



Contents

Preface xiii

How to Use This Book for Self-Study xviii

Digital Resources xix

About the Authors xxiv

Unit 1 Introduction

Number Systems and Conversion 1

Objectives 1

Study Guide 2

1.1 Digital Systems and Switching Circuits 6

1.2 Number Systems and Conversion 8

1.3 Binary Arithmetic 12

1.4 Representation of Negative Numbers 16

Sign and Magnitude Numbers 16

2's Complement Numbers 16

Addition of 2's Complement Numbers 17

1's Complement Numbers 19

Addition of 1's Complement Numbers 19

1.5 Binary Codes 21

Problems 24

Unit 2 Boolean Algebra 29

Objectives 29

Study Guide 30

2.1 Introduction 36

2.2 Basic Operations 37

2.3 Boolean Expressions and Truth Tables 39

2.4	Basic Theorems	41
2.5	Commutative, Associative, Distributive, and DeMorgan's Laws	43
2.6	Simplification Theorems	46
2.7	Multiplying Out and Factoring	49
2.8	Complementing Boolean Expressions	52
	Problems	53

Unit 3 Boolean Algebra (Continued) 60

	Objectives	60
	Study Guide	61
3.1	Multiplying Out and Factoring Expressions	66
3.2	Exclusive-OR and Equivalence Operations	68
3.3	The Consensus Theorem	70
3.4	Algebraic Simplification of Switching Expressions	72
3.5	Proving Validity of an Equation	74
	Programmed Exercises	77
	Problems	82

Unit 4 Applications of Boolean Algebra Minterm and Maxterm Expansions 87

	Objectives	87
	Study Guide	88
4.1	Conversion of English Sentences to Boolean Equations	94
4.2	Combinational Logic Design Using a Truth Table	96
4.3	Minterm and Maxterm Expansions	97
4.4	General Minterm and Maxterm Expansions	100
4.5	Incompletely Specified Functions	103
4.6	Examples of Truth Table Construction	104
4.7	Design of Binary Adders and Subtractors	108
	Problems	114

Unit 5 Karnaugh Maps 123

	Objectives	123
	Study Guide	124
5.1	Minimum Forms of Switching Functions	134
5.2	Two- and Three-Variable Karnaugh Maps	136

5.3	Four-Variable Karnaugh Maps	141
5.4	Determination of Minimum Expressions Using Essential Prime Implicants	144
5.5	Five-Variable Karnaugh Maps	149
5.6	Other Uses of Karnaugh Maps	152
5.7	Other Forms of Karnaugh Maps	153
	Programmed Exercises	154
	Problems	159

Unit 6 Quine-McCluskey Method 167

	Objectives	167
	Study Guide	168
6.1	Determination of Prime Implicants	173
6.2	The Prime Implicant Chart	176
6.3	Petrick's Method	179
6.4	Simplification of Incompletely Specified Functions	181
6.5	Simplification Using Map-Entered Variables	182
6.6	Conclusion	184
	Programmed Exercise	185
	Problems	189

Unit 7 Multi-Level Gate Circuits NAND and NOR Gates 193

	Objectives	193
	Study Guide	194
7.1	Multi-Level Gate Circuits	199
7.2	NAND and NOR Gates	204
7.3	Design of Two-Level NAND- and NOR-Gate Circuits	206
7.4	Design of Multi-Level NAND- and NOR-Gate Circuits	209
7.5	Circuit Conversion Using Alternative Gate Symbols	210
7.6	Design of Two-Level, Multiple-Output Circuits	214
	<i>Determination of Essential Prime Implicants for Multiple-Output Realization</i>	216
7.7	Multiple-Output NAND- and NOR-Gate Circuits	217
	Problems	218

Unit 8 Combinational Circuit Design and Simulation Using Gates 225

Objectives	225
Study Guide	226
8.1 Review of Combinational Circuit Design	229
8.2 Design of Circuits with Limited Gate Fan-In	230
8.3 Gate Delays and Timing Diagrams	232
8.4 Hazards in Combinational Logic	234
8.5 Simulation and Testing of Logic Circuits	240
Problems	243
Design Problems	246
Seven-Segment Indicator	246

Unit 9 Multiplexers, Decoders, and Programmable Logic Devices 252

Objectives	252
Study Guide	253
9.1 Introduction	260
9.2 Multiplexers	261
9.3 Three-State Buffers	265
9.4 Decoders and Encoders	268
9.5 Read-Only Memories	271
9.6 Programmable Logic Devices	275
<i>Programmable Logic Arrays</i>	275
<i>Programmable Array Logic</i>	278
9.7 Complex Programmable Logic Devices	280
9.8 Field-Programmable Gate Arrays	282
<i>Decomposition of Switching Functions</i>	283
Problems	286

Unit 10 Introduction to VHDL 294

Objectives	294
Study Guide	295
10.1 VHDL Description of Combinational Circuits	299
10.2 VHDL Models for Multiplexers	304
10.3 VHDL Modules	306
<i>Four-Bit Full Adder</i>	308

10.4	Signals and Constants	311
10.5	Arrays	312
10.6	VHDL Operators	315
10.7	Packages and Libraries	316
10.8	IEEE Standard Logic	318
10.9	Compilation and Simulation of VHDL Code	321
	Problems	322
	Design Problems	327

Unit 11 Latches and Flip-Flops 331

	Objectives	331
	Study Guide	332
11.1	Introduction	336
11.2	Set-Reset Latch	338
11.3	Gated Latches	342
11.4	Edge-Triggered D Flip-Flop	346
11.5	S-R Flip-Flop	349
11.6	J-K Flip-Flop	350
11.7	T Flip-Flop	351
11.8	Flip-Flops with Additional Inputs	352
11.9	Asynchronous Sequential Circuits	354
11.10	Summary	357
	Problems	358
	Programmed Exercise	367

Unit 12 Registers and Counters 370

	Objectives	370
	Study Guide	371
12.1	Registers and Register Transfers	376
	<i>Parallel Adder with Accumulator</i>	378
12.2	Shift Registers	380
12.3	Design of Binary Counters	384
12.4	Counters for Other Sequences	389
	<i>Counter Design Using D Flip-Flops</i>	393
12.5	Counter Design Using S-R and J-K Flip-Flops	395
12.6	Derivation of Flip-Flop Input Equations—Summary	398
	Problems	402

Unit 13 Analysis of Clocked Sequential Circuits 412

Objectives	412
Study Guide	413
13.1 A Sequential Parity Checker	419
13.2 Analysis by Signal Tracing and Timing Charts	421
13.3 State Tables and Graphs	425
<i>Construction and Interpretation of Timing Charts</i>	430
13.4 General Models for Sequential Circuits	432
Programmed Exercise	436
Problems	441

Unit 14 Derivation of State Graphs and Tables 453

Objectives	453
Study Guide	454
14.1 Design of a Sequence Detector	457
14.2 More Complex Design Problems	463
14.3 Guidelines for Construction of State Graphs	467
14.4 Serial Data Code Conversion	473
14.5 Alphanumeric State Graph Notation	476
14.6 Incompletely Specified State Tables	478
Programmed Exercises	480
Problems	486

Unit 15 Reduction of State Tables State Assignment 497

Objectives	497
Study Guide	498
15.1 Elimination of Redundant States	505
15.2 Equivalent States	507
15.3 Determination of State Equivalence Using an Implication Table	509
15.4 Equivalent Sequential Circuits	512
15.5 Reducing Incompletely Specified State Tables	514
15.6 Derivation of Flip-Flop Input Equations	517
15.7 Equivalent State Assignments	519
15.8 Guidelines for State Assignment	523
15.9 Using a One-Hot State Assignment	528
Problems	531

Unit 16 Sequential Circuit Design 545

Objectives	545
Study Guide	546
16.1 Summary of Design Procedure for Sequential Circuits	548
16.2 Design Example—Code Converter	549
16.3 Design of Iterative Circuits	553
<i>Design of a Comparator</i>	553
16.4 Design of Sequential Circuits Using ROMs and PLAs	556
16.5 Sequential Circuit Design Using CPLDs	559
16.6 Sequential Circuit Design Using FPGAs	563
16.7 Simulation and Testing of Sequential Circuits	565
16.8 Overview of Computer-Aided Design	570
Design Problems	572
Additional Problems	578

Unit 17 VHDL for Sequential Logic 585

Objectives	585
Study Guide	586
17.1 Modeling Flip-Flops Using VHDL Processes	590
17.2 Modeling Registers and Counters Using VHDL Processes	594
17.3 Modeling Combinational Logic Using VHDL Processes	599
17.4 Modeling a Sequential Machine	601
17.5 Synthesis of VHDL Code	608
17.6 More About Processes and Sequential Statements	611
Problems	613
Simulation Problems	624

Unit 18 Circuits for Arithmetic Operations 626

Objectives	626
Study Guide	627
18.1 Serial Adder with Accumulator	629
18.2 Design of a Binary Multiplier	633
18.3 Design of a Binary Divider	637
Programmed Exercises	644
Problems	648

Unit 19 State Machine Design with SM Charts 660

Objectives	660
Study Guide	661
19.1 State Machine Charts	662
19.2 Derivation of SM Charts	667
19.3 Realization of SM Charts	672
Problems	677

Unit 20 VHDL for Digital System Design 684

Objectives	684
Study Guide	685
20.1 VHDL Code for a Serial Adder	688
20.2 VHDL Code for a Binary Multiplier	690
20.3 VHDL Code for a Binary Divider	700
20.4 VHDL Code for a Dice Game Simulator	702
20.5 Concluding Remarks	705
Problems	706
Lab Design Problems	709

A Appendices 713

A MOS and CMOS Logic	713
B VHDL Language Summary	719
C Tips for Writing Synthesizable VHDL Code	724
D Proofs of Theorems	727
E Answers to Selected Study Guide Questions and Problems	729

References 785

Index 786

Description of the CD 792