# EEM16/CSM51A (Fall 2017)

## Logic Design of Digital Systems

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**Problem set 1**
**assigned Monday Oct. 9, 2017**
**due 4pm Monday Oct. 16, 2017**
**Show all work.**

### Instructions

This homework is to be done individually. You may consult with others to share thoughts and ideas, but all of your submitted work must be yours alone. Be sure to indicate with whom you've collaborated and in what manner.

You may use any tools or refer to published papers, books, or course notes. Youre allowed to make use of online tools such as Logisim, WolframAlpha, etc., provided you properly cite them in the space below.

You must submit all pages in this file based on the procedure below. Because of the grading methodology, you may find it easier to print the document and write out your solutions in the space provided in this problem set. You may alternately opt to digitally enter your solutions into the form entries then download or print the filled PDF.

Answers written on sheets other that the provided space will not be looked at or graded. Please write clearly and neatly - if we cannot easily decipher what you have written, you will get zero credit.

### Submission procedure

You need to submit your solution online at Gradescope:
`https://gradescope.com/`

Please see the following guide from Gradescope for submitting homework. You will need to upload a PDF and mark where each question is answered.
`http://gradescope-static-assets.s3-us-west-2.amazonaws.com/help/submitting_hw_guide.pdf`

### Collaborators

Identify with whom you've collaborated and in what manner, if any.

Kerry Zheng, reviewed answers

### Online resources

Identify which online tools you've used, if any.

Wolfram Alpha boolean expression simplifier to check if my simplification is correct

## 1.3 What size are your genes?

Oxytocin is a neuropeptide responsible for a number of psyc
anxiety, and bonding. It is made of 9 amino acids.

1.3(a). Using a labeling system as described in 1.2, how ma

1.3(b). If we translated that base-4 representation to a num
to write the numerical value for Oxytocin?

1.3(c). If instead we used the amino acids directly as a base
be necessary to write out the numerical value for Ox

1.1a) 2 $\log_2 4$

b) 5 $16 < 20 < 32; \log_2 32 = 5$

1.2 a) 3 $16 < 20 < 64; \log_4 64 = 3$

b) $64/20 \approx 3$

1.3a) 27 $9 \cdot 3$

b) 17 $4^{27} \approx 1.8 \times 10^{16}$

c) 12 $20^9 = 5.12 \times 10^{11}$

## 2.4 Don't care

If we specify a set of valid inputs for our system, we can choose what value our function assign...
("don't care" values) whichever way we would like in order to simplify our boolean expressions.

2.4(a). If we assume that our 5 bit input will represent a valid hour, come up with a simple boolean expres... (using no more than 3 literals) that returns true if the hour is a valid afternoon hour and false if it is a ... morning hour.

2.4(b). If instead we specify that the function must also be false for invalid hours, does the boolean expres... change? If so, what is the new expression?

2.4(c). Draw this function using only NOR gates.

2.1 a) 10/16 @ 4pm 1000010000

$\downarrow$ 16 $\downarrow$ 16

b) $d_4 \cdot h_4 \cdot \overline{(d_3 + d_2 + d_1 + d_0 + h_3 + h_2 + h_1 + h_0)}$

c) With one of De Morgan's Laws, it becomes $d_4 \bar{d_3} \bar{d_2} \bar{d_1} \bar{d_0} h_4 \bar{h_3} \bar{h_2} \bar{h_1} \bar{h_0}$
which is a minterm of the system, particularly for the input 1000010000

Use this page for more work on Problem 2.

2.2a)

| $d_4 d_3 d_2 d_1 d_0$ | $f$ | $d_4 d_3 d_2 d_1 d_0$ | $f$ |
|---|---|---|---|
| 00000 | N/A | 10000 | 0 |
| 00001 | 1 | 10001 | 0 |
| 00010 | 0 | 10010 | 0 |
| 00011 | 0 | 10011 | 0 |
| 00100 | 0 | 10100 | 0 |
| 00101 | 0 | 10101 | 1 |
| 00110 | 0 | 10110 | 1 |
| 00111 | 1 | 10111 | 0 |
| 01000 | 1 | 11000 | 0 |
| 01001 | 0 | 11001 | 0 |
| 01010 | 0 | 11010 | 0 |
| 01011 | 0 | 11011 | 0 |
| 01100 | 0 | 11100 | 1 |
| 01101 | 0 | 11101 | 1 |
| 01110 | 1 | 11110 | 0 |
| 01111 | 1 | 11111 | 0 |

$$f = \bar{d}_4 \bar{d}_3 \bar{d}_2 \bar{d}_1 d_0 + \bar{d}_4 \bar{d}_3 d_2 d_1 d_0 + \bar{d}_4 d_3 \bar{d}_2 \bar{d}_1 \bar{d}_0$$
$$+ \bar{d}_4 d_3 d_2 d_1 \bar{d}_0 + \bar{d}_4 d_3 d_2 d_1 d_0 + d_4 \bar{d}_3 d_2 \bar{d}_1 d_0$$
$$+ d_4 \bar{d}_3 d_2 d_1 \bar{d}_0 + d_4 d_3 d_2 \bar{d}_1 \bar{d}_0 + d_4 d_3 d_2 \bar{d}_1 d_0$$

b) Disjunctive, because there are less weekend days than weekdays $\Rightarrow$ less minterms
$\Rightarrow$ less work

2.3a) invalid:

$\rightarrow$ $00000 h_4 \ldots h_0$ (0th day)

$\rightarrow$ $[d_4 \ldots d_0 11000,\ d_4 \ldots d_0 11111]$ (24th – 31st hours)

$$f = \underbrace{M(0) \cdot M(1) \cdot \ldots \cdot M(31)}_{0^{th}\text{ day}} \cdot \underbrace{M(56) \cdot \ldots \cdot M(63)}_{1st\text{ day } 24^{th}-31^{st}\text{ hrs}} \cdot \underbrace{M(88) \cdot \ldots \cdot M(95)}_{2nd\text{ day } 24^{th}-31^{st}\text{ hrs}} \cdot \left\{ \begin{array}{l} \prod \text{Maxterms for } 24^{th}-31^{st}\text{ hours} \\ \text{in } 3^{rd}-31^{st}\text{ days} \end{array} \right\}$$

b) $f = (d_4 + d_3 + d_2 + d_1 + d_0) \cdot \overline{(h_4 \cdot h_3)}$

b) $f = (d_4 + d_3 + d_2 + d_1 + d_0) \cdot (h_4 \cdot h_3)$

c) $f^D = (\bar{d}_4 \cdot \bar{d}_3 \cdot \bar{d}_2 \cdot \bar{d}_1 \cdot \bar{d}_0) + (\overline{h_4 + h_3}) = (\bar{d}_4 \cdot \bar{d}_3 \cdot \bar{d}_2 \cdot \bar{d}_1 \cdot \bar{d}_0) + (\bar{h}_4 \cdot \bar{h}_3)$

2.4 a) $f = (h_4 + h_3 + h_2) \cdot (h_4 + h_3 + \bar{h}_2) \cdot (h_4 + \bar{h}_3 + h_2) = h_4 + (h_3 + h_2)(h_3 + \bar{h}_2)(\bar{h}_3 + h_2)$

input prefixes that make false outputs

000 → $(h_4 + h_3 + h_2)$

001 → $(h_4 + h_3 + \bar{h}_2)$

010 → $(h_4 + \bar{h}_3 + h_2)$

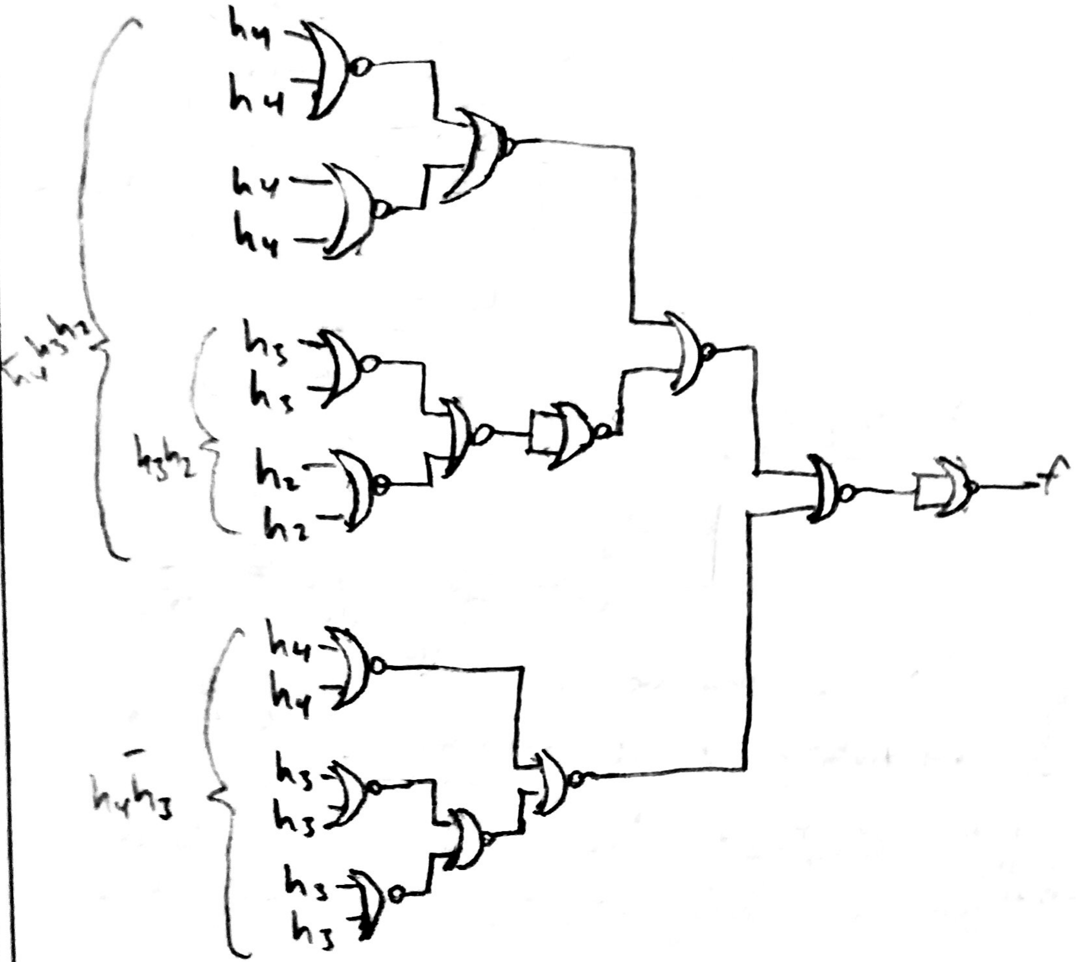
$= h_4 + (h_3 + h_2 h_3 + \bar{h}_2 h_3)(\bar{h}_3 + h_2) = h_4 + (h_3 h_2) = \boxed{h_4 + h_3 h_2}$

b) yes, it changes. Now inputs with prefix 11 must produce false outputs.

$f_1 = f \cdot (\overline{h_4 h_3}) = (h_4 + h_3 h_2)(\overline{h_4 h_3}) = (h_4 + h_3 h_2)(\bar{h}_4 + \bar{h}_3) = \boxed{\bar{h}_4 h_3 h_2 + h_4 \bar{h}_3}$

Use this page for more work on Problem 2.

c) $\bar{h}_4 h_3 h_2 + h_4 \bar{h}_3 = f$




useful properties:

NOT a = a NOR a

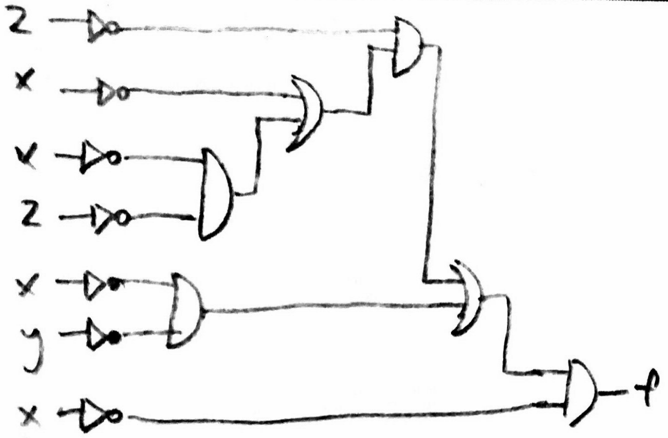
a AND b = NOT(NOT a OR NOT b) = NOT a NOR NOT b = (a NOR a) NOR (b NOR b)

I used these properties to express AND gates as NOR gates.

## Your turn

often said that you don't truly understand a subject until you can teach it. What was a topic that you struggled
h so far in this class? Write and solve a pset problem that sheds light on this particular topic.

Drawing diagrams of given functions, CMOS especially.




2.1a) write an expression for f that matches the above diagram.

2.1b) simplify the expression and draw the simplified function using gates

2.1c) draw the same function using only NAND gates

2.2a) Draw the CMOS diagram for the function from (2.1b)

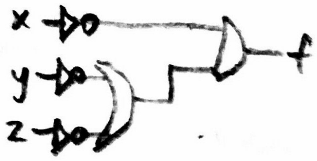
2.2b) Explain how the diagram from (2.1b) is related to that of (2.2a)

2.2c) Explain what is meant by "pullup" and "pulldown" and why each network is named so.

network is asked so.

2.(a) $f = \overline{x}\left(\overline{z}\,(\overline{x} + \overline{x}\,\overline{z}) + \overline{x}\,\overline{y}\right)$

b) $f = \overline{x}\left(\overline{z}\,\overline{x} + \overline{x}\,\overline{z} + \overline{x}\,\overline{y}\right) = \overline{x}\left(\overline{x}\,\overline{z} + \overline{x}\,\overline{y}\right) = \overline{x}\left(\overline{y} + \overline{z}\right)$

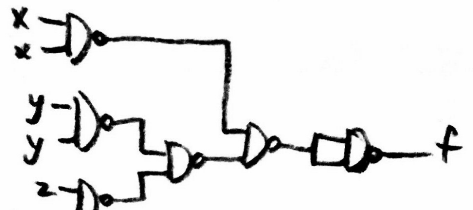



c)

| NAND | | out |
|---|---|---|
| 0 | 0 | 1 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 0 |

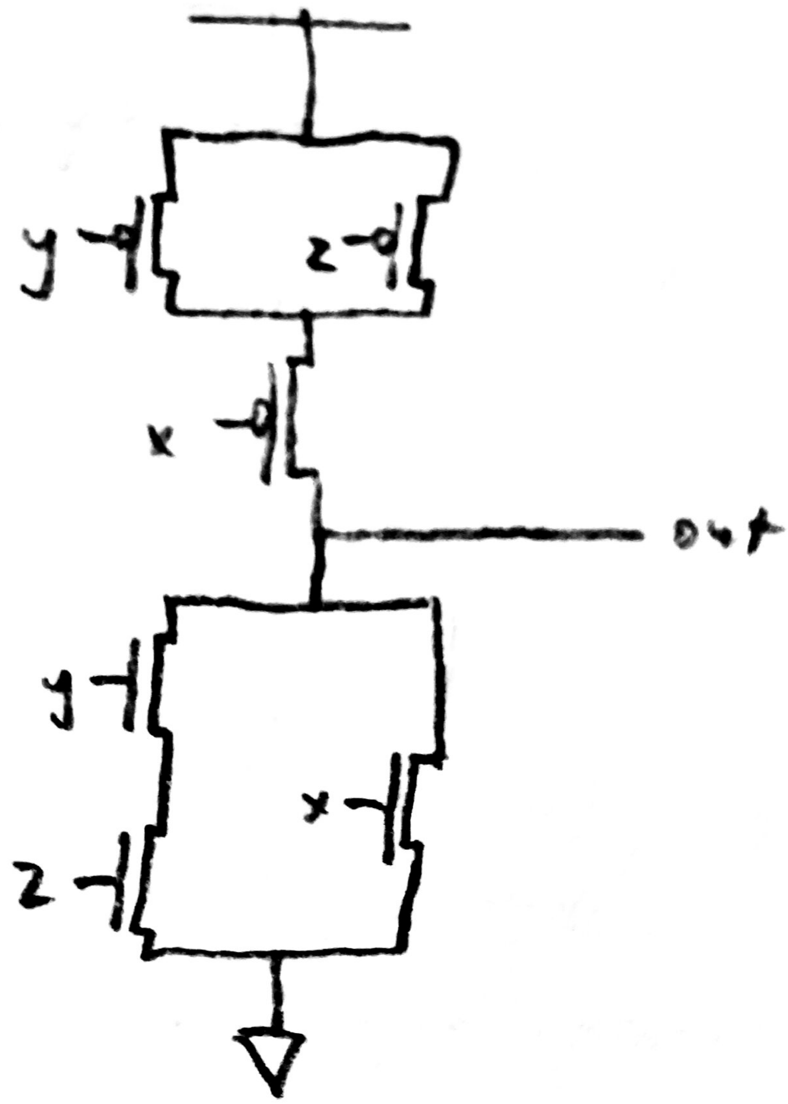
$\Rightarrow$ NOT a = a NAND a

a OR b = NOT( NOT a AND NOT b) = (a NAND a) NAND (b NAND b)



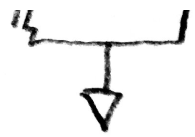
Use this page for more any more work that you may u

2.2 a) $f = \bar{x}(\bar{y} + \bar{z})$




b) The pullup network is the same

except the PD netw...



b) The pullup network is the same as the diagram from (2.1b) except the OR gate is replaced by parallel inputs and the AND gate is replaced by values in series. The pulldown network is then the complement of the pullup network.

c) The pullup network contains PFETs and is drawn at the top of the diagram. It is called "pullup" because it takes low inputs and produces higher outputs.

The pulldown network contains NFETs and is drawn at the bottom of the diagram. It is called "pulldown" because it takes high inputs and produces lower outputs,