EEE104 – Digital Electronics (I)

Lecture 5

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In This Session

- Logic Gates
  - Inverters
  - AND Gates
  - OR Gates
  - NAND Gate
  - NOR Gate
  - XOR Gate

Logic Gates

A gate is a circuit that performs a basic logic operation.

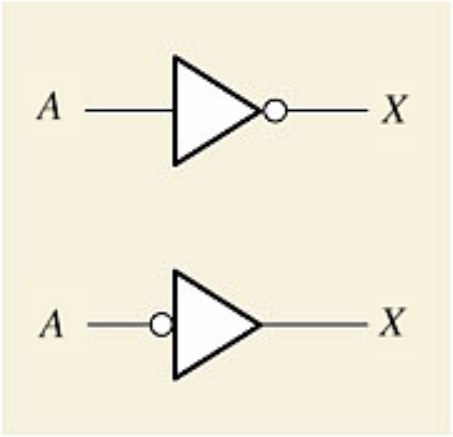
1. Inverter
2. AND gate
3. OR gate
4. NAND gate
5. NOR gate

The Exclusive-OR (XOR) gate and Exclusive-NOR (XNOR) Gate are sometimes thought as logic gates, but they are actually not.

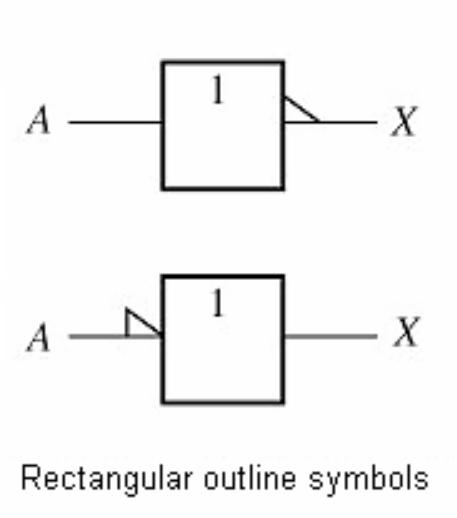
The Inverter

Symbols

- **Distinctive shape symbols** and **rectangular outline symbols**. The former is more widely used.
- **Active logic levels**: when an input or output line has no bubble or triangle on it, that line is said to be **active-HIGH**; otherwise it is **active-LOW**.



Distinctive shape symbols



Rectangular outline symbols

The Inverter

The Truth Table

A **truth table** is a table which shows the output for each possible input in terms of logic levels and bits.

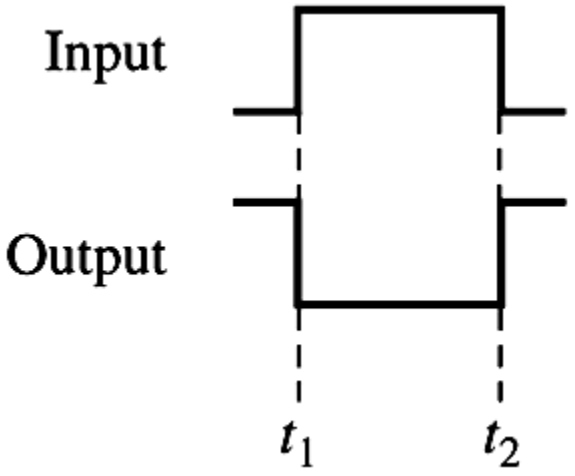
- When the input is HIGH, the output will be LOW.
- When the input is LOW, the output will be HIGH.

Input	Output
LOW (0)	HIGH (1)
HIGH (1)	LOW (0)

The Inverter

The Operation

- A **timing diagram** is a graph that displays the relationship of multiple waveforms on a time basis.
- An inverter produces an inverted output pulse or the complement of the input.



The Inverter

Logic Expression

- **Boolean algebra** is the mathematics of logic circuits.
- In Boolean algebra, a variable is designated by a letter and can take on a value of either 1 or 0
- For an inverter, if the input variable is A and the output variable is X, then

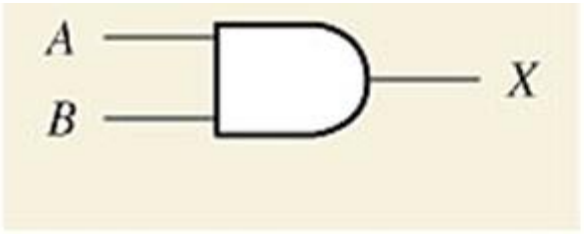
$$X = \overline{A}$$

- It is read as “X equals A bar” or “X equals not A”.

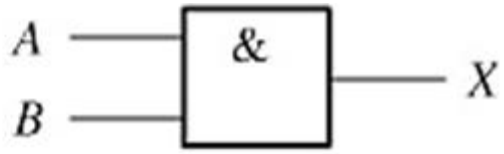
The AND Gate

Symbols

- An AND gate can have any number of inputs greater than one, though gates with two inputs are shown.



Distinctive shape symbol



Rectangular outline symbol

Logical Operation

- Output is HIGH if **all** inputs are HIGH.
- Output is LOW if **any** input is LOW.

The AND Gate

Truth Table

- An AND gate can have any number of inputs greater than one.
- The number of possible combinations of n binary inputs is $N = 2^n$

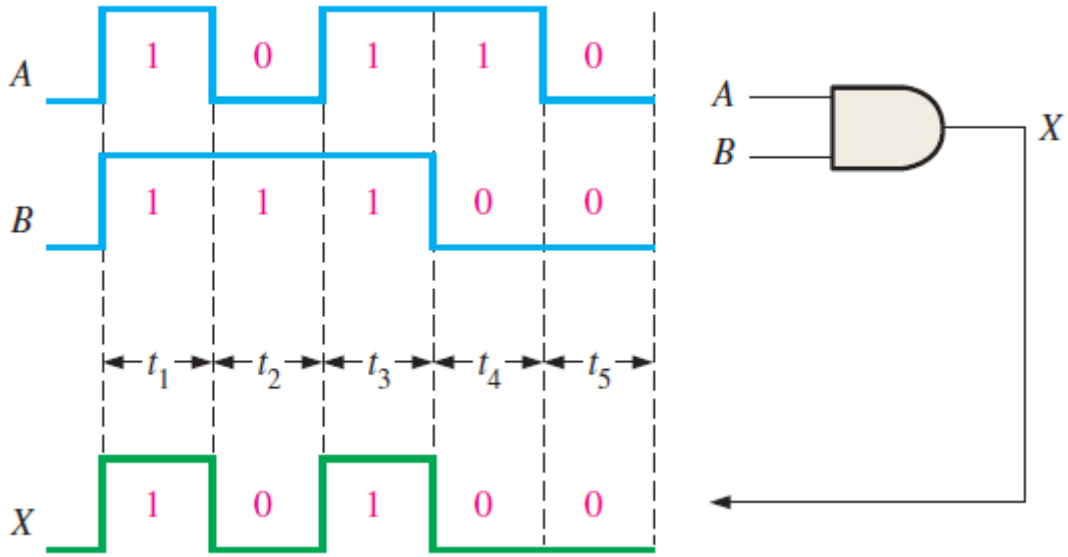
Inputs		Output
A	*B*	*X*
0	0	0
0	1	0
1	0	0
1	1	1

1 = HIGH, 0 = LOW

The AND Gate

Pulsed Operation

- Apply the truth table operation of the AND gate to each of the time intervals during which the levels are not changing.



The AND Gate

Logic Expression

- If the input variables are A and B, and the output variable is X, the Boolean expression is in either way

$$X = AB \qquad X = A \cdot B$$

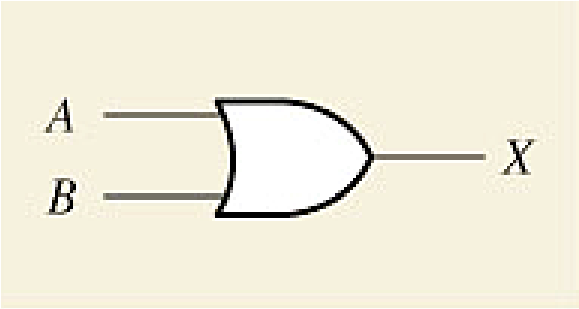
- It is read as “X equals A and B”.
- The AND operation is the same as **Boolean multiplication** with the basic rules:

$$0 \cdot 0 = 0$$
$$0 \cdot 1 = 0$$
$$1 \cdot 0 = 0$$
$$1 \cdot 1 = 1$$

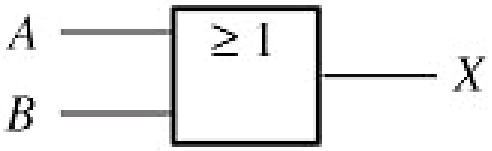
The OR Gate

Symbols

- An OR gate can have any number of inputs greater than one, though gates with two inputs are shown.



Distinctive shape symbol



Rectangular outline symbol

Logical Operation

- Output is HIGH if **any** input is HIGH.
- Output is LOW if **all** inputs are LOW.

The OR Gate

Truth Table

- A OR gate can have any number of inputs greater than one.
- The number of possible combinations of n binary inputs is $N = 2^n$

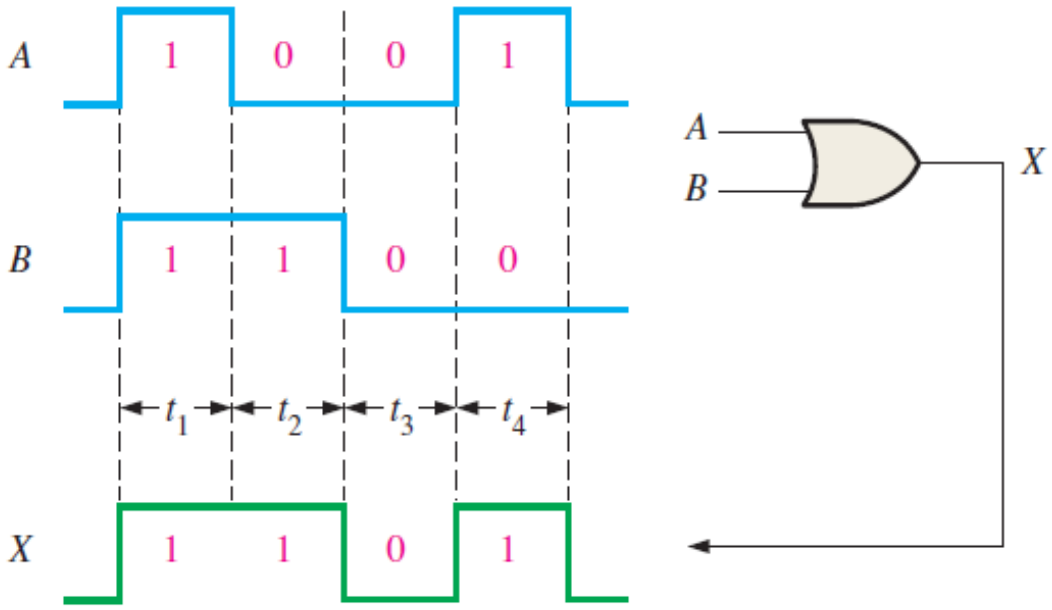
Inputs		Output
A	*B*	*X*
0	0	0
0	1	1
1	0	1
1	1	1

1 = HIGH, 0 = LOW

The OR Gate

Pulsed Operation

- Apply the truth table operation of the OR gate to each of the time intervals during which the levels are not changing.



The OR Gate

Logic Expression

- If the input variables are A and B, and the output variable is X, the Boolean expression is

$$X = A + B$$

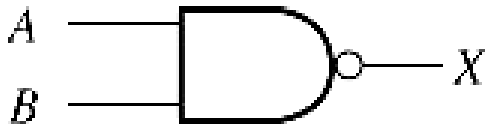
- It is read as “X equals A or B”.
- The OR operation is the same as **Boolean addition** with the basic rules:

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

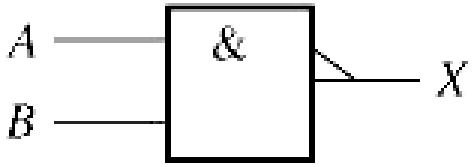
The NAND Gate

Symbols

- The term NAND is a contraction of NOT-AND.
- It is equivalent to an AND gate followed by an inverter.



Distinctive shape symbol



Rectangular outline symbol

The NAND Gate

Logical Operation

- Output is HIGH if **any** input is LOW.
- Output is LOW if **all** inputs are HIGH.

Truth Table

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

1 = HIGH, 0 = LOW.

The NAND Gate

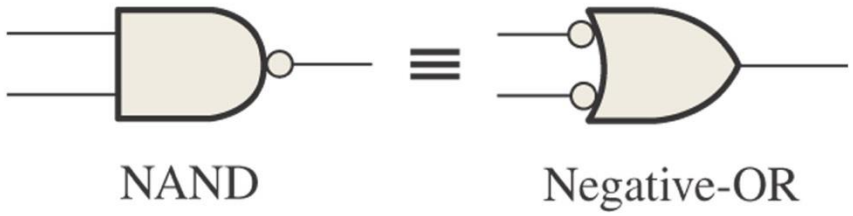
Logic Expression

- If the input variables are A and B, and the output variable is X, the Boolean expression is

$$X = \overline{AB}$$

Negative-OR Equivalent

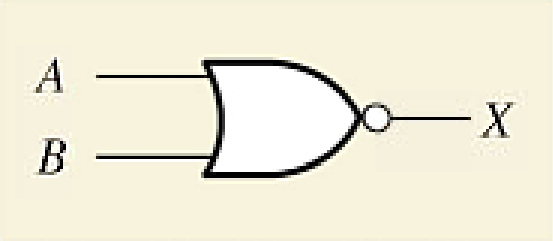
- A NAND gate is equivalent to a **negative-OR** gate which is an OR gate with all inputs active-LOW.



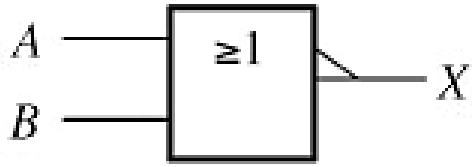
The NOR Gate

Symbols

- The term NOR is a contraction of NOT-OR.
- It is equivalent to an OR gate followed by an inverter.



Distinctive shape symbol



Rectangular outline symbol

The NOR Gate

Logical Operation

- Output is HIGH if **all** inputs are LOW.
- Output is LOW if any input is HIGH.

Truth Table

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

1 = HIGH, 0 = LOW.

The NOR Gate

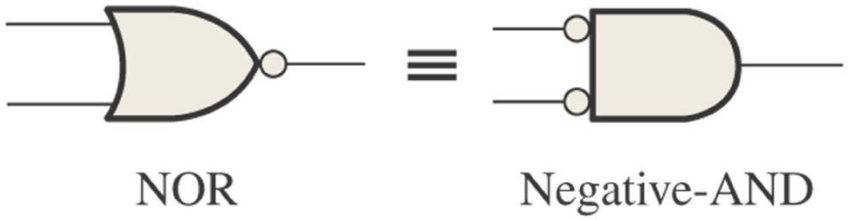
Logic Expression

- If the input variables are A and B, and the output variable is X, the Boolean expression is

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

Negative-AND Equivalent

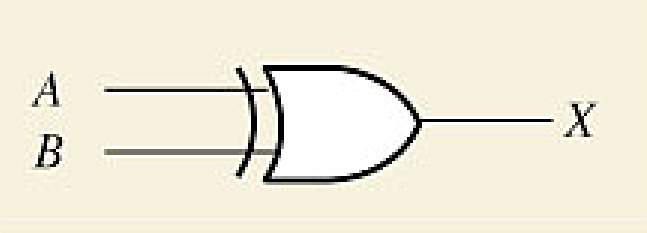
- A NOR gate is equivalent to a **negative-AND** gate which is an AND gate with all inputs active-LOW.



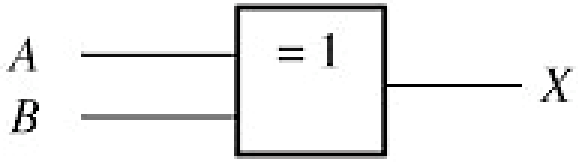
The Exclusive-OR Gate

Symbols

- It is a combination of the basic gates but often treated as a basic gate.
- It is written as **XOR** gate for short.
- It has only two inputs.



Distinctive shape symbol



Rectangular outline symbol

The Exclusive-OR Gate

Logical Operation

- Output is HIGH if two inputs are at different levels.
- Output is LOW if two inputs are the same level.

Truth Table

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

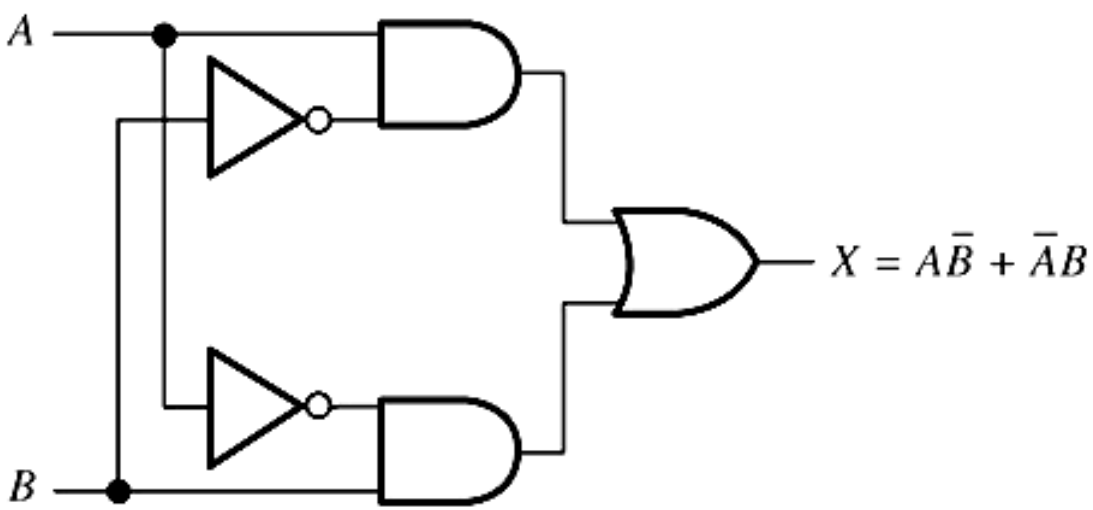
The Exclusive-OR Gate

Logic Expression

- If the input variables are A and B, and the output variable is X, the Boolean expression is

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

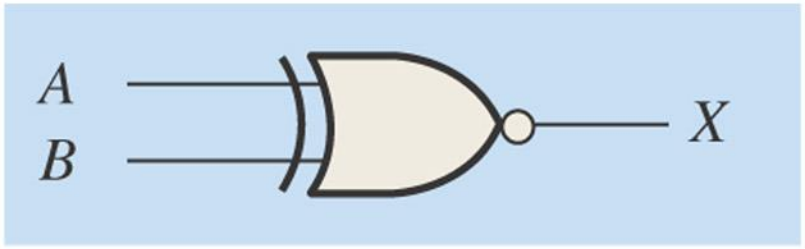
Implementation



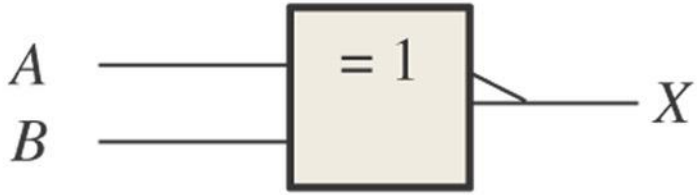
The Exclusive-NOR Gate

Symbols

- It is a combination of the basic gates but often treated as a basic gate.
- It is written as **XNOR** gate for short.
- It has only two inputs.



(a) Distinctive shape



(b) Rectangular outline

The Exclusive-NOR Gate

Logical Operation

- Output is LOW if two inputs are at different levels.
- Output is HIGH if two inputs are the same level.

Truth Table

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

The Exclusive-NOR Gate

Logic Expression

- If the input variables are A and B, and the output variable is X, the Boolean expression is

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