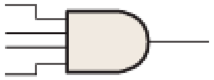
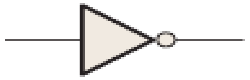
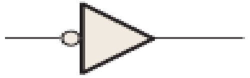


CHAPTER#03



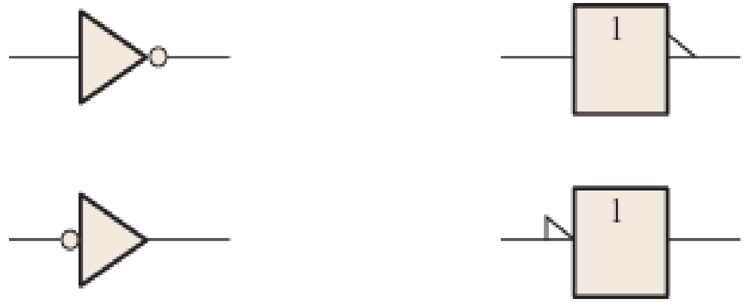


LOGIC GATES

The Inverter

- The inverter (NOT circuit) performs the inversion or complementation operation. The inverter changes one logic level to the opposite level. In terms of bits, it changes a 1 to a 0 and a 0 to a 1.

The Negation and Polarity Indicators The negation indicator is a “bubble” (0) that indicates inversion or complementation when it appears on the input or output of any logic element.

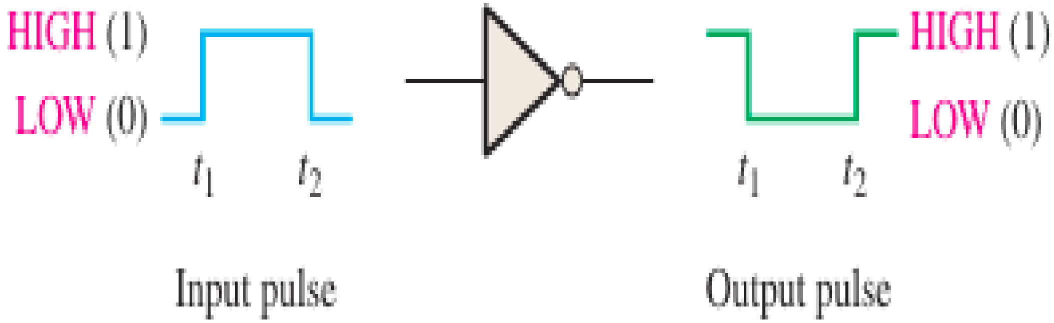


(a) Distinctive shape symbols with negation indicators

(b) Rectangular outline symbols with polarity indicators

Inverter truth table.

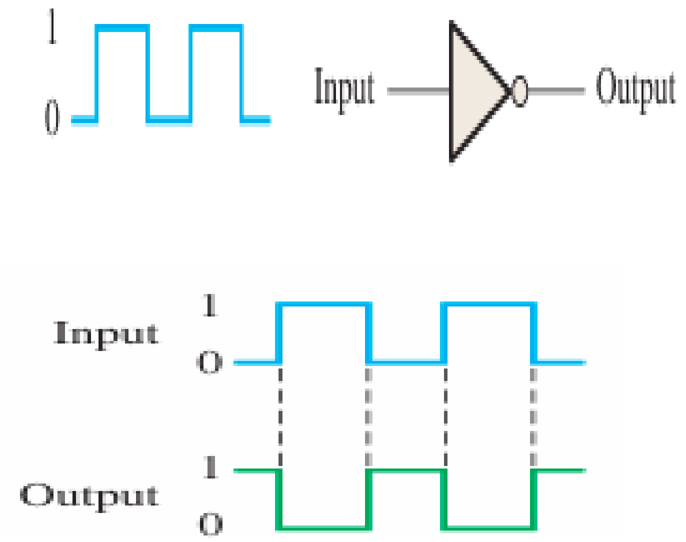
Input	Output
LOW (0)	HIGH (1)
HIGH (1)	LOW (0)



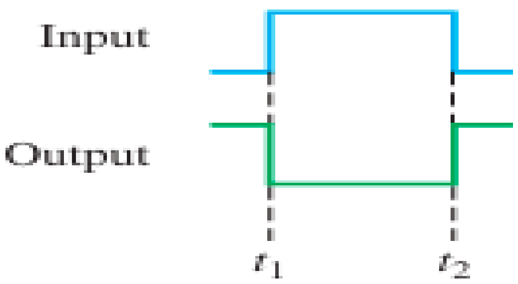
When the input is LOW, the output is HIGH; when the input is HIGH, the output is LOW, thereby producing an inverted output pulse.

Timing Diagrams

A timing diagram is basically a graph that accurately displays the relationship of two or more waveforms with respect to each other on a time basis.



A timing diagram shows how two or more waveforms relate in time.

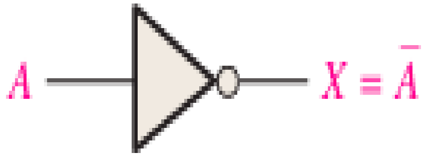


Logic Expression for an Inverter

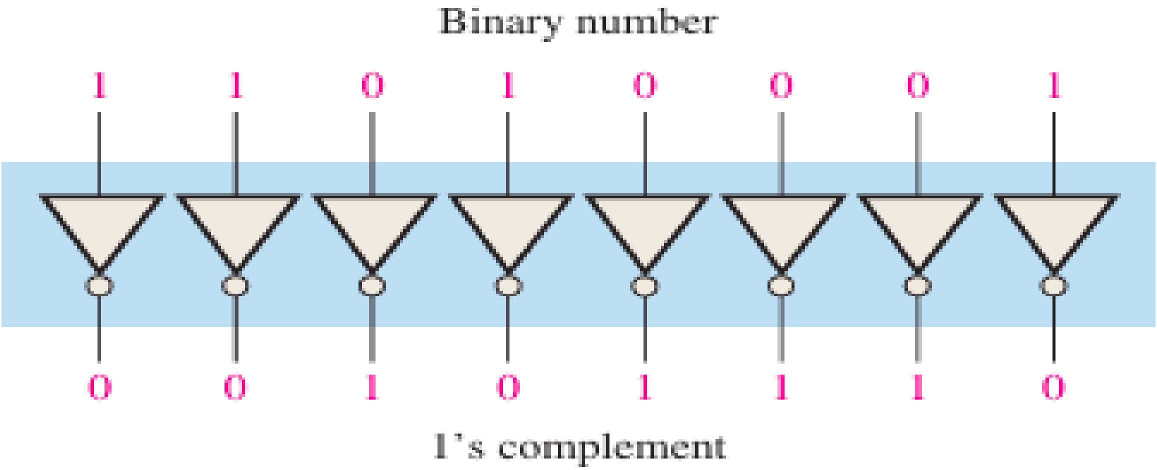
In Boolean algebra, which is the mathematics of logic circuits and will be covered thoroughly in a variable is generally designated by one or two letters, although there can be more.

Boolean algebra uses variables and operators to describe a logic circuit.

The complement of a variable is designated by a bar over the letter. A variable can take on a value of either 1 or 0. If a given variable is 1, its complement is 0, and vice versa. The operation of an inverter (NOT circuit) can be expressed as follows: If the input variable is called A and the output variable is called X, then

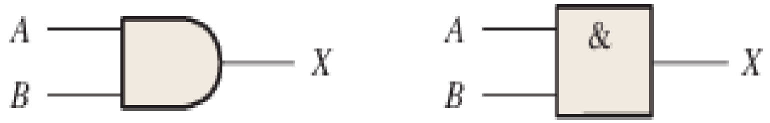


$$X = \overline{A}$$



The AND Gate

- The AND gate is one of the basic gates that can be combined to form any logic function.
- An AND gate can have two or more inputs and performs what is known as logical multiplication.



(a) Distinctive shape

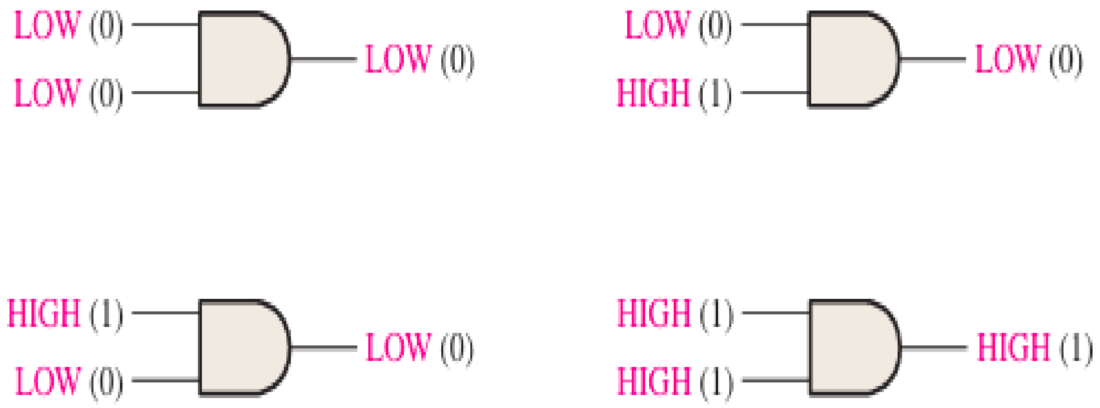
(b) Rectangular outline with the AND (&) qualifying symbol

An AND gate produces a HIGH output only when all the inputs are HIGH. When any of the inputs is LOW, the output is LOW.

For a 2-input AND gate, output X is HIGH only when inputs A and B are HIGH; X is LOW when either A or B is LOW, or when both A and B are LOW.

InfoNote

Logic gates are one of the fundamental building blocks of digital systems. Most of the functions in a computer, with the exception of certain types of memory, are implemented with logic gates used on a very large scale. For example, a microprocessor, which is the main part of a computer, is made up of hundreds of thousands or even millions of logic gates.



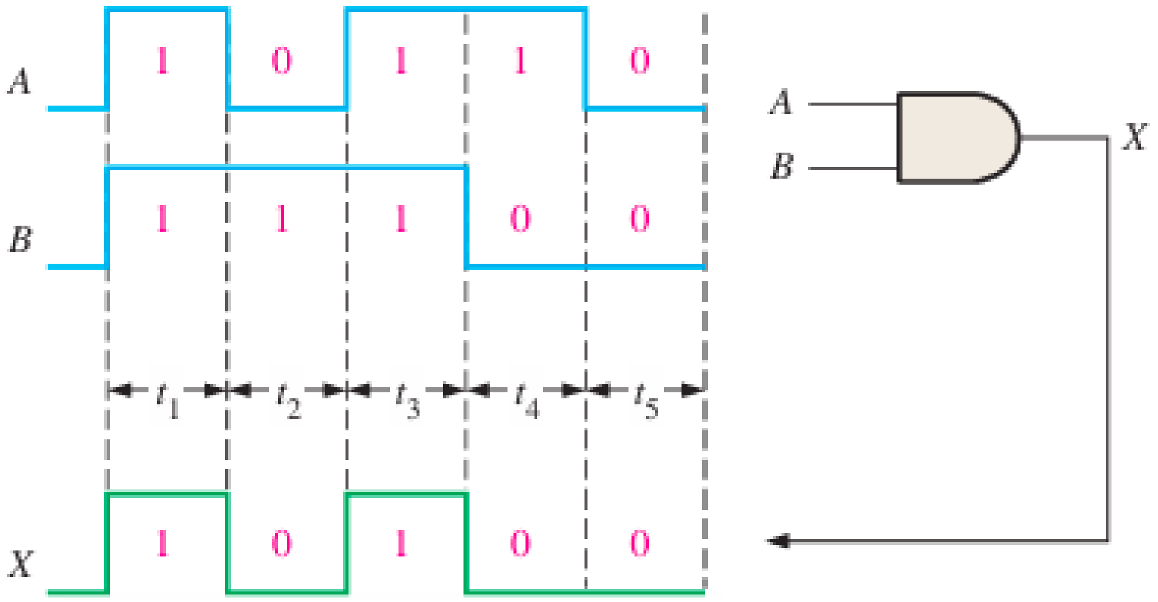
Truth table for a 2-input AND gate.

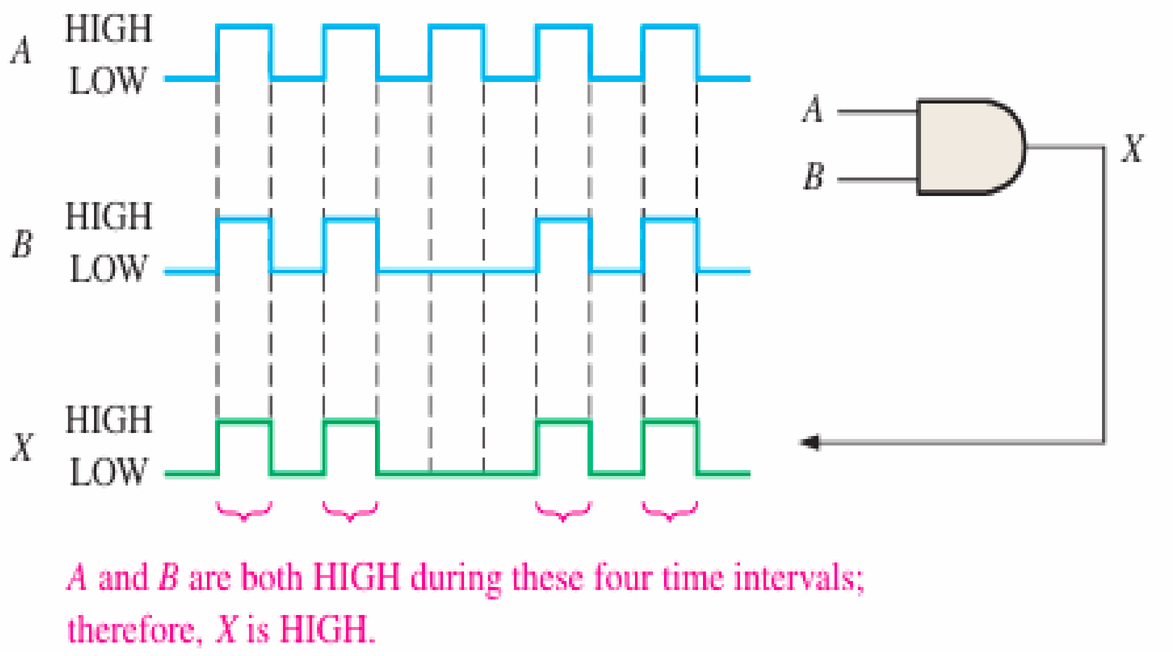
Inputs		Output
A	*B*	*X*
0	0	0
0	1	0
1	0	0
1	1	1

1 = HIGH, 0 = LOW

AND Gate Operation with Waveform Inputs

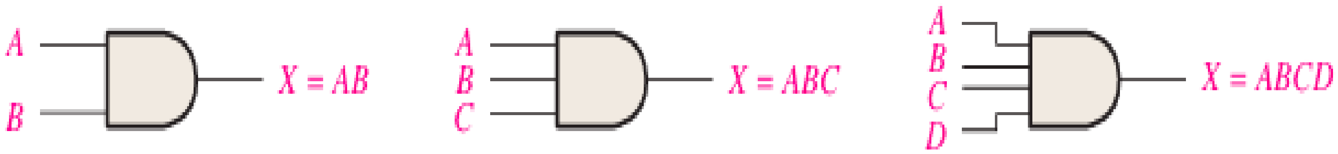
In most applications, the inputs to a gate are not stationary levels but are voltage waveforms that change frequently between HIGH and LOW logic levels.





Logic Expressions for an AND Gate

The logical AND function of two variables is represented mathematically either by placing a dot between the two variables, as (A . B), or by simply writing the adjacent letters without the dot, as AB.



(a) (b) (c)

Boolean expressions for AND gates with two, three, and four inputs.

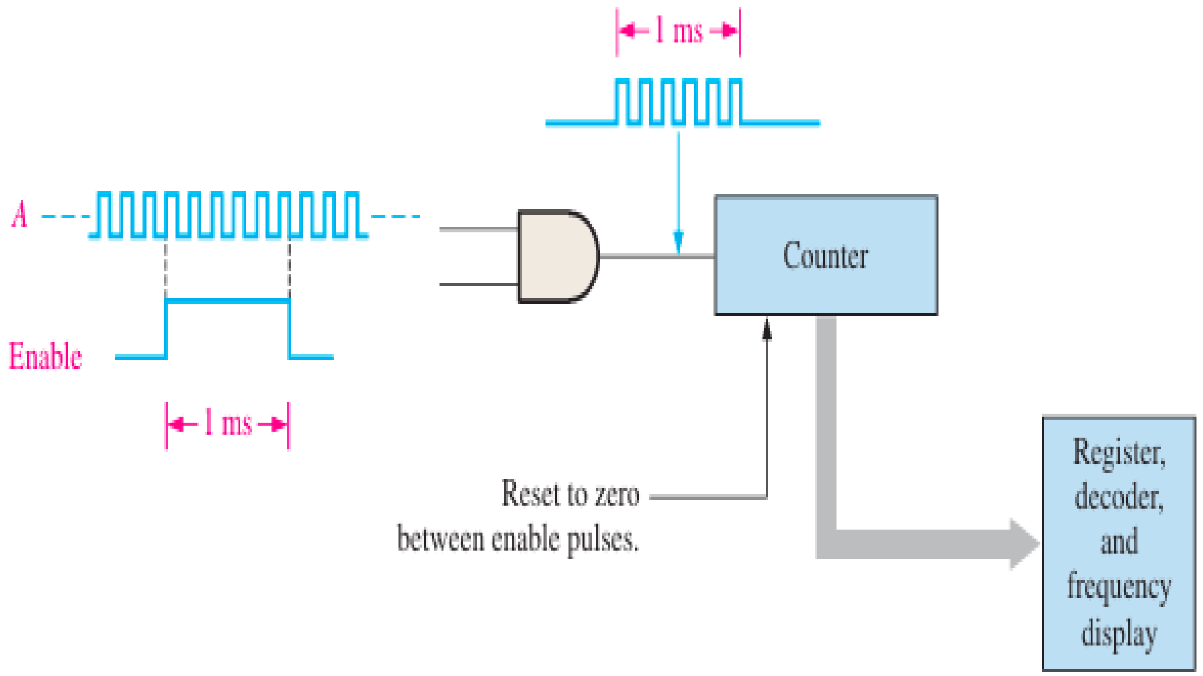
Boolean multiplication follows the same basic rules governing binary multiplication.

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

$$X = AB$$

Applications

A common application of the AND gate is to enable (that is, to allow) the passage of a signal (pulse waveform) from one point to another at certain times and to inhibit (prevent) the passage at other times.



The counter counts the number of pulses per second and produces a binary output that goes to a decoding and display circuit to produce a readout of the frequency.
The enable pulse repeats at certain intervals and a new updated count is made so that if the frequency changes, the new value will be displayed.
Between enable pulses, the counter is reset so that it starts at zero each time an enable pulse occurs.
The current frequency count is stored in a register so that the display is unaffected by the resetting of the counter.

The OR Gate

The OR gate is another of the basic gates from which all logic functions are constructed. An OR gate can have two or more inputs and performs what is known as logical addition.

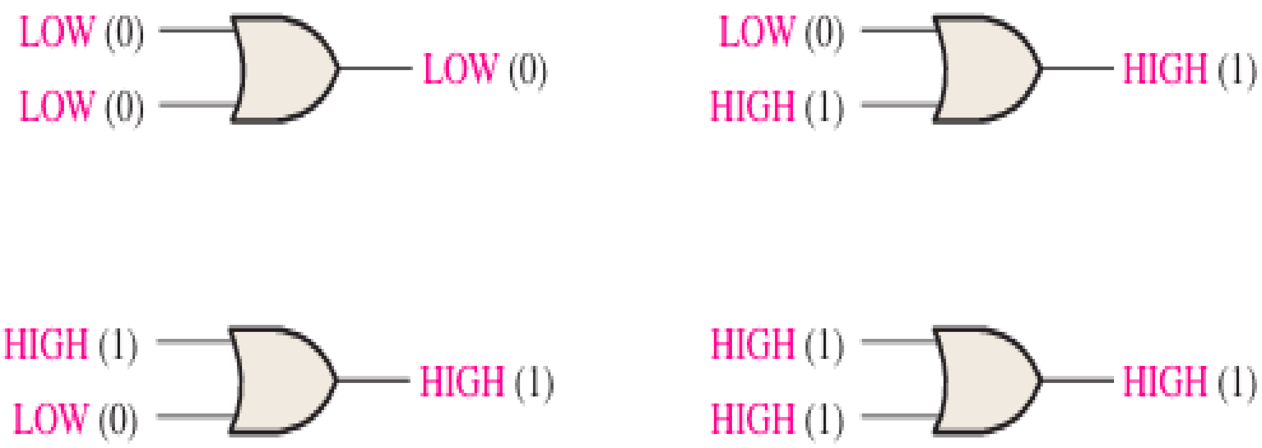
An OR gate can have more than two inputs.

(a) Distinctive shape

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

At least one HIGH input produces a HIGH output for an OR gate.

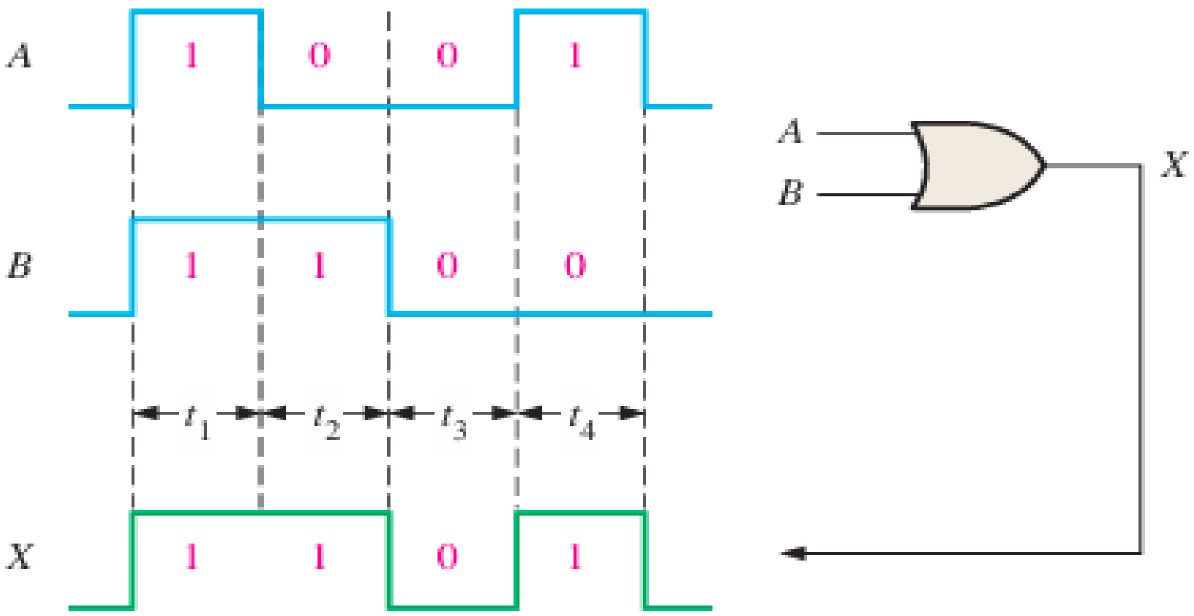
For a 2-input OR gate, output X is HIGH when input A or input B is HIGH, or when both A and B are HIGH; X is LOW only when both A and B are LOW.

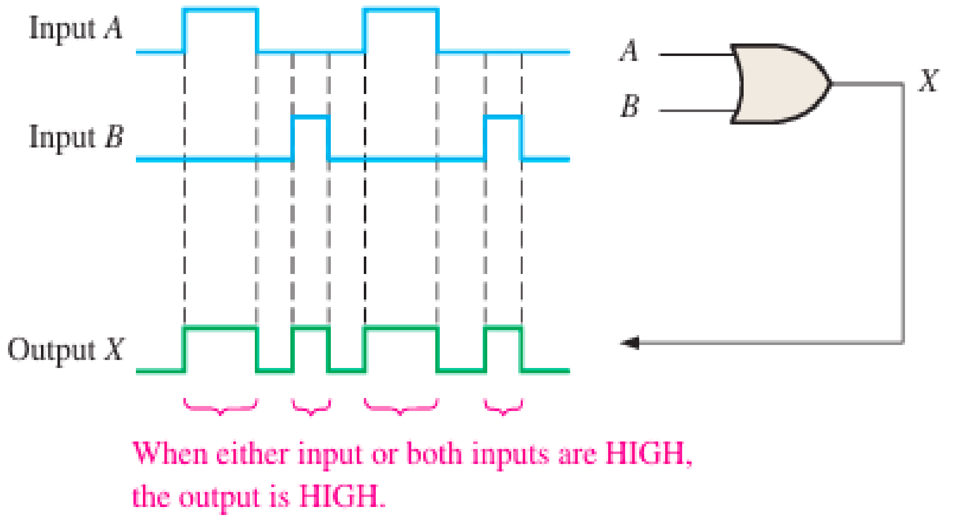


Truth table for a 2-input OR gate.

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

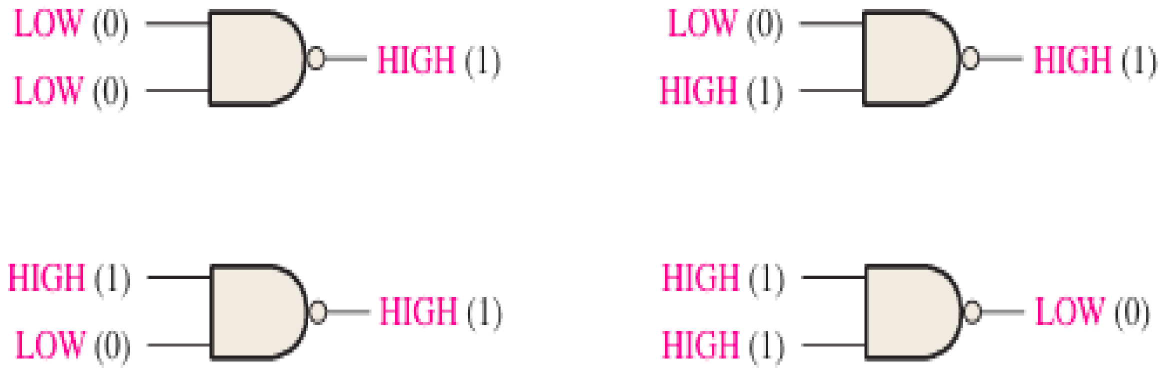
1 = HIGH, 0 = LOW





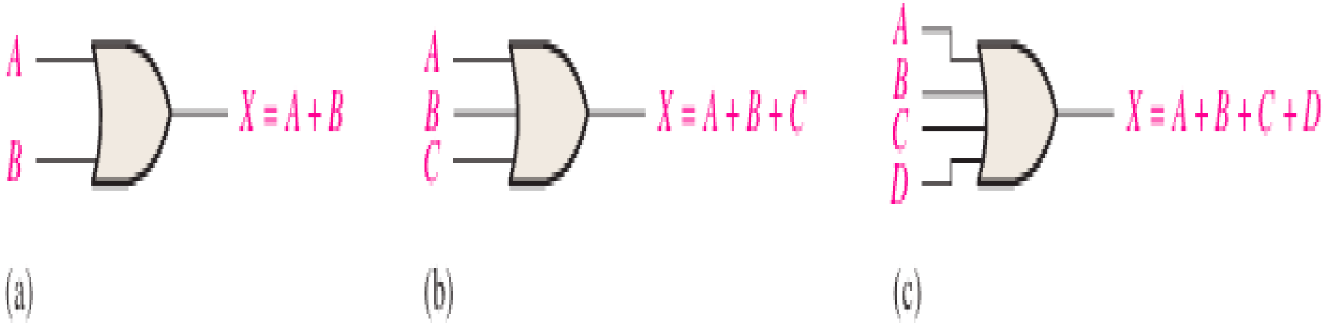
Logic Expressions for an OR Gate

The logical OR function of two variables is represented mathematically by a + between the two variables, for example, A + B. The plus sign is read as “OR.” Addition in Boolean algebra involves variables whose values are either binary 1 or binary 0. The basic rules for Boolean addition are as follows:



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

$$X = A + B$$



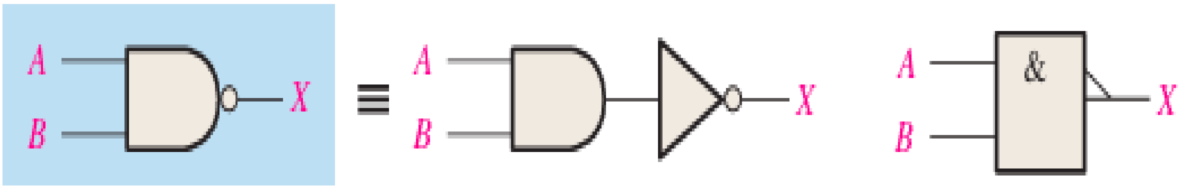
A	B	$A + B = X$
0	0	$0 + 0 = 0$
0	1	$0 + 1 = 1$
1	0	$1 + 0 = 1$
1	1	$1 + 1 = 1$

Boolean addition is the same as the OR function.

The NAND Gate

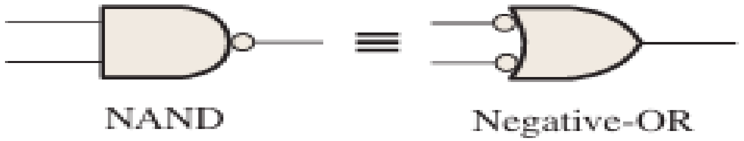
The NAND gate is a popular logic element because it can be used as a universal gate; that is, NAND gates can be used in combination to perform the AND, OR, and inverter operations.

The term NAND is a contraction of NOT-AND and implies an AND function with a complemented (inverted) output.



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

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



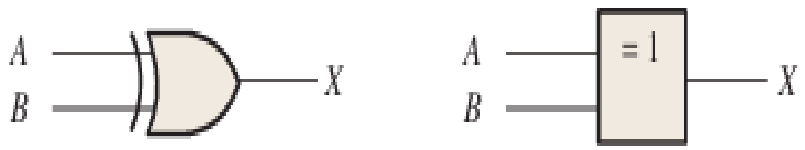
For a 2-input NAND gate, output X is LOW only when inputs A and B are HIGH; X is HIGH when either A or B is LOW, or when both A and B are LOW.

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

1 = HIGH, 0 = LOW.

The Exclusive-OR Gate



(a) Distinctive shape (b) Rectangular outline

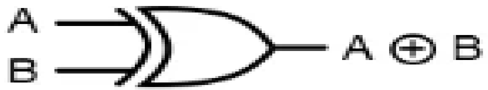
Standard logic symbols for the exclusive-OR gate.

For an exclusive-OR gate, output X is HIGH when input A is LOW and input B is HIGH, or when input A is HIGH and input B is LOW; X is LOW when A and B are both HIGH or both LOW.

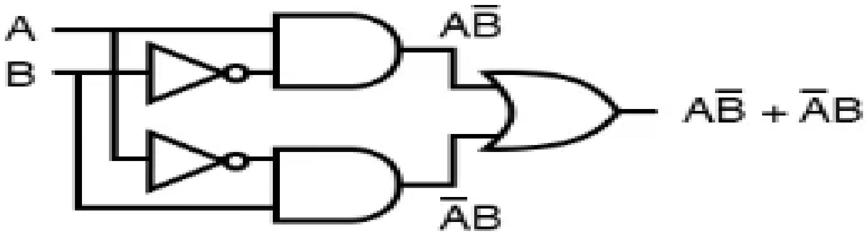
Truth table for an exclusive-OR gate.

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

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



. . . is equivalent to . .



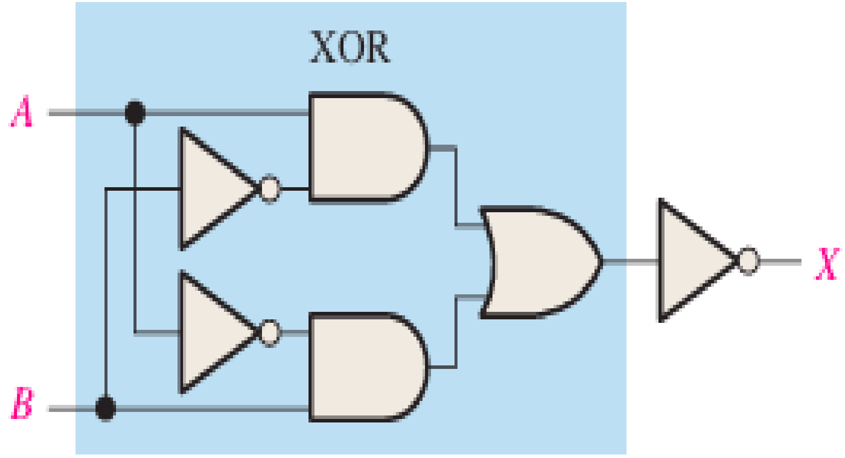
$A \oplus B = A\overline{B} + \overline{A}B$

Exclusive-OR gates connected to form an adder circuit allow a processor to perform addition, subtraction, multiplication, and division in its Arithmetic Logic Unit (ALU). An exclusive-OR gate combines basic AND, OR, and NOT logic.

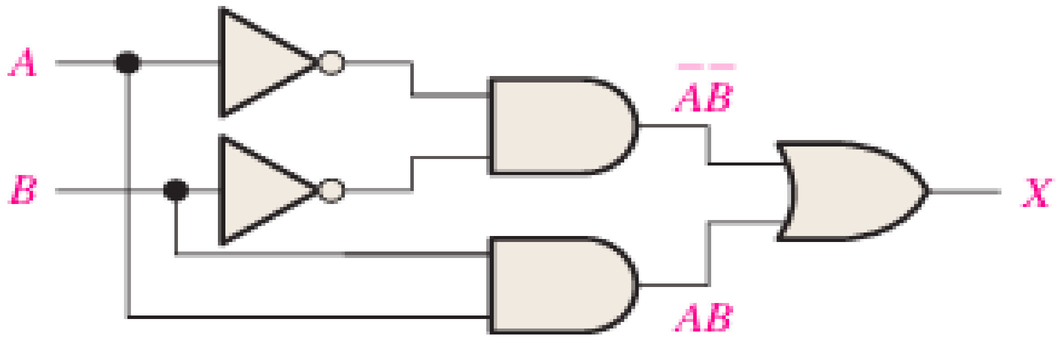
The Exclusive-NOR Gate

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

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



(a) $X = \overline{\overline{A}B + A\overline{B}}$



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

Boolean Expression

$$Y = (\overline{A \oplus B}) = (A\,.\,B + \overline{A}\,.\,\overline{B})$$

Logic Diagram Symbol