LJETNI 2014.

① pn dioda $S = 1\,mm^2$

$N_D = 5 \cdot 10^{18}\,cm^{-3}$ $N_A = 6 \cdot 10^{15}\,cm^{-3}$

$\mu_n = 620\,cm^2/Vs$ $\mu_p = 320\,cm^2/Vs$

$\tau_n = 0{,}7\,\mu s$ $\tau_p = 1\,\mu s$

$W_n = 300\,\mu m$ $W_p = 1{,}5\,\mu m$ $T = 300K$

$D_n = U_T \mu_n = 16{,}03$ $L_n = 3{,}35 \cdot 10^{-3}\,cm$ $n_{op} = 35042$

$D_p = U_T \mu_p = 8{,}276$ $L_p = 2{,}877 \cdot 10^{-3}\,cm$ $p_{on} = 42$

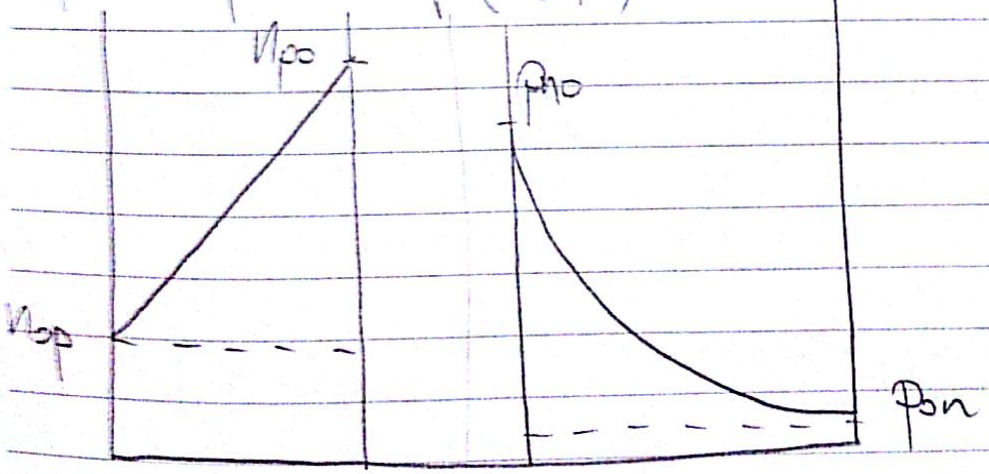
$W_n \gg L_p$ $W_p \ll L_n \Rightarrow$ široka n, uska p

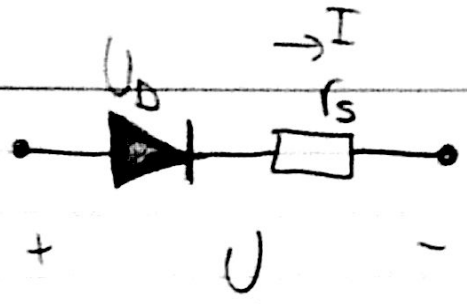
$$I_S = q \cdot S \left(D_n \frac{n_{op}}{W_p} + D_p \frac{p_{on}}{L_p} \right) = 5{,}9919 \cdot 10^{-12}\,A$$

$U_D = 0{,}5\,V$

$$n_{po} = n_{op} \cdot \exp\left(\frac{U}{U_T}\right) = 8{,}729 \cdot 10^{12}\,cm^{-3}$$

$$p_{no} = p_{on} \cdot \exp\left(\frac{U}{U_T}\right) = 1{,}046 \cdot 10^{10}\,cm^{-3}$$





$U_D = 0{,}5\,V$

$r_S = 4{,}5 = 9\,\Omega$

$U = U_D + I\,r_S$

$U = 0{,}5 + 1{,}493 \cdot 10^{-3} \cdot 9 = 0{,}513$

$I = I_S \cdot \left(\exp\frac{U}{m U_T} - 1\right)$

$I = 1{,}493\,mA$

$C_B = \varepsilon \cdot \frac{S}{d_B} = 4{,}662$

$d_B = \sqrt{\frac{2\varepsilon}{q}\left(\frac{1}{N_A} + \frac{1}{N_D}\right)(U_K - U)}$

$d_B = 1{,}13 \cdot 10^{-4}\,cm$

$U_K = U_T \ln\left(\frac{n_{on}\,p_{op}}{n_i^2}\right)$

$U_K = 0{,}84288\,V$

② $\lambda = 0V^{-1}$ p-kanalni, ostronaček

$$K = \mu \frac{\varepsilon_{ox}}{t_{ox}} \cdot \frac{W}{L}$$

$t_{ox} = 10nm$ $\mu_n = 150 \, cm^2/Vs$

$L = 0,35 \mu m$ $U_{GS0} = 0,5V$

$$A: I_{DA} = K\left((U_{GSA} - U_{GS0})U_{DS} - \frac{U_{DS}^2}{2}\right)$$

$g_{mA} = KU_{DS} = 1,5 \cdot 10^{-3}$

$$C: I_{DC} = \frac{K}{2}(U_{GSC} - U_{GS0})^2$$

$$B: I_{DB} = \frac{K}{2}(U_{GSB} - U_{GS0})^2$$

$$K = \frac{2I_{DC}}{(U_{GSC} - U_{GS0})^2} = -3 \cdot 10^{-3}$$

$I_{DA} = -1,125 \, mA$

$$W = K \cdot \frac{L \cdot t_{ox}}{\mu \, \varepsilon_{ox}} = 2,027 \cdot 10^{-3} \, cm$$

$I_{DB} = -6 \, mA$

$g_{mB} = K(U_{GSB} - U_{GS0}) = 6 \cdot 10^{-3}$

$\lambda = ?$ $U_{DSB} = -2,5V$

$I_{DB} = 6,15 \, mA$

$$I_{DB} = \frac{K}{2}(U_{GSB} - U_{GS0})^2(1 + \lambda U_{DS})$$

$$-6,15 \cdot 10^{-3} = -6 \cdot 10^{-3}(1 - \lambda \cdot 2,5)$$

$$1 - \lambda 2,5 = 1,025$$

$$\lambda = \frac{0,025}{-2,5} = -0,01$$

③ $U_{DD} = 12\,V$ $R_g = 500\,\Omega$ $R_1 = 300\,k\Omega$ $R_2 = 180\,k\Omega$
$R_D = 2\,k\Omega$ $R_T = 4{,}7\,k\Omega$

$K = 2{,}25\,mA/V^2$ $\lambda = 0{,}0045\,V^{-1}$

SPOJ ZAJEDNIČKE UPRAVLJAČKE ELEKTRODE

$U_{DS} = 3{,}5\,V$ $I_{D2} = 3\,mA$ $U_{GS} = 2\,V$

$I_{D2} = \frac{K}{2}(U_{GS} - U_{GSO})^2$ $I_{D2} = \frac{K}{2}(U_{GS}^2 - 2U_{GS}U_{GSO} + U_{GSO}^2)$

$U_{GG} = 4{,}5\,V$ $R_G = 112{,}5\,k\Omega$

$\frac{2I_{D2}}{K} - U_{GS}^2 + 2U_{GS}U_{GSO} - U_{GSO}^2 = 0$

$+1{,}33 - 4U_{GSO} + U_{GSO}^2 = 0$

$U_{GSO_{1,2}} = \frac{+4 \pm \sqrt{16 - 4 \cdot 1{,}33}}{2}$

$U_{GSO_1} = 3{,}63\,V$

$U_{GSO_2} = 0{,}366\,V$

KVK $U_{GG} = U_{GSQ} + I_{DQ}R_S$

$R_S = \frac{U_{GG} - U_{GSQ}}{I_{DQ}}$

$R_S = 833\,\Omega$

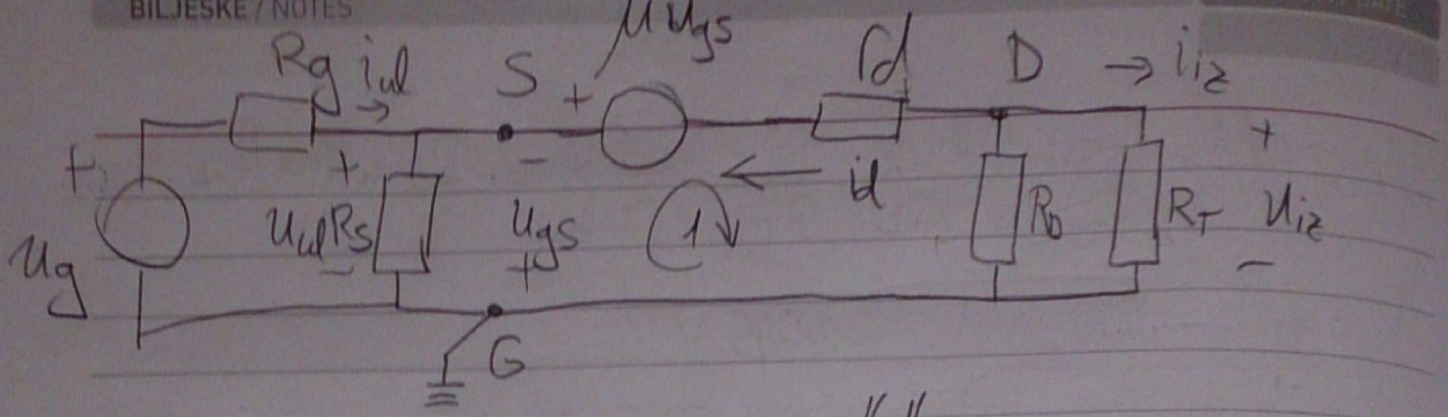
$|U_{DS}| > |U_{GSQ} - U_{GSO}|$

$|3{,}5| > |2 - 0{,}366|$ ✓ je u zasićenju!

DP $g_m = \left.\frac{\partial i_D}{\partial u_{GS}}\right|_Q = K(U_{GSQ} - U_{GSO})(1 + \lambda U_{DS}) = 3{,}73\,mA/V$

$r_d = \left.\frac{1}{\frac{\partial i_D}{\partial u_{DS}}}\right|_Q = \frac{1}{\frac{K\lambda}{2}(U_{GSQ} - U_{GSO})^2} = 73983\,\Omega$

$\mu = 275{,}957$



$$A_V = \frac{u_{iz}}{u_{ul}}$$

$$A_V = \frac{(1+\mu)\,u_{ul}}{u_{ul}}$$

$$A_V = \frac{(1+\mu)(R_D \| R_T)}{r_d + R_D \| R_T}$$

$$A_V = 5{,}15$$

"1"

$$-u_{gs} - \mu u_{gs} + r_d i_d + (R_D \| R_T) i_d = 0$$

$$i_d = \frac{-(1+\mu)\,u_{ul}}{r_d + R_D \| R_T}$$

$$u_{iz} = -\,i_d \cdot (R_D \| R_T)$$

$$u_{iz} = \frac{(1+\mu)\,u_{ul}}{r_d + R_D \| R_T}\,(R_D \| R_T)$$

$$A_{Vg} = \frac{u_{iz}}{u_{ul}} \cdot \frac{u_{ul}}{u_g} = A_V \cdot \frac{u_{ul}}{u_g} = 4{,}05 \qquad u_{ul} = u_g \cdot \frac{R_S}{R_g + R_S}$$

$$G_{Mg} = \frac{i_{iz}}{u_g}$$

$$i_{iz} = -\,i_d \cdot \frac{R_D}{R_D + R_T}$$

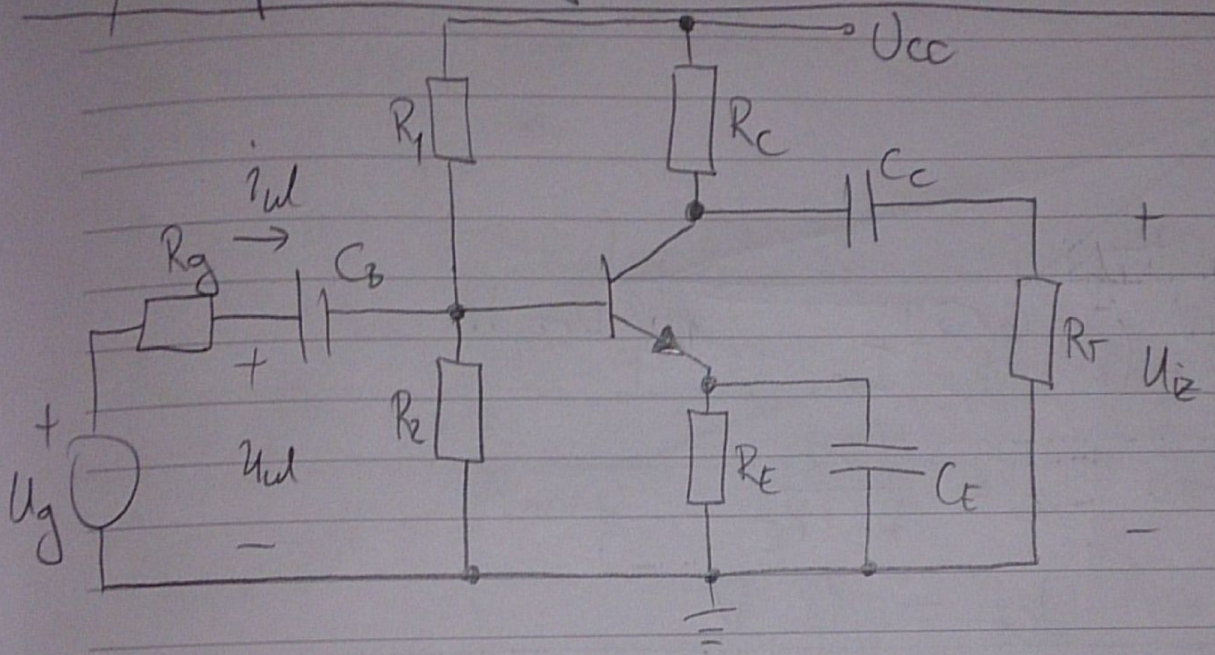
$$G_{Mg} = \frac{(1+\mu)(R_D \| R_T)}{r_d + R_D \| R_T} \cdot \frac{R_S}{R_g + R_S}$$

$$i_{iz} = \frac{(1+\mu)\cdot(R_D \| R_T)}{r_d + R_D \| R_T} \cdot u_g \frac{R_S}{R_g + R_S}$$

$$G_{Mg} = 4{,}05\ A/V$$

④ $R_1 = 12\,k\Omega$ $R_2 = 4{,}7\,k\Omega$ $R_E = 1\,k\Omega$ $R_C = 2\,k\Omega$ $R_T = 2\,k\Omega$
$R_g = 50\,\Omega$ $U_{CC} = 12\,V$

$\beta = h_{fe} = 150$ $U_\gamma = 0{,}7\,V$ $U_T = 25\,mV$



ZAJEDNIČKI EMITER

$U_{BB} = 3{,}377\,V$ $R_B = 3{,}377\,k\Omega$

JUK $U_{BB} = I_B \cdot R_B + U_{BE} + (I_B + I_C) R_E$ $I_C = \beta I_B$

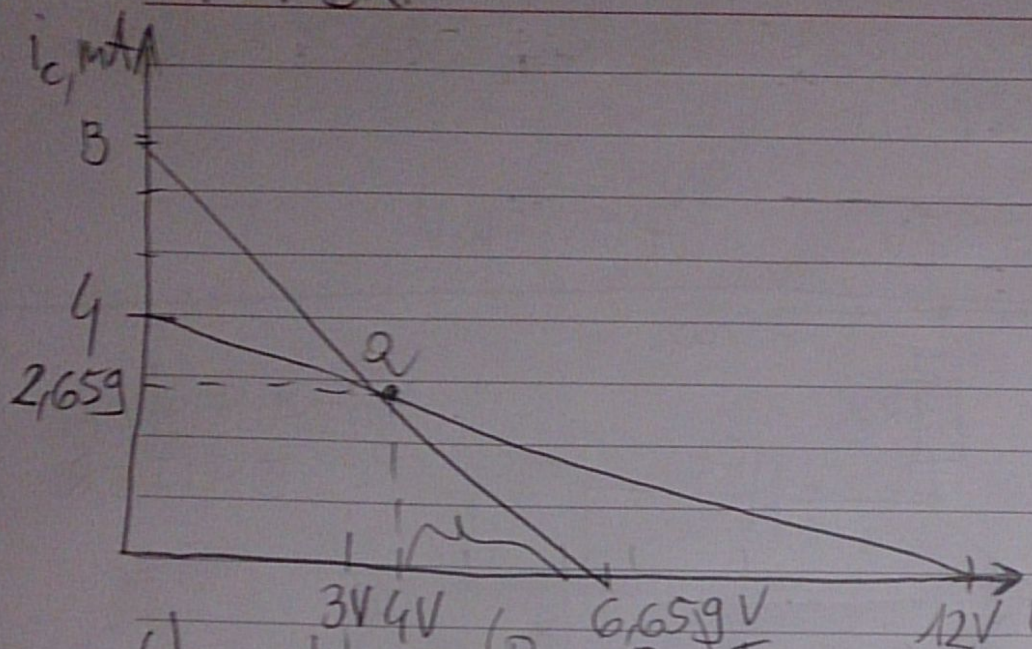
$I_{BQ} = \frac{U_{BB} - U_{BEQ}}{R_B + (1+\beta) R_E} = 1{,}773 \cdot 10^{-5}\,A$ $I_{CQ} = 2{,}659\,mA$

JIK $U_{CC} = I_C \cdot R_C + U_{CE} + (I_C + I_B) R_E$

$U_{CEQ} = U_{CC} - I_C R_C - (I_C + I_B) R_E = 4\,V$

DP $r_{be} = \frac{U_T}{I_{BQ}} = 1459\,\Omega$ $g_m = \frac{h_{fe}}{r_{be}} = 0{,}102834\,S$

SRP i DRP



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

$$U_{CE} = 0 \Rightarrow I_C = \frac{U_{CC}}{R_C + R_E} = 4\,mA$$

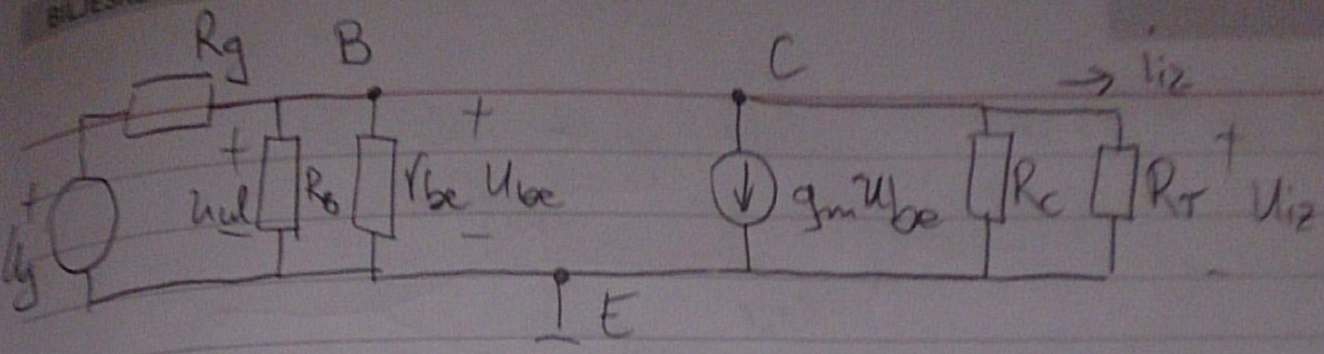
$$I_C = 0 \Rightarrow U_{CE} = 12\,V$$

$$u_{CE} = U_{CEQ} + \Delta U_{CE} = U_{CEQ} + (R_C \| R_T) I_{CQ} = 6,659\,V$$

$$i_C = I_{CQ} + \Delta i_C = I_{CQ} + U_{CEQ} / (R_C \| R_T) = 6,659\,mA$$

$$u_{izmax} = u_{cemax} = 6,659 - 4 = 2,659\,V$$

$$i_{izmax} = I_{cmax} \cdot \frac{R_C}{R_C + R_T} = 1,33\,mA$$



$A_{vg} = ?$ $A_v = \frac{u_{iz}}{u_{ul}}$ $u_{iz} = -g_m u_{be} \cdot (R_c \| R_T)$

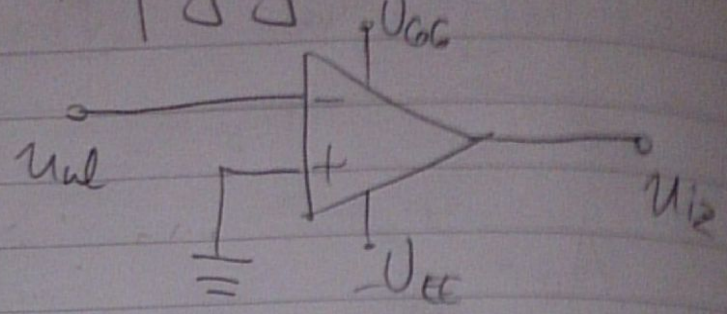
$u_{ul} = u_{be}$

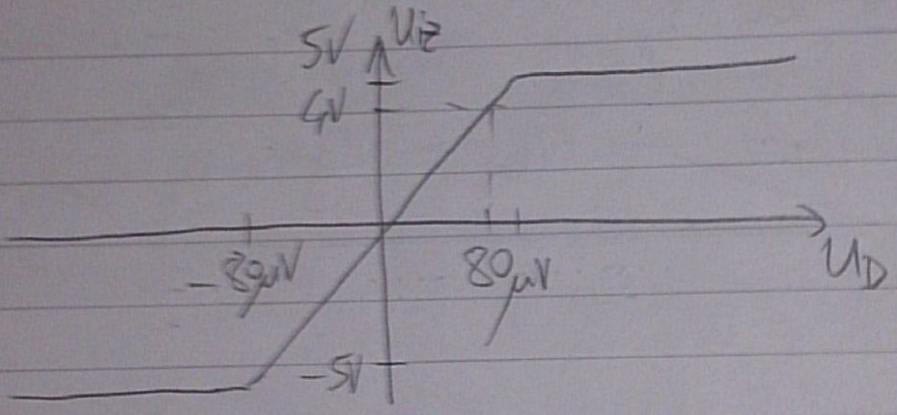
$A_v = -g_m (R_c \| R_T) = -102,834$

$A_{vg} = A_v \cdot \frac{u_{ul}}{u_g} = -99,427$ $u_{be} = u_g \cdot \frac{r_{be}}{R_g + r_{be}}$

$U_{g_{max}} = ?$

(5) $A_{VOP} = 50\,000$ napajanje $-5V, 5V$





$4 = 5000 \cdot x \Rightarrow x = 80\,\mu V$