SAMSUNG SHIP DESIGN FOR HIGH SCHOOL

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WEEK 3

A Primer on Digital Logic and Reasoning

This document provides an introduction to fundamental concepts in digital logic, reasoning, and decision-making. It covers topics ranging from Boolean algebra and binary systems to the principles of automation and the universality of logic gates.

1. Introduction to the Science of Reasoning and Decision Making

Reasoning is the cognitive process of using existing knowledge to draw conclusions, make predictions, or construct explanations. It involves critical thinking, logical analysis, and problem-solving. Decision-making, closely intertwined with reasoning, is the act of choosing between two or more alternatives.

Key Aspects of Reasoning:

- **Deductive Reasoning:** Drawing specific conclusions from general principles. (e.g., "All men are mortal. Socrates is a man. Therefore, Socrates is mortal.")
- **Inductive Reasoning:** Generalizing from specific observations. (e.g., "The sun has risen every day in the past. Therefore, the sun will rise tomorrow.")
- **Abductive Reasoning:** Inferring the best explanation for an observed phenomenon. (e.g., "The grass is wet. It rained or the sprinkler was on. It didn't rain. Therefore, the sprinkler was on.")

Decision-Making Process:

1. **Identify the problem or decision.**
2. **Gather information and assess alternatives.**
3. **Evaluate options, considering potential risks and benefits.**
4. **Select the best course of action.**
5. **Implement the decision and monitor results.**

Examples of Reasoning and Decision-Making in Everyday Life:

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- **Medical Diagnosis:** Doctors use deductive and inductive reasoning to diagnose illnesses based on patient symptoms and test results.
- **Legal Arguments:** Lawyers employ deductive reasoning to construct legal arguments and present evidence in court.
- **Scientific Research:** Scientists use inductive reasoning to formulate hypotheses and interpret experimental data.
- **Everyday Choices:** Decisions like what to eat, where to go, or what to wear involve evaluating options and making choices based on preferences and constraints.

2. Introduction to Boolean Systems

A Boolean system is a system that deals with variables that can only have two possible values: true or false, 1 or 0, on or off. This concept is fundamental to digital electronics and computer science.

Key Concepts:

- **Boolean Variables:** Variables that can only take on two values, typically represented as 0 and 1.
- **Boolean Operations:** Logical operations that combine Boolean variables. Common operations include:
    - **AND:** Outputs 1 only if all inputs are 1.
    - **OR:** Outputs 1 if at least one input is 1.
    - **NOT:** Inverts the input value (0 becomes 1, and 1 becomes 0).
- **Boolean Expressions:** Combinations of Boolean variables and operations.

3. Introduction to the Binary System

The binary system is a number system that uses only two digits: 0 and 1. It is the foundation of modern computing, as computers operate on the principle of representing information using electrical signals that are either on (1) or off (0).

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Key Concepts:

- **Place Value:** Each digit in a binary number represents a power of 2. The rightmost digit represents 2^0, the next digit represents 2^1, and so on.
- **Binary to Decimal Conversion:** Multiply each digit by its corresponding power of 2 and sum the results.
- **Decimal to Binary Conversion:** Repeatedly divide the decimal number by 2 and record the remainder until the quotient is 0. The remainders, read from bottom to top, form the binary representation.

4. Fundamentals of Logic Combinations

Logic gates are the fundamental building blocks of digital circuits. They implement Boolean operations and determine the flow of information within a digital system.

Common Logic Gates:

- **AND Gate: Outputs 1 only when all inputs are 1.**
- **OR Gate: Outputs 1 if at least one input is 1.**
- **NOT Gate: Inverts the input value.**
- **NAND Gate: Outputs 0 only when all inputs are 1 (NOT AND).**
- **NOR Gate: Outputs 1 only when all inputs are 0 (NOT OR).**
- **XOR Gate: Outputs 1 when the inputs are different**.

Truth Tables:

Truth tables are used to visualize the output of a logic gate or circuit for all possible input combinations. They provide a clear and concise representation of the gate's behavior.

Combinational Logic Circuits:

Combinational logic circuits are circuits whose output depends solely on the current input values. Examples include:

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- **Multiplexers:** Select one of multiple input signals based on a control signal.
- **Demultiplexers:** Distribute a single input signal to one of multiple output lines.
- **Adders:** Perform binary addition.
- **Decoders:** Convert a binary code to a set of individual signals.

5. Fundamentals of Automation Systems

An automation system is a system that uses technology to perform tasks with minimal human intervention. It often involves the use of sensors, actuators, and control systems.

Key Components:

- **Sensors:** Devices that measure physical quantities (e.g., temperature, pressure, light).
- **Actuators:** Devices that perform actions (e.g., motors, valves, switches).
- **Control Systems:** Systems that process sensor data and generate control signals for actuators.

Types of Automation Systems:

- **Programmable Logic Controllers (PLCs):** Widely used in industrial automation for controlling machinery and processes.
- **Robotics:** Systems that employ robots to perform tasks, such as manufacturing, assembly, and exploration.
- **Process Control Systems:** Used to monitor and control industrial processes, such as chemical production and oil refining.
- **Building Automation Systems:** Control building functions like heating, ventilation, and air conditioning.

6. Introduction to Boolean Algebra and Arithmetic

Boolean algebra is a branch of algebra that deals with Boolean variables and operations. It provides a formal framework for analyzing and simplifying Boolean expressions.

Key Concepts:

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- **Boolean Laws:** Fundamental rules that govern Boolean algebra, such as the commutative, associative, and distributive laws.
- **Boolean Theorems:** Derived from Boolean laws, these theorems provide useful relationships between Boolean expressions.
- **Boolean Functions:** Functions that map Boolean inputs to Boolean outputs.

Boolean Arithmetic:

Boolean arithmetic involves performing arithmetic operations on binary numbers. It includes operations like addition, subtraction, multiplication, and division, adapted for the binary system.

7. Introduction to Truth Tables

Truth tables are tabular representations that show the output of a logic gate or circuit for all possible input combinations. They are essential tools for analyzing and verifying the behavior of digital circuits.

AND Truth Table

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

OR Truth Table

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

XOR Truth Table

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

NOT Truth Table

A	B
0	1
1	0

Figure 1. Basic logic truth tables

Constructing Truth Tables:

1. **List all possible input combinations.**
2. **Determine the output for each input combination based on the logic gates or circuit.**

8. Introduction to De Morgan's Laws

De Morgan's laws are two important rules in Boolean algebra:

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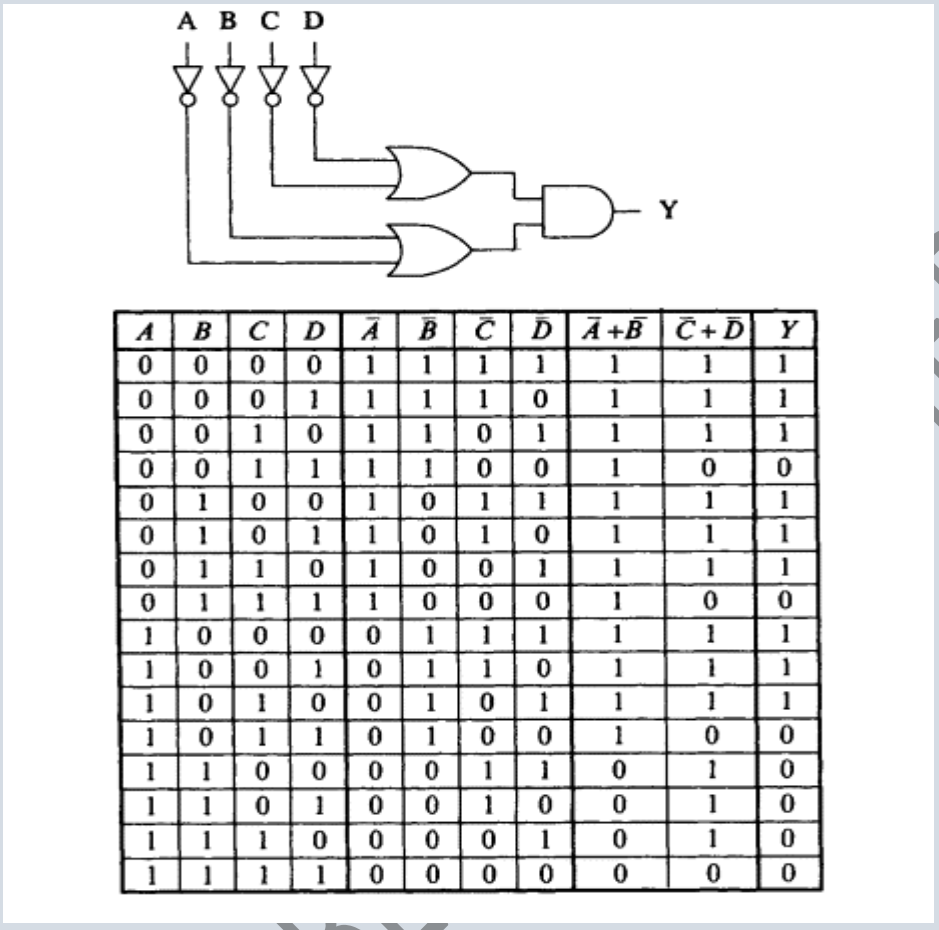
- **NOT (A AND B) = NOT A OR NOT B**
- **NOT (A OR B) = NOT A AND NOT B**

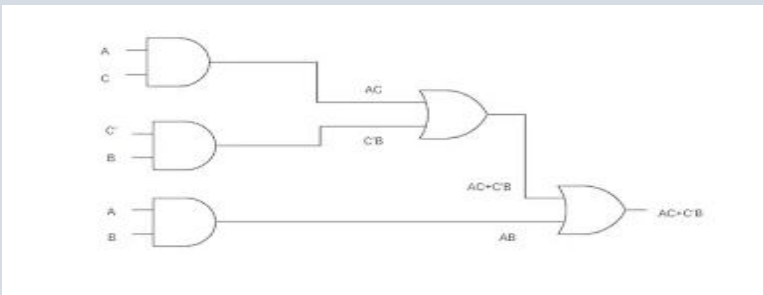


A	B	C	D	$\bar{A}$	$\bar{B}$	$\bar{C}$	$\bar{D}$	$\bar{A}+\bar{B}$	$\bar{C}+\bar{D}$	Y
0	0	0	0	1	1	1	1	1	1	1
0	0	0	1	1	1	1	0	1	1	1
0	0	1	0	1	1	0	1	1	1	1
0	0	1	1	1	1	0	0	1	0	0
0	1	0	0	1	0	1	1	1	1	1
0	1	0	1	1	0	1	0	1	1	1
0	1	1	0	1	0	0	1	1	1	1
0	1	1	1	1	0	0	0	1	0	0
1	0	0	0	0	1	1	1	1	1	1
1	0	0	1	0	1	1	0	1	1	1
1	0	1	0	0	1	0	1	1	1	1
1	0	1	1	0	1	0	0	1	0	0
1	1	0	0	0	0	1	1	0	1	0
1	1	0	1	0	0	1	0	0	1	0
1	1	1	0	0	0	0	1	0	1	0
1	1	1	1	0	0	0	0	0	0	0

These laws provide a way to express AND and OR operations in terms of each other using only the NOT operation.

9. Introduction to the Redundancy Theorem

The Redundancy Theorem states that any Boolean function can be implemented using only NAND gates or only NOR gates. This is significant because it demonstrates that NAND and NOR gates are "universal gates," meaning they can be used to construct any other logic gate.



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10. Visualizing "NAND" and "NOR" Operations as Universal Operations

NAND Gate as a Universal Gate:

By appropriately combining NAND gates, it is possible to implement any other logic gate:

- **NOT:** Connect both inputs of a NAND gate together.
- **AND:** Invert the output of a NAND gate.
- **OR:** Combine multiple NAND gates to implement the OR function.

NOR Gate as a Universal Gate:

Similarly, NOR gates can be combined to implement any other logic gate:

- **NOT:** Connect both inputs of a NOR gate together.
- **OR:** Invert the output of a NOR gate.
- **AND:** Combine multiple NOR gates to implement the AND function.

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