

INTERNATIONAL
EDITION



Digital and Analog Communication Systems

EIGHTH EDITION

Leon W. Couch II



ALWAYS LEARNING

PEARSON

DIGITAL AND ANALOG COMMUNICATION SYSTEMS

Eighth Edition

LEON W. COUCH II

*Professor Emeritus
Electrical and Computer Engineering
University of Florida, Gainesville*

International Edition contributions by

MURALIDHAR KULKARNI

*Professor
Department of Electronics and Communication Engineering
National Institute of Technology Karnataka, Surathkal*

U. SRIPATI ACHARYA

*Associate Professor
Department of Electronics and Communication Engineering
National Institute of Technology Karnataka, Surathkal*

PEARSON

Boston Columbus Indianapolis New York San Francisco Upper Saddle River Amsterdam
Cape Town Dubai London Madrid Milan Munich Paris Montréal Toronto Delhi
Mexico City São Paulo Sydney Hong Kong Seoul Singapore Taipei Tokyo

Digital & Analog Communication Systems

Table of Contents

Cover

CONTENTS

PREFACE

LIST OF SYMBOLS

1 INTRODUCTION

11 Historical Perspective

12 Digital and Analog Sources and Systems

13 Deterministic and Random Waveforms

14 Organization of the Book

15 Use of a Personal Computer and MATLAB

16 Block Diagram of a Communication System

17 Frequency Allocations

18 Propagation of Electromagnetic Waves

19 Information Measure

110 Channel Capacity and Ideal Communication Systems

111 Coding

Block Codes

Convolutional Codes

Code Interleaving

Code Performance

Trellis-Coded Modulation

112 Preview

113 Study-Aid Examples

Table of Contents

Problems

2 SIGNALS AND SPECTRA

21 Properties of Signals and Noise

Physically Realizable Waveforms

Time Average Operator

DC Value

Power

RMS Value and Normalized Power

Energy and Power Waveforms

Decibel

Phasors

22 Fourier Transform and Spectra

Definition

Properties of Fourier Transforms

Parsevals Theorem and Energy Spectral Density

Dirac Delta Function and Unit Step Function

Rectangular and Triangular Pulses

Convolution

23 Power Spectral Density and Autocorrelation Function

Power Spectral Density

Autocorrelation Function

24 Orthogonal Series Representation of Signals and Noise

Orthogonal Functions

Orthogonal Series

25 Fourier Series

Complex Fourier Series

Quadrature Fourier Series

Polar Fourier Series

Line Spectra for Periodic Waveforms

Table of Contents

Power Spectral Density for Periodic Waveforms

26 Review of Linear Systems

Linear Time-Invariant Systems

Impulse Response

Transfer Function

Distortionless Transmission

Distortion of Audio, Video, and Data Signals

27 Bandlimited Signals and Noise

Bandlimited Waveforms

Sampling Theorem

Impulse Sampling and Digital Signal Processing

Dimensionality Theorem

28 Discrete Fourier Transform

Using the DFT to Compute the Continuous Fourier Transform

Using the DFT to Compute the Fourier Series

29 Bandwidth of Signals

210 Summary

211 Study-Aid Examples

Problems

3 BASEBAND PULSE AND DIGITAL SIGNALING

31 Introduction

32 Pulse Amplitude Modulation

Natural Sampling (Gating)

Instantaneous Sampling (Flat-Top PAM)

33 Pulse Code Modulation

Sampling, Quantizing, and Encoding

Practical PCM Circuits

Bandwidth of PCM Signals

Table of Contents

Effects of Noise

Nonuniform Quantizing: μ -Law and A-Law Companding

34 Digital Signaling

Vector Representation

Bandwidth Estimation

Binary Signaling

Multilevel Signaling

35 Line Codes and Spectra

Binary Line Coding

Power Spectra for Binary Line Codes

Differential Coding

Eye Patterns

Regenerative Repeaters

Bit Synchronization

Power Spectra for Multilevel Polar NRZ Signals

Spectral Efficiency

36 Intersymbol Interference

Nyquist's First Method (Zero ISI)

Raised Cosine-Rolloff Nyquist Filtering

Nyquist's Second and Third Methods for Control of ISI

37 Differential Pulse Code Modulation

38 Delta Modulation

Granular Noise and Slope Overload Noise

Adaptive Delta Modulation and Continuously Variable Slope Delta Modulation

Speech Coding

39 Time-Division Multiplexing

Frame Synchronization

Synchronous and Asynchronous Lines

Table of Contents

TDM Hierarchy

The T1 PCM System

310 Packet Transmission System

311 Pulse Time Modulation: Pulse Width Modulation and Pulse
Position Modulation

312 Summary

313 Study-Aid Examples

Problems

4 BANDPASS SIGNALING PRINCIPLES AND CIRCUITS

41 Complex Envelope Representation of Bandpass Waveforms

Definitions: Baseband, Bandpass, and Modulation

Complex Envelope Representation

42 Representation of Modulated Signals

43 Spectrum of Bandpass Signals

44 Evaluation of Power

45 Bandpass Filtering and Linear Distortion

Equivalent Low-Pass Filter

Linear Distortion

46 Bandpass Sampling Theorem

47 Received Signal Plus Noise

48 Classification of Filters and Amplifiers

Filters

Amplifiers

49 Nonlinear Distortion

410 Limiters

411 Mixers, Up Converters, and Down Converters

412 Frequency Multipliers

Table of Contents

413 Detector Circuits

- Envelope Detector

- Product Detector

- Frequency Modulation Detector

414 Phase-Locked Loops and Frequency Synthesizers

415 Direct Digital Synthesis

416 Transmitters and Receivers

- Generalized Transmitters

- Generalized Receiver: The Superheterodyne Receiver

- Zero-IF Receivers

- Interference

417 Software Radios

418 Summary

419 Study-Aid Examples

Problems

5 AM, FM, AND DIGITAL MODULATED SYSTEMS

51 Amplitude Modulation

52 AM Broadcast Technical Standards and Digital AM Broadcasting

- Digital AM Broadcasting

53 Double-Sideband Suppressed Carrier

54 Costas Loop and Squaring Loop

55 Asymmetric Sideband Signals

- Single Sideband

- Vestigial Sideband

56 Phase Modulation and Frequency Modulation

- Representation of PM and FM Signals

- Spectra of Angle-Modulated Signals

Table of Contents

Narrowband Angle Modulation

Wideband Frequency Modulation

Preemphasis and Deemphasis in Angle-Modulated Systems

57 Frequency-Division Multiplexing and FM Stereo

58 FM Broadcast Technical Standards and Digital FM
Broadcasting

Digital FM Broadcasting

59 Binary Modulated Bandpass Signaling

On-Off Keying (OOK)

Binary Phase-Shift Keying (BPSK)

Differential Phase-Shift Keying (DPSK)

Frequency-Shift Keying (FSK)

510 Multilevel Modulated Bandpass Signaling

Quadrature Phase-Shift Keying and M-ary Phase-Shift Keying

Quadrature Amplitude Modulation (QAM)

OQPSK and $\pi/4$ QPSK

PSD for MPSK, QAM, QPSK, OQPSK, and $\pi/4$ QPSK

Spectral Efficiency for MPSK, QAM, QPSK, OQPSK, and $\pi/4$ QPSK with
Raised Cosine Filtering

511 Minimum-Shift Keying and GMSK

512 Orthogonal Frequency Division Multiplexing (OFDM)

513 Spread Spectrum Systems

Direct Sequence

Frequency Hopping

SS Frequency Bands

514 Summary

515 Study-Aid Examples

Problems

6 RANDOM PROCESSES AND SPECTRAL ANALYSIS

Table of Contents

61 Some Basic Definitions

Random Processes

Stationarity and Ergodicity

Correlation Functions and Wide-Sense Stationarity

Complex Random Processes

62 Power Spectral Density

Definition

Wiener-Khintchine Theorem

Properties of the PSD

General Formula for the PSD of Digital Signals

White-Noise Processes

Measurement of PSD

63 DC and RMS Values for Ergodic Random Processes

64 Linear Systems

Input-Output Relationships

65 Bandwidth Measures

Equivalent Bandwidth

RMS Bandwidth

66 The Gaussian Random Process

Properties of Gaussian Processes

67 Bandpass Processes

Bandpass Representations

Properties of WSS Bandpass Processes

Proofs of Some Properties

68 Matched Filters

General Results

Results for White Noise

Correlation Processing

Transversal Matched Filter

Table of Contents

69 Summary

610 Appendix: Proof of Schwarzs Inequality

611 Study-Aid Examples

Problems

7 PERFORMANCE OF COMMUNICATION SYSTEMS CORRUPTED BY NOISE

71 Error Probabilities for Binary Signaling

General Results

Results for Gaussian Noise

Results for White Gaussian Noise and Matched-Filter Reception

Results for Colored Gaussian Noise and Matched-Filter Reception

72 Performance of Baseband Binary Systems

Unipolar Signaling

Polar Signaling

Bipolar Signaling

73 Coherent Detection of Bandpass Binary Signals

On-Off Keying

Binary-Phase-Shift Keying

Frequency-Shift Keying

74 Noncoherent Detection of Bandpass Binary Signals

On-Off Keying

Frequency-Shift Keying

Differential Phase-Shift Keying

75 Quadrature Phase-Shift Keying and Minimum-Shift Keying

76 Comparison of Digital Signaling Systems

Bit-Error Rate and Bandwidth

Symbol Error and Bit Error for Multilevel Signaling

Synchronization

Table of Contents

77 Output Signal-to-Noise Ratio for PCM Systems

78 Output Signal-to-Noise Ratios for Analog Systems

Comparison with Baseband Systems

AM Systems with Product Detection

AM Systems with Envelope Detection

DSB-SC Systems

SSB Systems

PM Systems

FM Systems

FM Systems with Threshold Extension

FM Systems with Deemphasis

79 Comparison of Analog Signaling Systems

Ideal System Performance

710 Summary

711 Study-Aid Examples

Problems

8 WIRE AND WIRELESS COMMUNICATION APPLICATIONS

81 The Explosive Growth of Telecommunications

82 Telephone Systems

Historical Basis

Modern Telephone Systems and Remote Terminals

83 Digital Subscriber Lines (DSL)

G.DMT and G.Lite Digital Subscriber Lines

Video On Demand (VOD)

Integrated Service Digital Network (ISDN)

84 Capacities of Public Switched Telephone Networks

85 Satellite Communication Systems

Digital and Analog Television Transmission

Table of Contents

Data and Telephone Signal Multiple Access

Satellite Radio Broadcasting

86 Link Budget Analysis

Signal Power Received

Thermal Noise Sources

Characterization of Noise Sources

Noise Characterization of Linear Devices

Noise Characterization of Cascaded Linear Devices

Link Budget Evaluation

E_b/N_0 Link Budget for Digital Systems

Path Loss for Urban Wireless Environments

87 Fiber-Optic Systems

88 Cellular Telephone Systems

First Generation (1G) The AMPS Analog Circuit-switched System

Second Generation (2G) The Digital Circuit-switched Systems

Third Generation (3G) Digital with Circuit and Packet Switching

Fourth Generation (4G) Digital with Packet Switching

89 Television

Analog Black-and-White Television

MTS Stereo Sound

Analog Color Television

Standards for TV and CATV Systems

Digital TV (DTV)

810 Cable Data Modems

811 Wireless Data Networks

WiFi

WiMAX

812 Summary

813 Study-Aid Examples

Table of Contents

Problems

APPENDIX A: MATHEMATICAL TECHNIQUES, IDENTITIES, AND TABLES

A1 Trigonometry and Complex Numbers

Definitions

Trigonometric Identities and Complex Numbers

A2 Differential Calculus

Definition

Differentiation Rules

Derivative Table

A3 Indeterminate Forms

A4 Integral Calculus

Definition

Integration Techniques

A5 Integral Tables

Indefinite Integrals

Definite Integrals

A6 Series Expansions

Finite Series

Infinite Series

A7 Hilbert Transform Pairs

A8 The Dirac Delta Function

Properties of Dirac Delta Functions

A9 Tabulation of $Sa(x) = (\sin x)/x$

A10 Tabulation of $Q(z)$

APPENDIX B: PROBABILITY AND RANDOM VARIABLES

B1 Introduction

B2 Sets

Table of Contents

B3 Probability and Relative Frequency

Simple Probability

Joint Probability

Conditional Probabilities

B4 Random Variables

B5 Cumulative Distribution Functions and Probability Density Functions

Properties of CDFs and PDFs

Discrete and Continuous Distributions

B6 Ensemble Average and Moments

Ensemble Average

Moments

B7 Examples of Important Distributions

Binomial Distribution

Poisson Distribution

Uniform Distribution

Gaussian Distribution

Sinusoidal Distribution

B8 Functional Transformations of Random Variables

B9 Multivariate Statistics

Multivariate CDFs and PDFs

Bivariate Statistics

Gaussian Bivariate Distribution

Multivariate Functional Transformation

Central Limit Theorem

Problems

APPENDIX C: USING MATLAB

C1 About the MATLAB M-Files

Table of Contents

C2 Quick Start for Running M-Files

C3 Programming in MATLAB

REFERENCES

ANSWERS TO SELECTED PROBLEMS

INDEX