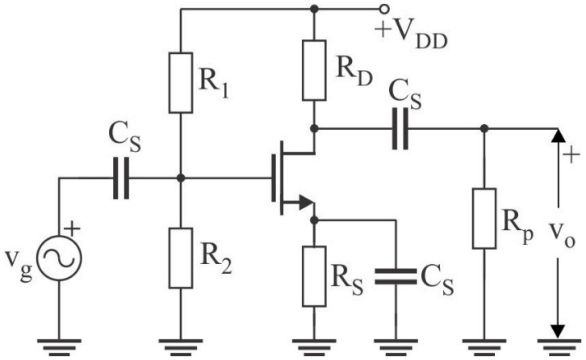
Elektronski fakultet Niš
Katedra za Elektroniku 28.03.2022.

OSNOVI ELEKTRONIKE
Modul elektroenergetika (3OEP3A01)

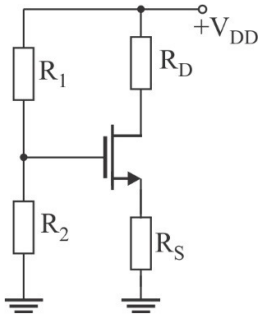
1. Zadatak

Za kolo pojačavača prikazano na slici odrediti:
a) Jednosmerni napon između drejna i sorsa V_{DS};
b) Transkonduktansu g_m;
c) Naponsko pojačanje $A_n = \frac{v_o}{v_g}$;

Elementi kola su: R_1= 700 kW; R_2= 300 kW;
R_S=0,5 kW; R_D=3 kW; R_P=3 kW; V_{DD}= 10 V;
$C_S \to \infty$. Parametri MOSFET-ova su: $A = 2\frac{mA}{V^2}$
$V_t = 1\,V$; $\lambda = 0$.



Rešenje:



(G) $\frac{V_G}{R_2} + \frac{V_G - V_{DD}}{R_1} = 0$

(S) $\frac{V_S}{R_S} - I_D = 0$

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

(G) $V_G = 0{,}3 \cdot V_{DD}$

(S) $V_S = I_D \cdot R_S$

$V_{GS} = V_G - V_S = 0{,}3 \cdot V_{DD} - R_S \cdot I_D$

$V_{GS} = 0{,}3\,V_{DD} - R_S \cdot A \cdot (V_{GS} - V_t)^2$

$V_x = V_{GS} - V_t$

$R_S \cdot A \cdot (V_{GS} - V_t)^2 \quad + (V_{GS} - V_t) + V_t - \ \ 0{,}3\, V_{DD} = 0$

$R_S \cdot A \cdot V_x^2 + V_x + V_t - 0{,}3\, V_{DD} = 0$

$V_x^2 + V_x - 2 = 0$

$V_x = \dfrac{-1 \pm \sqrt{1+8}}{2}$

$V_{x1} = 1\ V$

$V_{x1} = -2\ V$

Mora da bude zadovoljen uslov da je $V_{GS} > V_t$ što je isto kao:

$$V_x > 0$$

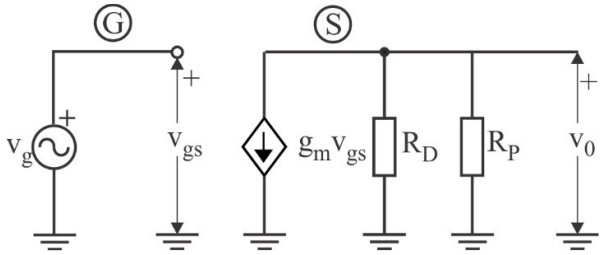
Znači prihvatljivo rešenje je $V_{x1} = 1\ V$

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

b)

$g_m = 2 \cdot \sqrt{A \cdot I_D} = 4\ mS$

c)



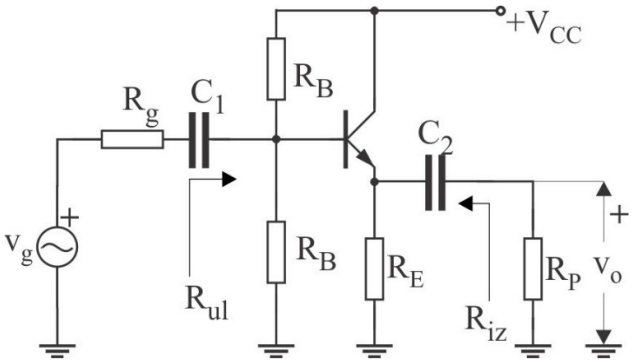
$v_{gs} = v_g$

$i_d = g_m \cdot v_{gs}$

$v_{iz} = -R_D || R_P \cdot i_d$

$A_n = \dfrac{v_{iz}}{v_g} = -(R_D \parallel R_p) \cdot g_m = -6$

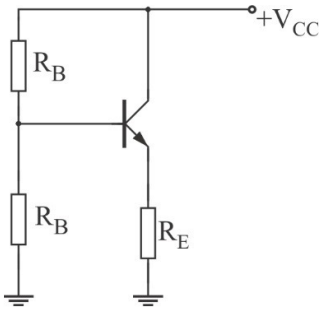
2. Zadatak



Za kolo pojačavača prikazano na slici odrediti:
a) Jednosmerni napon između kolektora i emitora tranzistora V_{CE};
b) Dinamičke parametre parametre: $h_{11E} = r_\pi$ i transkonduktansu g_m;
c) Ulaznu otpornost R_{ul};
d) Izlaznu otpornost R_{iz}.
Elementi kola su: R_B= 50 kΩ; R_E=R_p=5 kΩ;
R_g=1 kΩ; V_{CC}= 12 V; $C_1 \to \infty$; $C_2 \to \infty$.
Parametri tranzistora su: V_{BE}= 0,7 V; β=h_{21E}=100. Temperaturski potencijal iznosi $V_T = 26\ mV$.

Rešenje

a)



$$V_{BB} = \frac{R_B}{2 \cdot R_B} \cdot V_{CC} = \frac{V_{CC}}{2}$$

$$V_{BB} - \frac{R_B}{2} \cdot I_B - V_{BE} - R_E \cdot I_B \cdot (1 + \beta) = 0$$

$$I_B = \frac{V_{BB} - V_{BE}}{\frac{R_B}{2} + (1 + \beta) \cdot R_E} = 10\ \mu A$$

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

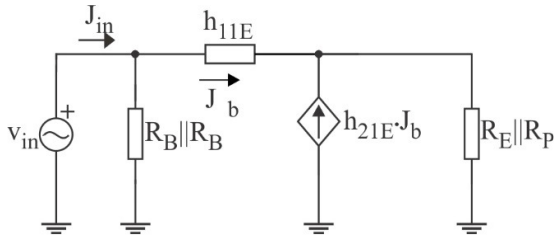
$$V_{CE} = V_{CC} - R_E \cdot (1 + \beta)\ I_B = 7\ V$$

b)

$$r_\pi = h_{11E} = \frac{V_T}{I_B} = \frac{26mV}{10\mu A} = 2{,}6\ k\Omega$$

$$g_m = \frac{I_C}{V_T} = 38{,}4\ mS$$

c)



$R_E \parallel R_P = R_{EC}$

$(B) \qquad 2 \cdot \frac{v_b}{R_B} + J_b - J_{in} = 0$

(E) $\qquad -J_b - h_{21E} \cdot J_b + \frac{v_e}{R_{EC}} = 0$

$J_b = \frac{v_b - v_e}{h_{11e}}$

(E) $\qquad v_e = R_{EC} \cdot J_b \cdot (1 + h_{21e})$

$J_b = \frac{v_{in} - R_{EC} \cdot J_b \cdot (1 + h_{21e})}{h_{11e}}$

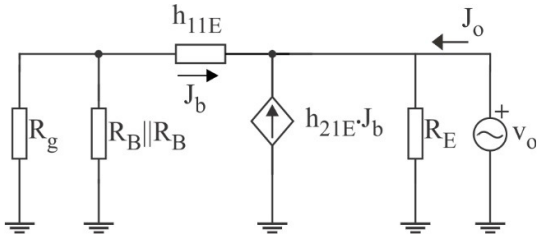
$J_b = \frac{v_{in}}{h_{11e} + R_{EC} \cdot (1 + h_{21e})}$

(B) $\qquad J_{in} = 2\frac{v_{in}}{R_B} + \frac{v_{in}}{h_{11e} + R_{EC} \cdot (1 + h_{21e})}$

$\frac{1}{R_{ul}} = \frac{J_{in}}{v_{in}} = \frac{2}{R_B} + \frac{1}{h_{11e} + R_{EC} \cdot (1 + h_{21e})}$

$R_{ul} = 22{,}7\ k\Omega$

d)



$R_B \parallel R_B \parallel R_g = R_{BC}$

$(B) \qquad \frac{v_b}{R_{BC}} + J_b = 0$

(E) $\qquad -J_o - h_{21E} \cdot J_b - J_b + \frac{v_e}{R_E} = 0$

$J_b = \frac{v_b - v_e}{h_{11e}}$

(B) $\quad v_b = -J_b \cdot R_{BC}$

$J_b = \frac{-J_b \cdot R_{BC} - v_o}{h_{11e}}$

$J_b = -\frac{v_o}{h_{11e} + R_{BC}}$

(E)

$J_o = -(h_{21E} + 1) \cdot J_b + \frac{v_o}{R_E} = (h_{21E} + 1) \cdot \frac{v_o}{h_{11e} + R_{BC}} + \frac{v_o}{R_E}$

$\frac{1}{R_{iz}} = \frac{J_o}{v_o} = \frac{1 + h_{21e}}{h_{11e} + R_{BC}} + \frac{1}{R_E}$

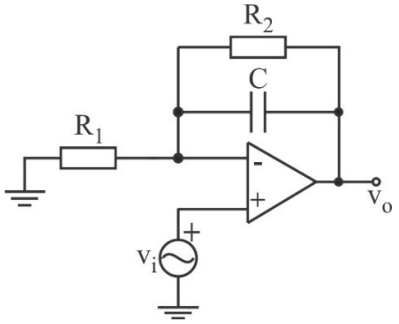
$R_{iz} = 35\ \Omega$

3. Zadatak

Za kolo sa slike odrediti:

a) Prenosnu funkciju $T(s) = \frac{V_o(s)}{V_i(s)}$;
b) Jednosmerno pojačanje;
c) Graničnu frekvenciju.

Poznato je: $R_1 = R_2 = R = 10\ k\Omega$; $C = 10\ nF$.



$$\frac{v_1}{R_1} + \frac{v_1 - v_o}{R_2} + s \cdot C \cdot (v_1 - v_o) = 0$$
$$v_1 = v_i$$

$$T(s) = \frac{v_o}{v_I} = \frac{R_1 + R_2 + s \cdot C \cdot R_1 \cdot R_2}{R_1 + s \cdot C \cdot R_1 \cdot R_2}$$
$$T(s) = \frac{R_1 + R_2}{R_1} \cdot \frac{1 + s \cdot C \cdot \frac{R_1 \cdot R_2}{R_1 + R_2}}{1 + s \cdot C \cdot R_2}$$

Ovaj filtar je **propusnik niskih frekvencija** jer kada frekvencija teži nuli pojačanje teži konačnoj vrednosti, a kada frekvencija teži beskonačnosti pojačanje teži nuli. Za propusnik niskih frekvencija nominalno pojačanje, To, se dobija za s=0.

$$T(s) = T_o \cdot \frac{1 + \frac{s}{\omega_z}}{1 + \frac{s}{\omega_p}}$$

Nominalno pojačanje je i jednosmerno pojačanje $T_o = \frac{R_2 + R_1}{R_1} = 2$

Frekvencija pola $\omega_p = \frac{1}{C \cdot R_2} = 10^4 \frac{rad}{s}$

Frekvencija nule $\omega_z = \frac{1}{C \cdot R_1 \parallel R_2} = 2 \cdot 10^4 \frac{rad}{s}$

Amplitudska karakteristika se dobijakao moduo prenosne funkcijekola:

$$|T(j\omega)| = \left| T_o \cdot \frac{1 + \frac{j \cdot \omega}{\omega_z}}{1 + \frac{j \cdot \omega}{\omega_p}} \right| = |T_o| \cdot \sqrt{\frac{1 + \left(\frac{\omega}{\omega_z}\right)^2}{1 + \left(\frac{\omega}{\omega_p}\right)^2}}$$

Granična frekvencija, ω_{3dB}, je frekvencija na kojoj je moduo pojačanje manji $\frac{1}{\sqrt{2}}$puta u odnosu na nominalno pojačanje.

$$|T(j\omega_{3dB})| = |T_o| \cdot \frac{1}{\sqrt{2}}$$

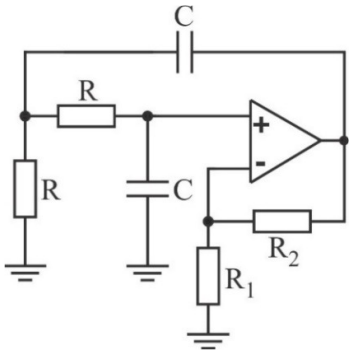
$$\frac{1 + \left(\frac{\omega_{3dB}}{\omega_z}\right)^2}{1 + \left(\frac{\omega_{3dB}}{\omega_p}\right)^2} = \frac{1}{2}$$

$$\omega_{3dB} = \frac{1}{\sqrt{\frac{1}{\omega_z^2} - \frac{2}{\omega_p^2}}} = \sqrt{2} \cdot \omega_p = 1{,}41 \cdot 10^4 \frac{rad}{s}$$

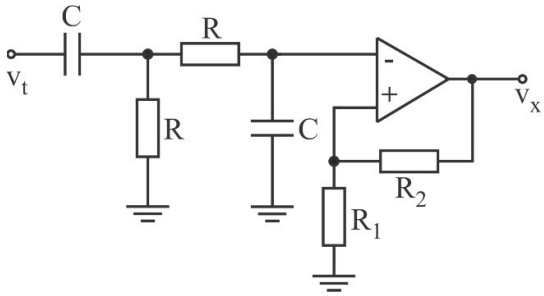
4. Zadatak

U kolu oscilatora prikazanog na slici poznato je:
$R = 1\ k\Omega\ \ C = 10\ nF\ \ R_1 = 1\ k\Omega$.
Operacioni pojačavač je idealan. Odrediti:

a. Kružno pojačanje
b. Frekvenciju oscilacija
c. Vrednost otpornika R_2 pri kojoj nastaju oscilacije.



Rešenje:



$$\frac{V_1}{R} + s \cdot C \cdot (V_1 - V_t) + (V_1 - V_2) \cdot \frac{1}{R} = 0$$

$$V_2 \cdot s \cdot C + \frac{1}{R} \cdot (V_2 - V_1) = 0$$

$$V_3 \cdot \frac{1}{R_1} + (V_3 - V_x) \cdot \frac{1}{R_2} = 0$$

$$V_2 = V_3$$

$$A \cdot B = \frac{V_x}{V_t} = \frac{R_1 + R_2}{R_1} \cdot \frac{s \cdot C \cdot R}{1 + 3 \cdot s \cdot C \cdot R + (s \cdot C \cdot R)^2}$$

$$A \cdot B(j\omega) = \frac{R_1 + R_2}{R_1} \cdot \frac{j \cdot \omega \cdot C \cdot R}{1 + 3 \cdot j \cdot \omega \cdot C \cdot R - \omega^2 \cdot (C \cdot R)^2}$$

Prema Barkhauzenovom uslovu oscilovanja neophodan uslov da nastupe oscilacije je da kružno pojačanje iznosi 1.

$$A \cdot B(j\omega) = 1$$

$$\frac{R_1 + R_2}{R_1} \cdot \frac{j \cdot \omega \cdot C \cdot R}{1 + 3 \cdot j \cdot \omega \cdot C \cdot R - \omega^2 \cdot (C \cdot R)^2} = 1$$

$$1 + 3 \cdot j \cdot \omega \cdot C \cdot R - \omega^2 (C \cdot R)^2 - \left(\frac{R_1 + R_2}{R_1}\right) \cdot j \cdot \omega \cdot C \cdot R = 0$$

Da bi ova jednačina bila ispunjena neophodno neophodno je da zbir realnih sabiraka bude jednak nuli i da zbir imaginarnih sabiraka bude jedank nuli. Odavde se dobijaju dve jednačine. Iz jedne od njih dobijamo uslov oscilovanja a iz druge frekvenciju oscilovanja.

$$1 - \omega^2 (C \cdot R)^2 = 0 \qquad\qquad 3 \cdot j \cdot \omega \cdot C \cdot R - \left(\frac{R_1 + R_2}{R_1}\right) \cdot j \cdot \omega \cdot C \cdot R = 0$$

$\omega_o = \frac{1}{R \cdot C}$

Frekvencija oscilovanja

$\omega_o = \frac{10^5}{1{,}6} = 10^5 \frac{rad}{s}$

$\frac{R_2}{R_1} = 2$

Uslov oscilovanja

$R_2 = 2\ k\Omega$