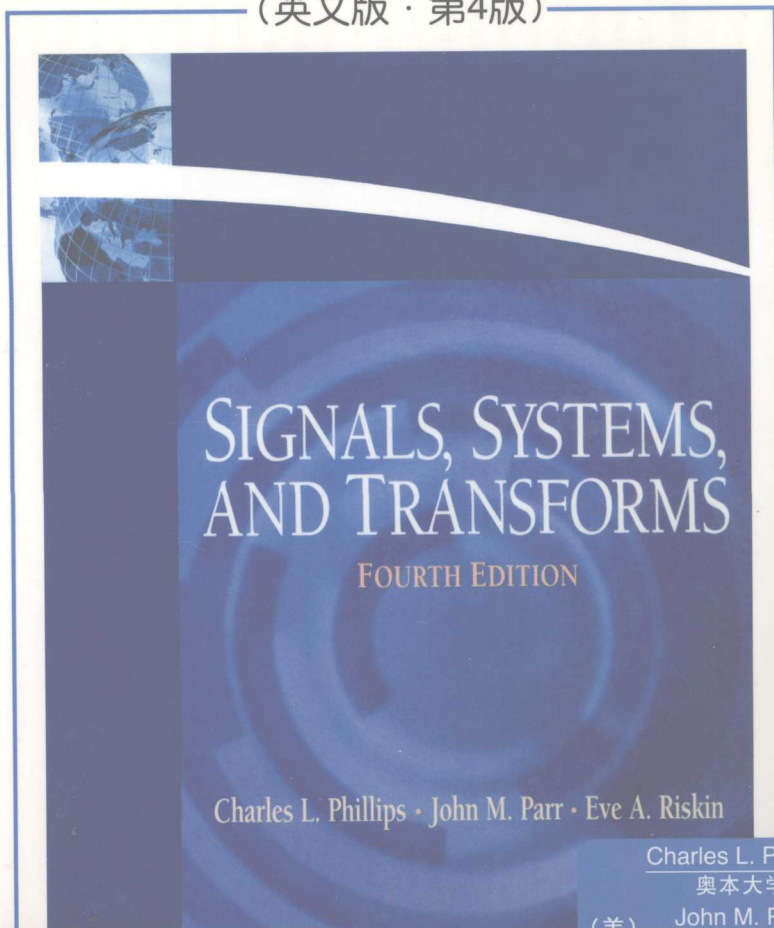


# 信号、系统和变换

(英文版·第4版)



Charles L. Phillips  
奥本大学

(美) John M. Parr  
艾温斯维尔大学

Eve A. Riskin  
华盛顿大学

著



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## 出版者的话

文艺复兴以降，源远流长的科学精神和逐步形成的学术规范，使西方国家在自然科学的各个领域取得了垄断性的优势；也正是这样的传统，使美国在信息技术发展的六十多年间名家辈出、独领风骚。在商业化的进程中，美国的产业界与教育界越来越紧密地结合，计算机学科中的许多泰山北斗同时身处科研和教学的最前线，由此而产生的经典科学著作，不仅肇划了研究的范畴，还揭示了学术的源变，既遵循学术规范，又自有学者个性，其价值并不会因年月的流逝而减退。

近年，在全球信息化大潮的推动下，我国的计算机产业发展迅猛，对专业人才的需求日益迫切。这对计算机教育界和出版界都既是机遇，也是挑战；而专业教材的建设在教育战略上显得举足轻重。在我国信息技术发展时间较短的现状下，美国等发达国家在其计算机科学发展的几十年间积淀和发展的经典教材仍有许多值得借鉴之处。因此，引进一批国外优秀计算机教材将对我国计算机教育事业的发展起到积极的推动作用，也是与世界接轨、建设真正的世界一流大学的必由之路。

机械工业出版社华章分社较早意识到“出版要为教育服务”。自1998年开始，华章分社就将工作重点放在了遴选、移译国外优秀教材上。经过多年的不懈努力，我们与Pearson, McGraw-Hill, Elsevier, MIT, John Wiley & Sons, Cengage等世界著名出版公司建立了良好的合作关系，从他们现有的数百种教材中甄选出Andrew S. Tanenbaum, Bjarne Stroustrup, Brian W. Kernighan, Dennis Ritchie, Jim Gray, Alfred V. Aho, John E. Hopcroft, Jeffrey D. Ullman, Abraham Silberschatz, William Stallings, Donald E. Knuth, John L. Hennessy, Larry L. Peterson等大师名家的一批经典作品，以“计算机科学丛书”为总称出版，供读者学习、研究及珍藏。大理石纹理的封面，也正体现了这套丛书的品位和格调。

“计算机科学丛书”的出版工作得到了国内外学者的鼎力襄助，国内的专家不仅提供了中肯的选题指导，还不辞劳苦地担任了翻译和审校的工作；而

原书的作者也相当关注其作品在中国的传播，有的还专程为其书的中译本作序。迄今，“计算机科学丛书”已经出版了近两百个品种，这些书籍在读者中树立了良好的口碑，并被许多高校采用为正式教材和参考书籍。其影印版“经典原版书库”作为姊妹篇也被越来越多实施双语教学的学校所采用。

权威的作者、经典的教材、一流的译者、严格的审校、精细的编辑，这些因素使我们的图书有了质量的保证。随着计算机科学与技术专业学科建设的不断完善和教材改革的逐渐深化，教育界对国外计算机教材的需求和应用都将步入一个新的阶段，我们的目标是尽善尽美，而反馈的意见正是我们达到这一终极目标的重要帮助。华章分社欢迎老师和读者对我们的工作提出建议或给予指正，我们的联系方法如下：

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# PREFACE

The basic structure and philosophy of the previous editions of *Signals, Systems, and Transforms* are retained in the fourth edition. New examples have been added and some examples have been revised to demonstrate key concepts more clearly. The wording of passages throughout the text has been revised to ease reading and improve clarity. In particular, we have revised the development of convolution and the Discrete Fourier Transform. Biographical information about selected pioneers in the fields of signal and system analysis has been added in the appropriate chapters. References have been removed from the end of each chapter and are collected in Appendix I.

Many end-of-chapter problems have been revised and numerous new problems are provided. Several of these new problems illustrate real-world concepts in digital communications, filtering, and control theory. The end-of-chapter problems have been organized so that multiple similar problems are provided. The answer to at least one of each set of similar problems is provided in Appendix H. The intent is to allow students to develop confidence by gaining immediate feedback about their understanding of new material and concepts. All MATLAB examples have been updated to ensure compatibility with the Student Version Release 14.

A companion web site at [http://www.ee.washington.edu/class/SST\\_textbook/textbook.html](http://www.ee.washington.edu/class/SST_textbook/textbook.html) contains sample laboratories, lecture notes for Chapters 1–7 and Chapters 9–12, and the MATLAB files listed in the textbook as well as several additional MATLAB files. It also contains a link to a second web site at <http://www.ee.washington.edu/class/235dl/>, which contains interactive versions of the lecture notes for Chapters 1–7. Here, students and professors can find worked-out solutions to all the examples in the lecture notes, as well as animated demonstrations of various concepts including transformations of continuous-time signals, properties of continuous-time systems (including numerous examples on time-invariance), convolution, sampling, and aliasing. Additional examples for discrete-time material will be added as they are developed.

This book is intended to be used primarily as a text for junior-level students in engineering curricula and for self-study by practicing engineers. It is assumed that

the reader has had some introduction to signal models, system models, and differential equations (as in, for example, circuits courses and courses in mathematics), and some laboratory work with physical systems.

The authors have attempted to consistently differentiate between signal and system models and physical signals and systems. Although a true understanding of this difference can be acquired only through experience, readers should understand that there are usually significant differences in performance between physical systems and their mathematical models.

We have attempted to relate the mathematical results to physical systems that are familiar to the readers (for example, the simple pendulum) or physical systems that students can visualize (for example, a picture in a picture for television). The descriptions of these physical systems, given in Chapter 1, are not complete in any sense of the word; these systems are introduced simply to illustrate practical applications of the mathematical procedures presented.

Generally, practicing engineers must, in some manner, validate their work. To introduce the topic of validation, the results of examples are verified, using different procedures, where practical. Many homework problems require verification of the results. Hence, students become familiar with the process of validating their own work.

The software tool MATLAB is integrated into the text in two ways. First, in appropriate examples, MATLAB programs are provided that will verify the computations. Then, in appropriate homework problems, the student is asked to verify the calculations using MATLAB. This verification should not be difficult because MATLAB programs given in examples similar to the problems are applicable. Hence, another procedure for verification is given. The MATLAB programs given in the examples may be downloaded from [http://www.ee.washington.edu/class/SST\\_textbook/textbook.html](http://www.ee.washington.edu/class/SST_textbook/textbook.html). Students can alter data statements in these programs to apply them to the end-of-chapter problems. This should minimize programming errors. Hence, another procedure for verification is given. However, all references to MATLAB may be omitted, if the instructor or reader so desires.

Laplace transforms are covered in Chapter 7 and z-transforms are covered in Chapter 11. At many universities, one or both transforms are introduced prior to the signals and systems courses. Chapters 7 and 11 are written such that the material can be covered anywhere in the signals and systems course, or they can be omitted entirely, except for required references.

The more advanced material has been placed toward the end of the chapters wherever possible. Hence, this material may be omitted if desired. For example, Sections 3.7, 3.8, 4.6, 5.5, 7.9, 10.7, 12.6, 12.7, and 12.8 could be omitted by instructors without loss of continuity in teaching. Further, Chapters 8 and 13 can be skipped if a professor does not wish to cover state-space material at the undergraduate level.

The material of this book is organized into two principal areas: continuous-time signals and systems, and discrete-time signals and systems. Some professors prefer to cover first one of these topics, followed by the second. Other professors prefer to cover continuous-time material and discrete-time material simultaneously.

The authors have taken the first approach, with the continuous-time material covered in Chapters 2–8, and the discrete-time material covered in Chapters 9–13. The material on discrete-time concepts is essentially independent of the material on continuous-time concepts so that a professor or reader who desires to study the discrete-time material first could cover Chapters 9–11 and 13 before Chapters 2–8. The material may also be arranged such that basic continuous-time material and discrete-time material are intermixed. For example, Chapters 2 and 9 may be covered simultaneously and Chapters 3 and 10 may also be covered simultaneously.

In Chapter 1, we present a brief introduction to signals and systems, followed by short descriptions of several physical continuous-time and discrete-time systems. In addition, some of the signals that appear in these systems are described. Then a very brief introduction to MATLAB is given.

In Chapter 2, we present general material basic to continuous-time signals and systems; the same material for discrete-time signals and systems is presented in Chapter 9. However, as stated above, Chapter 9 can be covered before Chapter 2 or simultaneously with Chapter 2. Chapter 3 extends this basic material to continuous-time linear time-invariant systems, while Chapter 10 does the same for discrete-time linear time-invariant systems.

Presented in Chapters 4, 5, and 6 are the Fourier series and the Fourier transform for continuous-time signals and systems. The Laplace transform is then developed in Chapter 7. State variables for continuous-time systems are covered in Chapter 8; this development utilizes the Laplace transform.

The z-transform is developed in Chapter 11, with the discrete-time Fourier transform and the discrete Fourier transform presented in Chapter 12. However, Chapter 12 may be covered prior to Chapter 11. The development of the discrete-time Fourier transform and discrete Fourier transform in Chapter 12 assumes that the reader is familiar with the Fourier transform. State variables for discrete-time systems are given in Chapter 13. This material is independent of the state variables for continuous-time systems of Chapter 8.

In Appendix A, we give some useful integrals and trigonometric identities. In general, the table of integrals is used in the book, rather than taking the longer approach of integration by parts. Leibnitz's rule for the differentiation of an integral and L'Hôpital's rule for indeterminate forms are given in Appendix B and are referenced in the text where needed. Appendix C covers the closed forms for certain geometric series; this material is useful in discrete-time signals and systems. In Appendix D, we review complex numbers and introduce Euler's relation, in Appendix E the solution of linear differential equations with constant coefficients, and in Appendix F partial-fraction expansions. Matrices are reviewed in Appendix G; this appendix is required for the state-variable coverage of Chapters 8 and 13. As each matrix operation is defined, MATLAB statements that perform the operation are given. Appendix H provides solutions to selected chapter problems so that students can check their work independently. Appendix I lists the references for the entire text, arranged by chapter.

This book may be covered in its entirety in two 3-semester-hour courses, or in quarter courses of approximately the equivalent of 6 semester hours. With the omission of appropriate material, the remaining parts of the book may be covered with



## viii Preface

fewer credits. For example, most of the material of Chapters 2, 3, 4, 5, 6, 8, 9, 10, 11 and 12 has been covered in one 4-semester-hour course. The students were already familiar with some linear-system analysis and the Laplace transform.

We wish to acknowledge the many colleagues and students at Auburn University, the University of Evansville, and the University of Washington who have contributed to the development of this book. In particular, the first author wishes to express thanks to Professors Charles M. Gross, Martial A. Honnell, and Charles L. Rogers of Auburn University for many stimulating discussions on the topics in this book, and to Professor Roger Webb, director of the School of Electrical Engineering at the Georgia Institute of Technology, for the opportunity to teach the signal and system courses at Georgia Tech. The second author wishes to thank Professors Dick Blandford and William Thayer for their encouragement and support for this effort, and Professor David Mitchell for his enthusiastic discussions of the subject matter. The third author wishes to thank the professors and many students in EE235 and EE341 at the University of Washington who contributed comments to this book and interactive web site, in particular Professors Mari Ostendorf and Mani Soma, Eddy Ferré, Wai Shan Lau, Bee Ngo, Sanaz Namdar, Jessica Tsao, and Anna Margolis. We would like to thank the reviewers who provided invaluable comments and suggestions. They are Leslie M. Collins, Duke University; William Eads, Colorado State University; Aleksandar Dogandzic, Iowa State University; and Bruce Eisenstein, Drexel University. The interactive web site was developed under a grant from the Fund for the Improvement of Postsecondary Education (FIPSE), U.S. Department of Education.

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