BINARY LOGIC AND LOGIC GATES

Digital logic design

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Binary Logic

- Definition of Binary Logic
  - *Binary logic consists of binary variables and a set of logical operations.*
  - *The variables are designated by letters of the alphabet, such as A, B, C, x, y, z, etc, with each variable having two and only two distinct possible values: 1 and 0,*
  - *Three basic logical operations: AND, OR, and NOT.*

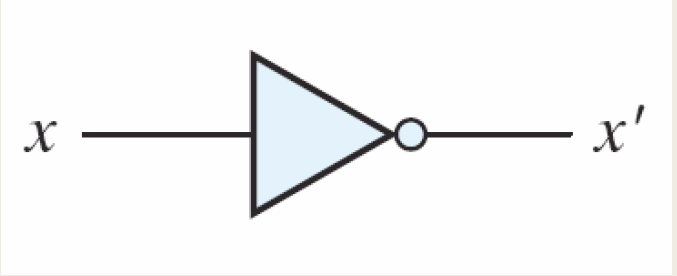
1. AND: This operation is represented by a dot or by the absence of an operator. For example, $x \cdot y = z$ or $xy = z$ is read "x AND y is equal to z," The logical operation AND is interpreted to mean that $z = 1$ if only $x = 1$ and $y = 1$; otherwise $z = 0$. (Remember that x, y, and z are binary variables and can be equal either to 1 or 0, and nothing else.)
2. OR: This operation is represented by a plus sign. For example, $x + y = z$ is read "x OR y is equal to z," meaning that $z = 1$ if $x = 1$ or $y = 1$ or if both $x = 1$ and $y = 1$. If both $x = 0$ and $y = 0$, then $z = 0$.
3. NOT: This operation is represented by a prime (sometimes by an overbar). For example, x' = z (or $\bar{x} = z$) is read "not x is equal to z," meaning that z is what z is not. In other words, if $x = 1$, then $z = 0$, but if $x = 0$, then $z = 1$, The NOT operation is also referred to as the complement operation, since it changes a 1 to 0 and a 0 to 1.

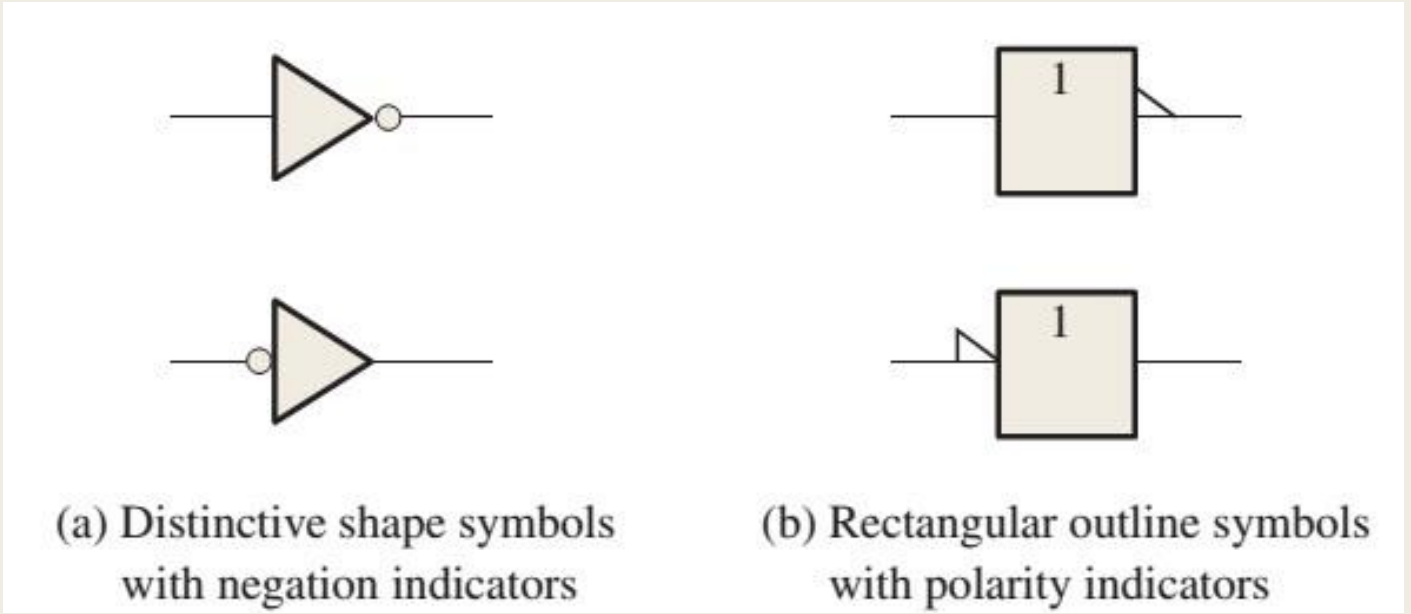
Not Function (NOT Gate)

- Complement operation
  - Single input
  - Inverts value of input
  - Symbolized by prime x’
- Truth table
  - Input combinations on the left
  - Output of function on the right
- Graphic symbol
  - NOT gate
  - Little circle indicates inversion

input output

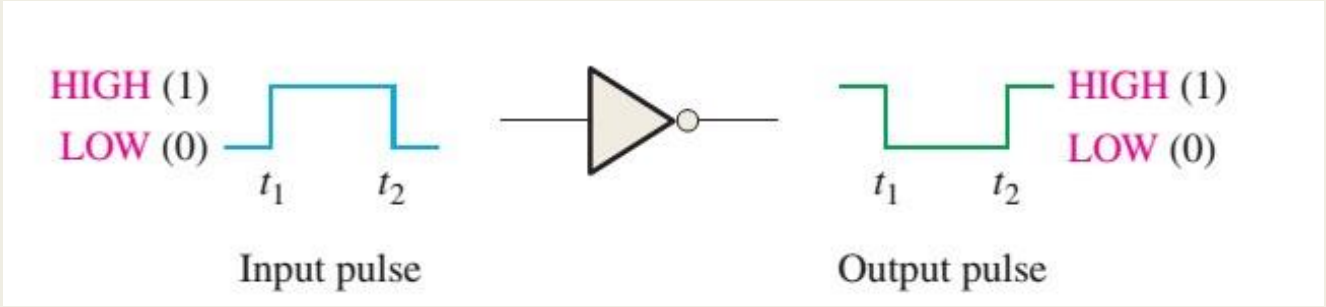
x	Not x
0	1
1	0





(a) Distinctive shape symbols with negation indicators

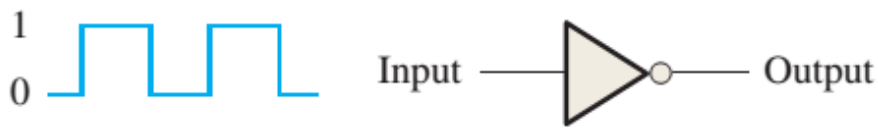
(b) Rectangular outline symbols with polarity indicators

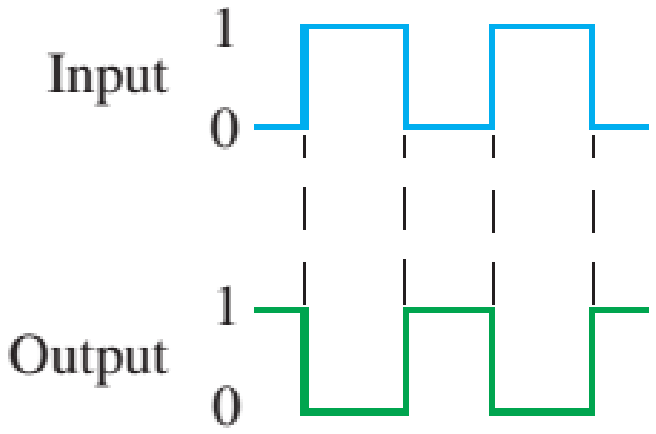


Input pulse

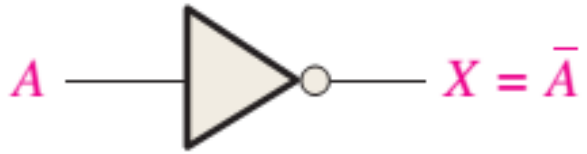
Output pulse

Timing Diagram





Logical Expression

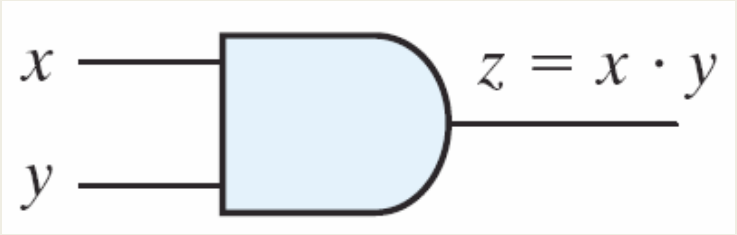


AND Gate

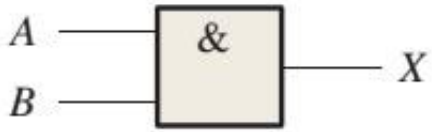
- Operation to check if two conditions are satisfied
  - Two inputs
  - Output = 1 if and only if both inputs are 1
  - Symbolized by dot or absence of operator

    $x \cdot y$ or xy
- Truth table
  - Needs to consider $2^2 = 4$ input combinations
- Graphic symbol
  - AND gate

inputs		output
x	y	z
0	0	0
0	1	0
1	0	0
1	1	1

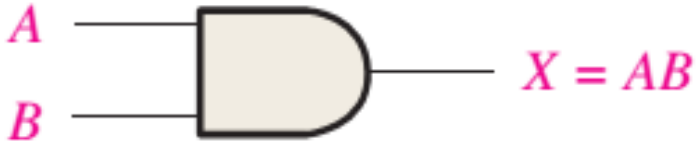


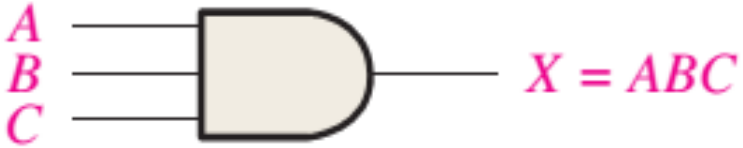
(a) Distinctive shape



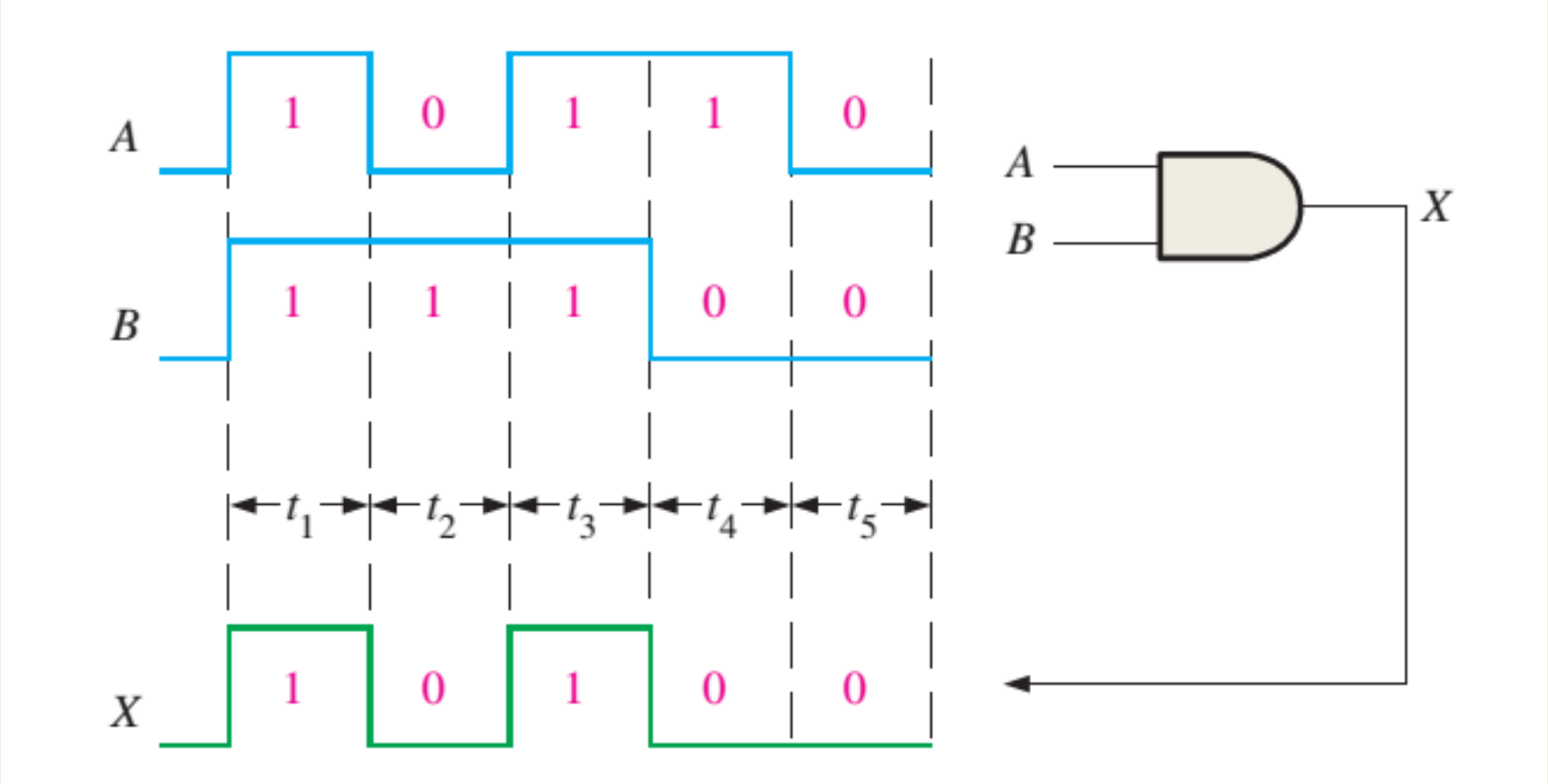
(b) Rectangular outline with the AND (&) qualifying symbol

Logical Expression





Timing Diagram of an AND gate



Application of an AND gate

Seat belt alarm system

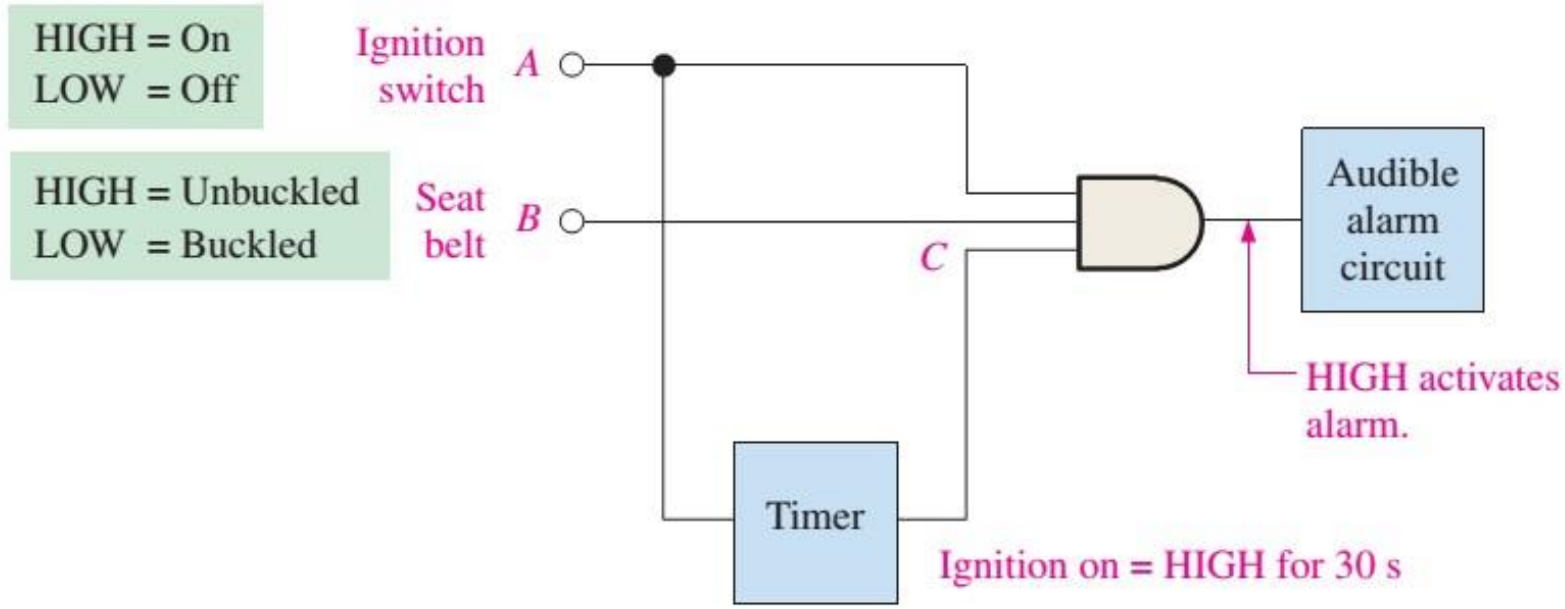
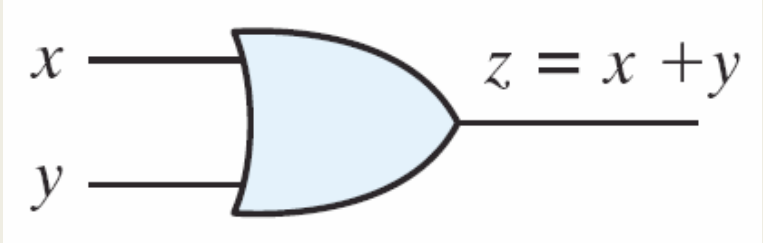


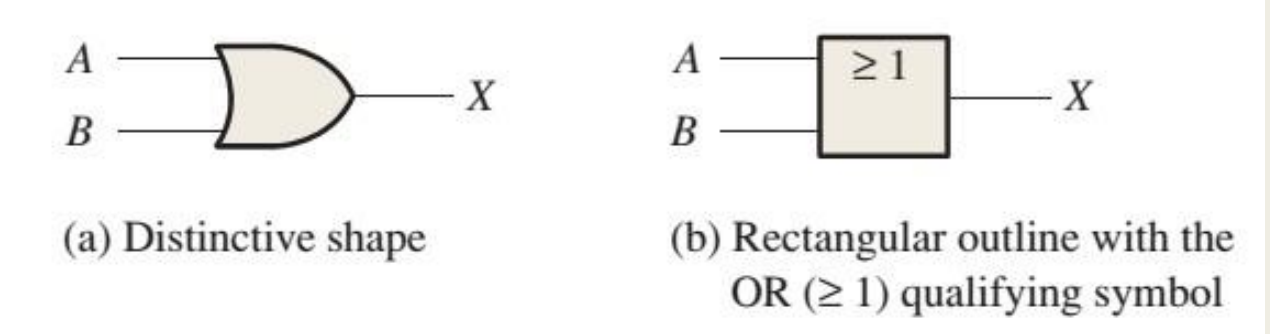
FIGURE 3–17 A simple seat belt alarm circuit using an AND gate.

OR Gate

- Operation to check if at least one condition is
  - met
    - *Two inputs*
    - *Output = 1 if any one or both inputs are 1*
    - *Symbolized by “plus” sign: x + y*
- Truth table
    - *Graphic symbol*
    - *OR gate*

x	y	z
0	0	0
0	1	1
1	0	1
1	1	1

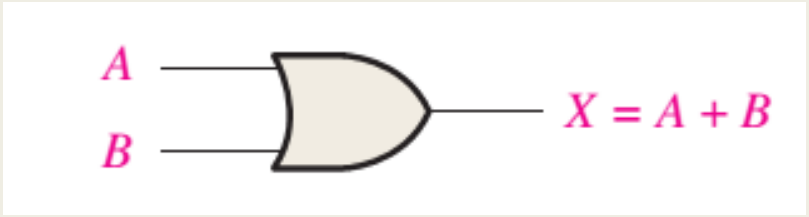


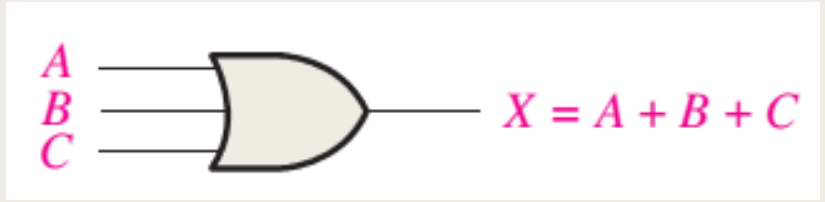


(a) Distinctive shape

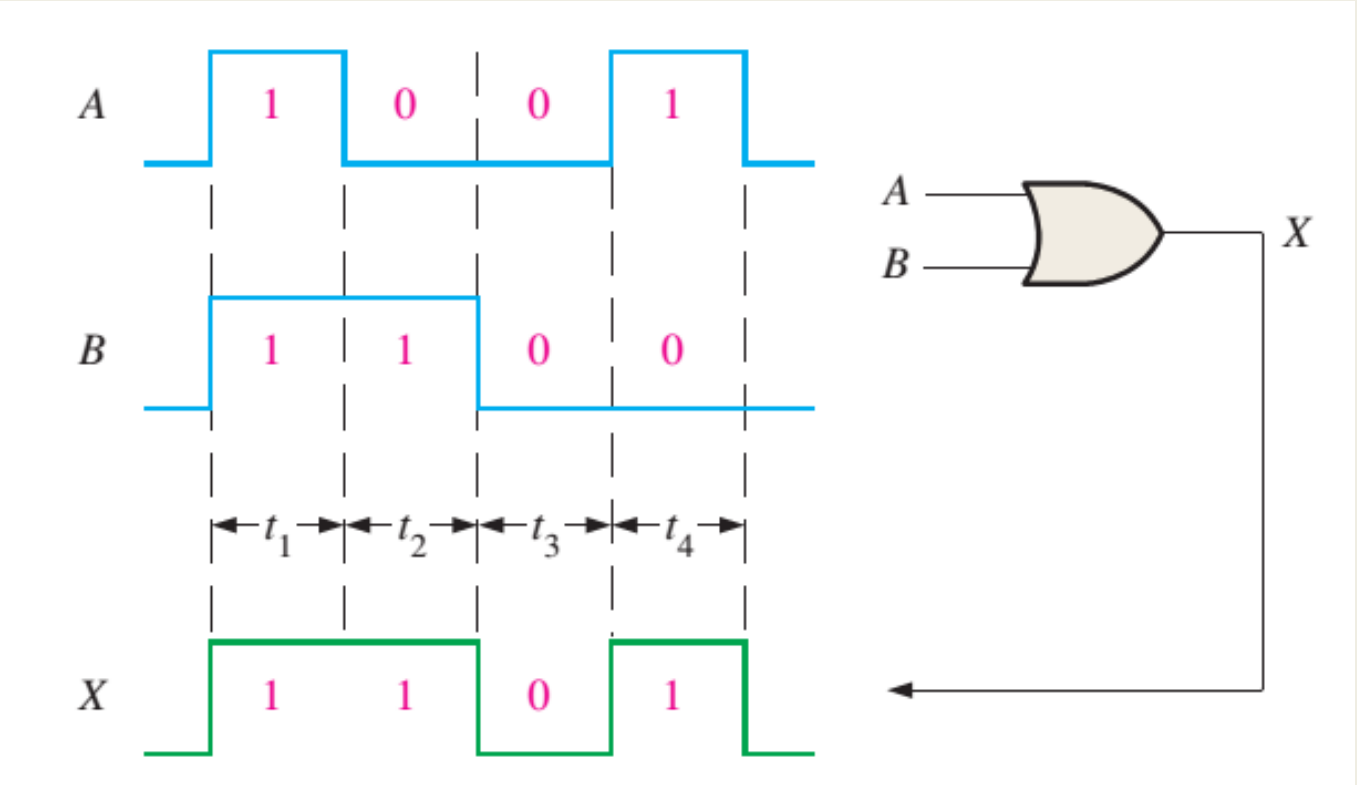
(b) Rectangular outline with the OR (≥ 1) qualifying symbol

Logical Expression





Timing Diagram of an OR gate



Application of an OR gate

Security system

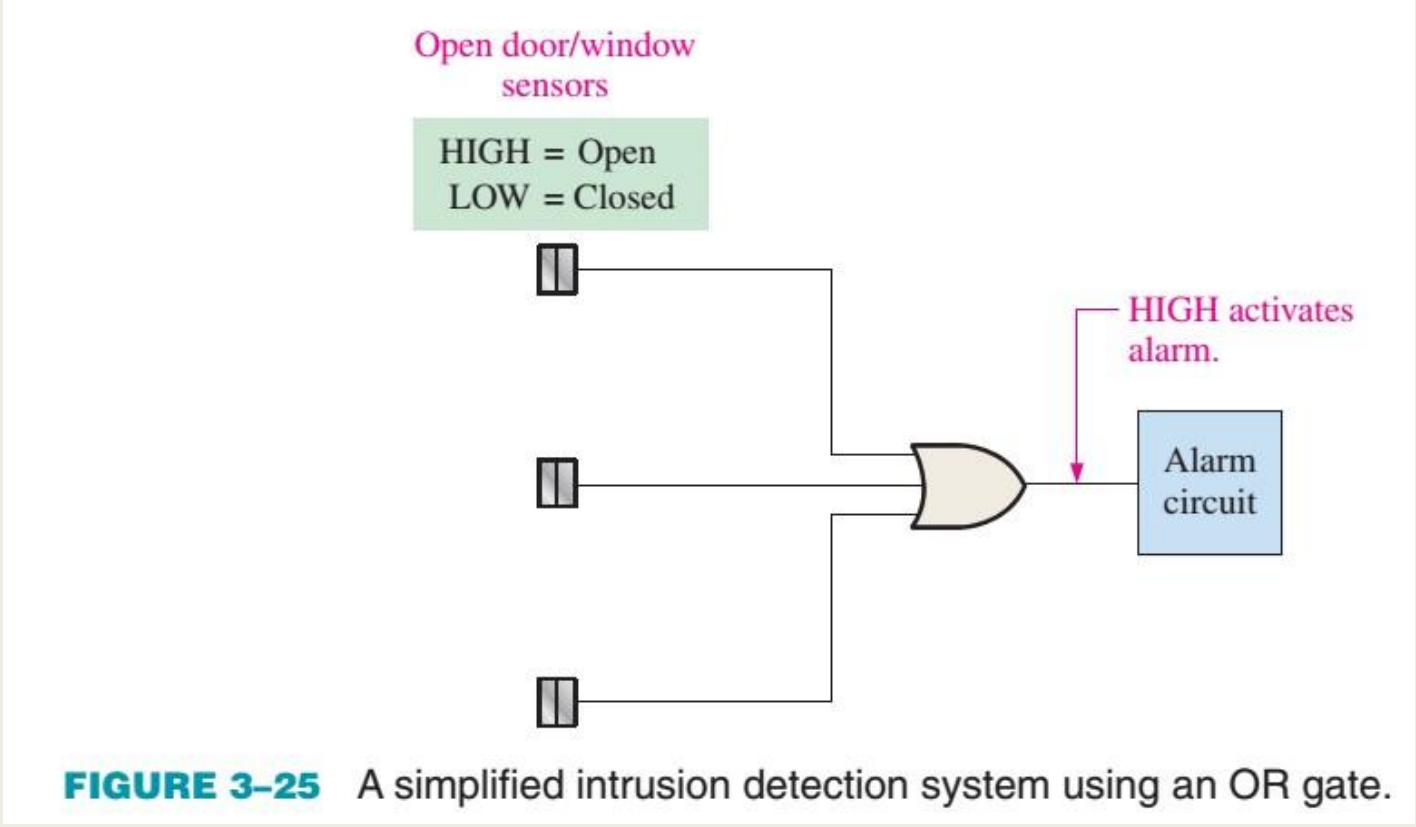


FIGURE 3–25 A simplified intrusion detection system using an OR gate.

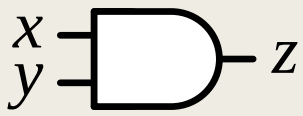
Binary Logic

- Truth Tables, Boolean Expressions, and Logic Gates

AND

x	y	z
0	0	0
0	1	0
1	0	0
1	1	1

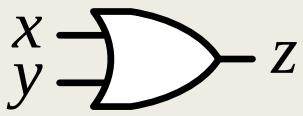
z = x • y = x y



OR

x	y	z
0	0	0
0	1	1
1	0	1
1	1	1

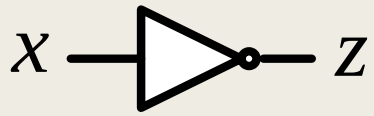
z = x + y



NOT

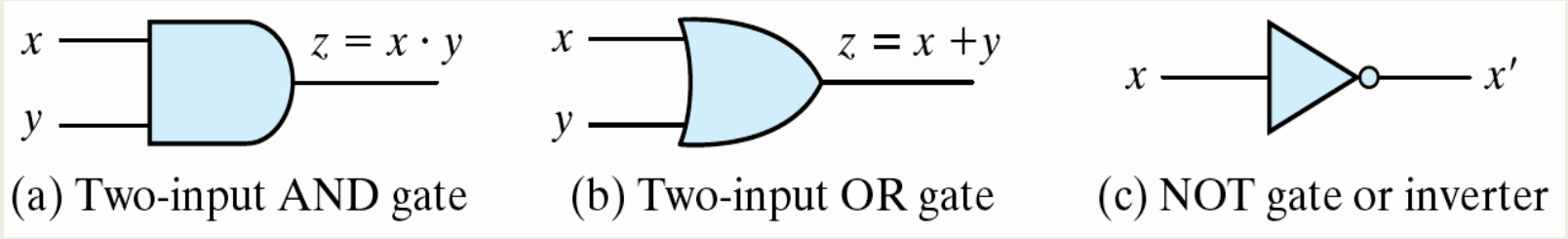
x	z
0	1
1	0

z = $\overline{x}$ = x'



Binary Logic

- Logic gates
  - *Graphic Symbols and Input-Output Signals for Logic gates:*



(a) Two-input AND gate (b) Two-input OR gate (c) NOT gate or inverter

Fig. 1.4 Symbols for digital logic circuits

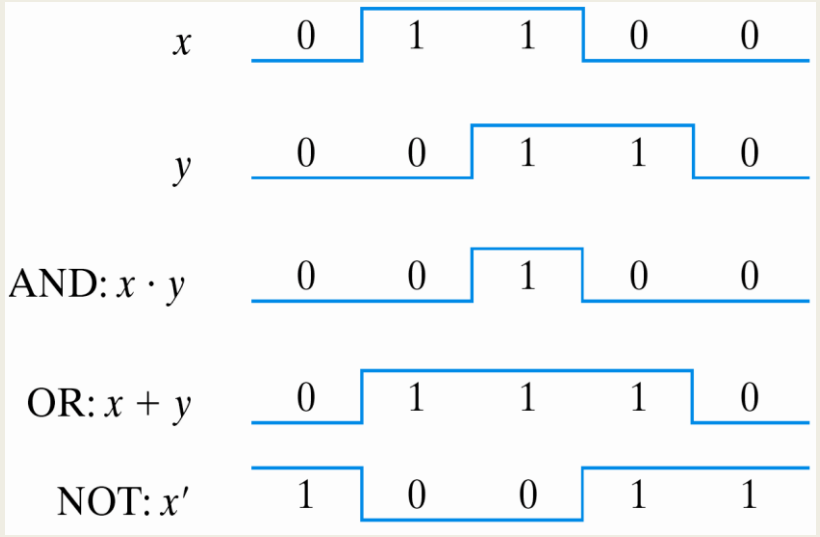


Fig. 1.5 Input-Output signals for gates

Binary Logic

- Logic gates
  - *Graphic Symbols and Input-Output Signals for Logic gates:*

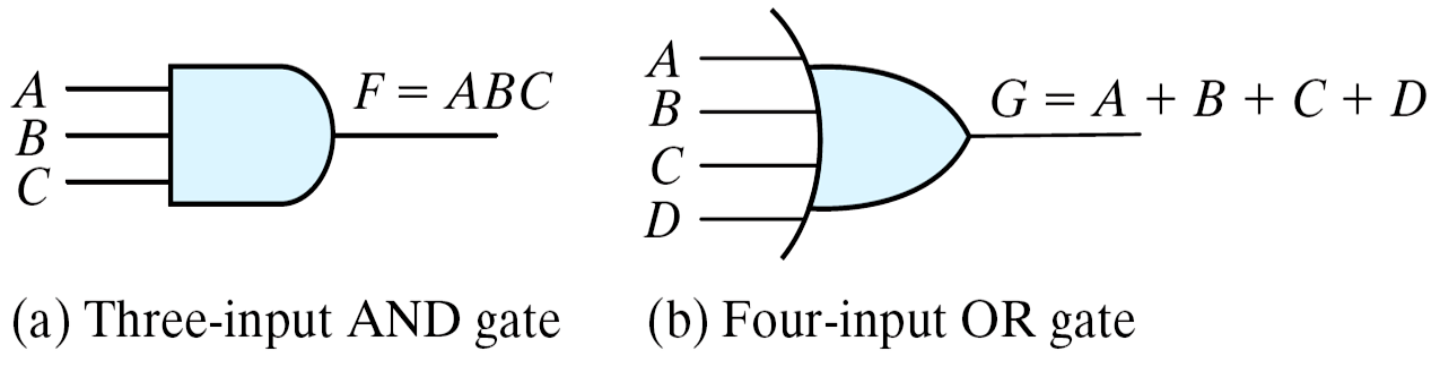


Fig. 1.6 Gates with multiple inputs

Some more about Logic Gates

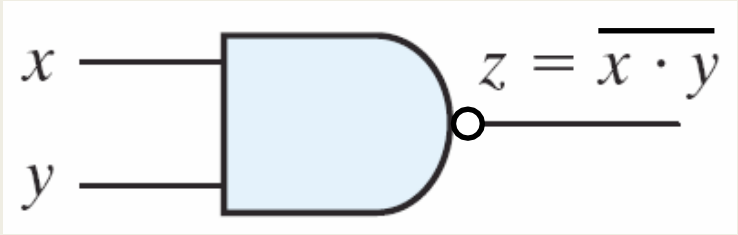
- Basic Gates
  - AND
  - OR
  - Not

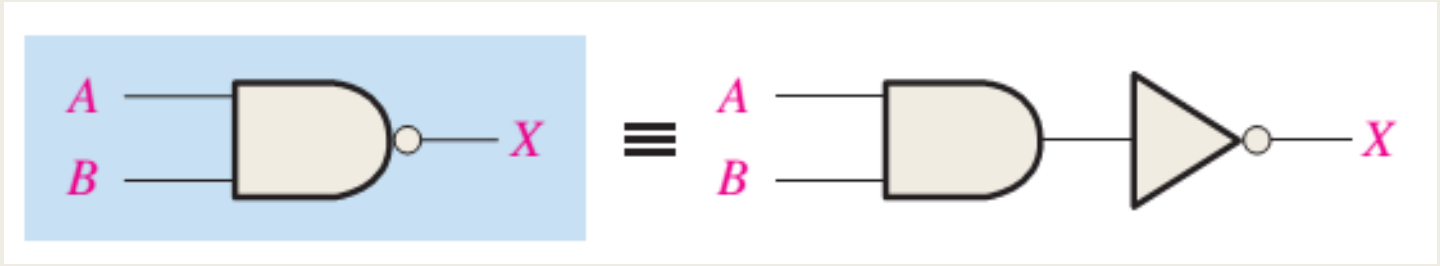
- Extended Gates
  - NAND
  - NOR
  - XOR
  - XNOR

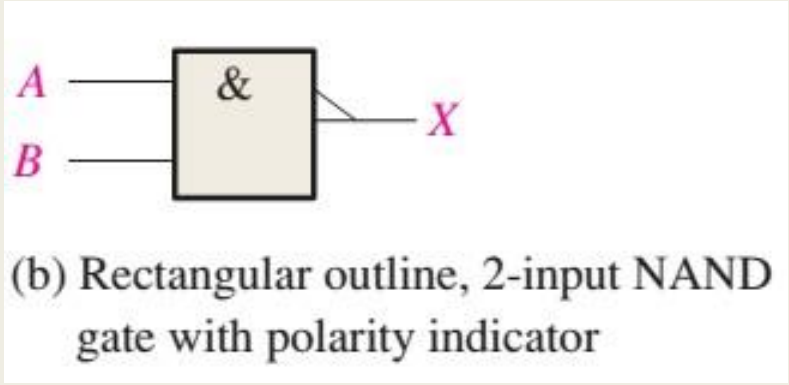
NAND Gate

- Operation to check if two conditions are met (for two input)
  - Output = 0 if and only if both inputs are 1
  - Symbolized by dot or absence of operator with a bar over them
  - $\overline{x \cdot y}$ or $\overline{xy}$
- Truth table
  - Needs to consider $2^2 = 4$ input combinations
- Graphic symbol
  - NAND gate

Inputs		Output
x	y	z
0	0	1
0	1	1
1	0	1
1	1	0



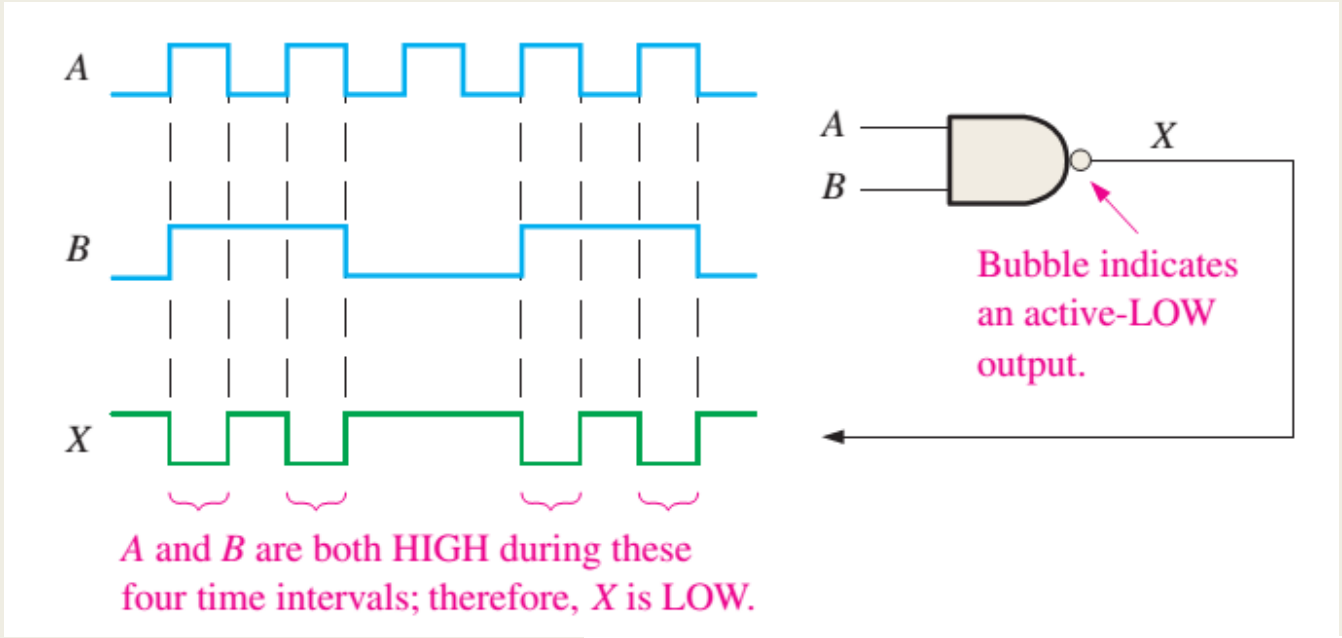


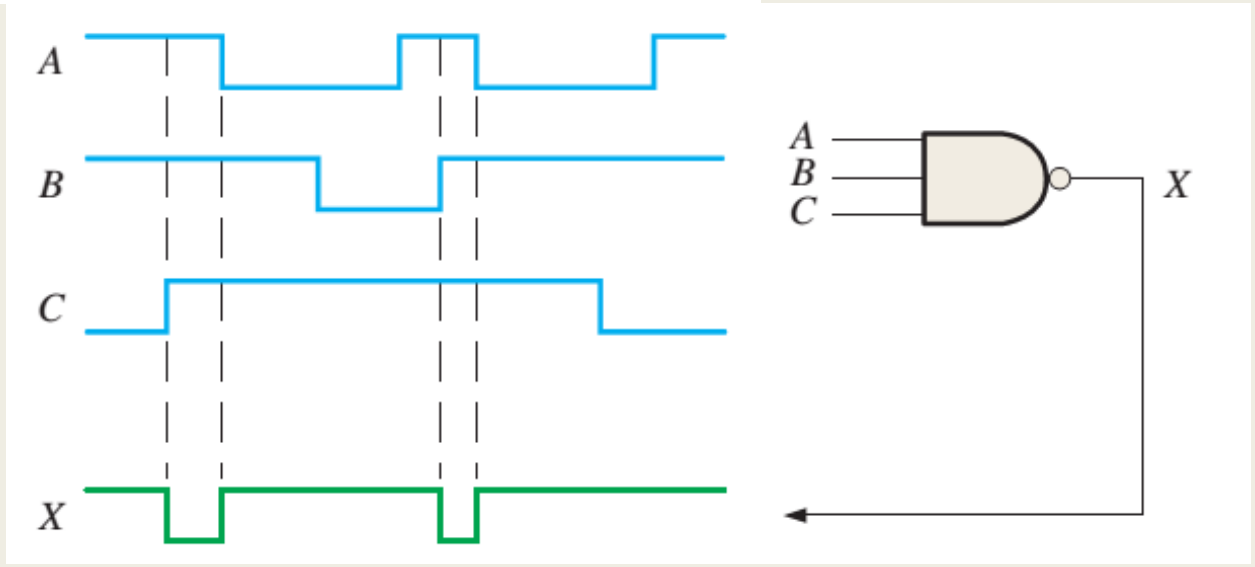


(b) Rectangular outline, 2-input NAND gate with polarity indicator

Logical Expression

$$X = \overline{AB}$$


A
B
X
A
B
X
Bubble indicates an active-LOW output.
A and B are both HIGH during these four time intervals; therefore, X is LOW.


A
B
C
X
A
B
C
X

NOR Gate

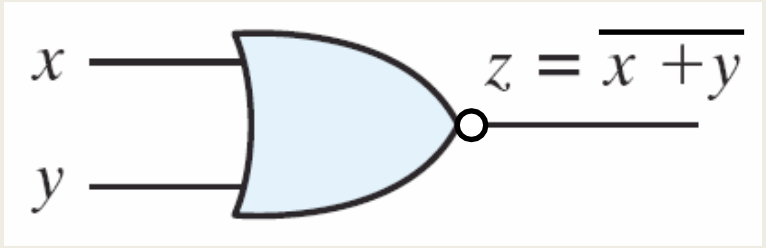
- Operation to check if two conditions are not met (for two input)
  - Output = 1 if and only if both inputs are 0
  - Symbolized by + operator with a bar over them

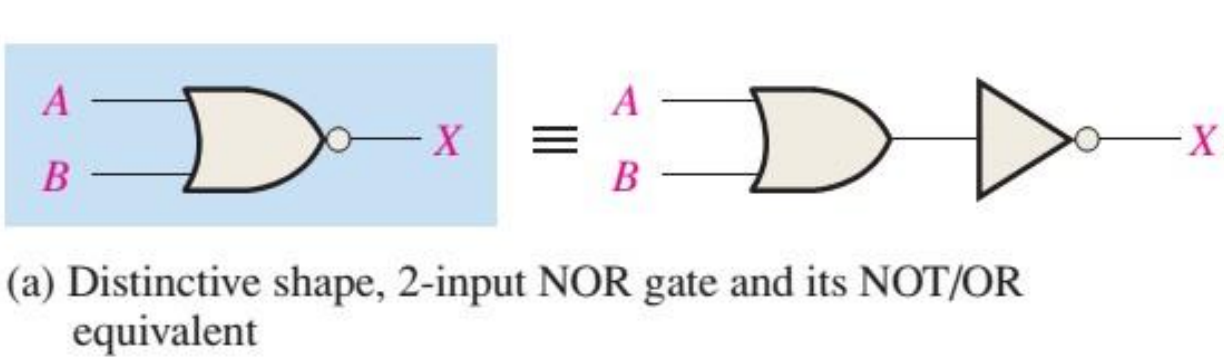
$$\overline{x+y}$$

- Truth table

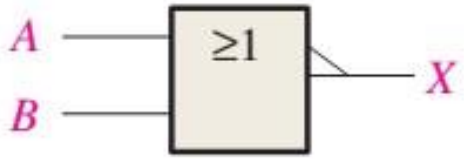
Inputs		Output
x	y	z
0	0	1
0	1	0
1	0	0
1	1	0

- Graphic symbol
  - NAND gate



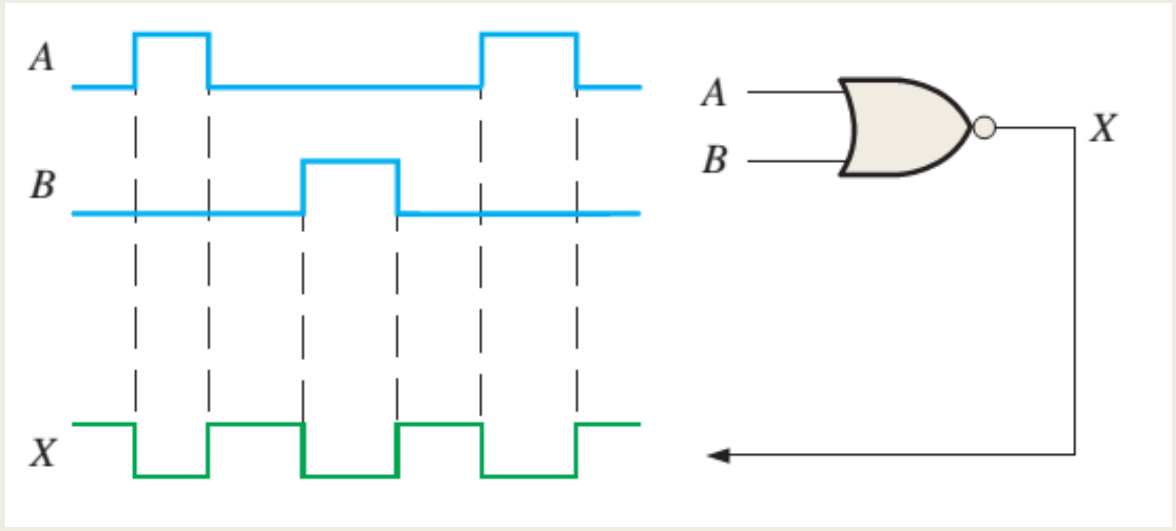


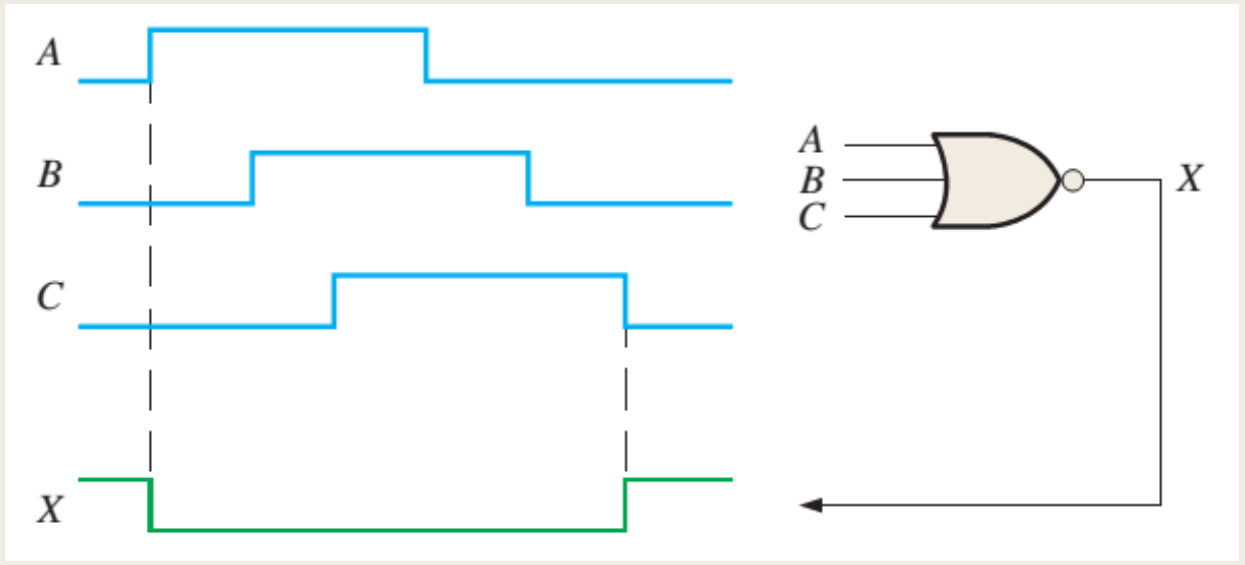
(a) Distinctive shape, 2-input NOR gate and its NOT/OR equivalent



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

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


A
B
X
A
B
X

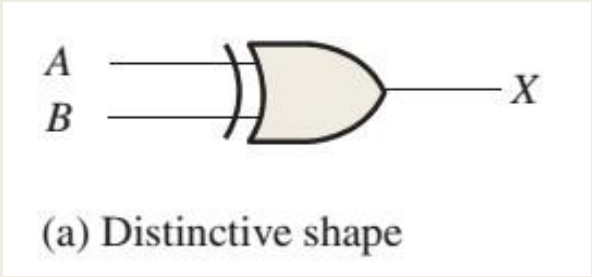

A
B
C
X
A
B
C
X

XOR Gate

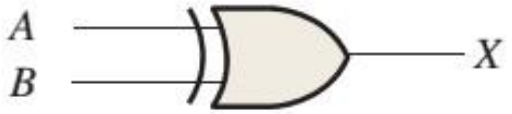
- Operation to check if two conditions are not met (for two input)
  - Output = 1 if one of the inputs is 1
  - Symbolized by $\oplus$ operator $x \oplus y$
- Truth table

Inputs		Output
x	y	z
0	0	0
0	1	1
1	0	1
1	1	0

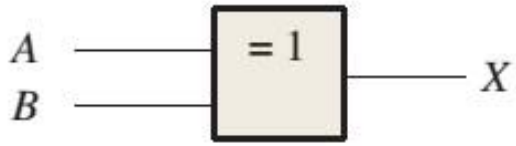
- Graphic symbol
  - XOR gate



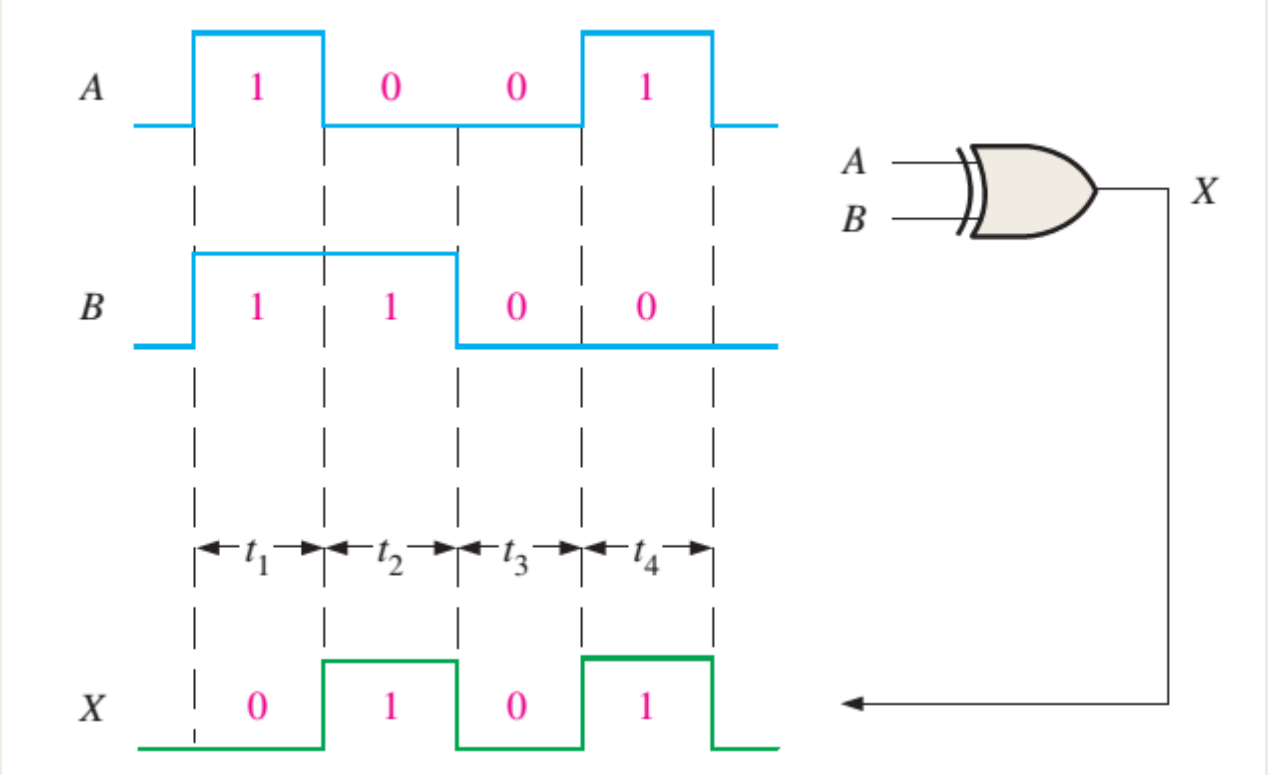
(a) Distinctive shape



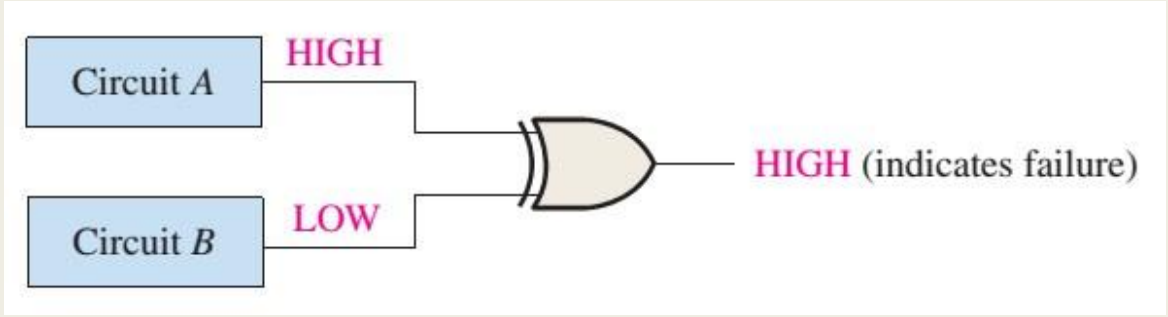
(a) Distinctive shape



(b) Rectangular outline

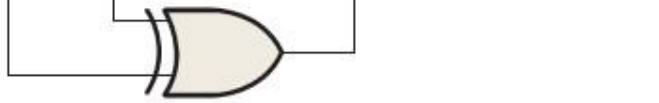

A
1
0
0
1
B
1
1
0
0
t_1
t_2
t_3
t_4
X
0
1
0
1
A
B
X

Two identical circuits connected in parallel

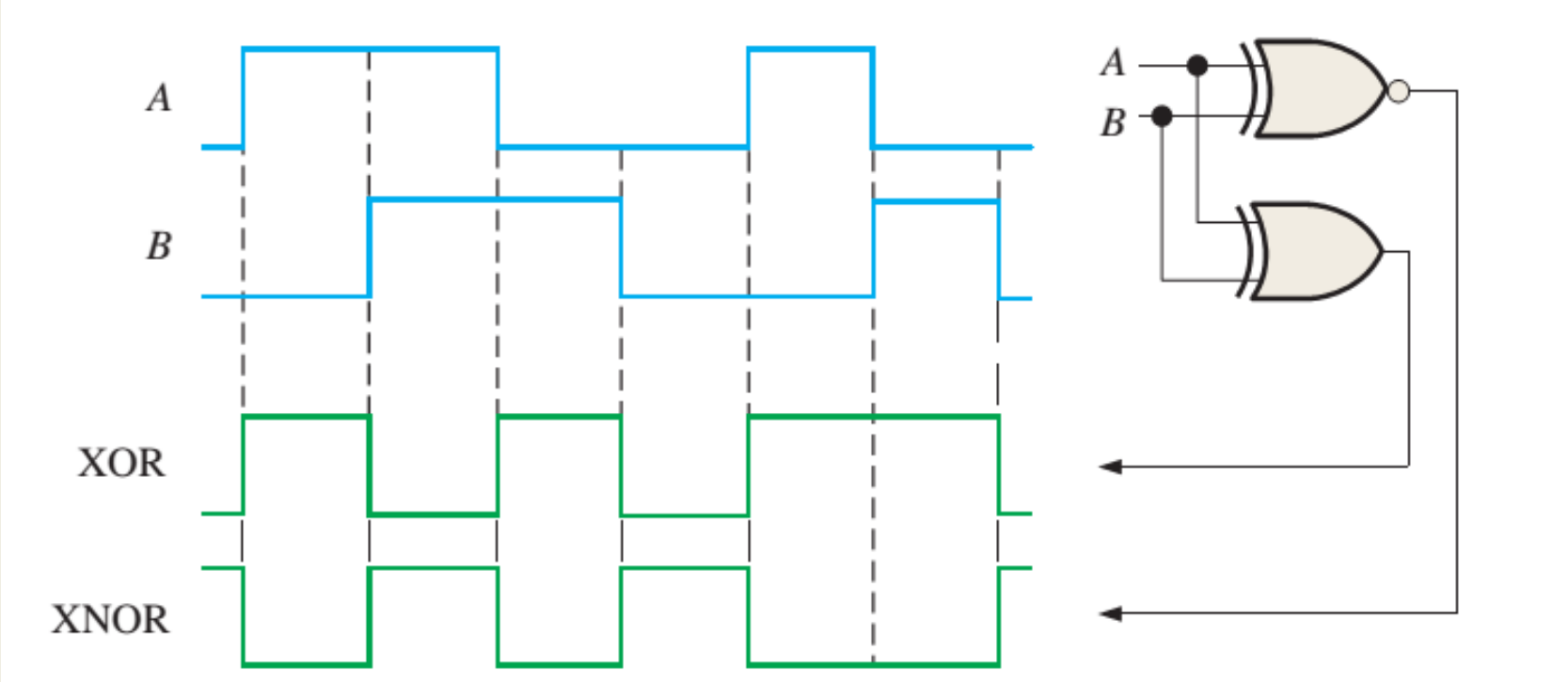


An XOR gate used to add two bits.

Input Bits		Output (Sum)	
A	*B*	Σ	
0	0	0	
0	1	1	
1	0	1	
1	1	0	(without the 1 carry bit)



XOR and XNOR



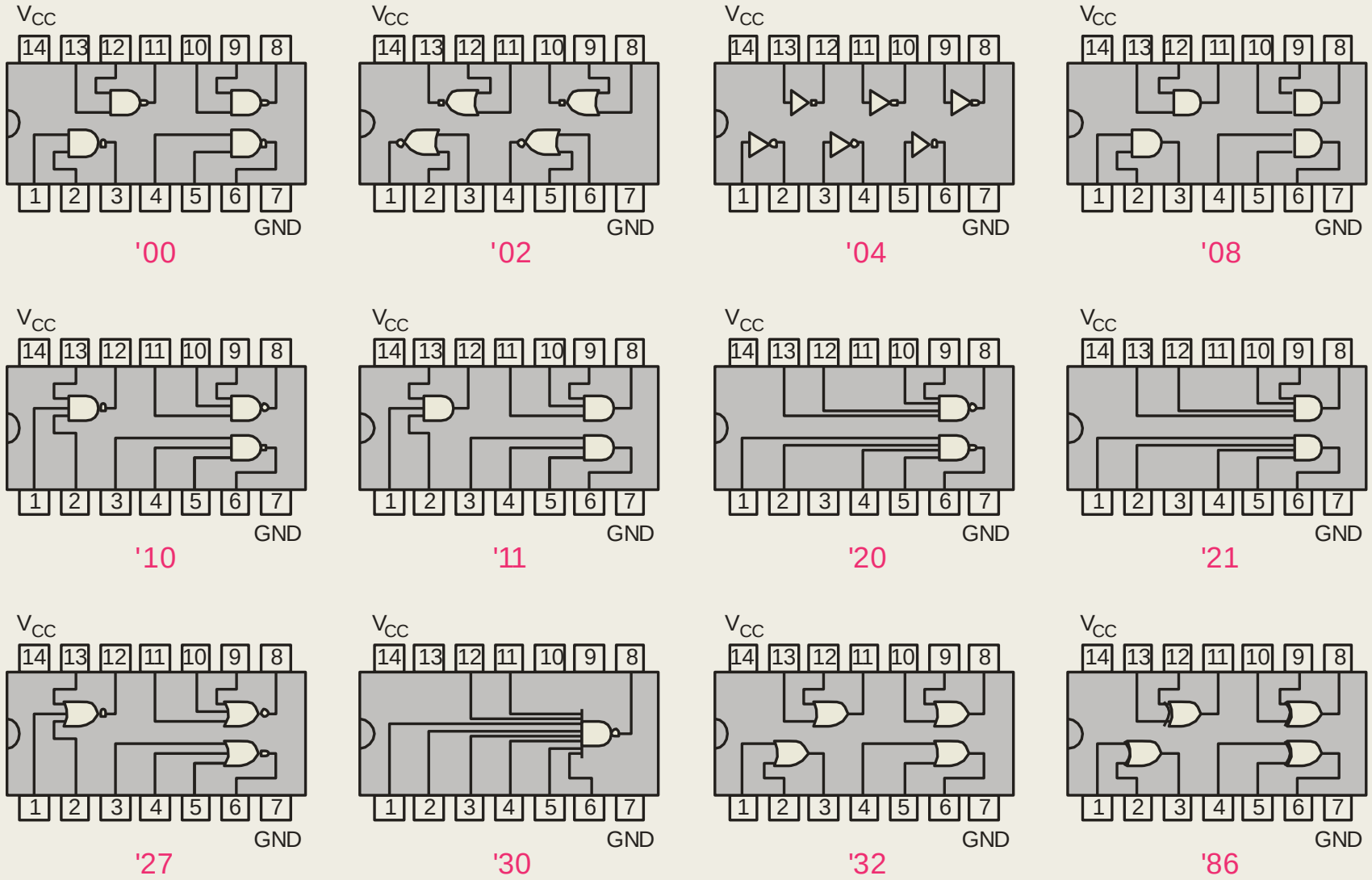
Multiple-input XOR

- Extension of exclusive-OR not straightforward
  - What is the definition for 3 variables?
- Turns into "odd" function
  - Function is 1 when there is
  - an odd number of 1's

x	y	z	x⊕y⊕z
0	0	0	0
0	0	1	1
0	1	0	1
0	1	1	0
1	0	0	1
1	0	1	0
1	1	0	0
1	1	1	1

Fixed function Logic

Some common gate configurations of 74 series are shown



Thank You