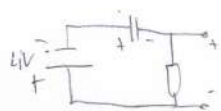
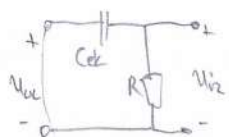
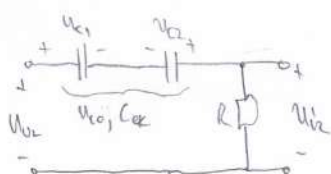


① $u_{uc} = u_{c1} + u_{c2} - u_{c2}$
 $= u_{c1} - u_{c2} + u_{c2}$



$$u_{c0} = u_{c10} - u_{c20} = 1.5 - 1.5 = 0V$$

$$C_{ek} = \left(\frac{1}{C_1} + \frac{1}{C_2} \right)^{-1} = \left(\frac{1}{C} + \frac{1}{C} \right)^{-1} = \frac{C}{2} = \frac{2}{2} = 1 \mu F$$

$$\tau = C_{ek} \cdot R = 10^{-6} \cdot 5.6 \cdot 10^3 = 5.6 \cdot 10^{-3} s = 5.6 ms$$

$$u_{c0} = 0V //$$

$$t=0^- \rightarrow u_{i2}(0^-) = 0V \quad u_{uc} = 0 \quad u_c = 0$$

$$t=0^+ \rightarrow u_{i2}(0^+) = -4V$$

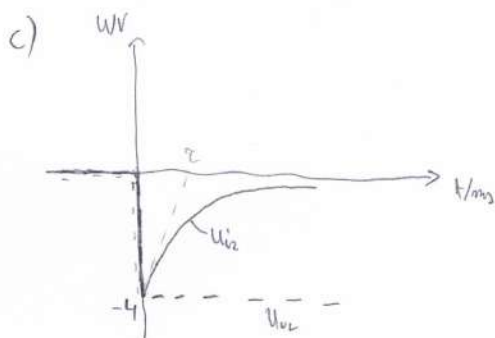
$$u_{c0} = u_{cp} = 0V$$

$$u_{ck} = -4V$$

a) $u_{i2}(t) = u_c(t) = u_{ck}(0^+) \exp\left(-\frac{t}{\tau}\right) //$

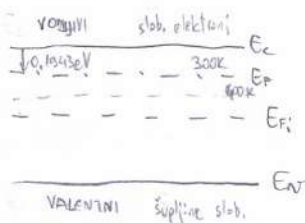
b) $t=0 \quad u_{i2}(0^-) = 0V \quad u_{i2}(0^+) = -4V$

$$t=5ms \quad u_{i2}(5ms) = -4 \exp\left(-\frac{5}{5.6}\right) = -1.64V //$$



$$N_D = 2 \cdot 10^{16} \text{ cm}^{-3} \quad (2)$$

a) $T = 300 \text{ K}$, $E_F = ?$



$$n_{0n} = N_c \exp \frac{E_F - E_c}{E_T} \Rightarrow E_F = E_c + E_T \ln \left(\frac{n_{0n}}{N_c} \right)$$

$$N_D = 2 \cdot 10^{16} \text{ cm}^{-3} \gg n_i = 1.45 \cdot 10^{10} \text{ cm}^{-3}$$

↓
EKSTENZIJAN Si: $n_{0n} = N_D = 2 \cdot 10^{16} \text{ cm}^{-3}$

$$N_c = C \cdot T^{3/2} = 7.07 \cdot 10^{15} \cdot (300)^{3/2} = 3.67 \cdot 10^{19} \text{ cm}^{-3} //$$

$$E_F = E_c + E_T \ln \left(\frac{n_{0n}}{N_c} \right) = E_c + \frac{300}{11600} \ln \left(\frac{2 \cdot 10^{16}}{3.67 \cdot 10^{19}} \right) = E_c - 0.1943 \text{ eV}$$

b) $T \uparrow \Rightarrow E_F$ ide proti E_F ; (medini razprazjenog pojasa)

Da bi $E_F \uparrow$ treba dodati donore

$$N_{DVK} = N_{D1} + N_{D2}$$

$$T = 400 \text{ K}$$

$$N_c = C T^{3/2} = 7.07 \cdot 10^{15} \cdot 400^{3/2} = 5.66 \cdot 10^{19} \text{ cm}^{-3}$$

$$n_i(400 \text{ K}) = C_1 T^{3/2} \exp \frac{-E_{g0}}{2kT} = \dots = 7.22 \cdot 10^{12} \text{ cm}^{-3}$$

$$E_c - E_F = 0.1943 \text{ eV}$$

$$E_F - E_c = -0.1943 \text{ eV}$$

$$n_{0n2} = N_c \exp \frac{E_F - E_c}{E_T} = 5.66 \cdot 10^{19} \exp \frac{-0.1943}{\frac{400}{11600}} = 2.02 \cdot 10^{17} \text{ cm}^{-3}$$

$$n_{0n2} \gg n_i \rightarrow \text{EKSTENZIJAN} \mid n_{0n2} = N_{DVK} = N_{D1} + N_{D2}$$

$$N_{D2} = n_{0n2} - N_{D1} \quad (\text{manj dodati one koje imamo})$$

$$N_{D2} = 2.02 \cdot 10^{17} - 2 \cdot 10^{16} = 1.82 \cdot 10^{17} \text{ cm}^{-3} //$$

1) -strana

p-manjški, nosilci

$$N_D = 4 \cdot 10^{15} \text{ cm}^{-3}, \mu_p = 300 \text{ cm}^2/\text{Vs}, \tau_p = 0.8 \mu\text{s}, W_m = 350 \mu\text{m} = 350 \cdot 10^{-4} \text{ cm}$$

2) -strana

$$N_A = 2 \cdot 10^{17} \text{ cm}^{-3}, \mu_n = 800 \text{ cm}^2/\text{Vs}, \tau_n = 0.5 \mu\text{s}, W_p = 0.8 \mu\text{m} = 0.8 \cdot 10^{-4} \text{ cm}$$

$$S = 1 \text{ mm}^2 = 10^{-2} \text{ cm}^2$$

a) RAVNOTEŽNE KONC

$$p_{om} = \frac{n_i^2}{n_{om}} = \frac{n_i^2}{N_D} = \frac{(1.45 \cdot 10^{10})^2}{4 \cdot 10^{15}} = 5.26 \cdot 10^4 \text{ cm}^{-3}$$

$$n_{op} = \frac{n_i^2}{p_{op}} = \dots = 1.05 \cdot 10^3 \text{ cm}^{-3}$$

RUBNE KONC

$$p_{mo} = p_{om} \exp \frac{U_D}{m U_T} = 5.26 \cdot 10^4 \exp \frac{0.55 \cdot 11600}{1.300} = 9.06 \cdot 10^{13} \text{ cm}^{-3}$$

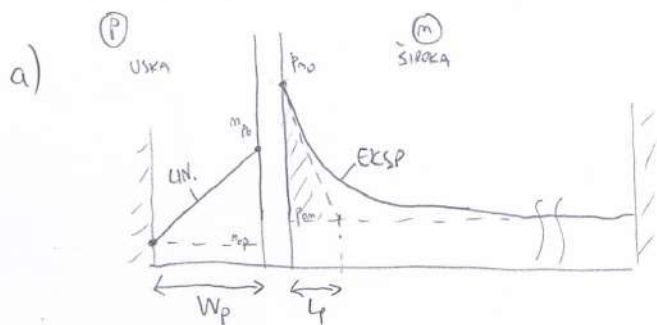
$$n_{po} = n_{op} \exp \frac{U_D}{m U_T} = \dots = 1.81 \cdot 10^{12} \text{ cm}^{-3}$$

$$L_m = \sqrt{D_m \tau_m} = \sqrt{\mu_n U_T \tau_n} = \sqrt{800 \cdot \frac{300}{11600} \cdot 0.5 \cdot 10^{-6}} = 32.2 \mu\text{m} = 32.2 \cdot 10^{-4} \text{ cm}$$

$$L_p = \sqrt{D_p \tau_p} = \sqrt{\mu_p U_T \tau_p} = \dots = 24.9 \mu\text{m} = 24.9 \cdot 10^{-4} \text{ cm}$$

$W_p \ll L_m \rightarrow$ uska p-strana

$W_m \gg L_p \rightarrow$ široka n-strana



stroje manjških nosilcev!!!

p-str m-str

$$I_s = I_{sn} + I_{sp} = qS \left[\frac{D_n}{\mu_n U_T} \frac{n_{op}}{W_p} + \frac{D_p}{\mu_p U_T} \frac{p_{om}}{L_p} \right]$$

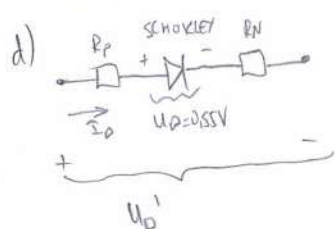
$$= qS U_T \left[\mu_n \frac{n_{op}}{W_p} + \mu_p \frac{p_{om}}{L_p} \right]$$

$$= 1.6 \cdot 10^{-19} \cdot 10^{-2} \cdot \frac{300}{11600} \left[800 \cdot \frac{1.05 \cdot 10^3}{0.8 \cdot 10^{-4}} + 300 \cdot \frac{5.26 \cdot 10^4}{24.9 \cdot 10^{-4}} \right]$$

$$b) I_s = 0.7 \cdot 10^{-12} \text{ A} = 0.7 \text{ pA}$$

$$c) I_D = I_s \left[\exp \left(\frac{U_D}{m U_T} \right) - 1 \right] = 0.7 \cdot 10^{-12} \left[\exp \frac{0.55 \cdot 11600}{1.300} - 1 \right]$$

$$I_D = 1.2 \text{ mA}$$



$$U_D' = U_D + I_D (R_p + R_n) = 0.55 + 1.2 \cdot 10^{-3} (5 + 7)$$

$$U_D' = 0.564 \text{ V}$$

1) U_{GS} postaja pozitivniji: $\rightarrow I_D \uparrow \rightarrow$ NMOS

moramo znati U_{GS0}

b) A: $I_{DA} = 1 \text{ mA}$

$U_{GSA} = 2 \text{ V}$

B: $I_{DB} = 9 \text{ mA}$

$U_{GSB} = 4 \text{ V}$

A i B u zasićenju: (1) $I_{DA} = \frac{K}{2} (U_{GSA} - U_{GS0})^2$

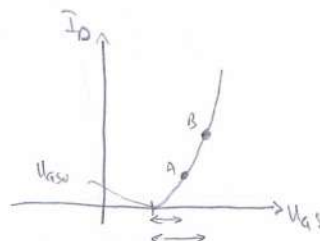
(2) $I_{DB} = \frac{K}{2} (U_{GSB} - U_{GS0})^2$

(2) : $\frac{I_{DB}}{I_{DA}} = \frac{(U_{GSB} - U_{GS0})^2}{(U_{GSA} - U_{GS0})^2} \sqrt{\quad}$

$\sqrt{\frac{I_{DB}}{I_{DA}}} = \frac{U_{GSB} - U_{GS0}}{U_{GSA} - U_{GS0}}$

$\sqrt{\frac{9}{1}} = \frac{U_{GSB} - U_{GS0}}{U_{GSA} - U_{GS0}}$

$(U_{GSB} - U_{GS0})$ i $(U_{GSA} - U_{GS0})$ imaju isti podrinak jer i u A i B imamo kanal



može tako da bi se formirao kanal i vodit struju
 $U_{GSA} > U_{GS0}$
 $U_{GSB} > U_{GS0}$

$3U_{GSA} - 3U_{GS0} = U_{GSB} - U_{GS0}$

$U_{GS0} = \frac{3U_{GSA} - U_{GSB}}{2} = \frac{3 \cdot 2 - 4}{2} = 1 \text{ V} //$

$K = \frac{2I_{DA}}{(U_{GSA} - U_{GS0})^2} = \dots = 2 \text{ mA/V}^2 //$

NMOS - obogaćeni p

$U_{GS0} = 1 \text{ V}$ u $U_{GS} = 0 \text{ V} \rightarrow I_D = 0$



c) $K = \mu_n C_{ox} \cdot \frac{W}{L} = \mu_n \cdot \frac{\epsilon_0 \epsilon_{ox}}{t_{ox}} \cdot \frac{W}{L} \Rightarrow t_{ox} = \frac{\mu_n \epsilon_0 \epsilon_{ox}}{K} \cdot \frac{W}{L} = \frac{350 \cdot 8,854 \cdot 10^{-14} \cdot 3,9}{2 \cdot 10^{-3}} \cdot 20$

$t_{ox} = 1,21 \cdot 10^{-6} \text{ m} = 12,1 \cdot 10^{-7} \text{ m} = 12,1 \text{ nm} //$

