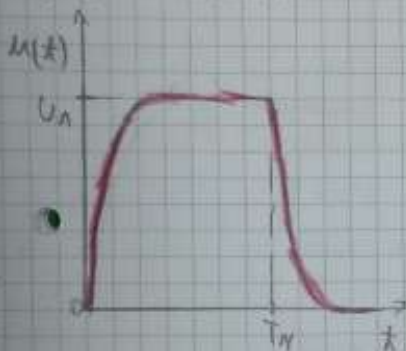


KORIČIĆ - PITANJA ZA USMENI

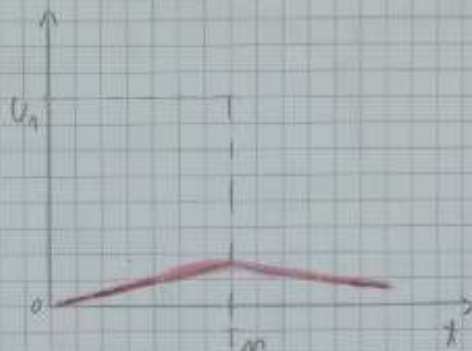
• 1.) RC i CR mreže

1. RC - mreža - niskopropusni filter

Stacionarno stanje:

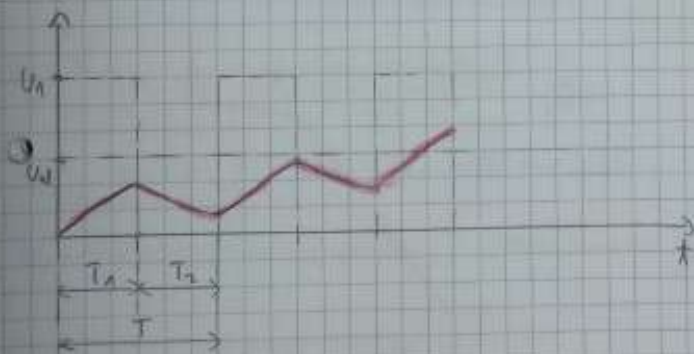


$\tau \ll T_n$



$\tau \gg T_n$

Prizlaska prirota:



$\tau = RC \Rightarrow$ vremenska konstanta

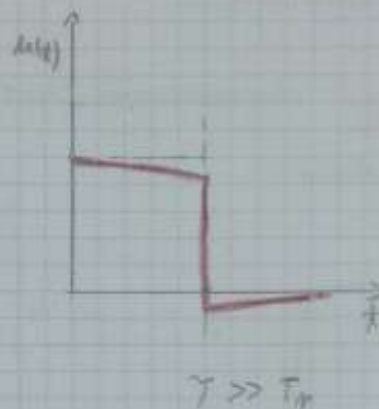
$t_r = t_{n0.9} - t_{n0.1} = 2.2 \tau \Rightarrow$ vreme porasta

$t_d = t_{n0.5} - t_{n0.05} = 0.69 \tau \Rightarrow$ vreme buđenja

u
 $u_{in}(t) = U_n [1 - e^{-\frac{t}{\tau}}] \Rightarrow$ izlazni napori

2. CR- mreža - diferencijalni filter

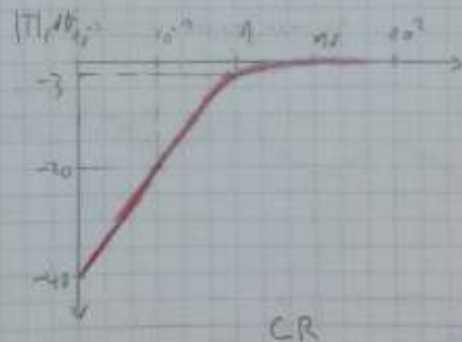
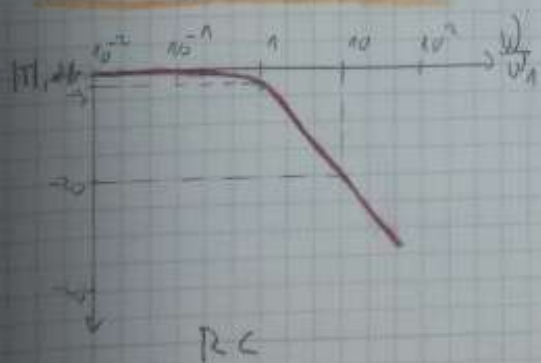
Stacionarno stanje:



$$\Delta t = \lambda_{\text{im},1} - \lambda_{\text{re},0,2} = 2,2 \gamma \Rightarrow \text{verzina moda}$$

$$U_{\text{rez}} = U_1 \cdot e^{-\frac{t}{\Delta t}} \Rightarrow \text{izlazni napon}$$

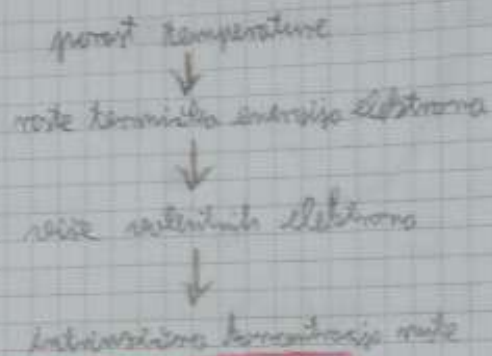
Frekvenzijske karakteristike:



2.) Svojstva poluvodiča

Intrinzična koncentracija:

- koncentracija nosilaca čistog poluvodiča
- raste s poluvodičkom materijalom i s temperaturom



$$n_i = C_A T^{\frac{3}{2}} e^{\left(-\frac{E_{g0}}{2kT}\right)} \Rightarrow \text{intrinzična koncentracija}$$

Učvrđivanje koncentracije nosilaca:

$$n_0 \cdot p_0 = n_i^2 \Rightarrow \text{zakon termičke ravnoteže}$$

- 12. zakon koji nam govori o tome i normalizaciji električnog naboja

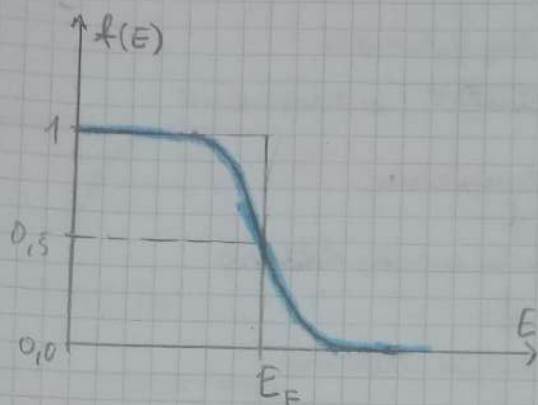
$$q(n_0 + N_0^+) = q(p_0 + N_A^-) \Rightarrow \text{zakon električne neutralnosti}$$

- 11. zakon koji nam govori o tome da pozitivnog naboja odgovara sumi negativnog naboja

6)

Određivanje položaja Fermijeve energije

- Fermijeva energija je energija za koju je vjerojatnost popunjivosti elektronom jednaka 0,5.



Fermi-Diracova funkcija vjerojatnosti

Intrinzični poluvodiči:

$$E_{Fi} = \frac{E_v + E_c}{2}$$

, E_{Fi} = Fermijeva energija intrinzičnog poluvodiča

- Fermijeva energija se nalazi na sredini zabranjenog pojasa.

Poluvodiči n-tipa:

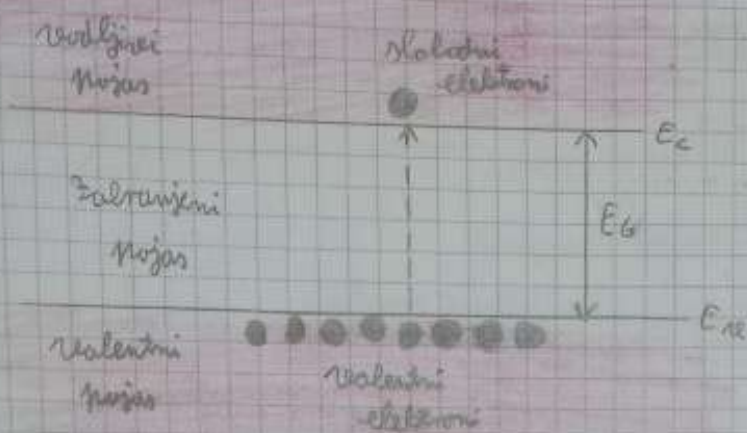
$$E_F = E_{Fi} + E_T \ln\left(\frac{n_0 n_i}{n_i}\right)$$

- Fermijeva energija nalazi se u gornjoj polovini zabranjenog pojasa

Poluvodiči p-tipa:

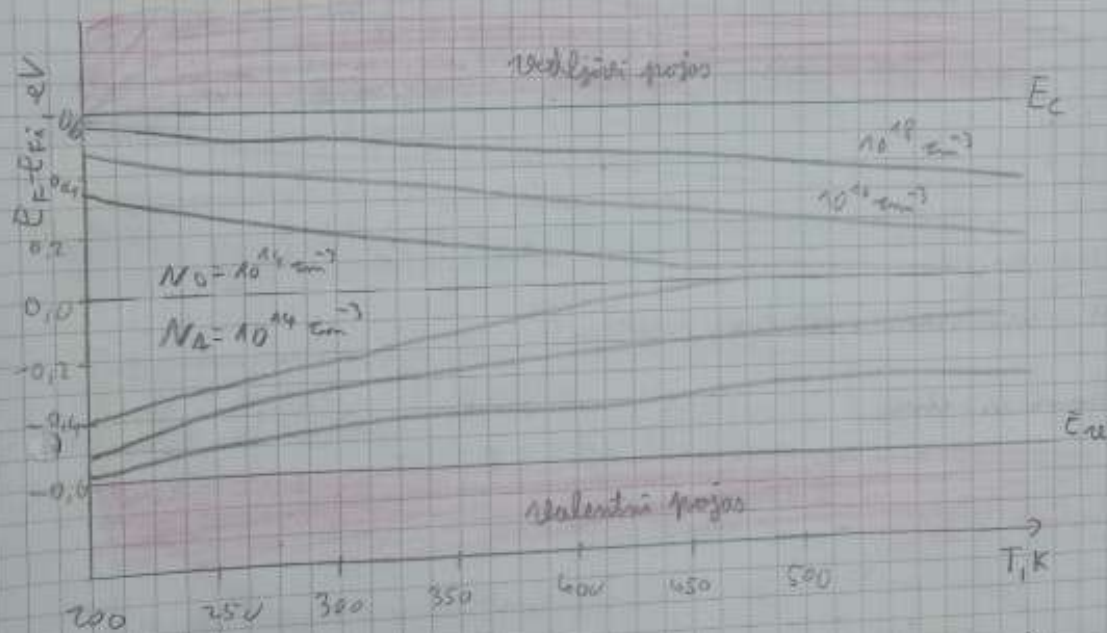
$$E_F = E_{Fi} - E_T \ln\left(\frac{n_0 n_i}{n_i}\right)$$

- Fermijeva energija nalazi se u donjoj polovini zabranjenog pojasa



Približno energijski nojas polimernih

Temperaturna odvisnost:



- Pri višji temperaturi, zaradi povečane intrinzične koncentracije n_i , Fermijeva energija se približuje sredini zalrajnega nojasa.
- Pri višji temperaturi zalrajni nojas se zužuje.

Driftinis srovės u polimerinėse:

Driftinė lygtis:

$$\begin{aligned} \vec{v}_{dn} &= -\mu_n \vec{F} \\ \vec{v}_{dp} &= \mu_p \vec{F} \end{aligned} \quad \begin{aligned} \vec{F} &= \text{elektrinis polys} \\ \mu_n, \mu_p &= \text{pobutėjimo koeficientas} \end{aligned}$$

- Pobutėjimo koeficientas priklauso nuo medžiagos polimerinės ir temperatūros.

Specifinė pobutėjimo polimerinėse:

$$\sigma = q(n\mu_n + p\mu_p)$$

Specifinė srovės polimerinėse:

$$\xi = \frac{1}{\sigma}$$

Driftinė srovė:

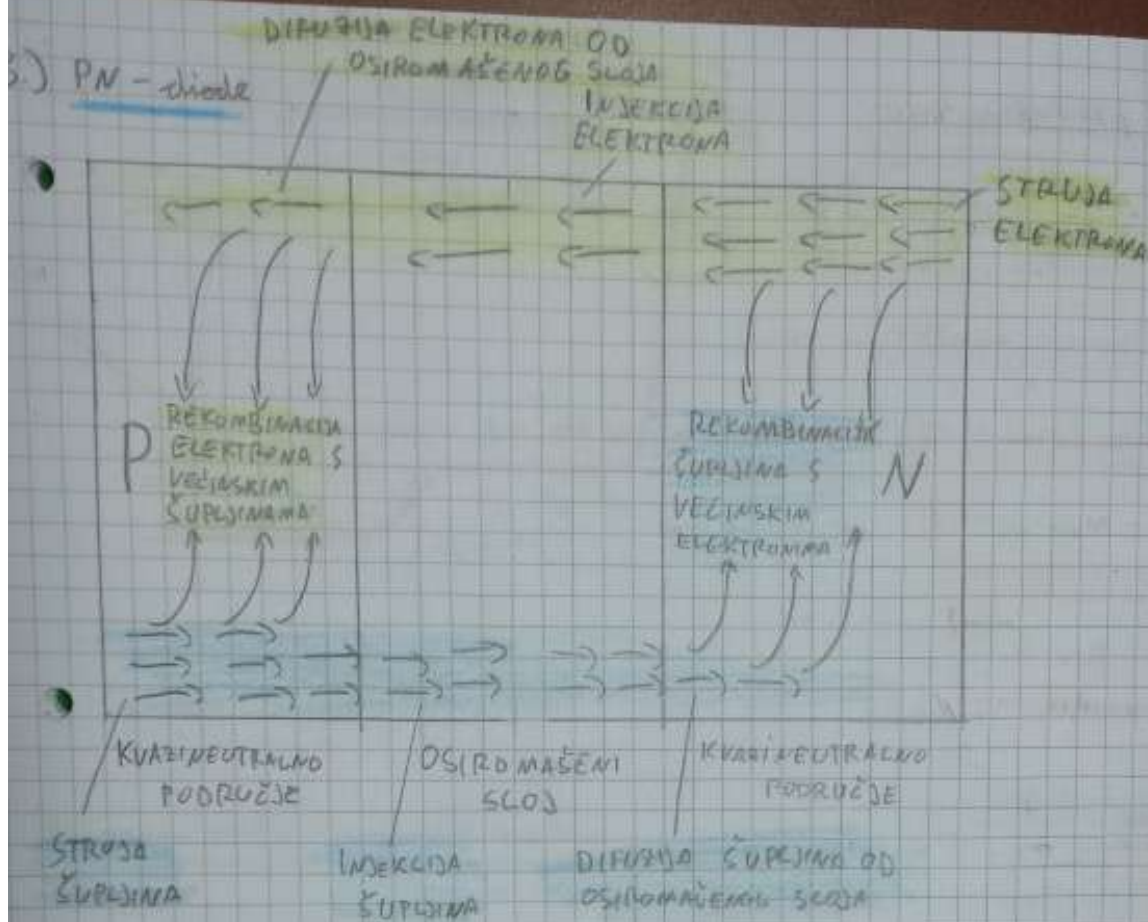
- srovės susidarymas elektrinio polio \vec{F} .

Lygtis driftinė srovė: $\vec{J}_F = \sigma \vec{F} \Rightarrow \begin{aligned} \vec{J}_{Fn} &= q n \mu_n \vec{F} \\ \vec{J}_{Fp} &= q p \mu_p \vec{F} \end{aligned} \Rightarrow \vec{J}_F = \vec{J}_{Fn} + \vec{J}_{Fp}$

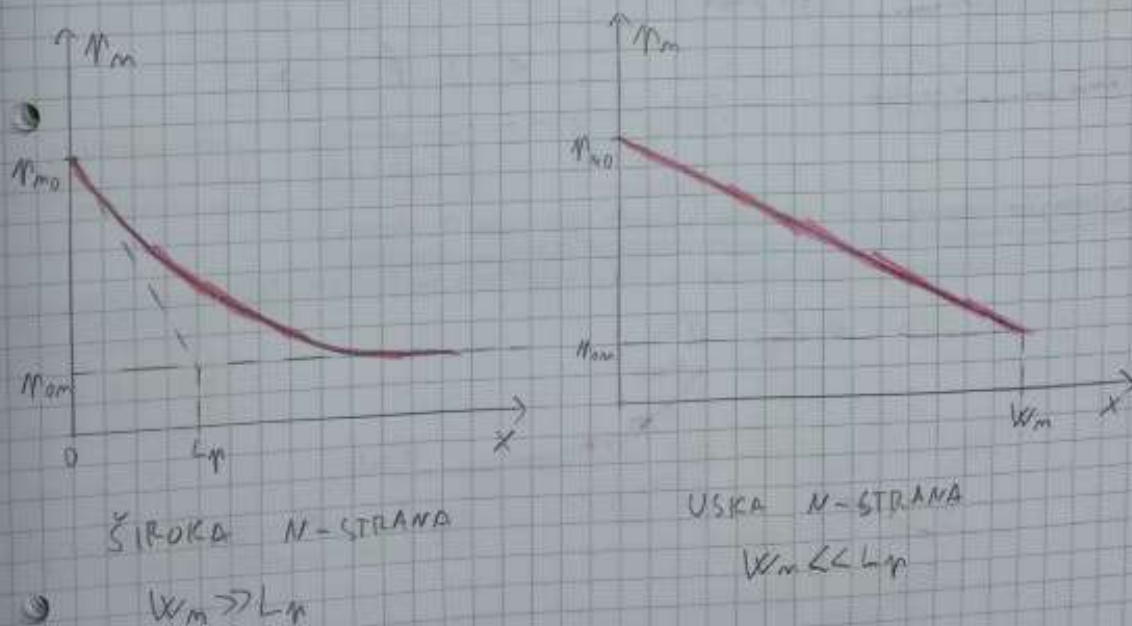
Diffuzinė srovė:

- srovės susidarymas difuzijomis medžiagoje, susidarymaso neįsijungusioje medžiagoje elektronais ir kumpijomis u polimerinėse.

$$\begin{aligned} \vec{J}_{Dn} &= q D_n \text{grad } n = q U_T \mu_n \text{grad } n \\ \vec{J}_{Dp} &= -q D_p \text{grad } p = -q U_T \mu_p \text{grad } p \end{aligned}$$



Disperzijske karakteristike šupčinskih proporcija polariziranog PN spoja



Średnia osiromasienowy slego:

$$d_E = \sqrt{\frac{2E}{q} \left(\frac{1}{N_A} + \frac{1}{N_D} \right) V_{TOT}}$$

Poltramennal jednolitość:

- odrednija koncentracje mianjinkich nozilaca w2 rub osiromasienowy slego

$$N_{MC} = N_{MP} e^{\frac{U}{U_T}}$$

$$N_{MO} = N_{MP} e^{\frac{U}{U_T}}$$

Difuzyjna dugość:

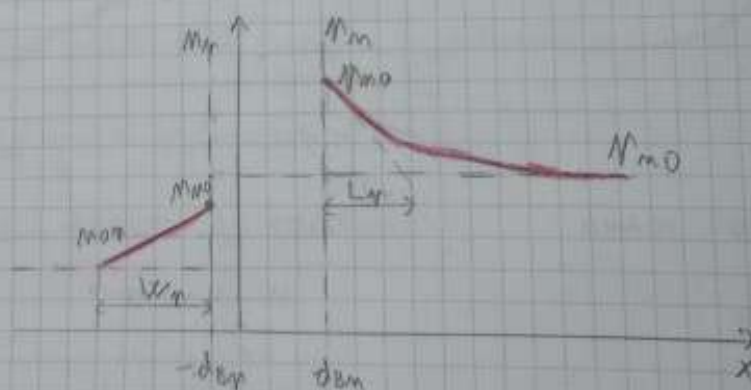
$$L_n = \sqrt{D_n \tau_n}$$

Strukturen jednolitość:

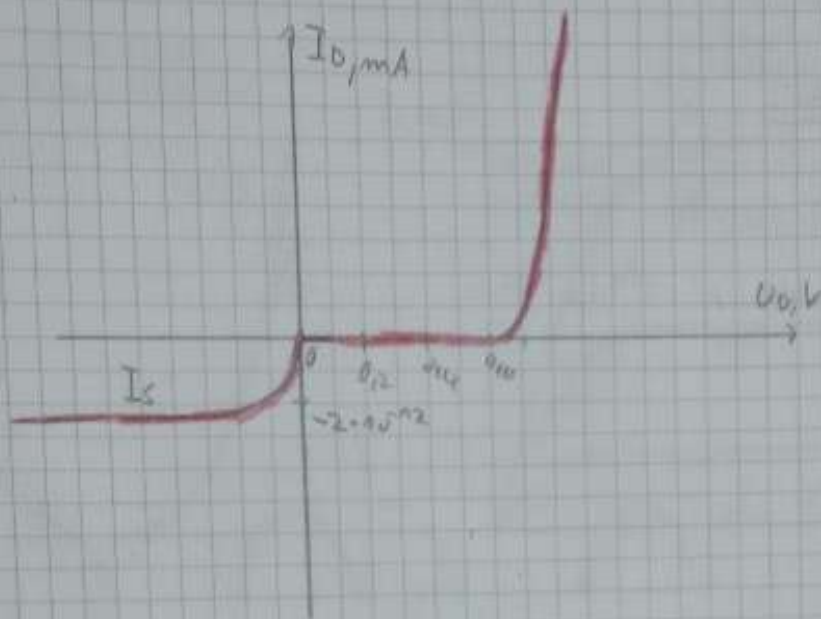
- odrednija strużno - napowntu baruklenstwu PN spwija

$$I_D = I_S \left(e^{\frac{U_D}{U_T}} - 1 \right)$$

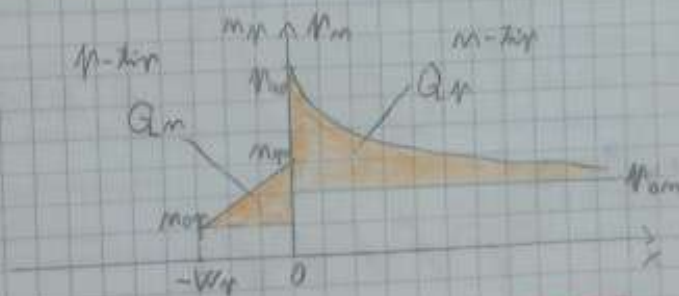
Strużnija mianjinkich nozilaca (kroto 1/2 dugo 1/2 strużno):



Strujno-naponska karakteristika:



Kalibrirani malvi marginalni model:



$$Q_n = I_m \cdot t_n$$

$$Q_p = I_p \cdot t_p$$

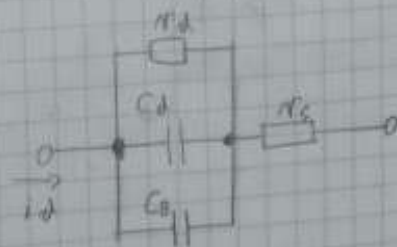
$$t = \frac{W^2}{2D}$$

Diffuzijski kapacitet: - određuje promenu nabijenoq malvija i napona

$$C_d = qd \frac{\tau}{2}$$

Kapacitet priromajnog sloja:

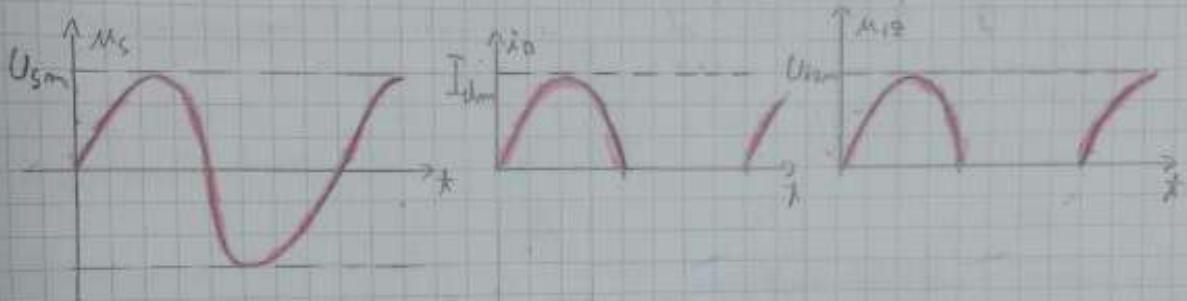
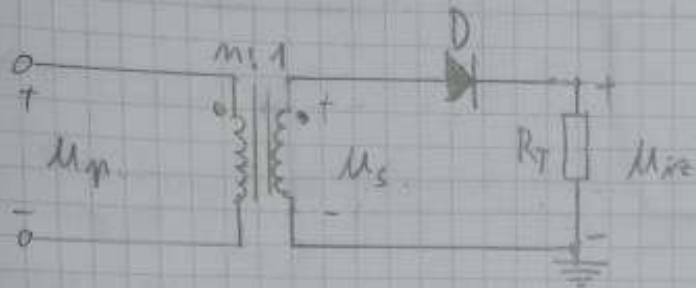
$$C_B = \epsilon \frac{S}{d_B}$$



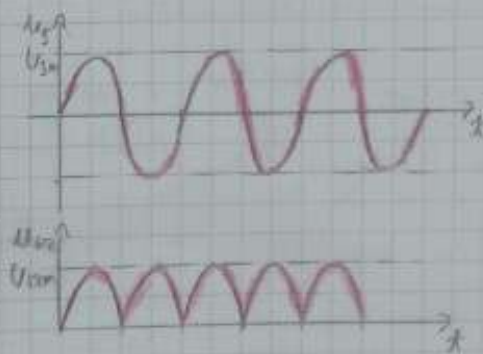
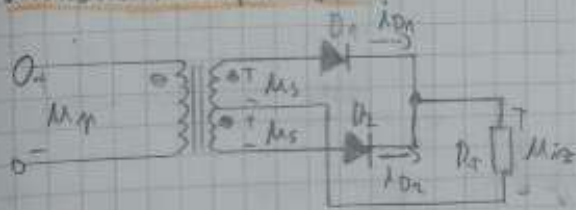
MODEL PN DIODE
ZA MALI SIGNAL

6.) Sklopovi s diodama

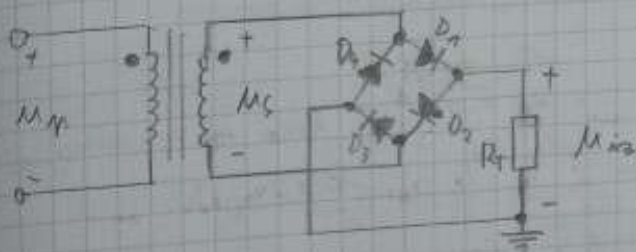
Jednoscilni ispravljači:



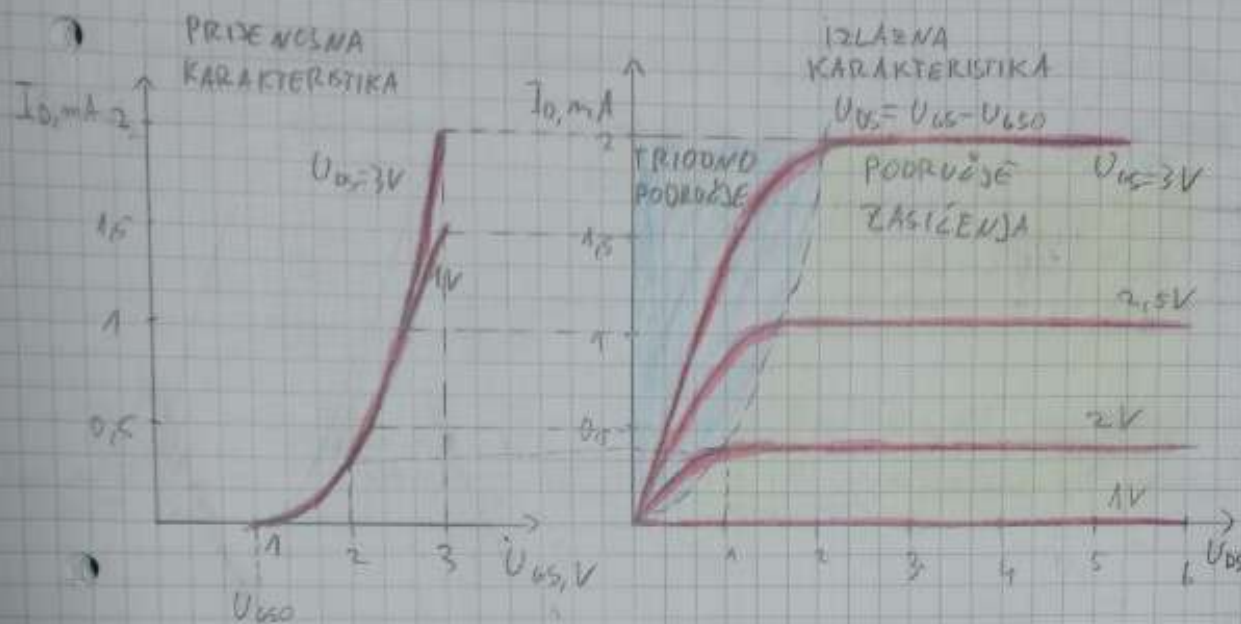
Dvuscilni ispravljači:



Dvuscilni ispravljači s Graetzovom Mrežom:



5.) Unipolarni tranzistori



$$0 \leq U_{DS} \leq U_{GS} - U_{GS0} \Rightarrow \text{TRIODNO PODRUČJE}$$

$$U_{DS} \geq U_{GS} - U_{GS0} \Rightarrow \text{PODRUČJE ZASIČENJA}$$

$$U_{GS} < U_{GS0} \Rightarrow \text{PODRUČJE ZAPIRANJA}$$

Supotet plovitost kondenzatora: $C_{ox} = \frac{\epsilon_{ox}}{t_{ox}}$

Strujni koeficijent: $K = \mu_n C_{ox} \frac{W}{L}$

Triodno područje:

- Pod uslovom da je napon na upravljačkoj elektrodi veći od napona praga ($U_{GS} \geq U_{GS0}$), u triodnom području kroz MOSFET teče struja koja je nelinearno ovisna o naponu U_{DS} :

$$I_D = K \left[(U_{GS} - U_{GS0}) U_{DS} - \frac{1}{2} U_{DS}^2 \right]$$

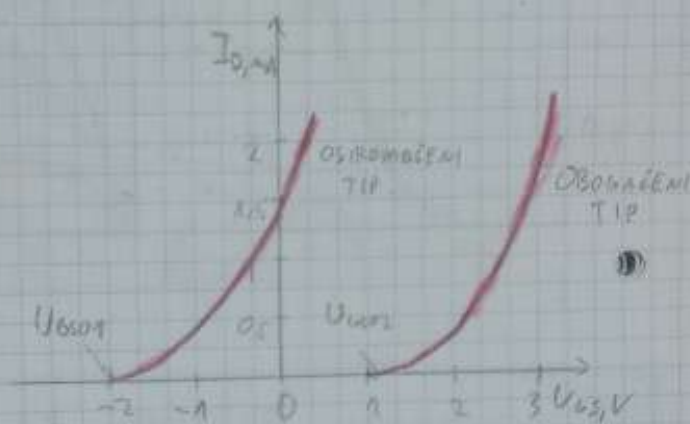
Područje zasićenja:

U području zasićenja struja I_D prelazi u zasićenje i postaje konstantna, a preostali dio napona U_{DS} se iskoristi na vrsnomosnom sloju kanal-podloga.

$$I_D = I_{DS} = \frac{1}{2} K (U_{GS} - U_{GS0})^2$$

Osiromašeni tip: $U_{GS0} < 0$

Oblagošćeni tip: $U_{GS0} > 0$



MMOS:

Karakteristike su jednake, osim što je U_{GS0} negativno (negativni strujni).

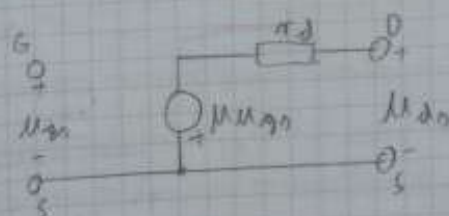
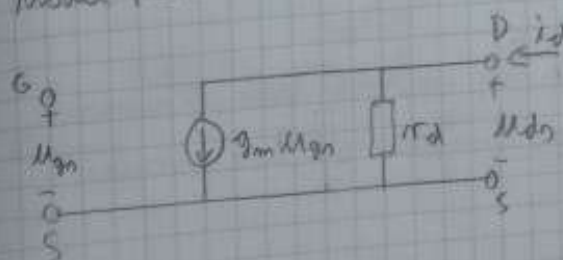
Dinamički parametri:

Stromovni

$$g_m = \left. \frac{dI_D}{dU_{GS}} \right|_{U_{GS} = U_{GS0}}$$

Voltna dinamička vodljivost: $g_d = \left. \frac{dI_D}{dU_{DS}} \right|_{U_{GS} = U_{GS0}}$

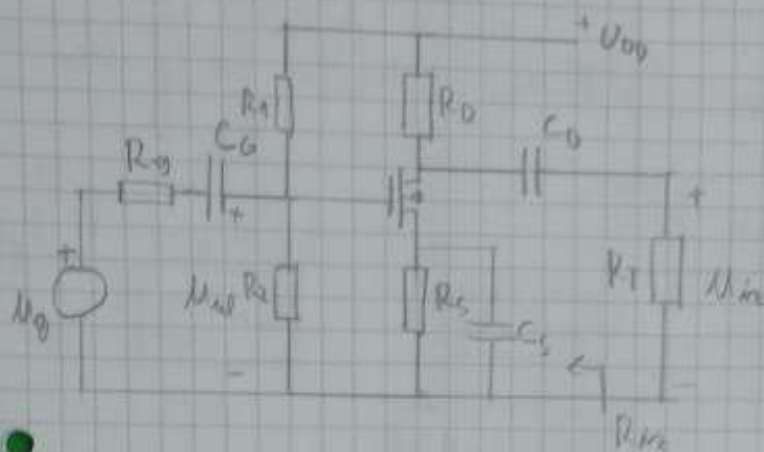
Model FET-a za mali signal:



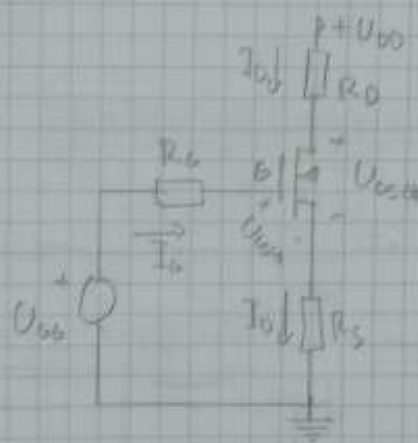
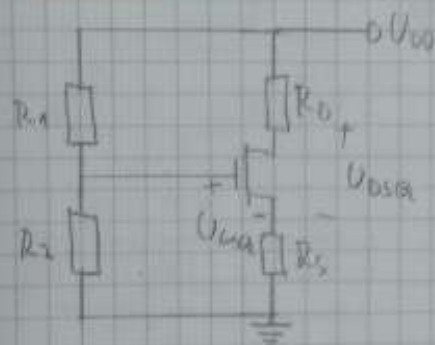
$$M = g_m r_d$$

6.) Sklopovi s unipolarnim tranzistorima

- Spis zadrživanja uzorka:



Statička analiza:



$$U_{GS} = \frac{R_2}{R_1 + R_2} U_{DD}$$

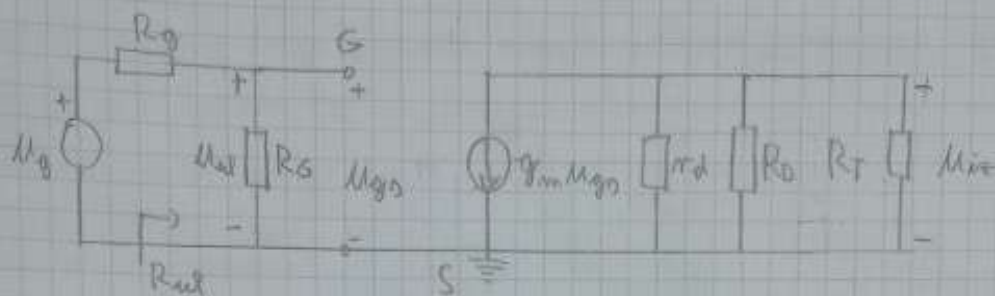
$$R_G = R_1 \parallel R_2$$

$$I_{DQ} = \frac{1}{2} K (U_{GS} - U_{GS0})^2 = \frac{U_{GS} - U_{GS0}}{R_s}$$

$$U_{GS0}^2 + 2 \cdot \left(\frac{1}{K R_s} - U_{GS0} \right) U_{GS} + U_{GS0}^2 - \frac{2 U_{GS}}{K R_s} = 0$$

$$U_{GS0} = U_{GS} - I_{DQ} \cdot (R_G + R_s)$$

Dinamička analiza:



$$u_{out} = -g_m \cdot u_{gs} \cdot r_d \parallel R_D \parallel R_T$$

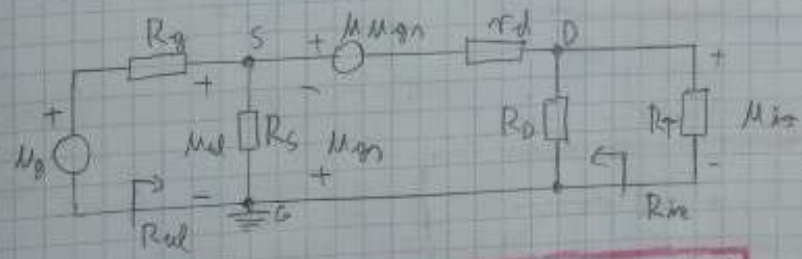
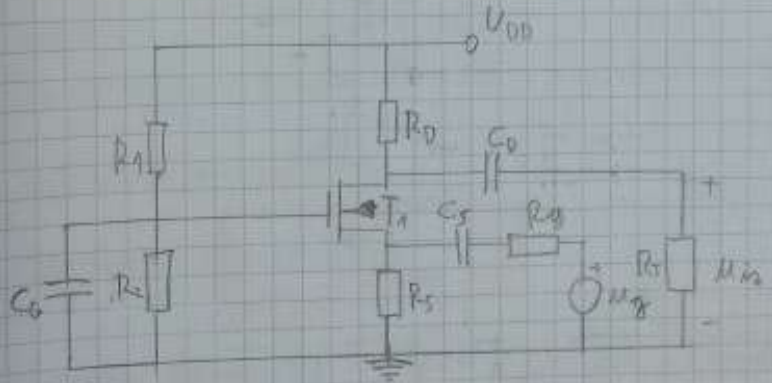
$$u_{ul} = u_{gs}$$

$$A_v = \frac{u_{out}}{u_{ul}}$$

$$R_{ul} = R_g$$

$$R_{ie} = r_d \parallel R_D$$

Sprijeznišne upravljačke elektrode:



$$u_{ul} = -u_{gs}$$

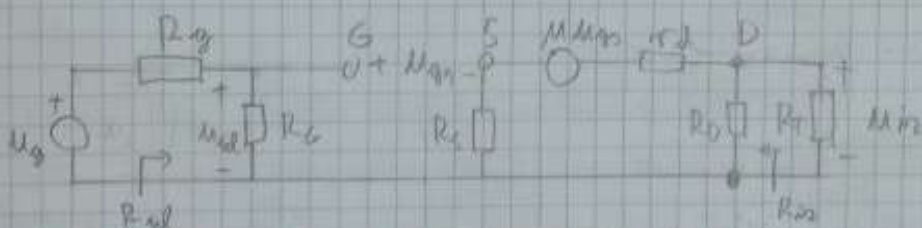
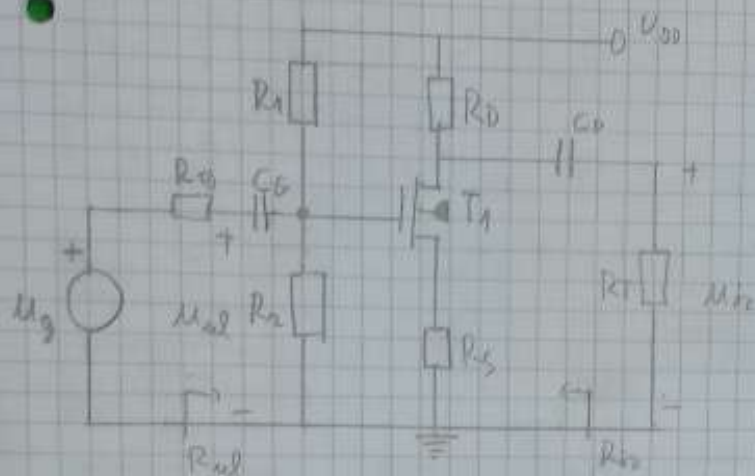
$$A_v \approx g_m (r_d \parallel R_D \parallel R_T)$$

$$u_{out} = -(R_D \parallel R_T) i_d$$

$$R_{ul} = R_g \parallel \frac{1}{g_m}$$

$$R_{ie} = R_D \parallel (r_d + (1 + \mu)(R_s \parallel R_g))$$

Spezi. Zweipolnetzwerk Leverts & universalem Degenerations



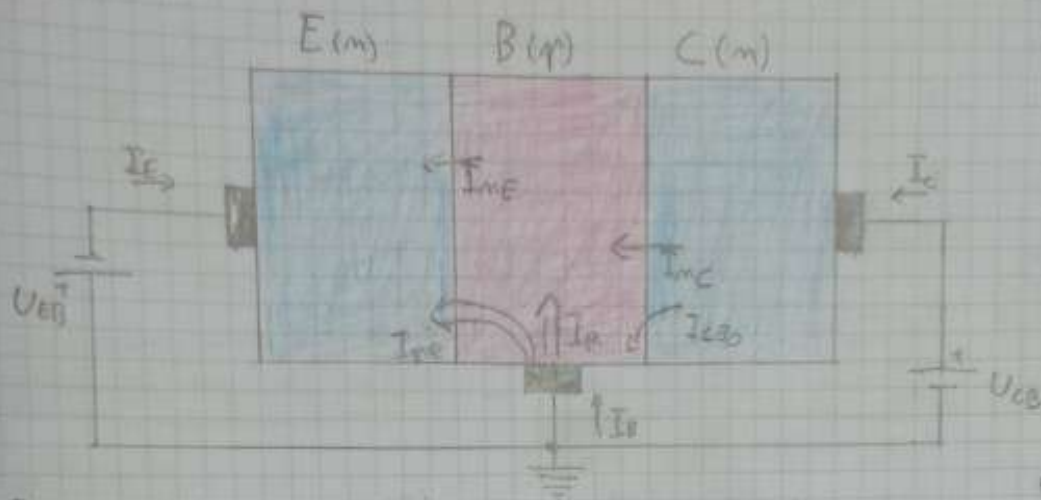
$$M_{ul} = M_{us} + i_d R_E$$

$$M_{is} = -(R_D \parallel R_{is}) i_d$$

$$A_v = \frac{-M (R_D \parallel R_{is})}{(1+M)R_E + r_d + R_D \parallel R_{is}} \approx \frac{-\beta_{m0} (R_D \parallel R_{is})}{1 + \beta_{m0} R_E} \approx \frac{-(R_D \parallel R_{is})}{R_E}$$

$$R_{ul} = R_G \quad R_{is} = R_D \parallel [(1+M)R_E + r_d]$$

7.) Bipolar transistor



Proportional concentration:

$$M_{0B} = \frac{n_i^2}{n_{0B}}$$

$$n_{0E} = \frac{n_i^2}{M_{0E}}$$

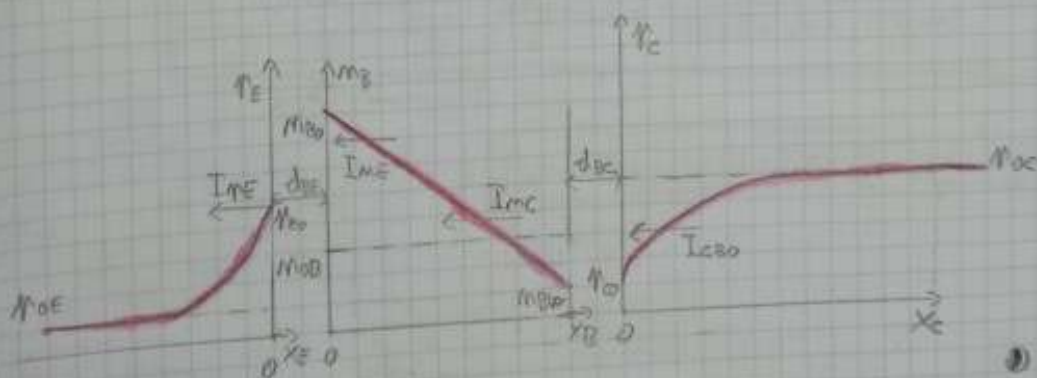
Reverse concentration:

$$M_{B0} = M_{0B} \cdot e^{\frac{V_{BE}}{U_T}}$$

$$n_{E0} = n_{0E} \cdot e^{\frac{V_{BE}}{U_T}}$$

$$M_{E0} = M_{0B} \cdot e^{\frac{V_{BC}}{U_T}} \approx 0$$

$$n_{C0} = n_{0C} \cdot e^{\frac{V_{BC}}{U_T}} \approx 0$$



Struje:

$$I_{nE} = q S D_{nE} \frac{M_{E0}}{W_E}$$

$$D = \mu \cdot U_T$$

$$I_{nB} = q S D_{nB} \frac{M_{B0}}{W_B}$$

$$I_{nC} = \beta^* I_{nE}$$

$$\beta^* = 1 - \frac{1}{2} \left(\frac{W_B}{\sqrt{D_{nB} \cdot \tau_{nB}}} \right)^2$$

$$I_R = I_{nE} - I_{nC}$$

$$I_E = -(I_{nE} + I_{nB})$$

$$I_B = I_{nE} + I_R$$

$$I_C = I_{nC}$$

Faktori:

$$\gamma = \frac{I_{nC}}{-I_E}$$

\Rightarrow Faktor inhibicije (efikasnost emitera)

- ovisi o dopiranjima emitera i odnosu na dopiranje baze

$$\beta^* = 1 - \frac{I_R}{I_{nC}}$$

\Rightarrow Transportni faktor

- ovisi o tome koliko je baze uska u odnosu na difuzijsku duljinu manjinskih elektrona u bazi

$$\alpha = \frac{I_C}{-I_E}$$

\Rightarrow Statistički faktor strujnog pojačanja ($S \rightarrow B$)

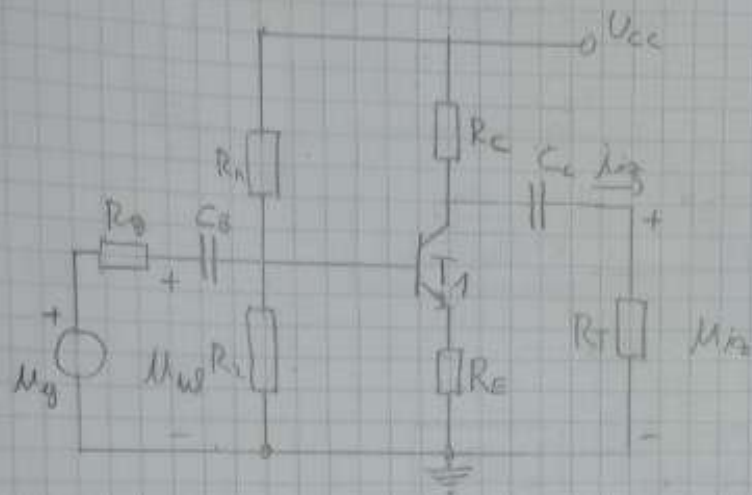
$$\beta = \frac{\alpha}{1 - \alpha}$$

\Rightarrow Statistički faktor strujnog pojačanja ($S \rightarrow E$)

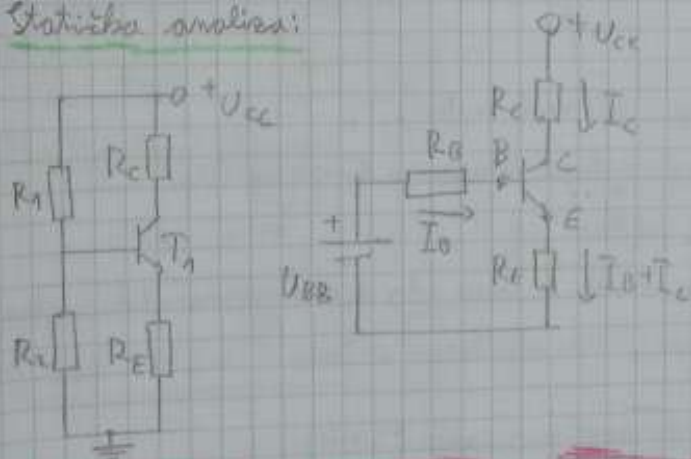
Polarizacija PN spoja		Emiter - baza	
		napojeno	zatvoreno
kolektor - baza	napojeno	ZASIĆENJE	INVERZNO AKTIVNO
	zatvoreno	NORMALNO AKTIVNO	ZAPIRANJE

8) Shlegova's bipolarnim tranzistorima

SZE s degeneracijom



Statistička analiza:



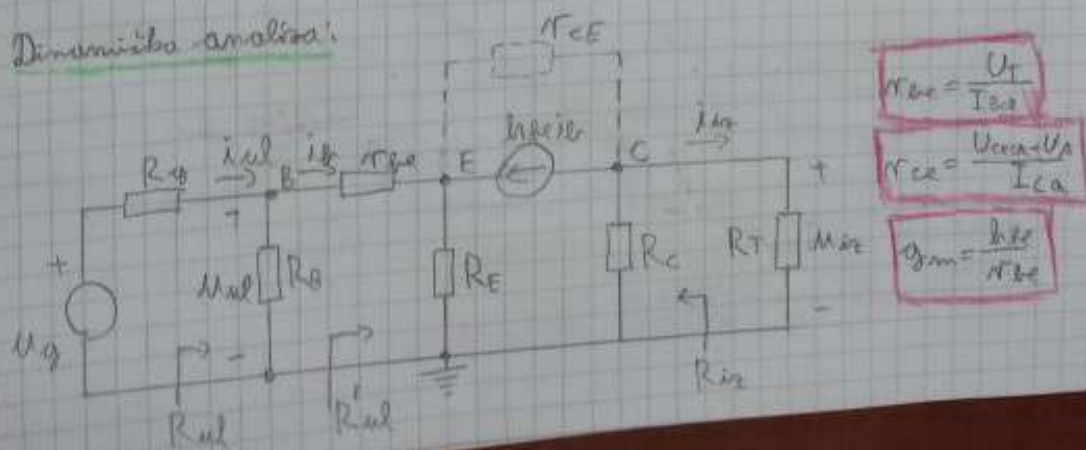
$$U_{BB} = \frac{R_2}{R_1 + R_2} U_{CC}$$

$$R_B = R_1 \parallel R_2$$

$$I_C = \beta I_B$$

$$I_{BQ} = \frac{U_{BB} - U_{BEQ}}{R_B + (1 + \beta) R_E}$$

Dinamička analiza:



$$r_{be} = \frac{U_T}{I_{BQ}}$$

$$r_{ce} = \frac{U_{CC} - U_{CEQ}}{I_{CQ}}$$

$$g_m = \frac{I_{CQ}}{U_T}$$

$$u_{ul} = i_b r_{be} + (1 + \beta_{be}) i_b R_E$$

$$u_{us} = -\beta_{be} i_b (R_C \parallel R_T)$$

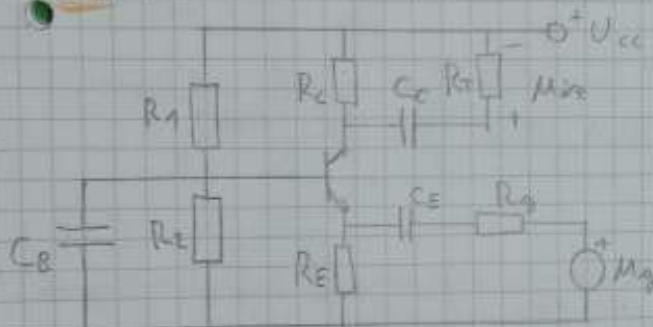
$$A_v = -\beta_{be} \frac{R_C \parallel R_T}{r_{be} + (1 + \beta_{be}) R_E} \approx -\frac{g_m (R_C \parallel R_T)}{1 + g_m R_E}$$

$$R_{ul} = R_B \parallel [r_{be} + (1 + \beta_{be}) R_E]$$

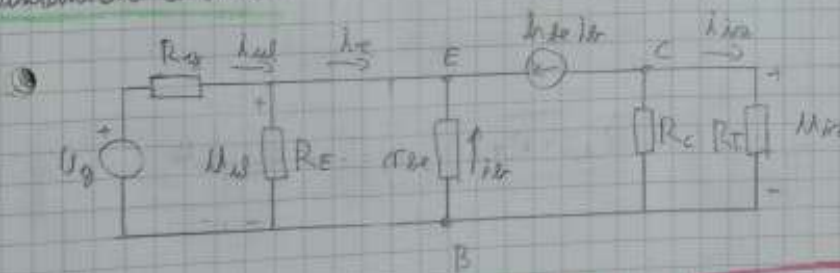
$$R_{us} = R_C$$

$$A_i = -\beta_{be} \frac{R_C}{R_C + R_T} \frac{R_B}{R_B + r_{be} + (1 + \beta_{be}) R_E}$$

SZB



Dinamička analiza:



$$u_{us} = -\beta_{be} i_b R_C \parallel R_T$$

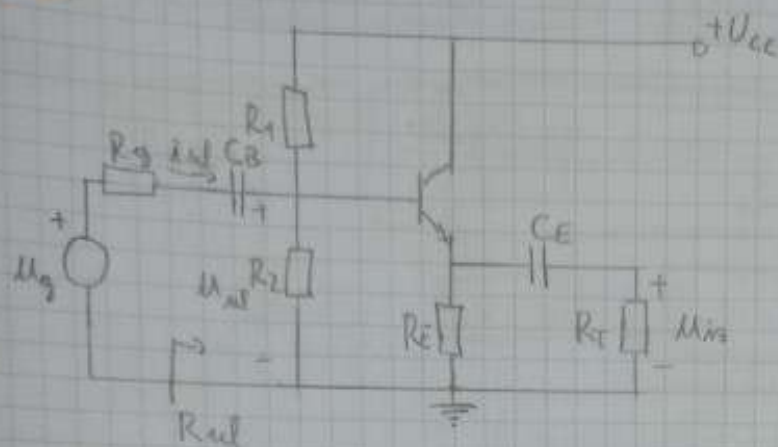
$$u_{ul} = -i_b r_{be}$$

$$A_v = \beta_{be} \frac{R_C \parallel R_T}{r_{be}}$$

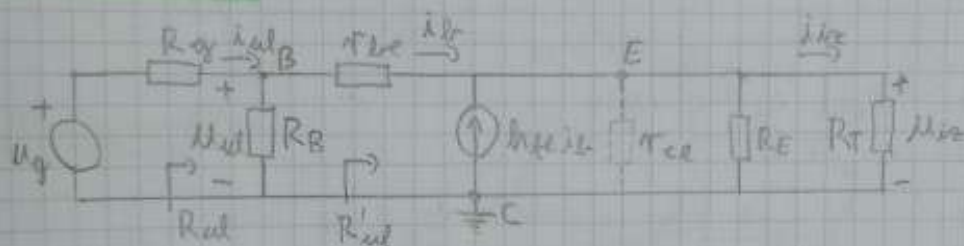
$$R_{ul} = R_E \parallel \left(\frac{r_{be}}{1 + \beta_{be}} \right)$$

$$R_{us} = R_C$$

S2C



Dinamička analiza



$$u_{Mz} = (1 + h_{fe}) i_{Bz} (R_C \parallel R_L)$$

$$u_{Mz} = i_{Bz} r_{Bz} + u_{Mz}$$

$$A_v \approx \frac{g_m (R_C \parallel R_L)}{1 + g_m (R_C \parallel R_L)}$$

$$R'_{ul} = r_{Bz} + (1 + h_{fe}) (R_C \parallel R_L)$$

$$A_I = (1 + h_{fe}) \frac{R_E}{R_E + R_L} \frac{R_B}{R_B + R'_{ul}}$$

$$R_{ul} = R_B \parallel R'_{ul} \quad R_{iz} = R_E \parallel \frac{R_C \parallel R_L + r_{Bz}}{1 + h_{fe}}$$

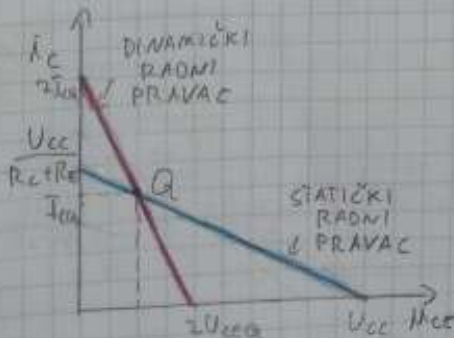
Radna tačka

Statički radni pravac:

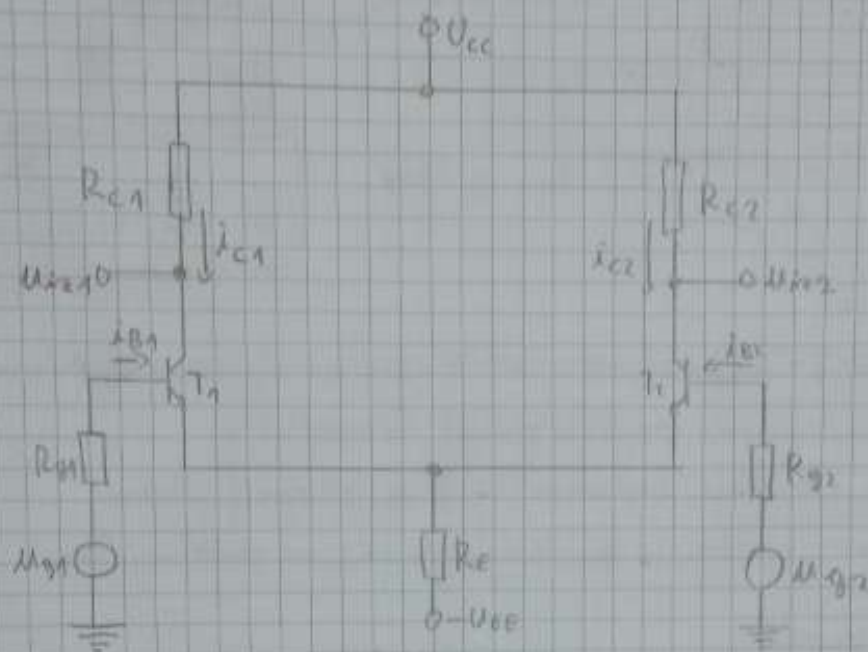
$$U_{CEQ} = U_{CC} - (R_C + R_E) I_{CQ}$$

Dinamički radni pravac:

$$u_{CE} = - (R_C \parallel R_L) i_c$$



Diferencijsko pojačalo



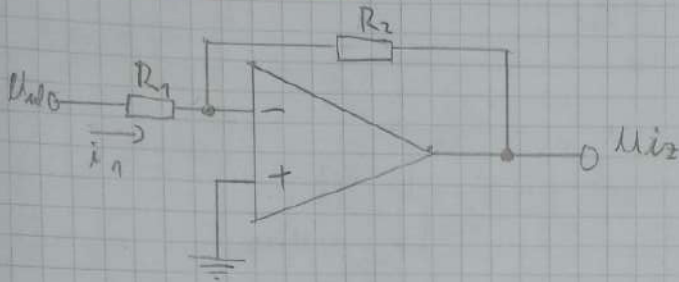
- Ako se koristi samo jedno od izlaza \Rightarrow ASIMETRIČNI IZLAZ
- Ako se koriste oba izlaza \Rightarrow SIMETRIČNI (DIFERENCIJSKI) IZLAZ

Zajednički signal: $I_{E2} = \frac{1}{2} (I_{E1} + I_{E2})$

Diferencijski signal: $I_{d1} = I_{E2} - I_{E1}$

10.) Sklopovi s operacijskim pojačalima

Invertirajuće pojačalo



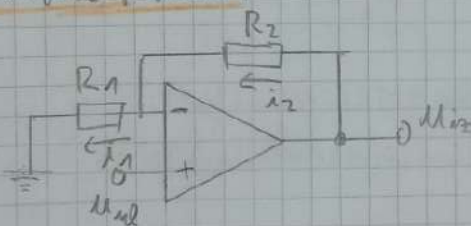
$$A_{v_i} = -\frac{R_2}{R_1}$$

$$A_{v_{ri}} = -\frac{R_2}{R_1} \frac{1}{1 + \frac{1}{A_{vOP}} \left(1 + \frac{R_2}{R_1}\right)}$$

Idealno pojačalo:

- zbog beskonačno velike ulazne impedancije, ulazne struje pojačala jednake su nuli
- zbog beskonačno velikog pojačanja ulazni približni pojačalo ima isti potencijal

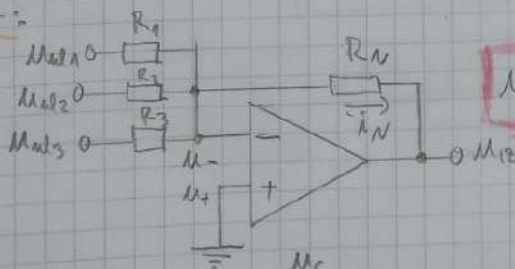
Neinvertirajuće pojačalo



$$A_{v_i} = 1 + \frac{R_2}{R_1}$$

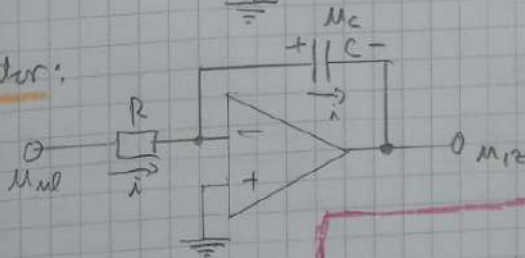
$$A_{v_{ri}} = \left(1 + \frac{R_2}{R_1}\right) \frac{1}{1 + \frac{1}{A_{vOP}} \left(1 + \frac{R_2}{R_1}\right)}$$

Sklopovi



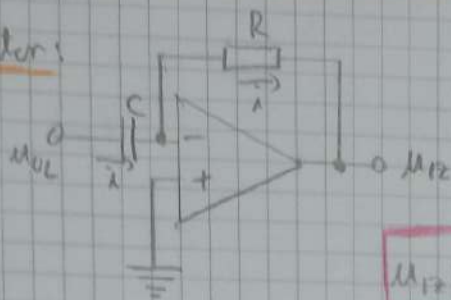
$$U_{iz} = -R_N \left(\frac{U_{ul1}}{R_1} + \frac{U_{ul2}}{R_2} + \frac{U_{ul3}}{R_3} \right)$$

Integrator



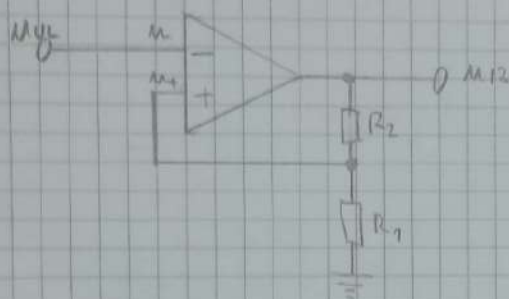
$$U_{iz}(t) = -U_c(t) = -\frac{1}{RC} \int_0^t U_{ul}(x) dx - U_{c0}$$

Derivator:



$$u_{U2}(t) = -R \dot{u}_U(t) = -RC \frac{d u_U(t)}{dt}$$

Di comparator:



$$\beta = \frac{R_1}{R_1 + R_2}$$

$$u_{U2} = \beta u_{U2}$$

$$U_{PN} = \beta U_{ref \max}$$

$$U_{PN} = -\beta U_{ref \max}$$

