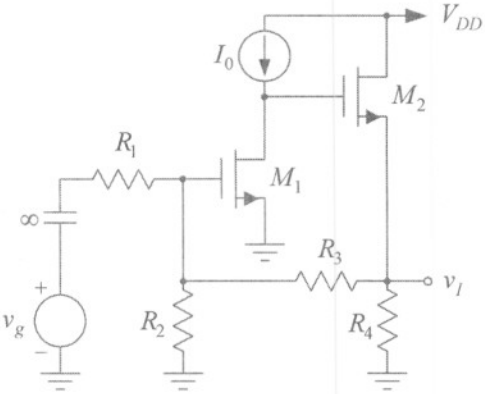
IME I PREZIME REŠENJA **BR. IND.** _____

1	2	$\sum$



Slika 1

1. Parametri tranzistora u pojačavaču sa slike 1 su: $V_T = 0{,}6\,\mathrm{V}$, $B_1 = \mu_n C_{ox}(W/L)_1 = 500\,\mu\mathrm{A/V}^2$, $(W/L)_2 = 100(W/L)_1$ i $\lambda = 0{,}05\,\mathrm{V}^{-1}$, dok je: $V_{DD} = 3{,}3\,\mathrm{V}$, $I_0 = 10\,\mu\mathrm{A}$, $R_1 = 10\,\mathrm{k\Omega}$, $R_2 = 68\,\mathrm{k\Omega}$, $R_3 = 100\,\mathrm{k\Omega}$ i $R_4 = 2\,\mathrm{k\Omega}$.

a) [2] Odrediti struje drejna i vrednost izlaznog napona u mirnoj radnoj tački. Zanemariti uticaj Earlyjevog efekta.

b) [2] Odrediti kružno pojačanje βa.

c) [2] Odrediti naponsko pojačanje $a = v_i / v_g$.

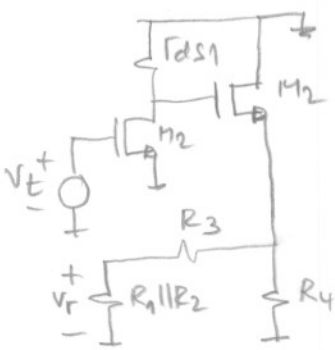
d) [2] Odrediti ulaznu otpornost R_u.

e) [2] Odrediti izlaznu otpornost R_i.

Rešenje:

a) $V_{GS1} = V_T + \sqrt{\frac{2I_0}{B_1}} = 0{,}8\,\mathrm{V} \Rightarrow V_I = \left(1 + \frac{R_3}{R_2}\right) V_{GS1} \approx 2\,\mathrm{V} \Rightarrow I_{D2} = \frac{V_I}{R_4} - \frac{V_I}{R_2 + R_3} \approx \frac{V_I}{R_4} = 1\,\mu\mathrm{A}$

b) $r_{ds1} = \frac{1}{\lambda I_0} = 2\,\mathrm{M\Omega}$, $r_{ds2} = \frac{1}{\lambda I_{D2}} = 20\,\mathrm{k\Omega}$, $g_{m1} = \sqrt{2 I_0 B_1} = 200\,\mu\mathrm{S}$, $g_{m2} = \sqrt{2 I_{D2} B_2} = 10\,\mathrm{mS}$



$\beta a = -g_{m1} r_{ds1} \cdot \frac{g_{m2} R_x}{1 + g_{m2} R_x} \cdot \frac{R_1 \| R_2}{(R_1 \| R_2) + R_3} = -15{,}19$, $R_x = R_4 \| r_{ds2} \| (R_3 + R_1 \| R_2)$

c) Asimptotska formula: $a = a_\infty \frac{T}{1+T} + \frac{a_0}{1+T}$

$T = -\beta a$; $g_{m1} \to \infty \Rightarrow v_{gs1} \to 0 \Rightarrow a_\infty = \frac{v_{i\infty}}{v_g} = -\frac{R_3}{R_1} = -10$

$g_{m1} \to 0 \Rightarrow a_0 = \frac{v_{i0}}{v_g} = \frac{\frac{R_2}{R_2 + R_3 + R_4 \| r_{ds2} \| \frac{1}{g_{m2}}}}{R_1 + R_2 \| \left(R_3 + R_4 \| r_{ds2} \| \frac{1}{g_{m2}}\right)} \cdot \left(R_4 \| r_{ds2} \| \frac{1}{g_{m2}}\right) = 7{,}6 \cdot 10^{-4}$

$\Rightarrow a \simeq a_\infty \frac{T}{1+T} = -9{,}38$

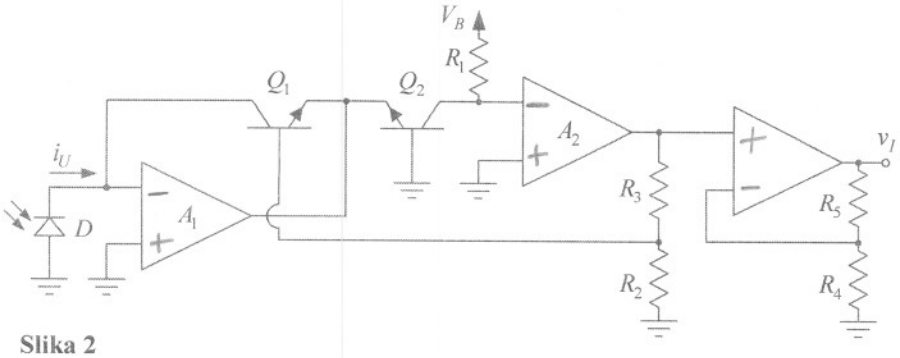
d) $R_u = R_1 + R_{u1}$, $R_{u1} = R_{u10} \frac{1 - \beta a_{KSU}}{1 - \beta a_{OUU}}$, $\beta a_{KSU} = 0$, $\beta a_{OUU} = -g_{m1} r_{ds1} \frac{g_{m2} \cdot R_Y}{1 + g_{m2} R_Y} \cdot \frac{R_2}{R_2 + R_3} = -76{,}7$

$R_Y = R_4 \| r_{ds2} \| (R_2 + R_3)$, $R_{u10} = R_2 \| \left(R_3 + R_4 \| r_{ds2} \| \frac{1}{g_{m2}}\right) = 40{,}5\,\mathrm{k\Omega}$

$\Rightarrow R_u = R_1 + \frac{R_{u10}}{1 - \beta a_{OUU}} = 10{,}52\,\mathrm{k\Omega}$

e) $R_i = R_{i0} \frac{1 - \beta a_{KSI}}{1 - \beta a_{OUI}}$, $\beta a_{KSI} = 0$, $\beta a_{OUI} = \beta a$, $R_{i0} = R_4 \| r_{ds2} \| \frac{1}{g_{m2}} \| (R_3 + R_1 \| R_2) = 94{,}7\,\Omega$

$\Rightarrow R_i = \frac{R_{i0}}{1 - \beta a} = 5{,}85\,\Omega$



Slika 2

2. Na ulaz pojačavača sa slike 2 priključena je foto-dioda čija se struja i_U menja u funkciji intenziteta svetlosti. Operacioni pojačavači se napajaju iz baterija $V_{CC} = -V_{EE} = 5\,\text{V}$ i može se smatrati da su idealni. Parametri tranzistora su: $I_S = 0{,}1\,\text{fA}$, $V_A \to \infty$, $\beta_F \to \infty$ i $V_{CES} = 0{,}2\,\text{V}$, dok je $V_t = kT/q = 25\,\text{mV}$, $V_B = V_{CC}/5$, $R_1 = 100\,\text{k}\Omega$, $R_2 = 1\,\text{k}\Omega$, $R_3 = 19\,\text{k}\Omega$, $R_4 = 50\,\text{k}\Omega$ i $R_5 = 50\,\text{k}\Omega$.

a) [2] Odrediti, uz obrazloženje, polaritet ulaznih priključaka operacionih pojačavača, tako da u kolu bude ostvarena negativna reakcija.

b) [2] Odrediti otpornost R_u koju vidi dioda. Smatrati da je u kolu ostvarena negativna reakcija.

c) [3] Odrediti zavisnost izlaznog napona u funkciji struje foto-diode $v_I = f(i_U)$. Smatrati da je u kolu ostvarena negativna reakcija.

d) [3] Odrediti opseg vrednosti struje foto-diode $i_{U\min} \le i_U \le i_{U\max}$ za koju važi zavisnost iz prethodne tačke.

Rešenje:

a) Videti sliku.

b) $R_u = 0$

c) $v_I = \left(1+\frac{R_5}{R_4}\right) v_{I2} = \left(1+\frac{R_5}{R_4}\right)\left(1+\frac{R_3}{R_2}\right) v_{B1}$, $v_{B1} = v_{BE1} - v_{BE2}$,

$v_{BE1} - v_{BE2} = V_t \ln \frac{i_{C1}}{i_{C2}} = V_t \ln \frac{i_U}{V_B/R_1} = V_t \ln \frac{R_1 i_U}{V_B}$

$\Rightarrow v_I = \left(1+\frac{R_5}{R_4}\right)\left(1+\frac{R_3}{R_2}\right) V_t \ln \frac{R_1 i_U}{V_B} = 1\text{V} \cdot \ln \frac{i_U}{10\mu\text{A}}$

d) $v_{I\max} = V_{CC} \Rightarrow i_{U\max} = 10\mu\text{A}\; e^{\frac{V_{CC}}{1\text{V}}} = 1{,}48\,\text{mA}$

$v_{I\min} = V_{EE} \Rightarrow i_{U\min} = 10\mu\text{A}\; e^{\frac{V_{EE}}{1\text{V}}} = 67{,}38\,\text{nA}$