INTRODUCTION TO DIGITAL SYSTEMS

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Modeling, Synthesis, and Simulation Using VHDL

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PREFACE

Digital system design requires rigorous modeling and simulation analysis that eliminates design risks and potential harm to users. Thus, the educational objective of this book is to provide an introduction to digital system design through modeling, synthesis, and simulation computer-aided design (CAD) tools. This book provides an introduction to analytical and computational methods that allow students and users to model, synthesize, and simulate digital principles using very high-speed integrated-circuit hardware description language (VHDL) programming. We present the practical application of modeling and synthesis to digital system design to establish a basis for effective design and provide a systematic tutorial of how basic digital systems function. In doing so, we integrate theoretical principles, discrete mathematical models, computer simulations, and basics methods of analysis. Students and users will learn how to use modeling, synthesis, and simulation concepts and CAD tools to design models for digital systems that will allow them to gain insights into their functions and the mechanisms of their control. Students will learn how to integrate basic models into more complex digital systems. Although the approach designed in this book focuses on undergraduate students, it can also be used for modeling and simulation students who have a limited engineering background with an inclination to digital systems for visualization purposes.

The book includes nine chapters. Each chapter begins with learning objectives that provide a brief overview of the concepts that the reader is about to learn. In addition, the learning objectives can be used as points for classroom discussion. Each chapter ends with problems that will enable students to practice and review the concepts covered in the chapter. Chapter 1 introduces modeling and simulation and its role in digital system evolution. The chapter provides a brief history of modeling and simulation in digital systems, VHDL programming, programmable and reconfigurable systems, and advantages of using modeling and simulation in digital system design. Chapter 2 introduces the mathematical foundations of digital systems and logical reasoning. Described are Boolean theory, its axioms and theorems, and basic logic gates as well as early modeling in digital system design using algebraic manipulations.

Chapter 3 provides an overview of number representations, number conversions, and number codes. The relationships between decimal representation and the less obvious digital number representations are described. Chapter 4 provides a brief history of VHDL programming, the reasons for its creation, and its impact on the evolution of digital systems and modern computer systems. Described are CAD tools, programming structure, and instructions and syntax of VHDL. Chapter 5 provides a simplified view of the progression of integrated systems and their application in

digital logic circuits and computer systems. The role of modeling and simulation in the optimization and verification of digital system design at the transistor level is described. Chapter 6 provides graphical means and Karnaugh maps to streamline and simplify digital system design using visualization schemes. Although these methods are used only when designing circuits with a small number of gates, they provide rudimentary means for the design of automatic CAD tools.

Chapter 7 introduces combinational logic and its applications in multiplexers, decoders, and arithmetic and logic circuits and systems. Chapter 8 introduces sequential logic, with a focus on sequential logic elementary circuits and their applications in complex circuits such as counters and registers. Chapter 9 provides an overview of finite-state machines, especially the synchronous sequential circuit models used to design simple finite-state machines. Also described is asynchronous sequential logic and its advantages and disadvantages for digital systems. All chapters illustrate circuit design using VHDL sample codes that allow students not only to learn and master VHDL programming but also to model and simulate digital circuits.

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