CIS 2400 Fall 2024 - First Written Homework

Assignment Instructions:
You will submit this assignment by uploading it to Gradescope. You do not need to print out this document and put your answers on it. You should probably instead put your answers on their own dedicated pages, and then properly indicate which question is being answered on all parts of each page.

You may write your answers and draw them by hand or type them and use an online program to draw the circuits. Whatever you do, please make sure your circuit is clear and readable. If you are drawing by hand, a straight-edge and/or graph paper may help with readability.

Please also note that this homework is graded manually and does not have "public test cases" like the other homeworks usually will have. **It also means that we will not grant late extensions that exceed 72 hours aside from special circumstances.**

3 problems: 50 pts total

Problem 1 (15 pts)
Design a CMOS transistor circuit that has 2 inputs, A and B, and produces a high output if and only if 2 the two inputs have the same value. In order to accomplish this, you can assume that you also have access to the inverses of A and B and that you can use those as inputs to your circuit.

Please remember that to get full points your circuit must be a proper CMOS circuit, label the pull down and pull up networks and make sure that these two circuits are complementary to each other.

Note that we ask you to create a "single CMOS transistor circuit". This means that you should not create multiple circuits and feed the output of one circuit into the input of another. This does not mean that you are restricted to only one CMOS transistor.

Problem 2 (30 pts)
NAND gates are sometimes termed universal gates since it turns out that you can implement any other logical function using only 2 input NAND gates.

Part 1 (8pts):
To show that this is true, produce circuits showing how you could implement the fundamental logical operations, NOT, AND and OR using only NAND gates. Since any logical function can be expressed in terms of these three; this suffices to prove the result.

Parts 2-6: (22 points total)
For each of the following gates, we want you to prove which ones are universal and which ones are not universal.

- If you think a gate is not universal then state all of the three fundamental logical operations you cannot implement and briefly justify why you can't implement each. If there are any fundamental operations you can implement, then please show them.
- If it is universal, please show an implementation of each of the three fundamental logic operations.

This is not a "proof" course, you do not have to be very formal at all when you prove you can't implement it. Plain english explanations are fine as long as they are correct and clear.

NOT gate

AND gate

OR gate

NOR gate

XOR gate

Problem 3 (5 pts)

The idea of Computational Sprinting was developed a few years ago here at Penn by a former Penn Professor, Milo Martin. Here is a link to a short article that describes the basic idea. You can find more information via a simple search if you are interested.

https://www.scientificamerican.com/article/computational-sprinting/

Explain in 2 or 3 sentences the basic idea of computational sprinting.