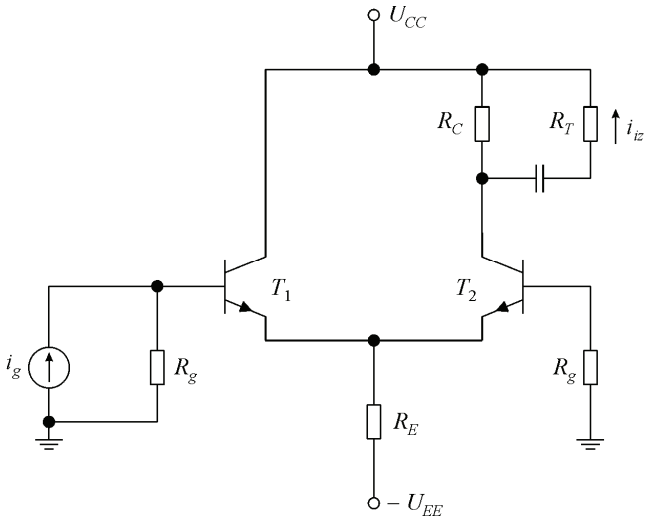
2. ljetni ispitni rok iz "Elektronike 2" - rješenja

1. zadatak

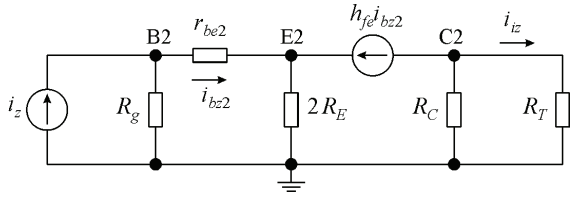


$$I_{BQ1} = I_{BQ2} = \frac{U_{EE} - U_{BEQ1}}{R_g + 2(1+\beta)R_E} = 14\ \mu\text{A}, \quad I_{CQ1} = I_{CQ2} = \beta I_{BQ1} = 1{,}4\ \text{mA},$$

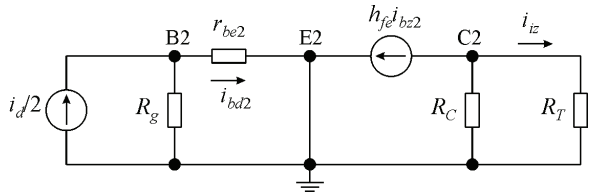
$$U_{CEQ1} \approx U_{CC} + U_{EE} - 2R_E I_{CQ1} = 12{,}8\ \text{V},$$

$$U_{CEQ2} \approx U_{CC} + U_{EE} - (R_C + 2R_E) I_{CQ1} = 12{,}2\ \text{V},$$

$$r_{be1} = r_{be1} = \frac{U_T}{I_{BQ1}} = 1{,}79\ \text{k}\Omega.$$



$$A_{Iz} = \frac{i_{iz}}{i_z} = -h_{fe}\frac{R_C}{R_C + R_T}\frac{R_g}{R_g + r_{be2} + 2(1+h_{fe})R_E} = -0{,}099.$$



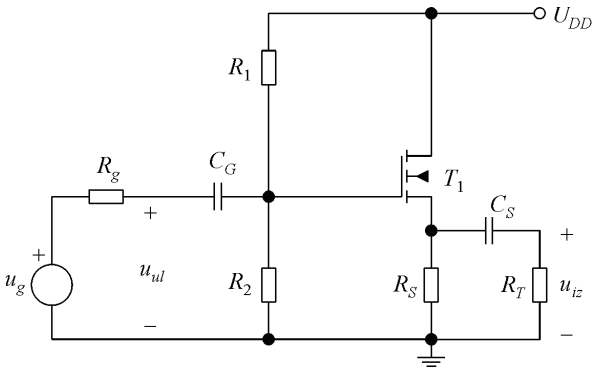
$$A_{Id} = \frac{i_{iz}}{i_d} = \frac{1}{2}\frac{i_{iz}}{i_d/2} = -\frac{h_{fe}}{2}\frac{R_C}{R_C + R_T}\frac{R_g}{R_g + r_{be2}} = -14{,}3\,,$$

$$\rho = \frac{\left|A_{Id}\right|}{\left|A_{Iz}\right|} = \frac{14{,}3}{0{,}099} = 144\,,$$

$$I_{zm} = \frac{I_{gm}}{2} = 5\ \mu\text{A}\,,\quad I_{dm} = -I_{gm} = -10\ \mu\text{A}\,,$$

$$I_{izm} = A_{Iz}\,I_{zm} + A_{Id}\,I_{dm} = 143\ \mu\text{A},\quad i_{iz} = 143\sin\omega t\ \mu\text{A}\,.$$

2. zadatak



$$U_{GG} = \frac{R_2}{R_1 + R_2}U_{DD} = 6\ \text{V}\,,\quad R_G = R_1 \,\|\, R_2 = 5\ \text{M}\Omega\,,$$

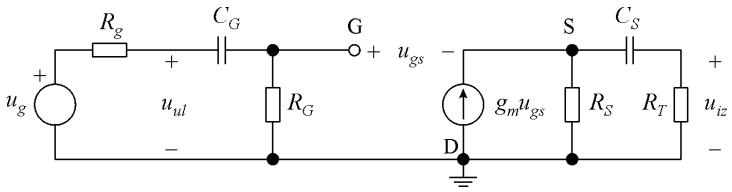
$$U_{GG} = U_{GSQ} + R_S\,I_{DQ} = U_{GSQ} + R_S\,\frac{K}{2}\left(U_{GSQ} - U_{GS0}\right)^2\,,$$

$$U_{GSQ}^2 + \left(\frac{2}{R_S\,K} - 2U_{GS0}\right)U_{GSQ} + U_{GS0}^2 - \frac{2U_{GG}}{R_S\,K} = 0 \quad\rightarrow\quad U_{GSQ}^2 - 1{,}944\cdot U_{GSQ} + 0{,}667 = 0\,,$$

$$U_{GSQ} = 0{,}972 + 0{,}527 = 1{,}5\ \text{V}\,,$$

$$I_{DQ} = \frac{U_{GG} - U_{GSQ}}{R_S} = 1{,}5\ \text{mA}\,,\quad U_{DSQ} = U_{DD} - R_S\,I_{DQ} = 7{,}5\ \text{V}\,,$$

$$g_m = K\left(U_{GSQ} - U_{GS0}\right) = 6\ \text{mA/V}\,.$$



$$\frac{U_{iz}}{U_{gs}} = g_m \left(R_S \left\| R_T \right. \right), \quad U_{gs} = U_{ul} - U_{iz} ,$$

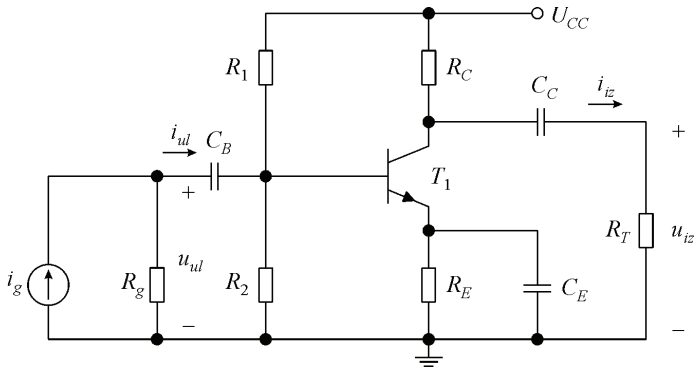
$$A_{Vg0} = \frac{U_{iz}}{U_g} = \frac{U_{iz}}{U_{gs}} \frac{U_{gs}}{U_{ul}} \frac{U_{ul}}{U_g} = \frac{g_m \left(R_S \left\| R_T \right. \right)}{1 + g_m \left(R_S \left\| R_T \right. \right)} \frac{R_G}{R_g + R_G} = 0{,}9 ,$$

$$\tau_G = \left(R_g + R_G \right) C_G = 50 \text{ ms} , \quad \omega_G = \frac{1}{\tau_G} = 20 \text{ rad/s} ,$$

$$\tau_S = \left(R_S \left\| \frac{1}{g_m} + R_T \right. \right) C_S = 6{,}32 \text{ ms} , \quad \omega_S = \frac{1}{\tau_S} = 158 \text{ rad/s} ,$$

$$\omega_d = \omega_S = 158 \text{ rad/s} , \quad f_d = \frac{\omega_d}{2\pi} = 25 \text{ Hz} .$$

3. zadatak

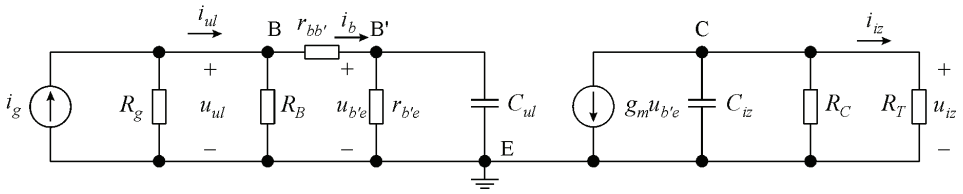


$$U_{BB} = \frac{R_2}{R_1 + R_2} U_{CC} = 2{,}4 \text{ V}, \quad R_B = R_1 \left\| R_2 \right. = 80 \text{ k}\Omega ,$$

$$I_{BQ} = \frac{U_{BB} - U_{BEQ}}{R_B + \left(1 + \beta \right) R_E} = 13 \text{ μA}, \quad I_{CQ} = \beta I_{BQ} = 1{,}3 \text{ mA} ,$$

$$U_{CEQ} \approx U_{CC} - \left(R_C + R_E \right) I_{CQ} = 7{,}45 \text{ V} ,$$

$$r_{b'e} = \frac{U_T}{I_{BQ}} = 1{,}92 \text{ k}\Omega, \quad g_m = \frac{I_{CQ}}{U_T} = 52 \text{ mA/V} .$$



$$A_{Ig0} = \frac{I_{iz}}{I_g} = \frac{I_{iz}}{U_{b'e}} \frac{U_{b'e}}{I_b} \frac{I_b}{I_g} = -g_m \frac{R_C}{R_C + R_T} \frac{r_{b'e}\left(R_g \left\| R_B\right.\right)}{\left(R_g \left\| R_B\right.\right) + r_{bb'} + r_{b'e}} = -52{,}8\,,$$

$$K = \frac{U_{iz}}{U_{b'e}} = -g_m\left(R_C \left\| R_T\right.\right) = -39\,,$$

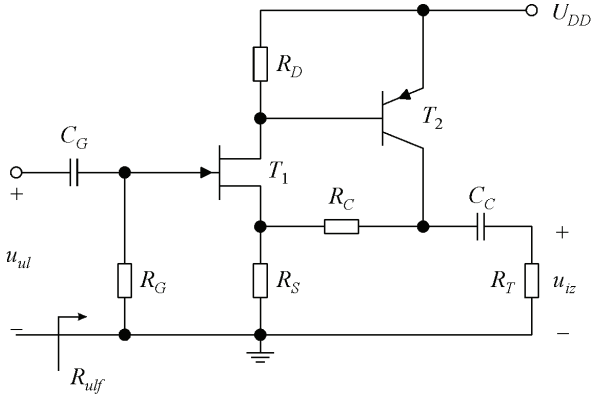
$$C_{ul} = C_{b'e} + C_{b'c}(1-K) = 100 \text{ pF}\,, \quad C_{iz} = C_{b'c}\frac{K-1}{K} = 2{,}05 \text{ pF}\,,$$

$$\tau_{ul} = \left[\left(R_g \left\| R_B + r_{bb'}\right.\right) \left\| r_{b'e}\right.\right] C_{ul} = 137 \text{ ns}\,, \quad \omega_{ul} = \frac{1}{\tau_{ul}} = 7{,}3 \cdot 10^6 \text{ rad/s}\,,$$

$$\tau_{iz} = \left(R_C \left\| R_T\right.\right) C_{iz} = 1{,}54 \text{ ns}, \quad \omega_{iz} = \frac{1}{\tau_{iz}} = 650 \cdot 10^6 \text{ rad/s}\,,$$

$$\omega_g = \omega_{ul} = 7{,}3 \cdot 10^6 \text{ rad/s}, \quad f_g = \frac{\omega_g}{2\pi} = 1{,}16 \text{ MHz}\,.$$

4. zadatak



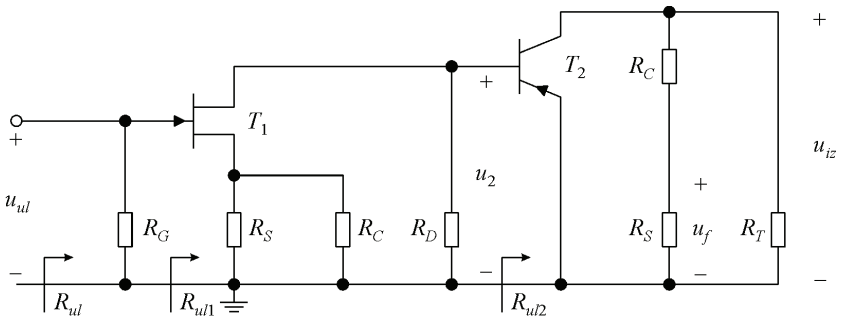
$$I_{DQ} R_D = -U_{BEQ} \quad \rightarrow \quad I_{DQ} = -\frac{U_{BEQ}}{R_D} = \frac{U_\gamma}{R_D} = 1 \text{ mA}\,,$$

$$I_{DQ} = I_{DSS}\left(1 - \frac{U_{GSQ}}{U_P}\right)^2 \quad \rightarrow \quad U_{GSQ} = U_P\left(1 - \sqrt{\frac{I_{DQ}}{I_{DSS}}}\right) = -1{,}5 \text{ V}\,,$$

$$U_{GSQ} + \left(I_{DQ} - I_{CQ}\right) R_S = 0 \quad \rightarrow \quad I_{CQ} = \frac{U_{GSQ}}{R_S} + I_{DQ} = -2 \text{ mA}\,,$$

$$g_m = -\frac{2\,I_{DSS}}{U_P}\left(1-\frac{U_{GSQ}}{U_P}\right) = 4\ \text{mA/V}\ ,\quad r_{be} = \frac{U_T}{-\,I_{BQ2}} = \frac{\beta U_T}{-\,I_{CQ2}} = 1{,}25\ \text{k}\Omega\ .$$

Povratna veza – naponska-serijska



$$A_{V2} = \frac{u_{iz}}{u_2} = -\,h_{fe}\frac{\left(R_C + R_S\right)\Big\|R_T}{r_{be}} = -\,230\ ,\quad R_{ul2} = r_{be} = 1{,}25\ \Omega\ ,$$

$$A_{V1} = \frac{u_2}{u_{ul}} = \frac{-\,g_m\left(R_D\,\|R_{ul2}\right)}{1 + g_m\left(R_S\,\|R_C\right)} = -0{,}637\ ,\quad R_{ul1} = \infty\ ,$$

$$A_V = \frac{u_{iz}}{u_{ul}} = \frac{u_{iz}}{u_2}\frac{u_2}{u_{ul}} = A_{V2}\,A_{V1} = 147\ ,\quad \beta = \frac{u_f}{u_{iz}} = \frac{R_S}{R_C + R_S} = \frac{1}{11}\ ,$$

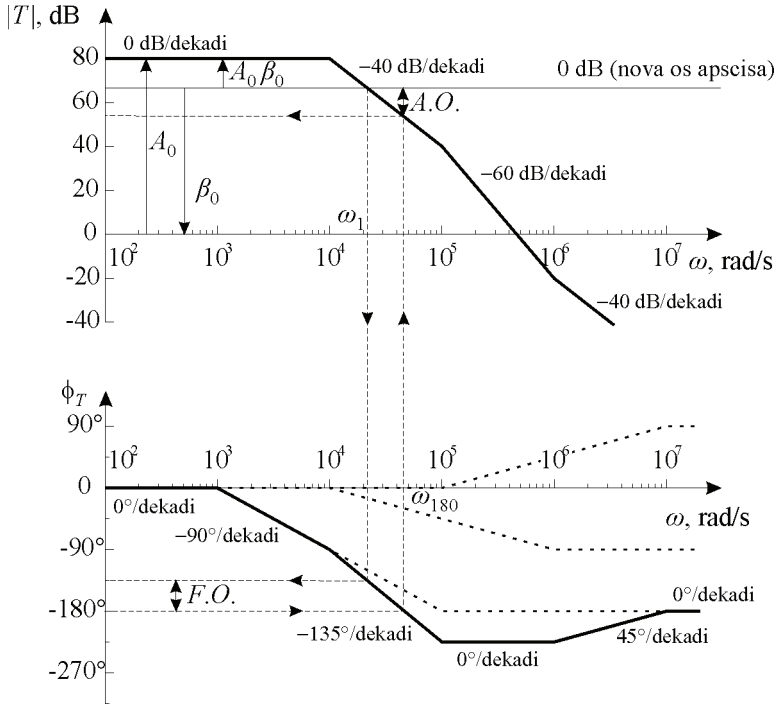
$$A_{Vf} = \frac{A_V}{1 + \beta\,A_V} = 10{,}2\ ,$$

$$R_{ul1f} = R_{ul1}\left(1 + \beta\,A_V\right) = \infty\ ,\quad R_{ulf} = R_G\,\|R_{ul1f} = R_G = 1\ \text{M}\Omega\ .$$

5. zadatak

$$A(j\omega) = \frac{-\,10^4\left(1 + j\omega/10^6\right)}{\left(1 + j\omega/10^4\right)\left(1 + j\omega/10^5\right)}\ ,\qquad \beta(j\omega) = \frac{\beta_0}{1 + j\omega/10^4}\ .$$

$$\text{Uz}\ \beta_0 = -1\ \ \rightarrow\ \ T(j\omega) = \beta(j\omega)\,A(j\omega) = \frac{10^4\left(1 + j\omega/10^6\right)}{\left(1 + j\omega/10^4\right)^2\left(1 + j\omega/10^5\right)}\ .$$



$$\phi_T(j\omega_{180}) = -180^\circ \quad \rightarrow \quad \left|T(j\omega_{180})\right| = \left|\beta(j\omega_{180})\, A(j\omega_{180})\right| = A.O. = -13 \text{ dB},$$

$$20\log\left|\beta_0\right| = 20\log\left|\beta_0\, A_0\right| - 20\log\left|A_0\right| = -67 \text{ dB} \quad \rightarrow \quad \beta_0 = -0,45\cdot 10^{-3},$$

$$\left|T(j\omega_1)\right| = 0 \text{ dB} \quad \rightarrow \quad \phi_T(j\omega_1) = -135^\circ \quad \rightarrow \quad F.O. = \phi_T(j\omega_1) + 180^\circ = 45^\circ.$$