Controle - Aula de Exercícios do Paulo - 13/6/14

3ª) P2) 2007

a)

$$FTMA = K\frac{(s+2)}{s+p} \cdot \frac{1}{(s^2-1)}$$

$$FTMF = \frac{K(s+2)}{K(s+2) + (s+p)(s^2-1)}$$

$$Ks + 2K + s^3 - s + ps^2 - p$$

$$s^3 + ps^2 + (K-1)s + 2K - p$$

s^3	1	$(K-1)$
s^2	p	$2K-p$
s^1	b_1	$b_2 = 0$
s^0	c_1	

$$b_1 = \frac{p(K-1) - (2K-p)}{p}$$

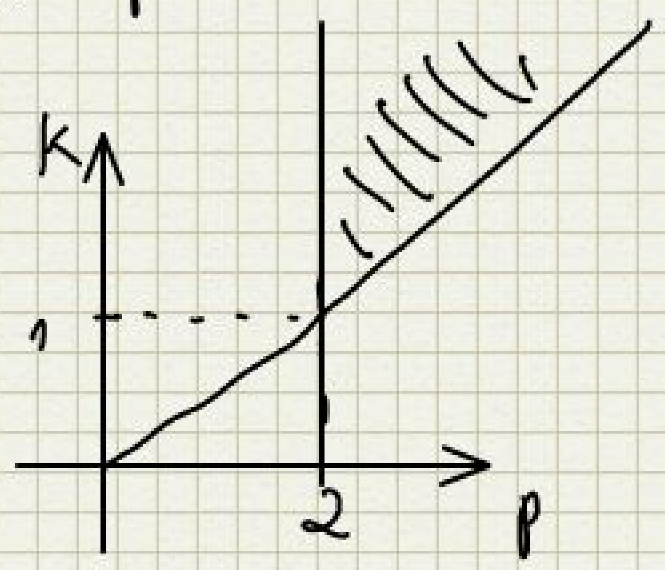
$$c_1 = \frac{\cancel{b_1}(2K-p) - p \cdot 0}{\cancel{b_1}}$$

$$b_1 > 0 \Rightarrow \frac{pK - 2K}{p} > 0 \Rightarrow K(p-2) > 0$$

$$p > 2$$

$$c_1 > 0 \Rightarrow 2K > p$$

$$K > p/2$$



b) $s = -\xi\omega_n \pm j\omega_d$

$$t_{s\,2\%} = \frac{4}{\xi\omega_n} = 5s \quad \therefore \quad \xi\omega_n = 0,8$$

$M_p = 16\%$

$$\xi = \sqrt{\frac{(\ln M_p)^2}{\pi^2 + (\ln M_p)^2}} \quad \therefore \quad \xi = 0,5038$$

$$\omega_n = \frac{0,8}{\xi} = 1,6 \text{ rad/s}$$

$$\omega_d = \omega_n\sqrt{1-\xi^2} \quad \therefore \quad \omega_d = 1,39 \text{ rad/s}$$

$$\boxed{s = -0,8 \pm j1,39}$$

$$FTMA = \frac{K(s+2)}{(s+p)} \cdot \frac{1}{(s-1)(s+2)}$$

Condição de fase

$$\angle FTMA = 180^\circ \pm n360^\circ$$

$$\angle s+2 - \angle s+p - \angle s-1 - \angle s+1 = 180^\circ \pm n360^\circ$$

$$\angle 1,2+j1,39 - \angle p-8+j1,39 - \angle -1,8+j1,39$$

$$- \angle 0,2+j1,39 = 180^\circ \pm n360^\circ$$

$$49{,}19° - \operatorname{arctg} \frac{1{,}39}{p-0{,}8} - (180° - 37{,}68°) - 81{,}81° =$$

$$= -174{,}94° - \operatorname{arctg} \frac{1{,}39}{p-0{,}8}$$

$$\operatorname{arctg} \frac{1{,}39}{p-0{,}8} = 5{,}06° \qquad \frac{1{,}39}{p-8} = \operatorname{tg} 5{,}06°$$

$$p - 0{,}8 = \frac{1{,}39}{\operatorname{tg} 5{,}06°} \quad \therefore \quad \boxed{p = 16{,}50}$$

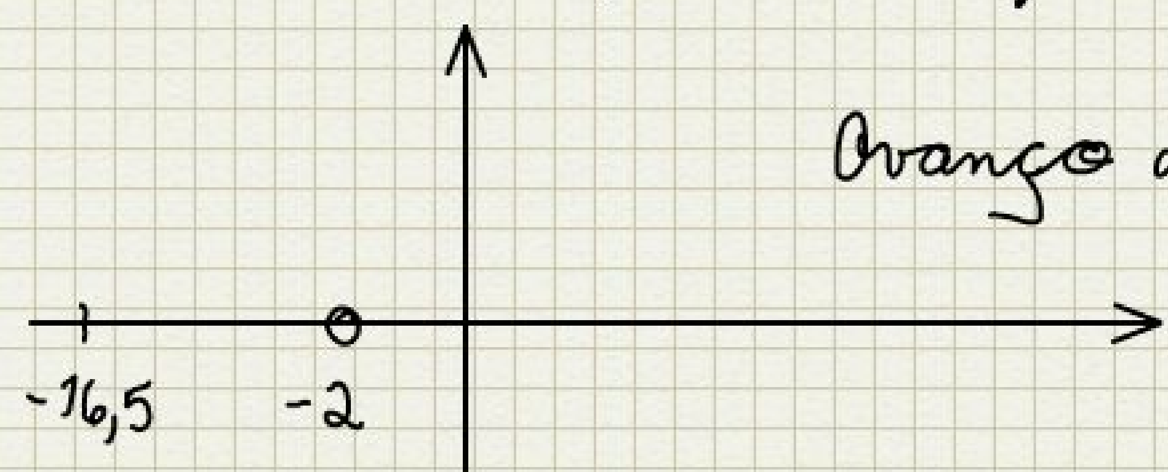
Condição de Ganho: (usar os módulos p/ o $s = -0{,}84 + j1{,}39$

FTMA = 1

$$\frac{K \cdot 1{,}84}{15{,}76 \cdot 2{,}27 \cdot 1{,}4} = 1 \quad \therefore \quad \boxed{K = 27{,}22}$$

$$G_c(s) = \frac{27{,}22\,(s+2)}{(s+16{,}5)}$$

c) Qual o tipo do Compensador?



Avanço de Fase

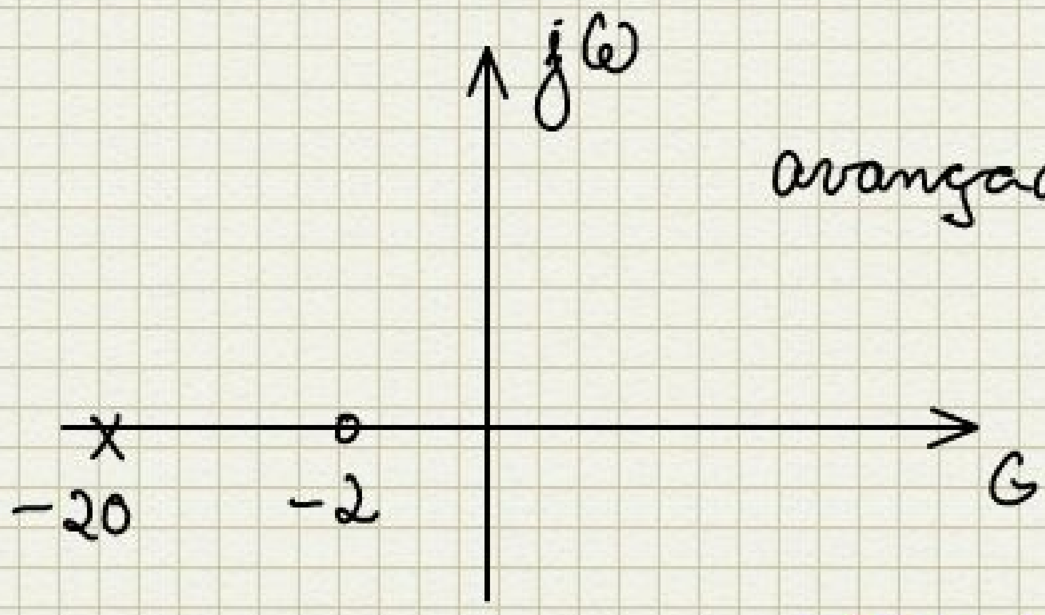
P2 - 2007 - Q2

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

$$G(s)G_c(s) = \frac{\left(\frac{1}{2}s+1\right)\cdot 10}{\left(\frac{1}{1}s+1\right)\left(\frac{1}{10}s+1\right)\left(\frac{1}{20}s+1\right)}$$

$$G_c(s) = \frac{\left(\frac{1}{2}s+1\right)}{\left(\frac{1}{20}s+1\right)}$$

a)



avançador de fase

b)

degrau

$$\underset{\substack{\uparrow \\ \text{TVF}}}{e_\infty =} \lim_{s\to 0} \cancel{s}\,\frac{1/\cancel{s}}{1+G}$$

$$e_\infty = \lim_{s\to 0} \frac{1}{1+G(s)} = \frac{1}{1+10} = \frac{1}{11}$$ sem compensador

$$e_\infty = \lim_{s\to 0} \frac{1}{1+G(s)G_c(s)} = \frac{1}{1+10} = \frac{1}{11}$$ com compensador

c) Pólos:

não compensado: $FTMF = \dfrac{G}{1+G}$

polos: $s = -5,5 \pm j\,8,93$

Compensado: $FTMF = \dfrac{G_c G}{1 + G_c G}$

$s = -1,8715$

$s = -14,5642 \pm j\,31,04$

$s = -\xi \omega_n \pm j\,\omega_d$

$\omega_d = \omega_n \sqrt{1-\xi^2}$

	Ñ C	C
ξ	0,524	0,4247
ω_n	10,48	34,3
ω_d	8,93	31,04
M_p	9,21	22,91
t_p	0,35	0,101
$t_{s\,2\%}$	0,727	0,1288

P2 - 2007 - Q1

$N = N_Z - N_P$ → polos no SPD da MF

↓ N_P ↳ polos no SPD da MA

nº de voltas entorno do $-1 + j0$ (sentido horário)

(+ / P)

$$\left.\begin{array}{l} N = +2 \\ N_P = 0 \end{array}\right\} N_Z = 2 \quad \text{(instável)}$$

horário

b) $K = 1$

MG - margem de ganho

$$MG = K = \frac{1}{\text{medida}} = \frac{1}{0{,}5} = 2 \quad \therefore \boxed{K > 2}$$

$$\left.\begin{array}{l} N = 0 \\ N_P = 0 \end{array}\right\} N_Z = 0 \quad \text{(estável)}$$

c) $\omega_\infty \to +\infty \to \angle -90°$

$\omega = 0^+ \to \angle +90°$

pólos na origem

zeros reais no SPE

$$\frac{(s+z_1)(s+z_2)}{s^3}$$

$$e_\infty = \lim_{s \to 0} s \frac{1/s^2}{1+G} = 0$$