Homework #5 - March 12, 1999

Due: March 19, 1999 at recitation

PLEASE WRITE YOUR RECITATION SESSION TIME ON YOUR PROBLEM SET SOLUTION.

1. (*10 points*) Problem E4-19 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 P4-5 of Howe and Sodini.

4. (*60 points*) **DC SPICE parameter extraction of an n-channel MOSFET**

This is an exercise in which you have to use an experimental *Web-based Microelectronic Device Characterization* system to characterize a MOSFET. From the measurements, you also have to extract suitable values for the DC SPICE parameters of the transistor. Refer to the User Manual handed out in class for instructions on how to use the system.

In this problem, an n-channel MOSFET is to be characterized. This is an integrated device. The details of the connections are available on line. Take the measurements specified below. When you are happy with the results (as judged by the characteristics displayed through the web), download the data to your local machine for more graphing and further analysis.

For all the following mesurements, hold V_{GS} between 0 and 3 V, and V_{DS} between 0 and 4 V. When relevant, examine 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 distinguisn between L and L_{eff} (see Section 4.6.1 in Howe & Sodini).

Here is your assignment.

1. (*5 points*) Measure and download the *output characteristics* of the transistor. These are I_D vs. V_{DS} with V_{GS} as parameter. Do this for $V_{BS} = 0$ V. In your local machine and using your favorite software tool, graph the output characteristics. Turn in a printout of this graph.
2. (*5 points*) Measure and download the *transfer characteristics* of the transistor. These are I_D vs. V_{GS} with V_{DS} as parameter. Do this for $V_{BS} = 0$ V. In your local machine, graph the transfer characteristics. Turn in a printout of this graph.
3. (*5 points*) Measure and download the *backgate characteristics in the linear regime* of the transistor. That is, I_D vs. V_{GS} with V_{BS} as parameter for $V_{DS} = 0.1$ V. In your local machine, graph the backgate characteristics. Turn in a printout of this graph.
4. (*15 points*) From the *backgate characteristics*, extract V_T as a function of V_{BS}. Graph this 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 $-\phi_p$ (the potential in the bulk), a suitable value for it should be in the range of 0.3 to 0.5. Pick up a value in this range and extract the value of **GAMMA** that best matches the data.

5. (*10 points*) From the *output characteristics*, extract the SPICE parameters **KP** and **LAMBDA** for the transistor (see Eq. 4.93 in Howe & Sodini).
6. (*15 points*) Using the SPICE parameter set just derived, play back 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.
    - Graph together the measured *output characteristics* of the MOSFET and those predicted from the SPICE model. Turn in this graph. Comment on the accuracy of the model.
    - Graph together the measured *transfer characteristics* of the MOSFET and those predicted from the SPICE model. Turn in this graph. Comment on the accuracy of the model.
    - Graph together the measured *backgate characteristics in the linear regime* of the MOSFET and those predicted from the SPICE model. Turn in this graph. Comment on the accuracy of the model.
7. (*5 points*) Give us feedback on this web-based experience. Tell us what works and what doesn't. 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 fancy numerical analysis. There is no need to do regressions or least-squares fits. The seven graphs you have to turn in need not be too fancy, just simply correct. They must have proper tickmarks, axis labeling and correct units. If there are several lines, each one should be properly identified (handwriting is OK).

Additional information and assorted admonitions:

- The system will be up between 8 AM on Friday March 12 and 8 AM on Friday March 19. 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 *lbrooks@mit* and cc *dwhite@mtl* and *alamo@mit*. For other problems related to this homework, contact *dwhite@mtl* and cc *alamo@mit*.
- 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.
- 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.
- 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.