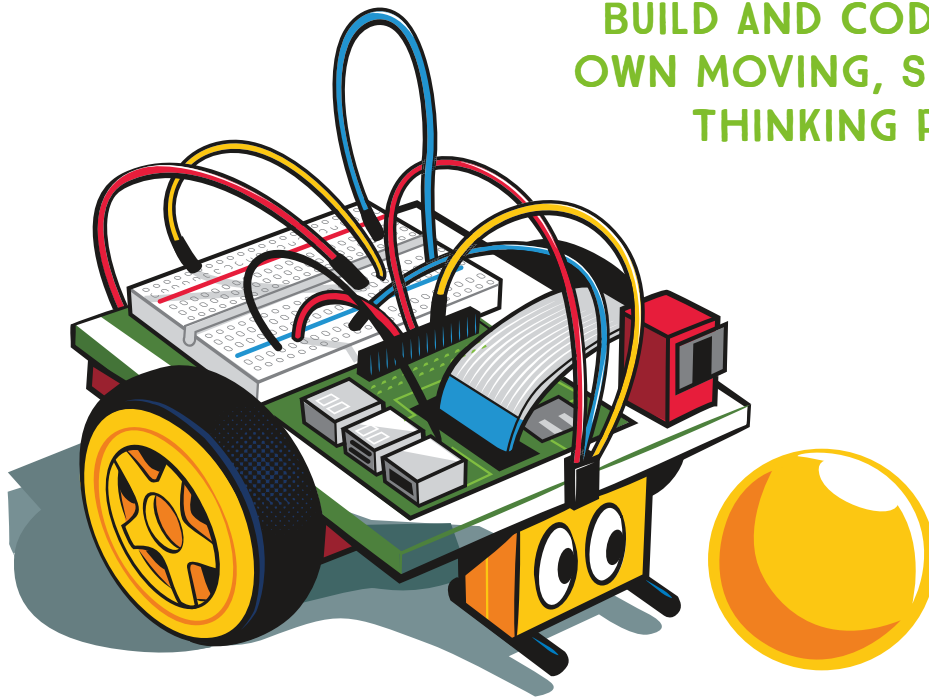


LEARN PYTHON AND ROBOTICS WITH RASPBERRY PI

BUILD AND CODE YOUR
OWN MOVING, SENSING,
THINKING ROBOTS



Adapted from book Learn
Robotics with Raspberry PI
by

MATT TIMMONS-BROWN

"The Raspberry Pi Guy"

Your First Taste of Pi

When you see your Raspberry Pi for the first time, you might find yourself bewildered. You probably associate a normal “computer” with a screen, keyboard, mouse, and storage—but the Raspberry Pi is a little different.

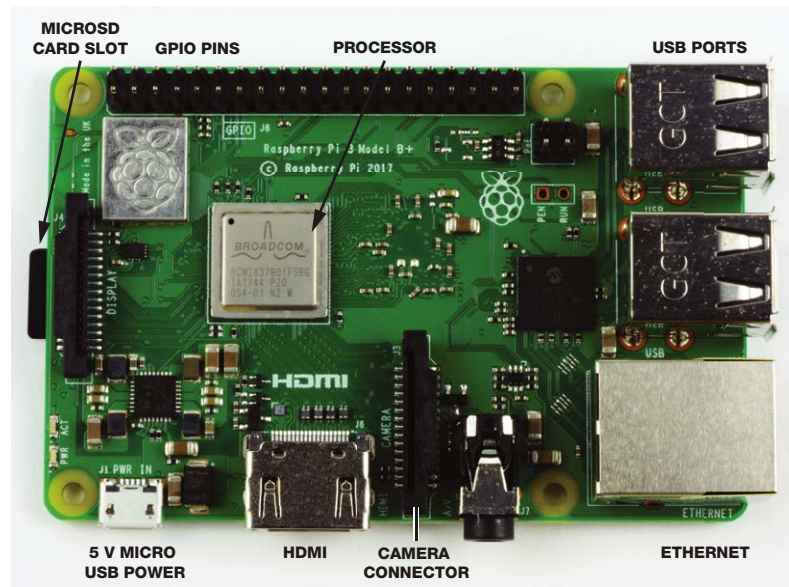
Unbox it, and you’ll find a bare-looking board with all sorts of components sticking out of it. If you have a Pi 3 B+, it should look exactly like Figure 1-3. Later versions might look slightly different, but they all have the same basic features.

NOTE

Raspberry Pi is not the only platform or computer you can build robots with, but it is one of the easiest and most accessible ways of doing so!

FIGURE 1-3

A top view of the
Raspberry Pi 3
Model B+



NOTE

Raspberry Pi is not the only platform or computer you can build robots with, but it is one of the easiest and most accessible ways of doing so!

If you don't have a Raspberry Pi yet, I recommend buying a Raspberry Pi 3 Model B+. There are sometimes new versions of the Pi, but great care is taken to ensure that they are all *backward compatible* (meaning they work with earlier versions), so you'll be able to follow along with this book even if a later version has been released.

You can find a distributor for your country on the Raspberry Pi Foundation website (<https://www.raspberrypi.org/products/>).

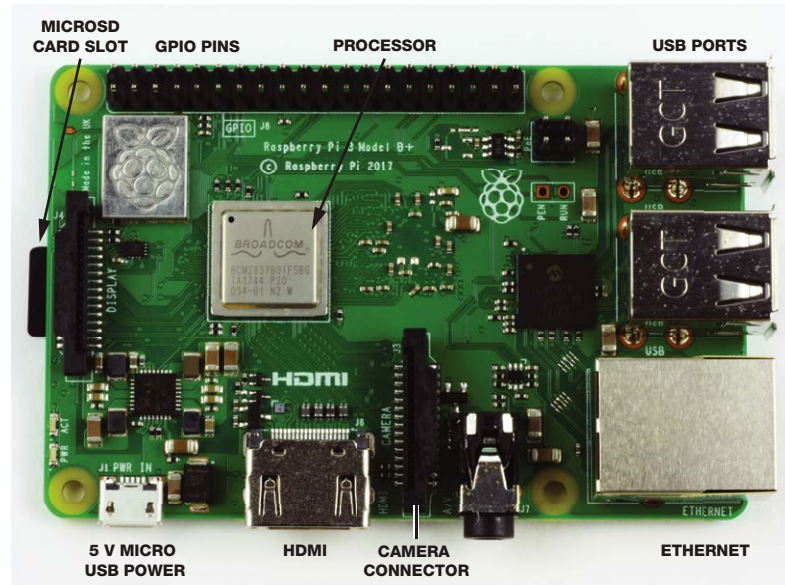
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FIGURE 1-3

A top view of the
Raspberry Pi 3
Model B+



Let's walk through what all these components do:

USB ports There are four USB ports you can use to plug in USB keyboards, mice, USB sticks, and other devices.

Ethernet network port This is for a wired internet connection.

HDMI port *HDMI* stands for *High-Definition Multimedia Interface*, and this port is what you'll use to connect your Pi to a screen like a TV or a computer monitor.

Micro USB power jack This is where you'll plug in the 5 V of power that every Raspberry Pi requires to work; this is the same sort of power input as many mobile phones. It's also worth noting that there is no power button! Your Pi will be on for as long as you keep the power cable connected.

MicroSD card slot While most computers have some form of built-in storage—your laptop often has a hard drive, for example—a Raspberry Pi has no “onboard” storage. Instead, the software your computer runs on, known as the *operating system* (OS), and all of your files are stored on a microSD card, much like you might find in a digital camera. As part of the setup process, I'll show you how to configure a microSD card and install the OS you need for your Pi.

Quad-Core 1.4GHz processor In the middle of your Pi you'll see the brain of your computer. You may be wondering just how powerful your new purchase is: is it as fast as a laptop or a desktop computer? The processor, coupled with the Pi's 1GB of RAM, gives the Raspberry Pi power that's roughly equivalent to some smartphones. As you'll find out later, you can do a *serious* amount of computing with this processor.

Camera connector Next to the HDMI port is a clip-like connector labeled *camera*. It's the input for the official Raspberry Pi Camera Module—something you'll use in this book to give your robot the ability to see!

GPIO pins One of the most alien features of a Raspberry Pi are the 40 shiny metal pins found on the top edge of the board, shown in Figure 1-4. These are called *GPIO pins*, which stands for General-Purpose Input/Output. You can program these pins to control a huge variety of electronics, components, and other parts including LEDs, sensors, and motors (see Figure 1-5).

FIGURE 1-4

The GPIO pins



FIGURE 1-5

A selection of hardware that you can connect to your Raspberry Pi using the GPIO pins



NOTE

The original Raspberry Pi 1 has only 26 GPIO pins. They still do exactly the same thing, but in later Raspberry Pi models, the Foundation was able to squeeze on an extra 14 pins onto the board! If you have the original model, you can still follow the instructions in this book, as the first 26 pins of the newer 40-pin Raspberry Pis are exactly the same and backward compatible.

These GPIO pins are the gateway to a world of *physical computing*. You'll be using them to wire up the electronic elements of your robot (motors, line-following sensors, and more). I'll then guide you through programming this new hardware so that it does your bidding!

What You'll Need

As you've noticed, your new computer is lacking in some fundamental features, like a screen and a keyboard. You'll need some extra hardware to get it set up and running. Fortunately, you'll likely have most of these lying around already.

A 5 V Micro-USB power adapter This is used to power the Raspberry Pi. Any old Android smartphone charger should be fine. Most power adapters will list their output voltage and current, so you just need to ensure the output voltage of the charger is 5 V and the output current is at least 2.5 A. There are a lot of power adapters around that *don't* meet this specification. It is quite common to encounter mysterious faults because of one of these supplies. If you don't have a spare power adapter lying around, grab an official one here: <https://www.raspberrypi.org/products/raspberry-pi-universal-power-supply/>.

A USB keyboard and mouse By default the Raspberry Pi has no form of input, so you'll need both a USB keyboard and mouse in order to interface with it in the beginning. If you have a desktop PC at home, just yank out the existing USB keyboard and mouse and use those. If not, you can pick them up online or at any computer store.

An 8GB+ microSD card As mentioned, the Raspberry Pi has no onboard storage, so you'll need a microSD card (or a normal SD card if you have a first-generation Raspberry Pi) to store the OS. These can also be picked up online or in a computer store. You'll need at least an 8GB card—the more space, the better!

An HDMI cable This will be used to connect your Raspberry Pi to an HDMI TV or monitor. This is a standard cable that you can pick up online or in your local store.

A monitor or TV You will need some sort of display output for your Raspberry Pi. Anything with an HDMI port will do, whether it's a computer monitor, TV, or another type of screen. Many computer monitors have a DVI input, and you can pick up an HDMI-to-DVI adapter or even cable.

It would also be incredibly helpful if you have access to a desktop computer or laptop. This isn't a *necessity*, but it will be an advantage in a variety of ways. First, you'll need to prepare an SD card with the software your Raspberry Pi will run on, which needs to be done on another machine. Second, you'll be wirelessly connecting to your Pi and controlling it over your local area network. This saves you from having to keep plugging and unplugging your Pi to your monitor, and you'll need a separate computer for that too. By using your Pi over your local area network, you'll only need a monitor or TV

for the initial setup process in this chapter. This shouldn't take more than half an hour!

If you aren't able to access another computer, don't fret. You can work around this and still follow along just fine.

In later chapters of this book we'll be using more hardware, components, and electronics, but you don't have to worry about that just yet. I'll be sure to tell you everything you need before we launch into each project.

SETTING UP YOUR RASPBERRY PI

Now that you've gathered all the tech, it's time to set up your Raspberry Pi. This can seem like a daunting task for a beginner, but I'll walk you through it. All you have to do is set up your microSD card, hook up your hardware, and then boot up your Pi and configure a few settings.

If you don't have access to another computer to follow these next steps, you can purchase microSD cards that are preloaded with the OS already set up. You can find these online by searching for "preinstalled NOOBS Raspberry Pi microSD cards."

If you do have another computer available, though, I would recommend installing the OS yourself, as it's a handy skill to know. That way, if anything goes wrong and you need to start afresh, you'll know what to do. Preinstalled microSD cards are also expensive!

Installing Your Pi's Operating System on Windows/macOS

The operating system is the software that every modern computer runs on, and while different operating systems can look quite similar, they're not all the same. You'll likely be most familiar with Windows or macOS, but your Raspberry Pi runs Linux operating systems.

Linux is a family of free and open source operating systems with different *distributions*, meaning that there are different variations of Linux for different purposes. For Raspberry Pi, most people use the *Raspbian* distribution, the operating system officially supported by the Raspberry Pi Foundation (see Figure 1-6). Raspbian was developed and refined to run smooth as butter on your Pi, and you'll find it has many features in common with the OS you normally use.

WHAT DOES OPEN SOURCE MEAN?

When we say software is *open source*, we mean that the source code—the code that the software is built from—is available for anyone to look at, change, and distribute. This means that programmers around the world can contribute to the open source project and work for the collective good of the end user. It also means Raspbian is free to download and use. Some operating systems, like Windows, are *proprietary* and require you to purchase a license key before you can use them on your computer.

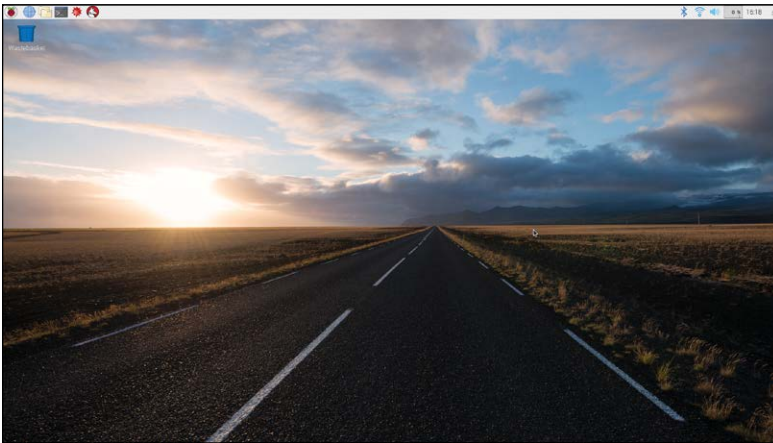


FIGURE 1-6

The Raspbian desktop environment

Preparing Your SD Card

Before you can install Raspbian on your microSD card, you first have to clear out anything that might already be stored on it. Even if your card is brand new, I recommend doing this, because it can sometimes come with stuff already on it. This process is called *formatting* your microSD card. Be sure to read the warning in the sidebar before you format your microSD card!

1. Insert your microSD card into your normal computer. Some computers have SD card or microSD card ports, but many don't. If your computer doesn't have a place you can plug in your SD card, you'll need to use a *USB SD card adapter*, like the one shown in Figure 1-7. This small device lets you plug your card into one of the USB slots on your PC. You can find this easily and cheaply online (just search "SD card USB adapter") or in your local computer store.

WARNING

During the formatting process, the storage device you have selected will be entirely and irreversibly erased. Make sure you double-check that you have selected the right drive name so you don't accidentally delete everything from another device and lose your data.

You may have noticed the 3 in the command `python3 helloworld.py`. This is telling your Pi to execute the file using Python 3, rather than Python 2. Python 3 is the newest version of Python, and while version 2 is still used a lot, using Python 3 is the preferred option. There's not a lot of difference, but there are some syntax and feature differences between them. All of the projects in this book will use Python 3.

SUMMARY

We've covered a lot in this chapter! You've gotten to know your new Raspberry Pi, set it up, and had your first taste of both the terminal and Python programming. You're now able to access and use your Pi remotely and understand how to do things like change preferences and set up an SD card.

In the next chapter I'll cover the basics of electronics and electricity, and you'll start doing some simple building in the form of mini-projects, like flashing LEDs, and more. This will give you the foundation of knowledge that you'll need before we move on to making robots!

2

ELECTRONICS BASICS

ELECTRONICS IS THE SCIENCE OF CONTROLLING AND MANIPULATING ELECTRICAL ENERGY TO DO SOMETHING USEFUL. IT'S ABOUT MAKING ELECTRONIC COMPONENTS LIKE LIGHTS, SENSORS, AND MOTORS DO EXACTLY WHAT YOU WANT THEM TO DO.

Many innovations stem from the different fields of electronics. Most interesting for us is the branch of *robotics*. To make your own robots, you'll need to understand the basics of electronics and bend this knowledge to your will! In this chapter, I'll give you your first taste of electronics in the form of two projects. You'll program an LED (light-emitting diode) to blink at regular intervals, and then wire up a button to print a message to your terminal when it's pressed. You'll be blinking LEDs and controlling the physical world in no time at all!

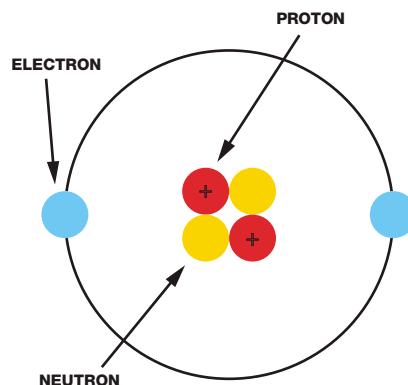
WHAT IS ELECTRICITY?

Electricity is everywhere in our day-to-day lives: electric currents are used to power electrical components and appliances, like the lights in your house, your TV screen, your toaster, and the motors of a Raspberry Pi robot. But what actually *is* electricity?

Electricity starts with *atoms*. Everything in the world is made out of billions of tiny atoms—even you! And as you may have learned in science class, atoms themselves are composed of three particles: *protons*, *neutrons*, and *electrons*. The protons and neutrons sit together in the center of the atom to form the atom's *nucleus*, and the electrons orbit that nucleus, as shown in Figure 2-1.

FIGURE 2-1

A diagram of an atom



Protons and electrons each have *electric charge*, which is a fundamental property of matter. Protons are positively charged, and electrons are negatively charged. Neutrons have no charge; that is, they are neutral. You may have heard the saying “opposites attract,” and that applies here. Because protons and electrons have opposite charges, they are attracted to each other and stay together, forming the atoms that make up everything around you.

Atoms come in many different arrangements called *elements*. Each element is defined by the number of protons, electrons, and

neutrons each atom contains. For example, the element copper usually has 29 protons and 35 neutrons, while gold has 79 protons and 118 neutrons. All metals, like copper, gold, and iron, are made out of collections of atoms all pressed up against each other. Some of these materials are *conductive*, which means that, when given energy, the electrons from one atom can move to the next atom. This causes a *flow of charge* in the material, known as an electric *current*. The number of electrons flowing through a point in a material at any given second is the size of the electric current, which is measured in *amperes (A)*.

For an electric current to flow, there must be a complete *circuit*. A circuit is a closed path, like a loop, around which an electric current moves. The circuit must be made of conductive material for the electricity to move through, and any gap in the circuit means the electricity cannot flow.

The circuit needs a source of energy to “push” the electric current around. This can be a battery, a solar panel, electrical mains, or any number of things. Crucially, these sources provide a *potential difference*, known as a *voltage*. A voltage simply pushes electrons through a conductor, such as copper wire, and the strength of a voltage is measured in *volts (V)*.

Power sources have a positive and negative terminal. In a simple circuit, like the one shown in Figure 2-2, the terminals of a battery could be connected by a thick copper wire. Electrons are negatively charged and are therefore attracted to the positive terminal of the battery, so they travel through the circuit from the negative end to the positive end, pushed along by the voltage.

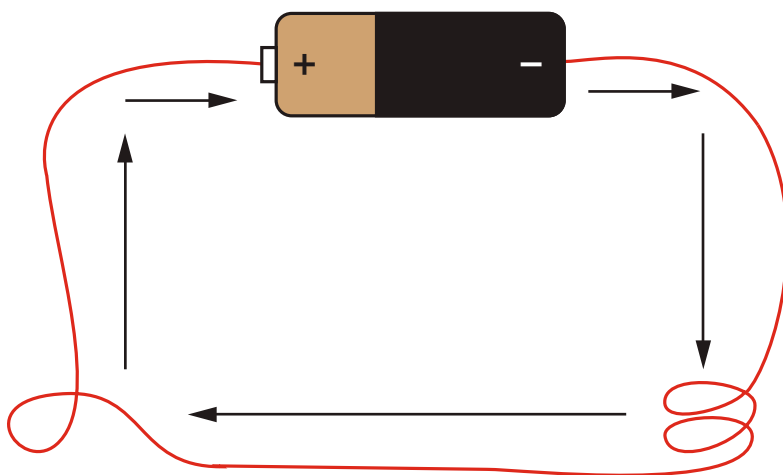


FIGURE 2-2

A circuit showing the flow of charge around a thick wire connected to the positive and negative terminals of a battery

Although the electrons flow from *negative to positive*, it is convention to think of the current flowing from *positive to negative*. The battery in this circuit has a fixed voltage. If this voltage is increased, more electrons would be pushed around the circuit and the current would be larger. Conversely, if this voltage is decreased, fewer electrons would be pushed around the circuit and the current would be smaller.

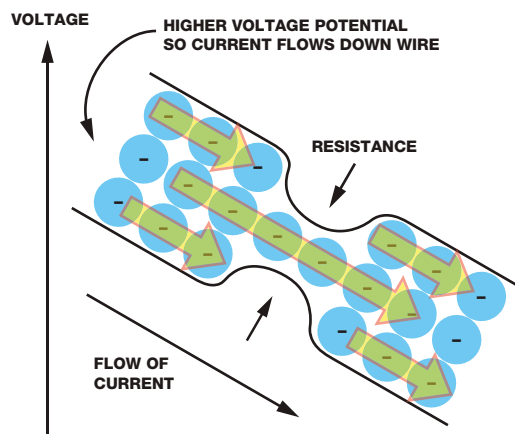
Resistance

Now that you have an understanding of circuits, we need to add another ingredient into the mix: *resistance*. Resistance simply reduces current. Outside the laboratory every material has some amount of resistance, which is measured in *ohms* (Ω). One way to think about resistance is to imagine a water pipe. The water flowing through the pipe is like electric current flowing through a copper wire. Imagine the water pipe has one end higher than the other. The water at the higher end of the pipe has more energy (potential energy) than water at the lower end. If the pipe is level, no water will flow. If the pipe is slightly sloping, a small flow will occur. The actual amount that flows depends on both the difference in height of the ends above ground and how wide the pipe is. The height difference of the pipe is like potential difference, or voltage.

Resistance, on the other hand, is like something squeezing the pipe and affecting how wide it is: the more it is squeezed, the less water is able to flow through it (see Figure 2-3). This translates to less electric current flowing through the circuit.

FIGURE 2-3

Resistance reduces the amount of current that can flow through a circuit.



Therefore, three ingredients make up an electric circuit: voltage, current, and resistance. They all seem to be pretty closely connected, right? You may even think that there must be a certain *mathematical* connection or *law* relating to them—and you’d be right.

Ohm’s Law of Electricity

Ohm’s law deals with the relationship between voltage, current, and resistance. It states that the *voltage across a conductor is proportional to the current running through it*.

Let’s break this down to see what it means. In a circuit, voltage is simply equal to current multiplied by resistance. We use V to stand for voltage, I for current, and R for resistance. So, the equation for voltage is written as follows:

$$V = I \times R$$

As with any mathematical equation, you can rearrange it to work out the equations for the other terms. For example, from Ohm’s law we know that the current in a circuit is equal to the voltage divided by the resistance. When you rearrange the equation for current and resistance, you get the following equations:

$$I = \frac{V}{R}$$

$$R = \frac{V}{I}$$

If all of this is a little confusing, don’t worry! As you make your own circuits, it will become easier to understand. Now that we have covered some of the basics of electricity and electronics, let’s get making!

MAKING AN LED BLINK: RASPBERRY PI GPIO OUTPUT

Just as “Hello, world!” is a traditional first program, making an LED blink is a traditional first electronics project since it very neatly demonstrates using the GPIO pins as outputs. This project will be your introduction to using your Pi’s GPIO pins. Before we begin, you might have some questions.

First, what is an LED? Short for *light-emitting diode*, an LED is a component that gives off light when an electric current is passed through it. LEDs are the modern equivalent of an old light bulb, but they use less power, don’t get hot, and have a longer life.

NOTE

For guidance about where to buy and source these parts, check the Introduction.

The Parts List

For your first foray into electronics, you're going to need a few extra things besides the Raspberry Pi you set up previously. Here's what you'll need for this project:

- A breadboard
- An LED (color of your choice)
- An appropriate resistor
- Jumper wires

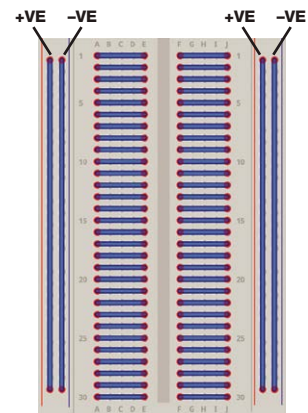
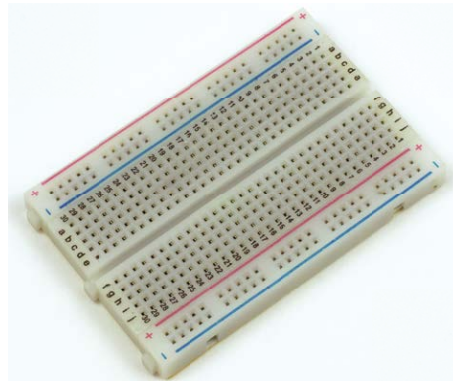
Before we wire these components up, I'll explain a little more about how they work and why you need them.

Breadboard

An electronics *breadboard* allows you to connect electronic components without having to fuse them together permanently (something that is called *soldering*; see “How to Solder” on page 204). This means you can quickly prototype circuits by inserting components into a breadboard's holes. The space between the holes of a breadboard is standardized (2.54 mm/0.1 inches), so all breadboard-friendly components should fit with no trouble. Breadboards come in several sizes with different numbers of holes (also known as *points*). I would recommend a 400-point breadboard, like the one in Figure 2-4.

FIGURE 2-4

A 400-point breadboard and a diagram of how the rows and columns are connected to each other



You can see in Figure 2-4 how the rows and columns of the breadboard are internally connected with metal strips. So, if you put one component into a row and put something else into the same row, for example, they will be connected in a circuit.

LEDs

LEDs come in all different shapes, sizes, and colors. Fortunately, they are also incredibly cheap. When bought in bulk they are quite literally *pennies* each. Make sure that your LED has two legs that can be arranged to fit in your breadboard, as shown in Figure 2-5.



Feel free to buy an LED in any color you wish—I have gone for blue. Make sure to check the voltage specification for the LED you buy. You need to make sure that the voltage required to light up the LED is less than 3.3 V. This is often referred to as the *forward voltage*. You can usually find this information in the online listing for your LED. The forward voltage of my LED is 2.5 V. The Raspberry Pi's GPIO pins work at 3.3 V, so if your LED has a forward voltage of 5 V, for example, your Pi won't be able to light it up!

You also need to find out the forward current of your LED. The *forward current* is the recommended current to run through your component. My LED has a recommended forward current of 30 mA (*milliamps* are one thousandth of an amp), which is the equivalent of 0.03 A. If you provide less current than recommended, your LED won't be very bright; if you provide too much current, it might blow up (you'll hear a small pop when this happens). This information will also most likely be in the LED's internet listing or packaging. If you aren't sure about the specifics of your LED, don't worry—small, cheap ones are usually just fine for our use. If you have no information about your LED, just assume that the forward voltage is around 2 V and the forward current is about 20 mA.

Resistors

To avoid overloading our LEDs, we'll use a *resistor*. Every material has resistance, but resistor components are designed specifically to create pure resistance in circuits.

FIGURE 2-5

A blue LED

LEDs, and most components, are quite sensitive to the amount of current that flows through them. If you were to connect an LED directly to a battery and create a circuit without a resistor, the amount of current that would flow through the LED could be large enough to cause it to overheat. A resistor lowers the current through the LED to prevent this from happening.

Resistors come in different values denoted by colored bands, which you can see in Figure 2-6. Take a look at the resistor guide on page 202 to learn what these bands mean and how to read them.

FIGURE 2-6

A resistor



To find out what resistor you need, you'll have to apply Ohm's law! From the equation you saw earlier, you know that resistance is equal to the voltage divided by the current, or $R = V/I$. In our case, the voltage is the difference between the voltage the Pi supplies, 3.3 V, and the forward voltage of the LED: it is the total source volts *minus* the LED volts. For me, that is $3.3 \text{ V} - 3 \text{ V} = 0.3 \text{ V}$. You should use *your* forward voltage here instead, or 2 V if you don't know it.

The current is the forward current of your LED. For me that is 0.03 A. Make sure that this value is in amps, not milliamps!

I can work out the value of the resistor I need to lower the current to 0.03 A by simply calculating the following equation: $0.3 / 0.03 = 10$. This means that I will need a resistor of approximately 10 Ω . Often you won't be able to find a resistor value for the specific number you've calculated. That's okay: in most cases, you can simply use the nearest valued resistor you can find. For my LED I was lucky and had a resistor that matched the value I needed exactly. I am using the 10 Ω resistor pictured in Figure 2-6.

If you're still unsure about the forward voltage and forward current of your LED, just err on the side of caution and fit a sensibly

NOTE

I recommend buying a selection of resistors, which are normally organized into something that looks like a book. That way, you'll have a resistor for every occasion and won't have to buy them individually.

large resistor of at least 100 Ω into your circuit. If the LED is too dim, downsize the resistor until you get to a suitable level of brightness (dim enough to not hurt your eyes is a good rule of thumb). Don't try to do this the other way around: you can't unexplode an LED!

Jumper Wires

Finally, you'll need some wires to connect everything up. Specifically, you'll need *jumper wires*, which are breadboard-friendly wires that allow you to connect things to the Pi's GPIO pins. You can see some examples of jumper wires in Figure 2-7.



FIGURE 2-7

A collection of jumper wires

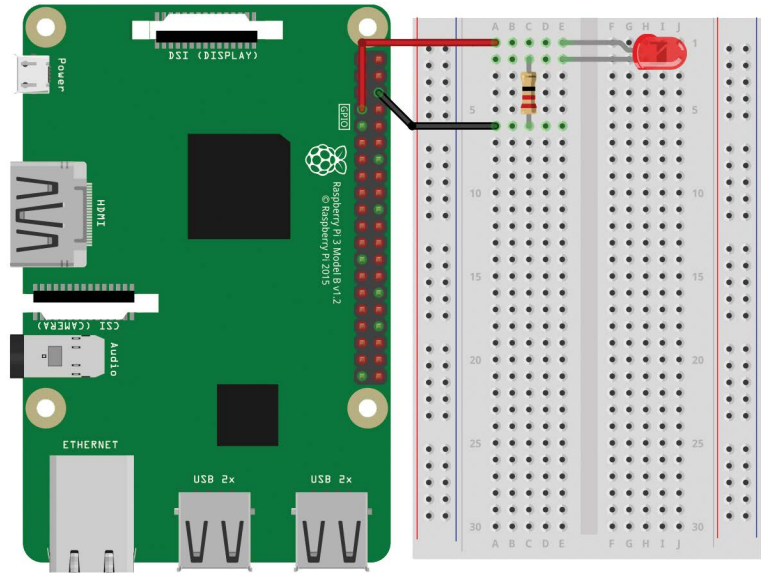
The ends of jumper wires are either *male* or *female*. A male end (often abbreviated as M) has a wire sticking out of it that you can insert into a breadboard's holes. A female end (abbreviated as F) instead has a hole into which you place a wire. I would recommend buying a variety so that you have a jumper wire for all situations. We'll be using a lot of these throughout the book! In Figure 2-7, you can see my collection of M-M, M-F, and F-F jumper wires. For making an LED blink, we'll need two M-F jumper wires.

Wiring Up Your LED

Now that you've collected your parts, it's time to wire up your LED and create your first circuit! You'll wire up your circuit as shown in Figure 2-8, so you can use this diagram as a reference as you go through the instructions.

FIGURE 2-8

Breadboard diagram for wiring up an LED



Depending on the breadboard you have, your circuit may look slightly different. To make sure your connections are correct, follow these instructions:

1. Insert the LED into the breadboard so that each leg is in a different row. If you put the LED's legs into the same row, they'll be connected to each other, but won't be connected to anything else. LEDs have a positive and negative side, which you need to align with the flow of the current. The long leg of the LED is the positive side—called the *anode*. The short leg is the negative side—the *cathode*. The LED bulb will usually be flat on the side of the cathode as an extra indicator.
2. Insert one leg of your resistor into the same row on the breadboard as your LED's shorter leg. Putting the resistor leg in the same row as your LED connects the two in a circuit. Connect the other leg of the resistor to any of the other points of the board.
3. Now, with your Raspberry Pi turned off, insert the male end of one of your M-F jumper wires into the breadboard, in the same row as the long leg of your LED. Locate physical pin 7 on your Raspberry Pi, also known as the *GPIO/BCM 4* pin (see “Raspberry Pi GPIO Diagram” on page 200 for an image of this), and connect the female end of the wire to it.

THE VARIOUS NAMES OF GPIO PINS

The Raspberry Pi's GPIO pins can have several names. First, you can refer to the pins from their physical numbers—that is, how they are laid out. However, the processor on the Raspberry Pi does not understand this numbering and has its own name for the GPIO pins, sometimes referred to as the BCM numbering of the pins. In our case, you have wired up your LED to physical pin 7: that's BCM pin 4! See “Raspberry Pi GPIO Diagram” on page 200 for a diagram of the GPIO pins and some further explanation.

4. Finally, insert the male end of your other M-F jumper wire into the row of the breadboard that contains only one leg of the resistor and none of the LED's legs. Then connect the female end to physical pin 6 on your Raspberry Pi. This is one of the *ground* pins. You can think of ground as the negative terminal of a battery. It is just the lower side of a voltage.

Programming Your Raspberry Pi to Blink Your LED

You should now have your circuit wired up, so boot up your Raspberry Pi and log in. It's time to write a program to blink that LED!

From the terminal, navigate from the home directory into the folder you created in Chapter 1 with the command:

```
pi@raspberrypi:~ $ cd robot
```

Now you'll create a new file and write a Python program to control your LED. Pick whatever name you like for your file, but ensure your filename ends with *.py*. I've called mine *blink.py*. The following command creates a new file and opens the Nano text editor:

```
pi@raspberrypi:~/robot $ nano blink.py
```

You'll now find yourself in a Nano text editor identical to the one you came across in Chapter 1.

Enter the code in Listing 2-1 to instruct your LED to flash on and off (the numbers in circles don't actually appear in the program, but we'll be using them for reference).

NOTE

When you power on your Raspberry Pi, your LED may be off, on, or even dimly lit. Don't worry! Your LED is fine in any of these states. You haven't yet instructed the pin to be a certain state, so your pin isn't quite sure what to do yet.

LISTING 2-1

Program to blink
an LED

```
❶ import gpiozero
import time

❷ led = gpiozero.LED(4)

❸ while True:
    ❹ led.on()
    ❺ time.sleep(1)
    ❻ led.off()
    ❼ time.sleep(1)
```

This eight-line Python program is easy to understand when you look at it one line at a time, so let's break it down.

Python is an *interpreted* programming language, meaning when this code is run, your Raspberry Pi (or any other computer) will execute your program line by line, starting at the top and moving down in a logical manner. That means the order of your code matters.

Python comes with all sorts of built-in abilities. For example, in Chapter 1 you *printed* text to the terminal, a capability Python has by default. There are hundreds of other things Python can do, but some abilities need to be imported from external sources. For example, Python is not able to control your Pi's GPIO pins on its own, so we import a library called GPIO Zero ❶. In programming, a *library* is a collection of functions a program can use. By importing a library, we bring these functions into the current program for our own use. The GPIO Zero library was created by the Raspberry Pi Foundation to give programmers a simple GPIO interface in Python. Importing this library enables your program to control your Pi's GPIO pins! Note that it's actually called `gpiozero` in the programming language, though, as we can't include spaces in library names and the convention is to use lowercase.

On the next line we import the `time` library, which allows your Python program to control timings. For example, you'll be able to pause the code, which will be very useful in our case!

Next, we make a variable ❷. In programming, *variables* are names used to store information to be referenced and manipulated in a program. They provide a way of labeling data, and they make code simpler, easier to understand, and more efficient.

In this case, we've created a variable called `led` that references the LED software from the GPIO Zero library. We give the `LED()` function the value 4 in parentheses to show that we are referring to an LED on GPIO/BCM pin 4. When we call `led` later in the program, the Pi knows we mean this pin.

Then we begin a `while` loop ❸, which is a *conditional statement* that will keep running the code inside it until the condition is no longer met. In simple English, we're telling the loop: while this condition is true, keep running the code. In this case, the condition is simply `True`. The `True` condition will always be true and will never be false, so the `while` loop will go around and around indefinitely. This is useful to us, as we'll be able to write the code to make the LED flash once, and the loop will take care of making the LED flash over and over again.

Within the `while` loop, you also come across a key structural feature of Python: *indentation*. Python knows that all the code indented by the same number of spaces belongs to the same group of code, known as a *block*. The four lines following the `while` loop are indented four spaces each; as long as the condition is true, the loop will run that whole block of code.

You can create indentation in different ways. Some people use two spaces, four spaces, or a `TAB`. You can use any method you like as long as you stay consistent throughout your Python program. I'm a `TAB` person myself.

At ❹, you switch the LED on using the command `led.on()`. Remember that `led` refers to the pin we connected the LED to and now we're telling that pin to be "on." The dot (.) separates the thing we're talking about, in this case the LED, from what we're asking it to do, in this case be turned on. Turning on a GPIO pin is also known as bringing that pin *high*, since the Raspberry Pi will apply a voltage of 3.3 V across your circuit when this line of code runs.

Next we use a `sleep()` statement ❺ to tell your program to pause for whatever number of seconds you give to it in parentheses. In this case, we entered a value of 1, so the program sleeps for just 1 second. After this, you switch the LED off using the command `led.off()` ❻. Repeat the `sleep()` statement at ❼ to make the program wait for another second before looping back around again to the start of the `while` loop. This sequence of on-wait-off-wait continues indefinitely.

Once you've finished entering the code for your program, you can exit the Nano text editor and save your work. To do this, press `CTRL-X`. You will then be asked whether you would like to save the changes you have made. Press the `Y` key to say yes. Nano will then prompt you for the filename you would like to write to, which in our case should be `blink.py` or the filename you entered when you opened the Nano editor. Press `ENTER` to confirm the filename.

Running Your Program: Make Your LED Blink

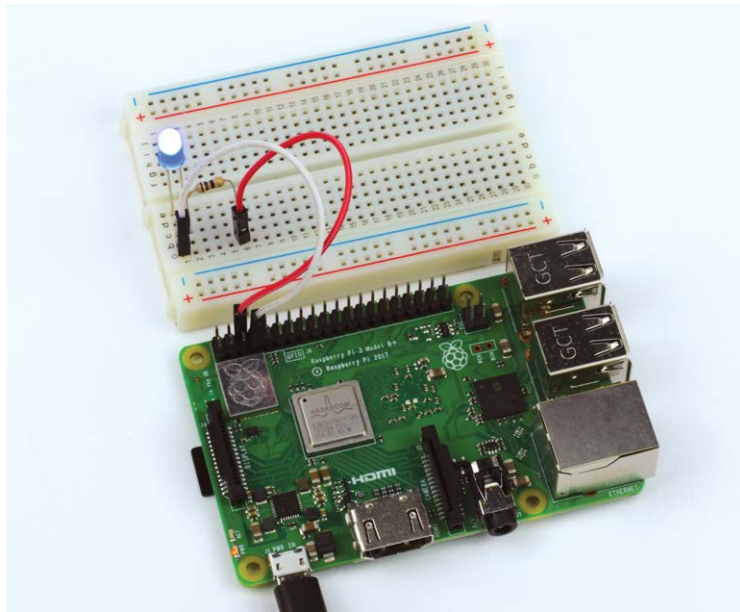
Now that you understand how your program works, it's time to run it. You'll follow the same process to execute your program as you did for the *helloworld.py* program you created in Chapter 1. Enter the following code into the Raspberry Pi's prompt:

```
pi@raspberrypi:~/robot $ python3 blink.py
```

Your LED should now start to blink on and off at regular intervals (see Figure 2-9). Congratulations, you've just successfully interfaced your Raspberry Pi with the outside world!

FIGURE 2-9

A happily blinking
LED connected to the
Raspberry Pi



To kill your program and stop the blinking LED, press CTRL-C.

just do nothing. Go back to the instructions and make sure you followed them accurately.

If this doesn't fix your problem, check the rest of your circuit. Is everything connected properly? Are all of the wires firmly in place? Check that you have wired up your circuit to the correct pins of your Pi's GPIO port—this is an easy mistake to make!

If you're convinced that your circuit is sound and your LED and resistor are appropriate (as explained in the parts list), then you may have a software issue. When you ran the program, did it crash? Did you get an error message? You may have made an error when copying the code from this book. Go back and check, or grab the code files from <https://nostarch.com/raspirobots/> and run the *blink.py* file from there instead.

The GPIO Zero library is included by default in all new Raspbian releases, but if you are running an older version of Raspbian, you may need to install the library manually. To do this, enter the command:

```
pi@raspberrypi:~/robot $ sudo apt-get update
```

followed by the command:

```
pi@raspberrypi:~/robot $ sudo apt-get install python3-gpiozero  
python-gpiozero
```

Challenge Yourself: Change the Timing

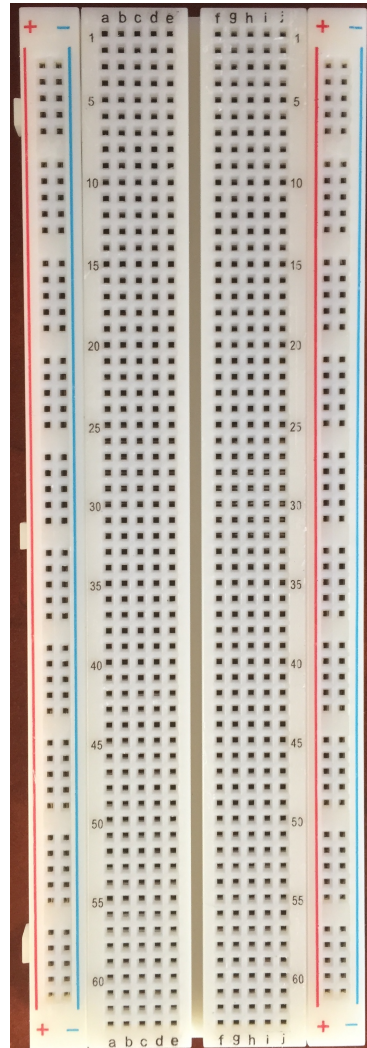
Take a look at the code you used to make your LED blink. What would happen if you modified some of it? For example, you could experiment by changing the timing of the `sleep()` statements and seeing what different patterns you can make! Play around a bit to see what effects your changes have.

INPUT FROM A BUTTON: RASPBERRY PI GPIO INPUT

Blinking an LED is the perfect first experiment for the world of electronics and physical computing with your Raspberry Pi, but it demonstrates only the *output* aspect of what the Pi's GPIO pins can do. GPIO pins can also take *input*, meaning they can take data from the outside world and react to it. In this section you'll wire a button up to your Raspberry Pi and write a program that is triggered when-ever that button is pressed.

NOTE

*If you want to shut down your Raspberry Pi, you should do so safely in software before yanking out the power cord. To commence a power down sequence, use the command **sudo shutdown now**. Wait a few seconds before pulling out the power cord. Or, choose the shutdown option in the main menu from the GUI if you're using a directly connected screen.*



Bread Board

The physical numbers simply correspond to the pin's actual physical location, starting at 1 and going all the way down to 40. The BCM number on each pin (for example, BCM 25) is known as the *Broadcom* pin number, or the *GPIO* number. These numbers are used internally by your Pi's processor, and you usually need to use them inside GPIO Zero and other programming libraries.

Some pins have alternate functions specified in brackets; if you want to learn more about these, see the official documentation on the Raspberry Pi website (<https://www.raspberrypi.org/documentation/usage/gpio/>).



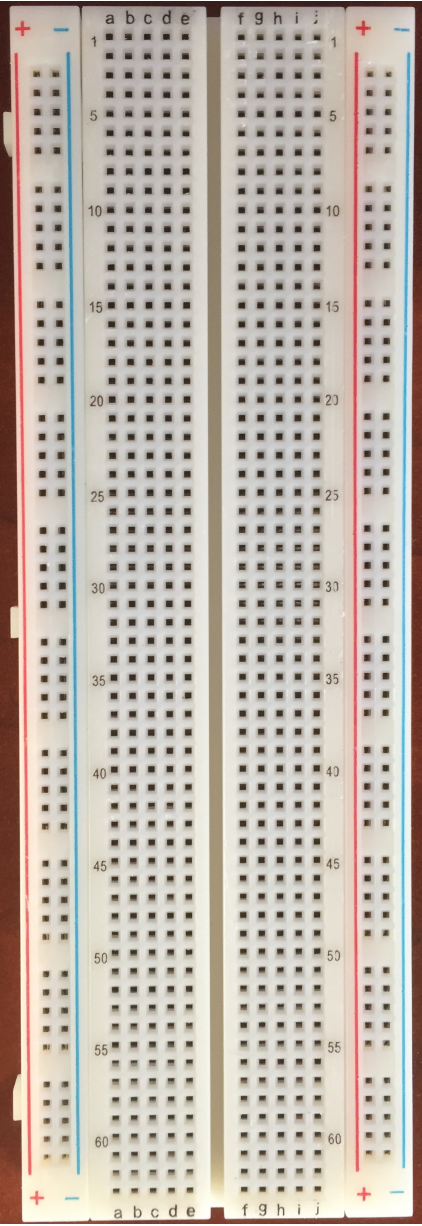
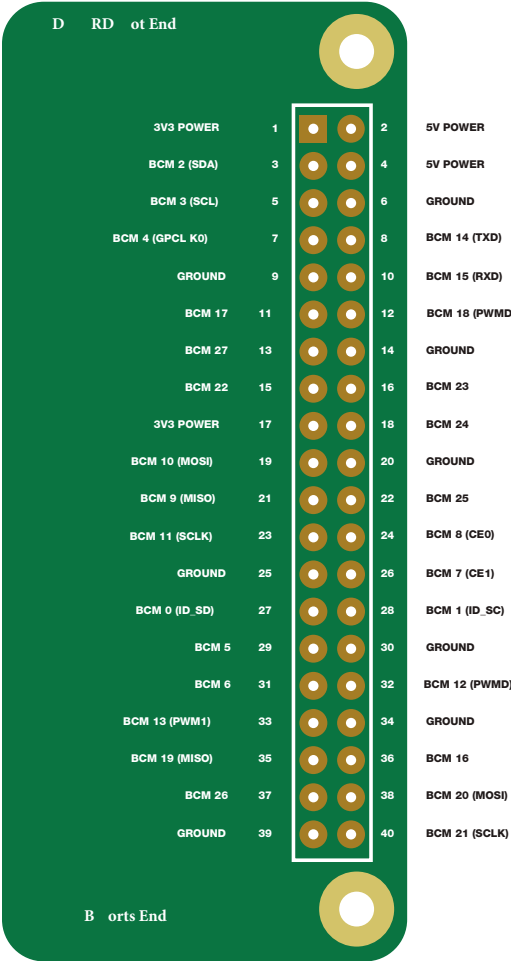
Resistor



Button



LED



D RD of End

3V3 POWER	1	2	3V POWER
BCM 2 (SDA)	3	4	5V POWER
BCM 3 (SCL)	5	6	GROUND
BCM 4 (GPCL_K0)	7	8	BCM 14 (TXD)
GROUND	9	10	BCM 15 (RXD)
BCM 17	11	12	BCM 18 (PWMD)
BCM 27	13	14	GROUND
BCM 22	15	16	BCM 23
3V3 POWER	17	18	BCM 24
BCM 10 (MOSI)	19	20	GROUND
BCM 9 (MISO)	21	22	BCM 25
BCM 11 (SCLK)	23	24	BCM 8 (CEO)
GROUND	25	26	BCM 7 (CE1)
BCM 0 (ID_SD)	27	28	BCM 1 (ID_SC)
BCM 5	29	30	GROUND
BCM 6	31	32	BCM 12 (PWMD)
BCM 13 (PWMD1)	33	34	GROUND
BCM 19 (MISO)	35	36	BCM 16
BCM 26	37	38	BCM 20 (MOS)

