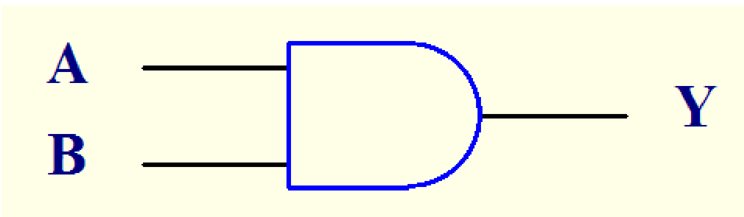
Logic gates

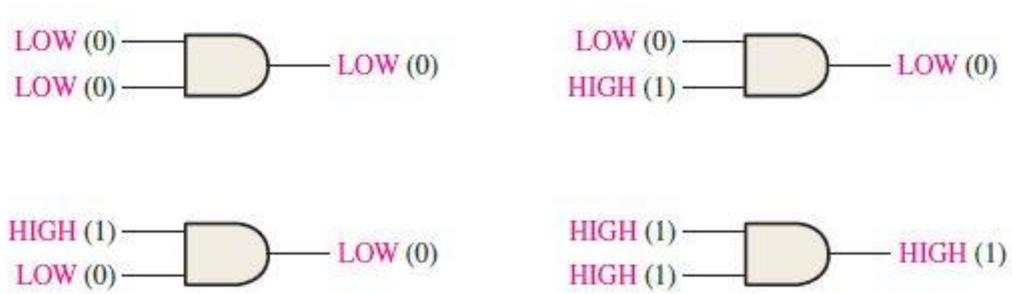
Basic definitions: AND, OR, NOT

1. **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.



Operation of an AND Gate:

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



All possible logic levels for a 2-input AND gate

AND Gate Truth Table:

The total number of possible combinations of binary inputs to a gate is determined by the following formula:

$$N = 2^n$$

Where **N** is the number of possible input combinations and **n** is the number of input variables. To illustrate,

For two input variables: $N = 2^2 = 4$ combinations
For three input variables: $N = 2^3 = 8$ combinations
For four input variables: $N = 2^4 = 16$ combinations

AND gate Truth table:

INPUTS		**OUTPUT**
A	**B**	Y
0	**0**	0
0	**1**	0
1	**0**	0
1	**1**	1

Boolean expression:

Y=A*B=AB

Y=1 when A AND B=1

Example:

(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.

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

Solution

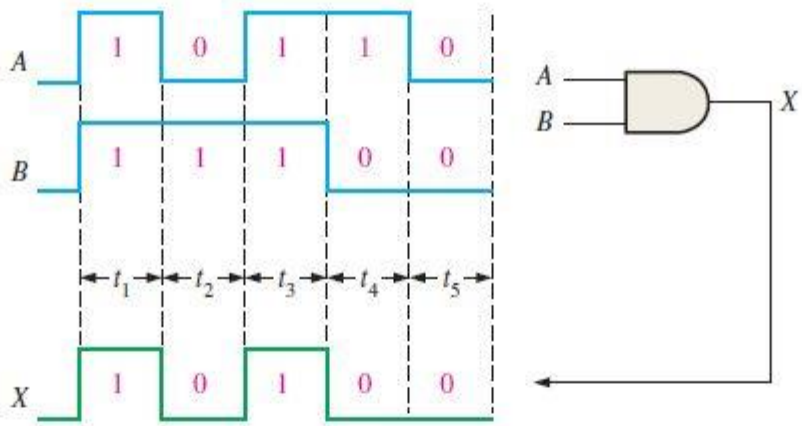
(a) There are eight possible input combinations ($2^3 = 8$) for a 3-input AND gate. The input side of the truth table (Table 3–3) shows all eight combinations of three bits. The output side is all 0s except when all three input bits are 1s.

(b) $N = 2^4 = 16$. There are 16 possible combinations of input bits for a 4-input AND gate.

Related Problem

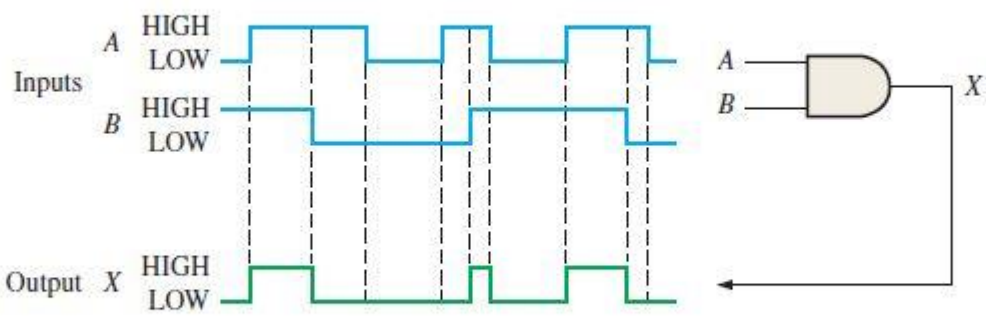
Develop the truth table for a 4-input AND gate.

AND Gate Operation with Waveform Inputs



EXAMPLE

For the two input waveforms, A and B, figure below shows the output waveform with its proper relation to the inputs.

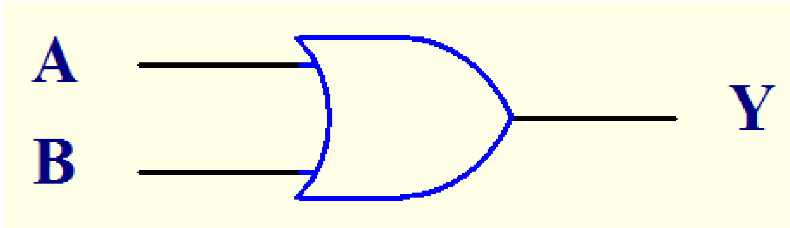


Solution

The output waveform is HIGH only when both of the input waveforms are HIGH as shown in the timing diagram.

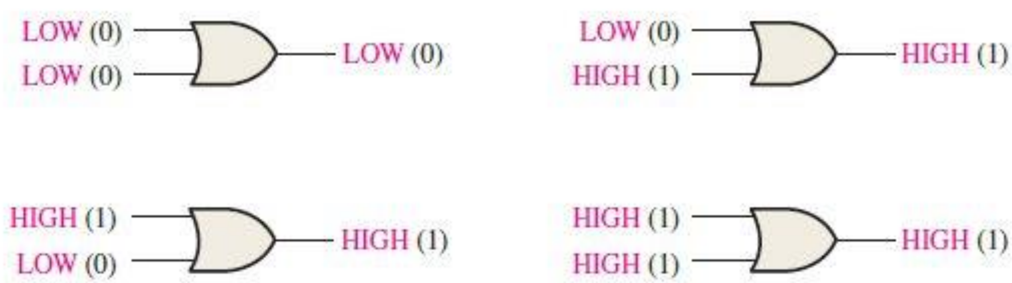
2. **OR gate:** The OR gate is another of the basic gates from which all logic functions are constructed. An OR gate can have two or more inputs and performs what is known as logical addition.

   An OR gate has two or more inputs and one output, as indicated by the standard logic symbols in figure below, where OR gates with two inputs are illustrated. An OR gate can have any number of inputs greater than one.



Operation of an OR Gate

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



All possible logic levels for a 2-input OR gate

OR Gate Truth Table:

The operation of a 2-input OR gate is described in the following Table. This truth table can be expanded for any number of inputs; but regardless of the number of inputs, the output is HIGH when one or more of the inputs are HIGH.

1= High
0= Low

Truth table:

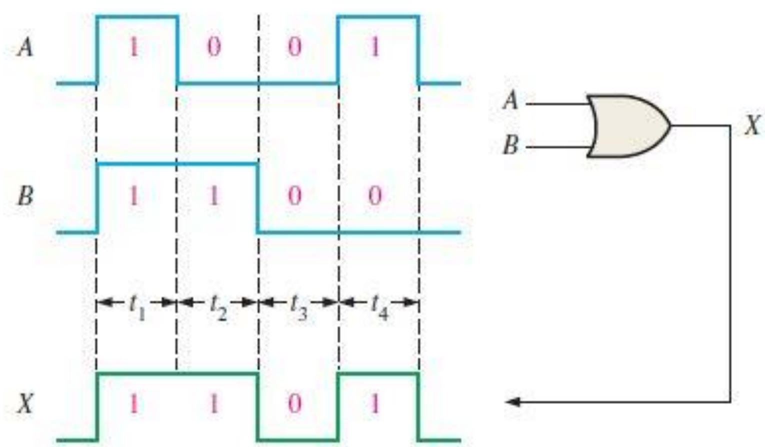
Y=1 when A OR B=1

Boolean expression:

Y=A’B+AB’+AB=A+B

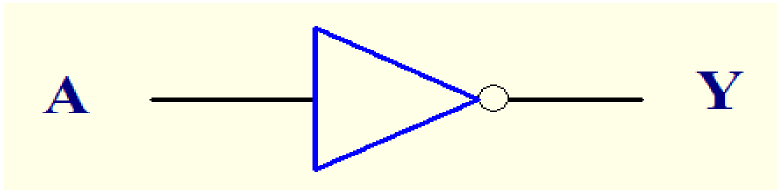
INPUTS		**OUTPUT**
A	**B**	Y
0	**0**	0
0	**1**	1
1	**0**	1
1	**1**	1

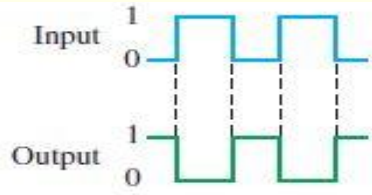
OR Gate Operation with Waveform Inputs



Example of OR gate operation with a timing diagram showing input and output time relationships.

3. **The Inverter (NOT):** The inverter (**NOT circuit**) performs the operation called ***inversion***. 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 1Standard logic symbols for the inverter are shown below.





Inverter Truth Table:

When a HIGH level is applied to an inverter input, a LOW level will appear on its output. When a LOW level is applied to its input, a HIGH will appear on its output. This operation is summarized in Table 1, which shows the output for each possible input in terms of levels and corresponding bits. A table such as this is called a truth table.

INPUTS	OUTPUT
A	Y
0	1
1	0

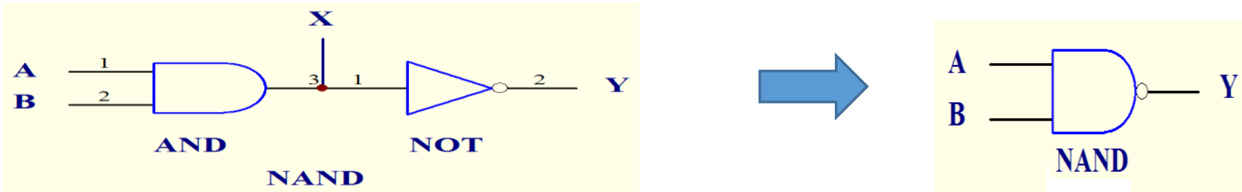
Y is NOT equal to A

Boolean expression:
Y=A'

Additional gates:

4. **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. The standard logic symbol for a 2-input NAND gate and its equivalency to an AND gate followed by an inverter are shown below.



Truth table:

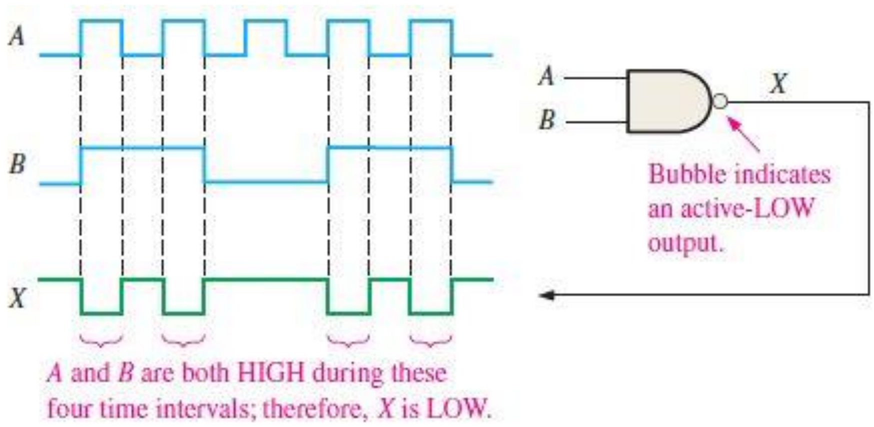
INPUTS		OUTPUTS	
A	B	X	Y
0	0	0	1
0	1	0	1
1	0	0	1
1	1	1	0

Boolean expression:
X=A*B
Y=X’
Y= (A*B)’=A’B’+A’B+AB’

INPUTS		OUTPUTS
A	B	Y
0	0	1
0	1	1
1	0	1
1	1	0

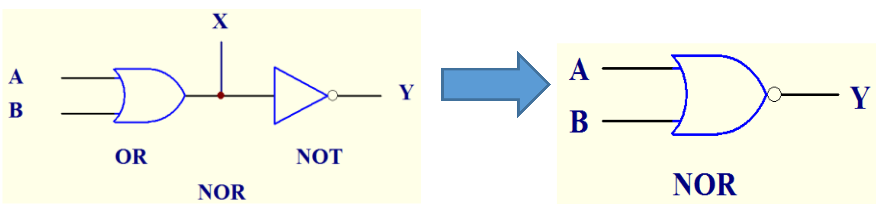
EXAMPLE:

If the two waveforms A and B shown below are applied to the NAND gate inputs, determine the resulting output waveform.



Solution: Output waveform X is LOW only during the four time intervals when both input waveforms A and B are HIGH as shown in the timing diagram.

5. <u>NOR gate</u> :



Truth table:

INPUTS		OUTPUTS	
A	**B**	**X**	**Y**
0	0	0	1
0	1	1	0
1	0	1	0
1	1	1	0

Boolean expression:

X=A+B

Y=X' Y= (A+B)'=A'B'

EXAMPLE

If the two waveforms shown below are applied to a NOR gate, what is the resulting output waveform?

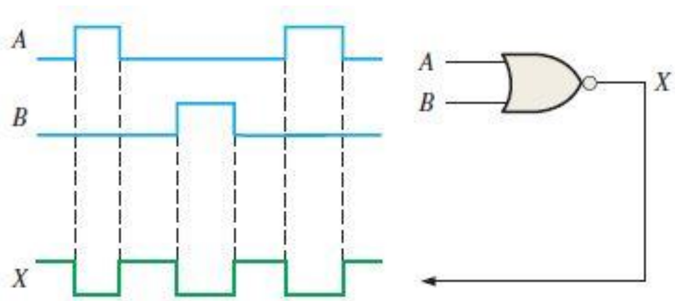
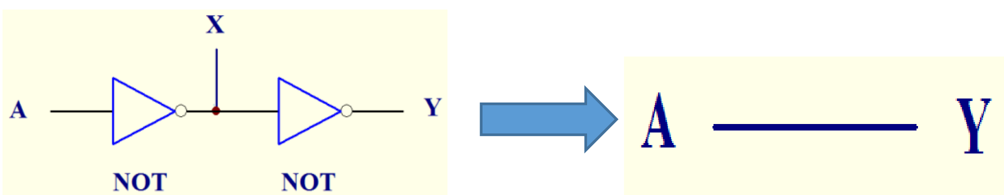


FIGURE 3–36

Solution

Whenever any input of the NOR gate is HIGH, the output is LOW as shown by the output waveform *X* in the timing diagram.

NOT NOT:



Truth table:

INPUT	OUTPUTS	
A	X	Y
0	1	0
1	0	1

Boolean expression:

X=A'

Y=X'

Y= A''=A

H.W.: What is the benefit of the above circuit!!! (1 Week).