Preface

Welcome to Digital Fundamentals, Ninth Edition. A strong foundation in the core fundamentals of digital technology is vital to anyone pursuing a career in this exciting, fast-paced industry. This text is carefully organized to include up-to-date coverage of topics that can be covered in their entirety, used in a condensed format, or omitted altogether, depending upon the course emphasis.

The topics in this text are covered in the same clear, straightforward, and well-illustrated format that has been so successful in the previous editions of Digital Fundamentals. Many topics have been strengthened or enhanced and numerous improvements can be found throughout the book.

You will probably find more topics than you can cover in a single course. This range of topics provides the flexibility to accommodate a variety of program requirements. For example, some of the design-oriented or system application topics may not be appropriate in some courses. Other programs may not cover programmable logic, while some may not have time to include topics such as computers, microprocessors, or digital signal processing. Also, in some courses there may be no need to go into the details of "inside-the-chip" circuitry. These and other topics can be omitted or lightly covered without affecting the coverage of the fundamental topics. A background in transistor circuits is not a prerequisite for this textbook although coverage of integrated circuit technology (inside-the-chip circuits) is included in a "floating chapter," which is optional.

Following this Preface is a color-coded table of contents to indicate a variety of approaches for meeting most unique course requirements. The text has a modular organization that allows inclusion or omission of various topics without impacting the other topics that are covered in your course. Because programmable logic continues to grow in importance, an entire chapter (Chapter 11) is devoted to the topic, including PALs, GALs, CPLDs, and FPGAs; specific Altera and Xilinx devices are introduced. Also a generic introduction to programmable logic software is provided and boundary scan logic is covered.

New in This Edition

- The Hamming error detecting and correcting code
- Carry look-ahead adders
- A brief introduction to VHDL
- Expanded and improved coverage of test instruments
- An expanded and reorganized coverage of programmable logic
- Improved troubleshooting coverage
- New approach to Digital System Applications

Features

- Full-color format
- Margin notes provide information in a very condensed form.
- Key terms are listed in each chapter opener. Within the chapter, the key terms are in boldface color. Each key term is defined at the end of the chapter, as well as at the end of the book in the comprehensive glossary along with other glossary terms that are indicated by black boldface in the text.
Chapter 14 is designed as a “floating chapter” to provide optional coverage of IC technology (inside-the-chip circuitry) at any point in your course.

Overview and objectives in each chapter opener

Introduction and objectives at the beginning of each section within a chapter

Review questions and exercises at the end of each section in a chapter

A Related Problem in each worked example

Computer Notes interspersed throughout to provide interesting information about computer technology as it relates to the text coverage

Hands-On Tips interspersed throughout to provide useful and practical information

The Digital System Application is a feature at the end of many chapters that provides interesting and practical applications of logic fundamentals.

Chapter summaries at the end of each chapter

Multiple-choice self-test at the end of each chapter

Extensive sectionalized problem sets at the end of each chapter include basic, troubleshooting, system application, and special design problems.

The use and application of test instruments, including the oscilloscope, logic analyzer, function generator, and DMM, are covered.

Chapter 12 provides an introduction to computers.

Chapter 13 introduces digital signal processing, including analog-to-digital and digital-to-analog conversion.

Concepts of programmable logic are introduced beginning in Chapter 1.

Specific fixed-function IC devices are introduced throughout.

Chapter 11 provides a coverage of PALs, GALs, CPLDs and FPGAs as well as a generic coverage of PLD programming.

Selected circuit diagrams in the text, identified by the special icon shown here, are rendered in Multisim® 2001 and Multisim® 7, and these circuit files are provided on the enclosed CD-ROM. These files (also available on the Companion Website at www.prenhall.com/floyd) are provided at no extra cost to the consumer and are for use by anyone who chooses to use Multisim software. Multisim is widely regarded as an excellent simulation tool for classroom and laboratory learning. However, successful use of this textbook is not dependent upon use of the circuit files.

Boundary scan logic associated with programmable devices is introduced in Chapter 11.

In addition to boundary scan, troubleshooting coverage includes methods for testing programmable logic, such as traditional, bed-of-nails, and flying probe. Boundary scan and these other methods are important in manufacturing and industry.

For those who wish to include ABEL programming, an introduction is provided on the Companion Website at www.prenhall.com/floyd.
Accompanying Student Resources

- Two CD-ROMs included with each copy of the text:
  - Circuit files in Multisim for use with Multisim software
  - Texas Instruments digital devices data sheets

Instructor Resources

- PowerPoint® slides. These presentations feature Lecture Notes and figures from the text. (On CD-ROM and online.)
- Companion Website. ([www.prenhall.com/floyd](http://www.prenhall.com/floyd)). For the instructor, this website offers the ability to post your syllabus online with our Syllabus Manager™. This is a great solution for classes taught online, that are self-paced, or in any computer-assisted manner.
- Instructor’s Resource Manual. Includes worked-out solutions to chapter problems, solutions to Digital System Applications, a summary of Multisim simulation results, and worked-out lab results for the lab manual by David M. Buchla. (Print and online.)
- Test Item File. This edition of the Test Item File features over 900 questions.
- TestGen.® This is an electronic version of the Test Item File, enabling instructors to customize tests for the classroom.

To access supplementary materials online, instructors need to request an instructor access code. Go to [www.prenhall.com](http://www.prenhall.com), click the Instructor Resource Center link, and then click Register Today for an instructor access code. Within 48 hours after registering you will receive a confirming e-mail including an instructor access code. Once you have received your code, go to the website and log on for full instructions on downloading the materials you wish to use.

Illustration of Chapter Features

**Chapter Opener**

Each chapter begins with a two-page spread, as shown in Figure P–1. The left page includes a list of the sections in the chapter and a list of chapter objectives. A typical right page includes an overview of the chapter, a list of specific devices introduced in the chapter (each new device is indicated by an IC logo at the point where it is introduced), a brief Digital System Application preview, a list of key terms, and a website reference for chapter study aids.

**Section Opener**

Each of the sections in a chapter begins with a brief introduction that includes a general overview and section objectives. An illustration is shown in Figure P–2.

**Section Review**

Each section ends with a review consisting of questions or exercises that emphasize the main concepts presented in the section. This feature is shown in Figure P–2. Answers to the Section Reviews are at the end of the chapter.
FUNCTIONS OF COMBINATIONAL LOGIC

CHAPTER OBJECTIVES
- Implement a basic binary decoder
- Use BCD-to-7-segment decoders in display systems
- Apply a decimal-to-BCD priority encoder in a simple keypad application
- Convert from binary-to-Gray code, and Gray code to binary by using logic devices
- Apply multiplexers to data selection, multiplexer displays, logic function generation, and simple communications systems
- Use decoders to demultiplex
- Explain the meaning of parity
- Use parity generation and checkers to detect bit errors in digital systems
- Implement a simple data communications system
- Identify glitches, common bugs in digital systems

6-11 Troubleshooting

Digital System Application

A FIGURE P-1
Chapter opener.

Worked Examples and Related Problems
An abundance of worked examples help to illustrate and clarify basic concepts or specific procedures. Each example ends with a Related Problem that reinforces or expands on the example by requiring the student to work through a problem similar to the example. A typical worked example with a Related Problem is shown in Figure P-3.

Troubleshooting Section
Many chapters include a troubleshooting section that relates to the topics covered in the chapter and that emphasizes troubleshooting techniques and the use of test instruments. A portion of a typical troubleshooting section is illustrated in Figure P-4.

Digital System Application
Appearing at the end of many chapters, this feature presents a practical application of the concepts covered in the chapter. This feature presents a "real-world" system in which analysis, troubleshooting, and design elements are implemented using procedures covered in the chapter. Some Digital System Applications are limited to a single chapter and others extend over two or more chapters. Specific Digital System Applications are as follows:

- Tablet counting and control system: Chapter 1
- Digital display: Chapters 4 and 11.
- Storage tank control system: Chapter 5
FIGURE P-2
Section opener and section review.

Review exercises end each section.

Introductory paragraph and a list of performance-based section objectives begin each section.

Computer Notes are found throughout the text.

A special icon indicates selected circuits that are on the CD-ROM packaged with the text.

Examples are set off from text.

Each example contains a problem related to the example.

FIGURE P-3
An example and related problem.

An example and related problem.

The AND gate is one of the basic gates that can be combined to form a logic function. An AND gate combiner two or more inputs and produces a low output only when all inputs are high. The logic symbol is a parallelogram with connected corners. The gates has two inputs and one output, and an AND gate has any number of inputs. The symbol for an AND gate is shown in Fig. 3-2(b). The distinctive shape symbol is shown in part (a) and is prominent in the text.

The truth table is used to define a circuit that performs a basic logic function. The AND gate is composed of two or more inputs and a single output, as indicated by the standard logic symbol shown in Fig. 3-1(a). The inputs are denoted as A and B, and the output is denoted as Y. The AND gate produces a HIGH output only when all inputs are HIGH. The logic equation for an AND gate is:

\[ Y = A \cdot B \]

For a 2-input AND gate, the output is HIGH (1) if both inputs A and B are LOW (0), or both input A and B are HIGH (1). A truth table can be developed from the AND-OR truth table in Table 5-1 by simply changing all LOWs to HIGH and all HIGHs to LOW.

EXAMPLE 5-2
Write the Boolean expression for the AND-OR-Invert logic in Fig. 5-4 and show that the output is HIGH (1) when any two of the inputs A, B, and C are LOW (0).

The logic diagram in Fig. 5-4 shows an AND-OR-Invert circuit and the development of the logic expression. The AND-OR-Invert circuit is composed of an AND gate followed by an inverter. The output of the AND gate is connected to the input of the inverter, and the output of the inverter is the final output of the circuit.

For a 3-input AND-OR-Invert circuit, the output is HIGH (1) if any two inputs A, B, and C are LOW (0) or all inputs A, B, and C are HIGH (1).

Two inputs A and B are used to control the operation of a single AND gate. The AND gate produces a HIGH output only when both inputs A and B are HIGH (1). The logic equation for an AND gate is:

\[ Y = A \cdot B \]

The truth table for a 2-input AND gate is shown in Table 3-1. The inputs are denoted as A and B, and the output is denoted as Y. The AND gate produces a HIGH output only when both inputs A and B are HIGH (1). The logic equation for an AND gate is:

\[ Y = A \cdot B \]

The logic diagram in Fig. 5-3 shows an AND-OR-Invert circuit and the development of the logic expression. The AND-OR-Invert circuit is composed of an AND gate followed by an inverter. The output of the AND gate is connected to the input of the inverter, and the output of the inverter is the final output of the circuit.

For a 3-input AND-OR-Invert circuit, the output is HIGH (1) if any two inputs A, B, and C are LOW (0) or all inputs A, B, and C are HIGH (1).

EXAMPLE 5-2
Write the Boolean expression for the AND-OR-Invert logic in Fig. 5-4 and show that the output is HIGH (1) when any two of the inputs A, B, and C are LOW (0).
Troubleshooting is the process of recognizing, isolating, and correcting a fault or failure in a circuit or system. To be an effective troubleshooter, you must understand how the circuit or system is supposed to work and be able to recognize incorrect performance. For example, to determine whether or not a certain logic gate is faulty, you must know what the output should be for given inputs.

After completing this section, you should be able to:
- Troubleshoot internal input and output failures in IC gates.

Representative pages from a portion of a typical Troubleshooting section.

- Traffic light control system: Chapters 6, 7, and 8
- Security system: Chapters 9 and 10

Digital System Applications may be treated as optional because omitting them will not affect any other material in the text. Figure P-5 shows a portion of a Digital System Application feature.

Chapter End

The following study aids end each chapter:
- Summary
- Key term glossary
- Self-test
- Problem set that includes some or all of the following categories: Basic, Troubleshooting, Digital System Application, Design, and Multisim Troubleshooting Practice
- Answers to Section Reviews
- Answers to Related Problems for Examples
- Answers to Self-Test

Book End

- Appendices: Code conversion and table of powers of two (Appendix A) and traffic light interface circuits (Appendix B)
In this digital system application, you begin working with a traffic light control system. In the section, the system requirements are established, a general block diagram is developed, and a state diagram is created to define the sequence of operation common to all signals and the methods of testing are considered. The testing of unexpected conditions of the system will be dealt with in Chapter 3 and 5.

**General System Requirements:**
A traffic controller is required to control a traffic light at the intersection of a busy street. The main street is to have a green light for a minimum of 25 sec and a yellow light for 5 sec. The red light is to be green (light on) for 15 sec. The yellow light follows the change from green to red on the main street and on the side street. These requirements are illustrated in the state diagram in Figure 6-44.

**Developing a Block Diagram of the System:**
From the requirements, you can develop a block diagram of the system first, and then know that the system must control the different phases of light. These are the red, yellow, and green light in both directions on the main street and the red, yellow, and green light in both directions on the side street. You can then draw a flowchart to develop a state diagram that you can use to generate the proper times.

**FIGURE 6-45**
A traffic light control logic diagram for a four-state latching system.

The state diagram is a state diagram showing these requirements. Using the electronic system block diagram, you can begin to fill in the details. The system has four states, as illustrated in Figure 6-45, and a single state is used to control the sequence of lights.

**FIGURE P-5**
Representative pages from a typical Digital System Application.

- Answers to odd-numbered problems
- Comprehensive glossary
- Index

**To the Student**
Digital technology is hot! Most everything has already gone digital or will in the near future. For example, cell phones and other types of wireless communication, television, radio, process controls, automotive electronics, consumer electronics, global navigation, military systems, to name only a few applications, depend heavily on digital electronics.

A strong foundation in the fundamentals of digital technology will prepare you for the highly skilled and high-paying jobs of the future. The single most important thing you can do is to understand the core fundamentals. From there you can go anywhere.

In addition, programmable logic is becoming extremely important in today's technology and that topic is introduced in this book. Of course, efficient troubleshooting is a skill that is also widely sought. Troubleshooting and testing methods from traditional testing to manufacturing techniques, such as bed-of-nails, flying probe, and boundary scan, are covered in this book. These are examples of the skills you can acquire with a serious effort to learn the concepts presented.

**The CD-ROMs**
Two CDs are included with this book. One contains Texas Instruments data sheets for digital integrated circuits. The other contains circuit files in Multisim for use with Multisim software Versions 2001 or 7. (These Version 2001 and Version 7 circuit files—as well as those for use with Multisim 8—also appear on the Companion Website at www.prenhall.com/floyd.)
User’s Guide for Instructors

Generally, time limitation or program emphasis determine the topics to be covered in a course. It is not uncommon to omit or condense topics or to alter the sequence of certain topics in order to customize the material for a particular course. The author recognizes this and has designed this textbook specifically to provide great flexibility in topic coverage.

Using a modular approach, certain topics are organized in separate sections or features such that if they are omitted, the rest of the coverage is not affected. Also, if these topics are included, they flow seamlessly with the rest of the coverage. The book is organized around a core of fundamental topics that are, for the most part, essential in any digital course. Around this core, there are other topics that can be included or omitted depending on the course emphasis or other factors. Figure P-6 illustrates this modular concept.

- Core Fundamentals The fundamental topics of digital logic should, for the most part, be covered in all programs. Linked to the core are several “satellite” topics that may be considered for omission or inclusion, depending on your course goals. Any block surrounding the core can be omitted without affecting the core fundamentals.

- Programmable Logic Although it is an important topic, programmable logic can be omitted, but it is recommended that you cover this topic if at all possible. You can cover as little or as much as you consider practical for your program.

- Troubleshooting Troubleshooting sections appear in many chapters.

- Digital System Applications System applications appear in many chapters.

- Integrated Circuit Technologies Some or all of the topics in Chapter 14 can be covered at selected points if you wish to discuss details of the circuitry that make up digital integrated circuits.

- Special Topics These topics are Introduction to Computers and Digital Signal Processing in Chapters 12 and 13, respectively. These are special topics and may not be essential to your digital course.

Also, within each block in Figure P-6 you can choose to omit or de-emphasize some topics because of time constraints or other priorities. For example, in the core fundamentals, error correction codes, carry look-ahead adders, sequential logic design, and other selected topics could be omitted.

Customizing the Table of Contents You can take anyone of several paths through Digital Fundamentals, Ninth Edition, depending on the goals of your particular program. Whether you choose a minimal coverage of only core fundamentals, a full-blown coverage of all the topics, or anything in between, this book can be adapted to your needs. The
Table of Contents following this preface is color coded to match the blocks in Figure P-6. This allows you to identify topics for omission or inclusion for customizing your course.

Several options for use of Digital Fundamentals, Ninth Edition are shown below in terms of topics color coded to Figure P-6. Other options are possible, too, including partial coverage of some topics.

Option 1
Option 2
Option 3
Option 4
Option 5

Acknowledgments

This innovative text has been realized by the efforts and the skills of many people. I think that we have accomplished what we set out to do, which was to produce a textbook second to none. At Prentice Hall, Kate Linsner and Rex Davidson have contributed a great amount of time, talent, and effort to move this project through its many phases in order to produce the book as you see it. Lois Porter has done a fantastic job of editing the manuscript. She has unraveled the mysteries of this author's markups and often nearly illegible notes and, from that tangled mess, extracted an unbelievably organized and superbly edited manuscript. Also, Jane Lopez has done another beautiful job with the graphics. Another individual who contributed significantly to this book is Gary Snyder, who has provided all of the Multisim circuit files (in Multisim Versions 2001, 7, and 8, all of which appear on the Companion Website at www.prenhall.com/floyd). I extend my thanks and appreciation to all of these people and others who were indirectly involved in the project.

In the revision of this and all textbooks, I depend on expert input from many users as well as non-users. I want to offer my sincere thanks to the following reviewers, who submitted many valuable suggestions and provided lots of constructive criticism: Bo Barry, University of North Carolina–Charlotte; Chuck McGlumphy, Belmont Technical College; and Amy Ray, Mitchell Community College.

My appreciation goes to David Buchla for his efforts to make sure that the lab manual is closely coordinated with the text and for his valuable input. I would also like to mention Muhammed Arif Shabir for his suggestion concerning shift registers.

I thank all of the members of the Prentice Hall sales force whose efforts have helped make my books available to a large number of users throughout the world. In addition, I am grateful to all of you who have adopted this text for your classes or for your own use. Without you we would not be in business. I hope that you find this book to be a valuable learning tool and reference for students.

Tom Floyd