EEG 213 (Signals and Systems Theory) 2units

Continuous and discrete signals , transformations and inverse transformations, spectral analysis of steps, ramps and impulse, signal descriptions by impulse and step functions.

The independent variable; definitions of rise-lime, settling time, overshoot, period magnitude and duration of a signal.

Fourier Analysis, Parseval’s Theorem, Periodic and Non-periodic signals, Devices and Models, Network analysis circuits with independent and dependent sources.

Time invariant and stationary systems

asaaazPre-requisite: PHS 121

SIGNALS AND SYSTEMS THEORY

The Engineering science discipline forms a body of signals and systems. We either want to figure out the response to a certain signal or figure out how to design a particular system to give a desired response to certain levels of excitation or inputs.

The act of analysing a system is called the **synthesis** of the system.

A signal is an abstraction of any measurable quantity that is a function of one or more independent variables such as time or space. For example, alternating current, AC is a signal

DC (Direct Current) may not be a signal because it is not variant with time

VARIATIONS OF SIGNALS

Signals (as) functions can be divided into variants

1. Single Variable Signal f(x), f(t)

2. Multi Variable Signal f(x,y). A signal with multiple independent variables.

CLASSIFICATION OF SIGNALS

1. Continuous time signals: Continuous time signals are signals that are present for every instant of time or space. If the signal is represented by x(t), then there is a value x(t) for every function of t. Just like in a continuous function. For example, Sinusoidal, Cosinusoidal, Triangular, Rectangular

2. Discrete time signals: These are signals that have values that are present and discrete instances, or points in time.

SYSTEM

A system is an abstraction of anything that takes on input signal, operates on it, and produces an output signal For example, a human being.

Coming to the engineering discipline, a computer is a system

A system might be useless if there is no signal be operated upon.

CLASSIFICATION OF SYSTEMS

Just like signals, systems can be cateorised into

1. Continuous Time Systems: These are systems that operate on continuous time signals.

2. Discrete Time Systems:

A theoretically achievable system is the Linear Time Invariant System. It provides sufficient approximation for the realisation of such systems

Linear time invariant (LTI) systems

This system operates on two fundamental properties

1. Linearity

2. Time Invariance

Assuming we have 2 separate systems,

On superimposing by addition, linearity states that

For time invariance, if there is a change in time in the input, the same should apply to the output.

Time invariance .

This means that the system and signal do not change with time however if there is a delay in time, if the input, the output should also be delayed in time

Most systems in the real world are usually not LTI systems however, theoretically, these LTI systems provide enough approximation when we have to analyse systems that are not LTI.

LTI systems produce the same output for the same input no matter the time. If there is a delay in the input, there will also be a delay in the input.

Given an input x(t) into an LTI system whose property is described by h(t), then we should have an output y(t) for which x(t) convolves with the parameter of the system h(t).

x(t) is the applied input signal or excitation

y(t) expected output signal or the response

h(t) impulse response of the system

\* is the convolution operator

The convolution operator is a tool for the time domain analysis of the system.

CONCEPTS OF SIGNALS AND SYSTEMS

1. The description of signals as functions of frequency. We want to express the system (which is in the time domain) in its frequency equivalent.

2. How systems respond to input of different frequencies

3. Provide tools for switching between time-domain and frequency domain representation.

4. Determination of which domain is suitable for a particular problem.

PROBLEMS IN SIGNALS AND SYSTEMS

1. Analysis Problem: Here, **we want to figure out the expected response in a system**. Given certain signals, we already know the input and system parameters so we just want to figure out the ouput.

2. Synthesis problem: Here we have an idea of the input and its properties and we know what the output should be but **how do we design the system to give the desired output**?

FURTHER CLASSSIFICATION OF SIGNALS

Asides classifying systems into continuous time signals and discrete time signals, there are other ways of categorising signals

METHOD 1:

1. Analog Signals: These are continuous time signals

2. Digital Signals: These are discrete time signals. For this signal, the amplitude is always constant

METHOD 2:

1. Real Signal: A signal whose value is a real number

2. Complex signals: A signal whose value is a complex number.

For a complex signal,

and are real values

METHOD 3

1. Deterministic signal: Its values are completely specified for any gien time interval e.g. step signal

2. Random signal: A signal whose values are random at any given instant of time e.g. Noise, speech, or sound signals

3. Even signals: These signals are symmetrical about the y-axis

Time reversal is that operation in signals that multiplies the time scale od the signal by a parameter . For which

Tis operation is meant to perform folding operation on the signal

Just like an even function, for an even signal, the output of the reversed signal is equalt to the resullt of the actual signal.

4. Odd Signals: These signals are anti-symmetrical about the x(t) or y-axis

An odd signal must be zero at t = 0, meaning odd signals pass through the origin.

Examples:

Show that the product of two even signals is an even signal

Let

If and are even signals, then

But for even signals,

Example: Product of two odd signals is an even signal.

Let

If and are odd signals,

Then

But,

Example: Show that the product of an even and an odd signal is an odd signal.

Note that, in pracctice, signals are expressed in an even and odd signal

Conjugate symmetric signal: A signal whose original signal is th same as the omplex conjugate of the time revrsed version of the signal.

So first, given the signal ,

We find the time reversed

Then we find the complex conjugate

This will be a conjugate symmetric signal if and only if

Given a complex signal, , the complex conjugat is given as

For example, if

Conjugate Anti-symmetric signal: This happens if and only if:

If

Do the time reversal x(-t)

Find the complex conjugate

The perform amplitude reversal.

For an operation,the operation is given as

AMPLITUDE REVERSAL

For amplitude reversal,

Periodic Signal → This is a continuous time signal, x(t)

The period signal is said to be periodic with period T if there is a positive non-zero value of T

The fundamental time period is the smallest positive value of T for which the signal is periodic

The DTS <sequence> x[n] is periodic with period N if there is a positive integer N for which

The fundamental time period of is the smallest positive integer N for which the sequence is periodic

If this is not periodic, we say the sequence is non-periodic or aperiodic

Consider a circuit of current i(t) and voltage v(t):

Assuming , Normalised Power

Average Power,

Average Energy,

More generally,

Non periodic signals are signals

Periodic signals are power signals

Power signals has

Energy signals have

Energy signal:

A signal x(t) is said to be an energy signal if and only if the total energy is finite

; Average power,

Energy signal must be absolutely integratable.

This is also a condition to have for a signal to have a foulier transfer

The energy must be the same under the graph

Average power,

POWER SIGNALS

x(t) is said to be a power signal if and only if its average power is finite

;

Periodic signals are power signals.

NEITHER ENERGY NOR POWER SIGNALS

For any given signal that does not obey the rules for energy and power signals and energy signals.

Energy, Power, NENP

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The step function u(t) changes the limits of integration

Since energy is finite, x(t) is an energy signal.

Given that

x(t) is periodic with a period

To find the average signal

3. x(t)=tx(t)

x(t) → NENP signal

For Discrete Time

Example:

x[n] is an energy signal.

Given a signal x(t) with a fundamental time period

Average power of x(t)

The average of x(t) over any interval T\_o given by

Once the limit is taken such the T is an integral multiple of the fundamental period

The Normalised energy content of x(t) over the interval T will be

K times Normalised energy content

**ANOTHER NOTE ON SIGNALS AND SYSTEMS**

A signal is a dependent variable or function of one or more independent variable.. Function f is the signal that depends on x\_1 through x\_10.

Any quantity is said to be a signal if it is relying on another variable. Anything which is constant is not a signal. From this description, it can be said that AC is a signal but DC is not a signal as it is constant and does not depend on the other variables like time and all. Time is an independent variable in alternating current.

TYPES OF SIGNALS

1. Single Variable signal

2. Multi variable signal: Depends on more that one independent variable.

SYSTEM

The meaningful interconnection of physical devices and components is called a system.

A system cannot work on its own. It needs to be linked to a signal. If you take a water pump for example, it can’t work on its own unless attached to electricity. When the system receives an input signal, it processes the signal and produces an output signal which is more desirable than the input signal. In case of the water pump, the output signal is the mechanical work to pump the water.

Note that mechanical work is not always more desirable. It is just that in the case of pumping water, it is very much desired over the electricity.

It should be noted that the input signal and output signal should both depend on the same variables.

For example if the input signal is f and the output signal is g. Since they should both depend on the same variables, we can have the input as f(x) and the output as g(x)

TYPES OF PROBLEMS

1. Analysis problems: In this case, we have input signal and the system. What we are trying to figure out is the output signal. These are the general types and there is usally a solution to it.

2. Synthesis Problems: In this problem, we have the input and outpupt signals. We are trying to figure out the system and the operations of the system. There may or may not be a solution

CONTINUOUS AND DISCRETE TIME SIGNALS

Continuous time signals: These are signals whose values are specified for every value of time. It is represented with . Notice that it is parentheses that is used to represent a continuous time signal. ,

When drawing a graph, the y-axis is for the signal and the x-axis is for the independent variable.

Discrete time signals: These are signals that are specified at discrete time intervals.

DTS

x[n]

n => integer.

Notice that we use square brackets instead of parentheses

. Meaning you can’t find signal x between a time interval as it is undefined.

Time interval, may or may not be the same.

If time interval is the same, we say the discrete time signals is uniformly sampled.

If time intervall is not the same, we say the discrete signal is non-uniformly sampled.

Another way of representing discrete time signals

x{n} = {1, 0, 1, 2, 2, 1}

The values are the amplitudes x[n] but we don’t know the actual values of n

ADDITION OF CTS(Continuous Time Signals)

We add the amplitudes of the signals at the same time to find the sum.