Introduction to digital electronics

Logic gates.

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Introduction

In this topic we are going to discuss the following:

- Definition of a logic gate.
- Use of logic gates.
- Types of basic logic gates and their symbols.
- Operation of basic logic gates.
- Constructing the truth tables for basic logic gates.
- Summary
- Quiz

Definition of a logic gate

- Think of a logic gate as a little **decision maker** in a **digital circuit** that looks at some given **input** (digital signals).
- These inputs are usually just a **yes (1)** or **no (0)**.
- The logic gate receives the inputs and gives out its own answer based on these given inputs.
- So a logic gate can be defined as **an electronic circuit that function based Boolean principles, making logical decisions in a digital system**.
- **Note**: *Boolean logic revolves around the idea of binary logic, where values are either true or false, represented by 1 and a 0 respectively.*

  *- Logic gates use **tiny transistors** as switches.*

Use of logic gates

- Logic gates are used **inside electronic devices** especially computers. In side the computer, logic gates take in digital signals (usually 1s and 0s) and make a **logical decision** based on these inputs, **helping the computer processing information**.
- In simple terms we can just say that logic gates are used in electronic devices **to make logic decisions by carrying logical operations on single or multiple binary inputs and give one binary output**.

Note: *Since we are focusing on electronic devices that use digital signals, we will consider our inputs to logic gates as **1**s and **0**s. As such our output will either also be a **1** or a **0** depending on the functionality of the logic gate being used.*

Types of basic logic gates

- Mainly we have four types **(main forms)** of logic gates used in performing logical operations in electronic devices.
- These are: **OR Gate**, **AND Gate**, **NOT Gate**, and **NOR Gate**.

OR Gate

- A logic gate that returns a **1** if **at least** one of the input is a **1**.
- If all inputs are **0**, then an **OR** gate returns a **0**.
- **Figure 1** shows a symbol of an **OR** gate:

Figure 1: Y = A + B

Types of basic logic gates

AND Gate

- A logic gate that returns a **1 only if all** of its inputs are **1s**.
- If one of the inputs is a **0**, then an **AND** gate returns a **0**.
- **Figure 2** shows a symbol of an **AND** gate:

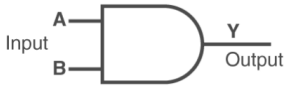


Figure 2: Y = A.B

NOT Gate

- Also called an **inverter**, because it changes a **1** to a **0**, and a **0** to a **1**.
- A logic gate that takes a single input and returns the opposite (inverse) the input.
- If input is **0**, then a **NOT** gate return a **1**.
- **Figure 3** shows a symbol of an **NOT** gate:

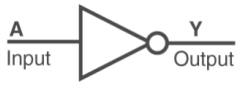


Figure 3: Y = A

Types of basic logic gates

NOR Gate

- A basic logic gate which is a **combination** of the **OR** gate and the **NOT** gate.
- The output is a **1 only if all** of its inputs are **0s**.
- **Figure 4** shows a symbol of an **AND** gate:

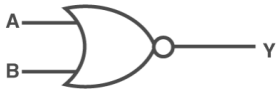


Figure 4: $Y = \overline{A + B}$

NAND Gate

- A basic logic gate which is a **combination** of the **AND** gate and the **NOT** gate.
- The output is a **1 unless all** of its inputs are **1s**.
- **Figure 5** shows a symbol of an **NAND** gate:

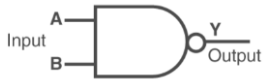


Figure 5: $Y = \overline{A.B}$

Other types of logic gates

Figure 6 shows other types of logic gates.

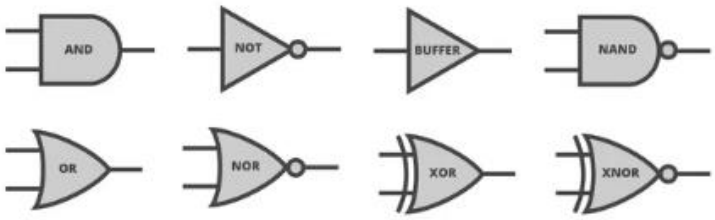


Figure 6

Operation of basic logic gates

- Logic gates are considered as building blocks of all logic circuits in digital systems.
- Logic gates operates by taking in signals (in our case **1**s and **0**s) as inputs. These signals are like answers to questions (usually **true** or **false** answers).
- The logic gates will make their own answer based on these signals.
- Depending on the type of the gate being used the answer might be **true (1)** if certain **conditions** are met, or **false (0)** if the conditions are not met.

Truth tables for basic logic gates

- A **truth table** is a simple and organized way to show how a logic gate behaves for all possible combinations of given inputs.
- A truth table **list every possible input combination along with the corresponding output of the given logic gate**.
- This table provide a **clear** and **systematic** way of understanding the operations of a particular given logic gate and also **helps to analyze** how a logic gate processes given input signals to generate output signals.
- **Note:** The number of rows in a truth table is calculated by:

  Number of rows = 2^n

  where n is the number of inputs to the logic gate.
- The next slide shows examples of logic gates and their respective truth tables.

Truth tables for basic logic gates

- Consider the **OR gate** below and its truth table:

OR Gate

Y = A + B

INPUT		OUTPUT (Y)
A	B	
0	0	0
0	1	1
1	0	1
1	1	1

- Consider the **AND gate** below and its truth table:

INPUT		OUTPUT (Y)
A	B	
0	0	0
0	1	0
1	0	0
1	1	1

AND Gate

Y = A . B

Truth tables for basic logic gates

- Consider the **NOR gate** below and its truth table:

NOR Gate

$Y = \overline{A + B}$

INPUT		OUTPUT (Y)
A	B	
0	0	1
0	1	0
1	0	0
1	1	0

- Consider the **NAND gate** below and its truth table:

INPUT		OUTPUT (Y)
A	B	
0	0	1
0	1	1
1	0	1
1	1	0

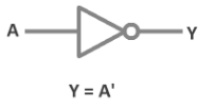
NAND Gate

$Y = \overline{A . B}$

Truth tables for basic logic gates

- Consider the **NOT gate** below and its truth table:

NOT Gate



Y = A'

INPUT A	OUTPUT (Y)
0	1
1	0

Quick activity 1

1. Discuss any **two** differences between a **NOT** gate and an **AND** gate. ***(4 marks)***
2. Construct a truth table for the logic gate shown in the figure below.

(8 marks)

Summary

- Logic gates are electronic switches which control the logical operations in digital systems such as computers.
- They operate by taking in inputs and then making a Boolean decision based on these inputs.
- We have the following basic logic gates **OR** gate, **AND** gate, **NOT** gate, **NOR** gate, and **NAND** gate.
- Truth tables are used to analyze the operation of a given logic gate by displaying all the possible input combinations and their corresponding outputs.
- Logic gates are applied in various electronic devices such as: smartphones, thermostats, Electronic door locks, Burglar alarms, Traffic lights control systems, remotes control…… and more.

Quiz

1. What is the output of an **OR** gate if both inputs are **0**? **(1)**
2. Describe the truth table for an **AND** gate with two input terminals. **(4)**
3. How does a **NAND** gate differ form an **AND** gate? **(2)**
4. Name any **two** electronic devices that use logic gates. **(2)**
5. **Figure 0** below shows an electronic circuit made up of logic gates.

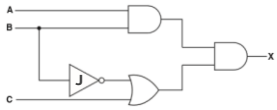


Figure 0

a. Name the logic gate marked **J**. **(1)**

b. Given the following truth table for the circuit in **Figure 0**, complete the truth table by give the correct **output** for the circuit: **(8)**

Inputs			**Output**
A	**B**	**C**	**X**
0	0	0	
0	1	0	
1	1	0	
1	1	1	