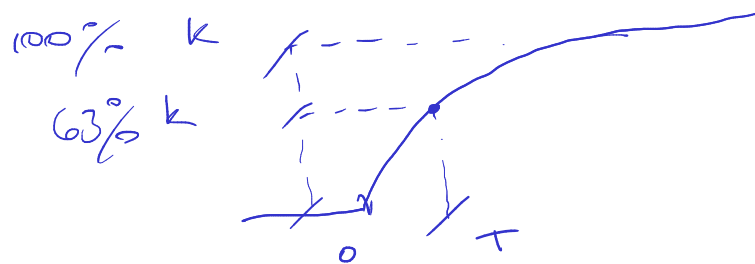


# Revisão de controle analógico:

$$G(s) = \frac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}$$

$$H(s) = \frac{k}{Ts + 1}$$

$k$  - ganho DC  
 $T \rightarrow$  cte tempo



$$k(1 - e^{-t/T})$$

$$t = T$$

$$k(1 - e^{-1})$$

$$\approx 0,63 \dots$$

2<sup>o</sup> ordem

2 reais  
 polos

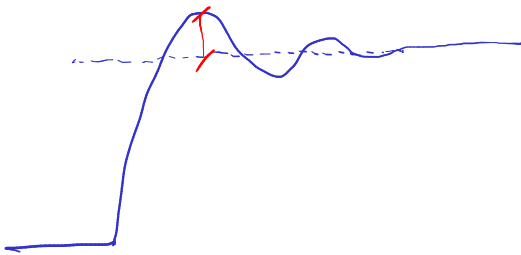
$\text{Im}(s) = 0$   
 em cima do eixo real  
 Sobreamortecido  
 $\zeta > 1$   
 0/ overshoot.

2 comp. conjugates.

$\text{Im}(s) \neq 0$   
subamort coils

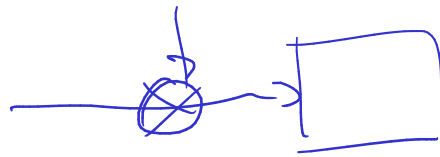
$$0 \leq \zeta < 1$$

overshoot.



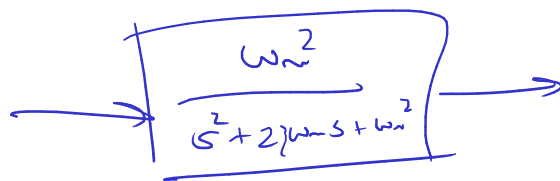
resp. as degree

part. additive



$$M_p = |\text{Max}(y) - 1|$$

$$U(s) = \frac{1}{s}$$



$$y(s)$$

$$0 < \zeta < 1$$

$$y(t) = 1 - e^{-\sigma t} \cos(\omega_d t + \phi)$$

$$s = -\sigma \pm j\omega_d$$

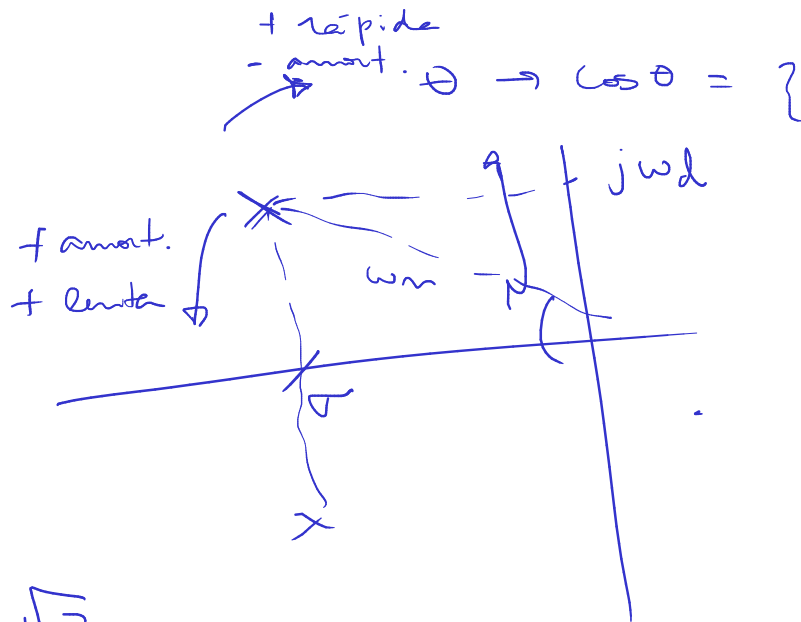
$$\rightarrow \begin{cases} \sigma = \zeta \omega_n \\ \omega_d = \omega_n \sqrt{1 - \zeta^2} \end{cases}$$

$$\phi = \angle \sigma + j\omega_d$$

$$M_p \rightarrow \frac{dy(t)}{dt} = 0 \rightarrow t_p \rightarrow M_p = y(t_p)$$

$$M_p = e^{-\frac{\pi \zeta}{\sqrt{1 - \zeta^2}}}$$

$$\zeta = \frac{\sqrt{2}}{2}$$



$$\zeta = \frac{\sqrt{2}}{2} \Rightarrow \sigma = \omega_d$$

$$G(s) = \frac{\omega_n^2}{(s + \sigma)^2}$$

$$X(s) = \frac{1}{s} \rightarrow$$

$$y(t) = \underline{R_1} e^{-\sigma_1 t} + \underline{R_2} e^{-\sigma_2 t} + \underline{1}$$

$$y(t) = 1 - e^{-\sigma t} \cos(\omega_d t + \phi)$$

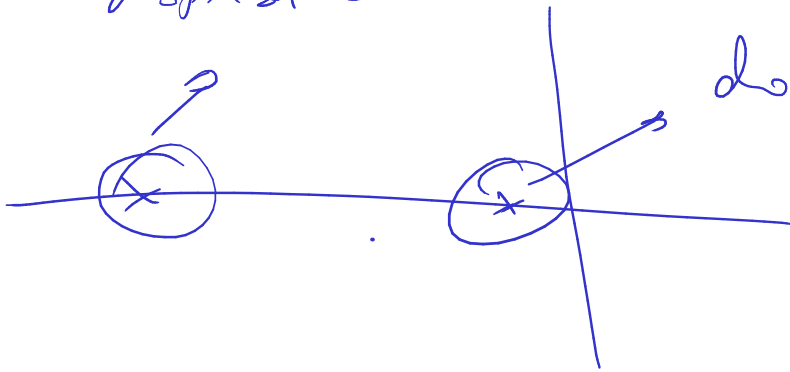
$$y(t) = \underset{\uparrow}{R_1} e^{-\sigma t} + \underset{\uparrow}{R_2} t e^{-\sigma t} + 1$$



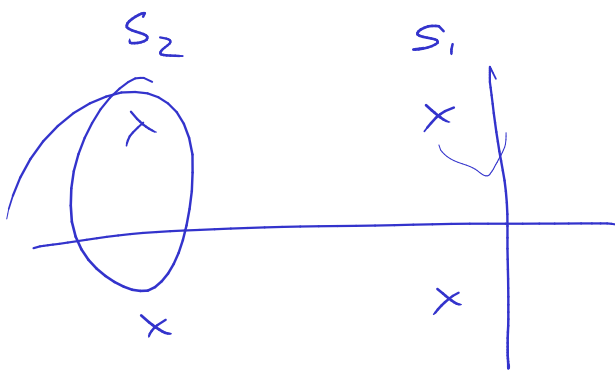
Mais de 2 poles?

desprezível

dominantes.

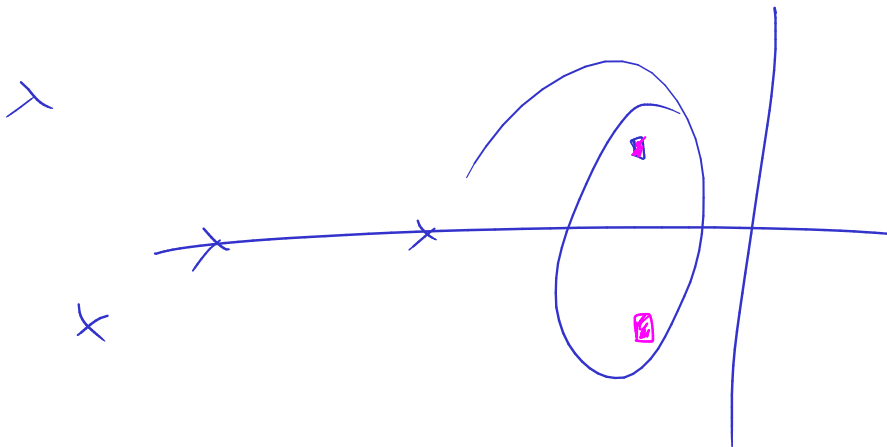


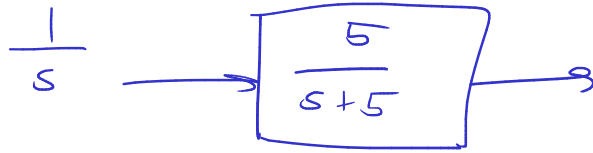
$$1 - \cancel{0.9}e^{-t} - 0.01e^{-100t} \approx 1 - e^{-t}$$



$$0 < \zeta < 1$$

$$y(t) = 1 - R_1 e^{-\sigma_1 t} \cos(\omega_1 t + \phi_1) - \cancel{R_2 e^{-\sigma_2 t} \cos(\omega_2 t + \phi_2)}$$





$$k = 1$$

$$T = 1/5 = 0,25$$

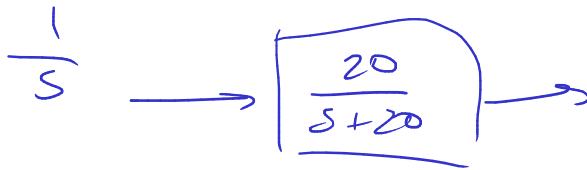
1<sup>st</sup> order

$$\left( \frac{k}{Ts + 1} \right)$$

$$\frac{5}{s+5} \cdot \frac{1/5}{1/5} = \frac{1}{\frac{s}{5} + 1}$$

$$y(t) = 1(1 - Re^{-5t})$$

$$= A - Be^{-5t}$$

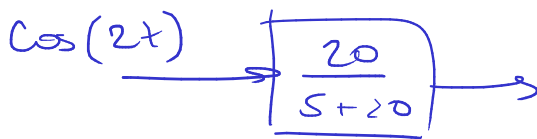


$$k = 1$$

$$\sigma = -20$$

$$T = 1/20$$

$$y(t) = A - Be^{-20t}$$



$$y(t) = Be^{-20t} + A \cos(2t + \phi)$$

$$A = 1 \cdot \left| \frac{20}{j \cdot 2 + 20} \right|$$

$$= 0,995$$

$$\phi = \angle \frac{20}{j2 + 20} = -5,7^\circ$$

$$\frac{20}{s+20}$$

$$\xrightarrow{s=j\omega}$$

$$\frac{20}{j\omega + 20}$$

$$\xrightarrow{\omega=2}$$

$$\frac{20}{j2 + 20}$$

$$\frac{2}{(s+2)(0s+1)}$$

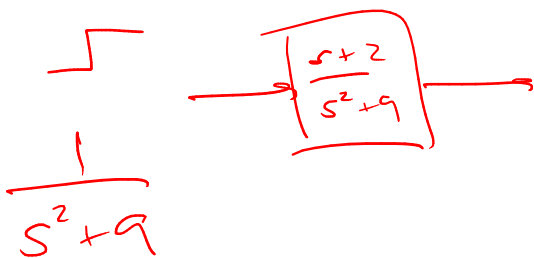
Sobre a mont.

$$-\frac{2}{s} = -\frac{1}{0} = -\infty$$

$$-3 \pm j 11,6$$

$$s^2 + 9 = 0$$

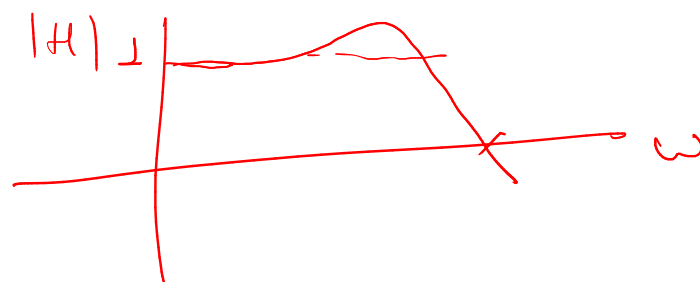
$$s = \pm \sqrt{-9} = \pm j 3$$

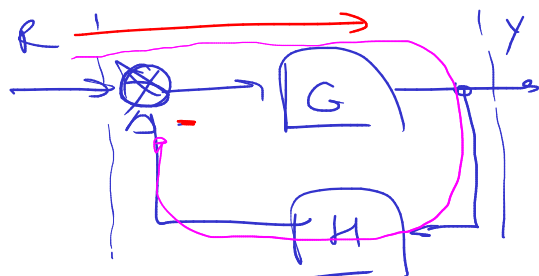
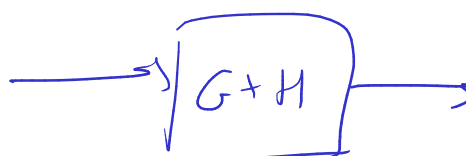
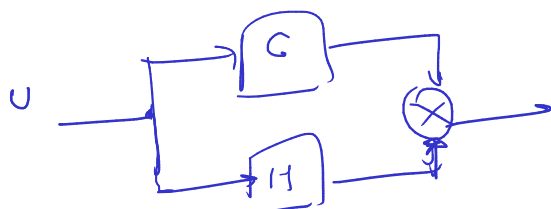
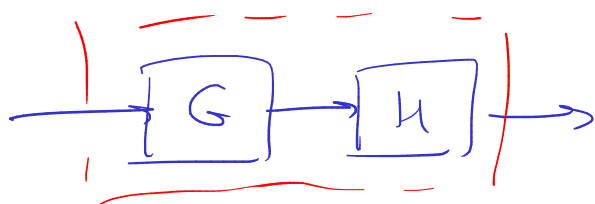
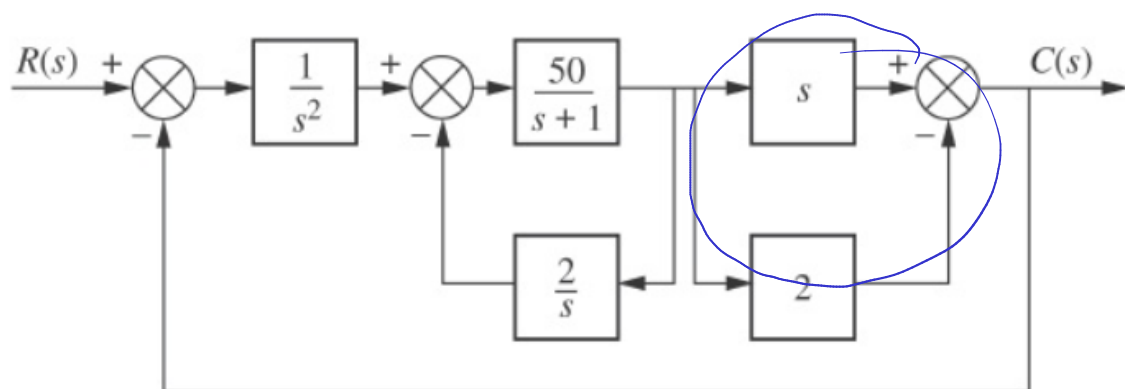


$$Y(s) = \frac{s+2}{(s^2+9)^2} \rightarrow y(t) = A_1 x \cos(3t + \phi)$$

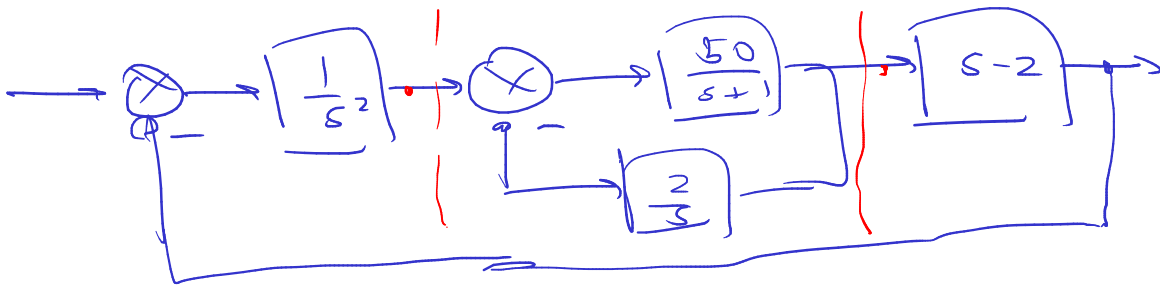
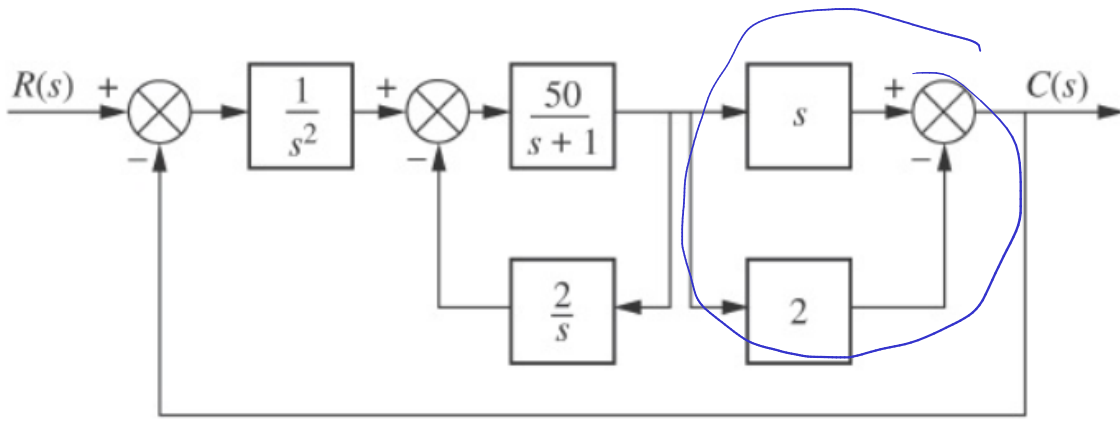
$$Y(s) = \frac{s+2}{(s^2+9)(s^2+36)} \rightarrow Y(t) = A \cos(3t + \phi) + B \cos(6t + \theta)$$

$$H(s) \rightarrow H(j\omega) \rightarrow |H(j\omega)| \quad 0 < \omega < \infty$$



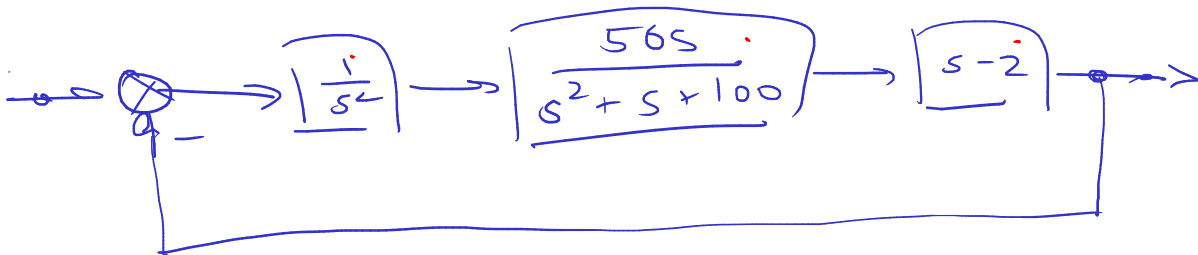


$$M = \frac{G}{1 + GH}$$



$$M_1(s) = \frac{\frac{50}{s+1}}{1 + \frac{50}{s+1} \cdot \frac{2}{s}} = \frac{50/s+1}{\frac{s(s+1)+100}{s(s+1)}}$$

$$= \frac{50}{s+1} \cdot \frac{s(s+1)}{s(s+1)+100} = \frac{50s}{s^2+s+100}$$



$$M_2(s) = \frac{\frac{1}{s^2} \cdot \frac{50s}{s^2+s+100} \cdot (s+2)}{1 + \frac{50s(s-2)}{s^2(s^2+s+100)}}$$



$$= \frac{50s(s-2)}{\cancel{s^2(s^2+s+100)}} \\ \hline \frac{s^2(s^2+s+100) + 50s(s-2)}{\cancel{s^2(s^2+s+100)}}$$

$$= \frac{50s(s-2)}{s^4 + s^3 + 100s^2 + 50s^2 - 100s}$$

$$= \frac{50\cancel{s}(s-2)}{\cancel{s^4} + \cancel{s^3} + 150s^2 - 100\cancel{s}} = \frac{50(s-2)}{s^3 + s^2 + 150s - 100}$$

