Process Control

Process Control emphasizes the importance of computers in this modern age of teaching and practicing process control. An introductory textbook, it covers the most essential aspects of process control suitable for a one-semester course.

The text covers classical techniques, but also includes discussion of state-space modeling and control, a modern control topic lacking in most chemical process control introductory texts. MATLAB®, a popular engineering software package, is used as a powerful yet approachable computational tool. Text examples demonstrate how root locus, Bode plots, and time-domain simulations can be integrated to tackle a control problem. Classical control and state-space designs are compared. Despite the reliance on MATLAB, theory and analysis of process control are well presented, creating a well-rounded pedagogical text. Each chapter concludes with problem sets, to which hints or solutions are provided. A Web site provides excellent support in the way of MATLAB outputs of text examples and MATLAB sessions, references, and supplementary notes.

A succinct and readable text, this book will be useful for students studying process control, as well as for professionals undertaking industrial short courses or looking for a brief reference.

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A First Course with MATLAB

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Preface

This is an introductory text written from the perspective of a student. The major concern is not of how much material is covered, but rather, how the most important and basic concepts that one should grasp in a first course are presented. If your instructor is using some other text that you are struggling to understand, I hope that I can help you too. The material here is the result of a process of elimination. The writing and the examples are succinct and self-explanatory, and the style is purposely unorthodox and conversational. To a great extent, the style, content, and the extensive use of footnotes are molded heavily by questions raised in class. I left out very few derivation steps. If they are left out, the missing steps are provided as hints in the Review Problems at the back of each chapter. I strive to eliminate those "easily obtained" results that baffle many of us. Most of you should be able to read the material on your own. You just need basic knowledge in differential equations, and it helps if you have taken a course on writing material balances. With the exception of Chapters 4, 9, and 10, which should be skipped in a quarter-long course, it also helps if you proceed chapter by chapter. The presentation of material is not intended for someone to just jump right in the middle of the text. A very strong emphasis is placed on developing analytical skills. To keep pace with the modern computer era, a coherent and integrated approach is taken to using a computational tool. I believe in active learning. When you read the chapters, it is very important that you have MATLAB with its Control Toolbox to experiment and test the examples firsthand.

Notes to Instructors

There are probably more introductory texts on control than on any other engineering disciplines. It is arguable whether we need another control text. As we move into the era of hundred-dollar textbooks, I believe we can lighten the economic burden and, with the Internet, assemble a new generation of modularized texts that soften the printing burden by off-loading selected material to the Web. Still, a key resolve is to scale back on the scope of a text to the most crucial basics. How much students can or be enticed to learn is inversely proportional to the number of pages that they have to read – akin to diminished magnitude and increased lag in frequency response. Therefore, as textbooks become thicker over the years in attempts to reach out to students and are excellent resources from the perspective of instructors, these texts are by no means more effective pedagogical tools. This project was started as a set of review notes when I found that students were having trouble identifying the key concepts in these expansive texts. I also found that these texts in many circumstances deter students from active learning and experimenting on their own.

At this point, the contents are scaled down to fit a one-semester course. On a quarter system, Chapters 4, 9, and 10 can be omitted. With the exception of Chapters 4 and 9, on state-space models, the organization has "evolved" to become very classical. The syllabus is chosen such that students can get to tuning proportional–integral–differential controllers before they lose interest. Furthermore, discrete-time analysis has been discarded. If there is to be one introductory course in the undergraduate curriculum, it is very important to provide an exposure to state-space models as a bridge to a graduate-level course. Chapter 10, on mutliloop systems, is a collection of topics that are usually handled by several chapters in a formal text. This chapter is written such that only the most crucial concepts are illustrated and that it could be incorporated comfortably into a one-semester curriculum. For schools with the luxury of two control courses in the curriculum, this chapter should provide a nice introductory transition. Because the material is so restricted, I emphasize that this is a "first-course" textbook, lest a student mistakenly ignore the immense expanse of the control field. I also have omitted appendices and extensive references. As a modularized tool, I use the *Web Support* to provide references, support material, and detailed MATLAB plots and results.

Homework problems are also handled differently. At the end of each chapter are short, mostly derivation-type problems that are called Review Problems. Hints or solutions are provided for these exercises. To enhance the skill of problem solving, the extreme approach is taken, more so than that of Stephanopoulos (1984), of collecting major homework problems at the back and not at the end of each chapter. My aim is to emphasize the need to understand and integrate knowledge, a virtue that is endearing to ABET, the engineering accreditation body in the United States. These problems do not even specify the associated chapter as many of them involve different techniques. A student has to determine the appropriate route of attack. An instructor may find it aggravating to assign individual parts of a problem, but when all the parts are solved, I hope the exercise will provide a better perspective on how different ideas are integrated.

To be an effective teaching tool, this text is intended for experienced instructors who may have a wealth of their own examples and material, but writing an introductory text is of no interest to them. The concise coverage conveniently provides a vehicle with which they can take a basic, minimalist set of chapters and add supplementary material that they deem appropriate. Even without supplementary material, however, this text contains the most crucial material, and there should not be a need for an additional expensive, formal text.

Although the intended teaching style relies heavily on the use of MATLAB, the presentation is very different from texts that prepare elaborate M-files and even menu-driven interfaces. One of the reasons why MATLAB is such a great tool is that it does not have a steep learning curve. Students can quickly experiment on their own. Spoon-feeding with our misguided intention would only destroy the incentive to explore and learn on one's own. To counter this pitfall, strong emphasis is placed on what students can accomplish easily with only a few MATLAB statements. MATLAB is introduced as walk-through tutorials that encourage students to enter commands on their own. As a strong advocate of active learning, I do not duplicate MATLAB results. Students again are encouraged to execute the commands themselves. In case help is needed, the *Web Support*, however, has the complete set of MATLAB results and plots. This organization provides a more coherent discourse on how one can make use of different features of MATLAB, not to mention save significant printing costs. Finally, the tutorials can easily be revised to keep up with the continual upgrade of MATLAB. At this writing, the tutorials are based on MATLAB Version 6.1 and the object-oriented functions in the Control System Toolbox Version 5.1. Simulink Version 4.1 is also utilized, but its scope is limited to simulating more complex control systems.

As a first-course text, the development of models is limited to stirred tanks, stirred-tank heaters, and a few other examples that are used extensively and repeatedly throughout the chapters. My philosophy is one step back in time. The focus is the theory and the building of a foundation that may help to solve other problems. The design is also formulated to be able to launch into the topic of tuning controllers before students may lose interest. The coverage of Laplace transforms is not entirely a concession to remedial mathematics. The examples are tuned to illustrate immediately how pole positions may relate to time-domain response. Furthermore, students tend to be confused by the many different design methods. As much as I could, especially in the controller design chapters, I used the same examples throughout. The goal is to help a student understand how the same problem can be solved by different techniques.

I have given up the pretense that we can cover controller design and still have time to do all the plots manually. I rely on MATLAB to construct the plots. For example, I take a unique approach to root-locus plots. I do not ignore it as some texts do, but I also do not go into the hand-sketching details. The same can be said of frequency-response analysis. On the whole, I use root-locus and Bode plots as computational and pedagogical tools in ways that can help students to understand the choice of different controller designs. Exercises that may help such thinking are in the MATLAB tutorials and homework problems.

Finally, I have to thank Costas Pozikidris and Florence Padgett for encouragement and support on this project, Raymond de Callafon for revising the chapters on state-space models, and Allan Cruz for proofreading. Last but not least, Henry Lim combed through the manuscript and made numerous insightful comments. His wisdom is sprinkled throughout the text.

Web Support (MATLAB outputs of text examples and MATLAB sessions, references, supplementary notes, and solution manual) is available at `http://us.cambridge.org/titles/0521002559.html`.