

## Homework 4

Due: Thursday, 9/21/00

Remember to turn in clearly written and easy to follow homework!

1. An nMOS transistor is formed in a Si substrate doped with  $N_A = 2 \times 10^{15} \text{ cm}^{-3}$ . If the device is biased for operation in the inversion region, and has  $V_{SB} = 0$ :

- What is the Fermi potential,  $\phi_b$ , in the semiconductor, and what is the electrostatic potential at the oxide-semiconductor interface ( $\phi_{sur}$ )?
- What is the depletion layer thickness,  $x_d$ ?
- If we assume  $x_d = 0.6 \mu\text{m}$ ,  $\phi = 0.3 \text{ V}$ , how much charge is in the depletion layer?

2. An nMOS transistor has the following data: the oxide capacitance is  $80 \text{ nF/cm}^2$ , the work function difference between the gate and the semiconductor is  $-0.1 \text{ V}$ ,  $\phi_F = 0.3 \text{ V}$ ,  $Q_b = -2.5 \times 10^{-8} \text{ coulombs/cm}^2$ , and  $Q_{ss} = 10^{-8} \text{ coulombs/cm}^2$ .

- Calculate the equilibrium threshold voltage,  $V_{to}$ ,
- If  $\gamma = 0.25 \text{ V}^{1/2}$ , what is the threshold voltage if  $V_{SB}$  is  $1 \text{ V}$ ?

3. An n-channel transistor has a substrate concentration of  $N_A = 1.4 \times 10^{17} \text{ cm}^{-3}$ ,  $\mu_n C_{ox} = 188 \mu\text{A/V}^2$ ,  $W = 6 \mu\text{m}$ ,  $L = 0.6 \mu\text{m}$ , and  $V_{th} = 0.8 \text{ V}$ .

- If the device is biased at  $V_{GS} = 1.2 \text{ V}$  and  $V_{DS} = V_{eff}$  ( $V_{eff} = V_{GS} - V_{th}$ ), which region of operation (cutoff, triode, saturation) is the device operating in?
- If we ignore channel length modulation, what is the drain current?
- If  $V_{DS}$  increases by  $0.5 \text{ V}$ , what is the new drain current if  $\lambda = 0.01 \text{ V}^{-1}$ ?

4. An nMOS transistor in the saturation region is measured to have the drain current of  $20 \mu\text{A}$  when  $V_{DS} = V_{eff}$ . When  $V_{DS}$  is increased by  $0.5 \text{ V}$ ,  $I_D$  increases to  $23 \mu\text{A}$ .

- Calculate the channel length modulation factor,  $\lambda$ , for this device.
- What is the output resistance,  $r_o$ , of this transistor?

5. An n-channel enhancement mode MOSFET has parameters:  $V_{th} = 2 \text{ V}$ ,  $K = 0.4 \text{ mA/V}^2$  ( $K = \frac{1}{2} \mu\text{C}_{ox} W/L$ )

- If  $V_{GS} = 4.3 \text{ V}$ , how large must  $V_{DS}$  be for constant current operation?
- What value of  $I_D$  flows for  $V_{GS} = 4.3 \text{ V}$ ?
- What region of operation is the device in if  $V_{DS}$  is reduced to  $2 \text{ V}$ ?
- What value of  $I_D$  flows at  $V_{DS} = 2 \text{ V}$ ?