Load Connected to the Motor by a Gear

- A gear is sometimes placed between the motor and the load with the aim of adjusting the loading on the motor.
- If the motor has to operate with maximum static error θ_{eL} then the motor has to operate with a static position error of $\theta_{eM} = N\theta_{eL}$.
- If the load torque is T_L then the torque on the motor is T_L/N (neglecting friction torque effects).
- For static operation, there is considerable advantage to using a high gear ratio to link the motor and load.

- Effects of gear friction and backlash degrade system performance. We assume an ideal gear train: negligible inertia, friction, and backlash.
- During dynamic operation

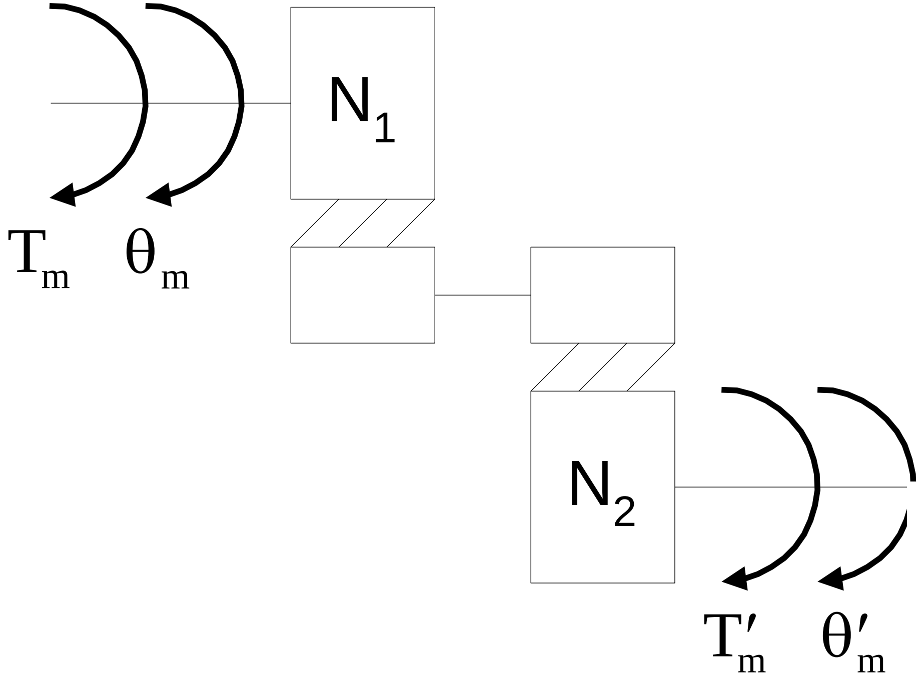
$$T_L = J_L \frac{d^2\theta_L}{dt^2}$$

$$T_M = \frac{T_L}{N} = \frac{J_L}{N^2} \frac{d^2\theta_M}{dt^2}$$

- The effective inertia at the motor is J_L/N^2. A high gear ratio would enable the motor to accelerate rapidly - BUT remember $\theta_L = \theta_M/N$.

- In summary:
  - High gear ratio
    - Low reflected inertia
    - Fast acceleration
    - Short load step length
    - High motor speed (high stepping rate)
    - Use when load movement involves substantial periods of acceleration and deceleration
  - Low gear ratio
    - High reflected inertia
    - Slow acceleration
    - Long load step length
    - Low motor speed (low stepping rate)

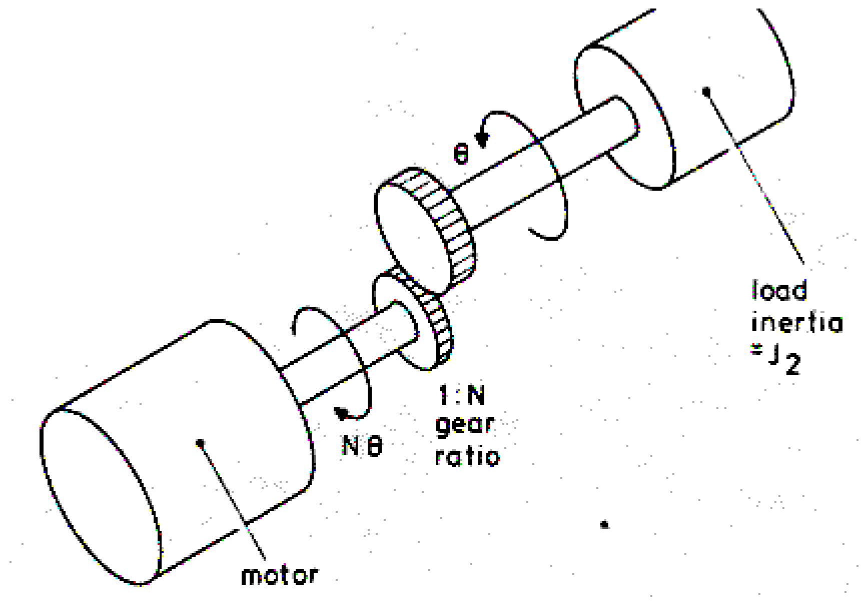
Gear Train Relations:



$$\frac{\theta_m}{\theta'_m} = \frac{N_2}{N_1} \equiv N$$

$$\frac{T_m}{T'_m} = \frac{N_1}{N_2} \equiv \frac{1}{N}$$

Motor Connected to Load by a Gear



Load Connected to the Motor by a Leadscrew

- Many linear loads are driven from a rotary stepping motor by a leadscrew, which may be an integral part of the motor.
- One revolution of the motor causes a load movement equal to the pitch *h* of the screw:

$$\frac{\theta}{2\pi} = \frac{x}{h}$$

- If the load is subject to a force *F* then, neglecting leadscrew friction,

$$Fx = T_L \theta$$

$$T_L = \frac{Fx}{\theta} = \frac{Fh}{2\pi}$$

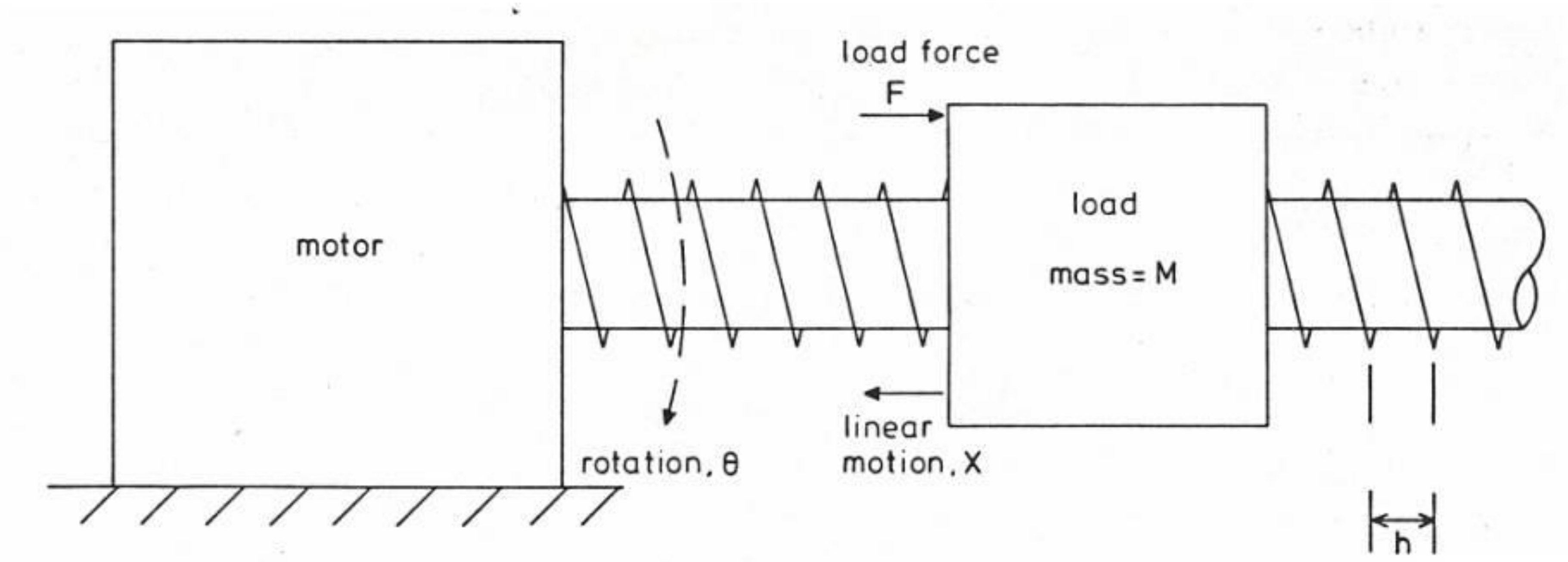
- The static position error for a system subject to a load force can be calculated as follows:
  - Calculate the effective load torque at the motor
  - From the motor static torque / rotor position error characteristic calculate the error in the motor's rotational position
  - Translate the rotational error into a linear error
- If the load is to be accelerated:

$$F = M\frac{d^2x}{dt^2}$$

$$T_L = \frac{Fh}{2\pi} = \frac{Mh}{2\pi}\frac{d^2x}{dt^2} = M\left(\frac{h}{2\pi}\right)^2\frac{d^2\theta}{dt^2}$$

$$J_{eff} = M\left(\frac{h}{2\pi}\right)^2$$

- In our analysis we assume an ideal leadscrew: negligible inertia, friction, and backlash.
- From a static point of view, a small screw pitch reduces the load torque at the motor.
- In the dynamic situation, there is a close parallel between the use of a small screw pitch and a high gear ratio. For small h, J_{eff} is reduced and the motor can accelerate rapidly, but it must attain a high stepping rate to compensate for the small increments of linear movement produced by each motor step.



Motor Connected to Load by a Leadscrew