OSNOVI ANALOGNE ELEKTRONIKE, OKTOBAR 2005.

IME I PREZIME ______________________________________ **BR. INDEKSA**__________

1	2	3	4	$\sum$

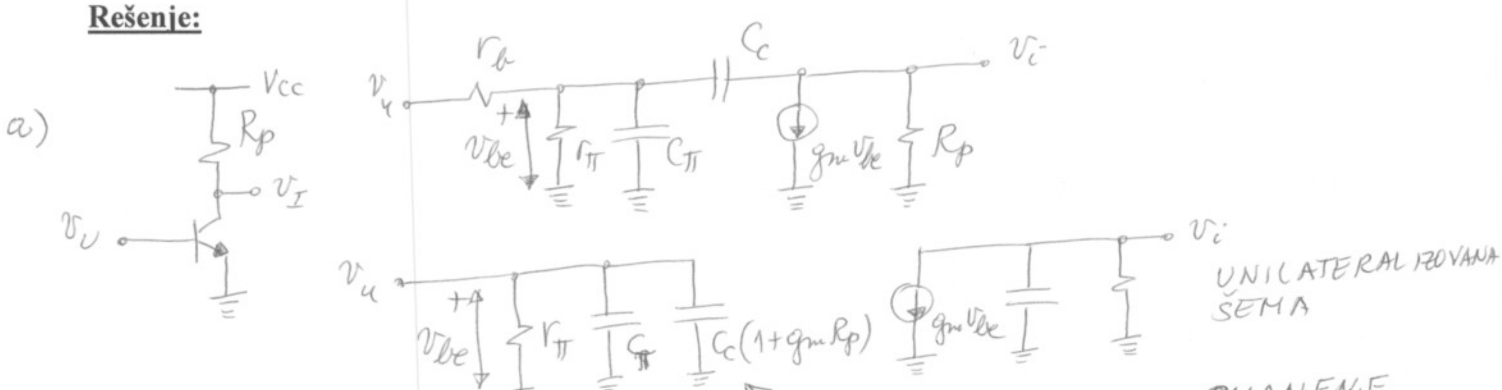
1. a) [3] Na primeru pojačavača sa zajedničkim emiterom objasniti smanjenje gornje granične učestanosti pojačavača usled Milerovog efekta.

b) [4] Nacrtati diferencijalni pojačavač sa mostnom povratnom spregom za kompenzaciju Milerovog efekta i objasniti način kompenzacije.

c) [3] Nacrtati realizaciju pojačavača iz b) u integrisanoj tehnologiji i objasniti koje dodatne elemente treba integrisati da bi se obezbedio ispravan rad kola.

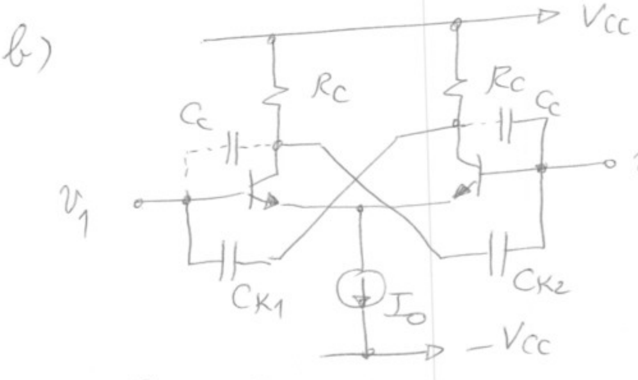
Rešenje:

a)



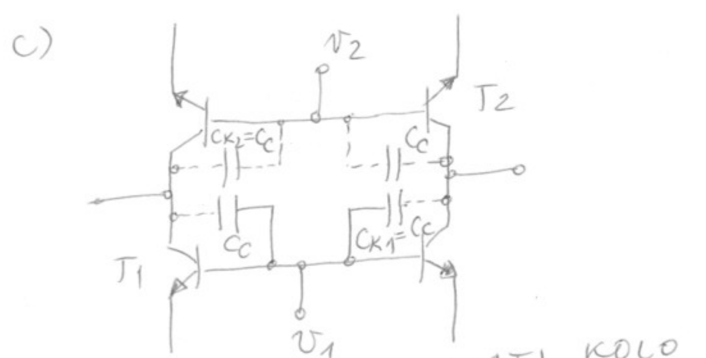
GLAVNI RAZLOG ZA SMANJENJE UČESTANOSTI POLA

b)



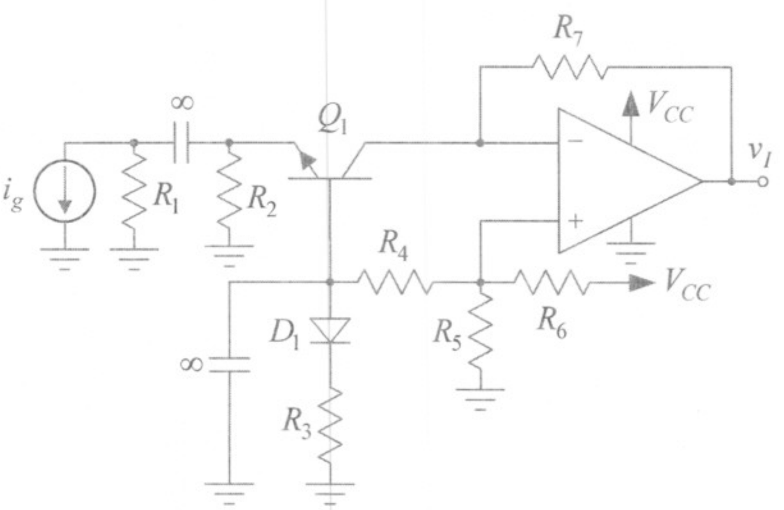
$C_{K1} = C_{K2} = C_c$

c)



POTREBNO JE INTEGRISATI KOLO ZA POLARIZACIJU DODATNA 2 TRANZISTORA

2. U kolu pojačavača sa slike operacioni pojačavač se može smatrati idealnim, dok je: $V_{CC} = 5\,\text{V}$, $V_t = kT/q = 25\,\text{mV}$, $\beta_F = \beta_0 \to \infty$, $V_D = V_{BE} = 0{,}7\,\text{V}$, $V_{CES} = 0{,}2\,\text{V}$, $R_1 = 50\,\text{k}\Omega$, $R_3 = R_6 = 1\,\text{k}\Omega$, $R_4 = 1{,}8\,\text{k}\Omega$ i $R_5 = 910\,\Omega$.



a) [5] Odrediti otpornosti R_2 i R_7 tako da je:

- transrezistansa $r_m = v_i / i_g$ u okolini mirne radne tačke $r_m = 1\,\text{k}\Omega$
- struja kolektora u mirnoj radnoj tački $I_C = 1\,\text{mA}$.

b) [2,5] Odrediti otpornost R_u koju vidi pobudni generator i_g.

c) [2,5] Odrediti maksimalnu amplitudu simetričnog neizobličenog napona na izlazu $V_{im\max}$.

Rešenje:

a) $R_2 = \frac{V_B - V_{BE}}{I_C}$, $V_B = V_D \cdot \frac{R_4 + (R_5 \| R_6)}{R_3 + R_4 + (R_5 \| R_6)} + V_{CC} \cdot \frac{R_5}{R_5 + R_6} \cdot \frac{R_3}{R_3 + R_4 + (R_5 \| R_6)} = 1{,}21\,V$

$\Rightarrow R_2 = 510\,\Omega$

$r_m = \frac{v_i}{i_g} = \left(R_1 \| R_2 \| \frac{1}{g_m}\right) g_m \cdot R_7 \Rightarrow R_7 = \frac{r_m}{\left(R_1 \| R_2 \| \frac{1}{g_m}\right) g_m} \approx r_m \frac{1 + g_m R_2}{g_m R_2} = 1{,}05\,k\Omega$

b) $R_u = R_1 \| R_2 \| \frac{1}{g_m} \approx R_2 \| \frac{1}{g_m} = \frac{R_2}{1 + g_m R_2} = 23{,}8\,\Omega$

c) $V_{im\max} = \min\left\{ v_{I\max} - V_I,\ V_I - v_{I\min} \right\}$

$V_I = V^+ + R_7 I_C$, $V^+ = \frac{R_5 \| (R_4 + R_3)}{R_6 + R_5 \| (R_4 + R_3)} V_{CC} + \frac{R_6 \| R_5}{R_3 + R_4 + R_6 \| R_5} V_D \cong 2{,}14\,V$

$\Rightarrow V_I \cong 3{,}19\,V$

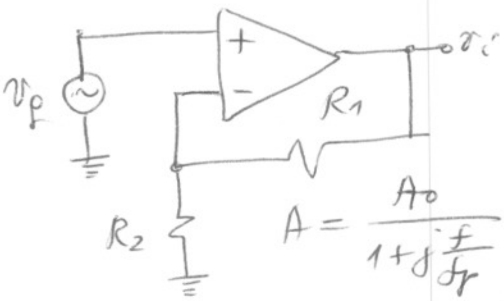
$v_{I\max} = V_{CC}$, $v_{I\min} = V^+ \cong 2{,}14\,V$

$\Rightarrow V_{im\max} = V_I - v_{I\min} = R_7 I_C = 1{,}05\,V$

3. Za neinvertujući pojačavač sa operacionim pojačavačem sa jednopolnom prenosnom karakteristikom i otpornom povratnom spregom izvesti i nacrtati Bodeove karakteristike:

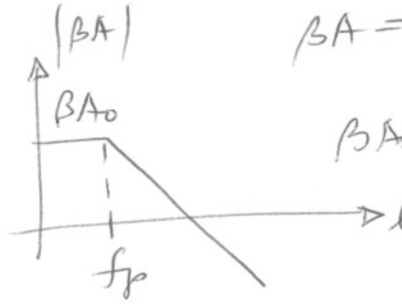
a) [2] kružnog pojačanja;
b) [2] pojačanja sa reakcijom;
c) [3] ulazne impedanse; i
d) [3] izlazne impedanse.

Rešenje:



$$A = \frac{A_0}{1 + j\frac{f}{f_p}}$$

a)

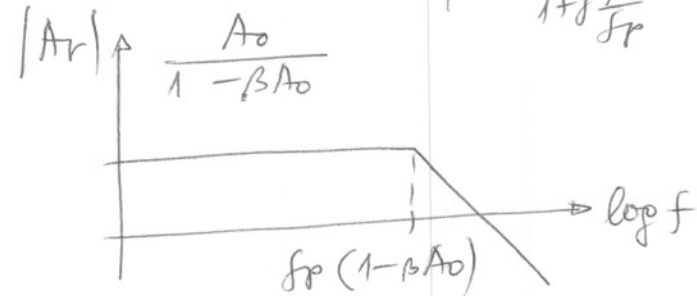


$$\beta A = \frac{\beta A_0}{1 + j\frac{f}{f_p}}$$

$$\beta A_0 < 0$$

b)

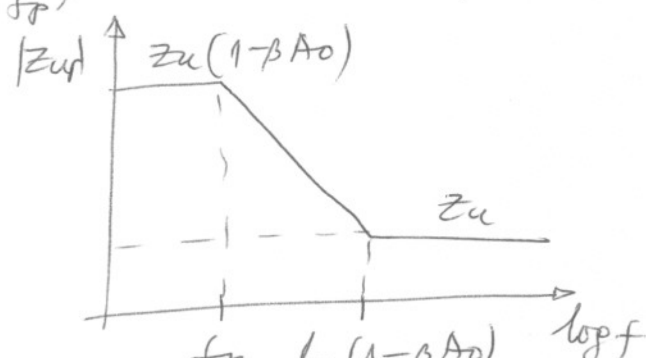
$$A_r = \frac{A}{1-\beta A} = \frac{\frac{A_0}{1+j\frac{f}{f_p}}}{1 - \frac{\beta A_0}{1+j\frac{f}{f_p}}} = \frac{A_0}{1+j\frac{f}{f_p} - \beta A_0} = \frac{\frac{A_0}{1-\beta A_0}}{1 + j\frac{f}{f_p(1-\beta A_0)}}$$



c)

$$Z_{ur} = Z_u(1-\beta A) = Z_u\left(1 - \frac{\beta A_0}{1+j\frac{f}{f_p}}\right) = Z_u \frac{1+j\frac{f}{f_p} - \beta A_0}{1+j\frac{f}{f_p}}$$

$$Z_{ur} = Z_u(1-\beta A_0)\,\frac{1 + j\frac{f}{f_p(1-\beta A_0)}}{1 + j\frac{f}{f_p}}$$

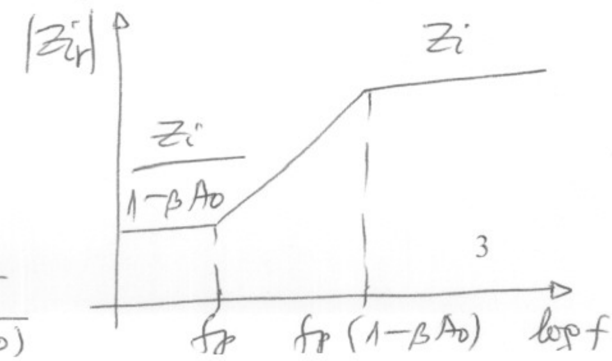


d)

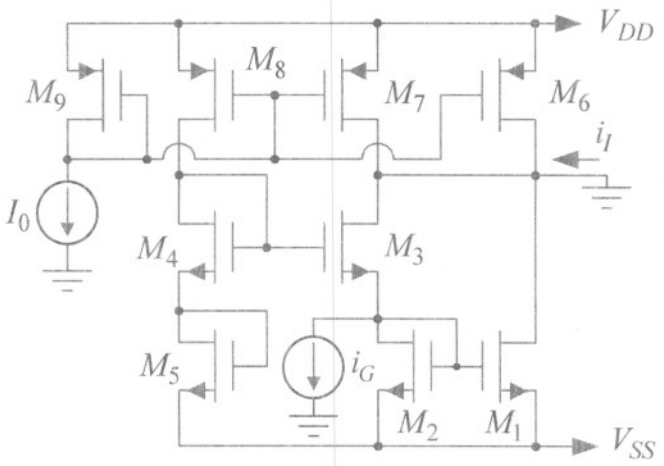
$$Z_{ir} = \frac{Z_i}{1-\beta A} = \frac{Z_i}{1 - \frac{\beta A_0}{1+j\frac{f}{f_p}}} = \frac{Z_i\left(1+j\frac{f}{f_p}\right)}{1+j\frac{f}{f_p} - \beta A_0}$$

$$Z_{ir} = \frac{Z_i\left(1+j\frac{f}{f_p}\right)}{\left(1+j\frac{f}{f_p(1-\beta A_0)}\right)(1-\beta A_0)}$$

$$Z_{ir} = \frac{Z_i}{1-\beta A_0}\,\frac{1+j\frac{f}{f_p}}{1+j\frac{f}{f_p(1-\beta A_0)}}$$



4. U kolu sa slike parametri MOS tranzistora su $B_N = \mu_n C_{ox}(W/L)_N = B = 1\text{mA/V}^2$, $B_P = \mu_p C_{ox}(W/L)_P = B$, $V_{TN} = V_T = 0{,}7\text{ V}$, $V_{TP} = -V_T$ i $\lambda_n = \lambda_p \to 0$, dok je $V_{DD} = -V_{SS} = 2{,}5\text{ V}$ i $I_0 = 20\mu\text{A}$. Ukoliko se drugačije ne naglasi smatrati da svi tranzistori rade u oblasti zasićenja.



a) [5] Odrediti zavisnost $i_I = f(i_G)$.

b) [5] Odrediti opseg ulazne struje $i_{G\min} \le i_G \le i_{G\max}$ u kojem važi zavisnost iz prethodne tačke.

Rešenje:

a) $i_I = i_{D3} + i_{D1} - i_{D6} - i_{D7}$, $i_{D6} = i_{D7} = I_0$,

$i_{D8} = i_{D9} = I_0$, $i_{D5} = i_{D4} = i_{D8} = I_0$,

$V_{GS1} + V_{GS3} = V_{GS4} + V_{GS5} = 2V_{GS5}$,

$i_{D3} = i_G + i_{D2} = i_G + i_{D1}$

$i_{D1} = \frac{B}{2}(V_{GS1} - V_T)^2$, $i_{D3} = \frac{B}{2}(V_{GS3} - V_T)^2 \Rightarrow V_{GS3} - V_{GS1} = \frac{i_G}{\sqrt{2 I_0 B}}$

$\Rightarrow V_{GS3} = V_{GS5} + \frac{i_G}{2\sqrt{2 I_0 B}}$ i $V_{GS1} = V_{GS5} - \frac{i_G}{2\sqrt{2 I_0 B}}$, $V_{GS5} = V_T + \sqrt{\frac{2I_0}{B}}$

$\Rightarrow i_{D3} + i_{D1} = \frac{B}{2}\left[(V_{GS3} - V_T)^2 + (V_{GS1} - V_T)^2\right] = 2I_0 + \frac{i_G^2}{8I_0}$

$\Rightarrow i_I = \frac{i_G^2}{8I_0}$

b) $V_{GS3} = V_T \Rightarrow i_G = i_{G\min} = -4I_0$

$V_{GS1} = V_T \Rightarrow i_G = i_{G\max} = 4I_0$.