Lab 4

First Stage

Cyber Security Science Department

Computer Organization and Logic Design

Lab 4: NAND and XOR Gates

By

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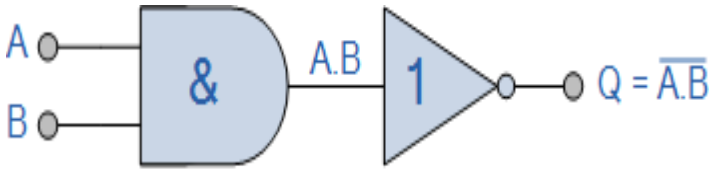
NAND and XOR Gates

1. NAND Gate

- The NAND gate is a popular logic element because it can be used as a universal gate; that is, NAND gates can be used in combination to perform the AND, OR, and inverter operations.
- The NAND gate is equivalent to an AND gate followed by NOT gate
- Boolean Expression Q =A B

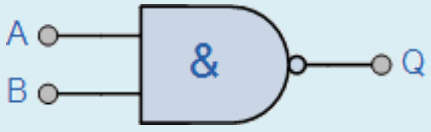
1.1 Logic NAND Gate Equivalence



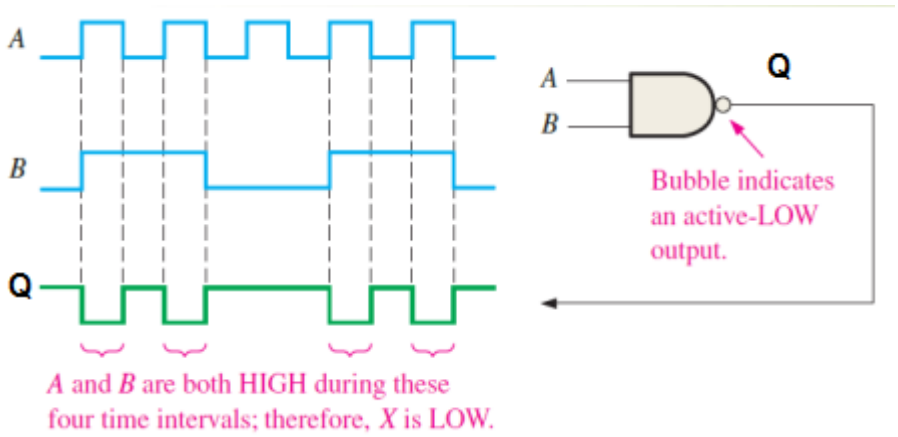
2-input "AND" gate plus a "NOT" gate

The logic or Boolean expression given for a logic NAND gate is that for *Logical Addition*, which is the opposite to the AND gate, and which it performs on the *complements* of the inputs. The Boolean expression for a logic NAND gate is denoted by a single dot or full stop symbol, (**.**) with a line or *Overline*, (¯) over the expression to signify the NOT or logical negation of the NAND gate giving us the Boolean expression of: $\overline{A.B} = Q$.

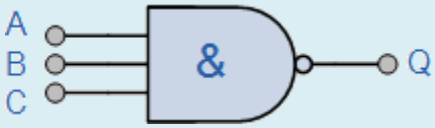
- **2-input Logic NAND Gate**

<table>
<tr><th>Symbol</th><th colspan="3">Truth Table</th></tr>
<tr><td rowspan="5"> 

2-input NAND Gate</td><td>B</td><td>A</td><td>Q</td></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>
<tr><td>Boolean Expression Q = $\overline{A.B}$</td><td colspan="3">Read as A AND B gives NOT Q</td></tr>
</table>

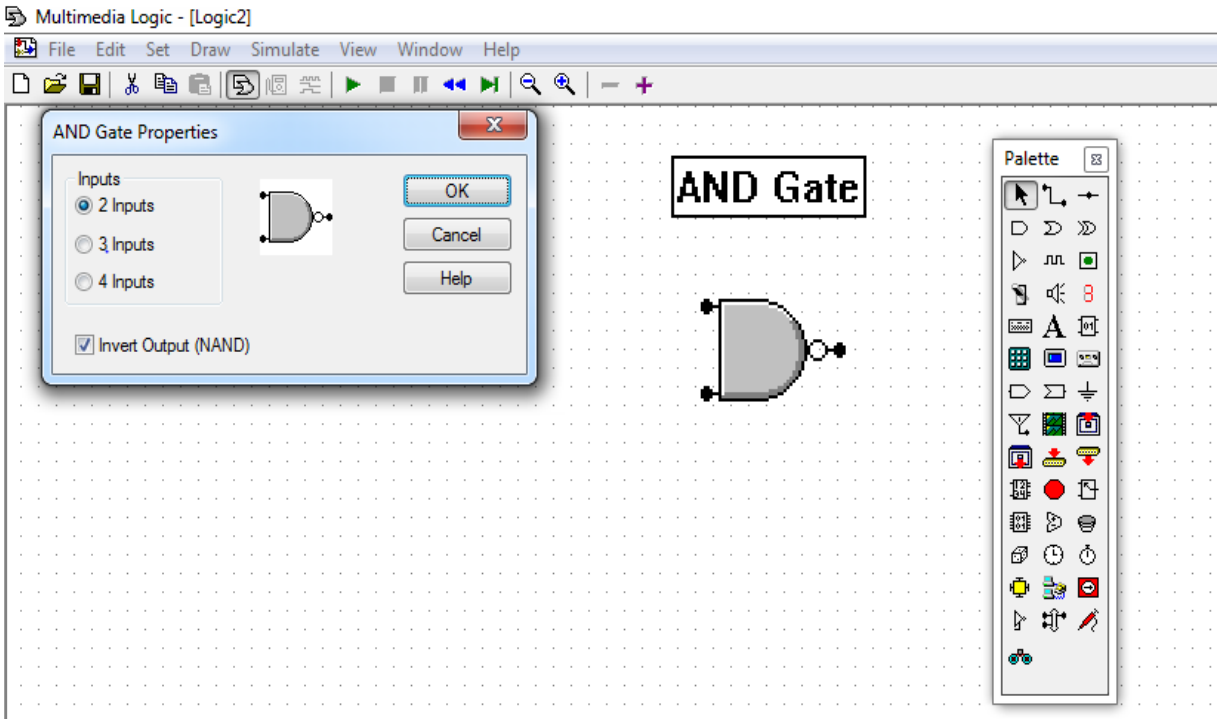


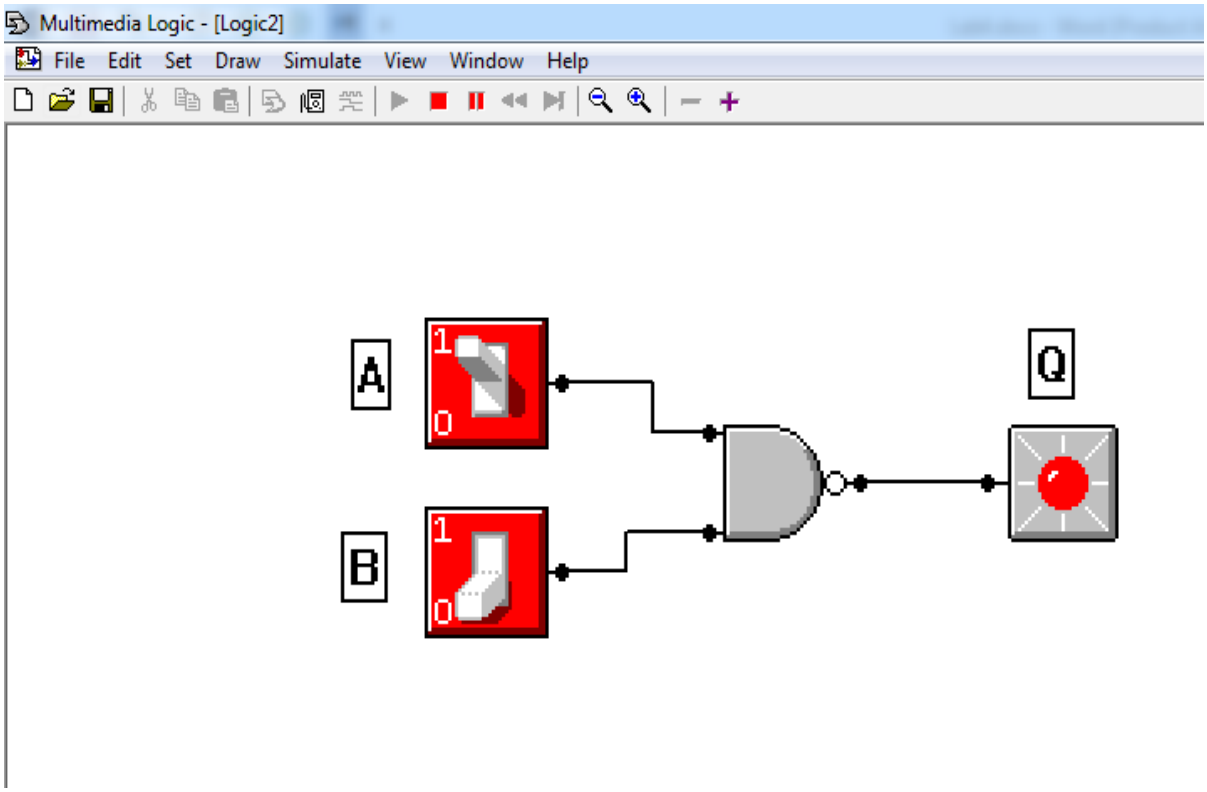
3-input Logic NAND Gate

Symbol	Truth Table			
 **3-input NAND Gate**	C	B	A	Q
	0	0	0	1
	0	0	1	1
	0	1	0	1
	0	1	1	1
	1	0	0	1
	1	0	1	1
	1	1	0	1
	1	1	1	0
Boolean Expression Q = $\overline{\boldsymbol{A}.\boldsymbol{B}.\boldsymbol{C}}$	Read as A **AND** B **AND** C gives **NOT** Q			

1.2 Implementation

1. AND gate with check Invert Output (NAND)



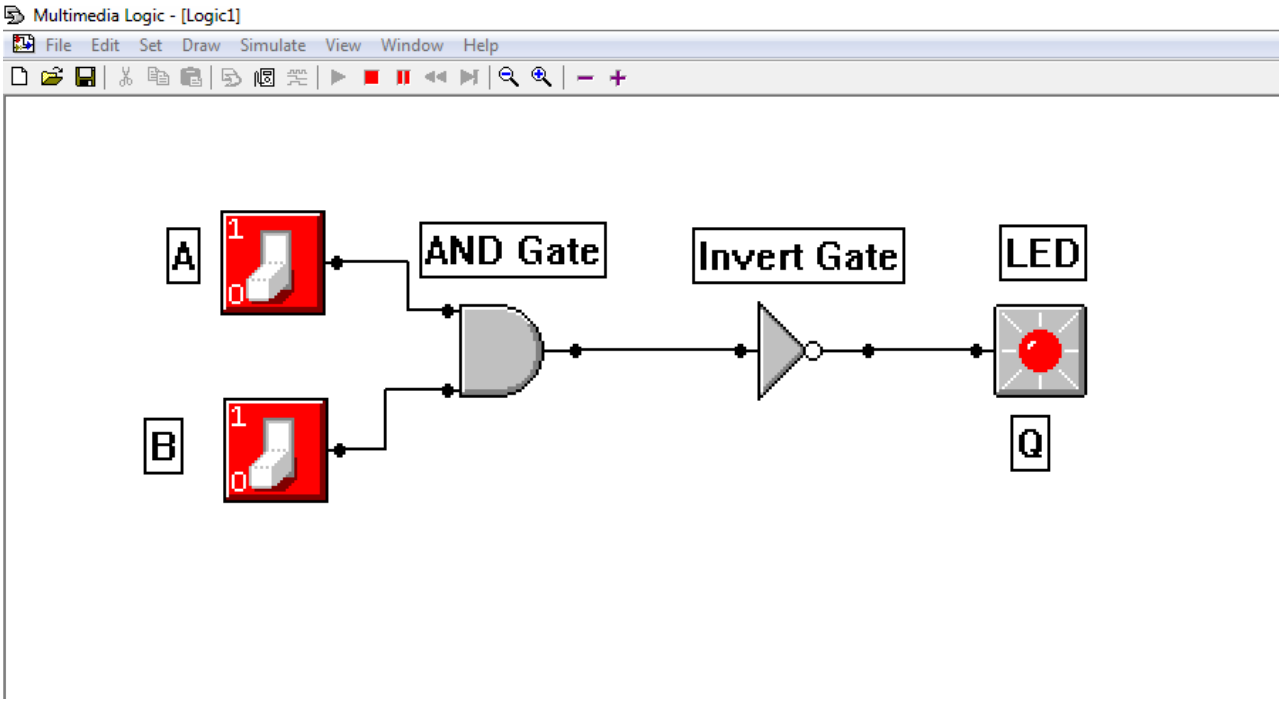


Truth Table

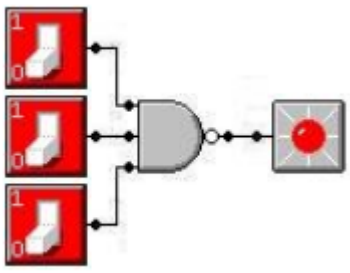
Switches		LED
0	**0**	**Lit / 1**
0	**1**	**Lit / 1**
1	**0**	**Lit / 1**
1	**1**	**Dark / 0**

NAND is short for Negative And. This gate combines an And Gate with its output connected through an Inverter Gate in one device. It will output a "0" only if both its inputs are a "1"

2. Use AND + NOT Gate



❖ 3-Input NAND Gate



Truth Table

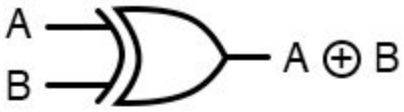
Switches			LED
0	**0**	**0**	**Lit / 1**
0	**0**	**1**	**Lit / 1**
0	**1**	**0**	**Lit / 1**
0	**1**	**1**	**Lit / 1**
1	**0**	**0**	**Lit / 1**
1	**0**	**1**	**Lit / 1**
1	**1**	**0**	**Lit / 1**
1	**1**	**1**	**Dark / 0**

This gate will output a "0" only if all of its inputs are a "1"

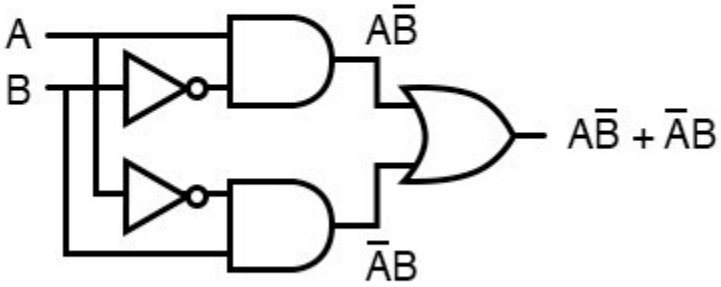
2. The Exclusive-OR Gate (XOR Gate)

The exclusive-OR gate performs modulo-2 addition. Standard symbols for an exclusive OR (X-OR) gate and Boolean expression for the output of a 2-input XOR gate can be written as:

$$\boldsymbol{Q = \bar{A}B + A\bar{B} = A \oplus B}$$



. . . is equivalent to . .

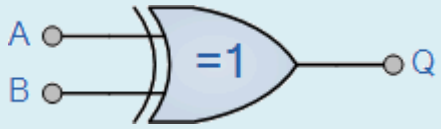


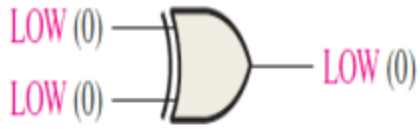
$$A \oplus B = A\bar{B} + \bar{A}B$$

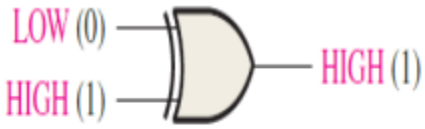
The X-OR gate has only two inputs. The four possible input combinations and the

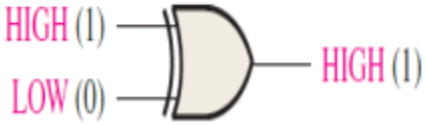
resulting outputs for an X-OR gate. The operation of an X-OR gate is summarized in the truth table shown

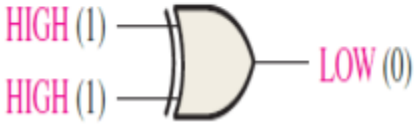
2-input XOR Gate

Symbol	**Truth Table**		
 **2-input Ex-OR Gate**	B	A	Q
	0	0	0
	0	1	1
	1	0	1
	1	1	0
Boolean Expression Q = A ⊕ B	A **OR** B but NOT **BOTH** gives Q		







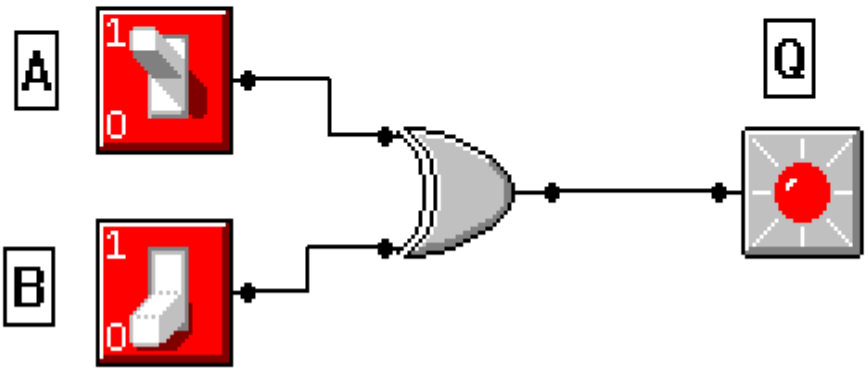


(Homework)

Giving the Boolean expression of:

$$Q = \overline{ABC} + AB\overline{C} + A \oplus B \oplus C$$

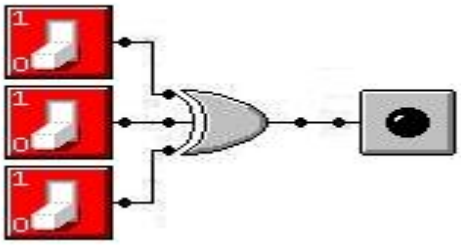
2.1 Implementation



Truth Table

Switches		LED
0	0	Dark / 0
0	1	Lit / 1
1	0	Lit / 1
1	1	Dark / 0

3-Input XOR Gate



Switches			LED
0	0	0	Dark / 0
0	0	1	Lit / 1
0	1	0	Lit / 1
0	1	1	Dark / 0
1	0	0	Lit / 1
1	0	1	Dark / 0
1	1	0	Dark / 0
1	1	1	Lit / 1

XOR is short for Exclusive Or. This gate will output a "1" if only one or all of its inputs are a "1"

2.2 XOR Circuit