

O'REILLY®

2nd Edition



# Raspberry Pi Cookbook

---

SOFTWARE AND HARDWARE PROBLEMS AND SOLUTIONS

Simon Monk

SECOND EDITION

---

# Raspberry Pi Cookbook

*Dr. Simon Monk*

Beijing • Boston • Farnham • Sebastopol • Tokyo

O'REILLY®

## Raspberry Pi Cookbook

by Simon Monk

Copyright © 2016 Simon Monk. All rights reserved.

Printed in the United States of America.

Published by O'Reilly Media, Inc., 1005 Gravenstein Highway North, Sebastopol, CA 95472.

O'Reilly books may be purchased for educational, business, or sales promotional use. Online editions are also available for most titles (<http://safaribooksonline.com>). For more information, contact our corporate/institutional sales department: 800-998-9938 or [corporate@oreilly.com](mailto:corporate@oreilly.com).

**Editors:** Susan Conant and Jeff Bleiel

**Production Editor:** Kristen Brown

**Copyeditor:** Nan Reinhardt

**Proofreader:** Gillian McGarvey

**Indexer:** Judy McConville

**Interior Designer:** David Futato

**Cover Designer:** Karen Montgomery

**Illustrator:** Rebecca Demarest

August 2014: First Edition

June 2016: Second Edition

### Revision History for the Second Edition

2016-05-17 First Release

See <http://oreilly.com/catalog/errata.csp?isbn=9781491939109> for release details.

The O'Reilly logo is a registered trademark of O'Reilly Media, Inc. *Raspberry Pi Cookbook*, the cover image, and related trade dress are trademarks of O'Reilly Media, Inc.

While the publisher and the author have used good faith efforts to ensure that the information and instructions contained in this work are accurate, the publisher and the author disclaim all responsibility for errors or omissions, including without limitation responsibility for damages resulting from the use of or reliance on this work. Use of the information and instructions contained in this work is at your own risk. If any code samples or other technology this work contains or describes is subject to open source licenses or the intellectual property rights of others, it is your responsibility to ensure that your use thereof complies with such licenses and/or rights.

978-1-491-93910-9

[LSI]

---

# Table of Contents

Preface to the Second Edition .....	xi
<b>1. Setup and Management .....</b>	<b>1</b>
1.0 Introduction	1
1.1 Selecting a Model of Raspberry Pi	1
1.2 Enclosing a Raspberry Pi	3
1.3 Selecting a Power Supply	5
1.4 Selecting an Operating System Distribution	7
1.5 Writing a MicroSD Card with NOOBS	7
1.6 Connecting the System	10
1.7 Connecting a DVI or VGA Monitor	12
1.8 Using a Composite Video Monitor/TV	12
1.9 Adjusting the Picture Size on Your Monitor	13
1.10 Maximizing Performance	15
1.11 Changing Your Password	18
1.12 Setting the Pi to Boot Straight into a Windowing System	19
1.13 Shutting Down Your Raspberry Pi	20
1.14 Installing the Raspberry Pi Camera Module	22
1.15 Using Bluetooth	25
<b>2. Networking .....</b>	<b>27</b>
2.0 Introduction	27
2.1 Connecting to a Wired Network	27
2.2 Finding Your IP Address	29
2.3 Setting a Static IP Address	31
2.4 Setting the Network Name of a Raspberry Pi	33
2.5 Setting Up a Wireless Connection	34
2.6 Connecting with a Console Lead	36

2.7 Controlling the Pi Remotely with SSH	39
2.8 Controlling the Pi Remotely with VNC	41
2.9 Controlling the Pi Remotely with RDP	43
2.10 File Sharing on a Mac Network	44
2.11 Sharing the Pi Screen on a Mac	46
2.12 Using a Raspberry Pi for Network Attached Storage	48
2.13 Network Printing	51
<b>3. Operating System.....</b>	<b>55</b>
3.0 Introduction	55
3.1 Moving Files Around Graphically	55
3.2 Starting a Terminal Session	57
3.3 Navigating the Filesystem Using a Terminal	58
3.4 Copying a File or Folder	62
3.5 Renaming a File or Folder	63
3.6 Editing a File	63
3.7 Viewing the Contents of a File	66
3.8 Creating a File Without Using an Editor	66
3.9 Creating a Directory	67
3.10 Deleting a File or Directory	68
3.11 Performing Tasks with Superuser Privileges	69
3.12 Understanding File Permissions	70
3.13 Changing File Permissions	71
3.14 Changing File Ownership	72
3.15 Making a Screen Capture	73
3.16 Installing Software with apt-get	74
3.17 Removing Software Installed with apt-get	75
3.18 Installing Python Packages with Pip	76
3.19 Fetching Files from the Command Line	77
3.20 Fetching Source Code with Git	78
3.21 Running a Program or Script Automatically on Startup	78
3.22 Running a Program or Script Automatically as a Service	79
3.23 Running a Program or Script Automatically at Regular Intervals	81
3.24 Finding Things	82
3.25 Using the Command-Line History	83
3.26 Monitoring Processor Activity	84
3.27 Working with File Archives	87
3.28 Listing Connected USB Devices	87
3.29 Redirecting Output from the Command Line to a File	88
3.30 Concatenating Files	89
3.31 Using Pipes	89
3.32 Hiding Output to the Terminal	90

3.33 Running Programs in the Background	90
3.34 Creating Command Aliases	91
3.35 Setting the Date and Time	92
3.36 Finding Out How Much Room You Have on the SD Card	93
<b>4. Software.....</b>	<b>95</b>
4.0 Introduction	95
4.1 Making a Media Center	95
4.2 Installing Office Software	97
4.3 Installing other Browsers	98
4.4 Using the Pi Store	100
4.5 Making a Webcam Server	101
4.6 Running a Vintage Game Console Emulator	104
4.7 Running Minecraft Pi Edition	105
4.8 Running a Minecraft Server	107
4.9 Running Open Arena	110
4.10 Raspberry Pi Radio Transmitter	111
4.11 Running GIMP	113
4.12 Internet Radio	114
<b>5. Python Basics.....</b>	<b>117</b>
5.0 Introduction	117
5.1 Deciding Between Python 2 and Python 3	117
5.2 Editing Python Programs with IDLE	118
5.3 Using the Python Console	121
5.4 Running Python Programs from the Terminal	122
5.5 Variables	123
5.6 Displaying Output	123
5.7 Reading User Input	124
5.8 Arithmetic	125
5.9 Creating Strings	125
5.10 Concatenating (Joining) Strings	126
5.11 Converting Numbers to Strings	127
5.12 Converting Strings to Numbers	128
5.13 Finding the Length of a String	129
5.14 Finding the Position of One String Inside Another	129
5.15 Extracting Part of a String	130
5.16 Replacing One String of Characters with Another Inside a String	131
5.17 Converting a String to Upper- or Lowercase	131
5.18 Running Commands Conditionally	132
5.19 Comparing Values	133
5.20 Logical Operators	135

5.21 Repeating Instructions an Exact Number of Times	135
5.22 Repeating Instructions Until Some Condition Changes	136
5.23 Breaking Out of a Loop	137
5.24 Defining a Function in Python	138
<b>6. Python Lists and Dictionaries.....</b>	<b>141</b>
6.0 Introduction	141
6.1 Creating a List	141
6.2 Accessing Elements of a List	142
6.3 Finding the Length of a List	143
6.4 Adding Elements to a List	143
6.5 Removing Elements from a List	144
6.6 Creating a List by Parsing a String	145
6.7 Iterating Over a List	146
6.8 Enumerating a List	146
6.9 Sorting a List	147
6.10 Cutting Up a List	148
6.11 Applying a Function to a List	149
6.12 Creating a Dictionary	150
6.13 Accessing a Dictionary	151
6.14 Removing Things from a Dictionary	152
6.15 Iterating Over Dictionaries	153
<b>7. Advanced Python.....</b>	<b>155</b>
7.0 Introduction	155
7.1 Formatting Numbers	155
7.2 Formatting Dates and Times	156
7.3 Returning More Than One Value	157
7.4 Defining a Class	158
7.5 Defining a Method	159
7.6 Inheritance	160
7.7 Writing to a File	161
7.8 Reading from a File	162
7.9 Pickling	163
7.10 Handling Exceptions	164
7.11 Using Modules	166
7.12 Random Numbers	167
7.13 Making Web Requests from Python	168
7.14 Command-Line Arguments in Python	169
7.15 Running Linux Commands from Python	170
7.16 Sending Email from Python	170
7.17 Writing a Simple Web Server in Python	172

7.18 Doing More Than One Thing at a Time	173
7.19 Doing Nothing in Python	175
7.20 Using Python with Minecraft Pi Edition	176
<b>8. Computer Vision.....</b>	<b>179</b>
8.0 Introduction	179
8.1 Installing SimpleCV	179
8.2 Setting Up a USB Camera for Computer Vision	180
8.3 Using a Raspberry Pi Camera Module for Computer Vision	182
8.4 Counting Coins	183
8.5 Face Detection	188
8.6 Motion Detection	189
8.7 Optical Character Recognition	193
<b>9. Hardware Basics.....</b>	<b>195</b>
9.0 Introduction	195
9.1 Finding Your Way Around the GPIO Connector	195
9.2 Keeping Your Raspberry Pi Safe When Using the GPIO Connector	199
9.3 Setting Up I2C	200
9.4 Using I2C Tools	202
9.5 Setting Up SPI	203
9.6 Installing PySerial for Access to the Serial Port from Python	204
9.7 Installing Minicom to Test the Serial Port	205
9.8 Using a Breadboard with Jumper Leads	206
9.9 Using a Breadboard with a Pi Cobbler	208
9.10 Using a Raspberry Squid	210
9.11 Using a Raspberry Squid Button	212
9.12 Converting 5V Signals to 3.3V with Two Resistors	214
9.13 Converting 5V Signals to 3.3V with a Level Converter Module	215
9.14 Powering a Raspberry Pi with Batteries	216
9.15 Powering a Raspberry Pi with a LiPo Battery	219
9.16 Getting Started with the Sense HAT	220
9.17 Getting Started with the Explorer HAT Pro	222
9.18 Getting Started with a RaspiRobot Board	224
9.19 Using a Pi Plate Prototyping Board	226
9.20 Making a Hardware At Top (HAT)	231
9.21 The Pi Compute Module	234
9.22 The Pi Zero	236
<b>10. Controlling Hardware.....</b>	<b>239</b>
10.0 Introduction	239
10.1 Connecting an LED	239

10.2 Leaving the GPIO Pins in a Safe State	242
10.3 Controlling the Brightness of an LED	243
10.4 Make a Buzzing Sound	245
10.5 Switching a High-Power DC Device Using a Transistor	247
10.6 Switching a High-Power Device Using a Relay	249
10.7 Controlling High-Voltage AC Devices	252
10.8 Making a User Interface to Turn Things On and Off	253
10.9 Making a User Interface to Control PWM Power for LEDs and Motors	255
10.10 Changing the Color of an RGB LED	256
10.11 Using Lots of LEDs (Charlieplexing)	260
10.12 Using an Analog Meter as a Display	263
10.13 Programming with Interrupts	265
<b>11. Motors.....</b>	<b>269</b>
11.0 Introduction	269
11.1 Controlling Servo Motors	269
11.2 Controlling Servo Motors Precisely	273
11.3 Controlling Many Servo Motors	276
11.4 Controlling the Speed of a DC Motor	279
11.5 Controlling the Direction of a DC Motor	281
11.6 Using a Unipolar Stepper Motor	287
11.7 Using a Bipolar Stepper Motor	291
11.8 Using a Stepper Motor HAT to Drive a Bipolar Stepper Motor	293
11.9 Using a RaspiRobot Board to Drive a Bipolar Stepper Motor	295
11.10 Building a Simple Robot Rover	297
<b>12. Digital Inputs.....</b>	<b>303</b>
12.0 Introduction	303
12.1 Connecting a Push Switch	303
12.2 Toggling with a Push Switch	306
12.3 Using a Two-Position Toggle or Slide Switch	308
12.4 Using a Center-Off Toggle or Slide Switch	309
12.5 Debouncing a Button Press	313
12.6 Using an External Pull-up Resistor	315
12.7 Using a Rotary (Quadrature) Encoder	316
12.8 Using a Keypad	320
12.9 Detecting Movement	323
12.10 Adding GPS to the Raspberry Pi	325
12.11 Intercepting Keypresses	329
12.12 Intercepting Mouse Movements	331
12.13 Using a Real-Time Clock Module	332

<b>13. Sensors.....</b>	<b>337</b>
13.0 Introduction	337
13.1 Using Resistive Sensors	337
13.2 Measuring Light	342
13.3 Measuring Temperature with a Thermistor	345
13.4 Detecting Methane	349
13.5 Measuring a Voltage	353
13.6 Reducing Voltages for Measurement	355
13.7 Using Resistive Sensors with an ADC	358
13.8 Measuring Temperature with an ADC	359
13.9 Measuring the Raspberry Pi CPU Temperature	362
13.10 Measuring Temperature, Humidity, and Pressure with a Sense HAT	363
13.11 Measuring Temperature Using a Digital Sensor	365
13.12 Measuring Acceleration with an MCP3008 Module	368
13.13 Using the Inertial Management Unit (IMU) of the Sense HAT	371
13.14 Finding Magnetic North with the Sense HAT	373
13.15 Sensing a Magnet with a Reed Switch	374
13.16 Sensing a Magnet with the Sense HAT	375
13.17 Measuring Distance	376
13.18 Capacitative Touch Sensing	379
13.19 Displaying Sensor Values	382
13.20 Logging to a USB Flash Drive	383
<b>14. Displays.....</b>	<b>387</b>
14.0 Introduction	387
14.1 Using a Four-Digit LED Display	387
14.2 Displaying Messages on an I2C LED Matrix	389
14.3 Using the Sense HAT LED Matrix Display	392
14.4 Displaying Messages on an Alphanumeric LCD HAT	394
14.5 Displaying Messages on an Alphanumeric LCD Module	396
14.6 Using an OLED Graphical Display	400
14.7 Using Addressable RGB LED Strips	403
<b>15. The Internet of Things.....</b>	<b>409</b>
15.0 Introduction	409
15.1 Controlling GPIO Outputs Using a Web Interface	409
15.2 Displaying Sensor Readings on a Web Page	415
15.3 Sending Email and Other Notifications with IFTTT	418
15.4 Sending Tweets Using ThingSpeak	423
15.5 CheerLights	425
15.6 Sending Sensor Data to ThingSpeak	427
15.7 Responding to Tweets Using Dweet and IFTTT	430

<b>16. Arduino and Raspberry Pi.....</b>	<b>435</b>
16.0 Introduction	435
16.1 Programming an Arduino from Raspberry Pi	436
16.2 Communicating with the Arduino by Using the Serial Monitor	439
16.3 Setting Up PyFirmata to Control an Arduino from a Raspberry Pi	441
16.4 Writing Digital Outputs on an Arduino from a Raspberry Pi	443
16.5 Using PyFirmata with TTL Serial	445
16.6 Reading Arduino Digital Inputs Using PyFirmata	448
16.7 Reading Arduino Analog Inputs Using PyFirmata	450
16.8 Analog Outputs (PWM) with PyFirmata	452
16.9 Controlling a Servo Using PyFirmata	454
16.10 Custom Communication with an Arduino over TTL Serial	456
16.11 Custom Communication with an Arduino over I2C	461
16.12 Using Small Arduinos with a Raspberry Pi	465
16.13 Getting Started with an aLaMode Board and a Raspberry Pi	466
16.14 Using an Arduino Shield with an aLaMode Board and a Raspberry Pi	470
<b>A. Parts and Suppliers.....</b>	<b>473</b>
<b>B. Raspberry Pi Pinouts.....</b>	<b>479</b>
<b>Index.....</b>	<b>481</b>

---

# Preface to the Second Edition

Launched in 2011, the Raspberry Pi has found a role both as a very low-cost Linux-based computer and as a platform for embedded computing. It has proven popular with educators and hobbyists alike.

Since the first edition of this book, several million more Raspberry Pis have been sold and a number of new models of Raspberry Pi have been produced. Some models—like the models B+, A+, and Pi 2 model B+—improve the specification of this device, culminating in the Raspberry Pi 2 with quad-core processor and the Raspberry Pi Compute model, which provide the Raspberry Pi as a plugin board that can become part of a larger system.

This edition has been thoroughly updated to encompass the new models of Raspberry Pi, as well as the many changes and improvements to its Raspbian operating system.

This edition contains a new chapter on computer vision and a chapter of recipes on making Internet of Things projects with your Raspberry Pi.

This book is designed in such a way that you can read it linearly as you would a regular book, or access recipes at random. You can search the table of contents or index for the recipe that you want and then jump right to it. If the recipe requires you to know about other things, it will refer you to other recipes, rather like a cookbook might refer you to base sauces before showing you how to cook something fancier.

The world of Raspberry Pi moves quickly. With a large, active community, new interface boards and software libraries are being developed all the time. In addition to examples that use specific interface boards or software, the book also covers basic principles so that you can have a better understanding of how to use new technologies that come along as the Raspberry Pi ecosystem develops.

As you would expect, a large body of code (mostly Python programs) accompanies the book. These programs are all open source and available on GitHub. You'll find a link to them at the [Raspberry Pi Cookbook website](#).

For most of the software-based recipes, all you need is a Raspberry Pi. I recommend a Raspberry Pi 2 or 3. When it comes to recipes that involve making your own hardware to interface with the Raspberry Pi, I have tried to make good use of ready-made modules, as well as solderless breadboard and jumper wires to avoid the need for soldering.

For those wishing to make breadboard-based projects more durable, I suggest using prototyping boards with the same layout as a half-sized breadboard, such as those sold by Adafruit, so that the design can easily be transferred to a soldered solution.

## Conventions Used in This Book

The following typographical conventions are used in this book:

*Italic*

Indicates new terms, URLs, email addresses, filenames, and file extensions.

**Constant width**

Used for program listings, as well as within paragraphs to refer to program elements such as variable or function names, databases, data types, environment variables, statements, and keywords.

**Constant width bold**

Shows commands or other text that should be typed literally by the user.

*Constant width italic*

Shows text that should be replaced with user-supplied values or by values determined by context.



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



This icon indicates a warning or caution.



This icon points you to the related video for that section.

## Using Code Examples

Supplemental material (code examples, exercises, etc.) is available for download at <http://www.raspberrypicookbook.com>.

This book is here to help you get your job done. In general, if example code is offered with this book, you may use it 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 O'Reilly books 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.

We appreciate, but do not require, attribution. An attribution usually includes the title, author, publisher, and ISBN. For example: “*Raspberry Pi Cookbook*, Second Edition, by Simon Monk (O'Reilly). Copyright 2016 Simon Monk, 978-1-491-93910-9.”

If you feel your use of code examples falls outside fair use or the permission given above, feel free to contact us at [permissions@oreilly.com](mailto:permissions@oreilly.com).

## Safari® Books Online



*Safari Books Online* is an on-demand digital library that delivers expert **content** in both book and video form from the world’s leading authors in technology and business.

Technology professionals, software developers, web designers, and business and creative professionals use Safari Books Online as their primary resource for research, problem solving, learning, and certification training.

Safari Books Online offers a range of **plans and pricing** for **enterprise**, **government**, **education**, and individuals.

Members have access to thousands of books, training videos, and prepublication manuscripts in one fully searchable database from publishers like O'Reilly Media, Prentice Hall Professional, Addison-Wesley Professional, Microsoft Press, Sams, Que, Peachpit Press, Focal Press, Cisco Press, John Wiley & Sons, Syngress, Morgan Kaufmann, IBM Redbooks, Packt, Adobe Press, FT Press, Apress, Manning, New Riders, McGraw-Hill, Jones & Bartlett, Course Technology, and hundreds **more**. For more information about Safari Books Online, please visit us **online**.

# How to Contact Us

Please address comments and questions concerning this book to the publisher:

O'Reilly Media, Inc.  
1005 Gravenstein Highway North  
Sebastopol, CA 95472  
800-998-9938 (in the United States or Canada)  
707-829-0515 (international or local)  
707-829-0104 (fax)

We have a web page for this book, where we list errata, examples, and any additional information. You can access this page at [http://bit.ly/rasp-pi-ckbk\\_2e](http://bit.ly/rasp-pi-ckbk_2e).

To comment or ask technical questions about this book, send email to [bookquestions@oreilly.com](mailto:bookquestions@oreilly.com).

For more information about our books, courses, conferences, and news, see our website at <http://www.oreilly.com>.

Find us on Facebook: <http://facebook.com/oreilly>

Follow us on Twitter: <http://twitter.com/oreillymedia>

Watch us on YouTube: <http://www.youtube.com/oreillymedia>

## Acknowledgments

As always, I thank my wife Linda for her patience and support.

I also thank the technical reviewer Duncan Amos for his keen eye, good humor, and excellent suggestions that have without a doubt contributed greatly to this book.

Thanks also to all the O'Reilly team, especially those I met at the Cambridge office, who were very welcoming when I visited, and of course Nan Reinhardt for her diligent copyediting.

# Setup and Management

## 1.0 Introduction

When you buy a Raspberry Pi, you are essentially buying an assembled printed circuit board. It does not even include a power supply or operating system.

The recipes in this chapter are concerned with getting your Raspberry Pi set up and ready for use.

Because the Raspberry Pi just uses standard USB keyboards and mice, most of the setup is pretty straightforward, so you will concentrate only on those tasks that are specific to the Raspberry Pi.

## 1.1 Selecting a Model of Raspberry Pi

### Problem

There are many models of Raspberry Pi and you are not sure which to use.

### Solution

If you want a Raspberry Pi for general use, then you should buy a Raspberry Pi 3 or 2 model B. With four times as much memory and a quad-core processor, it will cope with most tasks much better than the Pi Zero or model A+ with their single processors. The Raspberry Pi 3 model B has the great advantage of having WiFi built in, so there's no need for an extra USB WiFi adapter.

If, on the other hand, you are embedding a Raspberry Pi in a project for a single purpose, then using a model A+ or Pi Zero and saving a few dollars may well be an option.

## Discussion

Figure 1-1 shows the Pi Zero, model A+, and Raspberry Pi 2 B.

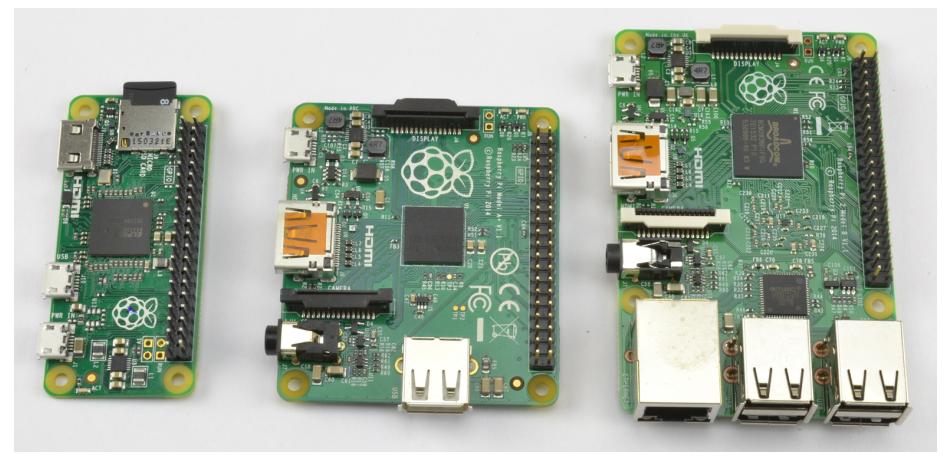


Figure 1-1. Raspberry Pi Zero (left), model A+ (center), and Raspberry Pi 2 model B (right)

As you can see from Figure 1-1, the model A+ is smaller than the Pi 2 and has a single USB socket and no RJ45 Ethernet socket. The Pi Zero is even smaller, saving space by using a mini HDMI socket and micro USB on-the-go socket. If you want to connect a keyboard monitor and mouse to a Pi Zero, you will need adapters for both the USB and HDMI ports before you can connect standard peripherals.

The differences between all the Raspberry Pi models to date are summarized in Table 1-1.

Table 1-1. Raspberry Pi models

Model	RAM	USB sockets	Ethernet port	Notes
3 B	1 GB	4	yes	Includes WiFi
Zero	512 MB	1 (micro)	no	Low cost
2 B	1 GB	4	yes	Quad-core
A+	256 MB	1	no	
B+	512 MB	4	yes	Discontinued
A	256 MB	1	no	Discontinued
B rev2	512 MB	2	yes	Discontinued
B rev1	256 MB	2	yes	Discontinued

If you have one of the older discontinued Raspberry Pi models, it is still useful. They do not have quite the performance of the latest Raspberry Pi 3 model B, but for many situations, that does not matter.

In [Recipe 9.21](#), the Raspberry Pi Compute module will be introduced. This is designed specifically to allow a Raspberry Pi to be built into a product.

## See Also

For more information on the Raspberry Pi models, see [http://en.wikipedia.org/wiki/Raspberry\\_Pi](http://en.wikipedia.org/wiki/Raspberry_Pi).

The low cost of the Pi Zero makes it ideal for embedding in electronics projects without worrying about the cost. See [Recipe 9.22](#).

# 1.2 Enclosing a Raspberry Pi

## Problem

You need an enclosure for your Raspberry Pi.

## Solution

The Raspberry Pi does not come with an enclosure unless you buy one as part of a kit. This makes it a little vulnerable, as there are bare connections on the underside of the circuit board that could easily be short-circuited if the Raspberry Pi is placed on something metal.

It is a good idea to buy some protection for your Raspberry Pi in the form of a case. If you intend to use the Raspberry Pi's GPIO pins, then the PiBow Coupé shown in [Figure 1-2](#) is a beautiful and practical design.

## Discussion

There is a vast array of case styles to choose from, including:

- Simple, two-part, click-together plastic boxes
- VESA mountable boxes (for attaching to the back of a monitor or TV)
- Lego-style boxes
- 3D-printed box designs
- Laser-cut, snap-together acrylic designs



Figure 1-2. A Raspberry Pi 2 in a PiBow Coupé

The case you buy is very much a matter of personal taste. However, some of the things you need to consider are:

- Do you need to have access to the GPIO connector? This is important if you plan to attach external electronics to your Raspberry Pi.
- Is the case well-ventilated? This is important if you plan to overclock your Raspberry Pi ([Recipe 1.10](#)) or run it hard playing videos or games, as these will all generate more heat.

You will also find heatsink kits that have tiny self-adhesive heatsinks to attach to the chips on the Raspberry Pi. These may be of some use if you are demanding a lot of your Raspberry Pi, say by playing a lot of videos, but generally they are the equivalent of “go-faster” stripes on a car.

## See Also

Adafruit has a nice range of [Raspberry Pi enclosures](#).

You will also find many styles of cases at other Raspberry Pi suppliers and on eBay.

# 1.3 Selecting a Power Supply

## Problem

You need to select a power supply for your Raspberry Pi.

## Solution

The basic electrical specification for a power supply suitable for a Raspberry Pi is that it supplies a regulated 5V DC (direct current).

The amount of current that the power supply must be capable of providing depends both on the model of Raspberry Pi and the peripherals attached to it. It is worth getting a power supply that can easily cope with the Raspberry Pi and you should consider 700mA to be a minimum.

If you buy your power supply from the same place that you buy the Raspberry Pi, then the seller should be able to tell you if it will work with the Raspberry Pi.

If you are going to be using a WiFi dongle or other USB peripherals that use significant amounts of power, then I would get a power supply capable of 1.5A or even 2A. Also beware of very low-cost power supplies that may not provide an accurate or reliable 5V.

## Discussion

The power supply and connector are actually the same as those found in many smartphone chargers. If they are terminated in a micro USB plug, then they are almost certainly 5V (but check). The only question, then, is if they can supply enough current.

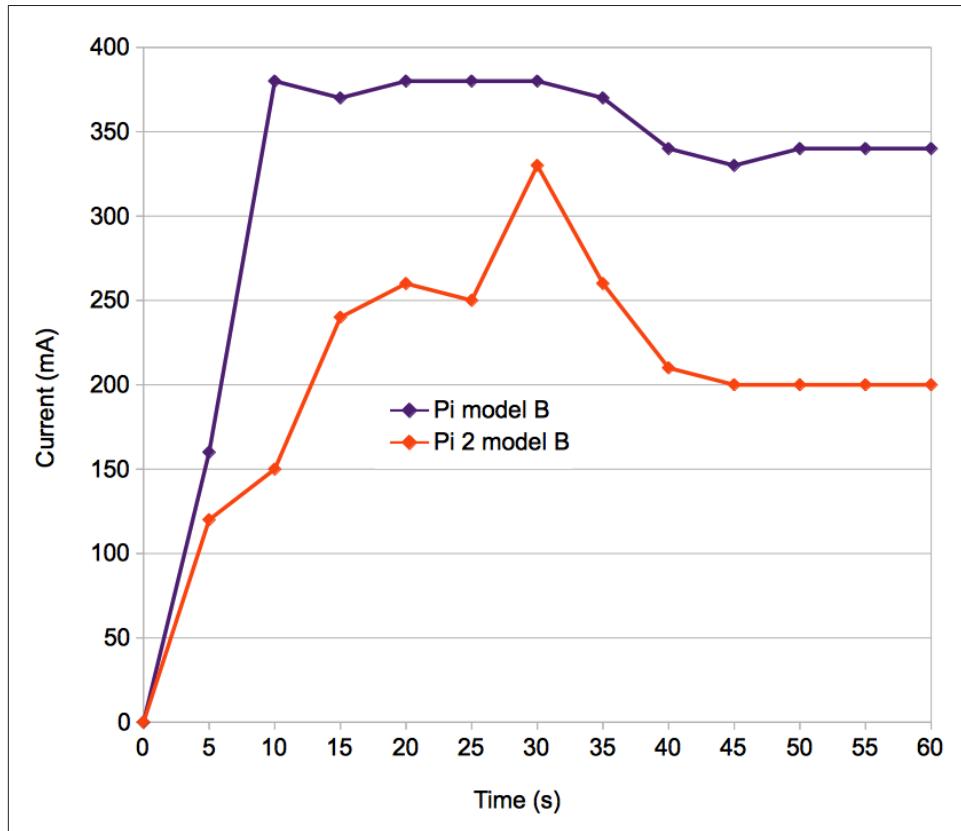
If they can't, then a few bad things can happen:

- They may get hot and be a potential fire risk.
- They may just fail.
- At times of high load (say, when the Pi is using a WiFi dongle), the voltage may dip and the Raspberry Pi may reset itself.

In general, look for a power supply that says it can supply 700mA or more. If it specifies a number of watts (W) rather than mA, divide the number of watts by 5 to get the mA figure. So, a 5V 10W power supply can supply 2A (2000mA).

Using a power supply with, say, a maximum current of 2A will not use any more electricity than a 700mA power supply. The Raspberry Pi will just take as much current as it needs.

In [Figure 1-3](#), I measure the current taken by a Raspberry Pi model B and compare it with a Raspberry Pi 2 model B.



*Figure 1-3. Raspberry Pi current consumption during booting*

The newer Raspberry Pis (the A+, B+, or Raspberry Pi 2) are far more power-efficient than the older models, but when the processor is fully occupied and has a lot of peripherals attached, they can still reach similar current requirements.

In [Figure 1-3](#), you can see that the current rarely gets above 500mA. However, the processor isn't really doing very much here. Were you to start playing HD video, the current would increase considerably. When it comes to power supplies, it's usually better to have something in reserve.

## See Also

You can buy a module that will turn off the power when the Raspberry Pi shuts down at <http://www.pi-supply.com/>.

# 1.4 Selecting an Operating System Distribution

## Problem

There are a number of different Raspberry Pi distributions. You are not sure which one to use.

## Solution

The answer to this question depends on what you intend to do with your Raspberry Pi.

For general use as a computer or for using in electronic projects, you should use Raspbian, the standard and official distribution for the Raspberry Pi.

If you plan to use your Raspberry Pi as a media center, there are a number of distributions specifically for that purpose (see [Recipe 4.1](#)).

In this book, we use the Raspbian distribution almost exclusively, although most of the recipes will work with any Debian-based distribution.

## Discussion

MicroSD cards are not expensive, so get a few and try out a few distributions. If you do this, it is a good idea to keep your own files on a USB flash drive so that you don't have to keep copying them onto each microSD card.

Note that if you are using one of the upcoming recipes to write your own SD card, then you need to have a computer that has an SD card slot (many laptops do), or you can buy an inexpensive USB SD card reader.

## See Also

[The official list of Raspberry Pi distributions](#)

# 1.5 Writing a MicroSD Card with NOOBS

## Problem

You want to write a microSD card using NOOBS (New Out of the Box Software).

## Solution

NOOBS is by far the easiest way to get an operating system onto your Raspberry Pi.

Download the NOOBS archive file from <http://www.raspberrypi.org/downloads>, extract it, and place it on a microSD card. To do this, you will need a computer with an SD card slot or a USB adapter and a SD-to-microSD adapter.

Once you have downloaded the NOOBS archive file, extract it and copy the folder contents onto the SD card. Note that if the archive extracts to a folder called `NOOBS_v1_3_12` or similar, it is the contents of the folder that should be copied to the root of the microSD card, not the folder itself.

Put the microSD card containing the extracted NOOBS files into your Raspberry Pi and then power up your Raspberry Pi. When it boots, the window shown in **Figure 1-4** will appear. From this screen, select Raspbian and then click the Install button.

If you are using NOOBS on an A+, you will see a shorter list of options because only the distributions for that simplified platform will be shown.

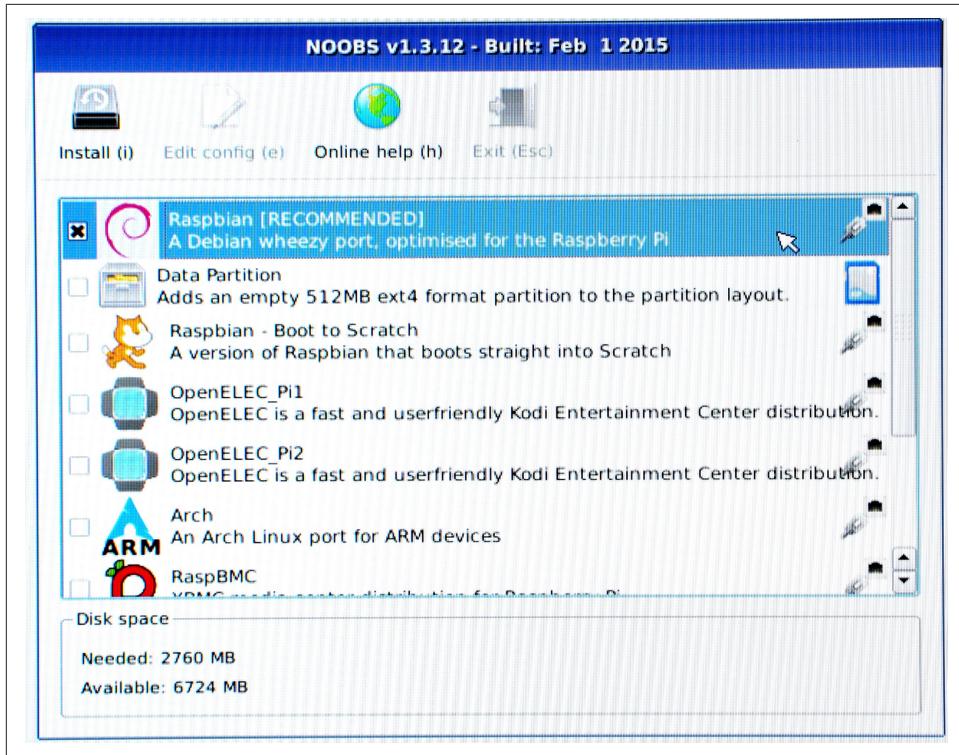


Figure 1-4. NOOBS first screen

You will get a warning message that the SD card will be overwritten (which is fine) and then as the distribution is installed onto the SD card, you will see a progress screen accompanied by helpful information about the distribution (Figure 1-5).



Figure 1-5. NOOBS overwriting the SD card

Once the file copying is complete, you will get the message *Image applied successfully*. When you hit return, the Raspberry Pi will reboot and then *raspi\_config* will automatically run so that you can configure the new installation.

Once you are up and running, the first thing you should do is connect your Raspberry Pi to the Internet (Recipes 2.1 and 2.5), open a command line by using LXTerminal (Recipe 3.2), and enter the following command to update your system to the latest version.

```
$ sudo apt-get update  
$ sudo apt-get upgrade
```

This will take some time.

## Discussion

For NOOBS to install correctly onto a microSD card, the card must be formatted as FAT32. Most SD and microSD cards are supplied already formatted in FAT32. If you are reusing an old card and need to format it as FAT32, then use your operating system's tool for formatting removable media.

The type of microSD card that you get will also affect how fast your Raspberry Pi runs once the operating system is installed. Look for a microSD card described as “class 10.”

## See Also

You can find further information on installing an operating system with NOOBS, including information about the different distributions available at <https://www.raspberrypi.org/help/noobs-setup/>.

# 1.6 Connecting the System

## Problem

You have everything that you need for your Raspberry Pi, and you want to connect it all together.

## Solution

Unless you are embedding your Raspberry Pi in a project or using it as a media center, you need to attach a keyboard, mouse, monitor, and probably a WiFi dongle, unless you have a Raspberry Pi 3.

Figure 1-6 shows a typical Raspberry Pi system.

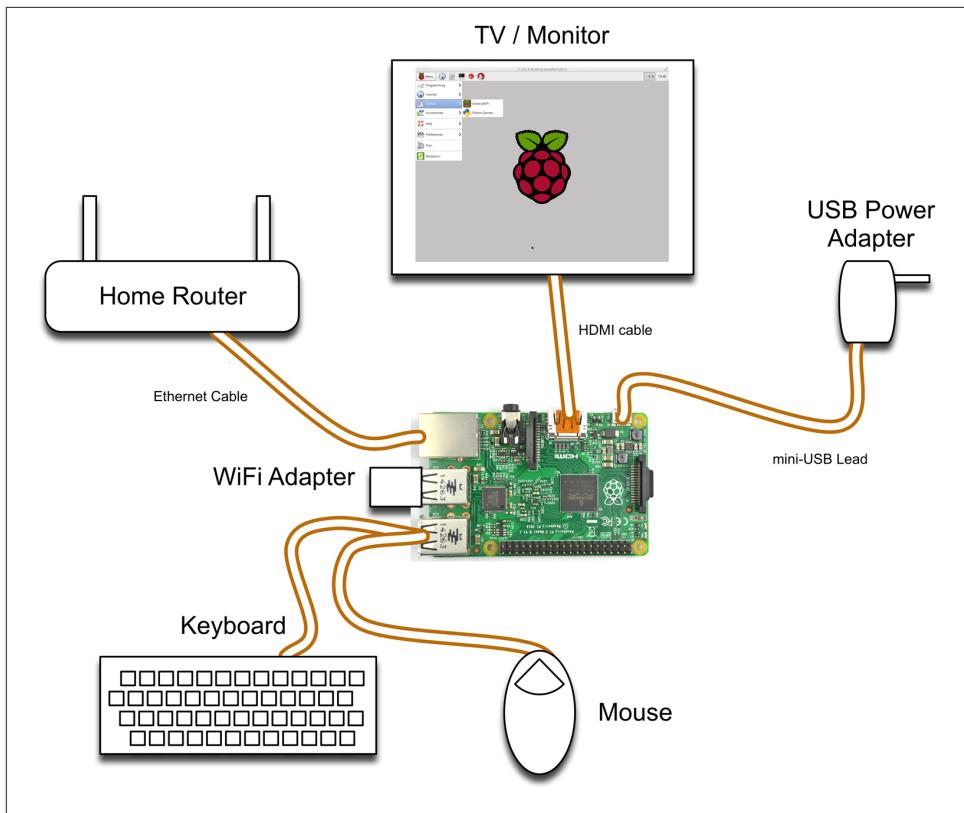


Figure 1-6. A typical Raspberry Pi system

## Discussion

The Raspberry Pi is perfectly happy with pretty much any keyboard or mouse, wired or wireless. The exception to this is Bluetooth wireless keyboards and mice, which will not work with the Raspberry Pi.

If you have an older Raspberry Pi or a model A or A+ and run out of USB sockets, then you will also need a USB hub.

## See Also

[The official Raspberry Pi Quick Start Guide](#)

## 1.7 Connecting a DVI or VGA Monitor

### Problem

Your monitor does not have an HDMI connector but you want to use it with your Raspberry Pi.

### Solution

Many people have been caught out by this problem. Fortunately, it is possible to buy adapters for monitors with a DVI or VGA input but no HDMI connectors.

DVI adapters are the simplest and cheapest. They can be found for less than \$5 if you search for “HDMI male to DVI female converter.”

### Discussion

Using VGA adapters is more complex because they require some electronics to convert the signal from digital to analog, so beware of leads that do not contain these. The official converter is called *Pi-View* and is available wherever the Raspberry Pi is sold. *Pi-View* has the advantage of having been tested and found to work with Raspberry Pi. You may find cheaper alternatives on the Internet, but often these won’t work.

### See Also

eLinux has [tips on what to look for in an converter](#).

## 1.8 Using a Composite Video Monitor/TV

### Problem

The text on your low-resolution composite monitor is illegible. You need to adjust the resolution of the Raspberry Pi for a small screen.

### Solution

The Raspberry Pi has two types of video output: HDMI and composite video from the audio jack, for which you need a special cord. Of these, the HDMI is much better quality. If you’re intending to use a composite video as your main screen, you may want to think again.

If you are using such a screen—say, because you need a really small screen—then you need to make a few adjustments to fit the video output to the screen. You need to

make some changes to the file `/boot/config.txt`. You can edit it on the Raspberry Pi by issuing the following command in a Terminal session:

```
$ sudo nano /boot/config.txt
```

If the text is too small to read and you do not have an HDMI monitor, then you can also edit the file by removing the SD card from the Raspberry Pi and inserting it into your computer. The file will then be in the top-level directory on the SD card, so you can use a text editor on your PC to modify it.

You need to know the resolution of your screen. For a lot of small screens, this will be 320 by 240 pixels. Find the two lines in the file that read:

```
#framebuffer_width=1280  
#framebuffer_height=720
```

Remove the # from the front of each line and change the two numbers to the width and height of your screen. In the following example, these lines have been modified to be 320 by 240:

```
framebuffer_width=320  
framebuffer_height=240
```

Save the file and restart your Raspberry Pi. You should find that everything has become a lot easier to read. You will probably also find that there is a big, thick border around the screen. To adjust this, see [Recipe 1.9](#).

## Discussion

There are many low-cost CCTV monitors that can make a great companion for the Raspberry Pi when you're making something like a retro games console ([Recipe 4.6](#)). However, these monitors are often very low resolution.

## See Also

For another tutorial on using composite monitors, see [this Adafruit tutorial](#).

Also, see [Recipes 1.7](#) and [1.9](#) to adjust your picture when you're using the HDMI video output.

# 1.9 Adjusting the Picture Size on Your Monitor

## Problem

When you first connect a Raspberry Pi to a monitor, you may find that some of the text cannot be read because it extends off the screen, or the picture isn't using all the space available on the screen.

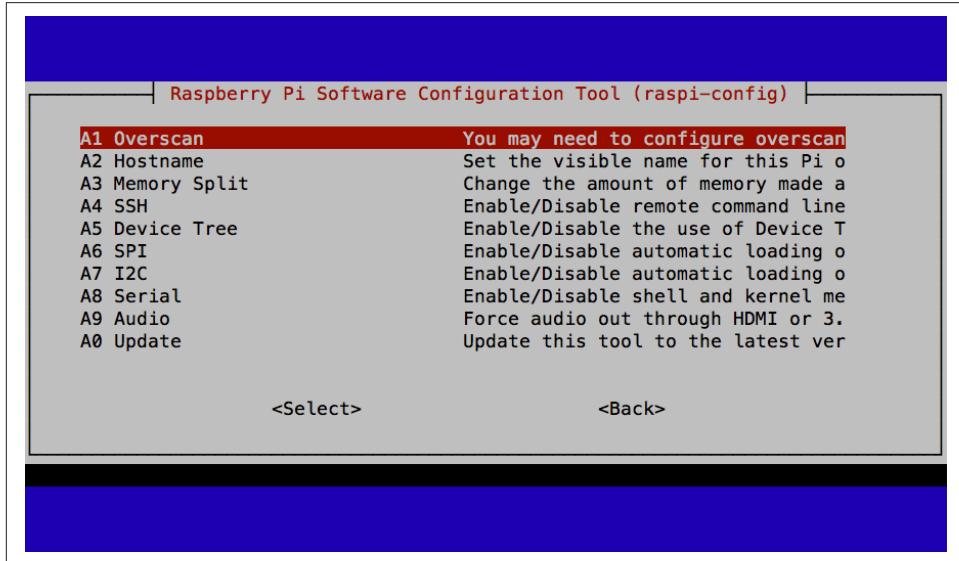
## Solution

If your text extends off the screen, use the `raspi-config` tool to turn overscan off.

To do this, run `raspi-config` by opening a Terminal session and issuing the command:

```
$ sudo raspi-config
```

Then use the cursor keys to scroll down to Advanced Options and then Overscan, and turn overscan off ([Figure 1-7](#)).



*Figure 1-7. Selecting the Overscan option*

If your problem is that there is a large black border around the picture, then you can reduce this (and possibly eliminate it entirely) by editing the file `/boot/config.txt` using the command:

```
$ sudo nano /boot/config.txt
```

Look for the section dealing with overscan. The four lines you need to change are shown in the middle of [Figure 1-8](#).

```
GNU nano 2.2.6          File: /boot/config.txt

# uncomment if you get no picture on HDMI for a default "safe" mode
#hdmi_safe=1

# uncomment this if your display has a black border of unused pixels visible
# and your display can output without overscan
#disable_overscan=1

# uncomment the following to adjust overscan. Use positive numbers if console
# goes off screen, and negative if there is too much border
#overscan_left=16
#overscan_right=16
#overscan_top=16
#overscan_bottom=16

# uncomment to force a console size. By default it will be display's size minus
# overscan.
#framebuffer_width=1280
#framebuffer_height=720

AC Get Help  A0 WriteOut  AR Read File  AY Prev Page  AC Cut Text  AC Cur Pos
AX Exit      AJ Justify   AW Where Is   AN Next Page  AU Uncut Text  AT To Spell
```

Figure 1-8. Adjusting overscan

For the lines to take effect, you first need to uncomment them by removing the # character from the start of each line.

Then, using trial and error, change the settings until the screen fills as much of the monitor as possible. Note that the four numbers should be negative. Try setting them all to -20 to start with. This will increase the area of the screen that is used.

## Discussion

Having to repeatedly restart the Raspberry Pi to see the effects of the changes in resolution is a little tedious. Fortunately, you will only have to do this procedure once. Many monitors and TVs work just fine without any adjustments.

## See Also

You can find much more information about the raspi-config tool at [http://elinux.org/RPi\\_raspi-config](http://elinux.org/RPi_raspi-config).

## 1.10 Maximizing Performance

### Problem

Your Raspberry Pi seems to be very slow, so you want to overclock it to make it run faster.

## Solution

If you have a Raspberry Pi 2 with its quad-core processor, you are unlikely to find it to be too slow. However, the older single-core Raspberry Pis can be pretty sluggish.

You can increase the clock frequency of a Raspberry Pi to make it run a little faster. This will make it use a bit more power and run a little hotter (see the Discussion next).

The method of overclocking described here is called *dynamic overclocking* because it automatically monitors the temperature of the Raspberry Pi and drops the clock speed back down if things start to get too hot.

To make your Pi overclock, run the `raspi_config` utility by issuing the following command in a Terminal:

```
$ sudo raspi-config
```

Select the Overclock option in the menu, and you are presented with the options in Figure 1-9.

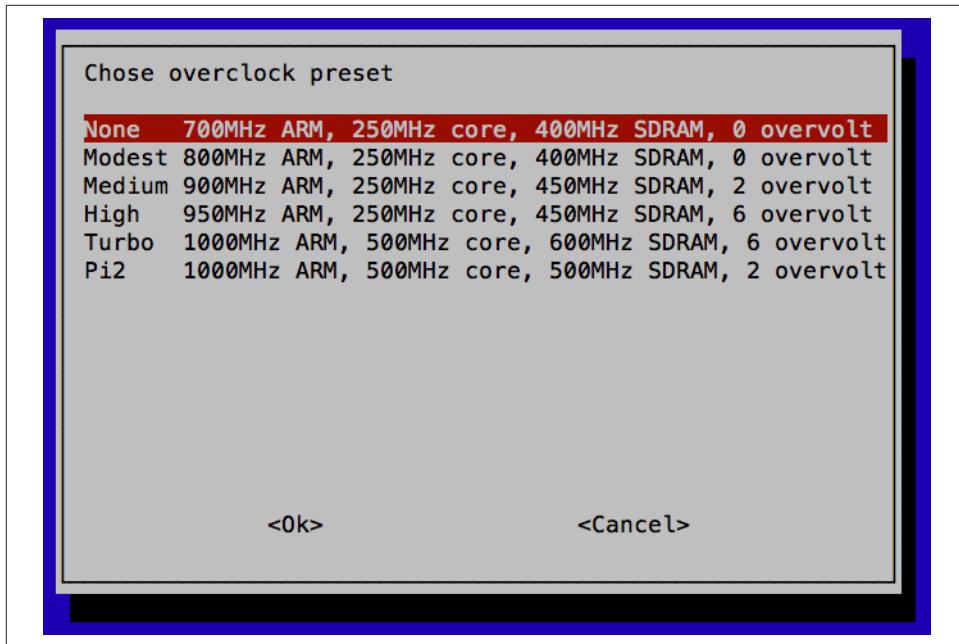


Figure 1-9. Overclocking options

Select an option. If you find that your Raspberry Pi starts to become unstable and hangs unexpectedly, then you may need to choose a more conservative option or turn overclocking off by setting it back to None.

## Discussion

The performance improvements from overclocking can be quite dramatic. To measure these, I used a Raspberry Pi model B, revision 2, without a case at an ambient room temperature of 15 degrees C.

The test program was the following Python script. This just hammers the processor and is not really representative of the other things that go on in a computer, such as writing to the SD card, graphics, and so on. But it does give a good indication of raw CPU performance if you want to test the effect of overclocking on your Raspberry Pi.

```
import time

def factorial(n):
    if n == 0:
        return 1
    else:
        return n * factorial(n-1)

before_time = time.clock()
for i in range(1, 10000):
    factorial(200)
after_time = time.clock()

print(after_time - before_time)
```

Check out the results of the test in [Table 1-2](#).

*Table 1-2. Overclocking*

	Speed test	Current	Temperature (degrees C)
700 MHz	15.8 seconds	360mA	27
1 GHz	10.5 seconds	420mA	30

As you can see, the performance has increased by 33% but at a cost of drawing more current and a slightly higher temperature.

A well-ventilated enclosure will help to keep your Raspberry Pi running at full speed. There have also been some efforts to add water-cooling to the Raspberry Pi. Frankly, this is just silly.

## See Also

You can find much more information about the `raspi-config` tool at [http://elinux.org/RPi\\_raspi-config](http://elinux.org/RPi_raspi-config).

## 1.11 Changing Your Password

### Problem

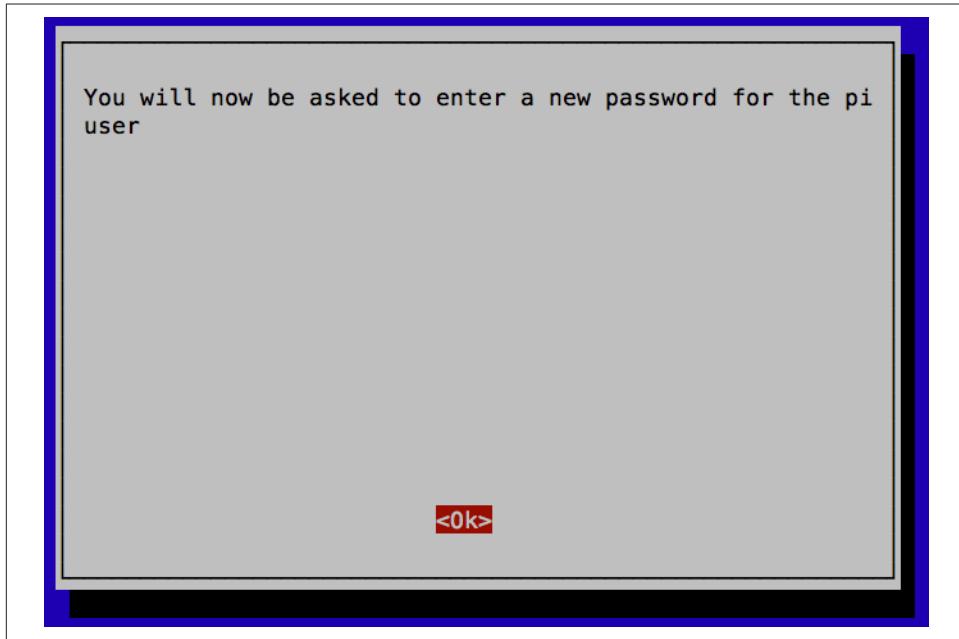
By default, the password for a Raspberry Pi will be *raspberry*. You want to change this.

### Solution

You can use the `raspi-config` tool to change your password. Run the `raspi_config` utility by issuing the following command in a Terminal (see [Recipe 3.2](#)):

```
$ sudo raspi-config
```

Then select the `change_pass` option in the menu and follow the prompts shown in [Figure 1-10](#).



*Figure 1-10. Changing the password*

Changing your password is one occasion where you do not have to restart your Raspberry Pi for the changes to take effect.

## Discussion

You can also change the password from a Terminal session simply by using the `passwd` command as follows:

```
$ passwd  
Changing password for pi.  
(current) UNIX password:  
Enter new UNIX password:  
Retype new UNIX password:  
passwd: password updated successfully
```

## See Also

You can find much more information about the `raspi-config` tool at [http://elinux.org/RPi\\_raspi-config](http://elinux.org/RPi_raspi-config).

## 1.12 Setting the Pi to Boot Straight into a Windowing System

### Problem

Every time you reboot your Raspberry Pi, you have to log in and then start the desktop manually. You want to make this automatic.

### Solution

You can use the `raspi-config` tool to change the boot behavior so that the Raspberry Pi automatically logs you in and starts the desktop. Run the `raspi_config` utility by issuing the following command in a Terminal:

```
$ sudo raspi-config
```

Then select the Enable Boot to Desktop/Scratch option and then “Desktop Log in as user *pi*”(Figure 1-11).

After you change the boot option, you are prompted to restart your Raspberry Pi for the changes to take effect.

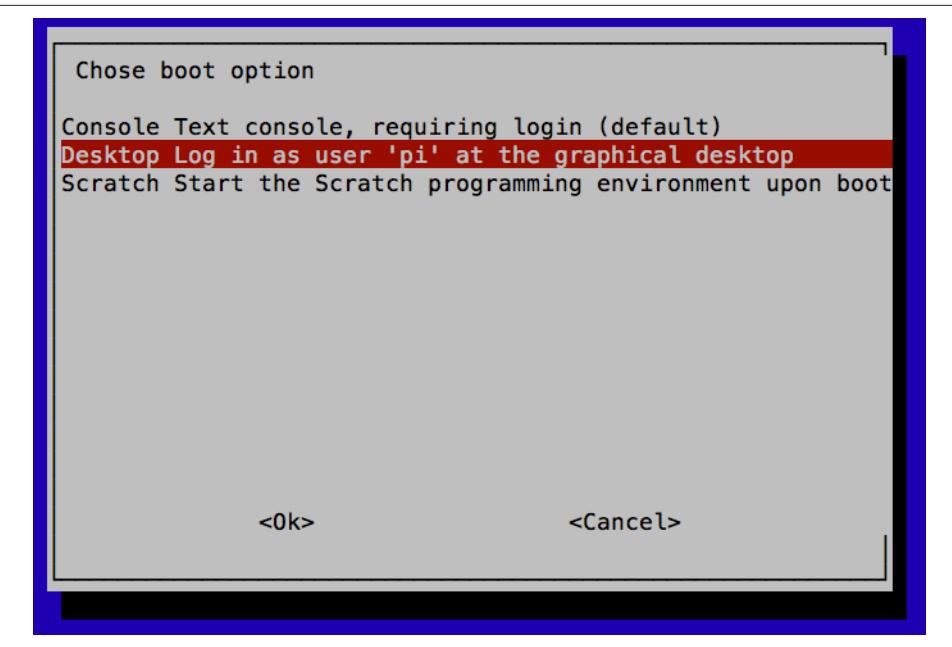


Figure 1-11. Automatic boot into a desktop

## Discussion

Clearly there are security implications in allowing the Raspberry Pi to log you in to the windowing environment automatically. But because the Raspberry Pi will generally be used as a personal computer, rather than being shared, the convenience usually outweighs any such disadvantages.

## See Also

You can find much more information about the `raspi-config` tool at [http://elinux.org/RPi\\_raspi-config](http://elinux.org/RPi_raspi-config).

## 1.13 Shutting Down Your Raspberry Pi

### Problem

You want to shut down your Raspberry Pi.

### Solution

Click on the Raspberry menu in the top-left corner of the desktop. This will display a number of options (Figure 1-12).

### *Shutdown*

Shuts down the Raspberry Pi. You will need to unplug the power and plug it in again to get the Raspberry Pi to boot up again.

### *Reboot*

Reboots the Raspberry Pi.

### *Logout*

Logs you out and displays a prompt to enter your login credentials so that you can log back in.



Figure 1-12. Shutting down your Raspberry Pi

You can also reboot from the command line by issuing the command:

```
sudo reboot
```

You may have to do this after installing some software. When you do reboot, you see the message shown in **Figure 1-13**, which illustrates the multiuser nature of Linux and warns all users connected to the Pi.

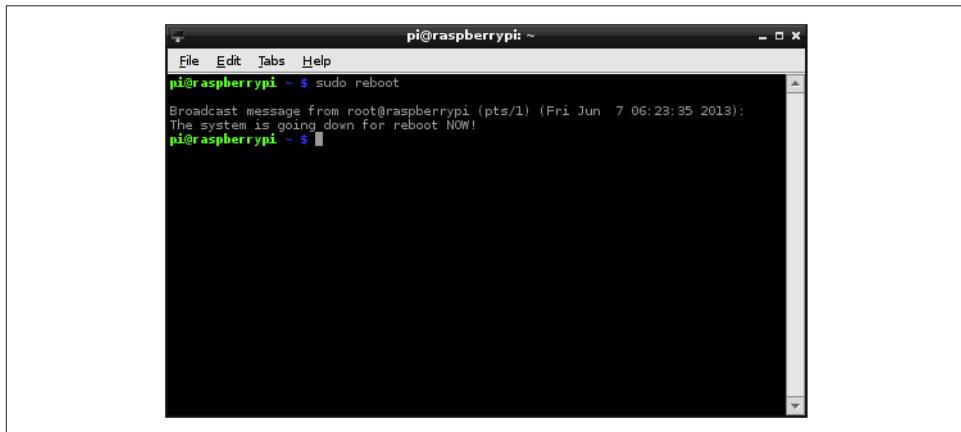


Figure 1-13. Shutting down your Raspberry Pi from the Terminal

## Discussion

It is better to shut your Raspberry Pi down as described above than to simply pull out the power plug, because the Raspberry Pi may be in the middle of writing to the microSD card as you power it down. This could lead to file corruption.

Unlike shutting down most computers, shutting down a Raspberry Pi does not actually turn off the power. It goes into a low-power mode—and it is a pretty low-power device anyway (but the Raspberry Pi hardware has no control over its power supply).

### See Also

You can buy a module that will turn off the power when the Raspberry Pi shuts down at <http://www.pi-supply.com/>.

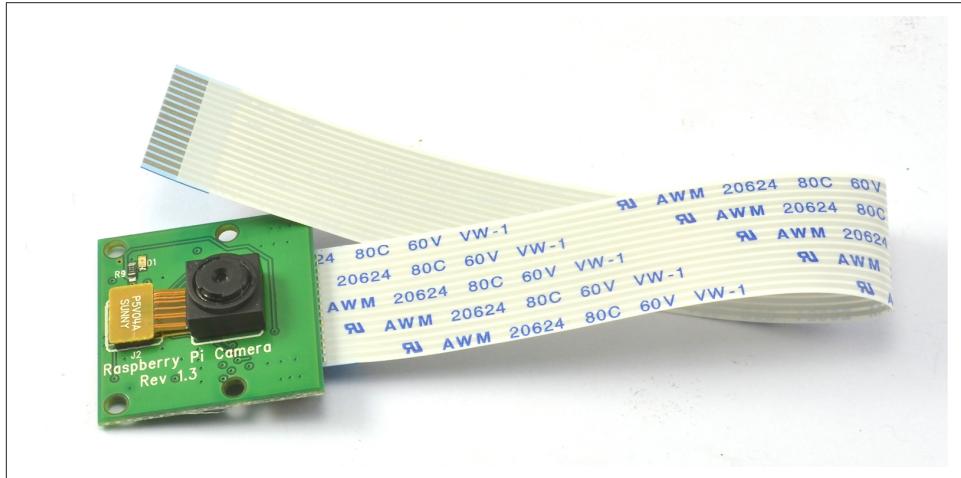
## 1.14 Installing the Raspberry Pi Camera Module

## Problem

You want to use the Raspberry Pi camera module (see Figure 1-14).

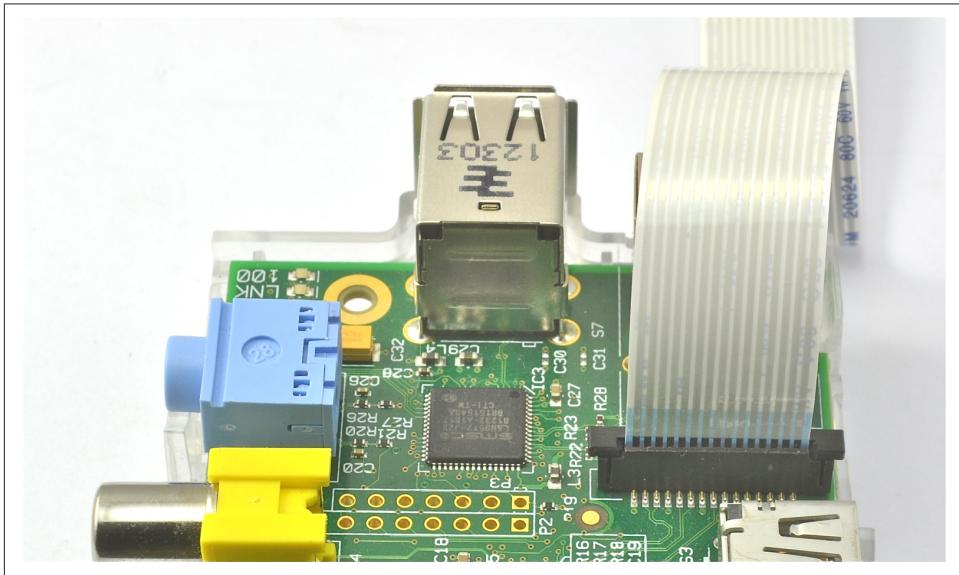
## Solution

The Raspberry Pi camera module ([Figure 1-14](#)) is attached to a Raspberry Pi by a ribbon cable.



*Figure 1-14. The Raspberry Pi camera module*

This cable attaches to a special connector between the audio and HDMI sockets on a Raspberry Pi 2. On an original Raspberry Pi model B, the connector is just behind the Ethernet socket. To fit it, pull up the levers on either side of the connector so that they unlock, and then press the cable into the slot with the connector pads of the cable facing away from the Ethernet socket. Press the two levers of the connector back down to lock the cable in place ([Figure 1-15](#)).



*Figure 1-15. Fitting a Raspberry Pi camera module attached to a Raspberry Pi model B*



The camera module packaging states that it is sensitive to static. Before handling it, ground yourself by touching something grounded like the metal case of a PC.

The camera module requires some software configuration. The easiest way to configure it is to use `raspi_config`. To run `raspi-config`, enter the following command into a Terminal session:

```
$ sudo raspi-config
```

You will see the Enable Camera option ([Figure 1-16](#)).

Two commands are available for capturing still images and videos: `raspistill` and `raspivid`.

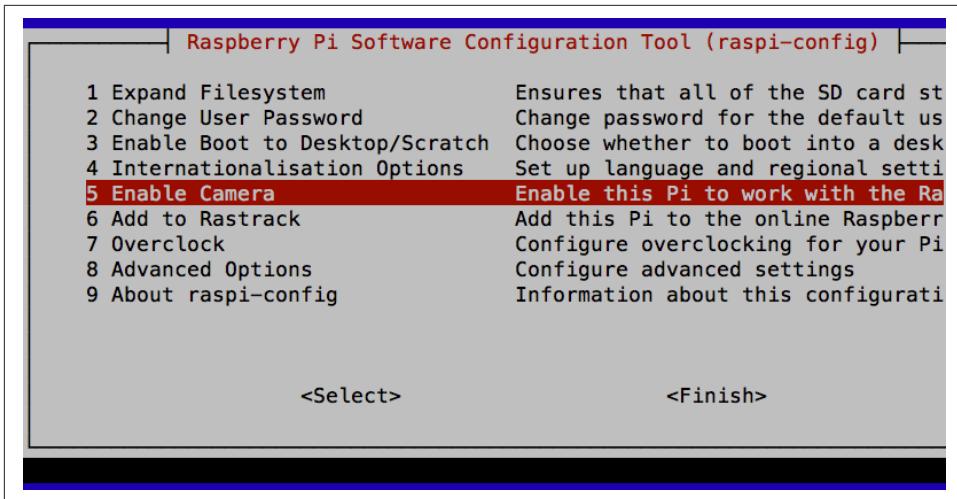


Figure 1-16. The updated raspi-config configuration tool

To capture a single still image, use the `raspistill` command as shown here:

```
$ raspistill -o image1.jpg
```

A preview screen displays for about five seconds and then takes a photograph and stores it in the file *image1.jpg* in the current directory.

To capture video, use the command `raspivid`:

```
$ raspivid -o video.h264 -t 10000
```

The number on the end is the recording duration in milliseconds—in this case, 10 seconds.

## Discussion

Both `raspistill` and `raspivid` have a large number of options. If you type either command without any parameters, help text displays options that are available.

The camera module is capable of high-resolution stills and video recording.

Here are some of the key features of the camera:

- 5-megapixel sensor
- Fixed focus f/2 lens
- Still resolution 1920×1080
- Video 1080p, 30fps

An alternative to the camera module is to use a USB webcam (see [Recipe 8.2](#)).

## See Also

The [RaspiCam documentation](#) includes `raspistill` and `raspivid`.

## 1.15 Using Bluetooth

### Problem

I want to use Bluetooth with my Raspberry Pi.

### Solution

Attach a USB Bluetooth adapter to the Raspberry Pi and install the supporting Bluetooth software.

Not all Bluetooth adapters are compatible with the Raspberry Pi. Most are, but to be sure, buy one that is advertised as working with the Raspberry Pi. [Figure 1-17](#) shows a Raspberry Pi 2 equipped with both a USB Bluetooth adapter (nearest to the camera) and a USB WiFi adapter.



*Figure 1-17. Raspberry Pi 2 with USB Bluetooth and WiFi adapters*

To install the software needed to support Bluetooth, enter the following commands:

```
$ sudo apt-get update  
$ sudo apt-get install bluetooth bluez-utils blueman bluez  
$ sudo usermod -G bluetooth -a pi
```

These commands should work for all Bluetooth adapters supported by the Raspberry Pi.

Plug your Bluetooth adapter in and then reboot your Raspberry Pi ([Recipe 1.13](#)).

You will now find a new entry on the Raspbian Start menu under the Preferences section called Bluetooth Manager. Open this utility and click Search to look for nearby Bluetooth devices ([Figure 1-18](#)). Make sure that there are some Bluetooth devices set to be discoverable.

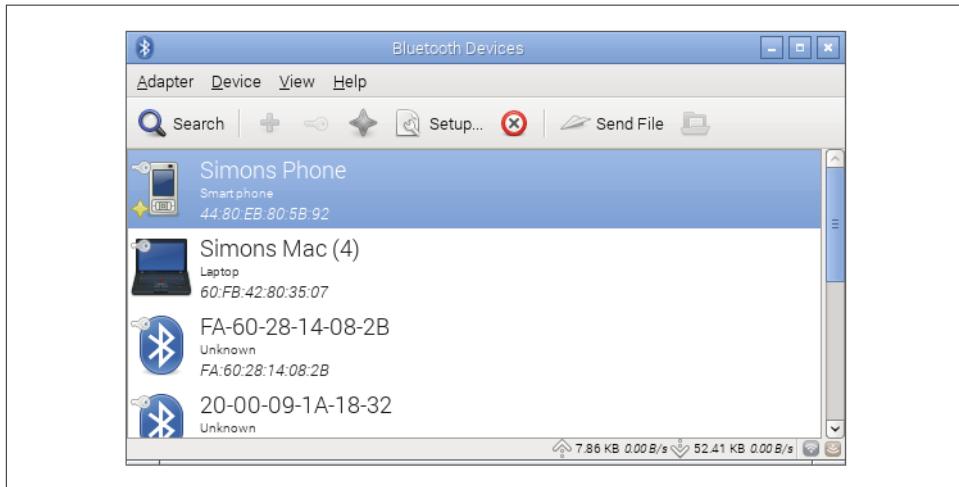


Figure 1-18. The Bluetooth Manager

## Discussion

From the Bluetooth Manager, you can pair with other Bluetooth devices, send them files, and configure the visibility of your Raspberry Pi to other Bluetooth devices.

## See Also

For a list of Bluetooth adapters that are compatible with the Raspberry Pi, see [http://elinux.org/RPi\\_USB\\_Bluetooth\\_adapters](http://elinux.org/RPi_USB_Bluetooth_adapters).