Fundamentals of Logic Design

Fourth Edition

Charles H. Roth, Jr.

▪ FOURTH EDITION

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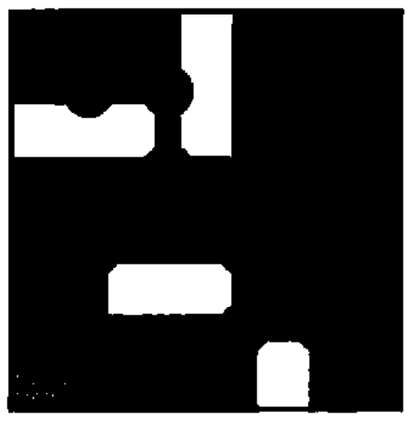

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Preface

After studying this text, you should be able to apply switching theory to the solution of logic design problems. This means that you will learn both the basic theory of switching networks and how to apply it. After a brief introduction, you will study Boolean algebra, which provides the basic mathematical tool needed to analyze and synthesize an important class of switching networks. Starting from a problem statement, you will learn to design networks of logic gates which have a specified relationship between signals at the input and output terminals. Then you will study the logical properties of flip-flops, which serve as memory devices in sequential switching networks. By combining flip-flops with networks of logic gates, you will learn to design counters, adders, sequence detectors and similar networks.

This text is designed so that it can be used in either a standard lecture course or in a self-paced course. In addition to the standard reading material and problems, study guides and other aids for self-study are included in the text. The content of the text is divided into 27 study units. These units form a logical sequence so that mastery of the material in one unit is generally a prerequisite to the study of succeeding units. Each unit consists of four parts. First, a list of objectives states precisely what you are expected to learn by studying the unit. Next, the study guide contains reading assignments and study questions. As you work through the unit, you should write out the answers to these study questions. The text material and problem set which follow are similar to a conventional textbook.

When you complete a unit, you should review the objectives and make sure that you have met them.

The 27 study units are divided into three main groups. The first 10 units treat Boolean algebra and the design of combinational logic networks. Units 11 through 22 are mainly concerned with the analysis and design of clocked sequential logic networks, including networks for arithmetic operations. Units 23 through 27 cover the special problems encountered in the analysis and design of asynchronous sequential networks. The first 21 units can typically be covered in a one semester course taught at the Sophomore or Junior level. The remaining units can then be used as enrichment material for the better students, or they can be covered in the first part of a second course in digital systems design.

Several of the units include simulation or laboratory exercises. These exercises provide an opportunity to design a logic network and then test its operation. A number of logic simulators, which run on personal computers, may be used to verify the logic designs. The lab equipment required for testing includes a logic patchboard with flip-flops and several types of logic gates. If such equipment is not available, the lab exercises can be simulated or just assigned as design problems. This is especially important for Units 10, 16, and 27 since the comprehensive design problems in these units help to review and tie together the material in several of the preceding units.

This text is written for a first course in the logic design of digital systems. It is written on the premise that the student should understand and learn thoroughly certain fundamental concepts in a first course. Examples of such fundamental concepts are the use of Boolean algebra to describe the signals and interconnections in a logic network, use of systematic techniques for simplification of a logic network, interconnection of simple components to perform a more complex logic function, analysis of a sequential logic network in terms of timing charts or a state graph, and use of a control network to control the sequence of events in a digital system.

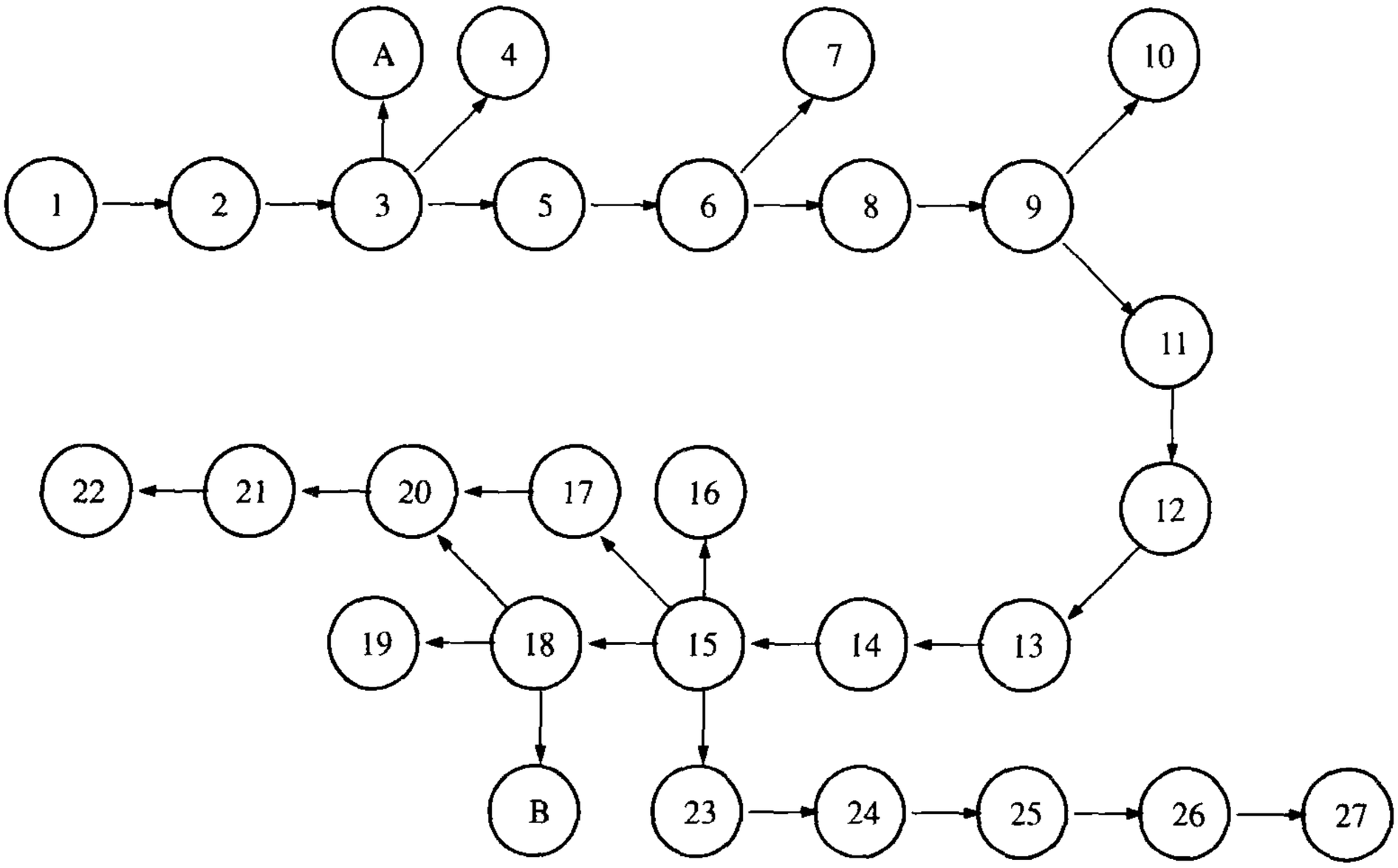
The text attempts to achieve a balance between theory and application. For this reason, the text does not overemphasize the mathematics of switching theory; however, it does present the theory which is necessary for understanding the fundamental concepts of logic design. After completing this text, the student should be prepared for a more advanced digital systems design course which stresses more intuitive concepts like the development of algorithms for digital processes, partitioning of digital systems into subsystems, and implementation of digital systems using currently available hardware. Alternatively, the student should be prepared to go on to a more advanced course in switching theory which further develops the theoretical concepts which have been introduced here.

Although the technology used to implement digital systems has changed significantly since the first edition of this text was published, the fundamental principles of logic design have not. Truth tables and state tables are still used to specify the behavior of logic networks, and Boolean algebra is still a basic mathematical tool for logic design. Even though programmable logic devices (PLDs) may be used instead of individual gates and flip-flops, reduction of logic equations is still necessary in order

to fit the equations into a small number of PLDs. Making a good state assignment is still required, because without a good assignment, the logic equations may not fit into one of the available PLDs.

This new edition offers a number of improvements over the third edition. Mixed logic and direct polarity notation are introduced and used for analysis and design of logic networks. Greater emphasis is placed on the use of programmable logic devices, and programmable gate arrays are introduced. The role of simulation and computer-aided design is discussed. New exercises and problems have been added to every unit, and several sections have been rewritten to clarify the presentation.

The text is suitable for both computer science and engineering students. All material relating to circuit aspects of logic gates is contained in Appendix A so that this material can conveniently be omitted by computer science students or other students with no background in electronic circuits. The text is organized so that Unit 4 on Algebraic Simplification and Unit 7 on the Quine-McCluskey procedure may be omitted without loss of continuity. Instructors who wish to place less emphasis on logic simplification can omit one or both of these units to allow more time for study of digital design techniques presented in the later units. The following diagram illustrates the unit prerequisite structure for the fourth edition:



Although many texts are available in the areas of switching theory and logic design, this text was developed specifically to meet the needs of a self-paced course in which students are expected to study the material on their own. Each of the units has undergone extensive class testing in a self-paced environment and has been revised based on student feedback.

Study guides and text material have been expanded as required so that students can learn from the text without the aid of lectures and so that almost all of the students can achieve mastery of all of the objectives. Supplementary materials were developed as the text was being written. An instructor's manual is available which includes suggestions for using the text in a standard or self-paced course, quizzes on each of the units, and suggestions for laboratory equipment and procedures. The instructor's manual also contains solutions to problems, to unit quizzes, and to lab exercises.

Since the computer plays an important role in the logic design process, integration of computer usage into the first logic design course is highly desirable. A computer-aided logic design program, called *LogicAid*™, is suggested for use with this textbook. *LogicAid* allows the student to easily derive simplified logic equations from minterns, truth tables, and state tables. This relieves the student of some of the more tedious computations and permits the solution of more complex design problems in a shorter time. *LogicAid* also provides tutorial help for Karnaugh maps and derivation of state graphs.

How to Use This Book for Self-Study

If you wish to learn all of the material in this text to mastery level, the following study procedures are recommended for each unit:

1. Read the *Objectives* of the unit. These objectives provide a concise summary of what you should be able to do when you complete study of the unit.
2. Work through the *Study Guide.* After reading each section of the text, *write* out the answers to the corresponding study guide questions. In many cases, blank spaces are left in the study guide so that you can write your answers directly in this book. By doing this, you will have the answers conveniently available for later review. The study guide questions will generally help emphasize some of the important points in each section or will guide you to a better understanding of some of the more difficult points. If you cannot answer some of the study guide questions, this indicates that you need to study the corresponding section in the text more before proceeding. The answers to selected study guide questions are given in the back of this book; answers to the remaining questions can generally be found within the text.
3. Several of the units (Units 3, 4, 6, 7, 11, 13, 14, 21, 24, and 25) contain one or more programmed exercises. Each programmed exercise will guide you step-by-step through the solution of one of the more difficult types of problems encountered in this text. When working through a programmed exercise, be sure to write down your answer

for each part in the space provided before looking at the answer and continuing with the next part of the exercise.

4. Work the assigned *Problems* at the end of the unit. Check your answers against those at the end of the book and rework any problems which you missed.
5. Reread the *Objectives* of the unit to make sure that you can meet all of them. If in doubt, review the appropriate sections of the text.
6. If you are using this text in a self-paced course, you will need to pass a readiness test on each unit before proceeding with the next unit. The purpose of the readiness test is to make sure that you have mastered the objectives of one unit before moving on to the next unit. The questions on the test will relate directly to the objectives of the unit, so that if you have worked through the study guide and written out answers to all of the study guide questions and to all of the problems, you should have no difficulty passing the test.

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