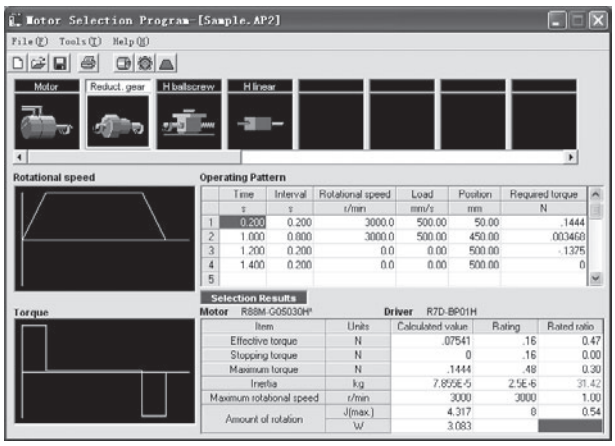
Servo Motor Selection Software

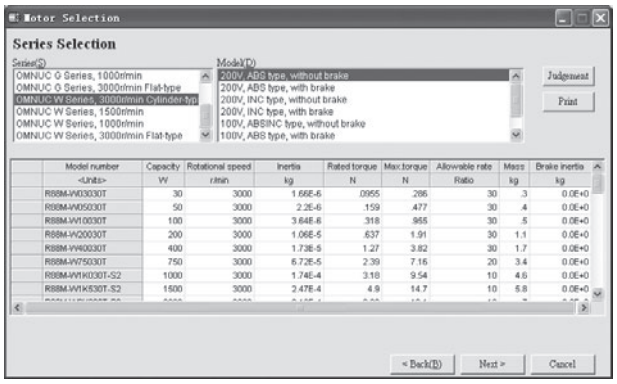
Use your PC to select a Servo Motor "Motor Selection Program for Windows"

Do you always feel "Calculation of Servo Motor selection is so complicated and difficult?"

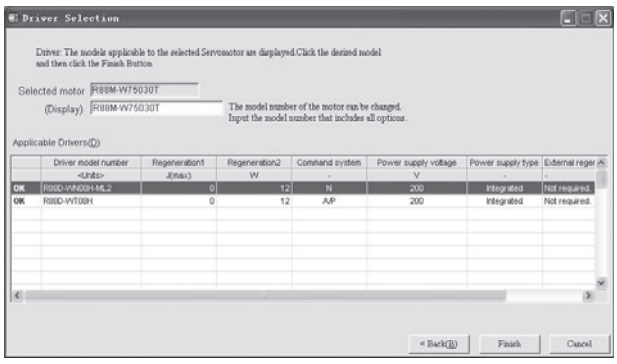
Refer to Pages 5 to 11 showing the "calculation formulas" to do your own calculation as well as Pages 12 to 13 showing "**sample calculations**". This software really helps you to easily select a motor.



Operation Pattern Setting Screen



Motor Selection/Decision Screen



Driver Selection Screen

Features

- You can refer to this motor used machine structure as a standard.
  Example of Standard Machine Combinations: Ball Screw, Rack and Pinion, Cart etc.
  Also you can refer to the method in which various mechanic elements can be combined one by one.
  Example of Elements: Decelerator, Gear, Belt, Roller, Linear Motion Load, Eccentric Disc Load, External Force, etc.
- You can set up easily an operation pattern.
  After selecting a motor, you can also have the rotation and torque graphs displayed.
- Since all of the model data for the Servo Motors/Drivers is compiled into a database, the optimal motor can be selected automatically, without needing to input data for each model.
- A table is displayed automatically that shows which drivers can be combined with the selected motor, and the driver's regenerative ability can also be determined automatically.

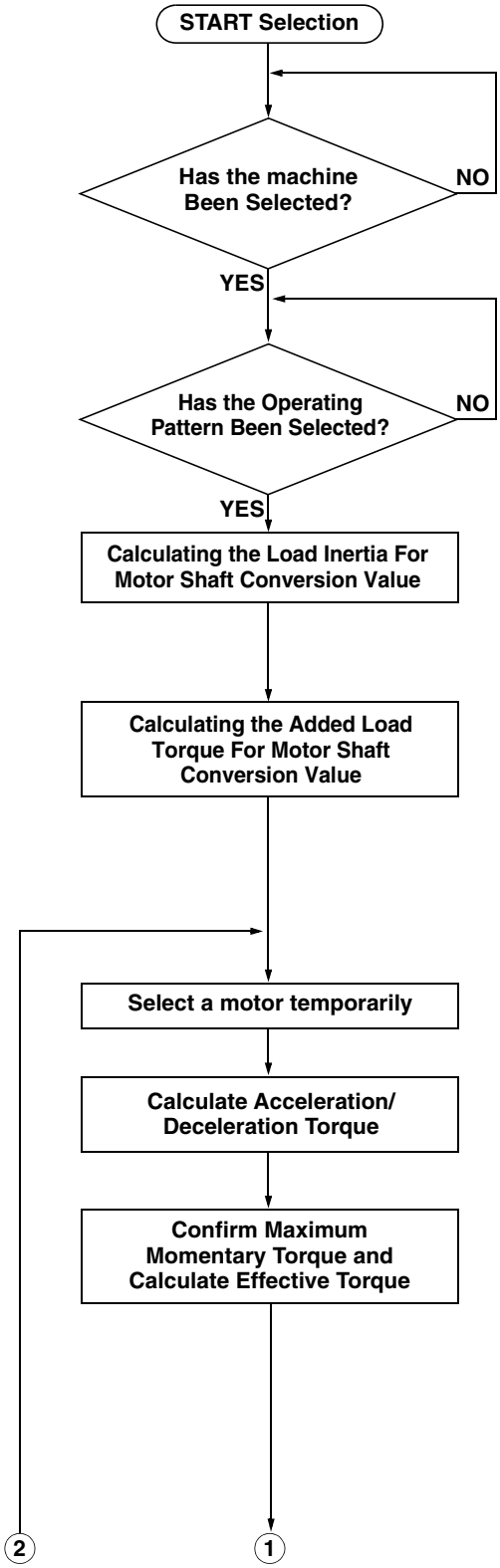
Operating Conditions

- OS : Microsoft Windows 2000/XP Japanese Version
- CPU : 486DX/66 MHz or above (Pentium processor recommended)
- Memory : 16 MB or above (32 MB or above recommended)
- Hard Disc : 10 MB or more required for installation
- Display : resolution of 640 × 480 or above (800 × 600 or above recommended)
- Disc Drive : CD-ROM Drive (only required for installation)

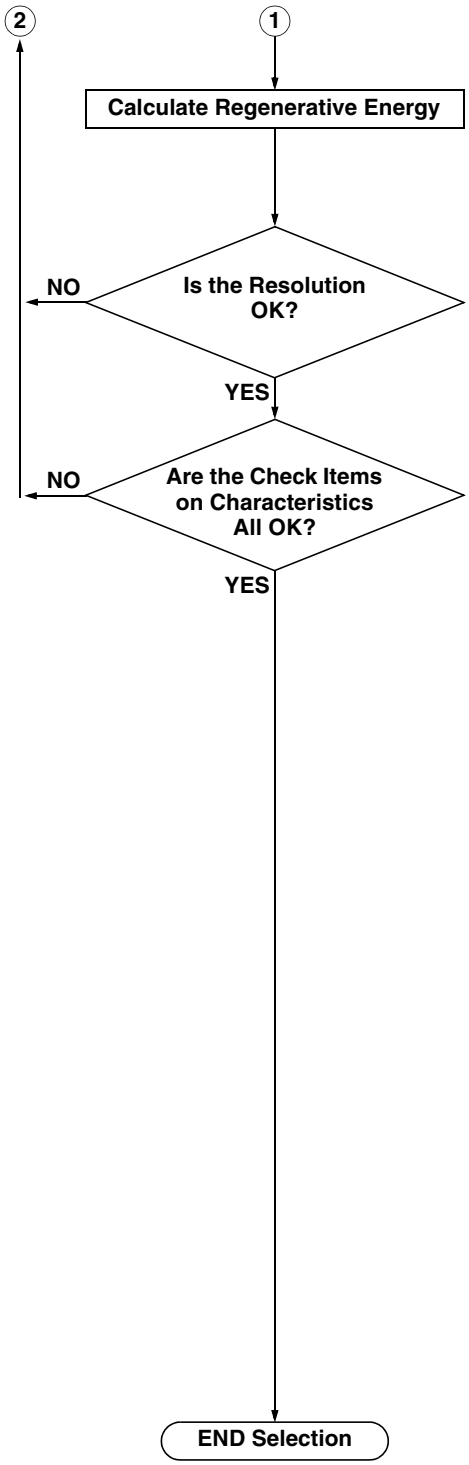
How to Get It

- You can refer to the "Motor Selection Program" to make the selection of motors even more convenient.
  Access it at the following URL.
  www.fa.omron.co.jp

Servo Motor Selection Flow Chart



Explanation	References
• Determine the size, mass, coefficient of friction, and external forces of all the moving part of the Servo Motor the rotation of which affects.	---
• Determine the operating pattern (relationship between time and speed) of each part that must be controlled. • Convert the operating pattern of each controlled element into the motor shaft operating pattern.	• Operation Pattern Formula
• The elements of the machine can be separated so that inertia can be calculated for each part that moves as the Servo Motor rotates. • Calculate the inertia applied to each element to calculate the total load inertia of the motor shaft conversion value.	• Inertia Formulas
• Calculation of Friction Torque Calculates the frictional force for each element, where necessary, and converts it to friction torque for a motor shaft. • Calculation of External Torque Calculates the external force for each element, where necessary, and converts it to external torque of a motor shaft. • Calculates the total load torque for the motor shaft conversion value.	• Load Torque Formulas
• Select a motor temporarily based upon the motor shaft converted load inertia, friction torque, external torque and r.p.m of a motor.	---
• Calculate the Acceleration/Deceleration Torque from the Load Inertia or Operating Pattern.	• Acceleration/Deceleration Torque Formulas
• Calculate the necessary torque for each part of the Operating Pattern from the Friction Torque, External Torque and Acceleration/ Deceleration Torque. • Confirm that the maximum value for the Torque for each operating part (Maximum Momentary Torque) is less than the Maximum Momentary Torque of the motor. • Calculate the Effective Torque from the Torque for each Operating part, and confirm that it is less than the Rated Torque for the motor.	• Calculation of Maximum Momentary Torque, Effective Torque



Explanation	References
• Calculate Regenerative Energy from the Torque of all the moving parts.	• Please see the user manual of each product for the details on calculation of the regenerative energy.
• Check if the the number of encoder pulses meets the system specified resolution.	• Accuracy of Positioning
• Check if the calculation meets the specifications of the temporarily selected motor. If not, change the temporarily selected motor and re-calculate it.	• The following table

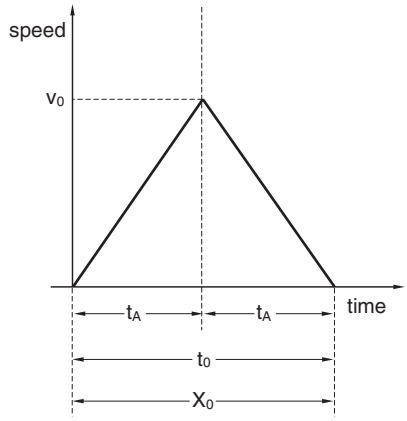
Specialized Check Items	Check Items
Load Inertia	Load Inertia ≤ Motor Rotor Inertia x Applicable Inertia Ratio
Effective Torque	Effective Torque < Motor Rated Torque • Please allow a margin of about 20%. ✻
Maximum Momentary Torque	Maximum Momentary Torque < Motor Maximum Momentary Torque • Please allow a margin of about 20%. ✻ • For the motor Maximum Momentary Torque, use the value that is combined with a driver and the one of the motor itself.
Maximum Rotation Speed	Maximum Rotation Speed ≤ Rated Rotation Speed of a motor • Try to get as close to the motor's rated rotations as possible. It will increase the operating efficiency of a motor. • For the formula, please see "**Straight-line Speed and Motor Rotation Speed**" **on Page 11**.
Regenerative Energy	Regenerative Energy ≤ Regenerative Energy Absorption of a motor • When the Regenerative Energy is large, connect a Regenerative Energy Absorption Resistance to increase the Absorption capacity of the driver.
Encoder Resolution	Ensure that the Encoder Resolution meets the system specifications.
Characteristics of a Positioner	Check if the Pulse Frequency does not exceed the Maximum Response Frequency or Maximum Command Frequency of a Positioner.
Operating Conditions	Ensure that values of the ambient operating temperature/ humidity, operating atmosphere, shock and vibrations meet the product specifications.

✻ When handling vertical loads and a load affected by the external torque, allow for about 30% of capacity.

Formulas

■Formulas for Operating Patterns

Triangular



Maximum Speed $v_0 = \frac{X_0}{t_A}$

X_0: Distance Moved in t_0 Time (mm)

v_0: Maximum Speed (mm/s)

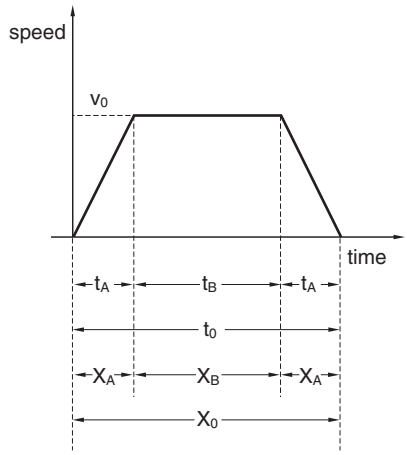
Acceleration/Deceleration Time $t_A = \frac{X_0}{v_0}$

t_0: Positioning Time (s)

t_A: Acceleration/ Deceleration Time (s)

Travel Distance $X_0 = v_0 \cdot t_A$

Trapezoid



Maximum Speed $v_0 = \frac{X_0}{t_0 - t_A}$

Acceleration/Deceleration Time $t_A = t_0 - \frac{X_0}{v_0}$

Total Travel Time $t_0 = t_A + \frac{X_0}{v_0}$

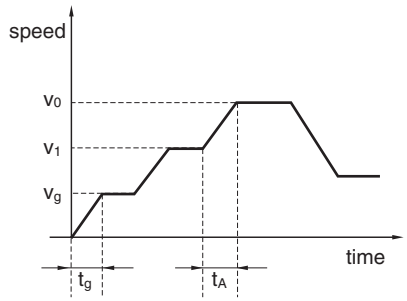
Constant-velocity travel time $t_B = t_0 - 2 \cdot t_A = 2\frac{2 \cdot X_0}{v_0} - t_0 = \frac{X_0}{v_0} - t_$

Total Travel Distance $X_0 = v_0 (t_0 - t_A)$

Acceleration/Deceleration Travel Distance $X_A = \frac{v_0 \cdot t_A}{2} = \frac{v_0 \cdot t_0 - X_0}{2}$

Constant-velocity travel distance $X_B = v_0 \cdot t_B = 2 \cdot X_0 - v_0 \cdot t_0$

Speed and Slope When Ascending



Speed Gradient $\alpha = \frac{v_g}{t_g}$

Ascending Time $t_A = \frac{v_0 - v_1}{\alpha}$

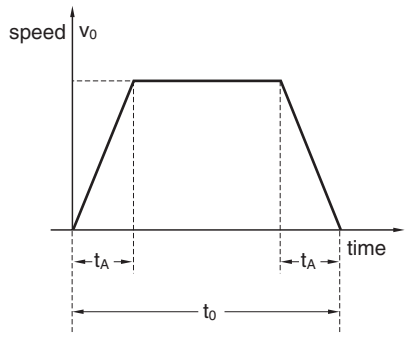
Ascending Time (t_A) including distance moved

$$X_A = \frac{1}{2}\alpha \cdot t_A^2 + v_1 \cdot t_A$$

$$= \frac{1}{2}\frac{(v_0 - v_1)^2}{\alpha} + v_1 \cdot t_A$$

Speed after Ascending $v_0 = v_1 + \alpha \cdot t_A$

Speed and Slope Trapezoid pattern



Conditions for Trapezoidal Operating Pattern

$$X_0 < \frac{t_0^2 \cdot \alpha}{4}$$

Maximum Speed

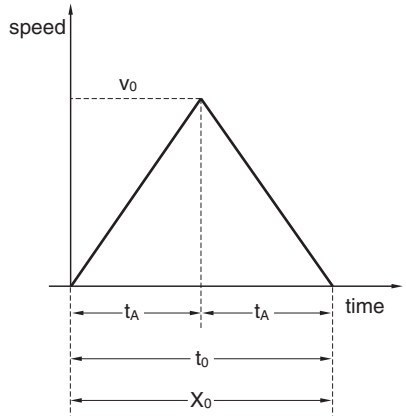
$$v_0 = \frac{t_0 \cdot \alpha}{2} \left(1 - \sqrt{1 - \frac{4X_0}{t_0 \cdot \alpha}}\right)$$

Ascending Time

$$t_A = \frac{v_0}{\alpha} = \frac{t_0}{2} \left(1 - \sqrt{1 - \frac{4X_0}{t_0 \cdot \alpha}}\right)$$

X_0: Positioning Distance (mm)
t_0: Positioning Time (s)
t_A: Acceleration/Deceleration Time (s)
v_0: Maximum Speed (mm/s)
α: Speed Gradient

Speed and Slope Triangular Pattern



Conditions for Triangular Operating Pattern

$$X_0 \geq \frac{t_0^2 \cdot \alpha}{4}$$

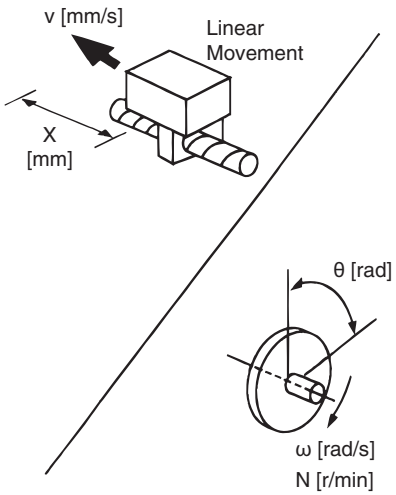
Maximum Speed

$$v_0 = \sqrt{\alpha \cdot X_0}$$

Ascending Time

$$t_A = \sqrt{\frac{X_0}{\alpha}}$$

Rotating Part



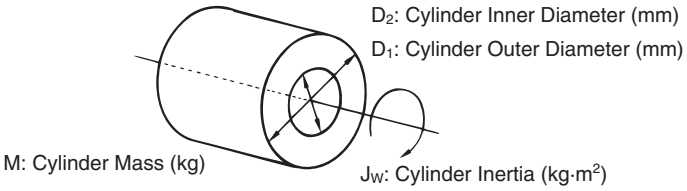
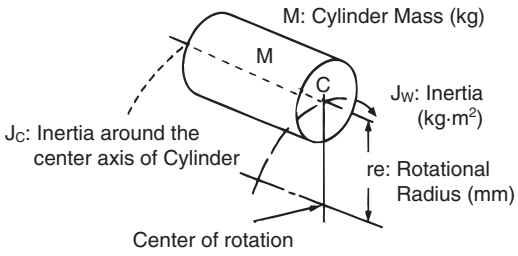
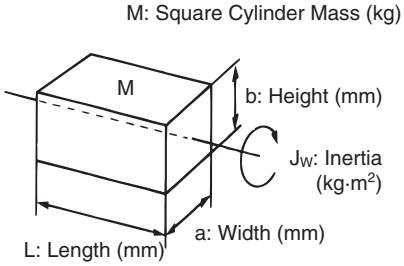
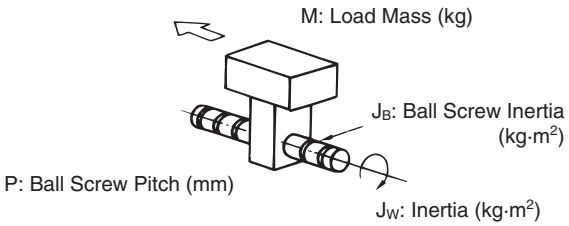
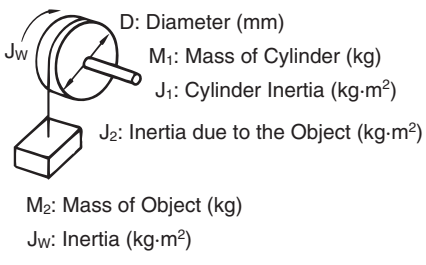
Perform the following unitary conversions

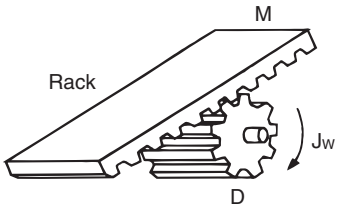
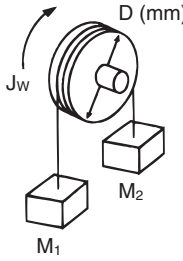
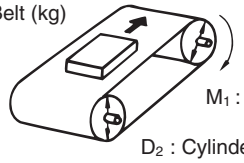
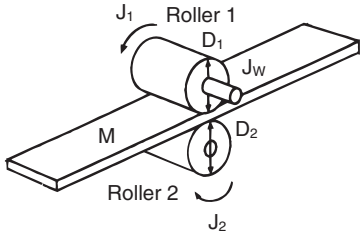
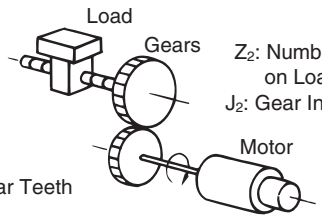
Linear Movement	Rotating Movement
X: Distance (mm)	θ: Angle (rad)
v: Speed (mm/s)	ω: Angular Velocity (rad/s)

$$\left(\omega = \frac{2\pi \cdot N}{60}\right)$$

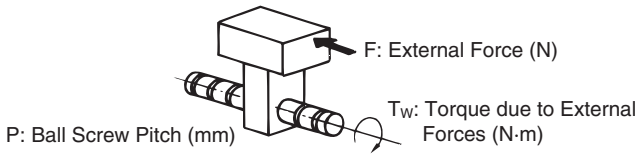
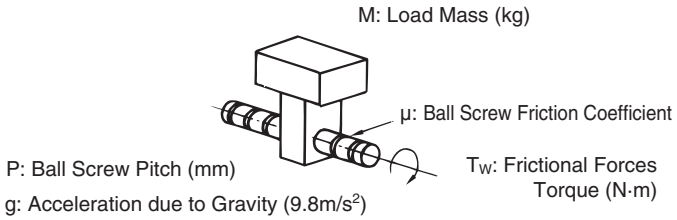
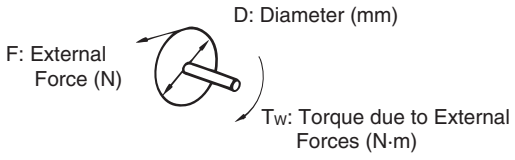
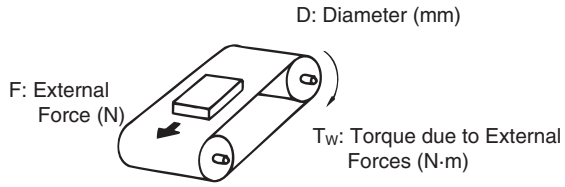
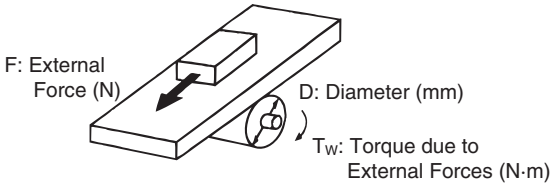
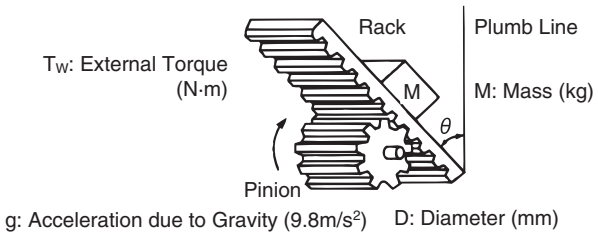
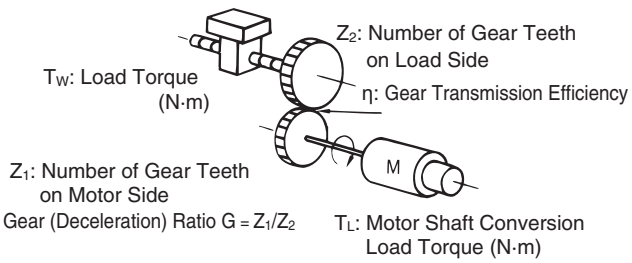
N: Rotating Speed (r/min)

■Inertia Formulas

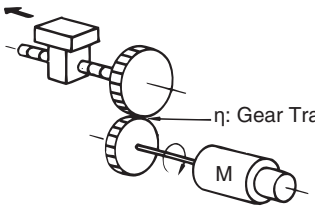
Cylindrical Inertia		$J_W = \frac{M(D_1^2 + D_2^2)}{8} \times 10^{-6}$ (kg·m^2)
Eccentric Disc Inertia (Cylinder which rotates off the center axis)		$J_W = J_C + M \cdot re^2 \times 10^{-6}$ (kg·m^2)
Inertia of Rotating Square Cylinder		$J_W = \frac{M(a^2 + b^2)}{12} \times 10^{-6}$ (kg·m^2)
Inertia of Linear Movement		$J_W = M\left(\frac{P}{2\pi}\right)^2 \times 10^{-6} + J_B$ (kg·m^2)
Inertia of Lifting Object by Pulley		$J_W = J_1 + J_2$ $= \left(\frac{M_1 \cdot D^2}{8} + \frac{M_2 \cdot D^2}{4}\right) \times 10^{-6}$ (kg·m^2)

Inertia of Rack and Pinion Movement	 M: Mass (kg) D: Pinion Diameter (mm)	$J_W = \frac{M \cdot D^2}{4} \times 10^{-6}$ (kg·m²)
Inertia of Suspended Counterbalance	 J_W: Inertia (kg·m²) M_1: Mass (kg) M_2: Mass (kg)	$J_W = \frac{D^2 (M_1 + M_2)}{4} \times 10^{-6}$ (kg·m²)
Inertia when Carrying Object via Conveyor Belt	M_3 : Mass of Object (kg) M_4 : Mass of Belt (kg)  J_W : Inertia (kg·m²) J_1 : Cylinder 1 Inertia (kg·m²) J_2 : Inertia due to Cylinder 2 (kg·m²) J_3 : Inertia due to the Object (kg·m²) J_4 : Inertia due to the Belt (kg·m²)	$J_W = J_1 + J_2 + J_3 + J_4$ $= \left(\frac{M_1 \cdot D_1^2}{8} + \frac{M_2 \cdot D_2^2}{8} \cdot \frac{D_1^2}{D_2^2} + \frac{M_3 \cdot D_1^2}{4} + \frac{M_4 \cdot D_1^2}{4} \right) \times 10^{-6}$ (kg·m²)
Inertia where Work is Placed between Rollers	J_W : System Inertia (kg·m²) J_1 : Roller 1 Inertia (kg·m²) J_2 : Roller 2 Inertia (kg·m²) D_1 : Roller 1 Diameter (mm) D_2 : Roller 2 Diameter (mm) M : Equivalent Mass of Work (kg) 	$J_W = J_1 + \left(\frac{D_1}{D_2} \right)^2 J_2 + \frac{M \cdot D_1^2}{4} \times 10^{-6}$ (kg·m²)
Inertia of a Load Value Converted to Motor Shaft	 J_W: Load Inertia (kg·m²) Z_1: Number of Gear Teeth on Motor Side J_1: Gear Inertia on Motor Side (kg·m²) Gear Ratio $G = Z_1/Z_2$ J_L: Motor Shaft Conversion Load Inertia (kg·m²)	$J_L = J_1 + G^2 (J_2 + J_W)$ (kg·m²)

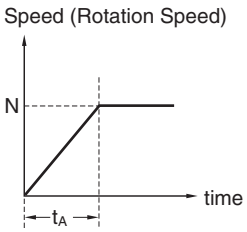
■Load Torque Formulas

Torque against external force		$T_W = \frac{F \cdot P}{2\pi} \times 10^{-3}$ (N·m)
Torque against frictional force		$T_W = \mu Mg \cdot \frac{P}{2\pi} \times 10^{-3}$ (N·m)
Torque when external force is applied to a rotating object		$T_W = F \cdot \frac{D}{2} \times 10^{-3}$ (N·m)
Torque of an object on the conveyer belt to which the external force is applied		$T_W = F \cdot \frac{D}{2} \times 10^{-3}$ (N·m)
Torque of an object to which the external force is applied by Rack and Pinion		$T_W = F \cdot \frac{D}{2} \times 10^{-3}$ (N·m)
Torque when work is lifted at an angle.		$T_W = Mg \cdot \cos\theta \cdot \frac{D}{2} \times 10^{-3}$ (N·m)
Torque of a Load Value Converted to Motor Shaft		$T_L = T_W \cdot \frac{G}{\eta}$ (N·m)

■Acceleration/Deceleration Torque Formula



J_L: Motor Shaft Conversion Load Inertia (kg·m^2)



Acceleration Time (s)

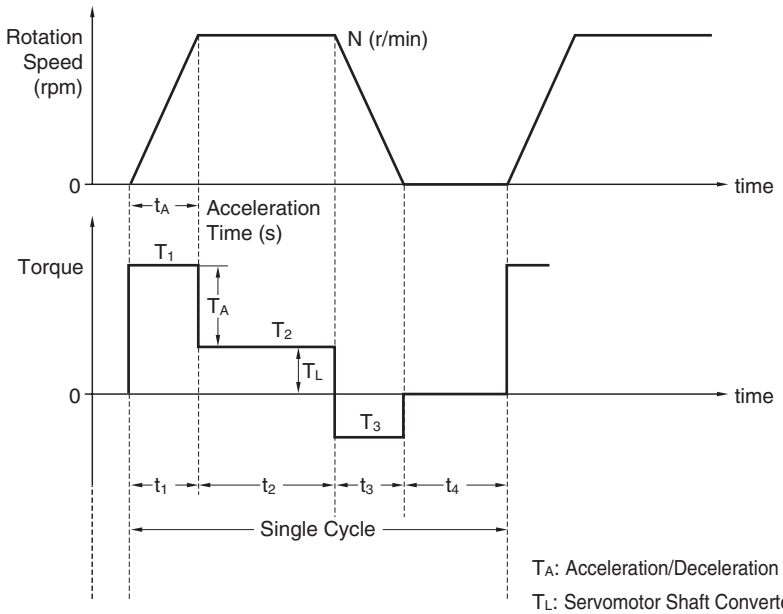
N: Rotation Speed (r/min)

T_A: Acceleration/Deceleration Torque (N·m)

Acceleration/Deceleration Torque (T_A)

$$T_A = \frac{2\pi N}{60 t_A}\left(J_M + \frac{J_L}{\eta}\right) (N{\cdot}m)$$

■Calculation of Maximum Momentary Torque, Effective Torque



T_A: Acceleration/Deceleration Torque (N·m)

T_L: Servomotor Shaft Converted Load Torque (N·m)

T_1: Maximum Momentary Torque (N·m)

Trms: Effective Torque (N·m)

Maximum Momentary Torque (T_1)

$T_1 = T_A + T_L$ (N·m)

Effective Torque (Trms)

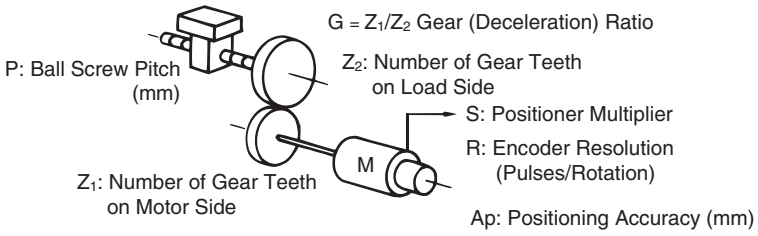
$$Trms = \sqrt{\frac{T_1^2 \cdot t_1 + T_2^2 \cdot t_2 + T_3^2 \cdot t_3}{t_1 + t_2 + t_3 + t_4}} \quad (N{\cdot}m)$$

$T_2 = T_L$ (N·m)

$T_3 = T_L - T_A$ (N·m)

$t_1 = t_A$ (N·m)

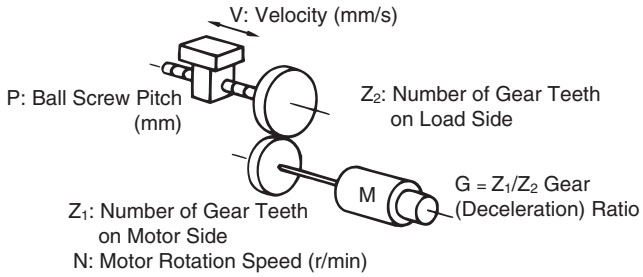
■Positioning Accuracy



Positioning Accuracy (A_P)

$$Ap = \frac{P \cdot G}{R \cdot S} \text{ (mm)}$$

■Straight Line Speed and Motor Rotation Speed



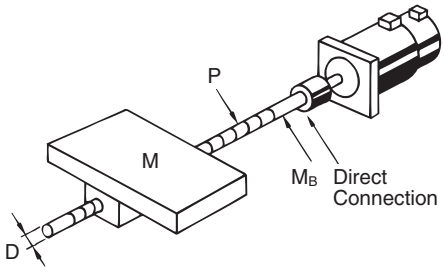
Motor Rotations

$$N = \frac{60V}{P \cdot G} \text{ (r/min)}$$

Sample Calculations

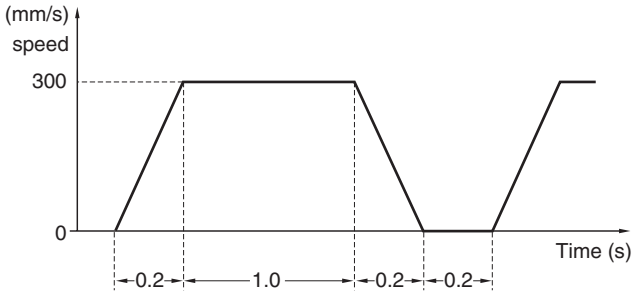
①Machinery Selection

- Load Mass M = 5 (kg)
- Ball Screw Pitch P = 10 (mm)
- Ball Screw Diameter D = 20 (mm)
- Ball Screw Mass M_B = 3 (kg)
- Ball Screw Friction Coefficient μ = 0.1
- Since there is no decelerator, G = 1, η = 1



②Determining Operating Pattern

- One Speed Change
- Velocity for a Load Travel V = 300 (mm/s)
- Strokes L = 360 (mm)
- Stroke Travel Time tS = 1.4 (s)
- Acceleration/Deceleration Time tA = 0.2 (s)
- Positioning Accuracy AP = 0.01 (mm)



③Calculation of Motor Shaft Conversion Load Inertia

Ball screw Inertia J_B	$J_B = \frac{M_B D^2}{8} \times 10^{-6}$	$J_B = \frac{3 \times 20^2}{8} \times 10^{-6} = 1.5 \times 10^{-4}\ (kg \cdot m^2)$
Load Inertia J_W	$J_W = M\left(\frac{P}{2\pi}\right)^2 \times 10^{-6} + J_B$	$J_W = 5 \times \left(\frac{10}{2 \times 3.14}\right)^2 \times 10^{-6} + 1.5 \times 10^{-4} = 1.63 \times 10^{-4}\ (kg \cdot m^2)$
Motor Shaft Conversion Load Inertia J_L	$J_L = G^2 \times (J_W + J_2) + J_1$	$J_L = J_W = 1.63 \times 10^{-4}\ (kg \cdot m^2)$

④Load Torque Calculation

Torque against Friction Torque T_W	$T_W = \mu Mg \frac{P}{2\pi} \times 10^{-3}$	$T_W = 0.1 \times 5 \times 9.8 \times \frac{10}{2 \times 3.14} \times 10^{-3} = 7.8 \times 10^{-3}\ (N \cdot m)$
Motor Shaft Conversion Load Torque T_L	$T_L = \frac{G}{\eta} \cdot T_W$	$T_L = T_W = 7.8 \times 10^{-3}\ (N \cdot m)$

⑤Calculation of Rotation Speed

Rotations N	$N = \frac{60V}{P \cdot G}$	$N = \frac{60 \times 300}{10 \times 1} = 1800\ (r/min)$

⑥Motor Temporary Selection [In case OMNUC U Series Servo Motor is temporarily selected]

The Rotor/Inertia of the selected servo motor is more than 1/30* of a load	$JM \geq \frac{J_L}{30}$	$\frac{J_L}{30} = \frac{1.63 \times 10^{-4}}{30} = 5.43 \times 10^{-6}\ (kg \cdot m^2)$ Temporarily selected Model R88M-U20030 ($J_M = 1.23 \times 10^{-5}$).
80% of the Rated Torque of the selected servo motor is more than the load torque of the servomotor shaft conversion value	$T_M \times 0.8 > T_L$	Rated Torque for R88M – U20030 Model from TM = 0.637 (N·m) $T_M = 0.637\ (N \cdot m) \times 0.8 > T_L = 7.8 \times 10^{-3}\ (N \cdot m)$

* Note that this value changes according to the Series.

⑦Calculation of Acceleration/Deceleration Torque

Acceleration/ Deceleration Torque T_A	$T_A = \frac{2\pi \cdot N}{60 t_A}\left(J_M + \frac{J_L}{\eta}\right)$	$T_A = \frac{2\pi \times 1800}{60 \times 0.2} \times \left(1.23 \times 10^{-5} + \frac{1.63 \times 10^{-4}}{1.0}\right) = 0.165\ (\text{N·m})$

⑧Calculation of Maximum Momentary Torque, Effective Torque

Required Max. Momentary Torque is

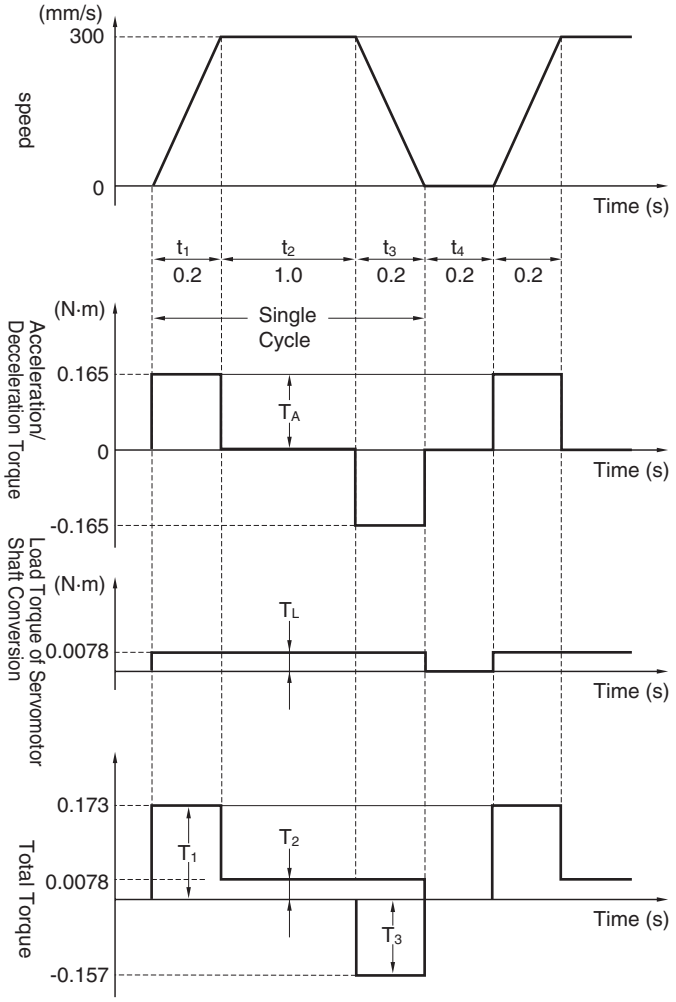
$T_1 = T_A + T_L = 0.165 + 0.0078$
$= 0.173\ (\text{N·m})$
$T_2 = T_L = 0.0078\ (\text{N·m})$
$T_3 = T_L - T_A = 0.0078 - 0.165$
$= -0.157\ (\text{N·m})$

Effective Torque Trms is

$$Trms = \sqrt{\frac{T_1^2 \cdot t_1 + T_2^2 \cdot t_2 + T_3^2 \cdot t_3}{t_1 + t_2 + t_3 + t_4}}$$

$$= \sqrt{\frac{0.173^2 \times 0.2 + 0.0078^2 \times 1.0 + 0.157^2 \times 0.2}{0.2 + 1.0 + 0.2 + 0.2}}$$

$= 0.0828\ (\text{N·m})$



⑨Result of Examination

Load Inertia	**[Load Inertia $J_L = 1.63 \times 10^{-4}$ (kg·m²)] ≤ [Motor Rotor Inertia $J_M = 1.23 \times 10^{-5}$] × [Applied Inertia = 30]**	**Conditions Satisfied**
Effective Torque	**[Effective Torque Trms = 0.0828 (N·m)] < [Servomotor Rated Torque 0.637 (N·m) × 0.8]**	**Conditions Satisfied**
Maximum Momentary Torque	**[Maximum Momentary Torque T_1 = 0.173 N·m < [Servomotor Maximum Momentary Torque 1.91 (N·m) × 0.8]**	**Conditions Satisfied**
Maximum Rotation Speed	**[Maximum Rotations Required N = 1800 (r/min)] ≤ [Servomotor Rated Rotation Speed 3000 (r/min)]**	**Conditions Satisfied**
Encoder Resolution	**The encoder resolution when the positioner multiplication factor is set to 1 is** $R = \frac{P \cdot G}{Ap \cdot S} = \frac{10 \times 1}{0.01 \times 1} = 1000$ (Pulses/Rotations) **The encoder specification of U Series 2048 (pulses/rotation) should be set 1000 with the Encoder Dividing Rate Setting.**	**Conditions Satisfied**

Note. This example omits calculations for the regenerative energy, operating conditions, or positioner characteristics.