POLITEKNIK MALAYSIA

KEMENTERIAN PENGAJIAN TINGGI

KOLEJ KOMUNITI MALAYSIA

INTRODUCTION SIGNAL AND SYSTEM

EMY SATIRA AZRIN MOHAMED HAKKE

ELECTRICAL ENGINEERING DEPARTMENT

POLITEKNIK SULTAN SALAHUDDIN ABDUL AZIZ SHAH

SIGNAL AND SYSTEM

INTRODUCTION SIGNAL AND SYSTEM

Author
Emy Satira Azrin Mohamed Hakke

Editor
Dr. Marlina Binti Ramli

SIGNAL AND SYSTEM
INTRODUCTION SIGNAL AND SYSTEM

EMY SATIRA AZRIN MOHAMED HAKKE

POLYTECHNIC SERIES

https://psa.mypolycc.edu.my/

SIGNAL AND SYSTEM
INTRODUCTION SIGNAL AND SYSTEM

EMY SATIRA AZRIN MOHAMED HAKKE

POLYTECHNIC SERIES

SIGNAL AND SYSTEM

INTRODUCTION SIGNAL AND SYSTEM

Emy Satira Azrin Mohamed Hakke

eISBN No: 978-967-2044-78-9

First Published in 2021 by:

UNIT PENERBITAN
Politeknik Sultan Salahuddin Abdul Aziz Shah
Persiaran Usahawan,
Seksyen U1,
40150 Shah Alam
Selangor

Telephone No. : 03 5163 4000
Fax No. : 03 5569 1903

PREFACE

Greeting To All.

We are very pleased to be given the opportunity to release the first edition of this book as a reference for students who are enroll in Diploma of Electrical Engineering Program.

The book contains a selected topic to signals and systems which includes subtopics of signal and system identification, signal classification, basic continuous and discrete time signals, basic operations and types of systems for students' understanding.

The book also provides exercises for students at the end of the topic.

Emy Satira Azrin Mohamed Hakke

Department of Electrical Engineering

Polytechnic of Sultan Salahuddin Abdul Aziz Shah

TABLE OF CONTENTS

CONTENTS

Definitions of SIGNAL

Signals are functions of time (continuous-time signals) or sequences in time (discrete-time signals) that are thought to reflect quantities of interest.

A signal is a collection of data information.

A signal processor that either modifies the signal or extracts data from the incoming signal. A signal is a function that represents a physical quantity and usually incorporates information about the phenomenons's behavior or nature.

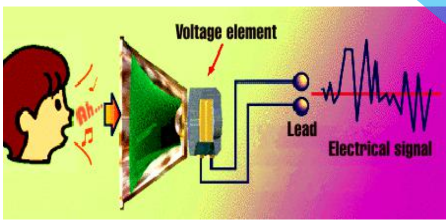


Figure 1.1: Electrical Signals Voltages and Currents in a circuit

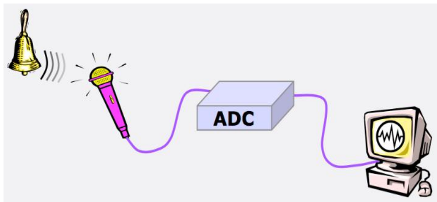
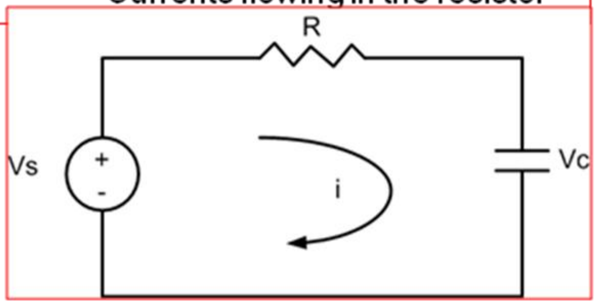


Figure 1.2: Acoustic signals pressure (sound) from time to time

Figure 1.3: Mechanical signals Velocity of a car from time to time

Ex: Electrical signals - Voltages across the capacitor
Currents flowing in the resistor



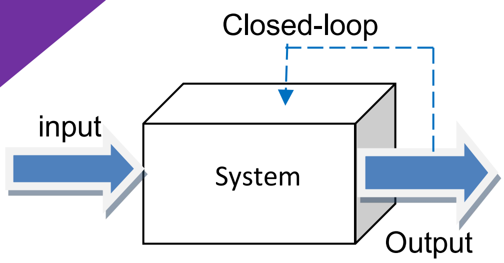


Figure 1.4: Process of System

Definitions of SYSTEM

The signal processor functions is to either change the signal or extract information from it once it has been received.

A physical device that generates a response or output signal in response to a particular input is referred to as a response generator.

To generate a new signal, it is necessary to go through the process of manipulating one or more signals in order to achieve a function.

A system is simply a function that has a domain and a range that is a set of time functions (or sequences in time) viewed from a more general point of view.

It is a tradition to use more interesting terms such as operator or mapping in place of functions, to describe such situations.

A transfer function is a function that connects a system output with an input signal and it is usually indicated by the symbol h (*).

For example: A system consists of an audio amplifier, attenuator, television, transmitter and receiver, among other components. A system can be any machine or engine.

Figure 1.5: Attenuator

Figure 1.6: Audio Amplifier

Figure 1.7: TV set

Signal and system relationship?

The Signals and Systems approach has wide applications such as in the use of electricity, mechanical, optical, acoustic, biological, financial, etc…..

The representation does not depend upon the physical substrate. It concentrates on information flow and abstracts away everything else. Component system representations can be simply merged.

Signal and system relationship:

There are one or more inputs in every system. (In particular, the application of energy to particles, objects, or physical systems)

Remember that a signal is an abstraction of a time-varying quantity of interest, while a system is an abstraction of a process that modifies that amount to produce a new time-varying quantity of interest.

There are one or more outputs in each system. It's known as response. The system's inputs and outputs are always signals.

CHAPTER 1A : Introduction of Signal and System

SIGNAL

- Signal classification and representation
  - Types of signals
  - Sampling theory
  - Quantization
- Signal analysis
  - Fourier Transform
    - Continuous time, Fourier series, Discrete Time Fourier Transforms, Windowed FT
  - Spectral Analysis

SYSTEM

- Linear Time-Invariant Systems
  - Time and frequency domain analysis
  - Impulse response
  - Stability criteria
- Digital filters
  - Finite Impulse Response (FIR)
  - Mathematical tools
    - Laplace Transform
      - Basics
    - Z- transform
      - Basics

For example

The form of component and composite systems is the same, and they are examined using the same methodologies.

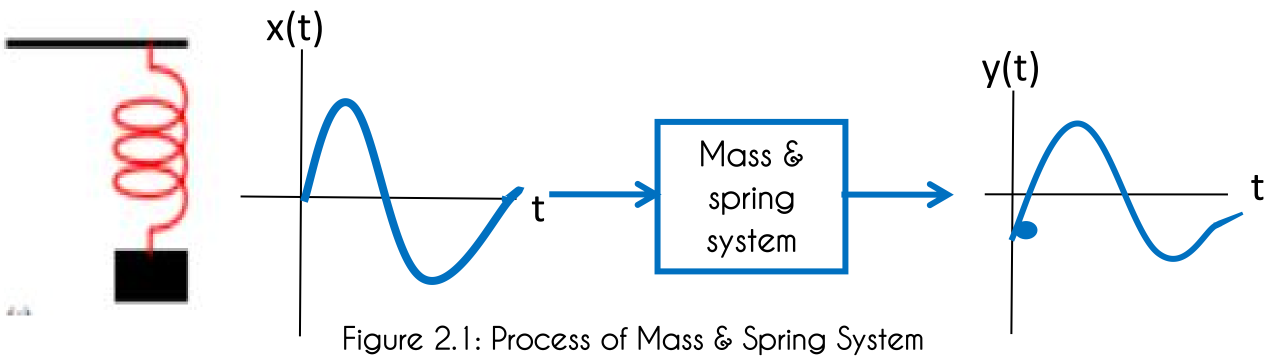


Figure 2.1: Process of Mass & Spring System

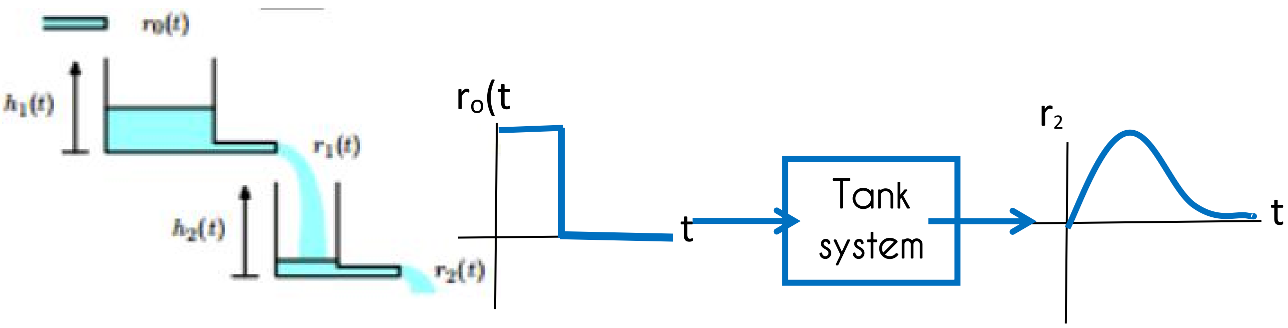


Figure: 2.2: Process of Tank System

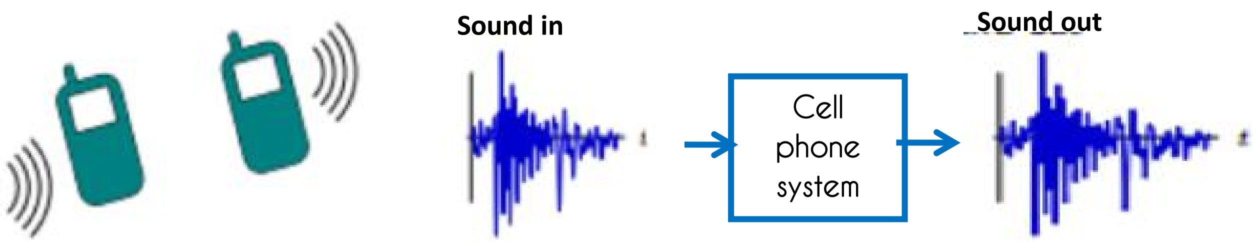


Figure 2.3: Process of Cell phone System

SIGNAL REPRESENTATION

Signals are represented mathematically as a **function** of one or more independent **variables**.

- Independent variable = time
- Dependent variable = voltage, flow rate and sound pressure

For example, the intensity of a black and white video stream is determined by x,y coordinates and time t,f, (x,y,t)

In this course, we will only be concerned with signals that are a function of a single variable: time.

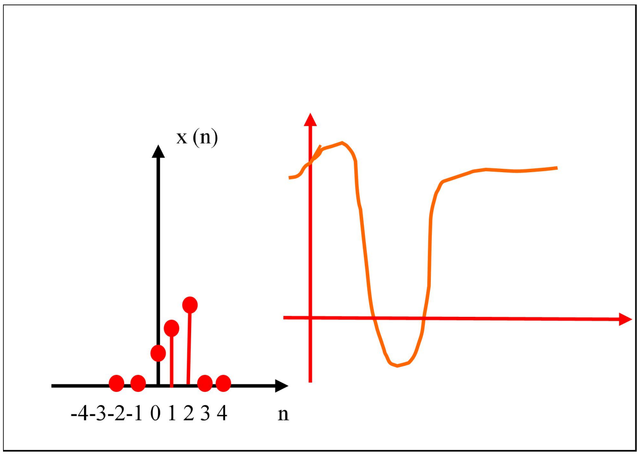


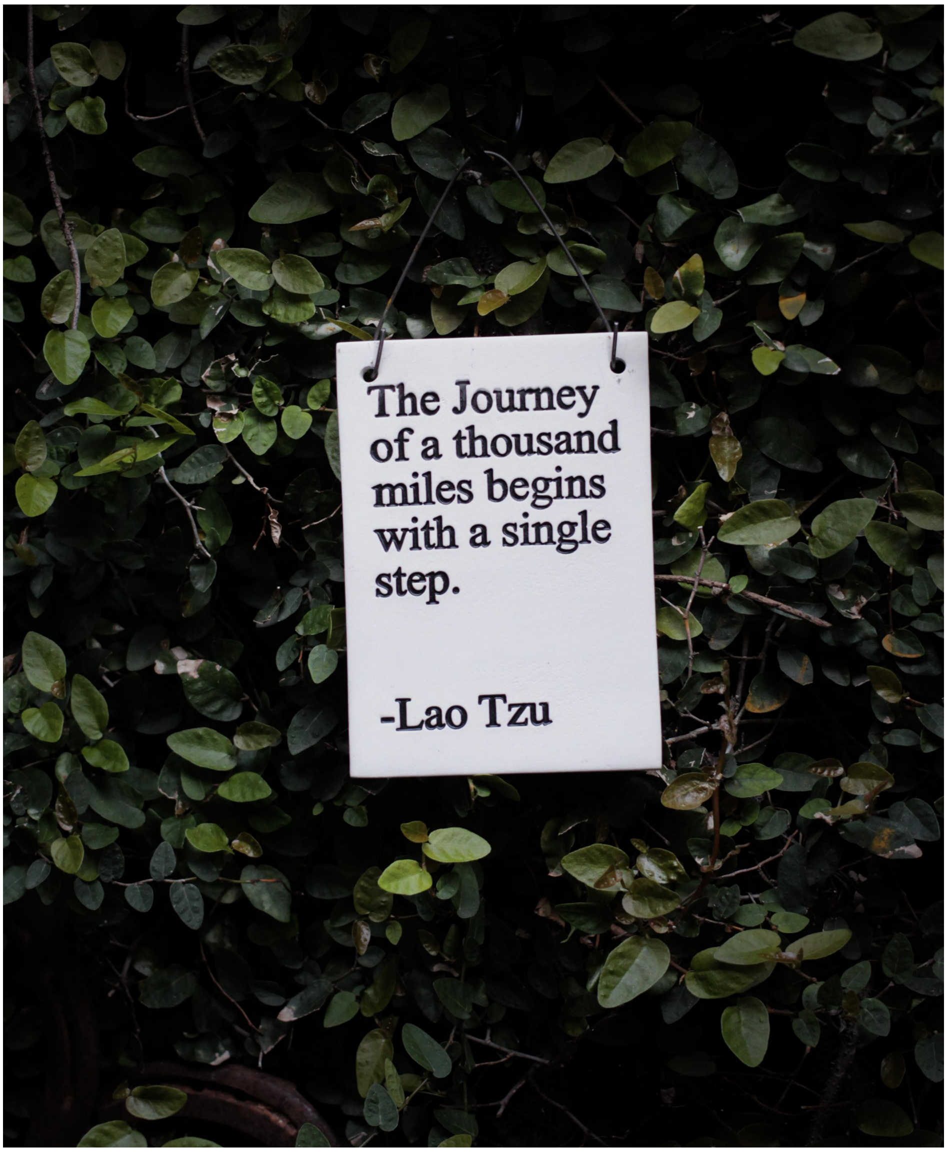
Figure 3.1: Graphical Representation

$$x[n] = \begin{cases} (\frac{1}{2})^n, & n \geq 0 \\ 0, & n < 0 \end{cases}$$

$$x[n] = \left\{ 1, \frac{1}{2}, \frac{1}{4}, ..., (\frac{1}{2})^n, \dots \right\}$$

$$x[n] = \begin{cases} 2, & n = 3,1 \\ 1, & n = 2 \\ 0, & n = -4, -3 \\ -1, & n = -2 \end{cases}$$

Figure 3.2: Function Representation


The Journey
of a thousand
miles begins
with a single
step.
-Lao Tzu

Classification of signals

A
Continuous-Time and Discrete-time Signals

B
Analog and Digital Signals

C
Real and Complex Signals

D
Deterministic and Random Signals

E
Even and Odd Signals

F
Periodic and Non periodic Signals

A. Continuous-Time and Discrete-Time Signals

The identification is based on HORIZONTAL (*x*-) AXIS or TIME

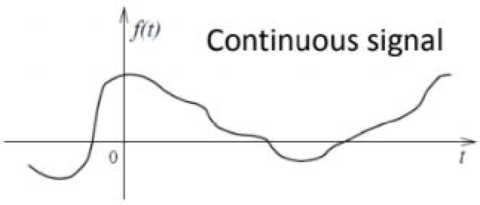


Figure 4.1: Time is continuously defined.

Continuous-Time Signals

01

A continuous time signal is one that is calculated for each different value of an independent variable. The independent variable is a continuous signal that can take any value along the axis.

02

An example is the voltage at certain point nodes in electrical circuits and room temperature at a specific location, both as a function of time.

03

The constant time signal is a function of x() t from the actual variable t specified for $-\infty < t < \infty$. The domain of the function representing the signal has the cardinality of real numbers

- Signal $\longleftrightarrow$ x = x(t)
- Independent variable $\longleftrightarrow$ time (t), position (x)
- For continuous-time signals: t € R

04

Sometimes it is mathematically convenient to consider complex-valued functions of t. However, the default is real-valued x()t, and indeed the type of sketch exhibited is valid only real-valued signals.

05

A sketch of a complex-valued signal $x(\ )t$ requires an additional dimension or multiple sketches, for example, a sketch of the real part, Re{ ( )} $x\ t$, versus t and a sketch of the imaginary part, Im{ ( )} $x\ t$, versus t.

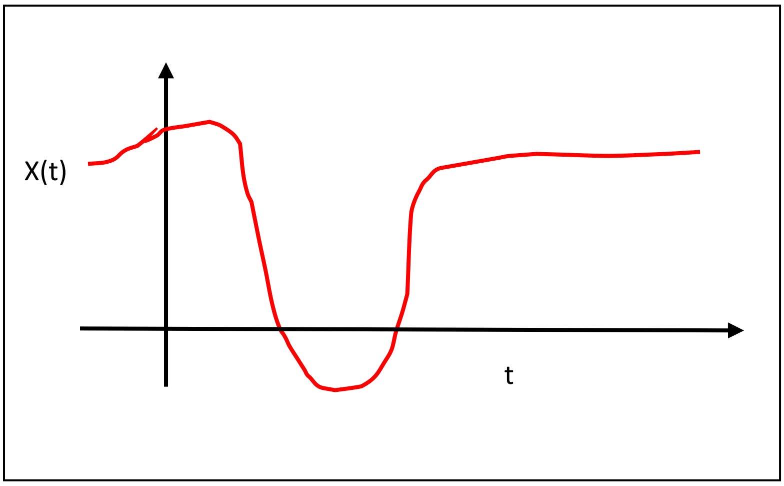


Figure 4.2: Graphical Representation – Continuous time-Signal

Discrete- Time Signals

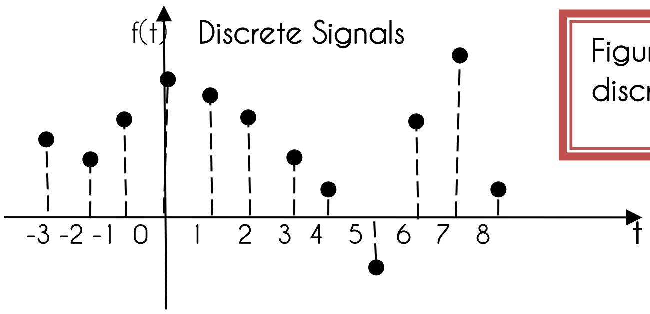


Figure 4.3: Time is discretely defined.

01

Discrete time signal that is specified only for discrete values of the independent variable. It is usually generated by sampling so it will only have values at equally spaced intervals along the time axis.

02

If t is a discrete variable that is, x (t) is defined at discrete times then x(t) is a discrete-time signal.

03

A discrete-time signal is a sequence x[ ] n defined for all integers $-\infty < n < \infty$. We display x[ ] n graphically as a string of lollypops of appropriate height. The domain of the function representing the signal has the cardinality of integer numbers

- Signal → x=x[n], also called "sequence"
- Independent variable → n
- For discrete-time functions: $t \in Z$

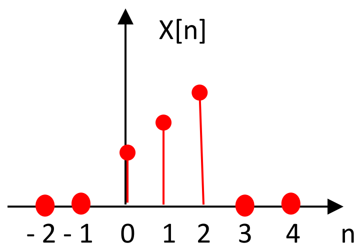


Figure 4.4: Gaphical Representation - Discrete-time Signal

04

Of course there is no concept of continuity in this setting. All of the statements regarding domains of definition, on the other hand, naturally apply to the discrete-time case. In addition, complex valued discrete-time signals often are mathematically convenient, though the default assumption is that x[ ]n is a real sequence.

05

In due course we discuss converting a signal from one domain to the another – sampling and reconstruction, also known as Analog – to – digital (A/D) and digital – to – Analog (D/A) conversion.

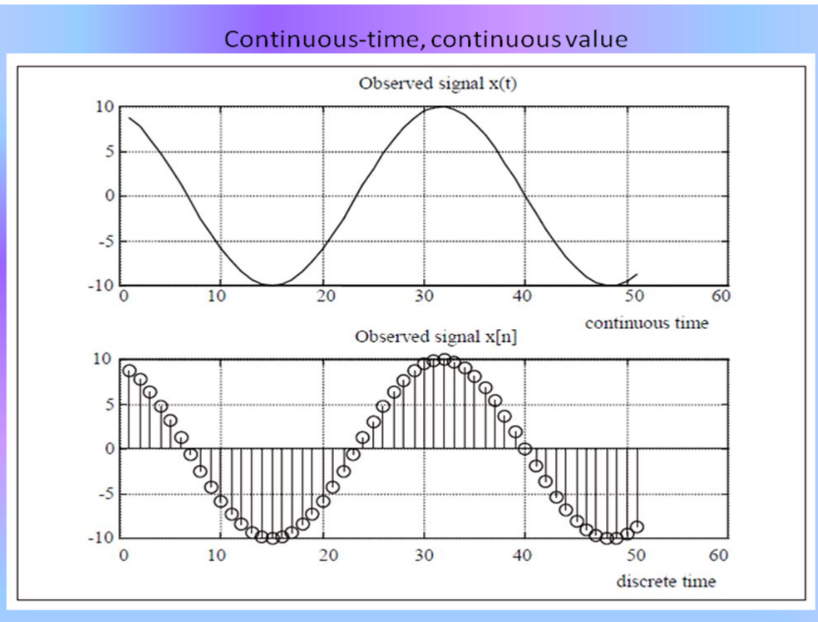


Figure 4.5: Comparison of $x(t)$ and $x[n]$

B. Analog and Digital Signals

Analog Signal

The amplitude of a signal that can take on any value in a continuous range. The cardinality of real numbers is the amplitude of the function f(t) (or f (x)).

- The distinction between analogue and digital is comparable to that between continuous and discontinuous time. The distinction in this scenario, however, is with respect to the function's value (y-axis).

A continuous y-axis relates to analogue, while a discrete y-axis refers to digital.

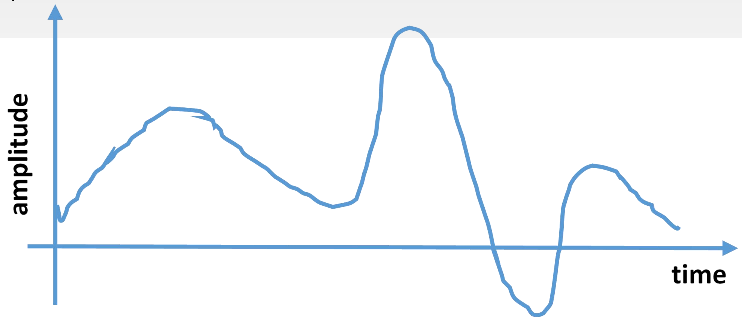


Figure 5.1: Example CT: Continuos time analog

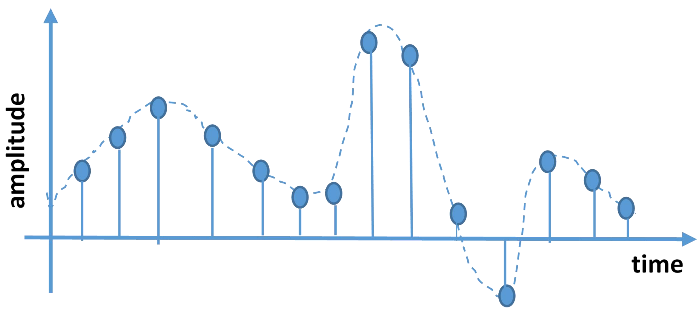


Figure 5.2: Example DT: Discrete time analog

CHAPTER 1B : Analog and Digital Signals

* Binary sequence, where the values of the function can be only be one or zero

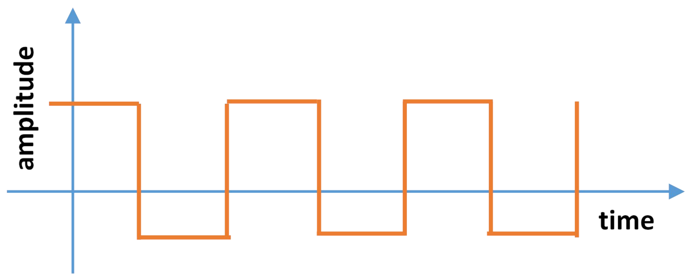


Figure 5.3: Example CT: Continuos time digital (or quantized)

Digital signal

Digital signal: is one whose amplitude can only take on a limited range of values (thus it is quantized). The amplitude of the function f ( ) has a limited number of possible values. A digital signal whose amplitude can take only M different values is said to be Mary

* Binary signals are a special case for M = 2

* Binary sequence, where the values of the function can only be one or zero

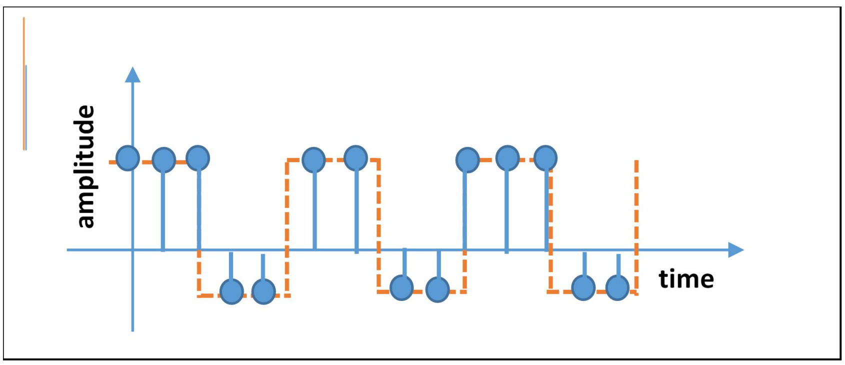


Figure 5.4: Example DT: Discrete time digital

Difference between Analog and Digital signals

ANALOG	DIGITAL
An Analog signal is a continuous signal that represent physical measurements.	Digital signals are time separated signals which are generated using digital modulation.
It is denoted by sine waves.	It is donated by square
It uses a continuous range of values that help to represent information.	Digital signal uses discrete 0 and 1 to represent information.
Temperature sensors, FM radio signals, Photocells, Light sensor, Resistive touch screen are examples of Analog signal.	Computers, CDs, DVDs are some examples of Digital signal.
The Analog signal bandwidth is low	The digital signal bandwidth is high.
Noise degrades analog signals during transmission and throughout the write/read cycle.	Relatively a noise-immune system without deterioration during the transmission process and write/read cycle.
Analog hardware is never versatile in terms of implementation.	Digital hardware offers flexibility in implementation.
It is suited for audio and video transmission.	It is suited for Computing and digital electronics.
The range of an analog signal is not fixed.	Digital signal has a finite number, i.e., 0 and 1.

C. Real and Complex Signals

A complex signal is made up of two real signals, one for the real part and the other for the imaginary. When a complex signal is linearly processed, such as with a time-variant linear filter, the processing is applied to both the real and imaginary parts of the signals.

A complex signal consists **of two real signals – one for the real and one for the imaginary part**. The linear processing of a complex signal, such as filtration with a time-variant linear filter, corresponds to applying the processing both to the real and the imaginary part of the signal.

Real and Complex Signals

A complex number with the complex portion zero can be used to represent a real signal. To represent a complex signal, real and imaginary components, as well as a complex number, must be used. the real signal is a type of complex signal in which the value of the imaginary components is zero.

If the value of x(t) is a real number, it is a genuine signal. If the value of x(t) is a complex number, it is a complex signal. A general complex signal x(t) is a function of the form:

$$X(t) = x_1(t) + jx_2(t)$$

where $x_1(t) and\ x_2(t)$ are real signals and $j = \sqrt{-1}$

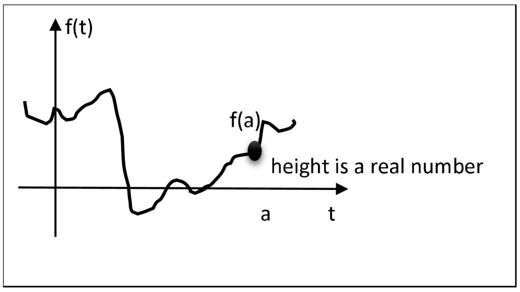
t represents either a continuous or a discrete variable.

For example

Complex, but not purely real nor imaginary

$x(t) = 3t + it$

Figure 6.1: Real Signal



Real

$x(t) = 3t$

Imaginary

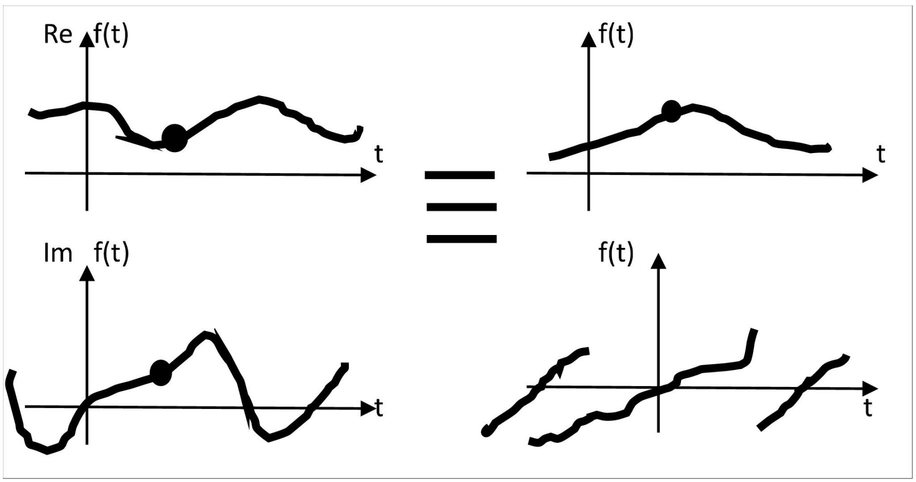
$x(t) = it$

Both Real and Imaginary

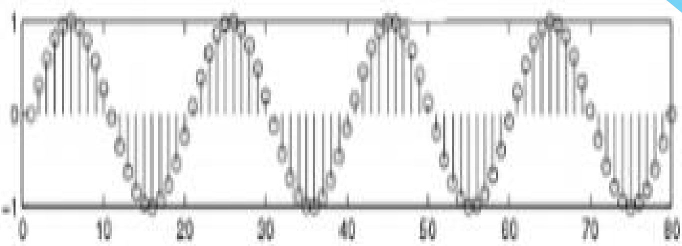
$x(t) = 0$, because $x(t) = 0$ can be rewritten as

$x(t) = 0 + j0$

Figure 6.2: Complex Signal



D. Deteministic and Random Signals



Deterministic

Figure 7.1: Pattern = redictable
DETEMINISTIC SIGNAL

Deterministic signals are signal behaviours that can be predicted with time. At any time, there is no doubt about the signal value. These signal can be expressed to mathematically. For example deterministic signal

- x(t) = sin (3t)
- x(t) = 5 cos (10 *t)

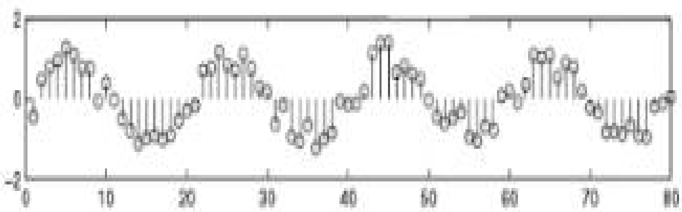


Figure 7.2: Pattern = Not Predictable
RANDOM SIGNAL

Random

Random signals are groups of functions or time signals, which are related to a variety of random experimental results. There is a deterministic function called the sample function or the realisation of XN(t) for each result. These signals aren't mathematically expressible. For example, the thermal noise signal generated in Figure 7.2 is non-deterministic signal.

The identification is based on the PATTERN of the signal

Deterministic	Random
• Deterministic signal: a signal whose physical description in known completely, • With complete confidence, future values of the deterministic signal can be calculated from past values. • Its amplitude values are unquestionably accurate. • Examples: signals defined through a mathematical function or graph.	• Probabilistic (or random) signals: the amplitude values are known only in terms of random descriptors. • The future values of a random signal cannot be accurately predicted and can usually only be guessed based on the averages of sets of signals. • They are realization of a Stochastic process for which a model could be available. • Examples : EEG, evocated potentials ,noise in CCD Capture devices for digital cameras.

E. Even and Odd Signals

A signal is said to be equal or symmetrical if the inverted signal is the same time as the signal itself.

When the reverse signal coincides with the signal's rejection, the signal is odd or anti- symmetrical. A signal is not symmetrical if it does not match the above two criteria.

Shortcut to find out if a signal is even or odd just by looking at the graph. If the signal is equal or unequal and odd, the signal can be written in the form of even components and odd components.

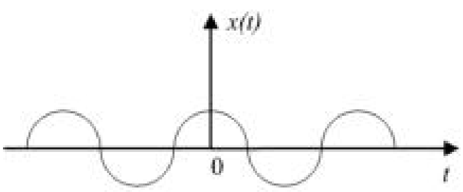
Even

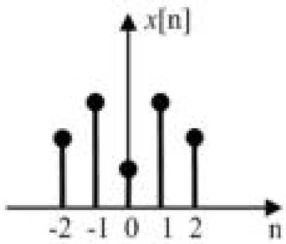
An even signal is any signal x such that x (t) = x (-t). Even signals can be easily spotted as they are symmetric or mirror image about the vertical y-axis.

Even signals

$x(-t) = x(t)$

$x[-n] = x[n]$





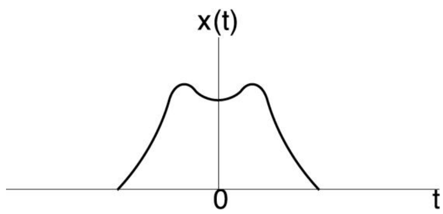


Figure 8.1: Example of Even signals

Odd Signals

$$x(-t) = -x(t)$$

$$x[-n] = -x[n]$$

Odd

An odd signal, are antisymmetric about the origin, is a signal x such that $x(t) = -(x(-t))$

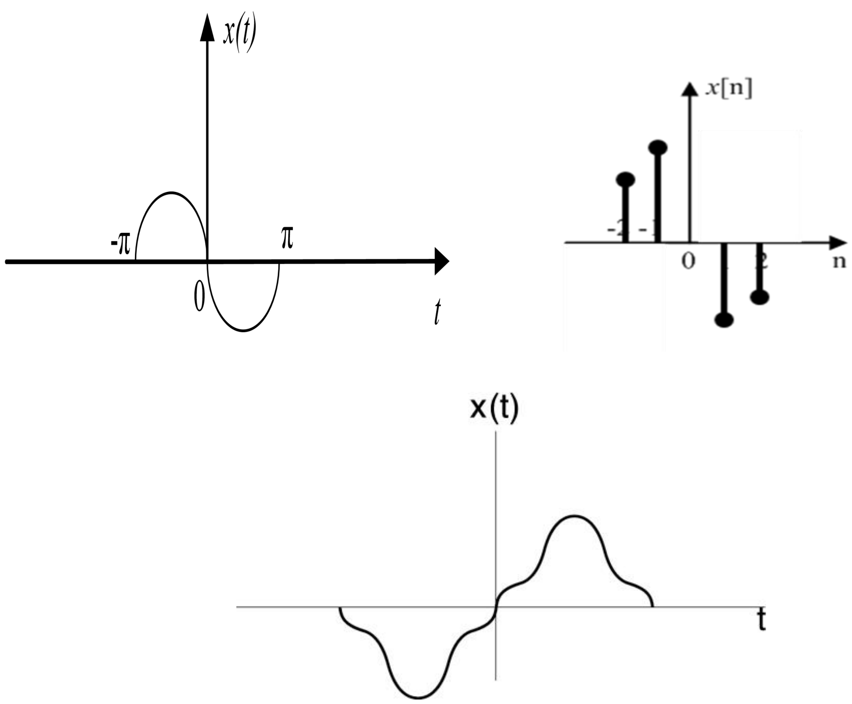


Figure 8.2: Example of Odd Signals

F. Periodic and Non Periodic Signals

Periodic

Periodic signal is a signal if it completes a pattern within a measurable time frame, called a period.

A period is the length of time it takes to complete one entire cycle. A cycle is defined as the completion of one whole pattern. T represents the duration of a period, which varies depending on the signal, but is constant for any periodic signal.

A continuous-time signal x(t) is an example of a Periodic signal that is said to be periodic with period T if there is a positive nonzero value of T for which $x(t + T) = x(t)$ (all t) where T is a constant and is called the fundamental period of the function.

$$T = \frac{2\pi}{\omega_0}$$

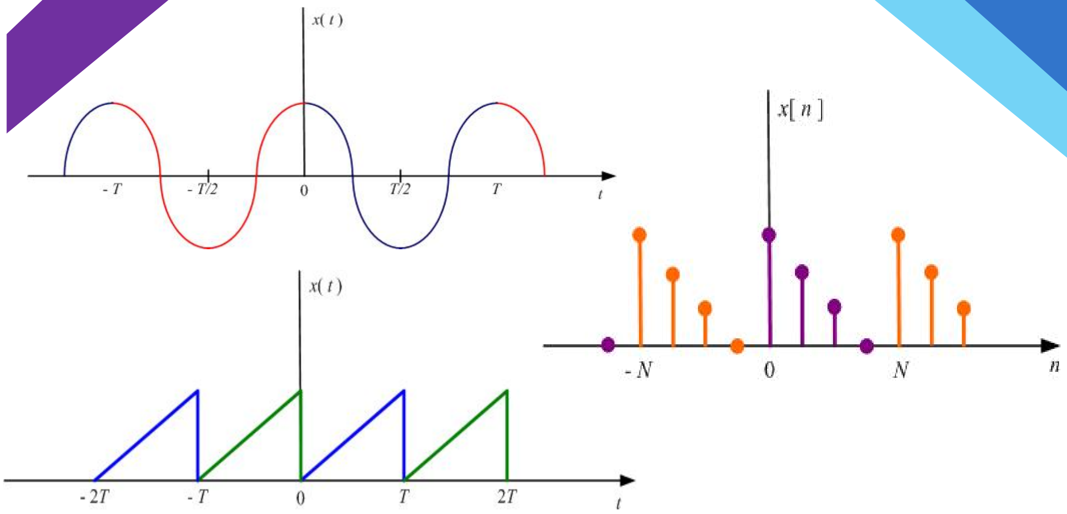


Figure 9.1: Example of Periodic Signals

A Non periodic or also known as A periodic signals, is one that changes over time without demonstrating a pattern or cycle. An infinite number of periodic signals can be decomposed from a non-periodic signal.

Non Periodic

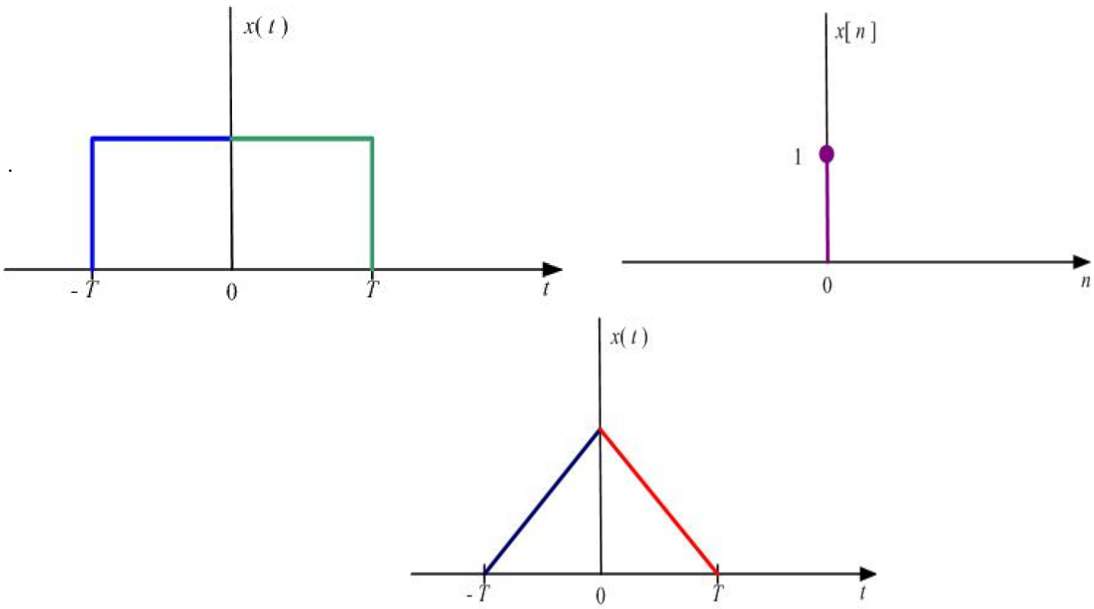


Figure 9.2: Example of Non Periodic Signals

IF YOU
NEVER KNOW
FAILURE
YOU WILL
NEVER KNOW
SUCCESS
-Sugar Ray Leonard
JAB_BOX

The Unit Step Function

It is called the unit step function u(t) because it takes a unit step at t = 0. It is also known as Heaviside unit function and it is defined as

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

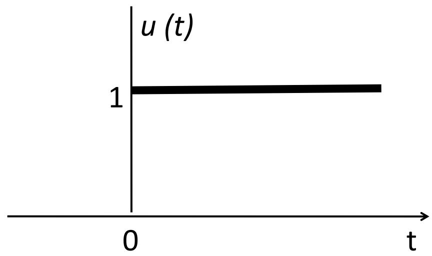


Figure 10.1: Unit Step Signal

In many circuits, waveforms are applied at specified intervals other than t = 0. Such a function may be described using the shifted (delayed) unit step function.

The shifted unit step function u (t –t_0) is defined as

$$U(t - t_0) = \begin{cases} 1 & t > t_0 \\ 0 & t < t_0 \end{cases}$$

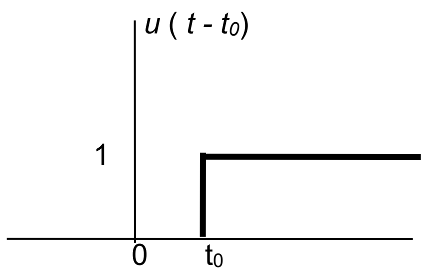


Figure 10.2: Unit Step Function

Example : Shifted Unit Step Function

$$f(t) = u(t - 3)$$

The equation means f(t) has value of 0 when $t < 3$ and 1 when $t > 3$. The sketch of the waveform is as follows

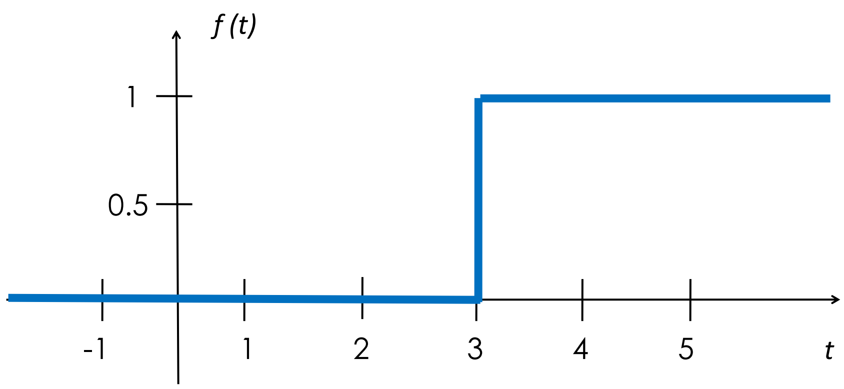
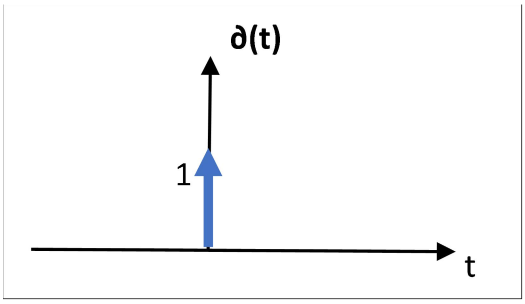


Figure 10.3: Graph of f(t) = u (t -3), a shifted unit step function

The Unit Impulse Function

The unit impulse function ∂ (t) also known as the Dirac delta function, plays a central role in system analysis.

A tall narrow spike function (an impulse) such as a point charge, point mass or electron point is modelled using the Dirac delta.



$$\delta(t) = \begin{cases} 1 & ; t = 0 \\ 0 & ; t \neq 0 \end{cases}$$

Figure 11.1: CT impulse is the 1st derivative of unit step

For Example

to calculate the dynamics of a baseball being hit by a bat

The delta function is commonly used in applied mathematics as a weak limit of a sequence of functions, each of which has an altitudinous shaft at the origin, for example, a succession of Gaussian distribution centred at the origin with friction approaching zero.

The delta function can be used to simulate the force of the bat impacting the baseball. Not only are the equations simplified, but the motion of the baseball can also be calculated by merely considering the entire impulse of the bat against the ball rather than having to know the intricacies of how the bat transferred energy to the ball.

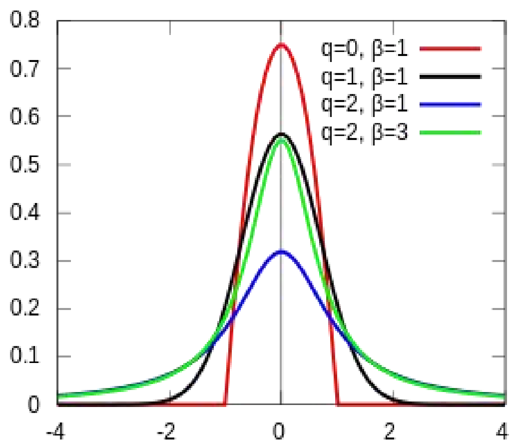


Figure 11.2: A dynamics graph of a baseball being hit by a bat

Complex Exponential Signals

The exponential is typically used to describe the natural growth or decay of a system's state

$$x(t) = e^{j\omega_0 t}$$

is an important example of a complex signal

OR

$x(t) = Ce^{at}$, C & a can be complex constants

σ - Real part

$a = \sigma + j\omega$ ω – Imaginary part

Euler's Formula

$$e^{j\Theta} = \cos(\Theta) + j\sin(\Theta)$$
$$e^{-j\Theta} = \cos(\Theta) - j\sin(\Theta)$$

$\cos(-\Theta) = \cos(\Theta)$ & $\sin(-\Theta) = -\sin(\Theta)$

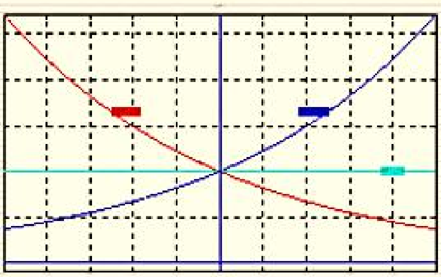
⬇

$\cos(\Theta) = \dfrac{e^{j\Theta} + e^{-j\Theta}}{2}$ & $\sin(\Theta) = \dfrac{e^{j\Theta} - e^{-j\Theta}}{2j}$

Example of Exponential Functions

C and a real, $x(t) = Ce^{at}$

- $a = \sigma$, $\sigma > 0$ - increasing Exponential:
  - Chemical Reactions, Uninhibited growth of bacteria, human population?
- $a = \sigma$, $\sigma < 0$ - Decaying Exponential:
  - Radioactive decay, response of an RC circuit, damped mechanical system.
- $a = \sigma$, $\sigma = 0$ - Constant (DC) signal.



Sinusoidal Signals

Sinusoids are important in physics and acoustics, as well as in simple harmonic motion.

it is periodic with fundamental period $T_0 = \frac{2\pi}{\omega_0}$

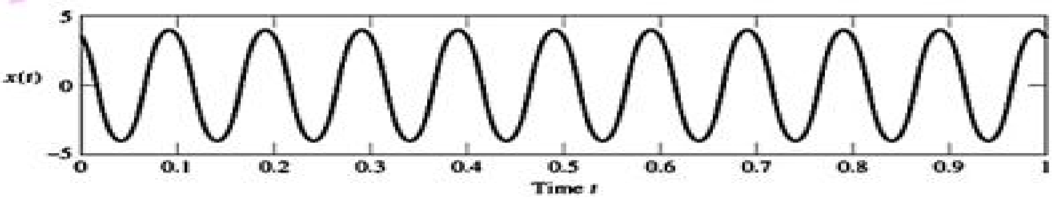
The reciprocal of the fundamental period T_0 is called the *fundamental frequency f_0:* $f_0 = \frac{1}{T_0}$ hertz (Hz)

A sinusoid is a function of time having the following form:

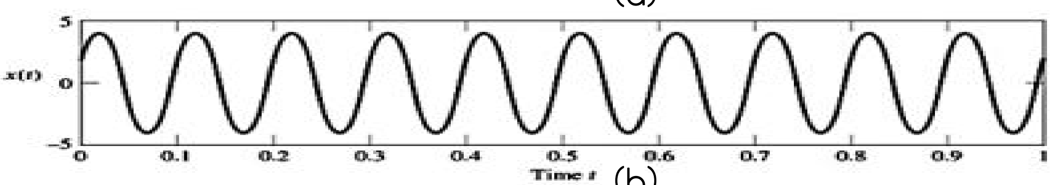
$$x(t) = A \sin(\omega t + \Phi),$$

where x is the quantity which varies over time and

$A \equiv$ peak amplitude
$\omega \equiv$ radian frequency (rad/sec) = $2\pi f$
$f \equiv$ frequency (Hz)
$t \equiv$ time (seconds)
$\Phi \equiv$ initial phase (radians)
$\omega t + \Phi \equiv$ instantaneous phase (radians



(a)



(b)

Figure 12: Example of
a) Sinusoidal signal $A \cos(\omega t + \phi)$ with phase $\phi = +\pi/6$ radians
b) Sinusoidal signal $A \sin(\omega t + \phi)$ with phase $\phi = +\pi/6$ radians

The Unit Step Sequence

The unit step sequence u[n] is defined as follows:

$$u[n] = \begin{cases} 1 & n \geq 0 \\ 0 & n < 0 \end{cases}$$

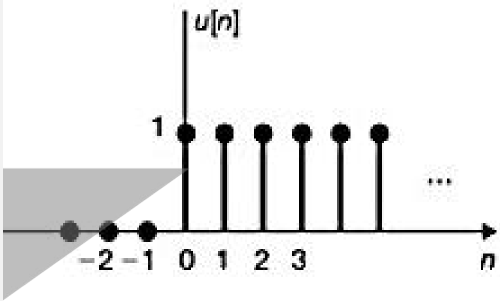


Figure 13.1: Unit step u[n] signal

The shifted unit step sequence u[n - k] is defined as

$$u[n-k] = \begin{cases} 1 & n \geq k \\ 0 & n < k \end{cases}$$

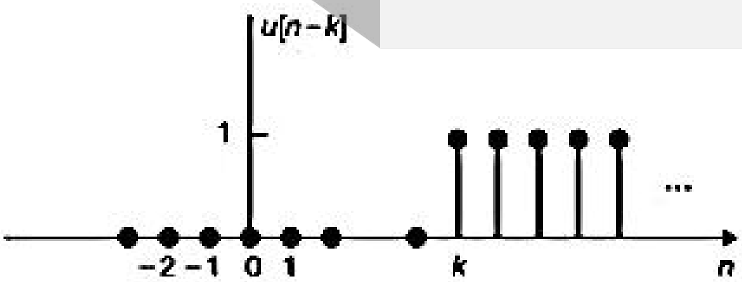


Figure 13.2: Unit Step u[n-k] signal

The Unit Impulse Sequence

The Unit Impulse (or unit sample) sequence $\partial[n]$ is defined as

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

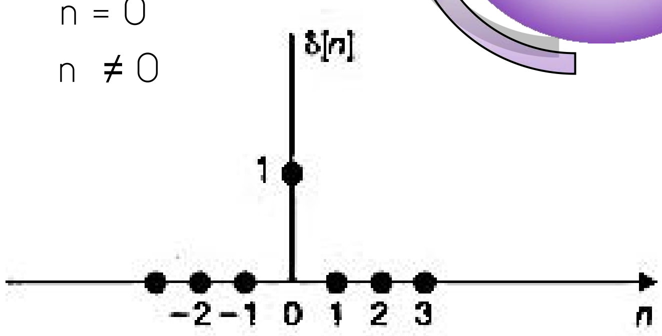


Figure 14.1: Unit Impulse Signal

Complex Exponential Sequence

The complex exponential sequence has the following shape:

$$X[n] = e^{j\Omega 0n}$$

Using Euler's formula, x[n] can be expressed as

$$X[n] = e^{j\Omega 0n} = \cos^{\Omega 0n} + j \sin^{\Omega 0n}$$

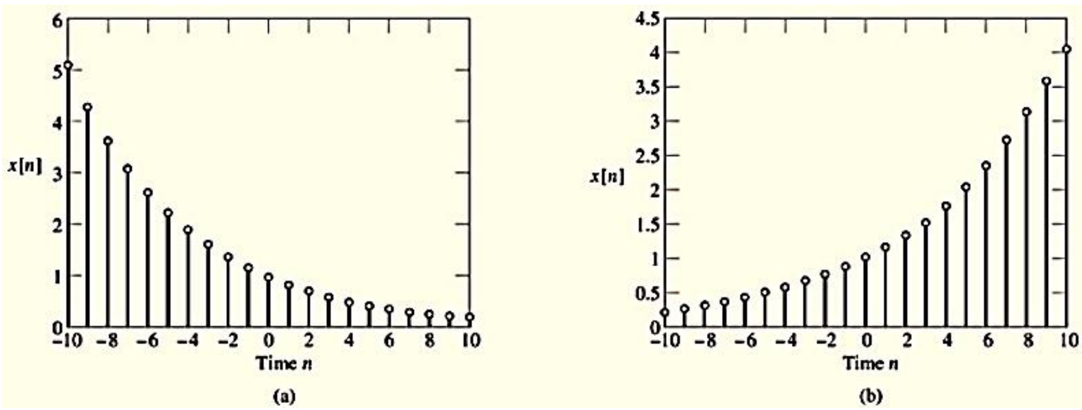


Figure 14.2: Example of
(a) Decaying exponential form of discrete-time signal.
(b) Growing exponential form of discrete-time signal.

Sinusoidal Sequence

A sinusoidal sequence can be expressed as

$$x[n] = A \cos (\Omega_0 n + \Theta)$$

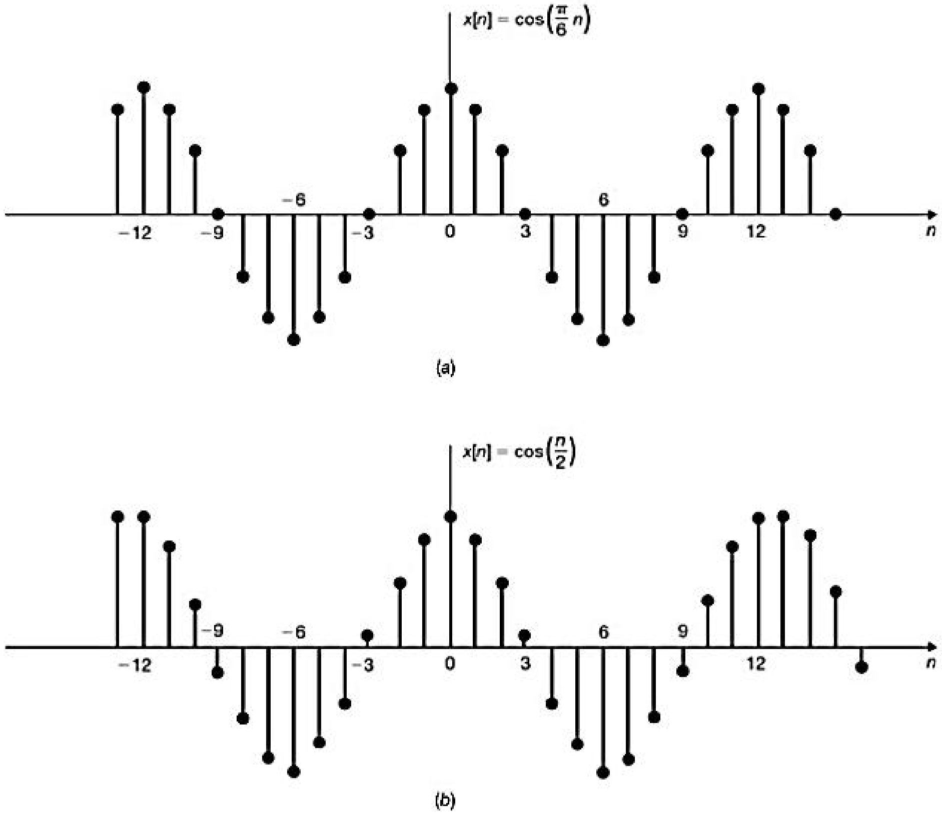


Figure 15: Example of
(a) sinusoidal sequence cos (π/6n)
(b) Sinusoidal sequence cos (n/2)


Create like an artist.
Solve like an engineer.
Act like an entrepreneur.

Basic Signals Operation

Transformation on Dependent variable (amplitude).
Operation performed on the dependent signals.

A
Amplitude Scaling

B
Addition

C
Multiplication

D
Differentiation

E
Intergration

A. Amplitude Scaling

ax(t) is a amplitude scaled version of Y(t) whose amplitude is scaled by a factor C

$$Y(t) = ax(t)$$

a < 1 : signal is attenuated

a > 1 : signal is amplified

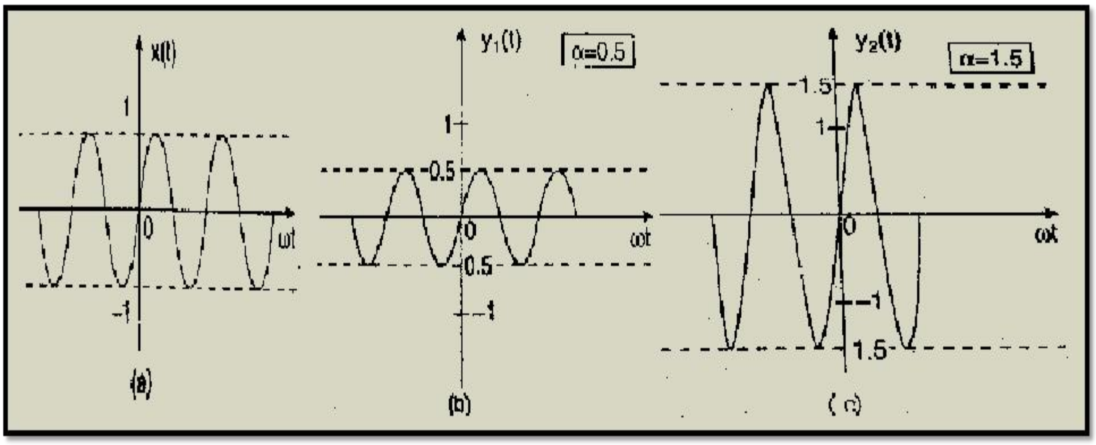


Figure 16.1: Distinguish of Amplitude signal
(a) a=0
(b) a=0.5
(c) a=1.5

CHAPTER 1D : Basic Signals Operation (Amplitude)

B. Addition

The addition of two signals is equal to the sum of their respective amplitudes. The best way to demonstrate this is to use the following example:

$$Y(t) = X1(t) + X2(t)$$

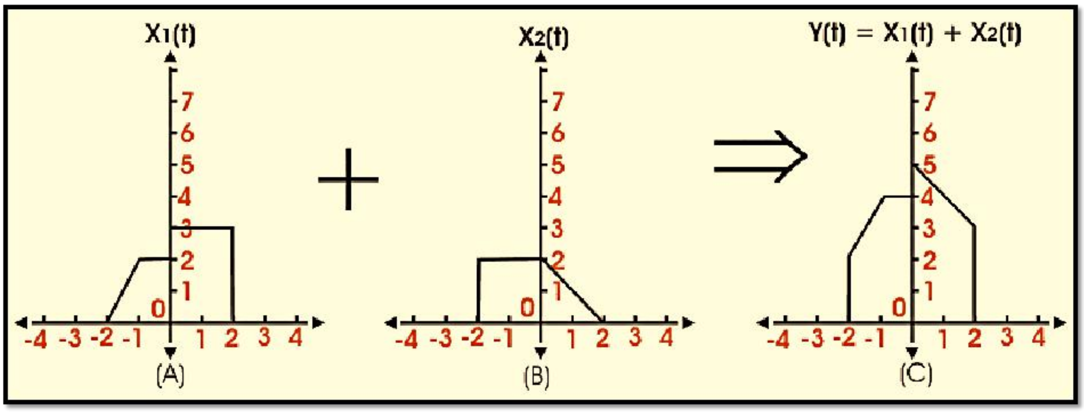


Figure 16.2: Example of addition two signal

C. Multiplication

Here the amplitudes of two or more signals are multiplied at each point in time, or any other independent variables that are shared by the signals are multiplied.
Multiplication of signals is illustrated in the diagram below, where x1(t) and x2(t) are two time dependent signals, on whom after performing the multiplication operation we get,

$$Y(t) = x1(t) \,.\, x2(t)$$

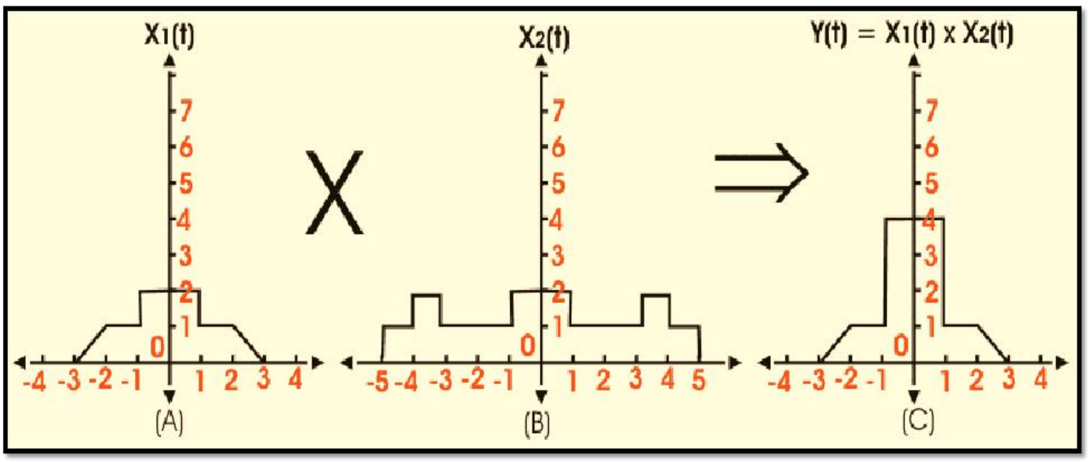


Figure 16.3: Example of Multiplication two signal

D. Differentiation

For differentiation of signals, it must be noted that this operation is only applicable for only continuous signals, as a discrete function cannot be differentiated. At all times, the modified signal we get via differentiation has tangential values of the parent signal. It can be stated mathematically as:

$$Y(t) = \frac{d}{dt}\, x(t)$$

Original Signal	Differentiated Signal
Ramp	Step
Step	Impulse
Impulse	1

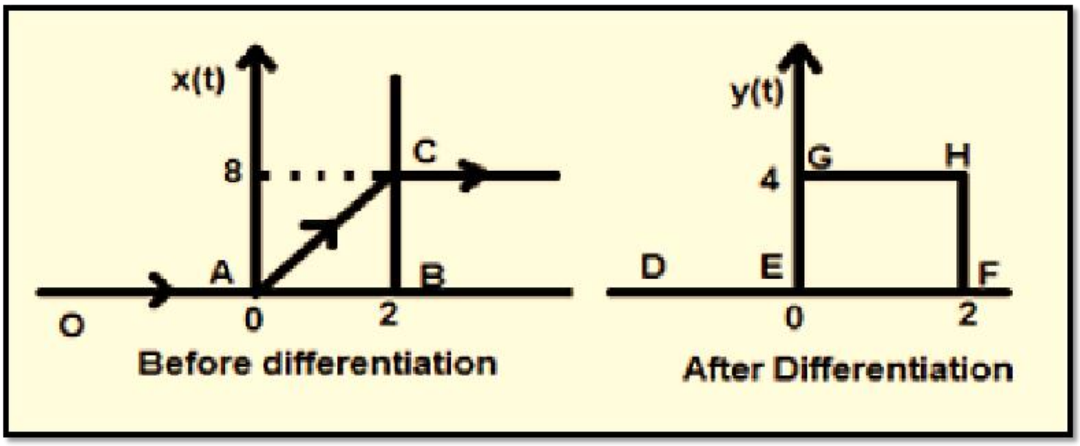


Figure 16.4: Example of Differentiation Signal

E. Integration

Integration of signals, like differentiation, is only applicable to continuous time signals. The integration limitations will be from -∞ to the current instance of time t. it can be stated numerically as,

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

Original Signal	Differentiated Signal
1	impulse
Impulse	step
Step	Ramp

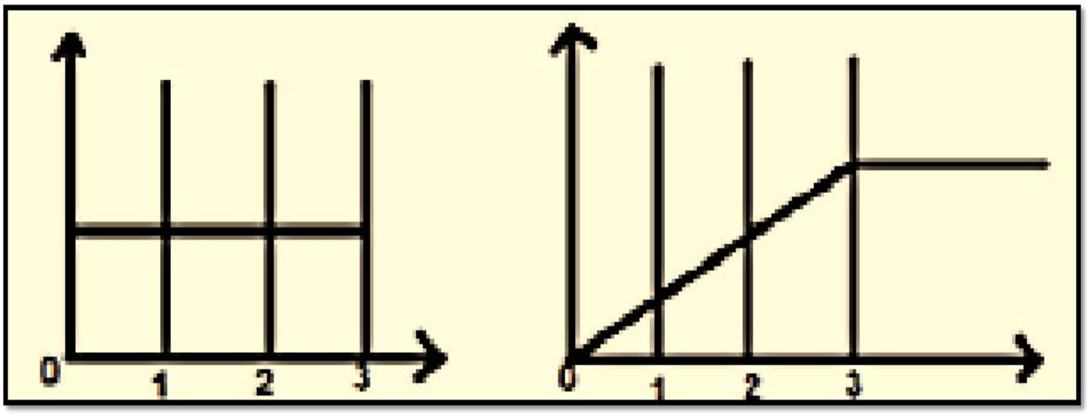


Figure 16.5: Example of Integration Signal

Basic Signals Operation

Transformation on Independent variable **(time).**
Operation performed on the independent signals.

A
Time Scaling

B
Reflection

C
Time Shifting

A. Time Scaling

Time scaling of signals of signal involves the modification of a periodicity of the signal, keeping its amplitude constant. Its mathematically, expressed as,

$$Y(t) = X(\beta t)$$

Where, X(t) represents the original, signal, and β is the scaling factor. If β > 1 implies, the signal is compressed and β < 1 implies, the signal is expanded. For a better understanding, this is depicted as a diagram.

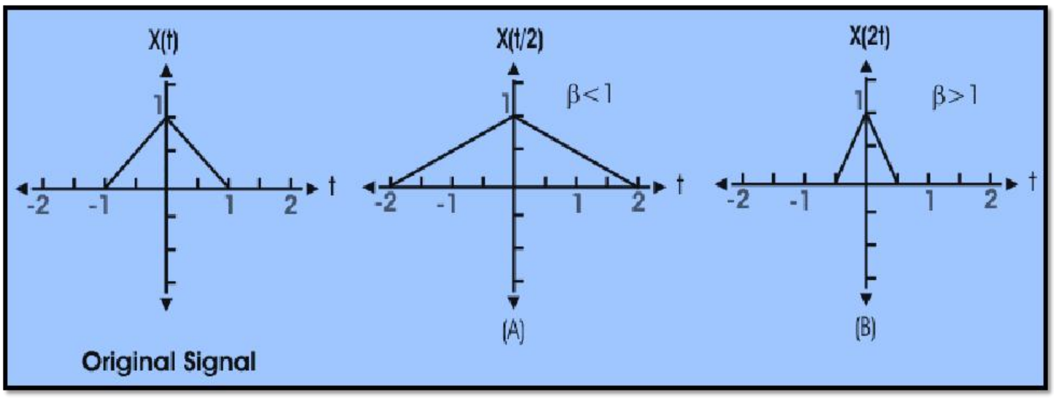


Figure 17.1: Example of Time scalling
(a) β<1 = x(t/2)
(b) β>1 = x(2t)

B. Reflection

Signal reflection is a fascinating technique that may be used to both continuous and discrete signals. The vertical axis works as a mirror in this scenario, and the altered image obtained is an exact mirror image of the source signal.

It can be defined as Y(t) = x(-t). The original signal is denoted by x(t). However, if the reflected signal x(-t) = x(t), it is referred to as an even signal. When x(-t) = x(t), however, it is referred to as an unusual signal. It's depicted in a diagram as follows:

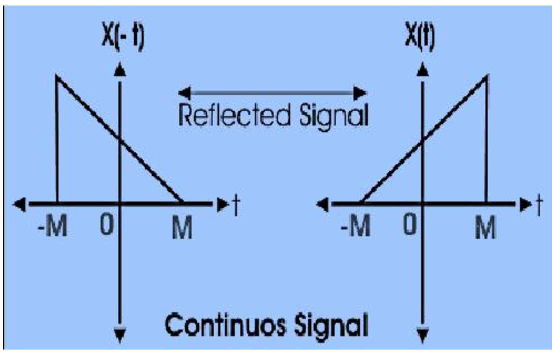


Figure 17.1(a): Reflected Continous Signal

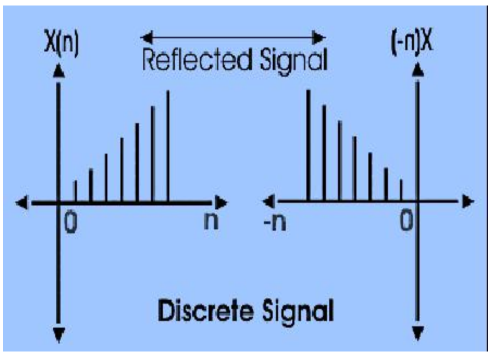


Figure 17.1(b): Reflected Discrete Signal

C. Time Shifting

Among the basic signal operations, time shifting of signals is undoubtedly the most significant and commonly employed. It's commonly utilised to fast-forward or delay a signal, which is important in most situations. Time shifting is mathematically expressed as,

$$Y(t) = X(t - t_0)$$

Where X(t) denotes the original signal and t_0 denotes the time shift. If the position shift $t_0 > 0$ for a signal x(t), the signal is then described as right-shifted or delayed. Similarly, if $t_0 < 0$, the signal is left shifted or delayed. This is depicted in diagram form in the diagram below. Where the original signal figure (a) is right shifted and also left shifted in figure (b) and (c) respectively.

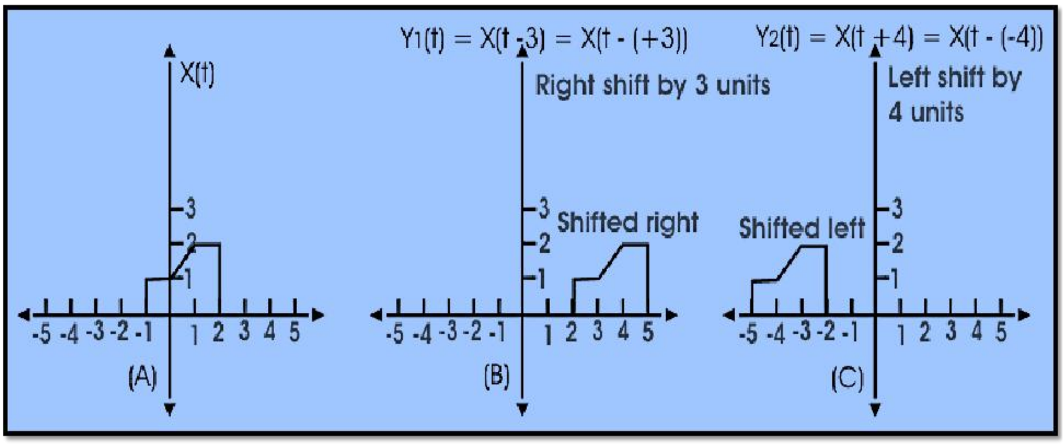


Figure 17.2 : Example of Time Shifting


"DON'T LOSE
HOPE.
WHEN THE
SUN GOES
DOWN, THE
STARS
COME OUT"
PASTOR B. CROUCH

Types of System

A system is a mathematical model that is one of the physical processes that relates between the input signal to an output (or response) signal. A Systems with single or multiple input and output signals.

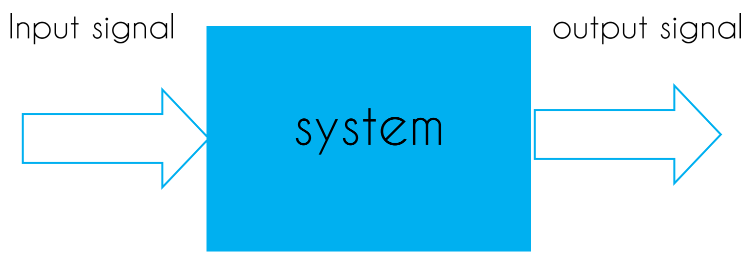
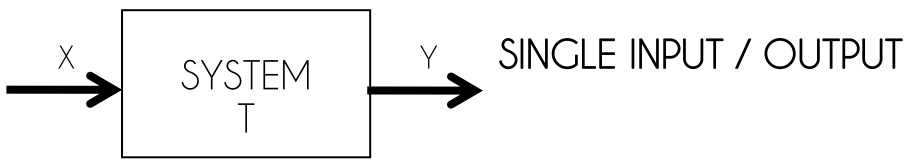
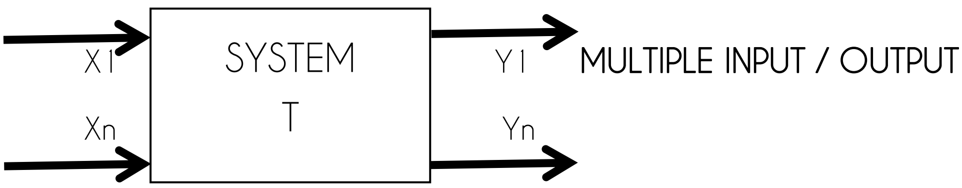


Figure 18: The process of Linear time invariant systems (LTIS)





Classification of the systems

A
Continuous Time and Discrete-Time Systems

B
Systems with Memory and without Memory

C
Causal and Noncausal Systems

D
Linear Systems and Nonlinear Systems

E
Time-Invariant and Time-Varying System

F
Linear Time-Invariant Systems

G
Stable Systems

H
Feedback Systems

A. Continuous Time and Discrete-Time Systems

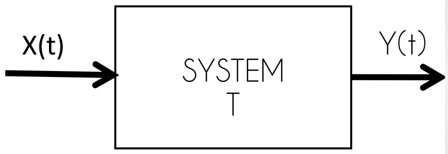


Figure 19.1: Continuous - time system

The system is called a continuous-time system if the input and output signals x dan y are continuous-time signals. A dicrete-time system is one in which the input and output signals are discrete-time signals or sequences.

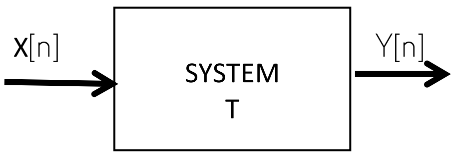


Figure 19.2: Discrete - time system

For example:

A system's ***x*** (input) and y (output) signals are viewed as a transformation (or mapping) of ***x*** into y

$$y = T\boldsymbol{x}$$

T : representing some well-defined rule by which ***x*** is transformed into y. It's possible to have many input and/or output signals. The majority of the examples are for single-input, single-output systems

B. <u>Systems with Memory and without Memory</u>

When output is only dependent on the input at any one time, the system is said to be memoryless. The system is said to have memory if it doesn't have any other features.

Example :

Memoryless system is a resistor R with the input ***x(t)*** taken as the current and the voltage taken as the output y(**t**).

A resistor's input-output relationship (Ohm's law) is:

$$y(t) = Rx(t)$$

A memory system consists of a capacitor C with current as input ***x(t)*** and voltage as output y(**t**); then

$$Y(t) = \frac{1}{C}\int_{-\infty}^{t} x(\tau)\, d\tau$$

C. Causal and Noncausal Systems

If a system's output at any given time is solely dependent on the current and/or past values of the input, it is referred to as causal.

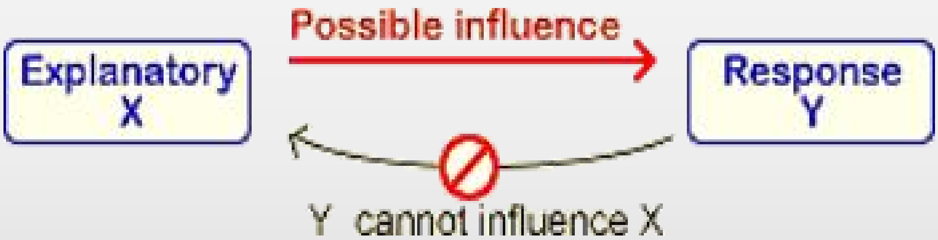
As a result, in a causal system, an output cannot be obtained before an input is supplied to the system.

A system is called noncausal (or anticipative) if its output at the present time depends on future values of the input.

Example of noncausal systems are

$Y[n] = 7x[n+2]$

$Y[n] = x[n] + 9x[n+5]$



$y[n] = x[n] + x[n-2]$

$y[n] = x[n-1] - x[n-3]$

$y[n] = 7x[n-5]$

D. Linear Systems and Nonlinear Systems

T is considered a linear operator and the system represented by a linear operator if the operator T in $Y = Tx$ meets the following two requirements. T is referred to as a linear system:

$$Y = X \text{ (LINEAR)}$$

$$Y = X^2 \text{ (NON LINEAR)}$$

$$Y = \cos X \text{ (NON LINEAR)}$$

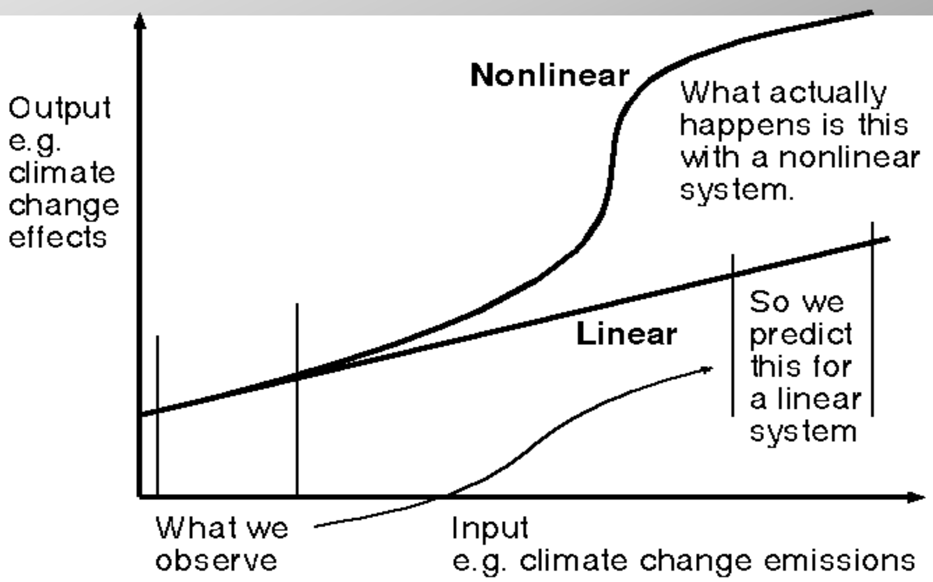


Figure 20: The example of Linear and Non linear Systems

Electronic circuits for peak detection, squaring, sine wave to square wave conversion, frequency doubling, and other non-sinusoidal systems are examples of non-linear systems.

Clipping, crossover distortion, and slewing are examples of common electronic distortion.

E. Time-Invariant and Time-Varying System

A Time-variant system is one in which some parameters affecting the system's behaviour change with time, causing the system to respond to the same input in various ways at different periods.

The input and output characteristic of a Time-invariant system do not change over time.

If a time shift (delay or advance) in the input signal induces the equal time shift in the output signal, the system is called Time-invariant. As a result, a continuous-time system is the time-invariant if,

$$T\{\, \boldsymbol{x}(\mathbf{t} - \boldsymbol{\tau})\} = \mathbf{y}(\mathbf{t} - \boldsymbol{\tau})$$

for any real value of ' τ '

For a discrete-time system, the system is time-invariant (or shift-invariant) if

$$T\{\, \boldsymbol{x}[n - k]\,\} = y[n - k]$$

For any integer k

F. Linear Time-Invariant Systems

A linear time-invariant (LTI) system is defined as one that is both linear and time-invariant.

Laplace and Fourier transforms are two well-known approaches for dealing with the response of linear time invariant systems.

G. Stable Systems

Stable System is a system that takes bounded input and produces bounded output (BIBO) in a stable manner.

When bounded input produces unbounded (infinite) output, a system is considered to be unstable at first.

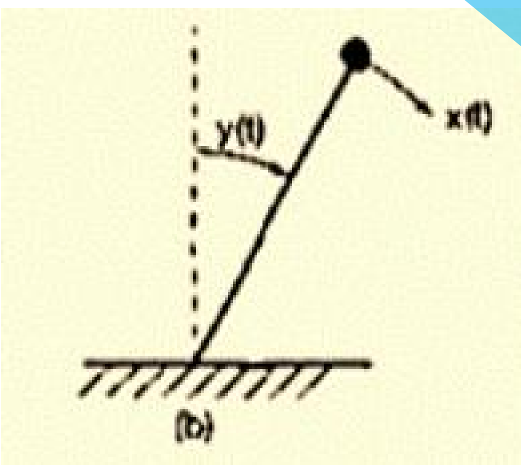


Figure 21.2: An unstable inverted pendulum

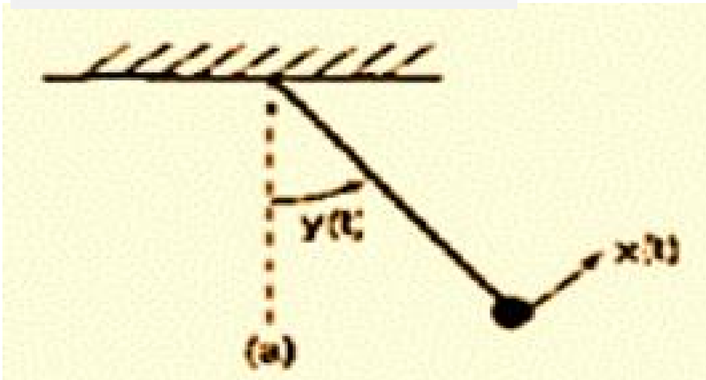


Figure 21.1: A stable pendulum

By applying bounded input, we can test the system's stability. The value of x(-n) should have a finite value. So when input is bounded, the output will be bounded as well. As a result, the given function is called Stable system.

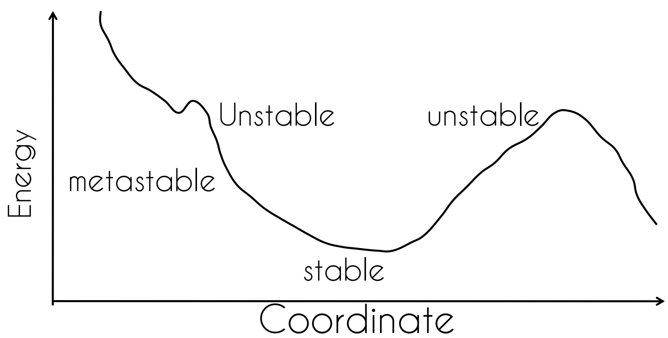


Figure 21.3: Example of stable and unstable signal

H. Feedback Systems

Systems with feedback are a specific type of system that is extremely important. The output signal is fed back and added to the system's input in a feedback system.

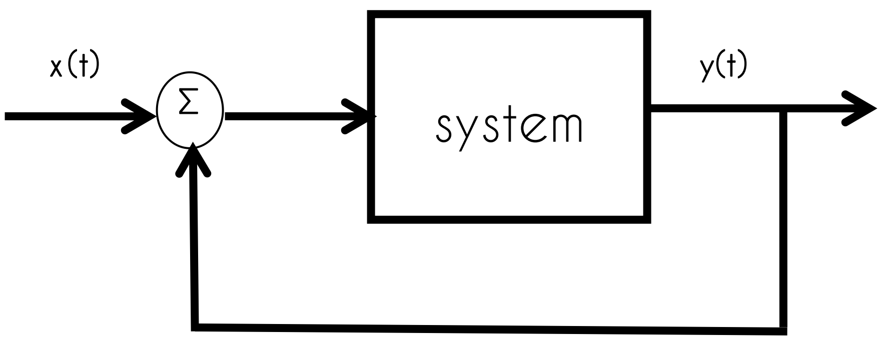


Figure 22: The process of Feedback System


Challenge
Yourself

Exercise

1

Explain Unit Step Function, $u(t)$ and Unit Impulse Function, $\partial\ (t)$ with the suitable diagram.

2

Sketch the function given below (show your steps)

$$x(t) = 2u\ (t-5) - u\ (t - 10)$$

Then, find $x\ (-t + 2)$

References

[1] *Basic Signal Operations*, Electrical4U, October 25, 2020

[2] Fall, *Signals and Systems*. 2011 6.003 .

[3] Gloria Menegaz, *Basics of Signals and Systems* , AA 2011-2012

[4] Haynes Miller and Jeremy Orlof. *Step and Delta Functions*, 18.031.

[5] Julius O. Smith III. *"Introduction to Digital Filters with Audio Applications"*, (September 2007 Edition). Center for Computer Research in Music and Acoustics (CCRMA), Stanford University.

[6] Prof. Paul Cuff Princeton University. *Lecture 1 ELE 301: Signals and Systems* , Fall 2011-12.

[7] Professor Alan V. Oppenheim. Resource: *Signals and Systems.*

[8] Sanjeet K Shriwastava Asst . Prof(ECE) LIT, Sarigam. Department of Electronics & Communication Engineering. *Presentation On Classification of Signals & Systems* . Laxmi Institute of Technology, Sarigam Affiliated to Gujarat Technological University, Ahmedabad.

[9] Wilson J. Rugh, *Signals and Systems, Department of Electrical and Computer Engineering*, Johns Hopkins University, over the period 2000 – 2005. Version 1.0.

[10] J.S. Katre, *Signal and system*
https://www.slideshare.net/vishalgohel12195/operations-on-signals.

[11] *Signals and Systems Introduction*
https://www.tutorialspoint.com/dip/signals_and_system_introduction.htm


You can do
the hard
things.

Terbitan:

POLITEKNIK MALAYSIA
SULTAN SALAHUDDIN ABDUL AZIZ SHAH

e ISBN 978-967-2044-78-9

9 789672 044789