Module 1

Chapter 1 : Introduction to Signals 1-1 to 1-61

Syllabus : Definitions of signal and system. Standard signals : Step, Ramp, Pulse, impulse, Real and Complex Exponentials and Sinusoids, Classification of signals : Continuous Time (CT) and Discrete Time (DT) signals, Periodic and Aperiodic signals, Deterministic and Random signals, Even and Odd, Energy and Power signals, Basic operations on signals : Folding, Scaling and Time shifting). Convolution in DT domain (Matrix method only).

1.1 Signal 1-2

1.2 CT and DT Signals 1-2

1.2.1 Continuous Time (CT) Signal 1-2

1.2.2 Discrete Time (DT) Signal 1-2

1.3 Standard Signals 1-3

1.3.1 Reasons for Using the Standard Signals 1-4

1.3.2 DC Signal 1-4

1.3.3 Sinusoidal Signals 1-4

1.3.4 Unit Step Signal 1-4

1.3.5 Signum Function 1-5

1.3.6 Rectangular Signals 1-5

1.3.7 Delta or Unit Impulse Function [$\delta(t)$] ... 1-6

1.3.7(A) Important Properties of a Delta Function 1-6

1.3.8 Unit Sample Signal $\delta(n)$ 1-7

1.3.9 Unit Ramp Signal 1-7

1.3.10 C.T. Complex Exponential Signals 1-8

1.3.11 Discrete Time Exponential Signals 1-8

1.3.12 Sinc Function 1-10

1.3.13 Unit Triangle Function 1-11

1.4 Mathematical Operations on Signals 1-11

1.5 Operations on Dependent Variables 1-12

1.5.1 Amplitude Scaling of a Signal 1-12

1.5.2 Addition of Signals 1-12

1.5.3 Subtraction of Signals 1-13

1.5.4 Multiplication of Two Signals 1-14

1.5.5 Differentiation 1-15

1.5.6 Integration 1-15

1.5.7 Accumulation for D.T. Signal 1-15

1.6 Operations on Independent Variable 1-15

1.6.1 Time Shifting 1-15

1.6.2 Time Scaling 1-18

1.6.3 Time Reversal (Time Inversion) or Folding 1-20

1.6.4 Folding and Delay 1-21

1.6.5 Folding and Advance 1-22

1.6.6 Precedence Rule for Time Shifting and Time Scaling 1-22

1.7 Classification of Signals 1-27

1.8 Periodic and Non-periodic Signals 1-28

1.8.1 Periodic CT Signal 1-28

1.8.2 Non-periodic CT Signal 1-28

1.8.3 Periodic discrete time signal 1-28

1.8.4 Non-periodic DT Signal 1-29

1.9 Deterministic and Random Signals 1-35

1.9.1 Deterministic Signal 1-35

1.9.2 Random Signals 1-35

1.10 Symmetrical (Even) or Antisymmetrical (Odd) Signals 1-36

1.10.1 C.T. Symmetrical (Even) Signal 1-36

1.10.2 C.T. Antisymmetrical (Odd) Signal 1-36

1.10.3 D.T. Symmetric (Even) Signals 1-36

1.10.4 Odd (Antisymmetric) D.T. Signal 1-36

1.10.5 Absolutely Integrable Signals 1-37

1.10.6 Stochastic Signals 1-37

1.11 Energy and Power Signals 1-37

1.11.1 Power Signal 1-37

1.11.2 Energy Signals 1-37

1.11.3 Average Value of a CT Signal 1-37

1.11.4 Power of a CT Signal 1-37

1.11.5 Energy of a CT Signal 1-38

1.11.6 Average Power of a DT Signal 1-38

1.11.7 Energy of a DT Signal 1-38

1.11.8 Power of the Energy Signals 1-39

1.11.9 Energy of a Power Signal 1-39

1.12 Causal and Anticausal Signals 1-46

1.12.1 Causal CT Signals 1-46

1.12.2 Causal DT Signals 1-46
1.13 Separating Even and Odd Parts 1-46
1.13.1 Even and Odd Parts of a CT Signal 1-46
1.13.2 Even and Odd Parts of a D.T. Signal 1-46
1.13.3 Solved Examples 1-46
1.14 Computation of Linear Convolution 1-49
1.14.1 Linear Convolution Using Graphical Method 1-49
1.14.1(A) Solved Examples on Graphical Method 1-49
1.14.2 Linear Convolution using Tabular Method 1-53
1.14.2(A) Solved Examples on Tabular Method...1-54
1.15 Solved University Examples 1-54
• **Review Questions.....1-61**

Module 1

Chapter 2 : Introduction to Systems 2-1 to 2-28

Syllabus : Classification of systems : Linear / Non-linear, Time- variant / Invariant, Causal / Anti causal, Stable / unstable, Memory / Memory less system (static and dynamic), Sampling theorem (Derivation is not required).

2.1 System 2-2
2.1.1 Examples of Practical Systems 2-2
2.2 Classification of Systems 2-2
2.2.1 Classification of C.T. Systems 2-2
2.2.2 Classification of D.T. Systems 2-3
2.3 Linear and Non linear Systems 2-3
2.3.1 Additivity and Homogeneity of Systems 2-3
2.3.2 Linear and Nonlinear C.T. Systems 2-3
2.3.3 Linearity of D.T. System 2-4
2.4 Time Variant or Time Invariant Systems 2-9
2.4.1 Time Invariant and Time Variant C.T. Systems 2-9
2.4.2 Shift Invariant and Shift Variant D.T. Systems 2-9
2.5 Causal or Noncausal Systems 2-13
2.5.1 Causal or Realizable C.T. Systems 2-13
2.5.2 Non-causal or Non-realizable C.T. Systems 2-13
2.5.3 Causal or Realizable DT Systems 2-13
2.5.4 Non-causal or Nonrealizable DT Systems 2-14
2.6 Stable or Unstable Systems 2-15
2.6.1 Stable and Unstable C.T. Systems 2-15
2.6.2 Stable and Unstable D.T. Systems 2-15
2.7 Static or Dynamic Systems 2-16
2.7.1 Static DT Systems 2-16
2.7.2 Dynamic DT Systems 2-16
2.7.3 Static or Dynamic C.T. Systems 2-17
2.8 Invertibility of Systems 2-18
2.9 Solved Examples 2-19
2.10 Low Pass and Band Pass Signals 2-24
2.10.1 Sampling Process 2-24
2.11 Sampling Theorem for Low Pass Signals in Time Domain 2-24
2.11.1 Aliasing or Foldover Error 2-26
2.11.2 Nyquist Rate and Nyquist Interval 2-27
2.11.3 Effect of Nonideal Filter 2-27
• **Review Questions 2-28**

Module 2

Chapter 3 : Z-Transform 3-1 to 3-55

Syllabus : z-Transform of bilateral signal, Definition of ROC, Properties of ROC, Properties of z- transform, Inverse z-Transform (only partial fraction). Formation of Difference Equation, Solution of difference Equation (with & without initial Conditions)

3.1 Introduction 3-2
3.2 Definition of z-Transform 3-2
3.3 z-Transform of Standard Sequences 3-10
3.3.1 z-Transform of Unit Impulse $\delta(n)$ 3-10
3.3.2 z-Transform of a Delayed Unit Impulse $\delta(n-k)$ 3-11
3.3.3 z-Transform of a Unit Step u(n) 3-11
3.3.4 z-Transform of Unit Ramp 3-12

3.4 Properties of z-Transform 3-13
3.4.1 Linearity 3-13
3.4.2 Time Shifting 3-14
3.4.3 Scaling 3-15
3.4.4 Time Reversal 3-15
3.4.5 Differentiation Property 3-16
3.4.6 Convolution 3-17
3.4.7 Initial Value Theorem 3-18
3.4.8 Final Value Theorem 3-18
3.5 Solved Examples on z-Transform 3-20
3.6 Inverse z-Transform 3-31
3.6.1 Partial Fraction Expansion Method 3-31
3.7 Relationship between The z-transform and Other Transforms 3-41
3.7.1 Relationship between Laplace Transform and z-Transform 3-41
3.7.2 Relationship between Fourier Transform and z-Transform 3-41
3.7.3 Relationship between DFT and ZT 3-42
3.8 Solved Examples 3-42
3.9 Solved University Examples 3-51
• **Review Questions.....3-55**

Module 2

Chapter 4 : Analysis & Characterization of LTI Systems using Z-Transform 4-1 to 4-24

Syllabus : Pole-zero plot in DT domain, Formation of Difference Equation, Zero input, Zero state and Total Response of the system

4.1 Introduction 4-2
4.1.1 Relation between Pole and Time Domain 4-2
4.2 Transfer Function 4-7
4.3 Checking Causality and Stability using z-Transform 4-13
4.4 Solved Examples 4-14
• **Review Questions.....4-24**

Module 3

Chapter 5 : Introduction to Fourier Series 5-1 to 5-30

Syllabus : Introduction to Fourier series : Representation of continuous time periodic signals, Convergence of Fourier series, Properties of continuous time Fourier series, Fourier series representation of discrete time periodic signals, Properties of discrete time Fourier series.

5.1 Frequency Domain Representation 5-2
5.1.1 How to Plot Line Spectrum ?.....5-2
5.1.2 Double Sided Line Spectrum 5-3
5.2 CT Fourier Series 5-4
5.2.1 Types of Fourier Series 5-4
5.2.2 Trigonometric or Quadrature Fourier Series 5-4
5.2.3 Polar Fourier Series 5-5
5.2.4 Exponential Fourier Series (or Complex Exponential Fourier Series) 5-6
5.2.5 Dirichlet Conditions for the Existence of Fourier Series 5-6
5.2.5(A) Knowledge of Waveform Symmetry used to Calculate Fourier Coefficient 5-7
5.2.6 Examples on Fourier Series 5-7
5.3 Properties of C.T. Fourier Series 5-22
5.3.1 Linearity 5-22
5.3.2 Time Shifting 5-23
5.3.3 Time Reversal 5-24
5.3.4 Time Scaling 5-24
5.3.5 Frequency Shifting 5-24
5.3.6 Differentiation 5-25
5.4 Fourier Series for Discrete Time Periodic Signals (DTFS) 5-25
5.5 Solved Examples 5-25
• **Review Questions 5-30**

Module 4

Chapter 6 : Discrete Fourier Transform (DFT) 6-1 to 6-68

Syllabus : DTFT, DFT & IDFT (Only Matrix Method), Properties of DFT

6.1 The Fourier Transform 6-2
6.2 Discrete Time Fourier Transform 6-2
6.2.1 DTFT of Standard Signals 6-3
6.3 Properties of DTFT 6-5
6.3.1 Linearity 6-5
6.3.2 Time Shifting 6-5
6.3.3 Time Reversal 6-5
6.3.4 Differentiation 6-6
6.3.5 Convolution Theorem 6-6
6.3.6 Windowing (Modulation) Theorem 6-7
6.4 Relationship between DTFT and DFT 6-7
6.5 Discrete Fourier Transform (DFT) 6-8
6.5.1 DFT of Simple Signals 6-8
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6.8 Computing DFT by Matrix Method 6-19
6.8.1 Solved Examples on DFT Matrix Method 6-23
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6.9.7 Complex Conjugate Property 6-46
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6.9.10 Circular Convolution Theorem 6-49
6.10 Circular Convolution 6-49
6.10.1 Concentric Circle Method 6-49
6.10.2 Matrix Method 6-52
6.10.3 Getting Linear Convolution from Circular Convolution 6-53
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6.11.1 Overlap -Save Method.....6-64
6.11.2 Overlap -Add Method 6-66
• **Review Questions.....6-68**

Module 4

Chapter 7 : Fast Fourier Transform 7-1 to 7-30

Syllabus : DIT FFT Algorithm (Radix-2)

7.1 Introduction 7-2
7.2 Computational Complexity of DFT 7-2
7.3 Radix-2 Decimation in Time FFT (DIT-FFT) 7-3
7.3.1 Bit Reversal Format 7-7
7.3.2 Solved Examples on DIT-FFT 7-8
7.4 Computational Complexity Comparison between DFT and FFT 7-25
7.4.1 Computation of Inverse DFT using FFT Algorithms 7-26
• **Review Questions 7-30**

Module 3

Chapter 8 : Basics of Digital Filter 8-1 to 8-19

Syllabus : Minimum phase, Maximum phase, Mixed phase and Linear, Phase System based on location of zeros, Low pass, high pass, Band pass and band reject system based on pass band frequency, Magnitude and phase response (only Analytical Method).

8.1 Introduction 8-2
8.2 Basics of Filters 8-2
8.2.1 Analog Filters 8-2
8.2.2 Digital Filters 8-3
8.2.3 Comparison of Analog and Digital Filters 8-3
8.2.4 Drawing the Frequency Response of Digital Filter 8-3
8.3 Ideal Filter Responses 8-5
8.4 Basics of Filtering 8-7
8.4.1 Ideal Filters 8-7
8.5 Types of Digital Filters 8-9
8.5.1 Difference between IIR and FIR Filters 8-10
8.5.2 Additional Points in Filters 8-10
8.6 Minimum, Maximum and Mixed Phase Systems 8-14
• **Review Questions 8-19**

Module 5

Chapter 9 : FIR Filter Design 9-1 to 9-32

Syllabus : Introduction to FIR System, Group Delay, phase Delay, Condition for Linear phase FIR system, Window Technique (only Rectangular window function, Hamming Window function)

9.1 Introduction 9-2

9.1.1 Characteristics of FIR Filters 9-2

9.1.2 Linear Phase 9-3

9.2 Designing of FIR Filters 9-3

9.2.1 Designing FIR Filters using Windows 9-3

9.3 Windowing Techniques 9-4

9.3.1 Rectangular Window 9-4

9.3.2 Hamming, Hanning, Blackman Window 9-12

9.4 Solved Examples on FIR Filter Design 9-15

9.5 Solved Examples 9-31

- **Review Questions.....9-32**

Module 6

Chapter 10 : IIR Filter Design 10-1 to 10-29

Syllabus : Introduction to IIR System & Bilinear Transformation, Digital Butterworth Filter design using Bilinear Transformation

10.1 Introduction 10-2

10.2 Stability of IIR Filter 10-2

10.2.1 Approach of IIR Filter Design 10-3

10.3 Bilinear Transformation Method 10-3

10.3.1 Frequency Warping 10-5

10.3.2 Solved Examples on Bilinear Transformation Method 10-5

10.4 Design of Analog Butterworth Filter 10-9

10.4.1 Steps Involved in Designing Butterworth Lowpass Filter 10-10

10.4.2 Solved Examples on Butterworth Filter 10-10

10.5 Frequency Transformation 10-22

10.5.1 Frequency Transformation in the Analog Domain 10-22

10.6 Solved Examples 10-25

- **Review Questions 10-29**

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