#### LEARNING MADE EASY



**3rd Edition** 

# Electronics

## ALL-IN-ONE





Books

in one!



## **Electronics**

#### ALL-IN-ONE

3rd Edition

by Doug Lowe



#### Electronics All-in-One For Dummies®, 3rd Edition

Published by: John Wiley & Sons, Inc., 111 River Street, Hoboken, NJ 07030-5774, <u>www.wiley.com</u>

Copyright @ 2022 by John Wiley & Sons, Inc., Hoboken, New Jersey

Published simultaneously in Canada

No part of this publication may be reproduced, stored in a retrieval system or transmitted in any form or by any means, electronic, mechanical, photocopying, recording, scanning or otherwise, except as permitted under Sections 107 or 108 of the 1976 United States Copyright Act, without the prior written permission of the Publisher. Requests to the Publisher for permission should be addressed to the Permissions Department, John Wiley & Sons, Inc., 111 River Street, Hoboken, NJ 07030, (201) 748-6011, fax (201) 748-6008, or online at http://www.wiley.com/go/permissions.

**Trademarks:** Wiley, For Dummies, the Dummies Man logo, Dummies.com, Making Everything Easier, and related trade dress are trademarks or registered trademarks of John Wiley & Sons, Inc. and may not be used without written permission. All other trademarks are the property of their respective owners. John Wiley & Sons, Inc. is not associated with any product or vendor mentioned in this book.

LIMIT OF LIABILITY/DISCLAIMER OF WARRANTY: THE PUBLISHER AND THE AUTHOR MAKE NO REPRESENTATIONS OR WARRANTIES WITH RESPECT TO THE ACCURACY OR COMPLETENESS OF THE CONTENTS OF THIS WORK AND SPECIFICALLY DISCLAIM ALL WARRANTIES, INCLUDING WITHOUT LIMITATION WARRANTIES OF FITNESS FOR A PARTICULAR PURPOSE. NO WARRANTY MAY BE CREATED OR EXTENDED BY SALES OR PROMOTIONAL MATERIALS. THE ADVICE AND STRATEGIES CONTAINED HEREIN MAY NOT BE SUITABLE FOR EVERY SITUATION. THIS WORK IS SOLD WITH THE UNDERSTANDING THAT THE PUBLISHER IS NOT ENGAGED IN RENDERING LEGAL, ACCOUNTING, OR OTHER PROFESSIONAL SERVICES. IF PROFESSIONAL ASSISTANCE IS REQUIRED, THE SERVICES OF A COMPETENT PROFESSIONAL PERSON SHOULD BE SOUGHT. NEITHER THE PUBLISHER NOR THE AUTHOR SHALL BE LIABLE FOR DAMAGES ARISING HEREFROM. THE FACT THAT AN ORGANIZATION OR WEBSITE IS REFERRED TO IN THIS WORK AS A CITATION AND/OR A POTENTIAL SOURCE OF FURTHER INFORMATION DOES NOT MEAN THAT THE AUTHOR OR THE PUBLISHER ENDORSES THE INFORMATION THE ORGANIZATION OR WEBSITE MAY PROVIDE OR **RECOMMENDATIONS IT MAY MAKE. FURTHER,** READERS SHOULD BE AWARE THAT INTERNET WEBSITES LISTED IN THIS WORK MAY HAVE CHANGED OR DISAPPEARED BETWEEN WHEN THIS WORK WAS WRITTEN AND WHEN IT IS READ.

For general information on our other products and services, please contact our Customer Care Department within the U.S. at 877-762-2974, outside the U.S. at 317-572-3993, or fax 317-572-4002. For technical support, please visit <a href="https://hub.wiley.com/community/support/dummies">https://hub.wiley.com/community/support/dummies</a>.

Wiley publishes in a variety of print and electronic formats and by print-on-demand. Some material included with standard print versions of this book may not be included in e-books or in print-on-demand. If this book refers to media such as a CD or DVD that is not included in the version you purchased, you may download this material at <u>http://booksupport.wiley.com</u>. For more
information about Wiley products, visit <u>www.wiley.com</u>.

Library of Congress Control Number: 2022932613

ISBN 978-1-119-82211-0 (pbk); ISBN 978-1-119-82212-7 (ebk); ISBN 978-1-119-82213-4 (ebk)

## Electronics All-in-One For Dummies®

To view this book's Cheat Sheet, simply go to <u>www.dummies.com</u> and search for "Electronics All-in-One For Dummies Cheat Sheet" in the Search box.

## **Table of Contents**

Cover **Title Page Copyright** Introduction About This Book **Foolish Assumptions** Icons Used in This Book Beyond the Book Where to Go from Here **Book 1: Getting Started with Electronics Chapter 1: Welcome to Electronics** What Is Electricity? But Really, What Is Electricity? What Is Electronics? What Can You Do with Electronics? Looking inside Electronic Devices

#### **Chapter 2: Understanding Electricity**

Pondering the Wonder of ElectricityLooking for ElectricityPeering Inside AtomsExamining the ElementsMinding Your ChargesConductors and InsulatorsUnderstanding CurrentUnderstanding VoltageComparing Direct and Alternating CurrentUnderstanding Power

#### **Chapter 3: Creating Your Mad-Scientist Lab**

Setting Up Your Mad-Scientist Lab Equipping Your Mad-Scientist Lab Stocking up on Basic Electronic Components One Last Thing

#### Chapter 4: Staying Safe

Facing the Realities of Electrical DangersOther Ways to Stay SafeKeeping Safety Equipment on HandProtecting Your Stuff from Static Discharges

#### **Chapter 5: Reading Schematic Diagrams**

Introducing a Simple Schematic Diagram Laying Out a Circuit To Connect or Not to Connect Looking at Commonly Used Symbols

Simplifying Ground and Power Connections

Labeling Components in a Schematic Diagram

Representing Integrated Circuits in a Schematic Diagram

#### **Chapter 6: Building Projects**

Looking at the Process of Building an Electronic Project Envisioning Your Project Designing Your Circuit Prototyping Your Circuit on a Solderless Breadboard Constructing Your Circuit on a Printed Circuit Board (PCB) Finding an Enclosure for Your Circuit

#### Chapter 7: The Secrets of Successful Soldering

Understanding How Solder Works

Procuring What You Need to Solder

Preparing to Solder

Soldering a Solid Solder Joint

Checking Your Work

**Desoldering** 

#### **Chapter 8: Measuring Circuits with a Multimeter**

Looking at Multimeters

What a Multimeter Measures

Using Your Multimeter

#### Chapter 9: Catching Waves with an Oscilloscope

Understanding Oscilloscopes

Examining Waveforms

Calibrating an Oscilloscope

**Displaying Signals** 

#### **Book 2: Working with Basic Electronic** Components

#### **Chapter 1: Working with Basic Circuits**

<u>What Is a Circuit?</u> <u>Using Batteries</u> <u>Building a Lamp Circuit</u> Project 1: A Simple Lamp Circuit

Working with Switches

Building a Switched Lamp Circuit

Project 2: A Lamp Controlled by a Switch **Understand Series and Parallel Circuits Building a Series Lamp Circuit** Project 3: A Series Lamp Circuit Building a Parallel Lamp Circuit Project 4: A Parallel Lamp Circuit Using Switches in Series and Parallel **Building a Series Switch Circuit Project 5: A Series Switch Circuit Building a Parallel Switch Circuit** Project 6: A Parallel Switch Circuit Switching between Two Lamps Project 7: Controlling Two Lamps with One Switch Building a Three-Way Lamp Switch Project 8: A Three-Way Light Switch Reversing Polarity Project 9: A Polarity-Reversing Circuit

#### **Chapter 2: Working with Resistors**

What Is Resistance?
Measuring Resistance
Looking at Ohm's Law
Introducing Resistors
Reading Resistor Color Codes
Understanding Resistor Power Ratings
Limiting Current with a Resistor
Project 10: Using a Current-Limiting Resistor
Combining Resistors in Series and Parallel
Dividing Voltage
Dividing Voltage with Resistors
Project 12: A Voltage Divider Circuit
Varying Resistance with a Potentiometer

#### **Chapter 3: Working with Capacitors**

What Is a Capacitor?

**Counting Capacitance** 

**Reading Capacitor Values** 

The Many Sizes and Shapes of Capacitors

<u>Calculating Time Constants for Resistor/Capacitor</u> <u>Networks</u>

Combining Capacitors

Putting Capacitors to Work

Charging and Discharging a Capacitor

Project 13: Charging and Discharging a Capacitor

Blocking DC while Passing AC

Project 14: Blocking Direct Current

#### **Chapter 4: Working with Inductors**

What Is Magnetism?Examining ElectromagnetsInducing CurrentCalculating RL Time ConstantsCalculating Inductive ReactanceCombining InductorsPutting Inductors to Work

#### **Chapter 5: Working with Diodes and LEDs**

What Is a Semiconductor? Introducing Diodes The Many Types of Diodes Using a Diode to Block Reverse Polarity Project 15: Blocking Reverse Polarity Putting Rectifiers to Work Building Rectifier Circuits

Project 16: Rectifier Circuits

Introducing Light Emitting Diodes

Using LEDs to Detect Polarity

Project 17: An LED Polarity Detector

#### **Chapter 6: Working with Transistors**

What's the Big Deal about Transistors? Amplifying with a Transistor Using a Transistor as a Switch An LED Driver Circuit Project 18: A Transistor LED Driver Looking at a Simple NOT Gate Circuit **Building a NOT Gate** Project 19: A NOT Gate Oscillating with a Transistor **Building an LED Flasher** Project 20: An LED Flasher Wrapping Up Our Exploration of Discrete Components

### **Book 3: Working with Integrated Circuits**

#### **Chapter 1: Introducing Integrated Circuits**

What Exactly Is an Integrated Circuit? Looking at How Integrated Circuits Are Made Integrated Circuit Packages Using ICs in Schematic Diagrams Powering ICs Avoiding Static and Heat Damage Reading IC Data Sheets Popular Integrated Circuits

#### **Chapter 2: The Fabulous 555 Timer Chip**

Looking at How the 555 Works Understanding 555 Modes Using the 555 in Monostable (One-Shot) Mode Using the 555 in Astable (Oscillator) Mode Using the 555 in Bistable (Flip-Flop) Mode Using the 555 Timer Output Doubling Up with the 556 Dual Timer Making a One-Shot Timer Project 21: A One-Shot 555 Timer Circuit

<u>Making an LED Flasher</u>

Project 22: An LED Flasher

Using a Set/Reset Switch

Project 23: An LED Flasher with a Set/Reset Switch

<u>Making a Beeper</u>

Project 24: An Audible Beeper

#### **Chapter 3: Working with Op-Amps**

Looking at Operational Amplifiers Understanding Open Loop-Amplifiers Looking at Closed Loop-Amplifiers Using an Op-Amp as a Unity Gain Amplifier Using an Op-Amp as a Voltage Comparator Adding Voltages Working with Op-Amp ICs

#### Book 4: Beyond Direct Current Chapter 1: Getting into Alternating Current

What Is Alternating Current?

Measuring Alternating Current

**Understanding Alternators** 

Understanding Motors

Understanding Transformers

Working with Line Voltage

Using Line Voltage in Your Projects

Wires and Connectors for Working with Line Voltage

Using Fuses to Protect Line-Voltage Circuits

Using Relays to Control Line-Voltage Circuits

#### **Chapter 2: Building Power Supplies**

<u>Using a Power Adapter</u> <u>Understanding What a Power Supply Does</u> <u>Transforming Voltage</u> <u>Turning AC into DC</u> <u>Filtering Rectified Current</u>

#### Regulating Voltage

#### **Chapter 3: Understanding Radio**

<u>Understanding Radio Waves</u> <u>Transmitting and Receiving Radio</u> <u>Understanding AM Radio</u> <u>Understanding FM Radio</u>

Building a Crystal Radio

#### **Chapter 4: Working with Infrared**

Introducing Infrared Light

Detecting Infrared Light

Project 25: A Simple IR Detector

Creating Infrared Light

Building a Proximity Detector

Building a Common-Emitter Proximity Detector

Project 26: A Common-Emitter Proximity Detector

Building a Common-Collector Proximity Detector

Project 27: A Common-Collector Proximity Detector

#### **Book 5: Doing Digital Electronics**

#### Chapter 1: Understanding Digital Electronics

Distinguishing Analog and Digital Electronics Understanding Binary Using Switches to Build Gates Project 28: A Simple AND Circuit

TOJECT 20. A Simple AND Circuit

Project 29: A Simple OR Circuit

Project 30: A Simple XOR Circuit

#### **Chapter 2: Getting Logical**

Introducing Boolean Logic and Logic Gates Looking at NOT Gates Looking at AND Gates Looking at OR Gates Looking at NAND Gates Looking at NOR Gates Looking at XOR and XNOR Gates De Marvelous De Morgan's Theorem All You Need Is NAND (Or NOR) Using Software to Practice with Gates

#### **Chapter 3: Working with Logic Circuits**

Creating Logic Gates with Transistors

Project 31: A Transistor NOT Gate

Project 32: A Transistor NAND Gate

Project 33: A Transistor NOR Gate

Introducing Integrated Circuit Logic Gates

Introducing the Versatile 4000-Series Logic Gates

Building Projects with the 4011 Quad Two-Input NAND Gate

Project 34: A CMOS NAND Gate

Project 35: A CMOS AND Gate

Project 36: A CMOS OR Gate

Project 37: A CMOS NOR Gate

#### **Chapter 4: Working with Flip-Flops**

Looking at Latches Project 38: An Active-High Latch Project 39: An Active-Low Latch Looking at Gated Latches Project 40: A Gated D Latch Introducing Flip-Flops Project 41: A D Flip-Flop Project 42: A Toggle Flip-Flop Debouncing a Clock Input

#### **Chapter 5: Introducing Microcontrollers**

Introducing Microcontrollers Programming a Microcontroller Working with I/O Pins

**Book 6: Working with Arduino Microprocessors** 

#### **Chapter 1: Introducing Arduino**

Introducing the Arduino UNO

Buying an UNO Starter Kit

Installing the Arduino IDE

Connecting to an UNO

Looking at a Simple Arduino Sketch

Running the Blink Program

Using a Digital I/O Pin to Control an LED

Project 43: Blinking an LED with an Arduino UNO

#### **Chapter 2: Creating Arduino Sketches**

Introducing C Working with a Prototyping Shield Building a Test Circuit Project 44: An Arduino LED Test Circuit Flashing the LEDs Using Comments **Creating Identifiers Using Variables** Doing Math A Program That Uses Variables and Math Using If Statements Using While Loops Using For Loops Crafting Your Own Functions **Chapter 3: More Arduino Programming Tricks** 

<u>Using a Push Button with an Arduino</u> <u>Checking the Status of a Switch in Arduino</u> <u>Project 45: A Push-Button Controlled Arduino LED Flasher</u> <u>Randomizing Your Programs</u> <u>Reading a Value from a Potentiometer</u> <u>Project 46: A Variable-Rate LED Flasher</u>

#### **Chapter 4: An Arduino Proximity Sensor**

Using an Ultrasonic Range Finder Using an LCD Building a Proximity Sensor Project 47: An Arduino Proximity Sensor

#### **Chapter 5: Adding Sound and Motion to Your Arduino Projects**

Using a Speaker with an Arduino

Project 48: Creating Sound with a Speaker

Using an MP3 Shield

Building an Arduino Music Player

Project 49: Using a Music Maker Shield to Play Sounds

Using a Servo with an Arduino

Project 50: Using a Servo with an Arduino

#### **Chapter 6: Keypads and Keyboards**

<u>Using a Keypad</u>

Setting Up a Keypad

Building a Keypad Circuit

Project 51: Using a Keypad

Using an Arduino for Computer Keyboard Input

Building a Windows Keypad Gadget

Project 52: A Windows Keypad Gadget

#### **Book 7: Working with Raspberry Pi**

#### **Chapter 1: Introducing Raspberry Pi**

Introducing the Raspberry Pi Considering Raspberry Pi Versions Setting Up a Raspberry Pi Installing the Raspberry Pi Operating System Starting Up Your Raspberry Pi Understanding the File System Writing Your First Raspberry Pi Program Examining GPIO Ports <u>Connecting an LED to a GPIO Port</u> <u>Flashing an LED in Python</u> <u>Building a Raspberry Pi LED Flasher</u> <u>Project 51: Blinking an LED with a Raspberry Pi</u>

#### **Chapter 2: Programming in Python**

Looking Closer at Python Building a Test Circuit Project 52: A Raspberry Pi LED Test Board Flashing the LEDs Using Comments Creating Identifiers Using Constants Using Constants Using Variables Creating Your Own Functions Using If Statements Using While Loops Using For Loops Looking at Python Lists

#### **Chapter 3: Reading Digital and Analog Input**

<u>Using a GPIO Port for Digital Input</u> <u>Checking the Status of a Switch in Python</u> <u>Project 53: A Push-Button-Controlled Raspberry Pi LED</u> <u>Flasher</u> <u>Reading Analog Input</u> <u>Enabling SPI on Your Raspberry Pi</u> <u>Using the MCP3008 in Python</u> <u>Using the mcp3008 Package</u> Project 54: A Variable-Rate LED Flasher

#### **Book 8: Special Effects**

#### **Chapter 1: Building a Color Organ**

Examining the Color Organ Project Understanding How the Color Organ Works Getting What You Need to Build the Color Organ Assembling the Color Organ Using the Color Organ

#### **Chapter 2: Animating Holiday Lights**

Introducing the ShowTime PC Controller Looking at a Basic Light-O-Rama Setup Understanding Channels and Sequences Choosing Lights for Your Display **Designing Your Layout** Assembling the ShowTime PC Controller Connecting the Controller to a Computer Testing the ShowTime PC Controller Using the Light-O-Rama Sequence Editor Understanding Sequences Creating a Musical Sequence

Visualizing Your Show

#### **Chapter 3: Building an Animatronic Prop** Controller

Looking at the Requirements of Animatronic Prop Control Examining a Typical Animatronic Prop Building the Prop Controller Programming the Prop-1 Controller Sending Commands to the RC-4 or AP-16+ Modules Programming the RC-4 Relay Control Module <u>A Sample AP-16+ Program</u> Programming the PIR Motion Detector Looking at Complete Jack-in-the-Box Program **Chapter 4: Re-Creating a Retro Science-**

## **Fiction Robot Head**

Looking to Robby and B-9 For Inspiration Conceiving VIN-e Introducing VIN-e 1.0

Looking at VIN-e's Electronics

#### A Final Word about Safety

Index About the Author Advertisement Page Connect with Dummies End User License Agreement

## **List of Tables**

#### **Book 1 Chapter 5**

TABLE 5-1 Common Symbols for Schematic Diagrams TABLE 5-2 Commonly Used Reference Identifiers

#### **Book 2 Chapter 2**

TABLE 2-1 Resistor Color Codes (Resistance Values)

TABLE 2-2 Resistor Color Codes (Tolerance Values)

TABLE 2-3 Series Resistance Measurements

TABLE 2-4 Series/Parallel Resistance Measurements

TABLE 2-5 Series Resistance Measurements

#### **Book 2 Chapter 3**

TABLE 3-1 Capacitance Markings TABLE 3-2 Capacitor Tolerance Markings

#### **Book 2 Chapter 5**

TABLE 5-1 Peak Inverse Voltages for 1N400x Diodes TABLE 5-2 Voltage Measurements

#### **Book 3 Chapter 2**

TABLE 2-1 Conversion of Resistance and Capacitance ValuesTABLE 2-2 Pinouts for the 555 Timer and 556 Dual-Timer Chips

#### Book 5 Chapter 1

TABLE 1-1 Powers of 2TABLE 1-2 Logical Operations for Binary Values

#### **Book 5 Chapter 2**

TABLE 2-1 The Most Common Types of Logic GatesTABLE 2-2 The Truth Table for an InverterTABLE 2-3 The Truth Table for a Two-Input AND GateTABLE 2-4 The Truth Table for a Three-Input AND GateTABLE 2-5 The Truth Table for a Two-Input OR GateTABLE 2-6 The Truth Table for a Two-Input NAND GateTABLE 2-7 The Truth Table for a Two-Input NOR GateTABLE 2-8 The Truth Table for a Two-Input XOR GateTABLE 2-9 The Truth Table for a Two-Input XNOR Gate

#### **Book 5 Chapter 3**

TABLE 3-1 NOT Gate Truth Table

TABLE 3-2 NAND Gate Truth Table

TABLE 3-3 NOR Gate Truth Table

TABLE 3-4 7400-Series TTL Logic Gates

TABLE 3-5 4000-Series CMOS Logic Gates

TABLE 3-6 NAND Gate Truth Table

TABLE 3-7 AND Gate Truth Table

TABLE 3-8 OR Gate Truth Table

TABLE 3-9 NOR Gate Truth Table

#### **Book 5 Chapter 4**

TABLE 4-1 Pinouts for the 4013 Dual D Flip-Flop IC xxx

#### **Book 6 Chapter 1**

TABLE 1-1 UNO Board Header Pins

#### **Book 6 Chapter 4**

TABLE 4-1 Pinouts for the HC-SR04 Ultrasonic Range FinderTABLE 4-2 Pinouts for an HD44780-Type LCD

TABLE 4-3 Pinouts for an HD44780-Type LCD

#### Book 7 Chapter 1

TABLE 1-1 Root-Level Directories in a Linux File System

#### **Book 7 Chapter 3**

## **List of Illustrations**

#### Book 1 Chapter 1

FIGURE 1-1: An insulated wire consists of a conductor surrounded by an insulato...

FIGURE 1-2: A simple electrical circuit consisting of a battery, a lamp, and so...

FIGURE 1-3: A typical electronic circuit board.

#### **Book 1 Chapter 2**

FIGURE 2-1: A common model of an atom.

FIGURE 2-2: Electrons transfer current through a wire much like a row of pool b...

FIGURE 2-3: You can use a multimeter like this to measure voltage.

FIGURE 2-4: Newton's Cradle works much like alternating current.

#### **Book 1 Chapter 3**

FIGURE 3-1: My Mad-Scientist Lab really is a mad-scientist lab!

FIGURE 3-2: Multicompartment storage boxes are ideal for storing small componen...

FIGURE 3-3: Basic hand tools you'll want to have.

FIGURE 3-4: The wire on the top was stripped with wire cutters; the one on the ...

FIGURE 3-5: The author modeling his favorite magnifying headgear.

FIGURE 3-6: A third hand can hold your stuff so that both your hands are free t...

FIGURE 3-7: A hobby vise.

FIGURE 3-8: A soldering iron with a stand.

FIGURE 3-9: An inexpensive multimeter.

FIGURE 3-10: A solderless breadboard.

FIGURE 3-11: Solid and stranded wire.

FIGURE 3-12: Jumper wires for working with a solderless breadboard.

FIGURE 3-13: Battery holders will help deliver power to your circuits.

FIGURE 3-14: Jumper clips are great for making quick connections.

FIGURE 3-15: Resistors are one of the most commonly used circuit components.

FIGURE 3-16: Capacitors come in many shapes and sizes.

FIGURE 3-17: An assortment of diodes.

FIGURE 3-18: Light-emitting diodes.

FIGURE 3-19: A look at a 2N3904 NPN transistor.

FIGURE 3-20: Two popular integrated circuits: A 555 timer and an LM741 op-amp.

FIGURE 3-21: Make sure your friends and family are properly warned.

#### **Book 1 Chapter 4**

FIGURE 4-1: A soldering iron resting on a stand.

FIGURE 4-2: An antistatic wristband.

#### **Book 1 Chapter 5**

FIGURE 5-1: A simple schematic of a circuit that lights a lamp.

FIGURE 5-2: Wires that cross may or may not actually be connected.

FIGURE 5-3: A typical schematic diagram.

FIGURE 5-4: A schematic diagram that uses a common ground to complete the circu...

FIGURE 5-5: A schematic diagram that uses a common ground to complete the circu...

FIGURE 5-6: Two equivalent diagrams showing positive and negative voltage sourc...

FIGURE 5-7: A schematic diagram with parts labeled.

FIGURE 5-8: A circuit that uses an integrated circuit.

#### **Book 1 Chapter 6**

FIGURE 6-1: One of my scarier electronics projects.

FIGURE 6-2: A hand-drawn sketch for an electronic coin tosser.

FIGURE 6-3: A schematic diagram for a simple coin-toss circuit.

FIGURE 6-4: The schematic diagram for the coin-toss circuit after it has been m...

FIGURE 6-5: A schematic diagram that indicates which components are on the main...

FIGURE 6-6: A typical solderless breadboard.

FIGURE 6-7: The contact holes in typical solderless breadboards are internally ...

FIGURE 6-8: How the pins are numbered on a 555 timer integrated circuit.

FIGURE 6-9: The breadboard after the IC has been inserted and connected to the ...

FIGURE 6-10: The breadboard after the LEDs have been connected.

FIGURE 6-11: The breadboard after the finger contact jumpers have been connecte...

FIGURE 6-12: The prototype of the coin tosser in operation.

FIGURE 6-13: A printed circuit board.

FIGURE 6-14: A preprinted PCB that uses a standard breadboard layout.

FIGURE 6-15: The layout for the PCB used in the coin-toss circuit.

FIGURE 6-16: The completed coin-tosser PCB.

FIGURE 6-17: Project boxes come in a variety of shapes and sizes.

FIGURE 6-18: Location for drilling holes in the lid of the project box.

FIGURE 6-19: Installing the standoffs.

FIGURE 6-20: The box with the push button, battery holder, and standoffs instal...

FIGURE 6-21: The circuit board with the LEDs turned around.

FIGURE 6-22: The circuit board attached to the lid and the finger contacts conn...

FIGURE 6-23: The completed coin-toss project.

#### **Book 1 Chapter 7**

FIGURE 7-1: A soldering iron.

FIGURE 7-2: Positioning the soldering iron.

FIGURE 7-3: Applying the solder.

FIGURE 7-4: A good solder joint.

FIGURE 7-5: A desoldering bulb and a desoldering braid.

#### **Book 1 Chapter 8**

FIGURE 8-1: You can buy a basic multimeter like this one for under \$20.

FIGURE 8-2: An analog multimeter.

FIGURE 8-3: A bench-top multimeter.

FIGURE 8-4: A simple circuit with a battery, a resistor, and an LED.

FIGURE 8-5: The LED circuit assembled on a breadboard.

FIGURE 8-6: Using an ammeter to measure current flow in the LED circuit.

FIGURE 8-7: Using a voltmeter to measure voltage in the LED circuit.

#### **Book 1 Chapter 9**

FIGURE 9-1: A typical oscilloscope.

FIGURE 9-2: An oscilloscope trace showing a sine wave.

FIGURE 9-3: Four common waveforms.

FIGURE 9-4: An oscilloscope trace showing a square wave.

FIGURE 9-5: Connecting an oscilloscope probe to an audio plug.

#### Book 2 Chapter 1

FIGURE 1-1: A simple circuit.

FIGURE 1-2: A short circuit.

FIGURE 1-3: What goes on inside a battery.

FIGURE 1-4: Common batteries.

FIGURE 1-5: A simple lamp circuit.

FIGURE 1-6: There are switches for every need.

FIGURE 1-7: Single- and double-throw switches.

FIGURE 1-8: The switched lamp project.

FIGURE 1-9: The DPDT knife switch.

FIGURE 1-10: Using a DPST switch to control a lamp.

FIGURE 1-11: Lamps connected in series and in parallel.

FIGURE 1-12: Lamps connected in series.

FIGURE 1-13: Lamps connected in parallel.

FIGURE 1-14: Schematic diagrams for series and parallel switch circuits.

FIGURE 1-15: The assembled series switch circuit.

FIGURE 1-16: The assembled parallel switch circuit.

FIGURE 1-17: The switch controls two lamps.

FIGURE 1-18: Another way to control two lamps.

FIGURE 1-19: The completed three-way light switch circuit.

FIGURE 1-20: The assembled polarity-reversing circuit.

#### **Book 2 Chapter 2**

FIGURE 2-1: Carbon film resistors.

FIGURE 2-2: Two ways to place a resistor in series with an LED.

FIGURE 2-3: The assembled circuit for Project 10.

FIGURE 2-4: Combining resistors in series.

FIGURE 2-5: Resistors in parallel.

FIGURE 2-6: Resistors in series and parallel.

FIGURE 2-7: A voltage divider circuit.

FIGURE 2-8: The assembled voltage divider circuit.

FIGURE 2-9: A potentiometer.

FIGURE 2-10: How a potentiometer works.

#### Book 2 Chapter 3

FIGURE 3-1: A capacitor creates an electric field between two charged plates se...

FIGURE 3-2: Capacitors are made in many different shapes and sizes.

FIGURE 3-3: A variable capacitor.

FIGURE 3-4: A capacitor charging circuit.

FIGURE 3-5: Combining capacitors in parallel.

FIGURE 3-6: Combing capacitors in series.

FIGURE 3-7: The capacitor discharge circuit (Project 13).

FIGURE 3-8: The finished AC/DC circuit (Project 14).

FIGURE 3-9: A 9 V AC power adapter.

#### **Book 2 Chapter 4**

FIGURE 4-1: The shape of a magnetic field revealed by iron filings.

FIGURE 4-2: An electromagnet.

FIGURE 4-3: Inductors are simple devices.

FIGURE 4-4: A typical transformer.

#### **Book 2 Chapter 5**

FIGURE 5-1: Several common varieties of diodes.

FIGURE 5-2: Silicon crystals are formed when each silicon atom shares its outer...

FIGURE 5-3: An N-type semiconductor has extra electrons.

FIGURE 5-4: A P-type semiconductor has holes where electrons should be.

FIGURE 5-5: A diode has a single p-n junction.

FIGURE 5-6: Forward and reverse bias on a diode.

FIGURE 5-7: Blocking reverse polarity (Project 15).

FIGURE 5-8: Using a diode to rectify alternating current.

FIGURE 5-9: A full-wave rectifier circuit, also known as a bridge rectifier.

FIGURE 5-10: A bridge rectifier package.

FIGURE 5-11: An LED. The shorter lead is the cathode.

FIGURE 5-12: A resistor should always be used in series with an LED.

FIGURE 5-13: The completed LED polarity detector (Project 17).

#### **Book 2 Chapter 6**

FIGURE 6-1: Transistors come in many shapes and sizes.

FIGURE 6-2: NPN and PNP transistors.

FIGURE 6-3: A basic transistor amplifier circuit.

FIGURE 6-4: Switching an LED with an NPN transistor.

FIGURE 6-5: The circuit for the LED driver (Project 18).

FIGURE 6-6: The schematic diagram for the NOT gate circuit.

FIGURE 6-7: The transistor NOT gate (Project 19).

FIGURE 6-8: An astable multivibrator.

FIGURE 6-9: Using a transistor to couple an output load to an astable multivibr...

FIGURE 6-10: The LED flasher project (Project 20).

#### Book 3 Chapter 1

FIGURE 1-1: Integrated circuits in common DIP packaging.

FIGURE 1-2: Solderless breadboards are designed with DIP chips in mind.

FIGURE 1-3: Identifying the pins on a DIP package.

FIGURE 1-4: An integrated circuit in a schematic diagram.

FIGURE 1-5: Independent sections within a single IC are often shown separately ...

FIGURE 1-6: A circuit for providing positive voltage, negative voltage, and gro...

FIGURE 1-7: DIP sockets let you avoid soldering delicate integrated circuits.

#### **Book 3 Chapter 2**

FIGURE 2-1: Pinout diagram for a 555 timer IC.

FIGURE 2-2: How a 555 timer chip is usually shown in a schematic diagram.

FIGURE 2-3: A 555 timer chip in monostable mode.

FIGURE 2-4: The imaginary switch inside the 555 that controls whether pin 7 cha...

FIGURE 2-5: A 555 timer chip in astable mode.

FIGURE 2-6: Timing the output wave created by an astable 555 timer circuit.

FIGURE 2-7: Using a diode to separately control the high and low part of the ou...

FIGURE 2-8: The schematic for a 555 timer circuit in bistable mode.

FIGURE 2-9: Sourcing and sinking output current for a 555 timer.

FIGURE 2-10: You can combine sourcing and sinking current for the output of a 5...

FIGURE 2-11: Using a transistor to drive a higher-current device.

FIGURE 2-12: 555 timers can be cascaded.

FIGURE 2-13: The two halves of a 556 dual-timer circuit can be cascaded.

FIGURE 2-14: The cascaded timer circuit with the 556 dual-timer chip drawn as a...

FIGURE 2-15: The finished one-shot timer project (Project 21).

FIGURE 2-16: The finished LED flasher (Project 22).

FIGURE 2-17: The completed circuit for Project 23.

FIGURE 2-18: The completed beeper project (Project 24).

#### Book 3 Chapter 3

FIGURE 3-1: Schematic symbol for an op-amp.

FIGURE 3-2: A split ±9V supply for an op-amp.

FIGURE 3-3: The output from an op-amp passes to ground through a load resistanc...

FIGURE 3-4: A op-amp configured as an open loop-amplifier.

FIGURE 3-5: An op-amp configured as an inverting amplifier.

FIGURE 3-6: An op-amp configured as a noninverting amplifier.

FIGURE 3-7: An op-amp configured as a unity gain follower.

FIGURE 3-8: An op-amp configured as a unity gain inverter.

FIGURE 3-9: An op-amp configured as a voltage comparator.

FIGURE 3-10: Using a diode in a voltage-comparator circuit.

FIGURE 3-11: A voltage comparator that tests for a voltage that's less than a r...

FIGURE 3-12: Two op-amps can be used to create a window comparator.

FIGURE 3-13: A basic summing amplifier circuit.

FIGURE 3-14: A summing amplifier can be combined with a voltage inverter to pre...

FIGURE 3-15: A simple audio mixer with four inputs.

FIGURE 3-16: Pinouts for the LM741 op-amp.

FIGURE 3-17: Pinouts for the LM324 quad op-amp.

#### **Book 4 Chapter 1**

FIGURE 1-1: Three ways to measure alternating current.

FIGURE 1-2: An alternator generates alternating current from a rotating magnet.

FIGURE 1-3: A transformer uses magnetic induction to pass current from one circ...

FIGURE 1-4: An external power adapter.

FIGURE 1-5: NMB cabling.

FIGURE 1-6: A standard electrical receptacle.

FIGURE 1-7: Wire nuts.

FIGURE 1-8: Barrier strips are useful for connecting wires that carry AC power.

FIGURE 1-9: A 2 A, 1<sup>1</sup>/<sub>4</sub>-x-<sup>1</sup>/<sub>4</sub>-inch AGC fuse.

FIGURE 1-10: A fuse in a schematic diagram.

FIGURE 1-11: Fuse holders.

FIGURE 1-12: A relay is a switch that is controlled by an electromagnet.

FIGURE 1-13: Using a relay to switch a line-voltage circuit.

FIGURE 1-14: Driving a relay from a 555 timer IC.

#### **Book 4 Chapter 2**

FIGURE 2-1: A center-tapped transformer provides two output voltages.

FIGURE 2-2: A half-wave rectifier uses just one diode.

FIGURE 2-3: A full-wave rectifier uses two diodes.

FIGURE 2-4: A bridge rectifier uses four diodes.

FIGURE 2-5: A capacitor can be used to filter the output from the rectifier.

FIGURE 2-6: A filter circuit smooths the output voltage.

FIGURE 2-7: Two capacitors and a resistor cut ripple voltage but also reduce th...

FIGURE 2-8: An inductor can be used in a filter circuit to minimize DC voltage ...

FIGURE 2-9: Using a 78XX voltage regulator.

FIGURE 2-10: Using an LM317 adjustable voltage regulator.

#### **Book 4 Chapter 3**

FIGURE 3-1: The basic components of a radio transmitter.

FIGURE 3-2: The basic components of a radio receiver.

FIGURE 3-3: The basic AM modulator circuit.

FIGURE 3-4: Using a transistor for amplitude modulation.

FIGURE 3-5: How the carrier wave and the audio signal are combined to produce a...

FIGURE 3-6: How the carrier wave and the audio signal are combined to produce a...

FIGURE 3-7: An FM modulator circuit that uses a varactor.

FIGURE 3-8: Schematic diagram for a crystal radio.

FIGURE 3-9: A finished crystal radio.

FIGURE 3-10: A coil wound on an empty soda bottle.

FIGURE 3-11: Layout for the crystal radio circuit.

FIGURE 3-12: Stringing your antenna.

FIGURE 3-13: A good ground connection.

#### **Book 4 Chapter 4**

FIGURE 4-1: Infrared light falls between visible light and microwaves.

FIGURE 4-2: A simple infrared detector circuit.

FIGURE 4-3: The assembled infrared detector circuit (Project 25).

FIGURE 4-4: Use a current-limiting resistor to protect an IR LED.

FIGURE 4-5: A common-emitter proximity detector circuit.

FIGURE 4-6: Using an IR LED and a phototransistor as a proximity detector (Proj...

FIGURE 4-7: A common-collector proximity detector circuit.

FIGURE 4-8: This circuit lights a red LED when the path between an IR LED and a...

#### Book 5 Chapter 1

FIGURE 1-1: Analog and digital clocks.

FIGURE 1-2: Implementing AND (top), OR (middle), and XOR (bottom) gates with kn...

#### **Book 5 Chapter 2**

FIGURE 2-1: The symbol for a NOT gate.

FIGURE 2-2: The symbol for a two-input AND gate.

FIGURE 2-3: A pair of two-input AND gates can be used to create a logic network...

FIGURE 2-4: An AND gate used in a home alarm system.

FIGURE 2-5: An AND gate used as an enable input.

FIGURE 2-6: The symbol for a two-input OR gate.

FIGURE 2-7: Three OR gates used to create a four-input OR gate.

FIGURE 2-8: OR gates used in a sensor circuit.

FIGURE 2-9: The symbol for a two-input NAND gate.

FIGURE 2-10: NAND gates used in a sensor circuit.

FIGURE 2-11: The symbol for a two-input NOR gate.

FIGURE 2-12: Using a NOR gate in a sensor circuit.

FIGURE 2-13: The symbols for two-input XOR and XNOR gates.

FIGURE 2-14: An XOR gate and an AND gate can be used to add two binary numbers.

FIGURE 2-15: NAND and NOR gates are equivalent to negative OR and negative AND ...