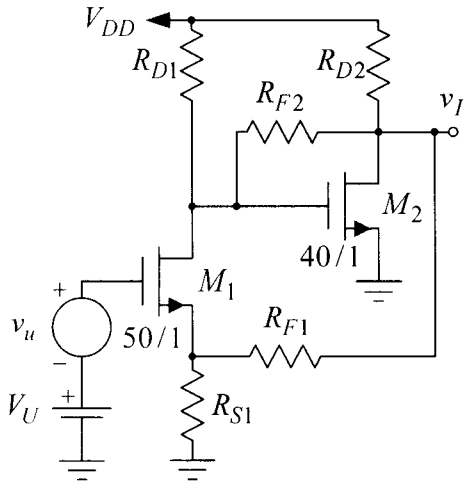
Ime i Prezime_____ Br. indeksa_____

1	2	∑

1. kolokvijum

1. a) [3] Nacrtati instrumentacioni pojačavač sa dvostrukim napajanjem.
b) [3] Izvesti izraz za naponsko pojačanje pojačavača iz a).
c) [2] Izvesti izraz za faktor potiskivanja signala srednje vrednosti za različite vrednosti otpornika u kolu povratne sprege dva ulazna operaciona pojačavača u kolu iz a).
d) [2] Modifikovati pojačavač iz a) tako da se omogući rad sa jednostrukim napajanjem.

Rešenje:



2. U kolu sa slike parametri tranzistora su: $V_T = 0{,}7\,\mathrm{V}$, $\mu_n C_{ox} = 100\,\mu\mathrm{A/V}^2$ i $\lambda \to 0$. Na slici je, pored svakog tranzistora, dat odnos širine i dužine kanala, dok je: $V_{DD} = 3\,\mathrm{V}$, $V_U = 1\,\mathrm{V}$, $R_{F1} = 10\,\mathrm{k\Omega}$ i $R_{F2} = 30\,\mathrm{k\Omega}$. Odrediti i izračunati:

a) [3] vrednosti nepoznatih otpornosti tako da u mirnoj radnoj tački bude: $V_I = V_{DD}/2$, $I_{D1} = 100\,\mu\mathrm{A}$ i $I_{D2} = 500\,\mu\mathrm{A}$;

b) [2] kružno pojačanje βa;

c) [3] naponsko pojačanje $a = v_i / v_u$;

d) [2] izlaznu otpornost pojačavača R_i.

Rešenje:

a) $V_{GS1} = V_T + \sqrt{\frac{2 I_{D1}}{\mu_n C_{ox} (W/L)_1}} = 0{,}9\,\mathrm{V}$, $V_{GS2} = V_T + \sqrt{\frac{2 I_{D2}}{\mu_n C_{ox} (W/L)_2}} = 1{,}2\,\mathrm{V}$

$\Rightarrow V_{S1} = V_U - V_{GS1} = 0{,}1\,\mathrm{V} \Rightarrow I_{D1} = \frac{V_{S1}}{R_{S1}} + \frac{V_{S1} - V_I}{R_{F1}}$

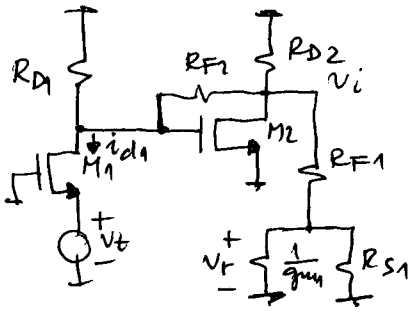
$\Rightarrow R_{S1} = \frac{V_{S1}}{I_{D1} - \frac{V_{S1} - V_I}{R_{F1}}} = 416{,}7\,\Omega$,

$\frac{V_{DD} - V_{GS2}}{R_{D1}} = I_{D1} + \frac{V_{GS2} - V_I}{R_{F2}} \Rightarrow R_{D1} = \frac{V_{DD} - V_{GS2}}{I_{D1} + \frac{V_{GS2} - V_I}{R_{F2}}} = 20\,\mathrm{k\Omega}$,

$\frac{V_{DD} - V_I}{R_{D2}} = I_{D2} + \frac{V_I - V_{GS2}}{R_{F2}} + \frac{V_I - V_{S1}}{R_{F1}}$

$\Rightarrow R_{D2} = \frac{V_{DD} - V_I}{I_{D2} + \frac{V_I - V_{GS2}}{R_{F2}} + \frac{V_I - V_{S1}}{R_{F1}}} = 2{,}31\,\mathrm{k\Omega}$.

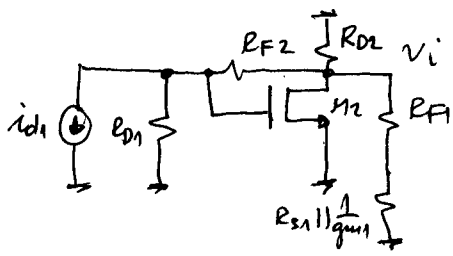
b) $g_{m1} = \sqrt{2 I_1 \mu_n C_{ox} (W/L)_1} = 1\,\mathrm{mS}$, $g_{m2} = \sqrt{2 I_{D2} \mu_n C_{ox} (W/L)_2} = 2\,\mathrm{mS}$.



$\beta a = \frac{v_r}{v_t} = \frac{v_r}{v_i} \cdot \frac{v_i}{i_{d1}} \cdot \frac{i_{d1}}{v_t}$

$\frac{v_r}{v_i} = \frac{\frac{1}{g_{m1}} \| R_{S1}}{\left(\frac{1}{g_{m1}} \| R_{S1}\right) + R_{F1}}$, $\frac{i_{d1}}{v_t} = -g_{m1}$

$\frac{v_i}{i_{d1}} = ?$

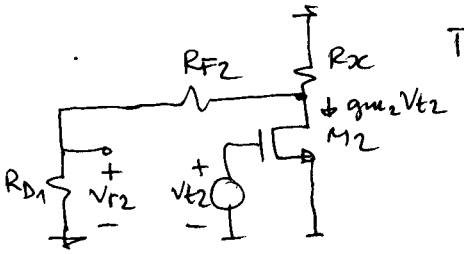


$\frac{v_i}{i_{d1}} = r_{in2} = r_{in2\infty} \frac{T_2}{1+T_2} + \frac{r_{in20}}{1+T_2}$

$g_{m2} \to \infty \Rightarrow r_{in2\infty} = R_{F2} = 30\,\mathrm{k\Omega}$

$g_{m2} = 0 \Rightarrow r_{in20} = -\frac{R_{D1}}{R_{D1} + R_{F2} + R_x} \cdot R_x = -726{,}5\,\Omega$

$R_x = R_{D2} \| \left[R_{F1} + \left(\frac{1}{g_{m1}} \| R_{S1}\right)\right]$



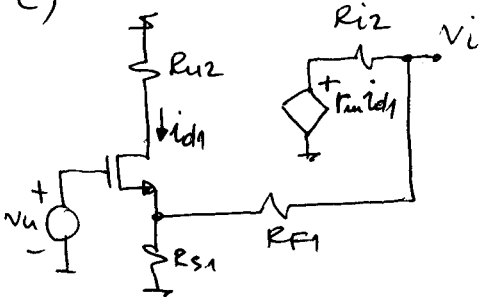
$$T_2 = -\beta a_2 = -\frac{V_{r2}}{V_{t2}} = g_{m2} \cdot \frac{R_x}{R_x + R_{F2} + R_{D1}} \cdot R_{D1}$$

$$\Rightarrow T_2 = 1{,}45$$

$$\Rightarrow r_{m2} = 17{,}47\ k\Omega$$

$$\Rightarrow \beta a = \frac{\frac{1}{g_{m1}} \| R_{S1}}{\left(\frac{1}{g_{m1}} \| R_{S1}\right) + R_{F1}} \cdot r_{m2} \cdot (-g_{m1}) = -0{,}5 .$$

c)



$$a = \frac{v_i}{v_u} = a_\infty \frac{T}{1+T} + \frac{a_0}{1+T} \approx a_\infty \frac{T}{1+T}$$

$$T = -\beta a$$

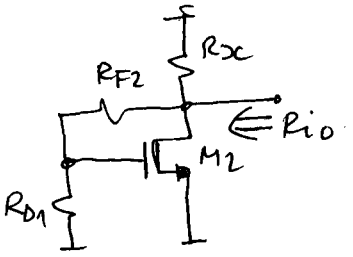
$$r_m \to \infty \Rightarrow i_{d1} \to 0 \Rightarrow v_{gs1} \to 0$$

$$\Rightarrow a_\infty = \frac{v_{i\infty}}{v_u} = 1 + \frac{R_{F1}}{R_{S1}} = 25$$

$$\Rightarrow a \approx \left(1 + \frac{R_{F1}}{R_{S1}}\right) \frac{T}{1+T} \approx 8{,}3 .$$

d) $R_i = R_{io} \frac{1 - \beta a_{ksi}}{1 - \beta a_{ovi}}$, $\beta a_{ksi} = 0$, $\beta a_{ovi} = \beta a$

$R_{io} = ?$



$$R_{io} = R_{ioo} \frac{1 - \beta a_{kso}}{1 - \beta a_{ovo}}, \quad \beta a_{kso} = 0$$

$$\beta a_{ovo} = \beta a_2$$

$$g_{m2} = 0 \Rightarrow R_{ioo} = R_x \| (R_{F2} + R_{D1}) = 1{,}816\ k\Omega$$

$$\Rightarrow R_{io} = 740{,}41\ \Omega$$

$$\Rightarrow R_i = 494\ \Omega .$$