2005/1a

elektronika : sredstvo za računanje!

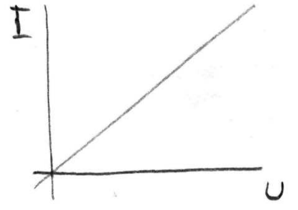
vrednost spremenljivk predstavljajo napetosti ali tokovi

$$x \to \boxed{A} \to z \quad \Rightarrow \quad z = A(x)$$

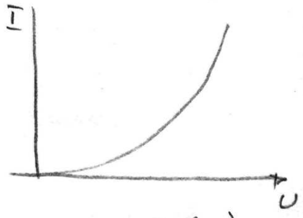
---

elektronika : osnovni pojmi :

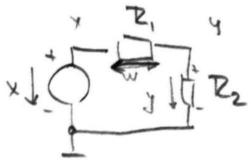
- el. potencial : elektroni se naberejo, potencial ovrednoti njihovo težnjo, da gredo narazen
- el. napetost : razlika dveh potencialov; običajno izberemo skupno točko → zemlja
- el. tok : gibanje nosilcev naboja, požene jih napetost na prevodni snovi
- upornost : napetost požene tok : upornost označuje razmerje
  ohmov zakon
  Thevenin



lin. upornost



$R = R(U)$



$\Sigma i = 0$

ostali →

mi se bomo ukvarjali z lin. vezji!
ostalo le na vzorce

lastnosti lin. vezij

- bloke povezujemo

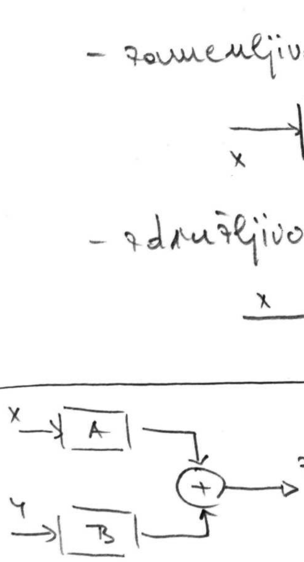
$$x \to \boxed{A} \to \boxed{B} \to z \qquad z = B(A(x)) = BAx$$

- zamenljivost

$$x \to \boxed{B} \to \boxed{A} \to z \qquad z = A(B(x)) = ABx = BAx$$

- združljivost

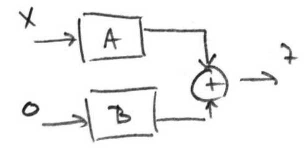
$$x \to \boxed{AB} \to z \qquad z = ABz$$

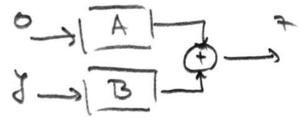


$z = Ax + By$

2005/1b

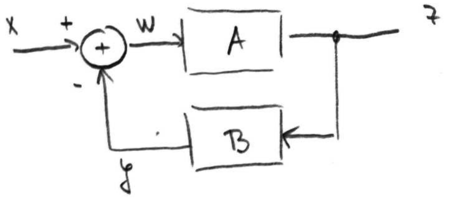
vezje lahko rešujemo po kosih

(1)  $\Rightarrow z_1 = Ax$

(2)  $\Rightarrow z_2 = By$

(3) $z = z_1 + z_2 = Ax + By$

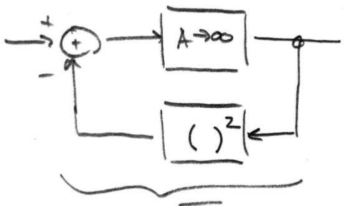
povratne veze:



$$y = Bz$$
$$w = x - y = x - Bz$$
$$z = Aw = Ax - ABz$$
$$z(1 + AB) = Ax \Rightarrow z = x\,\frac{A}{1+AB}$$

ekstrem: $A \to \infty \Rightarrow$ $z = x \lim_{A\to\infty} \frac{1}{\frac{1}{A} + B} = x\,\frac{1}{B}$

zgled:



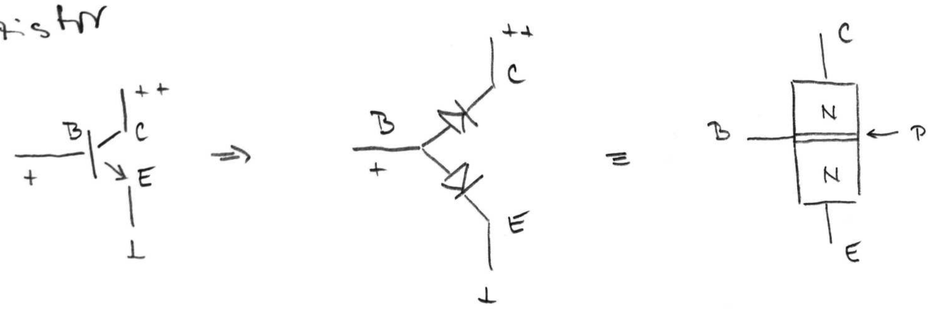
recipročna funkcija dela tudi za celim vezja

√

ojačevalnik: veliko ojačanje; manjše lahko nastavimo, vezje je problem

2005/12

tranzistor



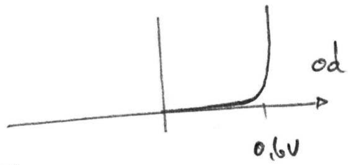
recipročni kmet

- lastnosti diode

$I = I_s\left(e^{U/U_T} - 1\right)$

$U_T = \frac{kT}{e_0} = 26mV$

β



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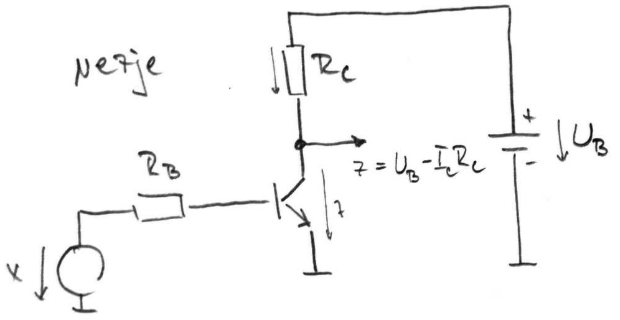
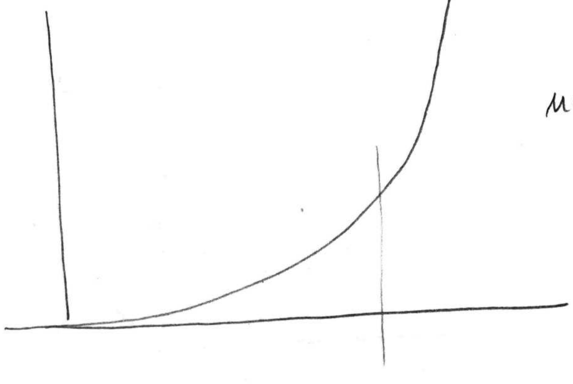
vezje



$z + U_{RC} = U_B$

$z = U_B - U_{RC} = U_B - I_C R_C$

$I_C = \beta I_B$



natančneje

↓

nelinearno

grobo:

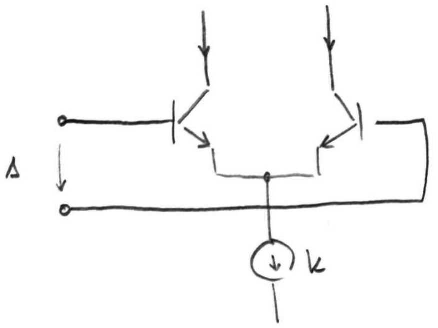
$x \gg U_{BE} = 0.6V \Rightarrow I_B = \frac{x - U_{BE}}{R_B} \Rightarrow z = U_B - \beta R_c \frac{x - U_{BE}}{R_B}$

$= U_B + \beta \frac{R_c}{R_B} U_{BE} - \beta \frac{R_c}{R_B} x$

deluje le za eno vrsto signalov, za +

za neg signale ni nič!

rešitev: postavi se na sredo, nato ↑↓ = delovne točke diferenciální pár



$$U_{BE1} = U_{BE} + \frac{\Delta}{2}$$

$$U_{BE2} = U_{BE} - \frac{\Delta}{2}$$

$$I_c = I_{c0}\left(e^{U/U_T} - 1\right)$$

$$I_{c1} = I_{c10}\left(e^{\frac{U_{BE}+\frac{\Delta}{2}}{U_T}} - 1\right)\beta_1$$

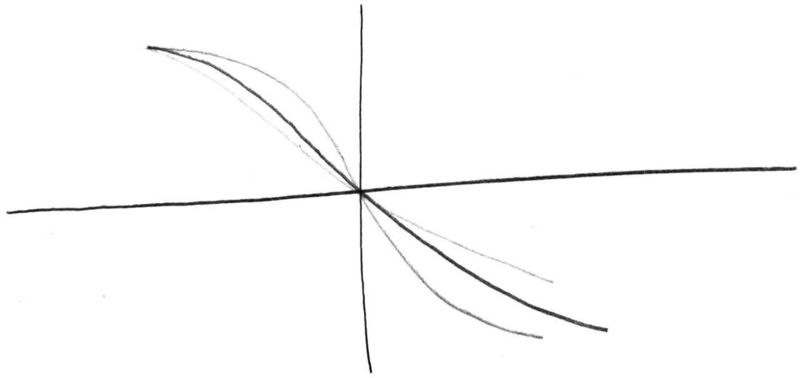
$$I_{c2} = I_{c20}\left(e^{\frac{U_{BE}-\frac{\Delta}{2}}{U_T}} - 1\right)\beta_2$$

$$\frac{I_{c1}}{I_{c2}} = \frac{\cancel{I_{c10}}\cdot\cancel{\beta_1}\left(e^{\frac{U_{BE}+\Delta/2}{U_T}} - \cancel{1}\right)}{\cancel{I_{c20}}\,\cancel{\beta_2}\left(e^{\frac{U_{BE}-\Delta/2}{U_T}} - \cancel{1}\right)} = e^{\frac{\Delta}{U_T}} \Rightarrow I_{c1} = I_{c2}\, e^{\Delta/U_T}$$

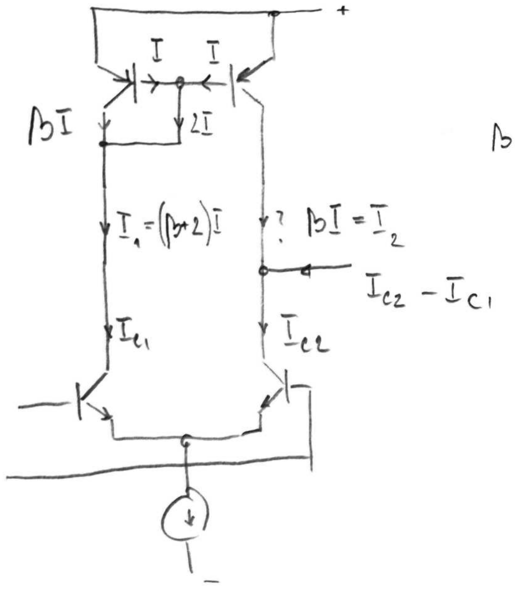
$$I_{c1} + I_{c2} = k = I_{c2}\left(1 + e^{\Delta/U_T}\right) \Rightarrow I_{c2} = \frac{k}{1+e^{\Delta/U_T}}$$

$$I_{c1} = k\,\frac{e^{\Delta/U_T}}{1+e^{\Delta/U_T}}$$

$$\boxed{I_{c1} - I_{c2} = -k\,\frac{1-e^{\Delta/U_T}}{1+e^{\Delta/U_T}}}$$



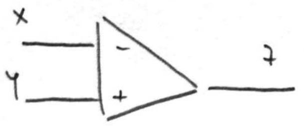
Tokovno ogledalo



β velik $\Rightarrow I_1 = I_2$

2005/1e

zelo :



OP. AMP. , napajanj običajno ne pišemo

$A \to \infty$

$I_B \to 0$, $R_{IN} \to \infty$

$R_{OUT} \to 0$

<u>idealno</u>

tud: 2005/2 (2A)

Vezja z OP

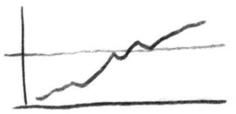
lastnosti OP že znate

a) kompartor

$z = \infty (y - x)$

primenjamo:
- je temperatura ok?
- kdaj je nap. pozitivna?

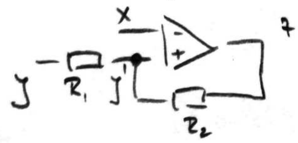
zašumljen signal in komparator



$\Rightarrow$?

kaj bi bilo koristno?

histereza: pozitivna p.v.

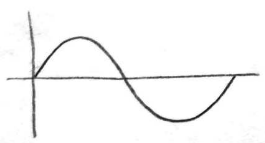


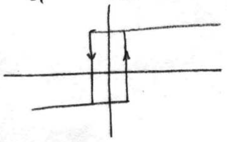
$$\frac{y'-y}{R_1} + \frac{y'-z}{R_2} = 0$$

$$y' = \frac{z-y}{R_1+R_2} \cdot R_1 + y = \left(\frac{-R_1}{R_1+R_2} + 1\right) y + z \frac{R_1}{R_1+R_2} =$$

$$= \frac{R_2}{R_1+R_2} y + z \frac{R_1}{R_1+R_2} \doteq$$

$$\underbrace{\doteq y + z \frac{R_1}{R_1+R_2}}$$

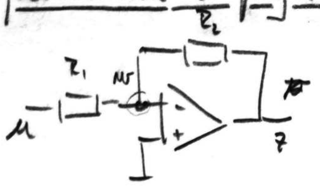




tolmači: besede, slika

koliko toka da OP?
uporabe komparatorja za gretje

b) ojačevalna stopnja - inv.



: račun: $z = A(\overset{0-w}{y - x}) = -Aw \Rightarrow \underline{\underline{w = -\frac{z}{A}}}$: $A \to \infty \Downarrow w \to 0$!

$$\frac{w-u}{R_1} + \frac{w-z}{R_2} = 0 \Rightarrow w(R_1+R_2) = zR_1 + uR_2$$

$$-z(R_1+R_2) - AR_1 z - uR_2 A = 0$$

$$z\left(R_2 + (A+1)R_1\right) = -AR_2 u$$

$$z = -u \frac{AR_2}{R_2 + (A+1)R_1}$$

$$= -u \left.\frac{R_2}{\frac{R_2}{A} + \frac{A+1}{A} R_1}\right|_{A \to \infty}$$

vhodni tok?
vhodna upornost?

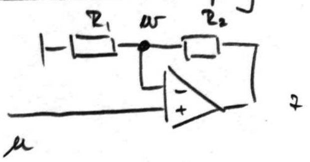
ojačevalnik $\longrightarrow$ $\boxed{z = -u \frac{R_2}{R}}$

- ojačanje določa razmerje uporov R_2/R_1
- obrne predznak

neg. pov. v. $\Rightarrow$ izhod skuša kompenzirati vhod!

c) seštevalnik : na vajah

d) ojačevalna stopnja - non. inv.



$z = (u - w)A \Rightarrow w \doteq u$

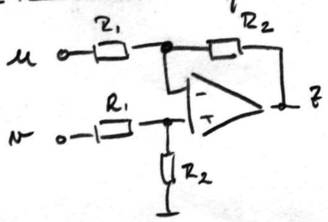
$\frac{w}{R_1} + \frac{w - z}{R_2} = 0 \Rightarrow \boxed{z = u\left(1 + \frac{R_2}{R_1}\right)}$

vhodni tok ?
vhodna upornost ?

ojačevalnik
- ojačanje določa razmerje uporov R_2/R_1, najmanj 1
- isti predznak

buffer

e) diferencialni ojačevalnik - zanima nas razlika (meri tok)

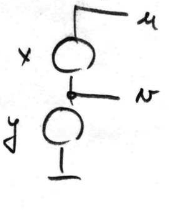


vezje je linearno : reši vzbujanje po kosih

$$\underbrace{\begin{array}{l} v = 0 \text{ in } u \neq 0 \\ v \neq 0 \text{ in } u = 0 \end{array}}$$

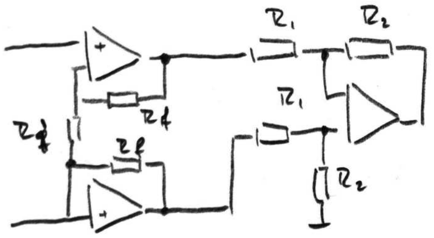
$$\boxed{z = \frac{R_2}{R_1}(v - u)}$$

naj: $R_1 \neq R_2$
skupno vzbujanje



vhodni tokovi ?
upornost ?

f) instrumentacijski ojačevalnik



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pojem prenosne funkcije : $\underbrace{z = x\left(1 + \frac{R_2}{R_1}\right)}$

izračuna izhod od vhoda

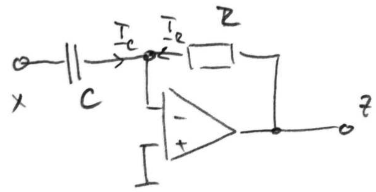
$$\frac{z}{x} = 1 + \frac{R_2}{R_1}$$

priključeni signali

lastnosti vezja !

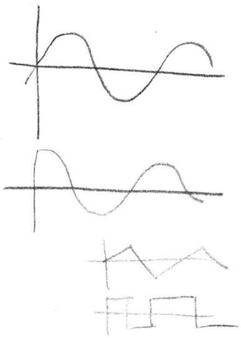
2005/3a

kaj delajo: ±1 ?



$I_c = C\frac{dU_c}{dt}$ ← to vemo od prej

$U_c = \frac{1}{C}\int_0^T I_c\,dt + U_{c0}$

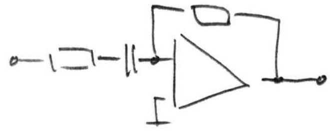


$I_c + I_R = 0$

$C\frac{dx}{dt} + \frac{z}{R} = 0 \Rightarrow z = -RC\frac{dx}{dt} = -RCx' = -\tau x'$

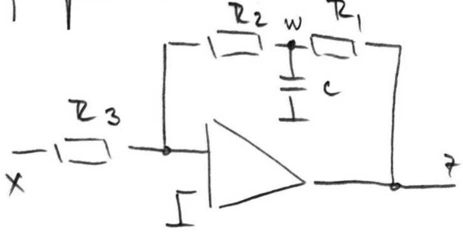
odvaja

pripomba: ni nujno stabilno → boljša vezava



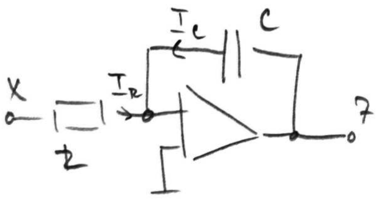
nezloži približki pri
$\omega \to \infty$

kaj pa tole?



kasneje, ko je na razpolago β

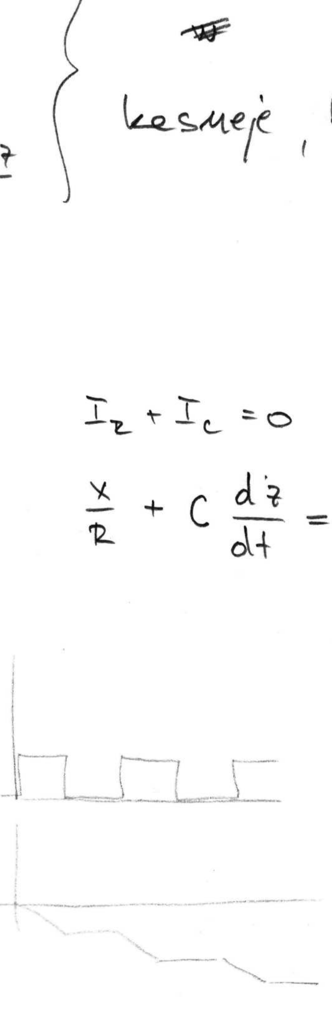
pa tole?



$I_R + I_C = 0$

$\frac{x}{R} + C\frac{dz}{dt} = 0 \Rightarrow \frac{dz}{dt} = -x\frac{1}{RC}$

integrator



$dz = -x\frac{1}{RC}\,dt \quad / \int$

reset!

$z = -\frac{1}{RC}\int x\,dt$

slabosti

$z = -\frac{1}{RC}\int_0^T x\,dt + z_0$

mreža, da lahko mrežo z C in L popišemo z dif. enačbami.

Red enačbe ≤ številu L, C

reševanje ni enostavno ⟶ klasična pot okoli = integralske transformacije

Laplace transformacija

$$\left.\begin{aligned} L(x(t)) &= \int^{\infty} e^{st}\, x(t)\, dt \\ x(t) &= \frac{1}{2\pi i}\int_{\delta - i\omega}^{\delta + i\omega} L(s)\, e^{st}\, ds \end{aligned}\right\} \text{tabelirano}$$

L prevede dif. enačbe v algebraične enačbe

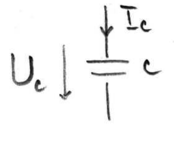
rešimo

L^{-1} prevede alg. enačbe v običajne, časovno odvisne funk.

---

mi po elektroniki

$$I_R = \frac{U_R}{R}$$



$$I_C = C\,\frac{dU_C}{dt}$$

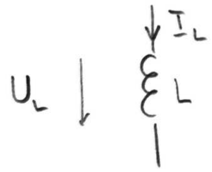
zapiši odvod z operatorjem p

$$I_C = C\,p\,U_C$$ še malo

$$I_C = \frac{U_C}{\frac{1}{Cp}}$$

podobno?

podobno?



$$U_L = L\,\frac{dI_L}{dt}$$

spet operator

$$U_L = L p I_L \Rightarrow I_L = \frac{U_L}{Lp}$$

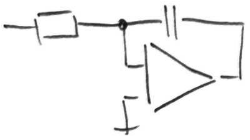
DA:

zato proglasimo: "upornost" kondenzatorja $X_C = \frac{1}{Cp}$

"upornost" tuljave $X_L = Lp$

; p = operator odvajanja

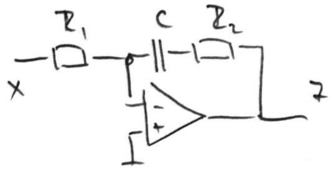
torej lahko prejšnji integrator, npr., računam



$$I_R + I_C = 0$$

$$\frac{x}{R} + \frac{z}{\frac{1}{Cp}} = 0 \Rightarrow z = -x\frac{1}{RCp} = -\frac{x}{\tau p}$$

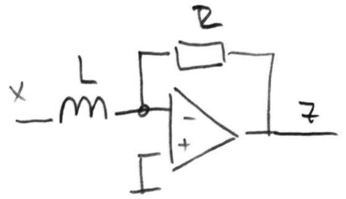
integr.



$$\frac{x}{R_1} + \frac{z}{R_2 + \frac{1}{Cp}} = 0$$

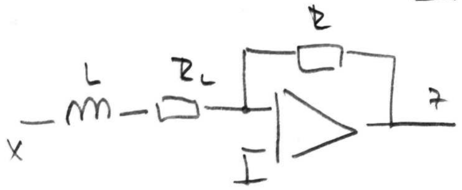
$$\frac{x}{R_1} + \frac{Cp\,z}{1 + R_2Cp} = 0 \Rightarrow z = -x\left[\frac{1}{R_1Cp} + \frac{R_2}{R_1}\right]$$

integrira ojači



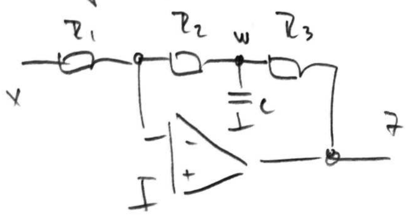
$$\frac{x}{Lp} + \frac{z}{R} = 0 \Rightarrow z = -x\frac{R}{Lp}$$

integrira



$$\frac{x}{Lp + R_L} + \frac{z}{R} = 0 \Rightarrow z = -x\underbrace{\frac{R}{Lp + R_L}}_{\text{tegale pa ne znam}}$$

morda gre pa tole:



$$\frac{x}{R_1} + \frac{w}{R_2} = 0 \Rightarrow w = -x\frac{R_2}{R_1}$$

$$\frac{w}{R_2} + \frac{w}{\frac{1}{Cp}} + \frac{w - z}{R_3} = 0$$

$\frac{V}{A}$ $\frac{As}{V}$ $\frac{V}{s}$

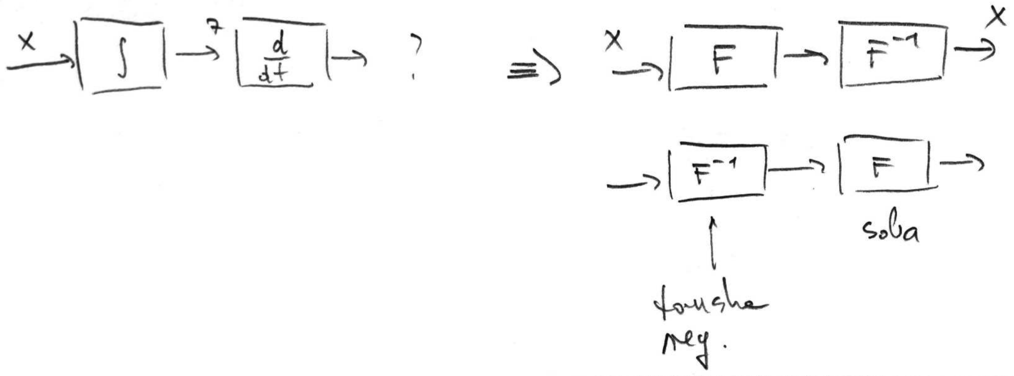
$$-\frac{x}{R_1} - \frac{x R_2 Cp}{R_1 \cancel{\frac{1}{Cp}}} - \frac{x\frac{R_2}{R_1} + z}{R_3} = 0$$

$$-xR_3 - xR_2R_3Cp - xR_2 - zR_1 = 0 \Rightarrow z = -x\left[\frac{R_3}{R_1} + \frac{R_2}{R_1} + \frac{R_2R_3}{R_1}Cp\right]$$

ojač ojač odvod

2005/3d

kaj dobim



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pojem prenosne funkcije

nas ne zanima samo le kako izgleda y
ampak pogosteje kaj počne škatla

↓

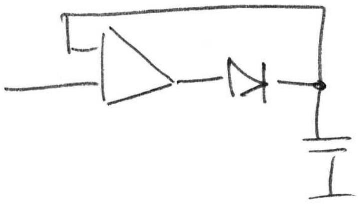
zanima nas $\boxed{\frac{y}{x}}$ ≡ kako škatla spremeni signal

prenosna funkcija $T(p) = \frac{y}{x}$

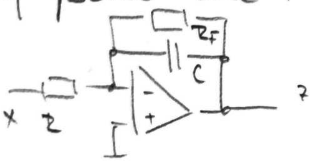
---

logaritemski ojač

usmernik



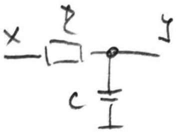
Kaj počne tole ?



$$\frac{x}{R} + \frac{z}{R_F} + \frac{z}{\frac{1}{Cp}} = 0 \Rightarrow z\left[\frac{1+R_F C p}{R_F}\right] = -\frac{x}{R}$$

$$z = -x\,\frac{R_F}{R}\,\underbrace{\frac{1}{1+R_F C p}}_{?}$$

podobno



$$y = x\,\frac{\frac{1}{Cp}}{R+\frac{1}{Cp}} = x\,\underbrace{\frac{1}{1+RCp}}_{?}$$

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išči analogije v fiziki

npr. termometer

toplota $Q_T = m_T c_p \cdot T_T$

$$\frac{dQ_T}{dt} = m_T \cdot c_p \cdot \frac{dT_T}{dt} \Leftarrow$$ toplotni tok je tudi sorazmeren ΔT

$$dQ = (T_0 - T_T)\,k\,dt$$

↓ prevodnost

$$\frac{dQ}{dt} = (T_0 - T_T)k$$

združi

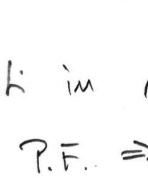
$$m_T c_p \frac{dT_T}{dt} = (T_0 - T_T)k$$

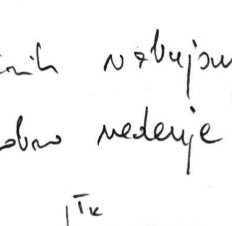
$$m_T c_p\, p T_T + T_T k = T_0 k$$

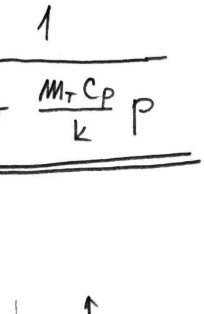
$$T_T\left[m_T c_p\, p + k\right] = T_0 k \Rightarrow T_T = T_0 \frac{1}{1 + \frac{m_T c_p}{k} p}$$

besedilo o podobnosti in različnih vzbujanjih

- podobne P.F. ⇒ podobno vedenje



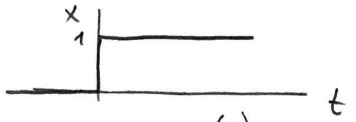




2005/46

Zato sedaj zares računamo: rešujemo L.D.E. 1. REDA

$$T(p) = \frac{z}{x} = \frac{1}{1+\tau p} \xRightarrow{\text{LDE}} z + \tau z' = x$$



$x = \mu(t)$

enotina stopnica $u(t)$

– velja so vzročna (kavzalna) → pred $t=0$ ni odziva!

① rešujemo homogeno LDE 1. R

$$z + \tau z' = 0 \quad , \quad \text{nastavek: } \underbrace{z = ke^{\alpha t} \quad , \quad z' = k\alpha e^{\alpha t}}$$

vstavi v HDE

$$ke^{\alpha t} + \tau k \alpha e^{\alpha t} = 0$$

$$ke^{\alpha t}\left[\underbrace{1 + \alpha\tau}_{=0}\right] = 0$$

$$\Rightarrow \quad \alpha = -\frac{1}{\tau} \Rightarrow \underline{\underline{z = ke^{-t/\tau}}}$$

② prilagoditev na vzbujanje

– variacija konstante

$$z = k(t)e^{-t/\tau} \rightarrow \underbrace{z' = \dot{k}(t)e^{-t/\tau} - k(t)\frac{1}{\tau}e^{-t/\tau}}$$

vstavi v prvotno D.E.

$$\cancel{k(t)e^{-t/\tau}} + \tau \dot{k}(t)e^{-t/\tau} - \cancel{k(t)e^{-t/\tau}} = x$$

$$\dot{k}(t) = \frac{x}{\tau}e^{t/\tau} \Rightarrow k(t) = \frac{x}{\tau}\int e^{t/\tau}dt$$

$$= xe^{t/\tau} + C$$

torej

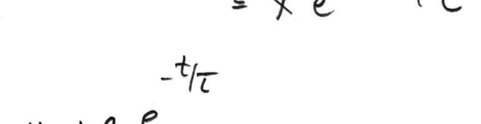
$$z = \left(xe^{t/\tau} + c\right)e^{-t/\tau} = x + ce^{-t/\tau}$$

– zač. pogoj

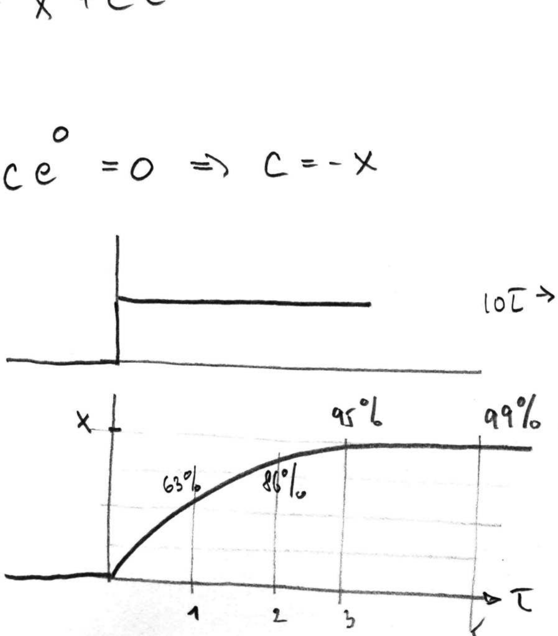
$$z(0) = 0 \Rightarrow x + ce^{0} = 0 \Rightarrow C = -x$$

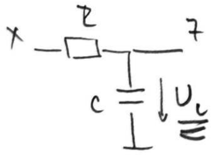
③ končno

$$z = x\left(1 - e^{-t/\tau}\right)$$



$10\tau \rightarrow 99{,}995\%$





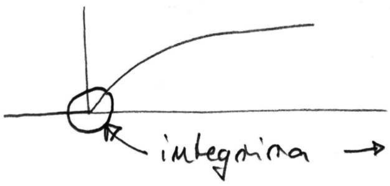
: se ne more hipoma spremeniti
v C mora priteči tok, omejuje ga R

kaj točno to vezje dela?

- integrira? → $U_c = \frac{1}{c}\int I_c \, dt$

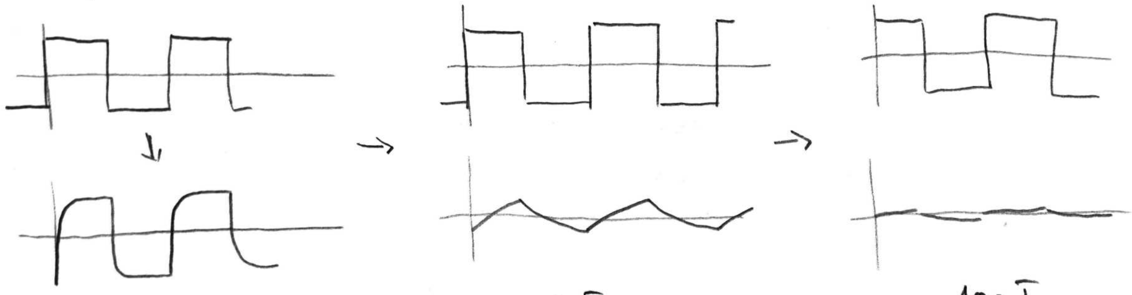
↳ ja, dokler je I_c odvisen le od x : integrira

dejansko: $I_c = \frac{x-y}{R}$ ⇒ dokler je $\boxed{x \gg y}$



integrira → približni integrator!

- še kaj?



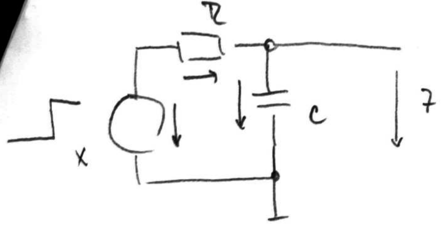
τ_0 $10\tau_0$ $100\tau_0$

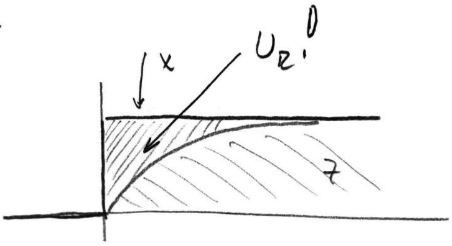
povprečevalnik!

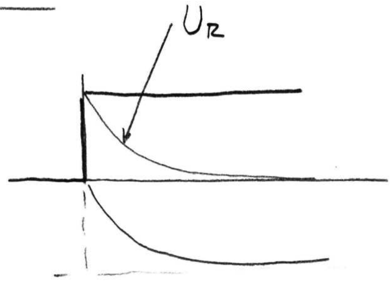
ob $\tau \gg \frac{1}{T_p}$

2005/14d

odziv istega, tokmet na R







$$x = U_C + U_R = z + U_R \Rightarrow U_R = x - z \Rightarrow$$

$$u(t) = u(t)\frac{1}{1+\tau p} + U_R$$

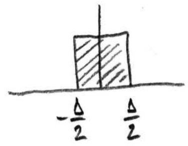
$$U_R = u(t)\frac{1+\tau p - 1}{1+\tau p} = \underline{\underline{\frac{\tau p}{1+\tau p}}}\, u(t) = u(t)\underbrace{\frac{1}{1+\tau p}}_{\text{kolezeno}} \cdot \underbrace{\tau p}_{\text{odvod}}$$

---

odziv istega na $\delta(t) \longrightarrow$

neskončno ozka
— " — visoka $\Big\}$ $\underline{\underline{\int_{-\infty}^{\infty} \delta(t)\,dt = 1}}$

naša δ



ploščina je 1
limita bo dala rezultat

enačba: $z + \tau z' = \delta$

$$z + \tau\frac{dz}{dt} = \delta$$

① določi vpliv vzbujanja
② rešuj homogeno DE

① $$z + \tau\frac{dz}{dt} = \delta \;\Big|\; \int_{-\frac{\Delta}{2}}^{\Delta/2} dt$$

$$\underbrace{\int_{-\Delta/2}^{\Delta/2} z\,dt}_{\text{b)}} + \tau\underbrace{\int_{-\Delta/2}^{\Delta/2}\frac{dz}{dt}\,dt}_{\text{a}} = \underbrace{\int_{-\Delta/2}^{\Delta/2}\delta\,dt}_{\text{je 1 po definiciji}}$$

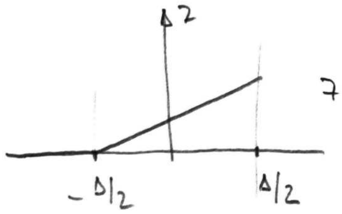
2005/4e

a) $\tau \int_{-\frac{\Delta}{2}}^{\Delta/2} dz = \tau z \Big|_{-\Delta/2}^{\Delta/2} = \tau z(\Delta/2) - \underbrace{\tau z(-\Delta/2)}_{0} = \tau z\left(\frac{\Delta}{2}\right)$

b) $\int_{-\Delta/2}^{\Delta/2} z\,dt = \int_{-\Delta/2}^{\Delta/2} (t+\Delta/2) k\,dt = k\frac{t^2}{2} + \frac{\Delta t}{2}k \Big|_{-\Delta/2}^{\Delta/2} =$

$= k\left[\cancel{\frac{\Delta^2}{8}} + \frac{\Delta^2}{4} - \cancel{\frac{\Delta^2}{8}} + \frac{\Delta^2}{4}\right] = \frac{\Delta^2}{2}$

linearizirej!



$z = \left(t + \frac{\Delta}{2}\right)k$

$\Downarrow$

δ je ozka

$\Downarrow$

$\lim_{\Delta\to 0} \int_{-\frac{\Delta}{2}}^{\Delta/2} z\,dt = \lim_{\Delta\to 0} \frac{\Delta^2}{2} = \phi$

torej

$0 + \tau z\left(\frac{\Delta}{2}\right) = 1 \Rightarrow \underline{\underline{z^+ = \frac{1}{\tau}}}$ $\quad z^+ \equiv z$ po vzbujanju

ostalo

$z + \tau \dot{z} = 0 \qquad z^+ = \frac{1}{\tau}$

nastavek: $z = ke^{\alpha t}$

$\dot{z} = \alpha k e^{\alpha t}$

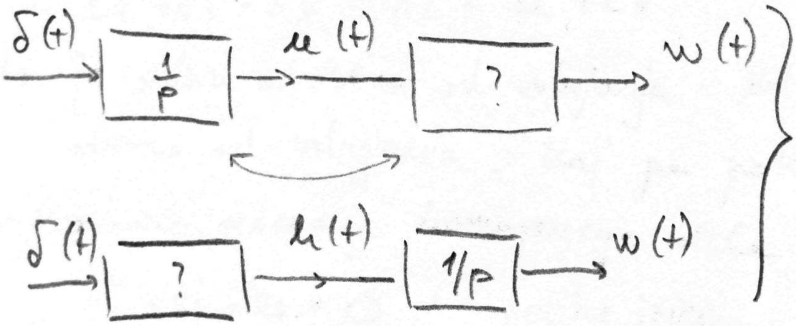
$ke^{\alpha t} + \tau \alpha k e^{\alpha t} = 0 \Rightarrow ke^{\alpha t}\left[1 + \alpha\tau\right] = 0 \Rightarrow \alpha = -\frac{1}{\tau}$

$z = ke^{-t/\tau}$

$z^+ = \frac{1}{\tau} = ke^{0} \to k = \frac{1}{\tau} \Rightarrow z = \frac{1}{\tau}e^{-t/\tau}$

2005/5a

ali je to kaj povezano? more biti!

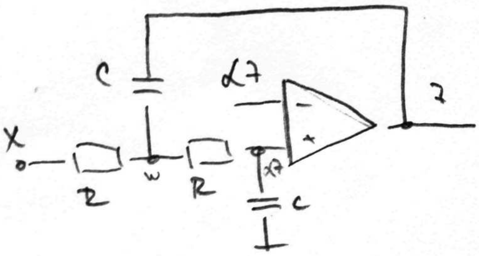


$$\boxed{h(t) = p\,w(t)}$$

- kaj pa za $T(p)$ višjega reda?

D.E. že ne znajo!!!

- poskusimo z nečim spodaj



$$\alpha z = w\,\frac{\frac{1}{Cp}}{R+\frac{1}{Cp}} = w\,\frac{1}{1+\tau p} \Rightarrow \underbrace{w = (1+\tau p)\alpha z}$$

$$\frac{w-x}{R} + \frac{w-\alpha z}{R} + \frac{w-z}{\frac{1}{Cp}} = 0$$

$$w - x + w - \alpha z + w\tau p - z\tau p = 0$$

$$w(2+\tau p) - x - \alpha z - z\tau p = 0$$

$$\alpha z(1+\tau p)(2+\tau p) - x - \alpha z - z\tau p = 0$$

$$z\left[2\alpha + 3\tau p\alpha + \tau^2 p^2 \alpha\right] - x - \alpha z - z\tau p = 0$$

$$z\left[2\alpha - \alpha - \tau p + 3\alpha\tau p + \alpha\tau^2 p^2\right] = x$$

$$z = x\,\frac{1}{\tau^2 p^2 + \tau p\left[3-\frac{1}{\alpha}\right] + 1}\,\frac{1}{\alpha} \quad ; \quad \alpha = 1$$

$$\downarrow$$

$$z = x\,\frac{1}{(1+\tau p)^2} = \text{dvakratni integrator}$$

o sploščenem bo tvoj P.F. 2. reda oblike

$$T(p) = \frac{Ap^2 + Bp + C}{Dp^2 + Ep + F}$$

iz tega sledi D.E. 2. reda

$$D\ddot{z} + E\dot{z} + Fz = A\ddot{x} + B\dot{x} + Cx$$

seveda je odziv odvisen od vzbujanja; vedenje vezja je odvisno od vzbujanja. Kaj pa potem? Po vzbujanju?

– ostane reševanje homogenega dela

$$D\ddot{z} + E\dot{z} + Fz = 0$$

rešitve iščemo v obliki

$$\begin{cases} z = Ae^{\alpha t} \\ \dot{z} = \alpha A e^{\alpha t} \\ \ddot{z} = \alpha^2 A e^{\alpha t} \end{cases}$$

↓ vstavi

$$DAe^{\alpha t} + E\alpha A e^{\alpha t} + F\alpha^2 A e^{\alpha t} = 0$$

$$\underbrace{Ae^{\alpha t}}_{\neq 0}\underbrace{\left[D + E\alpha + F\alpha^2\right]}_{0} = 0 \Rightarrow \alpha_{1,2} = \frac{-E \pm \sqrt{E^2 - 4DF}}{2F}$$

↓

možnosti

① $E^2 > 4DF \Rightarrow$ dva realna korena

a) oba negativna $\rightarrow$ $e^{-\alpha_1 t}$, $e^{-\alpha_2 t}$ izzveni

b) +/- $\Rightarrow$ $e^{\alpha_1 t}$, $e^{\alpha_2 t}$ ne izzveni če $\frac{DF}{E^2} > 1$

c) oba pozitivna ← ~~nemogoče~~ ne izzveni

② $E^2 = 4DF \Rightarrow$ dvojni koren $\Rightarrow$ išči rešitev v obliki $\alpha e^{\alpha t}$

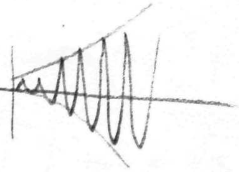
③ $E^2 < 4DF \Rightarrow$ konj. kompleksni koreni! sin! cos!

realni del definira izzvenevanje!

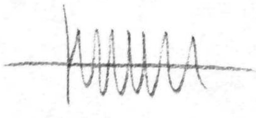
ali torej bo lahko izkoristimo?

- exp. naraščanje
- konst. amplitude ~ ✓
- exp. izzvenevanje ✓

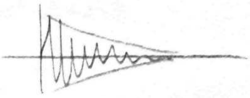
3 a



$Re(\alpha) > 0$



$Re(\alpha) = 0$



$Re(\alpha) < 0 \Rightarrow \underline{e^{-\alpha t}\, e^{i\omega t}}$

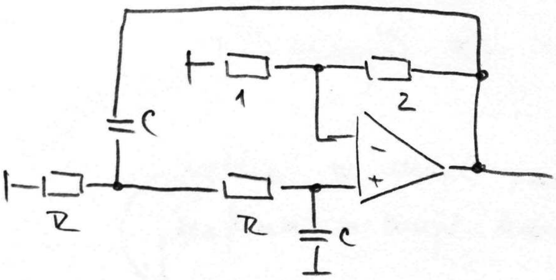
je prejšnje vezje torej lahko oscilator?

$$\tau^2 p^2 + \tau p\left[3 - \frac{1}{\alpha}\right] + 1$$

- izberi α tako, da bo $Re[\alpha_1, \alpha_2] = 0$

$$\alpha_{1,2} = \frac{-\left[3 - \frac{1}{\alpha}\right] \pm \sqrt{Det}}{2} = 0 \Rightarrow 3 - \frac{1}{\alpha} = 0$$

$$3\alpha = 1 \Rightarrow \boxed{\alpha = \frac{1}{3}}$$



težko doseči $\alpha = \frac{1}{3}$ stalno!

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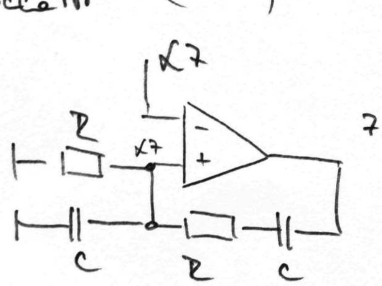
boljši oscilator (Wien)



$$\frac{\alpha z}{R} + \frac{\alpha z}{\frac{1}{Cp}} + \frac{\alpha z - z}{R + \frac{1}{Cp}} = 0$$

$$\frac{\alpha z}{R} + \alpha z Cp + \frac{(\alpha z - z)}{1 + \tau p} Cp = 0$$

2005 / d

$$(\alpha 7+\alpha 7\tau p)(1+\tau p)+(\alpha 7-7)\tau p=0$$

$$\alpha 7+\underline{\alpha 7\tau p}+\underline{\alpha 7\tau p}+\alpha 7\tau^2 p^2+\alpha 7\tau p-7\tau p=0$$

$$7\left[\alpha+3\alpha\tau p-\tau p+\alpha\tau^2p^2\right]=0$$

$$7\alpha\left[\tau^2p^2+\left(3-\frac{1}{\alpha}\right)\tau p+1\right]=0 \Rightarrow \text{niha, kadar } \underline{\underline{\alpha=\frac{1}{3}}}$$

za stabilnost:

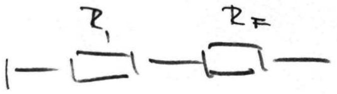
rešitve $\dfrac{-\left(3-\frac{1}{\alpha}\right)\pm\sqrt{Det}}{2}$ $\qquad e^{-\frac{3\alpha-1}{2\alpha}}$

$\alpha>\frac{1}{3} \Rightarrow e^{-} \Rightarrow$ ampl. pada

$\alpha<\frac{1}{3} \Rightarrow e^{+} \Rightarrow$ ampl. narašča

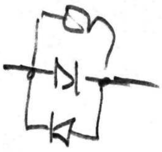
vrstni red

↓

b)  $\alpha=\dfrac{R_1}{R_F+R_1}$

večji ⇒ ampl. narašča

manjši ⇒ ampl. pada



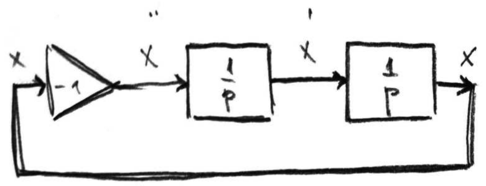
večja ampl. = ampl. pada =

velika = ampl. pada

majhna = ampl. narašča

a) 

oscilator



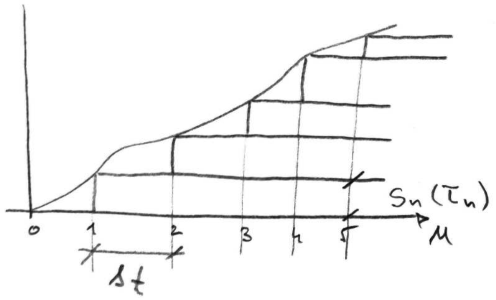
$$\ddot{x} = -x \Rightarrow \ddot{x} + x = 0$$

relaxacijski osc

2005 / 6 a

računanje splošnega odziva
znan je $w(t)$

dano $x(t)$ aprox. z neg. stopnicami



$\tau_n = \Delta t \cdot n$

$$S_n(\tau_n) = \Delta t \cdot \left.\frac{dx(t)}{dt}\right|_{t=\tau_n}$$

ampl. posamezne stopnice

$$\boxed{x(t) = \sum_n S_n(\tau_n) \cdot u(t-\tau_n)}$$ celoten vzbujelni signal

če gre $\Delta t \to 0 \Rightarrow$ aprox. je zelo dobra
signal $x(t)$ je izražen z $u(t)$ različnih ampl.

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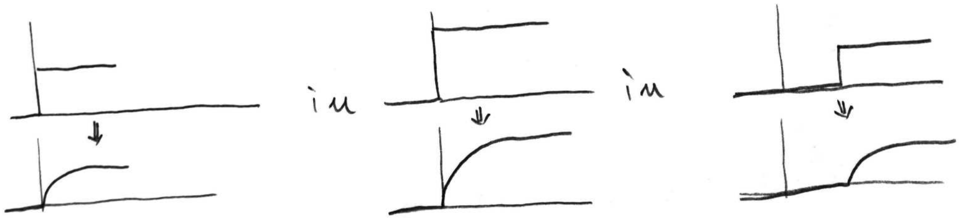
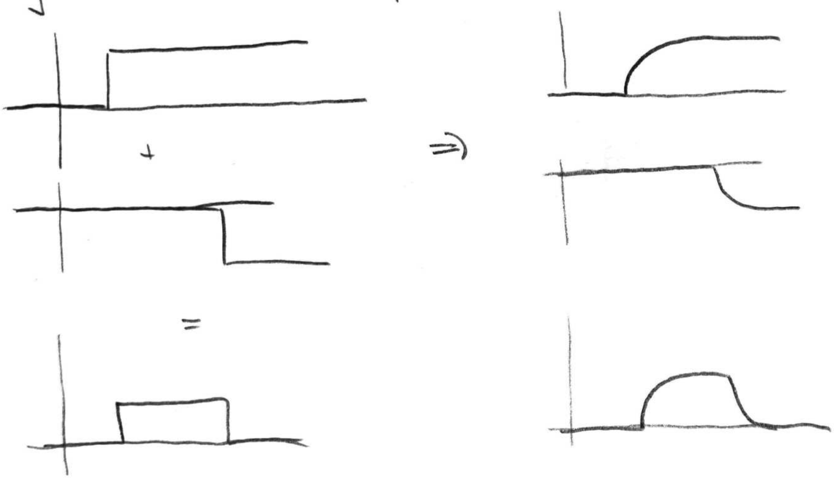
za lin. časovno nespremenljiv sistem velja

$$F(a+b) = F(a) + F(b)$$



za vzbujanje z eno stopnico
za vzbujanje z dvema stopnicama



odziv na eno stopnico zapišemo

$$z(t) = w(t) \cdot S_0$$

za dve stopnici

$$z(t) = w(t) S_0 + w(t-\Delta t) S_1$$

za tri stopnice

$$z(t) = w(t) S_0 + w(t-\Delta t) S_1 + (t-2\Delta t) S_2$$

celoten odziv pa

$$z(t) = \sum_n w(t-\tau_n) S_n(\tau_n)$$

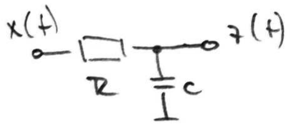
če potem limitiramo $\Delta t \to 0$ preide $\tau_n \to \tau$
diskr. zvezno

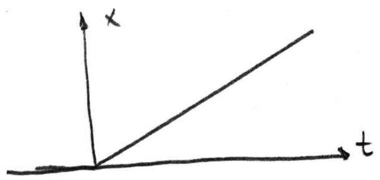
in dobimo

$$\boxed{z(t) = \int_{-\infty}^{t} \frac{dx}{dt} w(t-\tau) d\tau}$$

sp. meja = začetek vzb.
konvolucija

zgled





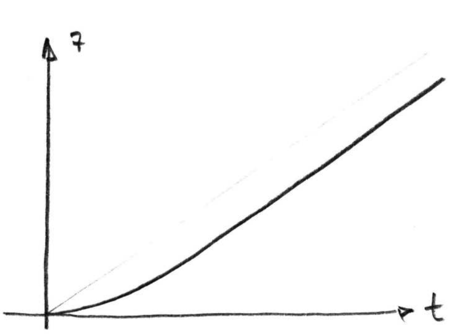
$$x(t) = \alpha t \Rightarrow \frac{dx}{dt} = \alpha$$

$$w(t) = 1 - e^{-t/\tau}$$

$$z(t) = \int_0^t \alpha \left(1 - e^{-\frac{t-\tau}{RC}}\right) d\tau = \alpha \tau \Big|_0^t - \alpha \int_0^t e^{-\frac{t}{RC}} e^{\frac{\tau}{RC}} d\tau =$$

$$= \alpha t - \alpha e^{-\frac{t}{RC}} \cdot RC\, e^{\frac{\tau}{RC}} \Big|_0^t = \alpha t - RC\alpha e^{-\frac{t}{RC}} \left[e^{\frac{t}{RC}} - 1 \right] =$$

$$= \alpha t - \alpha RC \left[1 - e^{-t/RC} \right]$$



2005 / c

kaj pa vzbujanje s sin ?

$T(p)$ opisuje odziv $\Rightarrow$ - rešuj d.e. $\Rightarrow$ močem
- nastavi sin iz stopnice $\Rightarrow$ močem
- drugače ??

lin. vezje ne more spremeniti frekvence
-"- ni ne more izmisliti novih signalov $\Big\} \Rightarrow$ izhod je prav tako sin oblike

spremeni se lahko le ampl. ali faza !!!

torej: $x(t) = \cos \omega t \rightarrow z(t) = A \cos(\omega t + \varphi)$

zgled za diferenciator: $T(p) = \tau p = \frac{z}{x}$

$$z = \tau \dot{x}$$

$$z = \tau(\cos \omega t)' = -\tau \omega \sin \omega t$$

p. f. iz tega : $\frac{z}{x} = -\frac{\tau \omega \sin \omega t}{\cos \omega t}$???

p. f. vsebuje obliko signala $\Rightarrow$ težko interpretiramo

zato: vzbujamo s kompleksnim signalom

$$x(t) = \cos \omega t + i \sin \omega t = \underline{\underline{e^{i\omega t}}}$$

zato pričakujemo na izhodu

$$z(t) = T(i\omega) e^{i\omega t}$$

2005 / d

poskusimo najti povezavo med A in AA s pomočjo $T(p)$

$$T(p) = \frac{Ap^2 + Bp + C}{Dp^2 + Ep + F} = \frac{z}{x}$$

$$x = e^{i\omega t} \qquad z = T(i\omega)\, e^{i\omega t}$$

$$\dot{x} = i\omega\, e^{i\omega t} \qquad \dot{z} = T(i\omega)\, i\omega\, e^{i\omega t}$$

$$\ddot{x} = -\omega^2\, e^{i\omega t} \qquad \ddot{z} = -T(i\omega)\, \omega^2\, e^{i\omega t}$$

$$-A\omega^2 \cancel{e^{i\omega t}} + Bi\omega \cancel{e^{i\omega t}} + C \cancel{e^{i\omega t}} = -T(i\omega)\,\omega^2 D \cancel{e^{i\omega t}} + T(i\omega)\, i\omega E \cancel{e^{i\omega t}} + T(i\omega) \cdot F \cancel{e^{i\omega t}}$$

$$T(i\omega) = \frac{-A\omega^2 + i\omega B + C}{-D\omega^2 + i\omega E + F} = \frac{A(i\omega)^2 + B(i\omega) + C}{D(i\omega)^2 + E(i\omega) + F}$$

primerjava: $\boxed{T(i\omega) = T(p)\big|_{p = i\omega}}$

$T(i\omega)$ .. kompleksna amplituda
- podaja amplitudo in fazo odziva pri vzbujanju s harm. signalom

$$\left.\begin{aligned} |T(i\omega)| &= \text{ampl.} \\ \operatorname{arc\,tg} \frac{\operatorname{Im}(T(i\omega))}{\operatorname{Re}(T(i\omega))} &= \text{fazni kot} \end{aligned}\right\} \text{zakaj?}$$

odgovor: vzbujamo ravno z realnim signalom, zato pričakujemo le realen odziv

2006 / e

$x(t) = \cos \omega t$

$z(t) = A \cos(\omega t + \varphi)$

$= T(i\omega)\, e^{i\omega t} = T(i\omega)\left[\cos \omega t + i \sin \omega t\right]$

realni del: $Re\left[z(t)\right] = Re\left[T(i\omega)(\cos \omega t + i \sin \omega t)\right] =$

$= Re\left[\left(Re(T(i\omega)) + Im(T(i\omega))\right)(\cos \omega t + i \sin \omega t)\right] =$

$= Re(T(i\omega)) \cos \omega t + Im(T(i\omega)) \cdot \sin \omega t =$

$= A(\omega) \cos(\omega t + \varphi)\ ;\ A(\omega) = \dots$

$\varphi = \dots$

poskusimo lahko tudi:

$T(i\omega) = |T(i\omega)|\, e^{i\varphi}$ zapis v polarni obliki

$$\left.\begin{aligned} |T(i\omega)| &= \sqrt{T(i\omega) \cdot T(-i\omega)} \\ \varphi &= \operatorname{arc\,tg} \frac{Im(T(i\omega))}{Re(T(i\omega))} \end{aligned}\right\}$$

tole je realno

$x(t) = e^{i\omega t} \Rightarrow \cos \omega t + i \sin \omega t$

$z(t) = T(i\omega)\, e^{i\omega t} = |T(i\omega)|\, e^{i\varphi} e^{i\omega t} =$

$= |T(i\omega)|\, e^{i(\omega t + \varphi)} =$

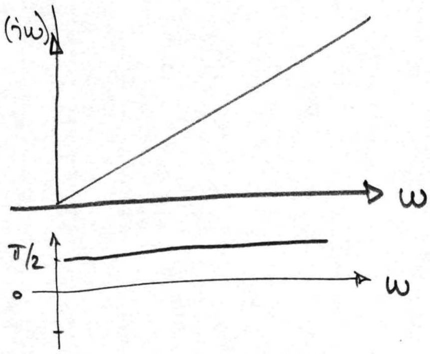
$= |T(i\omega)| \left[\cos(\omega t + \varphi) + i \sin(\omega t + \varphi)\right]$

$\Downarrow$

tole je realno

diferenciator

$$T(p) = \tau p \Rightarrow T(i\omega) = i\omega\tau \Rightarrow$$



$$\arg(T(i\omega)) = \operatorname{arc\,tg} \frac{\omega\tau}{0} =$$

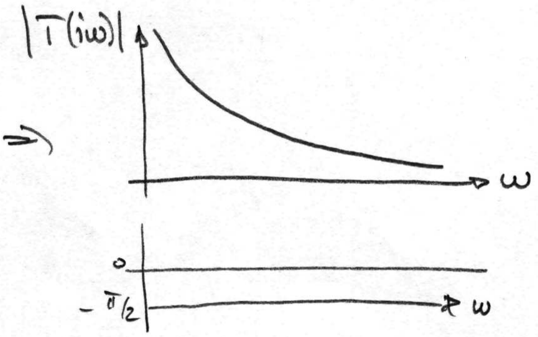
$$= \operatorname{arc\,tg} \infty = \frac{\pi}{2}$$

✓

sin → cos

integrator

$$T(p) = \frac{1}{\tau p} \Rightarrow T(i\omega) = \frac{1}{i\omega\tau} \Rightarrow$$

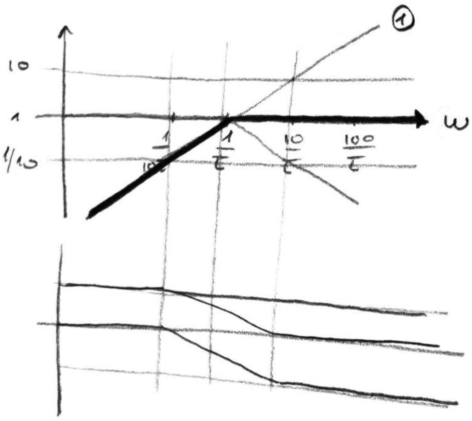


$$\arg(T(i\omega)) = \operatorname{arc\,tg} \frac{-1}{\omega\tau\cdot 0} =$$

$$= \operatorname{arctg} -\infty = -\frac{\pi}{2}$$

2005 / 7 a

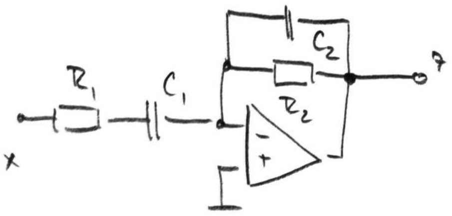
$$T(p) = \frac{\tau p}{1+\tau p} = \underset{①}{\tau p} \cdot \overset{②}{\frac{1}{1+\tau p}}$$



$\mathrm{arctg}\ \infty \Rightarrow +\pi/2$

$\mathrm{arctg}\ \frac{-\omega\tau}{1} \Rightarrow$

Torej lahko rišemo tudi bolj zamotane stvari



$$\underbrace{\frac{x}{R_1 + \frac{1}{C_1 p}} + \frac{y}{R_2} + \frac{y}{\frac{1}{C_2 p}} = 0}$$

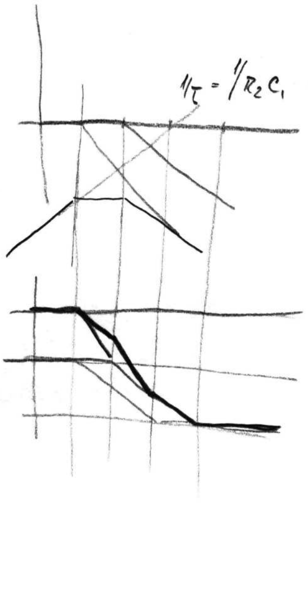
$$\Downarrow$$

$$T(i\omega) = -\frac{i\omega R_2 C_1}{(1+i\omega R_1 C_1)(1+i\omega R_2 C_2)}$$

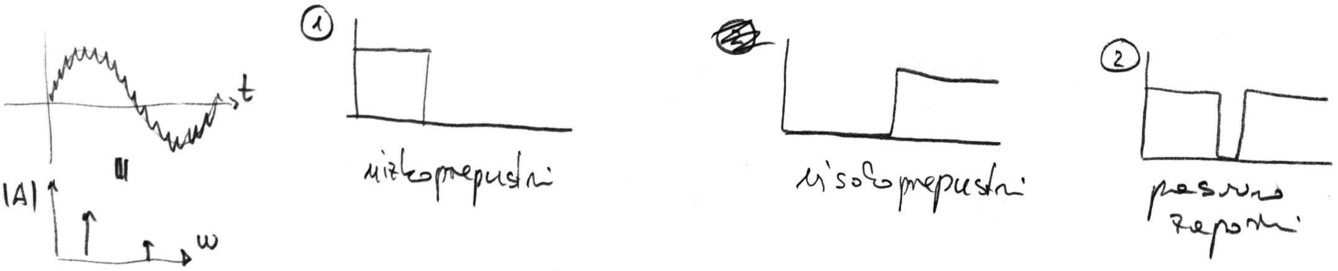
$$R_1 C_1 = \frac{R_2 C_1}{10}$$

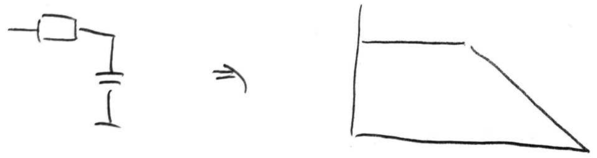
$$R_2 C_2 = \frac{R_2 C_1}{100}$$

$$T(i\omega) = -i\omega R_2 C_1 \cdot \frac{1}{(1+i\omega R_1 C_1)} \cdot \frac{1}{(1+i\omega R_2 C_2)} \Rightarrow$$



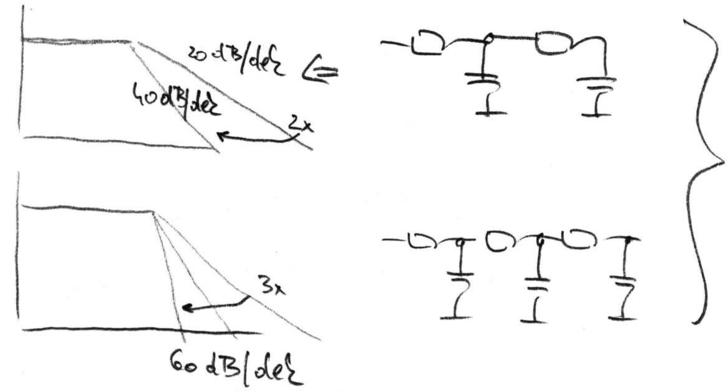
filter? ⇒ meje, ki: ① prepušča } del f. spektra
② ne prepušča





ni dovolj dobro

⇓



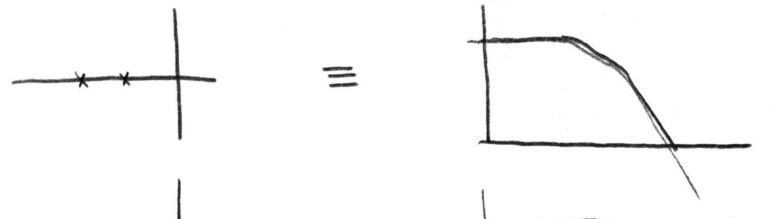
filtri višjih redov!

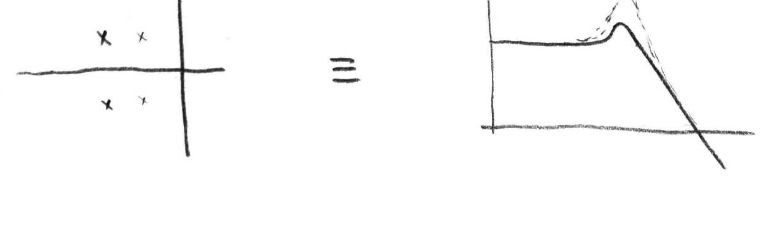
težave: prelomna f. ni ostro določena

2. red: $0.707 \cdot 0.707 = \frac{1}{\sqrt{2}} \cdot \frac{1}{\sqrt{2}} = \frac{1}{2}$ } [illegible]!

3. red: $\frac{1}{\sqrt{2} \cdot 2}$

rešitev: sestavi filter iz enot 2. reda!





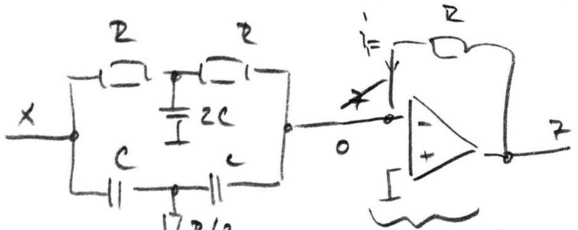
sestavi več delih

2005/ c

nastavljalci : Bessel
Butterworth
~~Chebyshev~~ Čebišev } različni kriteriji } različni efekti

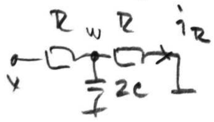
izločiti točno znano pas frekvence ⇒ iz množice signalov izločiti enega
— '' — močnej — '' — signal

poseben filter : dvojni T : twin-T



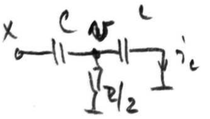
lažje je...

$i_F = \frac{z}{R}$



$$\frac{w-x}{R} + \frac{w}{R} + w2CpR=0$$

$$2w(1+\tau p) = x \Rightarrow w = \frac{x}{2}\frac{1}{1+\tau p} \Rightarrow i_R = \frac{x}{2R}\frac{1}{1+\tau p}$$



$$(v-x)CpR + vCpR + \frac{2v}{\cancel{R}} = 0$$

$$2v(1+\tau p) = x\tau p \Rightarrow v = \frac{x\tau p}{2}\frac{1}{1+\tau p} \Rightarrow i_C = \frac{x\tau p}{2}\frac{Cp}{1+\tau p}$$

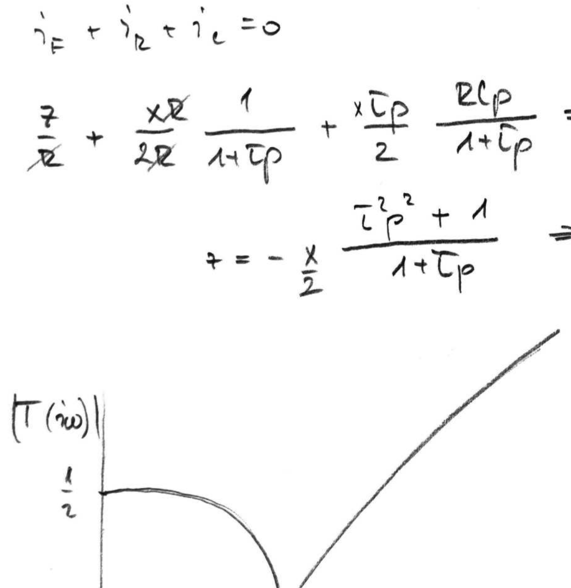
vse skupaj:

$$i_F + i_R + i_C = 0$$

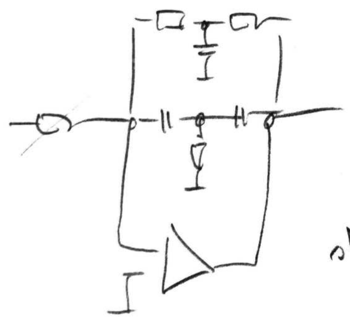
$$\frac{z}{\cancel{R}} + \frac{x\cancel{R}}{2\cancel{R}}\frac{1}{1+\tau p} + \frac{x\tau p}{2}\frac{RCp}{1+\tau p} = 0$$

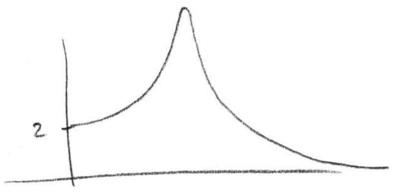
$$z = -\frac{x}{2}\frac{\tau^2p^2+1}{1+\tau p} \Rightarrow T(p) = -\frac{1+\tau^2p^2}{2(1+\tau p)}$$

$$T(i\omega) = -\frac{1}{2}\frac{1-\tau^2\omega^2}{1+i\omega\tau}$$ ima ničlo!



isti filter je lahko v povratni vezavi





sklepanje

nedušenje:

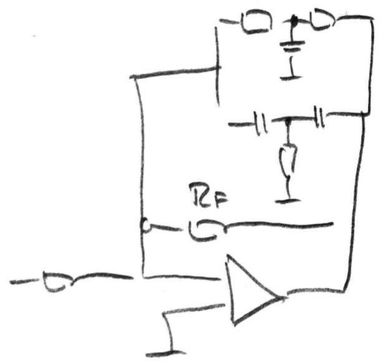
$$i_R + i_C = 0$$

$$\frac{z}{\cancel{2}R}\,\frac{1}{\cancel{1+\tau p}} + \frac{z\tau p}{\cancel{2}}\,\frac{Cp}{\cancel{1+\tau p}} = 0$$

$$z\left(1+\tau^2 p^2\right) = 0$$

$$z + \tau^2 \ddot{z} = 0 \Rightarrow$$ nihanje : harm. osc.!

vpelji še dušenje



$$i_R + i_C + i_F = 0$$

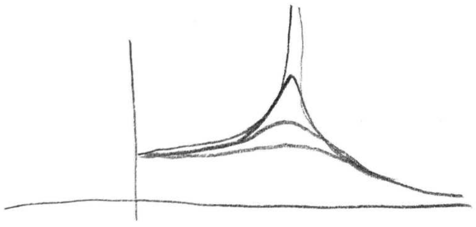
$$\frac{z}{\cancel{2R}}\,\frac{1}{\cancel{1+\tau p}} + \frac{z\tau p}{\cancel{2}}\,\frac{CpR}{\cancel{1+\tau p}} + \frac{2zR\,(1+\tau p)}{R_F} = 0$$

$$z\left[1+\tau^2 p^2 + 2\frac{R}{R_F}(1+\tau p)\right] = 0$$

↓

$R_F \to \infty$: ta del odpade

$R_F \neq \infty$: dušenje

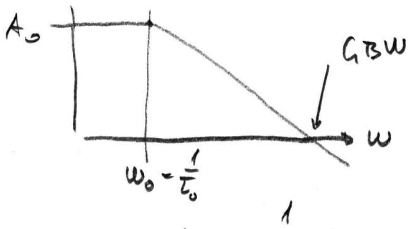


2001 | e

vpliv f. kom. op. na ojač. stopnjo

do sedaj: $A \neq A(\omega)$

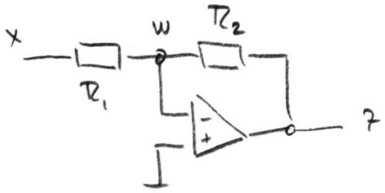
v resnici



$$A = A_0 \frac{1}{1 + i\omega\tau_0}$$

ω_0 : 10 Hz
A_0 : 10^5

nekateri OP imajo več polov



vemo: $G = \frac{R_2}{R_1}$

podrobno:

$$\frac{w - x}{R_1} + \frac{w - z}{R_2} = 0 \quad ; \quad z = A(0 - w) \Rightarrow w = -\frac{z}{A}$$

$$-\frac{z}{AR_1} - \frac{x}{R_1} - \frac{z}{AR_2} - \frac{z}{R_2} = 0$$

$$z\left[\frac{1}{AR_1} + \frac{1}{AR_2} + \frac{1}{R_2}\right] = -\frac{x}{R_1}$$

$$z\,\frac{R_2 + R_1 + AR_1}{AR_1R_2} = -\frac{x}{R_1} \Rightarrow z = -x\,\frac{R_2 A}{R_2 + R_1(A+1)}$$

$$z = -x\,\frac{1}{\frac{1}{A} + \frac{R_1}{R_2}\frac{A+1}{A}} = -x\frac{R_2}{R_1}\frac{A}{\frac{R_2}{R_1} + (A+1)}$$

vstavi se $A(\omega)$

$$z = -x\,\frac{R_2 A_0 \frac{1}{1+i\omega\tau}}{R_2 + R_1\left(A_0\frac{1}{1+i\omega\tau} + 1\right)} = -x\frac{R_2}{R_1}\frac{A_0\frac{1}{1+i\omega\tau}}{\frac{R_2}{R_1} + 1 + A_0\frac{1}{1+i\omega\tau}}$$

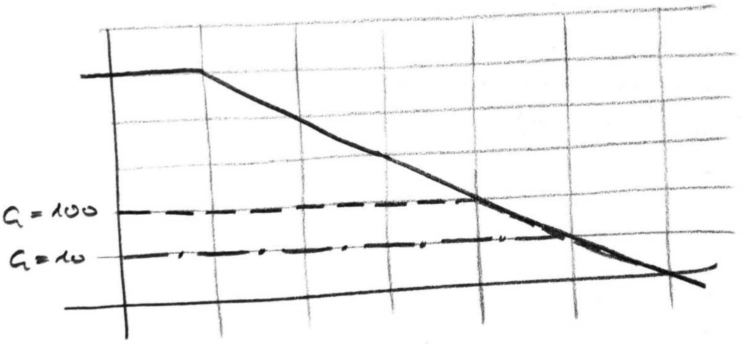
$$\tau(p) = -\frac{R_2}{R_1}\,\frac{A_0}{\left(\frac{R_2}{R_1}+1+A_0\frac{1}{1+i\omega\tau}\right)\cdot\left(1+i\omega\tau\right)} = -\frac{R_2}{R_1}\,\frac{A_0}{\frac{R_2}{R_1}+1+A_0\frac{1}{1+i\omega\tau}+\frac{R_2}{R_1}i\omega\tau+i\omega\tau+A_0}$$

$$= -\frac{R_2}{R_1}\,\frac{A_0\,\frac{1}{\cancel{1+i\omega\tau}}}{\frac{\frac{R_2}{R_1}(1+i\omega\tau)+1(1+i\omega\tau)+A_0}{\cancel{1+i\omega\tau}}} = -\frac{R_2}{R_1}\,\frac{A_0}{A_0+\left(\frac{R_2}{R_1}+1\right)\left(i\omega\tau+1\right)}$$

$$= -\frac{R_2}{R_1}\,\frac{A_0}{A_0+\frac{R_2}{R_1}+1+\left(\frac{R_2}{R_1}+1\right)i\omega\tau} = -\frac{R_2}{R_1}\,\frac{A_0}{A_0+1+\frac{R_2}{R_1}}\;\frac{1}{1+\frac{R_2/R_1+1}{A_0+1+\frac{R_2}{R_1}}\,i\omega\tau}$$

$$= -\frac{R_2}{R_1}\,\frac{A_0}{A_0+1+\frac{R_2}{R_1}}\;\frac{1}{1+i\omega\tau'}\;;\quad \tau' = \tau\,\frac{\frac{R_2}{R_1}+1}{A_0+1+\frac{R_2}{R_1}}$$

$$= \tau\,\frac{G+1}{A_0+1+G}$$



$$\left.\begin{aligned} A_0 &= 10^5 \\ G &= 100 \end{aligned}\right\}\quad \frac{101}{100101} \doteq 10^{-3}$$

$$\omega_p = \frac{1}{\tau'} = \frac{10^3}{\tau} = 10^3\,\omega$$

$$G = 10:\quad \frac{11}{100011} \doteq 10^{-4} \Rightarrow \omega_p = 10^4\,\omega$$

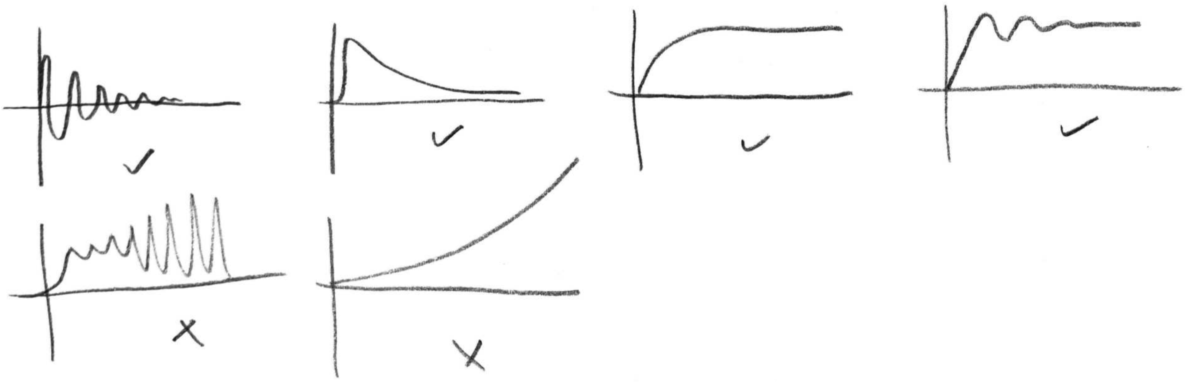
$$\Downarrow$$

nauk: bolje od OP ne gre !!!

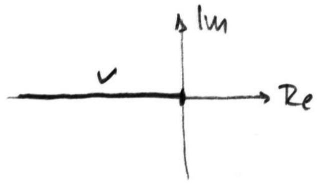
rešitev: več OP, vsak ima majhno ojačanje

Stabilnost

definicija stabilnosti : stabilno je tisto, kar se s časom umiri



vezja 1. reda : $T(p) = \frac{Ap+B}{Cp+D}$ $\equiv$ ~~stabilno po def.~~



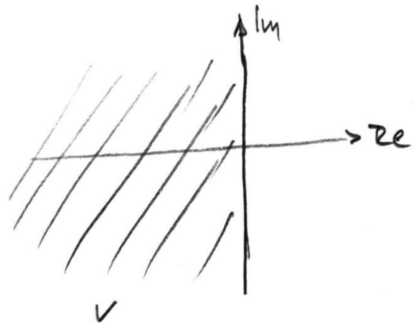
↓ DE 1. reda

rešitve v obliki $e^{\alpha t}$

↓

stabilno, če $\alpha < 0$!! ⇒ exp upadanje

vezja 2. reda : $T(p) = \frac{Ap^2+Bp+C}{Dp^2+Ep+F}$



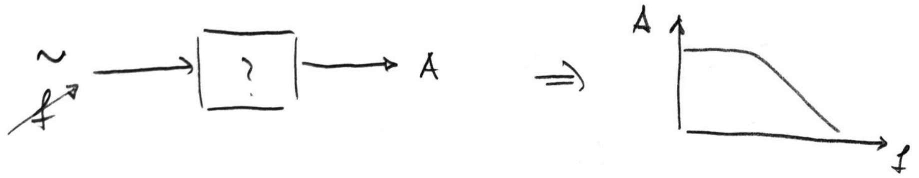
↓ DE 2. reda

rešitve spet v obliki $e^{\alpha t}$

↓

stabilno, če $\mathrm{Re}[\alpha] < 0$!! ⇒ exp izzveni kaj pa, če PF ne poznamo

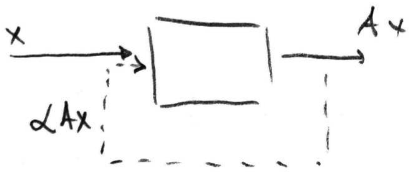
no, Frekv. karakt. lahko opišemo



premislimo

stabilno, mora biti!

kaj pa, če pride slučajno del izhoda nazaj na vhod?



izhod lahko pomaga vhodu!

$\alpha A < 1$: $x = 1$, $A = 10$, $Ax = 10$

$\alpha = 0.01$ $\alpha Ax = 0.1$

$\alpha x = 1$, $\alpha Ax = 0.01$

$\alpha x = 0.1$, $\alpha Ax = 0.001$

↓

izzveni!

✓

$\alpha A > 1$

$x = 1$, $A = 10$, $Ax = 10$

$\alpha = 1$, $\alpha Ax = 10$

$\alpha x = 10$, $\alpha Ax = 100$

$\alpha x = 100$, $\alpha Ax = 1000$

↓

gre proti neskončno

X

če povratna vezava pomaga vhodu ⇒ kolika je αA?

$A\alpha > 1 \rightarrow$ X

$A\alpha < 1 \rightarrow$ ✓

$A\alpha = 1 \rightarrow$ X

2005/8c

kaj pa, ko je povodni signal harmonski?

nelja isto: če izh. pomaga vhodu in je ojačanje n.p.r. > 1...

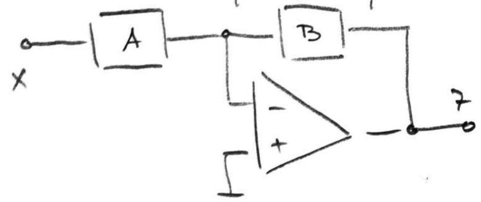
to je, kadar je $\varphi = 0°, 360°, 720° \ldots$

kriterij je torej ojačanje pri tisti frekvenci, kjer je $\varphi = 2\pi \cdot k$, $k = 0, 1, 2 \ldots$

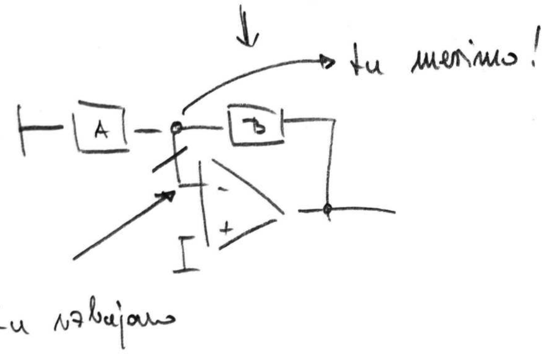
---

kako testirati?

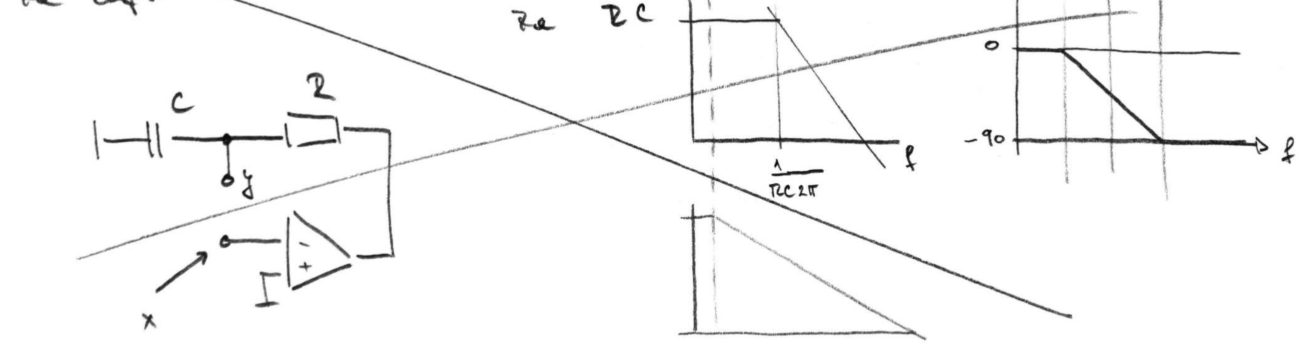
naše mreže imajo P.V. !!!



lastnosti OP poznamo
lastnosti P.V. izračunamo ali izmerimo



~~za diferenciator~~



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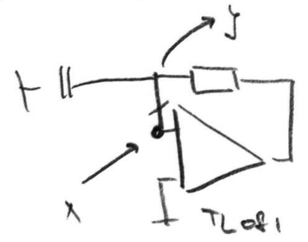
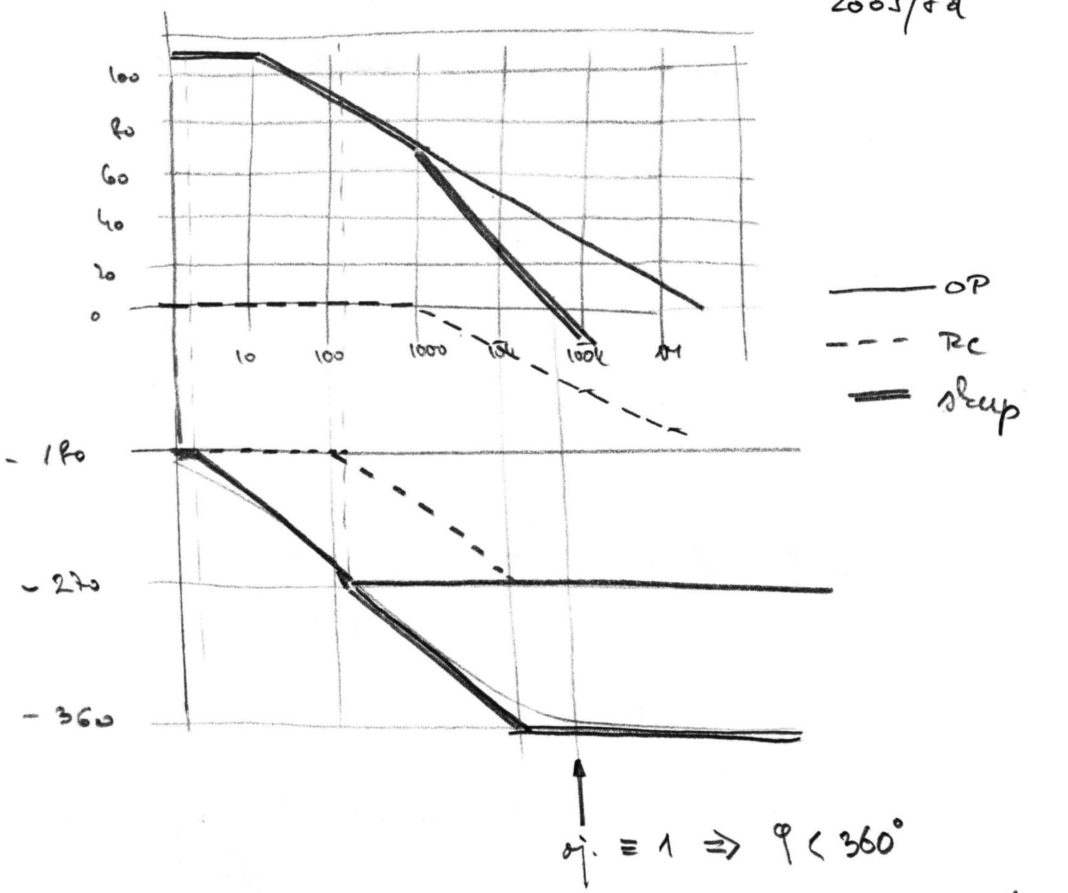
Za diferenciator



$A_0 = 110\,dB$

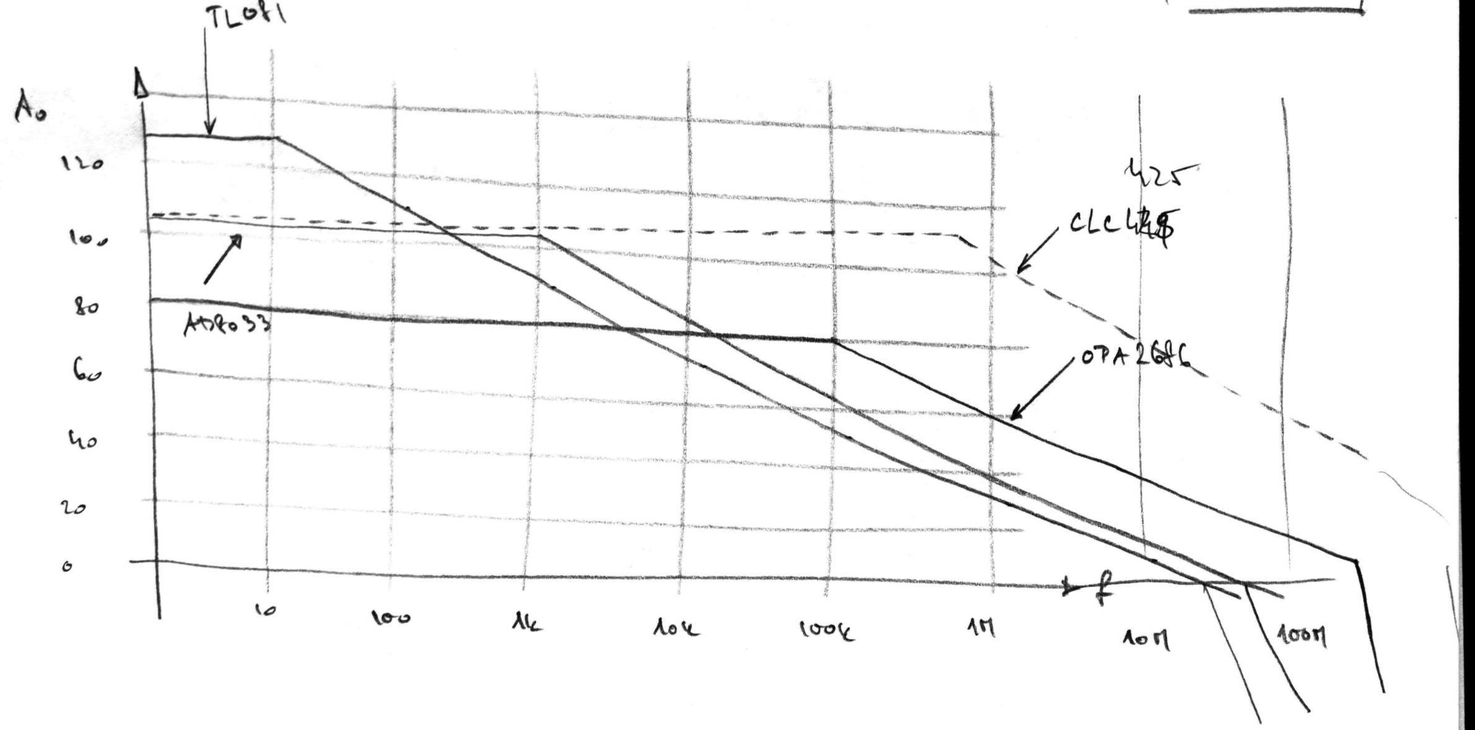
$f_p = 12\,Hz$

a)



$\alpha_i \equiv 1 \Rightarrow \varphi < 360^\circ$

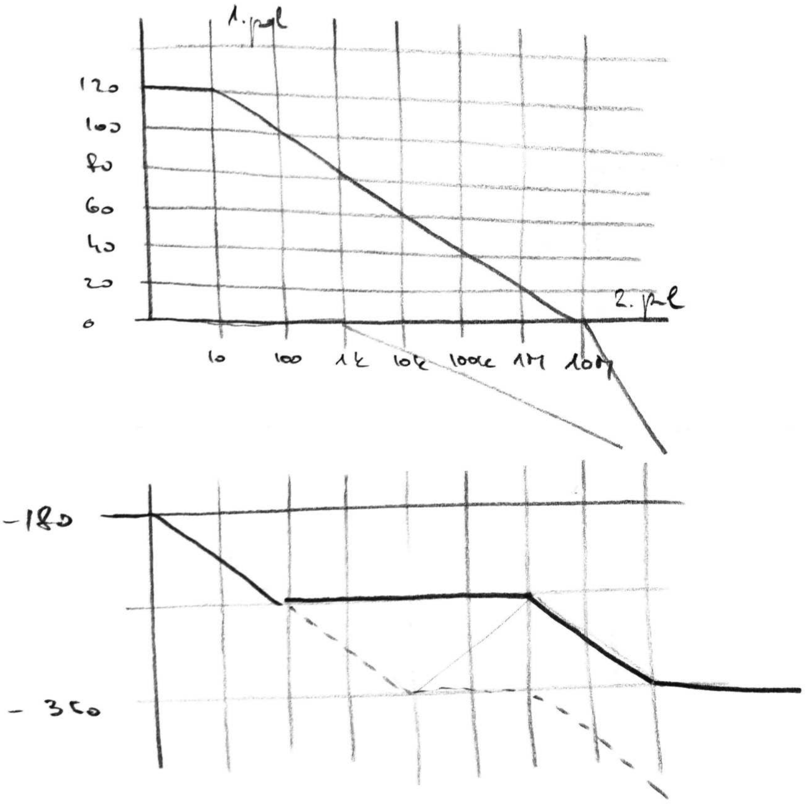
ne niha, malo manjka



OP	f_p	A_0
TL081	12 Hz	110 dB
AD8033	1k	105 dB
OPA2686	100k 800 MHz 800 MHz	80 dB
CLC 449 421	800 kHz	105

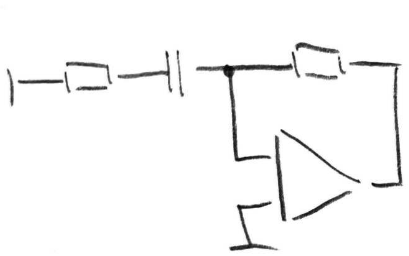
2005/8 e

kaj pa, če bi bil OP z dvema poloma, ki sta na videz nedolžna?

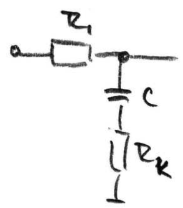


+ RC v P.V. = katastrofa!

rešitev

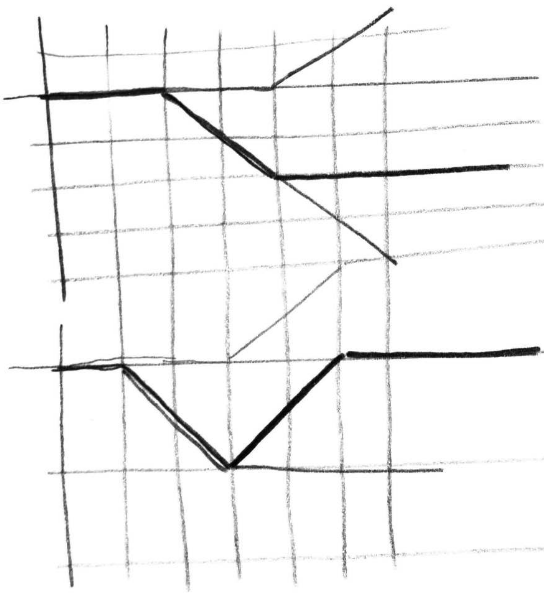


kar



$$Z = \frac{\frac{1}{j\omega C} + R_k}{R_1 + R_k + \frac{1}{j\omega C}}$$

$$Z = \frac{\frac{1 + j\omega R_k C}{j\omega C}}{\frac{1 + j\omega (R_1 + R_k) C}{j\omega C}} = \frac{1 + j\omega R_k C}{1 + j\omega (R_1 + R_k) C}$$

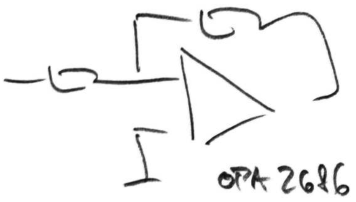


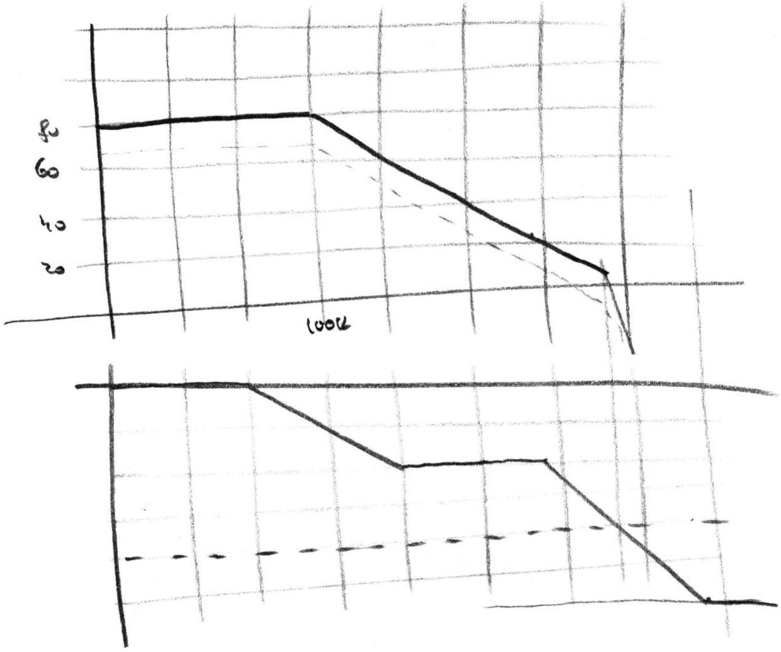
odviha !!

to na zg. sliki!

2005/ff

kaj pa ojačevalnik s tokovnim OP





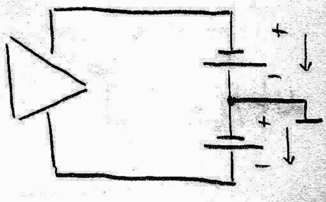
ojačanje > 5

⇓

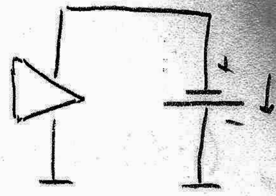
<u>stabilno</u>

stabilizacija   2005/99   1

napajalnik za OP



nekateri



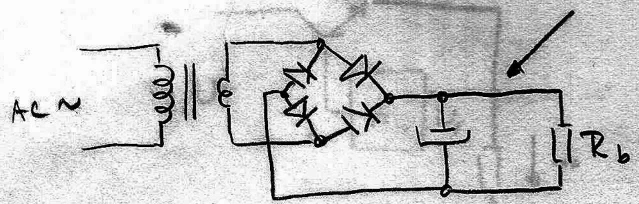
baterije : kapaciteta → drago

AA : 2000 mAh → 2000 mA / 1h
1000 mA / 2h
200 mA / 10h
} $2A \cdot 1{,}2V \cdot 1h = 2{,}4\,Wh$

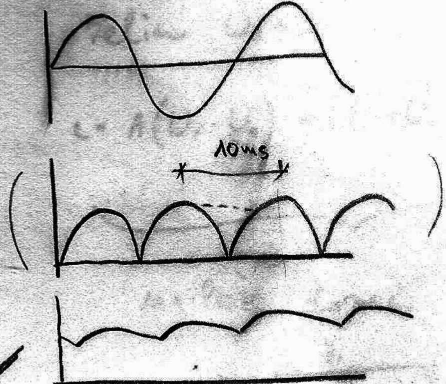
? stane elektrika iz omrežja ?

---

napajamo iz omrežja, 2×



C = 1000μ/A

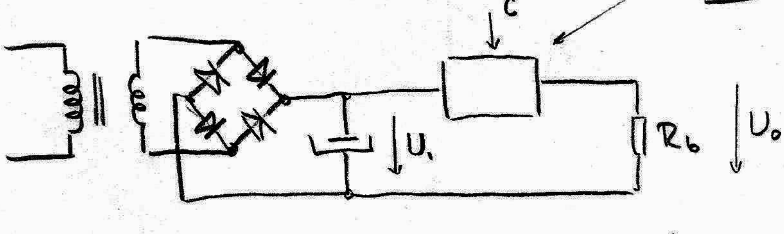


$Q = C \cdot U = I \cdot t \Rightarrow \Delta U = \frac{1A \cdot 10ms}{10^{-3}}$

$\Delta U = 10^{-2} \cdot 10^{3} = 10V$
veliko !

pulzira
velikost pulziranja je odvisna od C in R_b
sr. vrednost je odvisna od AC
↓
stabilizacija
↓

ventil : lastnosti : odprt toliko, da je U_o konst.



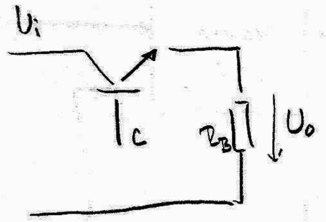
jasno : $U_{1\,min} > U_o$ ⇒ na ventilu se troši moč

$P_{VENT} = I_o \cdot (U_1 - U_o) = \frac{U_o}{R_b}(U_1 - U_o)$

↓
hladiti

iz omrežja vlečemo več moči (saj je poceni)

lastnosti ventila : uporabimo TR



TR = tokovni ojač.

$$I_C = I_B \cdot \beta \rightarrow I_E = I_B(\beta+1)$$

$$I_B = I_{B0}\left(e^{U/U_T}-1\right)$$

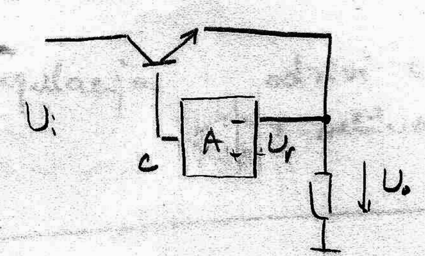
$$= I_{B0}\left(e^{\frac{c-U_0}{U_T}}-1\right) \text{ ker } I_B = \frac{U_0}{R_E(\beta+1)}$$

ventilska f. $I_0 = I_{0\phi} + \alpha(U_i - U_0) + \beta(c - U_0)$

$$U_0 + U_T \ln \frac{I_B}{I_{B0}} = c = U_0 + U_T \ln \frac{U_0}{(\beta+1) I_{B0} R_E}$$

primerjajmo U_0 z U_R, ojačano razliko uporabimo za krmiljenje c

želim $U_0 = U_r$

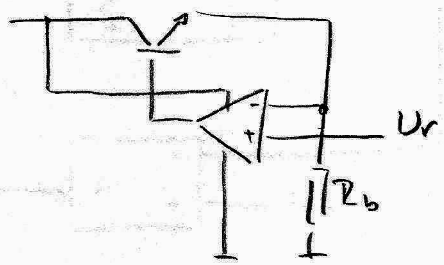


$$\underbrace{c = A(U_r - U_0) = U_0 + U_T \ln\frac{U_0}{(\beta+1) I_{B0} R_E}}_{\text{najlažje dosežemo za } A \rightarrow \infty}$$

$$\Downarrow$$

$$\boxed{U_0 = U_r}$$

torej



kako pa dobim U_r

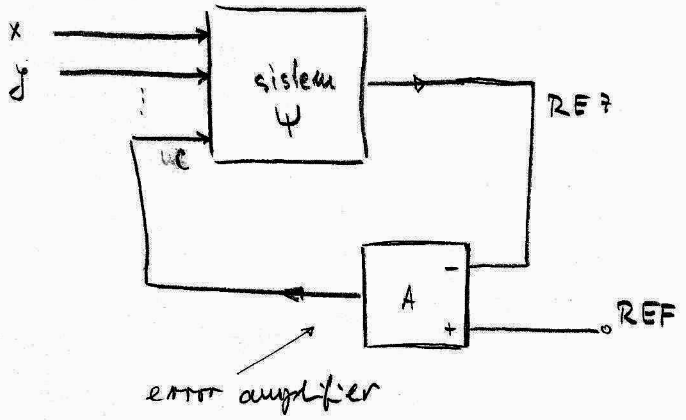
⇓

danes

⇓

tritočkovni

splošno



$$REZ = \Psi(x, y, \dots c)$$

$$\Downarrow$$

$$c = \Psi^{-1}(x, y, \dots REZ)$$

$$REZ = \Psi(x, y, \dots A(REF - RE$$

$$c = A(REF - REZ) \Rightarrow REZ = REF - \frac{c}{A}$$

$$A(REF - REZ) = \Psi^{-1}(x, y, \dots REZ) \quad ; \text{želimo } REF = REZ$$

najlaže dosežemo, če : $\underline{\underline{A \to \infty}}$

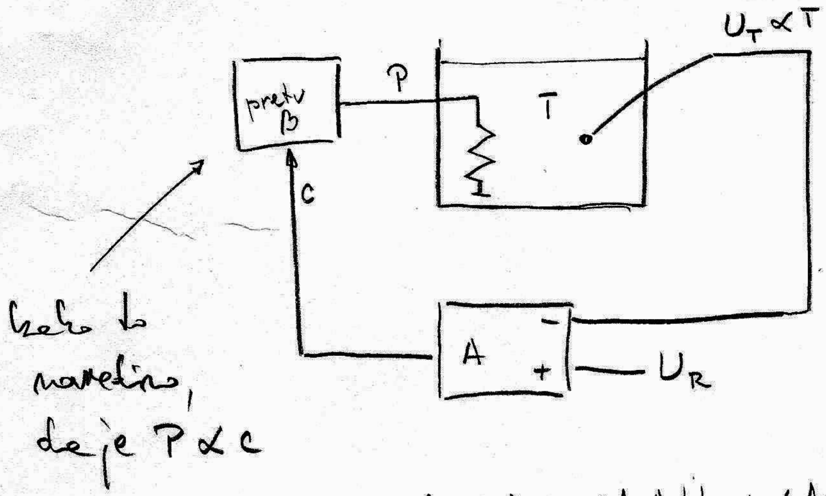
---

mostovna regulacija : odzivi so trenutni !
+ velikim ojačanjem v povratni zanki zmanjšamo se

---

kaj pa se zgodi, če je sistem zlobnejši ?

odcitovna $T \Rightarrow U_T = U_{R} \frac{1}{1+\tau\dots}$



$$P = \beta c$$

$$T = \alpha P \frac{1}{1+\tau p} = \alpha \beta c \frac{1}{1+\tau p}$$

$$c = \frac{U_T}{\alpha\beta}(1+\tau p) = A(U_R - U_T)$$

$$U_T(1+\tau p) - \alpha\beta A U_R + \alpha\beta A U_T = 0$$

$$U_T(1 + \alpha\beta A + \tau p) = \alpha\beta A U_R \Rightarrow U_T \Big[\frac{1}{\quad}$$

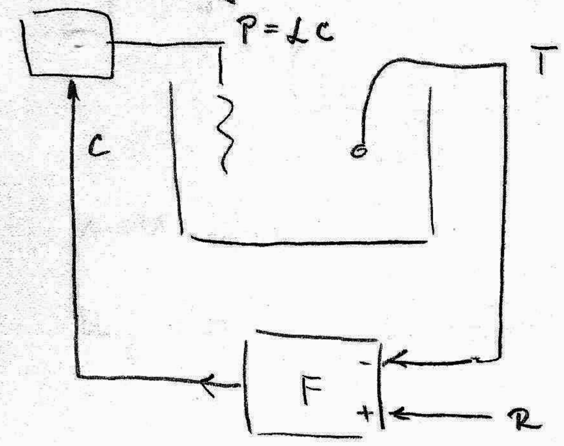
$$U_T = U_R \frac{1}{1 + \frac{1}{\alpha\beta A} + \frac{\tau}{\alpha\beta A} p}$$

asimptotična rešitev za $A \to \infty$ je $U_T = U_Z$

↘ ni napake

A velik ⇒ hitro izravnavanje ⇒ τ se navidez zmanjša

regulacija



$$T = T_v \frac{1}{1+\tau_T p}$$

$$T_v = P \frac{1}{1+\tau_v p} = \alpha C \frac{1}{1+\tau_v p}$$

$$F(R-T) = C = \frac{T_v}{\alpha}(1+\tau_v p) \quad ; \quad F = A$$

$$A\alpha R - A\alpha T_v \frac{1}{1+\tau_T p} = T_v(1+\tau_v p)$$

$$A\alpha R(1+\tau_T p) = \left[A\alpha \cancel{T_v} + \cancel{T_v}(1+\tau_v p)(1+\tau_T p)\right] T_v$$

$$T_v = A\alpha R \frac{1+\tau_T p}{A\alpha + 1 + (\tau_v+\tau_T)p + \tau_v\tau_T p^2}$$

$$T_v = R \frac{1+\tau_T p}{1 + \frac{1}{\alpha A} + \frac{\tau_v+\tau_T}{A\alpha} p + \frac{\tau_v \tau_T}{\alpha A} p^2}$$

stac. stanje?? členi do $p \to 0$

$A \to \infty$: kaže, da je $T_v = T_R$!

v resnici pa: dobiš pole p.f.

$$\frac{-\frac{\tau_v+\tau_T}{A\alpha} \pm \sqrt{\left(\frac{\tau_v-\tau_T}{A\alpha}\right)^2 - 4\frac{\tau_v\tau_T}{\alpha A}\left(1+\frac{1}{A\alpha}\right)}}{2\frac{\tau_v\tau_T}{\alpha A}}$$

$$\sqrt{(\tau_v+\tau_T)^2 - 4\tau_v\tau_T(A\alpha+1)}$$

ups! niha!

ojačanja ne moremo povečati nad

$$\frac{(\tau_v + \tau_T)^2}{4\tau_v\tau_T} - 1 > \alpha A \ !$$

sicer niha

kaj storiti : $\tau_T \ll \tau_v$, - τ_T lahko še zmanjšam

- τ_T lahko kompenziram
- τ_v lahko umetno povečam

---

kaj pa elektronsko? F naj ne bo le ojačanje

$$F = \frac{1}{\tau_1 p}$$

$$\frac{1}{\tau_1 p}(R - T) = \frac{T_v}{\alpha}(1+\tau_v p)\tau_1 p$$

$$\alpha R = \frac{T_v}{\alpha}(1+\tau_v p)\tau_1 p + T_v \frac{1\alpha}{1+\tau_T p}$$

$$\alpha R (1+\tau_T p) = T_v\left[\tau_1 p (1+\tau_v p)(1+\tau_T p) + \alpha\right]$$

$$T_v = \alpha R \frac{1+\tau_T p}{\tau_1 p(1+\tau_v p)(1+\tau_T p) + \alpha}$$ ⇒ še slabše ?? mišji red?

zanemari τ_T , ker $\tau_T \ll T_v , \tau_1$

$$T_v = \alpha R \frac{1+\tau_T p}{\tau_1 p (1+\tau_v p) + \alpha} = \alpha R \frac{1+\tau_T p}{\tau_1 p + \tau_1\tau_v p^2 + \alpha}$$

$$= \alpha R \frac{1+\tau_T p}{\tau_1\tau_v p^2 + \tau_1 p + \alpha}$$

stac. stanje : $T_v = R$ ne glede na ojačanje v p. z. !

τ_1 zagotovo lahko izberemo tako, da bo $D = 0$!

lahko pa tudi

$$F = A + \tau_D p$$

$$\Downarrow$$

$$(A+\tau_D p)(R-T) = \frac{T_v}{\alpha}(1+\tau_v p)$$

$$R - T_v \frac{1}{1+\tau_T p} = \frac{T_v}{\alpha(A+\tau_D p)}(1+\tau_v p)$$

$$T_v\left[1 + \frac{(1+\tau_v p)(1+\tau_T p)}{\alpha(A+\tau_D p)}\right] = R(1+\tau_T p)$$

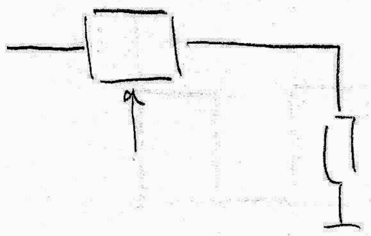
$$T_v = R\alpha \frac{(1+\tau_T p)(A+\tau_D p)}{\alpha A + \alpha\tau_D p + 1 + (\tau_T+\tau_v)p + \tau_T\tau_v p^2}$$

$$= R\alpha \frac{\text{— '' —}}{\tau_T\tau_v p^2 + (\tau_T+\tau_v+\alpha\tau_D)p + 1 + \alpha A}$$

stac. stanje: $A \to \infty$ za $T_v = R$

sedaj imam še en prost parameter τ_D in zato lahko naredim pole p.f. enake, realne!

konvertor z napajanjem



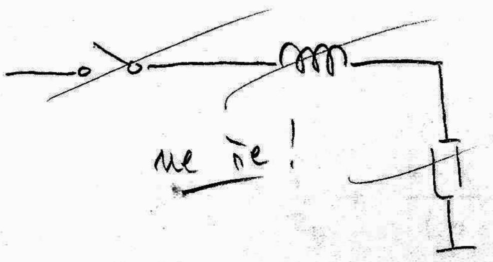
na ventilu se troši moč!

ali lahko naredimo regulator, kjer se moč ne meče stran?

↓

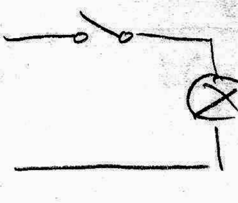
to pomeni, da ventil ne sme biti na pol odprt!

$$\left.\begin{array}{ll} \text{– čisto odprt :} & \Delta U = 0 \\ \text{– čisto zaprt :} & I = 0 \end{array}\right\} P = U \cdot I = 0 \; !$$

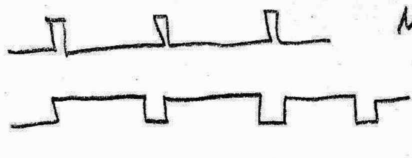


ne še!

za počasna bremena ni težav



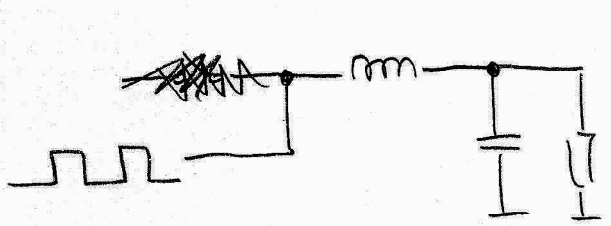
žarnica sveti toliko, kot to diktira povprečje toka skoznjo!

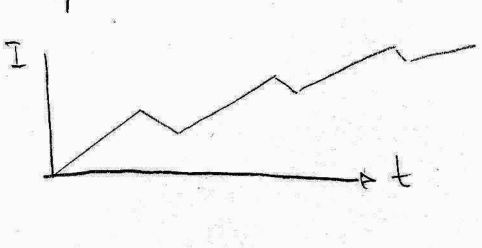


malo!

veliko!

ostala bremena bi želela gladko napetost ⇒ filtriranje

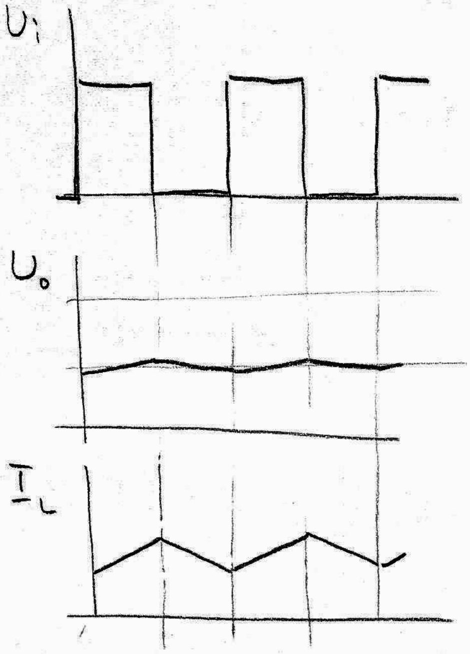




$$7 = x \frac{\frac{1}{Cp}}{\frac{1}{Cp} + Lp} = \frac{1}{1 + LCp^2}$$

poglej raje stac. stanje:

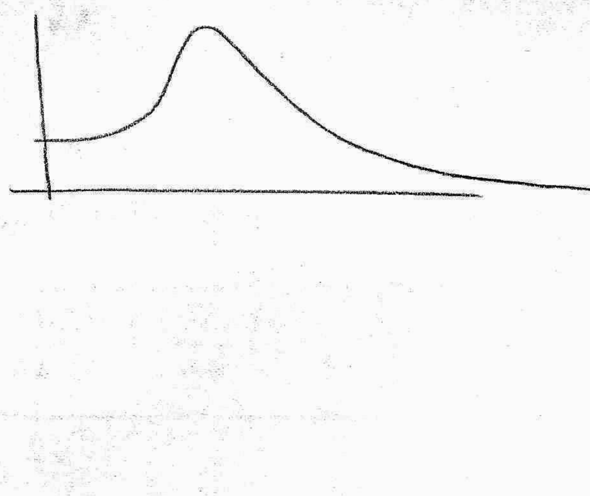
- postavi: C je dovolj velik, da je izh. nap. ~ konst.



$$zCp + \frac{z}{R_b} + \frac{z-x}{Lp} = 0$$

$$zLCp^2R_b + zLp + zR_b = xR_b$$

$$z = x\frac{R_bLp}{LCp^2R_b + Lp + R_b} \Rightarrow x\frac{R_b}{R_b + i\omega L - LCR_b\omega^2}$$



/ kabli

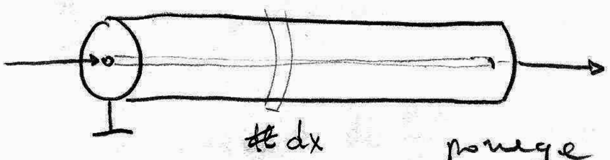
če želimo signal prenesti od ene enote do druge

motnje : a) elektromagn. ——→ zanka!
b) elektrostat.

a) v zanki se inducira napetost!

prepleti  ⇒ bolje

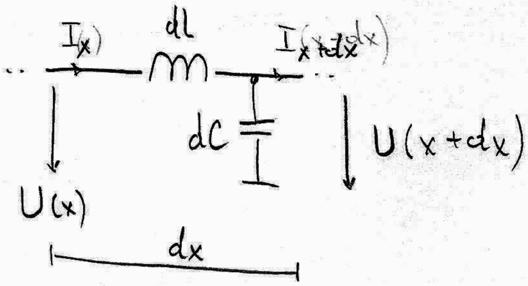
b) elektrostatsko : pomaga le oklop, ki je ozemljen



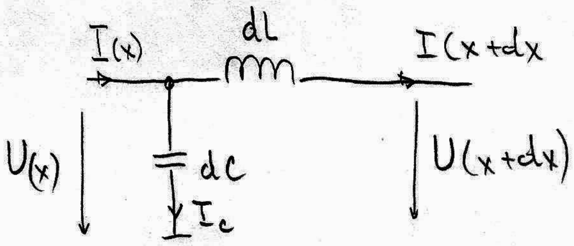
pomaga za oboje!

kaj je to v resnici
- vsaka žica ima induktivnost
- med vsakim parom žic je kapacitivnost

na dx velja



uvedimo: c ≡ kapaciteta na enoto dolžine kabla ⇒ $dC = c\,dx$
l ≡ induktivnost — " — ⇒ $dL = l\,dx$



$$I_c = \frac{dU(x)}{dt}\cdot dC \longrightarrow \quad I(x) = I_c + I(x+dx) =$$

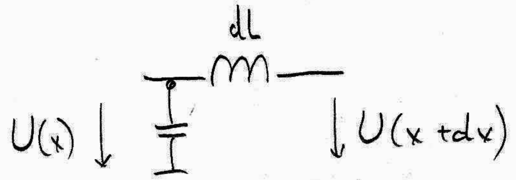
$$= dC\,\frac{dU(x)}{dt} + I(x+dx) =$$

$$= c\,dx\,\frac{dU(x)}{dt} + I(x) + \frac{\partial I(x)}{\partial x}dx$$

$$\cancel{I(x)} = c\,\cancel{dx}\,\frac{dU(x)}{dt} + \cancel{I(x)} + \frac{\partial I(x)}{\partial x}\cancel{dx}$$

$$\underline{\underline{\frac{\partial I(x)}{\partial x} = -\,c\,\frac{dU(x)}{dt}}}$$

podobno za napetost



$$dL: \quad U_i = L\,\frac{dI_L}{dt}$$

$$U(x) - U(x+dx) = dL\,\frac{dI_L}{dt} = \ell\,dx\,\frac{\partial I(x)}{\partial t}$$

$$\cancel{U(x)} - \cancel{U(x)} - \frac{\partial U(x)}{\partial x}\cancel{dx} = \ell\,\cancel{dx}\,\frac{\partial I(x)}{\partial t}$$

$$\underline{\underline{\frac{\partial U(x)}{\partial x} = -\,\ell\,\frac{\partial I(x)}{\partial t}}}$$

združi = in =

obe primerno parc. odvajaj

$$\frac{\partial I(x)}{\partial x} = -\,c\,\frac{\partial U(x)}{\partial t} \Big/ \frac{\partial}{\partial t} \Rightarrow \frac{\partial^2 I(x)}{\partial x\,\partial t} = -\,c\,\frac{\partial^2 U(x)}{\partial t^2}$$

$$\frac{\partial U(x)}{\partial x} = -\,\ell\,\frac{\partial I(x)}{\partial t} \Big/ \frac{\partial}{\partial x} \Rightarrow \frac{\partial^2 U(x)}{\partial x^2} = -\,\ell\,\frac{\partial^2 I(x)}{\partial t\,\partial x}$$

$$\boxed{\frac{\partial^2 U(x)}{\partial x^2} = \ell c\,\frac{\partial^2 U(x)}{\partial t^2}}$$

DE. 2. reda
valovna enačba

rešitve :

$$\boxed{U(t,x) = U_0 \sin\omega\left(t - \frac{x}{c_0}\right)} \quad ; \quad c_0 = \frac{1}{\sqrt{lc}}$$

po kablu se razširjajo valovi

$$c = \varepsilon_0 \frac{2\pi}{\ln\frac{r_1}{r_0}} \qquad l = \frac{\mu_0 \ln\frac{r_1}{r_0}}{2\pi}$$

$$c_0 = \frac{1}{\sqrt{\frac{\mu_0 \cancel{\ln\frac{r_1}{r_0}}}{\cancel{2\pi}}\,\varepsilon_0\,\frac{\cancel{2\pi}}{\cancel{\ln\frac{r_1}{r_0}}}}} = \frac{1}{\sqrt{\mu_0\varepsilon_0}}$$

↓

svetlobna hitrost

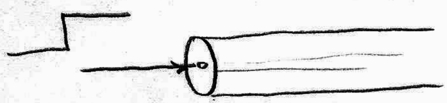
v kablu je izolacija, ki ni vakuum ⇒ $\varepsilon_r = 2$

$$c = c_0\frac{1}{\sqrt{\mu_r\varepsilon_r}} = \frac{c_0}{\sqrt{2}} \doteq 2\cdot10^8\,m/s = 0.2\,m/ns$$

---

kablu pripišemo impedanco!

dC se napolni na U v času dt



$c\cdot dt\cdot c_0$

$$dQ = dC\cdot U = I\cdot dt$$

$$c\cdot \cancel{dt}\cdot c_0\cdot U = I\cdot\cancel{dt} \Rightarrow Z = \frac{U}{I} = \frac{1}{c_0\cdot c} =$$

$60\cdot\ln\frac{r_1}{r_0}$

$$Z = \frac{\sqrt{lc}}{c} = \sqrt{\frac{l}{c}}$$

$\mu_0 = 4\pi\cdot10^{-7}$

$\varepsilon_0 = 8{,}8\cdot10^{-12}$

$$Z = \sqrt{\frac{\mu_0\mu_r\ln\frac{r_1}{r_0}\ln\frac{r_1}{r_0}}{2\pi\,\varepsilon_0\varepsilon_r\cdot2\pi}} =$$

$$= \sqrt{\frac{\mu_0\mu_r}{4\pi^2\varepsilon_0\varepsilon_r}\ln^2\frac{r_1}{r_0}} = \frac{\ln\frac{r_1}{r_0}}{2\pi}\sqrt{\frac{\mu_0\mu_r}{\varepsilon_0\varepsilon_r}}$$

$\frac{6}{1}$:

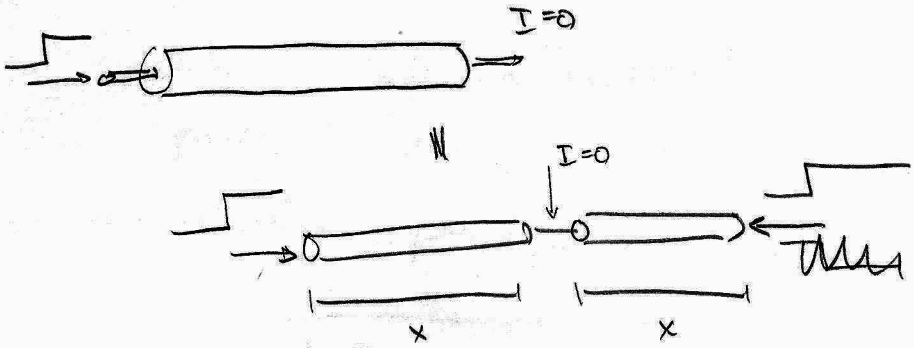
$\frac{10}{1}$: $100\,\Omega$

kabel se odprt konce!

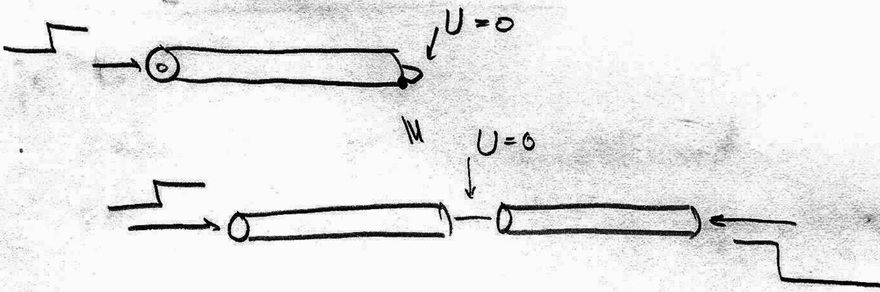
1. priključim
2. tok teče, ker se C kabla polni
3. kabel je napolnjen, tok ni več potreben, teče pa še ker
4. od konca kabla nazaj se začne naboj kopičiti

↓

signal se odbije



K.S. na koncu kabla



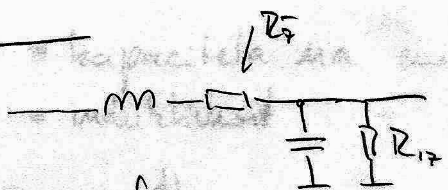
karakteristična impedanca in zaključitev

---

uporaba:
- kasnitev , formiranje pulzov
- prenos signalov

---

slabe strani :



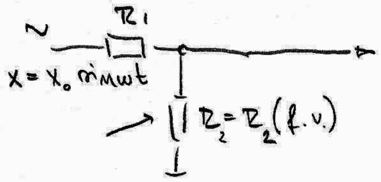
- izgube: odvisne od frekvence

hitrost razširjanja je odvisna od frekvence

Modulacija

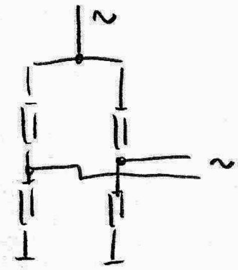
① Zakaj moduliramo?

saj pravzaprav ne, to se dogaja ob merjenjih!



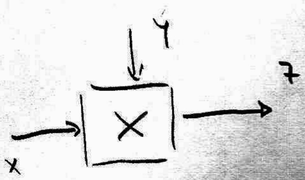
$$z = x_0 \frac{R_2}{R_1 + R_2} \sin \omega t$$

<u>modulacija</u>



~ enako!

amplitudna modulacija

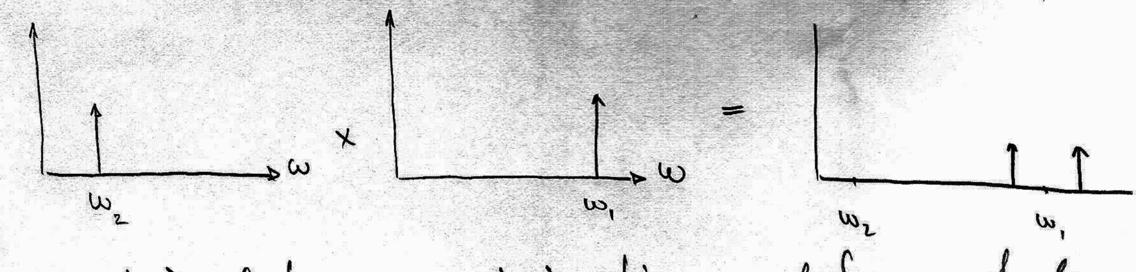


$$x = x_0 \sin \omega_1 t$$
$$y = y_0 \sin \omega_2 t$$

$$z = x_0 y_0 \sin \omega_1 t \sin \omega_2 t = \frac{x_0 y_0}{2}\left[\cos(\omega_2 - \omega_1)t - \cos(\omega_1 + \omega_2)t\right]$$

$\downarrow$

slike $z(t)$

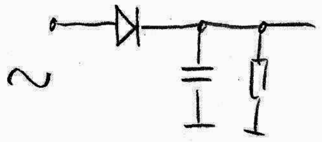


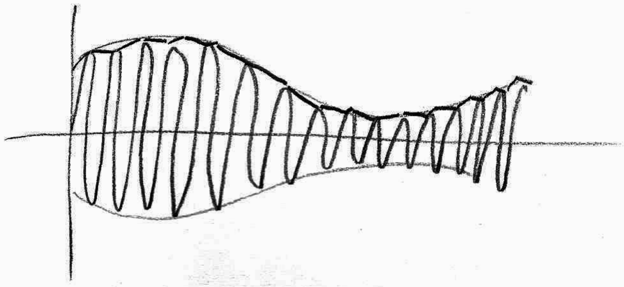
posledice: ojačevalnik mora ojačevati pas frekvenc okoli osnovne frekvence!

nerodno opisovanje: ~~ojačevalnik~~ zakaj napajamo z ~

diskusija o motnjah, šumih in filtriranju demodulacije

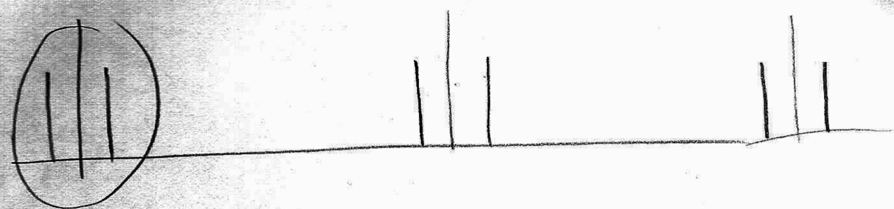
AM

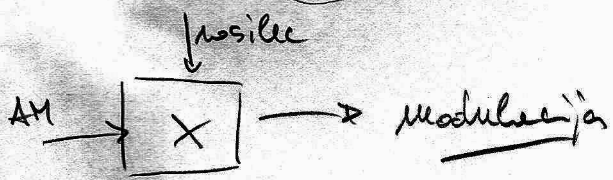




bolje

$$\text{AM signal} = \left[\sin(\omega_1+\omega_2)t + \sin(\omega_1-\omega_2)t\right]$$
$$\times$$
$$\sin \omega_1 t$$
$$=$$
$$\sin(2\omega_1+\omega_2)t + \sin\omega_2 t + \sin\omega_2 t + \sin(2\omega_1+\omega_2)t$$





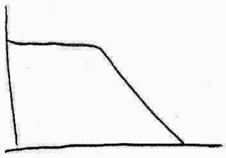
$$\text{AM} = A(y)\sin\omega t$$
$$\times$$
$$\sin\omega t$$
$$A(y)\sin^2\omega t = A(y)\frac{1-\underbrace{\cos 2\omega t}_{\text{povprečji}}}{2} \underset{\text{ostane}}{\Rightarrow} A(y)/2$$

---

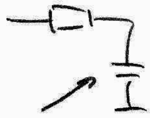
množenju se ognemo, množimo s ± 1

dejansko množimo s $\sin\omega t$, $\sin 3\omega t$, $\sin 5\omega t$ ...

diskusija o občutljivosti



RC



C = C(f.v.)

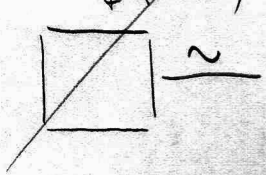
10 x CAP ≡ 10 x odziv

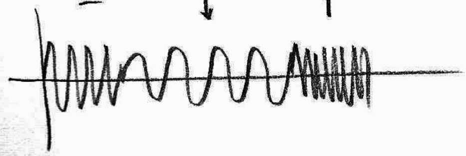
izberi pravo f.

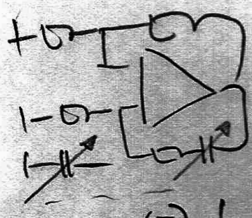
večja občutljivost ⇒ višji red!

ali gre tudi za drugačne modulacije?

f = f(f.v.)

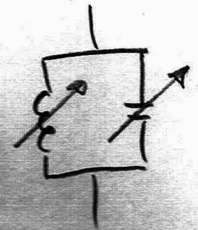






c(T) !

frekvenčne

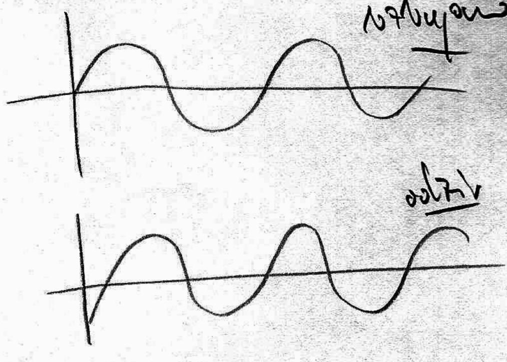


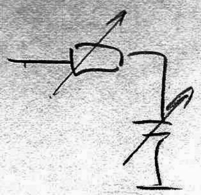
f = f(fres)

varicap

~~se da modulir~~

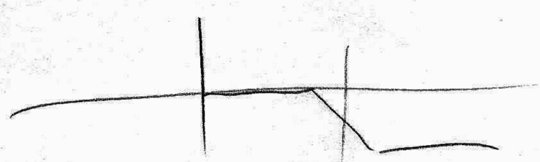
fazne!



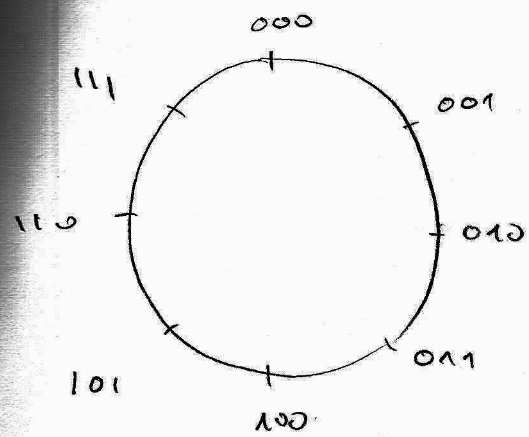


faza se menja

arc tg



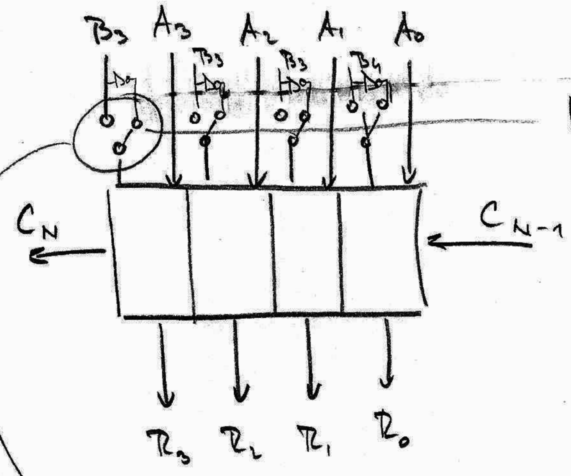
višji red



$$\left.\begin{aligned} R &= A - B = \\ &= A - B + 8 \end{aligned}\right\} \Rightarrow \underline{-B = 8 - B}$$

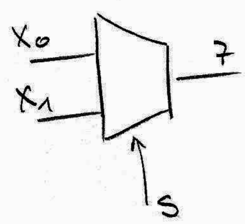
$$-B = 7 + 1 - B = (7 - B) + 1$$

B	7 − B	(7 − B) + 1 = −B
000	111	000
001	110	111
010	101	110
011	100	101
100	011	100
101	010	011
110	001	010
111	000	001

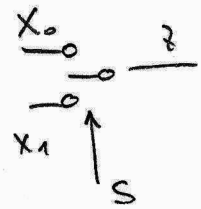


kontrola stikale

kaj je L? MUX?



$\equiv$



RELE?

NEEE!

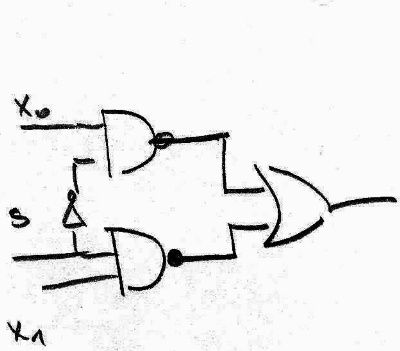
$$Z = X_0 \bar{S} + X_1 S$$

X_0	X_1	S	Z
0	X	0	0
X	0	1	0
1	X	0	1
X	1	1	1

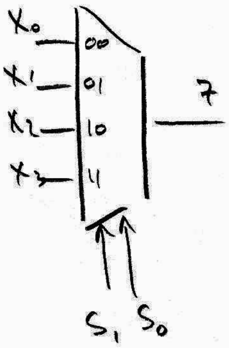
ali

X_0	X_1	S	Z
A	X	0	A
X	B	1	B

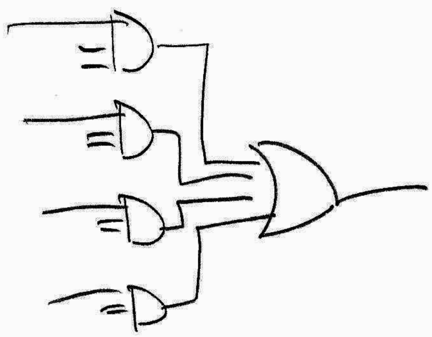
realizacija:



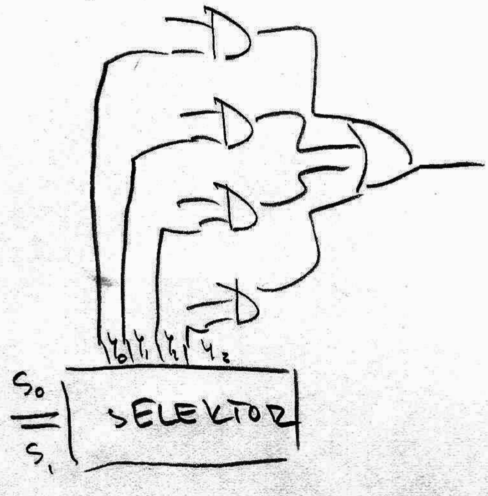
večji MUX



$$Z = x_0 \bar{S}_0 \bar{S}_1 + x_1 S_0 \bar{S}_1 + x_2 \bar{S}_0 S_1 + x_3 S_0 S_1$$



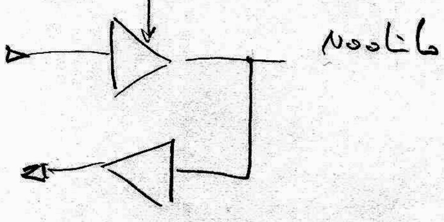
ali pa:



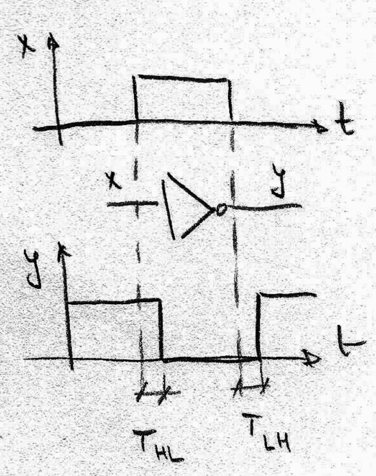
S_1	S_0	Y_3	Y_2	Y_1	Y_0
0	0	0	0	0	1
0	1	0	0	1	0
1	0	0	ɸ	0	0
1	1	1	0	0	0

tudi večji s pomočjo "enable" vhoda

MUX s 3-state izhodi, pojem <u>vodila</u>



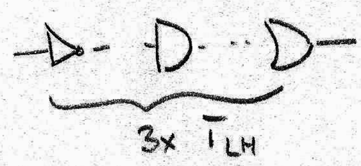
zamujanje



tipične vrednosti: ns

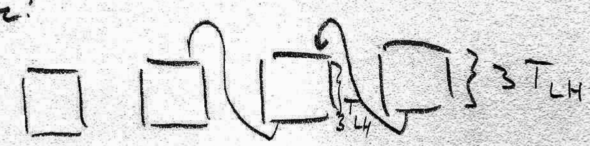
je to veliko?

mi smo delali vezja:



tule za streh

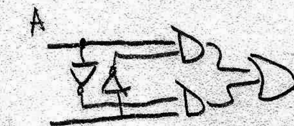
seštevalnik:



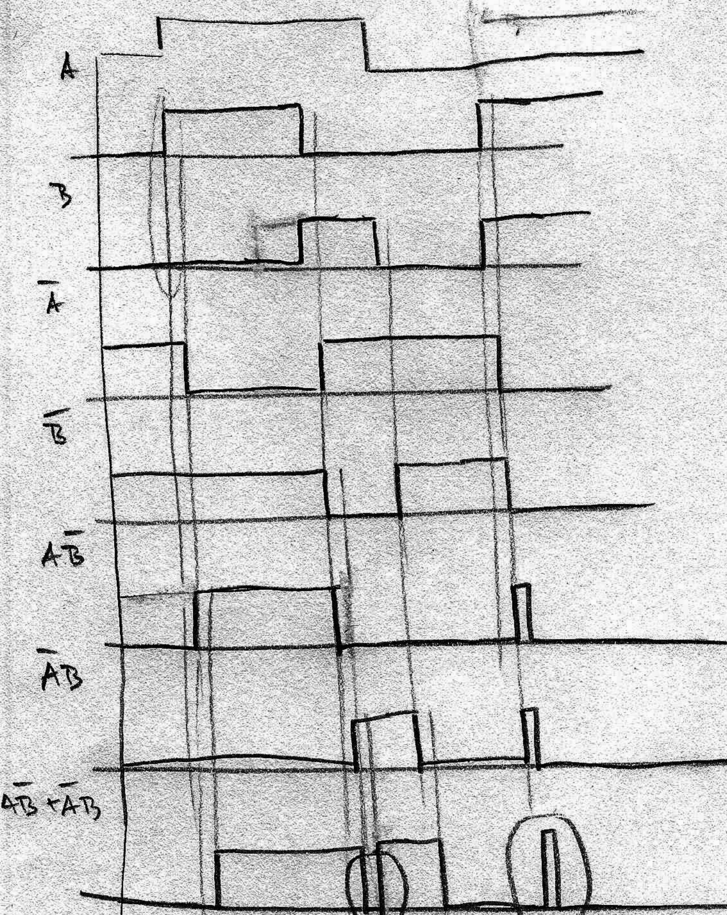
propagiranje kasnitev zaradi prenosa

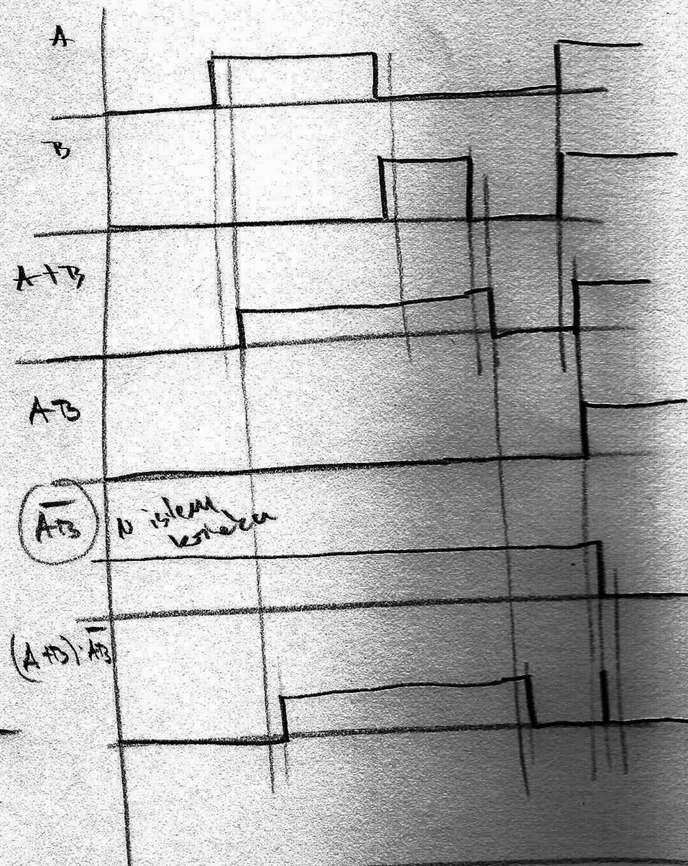
najprej za XOR

$y = A\bar{B} + \bar{A}B$



$y = (A+B)\cdot\overline{AB}$





iz tega sledi:

ker do izračuna rezultata mine nekaj časa,
je nesmiselno opazovati rezultat ves čas
nekaj časa po spremembi vh. spr. je izhod napačen!

prav tako je nesmiselno izdelati L. vezje, ki v enem
koraku izračuna L.F. do konca, saj bomo preveč
čakali in vse vezje izhod ki ves čas rabimo [?]

↓

razreži L.V. na kosce

kosi so aktivirani zaporedno!

vmes so pomnilni elementi ≡ **registri** = sp. celice

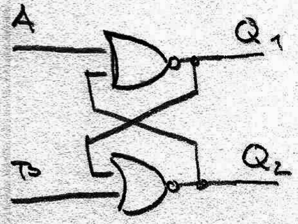
$x \rightarrow$ [log. vezje] $\rightarrow z$

⇓ razrežemo

$x \rightarrow$ [LV1] $\rightarrow$ [R1] $\rightarrow$ [LV2] $\rightarrow$ [R2] $\rightarrow \dots \rightarrow$ [LVN] $\rightarrow$ [RN] $\rightarrow z$

nujno torej rabimo registre!

Flip-flopi

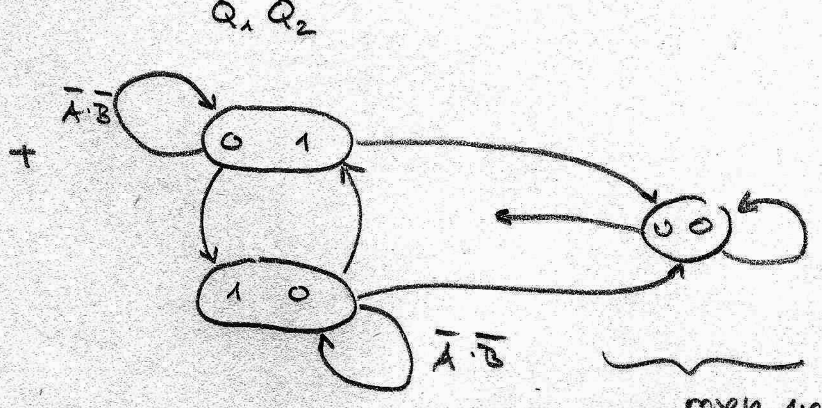


možne kombinacije

$Q_1 = \overline{A + Q_2} = \overline{A + \overline{B + Q_1}}$??? ne gre!

$\overline{Q}_1 = A + \overline{B + Q_1} = A + \overline{B} \cdot \overline{Q}_1$

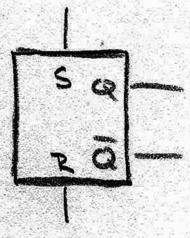
diagram prehodov



prepovedano stanje

↓

Q, $\overline{Q}$

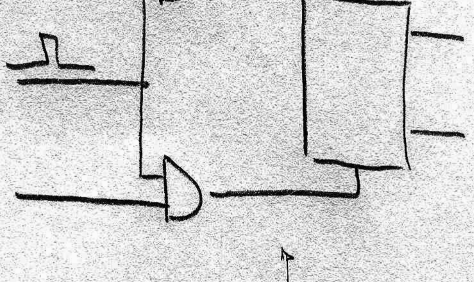


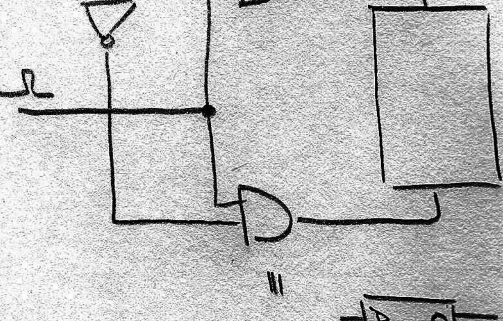
to ni vedno dovolj, ker nas čas vpisujejo!

↓

sinhroni vhod

ali (bolje)

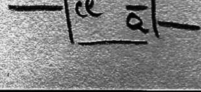




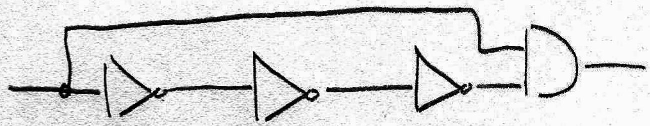
↑

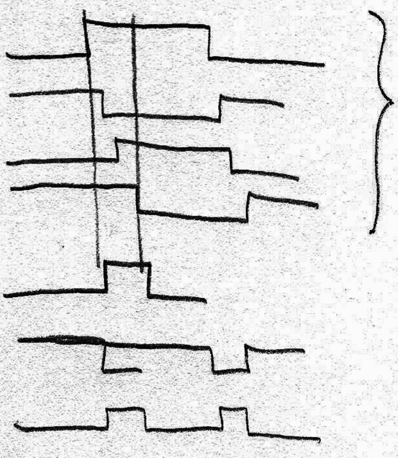
prepovedano stanje je možno!

$\equiv$



kako narediti



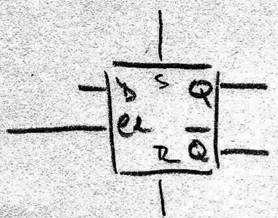


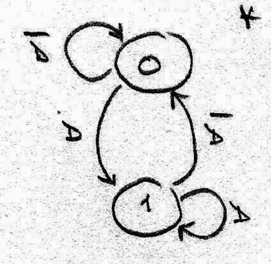
neparno število invertorjev!

↓

RC za daljše pulze

D-FF



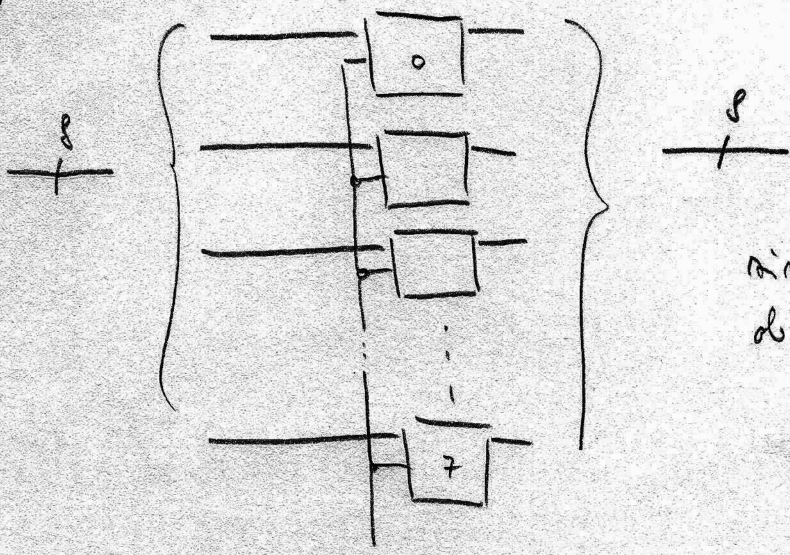


* prehodi so možni le ob Cl!

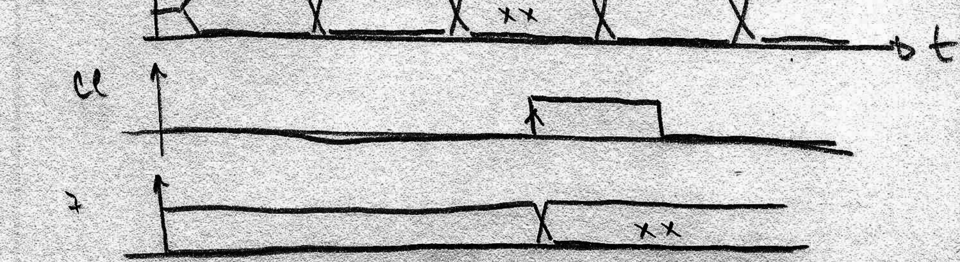
D	Q^+
0	0
1	1

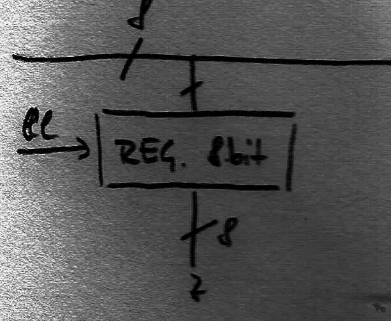
naloga: registri

zgled: 8-bit



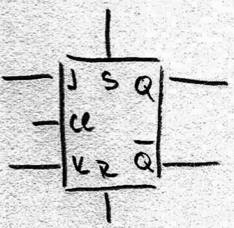
sinhroni vpis v 8DFF ob prehodu ure Cl



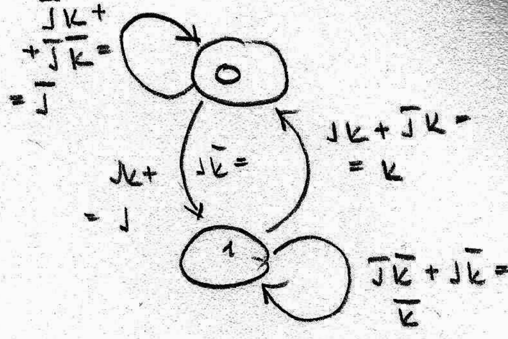


JK-FF

Včasih je D preveč enostaven → JK



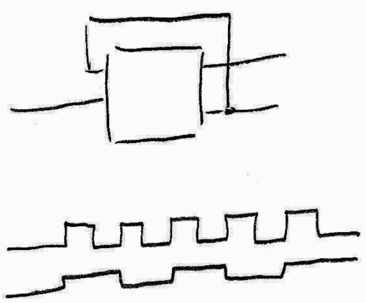
J	K	Q^+
0	0	Q
0	1	0
1	0	1
1	1	$\overline{Q}$



Delilnik frekvence z 2

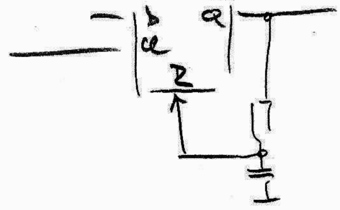
Pomični register deli ali množi z 2

asinhroni števci

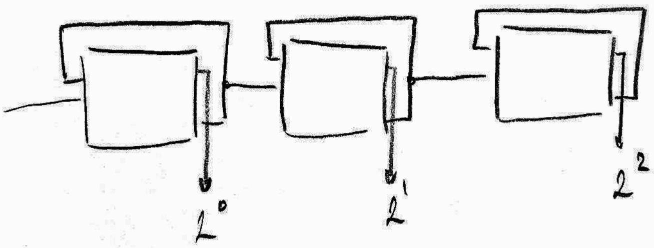


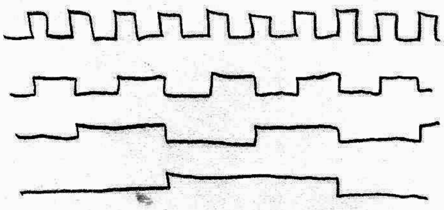
deli z 2
zna šteti 0,1

sinh. univibrator



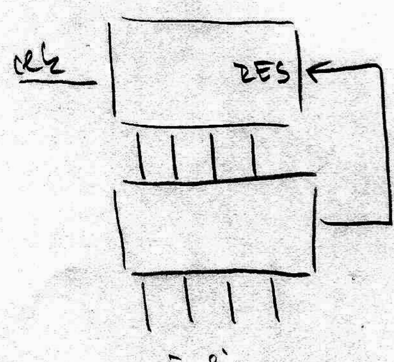
- več takih zaporedno



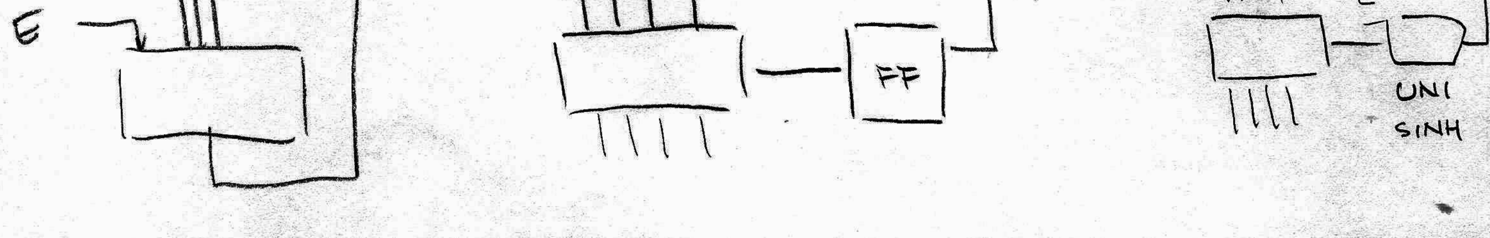


N števcev šteje do 2^N-1
ima N različnih stanj

- težave zaradi zamujanja v FF *
- težko narediti števec, ki ne šteje do 2^N-1
  - reset?

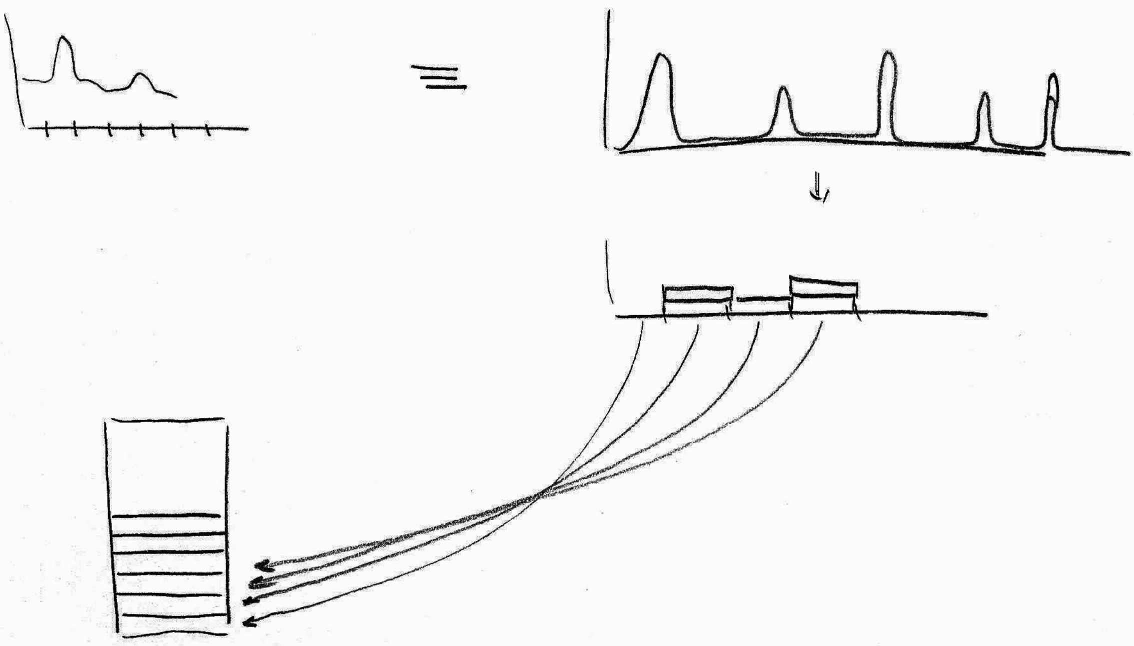


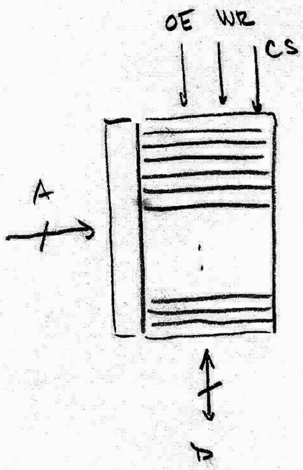
ali to gre?
- slabo! → težave zaradi *



Zgled : MCA

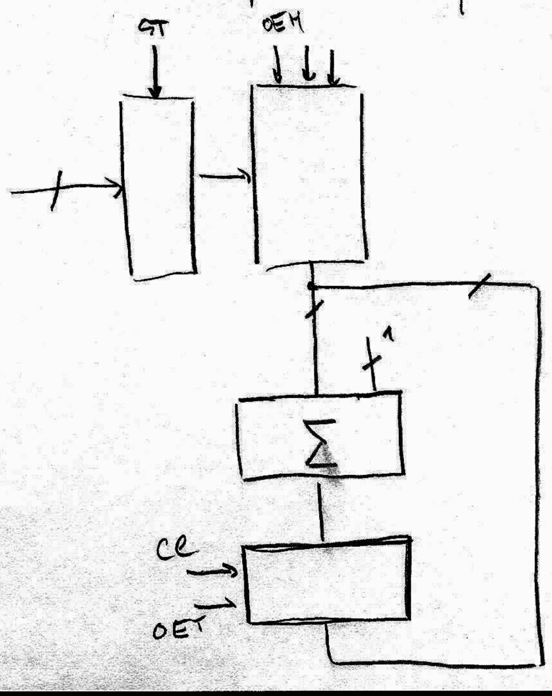
2005/119



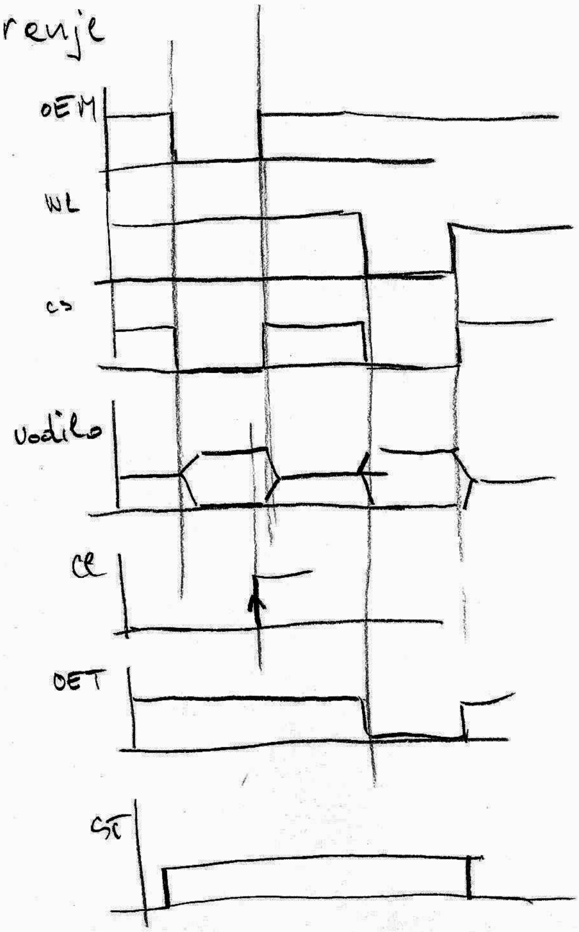


OE	WR	CS	MEM
x	x	1	spi
1	1	0	-"-
0	1	0	beremo
1	0	0	pišemo
0	0	0	ne velja!

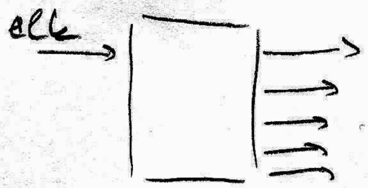
Naloga: iz dane lokacije preberi vrednost, prištej 1 in zapiši nazaj v isto lokacijo



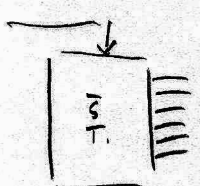
branje



potrebujemo torej avtomat, ki bo znal generirati kontrolne signale



možne izvedbe



števec & dekoder

števec & FF-ji

poseben števec → sinh. avtomat

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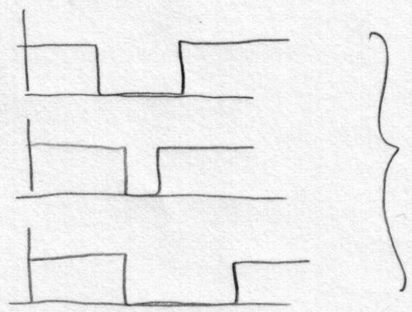
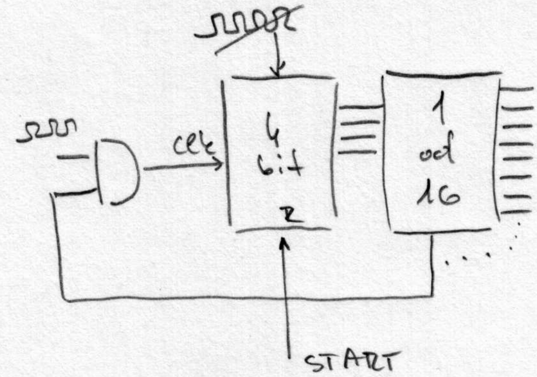
generiranje kontrolnih signalov



rešitev: števec & dekodiranje

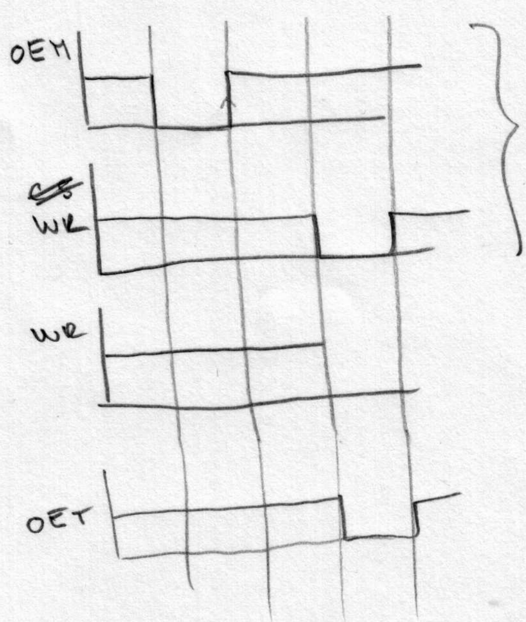


kombiniranje izhodov

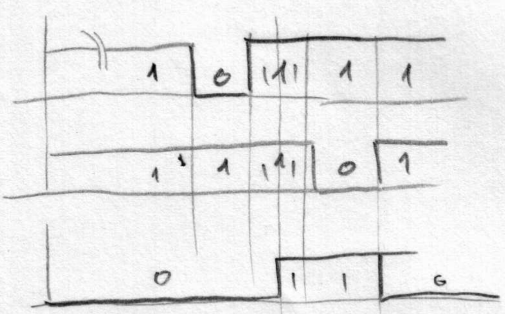
- logične vrata
- flopi

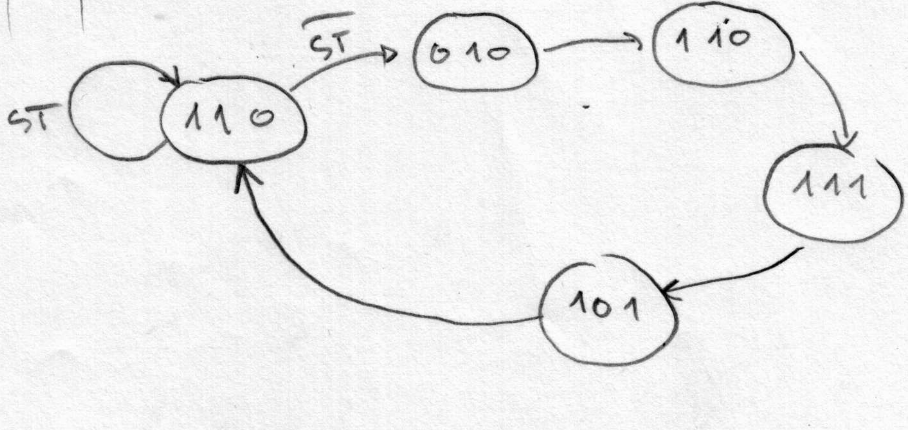
---

sinhroni avtomat ≡ števec, ki ne šteje po vrsti



samo tole dvoje

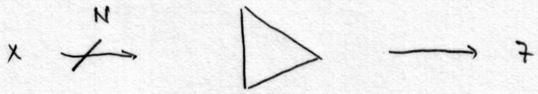




dvojno stanje

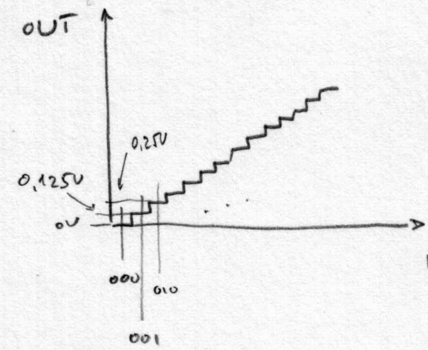
začetno stanje

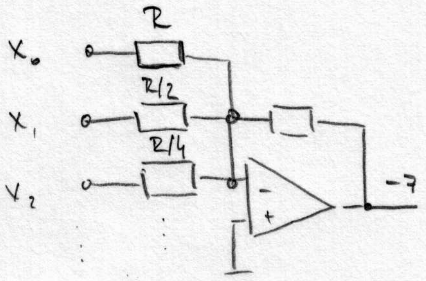
pretvorba DAC



digitalno — 2^N vrednosti

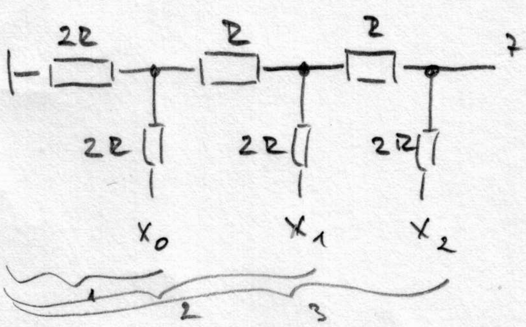
analogno — $U_{min} < z < U_{max}$





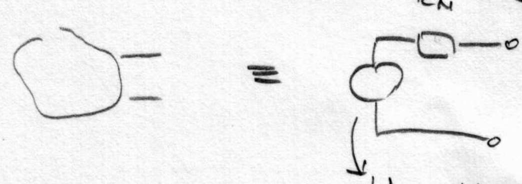
pomanjkljivosti: - malo bitov
- velika preciznost različnih uporov

bolje gre z R/2R lestvico



prednosti: enaki upori
~~dobra~~
enostavna izdelava / enačb

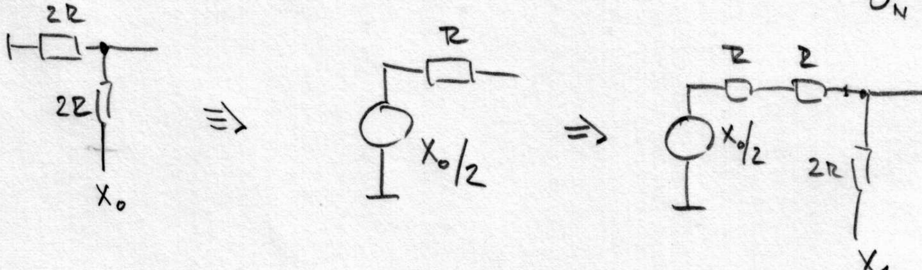
analiza: Thevenin:



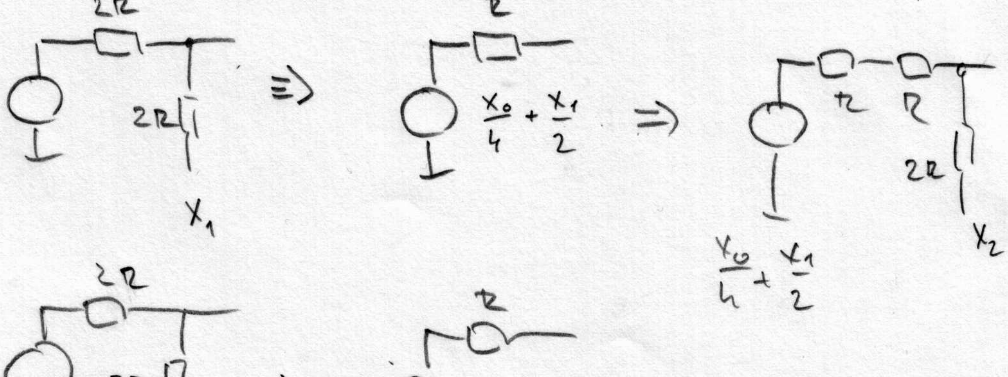
R_N - R izmerjena brez virov

U_N = U izmerjena o. s.

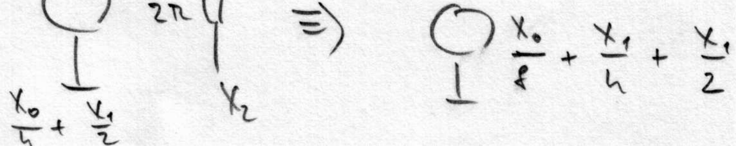
(1)



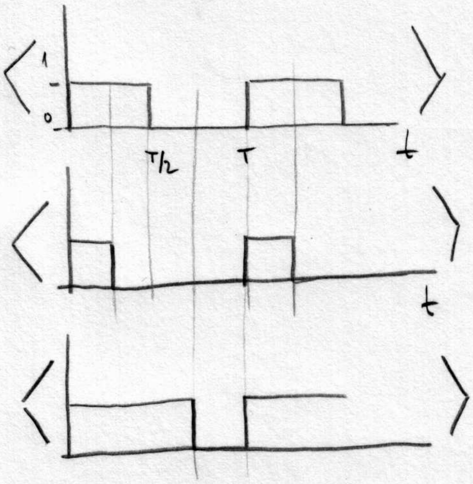
(2)



(3)



PWM



$\Rightarrow$ 1/2

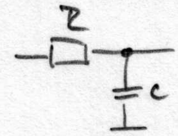
$\Rightarrow$ 1/4

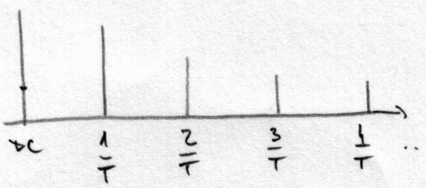
$\Rightarrow$ 3/4

ista frekvenca

s spreminjanjem trajanja pulza in povprečenjem dosežemo analogno vrednost

povprečenje :





povprečenje pomeni izfiltriranje vseh izmeničnih komponent $\Rightarrow$ filter s primerno f_p

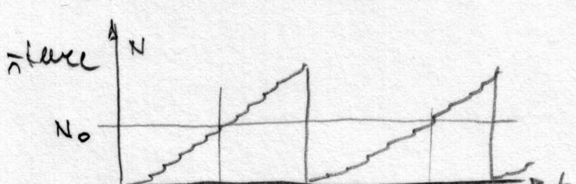
$$\omega_p = \frac{1}{\tau} \Rightarrow f_p = \frac{1}{2\pi RC}$$

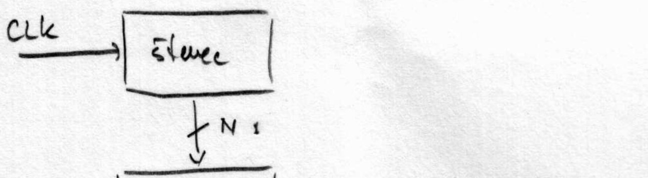
1. red: $\omega = \omega_0 \cdot 10 \Rightarrow$ ampl $= 1/10$

$\omega = \omega_0 \cdot 100 \Rightarrow$ ampl $= 1/100 \Rightarrow$ tole bi bilo dobro za 1% $\Rightarrow$ 7 bitni DAC

$$f = 1\,kHz \Rightarrow f_0 = 10\,Hz \Rightarrow \tau = \frac{1}{2\pi f_p} \doteq \frac{1}{100} \doteq 10\,ms$$

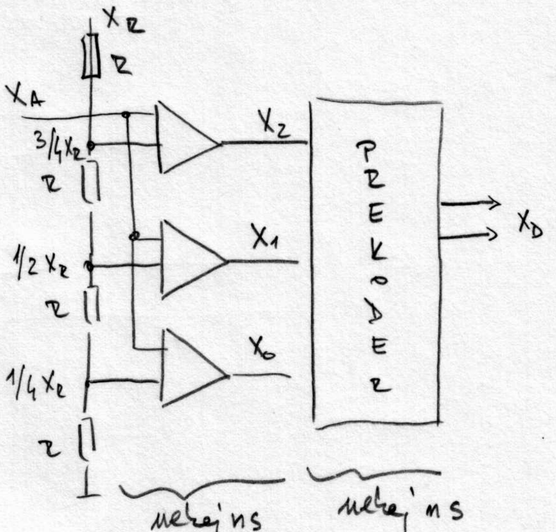
kako generirati PWM signal?





ADC

Flash



X_A	X_2	X_1	X_0	X_{D1}	X_{D0}
$0 \div 1/4 X_R$	0	0	0	0	0
$1/4 \div 2/4$	0	0	1	0	1
$2/4 \div 3/4$	0	1	1	1	0
$3/4 \div \infty$	1	1	1	1	1

$\underbrace{X_2 \; X_1 \; X_0}_{\text{ni binarno}}$

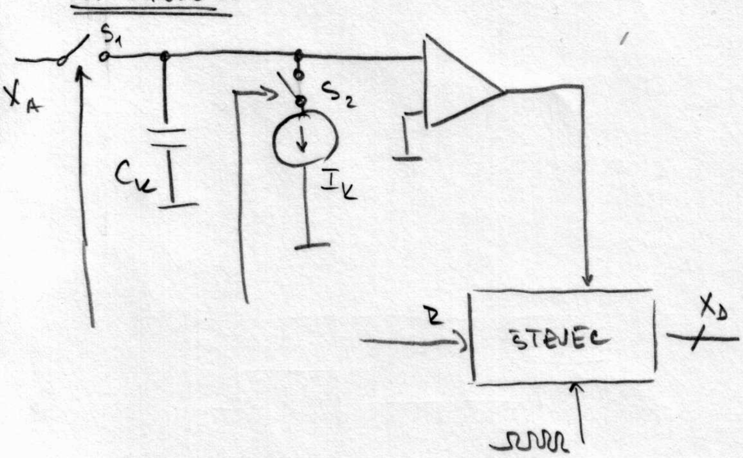
lastnosti: zelo hiter : $5 \div 10$ns $\longrightarrow$ 6bit 4GS/s

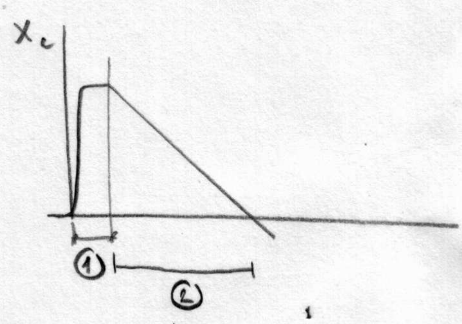
8bit 4ns

linearnost: slabe, odvisna od uporov in U_{offset}

slabost: veliko število komparatorjev!

Wilkinson





① naloži

② prazni do $x_c = 0$

meri čas praznjenja

vklop S_2 je start števca

števec ustavi, ko komp detektira ϕ

lastnosti: - srednje hiter $\Rightarrow$ clk = 100MHz $\Rightarrow T_{LSB} = 10$ns

8 bitni ADC $\Rightarrow 2^8 \cdot 10\text{ns} = 25.6\,\mu s$

- zelo linearen!

- slabost: veliko točnih vrednosti za točen rezultat: clk, I_K, C_K, U_o

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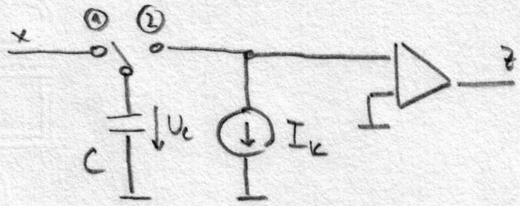
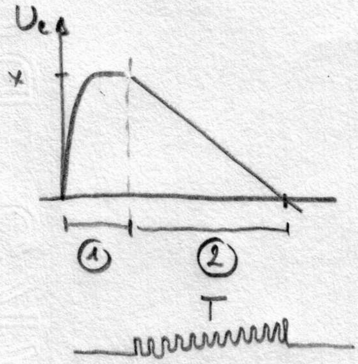
ADC $ WILKINSON





$$U_c = U_{c0} - \frac{I_k \cdot t}{C}$$

$$x - \frac{I_k \cdot t}{C} = 0$$

$$T = x \frac{C}{I_k}$$

; $x = 10V$, $C = 10^{-9} F$, $I_k = 10^{-3} A$

$$T = 10 \cdot \frac{10^{-9}}{10^{-3}} = \underline{10 \mu s}$$

u tem času do 1000

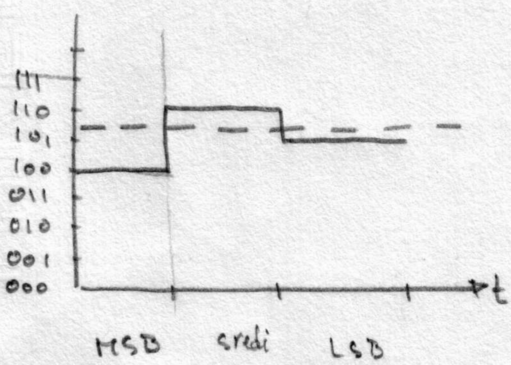
= 10 bit

⇓

100 MHz

množica referenčnih elementov! C, I_k, f_{clk}, komp.

ADC SA

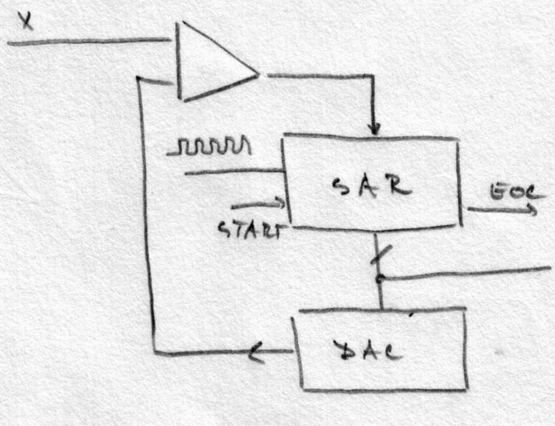


n korakov za N bitov

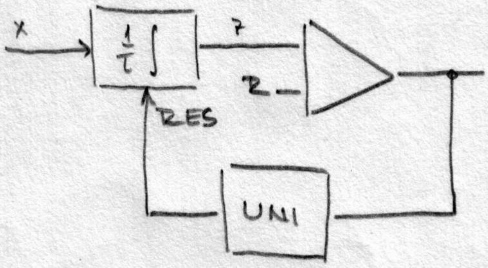
najhitreje do cilja

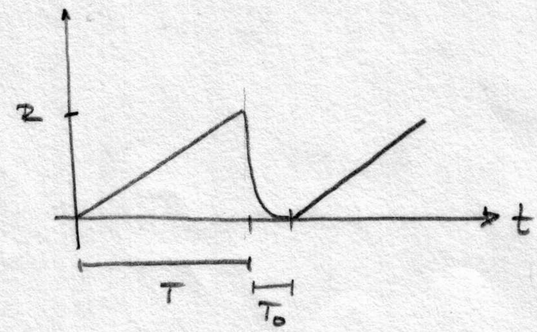
točen DAC, komparator

vsak korak traja T_p DAC + T_p komp + T_p lo



$V \rightarrow f$





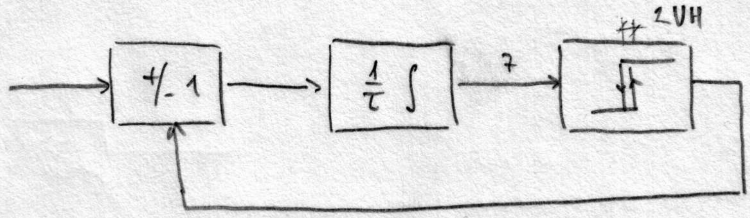
integrator: $z = x\frac{t}{\tau} \Rightarrow R = x\frac{T}{\tau} \Rightarrow T = \frac{R}{x}\tau$

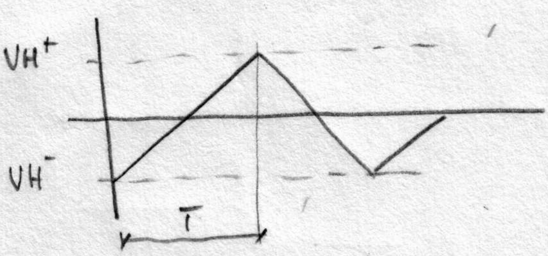
T_0 za reset integratorja

$$\Downarrow$$

$$f = \frac{1}{T+T_0} = \frac{x}{R\tau + \underbrace{T_0 x}_{\text{napaka, nelinearnost}}}$$

bolje

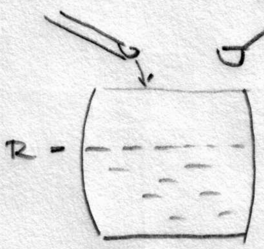




$$z = x\frac{t}{\tau} \Rightarrow T = \frac{2VH}{x}\tau$$

$$f = \frac{1}{2T} = x\frac{1}{\tau \cdot VH}$$

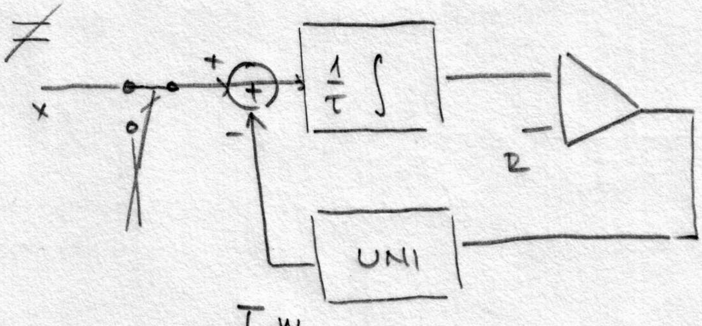
charge balance

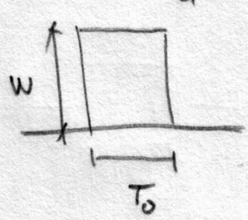


ko nivo naraste nad R,
zajemi vodo in jo zlij

↓

velja, da prineseš ven v povp.
enoto, kot priteče noter





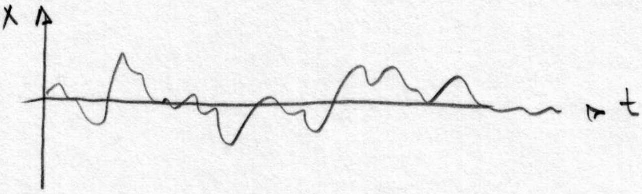
$$T_0 \cdot W \cdot f = x$$

↓

$$f = x \, \frac{1}{T_0 W}$$

Šumi

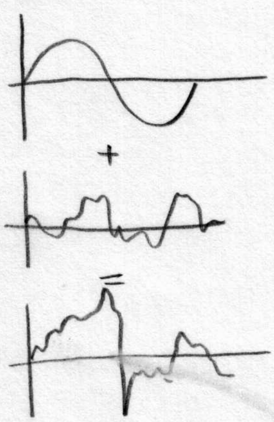
kaj je šum? → naključno spreminjajoči se signal



noise ≡ motnja

r. noise ≡ šum

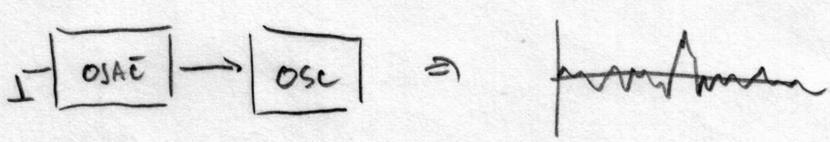
zakaj? ⇒ moti meritve



⇒ ne moremo dobiti ampl, faze, frekv.!

motnja ≡ splošno ni samo šum!

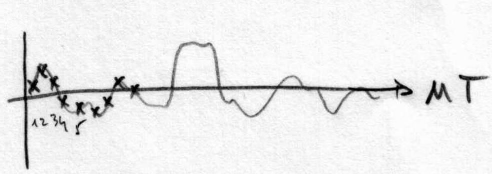
tudi elektronske naprave generirajo šum



loči: motnja 50Hz
lokalne rad. postaja
stikalni napajalniki
:

kako opisati šum?

- lahko je vzorčimo?

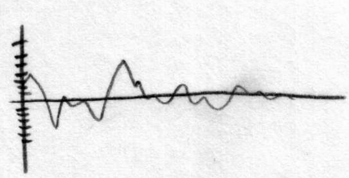


  dobimo $x(n)$

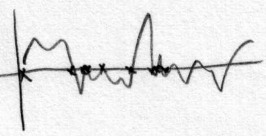
  ker je spreminjanje naključno, nimamo nič oprijemljivega!

- merimo amplitudo?

  spet nič pametnega



– merimo število prehodov skozi izbrano vrednost ≡ frekvenca ?



⇒ nič pametnega

---

matematika

– povprečna vrednost $\langle x(t)\rangle = \frac{1}{T}\int_{-\infty}^{\infty} x(t)\,dt = 0$ ⇒ ne koristi

– moč?

$$\langle x^2(t)\rangle \neq 0 \Rightarrow \text{OK, to koristi!}$$

– običajno vrednotimo tako, da dano f. poenostavimo (po možnosti v en sam številko), ki jo je lažje razumeti

↓

reduciramo podatke

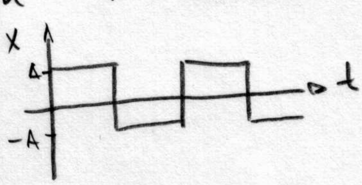
torej vzorčimo in reduciramo

a) po velikosti

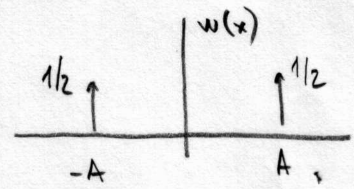
b) po frekvenci

---

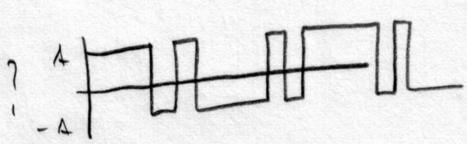
a) debata : kakšne vrednosti f. zavzame? kako pogosto?



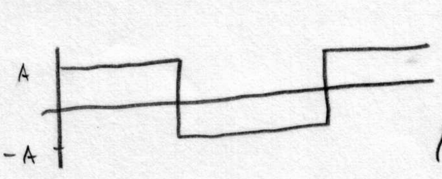
⇒ enostavno!



manj



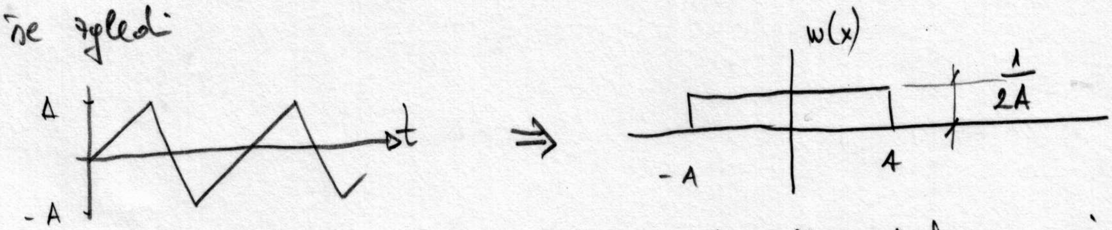
?



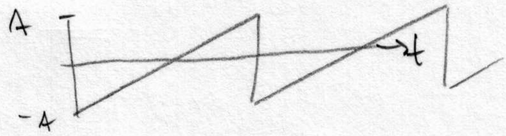
ničlično!

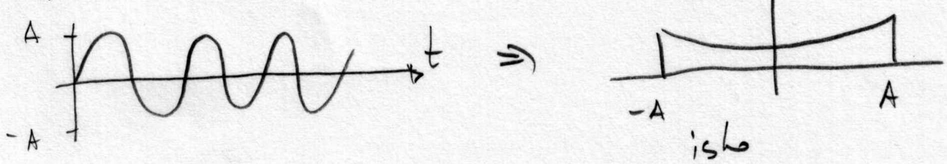
ni nujno, da je redukcija odstranljiva!
nekaj podatkov izgubimo (lahko)!

se zgledi



izgubimo frekvenco in fazo
obliko





isto

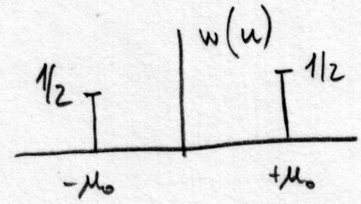
---

kaj pa za šum?

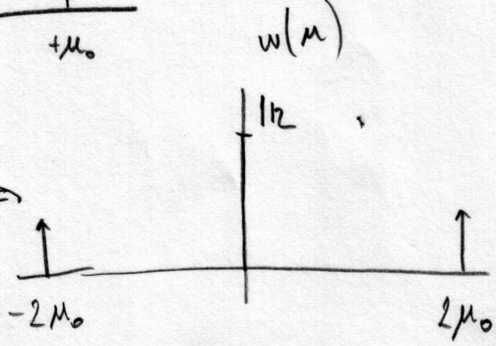
- šumni ~~napetost~~ tok povzročajo premikajoči se naboji (gibanje elektronov po prevodniku)
- tok skozi samo upornost ⇒ napetost šuma

model: enostaven
elektron se giblje $\underbrace{\uparrow\downarrow}_{\Downarrow}\ \underbrace{\rightarrow\ \leftarrow\ \otimes\ \odot}_{\text{ne vpliva}}$

1 elektron $\uparrow, \downarrow$

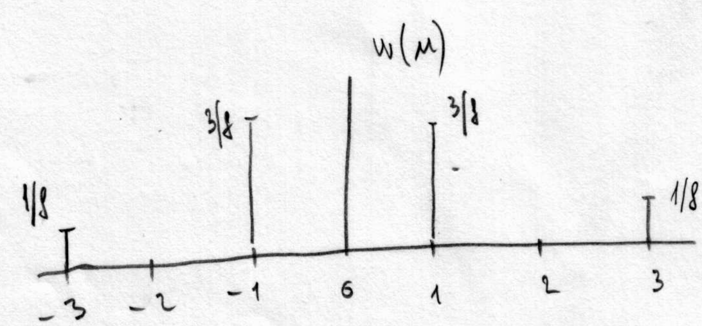


2 elektrona $\uparrow\uparrow, \uparrow\downarrow, \downarrow\uparrow, \downarrow\downarrow$ ⇒



3 elektroni

$$\left.\begin{array}{l} \uparrow\uparrow\uparrow \\ \uparrow\uparrow\downarrow,\ \uparrow\downarrow\uparrow,\ \downarrow\uparrow\uparrow \\ \downarrow\downarrow\uparrow,\ \downarrow\uparrow\downarrow,\ \uparrow\downarrow\downarrow \\ \downarrow\downarrow\downarrow \end{array}\right\}$$



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4 elektroni

↑↑↑↑

↑↑↑↓ , ↑↑↓↑ , ↑↓↑↑ , ↓↑↑↑

↑↑↓↓ , ↑↓↓↑ , ↓↓↑↑ , ↑↓↑↓ , ↓↑↓↑ , ↓↑↑↓

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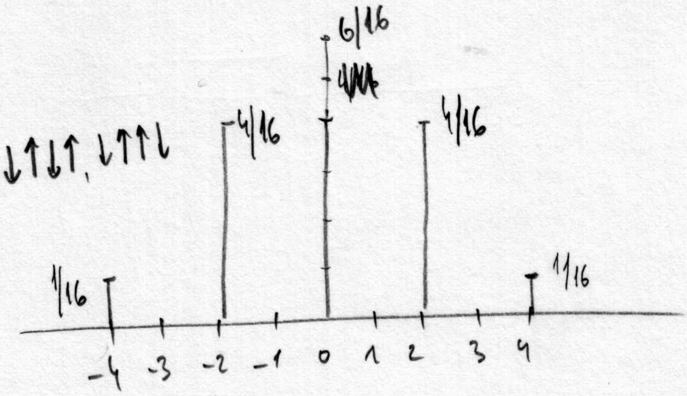
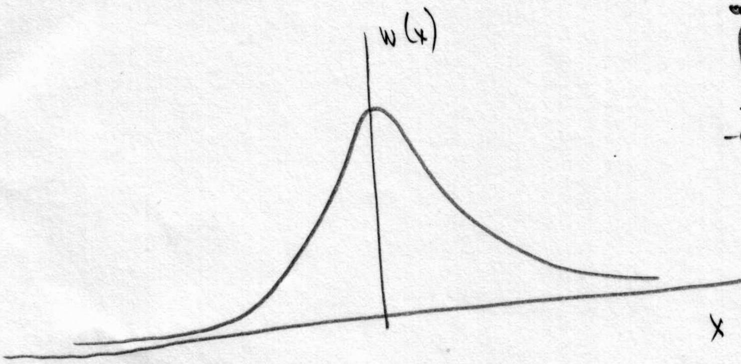


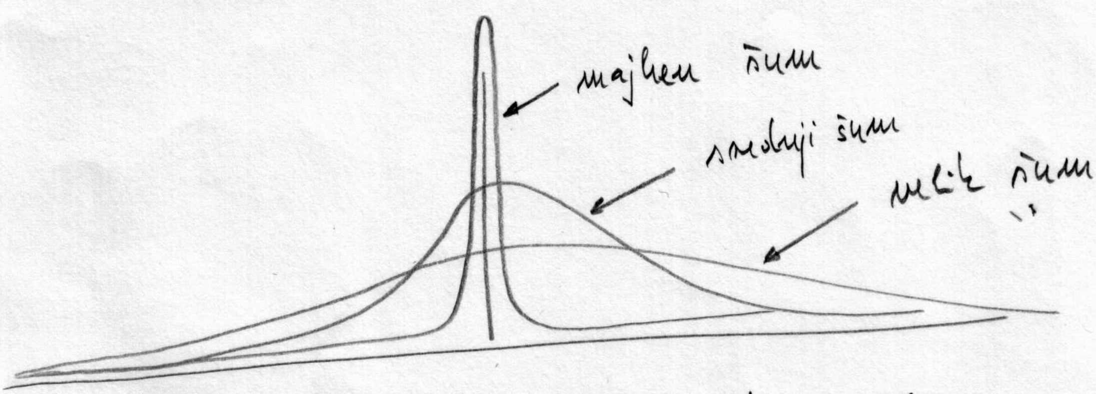
⋮

∞ elektronov $\Rightarrow$ Gaussova porazdelitev

$$\boxed{w(x) = \frac{1}{\sqrt{2\pi}\,\sigma}\, e^{-\frac{x^2}{2\sigma^2}}}$$

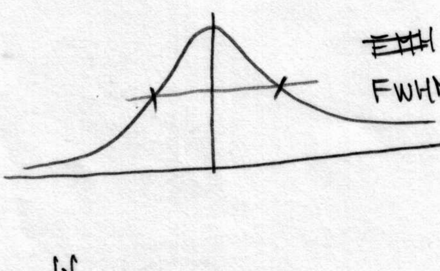


$$\int_{-\infty}^{\infty} w(x)\,dx = 1$$



kako meriti $\sigma \equiv$ merilo za razsutost vzorcev

- iz diagrama

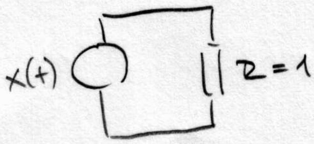


~~FWHM~~
FWHM : širina vrha je $2.35\,\sigma$

- iz vzorcev : matematika

$$\sigma^2 = \int_{-\infty}^{\infty} (x - \langle x \rangle)^2\, w(x)\,dx$$

iz <u>fizike</u>



na R se troši moč $P=\frac{U^2}{R}$

↑ trenutna moč

povprečna moč je merodajna:

$$\langle P\rangle = \frac{x^2(t)}{R}\Big|_{R=1} = \langle x^2\rangle$$

to izračunamo kot

$$\langle x^2\rangle = \lim_{T\to\infty}\frac{1}{2T}\int_{-T}^{T}x^2(t)\,dt = \underbrace{\int_{-\infty}^{\infty}w(x)\,x^2\,dx}_{\text{uči statistika}}$$

iz statistike prav tako vemo

$$\underbrace{\sigma^2 = \int_{-\infty}^{\infty}(x-\langle x\rangle)^2 w(x)\,dx = \int_{-\infty}^{\infty}x^2 w(x)\,dx = \langle x^2\rangle}_{\boxed{\sigma^2 = \langle x^2\rangle}}$$

$\sigma \Rightarrow$ merilo za moč

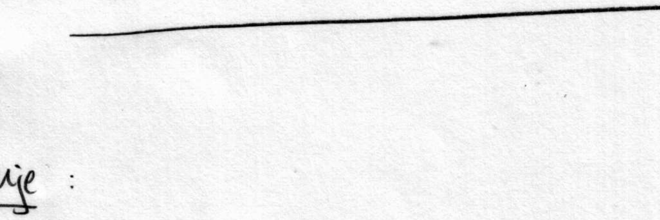
$$\sigma = \sqrt{\langle x^2\rangle} = \sqrt{\langle P\rangle}$$

sigma $=\sqrt{}$ iz povp. moči, ki greje upornik $R=1$

= RMS : root/mean/square = u_{eff}

<u>merjenje</u>:

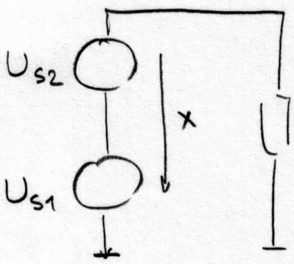
$P_s=\frac{\sigma^2}{R}$



$P_{DC}=\frac{y^2}{R}$

2005/23 f

sestavljanje virov



če sta vira DC

$$\left.\begin{aligned} P_1 &= \frac{U_1^2}{R} \\ P_2 &= \frac{U_2^2}{R} \end{aligned}\right\} P = \frac{(U_1+U_2)^2}{R}$$

$$P > P_1 + P_2$$

če sta vira te in f_1 ni v sorodu z f_2

nekorelirana $\Leftarrow$ $\left\{\begin{aligned} P_1 &= \frac{u_1^2}{R} \\ P_2 &= \frac{u_2^2}{R} \end{aligned}\right\}$ $P = \frac{(u_1+u_2)^2}{R} = \frac{u_1^2 + \cancel{2u_1u_2} + u_2^2}{R}$

$$P = \frac{u_1^2 + u_2^2}{R}$$ 0

isto velja za šum!

$$P = P_1 + P_2 \Rightarrow \boxed{X^2 = u_{š1}^2 + u_{š2}^2}$$

b) po frekvenci

Fourier trf. preslika $x(t) \to$ spekter

$$F(i\omega) = \int_{-\infty}^{\infty} x(t)\, e^{-i\omega t}\, dt \qquad x \to \text{spekter}$$

$$x(t) = \frac{1}{2\pi} \int_{-\infty}^{\infty} F(i\omega)\, e^{i\omega t}\, d\omega \qquad \text{spekter} \to x$$

---

kaj je smiselno : govorimo o nekljucnih pojmih ?

faze ??? nima pomena $\Rightarrow$ zanemari fazo

poglejmo spodnji integral :

$$\int_{-\infty}^{\infty} x^2(t)\, dt = \int_{-\infty}^{\infty} x(t) \cdot x(t)\, dt = \frac{1}{2\pi} \int_{-\infty}^{\infty} x(t) \cdot \left[\int_{-\infty}^{\infty} F(i\omega)\, e^{i\omega t}\, d\omega \right] dt =$$

$$= \frac{1}{2\pi} \int_{-\infty}^{\infty} F(i\omega) \left[\int_{-\infty}^{\infty} x(t)\, e^{i\omega t}\, dt \right] d\omega = \qquad \begin{aligned} \omega &= -\Omega \\ d\omega &= -d\Omega \end{aligned}$$

$$= \frac{-1}{2\pi} \int_{\infty}^{-\infty} F(-i\Omega) \left[\int_{-\infty}^{\infty} x(t)\, e^{-i\Omega t}\, dt \right] d\Omega =$$

$$= \frac{1}{2\pi} \int_{-\infty}^{\infty} F(-i\Omega)\, F(i\Omega)\, d\Omega =$$

$$= \frac{-1}{2\pi} \int_{\infty}^{-\infty} F(i\omega) F(-i\omega)\, d\omega = \frac{1}{2\pi} \int_{-\infty}^{\infty} F(i\omega) F(-i\omega)\, d\omega =$$

$$= \frac{1}{2\pi} \int_{-\infty}^{\infty} |F(i\omega)|^2\, d\omega = \int_{-\infty}^{\infty} x^2(t)\, dt$$

integral kvadrata amplitude pri dani frekvenci = integral kvadrata napetosti po času

$\downarrow$ energija na $R=1$ $\qquad$ $\downarrow$ energija na $R=1$

oboje je neskončno, zato raje moč

$$\underbrace{\lim_{T\to\infty} \frac{1}{2T}\int_{-T}^{T} x^2(t)\,dt}_{\text{pop. moč na } R=1} = \underbrace{\lim_{T\to\infty} \frac{1}{2T}\frac{1}{2\pi}\int_{-\infty}^{\infty} |F(i\omega)|^2\,d\omega}_{\text{to mora biti tudi pop. moč na } R=1\,!}$$

$\Downarrow$ $\quad \omega = 2\pi\nu$

$$= \lim_{T\to\infty} \frac{1}{2T}\frac{1}{\cancel{2\pi}}\int_{-\infty}^{\infty} |F(i\omega)|^2\,\cancel{2\pi}\,d\nu$$

$$= \int_{-\infty}^{\infty} \lim_{T\to\infty} \frac{1}{2T}|F(i\omega)|^2\,d\nu =$$

$$= \int_{0}^{\infty} \underbrace{\lim_{T\to\infty} \frac{1}{T}|F(i\omega)|^2}_{S(\omega)\text{: spektralna gostota šuma}}\,d\nu = \int_{0}^{\infty} S(\omega)\,d\nu$$

$$\boxed{u_{eff}^2 = \lim_{T\to\infty}\frac{1}{2T}\int_{-T}^{T} x^2(t)\,dt = \int_0^\infty S(\omega)\,d\nu}$$

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$$\int_{-\infty}^{\infty} x^2(t)\,dt = \frac{1}{2\pi}\int_{-\infty}^{\infty} |F(i\omega)|^2\,d\omega$$

energija $\equiv$ energija

↓ bolje na moč! energija $\to \infty$

$$\lim_{T\to\infty} \frac{1}{2T}\int_{-T}^{T} x^2(t)\,dt = \lim_{T\to\infty} \frac{1}{2T}\,\frac{1}{2\pi}\int_{-\infty}^{\infty} |F(i\omega)|^2\,d\omega =$$

$$= \lim_{T\to\infty} \frac{1}{\cancel{2}T}\,\frac{1}{\cancel{2\pi}}\,\cancel{2}\int_{0}^{\infty} |F(i\omega)|^2\,\cancel{2\pi}\,d\nu =$$

moč na $R = 1\Omega$ $$= \lim_{T\to\infty} \frac{1}{T}\int_{0}^{\infty} |F(i\omega)|^2\,d\nu$$

izluščimo

↓

$S(\omega)$ tako, da je

moč na $R=1\Omega$ $$= \int_0^{\infty} S(\omega)\,d\nu = U_{\check{s}\,eff}^2$$

za upornik velja: $S(\omega) = 4kTR$: **beli šum**

torej $$u_{\check{s}\,eff}^2 = \int_0^{f} 4kTR\,d\nu = 4kTR\,\Delta\nu$$

($T \to 293$, $k \to 1{,}38\cdot 10^{-23}$)

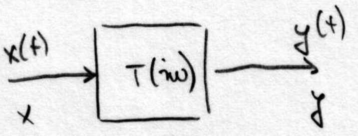
zgled: $R = 1k\Omega$, $\Delta\nu = 20\,kHz$

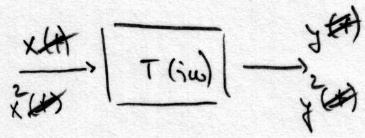
$$u_{\check{s}\,eff} = \sqrt{4\cdot 1{,}38\cdot 10^{-23}\cdot 293\cdot 10^{3}\cdot 20\cdot 10^{3}} = \underline{\underline{0{,}57\,\mu V}}$$

dejstvo: $10R$ šumi $\sqrt{10}$ bolj!

filtriranje šuma

- nk. signal je sestavljen iz množice komponent različnih frekvenc
- za šum je merodajna moč: vsaka komponenta neodvisno ogreva breme





normalno

~~$y(t) = x(t)\cdot T(i\omega)$~~

$y = |T(i\omega)|\cdot x$

amplitude

za moči

$\cancel{y(t)}\; y^2 = x^2 |T(i\omega)|^2$

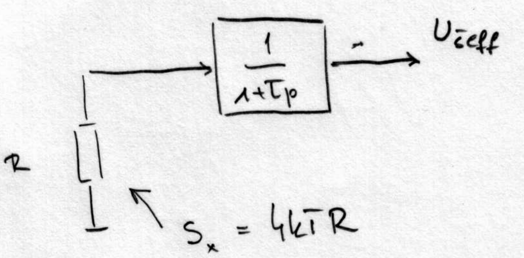
zanima nas le amplituda, ne faza

- zato $|T(i\omega)|$

zanima nas moč, zato $|T(i\omega)|^2$

$$\boxed{S_y = S_x\, T(i\omega)\cdot T(-i\omega) = S_x |T(i\omega)|^2}$$

zgled za filter

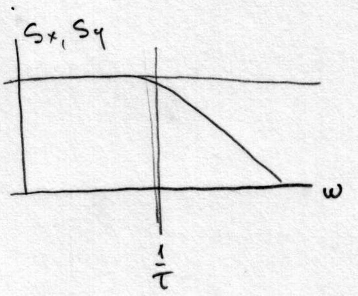


$$S_y = S_x|T(i\omega)|^2 = S_x \frac{1}{1+i\omega\tau}\cdot\frac{1}{1-i\omega\tau} = S_x\frac{1}{1+\omega^2\tau^2}$$

$$U_{\check{s}eff}^2 = \int_0^\infty S_y\, d\nu = \int_0^\infty S_x \frac{1}{1+\omega^2\tau^2}\, d\nu = S_x\int_0^\infty \frac{d\nu}{1+\omega^2\tau^2} =$$

$$= S_x\frac{1}{2\pi\tau}\int_0^\infty \frac{d\omega\tau}{1+\omega^2\tau^2} = S_x\frac{1}{2\pi\tau}\operatorname{arctg}\omega\tau\Big|_0^\infty =$$

$$= S_x\frac{1}{2\pi\tau}\frac{\pi}{2} = \frac{S_x}{4\tau} = \frac{4kTR}{4\tau} = \frac{kTR}{\tau}$$



samo zanimivost: koliko prispeva del po $\omega = \frac{1}{\tau}$?

izračunajmo, koliko ~~pr~~ dobimo za brickwall, $\Delta\nu \Rightarrow \frac{1}{\tau}$

$$\omega = \frac{1}{\tau} = 2\pi\nu \Rightarrow \nu = \frac{1}{2\pi\tau}$$

$$U_{\check{s}eff}'^{2} = 4kTR\,\Delta\nu = 2\cancel{4}kTR\,\frac{1}{\cancel{2}\pi\tau} = \frac{2kTR}{\pi\tau}$$

$$\frac{U_{\check{s}eff}^{2}}{U_{\check{s}eff}'^{2}} = \frac{\cancel{k}\,\cancel{kTR}\cdot\pi\cancel{\tau}}{\cancel{\tau}\cdot 2\cancel{kTR}} = \frac{\pi}{2} \Rightarrow \frac{U_{\check{s}eff}}{U_{\check{s}eff}'} = \sqrt{\frac{\pi}{2}} = \underline{1{,}25}$$

del po $\frac{1}{\tau}$ prispeva le 25% k skupni vrednosti šuma!

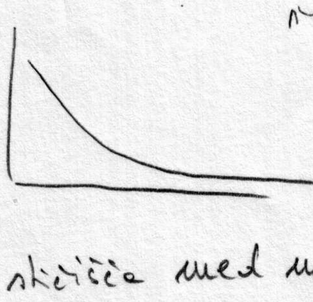
pri $T(i\omega)$ višjega reda prispeva še manj!

vrste šumov: $\boxed{\text{Termični šum}}$

- termično gibanje nosilcev naboja
- f do nekaj 10 GHz
- ~~ek~~ energija iz okolice! <u>$T=0 \Rightarrow e_n=0$!!!</u>
- $S(\omega)$ = <u>konst</u>!

- shot noise (šum zrnatosti)
  - naboj prihaja v kvantih e_0
  - beli šum ($S(\omega)$ = konst)
  - $I^2_{RMS} = 2 e_0 I_{DC} \Delta\nu \Rightarrow$ 57nA pri 1A, 10kHz
    56pA pri 1μA, 10kHz
  - izkaže se, da je v kovinah tega šuma manj

- nepopolna izdelava elementov: 1/f šum (flicker noise)
  rožnati šum
  - spekter



  - nepopolna stičišča med materiali (spoji ali mešanice)

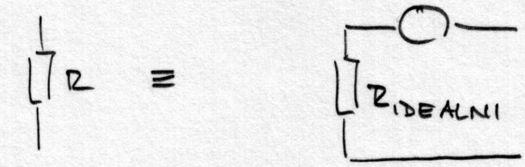
zgled: upori:

žični (homogeni)	–	0.01μV do 0.2μV
metal-film		0.02μV do 0.2μV
ogljeni plastni		0.05μV do 0.3μV
ogljeni masni		0.1μV do 3μV

- slaba izdelava: popcorn noise

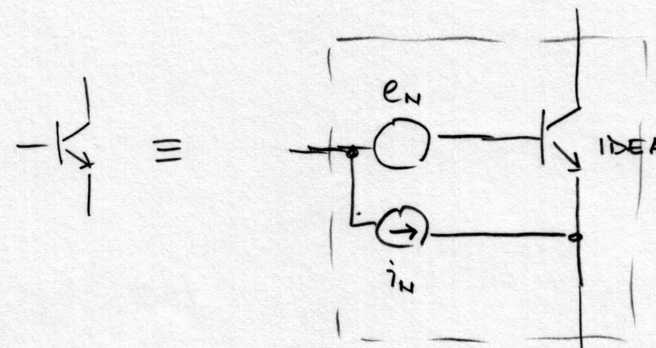
šumi pri O.P.

šumi: R:



C, L :

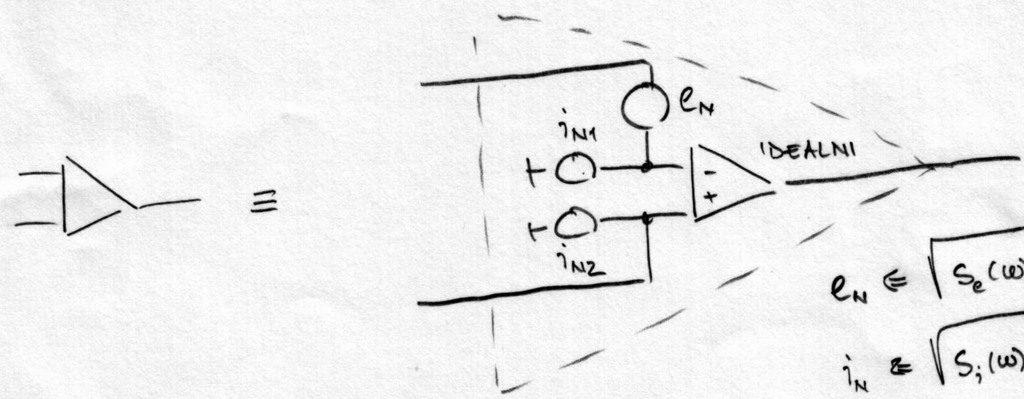
TR:



$e_N \Leftarrow \sqrt{S_u(\omega)}$ $nV/\sqrt{Hz}$

$i_N \Leftarrow \sqrt{S_i(\omega)}$ $nA/\sqrt{Hz}$

OP



$e_N \Leftarrow \sqrt{S_e(\omega)}$ $[nV/\sqrt{Hz}]$

$i_N \Leftarrow \sqrt{S_i(\omega)}$ $[pA/\sqrt{Hz}]$

---

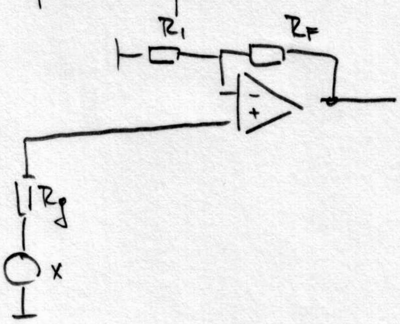
tipične vrednosti

	e_N	i_N
bipolarni TR:	nekaj $nV/\sqrt{Hz}$	desetinke $pA/\sqrt{Hz}$
FET:	več $nV/\sqrt{Hz}$	stotinke $pA/\sqrt{Hz}$

za večje R_g

primerni za majhne R_g

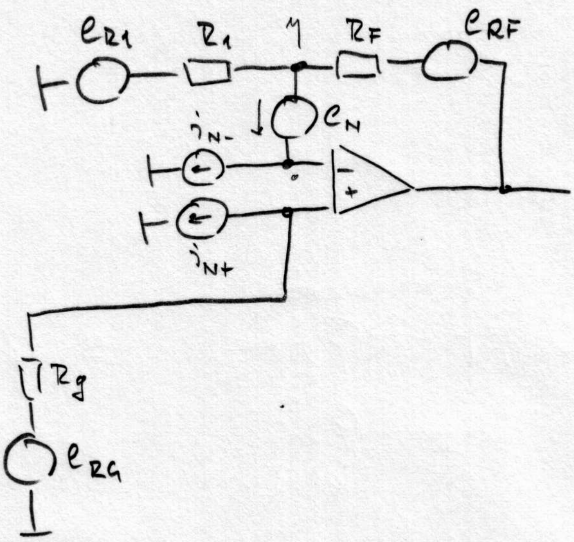
MOSFET: podobno FET, vendar ima drugačen spekter tipični ojačevalnik



$$\frac{u}{R_1} + \frac{u-7}{R_F} = 0$$

$$u = 7\,\frac{R_1}{R_1+R_F}$$

⇘



izh. šum je geometrijska vsota vseh šumov v vezju

predpostavimo: - vsi šumi so beli
- vsi šumi se enako razširjajo (enaka R. T(jω))
zato gledamo le v f. intervalu
- vezje je linearno

vezje

$e_{R1} = \sqrt{4kTR_1\Delta\nu}$ ⇒ razširja se kot $\frac{R_F}{R_1}\cdot e_{R1}$ } $\frac{1}{3}\cdot 10$ ojačenje vsaj 10 ⇓ zanemari e_{RF}!

$e_{RF} = \sqrt{4kTR_F\Delta\nu}$ ⇒ razširja se kot e_{RF} } 3x toliko

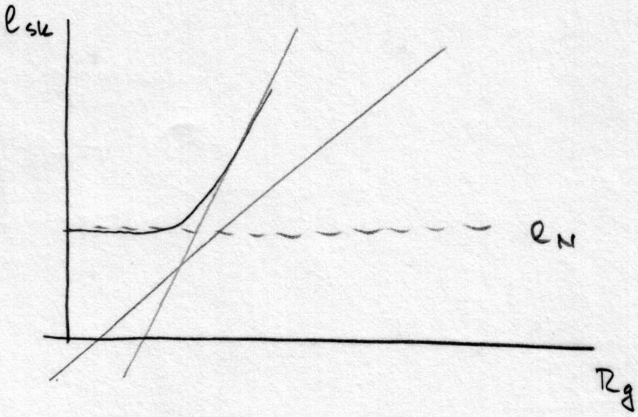
$e_{RG} = \sqrt{4kTR_G\Delta\nu}$ ⇒ razširja se kot $\frac{R_F}{R_1}\cdot e_{RG}$ ✓ } ker sem izbral $R_1 \ll R_g$ zanemari prispevke R_1 in R_F

op

$i_{N+} \to e_{IN+} = i_{N+}\cdot R_g\sqrt{\Delta\nu}$ ⇒ razširja se kot $\frac{R_F}{R_1}\cdot i_{N+}\cdot R_g$ ✓

$i_{N-} \to$ $\cdot\sqrt{\Delta\nu}$ razširja se kot $R_F\cdot i_{N-}$ } zanemari zaradi $R_1 \ll R_g$

e_N $\cdot\sqrt{\Delta\nu}$ razširja se kot $\left(\frac{R_F}{R_1}+1\right)\cdot e_N$ ✓



prispevki torej:

- e_{Rg} → ~~konst~~ narašča s $\sqrt{R_g}$
- $i_N \cdot R_g$ → narašča z R_g
- e_N → konst

$\left.\begin{array}{l} e_{Rg} \\ i_N \cdot R_g \\ e_N \end{array}\right\}$ reducirani na vhod tako, da je neodvisno od ojačanja

---

tipični O.P.	e_N	i_N	
LF 356	$12\,nV/\sqrt{Hz}$	$10\,fA/\sqrt{Hz}$	FET
OP 27	3	0.6pA	BIP
CLC 425	1.05	0.8pA	BIP
LMC 6044	83	2fA	CMOS

spektri

2005/27a

<u>šumi</u>: borba proti

① termični šum → <u>hladi</u>

a) tipično hladimo senzorje: jedrski detektor s tekočim dušikom
CCD s peltier-jem

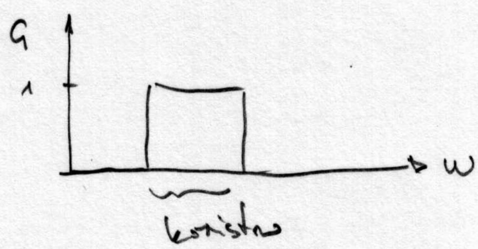
② ostali šumi

a) s primerno izbiro elementov, ki malo šumijo

b) z izbiro frekvenčnega pasu, kjer elementi malo šumijo

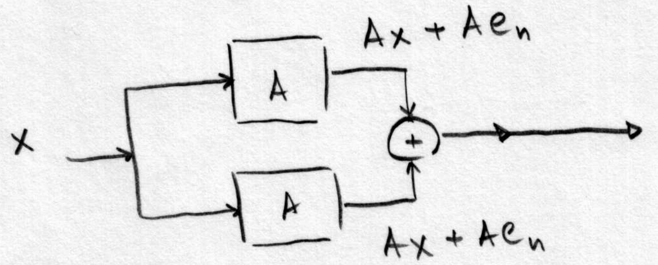
<u>za vse velja</u>

① filtriranje: opazuj signal le v tistem delu frekv. spektra, kjer so za signal relevantne komponente, ostalo izloči



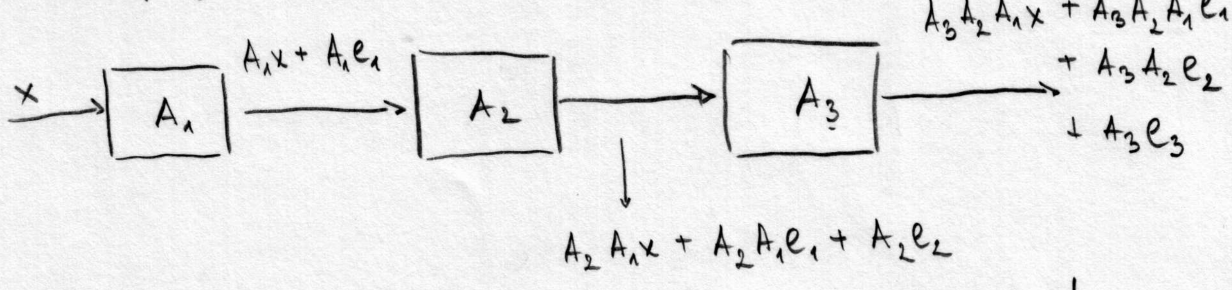
karakt. filtra

② vzporedne vezave:



šum se sešteva <u>geometrijsko</u>

③ vhodna stopnja



na skupni šum najbolj vpliva šum vhodne stopnje!

④ filtriranje

a) $x \to \boxed{A} \to \boxed{F} \to FAx + FAe_{nA} + Fe_{NF} = FAx + Fe_{NF} + F(Ae_{n}$

$Ax + Ae_{nA}$

b) $x \to \boxed{F} \to \boxed{A} \to FAx + FAe_{NF} + Ae_{NA} = FAx + A(Fe_{NF}) + Ae_{N}$

$Fx + Fe_{NF}$

isto.

b : <u>slabše</u>! ⇒ filtriraj na <u>koncu</u>

⑤ naknadna obdelava : povprečenje

a) koherentno: za znano vzbujanje
povprečimo ponavljajoč rezultat

b) nekoherentno: povprečimo spekter (lahko tudi koherentno!)

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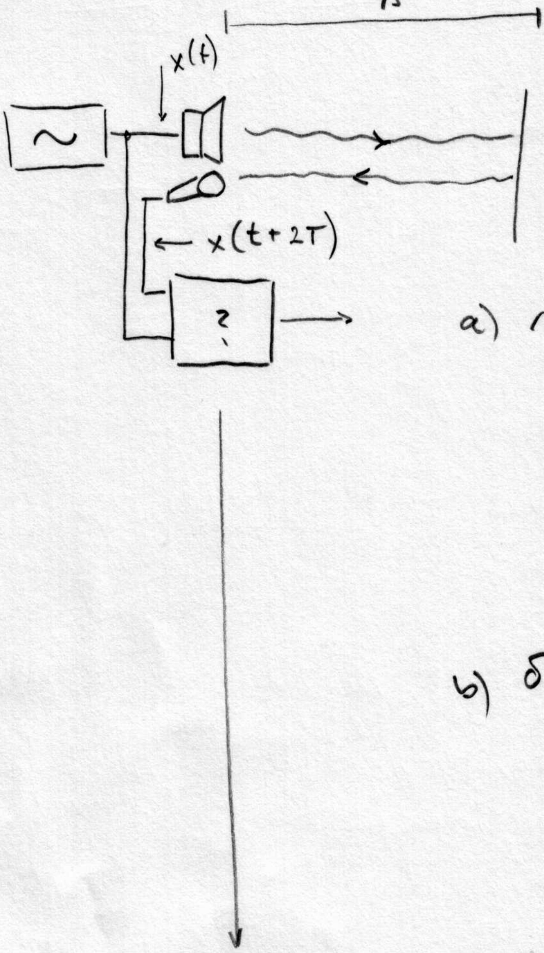
šum je lahko koristen!

Poskusimo meriti razdaljo

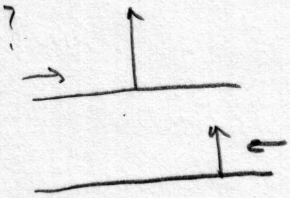


$s = v \cdot T$

a) sinusno nihanje ≡ meri fazo

- zamešaš se na prehode skozi 0
- periodično

b) δ ?



ne čisto:
- disperzija
- moč $\to \infty$

korelator

$$r(\tau) = \langle x(t) \cdot x(t+\tau) \rangle = \lim_{T \to \infty} \frac{1}{2T} \int_{-T}^{T} x(t) \cdot x(t+\tau)\, dt$$

- podaja merilo za sorodnost funkcij

c) naključna funkcija : šum

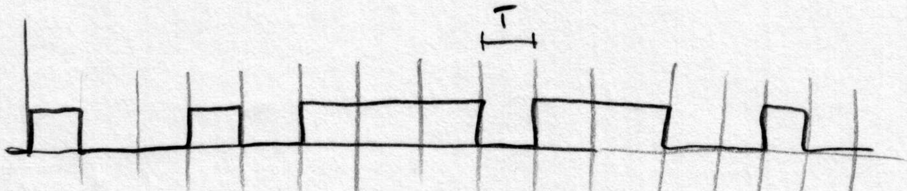
$$r(0) = \langle x(t) \cdot x(t) \rangle = \langle x^2(t) \rangle = u_{eff}^2$$

$$r(\tau) = 0$$

} Kuščer, Kodre Mat. metode v fiziki

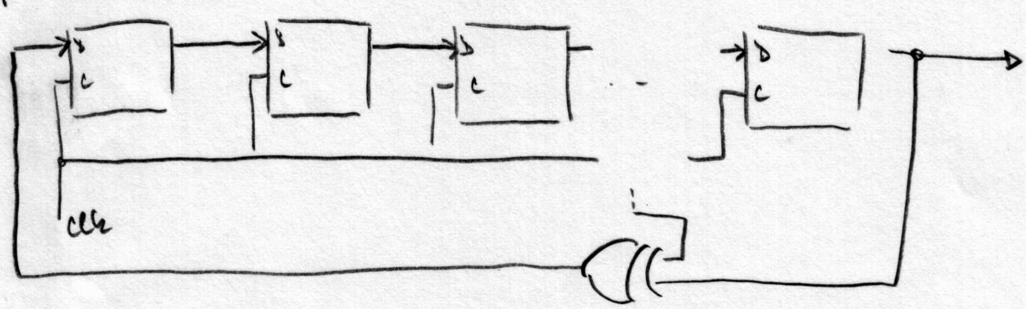
2005 | 2/6

vzemimo torej šum posebne vrste



pseudo šum: vrednost se ob času nT naključno zamenja

vezje



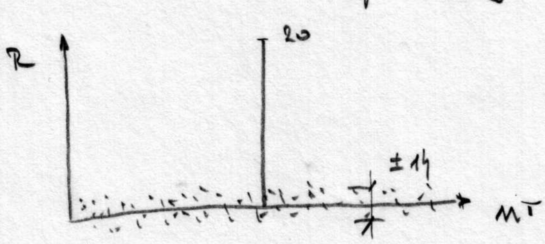
tak pseudo šum oddajamo in detektiramo odbito komp., nato računamo korelacijsko funkcijo ter iščemo maximum

primer: a) oddamo niz ~~200 T~~ ter sprejmemo niz 200T

b) $R(2\tau) = 200$ ujemanj!

$\tau \neq 2\tau \rightarrow$ načeloma 0

realno pričakujemo $\sigma = \sqrt{N} = \sqrt{200} = \pm 14$



! jasno vidno

2005/28c

preverimo kvaliteto detekcije : izgubi se 1/2 povrnjenega signala

$$\left.\begin{array}{l} R(2\tau) = 100 \pm \sqrt{100} = 100 \pm 10 \\ R(\tau \neq 2\tau) : \sqrt{200} = \pm 14 \end{array}\right\}$$ jasno vidno

izgubi se 90% signala

$$\left.\begin{array}{l} R(2\tau) = 20 \pm \sqrt{180} = 20 \pm 13 \\ R(\tau \neq 2\tau) = \sqrt{200} = \pm 14 \end{array}\right\}$$ verjetno izgubljeno!

rešitev : vzemimo 2000 vzorcev!

↓

$$\left.\begin{array}{l} R(2\tau) = 200 \pm \sqrt{1800} = 200 \pm 42 \\ R(\tau \neq 2\tau) = \sqrt{2000} = \pm 45 \end{array}\right\}$$ jasno vidno!

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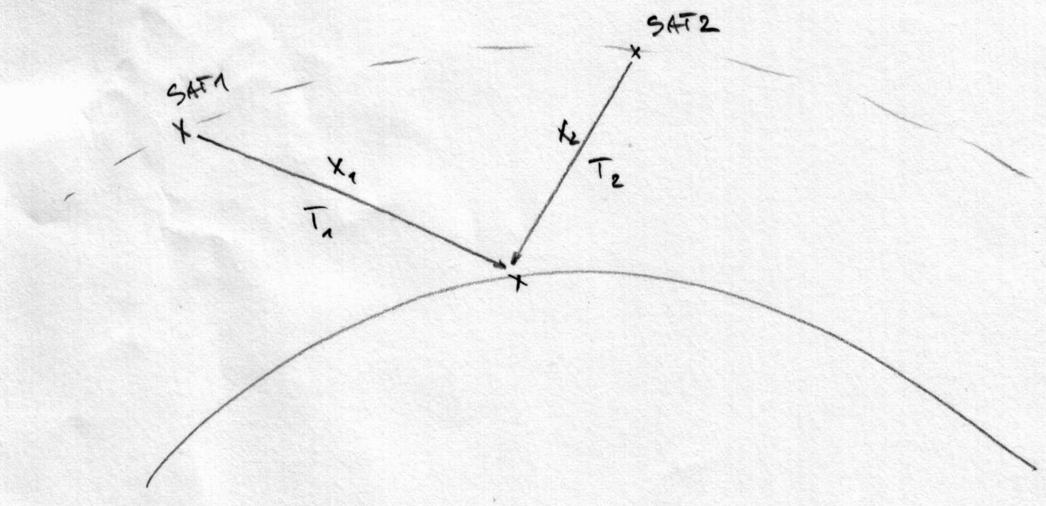
uporabe : GPS



če poznaš T_1, veš radij krogle okrog T_1

+ če poznaš T_2, veš krožnico, presek dveh krogel

+ če poznaš T_3 veš dve točki, ~~preseka~~ na krožnici, določeni v T_2

natančnost meritve ±10 m

sateliti 200 km visoko → $T = \frac{s}{v} = \frac{200 \cdot 10^3}{3 \cdot 10^8} = \underline{\underline{1 ms}}$

natančnost : $\frac{10}{3 \cdot 10^8} = 3 \cdot 10^{-8} = 30 ns \Rightarrow f = 30 MHz$