

Linear System Theory Design Chen Solution Manual

An extensive revision of the author's highly successful text, this third edition of Linear System Theory and Design has been made more accessible to students from all related backgrounds. After introducing the fundamental properties of linear systems, the text discusses design using state equations and transfer functions. In state-space design, Lyapunov equations are used extensively to design state feedback and state estimators. In the discussion of transfer-function design, pole placement, model matching, and their applications in tracking and disturbance rejection are covered. Both one- and two-degree-of-freedom configurations are used. All designs can be accomplished by solving sets of linear algebraic equations. The two main objectives of the text are to: 1. use simple and efficient methods to develop results and design procedures 2. enable students to employ the results to carry out design. All results in this new edition are developed for numerical computation and illustrated using MATLAB, with an emphasis on the ideas behind the computation and interpretation of results. This book develops all theorems and results in a logical way so that readers can gain an intuitive understanding of the theorems. This revised edition begins with the time-invariant case and extends through the time-varying case. It also starts with single-input single-output design and extends to multi-input multi-output design. Striking a balance between theory and

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applications, Linear System Theory and Design, 3/e, is ideal for use in advanced undergraduate/first-year graduate courses in linear systems and multivariable system design in electrical, mechanical, chemical, and aeronautical engineering departments. It assumes a working knowledge of linear algebra and the Laplace transform and an elementary knowledge of differential equations.

This book discusses analysis and design techniques for linear feedback control systems using MATLAB® software. By reducing the mathematics, increasing MATLAB working examples, and inserting short scripts and plots within the text, the authors have created a resource suitable for almost any type of user. The book begins with a summary of the properties of linear systems and addresses modeling and model reduction issues. In the subsequent chapters on analysis, the authors introduce time domain, complex plane, and frequency domain techniques. Their coverage of design includes discussions on model-based controller designs, PID controllers, and robust control designs. A unique aspect of the book is its inclusion of a chapter on fractional-order controllers, which are useful in control engineering practice.

This text's contemporary approach focuses on the concepts of linear control systems, rather than computational mechanics. Straightforward coverage includes an integrated treatment of both classical and modern control system methods. The text emphasizes design with discussions of problem formulation, design criteria, physical constraints, several design methods,

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and implementation of compensators. Discussions of topics not found in other texts—such as pole placement, model matching and robust tracking—add to the text's cutting-edge presentation. Students will appreciate the applications and discussions of practical aspects, including the leading problem in developing block diagrams, noise, disturbances, and plant perturbations. State feedback and state estimators are designed using state variable equations and transfer functions, offering a comparison of the two approaches. The incorporation of MATLAB throughout the text helps students to avoid time-consuming computation and concentrate on control system design and analysis.

Using a geometric approach to system theory, this work discusses controlled and conditioned invariance to geometrical analysis and design of multivariable control systems, presenting new mathematical theories, new approaches to standard problems and applied mathematics topics.

Digital controllers are part of nearly all modern personal, industrial, and transportation systems. Every senior or graduate student of electrical, chemical or mechanical engineering should therefore be familiar with the basic theory of digital controllers. This new text covers the fundamental principles and applications of digital control engineering, with emphasis on engineering design.

Fadali and Visioli cover analysis and design of digitally controlled systems and describe applications of digital controls in a wide range of fields. With worked examples and Matlab applications in every chapter and many end-of-chapter assignments, this text provides both theory

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and practice for those coming to digital control engineering for the first time, whether as a student or practicing engineer. Extensive Use of computational tools: Matlab sections at end of each chapter show how to implement concepts from the chapter Frees the student from the drudgery of mundane calculations and allows him to consider more subtle aspects of control system analysis and design An engineering approach to digital controls: emphasis throughout the book is on design of control systems. Mathematics is used to help explain concepts, but throughout the text discussion is tied to design and implementation. For example coverage of analog controls in chapter 5 is not simply a review, but is used to show how analog control systems map to digital control systems Review of Background Material: contains review material to aid understanding of digital control analysis and design. Examples include discussion of discrete-time systems in time domain and frequency domain (reviewed from linear systems course) and root locus design in s-domain and z-domain (reviewed from feedback control course) Inclusion of Advanced Topics In addition to the basic topics required for a one semester senior/graduate class, the text includes some advanced material to make it suitable for an introductory graduate level class or for two quarters at the senior/graduate level. Examples of optional topics are state-space methods, which may receive brief coverage in a one semester course, and nonlinear discrete-time systems Minimal Mathematics Prerequisites The mathematics background required for understanding most of the book is based on what can be

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reasonably expected from the average electrical, chemical or mechanical engineering senior. This background includes three semesters of calculus, differential equations and basic linear algebra. Some texts on digital control require more

Saturation nonlinearities are ubiquitous in engineering systems. In control systems, every physical actuator or sensor is subject to saturation owing to its maximum and minimum limits. A digital filter is subject to saturation if it is implemented in a finite word length format. Saturation nonlinearities are also purposely introduced into engineering systems such as control systems and neural network systems. Regardless of how saturation arises, the analysis and design of a system that contains saturation nonlinearities is an important problem. Not only is this problem theoretically challenging, but it is also practically imperative. This book intends to study control systems with actuator saturation in a systematic way. It will also present some related results on systems with state saturation or sensor saturation. Roughly speaking, there are two strategies for dealing with actuator saturation. The first strategy is to neglect the saturation in the first stage of the control design process, and then to add some problem-specific schemes to deal with the adverse effects caused by saturation. These schemes, known as anti-windup schemes, are typically introduced using ad hoc modifications and extensive simulations. The basic idea behind these schemes is to introduce additional feedbacks in such a way that the actuator stays properly within its limits. Most of these schemes lead to improved performance but poorly

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understood stability properties.

Numerous examples highlight this treatment of the use of linear quadratic Gaussian methods for control system design. It explores linear optimal control theory from an engineering viewpoint, with illustrations of practical applications. Key topics include loop-recovery techniques, frequency shaping, and controller reduction. Numerous examples and complete solutions. 1990 edition.

Linear System Theory, Second Edition, outlines the basic theory of linear systems in a unified, accessible, and careful manner, with parallel, independent treatment of continuous-time and discrete-time linear systems.

Recent years have seen a significant rise of interest in max-linear theory and techniques. Specialised international conferences and seminars or special sessions devoted to max-algebra have been organised. This book aims to provide a first detailed and self-contained account of linear-algebraic aspects of max-algebra for general (that is both irreducible and reducible) matrices. Among the main features of the book is the presentation of the fundamental max-algebraic theory (Chapters 1-4), often scattered in research articles, reports and theses, in one place in a comprehensive and unified form. This presentation is made with all proofs and in full generality (that is for both irreducible and reducible matrices). Another feature is the presence of advanced material (Chapters 5-10), most of which has not appeared in a book before and in many

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cases has not been published at all. Intended for a wide-ranging readership, this book will be useful for anyone with basic mathematical knowledge (including undergraduate students) who wish to learn fundamental max-algebraic ideas and techniques. It will also be useful for researchers working in tropical geometry or idempotent analysis.

The objective of this book is to present an introduction to adaptive estimation and control suitable for a graduate-level course or for self-study. Most of the theory is developed in continuous-time, but discrete-time algorithms are also given and yield more direct implementations. Examples and applications are provided to illustrate the results. The book is designed to be accessible with little knowledge beyond an introductory course on feedback control. Background material is included when appropriate. In addition to introducing the reader to adaptive estimation and control algorithms, the text provides many opportunities to apply knowledge of matrix analysis and systems theory in a meaningful context.

Provides a thorough introduction to the properties of linear, time-invariant models of dynamical systems, as required for further work in feedback control system design, power system design and analysis, communications, signal processing, robotics, and simulation. The state-space model is used throughout, since it is a fundamental conceptual tool,

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although the background analysis applies to other models. Modelling and stability of general nonlinear systems is introduced, with the detailed analysis concentrating on LTI systems.

Based on a streamlined presentation of the authors' successful work *Linear Systems*, this textbook provides an introduction to systems theory with an emphasis on control. Initial chapters present necessary mathematical background material for a fundamental understanding of the dynamical behavior of systems. Each chapter includes helpful chapter descriptions and guidelines for the reader, as well as summaries, notes, references, and exercises at the end. The emphasis throughout is on time-invariant systems, both continuous- and discrete-time.

This book is the result of our teaching over the years an undergraduate course on Linear Optimal Systems to applied mathematicians and a first-year graduate course on Linear Systems to engineers. The contents of the book bear the strong influence of the great advances in the field and of its enormous literature. However, we made no attempt to have a complete coverage. Our motivation was to write a book on linear systems that covers finite dimensional linear systems, always keeping in mind the main purpose of engineering and applied science, which is to analyze, design, and improve the performance of physical systems. Hence we discuss the effect of

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small nonlinearities, and of perturbations of feedback. It is our hope that the book will be a useful reference for a first-year graduate student. We assume that a typical reader with an engineering background will have gone through the conventional undergraduate single-input single-output linear systems course; an elementary course in control is not indispensable but may be useful for motivation. For readers from a mathematical curriculum we require only familiarity with techniques of linear algebra and of ordinary differential equations.

With the advancement of technology, engineers need the systems they design not only to work, but to be the absolute best possible given the requirements and available tools. In this environment, an understanding of a system's limitations acquires added importance. Without such knowledge, one might unknowingly attempt to design an impossible system. Thus, a thorough investigation of all of a system's properties is essential. In fact, many design procedures have evolved from such investigations. For use at the senior-graduate level in courses on linear systems and multivariable system design, this highly successful text is devoted to this study and the design procedures developed thereof. It is not a control text, per se--since it does not cover

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performance criteria, physical constraints, cost, optimization, and sensitivity problems. Chen develops major results and design procedures using simple and efficient methods. Thus, the presentation is not exhaustive; only those concepts which are essential in the development are introduced.

Problem sets--following each chapter--help students understand and utilize the concepts and results covered.

This book addresses two primary deficiencies in the linear systems textbook market: a lack of development of state space methods from the basic principles and a lack of pedagogical focus. The book uses the geometric intuition provided by vector space analysis to develop in a very sequential manner all the essential topics in linear state system theory that a senior or beginning graduate student should know. It does this in an ordered, readable manner, with examples drawn from several areas of engineering. Because it derives state space methods from linear algebra and vector spaces and ties all the topics together with diverse applications, this book is suitable for students from any engineering discipline, not just those with control systems backgrounds and interests. It begins with the mathematical preliminaries of vectors and spaces, then emphasizes the geometric properties of linear operators. It is from this foundation that the studies of stability, controllability and observability,

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realizations, state feedback, observers, and Kalman filters are derived. There is a direct and simple path from one topic to the next. The book includes both discrete- and continuous-time systems, introducing them in parallel and emphasizing each in appropriate context. Time-varying systems are discussed from generality and completeness, but the emphasis is on time-invariant systems, and only in time-domain; there is no treatment of matrix fraction descriptions or polynomial matrices. Tips for using MATLAB are included in the form of margin notes, which are placed wherever topics with applicable MATLAB commands are introduced. These notes direct the reader to an appendix, where a MATLAB command reference explains command usage. However, an instructor or student who is not interested in MATLAB usage can easily skip these references without interrupting the flow of text.

This Solutions Manual is designed to accompany Linear System Theory and Design, Third Edition by C.T. Chen, and includes fully worked out solutions to problems in the main text. It is available free to adopters of the text.

This book presents the mathematical foundations of systems theory in a self-contained, comprehensive, detailed and mathematically rigorous way. It is devoted to the analysis of dynamical systems and combines features of a detailed introductory textbook with that of a reference source. The book contains many examples

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and figures illustrating the text which help to bring out the intuitive ideas behind the mathematical constructions. Linear Stochastic Control Systems presents a thorough description of the mathematical theory and fundamental principles of linear stochastic control systems. Both continuous-time and discrete-time systems are thoroughly covered. Reviews of the modern probability and random processes theories and the Itô stochastic differential equations are provided. Discrete-time stochastic systems theory, optimal estimation and Kalman filtering, and optimal stochastic control theory are studied in detail. A modern treatment of these same topics for continuous-time stochastic control systems is included. The text is written in an easy-to-understand style, and the reader needs only to have a background of elementary real analysis and linear deterministic systems theory to comprehend the subject matter. This graduate textbook is also suitable for self-study, professional training, and as a handy research reference. Linear Stochastic Control Systems is self-contained and provides a step-by-step development of the theory, with many illustrative examples, exercises, and engineering applications.

Precise dynamic models of processes are required for many applications, ranging from control engineering to the natural sciences and economics. Frequently, such precise models cannot be derived using theoretical considerations alone. Therefore, they must be determined experimentally. This book treats the determination of dynamic models based on measurements taken at the process, which is known as

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system identification or process identification. Both offline and online methods are presented, i.e. methods that post-process the measured data as well as methods that provide models during the measurement. The book is theory-oriented and application-oriented and most methods covered have been used successfully in practical applications for many different processes. Illustrative examples in this book with real measured data range from hydraulic and electric actuators up to combustion engines. Real experimental data is also provided on the Springer webpage, allowing readers to gather their first experience with the methods presented in this book. Among others, the book covers the following subjects: determination of the non-parametric frequency response, (fast) Fourier transform, correlation analysis, parameter estimation with a focus on the method of Least Squares and modifications, identification of time-variant processes, identification in closed-loop, identification of continuous time processes, and subspace methods. Some methods for nonlinear system identification are also considered, such as the Extended Kalman filter and neural networks. The different methods are compared by using a real three-mass oscillator process, a model of a drive train. For many identification methods, hints for the practical implementation and application are provided. The book is intended to meet the needs of students and practicing engineers working in research and development, design and manufacturing. Linear System Theory and Design, Third Edition, International Edition OUP USA

A self-contained, highly motivated and comprehensive

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account of basic methods for analysis and application of linear systems that arise in signal processing problems in communications, control, system identification and digital filtering.

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applications, Linear System Theory and Design, 3/e, is ideal for use in advanced undergraduate/first-year graduate courses in linear systems and multivariable system design in electrical, mechanical, chemical, and aeronautical engineering departments. It assumes a working knowledge of linear algebra and the Laplace transform and an elementary knowledge of differential equations.

This open access Brief introduces the basic principles of control theory in a concise self-study guide. It complements the classic texts by emphasizing the simple conceptual unity of the subject. A novice can quickly see how and why the different parts fit together. The concepts build slowly and naturally one after another, until the reader soon has a view of the whole. Each concept is illustrated by detailed examples and graphics. The full software code for each example is available, providing the basis for experimenting with various assumptions, learning how to write programs for control analysis, and setting the stage for future research projects. The topics focus on robustness, design trade-offs, and optimality. Most of the book develops classical linear theory. The last part of the book considers robustness with respect to nonlinearity and explicitly nonlinear extensions, as well as advanced topics such as adaptive control and model predictive control. New students, as well as scientists from other backgrounds who want a concise and easy-to-grasp coverage of control theory, will benefit from the emphasis on concepts and broad understanding of the various approaches.

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Using the behavioural approach to mathematical modelling, this book views a system as a dynamical relation between manifest and latent variables. The emphasis is on dynamical systems that are represented by systems of linear constant coefficients. The first part analyses the structure of the set of trajectories generated by such dynamical systems, and derives the conditions for two systems of differential equations to be equivalent in the sense that they define the same behaviour. In addition the memory structure of the system is analysed through state space models. The second part of the book is devoted to a number of important system properties, notably controllability, observability, and stability. In the third part, control problems are considered, in particular stabilisation and pole placement questions. Suitable for advanced undergraduate or beginning graduate students in mathematics and engineering, this text contains numerous exercises, including simulation problems, and examples, notably of mechanical systems and electrical circuits.

Chen's system-first organization in *Signals and Systems* introduces sophomores and juniors to the fundamentals of signals and systems. Chen introduces the following five major topics- fundamental concepts (causality, linearity, time-variance, and lumpedness); system analysis (the Laplace transform and the z-transform), signal analysis (the Fourier transform and frequency spectrum); stabilities and their implications (filtering, frequency response, model reduction, and op-amp circuits); and state-variable equations and computer simulations. *Develops continuous-time system and

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signal analysis and discrete-time signal and system analysis in parallel for easy comparison; *Highlights current and practical applications, including the effect of worn-out shock absorbers on automobile suspension systems, and a discussion of the collapse of the Oakland elevated highway bridge from the perspectives of stability, resonance, and energy; *Provides thorough coverage of stability, reflecting its importance in current systems using operational amplifiers or digital hardware; *Discusses MATLAB at the end of most chapters to instruct students on the use of computers for analysis. This volume deals with controllability and observability properties of nonlinear systems, as well as various ways to obtain input-output representations. The emphasis is on fundamental notions as (controlled) invariant distributions and submanifolds, together with algorithms to compute the required feedbacks.

A Polynomial Approach to Linear Algebra is a text which is heavily biased towards functional methods. In using the shift operator as a central object, it makes linear algebra a perfect introduction to other areas of mathematics, operator theory in particular. This technique is very powerful as becomes clear from the analysis of canonical forms (Frobenius, Jordan). It should be emphasized that these functional methods are not only of great theoretical interest, but lead to computational algorithms. Quadratic forms are treated from the same perspective, with emphasis on the important examples of Bezoutian and Hankel forms. These topics are of great importance in applied areas such as signal processing, numerical linear algebra, and

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control theory. Stability theory and system theoretic concepts, up to realization theory, are treated as an integral part of linear algebra. Finally there is a chapter on Hankel norm approximation for the case of scalar rational functions which allows the reader to access ideas and results on the frontier of current research. Includes MATLAB-based computational and design algorithms utilizing the "Linear Systems Toolkit." All results and case studies presented in both the continuous- and discrete-time settings.

This book provides an introduction to the theory of linear systems and control for students in business mathematics, econometrics, computer science, and engineering; the focus is on discrete time systems. The subjects treated are among the central topics of deterministic linear system theory: controllability, observability, realization theory, stability and stabilization by feedback, LQ-optimal control theory. Kalman filtering and LQC-control of stochastic systems are also discussed, as are modeling, time series analysis and model specification, along with model validation.

During the past decade the interaction between control theory and linear algebra has been ever increasing, giving rise to new results in both areas. As a natural outflow of this research, this book presents information on this interdisciplinary area. The cross-fertilization between control and linear algebra can be found in subfields such as Numerical Linear Algebra, Canonical Forms, Ring-theoretic Methods, Matrix Theory, and Robust Control. This book's editors were challenged to present the latest results in these areas and to find

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points of common interest. This volume reflects very nicely the interaction: the range of topics seems very wide indeed, but the basic problems and techniques are always closely connected. And the common denominator in all of this is, of course, linear algebra. This book is suitable for both mathematicians and students.

"There are three words that characterize this work: thoroughness, completeness and clarity. The authors are congratulated for taking the time to write an excellent linear systems textbook!" —IEEE Transactions on Automatic Control

Linear systems theory plays a broad and fundamental role in electrical, mechanical, chemical and aerospace engineering, communications, and signal processing. A thorough introduction to systems theory with emphasis on control is presented in this self-contained textbook, written for a challenging one-semester graduate course. A solutions manual is available to instructors upon adoption of the text. The book's flexible coverage and self-contained presentation also make it an excellent reference guide or self-study manual. For a treatment of linear systems that focuses primarily on the time-invariant case using streamlined presentation of the material with less formal and more intuitive proofs, please see the authors' companion book entitled *A Linear Systems Primer*.

A fully updated textbook on linear systems theory

Linear systems theory is the cornerstone of control theory and a well-established discipline that focuses on linear differential equations from the perspective of control and estimation. This updated second edition of *Linear Systems Theory* covers the subject's key topics in a

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unique lecture-style format, making the book easy to use for instructors and students. João Hespanha looks at system representation, stability, controllability and state feedback, observability and state estimation, and realization theory. He provides the background for advanced modern control design techniques and feedback linearization and examines advanced foundational topics, such as multivariable poles and zeros and LQG/LQR. The textbook presents only the most essential mathematical derivations and places comments, discussion, and terminology in sidebars so that readers can follow the core material easily and without distraction. Annotated proofs with sidebars explain the techniques of proof construction, including contradiction, contraposition, cycles of implications to prove equivalence, and the difference between necessity and sufficiency. Annotated theoretical developments also use sidebars to discuss relevant commands available in MATLAB, allowing students to understand these tools. This second edition contains a large number of new practice exercises with solutions. Based on typical problems, these exercises guide students to succinct and precise answers, helping to clarify issues and consolidate knowledge. The book's balanced chapters can each be covered in approximately two hours of lecture time, simplifying course planning and student review. Easy-to-use textbook in unique lecture-style format Sidebars explain topics in further detail Annotated proofs and discussions of MATLAB commands Balanced chapters can each be taught in two hours of course lecture New practice exercises with solutions included

Cooperative Control of Multi-Agent Systems extends optimal control and adaptive control design methods to multi-agent systems on communication graphs. It develops Riccati design techniques for general linear dynamics for cooperative state feedback design, cooperative observer design, and cooperative dynamic output feedback design. Both continuous-time and discrete-time dynamical multi-agent systems are treated. Optimal cooperative control is introduced and neural adaptive design techniques for multi-agent nonlinear systems with unknown dynamics, which are rarely treated in literature are developed. Results spanning systems with first-, second- and on up to general high-order nonlinear dynamics are presented. Each control methodology proposed is developed by rigorous proofs. All algorithms are justified by simulation examples. The text is self-contained and will serve as an excellent comprehensive source of information for researchers and graduate students working with multi-agent systems.

Modern control theory and in particular state space or state variable methods can be adapted to the description of many different systems because it depends strongly on physical modeling and physical intuition. The laws of physics are in the form of differential equations and for this reason, this book concentrates on system descriptions in this form. This means coupled systems of linear or nonlinear

differential equations. The physical approach is emphasized in this book because it is most natural for complex systems. It also makes what would ordinarily be a difficult mathematical subject into one which can straightforwardly be understood intuitively and which deals with concepts which engineering and science students are already familiar. In this way it is easy to immediately apply the theory to the understanding and control of ordinary systems. Application engineers, working in industry, will also find this book interesting and useful for this reason. In line with the approach set forth above, the book first deals with the modeling of systems in state space form. Both transfer function and differential equation modeling methods are treated with many examples. Linearization is treated and explained first for very simple nonlinear systems and then more complex systems. Because computer control is so fundamental to modern applications, discrete time modeling of systems as difference equations is introduced immediately after the more intuitive differential equation models. The conversion of differential equation models to difference equations is also discussed at length, including transfer function formulations. A vital problem in modern control is how to treat noise in control systems. Nevertheless this question is rarely treated in many control system textbooks because it is considered to be too mathematical and too difficult in a second

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course on controls. In this textbook a simple physical approach is made to the description of noise and stochastic disturbances which is easy to understand and apply to common systems. This requires only a few fundamental statistical concepts which are given in a simple introduction which lead naturally to the fundamental noise propagation equation for dynamic systems, the Lyapunov equation. This equation is given and exemplified both in its continuous and discrete time versions. With the Lyapunov equation available to describe state noise propagation, it is a very small step to add the effect of measurements and measurement noise. This gives immediately the Riccati equation for optimal state estimators or Kalman filters. These important observers are derived and illustrated using simulations in terms which make them easy to understand and easy to apply to real systems. The use of LQR regulators with Kalman filters give LQG (Linear Quadratic Gaussian) regulators which are introduced at the end of the book. Another important subject which is introduced is the use of Kalman filters as parameter estimations for unknown parameters. The textbook is divided into 7 chapters, 5 appendices, a table of contents, a table of examples, extensive index and extensive list of references. Each chapter is provided with a summary of the main points covered and a set of problems relevant to the material in that chapter. Moreover each of the more advanced chapters (3 -

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7) are provided with notes describing the history of the mathematical and technical problems which lead to the control theory presented in that chapter.

Continuous time methods are the main focus in the book because these provide the most direct connection to physics. This physical foundation allows a logical presentation and gives a good intuitive feel for control system construction.

Nevertheless strong attention is also given to discrete time systems. Very few proofs are included in the book but most of the important results are derived. This method of presentation makes the text very readable and gives a good foundation for reading more rigorous texts. A complete set of solutions is available for all of the problems in the text. In addition a set of longer exercises is available for use as Matlab/Simulink 'laboratory exercises' in connection with lectures. There is material of this kind for 12 such exercises and each exercise requires about 3 hours for its solution. Full written solutions of all these exercises are available.

This text introduces the time, frequency, and transform domains in studying signals and systems and discusses their roles in signal processing and system design. It compares the four mathematical descriptions for the systems studied and explains why the same equation can be used to design seismometers and accelerometers.

The book blends readability and accessibility

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common to undergraduate control systems texts with the mathematical rigor necessary to form a solid theoretical foundation. Appendices cover linear algebra and provide a Matlab overview and files. The reviewers pointed out that this is an ambitious project but one that will pay off because of the lack of good up-to-date textbooks in the area.

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