$t_m < 1\,s$

$\sigma_m < 10\%$

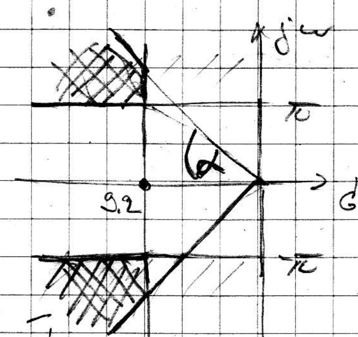
$t_{1\%} < 0.5\,s$

$t_m = \frac{\pi}{\omega_n\sqrt{1-\zeta^2}} < 1$ $\omega_n\sqrt{1-\zeta^2} > \pi$

$\sigma_m = 100\, e^{\frac{-\zeta\pi}{\sqrt{1-\zeta^2}}} < 10$

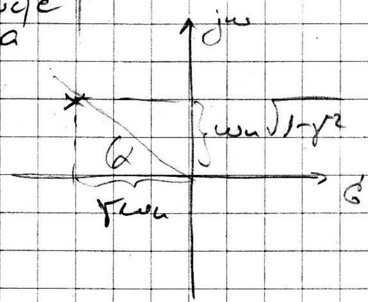
$\zeta = \frac{\ln\frac{100}{\sigma_m}}{\sqrt{\pi^2+\ln^2\frac{100}{\sigma_m}}}$

$\varphi = \arccos 0.5912$
$= 53^\circ$

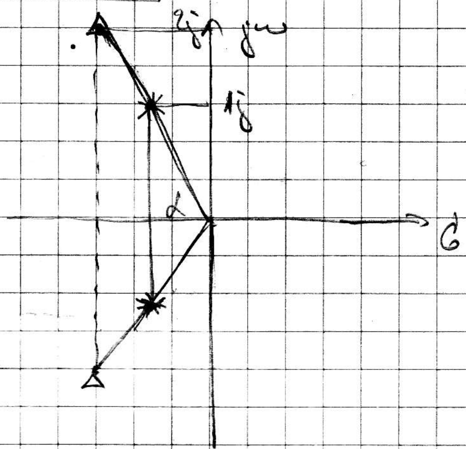


područje polova

$t_{1\%} = \frac{4.6}{\zeta\omega_n} < 0.5$ $\zeta\omega_n > 9.2$



$\boxed{\text{Zadatak}}$



$\alpha = 60^\circ$

$G_*(s)$
$G_\Delta(s)$

$\sigma \to$ nadvišenje

$\zeta_* = \zeta_\Delta \Rightarrow \boxed{\sigma_{m*} = \sigma_{m\Delta}}$

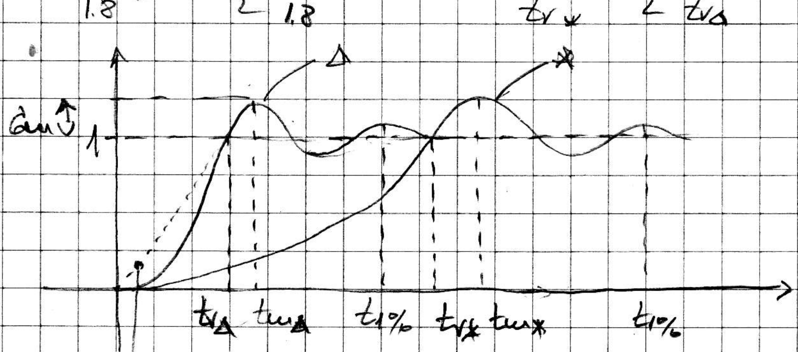
$(\omega_n\sqrt{1-\zeta^2})_* = \frac{1}{2}\,\omega_n(\sqrt{1-\zeta^2})_\Delta$ $/ : \pi$

$\frac{1}{t_{m*}} = \frac{1}{2}\, t_{m\Delta}$ $t_m = \frac{\pi}{\omega_n\sqrt{1-\zeta^2}}$

$\Rightarrow \boxed{t_{m*} = 2t_{m\Delta}}$

$(\zeta\omega_n)_* = \frac{1}{2}(\zeta\omega_n)_\Delta \Rightarrow \frac{1}{t_{1\%*}} = \frac{1}{2}\, t_{1\%\Delta}$ $t_{1\%} = 2t_{1\%\Delta}$

$\frac{\omega_n}{1.8}_* = \frac{1}{2}\frac{\omega_{n\Delta}}{1.8}$ $\frac{1}{t_{r*}} = \frac{1}{2}\frac{1}{t_{r\Delta}} \Rightarrow t_{r*} = 2t_{r\Delta}$



greška (ne smije biti ravna linija iz ishodišta)

Zadatak 3.

Funkcija procesa i regulator.

$$G(s) = \frac{1}{(s+5)(s-1)} \qquad G_R(s) = K_R \frac{1+T_i s}{T_i s} \qquad K_R>0,\ T_i>0$$

$$G(s) = G_R(s) \cdot G_p(s) \qquad \text{karak. jednadž.} \Rightarrow \quad 1+G_o(s)=0$$

$$T_i s(s+5)(s-1) + K_R(1+T_i s) = 0$$

$$\underset{a_3}{T_i s^3} + \underset{a_2}{4T_i s^2} + \underset{a_1}{T_i(K_R-5)s} + \underset{a_0}{K_R} = 0$$

① uvjet (nužan 8)

ako je a_3 (najveći član jednadž.) >0, svi ostali moraju biti veći od $\emptyset$

$$\left.\begin{array}{l} a_1>0 \\ T_i(K_R-5)>0 \\ K_R>5 \end{array} \quad K_R>0 \right\} \Rightarrow K_R>5$$

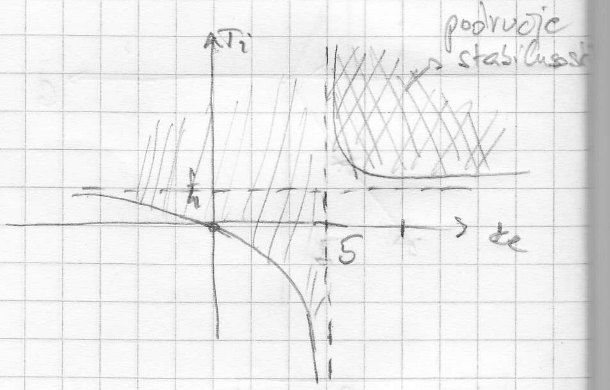
② uvjet ($D_n>0$)

$$D_i>0, \quad i=1 \ldots n-1 \qquad D_1 = \begin{vmatrix} a_1 & a_0 & 0 \\ a_3 & a_2 & a_1 \\ a_5 & a_4 & a_3 \end{vmatrix}$$

$$D_1 = a_1 > 0$$

$$D_2 = \begin{vmatrix} a_1 & a_0 \\ a_3 & a_2 \end{vmatrix} > 0 \qquad \begin{vmatrix} T_I(K_R-5) & K_R \\ T_I & 4T_i \end{vmatrix} > 0$$

$$4T_i^2(K_R-5) - K_R T_i > 0 \Rightarrow T_i > \frac{K_R}{4(K_R-5)}$$

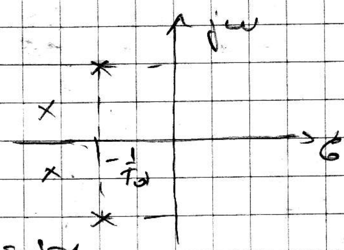


Zadatak

$$G_p(s) = k\,\frac{1-Ts}{(1+Ts)(T_1^2 s^2+1)} \qquad T = T_1 = 0.1\,s$$

Odredite podr. parametra **k** za koje dominant. vrem. konstan. zatvorenog kruga upravljanja s jediničnom povratnom vezom veća od 1s

Najveća vremenska konstanta je dominantna



karak. jednadžba:

$$1+G_o(s)=0$$

$$TT_1^2 s^3 + T_1^2 s^2 + T(1-k)s + k+1 = 0 \qquad s \to s-\frac{1}{T_d} = s-1$$

$T_d = 1$

$$TT_1^2 (s-1)^3 + T_1^2 (s-1)^2 + T(1-k)(s-1) + k+1 = 0$$

$T = T_1 = 0.1$

$$\underbrace{0.001}_{a_3} s^3 + \underbrace{0.007}_{a_2} s^2 + s\,\underbrace{(0.083-0.1k)}_{a_1} + \underbrace{0.909+1.1k}_{a_0} = 0$$

1) $a_3 > 0 \quad a_1 > 0 \Rightarrow k < 0.83$

$a_0 > 0 \Rightarrow k > -0.8264$ $\qquad -0.8264 \quad 0.83$

2) $D_1 = a_1 > 0$

$$D_2 = \begin{vmatrix} 0.083-0.1k & 0.909+1.1k \\ 0.001 & 0.007 \end{vmatrix} \Rightarrow k < -0.1822$$

$\Rightarrow k \in (-0.8264, -0.1822)$

$\boxed{\text{Zadatak}}$

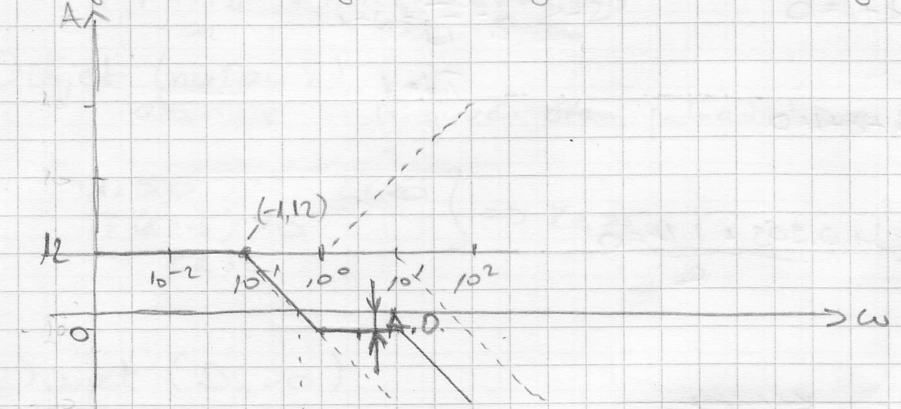
prijenosna otvorenog kruga

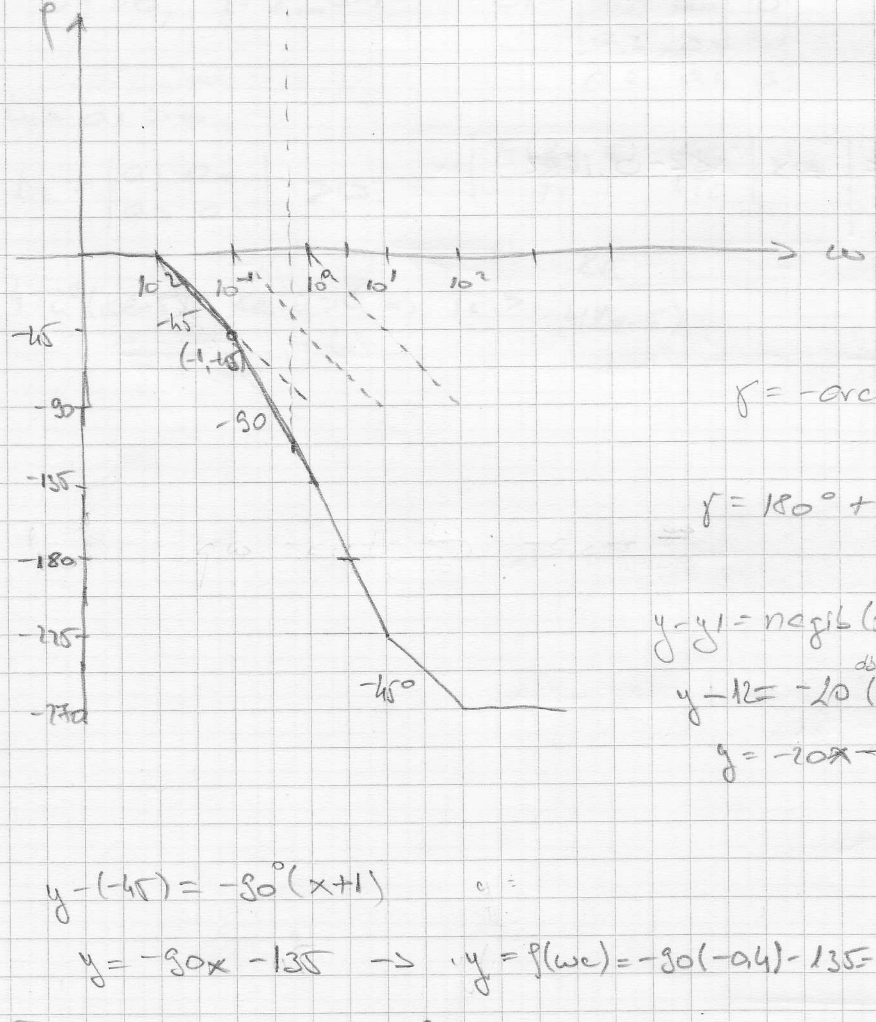
$G_o(s) = 4 \frac{1-s}{(1+10s)(1+0.1s)}$ Odredite ω_c, γ, ω_π, A_r koristeći jednadžbe pravaca. ↳A.O.

$$= 4 \frac{1-\frac{s}{10^0}}{\left(1+\frac{s}{10^{-1}}\right)\left(1+\frac{s}{10}\right)}$$

$$|G(j\omega)_{dB}| = 20\log 4 + 20\log\sqrt{1+\left(\frac{\omega}{10^0}\right)^2} - 20\log\sqrt{1+\left(\frac{\omega}{10^{-1}}\right)^2} - 20\log\sqrt{1+\left(\frac{\omega}{10}\right)^2}$$

$A = 20\log 4 \approx 12$





$\gamma = -\operatorname{arctg}\omega - \operatorname{arctg}\frac{\omega}{10^{-1}} - \operatorname{arctg}\frac{\omega}{10}$

$\gamma = 180° + \varphi(\omega_c)$

$y - y_1 = \text{nagib}(x - x_1)$

$y - 12 = \overset{dB/dek}{-20}(x - (-1))$

$y = -20x - 8$

$\omega_c\ (y=0)$ $\quad 0 = -20x - 8$

$8 = -20x$

$x_c = -\frac{8}{20} = -\frac{2}{5} = -0.4$

$\omega_c = 10^{-0.4} \approx 0.4$ rad/s

$y - (-45) = -90°(x+1)$

$y = -90x - 135 \rightarrow y = \varphi(\omega_c) = -90(-0.4) - 135 = -99°$

F.O. $= 180° - 99° = 81°$

A.O.

$\varphi = -180° \Rightarrow x = 0.5$

$\omega_\pi = 10^{0.5} \approx 3.16$ rad/s

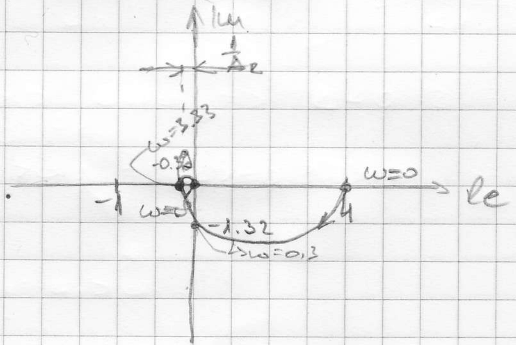
A.O. $= 8$ dB

$\boxed{\text{Zadatak}}$

$$G_o(s) = 4\,\frac{1-s}{(1+10s)(1+0.1s)}$$ Nyquist

$$G_o(j\omega) = 4\,\frac{1-j\omega}{(1+10j\omega)(1+0.1j\omega)} = 4\,\frac{1-j\omega}{(1-\omega^2+j(10.1\omega))}\cdot\frac{1-\omega^2-j(10.1\omega)}{1-\omega^2-j(10.1\omega)} = 4\,\frac{1-11.1\omega^2+j\omega(-11.1+\omega^2)}{(1-\omega^2)^2+(10.1\omega)^2}$$

$$\mathrm{Im}(G_o(j\omega)) = \frac{4\,\omega(\omega^2-11.1)}{(1-\omega^2)^2+(10.1\omega)^2} \qquad \mathrm{Re} = 4\,\frac{1-11.1\omega^2}{(1-\omega^2)^2+(10.1\omega)^2}$$



$\omega = 0 \Rightarrow \mathrm{Re} = 4$
$\mathrm{Im} = 0$

$\omega = \infty \Rightarrow \mathrm{Re} = 0$
$\mathrm{Im} = 0$

$\mathrm{Re} = 0 \Rightarrow \omega^2 = \frac{1}{11.1} \Rightarrow \omega = 0.3$ $\qquad \mathrm{Im}(\omega = 0.3) = -1.32$

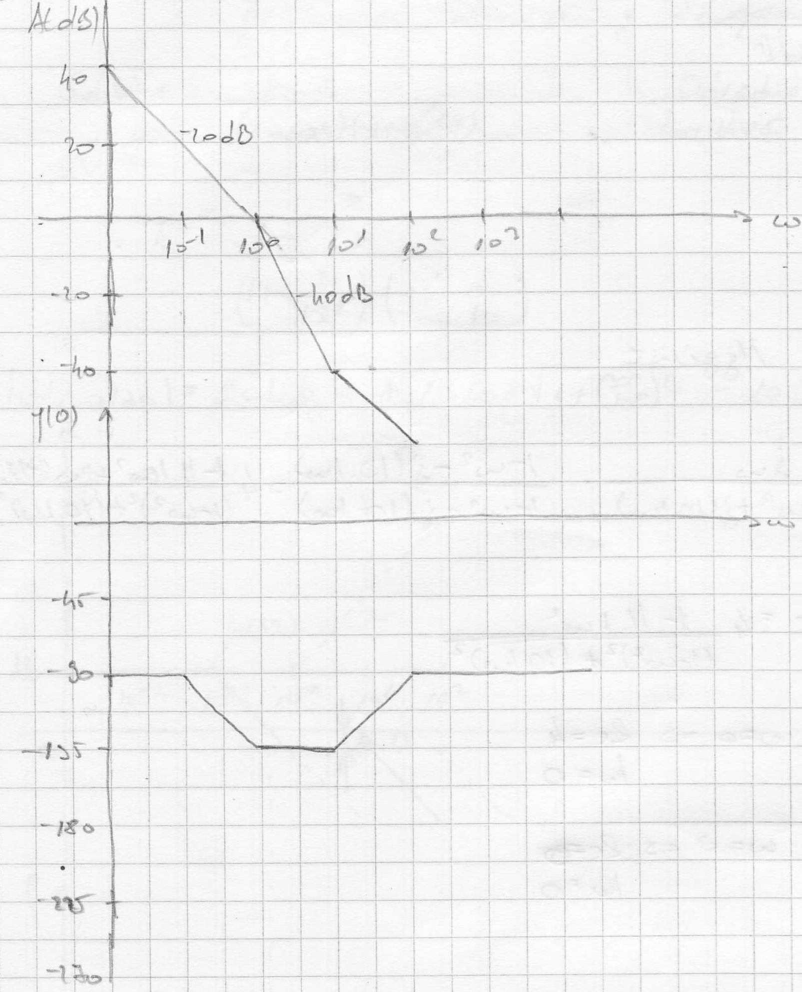
$\mathrm{Im} = 0 \Rightarrow \omega^2 = 11.1 \Rightarrow \omega = 3.33$ $\qquad \mathrm{Re}(\omega = 3.33) = -0.3961$

$\omega_\pi(-180°) = 3.33$ rad/s $\qquad$ sustav stabilan jer ne zaokružuje Re(-1)

$\frac{1}{A_R} = 0.3961$ $\qquad A_R = 2.5246$

$A = 20\log A_R = 8.04$ dB

Zadatak



$$G(s) = \frac{10^0}{s} \cdot \frac{1}{1 + \frac{s}{10^0}} \cdot \frac{1 + \frac{s}{10^1}}{1}$$

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