PROBLEM SET #1

Issued: Tuesday, Jan.20, 2009

Due: Tuesday, Feb.3, 2009, 6:00 p.m. in the EE 140 homework box in 240 Cory

1. (a) Calculate the built-in potential, depletion layer depths, and maximum field in a plane-abrupt *pn* junction in silicon with doping densities $N_A = 8 \times 10^{15}$ atoms/cm^3 and $N_D = 10^{17}$ atoms/cm^3. Assume a reverse bias of 5V. (b) Repeat (a) for zero external bias and 0.3V forward bias.

2. Calculate the zero-bias junction capacitance for the example in Problem 1, and also calculate the value at 5V reverse bias and 0.3V forward bias. Assume a junction area of 2×10^{-5} cm^2.

3. Derive and sketch the complete small-signal equivalent circuit for a bipolar transistor at $I_C = 0.2$ mA, $V_{CB} = 3$V, $V_{CS} = 4$V. Device parameters are: $C_{je0} = 20$fF, $C_{\mu 0} = 10$fF, $C_{CS0} = 20$fF, $\beta_0 = 100$, $\tau_F = 15$ps, $\eta = 10^{-3}$, $r_b = 200\Omega$, $r_c = 100\Omega$, $r_{ex} = 4\Omega$, and $r_\mu = 5\beta_0 r_o$. Assume $\psi_0 = 0.55$V for all junctions.

4. An NMOS transistor has parameters $W = 10\mu$m, $L = 1\mu$m, $k' = 194\ \mu$A/V^2, $\lambda = 0.024$ V^{-1}, $t_{ox} = 80$Å, $\Phi_f = 0.3$ V, $V_{t0} = 0.6$V, and $N_A = 5 \times 10^{15}$ atoms/cm^3. Ignore velocity saturation effects.

(a) Sketch the I_D-V_{DS} characteristics for V_{DS} from 0 to 3V and $V_{GS} = 0.5$V, 1.5V, and 3V. Assume $V_{SB} = 0$.

(b) Sketch the I_D-V_{GS} characteristics for $V_{DS} = 2$V as V_{GS} varies from 0 to 2V with $V_{SB} = 0$, 0.5V, and 1V.

5. Derive and sketch the complete small-signal equivalent circuit for the device of Problem 4 with $V_{GS} = 1$V, $V_{DS} = 2$V, and $V_{SB} = 1$V. Use $\psi_0 = 0.7$V, $C_{sb0} = C_{db0} = 20$fF, and $C_{gb} = 5$fF. Overlap capacitance from gate to source and gate to drain is 2fF.

6. Razavi, Chapter 2: Problem 2.15.