EECS-130

Integrated Circuit Devices

Midterm Exam #2, part one Solutions

(35% total point weighting)

March 14, 1996

1.

a.

$$Q_p = \int_{x_n}^{\infty} q\, p'(x)\,dx = \int_{x_n}^{\infty} q\, p_{nc}(e^{\frac{qV}{kt}} - 1)(e^{\frac{-(x-x_n)}{Lp}})\,dx$$

$$Q_p = q\frac{n_i^2}{N_d}(e^{\frac{qV_A}{kt}} - 1)L_p$$

$$Q_n = \int_{-x_p}^{\infty} q\, n'(x)\,dx = \int_{-x_p}^{\infty} q\, n_{pc}(e^{\frac{qV}{kt}} - 1)(e^{\frac{x+x_p}{L_n}})\,dx$$

$$Q_n = q\frac{n_i^2}{N_a}(e^{\frac{qV_A}{kt}} - 1)L_n$$

b.

$$J_n = \frac{Q_n}{\tau_n} \qquad J_p = \frac{Q_p}{\tau_p}$$

$$J_n = \frac{qn_i^2}{\tau_n N_d}(e^{\frac{qV_A}{kt}} - 1)L_n \qquad J_p = \frac{qn_i^2}{\tau_p N_d}(e^{\frac{qV_A}{kt}} - 1)L_p$$

$$J_{total} = J_n + j_p = \frac{Q_n}{\tau_n} + \frac{Q_p}{\tau_p}$$

c. The current supplied by forward biasing the p_n is that needed to replenish minority charge being lost due to recombination.

d.

$$J_{total} \propto n_i^2 \quad \rightarrow \quad J_{total} \propto T^3$$

$$L_p \propto T^{\frac{1}{2}} \qquad D_p \propto T^{\frac{1}{2}}$$

Current increases as temperature increases

2.

a.

$$I_{op} = qAD_p\frac{P_{no}}{L_p} = qA\cdot\frac{D_p}{\sqrt{D_p\tau_p}}\cdot\frac{n_i^2}{N_D} = 8.76\times10^{-15}A$$

b.

$$I_{on} = qAD_N\frac{n_{pi}}{L_N} = qA\cdot\frac{D_N}{\sqrt{D_N\tau_N}}\cdot\frac{n_i^2}{N_A} = 5.9\times10^{-15}A$$

c.

$$I_o = I_{on} + I_{op} = 14.66\times10^{-15}A$$

d.

i.

$$V_a = \frac{1}{2}\cdot\frac{kt}{q}\ln\left(\frac{N_D N_A}{n_i^2}\right) = .3204\,V$$

$$P_n'(x_n) = P_{nc}\left(e^{\frac{qV_A}{kt}} - 1\right) = n_i^2/N_D\left(e^{qV_A/kt} - 1\right) = 2.24\times10^{10}\,cm^{-3}\quad(injected)$$

$$p_n(x_n) = p_{no} + p_n'(x_n) \approx p_n'(x_n) = 2.24\times10^{10}\,cm^{-3}$$

ii.

iii.

iv.

$$n_p\left(\frac{L_n}{2}\right) = n_{po} + n_{po}\left(e^{\frac{qV_A}{kt}} - 1\right)e^{\frac{-x_n''}{L_n}}$$

$$n_p\left(\frac{L_n}{2}\right) = 2.72\times10^{9}\,cm^{-3}$$

e.

$$Q_p = QA\int_0^\infty p_n'(x')\,dx' = qA\int_0^\infty p_{no}\left(e^{qV_A/kt} - 1\right)e^{\frac{-x'}{L_p}}\,dx'$$

$$Q_p = qAp_o'(x_n)L_p$$

$$V_A = .3203\,V\ Q_p = 7.98\times10^{-16}\,C$$