Preface

An introductory course on 'Signals and Systems' essentially tries to cover classification, representation and transformation of signals besides the classification, representation, and analysis (time-domain and frequency-domain) of systems. Prior to the eighties, very few Indian universities used to offer such a course for the undergraduate students in Electrical Engineering disciplines. But, over the years, its usefulness has been well recognized and now almost all Indian universities have a course on Signals and Systems as a part of their curriculum for the Electrical Engineering disciplines – EEE, ECE and EIE. A course of this nature, introduced at the second year of the four-year engineering degree program, lays the foundation, and is a pre-requisite for the more advanced courses such as Communications, Signal Processing and Control Systems, which are offered generally in the third and fourth years.

I enjoyed teaching this course for several years at various institutions – at REC, Trichy (now renamed as NIT, Trichy); at Vasavi College of Engineering, affiliated to Osmania University; at GNITS, Hyderabad, affiliated to JNTU, and at ANITS, Visakhapatnam, affiliated to Andhra University. On a few occasions, during the last 20 years, I was also involved, along with some others, in framing the syllabus for this course at these as well as other universities. In one such exercise at REC, Trichy, on the suggestion of my colleague, Dr N Kalyanasundaram, the topic of Fourier series was recast so as to introduce it to the students as an orthogonal / orthonormal expansion. This necessitated the inclusion of basics of linear algebra, which unfortunately, does not find a place in the undergraduate engineering curriculum of most of the Indian universities. Teaching this revised course was a rewarding experience and it is the lecture notes prepared at that time and updated regularly that formed the basic material for writing this book.

Scope of the Book

The contents of the book have been so designed that the book almost fully covers the prescribed syllabus for a one-semester course on signals and systems of all the Indian universities except a few which have topics pertaining to 'Probability Theory' and 'Random Processes' in their signals-and-systems course. Thus, it is useful for

(i) All engineering undergraduate students specializing in Electrical and Electronics Engineering, Electronics and Communication Engineering, or Electronics and Instrumentation Engineering
(ii) All candidates preparing for IETE examinations
(iii) Those preparing for GATE and similar competitive examinations
(iv) Practicing engineers who wish to have working knowledge of the various concepts and tools presented in the book

Overview

The book contains twelve chapters and covers Signals and Systems of the continuous-time type as well as the discrete-time type. Except in the case of the topics on convolution and correlation covered in chapters 9 and 10, an integrated treatment of continuous-time type and discrete-time type is given in order to clearly bring

out the similarities of concepts, theories and techniques. Differences, wherever they existed, have been, however, emphasized. Laplace and Z-transforms have been clubbed together in one chapter, as the Z-Transform, which is essentially the discrete-time counterpart of the Laplace Transform, has similar properties, theorems and applications. This approach could not, however, be applied in the case of Fourier representation of continuous-time (periodic and aperiodic) and discrete-time (periodic and aperiodic) signals simply because the sheer volume of the material to be covered did not permit it.

Starting from a discussion on the concept of a signal, the first chapter deals with the classification, representation and some common operations on both continuous-time and discrete-time signals. The second chapter discusses Laplace Transform and Z-Transform of both unilateral and bilateral types. Transforms of some common signals have been derived, and properties, theorems and applications have been covered for both the transforms. The third chapter deals with Fourier series of continuous-time periodic signals. Since the topic is approached as an orthogonal expansion of a signal over a certain period, the necessary basics pertaining to linear algebra have been presented briefly. Both complex exponential and trigonometric Fourier series have been covered. Fourier representation of non-periodic continuous-time signals using Fourier Transform, is covered in Chapter 4. Properties and theorems of Fourier Transform have been derived and their significance and physical meaning explained. The fifth chapter dealing with the Fourier representation of discrete-time signals discusses Discrete-Time Fourier Transform (DTFT), the Discrete-Time Fourier Series (DTFS) and the Discrete Fourier Transform (DFT). The relationships between the Z-Transform, DTFT and DFT have been discussed. The sixth chapter deals with the sampling and reconstruction of band-limited signals of both lowpass variety and the bandpass variety. The various issues involved are thoroughly discussed.

Systems, their classification, representation of LTI and LSI systems by means of $h(t)$ or $h(n)$, their stability, and their eigensignals are discussed in Chapter 7, and the concept of transfer function of a system is developed on the basis of eigensignals. Chapter 8 discusses the time and frequency domain analysis of LTI and LSI systems. Block–diagram representation of a system, block–diagram reduction techniques, methods of realization of a given system function $H(s)$ or $H(z)$ through different realization structures, distortionless transmission of signals, and ideal and non-ideal filters of continuous-time and discrete-time types, are also discussed in this chapter. Continuous-time convolutions and correlations, their inter-relationship and properties, are discussed in Chapter 9, while Chapter 10 discusses discrete-time convolutions and correlations. Hilbert transforms, of both continuous-time and discrete-time type are discussed in Chapter 11 along with their applications. Finally, in Chapter 12, we discuss briefly, certain topics in communications and digital-signal processing, which help to bring out some of the areas of applications of the concepts and tools developed in the earlier chapters of the book.

To help the reader clearly understand the concepts and to illustrate how the various analytical tools developed in the text could be used for solving problems, a large number of worked-out examples have been given in every chapter. It is hoped that these would be extremely useful, especially to the self-learner. No course on 'Signals and Systems' or 'Digital Signal Processing' would be able to achieve its objectives without making the student use MATLAB for solving problems. It gives the student a better insight into the concepts and enhances his/her understanding of the theory, while making the process of learning thoroughly enjoyable. A typical MATLAB example is therefore included in each one of the chapters. A few MATLAB exercises are also given at the end of each chapter.

The book can serve as a good textbook for a one-semester course on 'Signals and Systems'. For students of Electronics and Communication Engineering, the first eleven chapters lay a solid foundation for more advanced courses relevant to their specialization and the applications given in the twelfth chapter are quite appropriate for them. For other branches of study, like Electrical and Electronics, and Electronics and

Instrumentation, however, the eleventh chapter, dealing with Hilbert Transform, as well as sections of Chapter 12 dealing with applications in communication may not be needed and so can be omitted.

Salient Features

From the pedagogical point of view, several useful features have been used in this book. These include the following:

(1) Clear explanations of concepts in an easily understandable language and style
(2) About **200** worked-out examples, carefully selected to reinforce the understanding of the concepts and to illustrate the way the tools developed can be used for solving problems
(3) *Summary* at the end of each chapter reinforces the learning objectives and summarizes the concepts
(4) A large number of appropriately selected *Problems* are given at the end of each chapter to enable the student to apply the techniques learned
(5) *Review questions* at the end of each chapter test the understanding of the key concepts
(6) A number of *Objective Questions* and *Multiple Choice Questions* (with a key) are given at the end of each chapter to drill in the concepts and tools
(7) MATLAB examples and MATLAB exercises are given to provide better insight into the concepts and issues.

Web Supplements

The Online Learning Center of the book can be accessed at http://www.mhhe.com/rao/signals and contains the following:

- **For Students**
  - Solution of University questions
- **For Instructors**
  - PowerPoint lecture slides

Acknowledgements

Writing this book required lot of effort over the last two years, and I received help and support from many. I would like to express my gratitude to the management of Anil Neerukonda Institute of Technology and Sciences (ANITS), Visakhapatnam, for the support extended. I am thankful to Dr Shankar Prakriya of IIT, Delhi, for the assistance in MATLAB Examples and Multiple Choice Questions. I also thank Mr Y Rajani Kanth of ANITS for patiently typing the manuscript copy and generating all the line diagrams neatly and accurately.

I am deeply grateful to the following reviewers who gave some very good suggestions for improving the book:

R K P Bhatt	*IIT, Delhi*
B Kumar	*Maharaja Surajmal Institute of Technology*, *New Delhi*
Dinesh Chandra	*JSS Academy of Technical Education, Noida, UP*

Prateek Kumar	*Maharana Pratap Engineering College, Kanpur, UP*
Sarika Sachdeva	*Galgotia College of Engineering snd Technology, Greater Noida, UP*
Pallavi Gupta	*Aligarh Muslim University, Aligarh, UP*
D K Sharma	*Meerut Institute of Engineering Technology, Meerut, UP*
Shyamalesh Kar	*Jadavpur University, Kolkata, West Bengal*
G Lohar	*Haldia Institute of Technology, Haldia, West Bengal*
Subrata Bhattacharya	*Indian School of Mines, Dhanbad, Jharkhand*
A K Singh	*National Institute of Technology, RIT, Jamshedpur, Jharkhand*
PM Patil	*Vishwakarma Institute of Technology, Pune, Maharashtra*
Varshah Shah	*Rizvi Educational Complex, Mumbai, Maharashtra*
T R Paul	*Watmull Institute of Technology, Mumbai, Maharashtra*
Y V Ramana Rao	*College of Engineering, Anna University, Chennai, Tamil Nadu*
Harikumar and A R Palanichamy	*Bannari Amman Institute of Technology, Sathyamangalam, Tamil Nadu*
M L Sudhir	*University Visveswaraya College of Engineering, Bangalore, Karnataka*
Geetha K S	*R V College of Engineering Bangalore, Karnataka*
Y Ravinder	*Osmania University, Hyderabad, AP*
Shamla Mathur	*College of Engineering, Osmania University, Hyderabad, AP*
K Satyaprasad	*JNTU College of Engineering, Kakinada, AP*
Tanish Zaveri	*Institute of Technology, Nirma University Ahmedabad, Gujarat*
Janak B Patel	*L D R P Institute of Technology and Research, Gandhinagar, Gujarat*
V K Thakar	*A D Patel Institute of Technology Anand, Gujarat*
Sanjay Nalbalwar	*Dr Babasaheb Ambedkar Technological University Raigad, MP*

Finally, I would like to thank the staff at Tata McGraw-Hill for their sincerity and constant cooperation in bringing out this book. My family members also deserve a special mention in this regard for their love, patience and understanding during the preparation of this book.

All efforts have been made to make the book error-free; still some errors might have crept in. Suggestions /criticisms from the readers for the improvement of the book are most welcome at prakriya37@hotmail.com

Visakhapatnam, 2008 **P Ramakrishna Rao**