Preface

The structure and philosophy of the previous editions of Feedback Control Systems remains unchanged in the fourth edition. However, the focus has been sharpened as a result of the experience using the first four editions and the reactions of colleagues who have taught from the book. Some explanations have been enhanced. Where appropriate, a number of examples have been improved. The majority of the end-of-chapter problems have been either altered or replaced. The simulation program SIMULINKTM, a block-diagram program to be used with MATLABTM, is introduced to illustrate the simulation of both continuous (analog) and discrete systems, and of nonlinear continuous systems. In addition, the symbolic mathematics of MATLAB is used in verifying the calculations of transforms, the solutions of differential equations, and in other appropriate applications. New capabilities of MATLAB have been added and most examples now contain short MATLAB programs. In this fifth edition, the MATLAB programs given in the examples may be downloaded from the Companion Website:

http://www.pearsoned.com/phillips

This book is intended to be used primarily as a text for junior- and senior-level students in engineering curricula and for self-study by practicing engineers with little or no experience in control systems. For maximum benefits, the reader should have had some experience in linear-system analysis.

The material of this book is organized into three principal areas: analog control systems, digital control systems, and nonlinear analog control systems. Chapter 1 in this book presents a brief introduction and an outline of the text. In addition, some control systems are described to introduce the reader to typical applications. Next a short history of feedback control systems is given. The mathematical models of some common components that appear in control systems are developed in Chapter 2.

Chapters 3 through 10 cover the analysis and design of linear analog systems; that is, control systems that contain no sampling. Chapter 2 develops the transfer function model of linear analog systems, and Chapter 3 develops the state-variable model.

Chapter 4 covers typical responses of linear analog systems, including the concept of frequency response. Since many of the characteristics of closed-loop systems cannot be adequately explained without reference to frequency response, this concept is developed early in the book. The authors believe that the frequency-response concept ranks in importance with the time-response concept.

Important control-system characteristics are developed in Chapter 5. Some of the applications of closed-loop systems are evident from these characteristics. The very important concept of system stability is developed in Chapter 6 along with the Routh-Hurwitz stability criterion. Chapter 7 presents analysis and design by root locus procedures, which are basically time-response procedures. The equally important frequency-response analysis and design procedures are presented in

Chapters 8 and 9. Chapter 10 is devoted to modern control-system design. Pole-placement design is developed, and the design of state estimators is introduced.

The material of Chapters 3 through 10 applies directly to analog control systems; that of Chapters 11 through 14 applies to digital control systems. Essentially all the analog analysis and design techniques of Chapters 3 through 9 are developed again for digital control systems. These topics include typical responses, characteristics, stability, root-locus analysis and design, and frequency-response analysis and design.

Nonlinear system analysis is presented in Chapter 15. These methods include the describing-function analysis, linearization, and the state-plane analysis.

Many examples are given, with an effort made to limit each example to illustrating only one concept. It is realized that in using this approach, many obvious and interesting characteristics of the systems of the examples are not mentioned; however, since this is a book for beginning students in feedback control, making the examples more complex would tend to add confusion.

Usually, nonlinear controls are not covered in introductory books in control. However, many of the important characteristics of physical systems cannot be explained on the basis of linear systems. For example, stability as a function of signal amplitude is one of the most common phenomena observed in closed-loop physical systems, and the describing function is included in Chapter 15 to offer an analysis procedure that explains this phenomenon. Lyapunovís first stability theorem is also presented to illustrate some of the pitfalls of linear-system stability analysis.

In general, the material of each chapter is organized such that the more advanced material is placed toward the end of the chapter. This placement is to allow the omission of this material by those instructors who wish to present a less intense course.

This book may be covered in its entirety as a three-hour one-semester course in analog control (Chapters 1 through 9), and a three-hour one-semester course in digital control and nonlinear control with an introduction to modern control (Chapters 10 through 15). The material may also be covered in two-quarter course sequence, with approximately five hours for each course. With the omission of appropriate material, the remaining material may be covered in courses with fewer credits. If a course in digital control is taught without the coverage of the first nine chapters, some of the material of the first nine chapters must be introduced; Chapters 11 through 13 rely on some of this material. A solutions manual containing the solutions to all problems at the ends of the chapters is available for teachers who have adopted the text for use in the classroom.

New to This Edition

The following improvements have been made to the Fifth Edition:

* More than 70% of the end-of-chapter problem sets are new or revised
* Additional examples
* Additional explanation of some concepts and procedures
* More extensive use of MATLAB in examples and problem sets.

* Companion Website contains M-files
* A new Appendix that introduces control system applications of MATLAB.
* A new Appendix with answers for selected end-of-chapter problems.
* The end-of-chapter problems are grouped into sets so that each set corresponds to a section of the chapter. In each set at least one problem has its answer provided in Appendix E. Other problems in the set are based on the same concepts as the one with its answer given. This can provide immediate feedback to students in cases where the problems do not provide a second method of verification.

_ A new chapter (14) on Discrete -Time Pole-Assignment and State Estimation has been added.

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Finally, we express our gratitude and love for our families, without whom this undertaking would not have been possible.

The e-mail address for John M. Parr is parr@evansville.edu.

Charles L. Phillips, Auburn University
John M. Parr, University of Evansville