This book describes the structure of simulators suitable for use in the design of digital electronic systems. Such systems are increasing rapidly in size and complexity, and the use of simulation provides a means to 'prototype' a design without ever building hardware. Other advantages over hardware prototyping are that sections of a design can be simulated in isolation, and that all internal signals are available.

This book includes the compiled code and event driven algorithms for digital electronic system simulators, together with timing verification. Limitations of the structures are also discussed. An introduction to the problems of designing models is included, partly to point to how user models might be constructed for application specific integrated circuits (ASICs) and so on, and partly to expose the limitations of the modelling process.

Simulators have two functions. The first is to confirm so far as possible that a design meets its specification. The second is to check if the test program will find a sufficient percentage of possible manufacturing faults. In the former case the user must supply test vectors. In the latter, tests can be generated by automatic means. As a guide to the use of simulators the book includes chapters which introduce the subjects of testing and design for testability. A major chapter is devoted to fault simulation. Finally, the text has an introduction to hardware accelerators and modellers.

The book is suitable for electronic engineers using digital techniques, including undergraduates using design software, and postgraduates and practising engineers using simulation for the first time. It will also be useful for computer scientists needing an introduction to simulation techniques.

Electronics texts for engineers and scientists

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Simulation in the design of digital electronic systems

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Preface

In attempting to come to grips with the problem of designing a simulator the author found very little in the way of overall descriptions of what a simulator is, what it does or how it works. The required information can be winkled out from many different sources, but not all are easily available. This book is an attempt to bring together in one place a comprehensive introduction to all aspects of simulation in the design of digital electronic systems.

The text begins with an introduction to the purpose of simulation, types of simulation and some of the problems that are encountered in the use and design of simulators. It continues with a brief review of computer aided design suites in order to set simulation within its overall context.

In order to use a simulator it is necessary to prepare test information. To get the best out of the simulator it is necessary to adopt good design techniques. Hence the next two chapters give an introduction to design for testability and to test program generation. These are followed by a brief description of the preparation of test programs using the VHPIC high level design language (VHDL). These three chapters are just an introduction for completeness in the book as a whole, and the reader is referred to much more comprehensive texts for a proper treatment.

Chapters 6 to 9 are the meat of this work. Chapter 6 describes the two main types of straightforward simulator and gives some examples of their use. That is followed by a description of a method by which the necessary models can be written. Chapter 8 deals with timing verification and Chapter 9 with fault simulation. So far as is known this is the only introduction to modelling or to timing verification in one place. Chapter 6 is also the most comprehensive description of simulators known.

Whilst in some ways Chapters 4 and 9 go together, the topics are put in the order as here because that is the order in which the user would meet the techniques in a typical design exercise. That is to say, a designer must consider design for test and testability very early, but will then do much functional simulation before beginning the test program generation and fault simulation in earnest.

Although mentioned in Chapter 1, circuit simulation and switch level modelling are not described in detail. Circuit simulation uses very different techniques to digital work and is beyond the scope of this book. Much switch level simulation can be handled by the techniques described in Chapters 6, 8 and 9, but some additional modelling considerations become important. Some hints to these are given but a full description is omitted for brevity.

The intended readership is undergraduates in Electrical and Computer Engineering and those studying computer aided design of electronic systems in Computer Science. It is aimed at both users of simulators and at those who may wish eventually to be involved in their design. Whilst some sections of the book will be more important to one group and other parts to a different group, the whole book is relevant to all. An understanding of the working of the simulator will lead to better use of it, and an understanding of the needs of users will lead to better design. In particular, whilst users will normally use models supplied with the CAD suite, they will still have to write high level models for their own design, possibly at a fairly detailed level.

A minimum of assumptions about the knowledge of the reader has been made. The primary assumptions are that the reader understand the basic operation of a gate and a flip-flop, although Chapter 1 contains a brief description of the working of a flip-flop. It is assumed that the reader understands the concept of there being a delay between application of an input to a circuit and the output changing. An indication of how this can become more complex is given. An awareness of the concepts of set-up and hold time would be helpful but not essential. Attention is drawn to the distinction between the terms 'latch' and 'flip-flop' given as a footnote in Section 3.2.

Some understanding of simple computer data structures will be helpful, as will some elementary knowledge of electronic circuits – current flow, input and output limitations etc. In both cases readers without this knowledge will need to take some statements on trust but should not find the lack of background serious. Diagrams of logical devices more complex than a gate are very few and use the dependency notation. Readers unfamiliar with this should investigate it as it makes the function of

modules very easy to understand.

Conventional drawing conventions are assumed. That is, signal flow is left to right and top to bottom unless otherwise indicated. Logic is drawn as nearly as possible to the IEEE standard on dependency notation. Digital signals are usually written as *1* or *0* as appropriate to indicate 'active' and 'inactive' respectively. Signal values are written in italic fount to distinguish from numbers or literal signal names.

Some of the references are used in the text, but others are added as pointers to additional reading. In many cases some comments are included. The selection of references is inevitably that of the author. It is limited to those which describe basic ideas well or which, in the author's opinion, are most likely to be of long term use. Since early papers often come into the former category there are rather more of them than might seem proper at first sight.

There are no tutorial questions provided as such. As Chapters 3 to 5 are introductory only, the reader should refer to specialist texts. In Chapters 6 to 9 some simple examples such as full adders or even just a two to one multiplexer can be used. It is not difficult to work out from knowledge of these devices what results the simulation and model should give and thus provide a check on the working of the example. In some places, notably in Chapter 9, some extensions of the example in the text are suggested and results provided.

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The author owes a considerable debt to Miss Hilary J. Kahn of the University of Manchester, with whom he has worked both as a user and as a designer of simulators over many years. Dr Andrew F. Carpenter, also at Manchester, has commented on the initial text and has assisted with a number of matters, in particular with the VHDL and fault simulator work. Daniel Cock also made several very important contributions in relation to fault simulators. Peter L. Jones, the publisher's series editor and another former colleague in Manchester has been most helpful throughout. The University of Manchester (through Dr Carpenter) has also provided facilities to check the VHDL and to check the models by use of VHDL. Lastly, the author's wife has suffered much and long in the process of getting the text to market.

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