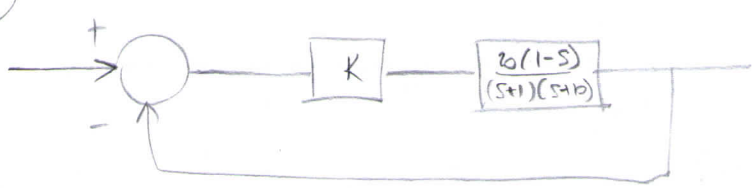
AUPR - AV. 23.1.'14.

1



odrediti K za koji je sustav na rubu stabilnosti

K = 1
K = 2
K = ?

$$G_0 = K\,\frac{20(1-s)}{(s+1)(s+10)}$$

$$G_0(j\omega) = \overbrace{\frac{20K(10-12\omega^2)}{(\omega^2+10)^2+(11\omega)^2}}^{Re} + j\,\overbrace{\frac{20K(\omega^3-21\omega)}{(\omega^2+10)^2-(11\omega)^2}}^{Im}$$

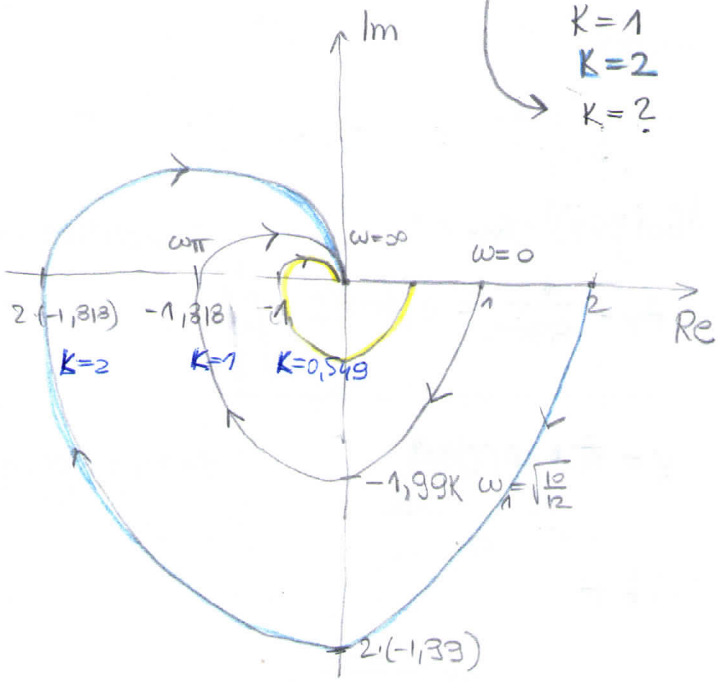
$\omega = 0$	$\omega = \infty$
$Re(0) = 2K$	$Re(\infty) = 0$
$Im(0) = 0$	$Im(\infty) = 0$

$Re(\omega_1) = 0 \rightarrow \omega_1 = \sqrt{\frac{10}{12}}$

$Im(\omega_1) = K \cdot (-1{,}99)$

$Im(\omega_2) = 0 \rightarrow \omega_2 = \sqrt{21} = \omega_\pi$

$Re(\omega_2) = -1{,}8184K$



Rub stabilnosti

$Re(\omega_\pi) = -1$

$Im(\omega_\pi) = 0$

$\omega_\pi = \sqrt{21}$

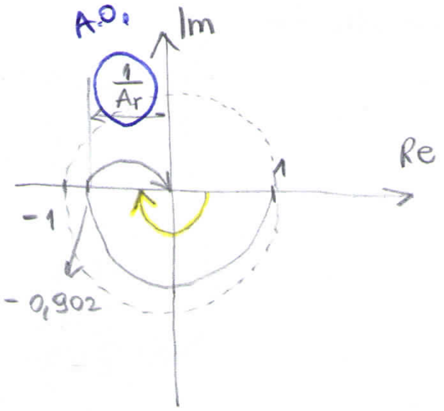
$$-1 = \frac{20K(10-21\omega^2)}{(\qquad)(\qquad)}$$

K=0,549

②

A.O i F.O

$K=0{,}5$ stabilnost sustava?



$|G_0(j\omega_\pi)| \cdot A_r = 1$ amplitudno osiguranje

$A_r = \frac{1}{0{,}902} = 1{,}1086$

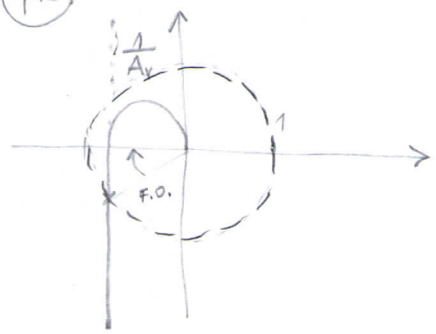
$\gamma = \pi + \underbrace{\varphi(\omega_c)}_{0}$ fazno osiguranje

! ω_c - presječna frekv.

$|G_0(j\omega_c)| = 1$

$\gamma = \pi$

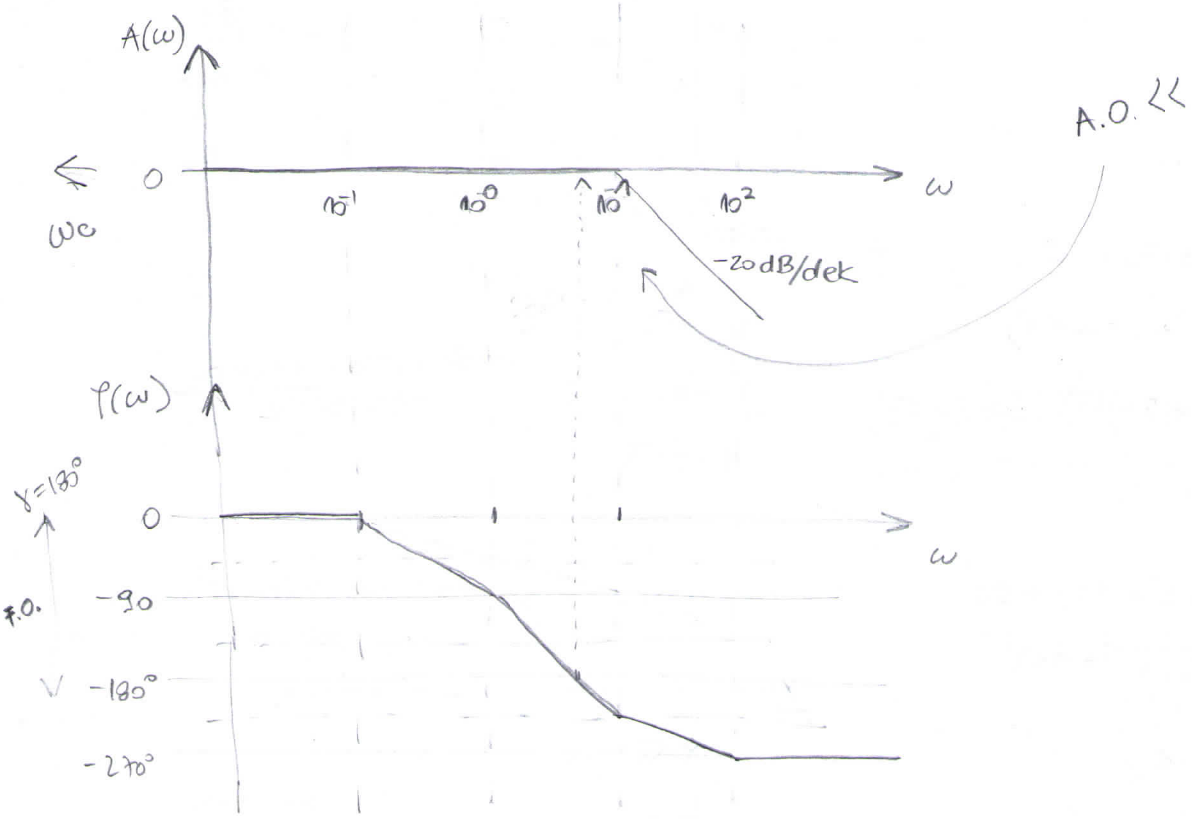
PR



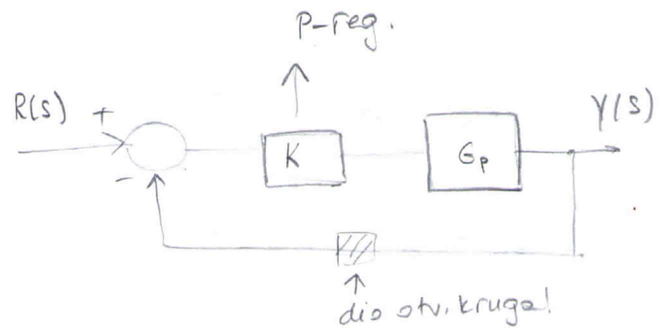
3.

$$G_0 = \frac{20(1-s)}{(s+1)(s+10)} \cdot 0{,}5 = \frac{10(1-s)}{(s+1)(s+10)}$$

$$G_0(j\omega) = \frac{1 - \frac{j\omega}{10}}{\left(\frac{j\omega}{10^2}+1\right)\left(\frac{j\omega}{10}+1\right)}$$



(4.) PID ; ZN1 metoda ↘ Rub stabilnosti



$$G_p = \frac{4}{(s+1)(s+2)(s+3)}$$

$K_{krit} = ?$

$$G_o = K_{krit} \cdot G_p = \frac{K \cdot 4}{(s+1)(s+2)(s+3)}$$

$\boxed{1 + G_o(s) = 0}$ karakteristična jednadžba

$(s+1)(s+2)(s+3) + 4 \cdot K =$

$$\alpha_z(s) = \underset{a_3}{s^3} + \underset{a_2}{6s^2} + \underset{a_1}{11s} + \underbrace{6+4K}_{a_0} = 0$$

I $\quad 6+4K > 0$

$K > -\frac{3}{2}$

II $\quad \begin{vmatrix} a_1 & a_0 \\ a_3 & a_2 \end{vmatrix} > 0$

$K < 15$

sustav stabilan za

$K \in \langle -\frac{3}{2}, 15 \rangle$

⇓

kritična pojačanja

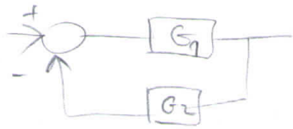
$K_{KR} = -\frac{3}{2}$

$G_z = \frac{G_0}{1+G_0} = \dots$

$\alpha_z(s) = s^3 + 6s^2 + 11s$

$= s(s^2 + 6s + 11)$

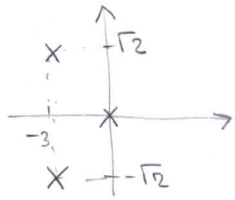
$= s(s+3+j\sqrt{2})(s+3-j\sqrt{2})$



← dir. gr.

$G_z = \frac{G_1}{1+\underbrace{G_1 G_2}_{G_0}}$

polovi

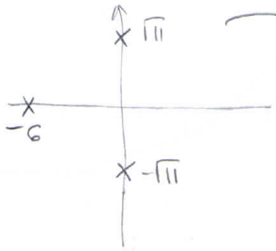


→ sustav nema oscilacije

$\boxed{K_{KR} = 15}$ ✓

$\alpha_z(s) = s^3 + 6s^2 + 11s + 66$

$= (s+6)(s^2+11)$



→ konjugirano-kompl. par polova

– oscilacije ✓

perj. pojava

trajne osc.

$\boxed{G_z = \frac{60}{(s+6)(s^2+11)}} = \frac{A}{s+6} + \frac{Bs+C}{s^2+11} \dots$

$A = \frac{60}{47}$

$B = -\frac{60}{47}$

$C = \frac{360}{47}$

$g(t) = \frac{A}{6} \cdot e^{-6t} + B\cos(\sqrt{11}t) + \frac{C}{\sqrt{11}} \sin(\sqrt{11}t)$

$\boxed{\omega_{kr} = \sqrt{11}}$

$\boxed{T_{KR} = \frac{2\pi}{\omega_{kr}} = \frac{2\pi}{\sqrt{11}}}$

PID regulator

$$\boxed{\begin{aligned} K_R &= 0{,}6 \cdot K_{KR} \\ T_I &= 0{,}5 \cdot T_{KR} \\ T_D &= 0{,}12 \cdot T_{KR} \end{aligned}}$$

... crtanje PID regulatora ... struktura

5. PID - ZN2 - prijelazna funkcija? procesa

$$G_p(s) = \frac{4}{(s+1)(s+2)(s+3)}$$

$$H(s) = \frac{1}{s} \cdot G_p(s) = \frac{4}{s(s+1)(s+2)(s+3)} = \frac{A}{s} + \frac{B}{s+1} + \frac{C}{s+2} + \frac{D}{s+3}$$

$A = \frac{2}{3}$
$B = -2$
$C = 2$
$D = -\frac{2}{3}$

$$h(t) = A + Be^{-t} + Ce^{-2t} + De^{-3t}$$

$$\dot{h}(t) = 2e^{-t} - 4e^{-2t} + 2e^{-3t}$$

$$\ddot{h}(t) = -2e^{-t} + 8e^{-2t} - 6e^{-3t} = 0$$

točka infleksije

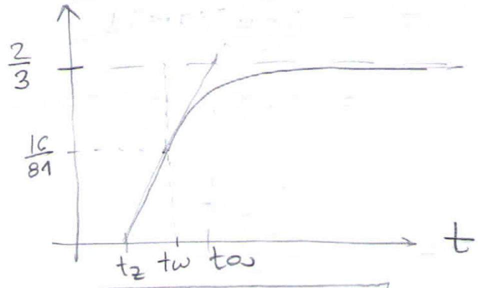
$$-2x + 8x^2 - 6x^3 = 0$$

$$x = e^{-t_w}$$

$t_w = \infty$

$t_w = 0$

$\boxed{t_w = \ln 3}$ ✓



$$\boxed{G = \frac{K_p}{1+T_a s} e^{-sT_z}}$$ aproks.

$\boxed{K_p = \frac{2}{3}}$ za $s = 0$

pojačanje u stacionarnom stanju $(t = \infty)$

$$h(t_w) = \frac{16}{81}$$

$$\dot{h}(t_w) = \frac{8}{27} \quad \text{- nagib}$$

$$y - y_1 = a(x - x_1)$$

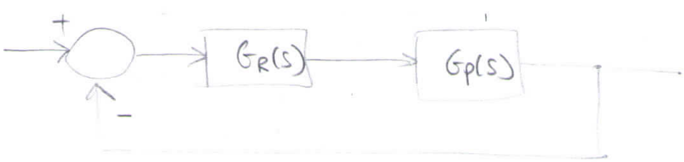
$$y - \frac{16}{81} = \frac{8}{27}(x - \ln 3)$$

$$y = 0 \rightarrow x = \boxed{\ln 3 - \frac{2}{3} = t_z}$$

$$y = \frac{2}{3} \rightarrow x = \frac{19}{12} + \ln 3 = t_z + t_a \Rightarrow \boxed{t_a = \frac{9}{4}}$$

zbirka

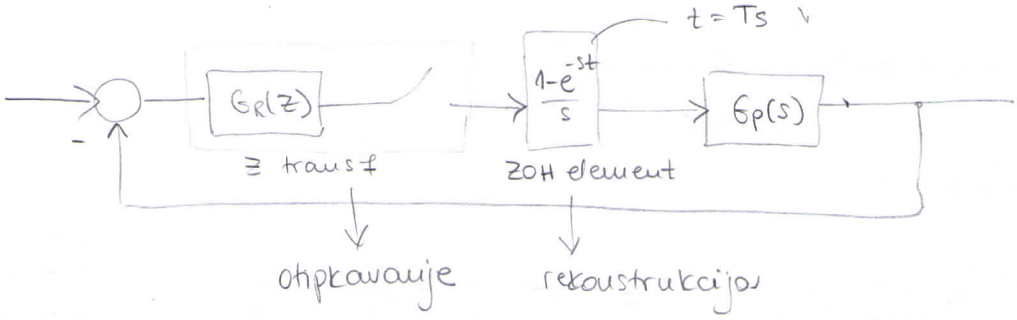
6.



$$G_R(s) = 0{,}7\,\frac{1+s}{s}$$

$$G_p(s) = \ldots$$

... diskretizacija



$$G_R(z) = \mathcal{Z}\{G_R(s)\}$$

$$G_P(z) = \cancel{ZOH\{G_P(s)\}}$$

$$= (1-z^{-1})\,\mathcal{Z}\left\{\frac{1}{s}G_P(s)\right\}$$

ZOH $\quad \dfrac{1-e^{-sT}}{s} \approx e^{-s\frac{T}{2}}$ kašnjenje

$$\boxed{\begin{aligned} \left|G_0 \cdot e^{-s\frac{T}{2}}\right| &= |G_0| \\ \varphi &= \varphi_0 - \omega\frac{T}{2} \end{aligned}}$$ → promjena faze

F.O. $\quad \gamma = 180° + \varphi - \omega_c\frac{T}{2}$ $\quad$ fazno osiguranje ↓

$\sigma = 70 - \gamma$ $\quad$ nadvišenje ↑