The UNIVERSITY *of* NORTH CAROLINA *at* CHAPEL HILL

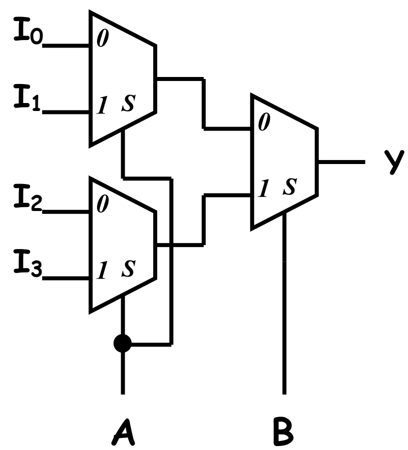
Comp 411 Computer Organization
Fall 2012

Solutions to Problem Set #3
Issued Monday, 10/29/12; Due Monday, 11/5/12

Note: You may use additional sheets of paper, but please enter your answers in the space provided in this document.

Problem 1. Mux Madness (16 points)

Suppose you wanted to implement a Boolean function *Y* of two inputs *A* and *B* using multiplexers, as shown in the figure.



Give binary values for I_0, I_1, I_2, and I_3 that implement the following functions on the two inputs *A* and *B:*

a) Y = NAND(A,B)
b) Y = (A != B)
c) Y = (A < B)
d) Y = XOR(A,B)

Answer:

Function Y=	I_0 (AB=00)	I_1 (AB=10)	I_2 (AB=01)	I_3 (AB=11)
NAND(A, B)	1	1	1	0
A != B	0	1	1	0
A < B	0	0	1	0
XOR(A, B)	0	1	1	0

Problem 2. "Go Forth and Multiply" (52 points)

a) [16 points] Complete the truth table below showing multiplication of two 2-bit unsigned integers A_1A_0 and B_1B_0, producing a 4-bit result $P_3P_2P_1P_0$. Please enter your answer directly in the table below.

$A_1A_0B_1B_0$	$P_3P_2P_1P_0$
0000	0 0 0 0
0001	0 0 0 0
0010	0 0 0 0
0011	0 0 0 0
0100	0 0 0 0
0101	0 0 0 1
0110	0 0 1 0
0111	0 0 1 1
1000	0 0 0 0
1001	0 0 1 0
1010	0 1 0 0
1011	0 1 1 0
1100	0 0 0 0
1101	0 0 1 1
1110	0 1 1 0
1111	1 0 0 1

b) [20 points] Suppose you wanted to compute the *fourth power* of a 2-bit number (i.e., A^4). Complete the truth table below in which the input column contains the 2-bit input ($A=A_1A_0$), and the output column is the 8-bit result.

A_1A_0	$P_7P_6P_5P_4P_3P_2P_1P_0$
0 0	0 0 0 0 0 0 0 0
0 1	0 0 0 0 0 0 0 1
1 0	0 0 0 1 0 0 0 0
1 1	0 1 0 1 0 0 0 1

c) [16 points] For each of the 8 output bits from part (b), give the sum-of-products Boolean equation (circuit not needed):
Answer:

$P_0 = \overline{A_1}A_0 + A_1A_0 = A_0$
$P_1 = 0$
$P_2 = 0$
$P_3 = 0$
$P_4 = A_1\overline{A_0} + A_1A_0 = A_1$
$P_5 = 0$
$P_6 = A_1A_0$
$P_7 = 0$

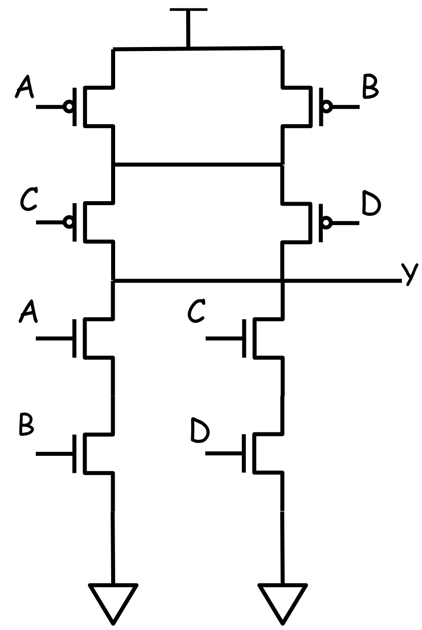
Note: The best implementation is the one that uses the most simplified Boolean expression for each of the outputs. Thus, P_0 and P_4 are simply implemented by A_0 and A_1, respectively. P_6 needs one AND gate. Thus, one can implement the equations using a *single* gate (an AND gate)! So, *one* AND gate, no OR gates, no inverters are all that is needed.

However, the question did not require you to simplify the Boolean expressions. So, your answer likely has more terms. In particular, P_0 and P_4 will each have two terms, requiring two AND gates each, and one OR gate each. Note also that it is possible to share the gate that produces A_1A_0 in both.

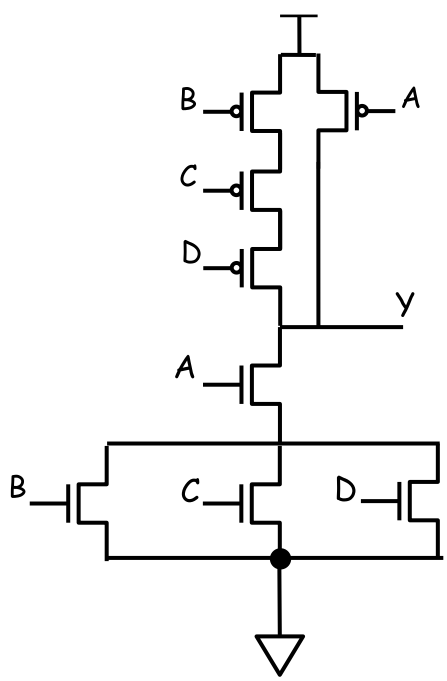
Any reasonable answer will be acceptable for this question with full credit.

Problem 3. "Fishing for Complements" (32 points). Show the complementary set of p-channel or n-channel transistors that complete the following CMOS circuits:

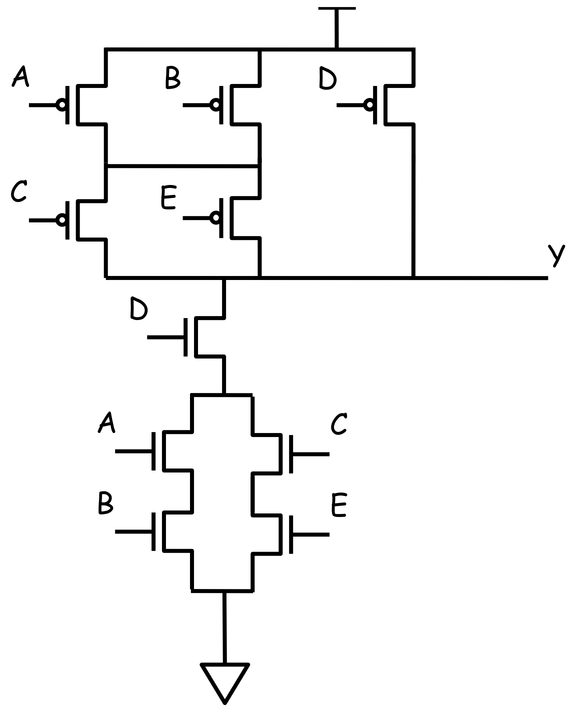
a)



b)



c)



d)