Chapter: 15

AN INTRODUCTORY OVERVIEW: FUNDAMENTALS OF LOGIC GATES

Sheeba*
Faculty, Glocal School of Science and Technology,
Glocal University, Saharanpur, U.P.
***Correspondence to:** sheeba@theglocaluniversity.in*

Mohd Nafees
Faculty, Glocal School of Science and Technology,
Glocal University, Saharanpur, U.P.
Email: mohd.nafees@theglocaluniversity.in

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ABSTRACT

A fundamental building component that applies a particular logical operation to one or more binary input signals (0 or 1) to produce a binary output in the context of computer science and digital electronics. These gates serve as the building blocks of digital circuitry and are used to design intricate digital systems. They are depicted using symbolic logic notations. In the ever-evolving landscape of digital technology, logic gates stand as the fundamental components that breathe life into the binary world of ones and zeros. They are the elemental logic operators that enable the transformation of abstract mathematical concepts into tangible digital reality. This abstract provides a glimpse into the world of logic gates, exploring their significance, principles, types, and diverse applications. In this chapter delves into the essence of logic gates, beginning with an introduction to the fundamental principles of logic and Boolean algebra. We unravel the binary nature of information representation and the elegance of Boolean logic, establishing a solid foundation upon which the rest of the chapter is built. The heart of our exploration lies in the various types of logic gates. From the straightforward AND gate that requires all inputs to be true for an output to be true, to the inclusive OR gate, and the ever-inverting NOT gate, we provide clear explanations, truth tables, and practical examples to demystify their behavior and utility. Furthermore, we delve into more complex gates like XOR and XNOR, unraveling their role in digital decision-making processes.

***Keywords**: Logic Gate Symbols, Binary Representation, Logic Gates, Basic Logic Gates, Building Blocks, Truth Tables*

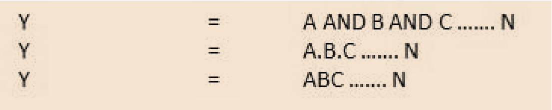
INTRODUCTION

Digital technology is what powers the modern world. Digital systems are found in everyday objects including cell phones, laptops, household appliances, and industrial machinery. These systems rely on the manipulation and processing of digital data, which can only be represented by the numbers 0 and 1. Digital electronics are built on this binary representation, and the logic gate notion sits at the core of this binary universe. Simple electronic devices called logic gates work with binary inputs to carry out fundamental logical processes. They take binary signals, which are frequently represented as voltage levels (high voltage for 1 and low voltage for 0), and, using a set of logical principles, produce a binary output. These guidelines specify how the result is calculated based on the inputs, and they help to form the foundation of the mathematical framework known as Boolean algebra, which powers digital logic. Since logic gates are the basic building blocks of digital circuits, understanding them is crucial. In turn, these circuits serve as the building blocks of contemporary digital and computational technology. Everything in the digital world, from microprocessors and memory chips to sophisticated control systems and communication devices, depends on logic gates to process and manipulate data.

We will explore deeper into each kind of logic gate, their truth tables, symbols, and use cases in the chapters that follow. As we set the foundation for a thorough understanding of digital electronics and computer science, we'll also look at how these gates can be integrated to create complex digital systems.

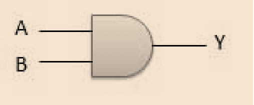
BASICS OF LOGIC GATES

i. **AND Gate:** This gate behaves as per the truth table. A HIGH output (1) results only if all the inputs to the AND gate are HIGH (1). If not all inputs to the AND gate are HIGH, LOW output results. A circuit which performs an AND operation is represented in figure. It has n input (n >= 2) and 1 output.

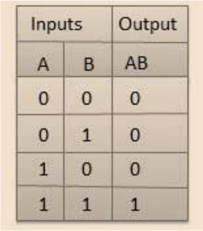


Y = A AND B AND C .... N
Y = A.B.C .... N
Y = ABC .... N

Logic diagram



Truth Table

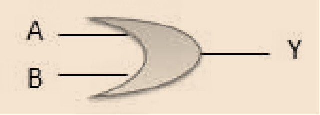


Inputs		Output
A	B	AB
0	0	0
0	1	0
1	0	0
1	1	1

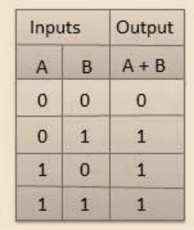
ii. **OR Gate:** A circuit which performs an OR operation is represented in figure. It has n input (n >= 2) and one output.

Y = A OR B OR C .... N
Y = A + B + C .... N

Logic diagram

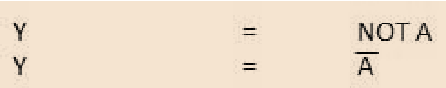


Truth Table



Inputs		Output
A	B	A + B
0	0	0
0	1	1
1	0	1
1	1	1

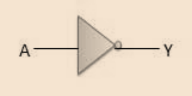
iii. **NOT Gate:** NOT gate is also referred as Inverter. It has one input A and one output Y.



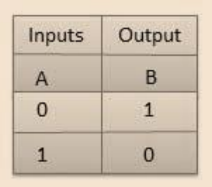
Y = NOT A

Y = $\overline{A}$

Logic diagram

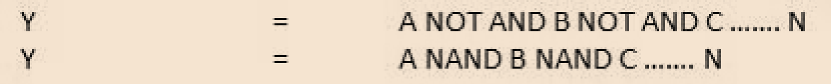


Truth Table



Inputs	Output
A	B
0	1
1	0

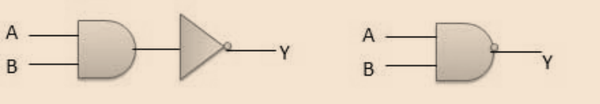
iv. **NAND Gate:** A NOT-AND operation is known as NAND operation. It has n input (n >= 2) and one output.



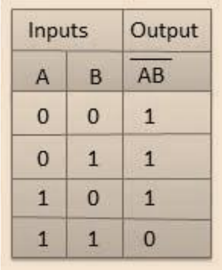
Y = A NOT AND B NOT AND C ……. N

Y = A NAND B NAND C ……. N

Logic diagram

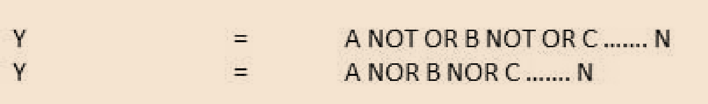


Truth Table

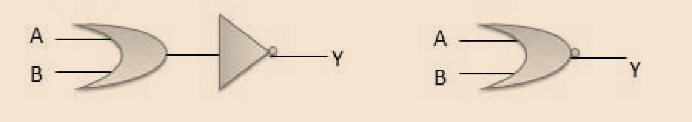


Inputs		Output
A	B	$\overline{AB}$
0	0	1
0	1	1
1	0	1
1	1	0

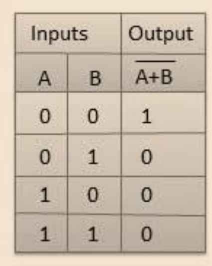
v. **NOR Gate:** A NOT-OR operation is known as NOR operation. It has n input (n >= 2) and one output.


Y = A NOT OR B NOT OR C .... N
Y = A NOR B NOR C .... N

Logic diagram

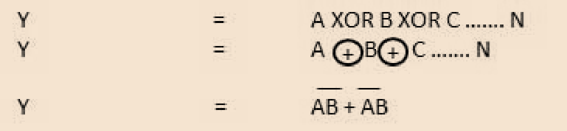


Truth Table

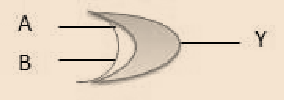


Inputs		Output
A	B	$\overline{A+B}$
0	0	1
0	1	0
1	0	0
1	1	0

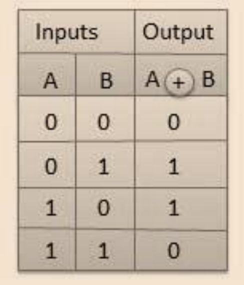
vi. **XOR Gate:** XOR or Ex-OR gate is a special type of gate. It can be used in the half adder, full adder and subtractor. The exclusive-OR gate is abbreviated as EX-OR gate or sometime as X-OR gate. It has n input (n >= 2) and one output.


Y = A XOR B XOR C .... N
Y = $A \oplus B \oplus C$ .... N
Y = $\overline{AB} + \overline{AB}$

Logic diagram

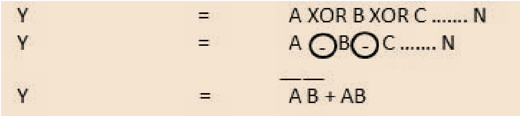


Truth Table



Inputs		Output
A	B	$A \oplus B$
0	0	0
0	1	1
1	0	1
1	1	0

vii. **XNOR Gate:** XNOR gate is a special type of gate. It can be used in the half adder, full adder and subtractor. The exclusive-NOR gate is abbreviated as EX-NOR gate or sometime as X-NOR gate. It has n input (n >= 2) and one output**.**

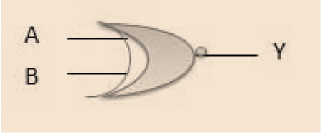


$$Y = A \text{ XOR } B \text{ XOR } C \ldots\ldots. N$$

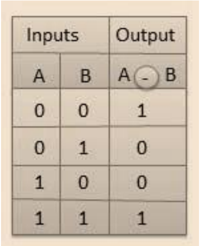
$$Y = A \odot B \odot C \ldots\ldots. N$$

$$Y = \overline{A}\,\overline{B} + AB$$

Logic diagram



Truth Table



Inputs		Output
A	B	$A \odot B$
0	0	1
0	1	0
1	0	0
1	1	1

LITERATURE REVIEW

We set out on a tour across the body of known information surrounding logic gates in this chapter. As the fundamental building blocks of digital circuitry, logic gates require a thorough literature examination to comprehend their historical evolution, theoretical underpinnings, and real-world applications. The development of logic gates can be credited to George Boole, whose Boolean algebra created the theoretical groundwork for digital logic in the middle of the 19th century. The fundamentals of logical operations like AND, OR, and NOT, which serve as the building blocks of logic gates, were first introduced by boolean algebra. One needs to understand the theoretical underpinnings of Boolean logic in order to understand logic gates. Early works by George Boole, such as "An Investigation of the Laws of Thought," continue to have an impact. The earliest implementations of logic gates were mechanical and electro-mechanical in nature. Claude Shannon's seminal thesis "A Symbolic Analysis of Relay and Switching Circuits" in 1937 marked a turning point. Shannon's work demonstrated that any Boolean expression could be realized using combinations of a few basic elements, laying the foundation for digital circuits. In the middle of the 20th century, logic gates and digital circuits underwent a rapid development. The invention of transistor-based digital logic, which led to the development of the first integrated circuits, and Howard H. Aiken's "The Design of Switching Circuits" are two key publications. The complexity and functionality of logic gates substantially increased with the development of integrated circuits. The first microchips were created thanks to ground-breaking work by Robert Noyce and Jack Kilby, changing the electronics sector.

CONCLUSION

In this chapter, we have explored the fundamental concept of logic gates, their historical significance, and the basic types of logic gates. These simple yet powerful devices serve as the foundation for digital logic design, enabling the creation of sophisticated electronic systems that power the modern world. In conclusion, the study of logic gates is a journey into the heart of digital technology—a journey that takes us from abstract mathematical principles to tangible real-world applications, and even beyond, into the uncharted territories of quantum computing. This chapter offers a thorough overview of the theoretical underpinnings, practical applications, and contemporary trends in the topic of logic gates. The following chapters of this book, which will go further into the particulars of individual logic gates, their applications, and useful design considerations, will build on this chapter as a foundation. The reading of this chapter has provided evidence of the importance of logic gates in creating the digital world and has opened the door to a deeper comprehension of their function in contemporary electronics and computing.

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