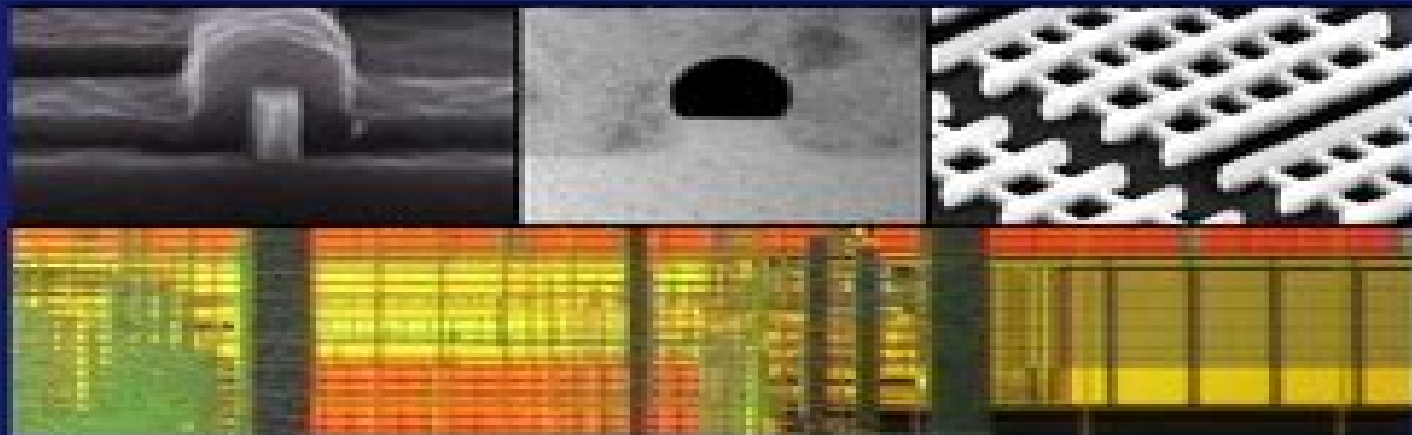


Second Edition

# FinFET/GAA Modeling for IC Simulation and Design

Using the BSIM-CMG Standard



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# Finfet Modeling For Ic Simulation And Design Using The Bsim Cmg Standard

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## **Finfet Modeling For Ic Simulation And Design Using The Bsim Cmg Standard:**

**FinFET Modeling for IC Simulation and Design** Yogesh Singh Chauhan, Darsen Lu, Sriramkumar Vanugopalan, Sourabh Khandelwal, Juan Pablo Duarte, Navid Payvadosi, Ali Niknejad, Chenming Hu, 2015-03-17 This book is the first to explain FinFET modeling for IC simulation and the industry standard BSIM CMG describing the rush in demand for advancing the technology from planar to 3D architecture as now enabled by the approved industry standard The book gives a strong foundation on the physics and operation of FinFET details aspects of the BSIM CMG model such as surface potential charge and current calculations and includes a dedicated chapter on parameter extraction procedures providing a step by step approach for the efficient extraction of model parameters With this book you will learn Why you should use FinFET The physics and operation of FinFET Details of the FinFET standard model BSIM CMG Parameter extraction in BSIM CMG FinFET circuit design and simulation Authored by the lead inventor and developer of FinFET and developers of the BSIM CM standard model providing an experts insight into the specifications of the standard The first book on the industry standard FinFET model BSIM CMG

**FinFET/GAA Modeling for IC Simulation and Design** Yogesh Singh Chauhan, Chenming Hu, S. Salahuddin, Girish Pahwa, Avirup Dasgupta, Darsen Lu, Sriramkumar Vanugopalan, Ali Niknejad, Sourabh Khandelwal, Juan Pablo Duarte, Navid Payvadosi, 2024-08-23 FinFET GAA Modeling for IC Simulation and Design Using the BSIM CMG Standard Second Edition is the first to book to explain FinFET modeling for IC simulation and the industry standard BSIM CMG describing the rush in demand for advancing the technology from planar to 3D architecture as now enabled by the approved industry standard The book gives a strong foundation on the physics and operation of FinFET details aspects of the BSIM CMG model such as surface potential charge and current calculations and includes a dedicated chapter on parameter extraction procedures thus providing a step by step approach for the efficient extraction of model parameters With this book users will learn Why you should use FinFET The physics and operation of FinFET Details of the FinFET standard model BSIM CMG Parameter extraction in BSIM CMG FinFET circuit design and simulation and more Authored by the lead inventor and developer of FinFET and developers of the BSIM CMG standard model providing an expert s insight into the specifications of the standard A new edition of the original groundbreaking book on the industry standard FinFET model BSIM CMG New to This Edition Includes a new chapter providing a comprehensive introduction to GAAFET including motivations device concepts structure benefits and the industry standard GAAFET model Covers the most recent developments in the BSIM CMG model Presents an updated RF modeling of FinFET using the BSIM CMG model including parameter extraction Includes a new chapter on cryogenic modeling

**FinFET Modeling for IC Simulation and Design: Using the BSIM-CMG Standard** , *Semiconductor Nanotechnology* Stephen M. Goodnick, Anatoli Korkin, Robert Nemanich, 2018-07-26 This book presents research dedicated to solving scientific and technological problems in many areas of electronics photonics and renewable energy Energy and information are interconnected and are essential elements for the

development of human society Transmission processing and storage of information requires energy consumption while the efficient use and access to new energy sources requires new information ideas and expertise and the design of novel systems such as photovoltaic devices fuel cells and batteries Semiconductor physics creates the knowledge base for the development of information computers cell phones etc and energy photovoltaic technologies The exchange of ideas and expertise between these two technologies is critical and expands beyond semiconductors Continued progress in information and renewable energy technologies requires miniaturization of devices and reduction of costs energy and material consumption The latest generation of electronic devices is now approaching nanometer scale dimensions new materials are being introduced into electronics manufacturing at an unprecedented rate and alternative technologies to mainstream CMOS are evolving Nanotechnology is widely accepted as a source of potential solutions in securing future progress for information and energy technologies Semiconductor Nanotechnology features chapters that cover the following areas atomic scale materials design bio and molecular electronics high frequency electronics fabrication of nanodevices magnetic materials and spintronics materials and processes for integrated and subwave optoelectronics nanoCMOS new materials for FETs and other devices nanoelectronics system architecture nano optics and lasers non silicon materials and devices chemical and biosensors quantum effects in devices nano science and technology applications in the development of novel solar energy devices and fuel cells and batteries

**Physics of Semiconductor Devices** Simon M. Sze, Yiming Li, Kwok K. Ng, 2021-03-19 The new edition of the most detailed and comprehensive single volume reference on major semiconductor devices The Fourth Edition of Physics of Semiconductor Devices remains the standard reference work on the fundamental physics and operational characteristics of all major bipolar unipolar special microwave and optoelectronic devices This fully updated and expanded edition includes approximately 1 000 references to original research papers and review articles more than 650 high quality technical illustrations and over two dozen tables of material parameters Divided into five parts the text first provides a summary of semiconductor properties covering energy band carrier concentration and transport properties The second part surveys the basic building blocks of semiconductor devices including p n junctions metal semiconductor contacts and metal insulator semiconductor MIS capacitors Part III examines bipolar transistors MOSFETs MOS field effect transistors and other field effect transistors such as JFETs junction field effect transistors and MESFETs metal semiconductor field effect transistors Part IV focuses on negative resistance and power devices The book concludes with coverage of photonic devices and sensors including light emitting diodes LEDs solar cells and various photodetectors and semiconductor sensors This classic volume the standard textbook and reference in the field of semiconductor devices Provides the practical foundation necessary for understanding the devices currently in use and evaluating the performance and limitations of future devices Offers completely updated and revised information that reflects advances in device concepts performance and application Features discussions of topics of contemporary interest such as applications of photonic devices that convert optical energy

to electric energy Includes numerous problem sets real world examples tables figures and illustrations several useful appendices and a detailed solutions manual for Instructor s only Explores new work on leading edge technologies such as MODFETs resonant tunneling diodes quantum cascade lasers single electron transistors real space transfer devices and MOS controlled thyristors Physics of Semiconductor Devices Fourth Edition is an indispensable resource for design engineers research scientists industrial and electronics engineering managers and graduate students in the field

**Proceedings of the Eighth International Conference on Soft Computing and Pattern Recognition (SoCPaR 2016)** Ajith

Abraham,Aswani Kumar Cherukuri,Ana Maria Madureira,Azah Kamilah Muda,2017-08-17 This volume presents 70 carefully selected papers from a major joint event the 8th International Conference on Soft Computing and Pattern Recognition SoCPaR 2016 and the 8th International Conference on Computational Aspects of Social Networks CASoN 2016 SoCPaR CASoN 2016 which was organized by the Machine Intelligence Research Labs MIR Labs USA and Vellore Institute of Technology VIT India and held at the VIT on December 19 21 2016 It brings together researchers and practitioners from academia and industry to share their experiences and exchange new ideas on all interdisciplinary areas of soft computing and pattern recognition as well as intelligent methods applied to social networks This book is a valuable resource for practicing engineers scientists and researchers working in the field of soft computing pattern recognition and social networks

**Artificial Intelligence and Algorithms in Intelligent Systems** Radek Silhavy,2018-05-26 This book presents the latest trends and approaches in artificial intelligence research and its application to intelligent systems It discusses hybridization of algorithms new trends in neural networks optimisation algorithms and real life issues related to the application of artificial methods The book constitutes the second volume of the refereed proceedings of the Artificial Intelligence and Algorithms in Intelligent Systems of the 7th Computer Science On line Conference 2018 CSOC 2018 held online in April 2018

**Mitigating Process Variability and Soft Errors at Circuit-Level for FinFETs** Alexandra Zimpeck,Cristina Meinhardt,Laurent Artola,Ricardo Reis,2021-03-10 This book evaluates the influence of process variations e g work function fluctuations and radiation induced soft errors in a set of logic cells using FinFET technology considering the 7nm technological node as a case study Moreover for accurate soft error estimation the authors adopt a radiation event generator tool MUSCA SEP3 which deals both with layout features and electrical properties of devices The authors also explore four circuit level techniques e g transistor reordering decoupling cells Schmitt Trigger and sleep transistor as alternatives to attenuate the unwanted effects on FinFET logic cells This book also evaluates the mitigation tendency when different levels of process variation transistor sizing and radiation particle characteristics are applied in the design An overall comparison of all methods addressed by this work is provided allowing to trace a trade off between the reliability gains and the design penalties of each approach regarding the area performance power consumption single event transient SET pulse width and SET cross section

5G Mobile Communications Wei Xiang,Kan Zheng,Xuemin (Sherman) Shen,2016-10-13 This

book provides a comprehensive overview of the emerging technologies for next generation 5G mobile communications with insights into the long term future of 5G Written by international leading experts on the subject this contributed volume covers a wide range of technologies research results and networking methods Key enabling technologies for 5G systems include but are not limited to millimeter wave communications massive MIMO technology and non orthogonal multiple access 5G will herald an even greater rise in the prominence of mobile access based upon both human centric and machine centric networks Compared with existing 4G communications systems unprecedented numbers of smart and heterogeneous wireless devices will be accessing future 5G mobile systems As a result a new paradigm shift is required to deal with challenges on explosively growing requirements in mobile data traffic volume 1000x number of connected devices 10 100x typical end user data rate 10 100x and device network lifetime 10x Achieving these ambitious goals calls for revolutionary candidate technologies in future 5G mobile systems Designed for researchers and professionals involved with networks and communication systems 5G Mobile Communications is a straightforward easy to read analysis of the possibilities of 5G systems

**Industry Standard FDSOI Compact Model BSIM-IMG for IC Design** Chenming Hu, Sourabh Khandelwal, Yogesh Singh Chauhan, Thomas Mckay, Josef Watts, Juan Pablo Duarte, Pragya Kushwaha, Harshit Agarwal, 2019-05-21 Industry Standard FDSOI Compact Model BSIM IMG for IC Design helps readers develop an understanding of a FDSOI device and its simulation model It covers the physics and operation of the FDSOI device explaining not only how FDSOI enables further scaling but also how it offers unique possibilities in circuits Following chapters cover the industry standard compact model BSIM IMG for FDSOI devices The book addresses core surface potential calculations and the plethora of real devices and potential effects Written by the original developers of the industrial standard model this book is an excellent reference for the new BSIM IMG compact model for emerging FDSOI technology The authors include chapters on step by step parameters extraction procedure for BSIM IMG model and rigorous industry grade tests that the BSIM IMG model has undergone There is also a chapter on analog and RF circuit design in FDSOI technology using the BSIM IMG model Provides a detailed discussion of the BSIM IMG model and the industry standard simulation model for FDSOI all presented by the developers of the model Explains the complex operation of the FDSOI device and its use of two independent control inputs Addresses the parameter extraction challenges for those using this model

*BSIM4 and MOSFET Modeling for IC Simulation* Weidong Liu, Chenming Hu, 2011 This book presents the art of advanced MOSFET modeling for integrated circuit simulation and design It provides the essential mathematical and physical analyses of all the electrical mechanical and thermal effects in MOS transistors relevant to the operation of integrated circuits Particular emphasis is placed on how the BSIM model evolved into the first ever industry standard SPICE MOSFET model for circuit simulation and CMOS technology development The discussion covers the theory and methodology of how a MOSFET model or semiconductor device models in general can be implemented to be robust and efficient turning device physics theory into a production worthy SPICE

simulation model Special attention is paid to MOSFET characterization and model parameter extraction methodologies making the book particularly useful for those interested or already engaged in work in the areas of semiconductor devices compact modeling for SPICE simulation and integrated circuit design *BSIM-Bulk MOSFET Model for IC Design - Digital, Analog, RF and High-Voltage* Chenming Hu, Harshit Agarwal, Chetan Gupta, Yogesh Singh Chauhan, 2023-04-26 BSIM Bulk MOSFET Model for IC Design Digital Analog RF and High Voltage provides in depth knowledge of the internal operation of the model The authors not only discuss the fundamental core of the model but also provide details of the recent developments and new real device effect models In addition the book covers the parameter extraction procedures addressing geometrical scaling temperatures and more There is also a dedicated chapter on extensive quality testing procedures and experimental results This book discusses every aspect of the model in detail and hence will be of significant use for the industry and academia Those working in the semiconductor industry often run into a variety of problems like model non convergence or non physical simulation results This is largely due to a limited understanding of the internal operations of the model as literature and technical manuals are insufficient This also creates huge difficulty in developing their own IP models Similarly circuit designers and researcher across the globe need to know new features available to them so that the circuits can be more efficiently designed Reviews the latest advances in fabrication methods for metal chalcogenide based biosensors Discusses the parameters of biosensor devices to aid in materials selection Provides readers with a look at the chemical and physical properties of reactive metals noble metals transition metals chalcogenides and their connection to biosensor device performance *MOSFET Modeling & BSIM3 User's Guide* Yuhua Cheng, Chenming Hu, 2007-05-08 Circuit simulation is essential in integrated circuit design and the accuracy of circuit simulation depends on the accuracy of the transistor model BSIM3v3 BSIM for Berkeley Short channel IGFET Model has been selected as the first MOSFET model for standardization by the Compact Model Council a consortium of leading companies in semiconductor and design tools In the next few years many fabless and integrated semiconductor companies are expected to switch from dozens of other MOSFET models to BSIM3 This will require many device engineers and most circuit designers to learn the basics of BSIM3 MOSFET Modeling BSIM3 User's Guide explains the detailed physical effects that are important in modeling MOSFETs and presents the derivations of compact model expressions so that users can understand the physical meaning of the model equations and parameters It is the first book devoted to BSIM3 It treats the BSIM3 model in detail as used in digital analog and RF circuit design It covers the complete set of models i e I V model capacitance model noise model parasitics model substrate current model temperature effect model and non quasi static model MOSFET Modeling BSIM3 User's Guide not only addresses the device modeling issues but also provides a user's guide to the device or circuit design engineers who use the BSIM3 model in digital analog circuit design RF modeling statistical modeling and technology prediction This book is written for circuit designers and device engineers as well as device scientists worldwide It is also suitable as a reference for graduate courses and

courses in circuit design or device modelling Furthermore it can be used as a textbook for industry courses devoted to BSIM3 MOSFET Modeling BSIM3 User's Guide is comprehensive and practical It is balanced between the background information and advanced discussion of BSIM3 It is helpful to experts and students alike

**Compact Modeling with BSIM-CMG and SRAM Design for Oxide Semiconductor and Cryogenic CMOS**, 2024 **FinFET Devices for VLSI Circuits and Systems** Samar K. Saha, 2020-07-15 To surmount the continuous scaling challenges of MOSFET devices FinFETs have emerged as the real alternative for use as the next generation device for IC fabrication technology The objective of this book is to provide the basic theory and operating principles of FinFET devices and technology an overview of FinFET device architecture and manufacturing processes and detailed formulation of FinFET electrostatic and dynamic device characteristics for IC design and manufacturing Thus this book caters to practicing engineers transitioning to FinFET technology and prepares the next generation of device engineers and academic experts on mainstream device technology at the nanometer nodes

Compact Models for Integrated Circuit Design Samar K. Saha, 2018-09-03 Compact Models for Integrated Circuit Design Conventional Transistors and Beyond provides a modern treatise on compact models for circuit computer aided design CAD Written by an author with more than 25 years of industry experience in semiconductor processes devices and circuit CAD and more than 10 years of academic experience in teaching compact modeling courses this first of its kind book on compact SPICE models for very large scale integrated VLSI chip design offers a balanced presentation of compact modeling crucial for addressing current modeling challenges and understanding new models for emerging devices Starting from basic semiconductor physics and covering state of the art device regimes from conventional micron to nanometer this text Presents industry standard models for bipolar junction transistors BJTs metal oxide semiconductor MOS field effect transistors FETs FinFETs and tunnel field effect transistors TFETs along with statistical MOS models Discusses the major issue of process variability which severely impacts device and circuit performance in advanced technologies and requires statistical compact models Promotes further research of the evolution and development of compact models for VLSI circuit design and analysis Supplies fundamental and practical knowledge necessary for efficient integrated circuit IC design using nanoscale devices Includes exercise problems at the end of each chapter and extensive references at the end of the book Compact Models for Integrated Circuit Design Conventional Transistors and Beyond is intended for senior undergraduate and graduate courses in electrical and electronics engineering as well as for researchers and practitioners working in the area of electron devices However even those unfamiliar with semiconductor physics gain a solid grasp of compact modeling concepts from this book

*FET Modeling for Circuit Simulation* Dileep A. Divekar, 2012-12-06 Circuit simulation is widely used for the design of circuits both discrete and integrated Device modeling is an important aspect of circuit simulation since it is the link between the physical device and the simulated device Currently available circuit simulation programs provide a variety of built in models Many circuit designers use these built in models whereas some



incorporate new models in the circuit simulation programs Understanding device modeling with particular emphasis on circuit simulation will be helpful in utilizing the built in models more efficiently as well as in implementing new models SPICE is used as a vehicle since it is the most widely used circuit simulation program However some issues are addressed which are not directly applicable to SPICE but are applicable to circuit simulation in general These discussions are useful for modifying SPICE and for understanding other simulation programs The generic version 2G 6 is used as a reference for SPICE although numerous different versions exist with different modifications This book describes field effect transistor models commonly used in a variety of circuit simulation programs Understanding of the basic device physics and some familiarity with device modeling is assumed Derivation of the model equations is not included SPICE is a circuit simulation program available from EECS Industrial Support Office 461 Cory Hall University of California Berkeley CA 94720

Acknowledgements I wish to express my gratitude to Valid Logic Systems Inc **Compact Models for Future Generation**

**CMOS** Darsen Duane Lu, 2011 Multiple gate MOSFETs with superior short channel control are expected to replace planar CMOS in the near future An accurate and computationally efficient compact transistor model is necessary to simulate circuits in multiple gate MOSFET technologies In this dissertation research a compact multiple gate MOSFET model BSIM MG is developed BSIM MG includes independent multi gate compact model BSIM IMG and common multi gate compact model BSIM CMG We focus on BSIM IMG for multiple gate MOSFETs with independent front and back gates The basic formulations for surface potential drain current and charge are derived and verified against TCAD simulations with excellent agreements The model preserves important property of multi gate MOSFETs such as volume inversion Non ideal effects including short channel effects length dependent back gate coupling transport models leakage currents parasitic resistances and capacitances temperature effects and self heating are considered in the model The model expressions are carefully formulated so that the symmetry of the source and drain is preserved Rules for maintaining symmetry are discussed in this dissertation For the common multi gate transistor model BSIM CMG the basic expressions have been improved so that it is compatible with a novel non quasi static effects modeling technique charge segmentation In addition a parasitic source drain resistance model is developed including three components the contact resistance the spreading resistance and the bias dependent extension resistance Both BSIM CMG and BSIM IMG models are verified against TCAD and measured data The use of the FinFET compact model to model manufacturing variation in a FinFET technology is further explored The model matches measured data well for both the nominal case and the statistical distribution for NMOS threshold voltage as well as the read static noise margin A non Gaussian threshold voltage distribution is observed for nFET devices and the compact model successfully captures the distribution We further outlined and demonstrated a Monte Carlo based procedure for designing FinFET SRAM cells using the extracted variation information Technology scaling has enabled numerous CMOS analog circuits for low cost radio frequency applications The modeling of MOSFET thermal noise becomes very important In

the final part of this dissertation research a new thermal noise model is developed for the industry standard BSIM4 model that enhances the existing thermal noise formulation in BSIM4 The model is verified against a segmented channel MOSFET model as well as measured data It is implemented in Berkeley SPICE3 and is ready for industry use A method to port the model to BSIM MG for thermal noise modeling in multi gate MOSFETs is also presented *MOSFET Models for SPICE Simulation* William Liu, 2001-02-21 An expert guide to understanding and making optimum use of BSIM Used by more chip designers worldwide than any other comparable model the Berkeley Short Channel IGFET Model BSIM has over the past few years established itself as the de facto standard MOSFET SPICE model for circuit simulation and CMOS technology development Yet until now there have been no independent expert guides or tutorials to supplement the various BSIM manuals currently available Written by a noted expert in the field this book fills that gap in the literature by providing a comprehensive guide to understanding and making optimal use of BSIM3 and BSIM4 Drawing upon his extensive experience designing with BSIM William Liu provides a brief history of the model discusses the various advantages of BSIM over other models and explores the reasons why BSIM3 has been adopted by the majority of circuit manufacturers He then provides engineers with the detailed practical information and guidance they need to master all of BSIM s features He Summarizes key BSIM3 components Represents the BSIM3 model with equivalent circuits for various operating conditions Provides a comprehensive glossary of modeling terminology Lists alphabetically BSIM3 parameters along with their meanings and relevant equations Explores BSIM3 s flaws and provides improvement suggestions Describes all of BSIM4 s improvements and new features Provides useful SPICE files which are available online at the Wiley ftp site *Compact Modeling* Gennady Gildenblat, 2010-06-22 Most of the recent texts on compact modeling are limited to a particular class of semiconductor devices and do not provide comprehensive coverage of the field Having a single comprehensive reference for the compact models of most commonly used semiconductor devices both active and passive represents a significant advantage for the reader Indeed several kinds of semiconductor devices are routinely encountered in a single IC design or in a single modeling support group Compact Modeling includes mostly the material that after several years of IC design applications has been found both theoretically sound and practically significant Assigning the individual chapters to the groups responsible for the definitive work on the subject assures the highest possible degree of expertise on each of the covered models

## Whispering the Secrets of Language: An Emotional Journey through **Finfet Modeling For Ic Simulation And Design Using The Bsim Cmg Standard**

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