

Signals and Systems

This textbook provides a solid foundation in system modelling, system analysis, and deterministic and random signals and systems, enabling students to develop an instinctive grasp of the fundamentals. The book begins with the basics of analog signals and introduces the concept of DT signals. It then covers the sampling processes in detail and discusses signals and operation on signals for both CT and DT signals. It includes Fourier transform and Laplace transform with adequate theory and numerical problems. With an emphasis on the advanced techniques used for signal processing, especially for speech and image processing, the properties of continuous time and discrete time signals are explained with many numerical problems. Real-life examples are provided to discuss the physical significance of different properties. Besides each concept is presented with MATLAB programs, output plots and simulation examples to help students execute simulations and verify their outputs. The book would interest students of electrical and communication engineering and computer science. This is an exceptional resource for anyone looking to develop their understanding of signals and systems.

Shaila Dinkar Apte is Professor at Rajarshi Shahu College of Engineering, Pune. She has been engaged in teaching and research for over 34 years. Her major areas of interest include signals and systems, digital signal processing and speech processing. She owns a patent related to generation of mother wavelet from speech signal. Professor Apte is also the author of the books *Digital Signal Processing* (2009), *Speech and Audio Processing* (2012) and *Advanced Digital Signal Processing* (2013).

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To

*my beloved husband Late Mr Dinkar
my grandchildren Aarohi, Shriya, Shreyas and Shruti
my students from W.C.E., Sangli and R.S.C.O.E., Pune*

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Preface

It gives me immense satisfaction in presenting this book to my students who have been eagerly waiting to see it. The difficulties encountered by students in understanding the physical significance of different concepts inspired me to write a student-friendly book, rich in technical content. The subject Signals and Systems is essential for undergraduate students of Electronics Engineering, Electrical Engineering, Computer Engineering, and Instrumentation Engineering disciplines. The subject has a diverse range of applications. A thorough knowledge of different transforms studied in Mathematics is essential for an understanding of the subject.

The subject involves a number of complex algorithms which require in-depth domain knowledge. If a concept is explained with concrete examples and programs, the reader will definitely take interest in the field. The reader will experience great joy when she observes tangible outcomes of an experiment on her computer screen. A number of signals occurring in nature like speech, ECG, EEG etc. have some random components. Research in this field is somewhat difficult. Despite significant progress in an understanding of the subject, there remain many things which are not well grasped. There is room for explaining the basic concepts of signals and systems, in a better manner. Different concepts are illustrated here using MATLAB programs. The outputs of the MATLAB programs are given in the form of graphs. With extensive experience in signals and systems research, I observed, that people require significant amount of time before they can begin grasping the subject. However with proper guidance, a person can acquire considerable knowledge in this field. The motivation behind this book has been, that a new comer be provided information about where and how to start and how to proceed.

There was a request from my students as well as from well wishers that I write a book on signals and systems. It was also suggested that the book include the theory of random signals. Several concrete examples have been given to illustrate the concepts pertaining to random signals. For better understanding, we have included output from many MATLAB programs. Interpretations of the results are also explained, which will not only help the reader but also enable instructors to incorporate the examples into their classroom teaching.

The book seeks to rigorously examine the subject of Deterministic and Random Signals and Systems. It will provide a solid foundation for specialized

courses in signal processing at both the undergraduate and postgraduate levels and will serve as a basic practical guide for PhD students.

I have enjoyed whatever little work I have done in signals and systems. Although I have stated that I undertook this project for new comers to the field, it was also done with a desire to further my own knowledge.

Acknowledgments

I am thankful for the encouragement that my late husband, Dinkar gave me. I have few words to describe my gratitude for his inspiration. I am also grateful for the inspiration provided by my students from Walchand College of Engineering, Sangli and from Rajarshi Shahu College of Engineering, Pune. I sincerely thank all the students who worked under my guidance for their undergraduate, postgraduate or PhD projects. Their painstaking efforts and sincerity encouraged me to seek newer challenges. We carried out lots of experiments in Signal Processing, which besides enriching the knowledge of my students also improved my understanding of the subject. The curiosity of the students to understand the physical significance of each concept prompted me to undertake this project after completion of projects titled “Digital Signal Processing”, “Speech and Audio Processing” and “Advance Digital Signal Processing”. The constant demand by my students that I write a book on “Signal and Systems” accelerated my work.

I got a lot of help and inspiration from my family members especially from my late husband Dinkar, my son Anand, daughter-in-law Aditi, daughter Amita and son-in-law Prasad. I thank my colleagues Bhalke and Tirmare for giving me useful suggestions; my student Prashul for helping me type some of the examples; the reviewers from different countries for reviewing and giving me concrete suggestions.

The idea of publishing the book materialized when Manish Choudhary from Cambridge University Press accepted the proposal for this book. I am grateful to him. I also express my gratitude to the team at Cambridge University Press for the cooperation and strong support during the review and proofreading stages.

Finally, I wish to thank all who helped me directly and indirectly for their support during the long process of producing this book.

I look forward to feedback on this book at: sdapte@rediffmail.com