DIGITAL ELECTRONICS
Course Code: PCC-CSE-205G

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- The physical quantities occurring in real world are mostly analog in nature.
- These quantities are measured, monitored, recorded, manipulated arithmetically and observed in most physical systems.

These quantities can be represented in 2 ways:

1) Analog representation
2) Digital representation

ANALOG REPRESENTATION

The quantity is represented by a continuous range of values.

Example: Speedometer
Analog Thermometer

DIGITAL REPRESENTATION

The quantity is represented by discrete values.

Example: Digital Clock
Digital weighing Scale

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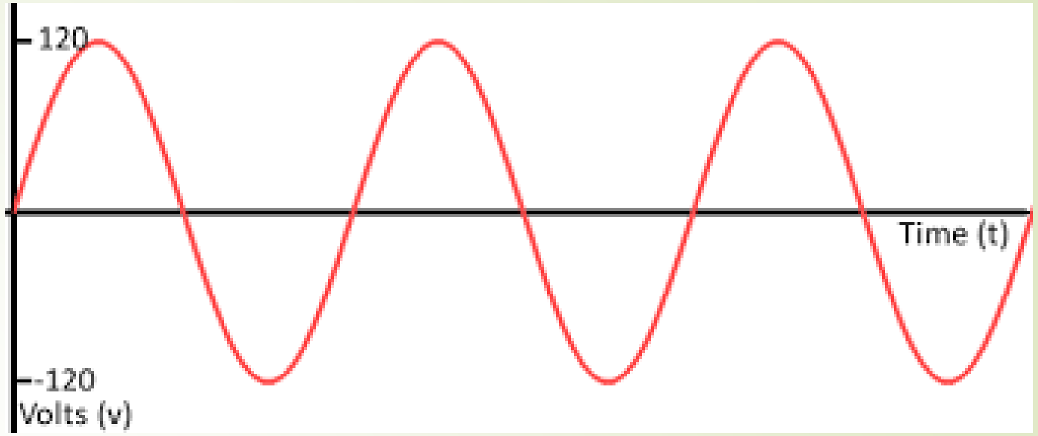
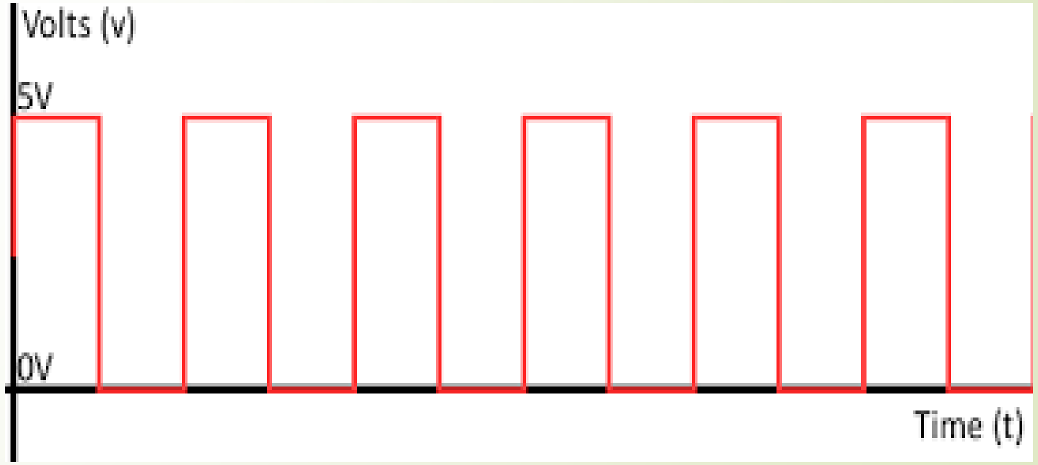
Analog Signals

- Continuous
- Infinite range of values
- More exact values , but are difficult to work with



Digital signals

- Discrete
- Finite range of values (binary ie. 2 values)
- Not as exact as analog, but easier to work with.



0 = 0 volts
1 = 5 volts

ADVANTAGES OF DIGITAL SYSTEM

1. Digital Systems are easier to design.
2. Information storage is easy.
3. Accuracy & precision are easier to maintain throughout the system.
4. Operations can be programmed.
5. Digital circuits are less affected by noise.
6. Digital circuits can be fabricated on IC chips

DISADVANTAGES OF DIGITAL SYSTEM

1. The real world is analogue in nature.
2. Digital systems can be fragile
3. Processing digitized signals takes time
4. Digital circuits use more energy than analogue circuits and produce more heat.
5. Digital circuits are sometimes more expensive.

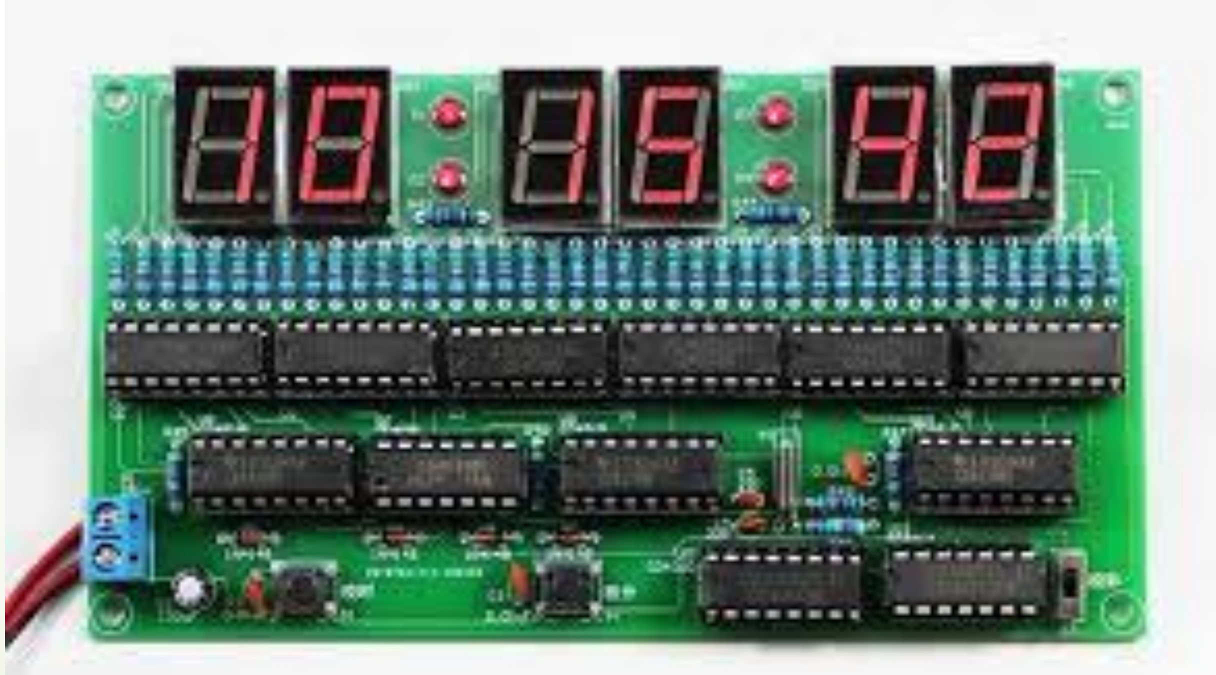
- Digital electronics or digital (electronic) circuits are electronics that operate on digital signals. In contrast, analog circuits manipulate analog signals.

- Digital electronics is a field of electronics involving the study of digital signals and the engineering of devices that use or produce them.

- The term digital in digital circuits is derived from the way circuits perform operations by counting digits.

- A digital circuit operates with binary numbers ie. Only in two state (0 and 1).

- Application of digital circuits:
  - Computers
  - Telephony
  - Data processing
  - Radar Navigation
  - Military Systems
  - Medical Instruments
  - Consumer products



- The most common fundamental unit of digital electronics is the logic gate. By combining numerous logic gates (from tens to hundreds of thousands) more complex systems can be created. The complex system of digital electronics is collectively referred to as a **digital circuit**.

- Digital circuits are usually made from large assemblies of logic gates, often packaged in integrated circuits.

- Each logic gate is designed to perform a function of Boolean logic when acting on logic signals.

- A logic gate is generally created from one or more electrically controlled switches, usually transistors (thermionic valves being used previously). The output of a logic gate can, in turn, control or feed into more logic gates.

LOGIC GATES

- A logic gate is a circuit which can have 2 or more number of inputs but only one output (except NOT gate).
- Logic gates process signals which represent true (1) or false (0). Normally the positive supply voltage +Vs represents true (1) and 0V represents false (0).
- Each gate has a distinct logic symbol and its operation can be described by means of an algebraic function.
- The relationship between input and output variables of each gate can be represented in a tabular form called a truth table.

Different kinds of logic gates:

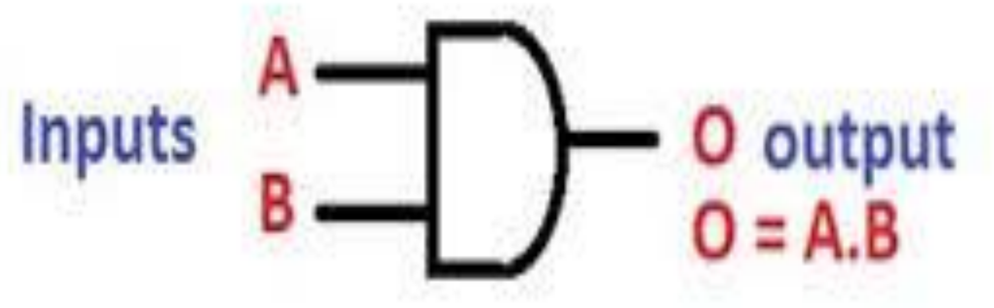
- AND gate
- OR gate
- Not Gate
- NAND gate
- NOR gate
- Ex-OR gate
- Ex-NOR gate

AND Gate

- The AND gate performs logical multiplication, commonly known as AND function
- AND gate has 2 or more inputs and 1 output.
- The output is high only when all the inputs are high

If A and B are 2 input variables of an AND gate and O is its output, then

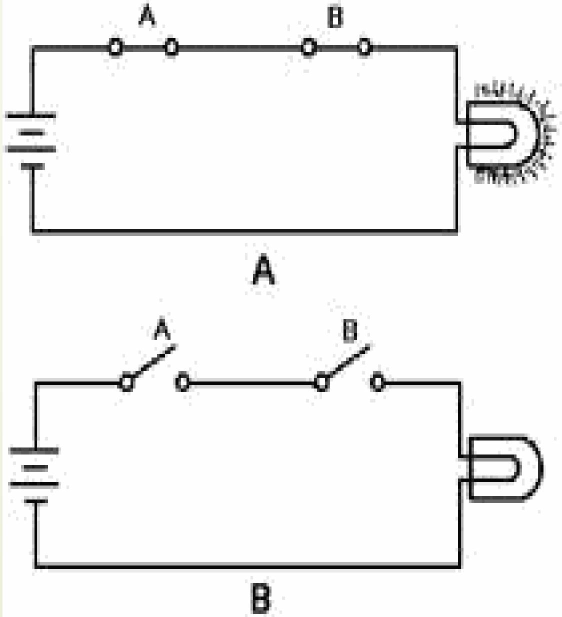
$$O = A . B$$



Symbol

Inputs		Output
A	B	O
0	0	0
0	1	0
1	0	0
1	1	1

Truth table



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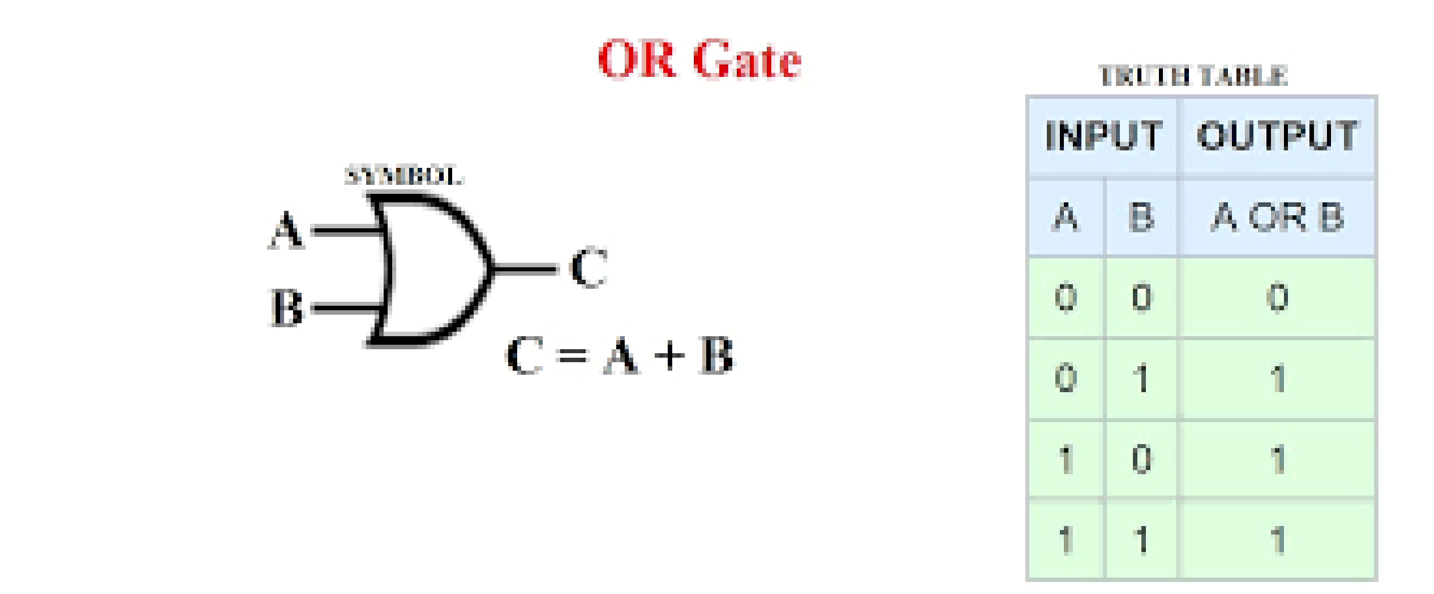
OR Gate

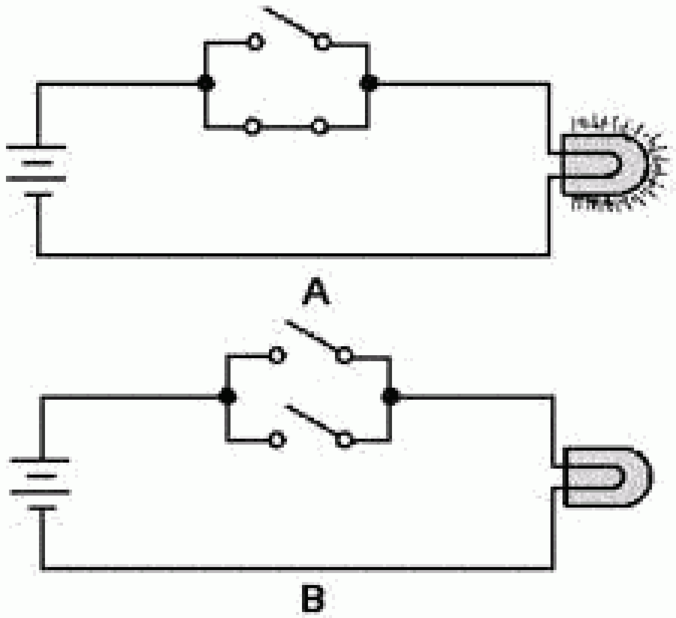
- The OR gate performs logical addition, commonly known as OR function
- OR gate has 2 or more inputs and 1 output.
- The output is high when any of the inputs is high. The output is low only when all the inputs are low.

If A and B are 2 input variables of an OR gate and C is its output, then

$$C = A + B$$



INPUT		OUTPUT
A	B	A OR B
0	0	0
0	1	1
1	0	1
1	1	1

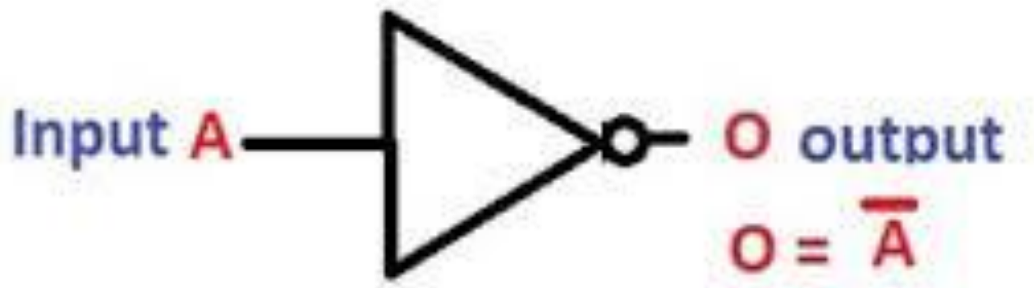


NOT Gate

- The NOT gate performs the basic logical function called inversion or complementation.
- It has one input and one output.
- When a high level is applied to an inverter, a low level appears at its output and vice versa.

If A represents the input and O represents the output then,

$$O = \overline{A}$$



Symbol

Inputs	Output
A	O
0	1
1	0

Truth table

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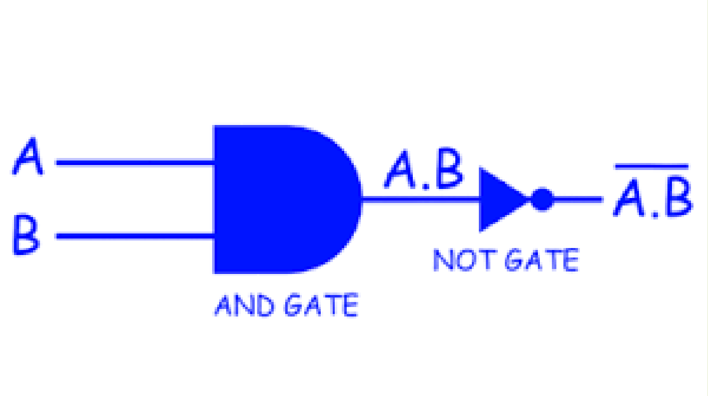
NAND Gate

- NAND is a contraction of the NOT-AND gates.
- It has 2 or more inputs and only 1 output.
- When all the inputs are High, the output is low. If any one or both the inputs are low, then the output is High.

Truth Table

INPUT		OUTPUT
A	B	A NAND B
0	0	1
0	1	1
1	0	1
1	1	0



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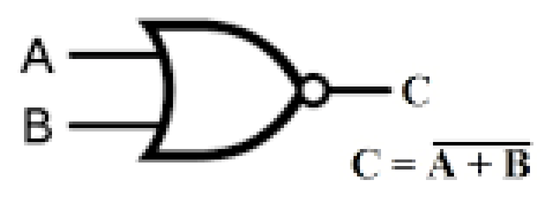
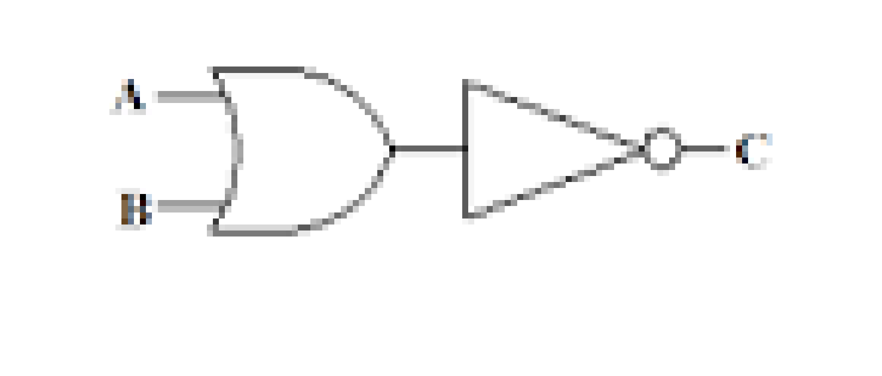
NOR Gate

- NOR is a contraction of the NOT-OR gates.
- It has 2 or more inputs and only 1 output.
- When all the inputs are low, the output is High. If any one or both the inputs are High, then the output is low.



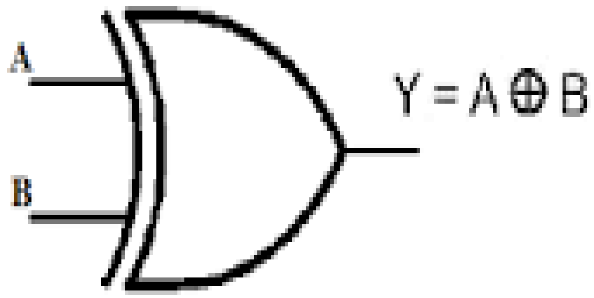
TRUTH TABLE

INPUT		OUTPUT
A	B	A NOR B
0	0	1
0	1	0
1	0	0
1	1	0

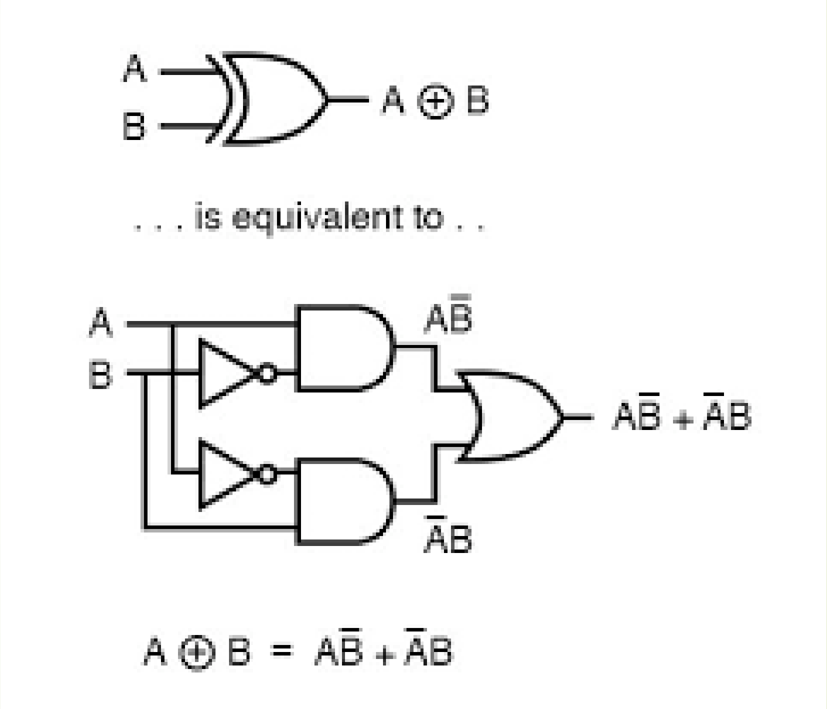


Ex-OR Gate

- The Exclusive-OR gate is a gate with 2 or more inputs and 1 output.
- The output is High if either input A or input B is High exclusively, and low when both are 1 or 0 simultaneously.

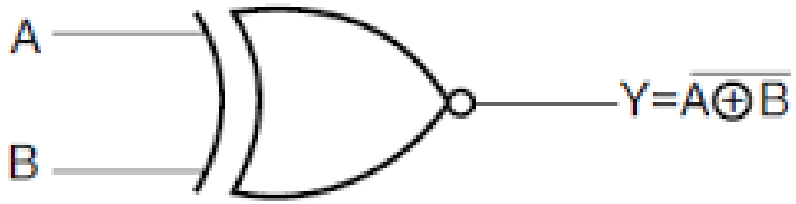


INPUT		OUTPUT
A	B	Y
0	0	0
0	1	1
1	0	1
1	1	0



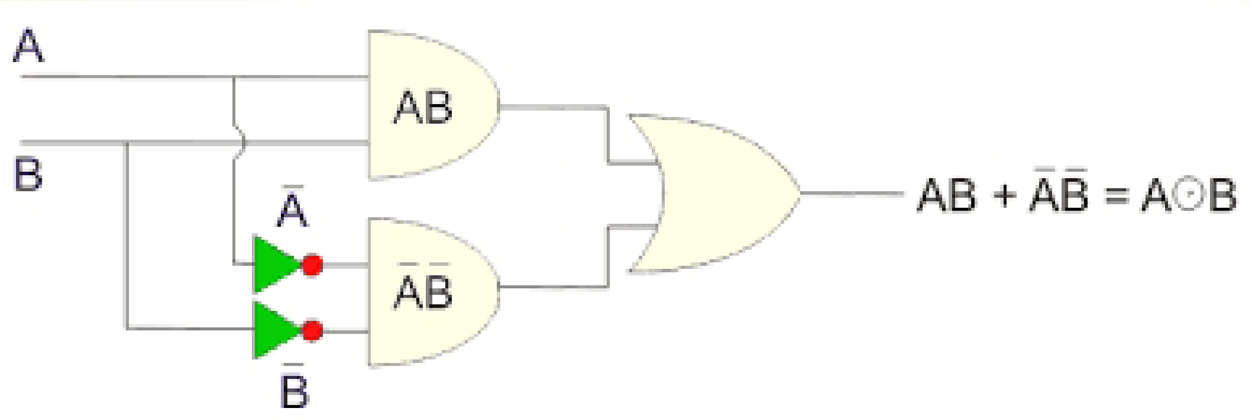
Ex- NOR Gate

- The Exclusive-NOR gate is a gate with 2 or more inputs and 1 output.
- The output is High if both the inputs assume the same logic state and its output is low when the inputs assume different logic states.



$$Y = (\overline{A \oplus B}) = (A.B + \overline{A}.\overline{B})$$

A	B	Y
0	0	1
0	1	0
1	0	0
1	1	1



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UNIVERSAL GATES

- NAND and NOR gates are called Universal gates or universal building blocks because both can be used to implement any gate like AND,OR and NOT or any combination of these basic gates.

SIMPLIFICATION OF DESIGN OF LOGIC CIRCUITS

- BOOLEAN ALGEBRA
- KARNAUGH MAP

BOOLEAN ALGEBRA

- Boolean algebra deals with the rules by which the logical operations are carried out.
- Here a digital circuit is represented by a set of input and output symbols and the circuit function expressed as a set of Boolean relationships between the symbols.

- Examples of Boolean expression : A, AB, $\overline{A}B+C$

- A Boolean function is an algebraic expression formed using binary constants, binary variables and basic logical operation symbols.
- Basic logical operations include AND function (logical multiplication), OR function (logical addition) and the NOT function (logical complementation).
- A Boolean function can be converted into a logic diagram composed of the AND, OR and NOT gates.

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Logical AND Operation

$$Y = A \cdot B$$

Logical OR operation

$$Y = A + B$$

Logical Complementation (Inversion)

$$Y = \overline{A}$$

NOT

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

AND

A	B	A · B
0	0	0
0	1	0
1	0	0
1	1	1

OR

A	B	A + B
0	0	0
0	1	1
1	0	1
1	1	1

BASIC LAWS OF BOOLEAN ALGEBRA

1) BOOLEAN ADDITION

0 + 0 = 0
0 + 1 = 1
1 + 0 = 1
1 + 1 = 1

2) BOOLEAN MULTIPLICATION

0 . 0 = 0
0 . 1 = 0
1 . 0 = 0
1 . 1 = 1

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3) PROPERTIES OF BOOLEAN ALGEBRA

- **Commutative Property** states that the interchanging of the order of operands in a Boolean equation does not change its result.

$$A + B = B + A$$
$$A . B = B . A$$

- **Associative Property**

$$A + (B + C) = (A + B) + C$$
$$A . (B . C) = (A . B) . C$$

- **Distributive Property**

$$A + BC = (A + B) (A + C)$$
$$A . (B + C) = A . B + A . C$$

- **Annulment law:**

  $A . 0 = 0$

  $A + 1 = 1$

- **Identity law:**

  $A . 1 = A$

  $A + 0 = A$

- **Idempotent law:**

  $A + A = A$

  $A . A = A$

- **Complement law:**

  $A + A' = 1$

  $A . A' = 0$

- **Double negation law**

$$((A)')' = A \quad \text{or} \quad \overline{\overline{A}} = A$$

- **Absorption law**

$$A \,.\, (A + B) = A$$
$$A + A \,.\, B = A$$
$$A + A'B = A + B$$
$$A \,.\, (A' + B) = AB$$

- **Consensus Laws**

$$AB + A'C + BC = AB + A'C$$
$$(A + B)(A' + C)(B + C) = (A + B)(A' + C)$$

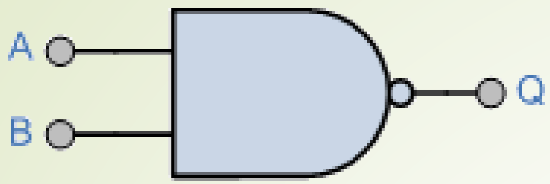
De Morgan’s Theorem

De Morgan's Law is also known as De Morgan's theorem, works depending on the principle of Duality. Duality states that interchanging the operators and variables in a function, such as replacing 0 with 1 and 1 with 0, AND operator with OR operator and OR operator with AND operator.

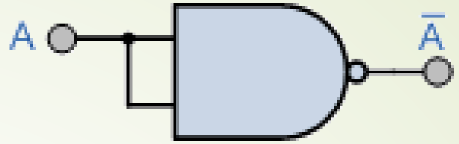
(A . B)’ = A' + B‘

(A + B)’ = A‘ . B'

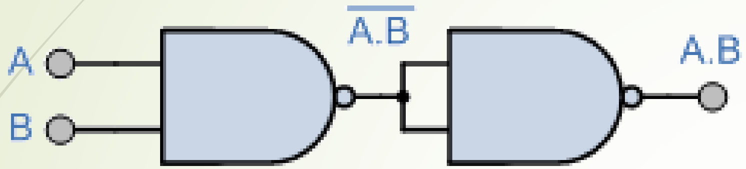
NAND Gate Symbol



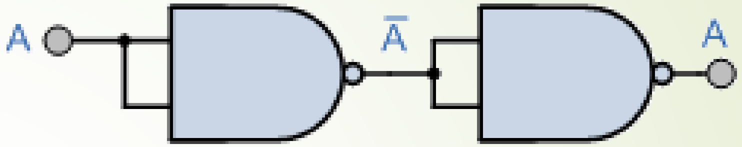
NOT Gate
(Inverter)



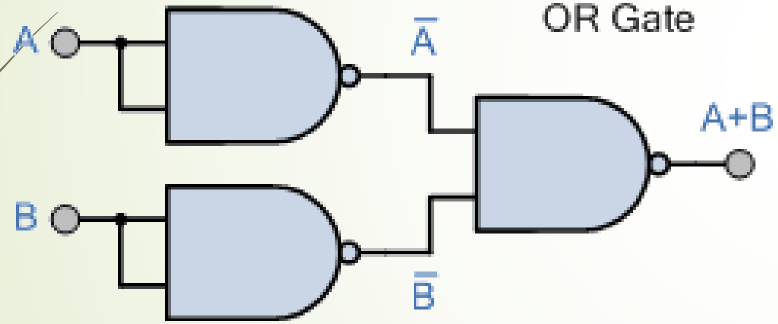
AND Gate



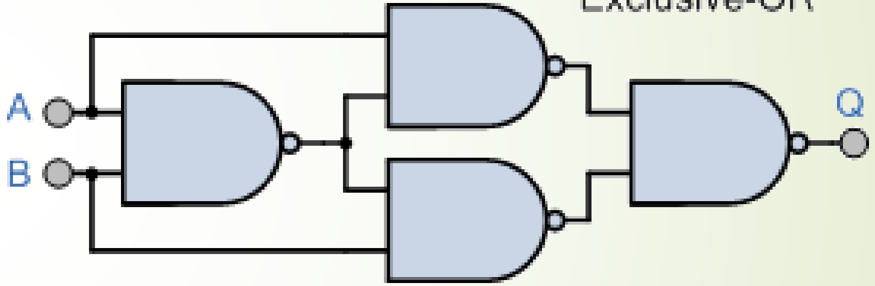
Buffer



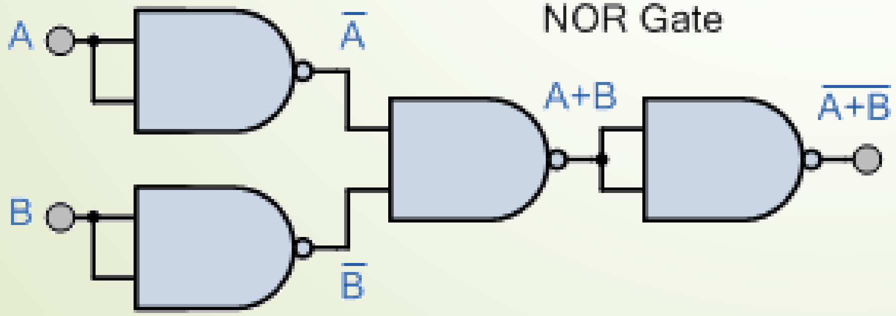
OR Gate



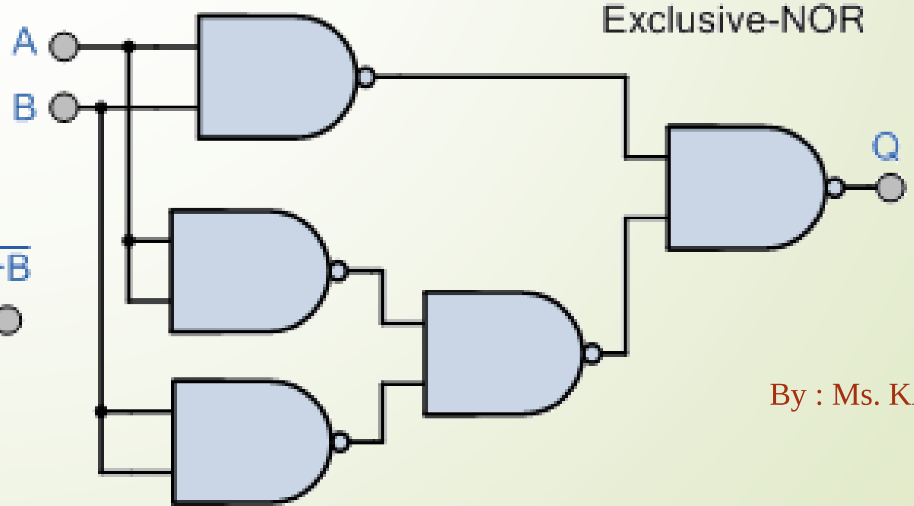
Exclusive-OR



NOR Gate



Exclusive-NOR



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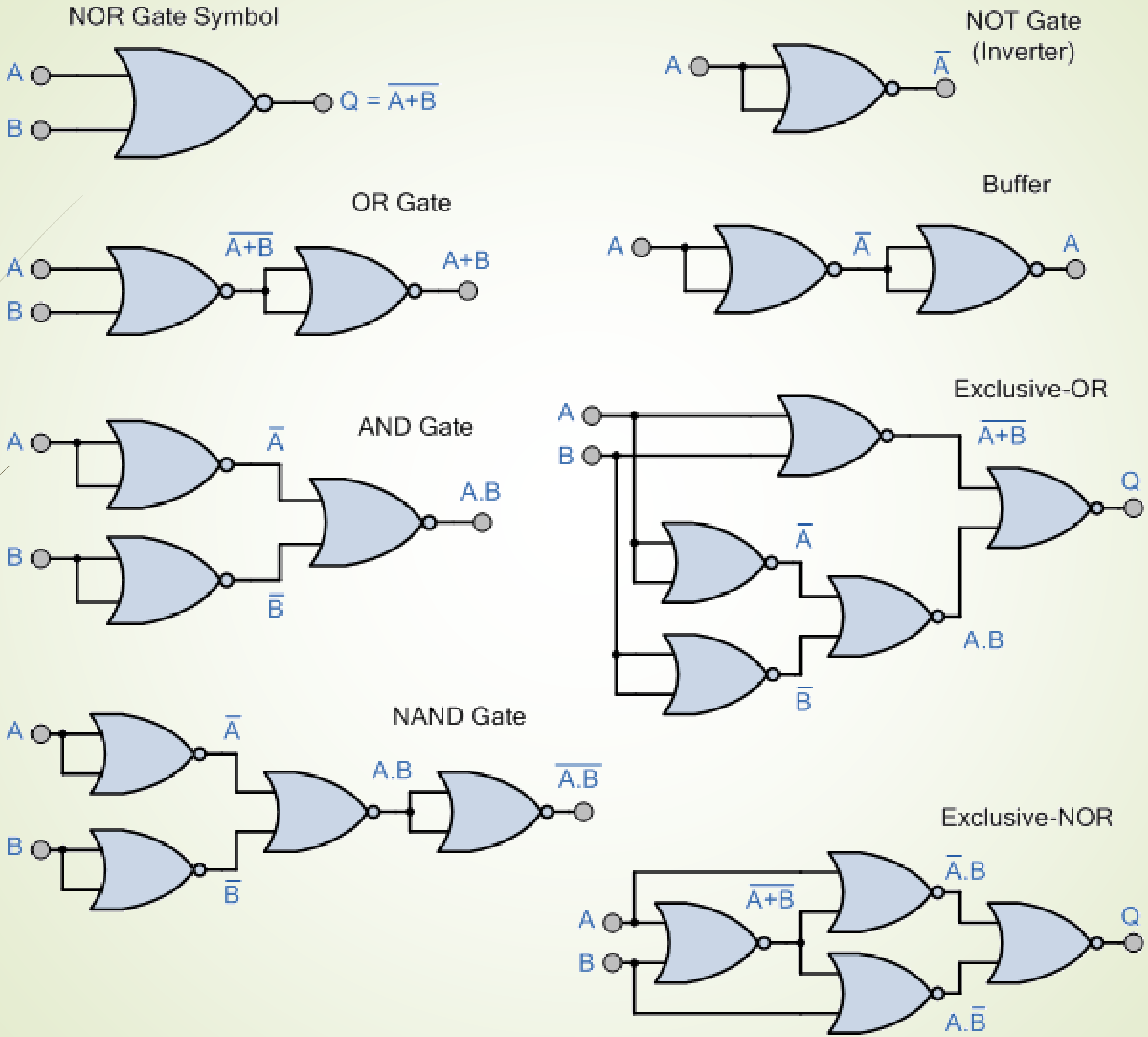

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Q. Prove AB + BC + B'C = AB + C

AB + BC + B'C

= AB + C (B + B') (As (B + B') = 1, Complement Law)
= AB + C . 1
= AB +C

Q. Simplify the expression A + A.B' + A'.B

A + A.B' + A'.B = A (1 + B') + A'.B (As (1 + B') = 1, Annulment Law)
= A . 1 + A'.B
= A + A'.B
= A + B (As (A + A'B) = A + B, Absorption Law)

Q.

$$
\begin{aligned}
\overline{(A\overline{B} + \overline{A}B)}(A + B) &= \overline{A\overline{B}}\,\overline{\overline{A}B}(A+B) \\
&= (\overline{A}+B)(A+\overline{B})(A+B) \\
&= (\overline{A}+B)(AA+AB + \overline{B}A + \overline{B}B) \\
&= (\overline{A}+B)(A + AB + A\overline{B} + \overline{B}B) \\
&= (\overline{A}+B)(A(1 + B + \overline{B}) + \overline{B}B) \\
&= (\overline{A}+B)(A(1) + \overline{B}B) \\
&= (\overline{A}+B)A \\
&= A\overline{A} + AB \\
&= AB
\end{aligned}
$$

Q.

- Given $Z = (\bar{A} + C).(B+\bar{D})$ .Simplified the equation below using De' Morgan Theorem.

Solution :

$$Z = \overline{(\bar{A} + C) \,.\, (B + \bar{D})}$$
$$= \overline{(\bar{A} + C)} + \overline{(B + \bar{D})}$$
$$= (\bar{\bar{A}} \,.\, \bar{C}) + (\bar{B} \,.\, \bar{\bar{D}})$$
$$= A\bar{C} + \bar{B}D$$

Q.

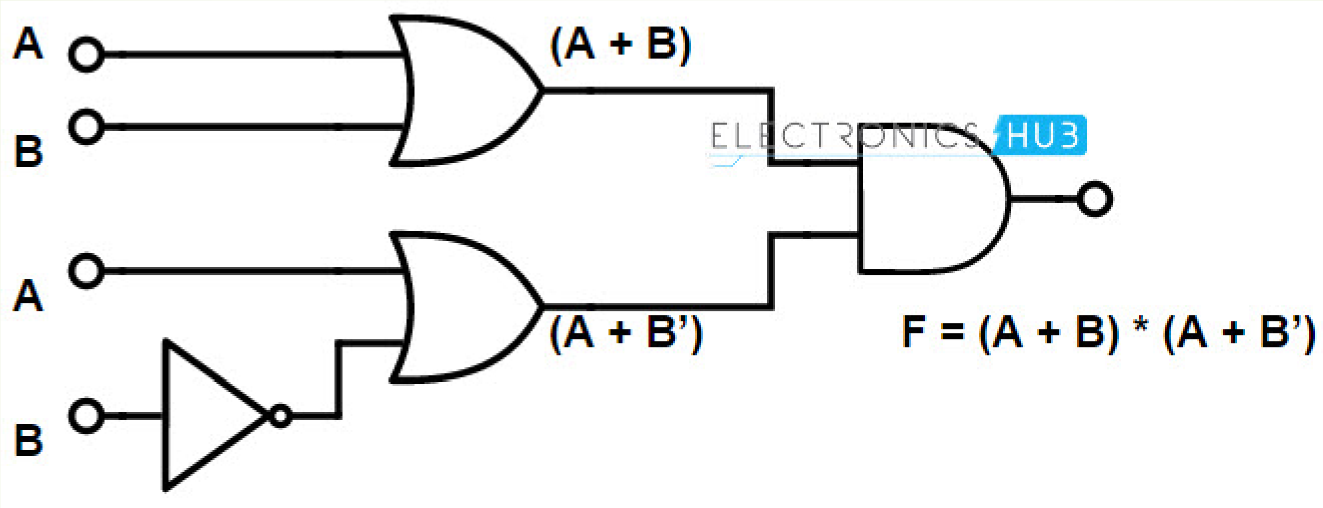
Ex. Simplify –

3. $(A + C)\,(AD + A\bar{D}) + AC + C$

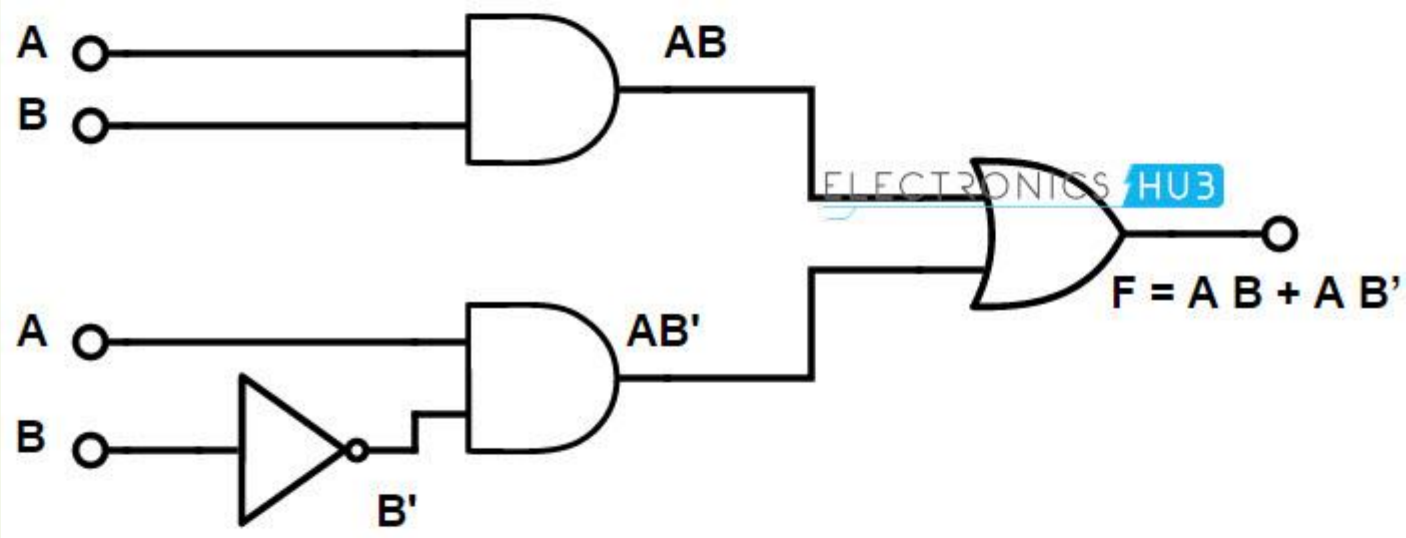
Solution - $(A + C)\,(AD + A\bar{D}) + AC + C$

$$= (A + C)\,A\,(D + \bar{D}) + AC + C$$
$$= (A + C)\,A + C$$
$$= AA + AC + C$$
$$= A + C$$

Q. Realise the logic expression F = (A + B) . (A + B’) using basic gates.



Q. Realise the logic expression F = A B + A B’ using basic gates.



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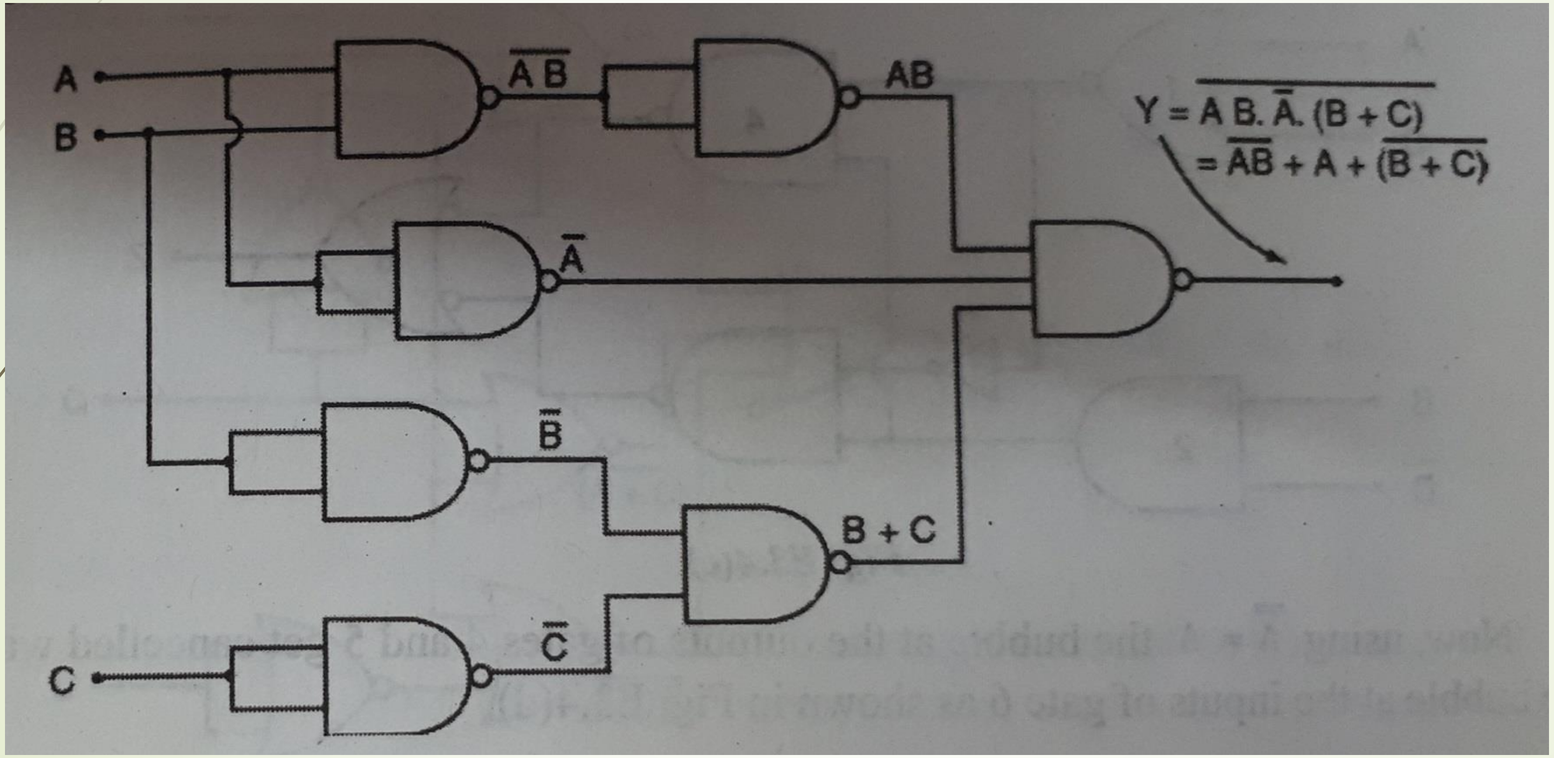
Q. Implement $Y = \overline{AB} + A + \overline{(B + C)}$ using NAND gates only.

$$\overline{AB} + A + \overline{(B + C)} = \overline{AB \,.\, \overline{A} \,.\, (B + C)}$$



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