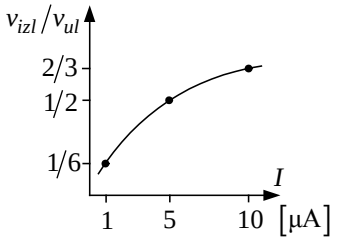
REŠENJA:

1.



a)

$$I_{D1} = I_{D2} = I_{D3} = I_{D4} = I/2$$

$$r_{d1} = V_T/I_{D1} = 2V_T/I = r_{d2} = r_{d3} = r_{d4} = r_d$$

$$r_{d\,ekv} = (r_{d1} + r_{d3}) \,||\, (r_{d2} + r_{d4}) = 2r_d \,||\, 2r_d = r_d$$

$$\frac{v_{izl}}{v_{ul}} = \frac{10\text{k}\Omega}{10\text{k}\Omega + r_{d\,ekv}} = \frac{10\text{k}\Omega}{10\text{k}\Omega + r_d} = \frac{10\text{k}\Omega}{10\text{k}\Omega + 2V_T/I} = \frac{1}{1 + 50\text{mV}/I/10\text{k}\Omega} = \frac{1}{1 + 5\mu\text{A}/I} = \frac{I}{I + 5\mu\text{A}}$$

b)

$$\Delta i_{D1} = -\Delta i_{D3} = -\Delta i_{D2} = \Delta i_{D4} = \Delta i_D = 0{,}1I = 0{,}5\mu\text{A}$$

$$|v_{izl}|_{\max} = |\Delta i_{D3} - \Delta i_{D4}| \cdot 10\text{k}\Omega = 1\mu\text{A} \cdot 10\text{k}\Omega = 10\text{mV}$$

$$|v_{izl}|_{\max} \cong \frac{I}{I + 5\mu\text{A}} |v_{ul}|_{\max} = \frac{1}{2} |v_{ul}|_{\max} \qquad |v_{ul}|_{\max} \cong 20\text{mV}$$

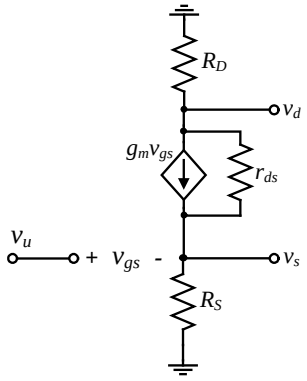
2. Beleške za predavanja, 11_Operacioni_pojacavac.pdf, slajdovi 31-33.

3. Beleške za predavanja, 13_Regulator_(stabilizator)_napona.pdf, slajd 2, 3.

4. a) $V_{GS} = V_T + \sqrt{\frac{2I_D}{B}} = 2\text{V}$

$$-V_{GS} - I_D R_S - V_{SS} = 0 \Rightarrow R_S = \frac{-V_{SS} - V_{GS}}{I_D} = 120\text{k}\Omega$$

b), c)



$$g_m = \sqrt{2I_D B} = 500\mu\text{S}, \; r_{ds} = \frac{1}{\lambda I_D} = 200\text{k}\Omega$$

$$\frac{v_s}{R_S} = -\frac{v_d}{R_D} \Rightarrow R_D = R_S = 120\text{k}\Omega$$

$$V_S = V_{SS} + I_D R_S = -2\text{V}$$

$$V_D = V_{DD} - I_D R_D = 2\text{V}$$

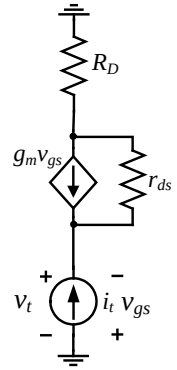
$$\left.\begin{aligned} v_{gs} &= v_u - v_s \\ g_m v_{gs} + g_{ds}(v_d - v_s) &= G_S v_s \\ v_d &= -v_s \end{aligned}\right\} \Rightarrow v_s = \frac{g_m}{G_S + 2g_{ds} + g_m} v_u$$

$$a_s = 0.965 = -a_d$$

$$v_S = V_S + a_s v_u = -2\text{V} + 96.5\text{mV}\sin 2\pi ft$$

$$v_D = V_D + a_d v_u = 2\text{V} - 96.5\text{mV}\sin 2\pi ft$$

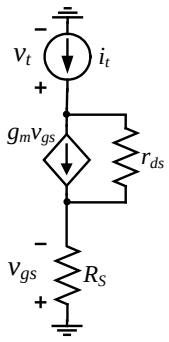
d)



$$\left.\begin{aligned} R_x &= R_S \,||\, R_{xs} \\ v_t &= i_t R_D + (i_t + g_m v_{gs}) r_{ds} \\ v_{gs} &= -v_t \end{aligned}\right\} \Rightarrow R_{xs} = \frac{v_t}{i_t} = \frac{R_D + r_{ds}}{1 + g_m r_{ds}}$$

$$R_x = R_S \,||\, \frac{R_D + r_{ds}}{1 + g_m r_{ds}} = 3.09\text{k}\Omega$$

e)

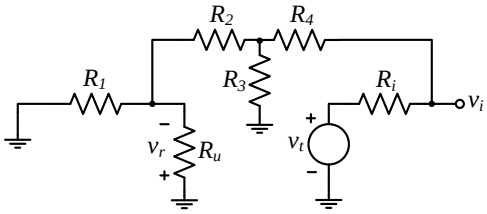


$$R_y = R_D \parallel R_{yd}$$

$$\left.\begin{aligned} v_t &= R_S i_t + (i_t - g_m v_{gs}) r_{ds} \\ v_{gs} &= -R_S i_t \end{aligned}\right\} \Rightarrow R_{yd} = \frac{v_t}{i_t} = R_S + r_{ds}(1 + R_S g_m)$$

$$R_y = R_D \parallel (R_S + r_{ds}(1 + R_S g_m)) = 118.8\text{k}\Omega$$

5.



a)

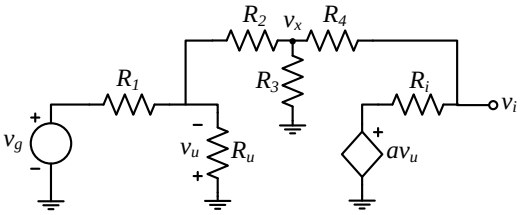
$$v_r = -\frac{(R_1 \parallel R_u + R_2) \parallel R_3}{(R_1 \parallel R_u + R_2) \parallel R_3 + R_4 + R_i} \frac{R_1 \parallel R_u}{R_1 \parallel R_u + R_2} v_t \Rightarrow$$

$$A_{inv} = \frac{v_r}{v_t} = -\frac{(R_1 \parallel R_u + R_2) \parallel R_3}{(R_1 \parallel R_u + R_2) \parallel R_3 + R_4 + R_i} \frac{R_1 \parallel R_u}{R_1 \parallel R_u + R_2} = -0.0832 \Rightarrow T = -aA_{inv} = 8.32$$

b)

$$a_{r\infty} = a_r(a \to \infty) \Rightarrow v_u = 0 \Rightarrow v_x = -R_2 \frac{v_g}{R_1} \Rightarrow v_i = v_x - R_4\left(\frac{v_g}{R_1} - \frac{v_x}{R_3}\right)$$

$$v_i = -\frac{v_g}{R_1}\left(R_2 + R_4 + \frac{R_2 R_4}{R_3}\right) \Rightarrow a_{r\infty} = -\frac{R_2 + R_4 + \frac{R_2 R_4}{R_3}}{R_1} = -8$$



$a_{r0} = a_r(a = 0) \Rightarrow$

c) $$v_i = \frac{R_u \parallel (R_2 + R_3 \parallel (R_4 + R_i))}{R_u \parallel (R_2 + R_3 \parallel (R_4 + R_i)) + R_1} \frac{R_3 \parallel (R_4 + R_i)}{R_3 \parallel (R_4 + R_i) + R_2} \frac{R_i}{R_i + R_4} v_g \Rightarrow a_{r0} = 0.017$$

d) $$a_r = a_{r\infty} \frac{T}{1+T} + a_{r0} \frac{1}{1+T} = -7.14$$

e) $$R_{ir} = R_{i0} \frac{1 + T_{ks}}{1 + T_{ov}}$$

$R_{i0} = R_i \parallel (R_4 + R_3 \parallel (R_2 + R_u \parallel R_1)) = 932\Omega$, $T_{ks} = 0$, $T_{ov} = T = 8.32$

$R_{ir} = 100\Omega$