Device Characterization Project

Part I: pn diode characterization - September 22, 2000

Due: various dates at lecture (see below)

This device characterization project is a new assignment in 6.720J/3.43J. It builds upon homework assignments in previous years that included device characterization problems. This project uses the *MIT Microelectronics WebLab*, a remote web-enabled microelectronics device characterization test station that is being developed in Prof. del Alamo's lab. The *MIT Microelectronics WebLab* is an experimental set up designed to allow the educational use of professional microelectronics characterization equipment by a large number of users in a remote way [1]. The *MIT Microelectronics WebLab* is accessed through http://weblab.mit.edu. A tentative manual for the use of this system can be downloaded from the weblab homepage.

In this device characterization project, you will carry out a fairly detailed DC characterization of an integrated n-channel MOSFET using an HP4155 Semiconductor Parameter Analyzer. This tool is basically a fancy curve tracer that allows you to obtain I-V characteristics of semiconductor devices. In a first part, you will characterize the source and drain p-n junction diodes. In a second part to follow shortly, you will characterize the MOSFET itself.

In both cases, you will carry the device characterization *before* the relevant theoretical material is presented in lecture. This is to alleviate scheduling problems, but also to see if this device characterization project serves as an effective motivational tool for some of the key material in this subject.

Part I: pn diode characterization *(30 points)*

This problem is about characterizing the source-body pn diode of the MOSFET that is currently connected to the MIT Microelectronics WebLab. The details of the device connection are available on-line (see manual). For this measurement, the drain and the gate of the MOSFET should be shorted out to the body. Refer to Appendix A for basic information about the pn diode.

[1] To know more about this new educational initiative, go to http://www-mtl.mit.edu/ alamo/weblab/index.html

You have to do the following:

I-1) (*10 points*) Obtain I-V characteristics of the source-body pn diode. Take measurements between -1.5 and 1.5 V. When you are happy with the result (as judged by the characteristics displayed through the web interface), download the data to your local machine and port them into your favorite spreadsheet program for graphing and analysis. Graph the I-V characteristics in a linear scale (**graph 1**) and in a semilog scale (**graph 2**). For this later part, you will have to graph the absolute of the current. Turn in these graphs. Think about the distribution of measurement points so that sufficient data are taken in all regions of interest.

I-2) (*10 points*) Devise a simple scheme to extract the saturation current, I_s, the ideality factor, n, and the series resistance, R_s of the diode (see Appendix A for details). Make necessary assumptions and state them. Describe your approach and give the parameter values that you have extracted. Assume the measurement temperature is 22^oC.

I-3) (*10 points*) Compare the experimental characteristics with those predicted by the theoretical models for the pn diode given in Appendix A. To do this, graph together the experimental measurements and the predictions of the following simple models (in both linear, **graph 3**, and semilog scales, **graph 4**):

- model 1: I-V characteristics obtained using the extracted values of I_S and n, and setting $R_s = 0$;
- model 2: I-V characteristics obtained using the extracted values of I_S and n, and R_s.

Comment on the importance of R_s in obtaining a good quality fit to the measured characteristics. Comment on the remaining shortcomings of the models. Can you speculate what is missing in the model that might be responsible for the residual discrepancies?

Deadlines:

- part I-1: due September 29 with homework (you should keep a copy for yourself),
- parts I-2, I-3: due October 6 with homework.

Additional information and assorted advice:

- The required graphs 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).
- If you encounter problems with the WebLab, please e-mail the TA, Jorg Scholvin (), Prof. del Alamo (alamo@mit.edu), or the weblab system manager, Jim Hardison (hardison@mit.edu).
- You have to exercise care with this device. Please do not apply a higher voltage than suggested. The MOSFET is real and it can be damaged. If the characteristics look funny, let us know.
- It will be to your advantage to make good use of the *Set-up* and *User-defined* functions that are built into the tool (see manual).
- The system keeps a record of all logins and all scripts that each user executes.

Note on collaboration policy

In carrying out this exercise (as in all exercises in this class), you may collaborate with somebody else that is taking the subject. In fact, collaboration is encouraged. However, this is not a group project to be divided among several participants. Every individual must have carried out the entire exercise, that means, using the web tool, graphing the data off line, and extracting suitable parameters. Everyone of these items contains a substantial educational experience that every individual must be exposed to. If you have questions regarding this policy, please ask the instructor. Prominently shown in your solutions should be the name of the person(s) you have collaborated with in this homework.

Appendix A: I-V characteristics of pn diode

The ideal I-V characteristics of a pn diode are given by:

$$I = I_s(\exp\frac{qV}{kT} - 1)$$

where I_s is the *saturation current*.

"Real" diodes have several non-idealities. First, the slope might not be perfectly ideal. This is captured by introducing an *ideality factor*, n. Second, there is always some *series resistance*, R_s, that reduces the voltage that is available to the junction. With these two non-idealities, the I-V characteristics of the diode are given by:

$$I = I_s[\exp\frac{q(V - IR_s)}{nkT} - 1]$$

The I-V characteristics look as graphed below.

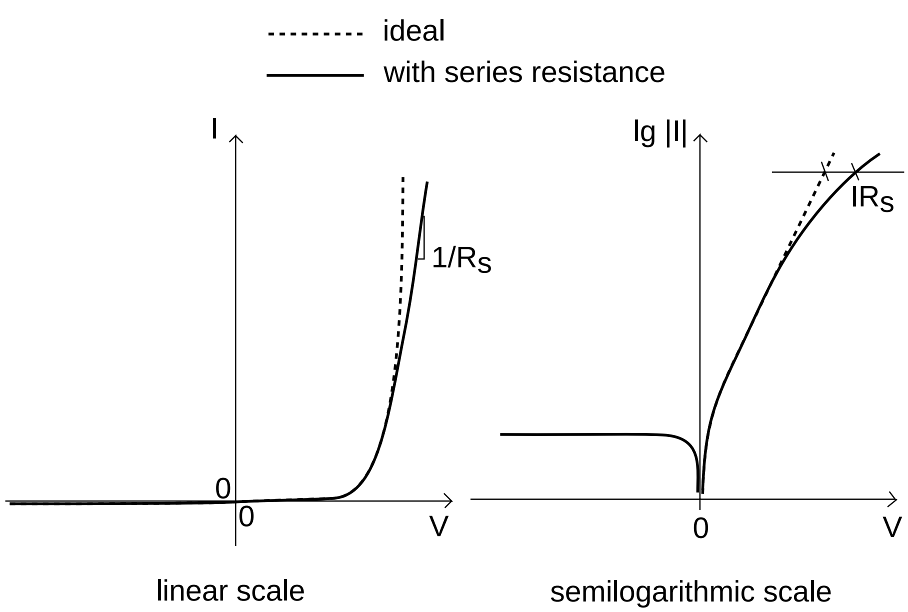

Figure 1: Sketch of I-V characteristics of ideal p-n junction in linear and semilogarithmic scales.