Seminar CEF

Amplificatoare de semnal mic - 2.

Se dă circuitul din fig. alăturată pentru care se cunosc:

Q_1 { $K_n = 0{,}1\ mA/V^2$; $V_T = 2V$

Q_2 { $K_p = 0{,}04\ mA/V^2$; $V_T = -2V$

$Q_{3,4}$ { $|V_{BE}| \simeq 0{,}6V$; $\beta_F = \beta_0 = 400$.

D_Z { $V_Z = 3{,}6V$; $I_{Z,min} = 1\ mA$; $R_Z \simeq 0$

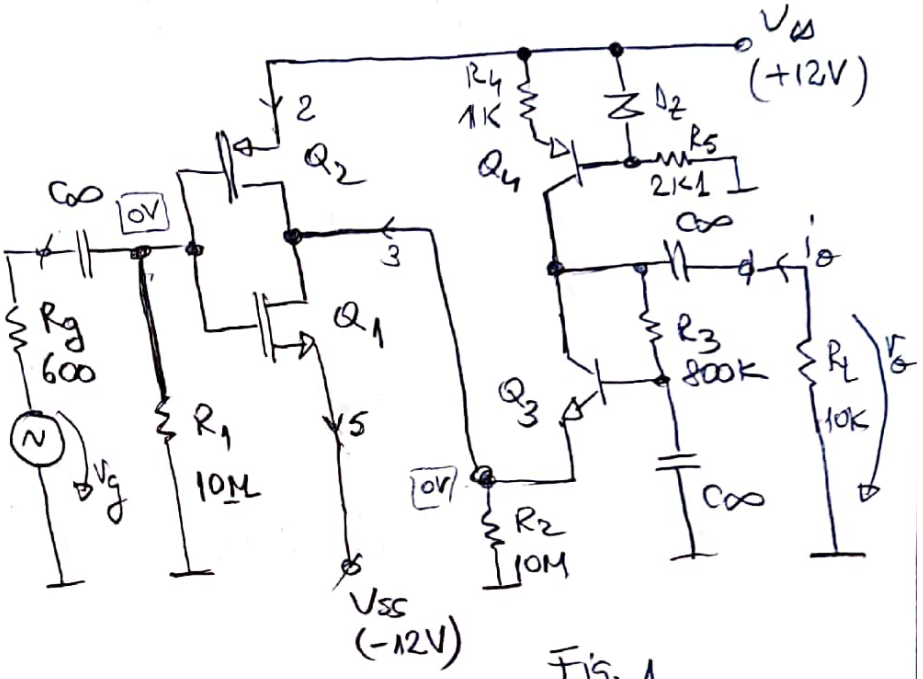


Fig. 1

Calculăm de c.a. ne vor realiza pth. semnal mic în joasă frecvență.

Se ne calculeze:

1) psf; 2) $A_V = ?$; 3) $R_i, R_o = ?$; 4) $A_{vg} = ?$; 5) $A_i, A_{ig}, A_z, A_{zg}, A_y, A_{yg} = ?$

1) psf

Pp. $Q_{1,2}$ în saturație, $Q_{3,4}$ în RAN și D_Z în stabilizare.

Rezultă $I_D = \frac{K}{2}(V_{GS} - V_T)^2$; $I_C = \beta \cdot I_B$; $V_Z = 3{,}6V$.

Acest $V_Z = 3{,}6V \Rightarrow I_{C4} = \frac{V_Z - V_{EB4}}{R_4} = 3\ mA$

$I_Z \simeq \frac{V_{DD} - V_Z}{R_5} = \frac{(12 - 3{,}6)V}{2{,}1\ k\Omega} = 4\ mA$.

Deoarece $\beta \to \infty \Rightarrow I_{C3} \simeq I_{E3} = I_{C4} = 3\ mA$.

Deoarece curenții de poartă ai tranzistoarelor Q_1 și Q_2 sunt zero $\Rightarrow I_{R1} = 0 \Rightarrow V_{R1} = R_1 \cdot I_{R1} = 0 \Rightarrow$ potențialul porților Q_1 și Q_2

este zero. Rezultă

$$V_{GS1} = V_{SG2} = 12V$$

$$I_{D1} = \frac{K_n}{2}(V_{GS} - V_T)^2 = \frac{0,1}{2} \cdot 10^2 mA = 5mA$$

$$I_{D2} = \frac{K_p}{2}(V_{GS} - V_T)^2 = \frac{0,04}{2} \cdot 10^2 mA = 2mA.$$

$$I_{SP} = I_{D2} + I_{C3} \Rightarrow I_{R2} = 0 \Rightarrow V_{R2} = 0V \Rightarrow$$

$$V_{SD2} = V_{DD} - V_{R2} = 12V$$

$$V_{DS1} = V_{R2} - V_{SS} = 12V$$

$$V_{CE3} = \frac{I_{C3}}{\beta} \cdot R_3 + V_{BE3} = \frac{3}{300} \cdot 200\,V + 0,6V = 6,6V$$

$$V_{EC4} = (V_{DD} - V_{R2}) - V_{CE3} - R_4 \cdot I_{C3} = (12 - 6,6 - 3)V = 2,4V$$

Q_1 { $V_{GS1} = 12V > V_T = 2V$; $I_{D1} = 5mA$; $V_{DS1} = 12V > V_{GS1} - V_T = 10V$ } $\Rightarrow$ not ;

Q_4 { $I_{C4} = 3mA$; $V_{EB} = 0,6V$; $V_{EC} = 2,4V > V_{EB}$ } $\Rightarrow$ RAN

Q_2 { $V_{GS2} = -12V < V_T = -2V$; $I_{D2} = 2mA$; $|V_{DS2}| = 12V > |V_{GS2} - V_T| = 10V$ } $\Rightarrow$ not ;

D_Z { $V_Z = 3,6V$; $I_Z = 4mA \Rightarrow I_{Z,min} = 1mA$ } $\Rightarrow$ blocat.

Q_3 { $I_{C3} = 3mA$; $V_{BE3} = 0,6V$; $V_{CE3} = 6,6V > V_{BE}$ } $\Rightarrow$ RAN.

$$g_{m1} = K_n (V_{GS} - V_T) = 1 K\Omega^{-1}$$

$$g_{m2} = K_p (V_{GS} - V_T) = 0,4 K\Omega^{-1}.$$

$$g_{m3} = 40 I_{C2} = 120 K\Omega^{-1}.$$

$$R_{i3} = \frac{\beta}{g_{m3}} = 3,33 K\Omega$$

2. $A_v = ?$

Schema de c.a.

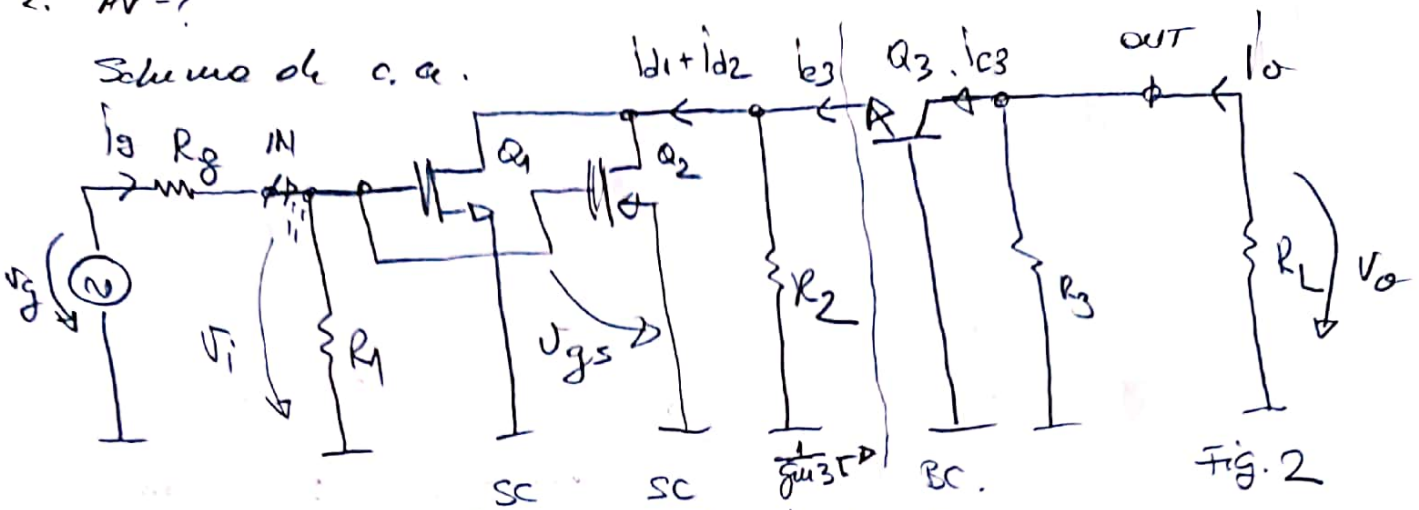


Fig. 2

$$A_v = \frac{v_o}{v_i} = \frac{v_o}{i_{C3}} \cdot \frac{i_{C3}}{i_{e3}} \cdot \frac{i_{e3}}{i_{d1}+i_{d2}} \cdot \frac{i_{d1}+i_{d2}}{v_{gs}} \cdot \frac{v_{gs}}{v_i} =$$

$$= -(R_3 // R_2) \cdot 1 \cdot \frac{R_2}{R_2 + \frac{1}{g_{m3}}} \cdot (g_{m1} + g_{m2}) \cdot 1 =$$

$$\cong -(g_{m1} + g_{m2}) \cdot R_L = -14.$$

$\boxed{A_v = -14}$

3) $R_i = \frac{v_i}{i_i} = R_1 = 10\,M\Omega$

$$R_o = \frac{v_o}{i_o}\Big|_{\substack{v_i = 0 \\ R_L = \infty}}$$

$v_i = 0 \Rightarrow v_{gs} = 0 \Rightarrow i_{d1} + i_{d2} = 0 \Rightarrow i_{e3} = 0 \Rightarrow i_{C3} = 0.$

$\Rightarrow$

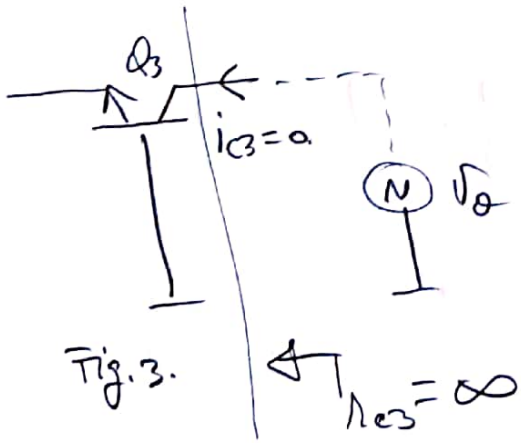


Fig. 3.

$\Rightarrow R_o = R_3 = 900\,k\Omega$

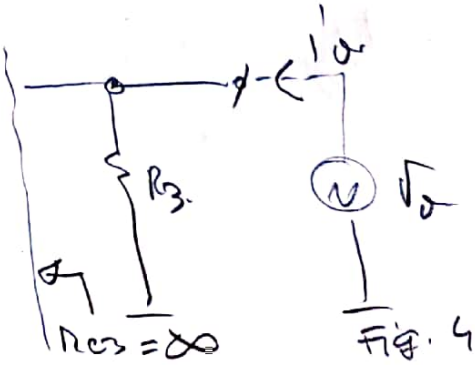
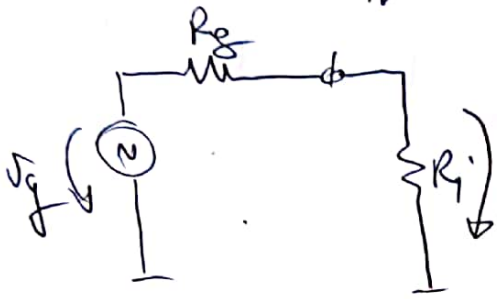


Fig. 4

4/ $A_{vg} = \frac{v_o}{v_g}$.

$$A_{vg} = \frac{v_o}{v_g} = \underbrace{\frac{v_o}{v_i}}_{A_v} \cdot \frac{v_i'}{v_g} = A_v \cdot \underbrace{\frac{R_i'}{R_i + R_g}}_{\simeq 1} = A_v = -14$$



$$v_i' = v_g \cdot \frac{R_i'}{R_i + R_g} \Rightarrow \frac{v_i'}{v_g} = \frac{R_i'}{R_i' + R_g}$$

5). $$A_i' = \frac{i_o}{i_i'} = \frac{i_o}{v_o} \cdot \frac{v_o}{v_i'} \cdot \frac{v_i'}{i_i'} = -\frac{R_i'}{R_L} \cdot A_v = 175$$

$$A_{ig} = \frac{i_o}{i_g}\Big|_{i_i' = i_g} = A_i'$$

$$A_z = \frac{v_o}{i_i'} = \frac{v_o}{v_i'} \cdot \frac{v_i'}{i_i'} = |A_v| \cdot R_i' = 140\,M\Omega$$

$$A_{zg} = \frac{v_o}{i_g}\Big|_{i_i' = i_g} = A_z$$

$$A_y = \frac{i_o}{v_i'} = \frac{i_o}{v_o} \cdot \underbrace{\frac{v_o}{v_i'}}_{A_v} = \left|-\frac{1}{R_L} \cdot A_v\right| = \frac{14}{10}\,k\Omega^{-1} = 1{,}4\,k\Omega^{-1}$$

$$A_{yg} = \frac{i_o}{v_g} = \frac{i_o}{v_o} \underbrace{\frac{v_o}{v_g}}_{A_{vg}} = \left|-\frac{1}{R_L} \cdot A_{vg}\right| = A_y =$$