



College of Engineering Department of Software Engineering

Course Title: Embedded System

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Chapter 1: Introduction to digital logic

Outline

Chapter 1: Introduction to digital logic

- 1.1 Logic algebra
- 1.2 Logic circuits
- 1.3 Logic devices such as counters, timers and finite state machines

Chapter 1: Introduction to digital logic

- Digital logic forms the fundamental building blocks of embedded systems, providing the basis for the design and implementation of intelligent and controlled functionalities.
- Understanding digital logic is crucial for software engineers working on embedded systems, as it lays the foundation for efficient information processing, decision-making, and interfacing with the physical world.
- Digital logic is the language through which embedded systems communicate and process information.
- Its principles are integral to both hardware and software aspects of embedded system design, making it a fundamental area of study for software engineers working in this field.

1.1 Logic algebra

- Logic algebra, also known as Boolean algebra, is a mathematical structure and set of operations that deals with binary variables and logic operations.
- It plays a fundamental role in the design and analysis of digital circuits, computer systems, and electronic devices.
- The algebraic rules of logic algebra are based on the work of mathematician and logician George Boole.

Logic algebra...

➤ Key Concepts:

1. Binary Variables: In logic algebra, variables can only take on one of two values: 0 or 1. These values represent the absence (0) or presence (1) of a logical condition.
2. Logical Operations: Logic algebra includes several fundamental logical operations, each with specific rules and symbols
 - AND (Conjunction): denoted by \wedge or \cdot
 - Represents the logical product. The result is 1 only if both operands are 1.
 - OR (Disjunction): denoted by $+$ or \vee
 - Represents the logical sum. The result is 1 if at least one operand is 1.
 - NOT (Negation): denoted by \neg or $'$
 - Represents the logical complement. Flips the value of the operand (1 becomes 0, and 0 becomes 1).

Logic algebra...

3. Boolean Expressions: Boolean expressions are combinations of binary variables and logical operations.

➤ They can be used to represent and analyse the behaviour of digital circuits and systems.

4. Truth Tables: Truth tables are used to represent the output of a Boolean expression for all possible combinations of input values.

➤ They provide a systematic way to analyse and understand the behaviour of logical operations.

Logic algebra...

➤ Basic Laws of Logic Algebra:

1. Identity Laws:

- $A+0=A$
- $A \cdot 1=A$

2. Domination Laws:

- $1+A=A'$
- $0+A=A$

3. Idempotent Laws:

- $A+A=A$
- $A \cdot A=A$

4. Commutative Laws:

- $A+B=B+A$
- $A \cdot B=B \cdot A$

5. Associative Laws:

- $(A+B)+C=A+(B+C)$
- $(A \cdot B) \cdot C=A \cdot (B \cdot C)$

6. Distributive Laws:

- $A \cdot (B+C)=(A \cdot B)+(A \cdot C)$
- $A+(B \cdot C)=(A+B) \cdot (A+C)$

7. De Morgan's Laws:

- $(A+B)'=A' \cdot B'$
- $(A \cdot B)'=A'+B'$

Logic algebra...

➤ Applications of Logic Algebra:

1. Digital Circuit Design: Logic algebra is extensively used in designing and analysing digital circuits, including combinational and sequential circuits.
2. Computer Systems: The principles of logic algebra are fundamental to computer architecture, where they govern the operations of logic gates, arithmetic units, and memory units.
3. Boolean Functions: Logic algebra is employed to represent and manipulate Boolean functions, which are essential in software design, control systems, and decision-making processes.

Logic algebra...

4. Coding and Error Detection: Error detection and correction codes, such as parity bits, rely on logic algebra to ensure data integrity in communication systems.

5. Automated Systems: Logic algebra is applied in designing automated systems, including robotics and industrial control systems, to model and control system behaviour.

➤ Logic algebra provides a systematic and mathematical foundation for understanding and manipulating binary variables and logical operations, forming a cornerstone in the fields of digital design, computer science, and automation.

1.2 Logic circuits

- Logic circuits are electronic circuits that perform logical operations based on Boolean algebra.
- These circuits use digital signals (binary, consisting of 0s and 1s) to process and manipulate information.
- Logic circuits are the building blocks of digital systems, such as computers, microcontrollers, and other electronic devices, enabling them to perform complex tasks through the combination of simple logic gates.
- Key Components of Logic Circuits:
 1. Logic Gates: Logic gates are the fundamental building blocks of logic circuits. They perform basic logical operations (AND, OR, NOT) on binary inputs to produce a binary output.

Logic circuits...

➤ Common types of logic gates include:

- AND Gate:
 - Output is 1 only if both inputs are 1.
 - Symbol: $A \cdot B$ or AB
- OR Gate:
 - Output is 1 if at least one input is 1.
 - Symbol: $A + B$ or $A \cup B$
- NOT Gate:
 - Output is the inverse of the input.
 - Symbol: \overline{A} or $'A'$
- Other gates, such as NAND, NOR, and XOR, are derived from combinations of these basic gates.

Logic circuits...

2. Flip-Flops: Flip-flops are memory elements that store binary information.
 - They are crucial for sequential logic circuits, allowing the storage of data and the creation of memory elements in electronic systems.
3. Registers: Registers are collections of flip-flops used for temporary data storage.
 - They are vital for tasks like data transfer, arithmetic operations, and control in digital systems.
4. Multiplexers and Demultiplexers: Multiplexers select one of several input data lines and direct it to a single output line.
 - Demultiplexers perform the reverse operation, directing one input to several output lines.

Logic circuits...

5. Arithmetic Logic Units (ALUs): ALUs perform arithmetic and logic operations on binary numbers.

➤ They are integral components of processors and microcontrollers, handling tasks like addition, subtraction, AND, OR, and other operations.

6. Decoder and Encoder: Decoders convert binary information from one code to another, while encoders perform the opposite task.

➤ They are essential for tasks such as data compression and decompression.

Logic circuits...

Types of Logic Circuits:

1. Combinational Logic Circuits: These circuits produce an output based solely on the current input values.
 - The output is determined by the combination of logic gates and does not depend on the circuit's previous state.
2. Sequential Logic Circuits: Sequential logic circuits include memory elements, such as flip-flops, and the output depends on both the current input values and the circuit's previous state. These circuits have a notion of time and memory.

Logic circuits...

3. Digital Signal Processors (DSPs): DSPs are specialized processors designed for digital signal processing tasks, such as audio and image processing.

➤ They often incorporate specialized logic circuits for efficient computation.

4. Microprocessors and Microcontrollers: These are central processing units (CPUs) that form the core of computers and embedded systems.

➤ They include extensive logic circuitry to execute instructions, manage memory, and control peripherals.

Logic

circuits...

Applications of Logic Circuits:

1. Computer Processors: Logic circuits are the foundation of central processing units (CPUs) in computers, executing instructions and performing arithmetic and logic operations.
2. Memory Systems: Flip-flops and registers in logic circuits form the basis of memory systems in computers and other digital devices.
3. Control Systems: Logic circuits are used in control systems to manage and coordinate the operation of various components in industrial, automotive, and robotic applications.
4. Communication Systems: Logic circuits are employed in communication systems for tasks such as signal modulation, demodulation, and error detection and correction.

Logic

circuits...

5. Consumer Electronics: Devices like smartphones, TVs, and digital cameras utilize logic circuits for processing and controlling various functions.
 6. Automotive Electronics: Logic circuits play a crucial role in automotive control systems, managing functions like engine control, airbag deployment, and entertainment systems.
 7. Embedded Systems: In embedded systems, logic circuits control and coordinate various functions, making them integral to devices such as IoT devices, medical instruments, and industrial controllers.
- Logic circuits are essential components in the world of digital electronics, enabling the creation of sophisticated and intelligent systems by combining simple logical operations.
 - They form the backbone of digital technology, contributing to the functionality and efficiency of a wide range of electronic devices.

1.3 Logic devices such as counters, timers and finite state machines

- They are crucial components in digital systems and electronic circuits.
- They serve specific functions and play essential roles in controlling and sequencing operations.
- Let's explore each of these logic devices:

1. Counters: Counters are sequential logic circuits that count in a prescribed sequence. They can count up, down, or in a more complex pattern based on the application requirements.

➤ Types of Counters:

- Binary Counters: Count in binary sequence (000, 001, 010, ...).
- Decade Counters: Count in decimal sequence (0, 1, 2, ..., 9).
- Up Counters: Count upwards.
- Down Counters: Count downwards.

Logic devices ...

- Synchronous Counters: The state of each flip-flop is updated simultaneously.
- Asynchronous Counters: The state of each flip-flop is updated sequentially.

➤ Applications of Counters:

- Digital Clocks: Counters are used to keep track of time in digital clocks.
- Frequency Dividers: Dividing the frequency of a signal.
- Event Counters: Counting occurrences of events in industrial automation.

Logic devices ...

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2. Timers: Timers are devices that measure the duration of time intervals. They can be used for precise time control and scheduling of events.

➤Types of Timers:

- Monostable Multivibrators: Output stays high for a fixed duration after triggering.
- Astable Multivibrators: Produce a continuous square wave output.
- Digital Timers: Implemented using digital logic circuits for more accurate timing.

Logic devices ...

➤ Applications of timers:

- . Industrial Automation: Timers control processes and events in manufacturing.
- . Microcontroller-based Systems: Timers are often integrated into microcontrollers for various timing functions.
- . Automotive Systems: Used in vehicle control systems for functions like fuel injection timing.

Logic devices ...

3. Finite State Machines (FSMs): Finite State Machines model the behaviour of systems that can exist in a finite number of states. They transition between states based on inputs and current states.

➤ Types of FSMs:

- Moore Machines: The output depends only on the current state.
- Mealy Machines: The output depends on both the current state and inputs.

➤ Applications:

- Digital Circuit Design: FSMs are used to design control units for processors.
- Communication Protocols: FSMs model the behaviour of communication protocols.
- Traffic Light Controllers: FSMs control the sequence of traffic lights in an intersection.

Logic devices ...

➤ Key Components of FSMs:

- States: Represent different modes or conditions.
- Transitions: Define conditions triggering state changes.
- Inputs: External signals influencing state transitions.
- Outputs: Actions or signals produced by the FSM in different states.

➤ Common Characteristics of These Devices:

- Sequential Logic: They rely on sequential logic circuits, typically flip-flops, to store and update information.
- Digital Control: All these devices are designed to operate in a digital environment using binary signals (0s and 1s).
- Timing and Sequencing: They involve precise timing and sequencing of events, making them crucial in digital systems.

Logic devices ...

- Counters, timers, and finite state machines are integral components in digital systems, providing essential control and sequencing functions.
- They find applications in diverse areas, from simple digital clocks to complex control systems in industrial automation.

**End of Chapter
One!!!**