 300 to 3000 r/min, with a constant starting torque. (With the **AXH** Series, the output torque at the maximum speed is approximately 50% of rated torque.) Unlike AC speed control motors, torque in a brushless DC motor package will not drop at low speeds. Unlike AC speed control motors, which have a limit to continuous use (safe operation line) because of the motor's temperature rise, brushless DC motors can be used continuously at rated torque from high to low speeds.

In addition to areas of continuous use, brushless DC motors also have short-term use areas. The torque generated in the short-term use areas, which is 1.2 times the rated torque (2 times for the **BX** Series), is effective for driving inertia loads. If operated for more than approximately five seconds in the short-term use area, the overload protection function of the driver or control unit may engage and the motor will automatically stop.

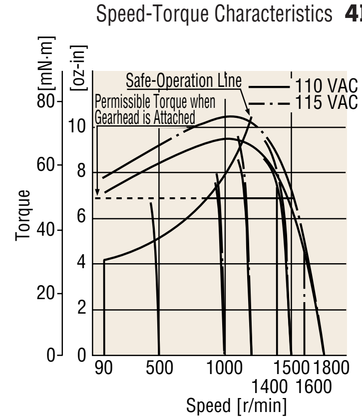
Speed–Torque Characteristics **FBL5120AW-□ FBL5120AW-A**



● AC Speed Control Motors

The speed-torque characteristic line shown in the figure below is typical for all AC speed control motors. Each set speed changes slightly according to the change in load torque.

Speed-Torque Characteristics **4IK25RGN-CWE/ES02**



◆ Safe Operation Line and Permissible Torque When Using a Gearhead

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.

The previous graph displays the relationship between the speed and torque characteristics of an AC speed control motor. The line is referred to as the safe operation line, while the area below the line is called the continuous operation area.

The safe operation line, measured according to motor temperature, indicates its operational limit for continuous usage with the temperature level below the permissible temperature. (In the case of a reversible motor, it is measured via 30-minute operation.)

Whether the motor can be operated at a specific torque and speed is determined by measuring the temperature of the motor case. In general, if the motor's case temperature is 194˚F (90˚C) or below, continuous motor 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 maximum permissible torque. If the actual torque required exceeds the maximum permissible torque, it may damage the motor/gear and/or shorten its life.

◆ Variable Speed Range (Speed Ratio) and Load Factor

When the ratio of minimum speed and maximum speed of a speed control motor is given as the motor's speed ratio, the speed ratio increases to as much as 18:1 in a range where the load factor (ratio of load torque to starting torque) is small (see the 50% load factor range in the following diagram), This widens the motor's range of operation. If the load factor is high, the speed ratio becomes low.

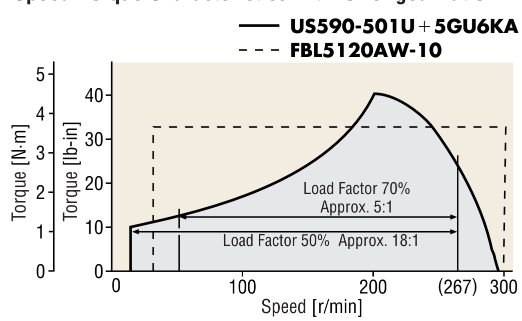
Load Factor and Speed Ratio

Under conditions of actual use, a motor is often used in combination with a gearhead. The following example assumes such a configuration.

The following table shows the continuous operation range and speed ratio of the **US** Series at load factors of 50% and 70%, respectively, as read from the diagram. Although the speed ratio is 18:1 when the load factor is 50%, it decreases when the load factor is 70%. As shown, generally AC speed control motors do not have a wide operation range (when the load factor is high). To operate your motor over a wide speed range, choose a type that offers high starting torque (i.e., a motor with the next larger frame size).

With a brushless DC motor system, such as in the **FBLII** Series, the operation range remains wide regardless of the load factor, as indicated by the dotted line.

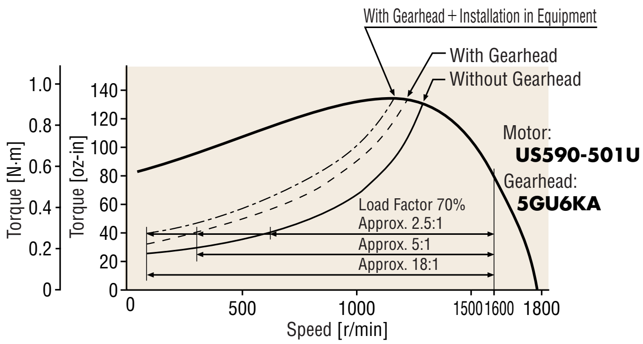
Speed-Torque Characteristics with lower gear ratio



Load Factor [%]	Continuous Operation Range		Speed Ratio
	Minimum Speed [r/min]	Maximum Speed [r/min]	
50	15	267	Approx. 18:1
70	50		Approx. 5:1

Speed Ratio with/without Gearhead

Because the speed control motor's continuous operation range is limited by motor temperature, the continuous operation range will widen if the motor's efficiency of heat dissipation is improved and the temperature rise is curbed. In that case, a motor with a gearhead will have a higher speed ratio than a motor used alone at the same load factor of 70%, as shown in the diagram below. The speed ratio will increase further if the motor with a gearhead is installed in the equipment, since the equipment itself serves as a heat sink.



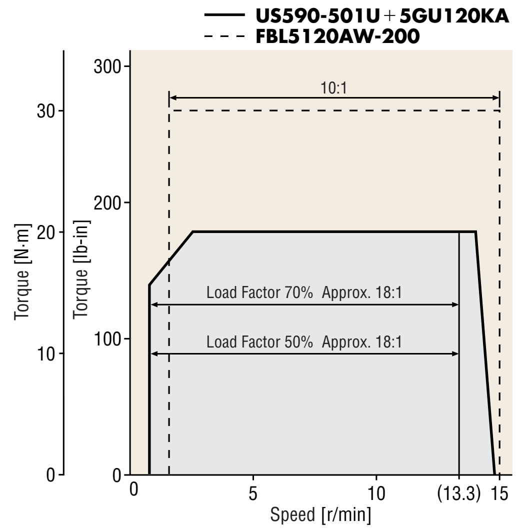
Due to the aforementioned advantage of heat dissipation, when a motor is installed in equipment it can often be operated at variable speeds with a speed ratio of 18:1, as long as the load factor does not exceed 70%.

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 6:1 was used. The diagram below shows what happens when a gearhead with a gear ratio of 120:1 is used.

Speed-Torque Characteristics with a High Gear Ratio



The maximum permissible torque of the **5GU120KA**, which has a gear ratio of 120:1, is 177 lb-in (20 N·m). The speed ratios at 50% and 70% load factors are shown in the table below:

Load Factor [%]	Continuous Operation Range		Speed Ratio
	Minimum Speed [r/min]	Maximum Speed [r/min]	
50	0.75	13.3	Approx. 18:1
70			

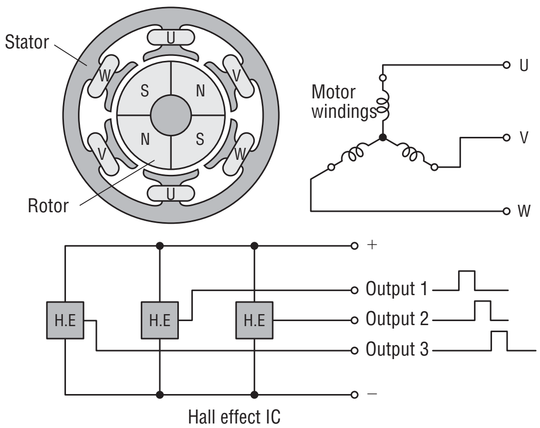
The table above demonstrates that high speed ratios can be obtained by combining a motor with a gearhead having a high gear ratio, in which case the load factor is one of minor concern.

Brushless DC Motor Construction and Principle of Operation

Motor

The construction of a brushless DC motor is similar to that of a standard AC motor, except that the brushless DC 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 DC motor uses three-phase windings in a "star" connection. A permanent magnet is used in the rotor.

Construction of Brushless DC Motor
U: Phase-U winding
V: Phase-V winding
W: Phase-W winding
Rotor: Magnet

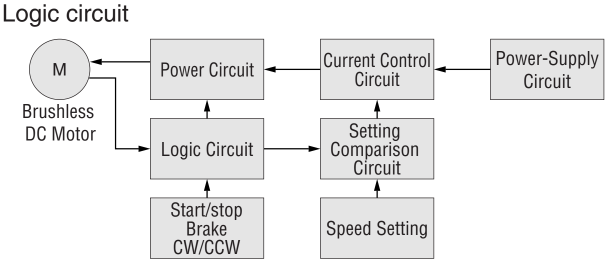


A Hall effect IC is used for the sensor's magnetic element. Three Hall effect ICs are placed within the stator, and send digital signals as the motor rotates.

Brushless DC Motor Drive Circuit

The drive circuit of the brushless DC 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 flow of current to the motor windings.

Current Control Circuit

The flow of current to the motor varies according to the size of the load. The current flow to the motor is constantly monitored and controlled so that the speed will not deviate from the specified range.

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 set speed 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.

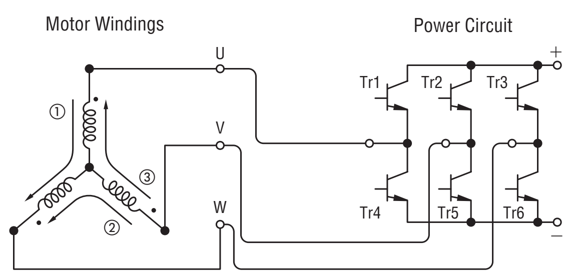
Power Supply Circuit

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

Principle of Brushless DC Motor Rotation

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 DC 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

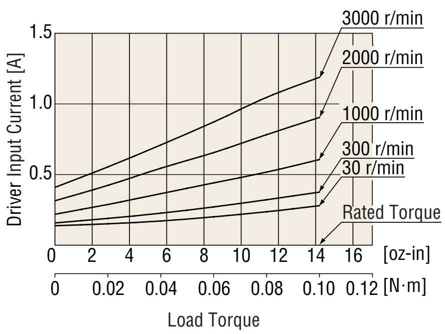
Load Torque–Driver Input Current Characteristics of a Brushless DC Motor and Driver System (reference values)

The driver or control unit input current for brushless DC 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 bidirectional motion requires greater current input, so the relationship does not apply to such operations.

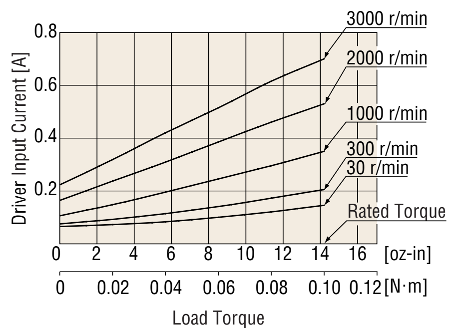
Data for combination type models indicates values for the motor unit only. The box (□) in the model name indicates the gear ratio.

● BX Series

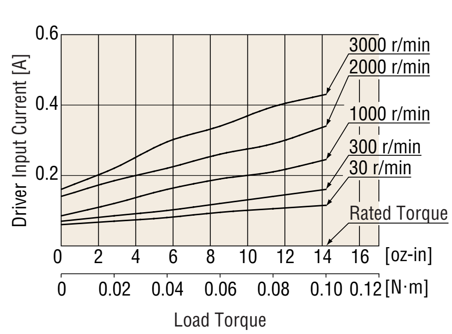
BX230A-□, BX230AM-□
BX230A-A, BX230AM-A



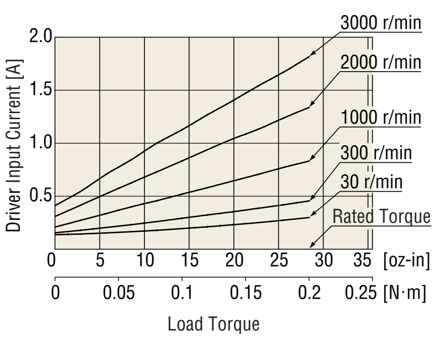
BX230C-□, BX230CM-□ (Single-Phase 200-230 VAC)
BX230C-A, BX230CM-A (Single-Phase 200-230 VAC)



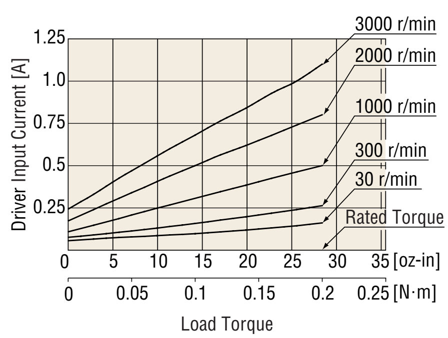
BX230C-□, BX230CM-□ (Three-Phase 200-230 VAC)
BX230C-A, BX230CM-A (Three-Phase 200-230 VAC)



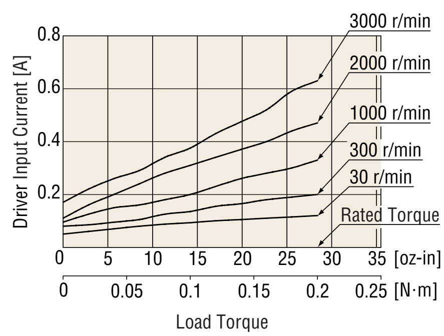
BX460A-□, BX460AM-□
BX460A-A, BX460AM-A



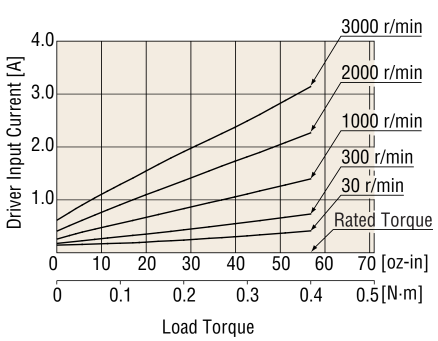
BX460C-□, BX460CM-□ (Single-Phase 200-230 VAC)
BX460C-A, BX460CM-A (Single-Phase 200-230 VAC)



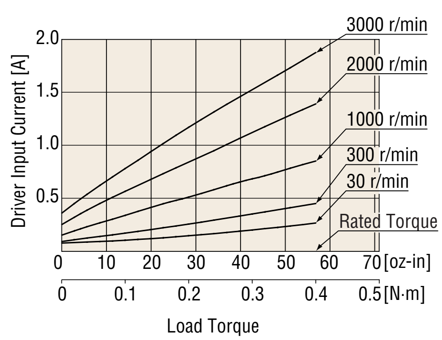
BX460C-□, BX460CM-□ (Three-Phase 200-230 VAC)
BX460C-A, BX460CM-A (Three-Phase 200-230 VAC)



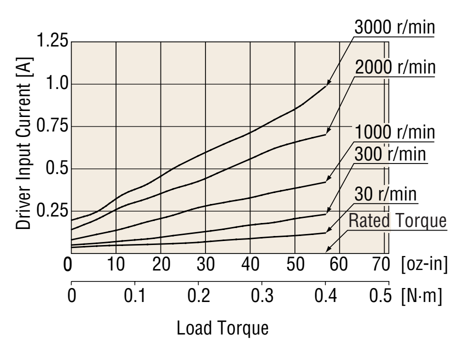
BX5120A-□, BX5120AM-□
BX5120A-A, BX5120AM-A



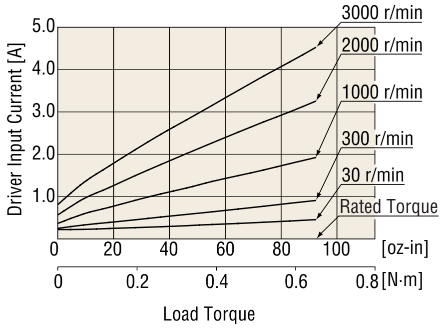
BX5120C-□, BX5120CM-□ (Single-Phase 200-230 VAC)
BX5120C-A, BX5120CM-A (Single-Phase 200-230 VAC)



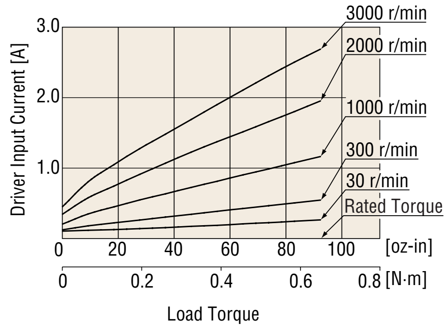
BX5120C-□, BX5120CM-□ (Three-Phase 200-230 VAC)
BX5120C-A, BX5120CM-A (Three-Phase 200-230 VAC)



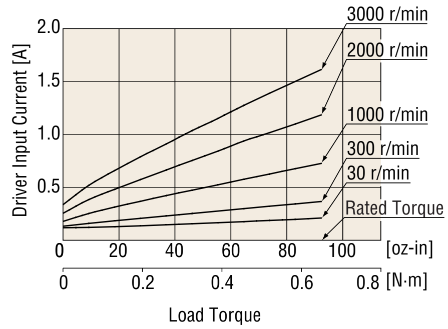
BX6200A-□, BX6200AM-□
BX6200A-A, BX6200AM-A



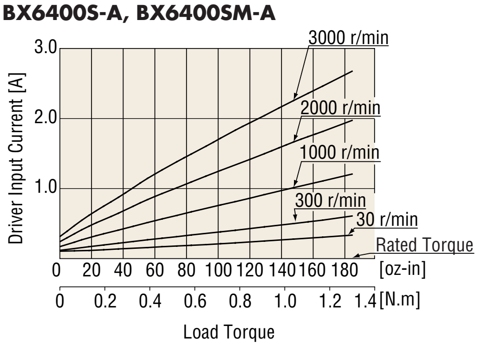
BX6200C-□, BX6200CM-□ (Single-Phase 200-230 VAC)
BX6200C-A, BX6200CM-A (Single-Phase 200-230 VAC)



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

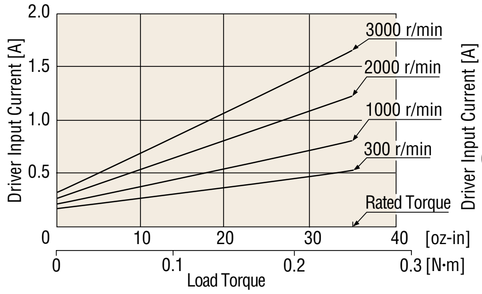


BX6400S-□, BX6400SM-□
BX6400S-A, BX6400SM-A

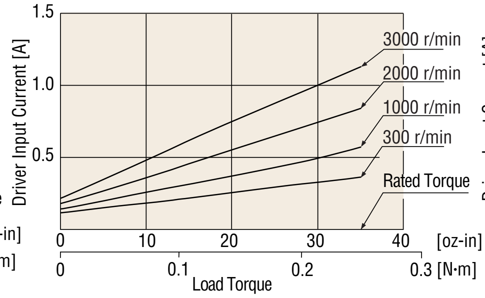


● FBLⅡ Series

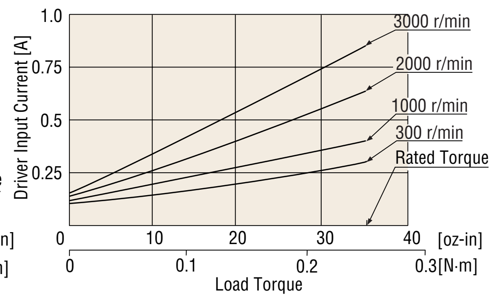
FBL575AW-□
FBL575AW-A



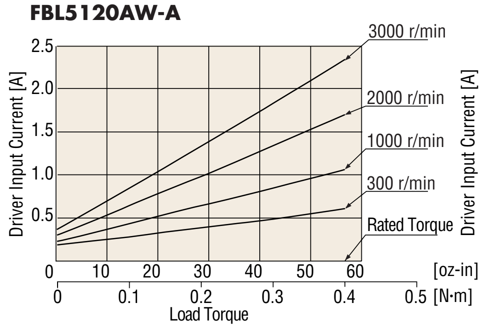
FBL575CW-□
FBL575CW-A



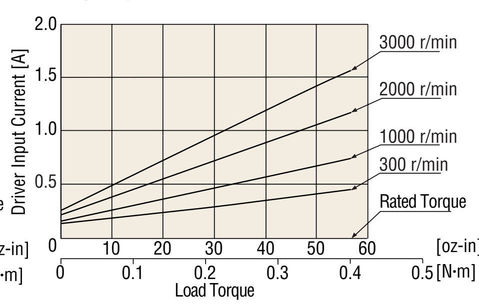
FBL575SW-□
FBL575SW-A



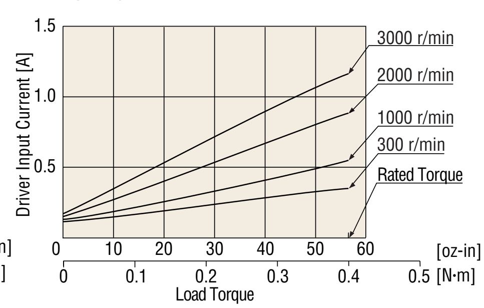
FBL5120AW-□
FBL5120AW-A



FBL5120CW-□
FBL5120CW-A

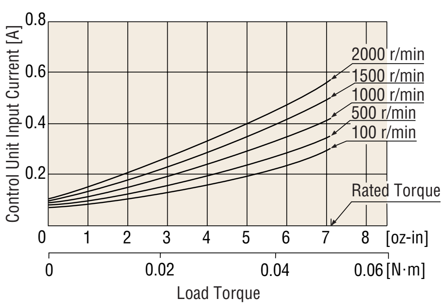


FBL5120SW-□
FBL5120SW-A

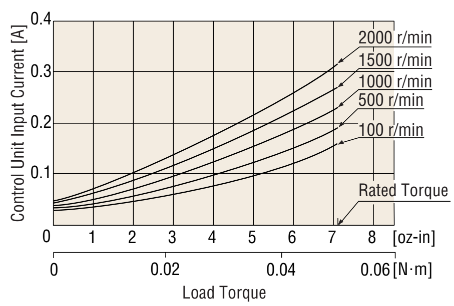


● AXU Series

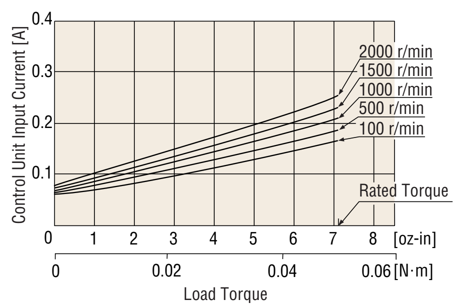
AXU210A-GN
AXU210A-A



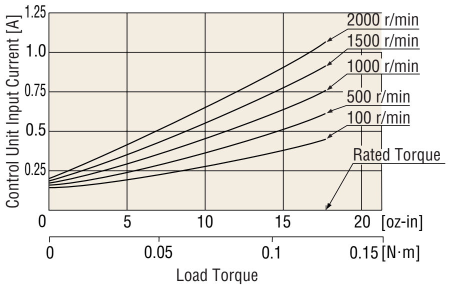
AXU210C-GN
AXU210C-A



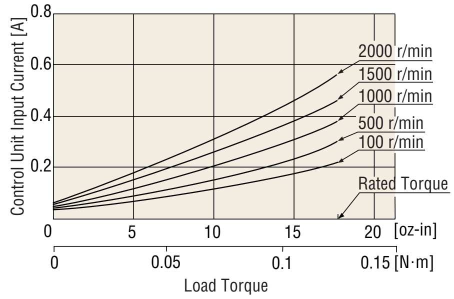
AXU210S-GN
AXU210S-A



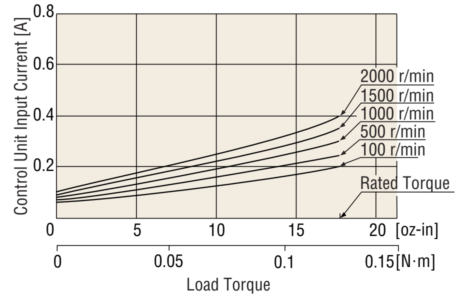
AXU425A-GN
AXU425A-A



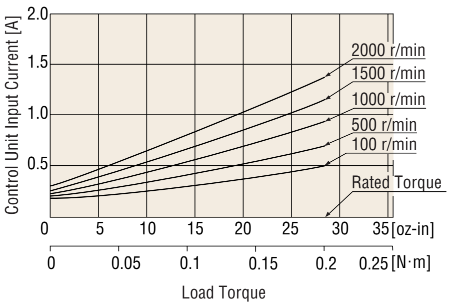
AXU425C-GN
AXU425C-A



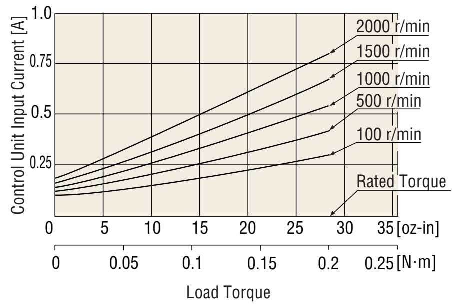
AXU425S-GN
AXU425S-A



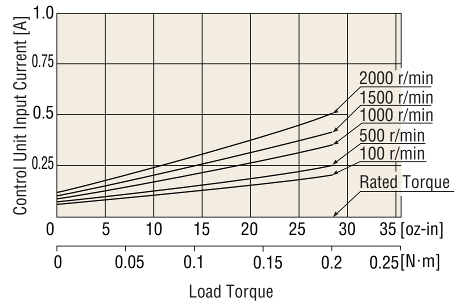
AXU540A-GN
AXU540A-A



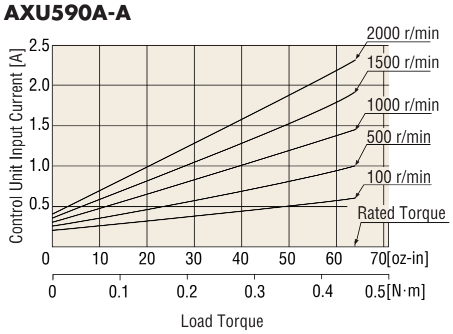
AXU540C-GN
AXU540C-A



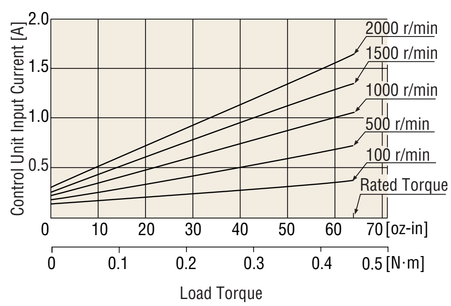
AXU540S-GN
AXU540S-A



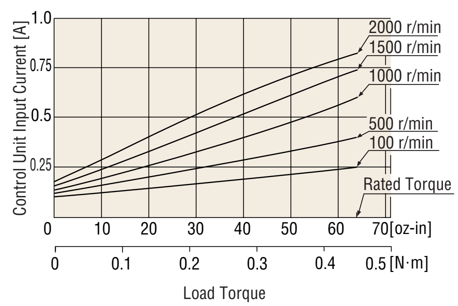
AXU590A-GU
AXU590A-A



AXU590C-GU
AXU590C-A

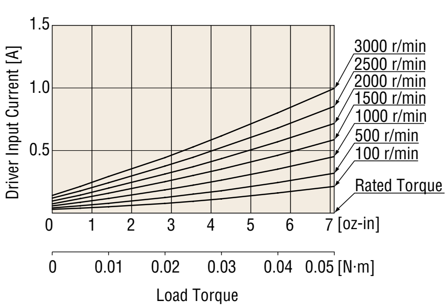


AXU590S-GU
AXU590S-A

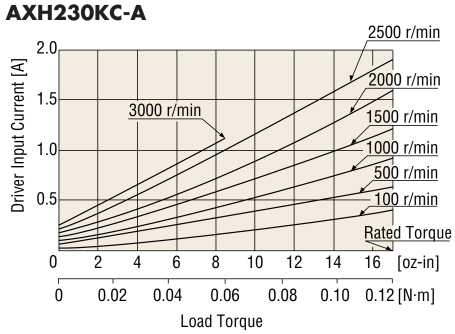


● AXH Series

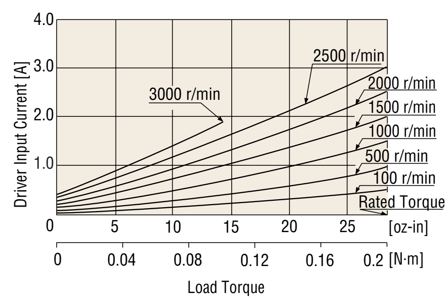
AXH015K-□
AXH015K-A



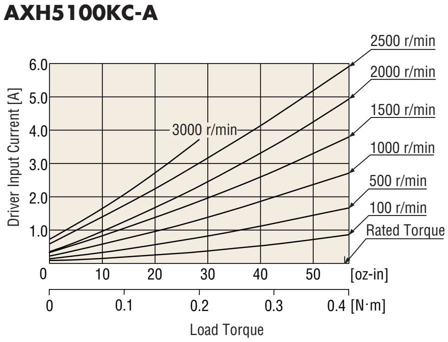
AXH230KC-□
AXH230KC-A



AXH450KC-□
AXH450KC-A



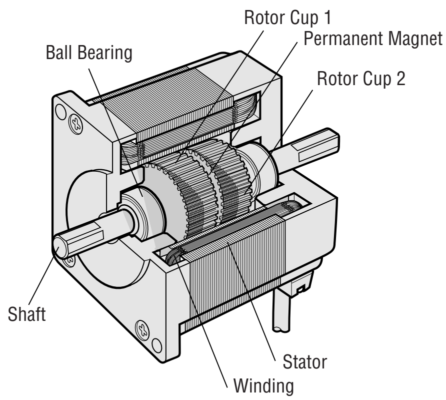
AXH5100KC-□
AXH5100KC-A



Stepping Motors

Structure of Stepping Motors

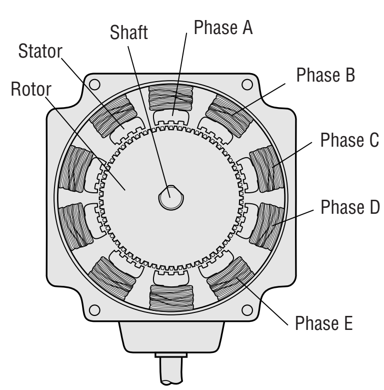
The figures below show two cross-sections of a 5-phase stepping motor. The stepping motor consists primarily of two parts: a stator and rotor. The rotor in turn is made up of three components: rotor cup 1, rotor cup 2 and a permanent magnet. The rotor is magnetized in the axial direction so that, for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



Motor Structural Diagram 1: Cross-Section Parallel to Shaft

The stator has 10 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 teeth on the outer perimeter of each rotor, with the teeth of rotor cup 1 and rotor cup 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.
Teeth: The teeth on the rotor and stator.



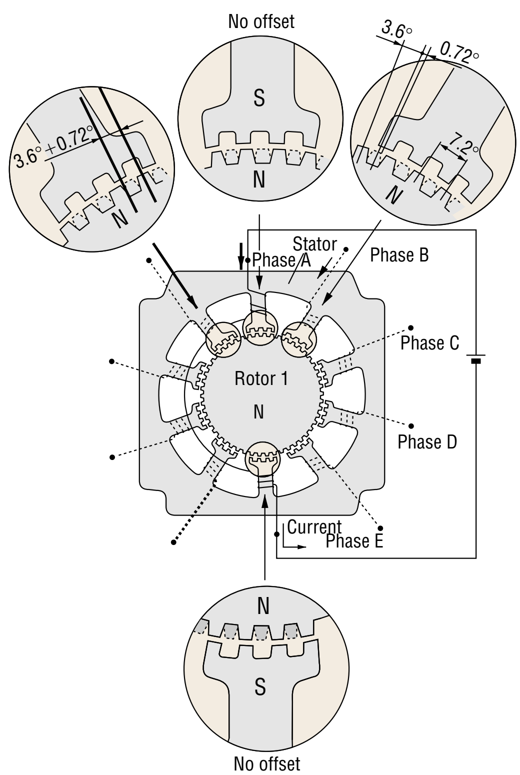
Motor Structural Diagram 2: Cross-Section Perpendicular to Shaft

Principles of Operation

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

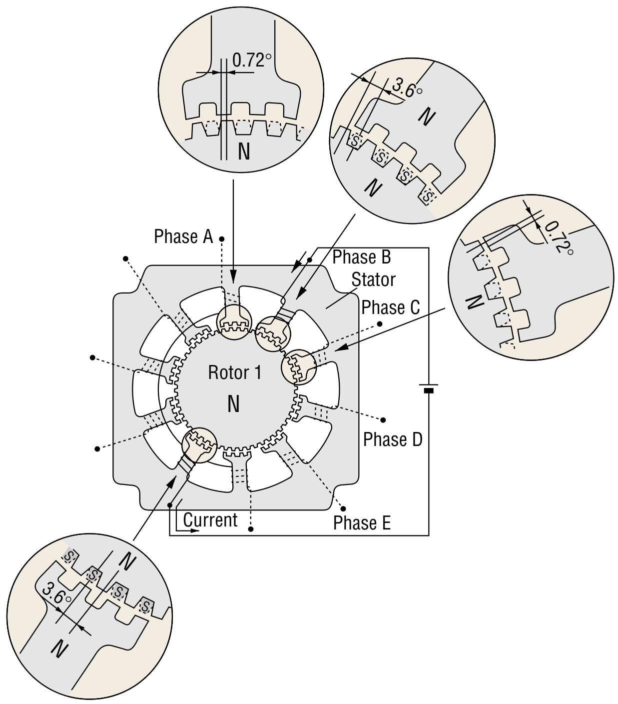
● When Phase "A" Is Excited

When phase A is excited, its poles are polarized south. This attracts the teeth of rotor cup 1, which are polarized north, while repelling the teeth of rotor cup 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 cup 1.



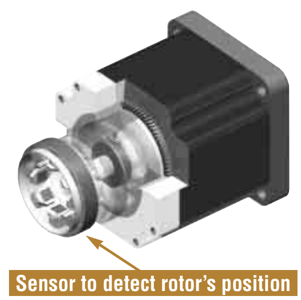
In other words, when excitation switches from phase A to B, the rotor rotates by 0.72˚. As excitation shifts from phase A, to phases B, C, D and E, then back around to phase A, the stepping motor rotates precisely in 0.72˚ steps.
To rotate in reverse, reverse the excitation sequence to phase A, E, D, 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.

■ αSTEP Stepping Motor

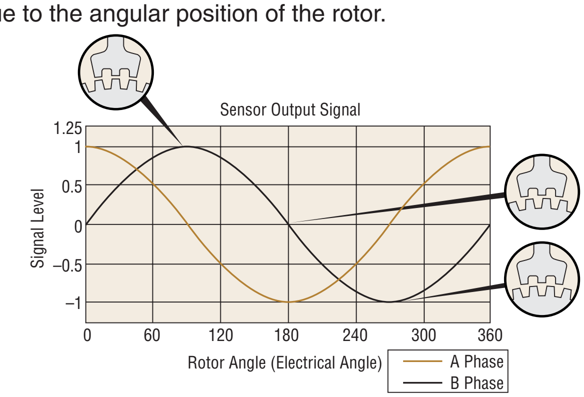
● Overview of the Control System

◆ Equipped with aproprietary rotor position sensor

A rotor position sensor is built-in the rear end of the motor shaft.



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

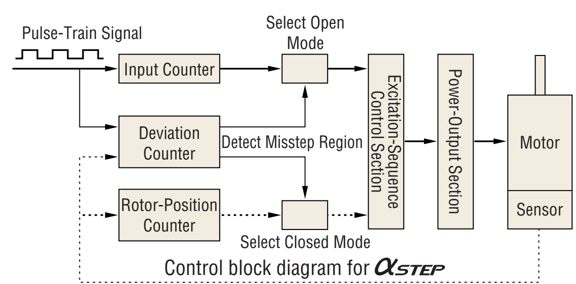


Output Signal of Rotor Position Sensor

◆ 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 train signal.
The calculation result is used to detect a "misstep region" and operate the motor by switching between open and closed modes.

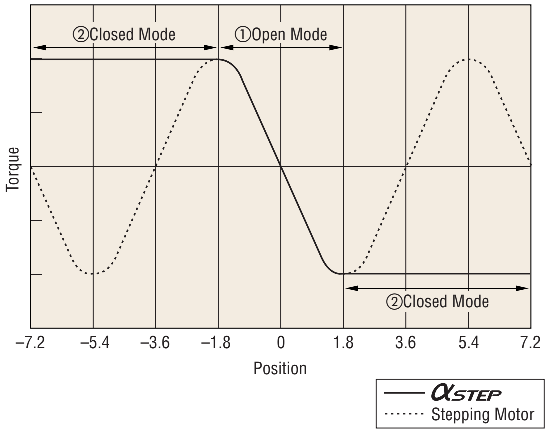
- If the positional deviation is less than ±1.8˚, the motor will run in the open mode.
- If the positional deviation is ±1.8˚ or more, the motor will run in the closed mode.



Control block diagram for αSTEP

Rotor position counter: Specifies an excitation sequence that would develop maximum torque for a given rotor position.

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 positions (misstep region) in the angle vs. torque characteristics.



Angle vs. Torque Characteristics

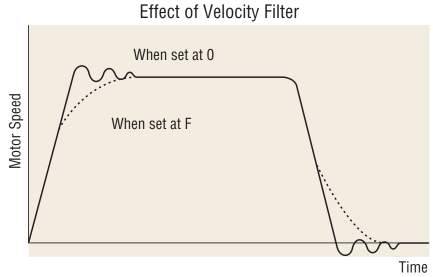
● Features of αSTEP

◆ 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 causing "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



■ Basic Characteristics of Stepping Motors

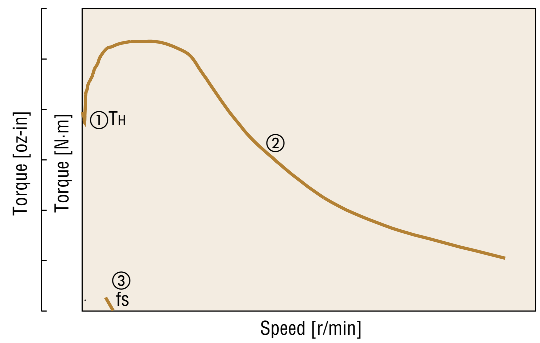
An important point to consider in the application of stepping motors is whether the motor characteristics are suitable to the operating conditions. The following sections describe the characteristics to be considered in the application of stepping motors.
The two main characteristics of stepping motor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

Dynamic Characteristics

These are the starting and rotational characteristics of a stepping motor, mainly affecting the unit'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 motor's level of precision.



Speed vs. Torque Characteristics

● Dynamic Characteristics

◆ Speed vs. Torque Characteristics

Below is a characteristic curve 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 motor's output-shaft speed, and the vertical axis represents the torque.
The speed vs. torque characteristics are determined by the motor and driver, and are greatly affected by the type of driver being used.

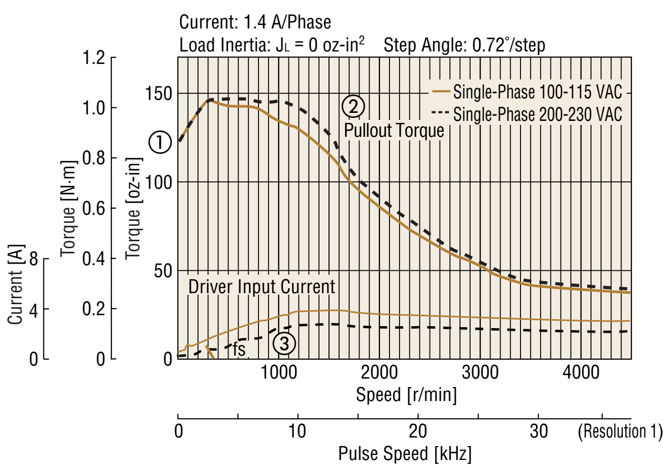
① Holding Torque
The holding torque is the stepping motor's maximum holding power (torque) when power is supplied (at rated current) when the motor is not rotating.

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 instantaneously start or stop (without an acceleration or deceleration period) when the stepping motor's frictional 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 a load inertia is added to the motor.
(Refer to the inertial load vs. maximum starting-frequency characteristics to the right.)

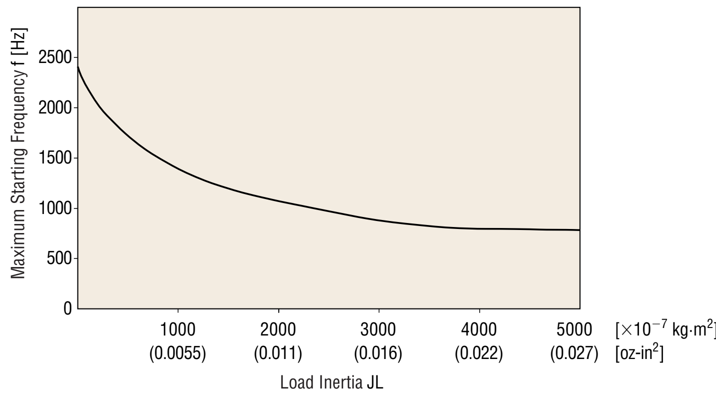
Maximum Response Frequency (f_R)
This is the maximum pulse speed at which the motor can be operated through gradual acceleration or deceleration when the stepping motor's frictional load and load inertia are 0.

The figure below shows the speed vs. torque characteristics of a 5-phase stepping motor and driver package.



◆ Load Inertia vs. 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 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.



Load Inertia vs. Starting Frequency Characteristics

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

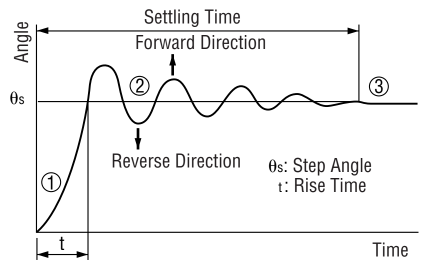
$$f = \frac{f_s}{\sqrt{1+\frac{J_L}{J_0}}} \ \text{[Hz]}$$

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

◆ Vibration Characteristics

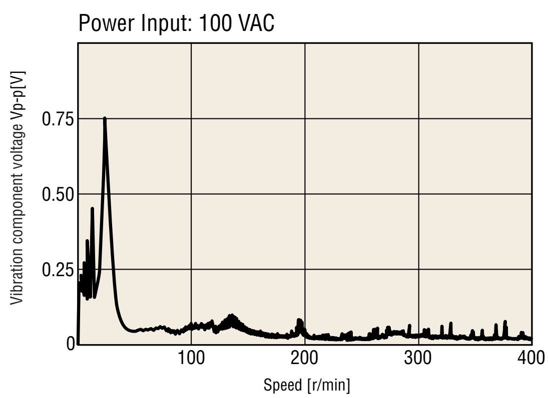
The stepping motor rotates through a series of stepping movements. A stepping movement may be described as a single-step response, as shown below:

① A single pulse input to a stopped stepping motor accelerates the motor toward the next stop position.
② The accelerated motor rotates through the step angle, 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.



Single Step Response

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

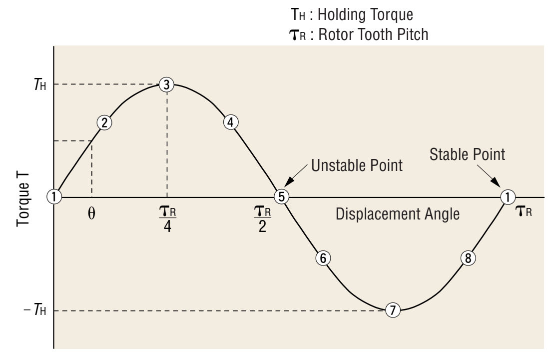


Vibration Characteristics

● Static Characteristics

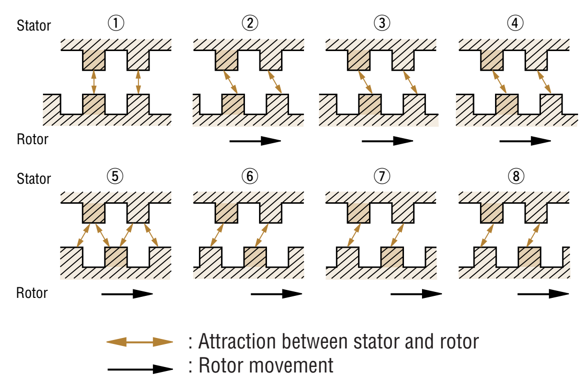
◆ Angle vs. Torque Characteristics

The angle vs. 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 energized at the rated current. The curve for this characteristic is shown below:



Angle vs. Torque Characteristics

The illustrations below 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 counterclockwise 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 holding torque T_H.
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:

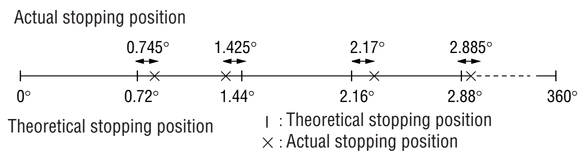
Points where the stator teeth and rotor teeth are half a pitch out of alignment. A rotor at these points will move to the next stable point to the left or right, even under the slightest external force.

◆ Angular Accuracy

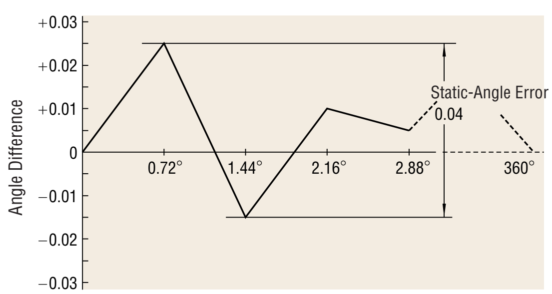
Under no-load conditions, a stepping motor has an angular accuracy within ±3 arc minutes (0.05˚). The small error arises from the difference in mechanical precision of the stator and rotor and a small variance in the DC resistance of the stator winding. Generally, the angular accuracy of the stepping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

◆ Static Angle Error

The static angle error 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 static angle error is the difference between the maximum (+) value and maximum (−) value in the set of measurements taken for each step of a full rotation.



The static angle error is within ±3 arc minutes (0.05˚), but only under no-load conditions. In actual applications there is always same amount of frictional load. The angular accuracy in such cases is produced by the angular displacement caused by the angle vs. torque characteristics based upon the frictional load. If the frictional load is constant, the angle of displacement will be constant for rotation in one direction. However, when operating in both forward and reverse, double the displacement angle is produced over a round trip. When high stopping accuracy is required, always position from one direction only.



■ Stepping Motor Packages

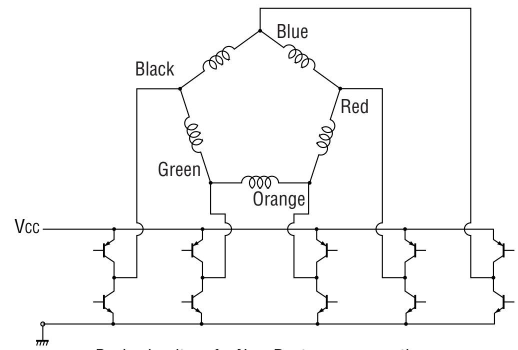
Every 5-phase unit listed in our catalog consists of a New Pentagon, five-lead wire motor and a driver incorporating a special excitation sequence. This combination, which is proprietary to Oriental Motor, offers the following benefits:

- Simple connections for five leads
- Low vibration

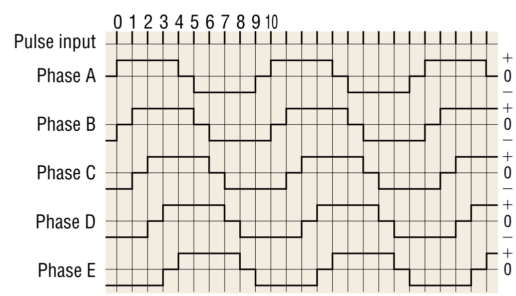
The following sections describe the wiring and excitation sequence.

● 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 stepping angle is 0.72° (0.36°). It offers a great damping effect, and therefore stable operation.



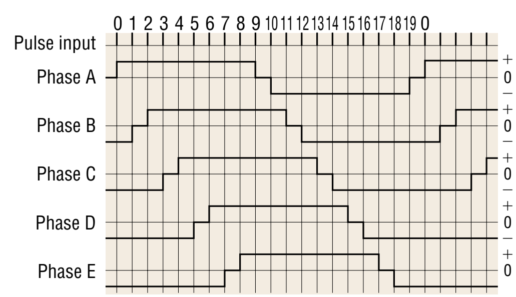
Basic circuitry of a New Pentagon connection



New Pentagon, 4-phase excitation sequence

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

A step sequence of alternating the four-phase and five-phase excitation produces rotation at 0.36˚ per step. One revolution may be divided into 1,000 steps.



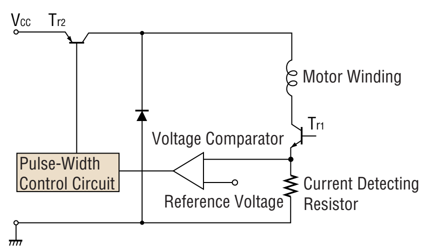
New Pentagon, 4-5-phase excitation sequence

Stepping Motor Drivers

There are two common ways 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 stepping motor and driver packages use the constant current drive system.

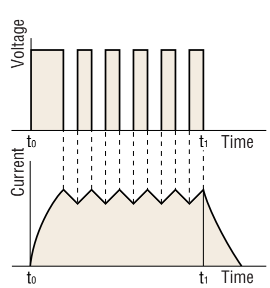
An Introduction to Constant Current Drivers

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.



Basic Circuitry for Constant Current Chopper Driver

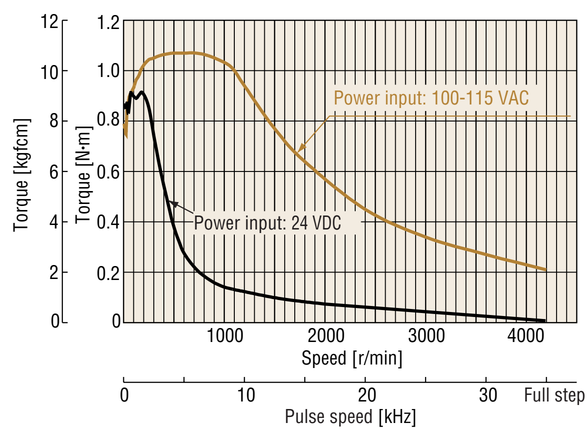
The current flowing to the motor windings, detected as a voltage through a current detecting resistor, is compared to the reference voltage. Current control is accomplished by holding the switching transistor Tr2 ON when the voltage across the detecting resistor is lower than the reference voltage (when it hasn't reached the rated current), or turning Tr2 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 drivers, 24 VDC is applied to the motor. In the 115 VAC and 220 VAC drivers the input is rectified to DC and then approximately 162 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 unit 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 units, which are compatible with a wider range of operating conditions, be considered for your applications.



Comparison of the characteristics of AC input and DC input

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 1/250th) 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 (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.

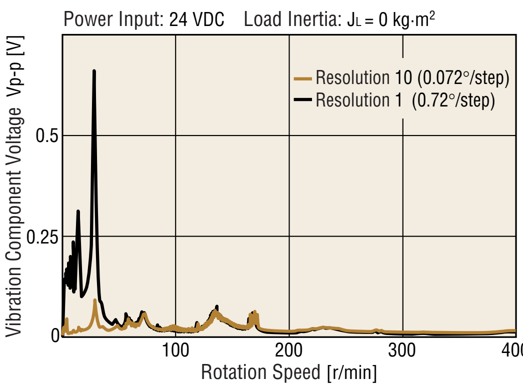
◆ Up to 250 Microsteps

Thanks to the microstep driver, different step angles (16 step resolutions up to 1/250) can be set to two step angle 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. The step angle can be switched at any given position, and switching will not cause the stop position to become misaligned.

Features of Microstep Driving

● Low Vibration

Microstep 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 technology—minimizes vibration more effectively. Anti-vibration measures can be dramatically simplified, so it's ideal for most vibration sensitive applications and equipment.



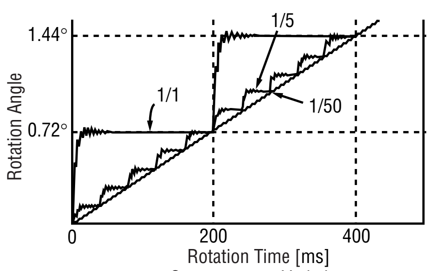
Vibration Characteristics

● Low Noise

Microstep 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.
- Shock normally resulting from the motions of starting and stopping can be lessened.



Step-response Variation

■ Relationship Between Cable Length and Transmission Frequency

A longer pulse line cable equates to a lower maximum frequency of transmission. 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 of the 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.

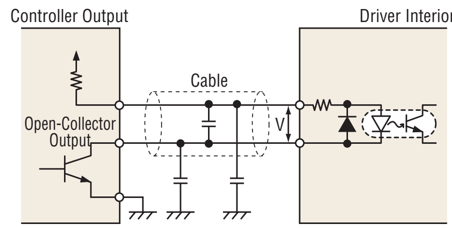


Image Diagram of Stray Capacitance in Cable

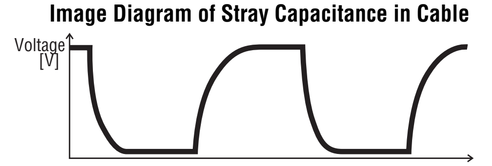


Image of Pulse Waveform

The following table shows the transmission frequencies (actual measurements provided for reference purposes) of the cables when used with Oriental Motor products.

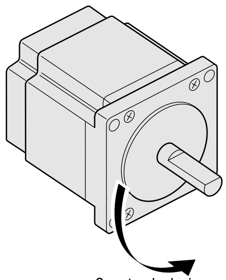
Maximum transmission frequencies (reference data)

Driver	Controller	Cable	Maximum transmission frequency
RK Series	**EMP400** Series	**CC01EMP5** (1 m)	170 kHz
		CC02EMP5 (2 m)	140 kHz
AS Series		**CC01EMP4** (1 m)	150 kHz
		CC02EMP4 (2 m)	120 kHz

Glossary

1-Step Response
The stepping motor rotates through a series of stepping movements. 1-step response refers to the step-like movement (the movement of one step and stop).

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



T.I.R.
Total Indicator Reading: Refers to the total dial gauge reading when the measurement section is rotated one revolution centered on the reference axis center.

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

Regeneration
This is the condition in which the motor is being rotated by an external force, or the generation of electric power through such rotation.

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 angular accuracy of the stepping motor is expressed in terms of the static angle error.

Angular Transmission Error
Angular transmission error is the difference between the theoretical angle of rotation of the output shaft, as calculated from the input pulse count, and the actual angle of rotation. It is generally observed when a speed reduction mechanism is provided. Angular transmission error is used to represent the accuracy of a speed 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-precision 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 rate 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 percent (approximately 40 percent in the **CSK** and **UMK** Series 2-phase motors) when the pulse signal is not input. This minimizes the heating of the motor and driver.
This function automatically reduces the motor current at motor standstill, and does so within approximately 0.1 second after the pulse signal stops.

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

Resonance
This refers to the phenomenon in which vibration becomes larger at specific speeds. For 2-phase stepping motors, the area between 100-200 Hz is a resonance area; 5-phase stepping motors have lower levels of resonance in their resonance area.

Vibration Component Voltage
Vibration component voltage is the level of deviation from the reference rotation speed.

Vibration Characteristics
A graph with the horizontal axis expressing the speed and the vertical axis expressing the vibration component voltage.

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

Static Angle Error

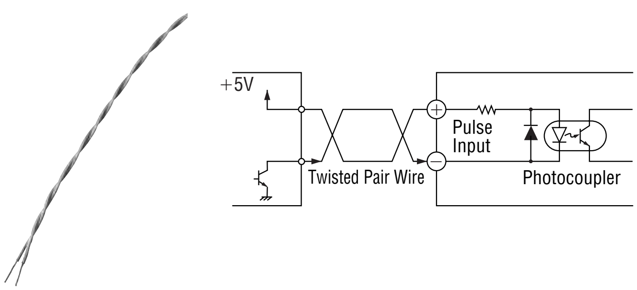
This refers to the difference between the rotor's theoretical stopping position and its actual stopping position. A given rotor stopping point is taken as the starting point, then the static angle error is the difference between the maximum (+) value and maximum (−) value in the set of measurements taken for each step of a full rotation. The static angle error is within ±3 arc minutes (0.05°), but only under no-load conditions. The small error arises from the difference in mechanical precision of the stator and rotor and a small variance in the resistance of the stator winding. However, in actual applications there is always frictional load.
The angular accuracy in such cases is produced by the angular displacement caused by the angle vs. torque characteristics based upon the frictional load.

Loss of Synchronism

Stepping motors are synchronized by pulses. They can lose their synchronization when speed changes rapidly or an overload occurs. Loss of synchronism is the term for losing synchronization with the input pulse.
The correctly selected and normally operated motor doesn't suffer a sudden loss of synchronism.

Twisted Pair Wires

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.



Electromagnetic Brake

The mechanical brake that is used to hold the motor in place. Oriental Motor uses a non-excitation type of electromagnetic brake that automatically holds the motor in place in the event of a power failure or other interruption.

Backlash

The play in the gear output shaft when the motor shaft is fixed. It affects positioning precision when positioning occurs from both directions. The term originally referred to looseness between gear teeth.

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 rotational 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" means that the photocoupler inside the driver is energized, and Input (Output) "OFF" means that the photocoupler inside the driver is not energized.

Photocoupler state OFF ON

Microstepping

Microstepping is a technology used to achieve greater 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, low noise 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 type of motor and excitation system.

Excitation Timing Output

This is a signal that indicates that the excitation sequence is initialized, which is a function of the driver. It is output every 7.2°. For 5-phase stepping motors, it is output every 10 pulses (for full step) or 20 pulses (for half step).

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 and brushless DC 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. By contrast, gearheads for stepping motors are designed for highly accurate positioning, where a high degree of precision, high permissible torque and high speed operation are important. The following sections describe these gearheads in detail.

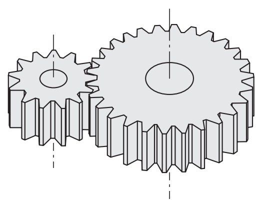
Gearheads for AC Motors

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.

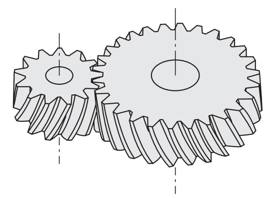
Parallel Shaft Gearheads

Parallel shaft gearheads are the most commonly used gear systems today. Our parallel shaft gearheads employ spur gears and helical gears. 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.



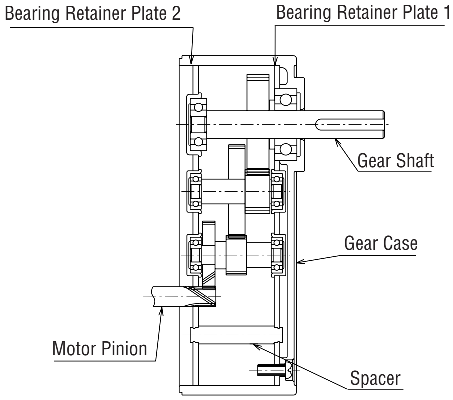
- Helical Gear
The helical gear is a cylindrical gear having teeth cut in a helical curve. Its high rate of contact, as compared to the spur gear, has the advantages of low noise and higher strength, but its axial thrust calls for careful consideration in design.



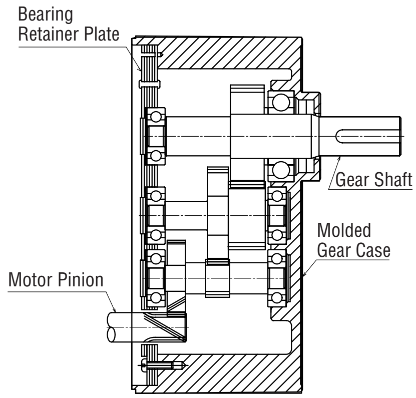
In both types of gearheads, the helical configuration is employed for the motor pinion and its mating gear. This contributes significantly to noise because of their high contact speeds, thereby achieving lower noise output.

The high-strength **GV** gearhead achieves total noise reduction by increasing the rigidity of the gear case while limiting the effect of alignment error at each shaft. The **GV** gearhead motors, with their hardened gears and larger bearings, also generate high torque, being equivalent to two to three times the level produced by the general purpose **GN** and **GU** Series motors. Moreover, the rated service life of the **GV** Series is twice that of its counterparts, meaning the **GV** gearhead will survive 20,000 hours of operation if used under the same torque commonly expected of conventional models (**GN**/**GU** Series). Indeed, the **GV** Series provides a great way to extend maintenance intervals and save energy and resources.

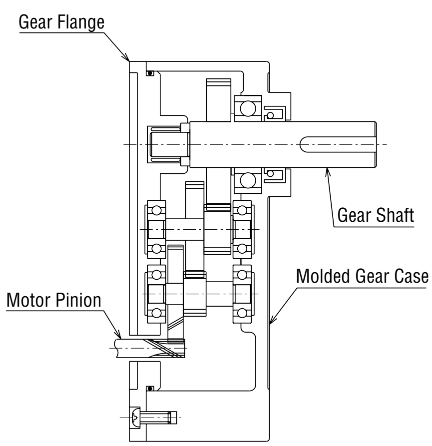
GN Gearhead



GU Gearhead



GV Gearhead



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

● Right-Angle Gearheads (solid and hollow shafts)

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 type). **RA** and **RH** right-angle shaft-type gearheads have worm gears, screw gears or hypoid gears.

Both right-angle gearheads incorporate right-angle gearing at the final stage, leaving the input end identical to that of the parallel shaft types. This facilitates the conversion from the parallel shaft to a right angle shaft gearhead without changing the motor.

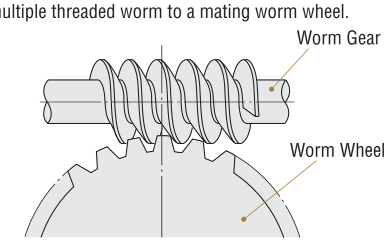
Hollow Shaft

Solid Shaft

◆ Worm Gears

The worm gear transmits power from a single or multiple threaded worm to a mating worm wheel. The worm gear's 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 inproved its efficiency over conventional types by increasing the lead.

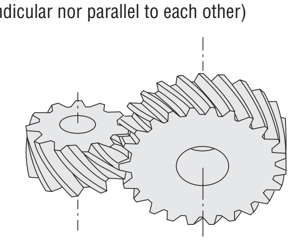
● Worm Gears
The worm gear transmits power from a single or multiple threaded worm to a mating worm wheel.

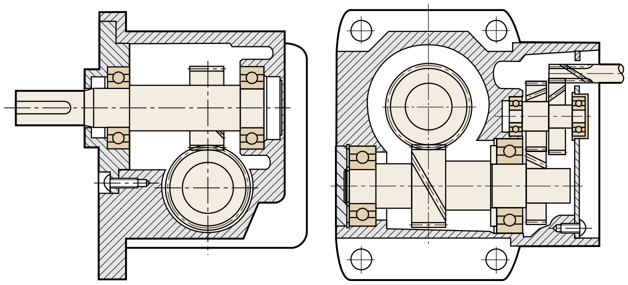


◆ Screw Gears

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 Gears
These are helical gears used on offset shafts (neither perpendicular nor parallel to each other)





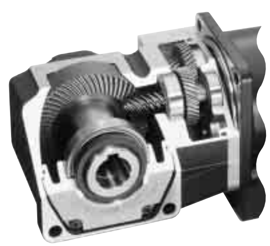
Structure of the Screw Gear

◆ Hypoid Gears

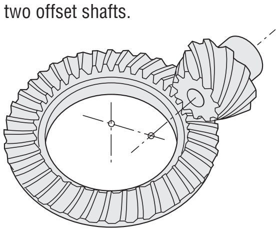
Generally, the differential gears for automotive use have been hypoid gears. Being something of a midpoint between the zero-offset bevel gear and maximum-offset worm gear, the hypoid gear achieves a combination of high strength and efficiency. The offset placement of the pinion gear allows the suppression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

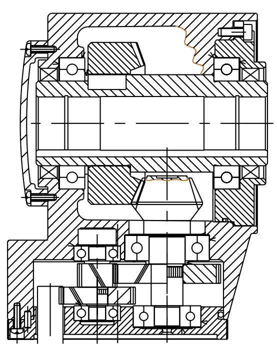
✻ Offset: In hypoid gears the two shafts do not cross but are in displaced planes, separated from each other at a right angle. The displacement is called the offset.

BH Series, hypoid gear



● Hypoid Gears
These are conical gears with curved teeth for transmitting power between two offset shafts.





Structure of the Hypoid Gear

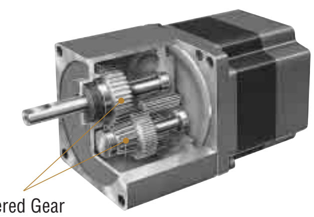
■ Stepping Motor Gears

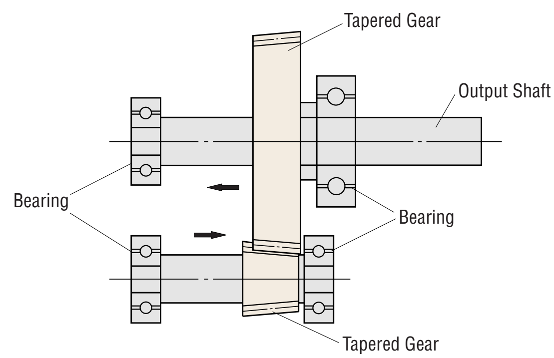
Since the stepping motor and other control motors are designed to allow accurate positioning, the gearheads used for these motors must provide the same level of accuracy. Accordingly, Oriental Motor has developed a mechanism to minimize backlash in gears used with stepping motors in order to ensure low backlash properties. The basic principles and structures of typical control motor gears are explained below.

● Taper Hobbed (TH) Gears

◆ Principle and Structure

Tapered hobbed 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 used at the final stage are adjusted in the direction of the arrows, as shown in the figure below to reduce backlash.



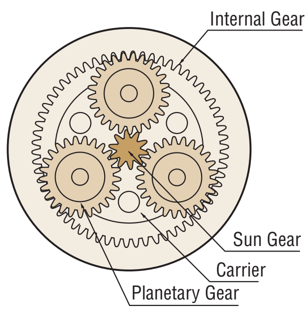


Structure of **TH** gear's final stage

● Planetary (**PN**) Gears

◆ Principle and Structure

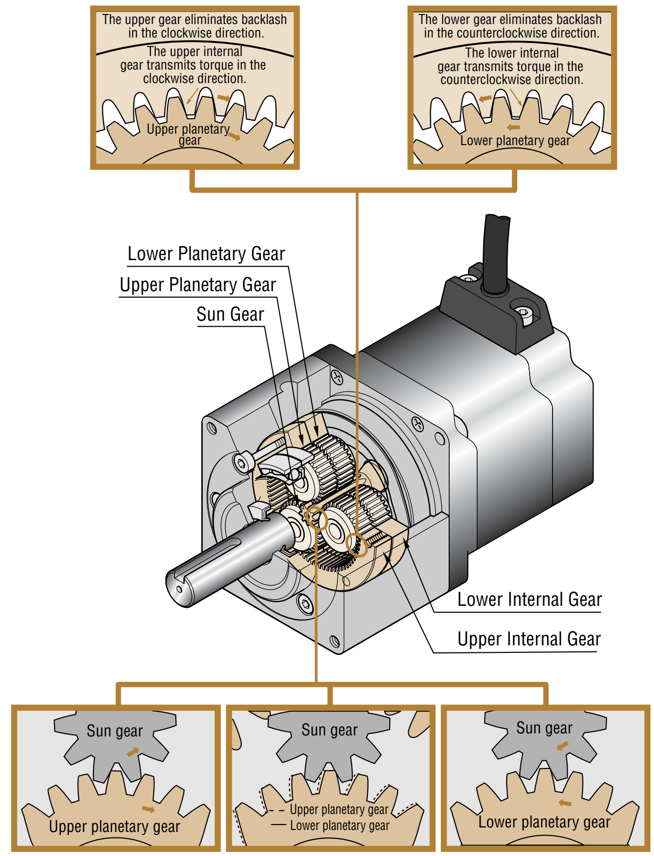
The planetary gear mechanism is comprised mainly of a sun gear, planetary gears and an internal tooth gear. The sun gear is installed on the central axis (in a single stage type, this is the motor shaft) surrounded by planetary gears enclosed in an internal tooth gear centered on the central axis. The 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 achieves the specified backlash of two 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 level internal gears and planetary gears reduce clockwise backlash; the lower level internal gears and planetary gear reduce counterclockwise backlash.



Relationship between upper and lower planetary gears

◆ 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)

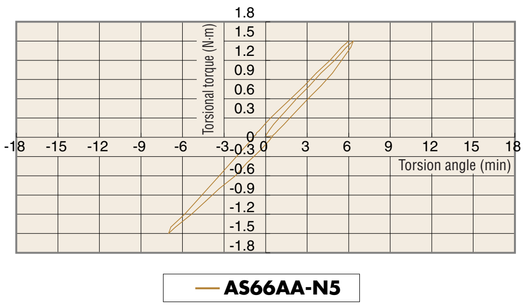
T': Total torque transference (N·m)
n: Number of planetary gears
k: Dispersion coefficient

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.

◆ Torsional Rigidity

When a load is applied to the **PN** gear's output shaft, displacement (torsion) is proportional to the spring constant. 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.

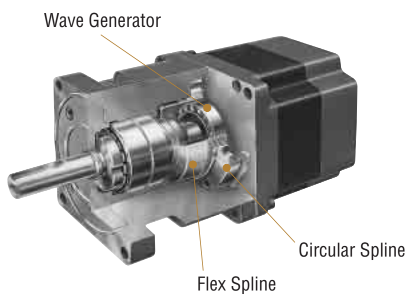
Torsional rigidity of **PN** geared types



● Harmonic (HG) Gears

◆ Principle and Structure

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



Wave Generator

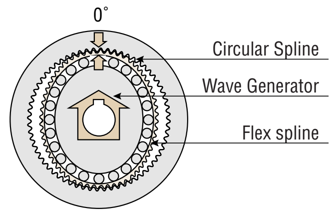
The wave generator is an oval-shaped component with a thin ball bearing placed around the outer circumference of the oval cam. The bearing's inner ring is attached to the oval cam, while the outer ring is subjected to elastic deformation via the balls. The wave generator is mounted onto the motor shaft.

Flex Spline

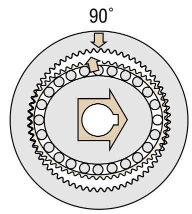
The flex spline is a thin, cup-shaped component made of elastic metal, with teeth formed along the outer circumference of the cup's opening. The gear's output shaft is attached to the bottom of the flex spline.

Circular Spline

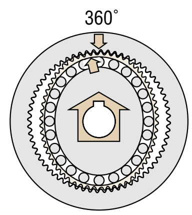
The circular spline is a rigid internal gear with teeth formed along its inner circumference. These teeth are the same size as those of the flex spline, but the circular spline has two more teeth than the flex spline. The circular spline is attached to the gearbox along its outer circumference.



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.



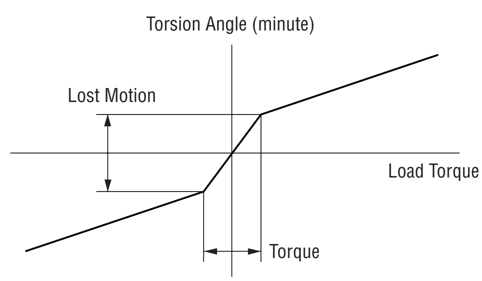
When the wave generator completes one revolution, the flex spline has rotated two fewer teeth than the circular spline has, resulting in the movement of flex spline for the difference in the tooth count (two teeth) in the opposite direction of the wave generator's rotation (i.e., counterclockwise). This 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 speed, thus achieving highly precise, zero-backlash performance. However, the gear's own torsion may become the cause of a problem when performing ultra-high precision positioning at an accuracy of two arc minutes or less. When using a harmonic gear for ultra-high precision positioning, remember the following three points.

Lost Motion

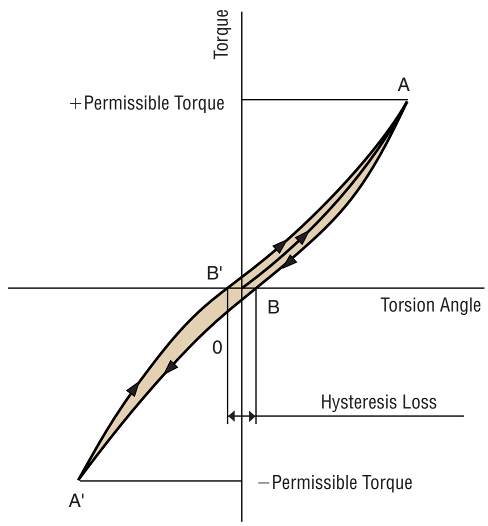
Lost motion is the total value of the displacement produced when about five percent of permissible torque is applied to the gear's output shaft. Since harmonic gears have no backlash, the measure indicating the gear's precision is represented as lost motion.



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 angle of torsion will become smaller as the torque is reduced. However, the angle of torsion never reaches zero, 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 from the clockwise or counterclockwise direction, this hysteresis loss occurs even with a frictional coefficient of 0. When positioning to two minutes or less, positioning must be done from a single direction.



Torsion Angle and Torque Characteristics

Torque and 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 frictional 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 an equation, as shown below.

Calculation method

The harmonic gear’s torsion angle/torque characteristic curve is not linear, and the characteristics can be expressed in one of the following three equations depending on the load torque:

1. Load torque T_L is T_1 or less.

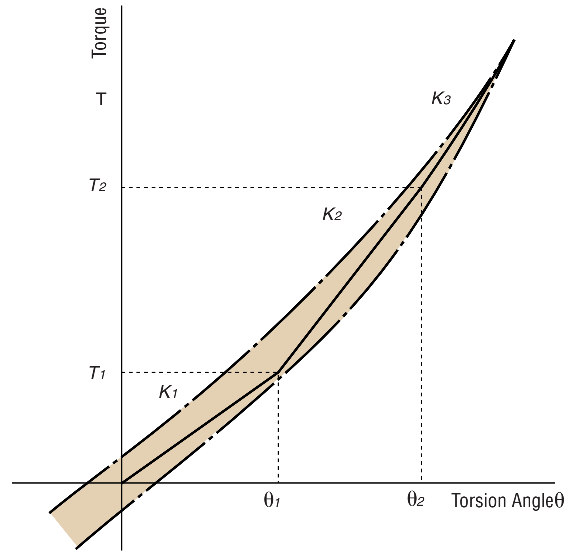
$$\theta = \frac{T_L}{K_1} \text{ [min.]}$$

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

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

3. Load torque T_L is greater than T_2.

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



Torsion Angle and Torque Characteristics

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

Values for Determining Torsion Angle

Item / Model	Gear ratio	T_1 lb-in (N·m)	K_1 lb-in/min (N·m/min.)	θ_1 min	T_2 lb-in (N·m)	K_2 lb-in/min N·m/min.	θ_2 min.	K_3 lb-in/min N·m/min.
ASC34-H50	50	13.2 (1.5)	20 (2.3)	—	—	—	—	—
ASC34-H100	100	17.7 (2)	23 (2.6)	—	—	—	—	—
AS46-H50 **ASC46-H50** **RK543-H50**	50	7 (0.8)	5.6 (0.64)	1.25	17.7 (2)	7.6 (0.87)	2.6	8.2 (0.93)
AS46-H100 **ASC46-H100** **RK543-H100**	100	7 (0.8)	6.9 (0.79)	1.02	17.7 (2)	8.7 (0.99)	2.2	11.3 (1.28)
AS66-H50 **ASC66-H50** **RK564-H50**	50	17.7 (2)	8.7 (0.99)	2	61 (6.9)	12.1 (1.37)	5.6	14.6 (1.66)
AS66-H100 **ASC66-H100** **RK564-H100**	100	17.7 (2)	12.1 (1.37)	1.46	61 (6.9)	15.6 (1.77)	4.2	18.5 (2.1)
AS98-H50 **RK596-H50**	50	61 (7)	33 (3.8)	1.85	220 (25)	46 (5.2)	5.3	59 (6.7)
AS98-H100 **RK596-H100**	100	61 (7)	41 (4.7)	1.5	220 (25)	64 (7.3)	4	74 (8.4)

Useful Life of a Gearhead

The useful life of a gearhead is reached when power can no longer be transmitted because the bearing's mechanical life has ended. Therefore, the actual life of a gearhead varies depending on the load size, how the load is applied, and the allowable speed of rotation. Oriental Motor defines service life under certain conditions as "rated lifetime," based on which the useful life under actual operation is calculated according to load conditions and other factors.

Rated Lifetime

Oriental Motor defines the rated lifetime as the useful life of a gearhead under the following operating conditions:

Torque: Permissible torque
Load: Uniform continuous load
Input rotational speed: Reference input rotational speed
Rotational speed at the rated lifetime of each gear type
Overhung load: Permissible overhung load
Thrust load: Permissible thrust load

Table 1: Rated Lifetime per Gear Type

Series/Motor Type	Gear Type	Reference-Input Rotational Speed	Rated Lifetime (L1)
αSTEP	**PN** geared type	3000 r/min	5000 hrs.
	TH geared type	1500 r/min	
	HG geared type		
RK Series	**PN** geared type	3000 r/min	
	TH geared type	1500 r/min	
	HG geared type		
5-phase **CSK** Series	**TH** geared type		
2-phase **CSK** Series	**SH** geared type		
2-phase **PK** Series	**SH** geared type		
PMC Series	**MG** geared type	3000 r/min	5000 hrs.
	HG geared type		2500 hrs.
AC Motor Brushless DC Motor	**GN**, **GU** gear type	1500 r/min	5000 hrs.
	BH (Pararell Shaft) combination type		
	GFB, **GFH**, **6GH** combination type	3000 r/min	
	GV, **GVH**, **GVR** combination type	1500 r/min	10000 hrs.
	BH (right angle) combination type		

Estimating Lifetime

Lifetime under actual conditions of use is calculated based on the permissible rotational speed, load size and load type, using the following formula:

$$\text{L (lifetime)} = L_1 \times \frac{K_1}{(K_2)^3 \times f} \text{ [h]}$$

L_1: Rated lifetime [hrs.]
See Table 1 above to find the applicable rated lifetime for the gear.

K_1: Rotational speed coefficient
The rotational speed coefficient (K_1) is calculated based on the reference input rotational speed listed in Table 1 above and the actual input rotational speed.

$$K_1 = \frac{\text{Reference input rotational speed}}{\text{Actual input rotation speed}}$$

K_2: Load factor
The load factor (K_2) is calculated based on actual operating torque and the allowable torque for each gear. The average torque may be considered operating torque if the gear is subjected to load while starting and stopping only, as when driving an inertial body. The calculation of average torque is explained later in this section.

$$K_2 = \frac{\text{Operating torque}}{\text{Permissible torque}}$$

Permissible torque is per the specified values listed in the product catalog and operating manual.

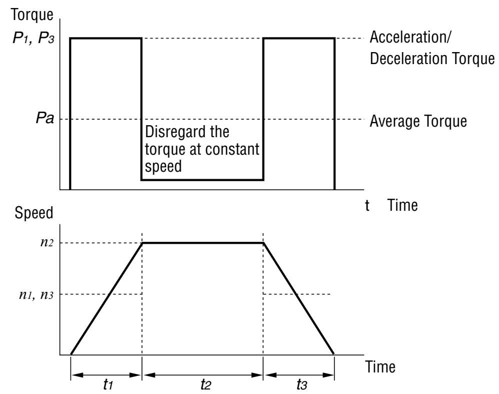
f: Load-type factor
The factor (f) may be determined based on load type, using the following examples as a reference:

Load Type	Example	Factor (f)
Uniform Load	• One-way continuous operation • For driving belt conveyors and film rollers that are subject to minimal load fluctuation.	1.0
Light Impact	• Frequent starting and stopping • Cam drive and inertial body positioning via stepping motor	1.5
Medium Impact	• Frequent instantaneous bidirectional operation, starting and stopping of reversible motors • Frequent instantaneous starting and stopping of brushless motors	2.0

Notes regarding the effects of overhung load and thrust load
- The above estimated lifetime is calculated according to the overhung and thrust loads, which are in proportion to a given load factor. For example, if the load factor is 50%, the lifetime is calculated using 50% overhung and thrust loads.
- The actual life of a gearhead having a low load factor and a large overhung or thrust load will be shorter than the value determined through the above equation.

How to Obtain the Average Torque

The stepping motor is used for intermittent operation of an inertial body, such as driving an index table and arm. If the stepping motor is used in such an application, the average torque shall be considered the operating torque, as described below. The load factor for driving an inertial body using an AC or DC brushless motor shall be 1.0.



$$\text{Pa} = \sqrt[3]{\frac{(P_1^3 \times n_1 \times t_1) + (P_3^3 \times n_3 \times t_3)}{(n_1 \times t_1) + (n_2 \times t_2) + (n_3 \times t_3)}}$$

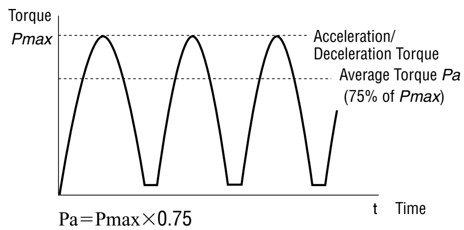
n_1, n_3 shows average speed in the t_1, t_3 periods.
In the above chart, $n_1 = n_3 = 1/2\ n_2$

◆ Driving an Inertial Load Directly

The previous graph shows torque generated in order to drive an inertial body over a long operating cycle. Friction load caused by bearings and other parts during constant-speed operation are negligible.

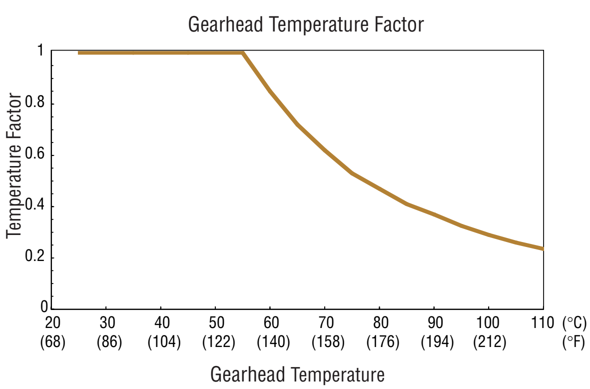
◆ Driving an Inertial Load using an Arm or Similar Object

When driving an arm or similar object, the gearhead may be subjected to load fluctuation as shown in the graph.
For example, such load fluctuation will occur when driving a double-joint arm or moving an arm in the vertical direction. In such an application, the average torque shall be 75 percent of the maximum acceleration/deceleration torque, as shown in the equation below.



● Operating Temperature

An increase in gearhead temperature affects the lubrication of the bearing. However, since the effect of temperature on gearhead life varies according to the condition of the load applied to the gearhead bearings, model number and many other factors, it is difficult to include the temperature effect in the equation to estimate the lifetime, which was described earlier.
The graph below shows the temperature effect on the gearhead bearings. The gearhead life is affected when the gearbox's surface temperature is 131°F (55˚C) or above.



Notes:
In some cases, a lifetime of several tens of thousands of hours may be obtained from the calculation. Use the estimated life as a reference only. The above life estimation is based on the bearing life. An application in excess of the specified value may adversely affect parts other than the bearings. Use the product within the range of specified values listed in the product catalog or operating manual.

■ 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 weight)
- High rigidity (motor less prone to the effects of fluctuation in friction load)
- Shorter positioning time for improved safety against inertial loads
- Low vibration

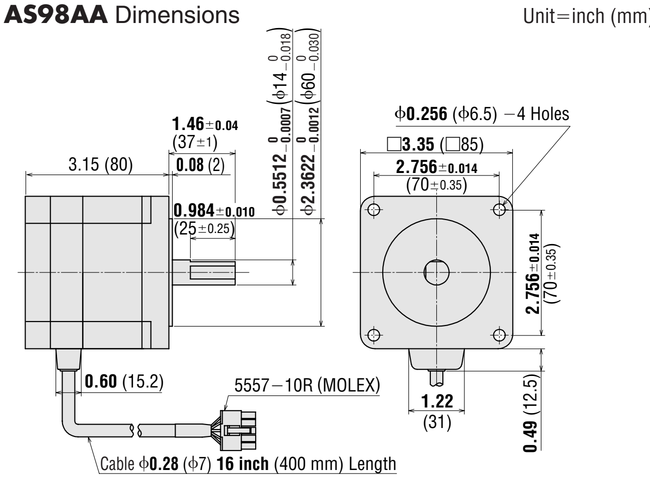
To further explain these four purposes using examples, comparisons will be made below between a motor (no gearhead) and a geared motor, both of which have similar output torque and allowable torque. If no problem exists in terms of rotational speed, the motor may be replaced by the geared motor.

● Downsizing

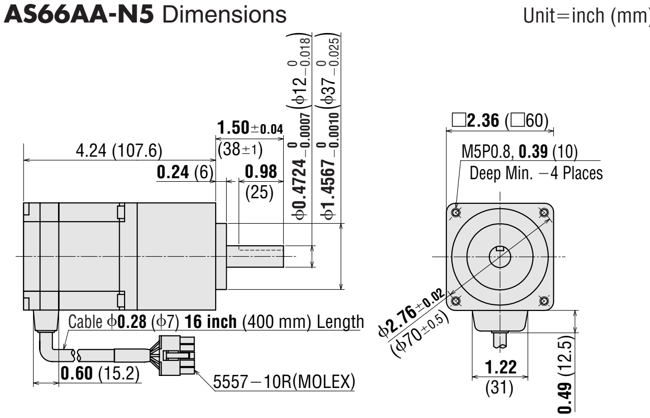
A motor may be switched to a smaller geared motor as long as both motors operate at equivalent torque. For example, a motor with a frame size of □3.35 in. (□85 mm) can be replaced by the geared motor with a frame size of □2.36 in. (□60 mm), thereby reducing the weight from 4.0 lb. (1.8 kg) to 3.3 lb. (1.5 kg) (comparison between **AS98AA** and **AS66AA-N5**).

Product Name / Item	Motor	Geared Motor	
	AS98AA	**AS66AA-T7.2**	**AS66AA-N5**
Frame Size in. (mm)	□3.35 (□85)	□2.36 (□60)	□2.36 (□60)
Gear Ratio	—	7.2 : 1	5 : 1
Maximum Holding Torque Permissible Torque lb-in (N·m)	17.7 (2)	22 (2.5)	30 (3.5)
Backlash arc min	—	15	2
Output Shaft's Rotation Speed r/min	0~4000	0~250	0~600

AS98AA Dimensions Unit=inch (mm)



AS66AA-N5 Dimensions Unit=inch (mm)



● 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 **AS66AA-T7.2** geared motor receives backlash effects at a light load of 0.88 lb-in (0.1N·m) torsional torque, but becomes less prone to twisting than the **AS98AA** as the torsion increases. The **AS66AA-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 Motor and Geared Motor

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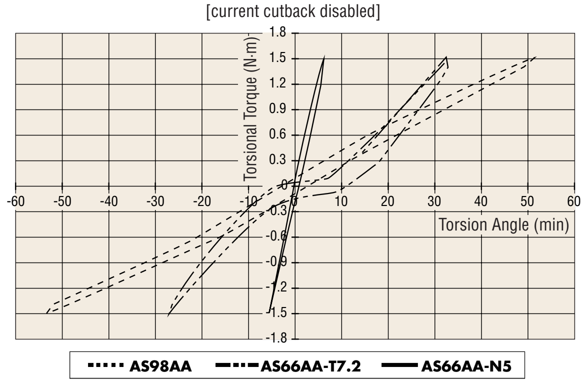
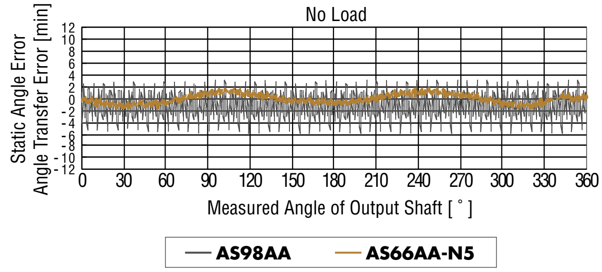
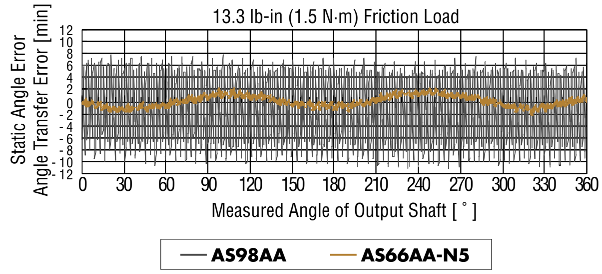


Positioning accuracy against the fluctuating friction load is an important determinant of motor rigidity. Positioning accuracy can be measured by the static angle error (angle transfer error for the geared motor). The static angle error (angle transfer error) refers to the difference between the theoretical angle of rotation (this is the rotation angle calculated from the number of input pulses) and the actual output shaft's rotation angle. The error closer to zero represents higher rigidity. The **AS98AA** motor and **AS66AA-N5** geared motor are compared by measuring the static angle error (angle transfer error) under no load and a friction load, at 0.36˚ intervals for a single revolution. The results of comparison show that motor's static angle error significantly increases when the load is applied while the geared motor's angle transfer 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 up/down motion and other applications in which friction load fluctuates due to the changing quantity and weight of the workpiece(s).

Comparison of Static Angle Error (angle transfer error) between **AS98AA** and **AS66AA-N5**



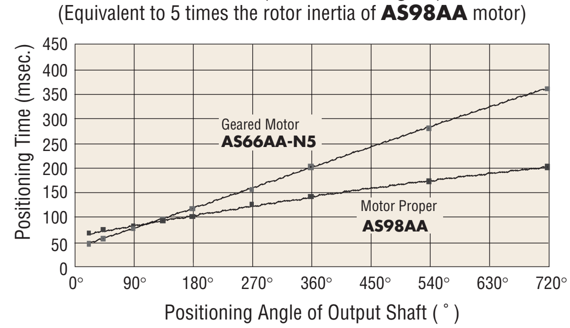


● Shorter Positioning Time for Improved Safety Against Load Inertia

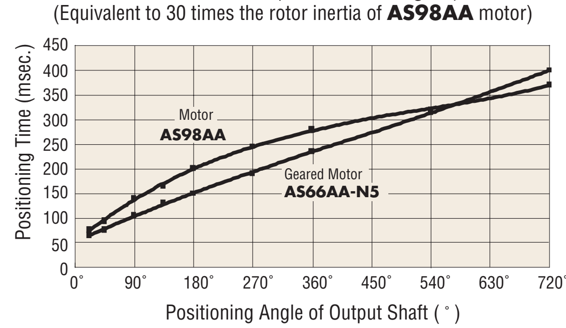
To drive a large load inertia within a short period of time, the use of a geared motor will achieve a shorter positioning time than a motor.

Assume that the **AS98AA** motor is connected to inertia loads that are 5 and 30 times the motor's rotor inertia, respectively, and that each of these inertia loads is connected to the **AS66AA-N5** geared motor. The shortest positioning time for each rotational speed is measured as shown in the graphs below.

J_L =38 oz-in^2 (7,000×10^{-7} kg·m^2)
(Equivalent to 5 times the rotor inertia of **AS98AA** motor)



J_L = 1230 oz-in^2 (42,000×10^{-7} kg·m^2)
(Equivalent to 30 times the rotor inertia of **AS98AA** motor)



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

The geared motor reduces positioning time for the following reasons:

- Load inertia to the motor shaft can be reduced through the use of gears, thereby ensuring quick acceleration and deceleration startups.

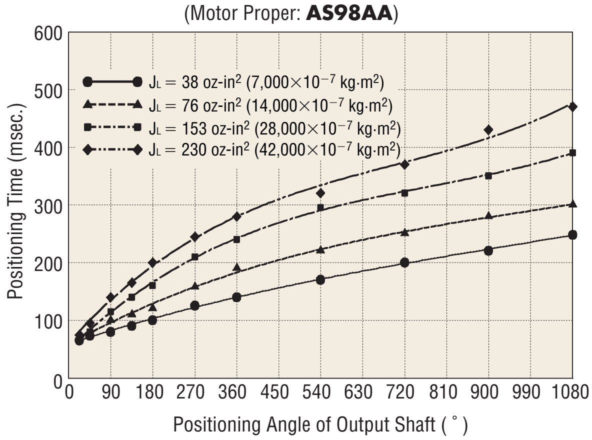
$$J_M \text{ (motor shaft inertia)} = \frac{J_G \text{ (gear shaft inertia)}}{I^2 \text{ (gear ratio)}}$$

  This formula indicates that a load inertia that is 30 times the rotor inertia of the motor can be reduced to nearly four times the motor shaft inertia when connected to the geared motor with a ratio of 5:1.

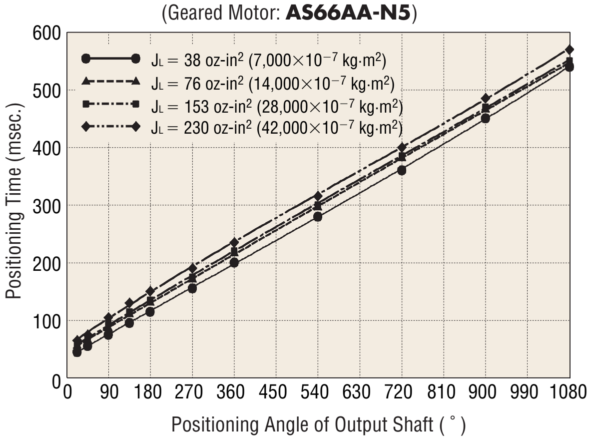
- Positioning for a small positioning angle is completed before the motor reaches the high rpm range (triangle drive instead of trapezoidal drive).

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

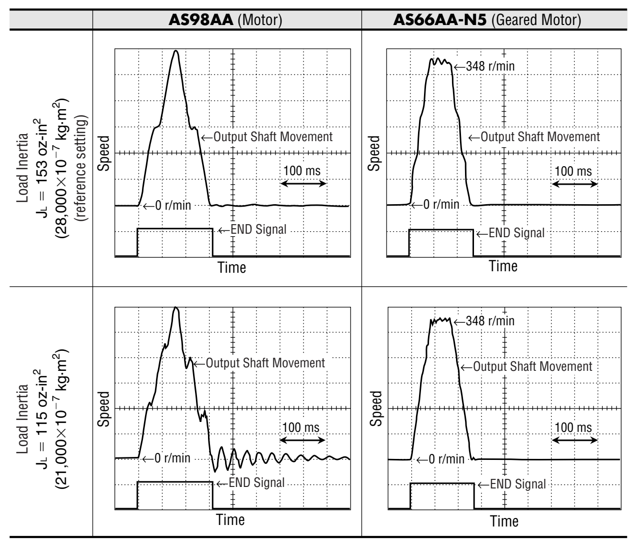
Changes in Positioning Time due to Variations in Load Inertia
(Motor Proper: **AS98AA**)



Changes in Positioning Time due to Variations in Load Inertia
(Geared Motor: **AS66AA-N5**)



While the shortest positioning time of the motor changes significantly with the increase in load inertia, that of the geared motor shows little change. In other words, the geared motor is capable of driving a larger load inertia within the most consistent, shortest positioning time.
No matter how quickly a motor can perform positioning, the failure to achieve stable operation against load inertia fluctuations may result in a problem. Therefore, it is also important to study how the operation waveform is shaped according to fluctuations in load inertia.
Connect the same inertial body to both the motor and geared motor, under the operating conditions that allow for the shortest positioning. Then switch the inertial body to a smaller load inertia without changing the operating conditions. The operation waveform for each of these cases is shown in the graphs below.



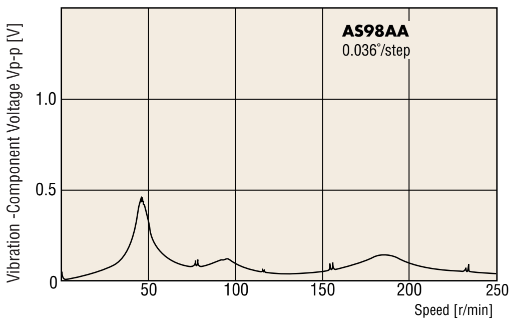
Even under the operating conditions that are optimized to reduce damping with a given load inertia, the damping characteristics of the motor will deteriorate with fluctuations in load inertia. For the motor it is therefore necessary to reset the operating conditions for optimal performance each time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

Low Vibration

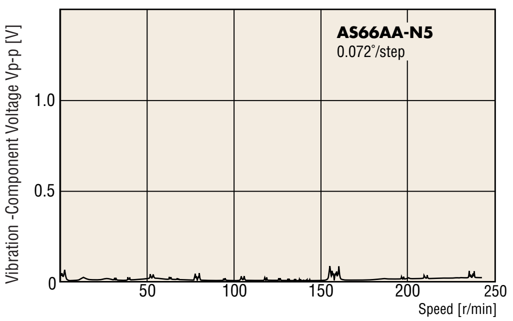
Vibration characteristics are represented in electric voltage, into which the vibration width of the output shaft in rotary motion is converted. Vibration of the geared motor can be reduced for the following reasons:

- 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 is run at higher speeds.
- Because the motor is smaller, its own vibration is reduced accordingly.

Vibration Characteristic of **AS98AA**



Vibration Characteristic of **AS66AA-N5**



Linear Motion

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 basic speed of a linear head can be calculated from the motor speed, by using the following equation.

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

V: Rack moving speed [inch/sec.]
N_S: Speed of motor used [r/min]
i: Ratio of gear unit on the linear head (see table on the right)
D_P: Pinion pitch circumference [inch] (see table on the right)

Maximum Transportable Mass

For the maximum transportable mass, see the specifications table for each product. When using a motor not listed in the specifications table, the thrust force can be calculated based on the torque generated by the motor using the equation below.

However, in the case of a high gear ratio or use in a horizontal direction, the solution obtained by the equation will indicate a thrust force sufficient to drive the load mass in excess of the gear's mechanical strength. Make sure the linear head's load mass is at or below its maximum transportable mass, regardless of the rack's direction of movement.

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

$$m = F/9.807$$

T_m: Motor torque (lb.) *
F: Thrust force (lb.)
m: Weight capacity (lb.)
i: Gear ratio of the linear head's gear unit (see on the right)
η_1: Transmission efficiency as determined by gear ratio (see on the right)
D_P: Pinion pitch circle diameter (inch) (see on the right)
η_2: Transmission efficiency of rack and pinion (=0.9)
* For motor torque, choose the lesser of starting torque or rated torque.

Any maximum transportable mass listed in the specifications tables or any calculated thrust force is the value for horizontal rack movement. The value for vertical movement can be obtained by subtracting the rack's mass (see dimensional drawing) or its mass-based force (rack's mass×9.807) from the value indicated in the specifications table.

Linear Head Model	Gear Ratio i	Transmission efficiency η_1	Pinion Pitch Diameter D_P inch (mm)
0LB (F) 20N-□	30	0.66	0.295 (7.5)
0LB (F) 10N-□	50	0.66	
0LB (F) 5N-□	100	0.59	
2LB (F) 50N-□	17.68	0.73	0.472 (12)
2LB (F) 25N-□	35.36	0.66	
2LB (F) 10N-□	86.91	0.59	
4LB (F) 45N-□	36	0.73	0.837 (21.25)
4LB (F) 20N-□	75	0.66	
4LB (F) 10N-□	150	0.66	
5LB (F) 45U-□	36	0.66	0.945 (24)
5LB (F) 20U-□	90	0.59	
5LB (F) 10U-□	180	0.59	

Holding Force

The following equation is used to calculate the holding force of the linear head when connected to a motor.

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

F_B: Holding force [lb.]
T_B: Holding torque of motor used [lb.]
i: Ratio of gear unit on the linear head (see table above)
D_P: Pinion pitch circumference [inch] (see table above)

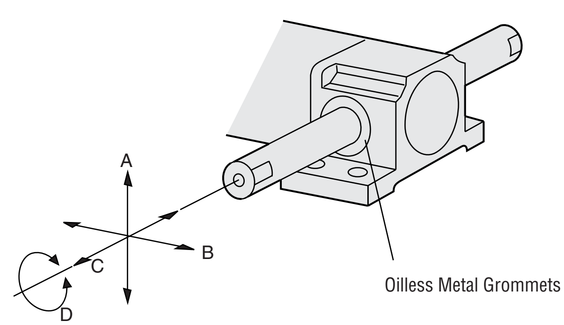
Any holding force listed in the specifications table or any calculated holding force is the value for horizontal rack installation. The value for vertical installation can be obtained by subtracting the rack's mass-based force (see dimensional drawing) (rack's mass×9.807) from the value indicated in the specifications table.

Rack Play (initial values)

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

Direction A or B	0.079 inch (2 mm) max.
Direction C	0.020 inch (0.5 mm) max.
Direction D	5° max.

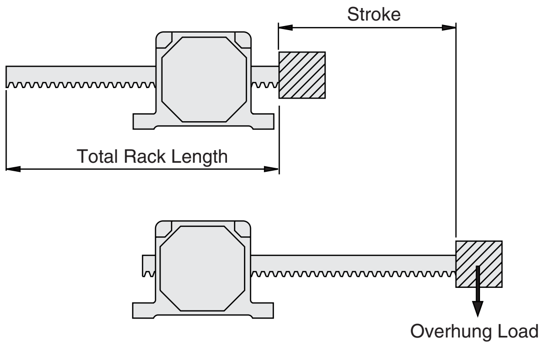
- Play in directions A and B has been measured at a point 20 in. (500 mm) from the case surface. Since the rack is round-shaped, play in the D direction is large.
- The rack play indicates an initial value which will increase during operation. If the rack play becomes a problem, install an external guide.



Glossary

Maximum Overhung Load

This is the load that can be applied to the rack in a direction perpendicular to the rack axis. If a load is applied continuously to the end of the rack, then the weight of that load will be applied to the rack as an overhung load.



Dog

The function of dogs is to trip limit switches and sensors. Dogs are attached to the rack to set the position where the rack should stop.

Rack

A gearcut rod is made of S45C or equivalent grade of steel and has a surface treated with nitride. Racks for linear motors are specially designed and machined, and have special cross sections. Those for linear heads have round cross sections.

Recommended Operating Conditions for DRL Series

Model	Resolution in. (mm)	Starting Speed in./s (mm/s)	Operating Speed in./s (mm/s)	Acceleration ft./s² (m/s²)	Maximum Transportable Mass (Horizontal) lb. (kg)	Maximum Transportable Mass (Vertical) lb. (kg)
DRL28PA1-03D	0.000079 (0.002)	0.0079 (0.2)	0.94 (24)	0.66 (0.2)	–	6.6 (3)
DRL42PA2-04D	0.00016 (0.004)	0.016 (0.4)	1.18 (30)	1.31 (0.4)	–	22 (10)
DRL60PA4-05D	0.00031 (0.008)	0.031 (0.8)	0.94 (24)	0.85 (0.26)	–	66 (30)
DRL28PA1G-03D	0.000079 (0.002)	0.0079 (0.2)	0.94 (24)	0.66 (0.2)	2.2 (1)	3.3 (1.5)
DRL42PA2G-04D	0.00016 (0.004)	0.016 (0.4)	1.18 (30)	1.31 (0.4)	4.4 (2)	11 (5)
DRL60PA4G-05D	0.00031 (0.008)	0.031 (0.8)	0.94 (24)	0.85 (0.26)	6.6 (3)	33 (15)
DRL28PB1-03D	0.000079 (0.002)	0.0079 (0.2)	0.94 (24)	0.66 (0.2)	–	6.6 (3)
DRL42PB2-04D	0.00016 (0.004)	0.016 (0.4)	1.18 (30)	1.31 (0.4)	–	22 (10)
DRL28PB1G-03D	0.000079 (0.002)	0.0079 (0.2)	0.94 (24)	0.66 (0.2)	2.2 (1)	3.3 (1.5)
DRL42PB2G-04D	0.00016 (0.004)	0.016 (0.4)	1.18 (30)	1.31 (0.4)	4.4 (2)	11 (5)

Compact Actuators DRL Series

Repetitive Positioning Accuracy of DRL Series

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

Sufficient Rigidity for Peripheral Equipment

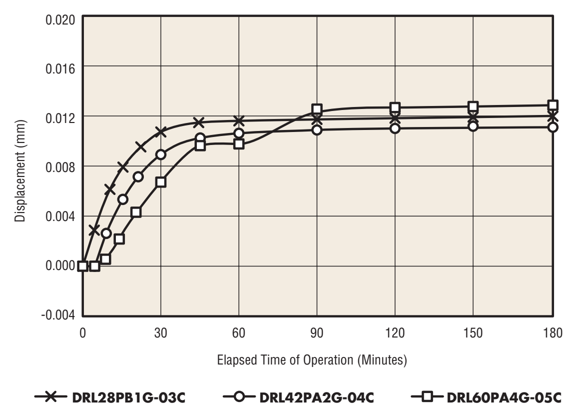
- The linear guides and other mechanical components to be used with the actuator should have rigidity sufficient to withstand the load mass and external forces. Insufficient rigidity may cause deflection, which will prevent the actuator from meeting the requirements defined in the specifications.
- The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

Sensor

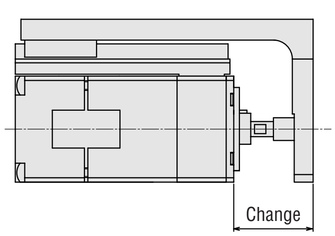
- Use a high-accuracy home position sensor (e.g. photomicrosensor). Home positioning accuracy is not included as part of the repetitive positioning accuracy.

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 figure below (reference data). 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 areas.



Conditions
Current down: Off
Operation duty: 80%
Measurement method: Using a laser displacement meter.



Cooling Fans

Air Flow/Static Pressure Characteristics

Pressure Loss

When air flows along a certain path, a form of resistance (called “air flow resistance”) is produced by anything in the path that inhibits that flow.

Comparing the cases illustrated in Fig. 1 and Fig. 2, we see that the device shown in Fig. 1 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. 2, which increases air flow resistance and decreases air flow.

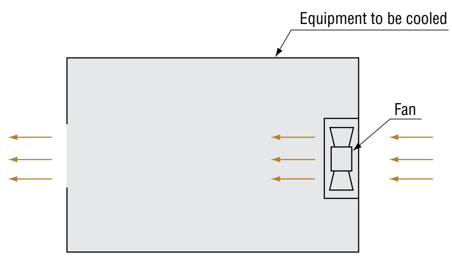


Fig. 1 Flow Path with Low Air Flow Resistance

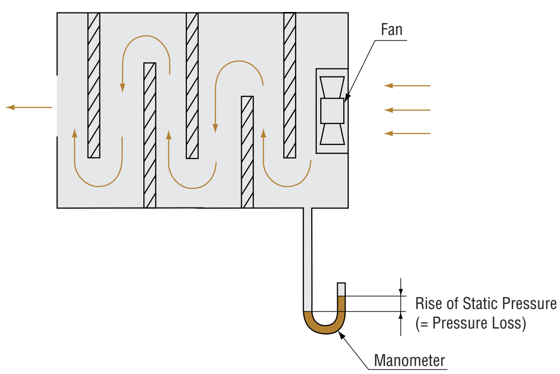


Fig. 2 Flow Path with High Air Flow Resistance

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 equation:

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

where 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 equation says that to achieve a certain air flow (Q), the fan must be able to supply static pressure sufficient to increase the pressure within 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 a characteristic curve of air flow versus static pressure.

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. 3, 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.

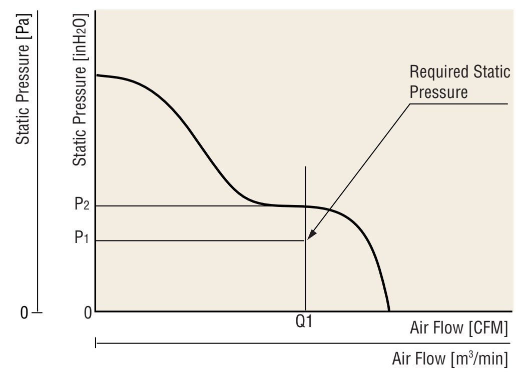


Fig. 3 Air Flow vs. Static Pressure Characteristics Curve

How to Measure the Characteristics of Air Flow/Static Pressure

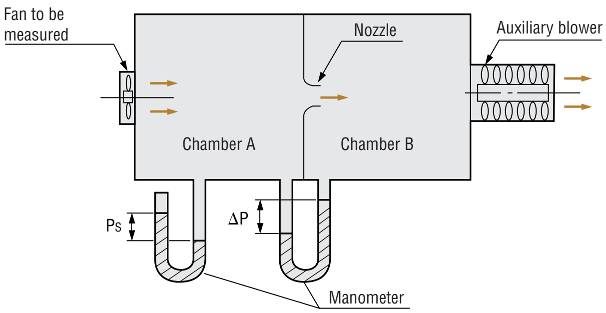


Fig. 4 Double-chamber Measuring Device

Two methods are available for measuring the air flow and static pressure: 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 in wide use throughout the world.

Moreover, Oriental Motor uses measuring equipment conforming to AMCA (Air Moving and Conditioning Association) standard 210, a fan measurement standard that is widely recognized around the world. In the double-chamber method the fan's air flow/static pressure characteristics are obtained by measuring the pre- and post-nozzle differential pressure (ΔP) and the pressure within the chamber (Ps), as shown in Fig. 4.
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 coefficient of flow (C).
Therefore:

$$Q = 60\,CA\bar{v}$$
$$= 60\,CA\sqrt{\frac{2\,\Delta P}{\rho}}\quad [\mathrm{m^3/min}]$$

where

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

The measurement of air flow vs. 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 with two fans installed

When using two fans combined it will change the characteristics depending on how the fans are installed.

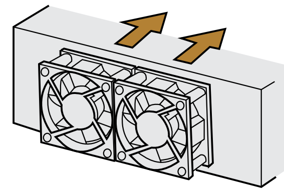


Fig. 5 Installing two fans

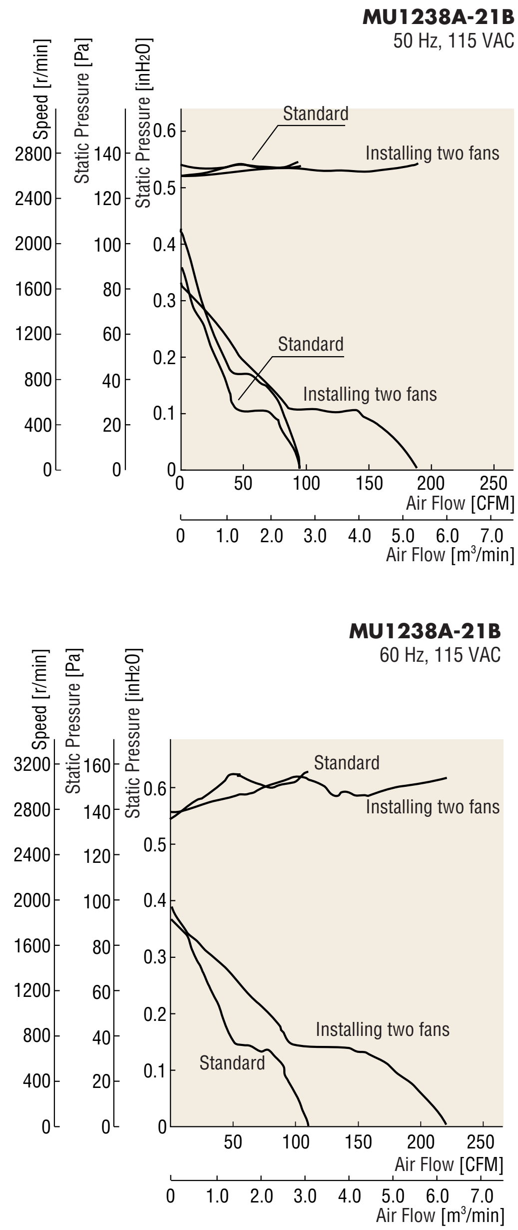


Fig. 6 Changes in fan characteristics of static pressure and amount of air flow

The graph above shows that when two fans are combined, doubles the maximum amount of air flow is achieved.

Changes in the Air Flow/Static Pressure Characteristics with Installation of Optional Parts

When installing a fan in equipment, the safety and reliability of the overall apparatus can be significantly improved by attaching optional parts 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 optional parts.

The graph in Fig. 7 shows data regarding pressure loss caused by its optional parts on a fan with the 4.69 in. sq. (119 mm sq.) frame size. The filter causes the most significant pressure loss, while the finger guard causes little loss.

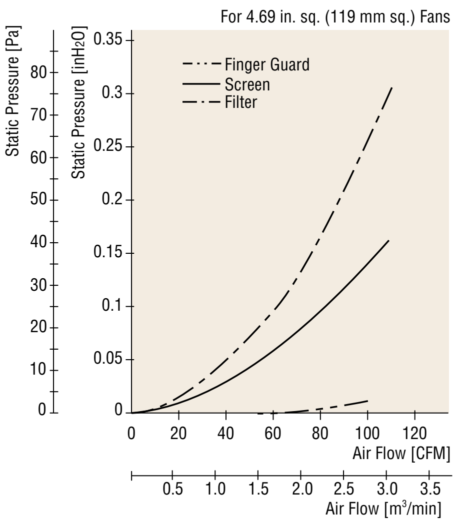


Fig. 7 Changes in Characteristics with Optional Parts

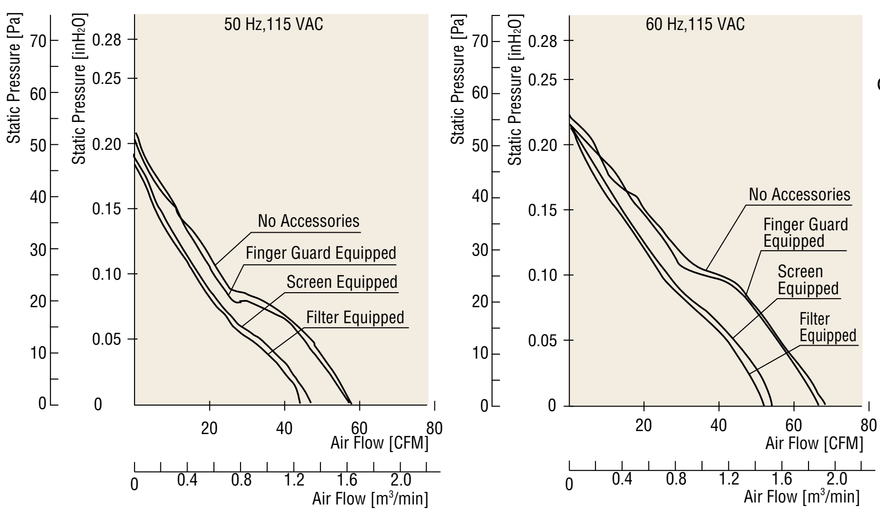


Fig. 8 Changes in Characteristics with Optional Parts Attached to the **MU1225S-21**

As the graphs show, the greater the pressure loss caused by optional parts, the greater the reduction in air flow and static pressure characteristics.

Noise

What is Noise?

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

Measuring Noise

The noise of Oriental Motor fans is measured in the A range at a distance of 3.3 feet (1m) from the intake (at a point above the center line of the intake).

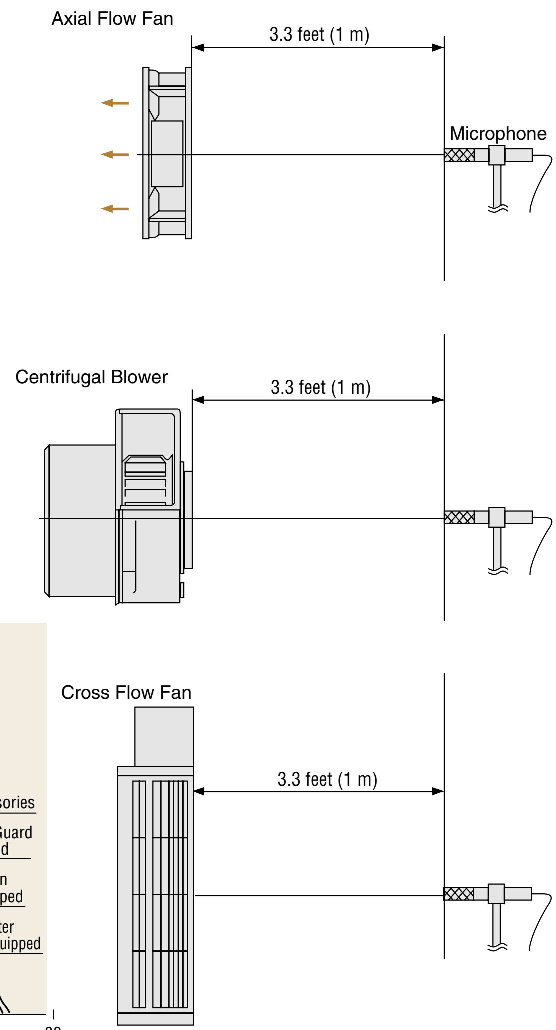


Fig. 9 Measurement of Fan Noise

Composition of Noise

This section discusses the noise value when using two fans, each of which produces 40 dB of noise.

Noise, or relative loudness, is expressed in decibel units, and combined 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 equation:

$J = \frac{P^2}{\rho c}$ where, (ρ = Air density, c = Speed of sound propagation)

Using the above equation, the noise value can be expressed in decibel units as follows:

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

P: Actual sound pressure

J: Measured noise energy

P_0, J_0: Minimum noise energy audible to the human ear

In this equation the noise value 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 equation will be:

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

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.

What would the combined noise level be if a 40 dB fan and a 50 dB fan were 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 x-axis of the graph, find the corresponding point on the curve and read the y-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 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.

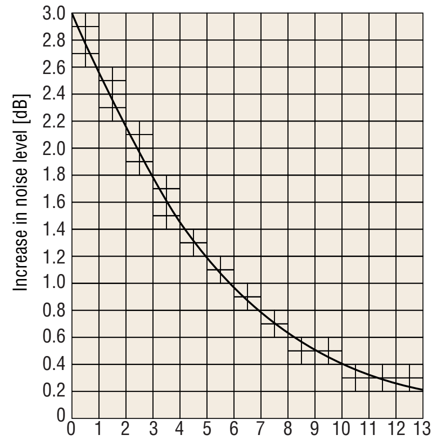


Fig. 10 Difference in Two Noise Levels

Noise and Distance

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

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

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 point 6.6 feet (2m) from a fan, whose noise level is 40 dB at a point 3.3 feet (1m) from the intake side, is calculated.

Since r_2 = 6.6 feet (2m), r_1 = 3.3 feet (1m), and SPL_1 = 40 dB, substituting in the expression gives

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

Thus, at a distance of 6.6 feet (2m), the noise level decreases by 6 dB. The value 20log r_2/r_1 in the above expression represents the ratio between two distances. Thus, if the values used above were 9.9 feet (3m) and 19.7 feet (6m), 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.

Fan Life

The term "fan life" refers to the condition in which the fan's blowing ability has deteriorated due to continuous fan operation for a certain period of time, or the fan can no longer be used due to significant noise.

① Rotation life: Fan life as defined by certain deterioration in fan rotation
② Acoustic life: Fan life as defined by certain increase in noise

Rotation life can be easily measured as long as the factors involved can be clearly specified numerically. This is usually what is meant when referring to "fan life".

Acoustic life, however, is defined by an increase in decibel level, while determining exactly what amount of increase marks the end of acoustic life depends on the user's judgment. Moreover, fans can still meet operating requirements even after reaching the predetermined increase level in noise. In general, standards relating to noise and the length of acoustic life have not been established.
Oriental Motor defines fan life by rotation life; a fan is judged to have reached the end of its service life when rotational speed drops to 70 percent of the rated speed.

Parts Determining Fan Life

Certain fan parts are most critical in determining fan life, beginning with the relationship between time and failure rate. Generally, when parts have been used for a long time, their failure rate relative to the duration of use fits the pattern of the wide, U-shaped curve shown in Fig. 11.

The first period is the initial failure period in which substandard parts tend to break down. The second is called the accidental failure period, characterized by a highly stable, low failure ratio. If this period were to continue forever, the part's life would not be a concern. However, depending on the part, the failure rate increases again, and enters a third period called the friction failure period. Bearings are the parts within a fan whose life is most affected by this friction failure period. Therefore, fan life could be said to be determined by the life of the bearings used.

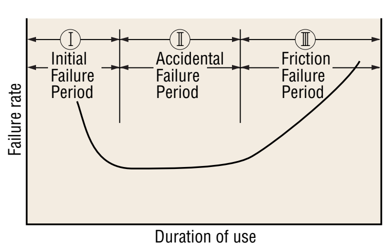


Fig. 11 Relationship between the Duration of Use and Failure Rate

Fan Bearing Life

Unlike the bearings of motors and gearheads, the load applied to fan bearings is negligible. Fan life is therefore determined by the deterioration of the grease in the bearings. Since the fan's operating and starting torques are significantly smaller than those of a motor, lack of lubrication due to grease deterioration will result in an extremely high voltage, which may prevent the fan from starting.
Deterioration of grease also increases the noise generated by the bearings, further affecting fan life.

Grease life is given by the following expression:

$$\log t = K_1 - K_2 \frac{n}{N \max} - \left(K_3 - K_4 \frac{n}{N \max}\right) T$$

where,

- t: Average grease life
- K_1, K_2, K_3, K_4: Constants determined by grease
- Nmax: Maximum rotation allowed by grease lubrication
- n: Rotational speed of bearings
- T: Operating temperature of bearings

As indicated by the above expression, Nmax is predetermined by the ball bearings, so grease life depends on temperature and the rotational speed of the bearings. However, Oriental Motor's products are designed so that the life of the bearings is only minimally affected by their rotational speed. Thus, the average grease life is determined by temperature, since $\frac{n}{N \max}$ is a constant value.

Estimated Product Life Curve

Figure 12 gives the estimated average life of the bearings of the **MU1238A** type fan. This is obtained by measuring the temperature rise of the ball bearings at the rated voltage and calculating life using the expression for ball bearing grease life.

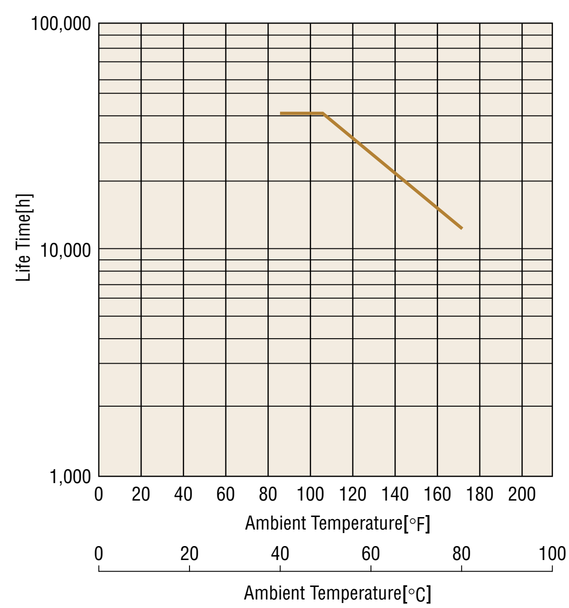


Fig. 12 Estimated Life Characteristics of the **MU1238A** Fan

Note:
The data shown in the above estimated life curve does not represent guaranteed values.

Capacitor

Capacitor-run motors contain an auxiliary winding offset by 90 electric degrees from the main winding. The capacitor is connected in series with the auxiliary winding, causing the current in the auxiliary winding to lag the current in the main winding.

The motor employs metallized electrode capacitor. 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 supplied with the fan. The capacitor's capacitance is expressed in microfarads (μF).

Rated Voltage

Using the capacitor at a voltage level exceeding the rated voltage may significantly reduce the capacitor's service life. Be sure to use the capacitor supplied 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 casing. 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, voltage, temperature and frequency. The standard life expectancy is 25,000 hours. We recommend that the capacitor be replaced after the rated conduction time.

Overheat Protection Device

If a fan in run-mode locks due to overload or the input increases for some reason, the fan temperature rises suddenly. If the fan is left in this state, the performance of the insulation within the fan may deteriorate, shortening service life and, in extreme cases, scorching the winding and causing a fire. In order to protect the fan from such thermal abnormalities, UL, CSA, EN and IEC standard fans from Oriental Motor are equipped with the following overheating protection devices.

Thermal Protector

The **MRS** Series, **MB** Series [certified products with runner diameters of 3.15 inch (80 mm) or more] and **MF** Series fans include a built-in, automatic-return type thermal protector. The structure of the thermal protector is shown in Figure 13. 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 248˚F±9˚F (120˚C±5˚C)
  close 170.6˚F±27˚F (77˚C±15˚C)

(The fan motor's allowable winding temperature, where the thermal protector is working, is slightly higher than the operating temperature listed above.)

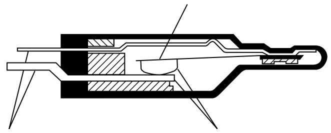


Fig. 13 Structure of Thermal Protector

Impedance Protection

The **MU** and **MB** Series (**MB520**, **MB630**) 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 input current will be minimized and the temperature will not rise beyond a certain level.

Glossary

Air Flow—Static Pressure Characteristics

With the air flow on the X-axis and static pressure on the Y-axis, the graph of air flow/static pressure characteristics shows how much static pressure is produced when the fan is generating a certain amount of air flow.

Point A in Figure 14 indicates the maximum amount of air flow that can be generated by a fan with a static pressure of zero, at which there is no loss of pressure. Point B indicates the maximum level of static pressure that can be produced by the fan, known as "maximum static pressure." However, in actual application a fan is rarely used at the maximum air flow or maximum static pressure. The maximum air flow or static pressure value is generally used for reference purposes to compare fan characteristics.

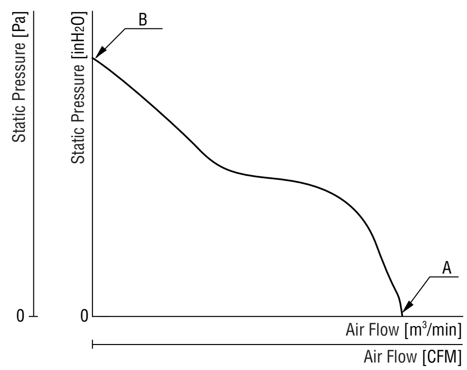


Fig. 14 Air Flow/Static Pressure Characteristics Curve

Noise Frequency Analysis

Oriental Motor adopts the "1/3-octave noise frequency analysis," in which the noise frequency components are expressed in the sound pressure level (average value) for each 1/3 octave band.

If the frequency is slightly off, the average human ear cannot detect it; Only when the frequency is off by about 1/3 of an octave can the difference be heard. The 1/3-octave noise frequency analysis therefore indicates the noise analysis data according to human audibility.

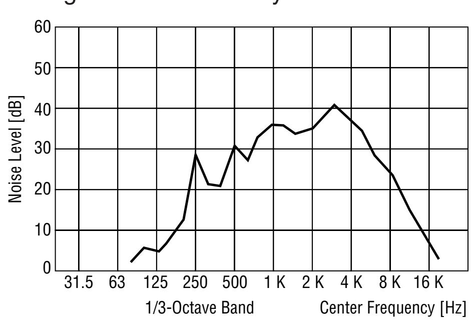


Fig. 15 Noise Frequency Analysis

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 5,000,000. In contrast, if noise (level of acoustic pressure) is expressed in decibels, then

Sound pressure level $= 20\log P/P_0$

P = Actual sound pressure

P_0 = Minimum sound pressure perceptible by the human ear

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

A Range

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 level of acoustic pressure must be corrected according to frequency in order to accurately reflect the human perception of loudness. This corrected range of measured acoustic pressure values is called the A range.

Figure 16 compares the frequency-corrected measured values (A range) with the uncorrected measured values (C range).

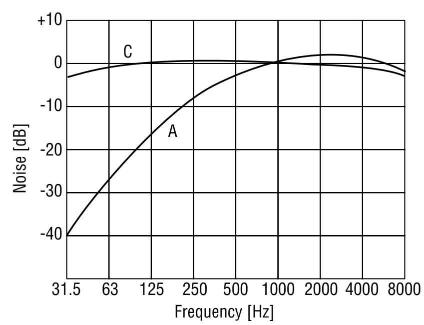


Fig. 16 Comparison of Sound-Pressure Level

Fire-Resistant Grade

The fire-resistant grade represents the degree of fire retardancy for plastic materials used in equipment parts. The generally accepted standards for fire-resistant grade are the UL-approved standards (UL94, standard for tests for flammability of plastic materials for parts in devices and appliances). The UL standards rate the fire-resistant grades 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. Fire resistance is rated in four different grades, as shown in the table below. ORIX FAN uses blades and frames with materials that receive the highest grade in this classification, V-0.

Grade	Fire Resistance
V-0	High
V-1	↑
V-2	
HB	Low

Q&A

Q1

Can fans be used above the range of operating voltage?

A1

The AC and DC fans are designed to operate properly within the range of operating voltage. Use these fans within the specified operating voltage range.

Q2

Are fans, like motors, equipped with overheat-protection devices?

A2

All AC fans in the ORIX FAN line that meet the UL, CSA and EN standards either have motors with impedance protection or are equipped with thermal protectors to prevent them from burning out. The DC fans include a current-detection function in their drive circuits. In the case of abnormalities, the fan's input current is controlled to prevent an increase in temperature and thus protect the fan motor from burning out. For details regarding impedance and thermal protection, see the section on overheating protection devices on page F-57.

Q3

Is there a simple, way to reduce the noise of a propeller fan?

A3

Noise usually decreases as fan speed drops. The **MU** Series fans are available in two fan speeds: standard-speed and middle-speed. Fan noise can be reduced by using the middle-speed of fan, operating at lower rate of rotation. For example, if you wish to reduce fan noise while maintaining the air flow of a standard-speed fan, you should simply choose a middle-speed fan in a larger size.
And, if you use thermostat (**AM1-WA1**, **AM1-XA1**) you can run the cooling fan when temperature inside the cabinet rise to pre-set temperature. Using this system it is possible to reduce total amount of noise.

Q4

Where should a fan be mounted to achieve the most effective ventilation and cooling?

A4

Three points should be kept in mind when using a fan for ventilation and cooling:
●Do not allow interference to air flow (Fig. 1).
●Do not let the air remain stagnant (Fig. 1).
●Do not allow short air flow paths (Fig. 2).
Based on the above, the ideal fan position is where air flows in one direction without interference, as shown in Fig. 3.
As long as the fan is mounted in an ideal position, there should basically be no significant difference as to whether an intake or exhaust fan is used. However, the exhaust fan will be more effective at maintaining uniform internal temperature.

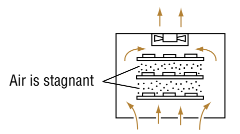


Fig. 1 Greater air flow interference, stagnant air

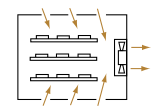


Fig. 2 Short airflow path

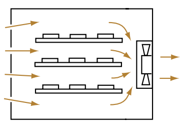


Fig. 3 Example of effective circulation and cooling