Logic Gates

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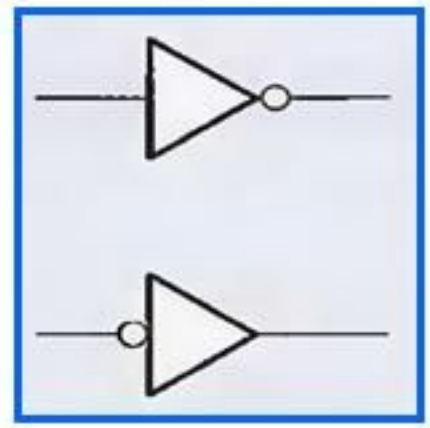
Logic gates

- **Commonly used logic gates are,**
  - **Inverter**
  - **AND**
  - **OR**
  - **NAND**
  - **NOR**
  - **XOR**
  - **XNOR**

- **Inverter**
  - The inverter (NOT circuit) performs the operation called inversion or complementation.
  - 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.
  - Standard logic symbols for the inverter is,

Distinctive shape symbols with negation indicators

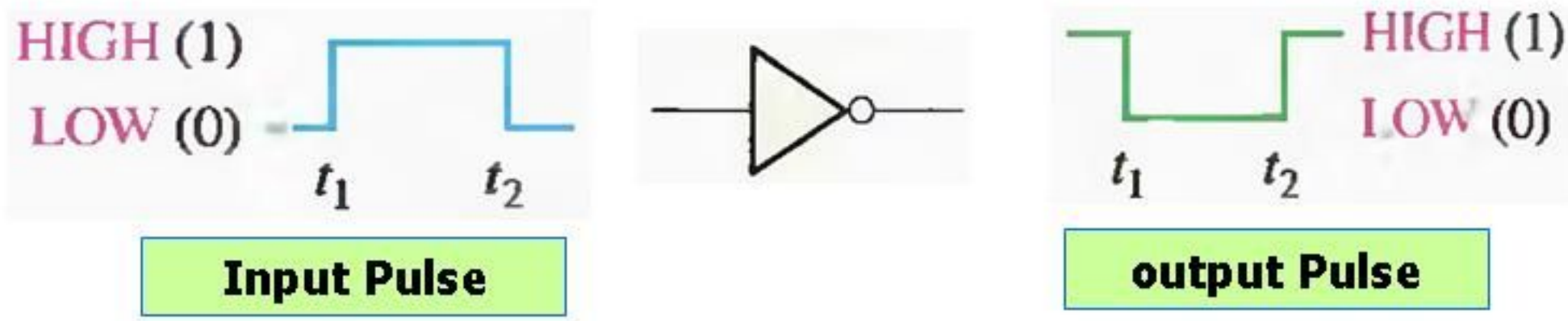


- **Inverter Truth Table**

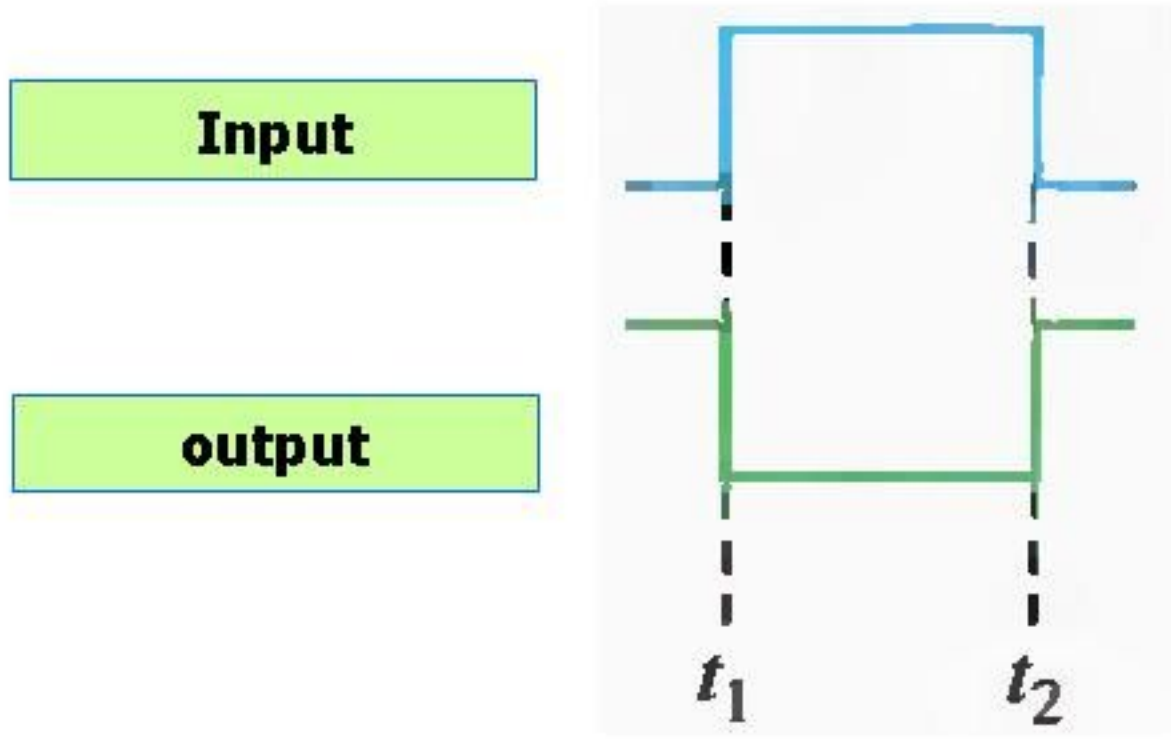
INPUT	OUTPUT
LOW (0)	HIGH (1)
HIGH (1)	LOW (0)

- A table such as this is called a truth table.
- When a HIGH level is applied to an inverter input, a LOW level will appear on its output.

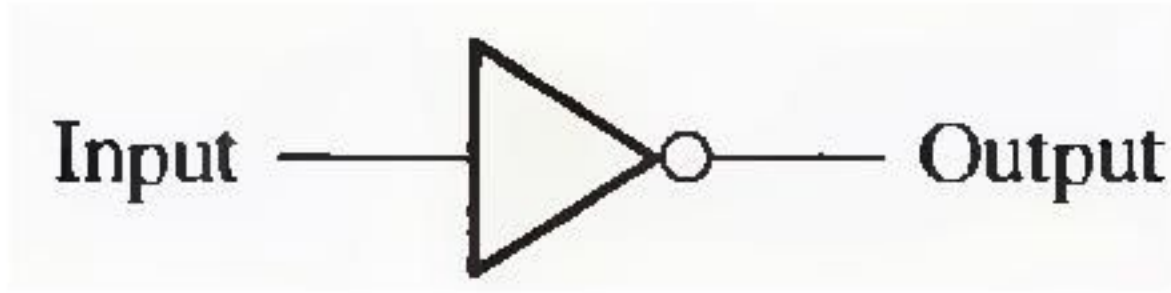
- **Inverter**
  - When the input is LOW, the output is HIGH and vice versa.
  - producing an inverted output pulse.
  - Standard logic symbols for the inverter is,



- Timing Diagram of Inverter
  - 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. .



Timing diagram example



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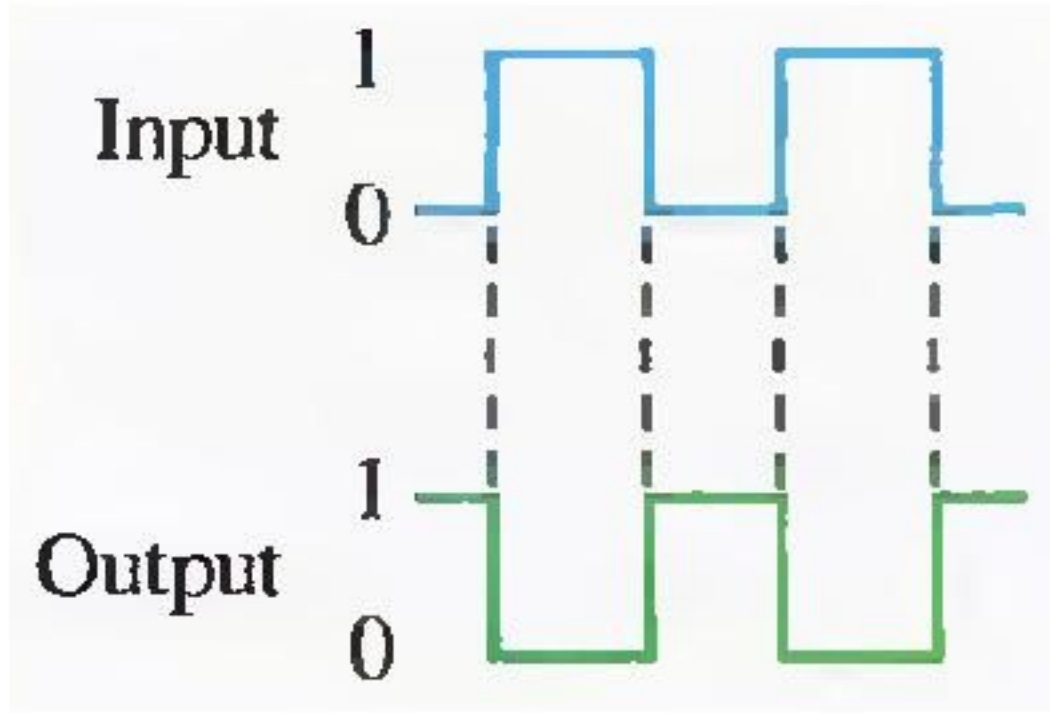
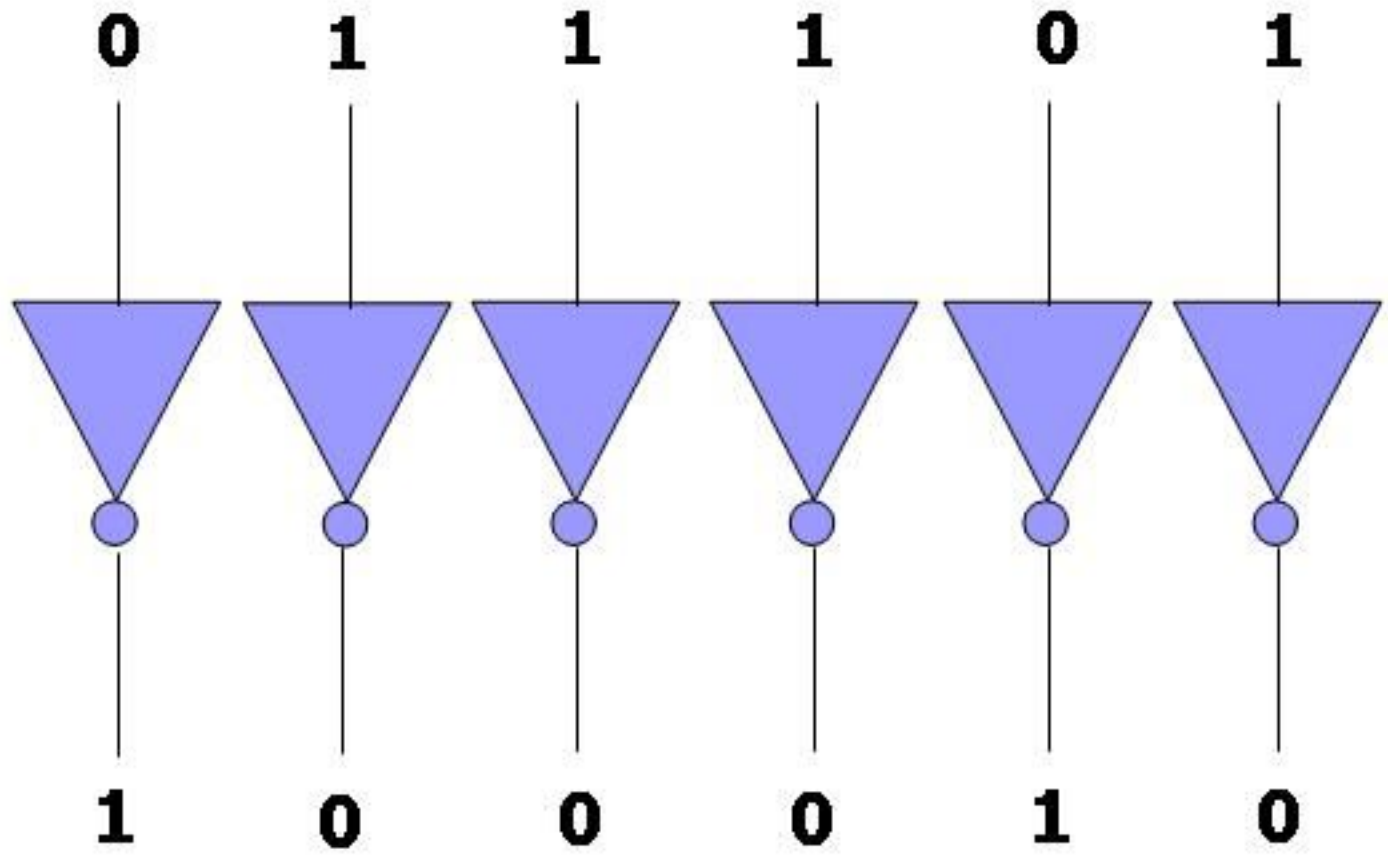
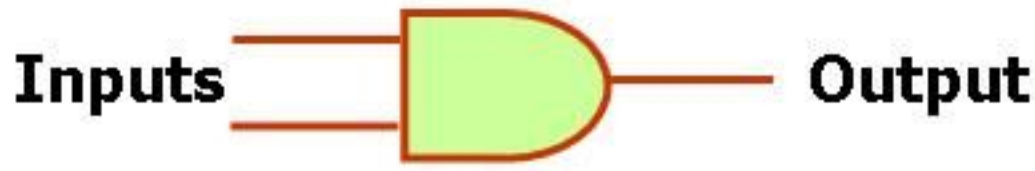


Application of Inverter



The AND Gate

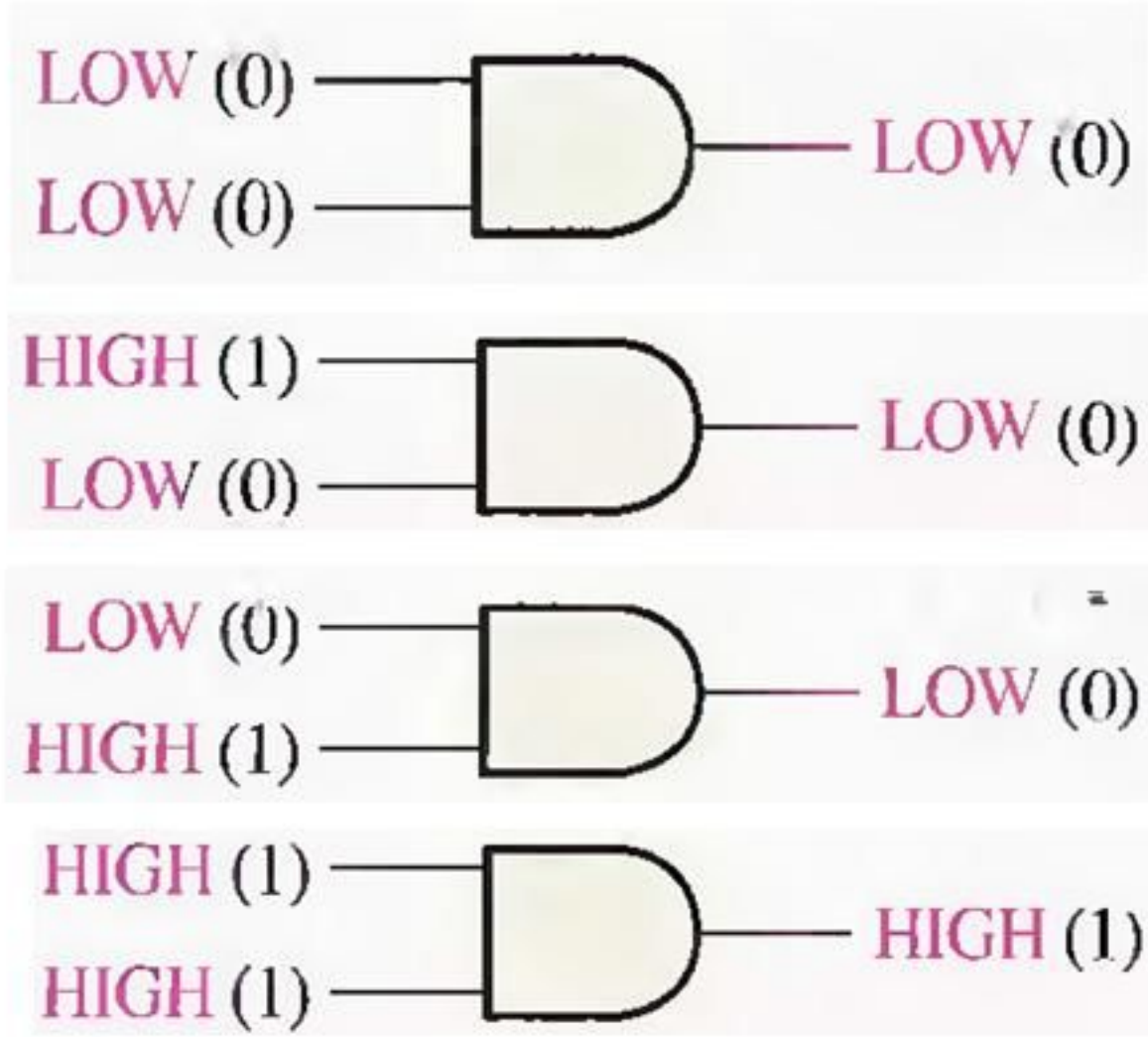
- **AND Gate**
  - The AND gate is one of the basic gates that can be combined to form any logic function.
  - An AND gate can have two or more inputs and performs what is known as logical multiplication.
  - The term gate is used to describe a circuit that performs a basic logic operation.
  - The AND gate is composed of two or more inputs and a single output.
  - Standard logical symbol of AND gate is,



- **Operations of an AND Gate**
  - An AND gate produces a HIGH output only when all of the inputs are HIGH.
  - When any of the inputs is LOW, the output is LOW.
  - Therefore, the basic purpose of an AND gate is to determine when certain conditions are simultaneously true.

AND Operation

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.



AND Gate

- AND Gate Truth Table.

INPUTS		OUTPUT
A	*B*	*X*
0	0	0
0	1	0
1	0	0
1	1	1

1= High, 0 = Low

AND Gate

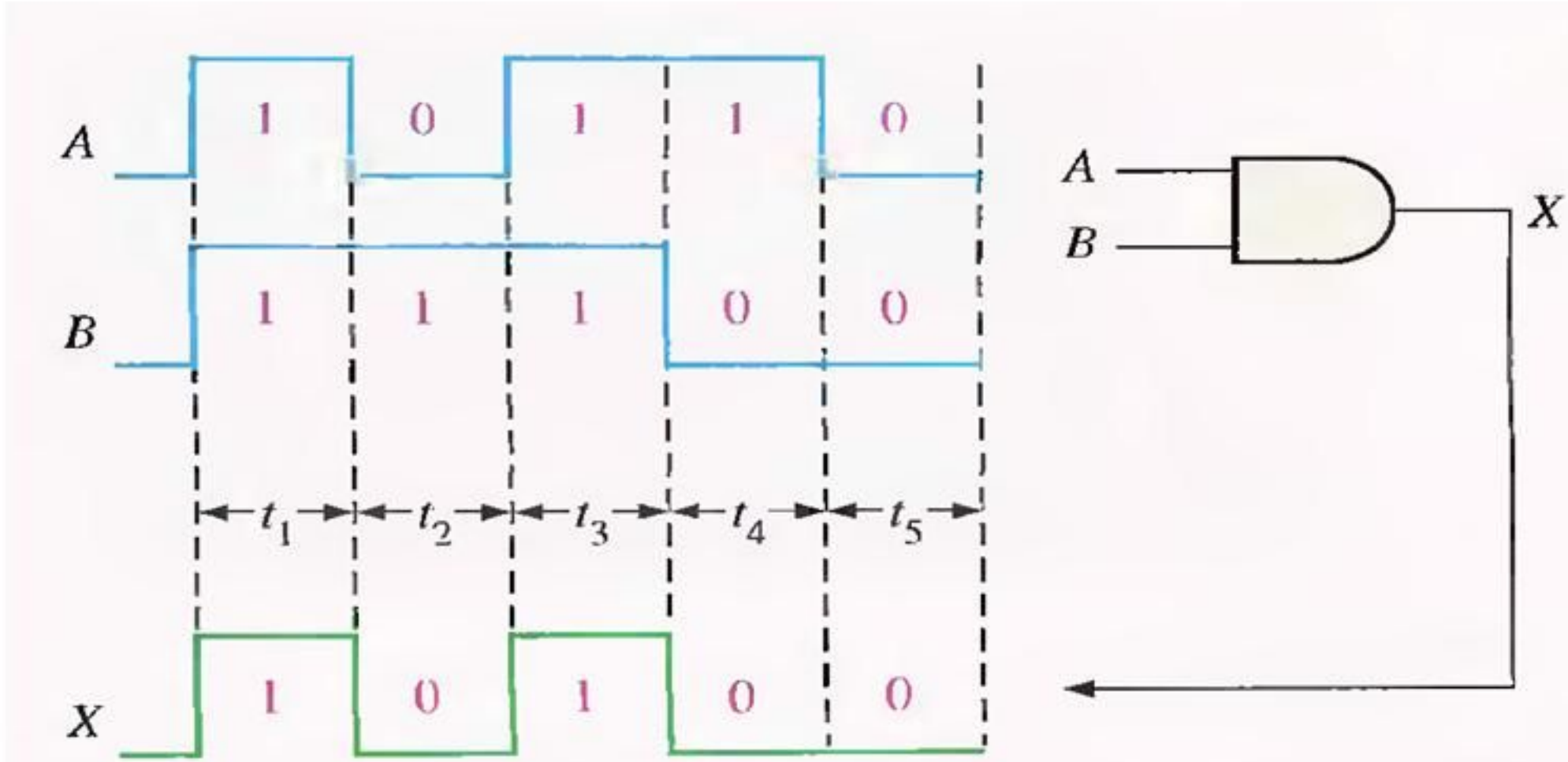
- Develop the truth table for a 3-input AND gate.

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

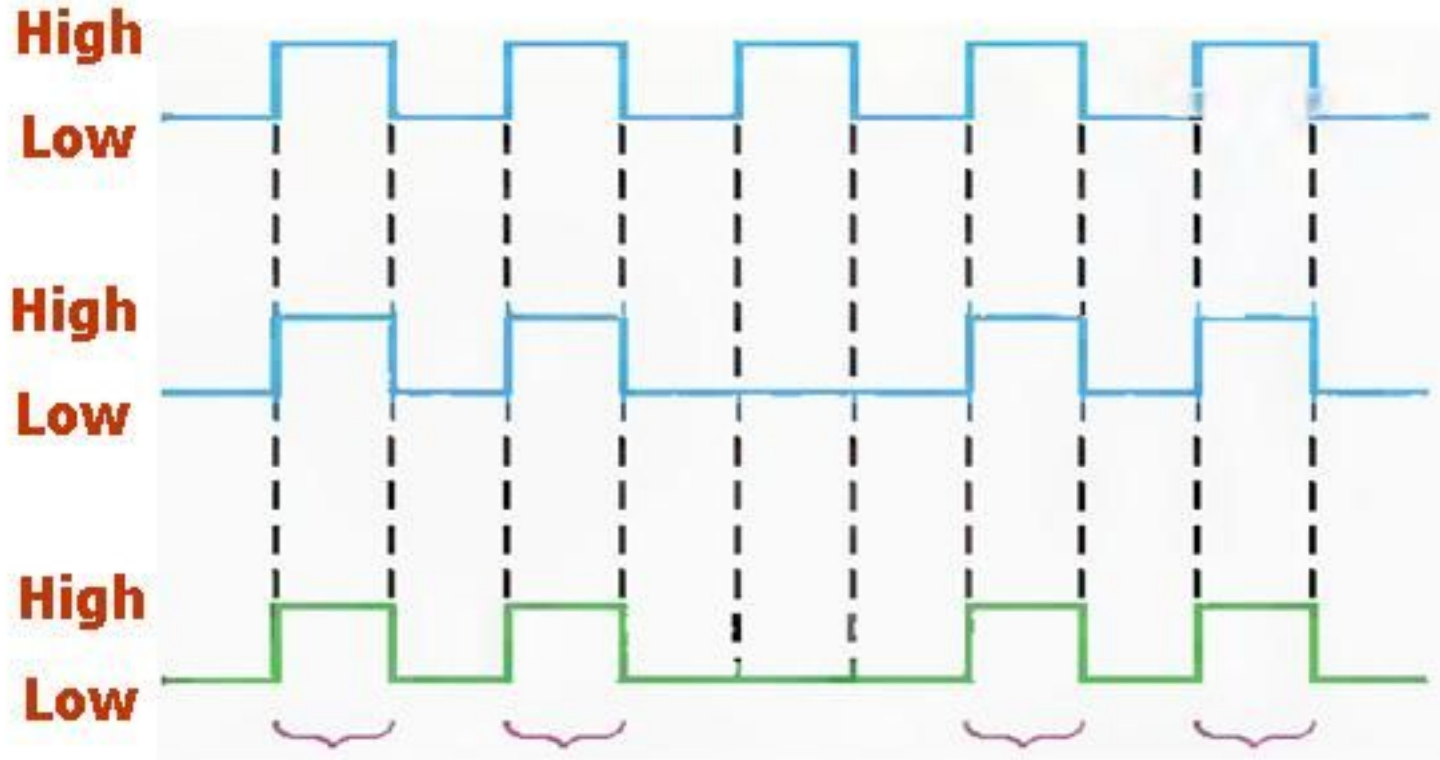
Related Problem: **Develop the truth table for a 4-input AND gate.**

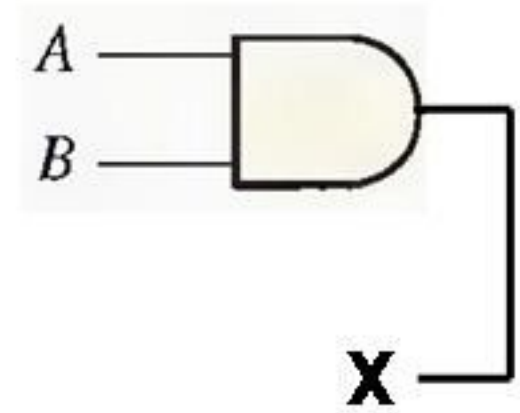
Timing Diagram of AND Gate

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



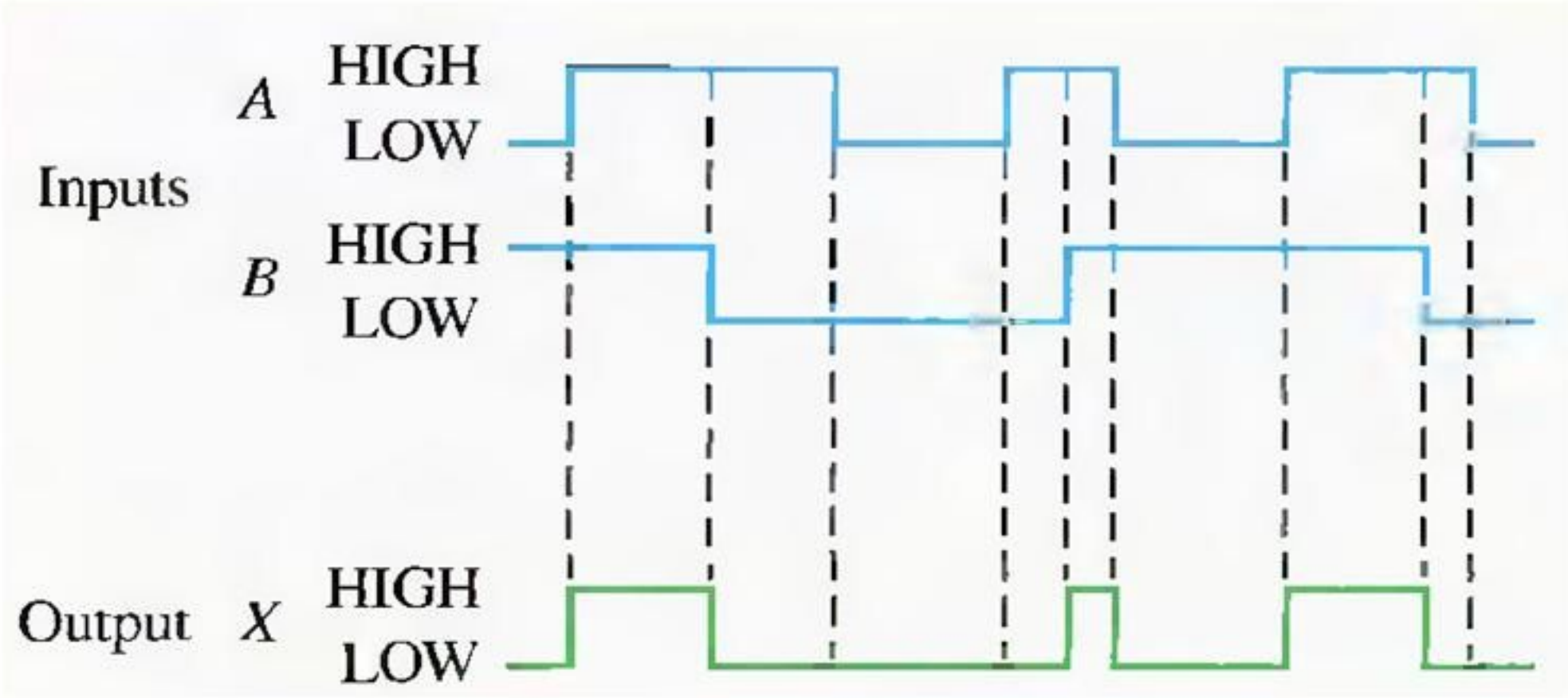
AND Gate Example (Timing Diagram)

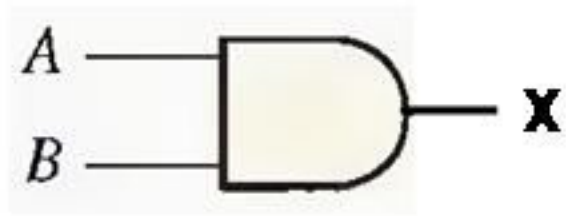




A and B are both HIGH during these four time intervals. Therefore X is HIGH.

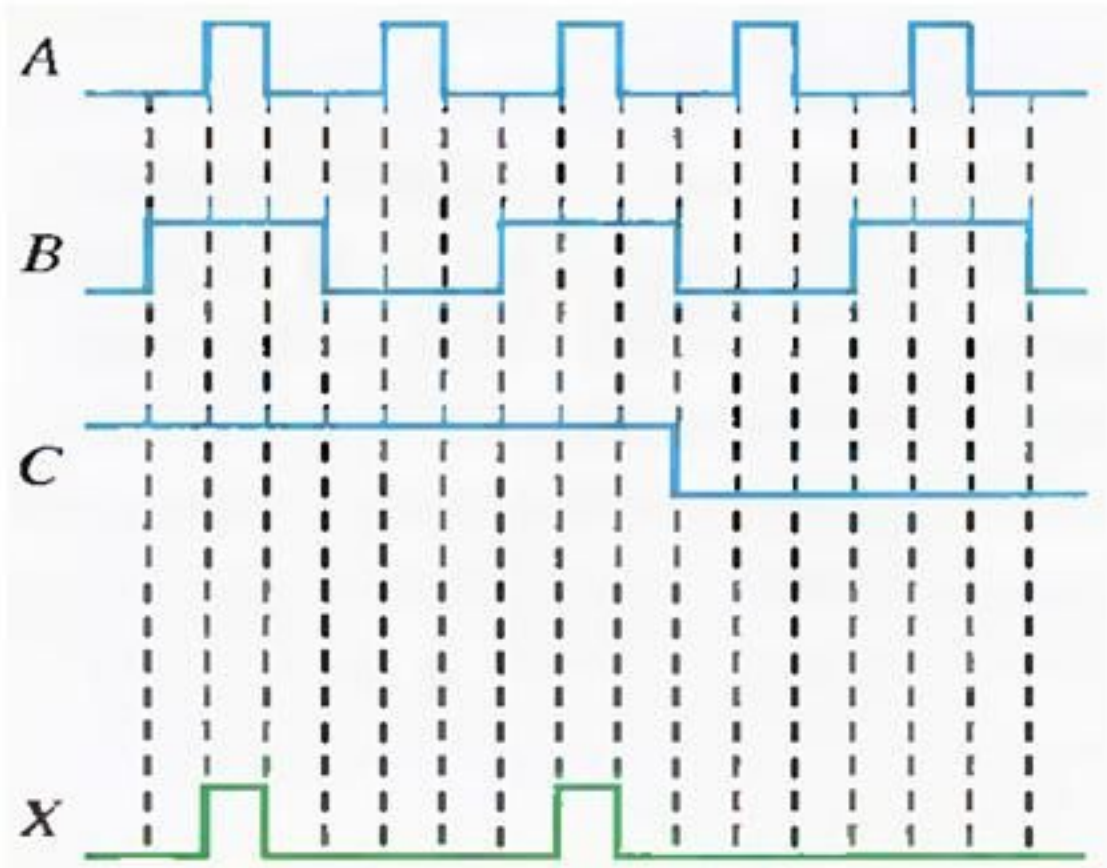
Example

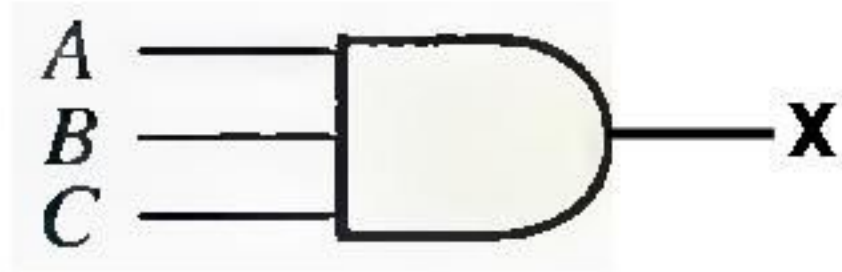




Example

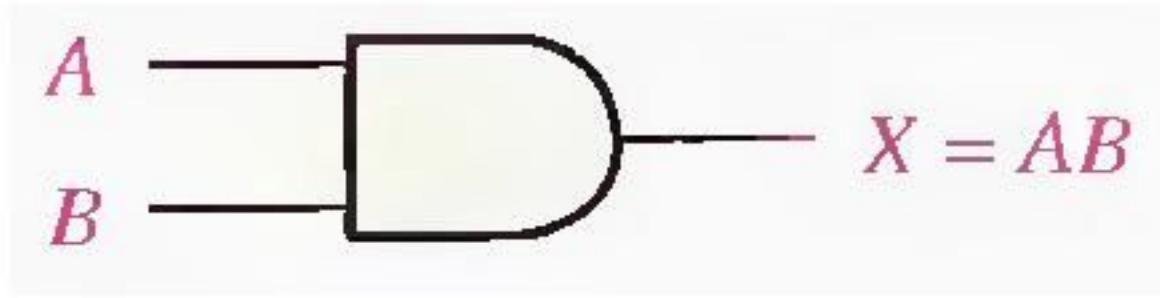
- For the 3-input AND gate in Figure below, determine the output waveform in relation to the inputs.

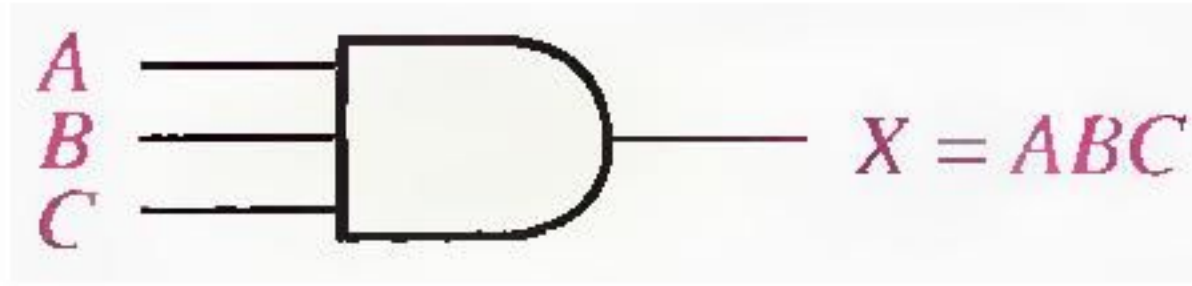


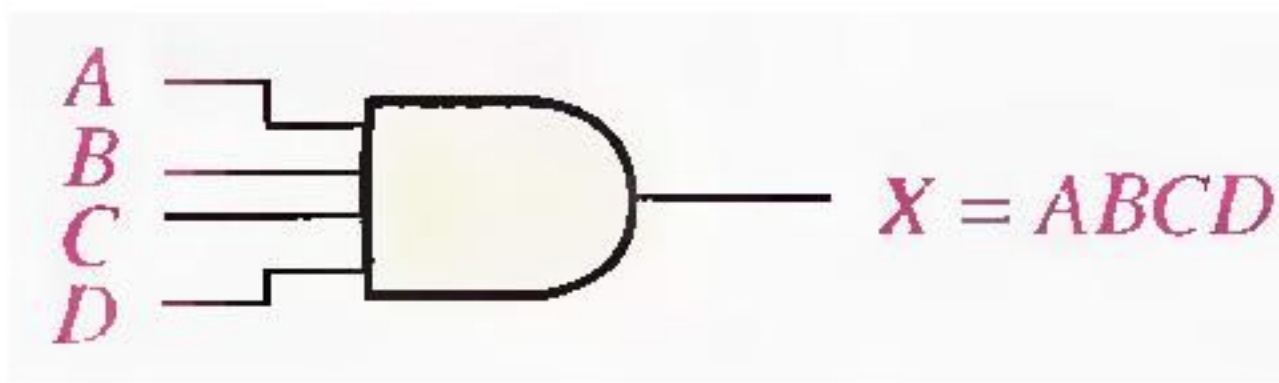


AND Gate

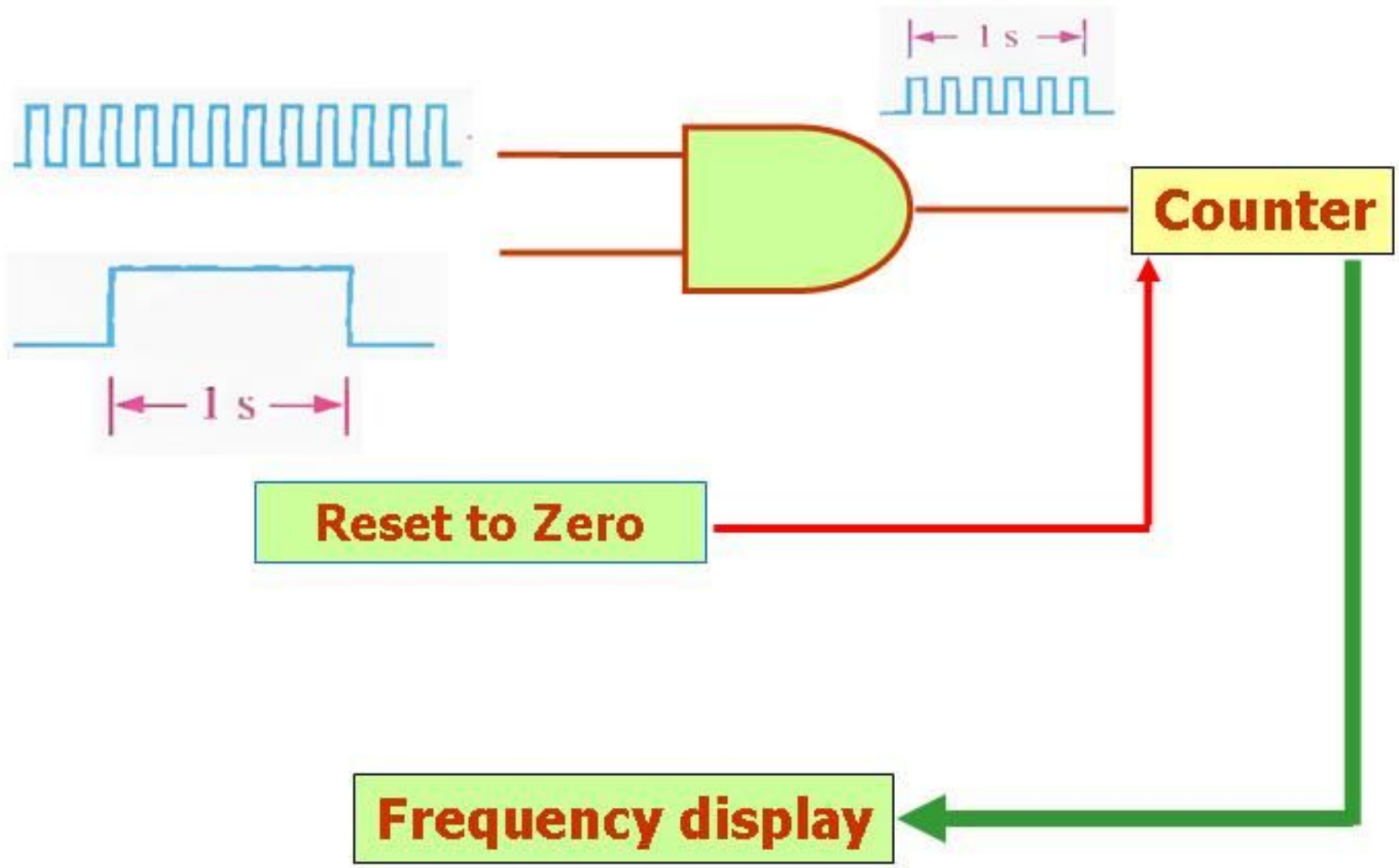
Boolean expressions for AND gates with two, three, and four inputs.





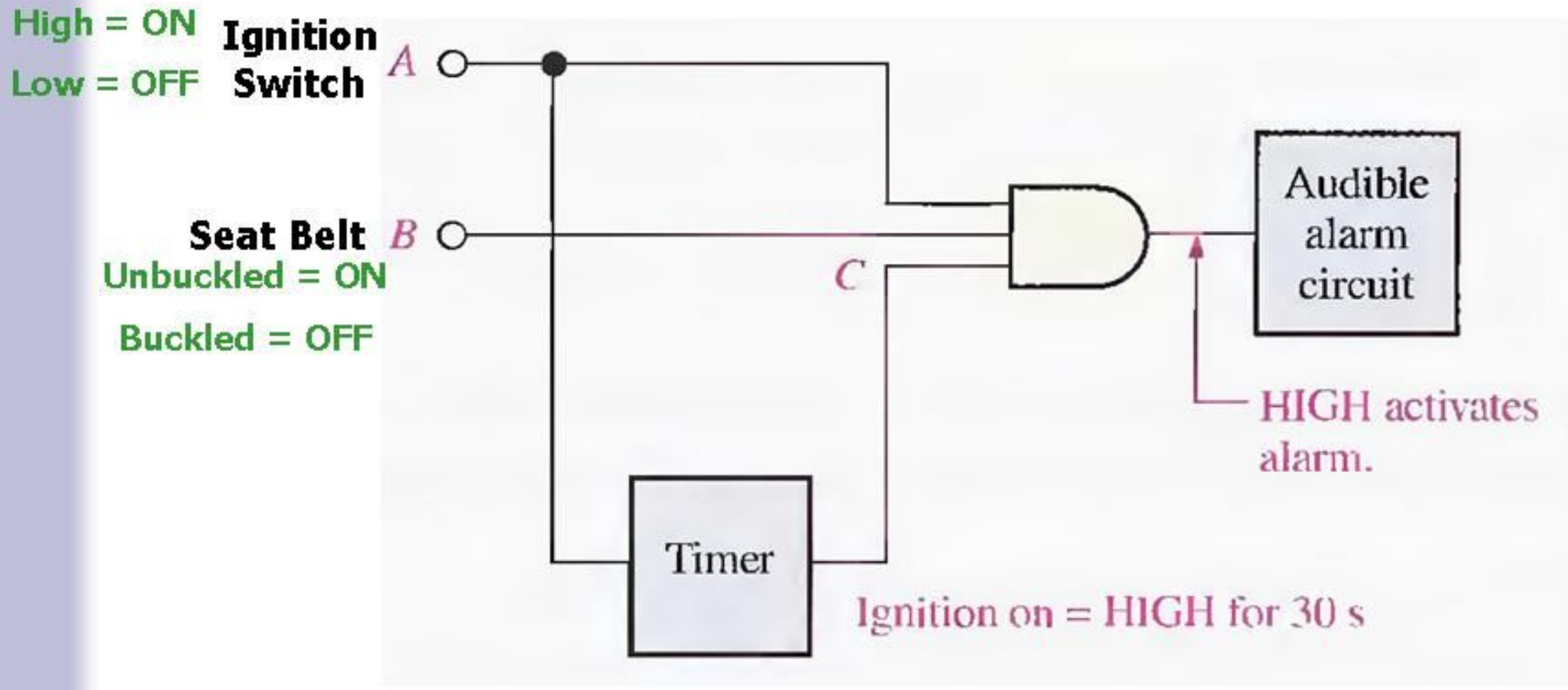


Application



An AND gate performing an enable/linhibit function for a frequency counter.

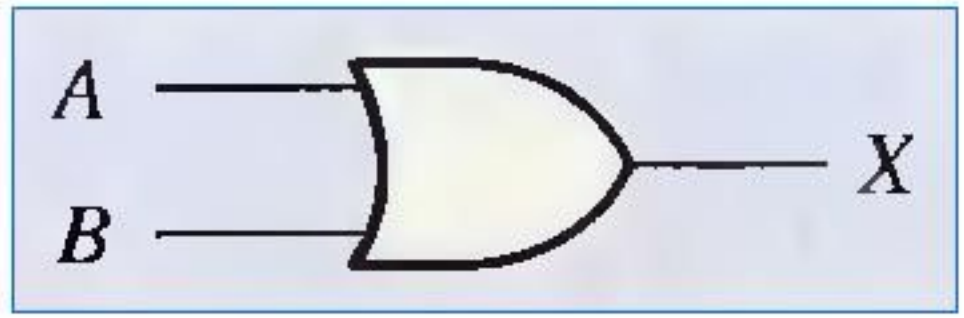
AND Gate Application



A simple seat belt alarm circuit using an AND gate.

The OR Gate

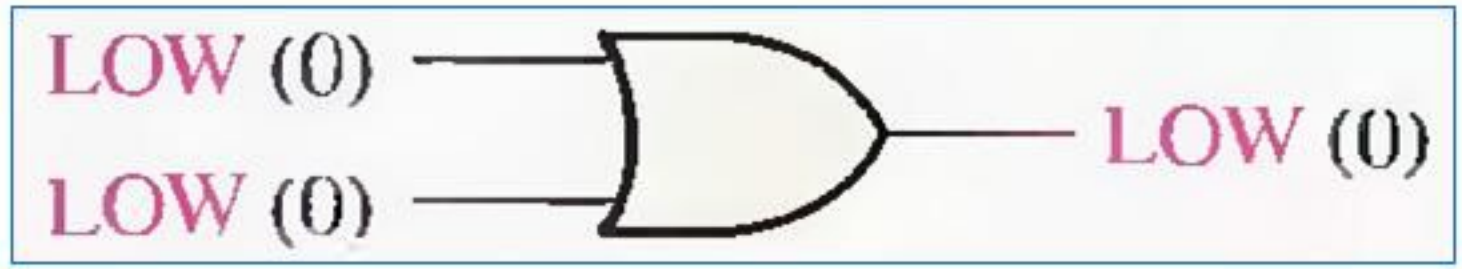
- An OR gate can have two or more inputs and performs what is known as logical addition.
- Standard logic symbols for the OR gate showing two input and single output.

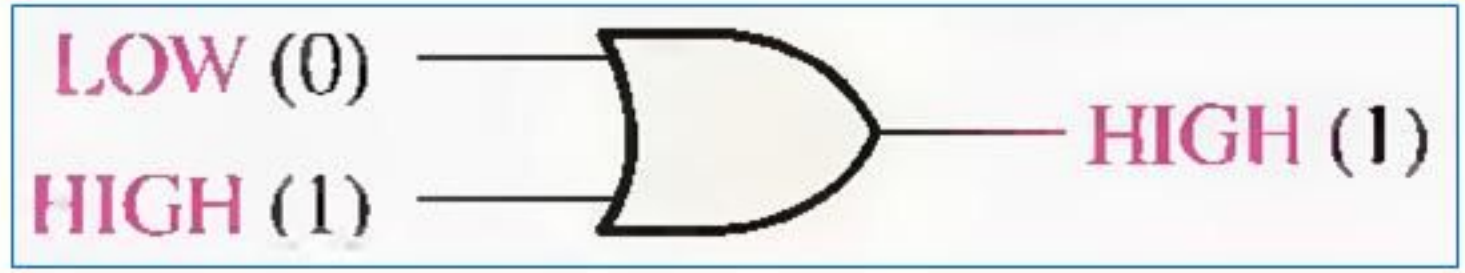


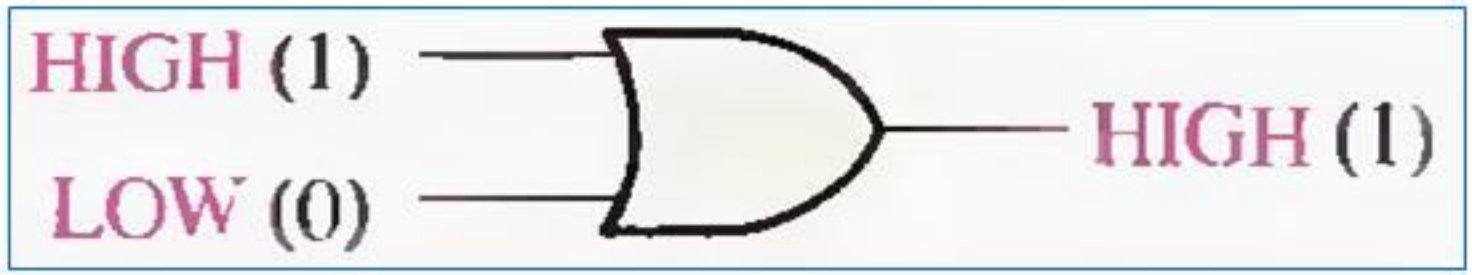
- An OR gate can have any number of inputs greater than one.
- An OR gate produces a HIGH on the output when any of the inputs is HIGH.
- The output is LOW only when all of the inputs are LOW.

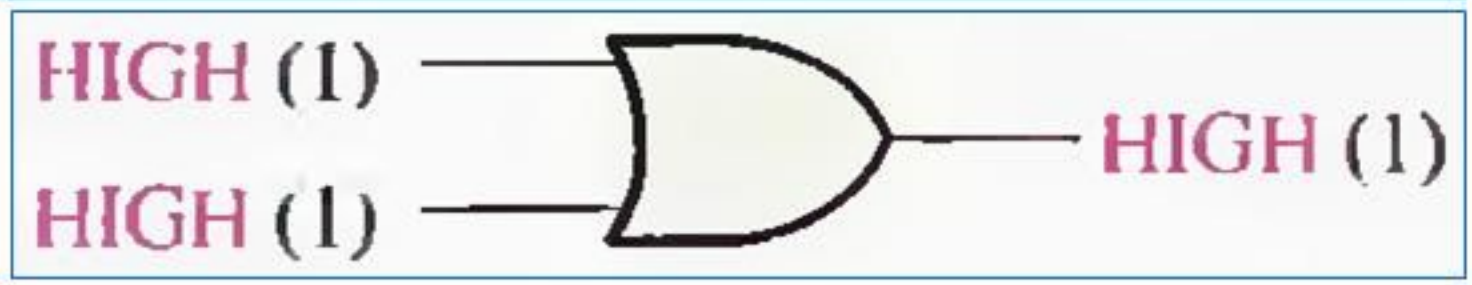
The OR Gate

For a 2-input OR gate, output X is HIGH when either 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.









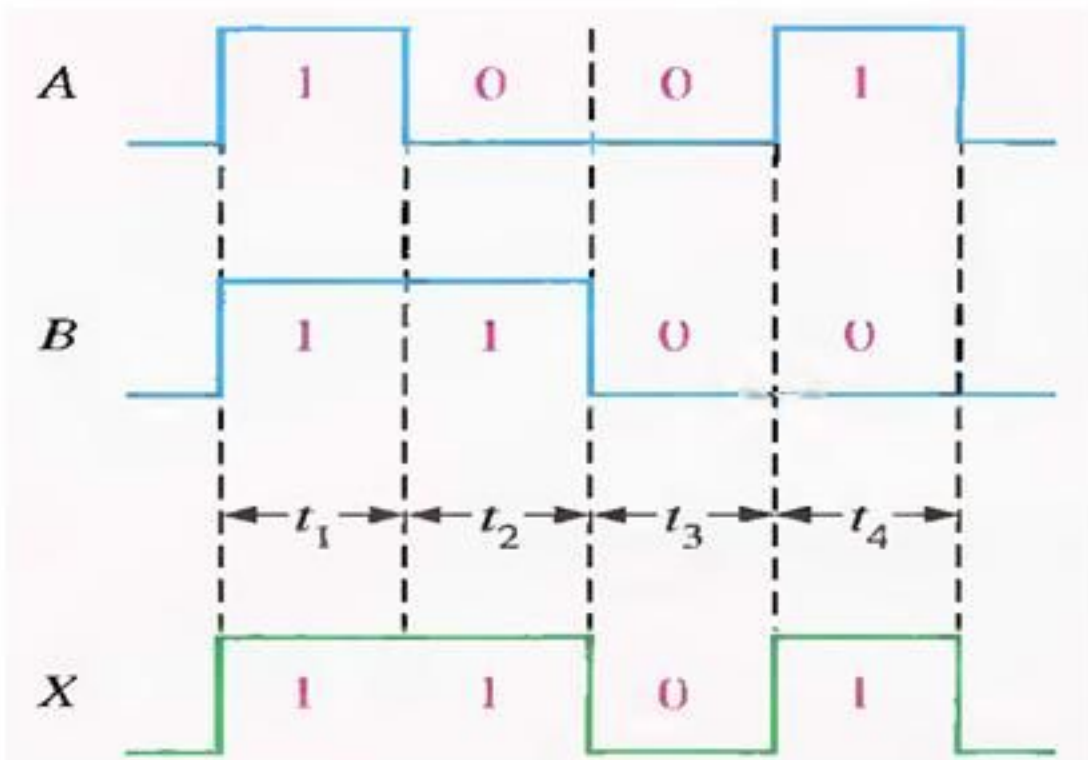
OR Gate Truth Table

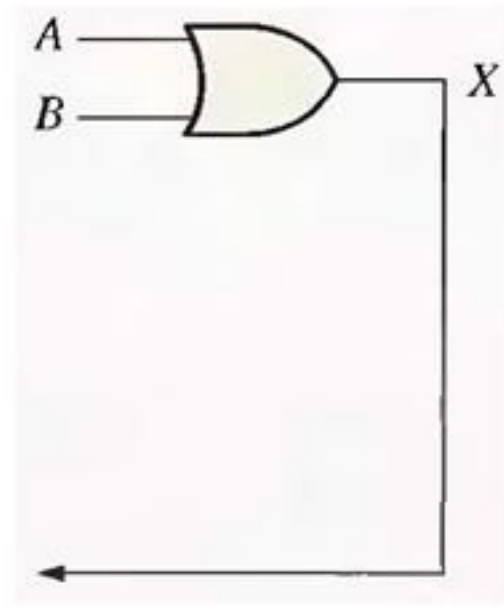
INPUTS		OUTPUT
A	B	X
0	0	0
0	1	1
1	0	1
1	1	1

1 = HIGH, 0 = LOW

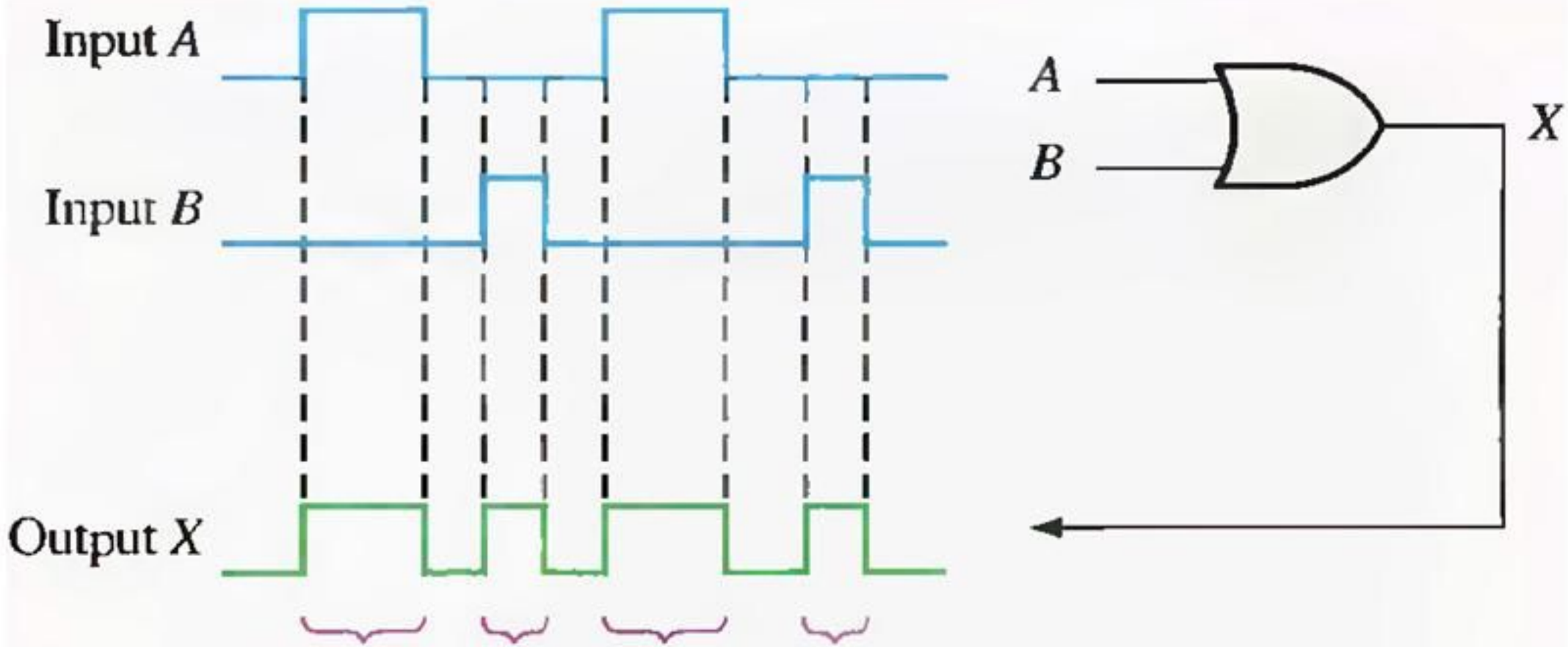
Operation with waveform inputs

In the figure below, inputs A and B are both HIGH (1) during time interval t_1' making output X HIGH (1).





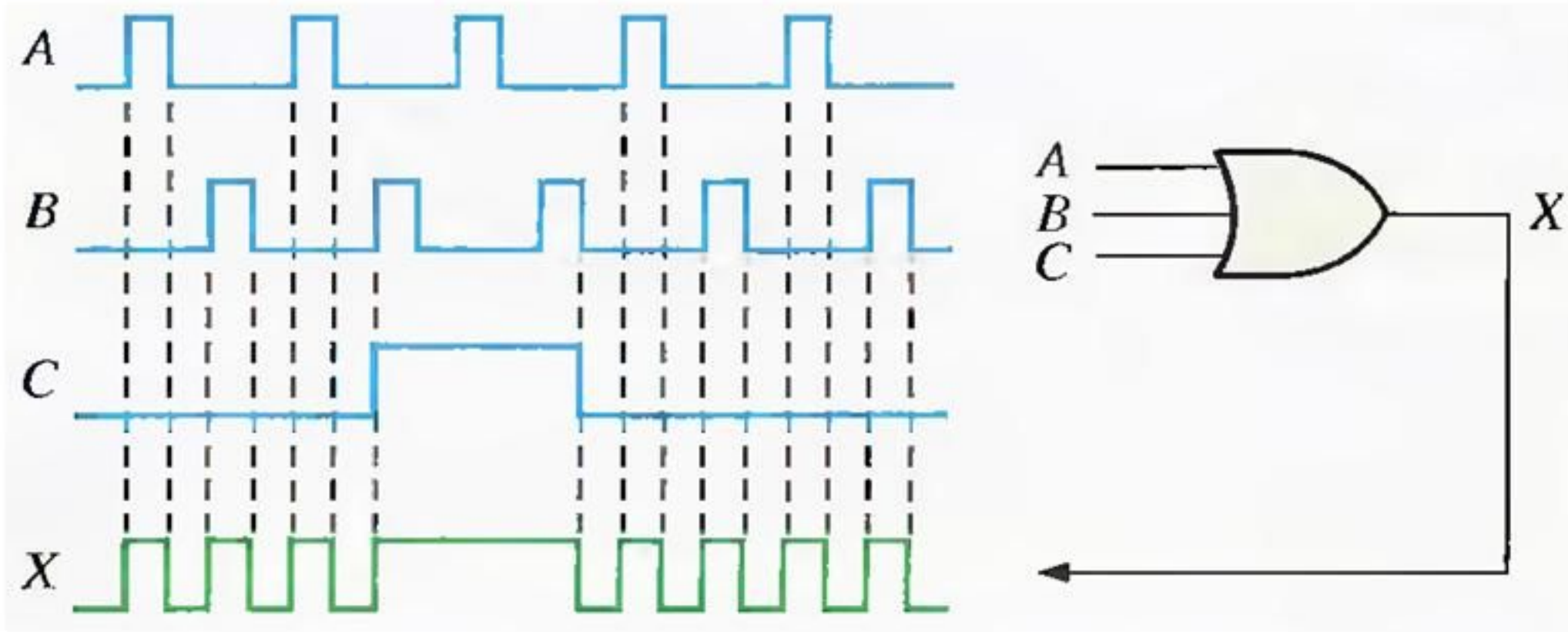
Example



When either input or both input arc HIGH, the output is HIGH.

Example

- For the 3-input OR gate in Figure below, determine the output waveform in proper time relation to the inputs.



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.
- Boolean addition is the same as the OR function.
- The basic rules for Boolean addition are as follows:

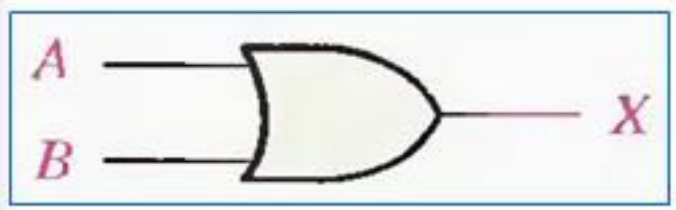
$$0 + 0 = 0$$
$$0 + 1 = 1$$
$$1 + 0 = 1$$
$$1 + 1 = 1$$

logic Expressions for an OR Gate

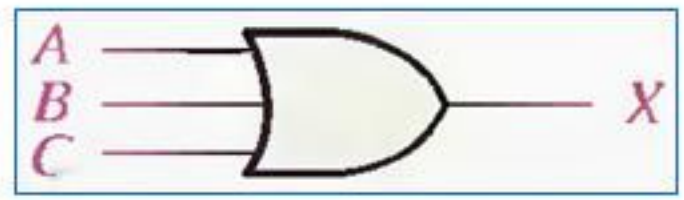
- The operation of a 2-input OR gate can be expressed as follows: If one input variable is A, if the other input variable is B, and if the output variable is X, then the Boolean expression is

$$X=A+B$$

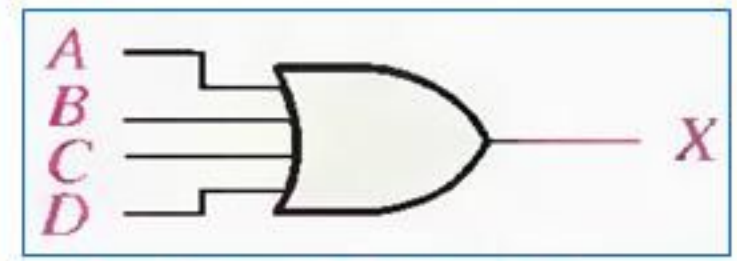
- Boolean expressions for OR gates with two, three, and four inputs,



A+B=X



A+B+C=X



A+B+C+D=X

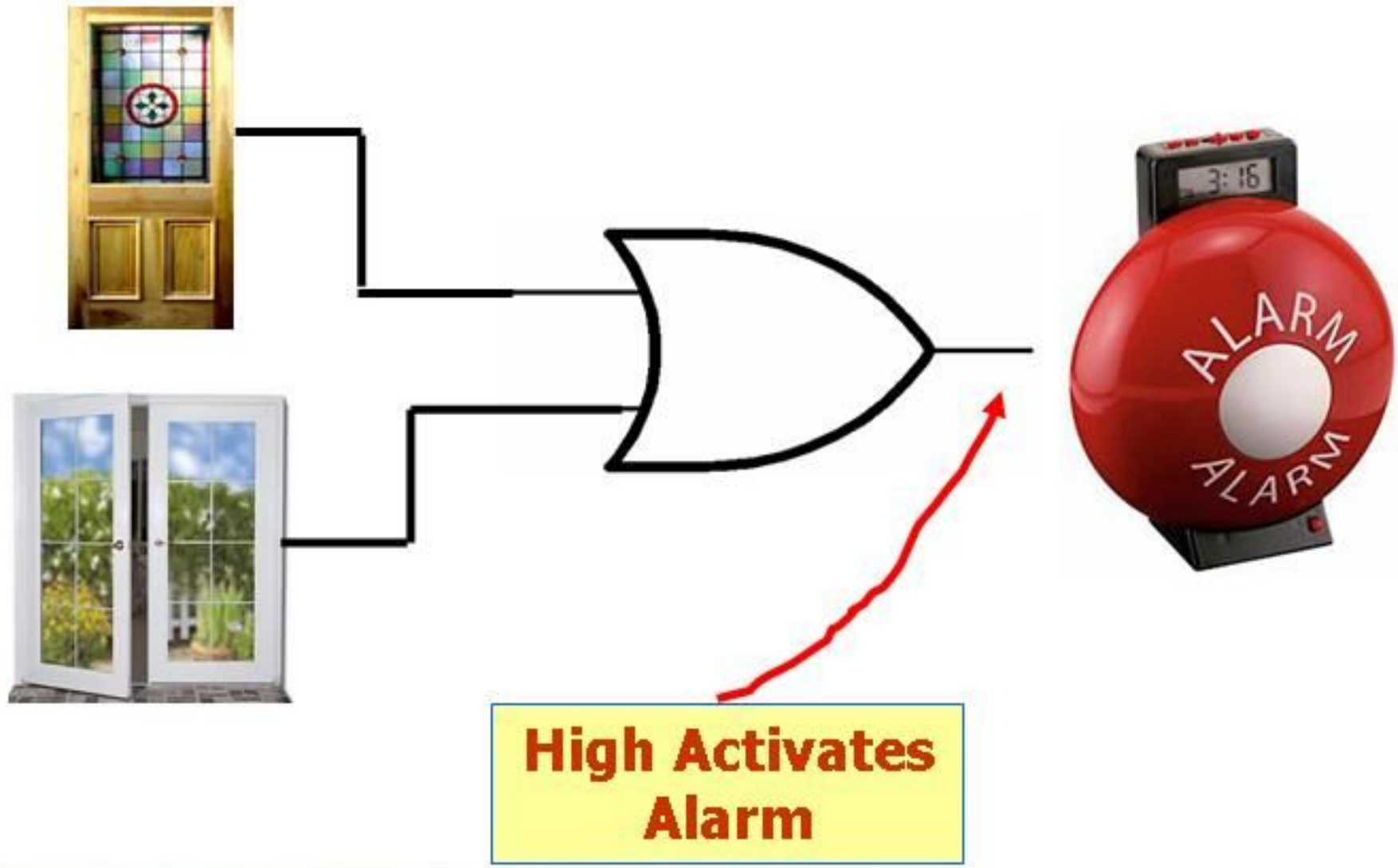
logic Expressions for an OR Gate

- OR gate operation can be evaluated by using the Boolean expressions for the output X by substituting all possible combinations of 1 and 0 values for the input variables,

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

Application

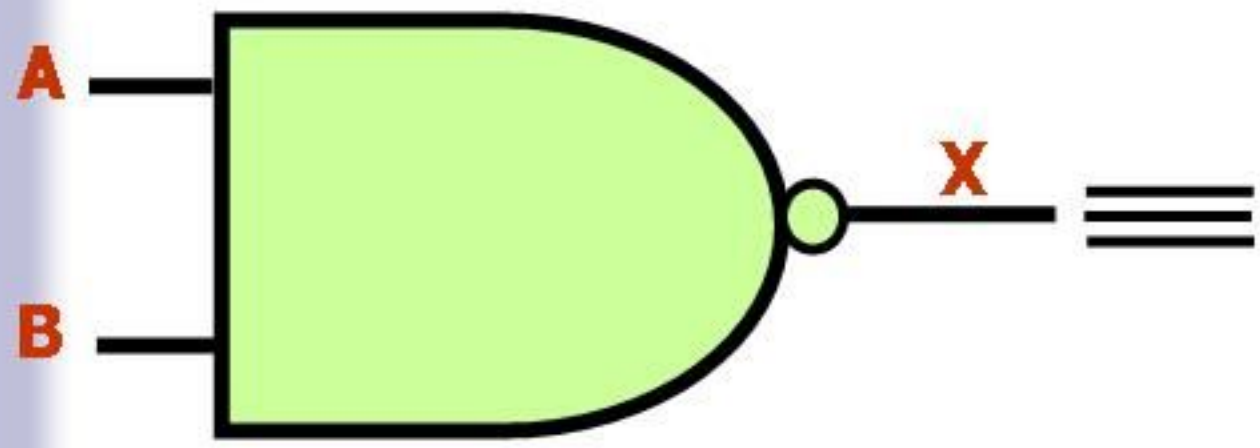
- A simplified portion of an intrusion detection and alarm system is shown in Figure,

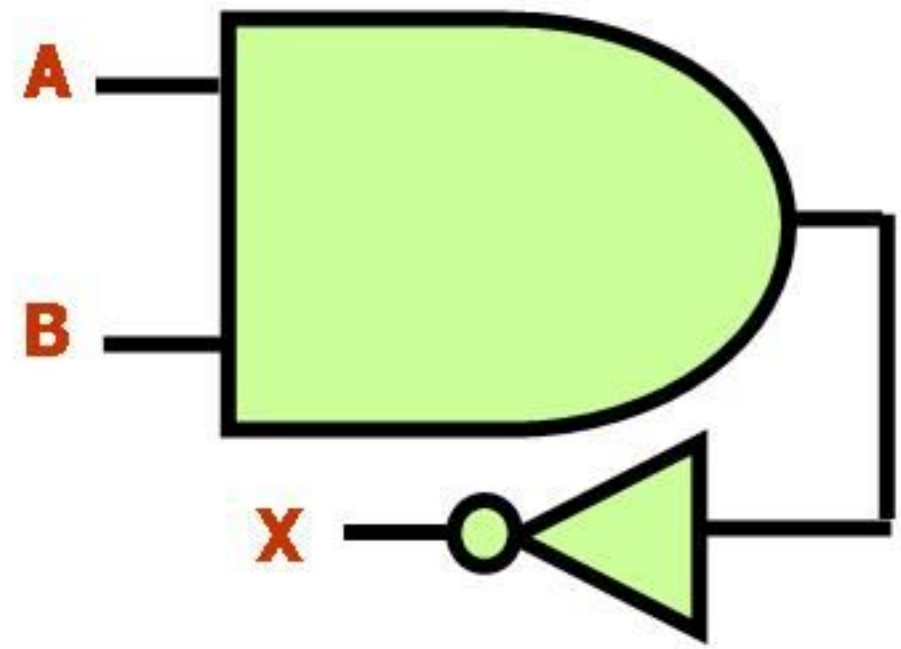


The NAND Gate

- The NAND gate is a popular logic element because it can be used as a universal gate.
- 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.

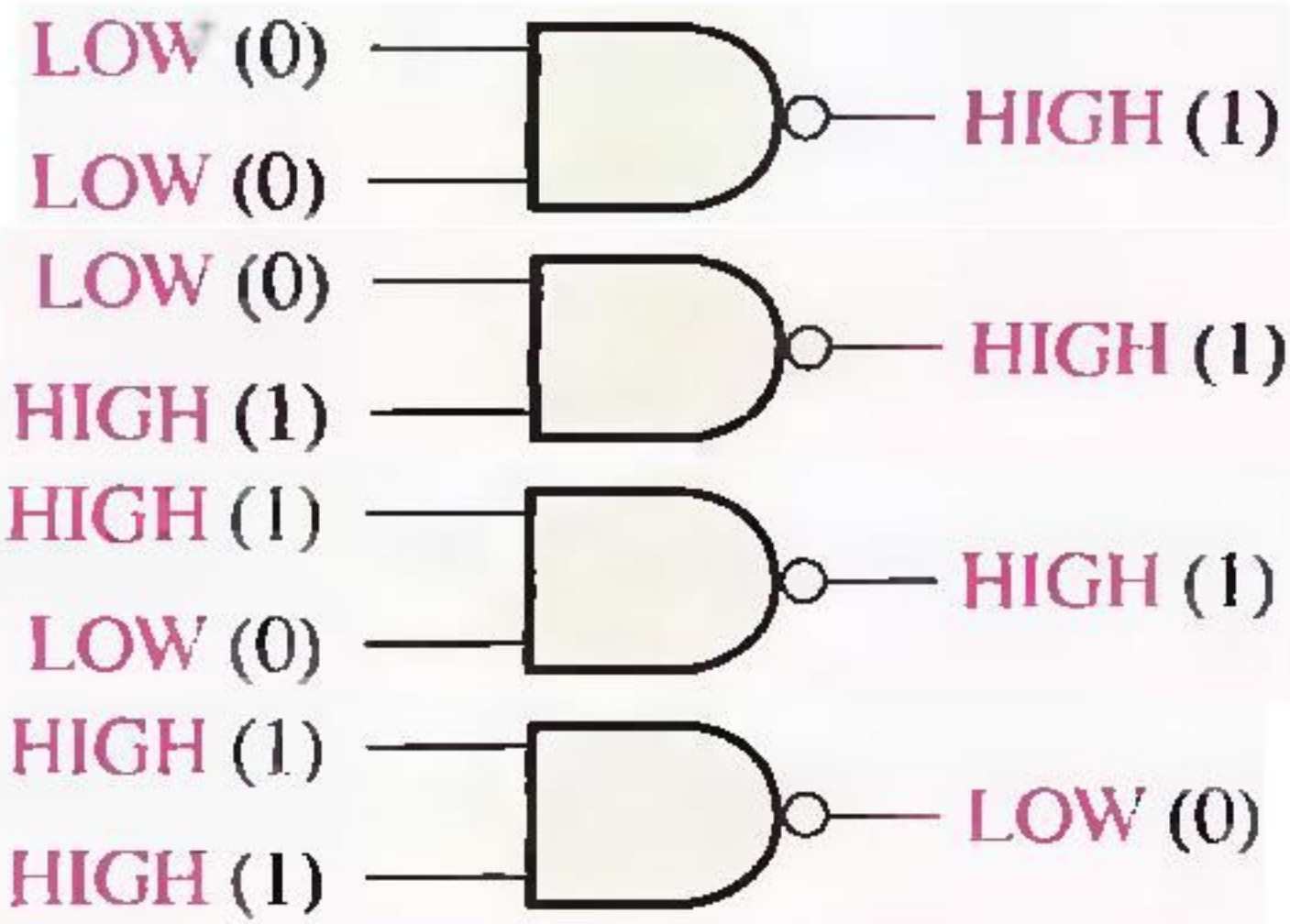
- Symbolic representation of NAND gate is,





Operation of NAND

- 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.



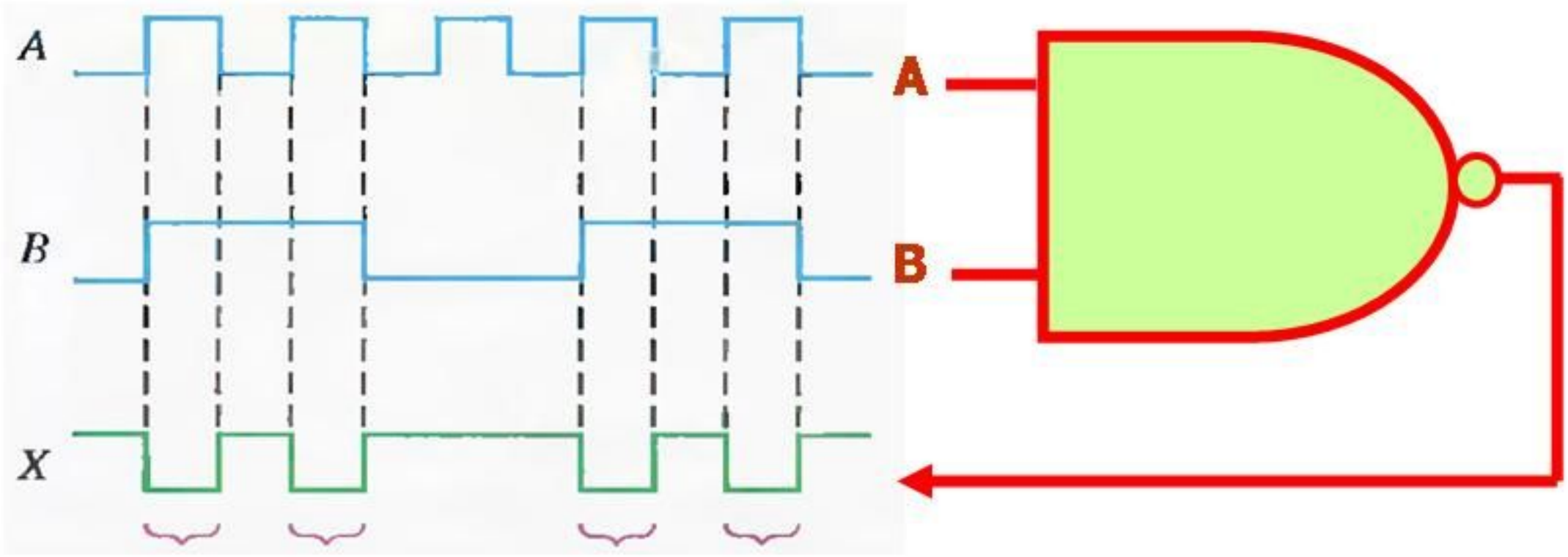
Truth table for a 2-input NAND

INPUTS		OUTPUT
A	B	X
0	0	1
0	1	1
1	0	1
1	1	0

1 = HIGH, 0 = LOW.

Operation with Waveform Inputs

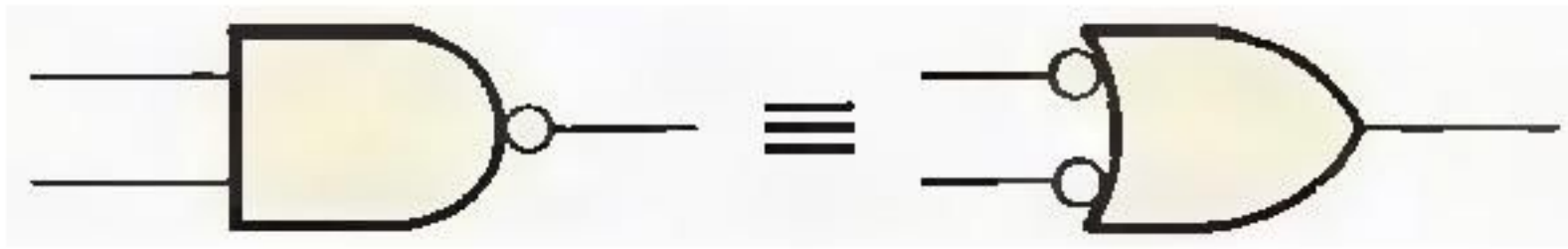
- If the two waveforms A and B shown in Figure 3-27 are applied to the NAND gate inputs, determine the resulting output waveform



A and B are both HIGH during these four time intervals Therefore X is LOW.

Negative-OR Equivalent Operation of a NAND Gate

- For a 2-input NAND gate performing a negative-OR operation, output X is HIGH when either input A or input B is LOW, or when both A and B are LOW.



NAND **Negative - OR**

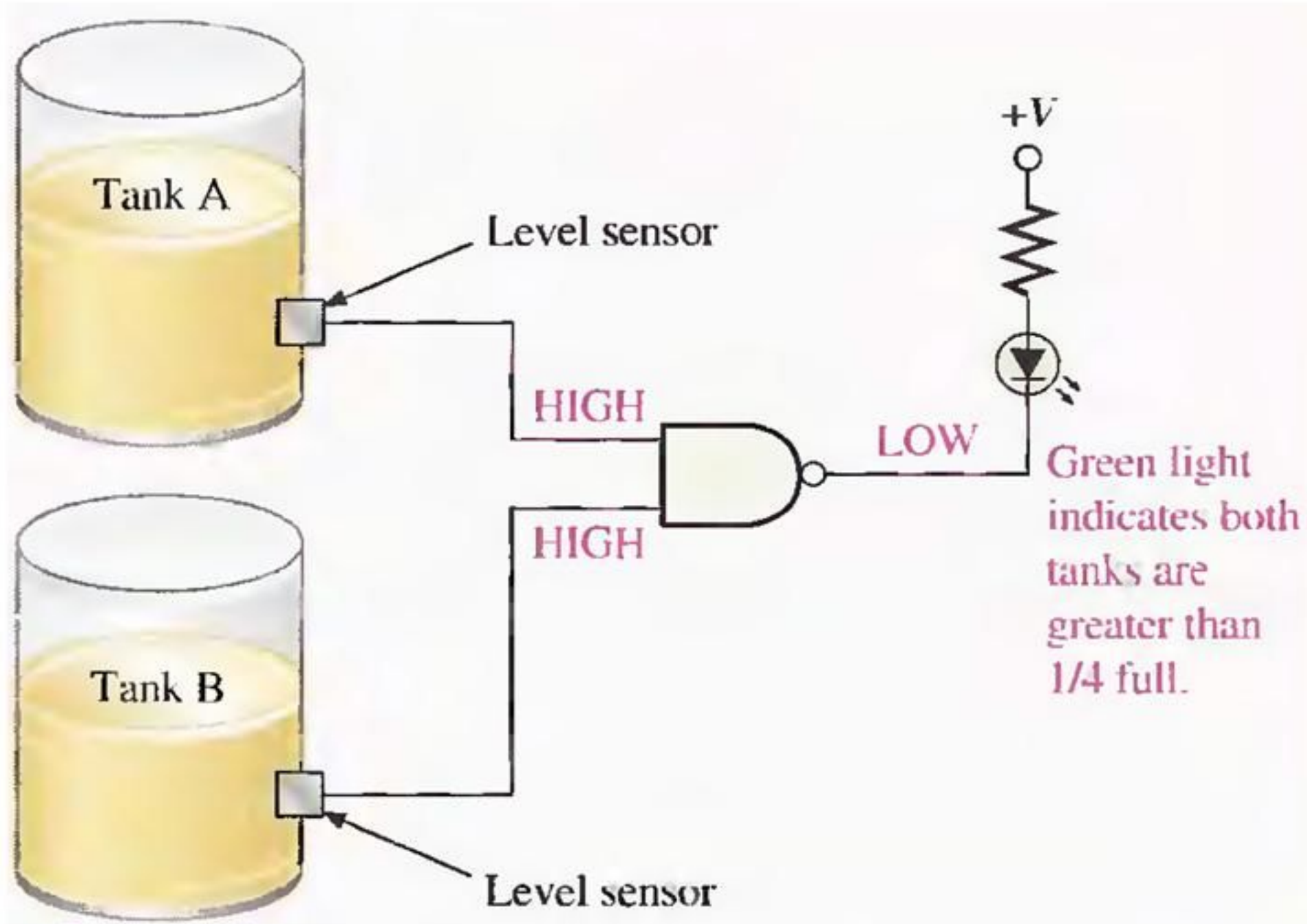
Application

- A manufacturing plant uses two tanks to store certain liquid chemicals that are required in a manufacturing process.
- Each tank has a sensor that detects when the chemical level drops to 25% of full.
- The sensors produce a HIGH level of 5 V when the tanks are more than one-quarter full.
- When the volume of chemical in a tank drops to one-quarter full, the sensor puts out a LOW level of 0 V.
- It is required that a single green light-emitting diode (LED) on an indicator panel show when both tanks are more than one-quarter full.

Application Example of NAND Gate

- Solution
  - A NAND gate with its two inputs connected to the tank level sensor and its output connected to the indicator panel are used. The operation can be stated as follows:
  - If tank A and tank B are above one-quarter full, the LED is on.
  - Pictorially it is presented on the next slide.

Application Example of NAND Gate

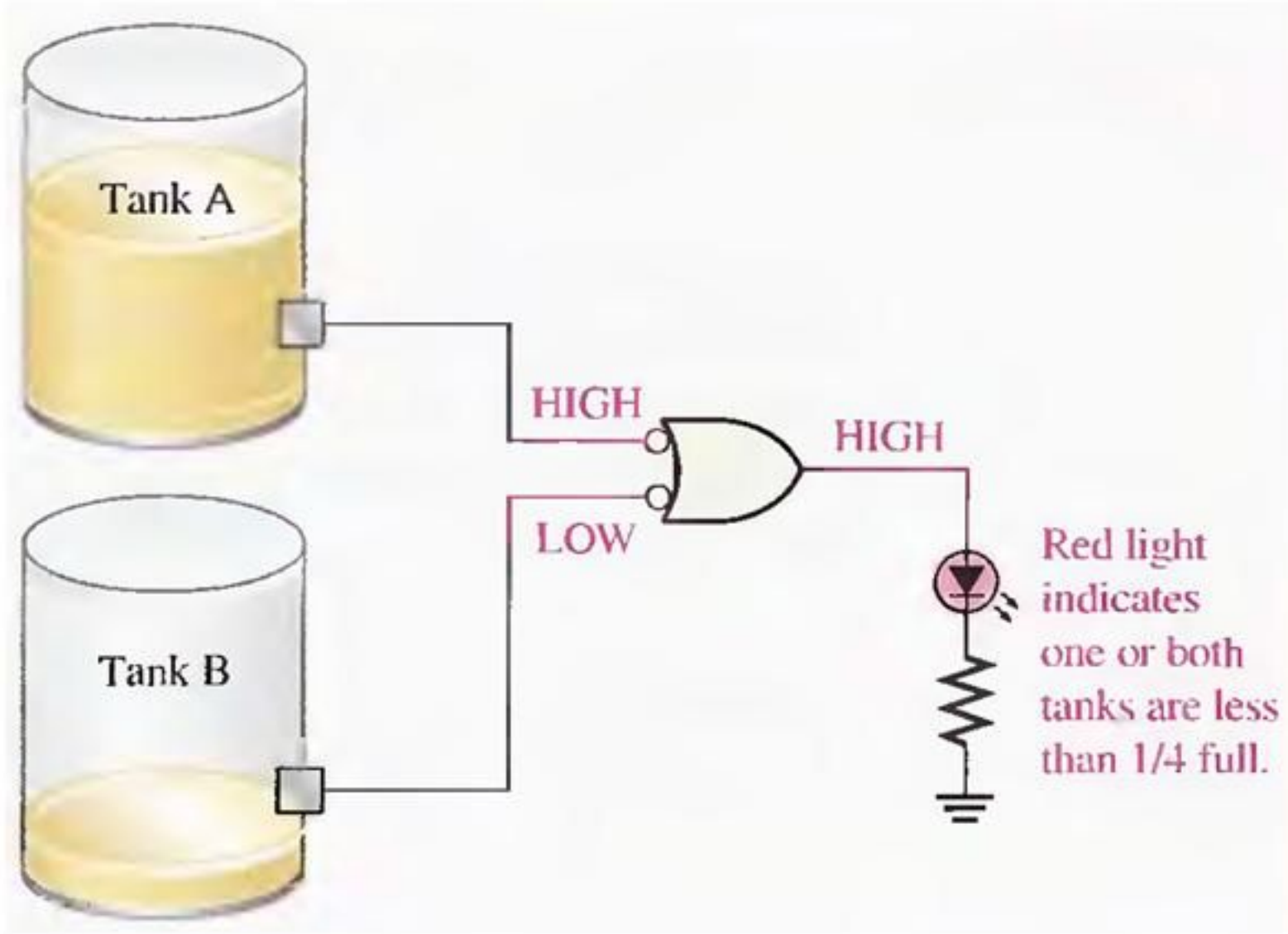


Application Example of NAND Gate

- Figure 3-31 shows a NAND gate operating as a negative-OR gate to detect the occurrence of at least one LOW on its inputs.
- A sensor puts out a LOW voltage if the volume in its tank goes to one-quarter full or less.
- When this happens, the gate output goes HIGH.
- The red LED circuit in the panel is arranged so that a HIGH voltage turns it on.

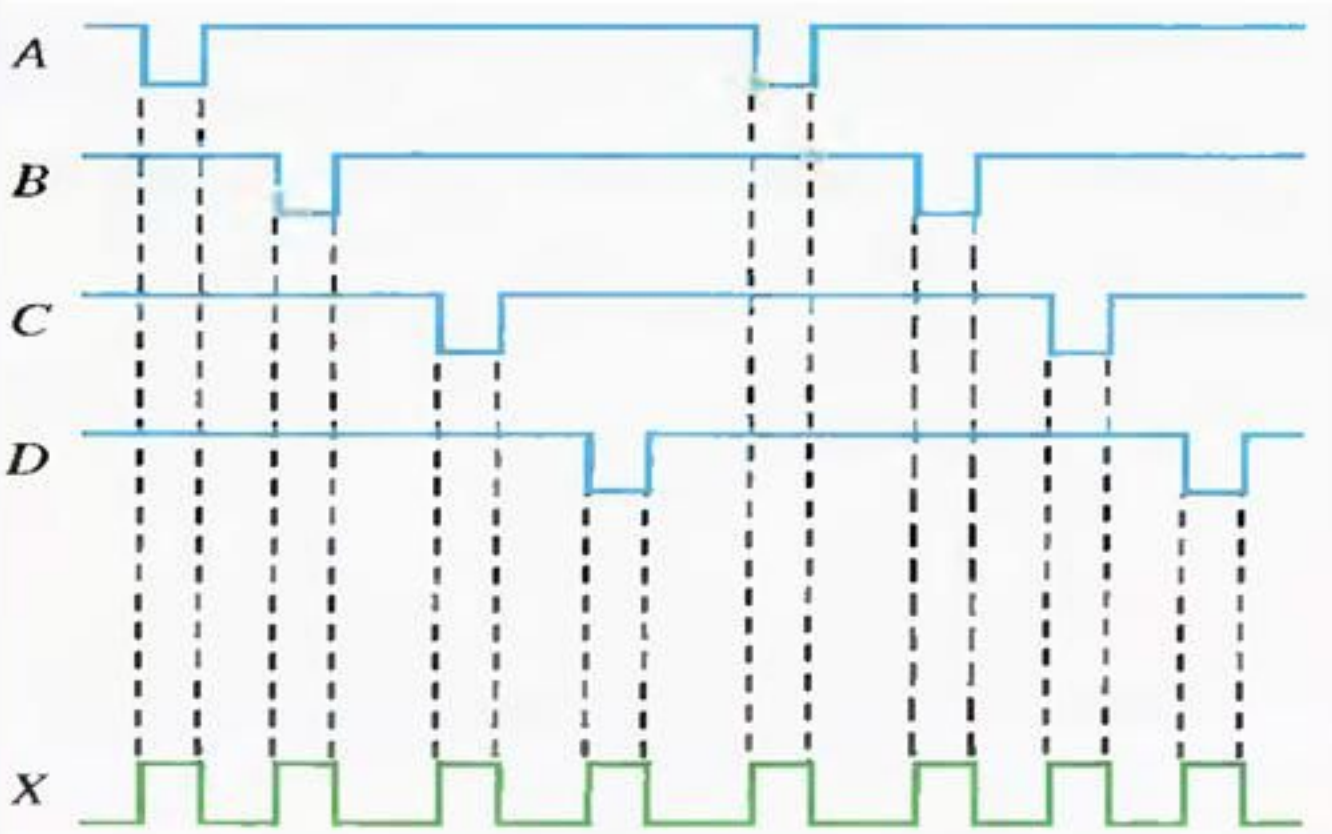
Application Example of NAND Gate

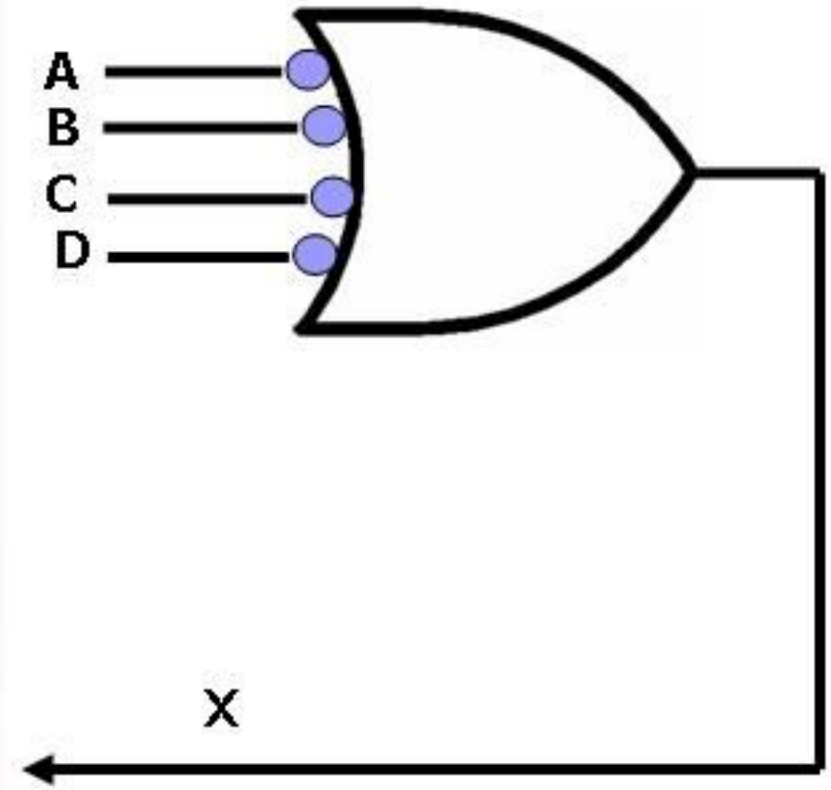
- The operation can be stated as follows: If tank A or tank B or both are below one-quarter full, the LED is on.



Operation with waveform inputs

- For the 4-input NAND gate in Figure 3-32. operating as a negative-OR. determine the output with respect to the inputs.





Logic Expressions for a NAND Gate

- The Boolean expression for the output of a 2-input NAND gate is,

$$X = \overline{AB}$$

- two input variables A and B, are first ANDed and then complemented, as indicated by the bar over the AND expression.

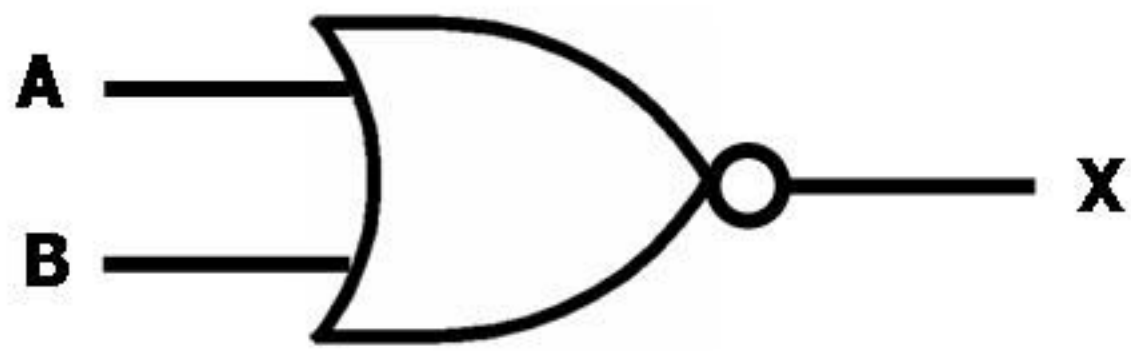
Truth Table of NAND

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	$\overline{1 \cdot 1} = \overline{1} = 0$

High = 1, Low = 0.

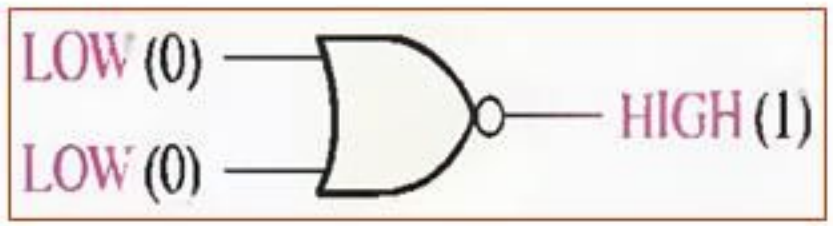
The NOR Gate

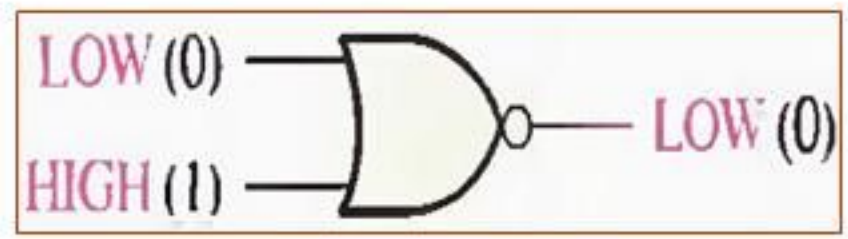
- The NOR gate, like the NAND gate, is a useful logic element because it can also be used as a universal gate.
- that is, NOR gates can be used in combination to perform the AND, OR, and inverter operations.
- The term NOR is a contraction of NOT-OR and implies an OR function with an inverted output.
- Symbol used,

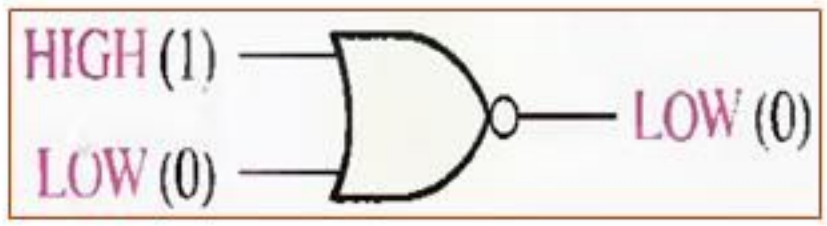


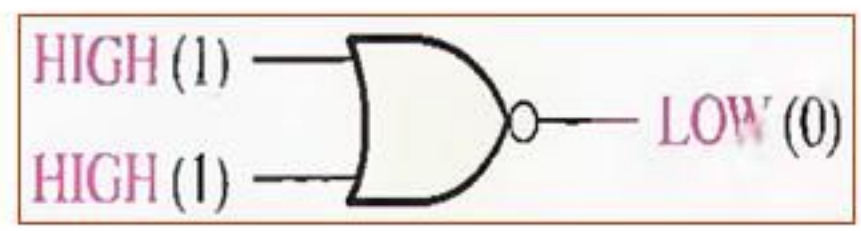
Operation of a NOR Gate

- For a 2-input NOR gate, output X is LOW when either input A or input B is HIGH, or when both A and B are HIGH; X is HIGH only when both A and B are LOW.









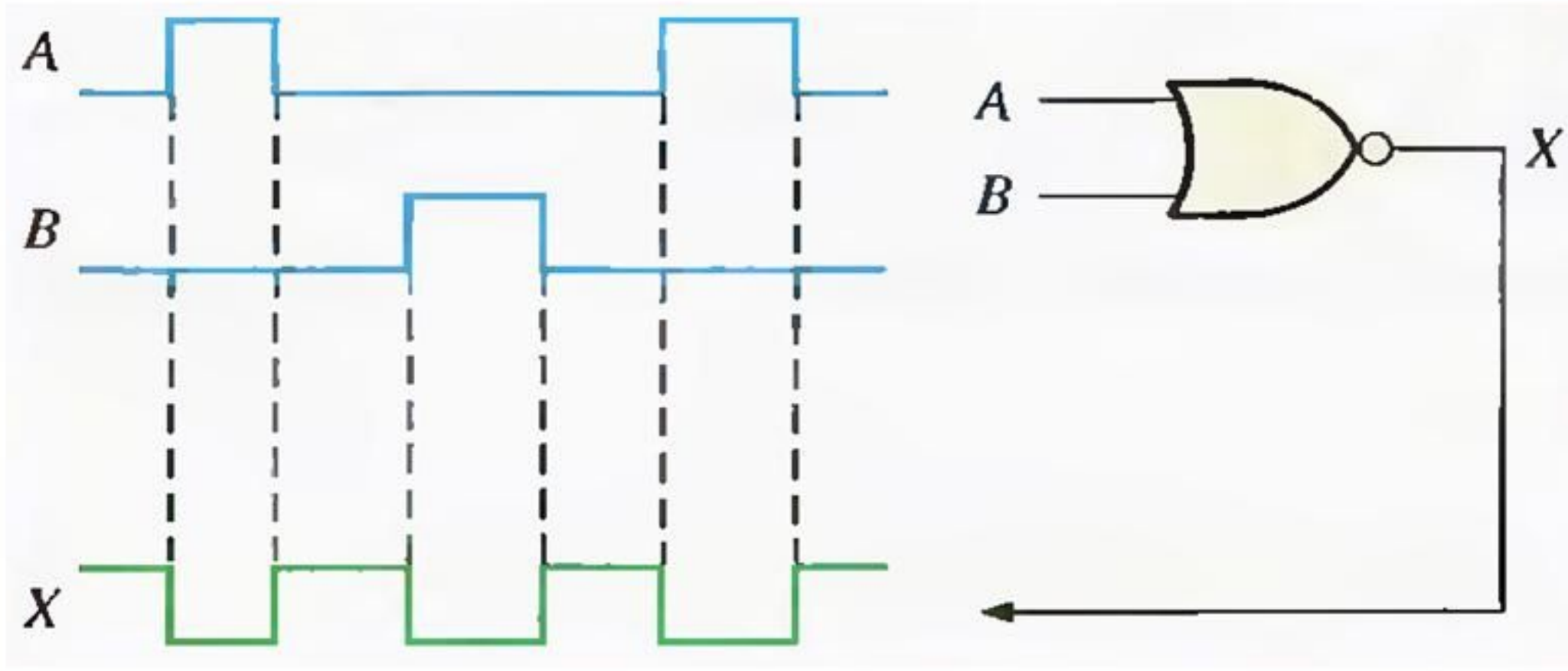
Truth Table of NOR Gate

INPUTS		OUTPUT
A	B	X
0	0	1
0	1	0
1	0	0
1	1	0

High = 1, Low = 0.

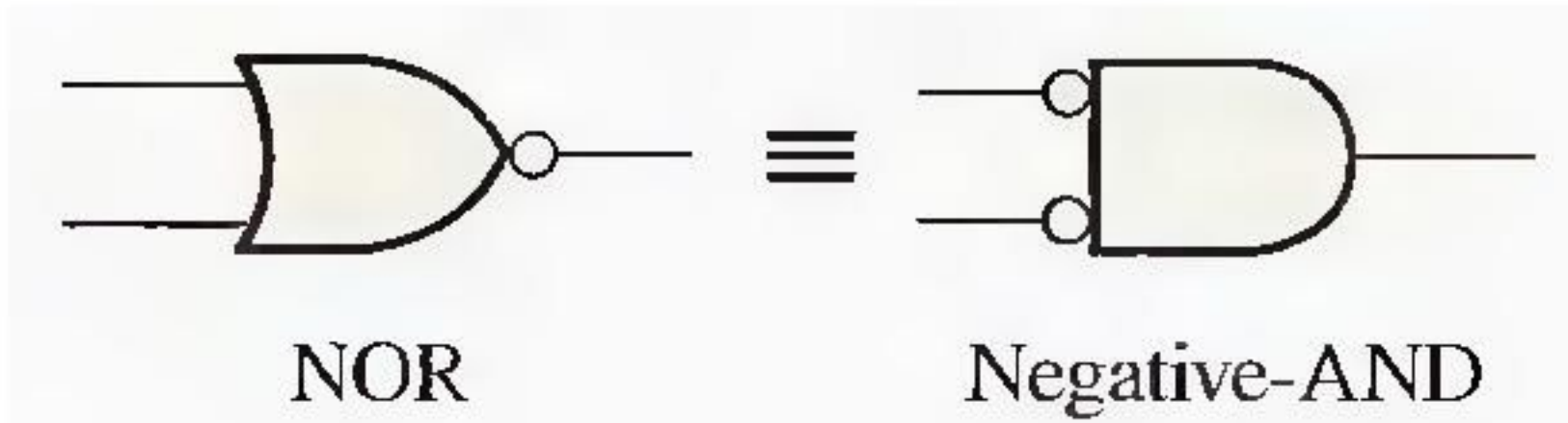
Operation with Waveform Inputs

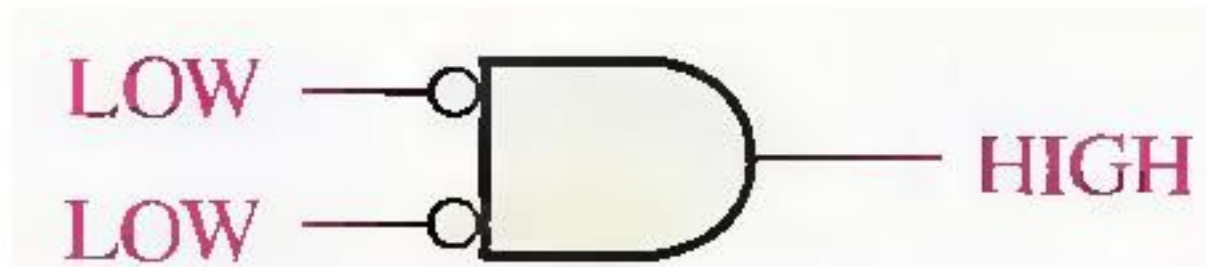
- If the two waveforms are applied to a NOR gate, the resulting output waveform is,



NOR Gate

- NOR Gate operation is equivalent is Negative AND,

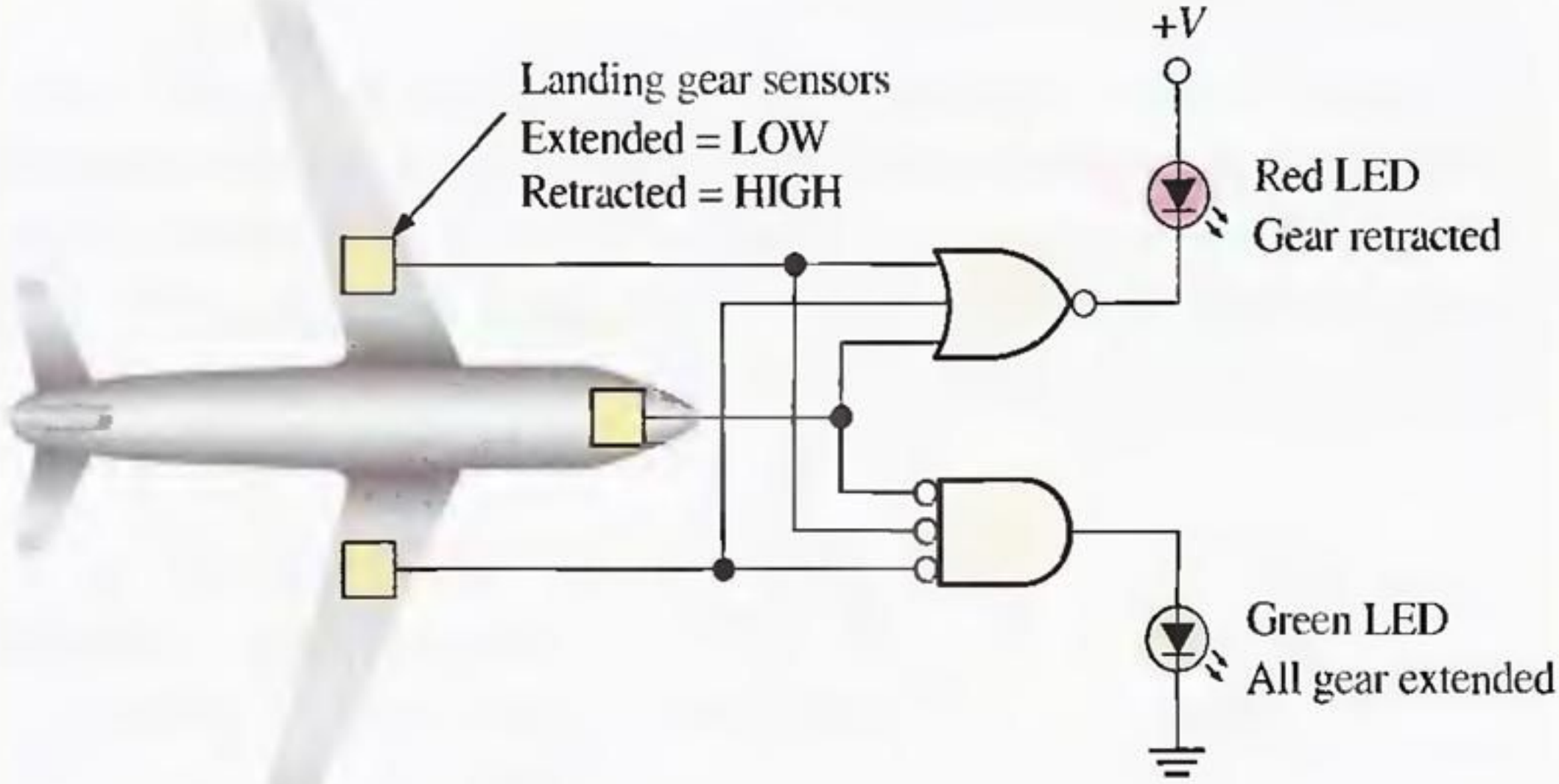




Application Example

- As part of an aircraft's functional monitoring system, a circuit is required to indicate the status of the landing gears prior to landing.
- A green LED display turns on if all three gears are properly extended when the "gear down" switch has been activated in preparation for landing.
- A red LED display turns on if any of the gears fail to extend properly prior to landing.
- When a landing gear is extended, its sensor produces a LOW voltage.
- When a landing gear is retracted. its sensor produces a HIGH voltage.
- Implement a circuit to meet this requirement.

Application Example

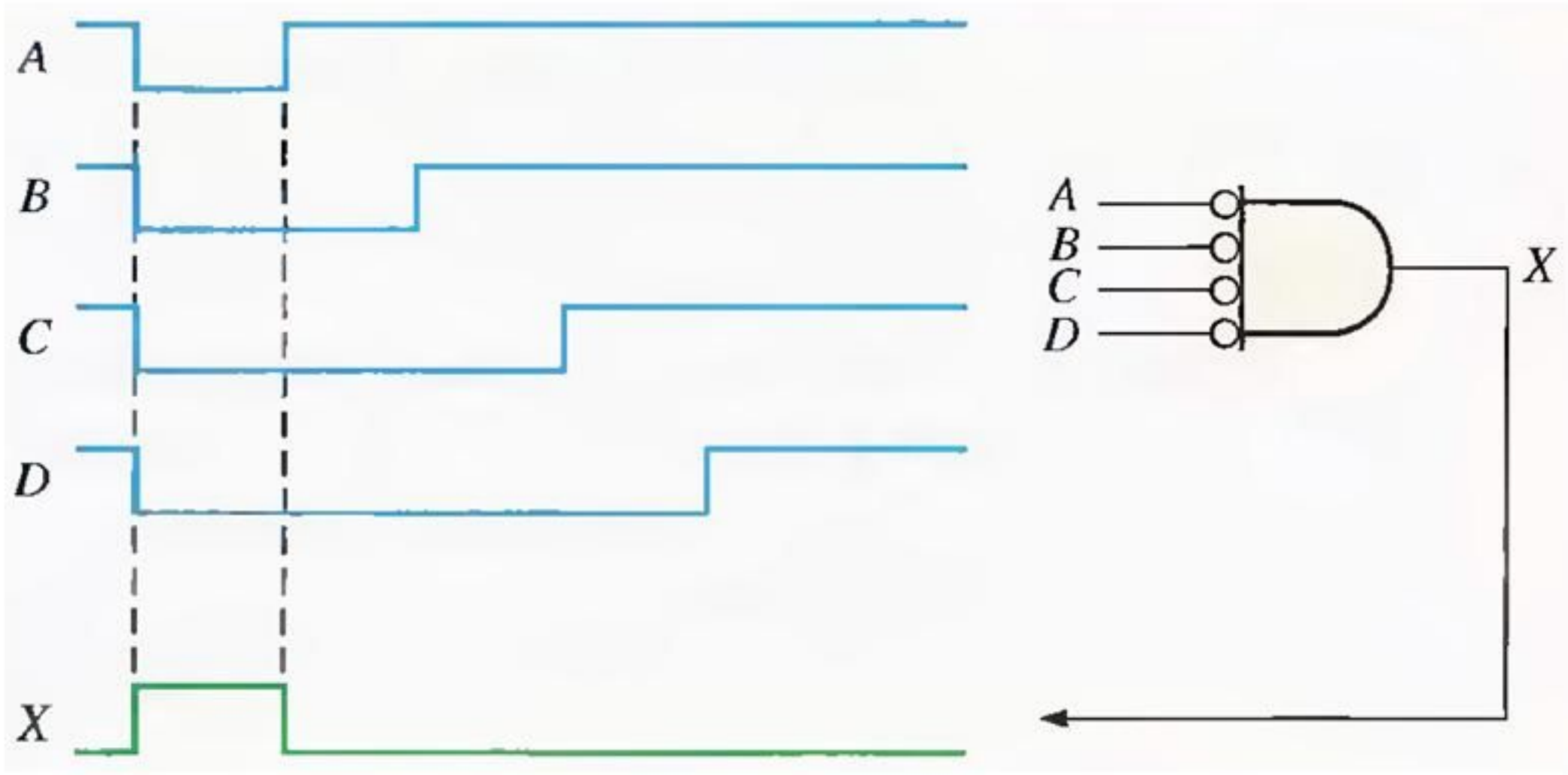


When all three of the gate inputs are LOW, the three landing gears are properly extended and the resulting HIGH output from the negative-AND gate turns on the green LED display.

Application Example

- The other NOR gate operates as a NOR to detect if one or more of the landing gears remain retracted.
- When one or more of the landing gears remain retracted (pulls in), the resulting HIGH from the is detected by the NOR gate. which produces a LOW output to turn on the red LED warning display.

Waveform representation of negative AND



Logic Expressions for a NOR Gate

- The Boolean expression for the output of a 2-input NOR gate can be written as,

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

- This equation says that the two input variables are first ORed and then complemented, as indicated by the bar over the OR expression.

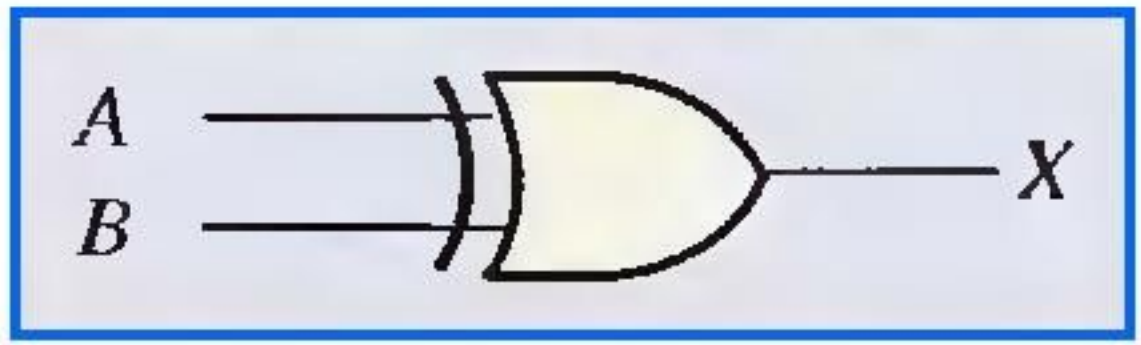
Truth Table of NOR Gate

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	$\overline{1+1}=\overline{1}=0$

High = 1, Low = 0.

Exclusive OR Gate

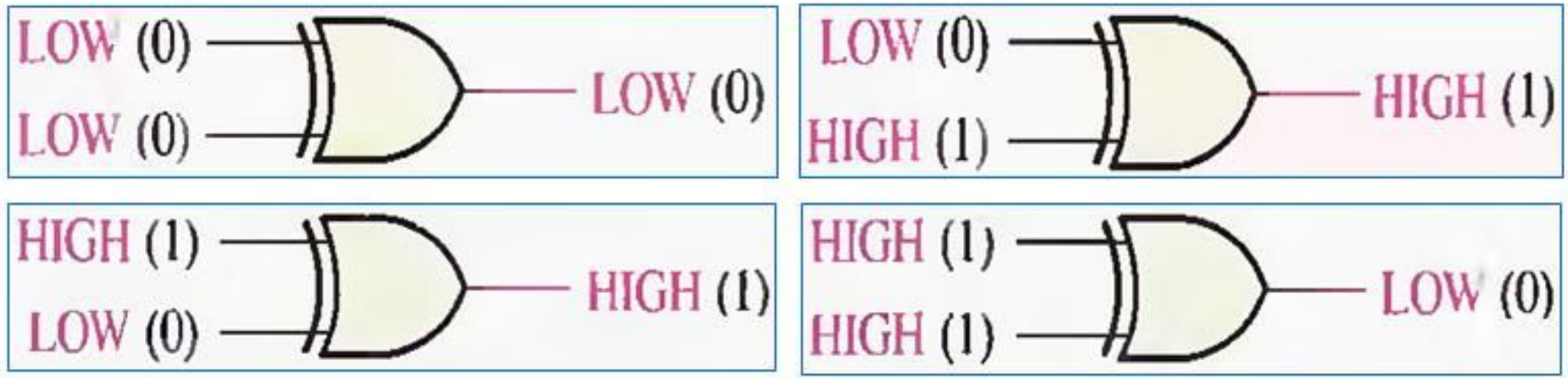
- Standard symbols for exclusive OR gate is,



- The output of an exclusive-OR gate is HIGH only when the two inputs are at opposite logic levels.

XOR Gate

- The four possible input combinations and the resulting outputs for an XOR gate are illustrated in figure,

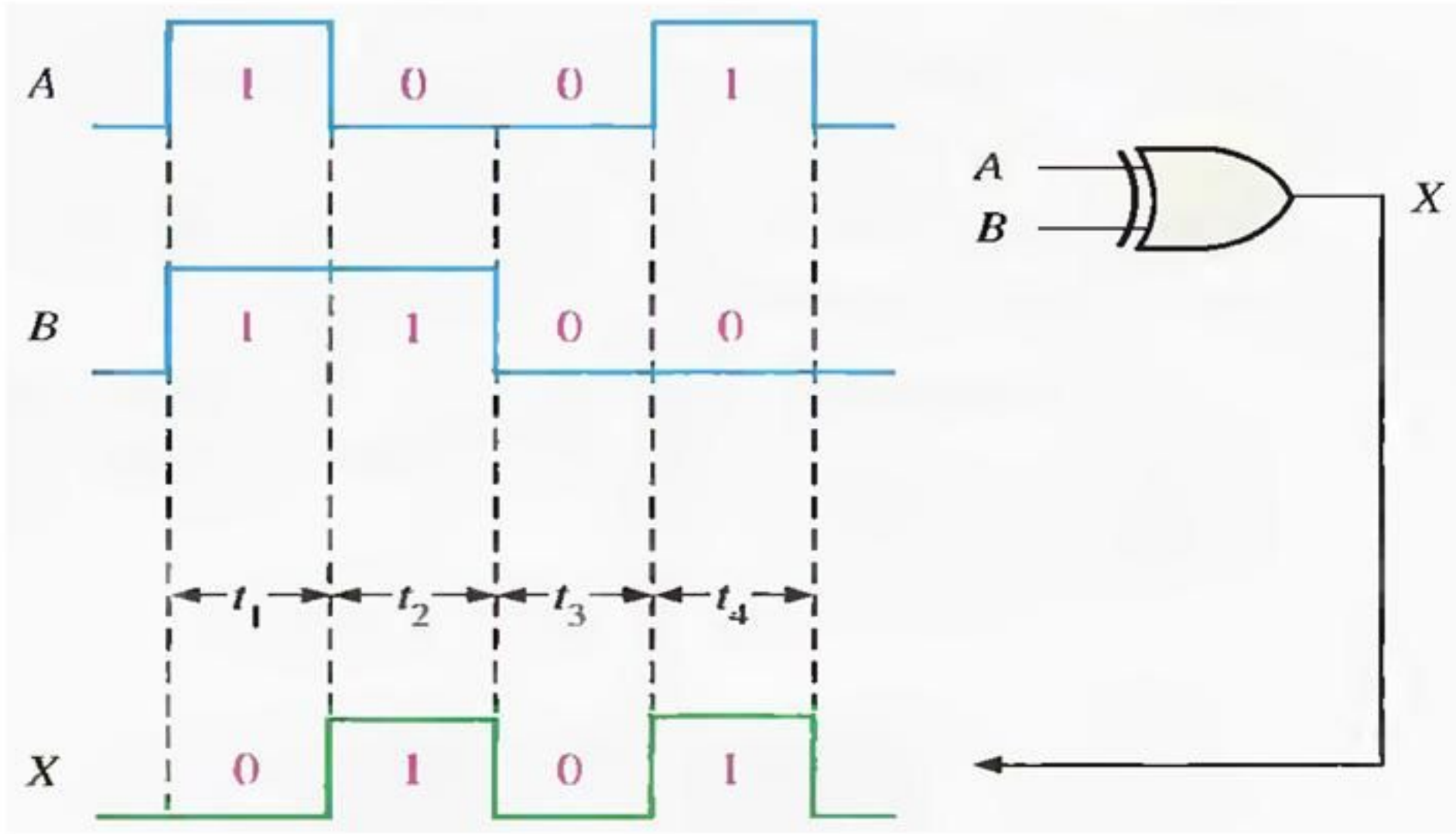


Truth Table of XOR Gate

INPUTS		OUTPUT
A	B	X
0	0	0
0	1	1
1	0	1
1	1	0

1 = HIGH, 0 = LOW.

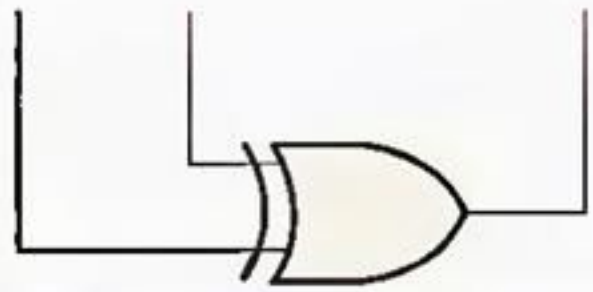
Operation with waveform inputs



Application of XOR Gate

An exclusive-OR gate can be used as a two-bit adder.

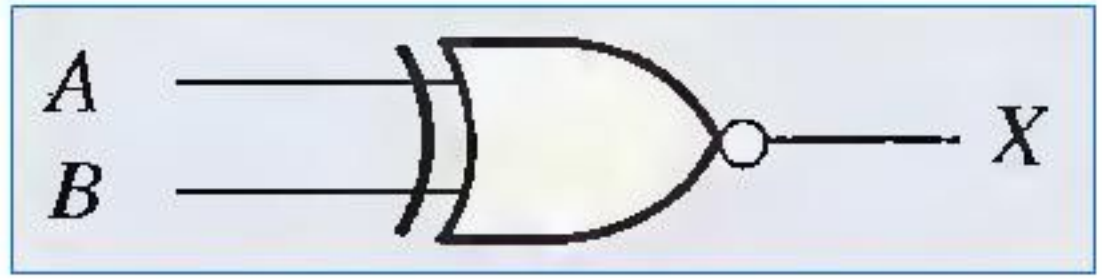
Input bits		Output (sum)	
A	*B*	Σ	
0	0	0	
0	1	1	
1	0	1	
1	1	0	(without 1 carry)



An XOR gate used to add two bits.

Exclusive NOR Gate

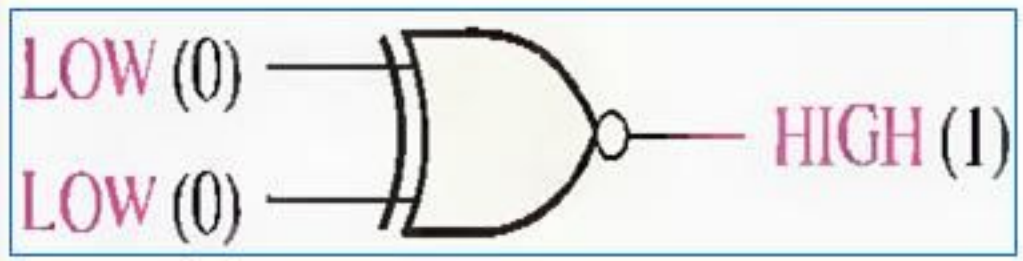
- Standard symbols for an exclusive-NOR (XNOR) gate are shown as,

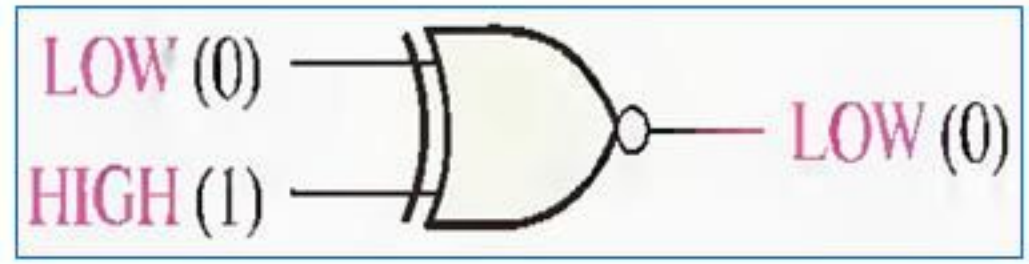


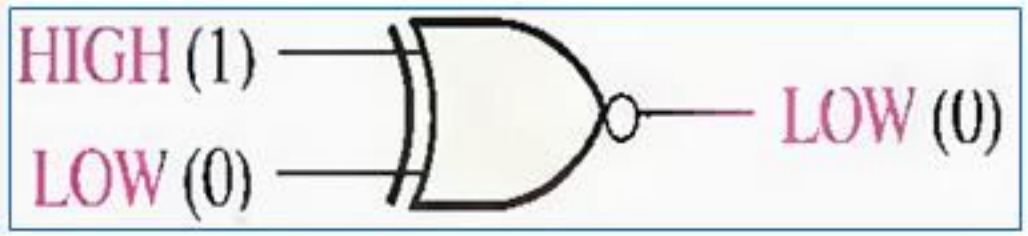
- The bubble on the output of the XNOR symbol indicates that its output is opposite that of the XOR gate.

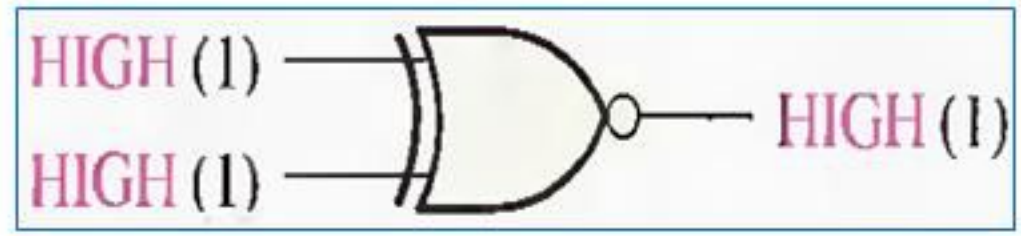
XNOR

- The four possible input combinations and the resulting outputs for an XNOR gate is shown as,







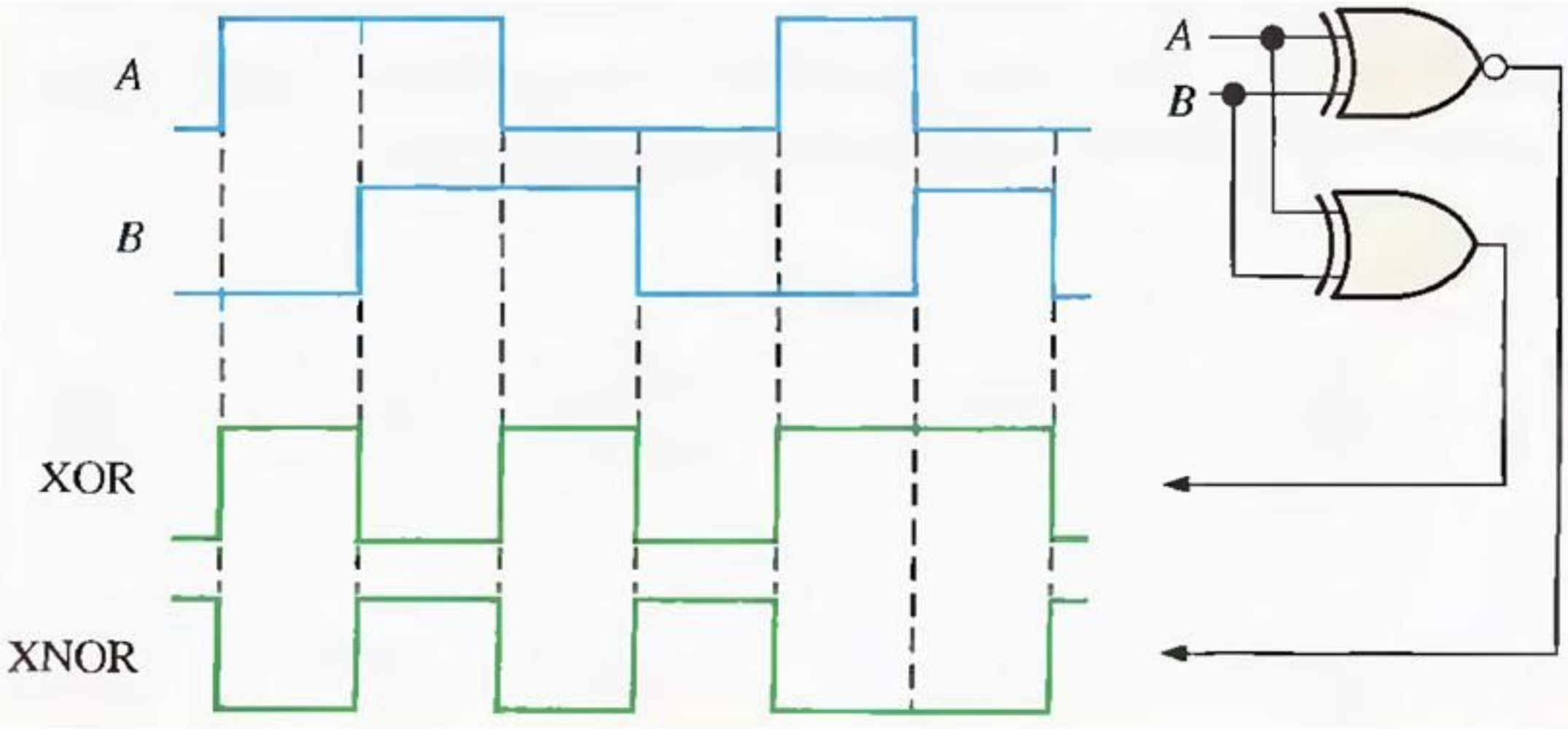


Truth Table of XNOR

INPUTS		OUTPUT
A	B	X
0	0	1
0	1	0
1	0	0
1	1	1

1 = HIGH, 0 = LOW.

Operation with waveform for XOR and XNOR




thanks
for the
tolerance