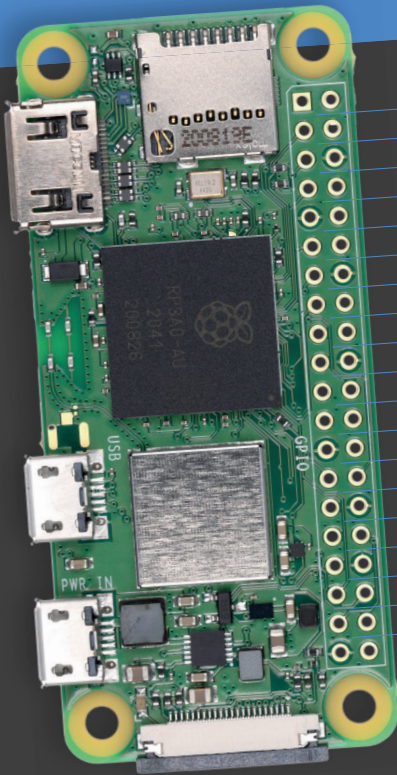


The Raspberry Pi Zero 2 W GO! Book

A Fast-Lane Ride From Concept to Project



3.3 V Power	5 V Power
Serial Data (I2C) GPIO 2	5 V Power
Serial Clock (I2C) GPIO 3	Ground
GPIO 4	GPIO 14 (UART TX)
Ground	GPIO 15 (UART TX)
Chip Enable-CE1 (SPI 1) GPIO 17	GPIO 18* Chip Enable-CE0 (SPI 1) BCK (I2S)
GPIO 27	Ground
GPIO 22	GPIO 23
3.3 V Power	GPIO 24
MOSI (SPI 0) GPIO 10	Ground
MISO (SPI 0) GPIO 9	GPIO 25
SCLK (SPI 0) GPIO 11	GPIO 8 Chip Enable-CE0 (SPI 0)
Ground	GPIO 7 Chip Enable-CE1 (SPI 0)
EEPROM Serial DATA (I2C) GPIO 0	GPIO 1 EEPROM Serial Clock (I2C)
GPIO 5	Ground
GPIO 6	GPIO 12*
GPIO 13*	Ground
MISO (SPI 1) LRCK (I2S) GPIO 19*	GPIO 16 Chip Enable-CE2 (SPI 1)
GPIO 26	GPIO 20 MISO (SPI 1) DIN (I2S)
Ground	GPIO 21 SCLK (SPI 1) DOUT (I2S)

* PWM

+ UDP/TCP + WiFi + Flask + Cloud + TFT + I²C +
 LCD + Arduino + Sensor HAT + Node-RED + Alexa +
 + IoT + MQTT + Bluetooth + Motors + Python +

Dogan Ibrahim

The Raspberry Pi Zero 2 W GO! Book

A Fast-Lane Ride From Concept to Project



Dogan Ibrahim

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Preface

The Raspberry Pi Zero 2 W is the latest member of the Raspberry Pi family of credit card sized computers that can be used in many applications including IoT, digital audio and video media centers, as a desktop computer, in industrial controllers, robotics, and in countless domestic, commercial, and industrial applications. In addition to many features found in "bigger" family members, the Raspberry Pi Zero 2 W also offers Wi-Fi and Bluetooth capability which makes it highly desirable in remote and Internet-based control and monitoring applications. The Raspberry Pi Zero 2 W replaces the older Raspberry Pi Zero W, provides 5 times more computing power, and in addition features Bluetooth capability. As a bonus feature, the Raspberry Pi Zero 2 W comes with a colored pinheader connector, making it easy to link hardware to its GPIO pins.

The book kicks off with the installation of the latest Raspberry Pi operating system on an SD card, followed by the configuration and practical use of the GPIOs. Next, the core of the book explains the use of the Raspberry Pi Zero 2 W running the Python programming language, always in simple terms and backed by many tested and working example projects. On part of the reader, familiarity with the Python programming language and some experience with one of the Raspberry Pi computers will prove helpful. Although previous electronics experience is not required, some knowledge of basic electronics is beneficial, especially when venturing out to modify the projects for your own applications.

The book includes many simple, software-only examples to widen your knowledge of Python. Besides these, over 30 tested and working hardware-based projects are given in the book, covering the use of Wi-Fi, communication with smartphones and with a Raspberry Pi Pico W computer. Additionally, there are Bluetooth projects including elementary communication with smartphones and with the popular Arduino Uno.

All the projects given in the book have been fully tested and are working. The following sub-headings are used in the projects where applicable:

- Project title
- Project description
- Aim of the project
- Block diagram
- Circuit diagram
- Program description using PDL
- Program listing with full documentation

All programs discussed in this book are contained in an archive file you can download free of charge from the Elektor website. Head to: www.elektor.com/books and enter the book title in the Search box. You can easily download and use these programs without any modifications. Alternatively, feel free to modify the programs to suit your own applications.

I hope you find the book helpful and enjoy reading it.

Prof Dogan Ibrahim
London, January 2023

Chapter 1 • The Raspberry Pi Zero 2 W

1.1 Overview

The Raspberry Pi Zero 2 W is an immensely popular member of the Raspberry Pi family of development boards for embedded microcontroller applications. In this chapter, you'll discover the hardware details of this development board and also learn how to install the latest operating system on an SD card for use with the Raspberry Pi Zero 2 W. From now on, this development board will be referred to as the *Zero 2 W* for short.

1.2 The Zero 2 W development board

The Zero 2 W (Figure 1.1) is essentially an upgraded replacement to the popular Raspberry Pi Zero W. It features an RP3A0 system-in-package (SiP), which is a quad-core 64-bit Arm Cortex-A53 CPU clocked at 1 GHz. A Broadcom BCM2710A1 die is incorporated with 512 MB of SDRAM (LPDDR2). The processor provides 40% more single-threaded performance and 5 times more multi-threaded performance than the standard Raspberry Pi Zero.

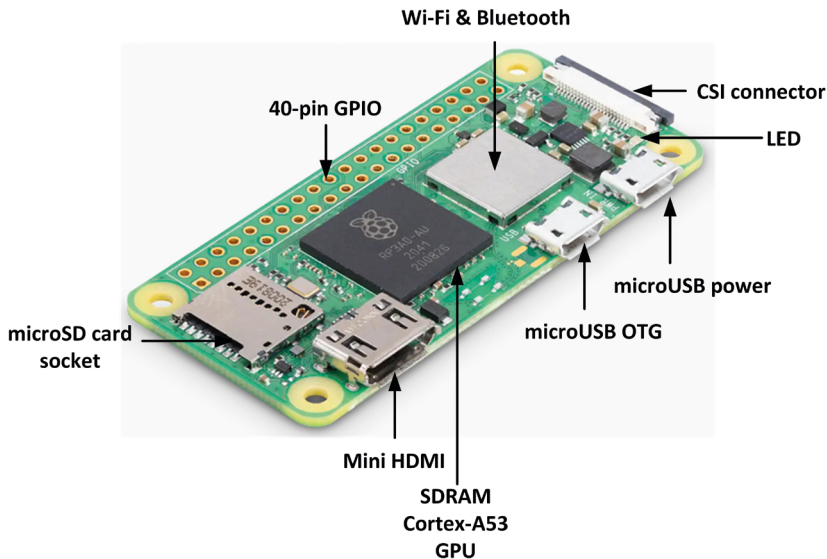


Figure 1.1: Raspberry Pi Zero 2 W.

The basic features of the Zero 2 W may be summarized as follows.

- 64-bit Arm Cortex-A53 processor @ 1 GHz
- Broadcom BCM2710A1 SiP
- 512 MB SDRAM
- 2.4-GHz IEEE 802.11b/g/n wireless LAN
- Bluetooth 4.2 BLE
- On-board antenna
- microSD card slot
- Mini HDMI and Composite video ports

- CSI-2 camera connector
- 1× MicroUSB OTG
- 1× MicroUSB power input
- H.264 MPEG-4 decode (1080p30)
- OpenGL ES 1.1, 2.0 graphics
- HAT compatible 40-pin I/O header
- 5 VDC, 2.5 A input power
- Size 30 mm × 65mm × 13mm
- Weight: 39.97 grams
- Temperature range: -20° to +70° (operation)
- Stated production lifetime: until 2028

The major advantage of the Zero 2 W is that the board incorporates both Wi-Fi and Bluetooth interface modules along with Bluetooth Low Energy (BLE). The board shares the same form factor as the original Raspberry Pi Zero and therefore fits inside existing Raspberry Pi Zero cases. The board is powered externally with 5 V, 2.5 A via a MicroUSB socket.

The Zero 2 W board is available with pre-soldered male color-coded header (**ZERO 2 WHC**) for ease of identifying the pins. This is shown in Figure 1.2. Thick internal copper layers are used to conduct heat away from the processor and consequently achieve higher performance without heating the processor.

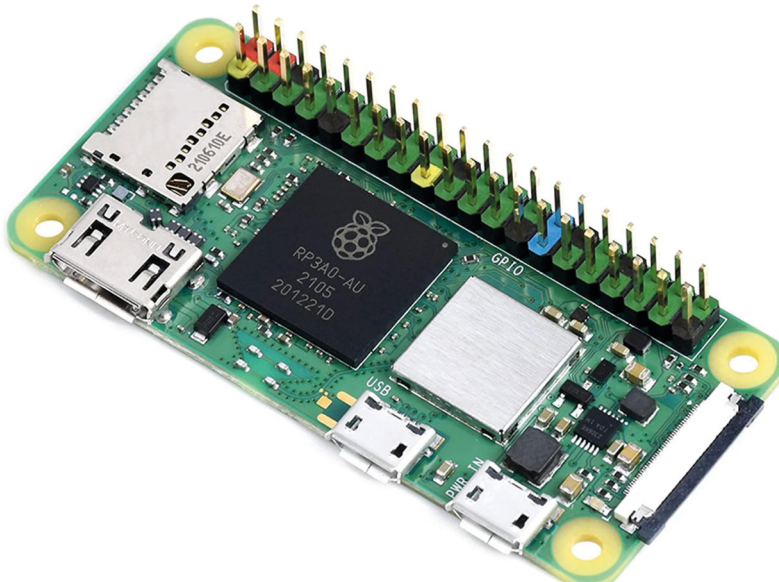


Figure 1.2: Color-coded pinheader.

Table 1.1 shows a comparison of the Zero 2 W with other Raspberry Pi Zero development boards. Notice that the Zero 2 W is a 64-bit device and about 5 times faster than the original Zero W.

	ZERO	ZERO W	ZERO 2 W	ZERO 2WH	ZERO 2 WHC
Processor	BCM2835		BCM2710A1		
CPU	32-bit Single core Arm11		64-bit Quad core Arm Cortex-A53		
Memory	512 MB SDRAM				
GPU	OpenGL ES 1.1, 2.0				
WIFI		2.4 GHz IEEE 802.11b/g/n			
Bluetooth		Bluetooth 4.1 BLE	Bluetooth 4.2 BLE		
USB					
Camera	CSI-2 connector				
GPIO	40-pin				
Pre-soldered header				Black	Colored

Table 1.1: Raspberry Pi Zero W and Zero 2 W comparison.

Figure 1.3 shows the pin configuration of the Zero 2 W board. In this book, the use of a Zero 2 WHC with color-coded header is assumed. The following colors are used on the header (Figure 1.4):

- Red = 5 V
- Orange = 3.3 V
- Black = GND
- Pink = I²C
- Purple = UART
- BLUE = SPI
- Yellow = DNC (reversed I²C)
- Green = GPIO

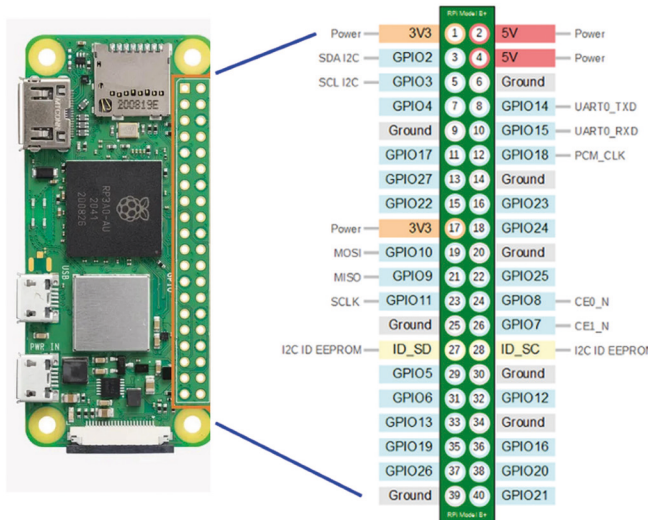


Figure 1.3: Pin configuration.

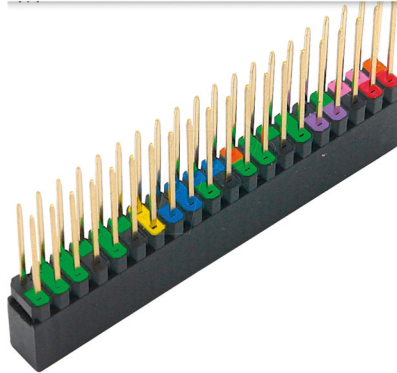


Figure 1.4: Colored header.

1.2.1 Zero 2 W current consumption, and GPIO voltages and currents

The Zero 2 W has 4 cores running at 1 GHz. In idle mode, the Zero 2 W's temperature is about 36.5 degrees Celsius and about 63.4 degrees Celsius when under heavy computing loads. Adding a heatsink helps to reduce the chip temperature. Additional cooling from a heatsink can reduce the temperature considerably.

The Zero 2 W operates at +3.3 V and **the GPIO pins are not +5 V tolerant**. It is therefore important not to connect any peripherals to Zero 2 W that operate at supply voltages exceeding +3.3 V. A voltage between +1.8 V and +3.3 V is read as logic High by the processor. A voltage lower than +1.8 V is read as logic Low.

The Zero 2 W draws about 280 mA when idle and 580 mA when under a heavy computing load. The current limit of a GPIO pin is about 17 mA and more than 51 mA should not be drawn from all GPIO pins at any time.

The GPIO pins can be configured as inputs or outputs. By default, they are configured as inputs on power-up, except GPIO 14 and GPIO 15.

1.3 Installing the operating system

The Raspberry Pi OS (called Raspbian previously) is an officially supported operating system for Raspberry Pi systems. It is a 32-bit Linux based OS that has been configured and optimized to run on Raspberry Pi systems.

The Raspberry Pi operating system is normally stored on an SD card although it is also possible to store it on other media such as an SSD drive. The Raspberry Pi operating system is complimentary and can be downloaded to a PC and then transferred to an SD card that can be used to boot the Raspberry Pi development boards.

The steps to download and transfer the operating system to an SD card are given below. Please note that these are the steps that apply if you are using a Windows PC.

- Go to the Raspberry Pi operating system website (Figure 1.5):

<https://www.raspberrypi.com/software/>

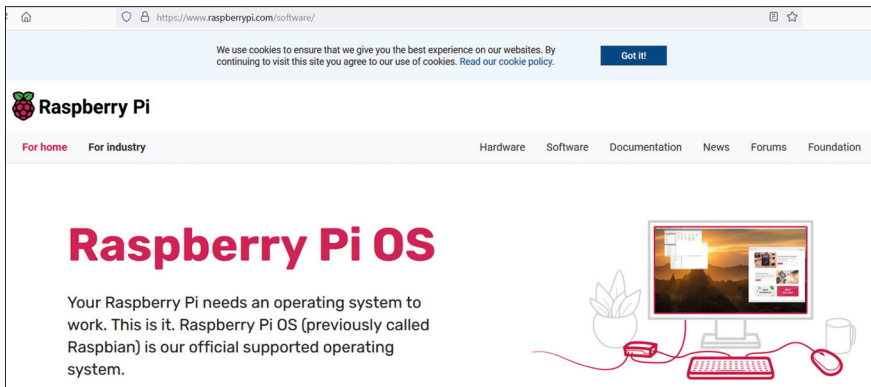


Figure 1.5: Raspberry Pi OS website.

- Scroll down and click **Download for Windows**.
- You should see a file with the name **imager_1.7.3.exe** downloaded to your PC (this was the filename at the time of authoring this book. Your filename may be different).
- Insert the micro SD card into the card holder of your PC (you may have to use an adapter).
- Double-click on the file to install it on your PC.
- Click **Finish** to run the Raspberry Pi Imager (Figure 1.6).



Figure 1.6: Run the Raspberry Pi Imager.

- Click **CHOOSE OS** and click to choose the **Raspberry Pi OS (32-bit)** as shown in Figure 1.7.

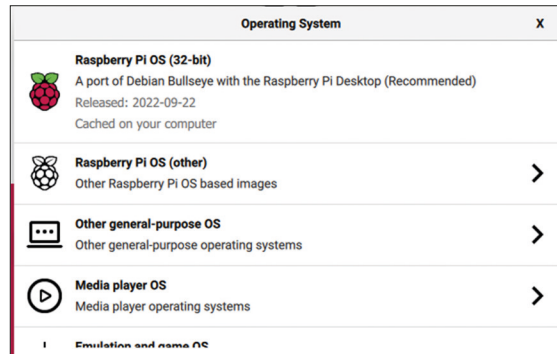


Figure 1.7: Choose the Raspberry Pi OS.

- Click **CHOOSE STORAGE** and select the SD card (Figure 1.8) as the storage medium. A 32-GB micro SD card was used for the examples in this book.

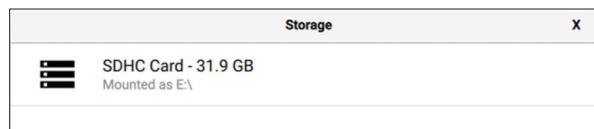


Figure 1.8: Select the SD card.

- Click the Settings icon (gear-shaped) at the bottom right of the screen and set the following (Figure 1.9):

Set hostname: raspberrypi
 Enable SSH
 Select password authentication
 Set Wi-Fi username and password
 Click configure wireless LAN and set the SSID and password
 Set the wireless LAN country: GB
 Set local settings if desired

- Click **Save** to save the settings.
- Click **Write** to write the operating system on the micro SD card. Wait until the write and verify operations are finished (Figure 1.10).

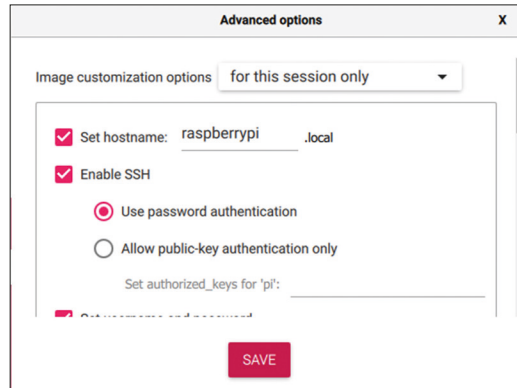


Figure 1.9: Settings options.

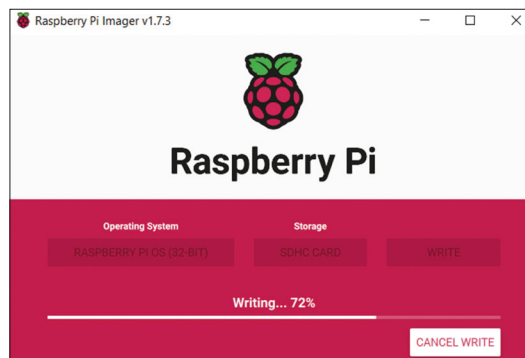


Figure 1.10: Copying the operating system to the micro SD card.

- Remove the micro SD card from the PC.

1.4 Powering-up the Zero 2 W

Insert the SD card into your Zero 2 W. Plug in a monitor and a keyboard if you have these. Plug in the MicroUSB power cable. Your Zero 2 W should boot. If you do not have a monitor and a keyboard you can access your Zero 2 W remotely as described in the next section.

1.5 Remote access

It is much easier to access the Raspberry Pi remotely over the Internet, for example using a PC rather than connecting a keyboard, mouse, and monitor to it. You can use the **Putty** program to access your Zero 2 W remotely from your PC. Before connecting to your Zero 2 W you have to know its IP address. This can be obtained from your Wi-Fi router, or by using an app on your smartphone. There are many freely available apps for both Android and iOS operating systems (e.g., **Who's on my Wi-Fi** for Android) that will scan the Wi-Fi network and display the IP addresses of the devices connected to the Wi-Fi router.

Copy **Putty** to your PC from the following website:

<https://www.putty.org/>

PuTTY is a standalone program and there is no need to install it. Simply double-click to run it and the **PuTTY** startup screen will be displayed. Click **SSH** and enter the Raspberry Pi IP address, then click **Open** (see Figure 1.11). The message shown in Figure 1.12 will be displayed the first time you access the Raspberry Pi. Click **Yes** to accept this security alert.

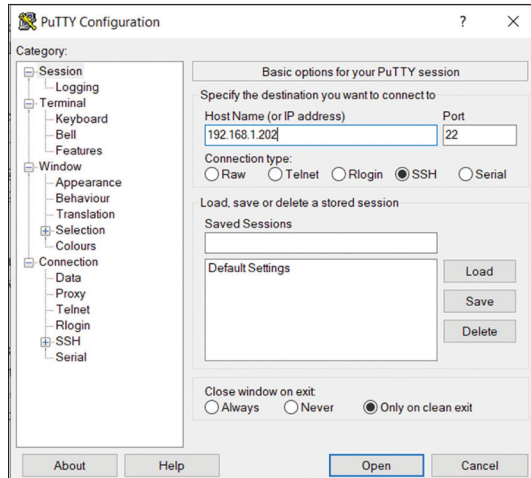


Figure 1.11: PuTTY startup screen.

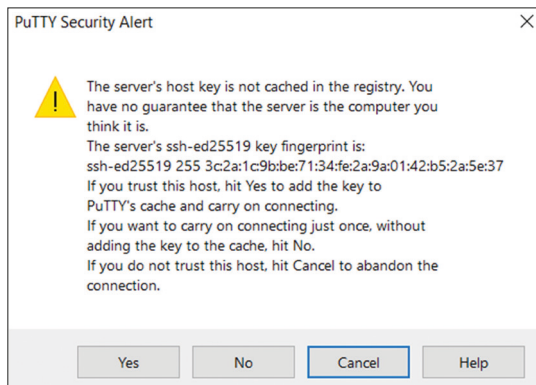


Figure 1.12 Click Yes to accept.

You will be prompted to enter the username and password. After a successful login, you should see the command mode as follows:

```
pi@raspberrypi:~ $
```

You should now enable **VNC** so that your Zero 2 W can be accessed graphically over the Internet using your PC. This can be done by entering the following command at the terminal session:

```
pi$raspberrypi:~ $ sudo raspi-config
```

Go to the configuration menu and select **Interface Options**. Go down to **P3 VNC** and enable VNC. Click **<Finish>** to exit the menu.

1.5.1 Configuring Putty

By default, the **Putty** screen background is black with white foreground characters. The author prefers to have white background with black foreground characters, with the character size set to 12 points bold. You should save your settings so that they are available next time you want to use the Putty. The steps to configure the Putty with these settings are given below.

- Restart Putty.
- Select **SSH** and enter the Raspberry Pi IP address.
- Click **Colors** under **Window**.
- Set the **Default Foreground** and **Default Bold Foreground** colors to black (Red:0, Green:0, Blue:0).
- Set the **Default Background** and **Default Bold Background** to white (Red:255, Green:255, Blue:255).
- Set the **Cursor Text** and **Cursor Color** to black (Red:0, Green:0, Blue:0).
- Select **Appearance** under **Window** and click **Change** in **Font settings**. Set the font to **Bold 12**.
- Select **Session** and give a name to the session (e.g., MyZero) and click **Save**.
- Click **Open** to open the **Putty** session with the saved configuration.
- Next time you restart **Putty**, select the saved session, and click **Load** followed by **Open** to start a session with the saved configuration.

1.5.2 Remote access of the Desktop

If you are using your Zero 2 W with a local keyboard, mouse, and display you can skip this section. If, on the other hand, you want to access your Desktop remotely over the network, you will find that SSH services cannot be used. The easiest and simplest way to access your Desktop remotely from a computer is by installing the VNC (Virtual Network Connection) client and server. The VNC server runs on your Pi and the VNC client runs on your computer. It is recommended to use the **tightvncserver** on your Zero 2 W. The steps are:

- Enter the following command:

```
pi@raspberrypi:~ $ sudo apt-get install tightvncserver
```

- Run the **tightvncserver**:

```
pi@raspberrypi:~ $ tightvncserver
```

You will be prompted to create a password for remotely accessing the Raspberry Pi desktop. You can also set up an optional read-only password. The password should be entered every time you want to access the Desktop. Enter a password and remember it.

- Start the VNC server after reboot by the following command:

```
pi@raspberrypi:~ $ vncserver :1
```

You can optionally specify the screen pixel size and color depth in bits as follows:

```
pi@raspberrypi:~ $ vncserver :1 -geometry 1920x1080 -depth 24
```

- You should now set up a VNC viewer on your laptop (or desktop) PC. There are many VNC clients available but the recommended one which is compatible with TightVNC is the **TightVNC for the PC** which can be downloaded from the following link:

<https://www.tightvnc.com/download.php>

- Download and install the **TightVNC** software for your PC. You will have to choose a password during the installation.
- Start the **TightVNC Viewer** on your PC and enter the Raspberry Pi IP address followed by :1. Click **Connect** to connect to your Raspberry Pi (Figure 1.13).

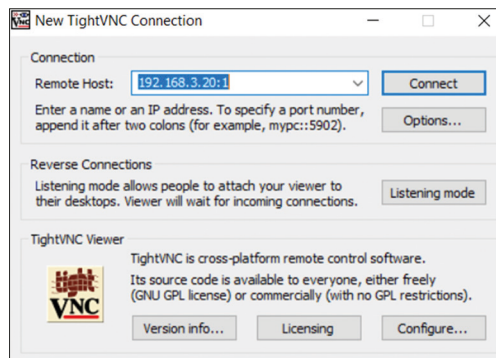


Figure 1.13: Connect to TightVNC Viewer.

- Enter the password you have chosen earlier. You should now see the Raspberry Pi Desktop displayed on your PC screen (Figure 1.14).

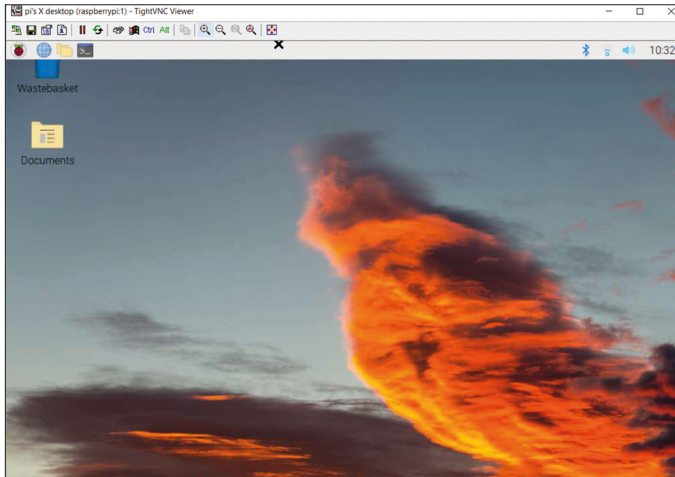


Figure 1.14: Raspberry Pi Desktop.

- The VNC server is now running on your Raspberry Pi Zero 2 W and you have access to the Desktop.

1.6 Assigning static IP address to your Zero 2 W

When you try to access your Raspberry Pi remotely over your local network, it is possible that the IP address given by your Wi-Fi router changes from time to time. This is annoying as you have to find out the new IP address allocated to your Raspberry Pi. Without a knowledge of the IP address, you cannot login using the SSH or the VNC.

In this section, you will learn how to fix your IP address so that it does not change between reboots. The steps are as follows:

- Log in to your Raspberry Pi via SSH.
- Check whether DHCP is active on your Raspberry Pi (it should normally be active):

```
pi@raspberrypi:~ $ sudo service dhcpd status
```

If DHCP is not active, activate it by entering the following commands:

```
pi@raspberrypi:~ $ sudo service dhcpd start  
pi@raspberrypi:~ $ sudo systemctl enable dhcpd
```

- Find the IP address currently allocated to you by entering command **ifconfig** or **hostname -I** (Figure 1.15). In this example the IP address was: 192.168.3.20. You can use this IP address as your fixed address since no other device on the network is currently using it.

```

pi@raspberrypi:~$ hostname -I
192.168.3.20
pi@raspberrypi:~$ █

```

Figure 1.15: Finding the IP address allocated to you.

- Find the IP address of your router by entering the command **ip r** (Figure 1.16). In this example, the IP address was: 192.168.3.1.

```

pi@raspberrypi:~$ ip r
default via 192.168.3.1 dev wlan0 proto dhcp src 192.168.3.20 metric 303
192.168.3.0/24 dev wlan0 proto dhcp scope link src 192.168.3.20 metric 303
pi@raspberrypi:~$ █

```

Figure 1.16 Finding the IP address of your router.

- Find the IP address of your DNS by entering the following command (Figure 1.17). This is usually same as your router address:

```

pi@raspberrypi:~$ grep "nameserver" /etc/resolv.conf

```

```

pi@raspberrypi:~$ grep "nameserver" /etc/resolv.conf
nameserver 192.168.3.1
pi@raspberrypi:~$ █

```

Figure 1.17: Finding the DNS address.

- Edit file **/etc/dhcpd.conf** by entering the command:

```

pi@raspberrypi:~$ nano /etc/dhcpd.conf

```

- Add the following lines to the bottom of the file (these will be different for your router). If these lines already exist, remove the comment character **#** at the beginning of the lines and change the lines as follows (you may notice that **eth0** for Ethernet is listed):

```

interface wlan0
static_routers=192.168.3.1
static domain_name_servers=192.168.3.1
static ip_address=192.168.3.20/24

```

- Save the file by entering **CNTRL + X** followed by **Y** and reboot your Raspberry Pi.
- In this example, the Raspberry Pi should reboot with the static IP address: 192.168.3.20.

Chapter 2 • Using a Text Editor in Command Mode

A text editor is used to create or modify the contents of a text file. There are many text editors around for the Linux operating system. Some popular ones go by the names of **nano**, **vim**, and **vi**. In this chapter, you will learn to use "**nano**" which is the most commonly used text editor in Linux. In later chapters, you will see that the **nano** text editor can be used to create your Python programs.

2.1 The "nano" text editor

Start the **nano** text editor by entering the word **nano**, followed by the filename you wish to create or modify. An example is given below where a new file called **first.txt** is created:

```
pi@raspberrypi ~ $ nano first.txt
```

You should see the editor screen as in Figure 2.1. The name of the file to be edited is written at the top middle part of the screen. The message **New File** at the bottom of the screen shows that this is a newly created file. The shortcuts at the bottom of the screen are there to perform various editing functions. These shortcuts are accessed by pressing the Ctrl key together with another key. Some of the useful shortcuts are given below.

Ctrl+W: Search for a word

Ctrl+V: Move to next page

Ctrl+Y: Move to previous page

Ctrl+K: Cut the current row of txt

Ctrl+R: Read file

Ctrl+U: Paste the text you previously cut

Ctrl+J: Justify

Ctrl+\: Search and replace text

Ctrl+C: Display current column and row position

Ctrl+G: Get detailed help on using the nano

Ctrl+-: Go to specified line and column position

Ctrl+O: Save (write out) the file currently open

Ctrl+X: Exit nano

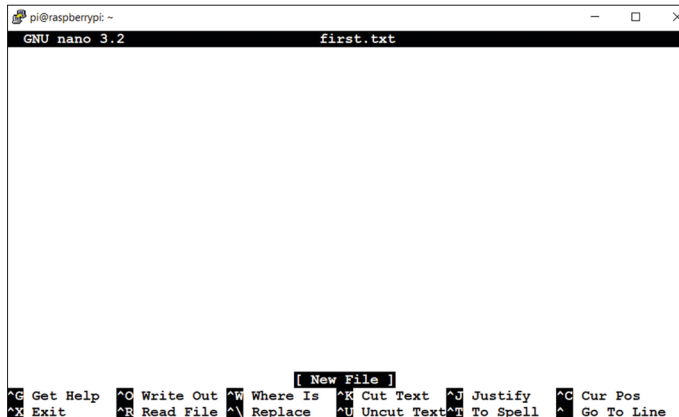


Figure 2.1: The nano text editor startup screen.

Now, type the following text into the file:

```
nano is a simple and yet powerful text editor.
This simple text example demonstrates how to use nano.
This is the last line of the example.
```

The use of **nano** is now demonstrated with the following steps:

Step 1: Go to the beginning of the file by moving the cursor.

Step 2: Look for word **simple** by pressing **Ctrl+W** and then typing **simple** in the window opened at the bottom left hand corner of the screen. Press the Enter key. The cursor will be positioned on the word **simple** (see Figure 2.2).

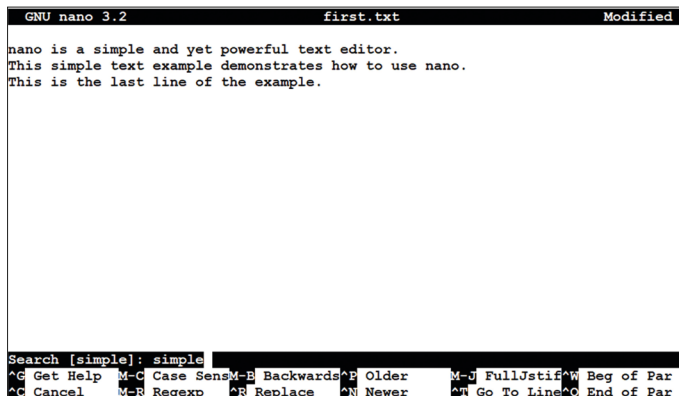


Figure 2.2 Searching for the word "simple".

Step 3: Cut the first line by placing the cursor anywhere on the line and then pressing **Ctrl+K**. The first line will disappear.