Elektronski fakultet Niš
Katedra za Elektroniku 20.04.2026.

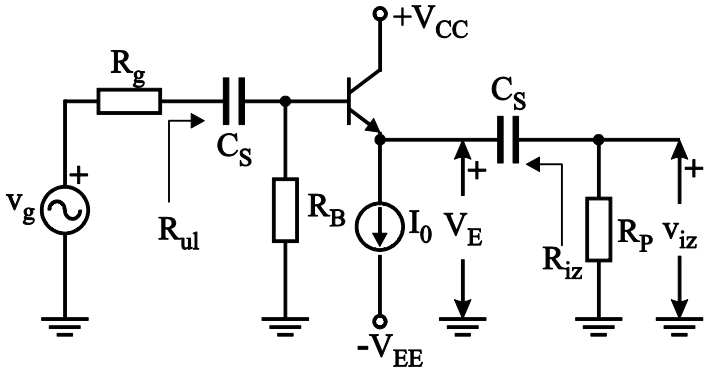
OSNOVI ELEKTRONIKE
Modul elektroenergetika (3OEP3A01, 2OEP3O03)

- **Studenti koji su položili zadatke na prvom kolokvijumu imaju mogućnost da rade samo drugu polovinu pismenog ispita (3 i 4 zadatak) ukoliko su zadovoljni rezultatima sa prvog kolokvijuma.**

1. Zadatak

Za kolo pojačavača sa slike 1 odrediti:

a) Jednosmerni napon na emitoru tranzistora, V_E;
b) Izlaznu otpornost R_{iz}.
c) Naponsko pojačanje $A_n = \frac{v_{iz}}{v_g}$



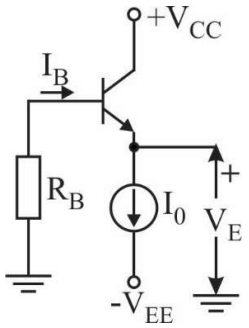
Parametri tranzistora su: $V_{BE} = 0{,}7\ V$
$h_{21E} = \beta = 100$; $h_{22E} = 0$ S
($r_o \to \infty$). Poznato su elementi kola:
$R_B = 40$ kΩ ; $R_p = 1$ kΩ ; $R_g = 1\ k\Omega$;
$I_0 = 5$ mA ; $V_{CC} = V_{EE} = 10$ V ; $C_S \to \infty$.

Rešenje:

a)

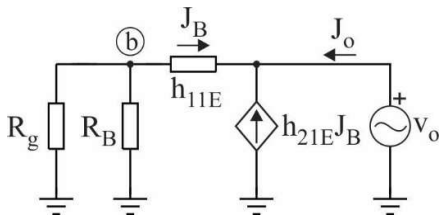
$$R_B I_B + V_{BE} = V_E$$
$$I_o = I_E = (1+\beta) I_B$$

$$V_E = -V_{BE} - \frac{I_o R_B}{1+\beta} = -2{,}7\ V$$



$$h_{11} = \frac{V_T}{I_B} = \frac{V_T}{I_C}\beta = 520\Omega$$

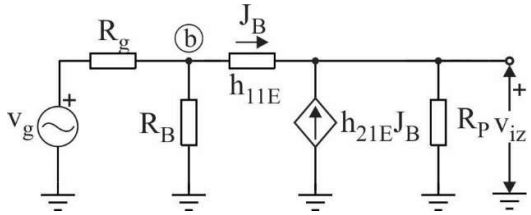
b)



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

$$R_{iz} = \frac{v_o}{i_o} = \frac{h_{11E} + R_g \parallel R_B}{(1 + h_{21E})} = 14{,}6\ \Omega$$

c)



$$\frac{v_b}{R_B} + i_b + \frac{v_b - v_g}{R_g} = 0$$
$$\frac{v_{iz}}{R_p} - h_{21E} \cdot i_b - i_b = 0$$
$$i_b = \frac{v_b - v_{iz}}{h_{11E}}$$

$$i_b = \frac{R_B}{h_{11E}(R_B + R_g) + R_B R_g} v_g - \frac{(R_B + R_g)}{h_{11E}(R_B + R_g) + R_B R_g} v_{iz}$$
$$v_{iz} = (1 + h_{21E}) i_b R_P$$

$$A_n = \frac{v_{iz}}{v_g} = \frac{R_B R_p (1 + h_{21E})}{h_{11E}(R_B + R_g) + R_B R_g + (1 + h_{21}\ ) R_p (R_B + R_g)} = 0{,}96$$

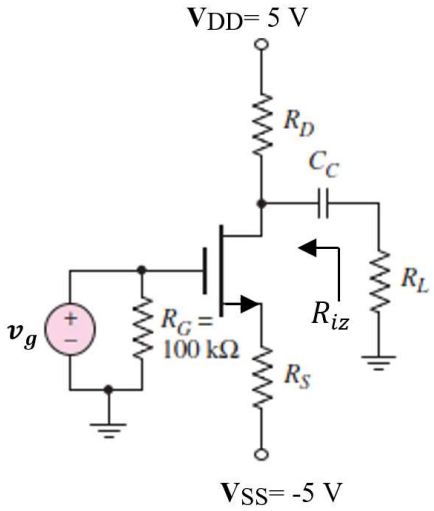
2. Zadatak

Parametri tranzistora u kolu sa slike su A = 0,5 mA/V^2 i V_t = 2,5 V, λ=0,01 V^{-1}. Elementi kola su: $R_S = 250\ \Omega$; $R_D = 2\ k\Omega$; $R_L = 6\ k\Omega$. Odrediti:

a) Radnu tačku tranzistora i dinamičke parametre tranzistora.

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

c) Izlaznu otpornost tranzistora R_{iz}.



Rešenje:

$V_S = R_S \cdot I_D + V_{SS}$

$V_{GS} = -V_S = -V_{SS} - R_S \cdot I_D$

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

$V_{GS} - V_t + V_t = -R_S \cdot A \cdot (V_{GS} - V_t)^2 - V_{SS}$

$R_S \cdot A \cdot V_x^2 + V_x + V_{SS} + V_t = 0$

$0{,}125 \cdot V_X^2 + V_X - 2{,}5 = 0$

$$V_X = \frac{-1 \pm \sqrt{1 + 4 \cdot 2{,}5 \cdot 0{,}125}}{0{,}25}$$

~~$V_{x1} = -10\ V$~~

$V_{x2} = 2\ V$

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

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

$$r_o = \frac{1}{\lambda \cdot I_D} = 50\ k\Omega$$

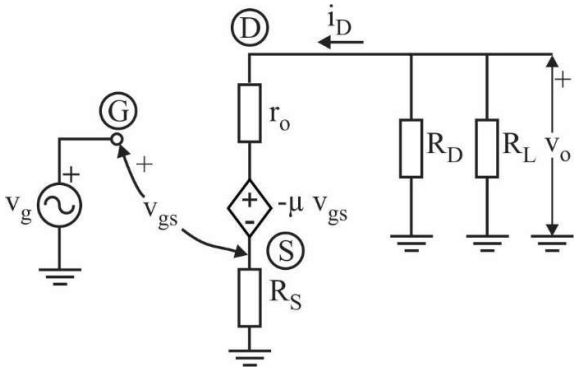
$\mu = r_o \cdot g_m = 100$

$$V_D = V_{DD} - R_D I_D = 1\ V$$

$$V_S = R_S I_S + V_{SS} = -4{,}5\ V$$

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

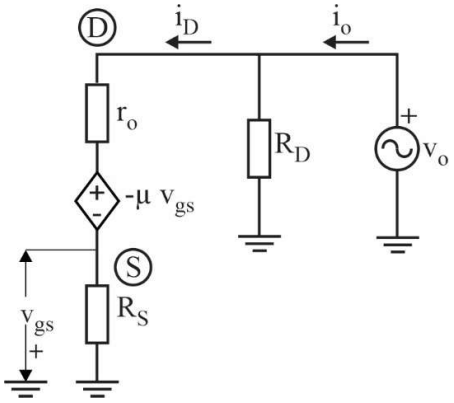
b)



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

$$R_D \parallel R_L \cdot i_d + r_o \cdot i_d - \mu \cdot v_g + \mu \cdot i_d \cdot R_S + R_s \cdot i_d = 0$$
$$i_d = \frac{\mu \cdot v_g}{R_D \parallel R_L + r_o + (\mu + 1) \cdot R_s}$$
$$v_{iz} = \frac{-R_D \parallel R_L \cdot \mu \cdot v_g}{R_D \parallel R_L + r_o + (\mu + 1) \cdot R_s}$$
$$A_n = \frac{v_{iz}}{v_g} = -\frac{R_D \parallel R_L \cdot \mu}{R_D \parallel R_L + r_o + (\mu + 1) \cdot R_s} = -1{,}96$$

c)



$$r_o \cdot i_d - \mu \cdot v_{gs} + R_s \cdot i_d = v_o$$
$$v_{gs} = -i_d \cdot R_S$$
$$i_o = i_d + \frac{v_o}{R_D}$$

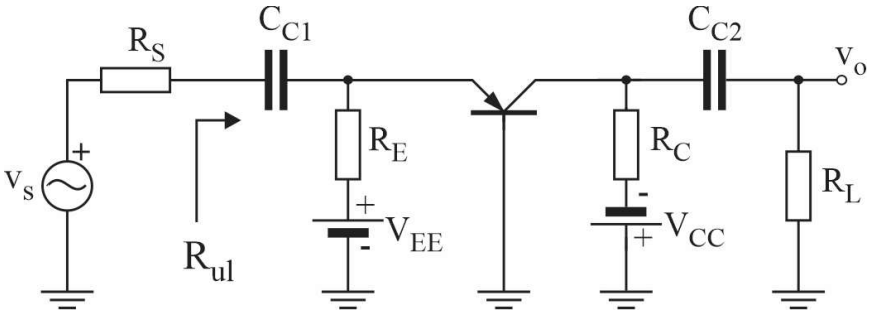
$$i_d = \frac{v_o}{r_o + (\mu + 1) \cdot R_s}$$
$$R_{izt} = \frac{v_o}{i_d}$$
$$R_{izt} = r_o + (\mu + 1) \cdot R_S = 75\ k\Omega$$

$$i_o = \frac{v_o}{R_{izt}} + \frac{v_o}{R_D}$$
$$R_{iz} = \frac{v_o}{i_o} = \frac{1}{\frac{1}{R_{izt}} + \frac{1}{R_D}} = R_{izt} \parallel R_D = 1{,}94\ k\Omega$$

3. Zadatak

Parametri tranzistora u kolu sa slike su: V_{BE}=-0,6 V; h_{21E} =β= 90; h_{22E} =0 S.
$V_{CC} = 12\,V$; $V_{EE} = 12\,V$; $R_E = 10\,k\Omega$; $R_S = 200\,\Omega$; $R_C = 6\,k\Omega$; $R_L = 12\,k\Omega$;
$C_{C1} = 1\,\mu F$ $C_{C2} = 0{,}2\,\mu F$.

a) dinamički parametre tranzistora, $h_{11E} = r_\pi$;
b) ulaznu otpornost R_{ul};
c) pojačanje na srednjim frekvencijama (za $C_{C1} \to \infty$, $C_{C2} \to \infty$);
d) donju graničnu frekvenciju pojačavača;
e) skicirati asimptotsku aproksimaciju amplitudske karakteristike ukoliko se usvoji da je $C_{C2} \to \infty$ (uzima se u obzir samo dominantni pol).



Rešenje:

a)

$V_E = -V_{BE}$

$I_E = \dfrac{V_{EE} - V_E}{R_E} = \dfrac{V_{EE} + V_{BE}}{R_E} = 1{,}14\,mA$

$I_B = \dfrac{I_E}{\beta + 1} = 12{,}5\,\mu A$

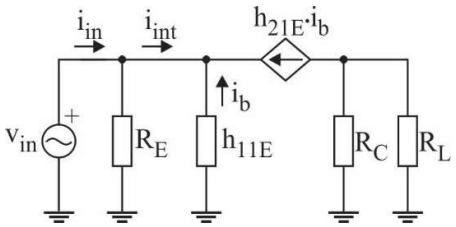
$h_{11E} = \dfrac{V_T}{I_B} = \dfrac{26mV}{12{,}5\mu A} = 2{,}08\,k\Omega$

b)

Odredjivanje ulazne otpornosti R_{in}

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

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



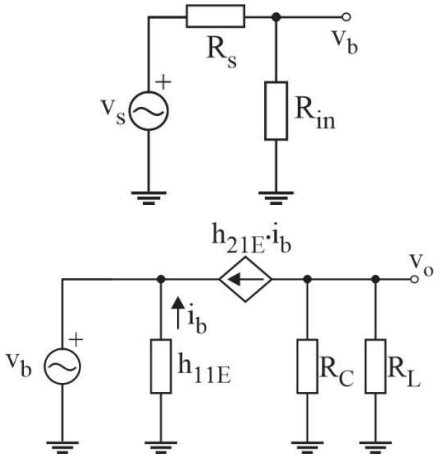
$R_{int} = \dfrac{v_{in}}{i_{int}} = \dfrac{h_{11E}}{1 + h_{21}} = 23\,\Omega$

$R_{in} = \dfrac{v_{in}}{i_{in}} = R_E \parallel R_{int} \approx R_{int}$

$R_{in} \approx 23\,\Omega$

c)

pojačanje na srednjim frekvencijama (za $C_{C1} \to \infty$, $C_{C2} \to \infty$)



$$v_b = \frac{R_{in}}{R_{in} + R_s} v_s$$

$$v_o = -h_{21E} R_C \parallel R_L$$

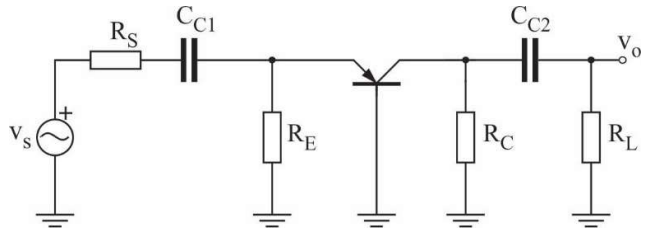
$$i_b = -\frac{v_b}{h_{11E}}$$

$$A_{no} = \frac{v_o}{v_s} = \frac{h_{21E}\, R_C \| R_L}{h_{11E}} \frac{R_{in}}{R_{in}+R_S}$$

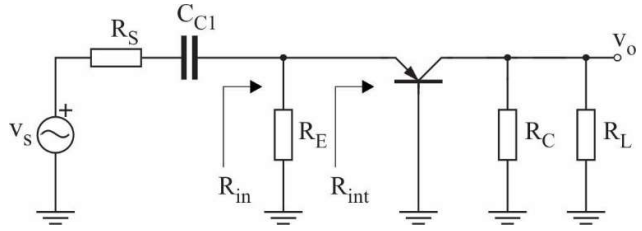
$$A_{no} = 18{,}56$$

d)

Određivanje donje granične frekvencije

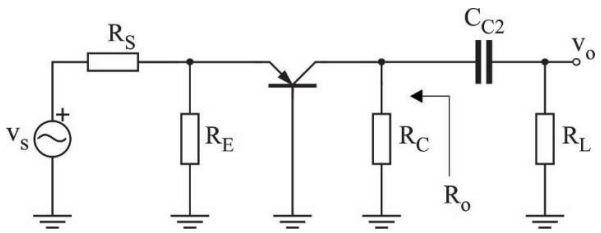


- Vremenska konstanta koja odgovara kondenzatoru C_{C1} , τ_1 odredjuje se iz kola koje je dole prikazano.

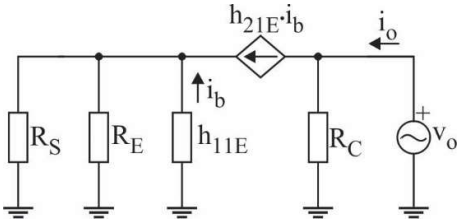


$$\tau_1 = C_{C1} \cdot (R_s + R_{in}) = 2{,}23 \cdot 10^{-4}\, S$$

- Vremenska konstanta koja odgovara kondenzatoru C_{C2} , τ_2 odredjuje se iz dole prikazanog kola.



Odredjivanje izlazne otporniosti Ro



$R_o = R_C$

$\tau_2 = C_{C2} \cdot (R_o + R_L) = 3{,}6 \cdot 10^{-3}\ S$

Donja granična frekvencija kola odredjuje se preko vremenskih konstnati:

$$\omega_d \approx \frac{1}{\tau_1} + \frac{1}{\tau_2} = 4760 \frac{rad}{s}$$

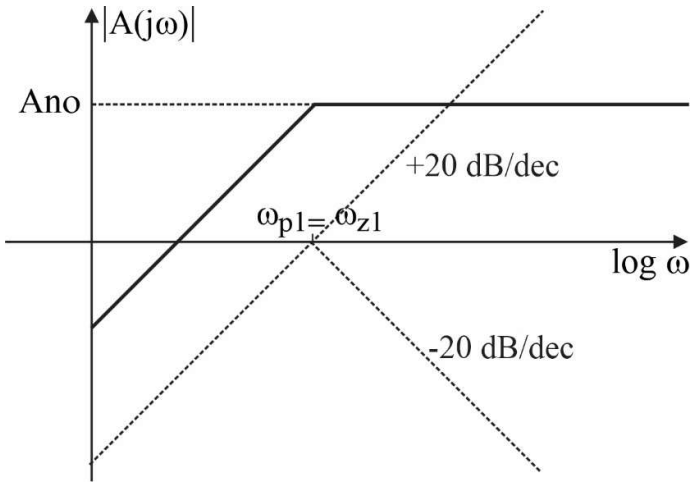
$$f_d = \frac{\omega_d}{2\pi} = 758\ Hz$$

e)

$$A(s) = A_{n0} \frac{s\tau_1}{1 + s\tau_1} = A_o \frac{\frac{s}{\omega_{z1}}}{1 + \frac{s}{\omega_{p1}}}$$

$$\omega_{p2} = \omega_z = 4484 \frac{rad}{s}$$

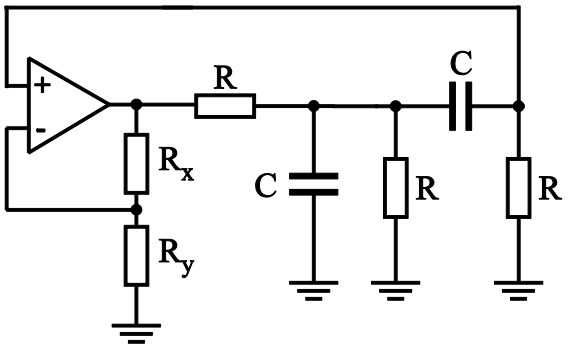
$$A_o = 20 \log_{10} 18{,}56 = 12\ dB$$



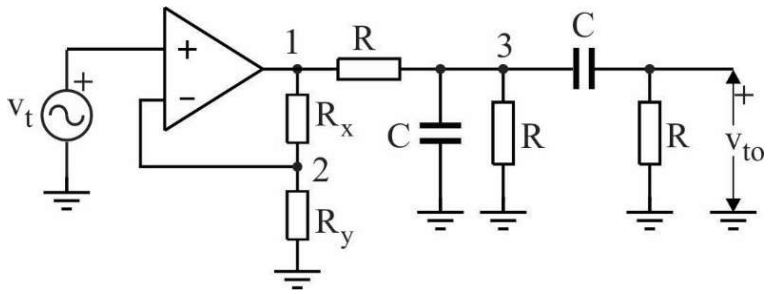
4. Zadatak

Za kolo oscilatora prikazano na slici 4 poznato je C=10 nF; $R = 1\ k\Omega$; R_y= 5 kΩ. Operacioni pojačavači su idealani. Odrediti:

a) Analitički izraz kružnog pojačanja;
b) Otpornost R_X tako da nastanu oscilacije;
c) Frekvenciju oscilacija kada je ispunjen uslov oscilovanja.



Rešenje:



$$\frac{V_2}{R_1} + (V_2 - V_1)\frac{1}{R_x} = 0$$

$$\frac{V_3}{R} + V_3 sC + \frac{V_3 - V_1}{R} + (V_3 - V_{to})sC = 0$$

$$\frac{V_{to}}{R} + (V_{to} - V_3)sC = 0$$

$$V_2 = V_t$$

$$AB = \frac{V_{to}}{V_t} = \frac{sCR(R_x + R_y)}{2R_y + 4sCRR_y + s^2C^2R^2R_y}$$

Iz uslova $AB = 1 + j0$ dobija se:

$$2R_y + 4j\omega CRR_y - \omega^2C^2R^2R_y = j\omega CR_xR + j\omega CR_yR$$

Realni deo jednačine

$$2R_y - \omega^2C^2R^2R_y = 0$$

$$\omega_o = \frac{\sqrt{2}}{CR} = 141\,000\frac{rad}{s}$$

$$f_o = \frac{\omega_o}{2\pi} = 22{,}4\ kHz$$

Imaginarni deo jednačine

$$4j\omega CRR_y - j\omega CR_xR - j\omega CR_yR = 0$$

$$3R_y - R_x = 0$$

$$R_x = 3R_y = 15\ k\Omega$$