

# Preface

Technology such as microprocessors, microcontrollers, and digital signal processors have become so advanced that they have had a dramatic impact on the disciplines of electronics engineering, computer engineering, and biomedical engineering. Engineers and technologists need to become familiar with digital signals and systems and basic digital signal processing (DSP) techniques. The objective of this book is to introduce students to the fundamental principles of these subjects and to provide a working knowledge such that they can apply DSP in their engineering careers.

The book is suitable for a two-semester course sequence at the senior level in undergraduate electronics, computer, and biomedical engineering technology programs. Chapters 1 to 8 provide the topics for a one-semester course, and a second course can complete the rest of the chapters. This textbook can also be used in an introductory DSP course in an undergraduate electrical engineering program at traditional colleges. Additionally, the book should be useful as a reference for undergraduate engineering students, science students, and practicing engineers.

The material has been tested for two consecutive courses in a signal processing sequence at Purdue University North Central in Indiana. With the background established from this book, students will be well prepared to move forward to take other upper-level courses that deal with digital signals and systems for communications and control.

The textbook consists of 14 chapters, organized as follows:

- Chapter 1 introduces concepts of DSP and presents a general DSP block diagram. Application examples are included.
- Chapter 2 covers the sampling theorem described in the time domain and frequency domain and also covers signal reconstruction. Some practical considerations for designing analog anti-aliasing lowpass filters and anti-image lowpass filters are included. The chapter ends with a section dealing with analog-to-digital conversion (ADC) and digital-to-analog conversion (DAC), as well as signal quantization and encoding.
- Chapter 3 introduces digital signals, linear time-invariant system concepts, difference equations, and digital convolutions.
- Chapter 4 introduces the discrete Fourier transform (DFT) and digital signal spectral calculations using the DFT. Methods for applying the DFT to estimate the spectra of various signals, including speech, seismic signals, electrocardiography data, and vibration signals, are demonstrated. The chapter ends with a section dedicated to illustrating fast Fourier transform (FFT) algorithms.
- Chapter 5 is devoted to the z-transform and difference equations.
- Chapter 6 covers digital filtering using difference equations, transfer functions, system stability, digital filter frequency responses, and implementation methods such as direct-form I and direct-form II.
- Chapter 7 deals with various methods of finite impulse response (FIR) filter design, including the Fourier transform method for calculating FIR filter coefficients, window method, frequency sampling design, and optimal design. Chapter 7 also includes applications that use FIR filters for noise reduction and digital crossover system design.

- Chapter 8 covers various methods of infinite impulse response (IIR) filter design, including the bilinear transformation (BLT) design, impulse-invariant design, and pole-zero placement design. Applications using IIR filters include audio equalizer design, biomedical signal enhancement, dual-tone multifrequency (DTMF) tone generation, and detection with the Goertzel algorithm.
- Chapter 9 introduces DSP architectures, software and hardware, and fixed-point and floating-point implementations of digital filters.
- Chapter 10 covers adaptive filters with applications such as noise cancellation, system modeling, line enhancement, cancellation of periodic interferences, echo cancellation, and 60-Hz interference cancellation in biomedical signals.
- Chapter 11 is devoted to speech quantization and compression, including pulse code modulation (PCM) coding, mu-law compression, adaptive differential pulse code modulation (ADPCM) coding, windowed modified discrete cosine transform (W-MDCT) coding, and MPEG audio format, specifically MP3 (MPEG-1, layer 3).
- Chapter 12 covers topics pertaining to multirate DSP and applications, as well as principles of oversampling ADC, such as sigma-delta modulation. Undersampling for bandpass signals is also examined.
- Chapter 13 introduces a subband coding system and its implementation. Perfect reconstruction conditions for a two-band system are derived. Subband coding with an application of data compression is demonstrated. Furthermore, the chapter covers the discrete wavelet transform (DWT) with applications to signal coding and denoising.
- Finally, Chapter 14 covers image enhancement using histogram equalization and filtering methods, including edge detection. The chapter also explores pseudo-color image generation and detection, two-dimensional spectra, JPEG compression using DCT, image coding using the DWT, and the mixing of two images to create a video sequence. Finally, motion compensation of the video sequence is explored, which is a key element of video compression used in MPEG.

MATLAB programs are listed whenever they are possible. Therefore, a MATLAB tutorial should be given to students who are new to the MATLAB environment.

- Appendix A serves as a MATLAB tutorial.
- Appendix B reviews key fundamentals of analog signal processing. Topics include Fourier series, Fourier transform, Laplace transform, and analog system basics.
- Appendixes C, D, and E review Butterworth and Chebyshev filters, sinusoidal steady-state responses in digital filters, and derivation of the FIR filter design equation via the frequency sampling method, respectively.
- Appendix F details the derivations of wavelet analysis and synthesis equations.
- Appendix G offers general useful mathematical formulas.

In this new edition, MATLAB projects dealing with practical applications are included in Chapters 2, 4, 6, 7, 8, 10, 12, and 13.

Instructor support, including solutions, can be found at <http://textbooks.elsevier.com>. MATLAB programs and exercises for students, plus real-time C programs can be found at [booksite.elsevier.com/9780124158931](http://booksite.elsevier.com/9780124158931).

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