

Chapter 1

The Shape of a Computer Phenomenon

THAT OLD SAYING about good things coming in small packages describes the Raspberry Pi perfectly. It also highlights an advance in computer architecture—the system-on-a-chip (SoC), a tiny package with a rather large collection of ready-to-use features. The SoC isn't so new—it's been around a long time—but the Raspberry Pi's designers have put it into a small, powerful package that is readily available to students and adults alike. All for a very low price.

A tiny piece of electronics about the size of a credit card, the Raspberry Pi single-board computer packs very respectable computing power into a small space. It provides tons of fun and many, many possibilities for building and controlling all sorts of fascinating gizmos. When something is small, after all, it fits just about anywhere. The Raspberry Pi does things conventional computers just can't do in terms of both portability and connectivity. Things you will find inspire your creativity—fun things!

What's not to like? Get ready for some truly exciting computer architecture.

In this chapter introducing the truly phenomenal Raspberry Pi line of computer boards, we look first at the Raspberry Pi's goals and history. We include the history of the Raspberry Pi's development and the visionary people at the Raspberry Pi Foundation who dreamed up the concept and achieved the reality, and we look at the advantages this tiny one-board computer has over much larger computers. We then take a tour of the Raspberry Pi board.

Growing Delicious, Juicy Raspberries

As significant advances in computing go, the Raspberry Pi's primary innovation was the lowering of the entry barrier into the world of embedded Linux. The barrier was twofold—price

and complexity. The Raspberry Pi's low price solved the price problem (cheap is good!) and the SoC reduced circuit complexity rather dramatically, making a much smaller package possible.

The road to the development of the Raspberry Pi originated at a surprising point—through a registered charity in the UK, which continues to operate today.

The Raspberry Pi Foundation, registered with the Charity Commission for England and Wales, first opened its doors in 2009 in Caldecote, Cambridgeshire. It was founded for the express purpose of promoting the study of computer science in schools. A major impetus for its creation came from a team consisting of Eben Upton, Rob Mullins, Jack Lang and Alan Mycroft. At the University of Cambridge's Computer Laboratory, they had noted the declining numbers and low-level skills of student applicants. They came to the conclusion that a small, affordable computer was needed to teach basic skills in schools and to instill enthusiasm for computing and programming.

Major support for the Foundation's goals came from the University of Cambridge Computer Laboratory and Broadcom, which is the company that manufactures the SoC—the Broadcom 2835 or 2836, depending on the model—that enables the Raspberry Pi's power and success. Later in this chapter you will read more on that component, which is the heart and soul of the Raspberry Pi.

The founders of the Raspberry Pi had identified and acted on the perceived need for a tiny, affordable computer. By 2012, the Model B had been released at a price of about £25. The fact that this represented great value for money was recognised immediately, and first-day sales blasted over 100,000 units. In less than two years of production, more than two million boards were sold.

The Raspberry Pi continued to enjoy good sales and wide acceptance following the highly successful release of the Model B+ (in late 2014). And in 2015, the fast, data-crunching Raspberry Pi 2 Model B with its four-core ARM processor and additional onboard memory sold more than 500,000 units in its first two weeks of release. Most recently, the Raspberry Pi Zero, a complete computer system on a board for £4—yes, £4—was released. It's an awesome deal if you can get one—the first batch sold out almost immediately.

In 2016, the Raspberry Pi Model 3 Model B arrived. It sports a 1.2GHz 64-bit quad-core ARMv8 CPU, 1 GB RAM, and built-in wireless and Bluetooth! All for the same low price.

The original founders of the Raspberry Pi Foundation included:

- Eben Upton
- Rob Mullins

- Jack Lang
- Alan Mycroft
- Pete Lomas
- David Braben

The organisation now consists of two parts:

- Raspberry Pi (Trading) Ltd. performs engineering and sales, with Eben Upton as CEO.
- The Raspberry Pi Foundation is the charitable and educational part.

The Raspberry Pi Foundation's website at www.raspberrypi.org (see Figure 1-1) presents the impetus that resulted in the Raspberry Pi. This is what they say on the About Us page:

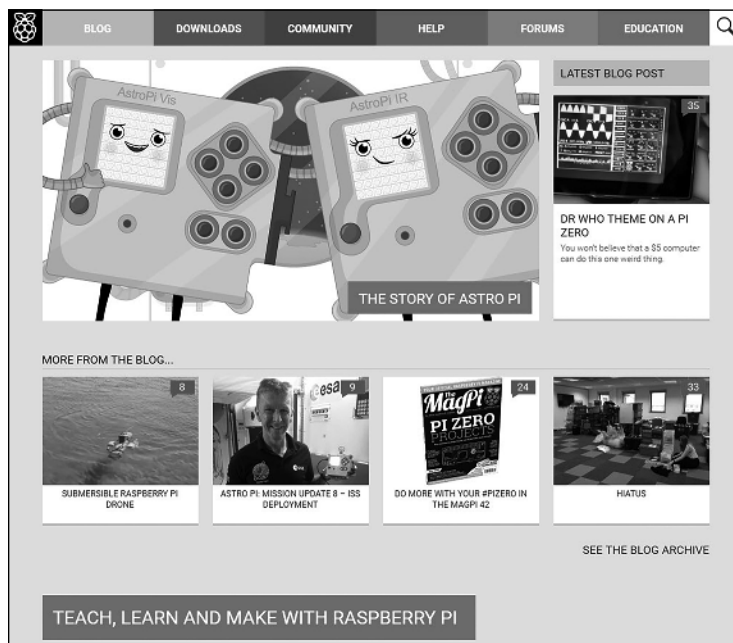


FIGURE 1-1: The Raspberry Pi official website

The idea behind a tiny and affordable computer for kids came in 2006, when Eben Upton, Rob Mullins, Jack Lang and Alan Mycroft, based at the University of Cambridge's Computer Laboratory, became concerned about the year-on-year decline in the numbers and skills levels of the A Level students applying to read Computer Science. From a situation in the 1990s

where most of the kids applying were coming to interview as experienced hobbyist programmers, the landscape in the 2000s was very different; a typical applicant might only have done a little web design.

As a result, the founders' stated goal was "to advance the education of adults and children, particularly in the field of computers, computer science and related subjects".

Their answer to the problem, of course, was the Raspberry Pi, which was designed to emulate in concept the hands-on appeal of computers from the previous decade (the 1990s). The intention behind the Raspberry Pi was to be a "catalyst" to inspire students by providing affordable, programmable computers everywhere.

The Raspberry Pi is well on its way to achieving the Foundation's goal in bettering computer education for students. However, another significant thing has happened; a lot of us older people have found the Raspberry Pi exciting. It's been adopted by generations of hobbyists, experimenters and many others, which has driven sales into new millions of units.

While the sheer compactness of the Raspberry Pi excites, resonates and inspires adults as well as youngsters, what truly prompted its success was its low price and scope of development. Embedded Linux has always been a painful subject to learn, but the Pi makes it simple and inexpensive. Continuing education in computers gets just as big a boost as initial education in schools.

System-on-a-Chip

An SoC or system-on-a-chip is an integrated circuit (IC) that has the major components of a computer or any other electronic system on a single chip. The components include a central processing unit (CPU), a graphics processing unit (GPU) and various digital, analogue and mixed signal circuits on just one chip.

This SoC component makes highly dense computing possible, such as all the power that is shoehorned into the Raspberry Pi. Figure 1-2 shows the Broadcom chip on the Raspberry Pi 2 Model B. It's a game-changing advance in computer architecture, enabling single-card computers that rival and often exceed the capabilities of machines that are many times their size. Chapter 8, "Operating Systems", covers these small but mighty chips in detail.

The Raspberry Pi features chips that are developed and manufactured by Broadcom Limited. Specifically, the older models as well as the latest (the £4 Raspberry Pi Zero) come with the Broadcom BCN2835 and the Raspberry Pi 2 has the Broadcom BCM2836, and the new Model 3 uses the Broadcom BCM2837. The biggest difference between these two SoC ICs is the replacement of the single-core CPU in the BCM2835 with a four-core processor in the BCM2836. Otherwise, they have essentially the same architecture.

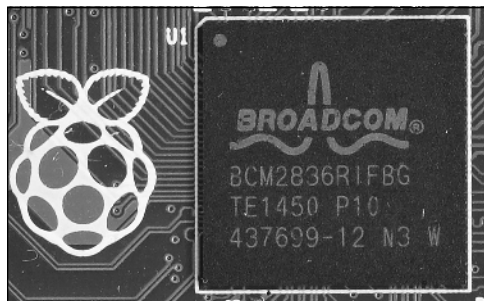


FIGURE 1-2: Broadcom chip on the Raspberry Pi 2 Model B

Here's a taste of the low-level components, peripherals and protocols provided by the Broadcom SoCs:

- **CPU:** Performs data processing under control of the operating system (a CPU with a single core on most of the Raspberry Pi models and a CPU with four cores on the Raspberry Pi 2 and Raspberry Pi 3).
- **GPU:** Provides the operating system desktop.
- **Memory:** Permanent memory used as registers for CPU and GPU operation, storage for bootstrap software, the small program which starts the process of loading the operating system and activating it.
- **Timers:** Allow software to be time-dependent for scheduling, synchronising and so on.
- **Interrupt controller:** Interrupts allow the operating system to control all the computer resources, know when the CPU is ready for new instructions and much more (this is covered in Chapter 8).
- **General purpose input output (GPIO):** Provides layout and enables control of connections, input, output and alternative modes for the GPIO pins that enable the Raspberry Pi to manage circuits, devices, machines and so on. In short, it turns the Raspberry Pi into an embeddable control system.
- **USB:** Controls the USB services and provides the Universal Serial Bus protocols for input and output, thus allowing peripherals of all types to connect to the Raspberry Pi's USB receptacles.
- **PCM/I²S:** Provides pulse code modulation (PCM, which converts digital sound to analogue sound such as speakers and headphones require) and known as Inter-IC Sound, Integrated Interchip Sound, or IIS, a high-level standard for connecting audio devices).

- **Direct memory access (DMA) controller:** Direct memory access control that allows an input/output device to bypass the CPU and send or receive data directly to the main memory for purposes of speed and efficiency.
- **I²C master:** Inter-integrated circuit often employed for connecting lower-speed peripheral chips to control processors and microcontrollers.
- **I²C/SPI (Serial Peripheral Interface) slave:** The reverse of the preceding bullet point. Allows outside chips and sensors to control or cause the Raspberry Pi to respond in certain ways; for example, a sensor in a motor detects it's running hot and the controller chip causes the Raspberry Pi to make a decision on whether to reduce the motor's speed or stop it.
- **SPI Interface:** Serial interfaces, accessed via the GPIO pins and allowing the daisy chaining of several compatible devices by the use of different chip-select pins.
- **Pulse width modulation (PWM):** A method of generating an analogue waveform from a digital signal.
- **Universal asynchronous receiver/transmitter (UART0, UART1):** Used for serial communication between different devices.

An Exciting Credit Card-Sized Computer

Just how powerful is the Raspberry Pi compared to a desktop PC? Certainly, it has far more computational ability, memory and storage than the first personal computers. That said, the Raspberry Pi cannot match the speed, high-end displays, built-in power supplies and hard-drive capacity of the desktop boxes and laptops of today.

However, you can easily overcome any disadvantages by hanging the appropriate peripherals on your Raspberry Pi. You can add large hard drives, 42-inch HDMI screens, high-level sound systems and much more. Simply plug your peripherals into the USB receptacles on the board or via other interfaces that are provided, and you're good to go. Finish it off by clicking an Ethernet cable into the jack on the Raspberry Pi or sliding in a wireless USB dongle, and worldwide connectivity goes live.

You can duplicate most features of conventional computers when you attach peripherals to a Raspberry Pi, such as in Figure 1-3, and you also gain some distinct advantages over large computers, including:

- The Raspberry Pi is *really* cheap—£25 retail or just £4 for the Raspberry Pi Zero.
- It's *really* small—all models are credit-card sized or smaller.

- You can replace the operating system in seconds simply by inserting a new SD or microSD card for almost instant reconfiguration.
- The Broadcom SoC gives the Raspberry Pi more interfaces, communications protocols and other features out of the box than conventional computers that sell for many times the price.
- The GPIO pins (see Figure 1-4) allow the Raspberry Pi to control real-world devices that have no other method of computer input/output.

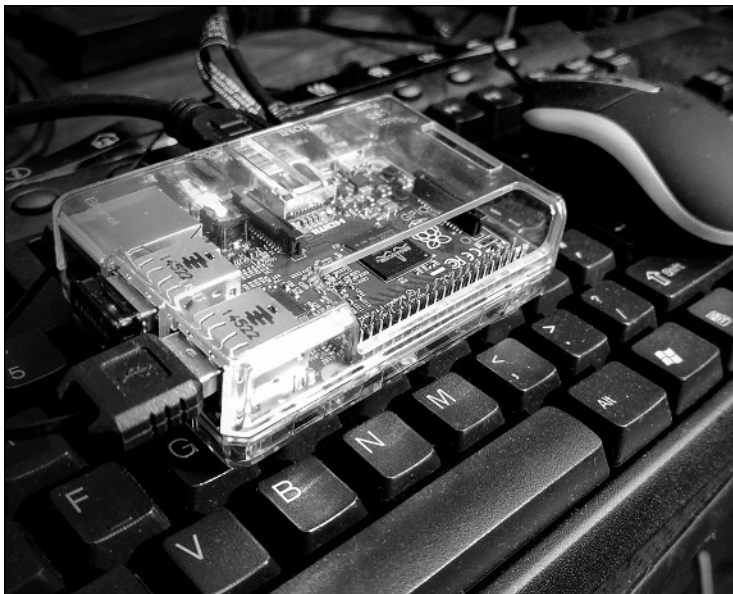


FIGURE 1-3: Peripherals attached to a Raspberry Pi 2 Model B

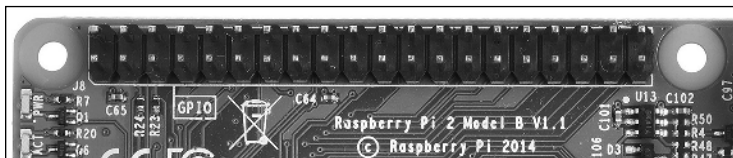


FIGURE 1-4: GPIO pins enable control of real world devices.

What Does the Raspberry Pi Do?

The Raspberry Pi excels as the brains for all sorts of projects. Here are some examples randomly picked from the many thousands of documented projects on the Internet. This list may inspire you in choosing some projects of your own:

- Home automation
- Home security
- Media centre
- Weather station
- Wearable computer
- Robot controller
- Quadcopter (drone) controller
- Web server
- Email server
- GPS tracker
- Web camera controller
- Coffee maker
- Ham radio EchoLink server and JT65 terminal
- Electric motor controller
- Time-lapse photography manager
- Game controller
- Bitcoin mining
- Automotive onboard computer

This list just scratches the surface of possible uses for the Raspberry Pi. There's not enough room to list everything you could do, but this book gives you the information you need to come up with your own ideas. Let your own desires, interests and imagination guide you. The Raspberry Pi does the rest.

Meeting and Greeting the Raspberry Pi Board

This section begins with an introduction to the features, components and layout of the Raspberry Pi board. We show contrasts between the various models but with an emphasis on the Raspberry Pi 2. Reading this section and examining the Raspberry Pi board is like looking at a map before setting off on a journey—it gives you the lay of the land. If you know where the various important parts of the board are and how they work, it makes imagining and creating projects a lot easier because you understand the board better.

We begin with the Raspberry Pi 2 Model B (there was no Model A in the 2 series or the new 3 series). After introducing you to the Raspberry Pi 2, we'll look at the other versions, including the Raspberry Pi 3 Model, which includes more processor speed, onboard Wi-Fi and Bluetooth.

If you want to follow along with your own board, orient it as shown in Figure 1-5, with the two rows of GPIO pins at the upper left.

GPIO Pins

The GPIO pins—the row of pins at the top of the board as it’s oriented in Figure 1-5—perform magic in tying the Raspberry Pi to the real world. Through these pins, you program the Raspberry Pi to control all sorts of devices. Chapter 12, “Input/Output”, looks at programming the Raspberry Pi and helps you understand inputs and outputs and shows methods of controlling various devices. Let’s examine these pins and get an understanding of how simple and powerful they are.

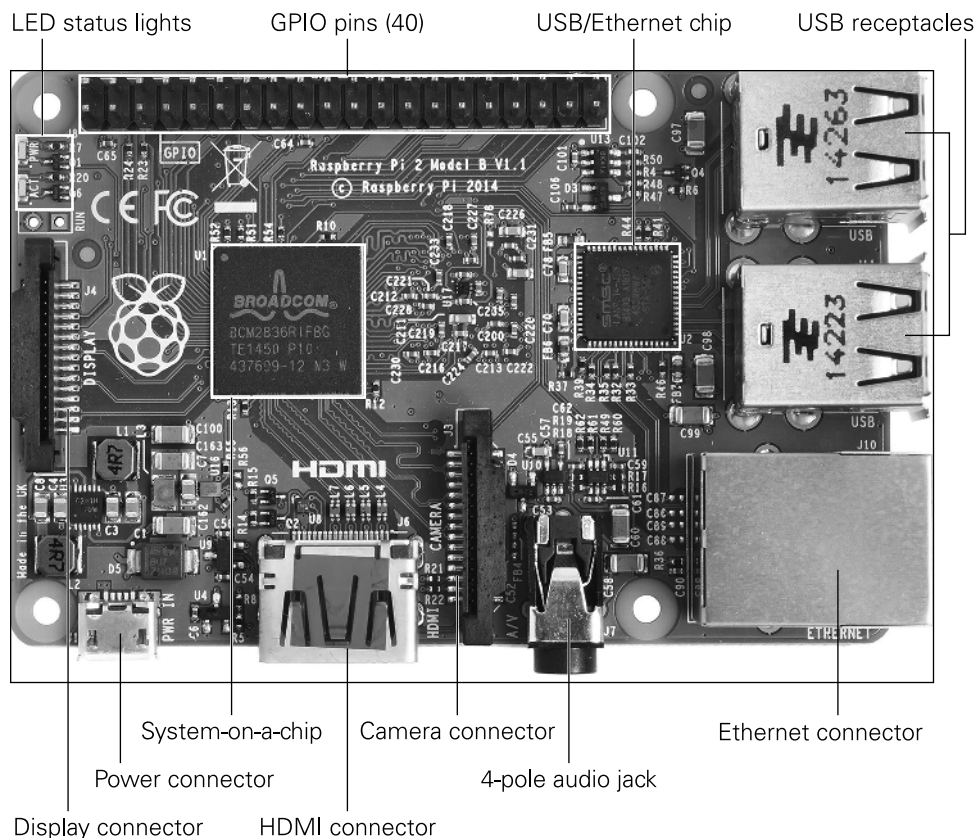


FIGURE 1-5: The Raspberry Pi 2 board with the GPIO pins at the upper left

Real-world devices—doorbells, light bulbs, model aircraft controls, lawn mowers, robots, thermostats, electric coffeepots and motors of all sorts, to name a few things—cannot normally connect to a computer or follow its orders. Through GPIO, the Raspberry Pi can do neat stuff with these real-world objects! That’s why we’re emphasising the GPIO pins; the pins enable you to do things with the Raspberry Pi that you can’t do with conventional computers.

NOTE

Being able to interface with real-world devices is not a distinction that’s unique to the Raspberry Pi; embedded computers are able to bridge this gap whereas conventional computers can’t.

We have 40 pins—two rows of 20. The bottom row of pins (left to right) consists of odd numbers: 1, 3, 5, 7, 9, 11, 13, 15, 17, 19, 21, 23, 25, 27, 29, 31, 33, 35, 37 and 39. The top are numbered 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34, 36, 38 and 40.

These pins are programmable; you can even change the layout of most of the pins! The power pins cannot be rerouted.

When you add simple external circuits, it becomes possible for the Raspberry Pi to switch all sorts of things on or off. It can also sense input from devices and respond accordingly. Thanks to the Raspberry Pi’s ability to communicate in various ways—such as by wireless, by Bluetooth or on the Internet—inputs and outputs do not even have to be local. With some additional hardware, you can control devices, programs and so forth from anywhere in the world.

NOTE

Read Chapter 12 to learn about the several modes of operation for GPIO pins. The majority of the pins can be input, output or one of six special modes.

Status LEDs

The status light-emitting diodes (LEDs) are to the lower left of the GPIO pins. These tiny babies put out a good deal of light. On the Raspberry Pi 2, they are labelled (from top to bottom) PWR (power) and ACT (activity); PWR lights red and ACT lights green.

Whenever power is present to the board (that is, a micro USB plug provides 5 volts direct current (VDC) from a USB source or a wall adapter), the PWR light glows red. The ACT LED indicates that a microSD card is available, and only lights up when the Raspberry Pi accesses the card.

The Model B+ has the same arrangement as on the Model B except that the LED status lights are located on the opposite side of the board, and there are five LEDs:

- **ACT** (activity, green): Indicates an SD card is plugged in and accessible
- **PWR** (power, red): Indicates power is present
- **FDX** (full duplex, green): Indicates a full duplex local area network (LAN) is connected
- **LNK** (link, flashing green): Indicates activity is happening on the LAN
- **100** (yellow): Indicates a 100-Mbit/s LAN is connected (as opposed to a 10-Mbit network)

With the Model B+, the last three LEDs functions were moved to the Ethernet jack, with the FDX and 100 being combined into one LED. So flashing green on the jack shows network activity on the right LED and either solid green or yellow on the left, showing a 10-Mbits/s (megabits per second) or 100-Mbits/s network connections, respectively.

All the Raspberry Pi models actually have five status lights; it's just that on the B+ and Raspberry Pi 2 there are two LEDs (PWR and ACT) on one side of the board, and the network indicators are on the other side as part of the Ethernet jack.

NOTE

The status LEDs give you a quick picture of what transpires on your Raspberry Pi board, especially during the boot-up process. It goes like this:

1. When you plug in the microUSB connector (there's no on/off switch), the PWR LED lights red to show that power is present. The PWR LED stays lit so long as power is flowing to the board.
2. The ACT LED flashes green a couple of times or so, indicating an SD card is present and readable. After boot-up, this green light flashes whenever SD card access occurs.
3. As the powering-up process continues, the green light on the right of the Ethernet jack (Model B+ and later) come on if a network is present. The light flashes whenever there is traffic on the network. The left LED flashes green for a slow network and is solid yellow if you are connected to a 100Mbit/s network.

So, at a glance, the status LEDs tell us the board has power, the SD card is working and the network is active.

USB Receptacles

On the right-hand side of the board are the Raspberry Pi 2 Model B's four USB 2.0 ports, as shown in Figure 1-6.

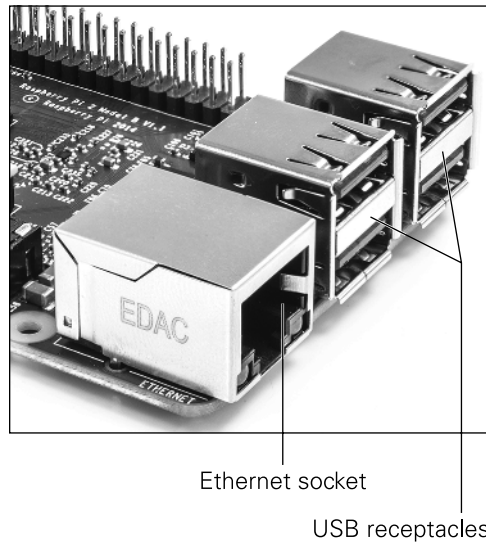


FIGURE 1-6: USB 2.0 ports and Ethernet port

NOTE

The ports appear in the same way on the Model B+ but the older Model B provides only two USB receptacles.

USB receptacles—or ports, as some people incorrectly call them—allow you to plug in and run a keyboard, mouse and all sorts of other devices—even big hard drives!

Ethernet Connection

All sorts of Raspberry Pi tasks require a connection to both your local network and the Internet itself. Upgrading the operating system and the Raspberry Pi's firmware requires Internet access. Networking is a necessity for downloading and installing programs, web surfing, using the Raspberry Pi as a media centre to deliver movies to your humungous flat-screen TV and many more reasons.

Fortunately, you have two ways of achieving network connectivity with the Raspberry Pi. The first is a wired connection using the Ethernet socket on the lower-right corner (as the board is oriented in Figure 1-5). Refer to Figure 1-6 to see what this socket looks like.

The second way of connecting involves the USB receptacles. You can use a wireless USB dongle (a dongle being a plug-in device) or a USB-to-Ethernet adapter. If you use the latter method, you can connect the Raspberry Pi to more than one network. One reason for doing this would be a typical server setup where the Raspberry Pi connects to both the Internet and a more secure local network. Using Raspbian, for example, you can turn your Raspberry Pi into a classic LAMP (standing for Linux, Apache, mySQL, PHP) server. The Raspberry Pi serves up websites with database back ends and so on, just like on much larger servers using the same software.

Using a wireless USB dongle comes in handy if you want your Raspberry Pi to be portable. With an external battery power supply and wireless access, you can carry it anywhere! Or at least anywhere with wireless access, which is true of more and more places these days.

Audio Out

On the bottom of the board is the 3.5 millimetre (mm) audio input/output jack (see Figure 1-7). Here you can plug in headphones, a computer sound card, speakers or anything thing else that takes and plays audio input.

The Model A and Model B did not have this feature but instead had separate connectors for video and audio.

NOTE

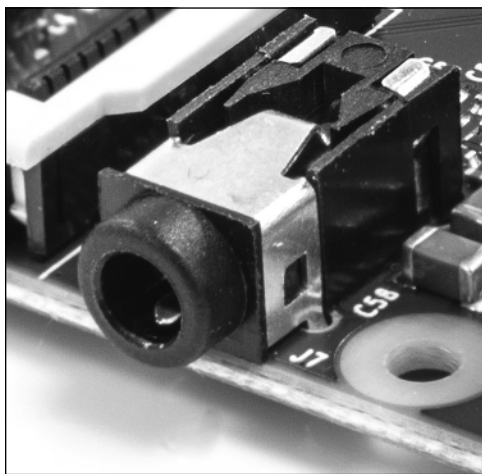


FIGURE 1-7: The audio output socket

The plug that goes into the socket on the Raspberry Pi board is a four-pole plug—in this case, a tip with three rings. However, it also accepts and works with a standard three-pole mini plug like those often found on headphones and computer speakers.

NOTE

Poles are the tip and rings of conductors. Four-pole had a tip and three rings; three-pole a tip and two rings.

Figure 1-7 shows how the connector appears on the Model B+ and later, and Figure 1-8 shows the connector's wiring.

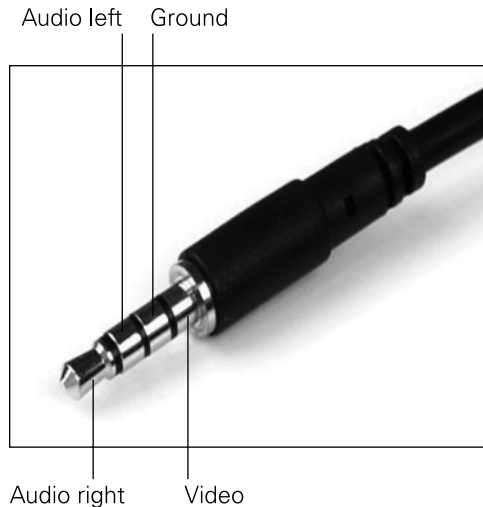


FIGURE 1-8: Connector for audio socket

Another of the Raspberry Pi limitations concerns quality of sound. The audio out from this connector is 11-bit (for truly good sounding music you'd want 16-bit). The High-Definition Multimedia Interface (HDMI) connector, which is described later in this chapter, has better audio but, of course, you have to have an HDMI device (like a big-screen TV) that has good speakers attached.

No worries, folks—like the limitations in Raspberry Pi power, solutions abound. For example, Adafruit sells a USB audio adapter, which works on the Raspberry Pi, for a very low price. It puts out better sound and allows for microphone input as well. This lets you use the Pi as a voice or music recorder or teach it to work via voice commands. Various computer soundboards designed specifically for the Raspberry Pi are also available

Even better, you can obtain high-quality sound using the I²S interface into an external digital-to-analogue convertor (DAC). Chapter 11, “Audio”, covers all that good stuff.

Composite Video

Using the same 3.5mm socket described in the last section, old-style composite video is also available.

When it boots up and finds a composite video device attached, the Raspberry Pi attempts to select the right resolution. Mostly it gives a usable display but sometimes it gets things wrong.

Having video composite output may seem old school in light of the modern era's profusion of HDMI devices hanging off every wall, but it fits in with the design philosophy Raspberry Pi Foundation co-founder Eben Upton recently described. He said, "It's a very cheap Linux PC device in the spirit of the 1980s, a device which turns your TV into a computer; plug in to TV, plug a mouse and a keyboard in, give it some power and some kind of storage, an operating system and you've got a PC".

CSI Camera Module Connector

Camera modules for the Raspberry Pi give you 5-megapixel stills and 1080 high-definition video for about £16. The Camera Serial Interface (CSI) connector shown in Figure 1-9 (located between the HDMI socket and the 3.5mm audio socket) provides a place to plug the camera module into the Pi.

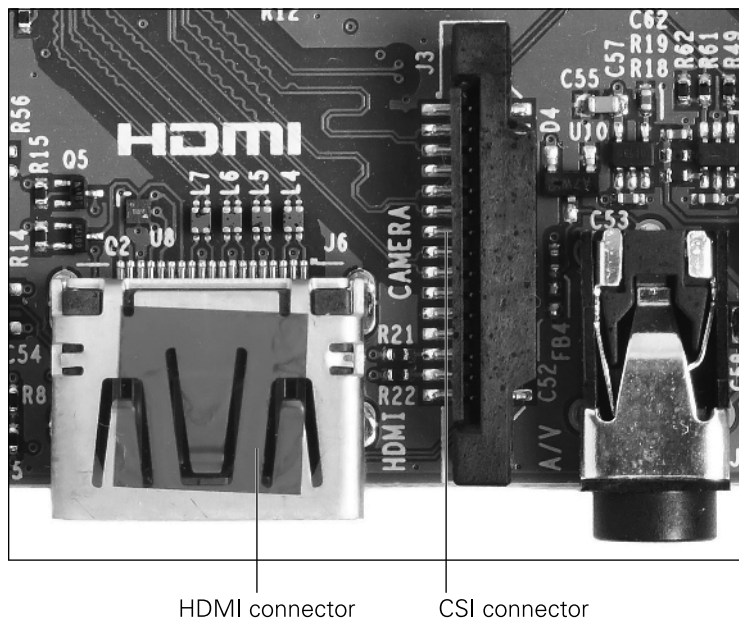


FIGURE 1-9: CSI and HDMI connectors

CSI connects the camera module via a 15-conductor flat flex cable. Getting this cable connected and the camera module working is a bit tricky sometimes. You can find a how-to video on the Raspberry Pi website at <https://www.raspberrypi.org/help/camera-module-setup/>.

However, after the cable sits in the socket properly, the camera works great. You can program it to do all sorts of neat stuff, such as take time-lapse photos and motion-triggered shots or record video footage.

HDMI

There's nothing as fine as a nice big display showing the colourful graphical user interface (GUI) of the Raspberry Pi. A display enables you to surf the web, watch videos, play games—all the stuff you expect a computer to do. The best solution for that involves HDMI.

High-Definition Multimedia Interface (HDMI) allows the transfer of video and audio from an HDMI-compliant display controller (in our case, the Raspberry Pi) to compatible computer monitors, projectors, digital TVs or digital audio devices.

HDMI's higher quality provides a marked advantage over composite video (such as what comes out of the audio socket on the Raspberry Pi board). It's much easier on the eyes and provides higher resolution instead of composite video's noisy and sometimes distorted video.

The HDMI connector on the Raspberry Pi Model B is approximately centred on the lower edge of the Raspberry Pi board (as we have it positioned in Figure 1-5). See Figure 1-9 for what it looks like.

Micro USB Power

The micro USB power connector is on the bottom left edge of the Raspberry Pi, as shown in Figure 1-10.

The micro USB adapter brings power into the Raspberry Pi board. You might know that most smartphones use this connector type, which means you can find usable cables and wall adapters all over the place. (This is one example of how the Raspberry Pi Foundation takes users' need for inexpensive operation into consideration.)

NOTE

You can also get a mobile version of a micro USB charging cable with an automotive power adaptor so you can power your Raspberry Pi in a car, using the built-in car power socket.

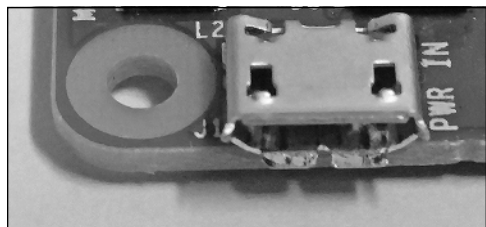


FIGURE 1-10: Micro USB connector used for obtaining power

The micro USB cable supplies 5VDC to the Raspberry Pi at about 1 ampere (1A) of current for the model B. Some recommendations for the B+ mention 1.5A, but if you're pushing heavy current through the USB ports (remember, four instead of two on the B+ and later), a 2A supply is smarter. For the Raspberry Pi 2, get at least a 2.4A supply.

Remember, there's no switch for turning the Raspberry Pi on and off (another saving to keep the price down). You just plug and unplug the micro USB connector. Of course, with a bit of tinkering and soldering, you could add a switch to the power cable easily enough.

Storage Card

Applying power to the Raspberry Pi causes a bit of computer code stored on the board, the bootloader, to check for the presence of the SD or (in newer Raspberry Pi versions) microSD card in its slot (see Figure 1-11) and look for code on the card telling it how to start and what to load into its RAM. If no card is there or that card has no information on it (because it's blank or corrupted) the Raspberry Pi does not start. Read more on the boot process in Chapter 8.

Do not insert or remove an SD card while the Raspberry Pi has power attached. Doing so has a very good chance of corrupting the SD card, causing you to lose the data and programs on it.

WARNING

The usual minimum size recommended for earlier editions of the Raspberry Pi was 8 gigabytes (8GB), although the original recommendation was 4GB. However, a number of people on the Internet report using 32GB cards, and at least one person even boasted of using a 128GB card. It seems, though, that any card larger than 32GB, under Raspbian at least, requires partitioning (using a software to specially format the SD).

Of course, you can hang just about any size of USB drive from one of the USB receptacles, if you use an external power supply. A terabyte would be a good start. The SD card is still needed to boot.

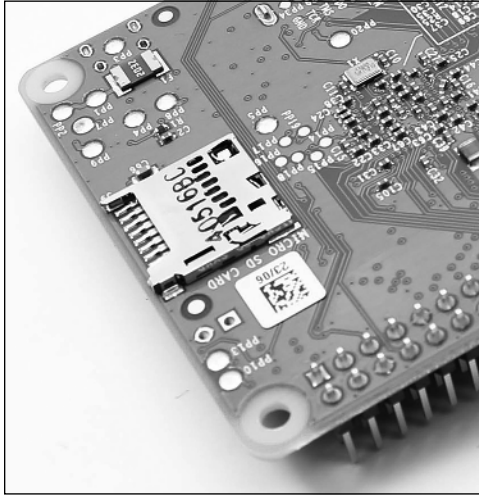


FIGURE 1-11: The micro SD slot on the bottom side of the Raspberry Pi 2

DSI Display Connection

Just right of the SD card slot but on top of the board is the Display Serial Interface (DSI) display connector. The DSI connector's design accommodates a flat 15-conductor cable that drives liquid crystal display (LCD) screens. Figure 1-12 shows the connector.

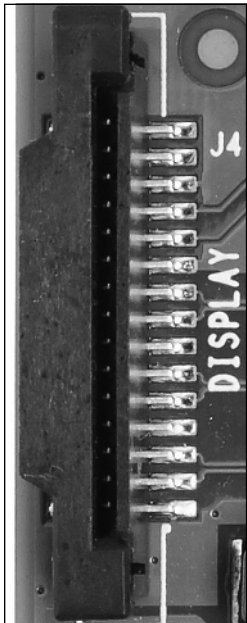


FIGURE 1-12: DSI display connection

Mounting Holes

It might seem minor, but the Model B+ and later models have four mounting holes—those reinforced holes in the board. The Model B only has two. Mounting holes come in handy when you want to secure the Raspberry Pi inside a box or case with other devices.

When you add four standoff insulators, you can use these insulated holes for fastening the board with screws to the standoffs to have a nice, safe installation.

The Chips

There are two large chips situated roughly on the centre of the left of the board (when the board is oriented with the GPIO pins at the top left; see Figure 1-13). The larger one shown is the Broadcom BCM2835 or BCM2836 on the Raspberry Pi 2 or BCM2037 on the Raspberry Pi 3. The other chip provides the Ethernet protocols for networking. You'll find more information about the what these systems-on-a-chip do in Chapter 12.

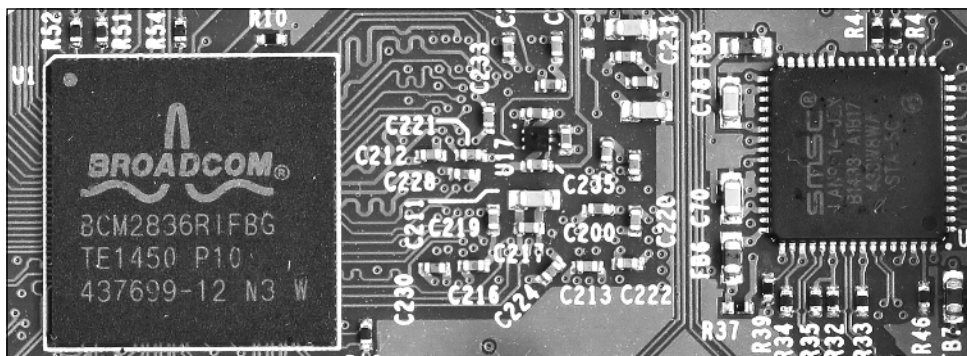


FIGURE 1-13: The SoC and USB/Ethernet chips

The Future

From its inception, the guiding principle of the Raspberry Pi was to enable and revolutionise the teaching of computer science by providing affordable, accessible hardware. It is certainly achieving this goal successfully through the widespread adoption of the Raspberry Pi as a teaching tool in schools worldwide.

The inspiration and excitement young people find, the lessons they learn and the experiments and projects they complete are significant. We are seeing the birth of a new generation of computer experts.

Something else has also happened. Those of us from prior generations—sometimes called “adults” and sometimes not—discovered the Raspberry Pi. Millions of us enthusiastically explore its incredible power and build various projects using its control functions. We, too, are learning things from this tiny computer, which takes the term “microcomputer” to a much smaller scale than those now-huge old desktops. Consequently, we are setting an example for our children. If adults can have so much fun with the Raspberry Pi, younger people realise they can as well, and so they do.

So the Raspberry Pi not only inspires the younger, student generation; it makes older generations better and more computer literate. That’s quite a gift.

What happens next? The next great movement, already in progress, is the Internet of Things. Using the Raspberry Pi, your refrigerator, your car—just about every device you can think of—can become wireless and be controlled by small, easily embedded computerised controls. More and more people will continue to adopt and adapt the means of making this automation a reality. With every new release, demand grows for the Raspberry Pi and the things it can do.

In the next few years, computer architecture will continue to shrink while it grows more capable. We yearn for a thumb drive-sized device that has a 24-core CPU running at 15GHz with 10GB of fast memory and a terabyte solid state drive, all on an SoC.

We anticipate that such a device will sport a purple Raspberry logo. It won’t be long now. The future rushes toward us.