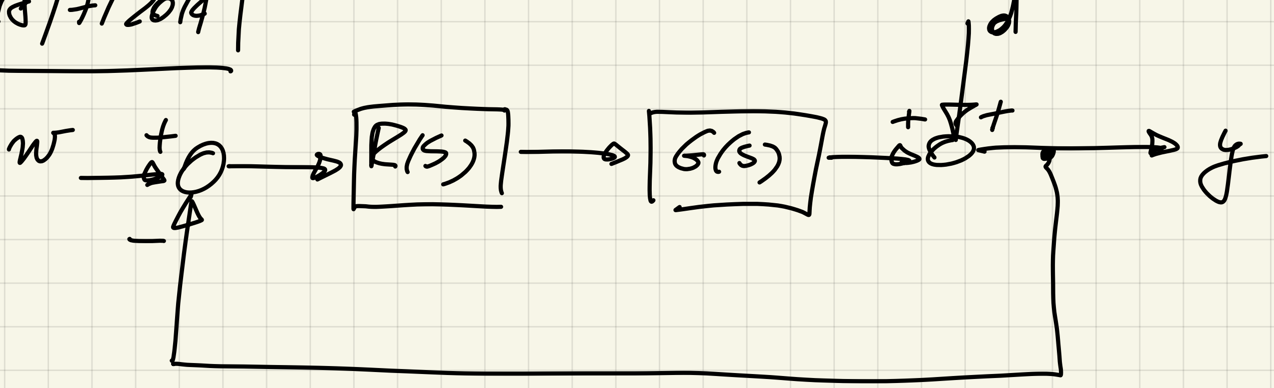
18/7/2014



$$G(s) = \frac{10}{1+10s} \cdot e^{-2s}$$

specifiche di progetto:

(a) $|e_\infty| \to 0$ per $w(t) = A \cdot 1(t)$, $d(t) = B \cdot 1(t)$, $A, B \in \mathbb{R}$

(b) $d \equiv 0$ $\quad \omega_c \geq 0{,}5$ rad/s

(c) $d=0$ $\quad \varphi_m \geq 30°$

$$\measuredangle G(j\omega) = \arg(10) - \arg(1+j10\omega) + \arg\left(e^{-2j\omega}\right)$$

$$= 0° - \operatorname{arctg}(10\omega) \underline{- 2\omega}$$

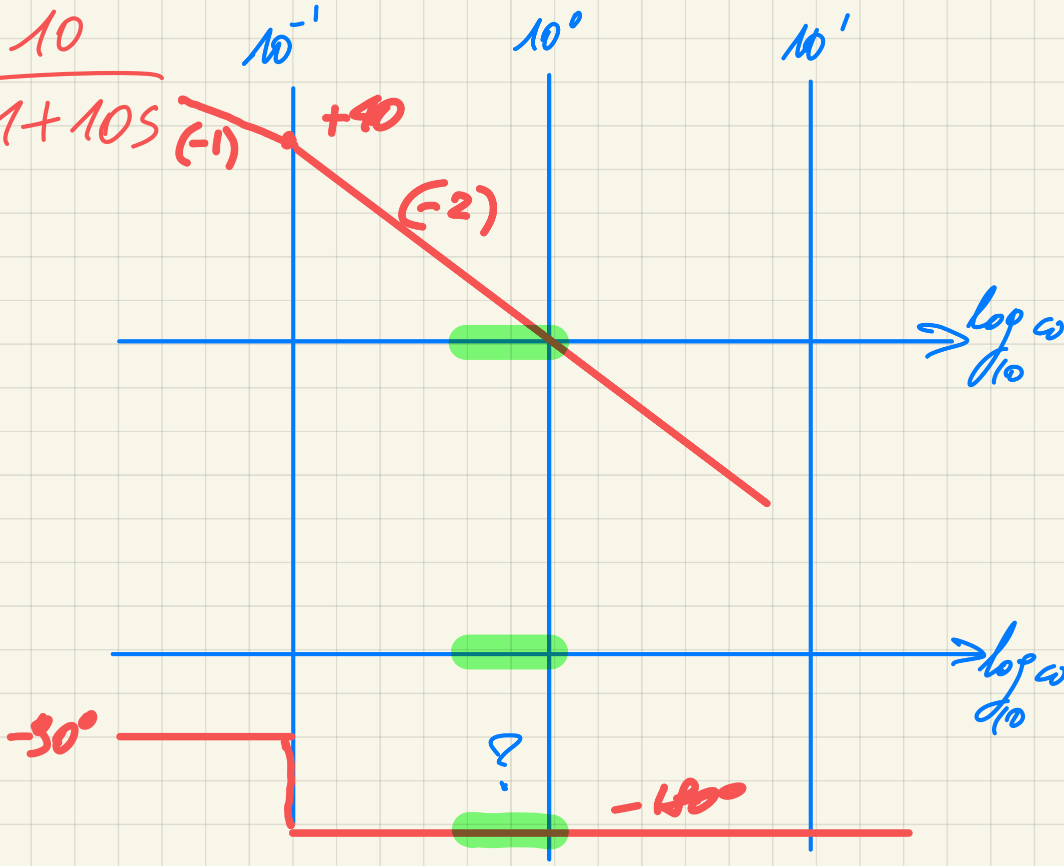
$\varphi_m \geq 30°$

$$G(s) = G'(s)\, e^{-2s}$$

$$G'(s) = \frac{10}{1+10s}$$

$$L'(s) = \frac{\mu_R}{s} \cdot \frac{10}{1+10s}$$

$\mu_R = 1$



$\varphi'_m \lesssim 30°$ $\measuredangle \simeq -180°$

$$\varphi_m = \varphi'_m - 2\omega_c < 30° \;!!$$

$$G(s) = \frac{10}{1+10s} e^{-2s} \qquad R_1(s) = \frac{\mu_R}{s}$$

$$L(s) = \frac{10\mu_R}{s(1+10s)} e^{-2s}$$

$$\measuredangle L(j\omega) \geq -150°$$

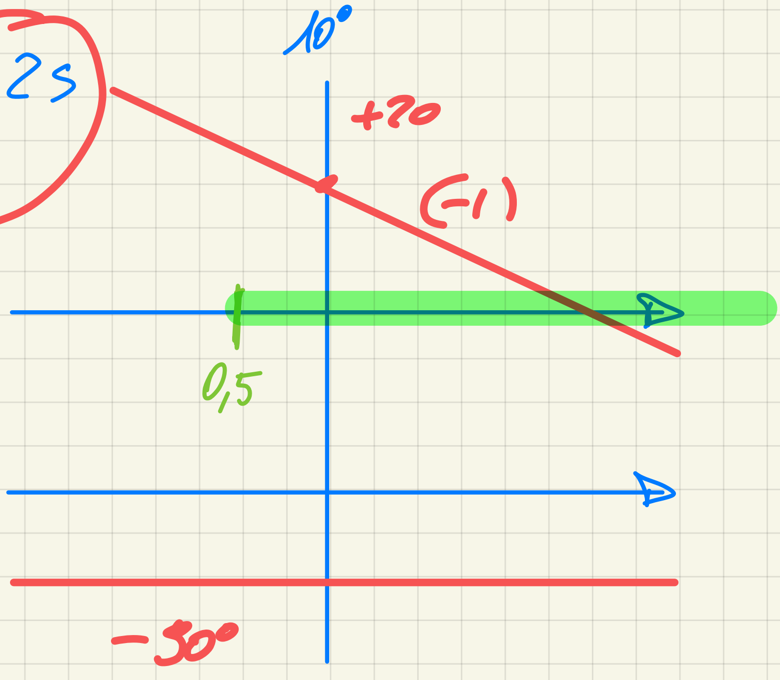
$$\underbrace{\arg(10\mu_R)}_{0°} - 30° - \operatorname{arctg}(10\omega) - 2\omega \geq -150°$$

$$\operatorname{arctg}(10\omega) \leq 60° - 2\omega$$

Come risolvere?
per via grafica?
ne vale la pena?

$$R_2(s) = \frac{\mu_R}{s}(1+10s)$$

$$L_2(s) = \frac{10\,\mu_R}{s} e^{-2s}$$



$$\mu_R = 1$$

$$\omega_c \geq 0{,}5$$

$$\varphi_M \geq 30°$$

$$\measuredangle L_2(j\omega) \geq -150° \Longleftrightarrow \varphi_M \geq 30°$$

$$-\frac{\pi}{2} - 2\omega \geq -\frac{5}{6}\pi$$

$$-2\omega \geq -\frac{\pi}{3}$$

$$\boxed{0{,}5 \leq \omega}$$

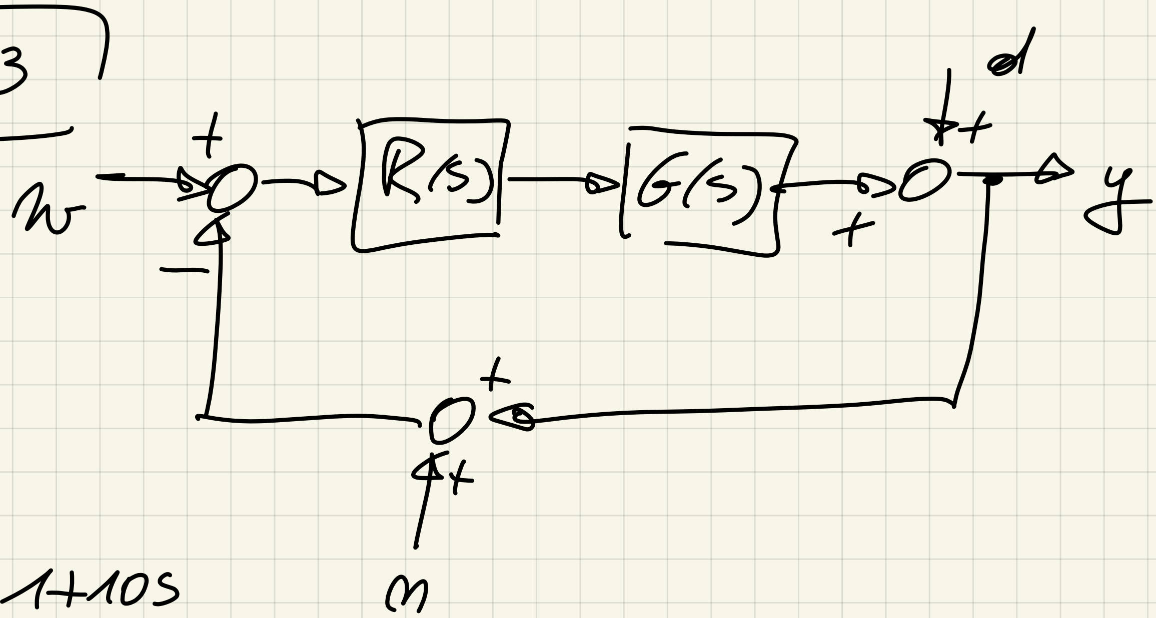
$\omega \leq \frac{\pi}{6} \simeq \boxed{0{,}52 \text{ rad/s}}$

$0{,}5 \leq \bar{\omega}_c < 0{,}52$

$e^{-0{,}2s}$

$|L_2(j\bar{\omega}_c)| = 1$

14/01/2013



$$G(s) = 2\,\frac{1+10s}{(1+s)^2}$$

R(s) fisic. realizzabile tale che:

(a) $|e_\infty| \to 0$ per $w(t) = 1(t)$

$d(t) \equiv 0$

(b) $d(t) \neq 0$ $\quad d(t) = D \,\text{sen}(\omega t)$

$\omega \in \left[\frac{1}{10}, \frac{1}{2}\right]$ rad/s

$D > 0$

$$|y^{d}_{reg}| \leq D/5$$

(c) $n(t) = N \sin(\omega t)$

$\omega \in [20, 200]$ rad/s

$N > 0$

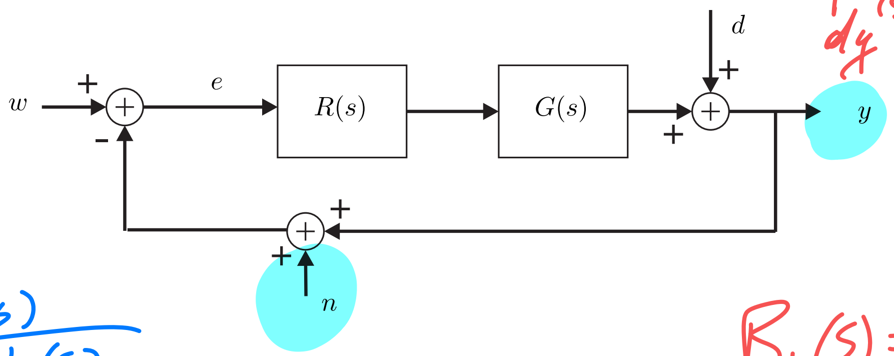
il rumore è definito in uscita ma attenuato almeno di un fattore 10 →

$$\left| y_{reg}^{n} \right| \leq \frac{N}{10}$$

Esercizio 5

Si faccia riferimento allo schema a blocchi seguente

$T_{dy}(s) = \dfrac{1}{1+L(s)} = S(s)$



$T_{ny} = -F(s) = -\dfrac{L(s)}{1+L(s)}$

Figura 2: Progetto di un regolatore.

$R_1(s) = \dfrac{\mu_R}{s}$

dove $G(s) = 2 \cdot \dfrac{(1+10s)}{(1+s)^2}$

Domanda 5.1. Utilizzando i diagrammi asintotici di Bode (si usi la carta logaritmica alla pagina seguente), si progetti un regolatore $R(s)$ **fisicamente realizzabile** tale da soddisfare le seguenti specifiche:

a

- errore a regime nullo nella risposta (a ciclo chiuso) allo scalino unitario $w(t) = 1(t)$

b

- supponendo che il disturbo $d(t)$ sia descrivibile come

  $S(j\omega)$

  $$d(t) = D \sin(\omega t) \quad \omega \in \left[\frac{1}{10}, \frac{1}{2}\right] \text{ rad/s} \quad D > 0$$

  l'uscita a regime a ciclo chiuso a fronte del solo disturbo $d(t)$ (con tutti gli altri ingressi posti a zero) possieda ampiezza non superiore a $\frac{D}{5}$.

c

- supponendo che il rumore $n(t)$ sia descrivibile come

  $T_{ny} = -\dfrac{L(s)}{1+L(s)}$

  $$n(t) = N \sin(\omega t) \quad \omega \in [20, 200] \text{ rad/s} \quad N > 0$$

  il rumore a regime in uscita a ciclo chiuso sia attenuato almeno di un fattore 10, cioè l'ampiezza dell'uscita a regime a ciclo chiuso quando sia applicato il solo rumore $n(t)$ (con tutti gli altri ingressi posti a zero) sia inferiore a $\frac{N}{10}$.

$$d(t) = D \,\mathrm{sen}(\bar{\omega} t) \qquad \bar{\omega} \in \left[\frac{1}{10} ; \frac{1}{2}\right]$$

$$y_d^{\infty}(t) = |S(j\bar{\omega})| \cdot D \,\mathrm{sen}(\bar{\omega} t + \measuredangle S(j\bar{\omega}))$$

$D/5$

$$\forall \bar{\omega} \in \left[\frac{1}{10} ; \frac{1}{2}\right] \quad |S(j\bar{\omega})| \leq \frac{1}{5}$$

$$|S(j\omega)| = \frac{1}{|1+L(j\omega)|} \simeq \begin{cases} \dfrac{1}{|L(j\omega)|} \ll 1 & \boxed{|L(j\omega)| \gg 1} \\ 1 & |L(j\omega)| \ll 1 \end{cases}$$

$$\frac{1}{|L(j\omega)|} \leq \frac{1}{5} \quad \forall \omega \in \left[\frac{1}{10} ; \frac{1}{2}\right]$$

$$\boxed{|L(j\omega)| \geq 5 \quad \forall \omega \in \left[\frac{1}{10} ; \frac{1}{2}\right]}$$

$$|L(j\omega)|_{dB} \geq 14\,dB \quad \forall \omega \in \left[\frac{1}{10} ; \frac{1}{2}\right]$$

$$T_{m y}(s) = -F(s) = -\frac{L(s)}{1+L(s)}$$

$$m(t) = N \operatorname{sen}(\tilde{\omega} t) \qquad \tilde{\omega} \in [20 ; 200]$$

$$y_m^{\infty}(t) = \underbrace{N \left| -F(j\tilde{\omega}) \right|}_{\leq N/10} \operatorname{sen}\left(\tilde{\omega} t + \measuredangle\left[-F(j\tilde{\omega})\right]\right)$$

$$\Rightarrow \left| -F(j\tilde{\omega}) \right| \leq \frac{1}{10}$$

$$\left| F(j\omega) \right| \leq \frac{1}{10} \qquad \omega \in [20 ; 200]$$

$$\left| F(j\omega) \right| = \frac{\left| L(j\omega) \right|}{\left| 1 + L(j\omega) \right|}$$

$|L| \ll 1$ $\simeq |L(j\omega)|$

$|L| \gg 1$ $\simeq 1$

$$\left| L(j\omega) \right| \leq \frac{1}{10} \quad \forall \omega \in [20 ; 200]$$

$$\left| L(j\omega) \right|_{dB} \leq -20 \, dB \quad \forall \omega \in [20 ; 200]$$

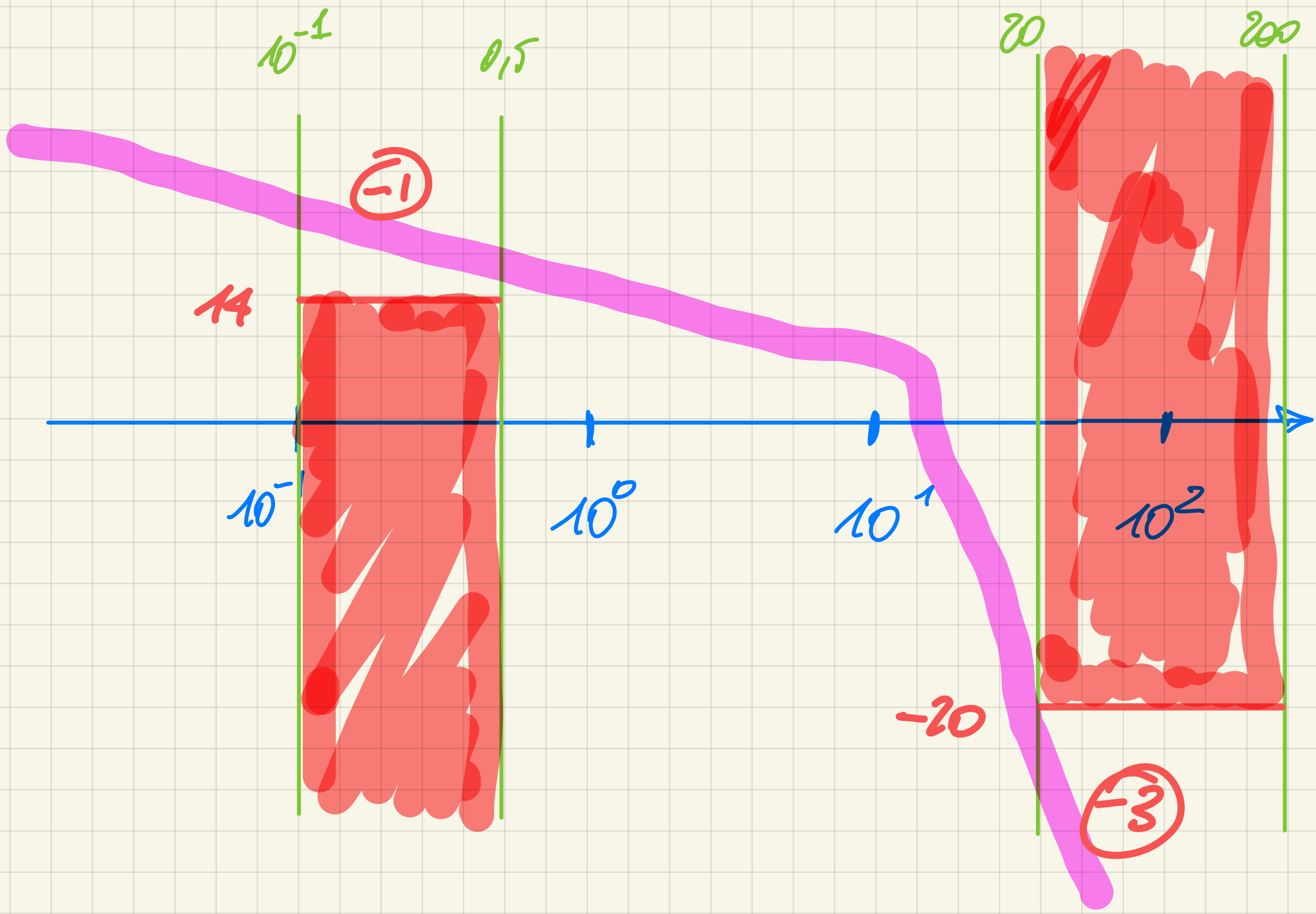
c

$$G(s) = \frac{2(1+10s)}{(1+s)^2} \qquad R_1(s) = \frac{\mu_R}{s}$$

$$|L(j\omega)|_{dB} \gg 14dB \quad \omega \in \left[\frac{1}{10} ; \frac{1}{2}\right]$$

$$|L(j\omega)|_{dB} \ll -20dB \quad \omega \in [20 ; 200]$$

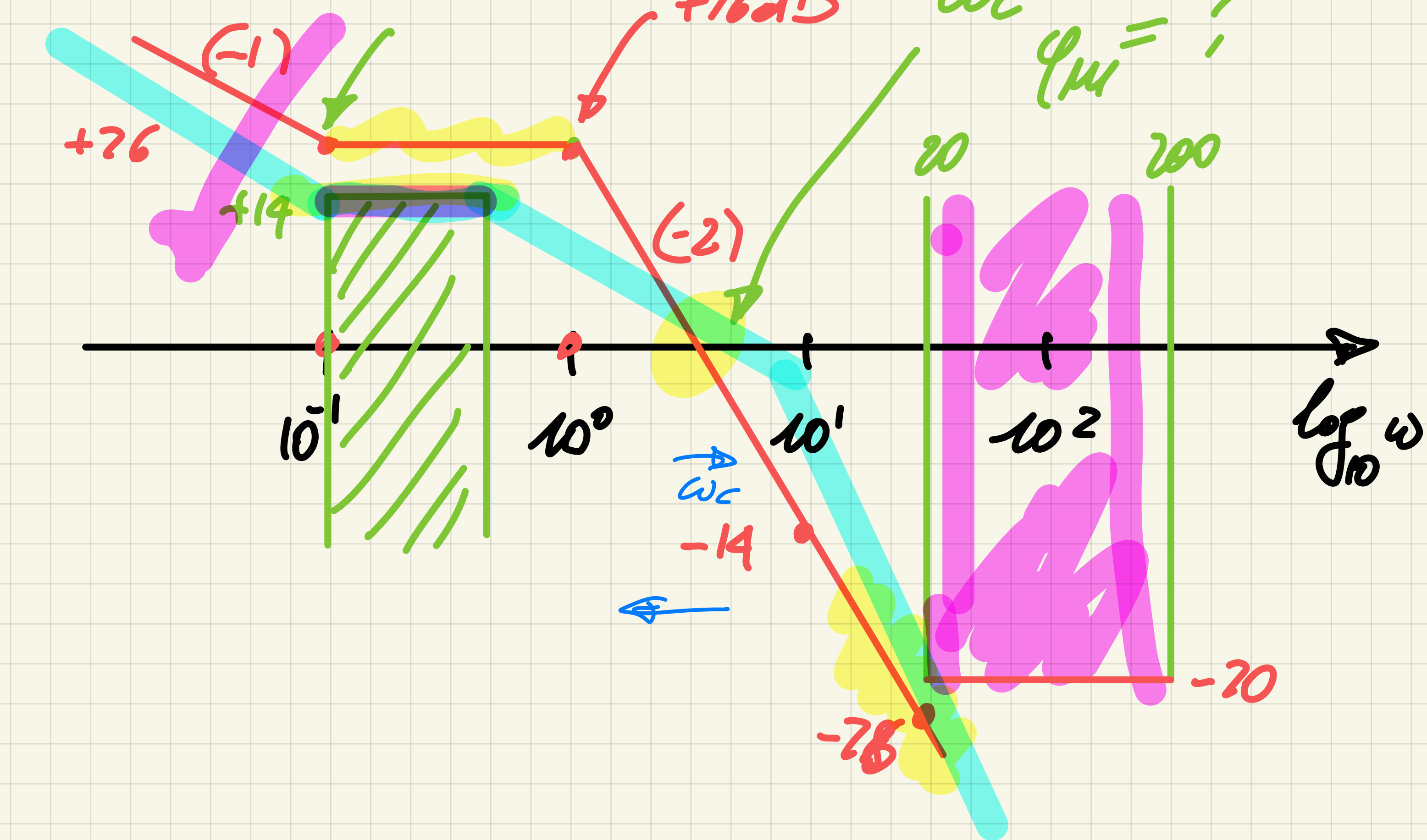
$$L_1(s) = \frac{2\mu_R(1+10s)}{s(1+s)^2}$$

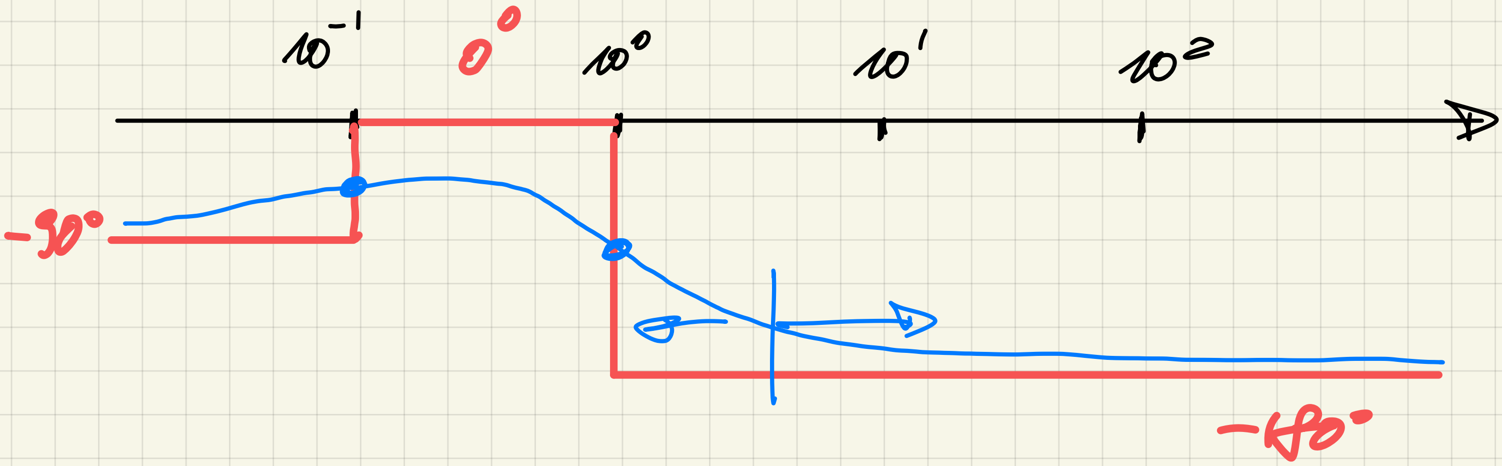


$$L_1(s) = \frac{2\mu_R(1+10s)}{s(1+s)^2} \qquad \mu_R = 1$$

$\omega_c = ?$

$\varphi_m = ?$





$\mu_R = 1 \qquad |L(j\omega_c)| = 1$

$$\frac{2\,|1+10j\omega_c|}{\omega_c\,\underbrace{|1+j\omega_c|^2}_{|1+j\omega_c|\cdot|1+j\omega_c|}} = 1$$

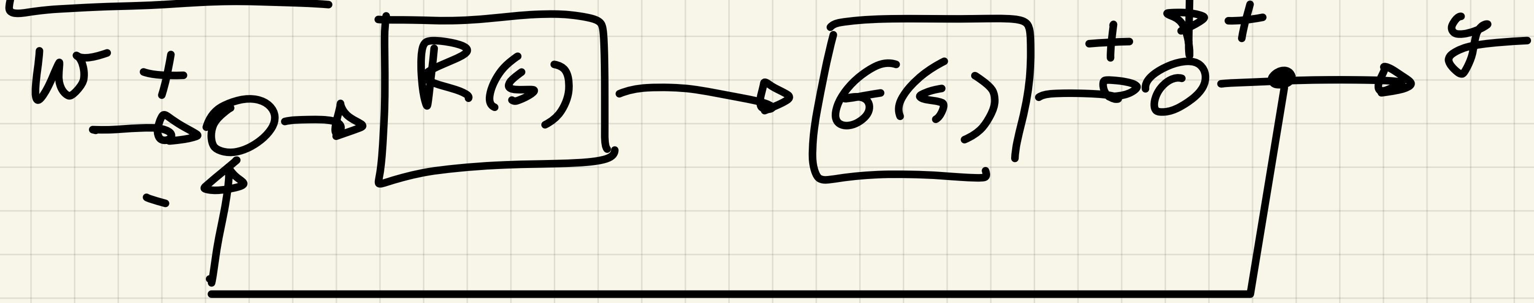
$$4(1+100\omega_c^2) = \omega_c^2(1+\omega_c^2)^2$$

$\omega_c \approx 4{,}36 \text{ rad/s}$

$\varphi_c \approx -155^\circ \; (= \sphericalangle L(j\omega_c))$

$\varphi_m \approx 25^\circ$ //

FA 6/02/23



$$G(s) = 9\,\frac{1+\frac{1}{10}s}{1+Ts} \qquad T \in \left[\tfrac{1}{2}\,;\,10\right]$$

incertezza intervallare

① $t_a \leq 10$ s

② $|e_\infty| = 0$ per $w(t) = 1(t)$ → $R_1(s) = \frac{\mu_R}{s}$

③ $\varphi_m \geq 40°$

$$L_1(s) = 9\mu_R\,\frac{\left(1+\frac{1}{10}s\right)}{s(1+Ts)} \qquad \mu_R > 0$$

(•) $|e_\infty| = 0$ → $R_1(s) = \frac{\mu_R}{s}$ ✓

(•) $t_a \leq 10$ → $\varphi_m > 75°$ ($\varphi_m > 40°$) $t_a \simeq \frac{5}{\omega_c} \leq 10$

$\omega_c \geq 0{,}5$ rad/s

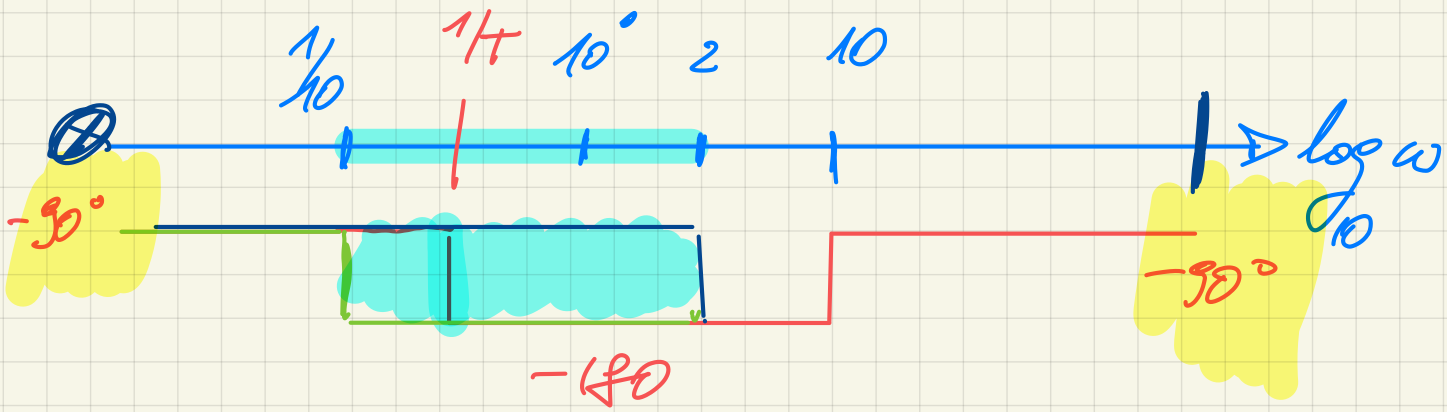
$\varphi_M = 40°$

$$t_a \simeq \frac{5}{\frac{\varphi_M}{100} \cdot \omega_c} \leq 10$$

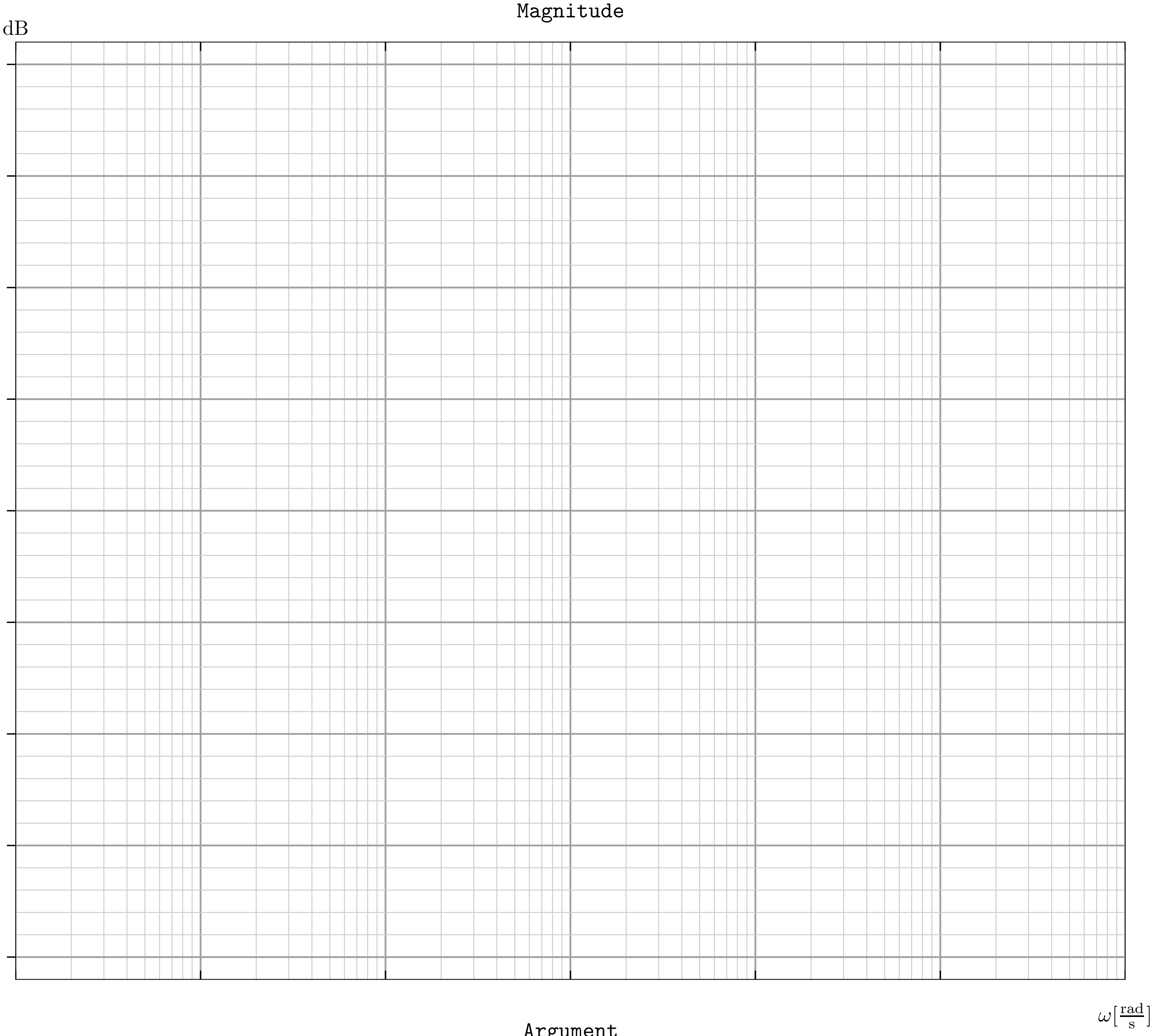
$$\frac{5}{0{,}4 \cdot \omega_c} \leq 10 \qquad \omega_c \geq \frac{5}{4}$$

$\omega_c \geq 1{,}25$ rad/s

$$L_1(s) = \mu_R \frac{1 + s/10}{s(1+Ts)} \qquad \frac{1}{T} \in \left[\frac{1}{10} ; 2\right]$$



Magnitude



Argument