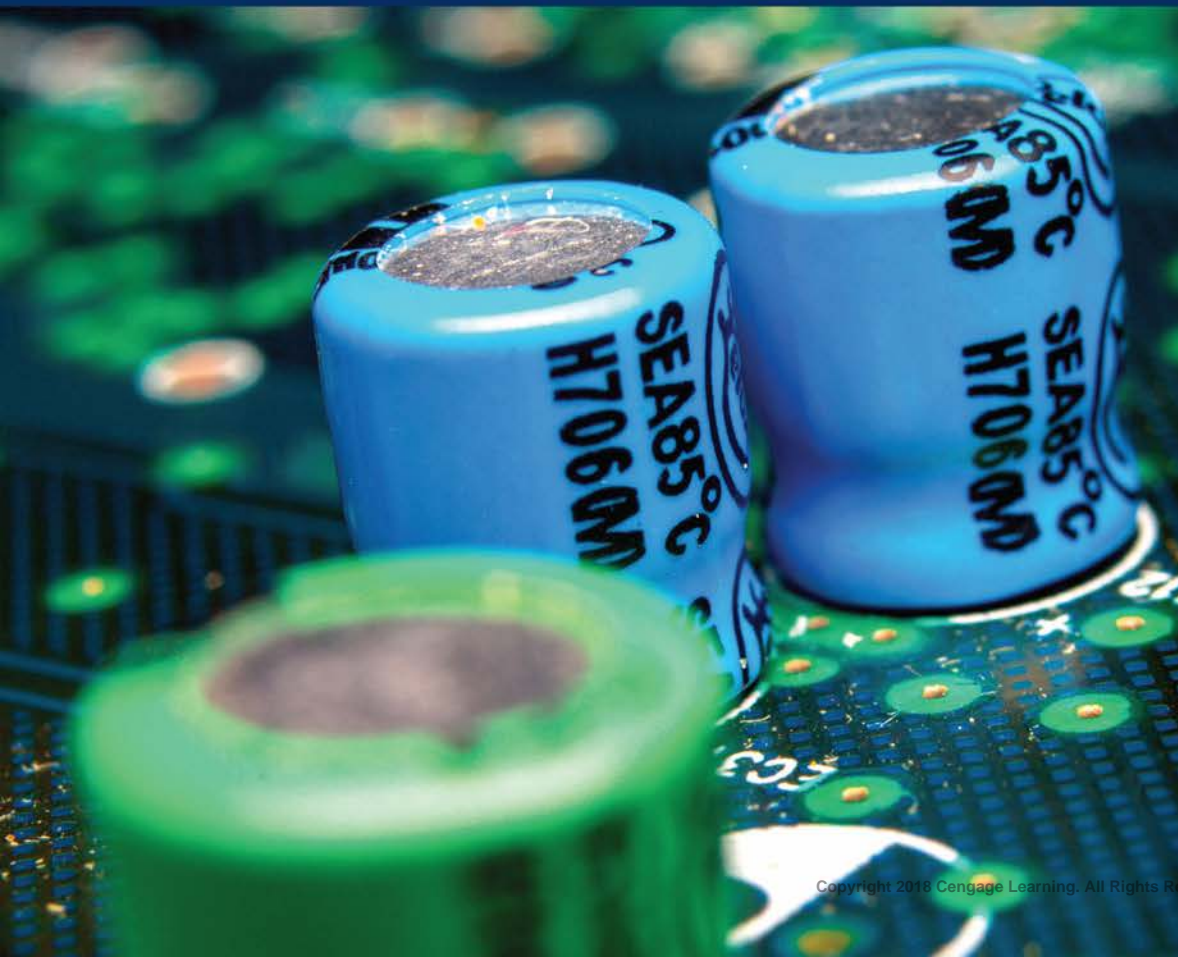


Electric Circuits

JAMES S. KANG



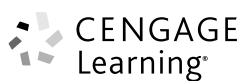


Electric Circuits



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Contents

Preface **x**
About the Author **xvi**

CHAPTER 1

VOLTAGE, CURRENT, POWER, AND SOURCES **1**

- 1.1 Introduction **1**
- 1.2 International System of Units **1**
- 1.3 Charge, Voltage, Current, and Power **4**
 - 1.3.1 Electric Charge 4
 - 1.3.2 Electric Field 4
 - 1.3.3 Voltage 5
 - 1.3.4 Current 7
 - 1.3.5 Power 9
- 1.4 Independent Sources **10**
 - 1.4.1 Direct Current Sources and Alternating Current Sources 11
- 1.5 Dependent Sources **15**
 - 1.5.1 Voltage-Controlled Voltage Source (VCVS) 16
 - 1.5.2 Voltage-Controlled Current Source (VCCS) 16
 - 1.5.3 Current-Controlled Voltage Source (CCVS) 16
 - 1.5.4 Current-Controlled Current Source (CCCS) 16
- 1.6 Elementary Signals **17**
 - 1.6.1 Dirac Delta Function 17
 - 1.6.2 Step Function 19
 - 1.6.3 Ramp Function 21
 - 1.6.4 Exponential Decay 23
 - 1.6.5 Rectangular Pulse and Triangular Pulse 24

SUMMARY 27

PROBLEMS 27

CHAPTER 2

CIRCUIT LAWS **31**

- 2.1 Introduction **31**
- 2.2 Circuit **31**
- 2.3 Resistor **33**
- 2.4 Ohm's Law **35**
- 2.5 Kirchhoff's Current Law (KCL) **38**

- 2.6 Kirchhoff's Voltage Law (KVL) **46**
- 2.7 Series and Parallel Connection of Resistors **53**
 - 2.7.1 Series Connection of Resistors 53
 - 2.7.2 Parallel Connection of Resistors 58
- 2.8 Voltage Divider Rule **74**
 - 2.8.1 Wheatstone Bridge 80
- 2.9 Current Divider Rule **82**
- 2.10 Delta-Wye (Δ -Y) Transformation and Wye-Delta (Y - Δ) Transformation **91**
- 2.11 PSpice and Simulink **100**
 - 2.11.1 Simulink 104

SUMMARY 104

PROBLEMS 105

CHAPTER 3

CIRCUIT ANALYSIS METHODS **117**

- 3.1 Introduction **117**
- 3.2 Nodal Analysis **118**
- 3.3 Supernode **142**
- 3.4 Mesh Analysis **153**
- 3.5 Supermesh **175**
- 3.6 PSpice and Simulink **190**
 - 3.6.1 PSpice 190
 - 3.6.2 VCVS 190
 - 3.6.3 VCCS 191
 - 3.6.4 CCVS 192
 - 3.6.5 CCCS 193
 - 3.6.6 Simulink 193

SUMMARY 194

PROBLEMS 194

CHAPTER 4

CIRCUIT THEOREMS **208**

- 4.1 Introduction **208**
- 4.2 Superposition Principle **209**
- 4.3 Source Transformations **221**

- 4.4 Thévenin's Theorem **234**
 - 4.4.1 Finding the Thévenin Equivalent Voltage V_{th} 235
 - 4.4.2 Finding the Thévenin Equivalent Resistance R_{th} 235
- 4.5 Norton's Theorem **263**
 - 4.5.1 Finding the Norton Equivalent Current I_n 264
 - 4.5.2 Finding the Norton Equivalent Resistance R_n 264
 - 4.5.3 Relation Between the Thévenin Equivalent Circuit and the Norton Equivalent Circuit 264
- 4.6 Maximum Power Transfer **284**
- 4.7 PSpice **296**
 - 4.7.1 Simulink 299

SUMMARY 300**PROBLEMS 301****CHAPTER 5****OPERATIONAL AMPLIFIER CIRCUITS 314**

- 5.1 Introduction **314**
- 5.2 Ideal Op Amp **315**
 - 5.2.1 Voltage Follower 322
- 5.3 Sum and Difference **333**
 - 5.3.1 Summing Amplifier (Inverting Configuration) 333
 - 5.3.2 Summing Amplifier (Noninverting Configuration) 336
 - 5.3.3 Alternative Summing Amplifier (Noninverting Configuration) 341
 - 5.3.4 Difference Amplifier 343
- 5.4 Instrumentation Amplifier **346**
- 5.5 Current Amplifier **347**
 - 5.5.1 Current to Voltage Converter (Transresistance Amplifier) 348
 - 5.5.2 Negative Resistance Circuit 349
 - 5.5.3 Voltage-to-Current Converter (Transconductance Amplifier) 350
- 5.6 Analysis of Inverting Configuration **351**
 - 5.6.1 Input Resistance 354
 - 5.6.2 Output Resistance 354
- 5.7 Analysis of Noninverting Configuration **358**
 - 5.7.1 Input Resistance 360
 - 5.7.2 Output Resistance 360
- 5.8 PSpice and Simulink **363**

SUMMARY 370**PROBLEMS 371****CHAPTER 6****CAPACITORS AND INDUCTORS 379**

- 6.1 Introduction **379**
- 6.2 Capacitors **380**
 - 6.2.1 Sinusoidal Input to Capacitor 389

- 6.3 Series and Parallel Connection of Capacitors **390**
 - 6.3.1 Series Connection of Capacitors 390
 - 6.3.2 Parallel Connection of Capacitors 392
- 6.4 Op Amp Integrator and Op Amp Differentiator **395**
 - 6.4.1 Op Amp Integrator 395
 - 6.4.2 Op Amp Differentiator 397
- 6.5 Inductors **397**
 - 6.5.1 Sinusoidal Input to Inductor 407
- 6.6 Series and Parallel Connection of Inductors **408**
 - 6.6.1 Series Connection of Inductors 408
 - 6.6.2 Parallel Connection of Inductors 409
- 6.7 PSpice and Simulink **413**

SUMMARY 416**PROBLEMS 416****CHAPTER 7****RC AND RL CIRCUITS 424**

- 7.1 Introduction **424**
- 7.2 Natural Response of RC Circuit **424**
 - 7.2.1 Time Constant 428
- 7.3 Step Response of RC Circuit **435**
 - 7.3.1 Initial Value 438
 - 7.3.2 Final Value 438
 - 7.3.3 Time Constant 438
 - 7.3.4 Solution to General First-Order Differential Equation with Constant Coefficient and Constant Input 440
- 7.4 Natural Response of RL Circuit **448**
 - 7.4.1 Time Constant 450
- 7.5 Step Response of RL Circuit **459**
 - 7.5.1 Initial Value 462
 - 7.5.2 Final Value 462
 - 7.5.3 Time Constant 462
 - 7.5.4 Solution to General First-Order Differential Equation with Constant Coefficient and Constant Input 464
- 7.6 Solving General First-Order Differential Equations **476**
- 7.7 PSpice and Simulink **488**

SUMMARY 494**PROBLEMS 495****CHAPTER 8****RLC CIRCUITS 505**

- 8.1 Introduction **505**
- 8.2 Zero Input Response of Second-Order Differential Equations **505**
 - 8.2.1 Case 1: Overdamped ($\alpha > \omega_0$ or $a_1 > 2\sqrt{a_0}$ or $\zeta > 1$) 507

- 8.2.2 Case 2: Critically Damped ($\alpha = \omega_0$ or $a_1 = 2\sqrt{a_0}$ or $\zeta = 1$) 509
- 8.2.3 Case 3: Underdamped ($\alpha < \omega_0$ or $a_1 < 2\sqrt{a_0}$ or $\zeta < 1$) 510
- 8.3 Zero Input Response of Series RLC Circuit **511**
 - 8.3.1 Case 1: Overdamped ($\alpha > \omega_0$ or $a_1 > 2\sqrt{a_0}$ or $\zeta > 1$) 513
 - 8.3.2 Case 2: Critically Damped ($\alpha = \omega_0$ or $a_1 = 2\sqrt{a_0}$ or $\zeta = 1$) 513
 - 8.3.3 Case 3: Underdamped ($\alpha < \omega_0$ or $a_1 < 2\sqrt{a_0}$ or $\zeta < 1$) 513
- 8.4 Zero Input Response of Parallel RLC Circuit **530**
 - 8.4.1 Case 1: Overdamped ($\alpha > \omega_0$ or $a_1 > 2\sqrt{a_0}$ or $\zeta > 1$) 532
 - 8.4.2 Case 2: Critically Damped ($\alpha = \omega_0$ or $a_1 = 2\sqrt{a_0}$ or $\zeta = 1$) 532
 - 8.4.3 Case 3: Underdamped ($\alpha < \omega_0$ or $a_1 < 2\sqrt{a_0}$ or $\zeta < 1$) 532
- 8.5 Solution of the Second-Order Differential Equations to Constant Input **545**
 - 8.5.1 Particular Solution 545
 - 8.5.2 Case 1: Overdamped ($\alpha > \omega_0$ or $a_1 > 2\sqrt{a_0}$ or $\zeta > 1$) 546
 - 8.5.3 Case 2: Critically Damped ($\alpha = \omega_0$ or $a_1 = 2\sqrt{a_0}$ or $\zeta = 1$) 547
 - 8.5.4 Case 3: Underdamped ($\alpha < \omega_0$ or $a_1 < 2\sqrt{a_0}$ or $\zeta < 1$) 548
- 8.6 Step Response of a Series RLC Circuit **549**
 - 8.6.1 Case 1: Overdamped ($\alpha > \omega_0$ or $a_1/2 > \sqrt{a_0}$ or $\zeta > 1$) 550
 - 8.6.2 Case 2: Critically Damped ($\alpha = \omega_0$ or $a_1 = 2\sqrt{a_0}$ or $\zeta = 1$) 552
 - 8.6.3 Case 3: Underdamped ($\alpha < \omega_0$ or $a_1 < 2\sqrt{a_0}$ or $\zeta < 1$) 553
- 8.7 Step Response of a Parallel RLC Circuit **566**
 - 8.7.1 Case 1: Overdamped ($\alpha > \omega_0$ or $a_1 > 2\sqrt{a_0}$ or $\zeta > 1$) 567
 - 8.7.2 Case 2: Critically Damped ($\alpha = \omega_0$ or $a_1 = 2\sqrt{a_0}$ or $\zeta = 1$) 569
 - 8.7.3 Case 3: Underdamped ($\alpha < \omega_0$ or $a_1 < 2\sqrt{a_0}$ or $\zeta < 1$) 570
- 8.8 General Second-Order Circuits **580**
- 8.9 PSpice and Simulink **600**
 - 8.9.1 Solving Differential Equations Using Simulink 600
 - 8.9.2 Solving Differential Equations Using PSpice 601

SUMMARY 603**PROBLEMS 604****CHAPTER 9****PHASORS AND IMPEDANCES 615**

- 9.1 Introduction **615**
- 9.2 Sinusoidal Signals **615**

- 9.2.1 Cosine Wave 615
- 9.2.2 Sine Wave 618
- 9.3 RMS Value **620**
- 9.4 Phasors **624**
 - 9.4.1 Representing Sinusoids in Phasor 627
 - 9.4.2 Conversion Between Cartesian Coordinate System (Rectangular Coordinate System) and Polar Coordinate System 629
 - 9.4.3 Phasor Arithmetic 635
- 9.5 Impedance and Admittance **638**
 - 9.5.1 Resistor 639
 - 9.5.2 Capacitor 640
 - 9.5.3 Inductor 642
- 9.6 Phasor-Transformed Circuit **644**
- 9.7 Kirchhoff's Current Law and Kirchhoff's Voltage Law for Phasors **649**
- 9.8 Series and Parallel Connection of Impedances **652**
- 9.9 Delta-Wye (Δ -Y) and Wye-Delta (Y- Δ) Transformation **656**
- 9.10 PSpice and Simulink **661**

SUMMARY 664**PROBLEMS 664****CHAPTER 10****ANALYSIS OF PHASOR-TRANSFORMED CIRCUITS 668**

- 10.1 Introduction **668**
- 10.2 Phasor-Transformed Circuits **669**
- 10.3 Voltage Divider Rule **669**
- 10.4 Current Divider Rule **672**
- 10.5 Nodal Analysis **676**
- 10.6 Mesh Analysis **678**
- 10.7 Superposition Principle **681**
- 10.8 Source Transformation **683**
- 10.9 Thévenin Equivalent Circuit **686**
 - 10.9.1 Finding the Thévenin Equivalent Voltage V_{th} 687
 - 10.9.2 Finding the Thévenin Equivalent Impedance Z_{th} 687
- 10.10 Norton Equivalent Circuit **689**
- 10.11 Transfer Function **692**
 - 10.11.1 Series RLC Circuits 701
 - 10.11.2 Parallel RLC Circuits 707
- 10.12 PSpice and Simulink **718**

SUMMARY 721**PROBLEMS 722**

CHAPTER 11**AC POWER 733**

- 11.1 Introduction 733
- 11.2 Instantaneous Power, Average Power, Reactive Power, Apparent Power 733
- 11.3 Complex Power 739
- 11.4 Conservation of AC Power 749
- 11.5 Maximum Power Transfer 752
 - 11.5.1 Maximum Power Transfer for Norton Equivalent Circuit 756
- 11.6 Power Factor Correction (PFC) 756
- 11.7 PSpice and Simulink 767

SUMMARY 770**PROBLEMS 770****CHAPTER 12****THREE-PHASE SYSTEMS 778**

- 12.1 Introduction 778
- 12.2 Three-Phase Sources 778
 - 12.2.1 Negative Phase Sequence 781
- 12.3 Balanced Y-Y Circuit 782
 - 12.3.1 Balanced Y-Y Circuit with Wire Impedance 786
- 12.4 Balanced Y- Δ Circuit 792
 - 12.4.1 Balanced Y- Δ Circuit with Wire Impedance 796
- 12.5 Balanced Δ - Δ Circuit 801
 - 12.5.1 Balanced Δ - Δ Circuit with Wire Impedance 805
- 12.6 Balanced Δ -Y Circuit 813
 - 12.6.1 Balanced Δ -Y Circuit with Wire Impedance 816
- 12.7 PSpice and Simulink 821

SUMMARY 825**PROBLEMS 825****CHAPTER 13****MAGNETICALLY COUPLED CIRCUITS 829**

- 13.1 Introduction 829
- 13.2 Mutual Inductance 829
 - 13.2.1 Faraday's Law 830
 - 13.2.2 Mutual Inductance 831
 - 13.2.3 Mutual Inductance of a Second Coil Wrapped Around a Solenoid 833
- 13.3 Dot Convention and Induced Voltage 835
 - 13.3.1 Combined Mutual and Self-Induction Voltage 838
- 13.4 Equivalent Circuits 848
- 13.5 Energy of Coupled Coils 853
- 13.6 Linear Transformer 855

- 13.7 Ideal Transformer 865

- 13.7.1 Autotransformer 874

- 13.8 PSpice and Simulink 879

SUMMARY 881**PROBLEMS 881****CHAPTER 14****THE LAPLACE TRANSFORM 886**

- 14.1 Introduction 886
- 14.2 Definition of the Laplace Transform 887
- 14.3 Properties of the Laplace Transform 891
 - 14.3.1 Linearity Property (Superposition Principle) 893
 - 14.3.2 Time-Shifting Property 894
 - 14.3.3 Frequency Translation Property 895
 - 14.3.4 Multiplication by $\cos(\omega_0 t)$ 898
 - 14.3.5 Multiplication by $\sin(\omega_0 t)$ 899
 - 14.3.6 Time Differentiation Property 900
 - 14.3.7 Integral Property 902
 - 14.3.8 Frequency Differentiation Property 904
 - 14.3.9 Frequency Integration Property 907
 - 14.3.10 Time-Scaling Property 908
 - 14.3.11 Initial Value Theorem and Final Value Theorem 910
 - 14.3.12 Initial Value Theorem 910
 - 14.3.13 Final Value Theorem 912
- 14.4 Inverse Laplace Transform 914
 - 14.4.1 Partial Fraction Expansion 923
 - 14.4.2 Simple Real Poles 925
 - 14.4.3 Complex Poles 928
 - 14.4.4 Repeated Poles 934
- 14.5 Solving Differential Equations Using the Laplace Transform 942
- 14.6 PSpice and Simulink 947

SUMMARY 950**PROBLEMS 951****CHAPTER 15****CIRCUIT ANALYSIS IN THE s -DOMAIN 954**

- 15.1 Introduction 954
- 15.2 Laplace-Transformed Circuit Elements 955
 - 15.2.1 Resistor 955
 - 15.2.2 Capacitor 956
 - 15.2.3 Inductor 957
- 15.3 Laplace-Transformed Circuit 958
 - 15.3.1 Voltage Divider Rule 958
 - 15.3.2 Current Divider Rule 961
- 15.4 Nodal Analysis 964
- 15.5 Mesh Analysis 971
- 15.6 Thévenin Equivalent Circuit in the s -Domain 980

15.7	Norton Equivalent Circuit in the s -Domain	990
15.8	Transfer Function	997
15.8.1	Sinusoidal Input	998
15.8.2	Poles and Zeros	999
15.9	Convolution	1020
15.9.1	Commutative Property	1021
15.9.2	Associative Property	1021
15.9.3	Distributive Property	1021
15.9.4	Time-Shifting Property	1021
15.10	Linear, Time-Invariant (LTI) System	1037
15.10.1	Impulse Response	1038
15.10.2	Output of Linear Time-Invariant System	1038
15.10.3	Step Response of LTI System	1039
15.11	Bode Diagram	1040
15.11.1	Linear Scale	1040
15.11.2	dB Scale	1041
15.11.3	Bode Diagram of Constant Term	1044
15.11.4	Bode Diagram of $H(s) = s + 1000$	1044
15.11.5	Bode Diagram of $H(s) = 100/s$	1045
15.11.6	Bode Diagram of $H(s) = s/1000$	1046
15.11.7	Bode Diagram of $H(s) = 10^4/(s + 100)^2$	1047
15.11.8	Complex Poles and Zeros	1059
15.12	Simulink	1062
	SUMMARY	1064
	PROBLEMS	1064

CHAPTER 16

FIRST- AND SECOND-ORDER ANALOG FILTERS 1074

16.1	Introduction	1074
16.2	Magnitude Scaling and Frequency Scaling	1075
16.2.1	Magnitude Scaling	1075
16.2.2	Frequency Scaling	1076
16.2.3	Magnitude and Frequency Scaling	1078
16.3	First-Order LPF	1079
16.4	First-Order HPF	1081
16.5	Second-Order LPF	1084
16.5.1	Frequency Response	1085
16.5.2	Magnitude Response	1085
16.5.3	Phase Response	1086
16.5.4	Series RLC LPF	1087
16.5.5	Parallel RLC LPF	1088
16.5.6	Sallen-Key Circuit for the Second-Order LPF	1090
16.5.7	Equal R , Equal C Method	1092
16.5.8	Normalized Filter	1093
16.5.9	Unity Gain Method	1098
16.6	Second-Order HPF Design	1100
16.6.1	Frequency Response	1101
16.6.2	Magnitude Response	1101

16.6.3	Phase Response	1102
16.6.4	Series RLC HPF	1102
16.6.5	Parallel RLC HPF	1104
16.6.6	Sallen-Key Circuit for the Second-Order HPF	1105
16.6.7	Equal R and Equal C Method	1108
16.6.8	Normalization	1109
16.6.9	Unity Gain Method	1110
16.6.10	Normalization	1111
16.7	Second-Order Bandpass Filter Design	1113
16.7.1	Frequency Response	1113
16.7.2	Magnitude Response	1113
16.7.3	Phase Response	1116
16.7.4	Series RLC Bandpass Filter	1116
16.7.5	Parallel RLC Bandpass Filter	1118
16.7.6	Sallen-Key Circuit for the Second-Order Bandpass Filter	1120
16.7.7	Equal R , Equal C Method	1122
16.7.8	Normalization	1123
16.7.9	Delyiannis-Friend Circuit	1125
16.7.10	Normalization	1126
16.8	Second-Order Bandstop Filter Design	1129
16.8.1	Frequency Response	1130
16.8.2	Magnitude Response	1130
16.8.3	Phase Response	1132
16.8.4	Series RLC Bandstop Filter	1132
16.8.5	Parallel RLC Bandstop Filter	1134
16.8.6	Sallen-Key Circuit for the Second-Order Bandstop Filter	1136
16.9	Simulink	1147
	SUMMARY	1148
	PROBLEMS	1155

CHAPTER 17

ANALOG FILTER DESIGN 1166

17.1	Introduction	1166
17.2	Analog Butterworth LPF Design	1167
17.2.1	Backward Transformation	1168
17.2.2	Finding the Order of the Normalized LPF	1168
17.2.3	Finding the Pole Locations	1171
17.3	Analog Butterworth HPF Design	1182
17.4	Analog Butterworth Bandpass Filter Design	1191
17.5	Analog Butterworth Bandstop Filter Design	1202
17.6	Analog Chebyshev Type 1 LPF Design	1214
17.7	Analog Chebyshev Type 2 LPF Design	1226
17.8	MATLAB	1242
	SUMMARY	1245
	PROBLEMS	1245

CHAPTER 18**FOURIER SERIES 1259**

- 18.1** Introduction **1259**
- 18.2** Signal Representation Using Orthogonal Functions **1259**
 - 18.2.1 Orthogonal Functions 1259
 - 18.2.2 Representation of an Arbitrary Signal by Orthogonal Functions 1270
 - 18.2.3 Trigonometric Fourier Series 1278
 - 18.2.4 Proof of Orthogonality 1279
 - 18.2.5 Exponential Fourier Series 1282
 - 18.2.6 Proof of Orthogonality 1283
- 18.3** Trigonometric Fourier Series **1283**
 - 18.3.1 Trigonometric Fourier Series Using Cosines Only 1286
 - 18.3.2 One-Sided Magnitude Spectrum and One-Sided Phase Spectrum 1287
 - 18.3.3 DC Level 1296
 - 18.3.4 Time Shifting 1298
 - 18.3.5 Triangular Pulse Train 1302
 - 18.3.6 Sawtooth Pulse Train 1306
 - 18.3.7 Rectified Cosine 1309
 - 18.3.8 Rectified Sine 1313
 - 18.3.9 Average Power of Periodic Signals 1317
 - 18.3.10 Half-Wave Symmetry 1320
- 18.4** Solving Circuit Problems Using Trigonometric Fourier Series **1324**
- 18.5** Exponential Fourier Series **1333**
 - 18.5.1 Conversion of Fourier Coefficients 1336
 - 18.5.2 Two-Sided Magnitude Spectrum and Two-Sided Phase Spectrum 1337
 - 18.5.3 Triangular Pulse Train 1343
 - 18.5.4 Sawtooth Pulse Train 1348
 - 18.5.5 Rectified Cosine 1350
 - 18.5.6 Rectified Sine 1353
 - 18.5.7 Average Power of Periodic Signals 1356
- 18.6** Properties of Exponential Fourier Coefficients **1357**
 - 18.6.1 DC Level 1357
 - 18.6.2 Linearity Property (Superposition Principle) 1358
 - 18.6.3 Time-Shifting Property 1358
 - 18.6.4 Time Reversal Property 1364
 - 18.6.5 Time Differentiation Property 1365
 - 18.6.6 Convolution Property 1365
- 18.7** Solving Circuit Problems Using Exponential Fourier Series **1365**
- 18.8** PSpice and Simulink **1373**

SUMMARY 1377**PROBLEMS 1384****CHAPTER 19****FOURIER TRANSFORM 1399**

- 19.1** Introduction **1399**
- 19.2** Definition of Fourier Transform **1399**
 - 19.2.1 Symmetries 1403
 - 19.2.2 Finding Fourier Transform from Fourier Coefficients 1407
- 19.3** Properties of Fourier Transform **1408**
 - 19.3.1 Linearity Property (Superposition Principle) 1411
 - 19.3.2 Time-Shifting Property 1411
 - 19.3.3 Time-Scaling Property 1414
 - 19.3.4 Symmetry Property (Duality Property) 1416
 - 19.3.5 Time-Reversal Property 1420
 - 19.3.6 Frequency-Shifting Property 1422
 - 19.3.7 Modulation Property 1425
 - 19.3.8 Time-Differentiation Property 1428
 - 19.3.9 Frequency-Differentiation Property 1431
 - 19.3.10 Conjugate Property 1432
 - 19.3.11 Integration Property 1433
 - 19.3.12 Convolution Property 1434
 - 19.3.13 Multiplication Property 1437
- 19.4** Fourier Transform of Periodic Signals **1439**
 - 19.4.1 Fourier Series and Fourier Transform of Impulse Train 1440
- 19.5** Parseval's Theorem **1443**
- 19.6** Simulink **1449**

SUMMARY 1452**PROBLEMS 1452****CHAPTER 20****TWO-PORT CIRCUITS 1457**

- 20.1** Introduction **1457**
- 20.2** Two-Port Circuit **1458**
 - 20.2.1 z -Parameters (Impedance Parameters) 1458
 - 20.2.2 y -Parameters (Admittance Parameters) 1464
 - 20.2.3 h -Parameters (Hybrid Parameters) 1470
 - 20.2.4 g -Parameters (Inverse Hybrid Parameters) 1473
 - 20.2.5 $ABCD$ -Parameters (Transmission Parameters, a -Parameters) 1477
 - 20.2.6 Inverse Transmission Parameters (b -Parameters) 1485
- 20.3** Conversion of Parameters **1489**
 - 20.3.1 Conversion of z -Parameters to All the Other Parameters 1489
 - 20.3.2 Conversion of z -Parameters to y -Parameters 1489
 - 20.3.3 Conversion of z -Parameters to $ABCD$ Parameters 1490

20.3.4 Conversion of z -Parameters to b -Parameters	1491
20.3.5 Conversion of z -Parameters to h -Parameters	1491
20.3.6 Conversion of z -Parameters to g -Parameters	1492
20.3.7 Conversion of y -Parameters to All the Other Parameters	1493
20.3.8 Conversion of h -Parameters to All the Other Parameters	1494
20.3.9 Conversion of g -Parameters to All the Other Parameters	1494
20.3.10 Conversion of $ABCD$ Parameters to All the Other Parameters	1495
20.3.11 Conversion of b -Parameters to All the Other Parameters	1496
20.4 Interconnection of Two-Port Circuits	1500
20.4.1 Cascade Connection	1500
20.4.2 Series Connection	1502
20.4.3 Parallel Connection	1505
20.4.4 Series-Parallel Connection	1507
20.4.5 Parallel-Series Connection	1508
20.4.6 Cascade Connection for b -Parameters	1508
20.5 PSpice and Simulink	1509
SUMMARY	1512
PROBLEMS	1513
Answers to Odd-Numbered Questions	1517
Index	1548



Preface

This book is intended to be an introductory text on the subject of electric circuits. It provides simple explanations of the basic concepts, followed by simple examples and exercises. When necessary, detailed derivations for the main topics and examples are given to help readers understand the main ideas. MATLAB is a tool that can be used effectively in Electric Circuits courses. In this text, MATLAB is integrated into selected examples to illustrate its use in solving circuit problems. MATLAB can be used to check the answers or solve more complex circuit problems. This text is written for a two-semester sequence or a three-quarters sequence on electric circuits.

Suggested Course Outlines

The following is a list of topics covered in a typical Electric Circuits courses, with suggested course outlines.

ONE-SEMESTER OR -QUARTER COURSE

If Electric Circuits is offered as a one-semester or one-quarter course, Chapters 1 through 12 can be taught without covering, or only lightly covering, sections 1.6, 2.10, 2.11, 3.6, 4.7, 5.6, 5.7, 5.8, 6.7, 7.6, 7.7, 8.8, 8.9, 9.9, 9.10, 10.12, 11.7, 12.5, 12.6, and 12.7.

TWO-SEMESTER OR -QUARTER COURSES

For two-semester Electric Circuit courses, Chapters 1 through 8, which cover dc circuits, op amps, and the responses of first-order and second-order circuits, can be taught in the first semester. Chapters 9 through 20, which cover alternating current (ac) circuits, Laplace transforms, circuit analysis in the s -domain, two-port circuits, analog filter design and implementation, Fourier series, and Fourier transform, can then be taught in the second semester.

THREE-QUARTER COURSES

For three-quarter Electric Circuit courses, Chapters 1 through 5, which cover dc circuits and op amps, can be taught in the first quarter; Chapters 6 through 13, which cover the responses of first-order and second-order circuits and ac circuits, can be taught in the second quarter, and Chapters 14 through 20, which cover Laplace transforms, circuit analysis in the s -domain, two-port circuits, analog filter design and implementation, Fourier series, and Fourier transform, can be taught in the third quarter.

Depending on the catalog description and the course outlines, instructors can pick and choose the topics covered in the courses that they teach. Several features of this text are listed next.

Features

After a topic is presented, examples and exercises follow. Examples are chosen to expand and elaborate the main concept of the topic. In a step-by-step approach, details are worked out to help students understand the main ideas.

In addition to analyzing RC, RL, and RLC circuits connected in series or parallel in the time domain and the frequency domain, analyses of circuits different from RC, RL, and RLC circuits and connected other than in series and parallel are provided. Also, general input signals that are different from unit step functions are included in the analyses.

In the analog filter design, the specifications of the filter are translated into its transfer function in cascade form. From the transfer function, each section can be designed with appropriate op amp circuits. The normalized component values for each section are found by adopting a simplification method (equal R equal C or unity gain). Then, magnitude scaling and frequency scaling are used to find the final component values. The entire design procedure, from the specifications to the circuit design, is detailed, including the PSpice simulation used to verify the design.

Before the discussion of Fourier series, orthogonal functions and the representation of square integrable functions as a linear combination of a set of orthogonal functions are introduced. The set of orthogonal functions for Fourier series representation consists of cosines and sines. The Fourier coefficients for the square pulse train, triangular pulse train, sawtooth pulse train, and rectified sines and cosines are derived. The Fourier coefficients of any variation of these waveforms can be found by applying the time-shifting property and finding the dc component.

MATLAB can be an effective tool in solving problems in electric circuits. Simple functions such as calculating the equivalent resistance or impedance of parallel connection of resistors, capacitors, and inductors; conversion from Cartesian coordinates to polar coordinates; conversion from polar coordinates to Cartesian coordinates; conversion from the wye configuration to delta configuration; and conversion from delta configuration to wye configuration provide accurate answers in less time. These simple functions can be part of scripts that enable us to find solutions to typical circuit problems.

The complexity of taking the inverse Laplace transforms increases as the order increases. MATLAB can be used to solve equations and to find integrals, transforms, inverse transforms, and transfer functions. The application of MATLAB to circuit analysis is demonstrated throughout the text when appropriate. For example, after finding inverse Laplace transforms by hand using partial fraction expansion, answers from MATLAB are provided as a comparison.

Examples of circuit simulation using OrCAD PSpice and Simulink are given at the end of each chapter. Simulink is a tool that can be used to perform circuit simulations. In Simulink, physical signals can be converted to Simulink signals and vice versa. Simscapes include many blocks that are related to electric circuits. Simulink can be used in computer assignments or laboratory experiments.

The Instructor's Solution Manual for the exercises and end-of-chapter problems is available for instructors. This manual includes MATLAB scripts for selected problems as a check on the accuracy of the solutions by hand.

Overview of Chapters

In **Chapter 1**, definitions of voltage, current, power, and energy are given. Also, independent voltage source and current source are introduced, along with dependent voltage sources and current sources.

In **Chapter 2**, nodes, branches, meshes, and loops are introduced. Ohm's law is explained. Kirchhoff's current law (KCL), Kirchhoff's voltage law (KVL), the voltage divider rule, and the current divider rule are explained with examples.

In **Chapter 3**, nodal analysis and mesh analysis are discussed in depth. The nodal analysis and mesh analysis are used extensively in the rest of the text.

Chapter 4 introduces circuit theorems that are useful in analyzing electric circuits and electronic circuits. The circuit theorems discussed in this chapter are the superposition

principle, source transformations, Thévenin's theorem, Norton's theorem, and maximum power transfer.

Chapter 5 introduces op amp circuits. Op amp is a versatile integrated circuit (IC) chip that has wide-ranging applications in circuit design. The concept of the ideal op amp model is explained, along with applications in sum and difference, instrumentation amplifier, and current amplifier. Detailed analysis of inverting configuration and noninverting configuration is provided.

In **Chapter 6**, the energy storage elements called *capacitors* and *inductors* are discussed. The current voltage relation of capacitors and inductors are derived. The energy stored on the capacitors and inductors are presented.

In **Chapter 7**, the transformation of RC and RL circuits to differential equations and solutions of the first-order differential equations to get the responses of the circuits are presented. In the general first-order circuits, the input signal can be dc, ramp signal, exponential signal, or sinusoidal signal.

In **Chapter 8**, the transformation of series RLC and parallel RLC circuits to the second-order differential equations, as well as solving the second-order differential equations to get the responses of the circuits are presented. In the general second-order circuits, the input signal can be dc, ramp signal, exponential signal, or sinusoidal signal.

Chapter 9 introduces sinusoidal signals, phasors, impedances, and admittances. Also, transforming ac circuits to phasor-transformed circuits is presented, along with analyzing phasor transformed circuits using KCL, KVL, equivalent impedances, delta-wye transformation, and wye-delta transformation.

The analysis of phasor-transformed circuits is continued in **Chapter 10** with the introduction of the voltage divider rule, current divider rule, nodal analysis, mesh analysis, superposition principle, source transformation, Thévenin equivalent circuit, Norton equivalent circuit, and transfer function. This analysis is similar to the one for resistive circuits with the use of impedances.

Chapter 11 presents information on ac power. The definitions of instantaneous power, average power, reactive power, complex power, apparent power, and power factor are also given, and power factor correction is explained with examples.

As an extension of ac power, the three-phase system is presented in **Chapter 12**. The connection of balanced sources (wye-connected or delta-connected) to balanced loads (wye-connected or delta connected) are presented, both with and without wire impedances.

Magnetically coupled circuits, which are related to ac power, are discussed in **Chapter 13**. Mutual inductance, induced voltage, dot convention, linear transformers, and ideal transformers are introduced.

The Laplace transform is introduced in **Chapter 14**. The definition of the transform, region of convergence, transform, and inverse transform are explained with examples. Various properties of Laplace transform are also presented with examples.

The discussion on Laplace transform is continued in **Chapter 15**. Electric circuits can be transformed into an s -domain by replacing voltage sources and current sources to the s -domain and replacing capacitors and inductors to impedances. The circuit laws and theorems that apply to resistive circuits also apply to s -domain circuits. The time domain signal can be obtained by taking the inverse Laplace transform of the s -domain representation. The differential equations in the time domain are transformed to algebraic equations in the s -domain. The transfer function in the s -domain is defined as the ratio

of the output signal in the s -domain to the input signal in the s -domain. The concept of convolution is introduced with a number of examples. Also, finding the convolution using Laplace transforms are illustrated in the same examples. Plotting the magnitude response and phase response of a circuit or a system using the Bode diagram is introduced.

The first-order and the second-order analog filters that are building blocks for the higher-order filters are presented in **Chapter 16**. The filters can be implemented by interconnecting passive elements consisting of resistors, capacitors, and inductors. Alternatively, filters can be implemented utilizing op amp circuits. Sallen and Key circuits for implementing second-order filters are discussed as well, along with design examples.

The discussion on analog filter design is extended in **Chapter 17**. A filter is designed to meet the specifications of the filter. The transfer function that satisfies the specification is found. From the transfer function, the corner frequency and Q value can be found. Then, the normalized component values and scaled component values are found. PSpice simulations can be used to verify the design.

Orthogonal functions and the representation of signals as a linear combination of a set of orthogonal functions are introduced in **Chapter 18**. If the set of orthogonal functions consists of harmonically related sinusoids or exponential functions, the representation is called the *Fourier series*. Fourier series representation of common signals, including the square pulse train, triangular pulse train, sawtooth waveform, and rectified cosine and sine, are presented in detail, with examples. The derivation and application of the time-shifting property of Fourier coefficients are provided. In addition, the application of the Fourier series representation in solving circuit problems are presented, along with examples.

As the period of a periodic signal is increased to infinity, the signal becomes nonperiodic, the discrete line spectrums become a continuous spectrum, and multiplying the Fourier coefficients by the period produces the Fourier transform, as explained in **Chapter 19**. Important properties of the Fourier transform, including time shifting, frequency shifting, symmetry, modulation, convolution, and multiplication, are introduced, along with interpretation and examples.

Two-port circuits are defined and analyzed in **Chapter 20**. Depending on which of the parameters are selected as independent variables, there are six different representations for two-port circuits. The coefficients of the representations are called *parameters*. The six parameters ($z, y, h, g, ABCD, b$) for two-port circuits are presented along with examples. The conversion between the parameters and the interconnection of parameters are provided in this chapter.

Instructor Resources

Cengage Learning's secure, password-protected Instructor Resource Center contains helpful resources for instructors who adopt this text. These resources include Lecture Note Microsoft PowerPoint slides, test banks, and an Instructor's Solution Manual, with detailed solutions to all the problems from the text. The Instructor Resource Center can be accessed at <https://login.cengage.com>.

MindTap Online Course

Electric Circuits is also available through **MindTap**, Cengage Learning's digital course platform. The carefully crafted pedagogy and exercises in this textbook are made even more effective by an interactive, customizable eBook, automatically graded assessments, and a full suite of study tools.

<
CHAPTER 6: CAPACITORS AND INDUCTORS
+
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Chapter 6: Capacitors and Inductors
Introduction - Capacitors - Series and Parallel Connection of Capacitors - Op Amp Integrator and Op Amp Differentiator - Inductors - Series and Parallel Connection of Inductors - PSpice and Simulink - Summary

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Watch this lecture on Capacitors and Inductors.

Chapter 6 Quiz
After you've read Chapter 6, answer the questions in this quiz.

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