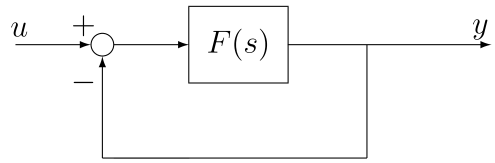
Domanda Scritta di Controlli Automatici - 13/07/2015

Esercizio 1

È dato il sistema in controreazione:



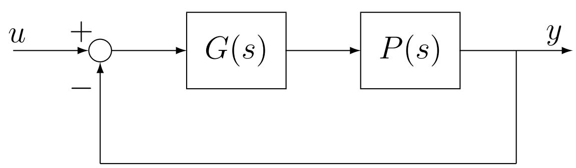
in cui:

$$F(s) = \frac{24K\left(s + \frac{4}{3}\right)}{s(s-2)(s+10)}, \quad K \in \mathbb{R}, \quad K \neq 0.$$

Utilizzando il criterio di Nyquist, e sapendo che $F(j2) = -K$, studiare la stabilità del sistema in catena chiusa al variare di K. Rispondere infine alla seguente domanda: esiste la risposta a regime permanente ad un ingresso a gradino per $K = 5$?

Esercizio 2

È dato il sistema di controllo:



in cui:

$$P(s) = \frac{s+3}{s(s^2+8s+25)};$$

Utilizzando il luogo delle radici, progettare $G(s)$ in modo che:

- il sistema sia di tipo 2, con $|\tilde{e}_2(t)| \leq 0.05$;
- tutti i poli a ciclo chiuso abbiano parte reale minore od uguale a -2.

1

$$F(s) = 24K \cdot \frac{(s+\frac{4}{3})}{s(s-2)(s+10)}$$

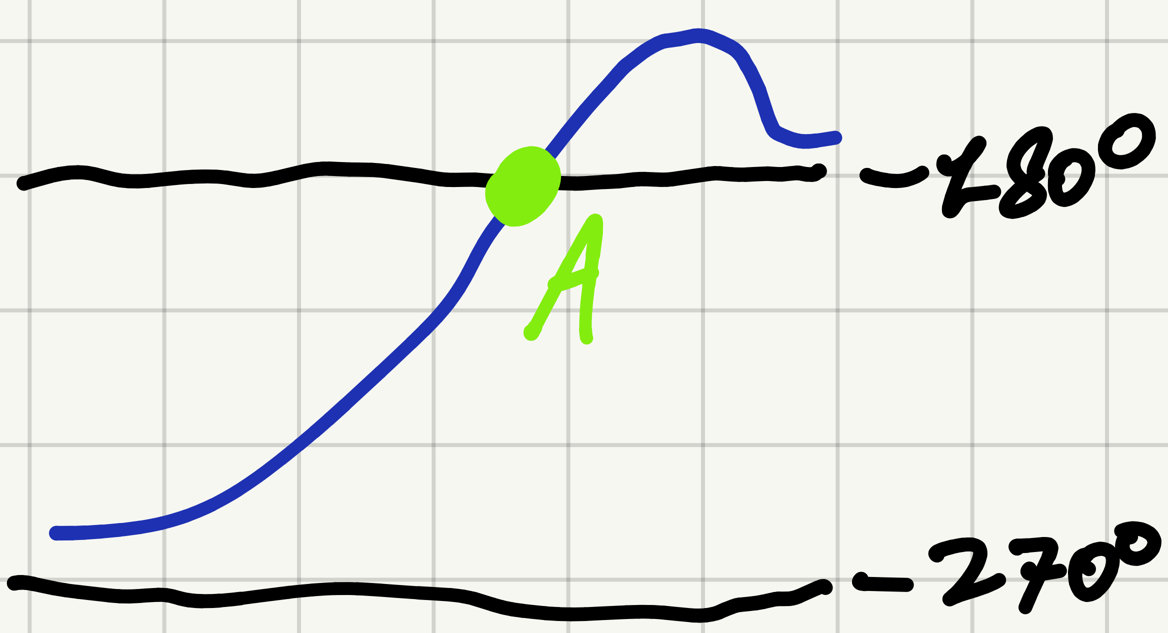
$$F(i\omega) = -\frac{8}{5}K \cdot \frac{(1+\frac{i\omega}{3/4})}{i\omega(1-\frac{i\omega}{2})(1+\frac{i\omega}{10})}$$

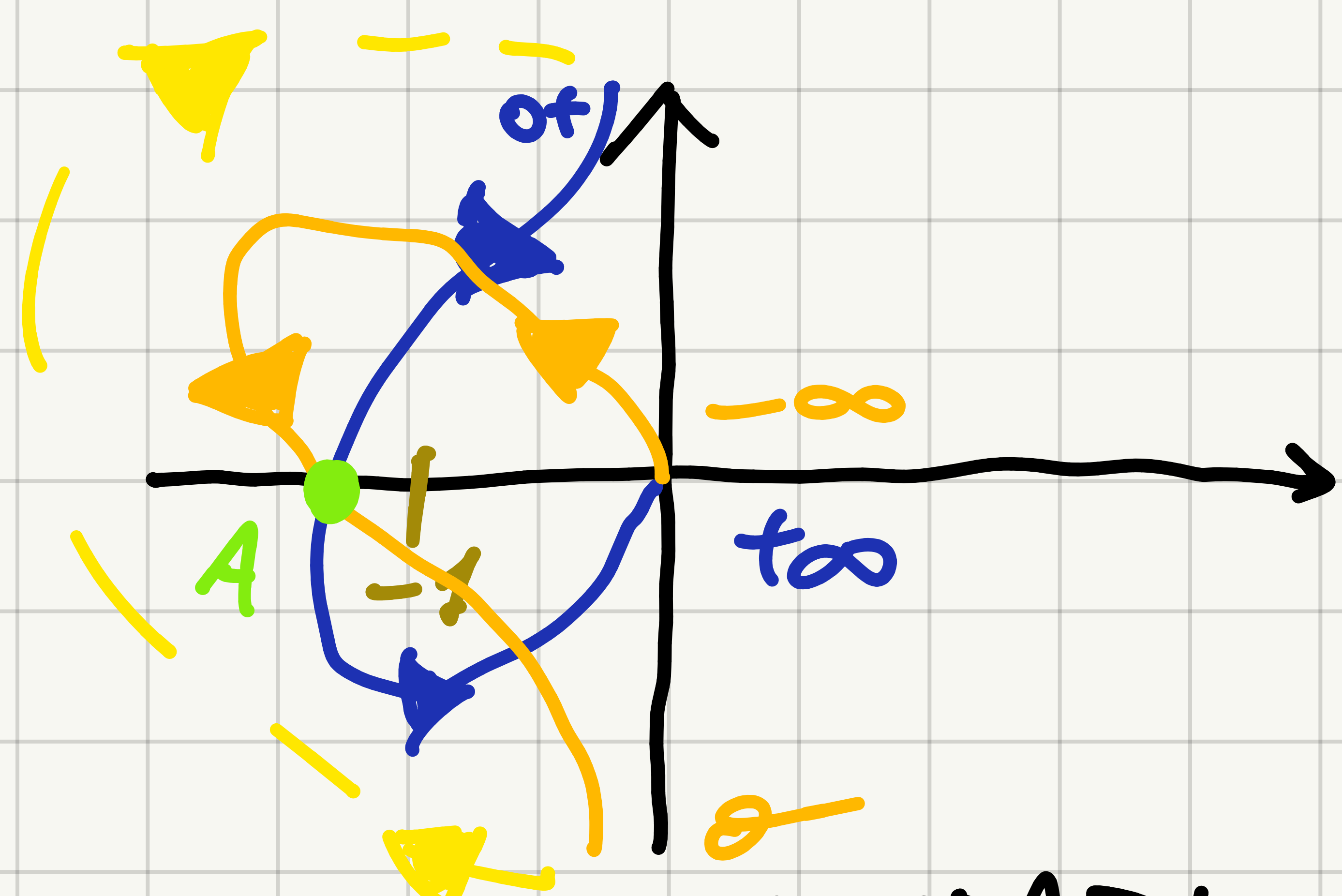
$P_+ = 1$

CASO 1: $K>0$

$M(0^+)=\infty$, $\varphi(0^+)=-270^\circ$

$M(+\infty)=0$, $\varphi(+\infty)=-180^\circ$





• $|A|>1 \Rightarrow \overset{\curvearrowright}{N}=-1 \Rightarrow$ SISTEMA STABILE

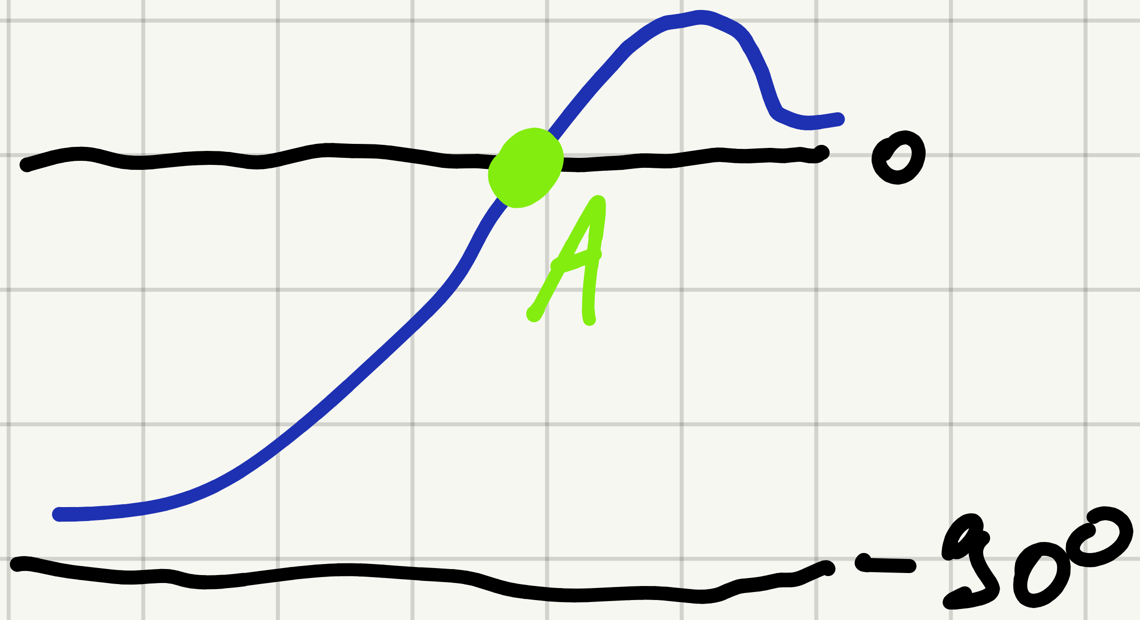
$F(2i)=-K \Rightarrow$ STAB. $-K<-1$
$\Rightarrow K>1$

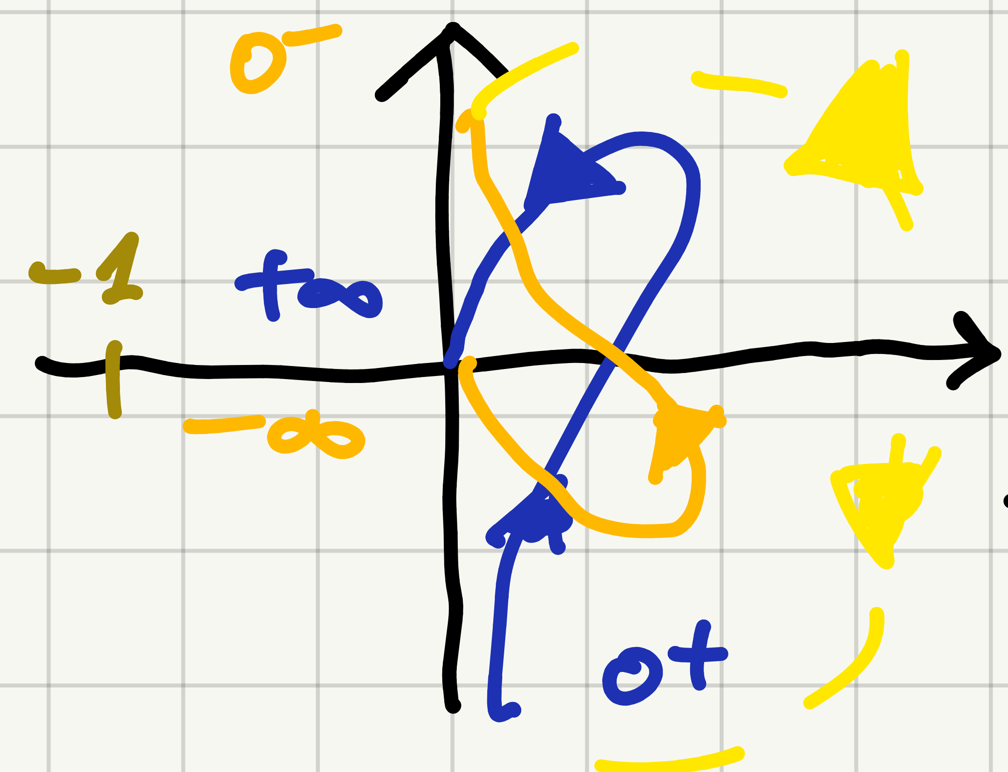
• $|A|<1 \Rightarrow \overset{\curvearrowright}{N}=1 \Rightarrow$ SISTEMA INSTABILE

CASO 2: $K<0$

$M(0^+)=\infty$, $\varphi(0^+)=-90^\circ$

$M(+\infty)=0$, $\varphi(+\infty)=0^\circ$





$\overset{\curvearrowright}{N}=0$

$\Downarrow$

INSTABILE

$\exists$ RISPOSTA A REGIME PERMANENTE PER $K=5$

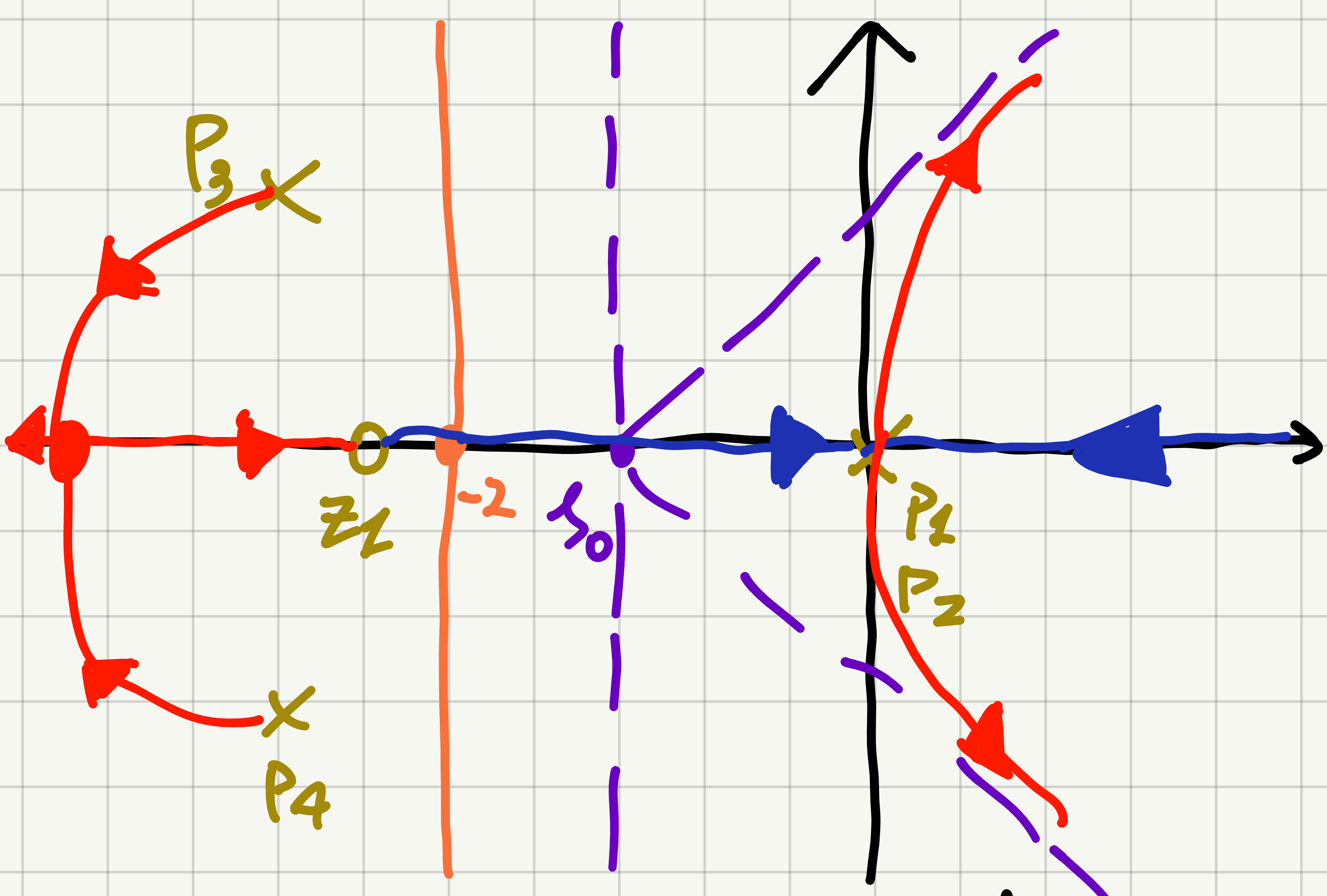
②

SISTEMA DI TIPO 2 $\Rightarrow G(s) = \frac{K}{s}$ $\quad K_p = \frac{3}{25}$

$|\tilde{e}_1(t)| = \left| \frac{1}{K_G K_p} \right| \leq 0{,}05 \Rightarrow K_1 \geq 167$

$F(s) = K \cdot \frac{(s+3)}{s^2(s^2+8s+25)}$ $\quad n=4, m=1 \Rightarrow n-m=3$

$P_1 = P_2 = 0,\ P_3 = -4+3i,\ P_4 = -4-3i;\ z_1 = -3$ $\quad s_0 = \frac{\Sigma p - \Sigma z}{n-m} = -\frac{5}{3}$



SPECIFICA NON SODDISFATTA

$n-m=2 \quad \rightarrow \quad G(s) = \frac{K}{s} \cdot (s-z_1)$

COPPIA POLO-ZERO PER SPOSTARE s_0

$G(s) = \frac{K}{s} \cdot \frac{(s-z_1)(s-z_2)}{(s-p)}$ $\quad (s-z_1)(s-z_2) = s^2+8s+25$

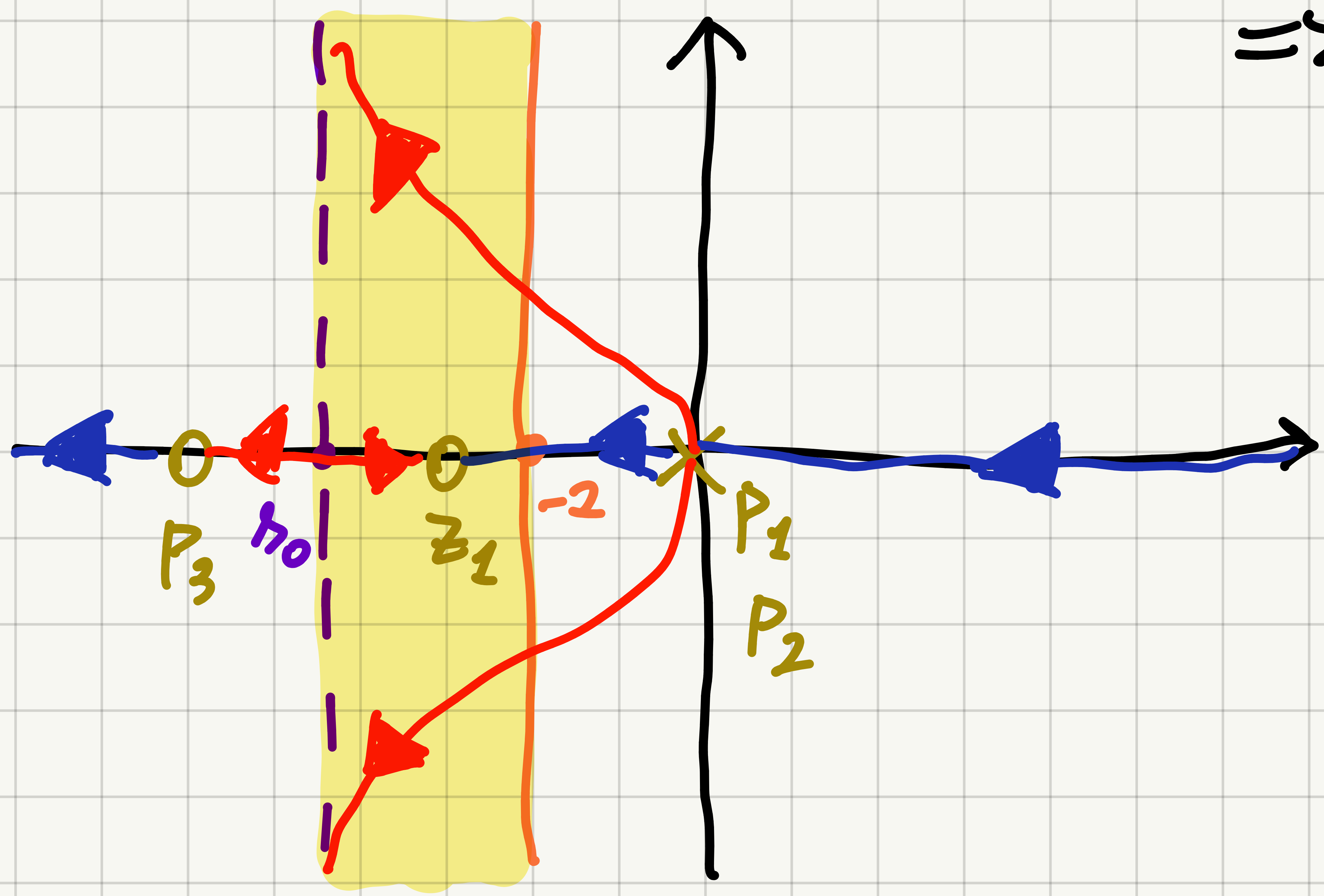
$F(s) = K \cdot \frac{(s+3)}{s^2(s-p)}$

$$s_0 = -4 = \frac{p+3}{3} \Rightarrow p = -11 \Rightarrow$$

$$G(s) = K \cdot \frac{(s^2+8s+25)}{s(s+9)} \Rightarrow F(s) = K \cdot \frac{(s+3)}{s^2(s+9)}$$

$$\frac{25}{11} K \geq 16x$$

$$\Rightarrow K \geq$$



$$f(s,K) = s^2(s+11) + K(s+3) \Big|_{s=-2} = 0$$

cont!

$$(\bar{s}-2)^2(\bar{s}+9) + K\bar{s} = 0$$

$$\bar{s}^3 + 3\bar{s}^2 + (K-24)\bar{s} + 28 = 0$$

3	1	$K-24$
2	3	28
1	$-\frac{100-3K}{3}$	
0	$K-24$	

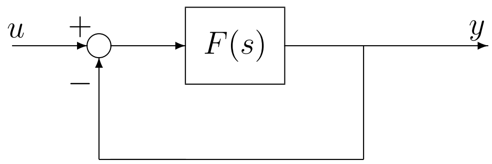
$$\begin{cases} \frac{-100+3K}{3} > 0 \\ K-24 > 0 \end{cases} \Rightarrow K > 34$$

$$K_G \geq 60$$

Esercitazione di Controlli sautomatici - 29/6/2015

Esercizio 1

È dato il sistema in controreazione:

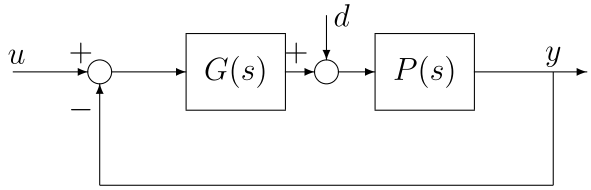


in cui $F(s) = \dfrac{K(s+1)(s+4)(s+5)}{(s-2)(s+10)(s^2+4s+8)}$, $K \in \mathbb{R}$.

- Tracciare il luogo positivo delle radici;
- tracciare il luogo negativo delle radici;
- determinare per quali valori di K il sistema a ciclo chiuso è asintoticamente stabile;
- se $K = 10$, esiste la risposta a regime permanente a ciclo chiuso per un ingresso a gradino? Motivare la risposta.

Esercizio 2

È dato il sistema di controllo:



in cui:

$$P(s) = \frac{10(s+0.1)}{s(s+2)^2}; \quad d(t) = \delta_{-1}(t).$$

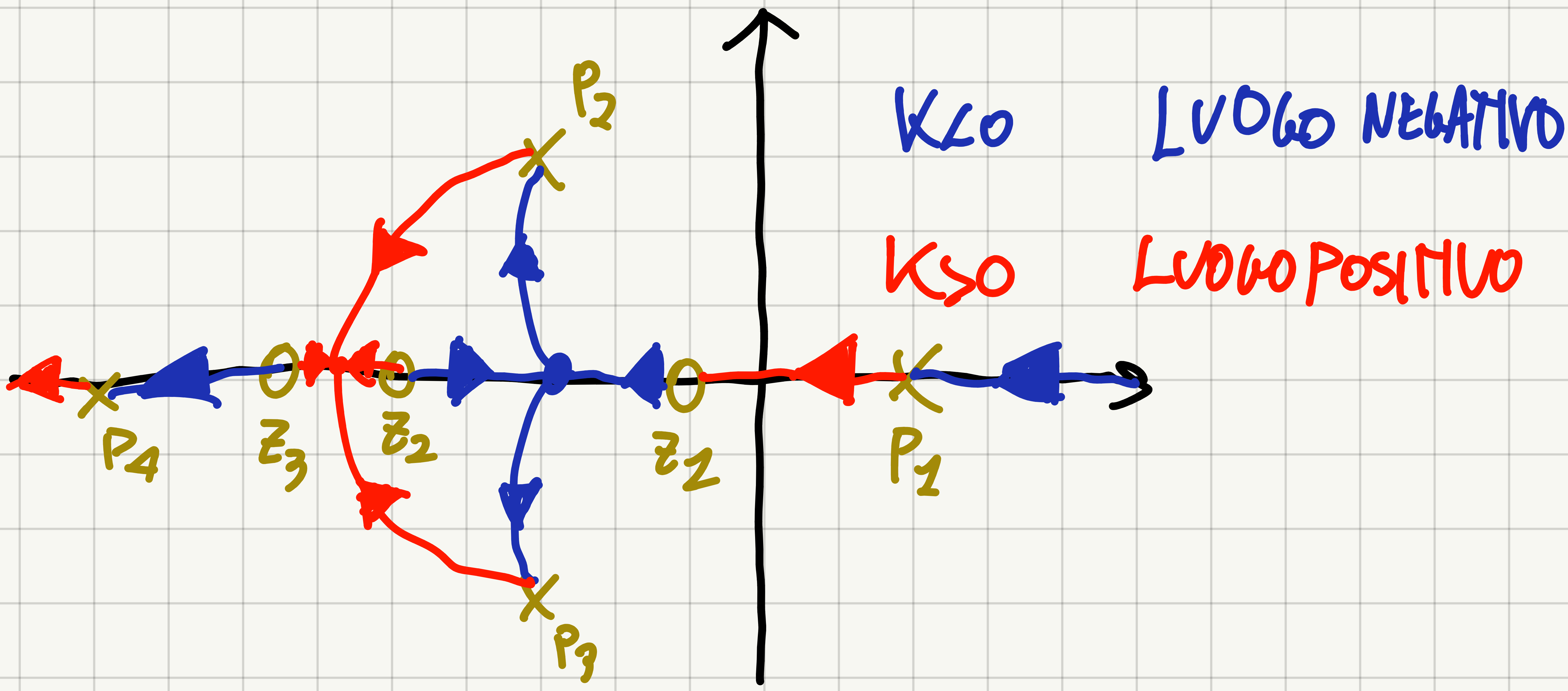
Progettare $G(s)$ con la sintesi per tentativi in ω in modo che:

- $|\tilde{y}_d(t)| \leq 0.05$, essendo $\tilde{y}_d(t)$ la risposta a regime permanente al disturbo $d(t)$;
- $M_r \leq 3\ dB$;
- $B_3 \simeq 1\ Hz$.

1

$$F(s)=\frac{K(s+1)(s+4)(s+5)}{(s-2)(s+10)(s^2+4s+8)}\qquad n=4,\ m=3 \Rightarrow n-m=1$$

$p_1=2,\ p_2=-2+2i,\ p_3=-2-2i,\ p_4=-10;\quad z_1=-1,\ z_2=-4,\ z_3=-5$



$$f(s,K)=(s-2)(s+10)(s^2+4s+8)+K(s+1)(s+4)(s+5)\Big|_{s=0}=0$$

$$-160+20K=0$$

$\Rightarrow$ SISTEMA STABILE $\forall\, K>8$

$\Rightarrow \exists$ RISPOSTA A REGIME PERMANENTE PER

$K=10$

2

$$|\tilde{y}_{d_1}(t)| = \left|\frac{K_d}{K_G}\right| \leq 0{,}05 \Longrightarrow K_G \geq 20 \quad G(s)=20$$

$$M_r \leq 3dB \Longrightarrow m_\varphi \geq 42°$$

$$B_3 \simeq 1Hz \Longrightarrow w_t = 3 \div 5 B_3 = 4B_3 = 4 \,rad/s$$

$$F(s) = R(s) \cdot G(s) \cdot P(s)$$

1° TENTATIVO: $R(s) = 1 \Longrightarrow F(iw) = 5 \dfrac{\left(1+\frac{iw}{0,1}\right)}{iw\left(1+\frac{iw}{2}\right)^2}$

PUNTI DI ROTTURA:

$5 \rightarrow 20\log_{10}(5) = 14\ dB$

$w=0$	$-20dB$	$-90°$	$-20dB$	$-90°$
$w=0,1$	$+20dB$	$+90°$	0	0
$w=2$	$-40dB$	$-180°$	$-40dB$	$-180°$

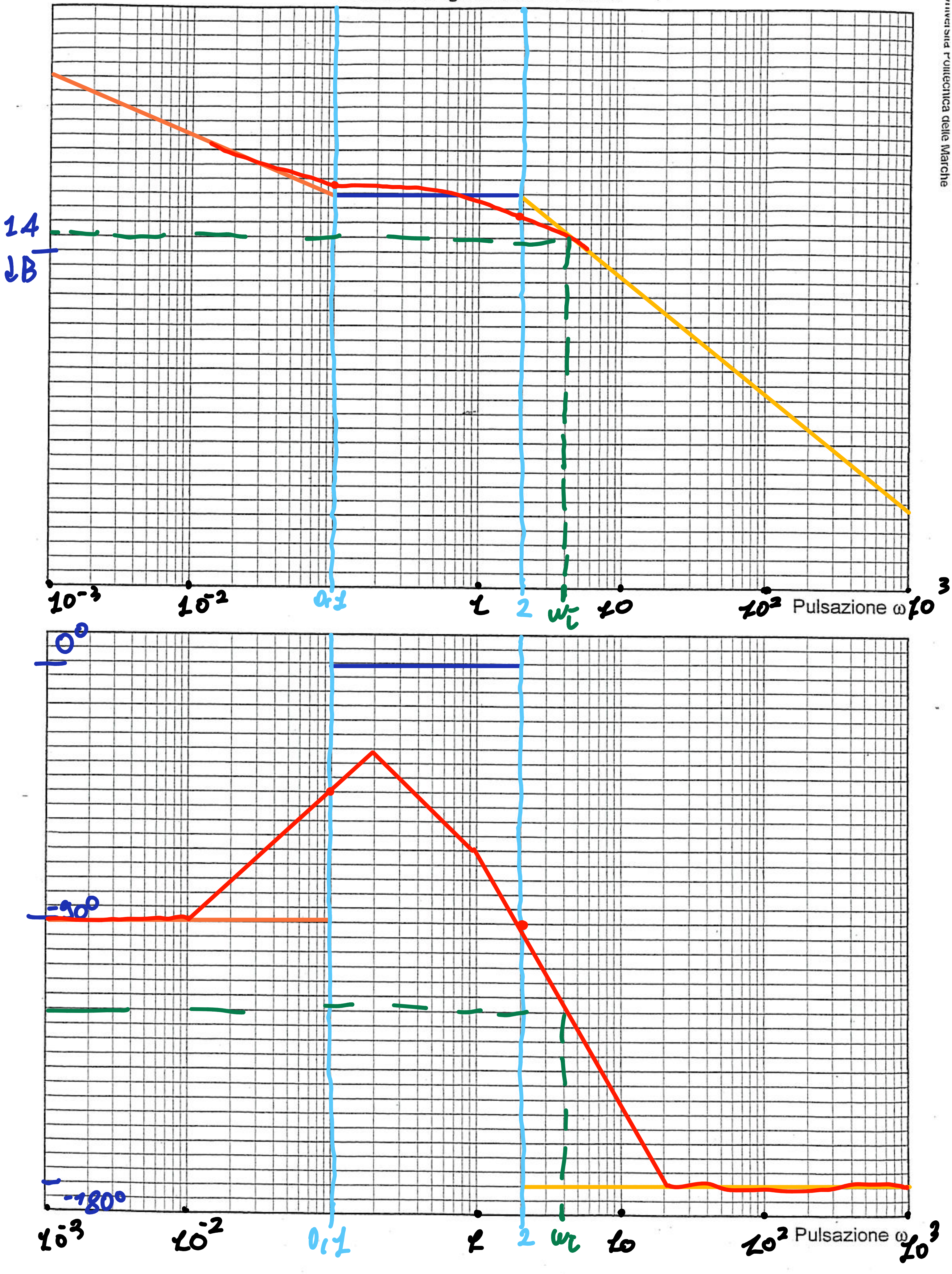
CORREZIONE MODULO

w	$1+\frac{iw}{0,1}$	$\left(1+\frac{iw}{2}\right)^2$	TOT
0,1	$+3dB$	0	$+3dB$
2	0	$-6dB$	$-6dB$

CORREZIONE FASE

w	iw	$1+\frac{iw}{0,1}$	$\left(1+\frac{iw}{2}\right)^2$	TOT
0,1	$-90°$	$+45°$	0	$-45°$
2	$-90°$	$+90°$	$-90°$	$-90°$

Carta semilogaritmica a 6 decadi



$$|F(i\omega_t)| = 19\,dB$$

$$\angle F(i\omega_t) = -120^\circ \Rightarrow M_\varphi = 60^\circ$$

OBIETTIVO:

$|F(i\omega_t)| = 0$ ✗

$M_\varphi \geq 42^\circ$ ✓ $\Rightarrow$ FUNZIONE ATTENUATRICE $R_i(s)$

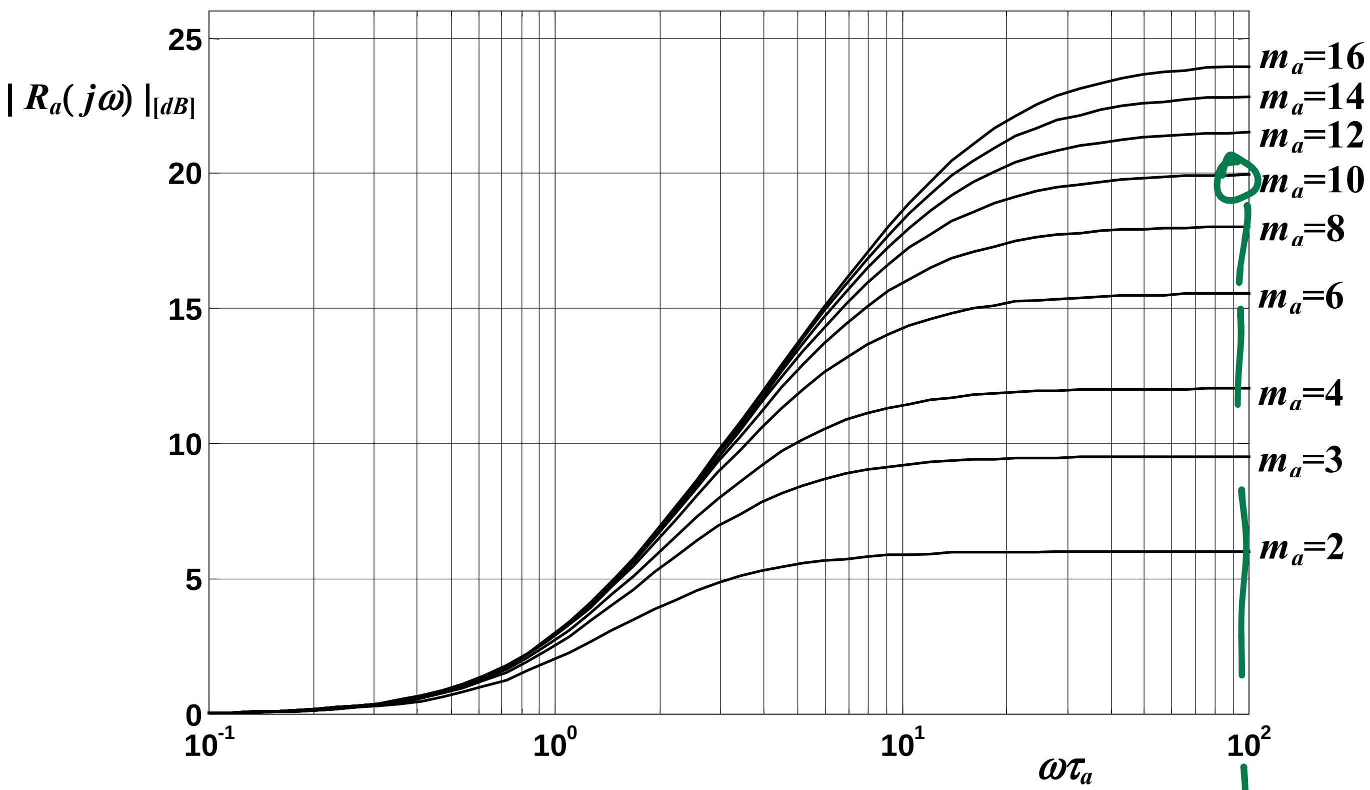
$$R(s) = \frac{1 + \frac{s}{m_i \omega_i}}{1 + \frac{s}{\omega_i}} \qquad \omega_t \tau_i = 100 \quad m_i = 10 \quad \Rightarrow \omega_i = \frac{\omega_t}{100} = 0{,}04$$

$$\Rightarrow R(s) = \frac{1 + \frac{s}{0{,}4}}{1 + \frac{s}{0{,}04}} \Rightarrow G(s) = 20 \cdot \frac{1 + \frac{s}{0{,}4}}{1 + \frac{s}{0{,}04}}$$

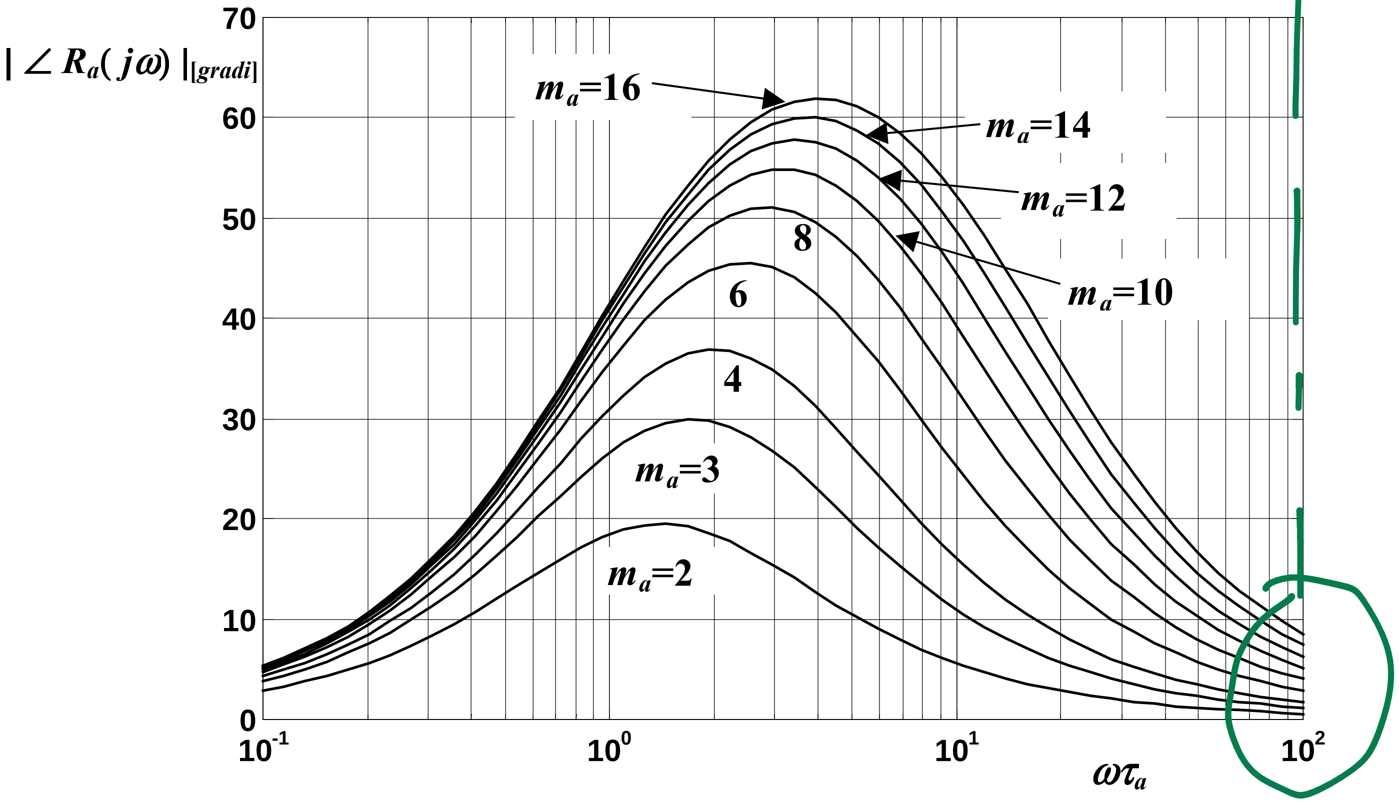
$$F(i\omega) = 5 \frac{\left(1 + \frac{i\omega}{0{,}1}\right)\left(1 + \frac{i\omega}{0{,}4}\right)}{i\omega\left(1 + \frac{i\omega}{2}\right)^2 \left(1 + \frac{i\omega}{0{,}04}\right)}$$

PUNTI DI ROTTURA:

$\omega = 0$	$-20\,dB$	-90°	$-20\,dB$	-90°
$\omega = 0{,}04$	$-20\,dB$	-90°	$-40\,dB$	-180°
$\omega = 0{,}1$	$+20\,dB$	$+90^\circ$	$-20\,dB$	-90°
$\omega = 0{,}4$	$+20\,dB$	$+90^\circ$	0	0
$\omega = 2$	$-40\,dB$	-180°	$-40\,dB$	-180°



| $R_a(j\omega)$ |[dB]
25
20
15
10
5
0
10-1
100
101
102
ωτa
ma=16
ma=14
ma=12
ma=10
ma=8
ma=6
ma=4
ma=3
ma=2



| ∠ $R_a(j\omega)$ |[gradi]
70
60
50
40
30
20
10
0
10-1
100
101
102
ωτa
ma=16
ma=14
ma=12
ma=10
8
6
4
ma=3
ma=2

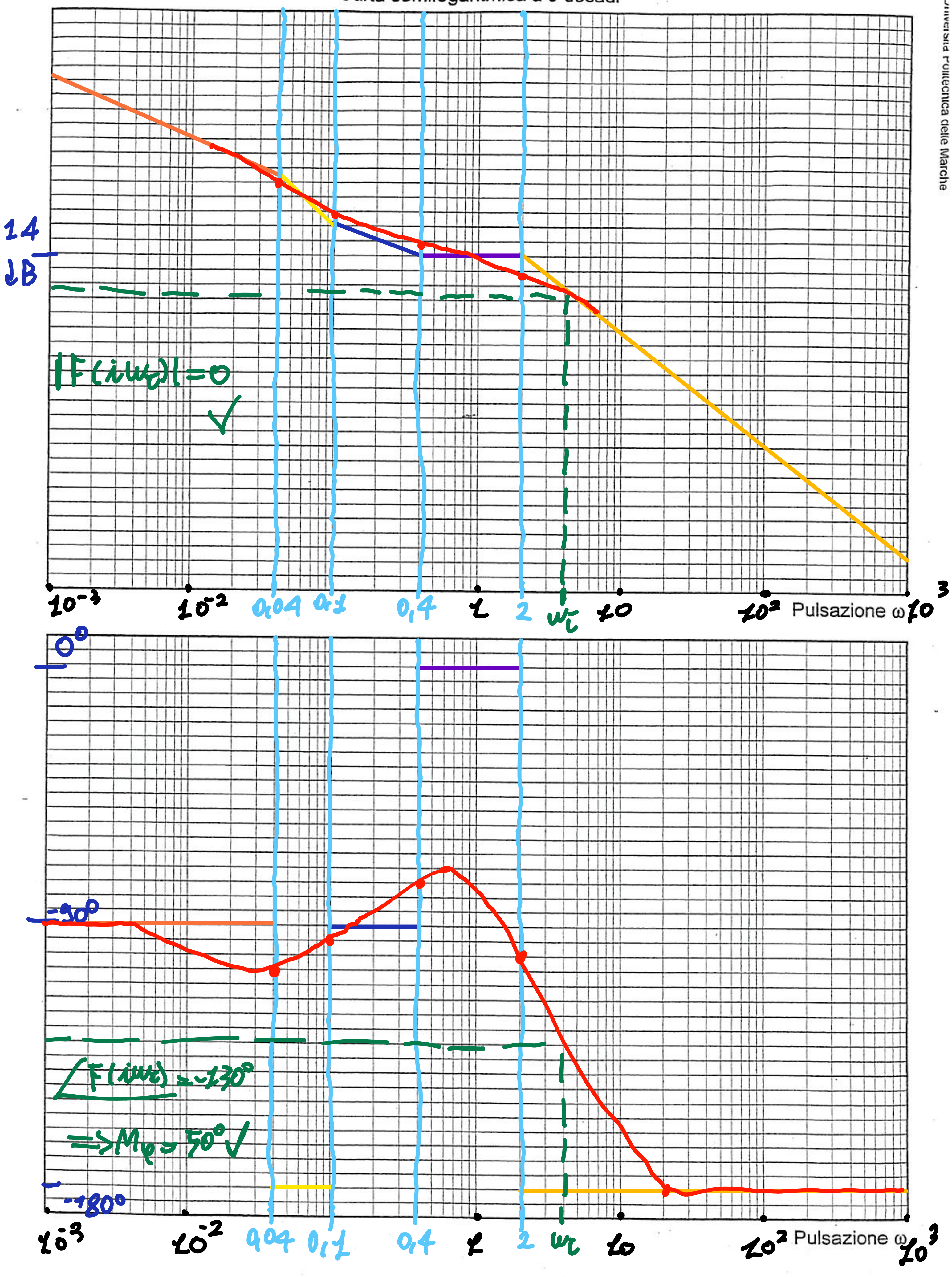
CORREZIONE MODULO

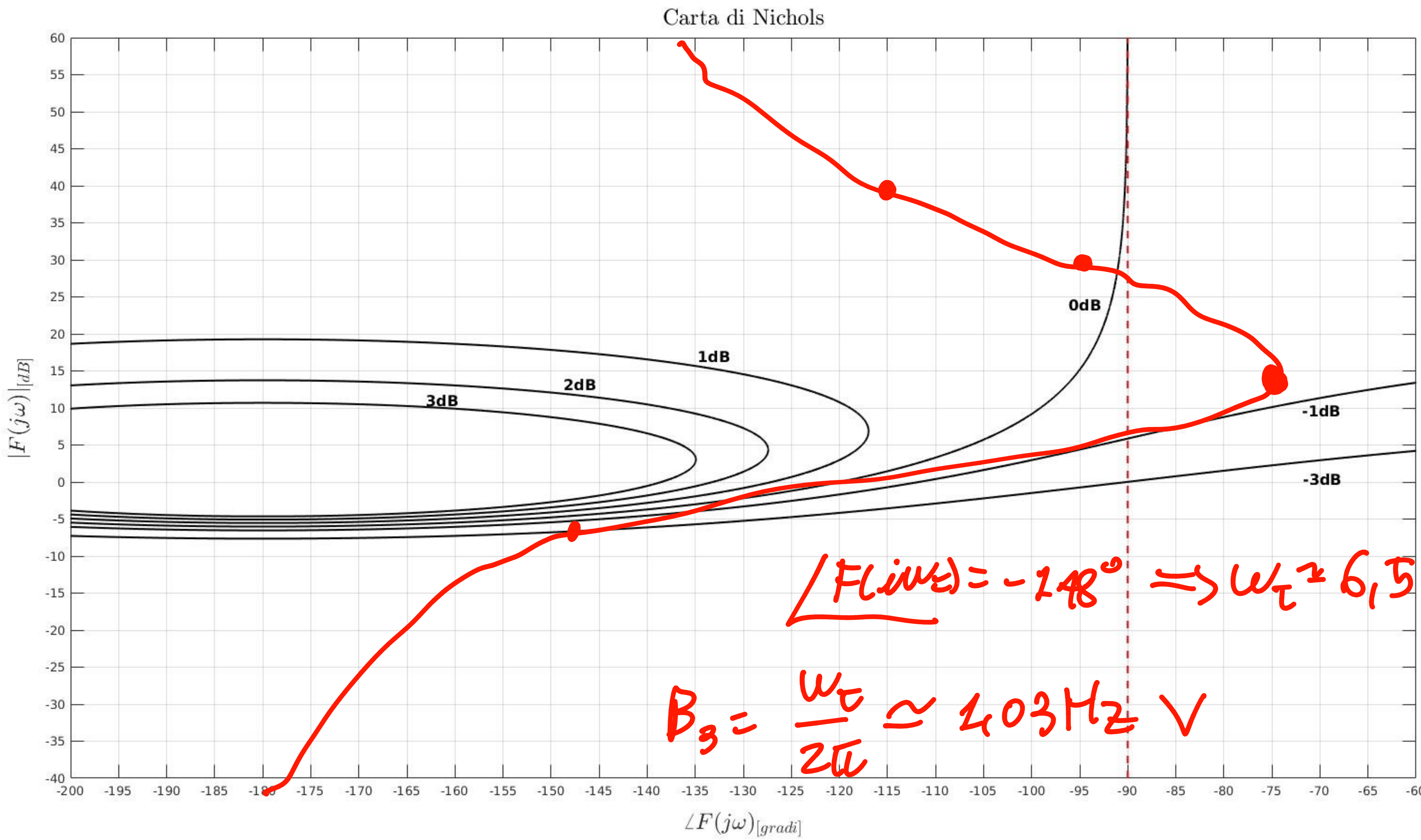
w	$1+\frac{iw}{0{,}04}$	$1+\frac{iw}{0{,}1}$	$1+\frac{iw}{0{,}4}$	$\left(1+\frac{iw}{2}\right)^2$	TOT
0,04	-3dB	+1dB	0	0	-2dB
0,1	-1dB	+3dB	0	0	+2dB
0,4	0	0	+3dB	0	+3dB
2	0	0	0	-6dB	-6dB

CORREZIONE FASE

w	iw	$1+\frac{iw}{0{,}04}$	$1+\frac{iw}{0{,}1}$	$1+\frac{iw}{0{,}4}$	$\left(1+\frac{iw}{2}\right)^2$	TOT
0,04	$-90°$	$-45°$	$+20°$	0	0	$-115°$
0,1	$-90°$	$-65°$	$+45°$	$+15°$	0	$-95°$
0,4	$-90°$	$-90°$	$+80°$	$+45°$	$-20°$	$-75°$
2	$-90°$	$-90°$	$+90°$	$+80°$	$-90°$	$-100°$

Carta semilogaritmica a 6 decadi



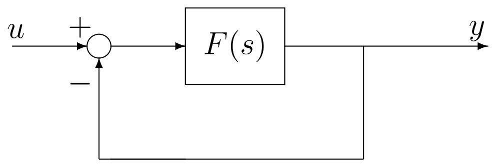


$$\underline{\angle F(j\omega_t) = -148^\circ} \Rightarrow \omega_t \approx 6{,}5$$

$$B_3 = \frac{\omega_t}{2\pi} \simeq 1{,}03\,Hz \checkmark$$

Domanda Scritta di Controlli Automatici - 7/09/2015

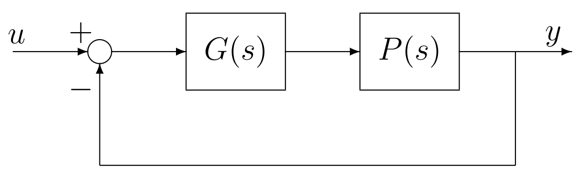
Esercizio 1
È dato il sistema in controreazione:



in cui $F(s) = \dfrac{K(s-2)(s+4)(s+10)}{(s^2+9)(s+1)(s+6)}$, $K \in \mathbb{R}$.

- Tracciare il luogo positivo delle radici;
- tracciare il luogo negativo delle radici;
- determinare per quali valori di K il sistema a ciclo chiuso è asintoticamente stabile.

Esercizio 2
È dato il sistema di controllo:



in cui: $P(s) = \dfrac{1}{(s+5)}$.

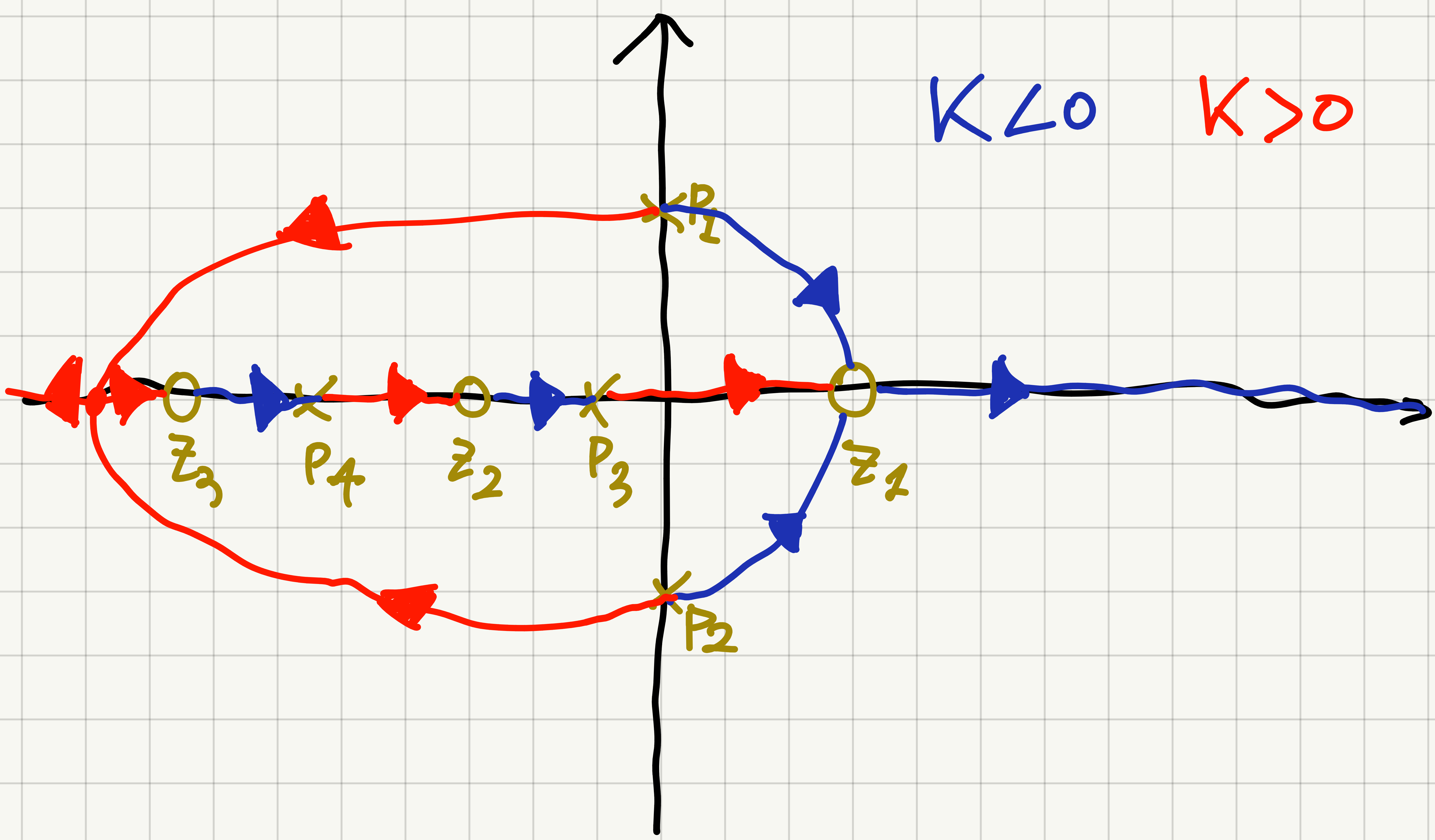
Utilizzando la sintesi per tentativi in ω, progettare $G(s)$ in modo che:

- $|\tilde{e}_1(t)| \leq 0.05$, essendo $\tilde{e}_1(t)$ l'errore a regime permanente per un ingresso a rampa unitaria;
- $M_r \leq 3\ dB$;
- $B_3 \simeq 1\ Hz$.

1

$$F(s)=\frac{K(s-2)(s+4)(s+10)}{(s^2+9)(s+1)(s+6)}$$ $n=4, m=3 \Rightarrow n-m=1$

$z_1=2, z_2=-4, z_3=-10; p_1=3i, p_2=-3i, p_3=-1, p_4=-6$



$$f(s,K)=(s^2+9)(s+1)(s+6)+K(s-2)(s+4)(s+10)\Big|_{s=0}=0$$

$54-80K=0$

$\Longrightarrow$ SISTEMA STABILE $\forall K>0{,}675$

2

$$|\tilde{e}_1(\tau)| = \left| \frac{K_d^2}{K_G K_P} \right| \leq 0{,}05 \quad K_P = \frac{1}{5} \Rightarrow K_G \geq 100$$

$$G(s) = \frac{100}{s} \cdot R(s) \qquad 1° \text{ TENTATIVO : } R(s) = 1$$

$$M_r \leq 3dB \Rightarrow M_p \geq 42° \qquad B_3 \simeq 1Hz \Rightarrow \omega_c \simeq 4\frac{rad}{s}$$

$$F(s) = G(s) \cdot P(s) \quad F(i\omega) = \frac{20}{i\omega\left(1+\frac{i\omega}{5}\right)} \quad 20 \to 20\log_{10}(20) = 26dB$$

PUNTI DI ROTTURA:

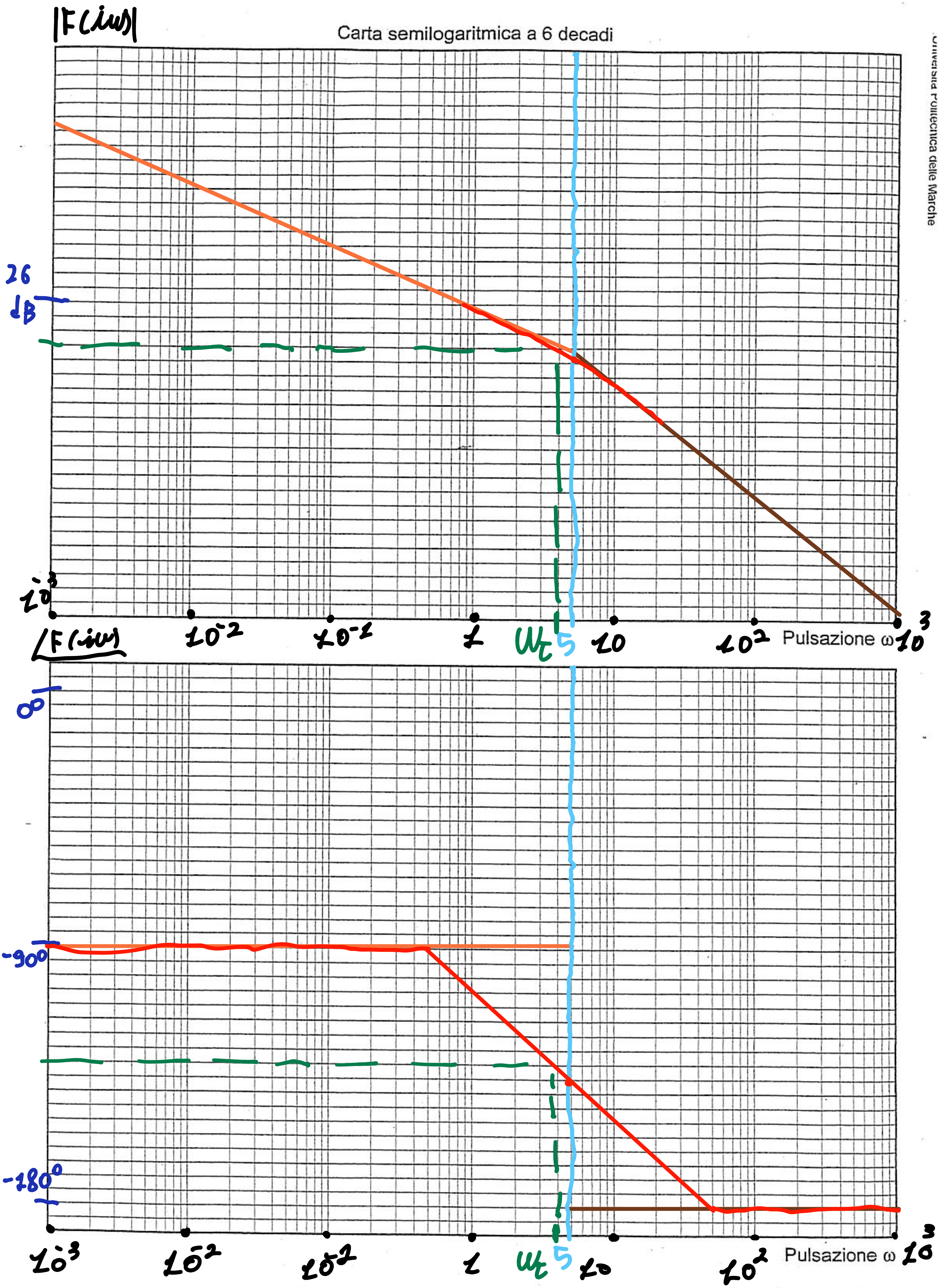
• $\omega = 0$	•	$-20dB$	$-90°$	$-20dB$	$-90°$
• $\omega = 5$	•	$-20dB$	$-90°$	$-40dB$	$-180°$

CORREZIONE MODULO

ω	$1+\frac{i\omega}{5}$	TOT
5	$-3dB$	$-3dB$

CORREZIONE FASE

ω	$i\omega$	$1+\frac{i\omega}{5}$	TOT
5	$-90°$	$-45°$	$-135°$



|F(iω)|
Carta semilogaritmica a 6 decadi
Politecnica delle Marche
26 dB
10^-3
10^-2
10^-1
1
ωt
5
10
10^2
Pulsazione ω
10^3
∠F(iω)
0°
-90°
-180°

$|F(i\omega_t)| = 11\,dB$

$\angle F(i\omega_t) \simeq -130^\circ \Rightarrow m_\varphi = 50^\circ$

OBIETTIVO:

- $|F(i\omega_t)| = 0$ ✗
- $m_\varphi \geq 42^\circ$ ✓

$\Rightarrow$ FUNZIONE ATTENUATRICE $R_i(s) = \dfrac{1+\frac{s}{m_i \omega_i}}{1+\frac{s}{\omega_i}}$

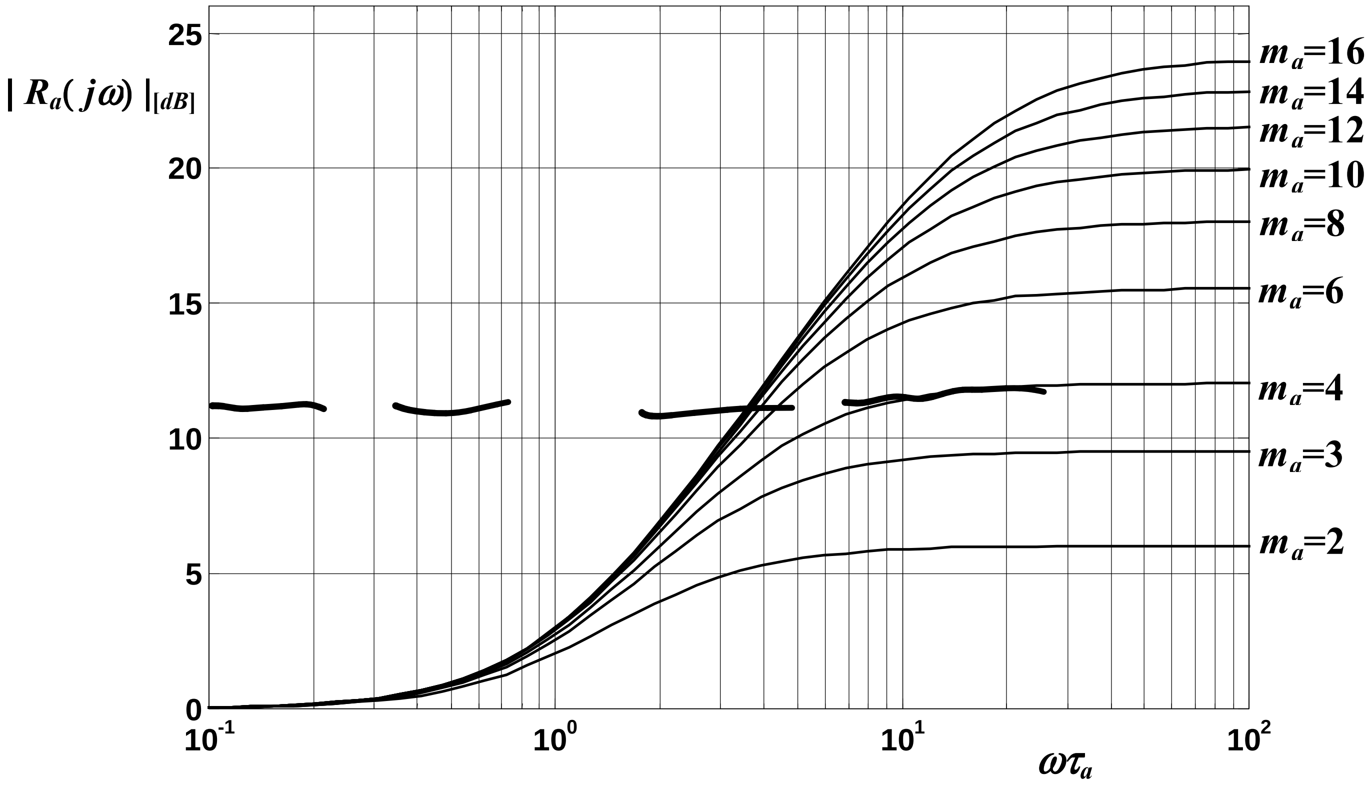
$m_i = 4,\ \omega_t \tau_i = 100 \Rightarrow \omega_i = \dfrac{\omega_t}{100} = 0{,}04$

$$\Rightarrow G(s) = 100 \cdot \frac{1+\frac{s}{0{,}16}}{1+\frac{s}{0{,}04}}$$

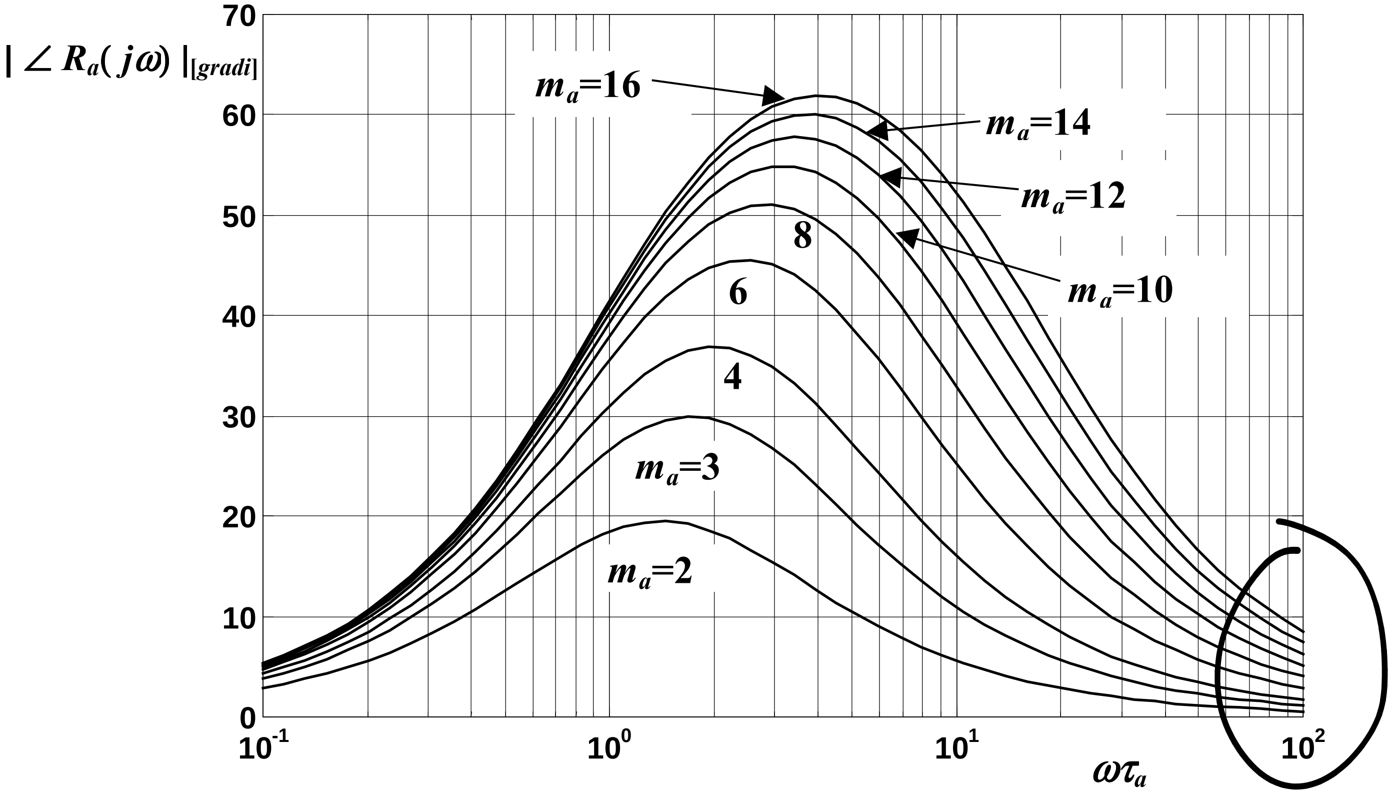
$$F(i\omega) = 20 \cdot \frac{1+\frac{i\omega}{0{,}16}}{i\omega\left(1+\frac{i\omega}{0{,}04}\right)\left(1+\frac{i\omega}{5}\right)}$$

PUNTI DI ROTTURA:

$\omega = 0$	$-20\,dB$	-90°	$-20\,dB$	-90°
$\omega = 0{,}04$	$-20\,dB$	-90°	$-40\,dB$	-180°
$\omega = 0{,}16$	$+20\,dB$	$+90^\circ$	$-20\,dB$	-90°
$\omega = 5$	$-20\,dB$	-90°	$-40\,dB$	-180°



$|R_a(j\omega)|_{[dB]}$
25
20
15
10
5
0
10^{-1}
10^{0}
10^{1}
10^{2}
$\omega\tau_a$
m_a=16
m_a=14
m_a=12
m_a=10
m_a=8
m_a=6
m_a=4
m_a=3
m_a=2



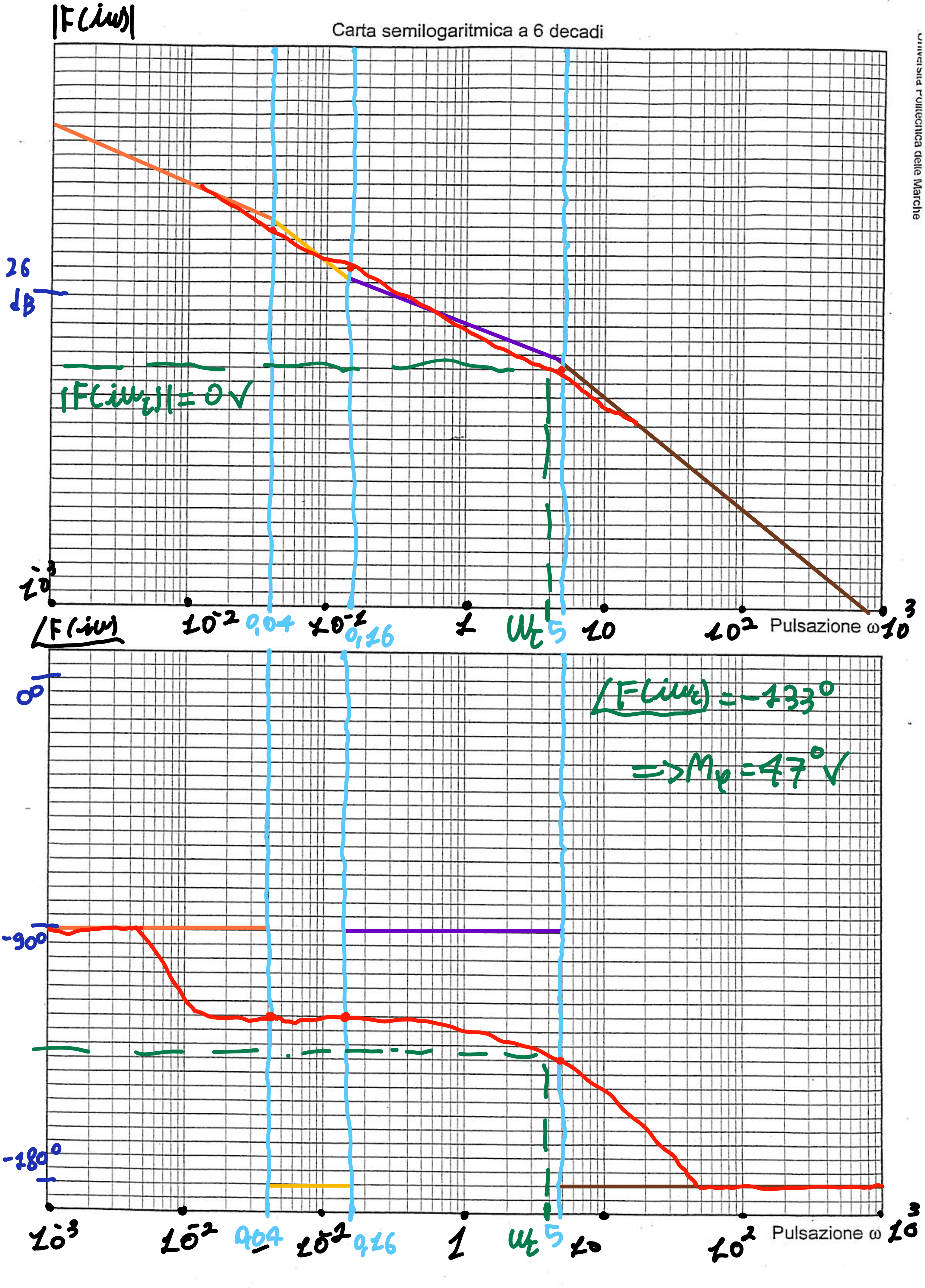
$|\angle R_a(j\omega)|_{[gradi]}$
70
60
50
40
30
20
10
0
10^{-1}
10^{0}
10^{1}
10^{2}
$\omega\tau_a$
m_a=16
m_a=14
m_a=12
m_a=10
8
6
4
m_a=3
m_a=2

CORREZIONE MODULO

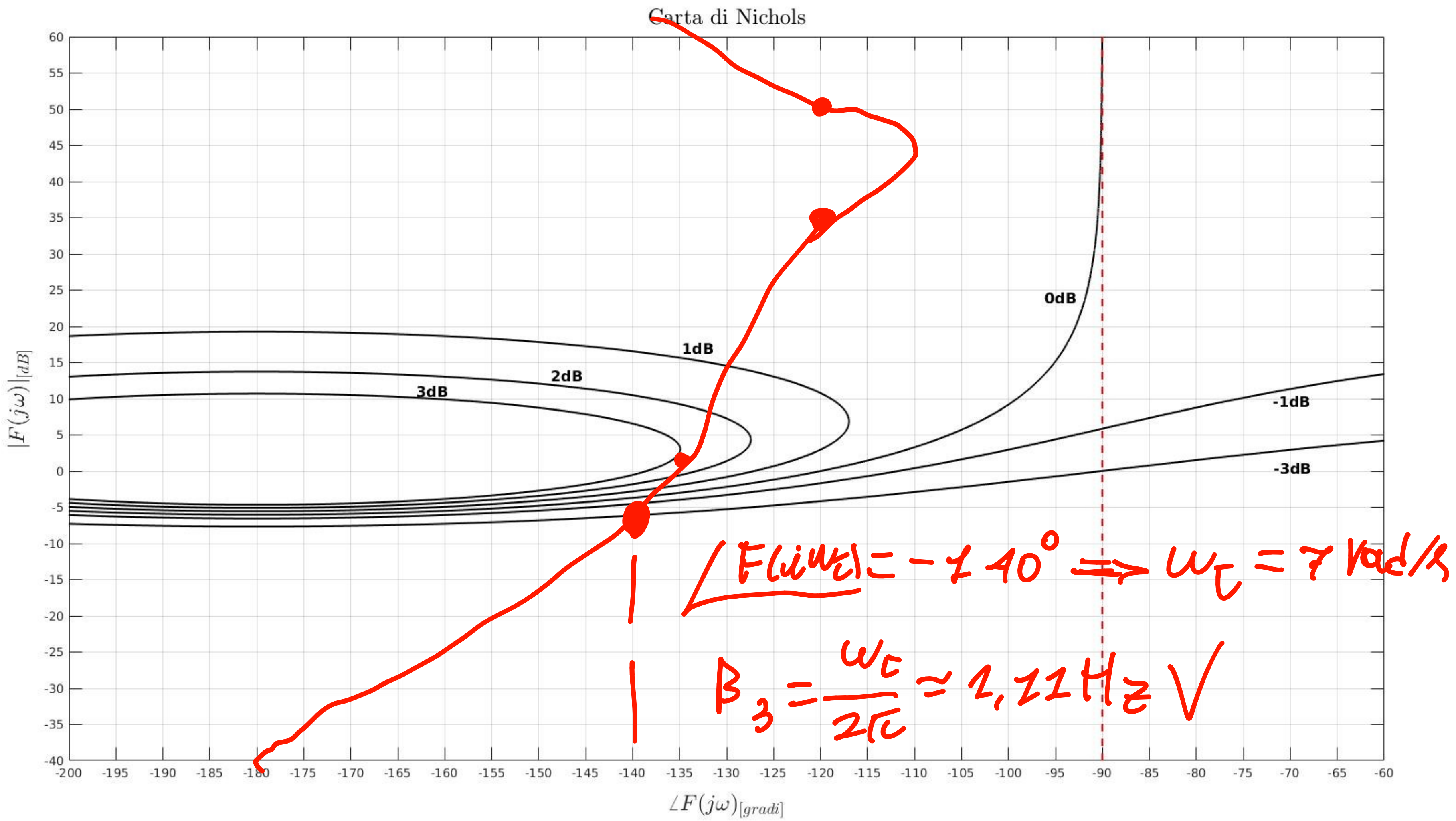
ω	$1+\frac{i\omega}{0,04}$	$1+\frac{i\omega}{0,16}$	$1+\frac{i\omega}{5}$	TOT
0,04	-3dB	0	0	-3dB
0,16	0	+3dB	0	+3dB
5	0	0	-3dB	-3dB

CORREZIONE FASE

ω	$i\omega$	$1+\frac{i\omega}{0,04}$	$1+\frac{i\omega}{0,16}$	$1+\frac{i\omega}{5}$	TOT
0,04	-90°	-45°	+15°	0	-120°
0,16	-90°	-75°	+45°	0	-120°
5	-90°	-90°	+90°	-45°	-135°



|F(iω)|
Carta semilogaritmica a 6 decadi
Politecnica delle Marche
26 dB
|F(iω_t)| = 0 ✓
10^-3
10^-2
0,04
10^-1
0,16
1
ω_t
5
10
10^2
Pulsazione ω
10^3
∠F(iω)
0°
∠F(iω_t) = -133°
=> M_φ = 47° ✓
-90°
-180°



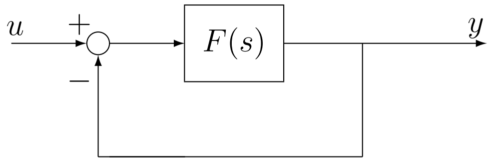
$\angle F(j\omega_t) = -140^\circ \Rightarrow \omega_t = 7\ rad/s$

$B_3 = \frac{\omega_t}{2\pi} \simeq 1{,}11\ Hz$ ✓

Domanda Scritta di Controlli Automatici - 9/11/2015

Esercizio 1

È dato il sistema in controreazione:



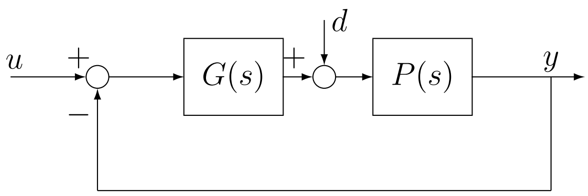
in cui:

$$F(s) = \frac{10\,(s+z)}{s^2(s+5)}, \quad z \in \mathbb{R}, \quad z \neq 0, \quad z \neq 5.$$

Utilizzando il criterio di Nyquist, studiare la stabilità del sistema in catena chiusa al variare di z.

Esercizio 2

È dato il sistema di controllo:



in cui:

$$P(s) = \frac{s+4}{s(s^2+6s+10)}; \quad d(t) = \delta_{-1}(t).$$

Utilizzando il luogo delle radici, progettare $G(s)$ in modo che:

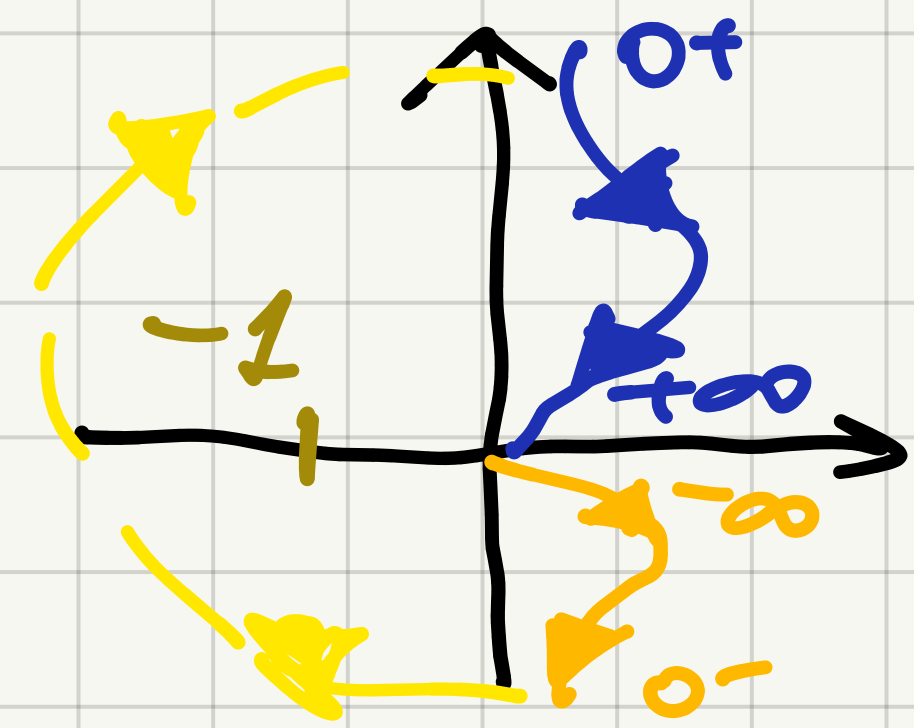
- il sistema sia astatico rispetto al disturbo $d(t)$;
- tutti i poli a ciclo chiuso abbiano parte reale minore od uguale a -2.

$$F(i\omega) = 2z \cdot \frac{\left(1+\frac{i\omega}{z}\right)}{(i\omega)^2\left(1+\frac{i\omega}{5}\right)}$$

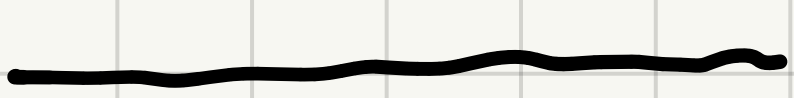
$P_+ = 0$

CASO 1: $z > 0$

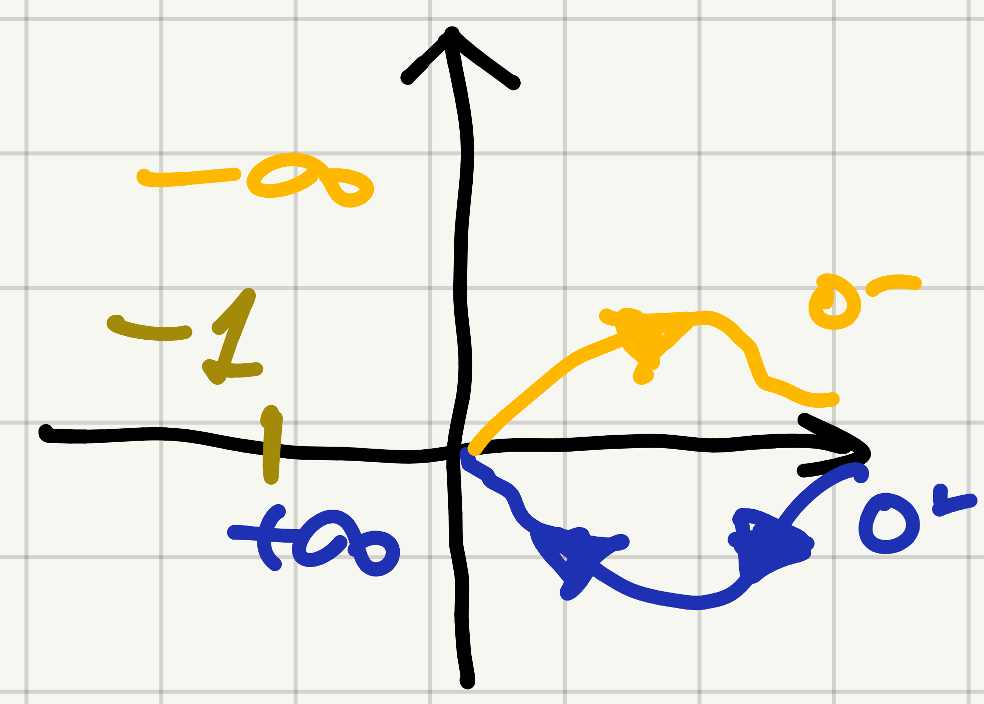
$M(0^+) = \infty, \ \varphi(0^+) = -360°$ $\quad M(+\infty) = 0, \ \varphi(+\infty) = -540°$



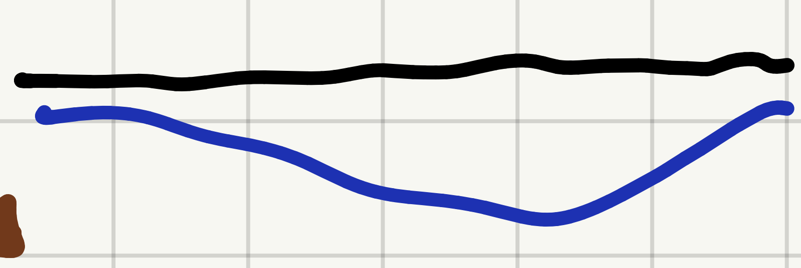
- $z < 5$



$N = 1$



- $z < 5$

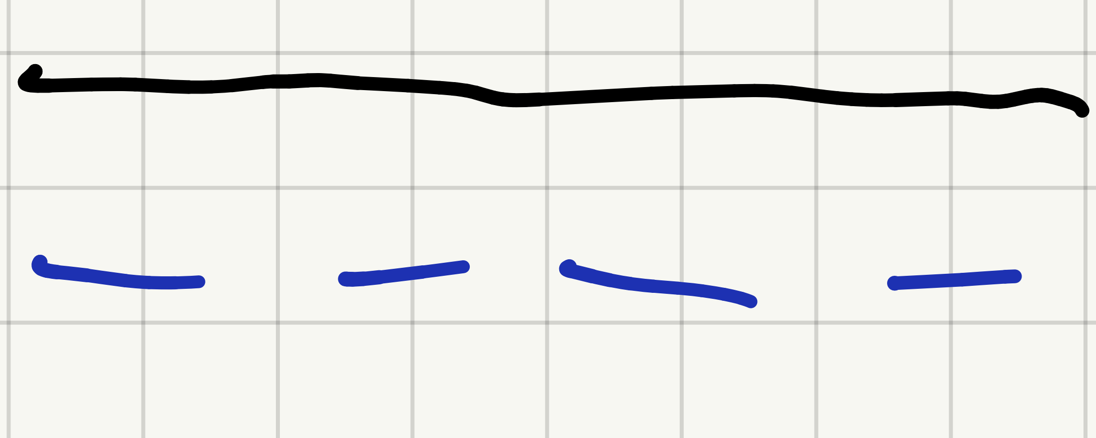


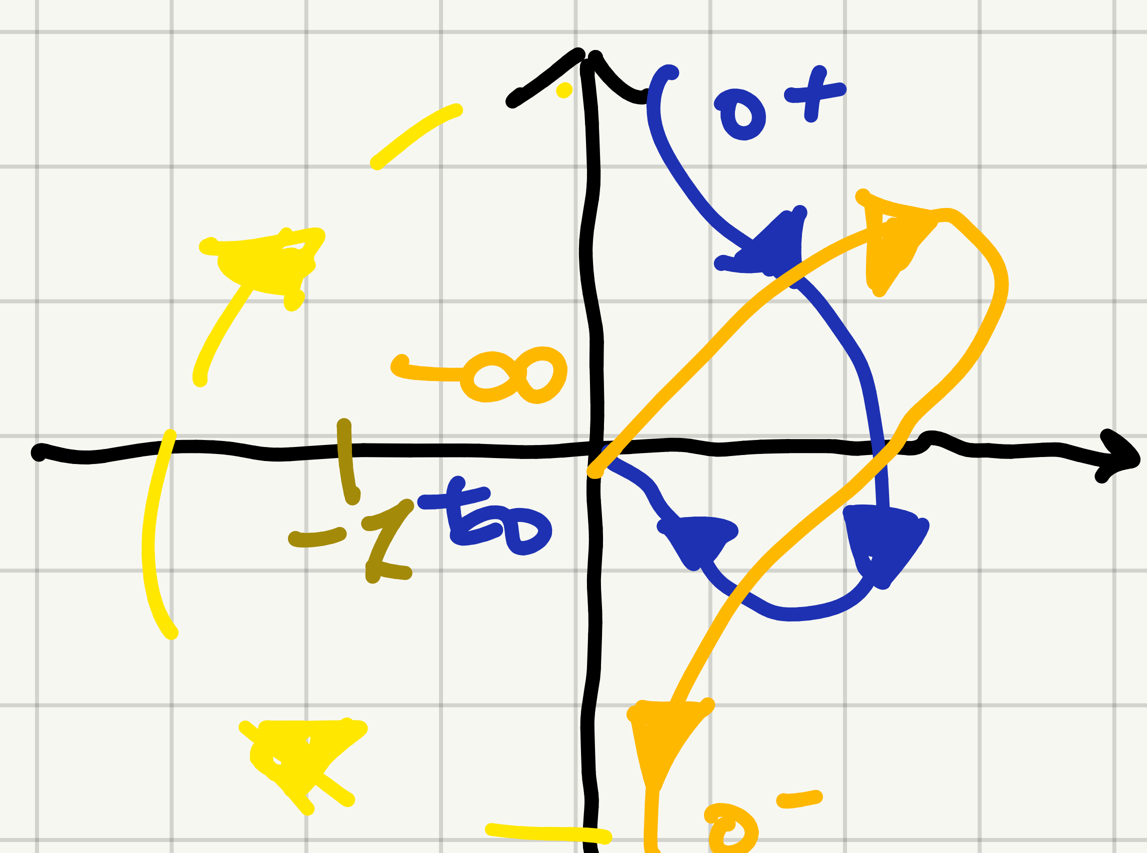
$N = 0$

SISTEMA STABILE PER $z > 5$

CASO 2: $z < 0$

$M(0^+) = \infty, \ \varphi(0^+) = -180°$ $\quad M(+\infty) = 0, \ \varphi(+\infty) = -360°$





$N = 1$

$N \neq -P_+ \Rightarrow$ SISTEMA INSTABILE

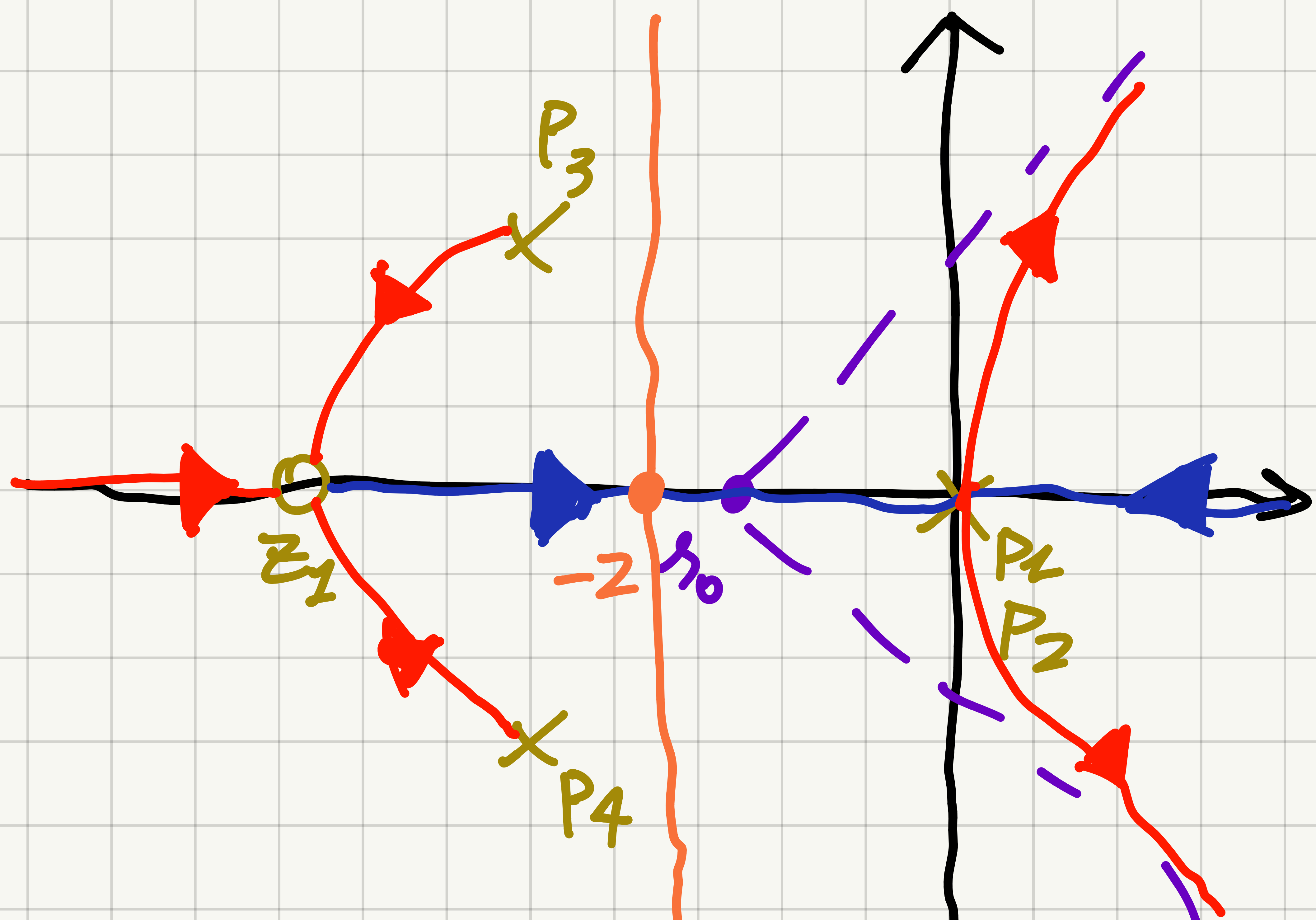
②

$$G(s)=\frac{K}{s} \Rightarrow F(s)=G(s)\cdot P(s)=K\cdot\frac{(s+4)}{s^2(s^2+6s+10)}$$

$$n=4,\ m=1 \Rightarrow n-m=3$$

$$z_1=-4;\ p_1=p_2=0,\ p_3=-3+4i,\ p_4=-3-4i$$

$$s_0=\frac{\Sigma p-\Sigma z}{n-m}=-\frac{2}{3}$$



SPECIFICA NON SODDISFATTA

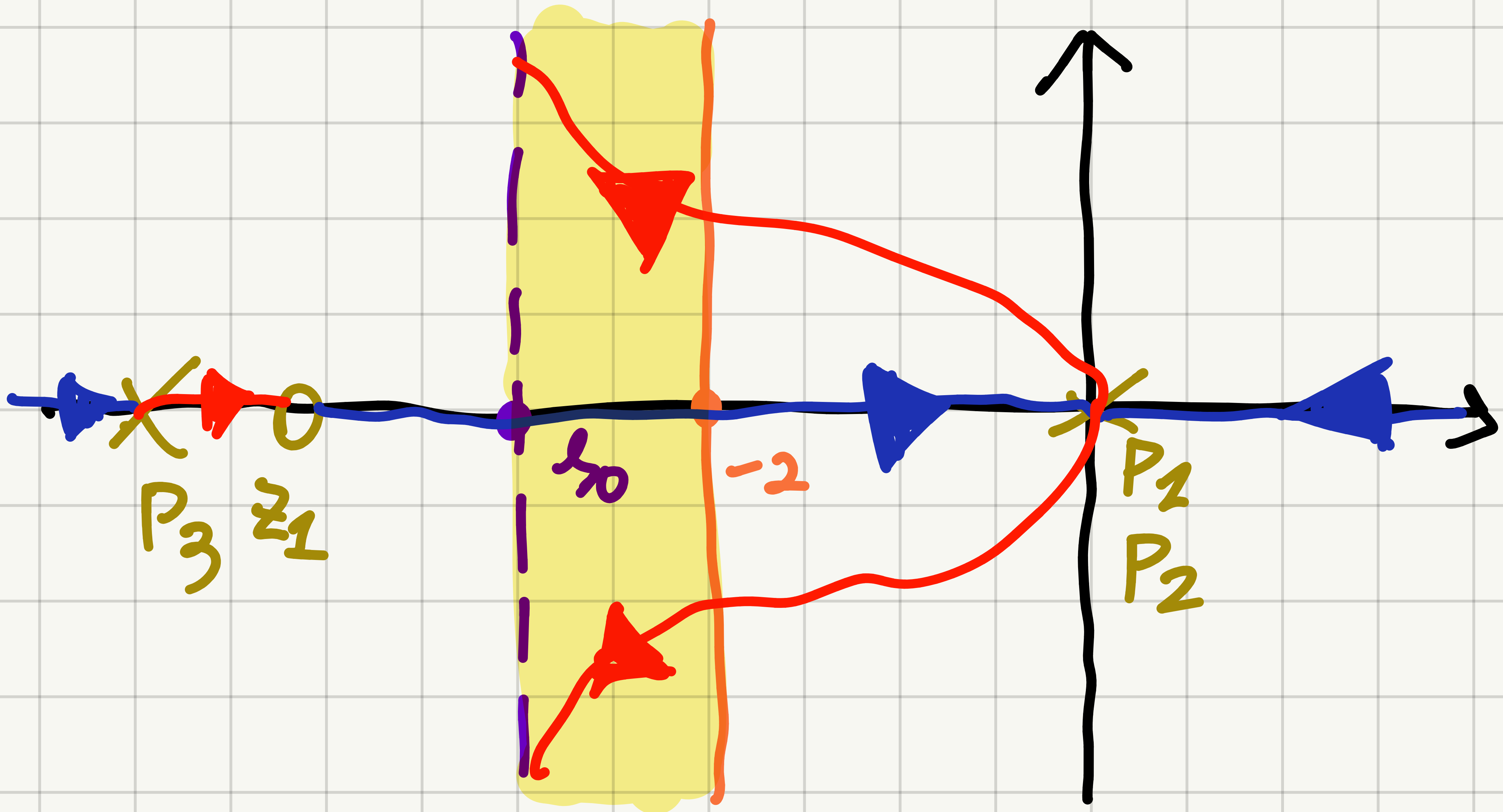
- $n-m=2 \rightarrow G(s)=\frac{K}{s}\cdot(s-z_2)$

- COPPIA POLO-ZERO $\rightarrow s_0=-3$ $\quad G(s)=\frac{K}{s}\cdot\frac{(s-z_1)(s-z_2)}{(s-p)}$

$$(s-z_1)(s-z_2)=s^2+6s+10$$

$$\Rightarrow F(s)=K\cdot\frac{(s+4)}{s^2(s-p)} \qquad -3=\frac{p+4}{2} \Rightarrow p=-10$$

$$\Rightarrow F(s)=K\cdot\frac{(s+4)}{s^2(s+10)}$$



$$f(s,K) = s^2(s+10) + K(s+4) \qquad s = \bar{s} - 2$$

$$(\bar{s}-2)^2(\bar{s}+8) + K(\bar{s}+2) = 0$$

$$\bar{s}^3 + 4\bar{s}^2 + (K-28)\bar{s} + (2K+32) = 0$$

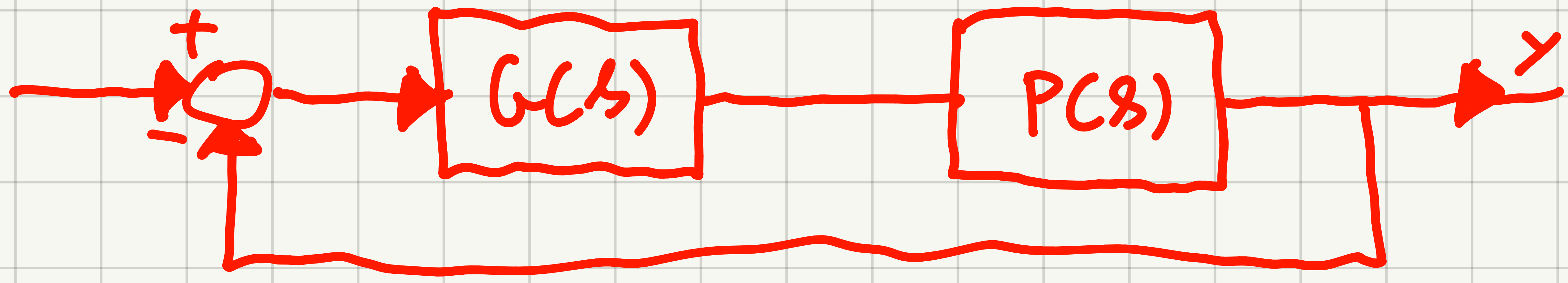
3	1	$K-28$
2	4	$2K+32$
1	$\frac{2K-144}{4}$	
0	$2K+32$	

$$\begin{cases} \dfrac{2K-144}{4} > 0 \\ 2K+32 > 0 \end{cases} \Rightarrow K > 72$$

$$\Rightarrow G(s) = 75 \cdot \frac{(s^2+6s+10)}{s(s+10)}$$

18/07/2022

È DATO IL SISTEMA DI CONTROLLO



IN CUI $P(s)=\dfrac{1}{(s-2)(s+3)}$.

UTILIZZANDO LA SINTESI CON IL LUOGO DELLE RADICI, PROGETTARE G(s) IN MODO CHE:

- $|\tilde{e}_1| \le 0{,}05$, ESSENDO $\tilde{e}_1$ L'ERRORE A REGIME PERMANENTE PER L'INGRESSO A RAMPA UNITARIA $u(t)=t\cdot\delta_{-1}(t)$
- TUTTI I POLI DELLA FUNZIONE DI TRASFERIMENTO IN CATENA CHIUSA ABBIANO PARTE REALE MINORE DI -2

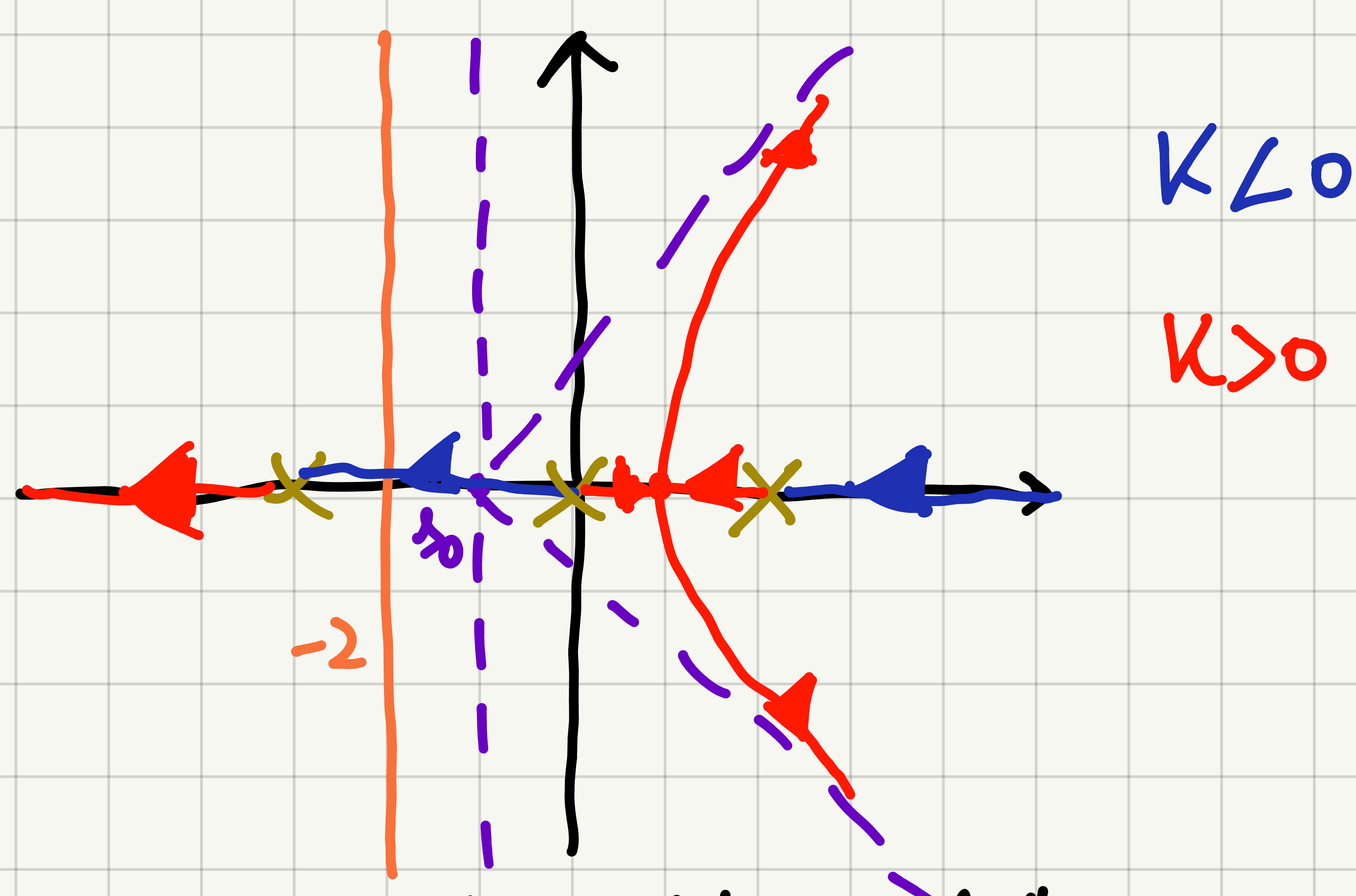
CALCOLARE INFINE LA RISPOSTA A REGIME PERMANENTE ALL'INGRESSO $u(t)=(5t+4)\cdot\delta_{-1}(t)$

$|\tilde{e}_1| = \left| \frac{K_d^2}{K_F} \right| \leq 0.05 \qquad K_F = K_G \cdot K_P = -\frac{K_G}{6} \qquad K_d = 1$

$\frac{6}{K_G} \leq 0{,}05 \Rightarrow K_G \geq 120 \qquad G(s) = \frac{K_G}{s}$

$F(s) = K_G \cdot \frac{1}{s(s-2)(s+3)} \qquad n=3, m=0 \Rightarrow n-m=3$

$P_1 = 2,\ P_2 = 0,\ P_3 = -3 \qquad s_0 = \frac{\Sigma p - \Sigma z}{n-m} = -\frac{1}{3}$



SPECIFICA NON SODDISFATTA

POSSO PORTARE AD $n-m=2$ (VALORE MINIMO POSSIBILE)

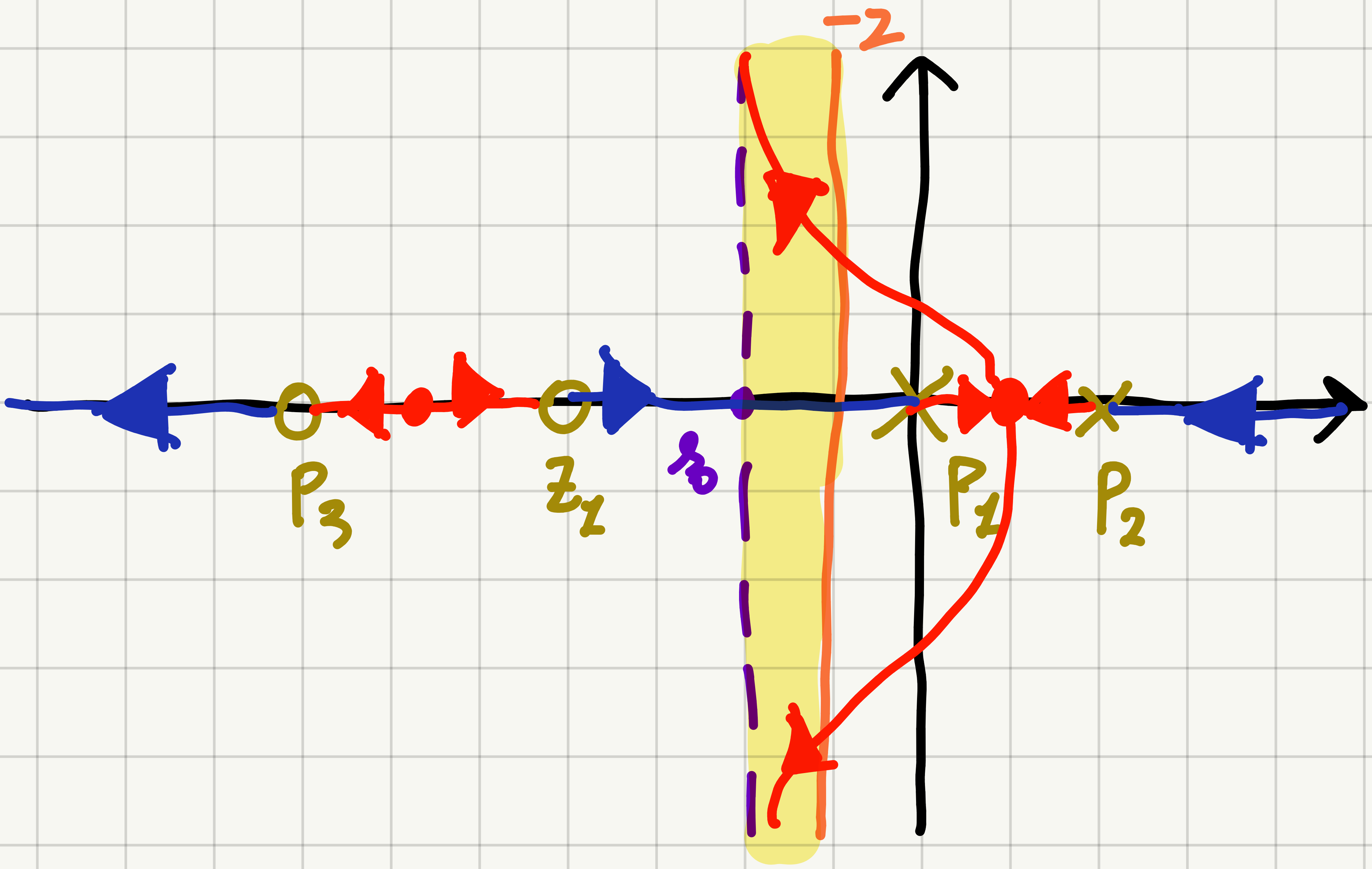
$G(s) = \frac{K_G}{s} \cdot (s - z_1) \qquad z_1 = -3.$ PER SPOSTARE s_0, INTRODUCO UNA COPPIA POLO-ZERO. $s_0 = -\frac{5}{2}$

$G(s) = \frac{K_G \cdot (s+3)}{s} \cdot \frac{(s-z_2)}{(s-p)} \Rightarrow F(s) = K_G \cdot \frac{(s-z_2)}{s(s-2)(s-p)}$

$z_2 = -4 \Rightarrow F(s) = K_G \cdot \frac{(s+4)}{s(s-2)(s-p)}$ $n=3, m=1 \Rightarrow n-m=2$

$-\frac{5}{2} = \frac{0-2-p+4}{2} \Rightarrow p=-7 \Rightarrow G(s) = K_G \cdot \frac{(s+3)(s+4)}{s(s+7)}$

$\Rightarrow F(s) = K_G \cdot \frac{(s+4)}{s(s-2)(s+7)}$



$f(s,K) = s(s-2)(s+7) + K(s+4)$

$(\bar{s}-2)(\bar{s}+5)\bar{s} + K(\bar{s}+2) = 0$

$\bar{s}^3 + (-7)\bar{s}^2 + (K+10)\bar{s} + (2K) = 0$

$$\begin{array}{c|cc} 3 & 1 & -10+K \\ 2 & -7 & 2K \\ 1 & \frac{9K-70}{7} & \\ 0 & 2K & \end{array} \qquad \frac{1}{7}\det\begin{vmatrix} 1 & -10+K \\ -7 & 2K \end{vmatrix}$$

$$\begin{cases} \frac{9K-70}{7} > 0 \\ 2K > 0 \end{cases} \Rightarrow K_G > \frac{70}{9} \simeq 7{,}8$$

$\Rightarrow K_G \geq 120 \cdot \frac{22}{7} \Rightarrow G(s) = 210 \cdot \frac{(s+3)(s+4)}{s(s+7)}$

$$F(s) = 120 \cdot \frac{(s+4)}{s(s-2)(s+7)} \qquad K_F = -\frac{240}{7}$$

$$u(t) = (5t+4)\delta_{-1}(t) = 5(t)\delta_{-1}(t) + (4)\delta_{-1}(t)$$
$$= 5u_1(t) + 4u_2(t)$$

- $u_1(t)$

$$\tilde{e}_{u_1}(t) = K_d u_1(t) - \tilde{y}_{u_1}(t)$$

$$\tilde{e}_{u_1}(t) = \frac{1}{K_d \cdot K_p} = \frac{1}{K_F} = -\frac{1}{60}$$

$$\tilde{y}_{u_1}(t) = K_d u_1(t) - \tilde{e}_{u_1}(t) = \left(t + \frac{1}{60}\right)\delta_{-1}(t)$$

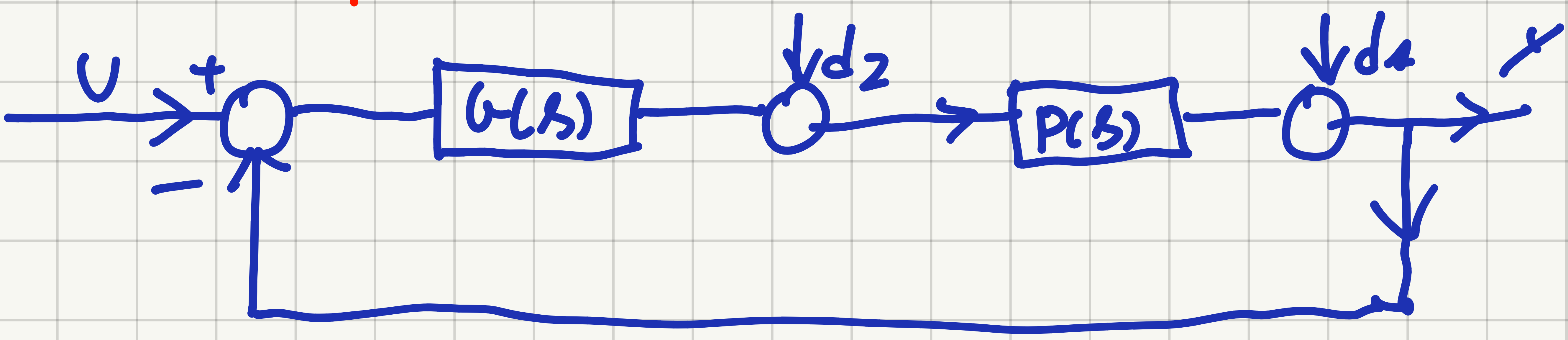
- $u_2(t)$

GRADO DI $u_2(t) <$ TIPO DI $F(s) \Rightarrow \tilde{y}_{u_2}(t) = \delta_{-1}(t)$

$$\Rightarrow \tilde{y}(t) = 5\left(t + \frac{1}{60}\right)\delta_{-1}(t) + 4\delta_{-1}(t)$$

FORMULARIO

RISPOSTE AI DISTURBI E AGLI INGRESSI



$$\tilde{y}_{d_2}(t) \approx \begin{cases} \dfrac{1}{K_T K_G} & (P(s) \text{ HA UN POLO IN } s=0) \\[2ex] \dfrac{K_P}{1+K_T K_G K_P} & (P(s) \text{ NON HA POLI IN } s=0) \end{cases}$$

$$\tilde{e}(t) \; (\text{INGRESSO DI TIPO } \geq 1) = \frac{K_d^2}{K_G K_P}$$

$$\tilde{y}_{sm}(t) = \left| \frac{1}{1+F(i\tilde{\omega})} \right|$$

$$y_{d_1}(t) = \frac{K_d^2}{K_G K_P} \quad (F(s) \text{ HA UN POLO IN } s=0)$$