Fundamental Logic Gates: AND, OR, NOT

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1 Introduction

Logic gates are the basic building blocks of digital circuits. They perform logical operations on binary inputs (0 and 1) and produce a single binary output. This lecture covers the three fundamental gates: AND, OR, and NOT.

2 AND Gate

2.1 Symbol and Boolean Expression

The AND gate performs logical conjunction. Its symbol and Boolean expression are:

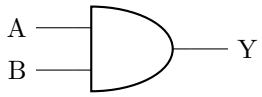

Figure 1: AND Gate Symbol

$$Y = A \cdot B \quad \text{(Boolean expression)}$$

2.2 Truth Table

The output is 1 (True) only if both inputs are 1.

A	**B**	**Y**
0	0	0
0	1	0
1	0	0
1	1	1

Table 1: AND Gate Truth Table

2.3 Real-World Analogy

Imagine a two-switch series circuit for a bulb: - The bulb lights up (Y=1) only if both switches (A and B) are ON (1). - If either switch is OFF (0), the bulb stays OFF (0).

2.4 Example

Design a circuit where a car starts (Y=1) only if the key is inserted (A=1) AND the brake is pressed (B=1).

3 OR Gate

3.1 Symbol and Boolean Expression

The OR gate performs logical disjunction. Its symbol and Boolean expression are:

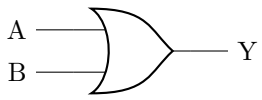

Figure 2: OR Gate Symbol

$$Y = A + B \quad \text{(Boolean expression)}$$

3.2 Truth Table

The output is 1 (True) if at least one input is 1.

A	**B**	**Y**
0	0	0
0	1	1
1	0	1
1	1	1

Table 2: OR Gate Truth Table

3.3 Real-World Analogy

Imagine a two-switch parallel circuit for a bulb: - The bulb lights up (Y=1) if either switch (A or B) is ON (1). - Only if both switches are OFF (0) does the bulb stay OFF (0).

3.4 Example

Design a security alarm (Y=1) that triggers if either the door sensor (A=1) OR the window sensor (B=1) is activated.

4 NOT Gate (Inverter)

4.1 Symbol and Boolean Expression

The NOT gate inverts the input. Its symbol and Boolean expression are:

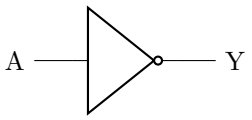

Figure 3: NOT Gate Symbol

$$Y = \overline{A} \quad \text{(Boolean expression)}$$

4.2 Truth Table

The output is the opposite of the input.

A	**Y**
0	1
1	0

Table 3: NOT Gate Truth Table

4.3 Concept of Inversion

- If the input is 0 (False), the output is 1 (True). - If the input is 1 (True), the output is 0 (False).

4.4 Example

A nightlight sensor turns ON (Y=1) when it's dark (A=0) and OFF (Y=0) when it's bright (A=1).

5 Practice Exercises

5.1 True or False

1. An AND gate outputs 1 only if all inputs are 1.

T
F
T

2. An OR gate outputs 0 if any input is 1.
3. NOT gate is also called an inverter.

5.2 Multiple Choice

1. What is the output of an AND gate if inputs are A=0, B=1?

   (a) 0

   (b) 1

   (c) undefined

2. Which gate is used to invert a signal?

   (a) AND

   (b) OR

   (c) NOT

3. In a two-input OR gate, when is the output 0?

   (a) A=0, B=0

   (b) A=1, B=0

   (c) A=1, B=1

A | B | C | Output
---
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

Output is 1 only when A = B = C = 1

5.3 Higher-Level Thinking

1. Design Problem: Construct a truth table for a 3-input AND gate.

2. Application Problem: A room light should turn ON if either the motion sensor (A) detects movement OR the manual switch (B) is pressed. Which gate should be used?

   - You need the light to turn ON if either the motion sensor (A) OR the manual switch (B) is active
   - So you should use an OR gate.

3. Error Analysis: A student builds an OR gate circuit, but it behaves like an AND gate. What could be the mistake?

   - If an OR gate behaves like an AND gate, the student likely miswired the circuit.
   - Wrong connections to the inputs or outputs