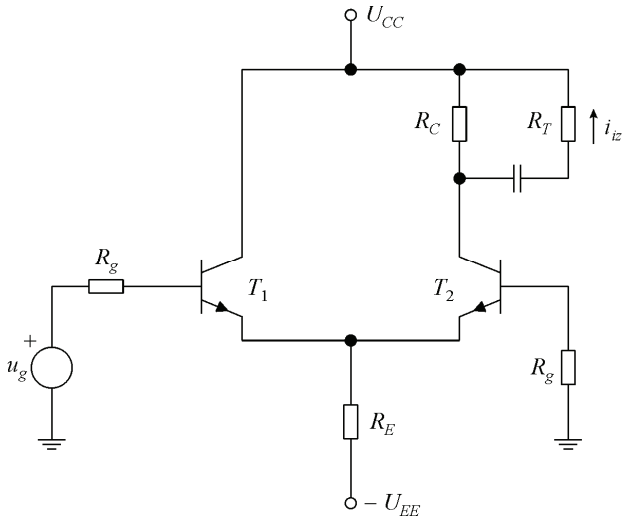
1. ispitni rok iz "Elektronike 2" - rješenja

1. zadatak

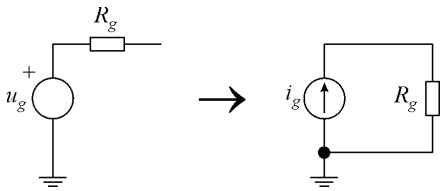


$$I_{BQ1} = I_{BQ2} = \frac{U_{EE} - U_{BEQ1}}{R_g + 2(1+\beta)R_E} = 11{,}1\ \mu\text{A}, \quad I_{CQ1} = I_{CQ2} = \beta I_{BQ1} = 1{,}11\ \text{mA},$$

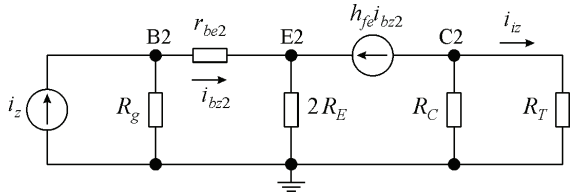
$$U_{CEQ1} \approx U_{CC} + U_{EE} - 2R_E I_{CQ1} = 12{,}9\ \text{V},$$

$$U_{CEQ2} \approx U_{CC} + U_{EE} - (R_C + 2R_E) I_{CQ1} = 11{,}2\ \text{V},$$

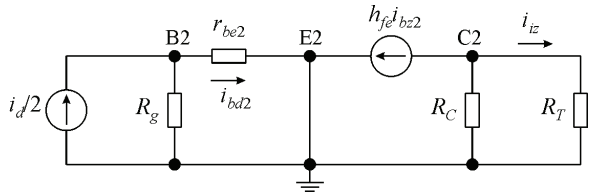
$$r_{be1} = r_{be1} = \frac{U_T}{I_{BQ1}} = 2{,}25\ \text{k}\Omega.$$



$$I_{gm} = \frac{U_{gm}}{R_g} = 10\ \mu\text{A}.$$



$$A_{Iz} = \frac{i_{iz}}{i_z} = -h_{fe}\frac{R_C}{R_C + R_T}\frac{R_g}{R_g + r_{be2} + 2(1+h_{fe})R_E} = -0{,}734.$$

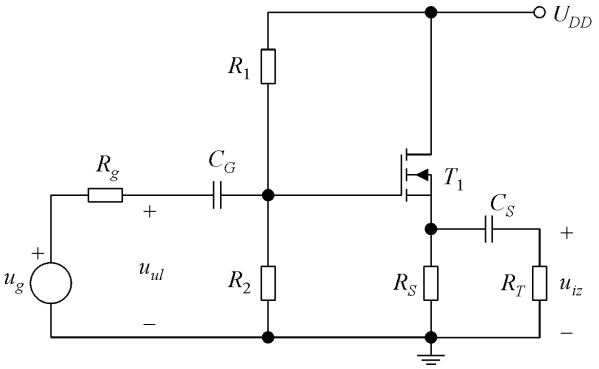


$$A_{Id} = \frac{i_{iz}}{i_d} = \frac{1}{2}\frac{i_{iz}}{i_d/2} = -\frac{h_{fe}}{2}\frac{R_C}{R_C + R_T}\frac{R_g}{R_g + r_{be2}} = -30{,}6\,,$$

$$I_{izm} = A_{Iz}\, I_{zm} + A_{Id}\, I_{dm} = 302\ \mu\text{A}\,,$$

$$I_{izm} = A_{Iz}\, I_{zm} + A_{Id}\, I_{dm} = 302\ \mu\text{A}, \quad i_{iz} = 302\sin\omega t\ \mu\text{A}\,.$$

2. zadatak



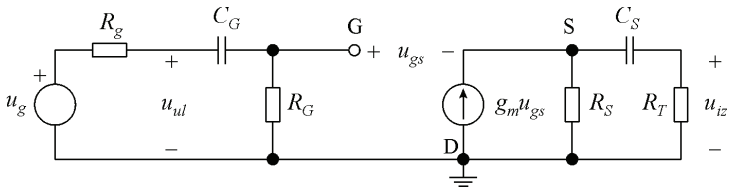
$$U_{GG} = \frac{R_2}{R_1 + R_2}U_{DD} = 9\ \text{V}, \quad R_G = R_1 \,\|\, R_2 = 2{,}4\ \text{M}\Omega\,,$$

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

$$U_{GSQ}^2 - 1{,}75\cdot U_{GSQ} - 9 = 0 \quad \rightarrow \quad U_{GSQ} = 0{,}875 \pm \sqrt{0{,}875^2 + 9} = 4\ \text{V}\,,$$

$$I_{DQ} = \frac{U_{GG} - U_{GSQ}}{R_S} = 12{,}5\ \text{mA}, \quad U_{DSQ} = U_{DD} - R_S\, I_{DQ} = 10\ \text{V}\,,$$

$$g_m = K\left(U_{GSQ} - U_{GS0}\right) = 10\ \text{mA/V}\,.$$



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

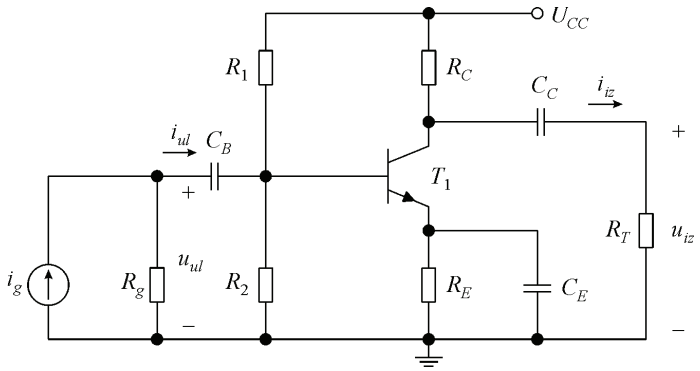
$$A_{Vg0} = \frac{U_{iz}}{U_g} = \frac{U_{iz}}{U_{gs}} \frac{U_{gs}}{U_{ul}} \frac{U_{ul}}{U_g} = \frac{g_m \left(R_S \left\| R_T \right. \right)}{1 + g_m \left(R_S \left\| R_T \right. \right)} \frac{R_G}{R_g + R_G} = 0,769 ,$$

$$\tau_G = \left(R_g + R_G \right) C_G = 36 \text{ ms}, \quad \omega_G = \frac{1}{\tau_G} = 27,8 \text{ rad/s} ,$$

$$\tau_S = \left(R_S \left\| \frac{1}{g_m} + R_T \right. \right) C_S = 5,2 \text{ ms}, \quad \omega_S = \frac{1}{\tau_S} = 192 \text{ rad/s} ,$$

$$\omega_d = \omega_S = 192 \text{ rad/s}, \quad f_d = \frac{\omega_d}{2\pi} = 30,6 \text{ Hz} .$$

3. zadatak

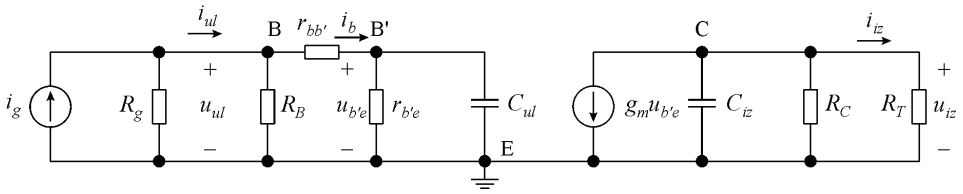


$$U_{BB} = \frac{R_2}{R_1 + R_2} U_{CC} = 4,8 \text{ V}, \quad R_B = R_1 \left\| R_2 \right. = 120 \text{ k}\Omega ,$$

$$I_{BQ} = \frac{U_{BB} - U_{BEQ}}{R_B + \left(1 + \beta \right) R_E} = 11 \text{ μA}, \quad I_{CQ} = \beta I_{BQ} = 1,1 \text{ mA} ,$$

$$U_{CEQ} \approx U_{CC} - \left(R_C + R_E \right) I_{CQ} = 5,73 \text{ V} ,$$

$$r_{b'e} = \frac{U_T}{I_{BQ}} = 2,27 \text{ k}\Omega, \quad g_m = \frac{I_{CQ}}{U_T} = 44 \text{ mA/V} .$$



$$A_{Ig0} = \frac{I_{iz}}{I_g} = \frac{I_{iz}}{U_{b'e}} \frac{U_{b'e}}{I_b} \frac{I_b}{I_g} = -\,g_m \frac{R_C}{R_C + R_T} \frac{r_{b'e}\left(R_g \,\|\, R_B\right)}{\left(R_g \,\|\, R_B\right) + r_{bb'} + r_{b'e}} = -\,75\,,$$

$$K = \frac{U_{iz}}{U_{b'e}} = -\,g_m \left(R_C \| R_T\right) = -\,28{,}2\,,$$

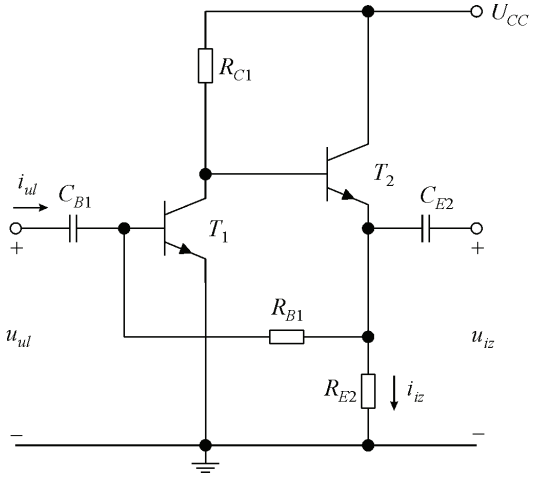
$$C_{ul} = C_{b'e} + C_{b'c}\,(1 - K) = 63{,}8 \text{ pF}, \quad C_{iz} = C_{b'c} \frac{K-1}{K} = 1{,}55 \text{ pF}\,,$$

$$\tau_{ul} = \left[\left(R_g \,\|\, R_B + r_{bb'}\right) \| \, r_{b'e}\right] C_{ul} = 136 \text{ ns}, \quad \omega_{ul} = \frac{1}{\tau_{ul}} = 7{,}35 \cdot 10^6 \text{ rad/s}\,,$$

$$\tau_{iz} = \left(R_C \,\|\, R_T\right) C_{iz} = 0{,}99 \text{ ns}, \quad \omega_{iz} = \frac{1}{\tau_{iz}} = 1{,}01 \cdot 10^9 \text{ rad/s}\,,$$

$$\omega_g = \omega_{ul} = 7{,}35 \cdot 10^6 \text{ rad/s}, \quad f_g = \frac{\omega_g}{2\pi} = 1{,}17 \text{ MHz}\,.$$

4. zadatak



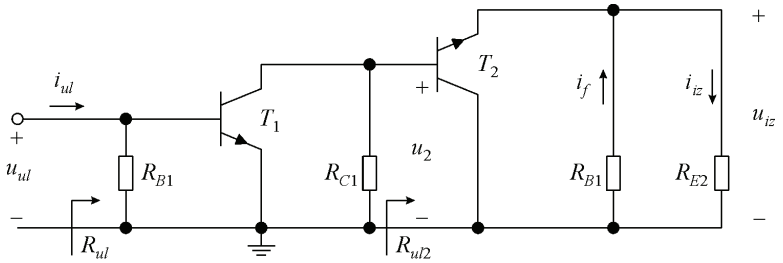
$$U_{CC} \approx \beta\, I_{BQ1} R_{C1} + U_{BEQ2} + I_{BQ1} R_{B1} + U_{BEQ1} \quad \rightarrow \quad I_{BQ1} \approx \frac{U_{CC} - 2U_{BEQ}}{\beta\, R_{C1} + R_{B1}} = 37{,}9 \text{ μA}\,,$$

$$\left[\left(1+\beta\right) I_{BQ2} - I_{BQ1}\right] R_{E2} = I_{BQ1} R_{B1} + U_{BEQ1} \quad \rightarrow \quad I_{BQ2} = \frac{U_{BEQ} + I_{BQ1}\left(R_{B1} + R_{E2}\right)}{\left(1+\beta\right) R_{E2}} = 37{,}3 \text{ μA}\,,$$

$$I_{CQ1} = \beta\, I_{BQ1} = 3,79 \text{ mA}, \quad I_{CQ2} = \beta\, I_{BQ2} = 3,73 \text{ mA},$$

$$r_{be1} = \frac{U_T}{I_{BQ1}} = 660\ \Omega, \quad r_{be2} = \frac{U_T}{I_{BQ2}} = 670\ \Omega.$$

Povratna veza – naponska-paralelna



$$A_{V2} = \frac{u_{iz}}{u_{ul}} = \frac{\left(1+h_{fe}\right)\left(R_{B1} \,\|\, R_{E2}\right)}{r_{be2} + \left(1+h_{fe}\right)\left(R_{B1} \,\|\, R_{E2}\right)} = 0,993,$$

$$R_{ul2} = r_{be2} + \left(1+h_{fe}\right)\left(R_{B1} \,\|\, R_{E2}\right) = 100 \text{ k}\Omega,$$

$$A_{V1} = \frac{u_2}{u_{ul}} = -\,h_{fe}\,\frac{R_{C1} \,\|\, R_{ul2}}{r_{be1}} = -\,297, \quad R_{ul} = R_{B1} \,\|\, r_{be1} = 655\ \Omega,$$

$$R_M = \frac{u_{iz}}{i_{ul}} = \frac{u_{iz}}{u_2}\,\frac{u_2}{u_{ul}}\,\frac{u_{ul}}{i_{ul}} = A_{V2}\, A_{V1}\, R_{ul} = -193 \text{ V/mA},$$

$$\beta = \frac{i_f}{u_{iz}} = -\,\frac{1}{R_{B1}} = -\,\frac{1}{80} \text{ mA/V}, \quad R_{Mf} = \frac{R_M}{1+\beta\, R_M} = -\,56,6 \text{ V/mA},$$

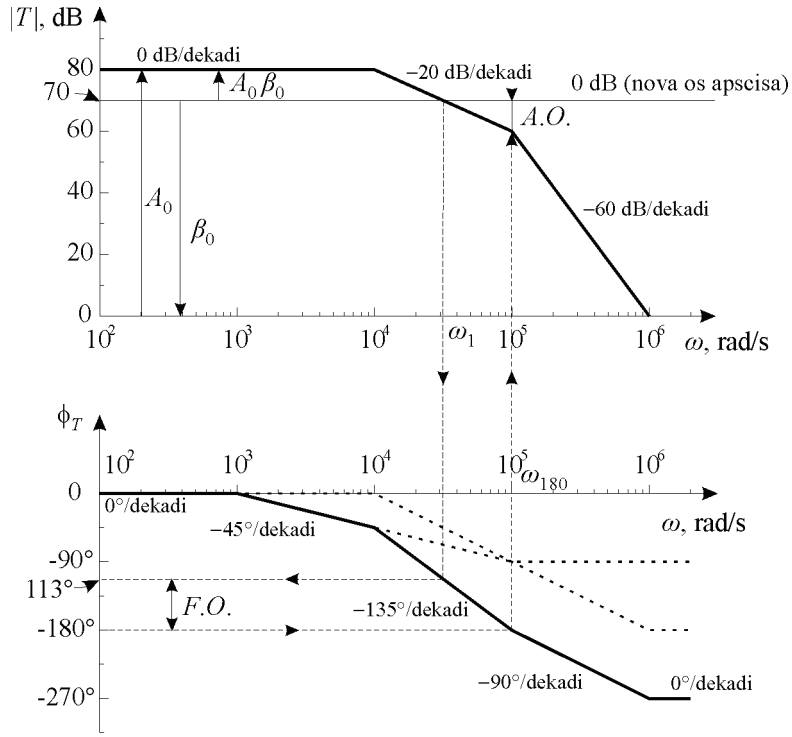
$$R_{ulf} = \frac{R_{ul}}{1+\beta\, R_M} = 192\ \Omega,$$

$$A_{Vf} = \frac{u_{iz}}{u_{ul}} = \frac{u_{iz}}{i_{ul}\, R_{ulf}} = \frac{R_{Mf}}{R_{ulf}} = -\,295, \quad A_{If} = \frac{i_{iz}}{i_{ul}} = \frac{u_{iz}/R_{E2}}{i_{ul}} = \frac{R_{Mf}}{R_{E2}} = -\,56,6.$$

5. zadatak

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

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



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

$$20\log|\beta_0| = 20\log|\beta_0 A_0| - 20\log|A_0| = -70 \text{ dB}, \quad \beta_0 = -3{,}16 \cdot 10^{-4},$$

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

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