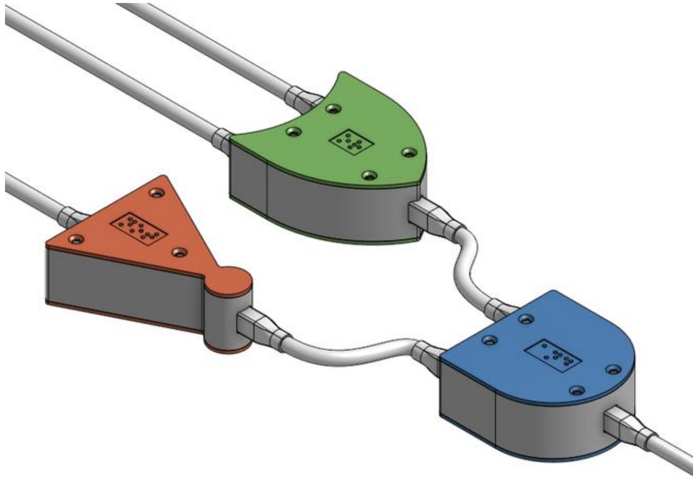

CS 211 - Digital Logic Design
211 عال - تصميم المنطق الرقمي

First Term - 1439/1440
Lecture #5

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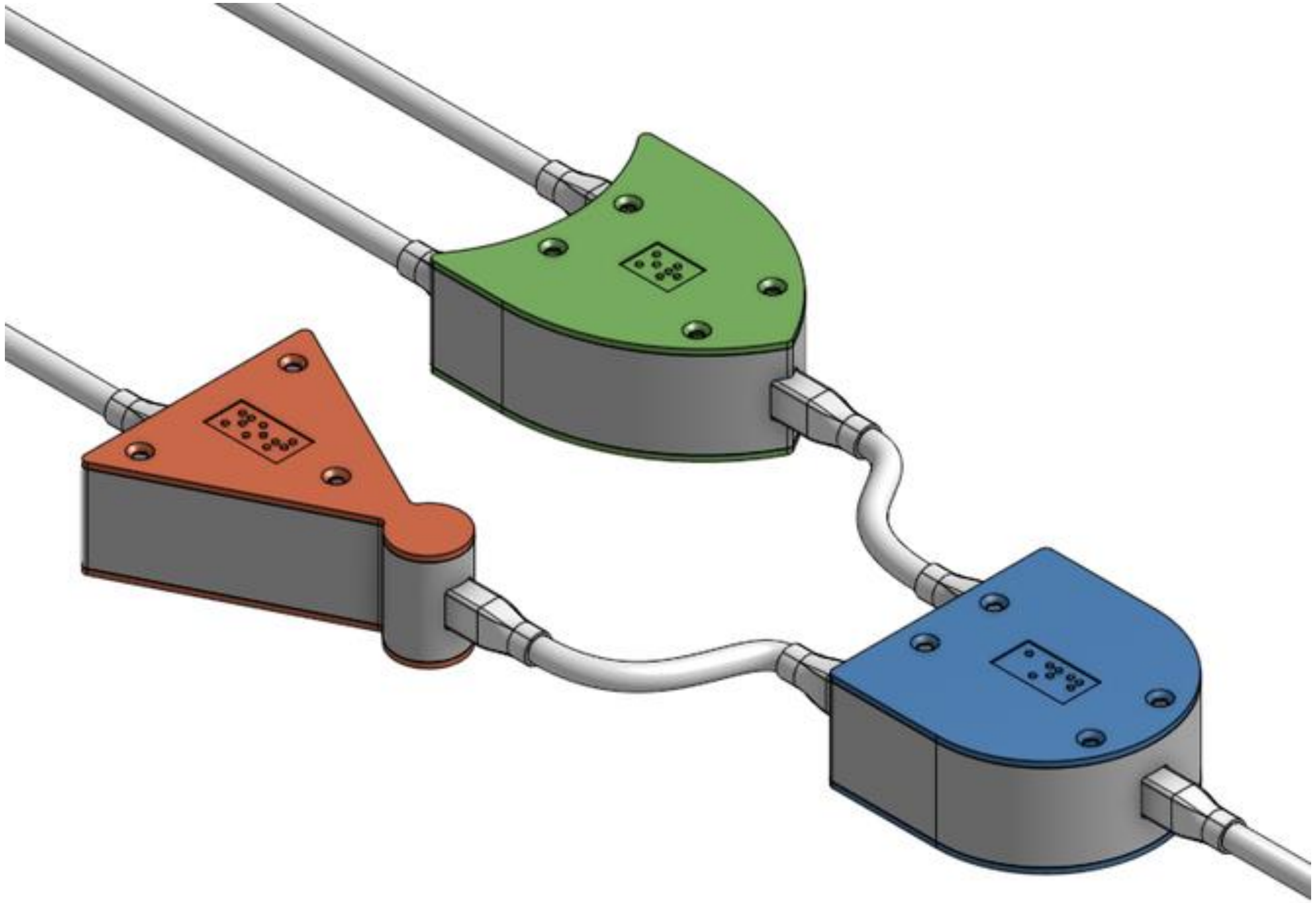
Administrivia

- Assignment #1:
  - Released on Sunday.
  - Due: **Sunday, October 7, 2018**.

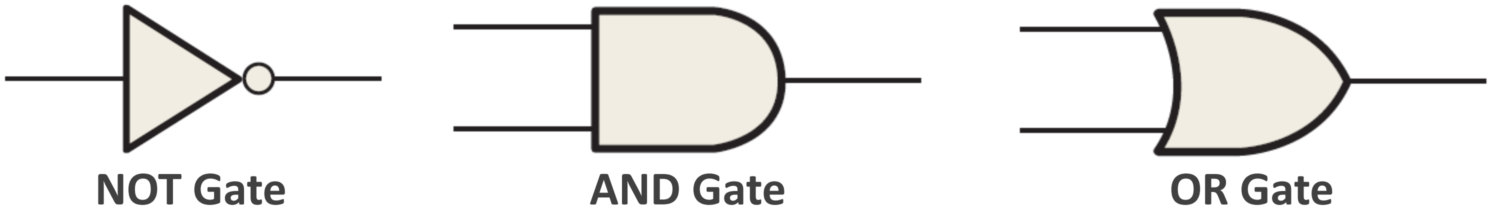
Website: http://hshehata.github.io/courses/su/cs211



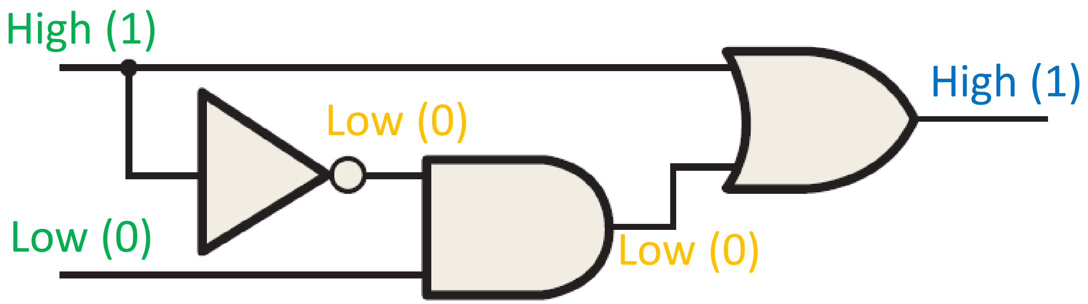
Chapter 2: Logic Gates

Logic Gates/Circuits

- **Logic Gate**: electronic device implementing a basic logical operation on 1+ binary input and producing 1 binary output.
  - Examples:

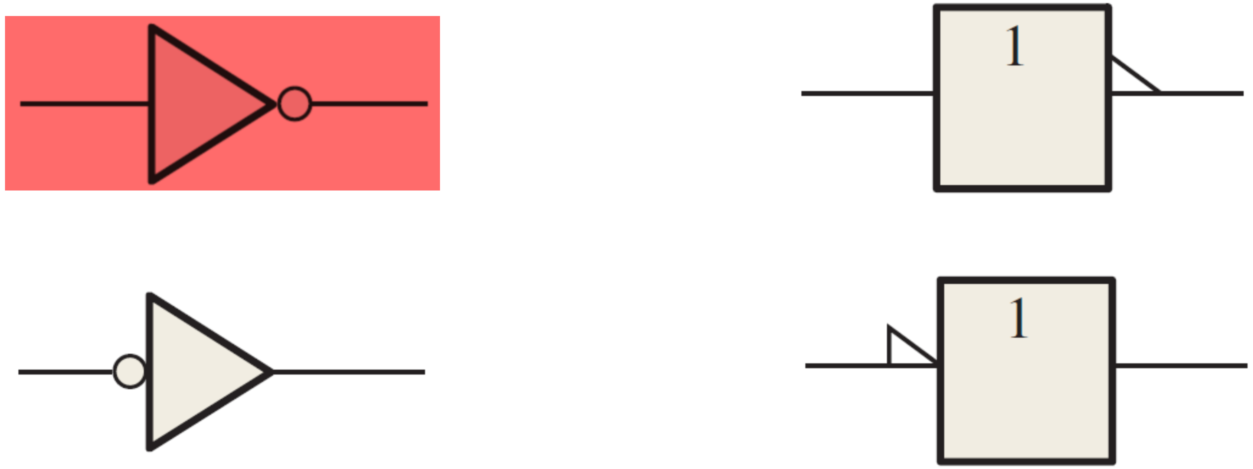


- **Logic Circuit**: electronic circuit built out of logic gates!
  - Each wire carries a single bit represented in terms of voltage level.
    - High voltage level (e.g., 5v) ➔ logical 1.
    - Low voltage level (e.g., 0v) ➔ logical 0.
  - Example:



Inverter (or NOT Gate)

- Performs operation called inversion or complementation.
  - Takes 1 (single-bit) input, and produces 1 (single-bit) output.
  - Output value equals the inverse of input value.
- Symbols:



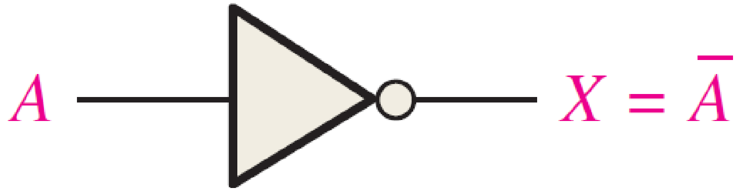
Operation of Inverter

- Possible scenarios:
  - Low voltage applied to input → High voltage produced at output
  - High voltage applied to input → Low voltage produced at output
- Operation can be represented as a Truth Table, that lists all input combinations with the corresponding outputs!

Input	Output
Low (0)	High (1)
High (1)	Low (0)

Logic Expression of Inverter

- **Boolean Algebra**: is a type of mathematics that uses variables and operators to describe logic circuits.
- Boolean expression that describes inverter is: $X = \bar{A}$

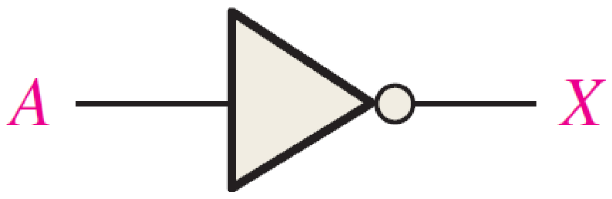


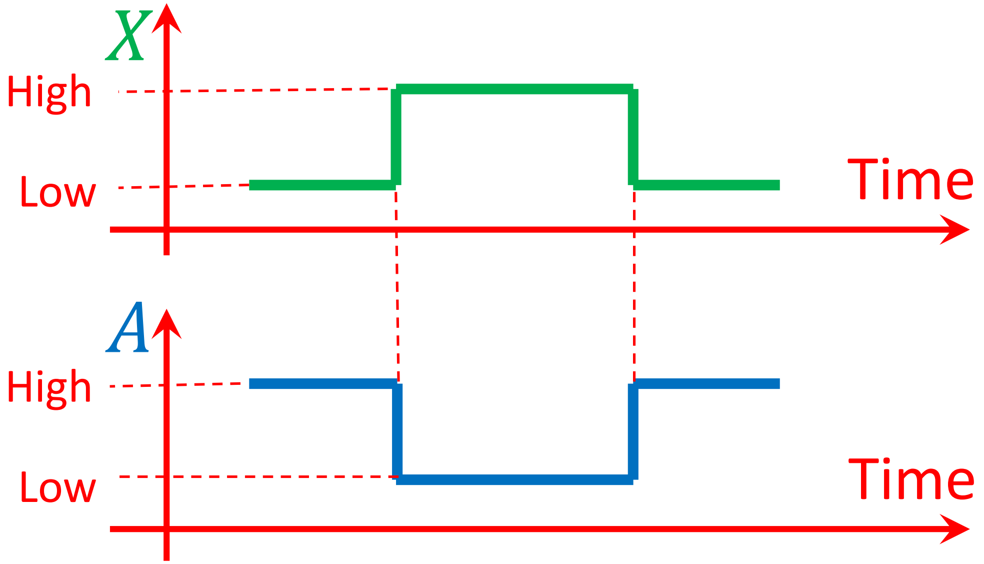
  - If $A = 0$, then $X = \bar{0} = 1$
  - If $A = 1$, then $X = \bar{1} = 0$

- Complemented variable $\bar{A}$ is read as: "A bar" or "not A".

Timing Diagram of Inverter

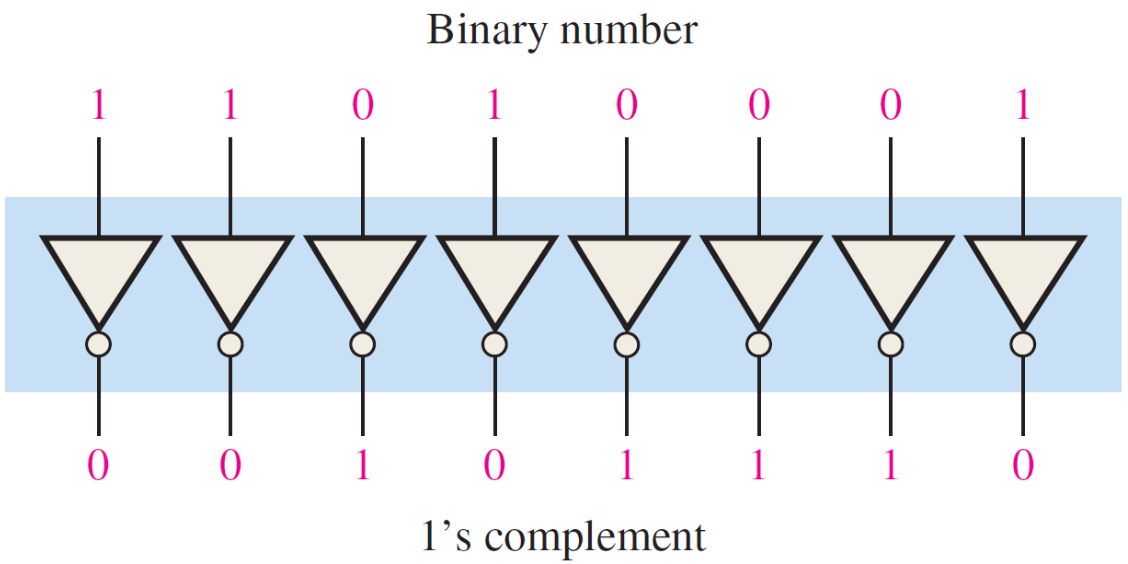
- Timing Diagram: represents how signals of a logic circuit change over time.
  - X-axis → time.
  - Y-axis → signals values. Either High (1) or Low (0).
- Example:





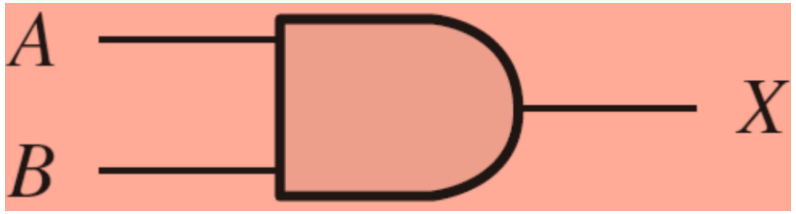
Application of Inverter

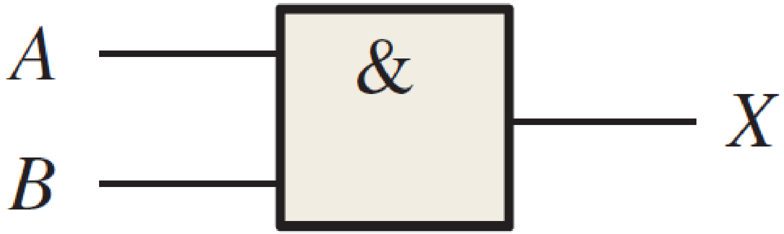
- Inverters can be used to calculate 1’s complement of binary numbers.
- Example: Circuit to produce 1’s comp. of an 8-bit number.



AND Gate

- Performs operation called logical multiplication.
  - Takes 2^+ inputs, and produces 1 output.
  - Output value is High (1) if and only if all inputs are High (1).
  - Output value is Low (0) if and only if 1^+ inputs are Low (0).
- Symbols:





AND Gate Truth Table

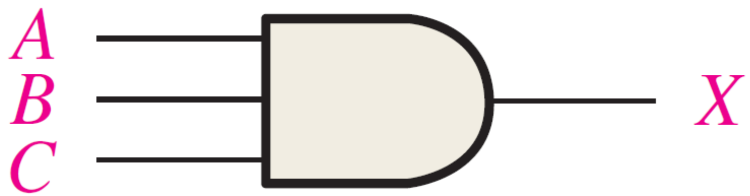
- For a 2-input AND Gate:

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

- Note: Number of possible binary input combinations to an n-input gate is: 2^n ➔ Truth table must have 2^n rows!

Example: Truth Table for 3-input AND Gate

$n = 3 \rightarrow N = 2^3 = 8$



Inputs			Output
A	B	C	X
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

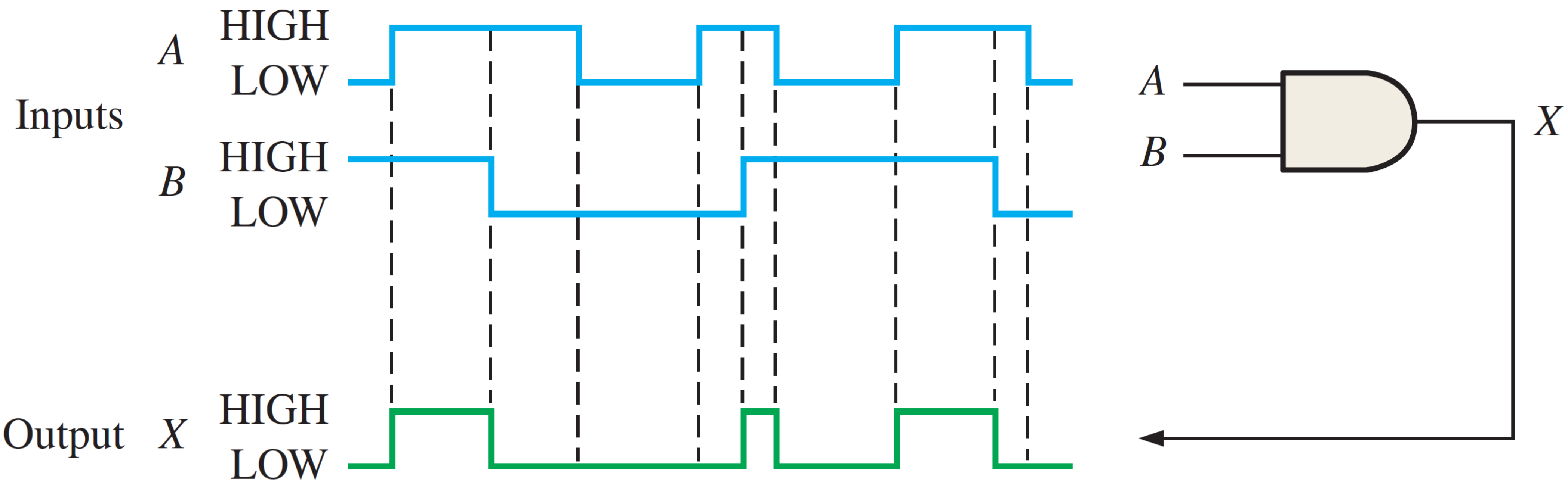
Logic Expression of AND Gate

- In Boolean algebra, AND gate is represented using Boolean multiplication operator ➔ " $\cdot$ "
  - Boolean multiplication is similar to binary multiplication:
  - $0 \cdot 0 = 0, 0 \cdot 1 = 0, 1 \cdot 0 = 0, 1 \cdot 1 = 1$
- Boolean expression for 2-input AND gate is:
  - $X = A \cdot B$, or $X = AB$

- Boolean expression for 3-input AND gate is:
  - $X = A \cdot B \cdot C$, or $X = ABC$

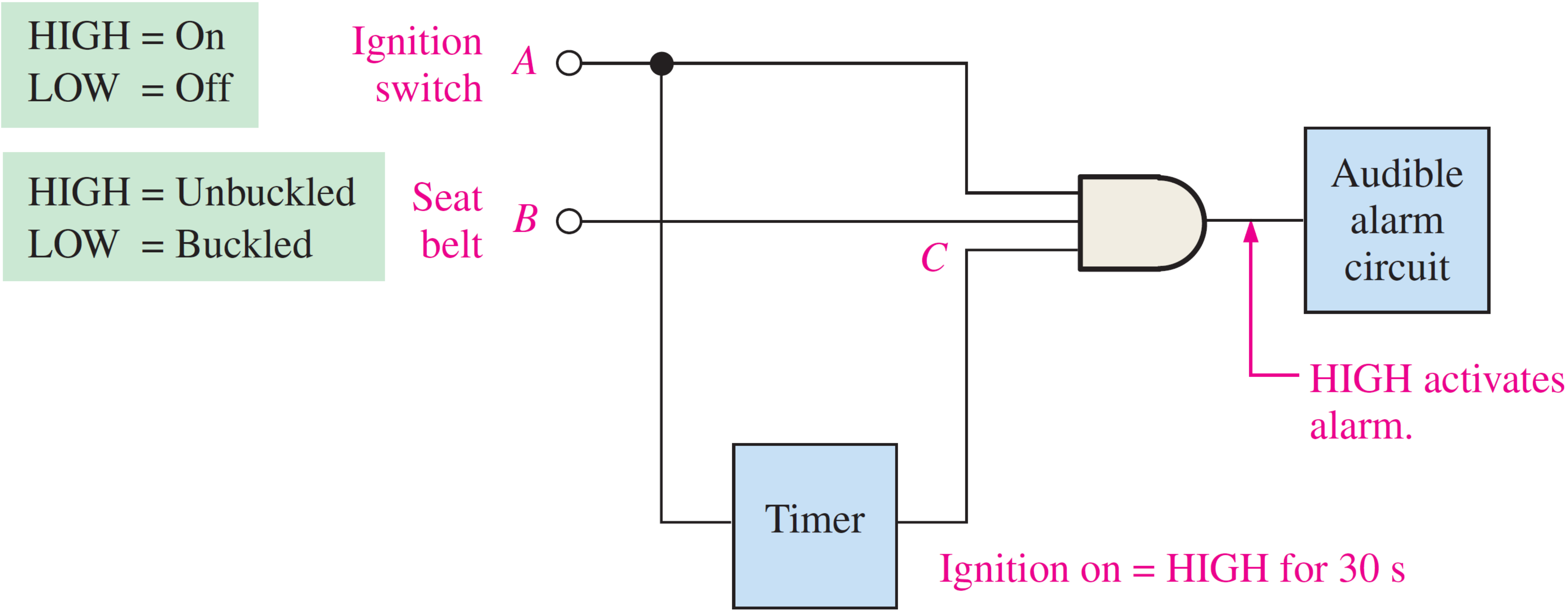
Timing Diagram of AND Gate

- Example: 2-input AND Gate



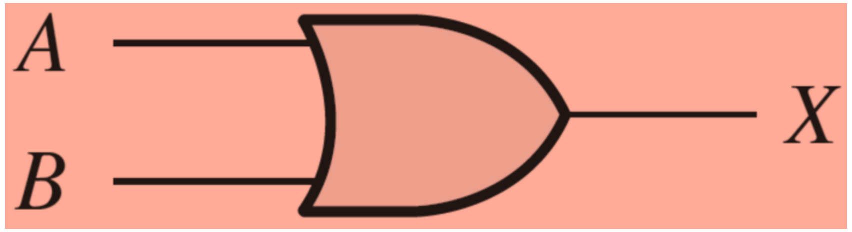
Application of AND Gate

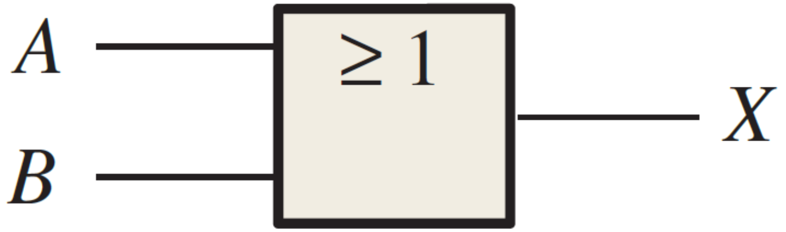
➢ Example: Seat Belt Alarm System



OR Gate

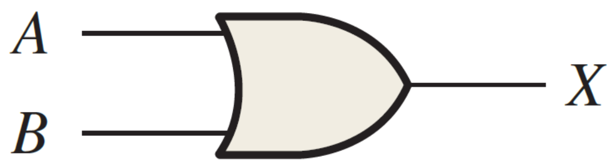
- Performs operation called logical addition.
  - Takes 2⁺ inputs, and produces 1 output.
  - Output value is High (1) if and only if 1⁺ inputs are High (1).
  - Output value is Low (0) if and only if all inputs are Low (0).
- Symbols:





OR Gate Truth Table

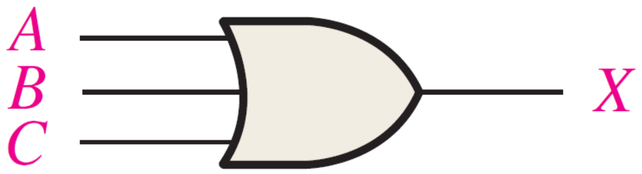
- For a 2-input OR Gate:



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

Example: Truth Table for 3-input OR Gate

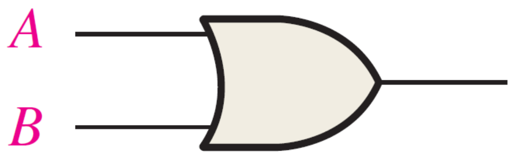
$n = 3 \rightarrow N = 2^3 = 8$



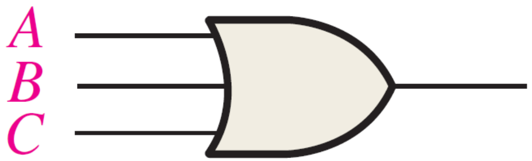
Inputs			Output
A	B	C	X
0	0	0	0
0	0	1	1
0	1	0	1
0	1	1	1
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	1

Logic Expression of OR Gate

- In Boolean algebra, OR gate is represented using Boolean addition operator ➔ " $+$ "
  - Boolean addition differs from binary addition in one case (1+1=?):
    - $0+0=0,\ 0+1=1,\ 1+0=1,\ \mathbf{1+1=1}$
- Boolean expression for 2-input AND gate is:
  - $X=A+B$

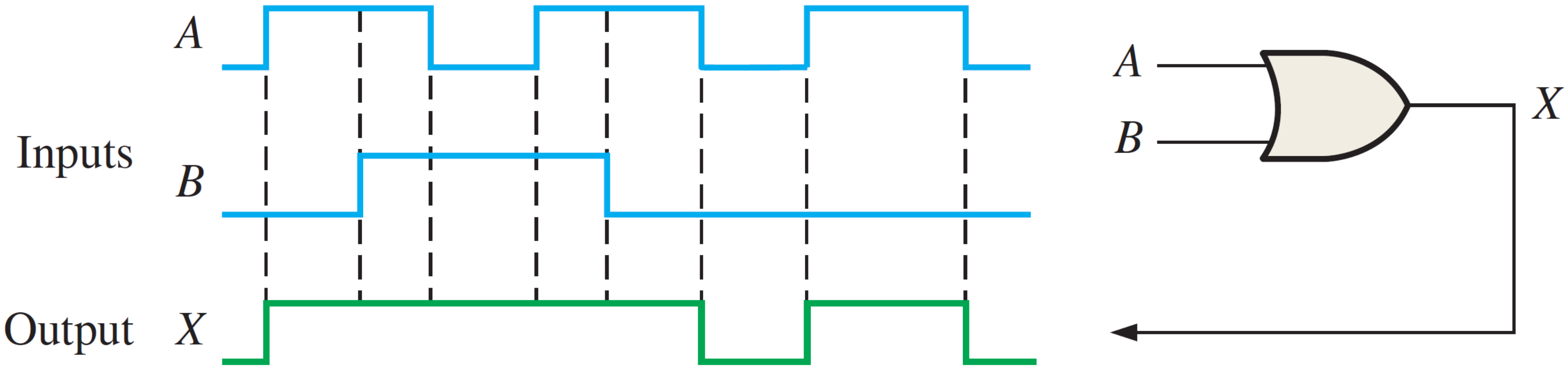


- Boolean expression for 3-input AND gate is:
  - $X=A+B+C$



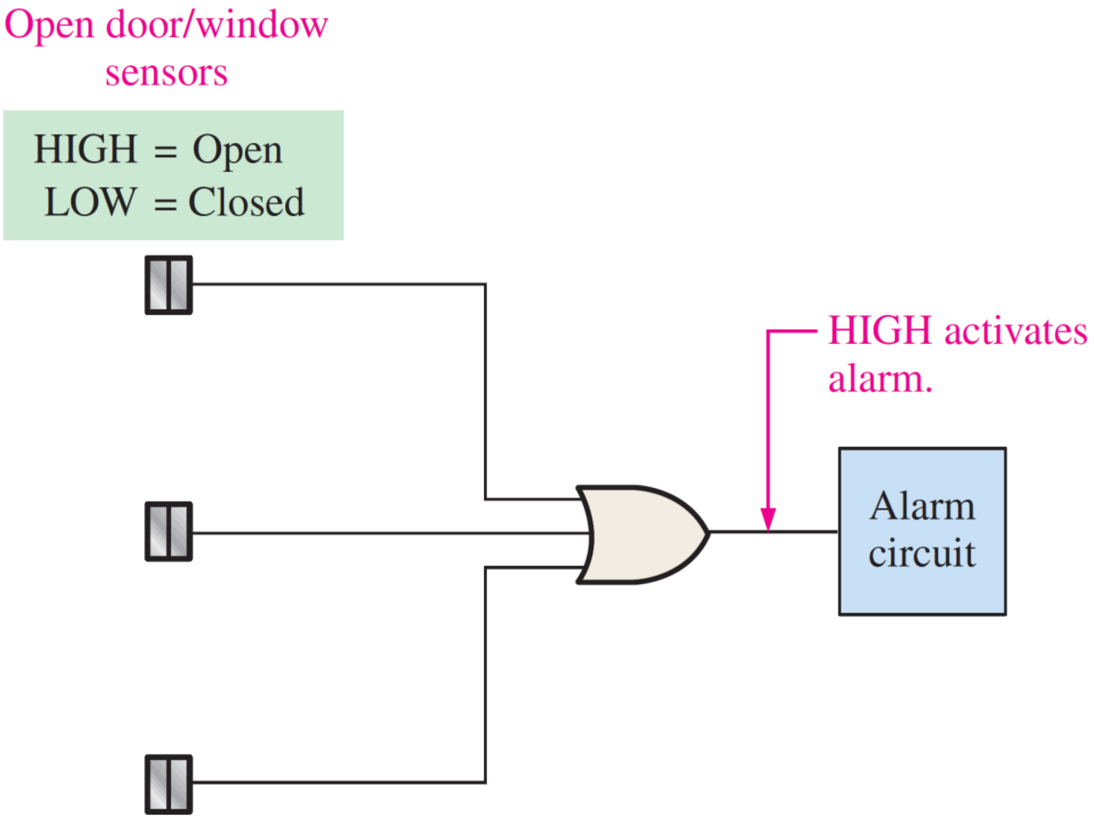
Timing Diagram of OR Gate

- Example: 2-input OR Gate



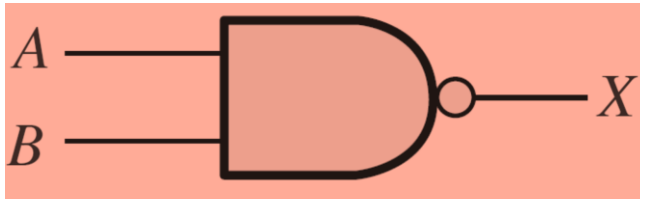
Application of OR Gate

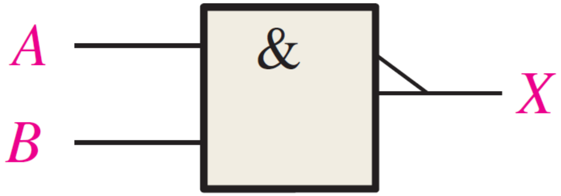
- Example: Simplified Intrusion Detection System



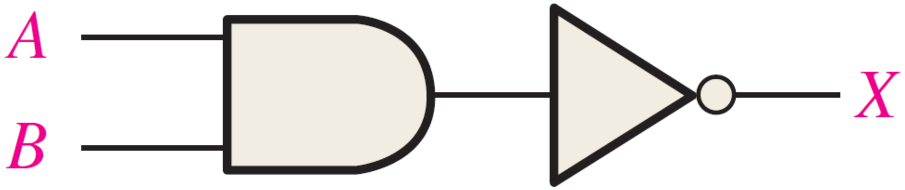
NAND Gate

- Contraction of NOT-AND ➔ AND with an inverted output.
  - Takes 2^+ inputs, and produces 1 output.
  - Output value is Low (0) if and only if all inputs are High (1).
  - Output value is High (1) if and only if 1^+ inputs are Low (0).
- Symbols:





- Equivalent to:



NAND Gate Truth Table

- For a 2-input NAND Gate:

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

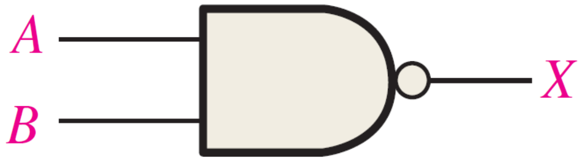
- Note: NAND Gate is equivalent to Negative-OR Gate.

Logic Expression of NAND Gate

- In Boolean algebra, NAND gate is represented by multiplication combined with complementation ➔ “$\overline{\cdot}$”

- Boolean expression for 2-input NAND gate is:
  - $X = \overline{A \cdot B}$, or $X = \overline{AB}$

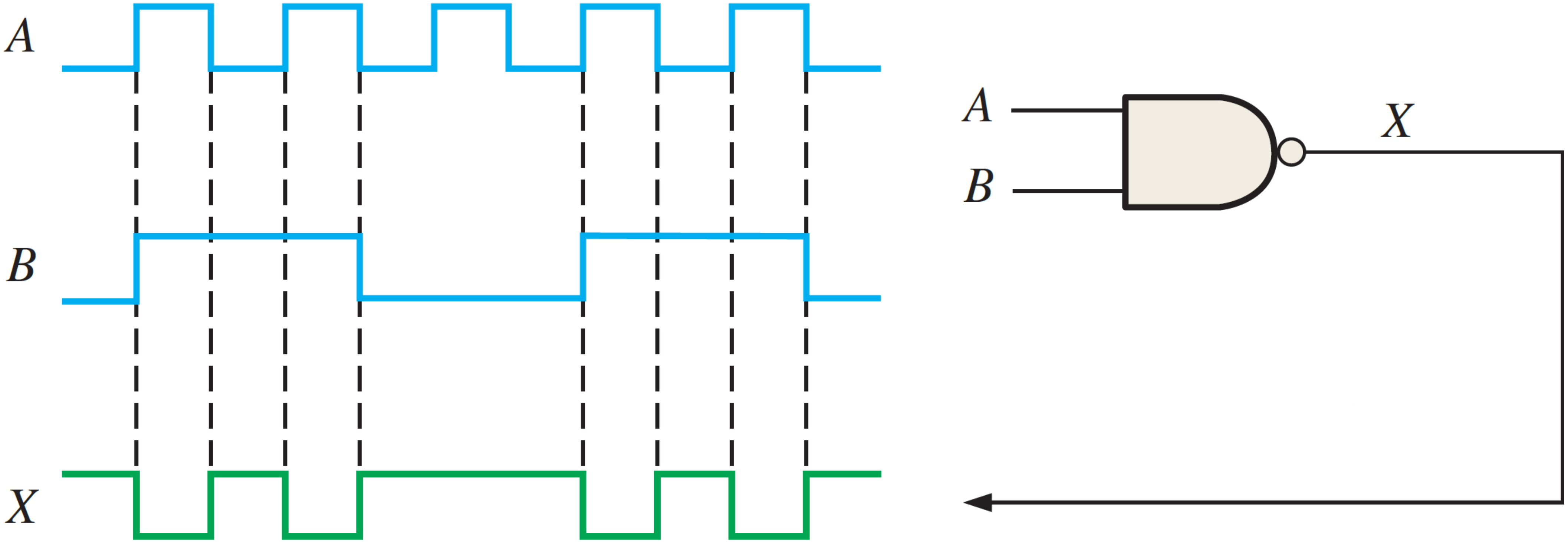
A	B	$\overline{AB} = X$
0	0	$\overline{0 \cdot 0} = \overline{0} = 1$
0	1	$\overline{0 \cdot 1} = \overline{0} = 1$
1	0	$\overline{1 \cdot 0} = \overline{0} = 1$
1	1	$\overline{1 \cdot 1} = \overline{1} = 0$



- Boolean expression for 3-input NAND gate is:
  - $X = \overline{A \cdot B \cdot C}$, or $X = \overline{ABC}$

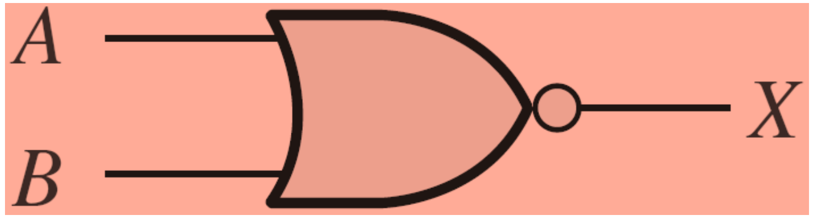
Timing Diagram of NAND Gate

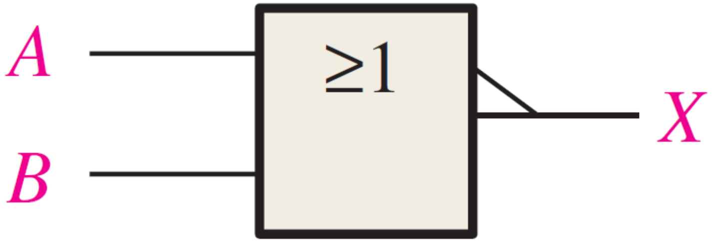
- **Example**: 2-input NAND Gate



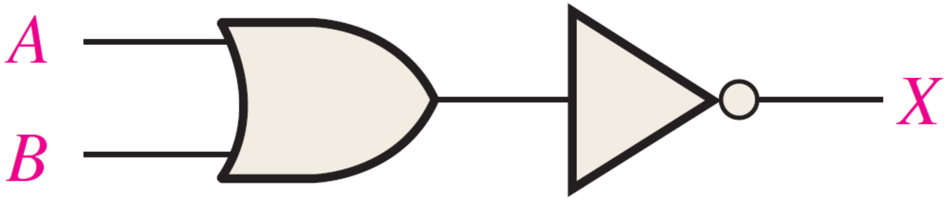
NOR Gate

- Contraction of NOT-OR → OR with an inverted output.
  - Takes 2^+ inputs, and produces 1 output.
  - Output value is Low (0) if and only if 1^+ inputs are High (1).
  - Output value is High (1) if and only if all inputs are Low (0).
- Symbols:



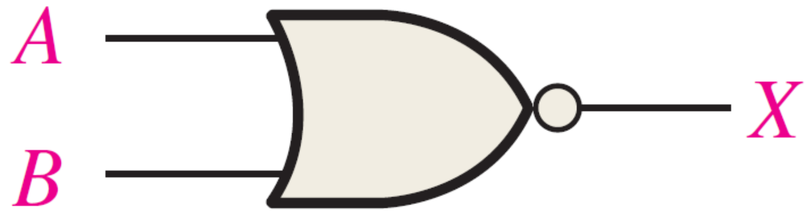


- Equivalent to:



NOR Gate Truth Table

- For a 2-input NOR Gate:



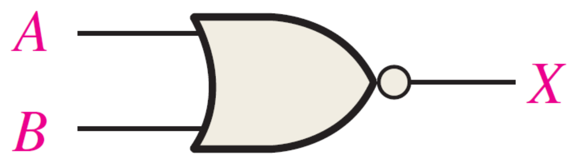
Inputs		Output
A	B	X
0	0	1
0	1	0
1	0	0
1	1	0

- Note: NOR Gate is equivalent to Negative-AND Gate.

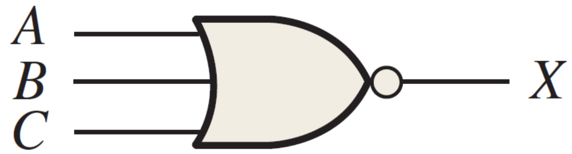
Logic Expression of NOR Gate

- In Boolean algebra, NOR gate is represented by addition combined with complementation ➔ " $\overline{+}$ "
- Boolean expression for 2-input NOR gate is:
  - $X = \overline{A + B}$

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

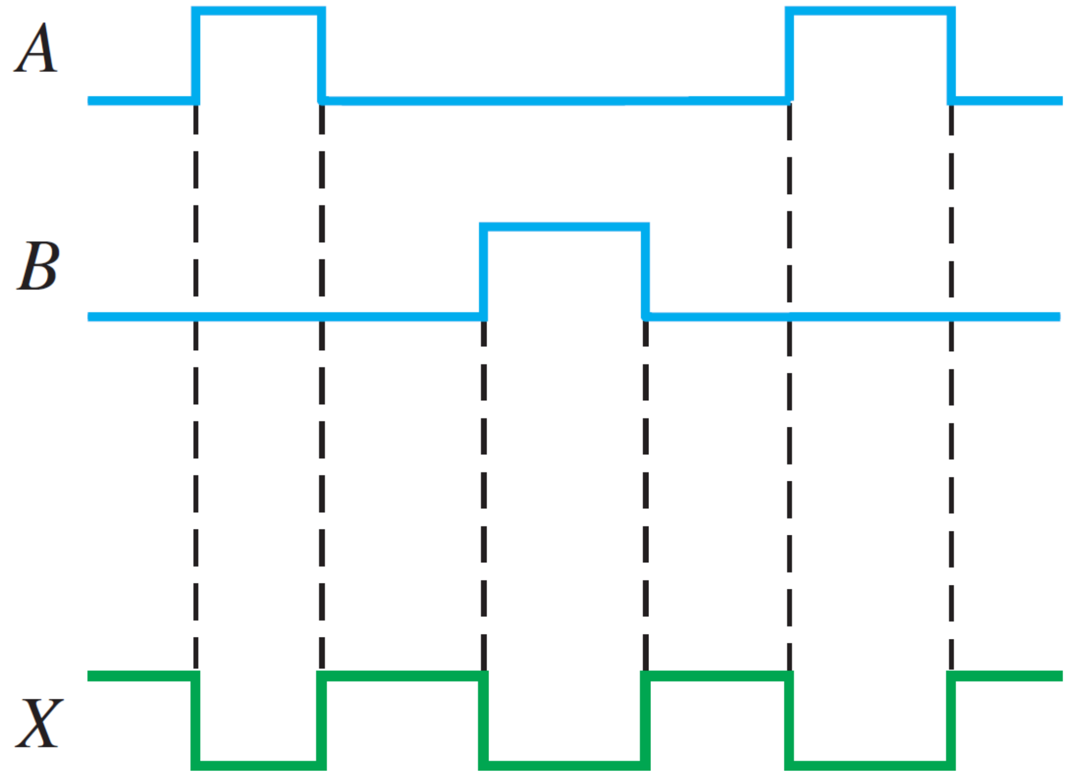


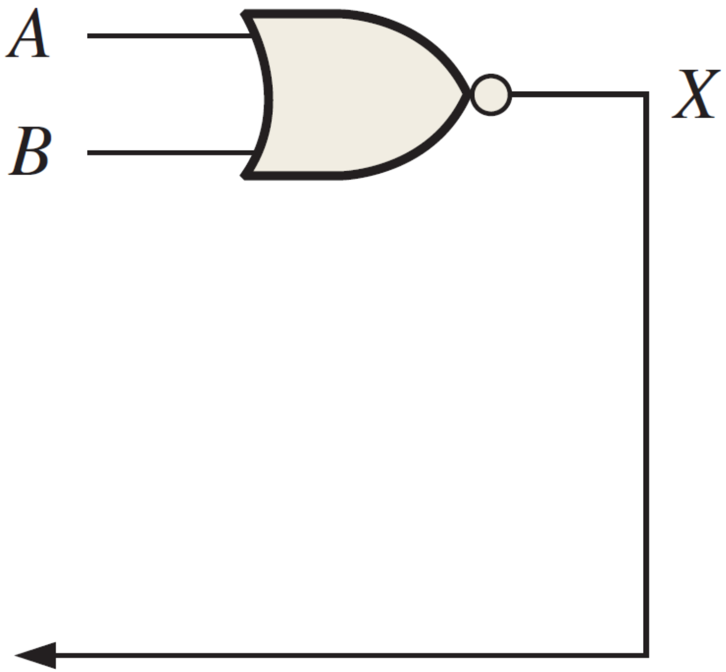
- Boolean expression for 3-input NOR gate is:
  - $X = \overline{A + B + C}$



Timing Diagram of NOR Gate

- **Example**: 2-input NOR Gate





Reading Material

- Floyd, Chapter 3:
  - Pages XX - XX