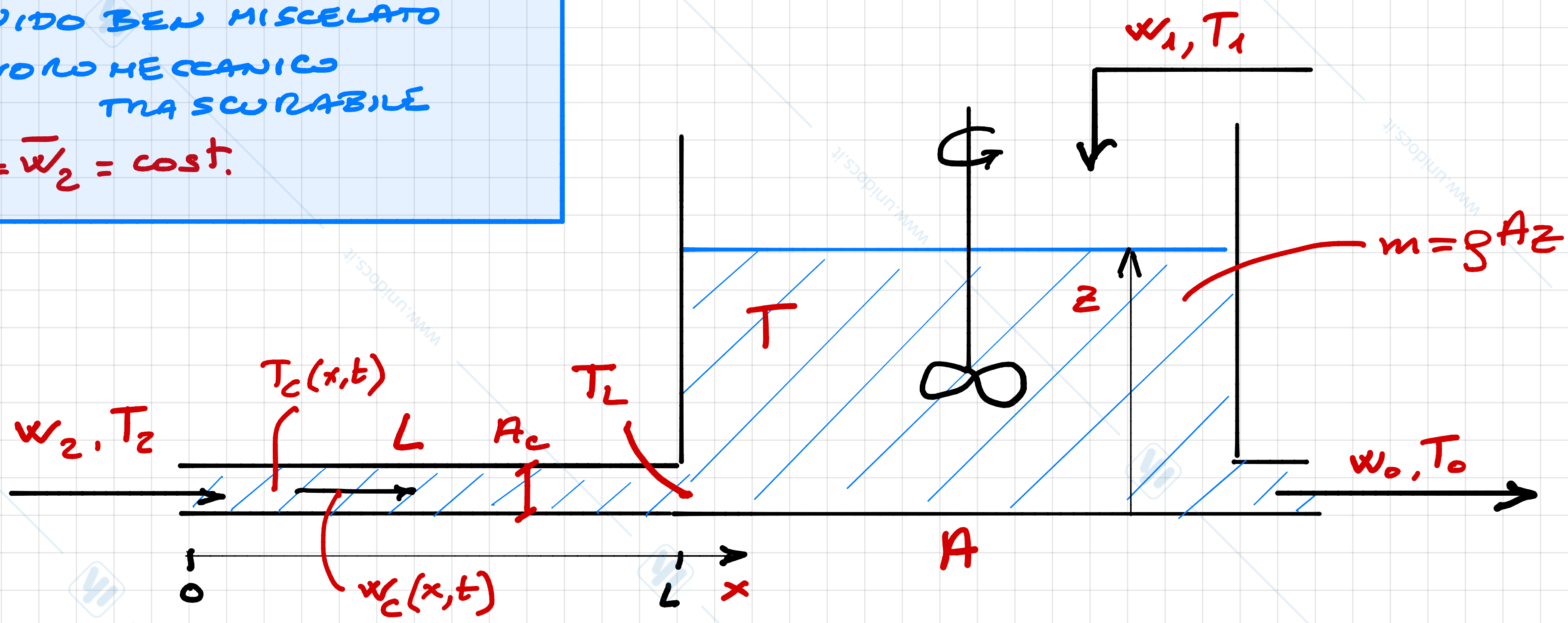
CONTROLLO DI UN MISCELATORE CON RITARDO

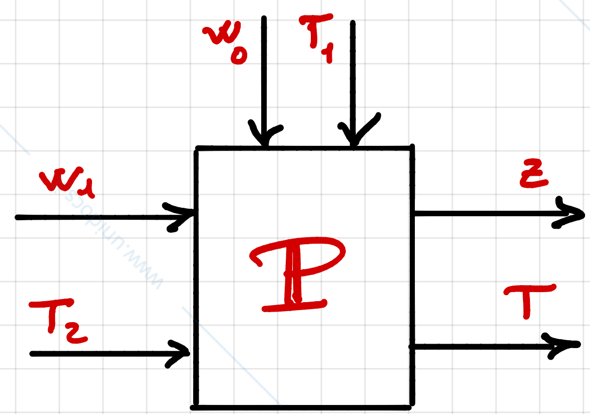
- MISCELATORE CON RITARDO

- IPOTESI
  - SCAMBI TERMICI TRASCURABILI
  - FLUIDO BEN MISCELATO
  - LAVORO MECCANICO TRASCURABILE

  $w_2 = \bar{w}_2 = cost.$



- PROBLEMA
  - CONTROLLO DI z, T MEDIANTE w_1, T_2



- MODELLO

- CONS. MASSA CONDOTTA: $w_c(x,t) = w_c(t) = \bar{w}_2$

- CONS. Q. DI MOTO CONDOTTA: —

- CONS. ENERGIA CONDOTTA: $\rho A_c \dfrac{\partial e(x,t)}{\partial t} + \bar{w}_2 \dfrac{\partial e(x,t)}{\partial x} = 0$

- CONS. MASSA SERBATOIO: $\dot{z}(t) = \dfrac{1}{\rho A}\left(w_1(t) + \bar{w}_2 - w_0(t)\right)$

- CONS. ENERGIA SERBATOIO

$$c\rho A z(t)\dot{T}(t) = c w_1(t)\left(T_1(t) - T(t)\right) + c\bar{w}_2\left(T_2(t) - T(t)\right)$$

$$\dot{T}(t) = \frac{1}{\rho A z(t)}\left(w_1(t)\left(T_1(t) - T(t)\right) + \bar{w}_2\left(T_2(t) - T(t)\right)\right)$$

- CONS. ENERGIA CONDOTTA

$$\rho A_c \frac{\partial e(x,t)}{\partial t} + \bar{w}_2 \frac{\partial e(x,t)}{\partial x} = 0 \qquad e(x,t) = c T_c(x,t)$$

$$c \rho A_c \frac{\partial T_c(x,t)}{\partial t} + c \bar{w}_2 \frac{\partial T_c(x,t)}{\partial x} = 0 \qquad \bar{w}_2 = \rho A_c \bar{v}_2$$

$$\frac{\partial T_c(x,t)}{\partial t} + \bar{v}_2 \frac{\partial T_c(x,t)}{\partial x} = 0$$

CONDIZIONE AL CONTORNO

$$T_c(0,t) = T_2(t)$$

- TRASF. LAPLACE $T_c(x,s) = \mathcal{L}[T_c(x,t)]$

EQ. DIFF. LINEARE DEL PRIMO ORDINE

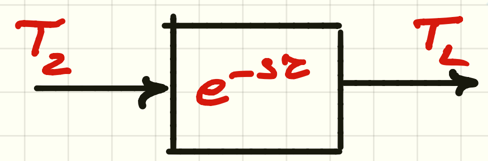
$$s T_c(x,s) + \bar{v}_2 \frac{\partial T_c(x,s)}{\partial x} = 0 \implies \frac{d}{dx} T_c(x,s) = -\frac{s}{\bar{v}_2} T_c(x,s)$$

CON $T_c(0,s) = T_2(s)$

$$T_c(x,s) = e^{-\frac{sx}{\bar{v}_2}} T_2(s)$$

$$T_L(s) = T_c(L,s) = e^{-\frac{sL}{\bar{v}_2}} T_2(s) = e^{-s\tau} T_2(s)$$

OVVERO $T_L(t) = T_2(t-\tau)$



$$\tau = \frac{L}{\bar{v}_2}$$

- MODELLO

SISTEMA DINAMICO MIMO NON LINEARE CON RITARDO

$n=2$

$$\begin{cases} \dot{z}(t) = \frac{1}{\rho A}\left(w_1(t) + \bar{w}_2 - w_0(t)\right) \\ \dot{T}(t) = \frac{1}{\rho A z(t)}\Big(w_1(t)\left(T_1(t) - T(t)\right) + \bar{w}_2\left(T_2(t-\tau) - T(t)\right)\Big) \end{cases}$$

- EQUILIBRIO

$$\begin{cases} 0 = \bar{w}_1 + \bar{w}_2 - \bar{w}_0 \\ 0 = \bar{w}_1(\bar{T}_1 - \bar{T}) + \bar{w}_2(\bar{T}_2 - \bar{T}) \end{cases} \Longrightarrow$$

$\bar{z}$ ARBITRARIO

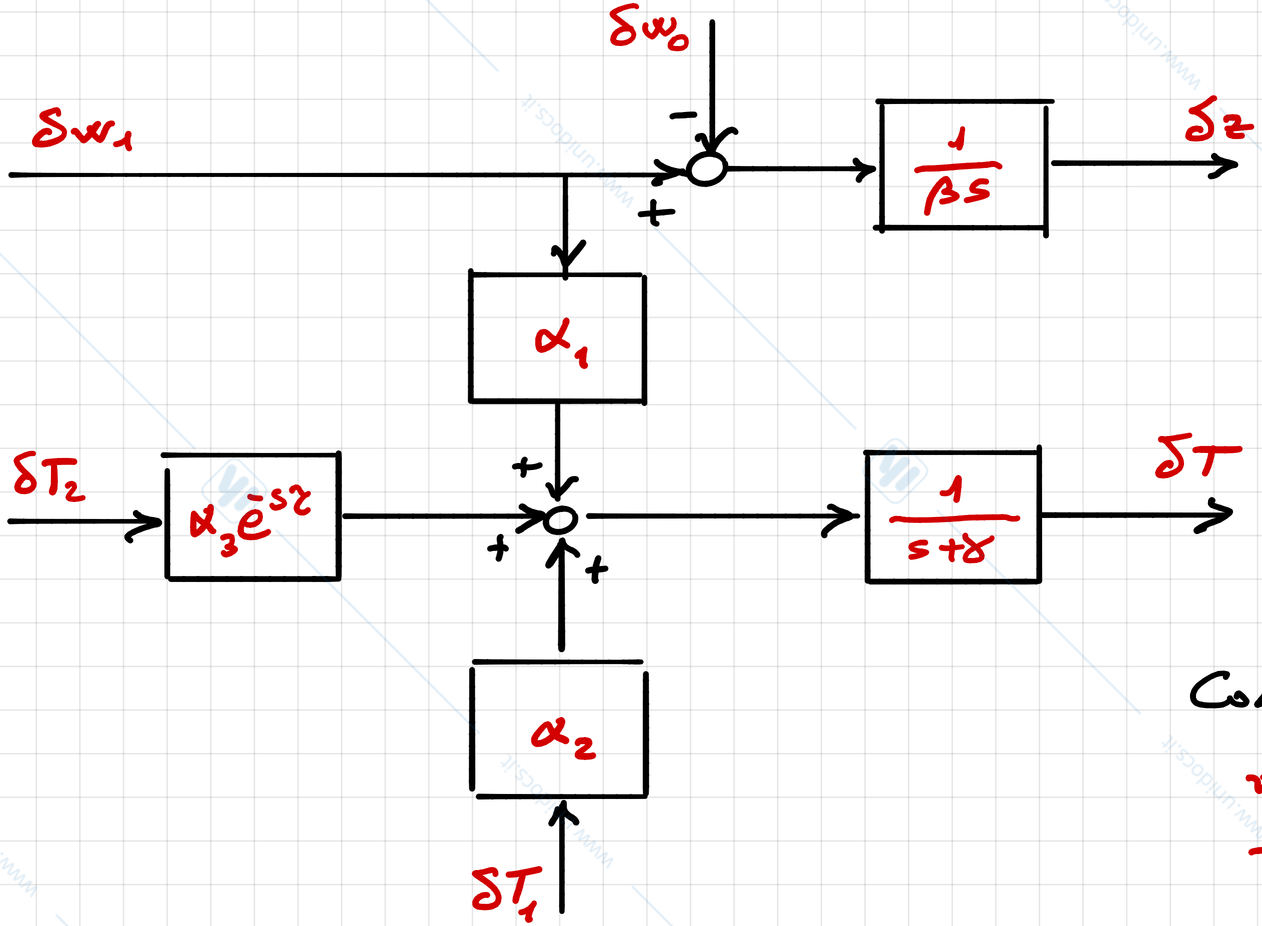
$$\bar{T} = \frac{\bar{w}_1\bar{T}_1 + \bar{w}_2\bar{T}_2}{\bar{w}_1 + \bar{w}_2}$$

- LINEARIZZAZIONE

$$\begin{cases} \delta\dot{z}(t) = \underbrace{\frac{1}{\rho A}}_{\beta}\left(\delta w_1(t) - \delta w_0(t)\right) \\ \delta\dot{T}(t) = -\underbrace{\frac{\bar{w}_1 + \bar{w}_2}{\rho A \bar{z}}}_{\gamma}\delta T(t) + \underbrace{\frac{\bar{T}_1 - \bar{T}}{\rho A \bar{z}}}_{\alpha_1}\delta w_1(t) + \underbrace{\frac{\bar{w}_1}{\rho A \bar{z}}}_{\alpha_2}\delta T_1(t) + \underbrace{\frac{\bar{w}_2}{\rho A \bar{z}}}_{\alpha_3}\delta T_2(t-\tau) \end{cases}$$

- CALCOLO FDT E SCHEMA A BLOCCHI

$$\begin{cases} Z(s) = \dfrac{1}{\beta s}\left(W_1(s) - W_0(s)\right) \\ T(s) = \dfrac{1}{s+\gamma}\left(\alpha_1 W_1(s) + \alpha_2 T_1(s) + \alpha_3 e^{-s\tau} T_2(s)\right) \end{cases}$$

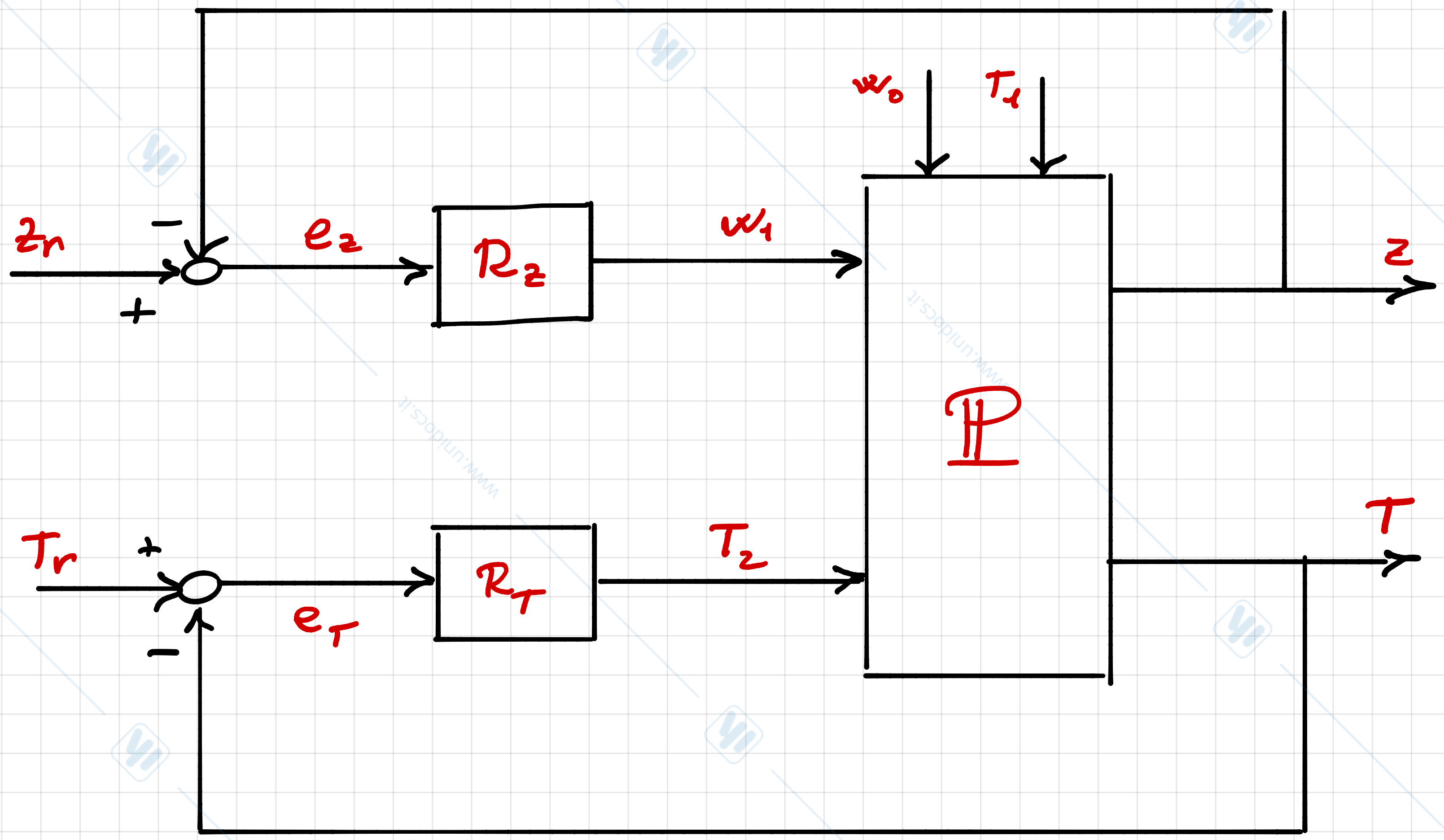


CONVIENE USARE

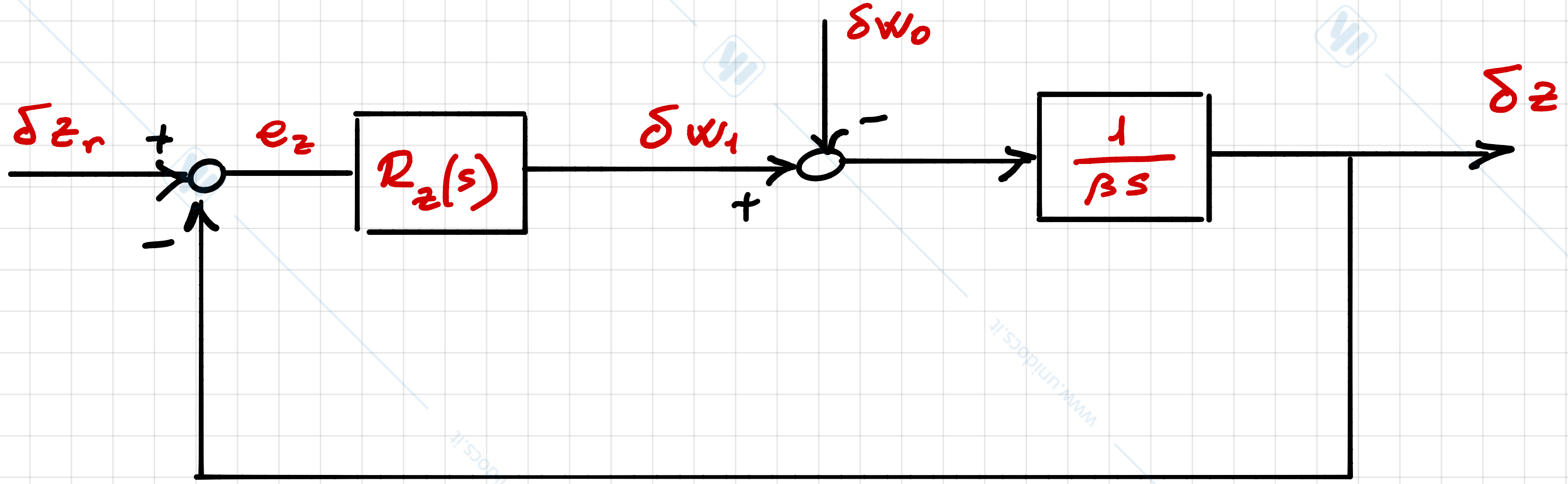
w_1 PER CONTROLLARE z

T_2 PER CONTROLLARE T

- SISTEMA DI CONTROLLO



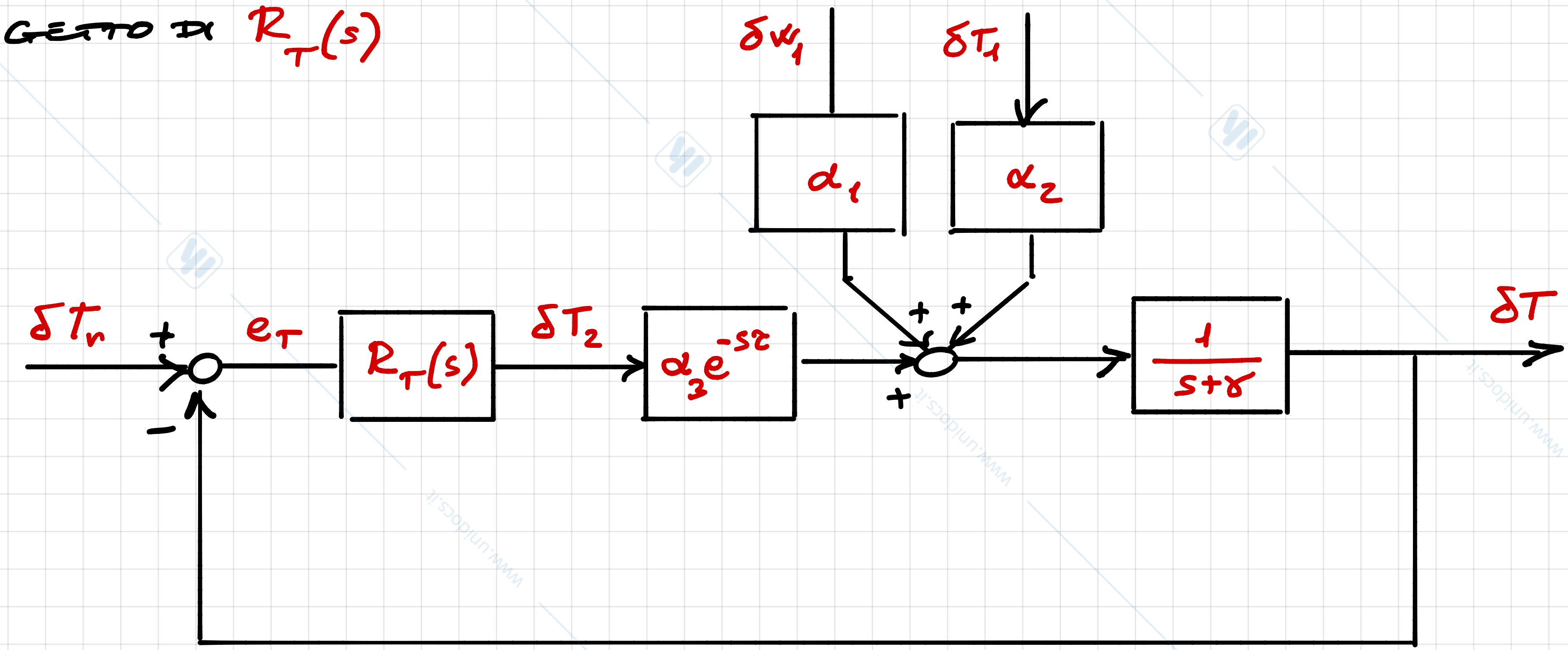
- PROGETTO DI $R_z(s)$



$R_z(s)$ DEVE AVERE:

- GUADAGNO POSITIVO
- AZIONE INTEGRALE (PER DISTURBO δw_0)
- UNO ZERO PER GARANTIRE AS. STABILITÀ

- PROGETTO DI $R_T(s)$



$R_T(s)$ DEVE AVERE:
- GUADAGNO POSITIVO
- AZIONE INTEGRALE

PER EVITARE LIMITAZIONI SU ω_c $\Longrightarrow$ PREDITTORE DI SMITH

- SCHEMA STANDARD

$$G_{\pi}(s) = \frac{\alpha_3/\gamma}{1+s/\gamma} e^{-s\tau} \qquad \frac{\alpha_3}{\gamma} = \frac{\bar{w}_2}{\bar{w}_1+\bar{w}_2} \qquad \tau = \frac{L}{\bar{v}_2} = \frac{L\rho A_c}{\bar{w}_2}$$

$$R_T(s) = \mu_R \frac{1+s/\gamma}{s} \implies L(s) = \frac{\mu_R \alpha_3}{\gamma s} e^{-s\tau}$$

$$\mu_R > 0$$

$$\omega_c = \frac{\mu_R \alpha_3}{\gamma}$$

$$\varphi_m = 90^\circ - \omega_c \tau \frac{180^\circ}{\pi}$$

- PER AVERE AS. STABILITÀ

$$\varphi_m > 0^\circ \implies \omega_c < \frac{\pi}{2\tau} \implies \mu_R < \frac{\pi\gamma}{2\tau\alpha_3} = \frac{\pi(\bar{w}_1+\bar{w}_2)}{2\rho L A_c}$$

LIMITAZIONI SULLA VELOCITÀ DI RISPOSTA

- SCHEMA A PREDITTORE DI SMITH

$$G_{TT}(s) = \underbrace{\frac{\alpha_3/\gamma}{1+s/\gamma}}_{G'_{TT}(s)} e^{-s\tau}$$

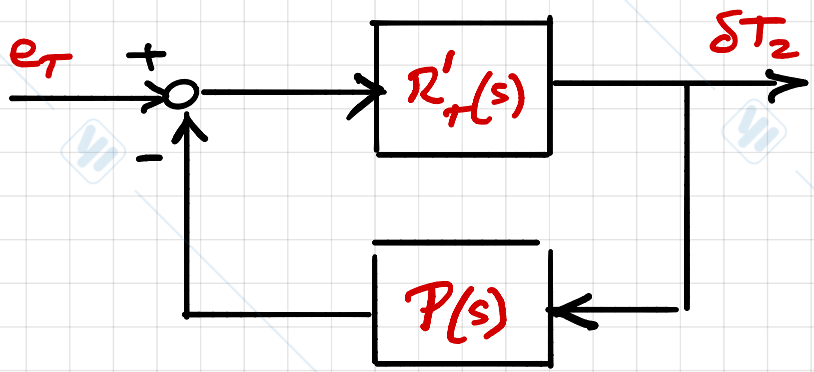
$R'_T(s)$ PROGETTATO SU $G'_{TT}(s)$

$$R'_T(s) = \mu'_R \frac{1+s/\gamma}{s} \implies L'(s) = \frac{\mu'_R \alpha_3}{\gamma s}$$

$$\omega'_c = \frac{\mu'_R \alpha_3}{\gamma}$$

ARBITRARIA

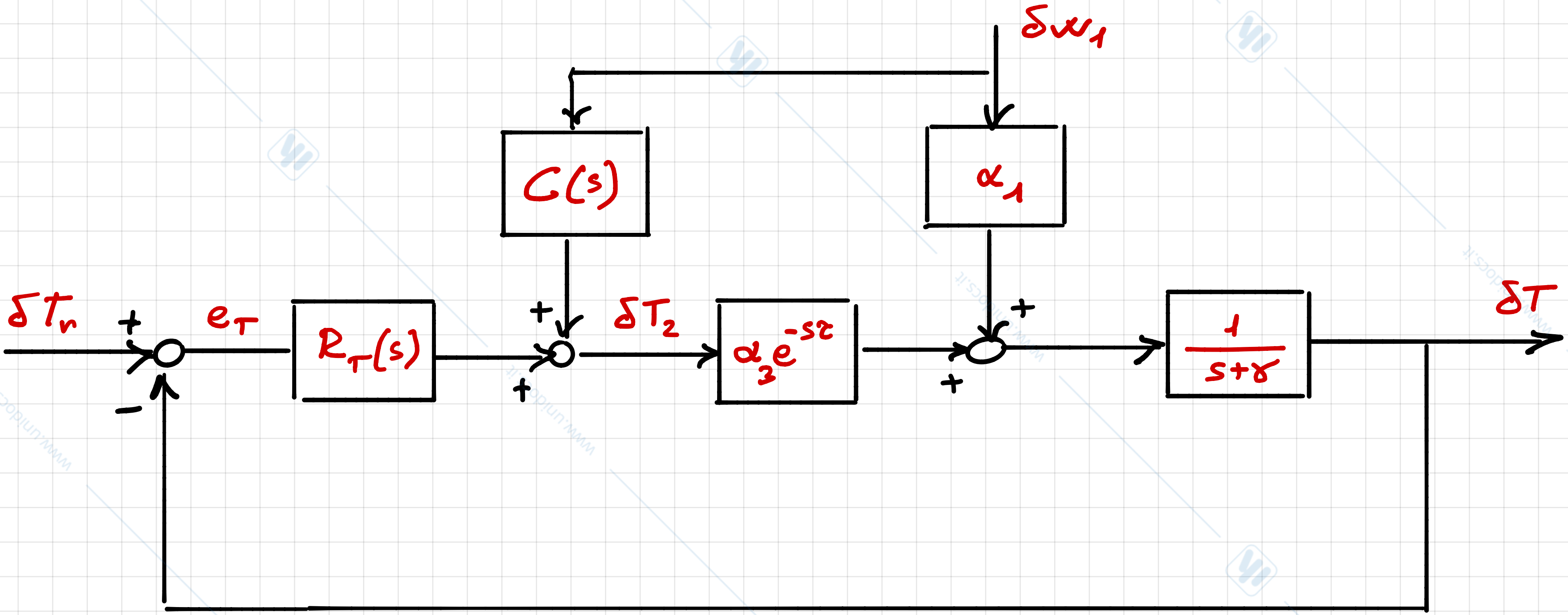
$$\varphi'_m = 90°$$



SCHEMA A PREDITTORE DI SMITH

$$P(s) = \frac{\alpha_3/\gamma}{1+s/\gamma}\left(1 - e^{-s\tau}\right)$$

- COMPENSAZIONE DEL DISTURBO δw_1



$$C^\circ(s) = -\frac{\alpha_1}{\alpha_3} e^{s\tau}$$ NON REALIZZABILE!

- COMP. STATICO $C(s) = -\frac{\alpha_1}{\alpha_3} = -\frac{\bar{T}_1 - \bar{T}}{\bar{w}_2}$

EFFICACIA ?

- Esempio Numerico

- Dati

$A = 8 \, [m^2]$ $\quad A_c = 0.125 \, [m^2]$ $\quad L = 15 \, [m]$

$\rho = 1000 \, [kg/m^3]$

$\bar{w}_2 = 10 \, [kg/s]$

- Equilibrio

$\bar{w}_1 = 10 \, [kg/s]$ $\quad \bar{w}_0 = 20 \, [kg/s]$

$\bar{T}_1 = 303 \, [K]$ $\quad \bar{T}_2 = 323 \, [K]$ $\quad \Longrightarrow \quad \bar{T} = 313 \, [K]$

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

- Parametri modello linearizzato

$\tau = 187.5 \, [s]$

$\beta = \rho A = 8000$

$\alpha_1 = -0.0013$ $\quad \alpha_2 = 0.0013$ $\quad \alpha_3 = 0.0013$

$\gamma = 0.0025$