Course: Basic Electronics (EC21101)

Course Instructor: Prof. Kapil Debnath

Lecture 9: Digital Logic gates

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Logic Gates

A logic gate is an elementary building block of a digital circuit. Most logic gates have two inputs and one output. At any given moment, every terminal is in one of the two binary conditions low (0) or high (1), represented by different voltage levels. The logic state of a terminal can, and generally does, change often, as the circuit processes data. In most logic gates, the low state is approximately zero volts (0 V), while the high state is approximately five volts positive (+5 V).

There are three basic logic gates: NOT, AND, OR

Two universal gates: NAND, NOR

Two Derived gates: XOR, XNOR

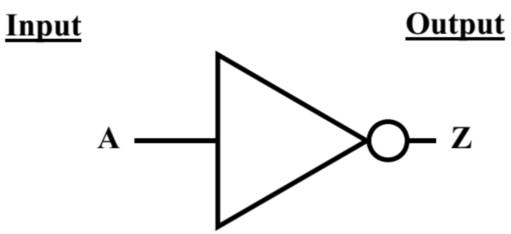
In this course we will study the basic gates and universal gates and simple digital circuits by combining some of the logic gates.

Truth table of Logic Gates

Truth tables specify how logic circuit's output depends on the logic levels present at the inputs.

BASIC GATES

NOT gate

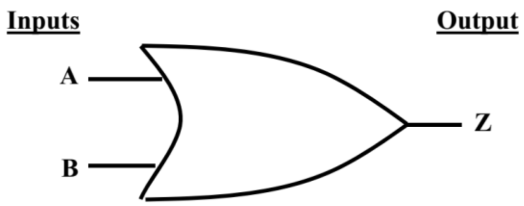


Logic Function: $Z = \overline{A}$

Truth table

Input	Output
A	**Z**
0	1
1	0

OR gate

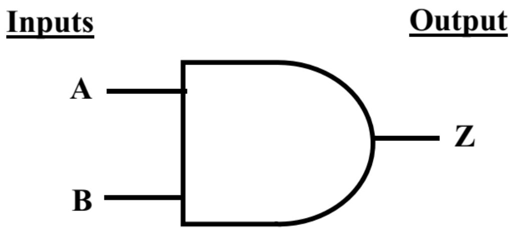


Logic Function: $Z = A + B$

Truth table

Inputs		Output
A	**B**	**Z**
0	0	0
0	1	1
1	0	1
1	1	1

AND gate



Logic Function: $Z = AB$

Truth table

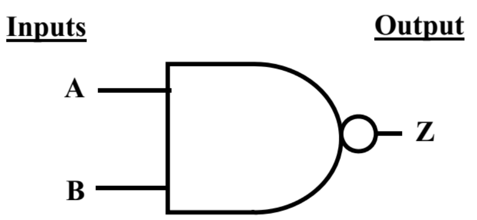
Inputs		Output
A	**B**	**Z**
0	0	0
0	1	0
1	0	0
1	1	1

Truth table of Logic Gates

A universal gate is a gate which can implement any Boolean function without need to use any other gate type. The NAND and NOR gates are universal gates.

UNIVERSAL GATES

NAND gate

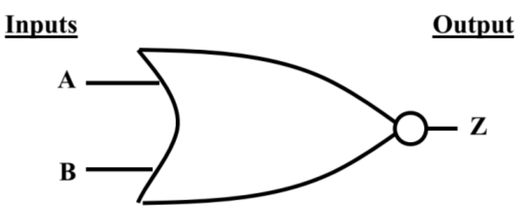


Logic Function: $Z = \overline{AB}$

Truth table

Inputs		Output
A	B	Z
0	0	1
0	1	1
1	0	1
1	1	0

NOR gate



Logic Function: $Z = \overline{A + B}$

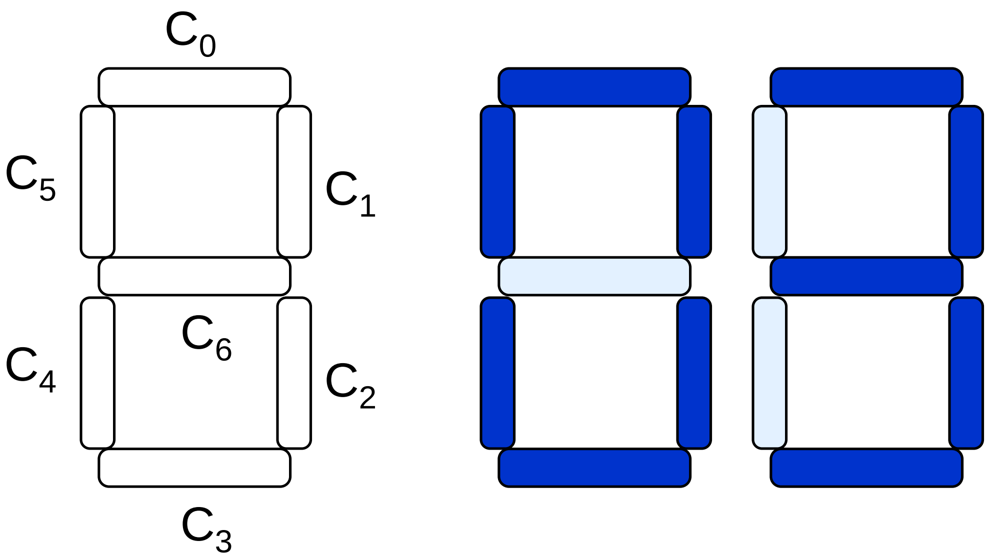
Truth table

Inputs		Output
A	B	Z
0	0	1
0	1	0
1	0	0
1	1	0

Example of a digital system

Lets say we want to display number '3' (i.e. binary 11).

When any of the display segment (C0 to C6) gets logic 1 (say 5V) it will glow



The truth table of the circuit to display number '3' becomes:

Input	C_0	C_1	C_2	C_3	C_4	C_5	C_6
1	1	1	1	1	1	1	0
1	1	1	1	1	0	0	1

Using the logic gates we can build a digital circuit to perform this task

De Morgan’s theorem

De Morgan’s Theorems are used to simplify Boolean expressions

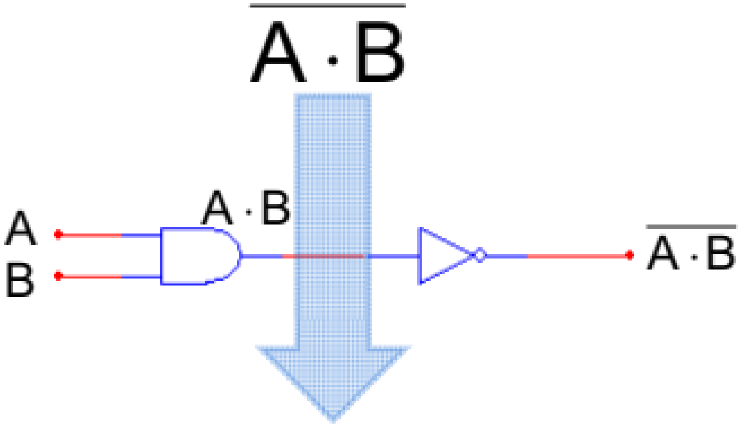
De Morgan’s First Theorems

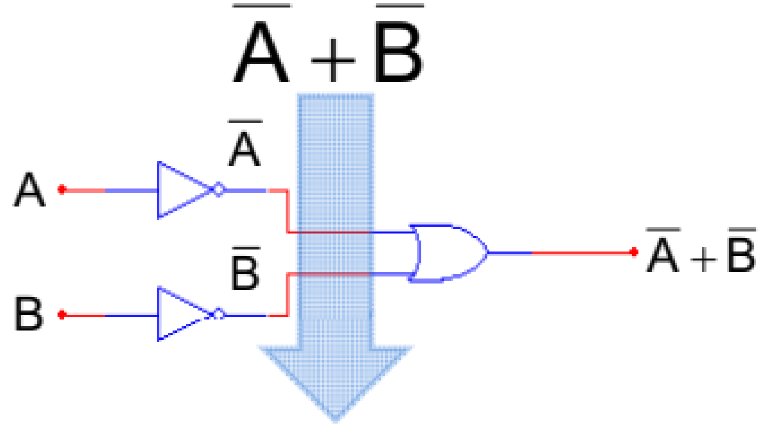
$$\overline{A + B} = \overline{A} \cdot \overline{B}$$

De Morgan’s Second Theorems

$$\overline{A \cdot B} = \overline{A} + \overline{B}$$

Proof of De Morgan's first theorem





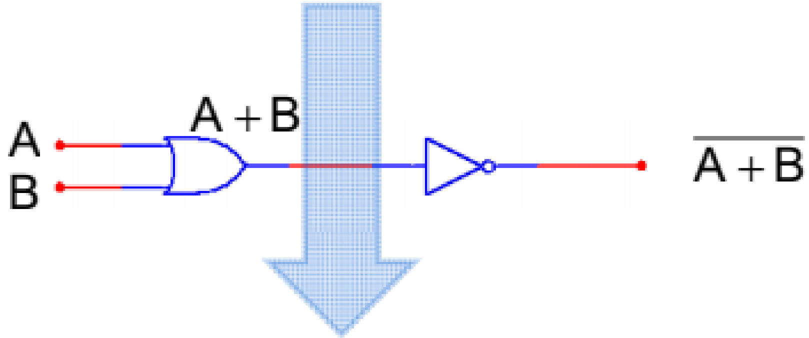
A	B	$A \cdot B$	$\overline{A \cdot B}$
0	0	0	1
0	1	0	1
1	0	0	1
1	1	1	0

A	B	$\overline{A}$	$\overline{B}$	$\overline{A} + \overline{B}$
0	0	1	1	1
0	1	1	0	1
1	0	0	1	1
1	1	0	0	0

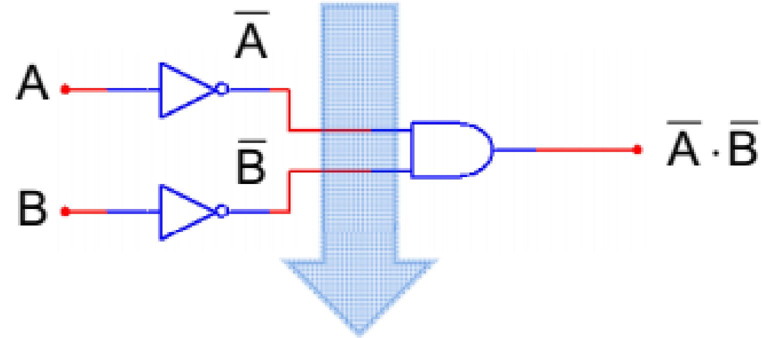
The truth-tables are equal; therefore, the Boolean equations must be equal.

Proof of De Morgan's second theorem

$$\overline{A + B}$$



$$\overline{A} \cdot \overline{B}$$



A	B	$A + B$	$\overline{A + B}$
0	0	0	1
0	1	1	0
1	0	1	0
1	1	1	0

A	B	$\overline{A}$	$\overline{B}$	$\overline{A} \cdot \overline{B}$
0	0	1	1	1
0	1	1	0	0
1	0	0	1	0
1	1	0	0	0

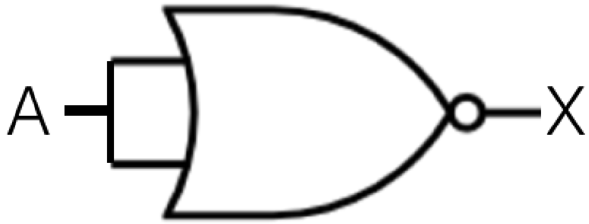
The truth-tables are equal; therefore, the Boolean equations must be equal.

Realizing Basic gates using universal gates

NOT gate

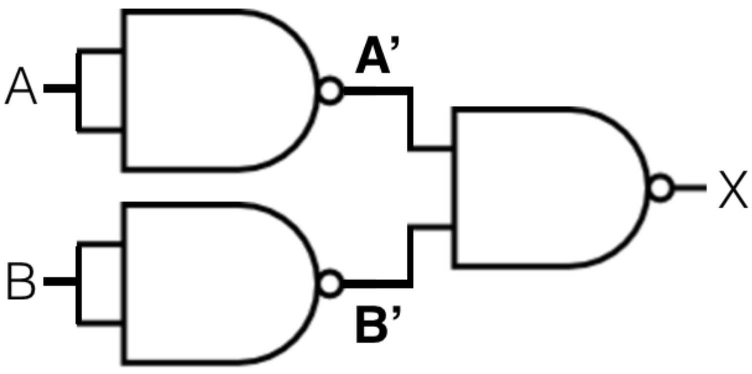
Using NAND gate

Using NOR gate

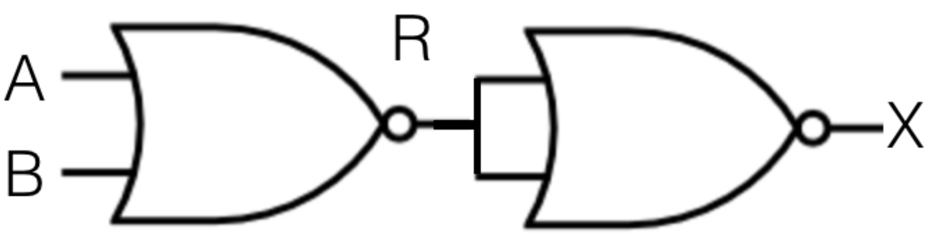


OR gate

Using NAND gate



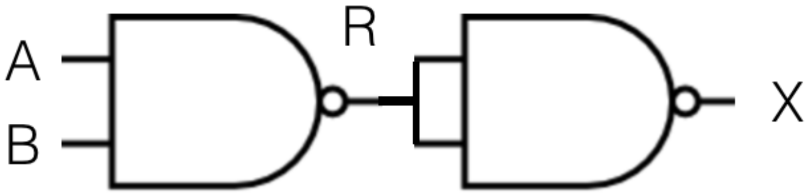
Using NOR gate



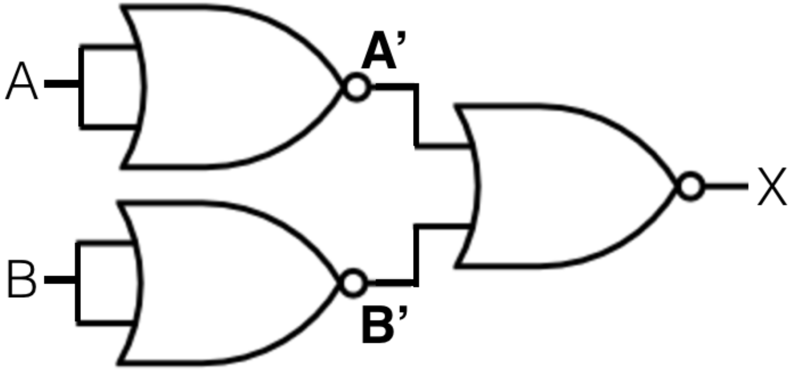
Realizing Basic gates using universal gates

AND gate

Using NAND gate



Using NOR gate

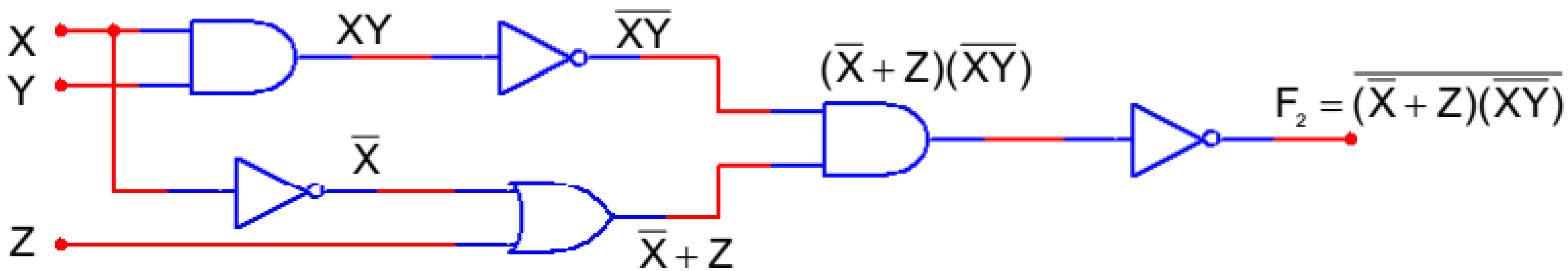


Use of De Morgan's theorem for circuit design

Realize a logic circuit to perform the following logic function

$$F = \overline{\left(\overline{X \cdot \bar{\bar{Y}}}\right) \cdot (\bar{Y} + Z)}$$

Without using De Morgan's theorem



By using De Morgan's theorem

$$F = \overline{\left(\overline{X \cdot \bar{\bar{Y}}}\right) \cdot (\bar{Y} + Z)} = \overline{\left(\overline{X \cdot \bar{\bar{Y}}}\right)} + \overline{(\bar{Y} + Z)} = X \cdot \bar{Y} + \left(\bar{\bar{Y}} \cdot \bar{Z}\right) = X\bar{Y} + Y\bar{Z}$$