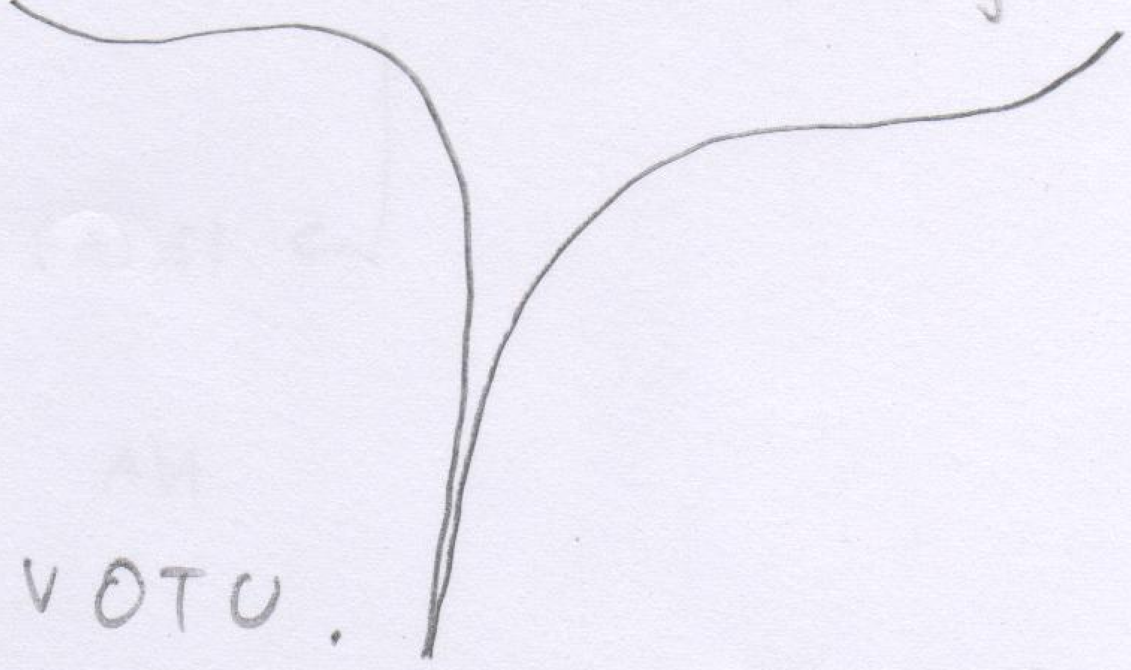
ANALOGNO DOBA → MEHANIKA, VAKUUMSKE CIJEVI, KONTINUIRANO PODRUČIJE



① ŠTO JE SMISAO PREDMETA ??

② NACRTATI MODEL.

③ VIZUALIZIRANJE U STVARNOM ŽIVOTU.

primjeri: VODOKOTLIĆ, PARNI STROJ, PRETVARAČ + ASINK. MOTOR

SINTEZA + ANALIZA ⇒ FIZIKALNI + MATEMATIČKI MODEL ⇒ JEDNADŽBE !

LABOS 1 ⇒ OPIS SUSTAVA POMOĆU DIFF. JEDNADŽBI

1° ZADATAK { RLC KRUG → NAPONI ČVOROVA {S DOMENA} ILI VREMENSKA DOMENA }

↳ ODREDITI NPR. $y'' + y' + y = 4u' + u$ ⇒ MOGUĆE ZBOG LINEARNOG SUSTAVA

2° ZADATAK → SVE ISTO SAMO JE SUSTAV NELINEARAN

$$y'' + y' + y = 4u' + \sqrt{u}$$

④ LINEARIZACIJA

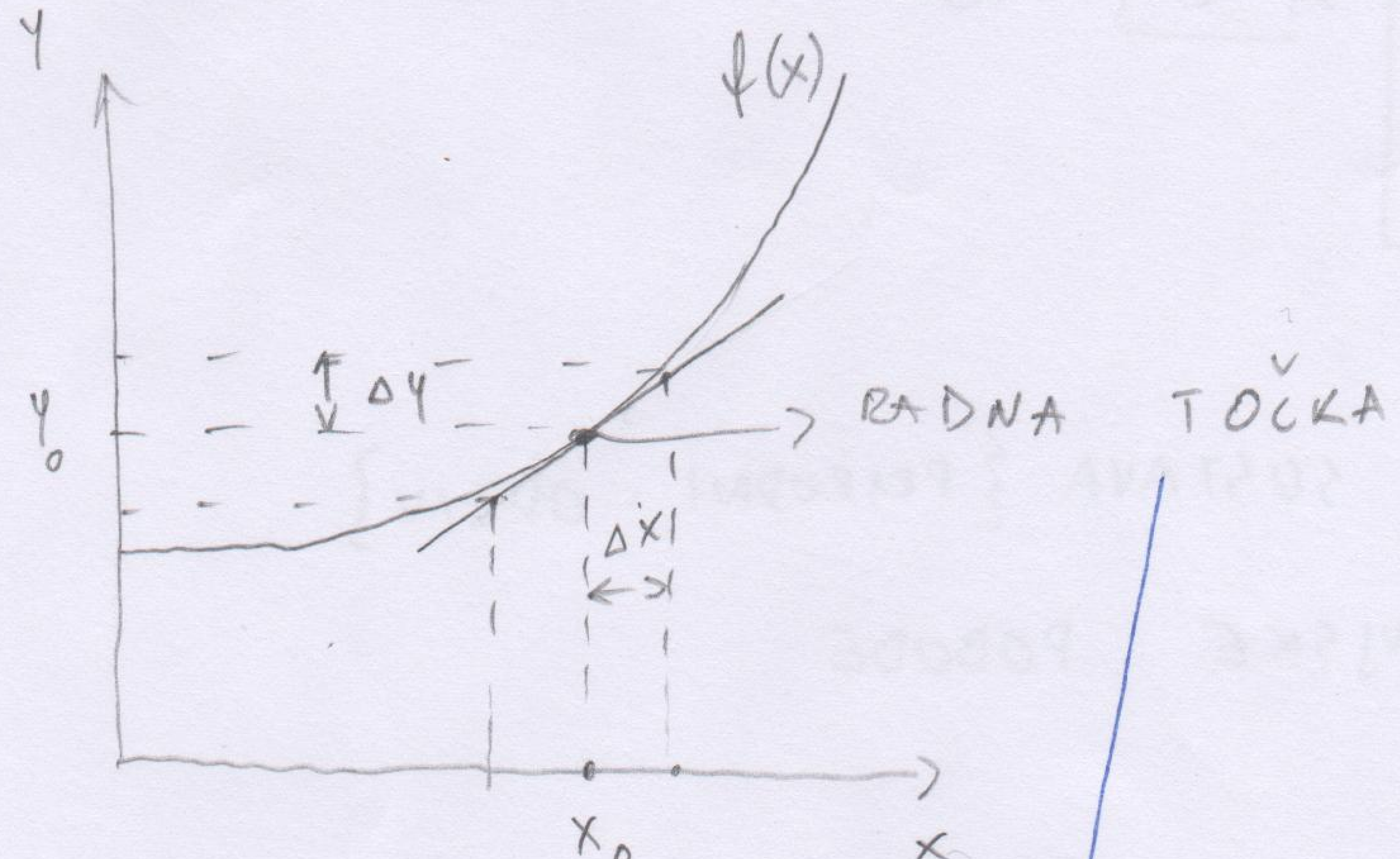
UVJETI LINEARNOSTI { ADITIVNOST $f(x_1 + x_2) = f(x_1) + f(x_2) \to \forall x \in D\{f\}$
HOMOGENOST $f(\alpha x) = \alpha f(x) \to \forall x \in D\{f\}$ i $\forall \alpha$ }

↓ LTI

α ↓ SKALAR

LINEARNOST JE UVJET ZA LAPLACEA { LINEARNA INTEGRALNA TRANSFORMACIJA }

$$F(s) = \int_{0^-}^{\infty} f(t)\, e^{-sT}\, dt$$



$y = f(x)$

$x = x_0 + \Delta x$
$y = y_0 + \Delta y$ } JAKO ZUMIRANO

$y = f(x_0 + \Delta x) \approx f(x_0) + \underbrace{K\Delta x}_{\Delta y}$

↓ NAGIB PRAVCA

$$K = \left.\frac{dy}{dx}\right|_{x_0}$$

NPR. KOLIČINA VODE U POSUDI JE UVIJEK KONSTANTNA

$z = \frac{1+w}{1-w}$ $\quad w = \frac{1-z}{1+z}$ $\quad z = e^{-sT}$ $\quad s = j\omega$

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

$w = j\, tg\, \omega \frac{T}{2} \Big\}$ $\quad w = jV$

↳ FIKTIVNA PSEUDOFREKVENCIJA

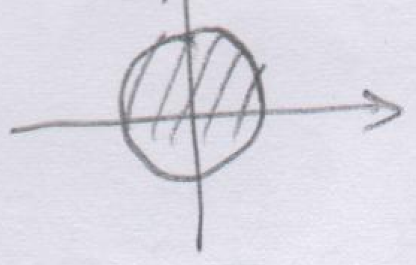
$z = e^{-sT}$ => PADEOVA APROKSIMACIJA $\quad e^{-sT} = \lim_{n\to\infty} \left(\frac{1 - \frac{Ts}{2n}}{1 + \frac{Ts}{2n}} \right)^n$

$n = 1 \Rightarrow e^{-sT} = \frac{1 - \frac{Ts}{2}}{1 + \frac{Ts}{2}}$

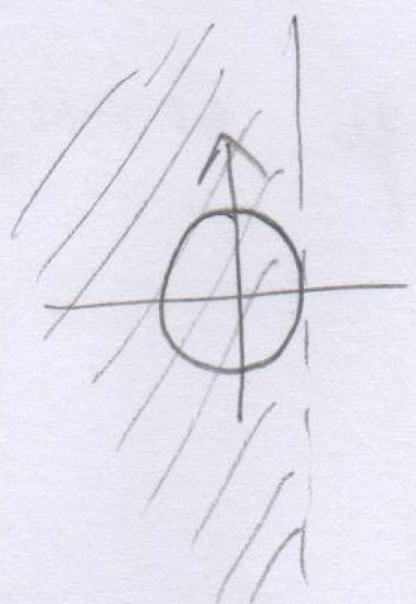
MODIFICIRAMO $\Omega = \frac{2}{T} \cdot w = \frac{2}{T} j\, tg\, \omega \frac{T}{2} = \omega^* j$ APSOLUTNA PSEUDOFREKVENCIJA

$$\omega^* = \frac{2}{T}\, tg\, \frac{\omega T_s}{2}$$

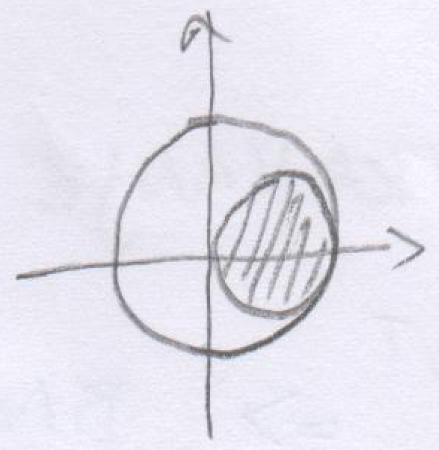
TUSTIN



EULER UNAPRIJEDNA (PREDIKCIJA)



EULER UNAZADNA (PROBLEM REZOLUCIJE)



5 LABOS

1° ZADATAK
- → ODREĐIVANJE KONSTANTI PREMA UNAPRIJED ZADANIM PARAMETRIMA
- → ODABIR VREMENA DISKRETIZACIJE
- → STABILNOST PREKO JURYA

SVI REGULATORI IMAJU JEDNAKE POLOVE

VAŽNO:

ODREDIMO σ_m [%], ω_c, γ U $G_o(s)$

BODE IZ VJEŽBE

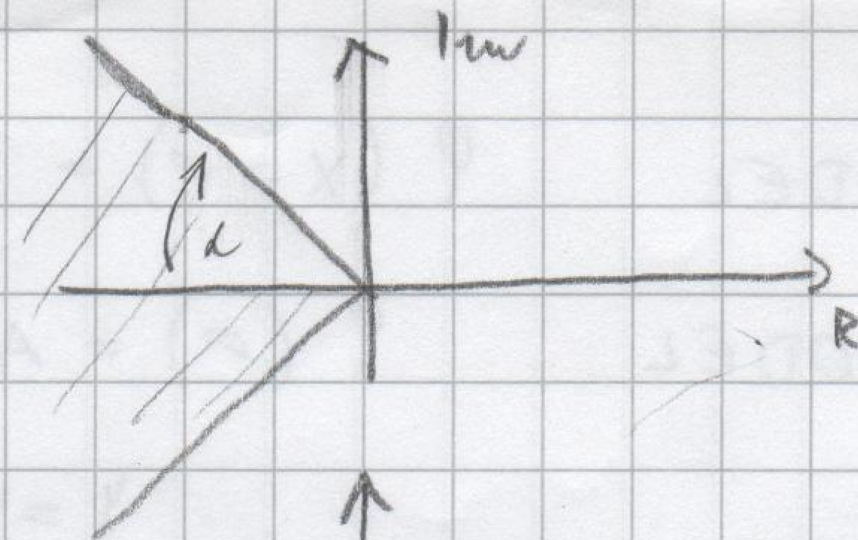
NAPRAVIMO TUSTINA $G_o(\Omega)$ => NACRTAMO BODEA $\{\omega^*\}$

↳ NADVIŠENJE SE POVEĆA γ SE SMANJI $\quad \omega_c$ JE ISTA t_m JE ISTO

DODAVANJEM POJAČANJA POVEĆAVAMO γ

AKO IZAĐEMO IZ DOPUŠTENOG INTERVALA T_s ODZIV SE VIŠE NE POKLAPA DOBRO SA KONTINUIRANIM

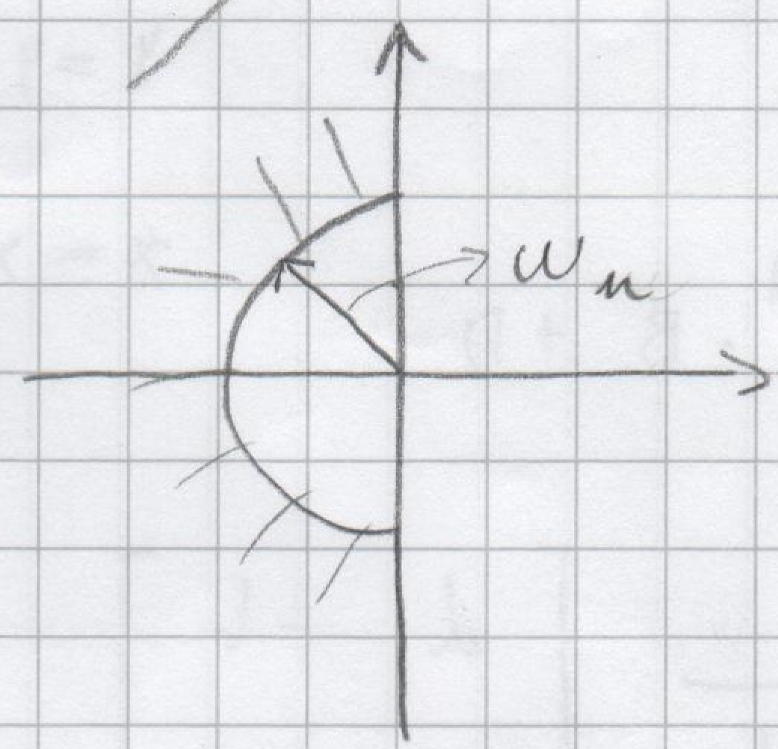
MAKSIMALNO NADVIŠENJE:



$\sigma_m < \sigma_{MAX} \rightarrow \zeta_m \geq \zeta_{MAX}$

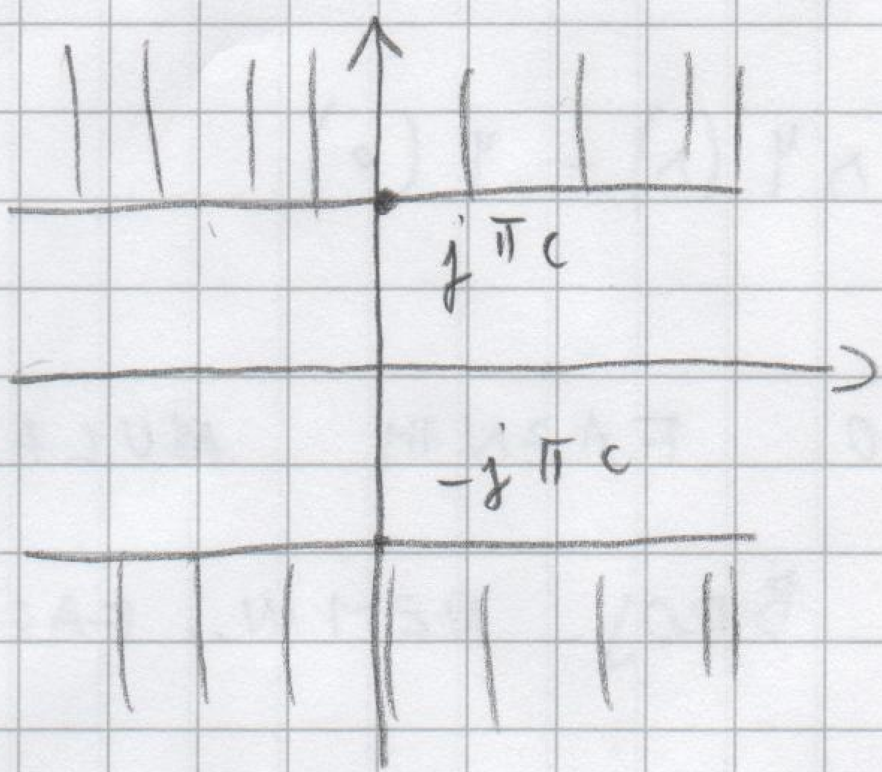
$\alpha \leq \arccos \zeta_{MAX}$

VRIJEME PORASTA:

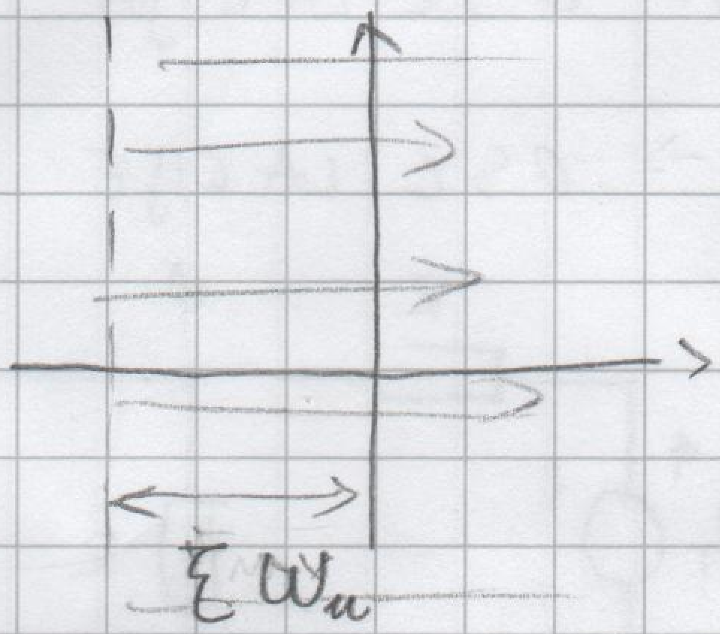


$t_r \leq t_{MAX}$ $\quad \omega_n \geq \omega_{MAX}$

$t_m < C$ $\quad \omega_n\sqrt{1-\zeta^2} > \pi \cdot C$



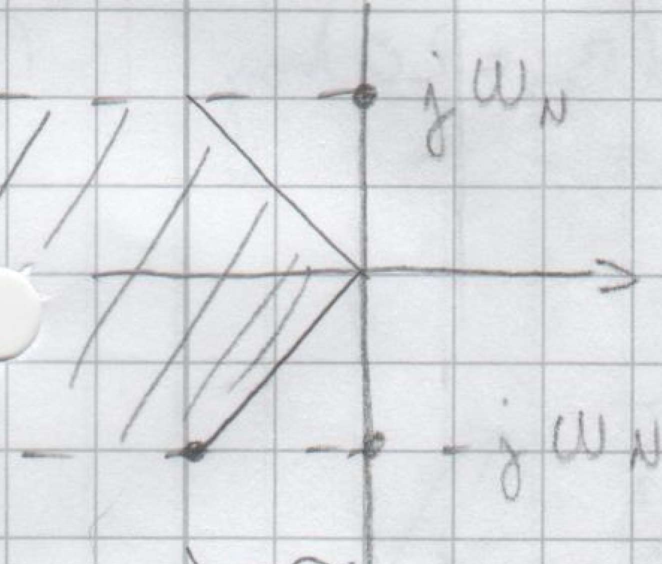
VRIJEME USTALJIVANJA:



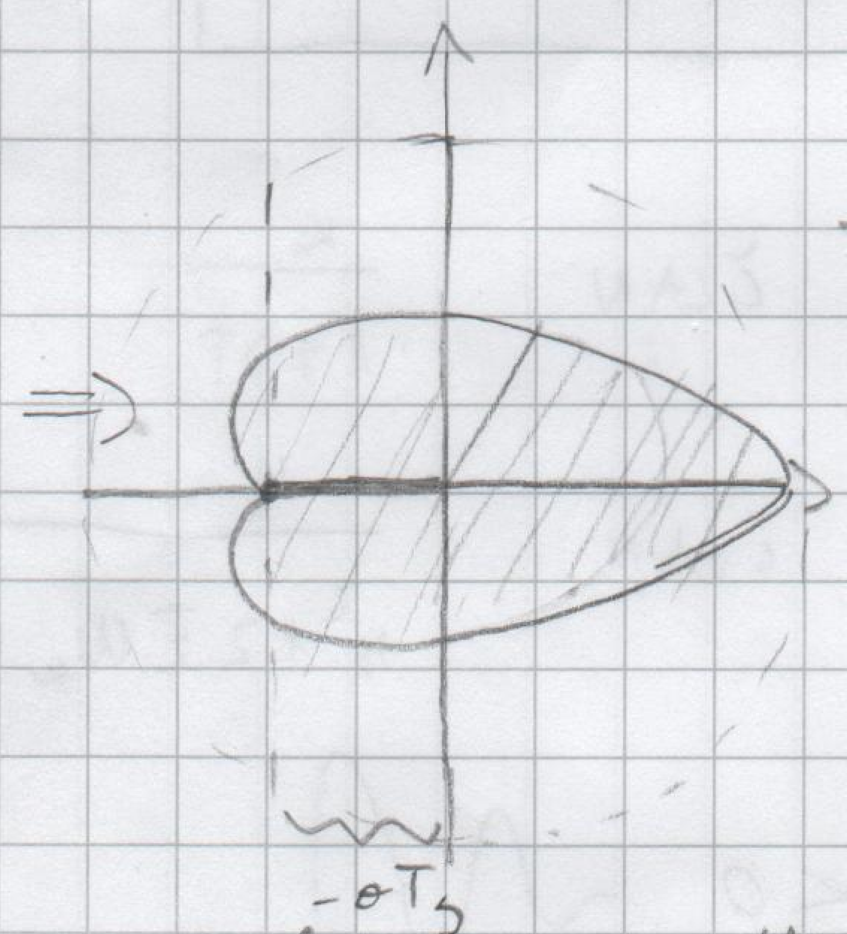
$t_\varepsilon \leq t_{MAX} \rightarrow \sigma \geq \sigma_{MAX}$

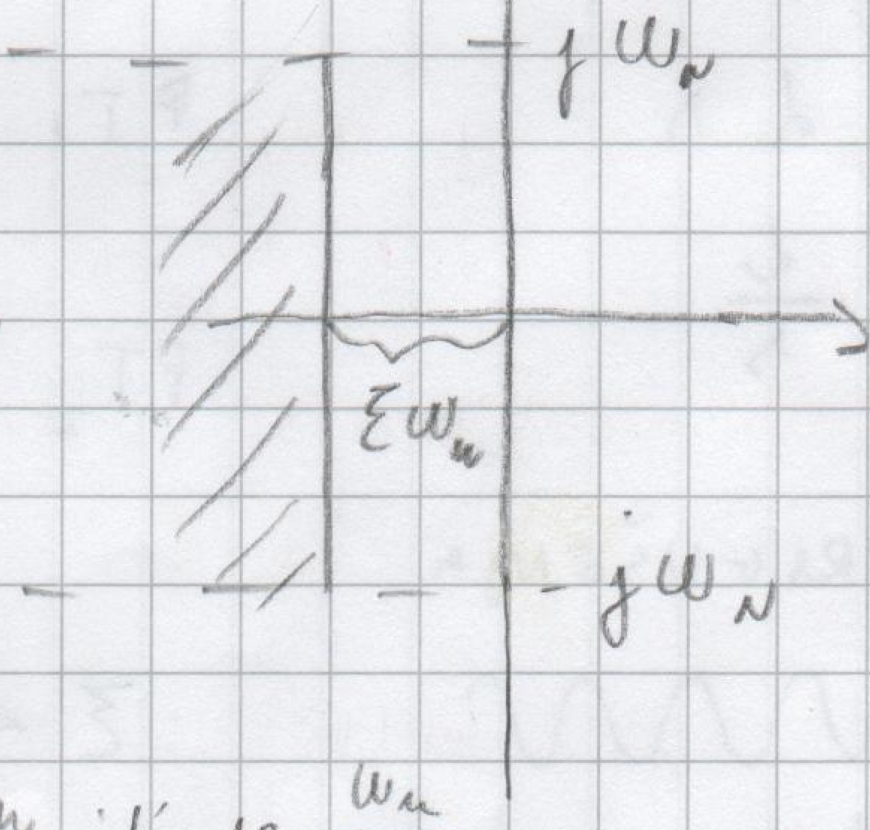
$\lim_{s\to 0}|G(s)| = \lim_{z\to 1}|G(z)|$

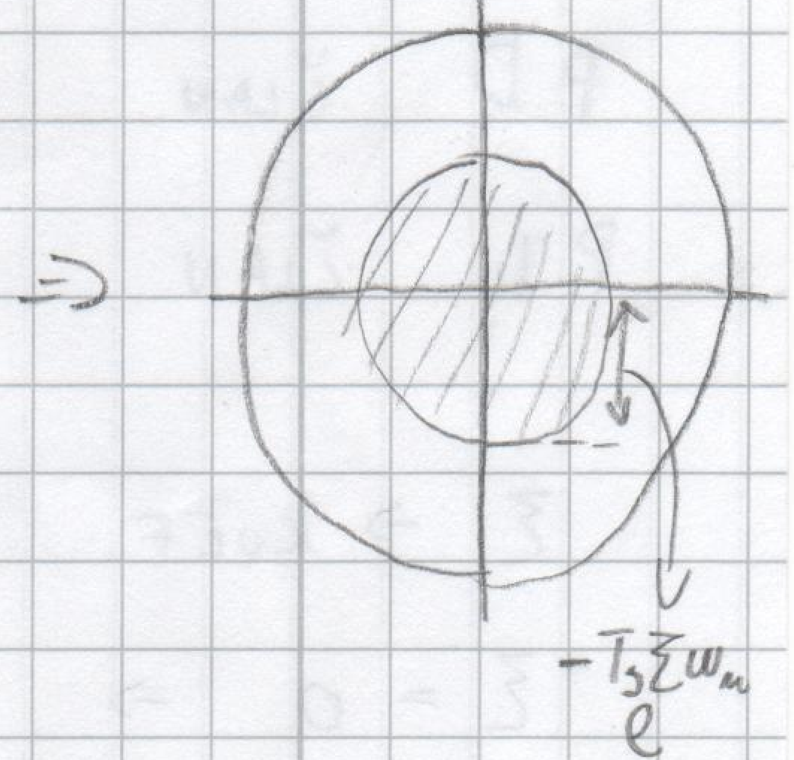
$= \lim_{z\to 1}(1-z^{-1})E(z)$



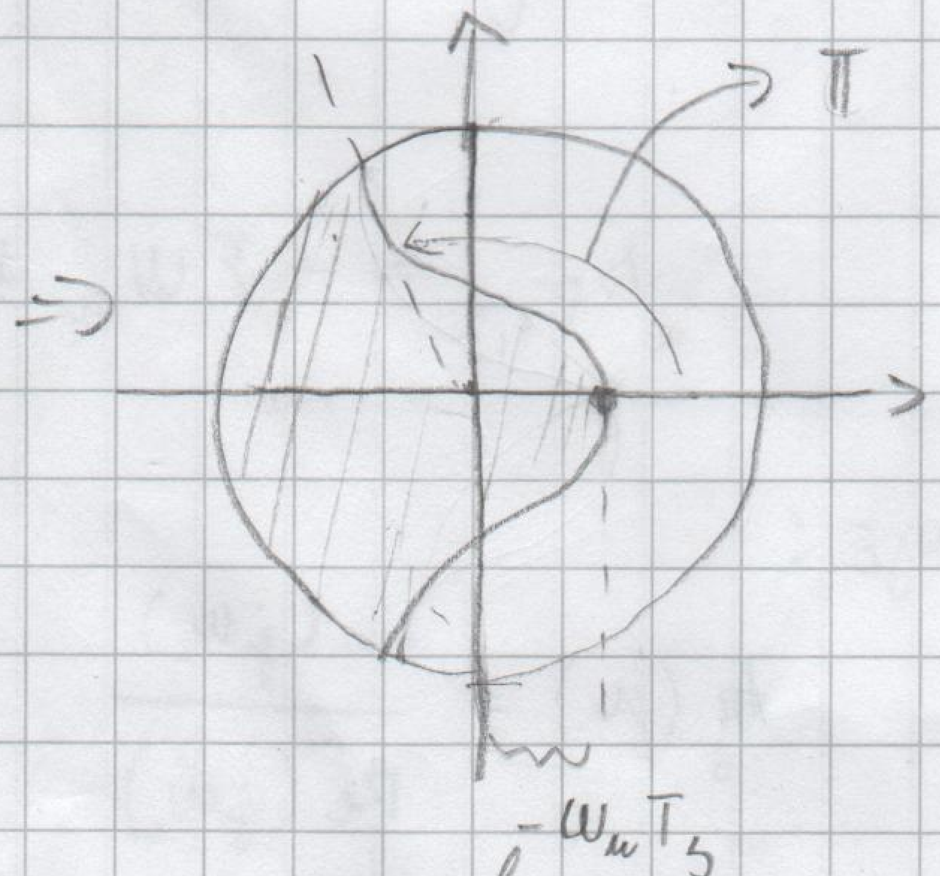
$\sigma = \frac{\zeta}{\sqrt{1-\zeta}}\omega_N$

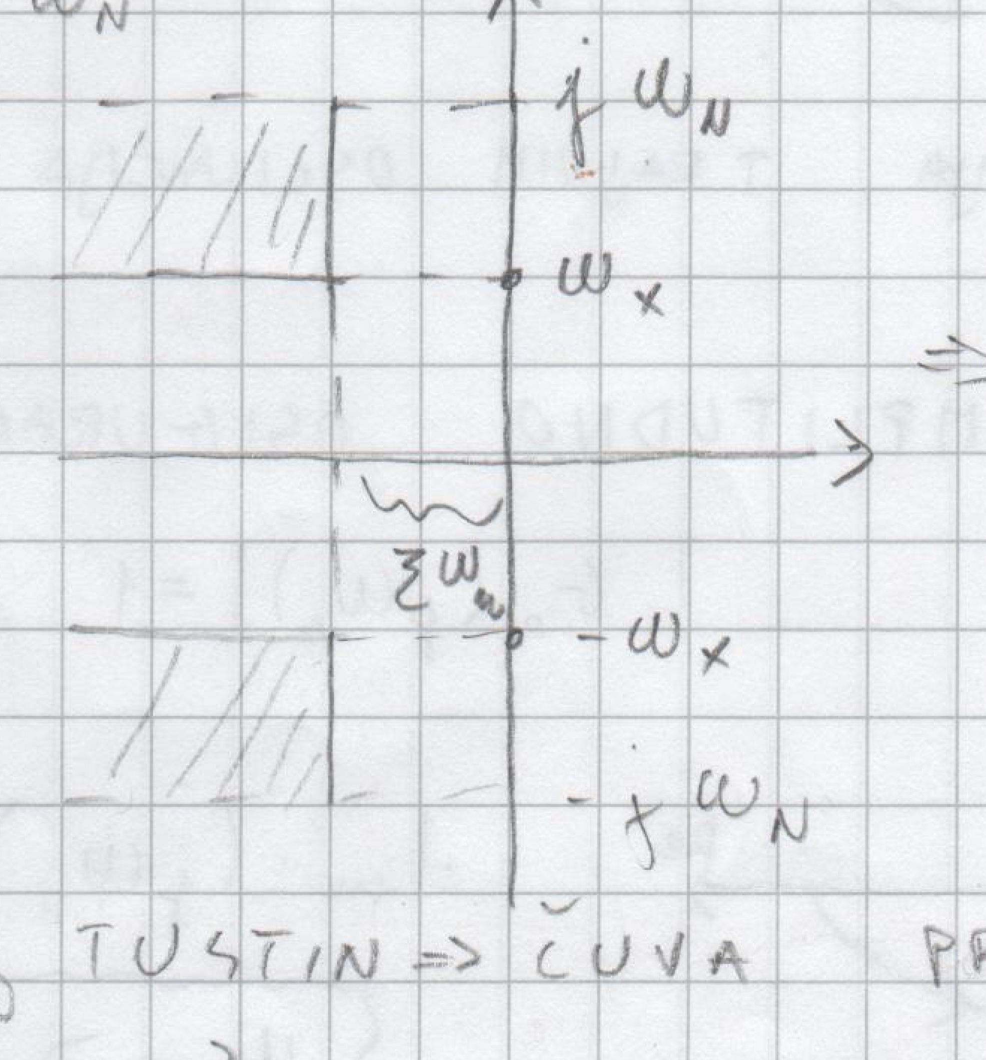


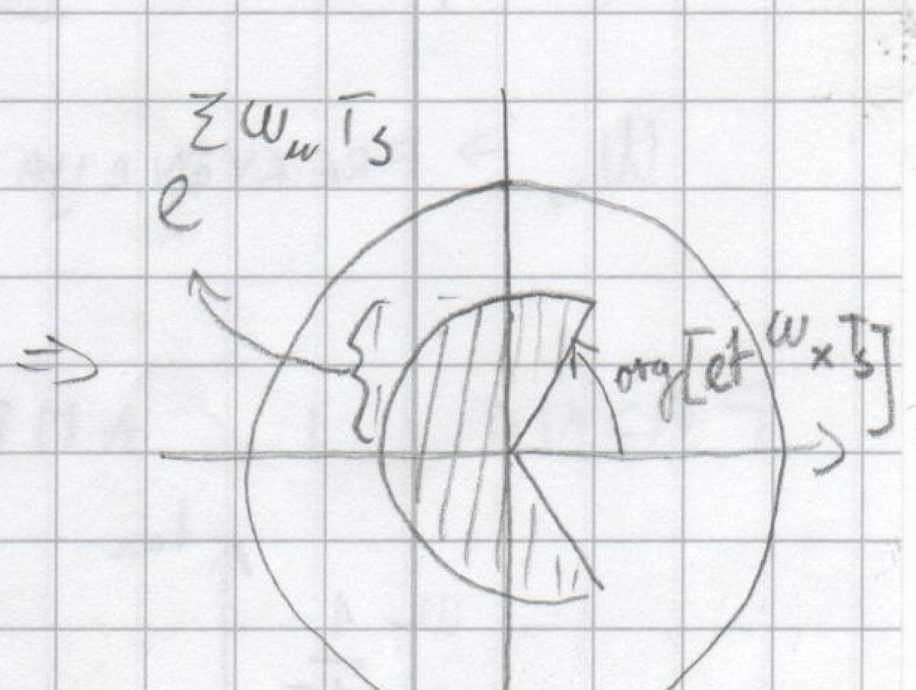




$\frac{\omega_n}{\omega_N}$ ili $180\frac{\omega_n}{\omega_N}$







$\mathcal{Z}\{G(s)\} \Rightarrow$ ČUVA TEŽINSKU FJU. $\{G_R\}$ TUSTIN $\Rightarrow$ ČUVA PRESJEČNU FREKVENCIJU

ZOH $\Rightarrow$ ČUVA PRIJELAZNU FJU. {UVIJEK G_P}

$y - y_1 = k(\log x - \log x_1)$

NELINEARNI MODEL $\quad y(x=\infty) = A(0) + A(\infty) \Rightarrow$ DERIVACIJE SU NULA

LINEARIZIRANI MODEL $\quad y(\infty) = A(0) + \underbrace{\Delta A(\infty)}$

$\dot{x} = Ax + Bu$

$y = Cx + Du$

$y = y_0 + \Delta y \qquad$ IZ PRIJENOSNE FUNKCIJE

$x = x_0 + \Delta x$

$G(s) = C(sI - A)^{-1} \cdot B + D$

$h(t) \Rightarrow$ PRIJELAZNA FUNKCIJA $y(t) \cdot S(t)$

$$\begin{bmatrix} a & b \\ c & d \end{bmatrix}^{-1} = \frac{1}{ad - bc} \begin{bmatrix} d & -b \\ -c & a \end{bmatrix}$$

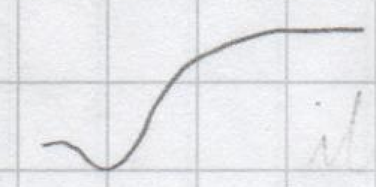
$g(t) = \dot{h}(t)$

$G(s) = sH(s)$

$\mathcal{L}(\dot{y}) = sY(s) - y(0) \qquad \mathcal{L}(\ddot{y}) = s\dot{Y} - \dot{y}(0)$

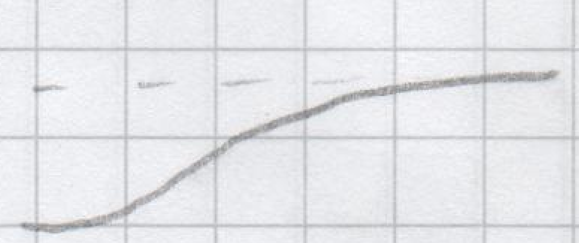
NEPARNI BROJ

NEMINIMALNO FAZNIH NULA NPR. $(s-1) \Rightarrow$ PODBAČAJ

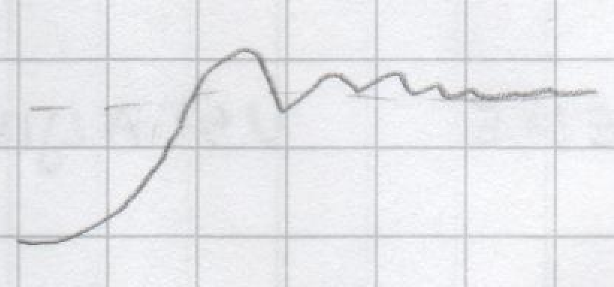


$\hookrightarrow$ PARNI BROJ NEMIN. FAZNIH NULA $\rightarrow$ NEMA PODBAČAJA

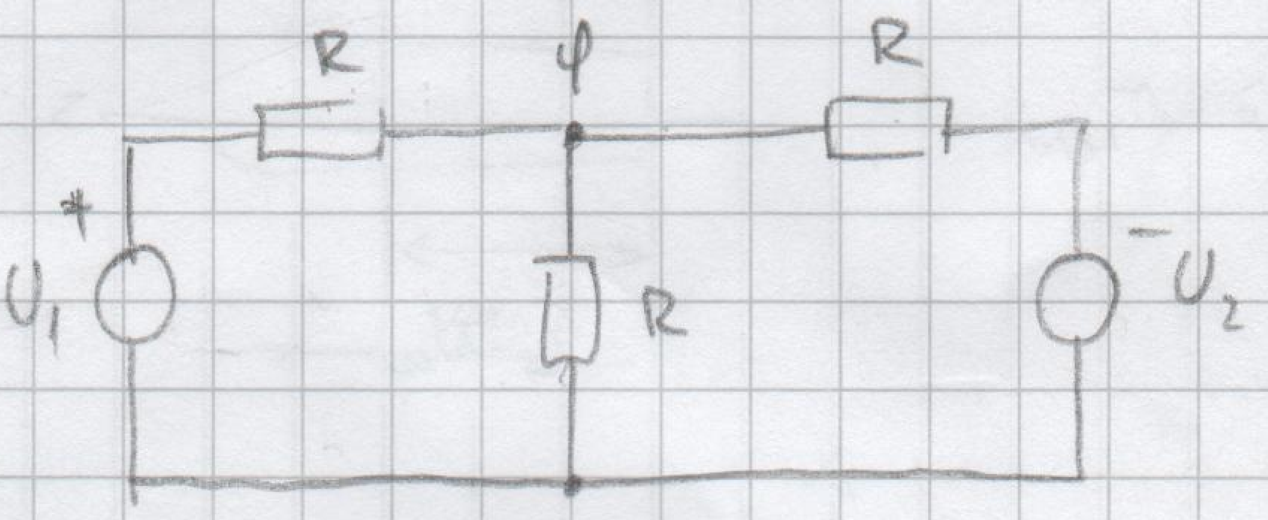
POLOVI $\rightarrow$ REALNI $\rightarrow$ NEMA OSCILACIJA



$\hookrightarrow$ KOMPL. KONJ. $\rightarrow$ OSCILACIJE I PREBAČAJ



POTENCIJAL ČVORA



$$\varphi\left(\frac{1}{R} + \frac{1}{R} + \frac{1}{R}\right) = \frac{U_1}{R} - \frac{U_2}{R}$$

$-3\,dB = 20 \log |G(j\omega_b)|$

PD ČLAN $\quad ks$

PI ČLAN $\quad \frac{k}{s}$

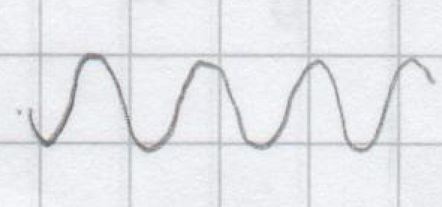
PT$_1$ ČLAN $\quad \frac{K}{1 + sT}$

PT$_2$ ČLAN $\quad \frac{K}{s^2 + 2\xi\omega_n s + \omega_n^2}$

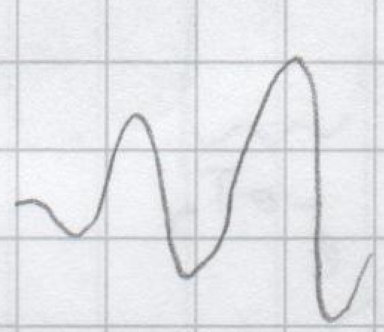
$$k' \frac{1}{\frac{s^2}{\omega_n^2} + \frac{2\xi}{\omega_n} s + 1}$$

$\xi \rightarrow$ KOEF. PRIGUŠENJA

$\xi = 0 \rightarrow$



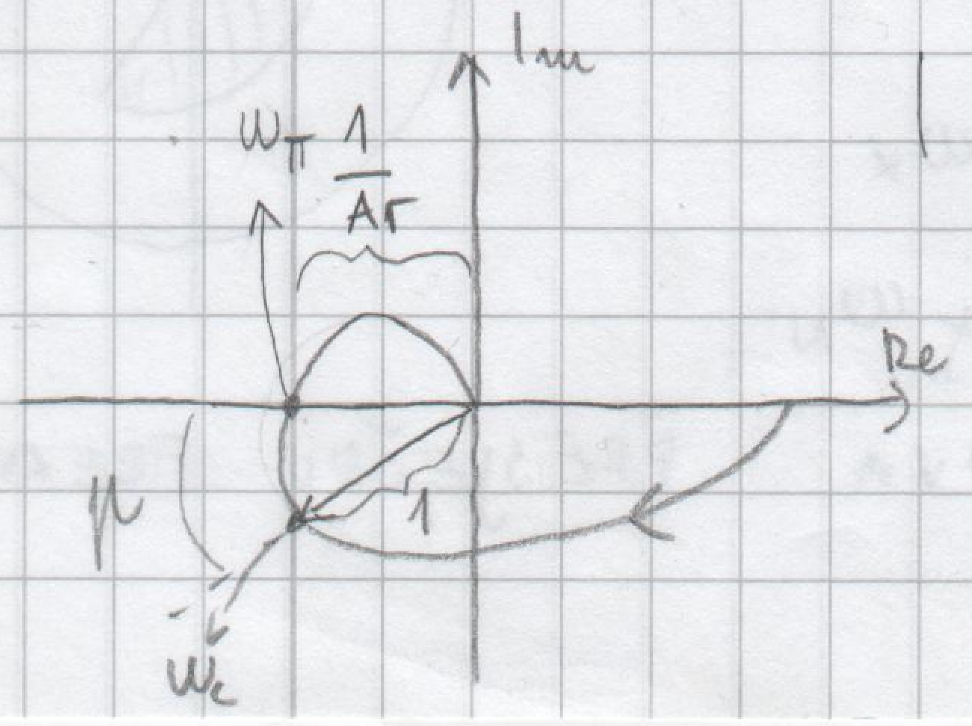
$\xi < 0$



$\xi = 1 \rightarrow$

$\omega_n \rightarrow$ FREKVENCIJA TRAJNIH OSCILACIJA $\qquad s_{p_{1,2}} = -\xi\omega_n \pm \omega_n\sqrt{\xi^2 - 1}$

FAZNO I AMPLITUDNO OSIGURANJE:



$|G_o(j\omega_c)| = 1 \qquad tg(\mu) = \frac{Im(j\omega_c)}{Re(j\omega_c)}$

$Im(j\omega_\pi) = 0$

$\boxed{\omega_\pi > \omega_c \Rightarrow \text{SUSTAV JE STABILAN}}$

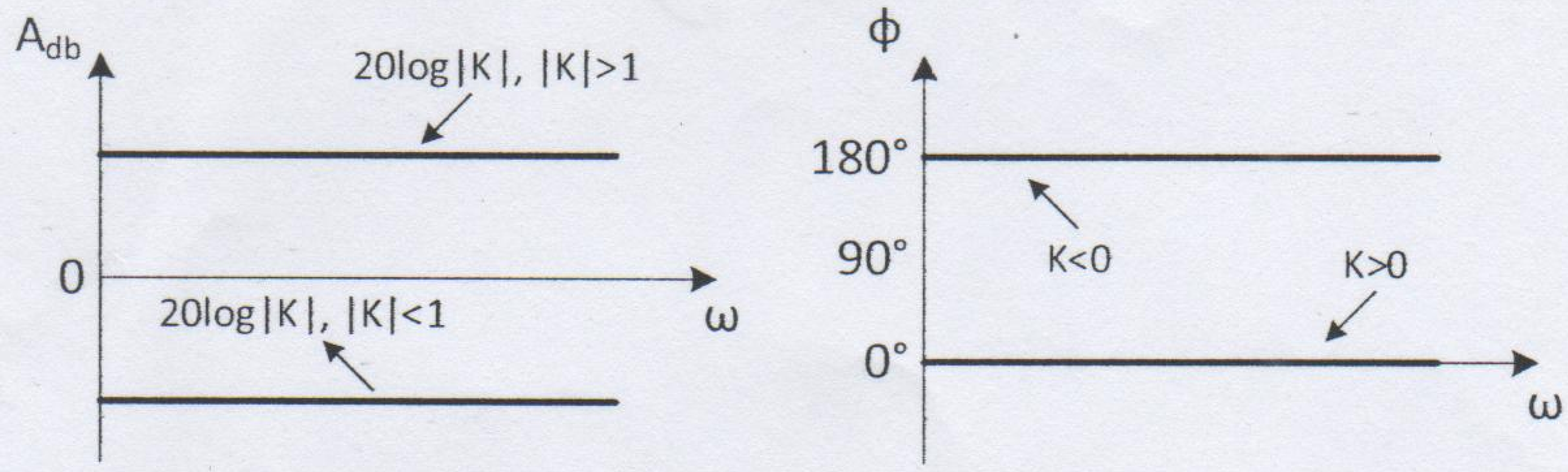
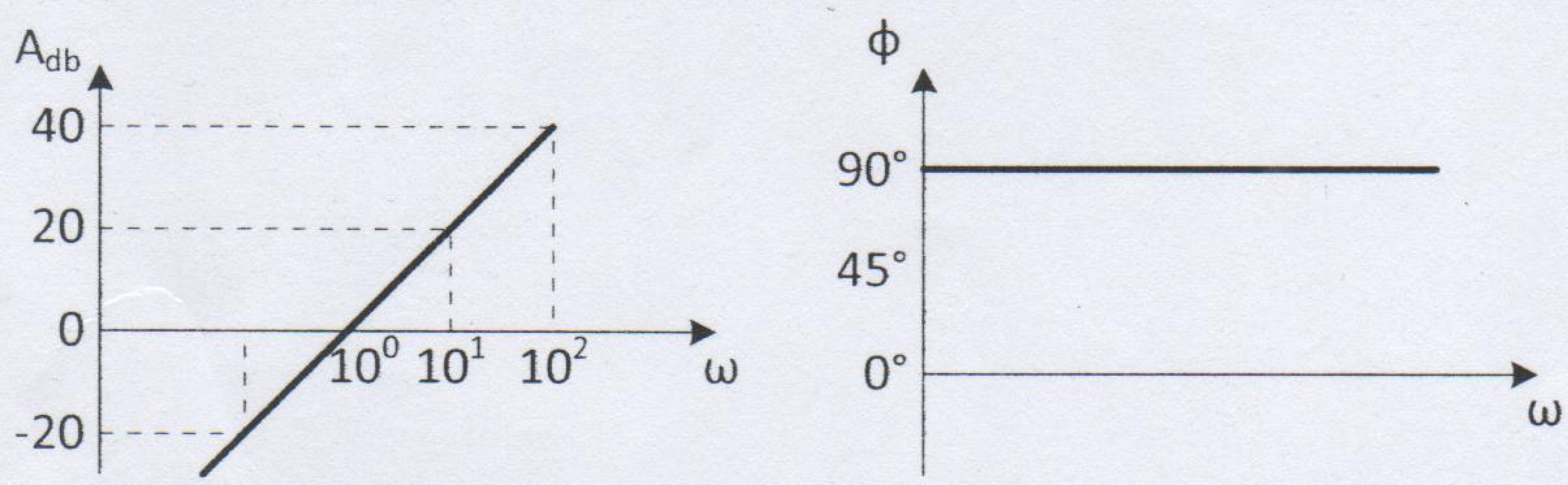
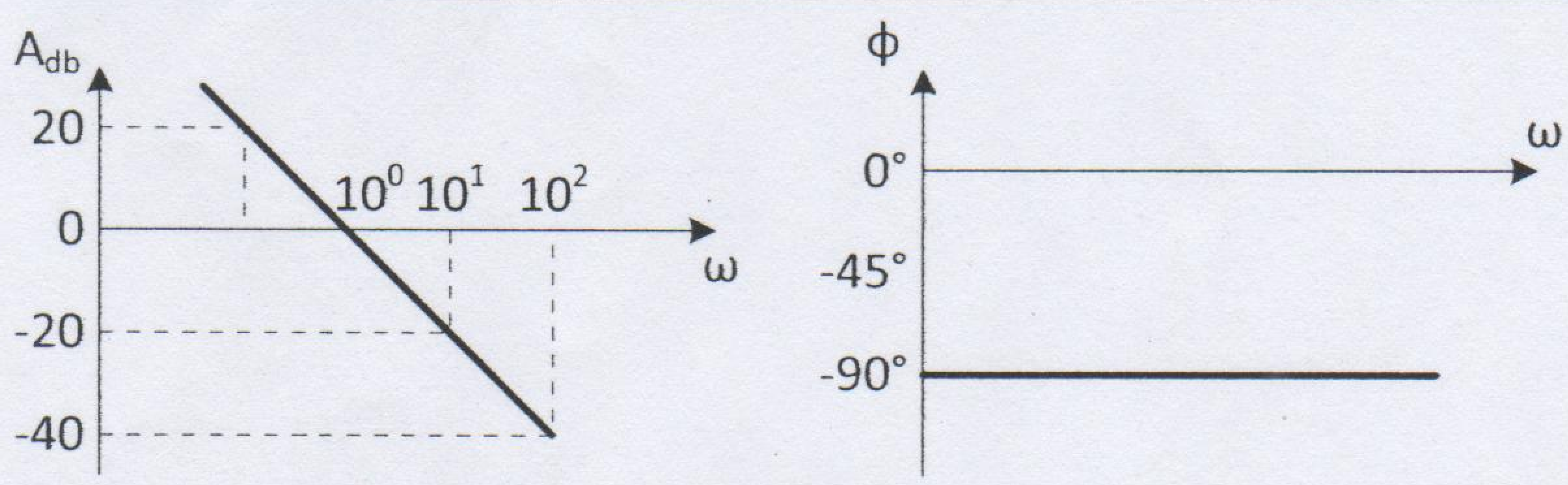
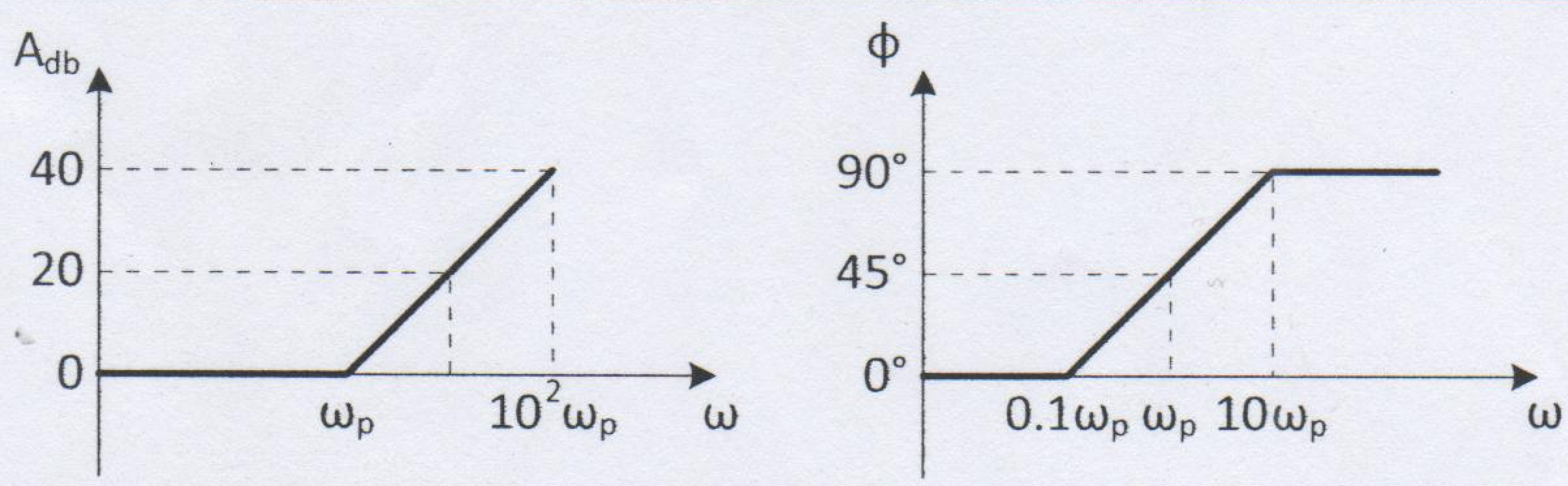
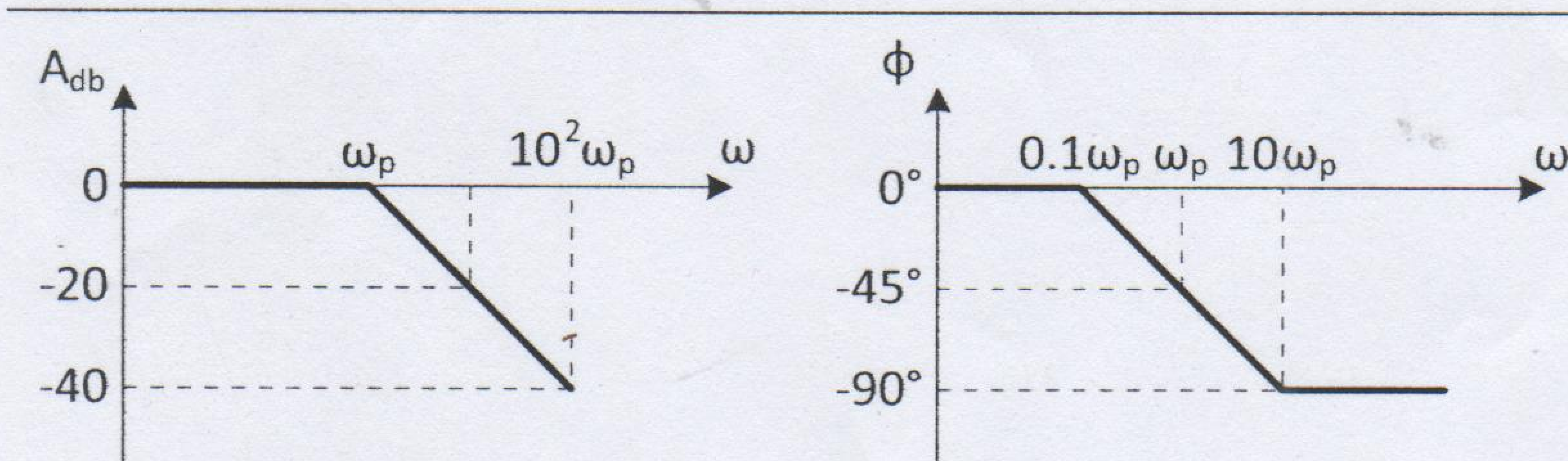
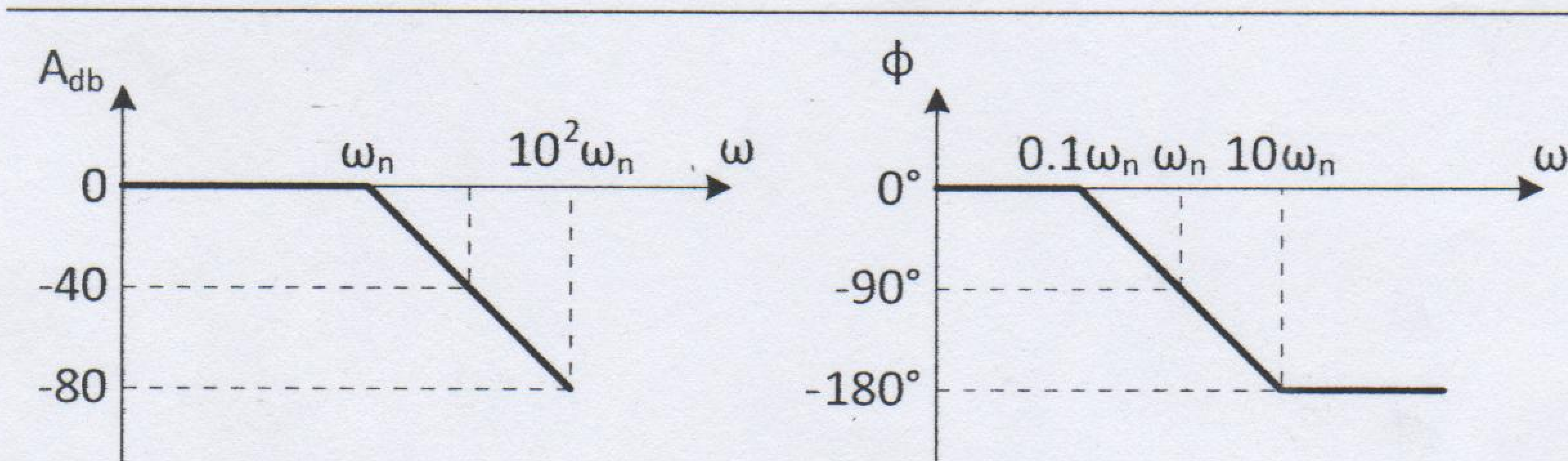
MRTVO VRIJEME

$\hookrightarrow$ FAZNO KAŠNJENJE

$\{-\omega_c T\}$

Sistematizacija osnovnih članova za prikaz amplitudno-frekvencijske i fazno-frekvencijske karakteristike Bodeovim načinom prikazana je u Tablici 4.3.

Tablica 4.3: Osnovni članovi Bodeovih dijagrama

Amplitudna i fazna karakteristika (Bodeov prikaz)	Prijenosna funkcija člana
	$G(j\omega) = K$ $A_{dB}(\omega) = 20 \log \lvert K \rvert$ $\phi(\omega) = \begin{cases} 0, & K > 0 \\ \pi, & K < 0 \end{cases}$
	$G(j\omega) = j\omega$ $A_{dB}(\omega) = 20 \log \omega$ $\phi(\omega) = \frac{\pi}{2}$
	$G(j\omega) = \frac{1}{j\omega}$ $A_{dB}(\omega) = -20 \log \omega$ $\phi(\omega) = -\frac{\pi}{2}$
	$G(j\omega) = 1 + j\frac{\omega}{\omega_p}$ $A_{dB}(\omega) = 20 \log \sqrt{1 + (\frac{\omega}{\omega_p})^2}$ $\phi(\omega) = \arctan \frac{\omega}{\omega_p}$
	$G(j\omega) = \frac{1}{1+j\frac{\omega}{\omega_p}}$ $A_{dB}(\omega) = -20 \log \sqrt{1 + (\frac{\omega}{\omega_p})^2}$ $\phi(\omega) = -\arctan \frac{\omega}{\omega_p}$
	$G(j\omega) = \frac{1}{1+2\xi j(\frac{\omega}{\omega_p})+(j\frac{\omega}{\omega_p})^2},$ $A_{dB}(\omega) \approx -40 \log \sqrt{1 + (\frac{\omega}{\omega_n})^2}$ VAŽNO $\phi(\omega) \approx -2 \arctan \frac{\omega}{\omega_n}$

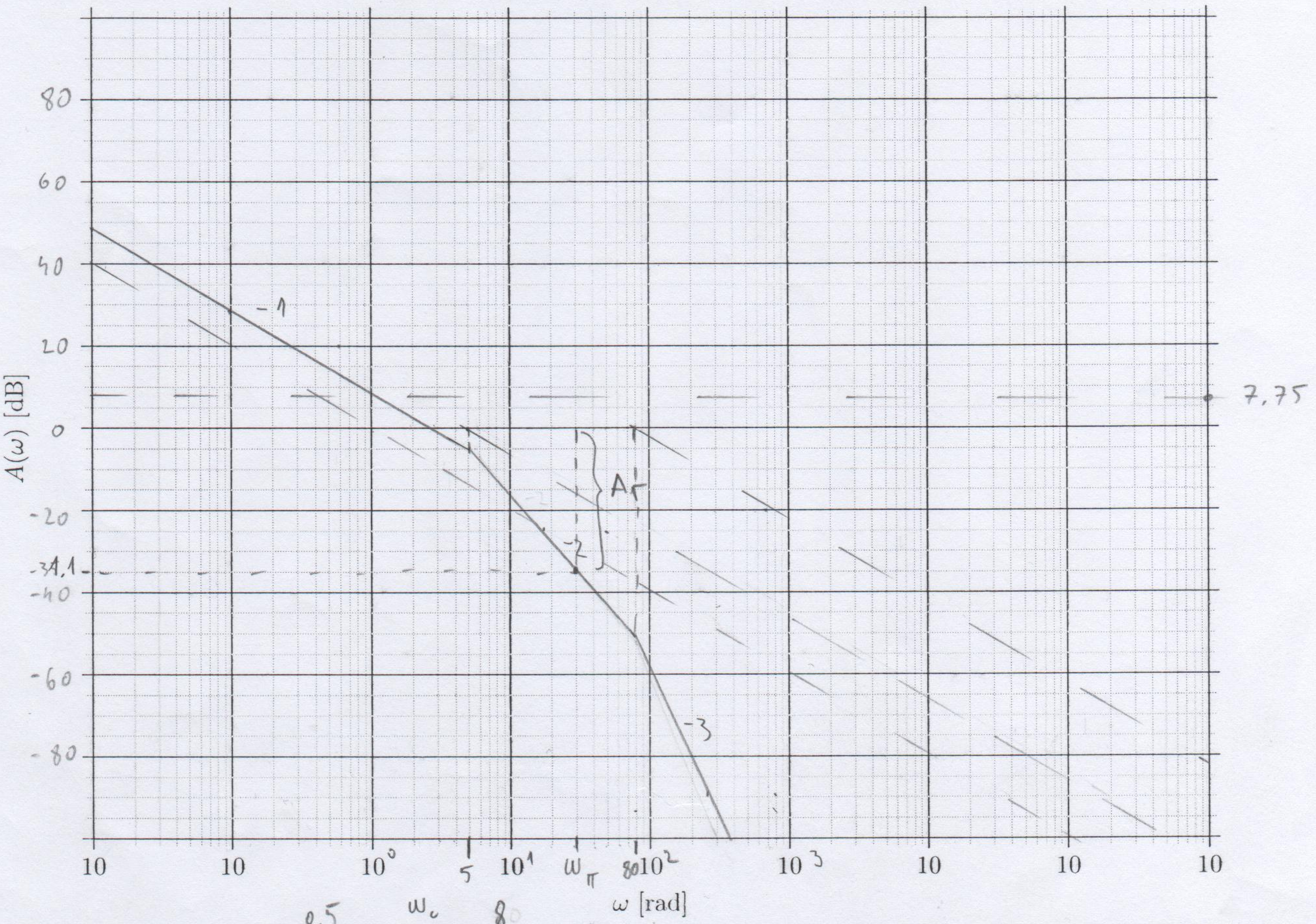
NEMINIMALNA FAZA

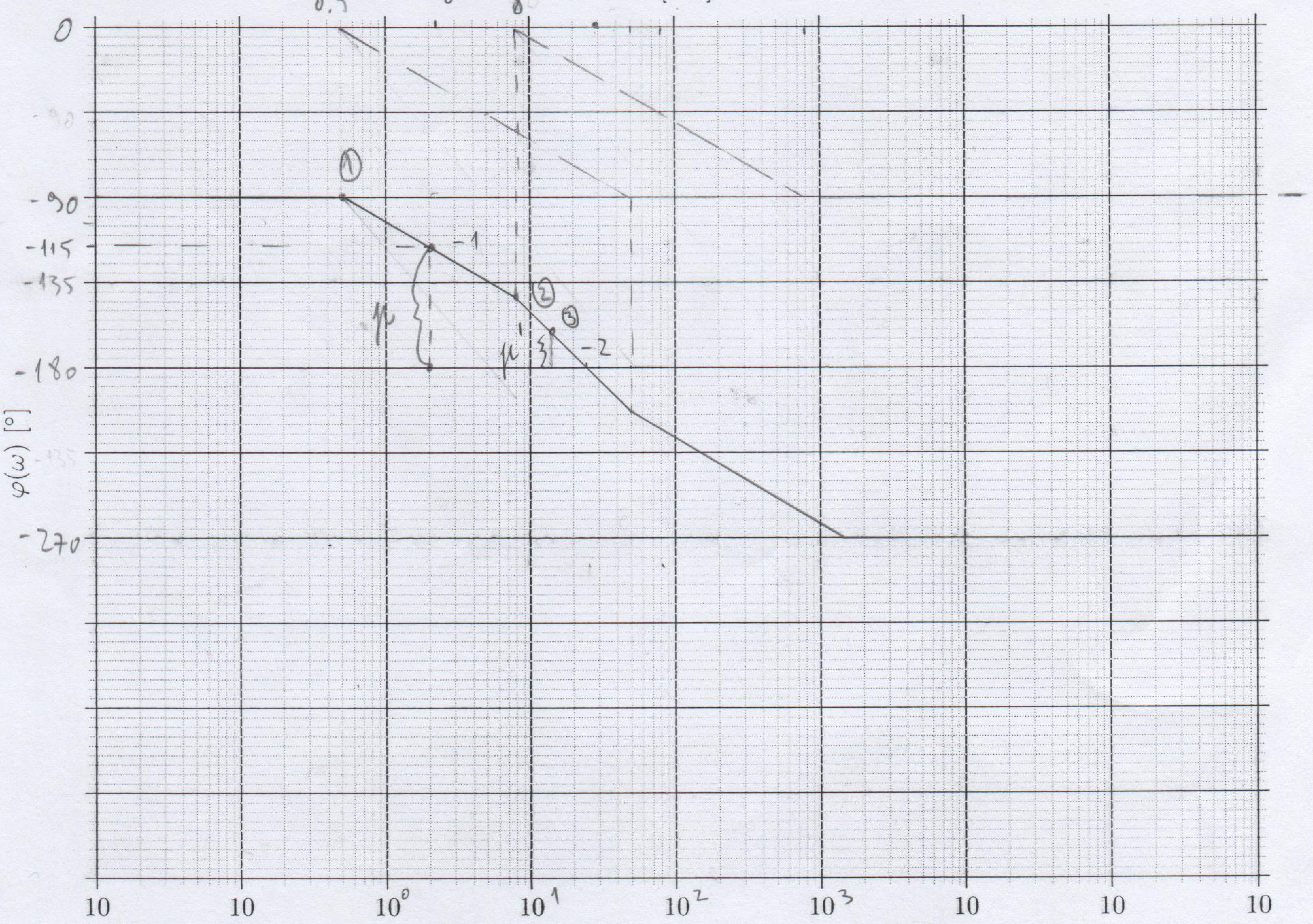
$$\sigma_m\% = \frac{h(t_m) - K}{K} \cdot 100 = 100\, e^{\frac{-\xi \pi}{\sqrt{1-\xi^2}}}$$

$$t_m = \frac{\pi}{\omega_n \sqrt{1-\xi^2}} \qquad t_r \approx \frac{1.8}{\omega_n}$$

$$t_\varepsilon \approx \frac{4.6}{\xi \omega_n}$$

SUSTAV 2. REDA BEZ NULA





$\mu - 180 = -115^\circ$

$\mu' = 15^\circ$

$\omega_\pi > \omega_c$ → PRESJEK $A_{DB}(\omega) = 0$

PRESJEK S $\varphi = -180$

SUSTAV JE STABILAN

LABOS 2

1° ZADATAK { LINEARIZIRATI JEDNADŽBU { $y = y_0 + \Delta y$, $x = x_0 + \Delta x$ }

PRIJENOSNA FJA → $G(s) = \dfrac{Y(s) \to \mathcal{L}(\Delta y)}{X(s) \to \mathcal{L}(\Delta x)}$

→ IZLAZ KOJI DOBIJEMO SIMULACIJOM {Δy} ZBROJIMO

NA $y_0 \to y = y_0 + \Delta y$

2° ZADATAK → LINEARIZIRATI SUSTAV IZ PRVOG LABOSA (NAPRAVITI MATLAB MODEL) I ODREDITI JEDNADŽBE STANJA PREKO UNAPRIJED ZADANIH PARAMETARA

→ PARALELNO SIMULIRATI LINEARIZIRANI I NELIN. MODEL ZA ZADANU RADNU TOČKU {TREBAJU BITI PRIBLIŽNO JEDNAKI}

→ POUKA: MODEL VRIJEDI SAMO ZA PRORAČUNATO RADNU TOČKU

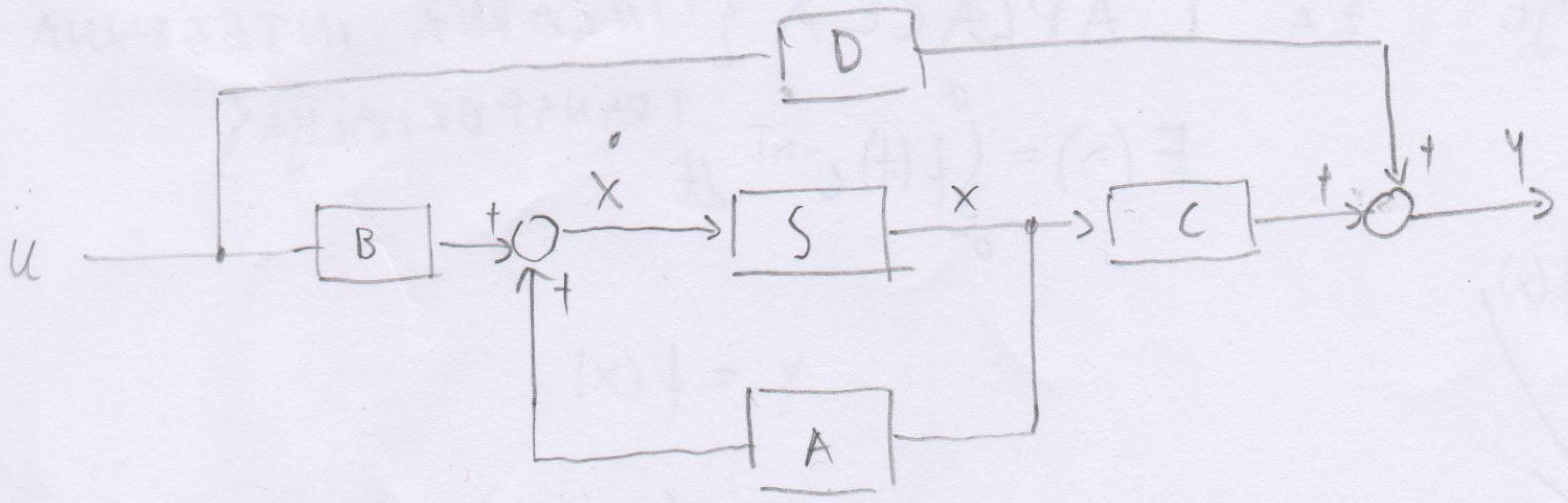
5 PRIKAZ U PROSTORU STANJA

{KORISTIMO ZA KOMPLEKSNE SUSTAVE}

PRIMJER → MATRICE NAPONA I STRUJA IZ ELEKTRIČNIH KRUGOVA

MOGUĆE PITANJE: NACRTAJ BLOKOVSKI PRIKAZ JEDN. STANJA

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



A → VLASTITO VLADANJE SUSTAVA {PRIRODNI ODZIV}

B → OPIS DJELOVANJA VANJSKE POBODE

C → IZLAZNA JEDNADŽBA

D → PROSLIJEĐUJE ULAZNE VELIČINE NA IZLAZ

(6) FREKVENCIJSKA DOMENA I STABILNOST

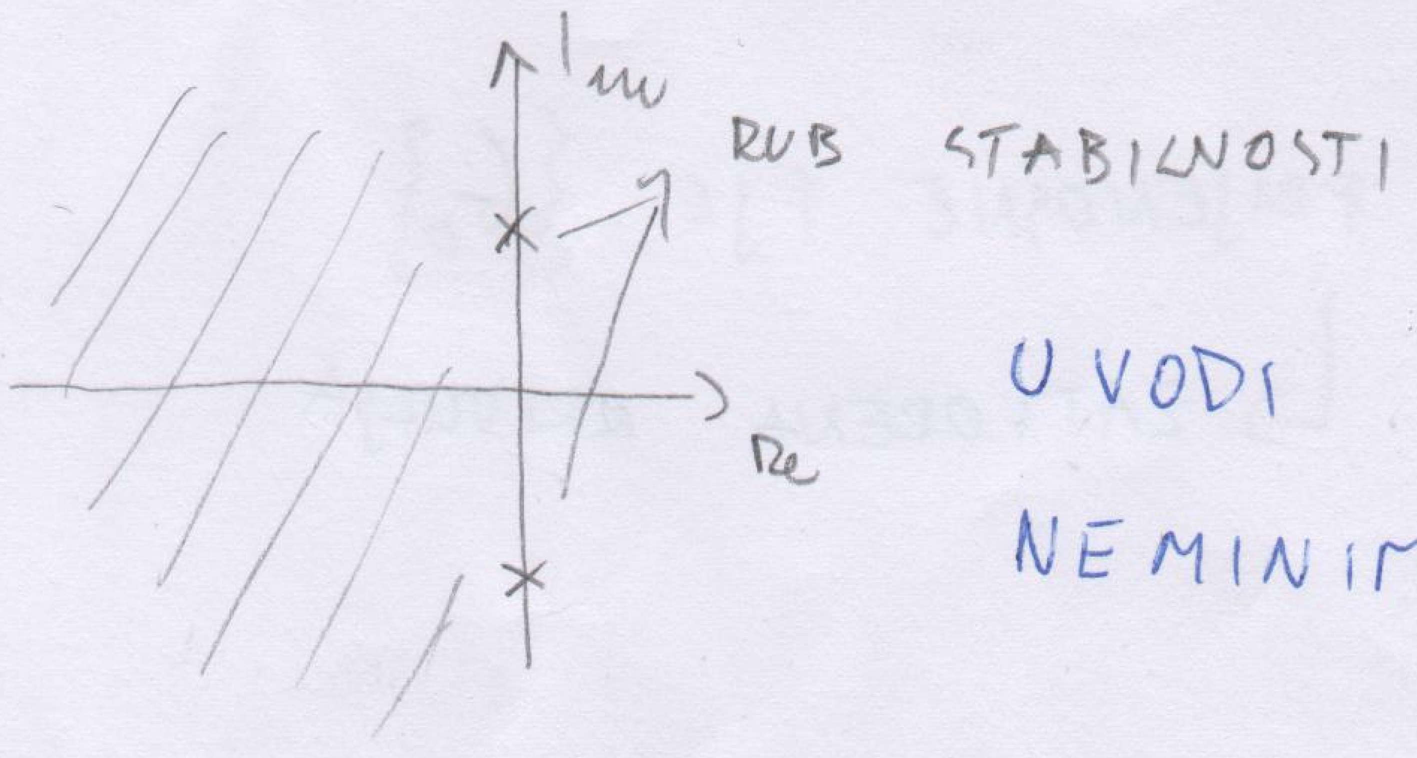
$g(t) \to$ TEŽINSKA FJA $\Rightarrow$ ODZIV NA $\delta(t)$ $\quad \left. \begin{matrix} \\ t \geq 0 \end{matrix} \right\}$ $\left\{ \begin{matrix} \text{KAUZALNI} \\ \text{SUSTAVI} \end{matrix} \right.$

$h(t) \to$ PRIJELAZNA FJA $\Rightarrow$ ODZIV NA $\mu(t)$

$$g(t) = \dot{h}(t) \qquad G(s) = s\,H(s)$$

SLOBODNI I PRISILNI ODZIV $\quad y' + y = 4u' \Rightarrow y = y_{SL} + y_{PRISILNI} \quad \{t\}$

$$Y(s) = \frac{B(s)}{N(s)} + \frac{B'(s)}{N'(s)} \cdot U(s)$$



UVODI SE POJAM

NEMINIMALNO FAZNA NULA ili POL

$$y(\infty) = \lim_{s \to 0} s\,G(s)$$

NFN $\to$ PARNI BROJ NEMA PODBAČAJA

$$y(0^+) = \lim_{s \to \infty} s\,G(s)$$

POLOVI $\to$ REALNI $\to$ NEMA OSCILACIJA

$\quad\;\to$ KOMP. KONJ $\to$ OSCILACIJE

NE UZIMAMO $\delta(t)$ U OBZIR

$\Downarrow$

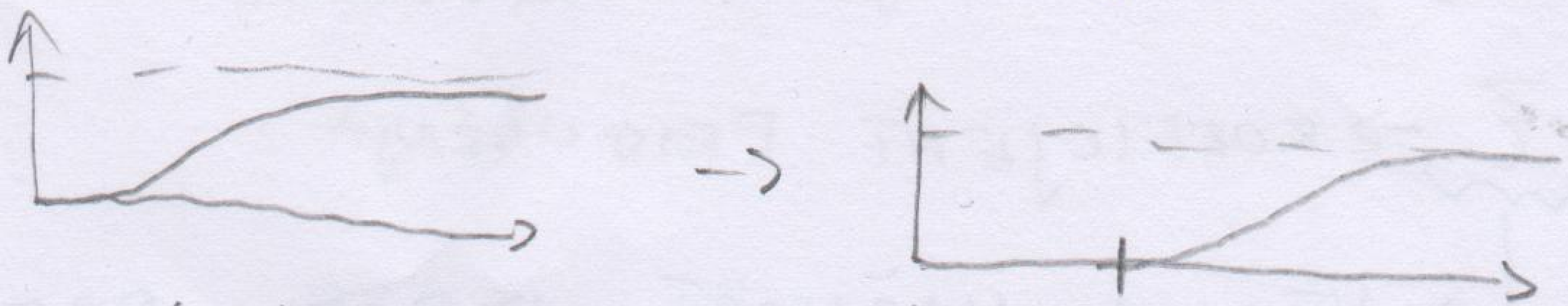
ODZIV NA HARMONIJSKU POBUDU $\quad y = 1 + \sin\omega t$

VIZUALIZACIJA PREKO ASINKRONOG MOTORA

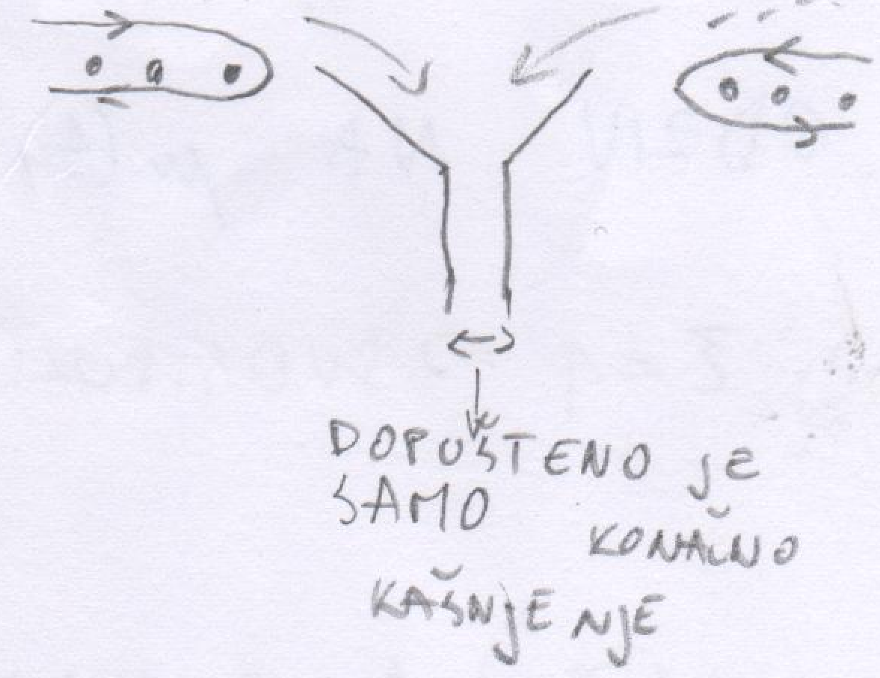
$$\boxed{\begin{matrix} A_Y = A_U A_G \\ \phi_Y = \phi_U + \phi_G \end{matrix}}$$

(7) MRTVO VRIJEME {TRANSPORTNO KAŠNJENJE} e^{-sT}

$\hookrightarrow$ U SUSTAVIMA U KOJIM SE PRENOSI MASA, ENERGIJA, PODATCI



$G(s) \qquad \to \qquad T_{kašnj} \quad G(s) \cdot e^{-sT_{kaš}}$



NE MIJENJA AMPLITUDU ALI UTJEČE NA FAZU

$$A = 1 = |e^{-sT}|$$

$$\varphi \to e^{-j\omega T} = \cos\omega T - j\sin\omega T \qquad \varphi = -\operatorname{arctg}\, \operatorname{tg}\omega T = -\omega T$$

⑧ ALATI ZA ODREĐIVANJE STABILNOSTI

↳ BIO JE POTREBAN NAČIN ODREĐIVANJA STABILNOSTI KOJI SE MOGAO KORISTITI U PRAKSI

ALGEBARSKI → HURWITZ

NYQUIST I BODE → SNIMANJEM FREKV KARAKT. LAGANO ODREĐIVANJE STABILNOSTI SUSTAVA

⑨ NYQUIST ⇒ PARAMETARSKI ZAPIS PRIJENOSNE FJE $\{G_0\}$

↳ ZATVORENA KRIVULJA

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

$G(0) = A(0)$ ⇒ STATIČKO POJAČANJE

POVEZANOST S BODEOM {ODMAH SE VIDI ULAZ U $\omega = \infty$}

⑩ BODE → APROKSIMACIJA PRAVCIMA → UVIJEK SE ZAJEDNO CRTAJU $A + \varphi$ KARAKT ZBOG MOGUĆIH NEMINIMALNO FAZNIH NULA

UZMI PAPIR

↳ ⑪ PRIKAZ U LOG SKALI

⑫ PT2 ČLAN → U PRAKSI NAJVAŽNIJI ČLAN {OPISUJE PONAŠANJE OSCILATORA}

↳ POSJEDUJE MODOVE {KOMPL.-KONJ. POLOVI} ⇒ UZROKUJU TITRANJE

→ LJUDSKA TEHNOLOGIJA SE TEMELJI NA TITRAJNIM KRUGOVIMA {☺}

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

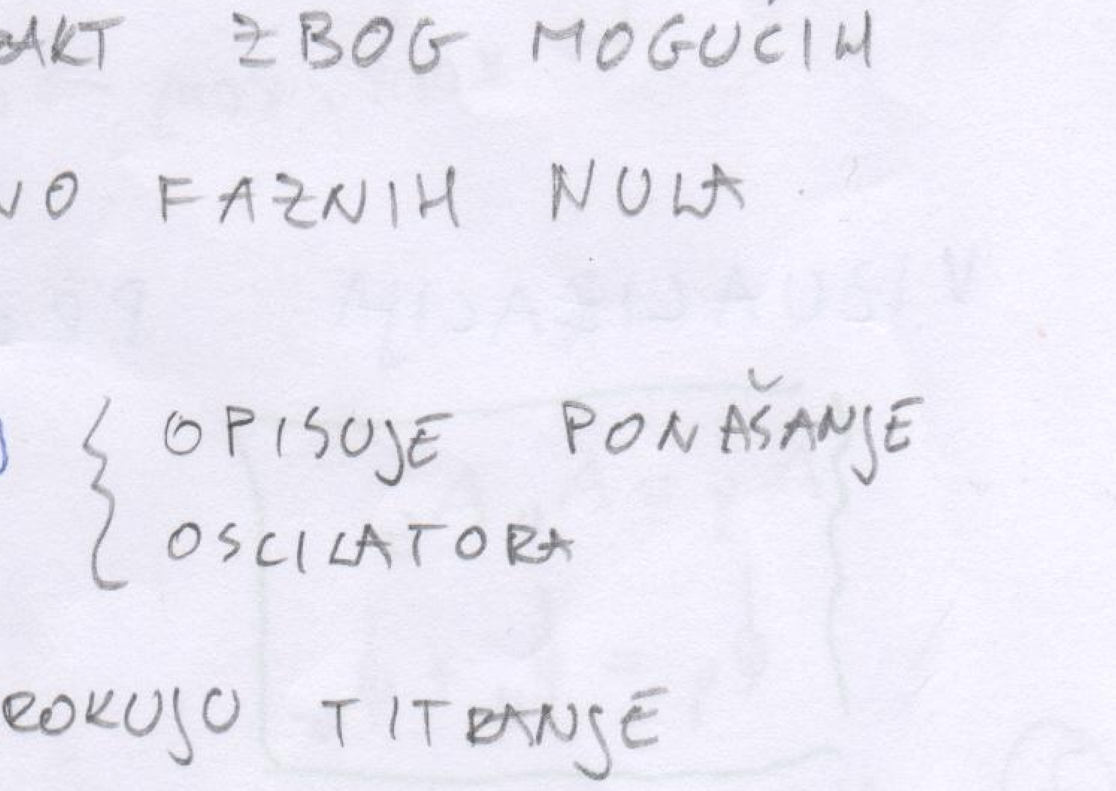
ω_n → FREKVENCIJA NEPRIGUŠENIH OSCILACIJA

ξ → KOEFICIJENT PRIGUŠENJA

↳ VELIKA VAŽNOST IZBORA PARAMETARA

ODZIV NA $\mu(t)$ U OVISNOSTI O ξ

$\xi = 1$ ⇒ DVOSTRUKI POL $G(s) = \dfrac{K}{\left(\frac{s}{\omega_n}+1\right)^2}$ ⇒ NEMA TITRANJA

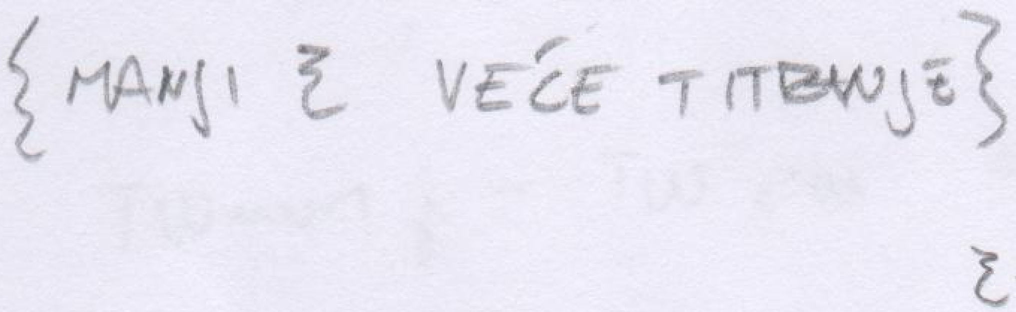


$0 < \xi < 1$ ⇒ IMAMO TITRANJE {MANJI ξ VEĆE TITRANJE}

↳ ŠTO SU POLOVI BLIŽE ISHODIŠTU VIŠE UTJEČU NA ODZIV

$\xi = 0$ → JEDNOSTRUKI POLOVI U ISHODIŠTU → RUB STABILNOSTI

$\xi < 0$ → NESTABILNOST

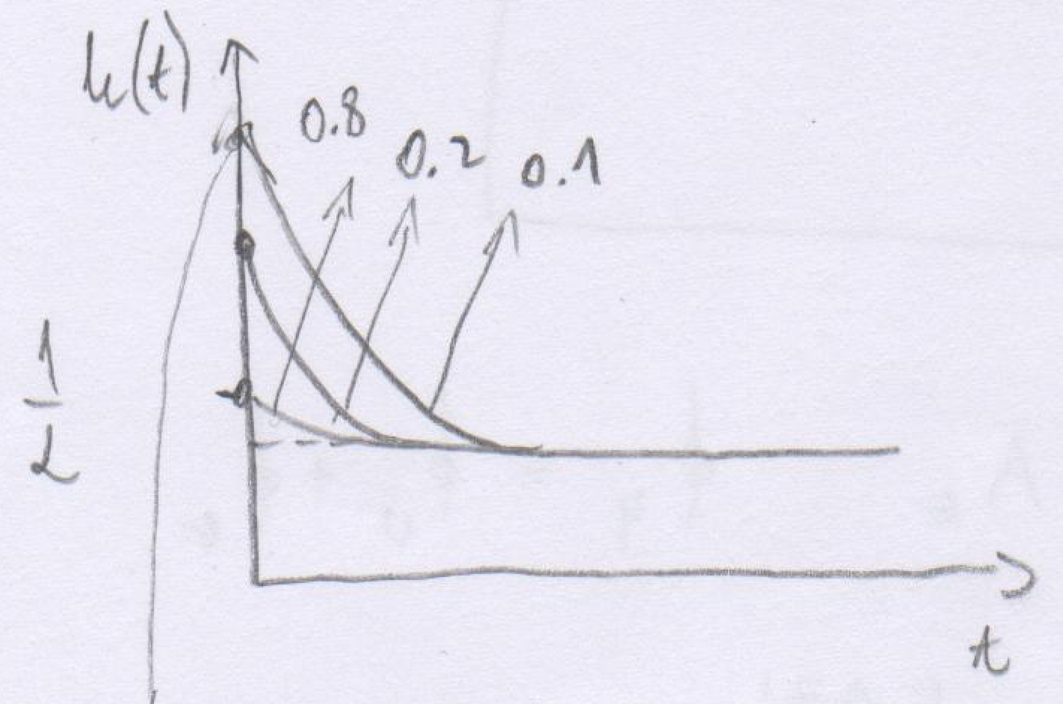


13 UTJECAJ POLOVA NA ODZIV

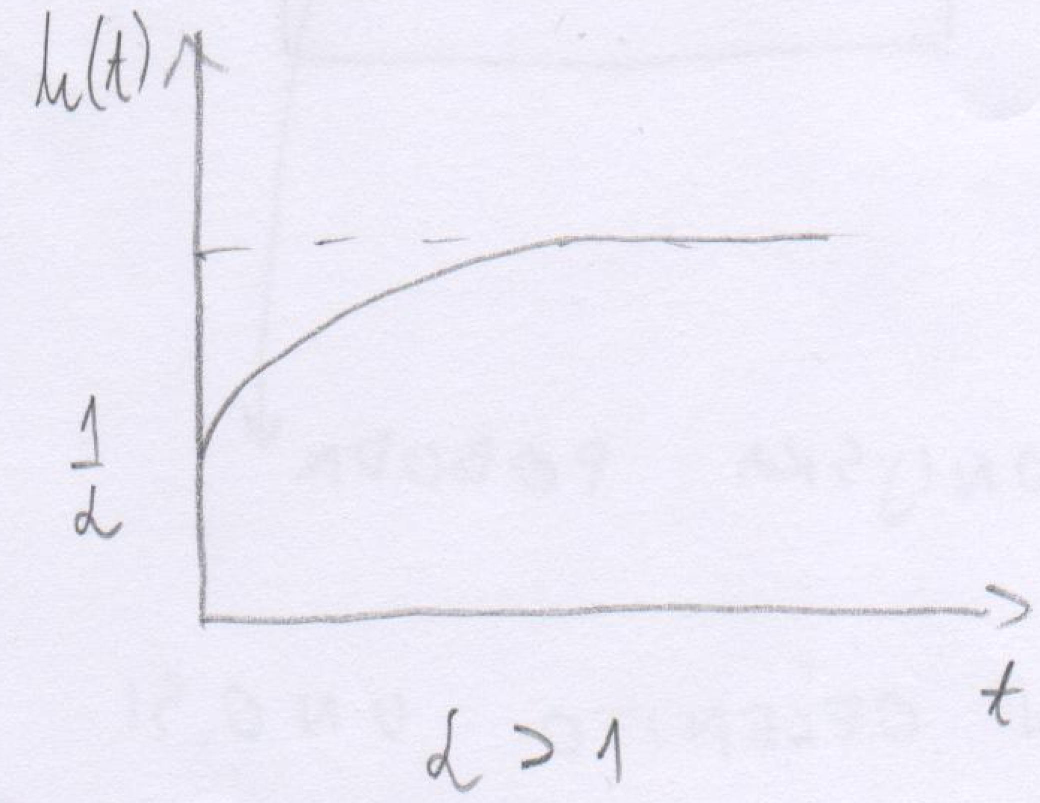
PRIMJER: $G(s) = \frac{1+s}{1+\alpha s}$ $\quad h(t) = 1 + \left(\frac{1}{\alpha} - 1\right) e^{-\frac{t}{\alpha}}$

α → PAREMETAR ZA PREMJEŠTANJE POLA U S RAVNINI

1°



2°



$\alpha > 1$

$\alpha \in \langle 0, 1]$

↳ ŠTO JE α BLIŽE NULI IMAMO VEĆI "ŠPIC"

↳ POTENCIJALNA NESTABILNOST

POUKA: SMANJUJUĆI α UDALJAVAMO POLOVE OD ISHODIŠTA ŠTO ZNAČI DA SMANJUJEMO NJIHOVU "DOMINANTNOST" {SUSTAV POSTAJE STABILNIJI}

VIZUALIZACIJA → PREVELIKI POČETNI MOMENT {KIDAMO OSOVINU}

~~PT2~~ PRIMJER: $G(s) = \frac{2}{(s+1)(s+2)}$ $\Rightarrow h(t) = 1 - 2e^{-t} + e^{-2t} \quad t \geq 0$

$s_{p_1} = -1 \quad s_{p_2} = -2$

↳ RASPORED NULA DIREKTNO UTJEČE NA TRAJANJE "PRIJELAZA" PRIJELAZNE FJE

↳ ŠTO SU BLIŽE ISHODIŠTU NADVIŠENJE JE VEĆE

DOLAZIMO DO DINAMIČKIH POKAZATELJA KVALITETE

↳ VRIJEME ZA BAN ŠALABAHTER

LABOS 3 → 1. ZADATAK {CRTANJE BODEOVOG DIJAGRAMA I USPOREDBA NYQUIST, ODZIV NA HARMONIJSKU POBUDU}

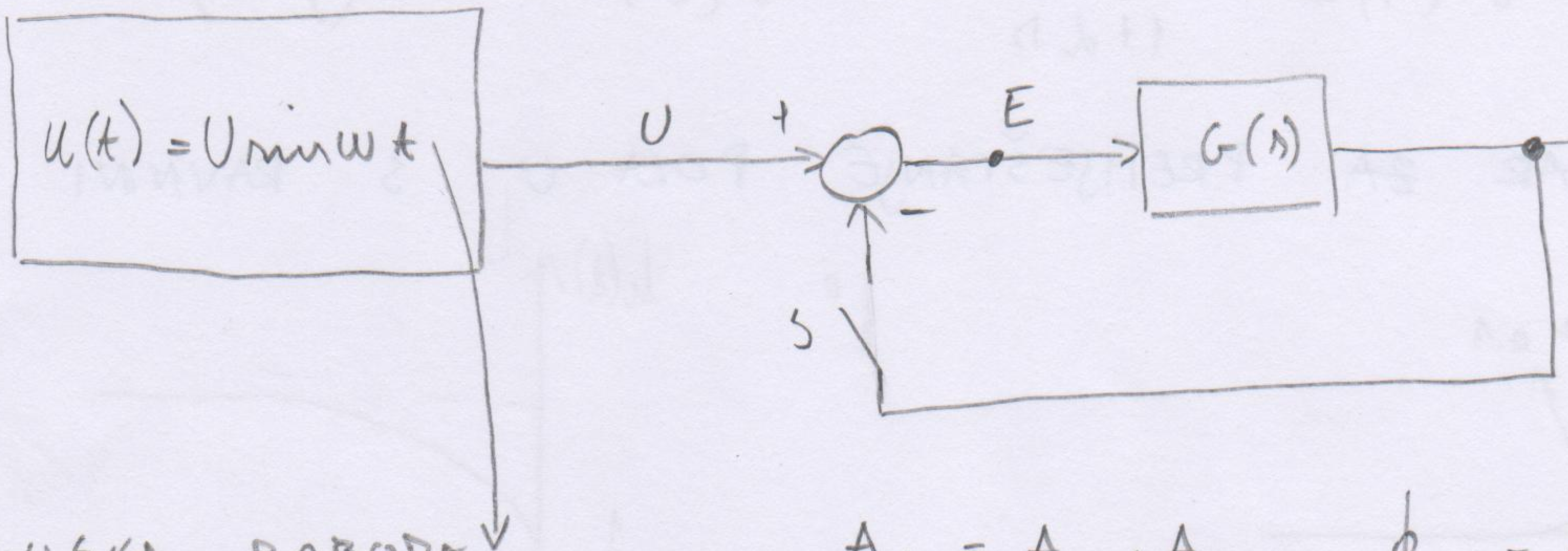
$G(s) = \frac{as+1}{(s+2)(s+7)}$ 2. ZADATAK {UTJECAJ NULA NA ODZIV

↳ VEĆI a → NULA BLIŽE ISHODIŠTU → VEĆI ŠILJAK (NADVIŠENJE)

$a < 1$ → PODBAČAJ}

$G(s) =$ 3. ZADATAK {PT2 ČLAN OVISNO O ZADANIM OGRANIČENJIMA SLUŽBENI ŠALABAHTER}

14 FIZIKALNO OBJAŠNJENJE PARAMETARA STABILNOSTI



MARMONIJSKA POBODA

$A_y = A_U \cdot A_G \qquad \phi_y = \phi_U + \phi_G$

SUSTAV OPĆENITO UNOSI KAŠNJENJE U FAZI

AKO JE FAZA ODZIVA $-180^\circ \rightarrow \omega_\pi$ $\Rightarrow$ $y = A_y \underline{|180^\circ}$ $\quad E = U - y$

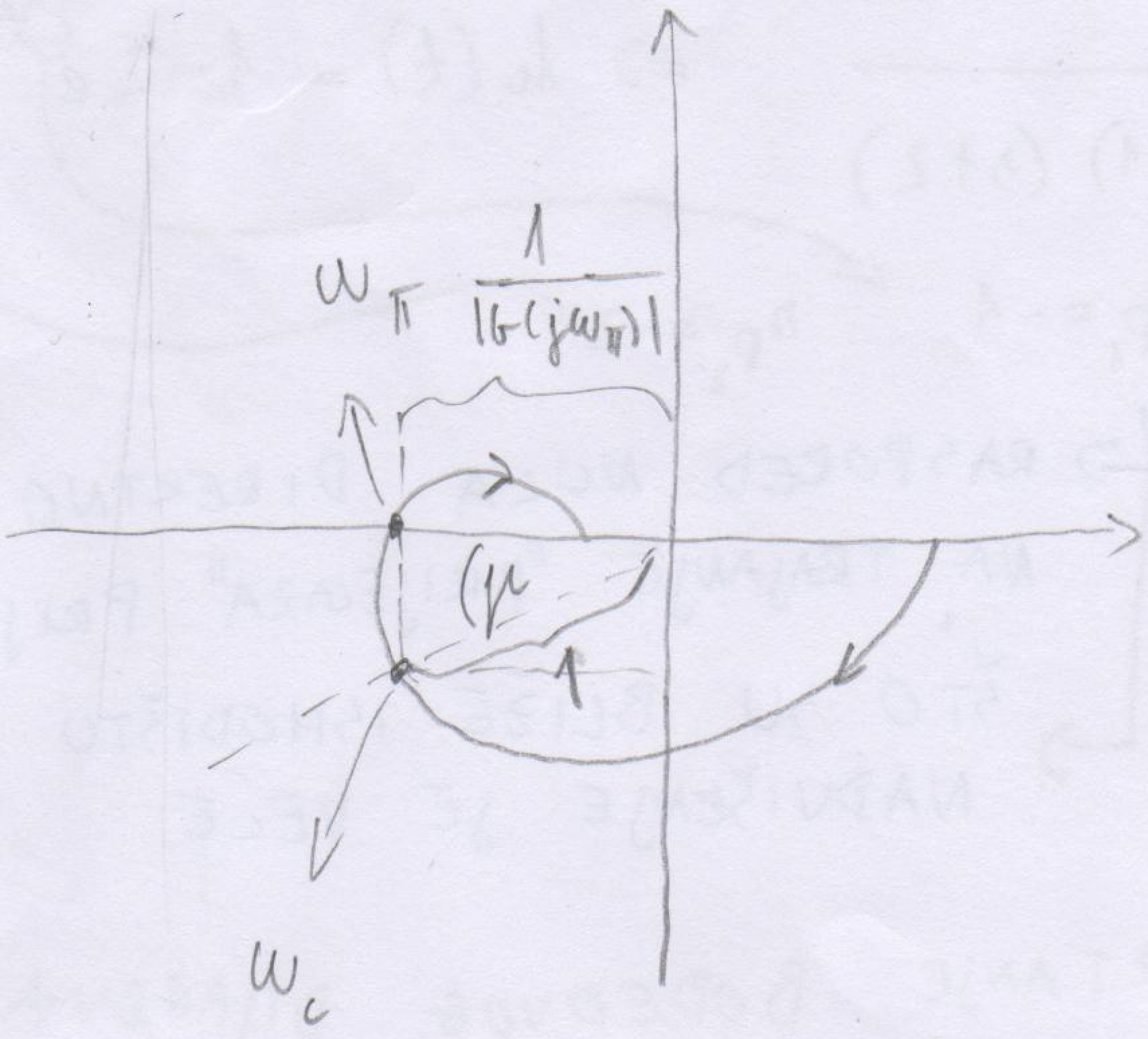
$U = A_U \underline{|\varphi}$ $\quad E = A_U(\varphi) + A_y$

AKO JE $A_y < 1 \Rightarrow$ NEMA PROBLEMA

ODZIV ĆE SE USTALITI NA NEKOJ VRIJEDNOSTI $\quad A_y = 1 \Rightarrow$ RUB STABILNOSTI

$A_y > 1 \Rightarrow$ NESTABILNOST $\qquad \omega_c \Rightarrow$ POJAČANJE $= 1$

15 FAZNO I AMPLITUDNO OSIGURANJE



$\omega_c < \omega_\pi$

↳ UVJET STABILNOSTI

$$\operatorname{tg} \mu = \frac{\operatorname{Im}(\omega_c)}{\operatorname{Re}(\omega_c)}$$

BODE $\Rightarrow$ UTJECAJ MRTVOG VREMENA, POJAČANJA NA FAZNO I AMPLIDUDNO OSIGURANJE $\Rightarrow$ ŠALABAHTER

↓

UZMI GRAF

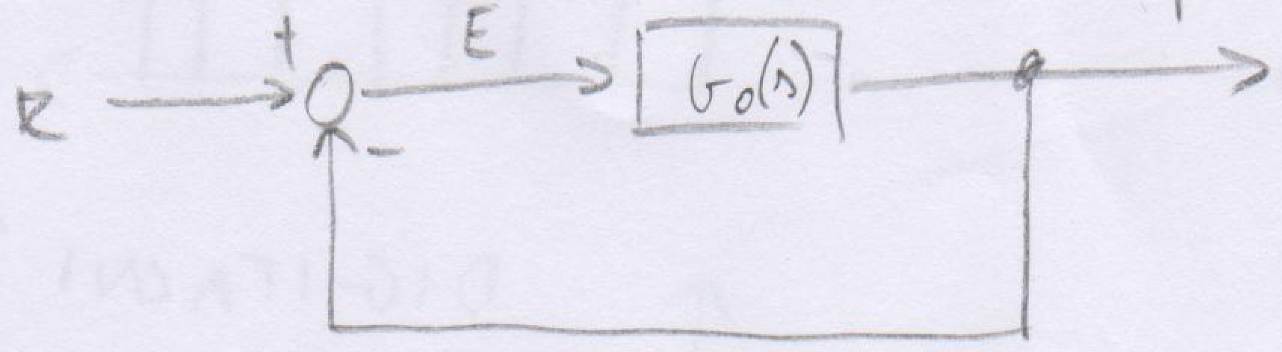
16 REGULACIJSKO ODSTUPANJE { CILJ POSTIĆI ŠTO MANJE ODSTUPANJE }

↳ LAGANO SE RAČUNA POMOĆU TEOREMA KONAČNE I POČETNE VRIJEDNOSTI

→ OVISI O REFERENCI I TIPU SUSTAVA { PRIJENOSNOJ FUNKCIJI }

→ OVISI O MJESTU DJELOVANJA REFERENCE

→ ASTATIZAM



$$G_0(s) = \frac{1}{s^k N(s)} \qquad E = R - y \qquad y = E \cdot G_0 \qquad E = \frac{R}{1 + G_0(s)}$$

$$R = \frac{1}{s^\alpha} \Bigg\} \begin{array}{l} \text{STEP } \alpha = 1 \\ \text{RAMPA } \alpha = 2 \\ \text{PARABOLA } \alpha = 3 \end{array} \qquad E = \frac{\frac{1}{s^\alpha}}{\frac{s^k N(s) + 1}{s^k N(s)}} = \frac{s^k N(s)}{s^\alpha \left(s^k N(s) + 1\right)}$$

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

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

$k = 0 \Rightarrow$ NEMA ASTATIZMA

$k = 1 \Rightarrow$ ASTATIZAM 1. REDA

" " "

POUKA: MIJENJAJUĆI REFERENCU UTJEČEMO NA REGULACIJSKO ODSTUPANJE

$\boxed{\text{LABOS 4}}$

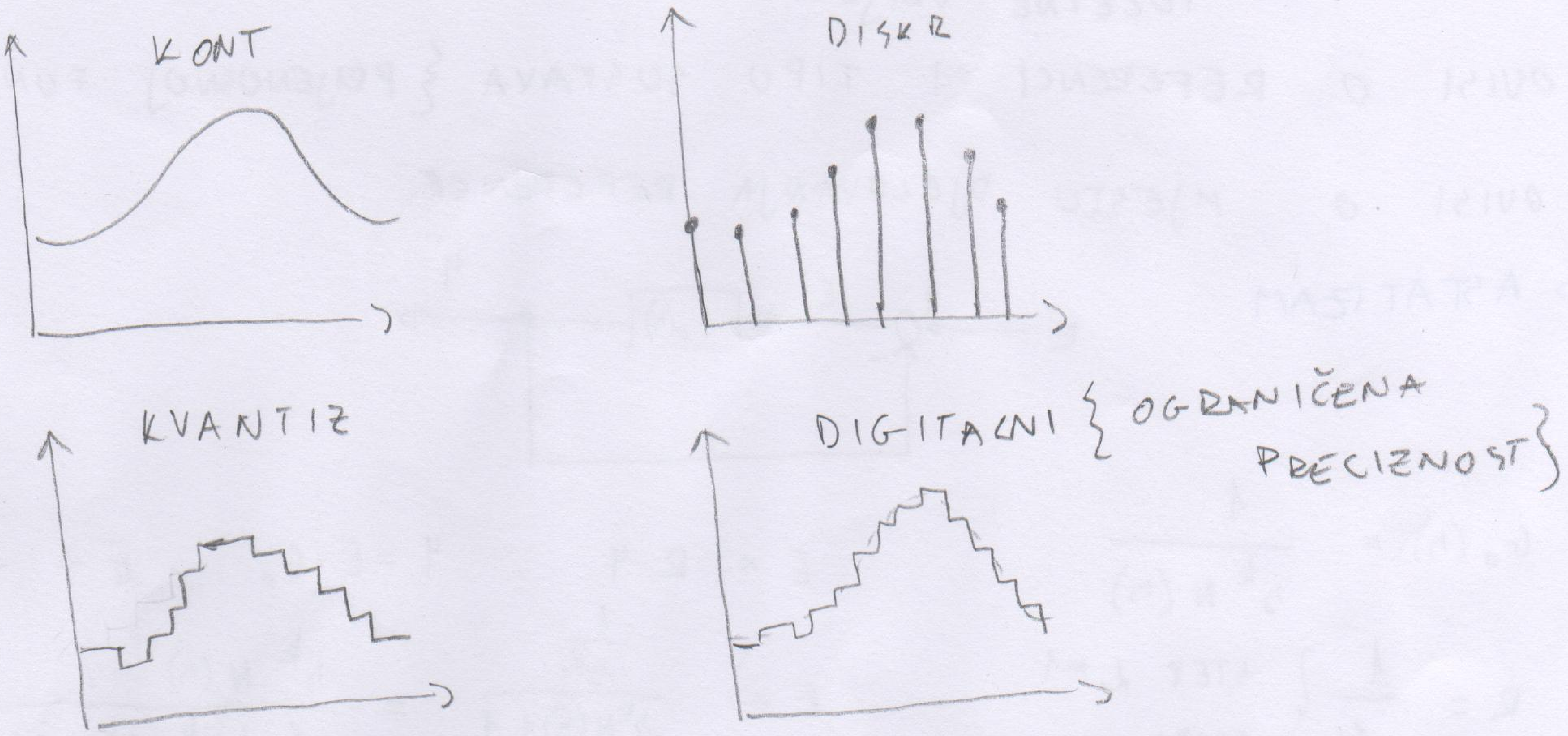
1° ZADATAK → HURWITZ

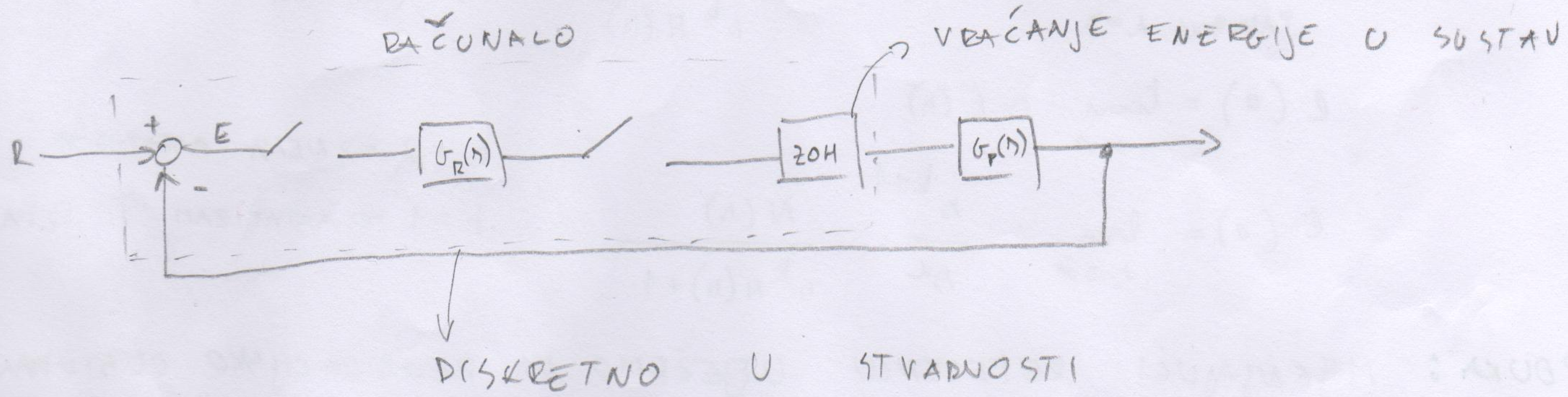
→ REGULACIJSKO ODSTUPANJE OVISNO O POBUDI { ASTATIZAM }

2° ZADATAK → BODE, NYQUIST → FAZNO, AMPL. OSIGURANJE

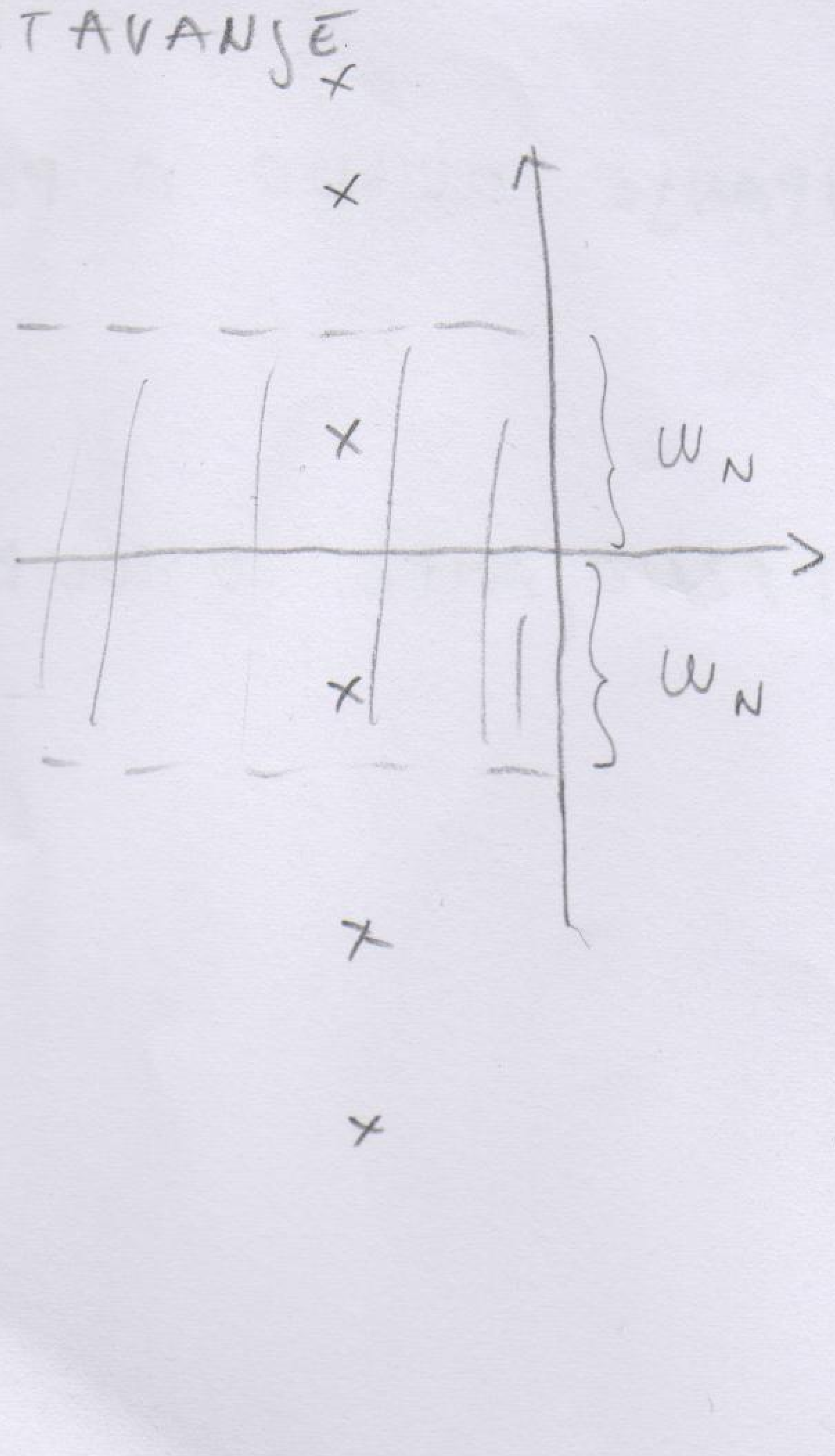
DIGITALNA ERA

(17) DISKRETNO PODRUČIJE { ZAŠTO ?! }





OČITAVANJE



$$e^{j\omega_N T_s} = e^{j(\omega T_s + 2k\pi)}$$ ALIASE

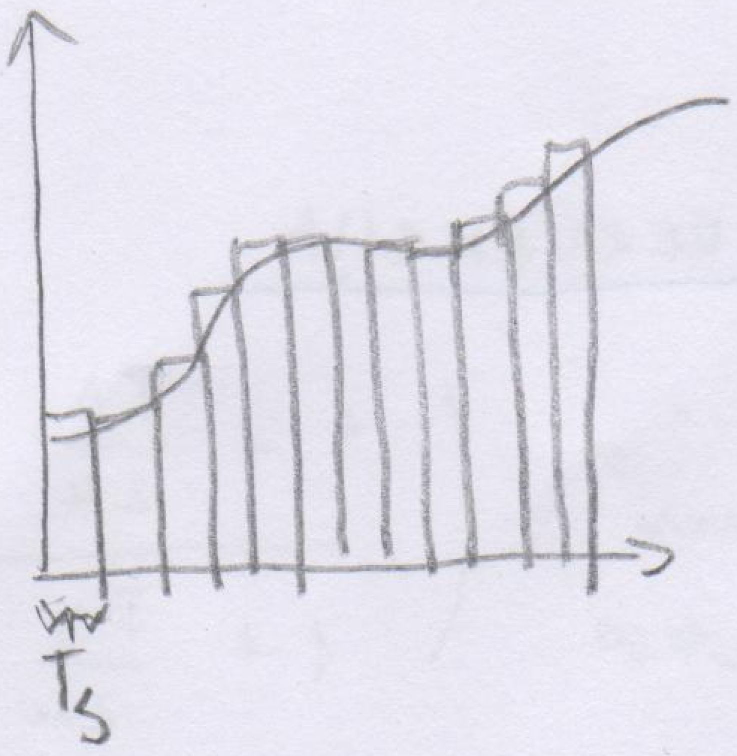
$$\omega_N = \frac{\pi}{T_s}$$

$$\omega_s > 2\,\omega_{NAJVEĆE}$$

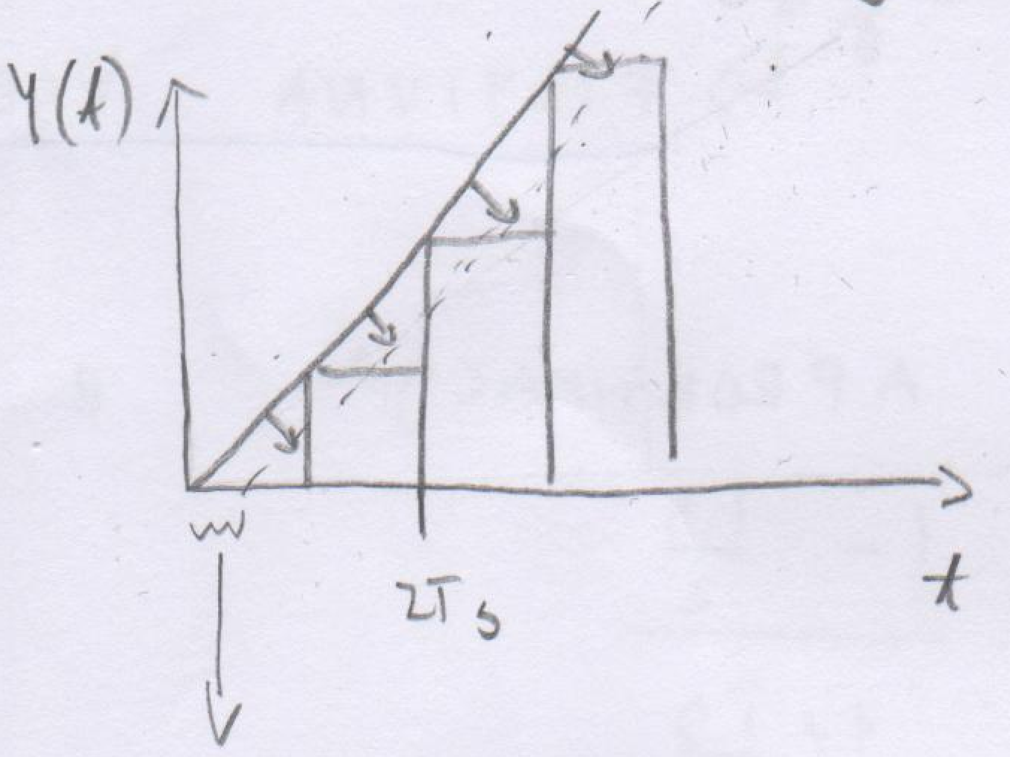
18) METODE UZORKOVANJA

- IDEALNI IMPULSNI ELEMENT {DOBIJEMO KRONEKEROV NIZ} => ČUVA TEŽINSKU FUNKCIJU
- ZOH, FOH -> REKONSTRUKTORI {$\boxed{D/A}$} $ZOH = (1-z^{-1})\,\mathcal{Z}\left\{\frac{G(s)}{s}\right\}$

ZOH



-> UNOSI KAŠNJENJE



$\left.\frac{1}{s} - \frac{1}{s}e^{-sT_s}\right\}$ STEPOVI

$\frac{T_s}{2}$ => NADOMJESNO MRTVO VRIJEME $e^{-s\frac{T_s}{2}}$

SPUŠTA FAZU I POVEĆAVA NADVIŠENJE ZA $\omega_c \frac{T_s}{2}$

IZVOD PREPORUČENOG VREMENA OČITAVANJA

-> ŽELIMO DA SE μ SMANJI MAX $5° - 10°$

$\mu[°] = 70 - \sigma_m[\%]$

$\Delta\mu[°] = \omega_c \frac{T_s}{2} \cdot \frac{180}{\pi}$

$(5° \text{ DO } 10°) = \frac{180}{\pi}\omega_c \frac{T_s}{2}$

$T_s = (0.17 \text{ DO } 0.34)\frac{1}{\omega_c}$

19. PRESLIKAVANJE NULA I POLOVA

$z = e^{-sT}$ => BAN ŽALABAMTER

20. POSTUPCI DISKRETIZACIJE

1° ZADRŽAVANJE TEŽINSKE FJE -> $\mathcal{Z}$

2° ZADRŽAVANJE PRIJELAZNE FJE -> ZOH

3° USKLAĐENE NULE I POLOVI

$G(s) = \frac{(s+1)^m B(s)}{(s+2)^n N(s)}$ $n - m > 1$ -> NAPRAVIMO $\mathcal{Z}$ TRANSFORMACIJU

DODAJEMO $n-m-1$ NULA U $z=-1$

4° OČUVANJE PRESJEČNE FREKVENCIJE (TUSTIN) -> MODIFICIRANA BILINEARNA