UNIVERSITI TEKNOLOGI MALAYSIA

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SCSR1013 DIGITAL LOGIC

MODULE 3:
LOGIC GATES

FACULTY OF COMPUTING

Outline

- For each gates, we will emphasize on the following:
    - i. Characteristics
    - ii. Symbols
    - iii. Operator
    - iv. Boolean expression
    - v. Truth Table
    - vi. Timing Diagram

- NOT Gate (Inverter)
- AND Gate
- OR Gate

Basic gates

- NAND Gate
- NOR Gate

Universal gate using 2 of the basic gates

- Exclusive-OR (XOR) Gate
- Exclusive-NOR (XNOR) Gate

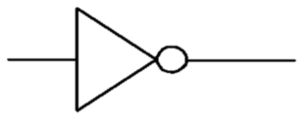
Arithmetic gates (also known as universal gates as above)

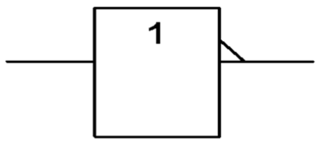
NOT Gate (Inverter)

- **Characteristics**

  Performs inversion or complementation
  - Changes a logic level to the opposite
  - 0(LOW) ➔ 1(HIGH) ; 1 ➔ 0

Symbols :



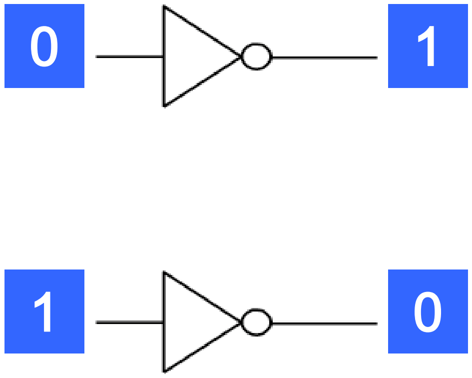


(a) Distinctive shape symbols with negation indicators

(b) Rectangular outline symbols with polarity indicators

Example :

"Output will be 0 if the input is 1"
"Output will be 1 if the input is 0"

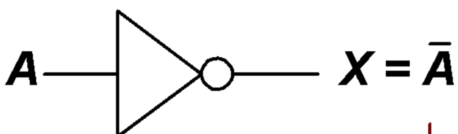


Continue…

- **Operator**
  - NOT Gate is represented by overbar

$\bar{A}$ → "A bar" "not A"

- Logic expression



X is the complement of A
X is the inverse of A
X is NOT A

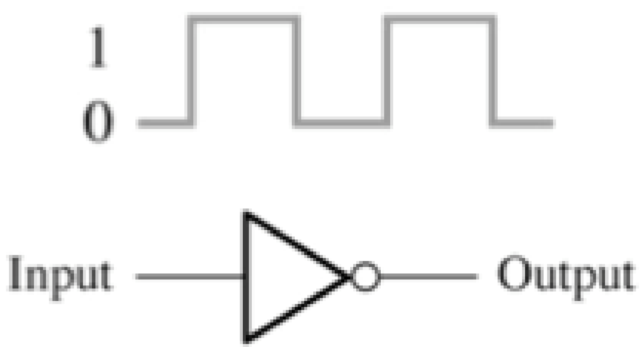
$X = \bar{A}$ or $X = A'$

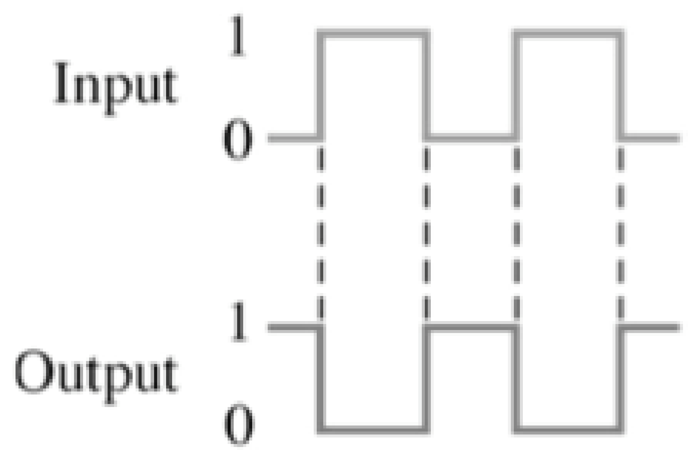
Continue…

- Truth table

A	X
0	1
1	0

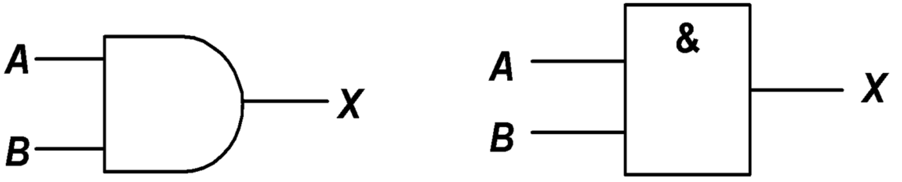
- **Timing diagrams**





AND Gate

- **Characteristics**
  - Performs 'logical multiplication'
    - If all of the input are HIGH, then the output is HIGH.
    - If any of the input are LOW, then the output is LOW.
      - *AND gate must at least have two (2) INPUTs, and must always have 1 (one) OUTPUT. The AND gate can have more than two INPUTs*
- **Symbols**



(a) Distinctive shape

(b) Rectangular outline with the AND (&) qualifying symbol

- Operator

$0 . 0 = 0$

$0 . 1 = 0$

$1 . 0 = 0$

$1 . 1 = 1$

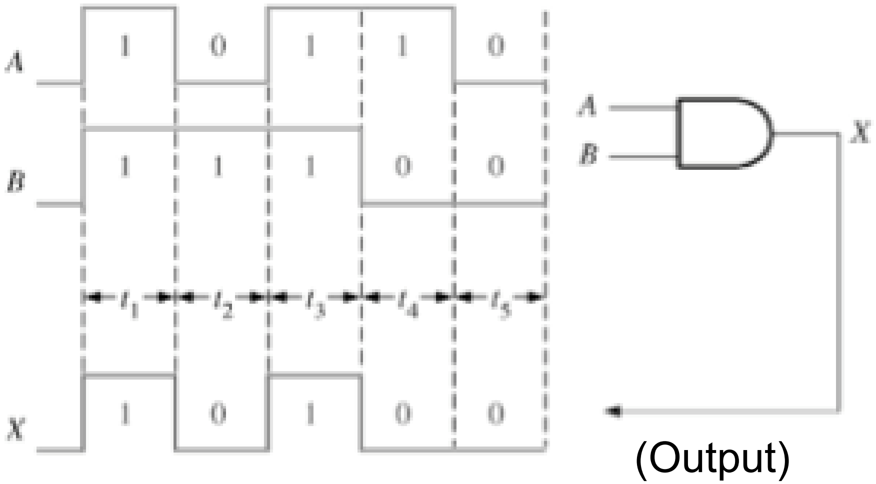
- Logic operation

$$X = A \bullet B$$

- Truth table

A B	X = A . B
0 0	0
0 1	0
1 0	0
1 1	1

- Timing Diagram

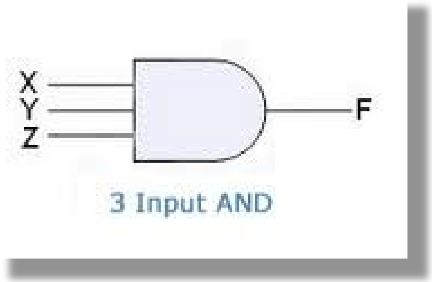


Exercise 3.1:

a) Develop the truth table for a 3-input AND gate.
b) Determine the total number of possible input combinations for a 4-input AND gate.

Solution :

(a) Possible input combinations = $2^3 = 8$



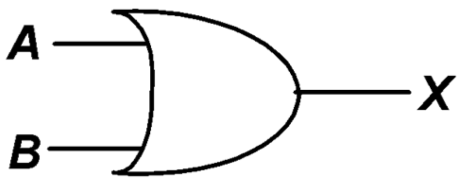
INPUTS			OUTPUT
X	Y	Z	F
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	0
1	0	1	0
1	1	0	0
1	1	1	1

(Output 1 when all inputs 1)

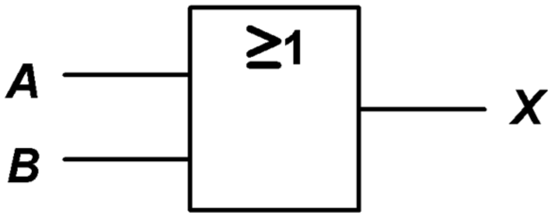
(b) Possible input combinations
$= 2^4 = 16$

OR Gate

- Performs '*logical addition*'
  - If any of the input are HIGH, then the output is HIGH.
  - If all of the input are LOW, then the output is LOW
- Symbols used:



(a) Distinctive shape



(b) Rectangular outline with the OR (≥1) qualifying symbol

Operator

OR operator can be represented by a plus sign "+"

OR gate performs Boolean addition

Boolean addition follows the basic rules as follows:

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

Logical Expression

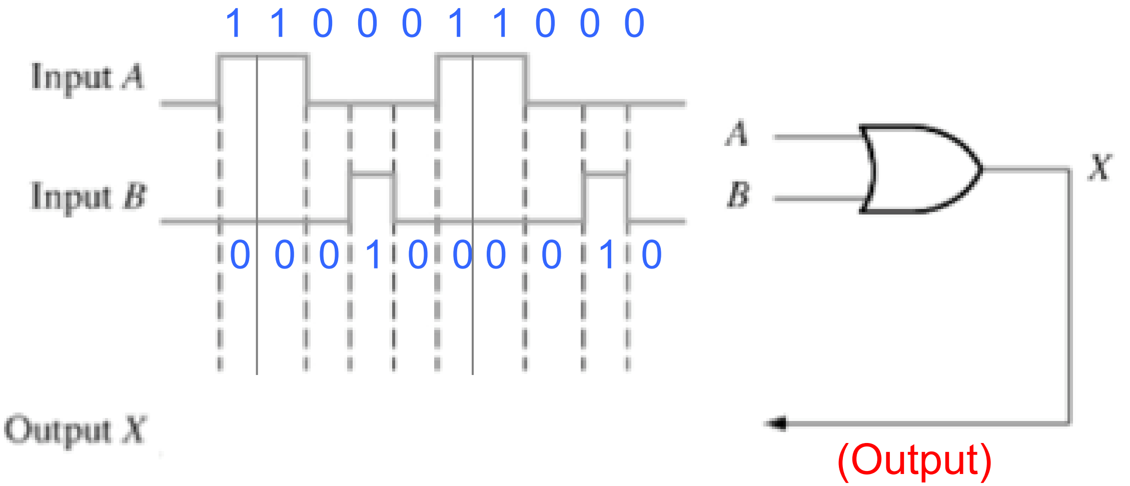
$$X = A + B$$

Continue…

Truth Table

A B	X = A + B
0 0	0
0 1	1
1 0	1
1 1	1

Timing Diagram



Exercise:
Draw the output waveform.

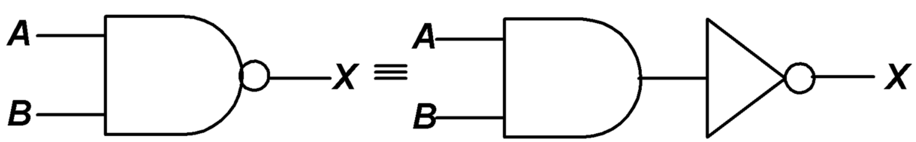
NAND Gate

- **NAND** ≡ NOT-AND

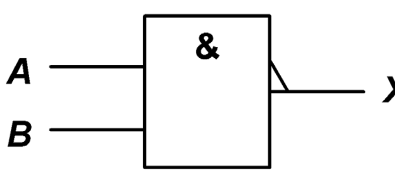
  ⇨ combines the AND gate and an inverter (NOT gate)

- Used as a universal gate
  - Combinations of NAND gates can be used to perform AND, OR and inverter operations
  - If all or any of the input are LOW, then the output is HIGH.
  - If all of the input are HIGH, then the output is LOW

- Symbol used:



(a) Distinctive shape: 2 input NAND gate and its NOT/AND equivalent



(b) Rectangular outline: 2 input NAND gate with polarity indicator

Operator

NAND operator can be represented by a dot with an overbar symbol

$$\overline{0.0} = \overline{0} = 1$$
$$\overline{0.1} = \overline{0} = 1$$
$$\overline{1.0} = \overline{0} = 1$$
$$\overline{1.1} = \overline{1} = 0$$

Logical Expression

$$X = \overline{A \bullet B}$$

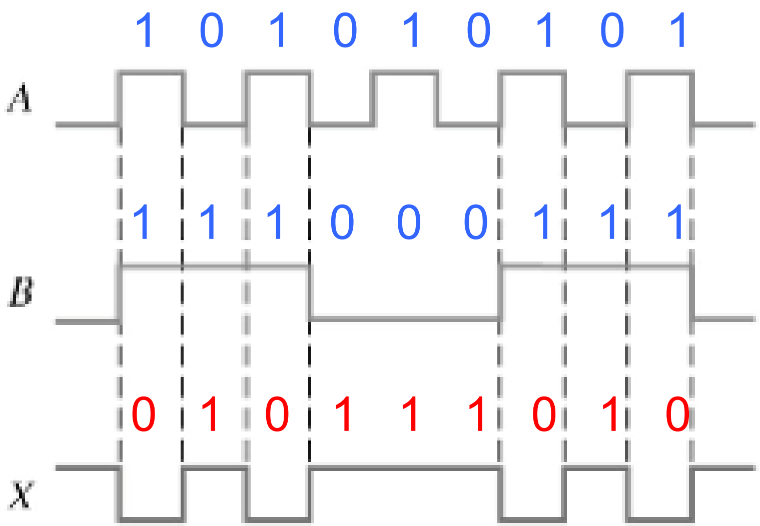
Truth Table

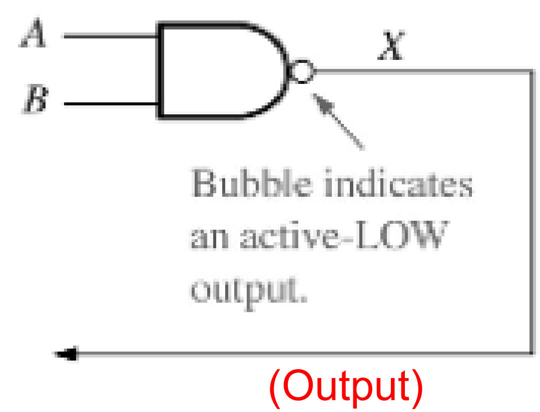
INPUTS A	INPUTS B	AB	OUTPUT $\rightarrow \overline{AB} = X$
0	0	0	$\overline{0.0} = \overline{0} = 1$
0	1	0	$\overline{0.1} = \overline{0} = 1$
1	0	0	$\overline{1.0} = \overline{0} = 1$
1	1	1	$\overline{1.1} = \overline{1} = 0$

Continue…

Timing Diagram

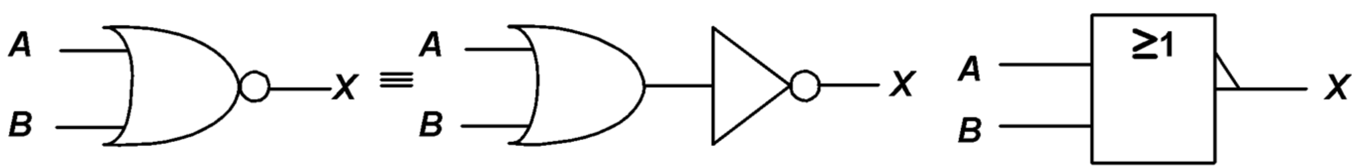
$$X = \overline{A \bullet B}$$





NOR Gate

- **NOR** ≡ NOT-OR
  ⇨ combines the OR gate and an inverter
- Used as a universal gate
  - Combinations of NOR gates can be used to perform **AND**, **OR** and **inverter** operations
  - If all or any of the input are HIGH, then the output is LOW.
  - If all of the input are LOW, then the output is HIGH
- Symbol used:



(a) Distinctive shape: 2 input NOR gate and its NOT/OR equivalent

(b) Rectangular outline with the OR (≥1) qualifying symbol

Continue…

Operator

NOR operator can be represented by a plus with an overbar symbols

$$\overline{0+0} = \overline{0} = 1$$

$$\overline{0+1} = \overline{1} = 0$$

$$\overline{1+0} = \overline{1} = 0$$

$$\overline{1+1} = \overline{1} = 0$$

Truth Table

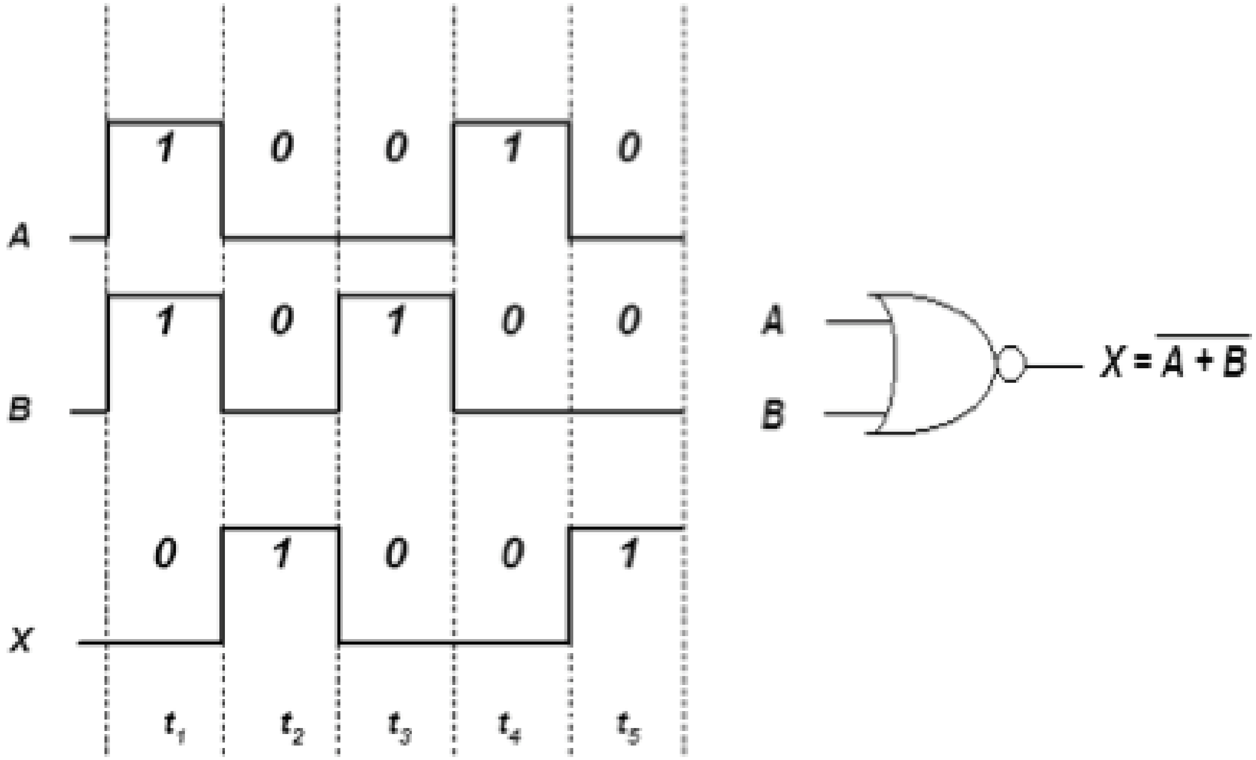
INPUTS		OUTPUT	
A	B	$A+B \longrightarrow$	$\overline{A+B} = X$
0	0	0	$\overline{0+0} = \overline{0} = 1$
0	1	1	$\overline{0+1} = \overline{1} = 0$
1	0	1	$\overline{1+0} = \overline{1} = 0$
1	1	1	$\overline{1+1} = \overline{1} = 0$

Logical Expression

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

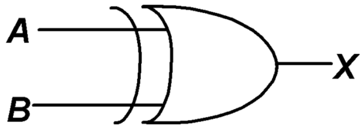
Continue…

Timing Diagram

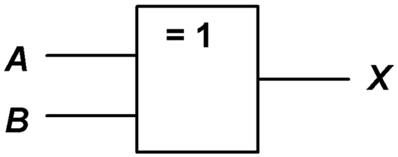


XOR Gate

- **Characteristics**
  - Combines basic logic circuits of AND, OR and Inverter.
  - Has only 2 inputs
  - Used as a universal gate
    - Can be connected to form an adder that allows a computer to do perform addition, subtraction, multiplication and division in ALU (Arithmetic and Logic Unit).
    - If both of the input are at the same logic level, then the output is LOW.
    - If both of the input are at opposite logic levels, then the output is HIGH
- **Symbol**

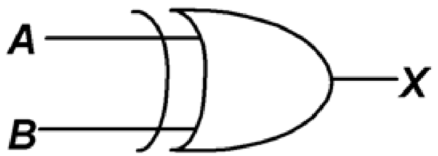


(a) Distinctive shape



(b) Rectangular outline

Continue…

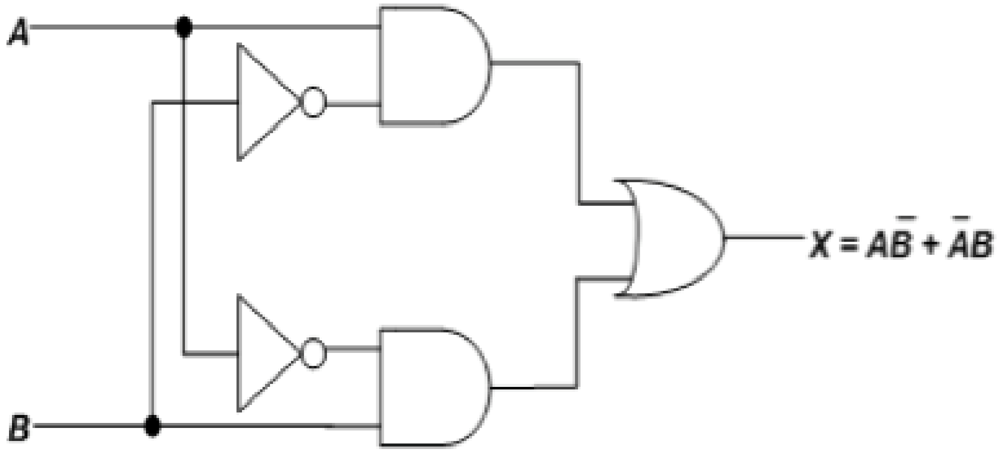


Operator

XOR operator can be represented by a $\oplus$ symbol

Logical Expression

$$X = A \oplus B$$
$$= A\overline{B} + \overline{A}B$$



XOR is a combination of 2 AND gates, 1 OR gate, and 2 NOT gates (inverter)

Continue…

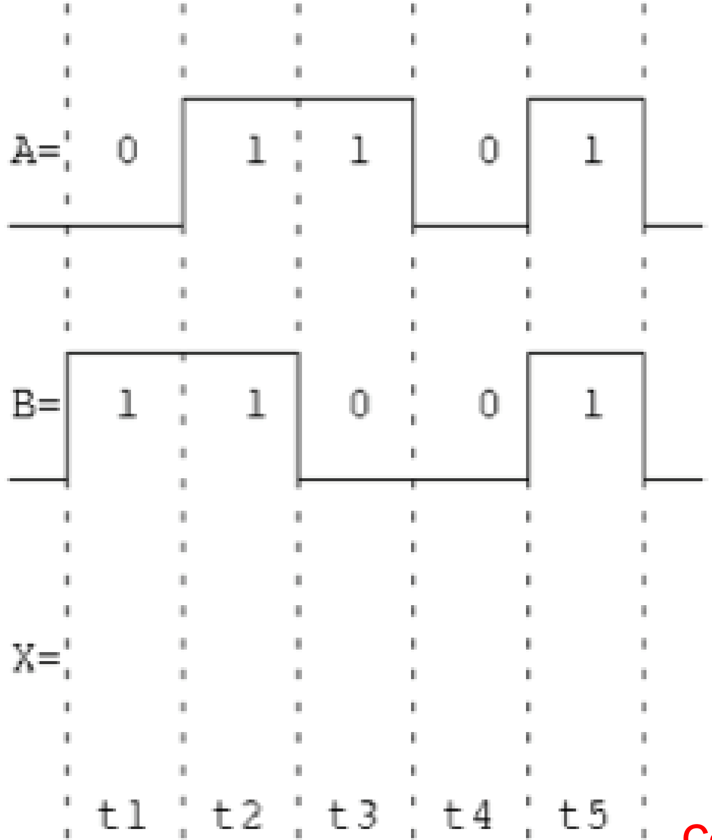
Timing Diagram (DIY)

Truth Table

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

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

X-OR truth table

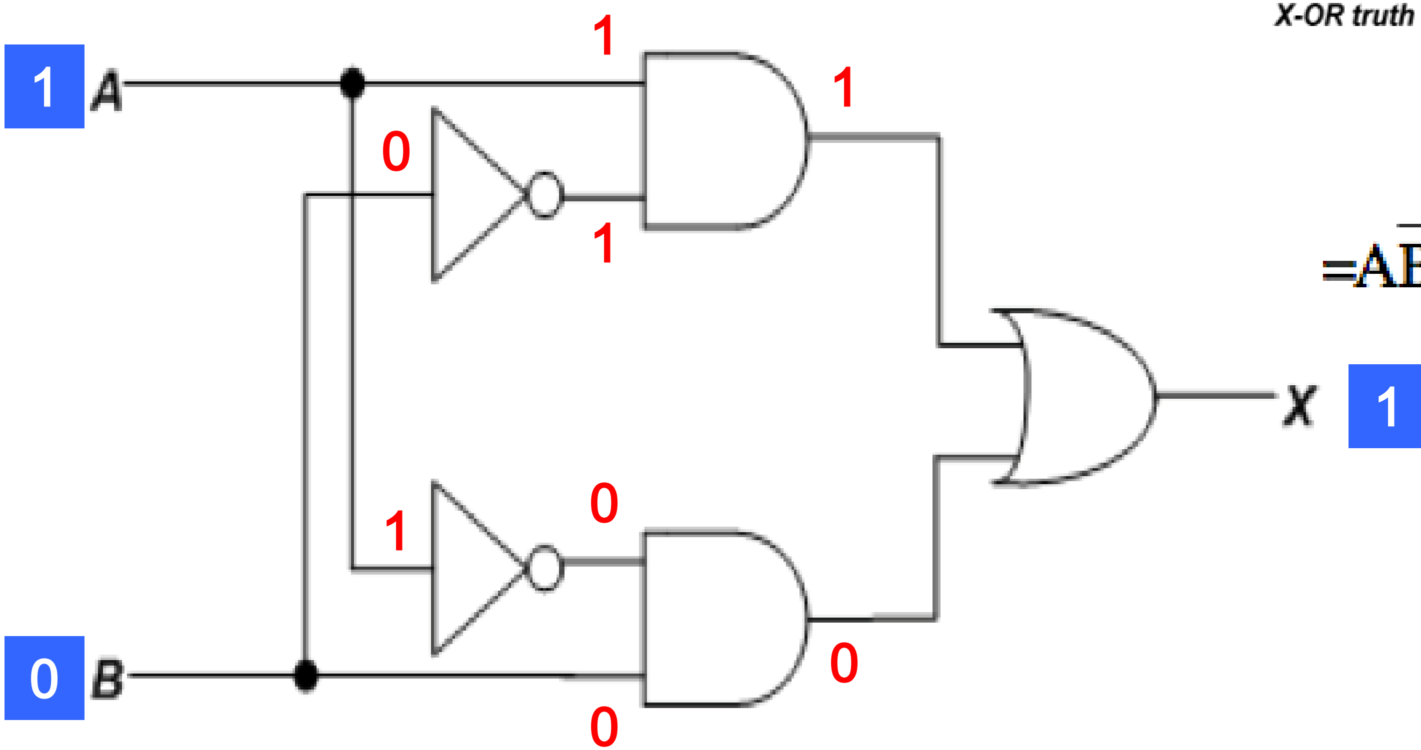


Continue…

Truth Table

A	*B*	*X*
0	0	0
0	1	1
1	0	1
1	1	0

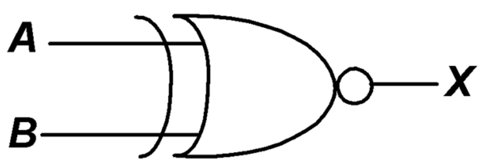
X-OR truth table



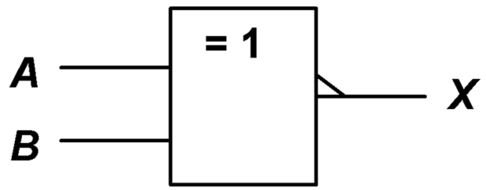
$$=A\overline{B}+\overline{A}B$$

XNOR Gate

- Has only 2 inputs, but output of XNOR is the opposite of XOR
  - If both of the input are at the same logic level, then the output is **HIGH**.
  - If both of the input are at opposite logic levels, then the output is **LOW**.
- Symbol used:



(a) Distinctive shape



(b) Rectangular outline

Continue…

XNOR Gate

Operator

XNOR operator can be represented by a $\odot$ symbol

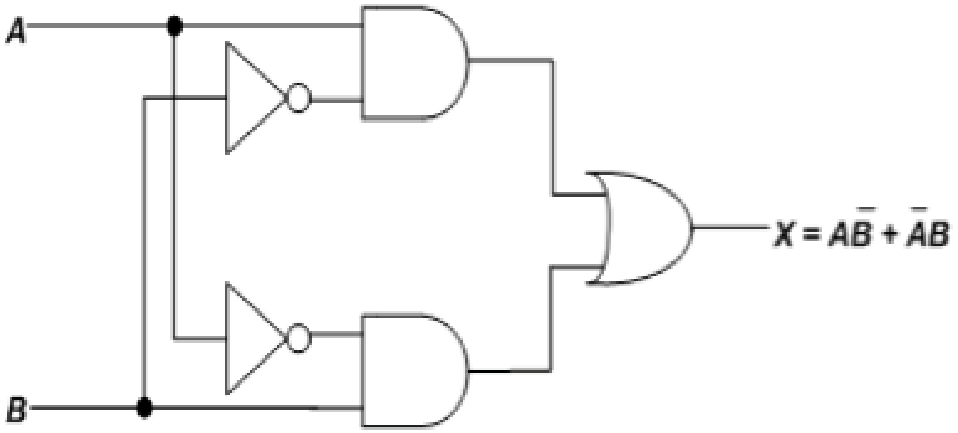
Logical Expression

$$X = A \odot B$$

$$= \overline{A \oplus B}$$

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

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



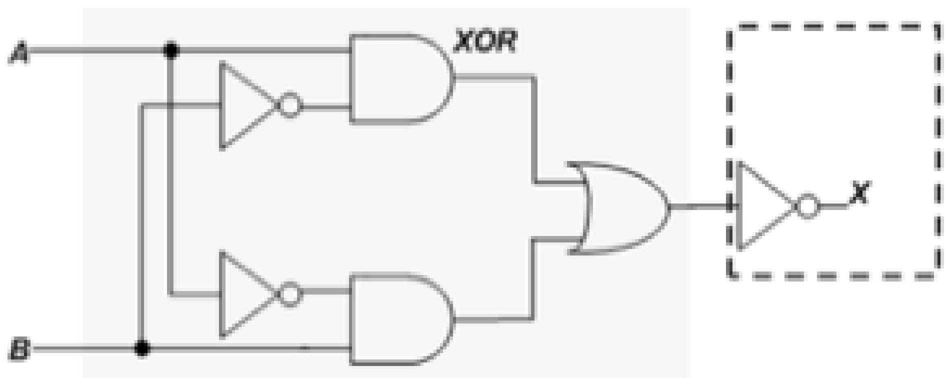
XOR is a combination of 2 AND gates, 1 OR gate and 2 inverters

Continue…

XNOR Implementation

- There are two ways in implementing XNOR Gate:
  - The first implementation by **complementing (inverting)** XOR circuit

1

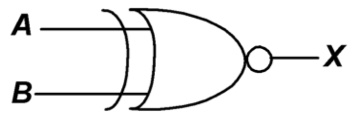


$$X = A\overline{B} + \overline{A}B$$

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

Continue…

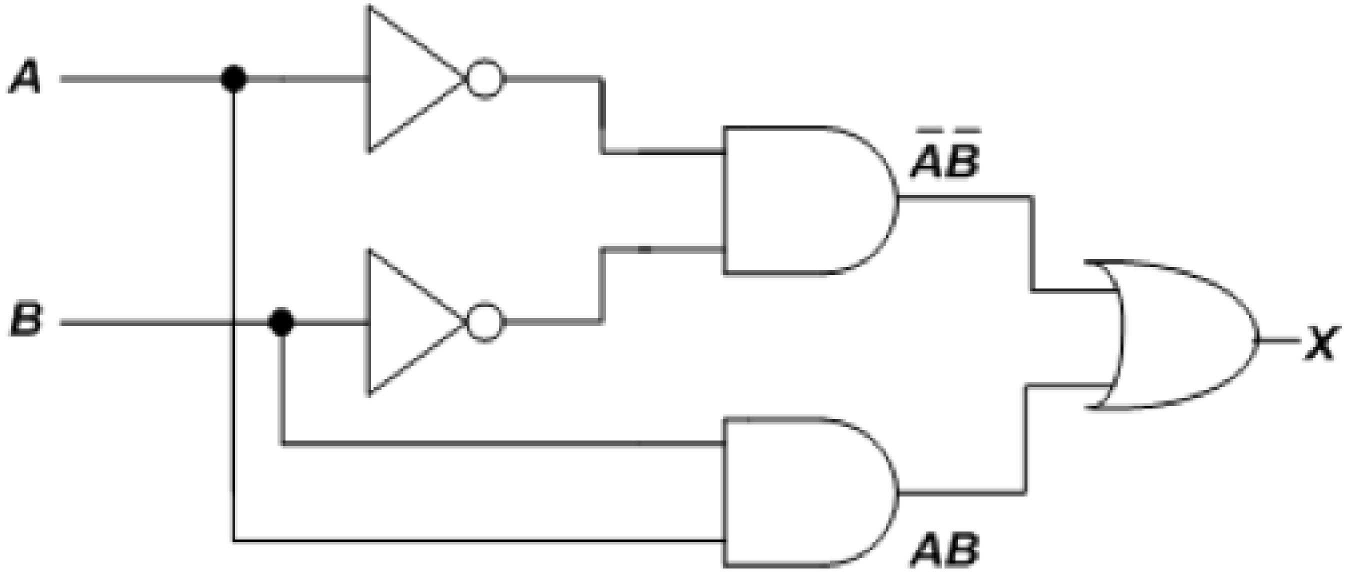
XNOR Implementation



Second implementation is by directly implementing the following expression:

2

$$X = AB + \overline{A}\,\overline{B}$$



Continue…

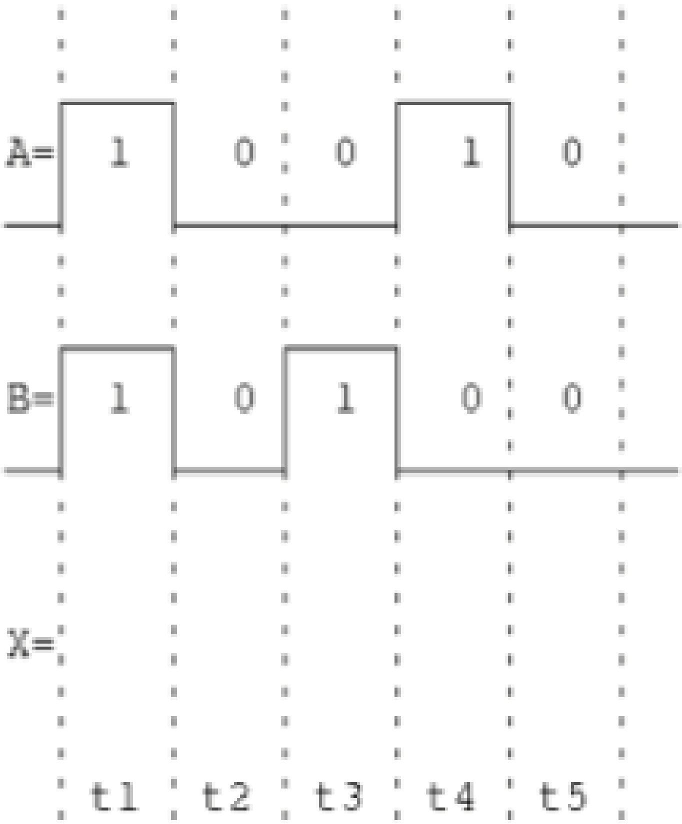
XNOR Gate

Truth Table

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

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

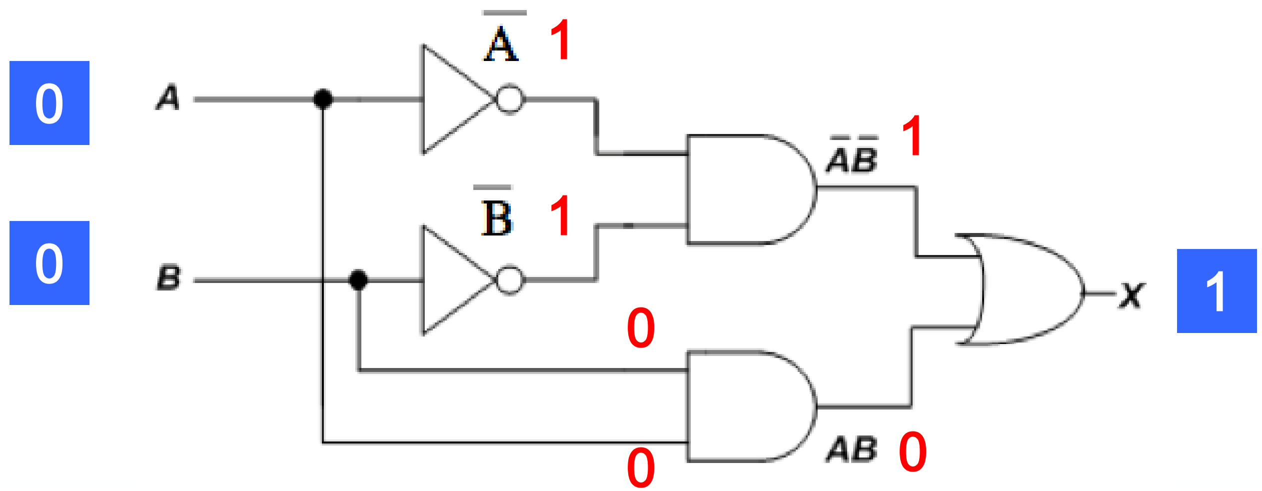
Timing Diagram



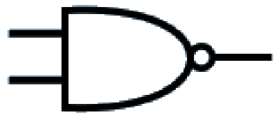
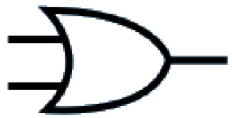
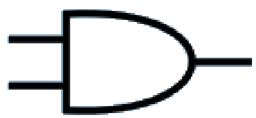
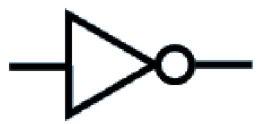
The characteristic of the above circuit can be proven by the following truth table

Example :

A	B	AB	$\bar{A}\ \bar{B}$	$X = AB + \bar{A}\,\bar{B}$
0	0	0	1	1
0	1	0	0	0
1	0	0	0	0
1	1	1	0	1



Summary

	NAND	Opposite of AND
	OR	Either is true (or both)
	XOR	Exactly one is true
	AND	Both are true
	NOT	Reverses the input
	NOR	Opposite of OR
	XNOR	Opposite of XOR