Chapter 11: Digital Electronics

WMC CS CLUB

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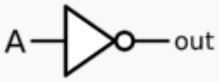
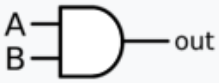
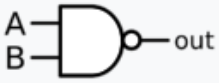
§1 Digital Electronics

A digital circuit is constructed from logic gates. Each logic gate performs a function of boolean logic based on its inputs, such as AND or OR. Each circuit can be represented as a Boolean Algebra expression; this topic is an extension of the topic of Boolean Algebra, which includes a thorough description of truth tables and simplifying expressions.

<table>
<tr><th>NAME</th><th>GRAPHICAL SYMBOL</th><th>ALGEBRAIC EXPRESSION</th><th>TRUTH TABLE</th></tr>
<tr><td>BUFFER</td><td> 
</td><td>X = A</td><td>
<table>
<tr><th>INPUT</th><th>OUTPUT</th></tr>
<tr><td>0</td><td>0</td></tr>
<tr><td>1</td><td>1</td></tr>
</table>
</td></tr>
<tr><td>NOT</td><td> 
</td><td>X = $\overline{A}$ or $\neg A$</td><td>
<table>
<tr><th colspan="2">INPUT</th><th>OUTPUT</th></tr>
<tr><th>A</th><th>X</th></tr>
<tr><td>0</td><td>1</td></tr>
<tr><td>1</td><td>0</td></tr>
</table>
</td></tr>
<tr><td>AND</td><td> 
</td><td>X = AB or $A \cdot B$</td><td>
<table>
<tr><th colspan="2">INPUT</th><th>OUTPUT</th></tr>
<tr><th>A</th><th>B</th><th>X</th></tr>
<tr><td>0</td><td>0</td><td>0</td></tr>
<tr><td>0</td><td>1</td><td>0</td></tr>
<tr><td>1</td><td>0</td><td>0</td></tr>
<tr><td>1</td><td>1</td><td>1</td></tr>
</table>
</td></tr>
<tr><td>NAND</td><td> 
</td><td>X = $\overline{AB}$ or $\overline{A \cdot B}$</td><td>
<table>
<tr><th colspan="2">INPUT</th><th>OUTPUT</th></tr>
<tr><th>A</th><th>B</th><th>X</th></tr>
<tr><td>0</td><td>0</td><td>1</td></tr>
<tr><td>0</td><td>1</td><td>1</td></tr>
<tr><td>1</td><td>0</td><td>1</td></tr>
<tr><td>1</td><td>1</td><td>0</td></tr>
</table>
</td></tr>
</table>

OR		$X = A + B$	INPUT / OUTPUT A B X 0 0 0 0 1 1 1 0 1 1 1 1
NOR		$X = \overline{A + B}$	INPUT / OUTPUT A B X 0 0 1 0 1 0 1 0 0 1 1 0
XOR		$X = A \oplus B$	INPUT / OUTPUT A B X 0 0 0 0 1 1 1 0 1 1 1 0
XNOR		$X = \overline{A \oplus B}$ or $A \odot B$	INPUT / OUTPUT A B X 0 0 1 0 1 0 1 0 0 1 1 1

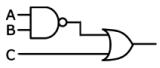
§2 Online Tools

The ACSL proposes the Logisim (http://www.cburch.com/logisim/index.html) application for digital electronics experimentation. Logisim is a wonderful tool for exploring this topic. Logisim is free to download and use; among its many features is support to automatically draw a circuit from a Boolean Algebra expression; to simulate the circuit with arbitrary inputs; and to complete a truth table for the circuit.

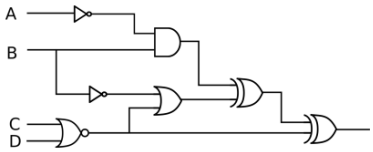
§3 Practice Problems

§3.1 Problems

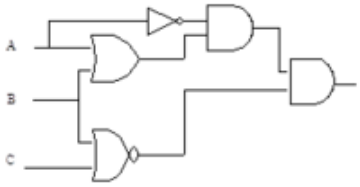
1. Find all ordered triplets (A, B, C) which make the following circuit FALSE:



2. How many ordered 4-tuples (A, B, C, D) make the following circuit TRUE?



3. Simplify the Boolean expression that this circuit represents.



§3.2 Answer Key

1. For the circuit to be FALSE, both inputs to the file OR gate must be false. Thus, input C must be FALSE, and the output of the NAND gate must also be false. The NAND gate is false only when both of its inputs are TRUE; thus, inputs A and B must both be TRUE. The final answer is (TRUE, TRUE, FALSE), or **(1, 1, 0)**.

2. We'll use a truth table to solve this problem. The rows in the truth table will correspond to all possible inputs - 16 in this case, since there are 4 inputs. From the truth table, there are **10** rows where the final output is TRUE.

3. The circuit can be simplified to **0**, or always false.