AUTOMATSKO UPRAVLJANJE

MASOVNE INSTRUKCIJE

- USMENI ISPIT

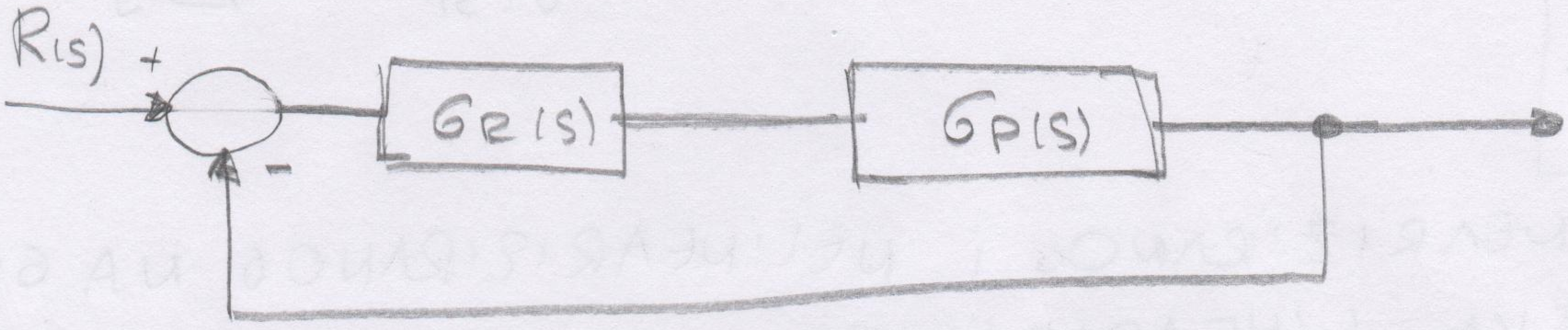
DATUM: 13. 02. 2012

AUTOR: CyRoZ

PREDAVAO: VENOMX

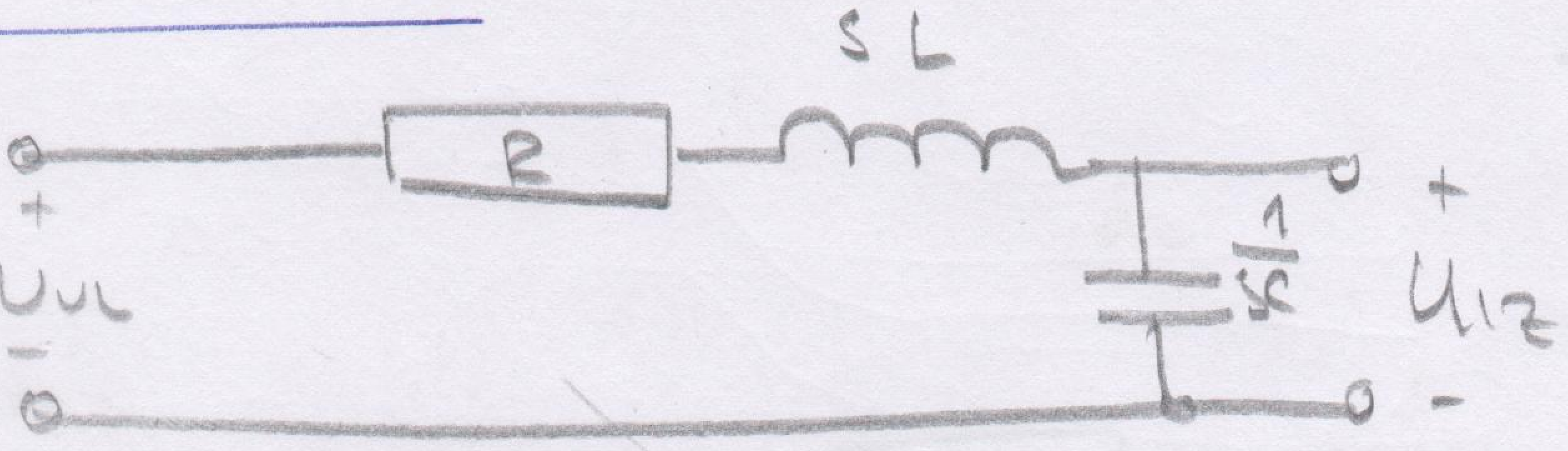
AK. GOD 2011/2012

AUTOMATSKO UPRAVLJANJE



• POVRATNA VEZA – RADI SUSTAV STABILNIM
– RADI REGULACIJE

LABOS 1



• OVO SU LINEARNI ELEMENTI

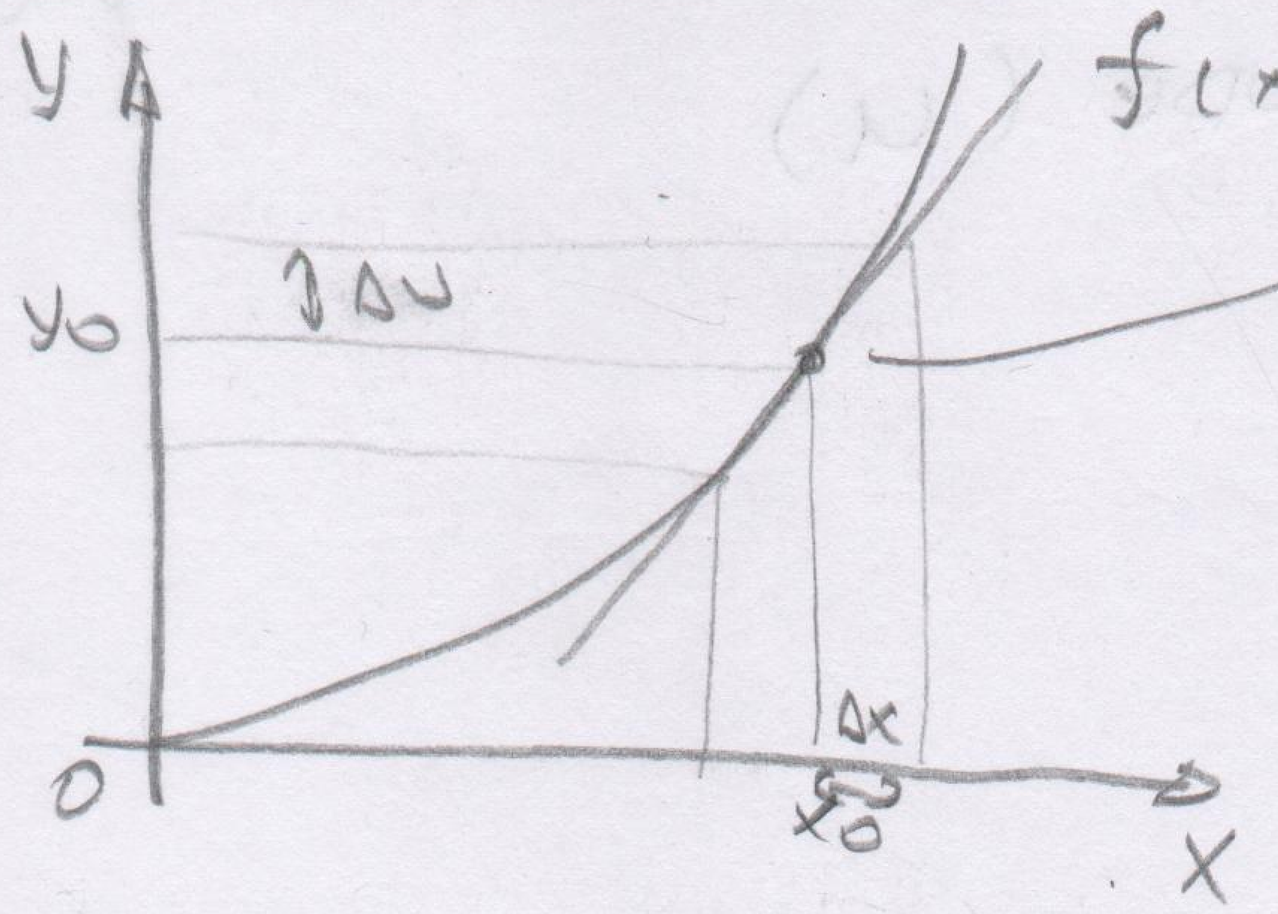
• DOBIMO DIF. JEDNADŽBE

$$\underbrace{\underbrace{\ddot{y} + \dot{y} + y = k\dot{u}}_{\text{LINEARAN SUSTAV}} + \sqrt{\dot{u}}}_{\text{NELINEARNI SUSTAV}}$$

$\boxed{\sin \dot{u}}$
↳ LINEARAN ILI NELINEARAN?

UVJETI LINEARNOSTI: ADITIVNOST $f(x_1+x_2) = f(x_1) + f(x_2)$
HOMOGENOST $f(\alpha x) = \alpha f(x)$

• LINEARIZACIJA –



$f(x) \Rightarrow$ AKO ZUMIRAMO: $x_0 = X_0 + \Delta X$

$f = f_0 + \Delta X$

$y = f_0(x_0 + \Delta x) + k\Delta X$

TAYLOROV RED

$k = \frac{dy}{dx}\Big|_{x_0}$

• TA

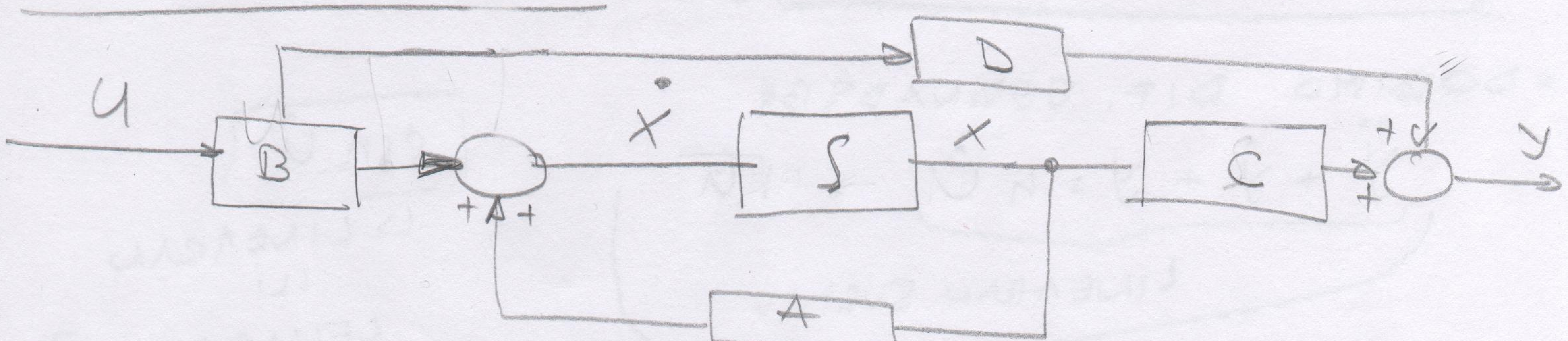
LABOS 2

$$\boxed{G(s) = \frac{Y(s)}{U(s)}}$$

$Y(s) \bullet\!\!-\!\!\circ\ \Delta Y$

- RAZLIKA LINEARIZIRANOG I NELINEARIZIRANOG NA GRAFU JE POGREŠKA LINEARIZACIJE
- AKO SE POMAKNEMO IZ RADNE TOČKE GUBIMO LINEARIZACIJU
- JEDNADŽBE STANJA

$$\dot{x} = Ax + Bu$$
$$\dot{y} = Cx + Du$$



C - IZLAZNE JEDNADŽBE - KAKO ĆE Y OVISITI O X

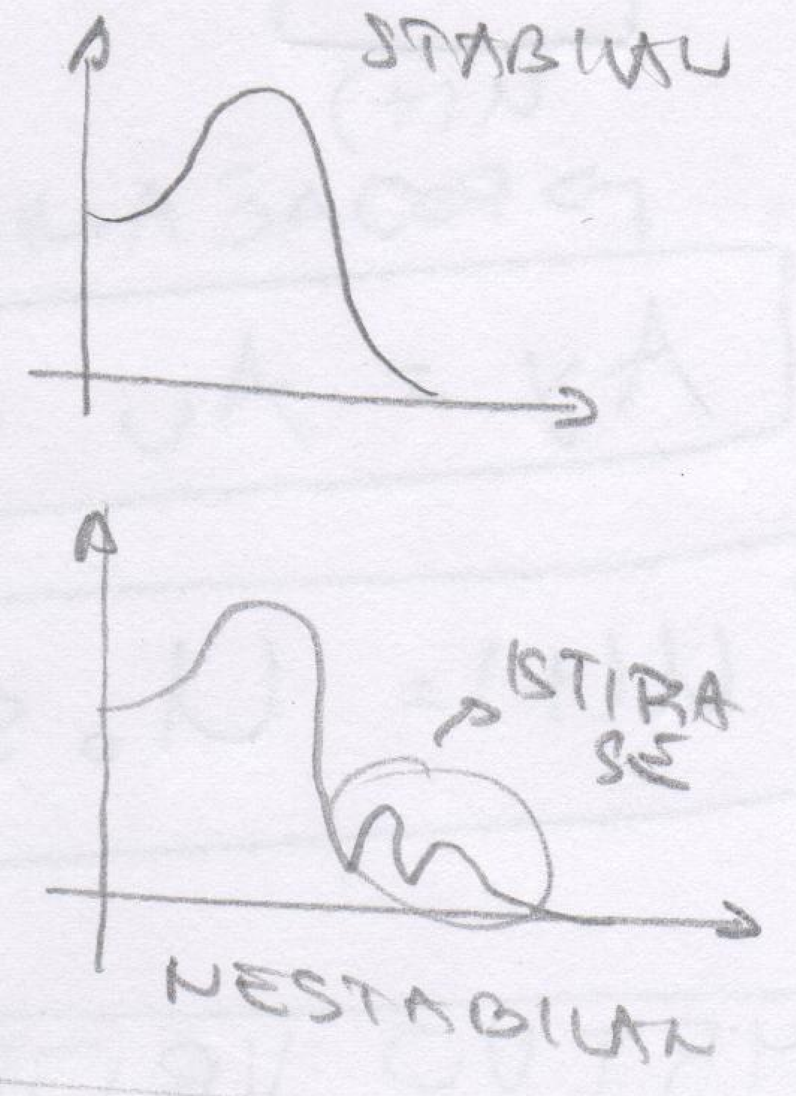
D - PROSLJEĐUJE ULAZ NA IZLAZ

A - VLASTITO VLADANJE, PRIRODNI ODZIV NA POČ UVJETE

B - OPIS VLADANJA VANJSKE POBUDE (U)

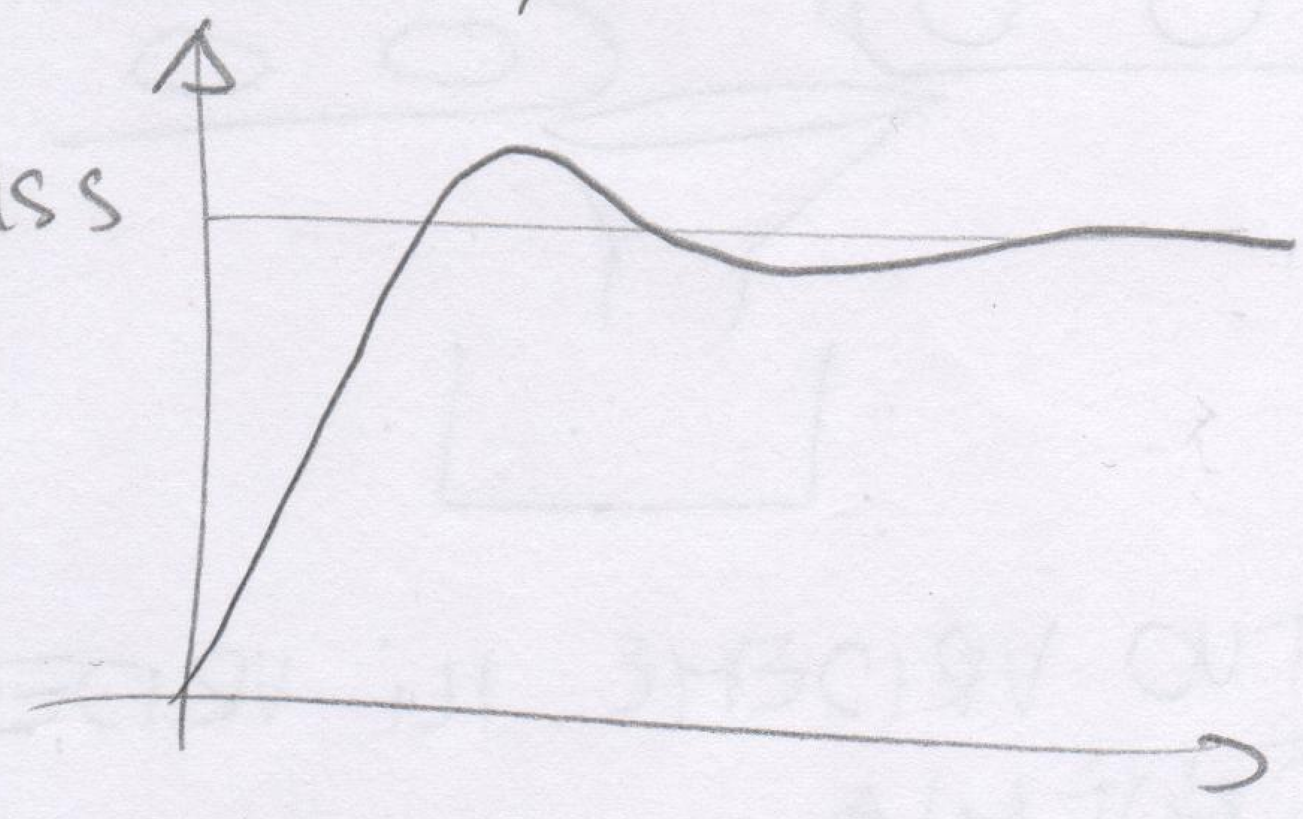
• FREKVENCIJSKA DOMENA I STABILNOST

• TEŽINSKA FUNKCIJA $g(t)$ – $u = \delta(t)$



• PRIJELAZNA FUNKCIJA – $h(t)$ $u = \mu(t)$

$$\boxed{G(s) = s \cdot H(s) \;\bullet\!\!-\!\!\circ\; g(t) = \dot{h}(t)}$$



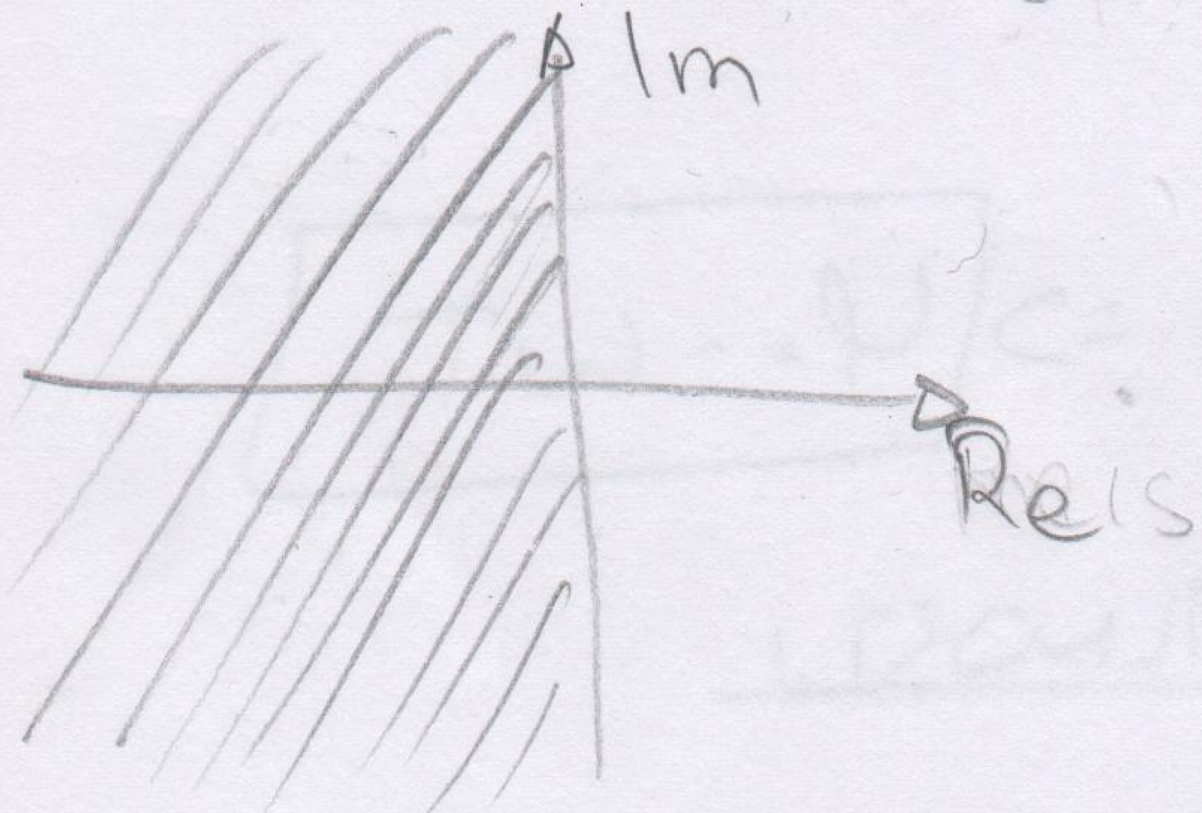
$$h(\infty) = \lim_{s \to 0} sH(s)$$

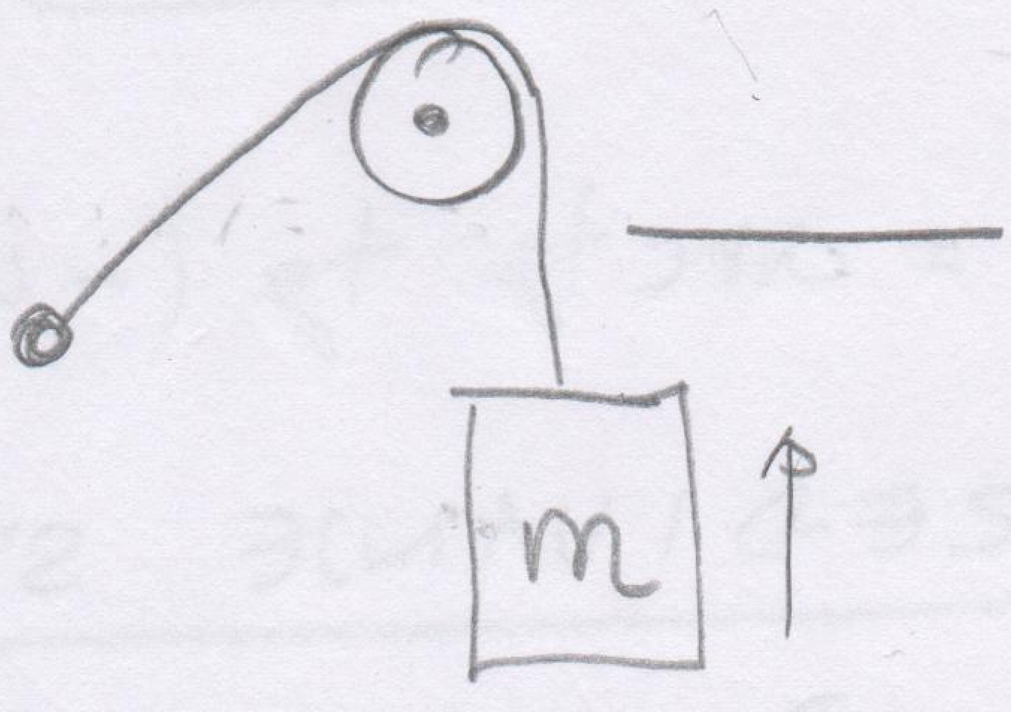
$$h(0) = \lim_{s \to \infty} sH(s)$$

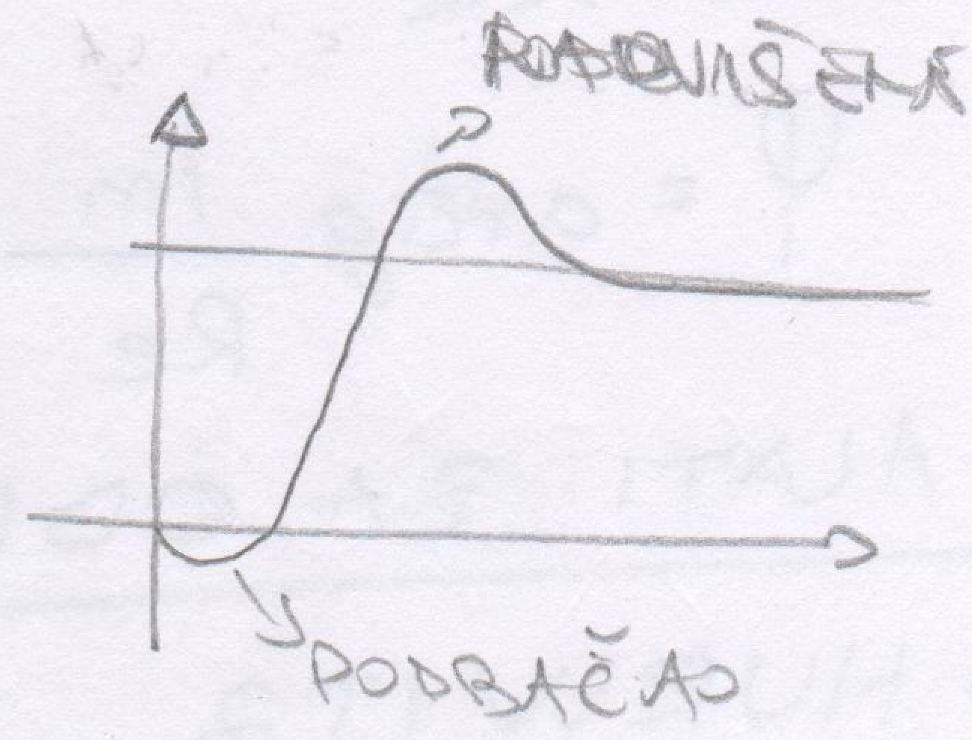
• STABILNOST

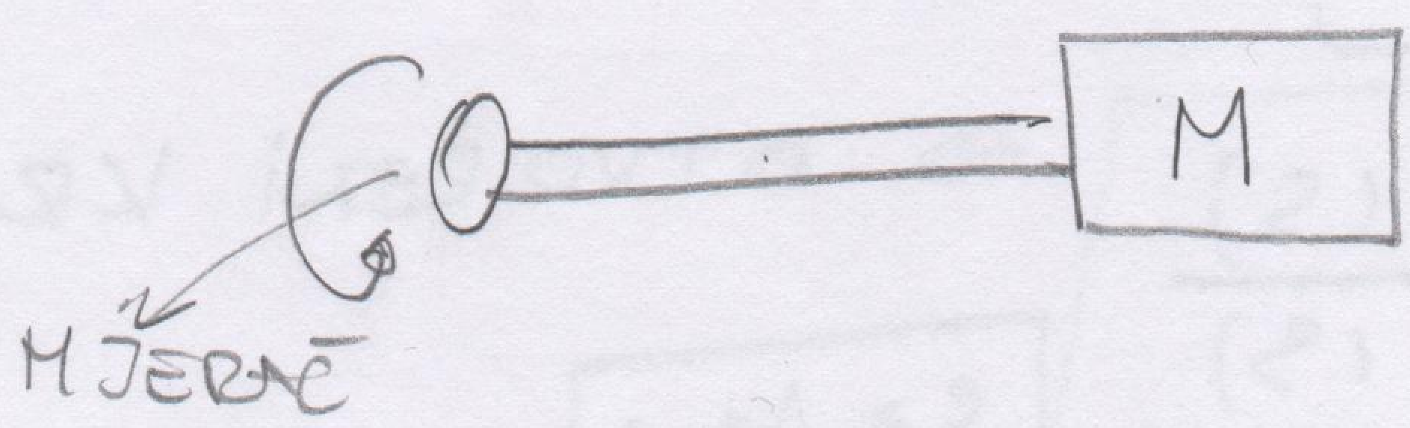
• NULE I POLOVI TREBAJU BITI U LIJEVOJ POLURAVNINI

• TO NE VRIJEDI KAD IMAMO PROMJENU U FAZI POLA I NULE

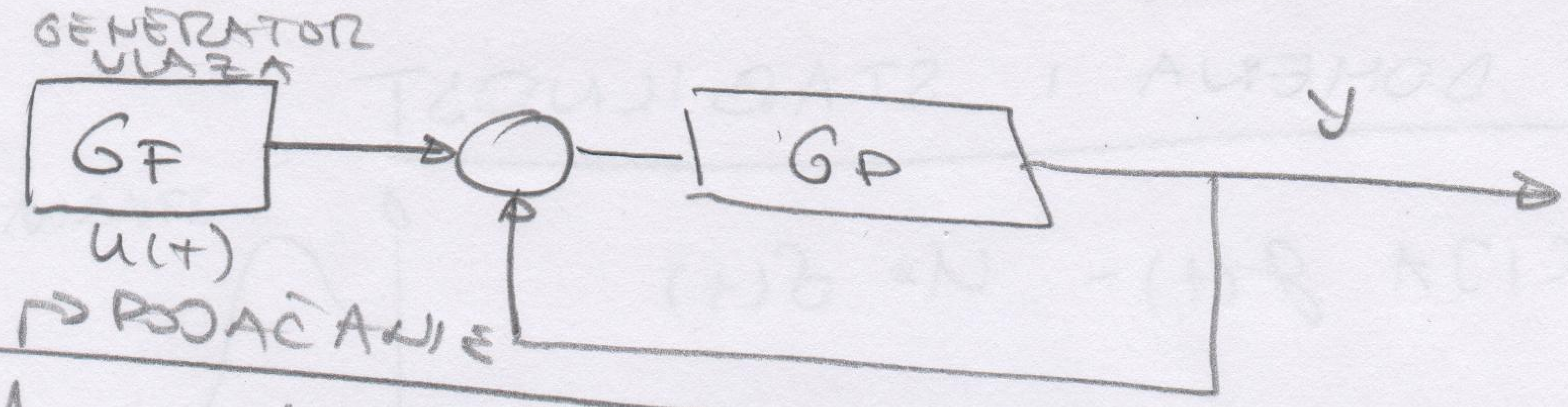








• NE OKREĆE SE MJERAČ ODMAH, NEGO SE DOGAĐA TORZIJA, TO JE PODBAČAJ!!!



→ POJAČANJE

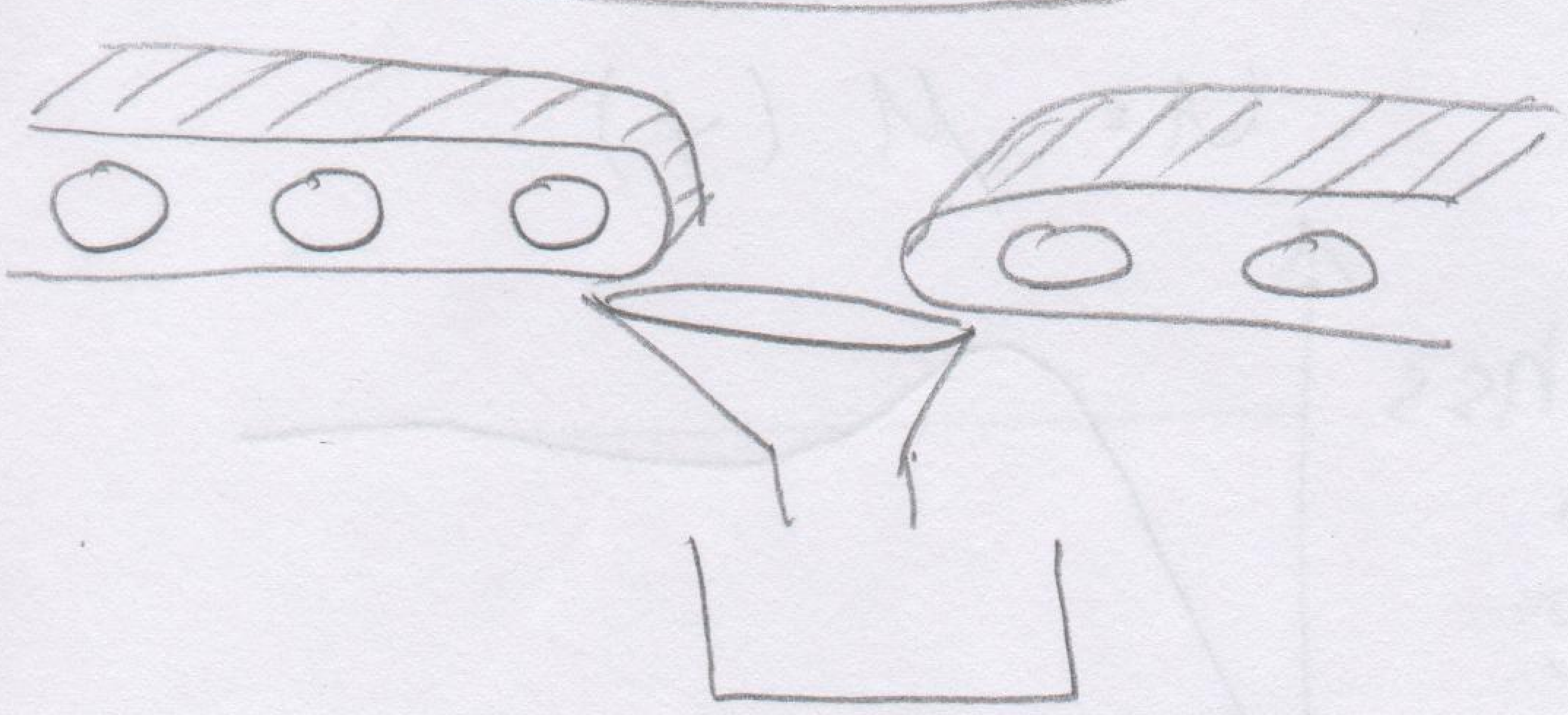
$$\boxed{A_y = A_U \cdot A_G}$$

$$\boxed{u(t) = U_0 \sin \omega t}$$

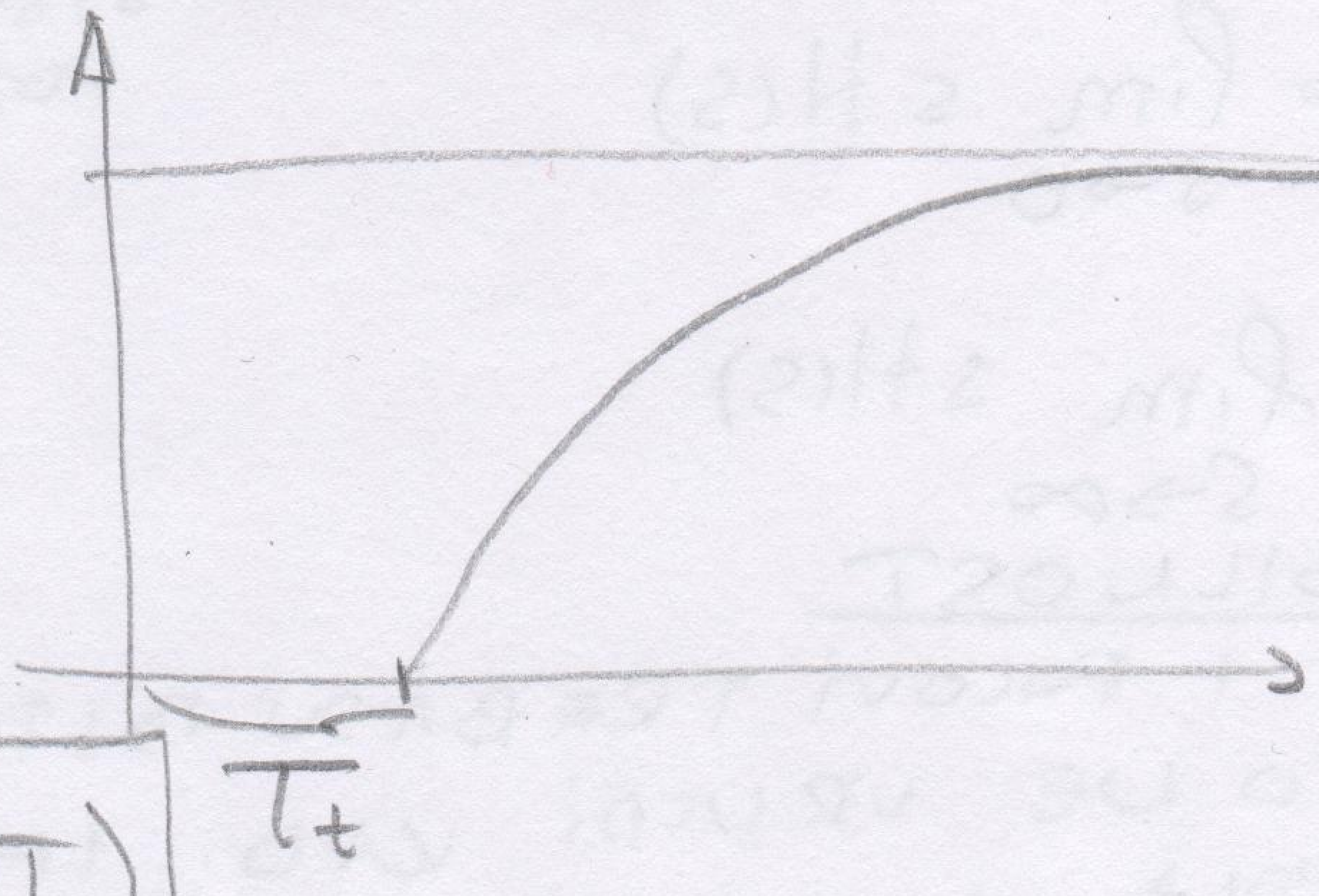
$$\boxed{\phi_y = \phi_U + \phi_G}$$

↳ FAZA

· MRTVO VRIJEME



· VRIJEME NAKON KOJEG ĆE DRUGA TRAKA MOĆ KRENUTI DA LI JE POBACA PAKETE



· MRTVO VRIJEME ILI VRIJEME KAŠNJENJA

$$e^{-\overset{\to j\omega}{s}T} = e^{-j\omega T} = \cos(\omega T) - j\sin(\omega T)$$

↳ EULER

$$\varphi = \operatorname{arctg} \frac{Im}{Re} = \operatorname{arctg} \operatorname{tg}(-\omega T) \Rightarrow \boxed{\varphi = -\omega T}$$

· ALATI ZA ODREĐIVANJE STABILNOSTI

· HURWITZ → ŠALABAHTER

$$\boxed{1 + G_0 = 0}$$

· NYQUIST

$$\boxed{G(s) = \frac{B(s)}{N(s)}}$$ → OTVORENI KRUG

$\boxed{s = j\omega}$

$Re(\omega)$ i $Im(\omega)$

· JEDNADŽBA ZA NYQUISTOVU KRIVULJU:

$$\boxed{G(j\omega) = A(j\omega) \cdot e^{j\varphi(\omega)}}$$

$$\boxed{|e^{-sT}| = 1}$$

- KAKO VIDIT IZ PRIJENOSNE FUNKCIJE KUT KOJIM FREKVENCIJA ULAZI U ∞?

$$G_0(s) = \frac{s+1 \quad +90}{(s+2)^2 \quad -180} \Bigg\} \begin{array}{l} \cdot \text{ POD } -90 \text{ ULAZIMO U } \infty \\ -90 \end{array}$$

BODEOV DIJAGRAM {APROKSIMACIJA PRAVCIMA}

- OSNOVNI ČLANOVI – $A(\omega)$ i $\varphi(\omega)$

DERIVACIJSKI D ČLAN

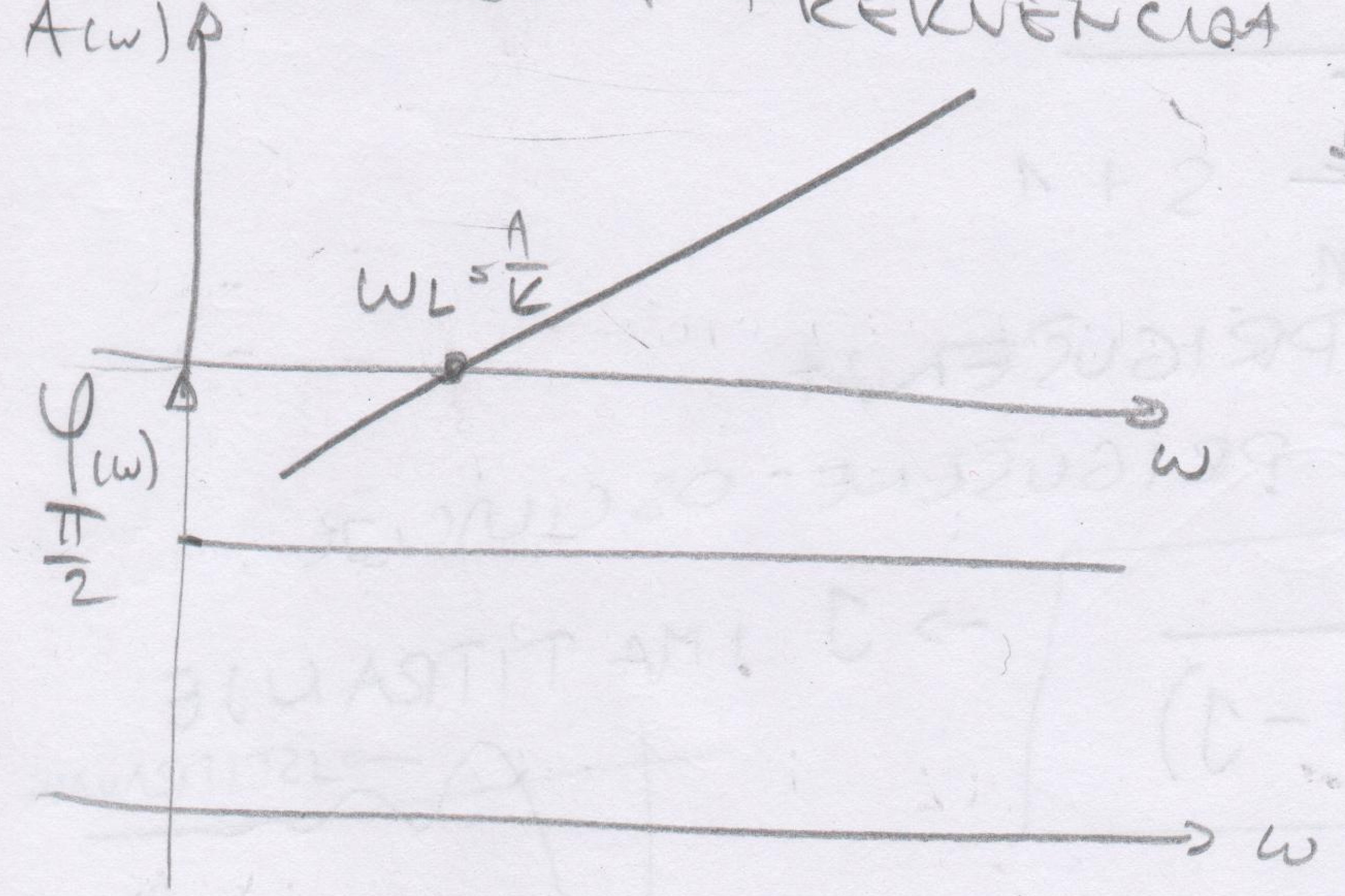
$G(j\omega) = j\omega \rightarrow G(s) = s$

$A = 20 \log k\omega = 20 \log \frac{\omega}{\frac{1}{k}}$

- AMPLITUDA $A = 20 \log \sqrt{(Re)^2 + (Im)^2} = 20 \log \frac{\omega}{\omega_P}$
- FAZA

$$\varphi = \text{arc tg} \frac{Im}{Re} = \text{arctg}\left(\frac{\omega}{0}\right) = \frac{\pi}{2} = 90^\circ$$

- ω_P – PRESJEČNA FREKVENCIJA



$\boxed{\omega_L = \frac{1}{k}}$ – LOMNA FREKVENCIJA

ZA $G(j\omega) = -k$

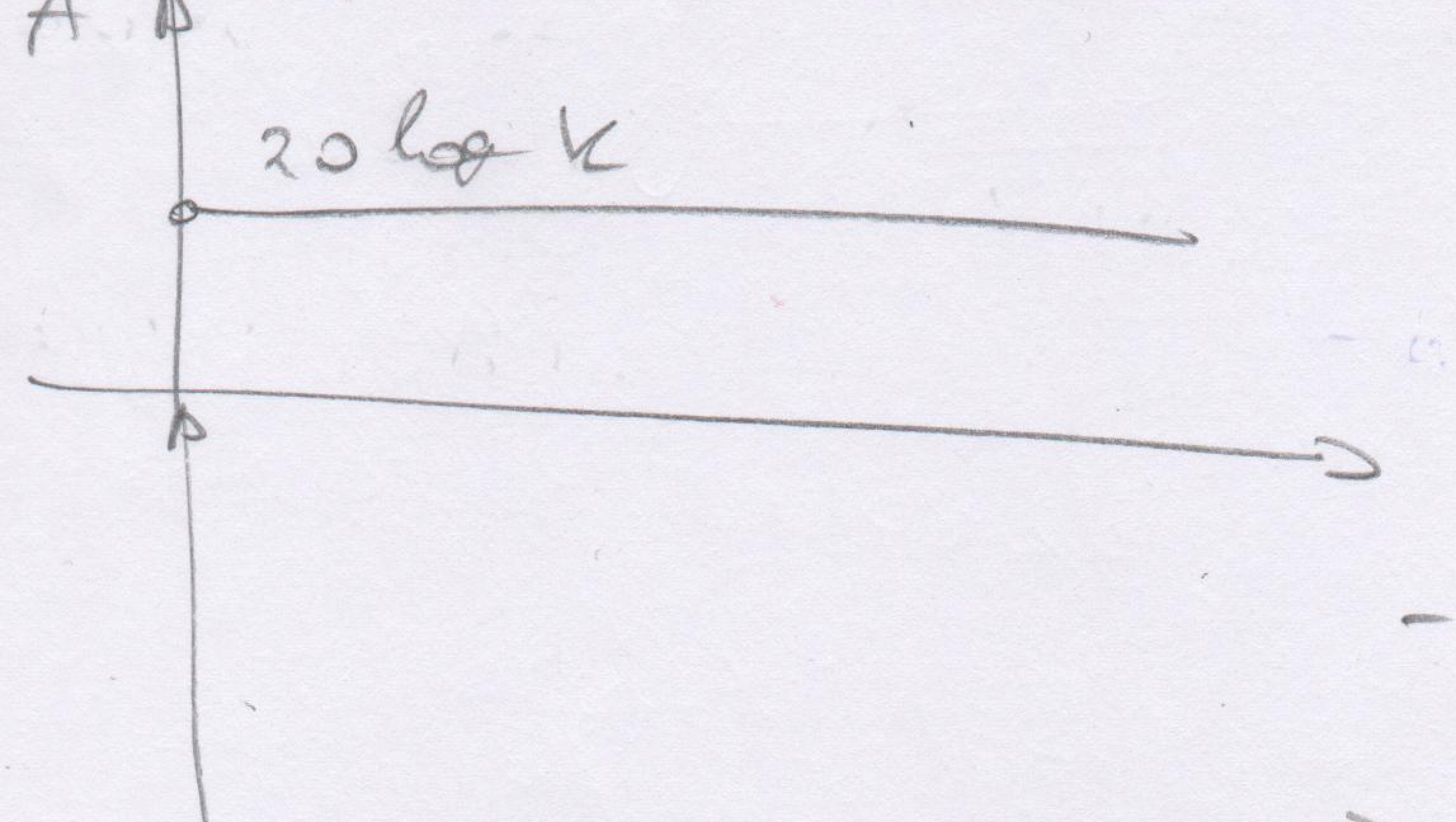
$A = -20 \log k$

$\boxed{\varphi = \text{arc} \frac{0}{-k}}$

PROPORCIONALNI P ČLAN

$G(j\omega) = k$

$A(j\omega) = 20 \log k$



– NEMA FAZE

• INTEGRACIJSKI ČLAN I $\quad G(s) = \frac{1}{T_I}$

$$G(j\omega) = \frac{1}{j\omega T_I} \qquad A = -20 \log \frac{\omega}{\omega_L}$$

PAUZA

• NEMINIMALNE FAZE I NULE

$$G(s) = \frac{\overbrace{s-3}^{A_1}}{\underbrace{s+2}_{A_2}} \qquad A_1 = 20 \log \sqrt{\left(\frac{\omega}{\omega_L}\right)^2 + 1}$$

$\hookrightarrow 3$

→ ONE SNIŽAVAJU FAZU $\quad \varphi_1 = - \operatorname{arctg} \frac{\omega}{\omega_L}$

→ FAZA PADA

• U AMPLITUDI NAJVEĆA GREŠKA $\Delta A = 3 dB$

• U FAZI $\Delta\varphi = 5.7°$

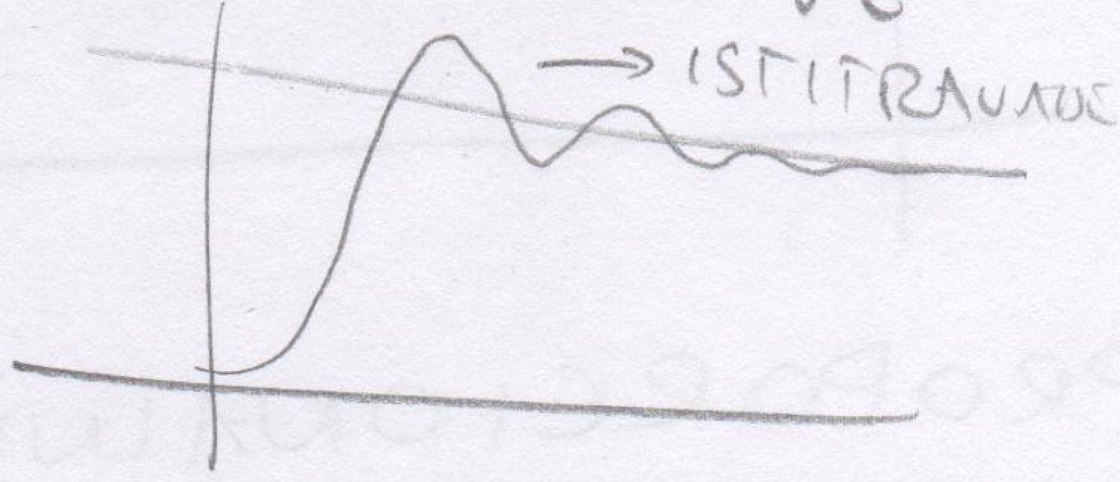
PT$_2$ ČLAN

$$G(s) = \frac{K}{\frac{s^2}{\omega_n^2} + \frac{2\xi}{\omega_n} s + 1}$$

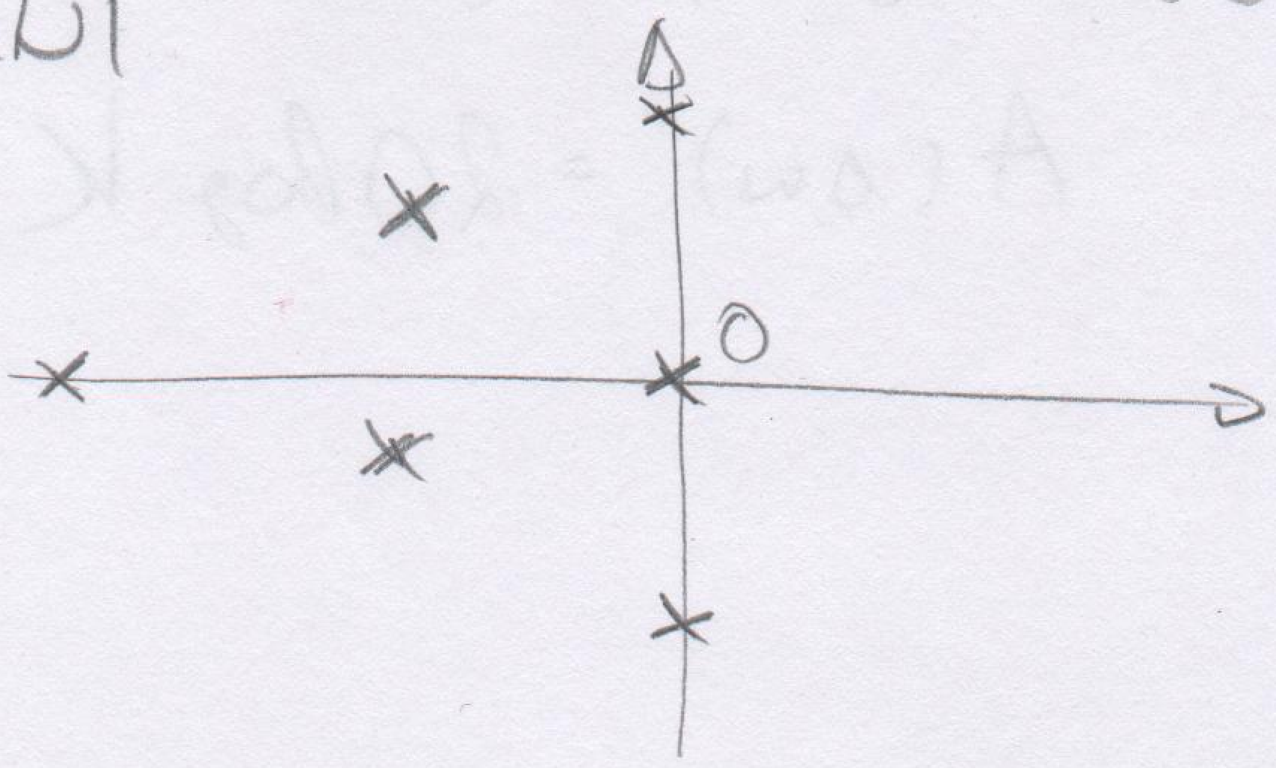
ξ - KOEFICIJENT PRIGUŠENJA

ω_n - FREKVENCIJA NE PRIGUŠENE OSCILACIJE

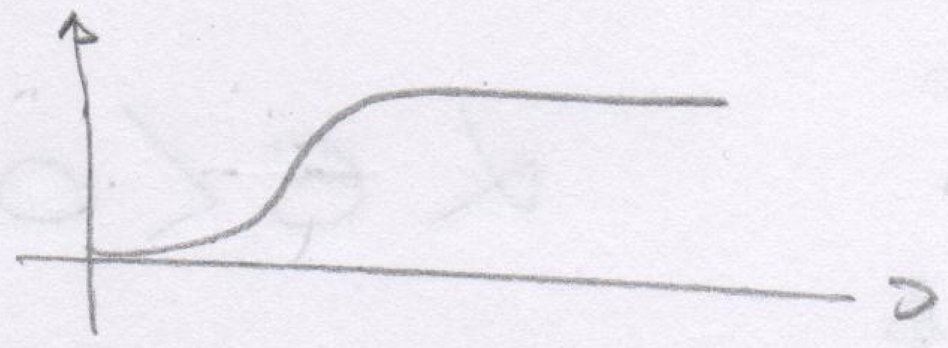
$$\boxed{G(s) = \frac{K}{(s+1+j)(s+1-j)}} \rightarrow j \text{ IMA TITRANJE}$$



• ISTITRAVANJE REGULIRAMO TAKO DA REGULIRAMO POLOVE U S RAVNINI

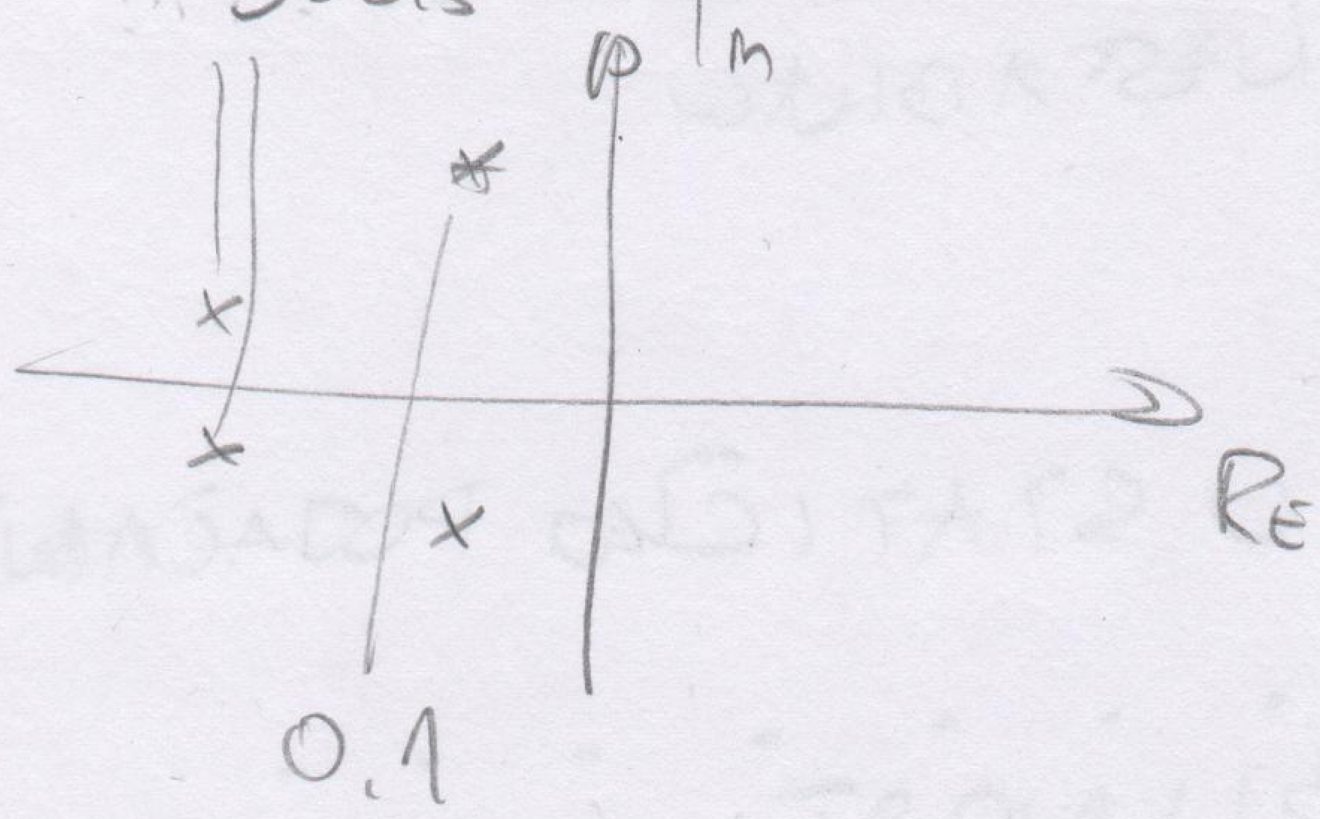


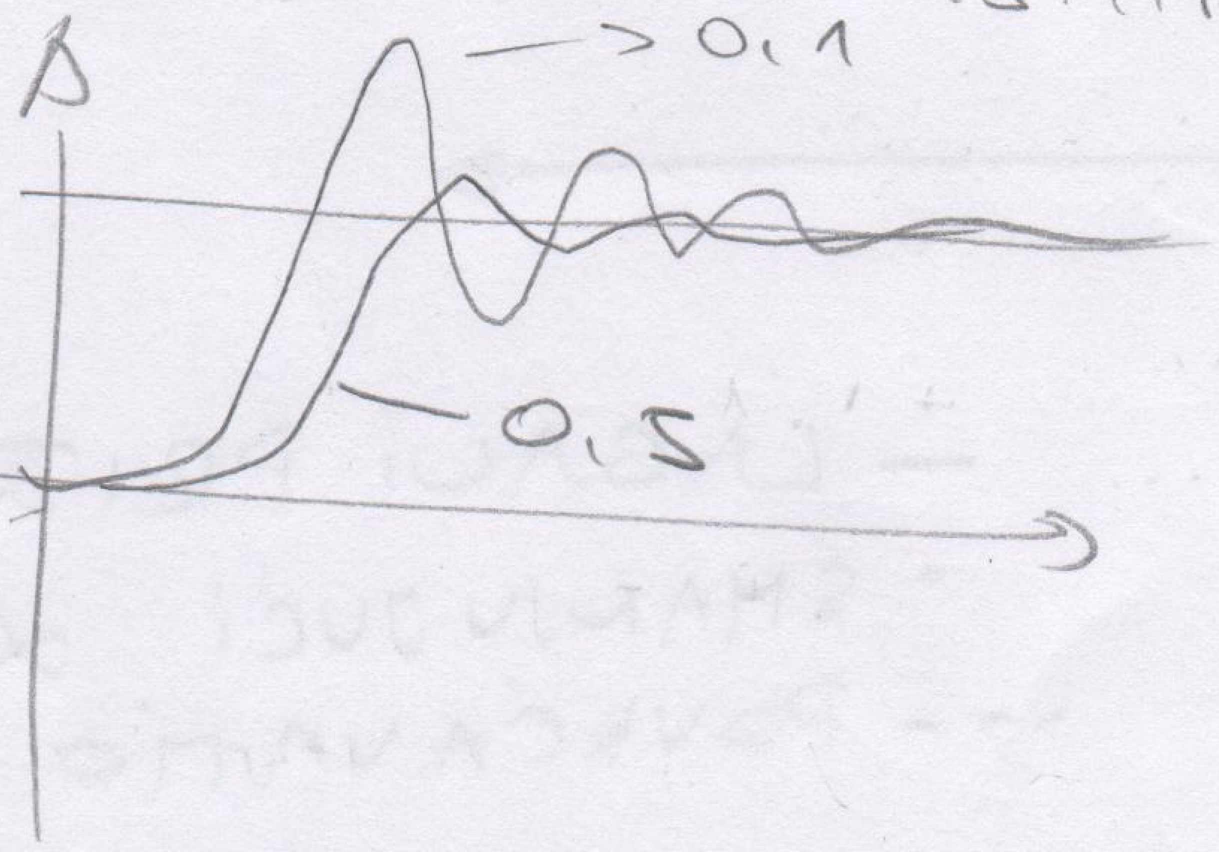
$\zeta = 1 \Rightarrow G(s) = \dfrac{K}{\left(\dfrac{s}{\omega_n} + 1\right)^2}$ → DVOSTRUKI POL NA REALNOJ OSI



$\boxed{\zeta < 1 \text{ i } \zeta > 0}$

- IMAMO KOMPLEKSNE POLOVE
- O VELIČINI ζ IMAMO VEĆE ILI MANJE ISTITRAVANJA



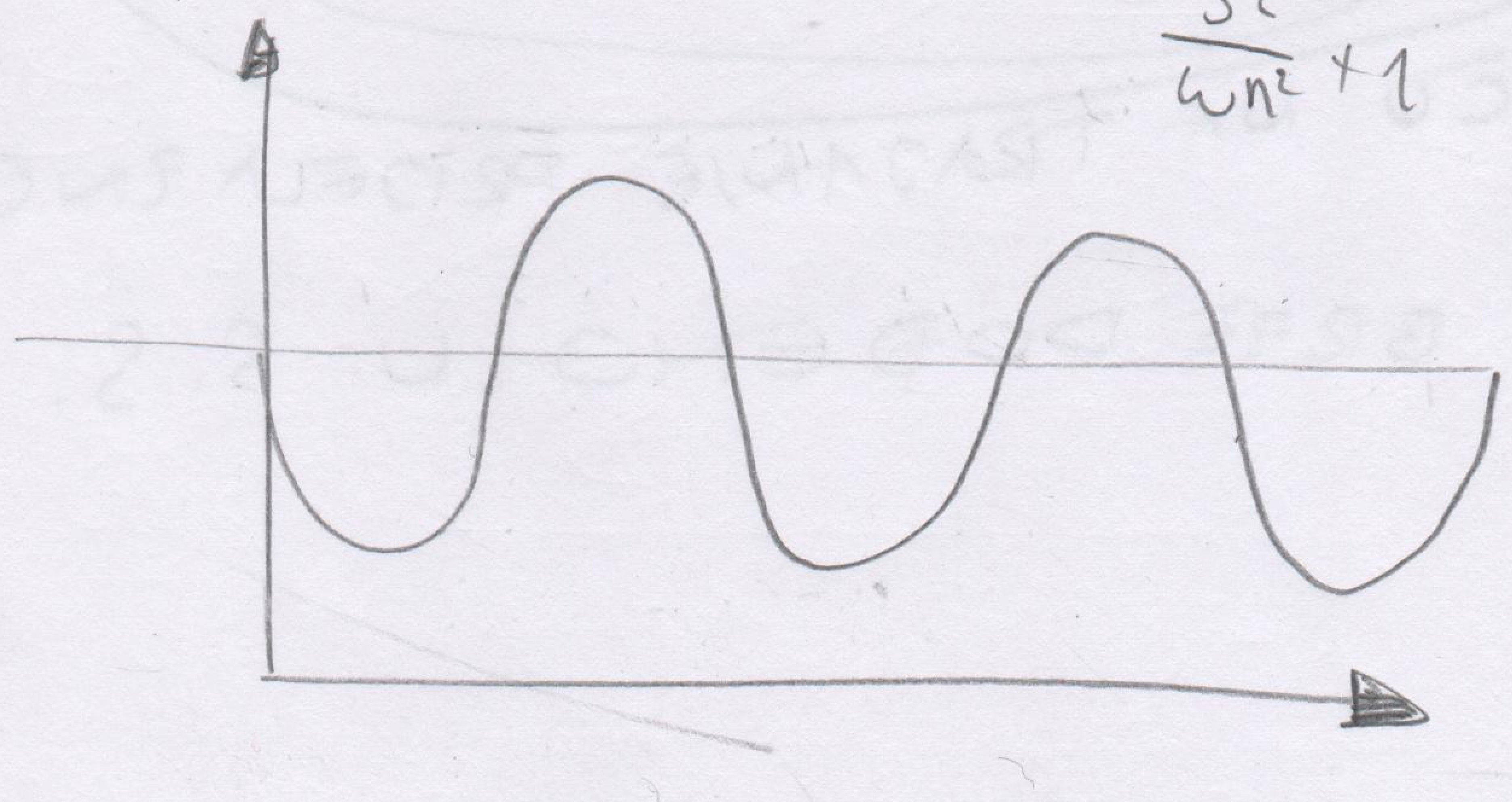


- ŠTO SU POLOVI DALJE OD ISHODIŠTA SUSTAV JE STABILNIJI

$\zeta = 0 \Rightarrow G(s) = \dfrac{K}{\dfrac{s^2}{\omega_n^2} + 1}$

- DVOSTRUKE POLOVI NA IMAGINARNOJ OSI GRANIČNO STABILAN

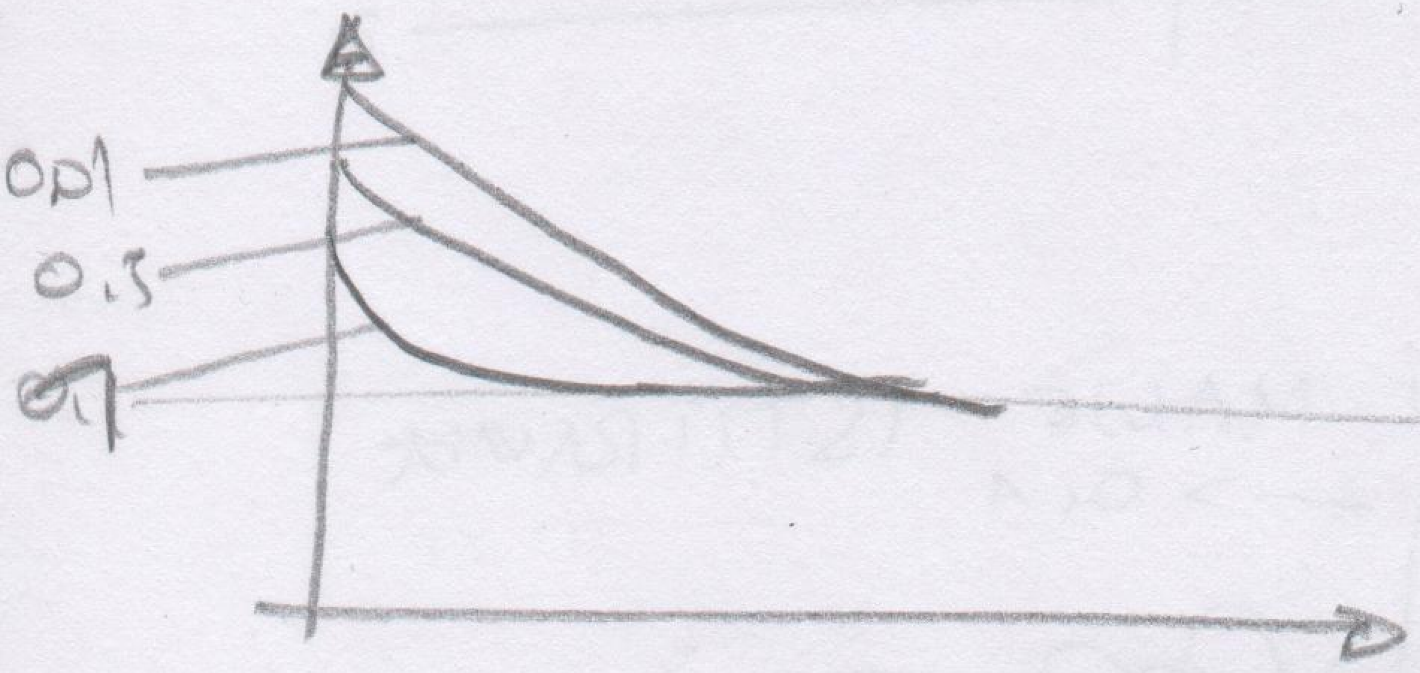
- SINUSOIDA



1. PR

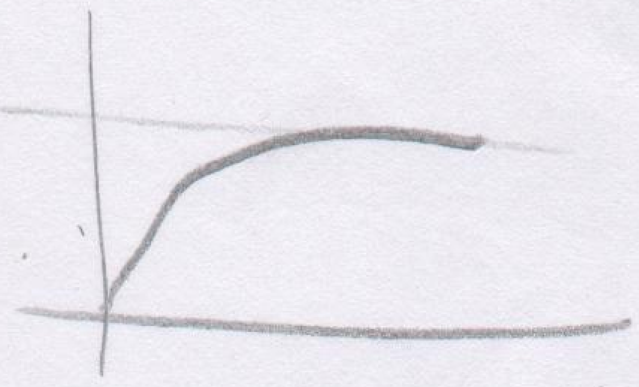
$$G(s) = \frac{1+s}{1+\alpha s} \rightarrow h(t) = 1 + \left(\frac{1}{\alpha} - 1\right) e^{-\frac{t}{\alpha}}, \alpha \in \langle 0, 1]$$

1° $\alpha \in \langle 0, 1]$



- ZA $\alpha \rightarrow 0$
ŠPIC U ISHODIŠTU $\rightarrow \infty$
SUSTAV POSTAJE NESTABILAN

2. $\alpha > 1$



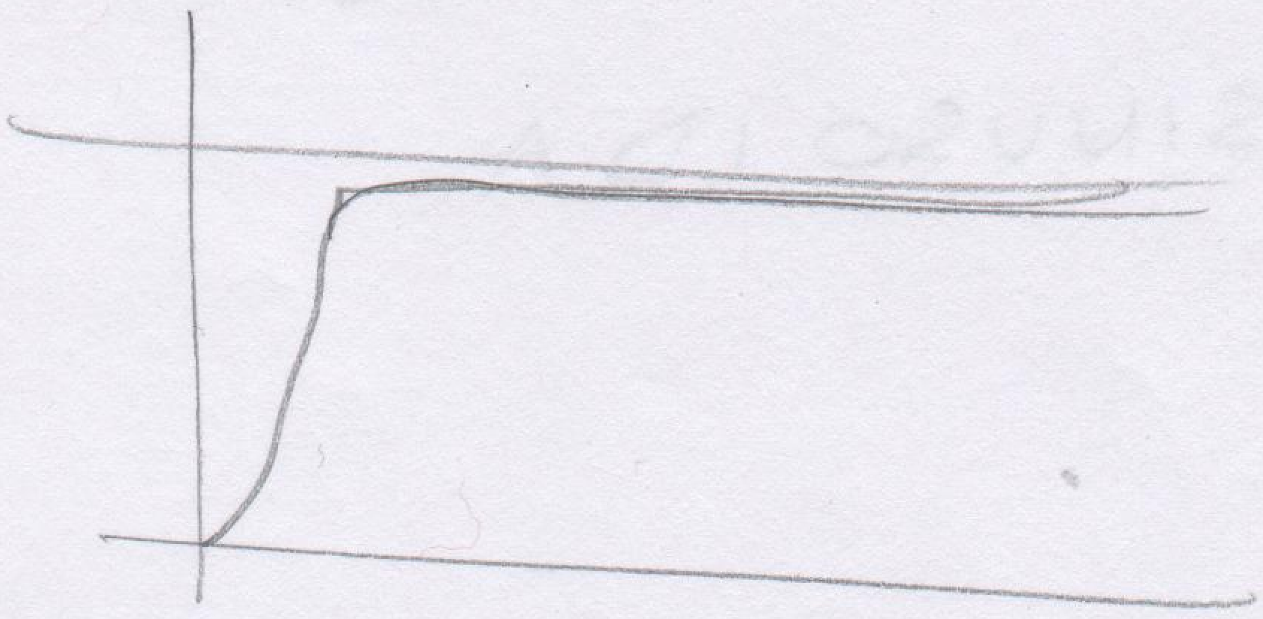
— LAGANI PRIJELAZ U STATIČKO POJAČANJE
- SMANJUJUĆI α .... POVEĆAVAMO STABILNOST

· PR 2

$$G(s) = \frac{2}{(s+1)(s+2)} \rightarrow h(t) = 1 - 2e^{-1t} + e^{-2t}$$

$s_{p1} = -1$ i $s_{p2} = -2$

- POLOVI DIREKTNO UTJEČU NA TRAJANJE PRIJELAZNE FUNKCIJE

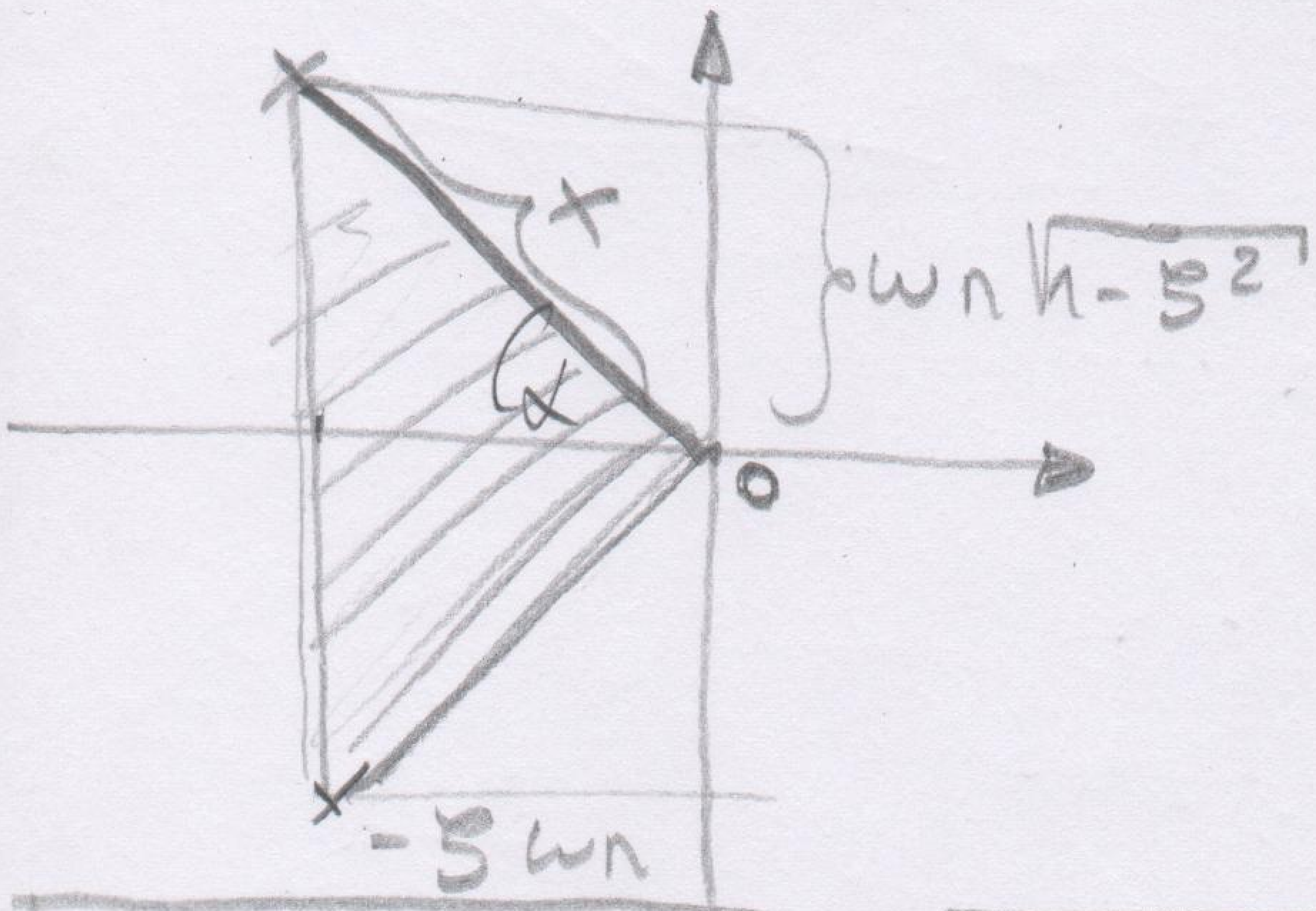


- BRŽE DOĐEMO U S.S.

LABOS 3

$$G(s)=\frac{\alpha s+1}{(s+2)(s+7)}\qquad \alpha\uparrow$$

- $\alpha < 1$ -o JE NEMINIMALNO FAZNI
  - PODBAČAJ



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

$$\boxed{\sigma_m[\%]=100\cdot e^{-\frac{\pi\cdot\zeta}{\sqrt{1-\zeta^2}}}}$$

$$\boxed{t_r=\frac{1.8}{\omega_n}}\quad \boxed{t_m\approx\frac{3}{\omega_c}}\quad \boxed{t_{1\%}=\frac{4.6}{\zeta\,\omega_n}}$$

$$\boxed{s_{p1,2}=-\zeta\omega_n\pm j\,\omega_n\sqrt{1-\zeta^2}}$$

- PRIMJER
- $\boxed{\sigma < \sigma_{MAX}}$ -> $$\boxed{\zeta=\frac{\ln\frac{\sigma}{100}}{\sqrt{\left(\ln\frac{\sigma}{100}\right)^2+1}}}$$

  ZADA NAM NETKO

$$\boxed{x^2=\omega_n^2(1-\zeta^2)+\zeta^2\omega_n^2}$$

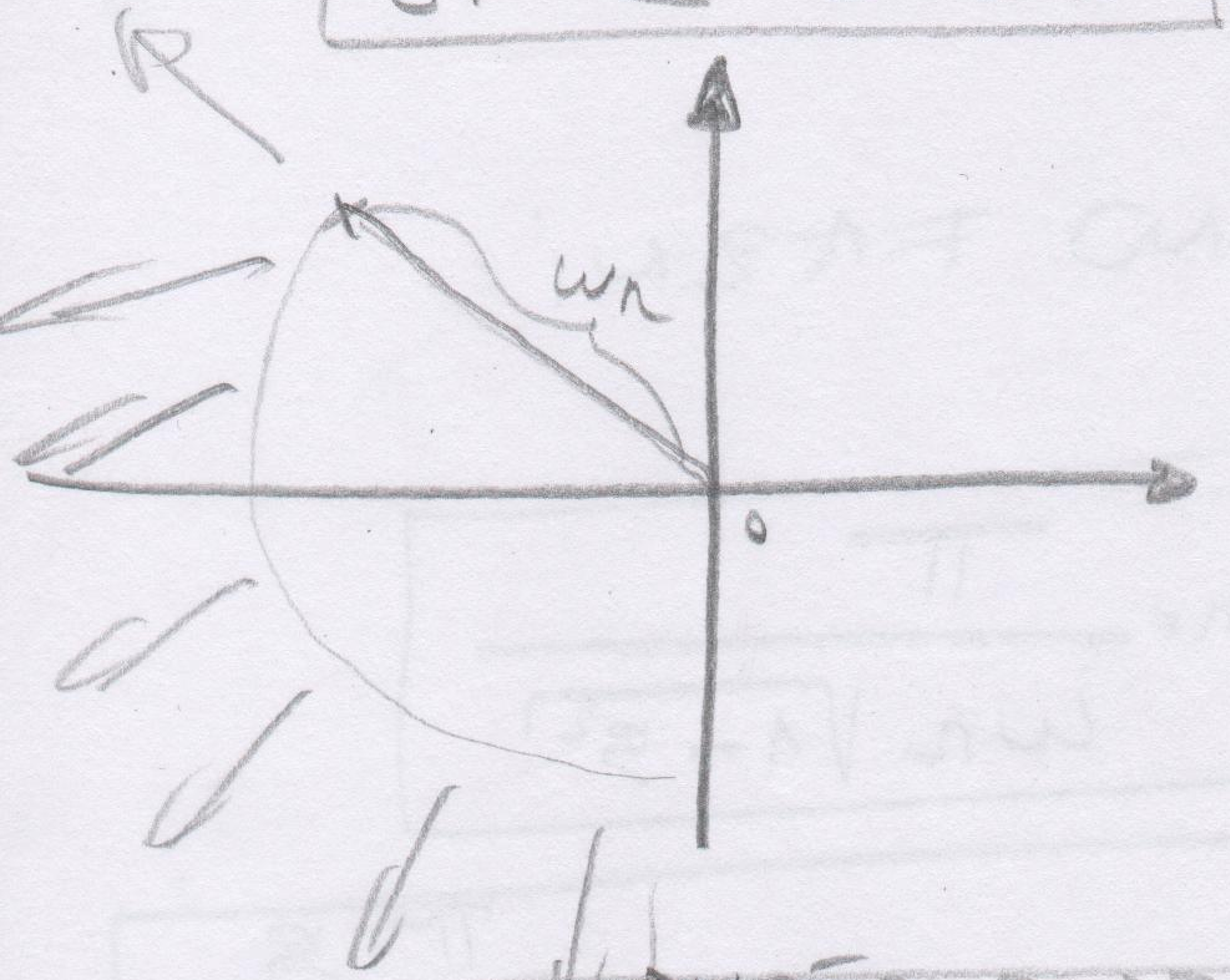
$$\boxed{x^2=\omega_n^2}$$

$\cos\alpha=\frac{\text{PRILEŽEĆA}}{\text{HIPOTENUZA}}$

$\cos\alpha=\zeta$ => $\boxed{\alpha=\arccos\zeta}$ => $\boxed{\alpha<\alpha_{MAX}}$

2. VRIJEME PORASTA

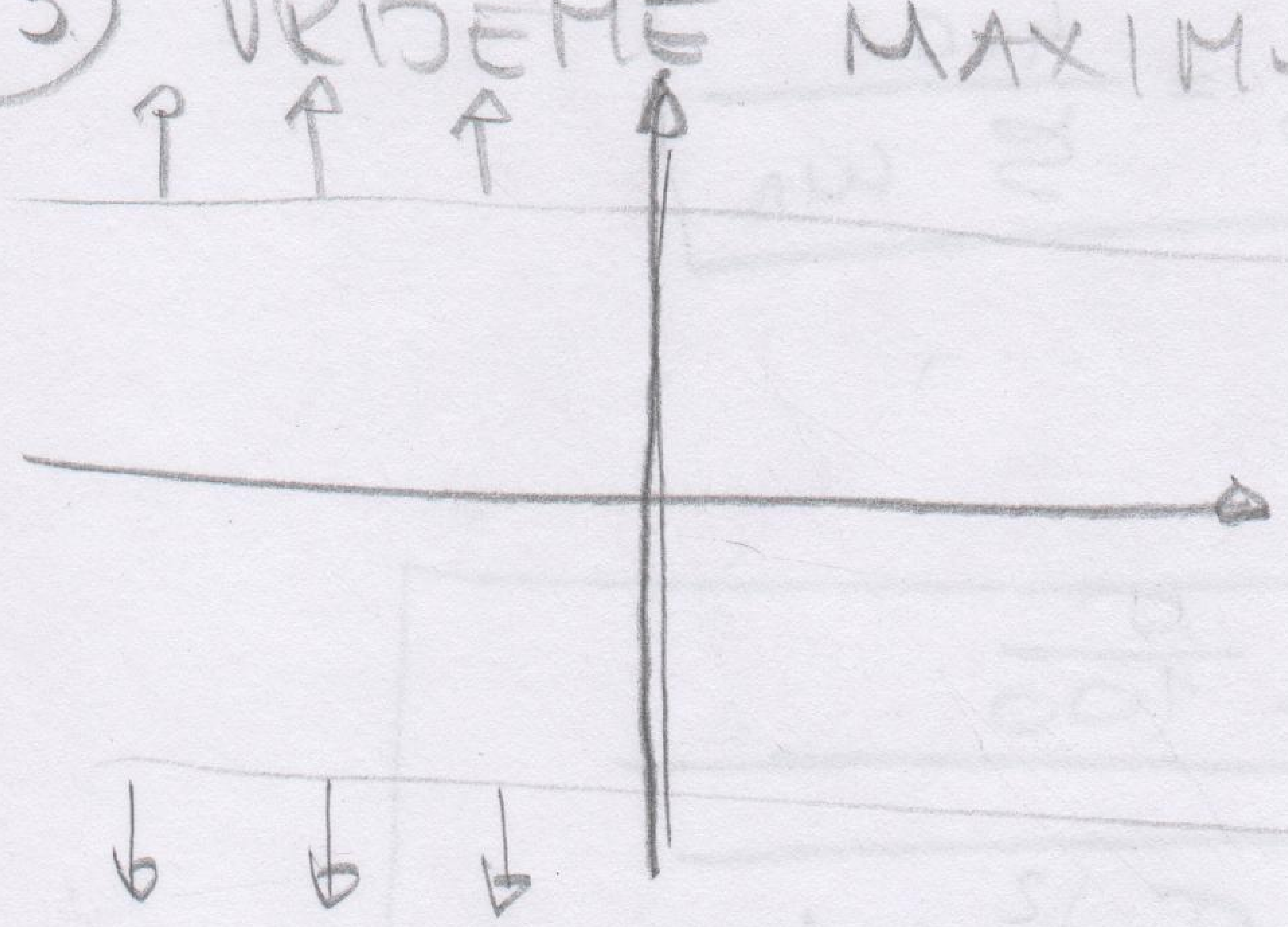
$$\boxed{t_r < t_{max}} \rightarrow \boxed{\omega_n \geq \omega_{max}}$$



SMJER PODRUČJA STABILNOSTI

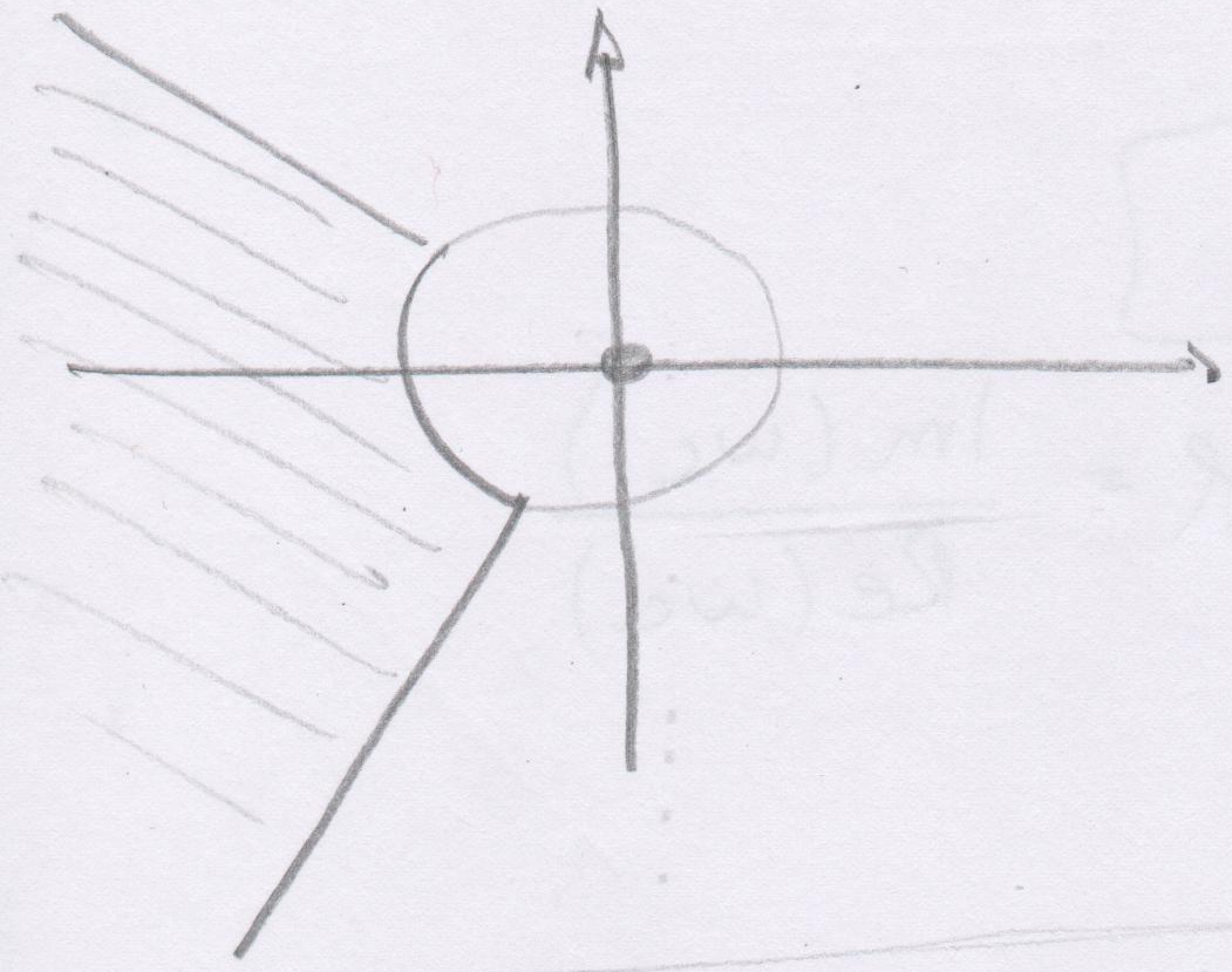
3. VRIJEME MAXIMUMA

$$\boxed{t_m < t_{MAX}}$$



4. $t_{1\%}$

• NA KOJE SVE PARAMETRE UTJEČE OVAKAV RASPORED POLOVA

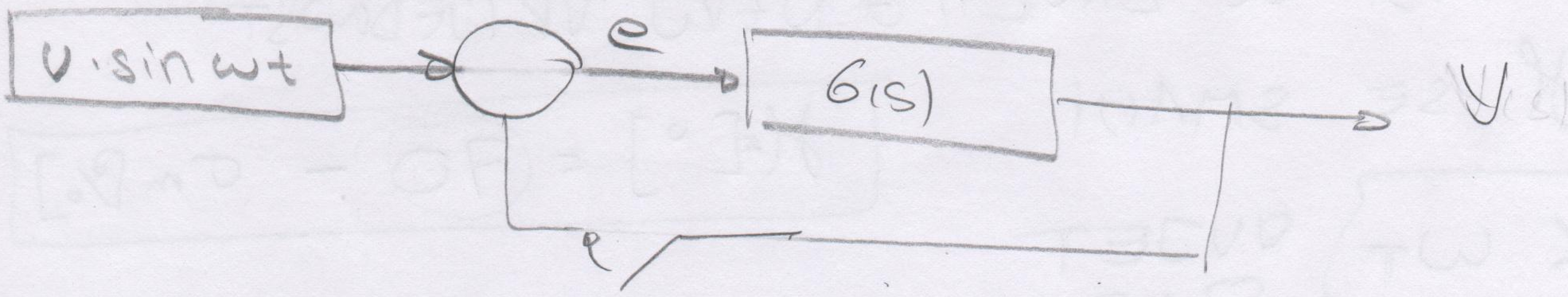


$\xi \Rightarrow \sigma$

t_r

$t_{1\%}$

• AKO SE MJENJA VRIJEME PRVOG MAXIMUMA
• MJENJAMO ω_n



• HARMONIJSKA POBUDA - KAD PROĐE USTALJENO STANJE IMAMO POBUDU

$$\boxed{A_y = A_u + A_G}$$

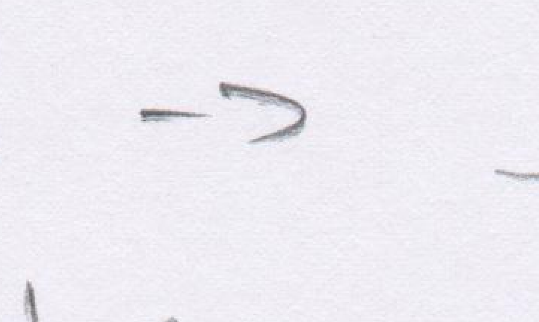
$$\boxed{\phi_y = \phi_u + \phi_G}$$

$$y = A_y \angle 180°$$

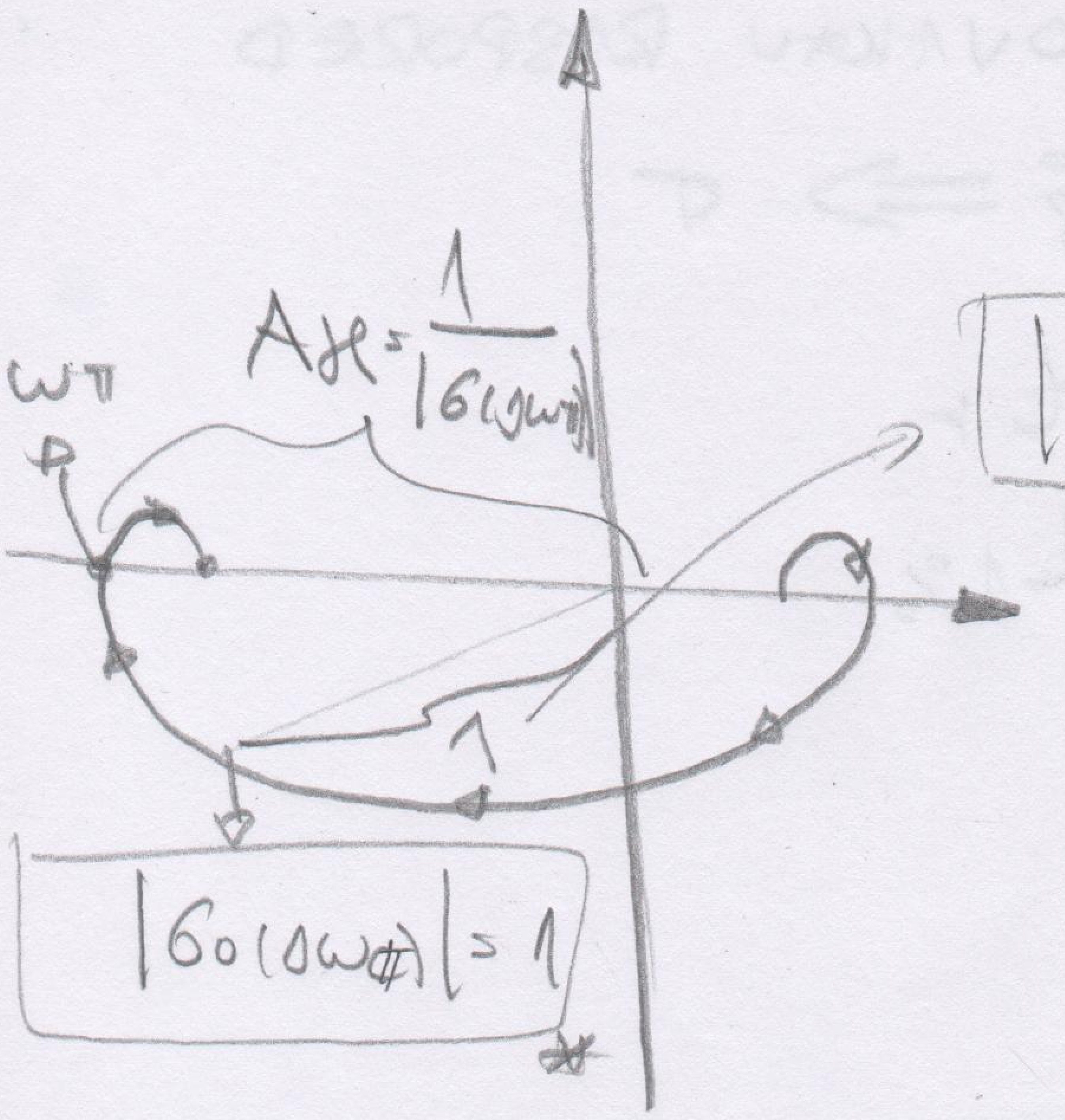
• ZA $A_y = 1 \Rightarrow 1 \angle 180°$

$$E = U - y = U + 1 \angle 0°$$

• ZA $A_y > 1 \rightarrow$ 

• $A_y < 1 \Rightarrow$ 

$A_y = A_u$ - AMP OSIGURATI



$$\boxed{|G_0(j\omega_c)| = 1}$$

$$tg\,\gamma = \frac{Im(w_c)}{Re(w_c)}$$

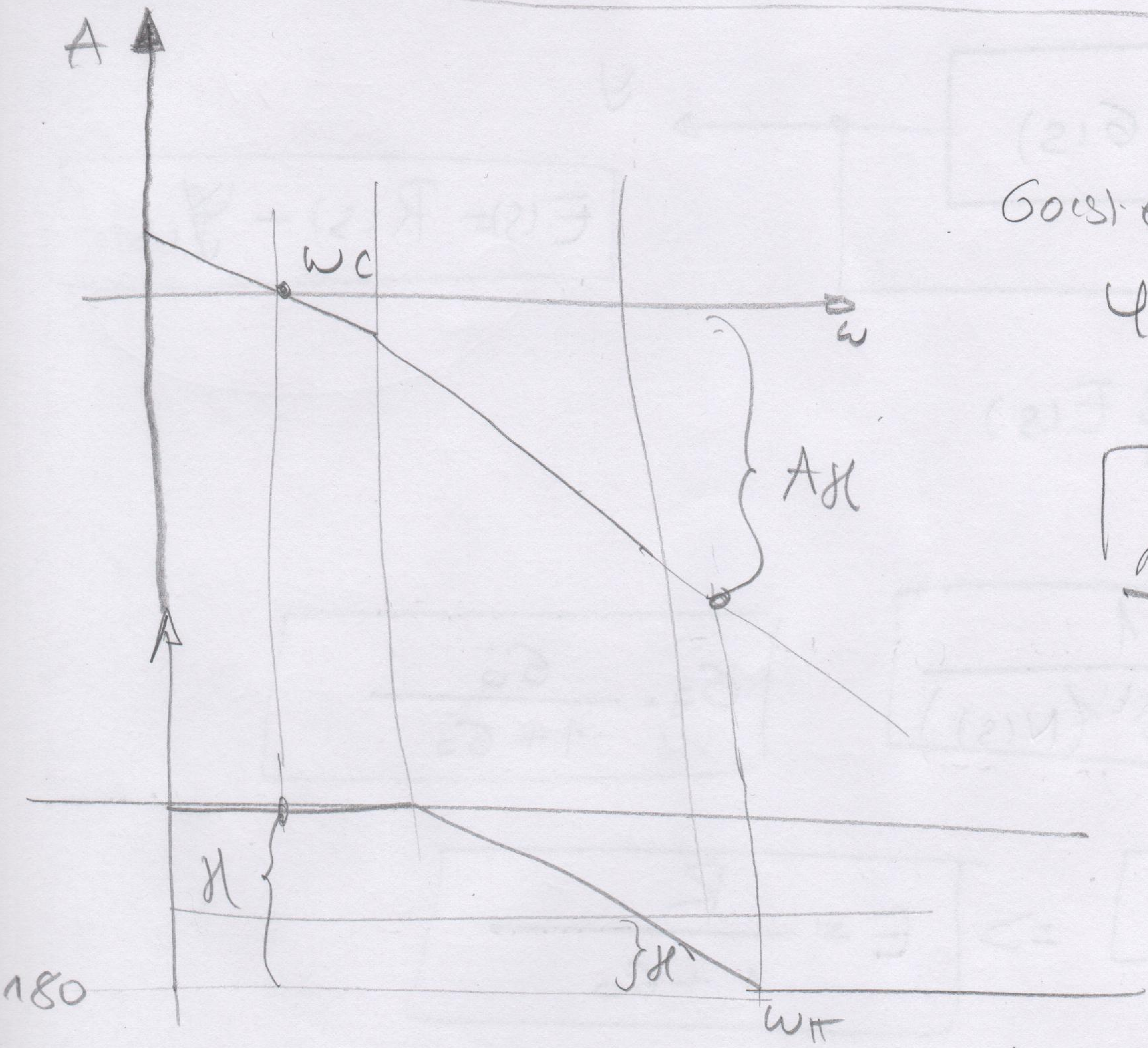
- KAKO GRAFIČKI ODREDIMO TOČKU U KOJOJ JE POJAČANJE 1
- UTJECAJ MRTVOG VREMENA NA γ
  - NYQUIST SE ZAVRTI ZA NEKU VRIJEDNOST

γ SE SMANJI

$$\boxed{\gamma[°] = 70 - \sigma_m[\%]}$$

$\boxed{\omega_c < \omega_T}$ UVJET STABILNOSTI

• UTJECAJ MRTVOG VREMENA NA STABILNOST

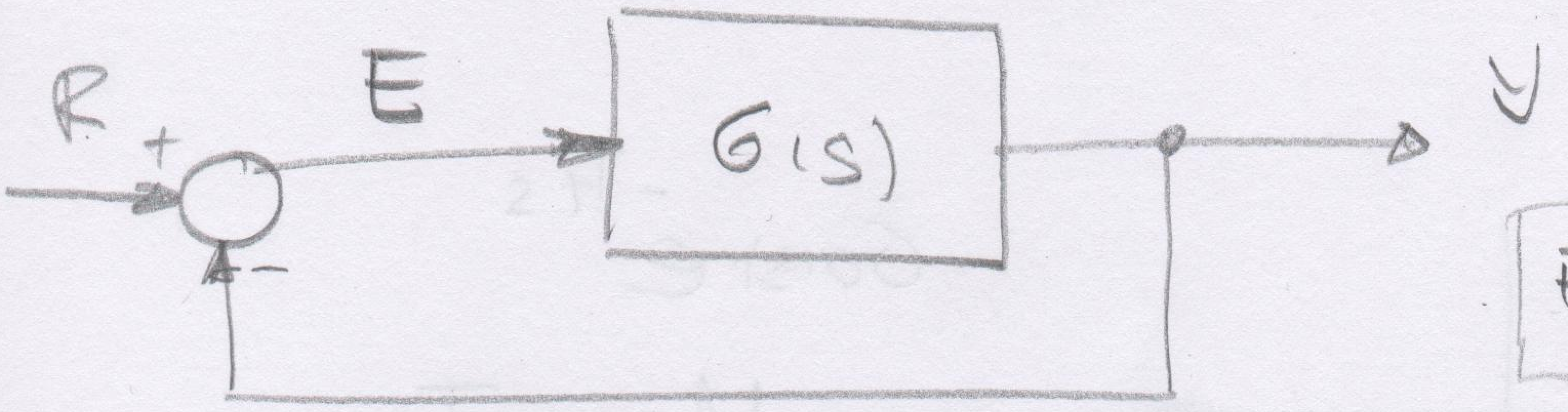


$G_o(s) \cdot e^{-T_t s}$

$\varphi = -\omega T$

$\boxed{H' < H}$

REGULACIJSKO ODSTUPANJE



$$\boxed{E(s) = R(s) - Y(s)}$$

$$e_\infty = \lim_{s \to 0} s\,E(s)$$

- ASTATIZAM –

$$\boxed{G_0(s) = \frac{1}{s^k (N(s))}} \qquad \boxed{G_z = \frac{G_0}{1 + G_0}}$$

$$\boxed{Y = G_0 \cdot E} \Rightarrow \boxed{E = \frac{R}{1 + G_0}}$$

$$\boxed{R = \frac{1}{s^\alpha}}$$ UVIJEK

$$E = \frac{s^k N(s)}{s^\alpha (s^k N(s) + 1)}$$

- ZA $k = 0$ – NEMA ASTATIZMA

$k = 1 \rightarrow$ ASTATIZAM 1. REDA

$$e_\infty = \lim_{s \to 0} \frac{s^{k+1}}{s^\alpha} \frac{N(s)}{s^k N(s) + 1}$$

$$\alpha > 1 \Rightarrow e_\infty = 1$$

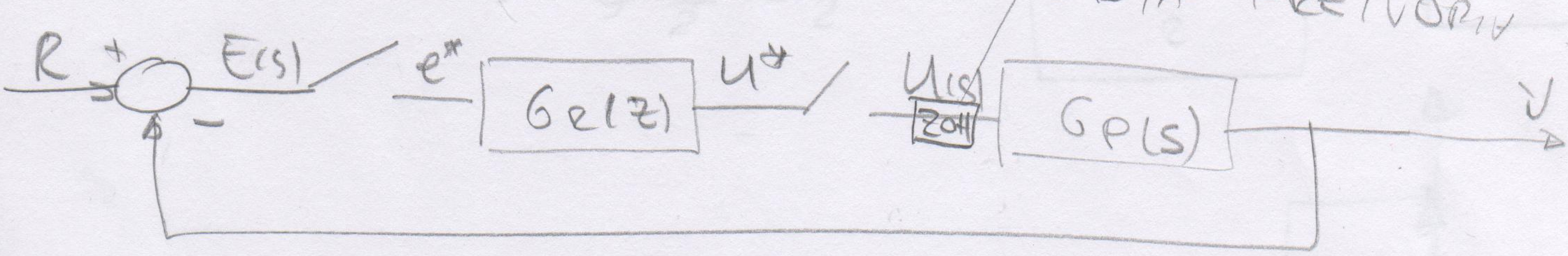
$$\alpha < 1 \Rightarrow e_\infty = \infty$$

• MJENJAJUĆI REFERENCU MJENJAMO REGULACIJSKO ODSTUPANJE

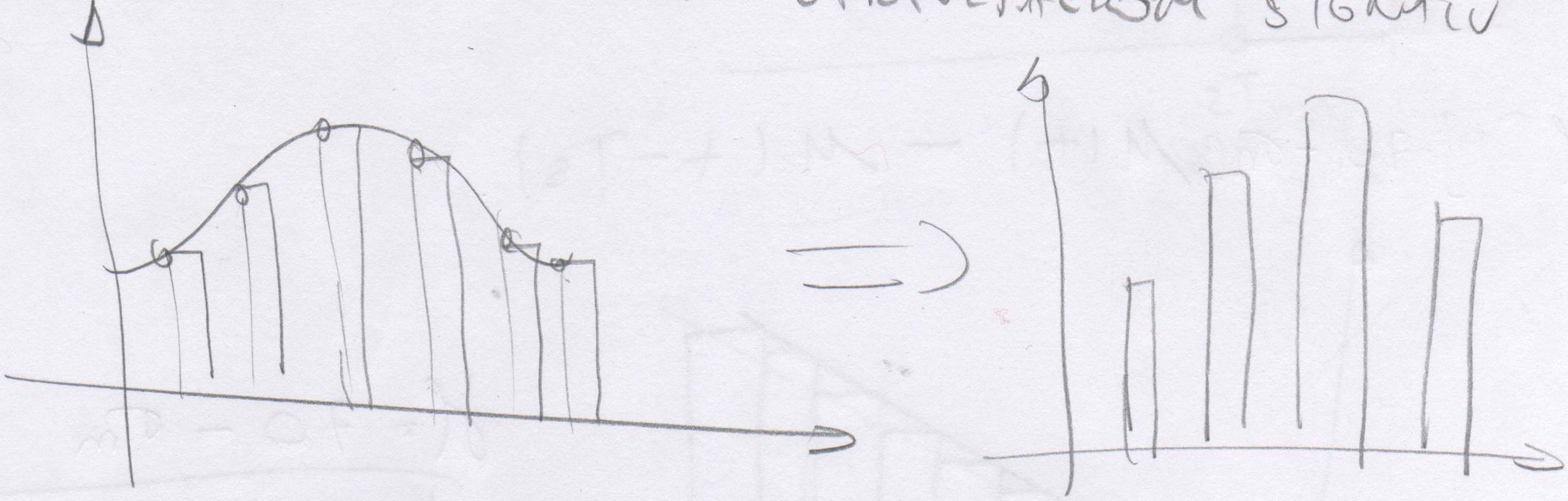
4. LABOS → - NO BED!! - IDEMO DALJE 

MOTHER OT AUPR!!

• DISKRETIZACIJE



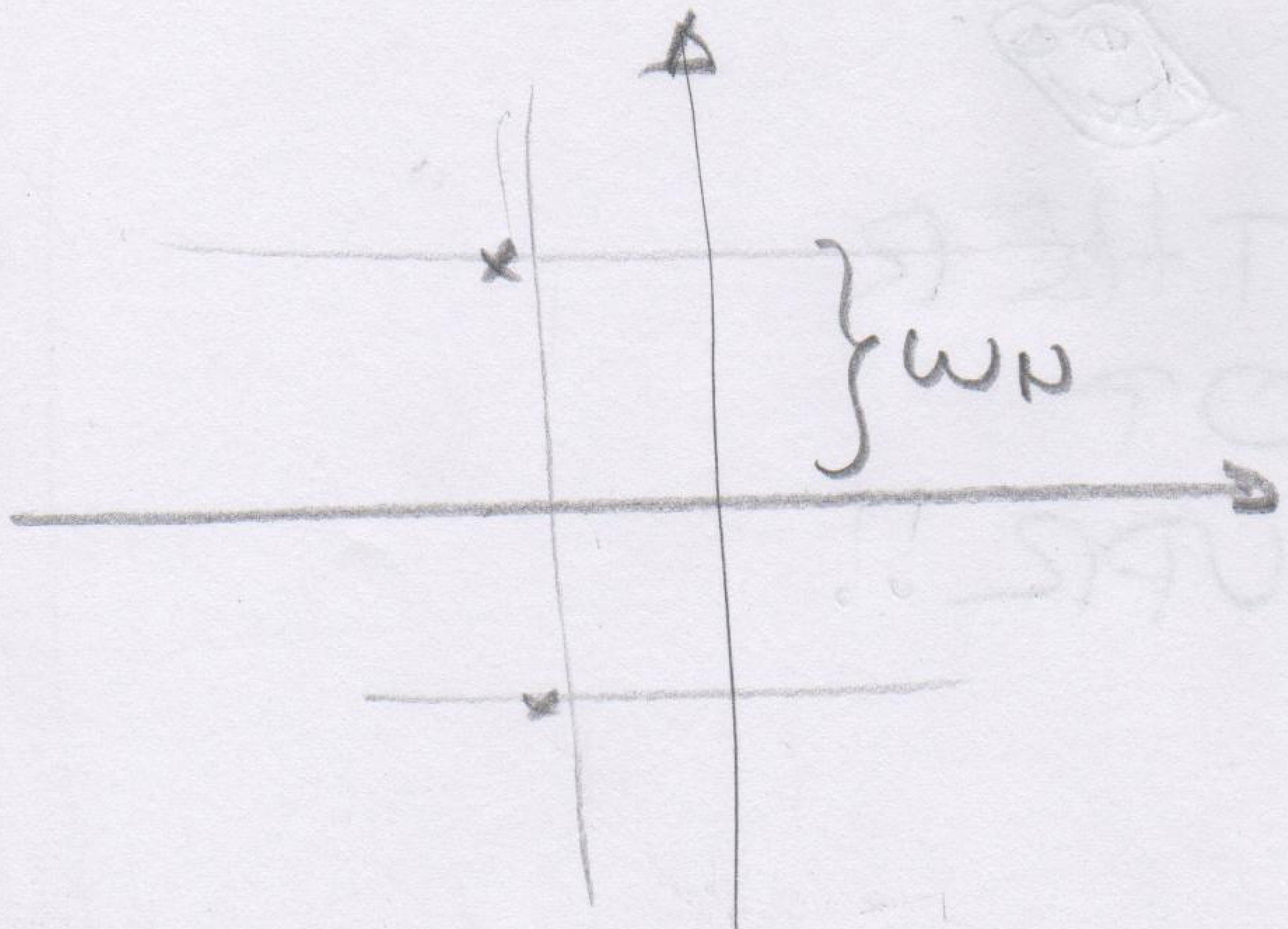
ZOH - VRAĆA ENERGIJU UPRAVLJAČKOM SIGNALU



• PROBLEM OČITAVANJA

$z = e^{+sT}$

$$e^{j\omega T_s} = \cos \omega T + j \sin \omega T = e^{j(\omega T + 2k\pi)}$$

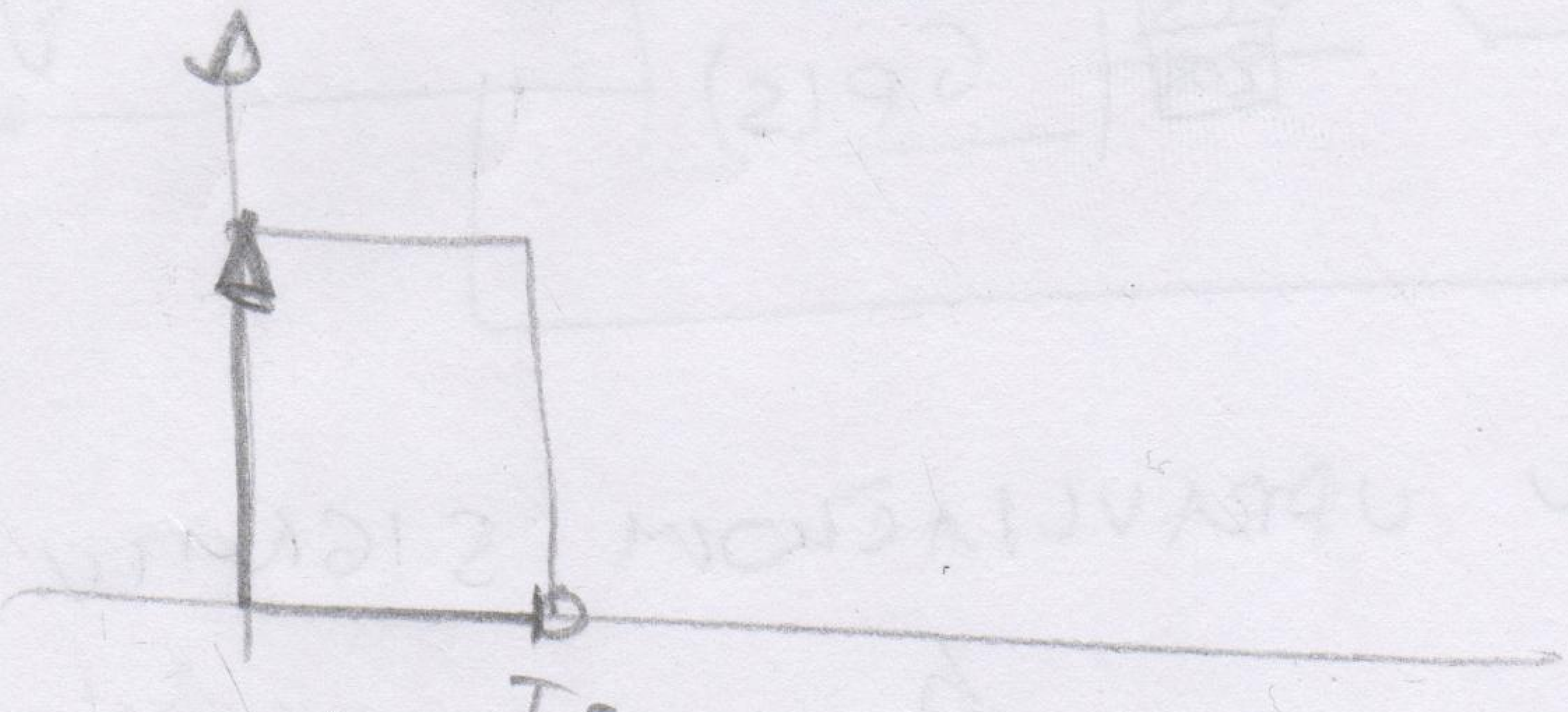


$$\omega_N = \frac{\pi}{T_s}$$

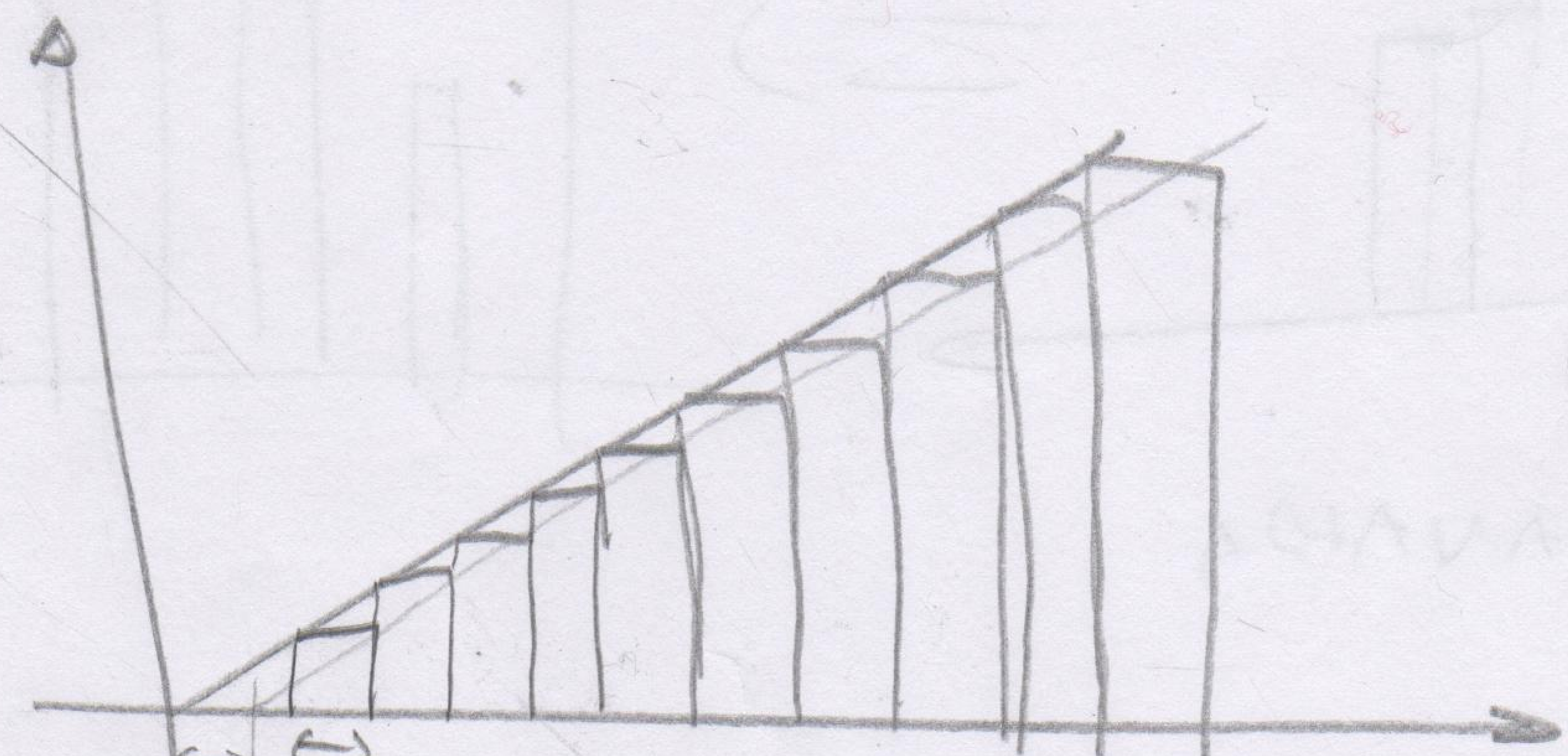
$$\boxed{\omega_{ocit} > 2\,\omega_{MAX}}$$

↳ ALIASING

$$\boxed{ZOH} = \boxed{\frac{1-e^{-sT_s}}{s}} \Rightarrow \frac{1}{s} - \frac{1}{s}e^{-st}$$



$H[°]\ 70 \div \sigma_m\%$ $\mu(t) - \mu(t - T_s)$



$$H = 70 - \sigma_m$$

$$\boxed{\Delta H = -\omega \frac{T_s}{2}}$$

$$\Delta \sigma = 70 + \omega_c \frac{T_s}{2}$$

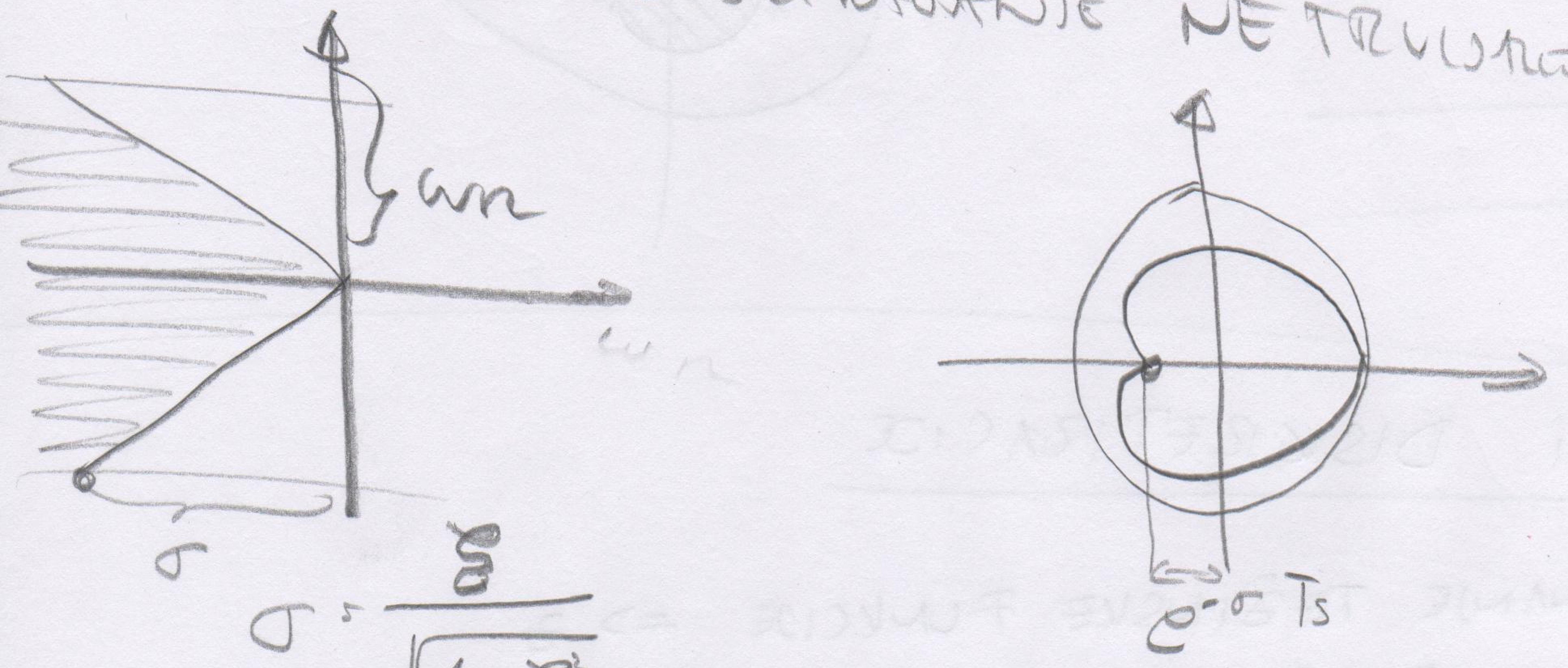
$$H^*[°] = (5° \text{ DO } 10°) = \frac{180}{\pi}\,\omega_c \frac{T_s}{2}$$

$$T_s = \frac{(0.17 \div 0.34)}{\omega_c}$$

· PRESLIKAVANJE $s \rightarrow z$

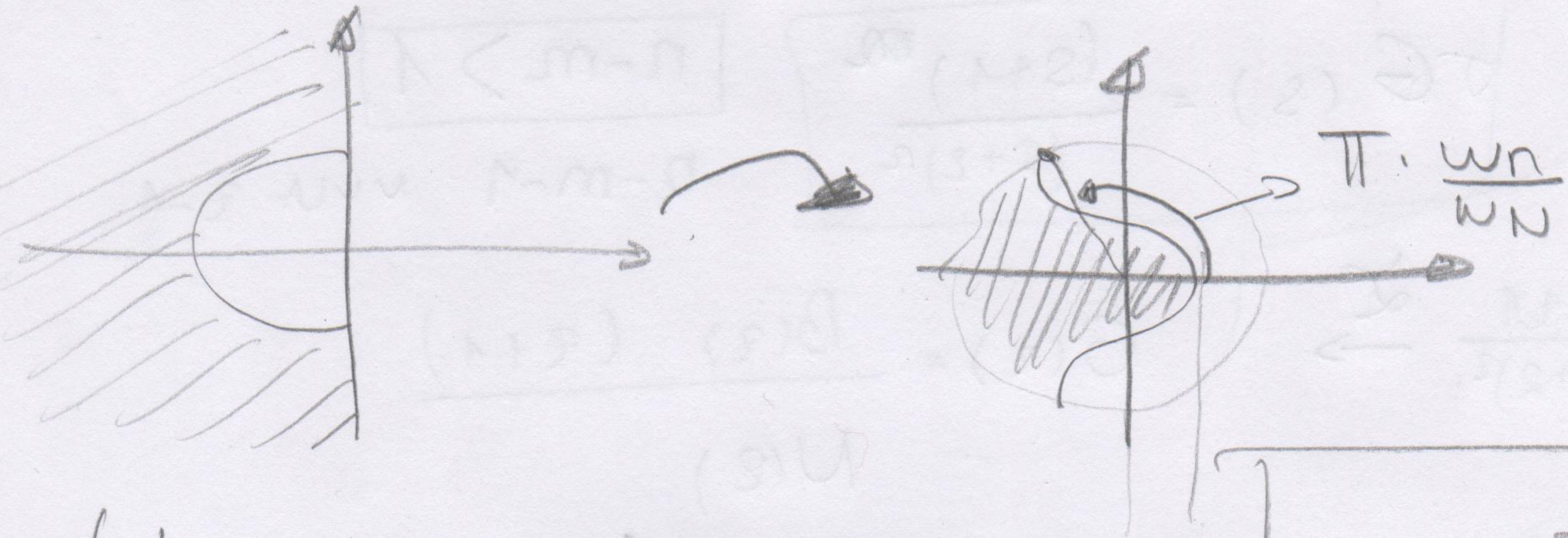
$G(s) = \frac{1}{s^2+1} \;\circ\!\!\xrightarrow{\mathcal{Z}}\!\!\bullet\; G(z) = \frac{z}{z^2+1}$ → POJAVE SE NEFIZIKALNE NULE

ZATO JER JE PRESLIKAVANJE NETRIVIJALNO

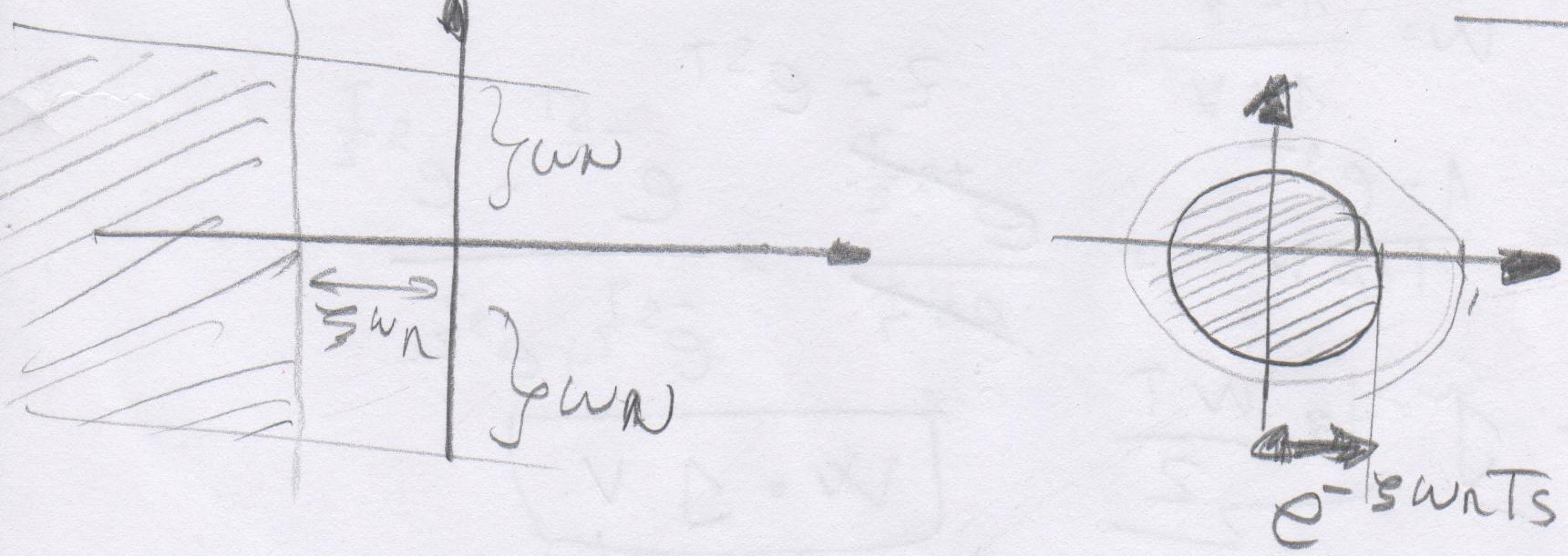


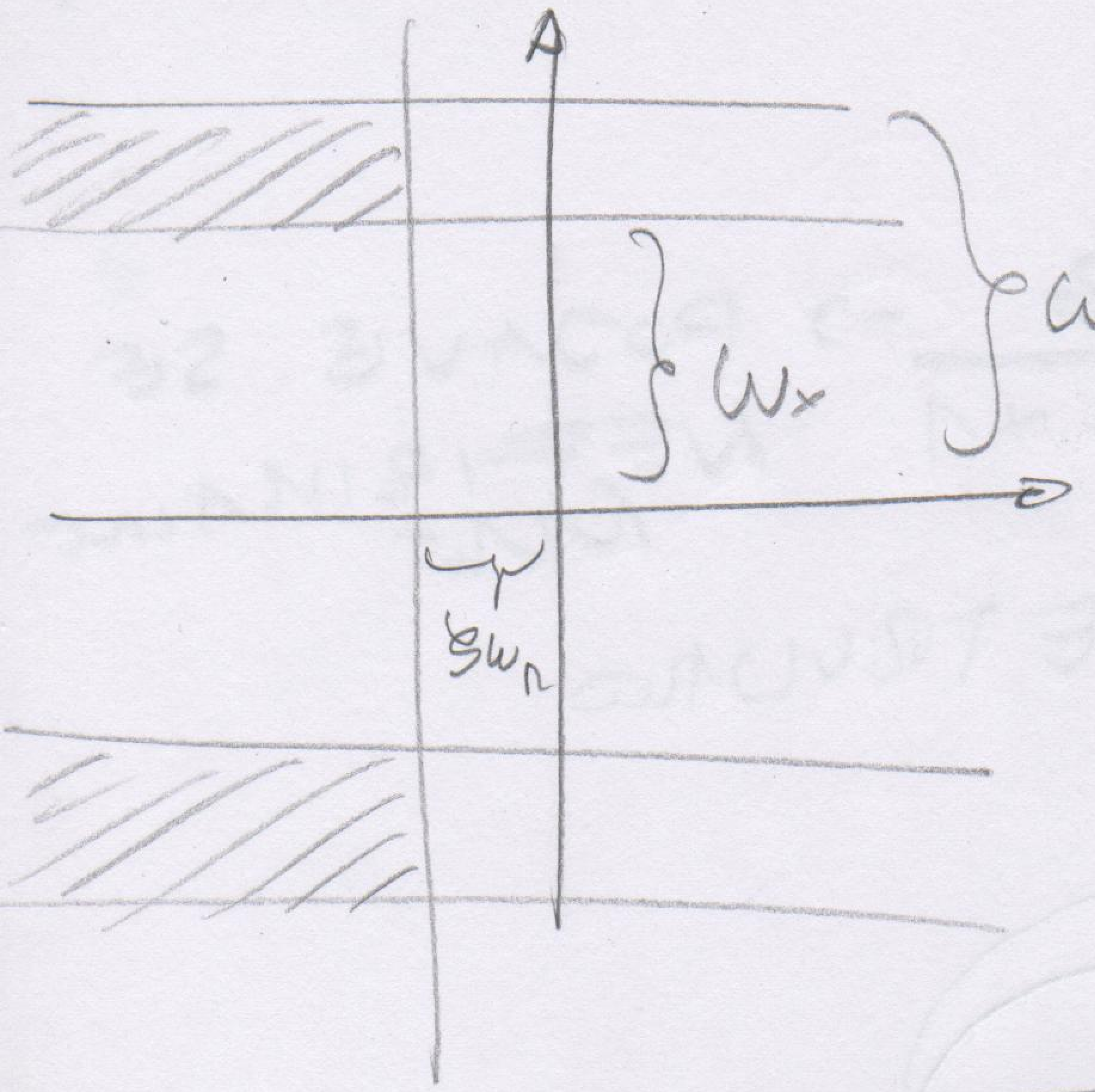
$\sigma = \frac{\xi}{\sqrt{1-\xi^2}}$

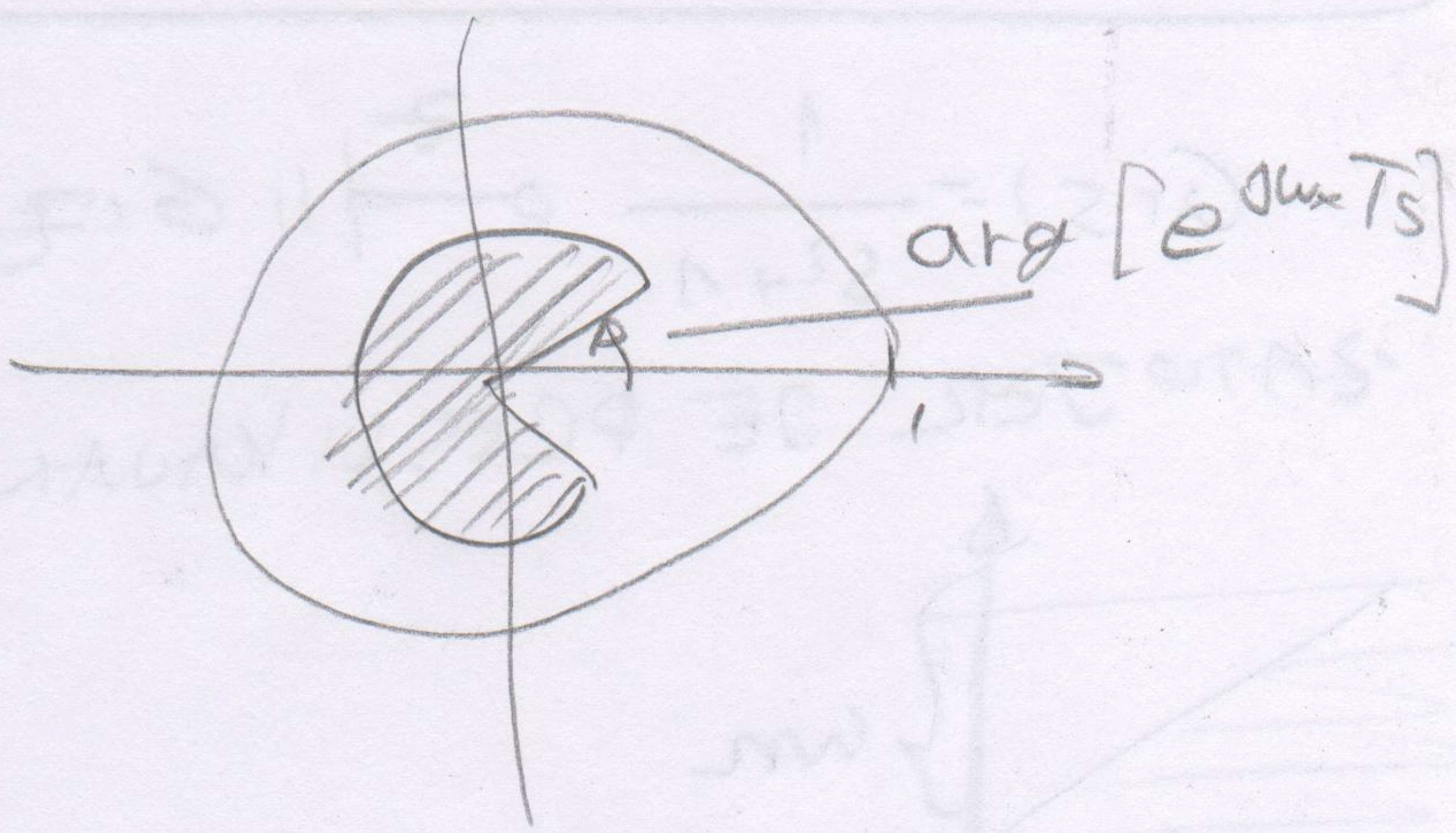
PR 2



ω_N - NYQUISTOVA → $\boxed{\omega_N = \frac{\pi}{T_s}}$







· POSTUPCI DISKRETIZACIJE

1 ZADRŽAVANJE TEŽINSKE FUNKCIJE => Z

2 ZADRŽAVANJE PRIJELAZNE -II- => ZOH

3 USKLAĐIVANJE NULA I POLOVA

$$G(s) = \frac{(s+1)^m}{(s+2)^n} \qquad \boxed{n-m>1}$$

$n-m-1$ NULA $z-1$

$$G(s) = \frac{s+1}{(s+2)^2} \xrightarrow{\mathcal{Z}} G(z) = \frac{B(z)\cdot(z+1)}{N(z)}$$

4. OČUVANJE ω_c → TUSTIN → MOD BILINEARNA

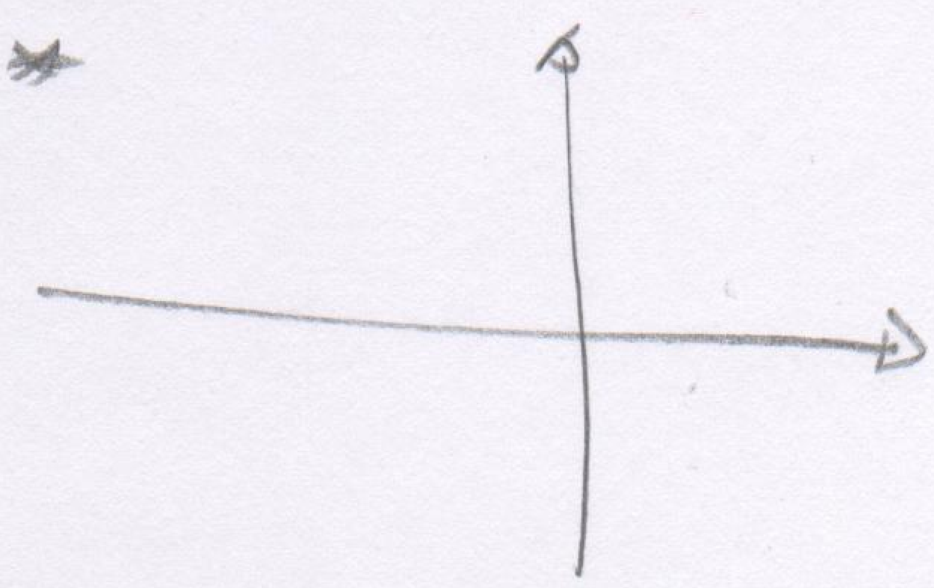
$$z = \frac{1+w}{1-w} \quad w = \frac{1-z}{1+z}$$

$$z = e^{sT}$$

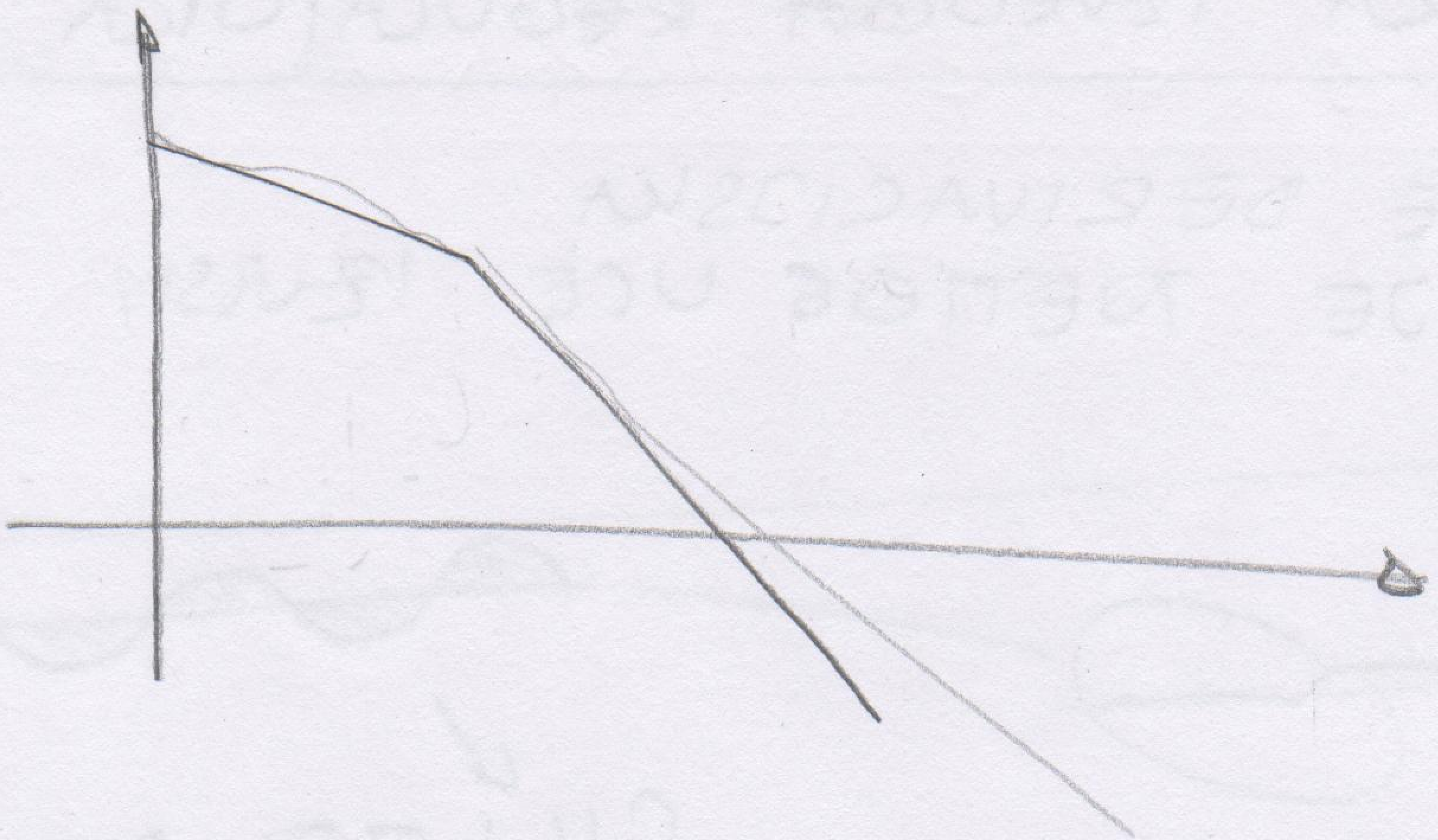
$$w = \frac{1-e^{sT}}{1+e^{sT}} = \frac{\cancel{e^{+s\frac{T}{2}}}}{\cancel{e^{s\frac{T}{2}}}} \cdot \frac{e^{-s\frac{T}{2}} - e^{s\frac{T}{2}}}{e^{-s\frac{T}{2}} + e^{s\frac{T}{2}}}$$

$$w = j\,\underbrace{tg\frac{\omega T}{2}}_{V} \qquad \boxed{w = jV}$$

$$\Omega = \frac{T}{2}w \Rightarrow \Omega = j\frac{2}{T_s}\,tg\,\omega\frac{T_s}{2} = j\omega^*$$



ω^* - PSEUDOFREKVENCIJA

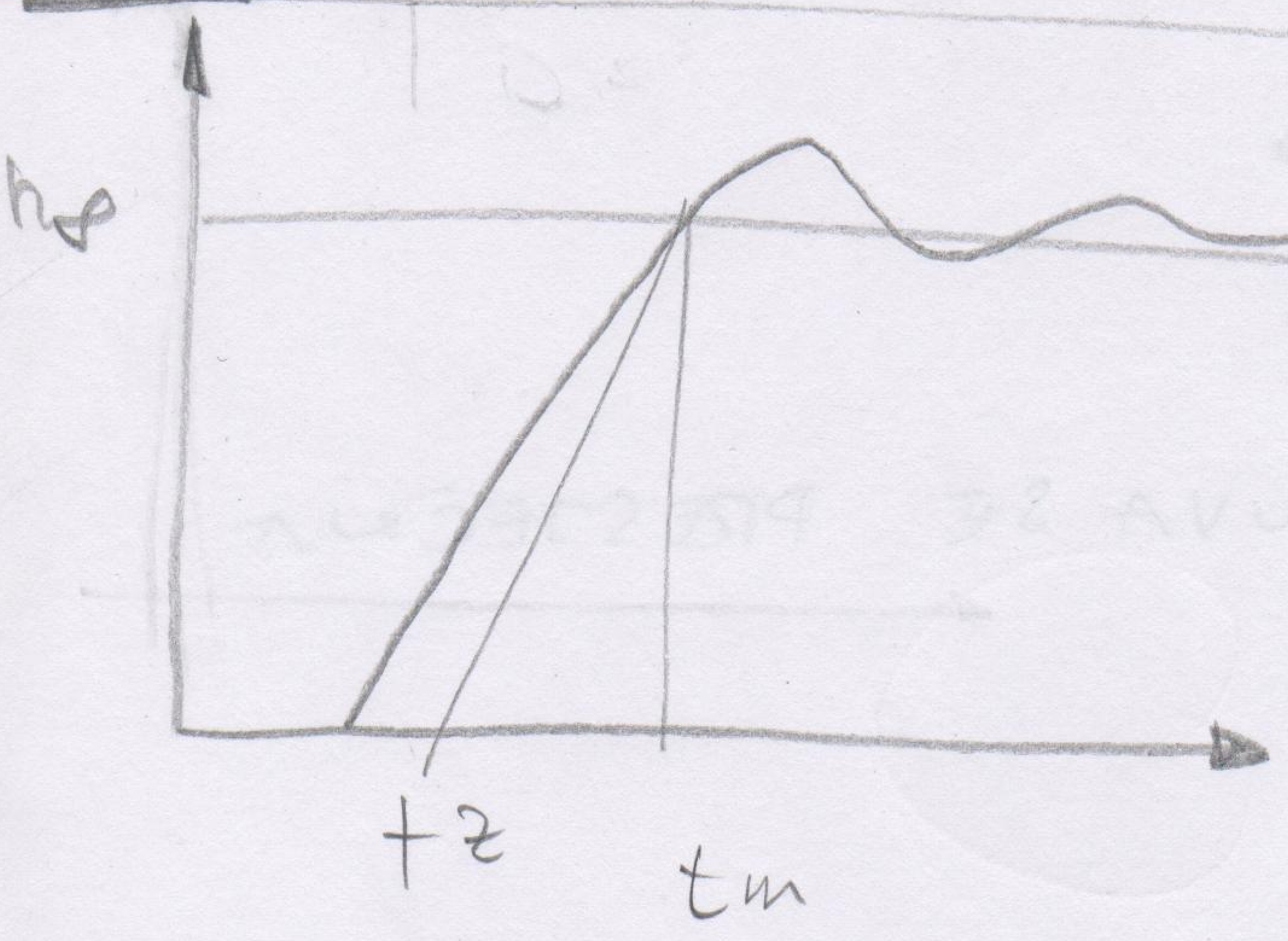


◦ SMANJUJE SE FAZNO OSIGURANJE ČUVA SE PRESJEČNA FREKVENCIJA

· PARALELNA I SERIJSKA IZVEDBA REGULATORA

· PROBLEM KOD NJIH JE DERIVACIJSKA KOMPONENTA I NJU JE NEMOGUĆE IZVESTI

ISE



CILJ JE DA INTEGRAL OVOG BUDE 0

$$\boxed{I = \int_0^\infty f[e(t)]\,dt}$$