# OSNOVI ANALOGNE ELEKTRONIKE, SEPTEMBAR 2006.

**Polaže se drugi kolokvijum (zadaci 3 i 4) ili kompletan ispit (svi zadaci)**

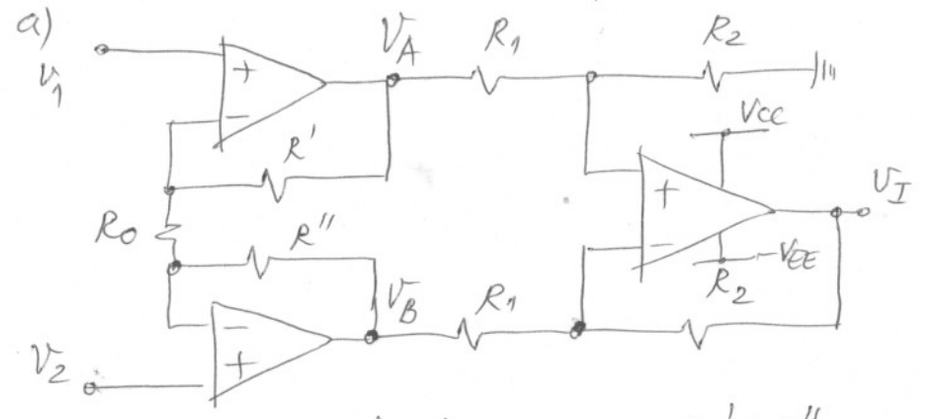
**IME I PREZIME** _____ **BR. INDEKSA**_____

| 1 | 2 | 3 | 4 | $\sum$ |
|---|---|---|---|---|
| | | | | |

**1. a)** [3] Nacrtati instrumentacioni pojačavač sa tri operaciona pojačavača.
**b)** [2] Odrediti odnose otpornika u ulaznom pojačavačkom stepenu tako da diferencijalno pojačanje ulaznog pojačavačkog stepena bude jednako 10.
**c)** [2] Odrediti odnose otpornika u izlaznom pojačavačkom stepenu tako da diferencijalno pojačanje izlaznog pojačavačkog stepena bude 10.
**d)** [3] Nacrtati vremenske dijagrame na izlazima sva tri operaciona pojačavača za ulazne napone $v_1(t) = 0.1\text{V} + 0.1\text{V} \cdot \sin \omega t$ i $v_2(t) = 0.1\text{V} - 0.1\text{V} \cdot \sin \omega t$, ako je napajanje operacionih pojačavača $V_{CC} = -V_{EE} = 15\text{V}$.

**Rešenje:**

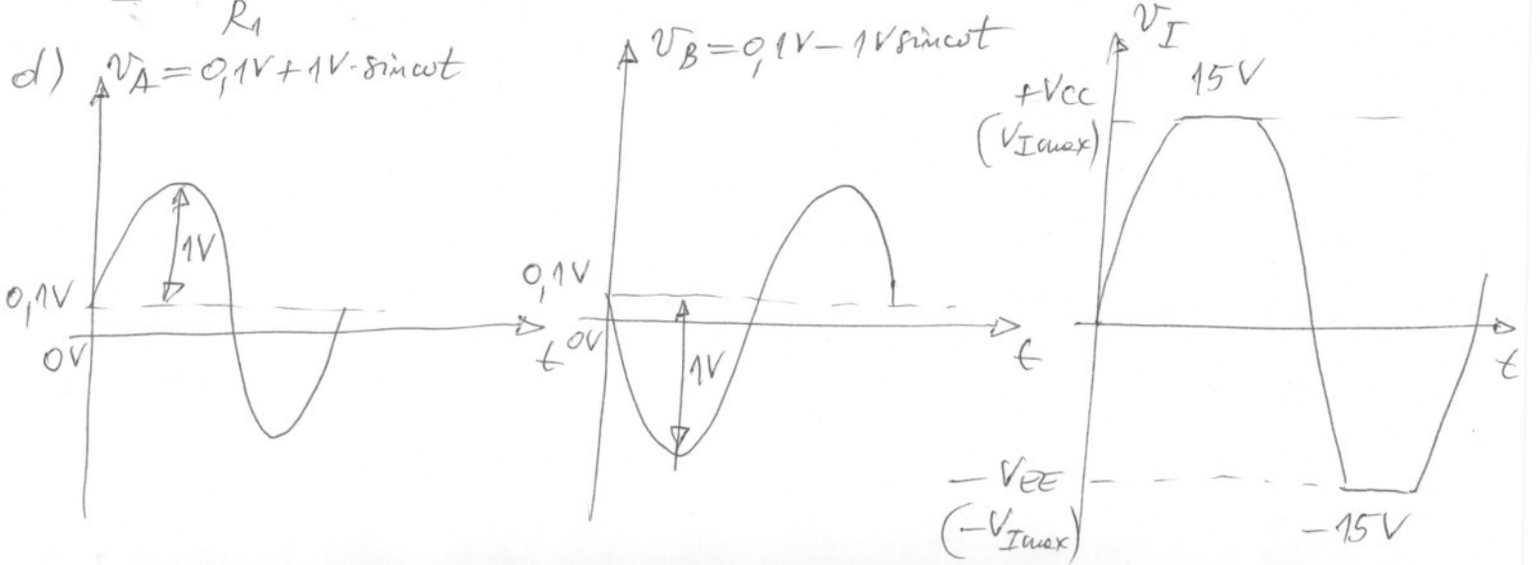
a)



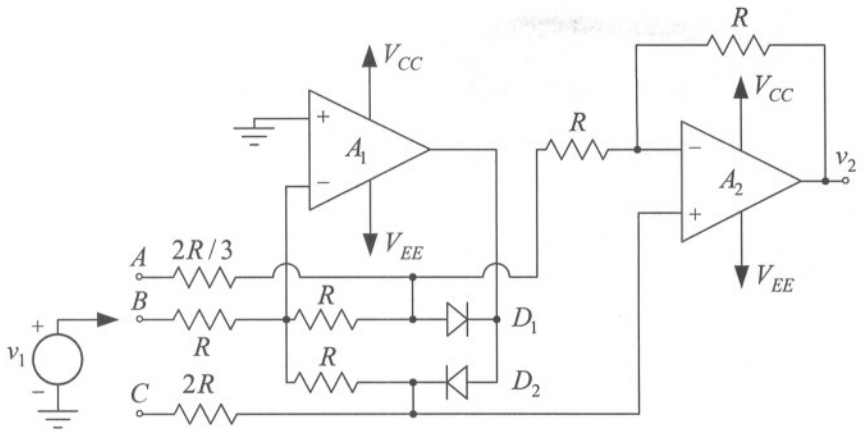

b) $A_1 = 1 + \frac{R'+R''}{R_0} = 10$ $\quad \frac{R'+R''}{R_0} = 9$ $\quad R' = R''$ $\quad \frac{R'}{R_0} = 4{,}5$

c) $A_2 = \frac{R_2}{R_1} = 10$

d)



**2.** U kolu sa slike operacioni pojačavači se mogu smatrati idealnim i napajaju se iz baterija $V_{CC} = -V_{EE} = 12\,\mathrm{V}$. Diode imaju pad napona $V_D = 0{,}6\,\mathrm{V}$, ostale karakteristike im se mogu smatrati idealnim, dok je $R = 10\,\mathrm{k\Omega}$.




**a)** [3] Ako je generator priključen u tačku A, odrediti i nacrtati zavisnost $v_2 = f(v_1)$, $V_{EE} \le v_1 \le V_{CC}$.

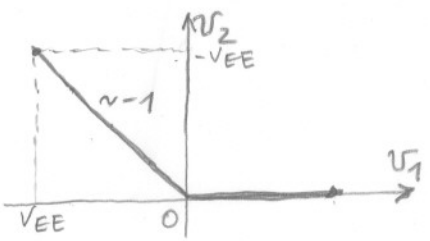
**b)** [3] Ponoviti prethodnu tačku kada je generator priključen u tačku B.

**c)** [2] Ponoviti tačku a) kada je generator priključen u tačku C.

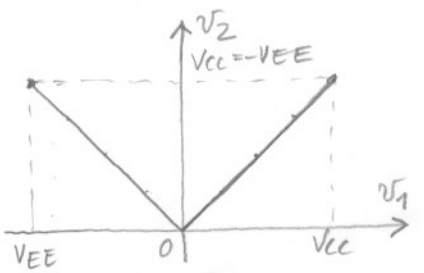
**d)** [2] Ako je $v_1 = V_m \sin(2\pi f t)$, $V_m = 1\,\mathrm{V}$ i $f = 1\,\mathrm{kHz}$, nacrtati vremenske dijagrame napona $v_2$ u tačkama a), b) i c).

**Rešenje:**

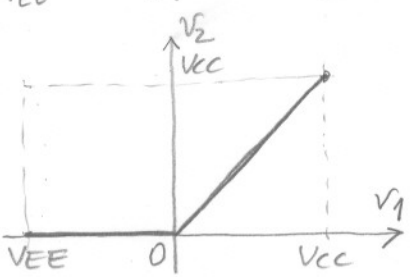
a) $v_1 > 0 \Rightarrow D_1$ on, $D_2$ OFF $\Rightarrow v_2 = 0$
$v_1 < 0 \Rightarrow D_2$ on, $D_2$ OFF $\Rightarrow v_2 = -v_1$
$v_1 = 0 \Rightarrow v_2 = 0$



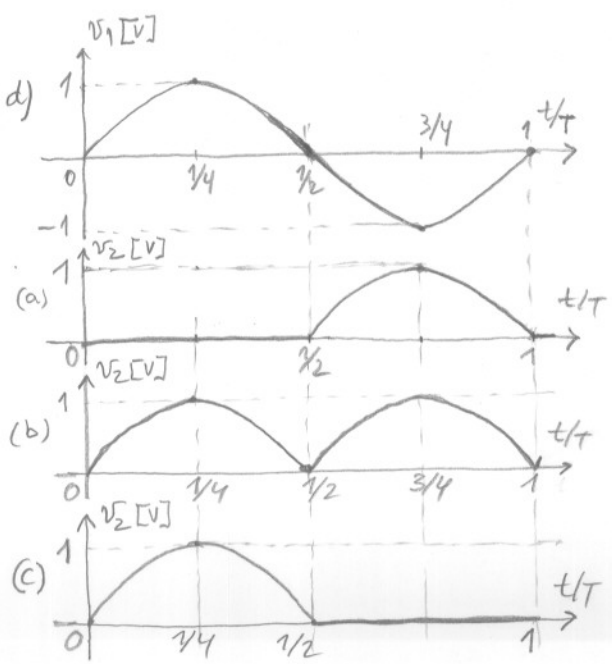

b) $v_1 > 0 \Rightarrow D_1$ on, $D_2$ OFF $\Rightarrow v_2 = v_1$
KADA $A_1$ UĐE U NEGATIVNO ZASIĆENJE
TADA ĆE $v_2 = 2V_{A2}^{+} - (V_{EE} + V_D)$, $V_{A2}^{+} = \frac{v_1 + (V_{EE} + V_D)}{2}$
$\Rightarrow v_2 = v_1$
$v_1 < 0 \Rightarrow D_2$ on, $D_1$ OFF $\Rightarrow v_2 = -v_1$
$v_1 = 0 \Rightarrow v_2 = 0$




c) $v_1 > 0 \Rightarrow D_1$ on, $D_2$ OFF $\Rightarrow v_2 = v_1$
$v_1 < 0 \Rightarrow D_2$ on, $D_1$ OFF $\Rightarrow v_2 = 0$
$v_1 = 0 \Rightarrow v_2 = 0$



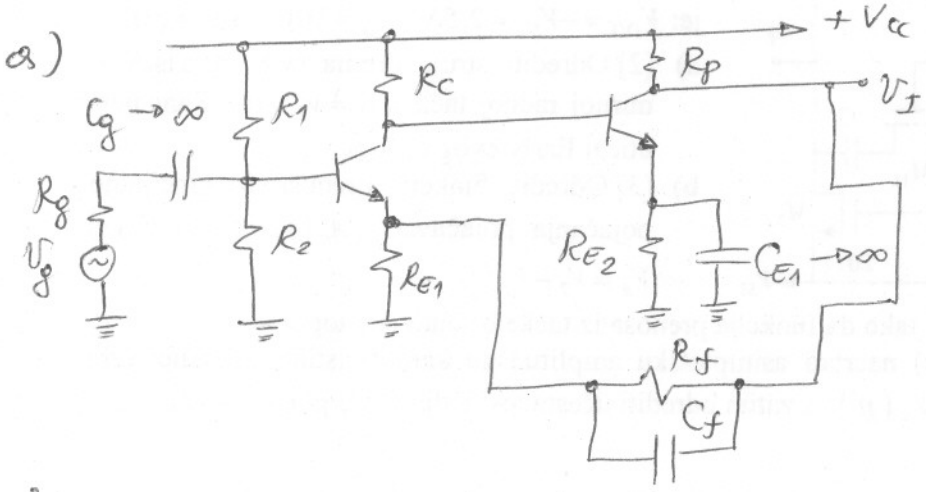

d)



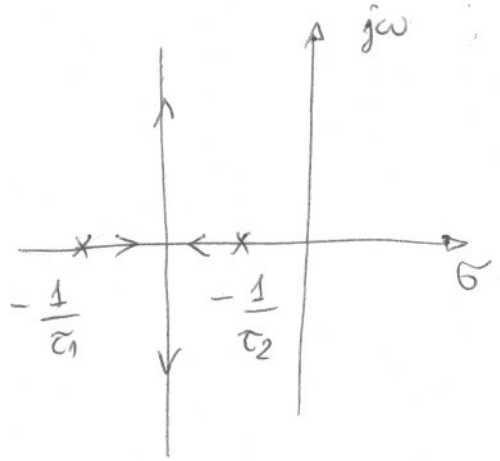
**3. a)** [4] Nacrtati dvostepeni širokopojasni pojačavač sa naponskim procesiranjem.
**b)** [3] Nacrtati putanju položaja polova pojačavača iz a) pri promeni vrednosti reakcijskog otpornika.
**c)** [3] Nacrtati putanju položaja polova pojačavača iz a) pri promeni vrednosti reakcijskog kondenzatora.

**Rešenje:**

a)

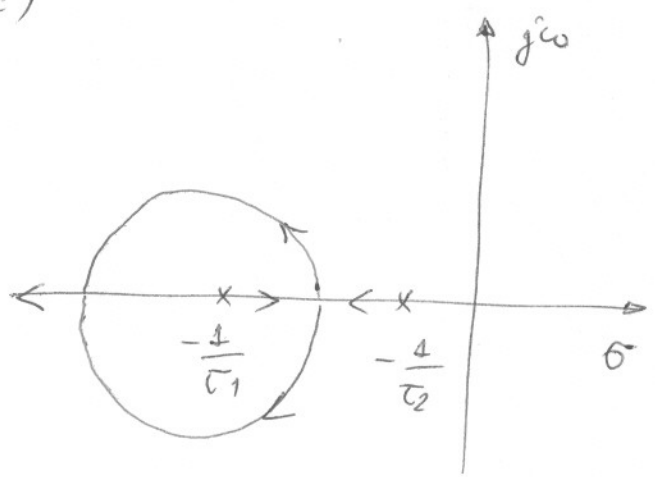



b)

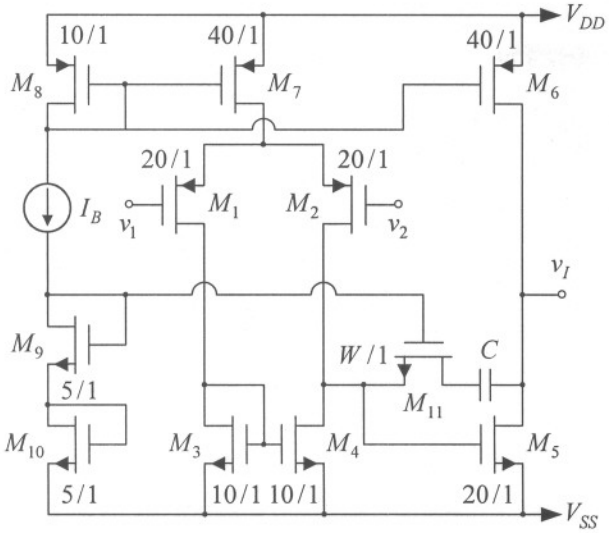



$$A_r(s) = \frac{\frac{A_0}{1+\beta_0 A_0}}{1 + s\frac{\tau_1+\tau_2}{1+\beta_0 A_0} + s^2\frac{\tau_1\tau_2}{1+\beta_0 A_0}}$$

c)




$$A_r(s) = \frac{\frac{A_0}{1+\beta_0 A_0}}{1 + s\left(\frac{\tau_1+\tau_2+\tau_f A_0\beta_0}{1+\beta_0 A_0}\right) + s^2\frac{\tau_1\tau_2}{1+\beta_0 A_0}}$$




**4.** Parametri tranzistora u pojačavaču sa slike su: $\mu_n C_{ox} = 110\,\mu\text{A/V}^2$, $\mu_p C_{ox} = 50\,\mu\text{A/V}^2$, $V_{TN} = 0{,}7\,\text{V}$, $V_{TP} = -V_{TN}$, $\lambda_n = 0{,}04\,\text{V}^{-1}$ i $\lambda_p = 0{,}05\,\text{V}^{-1}$. Na istoj slici je, pored svakog tranzistora, dat odnos širine i dužine kanala, dok je: $V_{DD} = -V_{SS} = 2{,}5\,\text{V}$, $I_B = 10\,\mu\text{A}$ i $C = 5\,\text{pF}$.

**a)** [2] Odrediti struje drejna svih tranzistora u mirnoj radnoj tački ($v_1 = v_2 = 0$). Zanemariti uticaj Earlyjevog efekta.

**b)** [3] Odrediti funkciju prenosa diferencijalnog pojačanja pojačavača, $A_d(s) = V_i(s)/V_d(s)$ $V_d = V_2 - V_1$.

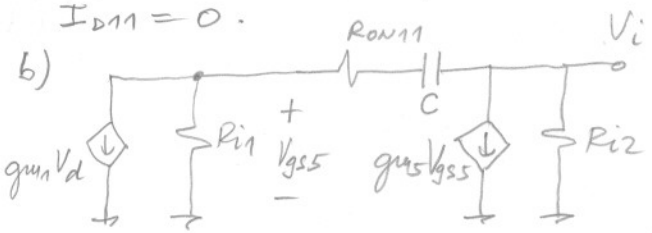
**c)** [3] Odrediti širinu kanala $W$ tako da funkcija prenosa iz tačke b) bude jednopolna.

**d)** [2] Pod uslovom iz tačke c) nacrtati asimptotsku amplitudsku karakteristiku diferencijalnog pojačanja $A_d(jf) = V_i(jf)/V_d(jf)$, a zatim odrediti učestanost jediničnog pojačanja $f_T$.

**Rešenje:**

a) $I_{D10} = I_{D9} = I_{D8} = I_B$, $I_{D7} = 4I_B$, $I_{D1} = I_{D2} = I_{D3} = I_{D4} = 2I_B$, $I_{D5} = I_{D6} = 4I_B$
$I_{D11} = 0$.

b)




$R_{i1} = r_{ds4} \| r_{ds2}$, $R_{i2} = r_{ds5} \| r_{ds6}$

$R_{ON11} = \dfrac{1}{B_{11}(V_{GS11} - V_T)}$, $B_{11} = \mu_n C_{ox} \dfrac{W}{1}$,

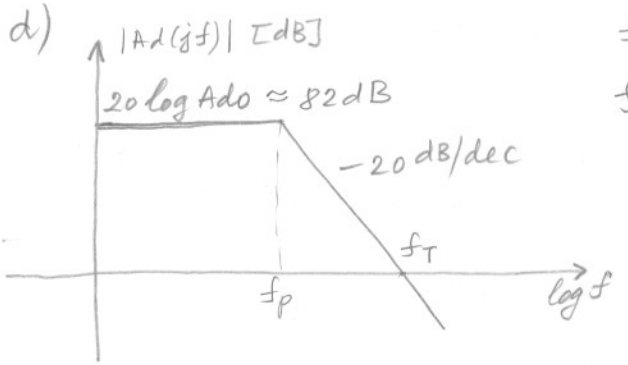
$A_d(s) = A_{do} \dfrac{1 + s/\omega_z}{1 + s/\omega_p}$, $\omega_z = \dfrac{1}{C\left(R_{ON11} - \frac{1}{g_{m5}}\right)}$, $\omega_p = \dfrac{1}{C\left(R_{ON11} + R_{i1} + R_{i2}(1 + g_{m5}R_{i1})\right)}$

$A_{do} = g_{m1}R_{i1} \cdot g_{m5}R_{i2} = 12950$

c) $\omega_z = 0 \Rightarrow g_{m5}R_{ON11} = 1 \Rightarrow \dfrac{B_5(V_{GS5} - V_T)}{B_{11}(V_{GS11} - V_T)} = 1$, $V_{GS11} = V_{GS9} + V_{GS10} - V_{GS5}$

$V_{GS9} = V_{GS10} = V_{GS5} \Rightarrow V_{GS11} = V_{GS5} \Rightarrow B_5 = B_{11} \Rightarrow W = 20\,\mu\text{m}$.

d)




$f_p = \dfrac{\omega_p}{2\pi} = 485{,}4\,\text{Hz}$

$f_T \cong A_{do} \cdot f_p = 6{,}28\,\text{MHz}$.