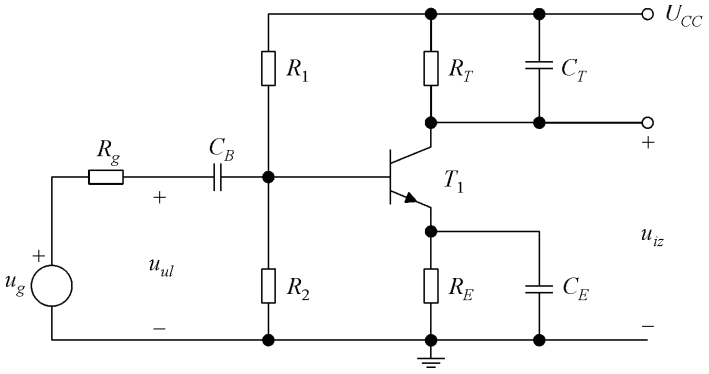
Završni ispit iz "Elektronike 2" - rješenja

Zadaci

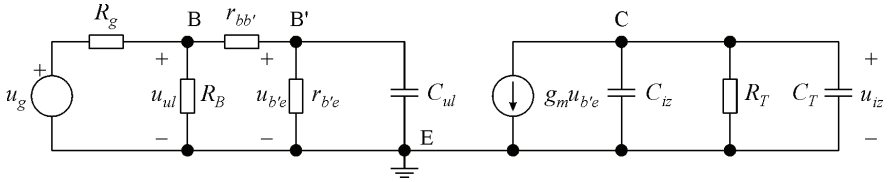


$$U_{BB} = \frac{R_2}{R_1 + R_2} U_{CC} = 2 \text{ V}, \quad R_B = R_1 \,\|\, R_2 = 100 \text{ k}\Omega ,$$

$$I_{BQ} = \frac{U_{BB} - U_{BEQ}}{R_B + (1+\beta) R_E} = 8{,}6 \text{ µA}, \quad I_{CQ} = \beta I_{BQ} = 0{,}86 \text{ mA} ,$$

$$U_{CEQ} \approx U_{CC} - (R_T + R_E) I_{CQ} = 8{,}13 \text{ V} ,$$

$$r_{b'e} = \frac{U_T}{I_{BQ}} = 2{,}9 \text{ k}\Omega, \quad g_m = \frac{I_{CQ}}{U_T} = 34{,}4 \text{ mA/V} .$$



$$A_{Vg0} = \frac{U_{iz}}{U_g} = \frac{U_{iz}}{U_{b'e}} \frac{U_{b'e}}{U_{ul}} \frac{U_{ul}}{U_g} = -g_m R_T \frac{r_{b'e}}{r_{bb'} + r_{b'e}} \frac{R_B \,\|\, (r_{bb'} + r_{b'e})}{R_g + R_B \,\|\, (r_{bb'} + r_{b'e})} = -79{,}7 ,$$

$$K = \frac{U_{iz}}{U_{b'e}} = -g_m R_T = -138 ,$$

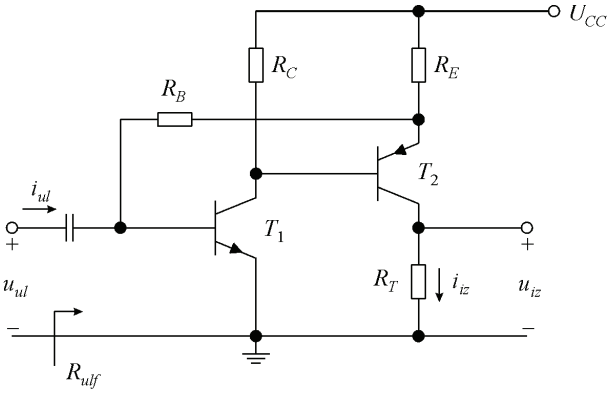
$$C_{ul} = C_{b'e} + C_{b'c}(1 - K) = 308 \text{ pF}, \quad C_{iz} = C_{b'c} \frac{K-1}{K} = 2 \text{ pF} ,$$

$$\tau_{ul} = \left[\left(R_g \,\|\, R_B + r_{bb'} \right) \,\|\, r_{b'e} \right] C_{ul} = 366 \text{ ns}, \quad \tau_{iz} = R_T (C_{iz} + C_T) = 88 \text{ ns} ,$$

$$\omega_{ul} = \frac{1}{\tau_{ul}} = 2,73 \cdot 10^6 \text{ rad/s}, \quad \omega_{iz} = \frac{1}{\tau_{iz}} = 11,4 \cdot 10^6 \text{ rad/s},$$

$$\omega_g = \omega_{ul} = 2,73 \cdot 10^6 \text{ rad/s}, \quad f_g = \frac{\omega_g}{2\pi} = 434 \text{ kHz}.$$

2. zadatak



$$U_{CC} \approx \beta_2 I_{BQ1} R_C + U_{BEQ2} + I_{BQ1} R_B + U_{BEQ1}, \quad U_{BEQ1} \approx -U_{BEQ2},$$

$$I_{BQ1} \approx \frac{U_{CC}}{\beta_1 R_C + R_B} = 18,5 \text{ μA},$$

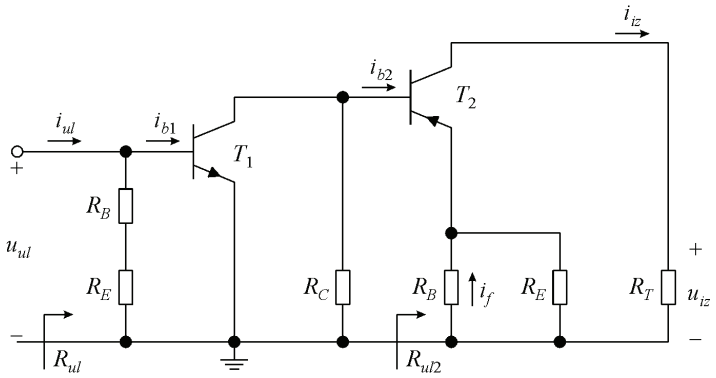
$$\beta_1 I_{BQ1} R_C \approx -\beta_2 I_{BQ2} R_E - U_{BEQ2}, \quad -I_{BQ2} \approx \frac{\beta_1 I_{BQ1} R_C + U_{BEQ2}}{\beta_2 R_E} = 34,2 \text{ μA},$$

$$I_{CQ1} = \beta_1 I_{BQ1} = 1,85 \text{ mA}, \quad -I_{CQ2} = -\beta_2 I_{BQ2} = 3,42 \text{ mA},$$

$$U_{CEQ1} \approx U_{CC} - R_C I_{CQ1} = 2,75 \text{ V}, \quad -U_{CEQ2} \approx U_{CC} + \left(R_E + R_T\right) I_{CQ2} = 2,77 \text{ V},$$

$$r_{be1} = \frac{U_T}{I_{BQ1}} = 1,35 \text{ kΩ}, \quad r_{be2} = \frac{U_T}{-I_{BQ2}} = 730 \text{ Ω}.$$

Povratna veza – strujna-paralelna



$$A_{I2} = \frac{i_{iz}}{i_{b2}} = -h_{fe2} = -100, \quad R_{ul2} = r_{be2} + \left(1 + h_{fe2}\right)\left(R_B \,\|\, R_E\right) = 249\ \text{k}\Omega\,,$$

$$A_{I1} = \frac{i_{b2}}{i_{ul}} = \frac{i_{b2}}{i_{b1}}\frac{i_{b1}}{i_{ul}} = -h_{fe1}\frac{R_C}{R_C + R_{ul2}}\frac{R_B + R_E}{R_B + R_E + r_{be1}} = -1{,}95\,,$$

$$A_I = \frac{i_{iz}}{i_{ul}} = \frac{i_{iz}}{i_{b2}}\frac{i_{b2}}{i_{ul}} = A_{I2}\,A_{I1} = 195, \quad \beta = \frac{i_f}{i_{iz}} \approx \frac{R_E}{R_B + R_E} = \frac{1}{61}\,.$$

$$R_{ul} = \left(R_B + R_E\right) \| r_{be1} = 1{,}34\ \text{k}\Omega\,,$$

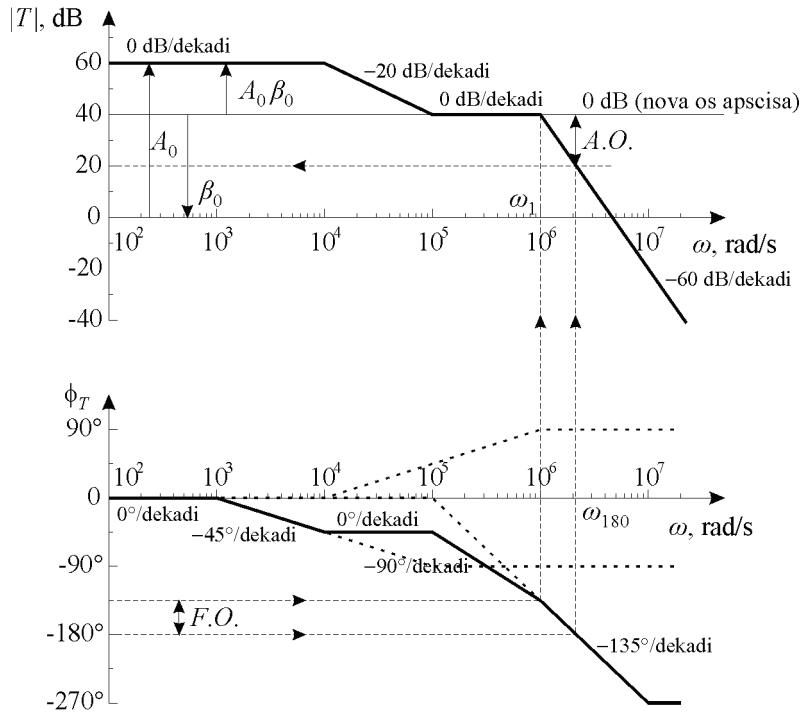
$$A_{If} = \frac{A_I}{1 + \beta\, A_I} = 46{,}5, \quad R_{ulf} = \frac{R_{ul}}{1 + \beta\, A_I} = 319\ \Omega\,,$$

$$A_{Vf} = \frac{u_{iz}}{u_{ul}} = \frac{i_{iz}\,R_T}{i_{ul}\,R_{ulf}} = A_{If}\frac{R_T}{R_{ulf}} = 29{,}2\,.$$

3. zadatak

$$A(j\omega) = \frac{-10^3\left(1 + j\omega/10^5\right)}{\left(1 + j\omega/10^4\right)\left(1 + j\omega/10^6\right)^2}\,, \qquad \beta(j\omega) = \frac{\beta_0}{1 + j\omega/10^6}\,.$$

$$\text{Uz } \beta_0 = -1 \quad \rightarrow \quad T(j\omega) = \beta(j\omega)\,A(j\omega) = \frac{10^3\left(1 + j\omega/10^5\right)}{\left(1 + j\omega/10^4\right)\left(1 + j\omega/10^6\right)^3}\,.$$



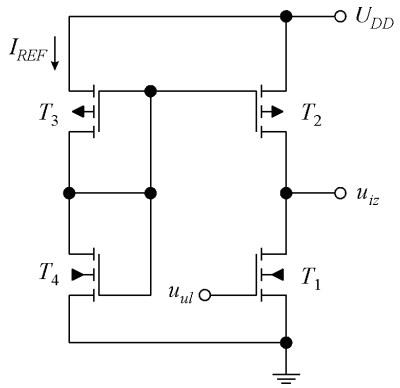
$$\phi_T(j\omega_1) = F.O. - 180° = 45° - 180° = -135° \quad \rightarrow \quad |T(j\omega_1)| = |\beta(j\omega_1)\, A(j\omega_1)| = 1 = 0 \text{ dB},$$

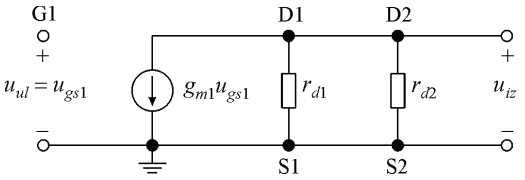
$$20\log|\beta_0| = 20\log|\beta_0\, A_0| - 20\log|A_0| = 20 - 60 = -40 \text{ dB},$$

$$\beta_0 = -0{,}01,$$

$$\phi_T(j\omega_{180}) = -180° \quad \rightarrow \quad A.O. = -|T(j\omega_{180})| = 20 \text{ dB}$$

4. zadatak





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

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

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

$$I_{REF} = \frac{2K_n'(W_1/L_1)}{A_V^2\left(\lambda_n - \lambda_p\right)^2} = 71\ \mu\text{A},$$

$$U_{GSQ3} = -\sqrt{\frac{-2I_{REF}}{K_p'(W_3/L_3)}} + U_{GS0p} = -1{,}04\ \text{V}, \quad U_{GSQ4} = U_{DD} + U_{GSQ3} = 2{,}26\ \text{V},$$

$$\frac{W_4}{L_4} = \frac{2I_{DQ4}}{K_n'\left(U_{GS4} - U_{GS0n}\right)^2} = 0{,}215.$$