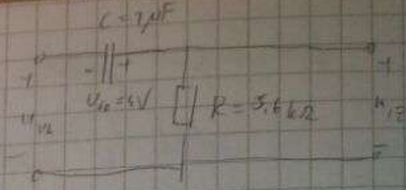
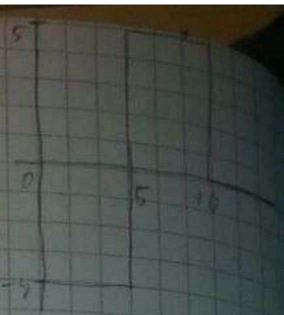
1) $t=0$: $|U_{C0}| = 4V$

$u_{UL}(0) = -4V$





a)

$\tau = RC = 5{,}6\,ms$

b) 1° $0 < t < 5\,ms$:

$|U_{C0}| = 4V$, ali obrati pažnju na polarizaciju napona - negativni ulazni napon od $-4V$ drži kondenzator na početnom naponu tj. U_C se ne mijenja, pa se ne mijenja ni $U_R = U_{IZ}$:

$$U_{UL} = U_C + U_R$$

$$-4V = -4V + U_R \Rightarrow U_R = U_{IZ} = 0V$$

2° $5\,ms < t < 10\,ms$

početni napon na kondenzatoru: $U_{CP} = U_{C0} = -4V$

napon kojem kondenzator teži: $U_{CK} = U_{UL}(5\,ms) = +5\,V$

$$\Rightarrow U_C = U_{CP} + (U_{CK} - U_{CP})\left[1 - \exp\left(\frac{-(t-t_P)}{\tau}\right)\right] \quad t_P = 5\,ms$$

$$= -4V + 5V + 4V - 9\exp\left(\frac{-(t-5)}{\tau}\right)[V]$$

$$\Rightarrow U_{IZ} = U_R = U_{UL} - U_C = 5V - 5V + 9\exp\left(\frac{-(t-5)}{\tau}\right)[V] = 9\exp\left(\frac{-(t-5)}{\tau}\right)$$

3° $10\,ms < t$

$U_{CP}(10\,ms) = $ *uvrsti u izraz za $5 < t < 10$* $= 1{,}375\,V$ || $U_{CK} = U_{UL} = 0$

$$\rightarrow U_C(t>10) = U_{CP}(10) + (U_{CK} - U_{CP}(10))\left[1 - \exp\left(\frac{t-t_P}{\tau}\right)\right] = U_{CP} + 0 - U_{CP} + U_{CP}\exp\left(\frac{t-t_P}{\tau}\right)$$

$$\rightarrow U_{IZ} = U_R = U_{UL} - U_C = -1{,}375\exp\left(\frac{-(t-10)}{\tau}\right)[V]$$

$U_{IZ}(1\,ms) = 0V$

$U_{IZ}(9\,ms) = 4{,}106V$

$U_{IZ}(12\,ms) = -0{,}92V$

2) $n-Si\,P \Rightarrow N_D = 2\cdot10^{16}\,cm^{-3}$

$T = 300K$

$n_i(300K) = \text{*formula*} = 1{,}55\cdot10^{10}\,cm^{-3}$

$N_D \gg n_i$

$\Rightarrow n_1 = N_D = 2\cdot10^{16}\,cm^{-3} \Rightarrow p_1 = \frac{n_i^2}{n_1} = 1{,}05\cdot10^{4}\,cm^{-3}$

a) nakon drugog dopiranja vodljivost pada:

$\sigma = e(n\mu_n + p\mu_p)$ - uvijek vrijedi $\mu_n > \mu_p$, a dodajemo samo jednu vrstu primjese, pa je jedini način da se vodljivost smanji dodavanje suprotne primjese, tako da n pada, a raste $\Rightarrow$ dodajemo šupljine $\Rightarrow E_F$ pada

b) $E_{F_1} = ?$

$n_1 = N_C \exp\left(\frac{E_{F_1} - E_C}{E_T}\right) \Big/ : N_C \Big/ \ln$

$\ln\left(\frac{n_1}{N_C}\right) = \frac{E_{F_1} - E_C}{E_T} \Big/ \cdot E_T$

$E_{F_1} = E_C + E_T \ln\left(\frac{n_1}{N_C}\right) \Big/\!/ N_C = CT^{\frac{3}{2}}$

$E_{F_1} = E_C - 0{,}194\,eV$

$\Rightarrow E_{F_2} = E_C - 0{,}294\,eV$

$\Rightarrow n_2 = N_C \exp\left(\frac{E_{F_2} - E_C}{E_T}\right) = 4{,}19\cdot10^{14}\,cm^{-3}$

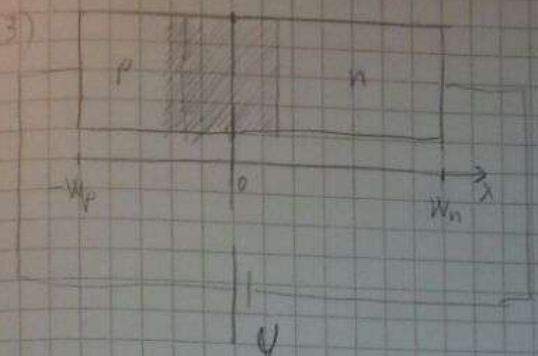
$\Rightarrow$ Koncentracija druge primjese je jednaka razlici koncentracija elektrona kao većinskih nosilaca prije i nakon drugog dopiranja

$\Rightarrow N_A = n_1 - n_2 = 1{,}96\cdot10^{16}\,cm^{-3}$

c) $n_1 = 2\cdot10^{16}$ $\quad n_2 = 4{,}19\cdot10^{14}$

$p_1 = 10^4$ $\quad p_2 = \frac{n_i^2}{n_2} = 5\cdot10^{5}$

3)



$T = 300K$

$N_D = 5 \cdot 10^{16}\ cm^{-3} >> n_i(300K) \Rightarrow n_{on} = N_D$

$\mu_{pp} = 388\ \frac{cm^2}{Vs}$ $\mu_{np} = 350\ \frac{cm^2}{Vs}$

$w_n >> L_p \Rightarrow$ široka n-strana $w_p = 1\mu m << L_n$

$\tau = 1\mu s$ $\Leftrightarrow$ uska p-strana

$S = 5\ mm^2 = 0.05\ cm^2$

$V = 0.65V$

a) $p_{on} = \frac{n_i^2}{n_{on}} = 4494\ cm^{-3}$

NOTE: izveli su neku čudnu spačku s podacima (pogotovo pokretljivost manjinskih elektrona na p-strani nema smisla), ali rezultati su prema rješenjima

$I_{Dn} = I_{Dp}$ // uvjet zadatka

$S q D_n \cdot \frac{n_{op}}{w_p} = S q \cdot D_p \cdot \frac{p_{on}}{L_p}$

$U_T \mu_{np} \frac{n_{op}}{w_p} = U_T \mu_{pp} \frac{p_{on}}{\sqrt{U_T \mu_{np} \tau_p}}$

$n_{op} = \ldots = 457\ cm^{-3}$

$p_{op} = \frac{n_i^2}{n_{op}} = 7.39 \cdot 10^{18}\ cm^{-3}$

b) $I_S = I_{Dn} + I_{Dp} = 2 I_{Dn} = 2q \cdot S \cdot D_n \frac{n_{op}}{w_p} = 2.192 \cdot 10^{-13}\ A$

$I_D = I_S \left[\exp\left(\frac{U}{U_T}\right) - 1\right] = 18\ mA$

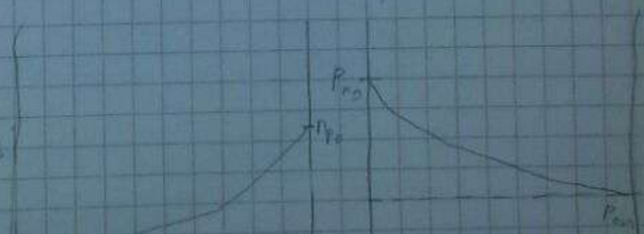
c) $d_B = \sqrt{\frac{2\varepsilon}{q}\left(\frac{1}{N_A} + \frac{1}{N_D}\right)(U_K - U)} \longrightarrow \varepsilon = 11.7 \cdot 8.854 \cdot 10^{-14}$

$U_K = U_T \ln\left(\frac{n_{on} p_{op}}{n_i^2}\right) = 0.865V$

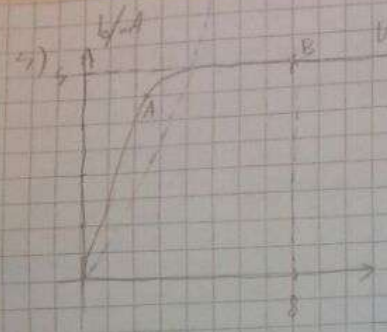
$d_B = 7.59\ \mu m$

d) $n_{p0} = n_{op} \exp\left(\frac{U}{U_T}\right) = 1.25 \cdot 10^{13}$

$p_{n0} = p_{on} \exp\left(\frac{U}{U_T}\right) = 3.35 \cdot 10^{14}$



=1)



$g_{mB} = 2\frac{mA}{V}$; $\lambda = 0$

B je u zasićenju

$I_{DB} = 4mA = \frac{K}{2}(V_{GSB} - V_{GS0})^2$

$K = \frac{8}{(V_{GSB} - V_{GS0})^2}$

$2\frac{mA}{V} = g_{mB} = \left.\frac{dI_D}{dV_{GS}}\right|_{V_{GSB}} = \frac{d}{dV_{GS}}\left[\frac{K}{2}(V_{GSB} - V_{GS0})^2\right] = K(V_{GSB} - V_{GS0}) = \frac{8}{V_{GSB} - V_{GS0}} = g_{mB}$

$V_{GSA} = \frac{8}{g_{mB}} + V_{GS0} = -2V$

$\Rightarrow K = \frac{8}{(2V - (-2V))^2} = \frac{8}{16} = 0.5\frac{mA}{V^2}$

$V_{DSA} = ?$ $\mu = 3 = g_{mA} \cdot r_d$ A je u triodnom području

$g_{mA} = \left.\frac{dI_{DA}}{dV_{DSA}}\right|_{V_{DSA}} = \frac{d}{dV_{DSA}}\left[K\left((V_{GSA} - V_{GS0})V_{DSA} - \frac{V_{DSA}^2}{2}\right)\right] =$

$= K V_{DSA}$

$r_d = \frac{1}{g_d} \;//\; g_d = \left.\frac{dI_{DA}}{dV_{DSA}}\right|_{V_{DSA}} = K(\overbrace{V_{GSA} - V_{GS0}}^{5V}) - K V_{DSA} = K(5 - V_{DSA})$

$\mu = g_m \cdot r_d = \frac{K V_{DSA}}{K(5 - V_{DSA})} = 3 \;/\cdot(5 - V_{DSA})$

$V_{DSA} = 15 - 3V_{DSA}$

$4V_{DSA} = 15V$

$V_{DSA} = 3V$ //

- pozitivna struja raste s pozitivnim naponom $\Rightarrow$ n-tip
- tranzistor vodi za $V_{GS} = 0V \Rightarrow$ osiromašenje