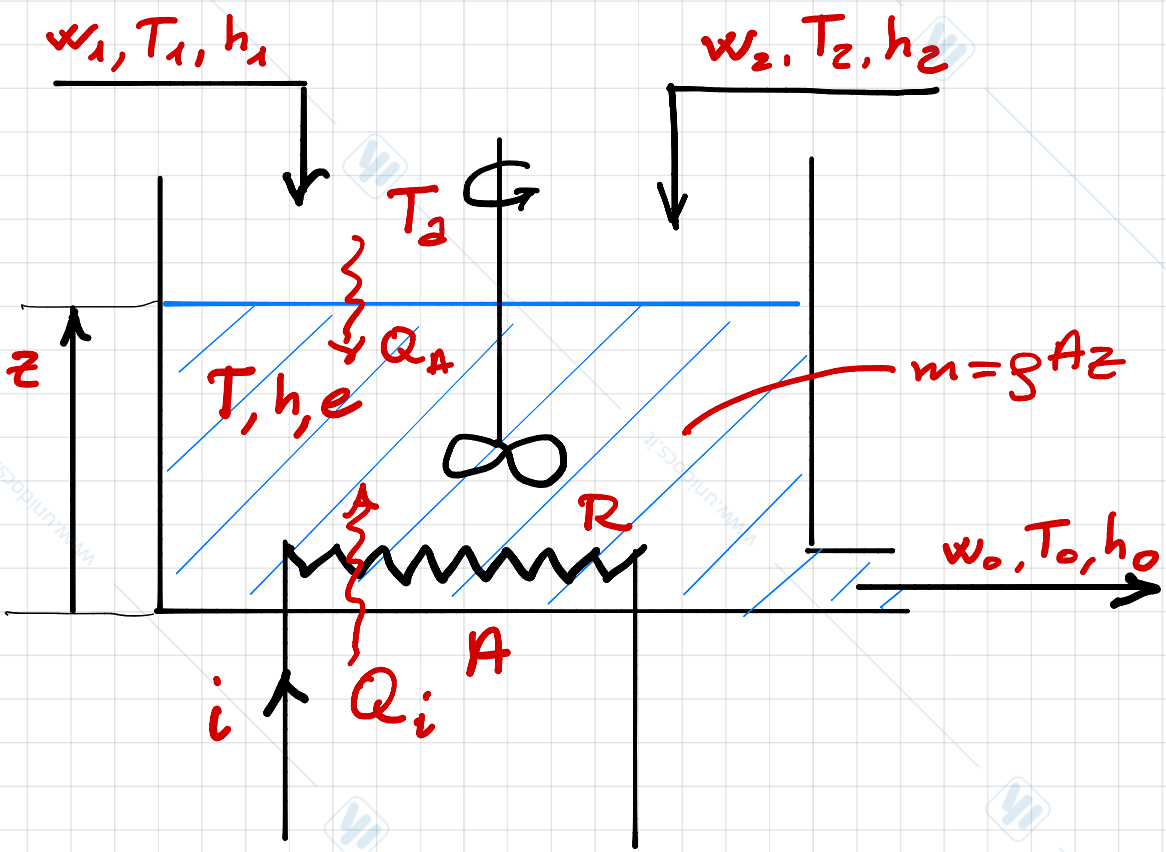
CONTROLLO DI UN MISCELATORE

- Controllo di un miscelatore



$\rho = \text{cost.}$ densità

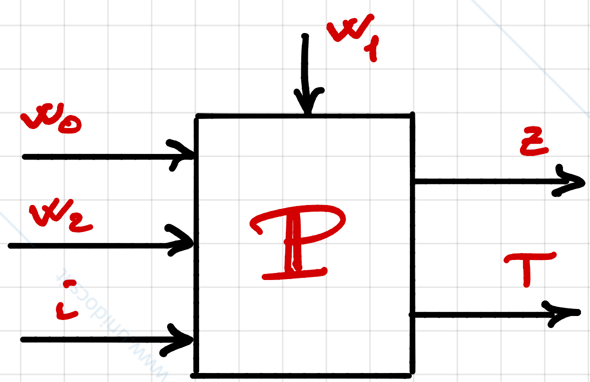
$T_1 > T_2$

T_1, T_2, T_a costanti

- Ipotesi
  - Pareti adiabatiche
  - Fluido ben miscelato
  - Lavoro meccanico trascurabile

- Problema

Controllo MIMO di z, T mediante w_0, w_2, i



- MODELLO (0-DIM)

- CONS. MASSA: $\dot{m} = \rho A \dot{z} = w_1 + w_2 - w_0$

POTENZA TERMICA: $\Phi = \Phi_i + \Phi_2$

- CONS. ENERGIA: $\frac{d}{dt}(me) = m\dot{e} + \dot{m}e = \Phi + w_1 h_1 + w_2 h_2 - w_0 h_0$

$$\Rightarrow m\dot{e} = \Phi - (w_1 + w_2 - w_0)e + w_1 h_1 + w_2 h_2 - w_0 h_0 =$$

$$= \Phi + w_1(h_1 - e) + w_2(h_2 - e) - \underbrace{w_0(h_0 - e)}_{\simeq 0} =$$

$$= \Phi + c w_1 (T_1 - T) + c w_2 (T_2 - T)$$

$e = cT$
$h_1 \simeq e_1 = cT_1$
$h_2 \simeq e_2 = cT_2$
$h_0 \simeq e_0 = cT_0$

EFFETTO JOULE: $\Phi_i = R i^2$

$\Phi_2 = kA(T_2 - T)$ — k: COEFF. SCAMBIO LIQUIDO/ARIA

$\dot{e} = c\dot{T}$

$\Downarrow$

$$c \rho A z \dot{T} = \Phi + c w_1 (T_1 - T) + c w_2 (T_2 - T)$$

- MODELLO

SIST. DINAMICO MIMO
NON LINEARE
DI ORDINE $n=2$

$$
\begin{cases}
\dot{z} = \dfrac{1}{\rho A}\left(w_1 + w_2 - w_0\right) \\
\dot{T} = \dfrac{1}{c\rho A z}\left(c w_1 (T_1 - T) + c w_2 (T_2 - T) + kA (T_a - T) + R i^2\right) \\
y = \begin{bmatrix} z \\ T \end{bmatrix}
\end{cases}
$$

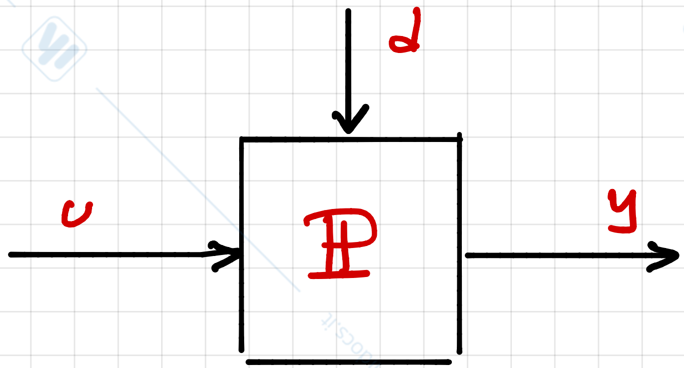
USCITA

$$u = \begin{bmatrix} w_0 \\ w_2 \\ i \end{bmatrix}$$

INGRESSI MANIPOLABILI

$$d = w_1$$

DISTURBO



- EQUILIBRIO

$$\begin{cases} \bar{w}_1 + \bar{w}_2 - \bar{w}_0 = 0 \\ (c\bar{w}_1 + c\bar{w}_2 + kA)\bar{T} = c\bar{w}_1 T_1 + c\bar{w}_2 T_2 + kAT_a + R\bar{i}^2 \end{cases}$$

FISSATI GLI INGRESSI $\bar{w}_1, \bar{w}_2, \bar{w}_0, \bar{i} \Rightarrow \bar{T}$ È UNICO

$\bar{z}$ È ARBITRARIO

- LINEARIZZAZIONE

$$\begin{cases} \delta\dot{z} = \frac{1}{\rho A}(\delta w_1 + \delta w_2 - \delta w_0) \\ \delta\dot{T} = \alpha_1 \delta z + \alpha_2 \delta T + \beta_1 \delta w_1 + \beta_2 \delta w_2 + \gamma \delta i \end{cases}$$

NOTA: $\alpha_1 = 0$ PERCHÉ

$\dot{T} = \frac{\mu}{z} f(T, w_1, w_2, i)$

$f(\bar{T}, \bar{w}_1, \bar{w}_2, \bar{i}) = 0$

$\Rightarrow$

$$\alpha_1 = \frac{\partial}{\partial z}\left(\frac{\mu}{z} f(T, w_1, w_2, i)\right)\Big|_{eq} = -\frac{\mu}{z^2} \underbrace{f(\bar{T}, \bar{w}_1, \bar{w}_2, \bar{i})}_{=0} = 0$$

- PARAMETRI MODELLO LINEARIZZATO

$$\begin{cases} \dot{z} = \dfrac{1}{\rho A}(w_1 + w_2 - w_0) \\ \dot{T} = \dfrac{1}{c\rho A z}\left(c w_1 (T_1 - T) + c w_2 (T_2 - T) + kA(T_a - T) + R i^2\right) \end{cases}$$

$\alpha_1 = 0$

$$\alpha_2 = -\frac{c\bar{w}_1 + c\bar{w}_2 + kA}{c\rho A \bar{z}} = -\frac{1}{\tau} < 0$$

$$\beta_1 = \frac{T_1 - \bar{T}}{\rho A \bar{z}} , \quad \beta_2 = \frac{T_2 - \bar{T}}{\rho A \bar{z}}$$

$$\gamma = \frac{2R\bar{i}}{c\rho A \bar{z}} > 0$$

$$\tau = \frac{c\rho A \bar{z}}{c\bar{w}_1 + c\bar{w}_2 + kA}$$

COSTANTE DI TEMPO

- CALCOLO FDT

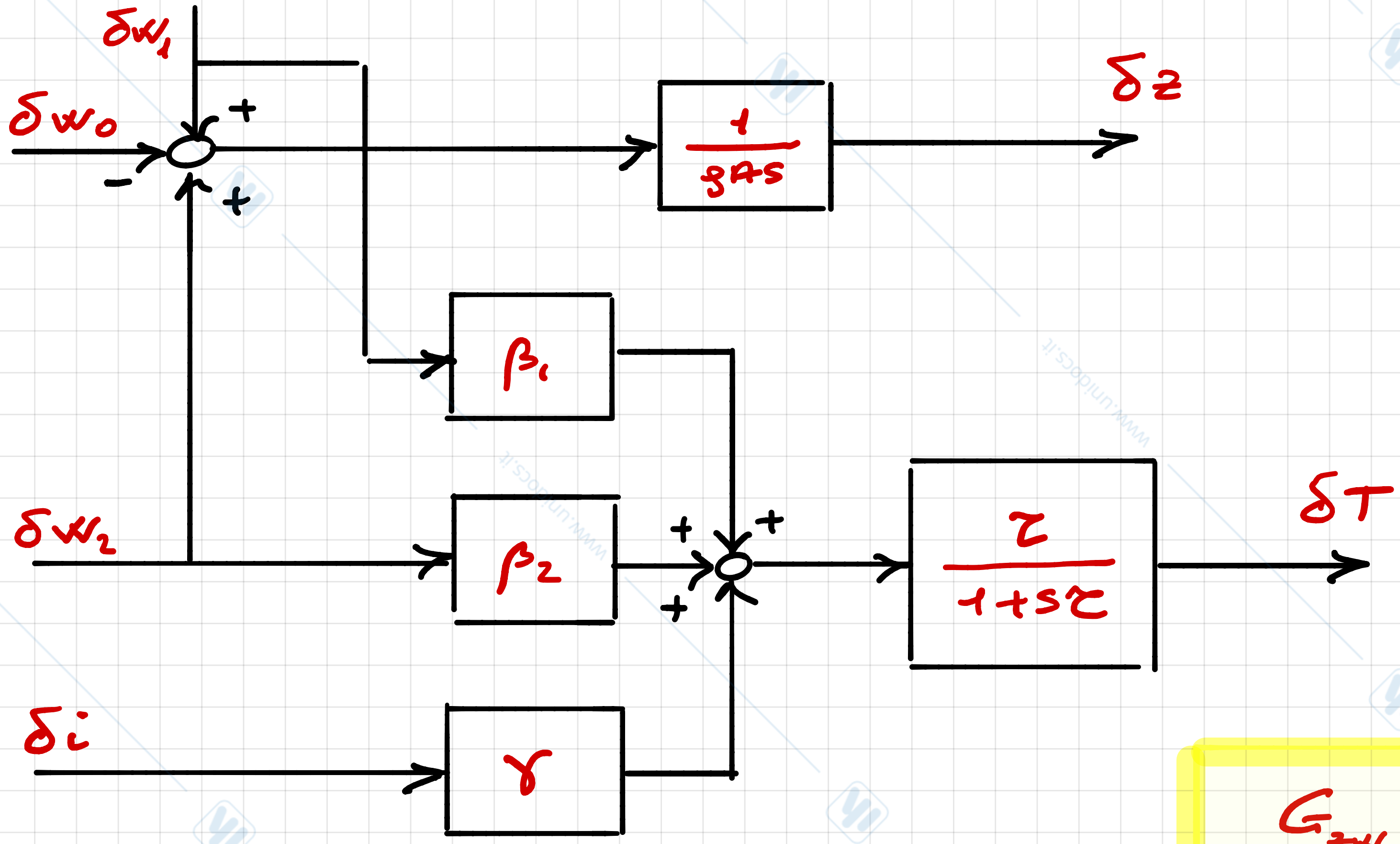
$$\begin{cases} \delta \dot{z} = \frac{1}{\rho A}\left(\delta w_1 + \delta w_2 - \delta w_0\right) \\ \delta \dot{T} = -\frac{1}{\tau}\delta T + \beta_1 \delta w_1 + \beta_2 \delta w_2 + \gamma \delta i \end{cases}$$

$$Z(s) = \frac{1}{\rho A s}\left(W_1(s) + W_2(s) - W_0(s)\right)$$

$$T(s) = \frac{1}{s + 1/\tau}\left(\beta_1 W_1(s) + \beta_2 W_2(s) + \gamma I(s)\right) =$$

$$= \frac{\tau}{1 + s\tau}\left(\beta_1 W_1(s) + \beta_2 W_2(s) + \gamma I(s)\right)$$

- Schema a Blocchi



$$\begin{bmatrix} Z(s) \\ T(s) \end{bmatrix} = \underbrace{\begin{bmatrix} G_{zw_0} & G_{zw_2} & 0 \\ 0 & G_{Tw_2} & G_{Ti} \end{bmatrix}}_{G(s)} \begin{bmatrix} W_0(s) \\ W_2(s) \\ I(s) \end{bmatrix}$$

$$G_{zw_0}(s) = -\frac{1}{\rho A s}$$

$$G_{zw_2}(s) = \frac{1}{\rho A s}$$

$$G_{Tw_2}(s) = \frac{\beta_2 \tau}{1+s\tau}$$

$$G_{Ti}(s) = \frac{\gamma \tau}{1+s\tau}$$

- SCELTA ACCOPPIAMENTI

$$G(s) = \begin{bmatrix} G_{zw_0} & G_{zw_2} & 0 \\ 0 & G_{Tw_2} & G_{Ti} \end{bmatrix}$$

POLI DI $G(s)$: $0, -\frac{1}{2}$

$\Downarrow$

$G(s)$ NON AS. STABILE

$\Downarrow$

ANALISI RGA NON UTILIZZABILE

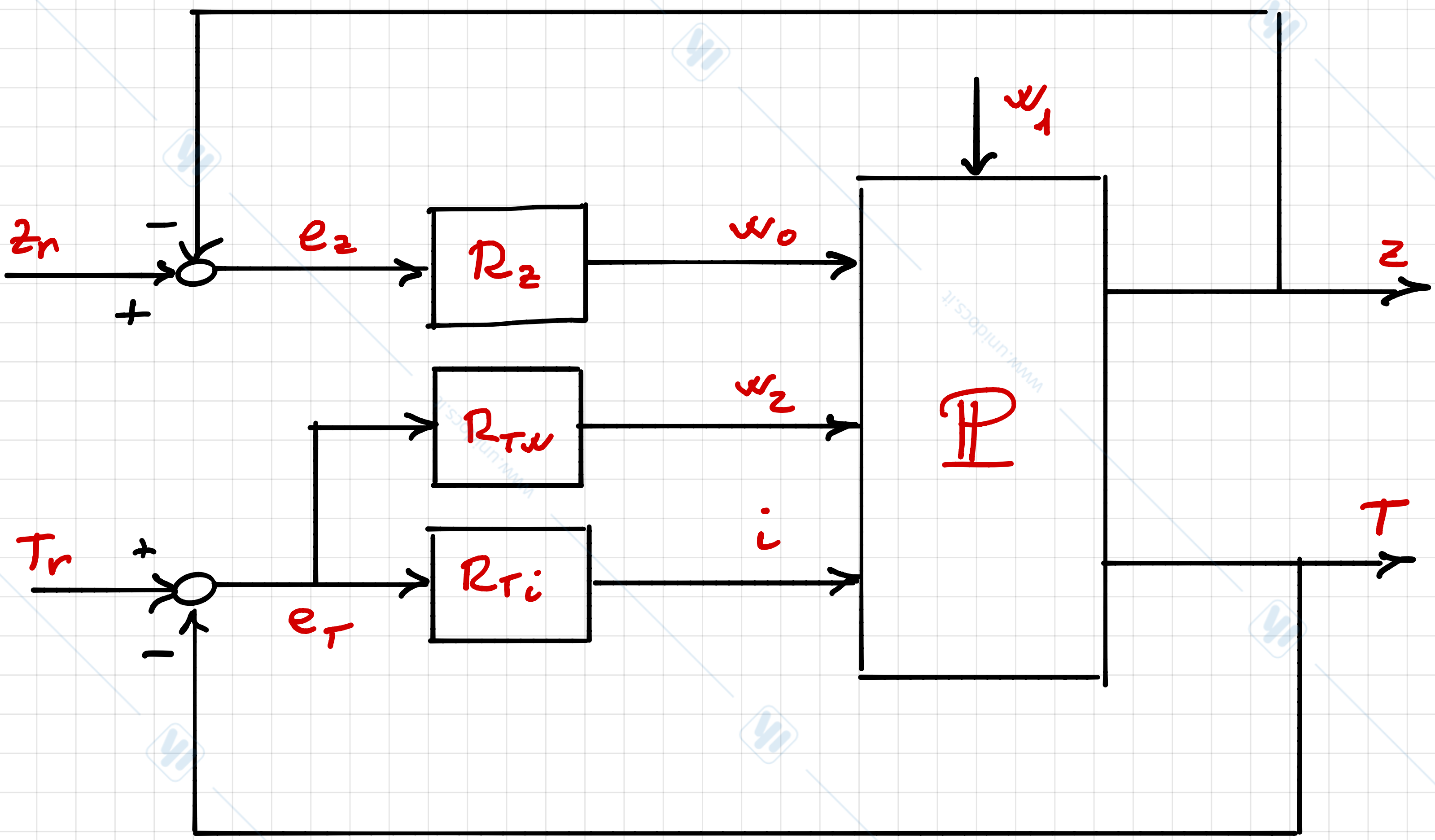
- SOLUZIONE MIGLIORE (MATRICE DIAGONALE)

w_0 CONTROLLA z
i CONTROLLA T

- SOLUZIONE "SPLIT-RANGE"

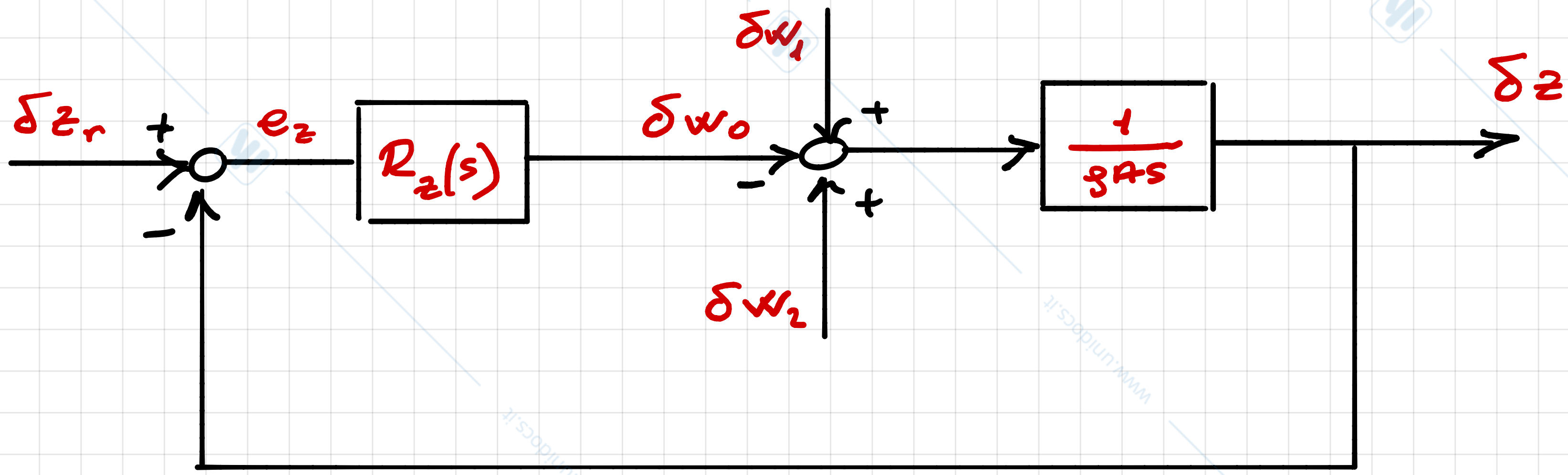
w_0 CONTROLLA z
w_2, i CONTROLLANO T

- CONTROLLO "SPLIT-RANGE"



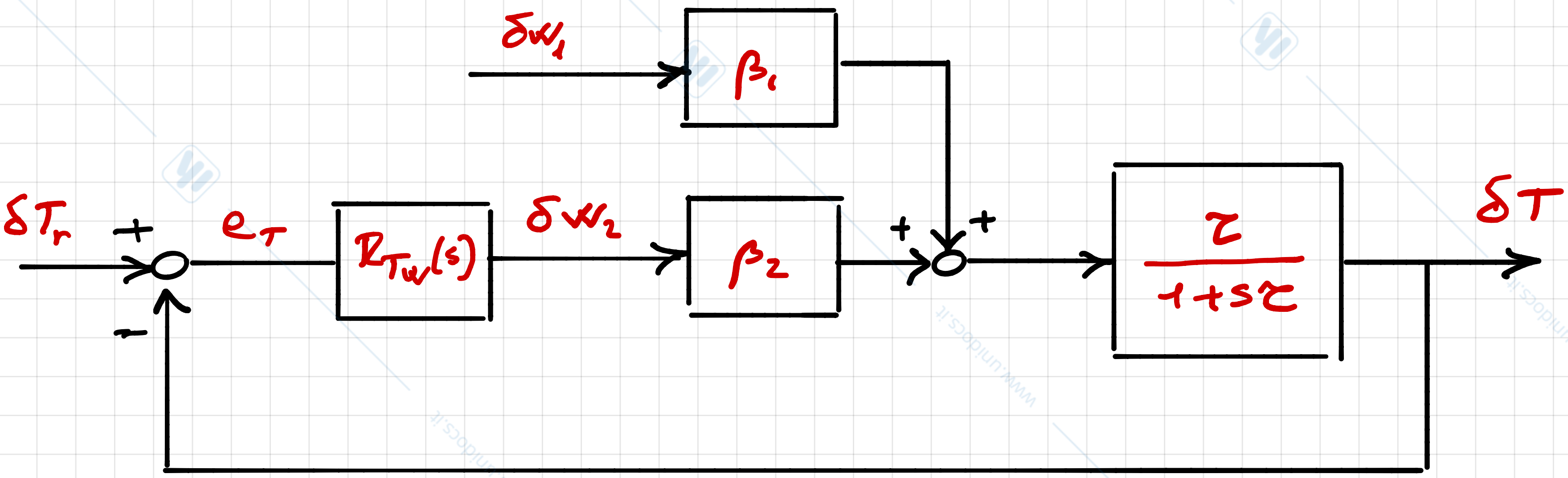
- PROGETTO DI $R_z(s)$ SU $G_{zw_0}(s) = -\frac{1}{\rho A s}$
- PROGETTO DI $R_{Tw}(s)$ SU $G_{Tw_2}(s) = \frac{\beta_2 \tau}{1+s\tau}$
- PROGETTO DI $R_{Ti}(s)$ SU $G_{Ti}(s) = \frac{\gamma \tau}{1+s\tau}$

- PROGETTO DI $R_z(s)$



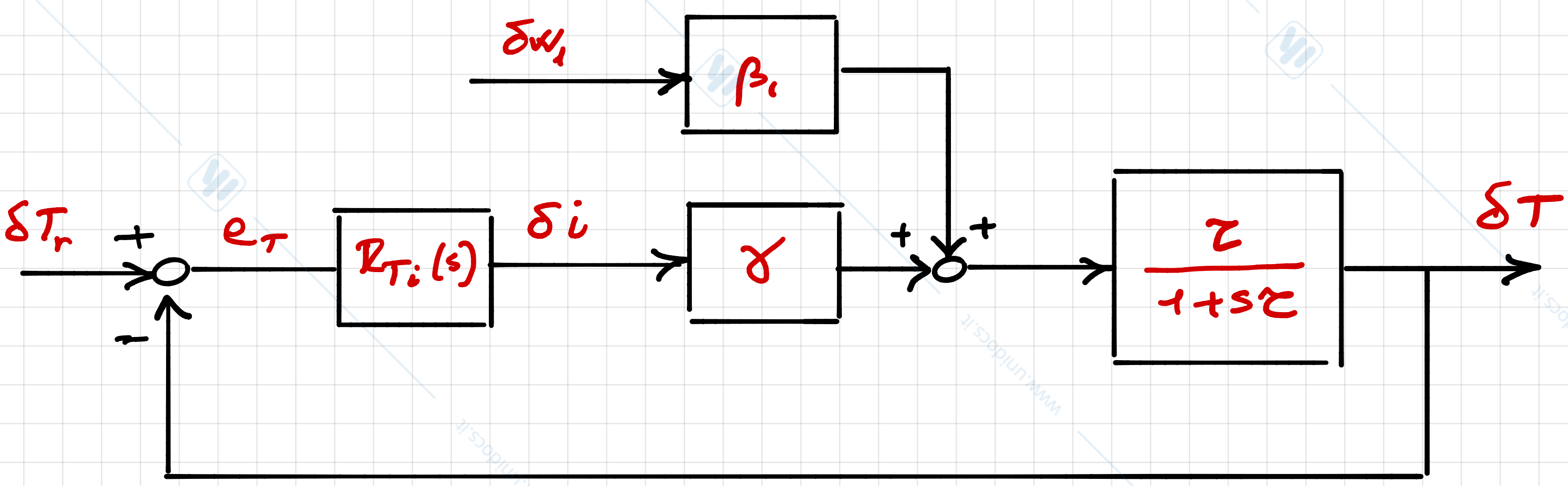
$R_z(s)$ DEVE AVERE :
- GUADAGNO NEGATIVO
- AZIONE INTEGRALE (PER DISTURBI $\delta w_1, \delta w_2$)

- PROGETTO DI $R_{Tw}(s)$



$R_{Tw}(s)$ DEVE AVERE:
- GUADAGNO NEGATIVO (SE $\beta_2 < 0$)
- AZIONE INTEGRALE

- PROGETTO DI $R_{Ti}(s)$



$R_{Ti}(s)$ DEVE AVERE:
- GUADAGNO POSITIVO
- AZIONE INTEGRALE

- Esempio Numerico

- Dati

$A_s = 3.14\ [m^2]$ $\quad c = 4200\ [J/kgK]$ $\quad$ Coeff. scambio termico $k = 0.36\ [kg/s^3K]$

$\rho = 1000\ [kg/m^3]$ $\quad R = 7.56 \cdot 10^3\ [\Omega]$

$T_1 = 323\ [K]$ $\quad T_2 = 283\ [K]$ $\quad T_a = 293\ [K]$

- Equilibrio

$\bar{w}_1 = 3\ [kg/s]$ $\quad \bar{w}_2 = 27\ [kg/s]$ $\quad \Longrightarrow \quad \bar{w}_0 = 30\ [kg/s]$

$\bar{T} = 293\ [K]$ $\quad \Longrightarrow \quad \bar{i} = 10\ [A]$

$\bar{z} = 1\ [m]$

- Parametri modello linearizzato

$\tau \simeq 105$

$\beta_1 \simeq 0.0095$ $\quad \beta_1 \tau \simeq 1$

$\beta_2 \simeq -0.0032$ $\quad \Longrightarrow \quad \beta_2 \tau \simeq -0.33$

$\gamma \simeq 0.0115$ $\quad \gamma \tau \simeq 1.2$

- SPECIFICHE

(a) $e(\infty) = 0$ CON RIFERIMENTI E DISTURBI COSTANTI

(b) $t_a \leq 165$ [s]

(c) NO OSCILLAZIONI

$\Rightarrow$ $\omega_c \geq 0.03$, $\varphi_m \geq 75°$