

CONTENTS

<i>Foreward</i>	<i>xxi</i>
<i>Preface</i>	<i>xxiii</i>
<i>Acknowledgements</i>	<i>xxix</i>
<i>Symbols and Abbreviations</i>	<i>xxxi</i>

1. INTRODUCTION TO PULSE WAVEFORMS 1

1.1	Functions, Signals, and Waveforms	1
1.2	Classification and Analysis of Pulse Waveforms	3
1.3	Passive and Active Pulse Circuits	4
1.4	Periodic Waveforms	4
1.5	Fourier Series	5
1.6	Fourier Transform	6
1.7	Laplace Transform	7
1.8	Laplace Transform Pair	8
1.9	Use of Laplace Transform	9
1.10	Transfer Function	10
1.11	Frequency Function	12
1.12	Pulse Waveforms	13
	<i>Test Your Understanding</i>	16

2. LINEAR WAVESHAPING CIRCUITS 19

2.1	Linear Waveshaping Circuits	20
2.2	Unique Property of Sinusoidal Waveform	21
2.3	RC High-Pass Filter	22
2.4	Response of the RC High-Pass Filter to a Sinusoidal Input	24
2.5	Average Value of the High-Pass Filter Output	26
2.6	Response of a First-Order Linear Circuit	27
2.7	Response of the RC High-Pass Filter to a Step Input	28
2.8	Definition of Time Constant	30
2.9	Response of the RC High-Pass Filter to a Pulse Input	32
2.10	Response of the RC High-Pass Filter to a Square Wave	36
2.11	Response of the RC High-Pass Filter to a Symmetrical Square Wave	46
2.12	Response of the RC High-Pass Filter to a Ramp Input	49
2.13	Response of the RC High-Pass Filter to an Exponential Input	54
2.14	RC Differentiator	60
2.15	Criterion for Good Differentiation	61

- 2.16 Op-Amp Differentiator 64
- 2.17 Double Differentiation 66
- 2.18 RC Low-Pass Filter 69
- 2.19 Response of the RC Low-Pass Filter to a Sinusoidal Input 71
- 2.20 Response of the RC Low-Pass Filter to a Step Input 72
- 2.21 Response of the RC Low-Pass Filter to a Pulse Input 74
- 2.22 Response of the RC Low-Pass Filter to a Square Wave 78
- 2.23 Response of the RC low-pass filter to a symmetrical square wave 82
- 2.24 Response of the RC Low-Pass Filter to a Ramp Input 86
- 2.25 Response of the RC Low-Pass Filter to an Exponential Input 93
- 2.26 RC Integrator 95
- 2.27 Criterion for Good Integration 96
- 2.28 RLC Ringing Circuit 99
- 2.29 Uncompensated and Compensated Attenuators 105
- 2.30 Laplace Transform Approach to Uncompensated Attenuator 115
Test Your Understanding 117

3. NON-LINEAR WAVESHAPING CIRCUITS 127

- 3.1 Non-Linear Waveshaping Circuits 128
- 3.2 Operation of Diode Clipping Circuits 128
- 3.3 Positive Limiting Operation 129
- 3.4 Series-Diode Positive Limiting Circuit 130
- 3.5 Parallel-Diode Positive Limiting Circuit 133
- 3.6 Diode Negative Limiting Operation 139
- 3.7 Series-Diode Clipping Circuit 141
- 3.8 Parallel-Diode Clipping Circuit 143
- 3.9 Practical Considerations 144
- 3.10 Methods for Analyzing Multi-Diode Circuits 145
- 3.11 Method of Assumed States 146
- 3.12 Application of Method of Assumed States 147
- 3.13 Method of Break Point 156
- 3.14 Series-Diode Noise Clipping Circuit 160
- 3.15 Unbiased Noise Clipping Circuit 161
- 3.16 Parallel-Diode Noise Clipping Circuit 162
- 3.17 Double Peak Limiter with Zener Diodes 162
- 3.18 Transistor Clipping Circuit 163
- 3.19 Emitter-Coupled Transistor Clipping Circuit 164
- 3.20 Diode Comparator Circuit 165
- 3.21 Introduction to Clamping Circuits 173
- 3.22 Restoration of the Lost DC Component 174
- 3.23 Clamping a Waveform to Zero Level 175
- 3.24 Simple Diode Circuit that Clamps the Positive Peaks to Zero 176
- 3.25 Self-Adjusting Diode Circuit that Clamps the Positive Peaks to Zero 178
- 3.26 Operation of a Practical Diode Clamping Circuit 181

- 3.27 Analysis of a Practical Diode Clamping Circuit 181
- 3.28 Practical Considerations 193
- 3.29 Distortion in the Clamped Waveform at the Reference Voltage 197
Test Your Understanding 199

4. SWITCHING CHARACTERISTICS OF DEVICES 208

- 4.1 Switching Characteristics of a Diode 209
- 4.2 Charge-control Model of a Diode 209
- 4.3 Switching Times in a Diode 210
- 4.4 Breakdown Mechanisms in a Diode 212
- 4.5 Diode Linear Models 213
- 4.6 Switching Times in a Transistor 214
- 4.7 Definitions of Transistor Switching Times 218
- 4.8 Transistor Breakdown Voltages 218
- 4.9 Common-Emitter Transistor Switch 219
- 4.10 Transistor at Saturation 220
- 4.11 Temperature Variation of Saturation Values 221
- 4.12 Transistor at Cut-Off 221
- 4.13 Commutating Capacitance 222
- 4.14 Design of a High-Speed Transistor Switch 224
- 4.15 Schottky Transistor 227
- 4.16 Common-Emitter Switch with Inductive Load 228
- 4.17 Function of Damping Diodes 232
- 4.18 Transistor Switch with Capacitive Load 233
- 4.19 Collector Catching Diodes 237
- 4.20 JFET Switches 240
- 4.21 NMOS and PMOS Switches 241
- 4.22 MOSFET Driver: Passive Load and Active Load 243
- 4.23 CMOS Switch 244
- 4.24 Dynamic Power Dissipation in CMOS Switch 245
Test Your Understanding 247

5. REGENERATIVE FEEDBACK AND MULTIVIBRATORS 250

- 5.1 Role of Feedback in Electronic Circuits 251
- 5.2 Closed-Loop System 251
- 5.3 Effect of Feedback on Amplifier Parameters 252
- 5.4 Loop Gain 253
- 5.5 Effect of Feedback on Stability 254
- 5.6 Stable, Unstable and Oscillatory Behaviour 255
- 5.7 Sinusoidal Oscillations 256
- 5.8 Principles of Multivibrators 257
- 5.9 Classification of Multivibrators 258
Test Your Understanding 261

6. TRANSISTOR BISTABLE MULTIVIBRATORS 265

- 6.1 Classification of Multivibrators 266
- 6.2 Quiescent Condition of a Bistable Multivibrator 269
- 6.3 Fixed-Bias Transistor Bistable Multivibrator 272
- 6.4 Effect of Loading of Collector on Output Swing 272
- 6.5 Collector-Catching Diodes 274
- 6.6 Self-Biased Transistor Bistable Multivibrator 292
- 6.7 Speed-up Capacitors 292
- 6.8 Basic Techniques in the Triggering of Bistable Multivibrators 310
- 6.9 Application of Trigger Input at the Base of the OFF Transistor 312
- 6.10 Application of Trigger Input at the Base of the on Transistor 312
- 6.11 Sensitivity of a Transistor to a Trigger Input 312
- 6.12 Unsymmetrical Triggering of a Bistable Multivibrator 314
- 6.13 Using the Bistable Multivibrator as T Flip-Flop 316
- 6.14 Symmetrical Triggering Applying a Step at the Common Emitters 318
- 6.15 Direct Connected Transistor Bistable Multivibrator 321
Test Your Understanding 323

7. TRANSISTOR SCHMITT TRIGGER CIRCUIT 327

- 7.1 Schmitt Trigger Circuit 328
- 7.2 Effect of Loop Gain on the Circuit 329
- 7.3 Stable Equilibrium and Unstable Equilibrium 332
- 7.4 Schmitt Trigger Circuit and the Conventional Bistable Multivibrator 332
- 7.5 Hysteresis of the Schmitt Trigger Circuit 334
- 7.6 Applications of the Schmitt Trigger Circuit 335
- 7.7 Analysis of a Schmitt Trigger Circuit 336
- 7.8 Comments on the Stability of V_{UTP} in Practice 338
- 7.9 Operating Transistor Q_2 in Saturation 339
- 7.10 Need to keep the Hysteresis Gap V_H Small 339
- 7.11 Calculation of V_{LTP} of a Schmitt Trigger Circuit 340
- 7.12 Adjustment of V_{LTP} and V_{UTP} for Controlling the Hysteresis Gap 342
- 7.13 Choosing R_s for proper functioning of the Circuit 357
- 7.14 Precautions to be Taken While Using R_{e1} and R_{e2} to Control V_H 357
Test Your Understanding 358

8. TRANSISTOR MONOSTABLE AND ASTABLE MULTIVIBRATORS 363

- 8.1 Monostable Multivibrator 364
- 8.2 Triggering of the Collector-Coupled Monostable Multivibrator 364

- 8.3 Expression for Gate Width T with $Q1$ in Active Region 367
- 8.4 Expression for Gate Width T with $Q1$ in Saturation 368
- 8.5 Waveforms of the Collector Coupled Monostable Multivibrator 369
- 8.6 Overshoot δ in Base Waveform of Transistor $Q2$ at $t = T$ 377
- 8.7 Emitter Coupled Monostable Multivibrator 379
- 8.8 Waveforms of the Emitter-Coupled Monostable Multivibrator 381
- 8.9 Expression for Gate width T 383
- 8.10 Collector-Coupled Transistor Astable Multivibrator 384
- 8.11 Voltage-to-Frequency Converter 390
- 8.12 Astable Multivibrator with Vertical-Edged Collector Waveforms 391
- 8.13 Gated Astable Multivibrator 393
- 8.14 Blocked Condition in an Astable Multivibrator 393
- 8.15 Emitter-Coupled Astable Multivibrator 394
- 8.16 Advantages and Disadvantages of Emitter-Coupled Astable Multivibrator 400
Test Your Understanding 401

9. VOLTAGE SWEEP CIRCUITS

405

- 9.1 Voltage Sweep Waveform 406
- 9.2 Departure from Linearity of a Voltage Sweep Waveform 407
- 9.3 Relationship between e_s , e_r , and e_d for an Exponential Waveform 408
- 9.4 Overview of Methods of Generating a Voltage Sweep Waveform 412
- 9.5 Generation of a Voltage Sweep Waveform through Exponential Charging 413
- 9.6 Free-Running Mode Operation 416
- 9.7 Triggered-Mode Operation 416
- 9.8 Free-Running UJT Sweep Waveform Generator 416
- 9.9 Free-Running UJT Circuit with Control-Lable Sweep and Retrace Intervals 419
- 9.10 Triggered UJT Sweep Waveform Generator 423
- 9.11 Transistor Constant-Current Sweep Circuit 428
- 9.12 Basic Principles Common to Miller and Bootstrap Approaches 430
- 9.13 Miller Voltage Sweep Circuit 433
- 9.14 Bootstrap Voltage Sweep Circuit 439
- 9.15 Comparison of Miller Sweep and Bootstrap Sweep Circuits 443
- 9.16 Transistor Miller Voltage Sweep Circuit 444
- 9.17 Single Transistor Bootstrap Voltage Sweep Circuit 446
- 9.18 Two-transistor Bootstrap Voltage Sweep Circuit 448
Test Your Understanding 458

10. CURRENT SWEEP CIRCUITS 463

- 10.1 Principle of Current Sweep Generation 464
- 10.2 Simple Current Sweep 464
- 10.3 Slope Error of the Current Sweep Waveform 466
- 10.4 Linearity Correction through Adjustment of Driving Waveform 468
- 10.5 Complete Practical Current Sweep Generator 472
- 10.6 Omission of Coil Capacitance 474
- 10.7 Circuits for Generating an Impulse 477
- 10.8 Improvement of Linearity of Current Driver for Yoke 478
- 10.9 Linearization of Trapezoidal Voltage 479
- 10.10 Mechanism to Generate a Fast Retrace Current Sweep 480
Test Your Understanding 482

11. SYNCHRONIZATION AND FREQUENCY DIVISION 485

- 11.1 Two Types of Synchronization 486
- 11.2 Relaxation Circuit 487
- 11.3 Synchronization of a Relaxation Circuit 487
- 11.4 Pulse Synchronization of an Astable Circuit 487
- 11.5 Frequency Division in the Sweep Circuits 489
- 11.6 Synchronization of Astable Multivibrator 490
- 11.7 Monostable Relaxation Circuit as Dividers 493
- 11.8 Phase Delay and Phase Jitters 494
- 11.9 Frequency Division without Phase Jitter 495
- 11.10 Synchronization of a Sweep Circuit with Symmetrical Signals
Test Your Understanding 497

12. SAMPLING GATES 499

- 12.1 Unidirectional Diode Gate 499
- 12.2 General Applications of Sampling Gates 501
- 12.3 Coincidence Gate 501
- 12.4 Unidirectional Diode Sampling Gate Insensitive to $-V_2$ 502
- 12.5 Bi-directional Diode Gates 503
- 12.6 Balance Conditions in a Bi-directional Diode Gate 506
- 12.7 Four-Diode Sampling Gate 508
- 12.8 Alternative form of a Four-Diode Sampling Gate 510
- 12.9 Six-Diode Sampling Gate 512
- 12.10 Transistor Sampling Gates 514
- 12.11 Chopper Amplifier 515
Test Your Understanding 517

13. BLOCKING OSCILLATORS 519

- 13.1 Pulse Transformers 520
- 13.2 Blocking Oscillators 520
- 13.3 Applications of Blocking Oscillator 520
- 13.4 Triggered Transistor Blocking Oscillator (Base Timing) 521
- 13.5 Triggered Transistor Blocking Oscillator (Emitter Timing) 527
- 13.6 Astable Transistor Blocking Oscillator (Diode-Controlled) 533
- 13.7 Astable Transistor Blocking Oscillator (RC-Controlled) 540
- Test Your Understanding 543*

14. NETWORK THEOREMS, TRANSIENTS, AND IMPEDANCE MATCHING 545

- 14.1 Network Theorems 546
- 14.2 Steady-State and Transient Responses 552
- 14.3 Response of a First-Order Linear Circuit 553
- 14.4 Electrical circuit Transients 554
- 14.5 Initial and Final Conditions 555
- 14.6 Properties of Passive Components 555
- 14.7 RC Circuit Transients 558
- 14.8 RL Circuit Transients 559
- 14.9 Voltage and Current Sources 560
- 14.10 Impedance Matching 563

15. REVIEW OF RLC CIRCUITS 566

- 15.1 Forced Response 567
- 15.2 Natural Response 567
- 15.3 Analysis of an RLC Circuit 567
- 15.4 Response of the RLC Circuit to a Step Waveform 570
- 15.5 Analysis of a Series RLC Circuit 576
- 15.6 Analogy between Electrical Circuits and Mechanical Systems 581

16. OP-AMP AND IC 555 TIMER 582

- 16.1 Operational Amplifier 583
- 16.2 Characteristics of an Ideal Op-amp 584
- 16.3 Voltage Constraint and Current Constraint 585
- 16.4 Inverting and Non-Inverting Op-amp Amplifiers 585
- 16.5 Op-amp Non-Inverting Amplifier 587
- 16.6 Simple Op-Amp Applications 588
- 16.7 Op-amp Differentiator 591
- 16.8 Practical Op-amp Differentiator 592
- 16.9 Op-amp Integrator 593
- 16.10 Practical Op-amp Integrator 594

- 16.11 Reasons for Preferring Integrators 594
 - 16.12 Op-Amp based Monostable Multivibrator 595
 - 16.13 Op-Amp based Astable Multivibrator 598
 - 16.14 Inverting Schmitt Trigger Circuit Using Op-Amp 600
 - 16.15 IC 555 Timer 603
 - 16.16 Monostable Multivibrator with IC 555 Timer 604
 - 16.17 Astable Multivibrator with IC 555 Timer 607
 - 16.18 Multivibrators Employing Negative-Resistance Devices 609
 - 16.19 Operating Point on the Volt–Ampere Characteristic 611
 - 16.20 Bistable Operation 616
 - 16.21 Monostable Operation 617
 - 16.22 Astable Operation 619
 - 16.23 Voltage-Controlled NR Switching Circuits 620
- Test Your Understanding 621*

17. DIGITAL LOGIC AND FLIP-FLOPS 624

- 17.1 Analog, Digital and Binary Signals 625
- 17.2 Basic Boolean Operations 625
- 17.3 Other Boolean Identities 627
- 17.4 NAND and NOR as the Universal Gates 627
- 17.5 NAND Realization 628
- 17.6 NOR Realization 629
- 17.7 Design of a Combinational Logic Circuit 629
- 17.8 Design of a Full Adder 630
- 17.9 Sequential Logic Circuits 632
- 17.10 SR Latch 633
- 17.11 Clocked SR Flip-Flop 634
- 17.12 JK Flip-Flop 636
- 17.13 Level-Triggered and Edge Triggered Flip-Flops 637
- 17.14 Master-Slave JK Flip-Flop 637
- 17.15 Registers and Counters 638

18. REVIEW OF SEMICONDUCTOR DIODES AND TRANSISTORS 641

- 18.1 Composition of Matter 642
- 18.2 Classification of Matter 642
- 18.3 Improving Conductivity of Semiconductors 644
- 18.4 Generation and Recombination of Hole-Electron Pairs 644
- 18.5 Controlled-Flow of Charge Carriers 645
- 18.6 Majority and Minority Carriers 646
- 18.7 Drift and Diffusion Currents 646
- 18.8 Semiconductor Diode Operation 647
- 18.9 Diode Characteristic 649
- 18.10 Concept of Load Line 652

18.11	Bipolar Junction Transistor	652	
18.12	Transistor Biasing Circuits	655	
18.13	Unijunction Transistor (UJT)	658	
	<i>Appendix</i>		661
	<i>Index</i>		664