LOGIC GATES
Boolean Algebra
Simplification
SOP-POS/Minterm-Maxterm

Logic Gate

- Digital systems are said to be constructed by using logic gates.
- These gates are the AND, OR, NOT, NAND, NOR, EXOR and EXNOR gates.
- The basic operations are described below with the aid of truth tables
- Truth tables are used to help show the function of a logic gate

- Boolean functions are practically implemented by using electronic gates

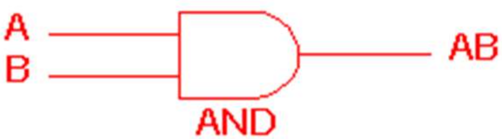
- Generally logic gate have 2 input 1 output
- Gate **INPUTS** are driven by voltages having two nominal values,

  0V logic 0 and 5V logic 1
- The **OUTPUT** of a gate provides two nominal values of voltage only

  0V logic 0 and 5V logic 1

Logic Gate

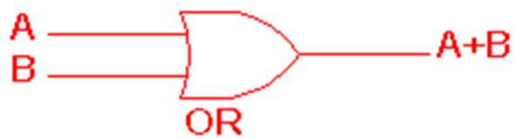
AND gate



2 Input AND gate		
A	B	A.B
0	0	0
0	1	0
1	0	0
1	1	1

high output (1) only if **all** its inputs are high

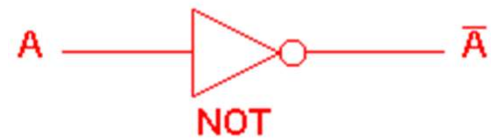
OR gate



2 Input OR gate		
A	B	A+B
0	0	0
0	1	1
1	0	1
1	1	1

high output (1) if **one or more** of its inputs are high.

NOT gate



NOT gate	
A	$\bar{A}$
0	1
1	0

produces an inverted version of the input at its output.

Circuit Implementation with Logic Gate

Step-1 Truthtable

Step-2 Minterm/SOP equation

Step-3 Simplification (Boolean algebra/K-Map)

Step-4 Circuit Design

1. Design a 2 input circuit produces high output for atleast 1 input logic low.

2. Design a 3-input circuit that produces a high output when at least one input is high.

Simplification

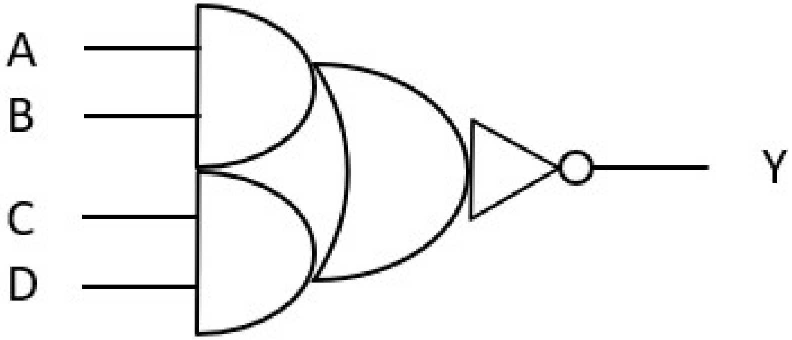
Draw schematic diagram of

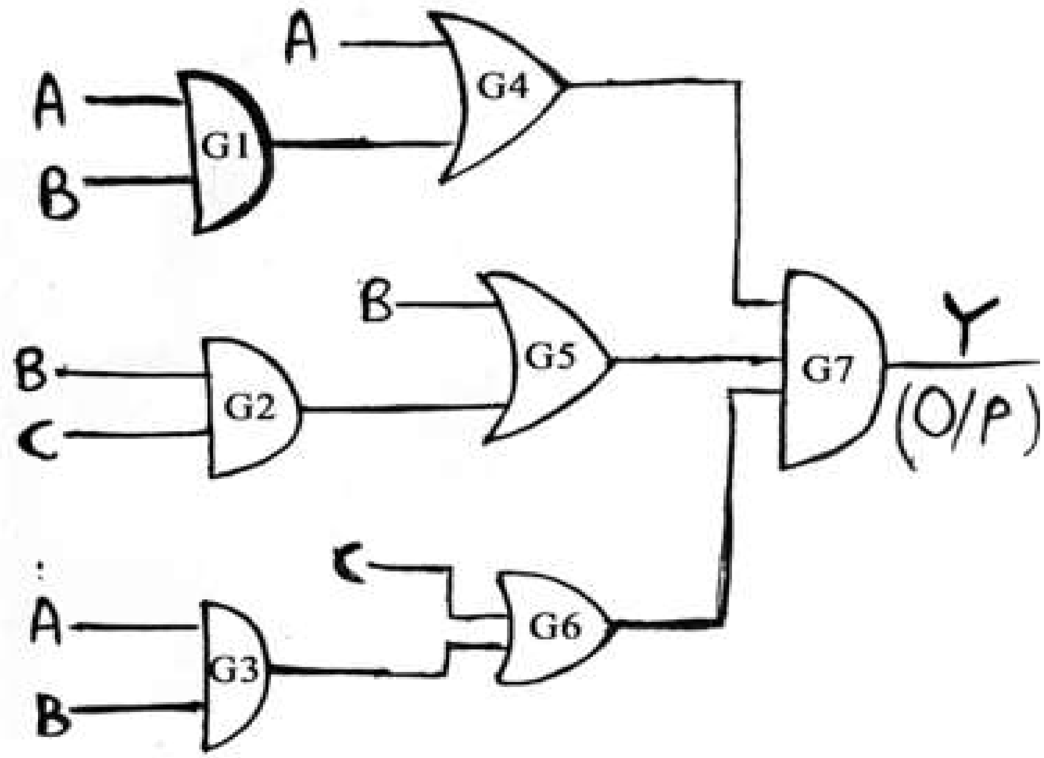
$Q(x,y) = x'y + xy'$

Simplification

Draw schematic diagram of

$$Q(A,B,C)=A\overline{B} + BC\overline{(B+C)}$$


A
B
C
D
Y


A
A
B
G1
G4
B
B
C
G2
G5
G7
Y
(O/P)
C
A
B
G3
G6

Complement

When complement is opened:

- Variable is complemented
- Functions change (+ → .) (. → +)

Logic Gate

NAND GATE

AND gate followed by a NOT gate.

2 Input NAND gate		
A	B	$\overline{A.B}$
0	0	1
0	1	1
1	0	1
1	1	0

high output (1) only if **all** its inputs are low

NOR GATE

OR gate followed by a NOT gate.

2 Input NOR gate		
A	B	$\overline{A+B}$
0	0	1
0	1	0
1	0	0
1	1	0

Low output (0) if **one or more** of its inputs are high.

NAND and NOR gates are called *universal*

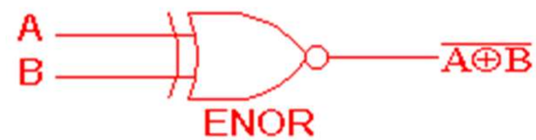
Logic Gate

EXOR GATE/XOR

2 Input EXOR gate		
A	B	$A \oplus B$
0	0	0
0	1	1
1	0	1
1	1	0

high output (1) for different input

EXNOR GATE/XNOR



2 Input EXNOR gate		
A	B	$\overline{A \oplus B}$
0	0	1
0	1	0
1	0	0
1	1	1

High output (1) for same input

Quiz Time

Identify the universal gate

A. AND-OR
B. NAND-NOR ✓
C. XOR-XNOR
D. All of above

Boolean Algebra

Analyze and simplify the digital (logic) circuits.

Variable used can have only two values, Binary 1 for HIGH and Binary 0 for LOW.

Commutative law (i) $A.B = B.A$ (ii) $A + B = B + A$

Associative law (i) $(A.B).C = A.(B.C)$ (ii) $(A + B) + C = A + (B + C)$

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

AND law

(i) $A.0 = 0$ (ii) $A.1 = A$

(iii) $A.A = A$ (iv) $A.\overline{A} = 0$

OR law

(i) $A + 0 = A$ (ii) $A + 1 = 1$

(iii) $A + A = A$ (iv) $A + \overline{A} = 1$

INVERSION law $\overline{\overline{A}} = A$

	Postulate / Theorem	Dual
1. Identity Element	$x + 0 = x$	$x . 1 = x$
2. Complementation	$x + x' = 1$	$x . x' = 0$
3. Idem potency	$x + x = x$	$x . x = x$
4. Null Law	$x + 1 = 1$	$x . 0 = 0$
5. Involution (Double negation)	$(x')' = x$	-
6. Commutative	$x + y = y + x$	$x y = y x$
7. Associative	$x + (y + z) = (x + y) + z$	$x (yz) = (x y) z$
8. Distributive	$x + yz = (x + y)(x + z)$	$x (y + z) = xy + xz$
9. De Morgan	$(x + y)' = x' y'$	$(xy)' = x' + y'$
10. Absorption	$x + xy = x$	$x (x + y) = x$
11. Simplification	$x + x'y = x + y$	$x (x' + y) = xy$
12. Consensus	$xy + x'z + yz = xy + x'z$	$(x+y)(x'+z)(y+z) = (x+y)(x'+z)$

Duality Theorem in Boolean Algebra

AND $\longleftrightarrow$ OR

1 $\longleftrightarrow$ 0

Example : Find the dual form of :

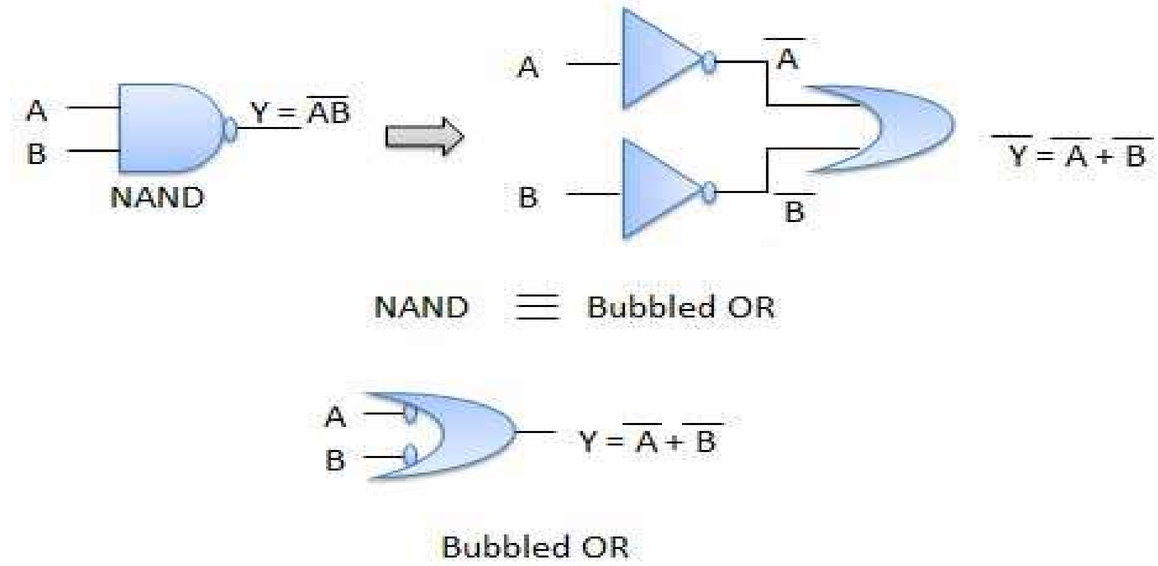
1) $A.0 = 0$

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

De Morgan Law

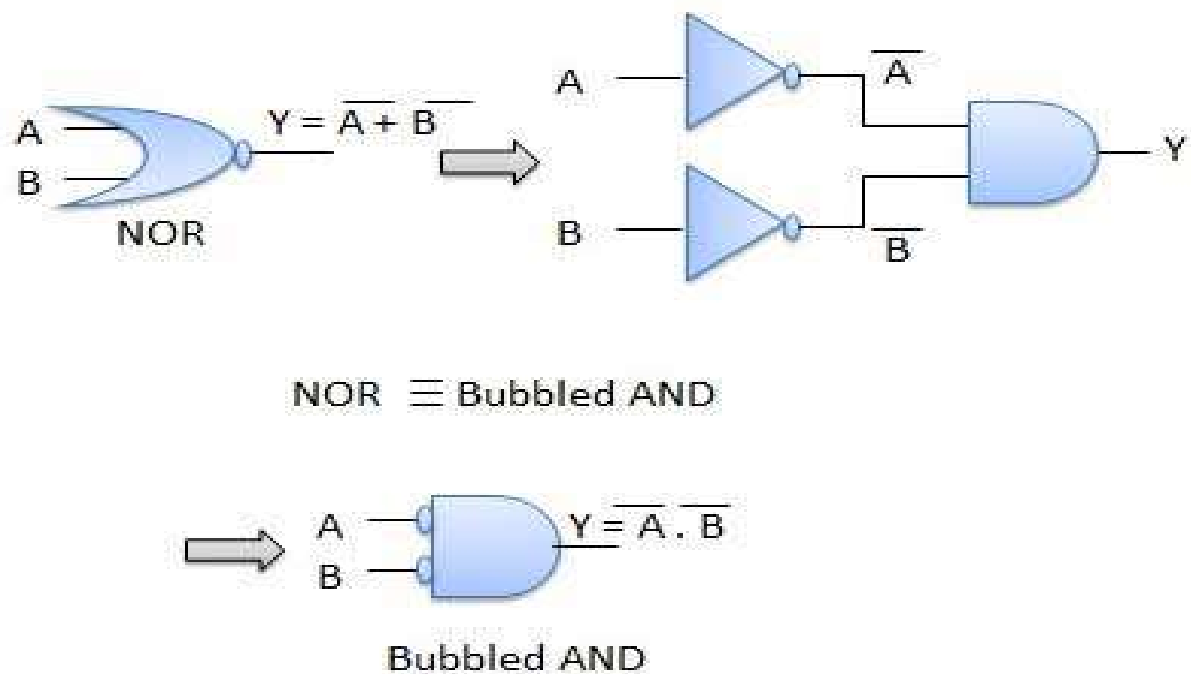
$$\overline{A.B} = \overline{A} + \overline{B}$$

NAND = Bubbled OR

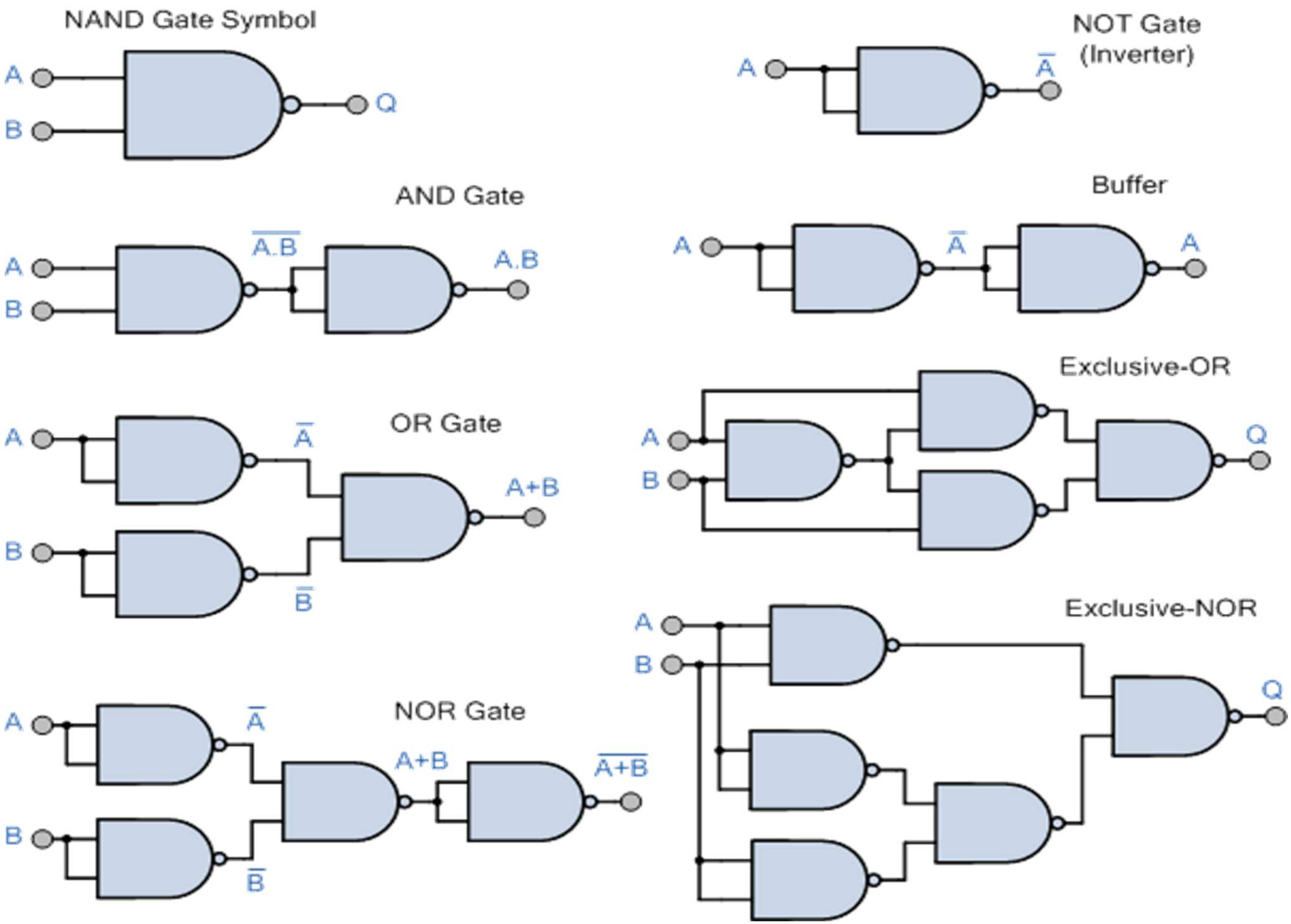


$$\overline{A + B} = \overline{A}.\overline{B}$$

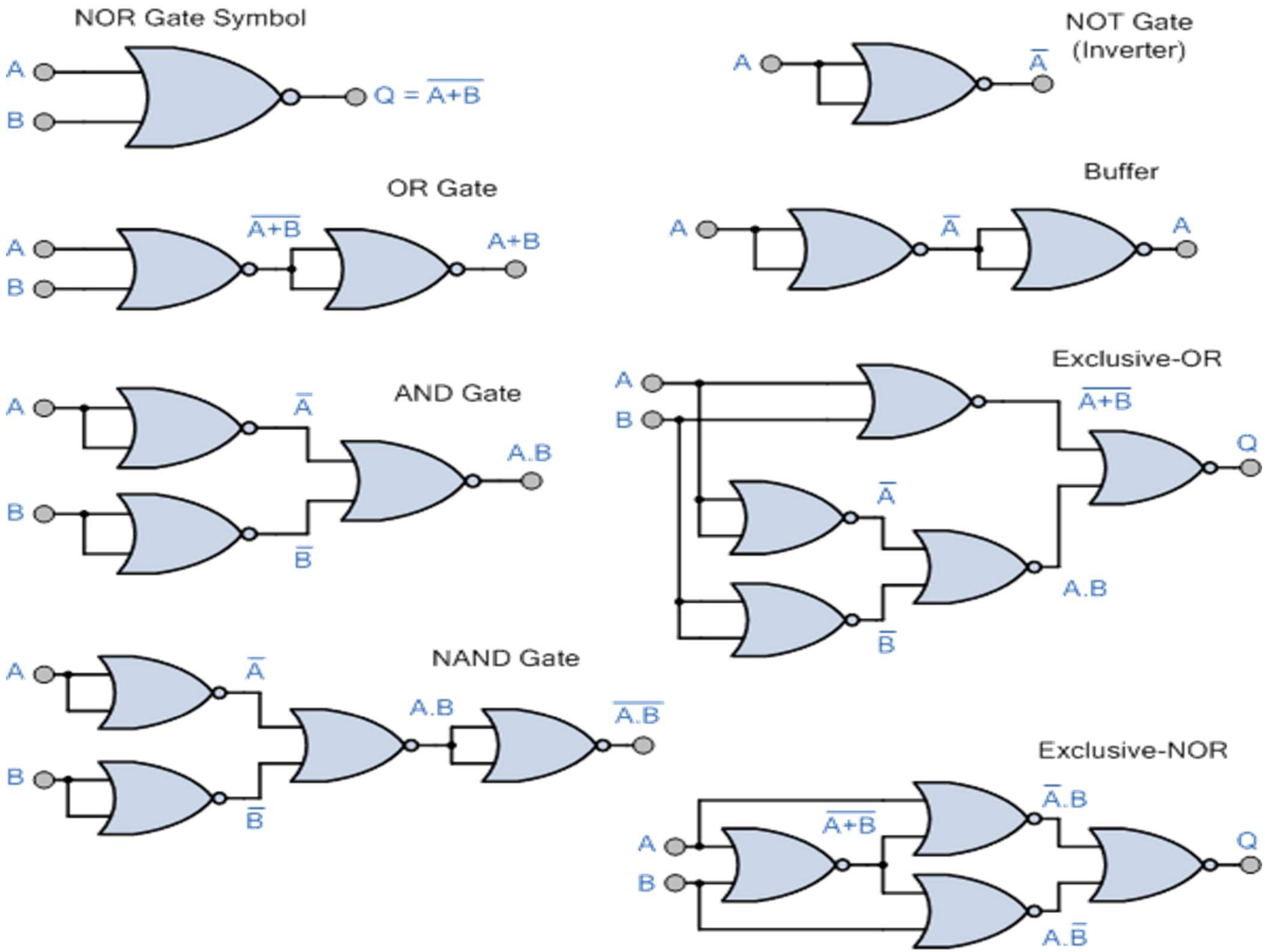
NOR = Bubbled AND



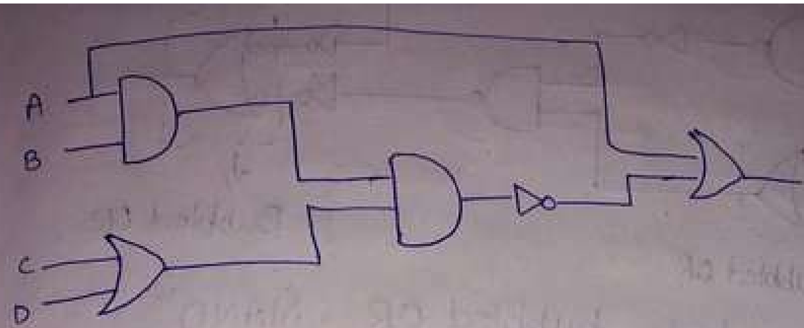
Implementation with NAND



Implementation with NOR

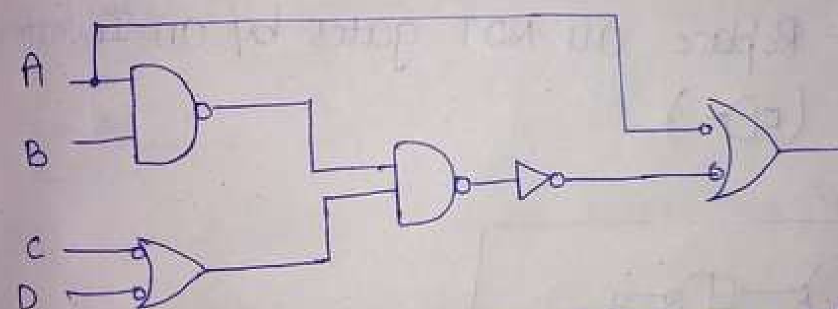


Convert AOI to NAND/NOR logic

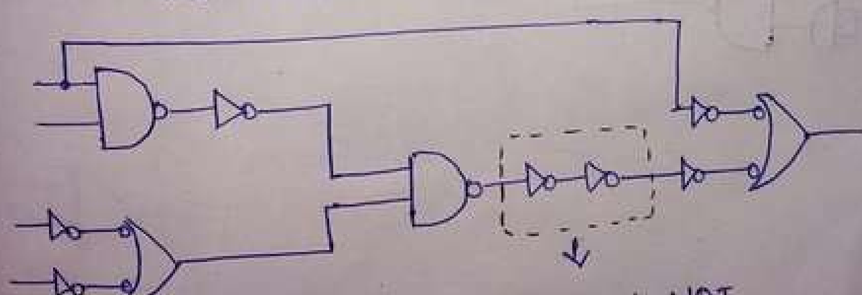


1. NAND logic:-

Step 1:- Add bubbles to the above circuit at the input of OR gates and the output of AND gate.



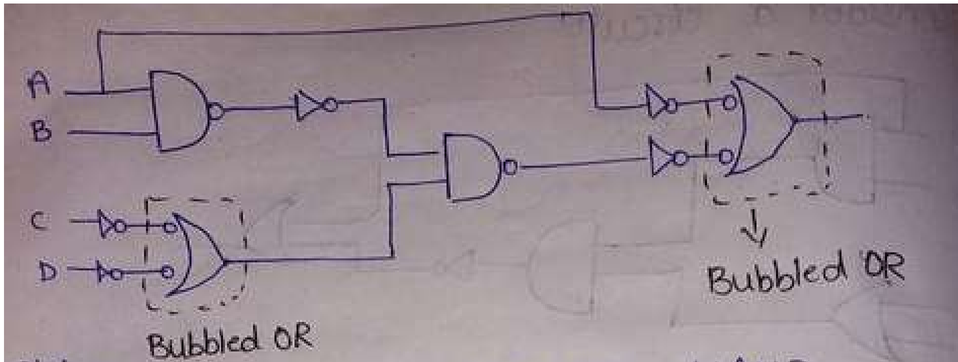
Step 2:- Now add ~~not~~ NOT gates whereever the bubbles are added



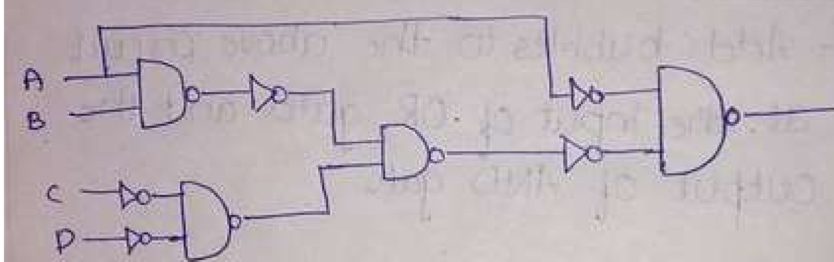
NOT of NOT

i.e $\overline{\overline{X}} = X$

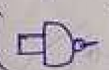
so these can be eliminated

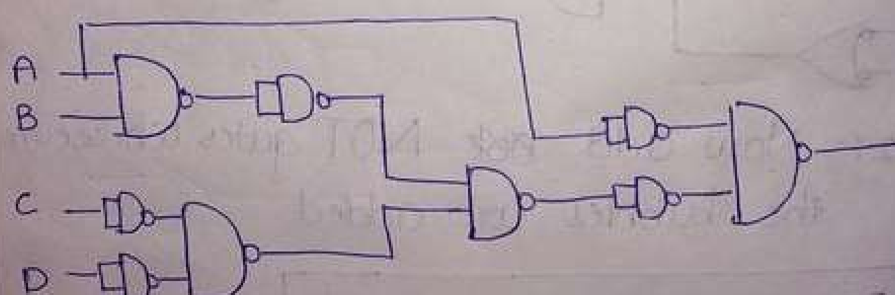


Step 3:-
In AOI logic bubbled OR = NAND

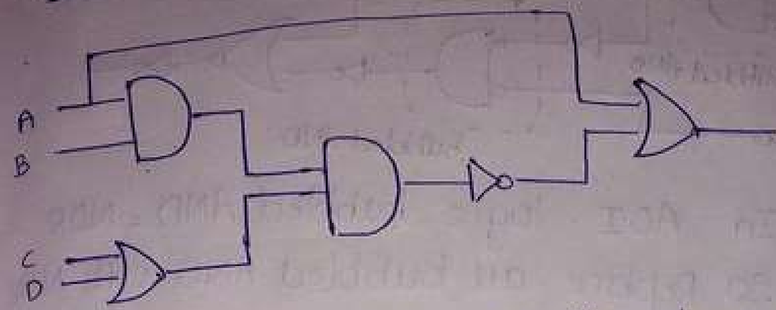


Step4:- Replace all NOT gates by an Inverter

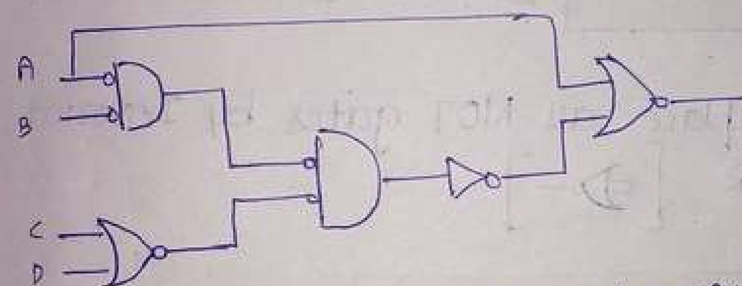
()



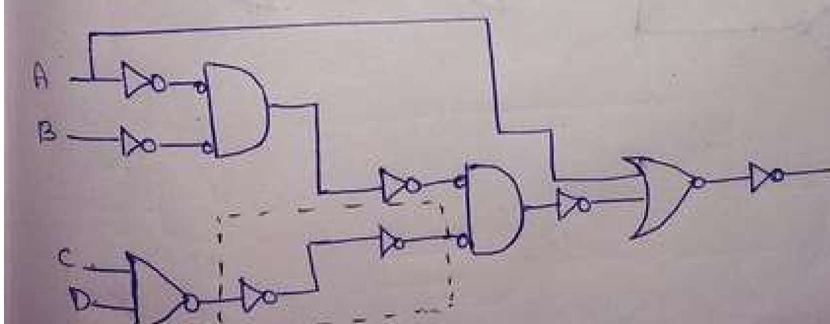
2. NOR Logic :-



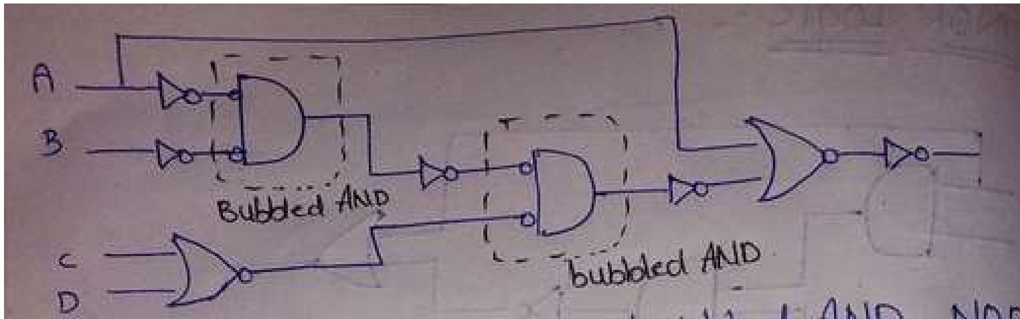
Step 1:- Add bubbles to the above circuit at the output of OR gate and the input of AND gate.



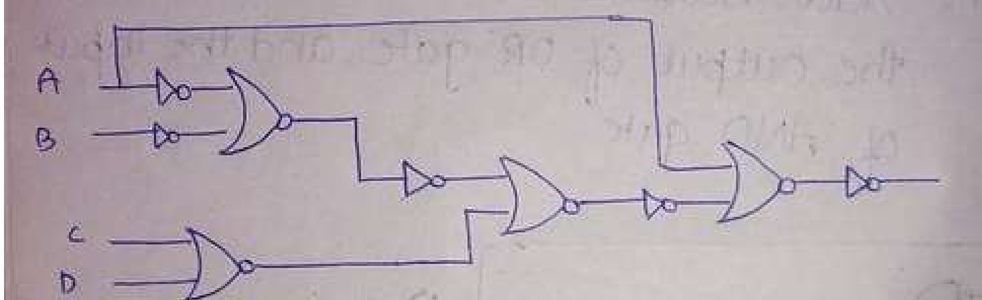
Step 2 :- Add NOT gates where ever the bubbles are added



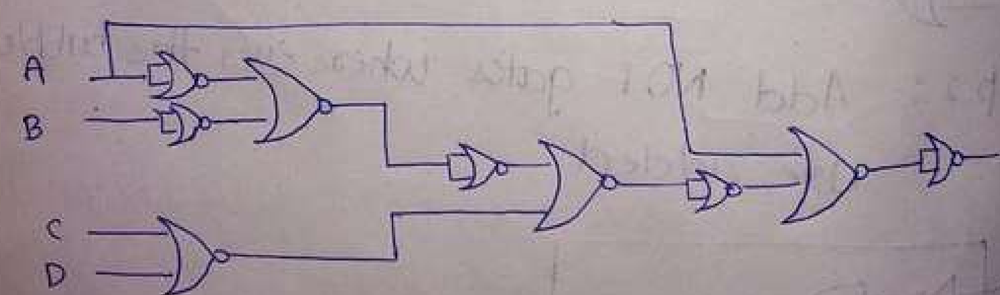
NOT of NOT
so these NOT gates can
be eliminated



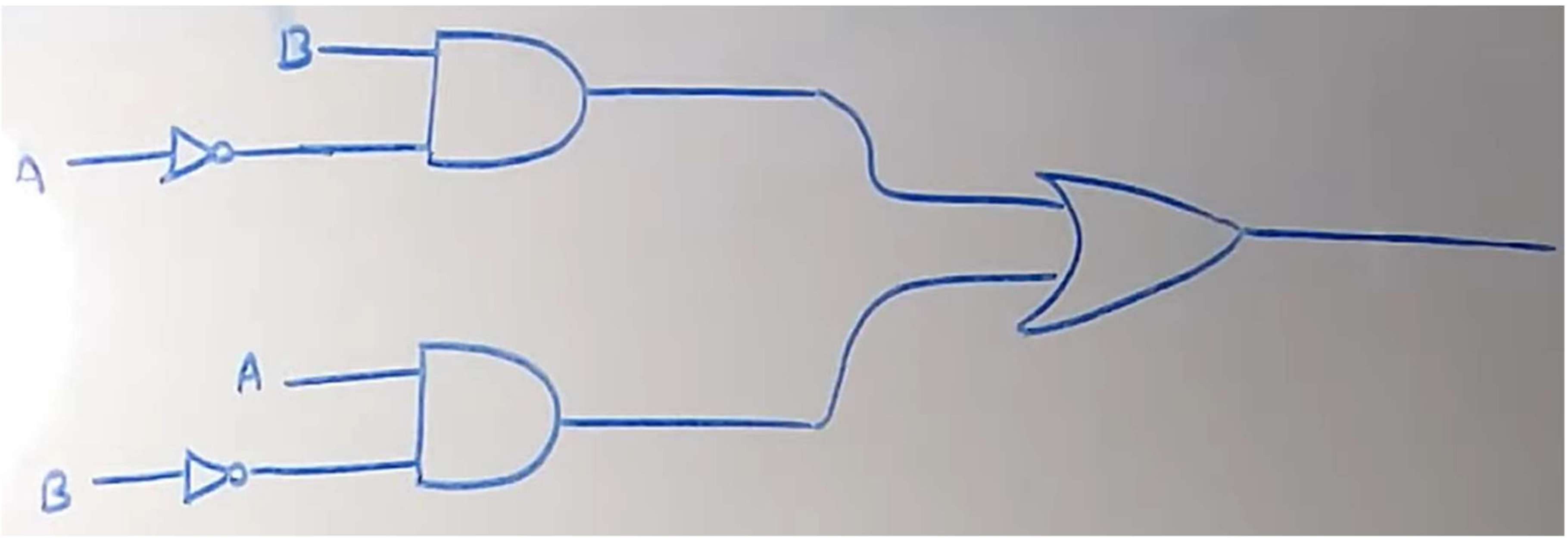
Step 3:- In AOI logic bubbled AND = NOR
so Replace all bubbled AND with NOR



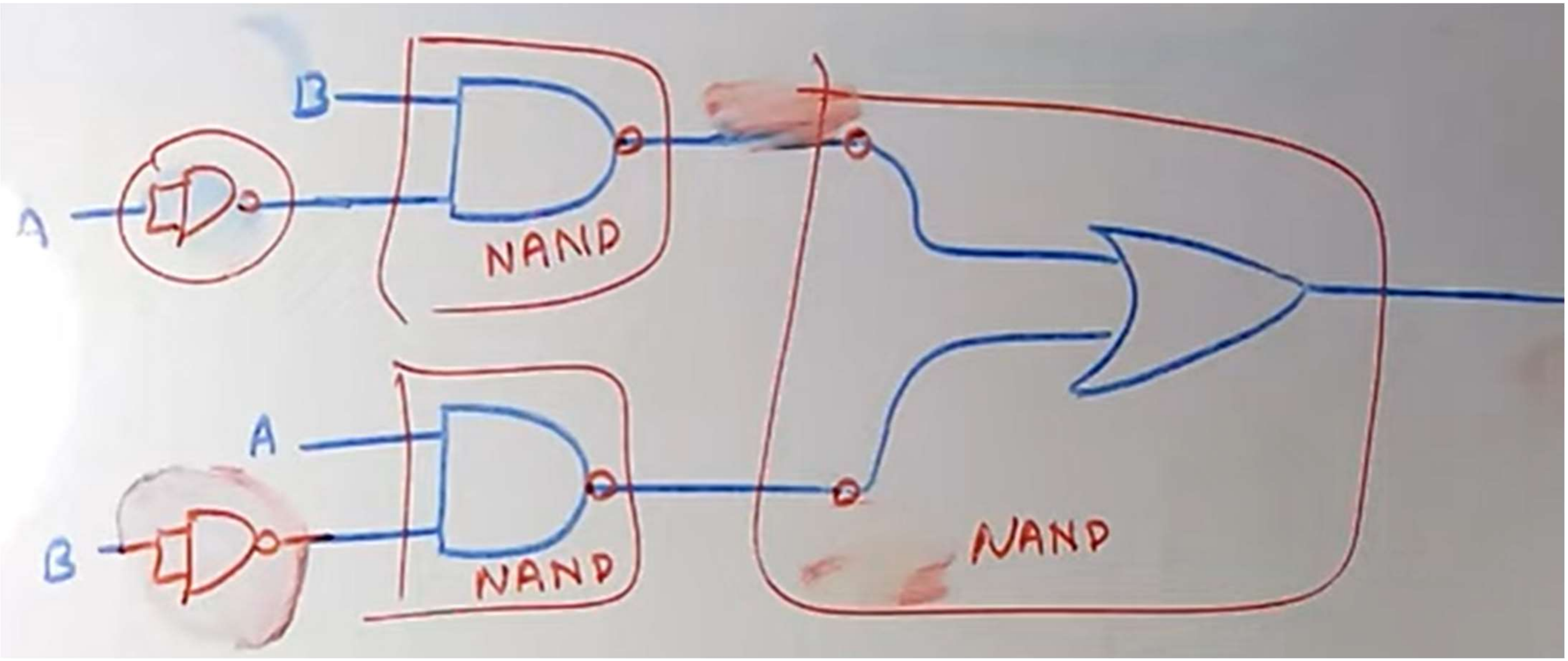
Step 4:- Replace all NOT gates by Inverted
OR [ ]



Convert AOI to NAND/NOR logic
Ex. 1



1. NAND
2. NOR
3. AOI to NOR



B
A
NAND
A
B
NAND
NAND

Sum of Product (SOP): Group of product terms (minterms) are ORed together

$$f(A, B, C) = \underbrace{ABC \overset{\text{sum}}{+} A\bar{B}\bar{C}}_{\text{product terms}}$$

$$f(P, Q, R, S) = \underbrace{\bar{P}Q \overset{\text{sum}}{+} QR \overset{\text{sum}}{+} RS}_{\text{Product terms}}$$

Product of Sum (POS): Group of OR terms (maxterms) are ANDed together

$$f(A, B, C) = \underbrace{(A + B) \overset{\text{Product}}{\bullet} (\bar{B} + C)}_{\text{Sum terms}}$$

$$f(P, Q, R, S) = \underbrace{(P + Q) \overset{\text{Product}}{\bullet} (R + \bar{S}) \overset{\text{Product}}{\bullet} (P + S)}_{\text{Sum terms}}$$

- Minterms- It is known as the product term. In the minterm, each uncomplemented term is indicated by '1', and each complemented term is indicated by '0’.
- Maxterms– It is known as the sum term. In maxterm, each uncomplemented term is indicated by '0' and each complemented term is indicated by '1'.

SOP

- Sum-of-Products (SOP)/ Minterm Form - variables operated by AND (product) are ORed(sum) together.

- ***Each product term is called a minterm (m).***

A	B	C	F
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

SOP Expression

1. Write AND term for each input combination that produces a HIGH o/p.
2. Write the input variables for 1 and complement for 0.
3. OR the AND terms to obtain the output function.

F(SOP) = A'BC + AB'C + ABC' + ABC

m3 + m5 + m6 + m7

POS is complement of SOP

POS

- Product-of-sums (POS)/Maxterm form - variables operated by OR (sum) are ANDed (product) together.

- ***Each sum term is called a maxterm (M).***

A	B	C	F
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

POS Expression

1. Write OR term for each input combination that produces a LOW o/p.
2. Write the input variables for 0 and complement for 1
3. AND the OR terms to obtain the output function.

F(POS)= (A + B + C) (A + B + C ‘) (A + B’ + C) (A’ + B + C)

M0 . M1 . M2 . M4

POS is complement of SOP

Table (1) Minterms and maxterms

Variables			Minterms	Maxterms
A	B	C		
0	0	0	$\bar{A}\bar{B}\bar{C} = m_0$	$A + B + C = M_0$
0	0	1	$\bar{A}\bar{B}C = m_1$	$A + B + \bar{C} = M_1$
0	1	0	$\bar{A}B\bar{C} = m_2$	$A + \bar{B} + C = M_2$
0	1	1	$\bar{A}BC = m_3$	$A + \bar{B} + \bar{C} = M_3$
1	0	0	$A\bar{B}\bar{C} = m_4$	$\bar{A} + B + C = M_4$
1	0	1	$A\bar{B}C = m_5$	$\bar{A} + B + \bar{C} = M_5$
1	1	0	$AB\bar{C} = m_6$	$\bar{A} + \bar{B} + \bar{C} = M_6$
1	1	1	$ABC = m_7$	$\bar{A} + \bar{B} + \bar{C} = M_7$

Each Minterm is represented by mi and each Maxterm is represented by Mi. The subscript i is the decimal number. The logical function can be represented with the help of these shorthand notations as follows:

1. $Y = \bar{A}\bar{B}\bar{C} + \bar{A}B\bar{C} + A\bar{B}C + ABC$

$$= m_0 + m_2 + m_5 + m_7$$

$$= \sum m(0,2,5,7)$$

2. $Y = (A + B + C)(\bar{A} + B + C)(\bar{A} + \bar{B} + \bar{C})$

$$= M_1 + M_4 + M_7$$

$$= \prod M(1,4,7)$$

where $\sum$ and $\prod$ denote the sum of product and product of sum respectively.

Table (2) Minterms

A	B	C	Y	
0	0	0	0	
0	0	1	1	$\leftarrow \bar{A}\bar{B}C$
0	1	0	0	
0	1	1	0	
1	0	0	1	$\leftarrow A\bar{B}\bar{C}$
1	0	1	0	
1	1	0	0	
1	1	1	1	$\leftarrow ABC$

Y = 1 when A = 0, B = 0 and C = 1. Or, ABC will make Y = 1 only. Similarly, Y = 1 for ABC and ABC.

Thus, the standard SOP form becomes

$$Y = \bar{A}\bar{B}C + A\bar{B}\bar{C} + ABC$$

Table (3) Maxterms

A	B	C	Y	
0	0	0	1	
0	0	1	0	$\leftarrow A+B+\overline{C}$
0	1	0	1	
0	1	1	1	
1	0	0	1	
1	0	1	0	$\leftarrow \overline{A}+B+\overline{C}$
1	1	0	1	
1	1	1	1	

From Table (3), Y = 0 when A = 0, B = 0 and C = 1. Therefore, A + B + C gives Y = O.Similarly, A + B + C gives Y = O. Thus, the standard product of sum form is

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

SOP-POS Conversion

- Convert the SOP expression to an equivalent POS expression:

$$\overline{A}\,\overline{B}\,\overline{C} + \overline{A}B\overline{C} + \overline{A}BC + A\overline{B}C + ABC$$

  - The evaluation is as follows:

$$000 + 010 + 011 + 101 + 111$$

  - There are 8 possible combinations. The SOP expression contains five of these, so the POS must contain the other 3 which are: 001, 100, and 110.

$$(A + B + \overline{C})(\overline{A} + B + C)(\overline{A} + \overline{B} + C)$$

Canonical/Standard Boolean Expression

Every product term involves every literal (all the variables of a function) or its complement.

$$f(A, B, C) = \underbrace{\boxed{A\bar{B}C} + \boxed{ABC} + \boxed{\bar{A}B\bar{C}}}_{}$$

Each product term consists of
all literals in either complemented
form or uncomplemented form

Canonical/Standard Boolean Expression

Convert the given expression in standard SOP format

$$F(A,B,C) = AC + AB + BC$$

Canonical/Standard Boolean Expression

Convert the given expression in standard SOP format

$$f(A, B, C) = \boxed{AC} + \boxed{AB} + \boxed{BC}$$

Literal A is missing

Literal C is missing

Literal B is missing

Canonical/Standard Boolean Expression

Convert the given expression in standard SOP format

$$f(A, B, C) = AC + AB + BC$$

Literal A is missing

Literal C is missing

Literal B is missing

Original product terms

$$f(A, B, C) = AC \cdot (B + \bar{B}) + AB \cdot (C + \bar{C}) + BC \cdot (A + \bar{A})$$

Missing literals and their complements

Omit repeated product terms

$$f(A, B, C) = ABC + A\bar{B}C + \boxed{ABC} + AB\bar{C} + \boxed{ABC} + \bar{A}BC$$

$$\therefore f(A, B, C) = ABC + A\bar{B}C + AB\bar{C} + \bar{A}BC$$

Convert the given expression in standard SOP format

$$f(\bar{A}, B, C) = A + ABC$$

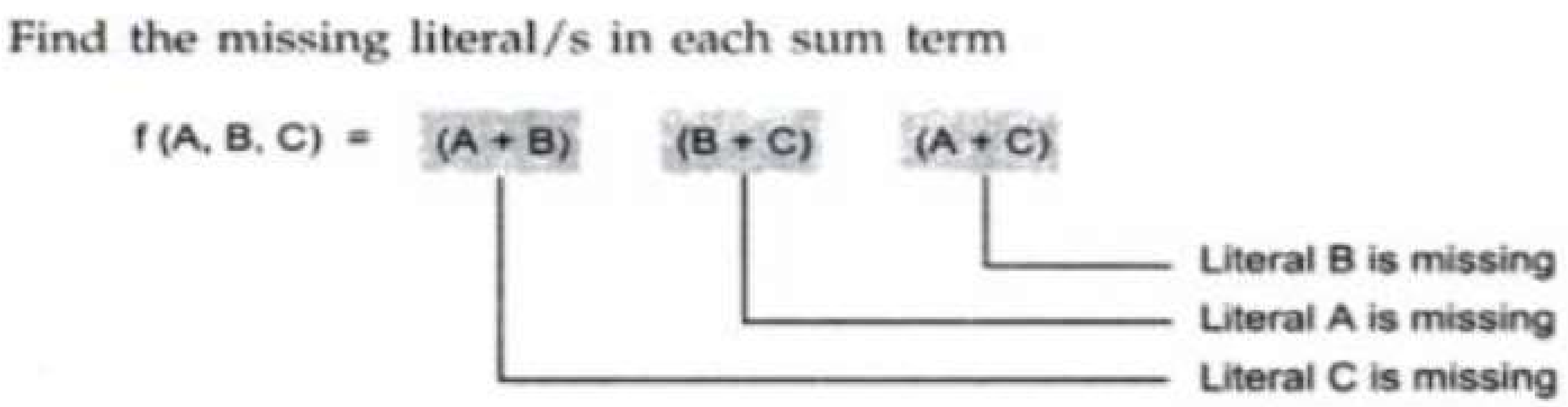
Canonical/Standard Boolean Expression

Convert the given expression in standard POS format

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

Convert the given expression in standard POS format

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



Convert the given expression in standard POS format

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

Find the missing literal/s in each sum term

$$f(A, B, C) = (A + B) \quad (B + C) \quad (A + C)$$

Literal B is missing

Literal A is missing

Literal C is missing

OR sum term with (missing literal • its complement)

Original sum terms

$$f(A, B, C) = A + B + (C \cdot \bar{C}) \quad B + C + (A \cdot \bar{A}) \quad A + C + (B \cdot \bar{B})$$

Missing literals and their complements

Repeated sum terms

$$f(A, B, C) = (A + B + C)(A + B + \bar{C})(A + B + C)(\bar{A} + B + C)(A + B + C)(A + \bar{B} + C)$$

$$\therefore f(A, B, C) = (A + B + C)(A + B + \bar{C})(\bar{A} + B + C)(A + \bar{B} + C)$$

We can show that a product of sums form derived from a truth table is logically equivalent to a sum of products form derived from the same truth table. From Table (3), we get

$$\text{SOP Form: } Y = \overline{A}\,\overline{B}\,\overline{C} + \overline{A}B\overline{C} + \overline{A}BC + A\overline{B}\,\overline{C} + AB\overline{C} + ABC$$

$$\text{POS Form: } Y = (A + B + \overline{C})(\overline{A} + B + \overline{C})$$

Let us simplify the POS form:

$$\begin{aligned}
Y &= (A + B + \overline{C})(\overline{A} + B + \overline{C}) \\
&= A\overline{A} + AB + A\overline{C} + \overline{A}B + BB + B\overline{C} + \overline{A}\,\overline{C} + B\overline{C} + \overline{C}\,\overline{C} \\
&= AB + A\overline{C} + \overline{A}B + B + B\overline{C} + \overline{A}\,\overline{C} + B\overline{C} + \overline{C}\,\overline{C} \\
&= AB(C + \overline{C}) + A\overline{C}(B + \overline{B}) + \overline{A}B(C + \overline{C}) + (A + \overline{A})B(C + \overline{C}) + (A + \overline{A})B\overline{C} \\
&\quad + \overline{A}\,\overline{C}(B + \overline{B}) + (A + \overline{A})B\overline{C} + (A + \overline{A})(B + \overline{B})\overline{C} \\
&= ABC + AB\overline{C} + AB\overline{C} + A\overline{B}\,\overline{C} + \overline{A}BC + \overline{A}B\overline{C} + AB\overline{C} + ABC + \overline{A}BC + \overline{A}B\overline{C} \\
&\quad + AB\overline{C} + \overline{A}B\overline{C} + \overline{A}B\overline{C} + \overline{A}\,\overline{B}\,\overline{C} + AB\overline{C} + \overline{A}B\overline{C} + AB\overline{C} + A\overline{B}\,\overline{C} + \overline{A}B\overline{C} + \overline{A}\,\overline{B}\,\overline{C} \\
&= \overline{A}\,\overline{B}\,\overline{C} + \overline{A}B\overline{C} + \overline{A}BC + AB\overline{C} + ABC
\end{aligned}$$

$$\therefore \qquad \begin{aligned}
Y &= m_0 + m_2 + m_3 + m_4 + m_6 + m_7 \\
&= \sum m(0,2,3,4,6,7) \\
&= \prod M(1,7)
\end{aligned}$$

- Hence, a complementary relationship exists between a function expressed in Minterms and Maxterms.
- Therefore, we can find logical expression in Minterms if the function's Maxterms are known, and vice versa.

Practice Question

Prove that $\mathbf{XY + XYZ + XYZ' + X'YZ = Y(X + Z)}$

Practice Question

$$XY + XYZ + XY\bar{Z} + \bar{X}YZ$$

$= XY(1 + Z) + XY\bar{Z} + \bar{X}YZ$

$= XY + XY\bar{Z} + \bar{X}YZ$ Theorem 2(a) : $[A + 1 = 1]$

$= XY(1 + \bar{Z}) + \bar{X}YZ$ Distributive

$= XY + \bar{X}YZ$ Theorem 2(a) : $[A + 1 = 1]$

$= Y(X + \bar{X}Z)$ Distributive

$= Y(X + Z)$ Theorem 5(a) : $[A + \bar{A}B = A + B]$

Practice Question

Simplify **AC + C(A + A'B)**

Practice Question

$$AC + C(A + \overline{A}B)$$

$$= AC + AC + \overline{A}BC$$

$$= AC + \overline{A}BC$$

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

$$= C(A + B)$$

Practice Question

Prove that

$$\overline{A}\,\overline{B}\,\overline{C} + \overline{A}\,\overline{B}\,C + \overline{A}\,B\,\overline{C} + A\,\overline{B}\,\overline{C} + A\,B\,\overline{C} = \overline{C} + \overline{A}\,\overline{B}$$

Practice Question

$$
\begin{aligned}
Y &= \bar{A}\,\bar{B}\,\bar{C} + \bar{A}\,\bar{B}\,C + \bar{A}\,B\,\bar{C} + A\,\bar{B}\,\bar{C} + A\,B\,\bar{C} \\
&= \bar{A}\,\bar{B}\,\bar{C} + A\,\bar{B}\,\bar{C} + \bar{A}\,B\,\bar{C} + A\,B\,\bar{C} + \bar{A}\,\bar{B}\,C && \text{rearranging terms} \\
&= \bar{B}\,\bar{C}\,(\bar{A} + A) + B\,\bar{C}\,(\bar{A} + A) + \bar{A}\,\bar{B}\,C \\
&= \bar{B}\,\bar{C} + B\,\bar{C} + \bar{A}\,\bar{B}\,C && \text{Postulate 5(a)} : [A + \bar{A} = 1] \\
&= \bar{C}\,(\bar{B} + B) + \bar{A}\,\bar{B}\,C && \text{Distributive} \\
&= \bar{C} + \bar{A}\,\bar{B}\,C && \text{Postulate 5(a)} : [A + \bar{A} = 1] \\
&= \bar{C} + \bar{A}\,\bar{B} && \text{Theorem 5(a)} : [A + \bar{A}\,B = A + B]
\end{aligned}
$$

Practice Question

Simplify $\overline{\overline{AB} + \overline{A} + AB}$

Prove that $AB + \overline{AC} + A\bar{B}C\,(AB + C) = 1$

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

$= AB + \overline{\overline{A}C} + AA\overline{B}BC + A\overline{B}CC$	Distributive
$= AB + \overline{\overline{A}C} + A\overline{B}CC$	Postulate 5(b) : $[A \cdot \overline{A} = 0]$
$= AB + \overline{\overline{A}C} + A\overline{B}C$	Theorem 1(b) : $[A \cdot A = A]$
$= AB + \overline{A} + \overline{C} + A\overline{B}C$	DeMorgan's Theorem 1 : $[\overline{AB} = \overline{A} + \overline{B}]$
$= \overline{A} + B + \overline{C} + A\overline{B}C$	Theorem 5(a) : $[A + \overline{A}B = A + B]$
$= \overline{A} + A\overline{B}C + B + \overline{C}$	Commutative
$= \overline{A} + \overline{B}C + B + \overline{C}$	Theorem 5(a) : $[A + \overline{A}B = A + B]$
	Here $B = \overline{B}C$
$= \overline{A} + B + \overline{C} + \overline{B}C$	Commutative
$= \overline{A} + B + \overline{C} + \overline{B}$	Theorem 5(a) : $[A + \overline{A}B = A + B]$
$= \overline{A} + \overline{C} + 1$	Postulate 5(a) : $[A + \overline{A} = 1]$
$= 1$	Theorem 2(a) : $[A + 1 = 1]$

Practice Question

$$Z = A + \overline{B} + C$$

a) $\overline{A + \overline{B} + C}$

b) $\overline{\overline{A} + B + \overline{C}}$

c) $\overline{\overline{A} \cdot B \cdot \overline{C}}$

d) $\overline{A \cdot \overline{B} \cdot C}$

Practice Question

$$Z = A + \overline{B} + C$$

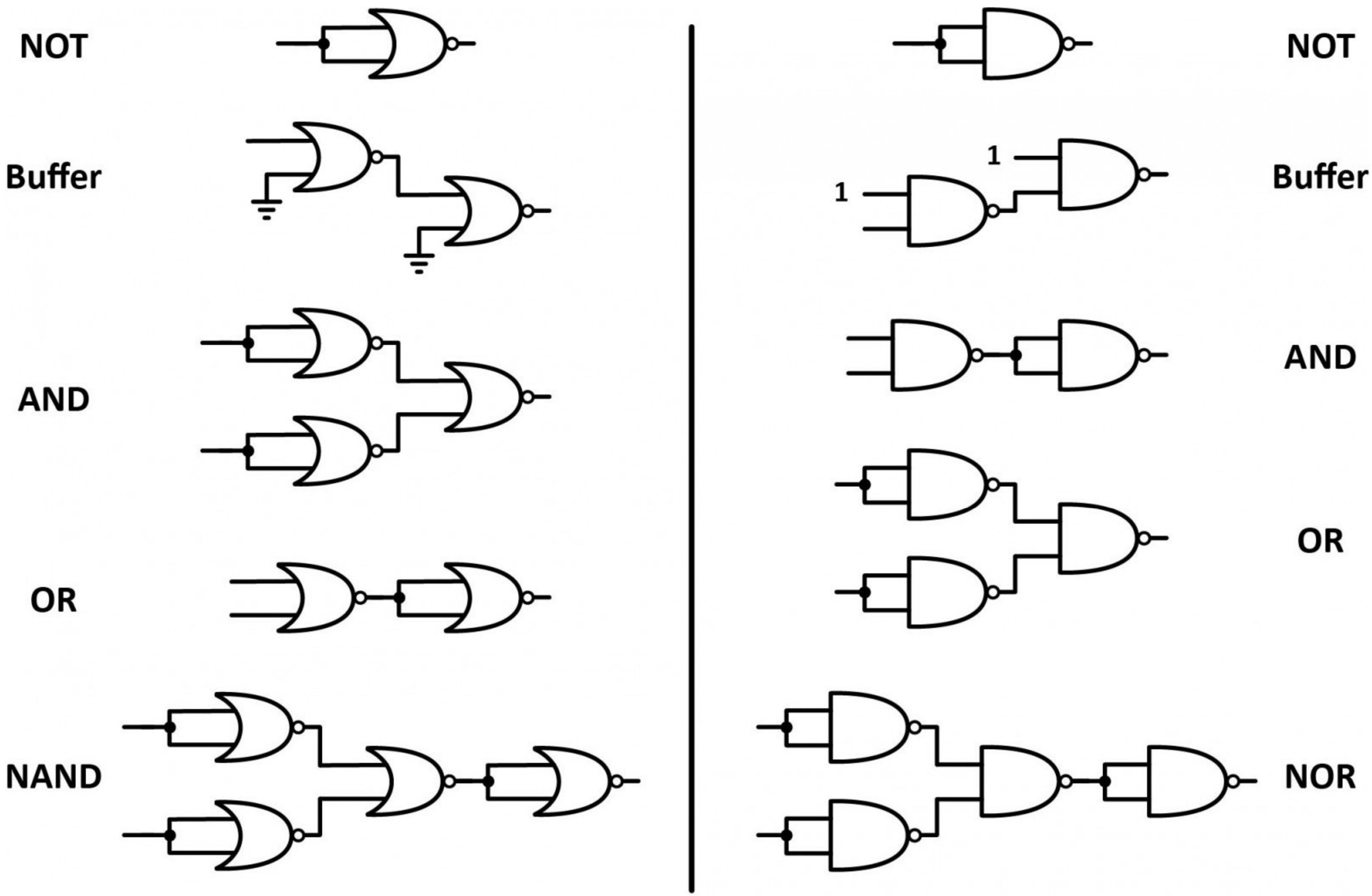
a) $\overline{A + \overline{B} + C}$

b) $\overline{\overline{A} + B + \overline{C}}$

c) $\overline{\overline{A} \cdot B \cdot \overline{C}}$ ✓

d) $\overline{A \cdot \overline{B} \cdot C}$

Logic Gate Implement with NAND-NOR



NOR **NAND**

How many Boolean functions are possible from 2 input system?

1. n^{2^n}
2. 2^n
3. n^{n^2}
4. 2^{2^n}

How many Boolean functions are possible from 2 input system?

1. n^{2^n}
2. 2^n
3. n^{n^2}
4. 2^{2^n} ✓

Quiz Time

How many Boolean functions are possible from 2 input system

A. 2

B. 4

C. 8

D. 16

Quiz Time

How many Boolean functions are possible from 2 input system

A. 2
B. 4
C. 8
D. 16 ✓

AB	f_0	f_1	f_2	f_3	f_4	f_5	f_6	f_7	f_8	f_9	f_{10}	f_{11}	f_{12}	f_{13}	f_{14}	f_{15}
00	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
01	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1
10	0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1
11	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1

Answer: Option (4)

Any variable 'a' can have 2 value i.e, 0 or 1.

For 'n' variables there are 2^n entries in the truth table.

And each output of any particular row in the truth table can be 0 or 1.

Hence, we have 2^{2^n} different Boolean functions with n variables.

Let's understand with the help of an example -

Let's say there are 2 variables a, and b: **n = 2**

There are 2^2 entries in the truth table, and each entry can be 0 or 1

So, we have 2^{2^2} **= 16** different Boolean functions with 2 variables.

Function	x	0	0	1	1
	y	0	1	0	1
Constant 0	0	0	0	0	0
And	$x \cdot y$	0	0	0	1
x And Not y	$x \cdot \bar{y}$	0	0	1	0
x	x	0	0	1	1
Not x And y	$\bar{x} \cdot y$	0	1	0	0
y	y	0	1	0	1
Xor	$x \cdot \bar{y} + \bar{x} \cdot y$	0	1	1	0
Or	$x + y$	0	1	1	1
Nor	$\overline{x + y}$	1	0	0	0
Equivalence	$x \cdot y + \bar{x} \cdot \bar{y}$	1	0	0	1
Not y	$\bar{y}$	1	0	1	0
If y then x	$x + \bar{y}$	1	0	1	1
Not x	$\bar{x}$	1	1	0	0
If x then y	$\bar{x} + y$	1	1	0	1
Nand	$\overline{x \cdot y}$	1	1	1	0
Constant 1	1	1	1	1	1