

Introduction to Advanced Control Systems - A Simplified Approach

by

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Introduction

An automatic control system is one whose various components, which include the sensors, process (or plant), controllers and actuators, are appropriately designed and subsequently suitably interconnected so that the overall system behaves in a prescribed manner.

Automatic control is one of today's most significant areas of science and technology. This is attributable to the fact that automation is linked with the development of almost every form of technology. For this reason automatic control courses are taught in a number of engineering disciplines. However, the subject of control engineering is often considered by students to be highly mathematical and generally difficult to comprehend. The author has produced a text that attempts to present in a simplified manner control engineering topics traditionally regarded as "dry" or "difficult".

Outline of the book

The text consists of nine chapters and four appendices. It is divided into four distinct parts aptly identified on the front cover page as:

1. Advanced linear control systems
2. Modern Control systems
3. Digital control systems
4. Nonlinear control systems

The actual chapters included in the text are as follows.

Chapter One constitutes Part 1 of the text. It treats graphical frequency-domain techniques based on use of constant M- and N-circles as well as Nichols Chart. In particular, the chapter treats the use of these techniques in dealing with control systems having inherent pure time delay.

Chapters Two to Five in Part 2 of the text treat concepts of modern control theory. Chapter Two starts with a brief introduction to modern control theory highlighting its advantages over classical or conventional control theory. After providing definitions of some state space terminologies, state space mathematical models are derived for representative physical systems. The chapter ends with the derivation of state space models from high order differential equations.

Chapter Three deals thoroughly with methods of obtaining state space models for control systems described by

- Block diagrams
- Transfer functions
- Signal flow graphs.

Chapter Four treats the relationship between a system's state-space and transfer function (input-output mapping) descriptions. It then discusses five different methods of solving state equations in order to obtain time domain responses to input signals.

Chapter Five deals with the modern control concepts of system controllability and observability. These concepts which students often find hard to grasp are essential in designing control systems that employ state feedback.

Chapters Six and Seven constitute Part 3 of the text and deal with digital control fundamentals. Chapter Six introduces the reader to sampled-data control systems. These are systems which incorporate a computer and therefore employ discrete-time signals entirely or in conjunction with continuous-time signals. The z-transform as the analytical tool for such systems is introduced simply from first principles and used in numerous illustrative examples to de-mystify it.

Chapter Seven develops the analysis of digital control systems further by treating the subject of system stability. The Chapter first establishes the relationship between the familiar complex and linear s-plane to the complex nonlinear z-plane. It then presents three methods of establishing stability of digital control systems.

Chapters Eight and Nine constitute Part 4 of the text and deal with aspects of nonlinear control engineering. This is a topic which is becoming increasingly important not only because all practical control systems have one or other form of nonlinearity but nonlinear controllers have proved to be much more robust than their linear counterparts. Chapter Eight describes characteristics of nonlinearities and their influence on system behaviour. The frequency-domain describing function approach to analyzing nonlinearities is fully expounded by the author. Chapter Nine is devoted to the phase-plane method of analyzing nonlinear systems. It is a graphical method for studying second-order nonlinear systems.

The text has four appendices that supplement the materials in Parts 2 and 4:

- Appendix A presents a review of elementary properties of matrices and matrix algebra.
- Appendix B presents spectral analysis of matrices in terms of eigenvalues and eigenvectors as well as similarity transformation into diagonal canonical forms.
- Appendix C briefly describes how the nature of a nonlinearity affects its Fourier series representation.
- Appendix D presents a MATLAB programme that generates and plots a phase portrait for second order systems.

Conclusions

After reading part of the manuscript and the new text and taking into account the experience I have gathered teaching control engineering to undergraduate and postgraduate students for over two decades now, I have come to the following conclusions about the text.

Advantages:

1. *This book is on systems rather than on mathematics.* Unlike many other texts in the field where a considerable part of the volume is solely devoted to essential mathematical prerequisites, every chapter of this book deals with system-theoretic properties of finite dimensional systems. Mathematical tools are introduced along with (and are motivated by) a corresponding system theoretic problem. These mathematical tools are limited to the barest minimum.
2. *The book is very carefully thought out.* The author has arranged the material very carefully. Explanation of concepts is made in concise and simple terms. Materials in each chapter are richly illustrated with worked examples to enhance understanding. Also the materials in each chapter are interspersed with sections for tutorial problems whose answers are provided immediately after each question. Furthermore, the book ends with a series of review questions, arranged chapter by chapter, aimed at testing the reader's overall understanding of the subject matter. An extensive list of bibliography is provided for further study.
3. *The necessity of the state-space approach is well motivated.* The extensive four chapters devoted to the state-space approach are well justified and will give a

diligent student the foundation to deal with this versatile way of control system analysis and design with a good measure of confidence.

4. *Unlike some other books, this text is almost completely free of errors.* The reader feels grateful for the time and efforts the author and the publisher have spent editing the text and proof reading. Errata sheets are provided at the end of the book. That is the ‘letter’ of the book. The ‘spirit’ lies in the expertise and elegance the author has brought to bear in exposing his long years of experience in teaching this interesting and important subject. I salute his effort.

Disadvantages:

1. *Absence of reference to computer-aided design and analysis tools.* The author has totally avoided the possibility of introducing the widely available computer-aided control system design packages which make life much easier for the control engineering student and practitioner. The computer is not only important in analyzing and designing control systems but is increasingly becoming the heart of control systems. Thus there is the need to gradually introduce students to programs and toolboxes in software such as MATLAB.
2. *More emphasis has been laid on analysis to the neglect of design.* Students must master design as well as analysis techniques. Design is central to all engineering and especially so to control systems. The text therefore needs to lay some more emphasis on design and practical implementation of control systems.

But these disadvantages may be discounted considering the fact that the author’s choice of materials for the text was dictated by the syllabus requirements for two courses in the Post-HND programme in the Department of Electrical Engineering of Kaduna Polytechnic. In the light of the text’s achievements, its negative aspects appear as minor quibbles.

On the whole, this reviewer finds the book very suitable as a text for self-study or classroom use on the topics it has treated and a welcome addition to the ever-growing library of control literature.