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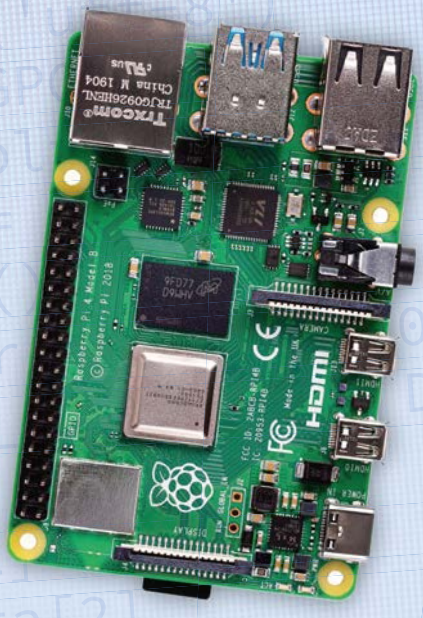
Raspberry Pi for Radio Amateurs

Program and build RPI-based ham station utilities, tools, and instruments.



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Preface

In recent years there has been major changes in the radio equipment used by radio amateurs around the globe (and in orbit!). Although much classical HF and mobile equipment is still in use by large number of amateurs, we see the use of computers and digital techniques becoming very popular among amateur radio operators or 'hams'. In early days of digital communications, personal computers were used by the amateurs to communicate with each other. Personal computers have the disadvantage that they are rather expensive and bulky. Nowadays, anyone can purchase a £40 Raspberry Pi computer and run almost all of the amateur radio software on this computer, which is slightly bigger than the size of a credit card.

Several authors have written books and published projects for using the Arduino in amateur radio projects. Although the Arduino can be used in hardware based projects, it is rather limited since it lacks an operating system. Raspberry Pi is an alternative to Arduino because of its popular operating system, large memory, and rich on-board peripheral support, such as USB, Bluetooth, Wi-Fi, camera interface, etc. As a result of this, Raspberry Pi is well suited to be used as a digital computer for amateur radio, and most of the amateur radio software packages that were available on PCs can now be installed and used on the Raspberry Pi.

The RTL-SDR devices have become very popular by the amateurs because of their very low cost (around £12) and rich features. A basic system may consist of a USB based RTL-SDR device (dongle) with a suitable antenna, a Raspberry Pi computer, an USB based external audio input-output adapter, and software installed on the Raspberry Pi computer. With such a simple setup it is possible to receive signals from around 24 MHz to over 1.7 GHz. With the addition of a low cost upconverter device, an RTL-SDR can easily and effectively receive the HF bands.

This book has four purposes: Firstly, it is aimed to teach the basic operating principles and features of the Raspberry Pi to beginners. Secondly, many hardware based projects are given using the Raspberry Pi together with the Python programming language. Although these projects are general, they have been chosen to be useful to the amateur radio operators. Thirdly, the book explains in some detail how to use the RTL-SDR devices together with a Raspberry Pi and popular RTL-SDR software to tune into and receive signals from a wide range of bands. Lastly, the book explains how to install and use some of the commonly used amateur radio software packages on the Raspberry Pi.

I hope you enjoy reading the book.

Prof Dogan Ibrahim, G7SCU

London, 2020

CHAPTER 1 • Raspberry Pi Models

1.1 Overview

The Raspberry Pi is a low-cost, single-board, powerful computer capable of running a full operating system and also capable of doing everything that a laptop or a desktop computer can do, such as creating and editing documents, getting on the Internet, receiving and sending mails, playing games, developing programs to monitor and control its environment via electronic sensors and actuators, and many more.

Currently, there are many different models of the Raspberry Pi available, each having slightly different features. The fundamental features of all the Raspberry Pi computers are very similar, all using ARM processors, all having the operating system installed on an SD card, all having on-board memory as well as input-output interface connectors. Some models, such as the Raspberry Pi 4, Raspberry Pi 3, and Raspberry Pi Zero W have built-in Wi-Fi and Bluetooth capabilities, making them easy to get online and to communicate with similar devices having Wi-Fi or Bluetooth connectivity.

In this book we shall be concentrating on the most advanced model, which was the Raspberry Pi 4 at the time of writing. All the projects developed in this book will run on this model and virtually all predecessors. Some of the projects may not run on the lower models such as the Raspberry Pi Zero W, but necessary information will be given at the beginning of each project.

In this Chapter we shall briefly take a look at the features of the different models of the Raspberry Pi computer. Interested readers can get further information from the following web site:

https://en.wikipedia.org/wiki/Raspberry_Pi

1.2 Raspberry Pi 1 Model A

This model pictured in Figure 1.1 was released in 2013 has the following features:

SOC:	Broadcom BCM2835
Processor:	ARM1176JZF-S
No of cores:	1
CPU clock:	700 MHz
RAM:	256 MB
Camera interface	
USB ports:	1
HDMI ports:	1
Composite video	
SD/MMC:	SD card
GPIO:	26 pins
Current:	200 mA
Cost:	$20

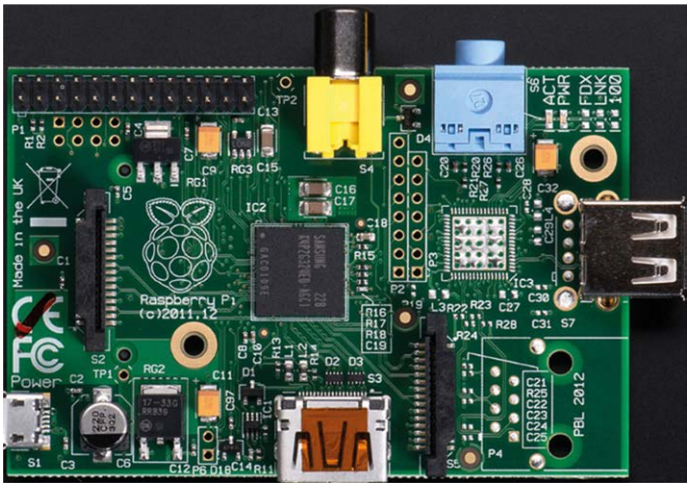

Figure 1.1: Raspberry Pi 1 Model A.

1.3 Raspberry Pi 1 Model A+

This model pictured in Figure 1.2 was released in 2014 and it has the following basic features:

SOC:	Broadcom BCM2835
Processor:	ARM1176JZF-S
No of cores:	1
CPU clock:	700 MHz
RAM:	256 MB
Camera interface	
USB ports:	1
HDMI ports:	1
Composite video	
SD/MMC:	microSD card
GPIO:	40 pins
Current:	200 mA
Cost:	$20

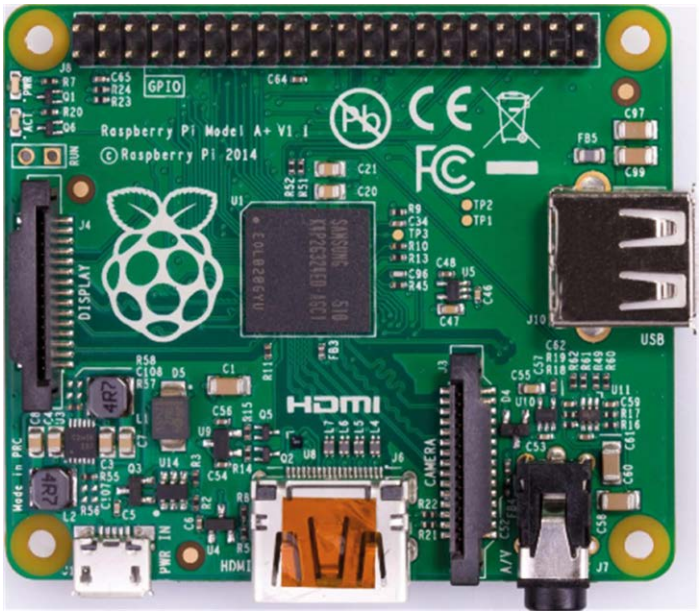

Figure 1.2: Raspberry Pi 1 Model A+.

1.4 Raspberry Pi 1 Model B

This model pictured in Figure 1.3 was released in 2012 and it has the following features:

SOC:	Broadcom BCM2835
Processor:	ARM1176JZF-S
No of cores:	1
CPU clock:	700 MHz
RAM:	512 MB
USB ports:	2
HDMI ports:	1
Ethernet ports:	1
Camera interface	
Composite video	
SD/MMC:	SD card
GPIO:	26 pins
Current:	700 mA
Cost:	$25

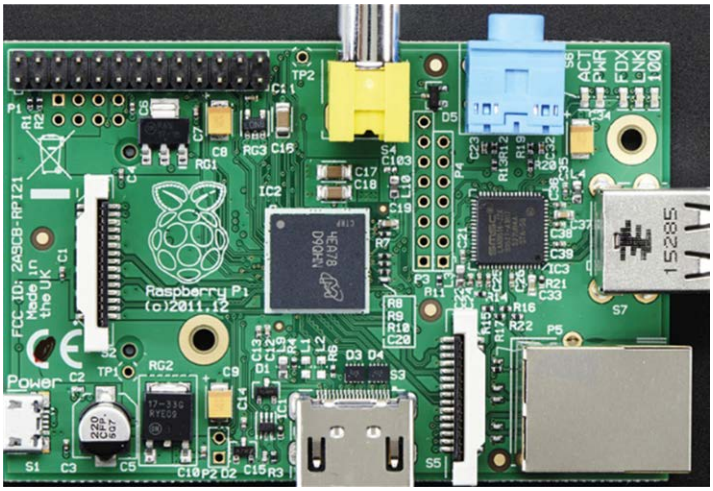

Figure 1.3: Raspberry Pi 1 Model B.

1.5 Raspberry Pi 1 Model B+

This model pictured in Figure 1.4 was released in 2014 and it has the following features:

SOC:	Broadcom BCM2835
Processor:	ARM1176JZF-S
No of cores:	1
CPU clock:	700 MHz
RAM:	512 MB
USB ports:	4
HDMI ports:	1
Camera interface	
Composite video	
Ethernet ports:	1
SD/MMC:	microSD card
GPIO:	40 pins
Current: 700 mA	
Cost:	$25

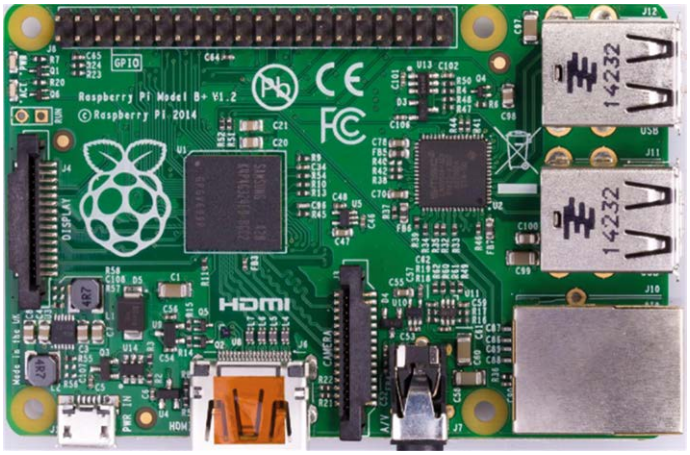

Figure 1.4: Raspberry Pi 1 Model B+

1.6 Raspberry Pi 2 Model B

This model pictured in Figure 1.5 was released in 2015 and it has larger memory, more USB ports, and a faster processor:

SOC:	Broadcom BCM2836
Processor:	Cortex-A7
No of cores:	4
CPU clock:	900 MHz
RAM:	1 GB
USB ports:	4
Ethernet ports:	1
HDMI ports:	1
Camera interface	
Composite video	
SD/MMC:	microSD card
GPIO:	40 pins
Current:	800 mA
Cost:	$35

Figure 1.5: Raspberry Pi 2 Model B.

1.7 Raspberry Pi Zero

This model pictured in Figure 1.6 was released in 2015 and it is a smaller board than the others, but has a fast processor. Its main features are:

SOC:	Broadcom BCM2835
Processor:	ARM1176JZF-S
No of cores:	1
CPU clock:	1 GHz
RAM:	512 MB
USB ports:	1 (micro)
Camera interface	
HDMI ports:	1 (mini)
SD/MMC:	microSD card
GPIO:	40 pins
Current:	160 mA
Cost:	$5

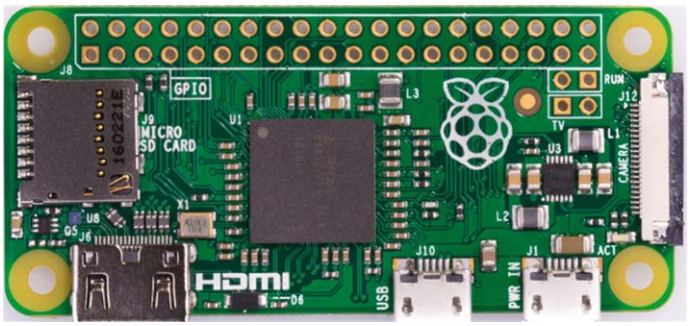

Figure 1.6: Raspberry Pi Zero.

1.8 Raspberry Pi 3 Model B

This model pictured in Figure 1.7 was released in 2016 and its main features are:

SOC:	Broadcom BCM2837
Processor:	Cortex A-53
No of cores:	4
CPU clock:	1.2 GHz
RAM:	1 GB
USB 2.0 ports:	4
Ethernet ports:	1 (10/100 Mbit/s)
HDMI ports:	1
Camera interface	
Composite video	
Wi-Fi:	b/g/n
Bluetooth:	4.1
SD/MMC:	microSD card
GPIO:	40 pins
Current:	1.34 A
Cost:	$35

Figure 1.7: Raspberry Pi 3 Model B.

1.9 Raspberry Pi Zero W

The Raspberry Pi Zero W pictured in Figure 1.8 was released in 2017, and it is a small board (half the size of Model A+) with low current consumption but has a surprising amount of power. Its main advantages are the on-board Wi-Fi and Bluetooth connectivity. The basic features of this model are:

SOC:	Broadcom BCM2835
Processor:	ARM1176JZF-S
No of cores:	1
CPU clock:	1 GHz
RAM:	512 MB
USB ports:	2 (micro)
Camera interface	
HDMI ports:	1 (mini)
Wi-Fi	
Bluetooth	
SD/MMC:	microSD card
GPIO:	40 pins
Current:	180 mA
Cost:	$10

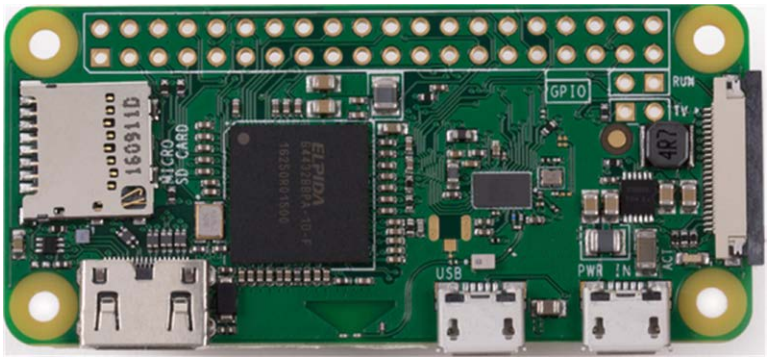

Figure 1.8: Raspberry Pi Zero W.

1.10 Raspberry Pi 3 Model B+

This model pictured in Figure 1.9 was released in 2018 and it has the second fastest processor speed of all the current models. Its main features are:

SOC:	Broadcom BCM2837B0
Processor:	Cortex A-53
No of cores:	4
CPU clock:	1.4 GHz
RAM:	1 GB
USB 2.0 ports:	4
Ethernet ports:	1 (10/100/1000 Mbit/s)
HDMI ports:	1
Camera interface	
Composite video	
Wi-Fi:	b/g/n/ac
Bluetooth:	4.2
SD/MMC:	microSD card
GPIO:	40 pins

Current:	1.13 A
Cost:	$35

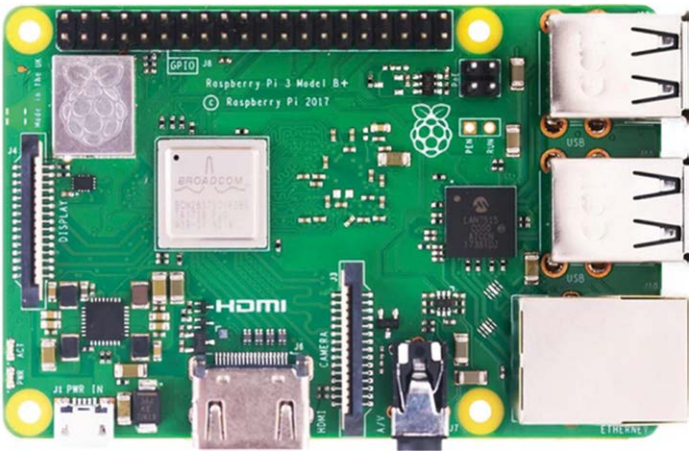

Figure 1.9: Raspberry Pi 3 Model B+.

1.11 Raspberry Pi 4 Model B

This is the latest and the fastest Raspberry Pi (Figure 1.10) that was available at the time of writing this book. The main features of this computer are:

SOC:	Broadcom BCM2711
Processor:	Cortex A-72
No of cores:	4
CPU clock:	1.5 GHz
RAM:	1, 2, 4, or 8 GB
USB 2.0 ports:	2
USB 3.0 ports:	2
USB-C:	1 (power)
Ethernet ports:	1 (10/100/1000 Mbit/s)
HDMI ports:	2
Camera interface	
Composite video	
Wi-Fi:	b/g/n/ac
Bluetooth:	5.0
SD/MMC:	microSD card
GPIO:	40 pins
Current:	1.25 A
Cost:	$35 - $75

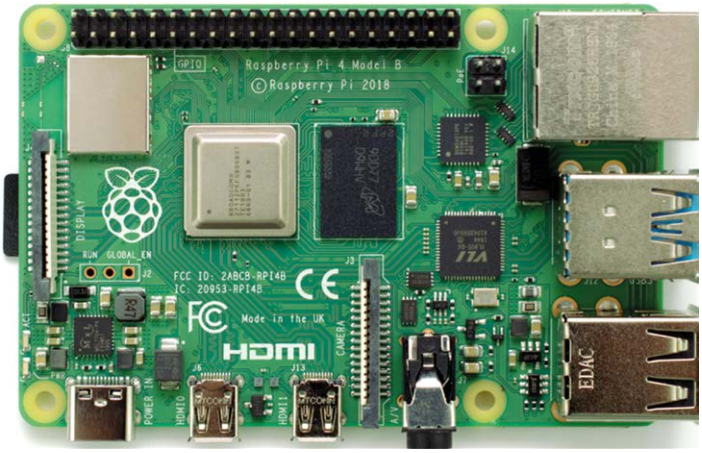

Figure 1.10: Raspberry Pi 4 Model B.

Since we will be using the Raspberry Pi 4 Model B in our projects, it is worthwhile to look at the details of this model in greater detail. In the remainder parts of this book, the name Model B will be dropped, and the board will just be named 'Raspberry Pi 4'.

The new BCM2711 SoC is a very powerful processor. One problem with this processor is that it can get very hot and a fan is recommended to cool it down. At the end of a 10-minute test, the temperature of the processor was measured to be 74.5 ºC (as a comparison, the temperature of a Raspberry Pi Model B+ reached 62.6 ºC during the same period). Several small fans with different shapes and sizes are available to cool the processor chip, and it is recommended that the users choose and use a suitable fan. The fans take their power from the header connector on the board. Some fans for the Raspberry Pi 4 are shown in Figure 1.11 and Figure 1.12. Although large fans are more efficient, it is recommended by the author not to use a too large fan since it can complicate access the GPIO header or the connection of a plug-in board (e.g. a HAT shield) onto the header connector. Because of the higher power consumption, a 3A external power supply is recommended for the Raspberry Pi 4. The power supply is connected to USB-C connector of the Raspberry Pi 4 (Figure 1.13).

Figure 1.11: Large Raspberry Pi 4 fan.

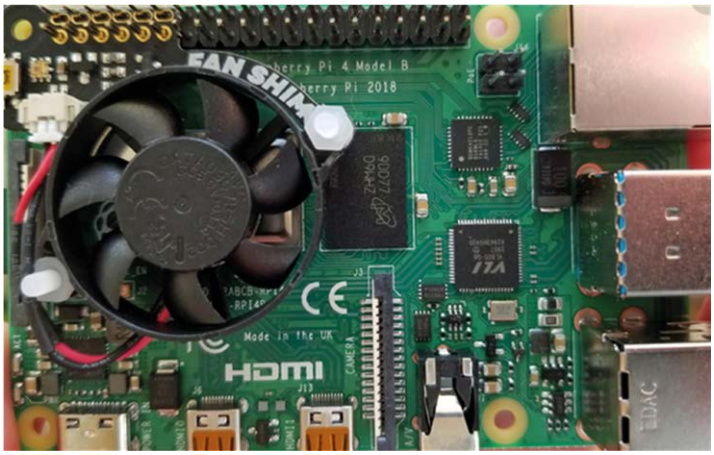

Figure 1.12: Small Raspberry Pi fan.

Figure 1.13: Raspberry Pi 4 USB-C power supply.

Although the Raspberry Pi 4 clock speed is only 100 MHz higher than that of the Raspberry Pi 3 Model B+, its performance is much better as it uses the highly efficient high-speed Cortex-A72 processor. Figure 1.14 shows the Linpack Benchmark speed comparison of the different models (see: https://medium.com/@ghalfacree/benchmarking-the-raspberry-pi-4-73e5afbcd54b). The high performance of the Raspberry Pi 4 is very clear from this figure.

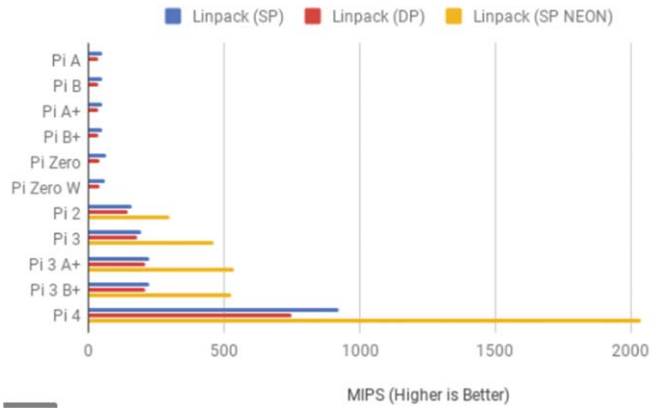

Figure 1.14: Linpack Benchmark.

Image processing time comparison is another benchmark normally used to compare different processors. Figure 1.15 shows the GIMP Image Editing Benchmark of different models. Again, the superiority of the Raspberry Pi 4 is clear from this figure. For example, compared to Raspberry Pi Zero W, the Pi 4 is about 8 times faster in processing an image.

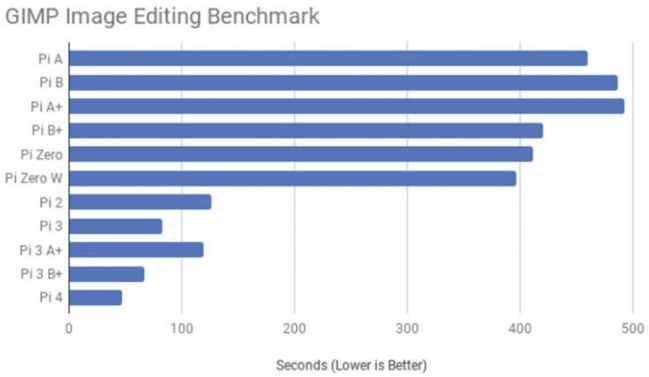

Figure 1.15: GIMP Image Editing Benchmark.

Figure 1.16 shows the component layout on the Raspberry Pi 4 (source: https://www.seeedstudio.com).

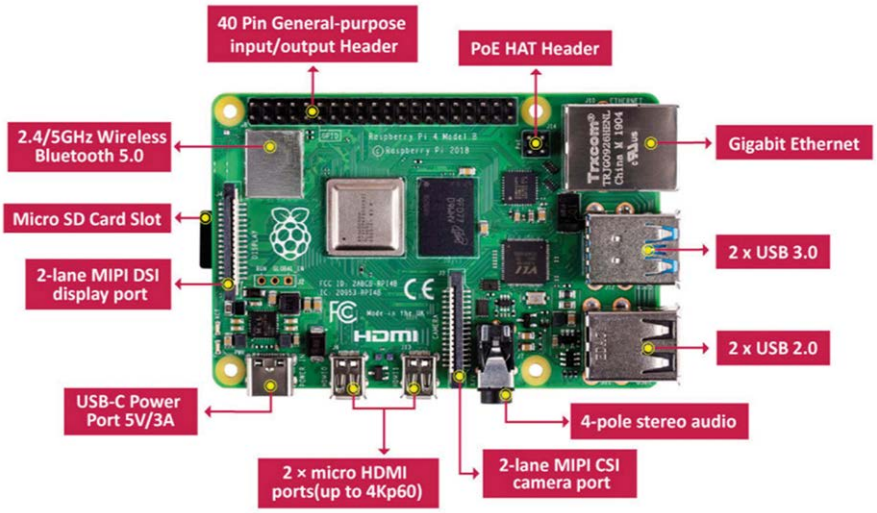

Figure 1.16: Raspberry Pi 4 component layout.

A brief description of the various components on the board is given below.

Processor: the processor is enclosed in a metal cap and it is based on Broadcom BCM2711B0, which consists of a Cortex A-72 core, operating at 1.5 GHz.

RAM: There are three versions of Raspberry Pi 4 depending on the amount of DDR4 RAM required: 1 GB, 2 GB, and 4 GB.

USB Ports: Raspberry Pi 4 includes 2 × USB 3.0, 2 × USB 2.0, and 1 × USB-C ports. USB 3.0 data transfer rate is 4,800 Mbps (megabits per second), while USB 2.0 can transfer at up to 480 Mbps, i.e. 10 times slower than the USB 2.0. The USB-C port enables the board to be connected to a suitable power source.

Ethernet: The Ethernet port enables the board to be connected directly to an Ethernet port on a router. The port supports Gigabit connections (125 Mbps).

HDMI: Two micro-HDMI ports are provided that support up to 4 K screen resolutions. HDMI adapters can be used to interface the board to standard size HDMI devices.

GPIO: A 40-pin header is provided as the GPIO (General Purpose Input Output). This is compatible with the earlier GPIO ports.

Audio and Video Port: A 3.5-mm jack type socket is provided for stereo audio and composite video interface. Headphones can be connected to this port. External amplifier devices will be required to connect speakers to this port. This port also supports composite video, enabling TV sets, projectors, and other composite video compatible display devices to be connected to the port.

CSI Port: This is the camera port (Camera Serial Interface), allowing a compatible camera to be connected to the Raspberry Pi.

DSI Port: This is the display port (Display Serial Interface), allowing a compatible display (e.g. 7-inch Raspberry Pi display) to be connected to the Raspberry Pi.

PoE Port: This is a 4-pin header, allowing the Raspberry Pi to receive power from a network connection.

Micro SD Card: This card is mounted at the card holder placed at the bottom of the board and it holds the operating system software as well as the operating system and user data.

1.11.1 Raspberry Pi 4 purchase and setup options

The user has two options:

- Purchase Raspberry Pi 4 as a kit (see Figure 1.17) including the processor board, power supply, micro SD card with the operating system already loaded, fan, cables, etc.

- Purchase the processor board, the power supply and a blank micro SD card and then build the operating system onto the SD card (the topic of next Chapter)

The choice of whether to purchase a kit or the individual components depends entirely on the user's finances and decisions.

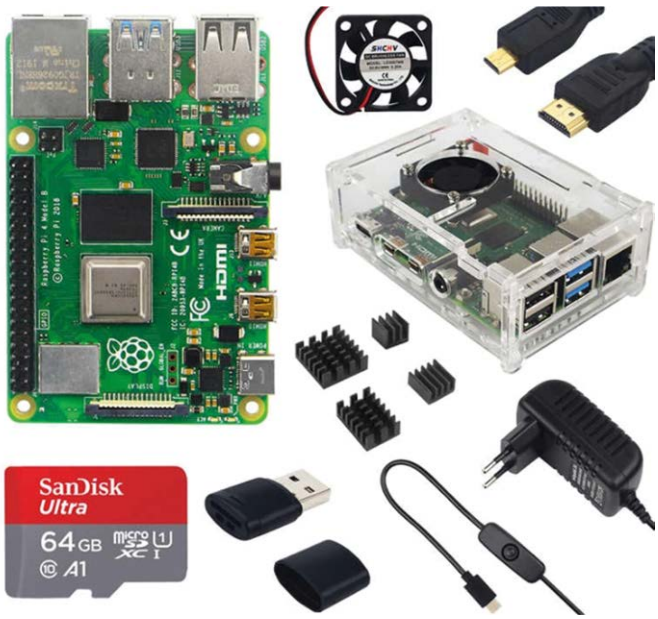

Figure 1.17: Raspberry Pi as a kit.

As shown in Figure 1.18, Raspberry Pi can be set up in two ways: using **direct connection**, or **connecting through a network**

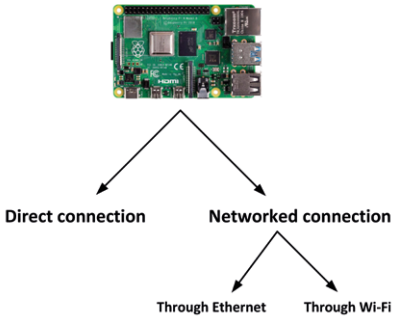

Figure 1.18: Setting up the Raspberry Pi.

Direct connection
This is perhaps the most expensive way of setting up and using the Raspberry Pi 4. In this configuration a monitor and a keyboard are connected to the Raspberry Pi 4. In this setup, the minimum required components are:

- Power supply
- Micro SD card
- Operating system software
- USB keyboard and mouse
- Micro HDMI cable to receive sound and video signals
- HDMI compatible display or TV (you may also need to have micro HDMI to DVI-D or VGA adapters. A 3.5-mm TRRS type cable and plug will be required if you will be using an old TV set with composite video)

Power Supply: As mentioned earlier, a 5 V 3 A power supply with USB-C type connector is required.

Micro SD Card: It is recommended to use a micro SD card with a capacity of at least 8 GB, although higher capacity (e.g. 16 GB or 32 GB) is better as there will be room to grow in the future. A Class 10 (or faster) card is recommended.

Operating System: You can purchase the operating system pre-loaded on a micro SD card, which requires minimum configuration before it is fully functional. The alternative is to purchase a blank micro SD card and upload the operating system on this card. The steps to prepare a new micro SD card with the operating system are given in the next Chapter.

USB Keyboard and Mouse: You can either use a wireless or wired keyboard and mouse pair. When using a wired pair, you should connect the keyboard to one of the USB ports and the mouse to another USB port. When using a wireless keyboard and mouse, you should connect the wireless dongle to one of the USB ports.

Display: A standard HDMI compatible display monitor with a micro HDMI to standard HDMI adapter can be used. Alternatively, a VGA type display monitor with a micro HDMI to VGA adapter or DVI-D adapter can be used. If you have an old TV set with composite video interface (CVBS), then you can connect it to the Raspberry Pi 3.5-mm port with a TRRS type connector.

You may also consider purchasing additional parts, such as a case, CPU fan, and so on. A case is very useful as it protects your Raspberry Pi electronics.

Figure 1.19 shows a possible direct connection setup. Here, depending on what type of display monitor we have, we can use an HDMI display, a VGA monitor, a DVI-D monitor, or a TV. Notice that depending on the external USB devices used, you can use either the USB 2.0 or the USB 3.0 ports.

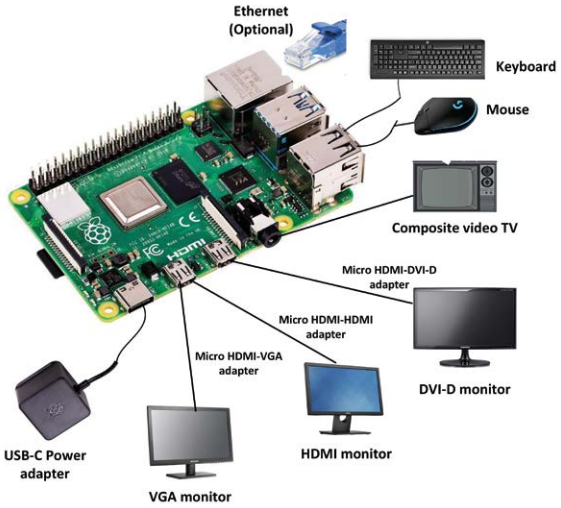

Figure 1.19: Raspberry Pi 4 setup — option 1.

Figure 1.20 shows another way of connecting to the Raspberry Pi directly. In this option, a powered hub is used to connect the USB devices.

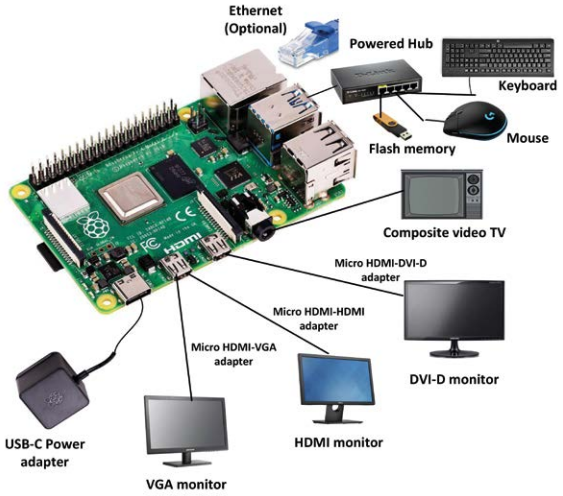

Figure 1.20: Raspberry Pi 4 setup — option 2.

Connecting through a network

Connecting through a network is recommended by the author since it is cheaper, requires less components and is easier to manage. There are two possible ways of setting up and using the Raspberry Pi through a network:

Connection through Ethernet: This option is only available if the Raspberry Pi is equipped with an Ethernet port, such as the Raspberry Pi 2/3/4. As shown in Figure 1.21, in this configuration the Ethernet port is connected directly to the Wi-Fi router (e.g. through a hub) and a PC is used to access the Raspberry Pi over the network. The disadvantage of this method is that the Raspberry Pi has to be close to the Wi-Fi router which may not always be possible or desirable.

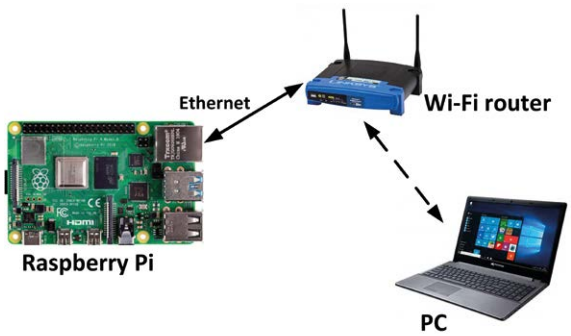

Figure 1.21: Connection through Ethernet.

Wi-Fi connection: This is perhaps the cheapest and the easiest way of using the Raspberry Pi. Here, the Raspberry Pi is connected to the external world through its on-board Wi-Fi module. Most Raspberry Pi models (e.g. Zero W, Pi 2/3/4 etc) are equipped with Wi-Fi

modules. As shown in Figure 1.22, Raspberry Pi is accessed over the Wi-Fi using a PC. The advantage of this method is that it is cheap, easy, and very flexible since the Raspberry Pi can be placed anywhere within the range of the Wi-Fi router.

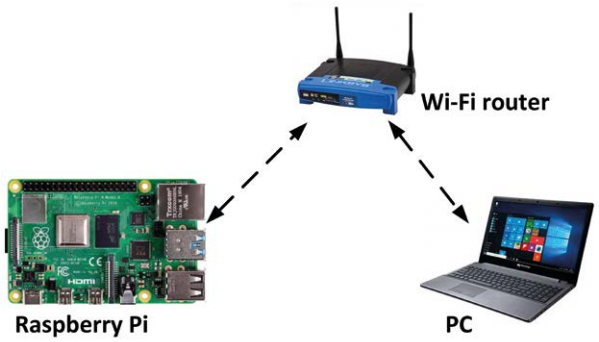

Figure 1.22: Wi-Fi connection.

1.12 Summary

In this Chapter we had a look at the basic features of the different models of the Raspberry Pi computer. It is recommended to use the small and low-cost latest model Raspberry Pi Zero W for Wi-Fi or Bluetooth based applications where 512 MB RAM and 1 GHz clock speed are sufficient. For higher speed and more memory requirements, the slightly more expensive Raspberry Pi 3 or Raspberry Pi 4 are recommended. The Raspberry Pi 4 is the model that is used in all the projects in this book.

In the next Chapter we will be seeing how to load the operating system to Raspberry Pi and how to connect to it through a network.

Chapter 2 • Installing the Operating System on Raspberry Pi

2.1 Overview

In this Chapter we will be learning how to install the latest operating system (**Raspbian Buster**) on the Raspberry Pi 4, and learn the different ways of using the Python programming language. Notice that the installation process given below applies to all Raspberry Pi models unless specified otherwise.

2.2 Raspbian Buster installation steps on Raspberry Pi 4

Raspbian Buster is the latest operating system of the Raspberry Pi. This section gives the steps for installing this operating system on a new blank SD card, ready to use with your Raspberry Pi 4. You will need a micro SD card with a capacity of at least 8 GB (16 GB is even better) before installing the new operating system on it.

The steps to install the Raspbian Buster are as follows:

- Download the Buster image to a folder on your PC (e.g. C:\RPIBuster) from the following link by clicking the Download ZIP under section **Raspbian Buster with desktop and recommended software** (see Figure 2.1). At the time of writing, the file was called: **2020-02-13-raspbian-buster-full.img**. You may have to use the Windows 7Zip software to unzip the download since some of the features are not supported by older unzip software.

  https://www.raspberrypi.org/downloads/raspbian/

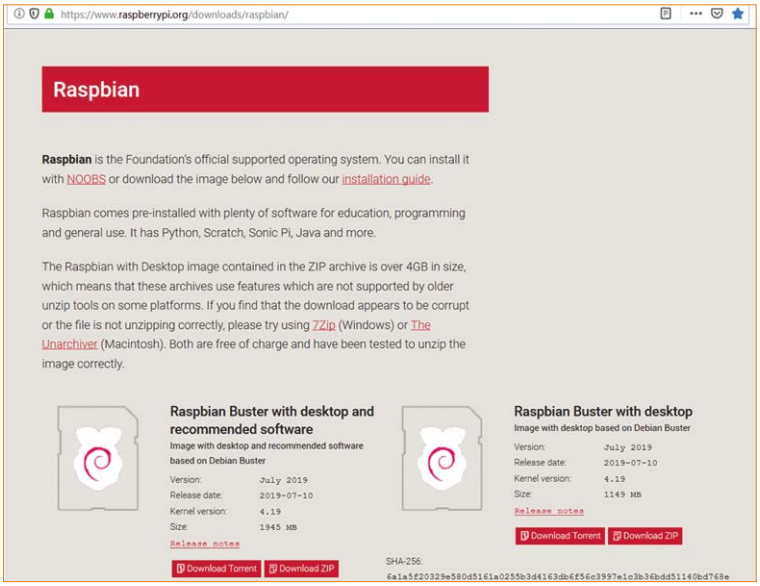

Figure 2.1: Raspbian Buster download page.

- Put your blank micro SD card into the card slot on your computer. You may need to use an adapter to do this.

- Download the Etcher program to your PC to flash the disk image. The link is (see Figure 2.2):

  https://www.balena.io/etcher/

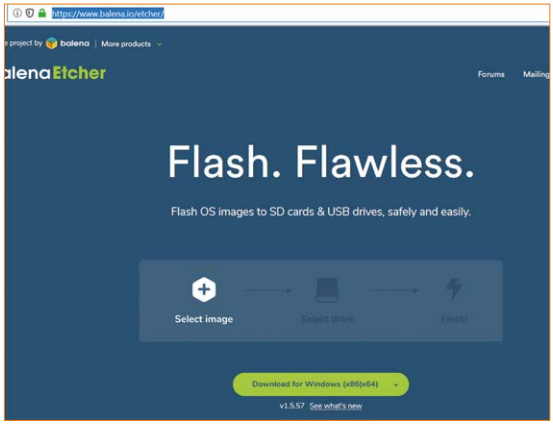

Figure 2.2: Download Etcher.

- Double click to Open Etcher, and click **Select image**. Select the Raspbian Buster file you just downloaded and unzipped.

- Click **Select target** and select the micro SD card

- Click **Flash** (see Figure 2.3). This may take several minutes, wait until it is finished. The program will then validate and unmount the micro SD card. You can remove your micro SD card after it is unmounted.

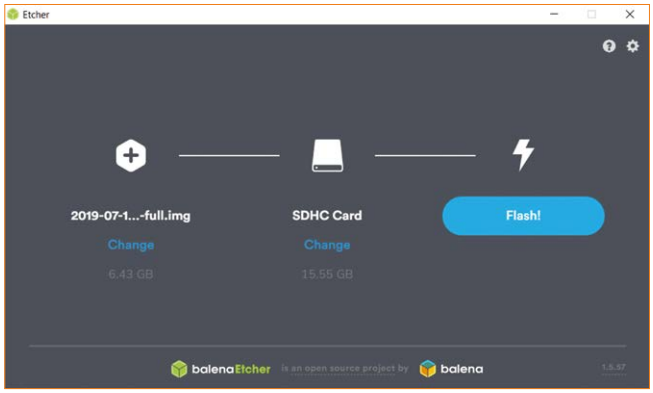

Figure 2.3: Click Flash to flash the disk image.