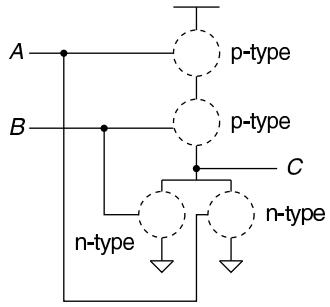
Intro. to Computer Architecture	**Homework 2**
CSE 240 Autumn 2004	**DUE: Fri. 24 September 2004**

Write your answers on these pages. Additional pages may be attached (with staple) if necessary. Please ensure that your answers are legible. Please show your work. Due at the ***beginning of class***. **Hints are provided for questions marked with** [⇝] **on the last page of the assignment.** Total points: 48.

1. [4 Points] **Transistors.** In the circuit given below, the transistors are shown as circles (just like in the circuits in Figures 3.4 and 3.5 of the textbook). In this problem you must determine whether or not each of these transistors conduct or not based on the inputs (*A* and *B*).



For all values (*i.e.*, 0 or 1) of inputs *A* and *B* indicate in the table below whether each transistor conducts (*i.e.*, act like a piece of wire, denoted "1") or does not conduct (*i.e.*, acts like an open circuit, denoted "0"). Also indicate the value (*i.e.*, 0 or 1) of the output *C*. (In the table, the upper and lower p-type transistors are called p-up and p-down, respectively, while the left and right n-type transistors are called n-left and n-right, respectively.)

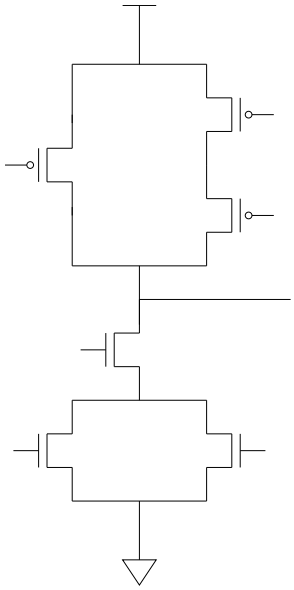
A	B	C	P-up	P-down	N-left	N-right
0	0					
0	1					
1	0					
1	1					

2. [8 Points] **Logic Gates.**

   (a) The transistor-level circuit given below implements the following logic equation.

   $$Y = \text{NOT}(A) \text{ OR } (\text{ NOT}(B) \text{ AND } \text{NOT}(C))$$

   Label all the transistor "gate" inputs with the input (*i.e.*, *A*, *B*, or *C*) that should be applied to it. Also label the output (wherever it may be) with *Y*.



   (b) Construct a transistor-level circuit (like the one above) for the following logic equation.

   $$Z = \text{NOT}(A) \text{ AND } (\text{ NOT}(B) \text{ OR } \text{NOT}(C))$$

   Be sure to include labels for *A*, *B*, *C*, and *Z*.

3. [12 Points] **Combinational Logic Circuits.** NAND is logically complete. Use only NAND gates to construct gate-level circuits that compute the following.

   (a) NOT

   (b) AND

(c) OR

(d) NOR

4. [12 Points] **Combinational Logic Circuits.**

(a) i. Complete the truth table for $Z = (A \text{ AND } B) \text{ OR } (B \text{ AND } C)$.

A	B	C	$Z = (A \text{ AND } B) \text{ OR } (B \text{ AND } C)$
0	0	0	
0	0	1	
0	1	0	
0	1	1	
1	0	0	
1	0	1	
1	1	0	
1	1	1	

ii. Construct the gate-level logic circuit for Z (above) using AND and OR .

iii. How many transistors does your circuit require if AND and OR gates are implemented as given in Figures 3.6 and 3.7 of the textbook (pages 56 and 57)?

(b) i. Complete the truth table for $Y =$ NOT(NOT(A AND B) AND NOT(B AND C)). You should find that Y is equivalent to Z (from previous question). Indeed, Y can be reduced to Z by application of DeMorgan's Law (and the fact that NOT(NOT(X)) $= X$).

A	B	C	$Y =$ NOT(NOT(A AND B) AND NOT(B AND C))
0	0	0	
0	0	1	
0	1	0	
0	1	1	
1	0	0	
1	0	1	
1	1	0	
1	1	1	

ii. [$\rightsquigarrow$] Construct the gate-level logic circuit for Y (above) using only NAND gates.

iii. How many transistors does your circuit require if NAND gates are implemented as described in Figure 3.7 of the textbook (page 57)? Does the NAND -based implementation require a greater or lesser number of transistors than the AND - OR implementation?

5. [12 Points] **Combinational Logic Circuits.** In this problem we will construct gate-level logic circuits to determine whether a number is zero, negative, or positive. For each part, below, assume the input (A_3, A_2, A_1, A_0) represents a 4-bit 2's complement integer (A_0 representing the least significant digit). You may use any logic gates discussed in the textbook (including gates with more than two inputs, *e.g.*, 4-input AND gates).

   (a) Output Z is 1 if and only if the input represents zero. Construct the gate-level logic circuit to produce output Z from the input. Be sure to label your inputs ($A_3 - A_0$) and output (Z).

   (b) [$\rightsquigarrow$] Output N is 1 if and only if the input represents a negative number. Construct the gate-level logic circuit to produce output N from the input. Be sure to label your inputs and output.

   (c) [$\rightsquigarrow$] Output P is 1 if and only if the input represents a positive number. Construct the gate-level logic circuit to produce output P from the input. Be sure to label your inputs and output.

6. [No Points] **Last and Most Important Question!** Please complete this question, and give us your feedback!

   (a) How many hours did you spend on this assignment?

   (b) On a scale of 1-5, how difficult did you find this assignment? (1-easiest, 5- most difficult)

   (c) Do you have any other comments on your experience completing this assignment? What are they?

Hints:

4bii: Note that $\text{NOT}(A \text{ AND } B) = (A \text{ NAND } B)$.

5b: This may not sound like a hint, but. . . This one is *really* as easy as you think!

5c: You may use logic for Z and N to implement the logic for P.