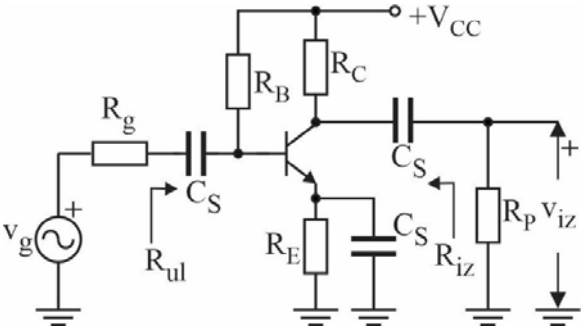
Elektronski fakultet Niš
Katedra za Elektroniku
19.01.2024.

OSNOVI ELEKTRONIKE
Modul elektroenergetika (3OEP3A01, 2OEP3O03)

1. Zadatak



Parametri tranzistora u kolu na slici su: $V_{BE} = 0{,}7\ V$; β= 80; $V_A = \ 50\ V$. Elementi kola su:
$R_B = 540\ k\Omega$, $R_C = 4\ k\Omega$, $R_E = 1{,}5\ k\Omega$, $R_g = 2\ k\Omega$, $R_p = 6\ k\Omega$, $V_{CC} = 9\ V$, $C_S \to \infty$.
Odrediti:

a) Radnu tačku tranzistora (V_{CE}, I_C);

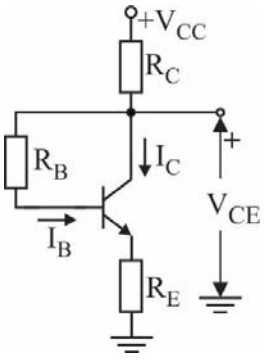
b) Parametre naizmeničnog režima rada ($r_\pi\ , r_o, g_m$);

c) Naponsko pojačanje $A = \dfrac{v_O}{v_g}$

d) Izlaznu otpornost R_{iz}

Rešenje:

a)



$$V_{CC} - R_B \cdot I_B - V_{BE} - R_E \cdot (1+\beta) \cdot I_B = 0$$

$$I_B = \frac{V_{CC} - V_{BE}}{R_B + R_E \cdot (1+\beta)} = 12.5\ \mu A$$

$$I_C = \beta I_B = 1\ mA$$

$$V_C = V_{CC} - R_C(I_C + I_B)$$

$$V_E = R_E I_E$$

$$V_{CE} = V_{CC} - R_C(I_C + I_B) - R_E I_E = 3.43\ V$$

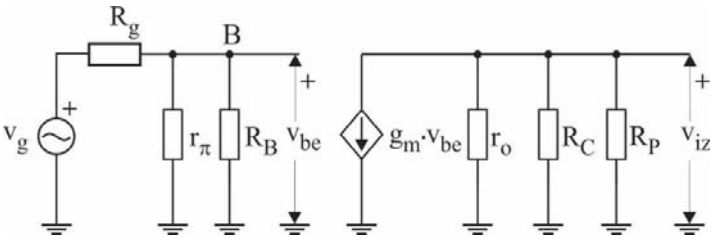
b)

$$r_\pi = \frac{V_T}{I_B} = \frac{26\ mV}{12{,}5 \mu A} = 2{,}08\ k\Omega$$

$$g_m = \frac{h_{21E}}{r_\pi} = \frac{I_C}{V_T} = 38{,}46\ mS$$

$$r_o = \frac{V_A}{I_c} = \frac{50\ V}{1\ mA} = 50\ k\Omega$$

b)



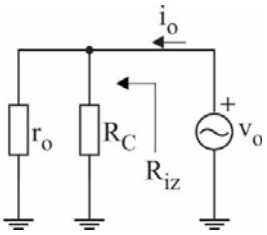
(B) $\frac{v_b}{R_B}+\frac{v_b}{r_\pi}+\frac{v_b-v_g}{R_g}=0$

$g_m v_{be}+\frac{v_{iz}}{r_o}+\frac{v_{iz}}{R_C}+\frac{v_{iz}}{R_P}=0$

$$A=\frac{v_{iz}}{v_g}=-g_m\left(r_o \parallel R_C \parallel R_p\right)\frac{r_\pi R_B}{R_g r_\pi+R_B R_g+r_\pi R_B}=44$$

c)

$$R_{iz}=\frac{v_o}{i_o}=R_C \parallel r_o=3{,}7\ k\Omega$$



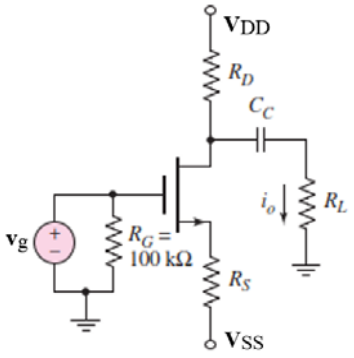
2. Zadatak

Parametri tranzistora u kolu sa slike su A = 0,5 mA/V^2, $V_t = 2{,}5\ V$, λ=0,01 V^{-1}. Elementi kola su $R_S = 250\ \Omega$. $R_D = 2\ k\Omega$; $R_L = 2\ k\Omega$,
$V_{DD} = 5V$, $V_{SS} = -5\ V$. Odrediti:

a) Radnu tačku tranzistora i dinamičke parametre tranzistora.

b) Naponsko pojačanje $A_n = v_{iz}/v_g$.

c) Izlaznu otpornost tranzistora R_{iz}.



Rešenje:

$V_S = R_S \cdot I_D + V_{SS}$

$V_{GS} = -V_S = -V_{SS} - R_S \cdot I_D$

$I_D = A \cdot (V_{GS} - V_t)^2$

$V_{GS} - V_t + V_t = -R_S \cdot A \cdot (V_{GS} - V_t)^2 - V_{SS}$

$R_S \cdot A \cdot V_x^2 + V_x + V_{SS} + V_t = 0$

$0{,}125 \cdot V_X^2 + V_X - 2{,}5 = 0$

$$V_X = \frac{-1 \pm \sqrt{1 + 4 \cdot 2{,}5 \cdot 0{,}125}}{0{,}25}$$

~~$V_{x1} = -10\ V$~~

$V_{x2} = 2\ V$

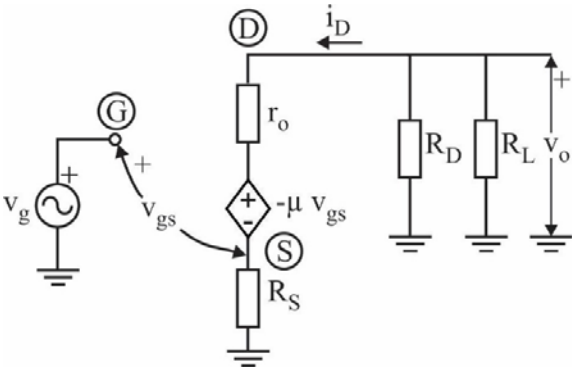
$I_D = A \cdot V_x^2 = 2\ mA$

$g_m = 2 \cdot \sqrt{A \cdot I_D} = 2\ mS$

$r_o = \frac{1}{\lambda \cdot I_D} = 50\ k\Omega$

$\mu = r_o \cdot g_m = 100$

b)



$R_D \parallel R_L \cdot i_d + r_o \cdot i_d - \mu \cdot v_{gs} + R_s \cdot i_d = 0$

$v_{gs} = v_g - i_d \cdot R_S$

$v_{iz} = -R_D \parallel R_L \cdot i_d$

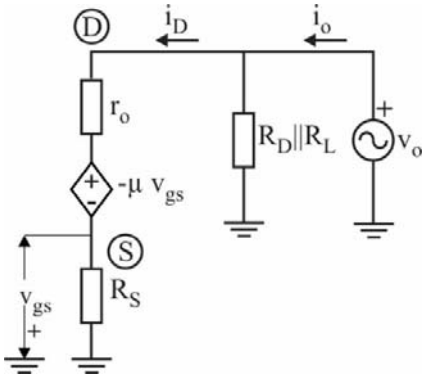
$R_D \parallel R_L \cdot i_d + r_o \cdot i_d - \mu \cdot v_g + \mu \cdot i_d \cdot R_S + R_s \cdot i_d = 0$

$i_d = \frac{\mu \cdot v_g}{R_D \parallel R_L + r_o + (\mu + 1) \cdot R_s}$

$v_{iz} = \frac{-R_D \parallel R_L \cdot \mu \cdot v_g}{R_D \parallel R_L + r_o + (\mu + 1) \cdot R_s}$

$A_n = \frac{v_{iz}}{v_g} = -\frac{R_D \parallel R_L \cdot \mu}{R_D \parallel R_L + r_o + (\mu + 1) \cdot R_s} = -13{,}1$

c)



$r_o \cdot i_d - \mu \cdot v_{gs} + R_s \cdot i_d = v_o$

$v_{gs} = -i_d \cdot R_S$

$i_o = i_d + \frac{v_o}{R_D \parallel R_L}$

$i_d = \frac{v_o}{r_o + (\mu + 1) \cdot R_s}$

$R_{izt} = \frac{v_o}{i_d}$

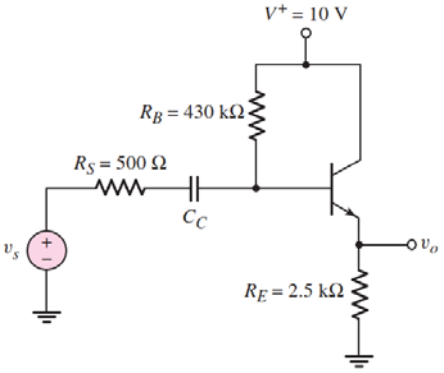
$R_{izt} = r_o + (\mu + 1) \cdot R_S = 75\ k\Omega$

$i_o = \frac{v_o}{R_{izt}} + \frac{v_o}{R_D \parallel R_L}$

$R_{iz} = \frac{v_o}{i_o} = \frac{1}{\frac{1}{R_{izt}} + \frac{1}{R_D \parallel R_L}} = R_{izt} \parallel R_D \parallel R_L = 0{,}98\ k\Omega$

3. Zadatak

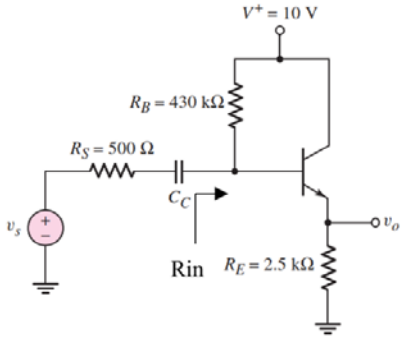
Kolo na slici je izlazni stepen audio pojačavača. Parametri tranzistora su: V_{BE}=0,6 V; h_{21E} =b= 200; h_{22E} =0 S. Odrediti kapacitivnost kondenzatora C_C tako da donja granična frekvencija ovog kola iznosi 15 Hz.



Rešenje:

Da bi odredili otpornost koja se vidi sa krajeva kondenzatora potrebno je odrediti ulaznu otpornost R_{in}.

$$\tau = C_C \cdot (R_S + R_{in})$$

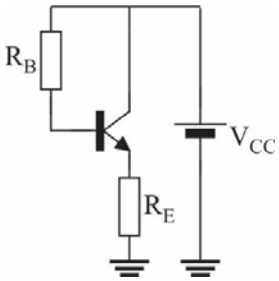


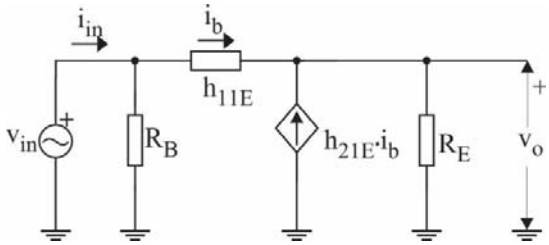
$$-V_{CC} + R_B \cdot I_B + V_{BE} + R_E \cdot I_E = 0$$

$$I_B = \frac{V_{CC} - V_{BE}}{R_B + R_E \cdot (1+\beta)} = 11{,}3\ \mu A$$

$$h_{11E} = r_\pi = \frac{V_T}{I_B} = \frac{26\ mV}{11{,}3\ \mu A} = 2{,}3\ k\Omega$$

$$h_{21E} = \beta$$





$$-i_{in} + \frac{v_{in}}{R_B} + i_b = 0$$

$$-i_b - h_{21E} \cdot i_b + \frac{v_o}{R_E} = 0$$

$$i_b = \frac{v_{in} - v_o}{h_{11E}}$$

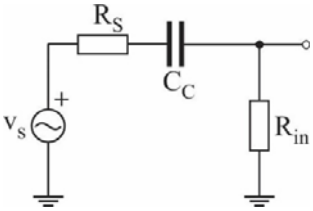
$$i_b \cdot h_{11E} = v_{in} - R_E \cdot (1 + h_{21E}) \cdot i_b$$

$$i_b = \frac{v_{in}}{h_{11E} + R_E \cdot (1 + h_{21E})}$$

$$R_t = \frac{v_{in}}{i_b} = h_{11E} + R_E \cdot (1 + h_{21E}) = 504{,}8\ k\Omega$$

$$i_{in} = \frac{v_{in}}{R_t} + \frac{v_{in}}{R_B}$$

$$R_{in} = R_B \parallel R_t = 232\ k\Omega$$



$$\tau = C_C \cdot (R_S + R_{in})$$

$$\omega_d = \frac{1}{\tau} = \frac{1}{C_C \cdot (R_S + R_{in})}$$

$$C_C = \frac{1}{\omega_d \cdot (R_S + R_{in})} = \frac{1}{6{,}28 \cdot 15 \cdot (2{,}32\ 10^5 + 500)} F = 46\ nF$$

4. Zadatak

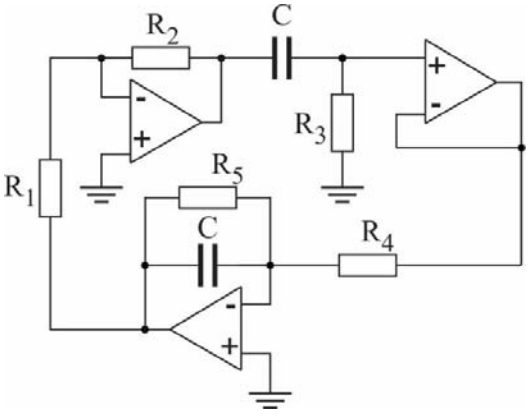
Za oscilator prostoperiodičnih oscilacija prikazan na slici odrediti:

a) Analitički izraz kružnog pojačanja;

b) Vrednost otpornika R_4 pri kojoj je ispunjen uslov oscilovanja;

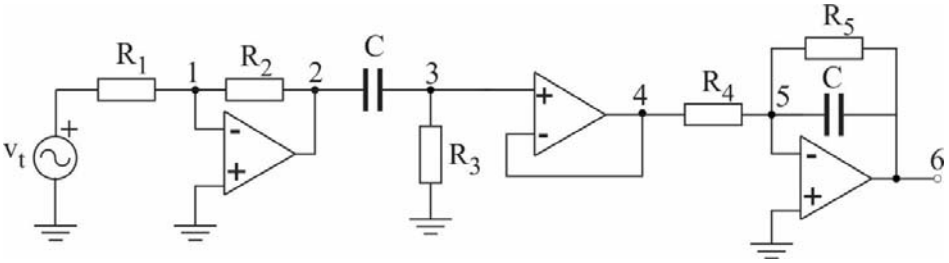
c) Frekvenciju oscilovanja.

Poznato je: $R_1 = 1k\Omega$ $R_2 = 4\ k\Omega$, $R_3 = 5\ k\Omega$, $R_5 = 5\ k\Omega$, $C = 1\ nF$. Operacioni pojačavači su idealni.



Slika 4

Rešenje:



$$V_1 \cdot \left(\frac{1}{R_1} + \frac{1}{R_2}\right) - V_t \frac{1}{R_1} - V_2 \frac{1}{R_2} = 0$$

$$V_3 \cdot \left(\frac{1}{R_3} + s \cdot C\right) - V_2 \cdot sC = 0$$

$$V_5 \cdot \left(\frac{1}{R_4} + \frac{1}{R_5} + sC\right) - V_4 \cdot \frac{1}{R_4} - V_6 \cdot \left(sC + \frac{1}{R_5}\right) = 0$$

$$V_1 = 0$$

$$V_3 = V_4$$

$$V_5 = 0$$

$$AB = \frac{V_6}{V_t} = \frac{V_6}{V_4} \cdot \frac{V_4}{V_2} \cdot \frac{V_2}{V_t} = 1 + j \cdot 0$$

$$AB = \frac{V_6}{V_t} = \left(-\frac{R_5}{R_4 + sCR_5R_4}\right) \cdot \frac{sCR_3}{sCR_3 + 1} \cdot \left(-\frac{R_2}{R_1}\right)$$

$$AB = \frac{SCR_2R_3R_5}{R_1R_4 + sCR_1R_4(R_3 + R_5) + s^2\,C^2R_1R_3R_4R_5}$$

Iz uslova AB=1+j 0 sledi:

$$R_1R_4 + sCR_1R_4(R_3 + R_5) + s^2\,C^2R_1R_3R_4R_5 = SCR_2R_3R_5$$

$$R_1R_4 + j\omega CR_1R_4(R_3 + R_5) - j\omega CR_2R_3R_5 - \omega^2\,C^2R_1R_3R_4R_5 = 0$$

b)

Kada se izdvoje imaginarni deo jednačине добија се:

$$j\omega CR_1R_4(R_3 + R_5) - j\omega CR_2R_3R_5 = 0$$

$$R_1R_4(R_3 + R_5) - R_2R_3R_5 = 0$$

$$R_4 = \frac{R_3R_5}{R_3 + R_5}\frac{R_2}{R_1} = 10\ k\Omega$$

c)

Izdvajanjem realnih sabiraka jednačine dobija se:

$$R_1R_4 - \omega^2\,C^2R_1R_3R_4R_5 = 1$$

$$\omega_0 = \frac{1}{C\sqrt{R_3R_5}} = 2 \cdot\ 10^5\ \frac{rad}{s}$$

$$f_o = \frac{\omega_o}{2\pi} = 31{,}8\ kHz$$