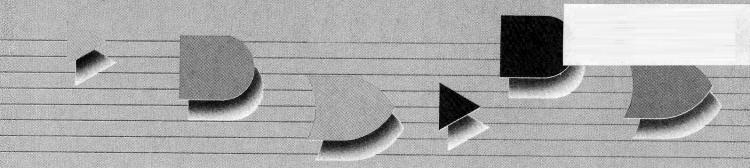
DIGITAL SYSTEMS

PRINCIPLES AND APPLICATIONS
FIFTH EDITION



Prentice-Hall International Editions

RONALD J. TOCCI



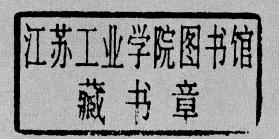
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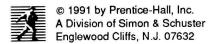
Monroe Community College





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PREFACE

This book is a comprehensive up-to-date study of the principles and techniques of modern digital systems. It is intended for use in two-year and four-year programs in technology, engineering, and computer science. Although a background in basic electronic devices is helpful, a major portion of the material requires no electronics training. Those portions of the text that utilize electronic concepts can be skipped over without adversely affecting the comprehension of the logic principles.

GENERAL IMPROVEMENTS

This fifth edition contains several general improvements to the previous edition. In addition to being updated, some of the material has been rewritten for greater clarity and thoroughness. The chapter glossaries have been combined into one comprehensive glossary located in Appendix I for more easy reference. The answers to all section review questions have now been provided and placed at the end of the chapter. Examples were added where it was felt they were needed to further illustrate the new principles or procedures, bringing the total number of examples to over 200. Shortanswer drill questions are now included with the end-of-chapter problems to provide a quick check on the reader's understanding of the basic concepts. Problems have been added to each chapter so that there are now about 450 of them. Some of these are applications that show how the logic devices or circuits presented in the chapter are used in a typical microcomputer system. The more difficult problems have been flagged as such for the instructor's convenience. The Answers to Selected Problems at the end of the text now include answers to almost all of the end-of-chapter questions and problems. Finally, a third color has been added to the book's design to help highlight certain elements of the material.

SPECIFIC CHANGES

In addition to these pedagogical improvements, there are several changes in the topical coverage. The major ones are:

- Chapter 4: New section on parity generator and checker circuits.
- Chapter 5: Introduction of state transition diagrams. New section on micro-computer application.
- **Chapter 7:** New optional section on design of synchronous counters. Extensive use of state transition diagrams. Introduction to and problems using a bidirectional shift register (the 74194).
 - Chapter 8: Material on different IC packages.
 - Chapter 9: New section on code converter circuits.
- Chapter 10: Added flowchart and timing diagram for SAC operation. New section on other ADC methods including tracking ADC and dual-slope ADC. New section on digital storage oscilloscope.

Chapter 11: Added function generator application. Expanded material on programmable logic devices to include PROM, PLA, PAL, and EPLDs with examples of how to determine and symbolize fuse conditions for a desired truth table. Added section on NVRAM. Decreased material on magnetic core and added coverage of optical disk and CD ROM.

RETAINED FEATURES

This edition retains all of the features that made the previous editions so widely accepted. It utilizes a block diagram approach to teach the basic logic operations without confusing the reader with the details of internal operation. All but the most basic electrical characteristics of the logic ICs are withheld until the reader has a firm understanding of logic principles. In Chapter 8 the reader is introduced to the internal IC circuitry. At that point, the reader can interpret a logic block's input and output characteristics and "fit" it properly into a complete system.

The treatment of each new topic or device typically follows these steps: the principle of operation is introduced; thoroughly explained examples and applications are presented often using actual ICs; short review questions are posed at the end of the section; and finally, in-depth problems are available at the end of the chapter. Ranging from simple to complex, these problems provide instructors with a wide choice of student assignments. These problems are often intended to reinforce the material without simple repetition of the principles. They require the student to demonstrate comprehension of the principles by applying them to different situations. This also helps the student develop confidence and expand his or her knowledge of the material.

The IEEE/ANSI standard for logic symbols is introduced and discussed with minimum disruption of the topic flow, and, if desired, can be omitted completely or in part. The extensive troubleshooting coverage is spread over Chapters 4 through 11 and includes presentation of troubleshooting principles and techniques, case studies, 25 troubleshooting examples, and 60 *real* troubleshooting problems. When supplemented with hands-on lab exercises, this material can help foster the development of good troubleshooting skills.

SEQUENCING

It is a rare instructor who uses the chapters of a textbook in the sequence in which they are presented. In fact, I must admit that, for many different reasons, I do not use my own books in that way. This book was written so that, for the most part, each chapter builds on previous material, but it is possible to alter the chapter sequence somewhat. The first part of Chapter 6 (arithmetic operations) can be covered right after Chapter 2 (number systems), although this would produce a long interval before the arithmetic circuits of Chapter 6 are encountered. Much of the material in Chapter 8 (IC characteristics) can be covered earlier (e.g., after Chapter 4 or 5) without causing any serious problems.

This book can be used in either a one-term course or in a two-term sequence. When used in one term, it may be necessary, depending on available class hours, to omit some topics. Here is a list of sections and chapters that can be deleted with minimum disruption. Obviously, the choice of deletions will depend on factors such as program or course objectives and student background.

- 1. Chapter 1: all
- 2. Chapter 2: Sections 6 and 7
- 3. Chapter 4: Sections 7 and 8; Sections 10–13 if troubleshooting is not to be covered
- 4. Chapter 5: Sections 3 and 25
- 5. Chapter 6: Sections 5, 7, 11, 13, 16, 18, 20

- **6.** Chapter 7: Sections 10, 14–23
- 7. Chapter 8: Sections 9, 17–21
- **8.** Chapter 9: Sections 6, 10, 11
- **9.** Chapter 10: Sections 6, 13–16
- 10. Chapter 11: Sections 9, 18-22
- 11. Chapter 12: all

ACKNOWLEDGMENTS

Prior to starting work on this edition, we sent an extensive questionnaire to many users and former users of previous editions. I am grateful to all of those who responded with their comments, critiques, and suggestions. Their input was invaluable as I went through the process of deciding what changes to incorporate in the new edition. I am particularly grateful to Gregory L. Moss of Purdue University for his many excellent suggestions. All of them were carefully considered, and most of them are part of this edition.

As always, the people at Prentice-Hall were a pleasure to work with. I was especially fortunate to have Ed Jones as my production editor again (I hope he has forgiven me for my unintentional failure to acknowledge his major contribution to the last edition). His thoroughness and attention to detail far exceeds that of any of the numerous production editors who have worked with me on previous writing projects. Once again, Alice Barr provided the combination of open-minded leadership, gentle encouragement, and infectious enthusiasm that I needed to keep me going.

Finally, another special thank you to my colleague and friend Frank Ambrosio, for his work on the glossary, index, and Instructor's Manual. The timely and dependable way in which he completed his tasks made it easy for me to stay on schedule.

Ron Tocci Monroe Community College

CONTENTS

	PRI	EFACE	xiii
1	INT	RODUCTORY CONCEPTS	1
		Digital Number Systems 6 Representing Binary Quantities 10 Digital Circuits 11 Parallel and Serial Transmission 13 Memory 15 Digital Computers 15 Problems 17	
2	NILIN	Answers to Section Review Questions 18 MBER SYSTEMS AND CODES	10
_	2-1	Binary-to-Decimal Conversions 21	19
	2-2		
		Decimal-to-Binary Conversions 21	
		Octal Number System 23	
		Hexadecimal Number System 26	
		BCD Code 29	
		Excess-3 Code 31	
		Gray Code 32	
	2-8	Alphanumeric Codes 33	

		Problems 37	
		Answers to Section Review Questions 40	
3	LOG	IC GATES AND BOOLEAN ALGEBRA	41
	3-1	Boolean Constants and Variables 43	
	3-2	Truth Tables 44	
	3-3	OR Operation 44	
	3-4	AND Operation 48	
	3-5	NOT Operation 51	
	3-6	Describing Logic Circuits Algebraically 52	
	3-7	Evaluating Logic-Circuit Outputs 54	
	3-8	Implementing Circuits from Boolean Expressions 56	
	3-9	NOR Gates and NAND Gates 58	
	3-10	Boolean Theorems 61	
	3-11	DeMorgan's Theorems 65	
	3-12	Universality of NAND Gates and NOR Gates 68	
	3-13	Alternate Logic-Gate Representations 72	
	3-14	Which Gate Representation to Use 75	
	3-15	IEEE/ANSI Standard Logic Symbols 80	
		Problems 84	
		Answers to Section Review Questions 90	
4	COM	BINATORIAL LOGIC CIRCUITS	91
	4-1	Sum-of-Products Form 93	
	4-2	Simplifying Logic Circuits 93	
	4-3	Algebraic Simplification 94	
	4-4	Designing Combinatorial Logic Circuits 98	
	4-5	Karnaugh Map Method 105	
	4-6	Exclusive-OR and Exclusive-NOR Circuits 115	
	4-7	Parity Generator and Checker 121	
	4-8	Inhibit Circuits 123	
	4-9	Basic Characteristics of Digital ICs 125	
	4-10	Troubleshooting Digital Systems 130	
	4-11	Internal Digital IC Faults 131	
	4-12	External Faults 135	
	4-13	Troubleshooting Case Study 137	
		Problems 139	
		Answers to Section Review Questions 149	

Parity Method for Error Detection

35

2-9

5	FLIP	-FLOPS AND RELATED DEVICES	150
	5-1	NAND Gate Latch 153	
	5-2	NOR Gate Latch 159	
	5-3	Troubleshooting Case Study 162	
	5-4	Clock Signals and Clocked Flip-Flops 163	
	5-5	Clocked S-C Flip-Flop 166	
	5-6	Clocked J-K Flip-Flop 169	
	5-7	Clocked D Flip-Flop 172	
	5-8	D Latch 174	
	5-9	Asynchronous Inputs 176	
	5-10	IEEE/ANSI Symbols 179	
	5-11	Flip-Flop Timing Considerations 182	
	5-12	Potential Timing Problem in FF Circuits 185	
	5-13	Master/Slave Flip-Flops 187	
	5-14	Flip-Flop Applications 187	
	5-15	Flip-Flop Synchronization 187	
	5-16	Detecting an Input Sequence 189	
	5-17	Data Storage and Transfer 190	
	5-18	Serial Data Transfer: Shift Registers 192	
-	5-19	Frequency Division and Counting 195	
	5-20	Microcomputer Application 199	
	5-21	Schmitt Trigger Devices 200	
	5-22	One-Shot (Monostable Multivibrator) 202	
	5-23	Analyzing Sequential Circuits 205	
	5-24	Astable Multivibrators 207	
	5-25	Troubleshooting Flip-Flop Circuits 209	
	5-26	Flip-Flop Summary 214	
		Problems 216	
		Answers to Section Review Questions 227	
6	DICIT	FAI ADITUMETIC, OPEDATIONS	
J		FAL ARITHMETIC: OPERATIONS CIRCUITS	220
	AND	CIRCUITS	229
	6-1	Binary Addition 231	
	6-2	Representing Signed Numbers 232	
	6-3	Addition in the 2's-Complement System 237	
	6-4	Subtraction in the 2's-Complement System 239	
	6-5	Multiplication of Binary Numbers 240	
	6-6	Binary Division 242	
	6-7	BCD Addition 242	

6-9	Arithmetic Circuits 246	
6-10	Parallel Binary Adder 248	
6-11	Design of a Full Adder 249	
6-12	Complete Parallel Adder with Registers 252	
6-13	Carry Propagation 254	
6-14	Integrated-Circuit Parallel Adder 255	
6-15	2's-Complement System 257	
6-16	BCD Adder 260	
6-17	Binary Multipliers 264	
6-18	Complex Arithmetic Integrated Circuits 268	
6-19	IEEE/ANSI Symbols 268	
6-20	Troubleshooting Case Study 269	
	Problems 271	
	Answers to Section Review Questions 277	
COLII	NTERS AND REGISTERS	278
	TOTAL OF THE REGISTERS	270
7-1	Asynchronous (Ripple) Counters 280	
7-2	Counters with Mod Numbers $< 2^N$ 283	
7-3	IC Asynchronous Counters 287	
7-4	Asynchronous Down Counter 292	
7-5	Propagation Delay in Ripple Counters 294	
7-6	Synchronous (Parallel) Counters 296	
7-7	Synchronous Down and Up/Down Counters 299	
7-8	Presettable Counters 301	
7-9	The 74193 (LS193/HC193) Counter 303	
7-10	More on the IEEE/ANSI Dependency Notation 308	
7-11	Decoding a Counter 310	
7-12	Decoding Glitches 313	
7-13	Cascading BCD Counters 316	
7-14	Synchronous Counter Design 317	
7-15	Shift-Register Counters 323	
7-16	Counter Applications: Frequency Counter 328	
7-17	Counter Applications: Digital Clock 333	
7-18	Integrated-Circuit Registers 336	
7-19	Parallel In/Parallel Out—The 74174 and 74178 337	
7-20	Serial In/Serial Out—The 4731B 340	
7-21	Parallel In/Serial Out—The 74165/74LS165/	

244

74HC165

341

6-8

Hexadecimal Arithmetic

	7-22	Serial In/Parallel Out—The 74164/74LS164/	
	7 22	74HC164 341	
	7-23	8	
	7-24	Troubleshooting 346 Problems 349	
		Answers to Section Review Questions 364	
8	INTE	GRATED-CIRCUIT LOGIC FAMILIES	366
	8-1	Digital IC Terminology 368	
	8-2	The TTL Logic Family 375	
	8-3	Standard TTL Series Characteristics 379	
	8-4	Other TTL Series 382	
	8-5	TTL Loading and Fan-Out 387	
	8-6	Other TTL Characteristics 392	
	8-7	TTL Open-Collector Outputs 396	
	8-8	Tristate (3-State) TTL 403	
	8-9	The ECL Digital IC Family 406	
	8-10	MOS Digital Integrated Circuits 410	
	8-11	The MOSFET 410	
1	8-12	Digital MOSFET Circuits 412	
V	8-13	Characteristics of MOS Logic 414	
V	8-14	Complementary MOS Logic 416	
	8-15	CMOS Series Characteristics 419	
	8-16	CMOS Open-Drain and Tristate Outputs 423	
	8-17	CMOS Transmission Gate (Bilateral Switch) 426	
	8-18	IC Interfacing 428	
	8-19	TTL Driving CMOS 429	
	8-20	CMOS Driving TTL 431	
	8-21	Troubleshooting 434	
		Problems 436	
		Answers to Section Review Questions 449	
•	MSI I	LOGIC CIRCUITS	451
	9-1	Decoders 453	
	9-2	BCD-to-7-Segment Decoder/Drivers 461	
	9-3	Liquid Crystal Displays 463	
	9-4	Encoders 465	
	9-5	IEEE/ANSI Symbols 471	
	9-6	Troubleshooting 472	

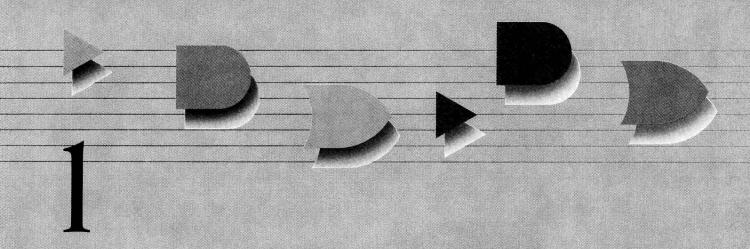
	9-8	Multiplexer Applications 479	
	9-9	Demultiplexers (Data Distributors) 485	
	9-10	More IEEE/ANSI Symbology 493	
	9-11	More Troubleshooting 494	
	9-12	Magnitude Comparator 497	
	9-13	Code Converters 500	
	9-14	Tristate Registers 504	
	9-15	Data Busing 506	
		Problems 513	
		Answers to Section Review Questions 526	
10	INTER	RFACING WITH THE ANALOG WORLD	528
	10-1	Interfacing with the Analog World 529	
	10-2	Digital-to-Analog Conversion 531	
	10-3	D/A-Converter Circuitry 539	
	10-4	DAC Specifications 544	
	10-5	DAC Applications 546	
	10-6	Troubleshooting DACs 547	
	10-7	Analog-to-Digital Conversion 548	
	10-8	Digital-Ramp ADC 550	
	10-9	Data Acquisition 554	
	10-10	Successive-Approximation ADC 557	
	10-11	Flash ADCs 563	
	10-12		
		Digital Voltmeter 567	
	10-14	Sample-and-Hold Circuits 569	
	10-15	Multiplexing 570	
	10-16	Digital Storage Oscilloscope (DSO) 572	
		Problems 573	
		Answers to Section Review Questions 584	
11	MEMO	DRY DEVICES	585
	11-1	Memory Terminology 588	
	11-2	General Memory Operation 591	
	11-3	CPU-Memory Connections 594	
	11-4	Read-Only Memories 595	
	11-5	ROM Architecture 597	
	11-6	ROM Timing 600	

Multiplexers (Data Selectors)

474

9-7

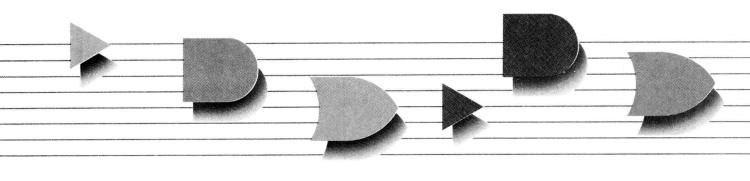
	11-7	Types of ROMs 601	
	11-8	ROM Applications 609	
	11-9	Programmable Logic Devices 612	
	11-10	Semiconductor RAMs 620	
	11-11	RAM Architecture 620	
	11-12	Static RAM (SRAM) 623	
	11-13	,	
	11-14	Dynamic RAM Structure and Operation 628	
	11-15	DRAM Read/Write Cycles 633	
	11-16	DRAM Refreshing 635	
	11-17	Expanding Word Size and Capacity 637	
	11-18	Nonvolatile RAM 643	
	11-19	Sequential Memories 644	
	11-20	Magnetic Memories 649	
	11-21	8	
	11-22	Testing ROM 661	
		Problems 662	
		Answers to Section Review Questions 673	
12		DDUCTION TO THE MICROPROCESSOR MICROCOMPUTER What Is a Digital Computer? 677 How Do Computers Think? 677 Secret Agent 89 677 Basic Computer System Organization 679 Basic µC Elements 681 Computer Words 684 Instruction Words 685 Executing a Machine-Language Program 688 Typical µC Structure 692 READ and WRITE Operations 695 Final Comments 699	675
	APPEN	NDIX I: Glossary	701
	APPEN	NDIX II: Manufacturers' IC Data Sheets	710
	ANSW	ERS TO SELECTED PROBLEMS	740
	INDEX		751



INTRODUCTORY CONCEPTS

Outline

- 1-1 Numerical Representations
- 1-2 Digital and Analog Systems
- 1-3 Digital Number Systems
- 1-4 Representing Binary Quantities
- 1-5 Digital Circuits
- 1-6 Parallel and Serial Transmission
- 1-7 Memory
- 1-8 Digital Computers



Objectives

Upon completion of this chapter, you will be able to:

- Distinguish between analog and digital representations.
- Name the advantages, disadvantages, and major differences among analog, digital, and hybrid systems.
- Understand the need for analog-to-digital converters (ADCs) and digital-to-analog converters (DACs).
- Convert between decimal and binary numbers.
- Identify typical digital signals.
- Cite several integrated-circuit fabrication technologies.
- Identify a timing diagram.
- State the differences between parallel and serial transmission.
- Name various memory elements.
- Describe the major parts of a digital computer and understand their functions.

Introduction

When most of us hear the term "digital," we immediately think of "digital calculator" or "digital computer." This can probably be attributed to the dramatic way that low-cost, powerful calculators and computers have become accessible to the average person. It is important to realize that calculators and computers represent only one of the many applications of digital circuits and principles. Digital circuits are used in electronic products such as video games, microwave ovens, and automobile control systems, and in test equipment such as meters, generators, and oscilloscopes. Digital techniques have also replaced a lot of the older "analog circuits" used in consumer products such as radios, TV sets, and high-fidelity sound recording and playback equipment.

In this book we are going to study the principles and techniques that are common to all digital systems from the simplest on/off switch to the most complex computer. If this book is successful, you should gain a deep understanding of how all digital systems work, and you should be able to apply this understanding to the analysis and troubleshooting of any digital system.

We start by introducing some underlying concepts that are a vital part of digital technology; these concepts will be expanded on as they are needed later in the text. We will also introduce some of the terminology that is necessary when embarking on a new field of study, and will add to it in every chapter. A complete glossary of terminology is presented in Appendix I.

1-1 NUMERICAL REPRESENTATIONS

In science, technology, business, and, in fact, most other fields of endeavor, we are constantly dealing with *quantities*. Quantities are measured, monitored, recorded, manipulated arithmetically, observed, or in some other way utilized in most physical systems. It is important when dealing with various quantities that we be able to represent their values efficiently and accurately. There are basically two ways of representing the numerical value of quantities: **analog** and **digital**.

Analog Representations In analog representation one quantity is represented by another which is proportional to the first. An example is an automobile speedometer, in which the deflection of the needle is proportional to the speed of the auto. The angular position of the needle represents the value of the auto's speed, and the needle follows any changes that occur as the auto speeds up or slows down.

Another example is the common room thermostat, in which the bending of the bimetallic strip is proportional to the room temperature. As the temperature changes gradually, the curvature of the strip changes proportionally.

Still another example of an analog quantity is found in the familiar audio microphone. In this device an output voltage is generated in proportion to the amplitude of the sound waves that impinge on the microphone. The variations in the output voltage follow the same variations as the input sound.

Analog quantities such as those cited above have an important characteristic: they can vary over a continuous range of values. The automobile speed can have any value between zero and, say, 100 mph. Similarly, the microphone output might be anywhere within a range of zero to 10 mV (for example, 1 mV, 2.3724 mV, 9.9999 mV).

Digital Representations In digital representation the quantities are represented not by proportional quantities but by symbols called digits. As an example, consider the digital watch, which provides the time of day in the form of decimal digits which represent hours and minutes (and sometimes seconds). As we know, the time of day changes continuously, but the digital watch reading does not change continuously; rather, it changes in steps of one per minute (or per second). In other words, this digital representation of the time of day changes in discrete steps, as compared with the representation of time provided by an analog watch, where the dial reading changes continuously.

The major difference between analog and digital quantities, then, can be simply stated as follows:

analog ≡ continuous digital ≡ discrete (step by step)