Homework #7

MOSFETs – *100 points*

DUE @ Beginning of Class: Thursday, October 26

1) E-Book, problem 10.33 (8 points)

2) E-Book, problem 10.36, note that the MOSFET is biased in saturation region (8 points)

3) E-Book, problem 10.44 (10 points)

4) E-Book, problem 10.46 (16 points)

5) E-Book, problem 10.51 (6 points)

6) E-Book, problem 10.56 (14 points)

7) Use the *MOSFet* simulator on nanohub.org to obtain the I-V_g (@ V_d = 0.05 V and 1.0 V) and I-V_d (@ max V_d = 1.0 V and min V_g = 0.5 V, max V_g = 1.0 V with 3 curves) characteristics for a Si MOSFET with the following attributes (use default for everything else): (22 points)

Channel Length = 50 nm   Oxide Thickness = 2 nm
Junction Depth = 10 nm   Substrate Thickness = 10 nm

Provide plots of the subthreshold, transfer, and output curves, with each correctly labeled. Extract the following from the I-V curves, showing how the extraction was done on the actual plotted curves:

i. Subthreshold swing
ii. Threshold voltage
iii. ON-current @ V_{DD} = 1 V
iv. Transconductance
v. Calculate the mobility, assuming W = 1 μm and V_{DS} = 1 V

8) Now change the oxide thickness, T_{ox} to 10 nm in the *MOSFet* simulator and rerun (all other parameters the same as in problem #7). What is different about this new device's performance compared to the device in problem #7 (include I-V curves (subthreshold) and at least one extracted performance metric to support your observation)? (8 points)

9) Keeping T_{ox} = 10 nm, change the dielectric constant to 20 and rerun. Compare the subthreshold curves from this device with those from the device in problem #8. What changed? Why? (*hint:* consider what happens to C_{ox}) (8 points)

1) E-Book, problem 10.33 (8 points)

10.33 Consider an n-channel MOSFET with the following parameters: $k_n' = 0.18$ mA/V^2, $W/L = 8$, and $V_T = 0.4$ V. Determine the drain current I_D for (*a*) $V_{GS} = 0.8$ V, $V_{DS} = 0.2$ V; (*b*) $V_{GS} = 0.8$ V, $V_{DS} = 1.2$ V; (*c*) $V_{GS} = 0.8$ V, $V_{DS} = 2.5$ V; and (*d*) $V_{GS} = 1.2$ V, $V_{DS} = 2.5$ V.

2) E-Book, problem 10.36, note that the MOSFET is biased in saturation region (8 points)

10.36 Consider a p-channel MOSFET with the following parameters: $k'_p = 0.12$ mA/V^2 and $W/L = 20$. The drain current is 100 μA with applied voltages of $V_{SG} = 0$, $V_{BS} = 0$, and $V_{SD} = 1.0$ V. (*a*) Determine the V_T value. (*b*) Determine the drain current I_D for $V_{SG} = 0.4$ V, $V_{SB} = 0$, and $V_{SD} = 1.5$ V. (*c*) What is the value of I_D for $V_{SG} = 0.6$ V, $V_{SB} = 0$, and $V_{SD} = 0.15$ V?

3) E-Book, problem 10.44 (10 points)

10.44 The transconductance of an n-channel MOSFET is found to be $g_m = \partial I_D / \partial V_{GS} = 1.25$ mA/V when measured at $V_{DS} = 50$ mV. The threshold voltage is $V_T = 0.3$ V. (*a*) Determine the conductance parameter K_n. (*b*) What is the current at $V_{GS} = 0.8$ V and $V_{DS} = 50$ mV? (*c*) Determine the current at $V_{GS} = 0.8$ V and $V_{DS} = 1.5$ V.

4) E-Book, problem 10.46 (16 points)

10.46 One curve of an n-channel MOSFET is characterized by the following parameters: $I_D(\text{sat}) = 2 \times 10^{-4}$ A, $V_{DS}(\text{sat}) = 4$ V, and $V_T = 0.8$ V.

(*a*) What is the gate voltage?

(*b*) What is the value of the conduction parameter?

(*c*) If $V_G = 2$ V and $V_{DS} = 2$ V, determine I_D.

(*d*) If $V_G = 3$ V and $V_{DS} = 1$ V, determine I_D.

(*e*) For each of the conditions given in (*c*) and (*d*), sketch the inversion charge density and depletion region through the channel.

5) E-Book, problem 10.51 (6 points)

10.51 The substrate doping and body-effect coefficient of an n-channel MOSFET are $N_a = 10^{16}\ \mathrm{cm}^{-3}$ and $\gamma = 0.12\ \mathrm{V}^{1/2}$, respectively. The threshold voltage is found to be $V_T = 0.5$ V when biased at $V_{SB} = 2.5$ V. What is the threshold voltage at $V_{SB} = 0$?

6) E-Book, problem 10.56 (14 points)

10.56 An n-channel MOSFET has the following parameters:

$$\mu_n = 400 \text{ cm}^2/\text{V-s} \qquad t_{ox} = 500 \text{ Å}$$
$$L = 2\ \mu\text{m} \qquad W = 20\ \mu\text{m}$$
$$V_T = +0.75 \text{ V}$$

Assume the transistor is biased in the saturation region at $V_{GS} = 4$ V. (*a*) Calculate the ideal cutoff frequency. (*b*) Assume that the gate oxide overlaps both the source and drain contacts by 0.75 μm. If a load resistance of $R_L = 10$ kΩ is connected to the output, calculate the cutoff frequency.

7) Use the *MOSFet* simulator on nanohub.org to obtain the I-V_g (@ V_d = 0.05 V and 1.0 V) and I-V_d (@ max V_d = 1.0 V and min V_g = 0.5 V, max V_g = 1.0 V with 3 curves) characteristics for a Si MOSFET with the following attributes (use default for everything else): (22 points)

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i. Subthreshold swing
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v. Calculate the mobility, assuming W = 1 µm and V_{DS} = 1 V

8) Now change the oxide thickness, T_{ox} to 10 nm in the *MOSFet* simulator and rerun (all other parameters the same as in problem #2). What is different about this new device's performance compared to the device in problem #2 (include I-V curves (subthreshold) and at least one extracted performance metric to support your observation)? (8 points)

9) Keeping T_{ox} = 10 nm, change the dielectric constant to 20 and rerun. Compare the subthreshold curves from this device with those from the device in problem #8. What changed? Why? (*hint:* consider what happens to C_{ox}) (8 points)