temperatures. Second, a process must be developed to produce a continuous conductor with reproducible properties at reasonable cost.

If these two conditions are met, then many of the potential applications for superconductors, which for a long time have been items on a “wish list,” can begin to be discussed in terms of economic realities. These include superconducting generators, motors, transformers, and transmission lines, and magnetically levitated trains. The overall impact could be enormous. But we should remember that this impact will develop in terms of an overall context of supply and demand, markets, and systems for energy, transportation, and services, not as the predictable consequence of a single invention.

This interview was conducted by Dr. Selden B. Crary, Senior Research Scientist at General Motors Research Laboratories, Warren, MI 48090.

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**Book Reviews**

*Optimal Estimation: With an Introduction to Stochastic Control*

by Frank L. Lewis

Wiley, New York

1986, 389 pages

This book presents the basic theory of the modern study of systems. It is divided into two major parts covered in eight chapters. Part 1 deals with optimal estimation problems, where the Kalman filter theory is the central focus of the subject. Part 2 introduces optimal control theory.

Chapter 1 covers classical estimation theory in terms of mean-square estimation and the Wiener filter. Basically, it provides the concept of estimating an unknown quantity from a given set of data by using mean-square estimation, maximum likelihood estimation, and recursive estimation. The data is usually random and requires filtering. The earlier theory of filtering due to Wiener and the solution of the Wiener-Hopf equation are outlined. Chapter 2 deals with estimation of the state of a discrete linear system, known as the Kalman filter. Both deterministic and stochastic linear systems are considered. Control schemes for state estimation of continuous-time systems are implemented digitally through discretization or sampled data. The error system is examined in terms of the residual that depends on “a priori estimation error.” It is concluded that if the residual (known as the innovations process) is a white noise process, then the Kalman filter is performed according to the original design. The design of an optimal steady-state filter and the link between the Kalman filter and the Wiener filter are outlined in terms of frequency-domain analysis.

Shaping filters for colored noise and correlated noise sequences are analyzed by using a Z-transform and a curve fitting. The concept of optimal smoothing, or the determination of the state estimate by using past and future data, is well explained in the last section of Chap. 2. The methods of deriving the continuous-time Kalman filter are presented in Chap. 3. These methods are based on “unsampling” the discrete-time Kalman filter and the Wiener-Hopf equation. All the notions described in Chap. 2 for the steady-state behavior of the discrete Kalman filter also hold for the continuous case. However, some of the details are different, and the differences are clarified.

The practical aspects of Kalman filter design, taking into account the effects of nonideal situations, are presented in Chap. 4. The author shows that it is possible to take advantage of the robustness of the Kalman filter with respect to process noise to compensate for an inaccurately known plant. In this regard, the concepts of modeling errors, divergence, and exponential data weighting are introduced. Two methods for preventing divergence are discussed: fictitious process noise injection and exponential data weighting. Some techniques for designing filters are presented. These include methods of reducing the dimension of the state vector in the Kalman filter and time-dependent (suboptimal) gains. Chapter 5 introduces the optimal estimation problem for nonlinear systems. The general equations for time and measurement updates of the entire hyperstate (i.e., the conditional probability density function of the unknown data) are derived. Equally important are the exact time and measurement updates for the mean and covariance of the nonlinear continuous system with discrete measurements.

The application of the state estimate for the optimal control of stochastic systems is the subject of the second part of the book. Chapter 6 presents the stochastic control theory for state-variable systems. Dynamic programming based on Bellman’s principle of optimality and the linear-quadratic-Gaussian problems for continuous and discrete cases constitute the main ingredients of this chapter. Stochastic control theory for polynomial discrete systems is discussed in Chap. 7. For continuous systems, the theory is not given, however, the basic results of discrete systems can be applied.

The book is ended by two appendices. The first contains a review of matrix algebra, while the second compiles some software for digital com-
puter simulation. The second appendix lists FORTRAN programs for plotting, time response, simulation of the optimal controller, and Kalman filter simulation.

Each chapter is supported by a number of solved examples, and there are many problems for each major section at the end of each chapter. The format of this book is very suitable for graduate students as a second course in modern control theory. The book is clear and readable for researchers who have background in probability theory and state-variable representation of systems.

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Quantum Processes in Semiconductors
by B. K. Ridley
Oxford University Press
New York

In a terse way, the title of this book summarizes both its contents and the writing style employed by the author. Using a limited number of pages (286) and relatively few words, Ridley examines and describes, from his own point of view, a broad range of topics in quantum semiconductor physics. The book is not nearly as encyclopedic as similar works by Ziman [1] or Seeger [2], nor nearly as general or descriptive as textbooks on solid-state physics like Kittel [3]. This book is different. The author purposefully targets and limits his discussions, derivations, and examples to the specialized topic of the bulk properties of common semiconductor materials such as Si and GaAs. Generalizations to other solid-state systems, including metals and insulators, are specifically avoided.

By his own admission, the author is "an experimentalist with a taste for doing his own theoretical work." From this somewhat unique perspective, Ridley succinctly summarizes the six major categories: (1) Band Theory of Semiconductors; (2) Energy Levels; (3) Lattice Scattering; (4) Impurity Scattering; (5) Radiative Transitions; and (6) Non-Radiative Processes. Only basic quantum mechanics is discussed, and the theoretical level is at elementary first- and second-order perturbation theory. A fair amount of referenced data on common semiconductor materials is presented along with the theory. Discussions of applications of the work, including any mention of solid-state devices and any treatment of experimental techniques necessary to measure materials parameters or verify the theory, are not included. Other areas not addressed include Semiconductor surfaces, carrier transport in either electric or magnetic fields, and tunneling.

As a reference manual for graduate students or research scientists in solid-state semiconductor physics, the book would be excellent. Material in the categories listed is presented in a concise and consistent style, with all of the important results clearly noted. The book is probably not sufficiently tutorial in nature to be useful as a general textbook.

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Computer-Aided Design and VLSI Device Development
by Kit Man Cham, Soo-Young Oh, Daeje Chin, and John L. Moll
Klewer Academic Publishers
300 pages, $42.50
1986

The current generation of process and device simulation programs has provided academic and industrial users with extremely powerful tools for the study of semiconductor devices. However, as these programs become more sophisticated and accurate, they also become increasingly difficult to understand and use. This situation has forced many users to abandon the newer programs in favor of older ones that are already well understood. Likewise, the simulation neophyte or engineering manager is often bewildered by the sheer number of software packages available to him. This book, Computer-Aided Design and VLSI Device Development, can help these groups become familiar with modern simulation software by providing fairly detailed descriptions of the numerical methods, models, input language, and output formats of a number of these programs implemented in a design system developed at Hewlett Packard Laboratories. Those already familiar with state-of-the-art simulation tools can also gain valuable information from a study of the case histories, which emphasize MOS structures, taken from the authors' work at Hewlett Packard. If used knowledgeably, the book can be a valuable supplement in a graduate course or as a desktop reference guide to the programs described within.

The book consists of two segments: the first three chapters provide descriptions of the simulation programs implemented at Hewlett Packard and the remaining ten chapters illustrate the utility and accuracy of the programs through a series of case histories. Chapter 1 contains a history of numerical process and device simulation and a justification for two-dimensional simulation when device geometries become small. The authors emphasize the necessity of creating simple and efficient user interfaces, because the programs were designed to be research tools rather than mature engineering design tools. They also discuss the use of hierarchical techniques to save computer time and the need for benchmarking to ensure accuracy.

The second chapter covers process simulation; a very important subject since these results will be used during later device simulations. Each program implemented at Hewlett Packard is described, and its usage is illustrated through simple examples. The SUPREM program from Stanford University, now a virtual standard, is the first to be discussed. Designed to provide two-dimensional process simulation without excessive computer...
costs, the SUPRA program, described next, features both a fast, analytic solution mode and a slower, but more accurate, numeric mode. SOAP, the last to be treated, allows simulation of oxide shapes near birds' beaks by modeling the flow of silicon dioxide under the combined influence of pressure and high temperature. Chapter 3 advances to the device simulation level, presenting, for each program, descriptions of the basic theory, numerical techniques, advantages, limitations, and an example. The chapter proceeds from the simple two-dimensional Poisson solver, GEMINI, to the more complex, Poisson and one-carrier continuity equation solver CADDET and, then, finally, to the general-geometry, two-carrier program, SIFCOD. The benchmarking mentioned earlier proved to be very important here, since it pointed out that the mobility models in the original CADDET and SIFCOD programs were not accurate enough. The highest level of simulation discussed is that of parasitic capacitance and resistance, which appears in the fourth chapter. The FCAP2 program, developed at Hewlett Packard to solve either Poisson's equation or Laplace's equation in two dimensions with an arbitrary geometry, represents this level. Along with the example, the chapter contains a discussion of several options that allow reduced simulation time for symmetric or periodic structures.

As a prelude to the case histories, Chap. 5 contains a set of general methodologies in device simulation designed to enhance user efficiency. The primary lesson taught here is the use of the basic physics of the problem to extract simple analytic results before proceeding to greater levels of abstraction (and computer costs). The authors also point out that the user should expect trends, rather than exact results, since the accuracy of the programs is limited. Actual techniques are presented in the sixth chapter, along with descriptions of the device parameters and physical effects that are of greatest interest. The short-geometry and hot-carrier effects contained in this chapter will be of particular interest to many advanced readers. The advantages and limitations of each program are briefly discussed, along with the applicability of many of the possible combinations of process and device tools for examining each parameter and effect. The chapter closes with a section detailing the relationship between device characteristics and process parameters.

The actual case histories begin with two chapters containing studies of conventional MOSFET structures. Chapter 7 examines drain-induced barrier lowering (DIBL) in short-channel MOSFETS using a combination of SUPREM-II and GEMINI. The potential-barrier height and the location of the punchthrough path are determined from plots produced by GEMINI, and the presence and extent of DIBL are characterized. The following chapter introduces the reader to typical submicron CMOS technology and examines the advantages and disadvantages of CMOS over NMOS. Working with an n-well CMOS variant, the combination of SUPREM-II and GEMINI is again used to minimize both the leakage current and the variation of threshold voltage with channel length, while varying the junction and counterdoping depths in the p-channel MOSFET. In the n-channel MOSFET, the threshold voltage variation is examined and the electric field near the drain is minimized to reduce the possibility of hot-electron degradation and avalanche breakdown.

CMOS isolation techniques are treated in Chaps. 9 and 10, with a study of trenches appearing in the former. The nonplanar surface of the trench and the small current injection suggest treating the trench as a very long channel MOSFET in the GEMINI program. This approach, combined with estimates of the surface-state charge density, allows the shape of the potential along the trench surface and the gain of the lateral parasitic bipolar transistor to be determined. Chapter 10 compares several different isolation methods for VLSI applications. The highly nonplanar nature of the isolation problem provides an ideal test for the SUPRA-GEMINI combination, with the surface potential being the quantity of interest. SOAP is then used for the SWAMI isolation simulation because of stress reduction in the oxide during high-temperature steps when the oxide can undergo plastic flow, substantially modifying its shape.

Performance issues motivate the following two chapters, beginning with a comparison of the lightly doped drain (LDD) MOSFET with its conventional counterpart in Chap. 11. Using the CADDET program, the LDD doping concentration is optimized so that the peak electric field (and, hence, the substrate current) and the series resistance inherent in LDD devices are reduced simultaneously. In Chap. 12, the combination of SUPREM-II and CADDET is used to study scaling effects in enhancement- and depleti on-mode MOSFETs. In particular, the variation of the threshold voltage with channel length and the effects of oxide thickness on current characteristics are discussed.

The final chapter explores the utility of FCAP2 for the simulation of the areal and peripheral coefficients of capacitance for metal lines embedded in field oxide over polysilicon, metal over a diffusion plane, and fringing fields between metal lines. Also, the authors emphasize the use of a Poisson solver, such as GEMINI, coupled with SUPREM or SUPRA, whenever the penetration of the depletion region into the substrate is too large to be ignored.

Although the authors intend this book as either a text or a reference, the absence of problems or exercises will make its use as a primary textbook difficult. However, its unusual combination of software descriptions and annotated examples should provide an excellent source of information for an introductory simulation class, if instructors are willing to fill the gaps with projects and additional information. The lack of continuity between chapters and the duplication of information was somewhat disturbing while reading the chapters in sequence, but this arrangement should actually aid researchers seeking specific information. Astute readers will notice that the information is occasionally somewhat dated, for example, SUPREM-III has been in common use for several years now, but is mentioned only in passing. The book will undoubtedly be popular with practicing engineers who have little time to delve into simulation software, and it would make a fine addition to the desk of anyone really interested in the practical application of process and device simulation software.

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In comparing van der Ziel's text with Buckingham's *Noise in Electronic Devices and Systems*, also distributed by Wiley (1983), I was struck with van der Ziel's forthright getting down to basics. A more encouraging note is that van der Ziel, although like Buckingham—identifying a variety of theorems and postulations—goes beyond Buckingham by offering his choice of the right theorem and/or equation. Dr. van der Ziel is first a teacher; his flair for guiding the student is manifestly evident in this text. Each chapter is a monument to this champion of noise studies, especially as we are led through Chap. 2, Mathematical Methods. Here, we are carefully instructed in probability density functions, Fourier analysis, the Langevin method for the analysis of thermal noise, the master equation for the determination of finding the probability of electrons in the conduction band, and concluding with what the author identifies as Ramo’s theorem for determining the current pulses induced by moving electrons.

His handling of Chaps. 3 and 4 is masterful—far clearer than even Mumford and Schelbe (*Noise Performance Factors in Communications Systems*, Horizon House, 1968). Here, the reader can, with van der Ziel's clear guidance, make meaningful measurements of shot noise and noise figure for both one-port (including both positive and negative conductance) stages, two-port and cascode stages. If the reader needs help in designing his test equipment, the chapter offers suggested circuits as well as identifying the part numbers!

Delving into Chap. 5, the reader is returned to basic mathematical proofs for the analysis of thermal (Nyquist) noise. Unlike the presentation of Chap. 2, the author introduces examples of JFETs, MOSFETS, the HEMT (high electron-mobility transistors) offering the reader the results of his students' work, graciously giving credit where credit is due.

Shot noise is expansively covered in Chap. 6, where the author provides detailed analysis of the Schottky diode and the tunnel diode, the more conventional (and unconventional) p-n diode and the pnp transistor. Again, as we witness throughout the text, the author graciously acknowledges the work of his students in the prosecution of the theorems and derivations.

Chapter 7, entitled "Generation-Recombination Noise," is especially gratifying to this reviewer, who himself plans to investigate the g-r noise phenomena of power MOSFETS in search of improving their long-term reliability. Although van der Ziel avoids any direct discussion of power MOSFETS, his coverage of recombination centers (traps), 1/f, and high-field effects should be of great help. He closes this chapter offering detailed analysis of his students' examination of g-r in JFETs.

Burst noise, more popularly called popcorn noise, winds up the chapter, based principally on the work of his students, whom, as before, are credited. But do not look for "popcorn noise" in the Index—it is not there.

Chapter 8 focuses on van der Ziel's seemingly favorite subject: flicker noise or 1/f noise. Here he begins with the ubiquitous nature of flicker noise found in practically every component. A detailed mathematical treatise is offered, beginning with the resistor—both the common types as well as what might be expected of deposited and diffused and ion-implanted silicon resistors. This is followed with 1/f in Schottky, p-n junctions, bipolar transistors, MOSFETS, GaAs MESFETs, and JFETs. However, regretfully, no mention is made of flicker noise in double-diffused power MOSFETS. The chapter concludes with 1/f phenomena in thin-metal films.

Beginning with Chap. 9, the author focuses the reader's attention to noise problems associated with specific high-frequency applications: masers and lasers, TDAs, GaAsFETs, and bipolar.

Chapter 10 focuses on mixers, where his introduction sets the stage by identifying the familiar Taylor expansion and subsequent Fourier coefficients with mixing (as we would expect) but also as a leading determinant in noise behavior (which, perhaps, unexpectedly makes sense). In addition to mixers of every type imaginable (Schottky, pn, GaAs diode, and GaAsFET, SIS), van der Ziel touches on the effects of nonlinearity in oscillators identifying the effects of feedback on noise performance. Of special note, but not directly mentioned by the author, this chapter clarified important fundamentals that restrict dynamic range. That is to say, the noise floor of a mixer limits the minimum detectable signal response.

Chapter 11, titled "Miscellaneous Problems," is not the catch-all as the title suggests. The author narrows his focus to ion-diffusion noise in GaAs and quantum 1/f noise.

Chapter 12, is a 2½-page review of a 1982 (Why 1982?) state-of-the-art comparison of low-noise microwave hardware.

The Appendix offers a variety of proofs and theorems, which together with the text offers the reader a complete compendium on noise.

An extensive bibliography concludes each chapter. A good index closes the book of 306 pages.

The prospective reader needs to be forewarned that this text, aside from Chaps. 3 and 4, is not aimed at the practicing engineer seeking quick solutions to noise problems. In my opinion, the text is primarily aimed at the physicist and engineer who seek an understanding of noise phenomena—led by the master mentor himself. More than once does the author caution the reader with the euphorism, "not 'either-or,' but 'and-and,' may prevail that only experimentation can verify."

Dr. van der Ziel, Professor at the University of Minnesota, is the acclaimed world authority on noise phenomena, and this text reflects on that genius. Every topic in this text receives a fully documented exegesis, complete with derivations and often accompanied by candid remarks concerning experiments conducted by his students.

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*Calculations and Programs for Power System Networks*  
by Y. Wallach  
Prentice Hall  
1986

When electric power engineering professors gather at meetings and conferences, one hears the perennial
Chapters 1 and 2 are reviews of key points in linear algebra. The emphasis is on sparse matrices, triangular factorization, optimal ordering, and singular-value decomposition. The treatment is generally quite thorough, but these sections are not for "beginners." The average college senior electrical engineer will have trouble with these sections because undergraduate students may not have the required sophistication in linear algebra. Practicing engineers who have been out of school for several years will also need a "second reading." Graduate students with more than a casual knowledge of linear algebra will come away from Chaps. 1 and 2 with a feeling that power engineering is indeed a modern technology.

Chapters 3 and 4 deal with load-flow and short-circuit studies. Diakoptics is a point of emphasis, and balanced fault studies are presented in notation and rigor consistent with the first two chapters. The connection between eigenvalues and singular-value decomposition is made, an SVD subroutine in Pascal is presented, and asymmetric faults are discussed. With regard to the latter, symmetrical components are (surprisingly) not treated as a matrix transformation of the phase variables: the imbalanced fault is treated in a fairly traditional way. Load-flow studies are treated with considerable rigor, albeit without a feel for what is happening. Perhaps, at this point, one might reiterate that the greatest strength of this text, namely the rigorous mathematical treatment of power system problems, is also the greatest weakness of the text. The average senior or beginning graduate student will not come away from Chap. 4 with a feeling for how power flow studies are used, or that \( P \) is connected closely to \( \delta \) while \( Q \) is connected closely to \( |V| \), or that off-nominal transformer taps are used to control reactive power flow, or many of the other traditional engineering insights common to this technology. But the students will have a solid understanding of the mathematics of the Newton-Raphson method, optimal ordering of the axes of the Jacobian, and other such mathematical fundamentals.

The foundations in linear algebra set
in the earlier chapters of the book lead very nicely to state estimation, the topic in Chap. 5. Included are excellent discussions of bad data, parallel processing and, again, singular-value decomposition. Previously, this information was available primarily in published papers. This chapter ties together many valuable concepts and may be a deciding factor to potential users for adoption as a course text.

Chapters 6 and 7 return to more traditional topics: optimal dispatch and stability. Optimal dispatch is presented with a least-squares flavor (for \( B \) coefficients). A rigorous discussion of parallel conjugate gradient methods is given (this method is not in widespread use, but the topic fits well into the approach taken throughout the text). Much of Chap. 6 is reprinted from the literature. Power system stability is treated relatively lightly, with the swing equation solved numerically by a few predictor formulas. A discussion of equivalents is included, but the terminology is not quite "mainstream power engineering." For example, a discussion of equivalents leads nicely to machine coherency. This connection is not made. Pattern recognition and Lyapunov methods are not discussed.

The last chapter deals with contingency analysis. The treatment is not too difficult for graduate students, and Wallach's characteristic mathematical rigor is used. Again, the average student would have to have seen such topics as distribution factors to follow the development.

Clearly, this is not a book for beginning students! Use of the text as a reference book might present a few semantic problems since the notation used is best followed sequentially starting with Chap. 1. Instructors and students alike will find the mathematical rigor a challenge—but a refreshing change from outdated approaches. There are no exercises for students—and there are few examples. The book will make you think!

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