

Preface

Metal Oxide Semiconductor (MOS) transistors are the basic building block of MOS integrated circuits (IC). Very Large Scale Integrated (VLSI) circuits using MOS technology have emerged as the dominant technology in the semiconductor industry. Over the past decade, the complexity of MOS IC's has increased at an astonishing rate. This is realized mainly through the reduction of MOS transistor dimensions in addition to the improvements in processing. Today VLSI circuits with over 3 million transistors on a chip, with effective or electrical channel lengths of 0.5 microns, are in volume production. Designing such complex chips is virtually impossible without simulation tools which help to predict circuit behavior before actual circuits are fabricated. However, the utility of simulators as a tool for the design and analysis of circuits depends on the adequacy of the device models used in the simulator. This problem is further aggravated by the technology trend towards smaller and smaller device dimensions which increases the complexity of the models.

There is extensive literature available on modeling these short channel devices. However, there is a lot of confusion too. Often it is not clear what model to use and which model parameter values are important and how to determine them. After working over 15 years in the field of semiconductor device modeling, I have felt the need for a book which can fill the gap between the theory and the practice of MOS transistor modeling. This book is an attempt in that direction.

The book deals with the MOS Field Effect transistor (MOSFET) models that are derived from basic semiconductor theory. Various models are developed ranging from simple to more sophisticated models that take into account new physical effects observed in submicron devices used in today's MOS VLSI technology. The assumptions used to arrive at the models are emphasized so that the accuracy of the model in describing the device characteristics are clearly understood. Due to the importance of designing reliable circuits, device reliability models have also been covered. Understanding these models is essential when designing circuits for state of the art MOS IC's.

Extracting the device model parameter values from device data is a very important part of device modeling which is often ignored. In this book the first detailed presentation of model parameter determination for MOS models is given. Since the device parameters vary due to inherent processing variations, how to arrive at worst case design parameters which ensure maximum yield is covered in some detail.

Presentation of the material is such that even an undergraduate student not well familiar with semiconductor device physics can understand the intricacies of MOSFET modeling. Chapter 1 deals with the overview of various aspects of device modeling for circuit simulators. Chapter 2 is a brief but complete (for understanding MOSFET models) review of semiconductor device physics and *pn* junction theory. The MOS transistor characteristics as applied to current MOS technologies are discussed in Chapter 3. The theory of MOS capacitors that is essential for the understanding of MOS models are covered in Chapter 4. Different MOSFET models, such as threshold voltage, DC (steady-state), AC and reliability models are the topic of discussion in Chapters 5, 6, 7 and 8, respectively. Chapters 9 and 10 deal with data measurements and model parameter extraction. The diode and MOSFET models implemented in Berkeley SPICE, a defacto industry standard circuit simulator, are covered in Chapter 11. Finally, the statistical variation of model parameters due to process variations are covered in Chapter 12.

It is my sincere hope that this book will serve as a technical source in the area of MOSFET modeling for state of the art MOS technology for both practicing device and circuit engineers and engineering students interested in the said area.

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