

Second Edition
Signals and Systems Simplified
for Anna University ECE Course

adheres to the latest syllabus of Anna University ECE course. An easy-to-understand text with crisp but complete explanation of topics will enable the students to understand the basic concepts easily.

This book is organized into 5 chapters. The fundamental concepts, modeling and analysis of signals and systems are presented in an easy and elaborative manner. Considering the highly mathematical nature of this subject, more emphasis has been given to problem-solving methodology. Throughout the book, carefully chosen examples are presented so that the reader will have a clear understanding of the concepts discussed. This book, with its lucid writing style and useful pedagogical features, will prove to be a master text for engineering students.

Salient Features

- Solution to university questions will enable students to score better in examinations.
- Clear explanation of concepts with appropriate diagrams.
- Different types of fonts for text, proof and solved problems for better understanding.
- Step-by-step presentation of proofs and solved problems.
- MATLAB programming will be useful for laboratory and other projects.

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QR code to
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CBS Catalogue

ISBN: 978-93-54661-01-3



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ECE Course

A Nagoor Kani

Founder, RBA Educational Group
Chennai

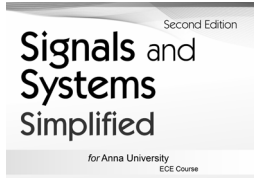


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ISBN: 978-93-5466-101-3

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Second Edition: 2022

First Edition: 2018

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Published by Satish Kumar Jain and produced by Varun Jain for

CBS Publishers & Distributors Pvt Ltd

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Printed at: Mudrak, Noida, UP, India.

to

Er T A Benazir

PREFACE

The main objective of this book is to explore the basic concepts of signals and systems in a simple and easy-to-understand manner.

This text on signals and systems has been crafted and designed to meet students' requirements. Considering the highly mathematical nature of this subject, more emphasis has been given on the problem-solving methodology. Considerable effort has been made to elucidate mathematical derivations in a step-by-step manner. Exercise problems with varied difficulty levels are given in the text to help students get an intuitive grasp on the subject.

This book with its lucid writing style and germane pedagogical features will prove to be a master text for engineering students and practitioners.

Salient Features

- Proof of important concepts and theorems are clearly highlighted by shaded boxes
- Wherever required, problems are solved in multiple methods
- Additional explanations for solutions and proofs are provided in separate boxes
- Different types of fonts are used for text, proof and solved problems for better clarity
- Keywords are highlighted by bold, italic fonts
- Easy, concise and accurate study material
- Extremely precise edition where concepts are reinforced by pedagogy
- Demonstration of multiple techniques in problem solving, additional explanations and proofs highlighted
- Ample figures and examples to enhance students' understanding
- Practice through MCQ's

Pedagogy

- Solved Numerical Examples: $44 + 46 + 35 + 38 + 59 = 222$ (excluding a, b, c, d,...)
- Short-Answer Questions: $27 + 32 + 18 + 20 + 35 = 132$
- Figures: $58 + 33 + 18 + 13 + 22 = 144$ (numbered figures excluding figures in problems and QA)
- Exercise Numerical Problems: $21 + 21 + 22 + 12 + 20 = 96$ (exercise problems excluding a, b, c, d,...)
- Review Questions: $40 + 35 + 18 + 15 + 32 = 140$
- MCQs: $35 + 48 + 13 + 18 + 18 = 132$
- Fill in the blanks and True/False: $55 + 46 + 21 + 20 + 31 = 173$

Organization

In this book, the concepts of signals and systems are organized in five chapters. Each chapter provides the foundations and practical implications of their own topic with large number of solved numerical examples and illustrative figures for better understanding. The important concepts are summarized at the end of each chapter which can help in quick reference. Another significant aspect of this book is that, it contains MATLAB based computer exercises for each chapter with complete explanation, which will be of great assistance to both instructor and student.

Chapter 1 starts with a general introduction about various types of signals, systems and their importance in real life. Basic definitions of signals, their mathematical representation, significance of their frequency domain analysis and usage of MATLAB in this course are presented in brief manner.

Chapter 1 explores various standard continuous time and discrete time signals, classifications of continuous time and discrete time signals and possible mathematical operations on signals such as amplitude and time scaling, folding, time shifting, addition, multiplication, etc. The concept of generation of discrete time signals is also presented in this chapter. The classification and properties of continuous time and discrete time systems are also presented in chapter 1 with appropriate examples.

Chapter 2 deals with analysis of continuous time signals using Fourier series, Fourier transform and Laplace transform. Chapter 2 starts with Fourier analysis of continuous time signals which forms the basics for frequency domain analysis. Fourier series in both trigonometric and exponential forms, Fourier coefficients of various signals with symmetry, properties of Fourier series, frequency spectrum using Fourier series and Gibbs phenomenon have been discussed. Then the Chapter 2 explains the development of Fourier transform from Fourier series, Fourier transform of some standard signals, various properties of Fourier transform and frequency spectrum via Fourier transform. The proof of properties of Fourier transform of continuous time signal are also presented with clear steps.

Also, Chapter 2 discusses about analysis of continuous time signals using Laplace transform. The properties of Laplace transform and proof with clear steps are presented. The rational functions of 's' and their representation in terms of poles and zeros, region of convergence of Laplace transform and its properties are presented in a crisp and clear manner. Further, chapter 2 discusses about the inverse Laplace transform using partial fraction method and convolution theorem. The relation between Fourier transform and Laplace transform of continuous time signals is also discussed in chapter 2.

Chapter 3 deals with analysis of Linear Time Invariant (LTI) continuous time systems in time domain, frequency domain and s-domain. The differential equation governing the LTI continuous time system in time domain and their direct solutions in time domain are discussed with examples. The time domain convolution operation that can be used to find the response of LTI system from its impulse response is explained with clear numerical examples. Another important thing in chapter 3 is that the graphical convolution operation of continuous time signals is discussed by clearly separating the shift index and time index that will aid in clear understanding.

Also, the Chapter 3 deals with detailed analysis of continuous time systems in s-domain using Laplace transform. The transfer function in s-domain, impulse response, response for specific inputs, convolution and deconvolution operations using Laplace transform are presented with appropriate numerical examples. The stability of the LTI systems in s-domain via Laplace transform is dealt clearly.

In addition, the Chapter 3 deals with analysis of continuous time systems in frequency domain using Fourier transform. The transfer function of continuous time system in frequency domain, impulse response, response for specific inputs and convolution using Fourier transform are

presented with appropriate numerical examples. The computation of frequency response of continuous time LTI systems using Fourier transform is also explained.

The standard realization structures for the continuous time systems characterized by differential equations are also presented in chapter 3.

Chapter 4 deals with analysis of discrete time signals using discrete time fourier transform (DTFT) and \mathcal{Z} -transform. Chapter 4 starts with Fourier transform analysis of discrete time signals which forms the basics for frequency domain analysis. The frequency spectrum, various properties of Fourier transform and Fourier transform of some standard signals are presented. The proof of properties of DTFT are presented with clear steps. The concept of sampling and aliasing in frequency spectrum are also discussed.

Also, Chapter 4 discusses about analysis of discrete time signals using \mathcal{Z} -transform. The properties of \mathcal{Z} -transform and proof with clear steps are presented. The rational functions of 'z' and their representation in terms of poles and zeros, region of convergence of \mathcal{Z} -transform and its properties are presented in detail with appropriate examples. Further, chapter 4 discusses about the various methods of inverse \mathcal{Z} -transform. The relation between Fourier transform and \mathcal{Z} -transform of discrete time signals is also discussed in chapter 4.

Chapter 5 deals with analysis of discrete time systems in time domain, frequency domain and z-domain. The difference equation governing the LTI discrete time system in time domain and their direct solutions in time domain are discussed with examples. The time domain discrete convolution operation that can be used to find the response of LTI discrete time system from its impulse response is explained with clear numerical examples. The graphical convolution operation of discrete time signals is illustrated with figures for each step that will aid in clear understanding.

Also, Chapter 5 deals with analysis of discrete time systems in frequency domain using Fourier transform. The transfer function of discrete time system in frequency domain, impulse response, response for specific inputs and convolution using Fourier transform are presented with appropriate numerical examples. The computation of frequency response of discrete time LTI systems using Fourier transform is also explained with examples.

In addition, Chapter 5 deals with detailed analysis of discrete time systems in z-domain using \mathcal{Z} -transform. The transfer function in z-domain, impulse response, response for specific inputs, convolution and deconvolution operations using \mathcal{Z} -transform are presented with appropriate numerical examples. The stability of the LTI systems in z-domain via \mathcal{Z} -transform is dealt clearly.

Also, Chapter 5 focuses on structures for realization of discrete time systems with special attention to IIR and FIR systems.

A Nagoor Kani

ACKNOWLEDGEMENTS

I express my heartfelt thanks to my wife Ms C Gnanaparanjothi Nagoor Kani and my sons N Bharath Raj alias Chandrakani Allaudeen and N Vikram Raj for the support, encouragement and cooperation they have extended to me throughout my career.

I thank Ms T A Benazir for the affection and care on my day-to-day activities.

It's my pleasure to acknowledge the contributions of our technical editors, Ms. E R Suhasini, Ms M A Aswathy, Ms C Mohana Priya, Ms Devi Asokan and Ms L Sharmila for editing, proof-reading and type-setting of the manuscript and preparing the layout of the book.

I thank all my office staff for their support and help in carrying my office work.

My sincere thanks to all reviewers for their valuable suggestions and comments which helps me to explore the subject to greater depth.

I am also grateful to Mr Satish K Jain, CMD, CBS Publishers & Distributors, for his keen interest in publishing this work in CBS banner. My sincere thanks to all team members of CBS Publishers & Distributors, for their concern and care in publishing this work.

Finally, a special note of appreciation is due to my sisters, brothers, relatives, friends, students and the entire teaching community for their overwhelming support and encouragement to my writing.

A Nagoor Kani

CONTENTS

<i>Preface</i>	<i>vii</i>
<i>List of Symbols and Abbreviations</i>	<i>xix</i>

CHAPTER 1: CLASSIFICATION OF SIGNALS AND SYSTEMS **1.1–1.150**

1.1 Introduction to Signals and Systems	1. 1
1.1.1 Signals	1. 1
1.1.2 Systems	1. 2
1.1.3 Frequency Domain Analysis of Continuous Time Signals and Systems	1. 2
1.1.4 Frequency Domain Analysis of Discrete Time Signals and Systems	1. 4
1.1.5 Importance of Signals and Systems	1. 4
1.1.6 Use of MATLAB in Signals and Systems	6
1.2 Continuous Time Signals	1. 6
1.2.1 Standard Continuous Time Signals	1. 7
1.2.2 Properties of Impulse Signal	1. 11
1.2.3 Representation of a Continuous Time Signal as Integral of Impulses	1. 13
1.2.4 Mathematical Operations on Continuous Time Signals	1. 15
1.2.5 Order of Mathematical Operations on Signals with Multiple Operations	1. 23
1.3 Discrete Time Signals	1. 27
1.3.1 Generation of Discrete Time signals	1. 28
1.3.2 Digital Signal	1. 28
1.3.3 Representation of Discrete Time signals	1. 30
1.3.4 Standard Discrete Time signals	1. 31
1.3.5 Representation of a Discrete Time Signal as Summation of Impulses	1. 35
1.3.6 Mathematical Operations on Discrete Time Signals	1. 36
1.4 Classification of Continuous Time Signals	1. 41
1.4.1 Deterministic and Nondeterministic (Random) Signals	1. 42
1.4.2 Periodic and Nonperiodic Signals	1. 42
1.4.3 Symmetric (Even) and Antisymmetric (Odd) Signals	1. 48

- 1.4.4 Energy and Power Signals 1. 52
- 1.4.5 Causal, Noncausal and Anticausal Signals 1. 56
- 1.5 Classification of Discrete Time Signals 1. 56
 - 1.5.1 Deterministic and Nondeterministic (Random) Signals 1. 56
 - 1.5.2 Periodic and Nonperiodic Signals 1. 57
 - 1.5.3 Symmetric (Even) and Antisymmetric (Odd) Signals 1. 62
 - 1.5.4 Energy and Power Signals 1. 64
 - 1.5.5 Causal, Noncausal and Anticausal Signals 1. 66
- 1.6 Continuous Time Systems 1. 67
- 1.7 Classification of Continuous Time Systems 1. 68
 - 1.7.1 Static and Dynamic Systems 1. 68
 - 1.7.2 Time Invariant and Time Variant Systems 1. 68
 - 1.7.3 Linear and Nonlinear Systems 1. 72
 - 1.7.4 Causal and Noncausal Systems 1. 76
 - 1.7.5 Stable and Unstable Systems 1. 79
 - 1.7.6 Feedback and Nonfeedback Systems 1. 83
 - 1.7.7 Invertible and Noninvertible Systems 1. 84
- 1.8 Discrete Time Systems 1. 89
- 1.9 Classification of Discrete Time Systems 1. 90
 - 1.9.1 Static and Dynamic Systems 1. 90
 - 1.9.2 Time Invariant and Time Variant Systems 1. 90
 - 1.9.3 Linear and Nonlinear Systems 1. 94
 - 1.9.4 Causal and Noncausal Systems 1.100
 - 1.9.5 Stable and Unstable Systems 1.102
 - 1.9.6 FIR and IIR Systems 106
 - 1.9.7 Recursive and Nonrecursive Systems 1.107
 - 1.9.8 Invertible and Noninvertible systems 1.107
- 1.10 Summary of Important Concepts 1.119
- 1.11 Short-Answer Questions 1.120
- 1.12 MATLAB Programs 1.129
- 1.13 Exercises 1.139

CHAPTER 2: ANALYSIS OF CONTINUOUS TIME SIGNALS**2.1–2.160**

- 2.1 Fourier Series Analysis of Continuous Time Signals 2. 1
 - 2.1.1 Trigonometric Form of Fourier Series 2. 1
 - 2.1.2 Conditions for Existence of Fourier Series 2. 2

-
- 2.1.3 Exponential Form of Fourier Series 2. 3
 - 2.1.4 Relation between Fourier Coefficients of Trigonometric and Exponential Form 2. 4
 - 2.1.5 Properties of Fourier Series 2. 4
 - 2.2 Fourier Coefficients of Signals with Symmetry 2. 6
 - 2.2.1 Even Symmetry 2. 6
 - 2.2.2 Odd Symmetry 2. 7
 - 2.2.3 Half Wave Symmetry (or Alternation Symmetry) 2. 9
 - 2.2.4 Quarter Wave Symmetry 2. 9
 - 2.3 Gibbs Phenomenon 2. 14
 - 2.4 Spectrum of Continuous Time Signals from Fourier Series 2. 15
 - 2.5 Fourier Transform 2. 40
 - 2.5.1 Development of Fourier Transform from Fourier Series 2. 40
 - 2.5.2 Definition of Fourier Transform 2. 42
 - 2.5.3 Conditions for Existence of Fourier Transform 2. 42
 - 2.5.4 Definition of Inverse Fourier Transform 2. 42
 - 2.5.5 Frequency Spectrum Using Fourier Transform 2. 43
 - 2.5.6 Comparison of Fourier Series and Fourier Transform 2. 43
 - 2.5.7 Properties of Fourier Transform 2. 43
 - 2.6 Fourier Transform of Some Important Signals 2. 53
 - 2.6.1 Fourier Transform of Unit Impulse Signal 2. 53
 - 2.6.2 Fourier Transform of Single Sided Exponential Signal 2. 53
 - 2.6.3 Fourier Transform of Double Sided Exponential Signal 2. 54
 - 2.6.4 Fourier Transform of a Constant 2. 55
 - 2.6.5 Fourier Transform of Signum Function 2. 56
 - 2.6.6 Fourier Transform of Unit Step Signal 2. 57
 - 2.6.7 Fourier Transform of Complex Exponential Signal 2. 58
 - 2.6.8 Fourier Transform of Sinusoidal Signal 2. 59
 - 2.6.9 Fourier Transform of Cosinusoidal Signal 2. 59
 - 2.6.10 Solved Problems in Fourier Transform 2. 65
 - 2.7 Laplace Transform 2. 77
 - 2.7.1 s-plane(or Complex Frequency Plane) 2. 78
 - 2.7.2 Definition of Laplace Transform 2. 78
 - 2.7.3 Poles and Zeros of Rational Function of s 2. 78
 - 2.8 Region of Convergence 2. 80
 - 2.8.1 ROC of Continuous Time Signal 2. 80
 - 2.8.2 ROC of Rational Function of s (ROC Using Poles) 2. 83
 - 2.8.3 Properties of ROC 2. 85

- 2.9 Properties and Theorems of Laplace Transform 2.101
- 2.10 Inverse Laplace Transform 2.116
 - 2.10.1 Inverse Laplace Transform by Partial Fraction Expansion Method 2.117
 - 2.10.2 Inverse Laplace Transform Using Convolution Theorem 2.122
- 2.11 Relation between Fourier and Laplace Transform 2.128
- 2.12 Summary of Important Concepts 2.129
- 2.13 Short-Answer Questions 2.130
- 2.14 MATLAB Programs 2.140
- 2.15 Exercises 2.148

CHAPTER 3: LINEAR TIME INVARIANT CONTINUOUS TIME SYSTEMS 3.1–3.136

- 3.1 Continuous Time System 3. 1
 - 3.1.1 Impulse Response 3. 1
 - 3.1.2 Differential Equation Governing LTI Continuous Time System 3. 2
- 3.2 Block Diagram Representation of Continuous Time System in Time Domain 3. 3
- 3.3 Response of LTI Continuous Time System in Time Domain 3. 5
 - 3.3.1 Homogeneous Solution 3. 6
 - 3.3.2 Particular Solution 3. 7
 - 3.3.3 Zero-Input and Zero-State Response 3. 8
 - 3.3.4 Total Response 3. 8
- 3.4 Convolution Integral 3. 14
 - 3.4.1 Procedure to Perform Convolution 3. 14
 - 3.4.2 Convolution of Impulse Signal 3. 14
 - 3.4.3 Response of LTI Continuous time System Using Convolution 3. 16
 - 3.4.4 Unit Step Response Using Convolution 3. 16
 - 3.4.5 Properties of Convolution 3. 17
- 3.5 Interconnection of Continuous Time Systems 3. 19
- 3.6 Analysis of LTI Continuous Time System Using Laplace Transform 3. 36
 - 3.6.1 Transfer Function of LTI Continuous Time System 36
 - 3.6.2 Impulse Response and Transfer Function 3. 37
 - 3.6.3 Response of LTI Continuous Time System Using Laplace Transform 3. 38
 - 3.6.4 Convolution and Deconvolution Using Laplace Transform 3. 39
 - 3.6.5 Stability in s-Domain 3. 40
- 3.7 Block Diagram Representation of LTI Continuous Time Systems in s-Domain 3. 74
 - 3.7.1 Direct Form-I Structure 3. 75
 - 3.7.2 Direct Form-II Structure 3. 76

3.7.3	Cascade Structure	3. 79
3.7.4	Parallel Structure	3. 80
3.8	Analysis of LTI Continuous Time System Using Fourier Transform	100
3.8.1	Transfer Function of LTI Continuous Time System in Frequency Domain	3.100
3.8.2	Impulse Response and Transfer Function	3.101
3.8.3	Response of LTI Continuous Time System Using Fourier Transform	3.102
3.8.4	Frequency Response of LTI Continuous Time System	3.102
3.9	Summary of Important Concepts	3.109
3.10	Short-Answer Questions	3.110
3.11	MATLAB Programs	3.116
3.12	Exercises	3.124

CHAPTER 4: ANALYSIS OF DISCRETE TIME SIGNALS**4.1–4.104**

4.1	Baseband Sampling	4. 1
4.1.1	Sampling and Aliasing	.4. 2
4.2	Fourier Transform of Discrete Time Signals (Discrete Time Fourier Transform)	4. 6
4.2.1	Definition of Discrete Time Fourier Transform	4. 6
4.2.2	Inverse Discrete Time Fourier Transform	4. 7
4.2.3	Properties of Discrete Time Fourier Transform	4. 9
4.3	Frequency Spectrum of Discrete Time Signal	4. 17
4.3.1	Aliasing in Frequency Spectrum Due to Sampling	4. 18
4.3.2	Antialiasing Filter	4. 20
4.3.3	Signal Reconstruction (Recovery of Continuous Time Signal)	4. 20
4.3.4	Sampling of Bandpass Signal	4. 21
4.4	z -Transform	4. 31
4.4.1	Z-Plane	4. 31
4.4.2	Definition of z -Transform	4. 32
4.4.3	Inverse z -Transform	4. 32
4.4.4	Poles and Zeros of Rational Function of z	4. 33
4.5	Region of Convergence of z -transform	4. 35
4.5.1	ROC of Discrete Time Signal	4. 35
4.5.2	ROC of Rational Function of z (ROC Using Poles)	4. 40
4.5.3	Properties of ROC	4. 41
4.6	Properties of z -Transform	4. 48
4.7	Relation between z -Transform and Discrete Time Fourier Transform	4. 66

- 4.8 Various Methods of Computing Inverse z -Transform 4. 67
 - 4.8.1 Inverse z -Transform by Contour Integration or Residue Method 4. 67
 - 4.8.2 Inverse z -Transform by Partial Fraction Expansion Method 4. 68
 - 4.4.3 Inverse z -Transform by Power Series Expansion Method 4. 71
- 4.9 Summary of Important Concepts 4. 90
- 4.10 Short-Answer Questions 4. 91
- 4.11 MATLAB Programs 4. 97
- 4.12 Exercises 4. 99

CHAPTER 5: LINEAR TIME INVARIANT DISCRETE TIME SYSTEMS**5.1–5.170**

- 5.1 Discrete Time System 5. 1
 - 5.1.1 Impulse Response 5. 1
 - 5.1.2 Difference Equation Governing Discrete Time System 5. 2
- 5.2 Block Diagram Representation of Discrete Time System 5. 3
- 5.3 Response of LTI Discrete Time System in Time Domain 5. 5
 - 5.3.1 Zero-Input Response or Homogeneous Solution 5. 6
 - 5.3.2 Particular Solution 5. 7
 - 5.3.3 Zero-State Response 5. 7
 - 5.3.4 Total Response 5. 8
- 5.4 Convolution Sum 5. 12
 - 5.4.1 Discrete or Linear Convolution 5. 12
 - 5.4.2 Representation of Discrete Time Signal as Summation of Impulses 5. 14
 - 5.4.3 Response of LTI Discrete Time system Using Discrete Convolution 5. 15
 - 5.4.4 Properties of Linear Convolution 5. 15
 - 5.4.5 Methods of Performing Linear Convolution 5. 17
- 5.5 Interconnections of Discrete Time Systems 5. 28
 - 5.5.1 Cascade Connected Discrete Time Systems 5. 28
 - 5.5.2 Parallel Connected Discrete Time Systems 5. 29
- 5.6 Analysis of LTI Discrete Time System Using Discrete Time Fourier Transform 5. 34
 - 5.6.1 Transfer Function of LTI Discrete Time System in Frequency Domain 5. 34
 - 5.6.2 Impulse Response and Transfer Function 5. 35
 - 5.6.3 Response of LTI Discrete Time System Using Discrete Time Fourier Transform 5. 36
 - 5.6.4 Frequency Response of LTI Discrete Time System 5. 36
 - 5.6.5 Properties of Frequency Response 5. 37

5.6.6	Frequency Response of First-Order Discrete Time System	5. 38
5.6.7	Frequency Response of Second-Order Discrete Time System	5. 44
5.7	Analysis of LTI Discrete Time System Using z -Transform	58
5.7.1	Transfer Function of LTI Discrete Time System	5. 58
5.7.2	Impulse Response and Transfer Function	5. 59
5.7.3	Response of LTI Discrete Time System Using z -Transform	5. 59
5.7.4	Convolution and Deconvolution Using z -Transform	5. 61
5.7.5	Stability in z -Domain	5. 61
5.8	Structures for Realization of IIR Systems	5. 96
5.8.1	Direct Form-I Structure of IIR System	5. 96
5.8.2	Direct Form-II Structure of IIR System	5. 97
5.8.3	Cascade Form Realization of IIR System	5.100
5.8.4	Parallel Form realization Of IIR System	5.101
5.9	Structures for Realization of FIR Systems	5.129
5.9.1	Direct Form Realization of FIR System	5.130
5.9.2	Cascade Form Realization of FIR System	5.130
5.9.3	Linear Phase Realization of FIR System	5.131
5.10	Summary of Important Concepts	5.137
5.11	Short-Answer Questions	5.138
5.12	MATLAB Programs	5.149
5.13	Exercises	5.157

APPENDICES**A. 1–A. 22**

Appendix 1: Important Mathematical Relations	A. 1
Appendix 2: MATLAB Commands and Functions	A. 5
Appendix 3: Summary of Various Standard Transform Pairs	A. 11
Appendix 4: Summary of Properties of Various Transform	A. 17

ANNA UNIVERSITY QUESTION PAPERS**Q. 1–Q. 20****INDEX****I. 1–I. 8**

LIST OF SYMBOLS AND ABBREVIATIONS

Symbols		Ω	Angular frequency of continuous time signal in rad/sec
a_o, a_n, b_n	Fourier coefficients of trigonometric form of Fourier series of $x(t)$	Ω_o	Fundamental angular frequency
B	Bandwidth in Hz	Ω_{max}	Maximum angular frequency in rad/sec
c_n	Fourier coefficients of exponential form of Fourier series of $x(t)$	ω	Angular frequency of discrete time signal
E	Energy of a signal	ω_k	Sampling frequency point
f	Frequency of discrete time signal in Hz/sample	σ	Neper frequency (Real part of s)
F	Frequency of continuous time signal in Hz	*	Convolution operator
F_o	Fundamental frequency of continuous time signal in Hz	\oint	Integration operator
F_m	Maximum frequency of continuous time signal	$\frac{d}{dt}$	Differentiation operator
F_s	Sampling frequency of continuous time signal in Hz		
\mathcal{H}	System operator	Standard/Input/Output Signals	
j	Complex operator, $\sqrt{-1}$	$h(n)$	Impulse response of discrete time system
L	Inductance	$h(t)$	Impulse response of continuous time system
$n\Omega_o$	Harmonic angular frequency, where $n = 1, 2, 3, \dots$	$\text{sgn}(t)$	Signum signal
P	Power of a signal	$\text{sinc}(t)$	Sinc signal
p	Pole	$u(n)$	Discrete time unit step signal
R	Resistor	$u(t)$	Continuous time unit step signal
s	Complex frequency ($s = \sigma + j\Omega$)	$x(n)$	Discrete time signal
t	Time in seconds	$x(n)$	Input of discrete time system
T	Time period in seconds	$x_o(n)$	Odd part of discrete time signal $x(n)$
W	Phase factor or twiddle factor	$x_e(n)$	Even part of discrete time signal $x(n)$
z	Complex variable ($z = u + jv$)	$x(n-m)$	Delayed or linearly shifted $x(n)$ by m units
z	Unit advance operator or zero	$x(t)$	Continuous time signal or Input of continuous time system
z^{-1}	Unit delay operator	$x_o(t)$	Odd part of continuous time signal $x(t)$

$x_e(t)$	Even part of continuous time signal	\mathcal{L}	Laplace transform
$x(t)$		\mathcal{L}^{-1}	Inverse Laplace transform
$x(t-m)$	Delayed or linearly shifted $x(t)$ by m units	$X(e^{j\omega})$	Discrete time fourier transform of $x(n)$
$y(n)$	Output/Response of discrete time system	$X_r(e^{j\omega})$	Real part of $X(e^{j\omega})$
$y_{zs}(n)$	Zero state response of discrete time system	$X_i(e^{j\omega})$	Imaginary part of $X(e^{j\omega})$
$y_{zi}(n)$	Zero input response of discrete time system	$X(j\Omega)$	Fourier transform of $x(t)$
$y(t)$	Output /Response of continuous time system	$X(s)$	Laplace transform of $x(t)$
$y_{zs}(t)$	Zero state response of continuous time system	$X(z)$	\mathcal{Z} -transform of $x(n)$
$y_{zi}(t)$	Zero input response of continuous time system	\mathcal{Z}	\mathcal{Z} -transform
$\delta(t)$	Continuous time impulse signal	\mathcal{Z}^{-1}	Inverse \mathcal{Z} -transform
$\delta(n)$	Discrete time impulse signal	Abbreviations	
$\Pi(t)$	Unit pulse signal	BIBO	Bounded Input Bounded Output
Transform Operators and Functions		CT	Continuous Time
\mathcal{F}	Fourier transform	CTFS	Continuous Time Fourier Series
\mathcal{F}^{-1}	Inverse Fourier transform	CTFT	Continuous Time Fourier Transform
$H(s)$	Laplace transform of $h(t)$	DT	Discrete Time
		DTFT	Discrete Time Fourier Transform
		FIR	Finite Impulse Response
		IIR	Infinite Impulse Response
		LHP	Left Half Plane
		LTI	Linear Time Invariant
		RHP	Right Half Plane
		ROC	Region of Convergence