

UNIT 1

Introduction

(2 Hours) — Digital Logic (CACSI05)

Digital Logic is the foundation of all modern computing and digital electronic systems. This unit introduces the basic building blocks of digital systems — digital signals, digital logic and its operation, the role of digital computers and integrated circuits (ICs), and the clock waveform that synchronizes digital operations. A solid understanding of these concepts is essential before moving into number systems, Boolean algebra, and logic circuit design.

1.1 Digital Signals and Waveforms

A signal is a physical quantity (usually voltage) that carries information and varies with time. Based on how the quantity varies, signals are classified into two broad types:

Analog Signal — a continuous signal that can take on an infinite number of values within a given range. Voltage changes smoothly over time (e.g. sound waves, temperature readings).

Digital Signal — a discrete signal that can take on only a finite number of distinct values, most commonly two — HIGH (1) and LOW (0). It changes abruptly between these fixed levels rather than continuously.

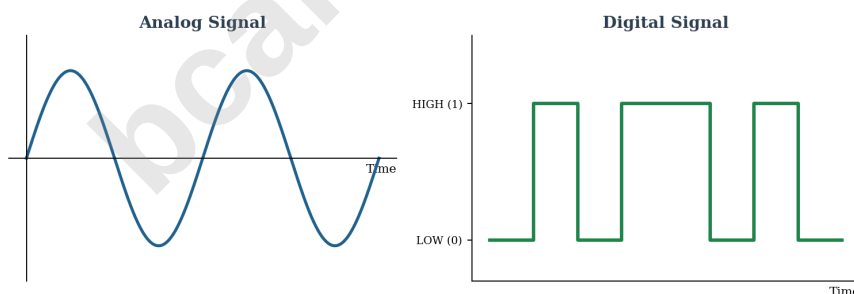


Fig. 1.1 — Analog signal (continuous) vs Digital signal (discrete levels)

A digital waveform is the graphical representation of a digital signal plotted against time. Because a digital signal has only two valid voltage levels, its waveform is made up of straight vertical and horizontal line segments, giving it a characteristic rectangular or “square-wave” shape. Some key waveform terms are:

Term	Meaning
HIGH level	The upper voltage level, typically representing binary 1 (e.g. +5V or +3.3V)
LOW level	The lower voltage level, typically representing binary 0 (e.g. 0V)
Rise time	Time taken for the signal to transition from LOW to HIGH

Term	Meaning
Fall time	Time taken for the signal to transition from HIGH to LOW
Pulse width	Duration for which the signal stays at the HIGH (or LOW) level

Note: In an ideal digital waveform, transitions between HIGH and LOW are assumed to be instantaneous, although in real circuits a small, finite rise/fall time always exists.

1.2 Digital Logic and Operation

Digital logic refers to the branch of electronics that deals with circuits operating on discrete binary values — 0 and 1 — rather than continuously varying quantities. These two values may represent TRUE/FALSE, ON/OFF, HIGH/LOW, or YES/NO depending on context. Digital logic forms the basis of Boolean algebra and the operation of all digital circuits.

The basic logical operations — AND, OR, and NOT — combine one or more binary inputs to produce a binary output, according to a fixed rule. The behaviour of a logic operation is usually summarized using a truth table, which lists the output for every possible combination of inputs.

Example 1.1 — Truth Table of the AND Operation

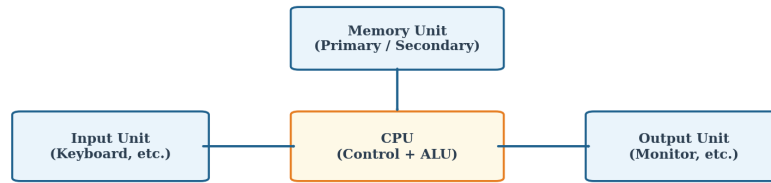
The AND operation gives an output of 1 only when both inputs are 1.

A	B	Output (A AND B)
0	0	0
0	1	0
1	0	0
1	1	1

Digital logic operation is important because it allows complex decision-making and computation to be built from very simple two-valued rules. By combining basic logic operations, engineers can design circuits that add numbers, store data, compare values, and control the sequencing of events inside a digital system.

1.3 Digital Computer and Integrated Circuits (IC)

A digital computer is an electronic device that processes data represented in binary (digital) form. It accepts input, processes it according to a stored set of instructions (a program), stores data, and produces output. At the block level, a digital computer consists of four cooperating units:



Digital computers process discrete (binary) signals using ICs built from logic gates

Fig. 1.2 — Basic block diagram of a digital computer

Input Unit — accepts data and instructions from the outside world (keyboard, mouse, sensors) and converts them into digital signals.

CPU (Control Unit + ALU) — interprets instructions, performs arithmetic/logic operations, and coordinates all other units.

Memory Unit — stores instructions and data, both temporarily (primary memory) and permanently (secondary memory).

Output Unit — converts processed digital data back into a form understandable to the user (monitor, printer, speaker).

1.2 Integrated Circuits (IC)

An Integrated Circuit (IC), also called a chip, is a small piece of semiconductor material (usually silicon) on which a complete electronic circuit — containing transistors, logic gates, resistors, and interconnections — is fabricated. ICs are the physical building blocks that implement digital logic inside a computer. Based on the number of logic gates (or transistors) packed onto a single chip, ICs are classified by their scale of integration:

Category	Approx. Gate Count	Typical Example
SSI — Small Scale Integration	1 – 10 gates	Basic logic gates (AND, OR, NOT)
MSI — Medium Scale Integration	10 – 100 gates	Adders, multiplexers, counters
LSI — Large Scale Integration	100 – 10,000 gates	Early microprocessors, small memories
VLSI — Very Large Scale Integration	> 10,000 gates	Modern microprocessors, RAM chips

Note: The trend from SSI toward VLSI reflects the continuous miniaturization of transistors, allowing far more logic to be packed into a chip of the same physical size — the basis of Moore's Law.

1.4 Clock Wave Form

Most digital systems do not operate continuously and randomly; instead, their operations are synchronized to a periodic timing signal called the clock. The clock is a special digital waveform that alternates repeatedly between HIGH and LOW at a fixed, known rate, and it acts as the “heartbeat” that coordinates when different parts of a digital circuit are allowed to change state.

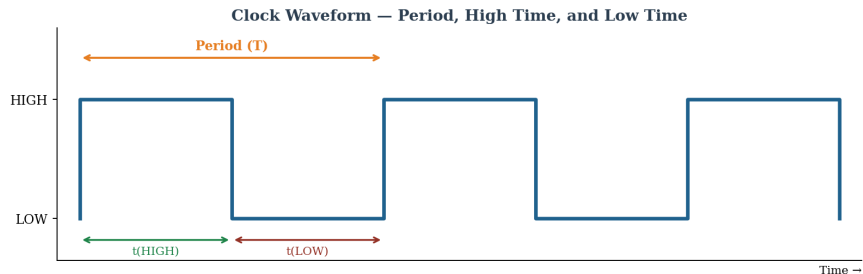


Fig. 1.3 — A periodic clock waveform showing period, HIGH time, and LOW time

The clock waveform is described using a few key parameters:

Parameter	Definition
Period (T)	Time taken to complete one full cycle (one HIGH + one LOW segment), measured in seconds
Frequency (f)	Number of cycles completed per second; $f = 1 / T$, measured in Hertz (Hz)
Duty Cycle	Percentage of one period during which the signal stays HIGH; a symmetric clock has a 50% duty cycle
Edge	The transition instant: rising edge (LOW→HIGH) or falling edge (HIGH→LOW)

Example 1.2 — Clock Frequency Calculation

A digital system uses a clock with a period $T = 0.5 \mu\text{s}$ (microseconds). Find its frequency.

Solution

$f = 1 / T = 1 / (0.5 \times 10^{-6})$ — using $f = 1/T$, we compute the reciprocal of the period.

$$f = 2 \times 10^6 \text{ Hz} = 2 \text{ MHz}$$

So the clock operates at a frequency of 2 MHz, meaning it completes 2 million cycles every second.

Note: Circuits that change state only on the rising or falling edge of the clock are called edge-triggered (synchronous) circuits, and they form the basis of registers, counters, and flip-flops studied in later units.

Key Takeaways

- ✓ Signals are classified as analog (continuous) or digital (discrete, two-level).
- ✓ A digital waveform represents a digital signal's HIGH/LOW levels over time.
- ✓ Digital logic operates on binary values (0, 1) using operations such as AND, OR, and NOT, summarized using truth tables.
- ✓ A digital computer has four basic units: Input, CPU, Memory, and Output.
- ✓ Integrated Circuits (ICs) implement digital logic on a chip and are classified as SSI, MSI, LSI, and VLSI based on gate density.
- ✓ The clock waveform synchronizes digital circuit operation; its key parameters are period (T), frequency ($f = 1/T$), and duty cycle.

— *End of Unit 1* —

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