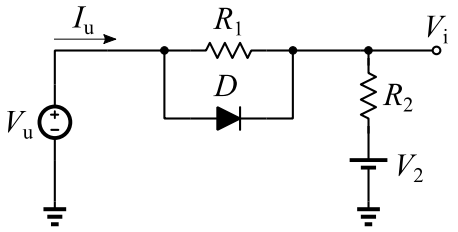
Elektronski fakultet u Nišu
Katedra za Elektroniku
Šifra: OEE3O01, OEM3O01, OET3O01, OEU3O02

Datum: 01. decembar 2023.

OSNOVI ELEKTRONIKE

Zadaci

1. Za diodno kolo sa Sl. 1 odrediti i nacrtati zavisnost:
a) izlaznog napona, V_i, i
b) ulazne struje, I_u, u funkciji ulaznog napona V_u.
Poznato je:
R_1=1kΩ, R_2=2kΩ, V_2=3V i –12V ≤ V_u ≤ 12V.
Parametri modela diode su:
V_{D0}=0.6V, r_d=0Ω.

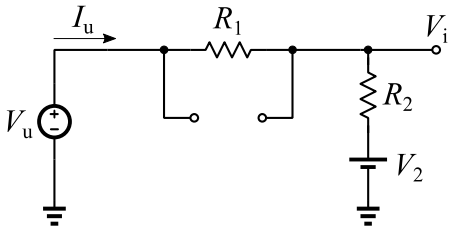


Sl. 1

Dioda ne vodi za $-12V \leq V_u < V_i + V_{D0} = 4.8V$, 10%

$$V_i = \frac{R_2}{R_2+R_1}V_u + \frac{R_1}{R_1+R_2}V_2 = \frac{2}{3}V_u + 1\ [V]$$ 5%

$$I_u = \frac{1}{R_2}(V_i - V_2) = \frac{1}{3}V_u - 1\ [mA]$$ 5%

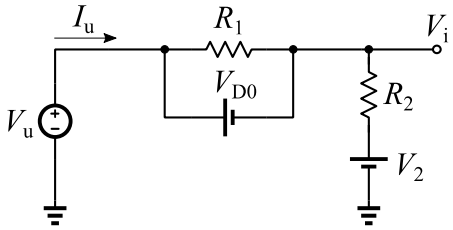


10%

Dioda vodi za $V_i + V_{D0} = 4.8V \leq V_u < 12V$, 10%

$$V_i = V_u - V_{D0} = V_u - 0.6\ [V]$$ 5%

$$I_u = \frac{1}{R_2}(V_i - V_2) = \frac{1}{2}V_u - 1.8\ [mA]$$ 5%



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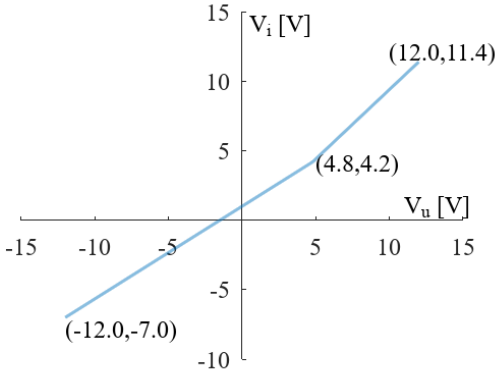

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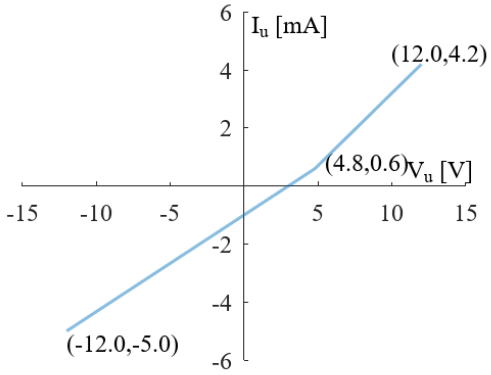

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2. Za pojačavač sa Sl. 2 odrediti:

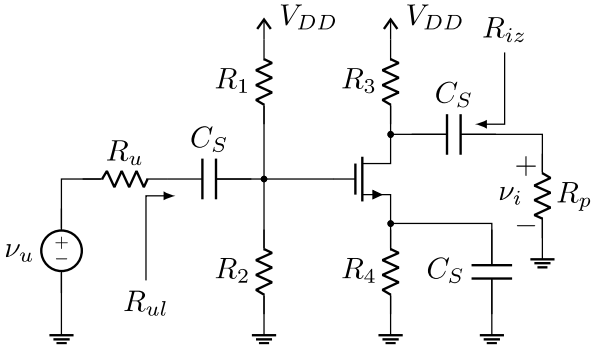
a) parametre modela za male signale, g_m, r_o i μ,
b) naponsko pojačanje, $A_n=v_i/v_u$,
c) ulaznu otpornost, R_{ul} i
d) izlaznu otpornost, R_{iz}.

Poznato je:

R_1=300kΩ, R_2=200kΩ, R_3=2kΩ, R_4=0.5kΩ, R_u=100Ω, R_p=2kΩ, V_{DD}=5V.

Parametri tranzistora su:

A=4mA/V^2, V_{TH}=1V, V_A=100V.



Sl. 2

(a)

(5%) $V_G = \dfrac{R_2}{R_2+R_1}V_{DD} = 2\text{ V}$

(5%) $V_G = V_{GS} + I_D R_4$

$V_G - V_{TH} = V_{GS} - V_{TH} + A\left(V_{GS}-V_{TH}\right)^2 R_4$

$AR_4V_{ov}^2 + V_{ov} - (V_G - V_{TH}) = 0$

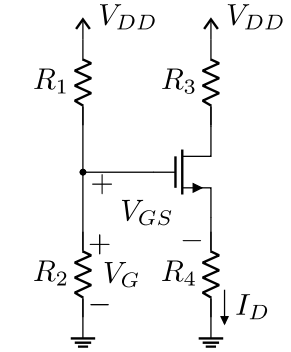
(5%) $V_{ov} = 0.5\text{ V}$

(5%) $I_D = AV_{ov}^2 = 1\text{ mA}$

(5%) $g_m = 2AV_{ov} = \dfrac{2I_D}{V_{ov}} = 2\sqrt{AI_D} = 4\text{ mS}$

(5%) $r_o = \dfrac{V_A}{I_D} = 100\text{ k}\Omega$

(5%) $\mu = g_m \cdot r_o = 400\text{ V/V}$



Šema za DC režim (5%)

(b)

(5%) $R_G = R_1 || R_2 = 120\text{ k}\Omega$

(5%) $R_{tev} = R_G || R_u = 99.92\ \Omega$

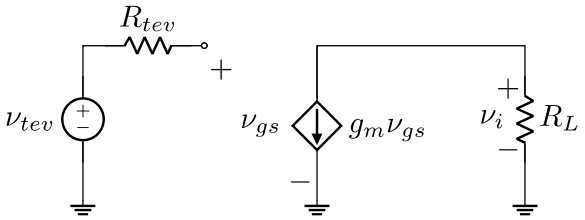
(5%) $R_L = r_o || R_3 || R_p = 990.1\ \Omega$

(5%) $v_{tev} = \dfrac{R_G}{R_G+R_u}v_u = 0.999 v_u$

(5%) $v_i = -g_m v_{gs} \cdot R_L$

(5%) $A_n = \dfrac{v_i}{v_u} = \dfrac{v_i}{v_{gs}} \cdot \dfrac{v_{gs}}{v_{tev}} \cdot \dfrac{v_{tev}}{v_u} =$

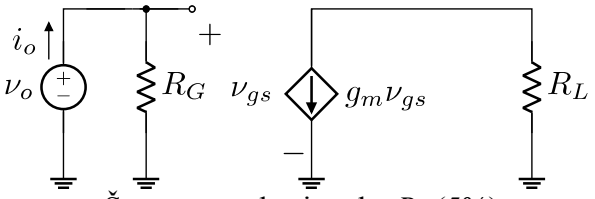
$= -g_m R_L \cdot \dfrac{R_G}{R_G+R_u} = -3.96\text{ V/V}$



Šema za male signale, A_n (5%)

(c)

(5%) $v_o = i_0 R_G \Rightarrow R_{ul} = \dfrac{v_o}{i_o} = R_G = 120\text{ k}\Omega$



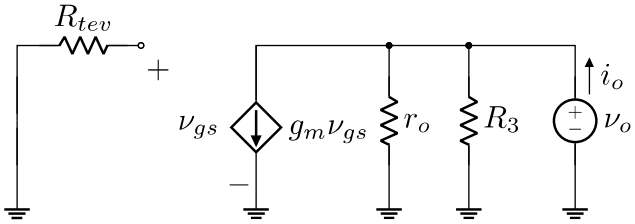
Šema za male signale, R_{ul} (5%)

(d)

(5%) $v_{gs} = v_g - v_s = 0\text{ V}$

(5%) $v_o = i_0\left(R_3 || r_o\right) \Rightarrow$

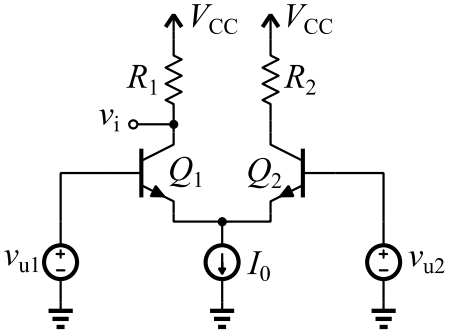
$R_{iz} = \dfrac{v_o}{i_o} = R_3 || r_o = 1.96\text{ k}\Omega$



Šema za male signale, R_{iz} (5%)

3. Za diferencijalni pojačavač sa Sl. 2 odrediti:

a) parametar za male signale, g_m, i jednosmernu vrednost izlaznog napona, V_I.
b) diferencijalno pojačanje, $A_d=v_i/(v_{u1}-v_{u2})$,
c) pojačanje srednje vrednosti, $A_c=2v_i/(v_{u1}+v_{u2})$ i
d) faktor potiskivanja srednje vrednosti, *CMRR*, ako je unutrašnja otpornost izvora konstantne struje R_0=10k.



Sl. 3

Poznato je:

R_1=R_2=2.5kΩ, I_0=2mA, V_T=25mV i V_{CC}=5V.

Parametri tranzistora su:

$V_{BE1,2}$=0.6V, $\beta_{1,2}\to\infty$, $V_{A1,2}\to\infty$ V.

a)

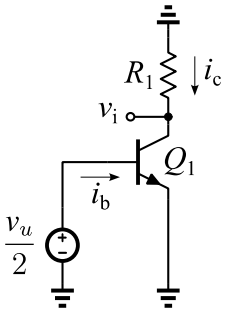
(5%) $I_E=\dfrac{I_0}{2}=1\text{mA}$

(5%) $I_C=\dfrac{\beta}{1+\beta}I_E=1\text{mA},$

(5%) $g_m=\dfrac{I_C}{V_T}=40\text{m S},$

(5%) $V_I=V_{CC}-I_C R_1=2.5\text{V}$

b)

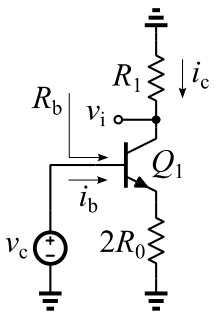


(10%) $v_{u1}=-v_{u2}=\dfrac{v_u}{2}$

(10%) $A_d=\dfrac{v_i}{v_u}=\dfrac{v_i}{i_c}\cdot\dfrac{i_c}{i_b}\cdot\dfrac{i_b}{v_u}=-R_1\cdot\beta\cdot\dfrac{1}{r_\pi}\cdot\dfrac{1}{2}=-\dfrac{g_m R_1}{2}=50\text{V/V}$

(10%)

c)



(10%) $v_{u1}=v_{u2}=v_c$

(10%) $R_b=r_\pi+(1+\beta)\,2R_0$

(10%) $A_c=\dfrac{v_i}{v_c}=\dfrac{v_i}{i_c}\cdot\dfrac{i_c}{i_b}\cdot\dfrac{i_b}{v_{u1}}\cdot\dfrac{v_{u1}}{v_u}$

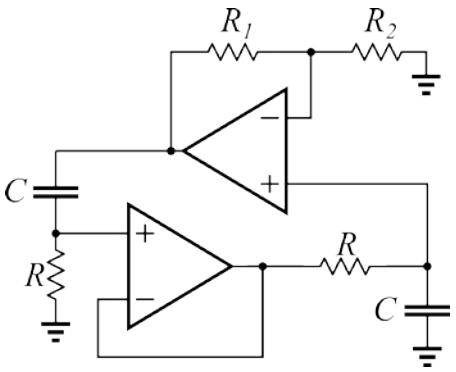
$=-R_1\cdot\beta\cdot\dfrac{1}{R_b}=-\dfrac{g_m R_1}{1+2g_m R_0}=-0.125\text{V/V}$

(10%)

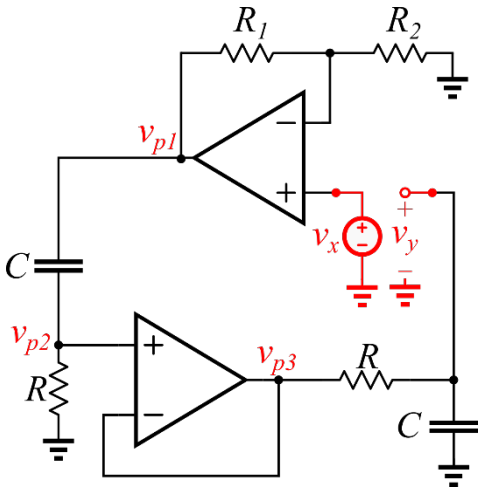
d) (10%) $CMRR=\left|\dfrac{A_d}{A_c}\right|=400$

4. Za oscilator sa Sl. 4 odrediti:
a) frekvenciju oscilovanja, f_0, i
b) uslov koji moraju ispuniti otpornosti R_1 i R_2 kako bi se oscilacije uspostavile.

Poznato je:
R=10kΩ, C=10nF
Operacioni pojačavači su idealni.



Sl. 4



Izraz za kružno pojačanje:

$$AF(s)=\frac{v_y}{v_x}=\frac{v_y}{v_{p3}}\cdot\frac{v_{p3}}{v_{p2}}\cdot\frac{v_{p2}}{v_{p1}}\cdot\frac{v_{p1}}{v_x}=\frac{\frac{1}{sC}}{R+\frac{1}{sC}}\cdot 1\cdot\frac{R}{R+\frac{1}{sC}}\cdot\left(1+\frac{R_1}{R_2}\right)=\left(1+\frac{R_1}{R_2}\right)\cdot\frac{sRC}{(1+sRC)^2}$$ (60%)

Na frekvenciji oscilovanja $\omega_0=2\pi f_0$ važi:

$$AF(j\omega_0)=\left(1+\frac{R_1}{R_2}\right)\cdot\frac{j\omega_0RC}{(1+j\omega_0RC)^2}=\left(1+\frac{R_1}{R_2}\right)\cdot\frac{j\omega_0RC}{1+2j\omega_0RC-(\omega_0RC)^2}=1+j0$$

Odnosno, $AF(j\omega_0)$ mora imati samo realni deo. Ovo se postiže ako je $1-(\omega_0RC)^2=0$, jer tada važi:

$$AF(j\omega_0)=\left(1+\frac{R_1}{R_2}\right)\cdot\frac{\cancel{j\omega_0RC}}{2\cancel{j\omega_0RC}}=\frac{1}{2}\left(1+\frac{R_1}{R_2}\right)=1$$

Iz prethodnog se dobija:

$$1-(\omega_0RC)^2=0\ \Rightarrow\ f_0=\frac{\omega_0}{2\pi}=\frac{1}{2\pi RC}=1.59\text{ kHz}$$ (20%)

$$\frac{1}{2}\left(1+\frac{R_1}{R_2}\right)=1\ \Rightarrow\ R_1=R_2$$ (20%)