Elektronski fakultet Niš
Katedra za Elektroniku 10.06.2022.

OSNOVI ELEKTRONIKE
Modul elektroenergetika (2OEP3O03) (3OEP3A01)

1. Zadatak

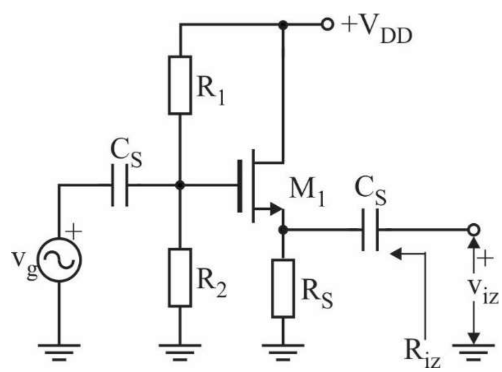
Za kolo pojačavača prikazano na slici odrediti:

a) Dinamičke parametre tranzistora: strminu g_m, izlaznu otpornost r_o i koeficijent naponskog pojačanja μ;

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

c) Izlaznu otpornost tranzistora R_{iz}.

Elementi kola su: $R_S = 6\ k\Omega$, $R_1 = 1\ M\Omega$, $R_2 = 2\ M\Omega$, $V_{DD} = 12\ V$, $C_S \to \infty$. Parametri tranzistora su: $A = 1\ mA/V^2$, $V_t = 1\ V$, $\lambda = 0{,}01\ V^{-1}$ (V_A=100 V).



Rešenje:

a)

$$V_G = \frac{R_2}{R_1 + R_2} \cdot V_{DD}$$

$$V_S = R_S \cdot I_D$$

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

$$V_x = V_{GS} - V_t$$

$$V_{GS} = \frac{R_2}{R_1 + R_2} \cdot V_{DD} - R_S \cdot A \cdot (V_{GS} - V_t)^2$$

$$R_S \cdot A \cdot (V_{GS} - V_t)^2 + (V_{GS} - V_t) + V_t - \frac{R_2}{R_1 + R_2} \cdot V_{DD} = 0$$

$$R_S \cdot A \cdot V_x^2 + V_x + V_t - \frac{R_2}{R_1 + R_2} \cdot V_{DD} = 0$$

$$V_x^2 + V_x - 2 = 0$$

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

$$V_{x1} = 1\ V$$

~~$V_{x1} = -2\ V$~~

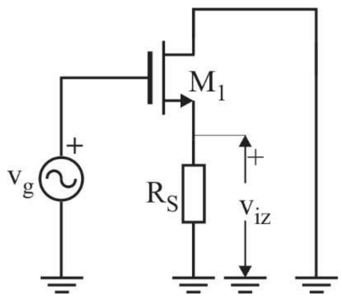
$$I_D = A \cdot V_x^2 = 1\ mA$$

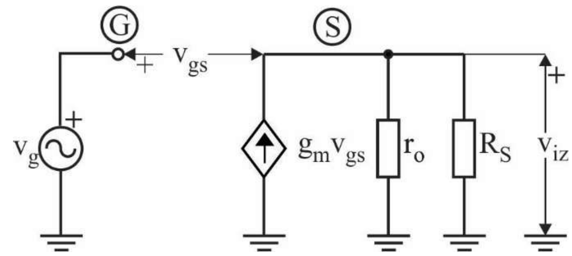
$$g_m = 2 \cdot \sqrt{A \cdot I_D} = 2\ mS$$

$$r_o = \frac{1}{\lambda \cdot I_D} = 100\ k\Omega$$

$$\mu = g_m \cdot r_o = 200$$

b)





$$-g_m \cdot v_{gs} + \frac{v_s}{r_o} + \frac{v_s}{R_s} = 0$$

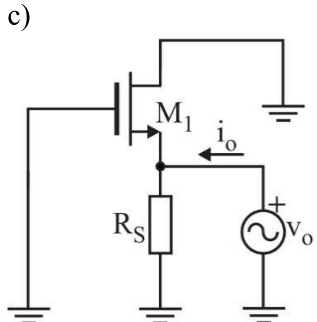
$$v_{gs} = v_g - v_s$$

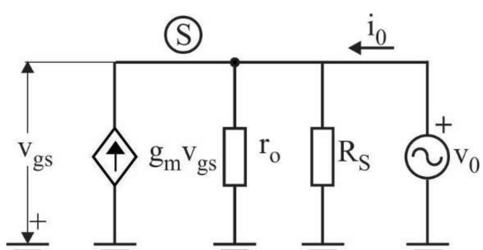
$$-g_m \cdot v_g + g_m \cdot v_s + \frac{v_s}{r_o} + \frac{v_s}{R_s} = 0$$

$$v_{iz} = v_s = \frac{g_m \cdot v_g}{g_m + \frac{1}{r_o} + \frac{1}{R_s}}$$

$$A_n = \frac{v_{iz}}{v_g} = \frac{g_m}{g_m + \frac{1}{r_o} + \frac{1}{R_s}} = 0.92$$

c)





$$i_o = \frac{v_o}{R_s} + \frac{v_o}{r_o} - g_m \cdot v_{gs}$$

$$v_{gs} = -v_s$$

$$R_{iz} = \frac{v_o}{i_o} = \frac{1}{\frac{1}{R_s} + \frac{1}{r_o} + g_m} = R_s \parallel r_o \parallel \left(\frac{1}{g_m}\right) = 497\ \Omega$$

$$\left(\frac{1}{g_m}\right) \ll R_s, r_o$$

$$R_{iz} = R_s \parallel r_o \parallel \left(\frac{1}{g_m}\right) \approx g_m$$

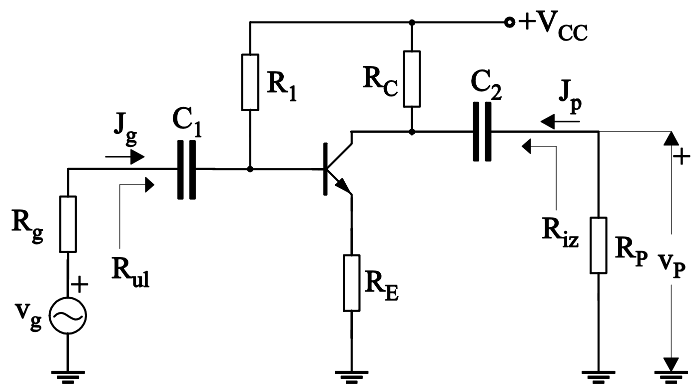
2. Zadatak

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) Naponsko pojačanje $A_n = \frac{v_p}{v_g}$.



Parametri tranzistora su: V_{BE}=0,6 V; $h_{12E} = 0$; $\beta = h_{21E} = 50$; h_{22E} =0 S ($r_o \to \infty$). Elementi kola su: $R_p = R_C = 5$ kΩ; $R_g = 1$ kΩ; $R_1 = 500$ kΩ; $R_E = 200$ Ω; V_{CC}=12 V; $C_1 \to \infty$; $C_2 \to \infty$. Temperaturski potencijal iznosi $V_T = 26\ mV$.

Rešenje:

a)

$$V_{CC} - R_1 \cdot I_B - V_{BE} - R_E \cdot (1+\beta) \cdot I_B = 0$$

$$I_B = \frac{V_{CC} - V_{BE}}{R_1 + R_E \cdot (1+\beta)} = 20\ \mu A$$

$$V_C = V_{CC} - R_C \cdot I_C$$

$$V_E = R_E \cdot I_E = R_E \cdot (1+\beta) \cdot I_B$$

$$V_{CE} = V_{CC} - R_C \cdot \beta \cdot I_B - R_E \cdot (1+\beta) \cdot I_B = 6{,}8\ V$$

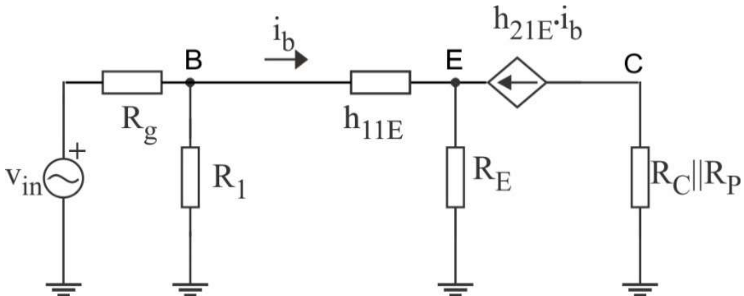
b)

$$h_{11E} = r_\pi = \frac{V_T}{I_B} = \frac{26\ mV}{20 \mu A} = 1{,}3\ k\Omega$$

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

$$g_m = \frac{h_{21}}{r_\pi} = \frac{I_C}{V_T}$$

c)



(E) $\frac{v_e}{R_E} - i_b - h_{21e} \cdot i_b = 0$

(B) $\frac{v_b}{R_1} + \frac{v_b - v_g}{R_g} + i_b = 0$

(C) $\frac{v_c}{R_C \| R_P} - h_{21E} \cdot i_b = 0$

$$i_b = \frac{v_b - v_e}{h_{11E}}$$

(E) $v_e = R_E \cdot i_b \cdot (1 + h_{21E})$

(B) $v_b = v_g \cdot \frac{R_1}{R_1 + R_g} - i_b \cdot \frac{R_1 \cdot R_g}{R_1 + R_g}$

$$i_b = \frac{v_g \cdot \frac{R_1}{R_1 + R_g}}{R_E \cdot (1 + h_{21E}) + \frac{R_1 \cdot R_g}{R_1 + R_g} + h_{11E}}$$

$$v_p = v_c = -h_{21E} \cdot i_b \cdot R_C \parallel R_P$$

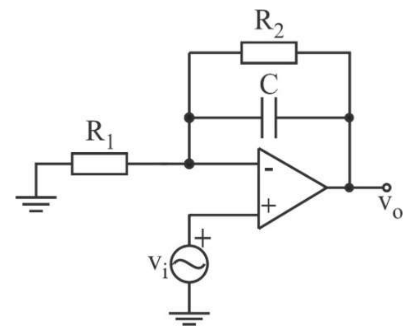
$$A_n = \frac{v_c}{v_p} = -\frac{h_{21E} \cdot R_C \parallel R_P \cdot \frac{R_1}{R_1 + R_g}}{R_E \cdot (1 + h_{21}\ \ ) + \frac{R_1 \cdot R_g}{R_1 + R_g} + h_{11E}} = 10$$

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: $R_1 = R_2 = R = 10\ k\Omega;\ C = 20\ nF.$



Rešenje:

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

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

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

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 $\omega_p = \frac{1}{C \cdot R_2} = 0{,}5 \cdot 10^4 \frac{rad}{s}$

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

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.

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

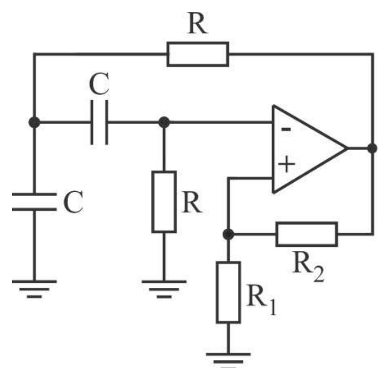
$$\frac{1+\left(\frac{\omega_{3dB}}{\omega_z}\right)^2}{1+\left(\frac{\omega_{3dB}}{\omega_p}\right)^2} = \frac{1}{2}$$

$$\omega_{3dB} = \frac{1}{\sqrt{\frac{1}{\omega_p^2} - \frac{2}{\omega_z^2}}} = \sqrt{2}\cdot\omega_{\mathrm{p}} = 0{,}71\cdot 10^4\,\frac{rad}{s}$$

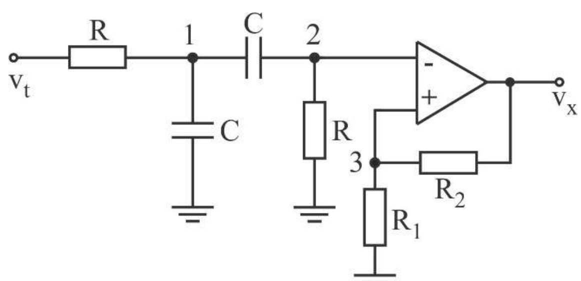
4. Zadatak

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:



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

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

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

$$V_2 = V_3$$

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

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

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.

$$1 - \omega^2 (C \cdot R)^2 = 0$$

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

Frekvencija oscilovanja

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

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

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

Uslov oscilovanja

$$R_2 = 2 \, k\Omega$$