



台達電子



HOW TO SELECT A SERVO SYSTEM



About This Presentation

Intended Audience

For the users who are interested in a servo system.

Presentation Revision

Revision: February 21, 2011

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Delta servo selection assistant software



Some Basic Physics Formulas

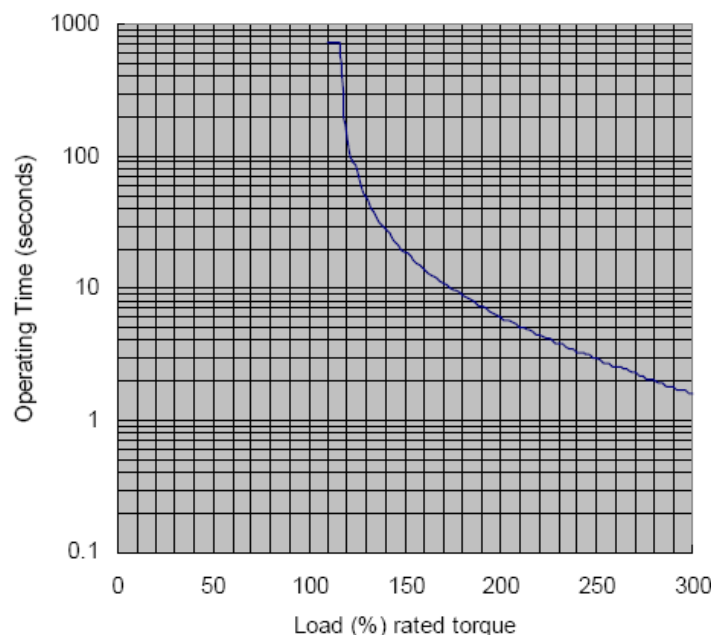
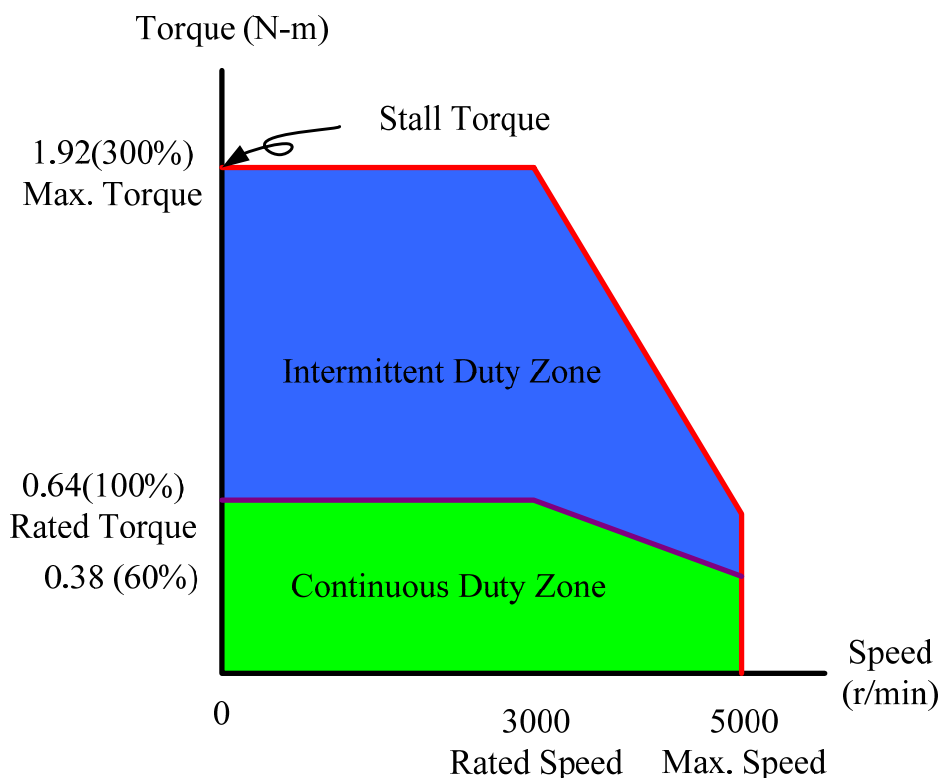
● The Power and Torque

- Power: $P = T * \omega$ (Power=Torque*Angular Speed);
watts = N-m * rad/sec
- Angular Velocity: RPM (revolutions per minute)
= 60* RPS (revolutions per second)
 $RPS * 2\pi$ (radians per second)
- Torque: $T = I * \alpha$ (Torque = Inertia*Angular Acceleration);
N-m = kg-m² * rad/sec²

The Speed-Torque Curve

● The Specification of a Servo Motor

- The Speed-Torque Curve presents the ability of a motor.
- How long a motor can work in the intermittent zone is defined by its “Chart of Load and Operating Time”.



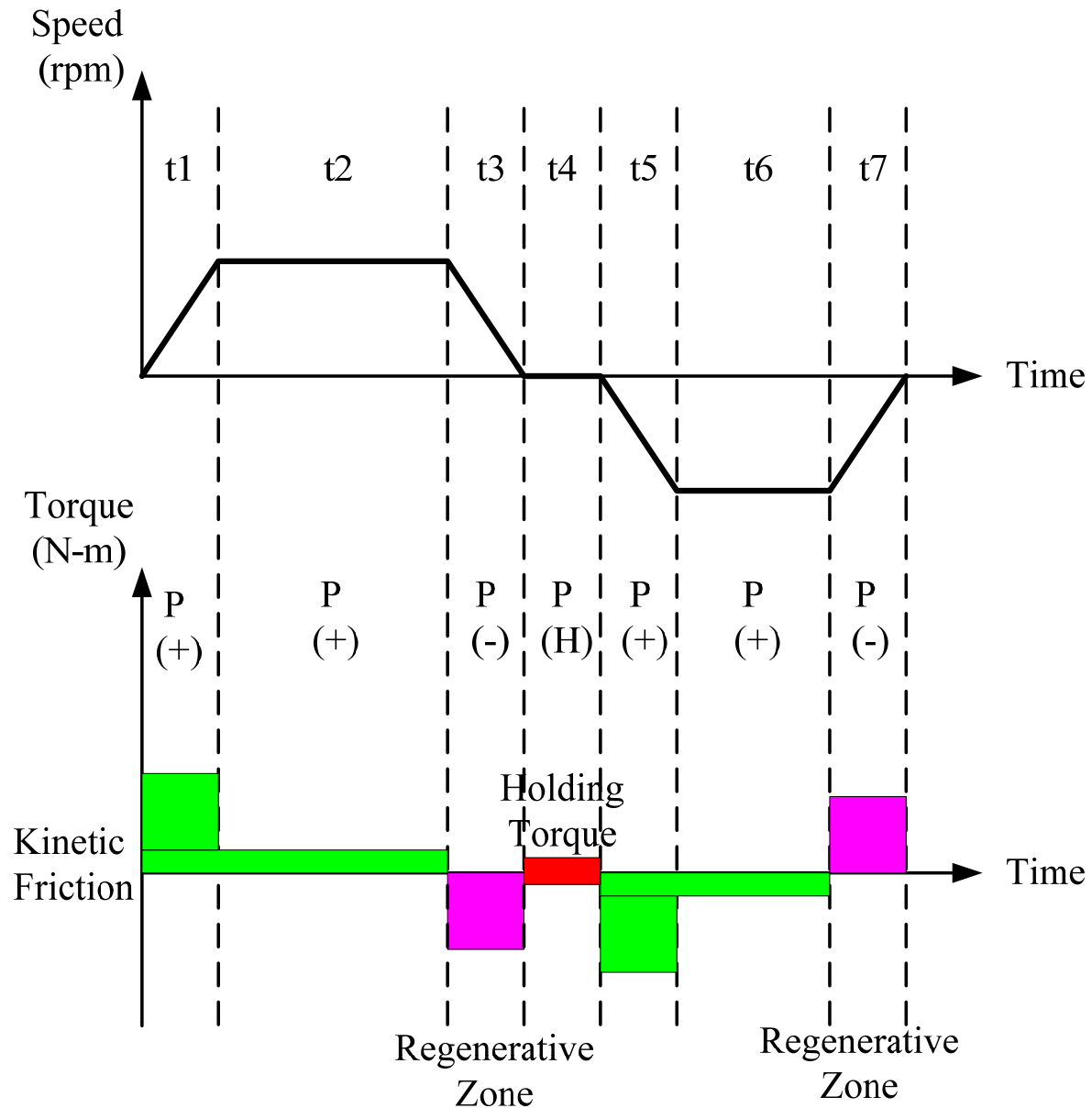
Load	Operating Time
120%	139.335s
140%	27.585s
160%	14.235s
180%	8.9625s
200%	6s
220%	4.4925s
240%	3.2925s
260%	2.58s
280%	2.07s
300%	1.6125s

The Motion Profile

● The Duty Cycle of a Servo System

- It denotes how the energy converted from electricity to kinetic power. The trapezoidal curve is a very typical profile for motion.

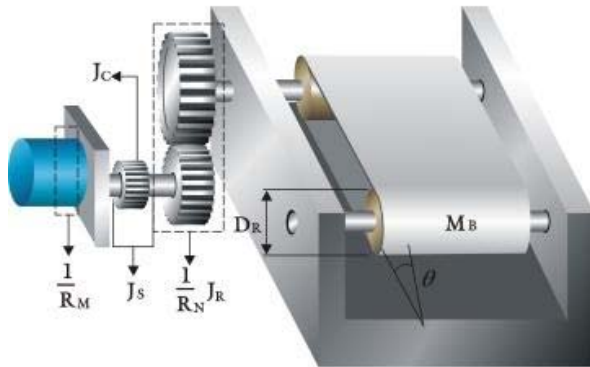
- $P = T * \omega$ (Power = Torque * Angular Speed).



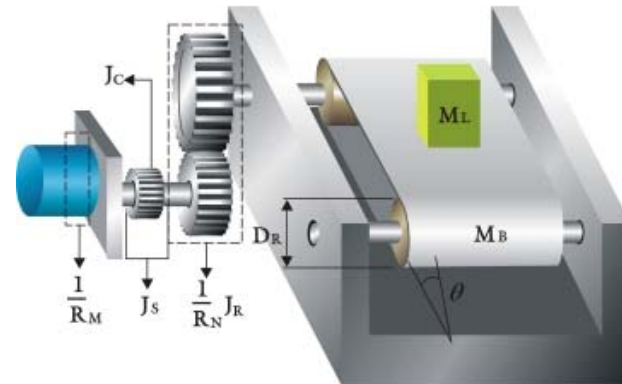
The Driving Target (1)

● The Inertia of a Machine

- The inertia of the mechanism for the worst scenario to the motor shaft must be known first.
- The highest speed, steepest acceleration, and max. load added for evaluating the inertia means “the worst scenario”.



The machine operated without load

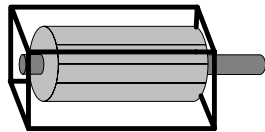


The machine operated with maximum load

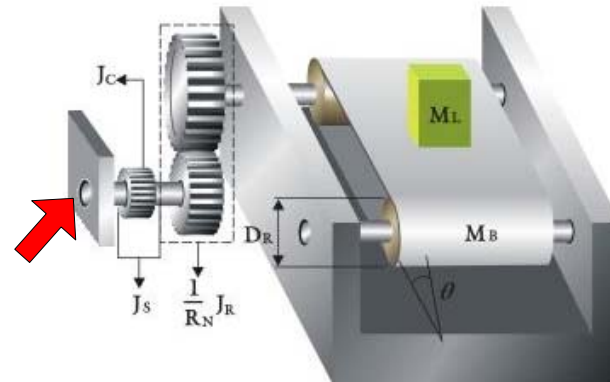
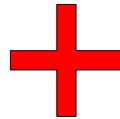
The Driving Target (2)

● The Inertia of a Servo Motor

- The rotor inertia of a motor should be included into the system inertia because it is linked to the system to move together.
- You can get on internet or refer to engineering books for calculating the system inertia.



The inertia of
the rotor



The inertia of the machine
to shaft of a motor

The Maximum Torque (1)

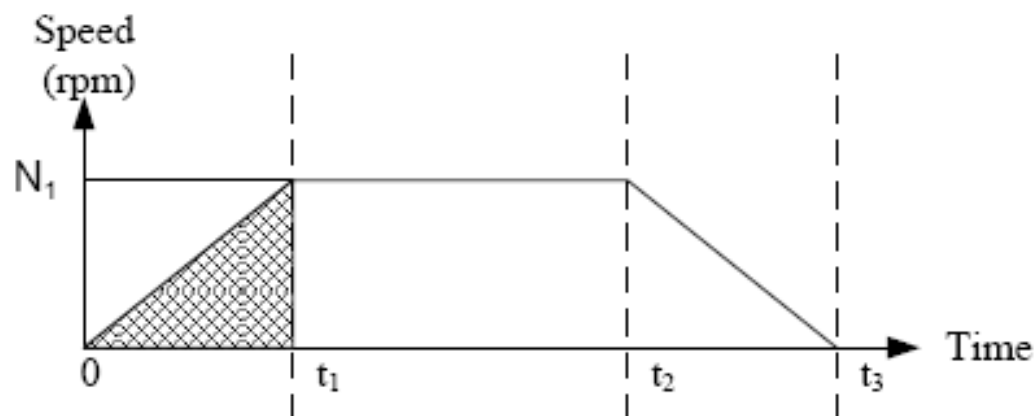
● From Motion

Profile to Torque Curve

- The maximum torque is applied to check the intermittency of a servo motor.

- The Torque Curve can be derived from its Motion Profile accompanying with driving inertia.

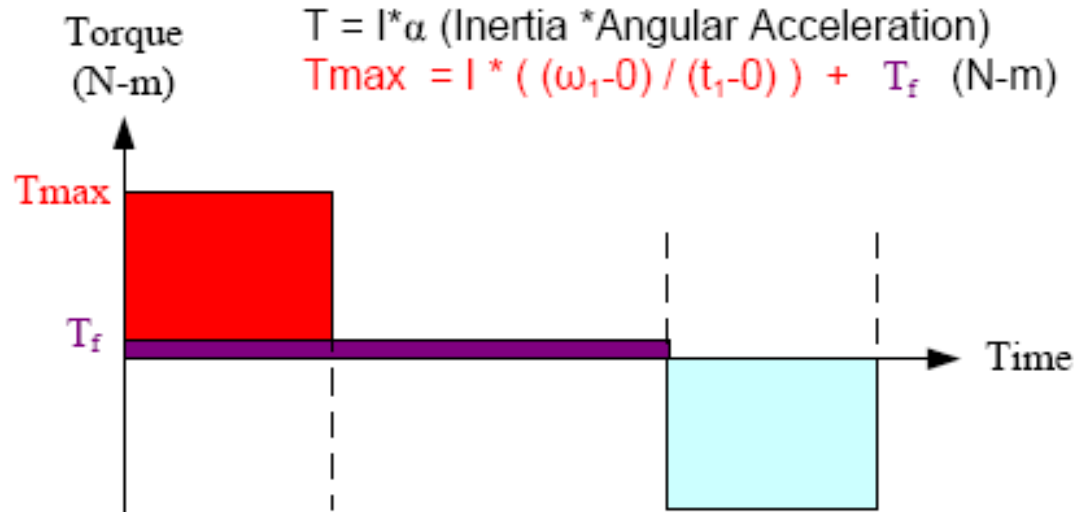
- The T_f stands for kinetic friction.



$$\omega_1 \text{ (rad/s)} = N_1 \text{ (rpm)} / 60 * 2\pi$$

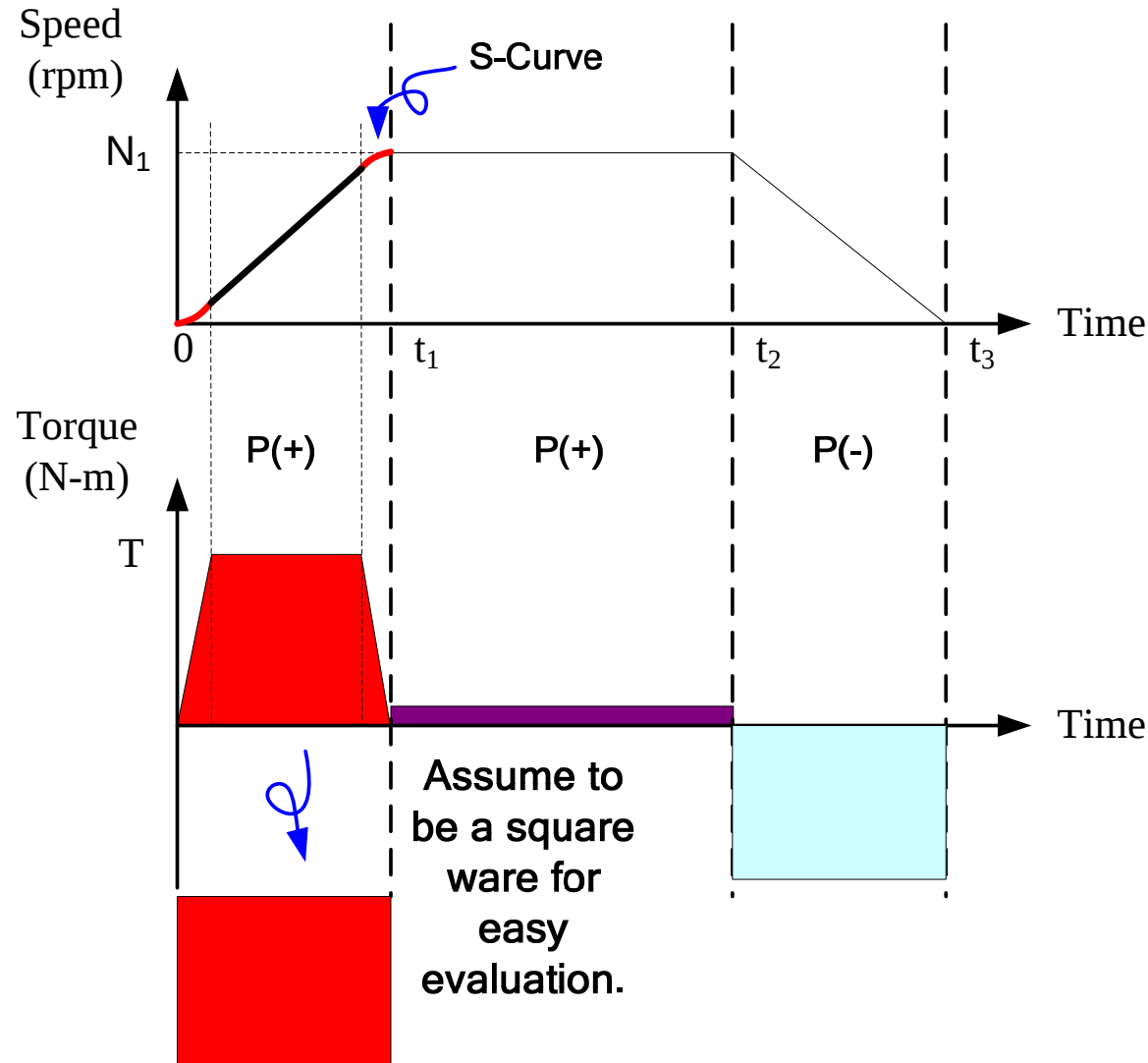
$$T = I * \alpha \text{ (Inertia * Angular Acceleration)}$$

$$T_{\max} = I * ((\omega_1 - 0) / (t_1 - 0)) + T_f \text{ (N-m)}$$



The Maximum Torque (2)

- **A way of approximation**
 - The speed profile employs a s-curve at both of the ends that will turn out a trapezoidal torque curve. Treat the trapezoidal torque curve as a square one for easy calculation.



The RMS Torque

● The RMS Torque Used to Fit Rated Torque

- The RMS torque is time-weighted average torque which can be thought as a long-term average torque.

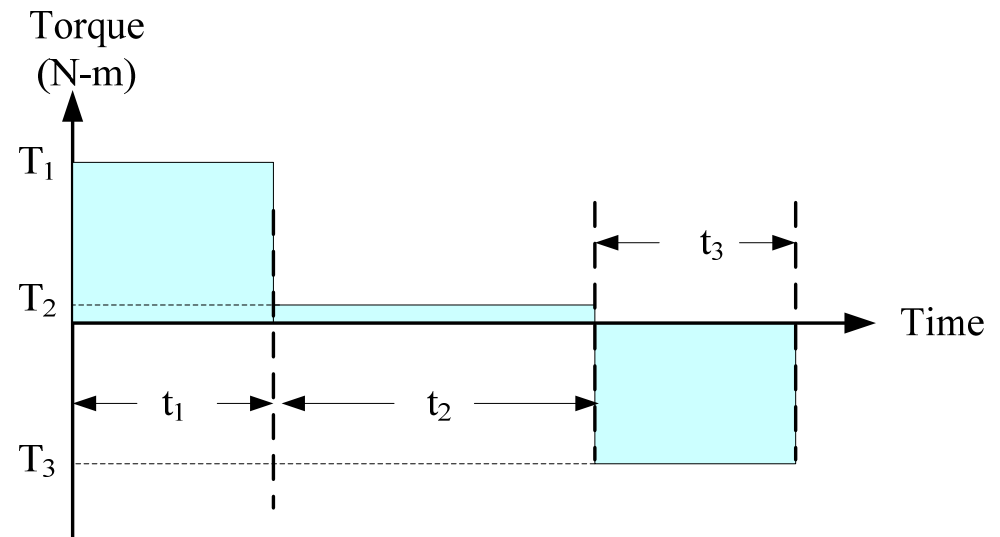
- The heat of a servo motor will build up and cross overload level if the RMS torque greater than its rated torque.

The definition of Trms:

$$T_{rms} = \sqrt{\frac{1}{t_n - t_1} \int_{t_1}^{t_n} T^2(t) dt}$$

The Trms in square wave:

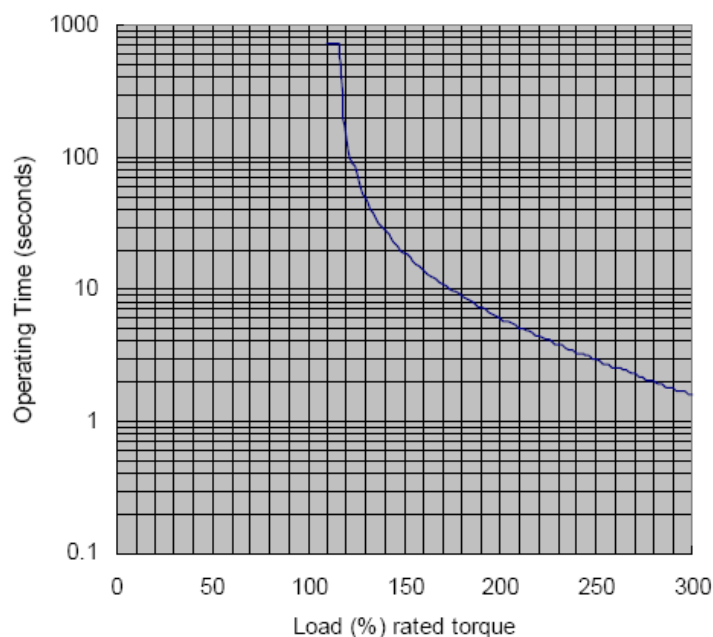
$$T_{rms} = \sqrt{\frac{(T_1^2 \times t_1) + (T_2^2 \times t_2) + (T_3^2 \times t_3)}{t_1 + t_2 + t_3}}$$



The Overload Triggered

● The Way ASDA System Triggers Overload Alarm

- If an application will be operated above 100% load frequently, the rule below should be checked.



Load	Operating Time
120%	139.335s
140%	27.585s
160%	14.235s
180%	8.9625s
200%	6s
220%	4.4925s
240%	3.2925s
260%	2.58s
280%	2.07s
300%	1.6125s

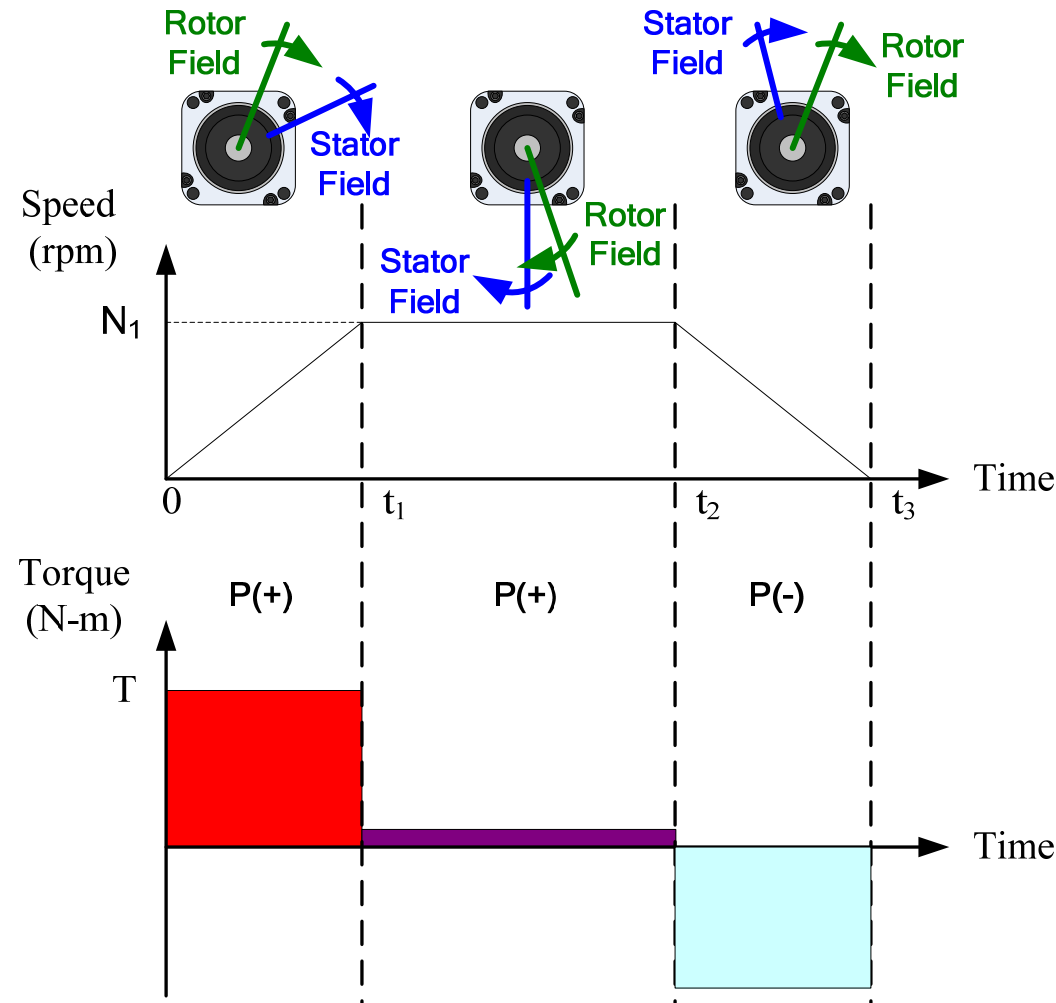
120% T1,
140% T2,
160% T3,
180% T4,
200% T5,
220% T6,
240% T7,
260% T8,
280% T9,
300% T10

$T1/139.335 + T2/27.585 + T3/14.235 + T4/8.9625 + T5/6 + T6/4.4925 + T7/3.2925 + T8/2.58 + T9/2.07 + T10/1.6125 < 1$, to avoid triggering Alarm 06.

The Regenerative Energy(1)

●How It works

- In the acceleration and constant speed periods, the stator field leads the rotor field that is the phenomena of a motor .
- During the deceleration period, the rotor field leads the stator field that is a generator effect and will pour the energy back to its system.

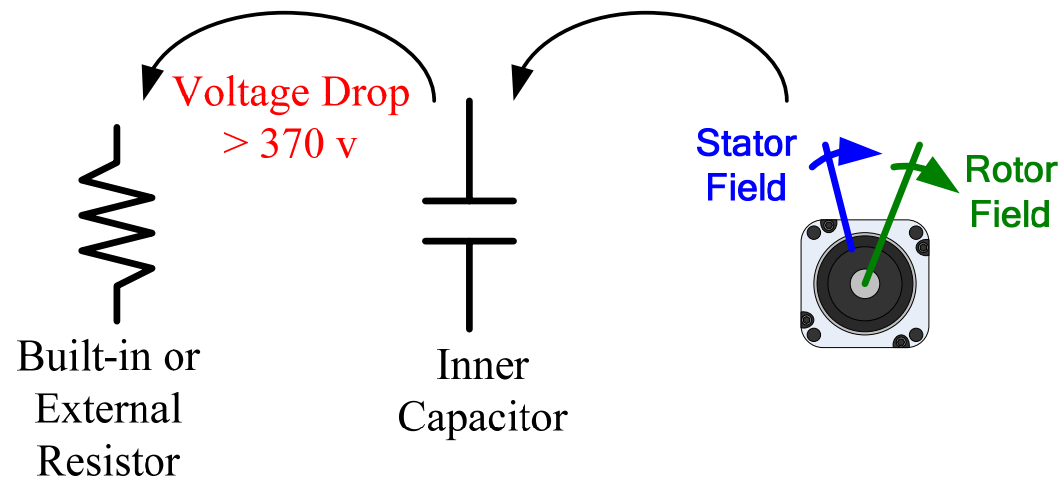


The Regenerative Energy(2)

●How the Servo Drive Handles it

-When the energy comes back to the servo drive, it will be kept inside the capacitors until reaching their designed voltage level, which is denoted by V-bus in Delta system.

- The energy will be dissipated on built-in or external resistor called regenerative resistor when the V-bus is at the designed voltage level 370V.



The Regenerative Energy(3)

●How to Select a Regenerative Resistor

$$-E_{RE} = J_S * ((N_1)^2 - (N_2)^2) / 182$$

E_{RE} : Regenerative Energy (Joules)

J_S : System inertia (kg-m²)

N_1, N_2 : The original speed and final speed (r/min, rpm)

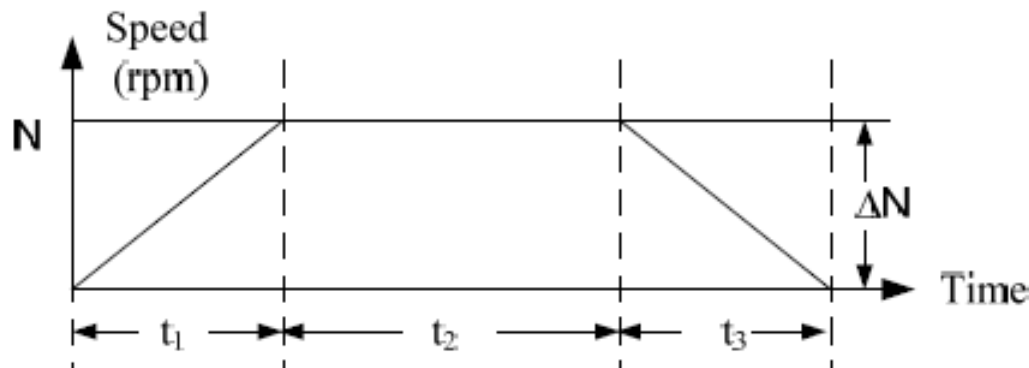
$$-W_R = (E_{RE} - E_C) / t_{decel} ; R_{max} = (370)^2 / W_R$$

W_R : Power dissipated on resistor (watts)

E_C : Energy stored in capacitors (Joules)

R_{max} : The maximum allowable resistance (ohm)

Minimum Resistance from Manual $\leq$ Regenerative Resistance $\leq R_{max}$



$$E_{RE} = J_S * (\Delta N)^2 / 182 \text{ (Joules)}$$

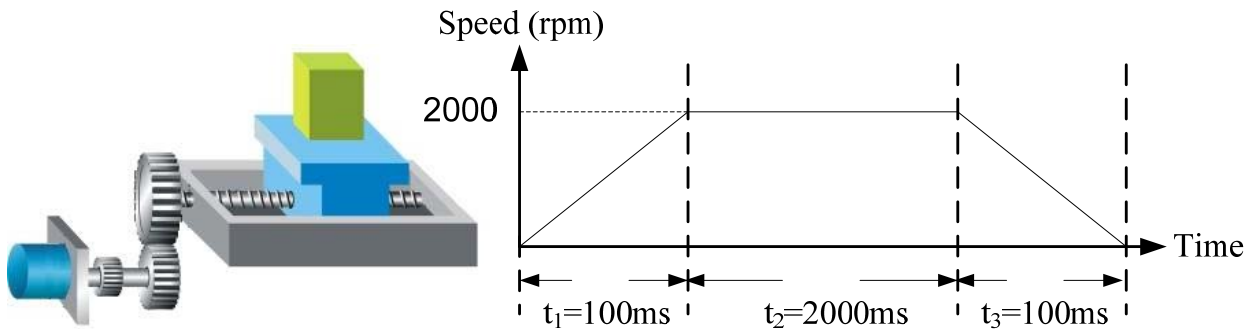
$$W_R = 2 * (E_{RE} - E_C) / t_3 \text{ (watts)}$$

$$R_{max} = (370)^2 / W_R \text{ (}\Omega\text{)}$$

A Servo Selection Example(1)

● The Maximum Torque of a System

- $I_{\text{machine}} = 0.00612 \text{ (kg-m}^2\text{)}$ (from the machine designer)
- The angular speed $= 2000/60 * 2\pi = 209.44 \text{ (rad/sec)}$
- $T_{\text{temp_max}} = I * \alpha = 0.00612 * ((209.44 - 0) / (0.1 - 0)) = 12.82 \text{ (N-m)}$
- Pick up ECMA-E11315: Max.T = 21.48 > 12.82 (N-m);
 $I_{\text{motor}} = 11.18\text{E-4 (kg-m}^2\text{)}$
- $T_{\text{max}} = I_{\text{system}} * \alpha = (I_{\text{machine}} + I_{\text{motor}}) * \alpha = (0.00612 + 0.001118) * (209.44/0.1) = 15.16 < 21.48 \text{ (N-m)}$
- A margin for kinetic friction should be kept.

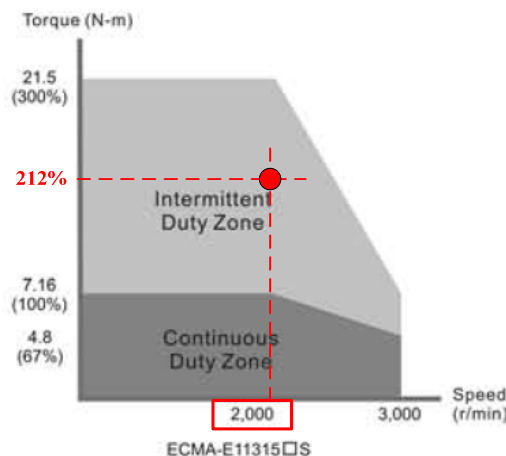
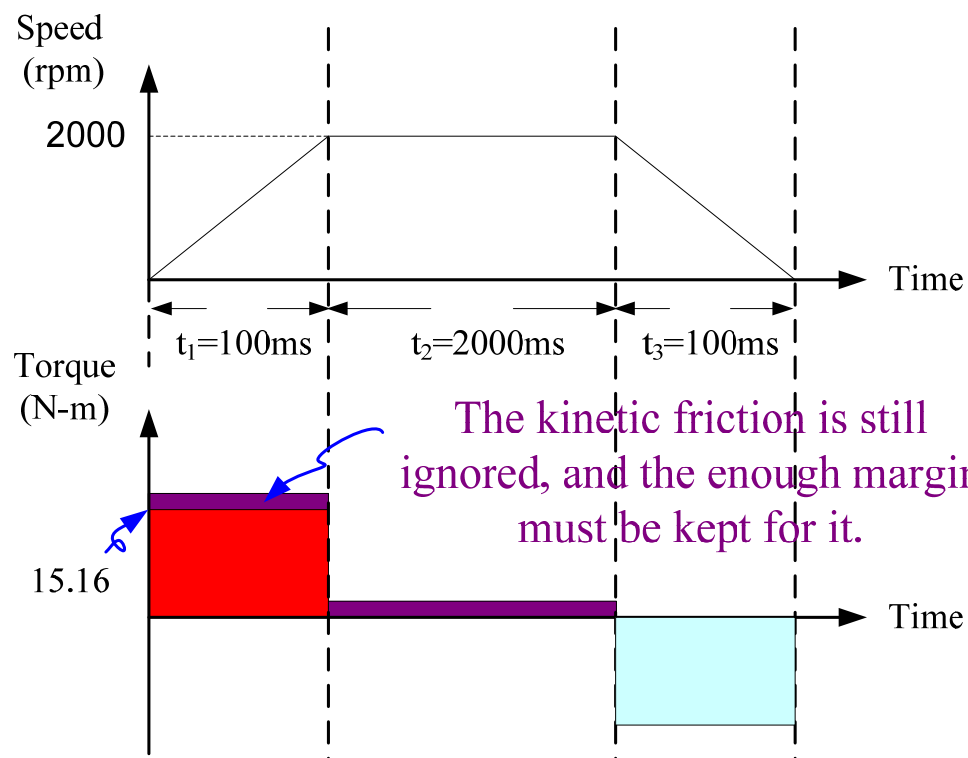


ECMA Series	E113			
	05	10	15	20
Rated output power (kW)	0.5	1.0	1.5	2.0
Rated torque (N-m)	2.39	4.77	7.16	9.55
Maximum torque (N-m)	7.16	14.3	21.48	28.65
Rated speed (r/min)			2000	
Maximum speed (r/min)				3000
Rated current (A)	2.9	5.6	8.3	11.01
Maximum current (A)	8.7	16.8	24.9	33.03
Power rating (kW/s)	7.0	27.1	45.9	62.5
Rotor moment of inertia (Kg.m ²) (without brake)	8.17E-4	8.41E-4	11.18E-4	14.59E-4

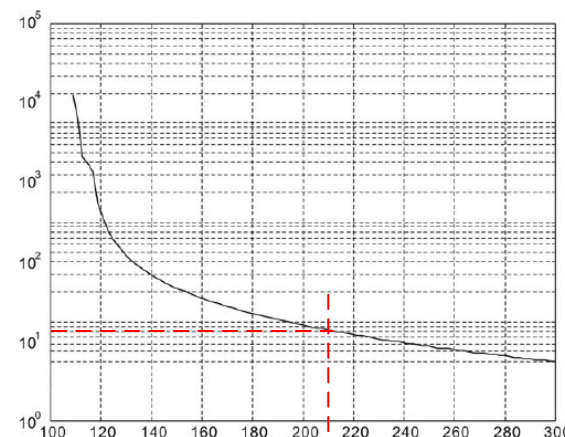
A Servo Selection Example(2)

● Check the Intermittent Operation from Specification

- $T_{\max}=15.16$ (N-m); $T_{\text{rated_motor}}= 7.16$ (N-m)
- The ratio of torque = $15.16 / 7.16 = 2.12=212\%$



ECMA Series	E113			
	05	10	15	20
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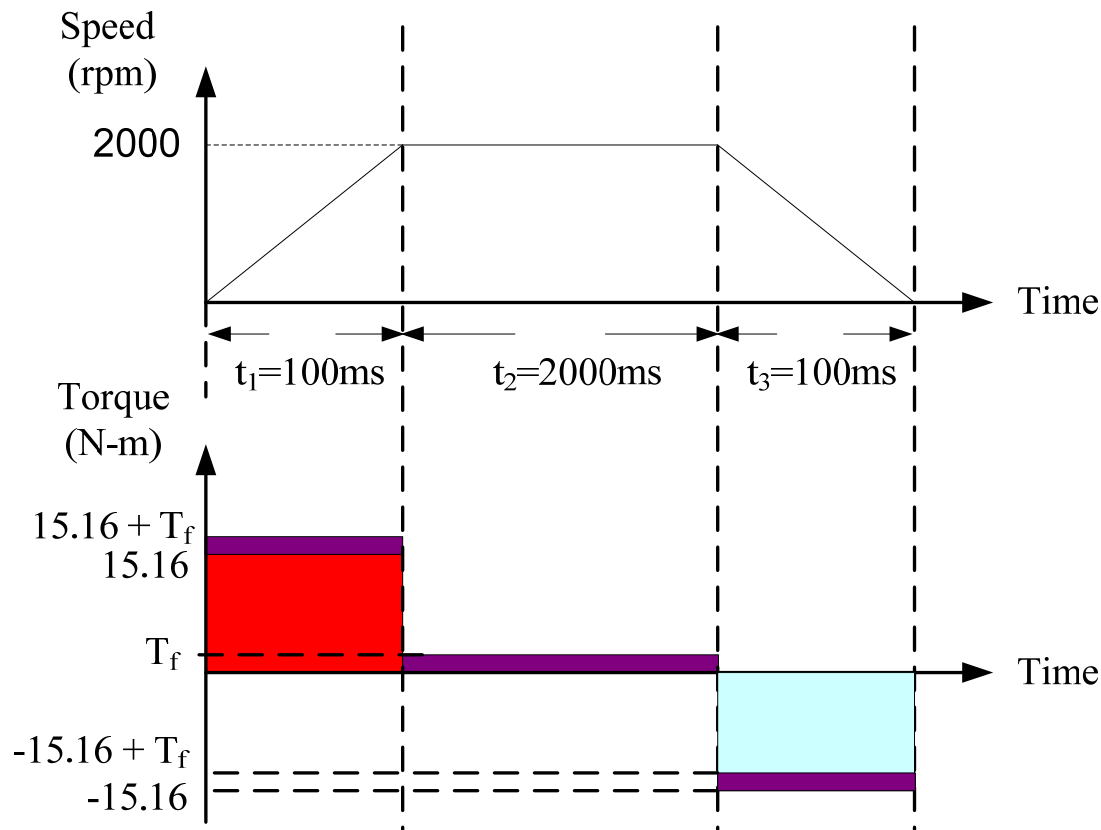
Load	Operating Time
120%	527.6s
140%	70.4s
160%	35.2s
180%	22.4s
200%	16s
220%	12.2s
240%	9.6s
260%	7.8s
280%	6.6s
300%	5.6s

> 100ms=0.1s

A Servo Selection Example(3)

● Check the Continuous Operation from Specification

- $T_{rms} = 4.57 \text{ (N-m)} < T_{rated} = 7.16 \text{ (N-m)}$
- The kinetic friction is ignored here.



$$T_{rms} = \sqrt{\frac{(15.16^2 \times 0.1) + ((-15.16)^2 \times 0.1)}{0.1 + 2 + 0.1}}$$

$$= 4.57 \text{ (N-m)}$$

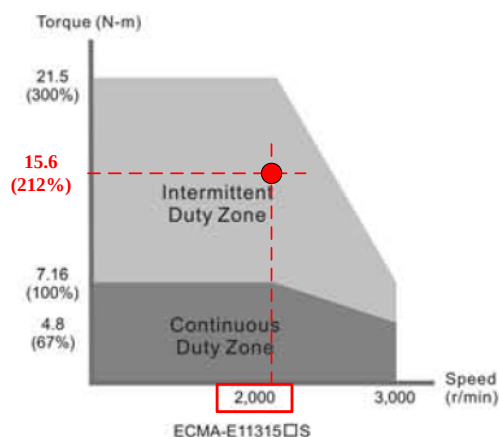
A Servo Selection Example(4)

● The Margin for Kinetic Friction

- The kinetic friction should be known in advance for the machine moving with high kinetic friction.
- For the machine with minor kinetic friction, it can be ignored by leaving some margin during selecting a system.
- If the kinetic friction is impossible to known until the machine is well assembled, upgrade the margin.

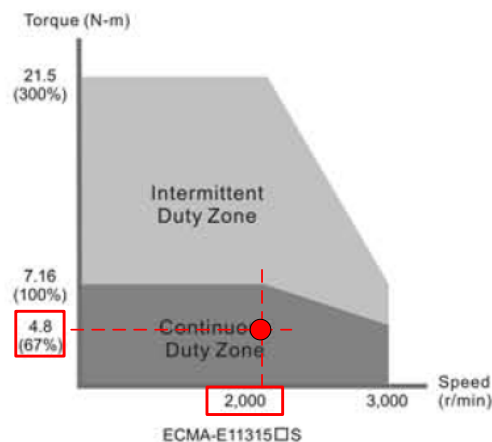
The margin in continuous duty zone:

The margin in intermittent zone:



$$T_{f_margin_I} = 21.5 - 15.6$$

$$= 5.9 \text{ (N-m)}$$



$$T_{rated} = 7.16 \text{ (N-m)} =$$

$$\sqrt{\frac{((15.16 + T_f)^2 \times 0.1) + ((T_f)^2 \times 2) + ((-15.16 + T_f)^2 \times 0.1)}{0.1 + 2 + 0.1}}$$

$$T_f = 5.5 \text{ (N-m)}$$

$$\text{Min } \{5.9, 5.5\} = 5.5 \text{ (N-m)}$$

A Servo Selection Example(5)

● The Regenerative Energy

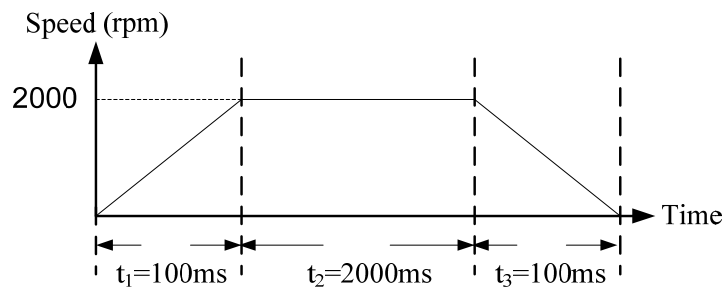
$$-E_{RE} = J_S * ((N_1)^2 - (N_2)^2) / 182 = (0.00612 + 0.001118) * (2000)^2 / 182 = 159.08 \text{ (Joules)}$$

$$-W_R = (E_{RE} - E_c) / t_{\text{decel}} = (159.08 - 18) / 0.1 = 1410.8 \text{ (watts)}$$

$$-R_{\text{max}} = (370)^2 / W_R = (370)^2 / 1410.8 = 97.03 \text{ } (\Omega)$$

-The built-in resistor is 60 watts which cannot meet this requirement; therefore, an external resistor is necessary.

$$20(\Omega) \leq (\text{The Resistor with min. 1410.8 w}) \leq 97.03(\Omega)$$



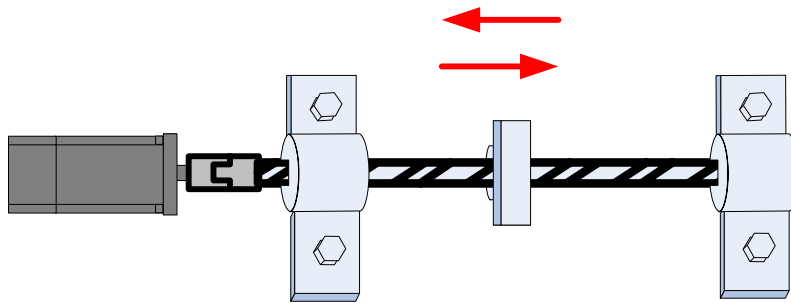
Built-in Regenerative Resistor Specifications				
Servo Drive (kW)	Resistance (Ohm) (parameter P1-52)	Capacity (Watt) (parameter P1-53)	Regenerative Power processed by built-in regenerative resistor (Watt) *1	Min. Allowable Resistance (Ohm)
0.2	-	-	50	30
0.4	-	-	40	30
0.75	40	60	30	20
1.0	40	60	30	20
1.5	40	60	30	20
2.0	20	100	60	10
3.0	20	100	60	10

The table is from 6.6.3 Regenerative Resistor of A2 manual.

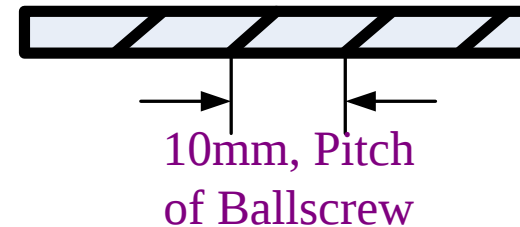
A Servo Selection Example(6)

●The Miscellaneous

- The dimension and frame size.
- The IP protection level.
- The reducer can help to lower the torque and will speed up the motor.
- The resolution of encoder.



The position accuracy is requested to 0.0001mm.



The resolution of encoder:
 $10\text{mm} / 0.0001\text{mm} = 100000$ (division / revolution)

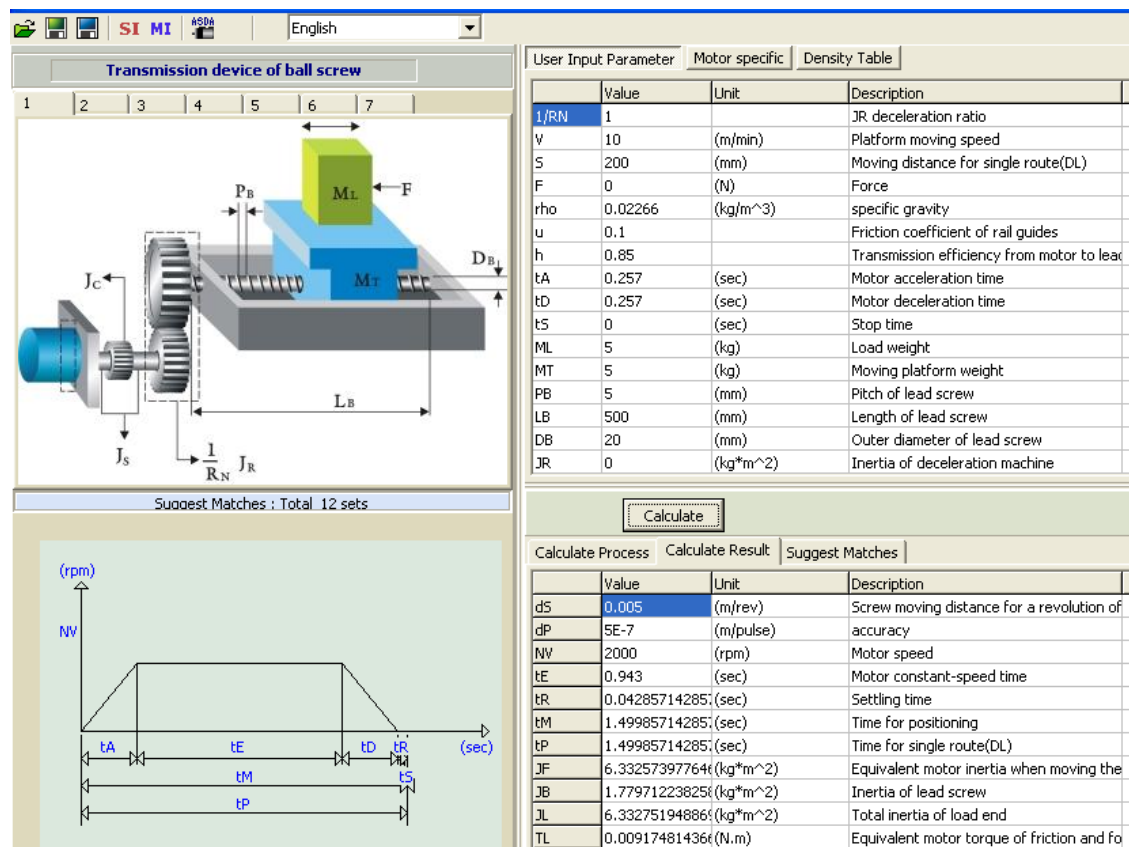
The MSizing Software

●The Assistant of Selecting a Servo System

-It can help some but not all.

-Select a close mechanism, set the parts' parameters to zero when not used.

-Follow the instruction, one click, and get the result.



Thank You

