Digital Filter Design

(Subject Code - EET 3134)

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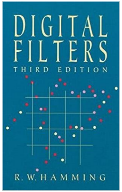
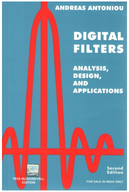
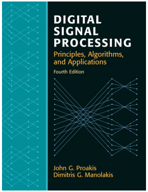
Course Syllabus and Format

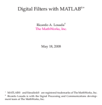
- Introduction, The Frequency Approach, Some Classical Applications, Fourier Series, Windows, Design of non-recursive filters, smooth non-recursive filters, The Fourier integral and the sampling theorem, kaiser windows and optimization, The spectrum, recursive filters, Chebysev Filters.
- Student will be required to design filters according to specifications.
- 4 credits course, 2 Classes/weak (1hr/Class), 2 Design Sessions/week (2hrs/Design Session)

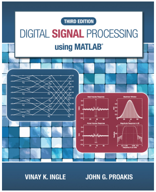
Text books











Text Books:

1. Digital Filters with MATLAB, Ricardo A. Losada
2. Digital Filters by Hamming, 3rd Edition, Dover Publications
3. Digital Filters : Analysis, Design and Applications

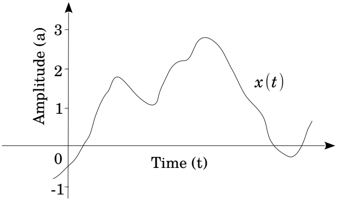
Reference books:

1. Digital Signal Processing, John G. Proakis, 4th Edition
2. Digital Signal Processing using MATLAB, Ingle and Proakis, 3rd Edition

Signals

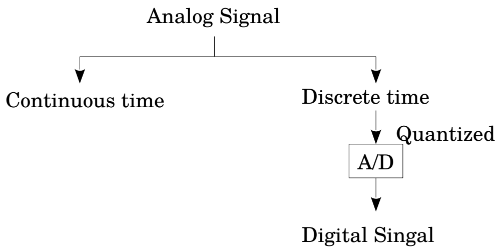
Signal

- Any physical quality that carries information and varies with time, temperature, pressure, space or with any independent variable. e.g. speech, image, video signals.



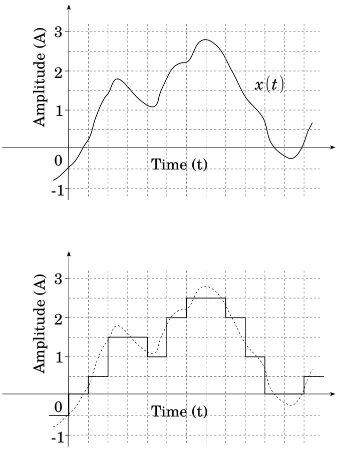
- $1D,\ 2D, \ldots,\ MD$
- Natural, Synthetic
- Analog signal (Continuous) and Digital signal

Signal



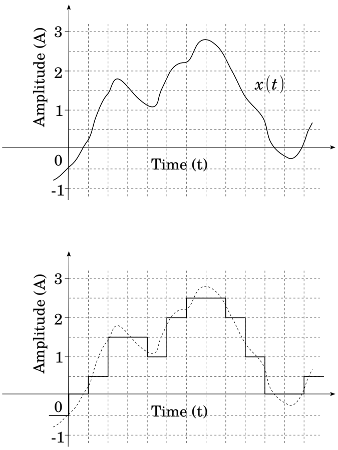
- Why study signal?
  - because it carries information.
- Why process them?
  - to obtain them in a more desirable form.

Types of signal



Types of signal

Continuous Time
Continuous Amplitude



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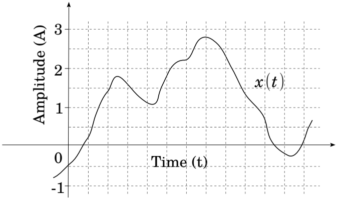
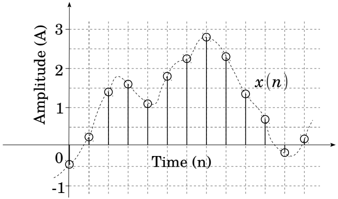
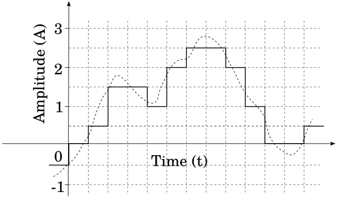
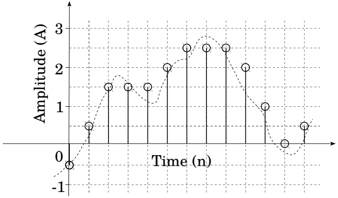


Discrete Time
Continuous Amplitude







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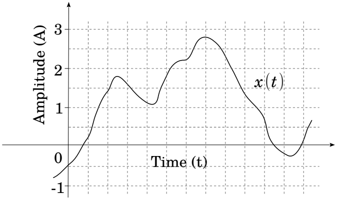

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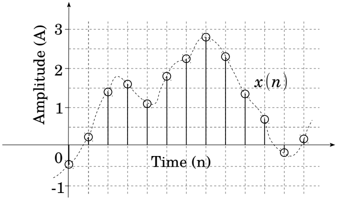
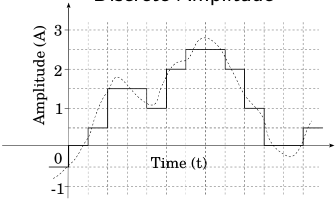
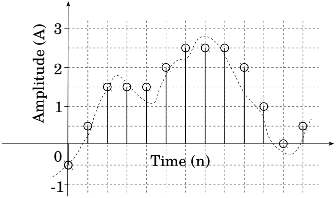
Continuous Amplitude



Continuous Time
Discrete Amplitude





Types of signal

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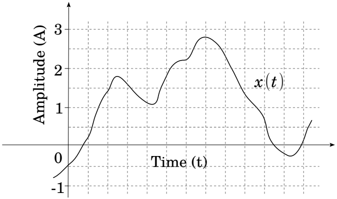
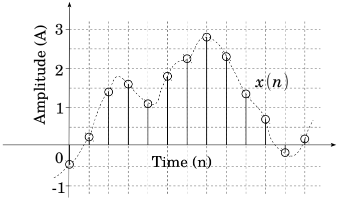
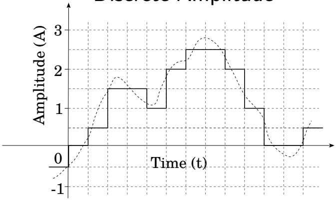


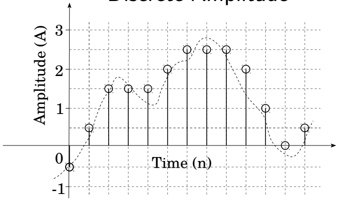
Discrete Time
Continuous Amplitude



Continuous Time
Discrete Amplitude

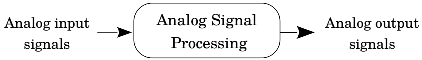


Discrete Time
Discrete Amplitude



What is signal processing?

- Signal processing is the analysis, interpretation, and manipulation of signal like sound, images, sensor data, etc.
- Types of signal processing:
  1. Analog signal processing



  2. Digital signal processing

- Most of the signals in practice are Analog. Then why we need to go for Digital?

Digital over analog signal processing

Advantages

- A digital programmable system allows flexibility in re-configuring the digital signal processing simply by changing the program.
- Accuracy
- Easily storage on magnetic media
- Cheaper
- Easier digital implementation
- Less power consumption
- Linear phase can be achieved easily

Disadvantages

- Complex to design
- Energy dissipation
- Sampling frequency limit.

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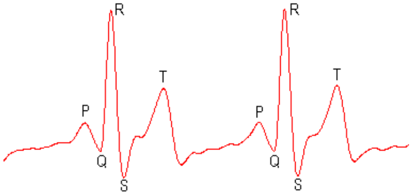
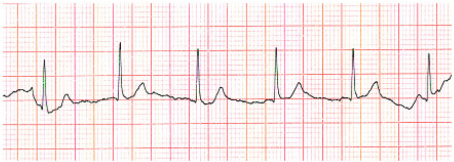
- Complex to design
- Energy dissipation (now it is not a disadvantage any more)
- Sampling frequency limit.

Digital over analog signal processing





Digital Systems

Digital System

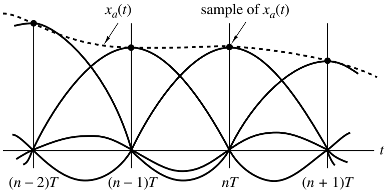
Analog signals → Sample & Hold → A/D Converter → Digital Processor → D/A Converter → Analog Lowpass → Analog signals

A/D converter

$x(t)$ → Sampler → $x(n)$ → Quantizer → $x_q(n)$ → Coder → 01011

Analog signals | Discrete time signal | Quantized signal | Digital signals

D/A converter



Digital Signals

Sequences

- Finite length sequence
- Infinite length sequence
- Even and Odd Sequence
- Periodic sequence
- Causal and Non-causal sequence
- Bounded sequence
  - Absolutely summable
  - Square summable sequence
- Finite Energy sequence
- Average power

Elementary digital signals

- Digital Impulse
- Digital Step
- Digital Ramp
- Exponential Sequence
- Sinusoidal Signal

Digital sinusoidal signal

$$A\cos(\omega n+\phi) \tag{1}$$

- Bounded and Periodic?
- Example: $\cos 3n$
- All analog sinusoidal signals are periodic but digital signals may or may not be periodic.

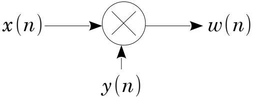
$$A\cos(\Omega t+\phi) \xrightarrow[T]{} A\cos(\Omega nT+\phi)$$

$$\omega=\Omega T=\frac{\Omega}{f_s}=2\pi\frac{f}{f_s} \quad =\text{normalized frequency} \tag{2}$$

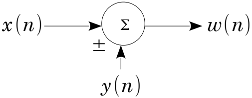
$$-\pi<\omega<\pi \tag{3}$$

Operation on sequences

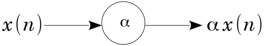
- Multiplication, $w(n) = x(n)y(n)$



- Addition, $w(n) = x(n) \pm y(n)$



- Scalar multiplication, $x(n) = \alpha x(n)$



Operation on sequences

- Time reversal, $x(n) = x(-n)$
- Delay, $x(n) = x(n-N)$

$$x(n) \longrightarrow \boxed{z^{-1}} \longrightarrow x(n-1)$$

$$x(n) \longrightarrow \boxed{z^{-1}} \longrightarrow \boxed{z^{-1}} \longrightarrow \cdots \longrightarrow \boxed{z^{-1}} \longrightarrow x(n-N)$$

- Up-sampler

$$y(n) = \begin{cases} x\left(\frac{n}{L}\right), & n = 0, \pm L, \pm 2L, \ldots \\ 0 & otherwise \end{cases} \tag{4}$$

- Down-sampler

$$y(n) = \begin{cases} x(Mn), & n = 0, 1, 2, \ldots \\ 0 & otherwise \end{cases} \tag{5}$$

Linear and time-invariant (LTI) system

- **Linear System**
  1. **Homogeneity**: if $x(n) \to y(n)$ then $Kx(n) \to Ky(n)$, where K is an arbitrary constant. or zero
  2. **Superposition**: if $K_1x_1(n) \to K_1y_1(n)$ and $K_2x_2(n) \to K_2y_2(n)$, Then

$$K_1x_1(n) + K_2x_2(n) \to K_1y_1(n) + K_2y_2(n)$$

     then the system satisfies the superposition.

- **Time-invariant**: If $x(n) \to y(n)$, and

$$x(n-M) \to y(n-M)$$

Then, the system is said to be time-invariant or shift-invariant.

Causal and non-causal systems

Causal System

- A system is said to be causal system if its output depends on present and past inputs only and not on future inputs.
  Ex. $y(n) = x(n) + x(n-1)$.
- Does not include future input samples; such system is practically realizable.
- Generally all real time systems are causal systems; because in real time applications only present and past samples are present.

Non-Causal System

- A system whose present response depends on future values of the inputs is called as a non-causal system.
  Ex. $y(n) = x(n) + x(n+1)$.
- A non-causal system is practically not realizable.
- Non-causal systems can be implemented for the application where data are stored in memory. Ex. Weather forecasting.

Convolution

$$\delta(n) \rightarrow h(n)$$

$$\delta(n-k) \rightarrow h(n-k) \qquad \rightarrow \text{time invariant}$$

$$x(k)\delta(n-k) \rightarrow x(k)h(n-k) \qquad \rightarrow \text{homogenity}$$

$$\underbrace{\sum_{k=-\infty}^{\infty} x(k)\delta(n-k)}_{x(n)} \rightarrow \underbrace{\sum_{k=-\infty}^{\infty} x(k)h(n-k)}_{y(n)}$$

Therefore,

$$y(n) = \sum_{k=-\infty}^{\infty} x(k)h(n-k) = x(n) * h(n)$$

- If signal is causal then how limit will vary?
- If system is also causal then how limit will vary?

Thank You

Queries?