

2.9.2014

① $R_p = 3.6 \text{ } \Omega \text{ cm} \gg R_n$
 $\mu_p = 460 \text{ cm}^2/\text{Vs}$
 $I_D = 5 \text{ mA}$
 $U_D = 0.56 \text{ V}$

objekt silnik

$$W_p \gg L_n$$

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$$\mu_n = 1380 \text{ cm}^2/\text{Vs}$$

$$S = 1 \text{ mm}^2$$

$$T = 300 \text{ K}$$

$$m = 1$$

2. bez. exponentialnog
pauze

$$Q_n = q S (n_{p0} - n_{op}) \cdot L_n$$

$$=$$

a) $R_p = ?$

$$G_p = q \cdot \mu_p \cdot P$$

$$R_p = \frac{1}{q \mu_p P}$$

$$N_A \approx P_{op} = \frac{1}{q \mu_p R_p} = 10 \cdot 10^{14} \text{ cm}^{-3}$$

$$n_{op} = \frac{n_i^2}{P_{op}} = 210 \cdot 250 \text{ cm}^{-3}$$

$$n_{p0} = n_{op} \exp\left(\frac{U}{U_T}\right) = 5.33 \cdot 10^{14} \text{ cm}^{-3}$$

$$D_n = \mu_n \cdot U_T = 35.69 \text{ cm}^2/\text{s}$$

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

fali mi τ_n za ovo

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

b) $U = 0.05$

$$I_S = 8.46 \cdot 10^{-4} \text{ A}$$

$$r_{ol} = \frac{U_T}{I_S \exp\left(\frac{U_D}{U_T}\right)} = 4.42 \text{ } \Omega$$

$$U = 0.6 \text{ V}$$

$$r_{ol} = 2.56 \cdot 10^{-9} \text{ } \Omega$$

②

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$$U_{GSB} = 4V$$

$$g_{mB} = 3mA/V$$

$$I_{DB} = 5mA$$

$$U_{DSB} = 15V$$

$$\frac{dI_D}{dU_{GS}} = K (U_{GS} - U_{GS0})$$

$$I_D = \frac{K}{2} (U_{GSB} - U_{GS0})^2 \quad \frac{3 \cdot 10^{-3}}{(4 - U_{GS0})} = K$$

$$2 \cdot 5 \cdot 10^{-3} = \frac{3 \cdot 10^{-3}}{(4 - U_{GS0})} (4 - U_{GS0})^2$$

$$\frac{10}{3} - 4 = -U_{GS0}$$

$$U_{GS0} = 0.67V$$

$$K = \frac{3 \cdot 10^{-3}}{4 - 0.67} = 0.9mA/V$$

$$c) U_{DS} \quad du \quad \mu = 3$$

$$\mu = g_m \cdot r_d$$

$$\frac{1}{r_d} = \frac{dI_D}{dU_{DS}}$$

$$3 = K \cdot \frac{1}{(U_{GSA} - U_{GS0}) \cdot K - U_{DSA}}$$

$$\frac{1}{r_d} = (U_{GSA} - U_{GS0}) \cdot K - U_{DSA}$$

$$g_m = \frac{dI_D}{dU_{GS}} = K$$

③ $V_{DD} = 3.3V$
 $R_g = 100 k\Omega$
 $R_1 = 520 k\Omega$
 $R_2 = 1.8 M\Omega$

$R_T = 270 k\Omega$
 $R_D = 530 \Omega$
 $K = 8 mA/V^2$
 $V_{GS0} = 1V$

$\lambda = 0,002 V^{-1}$

U_{kz} - gate
 i_{kz} - drain
 spoj zajedničkog SOURCE-a

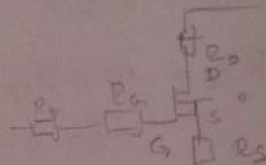
a) $I_{DQ} = 2 mA$

$V_{GG} = V_{DD} \cdot \frac{R_2}{R_1 + R_2} = 2.56V$

$R_G = R_1 || R_2 = 403,45 k\Omega$

JUK

$V_{GG} = V_{GSQ} + I_{DQ} \cdot R_S$



JIK

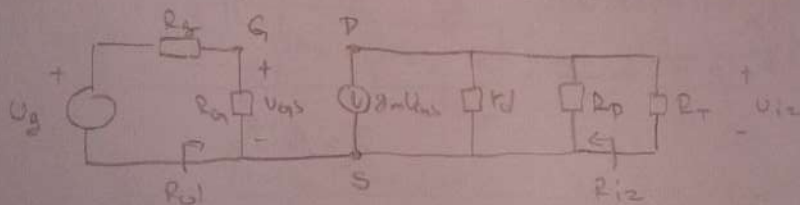
$V_{DD} = I_{DQ}(R_D + R_S) + V_{DSQ} \quad \sqrt{\frac{2I_D}{K}} + V_{GS0} = V_{GSQ}$

$R_S = \frac{V_{GG} - V_{GSQ}}{I_{DQ}} = 333 \Omega$

$V_{GSQ} = 1.894V$

$V_{DSQ} = 1.974V$

b) naponska i dinamička



$g_m = \frac{dI_D}{dV_{GS}} = K(V_{GSQ} - V_{GS0})(1 + \lambda V_{DSQ}) = 4.49 mA/V$

$\frac{1}{r_d} = \frac{dI_D}{dV_{DS}} = \frac{\lambda K}{2}(V_{GSQ} - V_{GS0})^2 = 3.98 \cdot 10^{-6} S$

$r_d = 250,23 k\Omega$

$M = g_m \cdot r_d = 1123,53$

$$c) A_{vg} = \frac{v_{i2}}{v_g}$$

$$v_{gs} = \frac{v_g \cdot R_G}{R_g + R_G}$$

$$A_{vg} = \frac{v_{i2}}{v_g} \cdot \frac{v_{o1}}{v_{i1}} = A_v \cdot \frac{v_{o1}}{v_g} = A_v \cdot \frac{v_g \cdot \frac{R_G}{R_g + R_G}}{v_g}$$

$$= A_v \cdot \frac{R_G}{R_g + R_G} = -g_m r_d \parallel R_D \parallel R_T \cdot \frac{R_G}{R_g + R_G} = -1.184$$

$$d) R_{i1} = R_{G1} = 403.45 \text{ k}\Omega$$

$$R_{i2} = r_d \parallel R_D \approx R_D = 330 \text{ }\Omega$$

\parallel
 329.57

$$\textcircled{4} \quad U_{CC} = 12 \quad R_1 = 47 \text{ k}\Omega \quad R_C = 4.3 \text{ k}\Omega$$

$$R_g = 50 \text{ }\Omega \quad R_2 = 15 \text{ k}\Omega \quad R_E = 2.4 \text{ k}\Omega$$

$$\beta = h_{fe} = 150 \quad U_g = 0.7 \text{ V} \quad R_T = 3.3 \text{ k}\Omega$$

$$U_T = 25 \text{ mV}$$

U_{i2} - emitter
 U_{o1} - kolektor } SZB

$$a) I_{BQ}, I_{CQ}, U_{CEQ}$$

$$U_{BB} = U_{CC} \cdot \frac{R_2}{R_1 + R_2} = 2.9 \text{ V}$$

$$R_B = R_1 \parallel R_2 = 11.37 \text{ k}\Omega$$

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$$I_C = \beta \cdot I_B$$

$$U_{BB} = (I_B + I_C) \cdot R_E + U_{BEQ} + I_B R_B$$

$$U_{BB} = I_B [R_B + (1 + \beta) R_E]$$

$$I_{BQ} = \frac{U_{BB} - U_{BEQ}}{R_B + (1 + \beta) R_E} = \boxed{5.89 \cdot 10^{-6} \text{ A}}$$

$$I_{CQ} = \beta \cdot I_{BQ} = \boxed{8.83 \cdot 10^{-4} \text{ A}}$$

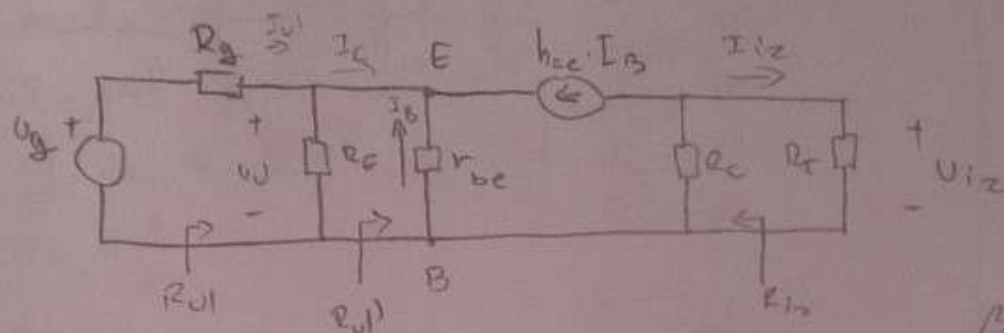
J1K

4) nastavak

$$U_{CC} = I_{CQ} R_C + (I_{BQ} + I_{CQ}) \cdot R_E + U_{CEQ}$$

$$(U_{CEQ} = 6.1 \text{ V})$$

b) naponska shema (crtam s obrnutim polaritetima U_{i2} jer su asistenti rekli da je to greška)

 $\beta \gg 1$

pa zanemarujemo r_{ce}

$$r_{be} = \frac{U_T}{I_{BQ}} = 4.244 \text{ k}\Omega$$

$$A_V = \frac{U_{i2}}{U_{U1}} = \frac{-h_{fe} i_b \cdot (R_C \parallel R_T)}{-i_b r_{be}} = h_{fe} \frac{(R_C \parallel R_T)}{r_{be}} = 66$$

$$R_{U1}' = \frac{r_{be}}{h_{fe}}$$

$$\begin{aligned} A_I = \frac{i_{i2}}{i_{U1}} &= \frac{-h_{fe} i_b \cdot \frac{R_C}{R_C \parallel R_T}}{-(1+h_{fe}) i_b \cdot \frac{R_E + R_{U1}'}{R_E}} \\ &= \frac{h_{fe}}{1+h_{fe}} \cdot \frac{R_C}{R_C + R_T} \cdot \frac{R_E}{R_E + R_{U1}'} = 0.56 \end{aligned}$$

$$R_{U1} = \frac{U_{U1}}{I_{U1}} = \frac{-i_b r_{be}}{-(1+h_{fe}) i_b \frac{R_E + R_{U1}'}{R_E}} = 217.78 \Omega$$

$$A_{Vg} = \frac{U_{i2}}{U_g} = A_V \cdot \frac{R_{U1}}{R_g + R_{U1}} = 23.57$$

⑤ $R_1 = 3 \text{ k}\Omega$

$R_2 = 9 \text{ k}\Omega$

a) U_{i2} u ovisešti $R_1, R_2, U_1, U_2, U_3, U_4$ i R

$U_{+1} = U_{-1}$

$U_{+2} = U_{-2} = 0$

① $I_1 = \frac{U_1 - U_{+1}}{R}$

$I_2 = \frac{U_2 - U_{+1}}{R}$

$I_3 = \frac{U_3 - U_{+1}}{R}$

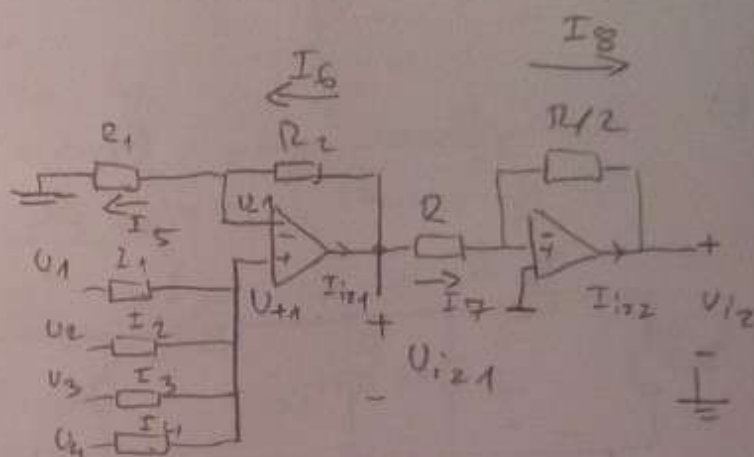
$I_4 = \frac{U_4 - U_{+1}}{R}$

$I_5 = \frac{U_{+1}}{R_1}$

$I_6 = \frac{U_{i21} - U_{+1}}{R_2}$

$I_7 = \frac{U_{i21}}{R}$

$I_8 = \frac{0 - U_{i2}}{R/2}$



\rightarrow
 $I_{1-4, 5, 6, 7, 8}$

② $I_1 + I_2 + I_3 + I_4 = 0$

$0 = \frac{U_1 - U_{+1}}{R} + \frac{U_2 - U_{+1}}{R} + \frac{U_3 - U_{+1}}{R} + \frac{U_4 - U_{+1}}{R}$

$0 = U_1 + U_2 + U_3 + U_4 - 4U_{+1}$

$U_{+1} = \frac{U_1 + U_2 + U_3 + U_4}{4} \quad (1)$

③ $I_5 = I_6$

$\frac{U_{+1}}{R_1} = \frac{U_{i21} - U_{+1}}{R_2} \Rightarrow U_{+1} \left(\frac{1}{R_1} + \frac{1}{R_2} \right) = \frac{U_{i21}}{R_2}$

$U_{i21} = \left(1 + \frac{R_2}{R_1} \right) \left(\frac{U_1 + U_2 + U_3 + U_4}{4} \right) \quad (2)$

$\frac{U_{i21}}{R} = - \frac{U_{i2}}{R/2}$

$U_{i2} = -2 U_{i21}$

c)

$U_{i21} = 10 \text{ V}$

$U_{i2} = -20 \text{ V}$