IR2OAE, IR3OAE Osnovi analogne elektronike - rešenja zadataka, popravni kolokvijum 2013:

1.

$$\frac{r_d \parallel R_p}{r_d \parallel R_p + R_g} = \frac{1}{3} \Rightarrow r_d \parallel R_p = R_g/2 = 0,5\text{k}\Omega;$$

$$r_d \parallel R_p = r_d \parallel (1\text{k}\Omega) = 0,5\text{k}\Omega \Rightarrow r_d = 1\text{k}\Omega = V_T/I$$

$$\Rightarrow I = V_T/r_d = 25\text{mV}/1\text{k}\Omega = 25\mu\text{A}$$

2.

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

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

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

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

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

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

3. Beleške za predavanja, slajd 4.

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

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

4.

$-12\text{V} \le v_G < V_1$, D1 – OFF, DZ1 – ON, DZ2 - ON

$$v_P = -V_Z - V_D,\ i_{Z1} = -i_{Z2} = \frac{v_G - v_P}{R_1} - \frac{v_P}{R_P}$$

$$P_{Z1} = V_D\left(\frac{v_G - v_P}{R_1} - \frac{v_P}{R_P}\right) = \frac{V_D}{R}v_G + \frac{2(V_Z+V_D)}{R}V_D = (0.6v_G + 4.56)\text{mW}$$

$$P_{Z2} = V_Z\left(\frac{v_G - v_P}{R_1} - \frac{v_P}{R_P}\right) = \frac{V_Z}{R}v_G + \frac{2(V_Z+V_D)}{R}V_Z = (3.2v_G + 24.32)\text{mW}$$

$$P_D = 0$$

Diode DZ1 i DZ2 se isključuju istovremeno, u trenutku kada struja kroz njih postane jednaka 0. Ulazni napon za koji se to dešava je:

$$\frac{V_1 + V_Z + V_D}{R_1} = \frac{-V_Z - V_D}{R_P} \Rightarrow V_1 = -2(V_Z + V_D) = -7.6\text{V}$$

$V_1 \le v_G < V_2$, D1 – OFF, DZ1 – OFF, DZ2 - OFF

$$v_P = \frac{R_P}{R_1 + R_P}v_g = \frac{v_g}{2},\ P_{Z1} = P_{Z2} = P_{D1} = 0$$

Diode DZ1 i D1 se uključuju istovremeno, u trenutku kada napon na izlazu dostigne vrednost $2V_D$. Ulazni napon za koji se to dešava je:

$$\frac{V_2}{2} = 2V_D \Rightarrow V_2 = 4V_D = 2.4\text{V}$$

$V_2 \le v_G < V_3$, D1 – ON, DZ1 – ON, DZ2 - OFF

$$\frac{v_G - v_P}{R_1} = \frac{v_P - 2V_D}{R_2} + \frac{v_P}{R_P} \Rightarrow v_P = \frac{v_G + 2V_D}{3},\ -i_{Z1} = i_{D1} = \frac{v_P - 2V_D}{R_2} = \frac{v_G - 4V_D}{3R_2}$$

$$P_{Z1} = P_D = V_D\left(\frac{v_G - 4V_D}{3R}\right) = (0.2v_G - 0.48)\text{mW}$$

$$P_{Z2} = 0$$

Pri naponu generatora V_3 počinje da vodi dioda DZ2. Na granici provođenja važi:

$$v_P - V_D = V_Z \Rightarrow \frac{V_3 + 2V_D}{3} = V_Z + V_D \Rightarrow V_3 = 3V_Z + V_D = 10.2\text{V}$$

$V_3 \le v_G \le 12\text{V}$, D1 – ON, DZ1 – ON, DZ2 - ON

$$v_P = V_Z + V_D = 3.8\text{V}$$

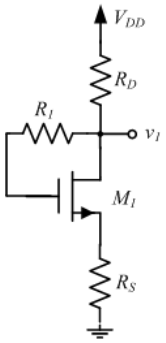
$$i_D = \frac{V_Z - V_D}{R_2} = 2.6\text{mA} \Rightarrow P_D = V_D i_D = 1.56\text{mW}$$

$$\frac{v_G - v_P}{R_1} = -i_{Z1} + \frac{v_P}{R_P} \Rightarrow -i_{Z1} = \frac{v_G - v_P}{R_1} - \frac{v_P}{R_P} = \frac{v_G}{R} - \frac{2(V_Z + V_D)}{R}$$

$$P_{Z1} = -V_D i_{Z1} = \frac{V_D}{R}v_G - \frac{2(V_Z + V_D)}{R}V_D = (0.6v_G - 4.56)\text{mW}$$

$$i_{Z2} = -i_{Z1} - i_D \Rightarrow P_{Z2} = \frac{V_Z}{R}v_G - \frac{2(V_Z + V_D)}{R}V_Z - i_D V_Z = (3.2v_G - 32.64)\text{mW}$$

5. a)



$$V_{DD} - I_D R_D - V_{GS} - I_D R_S = 0$$

$$I_D = (V_{DD} - V_{GS})\frac{1}{R_D + R_S} \Rightarrow \frac{B}{2}(V_{DD} - V_{GS})^2 = (V_{DD} - V_{GS})\frac{1}{R_D + R_S}$$ ako M1 radi u zasićenju

$$V_{GS}{}^2 - 2(V_T - \frac{1}{B(R_D + R_S)})V_{GS} + V_T{}^2 - \frac{2V_{DD}}{B(R_D + R_S)} = 0$$

$V_{GS1} = 4\text{V}$, $V_{GS2} = -0.667\text{V}$, druga vrednost ne zadovoljava uslov provođenja tranzistora

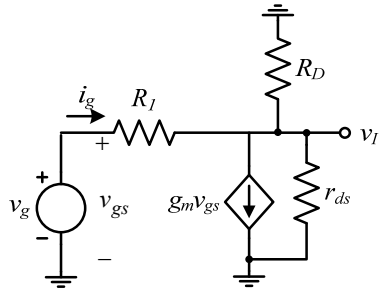
$$I_D = \frac{B}{2}(V_{DD} - V_{GS})^2 = 1\text{mA}$$

$$V_S = R_S I_D = 1\text{V}$$

$$V_G = V_S + V_{GS} = 5\text{V}$$

$$V_D = V_G = 5\text{V}$$

b) $g_m = \sqrt{2I_D B} = 1\text{mS}$, $r_{ds} = \frac{1}{\lambda I_D} = 100\text{k}\Omega$



$$i_g = \frac{v_g - v_i}{R_1}$$

$$v_i = (i_g - g_m v_g)(R_D \parallel r_{ds})$$

$$v_i(1 + \frac{R_D \parallel r_{ds}}{R_1}) = v_g(\frac{R_D \parallel r_{ds}}{R_1} - g_m(R_D \parallel r_{ds}))$$

$$a_v = \frac{v_i}{v_g} = \frac{(R_D \parallel r_{ds})(1 - g_m R_1)}{R_1 + R_D \parallel r_{ds}} = -1.95$$

c) $R_u = \frac{v_g}{i_g} = \frac{v_g}{v_g - v_i}R_1 = \frac{v_g}{v_g(1 - a_v)}R_1 = \frac{R_1}{(1 - a_v)} = 1.69\text{k}\Omega$

$R_i = R_D \parallel R_1 \parallel r_{ds} = 2.44\text{k}\Omega$

d) $v_G(t) = V_G + v_g(t) = (5 + 0.1\sin 2\pi ft)\text{V}$

$v_S(t) = V_S + v_s(t) = V_S = 1\text{V}$

$v_D(t) = V_D + v_d(t) = V_D + a_v v_g(t) = (5 - 0.0195\sin 2\pi ft)\text{V}$