

FOUNDATIONS OF DIGITAL ELECTRONICS

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Preface

This text is a product of lectures conducted by the author for undergraduate students in the Department of Electrical and Electronic Engineering at the University of Nairobi and at the School of Electrical and Electronic Engineering at the University of Natal. It covers the necessary foundation topics in both combinational and sequential logic design. The text is enhanced by an intensive presentation of the operating principles and characteristics of logic families. The material in this book has been used successfully as a first course in Digital Electronics for students with a basic understanding of electric circuits and semiconductor physics. The text will be of interest to undergraduate students in Physics and in Computer Science. It is also expected that diploma students taking the Electrical and Electronic Engineering course in polytechnics and other institutions will find the text extremely useful.

The chapter-by-chapter contents of the book are described below:

Chapter 1: Number Systems and Codes. This chapter presents the binary number system. It includes both the signed and the unsigned number schemes and the associated arithmetic operations. The chapter also presents the Octal and the Hex number systems, and the number codes such as the Gray, Excess-3, and the BCD. Popular character codes such as the ASCII, and the EBCDIC formats are described. A brief presentation of the floating point format is also given.

Chapter 2: Basic Combinational Logic Circuits. The chapter opens with a discussion on the elements of Boolean algebra and the application to simple switching circuits. The Karnaugh map is an established method of simplifying logic expressions and hence useful in the synthesis of logic circuits. It is given a detailed presentation in this chapter. The formulation of logic expressions as either sum-of-products or product-of-sums, which leads to NAND-NAND or to NOR-NOR implementation are given adequate coverage. A simple method of removing logic hazards is presented.

Chapter 3: Logic Families. The three main families of interest here are the TTL, ECL, and CMOS. Each of these families, and in some cases the sub-families too, is presented through the analysis of the circuits at the component level. The characteristics of the families in terms of power dissipation, propagation delay, fabrication density, logic levels, noise margins, and fan-out, are presented so as to give a basis for comparison between the three families. The interfacing of CMOS to TTL and TTL to CMOS is also covered.

Chapter 4: Combinational Logic Modules. This chapter provides a detailed coverage of combinational logic modules such as multiplexers, demultiplexers, decoders, encoders,

magnitude comparators, adders, code converters, and parity devices. The gate level implementation of each of these modules is presented so as to give a clear understanding of the operating principles. The implementation of higher capacity modules from lower capacity devices is discussed using several examples. The use of these devices in logic design is presented throughout the chapter.

Chapter 5: Flip-flops. In this chapter, the flip-flops, which are regarded as one of the basic building blocks for sequential logic circuits, are presented. The gate level circuits of the SR, JK, D, and T flip-flops are analysed. The use of characteristic tables, excitation tables, and state diagrams in the description of flip-flops is discussed with the aid of several examples. Two flip-flop applications, i.e. registers and counters, that are extensively discussed in later chapters are introduced.

Chapter 6: Counters. The chapter opens with a general description of a state machine using a state diagram. The design method presented here is based on the translation of the state diagram into a state table followed by deduction of an excitation table from the state diagram. The Boolean functions that describe the sequential circuit are obtained from the excitation table. This procedure is used for both Mealy and Moore state machines. The design of synchronous counters and the ripple counters is also discussed.

Chapter 7: Shift Registers. In this chapter, shift registers are introduced as sequential circuits realised from flip-flop elements. In particular, the following types of shift registers are presented: serial input, parallel-input, and the universal shift register. In addition, the Johnson shift register counter and the ring shift registers counter are discussed. A discussion of the use of shift registers in arithmetic circuits and in the generation of sequences is also included in the chapter.

Chapter 8: Semiconductor Memories. An introduction to semiconductor memories, and the basis of classification of memory types is given. The internal configuration and functional behaviour of the various devices are discussed. The timing diagrams form a central part of the presentation of the operating principles of these devices. The chapter assumes a good understanding of the material covered in Chapter 3 on logic families.

Chapter 9: Programmable Logic Devices. This chapter introduces Programmable Logic Devices (PLDs) which have now become an established method of digital systems design. In the chapter, simple programmable devices that can be used to replace many of the combinational and sequential logic modules discussed in Chapter 4, Chapter 6, and Chapter 7 of the book. Emphasis is on PALs and GALs and the use of ABEL hardware descriptive language in the design of a digital system.

Chapter 10: IEEE/ANSI Logic Symbols. The standard logic symbols, as approved by the Institute of Electrical and Electronic Engineers (IEEE) and the American National Standards Institute (ANSI) are presented. The discussion includes basic gates, decoders, multiplexers, demultiplexers, adders, comparators, flip-flops, registers, counters, and memory devices. The material in this chapter aims to help the reader in identifying and using various components that are found in design data books and catalogues.

Course Organisation

The material in this book can be presented as a course for one semester if teaching is done for four hours per week. A shorter 10 days course can also be offered if lectures are held for six hours per day. If the students have a prior understanding of number systems and codes, then the material in Chapter 1 can be omitted or assigned for self-study for those who may wish to review concepts. The contents of Chapter 3 on logic families can be taught much later as long as the presentation is given before the contents of Chapter 8 on semiconductor memories. It is also possible to skip most of the contents in logic families especially for students of computer science.

There are several worked examples in every chapter. These examples together with the end-of-chapter problems serve to strengthen understanding of the subject matter. It is therefore recommended that all the problems should be attempted. The instructor can also use some of the problems as the basis of laboratory experiments. The answers to odd numbered end-of-chapter problems are also given. Instructors who adopt this text can obtain a complete set of solutions from the author through the publisher. A list of recommended books for further reading is given in the bibliography.