

*Fifth Edition*

# Electronics Fundamentals

Circuits,  
Devices,  
and Applications

**Floyd**

# Contents

## PART I DC CIRCUITS

### 1 Components, Quantities, and Units 2

- 1-1 Electrical Components and Measuring Instruments 4
- 1-2 Electrical and Magnetic Units 9
- 1-3 Scientific Notation 10
- 1-4 Engineering Notation and Metric Prefixes 15
- 1-5 Metric Unit Conversions 18

### 2 Voltage, Current, and Resistance in Electric Circuits 26

- 2-1 Atoms 28
- 2-2 Electrical Charge 32
- 2-3 Voltage 34
- 2-4 Current 37
- 2-5 Resistance 39
- 2-6 The Electric Circuit 48
- 2-7 Basic Circuit Measurements 55
- 2-8 Electrical Safety 62
- Application Assignment: Putting Your Knowledge to Work 65

### 3 Ohm's Law, Energy, and Power 78

- 3-1 Ohm's Law 80
- 3-2 Application of Ohm's Law 84
- 3-3 Energy and Power 90
- 3-4 Power in an Electric Circuit 93
- 3-5 The Power Rating of Resistors 96
- 3-6 Energy Conversion and Voltage Drop in a Resistance 100
- 3-7 Power Supplies 101
- 3-8 Introduction to Troubleshooting 103
- Application Assignment: Putting Your Knowledge to Work 106

### 4 Series Circuits 120

- 4-1 Resistors in Series 122
- 4-2 Current in a Series Circuit 124
- 4-3 Total Series Resistance 126
- 4-4 Ohm's Law in Series Circuits 130
- 4-5 Voltage Sources in Series 135
- 4-6 Kirchhoff's Voltage Law 137

- 4-7 Voltage Dividers 141
- 4-8 Power in a Series Circuit 148
- 4-9 Circuit Ground 150
- 4-10 Troubleshooting 154
- Application Assignment: Putting Your Knowledge to Work 158

### 5 Parallel Circuits 174

- 5-1 Resistors in Parallel 176
- 5-2 Voltage in Parallel Circuits 179
- 5-3 Kirchhoff's Current Law 180
- 5-4 Total Parallel Resistance 184
- 5-5 Ohm's Law in Parallel Circuits 191
- 5-6 Current Dividers 195
- 5-7 Power in Parallel Circuits 199
- 5-8 Troubleshooting 201
- Application Assignment: Putting Your Knowledge to Work 205

### 6 Series-Parallel Circuits 222

- 6-1 Identifying Series-Parallel Relationships 224
- 6-2 Analysis of Series-Parallel Circuits 229
- 6-3 Voltage Dividers with Resistive Loads 237
- 6-4 Loading Effect of a Voltmeter 242
- 6-5 The Wheatstone Bridge 245
- 6-6 Thevenin's Theorem 250
- 6-7 The Superposition Theorem 262
- 6-8 Troubleshooting 264
- Application Assignment: Putting Your Knowledge to Work 269

### 7 Magnetism and Electromagnetism 288

- 7-1 The Magnetic Field 290
- 7-2 Electromagnetism 294
- 7-3 Electromagnetic Devices 300
- 7-4 Magnetic Hysteresis 304
- 7-5 Electromagnetic Induction 306
- 7-6 Applications of Electromagnetic Induction 310
- Application Assignment: Putting Your Knowledge to Work 314

**8 Introduction to Alternating Current and Voltage 324**

- 8-1 The Sine Wave 326
  - 8-2 Sinusoidal Voltage Sources 331
  - 8-3 Voltage and Current Values of Sine Waves 335
  - 8-4 Angular Measurement of a Sine Wave 339
  - 8-5 The Sine Wave Formula 343
  - 8-6 Ohm's Law and Kirchhoff's Laws in AC Circuits 346
  - 8-7 Superimposed DC and AC Voltages 348
  - 8-8 Nonsinusoidal Waveforms 350
  - 8-9 The Oscilloscope 357
- Application Assignment: Putting Your Knowledge to Work 364

**9 Capacitors 380**

- 9-1 The Basic Capacitor 382
  - 9-2 Types of Capacitors 389
  - 9-3 Series Capacitors 395
  - 9-4 Parallel Capacitors 399
  - 9-5 Capacitors in DC Circuits 401
  - 9-6 Capacitors in AC Circuits 409
  - 9-7 Capacitor Applications 415
  - 9-8 Testing Capacitors 419
- Application Assignment: Putting Your Knowledge to Work 422

**10 RC Circuits 438**

- 10-1 Sinusoidal Response of *RC* Circuits 440
  - 10-2 Impedance and Phase Angle of Series *RC* Circuits 441
  - 10-3 Analysis of Series *RC* Circuits 443
  - 10-4 Impedance and Phase Angle of Parallel *RC* Circuits 450
  - 10-5 Analysis of Parallel *RC* Circuits 453
  - 10-6 Series-Parallel Analysis 458
  - 10-7 Power in *RC* Circuits 463
  - 10-8 Basic Applications 467
  - 10-9 Troubleshooting 477
- Application Assignment: Putting Your Knowledge to Work 482

- 11-1 The Basic Inductor 502
  - 11-2 Types of Inductors 507
  - 11-3 Series Inductors 508
  - 11-4 Parallel Inductors 509
  - 11-5 Inductors in DC Circuits 511
  - 11-6 Inductors in AC Circuits 521
  - 11-7 Inductor Applications 527
  - 11-8 Testing Inductors 528
- Application Assignment: Putting Your Knowledge to Work 529

**12 RL Circuits 540**

- 12-1 Sinusoidal Response of *RL* Circuits 542
  - 12-2 Impedance and Phase Angle of Series *RL* Circuits 543
  - 12-3 Analysis of Series *RL* Circuits 545
  - 12-4 Impedance and Phase Angle of Parallel *RL* Circuits 550
  - 12-5 Analysis of Parallel *RL* Circuits 553
  - 12-6 Series-Parallel Analysis 556
  - 12-7 Power in *RL* Circuits 559
  - 12-8 Basic Applications 563
  - 12-9 Troubleshooting 569
- Application Assignment: Putting Your Knowledge to Work 574

**13 RLC Circuits and Resonance 588**

- 13-1 Impedance and Phase Angle of Series *RLC* Circuits 590
  - 13-2 Analysis of Series *RLC* Circuits 591
  - 13-3 Series Resonance 596
  - 13-4 Series Resonant Filters 603
  - 13-5 Parallel *RLC* Circuits 612
  - 13-6 Parallel Resonance 617
  - 13-7 Parallel Resonant Filters 625
  - 13-8 Applications 631
- Application Assignment: Putting Your Knowledge to Work 634

**14 Transformers 646**

- 14-1 Mutual Inductance 648
- 14-2 The Basic Transformer 649

- 14-3 Step-Up Transformers 653
- 14-4 Step-Down Transformers 654
- 14-5 Loading the Secondary 655
- 14-6 Reflected Load 657
- 14-7 Matching the Load and Source Resistances 660
- 14-8 The Transformer as an Isolation Device 663
- 14-9 Nonideal Transformer Characteristics 664
- 14-10 Other Types of Transformers 667
- 14-11 Troubleshooting 671
  - Application Assignment: Putting Your Knowledge to Work 674

## **15 Pulse Response of Reactive Circuits 686**

- 15-1 The  $RC$  Integrator 688
- 15-2 Single-Pulse Response of  $RC$  Integrators 689
- 15-3 Repetitive-Pulse Response of  $RC$  Integrators 694
- 15-4 Single-Pulse Response of  $RC$  Differentiators 699
- 15-5 Repetitive-Pulse Response of  $RC$  Differentiators 704
- 15-6 Pulse Response of  $RL$  Integrators 706
- 15-7 Pulse Response of  $RL$  Differentiators 711
- 15-8 Applications 715
- 15-9 Troubleshooting 718
  - Application Assignment: Putting Your Knowledge to Work 720

## **PART III DEVICES**

## **16 Introduction to Semiconductors 734**

- 16-1 Atomic Structure and Semiconductors 736
- 16-2 Atomic Bonding 737
- 16-3 Conduction in Semiconductors 739
- 16-4  $N$ -Type and  $P$ -Type Semiconductors 742
- 16-5 The  $PN$  Junction 744
- 16-6 Biasing the  $PN$  Junction 746
- 16-7 Diode Characteristics 751
  - Application Assignment: Putting Your Knowledge to Work 757

## **17 Diodes and Applications 768**

- 17-1 Half-Wave Rectifiers 770
- 17-2 Full-Wave Rectifiers 774
- 17-3 Power Supply Filters and Regulators 780
- 17-4 Diode Limiting and Clamping Circuits 786
- 17-5 Zener Diodes 792
- 17-6 Varactor Diodes 800
- 17-7 LEDs and Photodiodes 802
- 17-8 The Diode Data Sheet 806
- 17-9 Troubleshooting 811
  - Application Assignment: Putting Your Knowledge to Work 819

## **18 Transistors and Thyristors 834**

- 18-1 Bipolar Junction Transistors (BJTs) 836
- 18-2 Voltage-Divider Bias 840
- 18-3 The Bipolar Junction Transistor as an Amplifier 842
- 18-4 The BJT as a Switch 849
- 18-5 BJT Parameters and Ratings 851
- 18-6 The Junction Field-Effect Transistor (JFET) 854
- 18-7 JFET Characteristics 856
- 18-8 The Metal-Oxide Semiconductor FET (MOSFET) 860
- 18-9 FET Biasing 863
- 18-10 Unijunction Transistors (UJTs) 867
- 18-11 Thyristors 869
- 18-12 Transistor Packages and Terminal Identification 871
- 18-13 Troubleshooting 874
  - Application Assignment: Putting Your Knowledge to Work 879

## **19 Amplifiers and Oscillators 894**

- 19-1 Common-Emitter Amplifiers 896
- 19-2 Common-Collector Amplifiers 902
- 19-3 Common-Base Amplifiers 905
- 19-4 FET Amplifiers 908
- 19-5 Multistage Amplifiers 914
- 19-6 Class A Operation 917
- 19-7 Class B Push-Pull Amplifier Operation 920
- 19-8 Class C Operation 926

- 19-9 Oscillators 930
- 19-10 Troubleshooting 936
  - Application Assignment: Putting Your Knowledge to Work 940

## **20 Operational Amplifiers (Op-Amps) 954**

- 20-1 Introduction to Operational Amplifiers 956
- 20-2 The Differential Amplifier 957
- 20-3 Op-Amp Parameters 965
- 20-4 Negative Feedback 971
- 20-5 Op-Amp Configurations with Negative Feedback 973
- 20-6 Op-Amp Impedances 978
- 20-7 Troubleshooting 981
  - Application Assignment: Putting Your Knowledge to Work 984

## **21 Basic Applications of Op-Amps 996**

- 21-1 Comparators 998
- 21-2 Summing Amplifiers 1001
- 21-3 Integrators and Differentiators 1006
- 21-4 Oscillators 1012

- 21-5 Active Filters 1022
- 21-6 Voltage Regulator Fundamentals 1030
- 21-7 Application Assignment: Putting Your Knowledge to Work 1036

## **APPENDICES**

- A Table of Standard Resistor Values A-1**
- B Batteries A-2**
- C Capacitor Color Coding and Marking A-5**
- D The Current Source, Norton's Theorem, and Millman's Theorem A-9**
- E Devices Data Sheets A-15**
- Answers to Odd-Numbered Problems A-25**
- Glossary A-37**
- Index A-47**