Es. 1

Data $G(s) = 10 \dfrac{1-s}{(1+s/0{,}2)(1+s)^2}$ III ordine (no autovalori nascosti)

$y^\circ \longrightarrow \bigcirc \xrightarrow{e} \boxed{R(s)} \xrightarrow{u} \boxed{G(s)} \longrightarrow \overset{\downarrow d}{\bigcirc} \longrightarrow y$

$R(s) = K_p\left(1 + \dfrac{1}{sT_i}\right) = \mu_R \dfrac{1+s\tau}{s}$

1) Determinare μ_R e τ tali che
- $d(t) = \text{sen}(\omega_d t)$ sia attenuato $\underbrace{}_{\text{sull' uscita}}$ almeno di un fattore 10 $\forall \omega_d \le 0{,}01$ rad/s
- $y^\circ(t) = \text{sca}(t)$ e $d(t) = 0 \Rightarrow$ errore nullo a regime
- $y^\circ(t) = \text{sca}(t)$, $y(t)$ non sia oscillante

a) Traduzione delle specifiche

$y_{\infty, d(t)}(t) = A\,\text{sen}(\omega_d t + \alpha)$ $\quad |A| \le \dfrac{1}{10}$ $\quad \dfrac{Y(s)}{D(s)} = \dfrac{1}{1+L(s)} = S(s)$ $\quad |A| = 1\,|S(j\omega_d)| \le \dfrac{1}{10}$ $\forall \omega_d \le 0{,}01$

$|S(j\omega_d)| = \dfrac{1}{|1+L(j\omega_d)|} \approx \begin{cases} \dfrac{1}{|L(j\omega_d)|} & |L(j\omega_d)| >> 1 \longrightarrow \text{quando } \omega_d << \omega_c \\ 1 & |L(j\omega_d)| << 1 \end{cases}$

- $\omega_c >> \omega_d$ $\quad \omega_c \ge 0{,}01$ rad/s
- $\dfrac{1}{|L(j\omega)|} \le \dfrac{1}{10}$ $\quad |L(j\omega_d)| \ge 10$

$\forall \omega_d \le 0{,}01$

$L(s) = R(s)\,G(s) = \mu_R \dfrac{1+s\tau}{s}\,G(s)$

$e_{\infty, y^\circ} = 0$ $\quad e_{\infty, y^\circ} = \lim_{s \to 0} \left[s\,E(s) = s \dfrac{1}{1+L(s)} \dfrac{1}{s} = \dfrac{s}{s + \mu_R(1+s\tau)G(s)} \right] = 0$ $\quad \forall \mu_R, \tau$

- $\varphi_m \ge 70°$

$\begin{cases} \omega_c > 0{,}01 \text{ rad/s} \\ |L(j\omega)| \ge 10 \quad \forall \omega_d \le 0{,}01 \text{ rad/s} \\ \varphi_m \ge 70° \end{cases}$

b) Progetto statico $(\tau = 0)$ $\quad R(s) = \dfrac{\mu_R}{s}$ $\quad L(s) = \dfrac{10}{s}\mu_R \dfrac{1-s}{(1+s/0{,}2)(1+s)^2}$

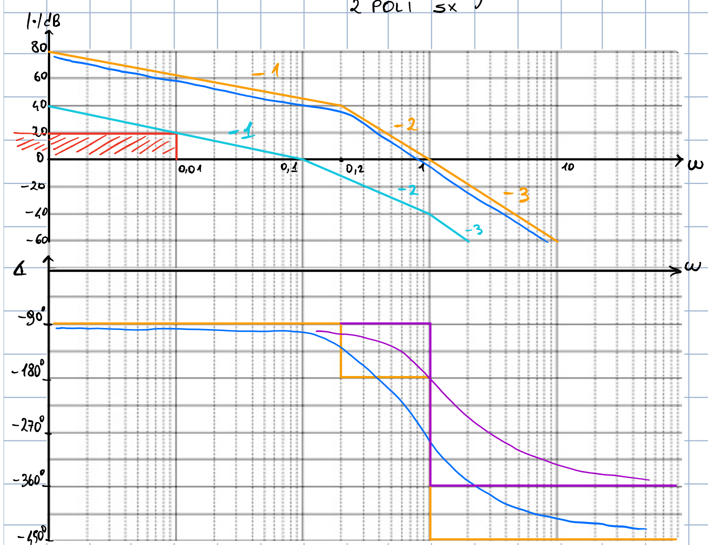
$\mu_L = 10\mu_R <$ $|\mu| = 10\,|\mu_R|$; $\mu_L > 0 \quad \mu_R > 0$

$\mu_R = 1$

$g_L = 1$

$\omega_1 = 0{,}2$ rad/s $\quad$ POLO SX $\quad \Delta p = -1 \quad \Delta\varphi = -90°$

$\omega_2 = 1$ rad/s $\quad$ ZERO DX, 2 POLI SX $\quad \Delta p = -1 \quad \Delta\varphi = -270°$



$|L(j0{,}01)| = \dfrac{10\,1}{0{,}01} \dfrac{|1-j0{,}01|}{|1+j\frac{0{,}01}{0{,}2}|\,|1+j0{,}01|^2} = 10^3 = 60\,\text{dB}$

$\omega_c \approx 1$ rad/s $\quad (> 0{,}01$ rad/s$)$

$\boxed{|L(j\omega_d)| \ge 10 = 20\,\text{dB}}$ $\quad \omega_d \le 0{,}01$ rad/s

(OK!)

$\angle L(j\omega_c) < -180°$ $\quad \varphi_m < 0° \Rightarrow \boxed{\text{NO!}}$

$\mu_R = 0{,}01$

$\angle L(j0{,}1) = \angle(10\mu_R) + \angle(1-j0{,}1) - \angle(j0{,}1) - \angle\left(1+j\frac{0{,}1}{0{,}2}\right) - 2\angle(1+j0{,}1) =$

$= 0° - tg^{-1}(0{,}1) - 90° - tg^{-1}\left(\frac{0{,}1}{0{,}2}\right) - 2tg^{-1}(0{,}1) = -134°$

$\varphi_m = 46° \quad (< 70°)$

b) Progetto dinamico $(\tau \neq 0)$ $R(s) = \frac{\mu_R}{s}(1+s\tau)$

$L(s) = \frac{10}{s}\mu_R \frac{1-s}{\left(1+\frac{s}{0{,}2}\right)(1+s)^2} = (1+s\tau)$

$= \frac{10}{s}\mu_R \frac{1-s}{(1+s)^2}$ $\tau = \frac{1}{0{,}2} = 5$

nel grafico

Es 2

$G(s) = \frac{1-s}{\left(1+\frac{s}{200}\right)\left(1+\frac{s}{10}\right)\left(1+\frac{s}{0{,}01}\right)}$ III ORDINE (NO Autov. NASCOSTI) AS STABILE

$\longrightarrow \boxed{G(s)} \longrightarrow \overset{\downarrow d}{\circ} \longrightarrow y$

1) Risposta a regime con $u(t) = sca(t)$ e tempo di assestamento
$d(t) = sen(0{,}01t)$

$y_\infty(t) = y_{\infty,u} + y_{\infty,d} = 1 + sen(0{,}01t)$

$y_{\infty,u}$ TVF $y_{\infty,u} = \lim_{s\to 0}\left[s\,G(s)\,\underbrace{\frac{1}{s}}_{U(s)}\right] = 1$ $\tau = \frac{1}{0{,}01} = 100$ udt $T_a = 5\tau = 500$ udt

$y_{\infty,d} = d(t) = sen(0{,}01t)$

2) μ_R, τ $R(s) = \frac{\mu_R}{s}(1+s\tau)$

Specs:
- errore nullo a regime se $y^\circ(t) = sca(t)$ e $d(t) = 0$
- $\varphi_m \approx 80°$
- tempo di assestamento ad anello chiuso di max 50 udt

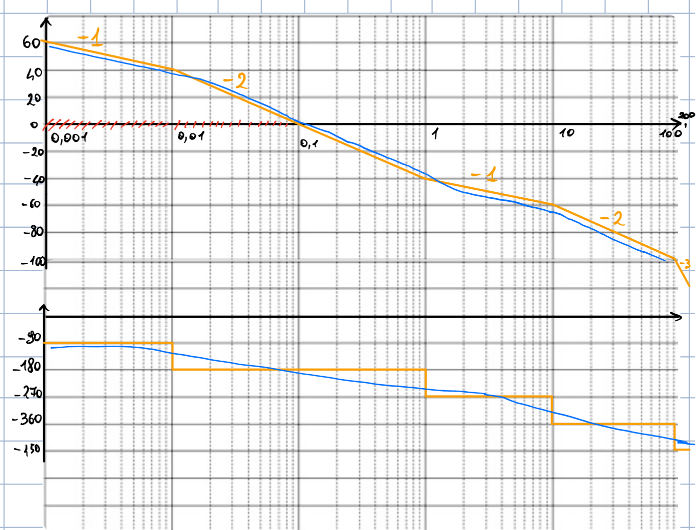
a) Traduzione specs
- $e_{\infty,y^\circ} = 0$ (se $g_L = 1 \Rightarrow$ SODDISFATTA)
- $\varphi_m \approx 80°$
- $T_a \leq 50$ udt $T_a = \frac{5}{\omega_c} \leq 50$ $\omega_c \geq 0{,}1$ rad/s

b) Progetto statico $(\tau = 0)$ $R(s) = \frac{\mu_R}{s}$ $L(s) = \frac{\mu_R}{s}\frac{1-s}{(1+s/0{,}01)(1+s/10)(1+s/200)}$

$\mu_L = \mu_R = 1$ → $|\mu_L| = 1$ / $\mu_L > 1$

$g_L = 1$

$\omega_1 = 0{,}01$ rad/s	POLO SX	$\Delta p = -1$	$\Delta\varphi = -90°$
$\omega_2 = 1$ rad/s	ZERO DX	$\Delta p = +1$	$\Delta\varphi = -90°$
$\omega_3 = 10$ rad/s	POLO SX	$\Delta p = -1$	$\Delta\varphi = -90°$
$\omega_4 = 200$ rad/s	POLO SX	$\Delta p = -1$	$\Delta\varphi = -90°$



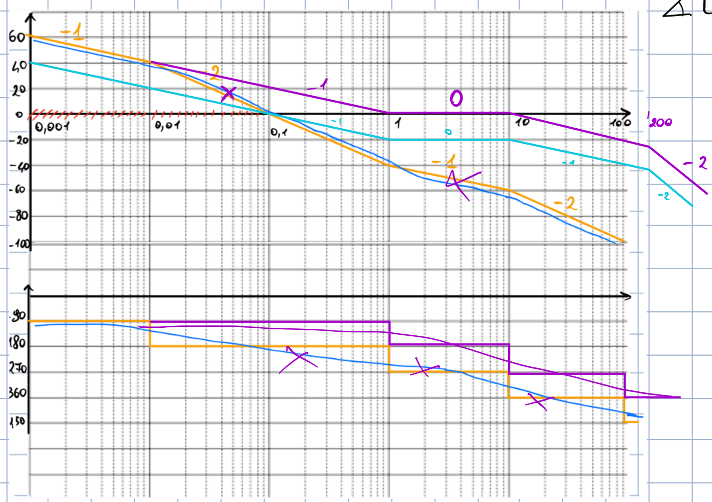
$\omega_c \approx 0{,}1$ rad/s

$\angle L(j\omega_c) = \angle(\mu_R) - \angle(j\omega_c) + \angle(1-j\omega_c) - \angle\left(1+j\frac{\omega_c}{0{,}01}\right) - \angle\left(1+j\frac{\omega_c}{10}\right)$
$- \angle\left(1+j\frac{\omega_c}{200}\right) = 0° - 90° - atan(0{,}1) - atan\left(\frac{0{,}1}{0{,}01}\right) - atan\left(\frac{0{,}1}{10}\right)$
$- atan\left(\frac{0{,}1}{200}\right) = -180°$

$\varphi_m = 0°$ $(\neq 80°)$

c) Progetto dinamico $(\tau \neq 0)$

$L(s) = \frac{\mu_R}{s} \frac{(1+s\tau)(1-s)}{\left(1+\frac{s}{0{,}01}\right)\left(1+\frac{s}{10}\right)\left(1+\frac{s}{200}\right)}$ $\tau = \frac{1}{0{,}01} = 100$ => ho cancellato ω_1



$\measuredangle L(j\omega_c) = \measuredangle(\mu_R) - \measuredangle(j\omega_c) + \measuredangle(1-j\omega_c) - \measuredangle\left(1+j\frac{\omega_c}{10}\right)$
$- \measuredangle\left(1+j\frac{\omega_c}{200}\right) = 0° - 90° - \text{atan}(1) - \text{atan}\left(\frac{1}{10}\right)$
$- \text{atan}\left(\frac{1}{200}\right) = -141°$

$\varphi_m = 39° \quad (\neq 80°)$

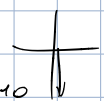
$\measuredangle = -96°$ $\qquad \varphi_m = 84° \; (\approx 80°)$

3) $y_\infty(t)$ A $d(t) = \text{sen}(0{,}01t)$

TRF: $y_\infty(t) = 1 \, |S(j0{,}01)| \, \text{sen}(0{,}01t + \measuredangle)$

$|S(j0{,}01)| = \frac{1}{|1+L(j0{,}01)|} \approx \frac{1}{|L(j0{,}01)|} \approx \frac{1}{10}$

$y_\infty(t) = 0{,}1 \; \text{sen} \; \left(0{,}01t + \frac{\pi}{2}\right)$



$1 - j10$
$\measuredangle L(j0{,}01) \approx -90°$
$\measuredangle S(j0{,}01) = -\measuredangle L = +90°$