Digital Fundamentals

ELEVENTH EDITION

Thomas L. Floyd

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Eleventh Edition | Global Edition

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Thomas L. Floyd

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PREFACE

This eleventh edition of *Digital Fundamentals* continues a long tradition of presenting a strong foundation in the core fundamentals of digital technology. This text provides basic concepts reinforced by plentiful illustrations, examples, exercises, and applications. Applied Logic features, Implementation features, troubleshooting sections, programmable logic and PLD programming, integrated circuit technologies, and the special topics of signal conversion and processing, data transmission, and data processing and control are included in addition to the core fundamentals. New topics and features have been added to this edition, and many other topics have been enhanced.

The approach used in *Digital Fundamentals* allows students to master the all-important fundamental concepts before getting into more advanced or optional topics. The range of topics provides the flexibility to accommodate a variety of program requirements. For example, some of the design-oriented or application-oriented topics may not be appropriate in some courses. Some programs may not cover programmable logic and PLD programming, while others may not have time to include data transmission or data processing. Also, some programs may not cover the details of "inside-the-chip" circuitry. These and other areas 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, and the coverage of integrated circuit technology (inside-the-chip circuits) is optionally presented.

New in This Edition

- New page layout and design for better visual appearance and ease of use
- Revised and improved topics
- Obsolete devices have been deleted.
- The *Applied Logic* features (formerly *System Applications*) have been revised and new topics added. Also, the VHDL code for PLD implementation is introduced and illustrated.
- A new boxed feature, entitled *Implementation*, shows how various logic functions can be implemented using fixed-function devices or by writing a VHDL program for PLD implementation.
- Boolean simplification coverage now includes the Quine-McCluskey method and the Espresso method is introduced.
- A discussion of Moore and Mealy state machines has been added.
- The chapter on programmable logic has been modified and improved.
- A discussion of memory hierarchy has been added.
- A new chapter on data transmission, including an extensive coverage of standard busses has been added.
- The chapter on computers has been completely revised and is now entitled "Data Processing and Control."
- A more extensive coverage and use of VHDL. There is a tutorial on the website at www.pearsonglobaleditions.com/floyd
- More emphasis on D flip-flops

Standard Features

- Full-color format
- Core fundamentals are presented without being intermingled with advanced or peripheral topics.
- *InfoNotes* are sidebar features that provide interesting information in a condensed form.
- A chapter outline, chapter objectives, introduction, and key terms list appear on the opening page of each chapter.
- Within the chapter, the key terms are highlighted in color boldface. Each key term is defined at the end of the chapter as well as in the comprehensive glossary at the end of the book. Glossary terms are indicated by black boldface in the text.
- Reminders inform students where to find the answers to the various exercises and problems throughout each chapter.
- Section introduction and objectives are at the beginning of each section within a chapter.
- Checkup exercises conclude each section in a chapter with answers at the end of the chapter.
- Each worked example has a *Related Problem* with an answer at the end of the chapter.
- *Hands-On Tips* interspersed throughout provide useful and practical information.
- Multisim files (newer versions) on the website provide circuits that are referenced in the text for optional simulation and troubleshooting.
- The operation and application of test instruments, including the oscilloscope, logic analyzer, function generator, and DMM, are covered.
- Troubleshooting sections in many chapters
- Introduction to programmable logic
- Chapter summary
- True/False quiz at end of each chapter
- Multiple-choice self-test at the end of each chapter
- Extensive sectionalized problem sets at the end of each chapter with answers to odd-numbered problems at the end of the book.
- Troubleshooting, applied logic, and special design problems are provided in many chapters.
- Coverage of bipolar and CMOS IC technologies. Chapter 15 is designed as a "floating chapter" to provide optional coverage of IC technology (inside-the-chip circuitry) at any point in the course. Chapter 15 is online at www.pearsonglobaleditions.com/floyd

Accompanying Student Resources

FIGURE P-1

- *Multisim Circuits*. The MultiSim files on the website includes selected circuits from the text that are indicated by the icon in Figure P-1.

Other student resources available on the website:

1. Chapter 15, "Integrated Circuit Technologies"
2. VHDL tutorial

3. Verilog tutorial
4. MultiSim tutorial
5. Altera Quartus II tutorial
6. Xilinx ISE tutorial
7. Five-variable Karnaugh map tutorial
8. Hamming code tutorial
9. Quine-McCluskey method tutorial
10. Espresso algorithm tutorial
11. Selected VHDL programs for downloading
12. Programming the elevator controller using Altera Quartus II

Using Website VHDL Programs

VHDL programs in the text that have a corresponding VHDL file on the website are indicated by the icon in Figure P-2. These website VHDL files can be downloaded and used in conjunction with the PLD development software (Altera Quartus II or Xilinx ISE) to implement a circuit in a programmable logic device.

FIGURE P-2

Instructor Resources

- *Image Bank* This is a download of all the images in the text.
- *Instructor's Resource Manual* Includes worked-out solutions to chapter problems, solutions to Applied Logic Exercises, and a summary of Multisim simulation results.
- *TestGen* This computerized test bank contains over 650 questions.
- **Download Instructor Resources from the Instructor Resource Center**
  To access supplementary materials online, instructors need to request an instructor access code. Go to www.pearsonglobaleditions.com/floyd to register for an instructor access code. Within 48 hours of registering, you will receive a confirming e-mail including an instructor access code. Once you have received your code, locate your text in the online catalog and click on the Instructor Resources button on the left side of the catalog product page. Select a supplement, and a login page will appear. Once you have logged in, you can access instructor material for all Pearson textbooks. If you have any difficulties accessing the site or downloading a supplement, please contact Customer Service at http://247pearsoned.custhelp.com/.

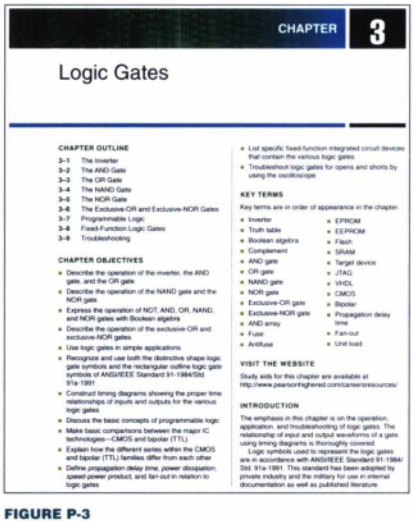
Illustration of Book Features

Chapter Opener Each chapter begins with an opener, which includes a list of the sections in the chapter, chapter objectives, introduction, a list of key terms, and a website reference for chapter study aids. A typical chapter opener is shown in Figure P-3.

Section Opener Each section in a chapter begins with a brief introduction that includes a general overview and section objectives. An illustration is shown in Figure P-4.

Section Checkup 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-4. Answers to the Section Checkups are at the end of the chapter.

Worked Examples and Related Problems There is an abundance of worked out examples that help to illustrate and clarify basic concepts or specific procedures. Each example ends



CHAPTER 3

Logic Gates

CHAPTER OUTLINE

3–1 The Inverter
3–2 The AND Gate
3–3 The OR Gate
3–4 The NAND Gate
3–5 The NOR Gate
3–6 The Exclusive-OR and Exclusive-NOR Gates
3–7 Programmable Logic
3–8 Fixed-Function Logic Gates
3–9 Troubleshooting

CHAPTER OBJECTIVES

- Describe the operation of the inverter, the AND gate, and the OR gate
- Describe the operation of the NAND gate and the NOR gate
- Express the operation of NOT, AND, OR, NAND, and NOR gates with Boolean algebra
- Describe the operation of the exclusive-OR and exclusive-NOR gates
- Use logic gates in simple applications
- Recognize and use both the distinctive shape logic gate symbols and the rectangular outline logic gate symbols of ANSI/IEEE Standard 91-1984/Std. 91a-1991
- Construct timing diagrams showing the proper time relationships of inputs and outputs for the various logic gates
- Discuss the basic concepts of programmable logic
- Make basic comparisons between the major IC technologies—CMOS and bipolar (TTL)
- Explain how the different series within the CMOS and bipolar (TTL) families differ from each other
- Define *propagation delay time*, *power dissipation*, *speed-power product*, and *fan-out* in relation to logic gates
- List specific fixed-function integrated circuit devices that contain the various logic gates
- Troubleshoot logic gates for opens and shorts by using the oscilloscope

KEY TERMS

Key terms are in order of appearance in the chapter.

- Inverter
- Truth table
- Boolean algebra
- Complement
- AND gate
- OR gate
- NAND gate
- NOR gate
- Exclusive-OR gate
- Exclusive-NOR gate
- AND array
- Fuse
- Antifuse
- EPROM
- EEPROM
- Flash
- SRAM
- Target device
- JTAG
- VHDL
- CMOS
- Bipolar
- Propagation delay time
- Fan-out
- Unit load

VISIT THE WEBSITE

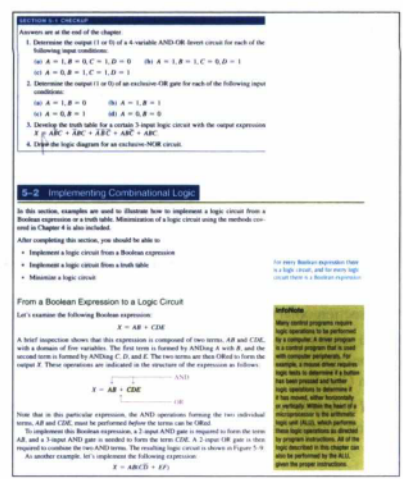
Study aids for this chapter are available at http://www.pearsonhighered.com/careersresources/

INTRODUCTION

The emphasis in this chapter is on the operation, application, and troubleshooting of logic gates. The relationship of input and output waveforms of a gate using timing diagrams is thoroughly covered.

Logic symbols used to represent the logic gates are in accordance with ANSI/IEEE Standard 91-1984/Std. 91a-1991. This standard has been adopted by private industry and the military for use in internal documentation as well as published literature.

FIGURE P-3



SECTION 5–1 CHECKUP

Answers are at the end of the chapter.

1. Determine the output (1 or 0) of a 4-variable AND-OR-Invert circuit for each of the following input conditions:
   (a) $A = 1, B = 0, C = 1, D = 0$ (b) $A = 1, B = 1, C = 0, D = 1$
   (c) $A = 0, B = 1, C = 1, D = 1$
2. Determine the output (1 or 0) of an exclusive-OR gate for each of the following input conditions:
   (a) $A = 1, B = 0$ (b) $A = 1, B = 1$
   (c) $A = 0, B = 1$ (d) $A = 0, B = 0$
3. Develop the truth table for a certain 3-input logic circuit with the output expression $X = \bar{A}\bar{B}\bar{C} + \bar{A}BC + A\bar{B}\bar{C} + A\bar{B}C + ABC$.
4. Draw the logic diagram for an exclusive-NOR circuit.

5–2 Implementing Combinational Logic

In this section, examples are used to illustrate how to implement a logic circuit from a Boolean expression or a truth table. Minimization of a logic circuit using the methods covered in Chapter 4 is also included.

After completing this section, you should be able to

- Implement a logic circuit from a Boolean expression
- Implement a logic circuit from a truth table
- Minimize a logic circuit

For every Boolean expression there is a logic circuit, and for every logic circuit there is a Boolean expression.

From a Boolean Expression to a Logic Circuit

Let's examine the following Boolean expression:

$$X = AB + CDE$$

A brief inspection shows that this expression is composed of two terms, AB and CDE, with a domain of five variables. The first term is formed by ANDing A with B, and the second term is formed by ANDing C, D, and E. The two terms are then ORed to form the output X. These operations are indicated in the structure of the expression as follows:

$$X = \underbrace{AB}_{\text{AND}} + \underbrace{CDE}_{\text{AND}}$$
$$\text{OR}$$

Note that in this particular expression, the AND operations forming the two individual terms, AB and CDE, must be performed *before* the terms can be ORed.

To implement this Boolean expression, a 2-input AND gate is required to form the term AB, and a 3-input AND gate is needed to form the term CDE. A 2-input OR gate is then required to combine the two AND terms. The resulting logic circuit is shown in Figure 5–9.

As another example, let's implement the following expression:

$$X = AB\bar{c}(\bar{D} + EF)$$

InfoNote

Many control programs require logic operations to be performed by a computer. A driver program is a control program that is used with computer peripherals. For example, a mouse driver requires logic tests to determine if a button has been pressed and further logic operations to determine if it has moved, either horizontally or vertically. Within the heart of a microprocessor is the arithmetic/logic unit (ALU), which performs these logic operations as directed by program instructions. All of the logic described in this chapter can also be performed by the ALU, given the proper instructions.

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 *Related Problem* is shown in Figure P-5.

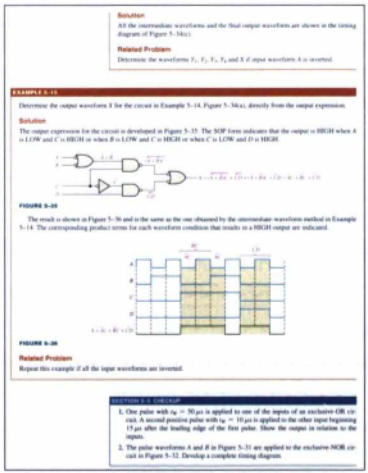


FIGURE P-5

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 and circuit simulation. A portion of a typical troubleshooting section is illustrated in Figure P-6.

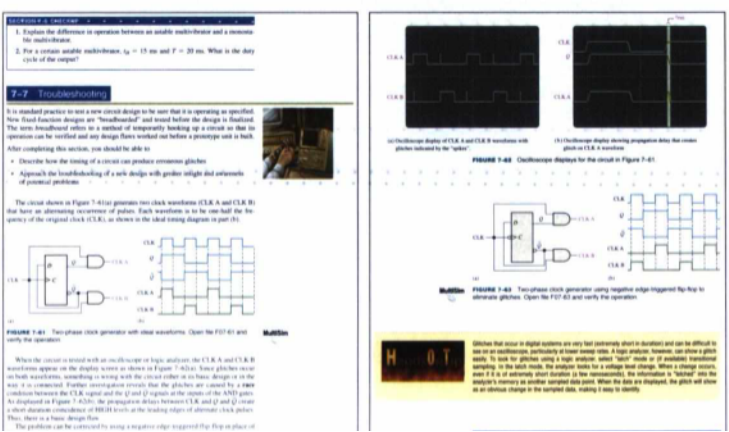


FIGURE P-6

Applied Logic Appearing at the end of many chapters, this feature presents a practical application of the concepts and procedures covered in the chapter. In most chapters, this feature presents a "real-world" application in which analysis, troubleshooting, design, VHDL programming, and simulation are implemented. Figure P-7 shows a portion of a typical Applied Logic feature.

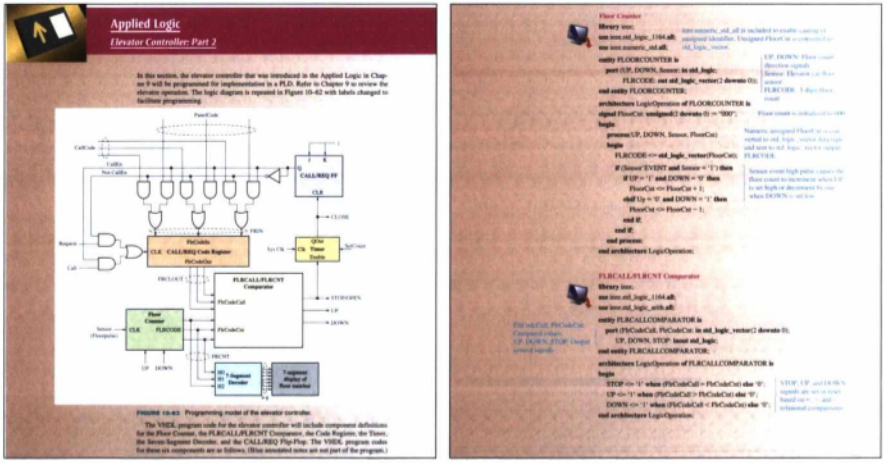


FIGURE P-7

End of Chapter

The following features are at the end of each chapter:

- Summary
- Key term glossary
- True/false quiz
- Self-test
- Problem set that includes some or all of the following categories in addition to core problems: Troubleshooting, Applied Logic, Design, and Multisim Troubleshooting Practice.
- Answers to Section Checkups
- Answers to Related Problems for Examples
- Answers to True/False quiz
- Answers to Self-Test

End of Book

The following features are at the end of the book.

- Answers to selected odd-numbered problems
- Comprehensive glossary

To the Student

Digital technology pervades almost everything in our daily lives. For example, cell phones and other types of wireless communications, television, radio, process controls, automotive electronics, consumer electronics, aircraft navigation— to name only a few applications— depend heavily on digital electronics.

A strong grounding in the fundamentals of digital technology will prepare you for the highly skilled 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 important in many applications and that topic in introduced in this book and example programs are given along with an online tutorial. Of course, efficient troubleshooting is a skill that is also widely sought after by potential employers. Troubleshooting and testing methods from traditional prototype testing to more advanced techniques such as boundary scan are covered.

To the Instructor

Generally, time limitations or program emphasis determines 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. This textbook is specifically designed to provide great flexibility in topic coverage.

Certain topics are organized in separate chapters, 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 and/or other factors. Even within the core, selected topics can be omitted. Figure P-8 illustrates this concept.

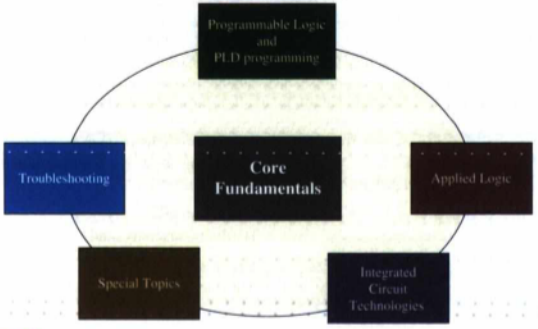


FIGURE P-8

- ***Core Fundamentals*** The fundamental topics of digital technology should 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. All topics presented in this text are important in digital technology, but each block surrounding the core can be omitted, depending on your particular goals, without affecting the core fundamentals.
- ***Programmable Logic and PLD Programming*** Although they are important topics, programmable logic and VHDL can be omitted; however, it is highly recommended that you cover this topic if at all possible. You can cover as little or as much as you

consider appropriate for your program.