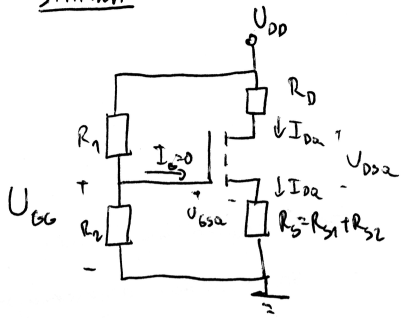
E1/ Z115

1. STATIKA



$$U_{GG} = U_{DD}\frac{R_2}{R_1+R_2} = 4{,}06\,V$$

$$U_{GSQ} = 3\,V$$

$$I_{DQ} = \frac{k}{2}(U_{GSQ}-U_{GS0})^2 = \frac{3}{2}(3-1{,}5)^2 = 2{,}25\,mA$$

$$U_{GSQ} = U_{GG} - I_{DQ}R_S \Rightarrow R_S = \frac{U_{GG}-U_{GSQ}}{I_{DQ}} = 0{,}47\,k\Omega = 470\,\Omega$$

$$R_S = R_{S1}+R_{S2} \Rightarrow R_{S1} = R_S - R_{S2} = 470-200 = 270\,\Omega$$

$$U_{DSQ} = U_{DD} - I_{DQ}(R_D+R_S) = 6{,}44\,V$$

DINAMIČKI PARAMETRI

$$i_D = \frac{k}{2}(u_{GS}-U_{GS0})^2(1+\lambda u_{DS})$$

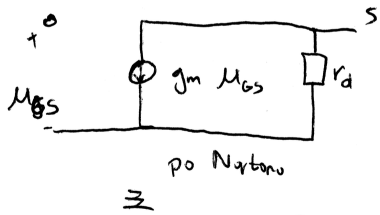
$$g_m = \frac{\partial i_D}{\partial u_{GS}}\bigg|_Q = k(U_{GSQ}-U_{GS0})(1+\lambda U_{DSQ}) = 3{,}09\,\frac{mA}{V}$$

$$r_d = \frac{1}{\frac{\partial i_D}{\partial u_{DS}}}\bigg|_Q = \frac{1}{\underbrace{\frac{k}{2}(U_{GSQ}-U_{GS0})^2\cdot\lambda}_{I_{DQ}}} = \frac{1}{\lambda I_{DQ}} = 98{,}8\,k\Omega$$

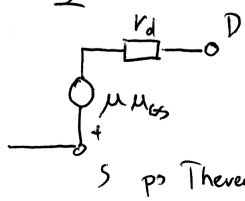
$$\mu = g_m \cdot r_d = 305$$

NADOMJESNA SHEMA

Kada je ulaz ili izlaz direktno spojen na masu



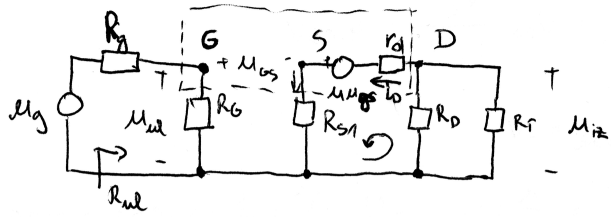
po Nortonu



po Theveninu

E1/ 21.15

$R_G = R_1 \| R_2 = 1.46\,M\Omega$



Spoj zajedničkog uvoda sa uvodskom degeneracijom

① $u_{iz} = -i_D (R_D \| R_T)$

② $i_D r_d - \mu u_{GS} + i_D R_{S1} + i_D (R_D \| R_T) = 0$

③ $u_{GS} = u_{ul} - i_D R_{S1}$

③ → ② $i_D (r_d + R_{S1} + R_D \| R_T) - \mu (u_{ul} - i_D R_{S1}) = 0$

$i_D [r_d + R_D \| R_T + (1+\mu) R_{S1}] = \mu u_{ul}$

$\Rightarrow i_D = \frac{\mu \cdot u_{ul}}{[\dots]}$ → ①

$u_{iz} = \frac{-\mu \cdot u_{ul}}{[\dots]} (R_D \| R_T) \quad / \cdot \frac{1}{u_{ul}}$

$\frac{u_{iz}}{u_{ul}} = A_v = \frac{-\mu (R_D \| R_T)}{r_d + R_D \| R_T + (1+\mu) R_{S1}} = -2.34$

za spoj zajedničkog uvoda pojačanje mora biti negativno!

$R_{ul} = \frac{u_{ul}}{i_{ul}} = \frac{i_{ul} \cdot R_G}{i_G} = R_G = 1.46\,M\Omega$

$A_{vg} = \frac{u_{iz}}{u_g} = \frac{u_{iz}}{u_{ul}} \cdot \frac{u_{ul}}{u_g} = A_v \frac{R_G}{R_G + R_g} = -2.34$

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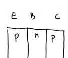
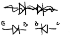
2,





$U_{BE} = -0{,}5V \Rightarrow$ propusno
$U_{CB} = 3V \Rightarrow$ zaporno $\Big\} \Rightarrow$ N.AK.

Ravnotežne koncentracije

$N_{AE} = 10^{18}\ cm^{-3}$

$p_{0E} = N_{AE} = 10^{18}\ cm^{-3}$

$n_{0E} = \frac{n_i^2}{p_{0E}} = \frac{(1{,}45 \cdot 10^{10})^2}{10^{18}} = 2{,}1 \cdot 10^2\ cm^{-3}$

$N_{DB} = 2 \cdot 10^{16}\ cm^{-3} = n_{0B}$

$p_{0B} = \frac{n_i^2}{n_{0B}} = 1{,}05 \cdot 10^4\ cm^{-3}$

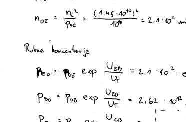
Rubne koncentracije

$n_{E0} = n_{0E} \exp \frac{U_{EB}}{U_T} = 2{,}1 \cdot 10^2 \cdot \exp \frac{0{,}5}{\frac{300}{11600}} = 5{,}23 \cdot 10^{10}\ cm^{-3}$

$p_{B0} = p_{0B} \exp \frac{U_{EB}}{U_T} = 2{,}62 \cdot 10^{12}\ cm^{-3}$

$p_{BW} = p_{0B} \exp \frac{U_{CB}}{U_T} = 0$

Raspodjele manjinskih nosilaca



b) $I_{pE} = q S D_{pB} \frac{p_{B0} - p_{BW}}{W_B}$ (uz $D_{pB} = \mu_p U_T$, $p_{BW} \approx 0$)

$W_B = 0{,}5\ \mu m$

$S = 1\ mm^2 = 1 \cdot 10^{-2}\ cm^2$

$= q S \mu_p U_T \frac{p_{B0}}{W_B} = 542\ \mu A$

$I_{nE} = q S D_{nE} \frac{n_{E0} - n_{0E}}{W_E} = q S \mu_n U_T \frac{n_{E0}}{W_E}$

$= 4{,}33\ \mu A$

$I_R = I_{pE} - I_{pC}$

$\tau_{pB} = 0{,}1\ \mu s$

$\beta^* = 1 - \frac{1}{2} \left(\frac{W_B}{L_{pB}}\right)^2$

$L_{pB} = \sqrt{D_{pB} \cdot \tau_{pB}} = \sqrt{250 \cdot \frac{300}{11600} \cdot 0{,}1 \cdot 10^{-6}} = 8{,}04 \cdot 10^{-4}\ cm$ ($D_{pB} = \mu_p \cdot U_T$)

$= 8{,}04\ \mu m$

$\beta^* = \frac{I_{pC}}{I_{pE}} = 1 - \frac{1}{2} \left(\frac{0{,}5}{8{,}04}\right)^2 = 0{,}9981$

računamo na 4 decimale do prve ne-devetke

$I_{pC} = \beta^* I_{pE} = 541\ \mu A$

$I_R = I_{pE} - I_{pC} = 1\ \mu A$

2,

$I_E = I_{nE} + I_{pE} = 546,33\,\mu A$ $\quad I_E > 0$

$I_C = -I_{pC} = -541\,\mu A$ $\quad I_C < 0$

$I_B = -I_E - I_C = -5,33\,\mu A$ $\quad I_B < 0$

$I_B = -I_R - I_{nE} = -5,3\,\mu A$

c) $\gamma = \frac{I_{pE}}{I_{pE} + I_{nE}} = 0,9921$

$\alpha = \gamma \cdot \beta^* = 0,9902$

$\beta = \frac{\alpha}{1-\alpha} = 101$

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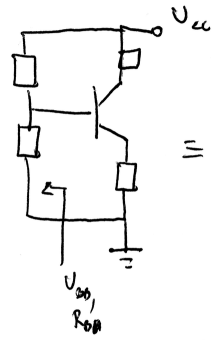
3. STATIKA



U_{BB}, R_{BB}

$U_{BB} = U_{cc} \frac{R_2}{R_1+R_2} = 3.84\,V$

$R_B = R_1 \parallel R_2 = 3.2\,k\Omega$

$I_{CQ} = \beta I_{BQ}$

$I_{EQ} = (1+\beta) I_{BQ}$

$0 = I_{BQ} R_B + U_{BEQ} + (1+\beta) I_{BQ} R_E - U_{BB}$

$I_{BQ} = \frac{U_{BB} - U_{BEQ}}{R_B + (1+\beta) R_E} = 7.05\,\mu A$

$I_{CQ} = \beta I_{BQ} = 1.41\,mA$

$U_{CEQ} = U_{cc} - I_{CQ} R_C - I_{EQ} R_E$ ($I_{CQ} \approx I_{EQ}$)

$U_{CEQ} = U_{cc} - I_{CQ}(R_C + R_E) = 5.8\,V$

DINAMIČKI PARAMETRI

$g_m = \frac{I_{CQ}}{U_T} = \frac{1.41}{0.25} = 56.4\,\frac{mA}{V}$ (strmina kod bipolarnog tranzistora je velika)

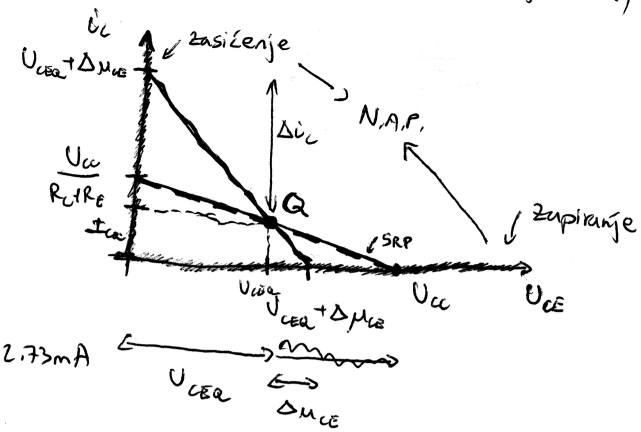
$r_{be} = \frac{U_T}{I_{BQ}} = 3.55\,k\Omega$

SRP:

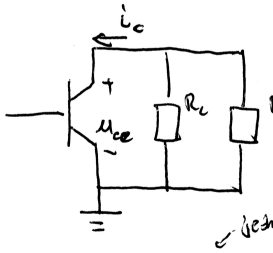
$U_{CE} = U_{cc} - I_C (R_C + R_E)$

$I_C = 0 \Rightarrow U_{CE} = U_{cc} = 12\,V$

$U_{CE} = 0 \Rightarrow I_C = \frac{U_{cc}}{R_C + R_E} = 2.73\,mA$



DRP



jednadžba dinamičkog radnog pravca

$u_{ce} = -i_c (R_C \parallel R_T)$

$u_{ce} = u_{CE} - U_{CEQ}$

$i_c = I_C - I_{CQ}$

$(u_{CE} - U_{CEQ}) = -(i_C - I_{CQ})(R_C \parallel R_T)$

$i_C = 0 \Rightarrow u_{CE} = U_{CEQ} + I_{CQ}(R_C \parallel R_T) = U_{CEQ} + \Delta u_{CE}$

$= 5.8 + 1.55 = 7.35\,V$

$u_{CE} = 0$: $i_C = I_{CQ} + \frac{U_{CEQ}}{R_C \parallel R_T}$

$i_C = I_{CQ} + \Delta i_C$

$i_C = 1.41 + 5.27$

$i_C = 6.68\,mA$

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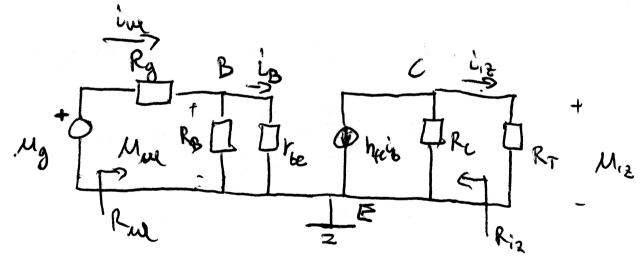
$$u_{izMAX} = u_{CEMAX} = MIN[U_{CEQ}, \Delta u_{CE}]$$

$$= MIN[5.8,\ 1.55] = 1.55V \cdot \Delta u_{CE}$$

$$i_{CMAX} = MIN[I_{CQ}, \Delta i_C] = I_{CQ}$$

$$i_{izMAX} = i_{CMAX} \cdot \frac{R_C}{R_C + R_T}$$

NADOMJESNA SHEMA



$$A_V = \frac{u_{iz}}{u_{ul}} = \frac{-h_{fe}i_b (R_C \| R_T)}{i_b \| r_{be}} = -62$$

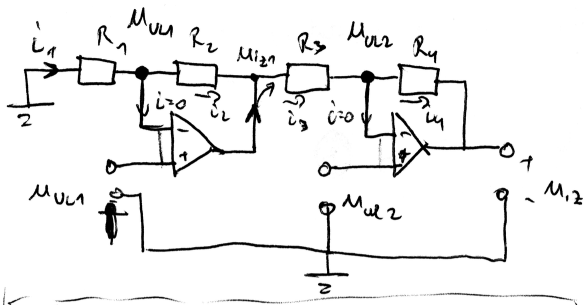
naponi i struje u probatnoj $\Leftrightarrow$ SZE

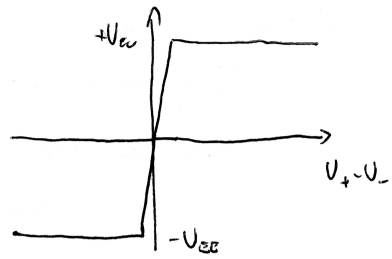
$$R_{ul} = \frac{u_{ul}}{i_{ul}} = \frac{i_{ul} \cdot (R_B \| r_{be})}{i_{ul}} = R_B \| r_{be} = 1.68\ k\Omega$$

$$A_I = \frac{i_{iz}}{i_{ul}} = \frac{\frac{u_{iz}}{R_T}}{\frac{u_{ul}}{R_{ul}}} = \frac{u_{iz}}{u_{ul}} \frac{R_{ul}}{R_T} = A_V \frac{R_{ul}}{R_T} = -47.35$$

E1/A15

4.





$$i = \frac{u_{ul1} - u_{ul2}}{R_2 + R_3}$$

nije ista struja!

NE SMIJE SE RASPISIVATI JEDNADŽBA ZA IZLAZNI ČVOR

$$* \quad u_{iz} = i\,(R_1 + R_2 + R_3 + R_4)$$

$$u_{iz} = \frac{u_{ul1} - u_{ul2}}{R_2 + R_3}\,(R_1 + R_2 + R_3 + R_4) \rightarrow \left(\frac{R_2 + R_3}{R_1 + R_2 + R_3 + R_4} \cdot u_{iz} - u_{ul1}\right) = -u_{ul2}$$

$i_1 = i_2$ $\qquad$ $i_3 = i_4$

$$\frac{0 - u_{ul1}}{R_1} = \frac{u_{ul1} - u_{iz1}}{R_2} \qquad \frac{u_{iz1} - u_{ul2}}{R_3} = \frac{u_{ul2} - u_{iz}}{R_4}$$

① $u_{iz1} = u_{ul}\left(1 + \frac{R_2}{R_1}\right)$

$$u_{iz} = u_{ul2} + \frac{R_4}{R_3}\,(u_{ul2} - u_{iz1})$$

② $= \underbrace{u_{ul2}\left(1 + \frac{R_4}{R_3}\right)}_{\text{neinvertirajuće pojačalo}} - \underbrace{\frac{R_4}{R_3}\,u_{iz1}}_{\text{invertirajuće pojačalo}}$

$$u_{iz} = \left(\frac{1 + R_4}{R_3}\right) U_{ul2} - \frac{R_4}{R_3}\left(1 + \frac{R_2}{R_1}\right) U_{ul1}$$

$$u_{ul2} = \frac{u_{iz} + \frac{R_4}{R_3}\left(1 + \frac{R_2}{R_1}\right) u_{ul1}}{1 + \frac{R_4}{R_3}} = 0{,}857\,V$$

E1/[illegible]15

1. U statici se ništa ne mijenja (C_S se ne vidi u statici)

$\Rightarrow I_{DA}$ se ne mijenja

$|A_v|$ pada jer raste otpor uvoda $\Rightarrow$ (B)

$$|A_v| \sim \frac{1}{(1+\mu)R_S}$$

2. Izlaz uzmemo iz mreže pmos / nMOS tranzistora

$$\overline{Y} = (C+E)\cdot(A+B\cdot D) \Rightarrow \text{(A)}$$

3. npn

$$\gamma = \frac{I_{nE}}{I_{nE}+I_{pE}} = \frac{1}{1+\frac{I_{pE}}{I_{nE}}}$$

$I_{pE} \sim \frac{1}{W_E}$ $I_{nE} \sim \frac{1}{W_B}$ $\Rightarrow I_{nE1} = I_{nE2}$ (širi emiter / uži emiter)

$\Downarrow$

$I_{pE1} < I_{pE2}$

$\gamma_1 > \gamma_2$

$\beta^* = \frac{I_{nC}}{I_{nE}}$, $I_{nE1} = I_{nE2}$ $\Rightarrow \beta_1^* = \beta_2^*$ (A)

4. ulaz $\rightarrow$ E $\quad i_{ul} = i_E$

izlaz $\rightarrow$ C $\quad i_{iz} = i_C$

zajednička BAZA

emiterska struja je najveća struja u tranzistoru $\quad |A_I| < 1$

na emiteru je ulijek (na kolektoru i bazi veći)

najmanji otpor $-R_{ul}$ je mali

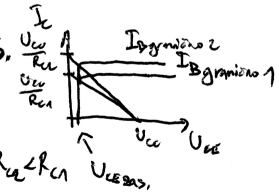
$$R_{ul} = R_E \,||\, \frac{r_{be}}{1+h_{fe}}$$

5. $U_{g1m} = 8mV$

$U_{g2m} = 0$ (B)

$U_{zm} = \frac{U_{g2m}+U_{g1m}}{2} = 4mV \Rightarrow \mu_z = 45\sin\omega t\ mV$

$|U_d| = |U_{g2m} - U_{g1m}| = 8mV \Rightarrow |\mu_d| = 8\sin\omega t\ mV$

6. 

$R_{C2} < R_{C1}$

$I_{Bgr\,max.} = \frac{I_{C\,zas.\,MAX}}{\beta_{MIN}} = \frac{U_{CC}-U_{CE\,zas.}}{\beta_{MIN}\,R_{CMIN}}$

$I_{B\,zas.\,MIN} > I_{Bgr\,max}$

$$\frac{U_{VL}-U_{BE\,zas.}}{R_{B\,MAX}} = I_{B\,zas.\,MIN} \Rightarrow \frac{U_{CC}-U_{CE\,zas.}}{\beta_{MIN}\cdot R_{CMIN}}$$

$$\beta_{MIN} > \frac{U_{CC}-U_{CE\,zas.}}{U_{VL}-U_{BE\,zas.}} \cdot \frac{R_{EMAX}}{R_{EMIN}}$$

$\beta_{MIN} > 91,43$ (B)

7. U_{izop} visoko $\Rightarrow \mu_{iz} = 3\cdot U_D = 2,1V$

U_{izop} nisko $\Rightarrow \mu_{iz} = -3\cdot U_D = -2,1V$

- negativna povratna veza s izlaza na invertirajući ulaz $\Rightarrow$ linearni vežim
- neinvertirajuće pojačalo

$\mu_{iz} = \mu_{UC}\left(1+\frac{R_2}{R_1}\right) = \mu_{ul}\cdot 2 = \boxed{+0,2V}$

$\mu_{iz} = MAX(\mu_{iz}, 2,1V)$