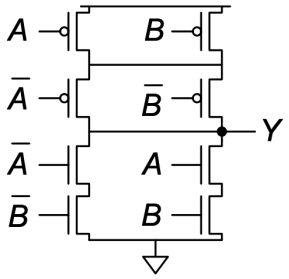
EECS 151/251A Homework 6

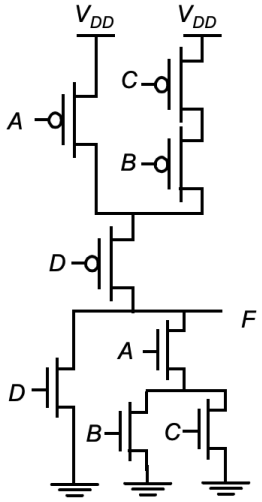
Due Friday, Oct 23rd, 2020

Problem 1: Complementary CMOS [8 pts]

(a) Write the simplified boolean expression for the function described by the CMOS circuit below. Hint: Writing a truth table with inputs A, B and output Y may make the answer more apparent. [2 pts]



(b) Write the simplified boolean expression for the function described by the CMOS circuit below. [2 pts]

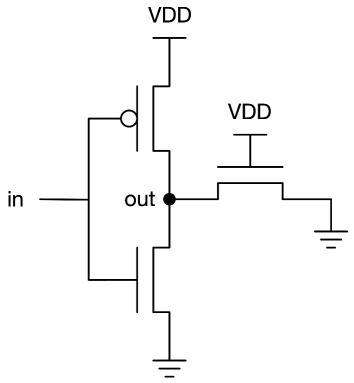


(c) Implement the logic function $Y = \overline{A + BC}$ using a complementary pull-up and pulldown network. [2 pts]

(d) Implement the logic function $Y = \overline{A(B + C) + \overline{B}\,C}$ using a complementary pull-up and pulldown network. For this question, assume you have $\overline{A}$, $\overline{B}$, and $\overline{C}$ available in addition to A, B, and C. [2 pts]

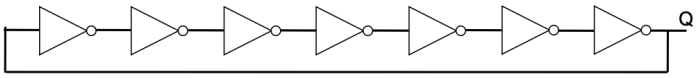
Problem 2: Voltage Transfer Characteristic (VTC) [4 pts]

Using the transistor-as-a-switch model, draw the voltage transfer characteristic for the circuit below. You will eventually recognize this as half of a 6T CMOS SRAM bitcell. Assume that $|V_{th,p}| = V_{th,n} < V_{DD}/2$ and that $R_{on,p} = R_{on,n}$.

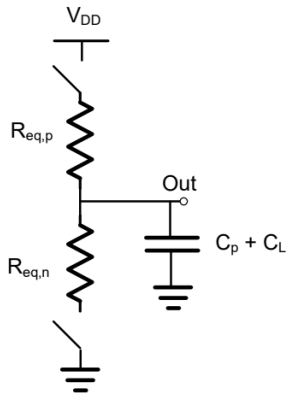


Problem 3: Inverter Delay [3 pts]

By taking advantage of the fact that logic gates take some time to propagate changes in their input, we can build a simple ring oscillator (a circuit that switches back and forth between 0 and 1) from an odd number of inverters, as shown below. Suppose we use 7 inverters to do so.



For this question, we will use the model of a transistor as a resistor and a capacitor. Here is the diagram of an inverter under this model:



(a) Say $R_{eq,n} = R_{eq,p} = 5m\Omega$ and $C_P = C_{in} = 2nF$. What is the propagation delay of an inverter in this design? [2 pts]

(b) At what frequency will the output signal oscillate? Assume Q is not connected to anything outside the ring. [1 pt]

(Note: Our solution here is easy to find because the inverters are connected in a loop. As you will find, this problem becomes more complicated when the chain of inverters is connected to a different circuit.)