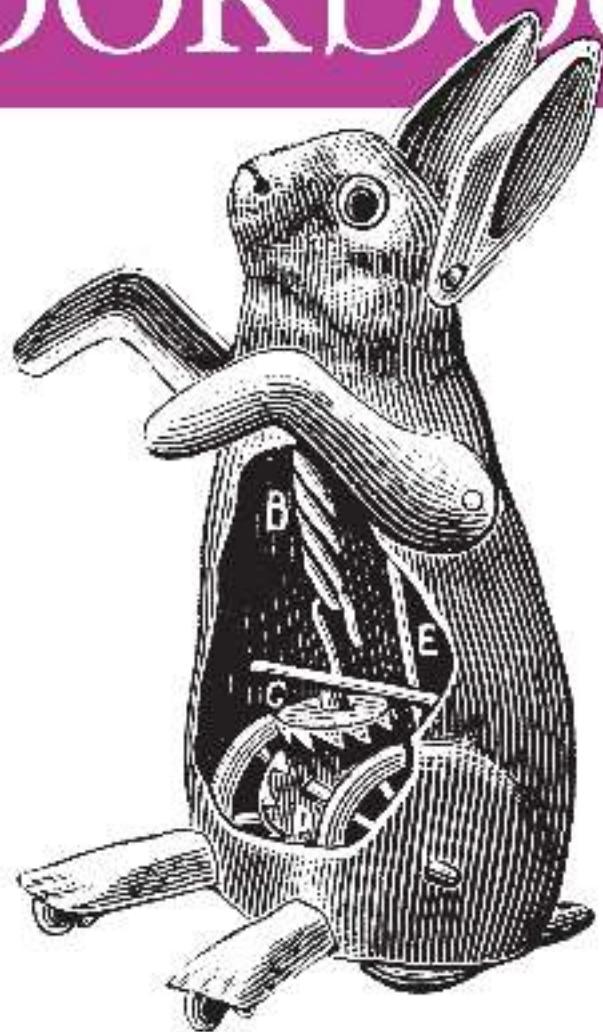


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—Mikal Hart  
Arduino Uno Advisory Team

Michael Margolis, a technologist in the field of real-time computing, has expertise in developing and delivering hardware and software for interacting with the environment. Formerly the Chief Technical Officer with Avaya, he has more than 30 years of experience with Sony, Microsoft, and Lucent/Bell Labs.

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# Arduino Cookbook



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# Arduino Cookbook

*Michael Margolis*

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## Arduino Cookbook

by Michael Margolis

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# Table of Contents

<b>Preface</b> .....	<b>xiii</b>
<b>1. Getting Started</b> .....	<b>1</b>
1.1 Installing the Integrated Development Environment (IDE)	4
1.2 Setting Up the Arduino Board	6
1.3 Using the Integrated Development Environment (IDE) to Prepare an Arduino Sketch	8
1.4 Uploading and Running the Blink Sketch	11
1.5 Creating and Saving a Sketch	13
1.6 Using Arduino	15
<b>2. Making the Sketch Do Your Bidding</b> .....	<b>19</b>
2.1 Structuring an Arduino Program	20
2.2 Using Simple Primitive Types (Variables)	21
2.3 Using Floating-Point Numbers	23
2.4 Working with Groups of Values	25
2.5 Using Arduino String Functionality	28
2.6 Using C Character Strings	30
2.7 Splitting Comma-Separated Text into Groups	32
2.8 Converting a Number to a String	34
2.9 Converting a String to a Number	36
2.10 Structuring Your Code into Functional Blocks	38
2.11 Returning More Than One Value from a Function	41
2.12 Taking Actions Based on Conditions	44
2.13 Repeating a Sequence of Statements	45
2.14 Repeating Statements with a Counter	47
2.15 Breaking Out of Loops	49
2.16 Taking a Variety of Actions Based on a Single Variable	50
2.17 Comparing Character and Numeric Values	52
2.18 Comparing Strings	54
2.19 Performing Logical Comparisons	55

2.20	Performing Bitwise Operations	56
2.21	Combining Operations and Assignment	58
<b>3.</b>	<b>Using Mathematical Operators</b>	<b>61</b>
3.1	Adding, Subtracting, Multiplying, and Dividing	61
3.2	Incrementing and Decrementing Values	62
3.3	Finding the Remainder After Dividing Two Values	63
3.4	Determining the Absolute Value	64
3.5	Constraining a Number to a Range of Values	65
3.6	Finding the Minimum or Maximum of Some Values	66
3.7	Raising a Number to a Power	67
3.8	Taking the Square Root	68
3.9	Rounding Floating-Point Numbers Up and Down	68
3.10	Using Trigonometric Functions	69
3.11	Generating Random Numbers	70
3.12	Setting and Reading Bits	72
3.13	Shifting Bits	75
3.14	Extracting High and Low Bytes in an int or long	77
3.15	Forming an int or long from High and Low Bytes	78
<b>4.</b>	<b>Serial Communications</b>	<b>81</b>
4.1	Sending Debug Information from Arduino to Your Computer	86
4.2	Sending Formatted Text and Numeric Data from Arduino	89
4.3	Receiving Serial Data in Arduino	92
4.4	Sending Multiple Text Fields from Arduino in a Single Message	95
4.5	Receiving Multiple Text Fields in a Single Message in Arduino	98
4.6	Sending Binary Data from Arduino	101
4.7	Receiving Binary Data from Arduino on a Computer	105
4.8	Sending Binary Values from Processing to Arduino	107
4.9	Sending the Value of Multiple Arduino Pins	109
4.10	How to Move the Mouse Cursor on a PC or Mac	112
4.11	Controlling Google Earth Using Arduino	115
4.12	Logging Arduino Data to a File on Your Computer	121
4.13	Sending Data to Two Serial Devices at the Same Time	124
4.14	Receiving Serial Data from Two Devices at the Same Time	128
4.15	Setting Up Processing on Your Computer to Send and Receive Serial Data	131
<b>5.</b>	<b>Simple Digital and Analog Input</b>	<b>133</b>
5.1	Using a Switch	136
5.2	Using a Switch Without External Resistors	139
5.3	Reliably Detecting the Closing of a Switch	141
5.4	Determining How Long a Switch Is Pressed	144



5.5	Reading a Keypad	149
5.6	Reading Analog Values	152
5.7	Changing the Range of Values	154
5.8	Reading More Than Six Analog Inputs	155
5.9	Displaying Voltages Up to 5V	158
5.10	Responding to Changes in Voltage	161
5.11	Measuring Voltages More Than 5V (Voltage Dividers)	162
<b>6.</b>	<b>Getting Input from Sensors</b>	<b>165</b>
6.1	Detecting Movement	167
6.2	Detecting Light	170
6.3	Detecting Motion (Integrating Passive Infrared Detectors)	171
6.4	Measuring Distance	173
6.5	Measuring Distance Accurately	176
6.6	Detecting Vibration	180
6.7	Detecting Sound	181
6.8	Measuring Temperature	185
6.9	Reading RFID Tags	187
6.10	Tracking the Movement of a Dial	190
6.11	Tracking the Movement of More Than One Rotary Encoder	193
6.12	Tracking the Movement of a Dial in a Busy Sketch	195
6.13	Using a Mouse	197
6.14	Getting Location from a GPS	201
6.15	Detecting Rotation Using a Gyroscope	206
6.16	Detecting Direction	208
6.17	Getting Input from a Game Control Pad (PlayStation)	211
6.18	Reading Acceleration	213
<b>7.</b>	<b>Visual Output</b>	<b>217</b>
7.1	Connecting and Using LEDs	220
7.2	Adjusting the Brightness of an LED	223
7.3	Driving High-Power LEDs	224
7.4	Adjusting the Color of an LED	226
7.5	Sequencing Multiple LEDs: Creating a Bar Graph	229
7.6	Sequencing Multiple LEDs: Making a Chase Sequence (Knight Rider)	232
7.7	Controlling an LED Matrix Using Multiplexing	234
7.8	Displaying Images on an LED Matrix	236
7.9	Controlling a Matrix of LEDs: Charlieplexing	239
7.10	Driving a 7-Segment LED Display	245
7.11	Driving Multidigit, 7-Segment LED Displays: Multiplexing	248
7.12	Driving Multidigit, 7-Segment LED Displays Using MAX7221 Shift Registers	250

---

7.13	Controlling an Array of LEDs by Using MAX72xx Shift Registers	253
7.14	Increasing the Number of Analog Outputs Using PWM Extender Chips (TLC5940)	255
7.15	Using an Analog Panel Meter As a Display	259
<b>8.</b>	<b>Physical Output</b>	<b>261</b>
8.1	Controlling the Position of a Servo	264
8.2	Controlling One or Two Servos with a Potentiometer or Sensor	266
8.3	Controlling the Speed of Continuous Rotation Servos	267
8.4	Controlling Servos from the Serial Port	269
8.5	Driving a Brushless Motor (Using a Hobby Speed Controller)	271
8.6	Controlling Solenoids and Relays	272
8.7	Making an Object Vibrate	273
8.8	Driving a Brushed Motor Using a Transistor	276
8.9	Controlling the Direction of a Brushed Motor with an H-Bridge	277
8.10	Controlling the Direction and Speed of a Brushed Motor with an H-Bridge	280
8.11	Using Sensors to Control the Direction and Speed of Brushed Motors (L293 H-Bridge)	282
8.12	Driving a Bipolar Stepper Motor	287
8.13	Driving a Bipolar Stepper Motor (Using the EasyDriver Board)	290
8.14	Driving a Unipolar Stepper Motor (ULN2003A)	293
<b>9.</b>	<b>Audio Output</b>	<b>297</b>
9.1	Playing Tones	299
9.2	Playing a Simple Melody	301
9.3	Generating More Than One Simultaneous Tone	303
9.4	Generating Audio Tones and Fading an LED	305
9.5	Playing a WAV File	308
9.6	Controlling MIDI	311
9.7	Making an Audio Synthesizer	314
<b>10.</b>	<b>Remotely Controlling External Devices</b>	<b>317</b>
10.1	Responding to an Infrared Remote Control	318
10.2	Decoding Infrared Remote Control Signals	321
10.3	Imitating Remote Control Signals	324
10.4	Controlling a Digital Camera	327
10.5	Controlling AC Devices by Hacking a Remote Controlled Switch	330
<b>11.</b>	<b>Using Displays</b>	<b>333</b>
11.1	Connecting and Using a Text LCD Display	334

11.2	Formatting Text	337
11.3	Turning the Cursor and Display On or Off	340
11.4	Scrolling Text	342
11.5	Displaying Special Symbols	345
11.6	Creating Custom Characters	347
11.7	Displaying Symbols Larger Than a Single Character	349
11.8	Displaying Pixels Smaller Than a Single Character	352
11.9	Connecting and Using a Graphical LCD Display	355
11.10	Creating Bitmaps for Use with a Graphical Display	359
11.11	Displaying Text on a TV	361
<b>12.</b>	<b>Using Time and Dates</b>	<b>367</b>
12.1	Creating Delays	367
12.2	Using millis to Determine Duration	368
12.3	More Precisely Measuring the Duration of a Pulse	372
12.4	Using Arduino As a Clock	373
12.5	Creating an Alarm to Periodically Call a Function	380
12.6	Using a Real-Time Clock	384
<b>13.</b>	<b>Communicating Using I2C and SPI</b>	<b>389</b>
13.1	Controlling an RGB LED Using the BlinkM Module	392
13.2	Using the Wii Nunchuck Accelerometer	397
13.3	Interfacing to an External Real-Time Clock	401
13.4	Adding External EEPROM Memory	404
13.5	Reading Temperature with a Digital Thermometer	408
13.6	Driving Four 7-Segment LEDs Using Only Two Wires	412
13.7	Integrating an I2C Port Expander	416
13.8	Driving Multidigit, 7-Segment Displays Using SPI	418
13.9	Communicating Between Two or More Arduino Boards	421
<b>14.</b>	<b>Wireless Communication</b>	<b>425</b>
14.1	Sending Messages Using Low-Cost Wireless Modules	425
14.2	Connecting Arduino to a ZigBee or 802.15.4 Network	431
14.3	Sending a Message to a Particular XBee	438
14.4	Sending Sensor Data Between XBees	440
14.5	Activating an Actuator Connected to an XBee	446
<b>15.</b>	<b>Ethernet and Networking</b>	<b>451</b>
15.1	Setting Up the Ethernet Shield	453
15.2	Obtaining Your IP Address Automatically	455
15.3	Resolving Hostnames to IP Addresses (DNS)	458
15.4	Requesting Data from a Web Server	462
15.5	Requesting Data from a Web Server Using XML	466

---

15.6	Setting Up an Arduino to Be a Web Server	469
15.7	Handling Incoming Web Requests	471
15.8	Handling Incoming Requests for Specific Pages	474
15.9	Using HTML to Format Web Server Responses	479
15.10	Serving Web Pages Using Forms (POST)	483
15.11	Serving Web Pages Containing Large Amounts of Data	486
15.12	Sending Twitter Messages	493
15.13	Sending and Receiving Simple Messages (UDP)	496
15.14	Getting the Time from an Internet Time Server	502
15.15	Monitoring Pachube Feeds	507
15.16	Sending Information to Pachube	510
<b>16.</b>	<b>Using, Modifying, and Creating Libraries</b>	<b>515</b>
16.1	Using the Built-in Libraries	515
16.2	Installing Third-Party Libraries	517
16.3	Modifying a Library	518
16.4	Creating Your Own Library	522
16.5	Creating a Library That Uses Other Libraries	527
<b>17.</b>	<b>Advanced Coding and Memory Handling</b>	<b>531</b>
17.1	Understanding the Arduino Build Process	532
17.2	Determining the Amount of Free and Used RAM	535
17.3	Storing and Retrieving Numeric Values in Program Memory	537
17.4	Storing and Retrieving Strings in Program Memory	540
17.5	Using #define and const Instead of Integers	542
17.6	Using Conditional Compilations	543
<b>18.</b>	<b>Using the Controller Chip Hardware</b>	<b>547</b>
18.1	Storing Data in Permanent EEPROM Memory	551
18.2	Using Hardware Interrupts	554
18.3	Setting Timer Duration	557
18.4	Setting Timer Pulse Width and Duration	559
18.5	Creating a Pulse Generator	562
18.6	Changing a Timer's PWM Frequency	565
18.7	Counting Pulses	567
18.8	Measuring Pulses More Accurately	569
18.9	Measuring Analog Values Quickly	571
18.10	Reducing Battery Drain	572
18.11	Setting Digital Pins Quickly	574
<b>A.</b>	<b>Electronic Components</b>	<b>579</b>
<b>B.</b>	<b>Using Schematic Diagrams and Data Sheets</b>	<b>585</b>

---

C. Building and Connecting the Circuit .....	591
D. Tips on Troubleshooting Software Problems .....	595
E. Tips on Troubleshooting Hardware Problems .....	599
F. Digital and Analog Pins .....	603
G. ASCII and Extended Character Sets .....	607
Index .....	611



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# Preface

This book was written by Michael Margolis with Nick Weldin to help you explore the amazing things you can do with Arduino.

Arduino is a family of microcontrollers (tiny computers) and a software creation environment that makes it easy for you to create programs (called *sketches*) that can interact with the physical world. Things you make with Arduino can sense and respond to touch, sound, position, heat, and light. This type of technology, often referred to as *physical computing*, is used in all kinds of things, from the iPhone to automobile electronics systems. Arduino makes it possible for anyone—even people with no programming or electronics experience—to use this rich and complex technology.

## Who This Book Is For

Unlike in most technical cookbooks, experience with software and hardware is not assumed. This book is aimed at a broad range of readers interested in using computer technology to interact with the environment. It is for people who want to quickly find the solution to hardware and software problems.

You may have no programming experience—perhaps you have a great idea for an interactive project but don't have the skills to develop it. This book will help you learn what you need to know to write code that works, using examples that cover the kinds of tasks you want to perform.

If you have some programming experience but are new to Arduino, the book will help you become productive quickly by demonstrating how to implement specific Arduino capabilities for your project.

People already using Arduino should find the content helpful for quickly learning new techniques, which are explained using practical examples. This will help you to embark on more complex projects by showing how to solve problems and use capabilities that may be new to you.

Experienced C/C++ programmers will find examples of how to use the low-level AVR resources (interrupts, timers, I2C, Ethernet, etc.) to build applications using the Arduino environment.

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## How This Book Is Organized

The book contains information that covers the broad range of the Arduino's capabilities, from basic concepts and common tasks to advanced technology. Each technique is explained in a recipe that shows you how to implement a specific capability. You do not need to read the content in sequence.

[Chapter 1, \*Getting Started\*](#), introduces the Arduino environment and provides help on getting the Arduino development environment and hardware installed and working.

The next couple of chapters introduce Arduino software development. [Chapter 2, \*Making the Sketch Do Your Bidding\*](#), covers essential software concepts and tasks, and [Chapter 3, \*Using Mathematical Operators\*](#), shows how to make use of the most common mathematical functions.

[Chapter 4, \*Serial Communications\*](#), describes how to get Arduino to connect and communicate with your computer and other devices. Serial is the most common method for Arduino input and output, and this capability is used in many of the recipes throughout the book.

[Chapter 5, \*Simple Digital and Analog Input\*](#), introduces a range of basic techniques for reading digital and analog signals. [Chapter 6, \*Getting Input from Sensors\*](#), builds on this with recipes that explain how to use devices that enable Arduino to sense touch, sound, position, heat, and light.

[Chapter 7, \*Visual Output\*](#), covers controlling light. Recipes cover switching on one or many LEDs and controlling brightness and color. This chapter explains how you can drive bar graphs and numeric LED displays, as well as create patterns and animations with LED arrays. In addition, the chapter provides a general introduction to digital and analog output for those who are new to this.

[Chapter 8, \*Physical Output\*](#), explains how you can make things move by controlling motors with Arduino. A wide range of motor types are covered: solenoids, servo motors, DC motors, and stepper motors.

[Chapter 9, \*Audio Output\*](#), shows how to generate sound with Arduino through an output device such as a speaker. It covers playing simple tones and melodies and playing WAV files and MIDI.

[Chapter 10, \*Remotely Controlling External Devices\*](#), describes techniques that can be used to interact with almost any device that uses some form of remote controller, including TV, audio equipment, cameras, garage doors, appliances, and toys. It builds on techniques used in previous chapters for connecting Arduino to devices and modules.

[Chapter 11, \*Using Displays\*](#), covers interfacing text and graphical LCD displays. The chapter shows how you can connect these devices to display text, scroll or highlight words, and create special symbols and characters.



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Chapter 12, *Using Time and Dates*, covers built-in Arduino time-related functions and introduces many additional techniques for handling time delays, time measurement, and real-world times and dates.

Chapter 13, *Communicating Using I2C and SPI*, covers the Inter-Integrated Circuit (I2C) and Serial Peripheral Interface (SPI) standards. These standards provide simple ways for digital information to be transferred between sensors and Arduino. This chapter shows how to use I2C and SPI to connect to common devices. It also shows how to connect two or more Arduino boards, using I2C for multiboard applications.

Chapter 14, *Wireless Communication*, covers wireless communication with XBee. This chapter provides examples ranging from simple wireless serial port replacements to mesh networks connecting multiple boards to multiple sensors.

Chapter 15, *Ethernet and Networking*, describes the many ways you can use Arduino with the Internet. It has examples that demonstrate how to build and use web clients and servers and shows how to use the most common Internet communication protocols with Arduino.

Arduino software libraries are a standard way of adding functionality to the Arduino environment. Chapter 16, *Using, Modifying, and Creating Libraries*, explains how to use and modify software libraries. It also provides guidance on how to create your own libraries.

Chapter 17, *Advanced Coding and Memory Handling*, covers advanced programming techniques, and the topics here are more technical than the other recipes in this book because they cover things that are usually concealed by the friendly Arduino wrapper. The techniques in this chapter can be used to make a sketch more efficient—they can help improve performance and reduce the code size of your sketches.

Chapter 18, *Using the Controller Chip Hardware*, shows how to access and use hardware functions that are not fully exposed through the documented Arduino language. It covers low-level usage of the hardware input/output registers, timers, and interrupts.

Appendix A, *Electronic Components*, provides an overview of the components used throughout the book.

Appendix B, *Using Schematic Diagrams and Data Sheets*, explains how to use schematic diagrams and data sheets.

Appendix C, *Building and Connecting the Circuit*, provides a brief introduction to using a breadboard, connecting and using external power supplies and batteries, and using capacitors for decoupling.

Appendix D, *Tips on Troubleshooting Software Problems*, provides tips on fixing compile and runtime problems.

Appendix E, *Tips on Troubleshooting Hardware Problems*, covers problems with electronic circuits.

---

[Appendix F, \*Digital and Analog Pins\*](#), provides tables indicating functionality provided by the pins on standard Arduino boards.

[Appendix G, \*ASCII and Extended Character Sets\*](#), provides tables showing ASCII characters.

## What Was Left Out

There isn't room in this book to cover electronics theory and practice, although guidance is provided for building the circuits used in the recipes. For more detail, readers may want to refer to material that is widely available on the Internet or to books such as the following:

- *Make: Electronics* by Charles Platt (O'Reilly)
- *Getting Started in Electronics* by Forrest Mims (Master Publishing)
- *Physical Computing* by Tom Igoe (Cengage)
- *Practical Electronics for Inventors* by Paul Scherz (McGraw-Hill)

This cookbook explains how to write code to accomplish specific tasks, but it is not an introduction to programming. Relevant programming concepts are briefly explained, but there is insufficient room to cover the details. If you want to learn more about programming, you may want to refer to the Internet or to one of the following books:

- *Practical C Programming* by Steve Oualline (O'Reilly)
- *A Book on C* by Al Kelley and Ira Pohl (Addison-Wesley)

My favorite, although not really a beginner's book, is the book I used to learn C programming:

- *The C Programming Language* by Brian W. Kernighan and Dennis M. Ritchie (Prentice Hall)

## Code Style (About the Code)

The code used throughout this book has been tailored to clearly illustrate the topic covered in each recipe. As a consequence, some common coding shortcuts have been avoided, particularly in the early chapters. Experienced C programmers often use rich but terse expressions that are efficient but can be a little difficult for beginners to read. For example, the early chapters increment variables using explicit expressions that are easy for nonprogrammers to read:

```
result = result + 1; // increment the count
```

Rather than the following, commonly used by experienced programmers, that does the same thing:

```
result++; // increment using the post increment operator
```

---

Feel free to substitute your preferred style. Beginners should be reassured that there is no benefit in performance or code size in using the terse form.

Some programming expressions are so common that they are used in their terse form. For example, the loop expressions are written as follows:

```
for(int i=0; i < 4; i++)
```

This is equivalent to the following:

```
int i;
for(i=0; i < 4; i = i+1)
```

See [Chapter 2](#) for more details on these and other expressions used throughout the book.

Good programming practice involves ensuring that values used are valid (garbage in equals garbage out) by checking them before using them in calculations. However, to keep the code focused on the recipe topic, very little error-checking code has been included.

## Arduino Platform Release Notes

The code has been tested using Arduino releases from version 0018 through version 0020. This book was written before Arduino v1.0 was finalized, and although almost all of the examples should still work, small changes required for running with v1.0 will be published on the site for the book:

<http://www.oreilly.com/catalog/9780596802479/>

There's also a link to errata there. Errata give readers a way to let us know about typos, errors, and other problems with the book. Errata will be visible on the page immediately, and we'll confirm them after checking them out. O'Reilly can also fix errata in future printings of the book and on Safari, making for a better reader experience pretty quickly.

If you have problems making examples work, check the web link to see if the code has been updated. If that doesn't fix the problem, see [Appendix D](#), which covers troubleshooting software problems. The Arduino forum is a good place to post a question if you need more help: <http://www.arduino.cc>.

We hope to keep this book updated for future Arduino versions, and we will also incorporate suggestions and complaints into future editions.

If you like—or don't like—this book, by all means, please let people know. Amazon reviews are one popular way to share your happiness (or lack of happiness), or you can leave reviews at the site for the book.

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## Conventions Used in This Book

The following font conventions are used in this book:

### *Italic*

Indicates pathnames, filenames, and program names; Internet addresses, such as domain names and URLs; and new items where they are defined

### Constant width

Indicates command lines and options that should be typed verbatim; names and keywords in programs, including method names, variable names, and class names; and HTML element tags

### Constant width bold

Indicates emphasis in program code lines

### Constant width *italic*

Indicates text that should be replaced with user-supplied values



This icon signifies a tip, suggestion, or general note.



This icon indicates a warning or caution.

## Using Code Examples

This book is here to help you make things with Arduino. In general, you may use the code in this book in your programs and documentation. You do not need to contact us for permission unless you're reproducing a significant portion of the code. For example, writing a program that uses several chunks of code from this book does not require permission. Selling or distributing a CD-ROM of examples from this book *does* require permission. Answering a question by citing this book and quoting example code does not require permission. Incorporating a significant amount of example code from this book into your product's documentation *does* require permission.

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