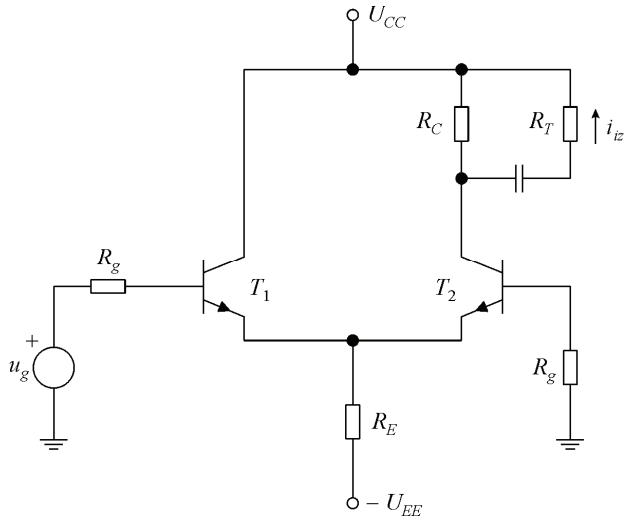
1. ispitni rok iz "Elektronike 2" - rješenja

1. zadatak

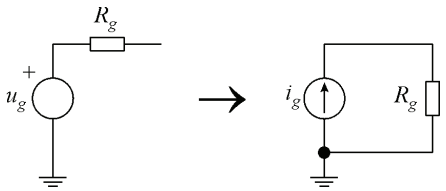


$$I_{BQ1} = I_{BQ2} = \frac{U_{EE} - U_{BEQ1}}{R_g + 2(1+\beta)R_E} = 27{,}9{,}1\ \mu\text{A}, \quad I_{CQ1} = I_{CQ2} = \beta I_{BQ1} = 2{,}79\ \text{mA},$$

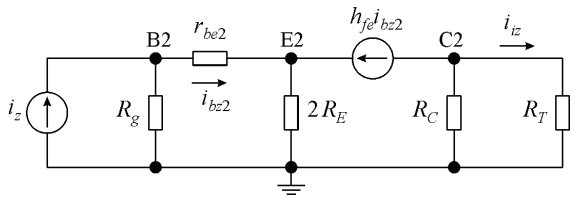
$$U_{CEQ1} \approx U_{CC} + U_{EE} - 2R_E I_{CQ1} = 12{,}8\ \text{V},$$

$$U_{CEQ2} \approx U_{CC} + U_{EE} - (R_C + 2R_E) I_{CQ1} = 10{,}1\ \text{V},$$

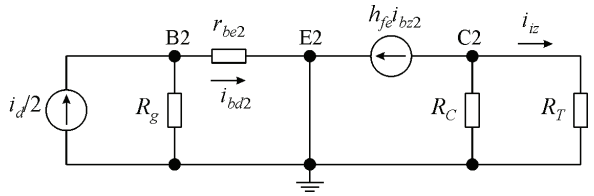
$$r_{be1} = r_{be1} = \frac{U_T}{I_{BQ1}} = 896\ \Omega.$$



$$I_{gm} = \frac{U_{gm}}{R_g} = 40\ \mu\text{A}.$$



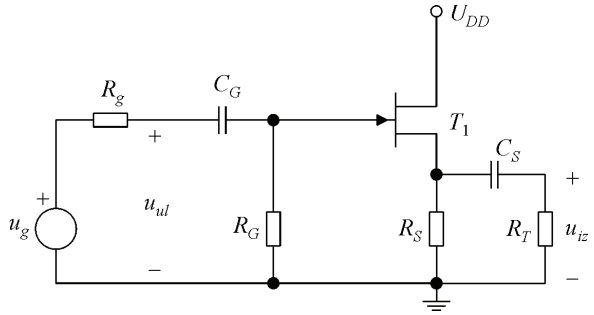
$$A_{Iz} = \frac{i_{iz}}{i_z} = -h_{fe} \frac{R_C}{R_C + R_T} \frac{R_g}{R_g + r_{be2} + 2(1+h_{fe})R_E} = -0{,}112.$$



$$A_{Id} = \frac{i_{iz}}{i_d} = \frac{1}{2}\frac{i_{iz}}{i_d/2} = -\frac{h_{fe}}{2}\frac{R_C}{R_C + R_T}\frac{R_g}{R_g + r_{be2}} = -16{,}3\,,$$

$$I_{izm} = A_{Iz}\, I_{zm} + A_{Id}\, I_{dm} = 650\ \mu\text{A}, \quad i_{iz} = 650 \sin \omega t\ \mu\text{A}\,.$$

2. zadatak



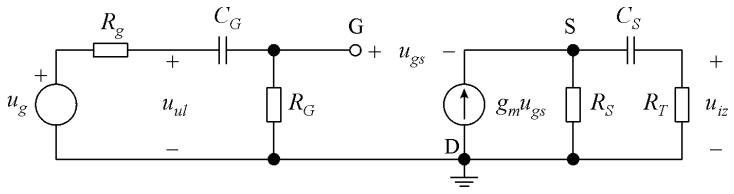
$$U_{GSQ} + I_{DQ} R_S = 0 \quad \rightarrow \quad I_{DQ} = I_{DSS}\left(1 - \frac{U_{GSQ}}{U_P}\right)^2 = -\frac{U_{GSQ}}{R_S},$$

$$U_{GSQ}^2 + \left(\frac{U_P^2}{R_S\, I_{DSS}} - 2U_P\right)U_{GSQ} + U_P^2 = 0\,,$$

$$U_{GSQ}^2 + 15U_{GSQ} + 36 = 0 \quad \rightarrow \quad U_{GSQ} = -7{,}5 + \sqrt{7{,}5^2 - 36} = -3\ \text{V}\,,$$

$$I_{DQ} = -\frac{U_{GSQ}}{R_S} = 3\ \text{mA}, \quad U_{DSQ} = U_{DD} - R_S\, I_{DQ} = 9\ \text{V}\,,$$

$$g_m = -\frac{2\, I_{DSS}}{U_P}\left(1 - \frac{U_{GSQ}}{U_P}\right) = 2\ \text{mA/V}\,.$$



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

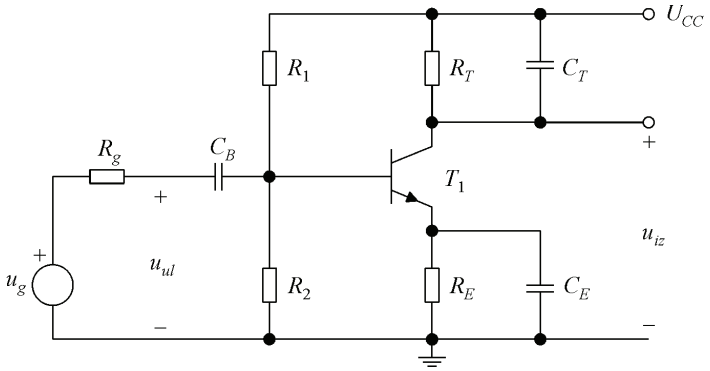
$$A_{Vg0} = \frac{U_{iz}}{U_g} = \frac{U_{iz}}{U_{gs}} \frac{U_{gs}}{U_{ul}} \frac{U_{ul}}{U_g} = \frac{g_m \left(R_S \,\|\, R_T \right)}{1 + g_m \left(R_S \,\|\, R_T \right)} \frac{R_G}{R_g + R_G} = 0{,}615 \,,$$

$$\tau_G = \left(R_g + R_G \right) C_G = 40 \text{ ms}, \quad \omega_G = \frac{1}{\tau_G} = 25 \text{ rad/s} \,,$$

$$\tau_S = \left(R_S \,\| \frac{1}{g_m} + R_T \right) C_S = 8{,}67 \text{ ms}, \quad \omega_S = \frac{1}{\tau_S} = 115 \text{ rad/s} \,,$$

$$\omega_d = \omega_S = 115 \text{ rad/s}, \quad f_d = \frac{\omega_d}{2\pi} = 18{,}3 \text{ Hz} \,.$$

3. zadatak

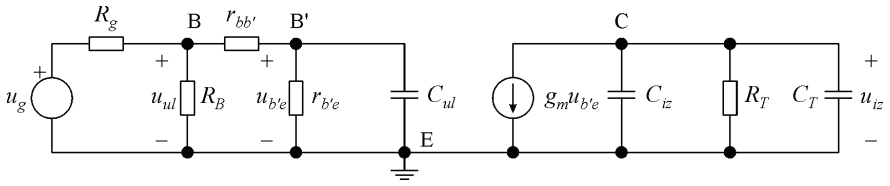


$$U_{BB} = \frac{R_2}{R_1 + R_2} U_{CC} = 2{,}4 \text{ V}, \quad R_B = R_1 \,\| R_2 = 80 \text{ k}\Omega \,,$$

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

$$U_{CEQ} \approx U_{CC} - \left(R_T + R_E \right) I_{CQ} = 6{,}15 \text{ V} \,,$$

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



$$A_{Vg0} = \frac{U_{iz}}{U_g} = \frac{U_{iz}}{U_{b'e}} \frac{U_{b'e}}{U_{ul}} \frac{U_{ul}}{U_g} = - \, g_m \, R_T \frac{r_{b'e}}{r_{bb'} + r_{b'e}} \frac{R_B \,\| \left(r_{bb'} + r_{b'e} \right)}{R_g + R_B \,\| \left(r_{bb'} + r_{b'e} \right)} = -161 \,,$$

$$K = \frac{U_{iz}}{U_{b'e}} = -\,g_m R_T = -\,208\,,$$

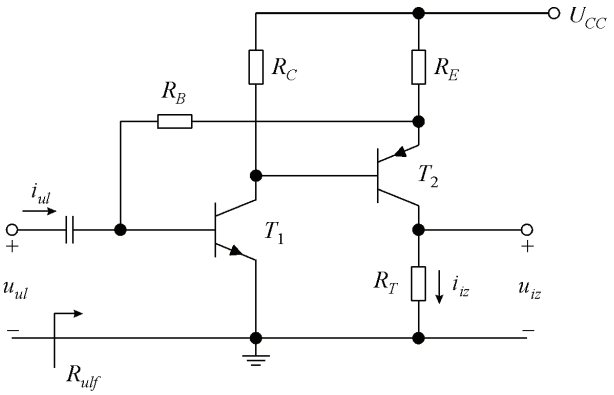
$$C_{ul} = C_{b'e} + C_{b'c}(1-K) = 468\ \text{pF}, \quad C_{iz} = C_{b'c}\frac{K-1}{K} = 2\ \text{pF}\,,$$

$$\tau_{ul} = \left[\left(R_g \,\|\, R_B + r_{bb'}\right) \| \, r_{b'e}\right] C_{ul} = 199\ \text{ns}, \quad \omega_{ul} = \frac{1}{\tau_{ul}} = 5{,}03\cdot 10^6\ \text{rad/s}\,,$$

$$\tau_{iz} = R_T\left(C_{iz} + C_T\right) = 48\ \text{ns}, \quad \omega_{iz} = \frac{1}{\tau_{iz}} = 20{,}8\cdot 10^6\ \text{rad/s}\,,$$

$$\omega_g = \omega_{ul} = 5{,}03\cdot 10^6\ \text{rad/s}, \quad f_g = \frac{\omega_g}{2\pi} = 800\ \text{kHz}\,.$$

4. zadatak



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

$$I_{BQ1} \approx \frac{U_{CC}}{\beta_1 R_C + R_B} = 34{,}3\ \mu\text{A}\,,$$

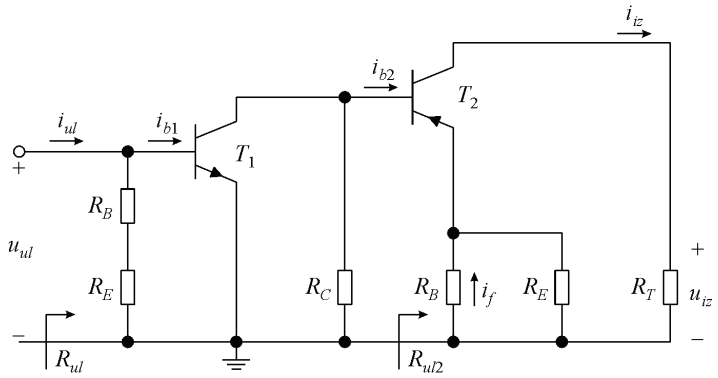
$$\beta_1 I_{BQ1} R_C \approx -\,\beta_2 I_{BQ2} R_E - U_{BEQ2}, \quad -\,I_{BQ2} \approx \frac{\beta_1 I_{BQ1} R_C + U_{BEQ2}}{\beta_2 R_E} = 30{,}8\ \mu\text{A}\,,$$

$$I_{CQ1} = \beta_1 I_{BQ1} = 3{,}43\ \text{mA}\,, \quad -\,I_{CQ2} = -\,\beta_2 I_{BQ2} = 3{,}08\ \text{mA}\,,$$

$$U_{CEQ1} \approx U_{CC} - R_C I_{CQ1} = 5{,}14\ \text{V}, \quad -\,U_{CEQ2} \approx U_{CC} + \left(R_E + R_T\right) I_{CQ2} = 4{,}30\ \text{V}\,,$$

$$r_{be1} = \frac{U_T}{I_{BQ1}} = 729\ \Omega\,, \quad r_{be2} = \frac{U_T}{-\,I_{BQ2}} = 812\ \Omega\,.$$

Povratna veza – strujna-paralelna



$$A_{I2} = \frac{i_{iz}}{i_{b2}} = -\,h_{fe2} = -100, \quad R_{ul2} = r_{be2} + \left(1 + h_{fe2}\right)\left(R_B \,\|\, R_E\right) = 200\ \text{k}\Omega\,,$$

$$A_{I1} = \frac{i_{b2}}{i_{ul}} = \frac{i_{b2}}{i_{b1}}\frac{i_{b1}}{i_{ul}} = -\,h_{fe1}\frac{R_C}{R_C + R_{ul2}}\frac{R_B + R_E}{R_B + R_E + r_{be1}} = -\,0{,}985\,,$$

$$A_I = \frac{i_{iz}}{i_{ul}} = \frac{i_{iz}}{i_{b2}}\frac{i_{b2}}{i_{ul}} = A_{I2}\,A_{I1} = 98{,}5, \quad \beta = \frac{i_f}{i_{iz}} \approx \frac{R_E}{R_B + R_E} = \frac{1}{76}\,.$$

$$R_{ul} = \left(R_B + R_E\right) \| r_{be1} = 726\ \Omega\,,$$

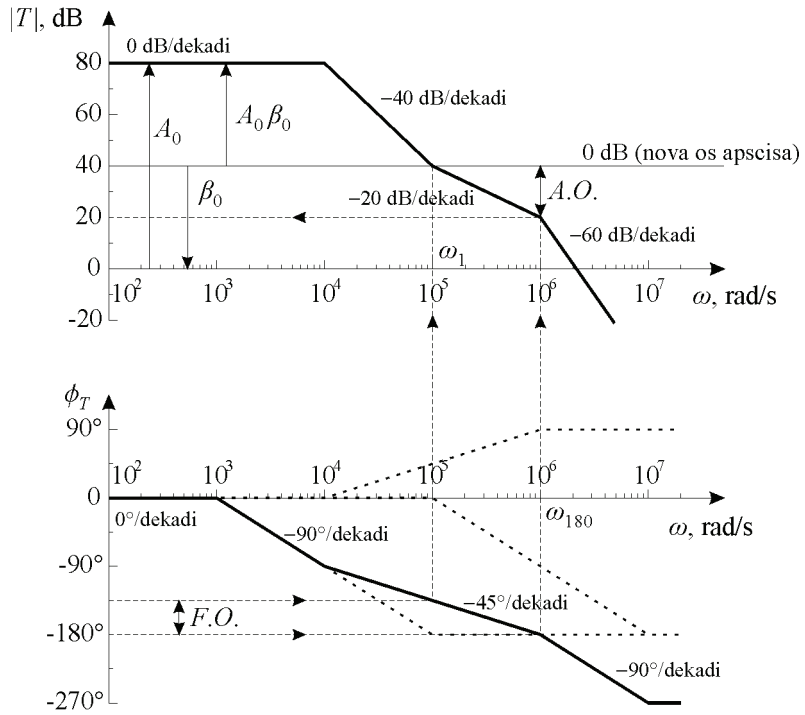
$$A_{If} = \frac{A_I}{1 + \beta\,A_I} = 42{,}9, \quad R_{ulf} = \frac{R_{ul}}{1 + \beta\,A_I} = 316\ \Omega\,,$$

$$A_{Vf} = \frac{u_{iz}}{u_{ul}} = \frac{i_{iz}\,R_T}{i_{ul}\,R_{ulf}} = A_{If}\frac{R_T}{R_{ulf}} = 67{,}9\,.$$

5. zadatak

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

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



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

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

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