

DIGITAL SIGNAL PROCESSING

► using MATLAB®

Suranaree University of Technology 31051000535904 Vinay K. Ingle John G. Proakis

BookWare Companion Series™

CONTENTS

PREFACE xi

1 INTRODUCTION 1

Overview of Digital Signal Processing 2 A Few Words about MATLAB® 5

2 DISCRETE-TIME SIGNALS AND SYSTEMS 7

Discrete-time Signals 7
Discrete Systems 20
Convolution 22
Difference Equations 29
Problems 35

3 THE DISCRETE-TIME FOURIER ANALYSIS 40

The Discrete-time Fourier Transform (DTFT) 40
The Properties of the DTFT 47

MATLAB is a registered trademark of The MathWorks, Inc.

The Frequency Domain Representation of LTI Systems 53
Sampling and Reconstruction of Analog Signals 60
Problems 74

4 THE z-TRANSFORM 80

The Bilateral z-Transform 80
Important Properties of the z-Transform 84
Inversion of the z-Transform 89
System Representation in the z-Domain 95
Solutions of the Difference Equations 105
Problems 111

5 THE DISCRETE FOURIER TRANSFORM 116

The Discrete Fourier Series 117
Sampling and Reconstruction in the z-Domain 124
The Discrete Fourier Transform 129
Properties of the Discrete Fourier Transform 139
Linear Convolution using the DFT 154
The Fast Fourier Transform 160
Problems 172

6 DIGITAL FILTER STRUCTURES 182

Basic Elements 183
IIR Filter Structures 183
FIR Filter Structures 197

Lattice Filter Structures 208
Problems 219

7 FIR FILTER DESIGN 224

Preliminaries 224
Properties of Linear-phase FIR Filters 228
Window Design Techniques 243
Frequency Sampling Design Techniques 264
Optimal Equiripple Design Technique 277
Problems 294

8 IIR FILTER DESIGN 301

Some Preliminaries 302
Characteristics of Prototype Analog Filters 305
Analog-to-Digital Filter Transformations 327
Lowpass Filter Design Using MATLAB 345
Frequency-band Transformations 350
Comparison of FIR vs. IIR Filters 363
Problems 364

9 APPLICATIONS IN ADAPTIVE FILTERING 371

LMS Algorithm for Coefficient Adjustment 373
System Identification or System Modeling 376
Suppression of Narrowband Interference in a
Wideband Signal 377
Adaptive Line Enhancement 380

Adaptive Channel Equalization 380 Summary 383

10 APPLICATIONS IN COMMUNICATIONS 384

Pulse-Code Modulation 384

Differential PCM (DPCM) 388

Adaptive PCM and DPCM (ADPCM) 392

Delta Modulation (DM) 396

Linear Predictive Coding (LPC) of Speech 399

Dual-tone Multifrequency (DTMF) Signals 403

Binary Digital Communications 408

Spread-Spectrum Communications 409

Summary 411

BIBLIOGRAPHY 412

INDEX 413