Problem Set #6

Assigned: Friday, October 12, 2007
Due: Friday, October 19, 2007 at recitation

Reading Assignments: Howe and Sodini 4.4
Lecture Notes #10 and #11

PLEASE WRITE YOUR RECITATION SESSION TIME ON YOUR PROBLEM SET SOLUTION

Problem 1. [10 points]

Problem E4.18 in Howe and Sodini.

Problem 2. [20 points]

Problem P4.17 in Howe and Sodini, but only questions (a) and (b).

Problem 3. [50 points]

MOSFET characterization

In this problem, you will explore the weak-inversion model of the n-MOSFET that was introduced in class and will compare it with real device data using iLab. We will use the "6.012 MOSFET" n-channel MOSFETS available in the Device Menu – same as in PS 5. When and if you do your own measurements obey all instructions from PS5.

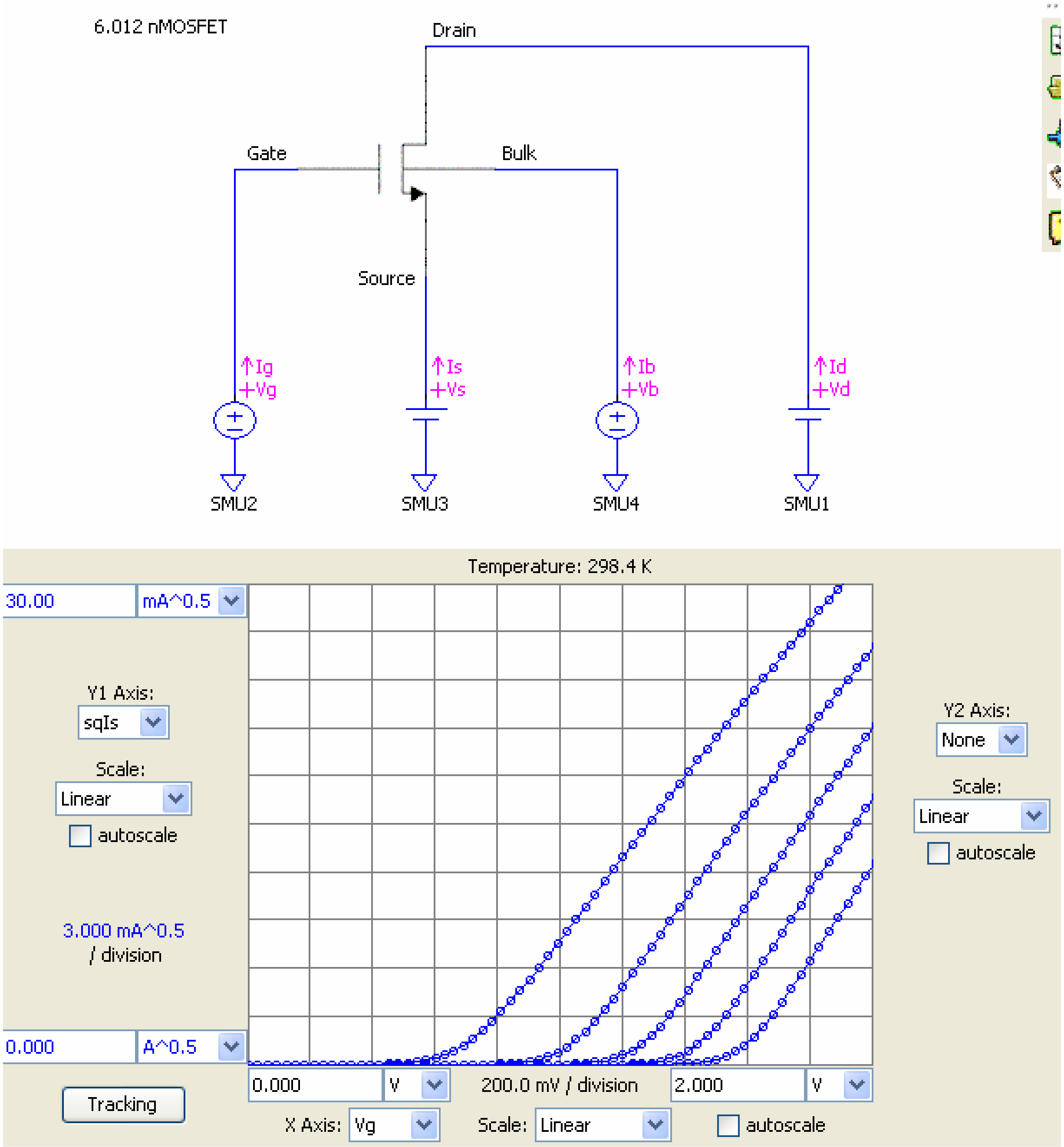
As inputs to this exercise, you will use for dimensions of the MOSFET: $L = 1.5\ \mu m$, $W = 46.5\ \mu m$, and $t_{ox}=33\ nm$. You are also asked to assume $\phi_{Fp}=0.4\ V$.

Here is your assignment:

1. From the attached plot of $\sqrt{I_D}$ vs. V_{GS} for various V_{SB} extract the V_{Tn}^* vs. V_{SB} (show a plot), and find a value of γ that best fits the data. Use the same procedure you used in PS 5 but with the value of ϕ_{Fp} above.
2. From the attached semilog transfer I-V's extract the value of the weak-inversion "non-ideality" factor, n, as function of V_{SB}. Comment on the self-consistency of γ and n based on the weak-inversion theory in Lecture 11.

3. In this device as in most practical MOSFETs γ is not exactly constant with V_{SB}, but varies somewhat. The reason is that the channel doping in not exactly constant with depth, but the detailed theory is not important at this point. It is easy to extract γ vs. V_{SB} by simply taking the derivative, $\partial V_{Tn} / \partial V_{SB}$, vs. V_{SB} (you can safely ignore terms including derivative of γ in doing this). Figure out a way to extract the derivative of V_{Tn} for the five values of V_{SB} (i.e. 0 to 4 V) using new measurements, along the lines of the two plots attached (but see note under last plot). You can use either $\sqrt{I_D}$ vs. V_{GS} plots or $\log(I_D)$ vs. V_{GS} plots, at different V_{SB} values. Explain your method and provide a plot of γ vs. V_{SB}. Can this new information explain the behavior of n vs. V_{SB}?

4. Assume a mobility value of 500 $cm^2/V.s$ and calculate the drain current at $V_{GS}=V_{Tn}(V_{SB})$ for this device. Using this current value in the given $\log(I_D)$ vs. V_{GS} plots extract the values of V_{Tn} vs. V_{SB}. Compare with V_{Tn}^* from question (1).



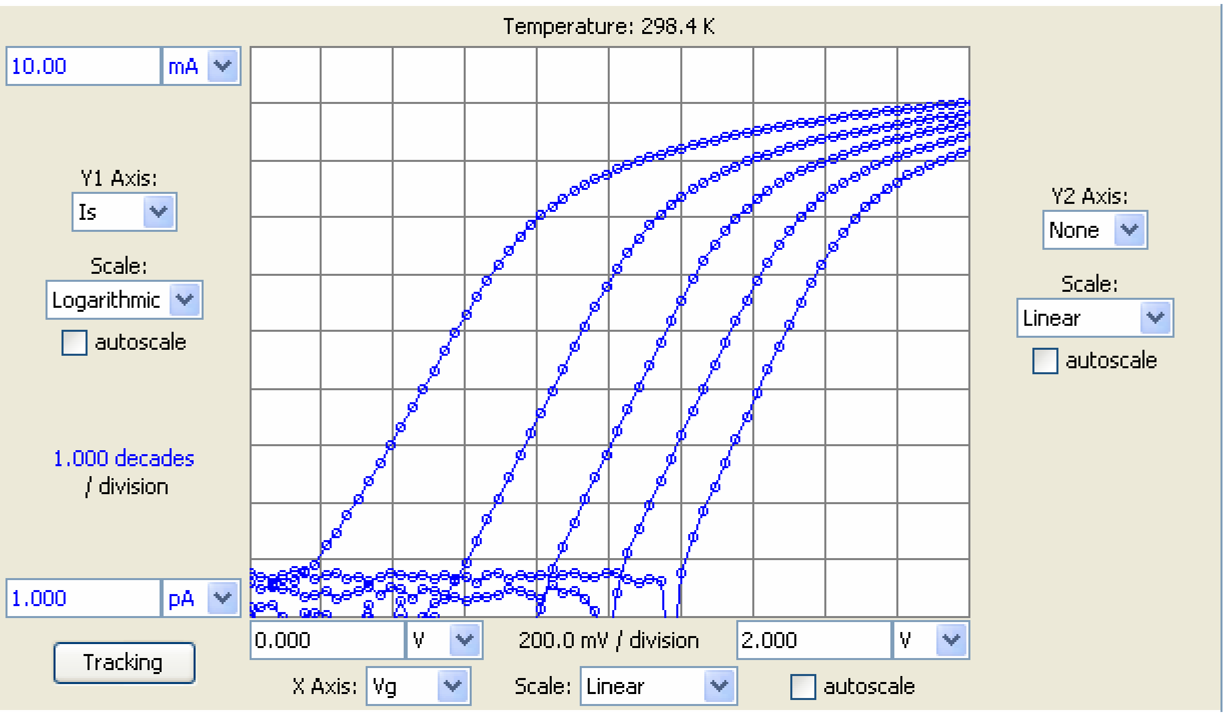
Temperature: 298.4 K

Y1 Axis: sqIs
Scale: Linear
☐ autoscale
30.00 mA^0.5
3.000 mA^0.5 / division
0.000 A^0.5

Y2 Axis: None
Scale: Linear
☐ autoscale

X Axis: Vg
Scale: Linear
☐ autoscale
0.000 V
200.0 mV / division
2.000 V

Plot of $\sqrt{I_D}$ vs. V_{GS} for various V_{SB}. V_{SB}=0, 1, 2, 3, 4 V



Temperature: 298.4 K

10.00 mA

Y1 Axis: Is

Scale: Logarithmic

☐ autoscale

1.000 decades / division

1.000 pA

0.000 V

200.0 mV / division

2.000 V

X Axis: Vg

Scale: Linear

☐ autoscale

Y2 Axis: None

Scale: Linear

☐ autoscale

V_{SB}=0, 1, 2, 3, 4 V

Important note 2: While you could have used data from PS 5, measurements have to be made again because the drain current, I_D, of the device at very low current levels may be "contaminated" by spurious junction leakage currents. Cleaner measurement of I_D can be obtained by measuring the source current, I_S, which represents the pure channel current. Then, simply remember that I_D=-I_S. As example above is a transfer I-V vs. V_{SB} in semilog scale. When you do measurement you should obtain similar characteristics.