Technical Reference

F

Selection Calculations

For Motors

Selecting a motor that satisfies the specifications required by the equipment is an important key to ensuring the desired reliability and economy of the equipment.
This section describes the procedure to select the optimum motor for a particular application, as well as the selection calculations, selection points and examples.

Selection Procedure

An overview of selection procedure is explained below.

Determine the drive mechanism	First, determine the drive mechanism. Representative drive mechanisms include simple body of rotation, ball screw, belt and pulley, and rack and pinion. Along with the type of drive mechanism, you must also determine the mass of load, dimensions of each part, friction coefficient of the sliding surface, and so on.
▼	
Check the required specifications (Equipment specifications)	Confirm the drive conditions such as the speed of movement, drive time, and also positioning distance and positioning time if positioning operation will be performed. Also confirm the stopping accuracy, resolution, position holding, operating voltage, operating environment, and so on.
▼	
Calculate the load	Calculate the values for load torque and load inertia at the motor drive shaft. Refer to the left column on page F-3 for the calculation of load torque for representative mechanisms. Refer to the right column on page F-3 for the calculation of inertia for representative shapes.
▼	
Select motor type	Select a motor type from standard AC motors, brushless motors or stepping motors based on the required specifications.
▼	
Selection calculation	Make a final determination of the motor after confirming that the specifications of the selected motor and gearhead satisfy all of the requirements, such as mechanical strength, acceleration time and acceleration torque. Since the specific items that must be checked will vary depending on the motor model, refer to the selection calculations and selection points explained on page F-4 and subsequent pages.

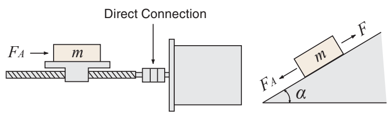
Calculate the Load Torque of Each Drive Mechanism T_L [N·m]

Calculate the Load Torque

◇Ball Screw Drive

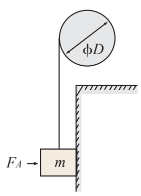
$$T_L = \left(\frac{FP_B}{2\pi\eta} + \frac{\mu_0 F_0 P_B}{2\pi}\right) \times \frac{1}{i} \ [\text{N·m}] \quad ①$$

$$F = F_A + mg(\sin\alpha + \mu\cos\alpha)\ [\text{N}] \quad ②$$



◇Pulley Drive

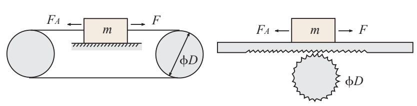
$$T_L = \frac{\mu F_A + mg}{2\pi} \times \frac{\pi D}{i} = \frac{(\mu F_A + mg)D}{2i}\ [\text{N·m}] \quad ③$$



◇Wire or Belt Drive, Rack and Pinion Drive

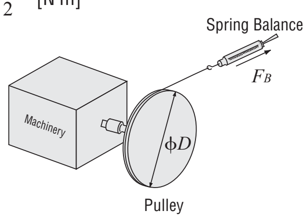
$$T_L = \frac{F}{2\pi\eta} \times \frac{\pi D}{i} = \frac{FD}{2\eta i}\ [\text{N·m}] \quad ④$$

$$F = F_A + mg(\sin\alpha + \mu\cos\alpha)\ [\text{N}] \quad ⑤$$



◇By Actual Measurement

$$T_L = \frac{F_B D}{2}\ [\text{N·m}] \quad ⑥$$



F : Force of moving direction [N]
F_0 : Preload [N] ($\fallingdotseq 1/3F$)
μ_0 : Internal friction coefficient of preload nut ($0.1 \sim 0.3$)
η : Efficiency ($0.85 \sim 0.95$)
i : Gear ratio (This is the gear ratio of the mechanism and not the gear ratio of the Oriental Motor's gearhead you are selecting.)
P_B : Ball screw lead [m/rev]
F_A : External force [N]
F_B : Force when main shaft begins to rotate [N]
(F_B = value for spring balance [kg] × g [m/s²])
m : Total mass of the table and load [kg]
μ : Friction coefficient of sliding surface (0.05)
α : Tilt angle [deg]
D : Final pulley diameter [m]
g : Gravitational acceleration [m/s²] (9.807)

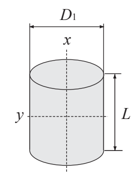
Calculate the Moment of Inertia J [kg·m²]

Calculate the Moment of Inertia

◇Inertia of a Cylinder

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

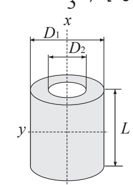
$$J_y = \frac{1}{4} m\left(\frac{D_1^2}{4} + \frac{L^2}{3}\right)\ [\text{kg·m}^2] \quad ⑧$$



◇Inertia of a Hollow Cylinder

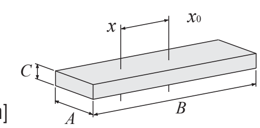
$$J_x = \frac{1}{8} m (D_1^2 + D_2^2) = \frac{\pi}{32} \rho L (D_1^4 - D_2^4)\ [\text{kg·m}^2] \quad ⑨$$

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



◇Inertia on Off-Center Axis

$$J_x = J_{x0} + ml^2 = \frac{1}{12} m (A^2 + B^2 + 12l^2)\ [\text{kg·m}^2] \quad ⑪$$

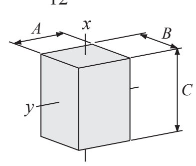


l : Distance between x and x_0 axes [m]

◇Inertia of a Rectangular Pillar

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

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



◇Inertia of an Object in Linear Motion

$$J = m\left(\frac{A}{2\pi}\right)^2\ [\text{kg·m}^2] \quad ⑭$$

A : Unit of movement [m/rev]

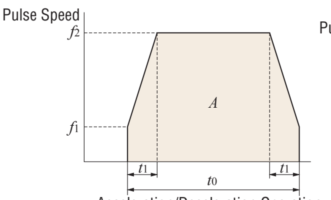
Density
Iron $\rho = 7.9 \times 10^3$ [kg/m³]
Aluminum $\rho = 2.8 \times 10^3$ [kg/m³]
Brass $\rho = 8.5 \times 10^3$ [kg/m³]
Nylon $\rho = 1.1 \times 10^3$ [kg/m³]
J_x : Inertia on x axis [kg·m²]
J_y : Inertia on y axis [kg·m²]
J_0 : Inertia on x_0 axis (passing through center of gravity) [kg·m²]
m : Mass [kg]
D_1 : Outer diameter [m]
D_2 : Inner diameter [m]
ρ : Density [kg/m³]
L : Length [m]

Motor Selection Calculations

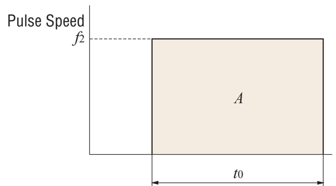
The following explains the calculation for selecting a stepping motor based on pulse control:

● Operating Pattern

There are two basic motion profiles.
Acceleration/deceleration operation is the most common. When operating speed is low and load inertia is small, start/stop operation can be used.



Acceleration/Deceleration Operation



Start/Stop Operation

f_1 : Starting pulse speed [Hz]
f_2 : Operating pulse speed [Hz]
A : Number of operating pulses
t_0 : Positioning time [s]
t_1 : Acceleration (deceleration) time [s]

● Calculate the Number of Operating Pulses A [Pulse]

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 load from point A to B.

$$A\,[\text{Pulse}] = \frac{l}{l\text{rev}} \times \frac{360°}{\theta s}$$

l : Movement distance from point A to B [m]
$l\text{rev}$: Movement distance per motor rotation [m/rev]
θs : Step angle [deg]

● Calculate the Operating Pulse Speed f_2 [Hz]

The operating pulse speed can be found from the number of operating pulses, the positioning time and the acceleration (deceleration) time.

① For acceleration/deceleration operation
The level of acceleration (deceleration) time is an important point in the selection. The acceleration (deceleration) time cannot be set hastily, because it correlates with the acceleration torque and acceleration/deceleration rate.
Initially, set the acceleration (deceleration) time at roughly 25% of the positioning time. (The setting must be fine-tuned before the final decision can be made.)

$$t_1\,[\text{s}] = t_0\,[\text{s}] \times 0.25$$

$$f_2\,[\text{Hz}] = \frac{A - f_1 \cdot t_1}{t_0 - t_1}$$

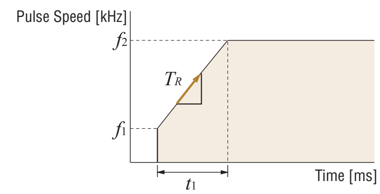
② For start/stop operation

$$f_2\,[\text{Hz}] = \frac{A}{t_0}$$

● Calculate the Acceleration/Deceleration Rate T_R [ms/kHz]

The values represent the specifications of Oriental Motor's controllers.
The acceleration/deceleration rate indicates the degree of acceleration of pulse speed and is calculated using the following formula:

$$T_R\,[\text{ms/kHz}] = \frac{t_1}{f_2 - f_1}$$



● Calculate the pulse speed in full-step equivalents.
● In this example, acceleration (deceleration) time is calculated in [kHz], while time is calculated in [ms].

● Calculate the Operating Speed N_M [r/min] from Operating Pulse Speed f_2 [Hz]

$$N_M\,[\text{r/min}] = f_2\,[\text{Hz}] \times \frac{\theta s}{360} \times 60$$

● Calculate the Load Torque

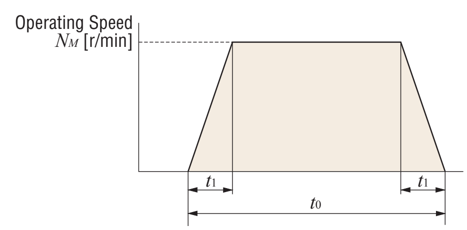
Refer to basic formulas on page F-3.

● Calculate the Acceleration Torque T_a [N·m]

Regardless of the motor type, the acceleration/deceleration torque must always be set if the speed is to be varied.
The basic formula is the same for all motors. However, different formula applies to stepping motors, as shown below, because the specifications of stepping motors are often calculated on the basis of pulse speed.

Brushless Motors, AC Motors

$$T_a\,[\text{N·m}] = \frac{(J_0 + J_L)}{9.55} \times \frac{N_M}{t_1}$$



Using Brushless Motors

J_0 : Rotor inertia [kg·m²]
J_L : Total load inertia [kg·m²]
N_M : Operating speed of motor [r/min]
t_1 : Acceleration (deceleration) time [s]

Stepping Motors

① For acceleration/deceleration operation

$$T_a\,[\text{N·m}] = (J_0 + J_L) \times \frac{\pi \cdot \theta s}{180} \times \frac{f_2 - f_1}{t_1}$$

② For start/stop operation

$$T_a\,[\text{N·m}] = (J_0 + J_L) \times \frac{\pi \cdot \theta s}{180 \cdot n} \times f_2^2 \qquad n: 3.6°/\theta s$$

● Calculate the Required Torque T_M [N·m]

The required torque is calculated by multiplying the sum of load torque and acceleration torque by the safety factor.

$$T_M = (T_L + T_a) \times S_f$$

T_M : Required torque [N·m]
T_L : Load torque [N·m]
T_a : Acceleration torque [N·m]
S_f : Safety factor

Selection Points

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

●Standard AC Motors

① Speed variation by load

The speed of induction motors and reversible motors varies by several percent with the load torque.
Therefore, when selecting an induction motor or reversible motor, the selection should take into account this possible speed variation by load.

② Time rating

There can be a difference of continuous and short time ratings, due to the difference in motor specifications, even if motors have the same output power. Motor selection should be based on the operating time (operating pattern).

③ Permissible load inertia of gearhead

If instantaneous stop (using a brake pack etc.), frequent intermittent operations or instantaneous bi-directional operations will be performed using a gearhead, an excessive load inertia may damage the gearhead. In these applications, therefore, the selection must be made so the load inertia does not exceed the permissible load inertia of gearhead. (Refer to page A-17)

●Stepping Motors

① Check the duty cycle

A stepping motor is not intended to be run continuously.
It is suitable for an application that the duty cycle, which represents rate of running time and stopping time, is 50% or less.

$$\text{Duty cycle} = \frac{\text{Running time}}{\text{Running time} + \text{Stopping time}} \times 100$$

② Check the inertia ratio

Large inertia ratios cause large overshooting and undershooting during starting and stopping, which can affect starting time and settling time. Depending on the conditions of usage, operation may be impossible.
Calculate the inertia ratio with the following formula and check that the value found is at or below the inertia ratios shown in the table.

$$\text{Inertia ratio} = \frac{J_L}{J_0}$$

Inertia Ratio (Reference values)

Product	Motor Frame Size	Inertia Ratio
αSTEP	28, 42, 60, 85	30 Max.
Stepping Motor and Driver Package	20, 28	5 Max.
	42, 60, 85	10 Max.

●Except for geared types

When the inertia ratio exceeds the values in the table, we recommend a geared type.
Using a geared type can increase the drivable load inertia.

$$\text{Inertia ratio} = \frac{J_L}{J_0 \cdot i^2} \qquad i\text{: Gear ratio}$$

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 previous formula and check that the value is at or above the acceleration/deceleration rate shown in the table.

Acceleration/Deceleration Rate (Reference values with **EMP** Series)

Product	Motor Frame Size	Acceleration/Deceleration Rate T_R [ms/kHz]
αSTEP	28, 42, 60, 85	0.5 Min.*
Stepping Motor and Driver Package	20, 28, 42, 60	20 Min.
	85, 90	30 Min.

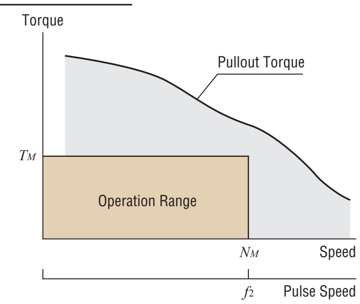
*This item need not be checked for αSTEP. The value in the table represents the lower limit of setting for the **EMP** Series.

④ Check the required torque

Check that the operation range indicated by operating speed N_M (f_2) and required torque T_M falls within the pullout torque of the speed – torque characteristics.

Safety Factor: Sf (Reference value)

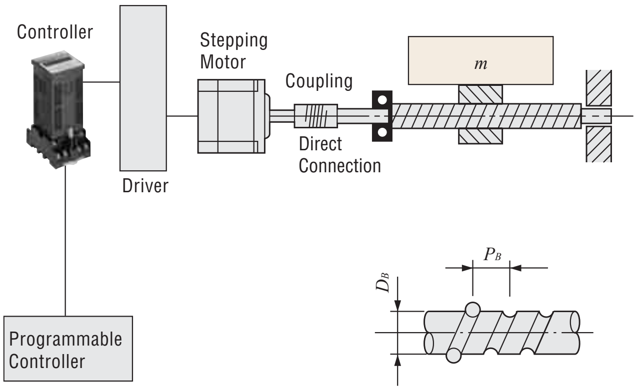
Product	Safety Factor (Reference value)
αSTEP	1.5~2
Stepping Motor and Driver Package	2



● Ball Screw Mechanism

Using Stepping Motors (αSTEP)

(1) Specifications and Operating Conditions of the Drive Mechanism



Total mass of the table and load .... $m = 40$ [kg]
Friction coefficient of sliding surface .... $\mu = 0.05$
Ball screw efficiency .... $\eta = 0.9$
Internal friction coefficient of preload nut ....$\mu_0 = 0.3$
Ball screw shaft diameter ....$D_B = 15$ [mm]
Total length of ball screw ....$L_B = 600$ [mm]
Ball screw material .... Iron (density $\rho = 7.9 \times 10^3$ [kg/m³])
Ball screw lead .... $P_B = 15$ [mm]
Desired resolution .... $\Delta l = 0.03$ [mm/step]
(feed per pulse)
Feed .... $l = 180$ [mm]
Positioning time ....t_0 = within 0.8 sec.
Tilt angle .... $\alpha = 0$ [deg]

(2) Calculate the Required Resolution θ_S

$$\theta_S = \frac{360^\circ \times \Delta l}{P_B} = \frac{360^\circ \times 0.03}{15} = 0.72^\circ$$

αSTEP can be connected directly to the application.

(3) Determine the Operating Pattern (Refer to page F-4 for formula)

① Calculate the number of operating pulses A [Pulse]

$$A = \frac{l}{P_B} \times \frac{360^\circ}{\theta_S}$$

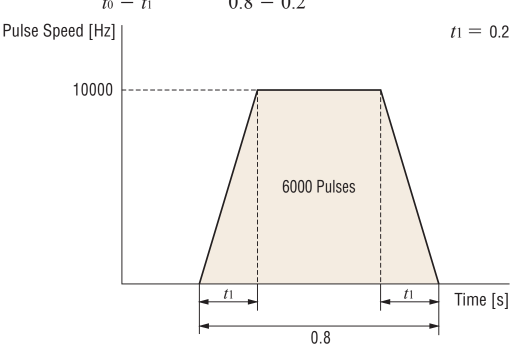
$$= \frac{180}{15} \times \frac{360^\circ}{0.72^\circ} = 6000 \text{ [Pulse]}$$

② Determine the acceleration (deceleration) time t_1 [s]
An acceleration (deceleration) time of 25% of the positioning time is appropriate.

$$t_1 = 0.8 \times 0.25 = 0.2 \text{ [s]}$$

③ Calculate the operating pulse speed f_2 [Hz]

$$f_2 = \frac{A - f_1 \times t_1}{t_0 - t_1} = \frac{6000 - 0}{0.8 - 0.2} = 10000 \text{ [Hz]}$$



④ Calculate the operating speed N_M [r/min]

$$N_M = f_2 \times \frac{\theta_S}{360} \times 60 = 10000 \times \frac{0.72}{360} \times 60$$

$$= 1200 \text{ [r/min]}$$

(4) Calculate the Required Torque T_M [N·m] (Refer to page F-4)

① Calculate the load torque T_L [N·m]

Force of moving direction $F = F_A + mg(\sin\alpha + \mu\cos\alpha)$

$$= 0 + 40 \times 9.807 (\sin 0 + 0.05 \cos 0)$$

$$= 19.6 \text{ [N]}$$

Preload $F_0 = \frac{F}{3} = \frac{19.6}{3} = 6.53$ [N]

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

$$= \frac{19.6 \times 15 \times 10^{-3}}{2\pi \times 0.9} + \frac{0.3 \times 6.53 \times 15 \times 10^{-3}}{2\pi}$$

$$= 0.0567 \text{ [N·m]}$$

② Calculate the acceleration torque Ta [N·m]

②-1 Calculate the moment of load inertia J_L [kg·m²]
(Refer to page F-3 for formula)

Inertia of ball screw $J_B = \frac{\pi}{32} \cdot \rho \cdot L_B \cdot D_B^4$

$$= \frac{\pi}{32} \times 7.9 \times 10^3 \times 600 \times 10^{-3} \times (15 \times 10^{-3})^4$$

$$= 0.236 \times 10^{-4} \text{ [kg·m}^2\text{]}$$

Inertia of table and load $J_T = m\left(\frac{P_B}{2\pi}\right)^2$

$$= 40 \times \left(\frac{15 \times 10^{-3}}{2\pi}\right)^2 = 2.28 \times 10^{-4} \text{ [kg·m}^2\text{]}$$

Load inertia $J_L = J_B + J_T$

$$= 0.236 \times 10^{-4} + 2.28 \times 10^{-4} = 2.52 \times 10^{-4} \text{ [kg·m}^2\text{]}$$

②-2 Calculate the acceleration torque Ta [N·m]

$$T_a = (J_0 + J_L) \times \frac{\pi \cdot \theta_S}{180^\circ} \times \frac{f_2 - f_1}{t_1}$$

$$= (J_0 + 2.52 \times 10^{-4}) \times \frac{\pi \times 0.72}{180^\circ} \times \frac{10000 - 0}{0.2}$$

$$= 628 J_0 + 0.158 \text{ [N·m]}$$

③ Calculate the required torque T_M [N·m]

$$T_M = (T_L + Ta) \times 2$$

$$= \{0.0567 + (628 J_0 + 0.158)\} \times 2$$

$$= 1256 J_0 + 0.429 \text{ [N·m]}$$

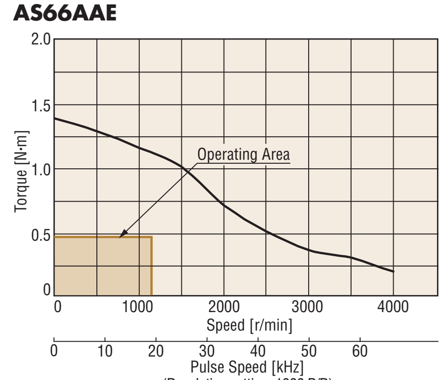
(5) Select a Motor

① Tentative motor selection

Model	Rotor Inertia [kg·m²]	Required Torque [N·m]
AS66AAE	405×10⁻⁷	0.48

② Determine the motor from the speed – torque characteristics

AS66AAE

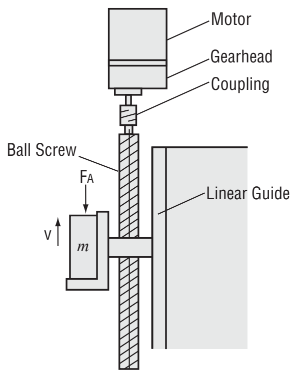


Select a motor for which the operating area indicated by operating speed and required torque falls within the pullout torque of the speed – torque characteristics.

Using Standard AC Motors

(1) Specifications and Operating Conditions of the Drive Mechanism

This selection example demonstrates an electromagnetic brake motor for use on a table moving vertically on a ball screw.
In this case, a motor must be selected that meets the following required specifications.



Total mass of the table and load .... $m = 45$ [kg]
Table speed .... $V = 15 \pm 2$ [mm/s]
External force .... $F_A = 0$ [N]
Ball screw tilt angle .... $\alpha = 90$ [deg]
Total length of ball screw .... $L_B = 800$ [mm]
Ball screw shaft diameter .... $D_B = 20$ [mm]
Ball screw lead .... $P_B = 5$ [mm]
Distance moved for one rotation of ball screw .... $A = 5$ [mm]
Ball screw efficiency .... $\eta = 0.9$
Ball screw material .... Iron (density $\rho = 7.9 \times 10^3$ [kg/m^3])
Internal friction coefficient of preload nut .... $\mu_0 = 0.3$
Friction coefficient of sliding surface .... $\mu = 0.05$
Motor power supply .... Single-Phase 115 VAC 60 Hz
Operating time .... Intermittent operation, 5 hours/day
Load with repeated starts and stops
Required load holding

(2) Determine the Gear Ratio

Speed at the gearhead output shaft $N_G = \dfrac{V \cdot 60}{A} = \dfrac{(15 \pm 2) \times 60}{5}$

$= 180 \pm 24$ [r/min]

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

Gear ratio $i = \dfrac{1450 \sim 1550}{N_G} = \dfrac{1450 \sim 1550}{180 \pm 24} = 7.1 \sim 9.9$

This gives us a gear ratio of $i = 9$.

(3) Calculate the Required Torque T_M [N·m]

Force of moving direction $F = F_A + m \cdot g\,(\sin\theta + \mu \cdot \cos\theta)$

$= 0 + 45 \times 9.807\,(\sin 90° + 0.05 \cos 90°)$

$= 441$ [N]

Ball screw preload $F_0 = \dfrac{F}{3} = 147$ [N]

Load torque $T'_L = \dfrac{F \cdot P_B}{2\pi\eta} + \dfrac{\mu_0 \cdot F_0 \cdot P_B}{2\pi}$

$= \dfrac{441 \times 5 \times 10^{-3}}{2\pi \times 0.9} + \dfrac{0.3 \times 147 \times 5 \times 10^{-3}}{2\pi}$

$= 0.426$ [N·m]

Allow for a safety factor of 2 times.

$T_L = T'_L \cdot 2 = 0.426 \times 2 = 0.86$ [N·m]

Select an electromagnetic brake motor and gearhead satisfying the permissible torque of gearhead based on the calculation results (gear ratio $i = 9$, load torque $T_L = 0.86$ [N·m]) obtained so far.
Here, **4RK25GN-AW2MU** and **4GN9SA** are tentatively selected as the motor and gearhead, respectively, by referring to the "gearmotor – torque table" on page A-125.
Next, convert this load torque to a value on the motor output shaft to obtain the required torque T_M, as follows:

$T_M = \dfrac{T_L}{i \cdot \eta_G} = \dfrac{0.86}{9 \times 0.81} = 0.118$ [N·m]$= 118$ [mN·m]

(Gearhead efficiency $\eta_G = 0.81$)

The starting torque of the **4RK25GN-AW2MU** motor selected earlier is 140 mN·m. Since this is greater than the required torque of 118 mN·m, this motor can start the mechanism in question.
Next, check if the gravitational load acting upon the mechanism in standstill state can be held with the electromagnetic brake.
Here, the load equivalent to the load torque obtained earlier is assumed to act.
Torque T'_M required for load holding on the motor output shaft:

$T'_M = \dfrac{T_L}{i} = \dfrac{0.86}{9} = 0.0956$ [N·m] $= 95.6$ [mN·m]

The static friction torque generated by the electromagnetic brake of the **4RK25GN-AW2MU** motor selected earlier is 100 mN·m, which is greater than 95.6 mN·m required for the load holding.

(4) Check the Moment of Load Inertia J [kg·m^2]

Inertia of ball screw $J_B = \dfrac{\pi}{32} \cdot \rho \cdot L_B \cdot D_B^4$

$= \dfrac{\pi}{32} \times 7.9 \times 10^3 \times 800 \times 10^{-3} \times (20 \times 10^{-3})^4$

$= 0.993 \times 10^{-4}$ [kg·m^2]

Inertia of table and load $J_m = m\,(\dfrac{A}{2\pi})^2$

$= 45\,(\dfrac{5 \times 10^{-3}}{2\pi})^2$

$= 0.286 \times 10^{-4}$ [kg·m^2]

Load inertia at the gearhead shaft J is calculated as follows:

$J = J_B + J_m = 0.993 \times 10^{-4} + 0.286 \times 10^{-4}$
$= 1.28 \times 10^{-4}$ [kg·m^2]

Here, permissible load inertia of gearhead **4GN9SA** (gear ratio $i = 9$) J_G is (Refer to page A-17):

$J_G = 0.31 \times 10^{-4} \times 9^2$
$= 25.1 \times 10^{-4}$ [kg·m^2]

Therefore, $J < J_G$, the load inertia is less than the permissible value, so there is no problem. There is margin for the torque, so the traveling speed is checked with the speed under no load (approximately 1750 r/min).

$V = \dfrac{N_M \cdot P_B}{60 \cdot i} = \dfrac{1750 \times 5}{60 \times 9} = 16.2$ [mm/s] $\quad N_M$: Motor speed

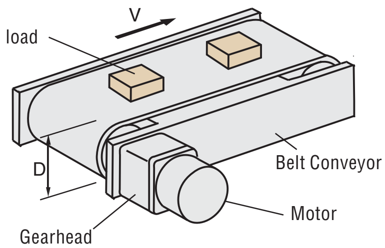
This confirms that the motor meets the specifications.
Based on the above, **4RK25GN-AW2MU** and **4GN9SA** are selected as the motor and gearhead, respectively.

●Belt and Pulley Mechanism

Using Standard AC Motors

(1) Specifications and Operating Conditions of the Drive Mechanism

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 required specifications.



Total mass of belt and load .... $m_1 = 25$ [kg]
External force .... $F_A = 0$ [N]
Friction coefficient of sliding surface .... $\mu = 0.3$
Roller diameter .... $D = 90$ [mm]
Roller mass .... $m_2 = 1$ [kg]
Belt and roller efficiency .... $\eta = 0.9$
Belt speed .... $V = 150$ [mm/s]$\pm 10\%$
Motor power supply ....Single-Phase 115 VAC 60 Hz
Operating time .... 8 hours/day

(2) Determine the Gear Ratio

$$\text{Speed at the gearhead output shaft } N_G = \frac{V \cdot 60}{\pi \cdot D} = \frac{(150 \pm 15) \times 60}{\pi \times 90} = 31.8 \pm 3.2 \text{ [r/min]}$$

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

$$\text{Gear ratio } i = \frac{1450 \sim 1550}{N_G} = \frac{1450 \sim 1550}{31.8 \pm 3.2} = 41.4 \sim 54.2$$

This gives us a gear ratio of $i = 50$.

(3) Calculate the Required Torque T_M [N·m]

Friction coefficient of sliding surface F is calculated as follows:

$$\begin{aligned} F &= F_A + m \cdot g (\sin\theta + \mu \cdot \cos\theta) \\ &= 0 + 25 \times 9.807 (\sin 0^\circ + 0.3 \times \cos 0^\circ) \\ &= 73.6 \text{ [N]} \end{aligned}$$

$$\text{Load torque } T'_L = \frac{F \cdot D}{2 \cdot \eta} = \frac{73.6 \times 90 \times 10^{-3}}{2 \times 0.9} = 3.68 \text{ [N·m]}$$

Allow for a safety factor of 2 times.

$$T_L = T'_L \cdot 2 = 3.68 \times 2 = 7.36 \text{ [N·m]}$$

Select an induction motor and gearhead satisfying the permissible torque of gearhead based on the calculation results (gear ratio $i = 50$, load torque $T_L = 7.36$ [N·m]) obtained so far.
Here, **5IK60GE-AW2U** and **5GE50SA** are tentatively selected as the motor and gearhead, respectively, by referring to the "gearmotor – torque table" on page A-49.
Next, convert this load torque to a value on the motor output shaft to obtain the required torque T_M, as follows:

$$T_M = \frac{T_L}{i \cdot \eta_G} = \frac{7.36}{50 \times 0.66} = 0.22 \text{ [N·m]} = 220 \text{ [mN·m]}$$

(Gearhead efficiency $\eta_G = 0.66$)

Since the starting torque of the **5IK60GE-AW2U** motor is 320 mN·m, this is greater than the required torque of 220 mN·m.

(4) Check the Moment of Load Inertia J [kg·m²]

$$\begin{aligned} \text{Inertia of belt and load } J_{m1} &= m_1 \left(\frac{\pi \cdot D}{2\pi}\right)^2 \\ &= 25 \times \left(\frac{\pi \times 90 \times 10^{-3}}{2\pi}\right)^2 \\ &= 507 \times 10^{-4} \text{ [kg·m}^2\text{]} \end{aligned}$$

$$\begin{aligned} \text{Inertia of roller } J_{m2} &= \frac{1}{8} \cdot m_2 \cdot D^2 \\ &= \frac{1}{8} \times 1 \times (90 \times 10^{-3})^2 \\ &= 10.2 \times 10^{-4} \text{ [kg·m}^2\text{]} \end{aligned}$$

Load inertia at the gearhead shaft J is calculated as follows:

$$\begin{aligned} J &= Jm_1 + Jm_2 \cdot 2 \\ &= 507 + 10.2 \times 2 \\ &= 528 \times 10^{-4} \text{ [kg·m}^2\text{]} \end{aligned}$$

Here, permissible load inertia of gearhead **5GE50SA** (gear ratio $i = 50$) J_G is (Refer to page A-17):

$$\begin{aligned} J_G &= 1.1 \times 10^{-4} \times 50^2 \\ &= 2750 \times 10^{-4} \text{ [kg·m}^2\text{]} \end{aligned}$$

Therefore, $J < J_G$, the load inertia is less than the permissible inertia, so there is no problem. Since the motor selected has a rated torque of 405 mN·m, which is greater than the actual load torque, the motor will operate at a higher speed than the rated speed.
Therefore, the belt speed is calculated from the speed under no load (approximately 1470 r/min), and thus determine whether the selected product meets the required specifications.

$$V = \frac{N_M \cdot \pi \cdot D}{60 \cdot i} = \frac{1750 \times \pi \times 90}{60 \times 50} = 165 \text{ [mm/s]}$$

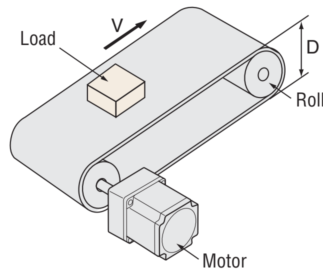
N_M: Motor speed

This confirms that the motor meets the specifications.
Based on the above, **5IK60GE-AW2U** and **5GE50SA** are selected as the motor and gearhead, respectively.

Using Brushless Motors

(1) Specifications and Operating Conditions of the Drive Mechanism

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



Belt speed .... $V_L = 0.05\sim1$ [m/s]
Motor power supply .... Single-Phase 115 VAC
Belt conveyor drive
Roller diameter .... $D = 0.1$ [m]
Roller mass .... $m_2 = 1$ [kg]
Total mass of belt and load .... $m_1 = 7$ [kg]
External force .... $F_A = 0$ [N]
Friction coefficient of sliding surface .... $\mu = 0.3$
Belt and roller efficiency .... $\eta = 0.9$

(2) Find the Required Speed Range

For the gear ratio, select 15:1 (speed range: 5.3~200) from the "Gearmotor – torque table of combination type" on page B-68 so that the minimum/maximum speed falls within the speed range.

$$N_G = \frac{60 \cdot V_L}{\pi \cdot D}$$ N_G: Speed at the gearhead shaft

Belt speed 0.015 [m/s] .... $\frac{60 \times 0.05}{\pi \times 0.1} = 9.55$ [r/min] (Minimum speed)

1 [m/s] .... $\frac{60 \times 1}{\pi \times 0.1} = 191$ [r/min] (Maximum speed)

(3) Calculate the Moment of Load Inertia J_G [kg·m²]

Inertia of belt and load $J_{m1} = m_1 \left(\frac{\pi \cdot D}{2\pi}\right)^2 = 7 \times \left(\frac{\pi \times 0.1}{2\pi}\right)^2$

$= 175 \times 10^{-4}$ [kg·m²]

Inertia of roller $J_{m2} = \frac{1}{8} \cdot m_2 \cdot D^2$

$= \frac{1}{8} \times 1 \times 0.1^2 = 12.5 \times 10^{-4}$ [kg·m²]

The load inertia J_G is calculated as follows:

$J_G = J_{m1} + J_{m2} \cdot 2 = 175 + 12.5 \times 2$
$= 200 \times 10^{-4}$ [kg·m²]

From the specifications on page B-70, the permissible load inertia of **BLF5120A-15** is 225×10^{-4} [kg·m²].

(4) Calculate the Load Torque T_L [N·m]

Friction coefficient of sliding surface $F = F_A + m \cdot g\,(\sin\theta + \mu \cdot \cos\theta)$
$= 0 + 7 \times 9.807\,(\sin 0^\circ + 0.3 \times \cos 0^\circ)$
$= 20.6$ [N]

Load torque $T_L = \frac{F \cdot D}{2\eta} = \frac{20.6 \times 0.1}{2 \times 0.9} = 1.15$ [N·m]

Select **BLF5120A-15** from the "gearmotor – torque table of combination type" on page B-68.
Since the permissible torque is 5.4 N·m, the safety factor is
$T_M / T_L = 5.4 / 1.15 ≒ 4.6$.
Usually, a motor can operate at the safety factor of 1.5~2 or more.

Using Low-Speed Synchronous Motors (**SMK** Series)

(1) Specifications and Operating Conditions of the Drive Mechanism

The mass of load is selected that can be driven with **SMK5100A-AA** when the belt-drive table shown in Fig. 1 is driven in the operation pattern shown in Fig. 2.

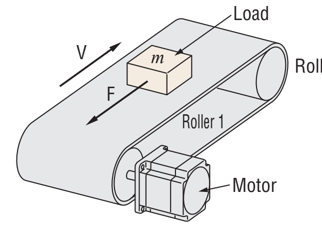


Fig. 1 Example of Belt Drive

Total mass of belt and load .... $m_1 = 1.5$ [kg]
Roller diameter .... $D = 30$ [mm]
Mass of roller .... $m_2 = 0.1$ [kg]
Frictional coefficient of sliding surfaces ... $\mu = 0.04$
Belt and pulley efficiency .... $\eta = 0.9$
Frequency of power supply .... 60 Hz (Motor speed: 72 r/min)

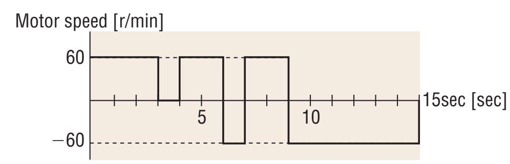


Fig. 2 Operating Pattern

Low-speed synchronous motors share the same basic operating principle with 2-phase stepping motors. Accordingly, the torque for a low-speed synchronous motor is calculated in the same manner as for a 2-phase stepping motor.

(2) Belt speed V [mm/s]

Check the belt (load) speed

$$V = \frac{\pi D \cdot N}{60} = \frac{\pi \times 30 \times 72}{60} = 113 \text{ [mm/s]}$$

(3) Calculate the Required Torque T_L [N·m]

Frictional coefficient of sliding surfaces $F = \mu \cdot m_1 \cdot g$
$= 0.04 \times 1.5 = 9.807 = 0.589$ [N]

Load Torque $T_L = \frac{F \cdot D}{2\eta} = \frac{0.589 \times 30 \times 10^{-3}}{2 \times 0.9} = 9.82 \times 10^{-3}$ [N·m]

(4) Calculate the Moment of Load Inertia J_G [kg·m²]

Load inertia of belt and load $J_{m1} = m_1 \times \left(\frac{\pi D}{2\pi}\right)^2$

$= 1.5 \times \left(\frac{\pi \times 30 \times 10^{-3}}{2\pi}\right)^2$

$= 3.38 \times 10^{-4}$ [kg·m²]

Load Inertia of Roller $J_{m2} = \frac{1}{8} \times m_2 \times D^2$

$= \frac{1}{8} \times 0.1 \times (30 \times 10^{-3})^2$

$= 0.113 \times 10^{-4}$ [kg·m²]

The load inertia J_L is calculated as follows:

$J_L = J_{m1} + J_{m2} \times 2 = 3.38 \times 10^{-4} + 0.113 \times 10^{-4} \times 2 = 3.5 \times 10^{-4}$ [kg·m²]

(5) Calculate the Acceleration Torque T_a [N·m]

$$T_a = (J_0 + J_L) \times \frac{\pi \cdot \theta s}{180 \cdot n} \times f^2 = (J_0 + 3.5 \times 10^{-4}) \times \frac{\pi \times 7.2}{180 \times 0.5} \times 60^2$$

$$= 905 \cdot J_0 + 0.32 \text{ [N·m]}$$

Here, $\theta s = 7.2°$, $f = 60$ Hz, $n = 3.6°/\theta s = 0.5$
J_0: Rotor Inertia

(6) Calculate the Required Torque T_M [N·m] (Look for a margin of safety of 2 times)

Required Torque $T_M = (T_L + T_a) \times 2$

$$= (9.82 \times 10^{-3} + 905 \cdot J_0 + 0.32) \times 2$$

$$= 1810 \cdot J_0 + 0.66 \text{ [N·m]}$$

(7) Select a Motor

Select a motor that satisfies both the required torque and the permissible load inertia.

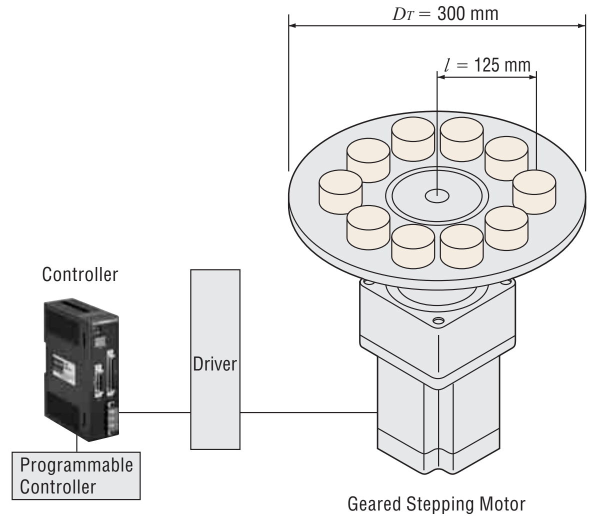
Motor	Rotor Inertia [kg·m²]	Permissible Load Inertia [kg·m²]	Output Torque [N·m]
SMK5100A-AA	1.4×10^{-4}	7×10^{-4}	1.12

When the required torque is calculated by substituting the rotor inertia, T_M is obtained as 0.914 N·m, which is below the output torque. Next, check the permissible load inertia. Since the load inertia calculated in (4) is also below the permissible load inertia, **SMK5100A-AA** can be used in this application.

●Index Mechanism

(1) Specifications and Operating Conditions of the Drive Mechanism

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



Index table diameter .... $D_T = 300$ [mm]
Index table thickness .... $L_T = 10$ [mm]
Load diameter .... $D_W = 40$ [mm]
Load thickness .... $L_W = 30$ [mm]
Material of table .... Iron (density $\rho = 7.9 \times 10^3$ [kg/m³])
Number of loads .... 10 (one every 36°)
Distance from center of index table to center of load........ $l = 125$ [mm]
Positioning angle .... $\theta = 36°$
Positioning time .... $t_0 = 0.25$ sec.

The αSTEP **PN** geared type (gear ratio = 10:1, resolution per pulse = 0.036°) can be used.
The **PN** geared type can be used at the maximum starting/stopping torque in the inertial drive mode.
Gear ratio .... $i = 10$
Resolution .... $\theta s = 0.036°$

(2) Determine the Operating Pattern (Refer to page F-4 for formula)

① Calculate the number of operating pulses A [Pulse]

$$A = \frac{\theta}{\theta s}$$

$$= \frac{36°}{0.036°}$$

$$= 1000 \text{ [Pulse]}$$

② Determine the acceleration (deceleration) time t_1 [s]
An acceleration (deceleration) time of 25% of the positioning time is appropriate.
Here we shall let

$t_1 = 0.1$ [s].

③ Calculate the operating speed N_M [r/min]

$$N_M = \frac{60}{360} \times \frac{\theta}{t_0 - t_1} = \frac{60}{360} \times \frac{36}{0.25 - 0.1}$$

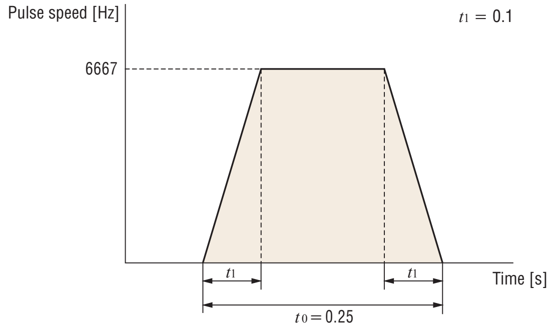
$$= 40 \text{ [r/min]}$$

The permissible speed range for the **PN** geared motor with a gear ratio of 10 is 0 to 300 r/min.

④ Calculate the operating pulse speed f_2 [Hz]

$$f_2 = \frac{A}{t_0 - t_1} = \frac{1000}{0.25 - 0.1}$$

$$= 6667 \text{ [Hz]}$$



(3) Calculate the Required Torque T_M [N·m] (Refer to page F-4)

① Calculate the load torque T_L [N·m]

Friction load is negligible and therefore omitted. The load torque is assumed as 0.

$$T_L = 0 \text{ [N·m]}$$

② Calculate the acceleration torque Ta [N·m]

②-1 Calculate the moment of load inertia J_L [kg·m²]
(Refer to page F-3 for formula)

Inertia of table $J_T = \frac{\pi}{32} \times \rho \times L_T \times D_T^4$

$$= \frac{\pi}{32} \times 7.9 \times 10^3 \times (10 \times 10^{-3}) \times (300 \times 10^{-3})^4$$

$$= 6.28 \times 10^{-2} \text{ [kg·m}^2\text{]}$$

Inertia of load $J_{W1} = \frac{\pi}{32} \times \rho \times L_W \times D_W^4$
(Center shaft of load)

$$= \frac{\pi}{32} \times 7.9 \times 10^3 \times (30 \times 10^{-3}) \times (40 \times 10^{-3})^4$$

$$= 0.596 \times 10^{-4} \text{ [kg·m}^2\text{]}$$

Mass of load $m_W = \frac{\pi}{4} \times \rho \times L_W \times D_W^2$

$$= \frac{\pi}{4} \times 7.9 \times 10^3 \times (30 \times 10^{-3}) \times (40 \times 10^{-3})^2$$

$$= 0.3 \text{ [kg]}$$

Inertia of load J_W [kg·m²] relative to the center of rotation can be obtained from distance L [mm] between the center of load and center of rotation, mass of load m_W [kg], and inertia of load (center shaft of load) J_{W1} [kg·m²].
Since the number of loads, $n = 10$ [pcs],

Inertia of load $J_W = n \times (J_{W1} + m_W \times L^2)$
(Center shaft of load)

$$= 10 \times \{(0.596 \times 10^{-4}) + 0.3 \times (125 \times 10^{-3})^2\}$$

$$= 4.71 \times 10^{-2} \text{ [kg·m}^2\text{]}$$

Load inertia $J_L = J_T + J_W$

$$= (6.28 + 4.71) \times 10^{-2}$$

$$= 11 \times 10^{-2} \text{ [kg·m}^2\text{]}$$

②-2 Calculate the acceleration torque Ta [N·m]

$$T_a = (J_0 \times i^2 + J_L) \times \frac{\pi \times \theta s}{180} \times \frac{f_2 - f_1}{t_1}$$

$$= (J_0 \times 10^2 + 11 \times 10^{-2}) \times \frac{\pi \times 0.036}{180} \times \frac{6667 - 0}{0.1}$$

$$= 4.19 \times 10^3 J_0 + 4.61 \text{ [N·m]}$$

③ Calculate the required torque T_M [N·m]
Safety factor $Sf = 2.0$

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

$$= \{0 + (4.19 \times 10^3 J_0 + 4.61)\} \times 2.0$$

$$= 8.38 \times 10^3 J_0 + 9.2 \text{ [N·m]}$$

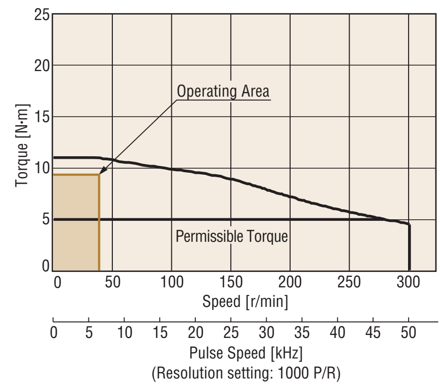
(4) Select a Motor

① Tentative motor selection

Model	Rotor Inertia [kg·m²]	Required Torque [N·m]
AS66AAE-N10	405×10^{-7}	9.55

② Determine the motor from the speed – torque characteristics

AS66AAE-N10



PN geared type can operate inertia load up at starting/stopping to acceleration torque less than maximum torque.
Select a motor for which the operating area indicated by operating speed and required torque falls within the speed – torque characteristics.
If the load torque is applied, the selection must be made so the value of the safety factor multiplied by the load torque does not exceed the permissible torque.

Selection Calculations

For Linear and Rotary Actuators

Motorized Linear Slides

After you have determined which to use, select an appropriate model. Select a linear slide of the size that satisfies your desired condition.
Select an appropriate model by following the steps below.

● Refer to page F-20 for selection calculations using a dual axes mounting bracket.

(1) Select a Linear Slide Satisfying the Transportable Mass

By referring to "■specifications of linear slide," select a linear slide satisfying the transportable mass.

Condition: Drive a load of 15 kg over a horizontal distance of 400 mm within 1.5 seconds.

EZS4: Specifications of Width 74 mm × Height 50 mm, 24 VDC Linear Slide

■Specifications of Linear Slide (RoHS)

Drive Method	Ball Screw	Repetitive Positioning Accuracy [mm]	±0.02	Resolution [mm]	0.01	Traveling Parallelism [mm]	0.03✻	Maximum Load Moment [N·m]	M_P: 8 M_Y: 8 M_R: 27.8

Model	Lead [mm]	Transportable Mass [kg]		Thrust [N]	Electromagnetic Brake Holding Force [N]	Maximum Speed (Stroke) [mm/s]			
		Horizontal	Vertical			50~550 mm	600 mm	650 mm	700 mm
EZS4D□-K	12	~15	–	~70	–	600	550	460	400
EZS4D□M-K			~7		70				
EZS4E□-K	6	~30	–	~140	–	300	270	220	200
EZS4E□M-K			~14		140				

● Enter the stroke length in the box (□) within the model name.
✻This applies when a parallelism is 0.06 mm or less along the mounting plate, per 200 mm of guide length.

Based on the "condition" and "specifications of linear slide," select **EZS4D040-K**.

(2) Check the Positioning Time

From the graph "■positioning distance – positioning time" below, check if the selected linear slide satisfies the desired positioning time. As a rough guideline, the positioning time required by the selected linear slide corresponds to the positioning time identified from the graph, multiplied by the "positioning time coefficient" applicable to the linear slide.

From the graph, find the "positioning time of 1.2 s" for the "positioning distance of 400 mm." You obtain the "positioning time of 1.2 s." Since the stroke is below 550 mm, multiply "positioning time of 1.2 s" by the "positioning time coefficient of 1.0" to obtain an approximate positioning time.

Notes:

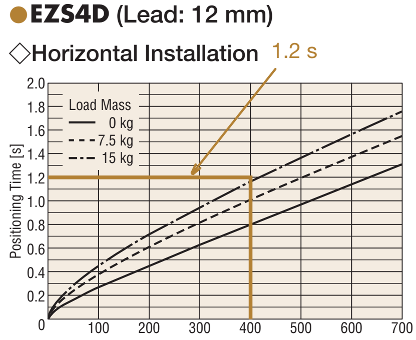
● The calculated positioning time does not include the settling time.
Use a settling time of 0.15 s as a reference.

● The duty cycle, which represents the relationship of running time and stopping time, should be kept to 50% or less (reference).
Duty cycle [%] = running time [s]×100/ (running time [s] + stopping time [s])

■Positioning Distance – Positioning Time

●EZS4D (Lead: 12 mm)

◇Horizontal Installation



Positioning Time Coefficient

Stroke [mm]	Load Mass					
	Horizontal Installation			Vertical Installation		
	0 kg	7.5 kg	15 kg	0 kg	3.5 kg	7 kg
50~550	1.0	1.0	1.0	1.0	1.0	1.0
600	1.0	1.0	1.0	1.0	1.0	1.0
650	1.2	1.1	1.0	1.2	1.0	1.0
700	1.4	1.1	1.1	1.3	1.0	1.0

(3) Check the Operating Speed and Acceleration of the Linear Slides

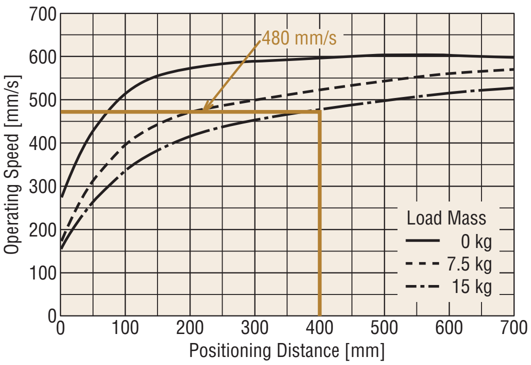
The time calculated from "■positioning distance – positioning time" assumes the operating speed and acceleration that achieve the shortest positioning time. Check the specific operating speed and acceleration at which to drive the linear slides based on the time calculated in step (2).

●Operating Speed and Acceleration of the Linear Slides

Check the operating speed and acceleration by referring to "■positioning distance – operating speed" and "■positioning distance – acceleration." If the identified speed exceeds the maximum speed specified in specifications of linear slide, use the maximum speed specified in specifications of linear slide as the operating speed of the linear slide.

Example) For a positioning distance of 400 mm on the graph, the operating speed is 480 mm/s, and the acceleration is 1.5 m/s^2.

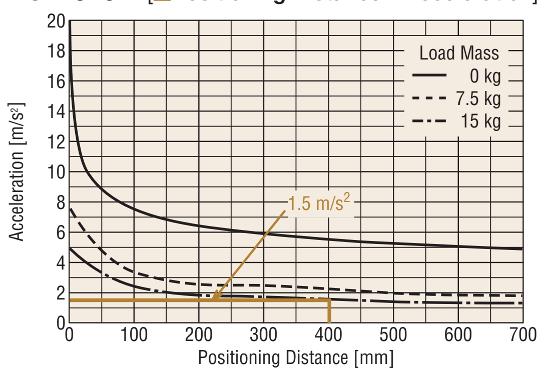
EZS4D040-K [■Positioning Distance – Operating Speed]



Maximum Speed by Stroke

Stroke [mm]	Max. Speed [mm/s]
50～550	600
600	550
650	460
700	400

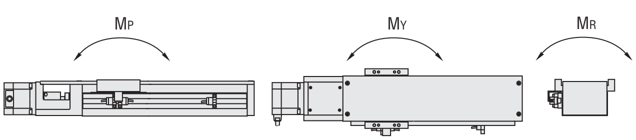
EZS4D040-K [■Positioning Distance – Acceleration]



(4) Check the Load Moment

Calculate the load that will generate under the applicable condition, and confirm that the calculated result is smaller than the "maximum load moment specified in specifications of linear slide." If the maximum load moment is exceeded, select another model.

The maximum load has been calculated by considering the estimated traveling life of each model. If a given model is operated at load exceeding the designed limit, the life of the linear slide will decrease. The life is also affected by the operating environment and conditions.



How to Calculate the Speed for Sensorless Return to Home Operation

The **EZSⅡ** Series can perform the high-speed, sensorless return to home operation. The maximum return to home speed is 100 mm/s when the lead is 12 mm, and the maximum speed becomes 50 mm/s when the lead is 6 mm. Select an applicable calculating formula by referring to the linear slide installation conditions and calculate the maximum settable speed for return to home operation from the specific overhung length and load mass.

Note that the load will receive impact if the sensorless return to home operation is performed at high speed.

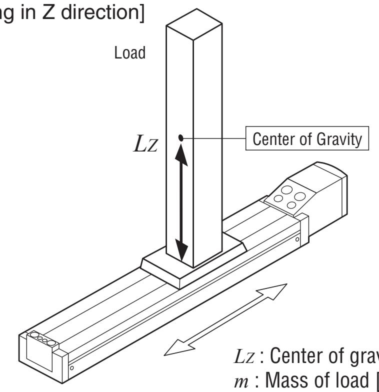
● If there are overhangs along both the Z-axis and Y-axis, compare V_Z and V_Y. The smaller of the two provides the maximum settable speed for return to home operation.

● Linear Slide Installation Conditions (Horizontal, wall-mounted or ceiling-mounted)

◇ Overhang in Z-Axis Direction

$$V_Z\,[\text{mm/s}] = \frac{k \times 10^3}{mL_Z} \times 100$$

[Overhang in Z direction]



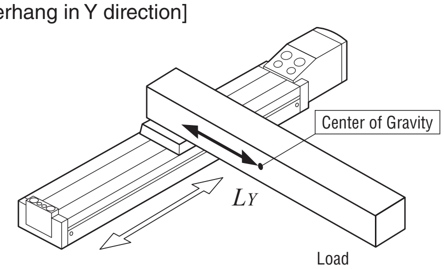
L_Z : Center of gravity of load [mm]
m : Mass of load [kg]

Linear Slide Size	Strength Coefficient k	
	Lead 12 mm	Lead 6 mm
EZS3	6.7	4.2
EZS4	7.1	6.3
EZS6	18.6	16.1

◇ Overhang in Y-Axis Direction

$$V_Y\,[\text{mm/s}] = \frac{k \times 10^3}{mL_Y} \times 100$$

[Overhang in Y direction]



L_Y : Center of gravity of load [mm]
m : Mass of load [kg]

Linear Slide Size	Strength Coefficient k	
	Lead 12 mm	Lead 6 mm
EZS3	0.6	0.5
EZS4	1.7	1.5
EZS6	7.5	6.4

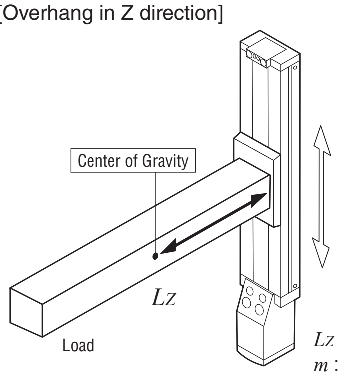
● Linear Slide Installation Conditions (Vertical)

If the linear slide is installed vertically, the applicable coefficient varies depending on the return to home direction (upward or downward). Use the correct coefficient according to the specific direction.

◇ Overhang in Z-Axis Direction

$$V_Z\,[\text{mm/s}] = \left(\frac{k \times 10^3}{mL_Z} + i\right) \times 100$$

[Overhang in Z direction]



L_Z : Center of gravity of load [mm]
m : Mass of load [kg]

Upward:

Linear Slide Size	Strength Coefficient k		Upward Coefficient i	
	Lead 12 mm	Lead 6 mm	Lead 12 mm	Lead 6 mm
EZS3	6.7	5.7	1.8	1.5
EZS4	9.6	13.7	2.6	3.7
EZS6	20.7	51.7	2.1	5.4

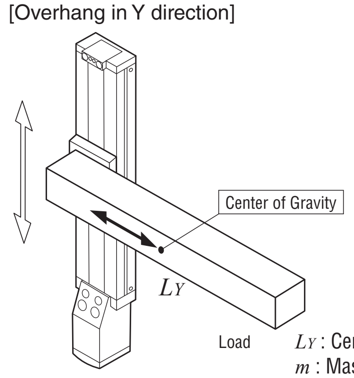
Downward:

Linear Slide Size	Strength Coefficient k		Downward Coefficient i	
	Lead 12 mm	Lead 6 mm	Lead 12 mm	Lead 6 mm
EZS3	5.3	3.1	−1.5	−0.9
EZS4	5.3	3.5	−1.5	−1.0
EZS6	11.2	12.2	−1.2	−1.3

◇ Overhang in Y-Axis Direction

$$V_Y\,[\text{mm/s}] = \left(\frac{k \times 10^3}{mL_Y} + i\right) \times 100$$

[Overhang in Y direction]



L_Y : Center of gravity of load [mm]
m : Mass of load [kg]

Upward:

Linear Slide Size	Strength Coefficient k		Upward Coefficient i	
	Lead 12 mm	Lead 6 mm	Lead 12 mm	Lead 6 mm
EZS3	0.7	0.6	1.8	1.5
EZS4	2.2	3.2	2.6	3.7
EZS6	8.3	20.8	2.1	5.4

Downward:

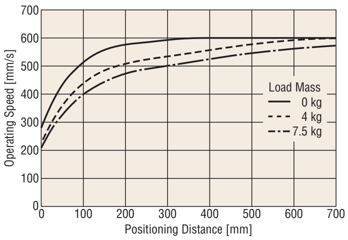
Linear Slide Size	Strength Coefficient k		Downward Coefficient i	
	Lead 12 mm	Lead 6 mm	Lead 12 mm	Lead 6 mm
EZS3	0.6	0.3	−1.5	−0.9
EZS4	1.2	0.8	−1.5	−1.0
EZS6	4.5	4.9	−1.2	−1.3

Positioning Distance – Operating Speed, Positioning Distance – Acceleration

●EZS3D□-K (Lead 12 mm, 24 VDC)

◇Horizontal Installation

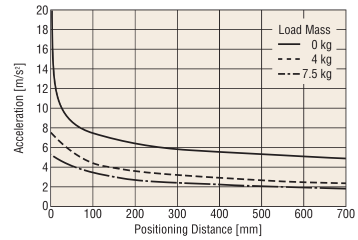
• Positioning Distance – Operating Speed



Maximum Speed by Stroke

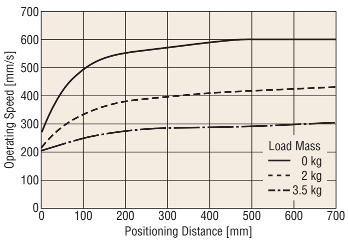
Stroke [mm]	Max. Speed [mm/s]
50~550	600
600	550
650	460
700	400

• Positioning Distance – Acceleration



◇Vertical Installation

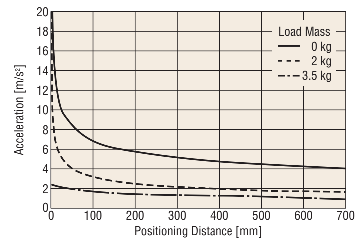
• Positioning Distance – Operating Speed



Maximum Speed by Stroke

Stroke [mm]	Max. Speed [mm/s]
50~550	600
600	550
650	460
700	400

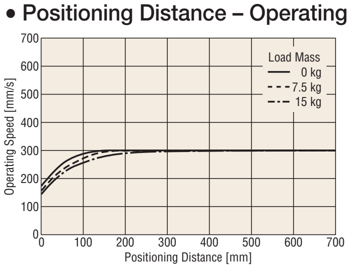
• Positioning Distance – Acceleration



●EZS3E□-K (Lead 6 mm, 24 VDC)

◇Horizontal Installation

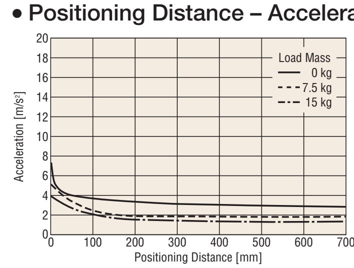
• Positioning Distance – Operating Speed



Maximum Speed by Stroke

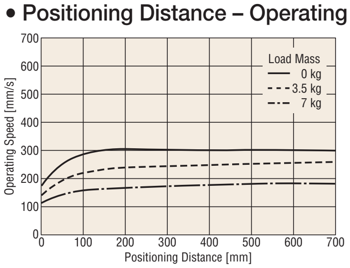
Stroke [mm]	Max. Speed [mm/s]
50~550	300
600	270
650	220
700	200

• Positioning Distance – Acceleration



◇Vertical Installation

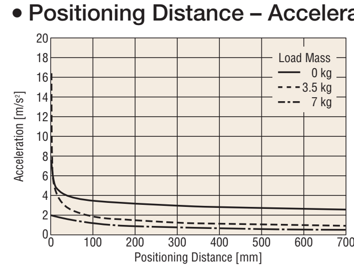
• Positioning Distance – Operating Speed



Maximum Speed by Stroke

Stroke [mm]	Max. Speed [mm/s]
50~550	300
600	270
650	220
700	200

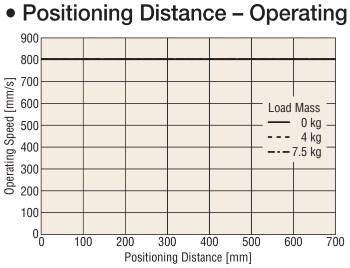
• Positioning Distance – Acceleration



●EZS3D□-A/EZS3D□-C (Lead 12 mm, Single-Phase 100-115 VAC/Single-Phase 200-230 VAC)

◇Horizontal Installation

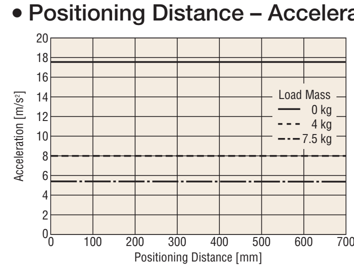
• Positioning Distance – Operating Speed



Maximum Speed by Stroke

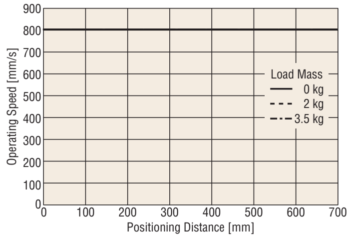
Stroke [mm]	Max. Speed [mm/s]
50~500	800
550	650
600	550
650	460
700	400

• Positioning Distance – Acceleration



◇Vertical Installation

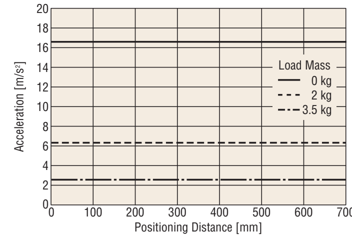
• Positioning Distance – Operating Speed



Maximum Speed by Stroke

Stroke [mm]	Max. Speed [mm/s]
50～500	800
550	650
600	550
650	460
700	400

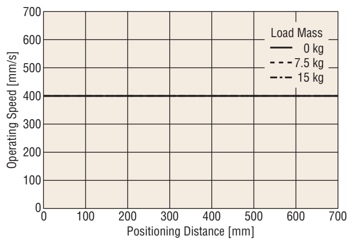
• Positioning Distance – Acceleration



●EZS3E□-A/EZS3E□-C (Lead 6 mm, Single-Phase 100-115 VAC/Single-Phase 200-230 VAC)

◇Horizontal Installation

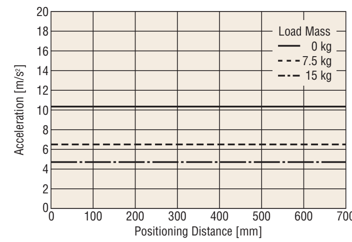
• Positioning Distance – Operating Speed



Maximum Speed by Stroke

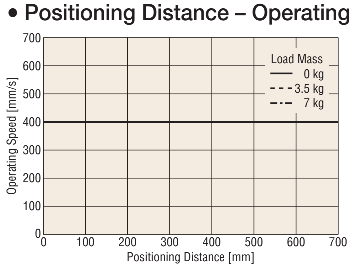
Stroke [mm]	Max. Speed [mm/s]
50～500	400
550	320
600	270
650	220
700	200

• Positioning Distance – Acceleration



◇Vertical Installation

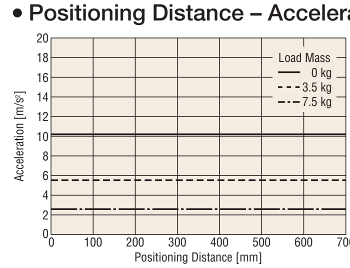
• Positioning Distance – Operating Speed



Maximum Speed by Stroke

Stroke [mm]	Max. Speed [mm/s]
50～500	400
550	320
600	270
650	220
700	200

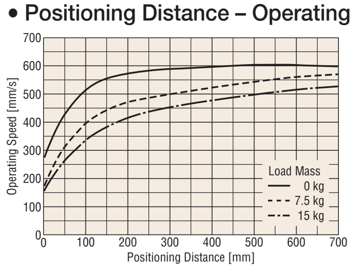
• Positioning Distance – Acceleration



●EZS4D□-K (Lead 12 mm, 24 VDC)

◇Horizontal Installation

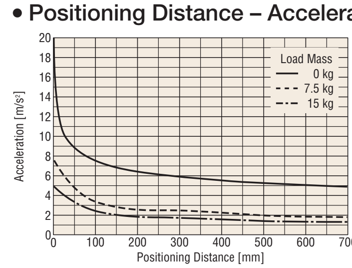
• Positioning Distance – Operating Speed



Maximum Speed by Stroke

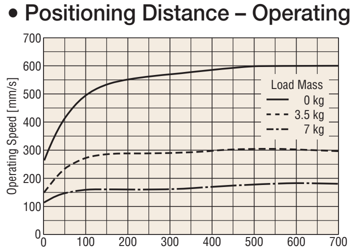
Stroke [mm]	Max. Speed [mm/s]
50～550	600
600	550
650	460
700	400

• Positioning Distance – Acceleration



◇Vertical Installation

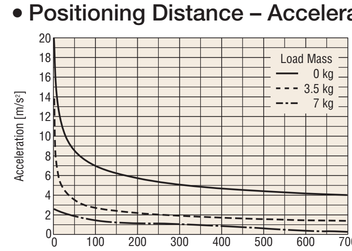
• Positioning Distance – Operating Speed



Maximum Speed by Stroke

Stroke [mm]	Max. Speed [mm/s]
50～550	600
600	550
650	460
700	400

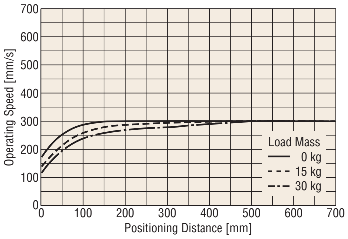
• Positioning Distance – Acceleration



●EZS4E□-K (Lead 6 mm, 24 VDC)

◇Horizontal Installation

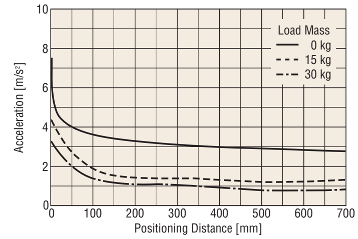
• Positioning Distance – Operating Speed



Maximum Speed by Stroke

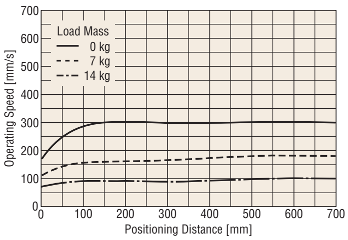
Stroke [mm]	Max. Speed [mm/s]
50~550	300
600	270
650	220
700	200

• Positioning Distance – Acceleration



◇Vertical Installation

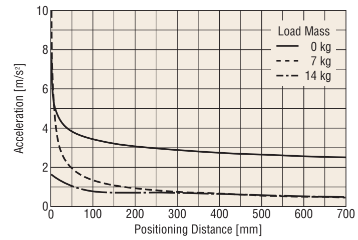
• Positioning Distance – Operating Speed



Maximum Speed by Stroke

Stroke [mm]	Max. Speed [mm/s]
50~550	300
600	270
650	220
700	200

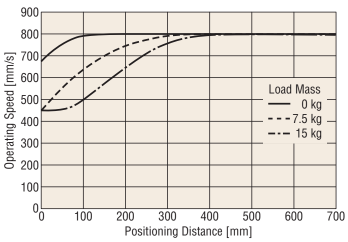
• Positioning Distance – Acceleration



●EZS4D□-A/EZS4D□-C (Lead 12 mm, Single-Phase 100-115 VAC/Single-Phase 200-230 VAC)

◇Horizontal Installation

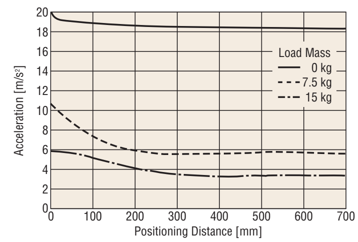
• Positioning Distance – Operating Speed



Maximum Speed by Stroke

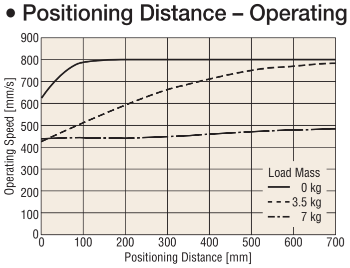
Stroke [mm]	Max. Speed [mm/s]
50~500	800
550	650
600	550
650	460
700	400

• Positioning Distance – Acceleration



◇Vertical Installation

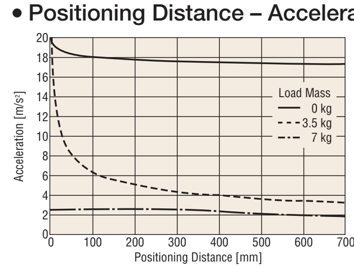
• Positioning Distance – Operating Speed



Maximum Speed by Stroke

Stroke [mm]	Max. Speed [mm/s]
50~500	800
550	650
600	550
650	460
700	400

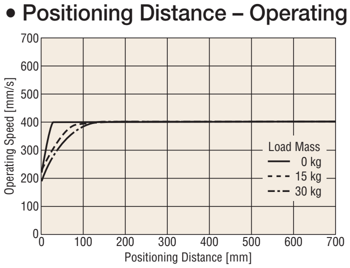
• Positioning Distance – Acceleration



●EZS4E□-A/EZS4E□-C (Lead 6 mm, Single-Phase 100-115 VAC/Single-Phase 200-230 VAC)

◇Horizontal Installation

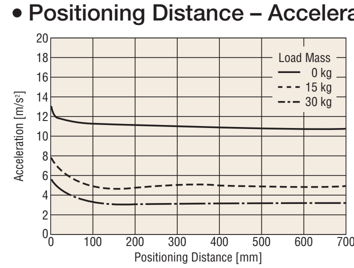
• Positioning Distance – Operating Speed



Maximum Speed by Stroke

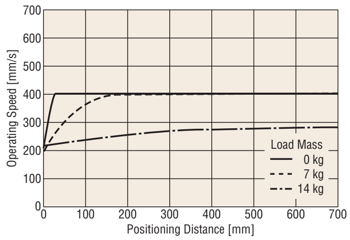
Stroke [mm]	Max. Speed [mm/s]
50~500	400
550	320
600	270
650	220
700	200

• Positioning Distance – Acceleration



◇Vertical Installation

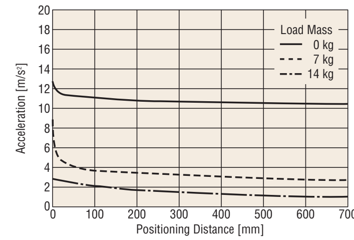
• Positioning Distance – Operating Speed



Maximum Speed by Stroke

Stroke [mm]	Max. Speed [mm/s]
50～500	400
550	320
600	270
650	220
700	200

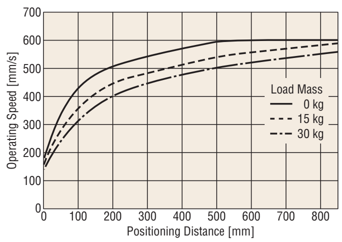
• Positioning Distance – Acceleration



● **EZS6D□-K** (Lead 12 mm, 24 VDC)

◇Horizontal Installation

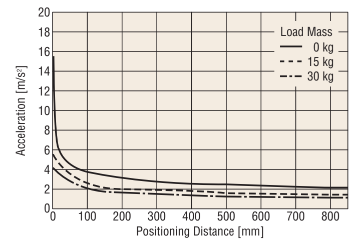
• Positioning Distance – Operating Speed



Maximum Speed by Stroke

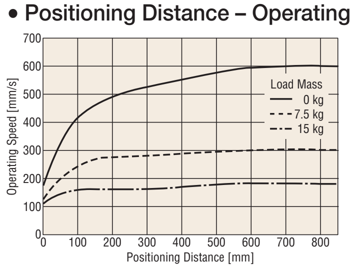
Stroke [mm]	Max. Speed [mm/s]
50～650	600
700	550
750	470
800	420
850	360

• Positioning Distance – Acceleration



◇Vertical Installation

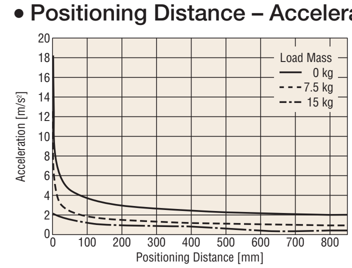
• Positioning Distance – Operating Speed



Maximum Speed by Stroke

Stroke [mm]	Max. Speed [mm/s]
50～650	600
700	550
750	470
800	420
850	360

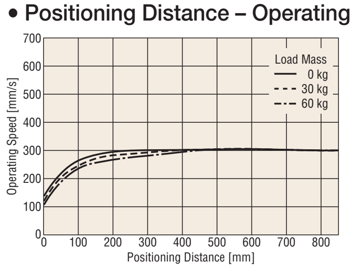
• Positioning Distance – Acceleration



● **EZS6E□-K** (Lead 6 mm, 24 VDC)

◇Horizontal Installation

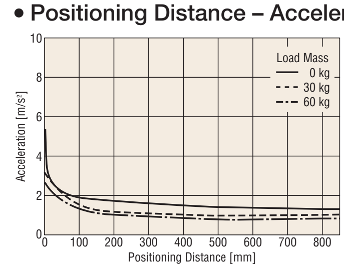
• Positioning Distance – Operating Speed



Maximum Speed by Stroke

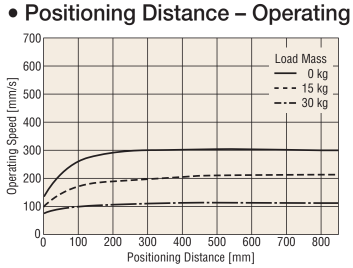
Stroke [mm]	Max. Speed [mm/s]
50～650	300
700	260
750	230
800	200
850	180

• Positioning Distance – Acceleration



◇Vertical Installation

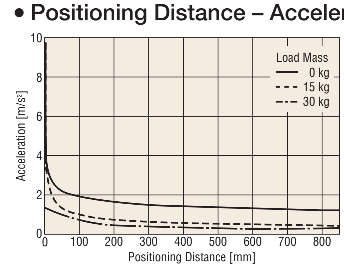
• Positioning Distance – Operating Speed



Maximum Speed by Stroke

Stroke [mm]	Max. Speed [mm/s]
50～650	300
700	260
750	230
800	200
850	180

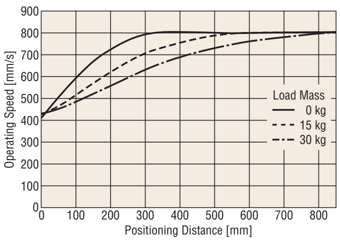
• Positioning Distance – Acceleration



●EZS6D□-A/EZS6D□-C (Lead 12 mm, Single-Phase 100-115 VAC/Single-Phase 200-230 VAC)

◇Horizontal Installation

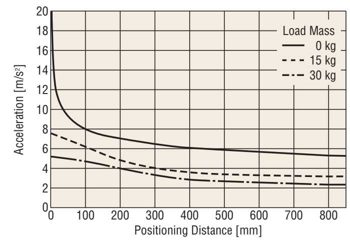
• Positioning Distance – Operating Speed



Maximum Speed by Stroke

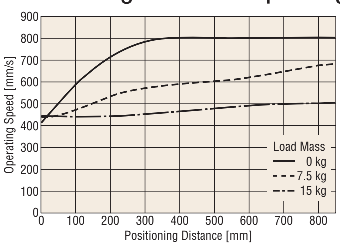
Stroke [mm]	Max. Speed [mm/s]
50～600	800
650	640
700	550
750	470
800	420
850	360

• Positioning Distance – Acceleration



◇Vertical Installation

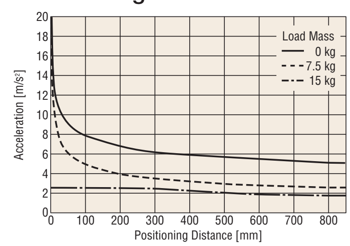
• Positioning Distance – Operating Speed



Maximum Speed by Stroke

Stroke [mm]	Max. Speed [mm/s]
50～600	800
650	640
700	550
750	470
800	420
850	360

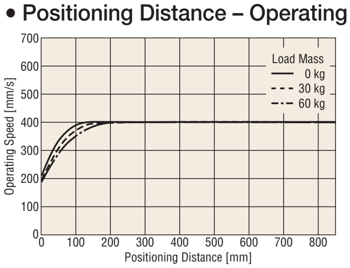
• Positioning Distance – Acceleration



●EZS6E□-A/EZS6E□-C (Lead 6 mm, Single-Phase 100-115 VAC/Single-Phase 200-230 VAC)

◇Horizontal Installation

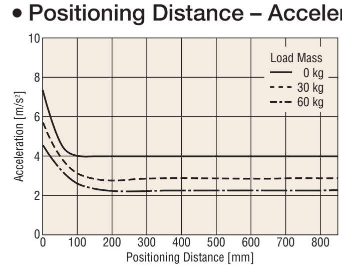
• Positioning Distance – Operating Speed



Maximum Speed by Stroke

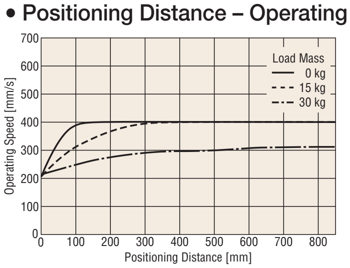
Stroke [mm]	Max. Speed [mm/s]
50～550	400
600	350
650	300
700	260
750	230
800	200
850	180

• Positioning Distance – Acceleration



◇Vertical Installation

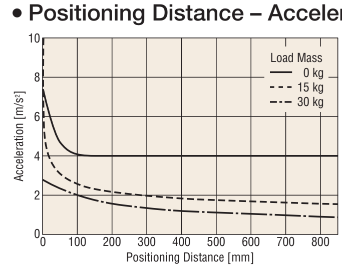
• Positioning Distance – Operating Speed



Maximum Speed by Stroke

Stroke [mm]	Max. Speed [mm/s]
50～550	400
600	350
650	300
700	260
750	230
800	200
850	180

• Positioning Distance – Acceleration



For Motorized Linear Slides Using Dual Axes Mounting Brackets

The following explains the calculation when using a dual axes mounting bracket dedicated to the **EZSII** Series. Required dual axes mounting bracket is determined by selecting any biaxial combination of the **EZSII** Series based on your conditions. You can select an optimum combination by following the procedure.

Selection Procedure

Check your conditions

▼

Select the combination of motorized linear slides
- Select the combination of motorized linear slides using the table of transportable mass per acceleration. Once the combination is determined, you can figure out required dual axes mounting bracket.

▼

Check the acceleration
Check the operating speed
- Find an acceleration from the table of transportable mass per acceleration, and check a speed of each axis in the speed – transportable mass characteristics graph.

▼

Check the positioning time
- Calculate a positioning time. Check if your preferred positioning time can be met.

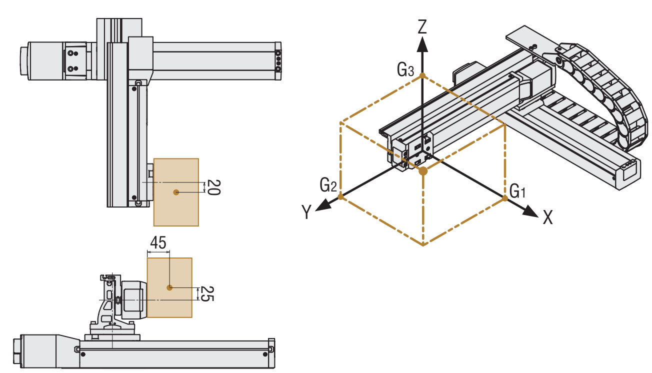
▼

Selection

Example of Selection

Follow the procedure for selection based on the following conditions.

[Conditions]
Load 3 kg mass in X-Y mounting with 100 mm in 0.5 s.
Moveable range is 500 mm in X-axis and 250 mm in Y-axis.
The center of gravity for load in Y-axis: (G_1, G_2, G_3) = (45, 20, 25)
Power supply voltage: 24 VDC input



(1) Select the Combination of Motorized Linear Slides and Dual Axes Mounting Bracket

Check the combination of motorized linear slides using the "transportable mass per acceleration" table (Refer to page F-22).
Find the maximum absolute value within G_1, G_2, G_3. As the conditions state $|G_1| = 45$ is the maximum value, check the table for center of gravity conditions of $30 < |G_n| \leqq 50$.
The following combination of linear slides can bear a mass of 3 kg with a 250 mm stroke.

[Combination 1] X-axis: **EZS6D** Y-axis: **EZS3D**
or
[Combination 2] X-axis: **EZS6D** Y-axis: **EZS4D**

Select [Combination 1] as the smaller product size.

The following products are tentatively selected.
X-axis: **EZS6D050-K**
Y-axis: **EZS3D025-K**
EZS6D is tentatively selected for the first axis, and **EZS3D** for the second. As the second axis stroke is 250 mm, and the combination pattern (Refer to page D-55) is **R**-type, the required dual axes mounting bracket can be determined as **PAB-S6S3R025**.

Transportable Mass per Acceleration

●X-Y Mounting　Y-axis transportable mass [kg]

		30< ǀGnǀ ≦ 50					
	Acceleration	Stroke [mm]					
		50	100	150	200	250	300
X-Axis: **EZS4D** Y-Axis: **EZS3D**	1.0 m/s²	2.0	1.6	1.3	1.0	0.7	0.4
	2.5 m/s²	1.1	0.8	0.5	0.2	–	–
	5.0 m/s²	0.3	–	–	–	–	–
	Acceleration	Stroke [mm]					
		50	100	150	200	250	300
X-Axis: **EZS6D** Y-Axis: **EZS3D**	1.0 m/s²	4.1	4.1	4.1	4.1	4.1	4.1
	2.5 m/s²	3.3	3.3	3.3	3.3	3.3	3.3
	5.0 m/s²	2.6	2.6	2.6	2.6	2.6	2.6
	Acceleration	Stroke [mm]					
		50	100	150	200	250	300
X-Axis: **EZS6D** Y-Axis: **EZS4D**	1.0 m/s²	8.7	8.7	8.7	8.1	7.0	6.0
	2.5 m/s²	7.0	7.0	7.0	6.3	5.3	4.5
	5.0 m/s²	5.3	5.3	5.2	4.3	3.6	2.9

●X-Y Mounting　Y-axis transportable mass [kg]

		30< ǀGnǀ ≦ 50					
	Acceleration	Stroke [mm]					
		50	100	150	200	250	300
X-Axis: **EZS6D** Y-Axis: **EZS3D**	1.0 m/s²	4.1	4.1	4.1	4.1	4.1	4.1
	2.5 m/s²	3.3	3.3	3.3	3.3	3.3	3.3
	5.0 m/s²	2.6	2.6	2.6	2.6	2.6	2.6

(2) Check the Acceleration of Linear Slides

Check an acceleration value from the "transportable mass per acceleration" table.
The maximum acceleration is 2.5 m/s² when a transportable mass is 3 kg.

(3) Check the Speed of Linear Slides

Check the "speed – transportable mass characteristics" graph (Refer to page F-23).
Draw a horizontal line for 3 kg mass in Y-axis.
The speed at which the acceleration 2.5 m/s² line intersects with the above-mentioned line is the maximum speed (upper limit) for dual axes combined configuration.

X-axis speed: 460 mm/s or less
Y-axis speed: 560 mm/s or less

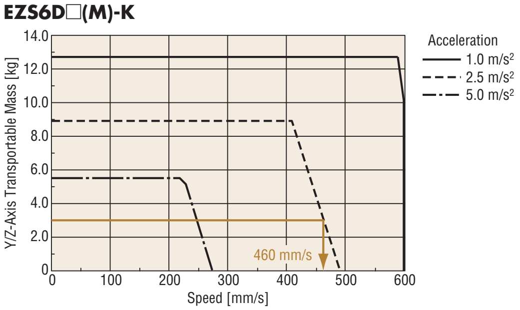
Speed and acceleration can be increased for the same mass, by replacing the power supply with single-phase 100-115 VAC/single-phase 200-230 VAC and/or by using linear slides with greater size.

Speed – Transportable Mass Characteristics

●X-Axis Speed

◇24 VDC

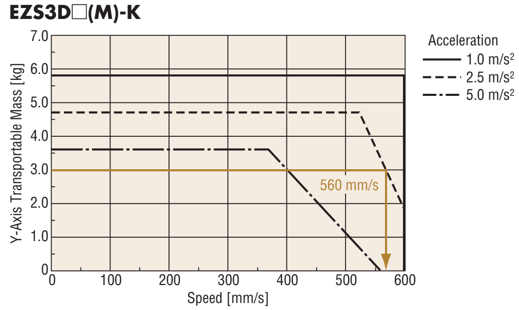
EZS6D□(M)-K



●Y-Axis Speed

◇24 VDC

EZS3D□(M)-K



(4) Check the Positioning Time

Make a simple calculation of the positioning time to verify if your preferred positioning time can be met.
The simple formulas are as follows:

① Check the operating pattern

$$V_{Rmax} = \sqrt{L \cdot a \times 10^3}$$

$V_{Rmax} \leqq V_R$ → Triangular drive

$V_{Rmax} > V_R$ → Trapezoidal drive

② Calculate the positioning time

Triangular drive

$$T = \frac{2 \cdot V_{Rmax}}{a \times 10^3} \quad \text{or} \quad T = \sqrt{\frac{L}{a \times 10^3}} \times 2$$

L : Positioning distance [mm]
a : Acceleration [m/s²]
V_R : Operating speed [mm/s]
V_{Rmax} : Maximum speed for triangular drive [mm/s]
T : Positioning time [s]

Trapezoidal drive

$$T = \frac{L}{V_R} + \frac{V_R}{a \times 10^3}$$

●Example of Calculation

Check if the combination on page F-20 can move 100 mm in 0.5 s.

◇X-Axis: EZS6D050-K

Conditions Speed V_R : 460 mm/s
Acceleration a : 2.5 mm/s²
Positioning distance L : 100 mm

Check the operating pattern $V_{Rmax} = \sqrt{100 \times 2.5 \times 10^3}$

$= 500 > V_R$ Trapezoidal drive

Calculate the positioning time $T = \dfrac{100}{460} + \dfrac{460}{2.5 \times 10^3}$

$= 0.401$ s

Calculation revealed that the preferred positioning time can be met.

◇Y-Axis: EZS3D025-K

Conditions Speed V_R : 560 mm/s
Acceleration a : 2.5 mm/s²
Positioning distance L : 100 mm

Check the operating pattern $V_{Rmax} = \sqrt{100 \times 2.5 \times 10^3}$

$= 500 \leqq V_R$ Triangular drive

Calculate the positioning time $T = \dfrac{2 \times 500}{2.5 \times 10^3}$

$= 0.400$ s

■Transportable Mass per Acceleration

●X-Y Mounting Y-axis transportable mass [kg]

		|Gn|≦30 [mm]						30<|Gn|≦50 [mm]						50<|Gn|≦100 [mm]					
X-Axis: **EZS4D** Y-Axis: **EZS3D**	Acceleration	Stroke [mm]						Stroke [mm]						Stroke [mm]					
		50	100	150	200	250	300	50	100	150	200	250	300	50	100	150	200	250	300
	1.0 m/s²	2.3	1.9	1.5	1.1	0.7	0.4	2.0	1.6	1.3	1.0	0.7	0.4	1.5	1.2	1.0	0.7	0.5	0.3
	2.5 m/s²	1.3	0.9	0.6	0.2	–	–	1.1	0.8	0.5	0.2	–	–	0.8	0.6	0.4	0.2	–	–
	5.0 m/s²	0.3	–	–	–	–	–	0.3	–	–	–	–	–	0.2	–	–	–	–	–
X-Axis: **EZS6D** Y-Axis: **EZS3D**	Acceleration	Stroke [mm]						Stroke [mm]						Stroke [mm]					
		50	100	150	200	250	300	50	100	150	200	250	300	50	100	150	200	250	300
	1.0 m/s²	5.8	5.8	5.8	5.8	5.8	5.8	4.1	4.1	4.1	4.1	4.1	4.1	2.3	2.3	2.3	2.3	2.3	2.3
	2.5 m/s²	4.8	4.8	4.8	4.8	4.8	4.8	3.3	3.3	3.3	3.3	3.3	3.3	1.9	1.9	1.9	1.9	1.9	1.9
	5.0 m/s²	3.6	3.6	3.6	3.6	3.6	3.6	2.6	2.6	2.6	2.6	2.6	2.6	1.5	1.5	1.5	1.5	1.5	1.5
X-Axis: **EZS6D** Y-Axis: **EZS4D**	Acceleration	Stroke [mm]						Stroke [mm]						Stroke [mm]					
		50	100	150	200	250	300	50	100	150	200	250	300	50	100	150	200	250	300
	1.0 m/s²	12.7	12.4	10.4	8.9	7.6	6.5	8.7	8.7	8.7	8.1	7.0	6.0	4.8	4.8	4.8	4.8	4.8	4.8
	2.5 m/s²	10.1	9.8	8.2	6.9	5.8	4.9	7.0	7.0	7.0	6.3	5.3	4.5	3.9	3.9	3.9	3.9	3.9	3.8
	5.0 m/s²	7.5	7.1	5.8	4.7	3.9	3.1	5.3	5.3	5.2	4.3	3.6	2.9	3.0	3.0	3.0	3.0	3.0	2.5

●X-Z Mounting Z-axis transportable mass [kg]

		|Gn|≦30 [mm]						30<|Gn|≦50 [mm]						50<|Gn|≦100 [mm]					
X-Axis: **EZS4D** Y-Axis: **EZS3D**	Acceleration	Stroke [mm]						Stroke [mm]						Stroke [mm]					
		50	100	150	200	250	300	50	100	150	200	250	300	50	100	150	200	250	300
	1.0 m/s²	3.5	3.3	3.0	2.7	2.5	2.2	2.6	2.6	2.5	2.3	2.0	1.8	1.6	1.6	1.6	1.6	1.5	1.3
	2.5 m/s²	2.1	1.7	1.4	1.0	0.7	0.4	1.7	1.4	1.2	0.9	0.6	0.4	1.2	1.0	0.8	0.7	0.5	0.3
	5.0 m/s²	0.7	0.3	–	–	–	–	0.5	0.3	–	–	–	–	0.4	0.2	–	–	–	–
X-Axis: **EZS6D** Y-Axis: **EZS3D**	Acceleration	Stroke [mm]						Stroke [mm]						Stroke [mm]					
		50	100	150	200	250	300	50	100	150	200	250	300	50	100	150	200	250	300
	1.0 m/s²	3.5	3.5	3.5	3.5	3.5	3.5	2.6	2.6	2.6	2.6	2.6	2.6	1.6	1.6	1.6	1.6	1.6	1.6
	2.5 m/s²	3.1	3.1	3.1	3.1	3.1	3.1	2.3	2.3	2.3	2.3	2.3	2.3	1.4	1.4	1.4	1.4	1.4	1.4
	5.0 m/s²	2.2	2.2	2.2	2.2	2.2	2.2	1.9	1.9	1.9	1.9	1.9	1.9	1.1	1.1	1.1	1.1	1.1	1.1
X-Axis: **EZS6D** Y-Axis: **EZS4D**	Acceleration	Stroke [mm]						Stroke [mm]						Stroke [mm]					
		50	100	150	200	250	300	50	100	150	200	250	300	50	100	150	200	250	300
	1.0 m/s²	6.7	6.7	6.7	6.7	6.7	6.7	4.9	4.9	4.9	4.9	4.9	4.9	3.0	3.0	3.0	3.0	3.0	3.0
	2.5 m/s²	5.9	5.9	5.9	5.9	5.9	5.9	4.3	4.3	4.3	4.3	4.3	4.3	2.6	2.6	2.6	2.6	2.6	2.6
	5.0 m/s²	4.9	4.9	4.9	4.9	4.9	4.9	3.6	3.6	3.6	3.6	3.6	3.6	2.2	2.2	2.2	2.2	2.2	2.2

●Gn represents the distance from table to center of gravity of the load (unit: mm).

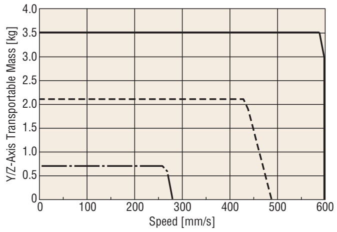
■Speed – Transportable Mass Characteristics

●X-Axis Speed (Common to electromagnetic brake type)*

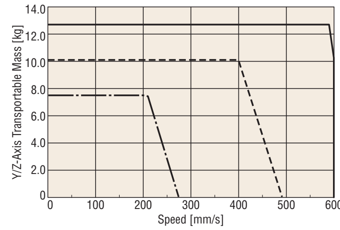
Acceleration
—— 1.0 m/s² - - - 2.5 m/s² —·— 5.0 m/s²

◇24 VDC

EZS4D□(M)-K

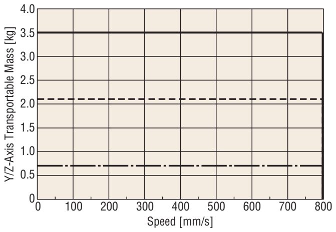


EZS6D□(M)-K

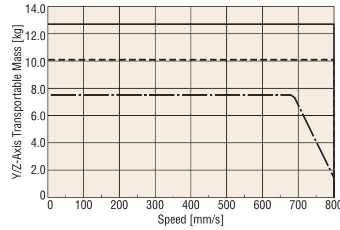


◇Single-Phase 100-115 VAC/Single-Phase 200-230 VAC

EZS4D□(M)-A/EZS4D□(M)-C



EZS6D□(M)-A/EZS6D□(M)-C



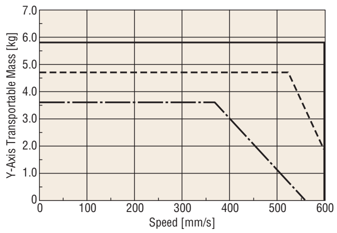
*For X-axis, the maximum speed read from the graph is limited by the stroke. Check the maximum speed for each stroke in EZSII Series products.

●Y-Axis Speed (Common to electromagnetic brake type)

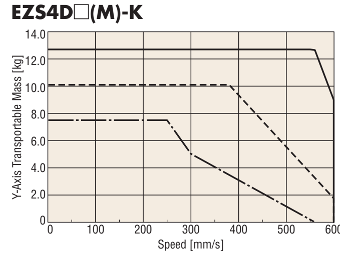
Acceleration
—— 1.0 m/s² - - - 2.5 m/s² —·— 5.0 m/s²

◇24 VDC

EZS3D□(M)-K

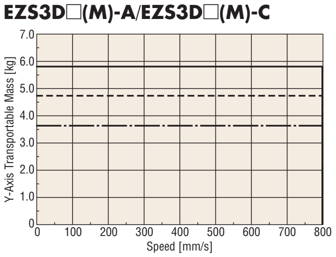


EZS4D□(M)-K

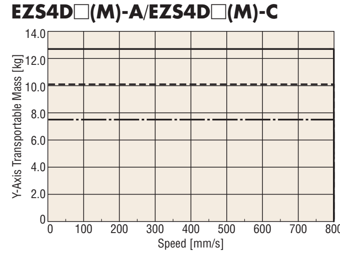


◇Single-Phase 100-115 VAC/Single-Phase 200-230 VAC

EZS3D□(M)-A/EZS3D□(M)-C



EZS4D□(M)-A/EZS4D□(M)-C



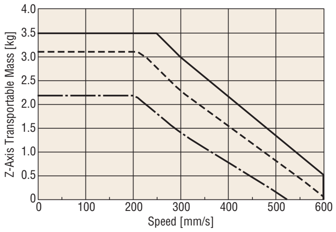
●Enter the stroke in the box (□) within the model name.

●Z-Axis Speed (Common to electromagnetic brake type)

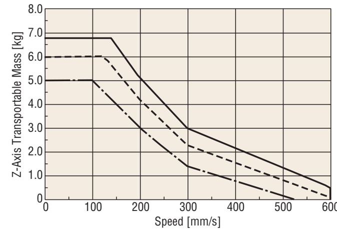
Acceleration
—— 1.0 m/s² - - - 2.5 m/s² –·– 5.0 m/s²

◇24 VDC

EZS3D□(M)-K

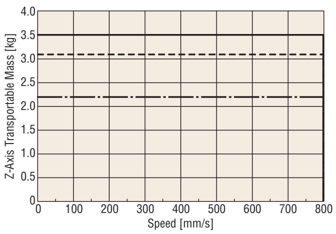


EZS4D□(M)-K

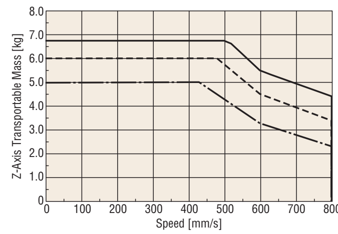


◇Single-Phase 100-115 VAC/Single-Phase 200-230 VAC

EZS3D□(M)-A/EZS3D□(M)-C



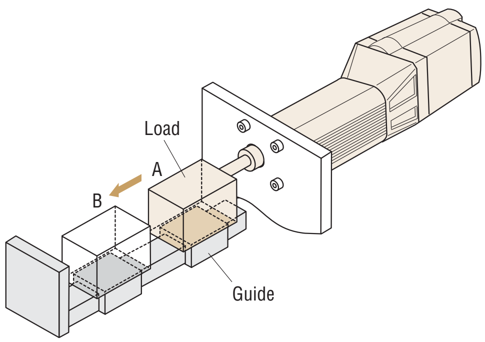
EZS4D□(M)-A/EZS4D□(M)-C



●Enter the stroke in the box (□) within the model name.

Motorized Cylinders

The parameters listed below are required when selecting motorized cylinders for transferring a load from A to B, as shown below.



The required parameters are as follows:

- Mass of load (m) or thrust force (F)
- Positioning distance (L)
- Positioning time (T)
- Repetitive positioning accuracy
- Maximum stroke

Among the above parameters, the thrust force and positioning time can be calculated using the formula shown below.

●Calculate the Thrust Force

The specified maximum thrust force indicates the value when no load is added to the rod, which is operating at a constant speed. In an application where an external force is pushed or pulled, it is general that the load mounted to the rod receives an external force. The method to check the thrust force in this application is explained below:

① Calculate the required thrust force when accelerating the load mounted to the rod.

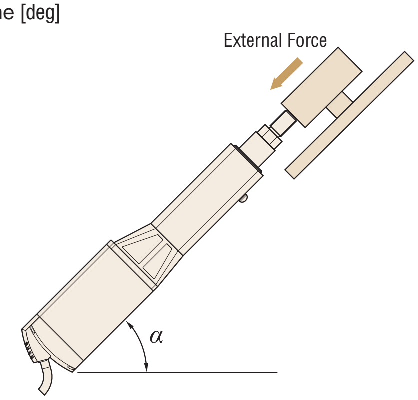
$$F_a = m \times \{a + g \times (\mu \times \cos\alpha + \sin\alpha)\}$$

② Calculate the thrust force that allows for pushing or pulling

$$F = F_{max} - F_a$$

If the external force applied to the load is smaller than F, then push-pull motion is enabled.

- F_{max} : Maximum thrust force of the motorized cylinder [N]
- F_a : Required thrust force during acceleration/deceleration operation [N]
- F : Thrust force that allows for pushing or pulling of external force [N]
- m : Mass of load mounted to the rod [kg]
- a : Acceleration [m/s²]
- g : Gravitational acceleration 9.807 [m/s²]
- μ : Friction coefficient of the guide supporting the load 0.01
- α : Angle formed by the traveling direction and the horizontal plane [deg]

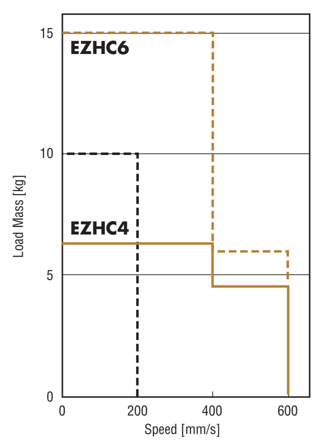


●Calculate the Positioning Time

Check to see if the motorized cylinders can perform the specified positioning within the specified time. This can be checked by determining a rough positioning time from a graph or by obtaining a fairly accurate positioning time by calculation. The respective check procedures are explained below.
The obtained positioning time should be used only as a reference, since there is always a small margin of error with respect to the actual operation time.

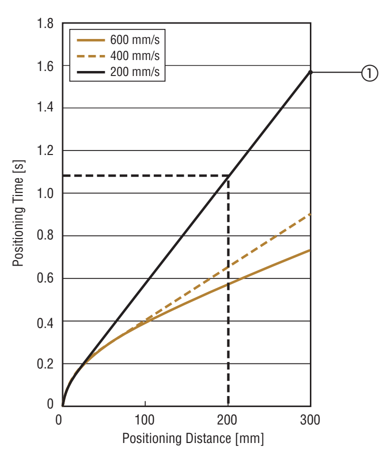
Obtaining from a Graph

In this section, the **EZHC** series will be used as an example.
For the **EZHC**, **EZC**, and **EZHP** Series, the speed will change depending on the mass of the load being transferred. The target load mass and speed must be confirmed using the graph shown in the catalog.



If the load mass is 10 kg and the speed is 200 mm/s, it will be **EZHC6**.

Example) Position a 10 kg load over a distance of 200 mm at the speed of 200 mm/s within 1.5 second via vertical drive, using **EZHC6A-30MA** (tentative selection).
Check line ① on the **EZHC6A-30MA** graph.



The above graph shows that the load can be positioned over 200 mm within 1.5 second.
If the load mass is less than 10 kg, the positioning time can be shortened. Calculate the positioning time using the following formula.
However, for the motorized cylinder(s), the load generated by the guide mechanism will become unknown when used in combination with the customer's guide mechanism. Therefore, the load of the guide mechanism will be assumed to be 0 in this section.

Obtaining by Calculations

① Check the operating conditions
Check the following conditions:
Mounting direction, load mass, positioning distance, starting speed, acceleration, operating speed

② From the above operating conditions, check to see if the drive pattern constitutes a triangular drive or trapezoidal drive.
Calculate the maximum speed of triangular drive from the positioning distance, starting speed, acceleration and operating speed. If the calculated maximum speed is equal to or below the operating speed, the operation is considered a triangular drive. If the maximum speed exceeds the operating speed, the operation is considered a trapezoidal drive.

$$V_{Rmax} = \sqrt{\frac{2 \times a_1 \times a_2 \times L}{a_1 + a_2} \times 10^3 + V_S^2}$$

$V_{Rmax} \leqq V_R$ → Triangular drive

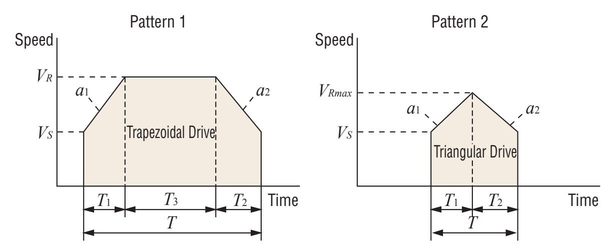
$V_{Rmax} > V_R$ → Trapezoidal drive

③ Calculate the positioning time
Trapezoidal drive

$$T = T_1 + T_2 + T_3$$
$$= \frac{V_R - V_S}{a_1 \times 10^3} + \frac{V_R - V_S}{a_2 \times 10^3} + \frac{L}{V_R} - \frac{(a_1 + a_2) \times (V_R^2 - V_S^2)}{2 \times a_1 \times a_2 \times V_R \times 10^3}$$

Triangular drive

$$T = T_1 + T_2$$
$$= \frac{V_{Rmax} - V_S}{a_1 \times 10^3} + \frac{V_{Rmax} - V_S}{a_2 \times 10^3}$$



V_{Rmax} : Calculated maximum speed of triangular drive [mm/s]
V_R : Operating speed [mm/s]
V_s : Starting speed [mm/s]
L : Positioning distance [mm]
a_1 : Acceleration [m/s²]
a_2 : Deceleration [m/s²]
T : Positioning time [s]
T_1 : Acceleration time [s]
T_2 : Deceleration time [s]
T_3 : Constant speed time [s]

Other conversion formula is explained below.
The pulse speed and operating speed can be converted to each other using the formula shown below. Keep the operating speed below the specified maximum speed:

$$\text{Pulse speed [Hz]} = \frac{\text{Operating speed [mm/s]}}{\text{Resolution [mm]}}$$

The number of operating pulses and movement can be converted to each other using the formula shown below:

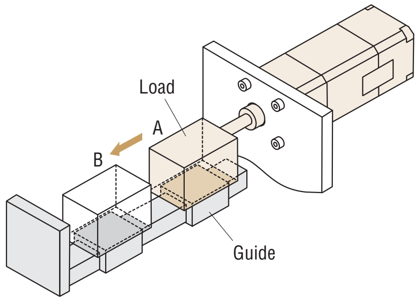
$$\text{Number of operating pulses [pulses]} = \frac{\text{Movement [mm]}}{\text{Resolution [mm]}}$$

The acceleration/deceleration rate and acceleration can be converted to each other using the formula shown below:

$$\text{Acceleration/deceleration rate [ms/kHz]} = \frac{\text{Resolution [mm]} \times 10^3}{\text{Acceleration [m/s}^2\text{]}}$$

Compact Linear Actuators (DRL Series)

The parameters listed below are required when selecting compact linear actuators for transferring a load from A to B, as shown below.



The required parameters are as follows:

- Mass of load (m) or thrust force (F)
- Positioning distance (L)
- Positioning time (T)

Among the above parameters, the thrust force and positioning time can be calculated using the formula shown below.

●Calculate the Thrust Force

The specified maximum thrust force indicates the value when no load is added to the screw shaft, which is operating at a constant speed.
In an application where an external force is pushed or pulled, it is general that the load receives an external force. The method to check the thrust force in this application is explained below:

① Calculate the required thrust force when accelerating the load

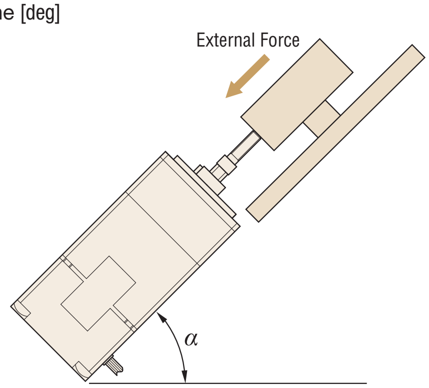
$$F_a = m \times \{a + g \times (\mu \times \cos\alpha + \sin\alpha)\}$$

② Calculate the thrust force that allows for pushing or pulling

$$F = F_{max} - F_a$$

If the external force applied to the load is smaller than F, then push-pull motion is enabled.

F_{max} : Maximum thrust force of the actuator [N]
F_a : Required thrust force during acceleration/deceleration operation [N]
F : Thrust force that allows for pushing or pulling of external force [N]
m : Mass of load [kg]
a : Acceleration [m/s^2]
g : Gravitational acceleration 9.807 [m/s^2]
μ : Friction coefficient of the guide supporting the load 0.01
α : Angle formed by the traveling direction and the horizontal plane [deg]

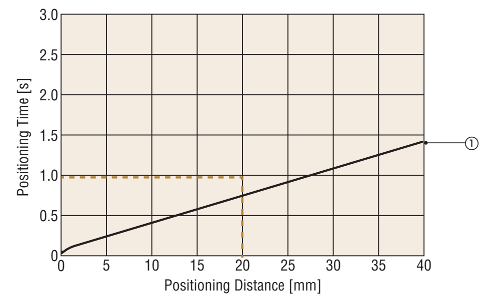


●Calculate the Positioning Time

Check to see if the actuators can perform the specified positioning within the specified time. This can be checked by determining a rough positioning time from a graph or by obtaining a fairly accurate positioning time by calculation. The respective check procedures are explained below.
The obtained positioning time should be used only as a reference, since there is always a small margin of error with respect to the actual operation time.

Obtaining from a Graph

Example) Position a 5 kg load over a distance of 20 mm within 1.0 second via vertical drive, using **DRL42PB2-04G** (tentative selection).
Check line ① on the **DRL42** graph.



The above graph shows that the load can be positioned over 20 mm within 1.0 second.
If the load mass is less than 10 kg, the positioning time can be shortened. Calculate the positioning time using the following formula.

Obtaining by Calculations

① Check the operating conditions
Check the following conditions:
Mounting direction, load mass, positioning distance, starting speed, acceleration, operating speed

② From the above operating conditions, check to see if the drive pattern constitutes a triangular drive or trapezoidal drive.
Calculate the maximum speed of triangular drive from the positioning distance, starting speed, acceleration and operating speed. If the calculated maximum speed is equal to or below the operating speed, the operation is considered a triangular drive. If the maximum speed exceeds the operating speed, the operation is considered a trapezoidal drive.

$$V_{Rmax} = \sqrt{\frac{2 \times a_1 \times a_2 \times L}{a_1 + a_2} \times 10^3 + V_S^2}$$

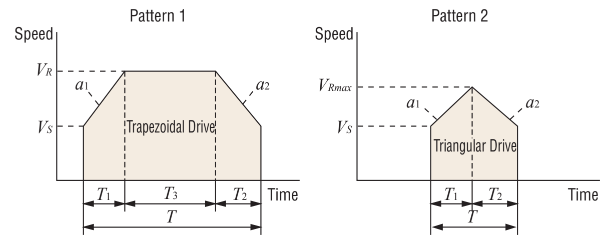
$V_{Rmax} \leqq V_R$ → Triangular drive
$V_{Rmax} > V_R$ → Trapezoidal drive

③ Calculate the positioning time
Trapezoidal drive

$$T = T_1 + T_2 + T_3$$
$$= \frac{V_R - V_S}{a_1 \times 10^3} + \frac{V_R - V_S}{a_2 \times 10^3} + \frac{L}{V_R} - \frac{(a_1 + a_2) \times (V_R^2 - V_S^2)}{2 \times a_1 \times a_2 \times V_R \times 10^3}$$

Triangular drive

$$T = T_1 + T_2$$
$$= \frac{V_{Rmax} - V_S}{a_1 \times 10^3} + \frac{V_{Rmax} - V_S}{a_2 \times 10^3}$$



V_{Rmax} : Calculated maximum speed of triangular drive [mm/s]
V_R : Operating speed [mm/s]
V_s : Starting speed [mm/s]
L : Positioning distance [mm]
a_1 : Acceleration [m/s^2]
a_2 : Deceleration [m/s^2]
T : Positioning time [s]
T_1 : Acceleration time [s]
T_2 : Deceleration time [s]
T_3 : Constant speed time [s]

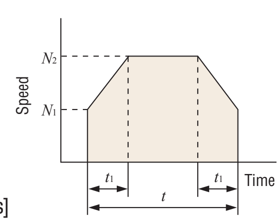
Hollow Rotary Actuators (DG Series)

The following sections describe the selection calculations for the **DG** Series.

●Calculate the Required Torque

① Calculate the inertia (load inertia) of the load.
Use less than 30 times the actuator inertia as a reference for the inertia of the load.
② Determine the positioning angle.
③ If there is no friction torque, check the positioning time from the load inertia – positioning time graph for the **DG** Series. Refer to page D-172 for the load inertia – positioning time graph.
④ Determine the positioning time and acceleration/deceleration time.
However, make sure that:
Positioning time ≧ shortest positioning time identified from the load inertia – positioning time graph
Acceleration/deceleration time $t_1 \times 2 \leqq$ positioning time
⑤ Determine the starting speed N_1, and calculate the operating speed N_2 using the following formula. Set N_1 to a low speed [0 to several r/min] but be careful not to increase it more than necessary.

$$N_2\,[\text{r/min}] = \frac{\theta \times 6N_1t_1}{6\,(t - t_1)}$$



N_2 : Operating speed [r/min]
θ : Positioning angle [deg]
N_1 : Starting speed [r/min]
t : Positioning time [s]
t_1 : Acceleration (deceleration) time [s]

If you cannot achieve $N_1 \leqq N_2 \leqq 200$ [r/min] with the above formula, return to ④ and review the conditions.
⑥ Calculate the acceleration torque using the following formula.

$$\text{Acceleration torque } T_a\,[\text{N·m}] = (J_1 + J_L) \times \frac{\pi}{30} \times \frac{(N_2 \times N_1)}{t_1}$$

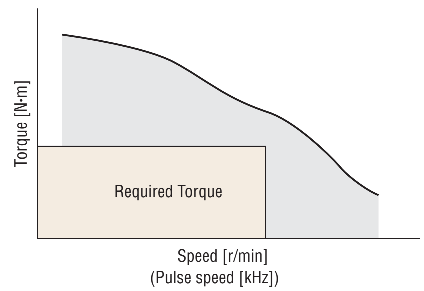
J_1 : Inertia of actuator [kg·m^2]
J_L : Total inertia [kg·m^2]
N_2 : Operating speed [r/min]
N_1 : Starting speed [r/min]
t_1 : Acceleration (deceleration) time [s]

⑦ Calculate the required torque. The required torque is equal to the load torque due to friction resistance plus the acceleration torque due to inertia, multiplied by the safety factor.

Required torque T = (load torque [N·m] + acceleration torque [N·m]) × safety factor
$= (T_L + T_a) \times S$

Set the safety factor S to at least 1.5.

⑧ Check whether the required torque T falls within the speed – torque characteristics. If the required torque does not fall within the range, return to ④ to change the conditions, and recalculate the value.



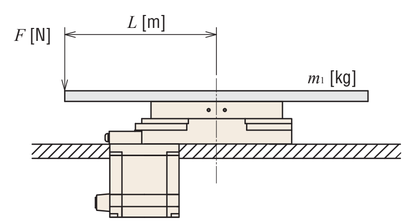
Use the following formula to convert the speed into a pulse speed.

$$f\,[\text{Hz}] = \frac{6N}{\theta s}$$

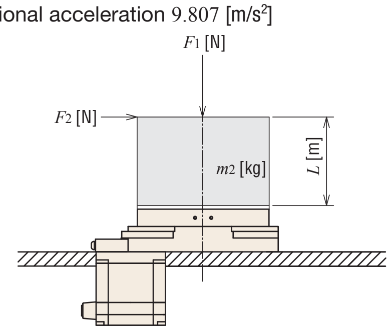
f : Pulse speed [Hz]
N : Speed [r/min]
θ_s : Output table step angle [deg/step]

●Calculate the Thrust Load and Moment Load

If the output table is subject to a load as indicated in the following diagram, use the formula below to calculate the thrust load and moment load, and check that the values are within the specified values.



Thrust load [N] $F_S = F + m_1 \times g$
Moment load [N·m] $M = F \times L$
g: Gravitational acceleration 9.807 [m/s^2]



Thrust load [N] $F_S = F_1 + m_2 \times g$
Moment load [N·m] $M = F_2 \times (L + a)$

Model	a
DG60	0.01
DG85	0.02
DG130	0.03
DG200	0.04

Selection Calculations

For Cooling Fans

Selection Procedure

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

●Specifications and Conditions of the Machinery

Determine the required internal temperature of the machinery.

●Heat Generation within the Device

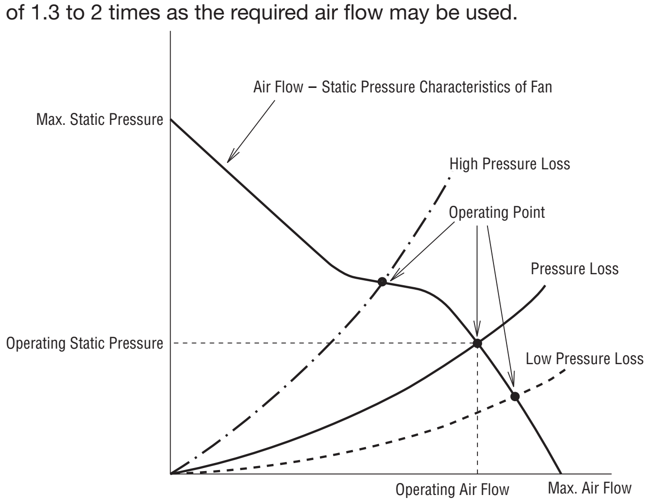
Determine the amount of heat generated internally by the machinery.

●Calculate Required Air Flow

Once you have determined the heat generation, 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 air flow – static pressure characteristics and the pressure loss of the machinery. It is difficult to calculate the pressure loss of the machinery, so the fan with a maximum air flow of 1.3 to 2 times as the required air flow may be used.



Air Flow – Static Pressure Characteristics

Fan Selection Procedure

Determine the requirements of the machinery
Determine how many degrees to lower the internal temperature based on the guaranteed operating temperatures of the internal components and elements of the machinery.

↓

Calculate the amount of heat produced
Calculate the amount of heat generated internally from the input/output of the machinery, efficiency, etc.

↓

Calculate the required air flow
Calculate the air flow required for desired temperature.

↓

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

Example of Selection – Ventilation and Cooling of Control Box

Specification of Control Box

Item		Letter	Specifications
Installation Environment			Factory Floor
Control Box	Size	*W* *H* *D*	Width 700 mm Height 1000 mm Depth 400 mm
	Surface Area	*S*	2.37 m²*
	Material		SPCC
	Overall Heat Transfer Coefficient	*U*	5 W/ (m²/K)
Permissible Temperature Rise		*ΔT*	20˚C Ambient temperature T_1: 25˚C Internal permissible temperature T_2: 45˚C
Total Heat Generation		*Q*	450 W
Power Supply			60 Hz 115 VAC

*Calculated by the formula below (assuming that all periphery is open) :
Surface of control box = side area + top area
$= 1.8 \times H \times (W + D) + 1.4 \times W \times D$

●Required Air Flow

The following explains a calculation method using the formula and a simple calculation method using the graph.

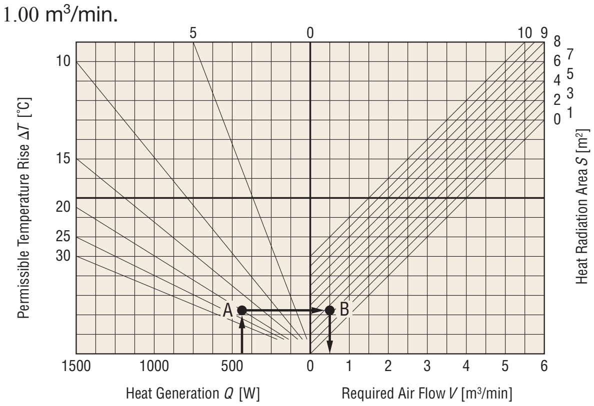
◇Obtaining by Calculations

$$V = 1 \div 20 \times (Q \div \Delta T - U \times S) \times Sf$$
$$= 1 \div 20 \times (450 \div 20 - 5 \times 2.37) \times 2$$
$$\fallingdotseq 1.07 \text{ [m}^3\text{/min]}$$

Internal pressure loss must be considered when calculating the required air flow.
In general, pressure loss inside the control box is not known. Therefore, the air flow at the operation point is assumed as 50% of the maximum air flow and a safety factor $Sf = 2$ is applied.

◇Obtaining by a Graph

① Search for the cross point A between heat generation Q (450 W) and permissible temperature rise ΔT (20˚C).
② Draw a line parallel with the horizontal axis from point A.
③ Search for the cross point B between the parallel line and surface area S (2.37 m²) line.
④ Draw a line perpendicular to the horizontal axis from point B. Required air flow is approximately 0.5 m³/min.
⑤ Allow for a safety factor (Sf) of 2 times. Required air flow will be 1.00 m³/min.



Graph to Determine Required Air Flow

●Applicable Fans

Based on the above, **FM** Series cooling module **FMB23BI-2H221** is selected.

FMB23BI-2H221 Specifications

Input Voltage VAC	Frequency Hz	Input W	Current A	Speed r/min	Max. Air Flow m^3/min	Max. Static Pressure Pa	Noise Level dB (A)
Single-Phase 115	60	14.0	0.18	2500	1.25	46	41

The **FM** Series is a cooling module integrated with an **MU** Series axial flow fan, filter and finger guard. Not only does the filter prevent ingress of foreign objects, but installation and maintenance are easy to perform, making it an optimal product for control box.