Problem Set #5

Assigned: October 13, 2000
Due: October 20, 2000 at recitation

Reading Assignments:	10/12/00	Sections 4.5 - 4.6 of Howe & Sodini
	10/17/00	Sections 5.1 - 5.3 of Howe & Sodini
	10/19/00	Sections 5.3 - 5.4 of Howe & Sodini

PLEASE WRITE YOUR RECITATION SESSION TIME ON YOUR PROBLEM SET SOLUTION

1. [10 points] Problem E4-20 of Howe and Sodini (note comment in p. 246 under "Exercises" heading).

2. [10 points] Problem P4-1 of Howe and Sodini.

3. [20 points] Problem P4-11 of Howe and Sodini.

4. [60 points] **DC SPICE parameter extraction of an n-channel MOSFET**

This is an exercise in which you use an experimental ***Web-based Microelectronic Device Characterization*** system to characterize a MOSFET (http://weblab.mit.edu). Professor Jesus del Alamo and his students developed the system. From the measurements, you also extract the DC SPICE parameters of the transistor. The User Manual is available on the ***weblab*** homepage.

In this problem, you will characterize an n-channel MOSFET. The details of how to select and connect the device are available online. Select one of the devices labeled "**6.012 NMOS**" under the "**Device**" Menu. Take the measurements specified below and download the data to your local machine for additional graphing and further analysis. *Only download the data when you have satisfactory results as would be indicated by the characteristics obtained and displayed through the web.*

For the following measurements, hold V_{GS} between 0 and 3 V , and V_{DS} between 0 and 4 V. When relevant, vary V_{BS} between 0 and -2.5 V. For the SPICE parameter determination you will need the following structural information about the transistor. The gate length of this transistor is L = 1.5 μm, and the gate width is W = 46.5 μm. In this exercise, we do not distinguish between L and L_{eff} (see Section 4.6.1 in Howe & Sodini).

Below is the characterization assignment.

a. (5 points) Measure the ***output characteristics*** of the transistor. These are I_D vs. V_{DS} measurements with V_{GS} as the stepping parameter and V_{BS} = 0 V. Download the data to your local machine and plot the ***output characteristics*** using your favorite software tool. Turn in a printout of this graph.

b. (5 points) Measure the ***transfer characteristics*** of the transistor. These are I_D vs. V_{GS} measurements with V_{DS} as the stepping parameter and V_{BS} = 0 V. Download the data to your local machine and plot the ***transfer characteristics*** using your favorite software tool. Turn in a printout of this graph.

c. (5 points) Measure the ***backgate characteristics in the linear regime*** of the transistor. That is, I_D vs. V_{GS} measurements with V_{BS} as the stepping parameter for V_{DS} = 0.1 V. Download the data to your local machine and plot the ***backgate characteristics*** using your favorite software tool. Turn in a printout of this graph.

d. (15 points) From the ***backgate characteristics***, extract V_T as a function of V_{BS}. Make a plot of V_T as a function of V_{BS} and turn in a printout of this graph. From this graph, extract the SPICE parameters **VTO**, **GAMMA** and **PHI** for the transistor (see Eq. 4.94 in Howe & Sodini). Note that it is not really possible to extract both **GAMMA** and **PHI** accurately. Since **PHI** plays the role of $-\phi_p$ (ϕ_p is the potential in the bulk), a suitable value for it should be in the range of 0.3 to 0.5. Pick a value in this range and extract the value of **GAMMA** that best matches the data.

e. (10 points) From the ***output characteristics***, extract the SPICE parameters **KP** and **LAMBDA** for the transistor (see Eq. 4.93 in Howe & Sodini).

f. (15 points) Using the SPICE parameter set just derived, plot the characteristics of the transistors (use Eqs. 4.93 and 4.94 in Howe & Sodini) and compare them with the measurement data. The most effective way to do this is to construct graphs that depict the measured data as individual dots and the model as continuous lines.

- Plot on the same graph the measured ***output characteristics*** of the MOSFET and those predicted by your SPICE model. Turn in this graph. Comment on the accuracy of the model.

- Plot on the same graph the measured ***transfer characteristics*** of the MOSFET and those predicted by your SPICE model. Turn in this graph. Comment on the accuracy of the model.

- Plot on the same graph the measured ***backgate characteristics in the linear regime*** of the MOSFET and those predicted by your SPICE model. Turn in this graph. Comment on the accuracy of the model.

g. (5 points) Give us feedback on this web-based experience. Tell us what works and what does not work. Make suggestions on how to improve it. Make an extra copy of your answer to this part on a separate page. You do not need to write your name on this page. Thanks!

The SPICE parameter determination should not demand extensive numerical analysis. There is no need to do regressions or least-squares fits. The seven graphs you have to turn in do not need to be too sophisticated, just simply correct. They must have proper tick marks, axis labeling and correct units. If there are several lines, each one should be properly identified (handwriting is OK).

Additional information

The system will be up between 8 AM on Friday October 13 and 8 AM on Friday October 20. The systems will be shut down after that. For short periods of time, the system may be down for maintenance and to change the device, if needed.

If you encounter network and system problems, please contact hardison@mit and cc jkfioren@mit.edu and akinwand@mtl.mit.edu. For other problems related to this homework, contact jkfioren@mtl.edu and cc akinwand@mtl.mit.edu.

The device is real and it can be damaged. Please be careful with the voltages that you present to this device. If the characteristics look funny, let us know. The device might have been damaged. We will replace it as soon as we realize it is damaged. Note that at any time, there are two devices you could characterize. The devices are labeled “6.012 NMOS” and they could be selected from under the “device” menu. If one of the devices appears damaged, check the other device.

The login page uses your Athena username (as provided by the Registrar) as username and your MIT ID as password. You should login as soon as you can to confirm that you have access to the system. If you have login problems, contact hardison@mit.edu

You should try to do the experimental portion of this homework early. We have built a queuing system in the server but we have never tested it with these many users. Besides, if the queue is long, you might need to wait for a while before you order is executed. It is to your advantage to get the data early and to download it to your local machine. Later on, you can work on parameter extraction and the rest of the homework.

The system keeps a log of all logins and the scripts that each user executes.

This is an experiment. Please be patient and give us plenty of feedback. If you are interested in participating in the further development of this system, please approach Prof. del Alamo (alamo@mit.edu).