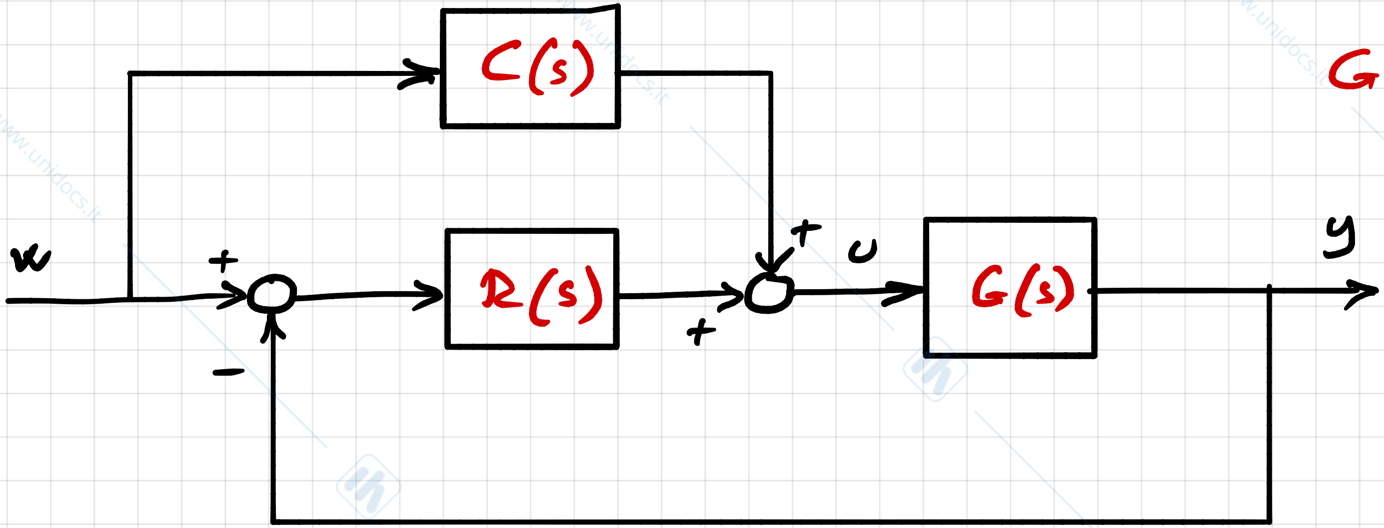
ESERCITAZIONE SUGLI

SCHEMI DI CONTROLLO AVANZATI

ESERCIZIO 1



$$G(s) = \frac{40(1-0.05s)}{(1+s)(1+0.05s)}$$

$$R(s) = 0.2$$

1. PROGETTARE UN COMPENSATORE IN F.F. "IDEALE"

2. PROGETTARE UN COMPENSATORE IN F.F. STATICO
   METTENDO IN EVIDENZA I VANTAGGI DI TALE SOLUZIONE

3. PROGETTARE UN PREFILTRO EQUIVALENTE AL COMPENSATORE STATICO

1

$$C^{o}(s) = \frac{1}{G(s)} = \frac{1}{40}\,\frac{(1+s)(1+0.05s)}{(1-0.05s)}$$

- NON REALIZZABILE
- INSTABILE !

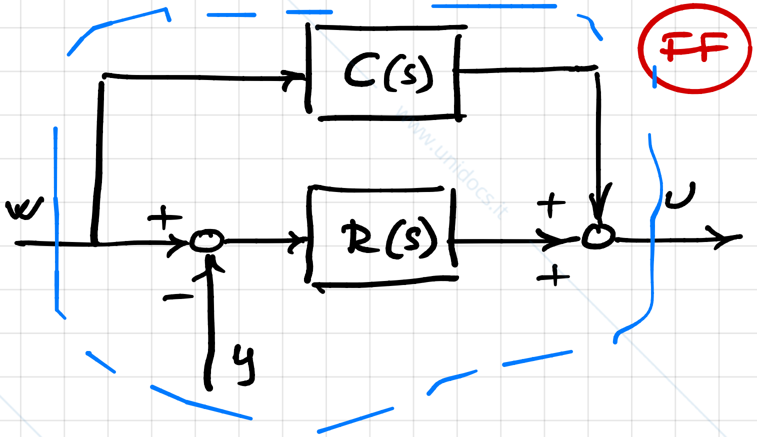
2

$$\boxed{\bar{C}(s) = \frac{1}{G(0)} = \frac{1}{40}}$$

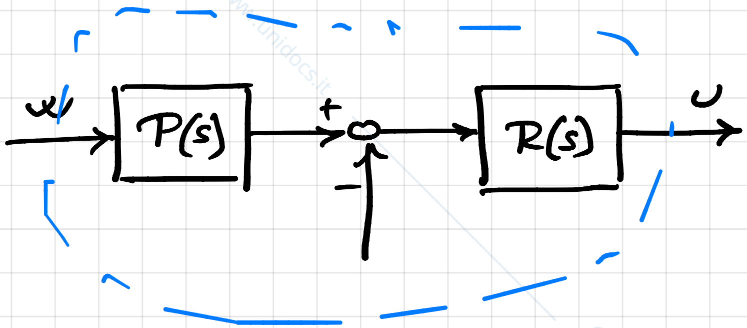
- CONFRONTO
  - SENZA $C(s) \Longrightarrow G_{yw}(s) = \dfrac{R(s)G(s)}{1+R(s)G(s)}$ $\quad G_{yw}(0) = \dfrac{\mu}{1+\mu} = \dfrac{8}{9} \neq 1$
  - CON $C(s) = \bar{C}(s) = \dfrac{1}{40} \Longrightarrow G_{yw}(s) = \dfrac{(C(s)+R(s))G(s)}{1+R(s)G(s)}$

$$\boxed{G_{yw}(0) = \frac{\left(\frac{1}{40}+\frac{2}{10}\right)\cdot 40}{1+8} = 1 \;!}$$

FF



PF

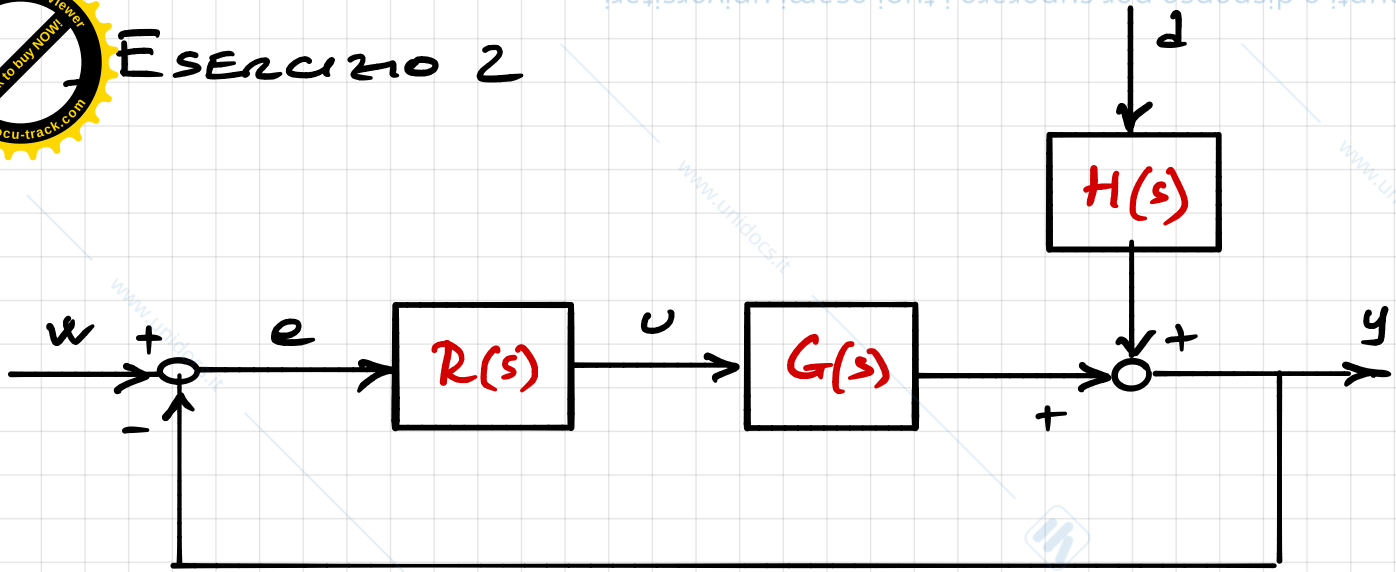


$$C(s) + R(s) = P(s)R(s) \implies P(s) = 1 + \frac{C(s)}{R(s)}$$

$$\boxed{P(s)} = 1 + \frac{\bar{C}(s)}{R(s)} = 1 + \frac{1/40}{2/10} = \boxed{\frac{9}{8}}$$

PREFILTRO STATICO

Esercizio 2



$$R(s) = 0.2$$

$$G(s) = \frac{10(1-0.1s)}{1+0.5s}$$

$$H(s) = \frac{0.2}{(1+2s)(1+0.5s)}$$

1. Progettare compensatore in A.A. del disturbo $d(t) = A\,\text{sen}(4t)$ con struttura $C(s) = \dfrac{\mu}{1+sT}$

2. Valutare degrado delle prestazioni con un ritardo $\tau = 0.01$ nella misura di $d(t)$

3. Verificare as. stabilità e valutare effetto a t. esaurito di un disturbo $d(t) = \text{sca}(t)$

$$d(t) = A\,\text{sen}(4t) \quad , \quad \omega = 4$$

$$C^{\circ}(s) = -\frac{H(s)}{G(s)} = \frac{-0.02}{(1+2s)(1-0.1s)}$$

INSTABILE!

È SUFFICIENTE IMPORRE

$$C(j4) = -\frac{H(j4)}{G(j4)}$$

$$\begin{cases} |C(j4)| = \left|-\dfrac{H(j4)}{G(j4)}\right| = \dfrac{0.02}{|1+j8|\,|1-j0.4|} \simeq \dfrac{0.02}{8.1} \simeq 0.002 \\[2ex] \measuredangle C(j4) = \measuredangle\left(-\dfrac{H(j4)}{G(j4)}\right) = -180^{\circ} - \measuredangle(1+j8) - \measuredangle(1-j0.4) = \\ = -180^{\circ} - \text{arctg}\,8 + \text{arctg}\,0.4 \simeq -241^{\circ} \end{cases}$$

$$C(s) = \frac{\mu}{1+sT} \quad , \quad \mu < 0$$

$$\measuredangle C(j4) = -180^{\circ} - \text{arctg}(4T) = -241^{\circ}$$

$$\Longrightarrow T = \frac{1}{4}\,\text{tg}(61^{\circ}) \simeq 0.45$$

$$|C(j4)| = \frac{|\mu|}{|1+j4T|} = \frac{|\mu|}{|1+j1.8|} = 0.002$$

$$\Longrightarrow |\mu| = 0.002\,|1+j1.8| \simeq 0.0047$$

CONCLUSIONE

$$C(s) = -\frac{0.0047}{1+0.45s}$$

- SE C'È UN RITARDO $\tau = 0.01$ NELLA MISURA DEL DISTURBO:

$$G_{yd}(s) = \frac{H(s) + C(s)G(s)e^{-\tau s}}{1 + R(s)G(s)}$$

$$|G_{yd}(j4)| = ?$$

$$M(s) = H(s) + C(s)G(s)e^{-\tau s}$$

- CON $\tau = 0 \Longrightarrow |M(j4)| = 0$
- CON $\tau = 0.01 \Longrightarrow |M(j4)| \simeq 0.016$

- SI NOTI CHE $|1 + R(j4)G(j4)| \simeq 1.44$

- CON $\tau = 0 \Longrightarrow |G_{yd}(j4)| = 0$
- CON $\tau = 0.01 \Longrightarrow |G_{yd}(j4)| \simeq \frac{0.016}{1.44} \simeq 0.011$

AMPIEZZA EFFETTO DEL RITARDO

- VERIFICA AS. STABILITÀ

$$L(s) = \frac{2(1-0.1s)}{1+0.5s}$$

$$\varphi_{AC}(s) = 1 + 0.5s + 2 - 0.2s = $$
$$= 0.3s + 3 = 0 \Rightarrow \underbrace{s = -10}_{\text{POLO IN A.C.}}$$

AS. STAB.

- EFFETTO A T. ESAURITO DI $d(t) = sca(t)$

$$G_{yd}(s) = \frac{H(s) + C(s)G(s)}{1 + R(s)G(s)} \qquad C(s) = -\frac{0.0047}{1+0.45s}$$

$$G_{yd}(0) = \frac{H(0) + C(0)G(0)}{1 + R(0)G(0)} = \frac{0.2 - 0.047}{1+2} = \frac{0.153}{3} \simeq 0.051$$

EFFETTO A REGIME

- NOTA: SENZA $C(s)$ AVREMMO $G_{yd}(0) = \frac{H(0)}{1+L(0)} = \frac{0.2}{3} \simeq 0.066$

ESERCIZIO 3

$$G(s) = \frac{e^{-s/2}}{1+s}$$

1. VERIFICARE CHE, CON SCHEMA STANDARD E $R(s)=\mu$
   E' IMPOSSIBILE OTTENERE $e(\infty) < 0.1A$ QUANDO $w(t) = A\,\text{sca}(t)$

2. PROGETTARE CONTROLLORE DI SMITH CHE ASSICURI LA PRESTAZIONE

3. CALCOLARE $R(s)$ DEL CONTROLLORE DI SMITH

4. APPROSSIMANTE DI PADE' DI $R(s)$ $\Longrightarrow$ $\tilde{R}(s)$

5. VALUTARE FDT D'ANELLO $\tilde{L}(s)$ (APPROX.)

6. PRESTAZIONI DINAMICHE (APPROX.)

$$L(s) = \mu \frac{e^{-s/2}}{1+s}$$

$$w(t) = A\,\mathrm{sca}(t)$$

$$e(\infty) = \frac{1}{1+\mu} \cdot A < 0.1A \implies \boxed{\mu > 9}$$

(SE $\mu > 1$)

- CALCOLO DI ω_c

$$|L(j\omega)| = \mu \frac{1}{\sqrt{1+\omega^2}} = 1 \implies 1+\omega^2 = \mu^2 \implies \omega_c = \sqrt{\mu^2-1}$$

$\omega_c \simeq \mu$ PER $\mu >> 1$

- CALCOLO DI φ_m

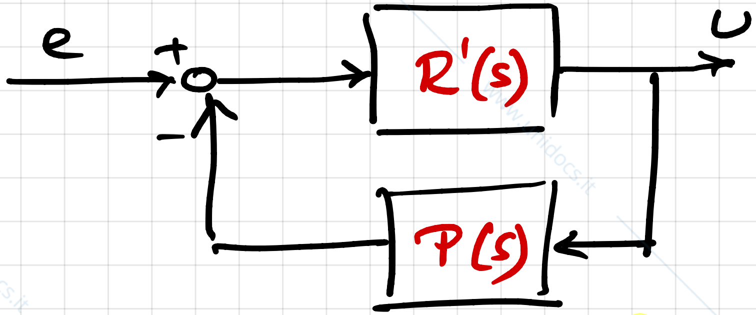
$$\varphi_c = \angle L(j\omega_c) = -\mathrm{arctg}\,\omega_c - \frac{1}{2}\omega_c \frac{180^\circ}{\pi}$$

$$\varphi_m = 180^\circ - |\varphi_c| = 180^\circ - \mathrm{arctg}\,\omega_c - \frac{1}{2}\omega_c \frac{180^\circ}{\pi}$$

INSTAB.

- CON $\mu = 9 \implies \varphi_m \simeq 180^\circ - \mathrm{arctg}\,9 - 4.5 \cdot 57^\circ \simeq -159^\circ < 0^\circ$

- CON $\mu > 9 \implies \boxed{\varphi_m < -159^\circ < 0^\circ}$ INSTAB.



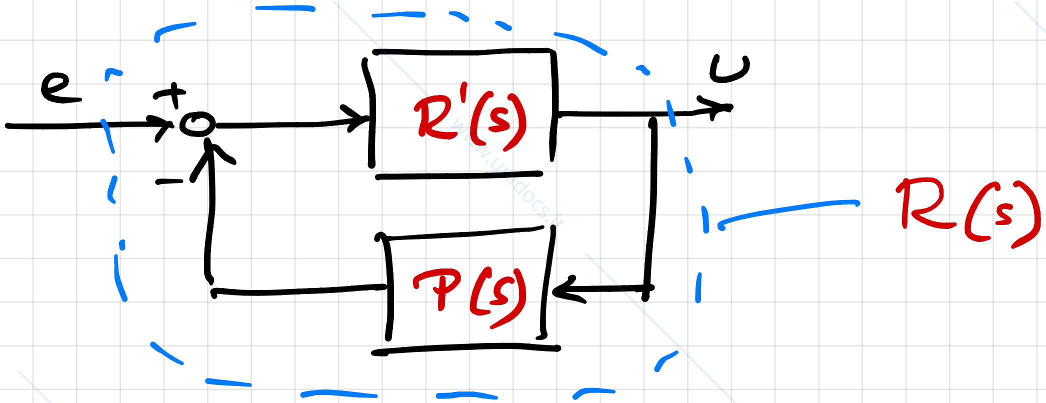
$R'(s)$ PROGETTATO SU $G'(s) = \dfrac{1}{1+s}$

$$R'(s) = \mu' \implies L'(s) = \frac{\mu'}{1+s}$$

μ' ARBITRARIAMENTE GRANDE

p.e. $\boxed{R'(s) = \mu' = 10}$ PER SODDISFARE SPEC. STATICA

$$\boxed{P(s)} = G'(s)\left(1 - e^{-\tau s}\right) = \boxed{\frac{1}{1+s}\left(1 - e^{-s/2}\right)}$$



$$R'(s) = 10$$

$$P(s) = \frac{1}{1+s}\left(1 - e^{-s/2}\right)$$

$$R(s) = \frac{R'(s)}{1 + R'(s)P(s)} = \frac{10(1+s)}{1+s+10\left(1-e^{-s/2}\right)} = \boxed{\frac{10(1+s)}{11+s-10e^{-s/2}}}$$

FDT NON RAZIONALE

$$R(s) = \frac{10(1+s)}{11+s-10e^{-s/2}}$$

APPROX. DI PADÈ DI $e^{-s/2}$

$$e^{-s/2} \simeq \frac{1-s/4}{1+s/4}$$

- APPROX. DI PADÈ DI $R(s)$

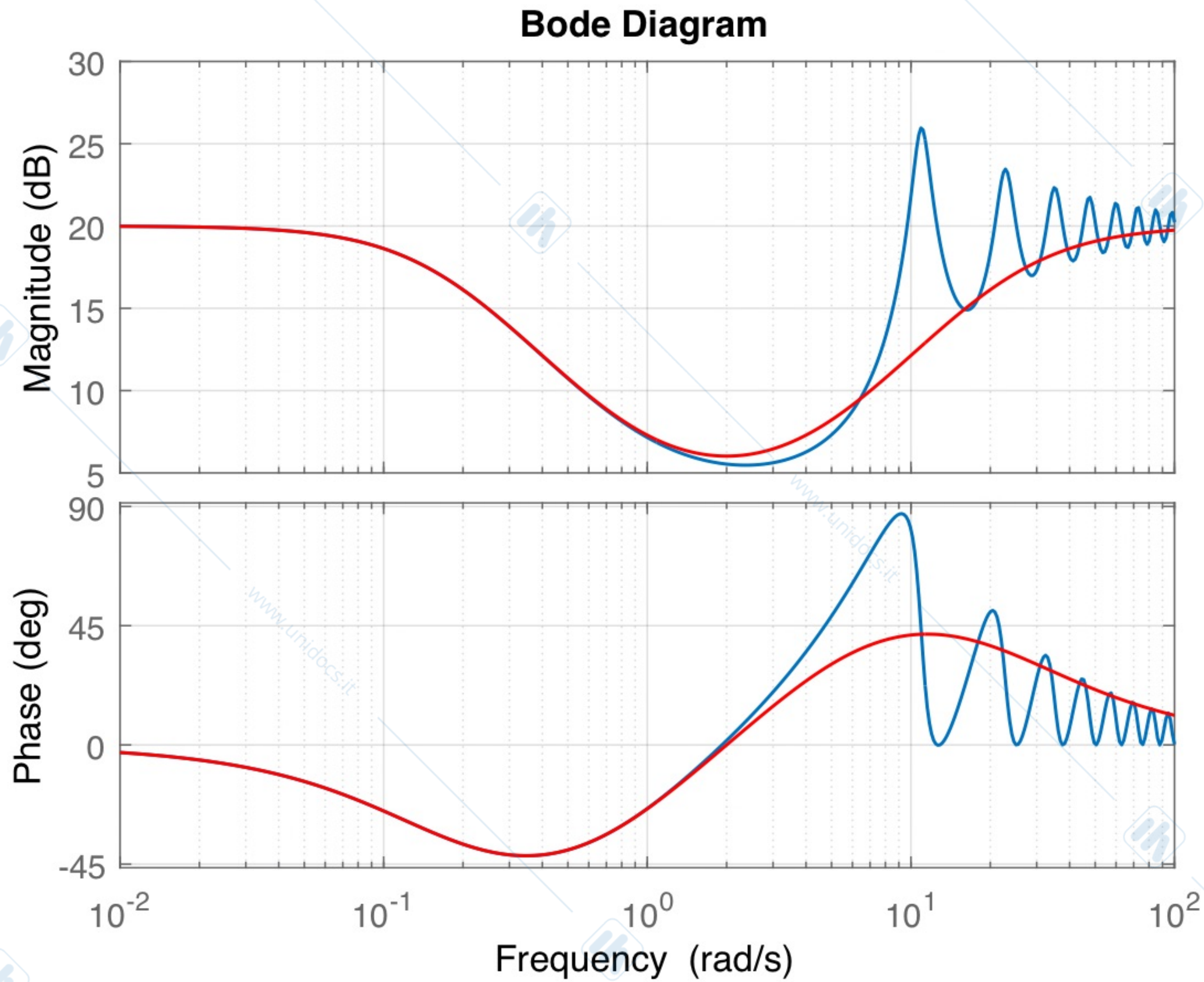
$$\tilde{R}(s) = \frac{10(1+s)}{11+s-10\frac{1-s/4}{1+s/4}} = \frac{10(1+s)(1+s/4)}{(11+s)(1+s/4)-10(1-s/4)} =$$

$$= \frac{10(1+s)(1+s/4)}{1+\frac{25}{4}s+\frac{1}{4}s^2} = \boxed{\frac{10(1+s)(1+0.25s)}{(1+6.25s)(1+0.04s)}}$$

FDT RAZIONALE

- NOTA: $\tilde{R}(s)$ HA LA STRUTTURA DI UNA "RETE A SELLA"

- DIAGRAMMI DI BODE DI $R(s)$ E $\tilde{R}(s)$



[illegible] + 6

$$\tilde{L}(s) = \tilde{R}(s)G(s) = \frac{10(1+0.25s)}{(1+6.25s)(1+0.04s)}\, e^{-s/2}$$

- DAI DIAGRAMMI DI BODE SI TROVA:

$$\tilde{\omega}_c \simeq 1.75$$
$$\tilde{\varphi}_m \simeq 65^\circ$$

$$\xi \simeq 0.65$$
$$\omega_n \simeq 1.75$$

- TEMPO DI ASSESTAMENTO

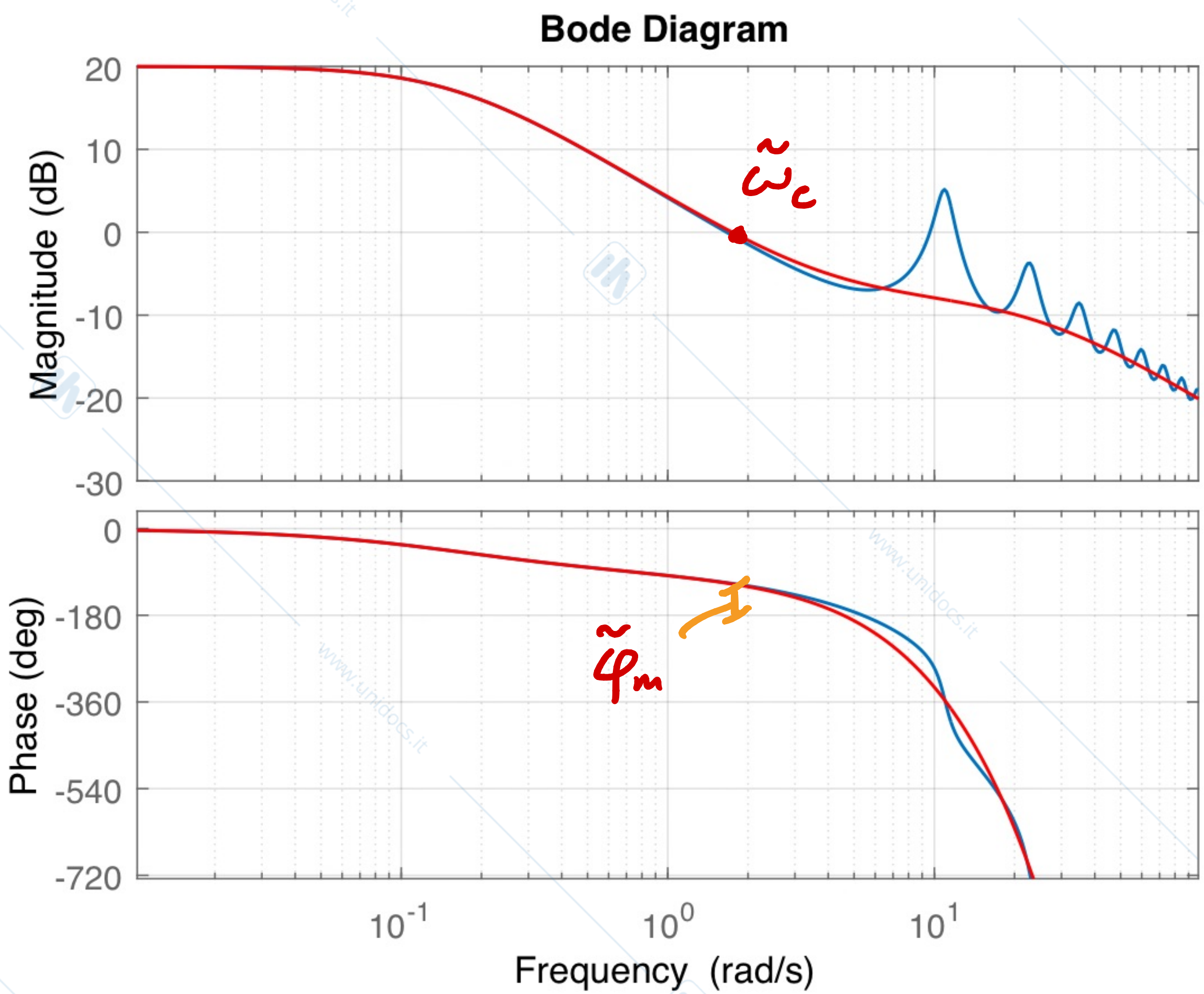
$$t_a \simeq \frac{5}{\xi\omega_n} \simeq \frac{500}{\tilde{\varphi}_m \tilde{\omega}_c} \simeq 4.4$$

- MAX SOVRAELONG. RELATIVA

$$\Delta = \exp\left(-\frac{\xi\pi}{\sqrt{1-\xi^2}}\right) \simeq 0.07$$

- NOTA: LE VALUTAZIONI NON SONO MOLTO ATTENDIBILI VISTO CHE $\tilde{\omega}_c$ È MOLTO VICINA A $\frac{1}{2} = 2$ (LIMITE DI VALIDITÀ APPROX. PADÈ)

- DIAGRAMMI DI BODE DI $L(s)$ E $\tilde{L}(s)$



Risposta di $y(t)$ a $w(t) = \text{sca}(t)$