9.1

$$G(s) = \frac{1 + 0.1s}{(1+10s)(1+s)(1+0.01s)}$$

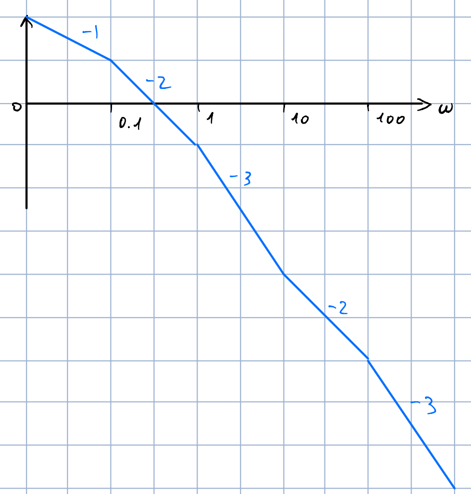
1) $e_\infty = 0$, $\mu = 1$ $\quad T_a = 5 \rightarrow \tau_d = 1$, $\quad \varphi_m > 60° \Rightarrow \omega_c \simeq 1$

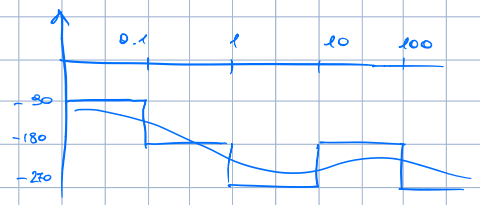
$\Downarrow$

polo nell'origine in $R(s)$

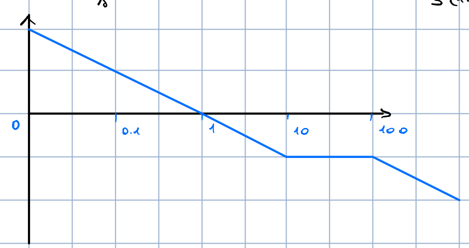
2) $d(t) = \sin(0.05t)$ $\quad \bar{\omega} = 0.05$, $\quad |L(j\bar{\omega})| \geq 10$

3) I) $R_1(s) = \frac{1}{s}$ $\quad L_1(s) = \frac{1}{s} \cdot \frac{1+0.1s}{(1+10s)(1+s)(1+0.01s)}$ $\quad \mu = 1$ $\quad z_1 = -10$ $\quad p_1 = -0.1$ $\quad p_2 = -1$ $\quad p_3 = -100$





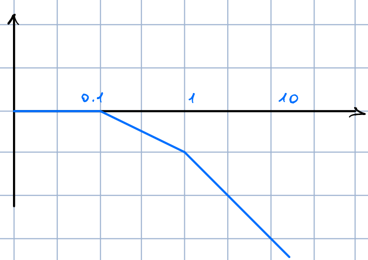
$$R_2(s) = \frac{(1+10s)(1+s)}{s} \qquad L_2(s) = \frac{1+0.1s}{s(1+0.01s)} \qquad z_1 = -10 \qquad p_1 = -100$$

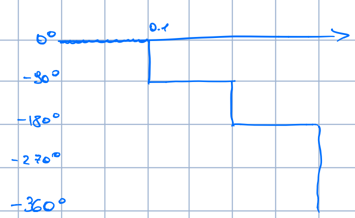


Aggiungo 1 polo in $R_2(s)$ in 100 $\Rightarrow$ $R(s) = \frac{(1+10s)(1+s)}{s(1+0.01s)}$

9.2

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





1) $|e_\infty| \leq 0.001 = 10^{-3} = -60\,dB$

con $y^o(t) = sca(t)$ $\quad d(t) = 0$

2) $\varphi_m \geq 50°$

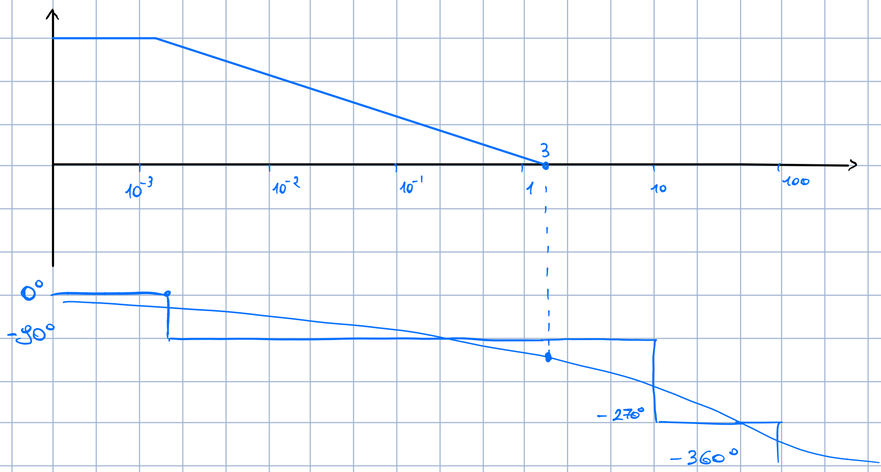
3) $\omega_c \geq 3$

$g_L = 0$ $\qquad H(s) = \frac{1}{1+L(s)}$, $\quad e_\infty = \lim_{s \to 0} sH(s)\frac{1}{s} = \frac{1}{1+\mu_L}$

$\frac{1}{1+\mu_L} \leq 0.001 \Rightarrow \mu_L > 10^3$

I) $R_1(s) = 1000$ ma $\varphi_m < 0$

II) $R_2(s) = \frac{1000(1+s)(1+10s)}{\left(1+\frac{s}{0.003}\right)\left(1+\frac{s}{100}\right)} \longrightarrow L(s) = 1000 \frac{1-0.1s}{(1+0.1s)\left(1+\frac{s}{0.003}\right)\left(1+\frac{s}{100}\right)}$

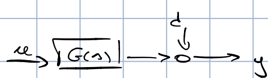


$\measuredangle L(j3) = \measuredangle(1-0{,}3j) - \measuredangle(1+0.3j) - \measuredangle(1+j1000) - \measuredangle(1+j\,0{,}03) = tg^{-1}(-0{,}3) - tg^{-1}(0{,}3) - 90° - tg^{-1}(0{,}03) = -33 - 90 - 2 = -125°$

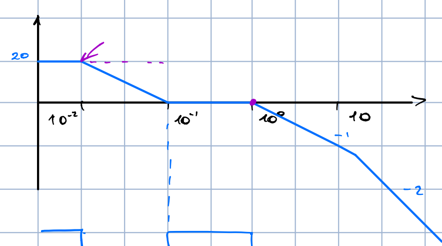
$\varphi_m > 50°$

9.3

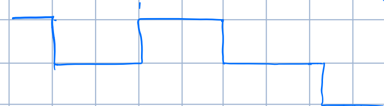
$G(s) = 30 \dfrac{0.1+s}{(30+s)(1+s)(0.01+s)}$



1) $\mu = 30 \dfrac{\frac{1}{10}}{30 \cdot \frac{1}{100}} = 10 = 20\,dB$



$z_1 = -0.1 \qquad p_1 = -30 \qquad p_2 = -1 \qquad p_3 = -0.01$

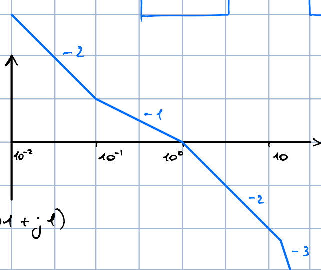


2) $e_\infty = 0 \qquad T_a = 5\,sdt \qquad$ No oscillazioni $\qquad \varphi_m > 60°$

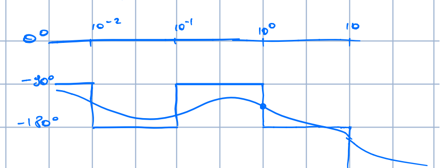
$\downarrow$

$g_R \geq 1 \qquad y^\circ = sca(t)$

$T_a = \dfrac{5}{\omega_c} \Rightarrow \omega_c = 1$

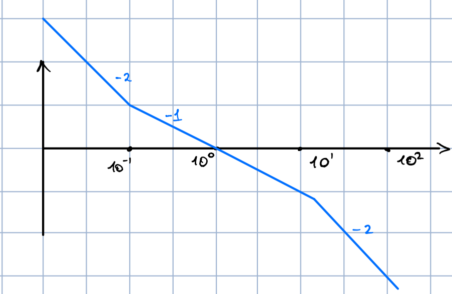


$R_1(s) = \dfrac{1}{s} \qquad L(s) = \dfrac{1}{s}\, 30 \dfrac{0.1+s}{(30+s)(1+s)(0.01+s)}$



$\measuredangle L(j1) = -tg^{-1}(j1) + tg^{-1}(0.1+j1) - tg^{-1}(30+j1) - tg^{-1}(1+j1) - tg^{-1}(0.01+j1)$

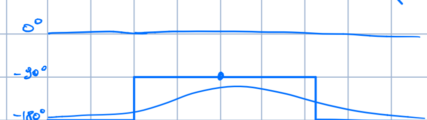
$= -90 + 84{,}3 - 2 - 45 - 89 = -141{,}17 \quad \times$



$R_2(s) = \dfrac{1+s}{s}$ aumenta fase a $\omega = 1$

$L(s) = \dfrac{30}{s} \dfrac{0.1+s}{(30+s)(0.01+s)}$

$\mu = \dfrac{30}{30} \dfrac{0.1}{0.01} = 10$



3) $e(t) = y^\circ(t) - y(t)$

$d(t) = \sin(0.1t) + 2sca(t)$

$y^\circ(t) = 0$

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

$d_1(t) = \sin(0.1t)$

$e_{\infty,1} = |H_d(j0.1)| \sin(0.1t + \measuredangle H_d(j0.1))$

$|H_d(j0.1)| = \dfrac{1}{|1+L(j0.1)|} \simeq 0{,}1$

TVF $\quad \lim_{s\to 0} s \cdot \dfrac{2}{s} \cdot \left(-\dfrac{1}{1+L(s)}\right) = \emptyset$

3.4

$$G(s) = \frac{100}{(s+1)(s+10)} \qquad H(s) = \frac{1}{s+1}$$

a) $y^{\circ}(t) = A\,\text{sca}(t)$, $y(t) \to A$ $\quad T_a = 1\,udt$

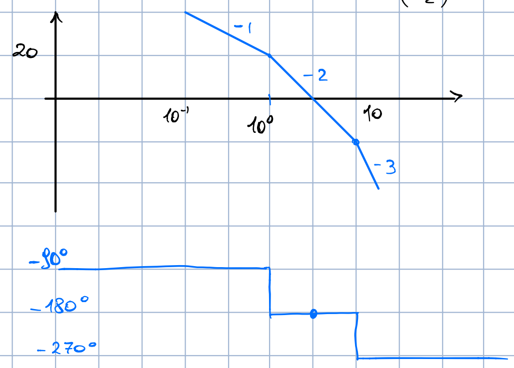
b) $\varphi_m \geq 45°$

c) Ord. minimo

$$g_R \geq 1 \, , \qquad \omega_c \simeq \begin{cases} \omega_c \geq 5 \\ \dfrac{5}{\xi\,\omega_c} \leq 1 \end{cases} \qquad \varphi_m > 60°$$

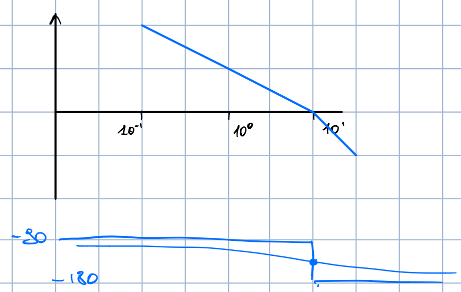
$$45° \leq \varphi_m \leq 60° \longrightarrow \omega_c \geq \frac{5}{\sin\left(\frac{\varphi_m}{2}\right)}$$

$$R_1(s) = \frac{1}{s} \qquad L_1(s) = \frac{100}{s(s+1)(s+10)}$$



Cancello polo in -1

$$R_2(s) = \frac{s+1}{s} \qquad L_2(s) = \frac{100}{s(s+10)}$$



$$\angle L(j10) = -90 - tg^{-1}(j10 + 10)$$
$$= -90 - 45 = -135$$
$$\varphi_m = 180 - 135 = 45°$$
$$\xi = \sin\left(\frac{45°}{2}\right) \simeq 0{,}38 \, , \qquad \frac{5}{\xi} > \omega_c$$

$$\omega_c = 5 \implies \mu_L = \frac{5\sqrt{5}}{2}$$

perché $|L(j5)| = \dfrac{\mu_L}{|j5|\cdot\left|1+j\frac{5}{10}\right|} = \dfrac{\mu_L}{5\sqrt{1+\frac{1}{4}}} = \dfrac{2}{5}\,\dfrac{\mu_L}{\sqrt{5}} = 1 \implies \mu_L = \dfrac{5}{2}\sqrt{5}$

$$\mu_R = \frac{\mu_L}{\mu_g} = \frac{5\sqrt{5}}{20} = \frac{\sqrt{5}}{4}$$

$$R_3(s) = \frac{\sqrt{5}}{4}\,\frac{1+s}{s} \qquad \varphi_m \simeq 63°$$

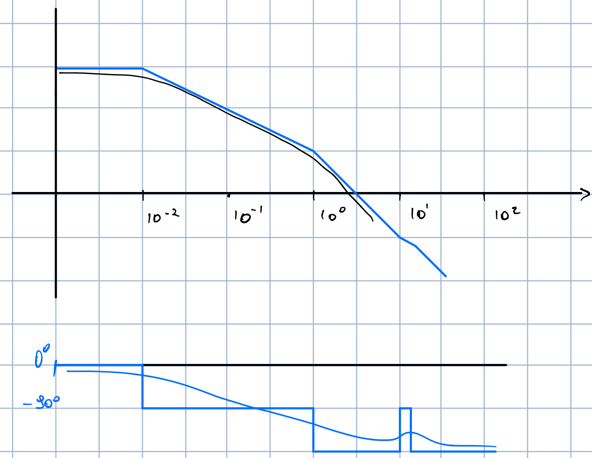
2) $d(t) = \sin(0.1t)$

e_{MAX} ? $\qquad$ Fdt $d \to e$: $E = -(DH + EL)$, $E(1+L) = -DH \to \dfrac{E}{D} = \dfrac{H(s)}{1+L(s)} = V(s)$

$$|V(j0.1)| \simeq \frac{|H(j0.1)|}{|1+L(j0.1)|} \simeq \frac{1}{\frac{\sqrt{5}}{4}\,\frac{\sqrt{1+0.1^2}}{0.1}\cdot\frac{100}{\sqrt{1+0.1^2}\cdot\sqrt{10^2+0.1^2}}} \simeq \frac{1}{\frac{\sqrt{5}}{\cancel{4}}\cdot\cancel{10}\cdot\frac{\cancel{100}\,25}{\cancel{10}}} = \frac{1}{25\sqrt{5}} \simeq 0.018$$

9.5

1) $G(s) = \dfrac{30\,(s+10)}{(s+30)(s+1)(s+0.01)}$



2)

$y^{o}(t) = sca(t) \qquad d(t) = 0$

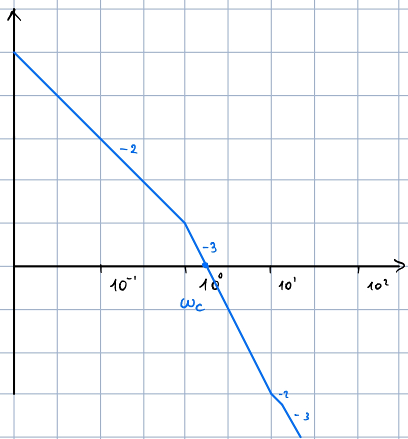
a) $y(t) = 1 \qquad T_a = 5 s d t \qquad \varphi_m > 60°$

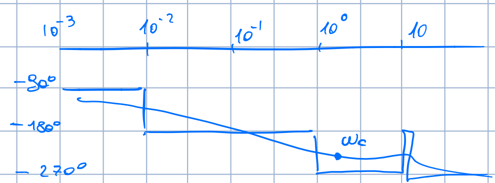
$g_R \geq 1 \qquad \Rightarrow \omega_c = 1$

$\Rightarrow e_\infty = \emptyset$

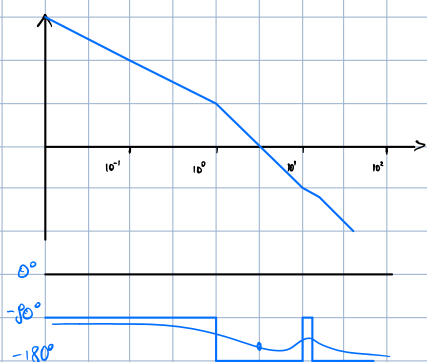
b) $d(t) = sca(t)$ attenuato su y

$R_1(s) = \dfrac{1}{s} \qquad L_1(s) = \dfrac{30}{s}\,\dfrac{(s+10)}{(s+30)(s+1)(s+0.01)}$





$R_2(s) = \dfrac{s+0.01}{s} \qquad L_2(s) = \dfrac{30}{s}\,\dfrac{s+10}{(s+30)(s+1)}$

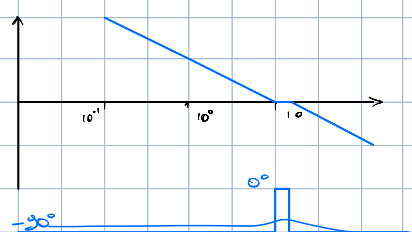


$\angle L_2(j\omega) = -90 + tg^{-1}\left(\frac{\omega}{10}\right) - tg^{-1}\left(\frac{\omega}{30}\right) - tg^{-1}(\omega)$

$\varphi_m < 60°$

Rimuovo polo in 1

$R_3(s) = \dfrac{(s+0.01)(s+1)}{s} \qquad L_3(s) = \dfrac{30}{s}\,\dfrac{s+10}{s+30}$



$\angle L(j1) = -90 + tg^{-1}\left(\frac{1}{10}\right) - tg^{-1}\left(\frac{1}{30}\right) = -86$

$\varphi_m > 60°$

$L_3(j1) = \dfrac{30}{1}\,\dfrac{\sqrt{100+1}}{\sqrt{900+1}} = \dfrac{30 \cdot 10}{30} = 10$

$R(s) = \dfrac{1}{10 s} \cdot \dfrac{(s+0.01)(s+1)}{(s+10)} = \dfrac{1}{10 s}\,\dfrac{\left(\frac{s}{0.01}+1\right) \cdot 10^{-3}\,(s+1)}{\cancel{10}\left(\frac{s}{10}+1\right)} = \dfrac{1}{10^{5}}\,\dfrac{\left(\frac{s}{0.01}+1\right)(s+1)}{s\left(\frac{s}{10}+1\right)}$

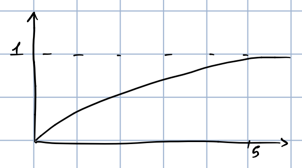
$R(s) = K\left(1 + \dfrac{1}{s T_I} + \dfrac{T_D\, s}{1 + s T_D/N}\right) = \dfrac{K}{T_I}\left(\dfrac{s T_I + s^2 T_I T_D/N + 1 + s T_D/N + s^2 T_I T_D}{s\,(1 + s T_D/N)}\right) = \dfrac{K}{T_I}\left(\dfrac{s\,(T_I + T_D/N) + s^2\,(T_I T_D/N + T_I T_D) + 1}{s\,(1 + s T_D/N)}\right)$

$$\begin{cases} \frac{K}{T_I} = \frac{1}{10^5} \\ \frac{T_D}{N} = \frac{1}{10} \\ T_I + \frac{T_D}{N} = 101 \\ T_I + \frac{T_D}{N} + T_I T_D = 100 \end{cases}$$

$$\begin{cases} T_I + \frac{1}{10} = 101 \rightarrow T_I = \frac{1009}{10} \sim 101 \\ \frac{T_D}{N} = \frac{1}{10} \\ \frac{1010}{10} + T_I \frac{N}{10} = 100 \rightarrow \frac{1009}{100} N = 100 - \frac{1010}{10} \rightarrow \frac{1009}{100} N = \frac{1000-1010}{10} \\ \frac{K}{T_I} = \frac{1}{10^5} \end{cases}$$

$\frac{1009}{100} N = -1$

$N = -\frac{100}{1009}$

3) 

4) $A = \frac{1}{1+0.01s}$ No, introduce un polo in -100 che non degrada modulo e fase nella zona di interesse

3.6

$$G(s) = 200 \frac{1}{(s+1)(s+20)(s+100)}$$

1) $R(s)$

a) $e_\infty \rightarrow 0$ con $y^* = sca(t)$ e $d(t) = 0$ $\Rightarrow g_R \geq 1$

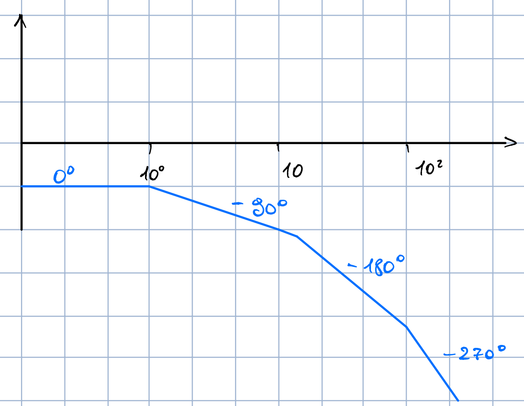
b) $\varphi_m \approx 90°$

c) $\omega_c \simeq 10$

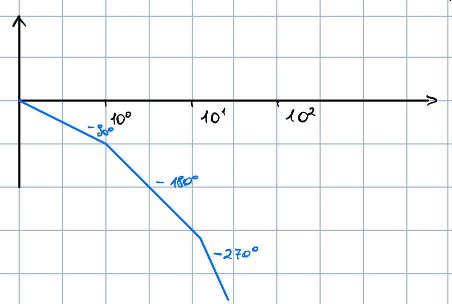
d) Ord. minimo

$G(s)$: $\mu = \frac{1}{10} = -20\,dB$

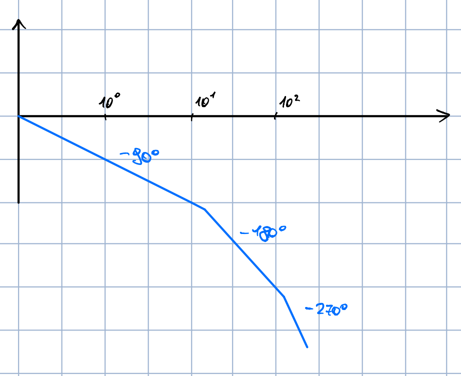
$p_1 = -1$ $p_2 = -20$ $p_3 = -100$



$R_1(s) = \frac{1}{s}$ $L_1(s) = \frac{200}{s} \frac{1}{(s+1)(s+20)(s+100)}$



$R_2(s) = \frac{s+1}{s}$ $L_2(s) = \frac{200}{s} \frac{1}{(s+20)(s+100)}$



$$\angle L_2(j10) = -90° - tg^{-1}\left(\frac{1}{2}\right) - tg^{-1}\left(\frac{1}{100}\right) \simeq -90° - 26{,}5° - 0{,}6°$$

$$\simeq -117{,}1$$

$\varphi_m \approx 62{,}9°$

$R_3(s) = \frac{(s+1)(s+20)}{s}$ $L_3(s) = \frac{200}{s} \frac{1}{s+100}$

$\angle L_3(j10) = -90° - 0{,}6° \simeq -90{,}6°$ $\varphi_m \approx 90°$

$$|L_3(j10)| = \frac{200\,\mu_R}{10} \frac{1}{\sqrt{100+100^2}} = 1 \rightarrow \frac{20\,\mu_R}{100} = 1 \rightarrow \mu_R = 5$$

$R_3(s) = \frac{5}{s}(s+1)(s+20)$ aggiungo un polo 2 decadi dopo $\omega_c \Rightarrow R(s) = \frac{5}{s}\frac{(s+1)(s+20)}{(1+\frac{s}{1000})}$

$$= \frac{5}{s} \cdot 20 (s+1)\left(1+\frac{s}{20}\right) = \frac{100}{s}(s+1)(s+20)$$

$$R(s) = \frac{100}{s}\frac{(s+1)\left(\frac{s}{20}+1\right)}{\left(1+\frac{s}{1000}\right)}$$

2) $d(t) = 0.2 \sin(1000t)$

$y^\circ(t) = 0$

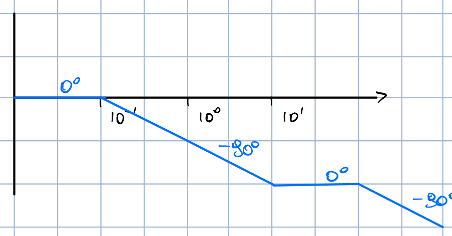
TRF: FdT $d \to y$: $Y = D + (-LY) \to \frac{Y}{D} = \frac{1}{1+L(s)} = H(s)$

$|H(j1000)| \simeq 1$ e ampiezza max è ~ 0.2 poichè $\bar{\omega} = 1000$ è maggiore di ω_c

<u>9.7</u>

$$G(s) = \frac{1}{2}\frac{s+20}{(s+0.1)(s+100)}$$

1) $\mu = G(0) = \frac{1}{2}\frac{20}{10} = 1 = 0\,dB$, $z_1 = -20$ $p_1 = -0.1$ $p_2 = -100$

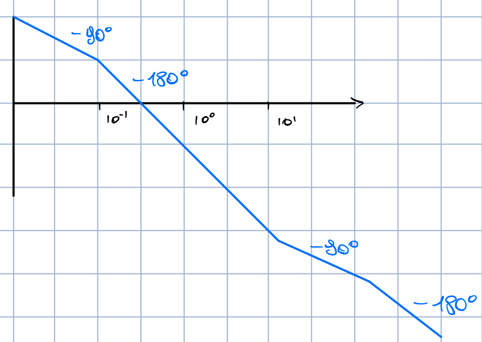


2) a) $e_\infty = 0 \Rightarrow g_R \geq 1$ $T_a \simeq 5s \to \omega_c \simeq 1$, $\varphi_m > 60°$

b) Ord minimo

$R_1(s) = \frac{1}{s}$ $L_1(s) = \frac{1}{2}\frac{s+20}{s(s+0.1)(s+100)}$

$\varphi_m < 0$

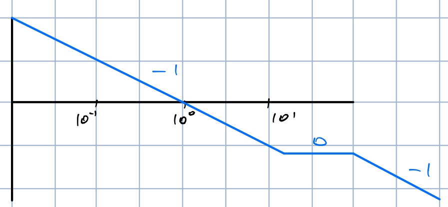


$R_2(s) = \frac{s+0.1}{s}$ $L_2(s) = \frac{1}{2}\frac{s+20}{s(s+100)}$

$$\angle L_2(j1) = -90° + tg^{-1}\left(\frac{1}{20}\right) - tg^{-1}\left(\frac{1}{100}\right) = \simeq -87,7°$$

$\varphi_m \simeq 92°$

$$R(s) = 10\frac{s+0.1}{s}$$



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

9.8

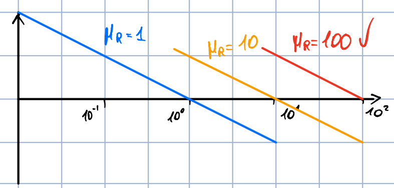
$$G(s) = \frac{1}{(1+10s)(1+0.001s)^2} \qquad R(s) = K\left(1+\frac{1}{sT_I}\right)$$

1) a) $d(t) = 0.1 \sin(\bar\omega t)$ $\bar\omega \le 10$ attenuato di almeno 10 $\Rightarrow |H(j10)| \le \frac{1}{10}$

b) $e_\infty = 0$

c) $\omega_c > 1$

$$|H(j\omega)| \simeq \begin{cases} \frac{1}{|R(j\omega)G(j\omega)|} & |R(j\omega)G(j\omega)| > 1 \\ 1 & |R(j\omega)G(j\omega)| < 1 \end{cases} \Longrightarrow \omega_c > 10$$



$$R_1(s) = \mu_R \frac{1+10s}{s} \qquad L_1(s) = \frac{\mu_R}{s}\frac{1}{(1+0.001s)^2}$$

$$R(s) = 100\,\frac{1+10s}{s} = K\left(\frac{sT_I+1}{sT_I}\right) = \frac{K}{T_I}\left(\frac{sT_I+1}{s}\right)$$

$$\begin{cases} \frac{K}{T_I} = 100 \\ sT_I + 1 = 1+10s \end{cases} \qquad \begin{cases} T_I = 10 \\ K = 1000 \end{cases}$$

2) Vero TRF: FdT $n \to y$: $Y = (Y+N)(-L) \to Y(1+L) = -NL \to V(s) = \frac{-L(s)}{1+L(s)}$

$$|V(j10^4)| = \frac{|L(j10^4)|}{|1+L(j10^4)|} \simeq |L(j10^4)| \simeq \frac{1}{100}$$

9.9

$$G(s) = 20\,\frac{1-s}{(s+0.01)(s+10)(s+200)}$$

1) $u(t) = sca(t)$ $\qquad \lim_{s\to 0} s\,\frac{1}{s}\,20\,\frac{1-s}{(s+0.01)(s+10)(s+200)} = \frac{20}{\frac{1}{100}\cdot 10 \cdot 200} = 1$

$d(t) = \sin(0.01t)$

$\tau_d = 100$ $\quad T_a = 500$ udt

$y(t) = 1 + \sin(0.01t)$

2) a) $e_\infty = 0 \Rightarrow g_R \ge 1$

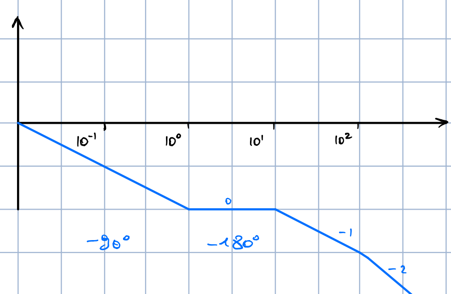
b) $\varphi_m \approx 90°$

c) $\omega_c \ge 0.1$

$$R_1(s) = \frac{1}{s} \qquad L_1(s) = \frac{20}{s}\,\frac{1-s}{(s+0.01)(s+10)(s+200)} \qquad \times$$

$$R_2(s) = \frac{s+0.01}{s} \qquad L_2(s) = \frac{20}{s}\,\frac{1-s}{(s+10)(s+200)}$$

$$R_3(s) = \frac{(s+0.01)}{10\,s} = \frac{0.01\left(\frac{s}{0.01}+1\right)}{10\,s} \qquad L_3(s) = \frac{2}{s}\,\frac{1-s}{(s+10)(s+200)}$$



con $\omega_c \simeq 10^{-1}$ e $\varphi_m \approx 90°$

3) $y^o(t) = sca(t)$ $\qquad d(t) = \sin(0.01t)$

$$y^o \to y:\ F(s) = \frac{L(s)}{1+L(s)} \simeq \frac{1}{1+\frac{s}{\omega_c}} = \frac{1}{1+10s} \qquad \tau_d = 10,\ T_a = 50 \text{ udt}$$

TVF: $y \to 1$

$d \to y$: $H(s) = \dfrac{1}{1+L(s)}$

TRF : $|H(j0.01)| \simeq 0.1$ $\quad \angle H(j0.01) \simeq +90° = \dfrac{\pi}{2}$

$y(t) = 1 + \sin(0.01t + \frac{\pi}{2}) \cdot \frac{1}{10} = 1 + 0.1 \sin(0.01 + \frac{\pi}{2})$

9.10

$G(s) = 2 \dfrac{s+500}{(s+100)(s^2+0.2s+1)}$

1) $g = 0 \quad z_1 = -500 \quad p_1 = -100 \quad p_{2-3} = \dfrac{-0.2 \pm \sqrt{0.2^2-4}}{2} = -0.1 \pm \sqrt{0.01-1} = -0.1 \pm j$

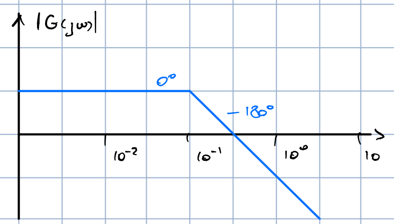
$\mu = 10$

$\tau_d = \dfrac{1}{0.1} = 10$

2) a) $y^o(t) = A_1 \, sca(t)$
$d(t) = A_2 \, sca(t)$ $\Big\}$ $y(t) \longrightarrow A_1$, $\varphi_m > 60°$ $\quad T_a = 0.5 \Rightarrow \omega_c = 10$

$\Rightarrow e_\infty = 0 \Rightarrow g_R \geq 1$

b)

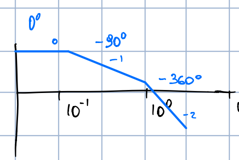


$R_1(s) = \mu_R \dfrac{(s^2+0.2s+1)}{s(1+\frac{s}{1000})}$

$L_1(s) = \dfrac{2\mu_R}{s} \dfrac{s+500}{(s+100)(1+\frac{s}{1000})}$

$|L(j10)| \simeq \dfrac{10}{|s|} \simeq \dfrac{10}{|j10|} = 1$

9.11



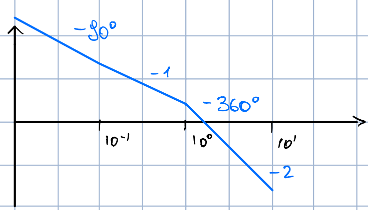
$G(s) = 2 \dfrac{1-s}{(s+0.2)(s^2+2s+1)}$ $\qquad \mu = 10 \quad z_1 = 1 \quad p_1 = -0.2 \quad p_{2-3} = -1$

1) $R(s) = k\left(1 + \dfrac{1}{sT_I}\right)$

a) $|L(j\bar\omega)| \geq 10 \quad \bar\omega \leq 0.01$

b) $e_\infty \to 0 \quad y^o(t) = sca(t) \Rightarrow g_R \geq 1$

c) $\varphi_m > 60°$



$R_1(s) = \dfrac{s+0.2}{s}$ $\qquad L_1(s) = \dfrac{2}{s} \dfrac{1-s}{(s+1)^2}$

$|L(j0.01)| = \dfrac{2\mu_R}{10^{-2}} \dfrac{|1-j10^{-2}|}{|1+j10^{-2}|^2} = 2\mu_R \cdot 100 = 200\mu_R = 10$

$\mu_R = \dfrac{1}{20}$

$\mu_R = 20 \to |L(j0.01)| = 10 \Rightarrow \omega_c = 10^{-1}$

$\angle L(j10^{-1}) = -90° + tg(-0.1) - 2\,tg(0.1) \simeq -107°$

$\varphi_m > 60°$

$R(s) = \dfrac{1}{20s}(s+0.2) = \dfrac{1}{100} \dfrac{(5s+1)}{s} = \dfrac{k}{T_I}\left(\dfrac{sT_I+1}{s}\right)$ $\quad \begin{cases} T_I = 5 \\ \frac{K}{5} = \frac{1}{100} \end{cases} \to K = \dfrac{1}{20}$

2) $y^o(t) = sca(t) \qquad d(t) = \sin(0.01t), \; t \geq 0$

TRF : $H(s) = \dfrac{1}{1+L(s)}$ $\qquad |H(j0.01)| \simeq \dfrac{1}{10}$

$y(t) = 1 + \frac{1}{10} \sin\left(0.01 t - \frac{\pi}{2}\right)$

$T_a = \frac{5}{\omega_c} \simeq 50$ udt

9.12

$G(s) = \dfrac{5(s+20)}{(s+0.1)(s+10)(s+100)}$

1) a) $e_\infty = 0 \implies g_R \geq 1$

b) $\omega_c \simeq 1 \qquad \varphi_m > 70°$

$\mu_G = \frac{1}{10} \implies \mu_R = 10 \qquad R(s) = \frac{100}{s}(s+0.1)$

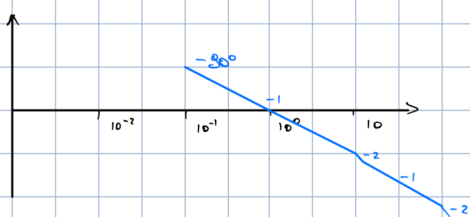
$L(s) = \frac{50}{s} \dfrac{s+20}{(s+10)(s+100)} \qquad \mu_L = 1 \qquad z_1 = -20 \quad p_1 = -10 \quad p_2 = -100$

$\measuredangle L(j1) = -90° + tg^{-1}\left(\frac{1}{20}\right) - tg^{-1}\left(\frac{1}{10}\right) - tg^{-1}\left(\frac{1}{100}\right)$

$= -90° + 3° - 0{,}6° - 6°$

$\simeq -93{,}6°$

$\varphi_m = 86{,}4°$



$|L(j1)| = \dfrac{50 \cdot 20}{10 \cdot 100} \simeq 1 \qquad R(s) = \frac{10}{s}(10s+1) = \frac{K}{T_I}\left(\frac{sT_I + 1}{s}\right) \qquad \begin{cases} T_I = 10 \\ K = 100 \end{cases}$

2) a) Attenuato TVF $= \emptyset$

b) Non attenuato $|H(j100)| \simeq 1$

c) Attenuato $|H(j0.1)| \simeq \dfrac{1}{|L(j0.1)|} = \dfrac{1}{10}$

3) a) Introduce un polo in $\omega = 500$ che non compromette la prop. di stabilità del S né prestazioni

b) $\omega_c \frac{180}{\pi} \tau = 86{,}4° \implies \tau = \frac{86{,}4°}{180°}\pi = 1{,}51$