Z1. n kanalni MOSFET

$U_{DD} = 20V$

$R_g = 2k\Omega$

$R_1 = 450k\Omega$

$R_2 = 100k\Omega$

$R_{S1} = 1k\Omega$

$R_{S2} = 1k\Omega$

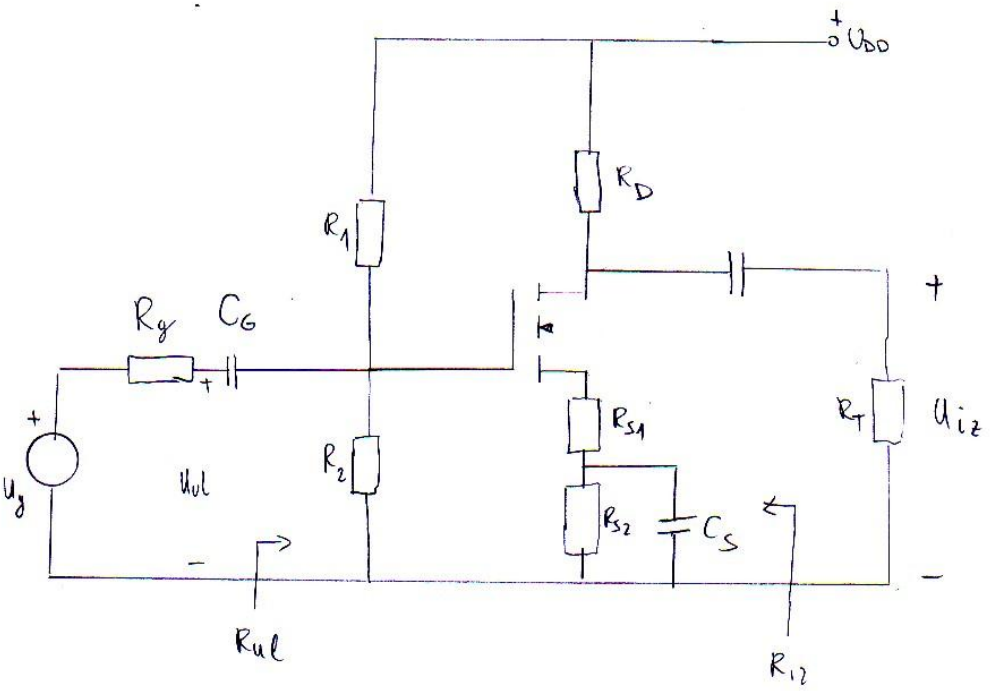
$R_D = 8k\Omega$

$R_T = 12k\Omega$

$K = 5mA/V^2$

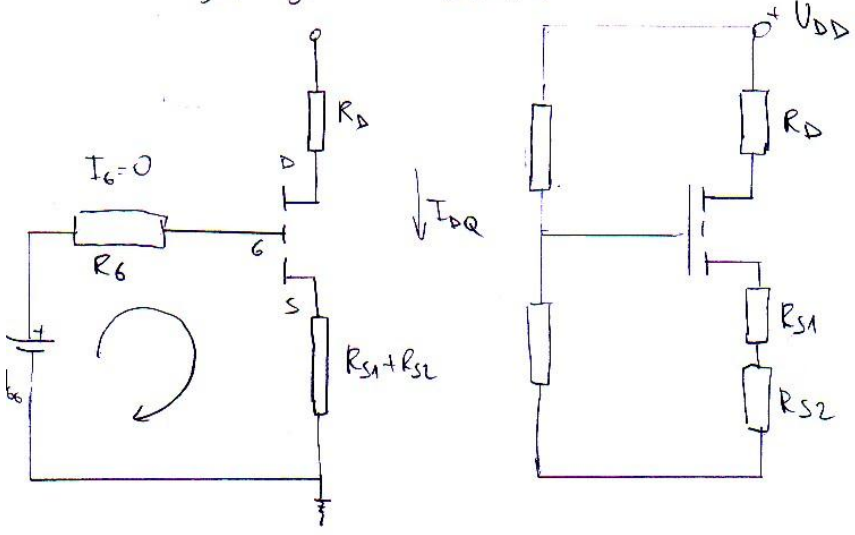
$U_{GSO} = 1V$

$\lambda = 0{,}005\ V^{-1}$



STATIKA

- ODSPOJIMO KONDEZATORE
- NADOMJESTANJE PO TRENUTNU



(1) $-U_{GG} + \phi + U_{GSQ} + I_{DQ}(R_{S1} + R_{S2}) = 0$

(2) $I_{DQ} = \frac{K}{2}(U_{GSQ} - U_{GSO})^2$ → UVRSTIĆE NJU

↳ $R_S = R_{S1} + R_{S2}$

Z1

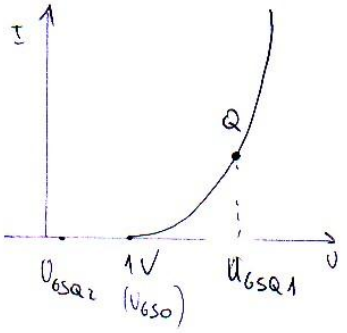
(2) -> (1)

$$U_{GSQ}^2 + 2\left(\frac{1}{K R_S} - U_{GSO}\right) U_{GSQ} + U_{GSO}^2 - 2\frac{U_{GG}}{K \cdot R_S} = 0$$

$$U_{GSQ}^2 + 1{,}8\, U_{GSQ} + 0{,}247 = 0$$

$U_{GSQ1} = 1{,}63\,V$

$U_{GSQ2} = 0{,}168\,V$



$U_{GSQ1} = 1{,}63\,V$ ✓

- fizikalno prihvatljivo
RADI $U_{GSO} = -1\,V$

$$I_{DQ} = \frac{K}{2}\left(U_{GSQ} - U_{GSO}\right)^2 = \ldots = 1\,mA$$

("U FORMULU UVRSTI BROJEVE PA AK KRIVO ZRAČUNAJ (PAK DOBIJEŠ BOD!)

ZA IZLAZNI KRUG

$$U_{DSQ} = U_{DD} - I_{DQ}\left(R_D + R_{S1} + R_{S2}\right) = \ldots = 10\,V$$

PROVJERA ZA RAD U ZASIĆENJU

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

ZASIĆENJE ✓

$$|10| > |1{,}63 - 1|$$

DINAMIČKI PARAMETRI

$$i_D = \frac{K}{2}\left(U_{GS} - U_{GSO}\right)^2 \left(1 + \lambda U_{DS}\right)$$

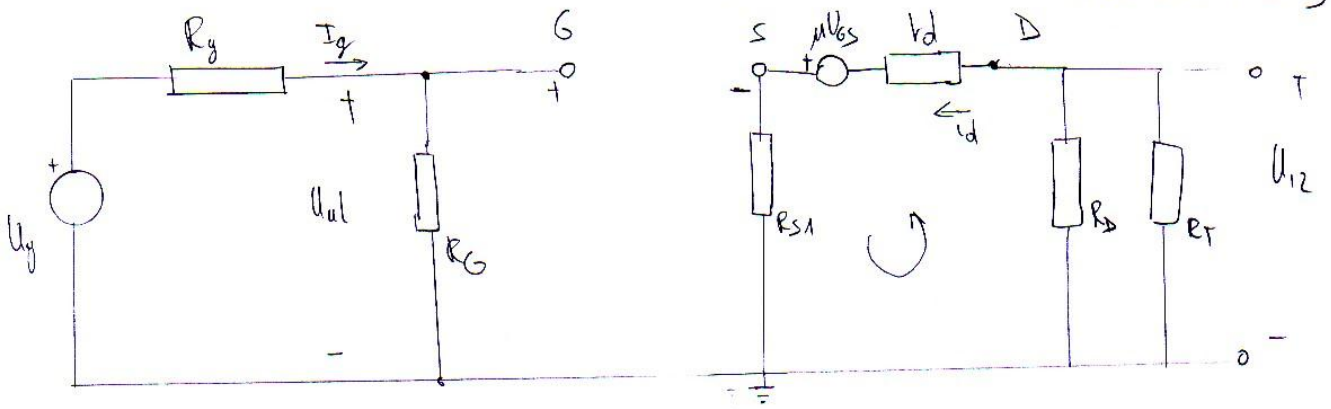
$$g_m = \left.\frac{\partial i_D}{\partial U_{GS}}\right|_Q = \frac{K}{2}\left(1 + \lambda U_{DSQ}\right) \cdot 2\left(U_{GS} - U_{GSO}\right) = \frac{5}{2}\left(1 + 0{,}001 \cdot 10\right) \cdot 2\left(1{,}63 - 1\right) = 3{,}3\,mA/V$$

$$r_d = \left.\frac{1}{\frac{\partial I_D}{\partial U_{DS}}}\right|_Q = \frac{1}{\frac{K}{2}\left(U_{GSQ} - U_{GSO}\right)^2 \cdot \lambda} = \frac{1}{I_{DQ} \cdot \lambda} = 200\,k\Omega$$

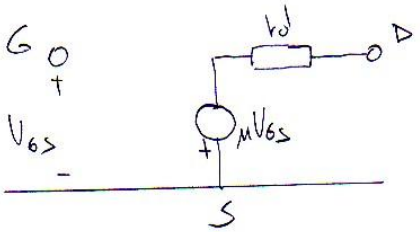
↳ I_{DQ}

7. DINAMIKA

→ "GASIMO" U_{DD} tj. spajamo na masu, KONDENZATORE PREDSTAVLJAJU KRATKI SPOJ



- PO THEVENINU (niti S niti D NISU DIREKTNO SPOJENI NA MASU)



(1) $U_{iz} = -i_d (R_D \| R_T)$

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

(3) $U_{GS} = U_{ul} - i_d R_{S1}$

(3) → (2)

$i_d (R_D \| R_T) + i_d r_d - \mu (U_{ul} - i_d R_{S1}) + i_d R_{S1} = 0$

$i_d \left[R_D \| R_T + r_d + (1+\mu) R_{S1} \right] = \mu U_{ul}$

$- \frac{U_{iz}}{R_D \| R_T} \left[R_D \| R_T + r_d + (1+\mu) R_{S1} \right] = \mu U_{ul}$

$A_v = \frac{U_{iz}}{U_{ul}} = \frac{-\mu (R_D \| R_T)}{(R_D \| R_T + r_d + (1+\mu) R_{S1})} = -3{,}60$

↳ ULOOSKA DEGENERACIJA

} SZS – protufaza

$A_v < 0$

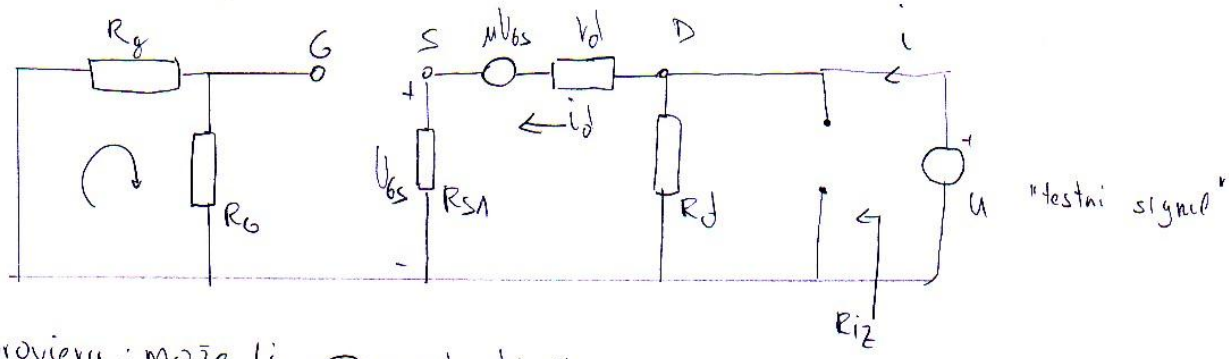
2₁

$$A_{vg} = \frac{u_{iz}}{u_g} = \frac{u_{iz}}{u_{ul}} \cdot \frac{u_{ul}}{u_g} = A_v \cdot \frac{R_G}{R_G + R_g} = -3{,}56$$

1c)

$$R_{ul} = \frac{u_{ul}}{I_{ul}} = \frac{i_{ul} \cdot R_G}{i_{ul}} = R_G = 81{,}8\ k\Omega$$

R_{iz} - gasimo pobudu $U_G = 0$



- provjera: može li ④ postaviti U_{GS} → može, imamo ZATVORENU PETLJU
  → ZAKLJUČAK: μU_{GS} moramo imati

$$i = i_d + \frac{U}{R_D}$$

$$u = i_d \cdot r_d - \mu U_{GS} - U_{GS} = i_d r_d - (1-\mu) U_{gs} \quad \Big\} U_{gs} = -i_d R_{S1}$$

$$u = i_d r_d + i_d (1+\mu) R_{S1} \rightarrow i_d = \frac{u}{r_d + (1+\mu) R_{S1}} \mapsto i = \frac{u}{r_d + (1+\mu) R_{S1}} + \frac{u}{R_D}$$

$$\rightarrow \frac{u}{i} = R_{iz} = R_D \,||\, [r_d + (1+\mu) R_{S1}] \approx 8\,k\Omega \sim R_D$$

↳ OVO SE VIDI U DRAIUU

$R_{iz} \simeq R_D$, ali se mora dokazat ako samo napisati

- u S mali otpor
- u D veliki otpor

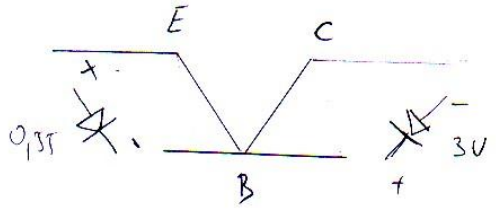
22. BIPOLARNI pnp

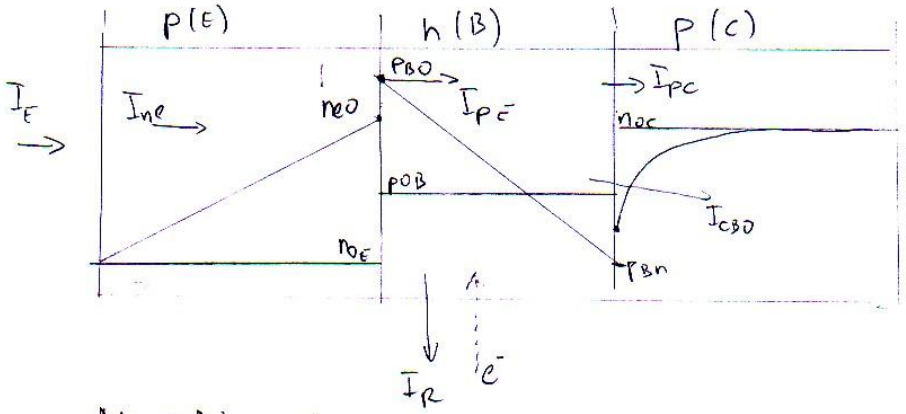
$U_{BE} = -0{,}55\,V \rightarrow U_{EB} = 0{,}5\,V$ NAP

PROPUSNO

$V_{CB} = -3\,V$

ZAPORNO





- emiter uzak – linear
- baza uska – linear
- kolektor širok – exp

$N_{AE} > N_{DB} > N_{AC}$

$p_{0E} > n_{0B} > p_{0C}$ – većinski $\qquad n_{0E} < p_{0B} < n_{0C}$ → manjinski

$$n_{0E} = \frac{n_i^2}{p_{0E}} \approx \frac{n_i^2}{N_{AE}} = 1{,}05 \cdot 10^7\ cm^{-3}$$

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

→ BOLTZMAN (PAZI NA PREDZNAK, OVO JE ZA PNP)

$$n_{E0} = n_{0E} \exp\left(-\frac{U_{BE}}{U_T}\right) = 3{,}76 \cdot 10^{11}\ cm^{-3}$$

$$p_{B0} = p_{0B} \cdot \exp\left(-\frac{U_{BE}}{U_T}\right) = 3{,}76 \cdot 10^{13}\ cm^{-3}$$

$$p_{Bn} = p_{0B} \cdot \exp\left(\frac{U_{CB}}{U_T}\right) \approx 0$$

2.

$$I_{PE} = q S D_{PB} \frac{P_{B0} P_{BU}}{W_B}$$

$$= q S \mu_P U_T \frac{P_{B0}}{W_B}$$

$W_B = 1\,\mu m = 10^{-4}\,cm$

$W_E = 1{,}7\,\mu m = 1{,}7 \cdot 10^{-4}\,cm$

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

$$I_{PE} = 1{,}6 \cdot 10^{-15} \cdot 2 \cdot 10^{-2} \cdot 280 \cdot \frac{300}{11600} \cdot \frac{3{,}76 \cdot 10^{14}}{10^{-4}} = 8{,}42\,mA$$

$$I_{nE} = q S D_{nE} \frac{n_{e0} n_{0E}}{W_E} = \ldots = 87{,}4\,\mu A$$

$$\beta^* = 1 - \frac{1}{2}\left(\frac{W_B}{L_{PB}}\right)^2 \qquad L_{PB} = \sqrt{D_{PB} \tau_{PB}} \quad \Rightarrow \quad \beta^* = 0{,}9982$$

$$\beta^* = \frac{I_{PC}}{I_{PE}} \qquad I_{PC} = \beta^* \cdot I_{PE} = 8{,}405\,mA$$

$$I_R = -I_{PE} - I_{PC} = -15\,\mu A$$

$$I_E = I_{nE} + I_{PE} = 8{,}5047\,mA$$

$$I_C = -I_{PC} = -8{,}405\,mA \qquad \{ I_{CBO} \approx 0 \text{ pa ne utiče} \}$$

$$I_C + I_B + I_E = 0 \qquad I_B = -114{,}7\,\mu A$$

pnp: $I_E > 0$ a $I_B, I_C < 0$ U NAP

$$\gamma = \frac{I_{PE}}{I_{PE} + I_{nE}} = 0{,}99004$$

$$\alpha = \gamma \cdot \beta^* = 0{,}9883$$

$$\beta = \frac{\alpha}{1-\alpha} = 84$$

β^*, α, γ RAČUNATI NA 4 DECIMALE

3. SZD

$R_E = 2{,}5\ k\Omega$

$R_C = R_T = 3\ k\Omega$

$R_G = 1\ k\Omega$

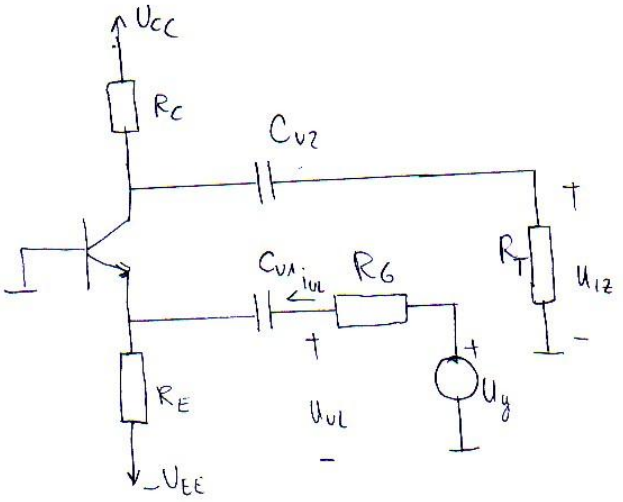
$U_{CC} = 12\ V$

$U_{EE} = 6\ V$

$\beta = h_{fe} = 100$

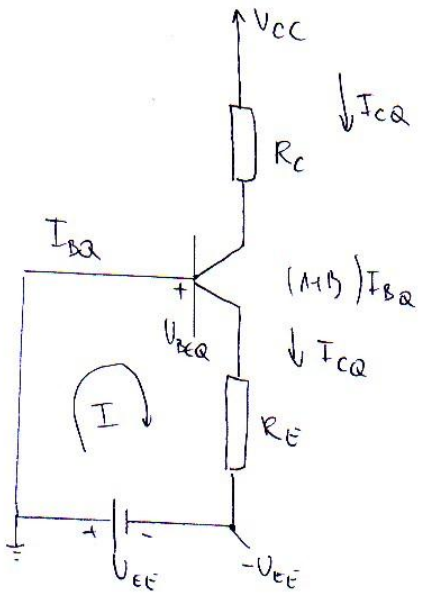
$U_\gamma = 0{,}7$

$U_T = 25\ mV$



STATIKA

- ODSPAJAMO GRANE S KONDENZATORIMA, RJEŠITI „ULAZNI KRUG" B-E



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

2) $U_{BEQ} = 0{,}7\ V$

$$I_{BQ} = \frac{U_{EE} - U_{BEQ}}{(1+\beta) R_E} = 21{,}7\ \mu A$$

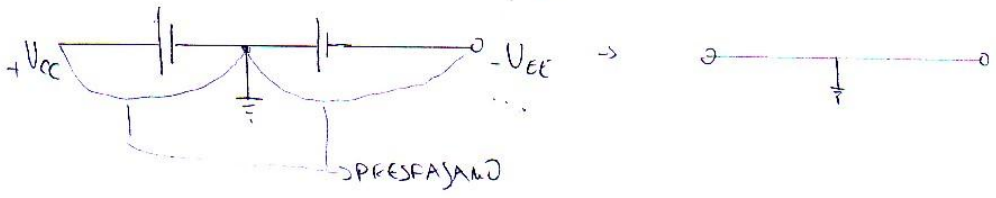
$$I_{CQ} = \beta \cdot I_{BQ} = 2{,}12\ mA$$

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

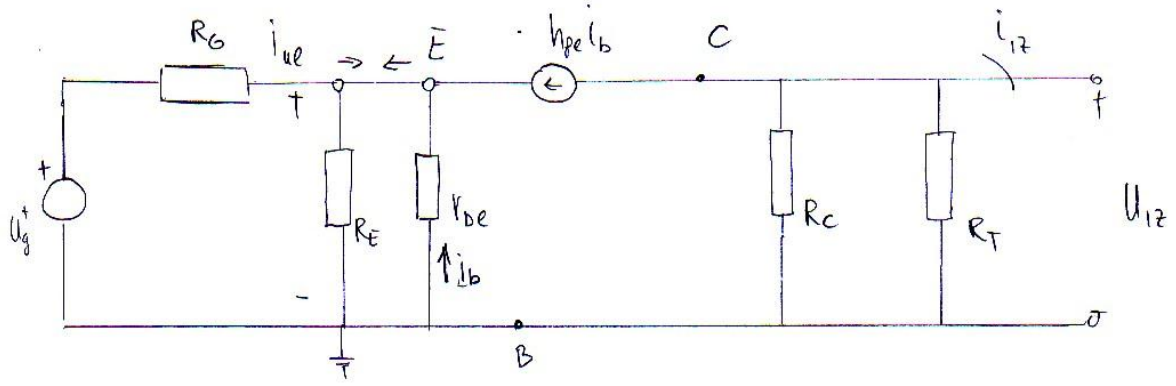
$$U_{CEQ} = 6{,}34\ V$$

$$r_{be} = \frac{U_T}{I_{BQ}} = 1180\ \Omega$$

DINAMIKA SIMETRIČNIH KAPACITETA



3 b) DINAMIKA



$$A_U = \frac{U_{iz}}{U_{ul}} = \frac{-h_{fe} i_b (R_C \| R_T)}{-i_b r_{be}} = \frac{h_{fe}(R_C \| R_T)}{r_{be}} = 127{,}12$$

$$R_{ul} = \frac{U_{ul}}{I_{ul}} \qquad i_{ul} = \frac{U_{ul}}{R_E} - (1 + h_{fe}) i_b = \frac{U_{ul}}{R_E} + \frac{(1+h_{fe}) U_{ul}}{r_{be}} = U_{ul}\left[\frac{1}{R_E} + \frac{1}{\frac{r_{be}}{1+h_{fe}}}\right]$$

$$U_{ul} = i_b \cdot r_{be} \Rightarrow \frac{U_{ul}}{i} = R_E \| \frac{r_{be}}{1+h_{fe}} = R_{ul} = 11{,}6\,\Omega$$

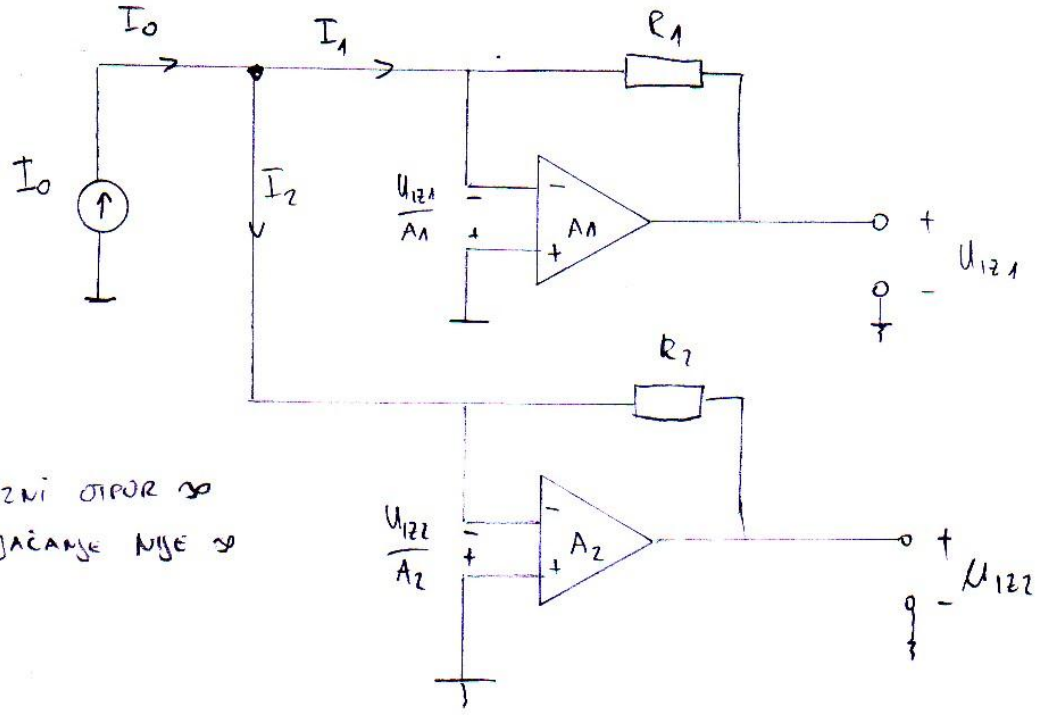
$$A_{Ug} = \frac{U_{iz}}{U_g} = \frac{U_{iz}}{U_{ul}} \cdot \frac{U_{ul}}{U_g} = A_U \frac{U_{ul}}{U_g} = A_U \frac{R_{ul}}{R_{ul} + R_G} = 1{,}46$$

$$U_{izm} = U_{gm} \cdot A_{Ug} = 10 \cdot 1{,}46 = 14{,}6\,mV \rightarrow U_{iz}(t) = 14{,}6 \sin(\omega t)\ [mV]$$

$$I_{izm} = \frac{U_{izm}}{R_T} = \frac{14{,}6\,mV}{3\,k\Omega} = 4{,}87\,\mu A \rightarrow i_{iz}(t) = 4{,}87 \sin(\omega t)\ [\mu A]$$

$$I_{ulm} = \frac{V_{gm}}{R_G + R_{ul}} = \frac{10}{1k + 11{,}6} = 9{,}885\,\mu A \quad i_{ul}(t) = 9{,}885 \sin \omega t\ [\mu A]$$

4. OP



- ULAZNI OTPOR ∞
- POJAČANJE NIJE ∞

JEDNADŽBE

① $I_0 = I_1 + I_2$

② $I_1 = \dfrac{-\frac{U_{IZ1}}{A_1} - U_{IZ1}}{R_1}$

③ $I_2 = \dfrac{-\frac{U_{IZ2}}{A_2} - U_{IZ2}}{R_2}$

} ①

.... UBTIMO... KOMBINIRAMO... FULAMO :)

④ $\dfrac{U_{IZ1}}{A_1} = \dfrac{U_{IZ2}}{A_2} \rightarrow U_{IZ1} : U_{IZ2}\dfrac{A_1}{A_2}$

$$\rightarrow U_{IZ1} = -\frac{A_1 I_0 \cdot R_1 R_2}{R_1(1+A_2) + R_2(1+A_1)} = \text{... UZ ZADANE URY ...} = -0{,}05\,V$$

$$U_{IZ2} = -\frac{A_2 I_0 \cdot R_1 R_2}{R_1(1+A_2) + R_2(1+A_1)} = \text{UZ ZADANE URY} = -0{,}1\,V$$

c) $R_1 = 100\,\Omega$ $A_1 = 10^4$

$R_2 = 200\,\Omega$ $A_2 = 2 \cdot 10^4$

$I_0 = 1\,mA$