EEE130 Digital Electronics I
Lecture #3

- Logic Gates -

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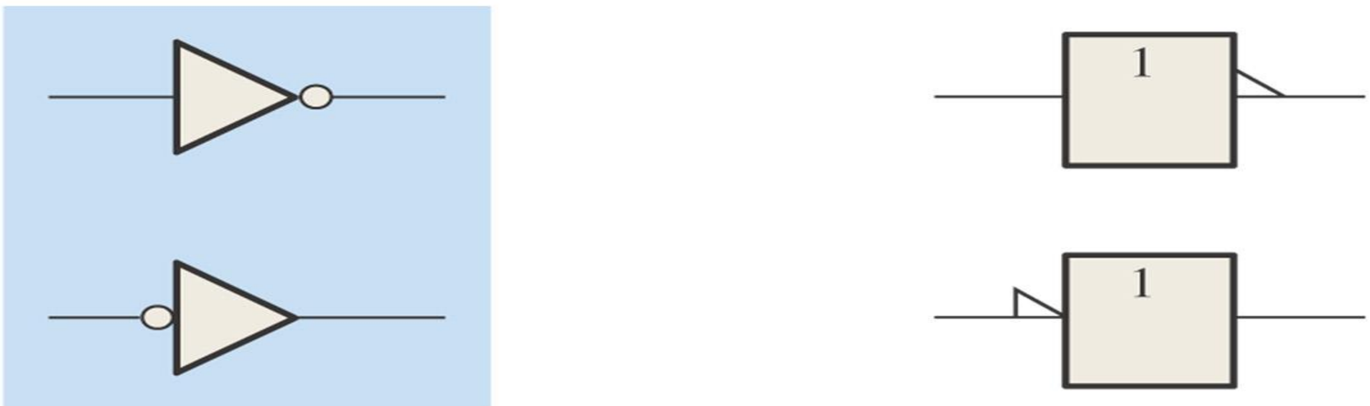
Topics to be discussed

- 3-1 The Inverter
- 3-2 The AND Gate
- 3-3 The OR Gate
- 3-4 The NAND Gate
- 3-5 The NOR Gate
- 3-6 The Exclusive-OR and Exclusive-NOR Gates
- 3-7 Programmable Logic
- 3-8 Fixed-Function Logic
- 3-9 Troubleshooting

3-1 The Inverter



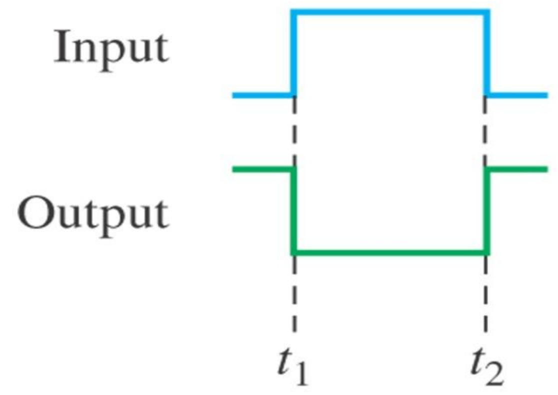
(a) Distinctive shape symbols with negation indicators

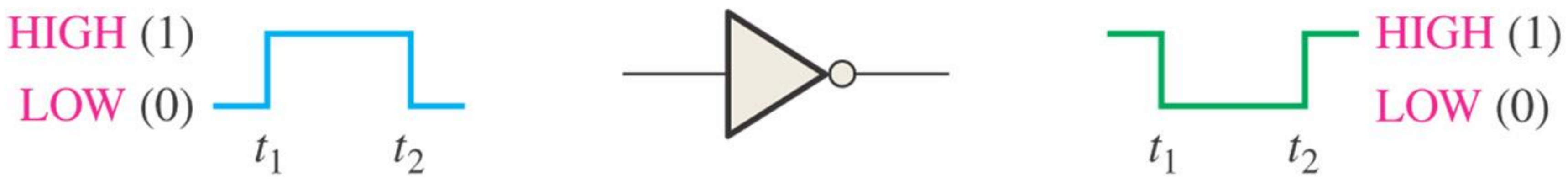
(b) Rectangular outline symbols with polarity indicators

- Be careful of the bubble (“ ° “) usage – to show active-LOW
- The triangle symbol in (b) indicates inversion

Inverter Truth Table

INPUT	OUTPUT
0	1
1	0

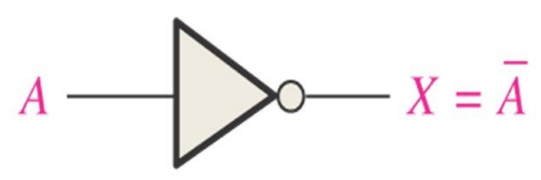




Input pulse

Output pulse

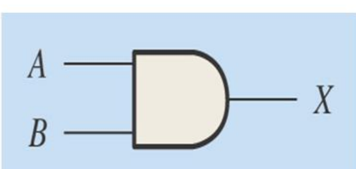
Logic expression: $X = \bar{A}$



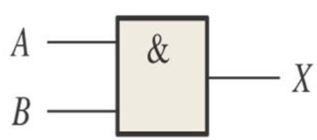
3-2 The AND Gate

- Significant about AND gate:
  - It produces a HIGH output only when ***all of the inputs are HIGH***
- The truth table:

Inputs		Outputs
0	0	0
0	1	0
1	0	0
1	1	1



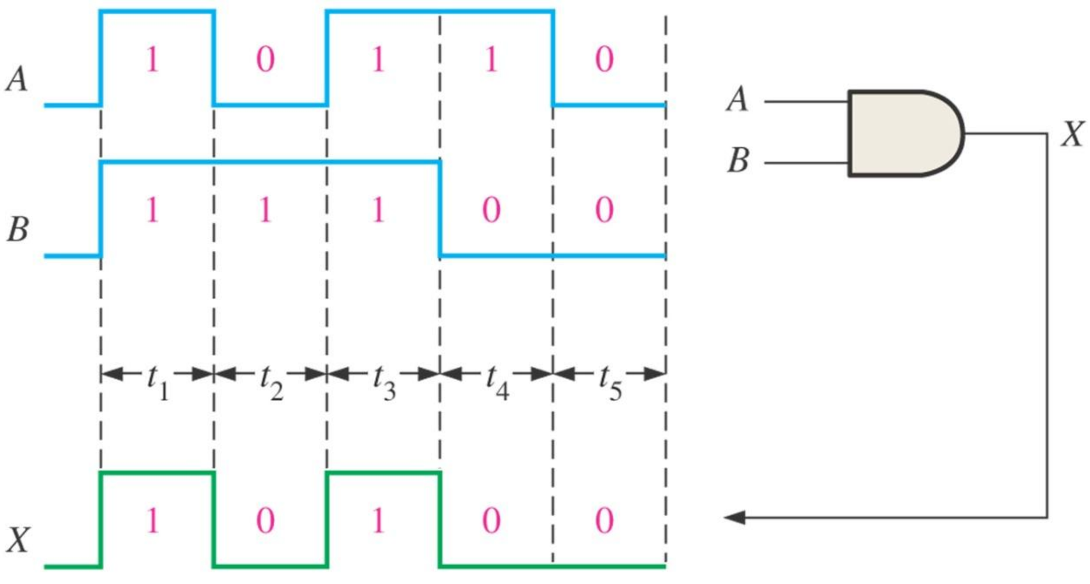
(a) Distinctive shape



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

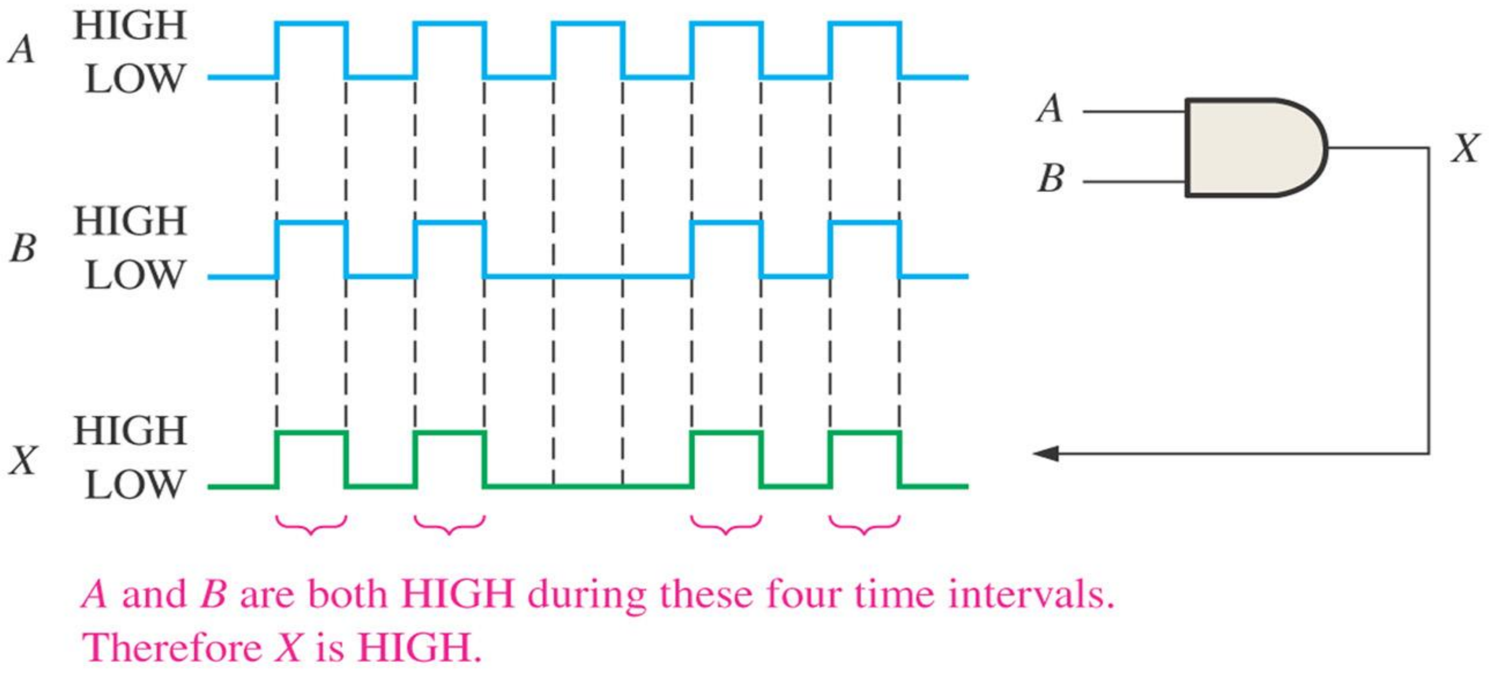
More about AND gate

- Combination can be made from AND gate
  - Depending on the input variables $N = 2^n$ where n is the total of inputs
- Operation with waveform inputs



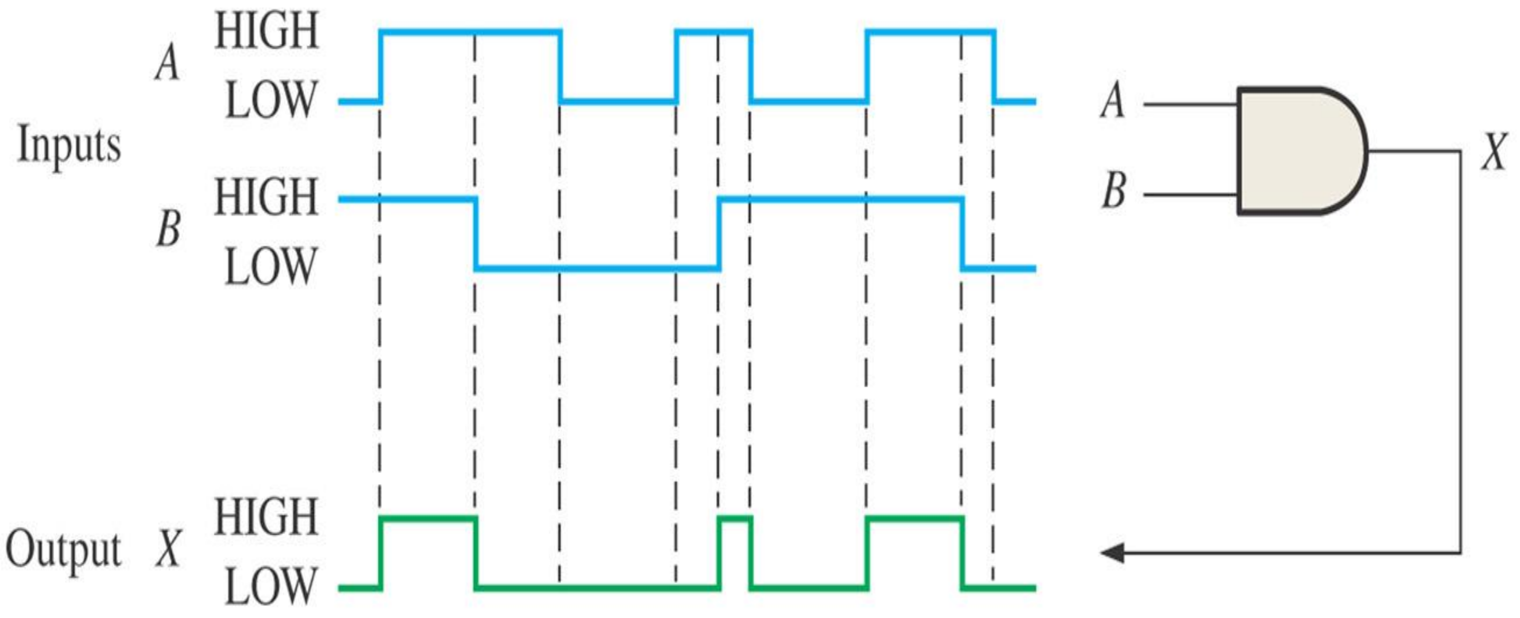
Example 3-3

- If two waveforms, A and B, are applied to the AND gate inputs, what is the resulting output waveform?



Example 3-4

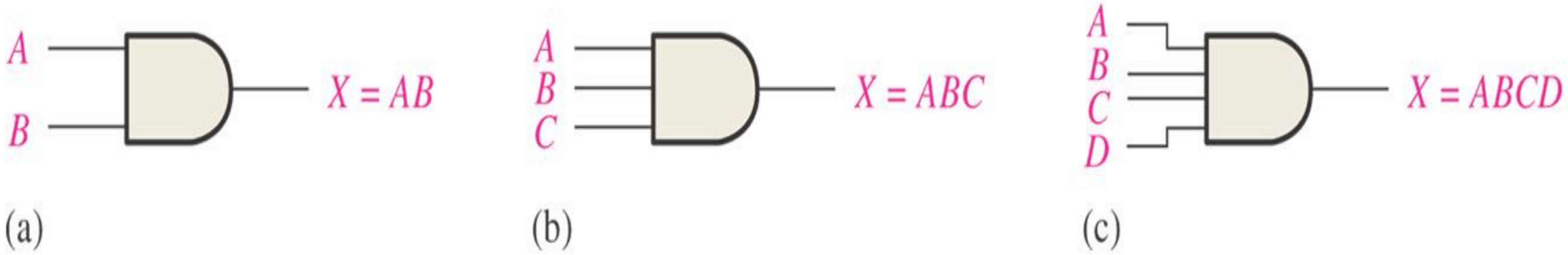
- For the two input waveforms, A and B, show the output waveform with its proper relation to the inputs.

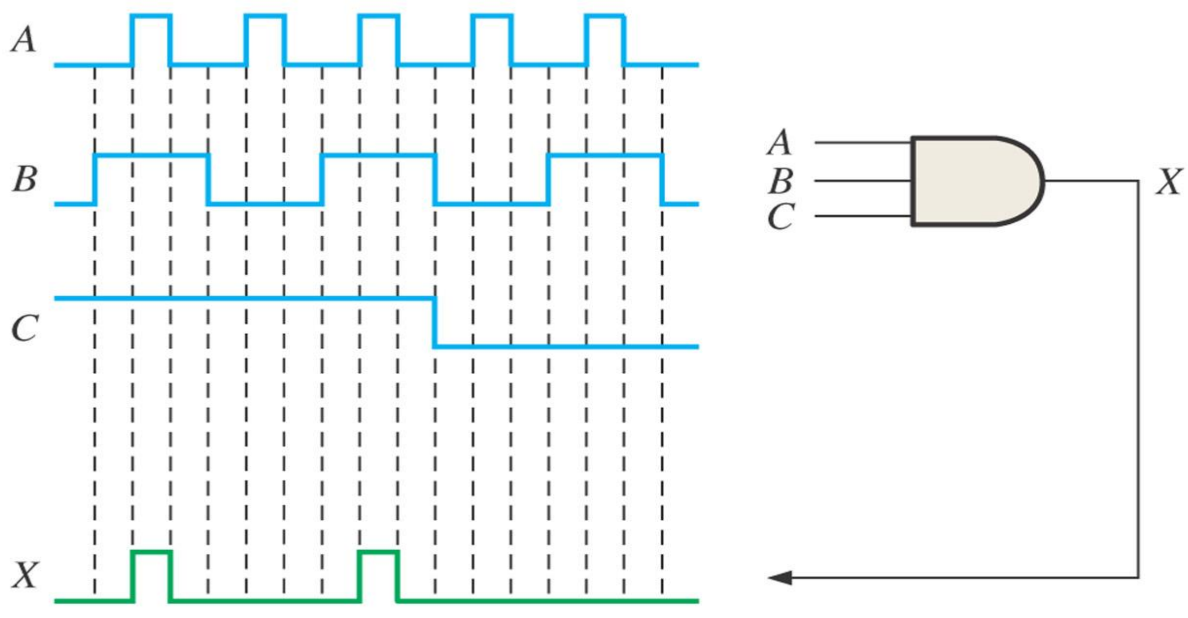


Logic expression for AND gate

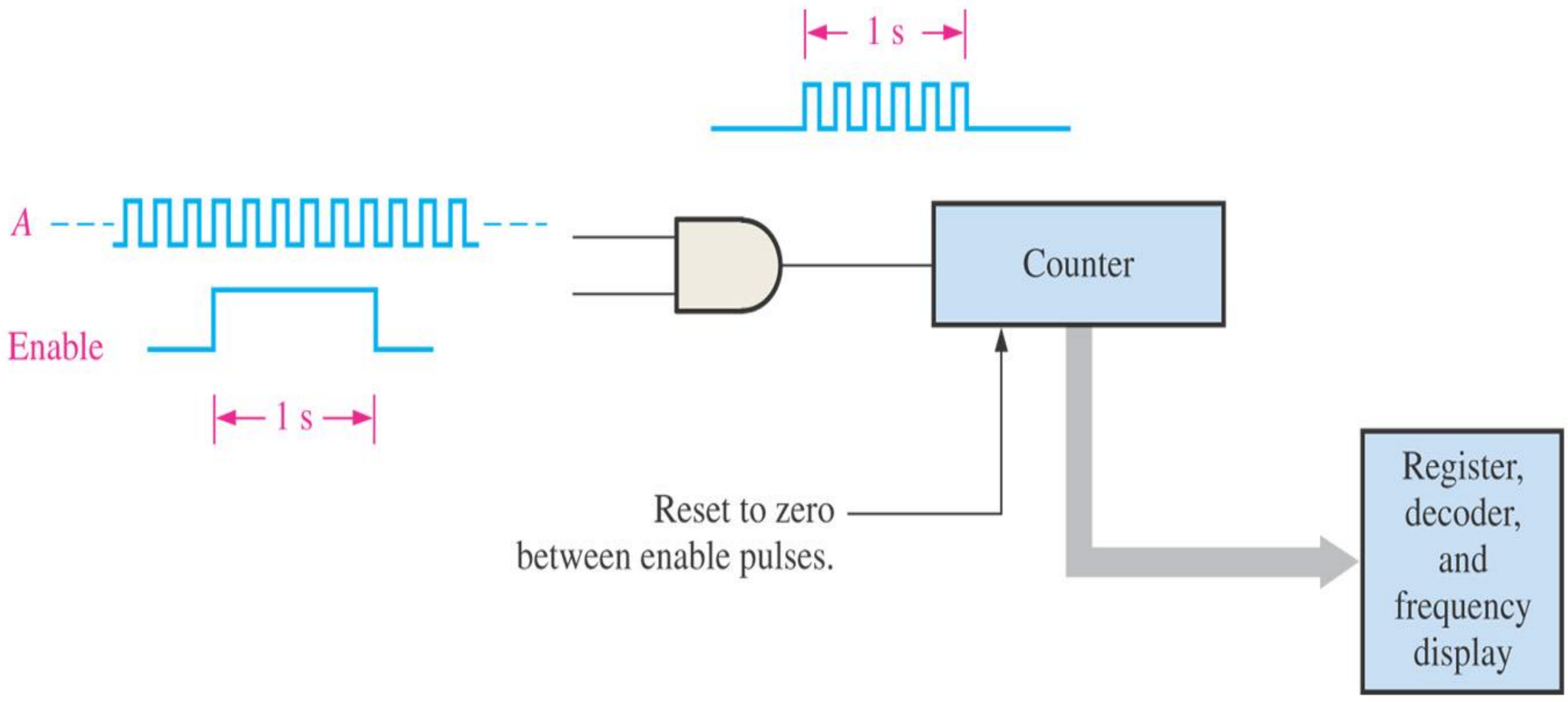
- The logical AND function of two variables is represented mathematically either by placing a dot between the two variable, or by writing the adjacent letter without the dot
  - $A \cdot B$ or AB
- Boolean multiplication = AND function

Advance for AND gate

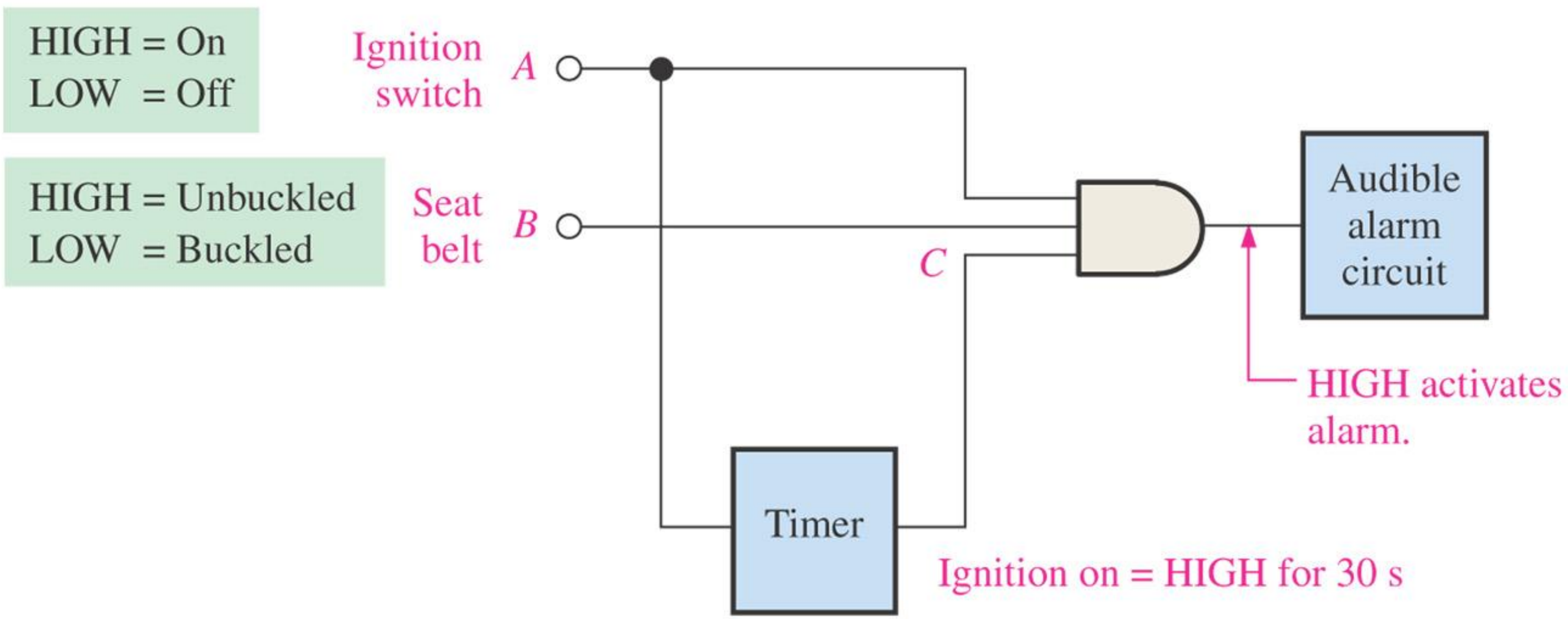




Applications – the AND gate as an enable/inhibit device



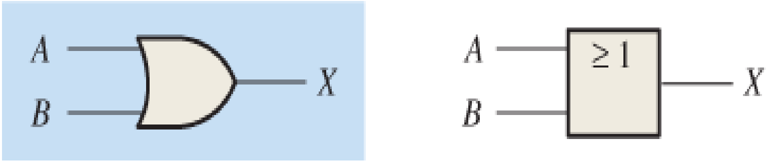
Applications – A seat belt alarm system



3-3 The OR Gate

- Significant about OR gate:
  - It produces a HIGH on the output when ***any of the inputs is HIGH***
- The truth table:

Inputs		Outputs
0	0	0
0	1	1
1	0	1
1	1	1

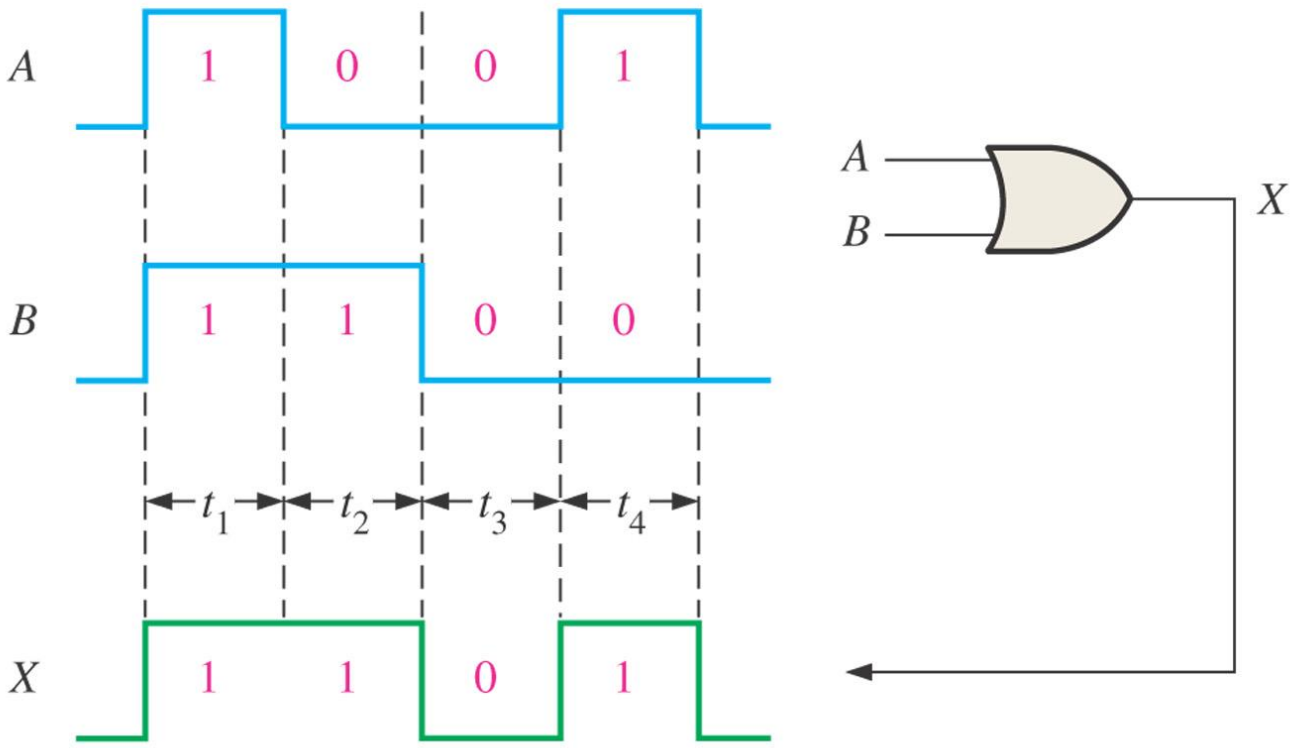


(a) Distinctive shape

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

More about OR gate(1)

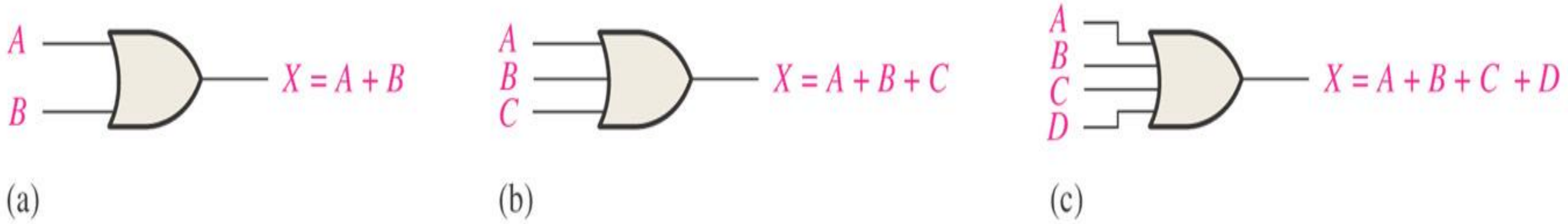
- Operation with waveform inputs



More about OR gate(2)

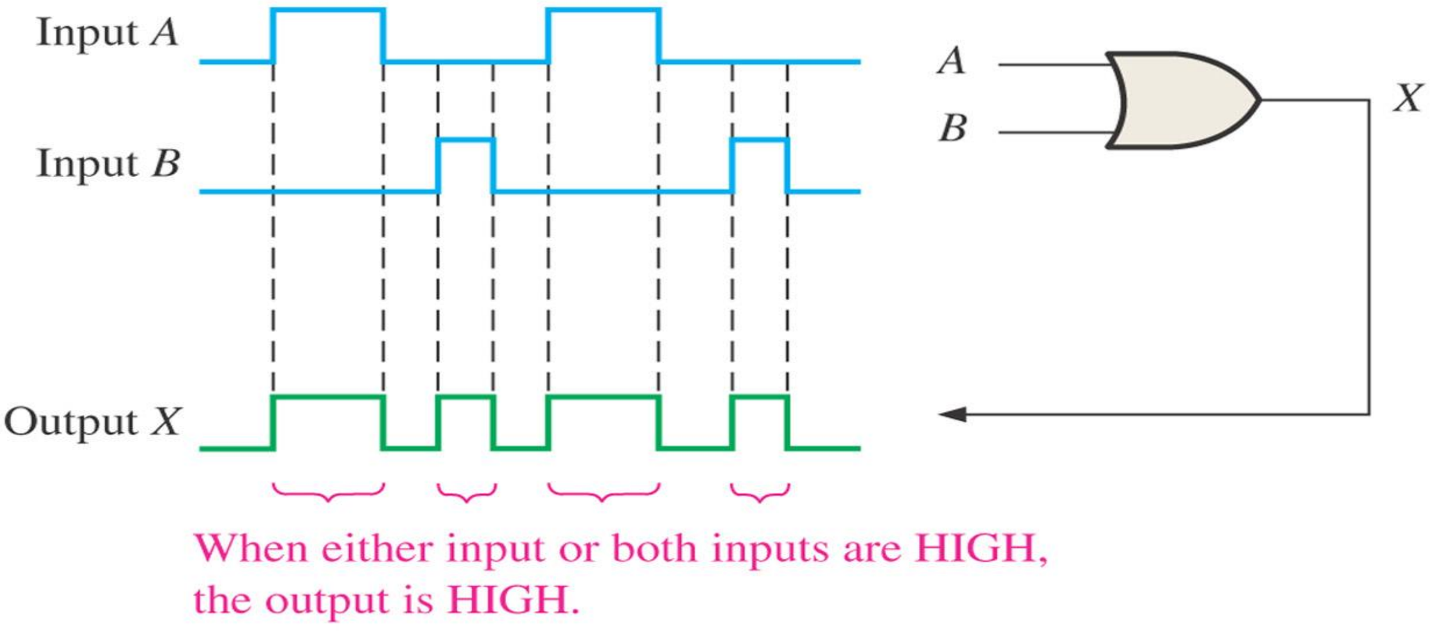
- Logic expression for an OR gate

$$X = A + B$$



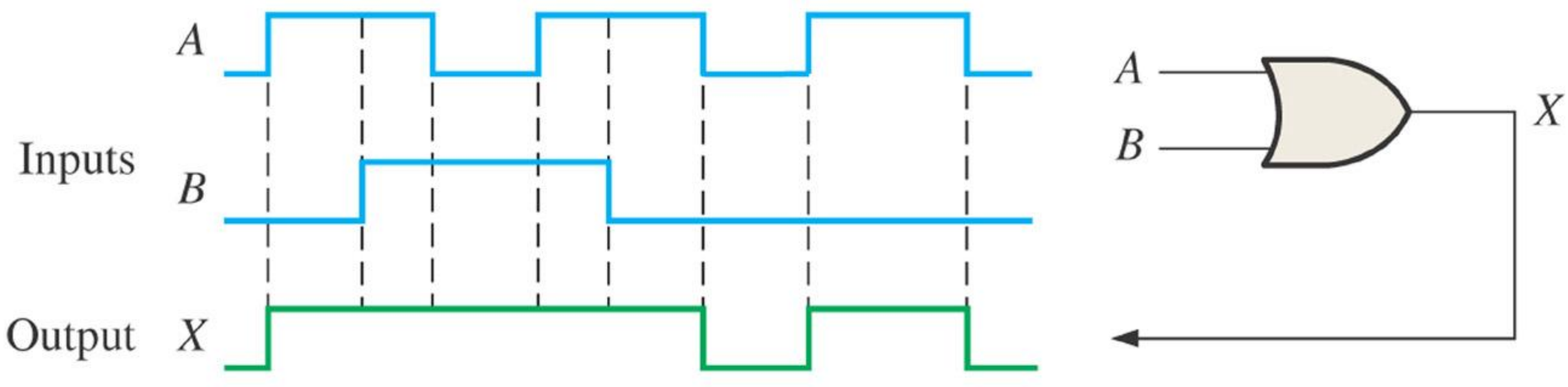
Example 3-6

- If the two input waveforms, A and B, are applied to the OR gate, what is the resulting output waveform?



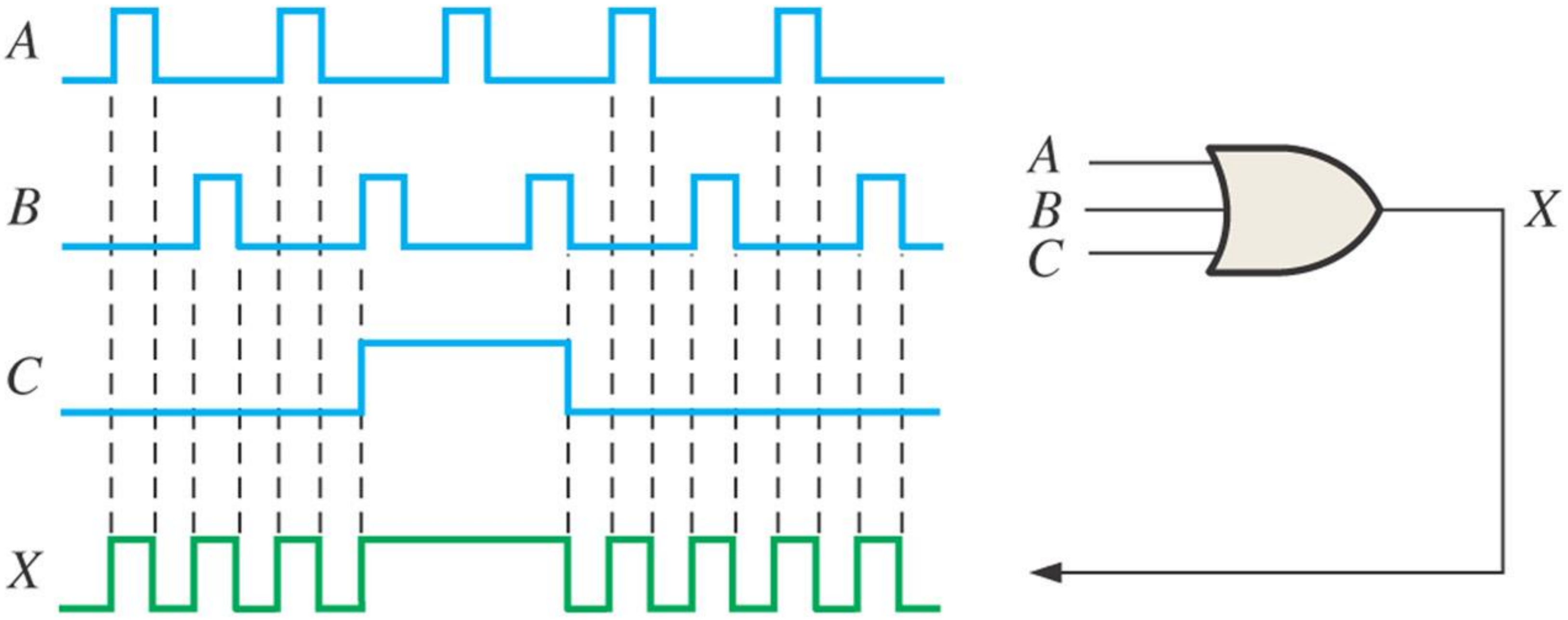
Example 3-7

- For the two input waveforms, A and B, show the output waveform with its proper relation to the inputs



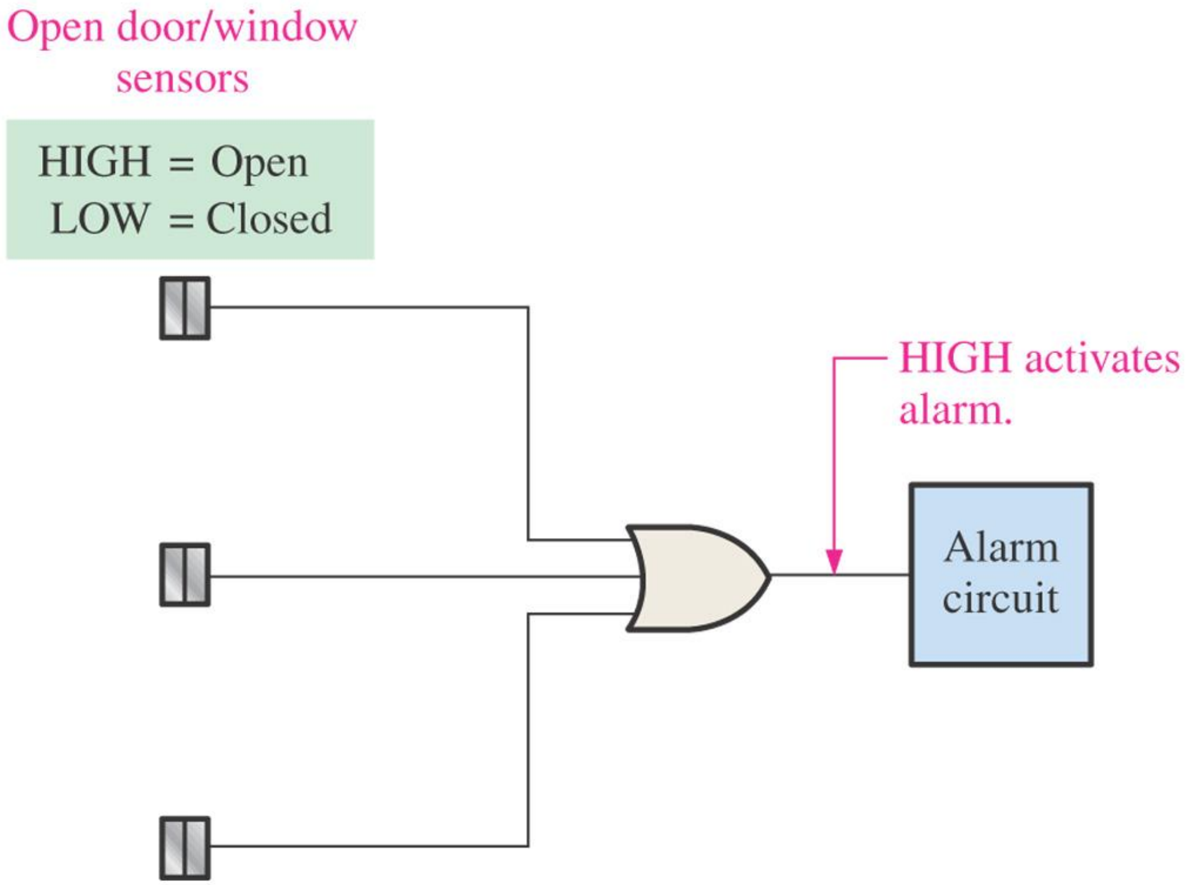
Example 3-8

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



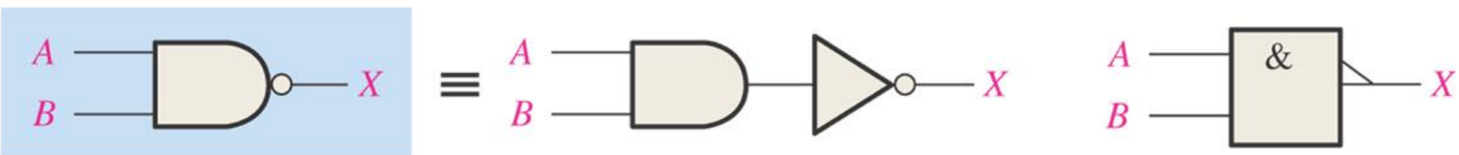
An application

- Intrusion detection and alarm system



3-4 The NAND Gate

- It produces a LOW output only when all the inputs are HIGH

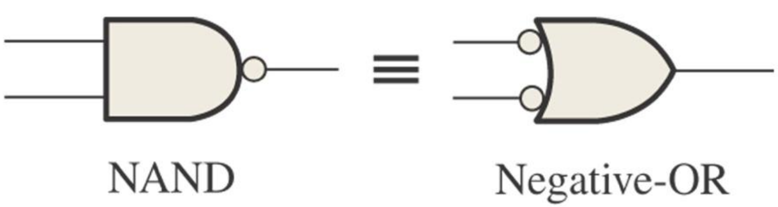


(a) Distinctive shape, 2-input NAND gate and its NOT/AND equivalent

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

Logic expression:

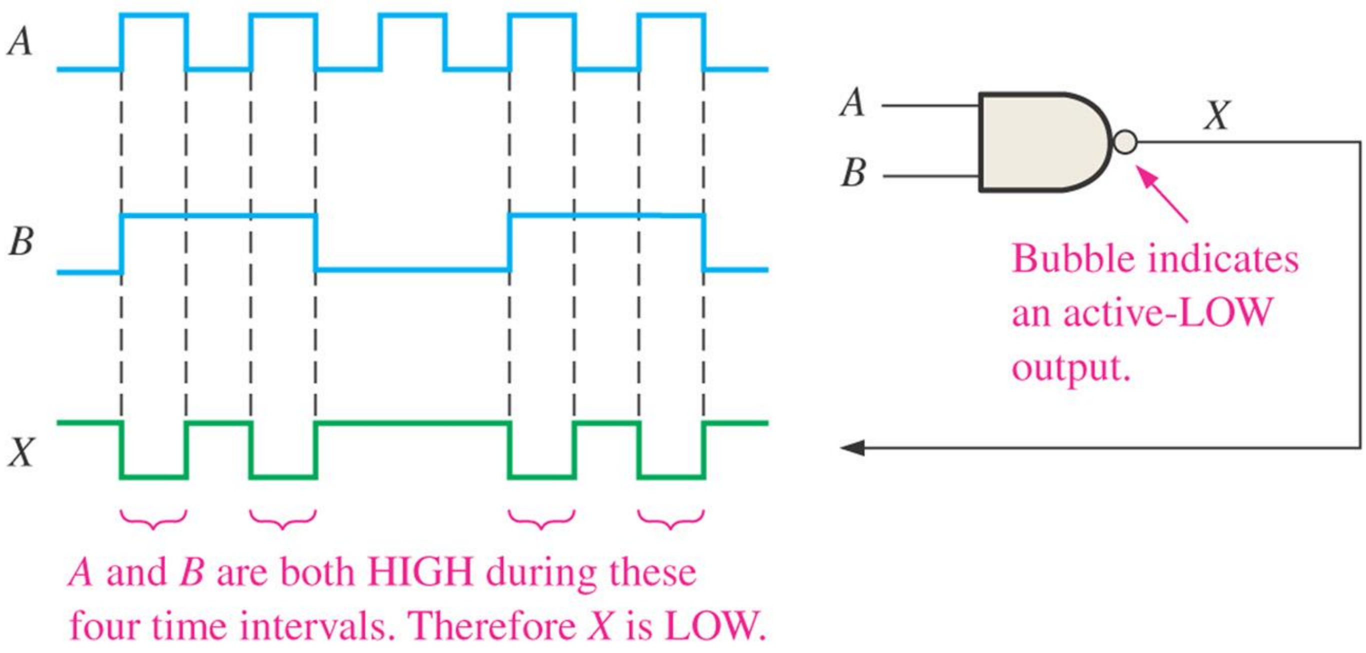
$$X = \overline{AB}$$



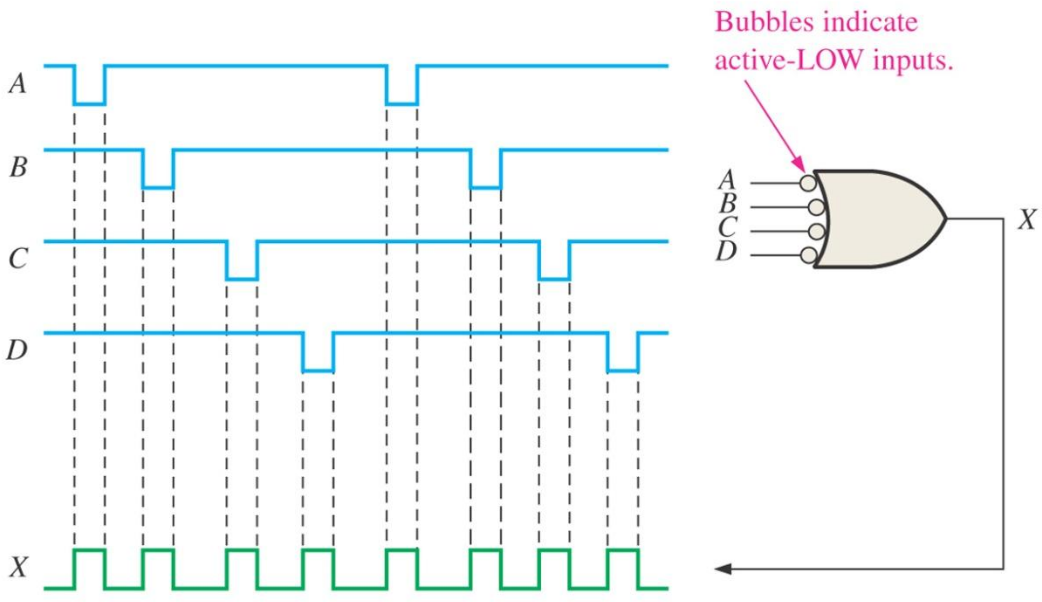
Inputs		Outputs
0	0	1
0	1	1
1	0	1
1	1	0

Example 3-9

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



Example 3-13 – 4-input NAND operating as negative-OR



NAND

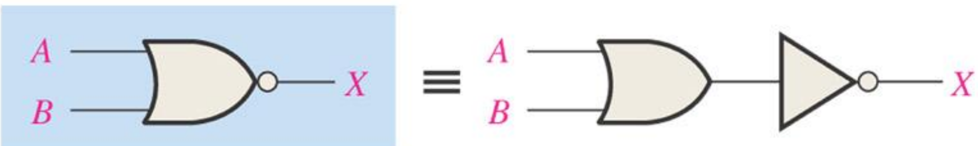
Input				Output
A	B	C	D	X
1	1	1	1	0
0	1	1	1	1
1	1	1	1	0
1	0	1	1	1

Neg-OR

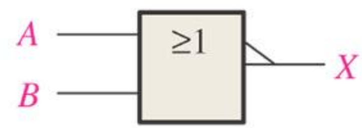
Input				Output
A	B	C	D	X
1	1	1	1	0
0	1	1	1	1
1	1	1	1	0
1	0	1	1	1

3-5 The NOR Gate

- It produces a LOW output when any of its inputs is HIGH



(a) Distinctive shape, 2-input NOR gate and its NOT/OR equivalent



(b) Rectangular outline, 2-input NOR gate with polarity indicator

Logic expression:

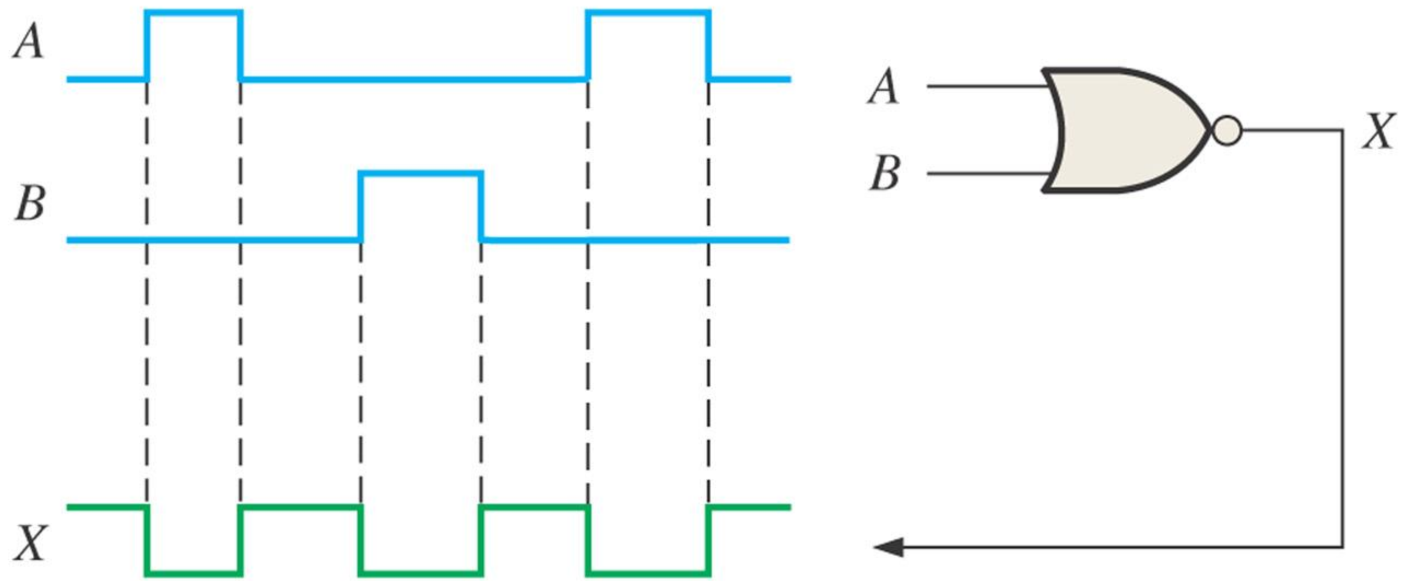
$$X = \overline{A + B}$$

NOR　　Negative-AND

Inputs		Outputs
0	0	1
0	1	0
1	0	0
1	1	0

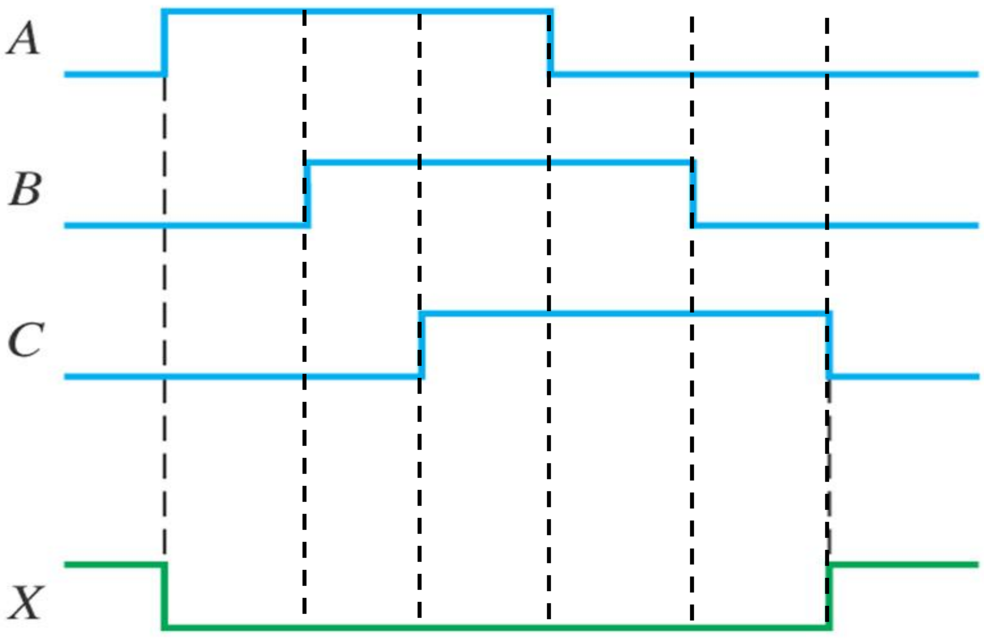
Example 3-14

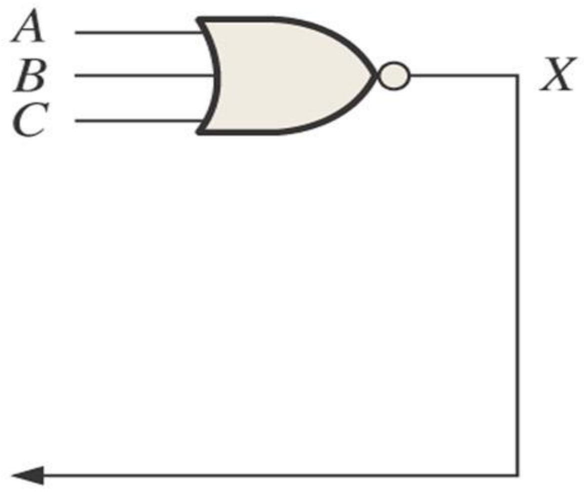
- If the two waveforms, A and B, are applied to a NOR gate, what is the resulting output waveform?



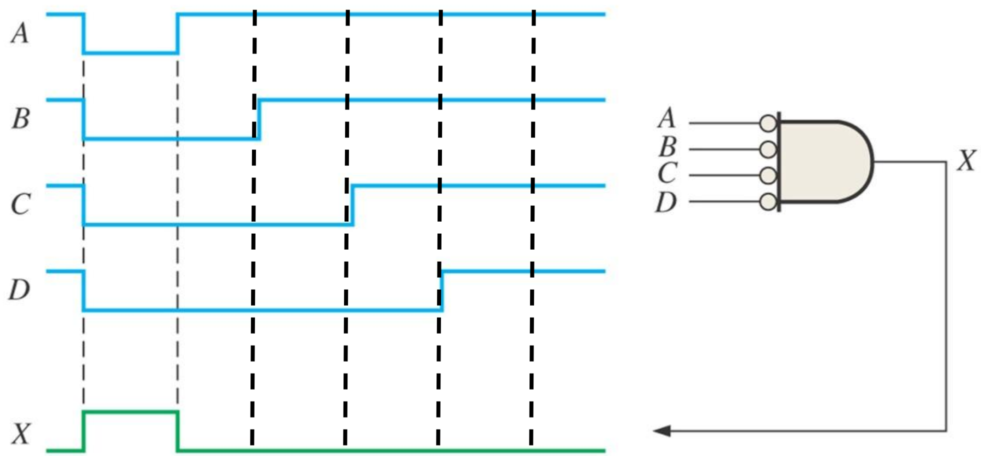
Example 3-15

- Show the output waveform for the 3-input NOR gate with the proper time relation to the inputs.





Example 3-18 – 4-input NOR gate operating on negative-AND gate



NOR

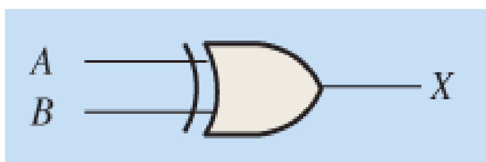
Input				Output
A	B	C	D	X
1	1	1	1	0
0	0	0	0	1
1	0	0	0	0
1	1	0	0	0

Neg-AND

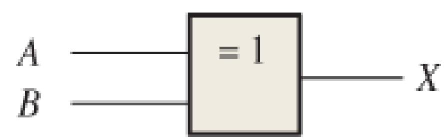
Input				Output
A	B	C	D	X
1	1	1	1	0
0	0	0	0	1
1	0	0	0	0
1	1	0	0	0

3-6(1) The Exclusive-OR

- The output is HIGH only when the two inputs are at opposite logic levels (has only two inputs)
- Exclusive OR is written as **XOR** and the symbols are given below



(a) Distinctive shape

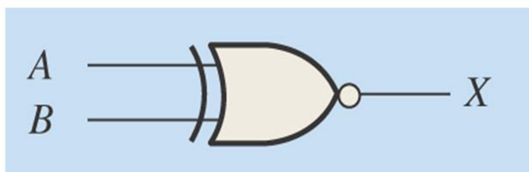


(b) Rectangular outline with the XOR

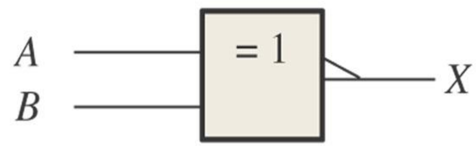
Inputs		Outputs
0	0	0
0	1	1
1	0	1
1	1	0

3-6(2) The Exclusive-NOR Gates

- The output is LOW only when the two inputs are at opposite logic levels (has only two inputs)
- The exclusive-NOR gate is written as **XNOR** and the symbol is written below



(a) Distinctive shape

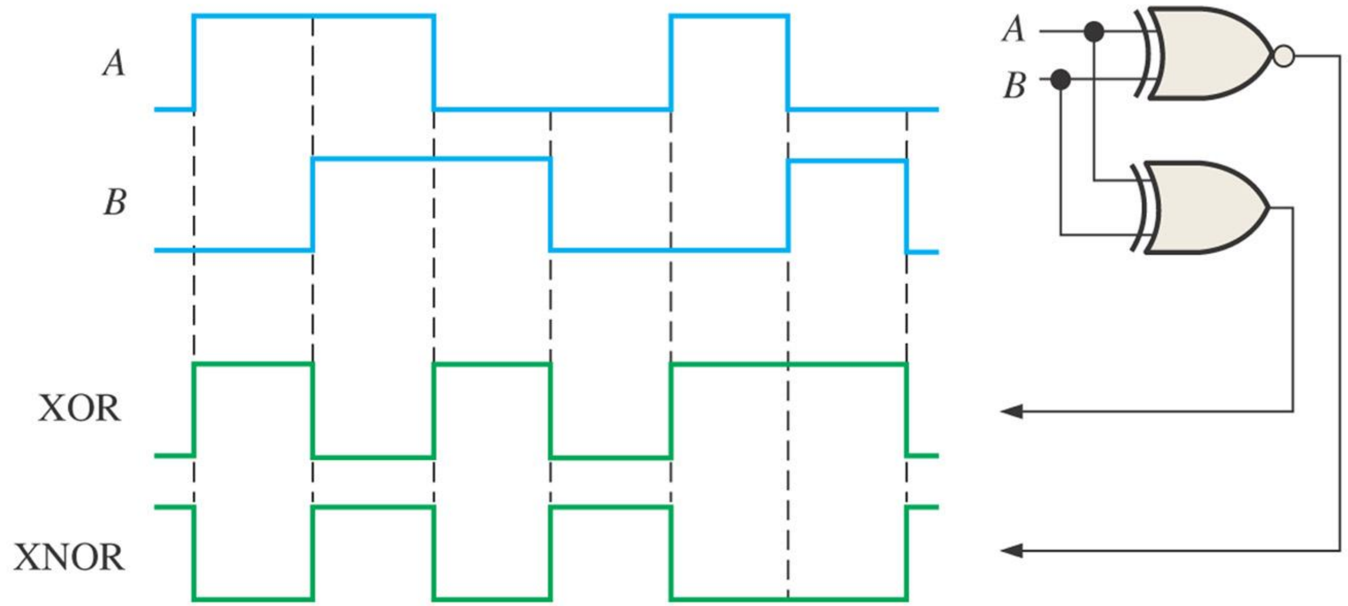


(b) Rectangular outline

Inputs		Outputs
0	0	1
0	1	0
1	0	0
1	1	1

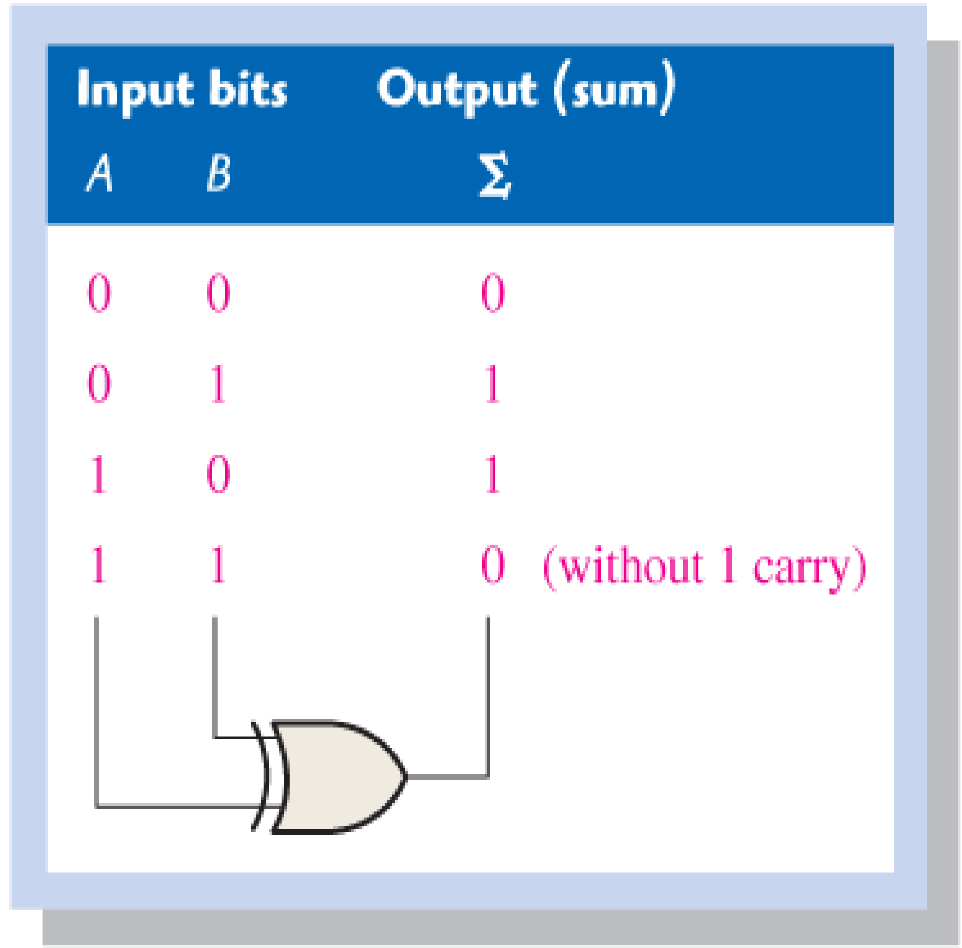
Example 3-20

- Determine the output waveforms for the XOR gate and for the XNOR gate, given the following inputs.

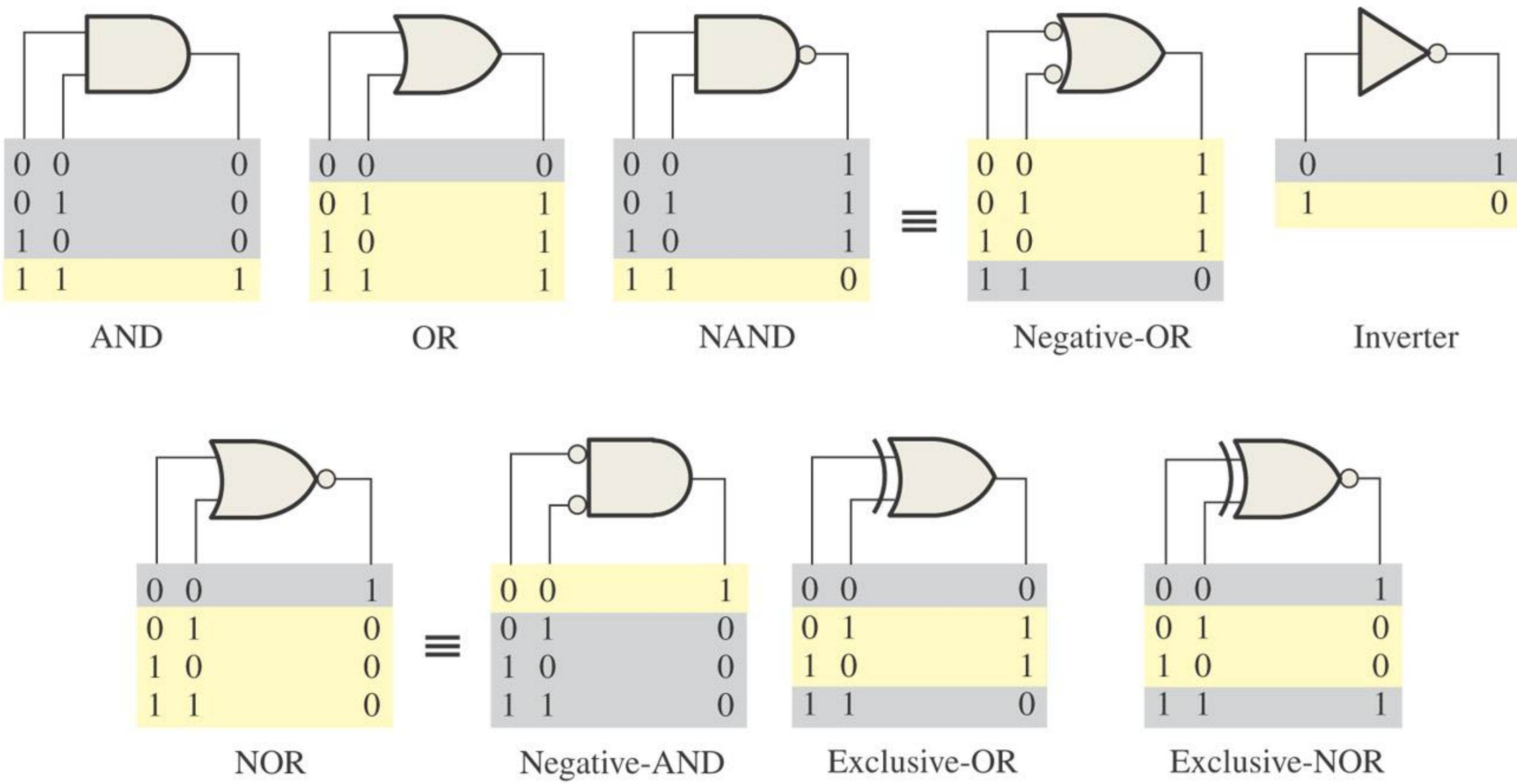


Application of XOR – as a two-bit adder

- From Chapter 2, we know that the basic rules for binary addition are: 0+0=0, 0+1=1, 0+1=1 and 1+1=10. In the last rule, if we need to discard the second bit (1), we can use XOR
- Why??
  - Please refer to the truth table on the right



Summary of Logic Gates



Note: Active states are shown in yellow.