

Contents

<i>Preface</i>	(vii)
----------------------	-------

CHAPTER 1

Introduction to Digital Signal Processing

1.1	Introduction	1
1.1.1	Signal and Signal Processing	1
1.1.2	Basic Elements of Digital Signal Processing Systems	2
1.1.3	Advantages of Digital Signal Processing over Analog Signal Processing	3
1.2	Discrete Time Signals and Sequences	3
1.2.1	Representation of Discrete-Time Signals.....	4
1.2.2	Elementary Discrete-Time Signals	5
1.2.3	Manipulation of Discrete-Time Signals	7
1.2.4	Classification of Discrete-Time Signals.....	9
1.3	Linear Shift Invariant System, Stability and Causality	12
1.3.1	Basic Building Blocks of a Discrete Time System	13
1.3.2	Classification of Discrete-Time Systems	13
1.3.3	Representation of Discrete Time Signal as Summation of Impulses	16
1.3.4	Response of Linear Time Invariant (LTI) System	17
1.3.5	Stability of an LTI System	19
1.4	Linear-Constant Coefficient Difference Equations	22
1.5	Frequency Domain Representation of Discrete-Time Systems and Signals	22
1.5.1	Frequency Domain Representation of Discrete-Time System	22
1.5.2	Frequency Domain Representation of Discrete-Time Signals	23
	Review Questions	24

CHAPTER 2

Discrete Fourier Series

2.1	Discrete Fourier Series	31
2.2	Properties of Discrete Fourier Series (DFS).....	33
2.3	DFS Representation of Periodic Sequences	38

2.4	Discrete-Fourier Transform.....	39
2.4.1	Development of Discrete Fourier Transform (DFT).....	39
2.5	Properties of DFT	46
2.6	Linear Convolution of Sequences using DFT	56
2.6.1	Linear Convolution	56
2.6.2	Circular Convolution (or) Periodic Convolution	69
2.6.3	Linear Convolution using Circular Convolution.....	81
2.6.4	Circular Convolution using Linear Convolution.....	82
2.6.5	Differences between Linear and Circular Convolutions	83
2.7	Computation of DFT	84
2.7.1	Fast Fourier Transform (FFT).....	85
2.7.2	Radix–2 FFT	85
2.7.3	Radix–2 Decimation in Time (DIT) Algorithm	85
2.7.4	Bit Reversal Operation (or) Scrambling Operation.....	94
2.7.5	Decimation-in-Frequency (DIF) FFT Algorithm.....	97
2.7.5.1	Differences between Radix–2 DIT FFT and DIF FFT Flow Graphs.....	103
2.7.6	Computing an Inverse DFT by using FFT	105
	Review Questions.....	109

CHAPTER 3

Z-transform

3.0	Introduction	114
3.1	The Z-transform.....	114
3.2	Properties of the Z-transform	122
3.2.1	Two Sided Z-transform Properties	122
3.2.2	One Sided Z-transform Properties	129
3.3	The Inverse Z-transform.....	134
3.3.1	Power Series Method	135
3.3.2	Partial Fraction Expansion Method.....	137
3.3.3	Residue Method	146
3.4	System Function	152

3.5	Solution of Difference Equations of Digital Filters.....	153
3.5.1	Response of System with Zero Initial Conditions.....	153
3.5.2	Response of System with Nonzero Initial Conditions	154
3.6	Poles and Zeros of the System.....	158
3.7	Stability Criterion	162
3.7.1	Schür-Cohn Stability Test.....	164
3.8	Frequency Response of Stable Systems	165
3.9	Realization of Digital Filters	168
3.9.1	Direct Form I Realization.....	168
3.9.2	Direct Form II (or) Canonic Form Realization	171
3.9.3	Cascade Form Realization.....	175
3.9.4	Parallel Form Realization.....	177
3.9.5	Comparison of Different Realizations of Discrete Filters.....	179
	Review Questions.....	182

CHAPTER 4

IIR Digital Filters

4.0	Introduction	188
4.0.1	Filter Types	189
4.1	Analog Filter Approximations.....	191
4.1.1	Filter Specifications	192
4.2	Butterworth Approximation	193
4.2.1	Poles of Butterworth Filter.....	196
4.3	Chebyshev Approximation	199
4.3.1	Type I Chebyshev Approximation	199
4.3.2	Poles of Chebyshev Filter	202
4.3.3	Type II Chebyshev Filter (or) Inverse Chebyshev Filter	205
4.3.4	Steps to Design an Analog Butterworth Lowpass Filter.....	206
4.3.5	Steps to Design an Analog Chebyshev Lowpass Filter.....	206
4.4	Analog Spectral Transformations.....	213
4.4.1	Lowpass to Lowpass Filter.....	213
4.4.2	Lowpass to Highpass Filter	213
4.4.3	Lowpass to Bandpass Filter	214
4.4.4	Lowpass to Bandstop filter.....	215

4.5	Design of IIR Digital Filters from Analog Filters	216
4.5.1	Impulse Invariant Transformation.....	216
4.5.2	Step Invariance Transformation.....	222
4.5.3	Bilinear Transformation (or) Tustin Transformation	225
4.5.3.1	Relation between Analog and Digital Filter Poles	226
4.5.3.2	Relation between Analog and Digital Frequency	227
4.5.3.3	Warping Effect.....	228
4.6	Digital Spectral Transformation.....	230
4.7	Filters and Transformations.....	279
4.7.1	Comparison of Digital and Analog Filters.....	279
4.7.2	Comparison of Butterworth and Chebyshev Filters.....	280
4.7.3	Comparison of Impulse Invariant Transformation and Bilinear Transformation.....	280
	Review Questions.....	281

CHAPTER 5

FIR Digital Filters

5.0	Introduction	287
5.1	Characteristics of FIR Digital Filters.....	288
5.1.1	Linear Phase FIR Filters.....	288
5.1.2	Frequency Response.....	291
5.1.3	Location of Zeros of Linear Phase FIR Filter	296
5.2	Design of FIR Filters using Window Techniques	298
5.2.1	Rectangular Window.....	299
5.2.2	Triangular (or) Barlett Window	306
5.2.3	Raised Cosine Window.....	308
5.2.4	Hanning Window	309
5.2.5	Hamming Window.....	311
5.2.6	Blackman Window.....	313
5.3	Comparison of IIR and FIR Filters.....	314
5.4	Applications of FFT in Spectrum Analysis and Filtering.....	315
5.4.1	Applications of FFT in Spectrum Analysis.....	315
5.4.2	Applications of FFT in Filtering	318
5.5	Applications of DSP to Speech Processing	319
5.6	Applications of DSP to Radar Signal Processing.....	319
	Review Questions.....	340

CHAPTER 6

Multirate Digital Signal Processing

6.1	Introduction	344
6.2	Decimation or Down Sampling	344
6.3	Interpolation or Up Sampling	346
6.4	Frequency Transforms of Decimated and Expanded Sequences	349
	6.4.1 Decimation	349
	6.4.2 Expansion	350
6.5	Sampling-Rate Conversion	351
6.6	Multistage Approach	354
6.7	Polyphase Filters	357
6.8	Applications of Multirate DSP	359
	<i>Review Questions and Answers</i>	365
	 <i>Index</i>	 377