

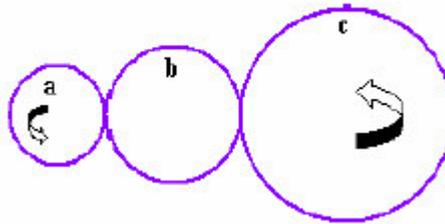
Spring, 2026

## MCT333/ MCT344: Mechatronic Systems Design

### Sheet 2: Actuator Sizing

Support your answer with sketches and diagrams as much as possible.

1. If the output torque  $T_c$  must be  $3T_a$  in Fig. 1, how many teeth should gears b and c have? Given gear a has 26-teeth.



2. A motor rated at 5000 rpm is used to turn the 50 mm-diameter wheels of a mobile robot. The robot is required to travel a 600 mm distance in about 8(sec). To this end, the motor angular velocity is to be geared down using a gear system. The available gear teeth are 10, 20, 50, and 100.
  - Find a proper gear system combination that achieves this objective as closely as possible.
  - The motor inertia is  $0.7 \times 10^{-7} \text{ kgm}^2$  and the wheel inertia is 20 times the motor inertia. Given the motor torque of 2.5 mNm, what will be the wheel's angular acceleration for the gear system designed in the previous part?
3. Consider the machine shown in the Figure below. If both axes are moving at the speed of 101 mm/s using trapezoidal velocity profile with  $t_a = 0.2 \text{ s}$ , how long will it take each axis to complete its move?

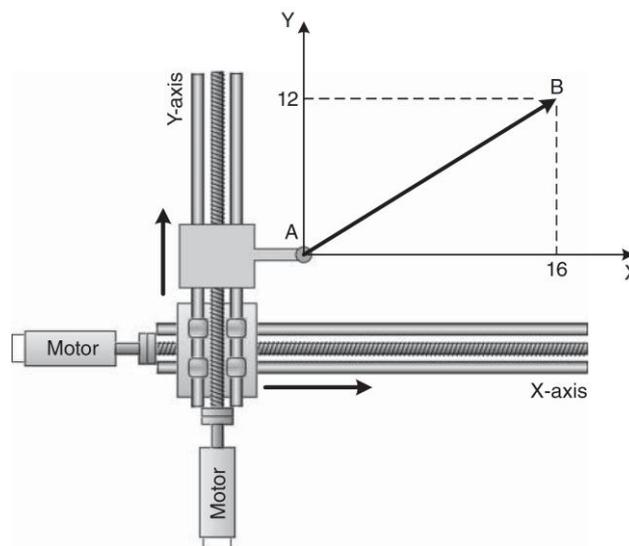
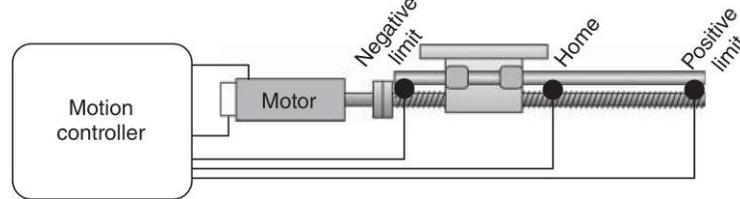
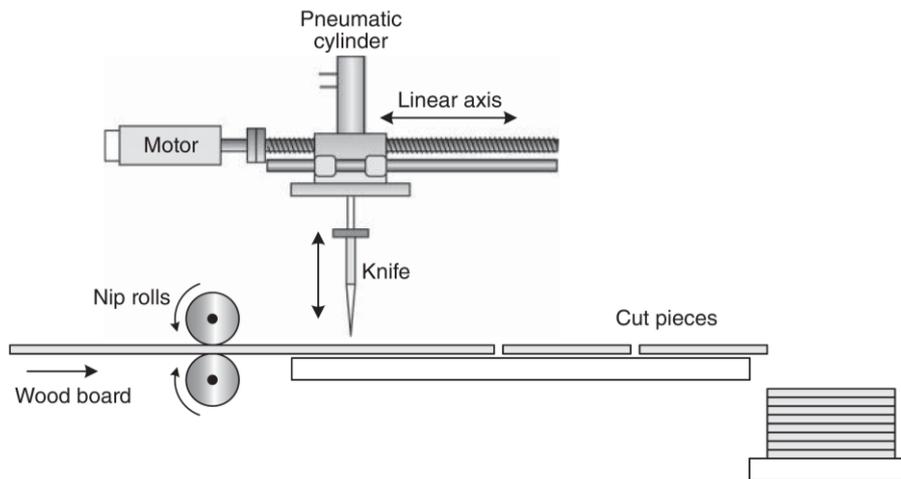


Figure : Multiaxis machine

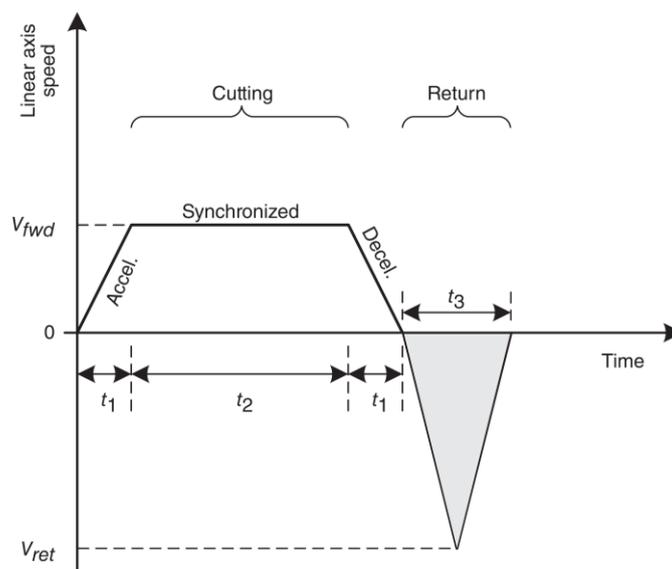
4. Motion controllers use counts (cts) to track position. The motor in the Figure below has an encoder that produces 8000 cts/rev. The ball-screw advances 10 mm/rev. A motion application requires the carriage of the linear axis to travel 406 mm at 101 mm/s with an acceleration of 254 mm/s<sup>2</sup>. Calculate the following parameters for the carriage in the units shown: speed (cts/ms), distance (cts), acceleration (cts/ms<sup>2</sup>), and move time (constant velocity time) in ms.



5. In the motion control application shown in Figure a below, the nip rolls feed long wood boards which are cut to equal length pieces. Figure b shows the velocity profile for one cycle of the linear axis that carries the shear. The shear waits at a hover position over the conveyor. When it gets a signal from the controller, it accelerates and matches the speed of the conveyor (constant velocity segment). During this time, the shear is lowered and retracted to make the cut. After that, the axis slows down to zero speed and returns to the hover position. Find the return velocity  $V_{ret}$  to be programmed into the controller.



(a)



(b)

Figure: (a) Flying shear machine to cut continuous material into fixed lengths. (b) Velocity profile for the shear

6. A new machine requires the use of a linear motor for high acceleration and speed. The following specifications summarize the system.
- Machine details: linear sliding roller Bearings, load: 60 kg, orientation: 20° relative to horizontal, air-cooling system to keep motor temperature around 25°C.
  - Machine motion profile: Type: 1/3- 1/3- 1/3 Trapezoid, distance: 600 mm, move time: 300 ms, dwell time: 330 ms.

Determine the peak and root mean square force of the linear motor.

7. Consider a rotary load driven by an electric servo motor. The rotary load is directly connected to the motor shaft without any gear reducer (Figure 1). The rotary load is a solid cylindrical shape made of steel material,  $d=60$  mm,  $l= 60$  mm,  $\rho= 7800$  kg/m<sup>3</sup>. The desired motion of the load is a periodic motion (Figure 2). The total distance to be traveled is 1/4 of a revolution. The period of motion is  $t_{cyc}= 400$  ms. and dwell portion of is  $t_{dw}= 100$  ms. and the remaining part of the cycle time is equally divided between acceleration, constant speed and deceleration periods. Determine the required motor size for this application when the working temperature around the motor is 50°C.

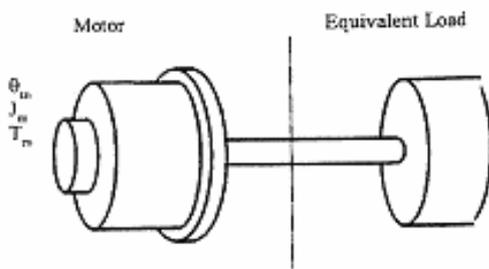


Figure 1

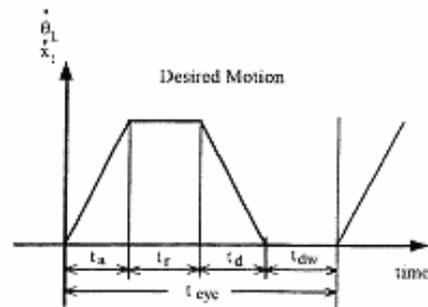
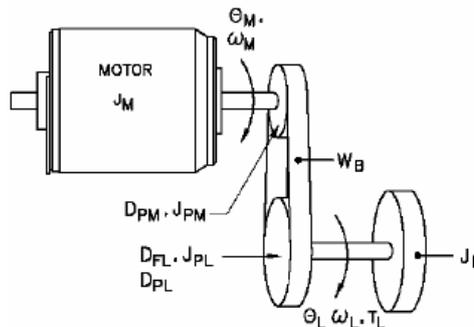


Figure 2

8. If the same rotary load in Figure 1 which is a solid cylindrical shape made of steel material,  $d= 50$  mm,  $l= 60$  mm,  $\rho= 7800$  kg/m<sup>3</sup>. The desired motion of the load is a periodic motion. The total distance to be traveled is 1/4 of a revolution. The period of motion is  $t_{cyc}= 250$  ms. and dwell portion of it is  $t_{dw}= 100$ ms. And the remaining part of the cycle time is equally divided between acceleration with an exponential form; according to the following equation:  $k(e^{10t} - 1)$ , constant speed and deceleration with a linear form. Determine the peak and root mean square torques of a suitable motor for this application.
9. Consider a machine with a rotary load ( $J_L$ ) driven by an electric servo motor. The machine is connected to the motor shaft through the timing belt. The following specifications summarize the system: The timing belt pulleys diameter ratio: 1:2, the rotary load is a solid cylindrical shape made of steel material,  $d= 100$  mm,  $l= 60$ mm,  $\rho= 7800$  kg/m<sup>3</sup>. The desired speed motion profile of the load is a trapezoid type: 1/3- 1/3- 1/3, move time: 120 ms, dwell time: 20 ms. The total rotation angle by the load is 3/4 of a revolution. Determine a suitable motor size to drive this machine if the working temperature is 45°C. Taking into consideration that inertia ratio between the load and the motor is 5:1.



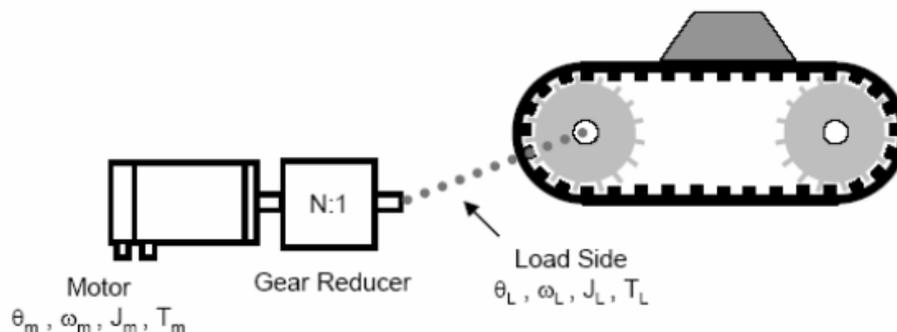
10. The specifications of a machine that utilizes a lead screw mechanism are:

- Lead screw: Diameter: 14 mm, length: 500 mm, pitch: 0.5 rev/mm, efficiency: 45%
- Mechanical data: Friction coefficient ( $\mu$ ): 0.1, load: 6 kg, orientation: inclined by  $10^\circ$  relative to horizontal. Taking into consideration that inertia ratio between the machine and the motor is 4:1
- Move profile: Type: 1/6- 2/3- 1/6 Trapezoid, distance: 8 mm, move time: 0.2s, dwell time: 0.1s. Determine the peak and root mean square torques of a suitable motor to drive this machine.

11. A servo AC motor connected to gearbox with reduction ratio 30:1 and 80% efficiency is used to drive a steel ballscrew system to lift 20kg vertical mass/load. The mass is subjected during movement to friction coefficient ( $\mu=0.1$ ). If the ballscrew has 15mm diameter, 400mm length, 4mm/rev pitch,  $\rho=7800 \text{ kg/m}^3$ , and 90% efficiency and taking into considerations that the inertia ratio between the effected mass/load and the motor inertia is 5:1, then:

- Calculate the total resistance torque reflected to (affecting on) the motor shaft due the vertical load and other forces.
- Calculate the reflected inertia of the vertical load/mass and the screw inertia to the motor side.
- If the move velocity trajectory profile: Type: 1/6- 2/3- 1/6 Trapezoid, distance: 8 mm, move time: 0.4 s, dwell time: 0.5 s. Determine the required motor size including (motor speed, peak and root mean square torque) to drive this machine when the working temperature is  $40^\circ\text{C}$ .
- Check the back-drivability of this system and comment on its backdrivability then suggest what do you need to add to improve the motor energy and power consumption.
- If the ballscrew is replaced by a power screw of the same diameter and length, but with an efficiency of 40%, how will the root mean square torque be affected?
- If vibrations occur during load movement along the previous given trajectory, what could be the cause of these vibrations, and how could they be reduced by selecting an appropriate trajectory velocity profile?

12. A conveyor system; shown in the figure below; is used to transfer bags 15 kg in a production line. The conveyor main roller is connected to main servomotor through a gear box with the following specifications: Roller diameter=300mm, Roller length=1000mm, gear box reduction ratio=50:1, orientation is horizontal, conveyor belt weight=10 kg, coefficient of friction between the conveyor belt its support surface is 0.05, working temperature= $35^\circ\text{C}$ , maximum number of bags on conveyor at the same time=10 bags. The motion profile: Type: 1/10 - 4/5 - 1/10 –Trapezoid, distance =500mm, move time=30s, dwell time=3s. Determine the peak and root mean square torque of the servo motor.



13. A geared AC motor with reduction ratio 30:1 and 85% efficiency is used to drive a conveyor. This conveyor transfer bags of cement with  $30^\circ$  inclination angle relative to the horizontal plane. If the maximum capacity of this conveyor is 500kg, conveyor roller diameter 300mm, coefficient of friction between the conveyor belt its support surface is 0.05, calculate the maximum total resistance torque reflected to (affecting on) the motor shaft. Then calculate the total reflected inertia load on the motor shaft.

14. The gantry machine in the Figure below carries a 20 kg load. The X-axis of the machine uses two [404XE-T13-VL](#) linear tracks in parallel. The Y-axis and Z-axis use [403XE-T04](#) and [402XE-T04](#) linear tracks by the same manufacturer. The X- and Y-axis tracks have 10mm screw leads. The Z-axis has 5mm screw lead. Each axis is equipped with a [BE230D motor](#). Each motor is connected to its axis using a cylindrical aluminum coupler with 28mm outer diameter and 38mm length. Referring to the data sheets, calculate the acceleration and continuous torque required to move each linear track of the X-axis at 250 cts/ms speed for 1s. Acceleration time is  $t_a = 50$  ms.

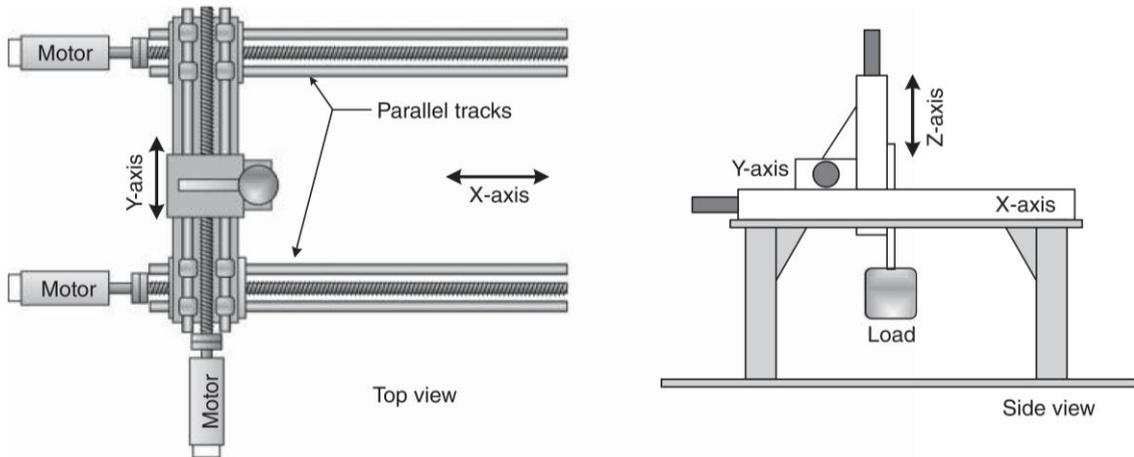


Figure: Gantry machine with two parallel linear tracks for X-axis