# THE BOUNDING APPROACH TO VSLI CIRCUIT SIMULATION

by

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# Bounding Approach To Vlsi Circuit Simulation

**Kenneth S. Kundert,Jacob K. White,Alberto L. Sangiovanni-Vincentelli**

**Bounding Approach To Vlsi Circuit Simulation:**

The Bounding Approach to VLSI Circuit Simulation C.A. Zukowski,2013-11-11 This book proposes a new approach to circuit simulation that is still in its infancy The reason for publishing this work as a monograph at this time is to quickly distribute these ideas to the research community for further study The book is based on a doctoral dissertation undertaken at MIT between 1982 and 1985 In 1982 the author joined a research group that was applying bounding techniques to simple VLSI timing analysis models The conviction that bounding analysis could also be successfully applied to sophisticated digital MOS circuit models led to the research presented here Acknowledgments me author would like to acknowledge many helpful discussions and much support from his research group at MIT including Lance Glasser John Wyatt Jr and Paul Penfield Jr Many others have also contributed to this work in some way including Albert Ruchli Mark Horowitz Rich Zippel Chtis Terman Jacob White Mark Matson Bob Armstrong Steve McCormick Cyrus Bamji John Wroclawski Omar Wing Gary Dare Paul Bassett and Rick LaMaire The author would like to give special thanks to his wife Deborra for her support and many contributions to the presentation of this research The author would also like to thank his parents for their encouragement and IBM for its financial support of t I Jis project through a graduate fellowship THE BOUNDING APPROACH TO VLSI CIRCUIT SIMULATION 1 INTRODUCTION The VLSI revolution of the 1970 s has created a need for new circuit analysis techniques **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 impor tant aspect of circuit simulation since it is the link between the physical device and the sim ulate d device Curren tly 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 sim ulation 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 sim ulation program How ever some issues are addressed which are not directly appli cable to SPICE but are applicable to circuit simulation in general These discussions are useful for modifying SPICE and for understanding other simulation programs The gen eric 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 sim ulation pro grams 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 sim ulation program available from EECS Industrial Support Office 461 Cory Hall University of Cali fornia Berkeley CA 94720 Acknowledgements I wish to express my gratitude to Valid Logic Systems Inc *Steady-State Methods for Simulating Analog and Microwave Circuits* Kenneth S. Kundert,Jacob K. White,Alberto L. Sangiovanni-Vincentelli,2013-03-09 The motivation for starting the work described in this book was the interest that Hewlett Packard s microwave circuit designers had in simulation techniques that could tackle the

problem of finding steady state solutions for nonlinear circuits particularly circuits containing distributed elements such as transmission lines Examining the problem of computing steady state solutions in this context has led to a collection of novel numerical algorithms which we have gathered along with some background material into this book Although we wished to appeal to as broad an audience as possible to treat the subject in depth required maintaining a narrow focus Our compromise was to assume that the reader is familiar with basic numerical methods such as might be found in dahlquist74 or vlach83 but not assume any specialized knowledge of methods for steady state problems Although we focus on algorithms for computing steady state solutions of analog and microwave circuits the methods herein are general in nature and may find use in other disciplines A number of new algorithms are presented the contributions primarily centering around new approaches to harmonic balance and mixed frequency time methods These methods are described along with appropriate background material in what we hope is a reasonably satisfying blend of theory practice and results The theory is given so that the algorithms can be fully understood and their correctness established      Mixed-Mode Simulation Resve A. Saleh,A. Richard Newton,2012-12-06 Our purpose in writing this book was two fold First we wanted to compile a chronology of the research in the field of mixed mode simulation over the last ten to fifteen years A substantial amount of work was done during this period of time but most of it was published in archival form in Masters theses and Ph D dissertations Since the interest in mixed mode simulation is growing and a thorough review of the state of the art in the area was not readily available we thought it appropriate to publish the information in the form of a book Secondly we wanted to provide enough information to the reader so that a proto type mixed mode simulator could be developed using the algorithms in this book The SPLICE family of programs is based on the algorithms and techniques described in this book and so it can also serve as docu mentation for these programs ACKNOWLEDGEMENTS The authors would like to dedicate this book to Prof D O Peder son for inspiring this research work and for providing many years of support and encouragement The authors enjoyed many fruitful discus sions and collaborations with Jim Kleckner Young Kim Alberto Sangiovanni Vincentelli and Jacob White and we thank them for their contributions We also thank the countless others who participated in the research work and read early versions of this book Lillian Beck provided many useful suggestions to improve the manuscript Yun cheng Ju did the artwork for the illustrations      **Testing and Reliable Design of CMOS Circuits** Niraj K. Jha,Sandip Kundu,2012-12-06 In the last few years CMOS technology has become increas ingly dominant for realizing Very Large Scale Integrated VLSI circuits The popularity of this technology is due to its high den sity and low power requirement The ability to realize very com plex circuits on a single chip has brought about a revolution in the world of electronics and computers However the rapid advance ments in this area pose many new problems in the area of testing Testing has become a very time consuming process In order to ease the burden of testing many schemes for designing the circuit for improved testability have been presented These design for testability techniques have begun to catch the attention of chip manufacturers The trend is towards placing

increased emphasis on these techniques Another byproduct of the increase in the complexity of chips is their higher susceptibility to faults In order to take care of this problem we need to build fault tolerant systems The area of fault tolerant computing has steadily gained in importance Today many universities offer courses in the areas of digital system testing and fault tolerant computing Due to the impor tance of CMOS technology a significant portion of these courses may be devoted to CMOS testing This book has been written as a reference text for such courses offered at the senior or graduate level Familiarity with logic design and switching theory is assumed The book should also prove to be useful to professionals working in the semiconductor industry **Gallium Arsenide Digital Circuits** Omar Wing,2012-12-06 Gallium Arsenide technology has come of age GaAs integrated circuits are available today as gate arrays with an operating speed in excess of one Gigabits per second Special purpose GaAs circuits are used in optical fiber digital communications systems for the purpose of regeneration multiplexing and switching of the optical signals As advances in fabrication and packaging techniques are made the operat ing speed will further increase and the cost of production will reach a point where large scale application of GaAs circuits will be economical in these and other systems where speed is paramount This book is written for students and engineers who wish to enter into this new field of electronics for the first time and who wish to embark on a serious study of the subject of GaAs circuit design No prior knowledge of GaAs technology is assumed though some previous experience with MOS circuit design will be helpful A good part of the book is devoted to circuit analysis to the extent that is possible for non linear circuits The circuit model of the GaAs transistor is derived from first principles and analytic formulas useful in predicting the approxi mate circuit performance are also derived Computer simulation is used throughout the book to show the expected performance and to study the effects of parameter variations **Computational Electronics** Karl Hess,J.P. Leburton,U. Ravaioli,2013-03-14 Large computational resources are of ever increasing importance for the simulation of semiconductor processes devices and integrated circuits The Workshop on Computational Electronics was intended to be a forum for the dis cussion of the state of the art of device simulation Three major research areas were covered conventional simulations based on the drift diffusion and the hydrodynamic models Monte Carlo methods and other techniques for the solution of the Boltzmann transport equation and computational approaches to quantum transport which are relevant to novel devices based on quantum interference and resonant tunneling phenomena Our goal was to bring together researchers from various disciplines that contribute to the advancement of device simulation These include Computer Sci ence Electrical Engineering Applied Physics and Applied Mathematics The suc cess of this multidisciplinary formula was proven by numerous interactions which took place at the Workshop and during the following three day Short Course on Computational Electronics The format of the course including a number of tutorial lectures and the large attendance of graduate students stimulated many discussions and has proven to us once more the importance of cross fertilization between the different disciplines **Models for Large Integrated Circuits** Patrick DeWilde,Zhen-Qiu

Ning,2012-12-06 A modern microelectronic circuit can be compared to a large construction a large city on a very small area A memory chip a DRAM may have up to 64 million bit locations on a surface of a few square centimeters Each new generation of integrated circuit generations are measured by factors of four in overall complexity requires a substantial increase in density from the current technology added precision a decrease of the size of geometric features and an increase in the total usable surface The microelectronic industry has set the trend Ultra large funds have been invested in the construction of new plants to produce the ultra large scale circuits with utmost precision under the most severe conditions The decrease in feature size to submicrons 0 7 micron is quickly becoming availabl does not only bring technological problems New design problems arise as well The elements from which microelectronic circuits are build transistors and interconnects have different shape and behave differently than before Phenomena that could be neglected in a four micron technology such as the non uniformity of the doping profile in a transistor or the mutual capacitance between two wires now play an important role in circuit design This situation does not make the life of the electronic designer easier he has to take many more parasitic effects into account up to the point that his ideal design will not function as originally planned

**Subband Image Coding** John W. Woods,2013-06-29 This book concerns a new method of image data compression which weil may supplant the well established block transfonn methods that have been state of the art for the last 15 years Subband image coding or SBC was first perfonned as such in 1985 and as the results became known at first through conference proceedings and later through journal papers the research community became excited about both the theoretical and practical aspects of this new approach This excitement is continuing today with many major research laboratories and research universities around the world investigating the subband approach to coding of color images high resolution images video including video conferencing and advanced tele vision and the medical application of picture archiving systems Much of the fruits of this work is summarized in the eight chapters of this book which were written by leading practitioners in this field The subband approach to image coding starts by passing the image through a two or three dimensional filter bank The two dimensional 2 D case usually is hierarchical consisting of two stages of four filters each Thus the original image is split into 16 subband images with each one decimated or subsampled by 4x4 resulting in a data conservation The individual channel data is then quantized for digital transmission In an attractive variation an octave like approach herein tenned subband pyramid is taken for the decomposition resulting in a total of just eleven subbands *Circuit Analysis, Simulation and Design* Albert E. Ruehli,1987 This book covers algorithmic aspects of computer aided circuit design for VLSI of large circuits The large scale aspect of VLSI requires a reorientation towards new and more efficient techniques Many algorithms have survived the test of time while others are suffering from the usual problem of polynominal or exponential running time complexity and storage requirements The approaches presented in this book are techniques which were developed in response to the VLSI problems The most recent exact circuit analysis and simulation techniques are presented such as

waveform relaxation and timing simulation The book concentrates on the analysis and simulation of large circuits which exceed the capabilities of general purpose analyzers in both compute time and storage Also discussed are circuit models for switch level simulation techniques and circuit models for interconnections capacitance and inductances and optimization techniques The language and notation have been kept uniform throughout the book to help the reader to maintain the continuity between the topics discussed in the different chapters All algorithms are written in a Pascal style The terminology used should reflect the emerging language used in most of the VLSI circuit design community The book includes proven approaches as well as techniques which are presently in a research state      Digital Timing Macromodeling for VLSI Design Verification Jeong-Taek Kong,David V. Overhauser,1995-05-31 Digital Timing Macromodeling for VLSI Design Verification first of all provides an extensive history of the development of simulation techniques It presents detailed discussion of the various techniques implemented in circuit timing fast timing switch level timing switch level and gate level simulation It also discusses mixed mode simulation and interconnection analysis methods The review in Chapter 2 gives an understanding of the advantages and disadvantages of the many techniques applied in modern digital macromodels The book also presents a wide variety of techniques for performing nonlinear macromodeling of digital MOS subcircuits which address a large number of shortcomings in existing digital MOS macromodels Specifically the techniques address the device model detail transistor coupling capacitance effective channel length modulation series transistor reduction effective transconductance input terminal dependence gate parasitic capacitance the body effect the impact of parasitic RC interconnects and the effect of transmission gates The techniques address major sources of errors in existing macromodeling techniques which must be addressed if macromodeling is to be accepted in commercial CAD tools by chip designers The techniques presented in Chapters 4 6 can be implemented in other macromodels and are demonstrated using the macromodel presented in Chapter 3 The new techniques are validated over an extremely wide range of operating conditions much wider than has been presented for previous macromodels thus demonstrating the wide range of applicability of these techniques      *Modeling and Simulation* ,1989      **VLSI: Integrated Systems on Silicon** Ricardo A. Reis,Luc Claesen,1997-08-31 VLSI very large scale integration technology is evolving to the point where complete systems are being integrated on a single chip including ASICs embedded processing hardware and software control analog and digital signal processing sensors and actuators In addition there is a demand for many systems to be compact portable with wireless communication efficient production and low battery power operation This book presents novel developments addressing the conception design CAD and realization of such new systems Among the important issues presented are VLSI systems on a chip electronic design automation ultra low voltage and low power automatic synthesis VLSI applications The book comprises the selected proceedings of the International Conference on Very Large Scale Integration VLSI 97 which was sponsored by the International Federation for Information Processing IFIP and was held in Gramado Brazil in August 1997 It is a state of the book for researchers and

managers working on system integration design and CAD     *IMACS '91, 13th World Congress on Computation and Applied Mathematics* Robert Vichnevetsky,1991     <u>Bounding Enhancements for VLSI Circuit Simulation</u> Charles Albert Zukowski,1985     <u>The Transactions of the Institute of Electronics, Information and Communication Engineers</u> ,1988     <u>Proceedings of the ... Midwest Symposium on Circuits and Systems</u> ,1990     **Proceedings** ,1985     *IEEE International Symposium on Circuits and Systems* IEEE Circuits and Systems Society,1993     <u>IMACS '91</u> Robert Vichnevetsky,John James Henry Miller,1991

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