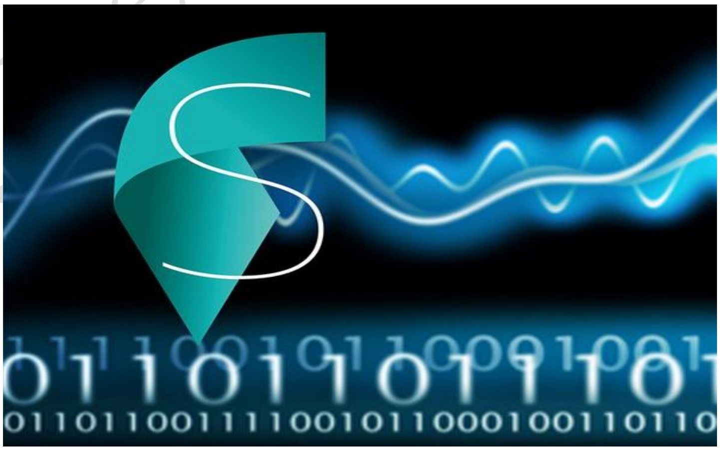
CYBER SECURITY TECHNOLOGY ENGINEERING DEPARTMENT

DIGITAL SIGNAL PROCESSING

THIRD STAGE

Lect.1 Signals, Systems, and Digital Signal Processing



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1. Introduction

This lecture introduces the fundamental concepts of signals, systems, and digital signal processing (DSP).

2. Signals, Systems, and Signal Processing

A signal is a function that conveys information about the behavior or attributes of some phenomenon. In engineering, a signal is defined as a physical quantity that varies with one or more independent variables such as time, space, or frequency. Mathematically, a signal can be expressed as a function s (t), where t represents time. These signals may be described mathematically, such as:

- s_1 (t) = 5t → A signal that grows linearly with time.
- s_2 (t) = $20t^2$ → A signal with quadratic growth.
- S(x, y) = 3x + 2xy + $10y^2$ → A two-dimensional signal.

- $s_1(t) = 5t$ or $s_1(t) = 5t^2$ → one variable
- $S(x,y) = 3x + 4xy + 6x^2$ → two variables x and y

In real-world applications, many signals are not easily expressed by simple functions. For example, a speech signal is highly complex and cannot be accurately described by basic equations. Instead, it can be approximated as a combination of sinusoidal components with varying amplitudes and frequencies.

Figure 1.1.1 shows an example of a speech signal:

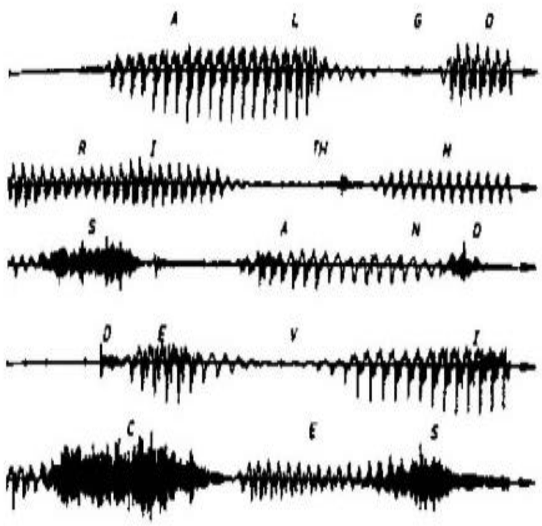
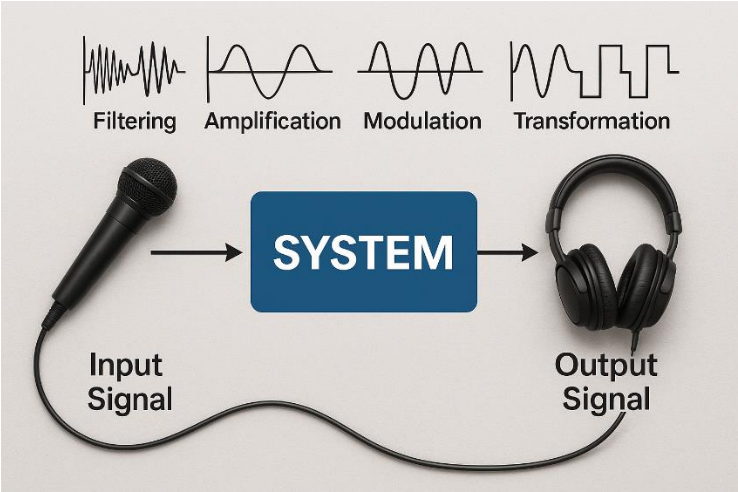


Figure 1.1.1
Example of a speech signal.

3. What is a System?

A system is any process that produces an output signal in response to an input signal. In signal processing, systems perform operations such as filtering, amplification, modulation, or transformation of signals.

For example, an audio equalizer is a system that filters frequency components of an audio signal.



4. Signal Processing

Signal processing refers to the analysis, manipulation, and interpretation of signals. There are **two main types of signal processing**: **analog and digital**. In analog signal processing, operations are carried out using continuous hardware components. In digital signal processing (DSP), operations are performed using algorithms executed on digital hardware such as microprocessors or digital signal processors.

5. Basic Elements of a Digital Signal Processing System

Most natural signals are analog and must be converted to digital form before digital processing. This is achieved through an Analog-to-Digital (A/D) converter, followed by a digital signal processor, and optionally a Digital-to-Analog (D/A) converter.

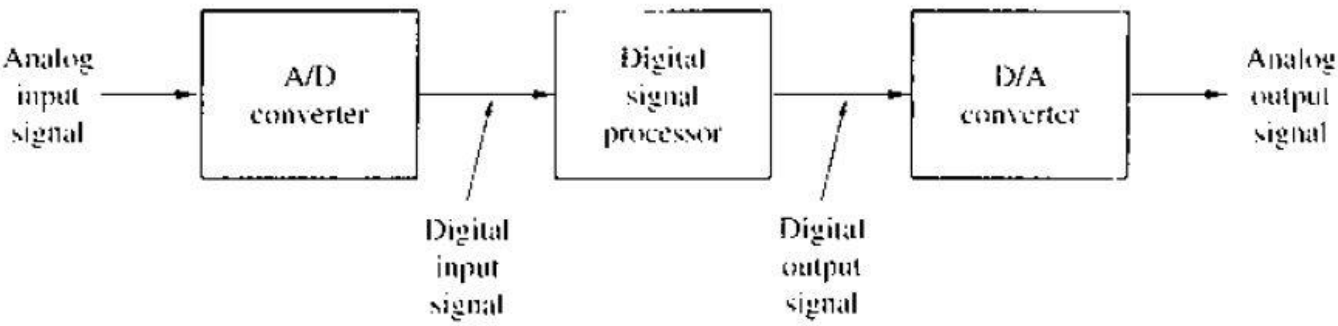


Figure 1.1.3 Block diagram of a digital signal processing system.

4. Advantages of Digital Signal Processing

Digital signal processing offers several advantages over analog processing:

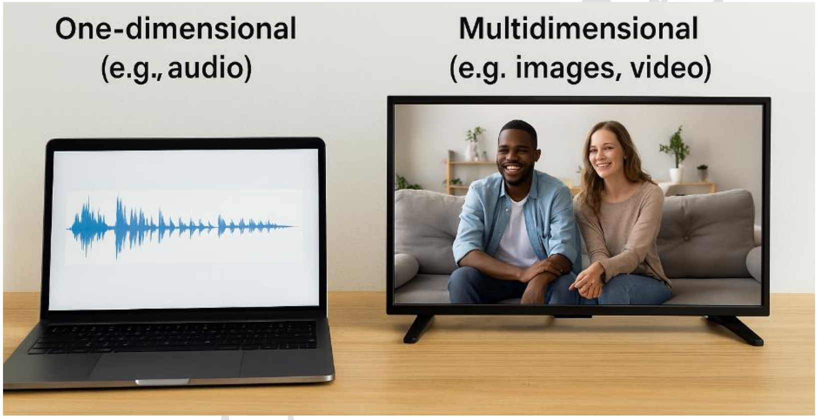
- Flexibility – Easily reprogrammed or updated.
- High precision – Better control over numeric computations.
- Storage – Easy to store, retrieve, and transmit.
- Reliability – Less affected by noise, and environmental conditions.
- Integration – DSP can be implemented on compact, low-power chips

5. Classification of Signals

Signals can be classified in multiple ways:

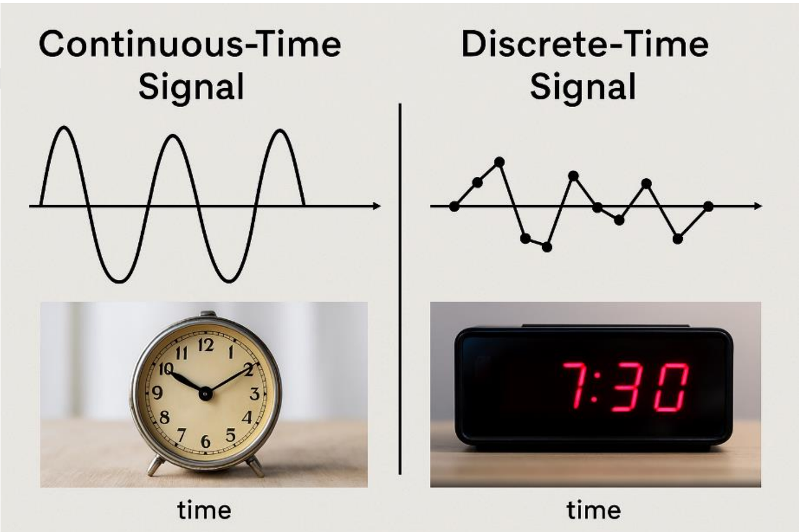
a) Based on the number of variables:

- One-dimensional (e.g., audio).
- Multidimensional (e.g., images, video).



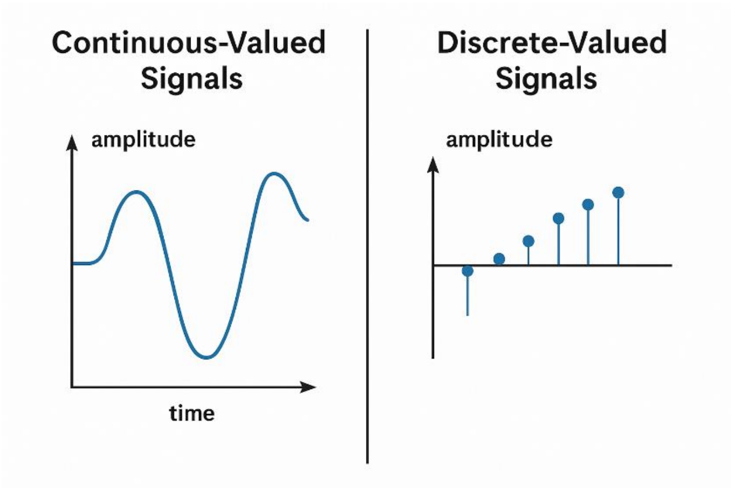
b) Based on time definition:

- Continuous-time signals – Defined for all time (analog).
- Discrete-time signals – Defined only at specific instances.



c) Based on amplitude range:

- Continuous-valued signals – Amplitude can take any value.
- Discrete-valued signals – Amplitude is quantized.



d) Based on predictability:

- Deterministic signals – Predictable and modeled by equations.
- Random signals – Unpredictable, modeled using probability.