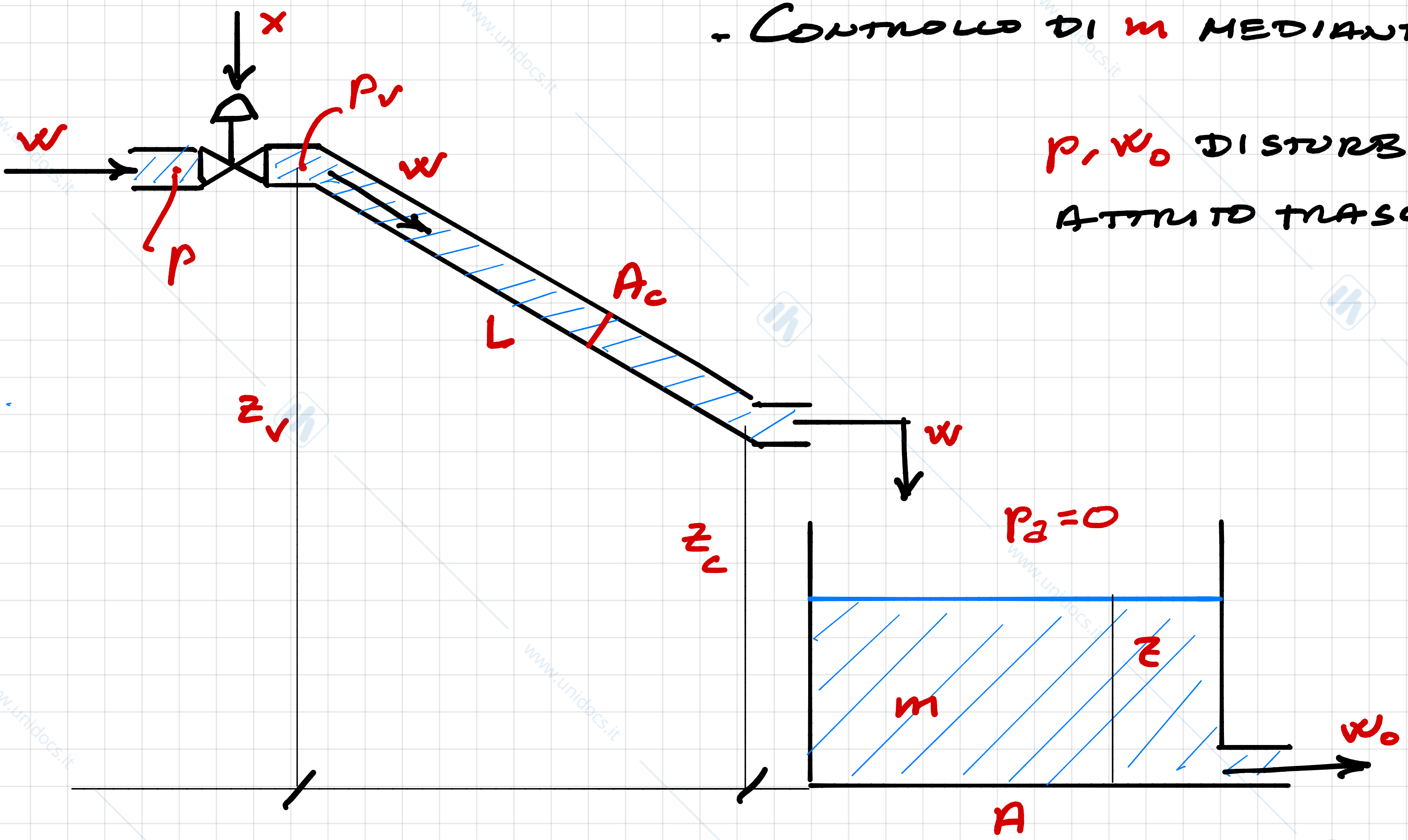
ESERCITAZIONE SUL

CONTROLLO DI PROCESSI TERMO-IDRAULICI

- ESERCIZIO 1



- CONTROLLO DI m MEDIANTE x

p, w_0 DISTURBI

ATTRITO TRASCURABILE

- MODELLO NON LINEARE

- CONS. MASSA SERBATOIO: $\boxed{\dot{m} = w - w_0}$

$z_c + \frac{p_a}{\rho g} = z_c$

- CONS. Q. DI MOTO CONDOTTA $\dot{w} = -\frac{\rho A_c g}{L}(z_c^* - z_v^*)$

$z_v + \frac{p_v}{\rho g}$

- VALVOLA: $w = k A_v x \sqrt{\rho(p - p_v)}$

$$p_v = p - \frac{w^2}{k^2 A_v^2 x^2 \rho}$$

$$\dot{w} = -\frac{\rho A_c g}{L}\left(z_c - z_v - \frac{p_v}{\rho g}\right) = \frac{\rho A_c g}{L}(z_v - z_c) + \frac{A_c}{L} p_v =$$

$$\boxed{= \frac{\rho A_c g}{L}(z_v - z_c) + \frac{A_c}{L} p - \frac{A_c w^2}{L k^2 A_v^2 x^2 \rho}}$$

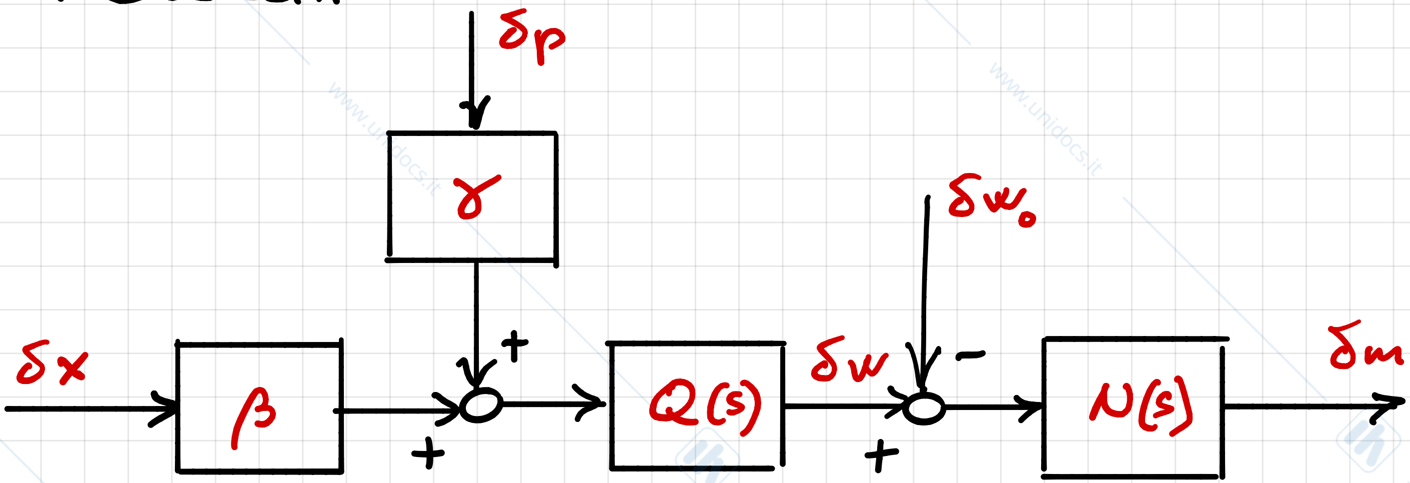
- Modello linearizzato

$$\begin{cases} \dot{m} = w - w_0 \\ \dot{w} = \dfrac{\rho A_c g}{L}(z_v - z_c) + \dfrac{A_c}{L} p - \dfrac{A_c w^2}{L k^2 A_v^2 x^2 \rho} \end{cases}$$

$$\begin{cases} \delta \dot{m} = \delta w - \delta w_0 \\ \delta \dot{w} = -\underbrace{\dfrac{2A_c}{L}\dfrac{\bar{w}}{k^2 A_v^2 \bar{x}^2 \rho}}_{\alpha} \delta w + \underbrace{\dfrac{A_c}{L}}_{\gamma} \delta p + \underbrace{\dfrac{2A_c}{L}\dfrac{\bar{w}^2}{k^2 A_v^2 \bar{x}^3 \rho}}_{\beta} \delta x \end{cases}$$

$$\begin{cases} M(s) = \dfrac{1}{s}\left(W(s) - W_0(s)\right) \\ W(s) = \dfrac{1}{s+\alpha}\left(\beta X(s) + \gamma P(s)\right) \end{cases}$$

- SCHEMA A BLOCCHI

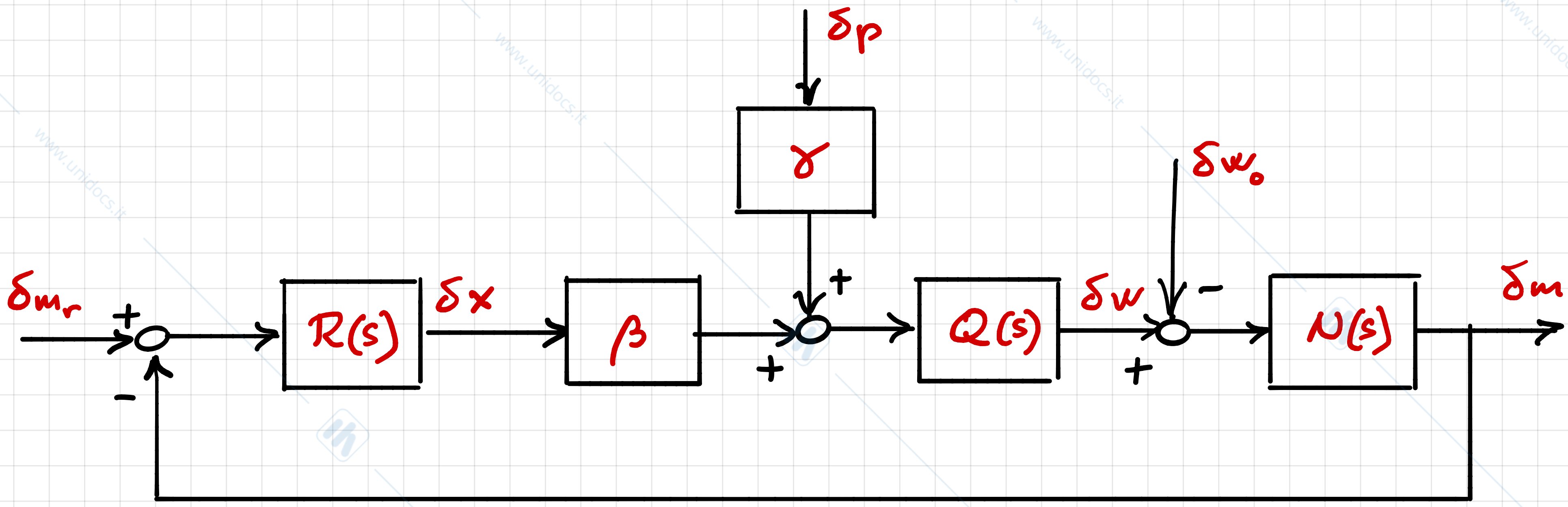


$$Q(s) = \frac{1}{s+\alpha}$$

$$\alpha, \beta, \gamma > 0$$

$$N(s) = \frac{1}{s}$$

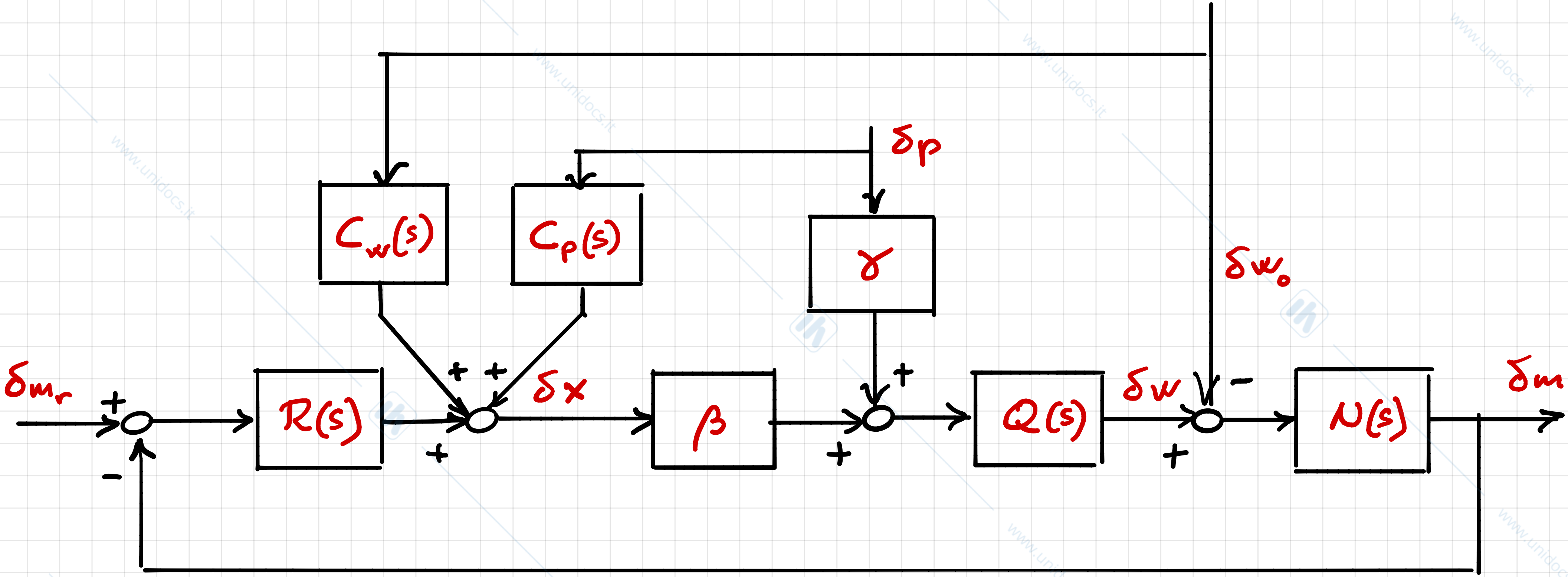
- PROGETTO DI UN CONTROLLORE DI MASSA



$R(s)$ PROGETTATO SU $G_{mx}(s) = \beta Q(s) N(s) = \dfrac{\beta}{s(s+\alpha)}$

- DEVE AVERE AZIONE INTEGRALE (PER DISTURBI $\delta p, \delta w_0$)
- DEVE AVERE GUADAGNO POSITIVO PER LA STABILITÀ
- POTREBBE AVERE UNO ZERO CON $T = \frac{1}{\alpha}$ PER CANCELLARE IL POLO, E UN ALTRO ZERO PER L'ASINTOTICA STABILITÀ

- COMPENSAZIONE IN A.A. DEI DISTURBI



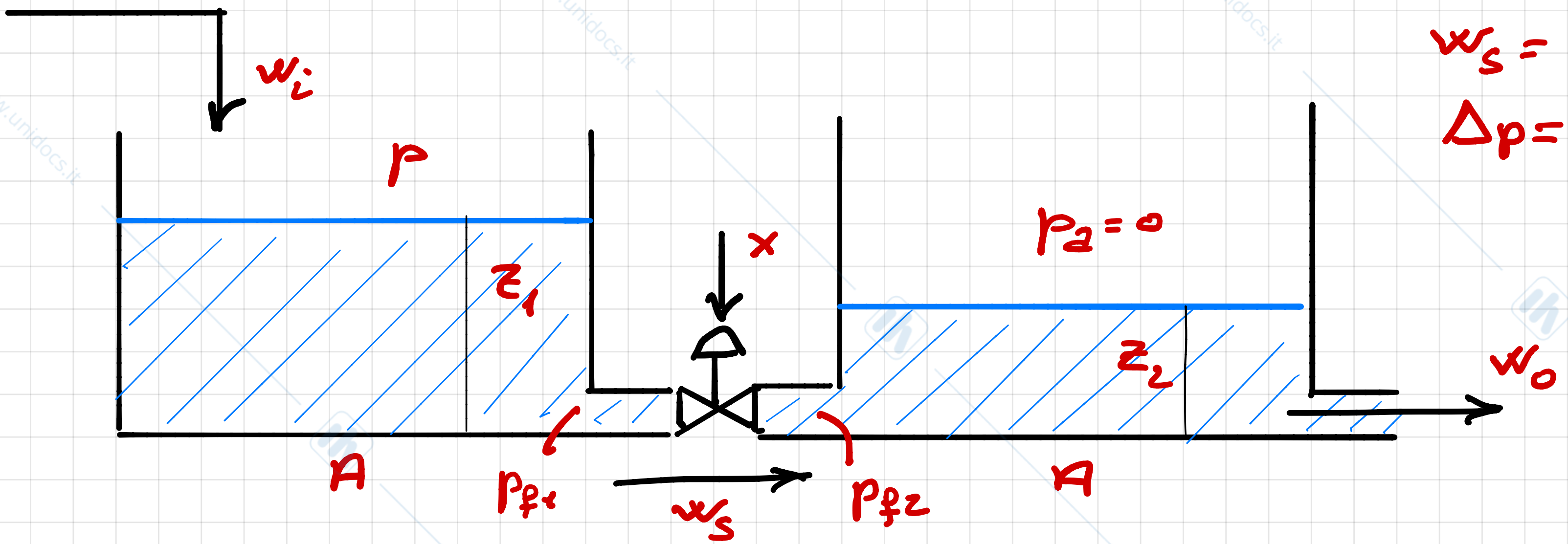
$$C_p(s) = -\frac{\gamma}{\beta} = -\frac{k^2 A_v^2 \bar{x}^3 \rho}{2\bar{w}^2}$$

$$C_w^o(s) = \frac{1}{\beta Q(s)} = \frac{s+\alpha}{\beta}$$

NON REALIZZABILE

$$C_w(s) = \begin{cases} \dfrac{s+\alpha}{\beta(1+s\tau)}, \quad \tau \ll \dfrac{1}{\alpha} \\ \text{OPPURE} \\ \dfrac{\alpha}{\beta} = \dfrac{\bar{x}}{\bar{w}} \end{cases}$$

- ESERCIZIO 2



- IPOTESI

$p > p_a$

$w_s = k x \sqrt{\Delta p}$

$\Delta p = p_{f1} - p_{f2}$

x, w_0 VARIABILI MANIPOLABILI

w_i DISTURBO

1 - MODELLO DINAMICO NON LINEARE

- SERBATOIO 1 : $\dot{z}_1 = \frac{1}{\rho A}(w_i - w_s)$

- SERBATOIO 2 : $\dot{z}_2 = \frac{1}{\rho A}(w_s - w_o)$

$$\Delta p = p_{f1} - p_{f2} = p + \rho g z_1 - \rho g z_2 = p + \rho g (z_1 - z_2)$$

$$w_s = k x \sqrt{p + \rho g (z_1 - z_2)}$$

$$\boxed{\begin{aligned} \dot{z}_1 &= \frac{1}{\rho A} w_i - \frac{k x}{\rho A}\sqrt{p + \rho g (z_1 - z_2)} \\ \dot{z}_2 &= \frac{k x}{\rho A}\sqrt{p + \rho g (z_1 - z_2)} - \frac{1}{\rho A} w_o \end{aligned}}$$

② - EQUILIBRIO CON $\bar{w}_i$ COSTANTE E $\bar{z}_1, \bar{z}_2$ DATI

$$\bar{w}_s = \bar{w}_i = k\bar{x}\sqrt{p+\rho g(\bar{z}_1-\bar{z}_2)} \Longrightarrow \bar{x} = \frac{\bar{w}_i}{k\sqrt{p+\rho g(\bar{z}_1-\bar{z}_2)}}$$

$$\bar{w}_0 = \bar{w}_i$$

ATTENZIONE! DEVE RISULTARE

$$\bar{x} \leq 1$$

③ - MODELLO LINEARIZZATO

$$\begin{cases} \delta \dot{z}_1(t) = -\alpha_1 \delta z_1(t) + \alpha_2 \delta z_2(t) - \alpha_3 \delta x(t) + \alpha_4 \delta w_i(t) \\ \delta \dot{z}_2(t) = \alpha_1 \delta z_1(t) - \alpha_2 \delta z_2(t) + \alpha_3 \delta x(t) - \alpha_5 \delta w_o(t) \end{cases}$$

$$\alpha_1 = \frac{k\bar{x}}{\cancel{\rho} A} \frac{\cancel{\rho} g}{2\sqrt{p + \rho g(\bar{z}_1 - \bar{z}_2)}}$$

$$\alpha_2 = \frac{k\bar{x}}{\cancel{\rho} A} \frac{\cancel{\rho} g}{2\sqrt{p + \rho g(\bar{z}_1 - \bar{z}_2)}} = \alpha_1$$

$$\alpha_3 = \frac{k}{\rho A} \sqrt{p + \rho g(\bar{z}_1 - \bar{z}_2)}$$

$$\alpha_4 = \alpha_5 = \frac{1}{\rho A}$$

4 - Progetto di un Regolatore PI di z_2

$$A = \begin{bmatrix} -\alpha_1 & \alpha_1 \\ \alpha_1 & -\alpha_1 \end{bmatrix} \qquad B = \begin{bmatrix} -\alpha_3 & 0 \\ \alpha_3 & -\alpha_4 \end{bmatrix} \qquad C = I$$

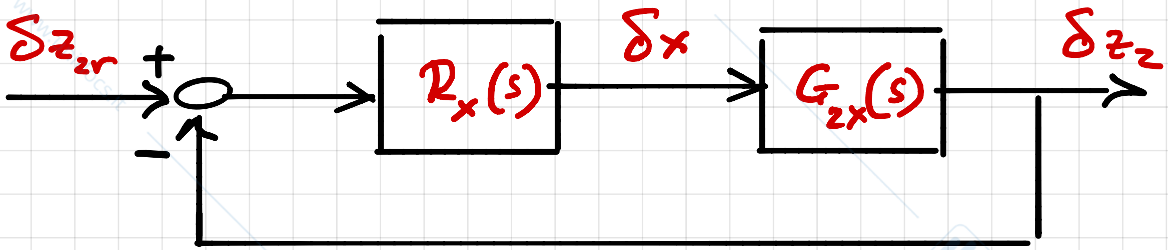
$$G(s) = \frac{1}{(s+\alpha_1)^2 - \alpha_1^2} \begin{bmatrix} s+\alpha_1 & \alpha_1 \\ \alpha_1 & s+\alpha_1 \end{bmatrix} \begin{bmatrix} -\alpha_3 & 0 \\ \alpha_3 & -\alpha_4 \end{bmatrix} =$$

$$= \frac{1}{s(s+2\alpha_1)} \begin{bmatrix} -\alpha_3 s & -\alpha_1 \alpha_4 \\ \alpha_3 s & -\alpha_4(s+\alpha_1) \end{bmatrix} = \begin{bmatrix} G_{1x} & G_{1w} \\ G_{2x} & G_{2w} \end{bmatrix}$$

4.1 Progetto con var. di controllo x su $G_{2x} = \dfrac{\alpha_3}{s+2\alpha_1}$

4.2 Progetto con var. di controllo w_0 su $G_{2w} = \dfrac{-\alpha_4(s+\alpha_1)}{s(s+2\alpha_1)}$

4.1 – Progetto con x



$$G_{2x}(s) = \frac{\alpha_3}{s + 2\alpha_1}$$

$$R_x(s) = \frac{K_p}{T_i} \frac{1 + sT_i}{s}$$

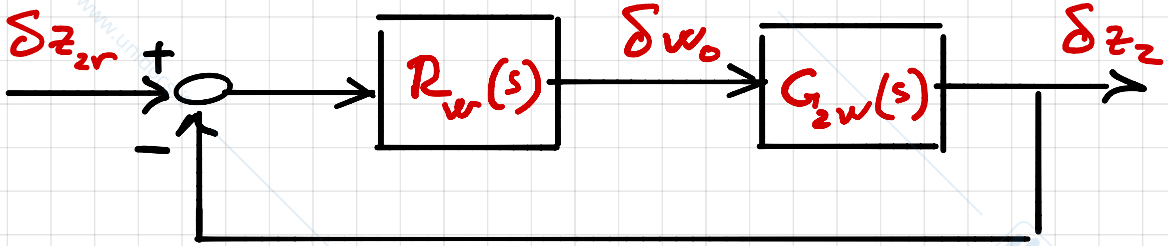
$$K_p > 0$$

$$T_i = \frac{1}{2\alpha_1}$$

$$L_x(s) = \frac{\alpha_3 K_p}{2\alpha_1 T_i} \frac{1}{s}$$

$$\begin{cases} \omega_c = \dfrac{\alpha_3 K_p}{2\alpha_1 T_i} \\ \varphi_m = 90^\circ \end{cases}$$

4.2 - PROGETTO CON w_0



$$G_{2w}(s) = -\frac{\alpha_4(s+\alpha_1)}{s(s+2\alpha_1)}$$

$$R_w(s) = -K_p$$

$$L_w(s) = \frac{\alpha_4 K_p}{2} \cdot \frac{1+s/\alpha_1}{s(1+s/2\alpha_1)}$$

$$K_p > 0$$

⑤ - Controllo Decentralizzato di z_1, z_2