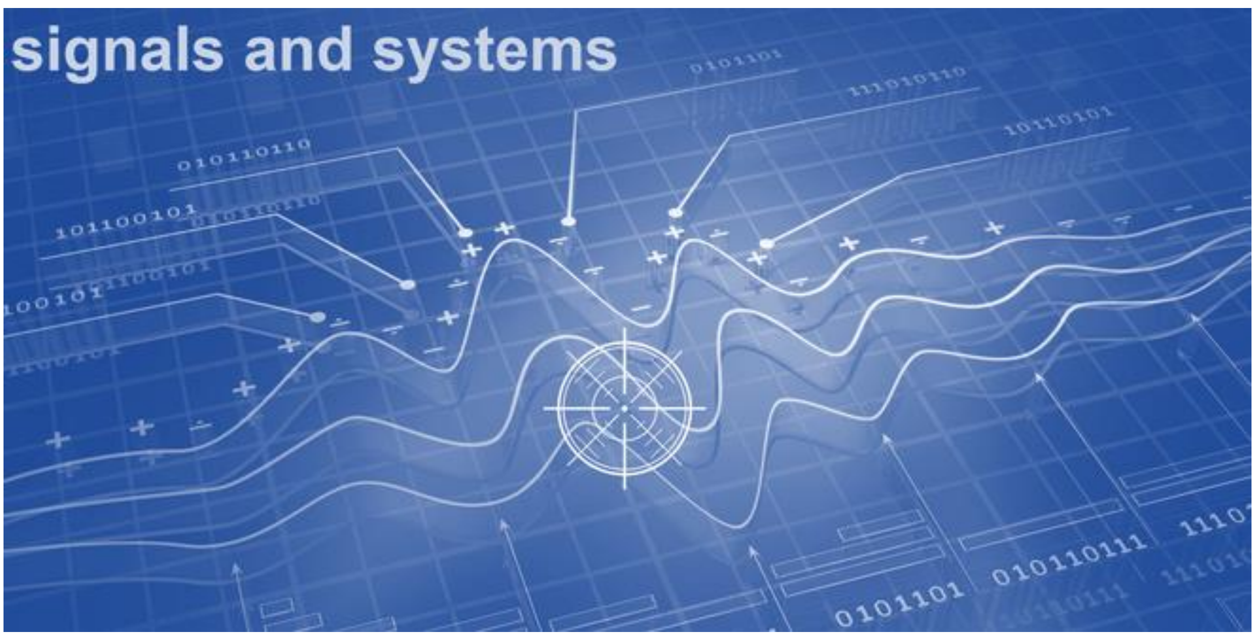
Al-Mustaqbal University
Department of Medical Instrumentation Techniques Engineering
Class: Third
Subject: Medical Communication Syatems
Lecturer: Prof. Dr. Bayan Mahdi Sabbar & M.Sc. Huda Wasfi Hassoon
Lecture:2

Lecture 2

Introduction to Signals and Systems



Lecturer: Prof. Dr. Bayan Mahdi Sabbar

M.Sc. Huda Wasfi Hassoon

Email: huda.wasfi@uomus.edu.iq

Al-Mustaqbal University
Department of Medical Instrumentation Techniques Engineering
Class: Third
Subject: Medical Communication Syatems
Lecturer: Prof. Dr. Bayan Mahdi Sabbar & M.Sc. Huda Wasfi Hassoon
Lecture:2

1.1 Introduction

The goal of this lecture is to introduce the fundamental concepts of signals and systems, laying the groundwork for upcoming lectures. We will explore these concepts in detail as follows.

Signals constitute an important part of our daily life. Anything that carries some information is called a signal. A signal is defined as a physical quantity that varies with time, space, or any independent variable. A signal may be represented in the time domain or frequency domain.

System is defined as a collection of interconnected elements or fundamental components that work together to produce an output in response to an input signal. Systems can be classified as either single-input, single-output (SISO) systems or multi-input, multi-output (MIMO) systems, depending on the number of inputs and outputs involved.

The process of communication involves:

- Generation of signal.
- Transmission of signal.
- Reception of signal.

1.2 Classification of Signals

Signals can be categorized into various classes. However, we will focus on the

Email: huda.wasfi@uomus.edu.iq

following specific classes, as they are essential for the upcoming lectures.

- Continuous-Time and Discrete-Time Signals.
- Analog and Digital Signals.
- Periodic and Aperiodic Signals.
- Even and Odd Signals.
- Deterministic and Random Signals.
- Energy and power signals.

1.2.1 Continuous-Time and Discrete-Time Signals

A signal is referred to as a continuous-time signal if it is defined for all values of the independent variable t. In contrast, a signal defined only at specific, discrete time intervals is known as a discrete-time signal.

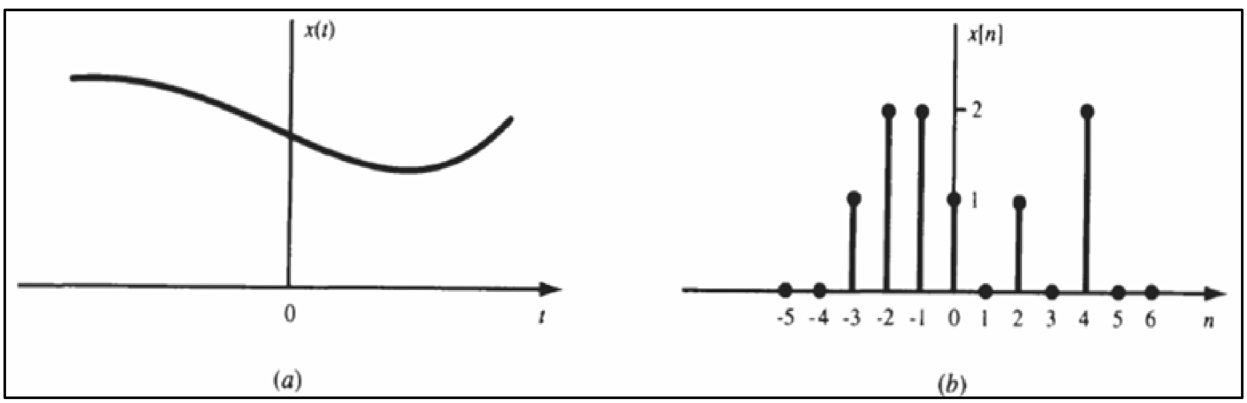


Fig. 1: Graphical representation of (a) continuous-time and (b) discrete-time signals.

Al-Mustaqbal University
Department of Medical Instrumentation Techniques Engineering
Class: Third
Subject: Medical Communication Syatems
Lecturer: Prof. Dr. Bayan Mahdi Sabbar & M.Sc. Huda Wasfi Hassoon
Lecture:2

1.2.2 Analog and Digital Signals

A second way to classify signals is based on their amplitude. Many real-world signals, such as voltage and current, vary continuously and are known as analog signals. In contrast, digital signals can only take on a finite set of amplitude values. A common example of a digital signal is a binary sequence.

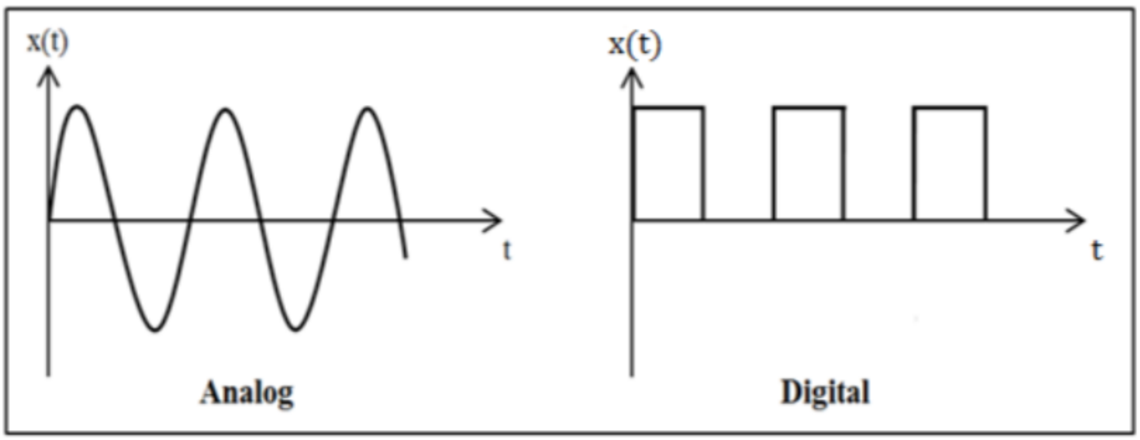


Fig. 2: Graphical representation of Analog and Digital signals.

1.2.3 Periodic and Aperiodic Signals

A signal which repeats itself after a specific interval of time is called Periodic signal, while a signal which does not repeat itself after a specific interval of time is called Aperiodic signal. In other word, a signal x(t) is Periodic signal if $x(t) = x(t + nT)$, where T is called the period and the integer $n > 0$. But if $x(t) \neq x(t + nT)$ then x(t) is a non-periodic or aperiodic.

Email: huda.wasfi@uomus.edu.iq

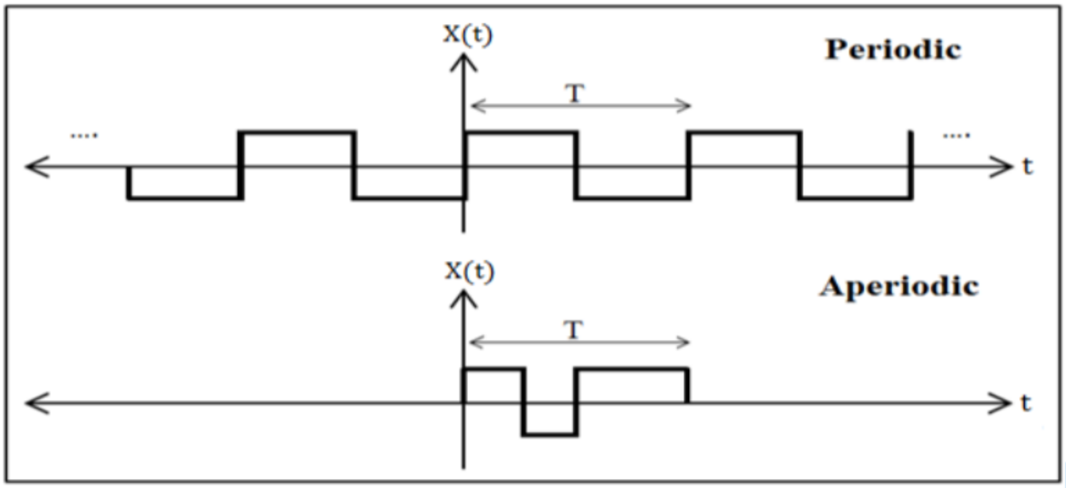


Fig. 3: Graphical representation of Periodic and Aperiodic signals.

1.2.4 Deterministic and Random Signals

If the value of a signal can be predicted for all time in advance without any error, it is referred to as a deterministic signal. Conversely, signals whose values cannot be predicted with complete accuracy for all time are known as random signals. Deterministic signals can generally be expressed in a mathematical, or graphical, form. Unlike deterministic signals, random signals cannot be modeled precisely.

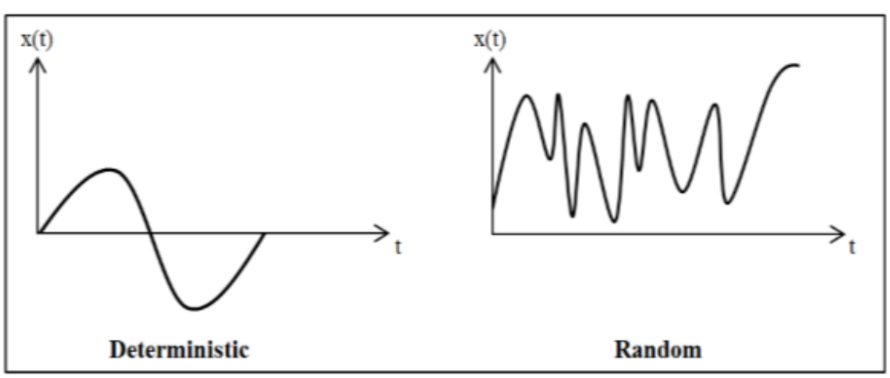


Fig. 4: Graphical representation of Deterministic and Random signals.

1.2.5 Even and Odd Signals:

A continuous-time signal $Xe(t)$ is said to be an even signal if:

$$X_e(t) = X_e(-t)$$

Conversely, a continuous-time signal $Xo(t)$ is said to be an odd signal if

$$X_o(t) = -X_o(-t)$$

From these equations, the even signal implies that an even signal is symmetric about the vertical axis ($t = 0$). Likewise, the odd signal implies that an odd signal is non-symmetric about the vertical axis ($t = 0$). In addition, there are signals does not exhibit any symmetry about the vertical axis. Such signals are classified in the "neither odd nor even" category.

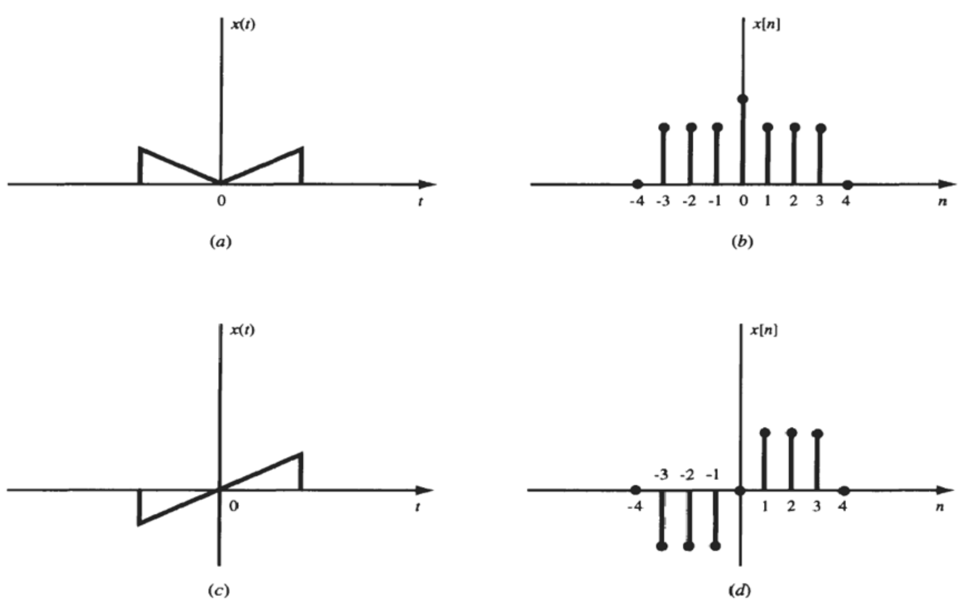


Fig. 5: Examples of **even** signals **(a and b)** and **odd** signals **(c and d)**.

Al-Mustaqbal University
Department of Medical Instrumentation Techniques Engineering
Class: Third
Subject: Medical Communication Syatems
Lecturer: Prof. Dr. Bayan Mahdi Sabbar & M.Sc. Huda Wasfi Hassoon
Lecture:2

1.2.6 Energy and Power Signals

An electrical signal can be represented as a voltage $v(t)$ or current $i(t)$ with instantaneous power $P(t)$ across a resistor R defined by:

$$P(t) = \frac{V^2(t)}{R} \quad \text{or} \quad P(t) = i^2(t)R$$

In communication systems, power is often normalized by assuming R to be 1Ω, although R may be another value in the actual circuit.

$$P(t) = x^2(t)$$

Where $x(t)$ is either a voltage or a current signal. The **energy** dissipated during the time interval $(-T/2, T/2)$ by a real signal with instantaneous power can then be written as:

$$E_g = \int_{-T/2}^{T/2} x^2(t)\, dt$$

And the **average power** dissipated by the signal during the interval is:

$$P_{av} = \frac{E_g}{T} = \frac{1}{T} \int_{-T/2}^{T/2} x^2(t)\, dt$$

We classify $x(t)$ as an **Energy signal** if, and only if, it has nonzero but finite energy $(0 < Eg < \infty)$ for all time, where

Email: huda.wasfi@uomus.edu.iq

$$E_g = \int_{-\infty}^{\infty} |x(t)|^2 dt$$

A signal is defined as a **Power signal** if, and only if, it has finite but nonzero power $(0 < Pav < \infty)$ for all time, where

$$P_{av} = \lim_{T\to\infty} \frac{1}{T} \int_{-T/2}^{T/2} |x(t)|^2 dt$$

The energy and power classifications are mutually exclusive. An energy signal has finite energy but zero average power, whereas a power signal has finite average power but infinite energy. Some signals are neither power nor energy signals.

Example1: Classify the following Signals:

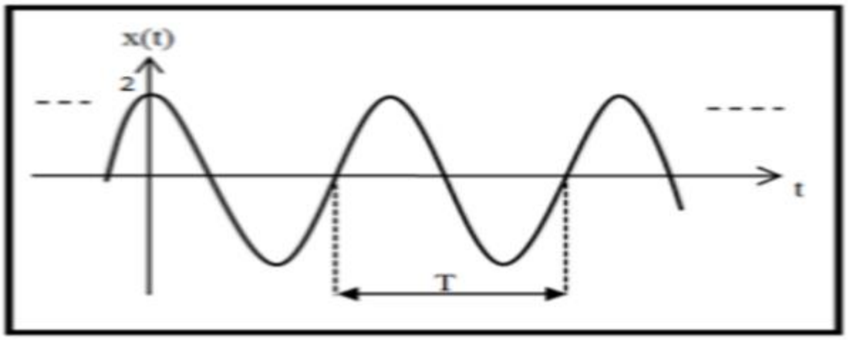
a. $x(t) = 2cos(3t)$

b. $x(t) = \begin{cases} 1 & 0 \leq t \leq 0 \\ 0 & otherwise \end{cases}$

Solution:

a. $x(t) = 2cos(3t)$

$$T = \frac{2\pi}{\omega} = \frac{2\pi}{3}$$



- ☑ **Continuous-Time**
- ☑ **Deterministic**
- ☑ **Analog**
- ☑ **Even**
- ☑ **Periodic**

Test Power:

$$P_{av} = \frac{1}{T}\int_{-T/2}^{T/2} |x(t)|^2 dt = \frac{1}{T}\int_{0}^{T} |x(t)|^2 dt$$

$$P_{av} = \frac{1}{T}\int_{0}^{T} 4cos^2(3t)dt$$

$$P_{av} = \frac{4}{T}\int_{0}^{T} \frac{1}{2}(1 + cos(6t))dt$$

$$P_{av} = \frac{2}{T}\int_{0}^{T} (1 + cos(6t))dt$$

$$P_{av} = \frac{3}{\pi}\int_{0}^{2\pi/3} (1 + cos(6t))dt$$

$$P_{av} = \frac{3}{\pi}[\int_{0}^{2\pi/3} 1dt + \int_{0}^{2\pi/3} cos(6t)dt$$

$$P_{av} = \frac{3}{\pi}[\left(\frac{2\pi}{3} - 0\right) + \frac{1}{6}(\sin(4\pi) - \sin(0))]$$

$$P_{av} = 2watt$$

Therefore $E_g = \infty$

- ☑ The signal is power signal

Test Energy

$$E_g = \int_{-\infty}^{\infty} |x(t)|^2 dt$$

$$E_g = \int_{-\infty}^{\infty} 4\, cos^2(3t)dt$$

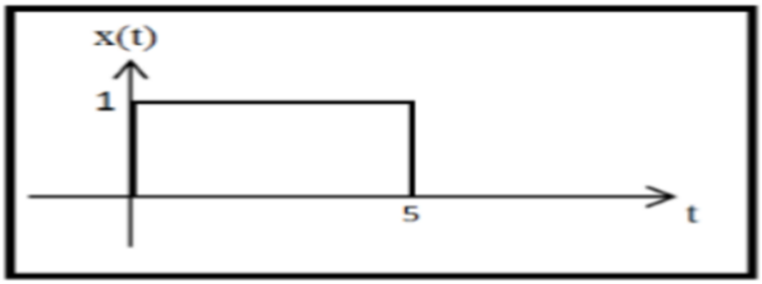
$$E_g = 4\int_{-\infty}^{\infty} \frac{1}{2}\,(1 + \cos(6t))dt$$

$$E_g = 2[\int_{-\infty}^{\infty} 1\, dt + \int_{-\infty}^{\infty} \cos(6t)\, dt]$$

$$E_g = \infty$$

Al-Mustaqbal University
Department of Medical Instrumentation Techniques Engineering
Class: Third
Subject: Medical Communication Syatems
Lecturer: Prof. Dr. Bayan Mahdi Sabbar & M.Sc. Huda Wasfi Hassoon
Lecture:2

b. $x(t) = \begin{cases} 1 & 0 \leq t \leq 5 \\ 0 & otherwise \end{cases}$



☑ Deterministic

☑ Aperiodic

☑ Neither odd nor even

Test Energy

$$E_g = \int_{-\infty}^{\infty} |x(t)|^2 dt$$

$$E_g = \int_{0}^{5} |1|^2 dt$$

$$E_g = \int_{0}^{5} 1 dt$$

$$E_g = 5 - 0 = 5 \; jouls$$

Therefore $P_{av} = 0$

☑ The signal is Energy signal

Email: huda.wasfi@uomus.edu.iq

Test Power

$$P_{av} = \lim_{T\to\infty} \frac{1}{T} \int_{-T/2}^{T/2} |x(t)|^2 dt$$

$$P_{av} = \lim_{T\to\infty} \frac{1}{T} \int_{0}^{5} |1|^2 dt$$

$$P_{av} = \frac{1}{\infty} [5] = 0$$

Assignment:

A continuous-time signal $x(t)$ is shown in Figure below. Classify this signal.