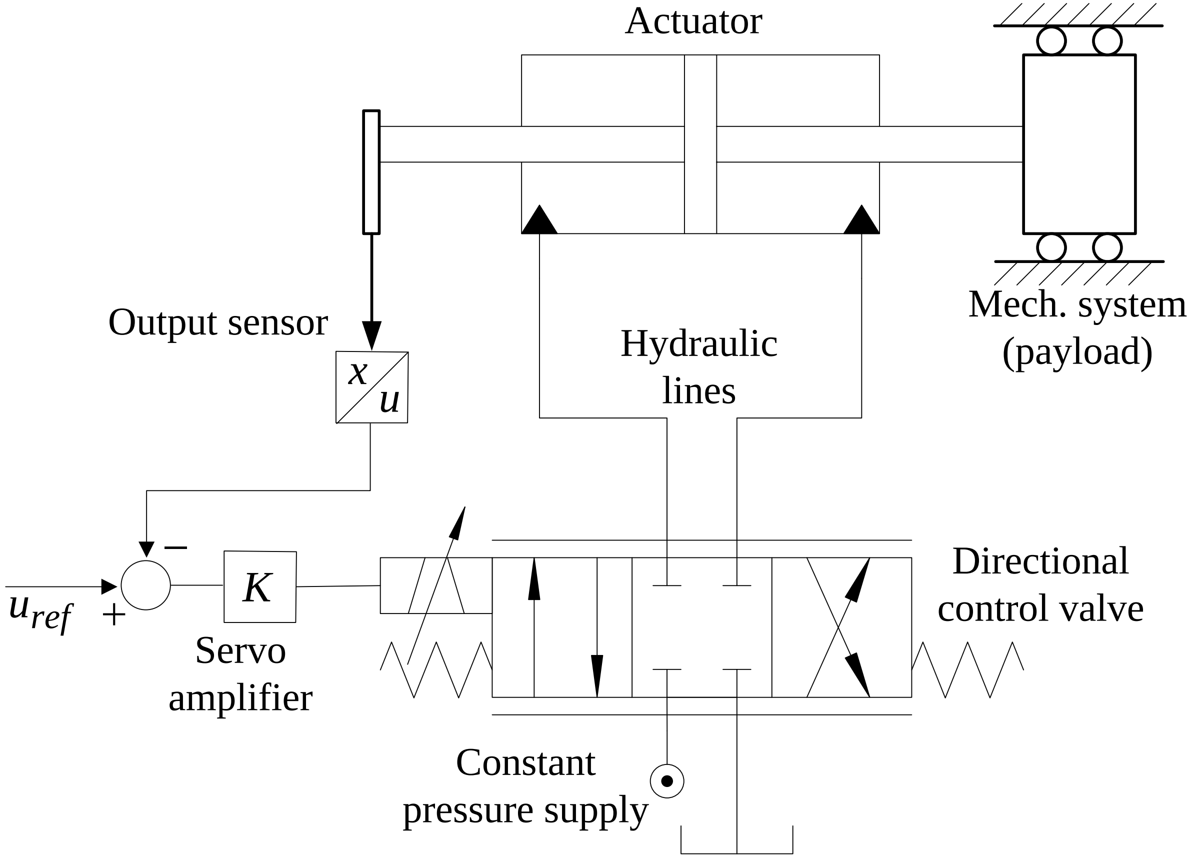
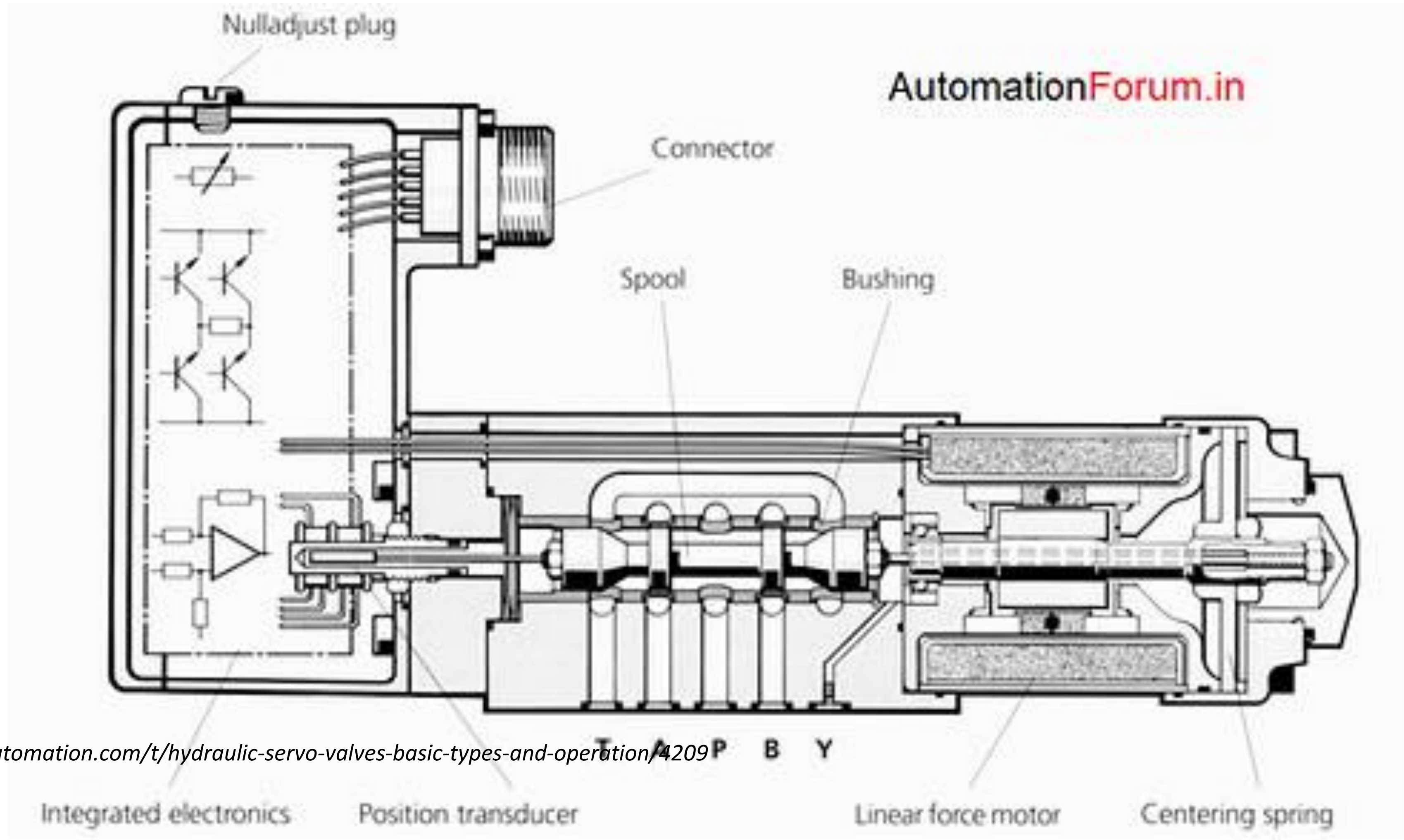
Servo system



Servo system characterized by the following

- Constant pressure source
- Directional control valve
- Hydraulic lines between valve and actuator
- Actuator
- Mechanical system - payload
- Output sensor
- Servo amplifier

Single stage servo valve

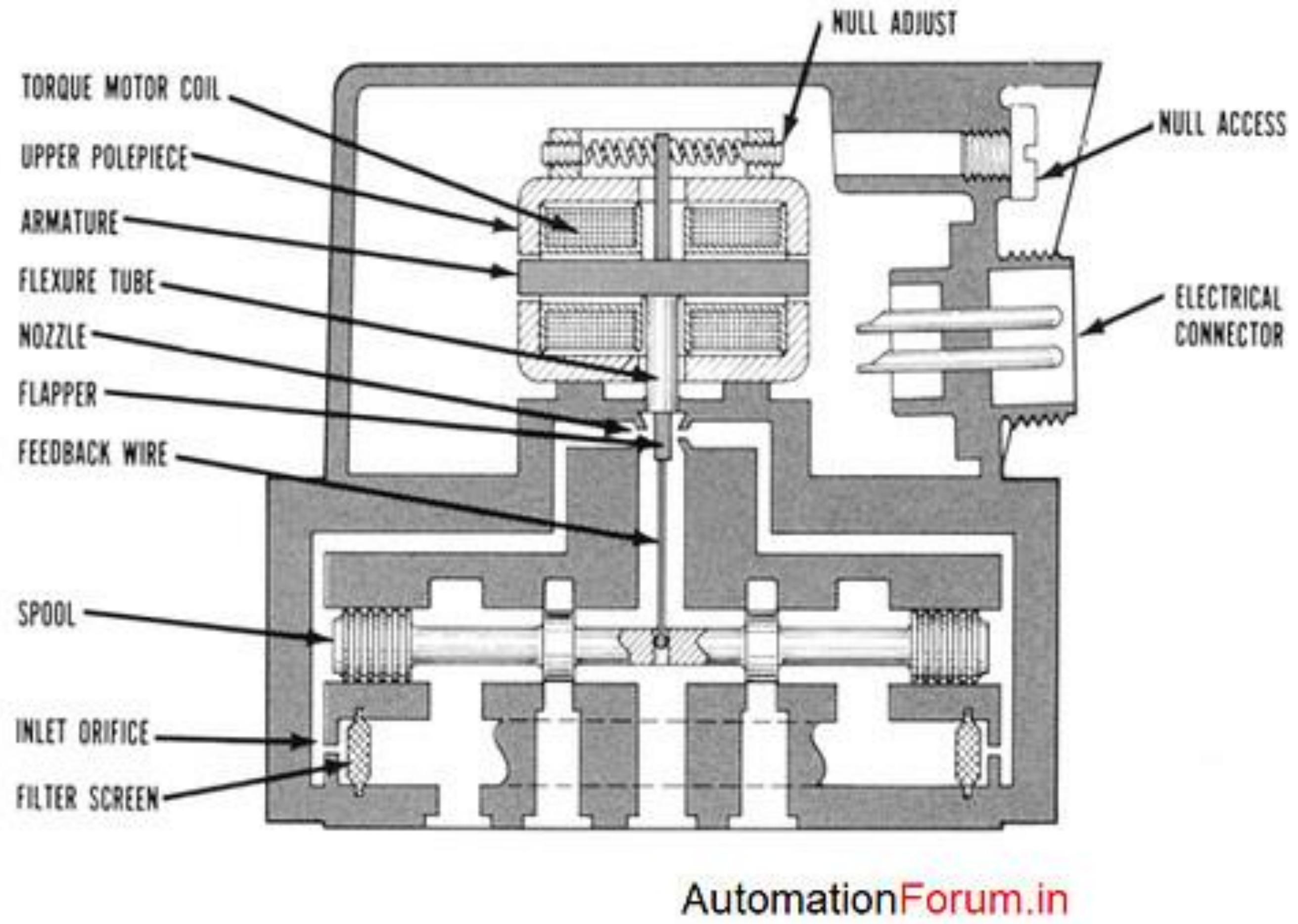


https://forumautomation.com/t/hydraulic-servo-valves-basic-types-and-operation/4209

https://forumautomation.com/t/hydraulic-servo-valves-basic-types-and-operation/4209

Hydraulic Components and Systems
Ref. Section 5.3

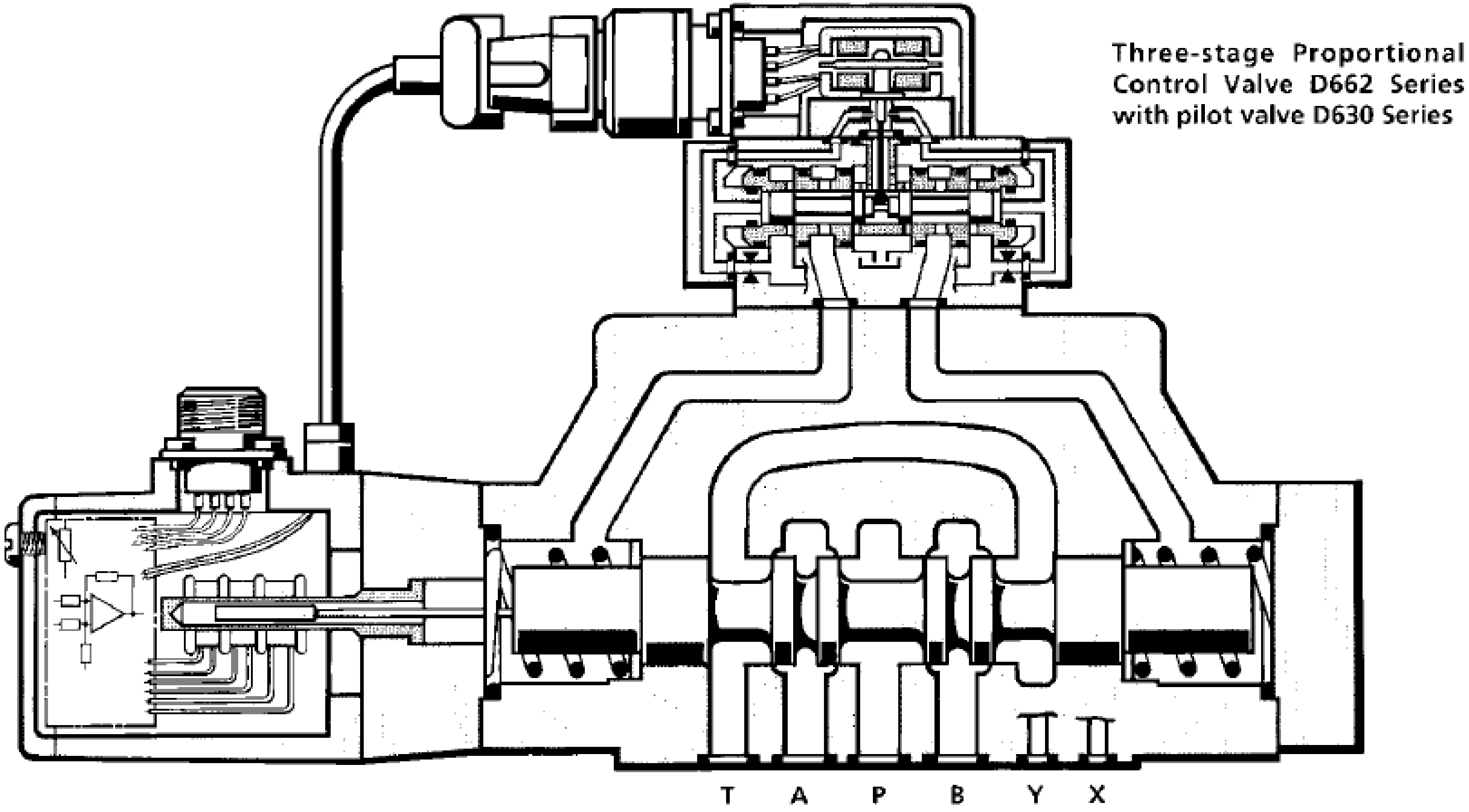
Two stage servo valve



https://forumautomation.com/t/hydraulic-servo-valves-basic-types-and-operation/4209

Hydraulic Components and Systems
Ref. Section 5.3

Three stage servo valve



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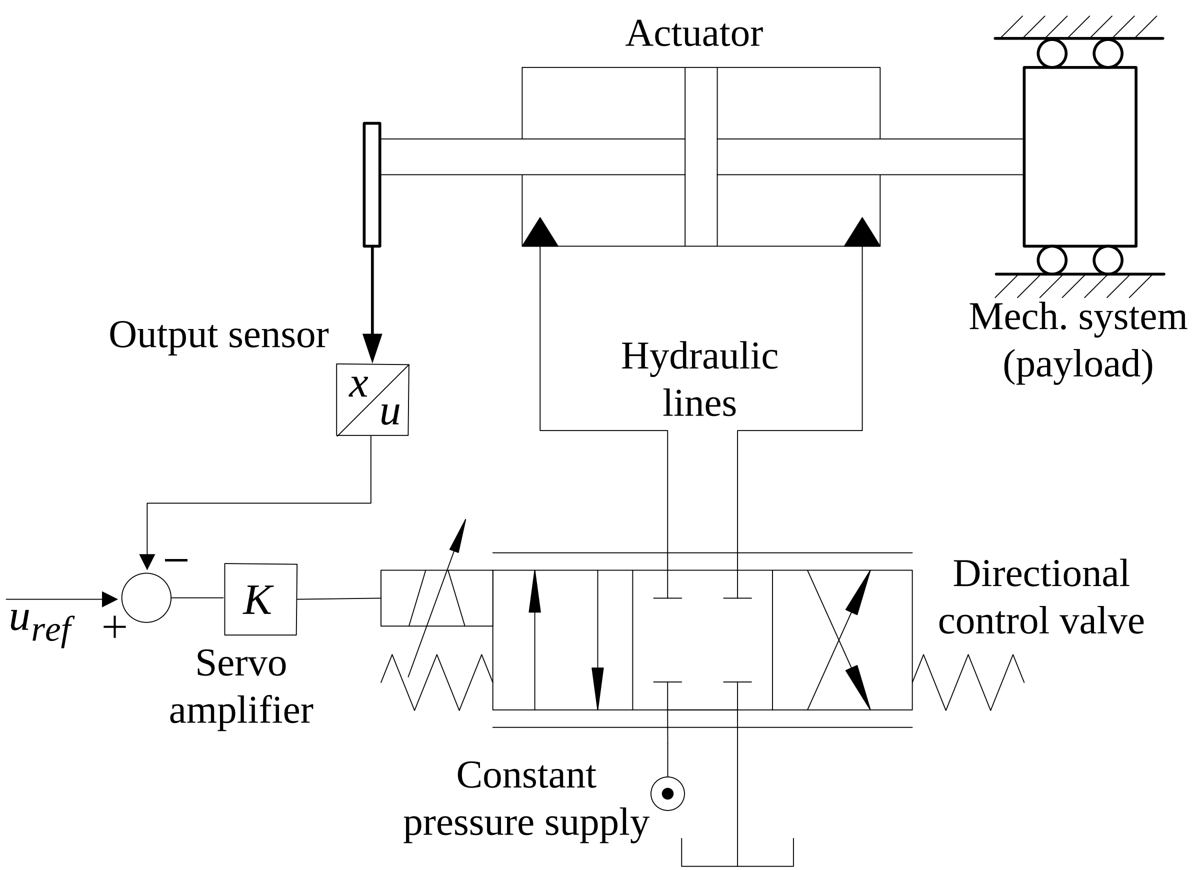
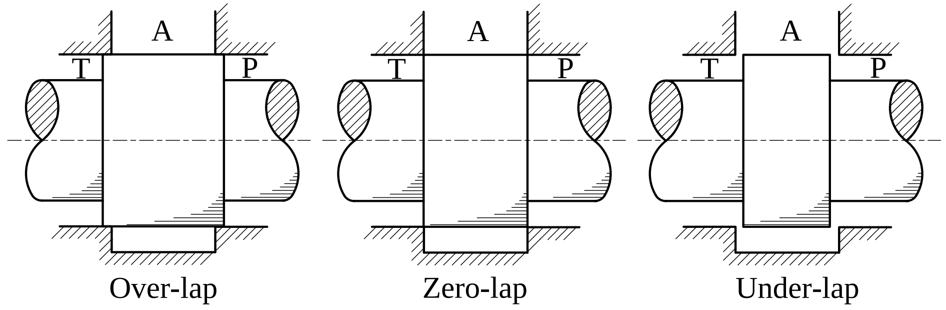
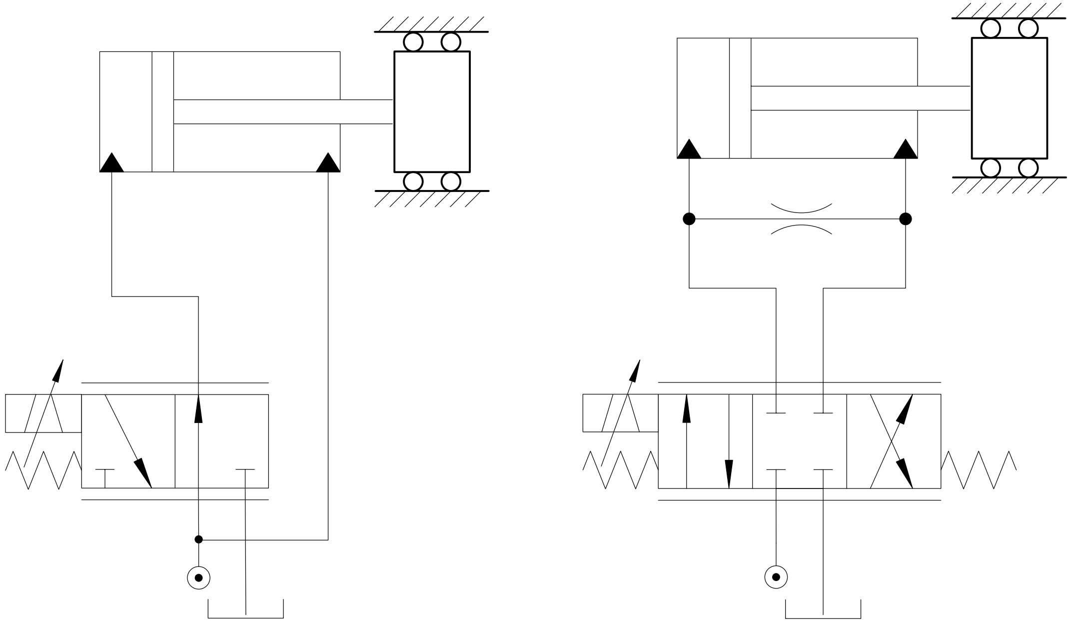
Ref. Section 5.3

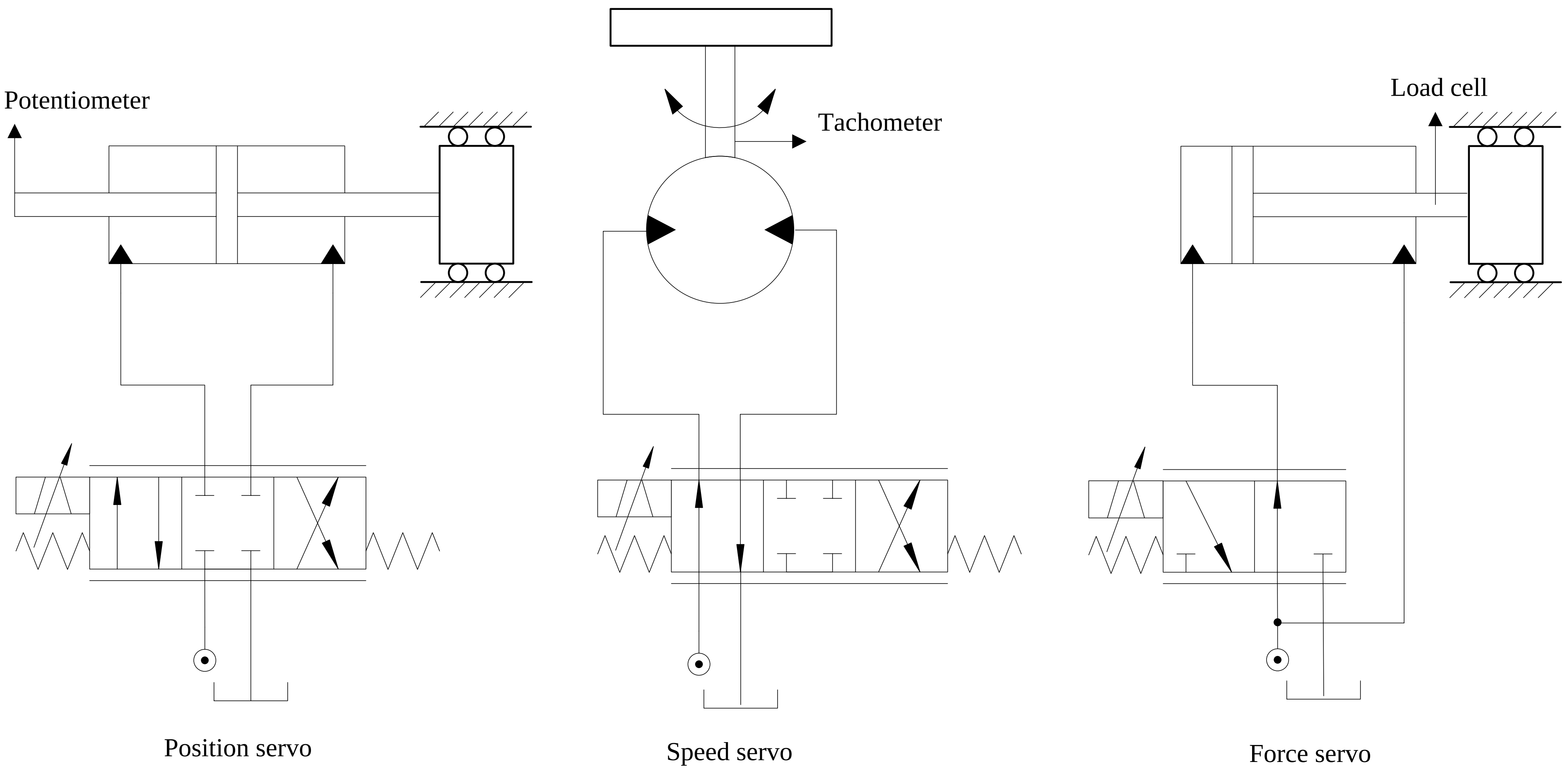
Servo system





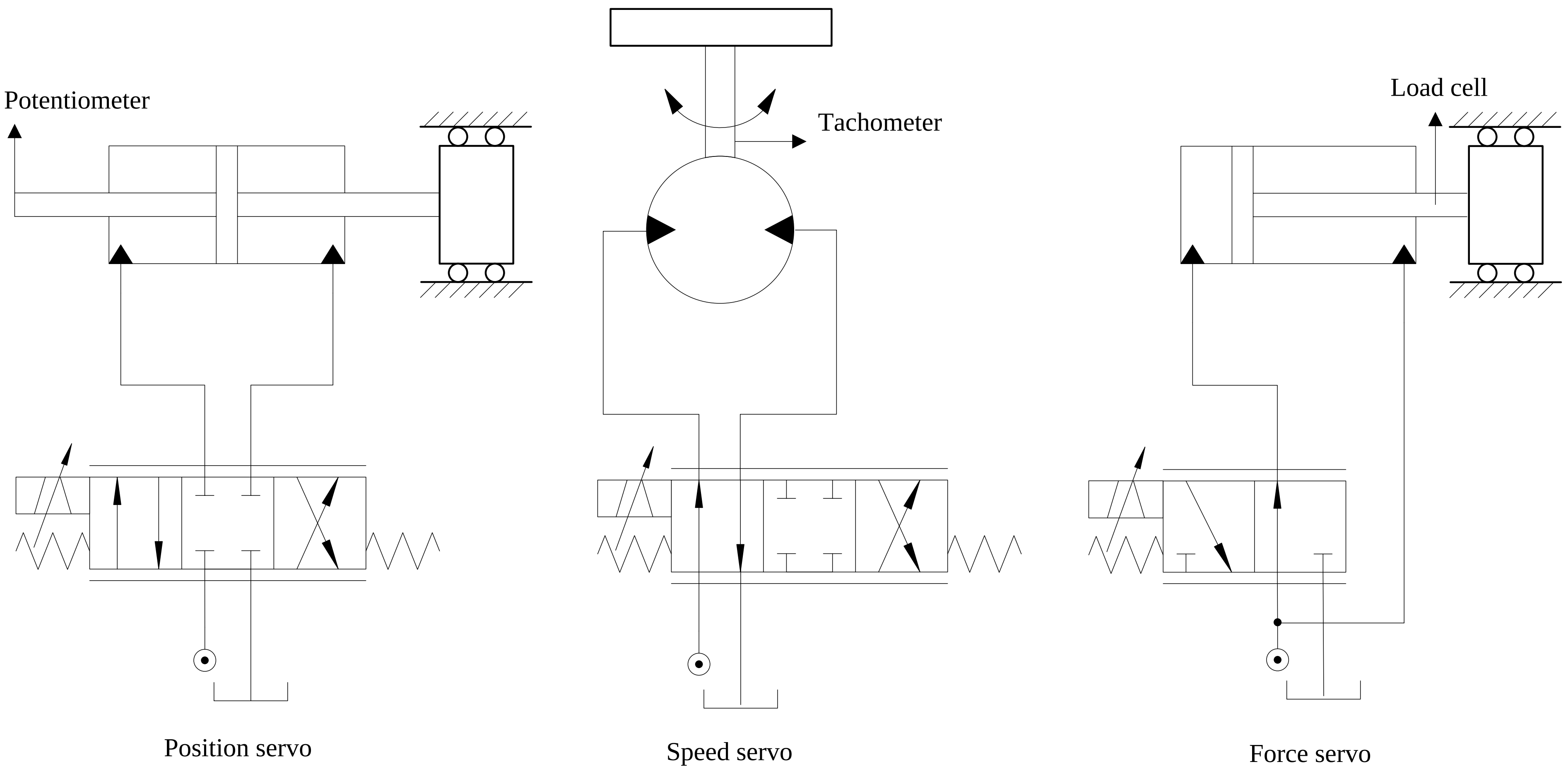


Servo system



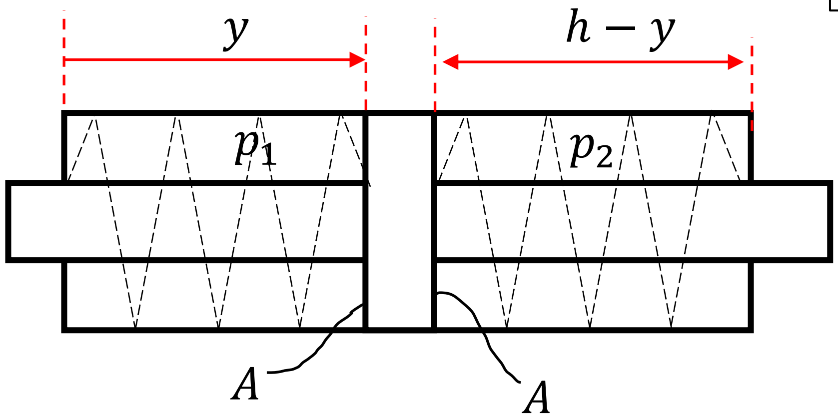
Hydraulic Components and Systems
Ref. Section 5.3

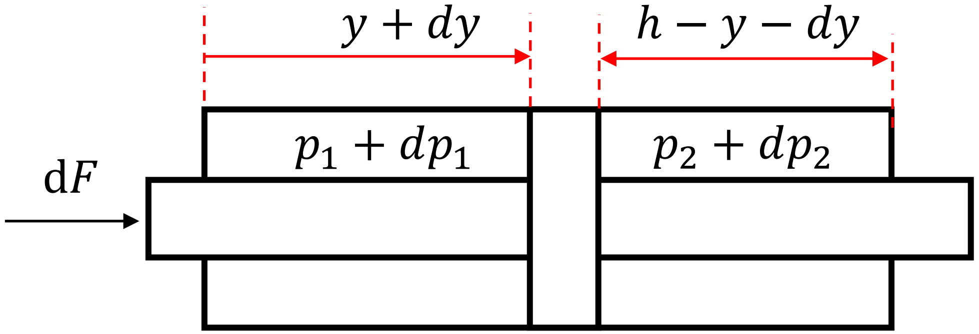
Servo system



Hydraulic Components and Systems
Ref. Section 5.3

Servo valve eigenfrequency





$$\mathrm{d}p_1 = \frac{-\beta \cdot dV_1}{V_1} = \frac{-\beta \cdot dy \cdot A}{V_1}$$

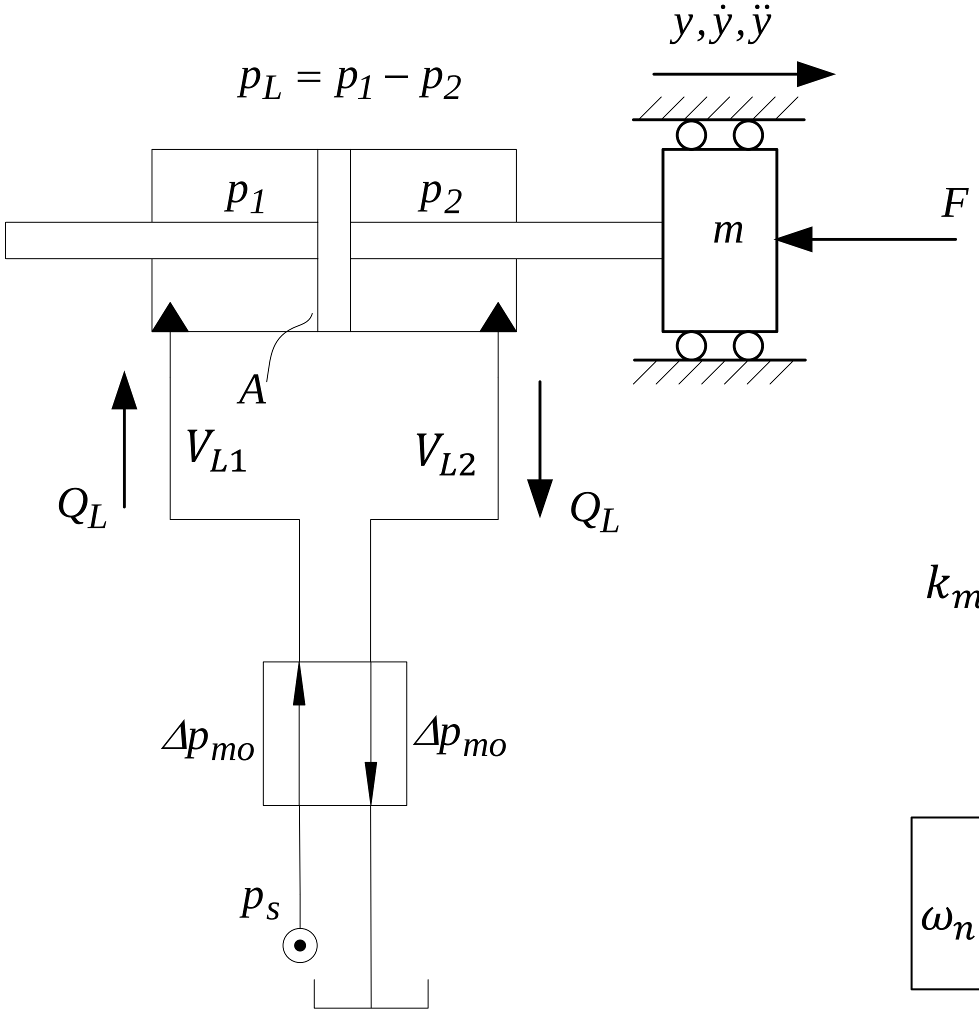
$$\mathrm{d}p_2 = \frac{-\beta \cdot dV_2}{V_2} = \frac{-\beta \cdot (-dy \cdot A)}{V_2} = \frac{\beta \cdot dy \cdot A}{V_2}$$

$$k = \frac{dF}{dy} = -\frac{dp_1 \cdot A}{dy} + \frac{dp_2 \cdot A}{dy}$$

$$k = -\frac{(-\beta \cdot dy \cdot A^2)}{V_1 \cdot dy} + \frac{\beta \cdot dy \cdot A^2}{V_2 \cdot dy}$$

$$\boxed{k = \frac{\beta \cdot A^2}{V_1} + \frac{\beta \cdot A^2}{V_2}}$$

Servo valve eigenfrequency



$$k = \frac{\beta \cdot A^2}{V_{L1} + y \cdot A} + \frac{\beta \cdot A^2}{V_{L2} + (h - y) \cdot A}$$

Assuming volume in both lines are equal to each other then:

$$V_{L1} = V_{L2} = \frac{V_L}{2}$$

$$k_{min} = k\left(y = \frac{h}{2}\right) \Rightarrow$$

$$k_{min} = \frac{2 \cdot \beta \cdot A^2}{\frac{V_L}{2} + \frac{h}{2} \cdot A} = \frac{4 \cdot \beta \cdot A^2}{V_{tot}}$$

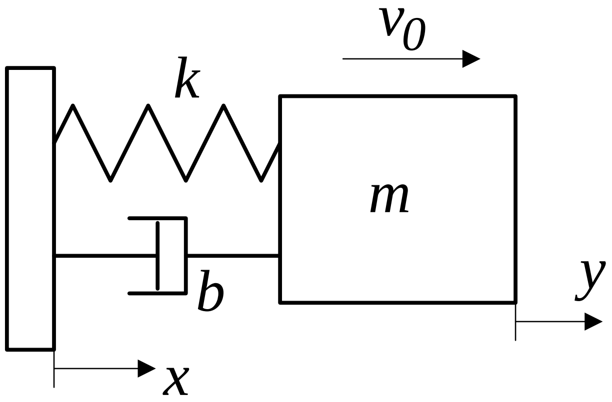
The total volume in the system is then the volume in the cylinder plus the volume in the two lines:

$$V_{tot} = h \cdot A + V_L$$

$$\boxed{\omega_n = \sqrt{\frac{k}{m}}}$$

$$\boxed{\omega_{n,min} = \sqrt{\frac{k_{min}}{m}} = 2 \cdot A \sqrt{\frac{\beta}{m \cdot V_{tot}}}}$$

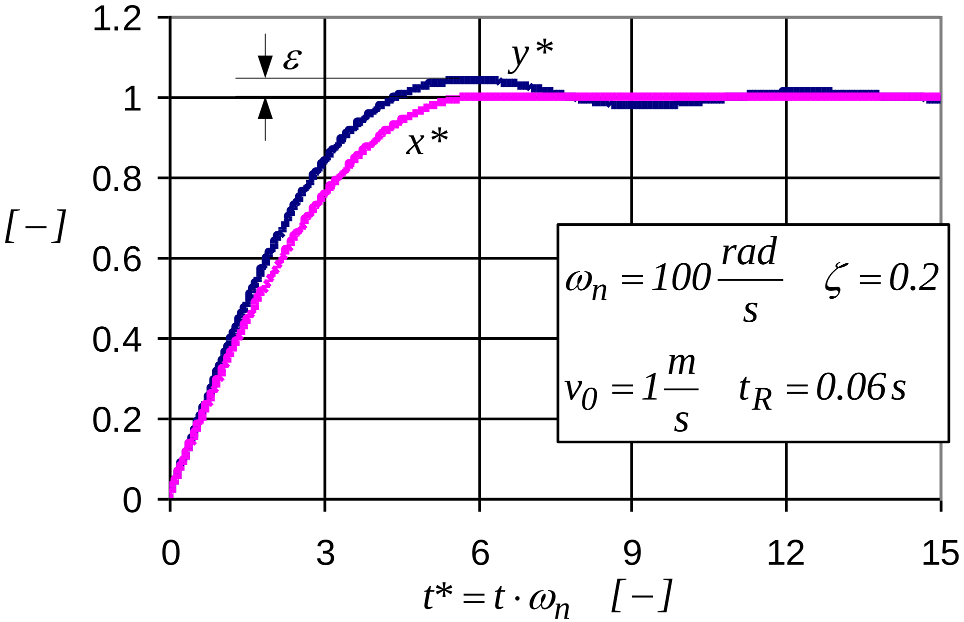
Motion reference

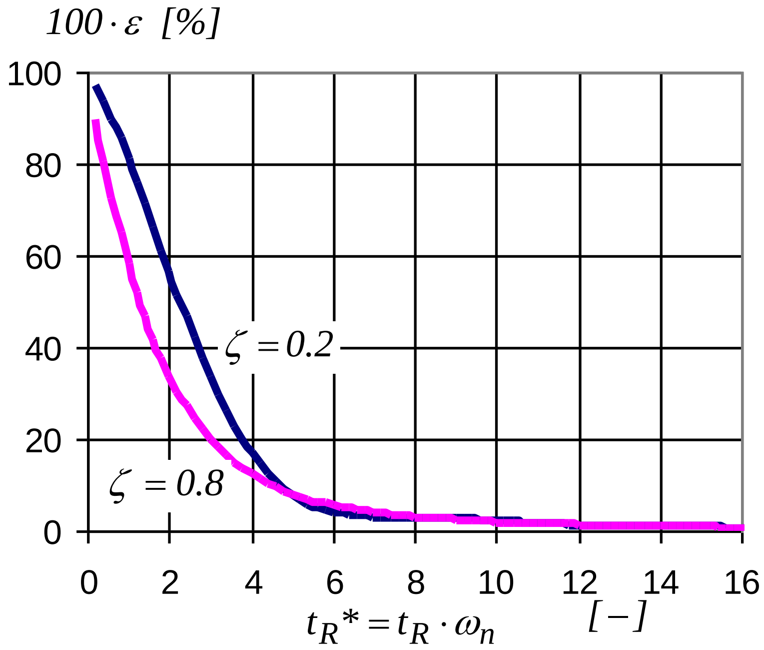


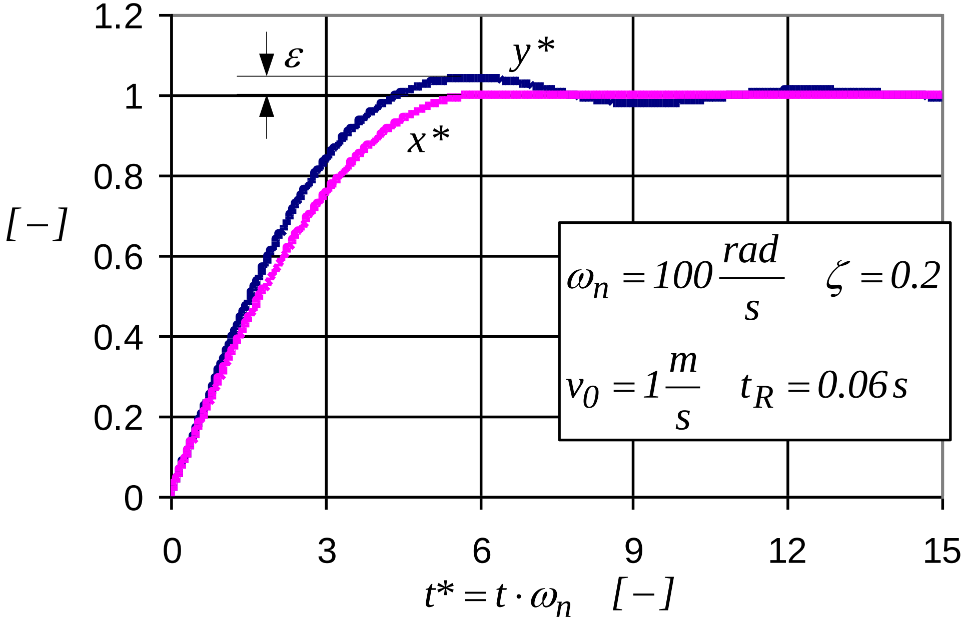
$$\dot{x} = v_0 \cdot \left[1 - \frac{t}{t_R}\right]$$

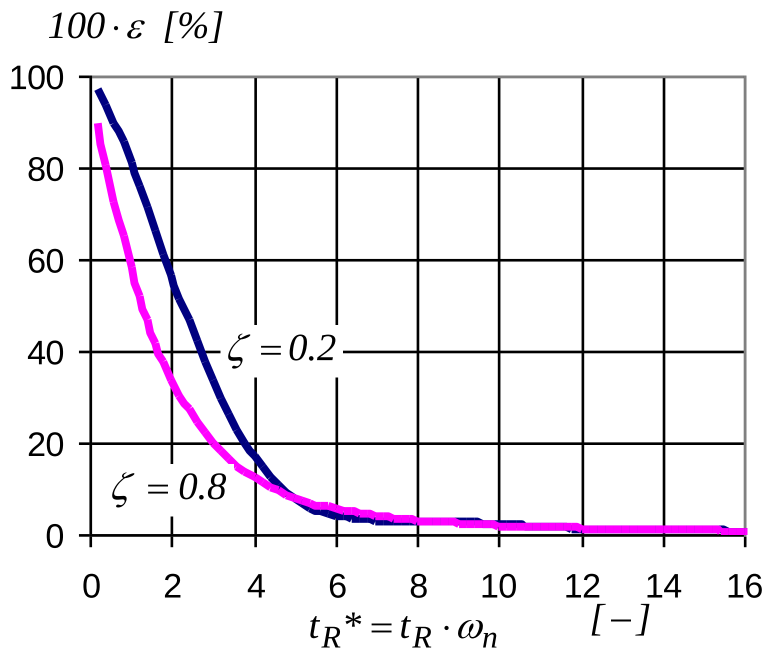
$$e = \left|x_{t=t_R} - y_{t=t_R}\right| = \frac{v_0}{\omega_n^2 \cdot t_R} \cdot \left\{1 - e^{-\alpha \cdot t_R} \cdot \left[\cos(\beta \cdot t_R) + \frac{\alpha}{\beta} \cdot \sin(\beta \cdot t_R)\right]\right\}$$

$$\varepsilon = \frac{e}{x_{t=t_R}} = \frac{2}{\omega_n^2 \cdot t_R^2} \cdot \left\{1 - e^{-\alpha \cdot t_R} \cdot \left[\cos(\beta \cdot t_R) + \frac{\alpha}{\beta} \cdot \sin(\beta \cdot t_R)\right]\right\}$$



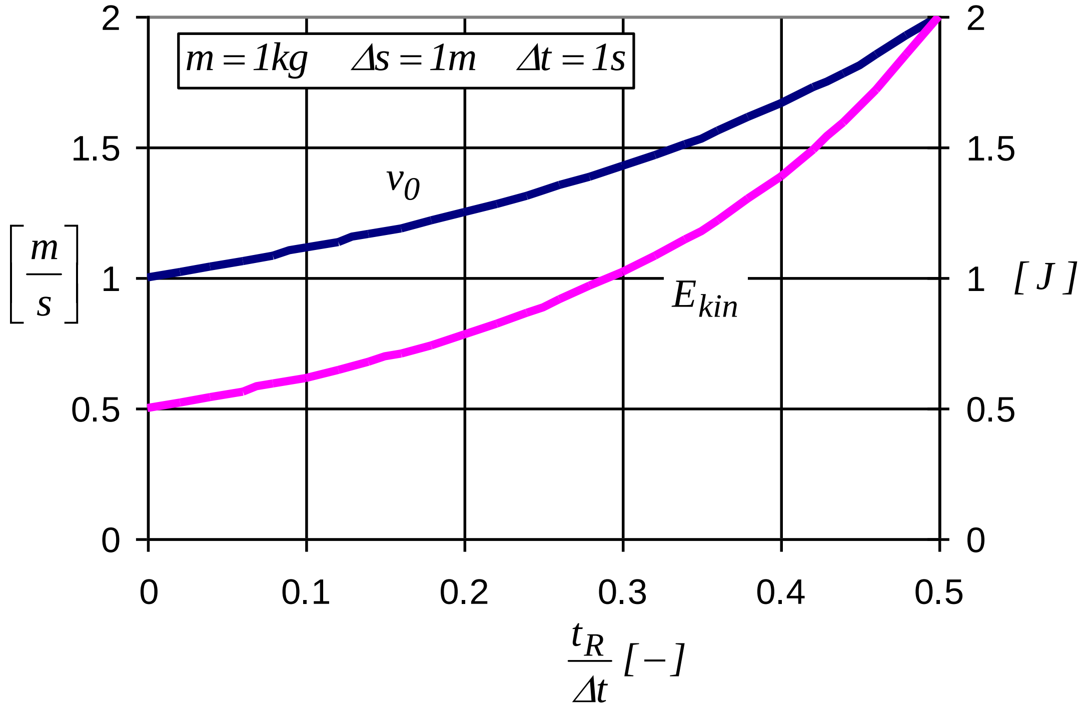


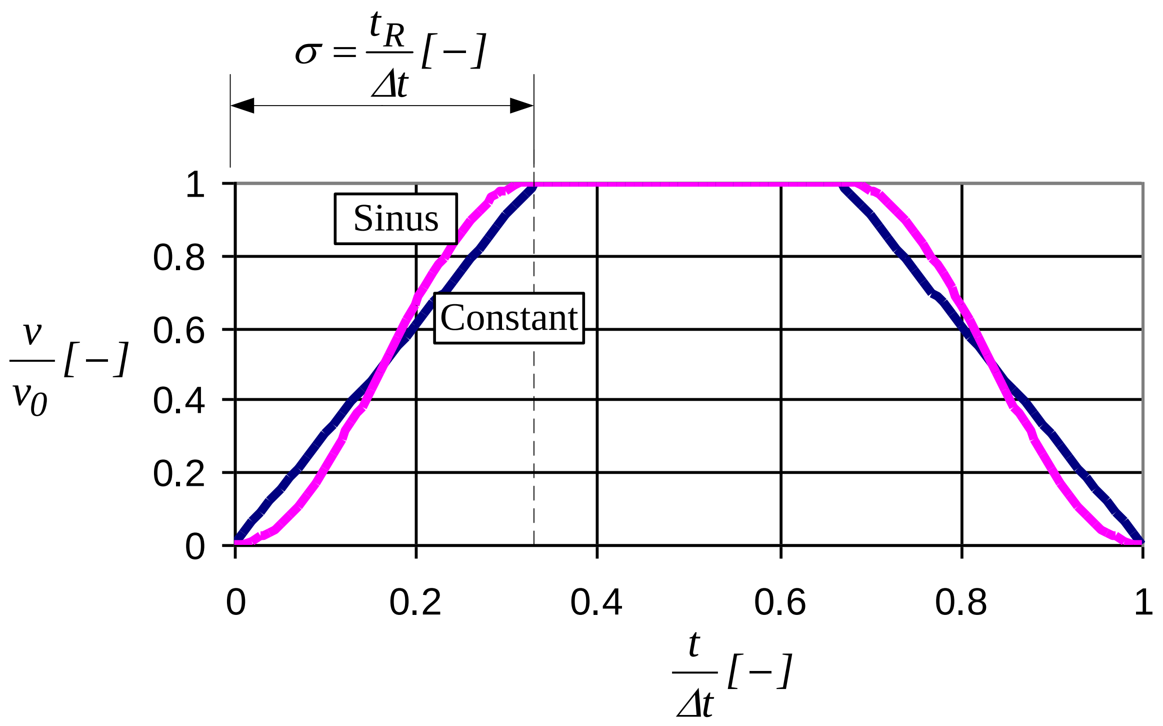




$$\boxed{t_R \geq \frac{6}{\omega_n}}$$

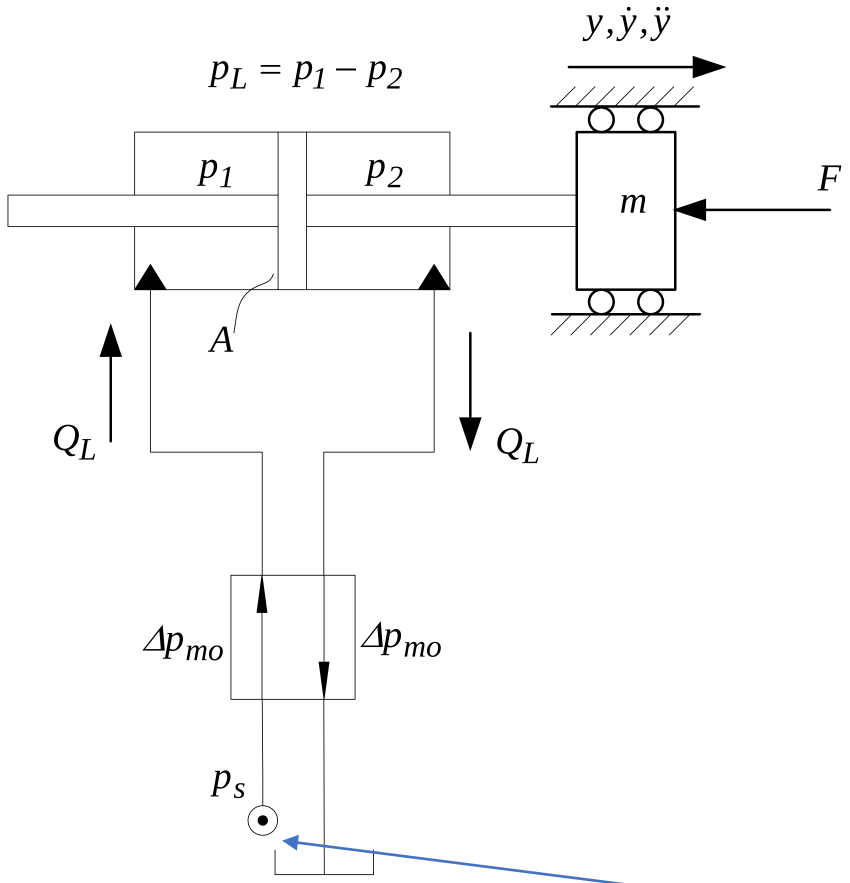
Motion reference





Hydraulic Components and Systems
Ref. Section 5.3

Servo system specification



$$p_L = \Delta p_{cyl} = p_1 - p_2$$

$$Q_L = C_d \cdot w \cdot x \cdot \sqrt{\frac{2}{\rho} \cdot \Delta p_{mo}} = C_d \cdot w \cdot x \cdot \sqrt{\frac{2}{\rho} \cdot \frac{p_s - p_L}{2}} = C_d \cdot w \cdot x \cdot \sqrt{\frac{1}{\rho} \cdot (p_s - p_L)}$$

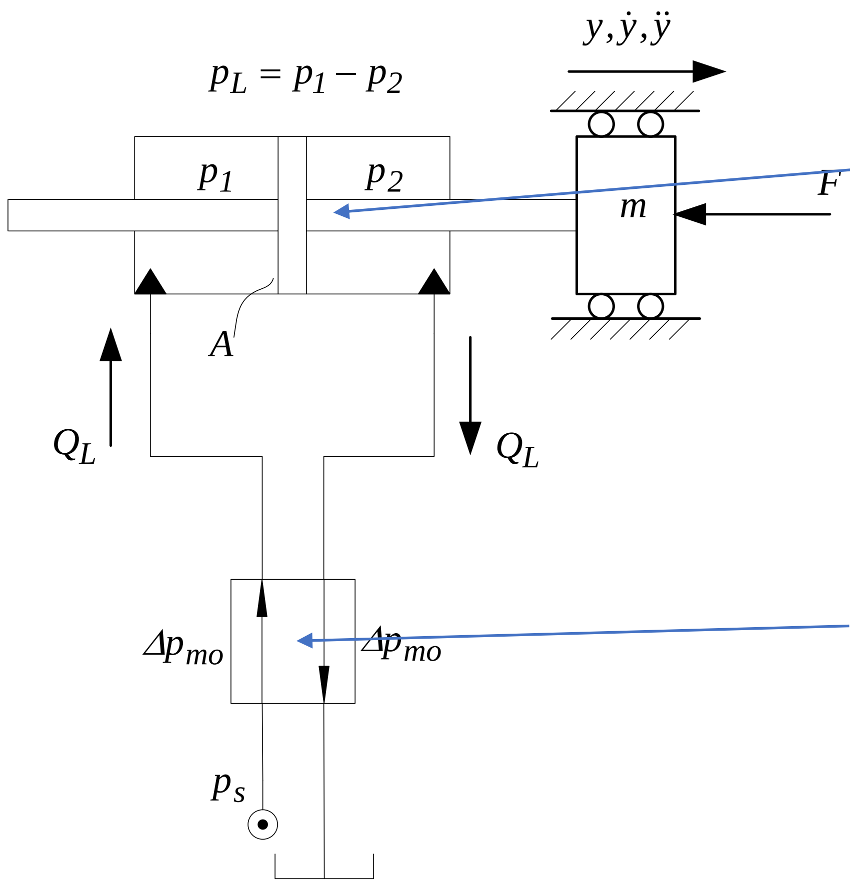
$$P_{F \to C} = p_L \cdot Q_L = p_L \cdot C_d \cdot w \cdot x \cdot \sqrt{\frac{1}{\rho} \cdot (p_s - p_L)}$$

$$\frac{\partial P_{F \to C}}{\partial p_L} = 0 \Rightarrow \frac{\partial \left\{ p_L \cdot \sqrt{p_s - p_L} \right\}}{\partial p_L} = 0$$

$$\Downarrow$$

$$\sqrt{p_s - p_L} - \frac{p_L}{2 \cdot \sqrt{p_s - p_L}} = 0 \Rightarrow p_L = \frac{2}{3} \cdot p_s$$

Servo system specification



$$p_L \cdot A = F + m \cdot \ddot{y} \Rightarrow A \geq \frac{(F + m \cdot \ddot{y})_{max}}{p_L}$$

$$Q(t) = A \cdot \dot{y}(t)$$

$$p_L(t) = \frac{F(t) + m \cdot \ddot{y}(t)}{A}$$

$$Q_{NL}(t) = Q(t) \cdot \sqrt{\frac{p_s}{p_s - p_L(t)}}$$

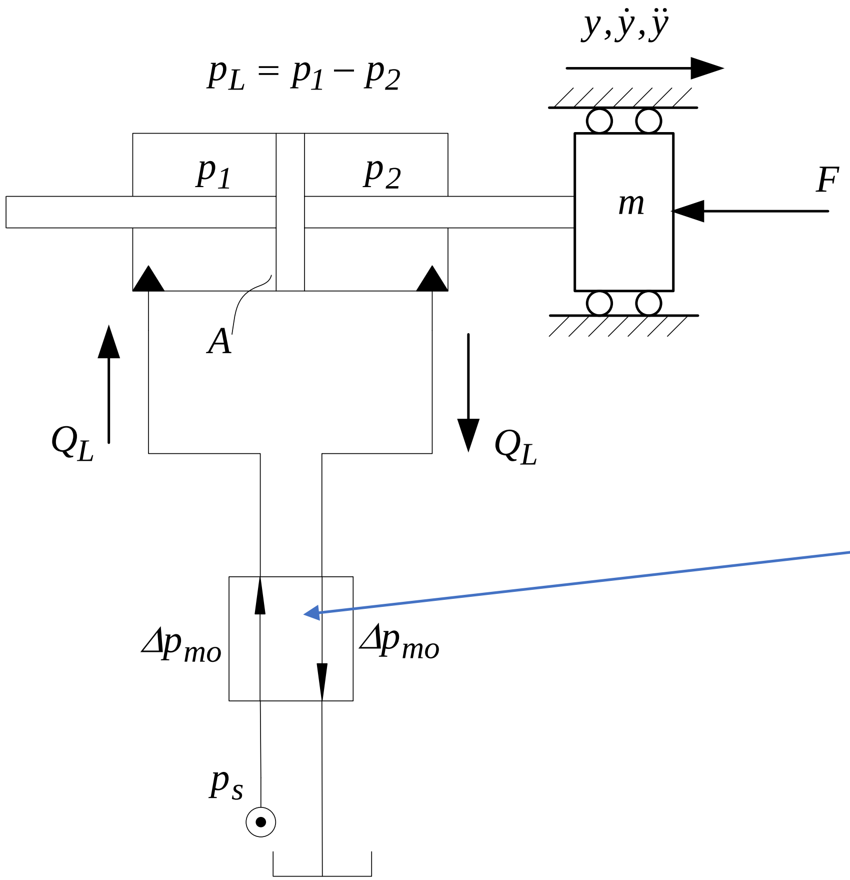
$$Q_{v,NL@p_s} \geq max\{Q_{NL}(t)\} = Q_{NL,max}$$

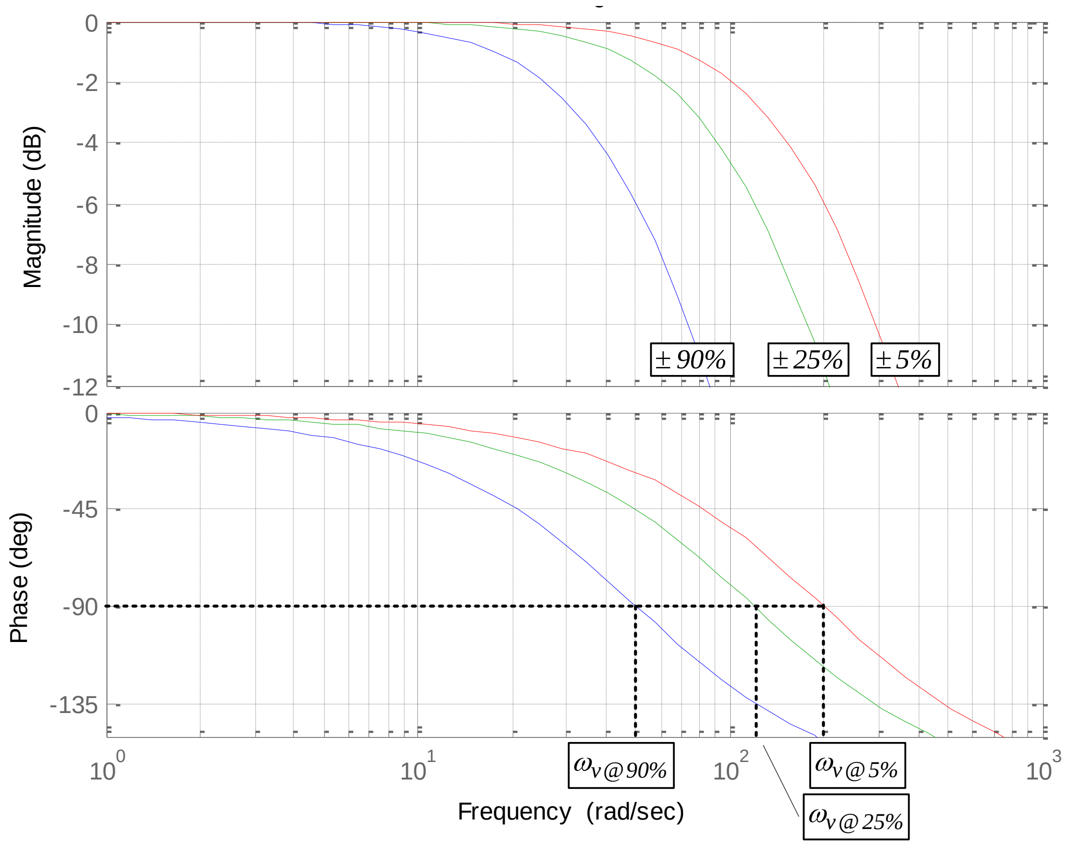
$$Q_{r,min} = 1.1 \cdot Q_{NL,max} \cdot \sqrt{\frac{p_r}{p_s}}$$

$$Q_r \geq Q_{r,min}$$

Hydraulic Components and Systems
Ref. Section 5.3

Servo system specification





$$\boxed{\omega_{v,min} = 3 \cdot \omega_n}$$

Hydraulic Components and Systems
Ref. Section 5.3