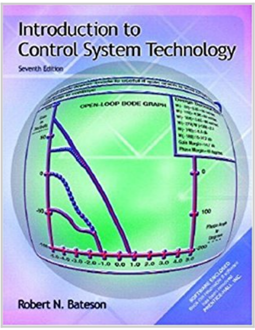

Introduction to Control System Technology (7th Edition)

By Robert N. Bateson

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Marrying an academic examination on control system technology with a reference that practicing engineers and technicians can include in their personal libraries, this carefully balanced study covers the terminology, concepts, principles, procedures, and computations used by engineers and technicians to analyze, select, specify, design, and maintain control systems. An accompanying diskette provides computer programs that emulate proven graphical design methods of analysis and design.   Basic concepts and terminology, measurement, manipulation, analysis and design.   For engineers and technicians interested in a comprehensive addition to their libraries.

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Editorial Review

From the Back Cover

Introduction to Control System Technology, Seventh Edition, is both a textbook on control system technology and a valuable reference that engineers and technicians will want in their personal libraries.

Outstanding features of this text include:

- A computer disk packaged with the text includes a graphical design program that emulates the classical Bode design method. Using this program, the designer can observe how each control mode changes the shape of the open-loop frequency response of the system. By trying different PID control mode values, the designer can use a "design-by-trial" procedure to search for the best possible design.
- The use of analogies to develop common elements for modeling and analyzing electrical, fluid flow, thermal, or mechanical components helps students translate knowledge of one type of component to components of other types.
- End-of-chapter exercises challenge students with practical problems at various levels of difficulty. The exercises are grouped by section numbers with multiple simple problems to reinforce student learning, followed by more complex problems to generate interest in the subject.

GOAL

The goal of *Introduction to Control System Technology* is to provide both a textbook on the subject and a reference that engineers and technicians can include in their personal libraries. This text can help students master the concepts and language of control and help engineers and technicians analyze and design control systems. The text covers the terminology, concepts, principles, procedures, and computations used by engineers and technicians to analyze, select, specify, design, and maintain control systems. Emphasis is on the application of established methods with the aid of examples and computer programs.

EVOLUTION OF TEXT

The writing of this text began 34 years ago when I faced the challenge of developing and teaching a control systems course in a 2-year engineering technology program. I had just entered the teaching profession after 10 years as a research engineer at General Mills, where I had become fascinated with control systems. I was especially intrigued by the combined electrical, mechanical, thermal, liquid, and gas elements in the mathematical models used to analyze and design control systems. This fascination led to the completion of an evening MSEE program with a major in control systems and a hands-on design course at Brown Institute in Philadelphia. In my course work, we used straight-line Bode diagrams to design control systems. This method works very well for processes with dead-time lags. The graphical approach gives the designer an "intuitive feel" of the way the controller changes the frequency response of the system. I found that this "feel" was very helpful working on plant start-ups. Indeed, the greatest benefit from learning the frequency-response design method was the understanding and judgment it imparted. It made me a much better engineer.

You can imagine the excitement with which I approached the teaching of my favorite subject. I wanted my students to feel that excitement. I wanted to impart some of the feeling and judgment that I acquired from frequency-response design of a control system. There was one major obstacle, however. There was no suitable text for my students. So I wrote 100 pages of notes on control fundamentals with emphasis on graphical design using straight-line Bode diagrams. These notes were the genesis of this text. The thrust of the notes was to bring students to the point where they could complete frequency-response design of control systems under my direction. My role was that of a control engineer, and my students were my engineering technicians. Those 100 pages of notes have grown to become the seventh edition of a 700-page textbook, but the thrust has not changed. The thrust of this text is to bring students to the point where they can complete computer-aided, frequency-response design of control systems under the direction of their instructor or control engineer.

Frequency-response graphs are constructed from the transfer functions of the system components. The chapters on common elements and Laplace transforms were written to give students the foundation required to determine these transfer functions. Analogies were used to develop common elements for modeling and analyzing electrical, thermal, mechanical, and fluid flow elements. These analogies helped students translate their knowledge of one type of component to components of other types. The parts on measurement, manipulation, and control extended the students' mastery of transfer functions and developed their ability to select, specify, and design measuring and manipulating systems. Finally, we reached the point where the students actually began the graphical design process. The frequency-response (or Bode) design method worked very well, but constructing and reconstructing Bode diagrams is very tedious and time consuming. By the time the students learned how to construct Bode diagrams, there was little time or energy left to learn how to design the controller. My goal was unfulfilled.

Then I had a dream. My dream was a computer program that would construct the Bode diagrams so that students, technicians, and engineers could concentrate on the design of the controller. The first attempt to realize my dream was a FORTRAN program that generated frequency-response data from the open-loop transfer function. The program made all the design decisions, and all the student had to do was input the transfer function. As an engineering tool, it was great, but as a teaching tool, it failed. Students could complete the design very well, but they did not understand the results. When design exceptions required an override of the program's results, students had no idea what to do—no pain but no gain.

The first program did too much, and the students did too little. The next program generated tables of frequency-response data that the students used to draw the Bode diagrams. It was not as good an engineering tool but was a much better teaching tool. Drawing the graphs took time, but the students did understand the design process.

The third version of the program uses the graphing capabilities of the QuickBASIC programming language. The program DESIGN is an interactive program that plots frequency-response graphs on the screen and accepts user inputs of the control modes. This program emulates the classical Bode design method with precise plots based on the transfer functions of the system components. The designer observes how each control mode changes the shape of the open-loop frequency response of the system. On-screen design decision data allow the designer to determine PID control mode values, which can be easily changed in a "what-if analysis. This enables the designer to use a "design-by-trial" procedure to search for the best possible control system design. It worked; my dream was fulfilled. DESIGN is both a good engineering design tool and a good teaching tool.

This text was developed to facilitate the education of engineering technicians. Its purpose is to train technicians who understand the language and methods used by engineers, technicians who can use established methods to complete engineering design work under the direction of a control engineer.

I believe an essential part of the education of the engineering technician is to develop the ability to communicate with engineers using their language. Mathematical terms are an essential part of this language. The engineering technician must understand and be comfortable with terms such as derivative, integral, transfer function, frequency domain, and Laplace transform—not at the theoretical level, of course, but certainly at the applied level. A goal of this text is to develop an understanding of the language of control, including the mathematical terms mentioned.

COMPUTER DISK ANCILLARY

The disk packaged with this text contains QuickBASIC and executable versions of the four programs used in the text. No knowledge of QuickBasic is required to use the executable versions of the programs. They can be executed directly from DOS on any IBM-compatible computer. **You may make copies of these programs and distribute them as you wish.** I hope you enjoy using the programs as much as I enjoyed creating them.

CHANGES TO THIS EDITION

The primary emphasis for the seventh edition was a complete rework of the exercises at the end of each chapter. Every section was examined, and every question was reviewed. Numerous exercises were added to provide students with multiple opportunities to develop their grasp of the material.

The review also provided ample opportunities to improve the clarity and accuracy of the text. Example 16.3, a walk-through of a run of program Design, was revised to provide better integration of the text and figures.

Most of the material in Appendix C, "Binary Codes," was deleted because most reviewers felt the material was covered in other courses. Only seven binary tables were retained as reference material.

ORGANIZATION

The book consists of five parts. Part One is an introduction to the terminology, concepts, and methods used to describe control systems. Parts Two, Three, and Four cover the three operations of control: measurement, manipulation, and control. Part Five is concerned with the analysis and design of control systems. Each chapter begins with a set of learning objectives and ends with a glossary of terms. There is sufficient material for a two-semester course, and there are a number of possible sequences of selected chapters for a one-semester course. The following are some suggested sequences for one- and two-semester courses.

Suggested One-Semester Sequences:
A. Process Control Analysis and Design:
Chapters 1-5, 6.1-6.3, 9.4, 9.5, 13.1-13.3, 14, 5.1-15.9, 16.1-16.6
B. Servo Control Analysis and Design:
Chapters 1-5, 6.1-6.3, 9.3, 10, 13, 14, 15, 16.1, 16.5-16.7
C. Sequential and PID Control:
Chapters 1, 2, 5, 9, 10.4, 11, 12, 13, 16.1-16.4
D. Data Acquisition and Control:
Chapters 1, 2, 5, 6, 7, 8, 13, 16.1-16.4

Suggested Two-Semester Sequence:
Semester 1: Data Acquisition: Chapters 1-8
Semester 2: Control: Chapters 9-16

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Robert N. Bateson

Users Review

From reader reviews:

Jennifer Oaks:

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Keith Devine:

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