Design of Digital Circuits (252-0028-00L), Spring 2018

Optional HW 2: Combinational Logic

**SOLUTIONS**

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## 1 Video Lecture Assignment

Write a summary of the Prof. Onur Mutlu's Inaugural Lecture.

You can watch the video here: `https://www.youtube.com/watch?v=kgiZlSOcGFM`

In your summary, please answer the following questions:

- What are your key takeaways?
- What did you learn?
- What did you like or dislike?

Please email your summary as a .pdf file to Prof. Onur Mutlu (omutlu@gmail.com)

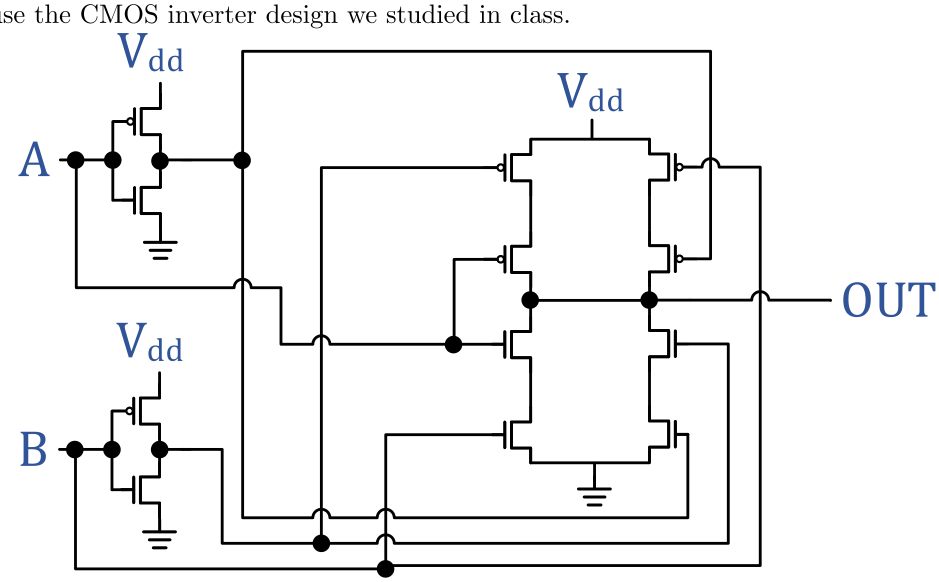
## 2 Transistor-Level Circuit Design

In Lecture 5, we learnt how to implement digital circuits using the CMOS technology (i.e., p-type and n-type MOS transistors). In this assignment, we ask you to schematically design circuits using CMOS transistors for the following logic gates:

- Exclusive OR Gate (XOR)

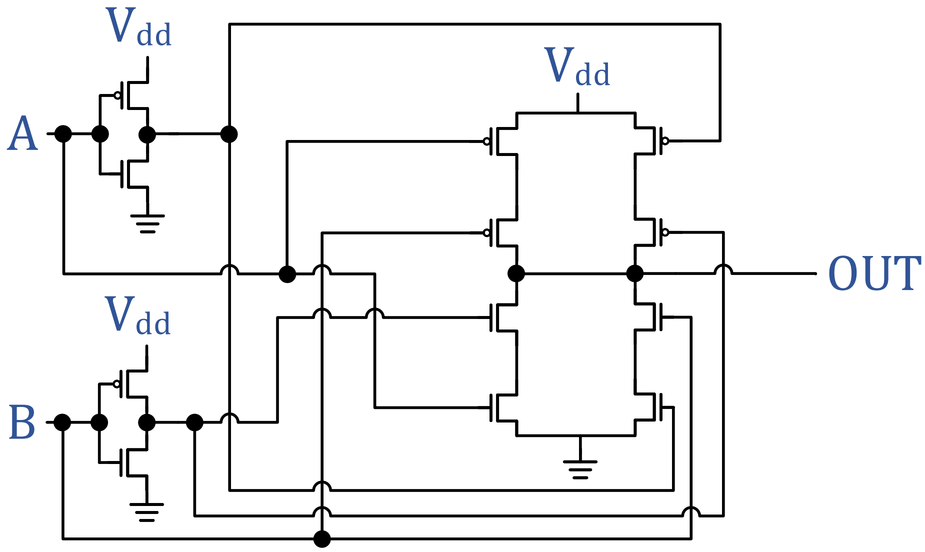
**Solution.**

The result of the XOR operation is logic-1 when the two inputs (e.g., A and B) have different values. Thus, to construct the pull-up network, we need to have $A.B'$ and $A'.B$ connected to $V_{dd}$ in parallel. By doing so, the pull-up network will be enabled when either (A=0, B=1) or (A=1, B=0). Similarly, to construct the pull-down network, we need to have $A.B$ and $A'.B'$ connector to ground in parallel. To invert A and B, we can use the CMOS inverter design we studied in class.



- Exclusive NOT OR Gate (XNOR)

**Solution.**

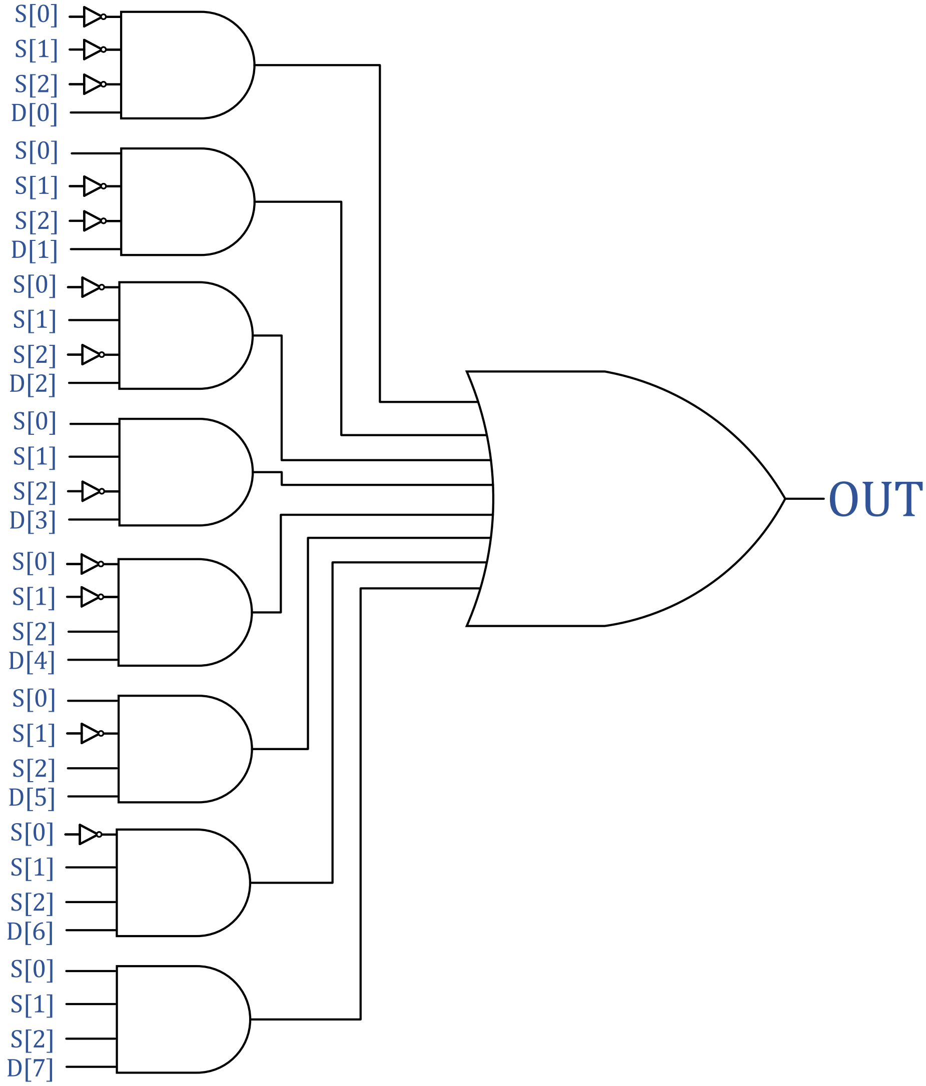


## 3 Multiplexer (MUX)

Draw the following schematics for an 8-input (8:1) MUX.

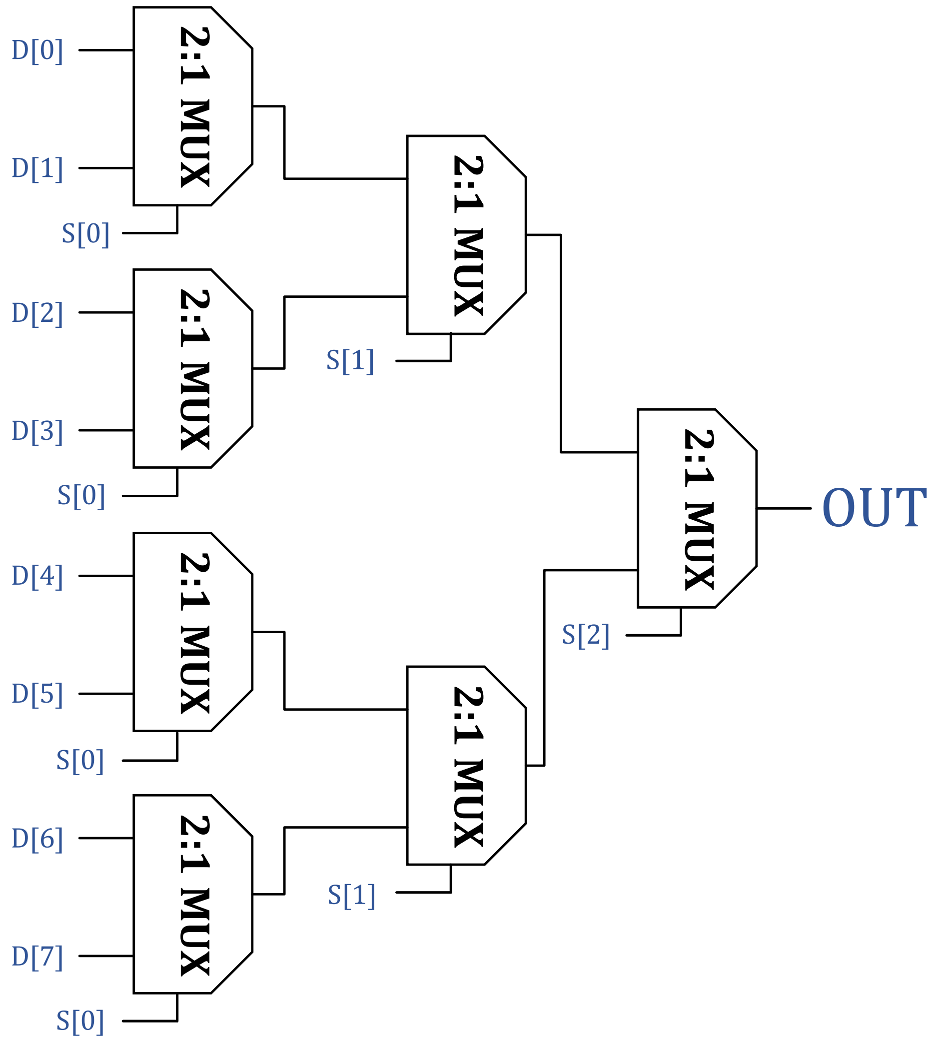
- Gate level: as a combination of basic AND, OR, NOT gates. Use as few gates as possible.

**Solution.**



- Module level: as a combination of 2-input (2:1) MUXes. Use as few 2-input MUXes as possible.

**Solution.**



## 4 Logical Completeness

The set of {AND, OR, and NOT} gates is logically complete. We can build a circuit to carry out the specification of any truth table we wish, without using any other kind of gate. From Lecture 5, you know that the NOR gate by itself is also logically complete. Prove that you can build a circuit to carry out the specification of any truth table, by using only NOR gate.

**Solution.**

To provide that the NOR gate is logically complete, it would be sufficient to show that it is possible to build the logically complete set of {AND, OR, and NOT} gates using only NOR gates. The figures below show how each of these gates can be implemented using NOR gates.