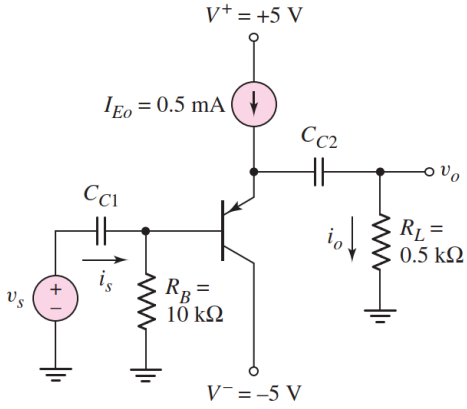
Elektronski fakultet Niš
Katedra za Elektroniku 29.09.2023.

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

1. Zadatak

Na slici je prikazan pojačavač u sprezi sa zajedničkom bazom.
Ukoliko je: β=80, V_{BE}=0,7 V, $V_A = 100\ V$ odrediti:

a) Ulaznu otpornost $R_{in} = \frac{v_s}{i_s}$
b) Naponsko pojačanje $A = \frac{v_O}{v_s}$
c) Izlaznu otpornost R_o

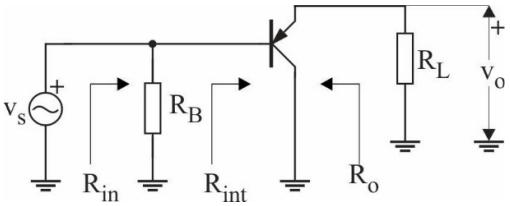


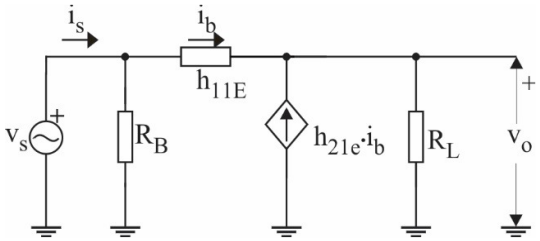
Rešenje:

a)

$$I_B = \frac{I_{Eo}}{1+\beta} = 6{,}17\ \mu A$$

$$h_{11E} = \frac{V_T}{I_B} = \frac{26\ mV}{6{,}17\ \mu V} = 4{,}2\ k\Omega$$





$$-i_b - h_{21E} \cdot i_b + \frac{v_0}{R_L} = 0$$

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

$$v_o = i_b \cdot R_L + h_{21E} \cdot i_b \cdot R_L$$

$$v_s = h_{11} \cdot i_b + v_o$$

$$v_s = h_{11} \cdot i_b + i_b \cdot R_L + h_{21E} \cdot i_b \cdot R_L$$

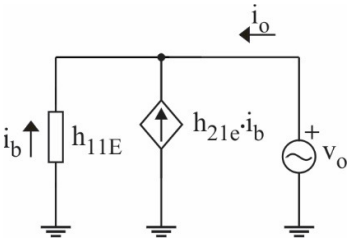
$$R_{int} = \frac{v_s}{i_b} = h_{11} + R_L + h_{21E} \cdot R_L = 44{,}7\ k\Omega$$

$$R_{in} = R_{int} \parallel R_B = 8{,}17\ k\Omega$$

b)

$$A_n = \frac{v_o}{v_s} = \frac{i_b}{v_s} \cdot \frac{v_o}{i_b} = \frac{1}{R_{int}} \cdot (1 + h_{21E}) \cdot R_L = \frac{(1 + h_{21E}) \cdot R_L}{h_{11} + R_L + h_{21E} \cdot R_L} = 0{,}9$$

c)

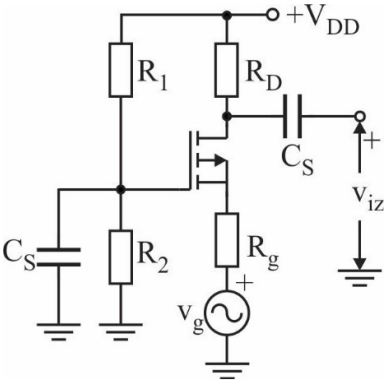


$$i_b = -\frac{v_o}{h_{11E}}$$
$$-i_o - i_b - h_{21E} \cdot i_b = 0$$

$$i_o = v_o \cdot \left(\frac{1 + h_{21E}}{h_{11E}}\right)$$
$$R_o = \frac{v_o}{i_o} = \frac{h_{11E}}{(1 + h_{21E})} = 52\ \Omega$$

2. Zadatak

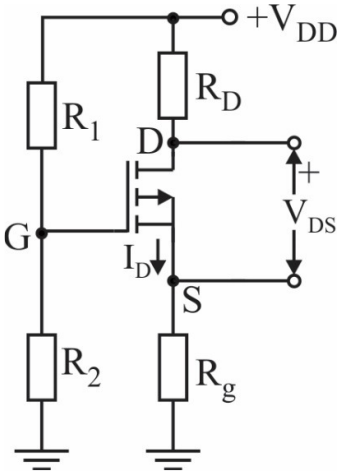
Za kolo pojačavača prikazano na slici odrediti:
a) Jednosmerni napon između drejna i sorsa V_{DS};
b) Transkonduktansu g_m;
c) Naponsko pojačanje $A_n = \frac{v_{iz}}{v_g}$;
Poznato je R_g = 1 kΩ, R_D = 6 kΩ, R_1 = 2 MΩ, R_2 = 1 MΩ, V_{DD} = 12 V. C_S teži beskonačnosti. Parametri tranzistora su: A = 1 mA/V^2 , V_T = 2 V i $\lambda = 0$ ($V_A \to \infty$).



Rešenje:

a)

U jednosmernom režimu naizmenični generator, vg, se modelira kao kratak spoj.



$$V_G \cdot \frac{1}{R_2} + (V_G - V_{DD}) \cdot \frac{1}{R_1} = 0$$
$$V_S = R_g \cdot I_D$$
$$I_D = A \cdot (V_{GS} - V_t)^2$$

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

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

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

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

$$V_x = \frac{-1 \pm \sqrt{1 + 28 \cdot 6}}{12}$$

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

~~$V_{x2} = -2\ V$~~

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

$$V_D = V_{DD} - R_D \cdot I_D = 6\ \text{V}$$

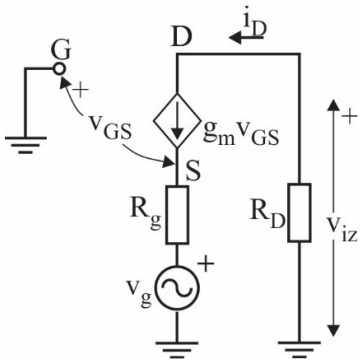
$$V_S = R_g \cdot I_D = 1\ V$$

$$V_{DS} = V_D - V_S = 5\ V$$

b)

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

b)



$$g_m \cdot v_{gs} + \frac{v_{iz}}{R_D} = 0$$

$$v_{gs} = 0 - (i_D \cdot R_g + v_g)$$

$$i_d = g_m \cdot v_{gs}$$

$$v_{gs} = -g_m \cdot v_{gs} \cdot R_g - v_g$$

$$v_{gs} = \frac{-v_g}{1 + g_m \cdot R_g}$$

$$v_{iz} = -R_D \cdot i_D$$
$$v_{iz} = \frac{R_D \cdot v_g}{1 + g_m \cdot R_g}$$
$$A_n = \frac{v_{iz}}{v_g} = \frac{R_D}{1 + g_m \cdot R_g} = 2$$

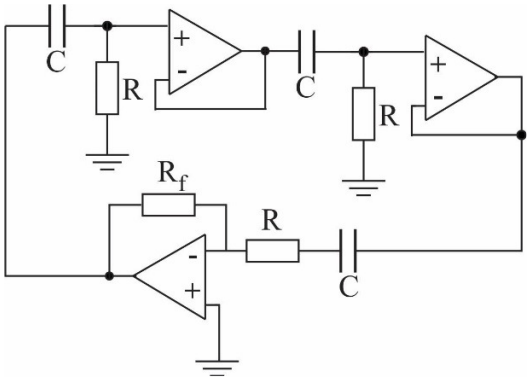
3. Zadatak

U kolu oscilatora prikazanog na slici poznato je: $R = 1\ k\Omega\ \ C = 10\ nF$. Operacioni pojačavači su idealani. Odrediti:

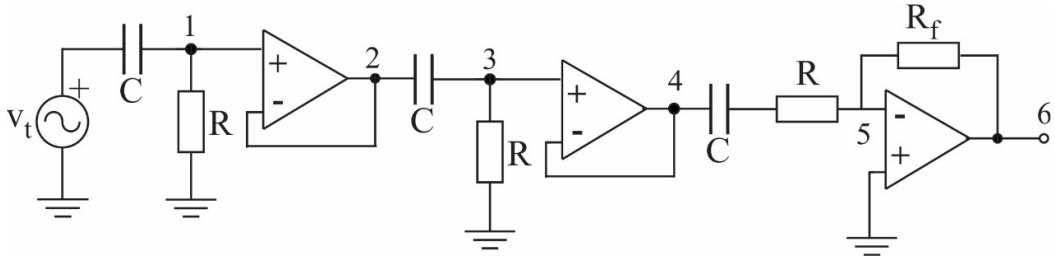
a) Kružno pojačanje;

b) Vrednost otpornika R_f pri kojoj nastaju oscilacije.

c) Frekvenciju oscilacija.



Rešenje:



$$v_1 \cdot \left(\frac{1}{R} + s \cdot C\right) - v_t \cdot sC = 0$$

$$v_3 \cdot \left(\frac{1}{R} + s \cdot C\right) - v_2 \cdot s \cdot C = 0$$

$$v_5 \cdot \left(\frac{1}{\frac{1}{s \cdot C} + R} + \frac{1}{R_f}\right) - v_6 \cdot \frac{1}{R_f} = 0$$

$$v_1 = v_2$$

$$v_3 = v_4$$

$$v_5 = 0$$

$$AB = \frac{v_6}{v_t} = -\frac{(SC)^3 \cdot R^2 \cdot R_f}{(1 + sCR)^3}$$

b)

$$AB = -\frac{(SC)^3 \cdot R^2 \cdot R_f}{(1 + sCR)^3} = 1$$

$$1 + 3 \cdot (SCR)^2 + 3SCR + (SCR)^3 + (SC)^3 \cdot R^2 \cdot R_f = 0$$

Izdvajanjem realnih sabiraka dobija se sledeća jednačina:

$1 + 3 \cdot (SCR)^2$=0

$1 - 3 \cdot (\omega CR)^2 = 0$

$$\omega_o = \frac{1}{\sqrt{3} \cdot C \cdot R} = 5{,}7 \cdot 10^4 \frac{rad}{s}$$

Izdvajanjem imaginarnih sabiraka dobija se

$$3SCR + (SCR)^3 + (SC)^3 \cdot R^2 \cdot R_f = 0$$

$$3 + (SCR)^2 + (SC)^2 \cdot R \cdot R_f = 0$$

$$3 - \frac{1}{3} - \frac{1}{3} \cdot \frac{R_f}{R} = 0$$

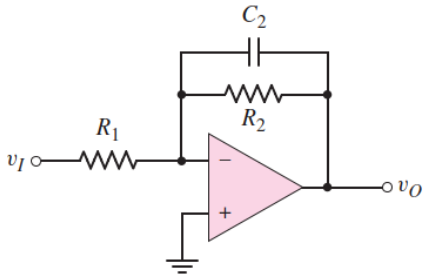
$$R_f = 8 \cdot R = 8\ k\Omega$$

4. Zadatak

Za kolo aktivnog filtra sa slike odrediti:

a) prenosnu funkciju $T(s) = \frac{V_i(s)}{V_g(s)}$ i tip filtra

Odrediti elementa kola tako da ulazna otpornost iznosi $20\ k\Omega$, jednosmerno pojačanje -15, granična frekvencija 5 KHz.



Rešenje:

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

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

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.

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

Nominalno pojačanje je $T_o = -\frac{R_2}{R_1}$

Frekvencija pola $\omega_p = \frac{1}{C \cdot R_2}$

Ulazna otpornost kola jednaka je otpornosti R_1.

$$R_{in} = \frac{V_{in}}{I_{in}} = R_1 = 20\ k\Omega$$

Iz uslova da nominalno pojačanje iznosi -15 dobija se R_2.

$$T_o = -\frac{R_2}{R_1} = -15$$
$$R_2 = -R_1 \cdot T_o = 300\ k\Omega$$

Amplitudska karakteristika se dobijakao moduo prenosne funkcijekola:

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

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

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

$$\omega_{3dB} = \omega_p = \frac{1}{C \cdot R_2}$$

$$C = \frac{1}{\omega_{3dB} \cdot R_2} = \frac{1}{2 \cdot \pi \cdot 5 \cdot 10^3 \cdot 3 \cdot 10^5}$$

$$C = 106\, pF$$