时代教育·国外高校优秀教材精选

数字电子学

(英文版·原书第4版)

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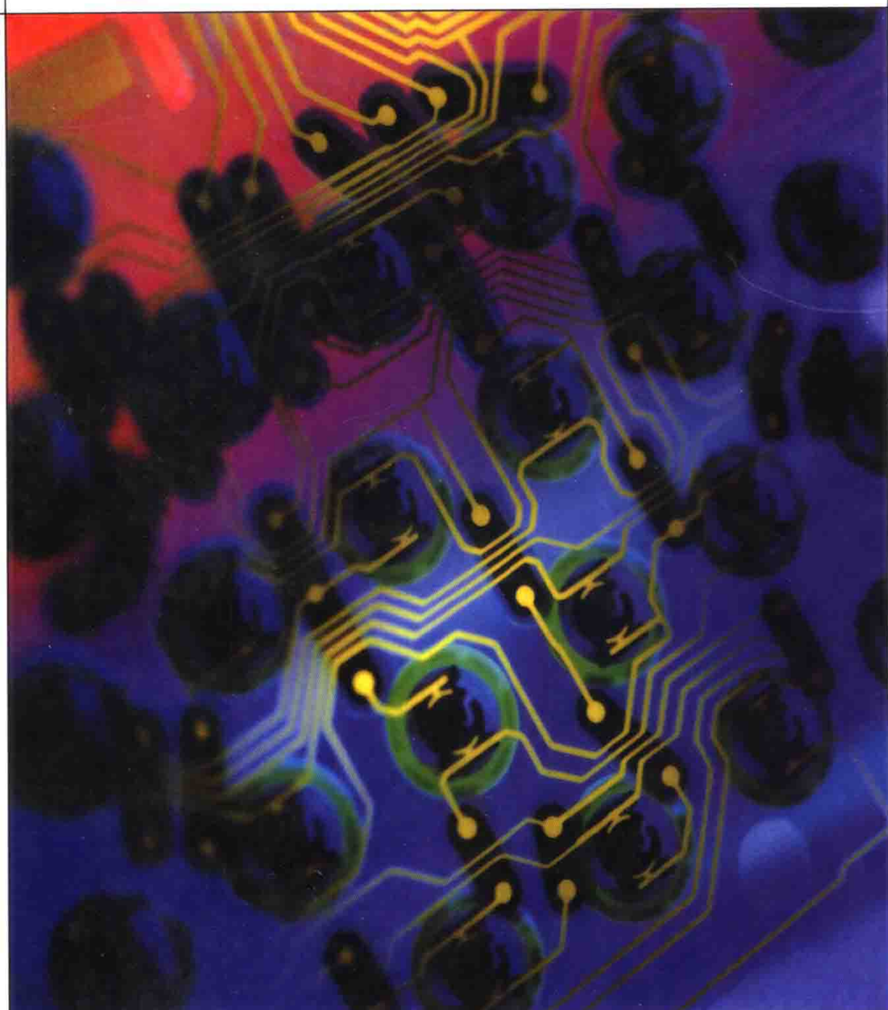

(美) 詹姆斯·比格内尔(James Bignell)
罗伯特·多诺万(Robert Donovan) 著

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出版说明

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引进国外优秀原版教材，在有条件的学校推动开展英语授课或双语教学，自然也引进了先进的教学思想和教学方法，这对提高我国自编教材的水平，加强学生的英语实际应用能力，使我国的高等教育尽快与国际接轨，必将起到积极的推动作用。

为了做好教材的引进工作，机械工业出版社特别成立了由著名专家组成的国外高校优秀教材审定委员会。这些专家对实施双语教学做了深入细致的调查研究，对引进原版教材提出许多建设性意见，并慎重地对每一本将要引进的原版教材一审再审，精选再精选，确认教材本身的质量水平，以及权威性和先进性，以期所引进的原版教材能适应我国学生的外语水平和学习特点。在引进工作中，审定委员会还结合我国高校教学课程体系的设置和要求，对原版教材的教学思想和方法的先进性、科学性严格把关，同时尽量考虑原版教材的系统性和经济性。

这套教材出版后，我们将根据各高校的双语教学计划，举办原版教材的教师培训，及时地将其推荐给各高校选用。希望高校师生在使用教材后及时反馈意见和建议，使我们更好地为教学改革服务。

机械工业出版社

2002年3月

序

Digital Electronics 4^{th}*ed* 是一本入门性教科书，不论是从应用还是从自学方面来看，对初学者都是很有帮助的教材，适用于计算机、电子信息与自动化类专业本科生使用。本书在写作风格上由浅入深，注意从应用的角度组织全书的教学内容，只要求学生具有直流和交流电路（DC/AC）的知识。本书的前 3 版已经以不同方式与计算机课程教学配合，一般在第一学期学习 DC/AC 电路，第二学期开设本课，也可在第一学期与 DC/AC 电路同步开课；或者将数字电子学和计算机课合在一起，分成微机原理（Ⅰ）、微机原理（Ⅱ）作为微机硬件电路在第二、第三两个学期使用。本书不涉及晶体管和门电路的内部结构，非常适合学生自学。

本书在第 4 版的编写上突出了以下几个特点：更大程度上强调的是开发技能方面的训练，在每章都增加了技能训练内容，包括在实际应用中碰到的实际问题的处理原则。其次，每一章都增加了新的 EWB 实验，这些实验都是在电路中嵌入了故障的基础上，训练学生用 EWB 分析和解决问题，教给他们解决问题的原理、思想和方法，以及熟练地掌握 EWB 工具软件和开发技巧。第三是把可编程逻辑器件（PLD）的内容也融合到各章内容之中，以便使 PLD 内部结构的学习循序渐进，以讨论和练习的方式学习。每章都有 PLD 应用的问题。另外，每一章都增加了数字电路在工业设计方面的应用。因此，本书可供学习数字电子技术参考。

陈文楷
北京工业大学
2003 年 4 月

Preface

Digital Electronics, Fourth Edition, is a streamlined, no-nonsense text that is ideal for the community college, Associate of Science degree student who needs a solid, introductory background in digital electronics. No previous knowledge in digital electronics is necessary, although a good working knowledge of dc circuits helps the student feel more comfortable with the concepts of voltage, current, and resistance. Students who complete this course are well prepared for the hardware encountered in a course in microprocessors.

Text Organization

This book is organized into sixteen chapters, one for each week of a full semester. Each chapter ends with laboratory exercises that closely correlate with the chapter material. It is in these labs that the theory comes alive and practical hands-on skills are learned; a balance is struck between theory and practice. The fourth edition is organized as follows:

Number Systems

Binary, hexadecimal, and binary-coded decimal number systems are covered in Chapter 1, along with binary addition.

Basic Gates

Basic gates and exclusive-Ors are covered in Chapters 2 through 4. Symbols, inverted-logic symbols, Boolean expressions, truth tables, enable/inhibit and gate expansion are stressed. Shift-counter and delayed-clock waveforms are used to introduce waveform analysis. Boolean algebra and Karnaugh map methods are used to implement given truth tables. Exclusive-OR gates are used as parity generators and parity checkers and as magnitude comparators.

Adders

1's and 2's complement method of subtraction is introduced in Chapter 5, along with binary-coded-decimal addition, and signed 2's complement numbers. 1's complement and 2's complement adder/subtractor circuits and binary-coded-decimal adder circuits are created by using the basic gates in conjunction with 4-bit full adders.

Specifications

Totem-pole and open-collector outputs are contrasted in Chapter 6. TTL and CMOS subfamily characteristics and parameters are contrasted. Emitter-coupled logic is introduced.

Flip-Flops
A progression of flip-flops is studied in Chapters 7 and 8, beginning with crossed NAND and progressing through gated, transparent, data, master-slave, and *JK* flip-flops. *JK* flip-flops and gates are used to create shift-counter and delayed-clock waveforms.

Digital Communications
Integrated circuit serial and parallel shift registers are presented in Chapter 9. The RS-232 standard and ASCII code are studied and a serial receiver is created from flip-flops and gates. In a "human-relations" lab exercise, four students work as a team to create a serial receiver from flip-flops and gates and shift register integrated circuits. The system includes shift-counter and delayed-clock circuits studied in Chapter 8. The lab is complete when each member of the group is able to receive and decode the RS-232 ASCII signals from a computer.

Timing Circuits
Decode-and-clear and synchronous counters are presented in Chapter 10. Both integrated circuit counters and counters created from flip-flops and gates are studied. The student learns to design and create synchronous counters that count in any sequence.

Schmitt-trigger gates are introduced in Chapter 11. Schmitt-trigger gates, 555 timers, CMOS gates, and crystals are used to create a variety of clock circuits.

Triggerable and non-retriggerable one-shot circuits are covered in Chapter 12. Both integrated circuit one-shots and one-shots created from Schmitt-trigger gates and 555 timers are studied.

Interface Circuits
Chapter 13 begins a sequence of topics concerned with interfacing digital control circuits with the external world.

Digital-to-analog and analog-to-digital converters are covered in Chapter 13. Count-up and compare, flash converters, and successive approximation converters are created with flip-flops, gates, and voltage comparators. The successive approximation circuit begins with shift-counter and delayed-clock circuits developed in Chapter 8. Integrated circuit converters are presented.

In Chapter 14, the concept of decoding is expanded into multiplexers and demultiplexers. Integrated circuit multiplexers and demultiplexers are presented. LED and liquid crystal seven-segment displays are introduced.

Chapter 15 introduces tri-state gates and bus drivers. Examples are given of interfacing control circuits to high-current, high-voltage devices.

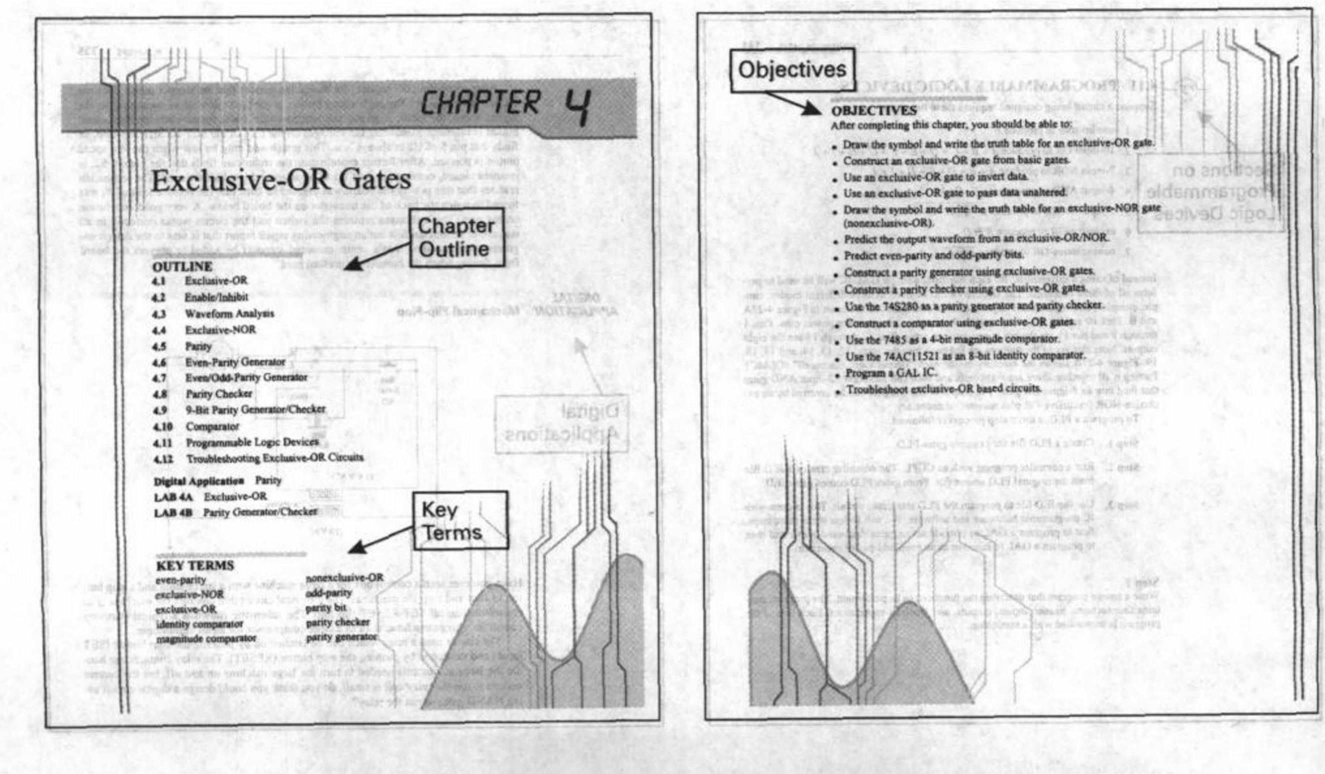
Introduction to Microcomputers
Chapter 16 is a bridge from digital electronics into microcomputers. The basic parts of a microcomputer are discussed. Memory-integrated circuits are presented.

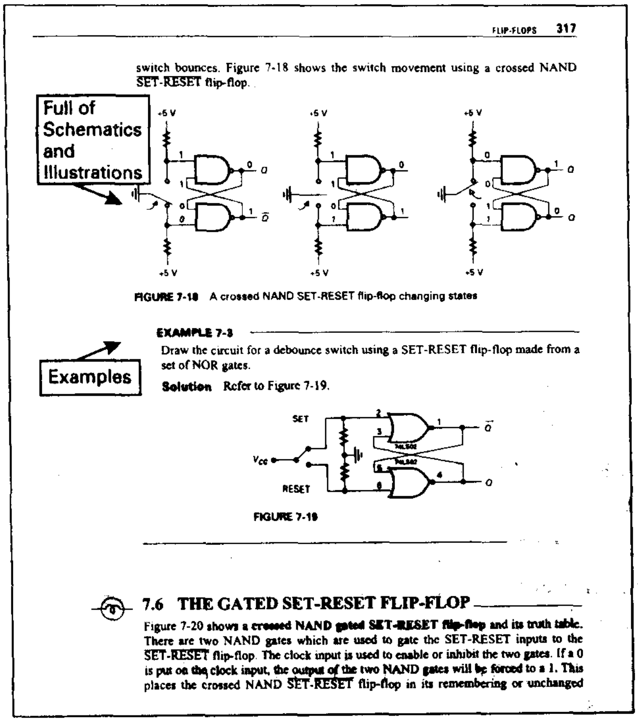
Appendixes

Appendix A contains plans and schematics for construction of a lab trainer. Appendix B contains a list of materials needed to construct the lab circuits. Pinouts for the integrated circuits used in the lab exercises are shown in Appendix C. Although handy, these pinouts are no substitute for good TTL and CMOS specification manuals (data books). It is recommended that data books be obtained from one or more of the major integrated circuit manufacturers.

How to Use the Book

1. An *Outline* and a list of *Key Terms* begins each chapter highlighting main topics and new terms the students will learn.
2. The *Objectives* for each chapter identifies the skills that the student will acquire after reading the material.
3. Each chapter contains *Self-Check* questions to keep the students focused on the material and to provide immediate feedback on their progress. The answers to the Self-Checks are included at the back of the book.
4. *Examples* are given to enhance the presentation of new material and to guide the student in solving problems.





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switch bounces. Figure 7-18 shows the switch movement using a crossed NAND $\overline{SET}$-$\overline{RESET}$ flip-flop.

FIGURE 7-18 A crossed NAND SET-RESET flip-flop changing states

EXAMPLE 7-3

Draw the circuit for a debounce switch using a SET-RESET flip-flop made from a set of NOR gates.

Solution Refer to Figure 7-19.

FIGURE 7-19

7.6 THE GATED SET-RESET FLIP-FLOP

Figure 7-20 shows a crossed NAND gated SET-RESET flip-flop and its truth table. There are two NAND gates which are used to gate the SET-RESET inputs to the $\overline{SET}$-$\overline{RESET}$ flip-flop. The clock input is used to enable or inhibit the two gates. If a 0 is put on the clock input, the output of the two NAND gates will be forced to a 1. This places the crossed NAND $\overline{SET}$-$\overline{RESET}$ flip-flop in its remembering or unchanged

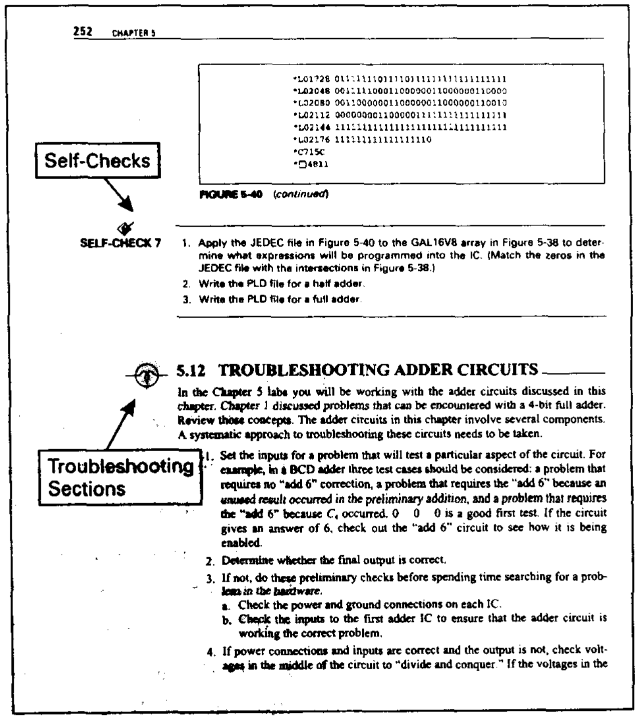

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FIGURE 5-40 *(continued)*

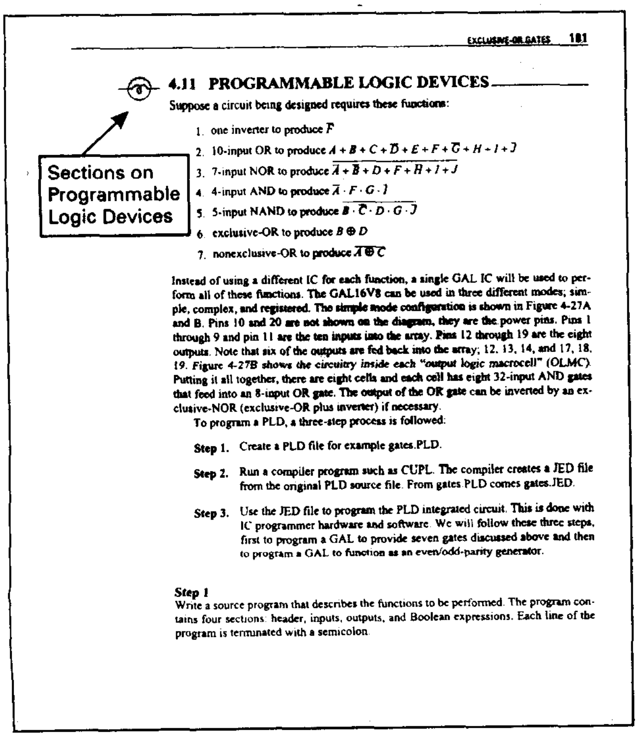
SELF-CHECK 7

1. Apply the JEDEC file in Figure 5-40 to the GAL16V8 array in Figure 5-38 to determine what expressions will be programmed into the IC. (Match the zeros in the JEDEC file with the intersections in Figure 5-38.)
2. Write the PLD file for a half adder.
3. Write the PLD file for a full adder.

5.12 TROUBLESHOOTING ADDER CIRCUITS

In the Chapter 5 labs you will be working with the adder circuits discussed in this chapter. Chapter 1 discussed problems that can be encountered with a 4-bit full adder. Review those concepts. The adder circuits in this chapter involve several components. A systematic approach to troubleshooting these circuits needs to be taken.

1. Set the inputs for a problem that will test a particular aspect of the circuit. For example, in a BCD adder three test cases should be considered: a problem that requires no "add 6" correction, a problem that requires the "add 6" because an unused result occurred in the preliminary addition, and a problem that requires the "add 6" because C_4 occurred. 0 0 0 is a good first test. If the circuit gives an answer of 6, check out the "add 6" circuit to see how it is being enabled.
2. Determine whether the final output is correct.
3. If not, do these preliminary checks before spending time searching for a problem in the hardware.
   a. Check the power and ground connections on each IC.
   b. Check the inputs to the first adder IC to ensure that the adder circuit is working the correct problem.
4. If power connections and inputs are correct and the output is not, check voltages in the middle of the circuit to "divide and conquer." If the voltages in the



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4.11 PROGRAMMABLE LOGIC DEVICES

Suppose a circuit being designed requires these functions:

1. one inverter to produce $\overline{F}$
2. 10-input OR to produce $A+B+C+\overline{D}+E+F+\overline{G}+H+I+J$
3. 7-input NOR to produce $\overline{A+\overline{B}+D+F+\overline{H}+I+J}$
4. 4-input AND to produce $\overline{A}\cdot F\cdot G\cdot \overline{I}$
5. 5-input NAND to produce $\overline{B\cdot \overline{C}\cdot D\cdot G\cdot \overline{J}}$
6. exclusive-OR to produce $B\oplus D$
7. nonexclusive-OR to produce $\overline{A\oplus C}$

Instead of using a different IC for each function, a single GAL IC will be used to perform all of these functions. The GAL16V8 can be used in three different modes; simple, complex, and registered. The simple mode configuration is shown in Figure 4-27A and B. Pins 10 and 20 are not shown on the diagram, they are the power pins. Pins 1 through 9 and pin 11 are the ten inputs into the array. Pins 12 through 19 are the eight outputs. Note that six of the outputs are fed back into the array; 12, 13, 14, and 17, 18, 19. Figure 4-27B shows the circuitry inside each "output logic macrocell" (OLMC). Putting it all together, there are eight cells and each cell has eight 32-input AND gates that feed into an 8-input OR gate. The output of the OR gate can be inverted by an exclusive-NOR (exclusive-OR plus inverter) if necessary.

To program a PLD, a three-step process is followed:

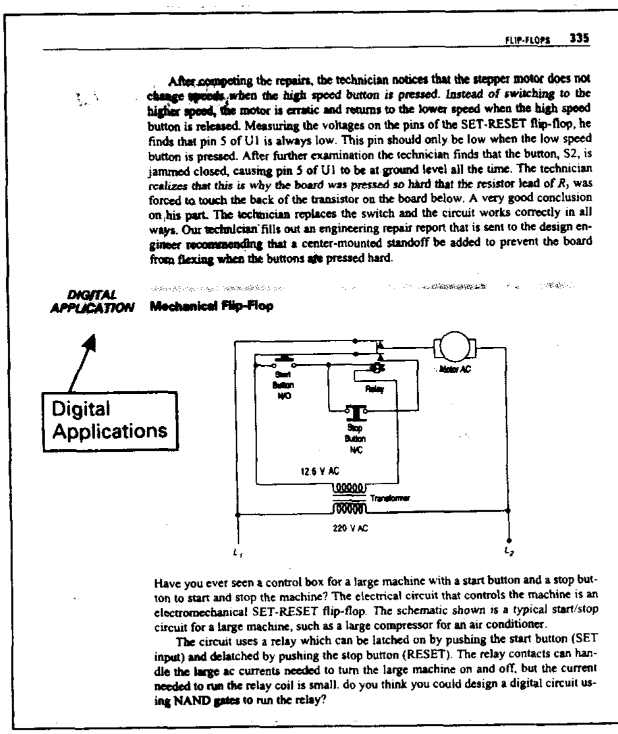
Step 1. Create a PLD file for example gates.PLD.

Step 2. Run a compiler program such as CUPL. The compiler creates a JED file from the original PLD source file. From gates.PLD comes gates.JED.

Step 3. Use the JED file to program the PLD integrated circuit. This is done with IC programmer hardware and software. We will follow these three steps, first to program a GAL to provide seven gates discussed above and then to program a GAL to function as an even/odd-parity generator.

Step 1

Write a source program that describes the functions to be performed. The program contains four sections: header, inputs, outputs, and Boolean expressions. Each line of the program is terminated with a semicolon.



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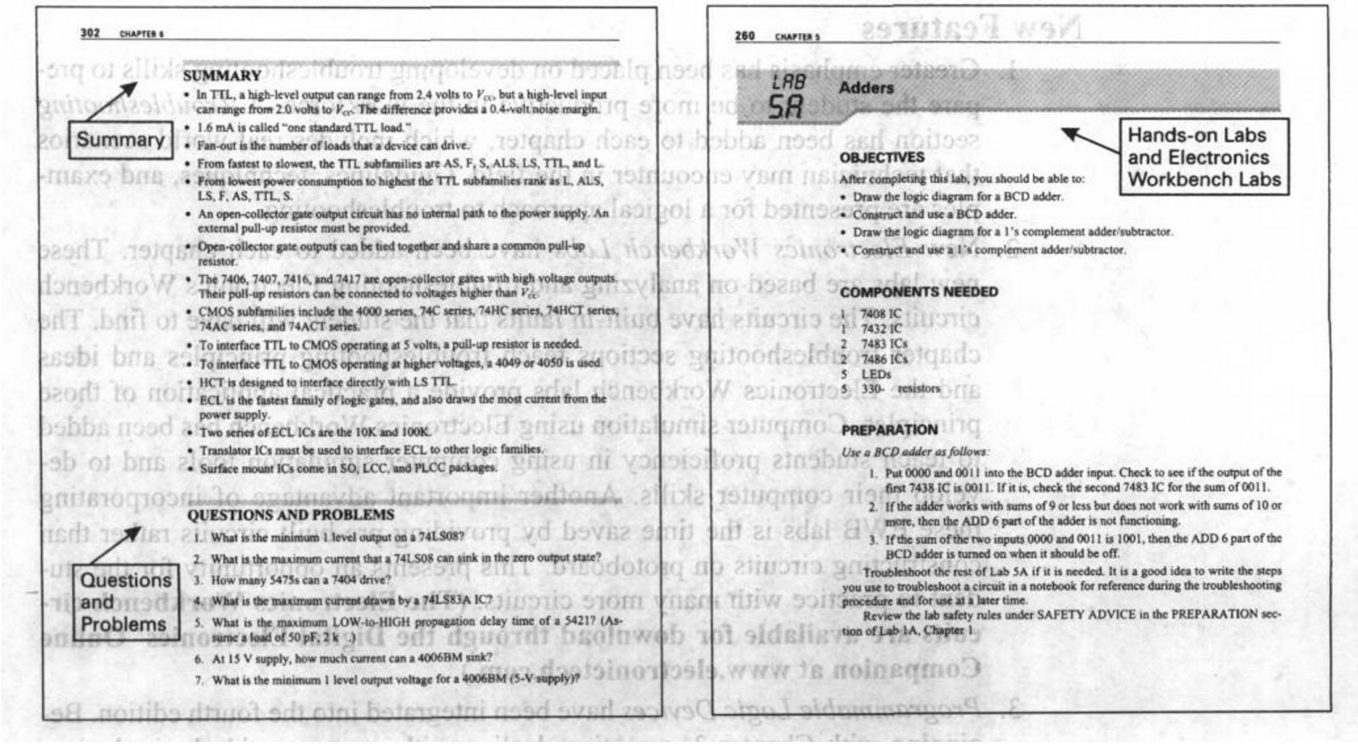
After completing the repairs, the technician notices that the stepper motor does not change speeds when the high speed button is pressed. Instead of switching to the higher speed, the motor is erratic and returns to the lower speed when the high speed button is released. Measuring the voltages on the pins of the SET-RESET flip-flop, he finds that pin 5 of U1 is always low. This pin should only be low when the low speed button is pressed. After further examination the technician finds that the button, S2, is jammed closed, causing pin 5 of U1 to be at ground level all the time. The technician realizes that this is why the board was pressed so hard that the resistor lead of R_1 was forced to touch the back of the transistor on the board below. A very good conclusion on his part. The technician replaces the switch and the circuit works correctly in all ways. Our technician fills out an engineering repair report that is sent to the design engineer recommending that a center-mounted standoff be added to prevent the board from flexing when the buttons are pressed hard.

DIGITAL APPLICATION **Mechanical Flip-Flop**

Have you ever seen a control box for a large machine with a start button and a stop button to start and stop the machine? The electrical circuit that controls the machine is an electromechanical SET-RESET flip-flop. The schematic shown is a typical start/stop circuit for a large machine, such as a large compressor for an air conditioner.

The circuit uses a relay which can be latched on by pushing the start button (SET input) and delatched by pushing the stop button (RESET). The relay contacts can handle the large ac currents needed to turn the large machine on and off, but the current needed to run the relay coil is small. do you think you could design a digital circuit using NAND gates to run the relay?



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SUMMARY

- In TTL, a high-level output can range from 2.4 volts to V_{CC}, but a high-level input can range from 2.0 volts to V_{CC}. The difference provides a 0.4-volt noise margin.
- 1.6 mA is called "one standard TTL load."
- Fan-out is the number of loads that a device can drive.
- From fastest to slowest, the TTL subfamilies are AS, F, S, ALS, LS, TTL, and L.
- From lowest power consumption to highest the TTL subfamilies rank as L, ALS, LS, F, AS, TTL, S.
- An open-collector gate output circuit has no internal path to the power supply. An external pull-up resistor must be provided.
- Open-collector gate outputs can be tied together and share a common pull-up resistor.
- The 7406, 7407, 7416, and 7417 are open-collector gates with high voltage outputs. Their pull-up resistors can be connected to voltages higher than V_{CC}.
- CMOS subfamilies include the 4000 series, 74C series, 74HC series, 74HCT series, 74AC series, and 74ACT series.
- To interface TTL to CMOS operating at 5 volts, a pull-up resistor is needed.
- To interface TTL to CMOS operating at higher voltages, a 4049 or 4050 is used.
- HCT is designed to interface directly with LS TTL.
- ECL is the fastest family of logic gates, and also draws the most current from the power supply.
- Two series of ECL ICs are the 10K and 100K.
- Translator ICs must be used to interface ECL to other logic families.
- Surface mount ICs come in SO, LCC, and PLCC packages.

QUESTIONS AND PROBLEMS

1. What is the minimum 1 level output on a 74LS08?
2. What is the maximum current that a 74LS08 can sink in the zero output state?
3. How many 5475s can a 7404 drive?
4. What is the maximum current drawn by a 74LS83A IC?
5. What is the maximum LOW-to-HIGH propagation delay time of a 5421? (Assume a load of 50 pF, 2 k.)
6. At 15 V supply, how much current can a 4006BM sink?
7. What is the minimum 1 level output voltage for a 4006BM (5-V supply)?

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LAB 5A Adders

OBJECTIVES

After completing this lab, you should be able to:

- Draw the logic diagram for a BCD adder.
- Construct and use a BCD adder.
- Draw the logic diagram for a 1's complement adder/subtractor.
- Construct and use a 1's complement adder/subtractor.

COMPONENTS NEEDED

1 7408 IC
1 7432 IC
2 7483 ICs
2 7486 ICs
5 LEDs
5 330- resistors

PREPARATION

Use a BCD adder as follows:

1. Put 0000 and 0011 into the BCD adder input. Check to see if the output of the first 7438 IC is 0011. If it is, check the second 7483 IC for the sum of 0011.
2. If the adder works with sums of 9 or less but does not work with sums of 10 or more, then the ADD 6 part of the adder is not functioning.
3. If the sum of the two inputs 0000 and 0011 is 1001, then the ADD 6 part of the BCD adder is turned on when it should be off.

Troubleshoot the rest of Lab 5A if it is needed. It is a good idea to write the steps you use to troubleshoot a circuit in a notebook for reference during the troubleshooting procedure and for use at a later time.

Review the lab safety rules under SAFETY ADVICE in the PREPARATION section of Lab 1A, Chapter 1.

5. A *Chapter Summary* lists pertinent facts for quick review and reinforcement.
6. End-of-chapter *Questions and Problems* offer review of material and practice at putting the material to work. The answers to odd-numbered problems are included at the back of the book.
7. Two *Labs* are included at the end of each chapter. The first is a *hands-on* construction project and the second is an *Electronics Workbench* analysis and troubleshooting project. Troubleshooting competence is developed by wiring and troubleshooting the lab circuits in the first lab and then by analyzing and troubleshooting the Electronics Workbench circuits in the second lab. By using both types of labs, a balance is struck between physically constructing a circuit and analyzing/troubleshooting circuits using computer simulation tools, such as Electronics Workbench. Students need to experience both approaches to fully understand circuit problems.
8. Many of the words and phrases used in this text are briefly defined in the *Glossary*. Refer to it often to familiarize yourself with the terminology.
9. A *concise, easy-to-read style* presents fundamental digital concepts in clear, understandable terms.
10. A comprehensive text accompanied by *schematics and illustrations* to help clarify material.

New Features

1. Greater emphasis has been placed on developing troubleshooting skills to prepare the student to be more productive in the workforce. A *Troubleshooting* section has been added to each chapter, which includes real-world scenarios that technician may encounter in the field. Guidelines, techniques, and examples are presented for a logical approach to troubleshooting.
2. New *Electronics Workbench Labs* have been added to each chapter. These new labs are based on analyzing and troubleshooting Electronics Workbench circuits. The circuits have built-in faults that the student will have to find. The chapter troubleshooting sections teach troubleshooting principles and ideas and the Electronics Workbench labs provide a practical application of those principles. Computer simulation using Electronics Workbench has been added to teach students proficiency in using computer simulation tools and to develop their computer skills. Another important advantage of incorporating these EWB labs is the time saved by providing pre-built circuits rather than constructing circuits on protoboard. This presents an opportunity for the student to practice with many more circuits. **(The Electronics Workbench circuits are available for download through the Digital Electronics' Online Companion at www.electronictech.com.)**
3. *Programmable Logic Devices* have been integrated into the fourth edition. Beginning with Chapter 3, a section dealing with programmable logic devices has been added to each chapter. In industry, more systems are using PLDs to replace numerous integrated circuits. This new coverage on PLDs provides a starting place for the student to become aware of these new devices and an introduction to the technology behind them.

   These sections are cumulative, beginning with discussions and exercises involving the internal architecture of a programmable logic device and the development of a source file (*.PLD) to program the internal logic into the desired combinatorial logic circuit. CUPL (Compiler for Universal Programmable Logic) software from Logical Devices, Inc. is used to compile the source file into a JEDEC file (*.JED). The JED file can then be used by an IC programming system (hardware and software) to program the actual integrated circuit. Each chapter presents an application of a PLD that is correlated to the material in the chapter.

   A Universal IC Programmer/Tester by Hi-Lo Systems was used to perform the PLD exercises in this text. The software and hardware used can be purchased from any electronics components catalog, such as Jameco (www.jameco.com). Other equivalent compilers and programmers can be used to program the PLDs.
4. A *Digital Application* section has been added to each chapter. The applications present industry-designed circuits and scenarios to illustrate the chapter's content.

5. Additional *Questions and Problems* give the student more opportunity to review and apply concepts just learned.
6. Based on reviewer feedback, additional content revisions include:
   - Math coverage of 1's complement subtraction and 2's complement subtraction has been moved to Chapter 5 to present material more logically.
   - Applications of DeMorgan's theorems have been simplified using a three step process.
   - Specification of low voltage CMOS subfamilies has been added to Chapter 6.
   - Added coverage of insulated gate bipolar transistors (IGBTs) in Chapter 15 exposes students to more of these common circuits. The new section on IBGTs demonstrates the use of digital signals to control high-current and high-voltage devices.
   - An introduction to microcontrollers and the Motorola 68HC11 has been added to Chapter 16.
   - Added description of more integrated circuits throughout the text gives the student broader knowledge of available ICs.

Course Options

This text has been used three different ways at Manatee Community College.

1. *Digital Electronics* was originally written to be used as a second semester text for students who had completed DC/AC circuits during their first semester. This worked well except, with digital being introduced in the second semester, only semesters three and four remained for microprocessor-based course work.
2. In order to introduce digital electronics earlier in the curriculum, it was moved to the first semester and taught concurrently with DC/AC circuits. Both formats worked well, but digital electronics was offered only to Electronics Engineering Technology majors.
3. A new format has now evolved, offering a survey of digital and microprocessors to networking and programming students. This fourth edition text is used as one of two books in a two-semester sequence, Digital/Microprocessors I and II. In the first course, Digital/Micro I, number systems, gates, and flip-flops (Chapters 1 through 5, 7, and 8) are covered during the first half of the semester. Assembly language programming of a microprocessor, associated hardware, and interfacing are taught during the second half of that first semester. Students majoring in electronics return for Digital/Micro II and

study the rest of *Digital Electronics* (Chapters 6 and 9 through 14) and additional microprocessor work, including interfacing processors to serial ports, parallel ports, programmable counters, and stepper motors. This new format is working well at Manatee Community College.

Supplementary Package

The majority of our students find this text refreshing, and challenging and are excited about continuing their studies in electronics. To augment the learning process we now offer these useful supplements to accompany *Digital Electronics*.

1. The *Laboratory Manual* contains additional activities to supplement the lab exercises contained in the text. For each chapter of *Digital Electronics* the *Laboratory Manual* contains three lab exercises. The first two contain circuits to be constructed on a protoboard and analyzed. The third lab is based on Electronics Workbench Student Edition, Version 5.12, ISBN: 0-7668-0330-9. These labs are well correlated with the text material.
2. The *Instructor's Guide* offers teaching hints for the text and lab manual and the answers to all text and lab manual questions and problems, ISBN: 0-7668-03295.
3. The *Digital Electronics' Online Companion* at www.electronictech.com includes the downloadable Electronics Workbench circuit files required in this text and lab manual, along with text updates, online quizzes, and more.

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Market Feedback

The authors can be reached for questions, comments, or suggestions at the following e-mail addresses. Robert Donovan can be contacted at donovar@bc.mcc.cc.fl.us and James Bignell can be contacted at biggy01@aol.com. We hope you enjoy using this text as much as we do.

James Bignell
Robert Donovan
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