

# Contents

## 1

### INTRODUCTION, 1

The Electrical/Electronics Industry, 1 | A Brief History, 2 | Units of Measurement, 7 | Systems of Units, 9 | Scientific Notation, 12 | Conversion Within and Between Systems of Units, 15 | Symbols, 17 | Conversion Tables, 18

## 2

### CURRENT AND VOLTAGE, 23

Atoms and Their Structure, 23 | Current, 25 | Voltage, 28 | Fixed (dc) Supplies, 30 | Conductors and Insulators, 37 | Semiconductors, 38 | Ammeters and Voltmeters, 38

## 3

### RESISTANCE, 45

Introduction, 45 | Resistance: Circular Wires, 46 | Wire Tables, 49 | Resistance: Metric Units, 52 |

Temperature Effects, 53 | Types of Resistors, 56 | Color Coding and Standard Resistor Values, 59 | Conductance, 61 | Ohmmeters, 63 | Thermistors, 64 | Photoconductive Cell, 64 | Varistors, 65

## 4

### OHM'S LAW, POWER, AND ENERGY, 71

Ohm's Law, 71 | Plotting Ohm's Law, 73 | Power, 76 | Wattmeters, 78 | Efficiency, 79 | Energy, 82 | Circuit Breakers and Fuses, 85 | Computer Analysis, 86

## 5

### SERIES CIRCUITS, 93

Introduction, 93 | Series Circuits, 94 | Voltage Sources in Series, 96 | Kirchhoff's Voltage Law, 97 | Interchanging Series Elements, 100 | Voltage Divider Rule, 100 | Notation, 103 | Internal Resistance of Voltage Sources, 106 | Voltage Regulation, 110 | Ammeters: Loading Effects, 111 | Computer Solutions, 111

# 6

## PARALLEL CIRCUITS, 121

Introduction, 121 | Parallel Elements, 121 | Total Conductance and Resistance, 122 | Parallel Networks, 127 | Kirchhoff's Current Law, 129 | Current Divider Rule, 132 | Voltage Sources in Parallel, 136 | Open and Short Circuits, 137 | Voltmeters: Loading Effect, 139

# 7

## SERIES-PARALLEL NETWORKS, 147

Series-Parallel Networks, 147 | Descriptive Examples, 152 | Ladder Networks, 158 | Ammeter, Voltmeter, and Ohmmeter Design, 161

# 8

## METHODS OF ANALYSIS AND SELECTED TOPICS (dc), 173

Introduction, 173 | Current Sources, 174 | Source Conversions, 176 | Current Sources in Parallel, 178 | Current Sources in Series, 179 | Determinants, 180 | Branch-Current Method, 186 | Mesh Analysis (General Approach), 189 | Mesh Analysis (Format Approach), 195 | Nodal Analysis (General Approach), 200 | Nodal Analysis (Format Approach), 204 | Bridge Networks, 209 | Y- $\Delta$  (T- $\pi$ ) and  $\Delta$ -Y ( $\pi$ -T) Conversions, 212

# 9

## NETWORK THEOREMS, 229

Introduction, 229 | Superposition Theorem, 229 | Thevenin's Theorem, 235 | Norton's Theorem, 243 | Maximum Power Transfer Theorem, 248 | Computer Analysis, 254 | Millman's Theorem, 256 | Substitution Theorem, 260 | Reciprocity Theorem, 261

# 10

## CAPACITORS, 271

Introduction, 271 | The Electric Field, 271 | Capacitance, 273 | Dielectric Strength, 279 | Leakage Current, 280 | Types of Capacitors, 280 | Transients in Capacitive Networks: Charging Phase,

284 | Discharge Phase, 290 | Instantaneous Values, 293 |  $\tau = R_{Th}C$ , 295 | The Current  $i_C$ , 298 | Capacitors in Series and Parallel, 300 | Energy Stored by a Capacitor, 304 | Stray Capacitances, 305

# 11

## MAGNETIC CIRCUITS, 313

Introduction, 313 | Magnetic Fields, 314 | Flux Density, 316 | Permeability, 317 | Reluctance, 318 | Ohm's Law for Magnetic Circuits, 319 | Magnetizing Force, 320 | Hysteresis, 321 | Ampère's Circuital Law, 326 | The Flux  $\Phi$ , 327 | Series Magnetic Circuits: Determining  $NI$ , 327 | Air Gaps, 332 | Series-Parallel Magnetic Circuits, 334 | Determining  $\Phi$ , 336

# 12

## INDUCTORS, 345

Introduction, 345 | Faraday's Law of Electromagnetic Induction, 345 | Lenz's Law, 346 | Self-Inductance, 347 | Types of Inductors, 348 | Induced Voltage, 348 | R-L Transients: Storage Cycle, 352 | R-L Transients: Decay Phase, 356 | Instantaneous Values, 360 |  $\tau = L/R_{Th}$ , 360 | Inductors in Series and Parallel, 362 | R-L and R-L-C Circuits with dc Inputs, 363 | Energy Stored by an Inductor, 365

# 13

## SINUSOIDAL ALTERNATING WAVEFORMS, 373

Introduction, 373 | Sinusoidal ac Voltage Generation, 374 | Defined Polarities and Direction, 378 | Definitions, 378 | The Sine Wave, 381 | General Format for the Sinusoidal Voltage or Current, 386 | Phase Relations, 390 | Average Value, 394 | Effective Values, 398 | ac Meters and Instruments, 402

# 14

## THE BASIC ELEMENTS AND PHASORS, 413

Introduction, 413 | The Derivative, 413 | Response of Basic  $R$ ,  $L$ , and  $C$  Elements to a Sinusoidal Voltage or Current, 415 | Frequency Response of the Basic

Elements, 425 | Average Power and Power Factor, 427 | Complex Numbers, 432 | Rectangular Form, 433 | Polar Form, 434 | Conversion Between Forms, 436 | Mathematical Operations with Complex Numbers, 438 | Techniques of Conversion, 447 | Phasors, 447 | Computer Methods: Conversion Routine, 453

## 15

### **SERIES AND PARALLEL $\alpha\text{c}$ CIRCUITS, 463**

Introduction, 463 | Impedance and the Phasor Diagram, 463 | Series Configuration, 470 | Voltage Divider Rule, 478 | Frequency Response of the R-C Network, 481 | Admittance and Susceptance, 485 | R-L, R-C, and R-L-C Parallel  $\alpha\text{c}$  Networks, 490 | Current Divider Rule, 497 | Equivalent Circuits, 498

## 16

### **SERIES-PARALLEL $\alpha\text{c}$ NETWORKS, 515**

Introduction, 515 | Illustrative Examples, 516 | Ladder Networks, 524

## 17

### **METHODS OF ANALYSIS AND SELECTED TOPICS ( $\alpha\text{c}$ ), 531**

Introduction, 531 | Independent versus Dependent (Controlled) Sources, 531 | Source Conversions, 532 | Mesh Analysis (Format Approach), 535 | Nodal Analysis (Format Approach), 540 | Bridge Networks ( $\alpha\text{c}$ ), 547 |  $\Delta$ -Y, Y- $\Delta$  Conversions, 553

## 18

### **NETWORK THEOREMS ( $\alpha\text{c}$ ), 565**

Introduction, 565 | Superposition Theorem, 565 | Thevenin's Theorem, 571 | Norton's Theorem, 583 | Maximum Power Transfer Theorem, 591 | Substitution, Reciprocity, and Millman's Theorems, 595

## 19

### **POWER ( $\alpha\text{c}$ ), 602**

Introduction, 603 | Resistive Circuit, 604 | Apparent Power, 606 | Inductive Circuit and Reactive Power,

608 | Capacitive Circuit, 611 | The Power Triangle, 613 | The Total  $P$ ,  $Q$ , and  $S$ , 615 | Power Factor Correction, 620 | The Wattmeter, 623 | Effective Resistance, 625 | Computer Analysis, 628

## 20

### **RESONANCE, 637**

Introduction, 637 | Series Resonant Circuit, 638 | The Quality Factor ( $Q$ ), 641 |  $\mathbf{Z}_T$  versus Frequency, 643 | Selectivity, 645 |  $\mathbf{V}_R$ ,  $\mathbf{V}_L$ , and  $\mathbf{V}_C$ , 649 | Examples (Series Resonance), 650 | Parallel Resonant Circuit, 652 | Selectivity Curve for Parallel Resonant Circuits, 655 | The Quality Factor  $Q_p$ , 656 | Effect of  $Q \geq 10$ , 658 | Examples (Parallel Resonance), 662 | Log Scales, 665 | R-C Filters, 667 | Bode Plots, 672 | Tuned Filters, 679

## 21

### **PULSE WAVEFORMS AND THE R-C RESPONSE, 693**

Introduction, 693 | Ideal versus Actual, 693 | Pulse Repetition Rate and Duty Cycle, 698 | Average Value, 700 | R-C Circuits with Initial Values, 702 | R-C Response to Square-Wave Inputs, 705 | Oscilloscope Attenuator and Compensating Probe, 713

## 22

### **POLYPHASE SYSTEMS, 719**

Introduction, 719 | The Three-Phase Generator, 720 | The Y-Connected Generator, 722 | Phase Sequence (Y-Connected Generator), 724 | The Y-Connected Generator with a Y-Connected Load, 725 | The Y- $\Delta$  System, 728 | The  $\Delta$ -Connected Generator, 729 | Phase Sequence ( $\Delta$ -Connected Generator), 731 | The  $\Delta$ - $\Delta$ ,  $\Delta$ -Y Three-Phase Systems, 731 | Power, 733 | The Three-Wattmeter Method, 739 | The Two-Wattmeter Method, 739 | Unbalanced Three-Phase, Four-Wire, Y-Connected Load, 741 | Unbalanced Three-Phase, Three-Wire, Y-Connected Load, 742 | Computer Techniques, 746

## 23

### **NONSINUSOIDAL CIRCUITS, 757**

Introduction, 757 | Fourier Series, 758 | Circuit Response to a Nonsinusoidal Input, 766 | Addition



and Subtraction of Nonsinusoidal Waveforms, 772 |  
Computer Addition of Nonsinusoidal Waveforms,  
772

## 24

### TRANSFORMERS, 781

Introduction, 781 | Mutual Inductance, 781 | Series  
Connection of Mutually Coupled Coils, 784 | The  
Iron-Core Transformer, 787 | Reflected Impedance  
and Power, 792 | Equivalent Circuit (Iron-Core  
Transformer), 796 | Frequency Considerations, 799 |  
Air-Core Transformer, 800 | The Transformer as an  
Isolation Device, 803 | Nameplate Data, 804 | Types  
of Transformers, 806 | Tapped and Multiple-Load  
Transformers, 808 | Networks with Magnetically  
Coupled Coils, 810

## 25

### TWO-PORT PARAMETERS (**z**, **y**, **h**), 817

Introduction, 817 | Impedance (**z**) Parameters, 818 |  
Admittance (**y**) Parameters, 823 | Hybrid (**h**)  
Parameters, 829 | Input and Output Impedances,  
833 | Conversion Between Parameters, 836

#### APPENDIXES

- A. Conversion Factors, 842
- B. Third-Order Determinants, 845
- C. Color Coding of Molded Mica Capacitors  
(Picofarads), 847
- D. Color Coding of Molded Tubular Capacitors  
(Picofarads), 848
- E. The Greek Alphabet, 849
- F. Magnetic Parameter Conversions, 850
- G. Answers to Selected Odd-Numbered Problems, 851

#### INDEX