CONTENTS

Preface ix

Chapter 1
INTRODUCTION TO DIGITAL ELECTRONICS 1

1.0 Introduction
1.1 Logic Functions 2
1.2 Karnaugh Maps 6
1.3 Integrated Circuit Fabrication Technology; Scale of Integration 12
1.4 Properties of Digital Circuits 20
1.5 The Ideal Digital Logic Element 21
1.6 Definition of Noise and Noise Margins 22
1.7 Definition of Transient Characteristics 23
1.8 Computer-Aided Design of Digital Circuits 25
1.9 Diode Logic and the Programmable Logic Array (PLA) 27
1.10 Summary 33
References 33
Problems 33

Chapter 2
METAL-OXIDE-SEMICONDUCTOR (MOS) TRANSISTOR 37

2.0 Introduction 37
2.1 Alternative MOS Processes 37
2.2 Structure and Operation of the MOS Transistor 39
2.3 Threshold Voltage of the MOS Transistor 43
2.4 Current-Voltage Characteristics 49
2.5 Capacitances of the MOS Transistor 52
2.6 Modeling the MOS Transistor for Circuit Simulation 55
*2.7 Limitations on MOS Transistors 59
2.8 Summary 63
References 63
Demonstrations 64
Problems 65

*Denotes material which may be omitted without loss of continuity.

Chapter 3
MOS INVERTERS AND GATE CIRCUITS 68

3.0 Introduction 68
3.1 Static NMOS Inverter Analysis 70
3.2 Transistors as Load Devices 73
3.3 Circuit Layout and Capacitances 85
3.4 Switching Time Analysis and Power-Delay Product 94
3.5 Complementary MOS (CMOS) Inverter Analysis 97
3.6 NMOS Gate Circuits 102
3.7 CMOS Gate Circuits 105
*3.8 Dynamic Logic Circuits 108
*3.9 Scaling of MOS Circuits 112
3.10 Summary 114
References 115
Demonstrations 116
Problems 117

Chapter 4
SEMICONDUCTOR DIODES 125

4.0 Introduction 125
4.1 *pn* Junction Diodes 127
4.2 The Equilibrium Barrier Potential 128
4.3 Depletion Region Charge 132
4.4 *pn* Junction with Forward Bias 138
4.5 *pn* Junction with Reverse Bias 143
4.6 Diode Switching Transients 144
4.7 Diode Structures 149
4.8 Diode Models for Circuit Simulation 153
4.9 Schottky-Barrier Diode 157
*4.10 Temperature Effects 159
*4.11 Breakdown Diodes 161
4.12 Summary 163
References 163
Demonstrations 164
Problems 165

Chapter 5
BIPOLAR JUNCTION TRANSISTOR 170

5.0 The Bipolar Junction Transistor 170
5.1 Transistor Operation in Forward Active Mode 170
5.2 Terminal Currents 177
5.3 Modes of Operation 180

5.4 BJT Model for Circuit Simulation Programs 186
5.5 Summary 193
References 193
Demonstrations 194
Problems 196

Chapter 6
BIPOLAR TRANSISTOR INVERTER 199

6.0 Introduction 199
6.1 Static Characteristics 199
6.2 Charge-Control Analysis 206
6.3 BJT Inverter Switching Times 228
6.4 Schottky-Clamped Inverter 236
6.5 Comparison with SPICE 238
6.6 Summary 242
References 243
Demonstrations 243
Problems 244

Chapter 7
BIPOLAR DIGITAL GATE CIRCUITS 248

7.0 Introduction 248
7.1 Resistor-Transistor Logic 249
7.2 Diode-Transistor Logic 251
7.3 Transistor-Transistor Logic 255
7.4 Emitter-Coupled Logic 271
7.5 Integrated Injection Logic 283
7.6 Integrated Schottky Logic 291
*7.7 Interfacing 293
7.8 Summary 298
References 299
Demonstrations 299
Problems 301

Chapter 8
REGENERATIVE LOGIC CIRCUITS 306

8.0 Introduction 306
8.1 Basic Bistable Circuit 307
8.2 SR Latch 308
8.3 JK Flip-Flop 310
8.4 *D* Flip-Flop 314
8.5 TTL Circuits 315
8.6 ECL Circuits 316
8.7 I^2L Circuits 319

*Denotes material which may be omitted without loss of continuity

8.8	NMOS Circuits	321
8.9	CMOS Circuits	327
8.10	Summary of Flip-Flop Circuits	329
8.11	Schmitt Trigger	332
8.12	Multivibrator Circuits	337
8.13	IC Timer	345
8.14	Summary	350
	References	351
	Demonstrations	351
	Problems	352

Chapter 9
SEMICONDUCTOR MEMORIES 359

9.0	Introduction and Definitions	359
9.1	Read-Only Memories	363
9.2	Static Read-Write Memories	378
9.3	Dynamic Read-Write Memories	386
9.4	Serial Memories	394
9.5	Summary	397
	References	397
	Problems	398

Chapter 10
CIRCUIT DESIGN FOR LSI AND VLSI 400

10.0	Introduction	400
10.1	Gate Arrays	401
10.2	Standard Cells	406
10.3	Programmable Logic Array (PLA)	407
10.4	Microprocessors and Microcomputers	408
10.5	Circuit Design for VLSI	410
10.6	Summary	421
	References	421
	Problems	422

Answers to Exercises 424

Index 431