Chapter 12

Exercise Solutions

E12.1

$$\frac{I_{D1}}{I_{D2}} = \frac{\exp\left(\frac{V_{GS1}}{V_t}\right)}{\exp\left(\frac{V_{GS2}}{V_t}\right)} = \exp\left(\frac{V_{GS1} - V_{GS2}}{V_t}\right)$$

or

$$V_{GS1} - V_{GS2} = V_t \ln\left(\frac{I_{D1}}{I_{D2}}\right)$$

Then

$$V_{GS1} - V_{GS2} = (0.0259)\ln(10) \Rightarrow$$

$$\underline{V_{GS1} - V_{GS2} = 59.64\ mV}$$

E12.2

$$\phi_{fp} = (0.0259)\ln\left(\frac{2x10^{16}}{1.5x10^{10}}\right) = 0.365\ V$$

$$V_{DS}(sat) = V_{GS} - V_T = 1 - 0.4 = 0.60\ V$$

Now

$$\Delta L = \left[\frac{2(11.7)(8.85x10^{-14})}{(1.6x10^{-19})(2x10^{16})}\right]^{1/2} \times\left[\sqrt{2(0.365) + 2.5} - \sqrt{2(0.365) + 0.60}\right]$$

or

$$\underline{\Delta L = 0.1188\ \mu m}$$

$$\frac{I'_D}{I_D} = \frac{L}{L - \Delta L} = \frac{1}{1 - 0.1188} \Rightarrow$$

$$\underline{\frac{I'_D}{I_D} = 1.135}$$

E12.3

$$\frac{I'_D}{I_D} = \frac{1}{1 - \left(\frac{\Delta L}{L}\right)} = 1.25 \Rightarrow \frac{\Delta L}{L} = \frac{1.25 - 1}{1.25}$$

or

$$\frac{\Delta L}{L} = 0.20$$

$$V_{DS}(sat) = 0.80 - 0.40 = 0.40\ V$$

Now

$$\Delta L = \left[\frac{2(11.7)(8.85x10^{-14})}{(1.6x10^{-19})(2x10^{16})}\right]^{1/2} \times\left[\sqrt{2(0.365) + 2.5} - \sqrt{2(0.365) + 0.40}\right]$$

or

$$\Delta L = 0.1867\ \mu m$$

Then

$$0.20 = \frac{0.1867}{L} \Rightarrow$$

$$\underline{L = 0.934\ \mu m}$$

E12.4

(a) $$I_D(sat) = \frac{\mu_n C_{ox} W}{2L}(V_{GS} - V_T)^2 = \frac{(1000)(10^{-8})(10^{-3})}{2(10^{-4})}(V_{GS} - 0.4)^2$$

or

$$I_D(sat) = 0.50x10^{-4}(V_{GS} - 0.4)^2$$

or

$$\underline{I_D(sat) = 50(V_{GS} - 0.4)^2\ \mu A}$$

(b) $$I_D(sat) = WC_{ox}v_{sat}(V_{GS} - V_T) = (10^{-3})(10^{-8})(5x10^{6})(V_{GS} = 0.4)$$

or

$$I_D(sat) = 5x10^{-5}(V_{GS} - 0.4)$$

or

$$\underline{I_D(sat) = 50(V_{GS} - 0.4)\ \mu A}$$

E12.5

$$L \to kL = (0.7)(1) \Rightarrow \underline{L = 0.7\ \mu m}$$

$$W \to kW = (0.7)(10) \Rightarrow \underline{W = 7\ \mu m}$$

$$t_{ox} \to kt_{ox} = (0.7)(250) \Rightarrow \underline{t_{ox} = 175\ \mathring{A}}$$

$$N_a \to \frac{N_a}{k} = \frac{5x10^{15}}{0.7} \Rightarrow \underline{N_a = 7.14x10^{15}\ cm^{-3}}$$

$$V_D \to kV_D = (0.7)(3) \Rightarrow \underline{V_D = 2.1\ V}$$

E12.6

$$C_{ox} = \frac{\in_{ox}}{t_{ox}} = \frac{(3.9)(8.85x10^{-14})}{250x10^{-8}} = 1.38x10^{-7}$$

$$\phi_{fp} = (0.0259)\ln\left(\frac{3x10^{15}}{1.5x10^{10}}\right) = 0.316\ V$$

$$x_{dT} = \left\{\frac{4(11.7)(8.85x10^{-14})(0.316)}{(1.6x10^{-19})(3x10^{15})}\right\}^{1/2}$$

or

$$x_{dT} = 0.522x10^{-4}\ cm$$

Now

$$\Delta V_T = \frac{-(1.6x10^{-19})(3x10^{15})(0.522x10^{-4})}{1.38x10^{-7}} \times\left\{\frac{0.3}{0.8}\left[\sqrt{1+\frac{2(0.522)}{0.3}}-1\right]\right\}$$

or

$$\underline{\Delta V_T = -0.076\ V}$$

E12.7

$$\phi_{ms} \cong +0.35$$

$$\phi_{fp} = (0.0259)\ln\left(\frac{10^{15}}{1.5x10^{10}}\right) = 0.288\ V$$

$$x_{dT} = \left\{\frac{4(11.7)(8.85x10^{-14})(0.288)}{(1.6x10^{-19})(10^{15})}\right\}^{1/2}$$

or

$$x_{dT} = 0.863\ \mu m$$

$$|Q'_{SD}(\max)| = (1.6x10^{-19})(10^{15})(0.863x10^{-4})$$

or

$$|Q'_{SD}(\max)| = 1.38x10^{-8}$$

$$Q'_{ss} = (1.6x10^{-19})(5x10^{10}) = 8x10^{-9}$$

Then

$$V_{TN} = \frac{(1.38x10^{-8} - 8x10^{-9})(200x10^{-8})}{(3.9)(8.85x10^{-14})} + 0.35 + 2(0.288)$$

or

$$\underline{V_{TN} = +0.959\ V}$$

We find

$$C_{ox} = \frac{(3.9)(8.85x10^{-14})}{200x10^{-8}} = 1.73x10^{-7}\ F/cm^2$$

Now

$$V_T = V_{TO} + \Delta V$$

or

$$+0.4 = +0.959 + \Delta V$$

which yields

$$\underline{\Delta V = -0.559\ V}$$

<u>Implant Donors</u> for negative shift

Now

$$|\Delta V_T| = \frac{eD_I}{C_{ox}} \Rightarrow D_I = \frac{|\Delta V_T|C_{ox}}{e}$$

so

$$D_I = \frac{(0.559)(1.73x10^{-7})}{1.6x10^{-19}} \Rightarrow$$

$$\underline{D_I = 6.03x10^{11}\ cm^{-2}}$$

E12.8

Using the results of E12.7

$$V_{TO} = +0.959\ V$$

$$V_T = V_{TO} + \Delta V$$

or

$$\Delta V = V_T - V_{TO} = -0.4 - 0.959 \Rightarrow$$

$$\underline{\Delta V = -1.359\ V}$$

<u>Implant donors</u> for a negative shift

Now

$$|\Delta V| = \frac{eD_I}{C_{ox}} \Rightarrow D_I = \frac{|\Delta V|C_{ox}}{e}$$

so

$$D_I = \frac{(1.359)(1.73x10^{-7})}{1.6x10^{-19}} \Rightarrow$$

or

$$\underline{D_I = 1.47x10^{12}\ cm^{-2}}$$