VE320 Intro to Semiconductor Devices

Summer 2024 – Problem Set 8

Due: 11:59pm, August 2nd

In all problems, assume the temperature is 300K, all are completely ionization and the semiconductor material is Si and oxide material is SiO_2.

1. Discuss why the threshold voltage changes when a reverse-biased source-to-substrate voltage is applied to a MOSFET.
   What is subthreshold conduction? Sketch a drain current versus gate voltage plot that shows the subthreshold current for the transistor biased in the saturation region.
   What is channel length modulation? Sketch an I–V curve that shows the channel length modulation effect.

2. A p-channel MOSFET has the following parameters: $k_p' = 0.10mA/V^2$, W/L = 15, and V_T = -0.4V. Calculate the drain current I_D for (a) V_{SG} = 0.8V, V_{SD} = 0.25V; (b) V_{SG} = 0.8V, V_{SD} = 1.0V; (c) V_{SG} = 1.2V, V_{SD} = 1.0V; and (d) V_{SG} = 1.2V, V_{SD} = 2.0V.

3. An ideal n-channel MOSFET has the following parameters: V_T = 0.45V, $\mu_n = 425cm^2/Vs$, t_{ox} = 11nm, W = 20um, and L = 1.2um. (a) Plot I_D vs V_{DS} for $0 \leq V_{DS} \leq 3V$ and for V_{GS} = 0, 0.6, 1.2, 1.8, and 2.4V. Indicate on each curve the V_{DS}(sat) point. (b) Plot $\sqrt{I_D(sat)}$ vs V_{GS} for $0 \leq V_{GS} \leq 2.4V$. (c) Plot I_D vs V_{GS} for $0 \leq V_{GS} \leq 2.4V$ and for V_{DS} = 0.1V.

4. The substrate doping and body-effect coefficient of an n-channel MOSFET are $N_a = 10^{16}cm^{-3}$ and $\gamma = 0.12V^{0.5}$, respectively. The threshold voltage is found to be V_T = 0.5V when biased at V_{SB} = 2.5V. What is the threshold voltage at V_{SB} = 0V?

5. A silicon n-channel MOSFET has a doping concentration of $N_a = 2 \times 10^{16}cm^{-3}$ and a threshold voltage of V_T = 0.40V. Determine the change in channel length, ΔL, for (a) V_{GS} = 1.0V, V_{DS} = 2.0V; (b) V_{GS} = 1.0V, V_{DS} = 4.0V; (c) V_{GS} = 2.0V, V_{DS} = 2.0V; and (d) V_{GS} = 2.0V, V_{DS} = 4.0V.

6. For a long channel NMOSFET with V_T = 1 V, calculate the V_{GS} required for an I_D(sat.) of 0.1 mA and V_{DS}(sat.) of 5 V. Calculate the small-signal output conductance g and the transconductance g_m(sat.) at V_{DS} = 10 V. Sketch the cross section of this MOSFET, and for V_{DS} = 1 V, 5 V, and 10 V. (V_G is constant in this problem)

7. The subthreshold current in a MOSFET is given by $I_D = I_S e^{\frac{V_{GS}}{nV_t}}$. Determine the change in applied V_{GS} for a factor of 10 increase in I_D for (a) n = 1; (b) n = 1.5, and (c) n = 2.1.