Homework Assignment 5
(Due Feb. 26th at the beginning of the class)

***** Submission policy: Please zip your source code and waveform screenshots into a single file and send it to daehyun@eecs.wsu.edu. The file name should be *firstname_lastname*.zip (or .tar.gz or .tar …)

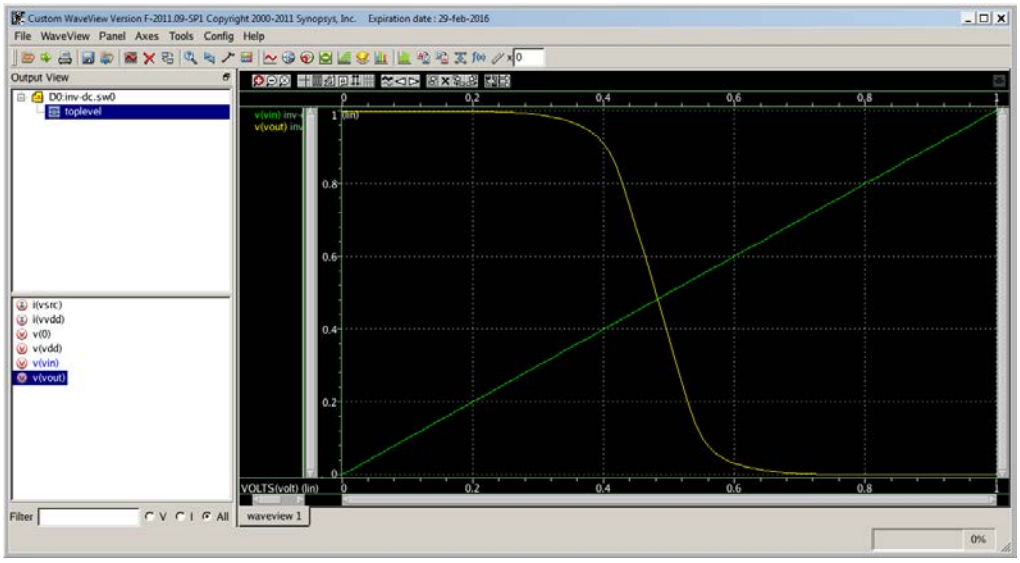
(1) **[Switching Characteristics of a CMOS Inverter, 10 points]** First, go to "Labs" and see "tut-hspice.pdf". It shows how to use HSPICE. Once you are done with it, download the following file into your working directory.

- http://eecs.wsu.edu/~ee434/Homework/hw05.zip
- Unzip it.
  - > unzip hw05.zip
- You will see the following files.
  - 45nm_PTM_HP_v2.1.pm (HSPICE transistor models)
  - inv-ac.sp (an HSPICE netlist for the simulation of switching characteristics of an inverter)
  - inv-dc.sp (an HSPICE netlist for the simulation of DC characteristics of an inverter)
- The size of the 1X inverter is (Wn, Wp) = (45nm, 70nm). The rise/fall time of the 1X inverter is 216ps as shown in the tutorial.
- Upsize the inverter to 2X, i.e., (Wn, Wp) = (45nm * 2, 70nm * 2) = (90nm, 140nm). Measure the rise and fall times again.
- [**Submit**] Fill the following table.

Inverter size	Rise time (ps)	Fall time (ps)
1X		
2X		
3X		
4X		
8X		
16X		
32X		

(2) **[DC Characteristics of a CMOS Inverter, 20 points]** Open "inv-dc.sp" in a text editor and see the contents of the file. We use ".DC" for DC simulation.

- Run HSPICE for the DC simulation.
  - > hspice inv-dc.sp
- Open the DC simulation result.
  - wv inv-dc.sw0
- Double-click v(vin) and v(vout) to visualize the DC characteristics of the inverter.
- Drag and drop one of the graphs into the other one as follows:



- Measure V_{IL}, V_{IH}, V_{OL}, V_{OH} (use "Difference" in the measurement tool).
- In my window, $V_{IL} = 375mV, V_{IH} = 580mV, V_{OL} = 45mV, and\ V_{OH} = 950mV$.
- $NM_L = 375mV - 45mV = 330mV, NM_H = 950mV - 580mV = 370mV$.
- [**Submit**] Use ($W_n = 90nm, W_p = 70nm$) and run DC sweep analysis again. Compute and submit NM_L and NM_H.
- [**Submit**] Use ($W_n = 45nm, W_p = 140nm$) and run DC sweep analysis again. Compute and submit NM_L and NM_H.
- [**Submit**] Use ($W_n = 90nm, W_p = 140nm$) and run DC sweep analysis again. Compute and submit NM_L and NM_H.