Homework #6 - October 21, 2005

Due: October 28, 2005 at recitation (Rm. 13-3101, 2 PM latest)
(late homework will not be accepted)

Please write your recitation session time on your problem set solution.

1. *[20 points]* Consider an n-channel MOSFET in the saturation regime.

a) Derive expressions and sketch the spatial dependence of $V_c(y)$, $E_y(y)$, $v_n(y)$, and $Q_n(y)$ from source to drain. Explain your results.

b) Obtain an expression for the transit time of electrons through the channel from source to drain by computing:

$$\tau_t = \int_0^L dt = \int_0^L \frac{dy}{v_n(y)}$$

2. *[35 points]* Consider a MOSFET that consists of a n$^+$-poly Si gate, a 55 Å silicon dioxide dielectric on a $N_A = 3 \times 10^{17}\ cm^{-3}$ p-type substrate. The gate length is 0.5 μm and the gate width is 2 μm. The inversion layer mobility is 700 $cm^2/V.s$.

Derive a complete high-frequency small-signal equivalent circuit model for this transistor for $V_{GS} = 2$ V, $V_{DS} = 4$ V, and $V_{SB} = 1$ V. The source and drain junction areas are 6 μm^2 each. The overlap capacitance is 0.2 fF/μm. Assume that $\lambda = 0.05\ V^{-1}$. Do not disregard substrate effects. $C_{JSW} = 0$.

3. *[45 points]* **MOSFET characterization** *(cont.)*

This is a continuation of the MOSFET characterization project started last week. For the work to be performed here, you should use the data downloaded during the last assignment. You may acquire the data again if you wish or if you cannot find it.

In this part of the project, you are to model the I-V characteristics of the 3 μm MOSFET using the ideal MOSFET model and the parameters that you extracted last time and compare them with the measured characteristics.

Important note: For all mesurements, hold V_{GS} between 0 and 2 V, and V_{DS} between 0 and 4 V. Unless specified, use $V_{BS} = 0\ V$. When relevant, examine V_{BS} between 0 and $-3\ V$. As inputs to this exercise, you need the dimensions of the MOSFET: $L = 3\ \mu m$ and $W = 20\ \mu m$.

Here is your assignment.

1. (*5 points*) On your local machine, using Matlab or your favorite spreadsheet program, graph the measured *output characteristics* of the MOSFET. This is a plot of I_D vs. V_{DS} with V_{GS} as parameter. Do this for $V_{BS} = 0\ V$.

   Graph 1: Linear plot of output characteristics (V_{DS} in x axis in linear scale, I_D in y axis in linear scale). Print this graph. Turn in this graph.

2. (*5 points*) On your local machine, graph the measured *transfer characteristics* of the MOSFET. This is a plot of I_D vs. V_{GS} with V_{DS} as parameter. Do this for $V_{BS} = 0\ V$.

   Graph 2: Linear plot of transfer characteristics (V_{GS} in x axis in linear scale, I_D in y axis in linear scale). Print this graph. Turn in this graph.

3. (*5 points*) On your local machine, graph the measured *backgate characteristics* of the MOSFET in the saturation regime. This is a plot of I_D vs. V_{GS} with V_{BS} as parameter. Do this for $V_{DS} = 4\ V$.

   Graph 3: Linear plot of backgate characteristics (V_{GS} in x axis in linear scale, I_D in y axis in linear scale). Print this graph. Turn in this graph.

4. (*30 points*) Using the parameter that you have extracted, "play back" the I-V characteristics of the transistors and compare them with the measurement data. The most effective way to do this is to program the model in matlab or your favorite spreadsheet program and construct graphs that depict the measured data as individual dots and the model as continuous lines.

   Graph 4: Graph together the measured *output characteristics* of the MOSFET and those predicted from the model. Print this graph. Turn in this graph. Comment on the accuracy of the model.

   Graph 5: Graph together the measured *transfer characteristics* of the MOSFET and those predicted by the model. Print this graph. Turn in this graph. Comment on the accuracy of the model.

   Graph 6: Graph together the measured *backgate characteristics* of the MOSFET in the saturation regime and those predicted by the model. Print this graph. Turn in this graph. Comment on the accuracy of the model.