G

Technical Reference

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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 a simple body of rotation, a ball screw, a belt pulley, and a rack-and-pinion. Along with the type of drive mechanism, you must also determine the dimensions, mass and friction coefficient etc., that are required for the load calculation. The general items are explained below. • Dimensions and mass (or density) of load • Dimensions and mass (or density) of each part • Friction coefficient of the sliding surface of each moving part
▼	
Check the required specifications (Equipment specifications)	● Check the equipment specifications. The general items are explained below. • Operating speed and operating time • Positioning distance and positioning time • Resolution • Stopping accuracy • Position holding • Power supply voltage and frequency • Operating environment
▼	
Calculate the load	● Calculate the values for load torque and load inertia at the motor drive shaft. Refer to the left column on page G-3 for the calculation of load torque for representative mechanisms. Refer to the right column on page G-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 G-4 and subsequent pages.

Sizing and Selection Service

We provide sizing and selection services for motor selection for load calculations that require time and effort.

● FAX

Product recommendation information sheets are shown from pages H-20 to H-25. Fill in the necessary information on this sheet and send it to the nearest Oriental Motor sales office.

● Internet

Simple requests for motors can be made using the selection form on our website.
www.orientalmotor.com

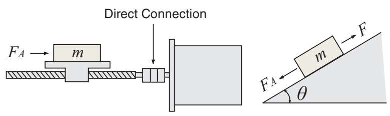
Calculate the Load Torque of Each Drive Mechanism T_L [N·m]

●Calculate the Load Torque

◇Ball Screw Drive

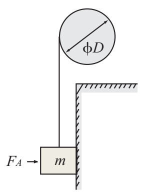
$$T_L = \left(\frac{F P_B}{2\pi\eta} + \frac{\mu_0 F_0 P_B}{2\pi} \right) \times \frac{1}{i} \text{ [N·m]} \quad \text{①}$$

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



◇Pulley Drive

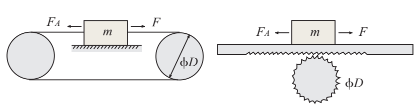
$$T_L = \frac{\mu F_A + mg}{2\pi} \times \frac{\pi D}{i} = \frac{(\mu F_A + mg)\,D}{2i} \text{ [N·m]} \quad \text{③}$$



◇Wire or Belt Drive, Rack and Pinion Drive

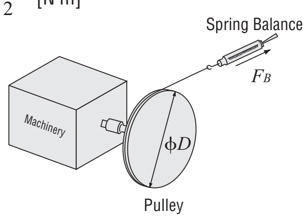
$$T_L = \frac{F}{2\pi\eta} \times \frac{\pi D}{i} = \frac{FD}{2\eta i} \text{ [N·m]} \quad \text{④}$$

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



◇By Actual Measurement

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



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] $\times$ g [m/s²])
m : Total mass of the table and load [kg]
μ : Friction coefficient of sliding surface (0.05)
θ : Tilt angle [deg]
D : Final pulley diameter [m]
g : Gravitational acceleration [m/s²] (9.807)

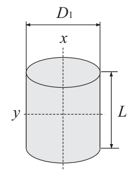
Calculate the Moment of Inertia J [kg·m²]

●Calculate the Moment of Inertia

◇Inertia of a Cylinder

$$J_x = \frac{1}{8} m D_1^2 = \frac{\pi}{32} \rho L D_1^4 \text{ [kg·m²]} \quad \text{⑦}$$

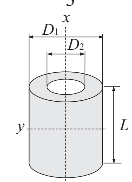
$$J_y = \frac{1}{4} m \left(\frac{D_1^2}{4} + \frac{L^2}{3} \right) \text{ [kg·m²]} \quad \text{⑧}$$



◇Inertia of a Hollow Cylinder

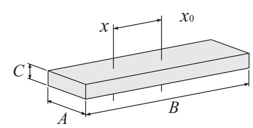
$$J_x = \frac{1}{8} m (D_1^2 + D_2^2) = \frac{\pi}{32} \rho L (D_1^4 - D_2^4) \text{ [kg·m²]} \quad \text{⑨}$$

$$J_y = \frac{1}{4} m \left(\frac{D_1^2 + D_2^2}{4} + \frac{L^2}{3} \right) \text{ [kg·m²]} \quad \text{⑩}$$



◇Inertia on Off-Center Axis

$$J_x = J_{x0} + ml^2 = \frac{1}{12} m (A^2 + B^2 + 12l^2) \text{ [kg·m²]} \quad \text{⑪}$$

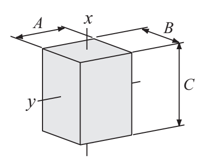


l : Distance between x and x_0 axes [m]

◇Inertia of a Rectangular Pillar

$$J_x = \frac{1}{12} m (A^2 + B^2) = \frac{1}{12} \rho ABC (A^2 + B^2) \text{ [kg·m²]} \quad \text{⑫}$$

$$J_y = \frac{1}{12} m (B^2 + C^2) = \frac{1}{12} \rho ABC (B^2 + C^2) \text{ [kg·m²]} \quad \text{⑬}$$



◇Inertia of an Object in Linear Motion

$$J = m \left(\frac{A}{2\pi} \right)^2 \text{ [kg·m²]} \quad \text{⑭}$$

A : Unit of movement [m/rev]

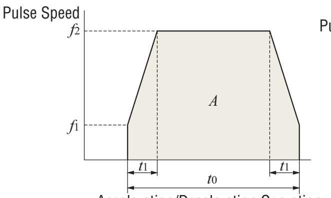
Density
Stainless $\rho = 8.0 \times 10^3$ [kg/m³]
Iron $\rho = 7.9 \times 10^3$ [kg/m³]
Aluminum $\rho = 2.8 \times 10^3$ [kg/m³]
Brass $\rho = 8.5 \times 10^3$ [kg/m³]
Nylon $\rho = 1.1 \times 10^3$ [kg/m³]
J_x : Inertia on x axis [kg·m²]
J_y : Inertia on y axis [kg·m²]
J_{x0}: Inertia on x_0 axis (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

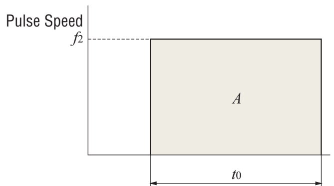
The following explains the calculation for selecting a stepping motor and servo motor based on pulse control:

●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.

$$A = \frac{l}{l\text{rev}} \times \frac{360°}{\theta s}$$

l : Movement distance from point A to B [m]
$l$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.)

$$t_1 = t_0 \times 0.25$$

$$f_2 = \frac{A - f_1 \cdot t_1}{t_0 - t_1}$$

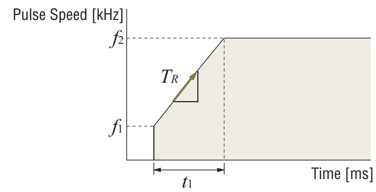
② For start/stop operation

$$f_2 = \frac{A}{t_0}$$

●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:

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



● Calculate the pulse speed in full-step equivalents.
● In this example, speed 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]

$$N_M = f_2 \times \frac{\theta s}{360} \times 60$$

●Calculate the Load Torque

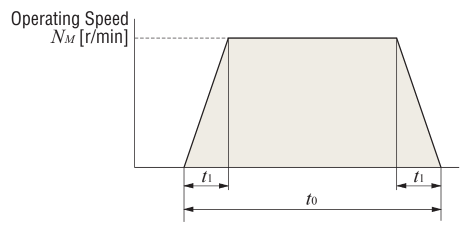
Refer to basic formulas on page G-3.

●Calculate the Acceleration Torque T_a [N·m]

If the motor speed is varied, the acceleration torque or deceleration torque must always be set.
The basic formula is the same for all motors. However, use the formulas below when calculating the acceleration torque for stepping motors on the basis of pulse speed.

[Common Basic Formula for All Motors]

$$T_a = \frac{(J_0 \times i^2 + J_L)}{9.55} \times \frac{N_M}{t_1}$$



Using Brushless Motors

J_0 : Rotor inertia [kg·m^2]
J_L : Total load inertia [kg·m^2]
N_M : Operating speed [r/min]
t_1 : Acceleration (deceleration) time [s]
i : Gear ratio

[When calculating the acceleration torque for stepping motors on the basis of pulse speed]
① For acceleration/deceleration operation

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

② For start/stop operation

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

●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.

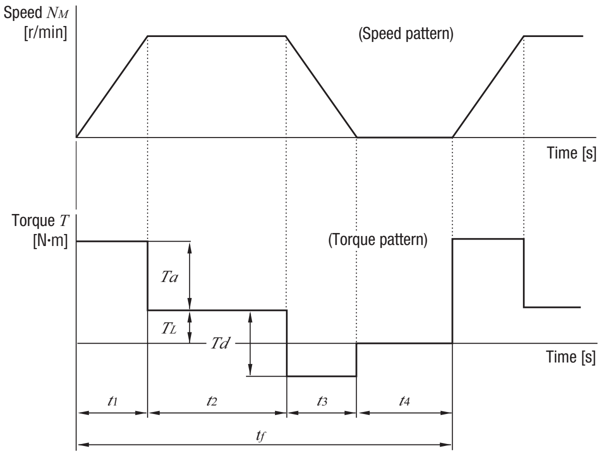
$$T_M = (T_L + T_a) \times S_f$$

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

●Formula for the Effective Load Torque T_{rms} [N·m]

Calculate the effective load torque when selecting the **BX** Series brushless motors and servo motors.
When the required torque for the motor varies over time, determine if the motor can be used by calculating the effective load torque.
The effective load torque becomes particularly important for operating patterns such as fast-cycle operations where acceleration/deceleration is frequent.

$$T_{rms} = \sqrt{\frac{(T_a + T_L)^2 \cdot t_1 + T_L{}^2 \cdot t_2 + (T_d - T_L)^2 \cdot t_3}{t_f}}$$



■Selection Points

There are differences in characteristics between standard AC motors, brushless motors, stepping motors and servo 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 C-18)

●Brushless Motors

① Permissible torque
Brushless motor combination types with a dedicated gearhead attached are listed on the permissible torque table based on the output gear shaft. Select products in which the load torque does not exceed the permissible torque.

② Permissible load inertia
A permissible load inertia is specified for the brushless motor for avoiding alarms using regenerative power during deceleration and for stable speed control. Ensure that the load inertia does not exceed the value of the permissible load inertia. For combination types, there are permissible load inertia combination types.
Select products with values that do not exceed the values of the combination types.

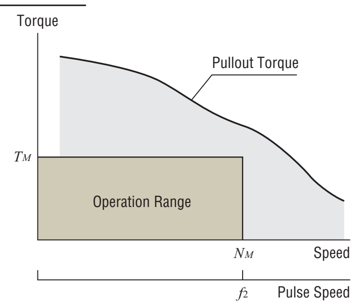
③ Effective load torque
For the **BX** Series, with its frequent starts and stops, make sure the effective load torque does not exceed the rated torque. If the rated torque is exceeded, the overload protective function triggers and stops the motor.

●Stepping Motors

① 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	2



② Check the duty cycle
A stepping motor is not intended to be run continuously.
It is suitable for an application the duty cycle represents rate of running time and stopping time of 50% or less.

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

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 [mm]	Acceleration/Deceleration Rate T_{RS} [ms/kHz]
αSTEP	28 (30), 42, 60, 85 (90)	0.5 Min.*
0.36°/0.72° Stepping Motors	20, 28 (30), 42, 60	20 Min.
	85 (90)	30 Min.
0.9°/1.8° Stepping Motors	20, 28 (30), 35, 42 50, 56.4, 60	50 Min.
	85 (90)	75 Min.

*This item need not be checked for αSTEP. The value in the table represents the lower limit of setting for the **EMP** Series
The acceleration/deceleration rates above apply even to geared type motors. However, the following conversion formula is required if a half-step system or microstep system is being used.

$$T_{RS} \cdot \frac{\theta_S}{\theta_B} \cdot i$$

T_{RS} : Acceleration/deceleration rate [ms/kHz]
θ_S : Microstepping step angle [deg]
θ_B : Refer to table below
i : Gear ratio of geared type

Coefficient

Product	θ_B
αSTEP	0.36°
0.72° stepping motor	0.72°
1.8° stepping motor	1.8°

④ 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.

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

when using a geared motor

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

Inertia Ratio (Reference values)

Product	Motor Frame Size [mm]	Inertia Ratio
αSTEP	28, 42, 60, 85	30 Max.
Stepping Motor	20, 28, 35	5 Max.
	42, 50, 56.4, 60, 85	10 Max.

●Except for geared types

When the inertia ratio exceeds the values in the table, we recommend a geared type.

●Servo Motors

① Permissible Load Inertia

A permissible load inertia is specified to enable stable control of the servo motor. Please select a load inertia that does not exceed this permissible value.

Product	Permissible Load Inertia
NX Series	50 times the rotor inertia or less*

✻Up to 50 times the rotor inertia can be supported with auto-tuning and up to 100 times with manual tuning.

② Rated Torque

The motor can be operated if the ratio between load torque T_L and the rated torque of the servo motor is 1.5 to 2 or higher.

$$\frac{\text{Rated torque}}{\text{Load torque}} \geqq 1.5\sim2$$

③ Maximum Instantaneous Torque

Confirm that the required torque is no higher than the maximum instantaneous torque of the servo motor (the safety factor S_f of the required torque should be 1.5 to 2).

Note, the amount of time the maximum instantaneous torque can be used varies depending on the motor.

Maximum instantaneous torque and operating time

Product	Operating Time	Maximum Instantaneous Torque
NX Series	Approximately 0.5 seconds or less	3 times the rated torque (at rated speed)

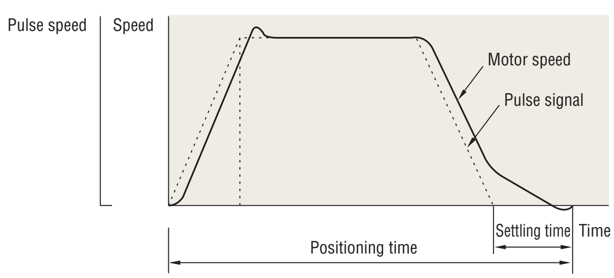
④ Effective Load Torque

The motor can be operated if the effective load safety factor, the ratio between effective load torque and the rated torque of the servo motor, is 1.5 to 2 or higher.

$$\text{Effective load safety factor} = \frac{\text{Rated torque}}{\text{Effective load torque}}$$

⑤ Settling Time

With servo motors, there is a lag between the position command from the pulse signal and actual operation of the motor. This difference is called the settling time. Therefore, this settling time added to the positioning time calculated from the operation pattern is the actual positioning time.



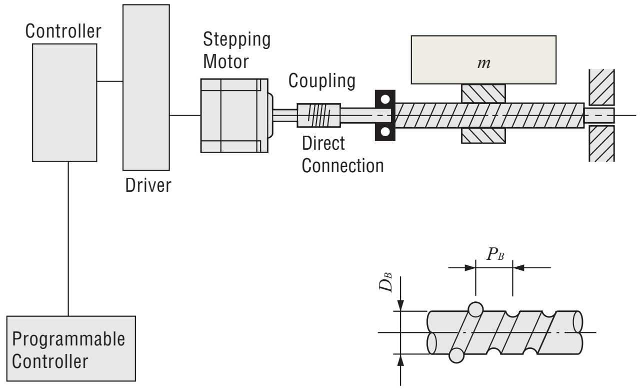
●The settling time at the time of shipment is 60 to 70 ms in the **NX** series. However, the settling time changes when the gain parameters are adjusted with the mechanical rigidity setting switch.

■Calculation Example

●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 .... $\theta = 0$ [deg]

(2) Calculate the Required Resolution θ_s

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

AR Series can be connected directly to the application.

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

① Calculate the number of operating pulses A [Pulse]

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

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

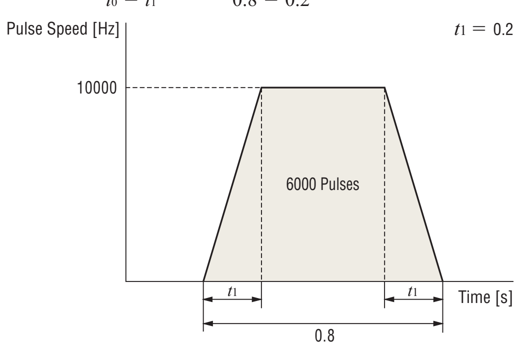
② Determine the acceleration (deceleration) time t_1 [s]

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]

$$N_M = f_2 \times \frac{\theta s}{360} \times 60 = 10000 \times \frac{0.72^\circ}{360} \times 60$$

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

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

① Calculate the load torque T_L [N·m]

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

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

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

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 G-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]

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

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

$$= 628 J_0 + 0.158 \text{ [N·m]}$$

③ Calculate the required torque T_M [N·m]

Safety factor $S_f = 2$

$$T_M = (T_L + Ta)\, S_f$$

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

$$= 1256 J_0 + 0.429 \text{ [N·m]}$$

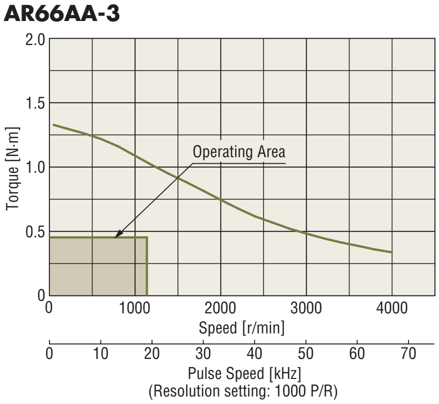
(5) Select a Motor

① Tentative motor selection

Model	Rotor Inertia [kg·m²]	Required Torque [N·m]
AR66AA-3	380×10^{-7}	0.48

② Determine the motor from the speed – torque characteristics

AR66AA-3



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.

(6) Check the Inertia Ratio (Refer to formula on page G-6)

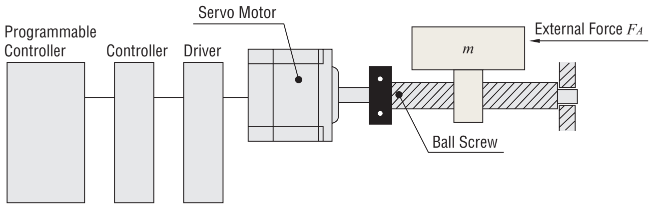
$$\frac{J_L}{J_0} = \frac{2.52 \times 10^{-4}}{380 \times 10^{-7}} \doteqdot 6.6$$

Since the inertia ratio of **AR66AA-3** is 30 or less, if the inertia ratio is 6.6 you can judge whether motor operation is possible.

Using Servo Motors

(1) Specifications and Operating Conditions of the Drive Mechanism

A servo motor for driving a single-axis table is selected, as shown in the figure below.



Max. speed of table .... $V_L = 0.2$ [m/s]
Resolution .... $\Delta l = 0.02$ [m/s]
Motor power supply .... Single-Phase 115 VAC
Total mass of table and load .... $m = 100$ [kg]
External force .... $F_A = 29.4$ [N]
Friction coefficient of sliding surface .... $\mu = 0.04$
Efficiency of ball screw .... $\eta = 0.9$
Internal friction coefficient of preload nut .... $\mu_0 = 0.3$
Ball screw shaft diameter .... $D_B = 25$ [mm]
Total length of ball screw .... $L_B = 1000$ [mm]
Ball screw lead .... $P_B = 10$ [mm]
Ball screw material .... Iron (density $\rho = 7.9 \times 10^3$ [kg/m³])
Operating cycle ... Operation for 2.1 sec./stopped for 0.4 sec. (repeated)
Acceleration/deceleration time .... $t_1 = t_3 = 0.1$ [s]

(2) Calculation of the Required Resolution θ

The resolution of the motor is calculated from the resolution required to drive the table.

$$\theta = \frac{360^\circ \cdot \Delta l}{P_B} = \frac{360^\circ \times 0.02}{10} = 0.72^\circ$$

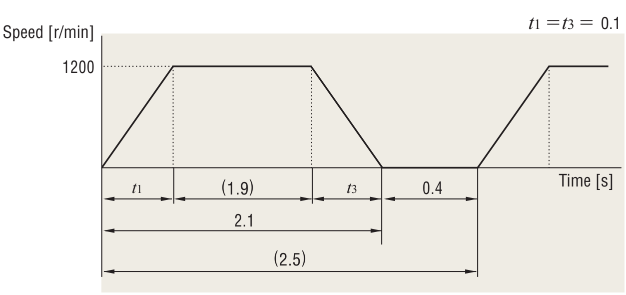
The resolution of the **NX** series, $\theta_M = 0.36^\circ$/pulse, satisfies this condition.

(3) Determination of Operating Pattern

The motor speed N_M is calculated using the following formula.

$$N_M = \frac{60 \cdot V_L}{P_B} = \frac{60 \times 0.2}{10 \times 10^{-3}} = 1200 \text{ [r/min]}$$

A speed pattern is created from this N_M and operating cycle, as well as the acceleration/deceleration time.



(4) Calculation of Load Torque T_L [N·m]

Force of moving direction

$$F = F_A + m \cdot g (\sin\theta + \mu \cdot \cos\theta)$$
$$= 29.4 + 100 \times 9.807 (\sin 0^\circ + 0.04 \cos 0^\circ)$$
$$= 68.6 \text{ [N]}$$

Load torque of motor shaft conversion

$$T_L = \frac{F \cdot P_B}{2\pi \cdot \eta} + \frac{\mu_0 \cdot F_0 \cdot P_B}{2\pi}$$
$$= \frac{68.6 \times 10 \times 10^{-3}}{2\pi \times 0.9} + \frac{0.3 \times 22.9 \times 10 \times 10^{-3}}{2\pi}$$
$$\fallingdotseq 0.13 \text{ [N·m]}$$

Here, the ball screw preload $F_0 = \frac{1}{3} F$.

(5) Calculation of Load Inertia J_L [kg·m²]

Inertia of ball screw

$$J_B = \frac{\pi}{32} \cdot \rho \cdot L_B \cdot D_B^4$$
$$= \frac{\pi}{32} \times 7.9 \times 10^3 \times 1000 \times 10^{-3} \times (25 \times 10^{-3})^4$$
$$\fallingdotseq 3.03 \times 10^{-4} \text{ [kg·m}^2\text{]}$$

Inertia of table and work

$$J_m = m \left(\frac{P_B}{2\pi}\right)^2$$
$$= 100 \times \left(\frac{10 \times 10^{-3}}{2\pi}\right)^2$$
$$\fallingdotseq 2.53 \times 10^{-4} \text{ [kg·m}^2\text{]}$$

Load inertia

$$J_L = J_B + J_m$$
$$= 3.03 \times 10^{-4} + 2.53 \times 10^{-4} = 5.56 \times 10^{-4} \text{ [kg·m}^2\text{]}$$

(6) Tentative Selection of Servo Motor

Safety factor $S_f = 1.5$

Load torque

$$T'_L = S_f \cdot T_L$$
$$= 1.5 \times 0.13 = 0.195 \text{ [N·m]}$$

Load inertia $J_L = 5.56 \times 10^{-4}$ [kg·m²]

This gives us a speed of 1200 [r/min], and a rated torque of 0.195 [N·m] or higher is output. A servo motor with a permissible load inertia of 5.56×10^{-4} [kg·m²] or higher is selected.

→ **NX620AA-3**

Rated speed $N = 3000$ [r/min]
Rated torque $T_M = 0.637$ [N·m]
Rotor inertia $J_0 = 0.162 \times 10^{-4}$ [kg·m²]
Permissible load inertia $J = 8.1 \times 10^{-4}$ [kg·m²]
Maximum instantaneous torque $T_{MAX} = 1.91$ [N·m]
The above values are appropriate.

(7) Calculation of Acceleration Torque Ta [N·m] and Deceleration Torque Td [N·m]

Acceleration/deceleration torque is calculated using the following formula.

$$T_a = (T_d) = \frac{(J_L + J_0) N_M}{9.55 t_1}$$
$$= \frac{(5.56 \times 10^{-4} + 0.162 \times 10^{-4}) \times 1200}{9.55 \times 0.1} \fallingdotseq 0.72 \text{ [N·m]}$$

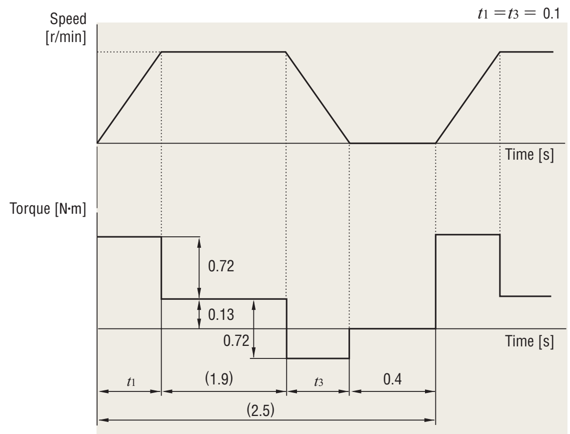
(8) Calculation of Required Torque T [N·m]

$$T = Ta + T_L$$
$$= 0.72 + 0.13 = 0.85 \text{ [N·m]}$$

This required torque can be used with **NX620AA-3** in order to keep the maximum instantaneous torque of **NX620AA-3** at 1.91 [N·m] or less.

(9) Determination of Torque Pattern

The torque pattern is determined with the operating cycle, acceleration/deceleration torque, load torque and acceleration time.



(10) Calculation of Effective Load Torque T_{rms} [N·m]

The effective load torque T_{rms} is determined with the torque pattern and the following formula.

$$T_{rms} = \sqrt{\frac{(T_a + T_L)^2 \cdot t_1 + T_L^2 \cdot t_2 + (T_d - T_L)^2 \cdot t_3}{t_f}}$$

$$= \sqrt{\frac{(0.72 + 0.13)^2 \times 0.1 + 0.13^2 \times 1.9 + (0.72 - 0.13)^2 \times 0.1}{2.5}}$$

$$\fallingdotseq 0.24 \text{ [N·m]}$$

Here, from the operating cycle, $t_1 + t_2 + t_3 = 2.1$ [s] and the acceleration/deceleration time $t_1 = t_3 = 0.1$. Based on this, $t_2 = 2.1 - 0.1 \times 2 = 1.9$ [s].

The ratio between this T_{rms} and the rated torque T_M of the servo motor (the effective load safety factor) is determined with the following formula.

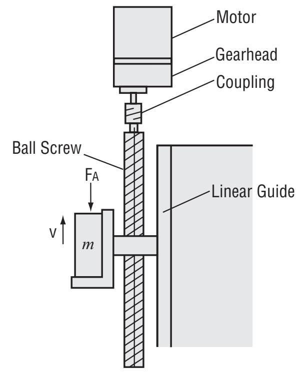
$$\frac{T_M}{T_{rms}} = \frac{0.637}{0.24} = 2.65$$

In general, a motor can operate at an effective load safety factor of 1.5 to 2.

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 $N_G = \frac{V \cdot 60}{A} = \frac{(15 \pm 2) \times 60}{5}$

$= 180 \pm 24$ [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 $i = \frac{1450 \sim 1550}{N_G} = \frac{1450 \sim 1550}{180 \pm 24} = 7.1 \sim 9.9$

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 $F_0 = \frac{F}{3} = 147$ [N]

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

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

$= 0.426$ [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 C-125.
Next, convert this load torque to a value on the motor output shaft to obtain the required torque T_M, as follows:

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

(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:

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

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·m²]

$$\text{Inertia of ball screw } J_B = \frac{\pi}{32} \cdot \rho \cdot L_B \cdot D_B^4$$
$$= \frac{\pi}{32} \times 7.9 \times 10^3 \times 800 \times 10^{-3} \times (20 \times 10^{-3})^4$$
$$= 0.993 \times 10^{-4} \text{ [kg·m}^2\text{]}$$

$$\text{Inertia of table and load } J_m = m \left(\frac{A}{2\pi}\right)^2$$
$$= 45 \left(\frac{5 \times 10^{-3}}{2\pi}\right)^2$$
$$= 0.286 \times 10^{-4} \text{ [kg·m}^2\text{]}$$

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

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

Here, permissible load inertia of gearhead **4GN9SA** (gear ratio $i = 9$) J_G is (Refer to page C-18):

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

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).

$$V = \frac{N_M \cdot P_B}{60 \cdot i} = \frac{1750 \times 5}{60 \times 9} = 16.2 \text{ [mm/s]}$$

N_M: Motor speed

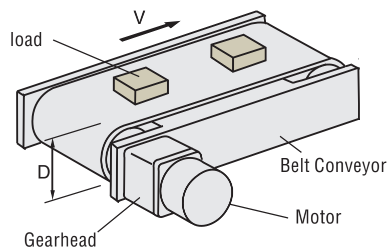
This confirms that the motor meets the specifications.
Based on the above, **4RK25GN-AW2MU** and **4GN9SA** are selected as the motor and gearhead, respectively.

●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]±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:

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

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

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 C-47.
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]

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

$$= 25 \times \left(\frac{\pi \times 90 \times 10^{-3}}{2\pi} \right)^2$$

$$= 507 \times 10^{-4} \text{ [kg·m}^2\text{]}$$

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

$$= \frac{1}{8} \times 1 \times (90 \times 10^{-3})^2$$

$$= 10.2 \times 10^{-4} \text{ [kg·m}^2\text{]}$$

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

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

Here, permissible load inertia of gearhead **5GE50SA** (gear ratio $i = 50$) J_G is (Refer to page C-18):

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

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 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.

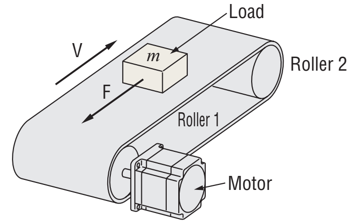


Fig. 1 Example of Belt Drive

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)

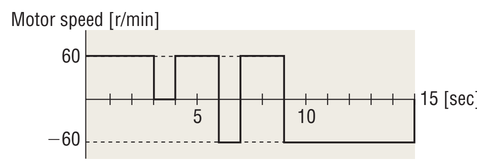


Fig. 2 Operating Pattern

Low-speed synchronous motors share the same basic operating principle with 1.8° stepping motors. Accordingly, the torque for a low-speed synchronous motor is calculated in the same manner as for a 1.8° 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 $F = F_A + m_1 \cdot g (\sin\theta + \mu \cdot \cos\theta)$

$$= 0 + 1.5 \times 9.807 (\sin 0^\circ + 0.04 \cos 0^\circ)$$
$$= 0.589 \text{ [N]}$$

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 $J_{m1} = m_1 \times \left(\frac{\pi D}{2\pi}\right)^2$

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

$$= 3.38 \times 10^{-4} \text{ [kg·m}^2\text{]}$$

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

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

$$= 0.113 \times 10^{-4} \text{ [kg·m}^2\text{]}$$

The load inertia J_L is calculated as follows:

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

(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)

$$\text{Required Torque } T_M = (T_L + T_a) \times 2$$
$$= (9.82 \times 10^{-3} + 905 \cdot J_0 + 0.32) \times 2$$
$$= 1810 \cdot J_0 + 0.66 \text{ [N·m]}$$

(7) Select a Motor

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

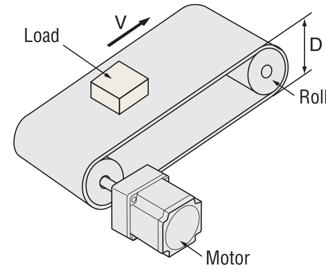
Motor	Rotor Inertia [kg·m²]	Permissible Load Inertia [kg·m²]	Output Torque [N·m]
SMK5100A-AA	1.4×10^{-4}	7×10^{-4}	1.12

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.

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 D-67 so that the minimum/maximum speed falls within the speed range.

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

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

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

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

$$\text{Inertia of belt and load } J_{m1} = m_1 \left(\frac{\pi \cdot D}{2\pi}\right)^2 = 7 \times \left(\frac{\pi \times 0.1}{2\pi}\right)^2$$
$$= 175 \times 10^{-4} \text{ [kg·m}^2\text{]}$$

$$\text{Inertia of roller } J_{m2} = \frac{1}{8} \cdot m_2 \cdot D^2$$
$$= \frac{1}{8} \times 1 \times 0.1^2 = 12.5 \times 10^{-4} \text{ [kg·m}^2\text{]}$$

The load inertia J_G is calculated as follows:

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

From the specifications on page D-69, the permissible load inertia of **BLF5120A-15** is 225×10^{-4} [kg·m²].

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

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

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

Select **BLF5120A-15** from the "Gearmotor – Torque Table of Combination Type" on page D-67.

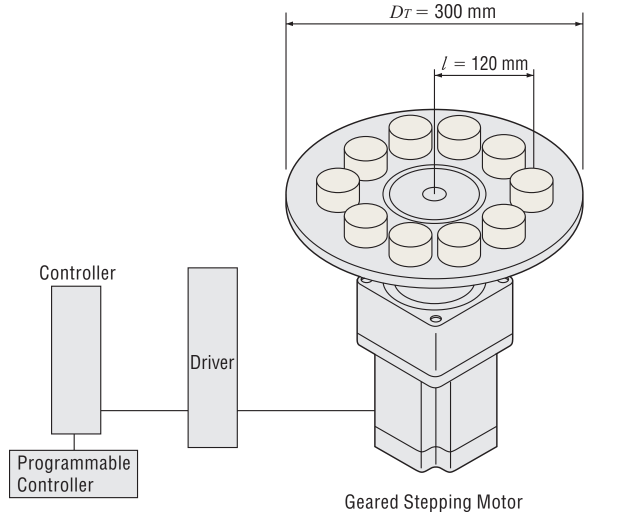
Since the permissible torque is 5.4 N·m, the safety factor is $T_M / T_L = 5.4 / 1.15 \fallingdotseq 4.6$.

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

●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 .... $L_T = 5$ [mm]
Load diameter .... $D_W = 40$ [mm]
Load thickness .... $L_W = 30$ [mm]
Material of table .... Aluminum (density $\rho = 2.8 \times 10^3$ [kg/m³])
Number of loads .... 10 (one every 36°)
Material of loads.................... Aluminum (density $\rho = 2.8 \times 10^3$ [kg/m³])
Distance from center of index table to center of load......... $l = 120$ [mm]
Positioning angle .... $\theta = 36°$
Positioning time .... $t_0 = 0.25$ sec.

The **RK** Series **PN** geared type (gear ratio 10, resolution per pulse = 0.072°) 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 .... $\theta s = 0.072°$

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

① Calculate the number of operating pulses A [Pulse]

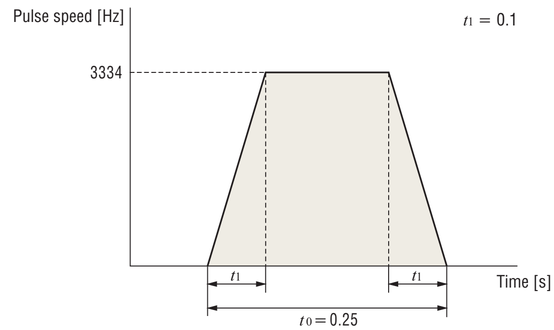
$$A = \frac{\theta}{\theta s} = \frac{36°}{0.072°} = 500 \text{ [Pulse]}$$

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

$$t_1 = 0.1 \text{ [s]}.$$

③ Calculate the operating pulse speed f_2 [Hz]

$$f_2 = \frac{A}{t_0 - t_1} = \frac{500}{0.25 - 0.1} \fallingdotseq 3334 \text{ [Hz]}$$



④ Calculate the operating speed N_M [r/min]

$$N_M = \frac{\theta s}{360°} \cdot f_2 \cdot 60 = \frac{0.072°}{360°} \times 3334 \times 60 \fallingdotseq 40 \text{ [r/min]}$$

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

(3) Calculate the Required Torque T_M [N·m] (Refer to page G-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 G-3 for formula)

$$\text{Inertia of table } J_T = \frac{\pi}{32} \times \rho \times L_T \times D_T^4$$
$$= \frac{\pi}{32} \times 2.8 \times 10^3 \times (5 \times 10^{-3}) \times (300 \times 10^{-3})^4$$
$$= 1.11 \times 10^{-2} \text{ [kg·m}^2\text{]}$$

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

$$= \frac{\pi}{32} \times 2.8 \times 10^3 \times (30 \times 10^{-3}) \times (40 \times 10^{-3})^4$$
$$= 0.211 \times 10^{-4} \text{ [kg·m}^2\text{]}$$

$$\text{Mass of load } m_W = \frac{\pi}{4} \times \rho \times L_W \times D_W^2$$
$$= \frac{\pi}{4} \times 2.8 \times 10^3 \times (30 \times 10^{-3}) \times (40 \times 10^{-3})^2$$
$$= 0.106 \text{ [kg]}$$

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)

$$= 10 \times \{(0.211 \times 10^{-4}) + 0.106 \times (120 \times 10^{-3})^2\}$$
$$= 1.55 \times 10^{-2} \text{ [kg·m}^2\text{]}$$

$$\text{Load inertia } J_L = J_T + J_W$$
$$= (1.11 + 1.55) \times 10^{-2}$$
$$= 2.66 \times 10^{-2} \text{ [kg·m}^2\text{]}$$

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

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

$$= (J_0 \times 10^2 + 2.66 \times 10^{-2}) \times \frac{\pi \times 0.072°}{180°} \times \frac{3334 - 0}{0.1}$$

$$= 4.19 \times 10^3 J_0 + 1.11 \text{ [N·m]}$$

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

$$T_M = (T_L + Ta) \times S_f$$
$$= \{0 + (4.19 \times 10^3 J_0 + 1.11)\} \times 2.0$$
$$= 8.38 \times 10^3 J_0 + 2.22 \text{ [N·m]}$$

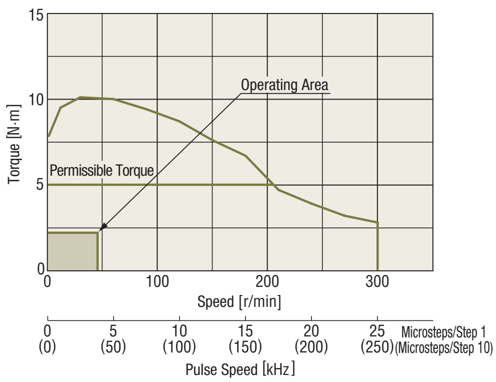
(4) Select a Motor

① Tentative motor selection

Model	Rotor Inertia [kg·m²]	Required Torque [N·m]
RK566AAE-N10	280×10⁻⁷	2.45

② Determine the motor from the speed – torque characteristics

RK566AAE-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.
Check the inertia ratio and acceleration/deceleration rate to ensure that your selection is the most appropriate.

(5) Check the Inertia Ratio (Refer to page G-6)

The **RK566AAE-N10** has a gear ratio 10, therefore, the inertia ratio is calculated as follows.

$$\frac{J_L}{J_0 \cdot i^2} = \frac{2.66 \times 10^{-2}}{280 \times 10^{-7} \times 10^2}$$

$$\fallingdotseq 9.5$$

RK566AAE-N10 motor is the equivalent of the **RK566AAE** motor. Since the inertia ratio is 10 or less, if the inertia ratio is 9.5, you can judge that motor operation is possible.

(6) Check the Acceleration/Deceleration Rate (Refer to page G-6)

Note when calculating that the units for acceleration/deceleration rate T_R are [ms/kHz].

$$T_R = \frac{t_1}{f_2 - f_1} = \frac{0.1 \text{ [s]}}{3334 \text{ [Hz]} - 0 \text{ [Hz]}}$$

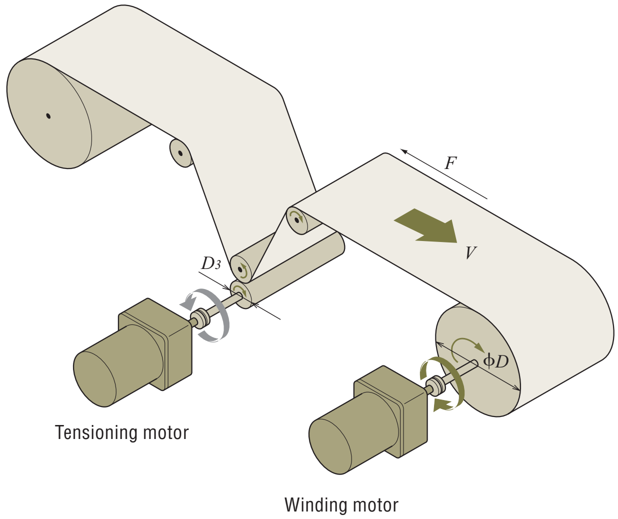
$$= \frac{100 \text{ [ms]}}{3.334 \text{ [kHz]} - 0 \text{ [kHz]}}$$

$$\fallingdotseq 30 \text{ [ms/kHz]}$$

The **RK566AAE-N10** motor is the equivalent of the **RK566AAE** and it has an acceleration/deceleration rate of 20 [ms/kHz] or more. Therefore an acceleration/deceleration rate of 30 [ms/kHz] allows you to judge whether motor operation is possible.

Winding Mechanism

This example demonstrates how to select winding equipment when a torque motor is used.



(1) Specifications and Operating Conditions of the Drive Mechanism

Winding roller diameter ϕD

Diameter at start of winding ....$D_1 = 15$ [mm] $= 0.015$ [m]

Diameter at end of winding ....$D_2 = 30$ [mm] $= 0.03$ [m]

Tensioning roller diameter ....$D_3 = 20$ [mm] $= 0.02$ [m]

Winding speed .... $V = 47$ [m/min] (constant)

Tension ....$F = 4$ [N] (constant)

Power .... Single-phase 115 VAC

Operating time ....Continuous

(2) Select a Winding Motor

In general, a winding motor must satisfy the following conditions:

- Able to provide a constant winding speed
- Able to apply a constant tension to prevent slackening of material

To meet the above conditions, the following points must be given consideration when selecting a motor:

- Since the winding diameter is different between the start and end of winding, the motor speed must be varied according to the winding diameter to keep the winding speed constant.
- If the tension is constant, the required motor torque is different between the start and end of winding. Accordingly, the torque must be varied according to the winding diameter.

Torque motors have ideal characteristics to meet these conditions.

① Calculate the Required Speed

Calculate the speed N_1 required at the start of winding.

$$N_1 = \frac{V}{\pi \cdot D_1} = \frac{47}{\pi \times 0.015} = 997.9 \text{ [r/min]} \fallingdotseq 1000 \text{ [r/min]}$$

Calculate the speed N_2 required at the end of winding.

$$N_2 = \frac{V}{\pi \cdot D_2} = \frac{47}{\pi \times 0.03} = 498.9 \text{ [r/min]} \fallingdotseq 500 \text{ [r/min]}$$

② Calculate the Required Torque

Calculate the torque T_1 required at the start of winding.

$$T_1 = \frac{F \cdot D_1}{2} = \frac{4 \times 0.015}{2} = 0.03 \text{ [N·m]}$$

Calculate the torque T_2 required at the end of winding.

$$T_2 = \frac{F \cdot D_2}{2} = \frac{4 \times 0.03}{2} = 0.06 \text{ [N·m]}$$

This winding motor must meet the following conditions:

Start of Winding:

Speed $N_1 = 1000$ [r/min], Torque $T_1 = 0.03$ [N·m]

End of Winding:

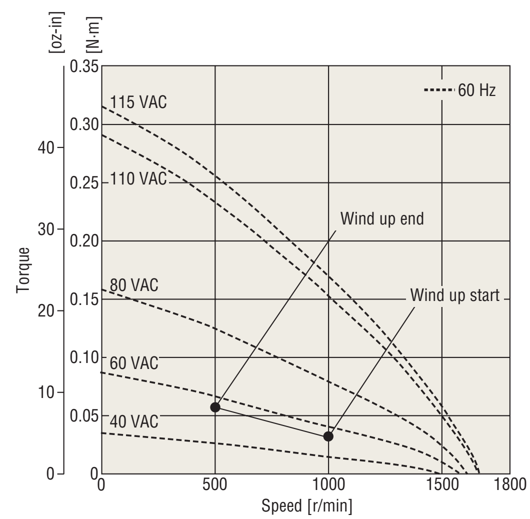
Speed $N_2 = 500$ [r/min], Torque $T_2 = 0.06$ [N·m]

③ Select a Motor

Check the Speed – Torque Characteristics

Select a motor that meets the required conditions specified above. If the required conditions are plotted on the Speed – Torque Characteristics for **4TK10A-AW2U**, it is clear that the conditions roughly correspond to the characteristics at a torque setting voltage of 1.9 VDC.

Speed – Torque Characteristics
4TK10A-AW2U



Check the Operation Time

4TK10A-AW2U has a five-minute rating when the voltage is 115 VAC and a continuous rating when it is 60 VDC. Under the conditions given here, the voltage is 60 VDC max., meaning that the motor can be operated continuously.

Note
- If a torque motor is operated continuously in a winding application, select conditions where the service rating of the torque motor remains continuous.

Motors
Selection Calculations
Linear and Rotary Actuators
Cooling Fans
Service Life
Stepping Motors
Servo Motors
Standard AC Motors
Brushless Motors/AC Speed Control Motors
Gearheads
Linear and Rotary Actuators
Cooling Fans

(3) Select a Tensioning Motor

If tension is not applied, the material slackens as it is wound and cannot be wound neatly. Torque motors also have reverse-phase brake characteristics and can be used as tensioning motors.
How to select a tensioning motor suitable for the winding equipment shown on page G-16 is explained below.

① Calculate the Required Speed N_3

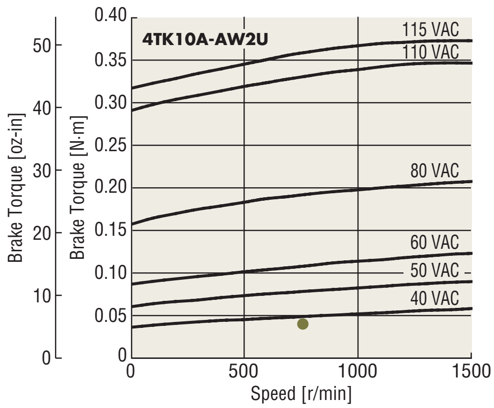
$$N_3 = \frac{V}{\pi \cdot D_3} = \frac{47}{\pi \times 0.02} = 748.4 \text{ [r/min]} \fallingdotseq 750 \text{ [r/min]}$$

② Calculate the Required Torque T_3

$$T_3 = \frac{F \cdot D_3}{2} = \frac{4 \times 0.02}{2} = 0.04 \text{ [N·m]}$$

③ Select a Motor
Select a motor that meets the required conditions specified above.
If the required conditions are plotted on the speed – brake torque characteristics* for the **4TK10A-AW2U** reverse-phase brake, it is clear that the conditions roughly correspond to the characteristics at a torque setting voltage of 1.0 VDC.

Speed – Brake Torque Characteristics with Reverse-Phase Brake



Note
- If a torque motor is operated continuously in a brake application, how much the motor temperature rises varies depending on the applicable speed and torque setting voltage. Be sure to keep the temperature of the motor case at 90˚C max.

From the above checks, the **4TK10A-AW2U** can be used both as a winding motor and tensioning motor.

*Please contact the nearest Oriental Motor sales office or customer support centre for information on the speed – brake torque characteristics of each product.

Selection Calculations

For Linear and Rotary Actuators

Motorized Linear Slides and Cylinders

EZSII Series, EZCII Series

First determine your series, then select your product.
Select the actuator that you will use based on the following flow charts:

1 Determine the Actuator Type

Select the actuator type that you will use.
(Linear slide type or cylinder type)

2 Check the Actuator Size and Transport Mass

Select the cylinder or linear slide size that satisfies your desired conditions. (Check the frame size, table height, transport mass and thrust force.)

3 Check the Positioning Time

Check whether your desired positioning time is sufficient using the "Positioning Distance – Positioning Time" graph. As a reference, the positioning time by the linear slide corresponds to the positioning time calculated from the graph, multiplied by the "positioning time coefficient" corresponding to the applicable stroke.

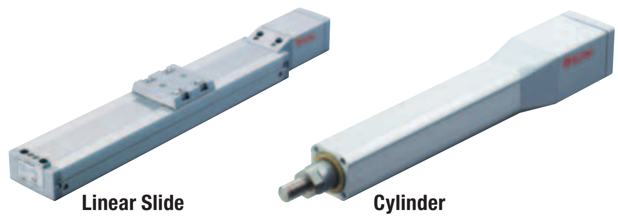
4 Check the Operating Conditions

Check that the operating speed and acceleration satisfy the conditions in 3 using the "Positioning Distance – Operating Speed" and "Positioning Distance – Acceleration" graphs.

5 Check the Moment (Linear slide only)

Include the calculated acceleration conditions and check that it is within the specified values of the dynamic permissible moment applied to the motorized linear slides. Refer to the following page for the moment calculation methods.

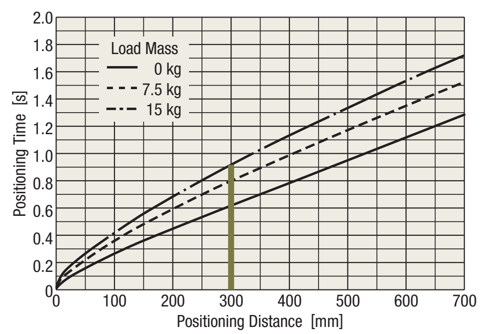
Selection complete



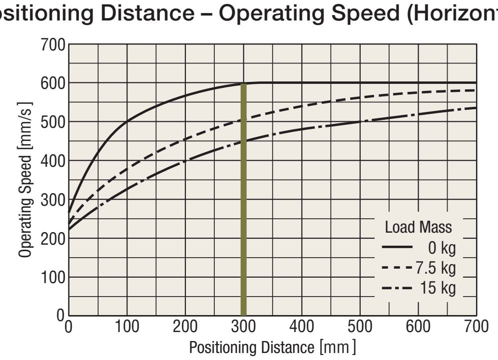
Linear Slide　　Cylinder

Example: Check of the operating speed and acceleration in order to execute the positioning time and this operation at a positioning distance of 300 mm.

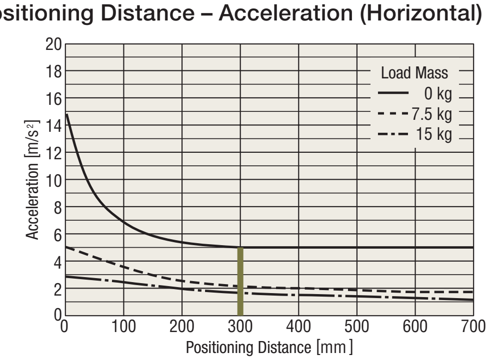
● Positioning Distance – Positioning Time (Horizontal)



● Positioning Distance – Operating Speed (Horizontal)

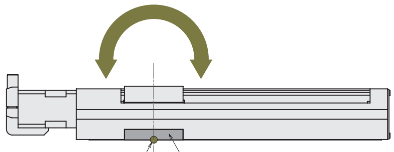
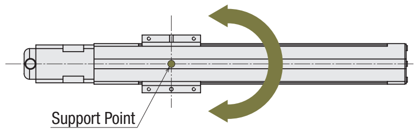
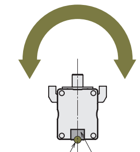


● Positioning Distance – Acceleration (Horizontal)



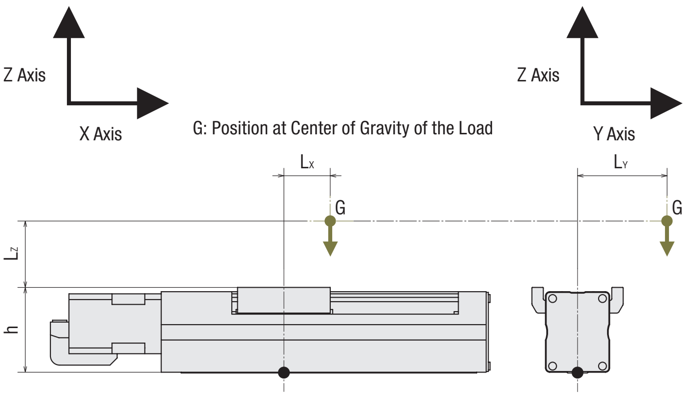
Calculating Load Moment

When a load is transported with the motorized linear slides, the load moment acts on the linear guide if the load position is offset from the center of the table. The direction of action applies to three directions, pitching (M_P), yawing (M_Y), and rolling (M_R) depending on the position of the offset.

Pitching Direction (M_P)	Yawing Direction (M_Y)	Rolling Direction (M_R)
		
(Linear slide bottom face, center of table)	(Center of table)	(Linear slide bottom face, center of table)

Even though the selected actuator satisfies the transport mass and positioning time, when the fixed load is overhung from the table, the run life may decrease as a result of the load moment. Load moment calculations must be completed and the conditions entered in as specified values must be checked. The moment applied under static conditions is the static permissible moment. The moment applied under movement is the dynamic permissible moment.

Calculate the load moment of the linear slide based on loads. Check that the static permissible moment and dynamic permissible moment are within limits and check that strength is sufficient.



m: Load mass (kg)
g: Gravitational acceleration 9.807 (m/s^2)
a: Acceleration (m/s^2)
h: Linear slide table height (m)

L_X: Overhung distance in the direction of the x-axis (m)
L_Y: Overhung distance in the direction of the y-axis (m)
L_Z: Overhung distance in the direction of the z-axis (m)

ΔM_P: Load moment in the pitching direction (N·m)
ΔM_Y: Load moment in the yawing direction (N·m)
ΔM_R: Load moment in the rolling direction (N·m)

Load Moment Formula:

$$\frac{|\Delta M_P|}{M_P} + \frac{|\Delta M_Y|}{M_Y} + \frac{|\Delta M_R|}{M_R} \leqq 1$$

When there are several overhung loads, etc., this equation determines the moment from all loads.

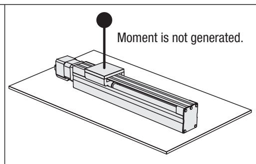
When there are multiple loads (n loads)

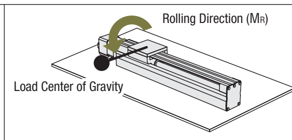
$$\frac{|\Delta M_{P1} + \Delta M_{P2} + \cdots \Delta M_{Pn}|}{M_P} + \frac{|\Delta M_{Y1} + \Delta M_{Y2} + \cdots \Delta M_{Yn}|}{M_Y} + \frac{|\Delta M_{R1} + \Delta M_{R2} + \cdots \Delta M_{Rn}|}{M_R} \leqq 1$$

●Concept of Static Permissible Moment Application

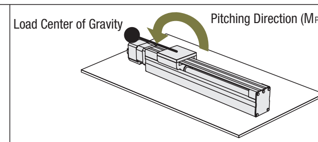
Check the static permissible moment when the load moment is applied to the stopped linear slide.

Horizontal



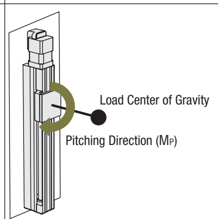


$$\Delta M_R = m \cdot g \cdot L_Y \qquad \frac{|\Delta M_R|}{M_R} \leqq 1$$

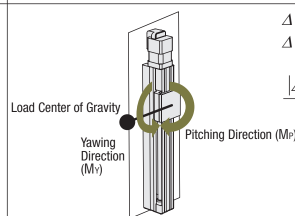


$$\Delta M_P = m \cdot g \cdot L_X \qquad \frac{|\Delta M_P|}{M_P} \leqq 1$$

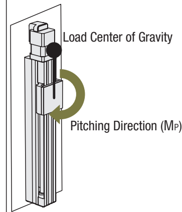
Vertical



$$\Delta M_P = m \cdot g \cdot (L_Z + h)$$
$$\frac{|\Delta M_P|}{M_P} \leqq 1$$

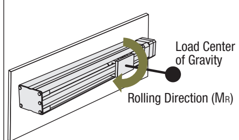


$$\Delta M_P = m \cdot g \cdot (L_Z + h)$$
$$\Delta M_Y = m \cdot g \cdot L_Y$$
$$\frac{|\Delta M_P|}{M_P} + \frac{|\Delta M_Y|}{M_Y} \leqq 1$$

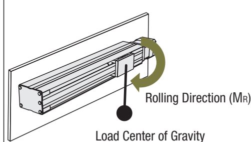


$$\Delta M_P = m \cdot g \cdot (L_Z + h)$$
$$\frac{|\Delta M_P|}{M_P} \leqq 1$$

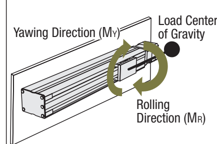
Wall Mounting



$$\Delta M_R = m \cdot g \cdot (L_Z + h)$$
$$\frac{|\Delta M_R|}{M_R} \leqq 1$$



$$\Delta M_R = m \cdot g \cdot (L_Z + h)$$
$$\frac{|\Delta M_R|}{M_R} \leqq 1$$

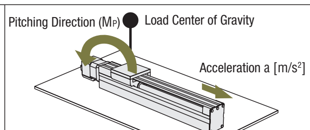


$$\Delta M_Y = m \cdot g \cdot L_X$$
$$\Delta M_R = m \cdot g \cdot (L_Z + h)$$
$$\frac{|\Delta M_Y|}{M_Y} + \frac{|\Delta M_R|}{M_R} \leqq 1$$

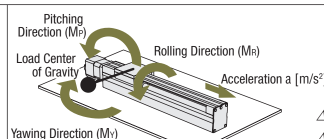
●Concept of Dynamic Moment Application

Take into account the acceleration and check that the dynamic permissible moment is not exceeded when the load moment is applied during linear slide operation.

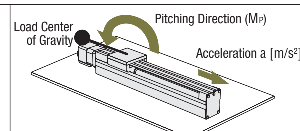
Horizontal



$$\Delta M_P = m \cdot a \cdot (L_Z + h)$$
$$\frac{|\Delta M_P|}{M_P} \leqq 1$$

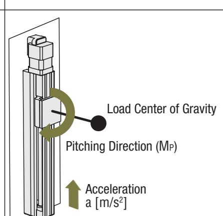


$$\Delta M_P = m \cdot a \cdot (L_Z + h)$$
$$\Delta M_Y = m \cdot a \cdot L_Y$$
$$\Delta M_R = m \cdot g \cdot L_Y$$
$$\frac{|\Delta M_P|}{M_P} + \frac{|\Delta M_Y|}{M_Y} + \frac{|\Delta M_R|}{M_R} \leqq 1$$

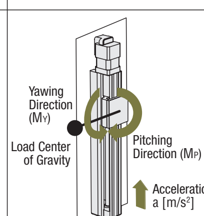


$$\Delta M_P = m \cdot g \cdot L_X + m \cdot a \cdot (L_Z + h)$$
$$\frac{|\Delta M_P|}{M_P} \leqq 1$$

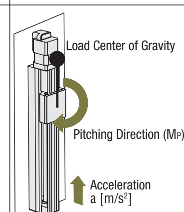
Vertical



$$\Delta M_P = m \cdot g \cdot (L_Z + h) + m \cdot a \cdot (L_Z + h)$$
$$\frac{|\Delta M_P|}{M_P} \leqq 1$$

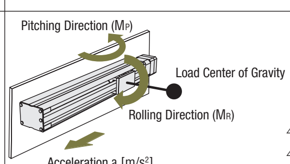


$$\Delta M_P = m \cdot g \cdot (L_Z + h) + m \cdot a \cdot (L_Z + h)$$
$$\Delta M_Y = m \cdot g \cdot L_Y + m \cdot a \cdot L_Y$$
$$\frac{|\Delta M_P|}{M_P} + \frac{|\Delta M_Y|}{M_Y} \leqq 1$$

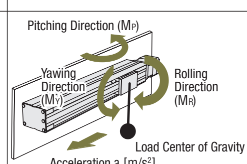


$$\Delta M_P = m \cdot g \cdot (L_Z + h) + m \cdot a \cdot (L_Z + h)$$
$$\frac{|\Delta M_P|}{M_P} \leqq 1$$

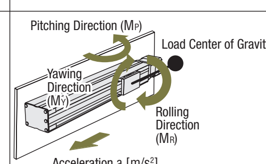
Wall Mounting



$$\Delta M_P = m \cdot a \cdot (L_Z + h)$$
$$\Delta M_R = m \cdot g \cdot (L_Z + h)$$
$$\frac{|\Delta M_P|}{M_P} + \frac{|\Delta M_R|}{M_R} \leqq 1$$



$$\Delta M_P = m \cdot a \cdot (L_Z + h)$$
$$\Delta M_Y = m \cdot a \cdot L_Y$$
$$\Delta M_R = m \cdot g \cdot (L_Z + h)$$
$$\frac{|\Delta M_P|}{M_P} + \frac{|\Delta M_Y|}{M_Y} + \frac{|\Delta M_R|}{M_R} \leqq 1$$



$$\Delta M_P = m \cdot a \cdot (L_Z + h)$$
$$\Delta M_Y = m \cdot g \cdot L_X$$
$$\Delta M_R = m \cdot g \cdot (L_Z + h)$$
$$\frac{|\Delta M_P|}{M_P} + \frac{|\Delta M_Y|}{M_Y} + \frac{|\Delta M_R|}{M_R} \leqq 1$$

The linear guide of the linear slide is designed with an expected life of 5000 km. However, when the load factor of the load moment for the calculated dynamic permissible moment is one or more, the expected life distance is halved. How much of the expected life distance can be checked in the formula below.

$$\text{Expected life}^{*}\ (\text{km}) = \text{Reference value of the service life of each series}^{*} \times \left(\frac{1}{\frac{|\Delta M_P|}{M_P} + \frac{|\Delta M_Y|}{M_Y} + \frac{|\Delta M_R|}{M_R}} \right)^3$$

✻Refer to "●Concept of Service Life" on page G-38 for the reference value of the service life of each series.

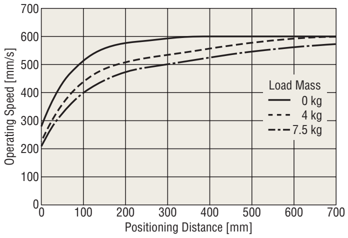
EZSII Series

Positioning Distance – Operating Speed, Positioning Distance – Acceleration

●EZS3D□-K (Lead 12 mm, 24 VDC)

◇Horizontal Installation

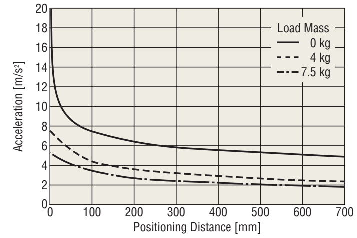
• Positioning Distance – Operating Speed



Maximum Speed by Stroke

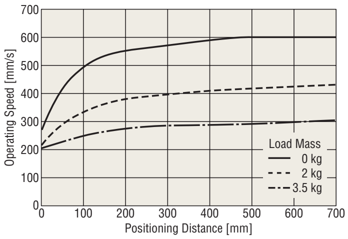
Stroke [mm]	Max. Speed [mm/s]
50~550	600
600	550
650	460
700	400

• Positioning Distance – Acceleration



◇Vertical Installation

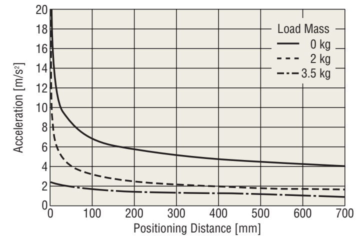
• Positioning Distance – Operating Speed



Maximum Speed by Stroke

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

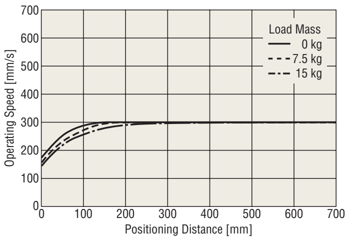
• Positioning Distance – Acceleration



●EZS3E□-K (Lead 6 mm, 24 VDC)

◇Horizontal Installation

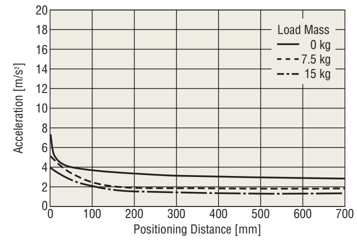
• Positioning Distance – Operating Speed



Maximum Speed by Stroke

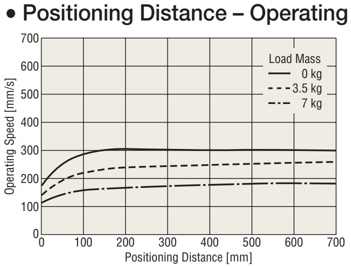
Stroke [mm]	Max. Speed [mm/s]
50~550	300
600	270
650	220
700	200

• Positioning Distance – Acceleration



◇Vertical Installation

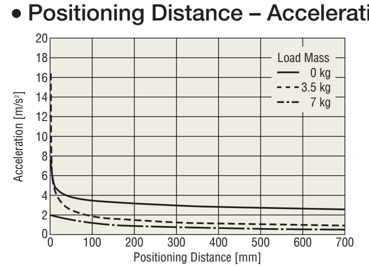
• Positioning Distance – Operating Speed



Maximum Speed by Stroke

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

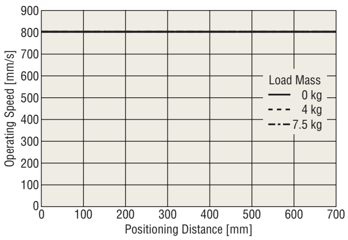
• Positioning Distance – Acceleration



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

◇Horizontal Installation

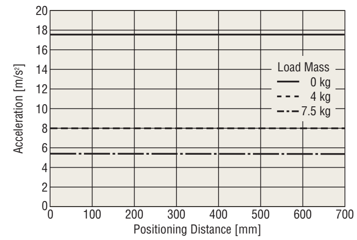
• Positioning Distance – Operating Speed



Maximum Speed by Stroke

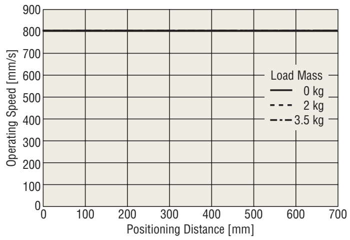
Stroke [mm]	Max. Speed [mm/s]
50~500	800
550	650
600	550
650	460
700	400

• Positioning Distance – Acceleration



◇Vertical Installation

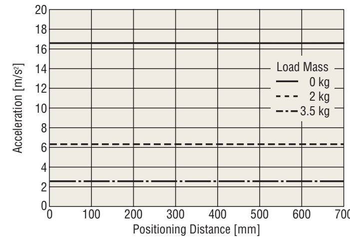
• Positioning Distance – Operating Speed



Maximum Speed by Stroke

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

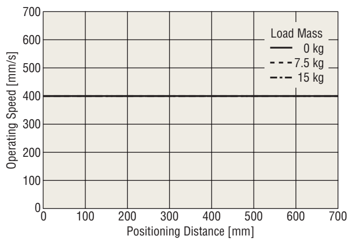
• Positioning Distance – Acceleration



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

◇Horizontal Installation

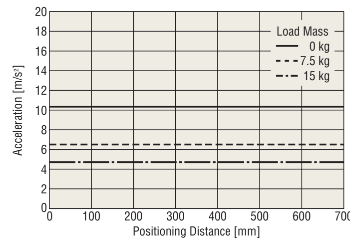
• Positioning Distance – Operating Speed



Maximum Speed by Stroke

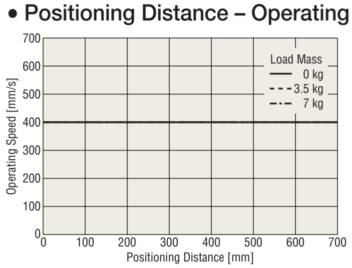
Stroke [mm]	Max. Speed [mm/s]
50~500	400
550	320
600	270
650	220
700	200

• Positioning Distance – Acceleration



◇Vertical Installation

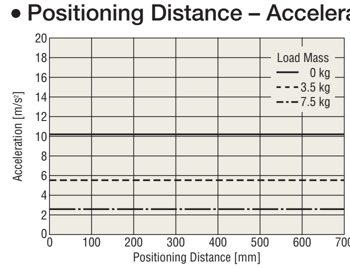
• Positioning Distance – Operating Speed



Maximum Speed by Stroke

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

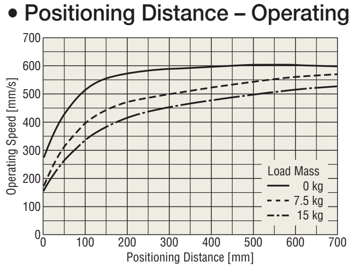
• Positioning Distance – Acceleration



●EZS4D□-K (Lead 12 mm, 24 VDC)

◇Horizontal Installation

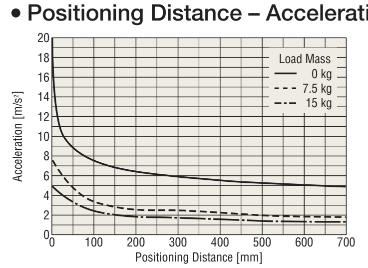
• Positioning Distance – Operating Speed



Maximum Speed by Stroke

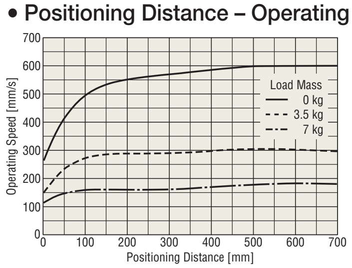
Stroke [mm]	Max. Speed [mm/s]
50~550	600
600	550
650	460
700	400

• Positioning Distance – Acceleration



◇Vertical Installation

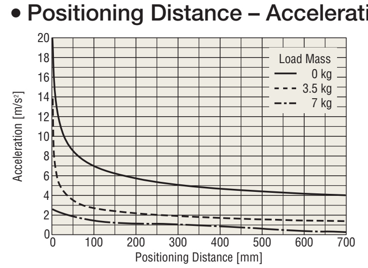
• Positioning Distance – Operating Speed



Maximum Speed by Stroke

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

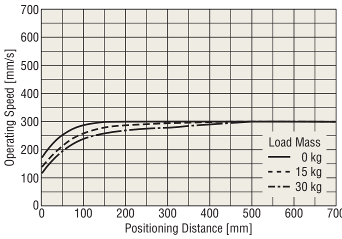
• Positioning Distance – Acceleration



●EZS4E□-K (Lead 6 mm, 24 VDC)

◇Horizontal Installation

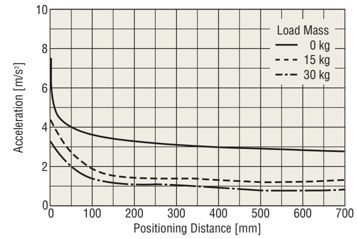
• Positioning Distance – Operating Speed



Maximum Speed by Stroke

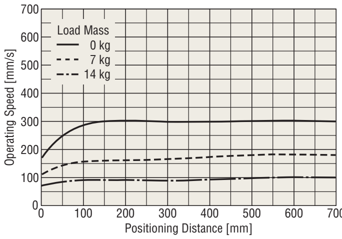
Stroke [mm]	Max. Speed [mm/s]
50~550	300
600	270
650	220
700	200

• Positioning Distance – Acceleration



◇Vertical Installation

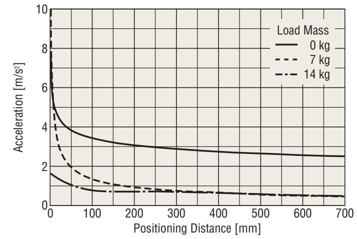
• Positioning Distance – Operating Speed



Maximum Speed by Stroke

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

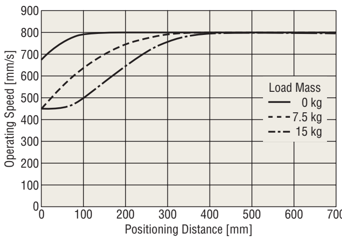
• Positioning Distance – Acceleration



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

◇Horizontal Installation

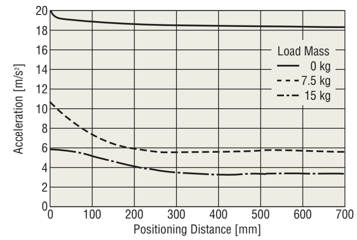
• Positioning Distance – Operating Speed



Maximum Speed by Stroke

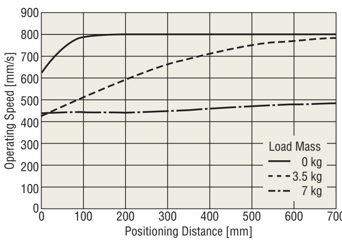
Stroke [mm]	Max. Speed [mm/s]
50~500	800
550	650
600	550
650	460
700	400

• Positioning Distance – Acceleration



◇Vertical Installation

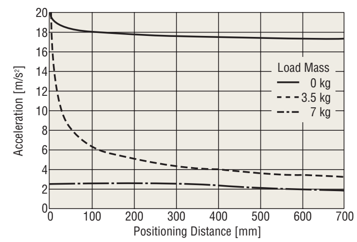
• Positioning Distance – Operating Speed



Maximum Speed by Stroke

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

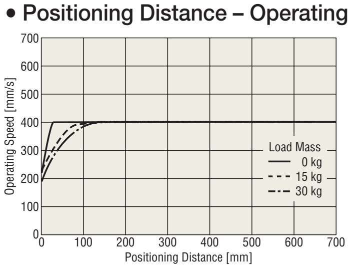
• Positioning Distance – Acceleration



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

◇Horizontal Installation

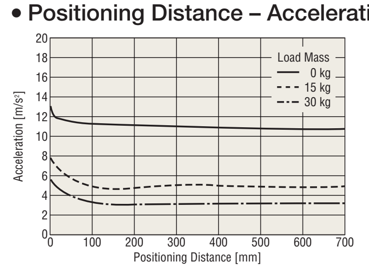
• Positioning Distance – Operating Speed



Maximum Speed by Stroke

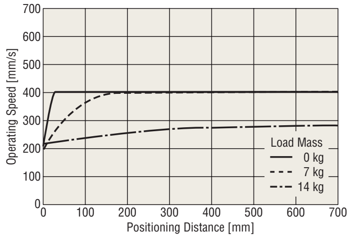
Stroke [mm]	Max. Speed [mm/s]
50~500	400
550	320
600	270
650	220
700	200

• Positioning Distance – Acceleration



◇Vertical Installation

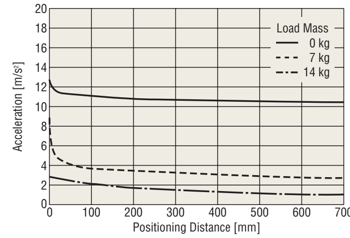
• Positioning Distance – Operating Speed



Maximum Speed by Stroke

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

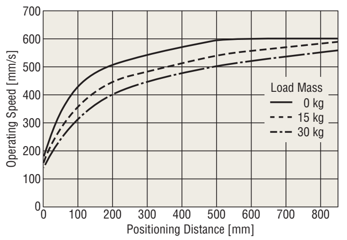
• Positioning Distance – Acceleration



●EZS6D□-K (Lead 12 mm, 24 VDC)

◇Horizontal Installation

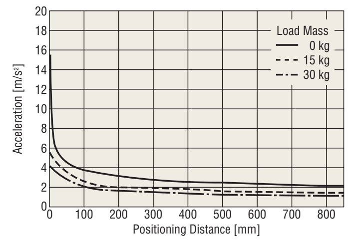
• Positioning Distance – Operating Speed



Maximum Speed by Stroke

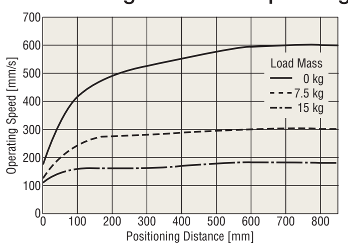
Stroke [mm]	Max. Speed [mm/s]
50～650	600
700	550
750	470
800	420
850	360

• Positioning Distance – Acceleration



◇Vertical Installation

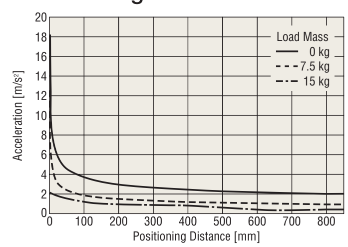
• Positioning Distance – Operating Speed



Maximum Speed by Stroke

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

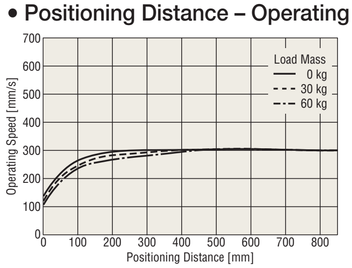
• Positioning Distance – Acceleration



●EZS6E□-K (Lead 6 mm, 24 VDC)

◇Horizontal Installation

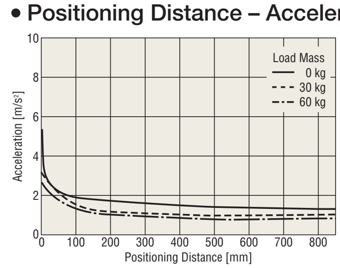
• Positioning Distance – Operating Speed



Maximum Speed by Stroke

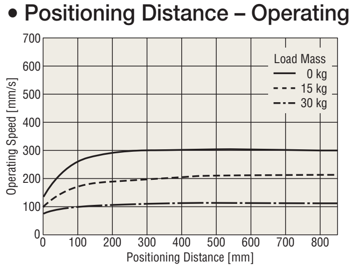
Stroke [mm]	Max. Speed [mm/s]
50～650	300
700	260
750	230
800	200
850	180

• Positioning Distance – Acceleration



◇Vertical Installation

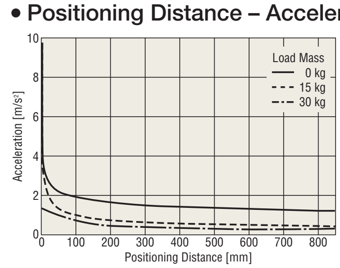
• Positioning Distance – Operating Speed



Maximum Speed by Stroke

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

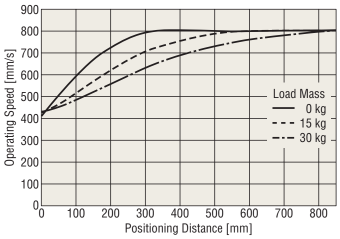
• Positioning Distance – Acceleration



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

◇Horizontal Installation

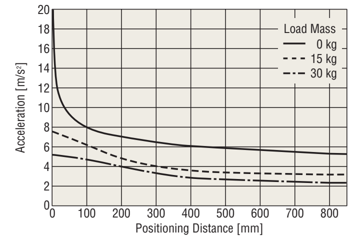
• Positioning Distance – Operating Speed



Maximum Speed by Stroke

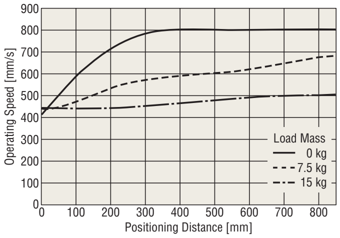
Stroke [mm]	Max. Speed [mm/s]
50～600	800
650	640
700	550
750	470
800	420
850	360

• Positioning Distance – Acceleration



◇Vertical Installation

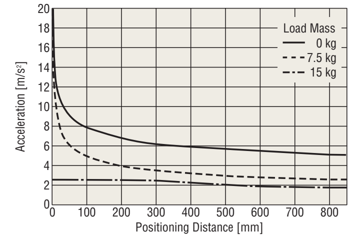
• Positioning Distance – Operating Speed



Maximum Speed by Stroke

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

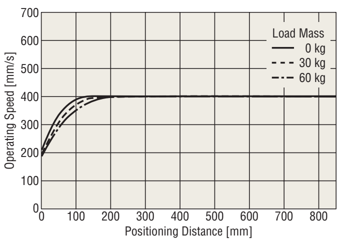
• Positioning Distance – Acceleration



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

◇Horizontal Installation

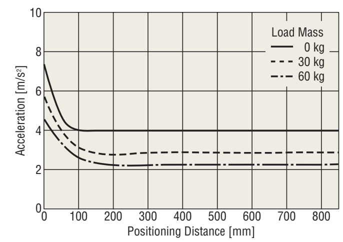
• Positioning Distance – Operating Speed



Maximum Speed by Stroke

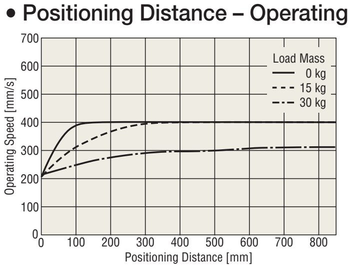
Stroke [mm]	Max. Speed [mm/s]
50～550	400
600	350
650	300
700	260
750	230
800	200
850	180

• Positioning Distance – Acceleration



◇Vertical Installation

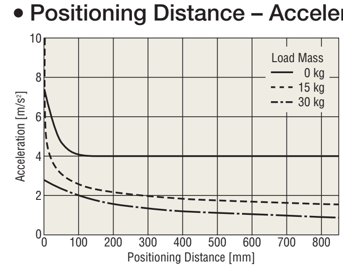
• Positioning Distance – Operating Speed



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



■EZCII Series

Positioning Distance-Operating Speed, Positioning Distance-Acceleration

➜Refer to pages E-62 to E-69 for the **EZCII** series.

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.
A required dual axes mounting bracket is determined by selecting any biaxial combination of the **EZSII** Series based on your conditions. Select an optimum combination by using the 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.

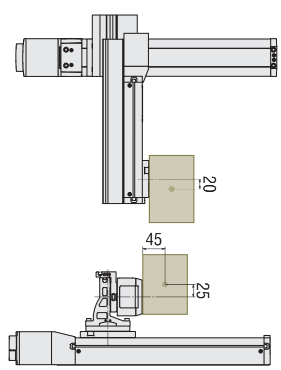
▼

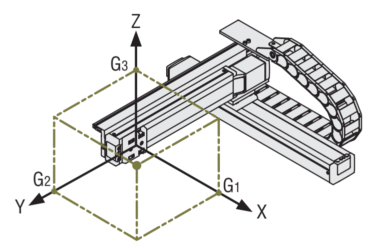
Selection

●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 G-27).
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 $30 < |Gn| \leqq 50$.
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 E-105) 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< |Gn| ≦ 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< |Gn| ≦ 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 G-29).
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

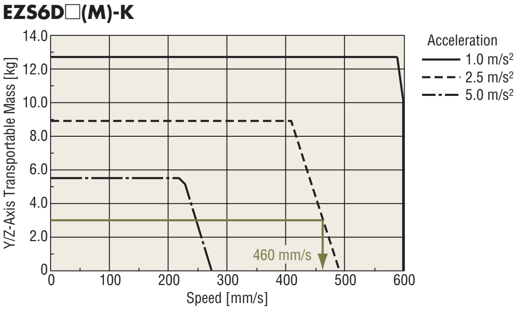
Speed and acceleration can be increased for the same mass, by replacing the power supply with single-phase 100-115 VAC/single-phase 200-230 VAC and/or by using linear slides with greater size.

● Speed – Transportable Mass Characteristics

◇X-Axis Speed

● 24 VDC

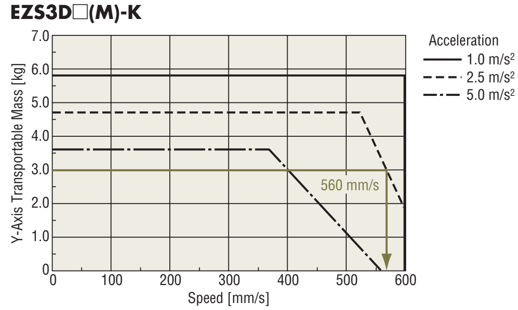
EZS6D□(M)-K



◇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

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

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

$V_{Rmax} > V_R \rightarrow$ Trapezoidal drive

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]

② Calculate the positioning time

Triangular drive

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

Trapezoidal drive

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

◇Example of Calculation

Check if the combination on page G-26 can move 100 mm in 0.5 seconds.

• 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 $T = \frac{100}{460} + \frac{460}{2.5 \times 10^3}$

$= 0.401\ s$

• 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 $T = \frac{2 \times 500}{2.5 \times 10^3}$

$= 0.400\ s$

Calculation revealed that the preferred positioning time can be met.

●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).

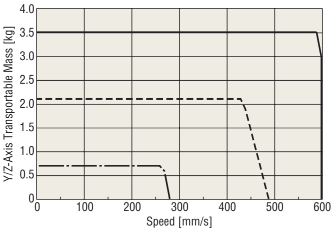
●Speed – Transportable Mass Characteristics

◇X-Axis Speed (Common to electromagnetic brake type)✻

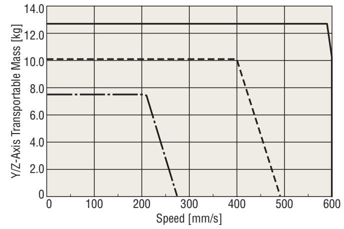
Acceleration
—— 1.0 m/s² – – – 2.5 m/s² –·– 5.0 m/s²

● 24 VDC

EZS4D□(M)-K

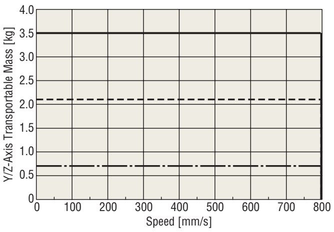


EZS6D□(M)-K

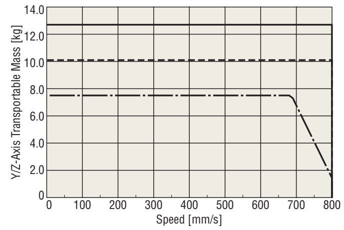


● Single-Phase 100-115 VAC/Single-Phase 200-230 VAC

EZS4D□(M)-A/EZS4D□(M)-C



EZS6D□(M)-A/EZS6D□(M)-C



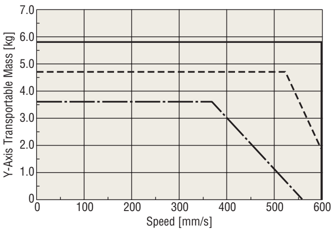
✻For X-axis, the maximum speed read from the graph is limited by the stroke. Check the maximum speed for each stroke in **EZSⅡ** Series products.

◇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



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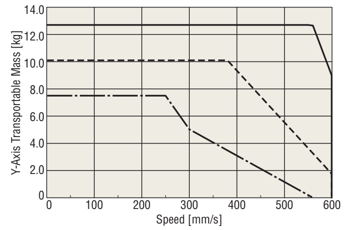
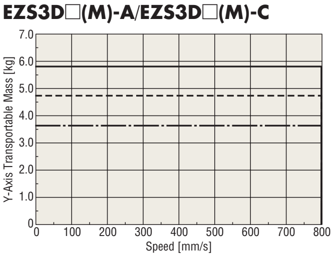
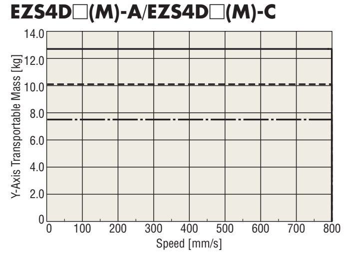


● Single-Phase 100-115 VAC/Single-Phase 200-230 VAC

EZS3D□(M)-A/EZS3D□(M)-C



EZS4D□(M)-A/EZS4D□(M)-C



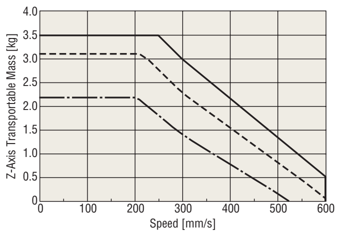
●Enter the stroke in the box (□) within the model name.

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

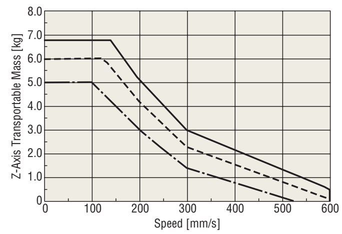
Acceleration
—— 1.0 m/s² – – – 2.5 m/s² –·– 5.0 m/s²

● 24 VDC

EZS3D□(M)-K

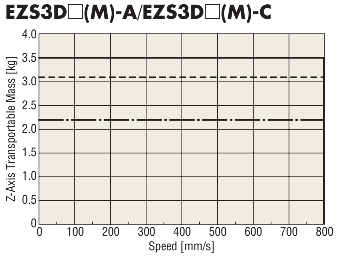


EZS4D□(M)-K

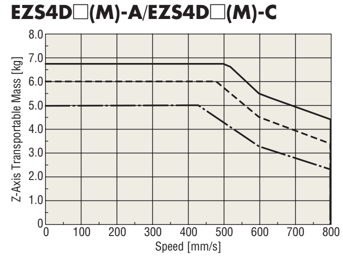


● Single-Phase 100-115 VAC/Single-Phase 200-230 VAC

EZS3D□(M)-A/EZS3D□(M)-C



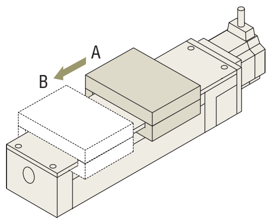
EZS4D□(M)-A/EZS4D□(M)-C

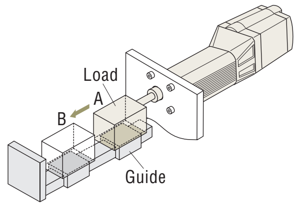


● Enter the stroke in the box (□) within the model name.

Motorized Linear Slides and Motorized Cylinders (Obtained by calculations)

The parameters listed below are required when selecting motorized linear slides and 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, the load is generally mounted to the rod receives and 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.

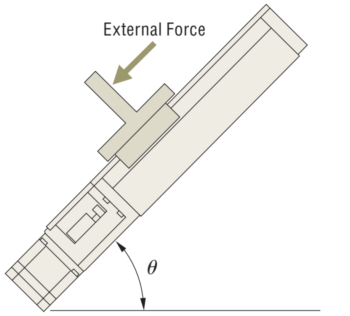
$$F_a = m \times \{a + g \times (\mu \times \cos\alpha + \sin\alpha)\}$$

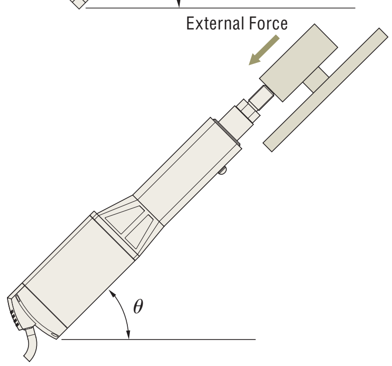
② Calculate the thrust force that allows for pushing or pulling

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

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
θ : Angle formed by the traveling direction and the horizontal plane [deg]





●Calculate the Positioning Time

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.

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

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

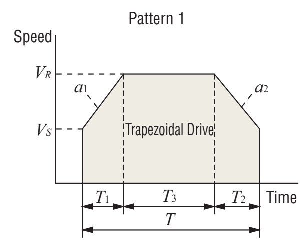
$V_{Rmax} > V_R \rightarrow$ Trapezoidal drive

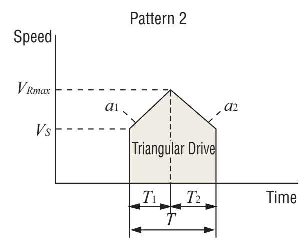
③ Calculate the positioning time
Trapezoidal drive

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

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:

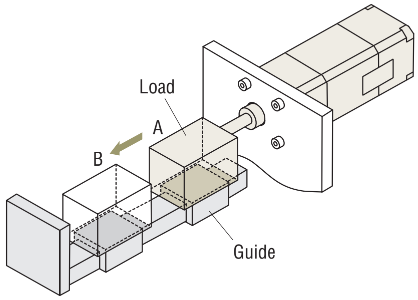
$$\text{Number of operating pulses [pulses]} = \frac{\text{Movement [mm]}}{\text{Resolution [mm]}}$$

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

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

■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, the load is generally mounted to the rod receives and 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

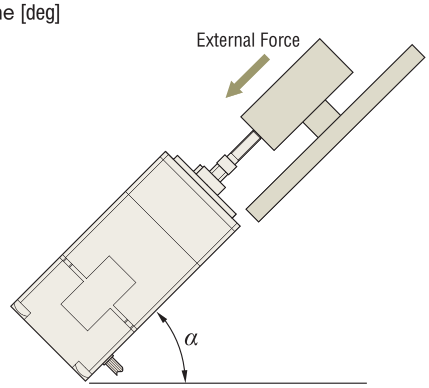
$$F_a = m \times \{a + g \times (\mu \times \cos\alpha + \sin\alpha)\}$$

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/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]

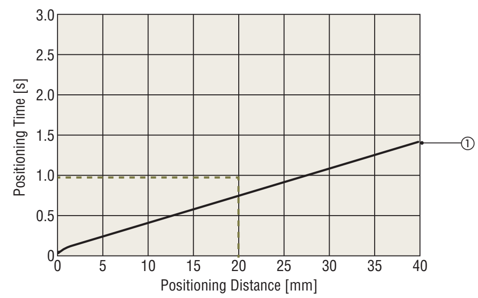


●Calculate the Positioning Time

Check to see if the 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.

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.

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

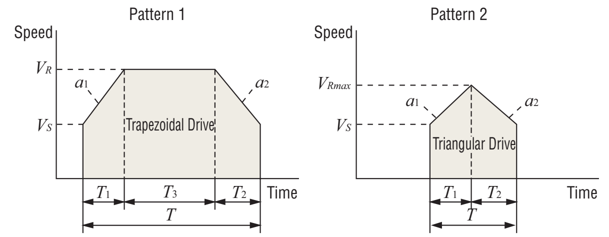
$V_{Rmax} \leqq V_R$ → Triangular drive
$V_{Rmax} > V_R$ → Trapezoidal drive

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]

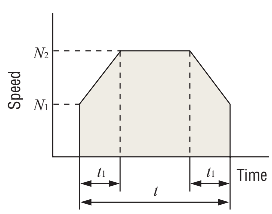
Hollow Rotary Actuators (DG Series)

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 E-136 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.

$$N_2\,[\text{r/min}] = \frac{\theta \times 6N_1 t_1}{6\,(t - t_1)}$$



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.

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

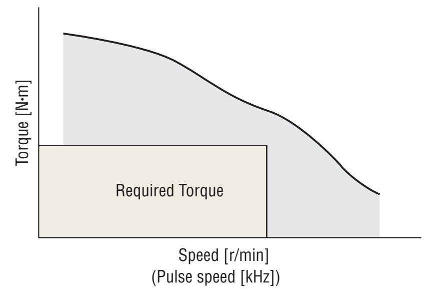
J_1 : Inertia of actuator [kg·m^2]
J_L : Total inertia [kg·m^2]
N_2 : Operating speed [r/min]
N_1 : Starting speed [r/min]
t_1 : Acceleration (deceleration) time [s]

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.

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

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.



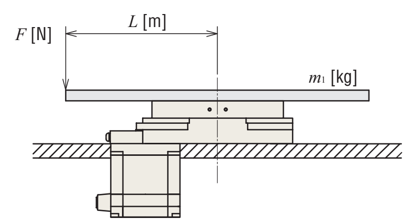
Use the following formula to convert the speed into a pulse speed.

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

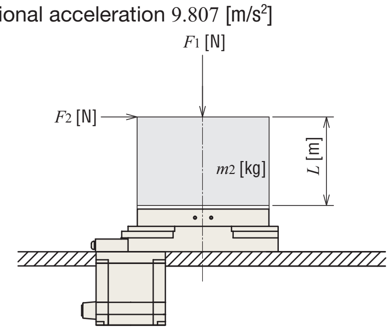
f : Pulse speed [Hz]
N : Speed [r/min]
θ_s : Output table step angle [deg/step]

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



Thrust load [N] $Fs = F_1 + m_2 \times g$
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

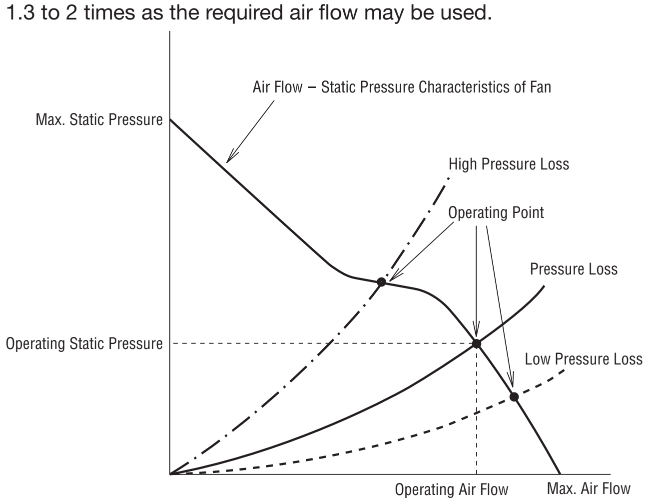
Determine the amount of heat generated internally by the machinery.

●Calculate Required Air Flow

Calculate the air flow required once you have determined the heat generation, the number of degrees the temperature must be lowered and what the ambient temperature should be.

●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 a 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.

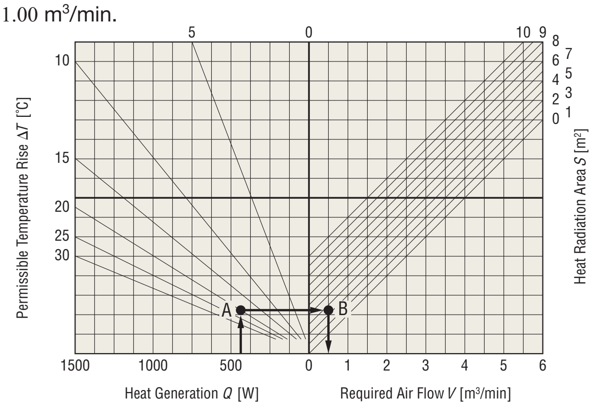
◇Obtaining by Calculations

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

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, **MU** Series **MU925M-21** is selected.

MU925M-21 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	8	0.1	2700	1	44	36