UNIVERSITY OF CALIFORNIA, BERKELEY

Department of Electrical Engineering and Computer Sciences

EE251B Advanced Digital Circuits and Systems

Spring 2024, Prof. Borivoje Nikolic — Issued: Friday, Febuary 16th, 2024

Homework 2 — Due: Friday, March 8th 11:59pm

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1 Transistor IV Models (50 %)

(a) Use simulator of your choice (Spectre or HSpice) to simulate the VGS/IDS curve for the following device

Cell	`nfet_01v8`
Width	$.64\mu m$
Length	$.15\mu m$
Process Corner	tt

Ground the body of the device ($V_{BS} = 0$). The device should be in saturation ($V_{DS} > V_{GS} - V_{th}$).

Provide your simulated V_{GS}/I_{DS} curve. What is the device's V_{th}?

Hints:

- Set the drain of the device to V_{DD}(1.8v) and the source to a 0ohm resistor, with the other terminal of the resistor ground. You can measure the current through the resistor as your device's I_{DS}.
- Here is some starter code for a testbench that may be useful:

```
.lib '/home/ff/eecs251b/sky130/sky130_cds/sky130_release_0.0.1/models/sky130.lib.spice'
tt
.include '/home/ff/eecs251b/sky130/sky130_conv.spice'
xnfet drain gate source body nfet_01v8 w=0.64u l=0.15u
```

(b) For the I_{DSat} model used in class ($I_{DSat} = \frac{W}{L}\frac{\mu_{eff}E_C L}{2}\frac{(V_{GS}-V_{Th})^2}{V_{GS}-V_{Th}+E_C L}$), find the values of $E_C L$ and μ_{eff} that best fits your device's curve. Use the V_{th} value you found in part a).

Note that you may want to modify the $I_{Dsat}c$ equation to account for finite output resistance.

Hint: The `lsqcurvefit` function in MATLAB[1] may be useful.

(c) Fit the simulated IV curve to the alpha-power-law model $I_D = K(V_{GS} - VTh)^{\alpha}$. Report K, V_{Th}, and α; Attach an image of the fitted curve superimposed on top of the simulated one.

i. is your fitted V_{th} different from the device model's? Why might this occur?

ii. We fit this curve for a device in saturation. when might this model be useful when the I_{DSat} one is not?

Hint: the `lsqcurvefit` function in MATLAB may also be useful here.

[1] You can find an example for how to export Spectre data to MATLAB at `https://courses.grainger.illinois.edu/ece483/sp2024/data/cadence/ECE483_MATLAB_export.pdf`

2 Standard Cells (50 %)

You have been tasked with providing useful delay modeling abstractions to a digital design team. Your responses should reference the following Sky130 LIB file: `sky130_fd_sc_hd__tt_025C_1v80.lib`. It can be found in `/home/ff/eecs251b/sky130/sky130A/libs.ref/sky130_fd_sc_hd/lib/`

(a) Using the lib file for `sky130_fd_sc_hd__inv_1`, plot (for both rising and falling outputs) the fanout (load) versus delay of using the tool of your choice.

Hint: the device has two 2d "delay" arrays, one for rise time (`cell_rise`) and one for fall time (`cell_fall`). One of the dimensions is the fanout (load) that device is driving.

(b) Simulate and plot the fanout (load) versus delay of `sky130_fd_sc_hd__inv_1` using SPICE simulations. Does it differ from the .lib defined behavior?

Hint: what is the second column of the .delay array? What must you change in your simulation setup to ensure you are matching the environment the .lib parameters were extracted from?

(c) Draw the schematic you could simulate to characterize the FO4 delay of an inverter `inv_custom` with size $\frac{W}{L}$.

(d) Given the inverter `sky130_fd_sc_hd__inv_1` as your reference device, what is the logical effort of `sky130_fd_sc_hd__and2_0`? You may reference the `.lib` values.