

# EE240B HW 1

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## 1 HW1

1. For a transistor in strong inversion, the current is dominated by drift rather than diffusion. The channel profile is nevertheless non-uniform which means there is a drift current even in strong inversion. Assuming the square law model (which ignores drift) is a good estimate of the channel charge profile, calculate the diffusion current and compare it to the drift current.
2. For your technology DK, what is the compact model used? Which version number? Does the model use binning? If so, by which parameters?

I'm using GPDK 45nm. The compact model is BSIM v4 based. Binning is done using the  $l_{min}, l_{max}, w_{min}, w_{max}$  parameters present in each model. There are 30 different bins for NMOS transistors. Binning changes  $V_{th}$ -related parameters (like  $v_{th0}, lv_{th0}, wv_{th0}, pv_{th0}$ ), mobility-related parameters (like  $u0, lu0, wu0, pu0$ ), subthreshold-related parameters (like  $v_{off}, lv_{off}, wv_{off}, pv_{off}$ ), and output resistance-related parameters (like  $pdiblc2, lpdiblc2$ ).

3. Besides  $W$  and  $L$ , what are the supported instance parameters for your model? Why are detailed layout dependent parameters (such as distance to well edge) used in some models?
  - finger width ( $W$ )
  - number of fingers ( $W$ )
  - folding threshold (finger width at which to apply device folding in layout)
  - S/D metal width (width of metal used to short source and drain)
  - some other ones I don't think matter

The layout dependent parameters are auto-derived from the basic instance parameters (I guess for the PDK-reference layout of this transistor). These layout dependent parameters can be overridden as instance parameters. These detailed layout parameters can be used to estimate device parasitics at schematic-design time.

4. Set up a schematic (don't rely on the simulator to output small-signal parameters) and plot the intrinsic gain ( $a_{v0}$ ) of the minimum sized transistor versus  $V_{gs}$ . Make sure you hold  $V_{DS}$  constant (use an ideal op-amp - VCVS) to setup the simulation. Plot the intrinsic gain versus  $I_{ds}$  and  $V^*$ . What is your conclusion? Do you expect a strong bias current dependence? Explain.

I'm holding  $V_{DS}$  at mid rail =  $\frac{1.1}{2}$  and sweeping  $I_{ds}$ . I'm using a SVT transistor with minimum size ( $L_{min} = 45n, W_{min} = 120n$ ). Here are the plots:

- $a_{v0}$  has an inverse relationship to drain current  $I_{ds}$  (logarithmic) and  $V_{gs}$  (linear)

- This is expected because the  $r_o$  of the device decreases more rapidly than the  $g_m$  increases as  $I_{ds}, V_{gs}$  increase.
  - $a_{v0}$  versus  $V^*$ , follows the  $I_{ds}$  relationship and this is one reason for using the  $V^*$  design methodology to choose the transistor's operating point.
5. Now re-plot the intrinsic gain  $a_{v0}$  for a few non-minimum length devices. Try  $2L_{min}$ ,  $3L_{min}$ , and  $L_{max}$ . Does the gain depend on  $W$ ? Explain why you should avoid using a very small  $W$ .  $L_{max}$  is the longest channel length supported by the DK

In this process  $L_{max} = 10\mu m$

- The intrinsic gain generally doesn't depend on  $W$  since  $r_o$  and  $g_m$  both scale linearly with the transistor width.
  - A very small  $W$  however has a proportionally larger  $C_{dd}$  and  $C_{gg}$  than a wider transistor, which can lead to significant schematic/layout mismatches post-layout and extraction.
6. Which capacitance model does your model use? What is the charge partition scheme?
- Look at capmod, xpart (in the capacitance parameter section), look these up the bsim manual
7. Setup a simulation to plot the normalized input capacitances seen from the gate ( $C_{gs}, C_{gd}, C_{gb}$ ) of a MOS device as you vary  $V_{gs}$  and hold  $V_{ds}$  constant in triode and saturation (normalize by  $C_{ox}$ ). Are the expected symmetry properties upholding? Specify as many physical constraints as possible and check to see they are upheld by the model

Hold off on this until the SS gain parameters are done.

8. Plot  $\frac{g_m}{I_d}$  versus  $V_{gs}$  for the minimum,  $2L_{min}$ ,  $3L_{min}$ , and  $L_{max}$  of your technology. Superimpose the expected sub-threshold and square-law behavior and compare.
- I can do this with the data I already have.
9. Plot  $V^*$  versus  $V_{gs}$  for the minimum,  $2L_{min}$ ,  $3L_{min}$ , and  $L_{max}$  of your technology. Superimpose the expected sub-threshold and square-law behavior and compare.

Same data can be analyzed.

10. Plot  $f^T$  vs  $V^*$ . Make sure to set up a schematic to extract  $f^T$  rather than using the SS-parameters of the model. Use  $L_{min}$ ,  $2L_{min}$ ,  $3L_{min}$ , and  $L_{max}$  of your technology. Explain the trends.

I need to update the schematic to include  $f^T$  calculation.

11. Plot the product of  $f^T$  and  $a_{v0}$  vs  $V^*$  for  $L_{min}$ ,  $2L_{min}$ ,  $3L_{min}$ , and  $L_{max}$ . For which  $V^*$  is the product maximum for each case? Once I have  $f^T$  this is easy.
12. Design an amplifier that achieves a DC gain of 20 and a unity gain frequency of 500 Mhz while driving a load of 1pF. Specify the required  $V^*$ , bias current,  $V_{gs}$ , and device dimensions. Use the results of the previous problems to guide the design choices. Verify with SPICE.