REŠENJA:

1.

$$I_{BQ} = I_{EQ}/(\beta+1) = I/(\beta+1) = 19,6\mu\text{A} \simeq 20\mu\text{A}$$

$$V_{BQ} = \frac{R_2}{R_1+R_2}V_{CC} - (R_1 \parallel R_2)I_{BQ} = 2\text{V} - 20\text{k}\Omega \cdot 20\mu\text{A} = 1,6\text{V}$$

$$V_{EQ} = V_{BQ} - V_{BE} = 1\text{V} \qquad I_{CQ} = \beta I_{BQ} = 0,98\text{mA}$$

$$V_{CQ} = V_{CC} - R_C I_{CQ} = 5,1\text{V} \qquad V_{CEQ} = V_{CQ} - V_{EQ} = 4,1\text{V}$$

$$g_m = I_{CQ}/V_T = 39,2\text{mS} \qquad r_e = V_T/I_{EQ} = 25\Omega$$

$$A_v = g_m(R_C \parallel R_p)r_e/(R_g + r_e) = 4,66$$

2. Beleške za predavanja, slajd 4.

$$I_{IZL}R_E = V_T \ln\left(\frac{I_{REF}}{I_{IZL}}\right) = (25\text{mV})\ln\left(\frac{200\mu\text{A}}{10\mu\text{A}}\right) = 74.8933\text{mV}$$

$$R_E = \frac{74.8933\text{mV}}{I_{IZL}} = \frac{74.8933\text{mV}}{10\mu\text{A}} = 7.48933\text{k}\Omega$$

3. Beleške za predavanja, „9_Izlazni_pojacavacki_stepeni.pdf“, slajdovi 10-11 (+ 6-8).

4.

I $0 \le v_U < V_T$, DZ2 u proboju, M1 isključen

$$i_Z = \frac{V_{DD} - V_Z}{R_D} = 5\text{mA}$$

$$i_D = 0$$

$$v_I = V_Z$$

II $V_T \le v_U < V_1$, DZ2 u proboju, M1 vodi u zasićenju

$$i_D = \frac{B}{2}(v_U - V_T)^2$$

$$i_Z = \frac{V_{DD} - V_Z}{R_D} - i_D$$

$$v_I = V_Z$$

$V_{1,1} < V_Z + V_T = 6\text{V}$ - granica zasićenja i triodne oblasti

$$i_Z \ge 0 \Rightarrow i_D \le \frac{V_{DD} - V_Z}{R_D} \Rightarrow V_{1,2} \le V_T + \sqrt{\frac{2}{B}\frac{V_{DD} - V_Z}{R_D}} = 5.47\text{V}$$ - granica zakočenja zener diode

$$V_1 = \min\{V_{1,1}, V_{1,2}\} = V_{1,2} = 5.47\text{V}$$

III $V_1 \le v_U < V_2$, DZ2 je isključena, M1 vodi u zasićenju

$$i_Z = 0$$

$$i_D = \frac{B}{2}(v_U - V_T)^2$$

$$v_I = V_{DD} - i_D R_D$$

$v_I(V_2) - V_2 = -V_T$ - granica zasićenja i triodne oblasti

$$V_{DD} - \frac{B}{2}(V_2 - V_T)^2 R_D - V_2 = -V_T$$

$$V_2^2 - 2\cdot\left(V_T - \frac{1}{R_D B}\right)\cdot V_2 + V_T^2 - \frac{2}{R_D B}\cdot\left(V_T + V_{DD}\right) = 0 \Rightarrow V_2 = 5.63\text{V}$$

Međutim već pri naponu $V_2 = V_Z + V_D = 5.6\text{V}$ će provesti diode DZ1 i D1.

IV $V_2 \le v_U < V_{DD}$, DZ2 je isključena, M1 vodi u triodnoj oblasti

$$i_Z = 0$$

$$i_D = \frac{B}{2}(V_Z + V_D - V_T)^2 = 5.29\text{mA}$$

$$v_I = V_{DD} - i_D R_D = 4.71\text{V}$$

5.

a) ,b)

$$v_{IOP} = \frac{v_1}{2} - R_X\,\frac{v_1}{2R} = \frac{v_1}{2}\left(1 - \frac{R_X}{R}\right)$$

$$v_I = -4v_{IOP} - v_2 = -2\left(1 - \frac{R_X}{R}\right)v_1 - v_2$$

Za $v_I = -v_2 - v_1$ potrebno je da bude ispunjeno $2\left(1 - \frac{R_X}{R}\right) = 1 \Rightarrow R_X = \frac{R}{2}$

Za $v_I = -v_2 + v_1$ potrebno je da bude ispunjeno $2\left(1 - \frac{R_X}{R}\right) = -1 \Rightarrow R_X = \frac{3R}{2}$

c) Kritičan je izlaz drugog operacionog pojačavača (pri vrednostima $R_X = 0$ i $R_X = 2R$) koji ulazi u zasićenje pri $V_m = \frac{10}{3}\text{V}$.

d)