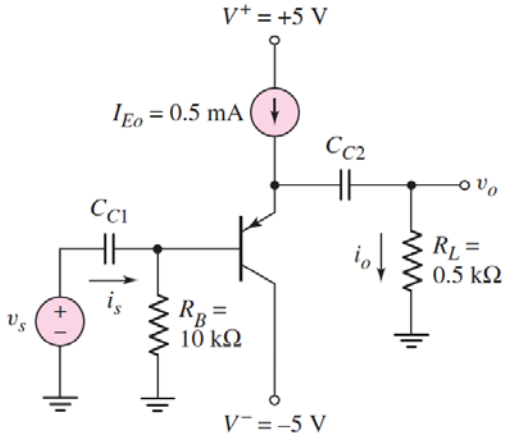
Elektronski fakultet Niš
Katedra za Elektroniku 25.03.2024.

OSNOVI ELEKTRONIKE
Modul elektroenergetika (3OEP3A01, 2OEP3O03)

1. Zadatak

Na slici 1 prikazan je pojačavač u sprezi sa zajedničkom bazom. Polarizacija kola je realizovana jednosmernim strujnim generatorom $I_{Eo} = 0{,}5\ mA$. Poznato je: β=80, V_{BE}=0,7 V; $C_{c1} \to \infty$, $R_B = 10\ k\Omega$; $R_L = 500\ \Omega$. U tačkama a,b i c smatrati da $C_{c2} \to \infty$. Odrediti:



Slika 1

a) Ulaznu otpornost $R_{in} = \dfrac{v_s}{i_s}$

b) Naponsko pojačanje $A = \dfrac{v_O}{v_s}$

c) Izlaznu otpornost R_o;

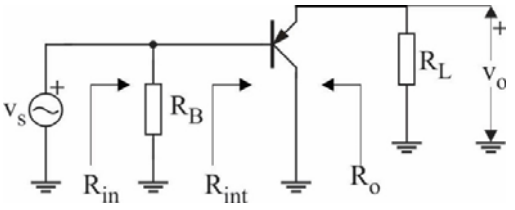
d) Donju graničnu frekvenciju pojačavača ukoliko je $C_2 = 0{,}1\ \mu F$

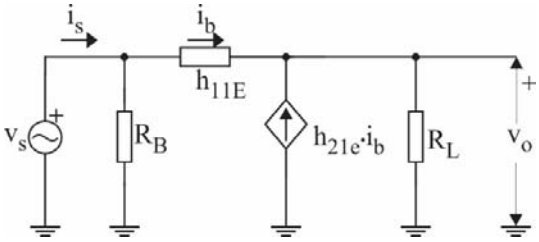
Rešenje

a)

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

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





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

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

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

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

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

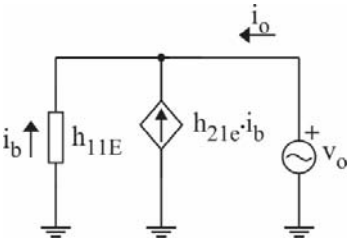
$$R_{int} = \frac{v_s}{i_b} = h_{11} + R_L + h_{21E} \cdot R_L = 44{,}7\ k\Omega$$

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

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)



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

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

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

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

d)

$$\tau = C_{C2} \cdot (R_o + R_L)$$

$$\omega_d = \frac{1}{\tau} = \frac{1}{C_{C2}(R_o + R_L)} = 1{,}81 \cdot 10^4 \frac{rad}{s}$$

$$f_d = \frac{\omega_d}{2\pi} = 2.89\ kHz$$

2. Zadatak

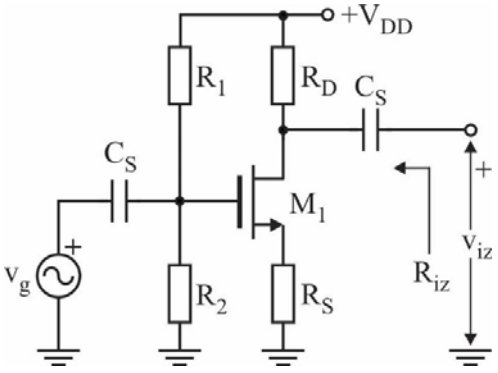
Za kolo pojačavača sa slike odrediti:

a) Dinamičke parametre tranzistora: strminu g_m, izlaznu otpornost r_o i koeficijent naponskog pojačanja μ ako je $\lambda = 0{,}01\ V^{-1}$;

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

c) Izlaznu otpornost tranzistora R_{iz};

Poznato je $R_S = 1\ k\Omega$, $R_D = 6\ k\Omega$, $R_1 = 3\ M\Omega$, $R_2 = 1\ M\Omega$ i $V_{DD} = 12\ V$. C_S teži beskonačnosti. Parametri tranzistora su: $A = 1\ mA/V^2$ i $V_t = 1\ V$.



Rešenje

a)

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

$$V_S = R_S \cdot I_D$$

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

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

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

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

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

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

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

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

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

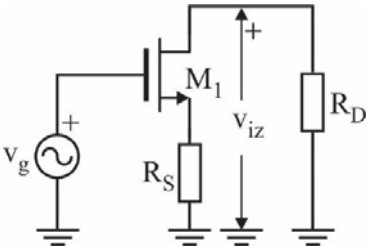
$$I_D = A \cdot V_x^2 = 1\ mA$$

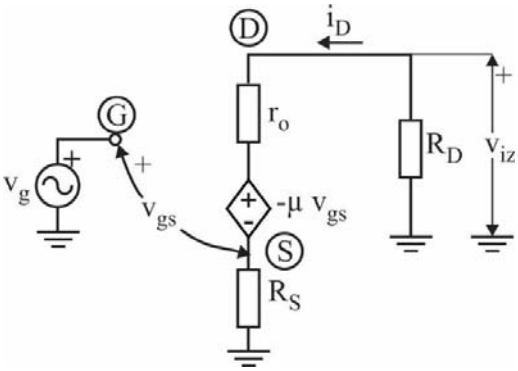
$$g_m = 2 \cdot \sqrt{A \cdot I_D} = 2\ mS$$

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

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

b) Otpornici R1 i R2 su izostavljeni iz šeme jer ne uticu na naponsko pojačanje. Ova dva otpornika imaju uticaj samo na ulaznu otoprnost.

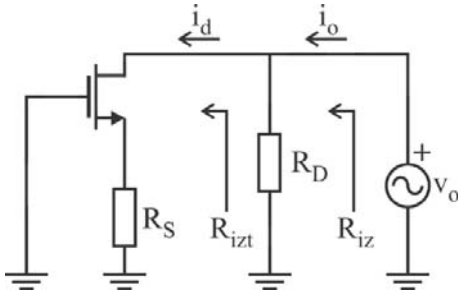


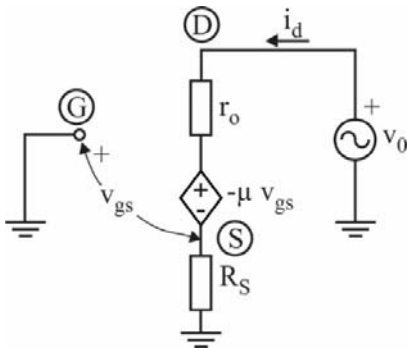


$$R_D \cdot i_d + r_o \cdot i_d - \mu \cdot v_{gs} + R_s \cdot i_d = 0$$
$$v_{gs} = v_g - i_d \cdot R_S$$
$$v_{iz} = -R_D \cdot i_d$$

$$R_D \cdot i_d + r_o \cdot i_d - \mu \cdot v_g + \mu \cdot i_d \cdot R_S + R_s \cdot i_d = 0$$
$$i_d = \frac{\mu \cdot v_g}{R_D + r_o + (\mu + 1) \cdot R_s}$$
$$v_{iz} = \frac{-R_D \cdot \mu \cdot v_g}{R_D + r_o + (\mu + 1) \cdot R_s}$$
$$A_n = \frac{v_{iz}}{v_g} = \frac{-R_D \cdot \mu}{R_D + r_o + (\mu + 1) \cdot R_s} = -3{,}9$$

c)





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

$$v_o = r_o \cdot i_d + \mu \cdot R_s \cdot i_d + R_s \cdot i_d$$
$$R_{izt} = \frac{v_o}{i_d} = r_o + (\mu + 1) \cdot R_s = 301\ k\Omega$$
$$R_{iz} = R_{izt} \parallel R_D = 5{,}88\ k\Omega$$
$$R_{iz} \approx R_D$$

3. Zadatak

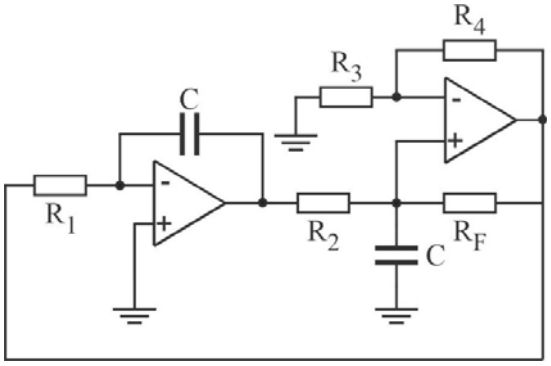
Za oscilator prostoperiodičnih oscilacija prikazan na slici odrediti:

a) Analitički izraz kružnog pojačanja;

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

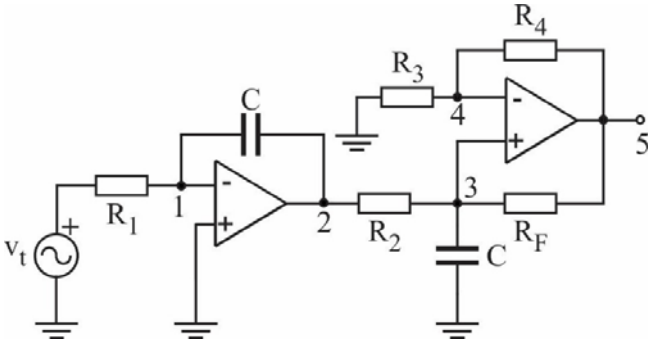
c) Frekvenciju oscilovanja.

Poznato je: R_1=2 kΩ, $R_2 = 1\ k\Omega$, $R_3 = R_4 = 5\ k\Omega$, $C = 10\ nF$. Operacioni pojačavači su idealni.



Rešenje

a)



$$V_1 \cdot \left(\frac{1}{R_1} + sC\right) - V_t \frac{1}{R_1} - V_2 sC = 0$$
$$V_3 \cdot \left(\frac{1}{R_2} + \frac{1}{R_F} + s \cdot C\right) - V_2 \cdot \frac{1}{R_2} - V_5 \cdot \frac{1}{R_F} = 0$$
$$V_4 \cdot \left(\frac{1}{R_3} + \frac{1}{R_4}\right) - V_5 \cdot \frac{1}{R_4} = 0$$
$$V_1 = 0$$
$$V_3 = V_4$$

$$AB = \frac{V_5}{V_t} = \frac{V_2}{V_t} \cdot \frac{V_5}{V_2} = \left(-\frac{1}{sCR_1}\right) \cdot \frac{R_F(R_4 + R_3)}{R_F R_3 - R_2 R_4 + sCR_2 R_3 R_F}$$

Iz uslova AB=1+j 0 sledi:

$$sCR_1R_3R_F - sCR_1R_2R_4 + s^2\ C^2R_1R_2R_3R_F = -R_FR_4 - R_FR_3$$

$$-\omega^2\ C^2R_1R_2R_3R_F + j\omega CR_1R_3R_F - j\omega CR_1R_2R_4 + R_FR_4 + R_FR_3 = 0$$

b)

Kada se izdvoje imaginarni deo jednačине добија се:

$$j\omega CR_1R_3R_F - j\omega CR_1R_2R_4 = 0$$

$$R_3R_F - R_2R_4 = 0$$

$$R_4 = \frac{R_2R_4}{R_3} = 1\ k\Omega$$

c)

Izdvajanjem realnih sabiraka jednačine dobija se:

$$-\omega^2\ C^2R_1R_2R_3R_F + R_FR_4 + R_FR_3 = 0$$

Frekvencija oscilovanja je:

$$\omega_0 = \sqrt{\frac{R_3 + R_4}{C^2R_1R_2R_3}} = 10^5\ \frac{rad}{s}$$

$$f_o = \frac{\omega_o}{2\pi} = 15{,}9\ kHz$$