104. Computer Organization

Unit – 3
Gates and Boolean Algebra

Digital Signals

◇ **Digital Signals have two basic states:**
        1 (logic "high", or H, or "on")
        0 (logic "low", or L, or "off")

◇ **Digital values are in a *binary* format. Binary means 2 states.**

◇ **A good example of binary is a light (only <u>on</u> or <u>off</u>)**

ON

Logic Gates

◇ ***A logic gate*** **is an electronic circuit which implements logical operation produces a typical output signal depending on its input signal.**

◇ **Binary information is represented in digital computers using electrical signals**

◇ **Logic circuits are built from components called logic gates.**

◇ **The logic gates correspond to Boolean operations +, *, '.**

◇ **Binary operations have two inputs, unary has one**

Digital Logic
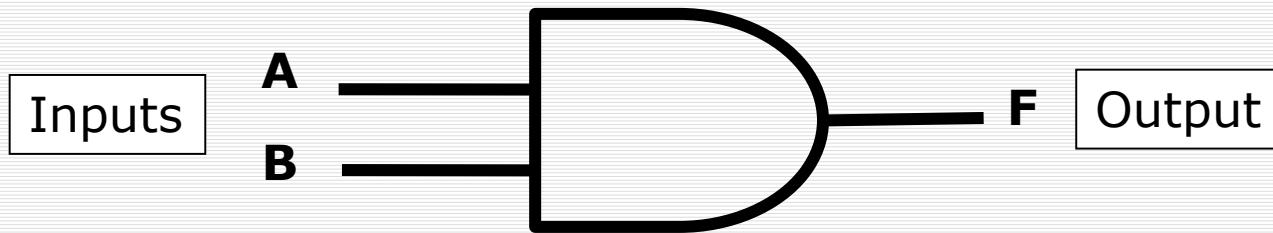
◇ **Basic Digital logic is based on 3 primary functions (the basic gates):**

◇ **AND**

◇ **OR**

◇ **NOT**

The AND Gate

◇ **The AND function:**
- ◇ **If all the inputs are high , the output is high**
- ◇ **If any input is low, the output is low**

AND Logic Symbol

Boolean Function : F = AB

Inputs

A

B
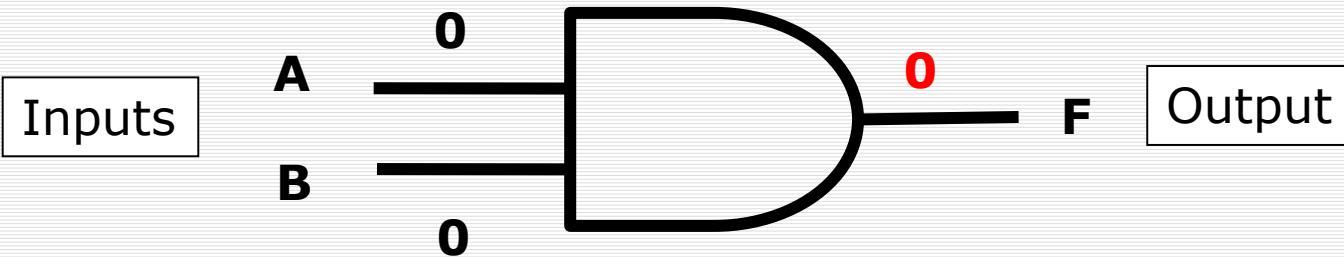
F Output

If all inputs are 1, the output is 1

If any input is 0, the output is 0

AND Logic Symbol
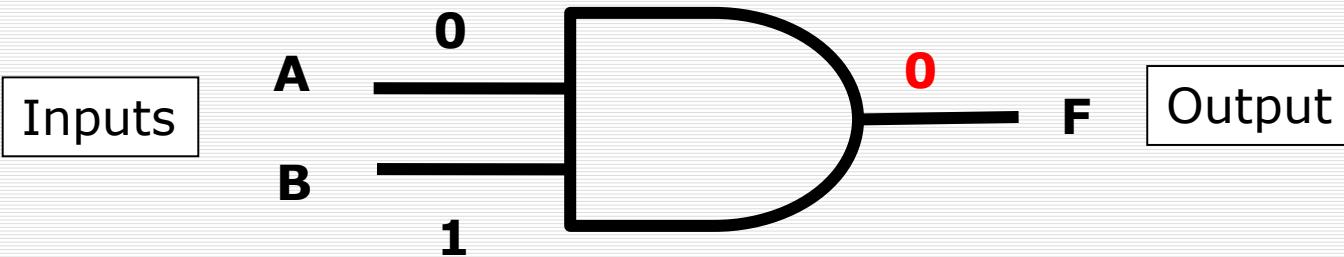
Inputs

A —— 0

B —— 0

F = 0

Output

Determine the output

Boolean Function : F = AB

= (0)(0)

= 0

AND Logic Symbol

Inputs

A   0

B

1

0
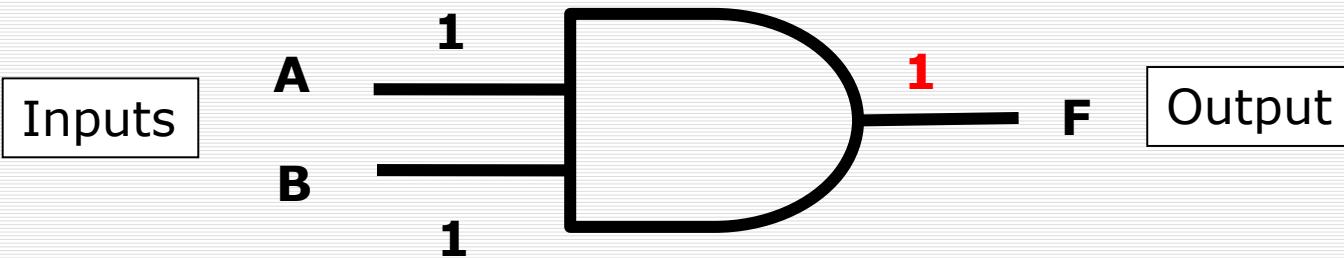
F   Output

Determine the output

Boolean Function : F = AB
$$= (0)(1)$$
$$= 0$$

AND Logic Symbol

Inputs

A 1

B 1

1 F

Output

Determine the output

Boolean Function : F = AB
=(1)(1)
=1

AND Truth Table

◇ **To help understand the function of a digital device, a Truth Table is used:**
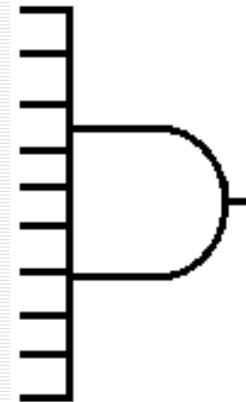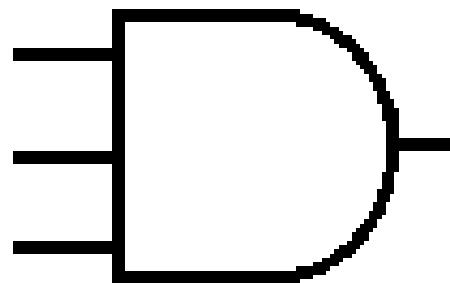
Every possible input combination

Input		Output
0	0	0
0	1	0
1	0	0
1	1	1

AND Function

AND Gates

◊ **It is possible to have AND gates with more than 2 inputs. The same logic rules apply – "if any input…"**
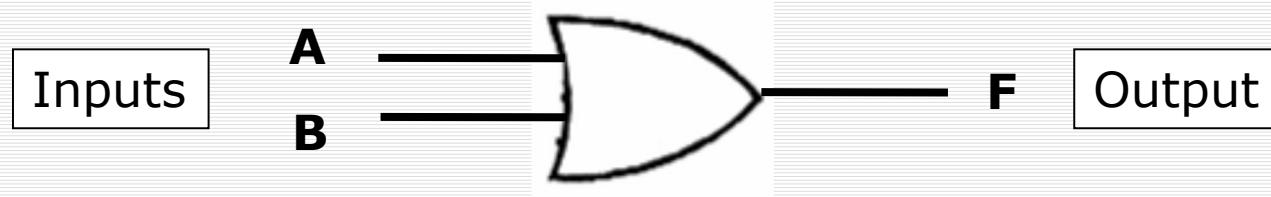
The OR Gate

◊ **The OR function:**

    ◊ **if any input is high, the output is high**

   ◊ **if all inputs are low, the output is low**

OR Logic Symbol

Boolean Function : F = A+B

Inputs

A

B

F
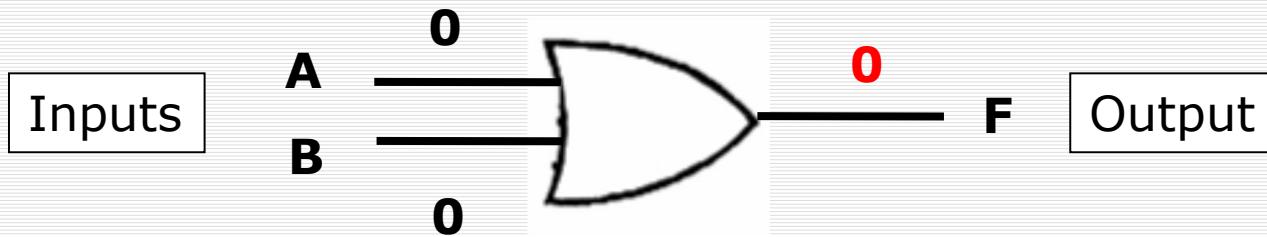
Output

If any input is 1, the output is 1

If all inputs are 0, the output is 0

OR Logic Symbol

Inputs

A $\quad$ 0

B $\quad$ 0

0
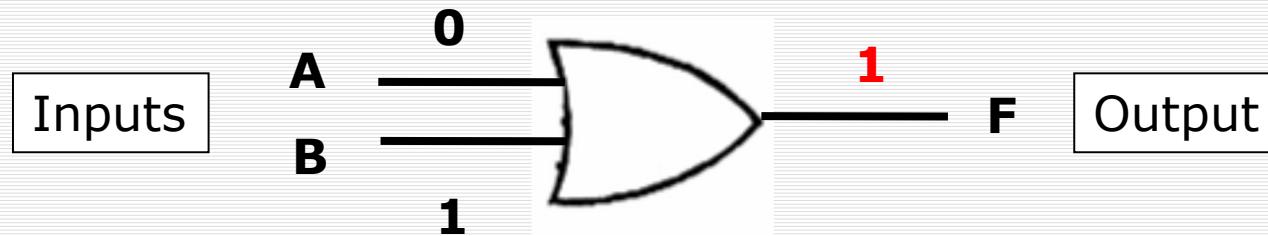
F $\quad$ Output

Determine the output

Boolean Function : F = A+B

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

OR Logic Symbol

Inputs

A   0

B   1
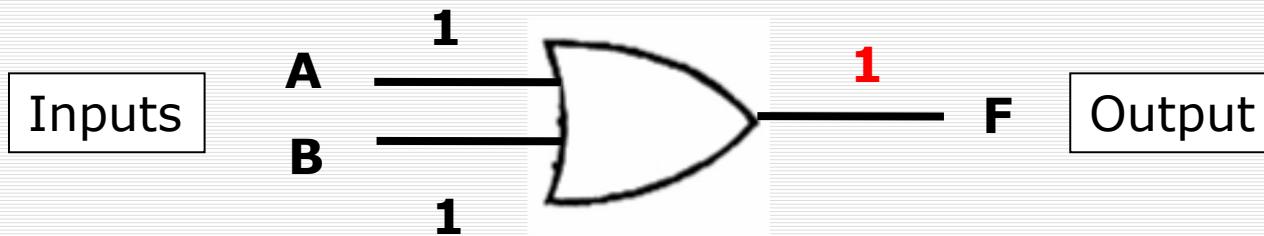
F   Output   **1**

Determine the output

Boolean Function : F = A+B

$$= 0 + 1$$

$$= 1$$

OR Logic Symbol

Inputs

A ─── 1

B ─── 1

F Output

Determine the output

Boolean Function : F = A+B
= 1 + 1
= 1

OR Truth Table

◊ **Truth Table**

| Input		Output
0	0	0
0	1	1
1	0	1
1	1	1
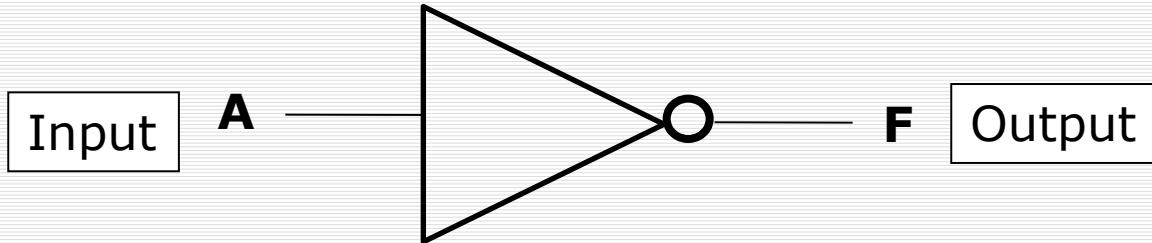
OR Function

The NOT Gate

◊ **The NOT function:**
- ◊ **If any input is high, the output is low**
- ◊ **If any input is low, the output is high**

◊ **"The output is the opposite state of the input"**

◊ **The NOT function is often called INVERTER**

NOT Logic Symbol
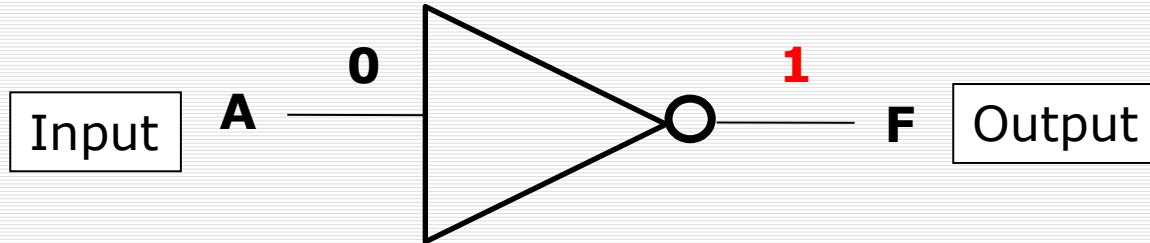
Boolean Function : F = A′

Input   **A** ⊳○— **F**   Output

If the input is 1, the output is 0

If the input is 0, the output is 1

NOT Logic Symbol

Input **A** — **0** ⊳◦ **1** — **F** Output
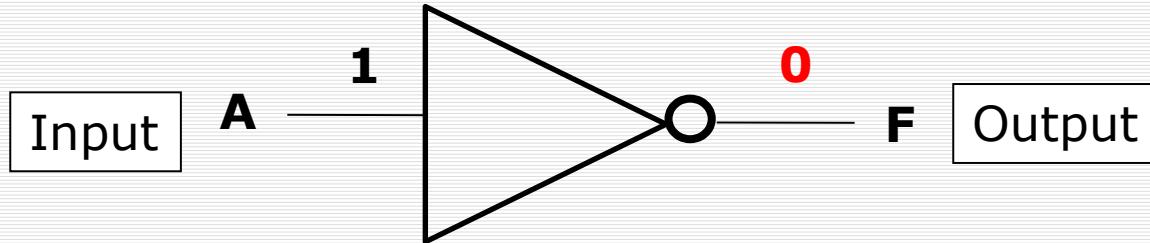
Determine the output

Boolean Function : F = A′
$$= (0)'$$
$$= 1$$

NOT Logic Symbol

Input — **A** — **1** ▷○— **0** — **F** — Output

Determine the output

Boolean Function : F = A'
$$= (1)'$$
$$= 0$$

NOT Truth Table
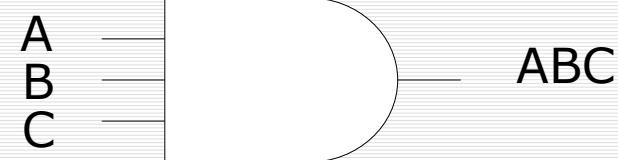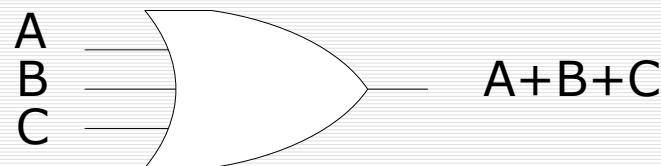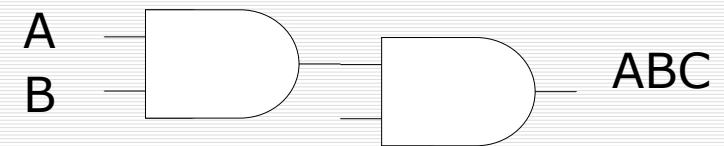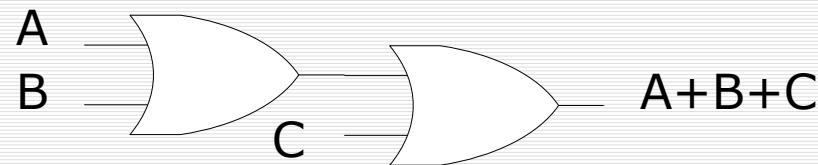
◇ **Truth Table**

| Input	Output
0	1
1	0

NOT Function
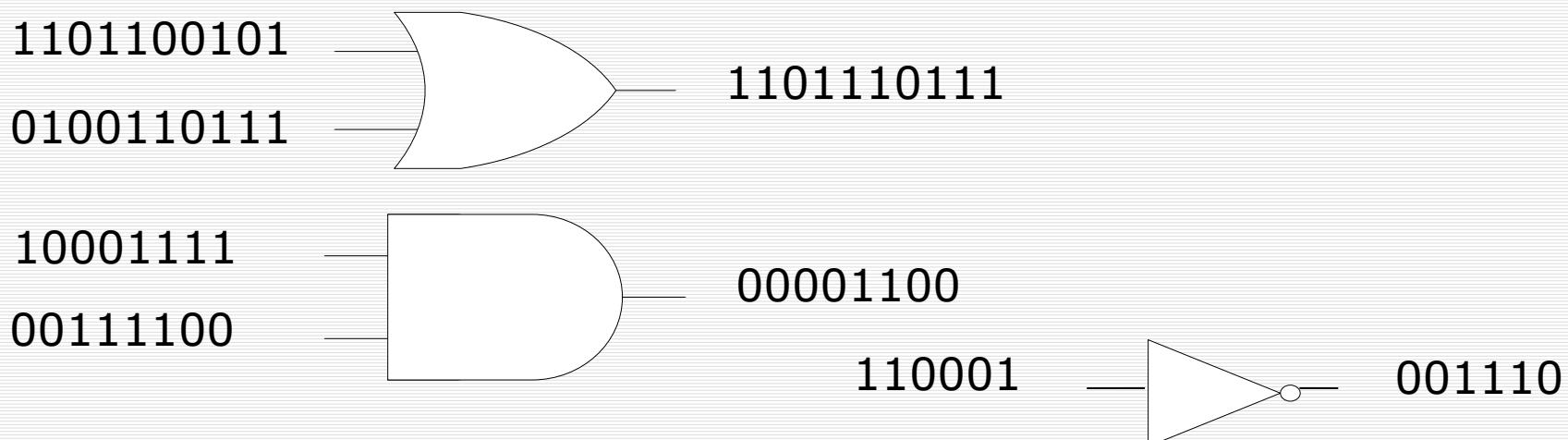
n-input Gates

◇ **Because + and * are binary operations, they can be cascaded together to OR or AND multiple inputs.**

n-bit Inputs

◇ **For convenience, it is sometimes useful to think of the logic gates processing n-bits at a time. This really refers to n instances of the logic gate, not a single logic gate with n-inputs.**
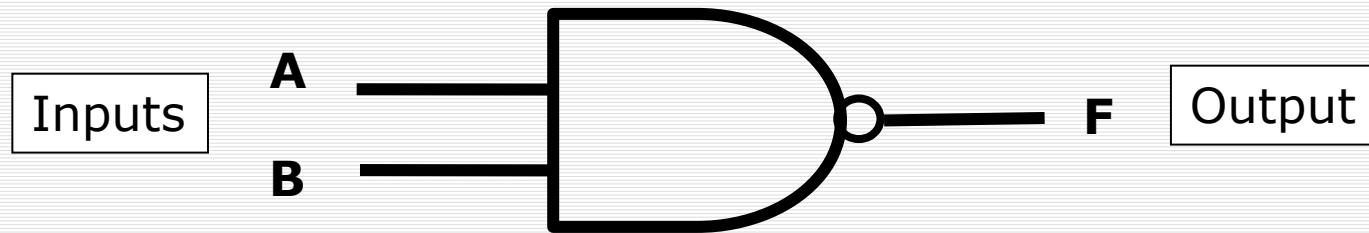
The NAND Gate

◊ **The NAND function:**
  - ◊ **If all the inputs are high, the output is low**
  - ◊ **If any input is low, the output is high**

NAND Logic Symbol

Boolean Function : F = (AB)' or F = $\overline{AB}$

A

Inputs

B

F
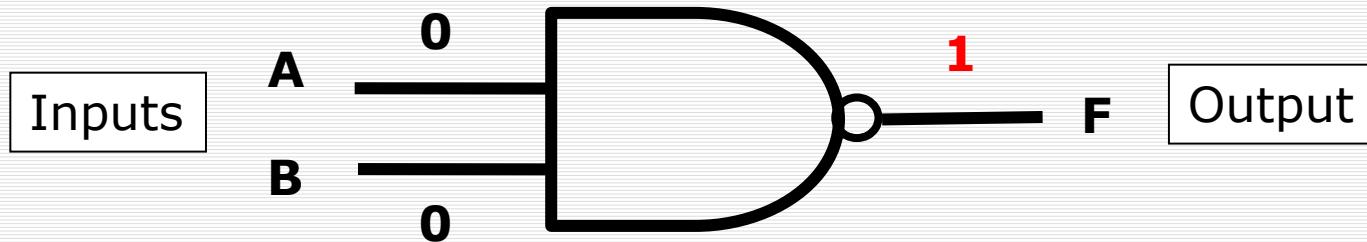
Output

If any input is 0, the output is 1

If all inputs are 1, the output is 0
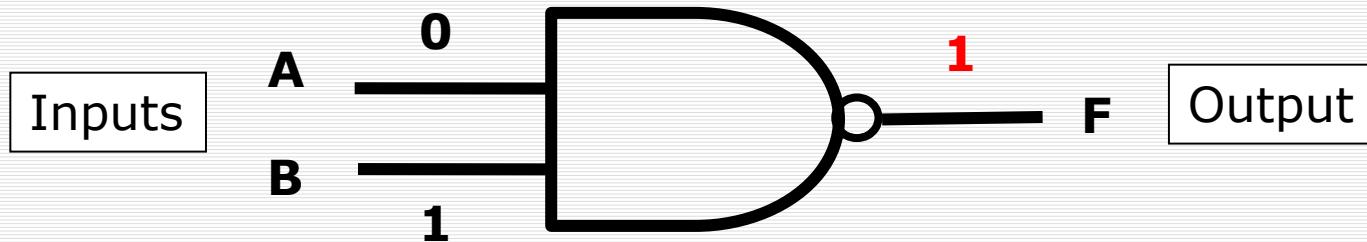
NAND Logic Symbol

Inputs

A   **0**

B   **0**

1

F   Output

Determine the output

Boolean Function : F = (AB)' or F = $\overline{AB}$

$$= [(0)(0)]'$$
$$= (0)'$$
$$= 1$$

NAND Logic Symbol

Inputs

A   0

B   1

1
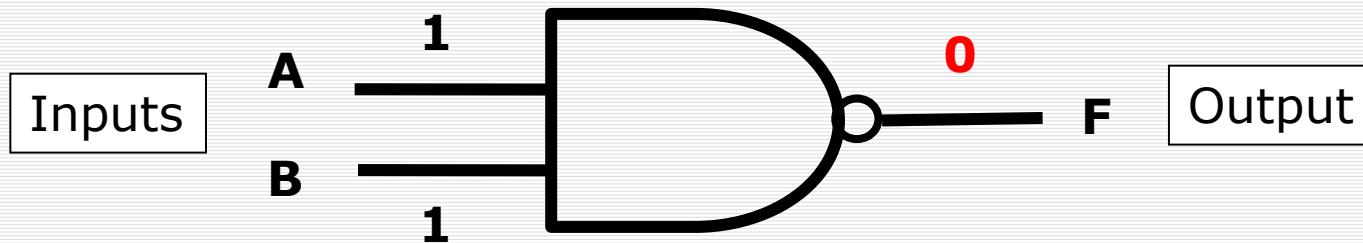
F   Output

Determine the output

Boolean Function : F = (AB)' or F = $\overline{AB}$

$$= [(0)(1)]'$$
$$= (0)'$$
$$= \mathbf{1}$$

29

NAND Logic Symbol

Inputs

A   1

B   1

0

F   Output

Determine the output

Boolean Function : F = (AB)' or F = $\overline{AB}$

$$= [(1)(1)]'$$
$$= (1)'$$
$$= 0$$

NAND Truth Table

◇ **Truth Table**

| Input		Output
0	0	1
0	1	1
1	0	1
1	1	0
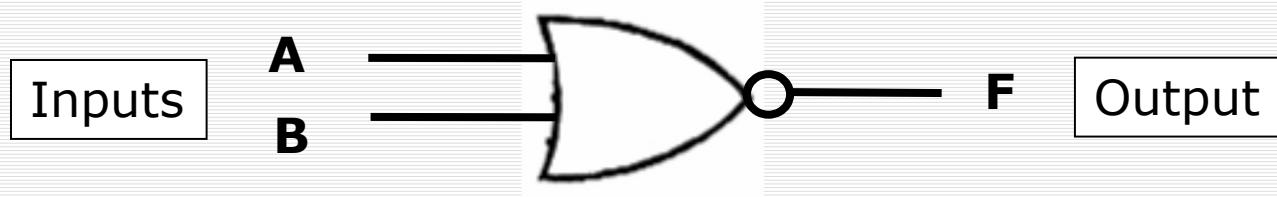
NAND Function

The NOR Gate

◇ **The NOR function:**
  - ◇ **If all the inputs are low, the output is high**
 - ◇ **If any input is high, the output is low**

NOR Logic Symbol
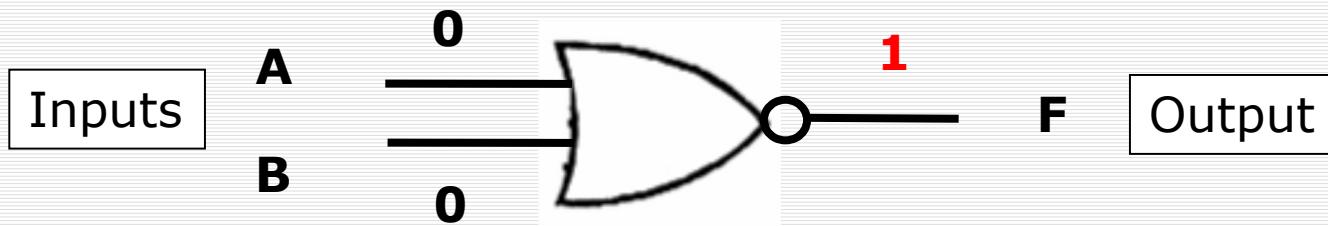
Boolean Function : F = (A+B)' or F = $\overline{A+B}$

Inputs

A
B

F   Output

If any input is 1, the output is 0

If all inputs are 0, the output is 1
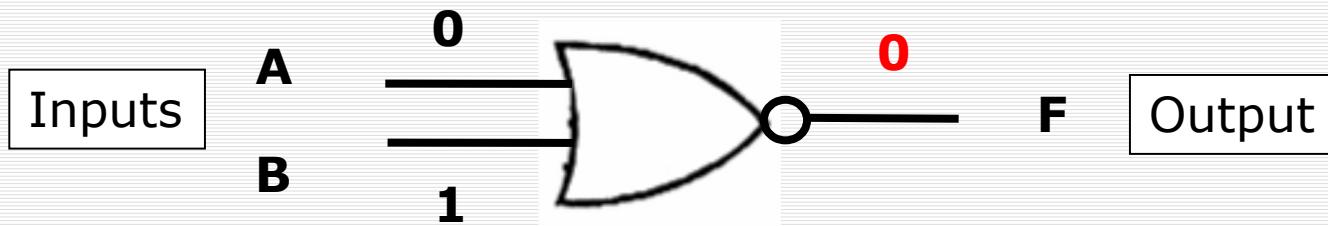
NOR Logic Symbol

Inputs   **A**   **0**

         B   **0**

         1   **F**   Output

Determine the output

Boolean Function : F = (A+B)' or F = $\overline{A+B}$

$$= [(0)+(0)]'$$
$$= (0)'$$
$$= 1$$
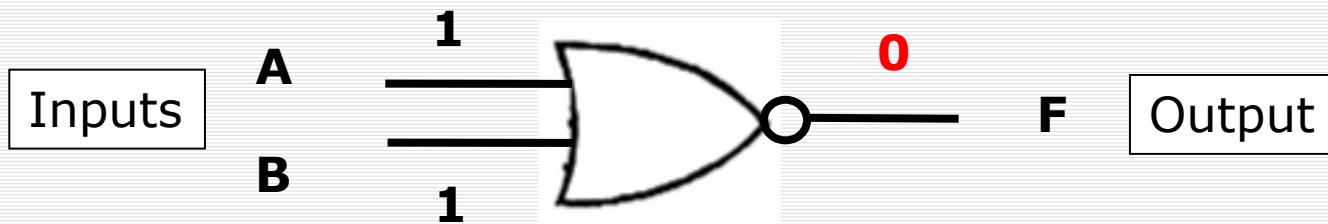
NOR Logic Symbol

Boolean Function : F = (A+B)' or F = $\overline{A+B}$

$$= [(0)+(1)]'$$
$$= (1)'$$
$$= 0$$

NOR Logic Symbol

Inputs

A

1

B

1

0

F

Output

Determine the output

Boolean Function : F = (A+B)′ or F = $\overline{A+B}$

$$= [(1)+(1)]′$$
$$= (1)′$$
$$= 0$$

NOR Truth Table

◇ **Truth Table**

| Input		Output
0	0	1
0	1	0
1	0	0
1	1	0
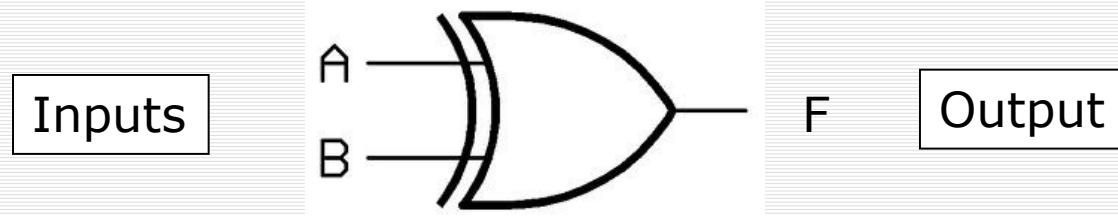
NOR Function

The XOR Gate

◇ **The XOR function:**
  ◇ **If either, but not both of its two inputs are high or low, the output is high**
 ◇ **If all inputs are high or all input are low, the output is low**

XOR Logic Symbol

Boolean Function : F = (A $\oplus$ B)

Inputs

A ——

B ——

F
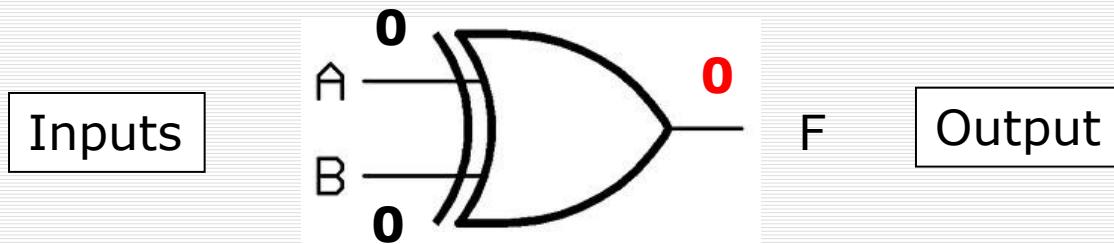
Output

If any input is 1 or 0, the output is 1

If all inputs are 0 or 1, the output is 0
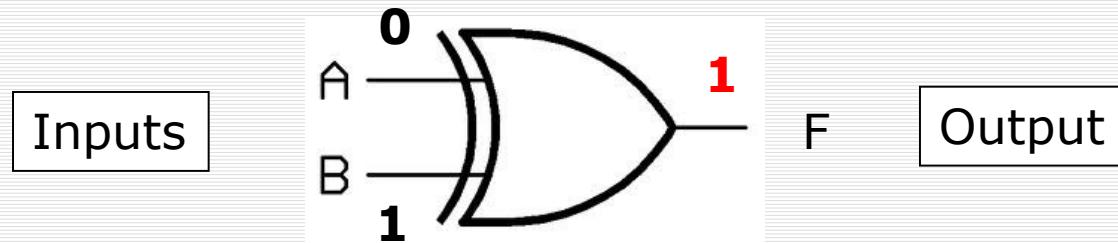
XOR Logic Symbol
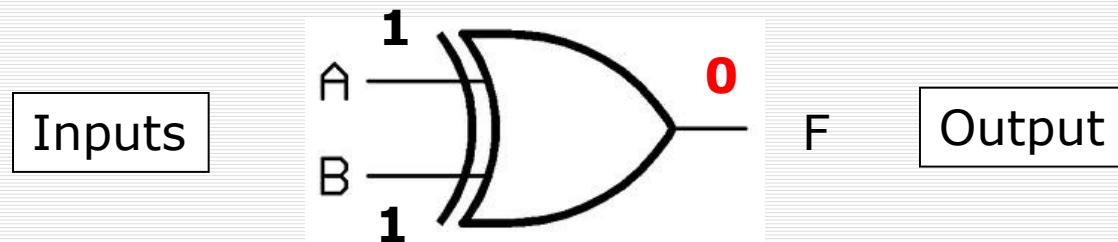
0

A

B

0

0

F

Inputs

Output

Determine the output

Boolean Function : F = (A $\oplus$ B)

= (0 $\oplus$ 0)

= 0

XOR Logic Symbol

Inputs

0
A

B
1

1

F

Output

Determine the output

Boolean Function : F = (A $\oplus$ B)

$$= (0 \oplus 1)$$

$$= 1$$

XOR Logic Symbol

Inputs

A — 1

B — 1

0 — **F** — **Output**

Determine the output

Boolean Function : F = (A $\oplus$ B)

$$= (1 \oplus 1)$$

$$= 0$$

XOR Truth Table

◇ **Truth Table**

| Input		Output
0	0	0
0	1	1
1	0	1
1	1	0
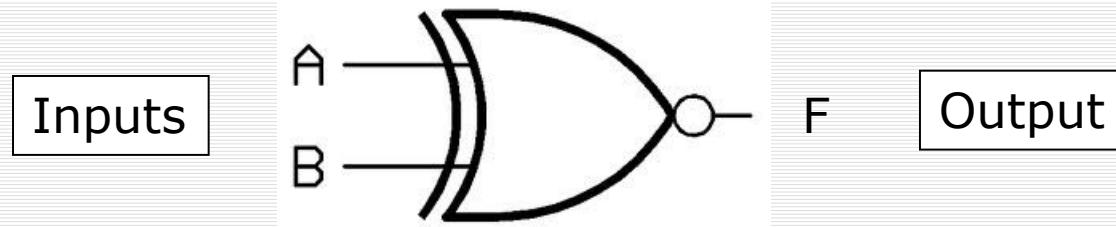
XOR Function

The XNOR Gate

◊ **The XNOR function:**

◊ **If either, but not both of its two inputs are high or low, the output is low**

◊ **If all input are high or all input are low, the output is high**

XNOR Logic Symbol

Boolean Function : F = (A $\oplus$ B)'

Inputs   A   B   F   Output
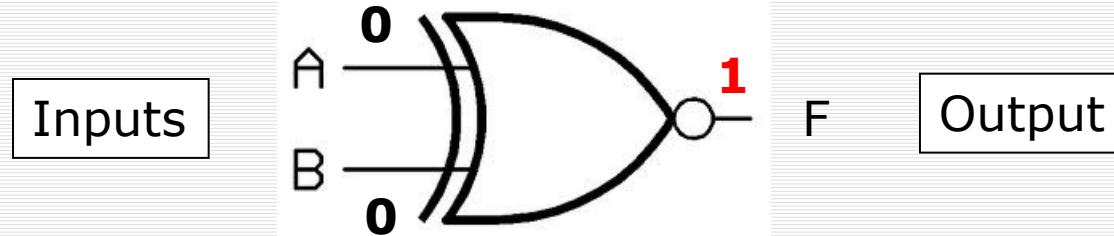
If any input is 1 or 0, the output is 0

If all inputs are 0 or 1, the output is 1

45

XNOR Logic Symbol

Inputs
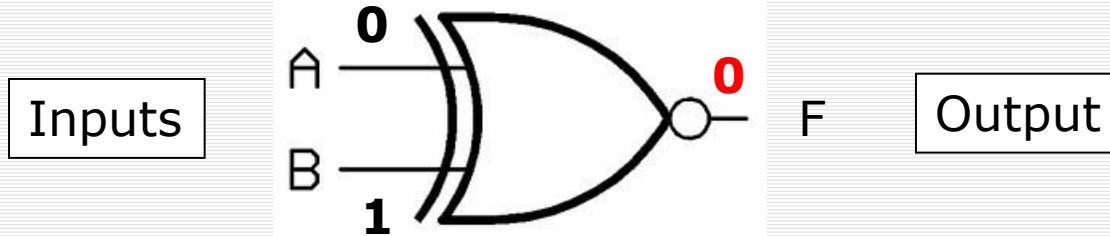
Output

Determine the output

Boolean Function : F = (A $\oplus$ B)′
$$= (0 \oplus 0)'$$
$$= 1$$
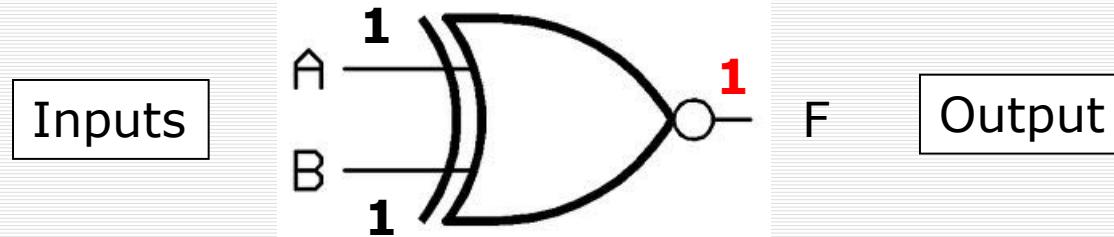
XNOR Logic Symbol

Inputs

Output

Determine the output

Boolean Function : F = (A $\oplus$ B)′
$$= (0 \oplus 1)′$$
$$= 0$$

XNOR Logic Symbol

Inputs

$$A \quad 1$$
$$B \quad 1$$
$$F \quad 1$$

Output

Determine the output

Boolean Function : F = (A $\oplus$ B)'
$$= (1 \oplus 1)'$$
$$= 1$$

XNOR Truth Table

◊ **Truth Table**

Input		Output
0	0	1
0	1	0
1	0	0
1	1	1

XNOR Function

REVIEW

◊ **Digital Electronics works in Binary:**

◊ **There are 2 logic levels: high and low, or 1 and 0.**

◊ **A switch can be used to provide a logic level.**

Exercise 1

◇ **Complete the sentences:**

   ◇ **If all inputs of an OR gate are low, the output is** _____

   ◇ **If any input of an AND gate is low, the output is** _____

   ◇ **The output of a NOT gate is always the** _____ **of the input.**