

Dram Circuit Design A Tutorial Ieee Press Series On Microelectronic Systems

One of the grand challenges in the nano-scopic computing era is guarantees of robustness. Robust computing system design is confronted with quantum physical, probabilistic, and even biological phenomena, and guaranteeing high reliability is much more difficult than ever before. Scaling devices down to the level of single electron operation will bring forth new challenges due to probabilistic effects and uncertainty in guaranteeing 'zero-one' based computing. Minuscule devices imply billions of devices on a single chip, which may help mitigate the challenge of uncertainty by replication and redundancy. However, such device densities will create a design and validation nightmare with the shear scale. The questions that confront computer engineers regarding the current status of nanocomputing material and the reliability of systems built from such miniscule devices, are difficult to articulate and answer. We have found a lack of resources in the confines of a single volume that at least partially attempts to answer these questions. We believe that this volume contains a large amount of research material as well as new ideas that will be very useful for some one starting research in the arena of nanocomputing, not at the device level, but the problems one would face at system level design and validation when nanoscopic physicality will be present at the device level. This title introduces state-of-the-art design principles for SOI circuit design, and is primarily concerned with circuit-related issues. It considers SOI material in terms of implementation that is promising or has been used elsewhere in circuit development, with historical perspective where appropriate.

In two editions spanning more than a decade, The Electrical Engineering Handbook stands as the definitive reference to the multidisciplinary field of electrical engineering. Our knowledge continues to grow, and so does the Handbook. For the third edition, it has grown into a set of six books carefully focused on specialized areas or fields of study. Each one represents a concise yet definitive collection of key concepts, models, and equations in its respective domain, thoughtfully gathered for convenient access. Combined, they constitute the most comprehensive, authoritative resource available. Circuits, Signals, and Speech and Image Processing presents all of the basic information related to electric circuits and components, analysis of circuits, the use of the Laplace transform, as well as signal, speech, and image processing using filters and algorithms. It also examines emerging areas such as text to speech synthesis, real-time processing, and embedded signal processing. Electronics, Power Electronics, Optoelectronics, Microwaves, Electromagnetics, and Radar delves into the fields of electronics, integrated circuits, power electronics, optoelectronics, electromagnetics, light waves, and radar, supplying all of the basic information required for a deep understanding of each area. It also devotes a section to electrical effects and devices and explores the emerging fields of microlithography and power electronics. Sensors, Nanoscience, Biomedical Engineering, and Instruments provides thorough coverage of sensors, materials and nanoscience, instruments and measurements, and biomedical systems and devices, including all of the basic information required to thoroughly understand each area. It explores the emerging fields of sensors, nanotechnologies, and biological effects. Broadcasting and Optical Communication Technology explores communications, information theory, and devices, covering all of the basic information needed for a thorough understanding of these areas. It also examines the emerging areas of adaptive estimation and optical communication. Computers, Software Engineering, and Digital Devices examines digital and logical devices, displays, testing, software, and computers, presenting the fundamental concepts needed to ensure a thorough understanding of each field. It treats the emerging fields of programmable logic, hardware description languages, and parallel computing in detail. Systems, Controls,

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Embedded Systems, Energy, and Machines explores in detail the fields of energy devices, machines, and systems as well as control systems. It provides all of the fundamental concepts needed for thorough, in-depth understanding of each area and devotes special attention to the emerging area of embedded systems. Encompassing the work of the world's foremost experts in their respective specialties, *The Electrical Engineering Handbook, Third Edition* remains the most convenient, reliable source of information available. This edition features the latest developments, the broadest scope of coverage, and new material on nanotechnologies, fuel cells, embedded systems, and biometrics. The engineering community has relied on the Handbook for more than twelve years, and it will continue to be a platform to launch the next wave of advancements. The Handbook's latest incarnation features a protective slipcase, which helps you stay organized without overwhelming your bookshelf. It is an attractive addition to any collection, and will help keep each volume of the Handbook as fresh as your latest research.

Using the book and the software provided with it, the reader can build his/her own tester arrangement to investigate key aspects of analog-, digital- and mixed system circuits. Plan of attack based on traditional testing, circuit design and circuit manufacture allows the reader to appreciate a testing regime from the point of view of all the participating interests. Worked examples based on theoretical bookwork, practical experimentation and simulation exercises teach the reader how to test circuits thoroughly and effectively.

Is your memory hierarchy stopping your microprocessor from performing at the high level it should be? *Memory Systems: Cache, DRAM, Disk* shows you how to resolve this problem. The book tells you everything you need to know about the logical design and operation, physical design and operation, performance characteristics and resulting design trade-offs, and the energy consumption of modern memory hierarchies. You learn how to tackle the challenging optimization problems that result from the side-effects that can appear at any point in the entire hierarchy. As a result you will be able to design and emulate the entire memory hierarchy. Understand all levels of the system hierarchy -Xcache, DRAM, and disk. Evaluate the system-level effects of all design choices. Model performance and energy consumption for each component in the memory hierarchy.

Based on the authors' expansive collection of notes taken over the years, *Nano-CMOS Circuit and Physical Design* bridges the gap between physical and circuit design and fabrication processing, manufacturability, and yield. This innovative book covers: process technology, including sub-wavelength optical lithography; impact of process scaling on circuit and physical implementation and low power with leaky transistors; and DFM, yield, and the impact of physical implementation.

A practical guide to the effects of radiation on semiconductor components of electronic systems, and techniques for the designing, laying out, and testing of hardened integrated circuits. This book teaches the fundamentals of radiation environments and their effects on electronic components, as well as how to design, lay out, and test cost-effective hardened semiconductor chips not only for today's space systems but for commercial terrestrial applications as well. It provides a historical perspective, the fundamental science of radiation, and the basics of semiconductors, as well as radiation-induced failure mechanisms in semiconductor chips. *Integrated Circuits Design for Radiation Environments* starts by introducing readers to semiconductors and radiation environments (including space, atmospheric, and terrestrial environments) followed by circuit design and layout. The book introduces radiation effects phenomena (including single-event effects, total ionizing dose damage and displacement damage) and shows how technological solutions can address both phenomena. Describes the fundamentals of radiation environments and their effects on electronic components. Teaches readers how to design, lay out and test cost-effective hardened semiconductor chips for space systems and commercial terrestrial applications.

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Covers natural and man-made radiation environments, space systems and commercial terrestrial applications Provides up-to-date coverage of state-of-the-art of radiation hardening technology in one concise volume Includes questions and answers for the reader to test their knowledge Integrated Circuits Design for Radiation Environments will appeal to researchers and product developers in the semiconductor, space, and defense industries, as well as electronic engineers in the medical field. The book is also helpful for system, layout, process, device, reliability, applications, ESD, latchup and circuit design semiconductor engineers, along with anyone involved in micro-electronics used in harsh environments.

The fundamentals and implementation of digital electronics are essential to understanding the design and working of consumer/industrial electronics, communications, embedded systems, computers, security and military equipment. Devices used in applications such as these are constantly decreasing in size and employing more complex technology. It is therefore essential for engineers and students to understand the fundamentals, implementation and application principles of digital electronics, devices and integrated circuits. This is so that they can use the most appropriate and effective technique to suit their technical need. This book provides practical and comprehensive coverage of digital electronics, bringing together information on fundamental theory, operational aspects and potential applications. With worked problems, examples, and review questions for each chapter, Digital Electronics includes: information on number systems, binary codes, digital arithmetic, logic gates and families, and Boolean algebra; an in-depth look at multiplexers, de-multiplexers, devices for arithmetic operations, flip-flops and related devices, counters and registers, and data conversion circuits; up-to-date coverage of recent application fields, such as programmable logic devices, microprocessors, microcontrollers, digital troubleshooting and digital instrumentation. A comprehensive, must-read book on digital electronics for senior undergraduate and graduate students of electrical, electronics and computer engineering, and a valuable reference book for professionals and researchers.

A systematic description of microelectronic device design. Topics range from the basics to low-power and ultralow-voltage designs, subthreshold current reduction, memory subsystem designs for modern DRAMs, and various on-chip supply-voltage conversion techniques. It also covers process and device issues as well as design issues relating to systems, circuits, devices and processes, such as signal-to-noise and redundancy.

"Presents the latest developments in the programming and design of programmable digital signal processors (PDSPs) with very-long-instruction word (VLIW) architecture, algorithm formulation and implementation, and modern applications for multimedia processing, communications, and industrial control."

This book describes intuitive analog design approaches using digital inverters, providing filter architectures and circuit techniques enabling high performance analog circuit design. The authors provide process, supply voltage and temperature (PVT) variation-tolerant design techniques for inverter based circuits. They also discuss various analog design techniques for lower technology nodes and lower power supply, which can be used for designing high performance systems-on-chip.

A modern, comprehensive introduction to DRAM for students and practicing chip designers Dynamic Random Access Memory (DRAM) technology has been one of the greatest driving forces in the advancement of solid-state technology. With its ability to produce high product volumes and low pricing, it forces solid-state memory manufacturers to work aggressively to cut costs while maintaining, if not increasing,

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their market share. As a result, the state of the art continues to advance owing to the tremendous pressure to get more memory chips from each silicon wafer, primarily through process scaling and clever design. From a team of engineers working in memory circuit design, DRAM Circuit Design gives students and practicing chip designers an easy-to-follow, yet thorough, introductory treatment of the subject. Focusing on the chip designer rather than the end user, this volume offers expanded, up-to-date coverage of DRAM circuit design by presenting both standard and high-speed implementations. Additionally, it explores a range of topics: the DRAM array, peripheral circuitry, global circuitry and considerations, voltage converters, synchronization in DRAMs, data path design, and power delivery. Additionally, this up-to-date and comprehensive book features topics in high-speed design and architecture and the ever-increasing speed requirements of memory circuits. The only book that covers the breadth and scope of the subject under one cover, DRAM Circuit Design is an invaluable introduction for students in courses on memory circuit design or advanced digital courses in VLSI or CMOS circuit design. It also serves as an essential, one-stop resource for academics, researchers, and practicing engineers.

KEY BENEFIT : Learn the fundamentals of processor and computer design from the newest edition of this award winning text. **KEY TOPICS :** Introduction; Computer Evolution and Performance; A Top-Level View of Computer Function and Interconnection; Cache Memory; Internal Memory Technology; External Memory; I/O; Operating System Support; Computer Arithmetic; Instruction Sets: Characteristics and Functions; Instruction Sets: Addressing Modes and Formats; CPU Structure and Function; RISCs; Instruction-Level Parallelism and Superscalar Processors; Control Unit Operation; Microprogrammed Control; Parallel Processing; Multicore Architecture. **Online Chapters:** Number Systems; Digital Logic; Assembly Language, Assemblers, and Compilers; The IA-64 Architecture. **MARKET :** Ideal for professionals in computer science, computer engineering, and electrical engineering.

Electronic Concepts provides a detailed introduction to modern microelectronics. Equal emphasis is placed on analog and digital circuits, and the applications of particular devices and circuits are described within the context of actual electronic systems. The author begins with an overview of several important electronic systems, discussing in detail the types of signals that circuits are used to process. In the following chapters, he deals with individual devices. For each device he presents a brief physical description and demonstrates the use of different models in describing the device's behaviour in a particular circuit application. SPICE computer simulations are used throughout the text to supplement analytic descriptions. The book contains over 500 circuit diagrams and figures, over 400 homework problems, and over 100 simulation and design exercises. It includes many worked examples and is an ideal textbook for introductory courses in electronics. Laboratory experiments are available via the internet.

A widely read and authoritative book for hardware and software designers. This innovative book exposes the characteristics of performance-optimal single- and multi-level cache hierarchies by approaching the cache design process through the novel perspective of minimizing execution time.

Demand for bandwidth in serial links has been increasing as the communications industry demand higher quantity and quality of information. Whereas traditional gigabit per second links has been in bipolar or GaAs, this research aims to push the use of

CMOS process technology in such links. Intrinsic gate speed limitations are overcome by parallelizing the data. The on-chip frequency is maintained at a fraction (1/16) of the off-chip data rate. Clocks with carefully controlled phases tapped from a local ring oscillator are driven to a bank of input samplers to convert the serial bit stream into parallel data. Similarly, the overlap of multiple-phased clocks are used to synchronize the multiplexing of the parallel data onto the transmission line. To perform clock/data recovery, data is further oversampled with finer phase separation and passed to digital logic. The digital logic operates upon the samples to detect transitions in the bit stream to track the bit boundaries. This tracking can operate at the cycle rate of the digital logic allowing robustness to systematic phase noise. The challenge lies in the capturing of the high frequency data stream and generating low jitter, accurately spaced clock edges. A test chip is built demonstrating the transmission and recovery of a 4.0-Gb/s bit streams with

Presenting a comprehensive overview of the design automation algorithms, tools, and methodologies used to design integrated circuits, the Electronic Design Automation for Integrated Circuits Handbook is available in two volumes. The second volume, EDA for IC Implementation, Circuit Design, and Process Technology, thoroughly examines real-time logic to GDSII (a file format used to transfer data of semiconductor physical layout), analog/mixed signal design, physical verification, and technology CAD (TCAD). Chapters contributed by leading experts authoritatively discuss design for manufacturability at the nanoscale, power supply network design and analysis, design modeling, and much more. Save on the complete set.

Surface interactions and modifications have become increasingly critical for a broad range of manufacturing technologies. Applications can be in traditional manufacturing sectors and in manufacturing processes for microelectronics, optics, and micro-/nanoelectromechanical systems (MEMS/NEMS). Many applications demand engineered surfaces at different length scales that will function under extreme conditions. The goal of this book is to advance understanding of these diverse applications. In the field of tribological coatings, the increasing sophistication of coating processes to provide control over materials and composition gradients is being exploited to tailor properties such as adhesion, stresses, thermal barrier and wear resistance. Understanding the influence of nanostructure in coatings has become pivotal in the development of hard and wear-resistant materials. Modeling and simulation continue to make contributions to the understanding and predication of surface properties and surface interactions. Advances in this field have focused on the microstructure and organization of organic thin films. In tribology, the combination of modeling, with experimental probe techniques, is increasing our understanding of erosion and wear mechanisms.

Praise for CMOS: Circuit Design, Layout, and Simulation Revised Second Edition from the Technical Reviewers "A refreshing industrial flavor. Design concepts are presented as they are needed for 'just-in-time' learning. Simulating and designing circuits using SPICE is emphasized with literally hundreds of examples. Very few textbooks contain as much detail as this one. Highly recommended!" --Paul M. Furth, New Mexico State University "This book builds a solid knowledge of CMOS circuit design from the ground up. With coverage of process integration, layout, analog and digital models, noise mechanisms, memory circuits, references, amplifiers, PLLs/DLLs, dynamic circuits, and

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data converters, the text is an excellent reference for both experienced and novice designers alike." --Tyler J. Gomm, Design Engineer, Micron Technology, Inc. "The Second Edition builds upon the success of the first with new chapters that cover additional material such as oversampled converters and non-volatile memories. This is becoming the de facto standard textbook to have on every analog and mixed-signal designer's bookshelf." --Joe Walsh, Design Engineer, AMI Semiconductor CMOS circuits from design to implementation CMOS: Circuit Design, Layout, and Simulation, Revised Second Edition covers the practical design of both analog and digital integrated circuits, offering a vital, contemporary view of a wide range of analog/digital circuit blocks, the BSIM model, data converter architectures, and much more. This edition takes a two-path approach to the topics: design techniques are developed for both long- and short-channel CMOS technologies and then compared. The results are multidimensional explanations that allow readers to gain deep insight into the design process. Features include: Updated materials to reflect CMOS technology's movement into nanometer sizes Discussions on phase- and delay-locked loops, mixed-signal circuits, data converters, and circuit noise More than 1,000 figures, 200 examples, and over 500 end-of-chapter problems In-depth coverage of both analog and digital circuit-level design techniques Real-world process parameters and design rules The book's Web site, CMOSedu.com, provides: solutions to the book's problems; additional homework problems without solutions; SPICE simulation examples using HSPICE, LTspice, and WinSpice; layout tools and examples for actually fabricating a chip; and videos to aid learning

Surveys the electrical and layout perspectives of System-in-Package, the system integration technology that has emerged as a required technology to reduce the system board space and height in addition to the overall time-to-market and design cost of consumer electronics products such as those of cell phones, audio/video players and digital cameras.

In two editions spanning more than a decade, *The Electrical Engineering Handbook* stands as the definitive reference to the multidisciplinary field of electrical engineering. Our knowledge continues to grow, and so does the Handbook. For the third edition, it has expanded into a set of six books carefully focused on a specialized area or field of study. Each book represents a concise yet definitive collection of key concepts, models, and equations in its respective domain, thoughtfully gathered for convenient access. *Computers, Software Engineering, and Digital Devices* examines digital and logical devices, displays, testing, software, and computers, presenting the fundamental concepts needed to ensure a thorough understanding of each field. It treats the emerging fields of programmable logic, hardware description languages, and parallel computing in detail. Each article includes defining terms, references, and sources of further information. Encompassing the work of the world's foremost experts in their respective specialties, *Computers, Software Engineering, and Digital Devices* features the latest developments, the broadest scope of coverage, and new material on secure electronic commerce and parallel computing.

Because of their widespread use in mainframes, PCs, and mobile audio and video devices, DRAMs are being manufactured in ever increasing volume, both in stand-alone and in embedded form as part of a system on chip. Due to the optimum design of their components—access transistor, storage capacitor, and peripherals—DRAMs are the

cheapest and densest semiconductor memory currently available. As a result, most of DRAM structure research and development focuses on the technology used for its constituent components and their interconnections. However, only a few books are available on semiconductor memories in general and fewer on DRAMs. Dynamic RAM: Technology Advancements provides a holistic view of the DRAM technology with a systematic description of the advancements in the field since the 1970s, and an analysis of future challenges. Topics Include: DRAM cells of all types, including planar, three-dimensional (3-D) trench or stacked, COB or CUB, vertical, and mechanically robust cells using advanced transistors and storage capacitors Advancements in transistor technology for the RCAT, SCAT, FinFET, BT FinFET, Saddle and advanced recess type, and storage capacitor realizations How sub 100 nm trench DRAM technologies and sub 50 nm stacked DRAM technologies and related topics may lead to new research Various types of leakages and power consumption reduction methods in active and sleep mode Various types of SAs and yield enhancement techniques employing ECC and redundancy A worthwhile addition to semiconductor memory research, academicians and researchers interested in the design and optimization of high-density and cost-efficient DRAMs may also find it useful as part of a graduate-level course.

Kevin Zhang Advancement of semiconductor technology has driven the rapid growth of very large scale integrated (VLSI) systems for increasingly broad applications, including high-end and mobile computing, consumer electronics such as 3D gaming, multi-function or smart phone, and various set-top players and ubiquitous sensor and medical devices. To meet the increasing demand for higher performance and lower power consumption in many different system applications, it is often required to have a large amount of on-die or embedded memory to support the need of data bandwidth in a system. The varieties of embedded memory in a given system have also become increasingly more complex, ranging from static to dynamic and volatile to nonvolatile. Among embedded memories, six-transistor (6T)-based static random access memory (SRAM) continues to play a pivotal role in nearly all VLSI systems due to its superior speed and full compatibility with logic process technology. But as the technology scaling continues, SRAM design is facing severe challenge in maintaining sufficient cell stability margin under relentless area scaling. Meanwhile, rapid expansion in mobile application, including new emerging application in sensor and medical devices, requires far more aggressive voltage scaling to meet very stringent power constraint. Many innovative circuit topologies and techniques have been extensively explored in recent years to address these challenges.

Proceedings of SPIE present the original research papers presented at SPIE conferences and other high-quality conferences in the broad-ranging fields of optics and photonics. These books provide prompt access to the latest innovations in research and technology in their respective fields. Proceedings of SPIE are among the most cited references in patent literature.

Top-down approach to practical, tool-independent, digital circuit design, reflecting how circuits are designed.

This up-to-date book, with its introductory tutorial, provides extensive coverage on BiCMOS, potentially the most important silicon technology of the 1990's. Many commercial products are currently utilizing BiCMOS ICs and an exponential growth is

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expected. Elmasry provides the latest information on processing technologies, circuit analysis, and techniques, and applications in the areas of analog, digital, and smart power. BiCMOS Integrated Circuit Design is an important guide for engineers working in BiCMOS processing, modeling, characterization, circuit design, and applications, as well as a valuable learning tool for college seniors and graduate students.

Special Features: · Written by the author of the best-seller, CMOS: Circuit Design, Layout, and Simulation· Fills a hole in the technical literature for an advanced-tutorial book on mixed-signal circuit design from a circuit designer's point of view· Presents more advance topics, and will be an excellent companion to the first volume About The Book: This book will fill a hole in the technical literature for an advanced-tutorial book on mixed-signal circuit design. There are no competitors in this area. Mixed-signal design is performed in industry by a select few gurus . The techniques can be found in hard-to-digest technical papers.

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Reconfigurable Computing marks a revolutionary and hot topic that bridges the gap between the separate worlds of hardware and software design—the key feature of reconfigurable computing is its groundbreaking ability to perform computations in hardware to increase performance while retaining the flexibility of a software solution. Reconfigurable computers serve as affordable, fast, and accurate tools for developing designs ranging from single chip architectures to multi-chip and embedded systems. Scott Hauck and Andre DeHon have assembled a group of the key experts in the fields of both hardware and software computing to provide an introduction to the entire range of issues relating to reconfigurable computing. FPGAs (field programmable gate arrays) act as the “computing vehicles to implement this powerful technology. Readers will be guided into adopting a completely new way of handling existing design concerns and be able to make use of the vast opportunities possible with reconfigurable logic in this rapidly evolving field. Designed for both hardware and software programmers Views of reconfigurable programming beyond standard programming languages Broad set of case studies demonstrating how to use FPGAs in novel and efficient ways

Intelligent readers who want to build their own embedded computer systems-- installed in everything from cell phones to cars to handheld organizers to refrigerators-- will find this book to be the most in-depth, practical, and up-to-date guide on the market. Designing Embedded Hardware carefully steers between the practical and philosophical aspects, so developers can both create their own devices and gadgets and customize and extend off-the-shelf systems. There are hundreds of books to choose from if you need to learn programming, but only a few are available if you want to learn to create hardware. Designing Embedded Hardware provides software and hardware engineers with no prior experience in embedded systems with the necessary conceptual and design building blocks to understand the architectures of embedded systems. Written to provide the depth of coverage and real-world examples developers need, Designing Embedded Hardware also provides a road-map to the pitfalls and traps to avoid in designing

embedded systems. Designing Embedded Hardware covers such essential topics as: The principles of developing computer hardware Core hardware designs Assembly language concepts Parallel I/O Analog-digital conversion Timers (internal and external) UART Serial Peripheral Interface Inter-Integrated Circuit Bus Controller Area Network (CAN) Data Converter Interface (DCI) Low-power operation This invaluable and eminently useful book gives you the practical tools and skills to develop, build, and program your own application-specific computers.

"DRAM Circuit Design" teaches readers the introductory level design of DRAM memory chips. It focuses on giving readers a reference that can be used to educate students or practicing design engineers in DRAM circuit design. This book provides a structured treatment of the key principles and techniques for enabling efficient processing of deep neural networks (DNNs). DNNs are currently widely used for many artificial intelligence (AI) applications, including computer vision, speech recognition, and robotics. While DNNs deliver state-of-the-art accuracy on many AI tasks, it comes at the cost of high computational complexity. Therefore, techniques that enable efficient processing of deep neural networks to improve key metrics—such as energy-efficiency, throughput, and latency—without sacrificing accuracy or increasing hardware costs are critical to enabling the wide deployment of DNNs in AI systems. The book includes background on DNN processing; a description and taxonomy of hardware architectural approaches for designing DNN accelerators; key metrics for evaluating and comparing different designs; features of DNN processing that are amenable to hardware/algorithm co-design to improve energy efficiency and throughput; and opportunities for applying new technologies. Readers will find a structured introduction to the field as well as formalization and organization of key concepts from contemporary work that provide insights that may spark new ideas.

We live in a time of great change. In the electronics world, the last several decades have seen unprecedented growth and advancement, described by Moore's law. This observation stated that transistor density in integrated circuits doubles every 1.5–2 years. This came with the simultaneous improvement of individual device performance as well as the reduction of device power such that the total power of the resulting ICs remained under control. No trend remains constant forever, and this is unfortunately the case with Moore's law. The trouble began a number of years ago when CMOS devices were no longer able to proceed along the classical scaling trends. Key device parameters such as gate oxide thickness were simply no longer able to scale. As a result, device on-state currents began to creep up at an alarming rate. These continuing problems with classical scaling have led to a leveling off of IC clock speeds to the range of several GHz. Of course, chips can be clocked higher but the thermal issues become unmanageable. This has led to the recent trend toward microprocessors with multiple cores, each running at a few GHz at the most. The goal is to

continue improving performance via parallelism by adding more and more cores instead of increasing speed. The challenge here is to ensure that general purpose codes can be efficiently parallelized. There is another potential solution to the problem of how to improve CMOS technology performance: three-dimensional integrated circuits (3D ICs).

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