Fundamentals of Digital Circuits - Logic Gates

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What are logic gates?

- In the binary lesson, we discussed the switches inside a computer
- Logic gates are the switches that turn ON or OFF depending on what the user is doing!
- They are the building blocks for how computers work.

Logic Circuits

- A collection of individual logic gates connect with each other and produce a logic design known as a Logic Circuit
- The following are the types of logic circuits:
  - Decision making
  - Memory
  - A gate has two or more binary inputs and single output.

Basic Logic Gates

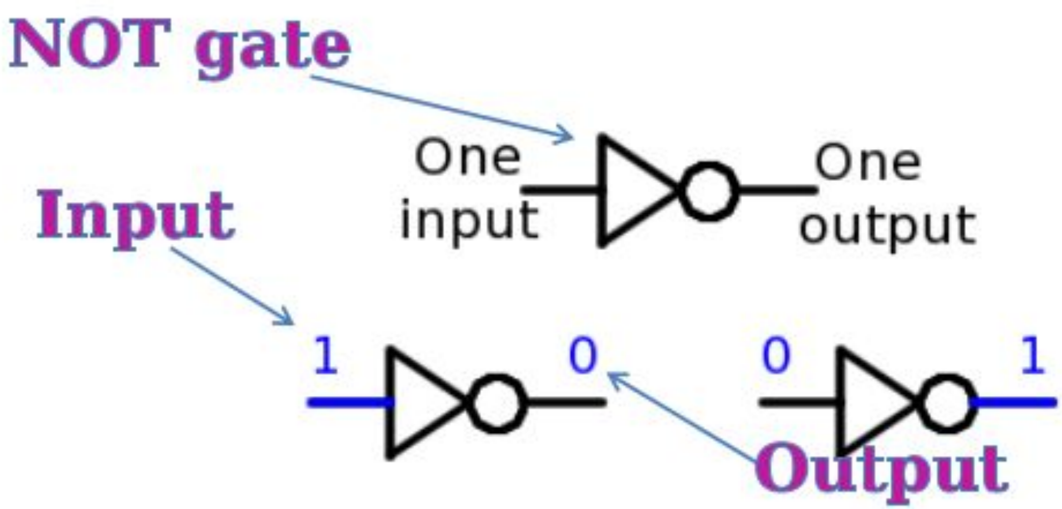
- The following are the three basic gates:
  - NOT
  - AND
  - OR
  - Each logic gate performs a different logic function. You can derive logical function or any Boolean or logic expression by combining these three gates.

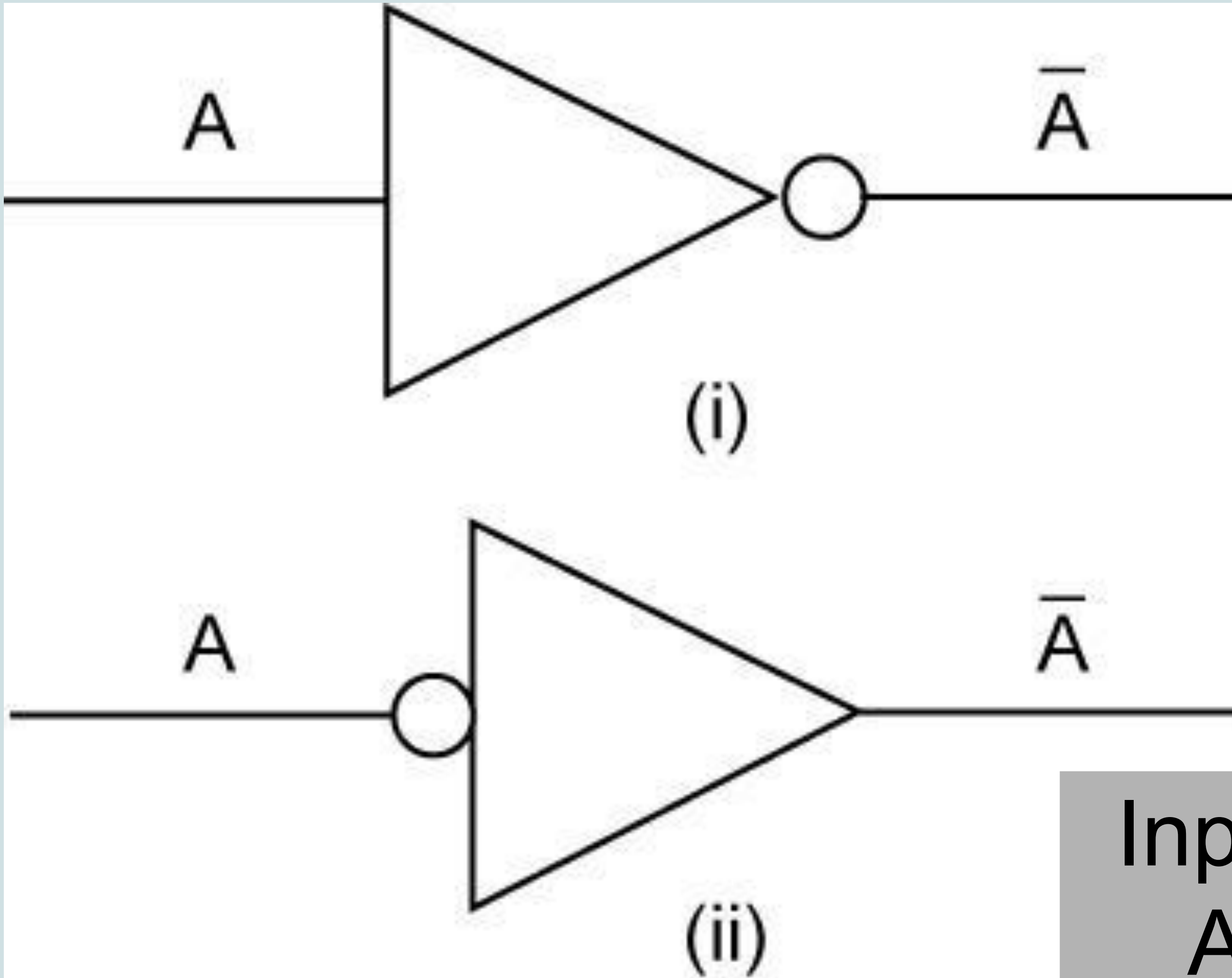
NOT Gate

- The simplest form of a digital logic circuit is the inverter or the NOT gate
- It consists of one input and one output and the input can only be binary numbers namely; 0 and 1

NOT

- NOT is the most simple logic gate.
- All it does is take in an input that is either ON or OFF and spits out the opposite.
- So for a 1 it will give a 0, and for a 0 it will give a 1.
- Another name for a NOT gate is inverter, because it inverts (makes opposite) the input

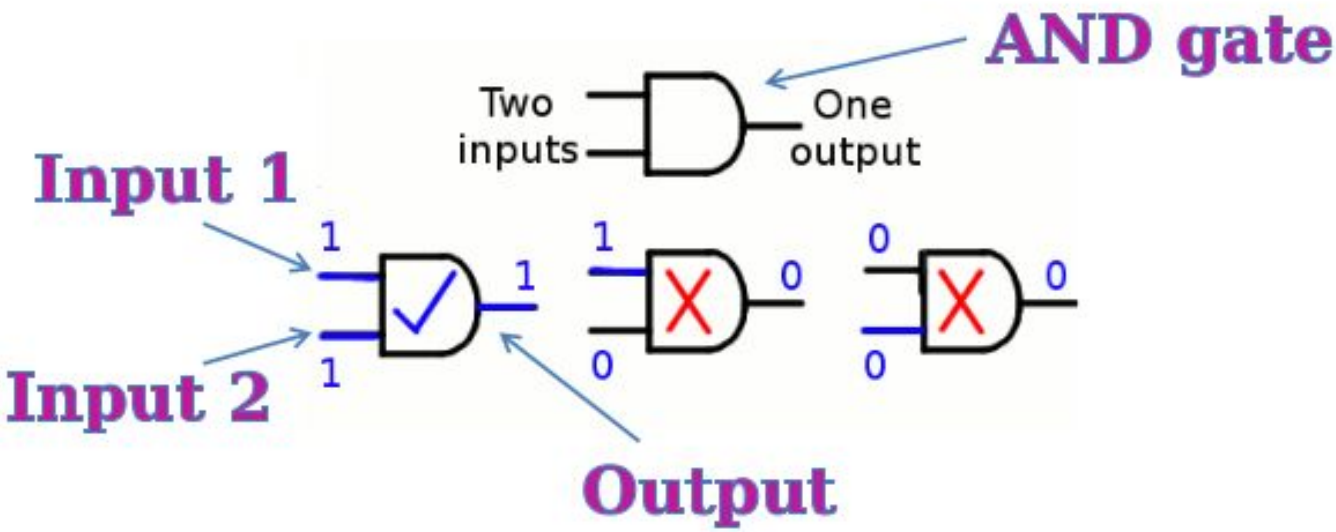




Input A	Output ~A
0	**1**
1	**0**

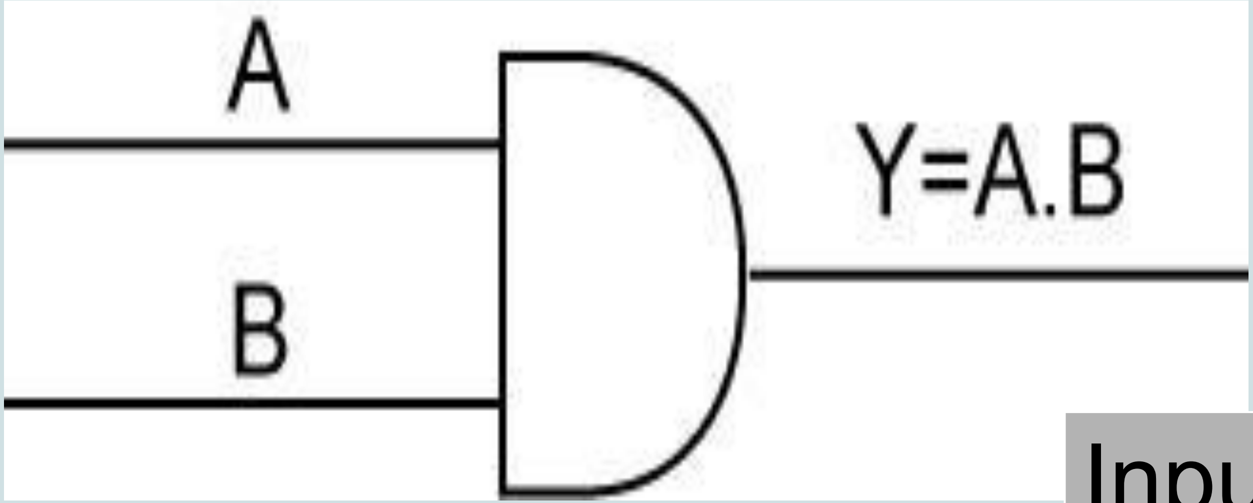
AND

- Unlike NOT, AND needs two inputs
- It only turns on when both inputs are ON
- If only one input is on, it spits out OFF
- If both inputs are off, it spits out OFF



AND Gate

- The AND gate is a logic circuit that has two or more inputs and a single output
- The operation of the gate is such that the output of the gate is a binary 1 if and only if all inputs are binary 1
- Similarly, if any one or more inputs are binary 0, the output will be binary 0.



Input		Output
A	B	Y=A.B
0	0	0
0	1	0
1	0	0
1	1	1

AND Truth Table

- A convenient way to visualize the outputs for the logic gates is through a truth table
- The truth table depicts the gate's response to each possible set of inputs

Input 1

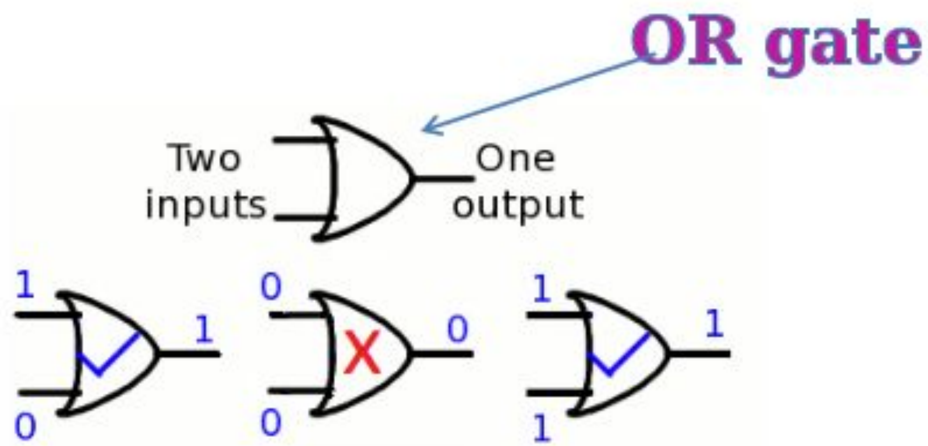
	0	1
0	0	0
1	0	1

Input 2

Output

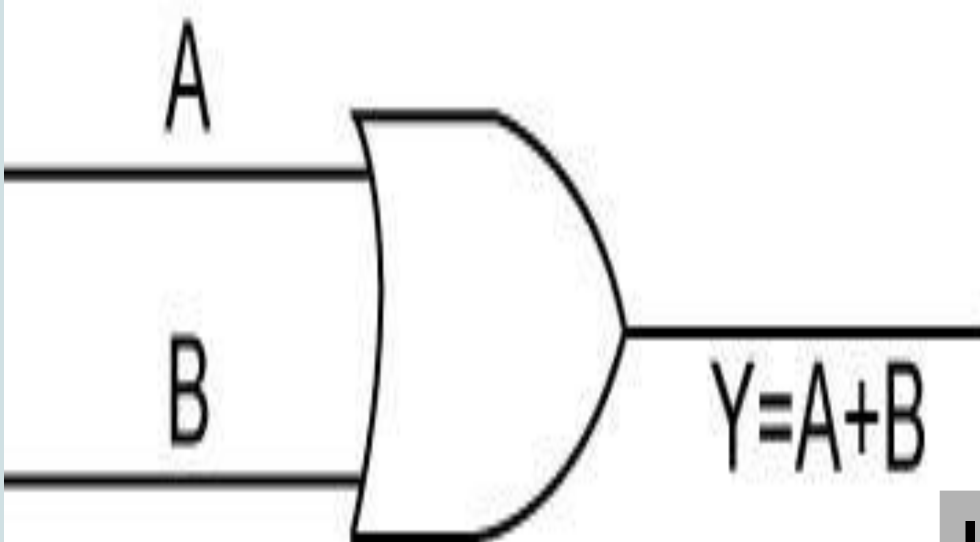
OR

- OR also needs two inputs
- OR needs one input to be ON for it to spit out ON
- It is also ON when both inputs are ON
- It is OFF when both inputs are OFF



OR Gate

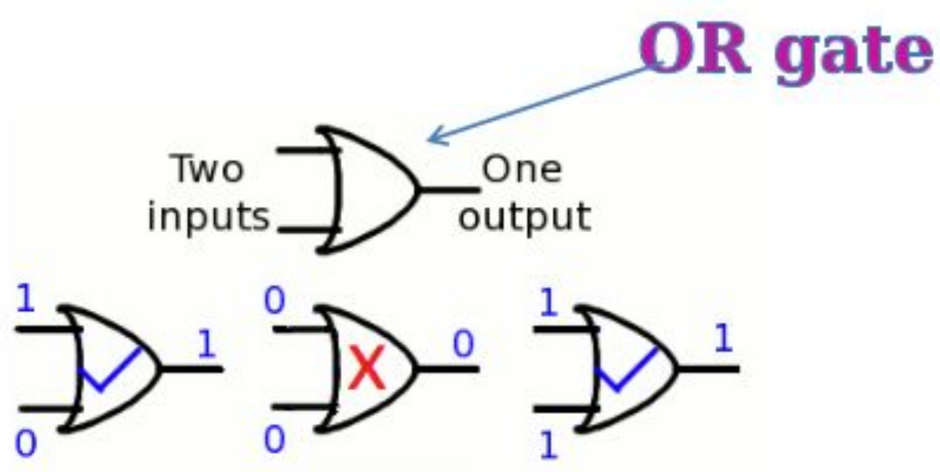
- The OR gate is another basic logic gate
- Like the AND gate, it can have two or more inputs and a single output
- The operation of OR gate is such that the output is a binary 1 if any one or all inputs are binary 1 and the output is binary 0 only when all the inputs are binary 0



Input		Output
A	B	Y=A+B
0	0	0
0	1	1
1	0	1
1	1	1

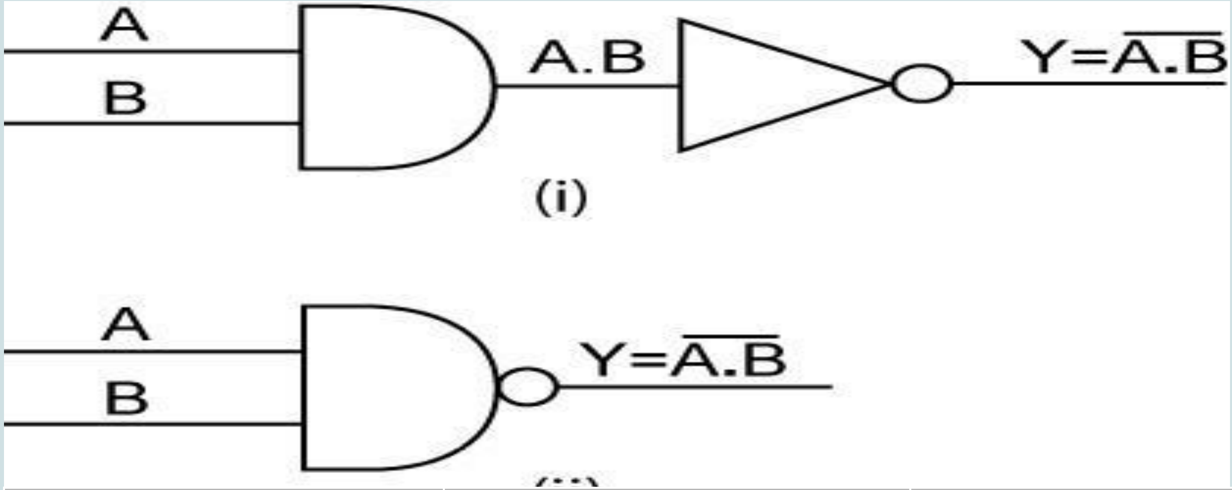
OR

- OR also needs two inputs
- OR needs one input to be ON for it to spit out ON
- It is also ON when both inputs are ON
- It is OFF when both inputs are OFF



NAND Gate

- The term NAND is a contraction of the expression NOT-AND gate
- A NAND gate, is an AND gate followed by an inverter
- The algebraic output expression of the NAND gate is $Y = A.B$

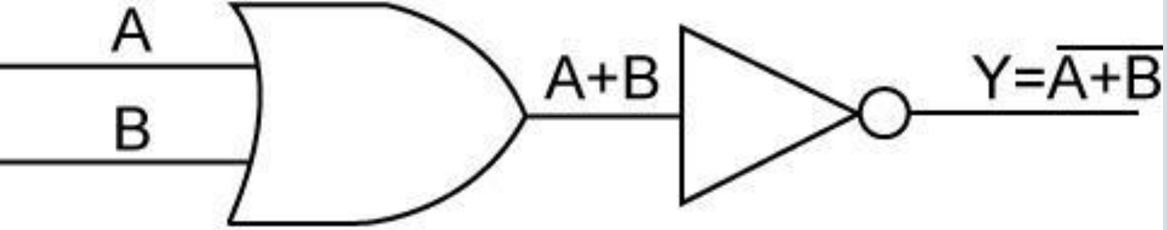


Input		Output
A	B	Y=(~A.B)
0	0	1
0	1	1
1	0	1
1	1	0

Input		Output	Output
A	B	Y=A. B	Y= (~Y)
0	0	0	1
0	1	0	1
1	0	0	1
1	1	1	0

NOR Gate

- The term NOR is a contradiction of the expression NOT-OR
- A NOR gate, is an OR gate followed by an inverter
- The algebraic output expression of the NOR gate is $Y = A + B$



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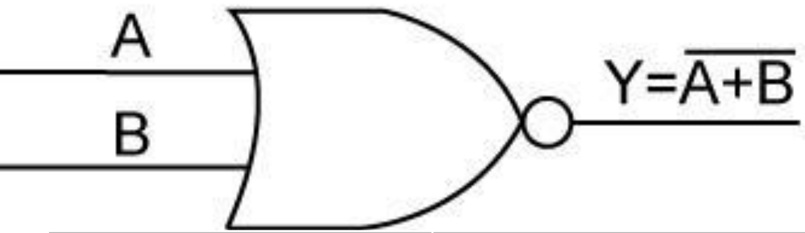
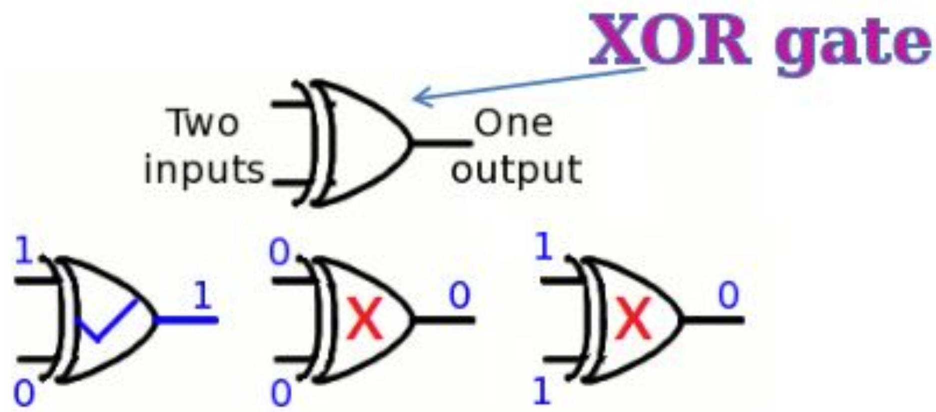


Input		Output
A	B	Y=~(A+B)
0	0	1
0	1	0
1	0	0
1	1	0

Input		Output	Output
A	B	Y=A+B	Y= (~Y)
0	0	0	1
0	1	1	0
1	0	1	0
1	1	1	0

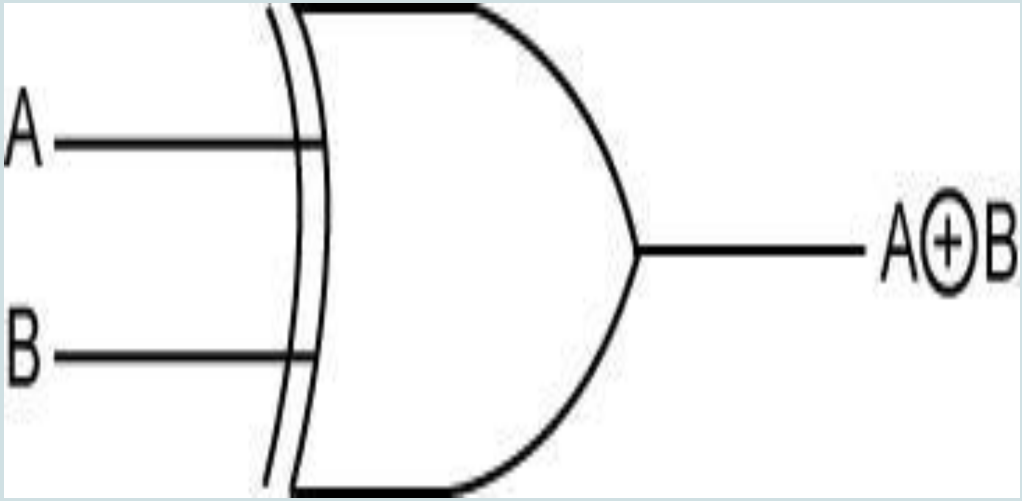
XOR

- XOR is the short way to say “Exclusive OR”
- Like OR, XOR also only needs one input to be ON for it to spit out ON
- But unlike OR, when both inputs are ON, XOR spits out OFF
- It is also OFF when both inputs are OFF



EX-OR Gate

- The Ex-OR (Exclusive- OR) gate returns high output with one of two high inputs (but not with both high inputs or both low inputs)
- For example, if both the inputs are binary 0 or 1, it will return the output as 0. Similarly, if one input is binary 1 and another is binary 0, the output will be 1 (high)
- The operation for the Ex-OR gate is denoted by encircled plus symbol
- The Ex-OR operation is widely used in digital circuits.
- The algebraic output expression of the Ex-OR gate is
- **$Y = A \oplus B$**



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

Input				Output		Output
A	~A	B	. ~B	Y=~AB + A~B		Y
0	1	0	1	0	0	0
0	1	1	0	1	0	1
1	0	0	1	0	1	1
1	0	1	0	0	0	0

EX-OR and EX-NOR Gates

- EX-OR and EX-NOR are digital logic circuits that may use two or more inputs
- EX-NOR gate returns the output opposite to EX-OR gate
- EX-OR and EX-NOR gates are also denoted by XOR and XNOR respectively.

EX-NOR Gate

- The Ex-NOR (Exclusive- NOR) gate is a circuit that returns low output with one of two high inputs (but not with both high inputs)
- For example, if both the inputs are binary 0 or 1, it will return the output as 1. Similarly, if one input is binary 1 and another is binary 0, the output will be 0 (low)
- The symbol for the Ex-NOR gate is denoted by encircled plus symbol which inverts the binary values
- The algebraic output expression of the Ex-NOR gate is
- Y = $\overline{A \oplus B}$

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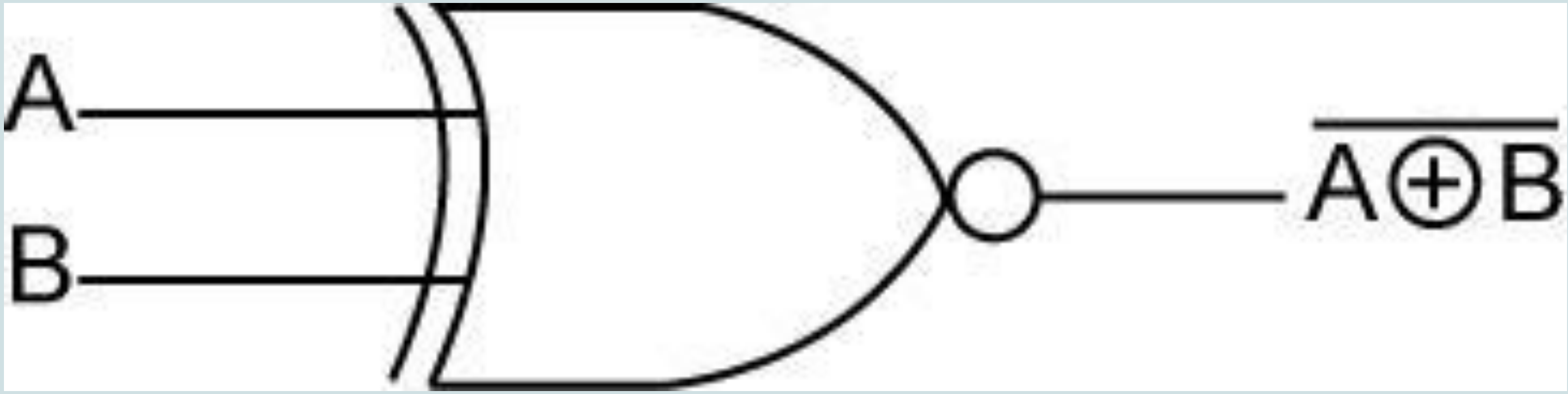

Input		Output	Output
A	B	Y=A EXOR B	Y= (~Y)
0	0	0	1
0	1	1	0
1	0	1	0
1	1	0	1

Applications of Logic Gates

- The following are some of the applications of Logic gates:
  - Build complex systems that can be used to different fields such as
    - Genetic engineering,
    - Nanotechnology,
    - Industrial Fermentation,
    - Metabolic engineering and
    - Medicine
  - Construct multiplexers, adders and multipliers.
  - Perform several parallel logical operations
  - Used for a simple house alarm or fire alarm or in the circuit of automated machine manufacturing industry

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