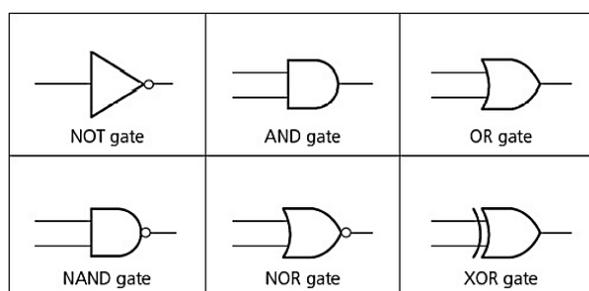


### Objective:

- ☞ Identify and use the standard symbols for logic gates
- ☞ Define and understand the functions of logic gates Including: – NOT – AND – OR – NAND – NOR – XOR (EOR)
- ☞ Use logic gates to create given logic circuits from a: (i) problem statement (ii) logic expression (iii) truth table
- ☞ Logic circuits will be limited to a maximum of three inputs and one output
- ☞ Complete a truth table from a: (i) problem statement (ii) logic expression (iii) logic circuit
- ☞ Write a logic expression from a: (i) problem statement (ii) logic circuit (iii) truth table

**Logic gate** is simple electronic circuit which process **two states** signal according to logical rule. Each gate has one or more inputs and single output.

### Example of Logic Gate:



Logic gates take **binary inputs** and produce a binary output. Several **logic gates** combined together form a **logic circuit**.

### Truth Table:

Truth tables are used to show **logic gate functions**. NOT gate has only one input, but all others have two inputs.

When constructing a truth table, binary values 1 and 0 are used. Every possible combination, depending on number of inputs, is produced. Number of possible combinations of 1s and 0s is  $2^n$ , where  $n$  = number of inputs.

**For example**, 2 inputs have  $2^2$  combinations (i.e. 4), 3 inputs have  $2^3$  combinations (i.e. 8) and so on.

Inputs	
A	B
0	0
0	1
1	0
1	1

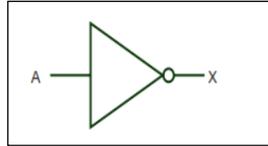
Inputs		
A	B	C
0	0	0
0	0	1
0	1	0
0	1	1
1	0	0
1	0	1
1	1	0
1	1	1

## Logic Circuits and Logic Gates

### NOT Gate:

Not Gate have only one input. Its main function is to invert input signal applied. If applied input is zero then the output becomes one and vice versa.

INPUT	OUTPUT
A	NOT A
0	1
1	0



We can write this as

$$X = \text{NOT } A \quad (\text{logic notation})$$

$$X = \bar{A} \quad (\text{Boolean algebra})$$

### AND Gate

Output (X) is true (i.e. 1 or ON) if: INPUT A AND INPUT B are BOTH TRUE (i.e. 1 or ON).

AND gate can be written as:

$$X = A \text{ AND } B \quad (\text{logic notation})$$

$$X = A \cdot B \quad (\text{Boolean algebra})$$



INPUT A	INPUT B	OUTPUT X
0	0	0
0	1	0
1	0	0
1	1	1

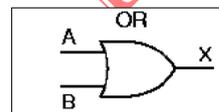
### OR Gate

Output (X) is true (i.e. 1 or ON) if: INPUT A OR INPUT B is TRUE (i.e. 1 or ON)

OR gate can be written as:

$$X = A \text{ OR } B \quad (\text{logic notation})$$

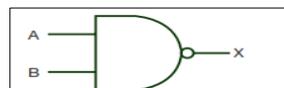
$$X = a + b \quad (\text{Boolean algebra})$$



INPUT A	INPUT B	OUTPUT X
0	0	0
0	1	1
1	0	1
1	1	1

### NAND Gate

Output (X) is true (i.e. 1 or ON) if: INPUT A AND INPUT B are NOT BOTH TRUE (i.e. 1 or ON).



NAND gate can be written as :

$$X = A \text{ NAND } B \quad (\text{logic notation})$$

$$X = \overline{a \cdot b} \quad (\text{Boolean algebra})$$

INPUT A	INPUT B	OUTPUT X
0	0	1
0	1	1
1	0	1
1	1	0

### NOR Gate

Output (X) is true (i.e. 1 or ON) if: INPUT A OR INPUT B are NOT BOTH TRUE (i.e. 1 or ON)

$$X = A \text{ NOR } B \quad (\text{logic notation})$$

$$X = \overline{a + b} \quad (\text{Boolean algebra})$$



INPUT A	INPUT B	OUTPUT X
0	0	1
0	1	0
1	0	0
1	1	0

# 3.3 Boolean Logic EMK Notes

## XOR (EOR) Gate:



$$X = A \text{ XOR } B \text{ (logic notation)}$$

Output, X, is 1 if:  
(input A is 1 **AND** input B is 0)  
**OR**  
(input A is 0 **AND** input B is 1)

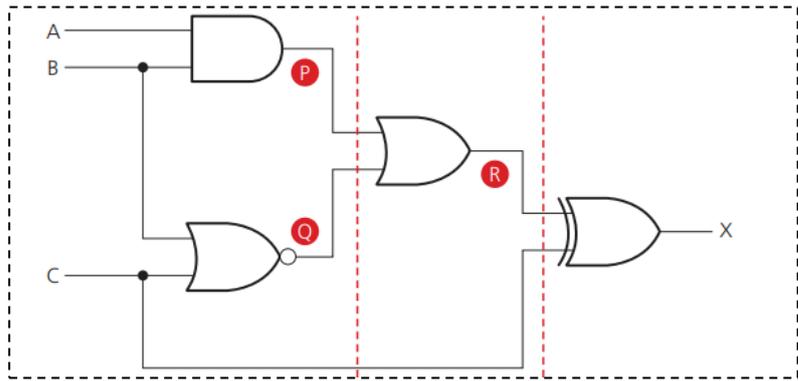
INPUT A	INPUT B	OUTPUT X
0	0	0
0	1	1
1	0	1
1	1	0

In Boolean Algebra, . represents the AND operation, + represents the OR operation and a bar above the letter represents the NOT operation.

## Logic Circuit

When logic gates are combined together to carry out particular function, such as controlling a robot, they form a logic circuit. Output from a logic circuit (network) is checked by producing a truth table.

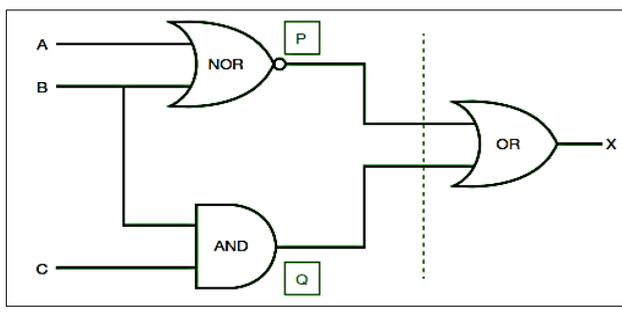
### Example # 1



Truth Table for above logic gate is as below,

Input values			Intermediate values			Output
A	B	C	P	Q	R	X
0	0	0	0	1	1	1
0	0	1	0	0	0	1
0	1	0	0	0	0	0
0	1	1	0	0	0	1
1	0	0	0	1	1	1
1	0	1	0	0	0	1
1	1	0	1	0	1	1
1	1	1	1	0	1	0

Home Task: Write truth table for following logic circuit.

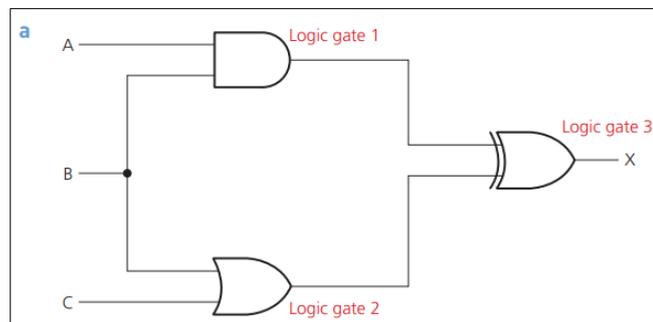


There are **three** inputs to logic circuit, so there will be **eight** possible binary values which can be input.

INPUT A	INPUT B	INPUT C	OUTPUT X
0	0	0	1
0	0	1	1
0	1	0	0
0	1	1	1
1	0	0	0
1	0	1	0
1	1	0	0
1	1	1	1

**Example 2**

Write logic expressions of following logic circuits:



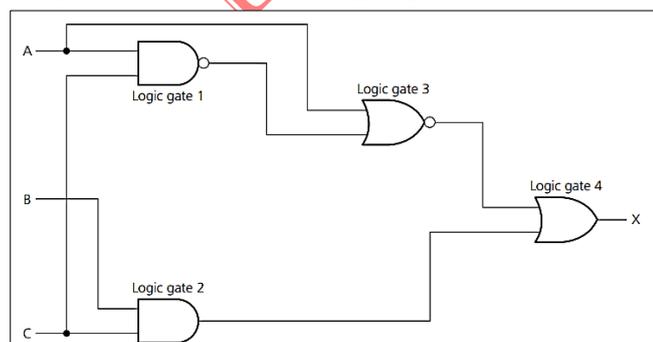
logic gate 1:  $(A \text{ AND } B)$

logic gate 2:  $(B \text{ OR } C)$

Now join Logic Gate 1 and Logic Gate 2 together using logic gate 3:

Logic Expression :  $(A \text{ AND } B) \text{ XOR } (B \text{ OR } C)$

Home Task: Write logic expressions of following logic circuits.



logic gate 1:  $(A \text{ NAND } C)$

logic gate 2:  $(B \text{ AND } C)$

logic gate 3: (logic gate 1) NOR A, Replace (logic gate 1) by expression  $((A \text{ NAND } C) \text{ NOR } A)$

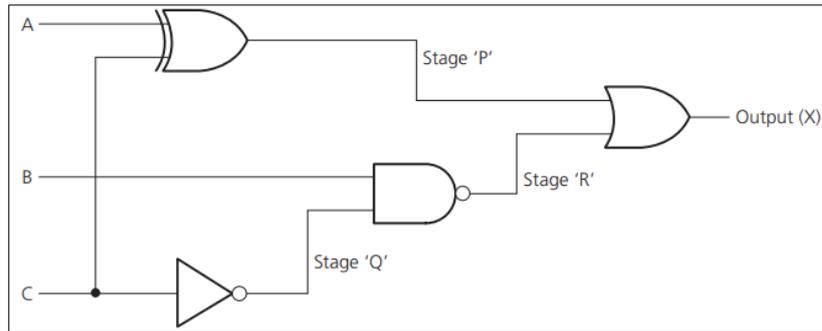
Final logic Gate 4:  $((A \text{ NAND } C) \text{ NOR } A) \text{ OR } (B \text{ AND } C)$

**Example 3**

Produce a logic circuit and a truth table from logic statement.

## 3.3 Boolean Logic EMK Notes

$(A \text{ XOR } C) \text{ OR } (\text{NOT } C \text{ NAND } B)$



**Truth Table of above Circuit:**

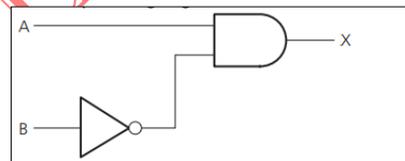
Input values			Values at stages:			Output
A	B	C	'P'	'Q'	'R'	X
0	0	0	0	1	1	1
0	0	1	1	0	1	1
0	1	0	0	1	0	0
0	1	1	1	0	1	1
1	0	0	1	1	1	1
1	0	1	0	0	1	1
1	1	0	1	1	0	1
1	1	1	0	0	1	1

### Example 4

Produce a logic expression and logic circuit from truth table

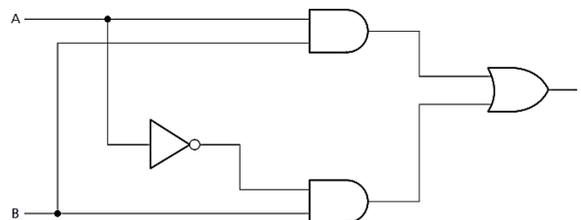
Inputs		Output
A	B	X
0	0	0
0	1	0
1	0	1
1	1	0

**Logic expression: A AND NOT B**



Inputs		Output
A	B	X
0	0	0
0	1	1
1	0	0
1	1	1

**Logic Expression: (NOT A AND B) OR (A AND B)**



A	B	C	X
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	1
1	0	0	0
1	0	1	1
1	1	0	1
1	1	1	1

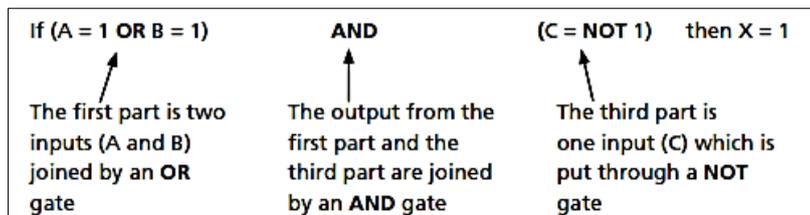
**Logic Expression from Truth Table**  
 (NOT A AND B AND C) OR (A AND NOT B AND C)  
 OR (A AND B AND NOT C) OR (A AND B AND C)

**Example 5**

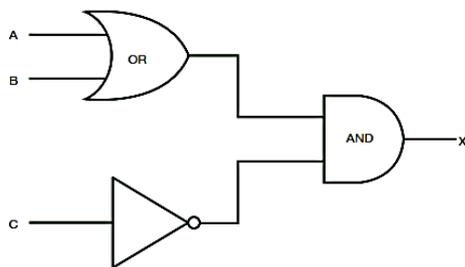
Consider following problem.

System used 3 switches A, B, C; Combination of switches determines whether alarm, X, sounds: **If switch A or switch B are in the ON position and if switch C is in OFF position then a signal to sound an alarm, X is produced.**

It is possible to convert this problem into a logic statement.



So we get following logic circuit.



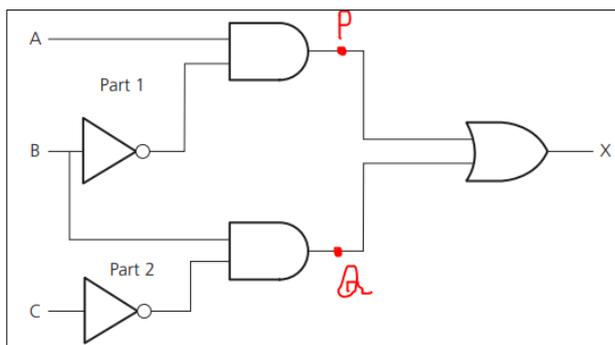
INPUT A	INPUT B	INPUT C	OUTPUT X
0	0	0	0
0	0	1	0
0	1	0	1
0	1	1	0
1	0	0	1
1	0	1	0
1	1	0	1
1	1	1	0

**Home Task: System uses three inputs to a logic circuit.**

Alarm, X, sounds if input A represents ON and input B represents OFF; or if input B represents ON and input C represents OFF.

Produce a logic circuit and truth table.

**Ans:** Logic expression: (A AND NOT B) OR (B AND NOT C)



Inputs			Intermediate values		Output
A	B	C	P	Q	X
0	0	0	0	0	0
0	0	1	0	0	0
0	1	0	0	1	1
0	1	1	0	0	0
1	0	0	1	0	1
1	0	1	1	0	1
1	1	0	0	1	1
1	1	1	0	0	0

# 3.3 Boolean Logic EMK Notes

### Example 6

Manufacturing process is controlled by built in logic circuit which is made of AND, OR and NOT gates only. Process receives STOP signal (i.e.  $X = 1$ ) depending on following conditions,

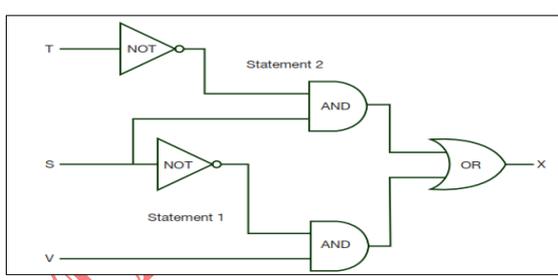
INPUTS	BINARY VALUES	CONDITION IN PROCESS
V	1	Volume > 1000 litres
	0	Volume <= 1000 litres
T	1	Temperature > 750°C
	0	Temperature <= 750°C
S	1	Speed > 15 metres/second (m/s)
	0	Speed <= 15 metres/ second (m/s)

**A stop signal ( $X = 1$ ) occurs when:**  
 either Volume,  $V > 1000$  litres **and** Speed,  $S \leq 15$  m/s  
 or Temperature,  $T \leq 750^\circ\text{C}$  **and** Speed,  $S > 15$  m/s

Draw logic circuit and truth table.

**Logic statement :**

**$X = 1$  if ( $V = 1$  AND  $S = \text{NOT } 1$ )**  
**OR ( $T = \text{NOT } 1$  AND  $S = 1$ )**



**Truth Table:**

INPUT V	INPUT T	INPUT S	OUTPUT X
0	0	0	0
0	0	1	1
0	1	0	0
0	1	1	0
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	0

**Home Task:** A wind turbine has a safety system which uses three inputs to a logic circuit.

parameter description	parameter	binary value	description of condition
turbine speed	S	0	turbine speed <= 1000 rpm
		1	turbine speed > 1000 rpm
bearing temperature	T	0	bearing temperature <= 80°C
		1	bearing temperature > 80°C
wind velocity	W	0	wind velocity <= 120 kph
		1	wind velocity >120 kph

Output, X, have a value 1 if any of following combination of conditions occur:

- Either** turbine speed <= 1000 rpm and bearing temperature > 80°C
- Or** turbine speed > 1000 rpm and wind velocity > 120 kph
- Or** bearing temperature <= 80°C and wind velocity > 120 kph



Engr M Kashif

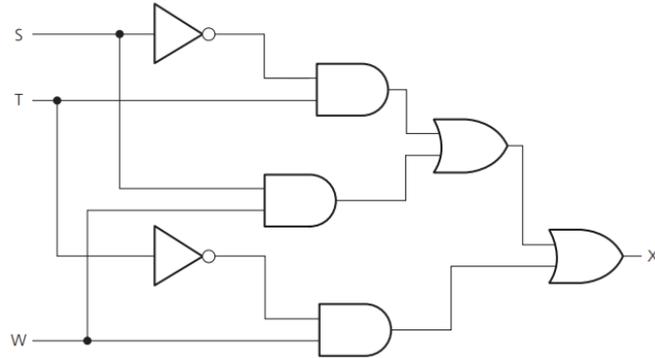
O/A level Computer Science

# Logic Gate Revision Notes BY EMK



Compiled By  
Engr M Kashif

Logic Circuit:



Inputs			Intermediate values				Output
S	T	W	(i) (NOT S AND T)	(ii) (S AND W)	(iii) (NOT T AND W)	(iv)	X
0	0	0	0	0	0	0	0
0	0	1	0	0	1	0	1
0	1	0	1	0	0	1	1
0	1	1	1	0	0	1	1
1	0	0	0	0	0	0	0
1	0	1	0	1	1	1	1
1	1	0	0	0	0	0	0
1	1	1	0	1	0	1	1

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