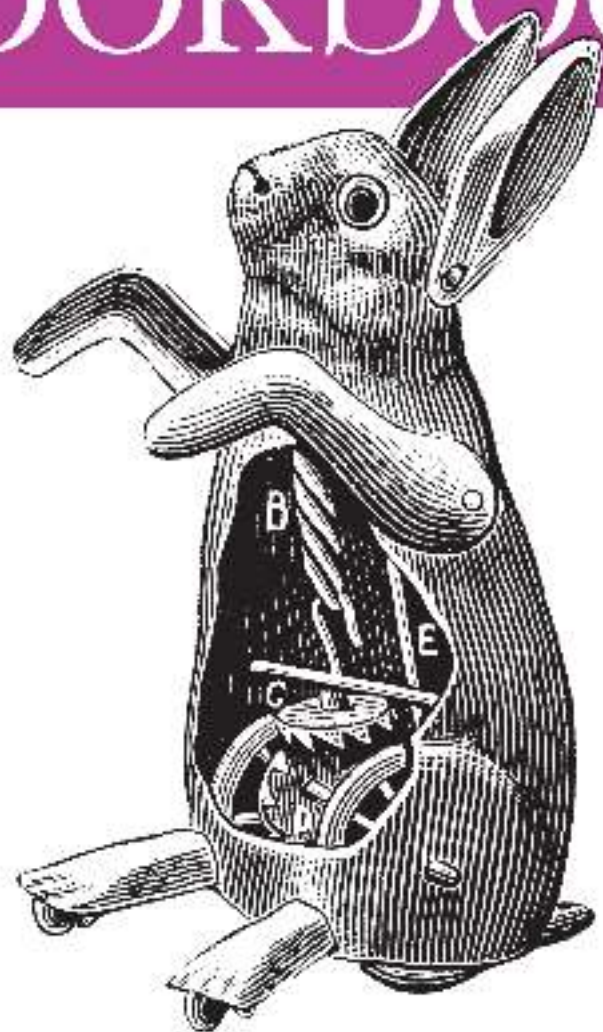


Recipes to Begin, Expand, and Enhance Your Projects

Arduino Cookbook



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Michael Margolis

Arduino Cookbook

Create your own toys, remote controllers, alarms, detectors, robots, and many other projects with the Arduino device. This simple microcontroller board lets artists and designers build a variety of amazing objects and prototypes that interact with the physical world. With this cookbook, you can dive right in and experiment with more than a hundred tips and techniques, no matter what your skill level is.

The recipes in this book provide solutions for most common problems and questions Arduino users have, including everything from programming fundamentals to working with sensors, motors, lights, and sound, and communicating over wired and wireless networks. You'll find the examples and advice you need to begin, expand, and enhance your projects right away.

- Get to know the Arduino development environment
- Understand the core elements of the Arduino programming language
- Use common output devices for light, motion, and sound
- Interact with almost any device that has a remote control
- Learn techniques for handling time delays and time measurement
- Transfer digital information from sensors to the Arduino device
- Create complex projects that incorporate shields and external modules
- Use and modify existing Arduino libraries, and learn how to create your own

Previous programming experience is recommended.

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"Michael Margolis's comprehensive set of recipes is a fine gift to the burgeoning Arduino community. Whatever your background or skill, the Cookbook provides solutions for that project you're wrestling with today and fuel for imagining what you'll build tomorrow. I doubt it will ever leave my workbench table."

—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

Arduino Cookbook

Michael Margolis

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Arduino Cookbook

by Michael Margolis

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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.

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.

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.

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

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