# Technical information

## Mechatronics formulae

### Linear movement

| Symbol | Description | Units |
|---|---|---|
| s | Space | m |
| v | Velocity | m/s |
| a | Acceleration | m/s² |
| F | Force | N |
| P | Power | W |
| W | Energy | J |
| t | Time | s |
| μ | Friction coefficient | -- |
| g | Gravity acceleration | m/s² |
| m | Mass | Kg |

Speed (m/s)

$$v = \frac{\partial s}{\partial t}$$

Acceleration (m/s²)

$$a = \frac{\partial v}{\partial t}$$

Acceleration force (N)

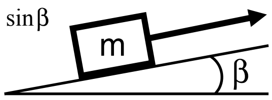
$$F_a = m \cdot a$$

Force friction (N)

$$F_\mu = \mu \cdot m \cdot g \cdot \cos\beta$$

Force gravity (N)

$$F_g = m \cdot g \cdot \sin\beta$$




Force root means square (N)

$$F_{rms} = \sqrt{\frac{\sum_i t_i \cdot F_i^2}{\sum_i t_i}}$$

Power (W)

$$P = F \cdot v$$

Cynetic energy

$$W = \frac{1}{2} \cdot m \cdot v^2$$

### Rotary movement

| Symbol | Description | Units |
|---|---|---|
| Φ | Angle | rad |
| ω | Angular velocity | rad/s |
| α | Angular acceleration | rad/s² |
| T | Torque | Nm |
| P | Power | W |
| W | Energy | J |
| t | Time | s |
| i | Gear reduction | -- |
| r | Radius | m |
| J | Inertia | Kgm² |

Speed (rad/s)

$$\omega = \frac{\partial \phi}{\partial t}$$

Acceleration (rad/s²)

$$\alpha = \frac{\partial \omega}{\partial t}$$

Acceleration torque (Nm)

$$T_\alpha = J \cdot \alpha$$

Torque root means square (Nm)

$$T_{rms} = \sqrt{\frac{\sum_i t_i \cdot T_i^2}{\sum_i t_i}}$$

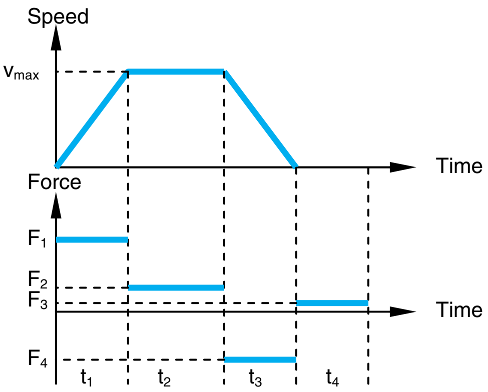
Power (W)

$$P = T \cdot \omega$$

Cynetic energy

$$W = \frac{1}{2} \cdot J \cdot \omega^2$$

**Example in case of trapezoidal profile (linear):**




1. Acceleration

$$a = \frac{v_{max}}{t_1}$$

$$s_1 = \frac{1}{2} \cdot v_{max} \cdot t_1$$

$$F_a = m \cdot a$$

$$F_{1\_\mathrm{Total}} = F_a + F_\mu + F_{ext}$$

2. Constant speed

$$a = 0$$
$$s_2 = v_{max} \cdot t_2$$
$$F_{2\_\mathrm{Total}} = F_\mu + F_{ext}$$

3. Deceleration

$$d = \frac{v_{max}}{t_3}$$

$$s_3 = \frac{1}{2} \cdot v_{max} \cdot t_3$$

$$F_d = m \cdot d$$

$$F_{3\_\mathrm{Total}} = F_\mu + F_{ext} - F_d$$

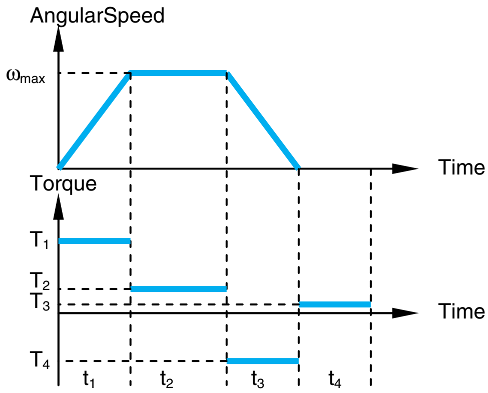
4. Dwell

$$s_4 = 0$$
$$F_{4\_\mathrm{Total}} = F_{ext}$$

Force rms:

$$F_{rms} = \sqrt{\frac{t_1 \cdot F_1^2 + t_2 \cdot F_2^2 + t_3 \cdot F_3^2 + t_4 \cdot F_4^2}{t_1 + t_2 + t_3 + t_4}}$$

**Example in case of trapezoidal profile (rotary):**




1. Angular acceleration

$$\alpha = \frac{\omega_{max}}{t_1}$$

$$\phi_1 = \frac{1}{2} \cdot \omega_{max} \cdot t_1$$

$$T_\alpha = J \cdot \alpha$$

$$T_{1\_\mathrm{Total}} = T_\alpha + T_\mu + T_{ext}$$

2. Constant speed

$$\alpha = 0$$
$$\phi_2 = \omega_{max} \cdot t_2$$
$$T_{2\_\mathrm{Total}} = T_\mu + T3_{ext}$$

3. Deceleration

$$\gamma = \frac{\omega_{max}}{t_3}$$

$$\phi_3 = \frac{1}{2} \cdot \omega_{max} \cdot t_3$$

$$T_\gamma = J \cdot \gamma$$

$$T_{3\_\mathrm{Total}} = T_\mu + T_{ext} - T_d$$

4. Dwell

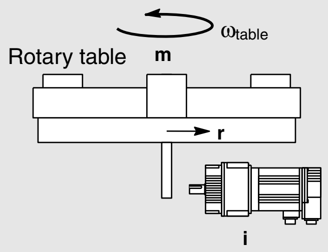
$$\phi_4 = 0$$
$$T_{4\_\mathrm{Total}} = T_{ext}$$

Torque rms:

$$T_{rms} = \sqrt{\frac{t_1 \cdot T_1^2 + t_2 \cdot T_2^2 + t_3 \cdot T_3^2 + t_4 \cdot FT_4^2}{t_1 + t_2 + t_3 + t_4}}$$

For linear motors you have just to apply the formulae for linear motors considering the mass of the load plus the mass of the motor. For rotary motors it is necessary to apply some cinematic transformations to have the magnitudes **from the motor side**.

Case of rotary table:

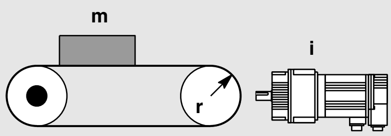



$$J_{total} = J_{motor} + \frac{\frac{1}{2} \cdot m \cdot r^2}{i^2}$$

$$\omega_{motor} = \omega_{table} \cdot i$$

$$T_{motor\_side} = J_{total} \cdot \alpha_{motor\_side}$$

Case of a belt drive with two pulleys:



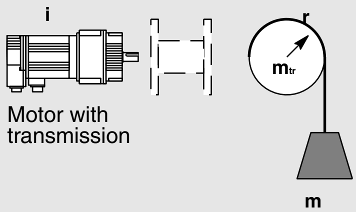

$$J_{total} = J_{motor} + \frac{2 \cdot J_{pulley} + J_{load}}{i^2}$$

$$J_{total} = J_{motor} + \frac{2 \cdot \frac{1}{2} \cdot m_{pulley} \cdot r^2 + m_{load} \cdot r^2}{i^2}$$

$$\alpha_{motor\_side} = a \cdot \frac{2\pi}{r} \cdot i$$

$$T_{motor\_side} = J_{total} \cdot \alpha_{motor\_side} + \frac{m \cdot \mu \cdot g \cdot r}{i}$$

Case of an hanging load:




$$J_{total} = J_{motor} + \frac{2 \cdot J_{reel} + J_{load}}{i^2}$$

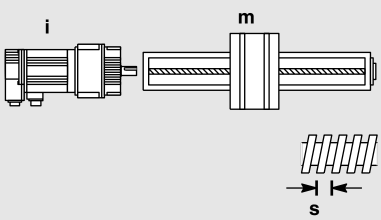
$$J_{total} = J_{motor} + \frac{\frac{1}{2} \cdot m_{reel} \cdot r^2 + m_{load} \cdot r^2}{i^2}$$

$$\alpha_{motor\_side} = a \cdot \frac{2\pi}{r} \cdot i$$

$$T_{motor\_side} = J_{total} \cdot \alpha_{motor\_side} \pm \frac{m \cdot g \cdot r}{i}$$

Note: The sign (±) depends on the direction of the movement

Case of a ballscrew:




$$J_{total} = J_{motor} + \frac{\left(\frac{s}{2\pi}\right)^2 \cdot m + \frac{1}{2} \cdot m_{screw} \cdot r^2_{screw}}{i^2}$$

$$\alpha_{motor\_side} = a \cdot \frac{2\pi}{s} \cdot i$$

$$T_{motor\_side} = J_{total} \cdot \alpha_{motor\_side} + \frac{m \cdot \mu \cdot g \cdot \frac{s}{2\pi}}{i}$$

## Motor selection

### Linear motor

The selected linear motor must match the next conditions.

$$v_{\text{max\_motor}} > v_{\text{max\_application}}$$

$$F_{\text{max\_motor}} > \frac{F_{\text{peak\_application}}}{\eta}$$

$$F_{\text{rated\_motor}} > \frac{F_{rms}}{\eta}$$

Where: η=Mechanical efficiency

**Note 1:** To calculate $F_{peak\_application}$ and $F_{rms}$ it is necessary to consider the motor mass. This may deal to do some iteration to get the right motor.

**2:** At high speed the motor reduces its rated and maximum force. This may be taken into consideration for high speed application.

**3:** For linear motors it is important to calculate the surface temperature of the motor in addition to the above calculation.

### Rotary motor

The selected linear motor must match the next conditions:

$$\omega_{\text{max\_motor}} > \omega_{\text{max\_application}}$$

$$T_{\text{max\_motor}} > \frac{T_{\text{peak\_application}}}{\eta}$$

$$T_{\text{rated\_motor}} > \frac{T_{rms}}{\eta}$$

Where: η=Mechanical efficiency

**Note 1:** To calculate $T_{peak\_application}$ and $T_{rms}$ it is necessary to consider the motor inertia. This may deal to do some iteration to get the right motor.

**2:** Above rated speed the motor reduces its rated and maximum torque. This may be taken into consideration for high speed application. Refer to the Speed-Torque curves of the motor for details.