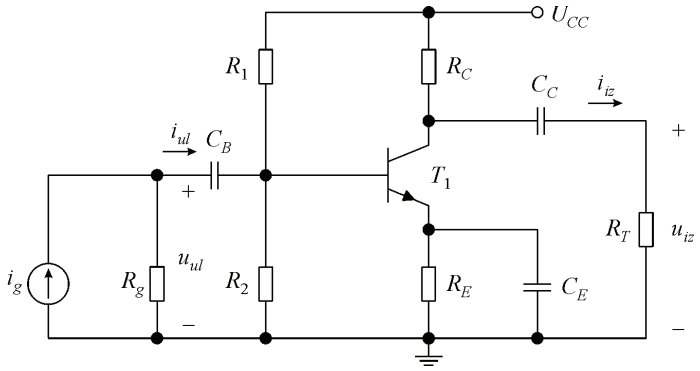
Završni ispit iz "Elektronike 2" - rješenja

Zadaci

1. zadatak

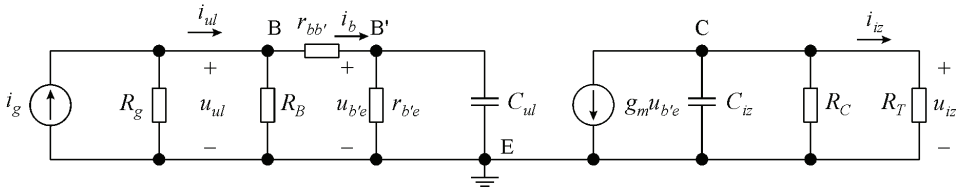


$$U_{BB} = \frac{R_2}{R_1 + R_2} U_{CC} = 3 \text{ V}, \quad R_B = R_1 \,\|\, R_2 = 37{,}5 \text{ k}\Omega ,$$

$$I_{BQ} = \frac{U_{BB} - U_{BEQ}}{R_B + (1+\beta) R_E} = 9{,}6 \text{ μA}, \quad I_{CQ} = \beta I_{BQ} = 0{,}96 \text{ mA} ,$$

$$U_{CEQ} \approx U_{CC} - (R_C + R_E) I_{CQ} = 6{,}24 \text{ V} ,$$

$$r_{b'e} = \frac{U_T}{I_{BQ}} = 2{,}60 \text{ k}\Omega, \quad g_m = \frac{I_{CQ}}{U_T} = 38{,}4 \text{ mA/V} .$$



$$A_{Ig0} = \frac{I_{iz}}{I_g} = \frac{I_{iz}}{U_{b'e}} \frac{U_{b'e}}{I_b} \frac{I_b}{I_g} = -\, g_m \frac{R_C}{R_C + R_T} \frac{r_{b'e} \left(R_g \,\|\, R_B \right)}{\left(R_g \,\|\, R_B \right) + r_{bb'} + r_{b'e}} = -\, 59{,}8 ,$$

$$K = \frac{U_{iz}}{U_{b'e}} = -\, g_m R_T = -\, 30{,}7 ,$$

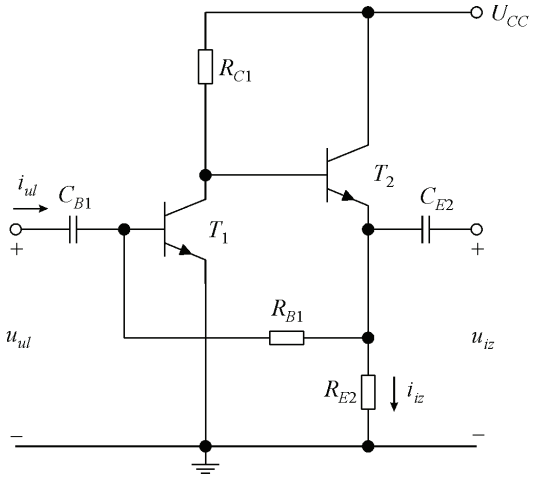
$$C_{ul} = C_{b'e} + C_{b'c} (1 - K) = 88{,}4 \text{ pF}, \quad C_{iz} = C_{b'c} \frac{K - 1}{K} = 2{,}06 \text{ pF} ,$$

$$\tau_{ul} = \left[\left(R_g \,\|\, R_B + r_{bb'} \right) \| \, r_{b'e} \right] C_{ul} = 173 \text{ ns}, \quad \tau_{iz} = \left(R_C \,\|\, R_T \right) C_{iz} = 1{,}65 \text{ ns} ,$$

$$\omega_{ul} = \frac{1}{\tau_{ul}} = 5,78 \cdot 10^6 \text{ rad/s}, \quad \omega_{iz} = \frac{1}{\tau_{iz}} = 606 \cdot 10^6 \text{ rad/s},$$

$$\omega_g = \omega_{ul} = 5,78 \cdot 10^6 \text{ rad/s}, \quad f_g = \frac{\omega_g}{2\pi} = 0,92 \text{ MHz}.$$

2. zadatak



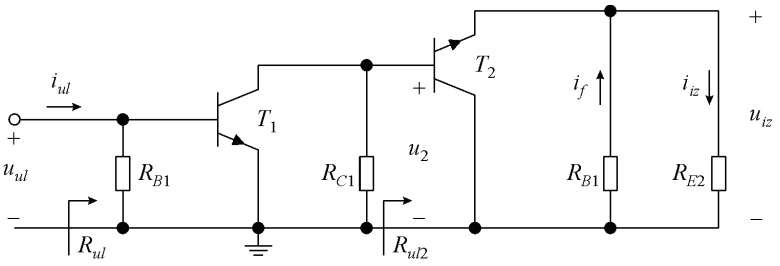
$$U_{CC} \approx \beta I_{BQ1} R_{C1} + U_{BEQ2} + I_{BQ1} R_{B1} + U_{BEQ1} \quad \rightarrow \quad I_{BQ1} \approx \frac{U_{CC} - 2U_{BEQ}}{\beta R_{C1} + R_{B1}} = 21,2 \text{ μA},$$

$$\left[\left(1+\beta\right) I_{BQ2} - I_{BQ1}\right] R_{E2} = I_{BQ1} R_{B1} + U_{BEQ1} \rightarrow I_{BQ2} = \frac{U_{BEQ} + I_{BQ1}\left(R_{B1} + R_{E2}\right)}{\left(1+\beta\right) R_{E2}} = 14,2 \text{ μA},$$

$$I_{CQ1} = \beta I_{BQ1} = 2,12 \text{ mA}, \quad I_{CQ2} = \beta I_{BQ2} = 1,42 \text{ mA},$$

$$r_{be1} = \frac{U_T}{I_{BQ1}} 1,18 \text{ kΩ}, \quad r_{be2} = \frac{U_T}{I_{BQ2}} = 1,76 \text{ kΩ}.$$

Povratna veza – naponska-paralelna



$$A_{V2} = \frac{u_{iz}}{u_{ul}} = \frac{\left(1+h_{fe}\right)\left(R_{B1} \| R_{E2}\right)}{r_{be2} + \left(1+h_{fe}\right)\left(R_{B1} \| R_{E2}\right)} = 0,991,$$

$$R_{ul2} = r_{be2} + \left(1 + h_{fe}\right)\left(R_{B1} \,\|\, R_{E2}\right) = 200\ \text{k}\Omega\,,$$

$$A_{V1} = \frac{u_2}{u_{ul}} = -\,h_{fe}\,\frac{R_{C1} \,\|\, R_{ul2}}{r_{be1}} = -\,332\ , \quad R_{ul} = R_{B1} \,\|\, r_{be1} = 1{,}17\ \text{k}\Omega\,,$$

$$R_M = A_{V2}\,A_{V1}\,R_{ul} = -\,385\ \text{V/mA}\ , \quad \beta = \frac{i_f}{u_{iz}} = -\,\frac{1}{R_{B1}} = -\,\frac{1}{100}\ \text{mA/V}\,,$$

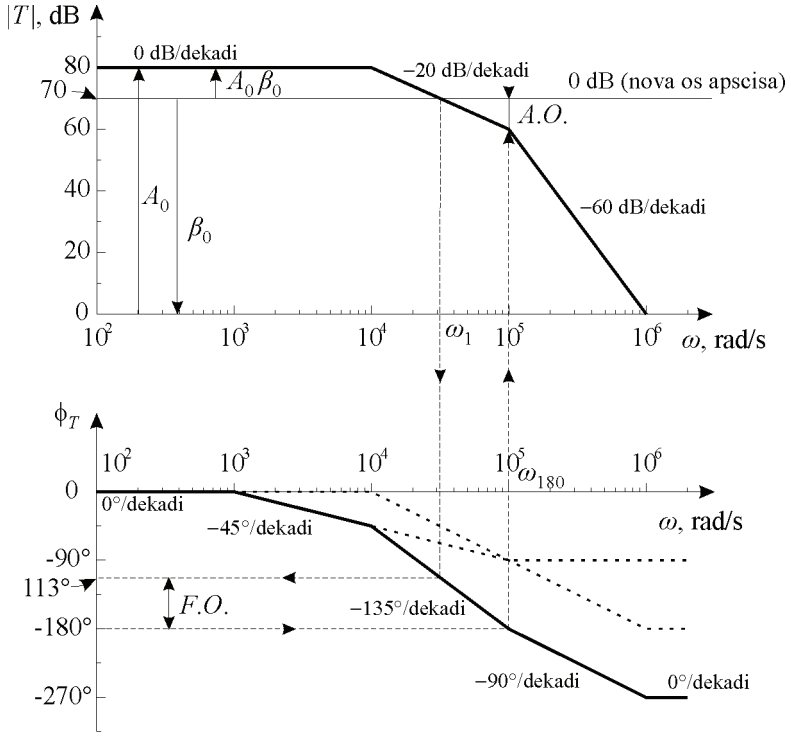
$$R_{Mf} = \frac{R_M}{1 + \beta\,R_M} = -\,79{,}4\ \text{V/mA}\ , \quad R_{ulf} = \frac{R_{ul}}{1 + \beta\,R_M} = 243\ \Omega\,,$$

$$A_{Vf} = \frac{u_{iz}}{u_{ul}} = \frac{u_{iz}}{i_{ul}\,R_{ulf}} = \frac{R_{Mf}}{R_{ulf}} = -\,327\ , \quad A_{If} = \frac{i_{iz}}{i_{ul}} = \frac{u_{iz}/R_{E2}}{i_{ul}} = \frac{R_{Mf}}{R_{E2}} = -\,39{,}7\,.$$

3. zadatak

$$A(j\omega) = \frac{-10^{18}}{\left(10^4 + j\omega\right)\left(10^5 + j\omega\right)^2}\ .$$

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



$$\phi_T(j\omega_{180}) = -180° \quad \rightarrow \quad \left|T(j\omega_{180})\right| = A.O. = -10\ \text{dB}\,,$$

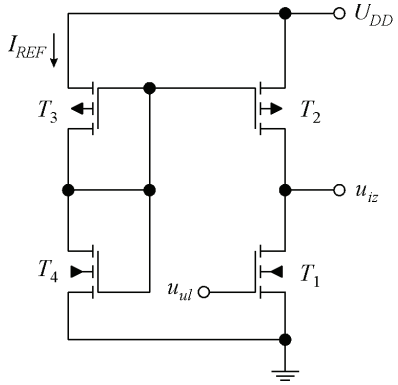
$$20\log|\beta| = 20\log|\beta A_0| - 20\log|A_0| = 10 - 80 = -70 \text{ dB},$$

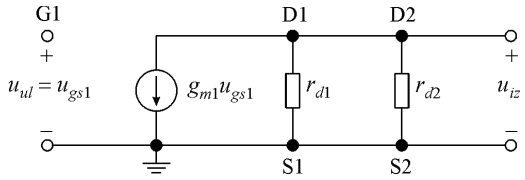
$$\beta = -3{,}16 \cdot 10^{-4},$$

$$|T(j\omega_1)| = |\beta(j\omega_1) A(j\omega_1)| = 1 = 0 \text{ dB} \quad \rightarrow \quad \phi_T(j\omega_1) = -112{,}5°,$$

$$F.O. = \phi_T(j\omega_1) + 180° = 67{,}5°$$

4. zadatak





$$I_{DQ1} = -I_{DQ2} = -I_{DQ3} = I_{REF}, \quad g_{m1} = \sqrt{2K_n'(W_1/L_1)I_{DQ1}} = \sqrt{2K_n'(W_1/L_1)I_{REF}},$$

$$r_{d1} = \frac{1}{\lambda_n I_{DQ1}} = \frac{1}{\lambda_n I_{REF}}, \quad r_{d2} = \frac{1}{\lambda_p I_{DQ2}} = \frac{1}{-\lambda_p I_{REF}},$$

$$A_V = \frac{u_{iz}}{u_{ul}} = \frac{u_{iz}}{u_{gs1}} = -g_{m1}\left(r_{d1} \| r_{d2}\right) = -\frac{g_{m1}}{1/r_{d1} + 1/r_{d2}} = -\frac{\sqrt{2K_n'(W_1/L_1)}}{\lambda_1 - \lambda_2}\frac{1}{\sqrt{I_{REF}}}.$$

$$I_{REF} = \frac{2K_n'(W_1/L_1)}{A_V^2\left(\lambda_n - \lambda_p\right)^2} = 34{,}1 \text{ μA},$$

$$U_{GSQ3} = -\sqrt{\frac{-2I_{REF}}{K_p'(W_3/L_3)}} + U_{GS0p} = -0{,}97 \text{ V}, \quad U_{GSQ4} = U_{DD} + U_{GSQ3} = 2{,}53 \text{ V},$$

$$\frac{W_4}{L_4} = \frac{2I_{DQ4}}{K_n'\left(U_{GS4} - U_{GS0n}\right)^2} = 0{,}085.$$