the Second Edition, very useful as it contains the solutions to the remaining problems (two thirds), plus four recommended, detailed, course outlines based on the student's level of learning, background, and proficiency. This will be an excellent asset for instructors formulating a course in control systems.

This very clearly written book is an excellent instructional text for the undergraduate student, the first-year graduate student, and the practicing control system engineer who wishes to update his basic knowledge (either by self-study or as a text in an industrial continuing education program). Shinners has succeeded in writing a very clear, easy to follow, comprehensive text. In reviewing this very carefully edited book, I could find no errors. The index, which is especially well done, makes the book an excellent reference too. In summary, the book by Shinners constitutes a very well-written and elegant addition to the control literature and is very suitable as a text for both undergraduate and graduate students, and is also useful for self-study by the practicing engineer. This thought-provoking book will be very welcome in the control field by instructors, students, and practicing engineers. I cast my vote for Shinners' book!

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Applied Optimal Control: Optimization, Estimation, and Control—Arthur E. Bryson, Jr. and Yu-Chi Ho (Washington, DC: Hemisphere, 1975, 481 pp.). *Reviewed by George M. Siouris, U.S. Army Avionics R&D Activity, DAVAA-N, Fort Monmouth, NJ 07703.*

For more than fifteen years, modern optimal control theory has become an established tool for systems analysts. Optimal control theory has been applied with success in a number of scientific disciplines. The present revised printing of this well-known textbook, which first appeared in 1969, covers essentially the same topics, but incorporates a number of improvements in clarity, graphical illustrations, and corrections of typographical errors. As in the first edition, the text is extremely well presented, and the development of the arguments is logical and clear, with detailed descriptions and examples where necessary, making the volume ideal for self-study. This textbook provides a useful and compact introduction to the fundamentals of optimal control theory. Moreover, as the title of the book indicates, the authors direct their effort toward applications of optimal control theory. The authors are well-known teachers and researchers and have been prolific contributors to the field of optimal control theory.

The book is divided into 14 chapters. The fundamental concepts of parameter optimization are covered in Chapter 1. Parameter optimization problems with and without equality constraints, necessary conditions for a stationary point, sufficient conditions for a local minimum, neighboring optimum solutions and the interpretation of Lagrange multipliers, numerical solution by first- and second-order gradient methods, linear programming problems, and the penalty function method are discussed with great clarity. Chapter 2 discusses optimization problems for dynamic systems. Among the topics addressed are single and multistage systems, continuous systems with no terminal constraints, fixed terminal time, continuous systems with unspecified terminal time, and minimum-time problems. Chapter 3 discusses further optimization problems for dynamic systems, but with path constraints. Integral constraints, control variable equality constraints, equality constraints on functions of the control and state variables, interior-point constraints, discontinuities in the system and the state variables at interior points, inequality constraints on the control variables, linear optimization and "bang-bang" control, inequality constraints on functions of the control and state variables, and corner conditions are treated in depth. Optimal feedback control is presented in Chapter 4. This chapter treats briefly the extremal field approach, dynamic programming, and reducing the dimension of the state space by use of dimensionless variables. Although feedback has the potentiality to reduce the effects of parameter variations, the mere fact that a control is in feedback form does not in itself guarantee that the effects of parameter variations are reduced. In connection with the dynamic programming, it might be pointed out that, having established the generalized Legendre–Clebsch condition

$$(-1)^p \frac{\partial}{\partial u}\left[\frac{d^{2p}}{dt^{2p}} H_u\right] \geq 0, \qquad \text{for all } t \in [t_0, t_f]$$

where p is the order of the singular arc, researchers began to look for generalizations of the known sufficient conditions for the nonsingular problem.

A problem of interest and importance in optimal control theory is that of minimizing a quadratic performance criterion (or cost functional) subject to a constraining set of linear ordinary differential equations and a set of linear terminal equality constraints. Chapter 5 is concerned with this important class of linear systems with quadratic criteria. When the linear plant is time invariant and when the quadratic performance index is an integral over an infinite period, the control law feedback matrix is constant, yielding a time-invariant regulator system. In their order of appearance, the topics covered in this chapter are an introduction to terminal controllers and regulators, terminal controllers with quadratic penalty function on terminal error, terminal controllers with zero terminal error and controllability, and regulators and stability. Chapter 6 deals with neighboring extremals and the second variation. An in-depth treatment of neighboring extremal paths with final time specified and unspecified, determination of neighboring extremal paths by the backward sweep method, sufficient conditions for a local minimum, perturbation feedback control, sufficient conditions for a strong minimum, a multistage version of the backward sweep method, and sufficient conditions for a local minimum for multistage systems is given. Chapter 7 is entitled "Numerical Solution of Optimal Programming and Control Problems." Here the reader will find useful algorithms for neighboring extremals, first- and second-order gradients, and conjugate-gradients.

In Chapter 8, the authors treat the singular solutions of optimization and control problems. This chapter discusses singular solutions of optimization problems for linear dynamic systems with quadratic criteria, singular solutions of optimization problems for nonlinear dynamic systems, generalized conditions for singular arcs, and a resource allocation problem involving inequality constraints and singular arcs. Chapter 9, "Differential Games," deals with discrete and continuous games, linear-quadratic pursuit–evasion games, and a minimax-time intercept problem with bounded controls. The topic is handled well, with a good balance between breadth and depth of coverage. Historically, the study of differential games can be traced to R. Isaacs in 1954, where he made use of what is known today as dynamic programming. Later authors, notably L. D. Berkowitz and W. H. Fleming in 1957, applied the techniques of the calculus of variations to differential games. Chapters 10 and 11 present introductory material on probability concepts and random processes, respectively. Readers familiar with the content matter of these chapters may go directly to Chapter 12. Chapter 12 on optimal filtering and prediction, covers the ideas of estimation of parameters using weighted least-squares, optimal filtering for single-stage linear transitions, optimal filtering and prediction for linear multistage processes, optimal filtering for continuous linear dynamic systems with continuous measurements, optimal filtering for nonlinear dynamic processes, estimation of parameters using a Bayesian approach, Bayesian approach to optimal filtering and prediction for multistage systems, and detection of Gaussian signal in noise. The concepts of controllability (discussed in Chapter 5) and observability are of particular importance in the design of linear feedback controllers and linear filters for stationary systems in the presence of white Gaussian disturbances. Moreover, it is an important fact that if the system is controllable, then the linear feedback system obtained by using the theory of optimal control with a quadratic cost is asymptotically stable.

Chapter 13 is an extension of Chapter 12, covering optimal smoothing for single-stage and multistage systems, optimal smoothing and interpolation for continuous processes, optimal smoothing for nonlinear dynamic processes, sequentially correlated measurement noise, and time-correlated measurement noise. The final chapter, Chapter 14, is devoted to optimal feedback control in the presence of uncertainty. Optimal control theory has had many successful applications in the design of feedback controllers for systems without time lag. Notable among these developments has been the solution for optimal feedback controllers for linear systems through the use of a quadratic performance criterion. For the most part, this chapter covers the so-called "Linear-Quadratic-Gaussian" problem. The Gaussian assumption allows one to parametrize the conditional density by its conditional mean and covariance. The authors treat many standard optimal control topics, including continuous linear systems with white process noise and perfect knowledge of the state, continuous linear systems with process and measurements containing additive white noise, average behavior of an optimally controlled system, synthesis of regulators for stationary linear systems with stationary additive white noise, synthesis of terminal controllers for linear systems with additive white noise, multistage linear systems with additive purely random noise, and optimum feedback control for nonlinear systems with additive white noise. Two appendices at the end of the book serve as a reference and help to the student; these appendices review matrix algebra, elementary differential equations, linear algebraic equations, controllability, observability, stability, and canonical transformations. An extensive bibliography of books and publications pertaining to all aspects of control theory adds to the book's value as research tool.

In summary, this reviewer rates this book highly and recommends it to students, engineers, and scientists engaged primarily in theory and applications of optimal control theory. The numerous problems given in each chapter will be most useful for teaching purposes. By way of criticism, the bulk of the material in the book depends heavily on the classical calculus of variations and does not treat a number of the modern techniques used in optimal control theory. Also, although this revised printing appears reasonably free from errors, there are a few minor things to differ with.

Servomotoare Amplificatoare—Teorie Si Aplicatii (Amplifier Servomotors —Theory and Applications)—Dan Teodorescu (Bucharest: Editura Academii Replublicii Socialiste Romania, 1977, 283 pp.). *Reviewed by George M. Siouris, U.S. Army Avionics R&D Activity, DAVAA-N, Fort Monmouth, NJ 07703.*

This book presents for the first time in a self-contained form the theory, design, and industrial applications of a new class of servomotors: namely, the amplifier-servomotors. This new class of servomotors was first introduced by the author in the *Proceedings of the IEE*, vol. 115, no. 6, 1968.

The amplifier-servomotor finds extensive use in automatic control systems such as dc/ac converters, amplifiers, and actuators. The servomotor may be controlled with dc signals directly from transducers (e.g., photodiodes, etc.). Thus, this method leads into a considerable simplification in the structure of the automatic system, resulting in low-cost reliable systems, since it does not use relays or other mechanical moving parts.

The book is divided into three parts, covering 12 chapters. Part I of the book covers "Shaded-Pole Amplifier-Servomotors." The first chapter introduces some basic concepts of shaded-pole amplifier-servomotors, their definition, classification, and characteristics. Chapter 2 is devoted to an analysis of the amplifier-servomotors. Bessel functions and Fourier series are used extensively in order to derive the various expressions. Some other topics include the analytical method of the equivalent air-gap, and the grapho-analytical method of the air gap. Starting methods, rotor currents, the induction of the air gap, and fluxes and magnetomotive forces are covered in Chapter 3. Chapter 4 describes the mechanical characteristics of the shaded-pole servomotors. This chapter includes such topics as fluxes and magnetomotive forces both by neglecting and considering leakage inductance, currents in the running regime, and torques. In Chapter 5, the author considers speed control, controlling the mechanical characteristics of these motors, transient phenomena, and the amplifier-servomotor with quasilinear and nonlinear characteristics.

Part II of the book contains three chapters devoted to ferroresonant servomotors. After a brief introduction, Chapter 6 discusses at length the working principle of the ferroresonant servomotor, ferroresonant servomotors with one and two stages of amplification, and some particular features of this class of servomotors. Chapter 7 deals with starting methods. In particular, eddy currents, fluxes and magnetomotive forces, and starting torques receive special attention. Chapter 8 covers the following topics: rotor currents in the running regime, fluxes and magnetomotive forces with and without leakage inductances, torque and mechanical characteristics of the ferroresonant servomotor, and the single-phase ferroresonant servomotor.

The last part of the book, Part III, includes four chapters on the applications of the ferroresonant servomotors. Chapter 9 considers such industrial applications as recorders, temperature controllers, and proportional controllers. Chapter 10 is entirely devoted to the analysis of the dynamic behavior of systems with ferroresonant servomotors. Especially, transients in recorders forms the most substantial section of this chapter. Chapter 11 discusses a variety of design methods for systems with ferroresonant servomotors. Starting with a brief introduction, the chapter proceeds to discuss in detail with matrix-plane method, design procedures based on the matrix-plane method, and systems with ferroresonant servomotors with double input. The last chapter, Chapter 12, contains some modern applications of these servomotors such as optimization methods, sampled-data methods, and optimization via optimal-limit models. The author shows in this chapter that, using these procedures, automatic systems with time-optimal responses are obtained in a simple and general manner. An extensive bibliography with 131 references widely covers the literature of amplifier servomotors. The book concludes with an appendix giving in tabular form several matrices which are used in the text and an abstract in English.

The topics discussed are specialized, but their unified treatment makes this book particularly useful to servomotor designers and control engineers. The author, judging from his numerous publications, is extremely capable in presenting complex ideas in a simplified and understandable manner. Finally, this book is recommended for research scientists and practicing engineers whose interests center around this class of servomotors.