Instrumentation Engineering

Communication

Comprehensive Theory

with **Solved Examples** and **Practice Questions**

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Chapter 1

Introduction to Communication Systems

1.1 Historical Sketch

The development of communication technology has proceeded in step with the development of electronic technology as a whole. For example, the demonstration of telegraphy by Joseph Henry in 1832 and by Samuel F.B. Morse in 1838 followed hard on the discovery of electromagnetism by Oersted and Ampere early in 1820's. Similarly, Hertz's verification late in the 1880's of Maxwell's postulation (1873) predicting the wireless propagation of electromagnetic energy led within 10 years of the radio-telegraph experiments of Marconi and Popov. The invention of diode by Flaming in 1904 and of triode by deforest in 1906 made possible the rapid development of long distance telephony, both by radio and wireless.

1.2 Why Study Communication

The rapidly changing face of technology necessitates learning of new technology. Today the question is no longer in the field of invention but of innovation. The question today in the twenty first century in not how to transmit data from point A to point B but how efficiently can we do it. To be able to answer this question, first we should be able to diagnose the problem. This can be done only by studying communication from the beginning to its modern form.

1.3 What is Communication

In the most fundamental sense, communication involves implicitly the transmission of information from one point to another through a succession of processes, as described here:

1. The generation of a message signal: voice, music, picture, or computer data.
2. The description of that message signal with a certain measure of precisions, by a set of symbols: electrical, audio, or visual.
3. The encoding of these symbols in a form that is suitable for transmission over a physical medium of interest.
4. The transmission of the encoded symbols to the desired destination.
5. The decoding of the reproduction of the original symbols.
6. The re-creation of the original message signal, with a definable degradation in quality; the degradation is caused by imperfections in the system.

There are, of course, many other forms of communication that do not directly involve the human mind in real time. For example, in computer communications involving communication between two or more computers, human decisions may enter only in setting up the programs or commands for the computer, or in monitoring the results.

1.4 Communication Model

The study of communication becomes easier, if we break the whole subject of communication in parts and then study it part by part. The whole idea of presenting the model of communication is to analyse the key concepts used in communication in isolated parts and then combining them to form the complete picture.

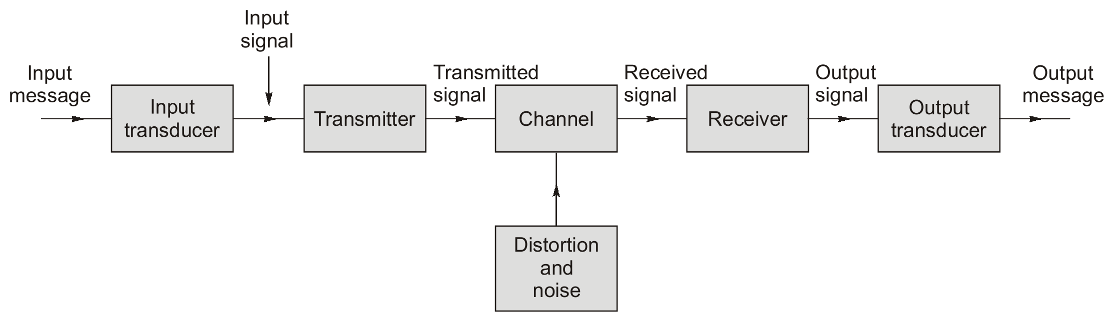


Figure-1.1 : *Model of communication system*

Source

The source originates a message, such as a human voice, a television picture, an e-mail message, or data. If the data is non-electric (e.g., human voice, e-mail text, television video), it must be converted by an **input transducer** into an electric waveform referred to as the **baseband signal** or **message signal** through physical devices such as a microphone, a computer keyboard or a CCD camera.

Transmitter

The transmitter modifies the baseband signal for efficient transmission. The transmitter may consist of one or more subsystems: an A/D converter, an encoder and a modulator. Similarly, the receiver may consists of a demodulator, a decoder and a D/A converter.

Channel

The channel is a medium of choice that can carry the electric signals at the transmitter output over a distance. A typical channel can be a pair of twisted copper wires (telephone and DSL), coaxial cable (television and internet), an optical fibre or a radio link. Channel may be of two types.

1. **Physical channel:** When there is a physical connection between the transmitter and receiver through wires. eg. coaxial cable.
2. **Wireless channel:** When no physical channel is present and transmission is through air. eg. mobile communication.

It is inevitable that the signal will deteriorate during the process of transmission and reception as a result of some distortion in the system, or because of the introduction of noise, which is unwanted energy, usually of random character, present in a transmission system, due to a variety of causes. Since noise will be received together with the signal, it places a limitation on the transmission system as a whole. When noise is severe, it may mask a given signal so much that the signal becomes undetectable and therefore useless. Noise may interfere with signal at any point in a communications system, but it will have its greatest effect when the signal is weakest. This means that noise in the channel or at the input to the receiver is the most noticeable.

Receiver

The receiver reprocesses the signal received from the channel by reversing the signal modifications made at the transmitter and removing the distortions made by the channel. The receiver output is fed to the output transducer, which converts the electric signal to its original form i.e. the message signal.

Destination

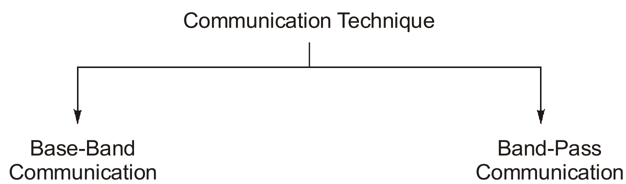
The destination is the unit to which the message is communicated.

1.5 Modes of Communication

There are two basic modes of communication:

1. **Broadcasting**, which involves the use of a single powerful transmitter and numerous receivers that are relatively inexpensive to build. Here information-bearing signals flow only in one direction.
2. **Point-to-point communication**, in which the communication process takes place over a link between a single transmitter and a receiver. In this case, there is usually a bidirectional flow of information-bearing signals, which requires the use of a transmitter and receiver at each end of the link.

1.5.1 Communication Technique



1. Base Band Communication:

It is generally used for short distance communication. In this type of communication message is directly sent to the receiver without altering its frequency.

2. Band Pass Communication:

It is used for long distance communication. In this type of communication, the message signal is mixed with another signal called as the carrier signal for the process of transmission. This process of adding a carrier to a signal is called as modulation.

1.5.2 Need of Modulation

1. To avoid the mixing of signals

   All messages lies within the range of 20 Hz - 20 kHz for speech and music, few MHz for video, so that all signals from the different sources would be inseparable and mixed up. In order to avoid mixing of various signals, it is necessary to translate them all to different portions of the electromagnetic spectrum.

2. To decrease the length of transmitting and receiving antenna

   For a message at 10 kHz, the antenna length 'l' for practical purposes is equal to $\lambda/4$ (from antenna theory) i.e.,

$$\lambda = \frac{3\times10^8}{10\times10^3} = 3\times10^4 \text{ m}$$

and

$$l = \frac{\lambda}{4} = \frac{3\times10^4}{4} = 7500 \text{ m}$$

   An antenna of this size is impractical and for a message signal at 1 MHz

$$\lambda = \frac{3\times10^8}{10^6} = 300 \text{ m}$$

and

$$l = \frac{\lambda}{4} = 75 \text{ m (practicable)}$$

3. To allow the multiplexing of signals

   By translating all signals from different sources to different carrier frequency, we can multiplex the signals and able to send all signals through a single channel.

4. To remove the interference
5. To improve the quality of reception i.e. increasing the value of S/N ratio
6. To increase the range of communication

1.6 Types of Modulation

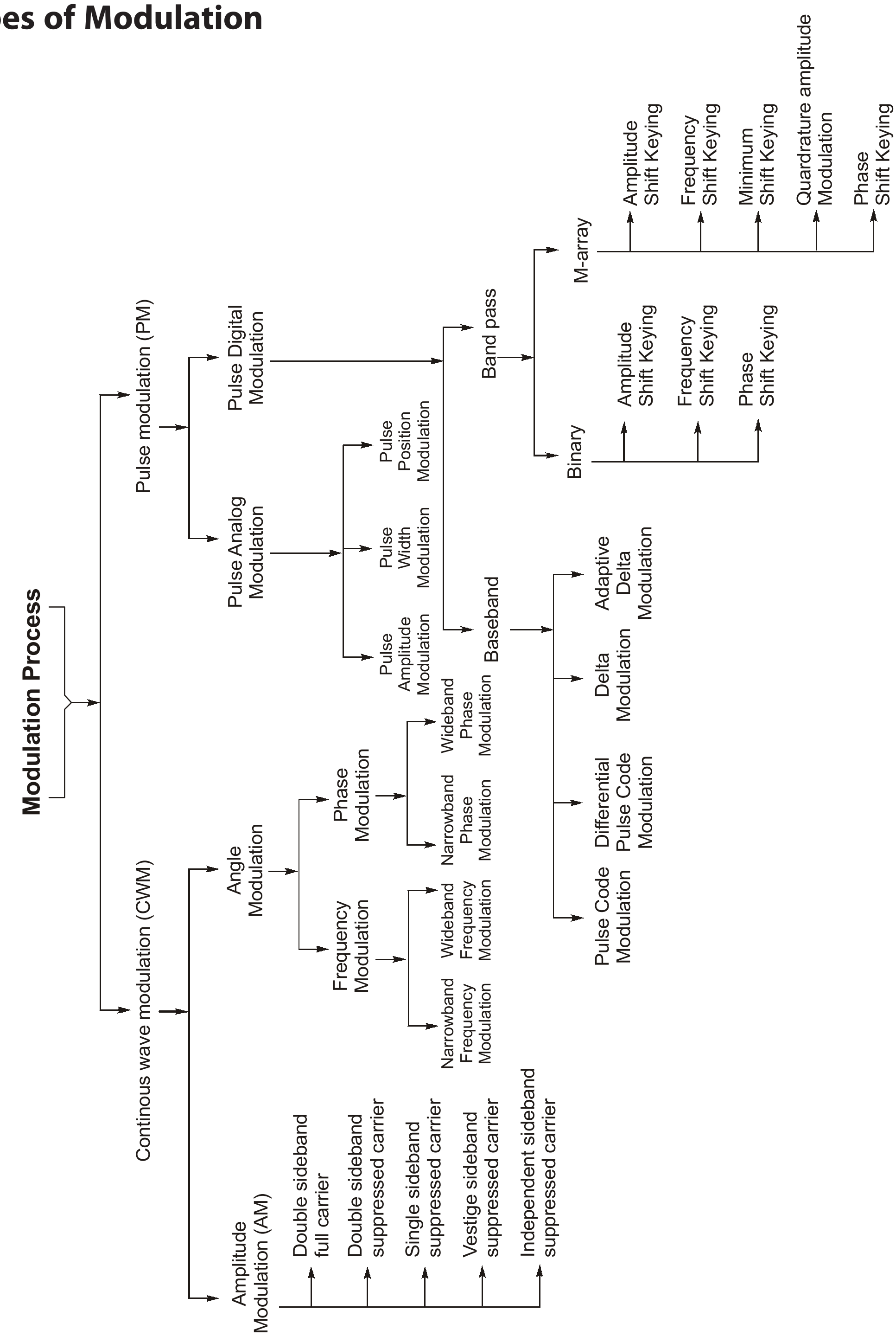


Figure-1.2

1.7 An Exam Oriented Approach

Communication is a modern technology is undergoing many changes. The main focus of a student should be to single out on optimum path in which he develops a theoretically strong background of the subject while keeping in mind that he should be able to solve questions asked in various exams using the theory they have studied. Focusing on one aspect leads to failure in written exam or in the interview. Thus this book and communication both have the same approach and that is "optimization" and being a communication engineer one should have this approach too.

Frequency (f) range	Wavelength (λ) range	EM Spectrum Nomenclature	Typical Application
30 – 300 Hz	$10^7 - 10^6$ m	Extremely low frequency (ELF)	Power line communication
0.3 – 3 kHz	$10^6 - 10^5$ m	Voice frequency (VF)	Face to face speech, communication intercom
3 – 30 kHz	$10^5 - 10^4$ m	Very low frequency (VLF)	Submarine communication
30 – 300 kHz	$10^4 - 10^3$ m	Low frequency (LF)	Marine communication
0.3 – 3 MHz	$10^3 - 10^2$ m	Medium frequency (MF)	AM broadcasting
3 – 30 MHz	$10^2 - 10^1$ m	High frequency (HF)	Landline telephony
30 – 300 MHz	$10^1 - 10^0$ m	Very high frequency (VHF)	FM broadcasting, TV
0.3 – 3 GHz	$10^0 - 10^{-1}$ m	Ultra high frequency (UHF)	TV, Cellular telephony
3 – 30 GHz	$10^{-1} - 10^{-2}$ m	Super high frequency (SHF)	Microwave oven, radar
30 – 300 GHz	$10^{-2} - 10^{-3}$ m	Extremely high frequency (EHF)	Satellite communication, radar
0.3 – 3 THz	0.1 – 1 mm	Experimental	For all new explorations
3 – 430 THz	100 – 0.7 μm	Infrared	LED, Laser, TV remote
430 – 750 THz	0.7 – 0.4 μm	Visible light	Optical communication
750 – 3000 THz	0.4 – 0.1 μm	Ultraviolet	Medical application
> 3000 THz	< 0.1 μm	X-rays, gamma rays, cosmic rays	Medical application

Table-1.1: *EM Spectrum*

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CHAPTER 2

Basics of Signal and System

Introduction

Just as a carpenter requires proper set of tools before he can sit down to make a piece of furniture, in a similar manner a communication engineer needs to know about signals before he can start the process of learning communication.

2.1 Signal and System

The communication technology can be conveniently broken down into three interacting parts.

- Signal processing operations performed.
- The device that performs these operations.
- The underlining physics.

Thus to study the basic form of modulation and signal processing used in the communication it will be fruitful to have a quick review of the concepts of signal and system.

2.1.1 Some Basic Signals

It will be very helpful to study some signals before hand, so that the analysis of the communication system becomes easier. Some important and frequently used signals and their properties are mentioned in this section.

The Impulse Signal

Impulse function is not a function in its strict sense. It is a distributed or generalized function. A generalized function is defined in terms of its effect on other function. The unit impulse function is generalised as any function that follow the following condition:

1. Impulse signal (Dirac delta function):

$$\delta(t) = \begin{cases} \infty ; & t = 0 \\ 0 ; & t \neq 0 \end{cases}$$

and
$$\int_{-\infty}^{\infty} \delta(t)dt = 1$$

2. Unit impulse signal:

$$\delta[n] = \begin{cases} 1 ; & n = 0 \\ 0 ; & n \neq 0 \end{cases}$$

Properties of Impulse Function

1. Product property

$$x(t)\,\delta(t) = x(0)\,\delta(t)$$

Similarly, $x(t)\,\delta(t-\alpha) = x(\alpha)\,\delta(t-\alpha)$

2. Shifting property

$$\int_{-\infty}^{\infty} x(t)\,\delta(t)dt = x(0)$$

Similarly,

$$\int_{-\infty}^{\infty} x(t)\,\delta(t-\alpha)dt = x(\alpha)$$

$$\int_{-\infty}^{\infty} \delta(t)dt = 1$$

3. Scaling property

$$\delta(\alpha t) = \frac{1}{|\alpha|}\delta(t)$$

Example 2.1 Find the impulse function form if $x(t) = 4t^2\,\delta(2t-4)$, where $x(t)$ is an arbitrary signal.

***Solution*:**

$$x(t) = 4t^2\,\delta(2t-4)$$
$$= 4t^2\,\delta\{2(t-2)\}$$
$$= 4t^2\cdot\frac{1}{2}\delta(t-2) \quad \text{... from scaling property}$$
$$= 2t^2\,\delta(t-2)$$

Now, from product property we have,

$$x(t)\,\delta(t-\alpha) = x(\alpha)\,\delta(t-\alpha)$$

So, $x(t) = 2t^2\big|_{t=2}\cdot\delta(t-2) = 8\,\delta(t-2)$

Example 2.2 Let $\delta(t)$ denote the delta function. The value of the integral $\int_{-\infty}^{\infty}\delta(t)\cos\left(\frac{3t}{2}\right)dt$ is

(a) 1 (b) –1 (c) 0 (d) $p/2$

***Solution*: (a)**

We know,

$$\int_{-\infty}^{\infty}\delta(t)\,x(t)\,dt = x(0)$$

So here, $\int_{-\infty}^{\infty}\delta(t)\cos\left(\frac{3t}{2}\right)dt = \cos 0 = 1$

Do you know? Impulse signals do not occur naturally but they are important functions providing a mathematical frame work for the representation of various processes and signals. These come under a special class of functions known as generalized functions.

Gate Function/Rectangular Pulse

Let us consider a rectangular pulse as shown in figure below:

$$x(t) = A\,\text{rect}(t) = \begin{cases} A, & \text{for } \frac{-1}{2} < t < \frac{1}{2} \\ 0 & \text{otherwise} \end{cases}$$

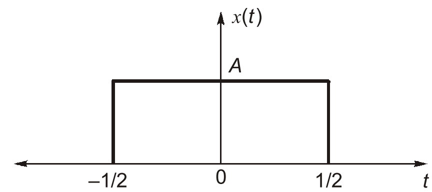


Figure-2.1

$$x(t) = A\,rect\left(\frac{t}{\tau}\right) = \begin{cases} A, & \text{for } \frac{-\tau}{2} < t < \frac{\tau}{2} \\ 0 & \text{otherwise} \end{cases}$$

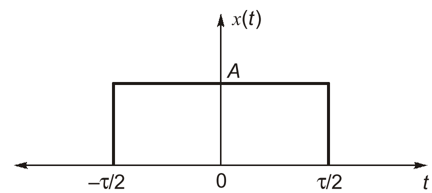


Figure-2.2

Step Signal

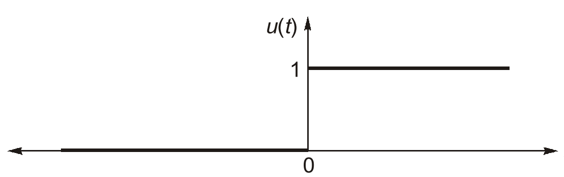


Figure-2.3 : *Continuous-time version of the unit-step function of unit amplitude*

The continuous-time version of the unit-step function is defined by

$$u(t) = \begin{cases} 1; & t > 0 \\ 0; & t < 0 \end{cases}$$

NOTE

- Figure depicts the unit-step function $u(t)$. It is said to exhibit discontinuity at $t = 0$, since the value of $u(t)$ changes instantaneously from 0 to 1 when $t = 0$. It is for this reason that we have left out the equal sign in equation; that is $u(0)$ is undefined.
- Unit step function denote sudden change in real time and a frequency or phase selectivity in frequency domain.

There is one more definition of unit step function.

$$u(t) = \begin{cases} 0 & ; t < 0 \\ 1/2 & ; t = 0 \\ 1 & ; t > 0 \end{cases}$$

Properties of Unit-Step Function

1. $u(t - t_0) = [u(t - t_0)]^2 = u[u(t - t_0)]^k$, with k being any positive integer.

2. $u(at - t_0) = u\left(t - \frac{t_0}{a}\right); a > 0$

3. $\delta(t) = \dfrac{d}{dt}u(t)$

4. $u(t) = \int_{-\infty}^{t} \delta(\tau)\,d\tau = \begin{cases} 1, & t > 0 \\ 0, & t < 0 \end{cases}$

Do you know? The unit-step function $u(t)$ may also be used to construct other discontinuous waveforms. The value at $t = 0$ gives rise to Gibb's phenomenon when unit step function is constructed by sinusoidal signals.

Sampling/Interpolating/Sinc Function

The function $\dfrac{\text{"}\sin\pi x\text{"}}{\pi x}$ is the **"sine over argument"** function and it is denoted by "sinc (x)". It is also known as **"filtering function"**.

Mathematically,

$$\text{sinc}(x) = \frac{\sin \pi x}{\pi x} = Sa(\pi x)$$

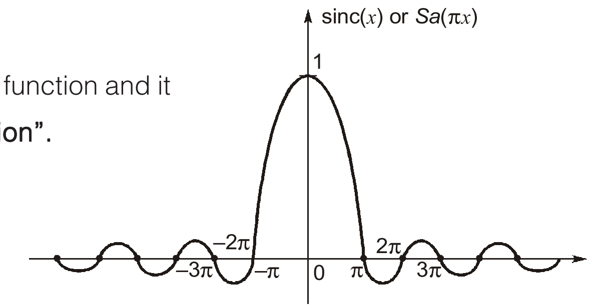


***Figure-2.4 :** Sinc Function*

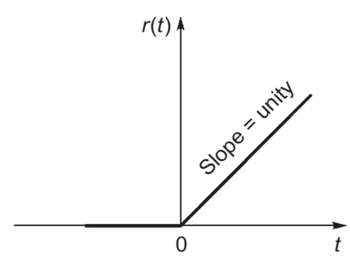
Do you know? Just like impulse function sinc (x) is also a conceptual function since it can not be realized.

The Unit-Ramp Function

The ramp function $r(t)$ is a linearly growing function for positive values of independent variable t. The ramp function shown in figure is defined by

$$r(t) = \begin{cases} t, & t \geq 0 \\ 0, & t < 0 \end{cases}$$

or $\quad r(t) = tu(t)$



The ramp function is obtained by integrating the unit step function

$$\int_{-\infty}^{t} u(\tau)\,d\tau = r(t)$$

The relationship between the impulse, step and ramp signals are represented below:

Remember: Relationship between impulse, step and ramp signals

$$\delta(t) \xrightarrow{\text{Integrate}} u(t) \xrightarrow{\text{Integrate}} r(t)$$

$$r(t) \xrightarrow{\text{Differentiate}} u(t) \xrightarrow{\text{Differentiate}} \delta(t)$$

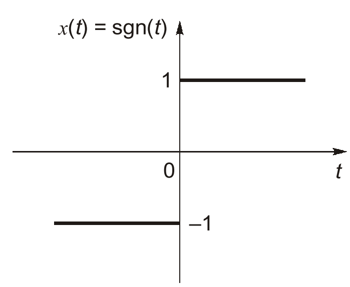
Unit Signum Function

The unit signum function shown in figure is defined as follows

$$\text{sgn}(t) = \begin{cases} 1 & t > 0 \\ 0 & t = 0 \\ -1 & t < 0 \end{cases}$$

This function can be expressed in terms of unit step function as

$$\text{sgn}(t) = -1 + 2u(t)$$



Unit Signum Function

2.1.2 Signal-Classification

Continuous-Time and Discrete-Time signals

The signals that are defined at each instant of time are known as continuous time signals. However, if the signals are defined only at certain time instants, it is called as discrete-time signals.

Based upon above discussion, four combinations are possible:

- Continuous time continuous amplitude signal (Analog signal)
- Continuous time discrete amplitude signal (Quantized signal)
- Discrete time continuous amplitude signal (Sampled signal)
- Discrete time discrete amplitude signal (Digital signal)

Analog and Digital Signal

If the amplitude of the signal can take all possible values in its dynamic range, it is called as analog signal. On the other hand, a digital signal is one whose amplitude take some specific values in its dynamic range.

Periodic and Aperiodic Signals

A signal is said to be periodic if it repeats itself after a certain time interval. For a signal to be periodic, it must satisfy the following condition.

1. It should exist for all values of 't'.
2. $x(t) = x(t + T)$, where T is the least value after which the signal repeats itself.
3. The value of T should be a fixed positive constant.

'T' is referred as fundamental period.

Any signal which do not follow these conditions are termed as aperiodic signal.

NOTE

Periodicity of Signal $x_1(t) + x_2(t)$:

A signal $x(t)$ that is a linear combination of two periodic signals, $x_1(t)$ with fundamental period T_1 and $x_2(t)$ with fundamental period T_2 as follows:

$$x(t) = x_1(t) + x_2(t)$$

is periodic if, $\frac{T_1}{T_2} = \frac{m}{n}$ = a rational number

Period of $x(t)$, $T = nT_1 = mT_2$

or, $T = \text{LCM}(T_1, T_2)$

Deterministic and Random Signal

A signal is said to be deterministic, if they can be completely represented by a mathematical expression at any instance of time. Signals, which cannot be represented by any mathematical expression is called random signal.

Note: For analysis purpose random signal can also be approximated by their statistical property.

Energy Signals and Power Signals

$x(t)$ is an energy signal if

$0 < E < \infty$ and $P = 0$

where 'E' is the energy and 'P' is the power of the signal $x(t)$.

For a continuous-time signal (CTS),

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

For an energy signal, energy is finite while power is zero.

NOTE

If $x(t) \longrightarrow E$, [where, E is energy of $x(t)$]

then $x\left(\frac{t}{\alpha}\right) \longrightarrow \alpha E$

$x(\alpha t) \longrightarrow \frac{E}{\alpha}$

$ax(t) \longrightarrow a^2E$

$x(t)$ is a Power Signal if

if, $0 < P < \infty$ and $E = \infty$

where E = Energy of signal $x(t)$

P = Power of signal $x(t)$

Almost all the practical periodic signals are **"power signals"**, since their average power is finite and non-zero. For a CTS, the average power of a signal $x(t)$ is,

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

NOTE

- If $x(t) = A \cos \omega t$ or $A \sin \omega t$, then $P_x = A^2/2$
- If $x(t) = Ae^{\pm j\omega t} \Rightarrow P_x = A^2$
- If $x(t) = A \Rightarrow P_x = A^2$
- If $x(t) \longrightarrow P$, then $x\left(\frac{t}{\alpha}\right) \longrightarrow P$

  $x(\alpha t) \longrightarrow P$ and $ax(\alpha t) \longrightarrow a^2P$
- For an **unit step signal**, $x(t) = u(t)$ and $P_x = \frac{1}{2}$

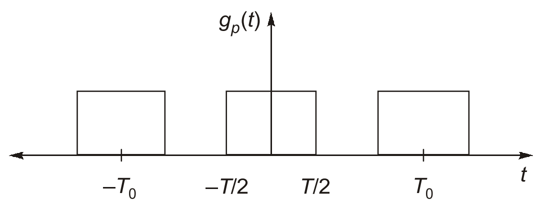
Energy Signal	Power Signal
1. The total energy is obtained using $E = \lim_{T\to\infty}\int_{-T}^{T}\lvert x(t)\rvert^2 dt$	The average power is obtained $P = \lim_{T\to\infty}\int_{-T}^{T}\frac{1}{2T}\lvert x(t)\rvert^2 dt$
2. For the energy signal, $0 < E < \infty$, and the average power $P = 0$	For the power signal, $0 < P < \infty$, and the energy $E = \infty$.
3. Non-periodic and finite duration signals are in general energy signals.	Periodic signals are power signals. However, all power signals need not be periodic.
4. Energy signals are time limited.	Power signals exist over infinite time.

Table-2.1

NOTE

From the analysis equation in trigonometric Fourier series we conclude that:
- The trigonometric Fourier series of an even function of time contains only D.C. term and cosine terms.
- The trigonometric Fourier series of an odd function of time contains only sine terms.

Example 2.3 Given a periodic signal $g_p(t)$ as shown the figure below.



Find the complex Fourier coefficient C_n.

***Solution*:**

$$g_p(t) = \begin{cases} A & -T/2 \le t \le T/2 \\ 0 & \text{for the remainder of the period} \end{cases}$$

Now,
$$C_n = \frac{1}{T_0}\int_{-T/2}^{T/2} A\exp\left(\frac{-i2\pi nt}{T_0}\right)dt$$

∴
$$C_n = \frac{A}{n\pi}\sin\left(\frac{n\pi T}{T_0}\right) \quad ; \quad n = 0, \pm 1, \pm 2 \ldots$$

Example 2.4 The Fourier series representation of an impulse train denoted by $s(t) = \sum_{n=-\infty}^{\infty} \delta(t - nT_0)$ is given by

(a) $\frac{1}{T_0}\sum_{n=-\infty}^{\infty} \exp -\left(\frac{j2\pi nt}{T_0}\right)$

(b) $\frac{1}{T_0}\sum_{n=-\infty}^{\infty} \exp -\left(\frac{j\pi nt}{T_0}\right)$

(c) $\frac{1}{T_0}\sum_{n=-\infty}^{\infty} \exp\left(\frac{j\pi nt}{T_0}\right)$

(d) $\frac{1}{T_0}\sum_{n=-\infty}^{\infty} \exp\left(\frac{j2\pi nt}{T_0}\right)$

***Solution*: (d)**

In this discrete case,

$$C_n = \frac{1}{T_0}$$

and we know that the Fourier series is represented as,

$$F.S = \sum_{n=-\infty}^{\infty} C_n\, e^{j\omega_0 kt} = \frac{1}{T_0}\sum_{n=-\infty}^{\infty} \exp\frac{j2\pi.nt}{T_0}$$

Student's Assignments 1

Q.1 A modulated signal is given by,

$s(t) = m_1(t)\cos(2\pi f_c t) + m_2(t)\sin(2\pi f_c t)$

where the baseband signal $m_1(t)$ and $m_2(t)$ have bandwidths of 10 kHz and 15 kHz, respectively. The bandwidth of the modulated signal, in kHz, is

(a) 10 (b) 15
(c) 25 (d) 30

Q.2 Let $\delta(t)$ denote the delta function. The value of the integral $\int_{-\infty}^{\infty} \delta(t)\cos\left(\frac{3t}{2}\right)dt$ is

(a) 1 (b) –1
(c) 0 (d) $\frac{\pi}{2}$

Q.3 If a signal $f(t)$ has energy E, the energy of the signal $f(5t)$ is equal to

(a) E (b) $\frac{E}{5}$
(c) $5E$ (d) $10E$

Q.4 The trigonometric Fourier series of an even function of time does not have

(a) the dc term (b) cosine terms
(c) sine terms (d) odd harmonic terms

Q.5 The trigonometric Fourier series of a periodic time function can have only

(a) cosine terms
(b) sine terms
(c) cosine and sine terms
(d) dc and cosine terms

Q.6 The expression of trigonometrical Fourier series coefficient b_n in terms of exponential Fourier series coefficient C_n is

(a) $j(C_n + C_{-n})$ (b) $j\left(\frac{C_n + C_{-n}}{2}\right)$
(c) $j(C_n - C_{-n})$ (d) $j\left(\frac{C_n - C_{-n}}{2}\right)$

Q.7 Consider a real time domain signal $x(t)$ whose Fourier transform is $X(j\omega)$. Which of the following properties are true:

(i) $\text{Even}\{x(t)\} \longleftrightarrow \text{Re}\{X(j\omega)\}$

(ii) $\text{Odd}\{x(t)\} \longleftrightarrow jIm\{X(j\omega)\}$

(iii) $x^*(t) \longleftrightarrow X^*(j\omega)$

(iv) $\int_{-\infty}^{t} x(\tau)\,d\tau \longleftrightarrow \frac{X(j\omega)}{j\omega}$

(a) (i) and (ii) (b) (i), (ii) and (iii)
(c) (i) and (iii) (d) All the above are true

Q.8 Consider two periodic signal $x_1(t)$ and $x_2(t)$, these signal can be represented in terms of linear combination of complex exponential as:

$$\text{If } x_1(t) = \sum_{k=-100}^{100} \cos(k\pi)e^{jk\left(\frac{2\pi}{50}\right)t}$$

$$\text{and} \quad x_2(t) = \sum_{k=-100}^{100} j\sin(k\pi)e^{jk\left(\frac{2\pi}{50}\right)t}$$

then which of the following option is true

(a) $x_1(t)$ is real and even
(b) $x_2(t)$ is real and even
(c) $x_1(t)$ and $x_2(t)$ are real and even
(d) $x_2(t)$ is imaginary and odd

Q.9 If $f(t)$ is an even function, then what is its fourier transform $F(j\omega)$?

(a) $\int_{0}^{\infty} f(t)\cos(2\omega t)dt$ (b) $2\int_{0}^{\infty} f(t)\cos(\omega t)dt$

(c) $2\int_{0}^{\infty} f(t)\sin(\omega t)dt$ (d) $\int_{0}^{\infty} f(t)\sin(2\omega t)dt$

Q.10 If the fourier transform of $f(t)$ is $f(j\omega)$, then what is the fourier transform of $f(-t)$?

(a) $f(j\omega)$
(b) $f(-j\omega)$
(c) $-F(j\omega)$
(d) complete conjugate of $f(j\omega)$

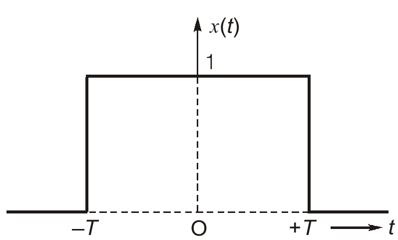
Q.11 The trigonometric fourier series expansion of an odd function shall have
(a) only sine terms
(b) only cosine terms
(c) odd harmonics of both sine and cosine terms
(d) none of the these

ANSWERS

1.	(d)	**2.**	(a)	**3.**	(b)	**4.**	(c)	**5.**	(c)
6.	(c)	**7.**	(a)	**8.**	(a)	**9.**	(b)	**10.**	(b)
11.	(a)								

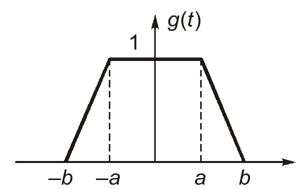
Student's Assignments 2

Q.1 For the rectangular pulse shown in the figure below, determine the Fourier Transform of $x(t)$ and sketch the magnitude spectrum with respect to frequency.



Q.2 State and prove convolution theorem in Fourier transform.

Q.3 Using time shifting and time differentiation properties, find the Fourier transform of the trapezoidal signal shown.



Q.4 State and explain Parseval's theorem.

Q.5 A white Gaussian noise is passed through an ideal bandpass filter with power spectral density of noise being a $\eta = \frac{N_0}{2}$. Derive the expression for the autocorelation function of the input and output noise.

ANSWERS

1. $X(j\omega) = \dfrac{2\sin\omega T}{\omega}$

3. $G(j\omega) = \dfrac{4}{\omega^2(b-a)}\sin\dfrac{\omega(a+b)}{2}.\sin\dfrac{\omega(b-a)}{2}$

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