Elektronski fakultet Niš
Katedra za Elektroniku

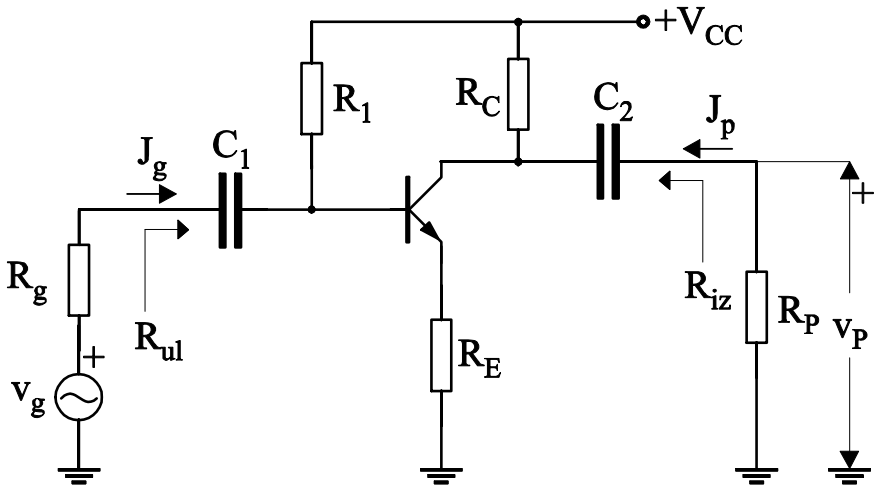
18.09.2023.

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

1. Zadatak

Kolo na slici predstavlja jednostepeni pojačavač sa bipolarnim tranzistorom. Parametri tranzistora su: V_{BE}=0,6 V; $h_{12E} = 0$; $h_{21E} = \beta = 50$; $h_{22E} = 0$ S. 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; $C_1 \to \infty$; $C_2 \to \infty$.
Odrediti:

a) ulaznu otpornost pojačvača R_{in};
b) naponsko pojačanje $A = \frac{v_p}{v_g}$.



Rešenje:

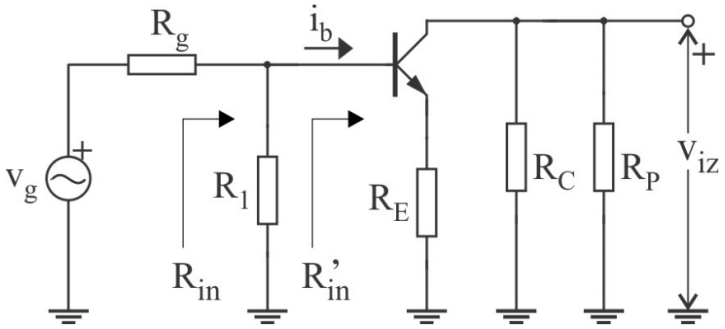
$$V_{CC} - R_1 \cdot I_B - V_{BE} - R_E \cdot (1 + \beta) \cdot I_B = 0$$

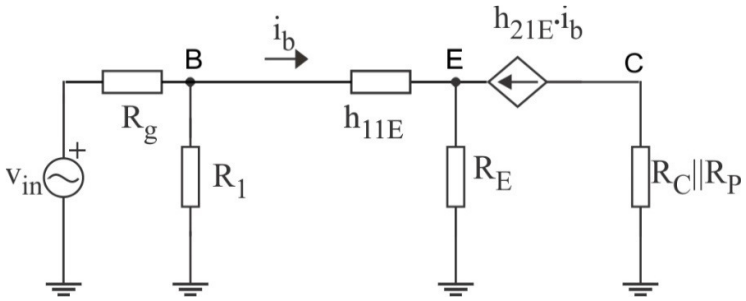
$$I_B = \frac{V_{CC} - V_{BE}}{R_1 + R_E \cdot (1 + \beta)} = 20\ \mu A$$

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

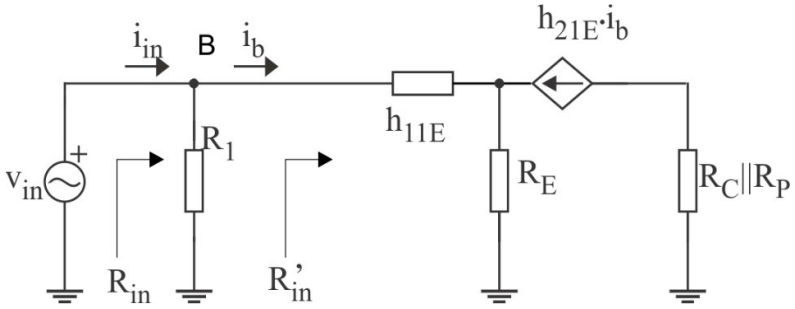
$$h_{21E} = \beta$$

$$g_m = \frac{h_{21E}}{r_\pi} = \frac{I_C}{V_T} = 38{,}5\ mS$$





a)



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

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

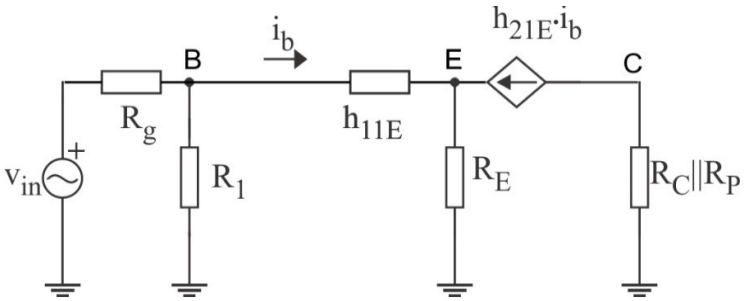
(E) $v_e = R_E \cdot i_b \cdot (1 + h_{21E})$

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

$R'_{in} = \frac{v_{in}}{i_b} = h_{11E} + R_E \cdot (1 + h_{21E}) = 11{,}5\ k\Omega$

$R_{in} = R'_{in} \parallel R_1 = 11{,}24\ k\Omega$

b)



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

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

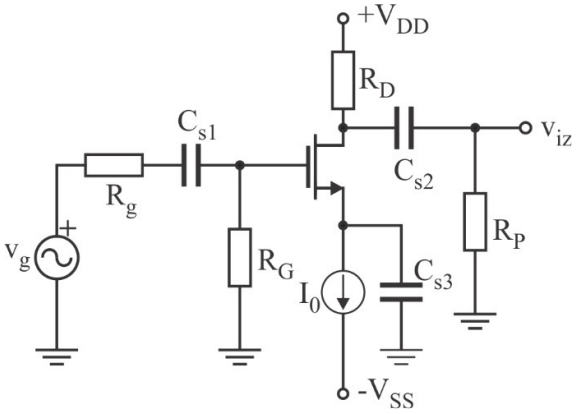
$$v_p = v_c = -h_{21E} \cdot i_b \cdot R_C \parallel R_P$$

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

2. Zadatak

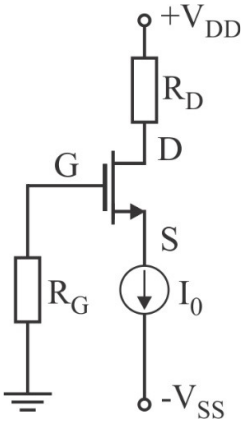
Parametri MOSFET-a u kolu sa slike su: A = 2 mA/V^2 ; V_t = 1,5 V; λ=0,01 V^{-1} ($V_A = 100\ V$). Poznati su elementi kola: R_g = 100 kΩ; R_G = 4,7 MΩ; R_D = 5 kΩ; R_P = 20 kΩ; I_o= 0,5 mA; V_{DD}= 5 V; V_{SS}= 5 V. Smatrati da: $C_{S1} \to \infty$, $C_{S2} \to \infty$, $C_{S3} \to \infty$. Odrediti:

a) Radnu tačku tranzistora (V_{DS}, I_D);
b) Strminu tranzistora g_mi iznaznu otpornost tranzistora r_o;
c) Naponsko pojačanje. $A_n = \frac{v_{iz}}{v_g}$.



Rešenje:

a)



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

$$V_{GS} = \sqrt{\frac{I_D}{A}} + V_t$$

$$V_{GS} = \sqrt{\frac{I_o}{A}} + V_t = 2\ V$$

$$V_S = V_G - V_{GS} = -V_{GS} = -2\ V$$

$$V_D = V_{DD} - R_D I_D = 2,5\ V$$

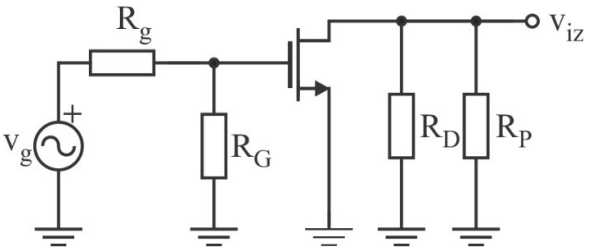
$$V_{DS} = V_D - V_S = 4,5\ V$$

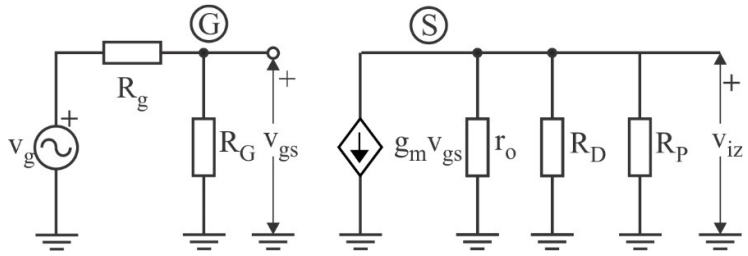
b)

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

$$r_o = \frac{1}{\lambda I_D} = \frac{1}{\lambda I_o} = 200\ k\Omega$$

c)





$$\frac{v_{gs}}{R_G} + \frac{v_{gs} - v_g}{R_g} = 0$$

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

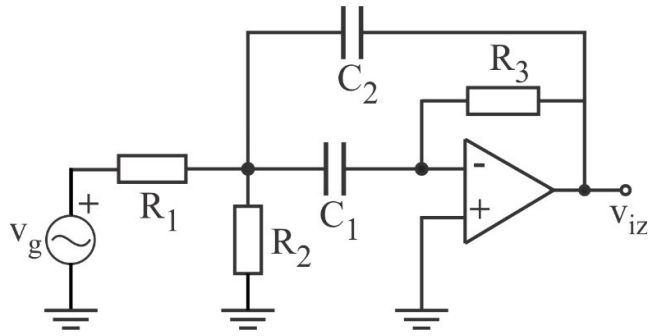
$$A_n = \frac{v_{iz}}{v_i} = -\frac{R_G}{R_G + R_g} g_m \cdot R_D \parallel r_o \parallel R_P = 7{,}8$$

3. Zadatak

Za kolo aktivnog filtra sa slike 3 odrediti:

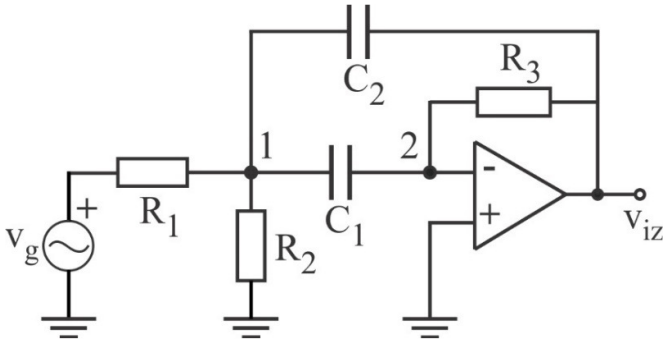
a) Prenosnu funkciju $T(s) = \frac{V_{iz}(s)}{V_{ul}(s)}$ i tip filtra;

b) Izraz za amplitudsku karakteristiku u funkciji od elemenata kola.



Slika 3

Rešenje:



Sistem jednačina koji opisuje kolo sa slike je:

$$\frac{V_1 - V_g}{R_1} + \frac{V_1}{R_2} + (V_1 - V_2)\cdot sC_1 + (V_1 - V_{iz})\cdot sC_2 = 0$$

$$\frac{V_2 - V_{iz}}{R_3} + (V_2 - V_1)\cdot sC_1 = 0$$

$$V_2 = 0$$

$$V_1 = -\frac{1}{sC_1R_3}V_{iz}$$

$$-\frac{1}{sC_1R_3}\left(\frac{1}{R_1}+\frac{1}{R_2}+sC_1+sC_2\right)V_{iz}-\frac{V_g}{R_1}-V_{iz}sC_2=0$$

$$T(s)=\frac{V_{iz}(s)}{V_g(s)}=\frac{-sC_1R_3}{1+\frac{R_1}{R_2}+s\cdot(C_1+C_2)R_1+s^2C_1C_2R_1R_3}$$

$$T(s)=\frac{V_{iz}(s)}{V_g(s)}=-\frac{R_2}{R_1+R_2}\frac{sC_1R_3}{1+s\cdot(C_1+C_2)\frac{R_1R_2}{R_1+R_2}+s^2C_1C_2\frac{R_1R_2R_3}{R_1+R_2}}$$

b)

Kada se zameni kompleska učestanost s sa $j\omega$ dobija se

$$T(j\omega)=-\frac{R_2}{R_1+R_2}\frac{j\omega C_1R_3}{1+j\omega\cdot(C_1+C_2)\frac{R_1R_2}{R_1+R_2}-\omega^2C_1C_2\frac{R_1R_2R_3}{R_1+R_2}}$$

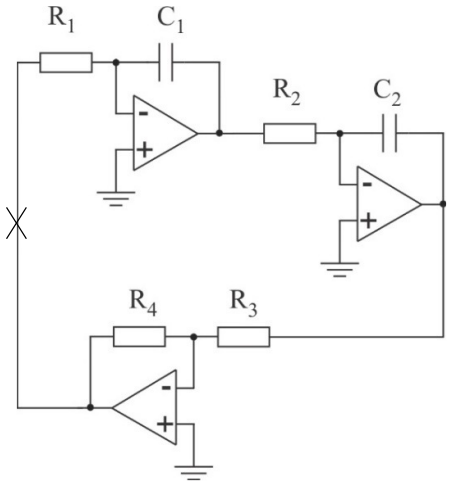
$$|T(j\omega)|=\left|\frac{N(j\omega)}{D(j\omega)}\right|=\frac{|N(j\omega)|}{\sqrt{\{Re(D(j\omega)\}^2+\{Im(D(j\omega)\}^2}}$$

Izraz za amplitudsku karakteristiku u funkciji od elemenata kola je:

$$|T(j\omega)|=\frac{R_2}{R_1+R_2}\frac{\omega C_1R_3}{\sqrt{\left(1-\omega^2C_1C_2\frac{R_1R_2R_3}{R_1+R_2}\right)^2+\omega^2(C_1+C_2)^2\left(\frac{R_1R_2}{R_1+R_2}\right)^2}}$$

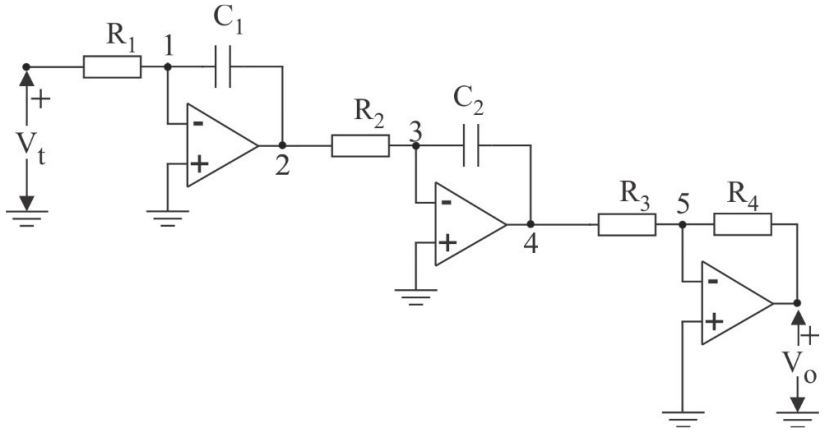
4. Zadatak

Na slici prikazano je kolo oscilatora prostoperiodičnih oscilacija. Odrediti učestanost oscilovanja ako je $R_1 = R_2 = R_3 = R_4 = 10\ \text{k}\Omega$; $C_1 = C_2 = 1{,}6\ \mu\text{F}$. Smatrati da su operacioni pojačavači idealni.



Rešenje:

U slučaju kada se analizira oscilator sa operacionim pojačavačima najpogodnije je da se kolo povratne sprege prekine na izlazu ili ulazu jednog od operacionih pojačavača.



$$\frac{1}{R_1}(V_1 - V_t) + s \cdot C_1(V_1 - V_2) = 0$$

$$\frac{1}{R_2}(V_3 - V_2) + s \cdot C_2(V_3 - V_4) = 0$$

$$\frac{1}{R_3}(V_5 - V_4) + \frac{1}{R_4}(V_5 - V_o) = 0$$

$$V_1 = V_3 = V_5 = 0$$

$$V_2 = \frac{-1}{s \cdot C_1 \cdot R_1} \cdot V_t$$

$$V_4 = \frac{-1}{s \cdot C_2 \cdot R_2} \cdot V_2$$

$$V_o = \frac{-R_4}{R_3} \cdot V_4$$

$$V_4 = \frac{1}{s^2 \cdot C_1 \cdot C_2 \cdot R_1 \cdot R_2} \cdot V_t$$

$$V_o = \frac{-R_4}{R_3} \cdot \frac{1}{s^2 \cdot C_1 \cdot C_2 \cdot R_1 \cdot R_2} \cdot V_t$$

$$A \cdot B = \frac{V_o}{V_t} = \frac{-R_4}{R_3} \cdot \frac{1}{s^2 \cdot C_1 \cdot C_2 \cdot R_1 \cdot R_2} \qquad s^2 = (j \cdot \omega)^2 = -\omega^2$$

Da bi nastupile oscilacije potrebno je da kružno pojačanje na frekvenciji oscilovanja ω_o iznosi 1.

$$A \cdot B(j\omega_o) = \frac{R_4}{R_3} \cdot \frac{1}{\omega^2 \cdot C_1 \cdot C_2 \cdot R_1 \cdot R_2} = 1$$

$$\omega_o = \sqrt{\frac{R_4}{R_3} \cdot \frac{1}{C_1 \cdot C_2 \cdot R_1 \cdot R_2}}$$

$$R_1 = R_2 = R_3 = R_4 = R \quad C_1 = C_2 = C$$

$$\omega_o = \frac{1}{R \cdot C} = \frac{1}{10^4 \cdot 1{,}6 \cdot 10^{-6}} \frac{rad}{s} = 62{,}5 \ \frac{rad}{s}$$

$$f_o = \frac{\omega_o}{2 \cdot \pi} = 10 \ Hz$$