Fall 2008

EE 612: Nanoscale Transistors

HW1: DUE TUESDAY, SEPTEMBER 2, 2008

MOSFET Review

The purpose of this exercise is to help you review the basic theory of the MOSFET, device some key device parameters, and give you a feel for the typical values of key device performance metrics for state-of-the-art MOSFETs

Step 1: View the online presentation: "A Review of MOSFET Fundamentals," by Mark Lundstrom. This online lecture is available at nanoHUB.org at https://www.nanohub.org/resources/5307

Step 2: For the exercises below, you will need to run the simulation program, nano-CMOS, on nanoHUB.org. For these exercises, you will run the nano-CMOS simulation tool on nanoHUB.org. To run a simulation tool, you will first have to apply for a nanoHUB account, which you can do with the Register link at the upper left of the nanoHUB main page. As soon as you have an account, you can proceed with the exercises below.

Step 3: Answer the last question on a separate sheet of paper attached at the end of your HW.

1) Locate the simulation tool, nano-CMOS, and use it to examine the IV characteristics of "45nm" N-channel CMOS technology. Select "NMOS 45nm," and use the default values. Push the "Simulate" button, and then answer the following questions.

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You should clearly describe how you obtain each parameter. You can download images from the nanoHUB and insert them in a Word file to document your work. Note that you are able to change the minimum and maximum axes scales and to select either linear or logarithmic scales.

a) Determine the on-current in μA/μm
b) Determine the off-current in μA/μm
c) Determine the subthreshold swing, S, in mV/decade
d) Estimate V_{DSAT} for $V_{GS} = 1.0$V. (Do not simply "eyeball" the answer; develop a simple methodology so that another person who follows it would get the same answer.
e) Estimate the DIBL in mV/V
f) Estimate V_T(lin) and V_T(sat) in V
g) Estimate the output resistance, R_o in Ω-μm

h) Estimate the channel resistance, R_{ch} in Ω-μm

i) Estimate the transconductance, g_m, in mS/mm at the maximum gate voltage.

j) The "self-gain," $A = g_m R_o$ is often used as a metric for analog applications (it is roughly the maximum small signal gain that could be achieved in an amplifier circuit with this transistor). Estimate the self-gain for this transistor.

2) Repeat problem 1) for a p-channel MOSFET by selecting "PMOS 45nm," and pushing the "Simulate" button. You should use the default values. Estimate all of the device parameters from problem 1) for the PMOS transistor. Discuss the main difference that you see.

3) In EE-612, we will discuss the physics of MOSFETs and explain what controls key performance metrics like DIBL, subthreshold swing, etc. Use the nano-CMOS program in a "discovery" mode to determine which technology parameters (e.g. Leff, Vth, Vdd, Tox, Rdsw, Temperature) have the strongest effect on DIBL. You should use the 45nm NMOS device and develop a simple, logical way to explore the parameter space near the default values. Your final answer should be a list of the two technology parameters that have the biggest effect on DIBL and a brief description of the process you use to arrive at this conclusion.

4) On a separate page, state your name and tell me a little about yourself (e.g. where you did your undergraduate degree, what degree you are working on now, your current technical focus, and what you hope to get out of this course. Include a photo of yourself if you wish.

A note on documenting simulation homeworks and about collaboration on HW assignments

You should document the input parameters (or state that you used the default values) to show exactly what simulation you did. You can download images from nanoHUB simulation tools and insert them in a Word file to document your work. Note that you are able to change the minimum and maximum axes scales and to select either linear or logarithmic scales. Include only the plots and data that are relevant to answering each specific question. Clearly identify each answer and discuss it, when that is appropriate. Annotations to discuss the answer should be clearly identified by writing them by hand on the printed copy or by using a different typeface e.g. bold). The key message is that clarity and brevity are highly valued in documenting your simulation homework.

I encourage students to discuss homework with each other, but I assume that you are each doing your own work. The rule is that you can discuss how you approached the problem, but **DO NOT** show someone else your solution. If you have not done your own work, it will be very clear when grading homework.