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Preface

For such a small, inexpensive device the Raspberry Pi has become a huge global sensation. Creation of this book has provided me, Mike McGrath, a welcome opportunity to demonstrate features of the Raspberry Pi that encourage an interest in computing and programming. Example code listed in this book describes how to develop programs in easy steps – and the screenshots illustrate the actual results. I sincerely hope you enjoy discovering the exciting possibilities of Raspberry Pi and have as much fun with it as I did in writing this book.

In order to clarify the code listed in the steps given in each example, I have adopted certain colorization conventions. Components of the Python programming language are colored blue, programmer-specified names are red, numeric and string data values are black, and comments are green, like this:

```
# Write the traditional greeting.
greeting = "Hello World!"
print( greeting )
```

Additionally, in order to identify each source code file described in the steps, a file icon and file name appears in the margin alongside the steps:

script.py data.txt image.gif sound.wav font.ttf

For convenience, I have placed source code files from the examples featured in this book into a single ZIP archive. You can obtain the complete archive by following these easy steps:

1. Browse to **www.ineasysteps.com** then navigate to Free Resources and choose the Downloads section

2. Find Raspberry Pi 3 in easy steps in the list, then click on the hyperlink entitled All Code Examples to download the archive

3. Next, extract the archive contents to your home directory folder, such as **/home/pi**

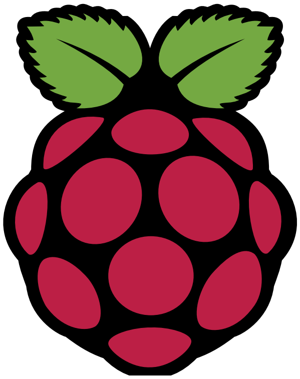
4. Now, call upon the Python interpreter from a Terminal to execute any code example, for instance issue the command **python hello.py** to see the output

1 Getting started

Welcome to the exciting world of the Raspberry Pi. This chapter demonstrates how to establish a fully functional computer system.

Introducing Raspberry Pi

The Raspberry Pi is an inexpensive computer built on a single printed-circuit board. It was developed in the UK by the Raspberry Pi Foundation to encourage the teaching of basic computer science in schools and to put the fun back into learning about computing. The foundation recognized that the school ICT curriculum had changed, placing emphasis on the use of applications, such as Word and Excel, or to writing web pages. Additionally, they noticed that the home PC and games console had replaced the Amigas, BBC Micros, Spectrum ZX and Commodore 64 machines that people of an earlier generation learned to program on. Nowadays, young people have become merely passive users of computers who the foundation considers could benefit from knowing how computers work and how to program them – so they created the cheap, accessible Raspberry Pi computer.



Discover more about Raspberry Pi online at **raspberrypi.org**

In order to keep the price low, the Raspberry Pi 3 Model B has some innovative design features:

- At its heart is an ARM processor that has System-on-Chip (SoC) architecture to integrate several traditionally separate components onto a single chip. The ARM processor runs at 1.2GHz. Typically, ARM processors have previously been used mainly in cellphones.

- Unlike traditional computer design, the Raspberry Pi does not have a hard drive but instead employs a Micro SD card to contain the operating system and to store the files you create. The operating system can be one of several specially optimized variants of the Linux operating system or Windows 10 IoT.

Hot tip

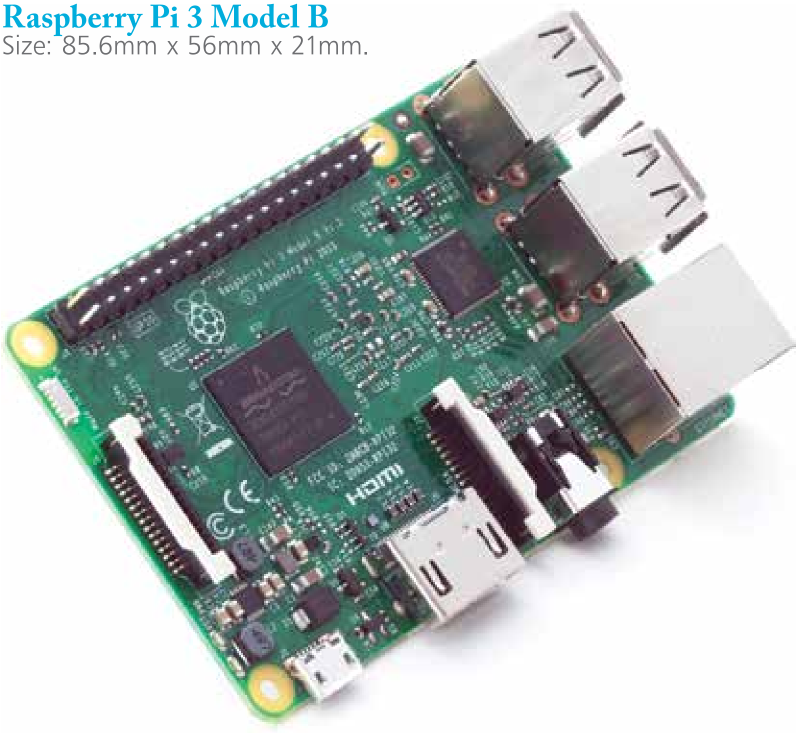
The choice of Linux distributions optimized for the Raspberry Pi are described on page 12.

- The Raspberry Pi 3 Model B has a total memory of just 1GB – which is small compared to that of today's traditional computers. Even with this limitation, surprisingly good performance is achieved as neither the processor nor the operating system are "memory hungry". This in turn allows programs running on the Raspberry Pi to use very low amounts of memory.

- Most noticeably, each Raspberry Pi is supplied without a case so it can be easily built into another device, such as a monitor, and its components can be easily identified.

Raspberry Pi 3 Model B

Size: 85.6mm x 56mm x 21mm.



Component:	Specification:
CPU	1.2GHz 64-bit Quad-core ARMv8
SoC	Broadcom BCM2837 chipset
GPU	Dual-core VideoCore 4 3D
RAM	1GB LPDDR2
Network	802.11 b/g/n Wireless LAN 10/100 Ethernet port (RJ45) Bluetooth 4.1 (Classic & Low Energy)
USB	4 x USB 2.0 ports
GPIO	40 header pins
Video	Full HDMI port
Audio	3.5mm jack and composite video
Camera	Camera Serial Interface (CSI)
Display	Display Serial Interface (DSI)
Storage	Micro SD card slot (push-pull)

Hot tip

The Raspberry Pi 3 has an identical form factor to the previous Pi 2 (and Pi 1 Model B+) and has complete compatibility with Raspberry Pi 1 & 2.

Hot tip

The Raspberry Pi 3 Model B is recommended for use in schools and for general use, but the Pi Zero and the Pi 1 Model A+ are useful for embedded projects that require low power.

Gathering the components

The first step in establishing a computer system with Raspberry Pi is to gather together all the necessary components listed below:

- **Raspberry Pi** – first you will need to get your hands on a Raspberry Pi board itself, available worldwide through Premier Farnell/Element 14, Allied Electronics, and RS Components.
- **Micro SD card** – to contain the operating system, so is recommended at least 8GB capacity and Class 4 or higher.
- **Micro SD card reader** – to write the operating system onto the card, unless you have pre-installed system card.
- **Micro USB 5 volt power source** – typically an cellphone charger or e-book reader charger, providing a power supply output of at least 5V.
- **USB mouse** – any standard mouse.
- **USB keyboard** – any standard keyboard.
- **TV or monitor** – any HDMI/DVI monitor or TV should work, but for best results use one with HDMI input.
- **HDMI cable** – to connect to a TV/monitor.
- **Ethernet cable** – for wired internet connection, unless you use the built-in Wi-Fi adapter to connent to a router wirelessly.

This seemingly long list of requirements is broadly similar to the components of a traditional PC so you may well already have some items on this list, but others you may need to purchase.

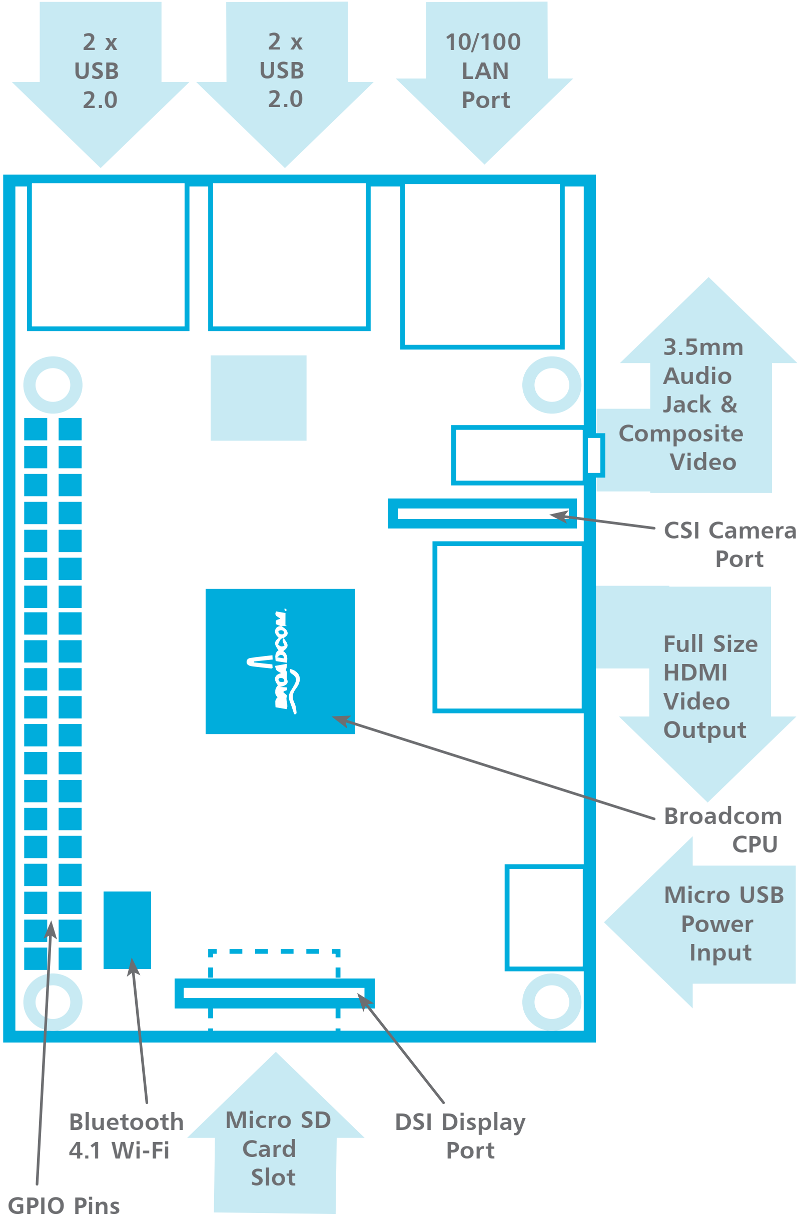
Don't forget

You can find the Raspberry Pi suppliers online at **farnell.com** and at **alliedelec.com** or at **rs-components.com**

Beware

Don't confuse the larger Mini USB standard socket, found on many digital cameras, with the Micro USB standard power socket found on the Raspberry Pi.

Raspberry Pi 3 Model B



When you have gathered together all necessary components they can be connected as shown above – but the Raspberry Pi is not yet functional as the SD card doesn't contain an operating system.

Hot tip

The Camera Serial Interface (CSI) port allows connection of the official Camera Module accessory – an extra available from Raspberry Pi stockists.

Hot tip

The Display Serial Interface (DSI) port allows connection of the official 7" Touchscreen Display accessory – an extra available from Raspberry Pi stockists.

Setting up the SD card

The operating system used by the Raspberry Pi can be one of several specially optimized versions of the Linux operating system. These are known as “distributions”, or “distros” for short. Each available distro is offered as a disk image which must be written onto the Micro SD card to be inserted into the Raspberry Pi. The choice of currently available distros are listed for free download at **raspberrypi.org/downloads**
At the time of writing, the list includes these distros:

- **Raspbian** – recommended for beginners, this distro provides a comprehensive system with a graphical desktop, web browser, and development tools to get you started programming.
- **Ubuntu MATE** – regular Ubuntu desktop distro optimized for Raspberry Pi 2 and Raspberry Pi 3.
- **OSMC** – Open Source Media Center that allows media playback from your local network, attached storage, or the web.
- **OpenELEC** – embedded operating system that provides an open source media hub.
- **PiNet** – classroom operating system that provides centralized student accounts and file storage.
- **RISC OS** – non-Linux alternative operating system.
- **Windows10 IoT** – Microsoft system for Core devices.

Raspbian is a free operating system based on Debian Linux and optimized for Raspberry Pi hardware.

Formatting the SD card

It is recommended that you format the Micro SD card before writing any distro onto the card to ensure best performance:

1. Visit **sdcard.org/downloads/formatter_4** to download a free SD Formatter for Windows or Mac

2. Follow the instructions to install the SD Formatter, then insert your Micro SD card into your card reader and make a note of the drive letter allocated to it, e.g. **E:/**

3. Run SD Formatter then select the drive letter of your Micro SD card and format the card

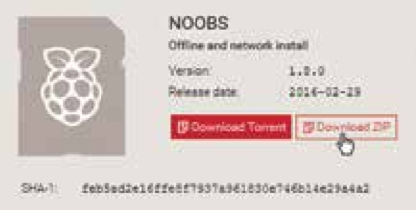
The Micro SD card should be at least 8GB capacity and at least Class 4 speed.

…cont'd

Installing the Raspbian operating system

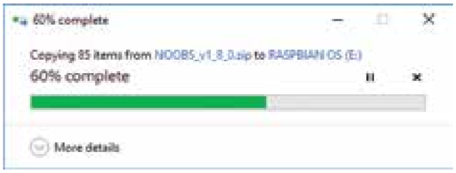
This book demonstrates the officially recommended Raspbian distro that can be written onto your Micro SD card using the "NOOBS" (**N**ew **O**ut **O**f the **B**ox **S**oftware) easy installer.

1. Go to **raspberrypi.org/downloads/noobs** and click the **Download ZIP** button to download the installer



NOOBS
Offline and network install
Version: 1.8.0
Release date: 2016-02-29
SHA-1: feb5ed2e16ffe8f7937a961830e746b14e29a4a2

2. Extract all contents in the downloaded ZIP file to your Micro SD card to copy the installer



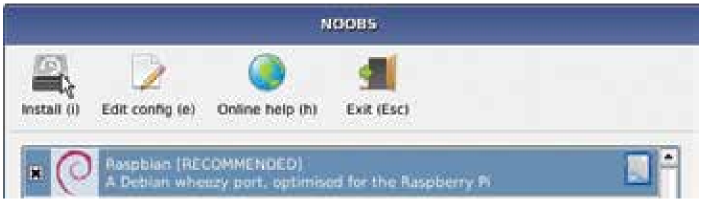
60% complete
Copying 85 items from NOOBS_v1_8_0.zip to RASPBIAN OS (E:)
60% complete

3. Remove the Micro SD card from the card reader and insert it into your Raspberry Pi

4. Plug in your keyboard, mouse and monitor cables

5. Now, plug in the USB power cable to your Raspberry Pi to see it boot to a window offering a list of operating systems you can install

6. Check the box next to the "Raspbian" option, then click the **Install** button to install the operating system



☒ Raspbian [RECOMMENDED]
A Debian wheezy port, optimised for the Raspberry Pi

7. When the installation process has completed, you can turn the power off, then back on, to start the operating system

Hot tip

You can alternatively purchase a pre-installed NOOBS Micro SD card from Raspberry Pi retailers.

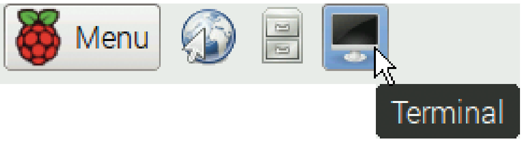
Beware

The drive letter assigned to the SD card on your system may be different to the one shown here.

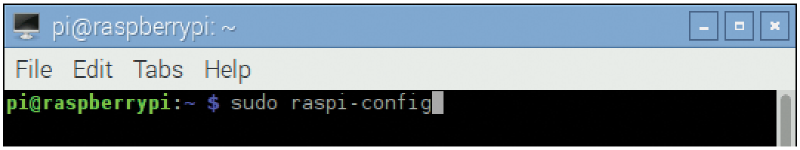
Configuring the system

After you start up your Raspberry Pi you can set up various system options using the configuration tool:

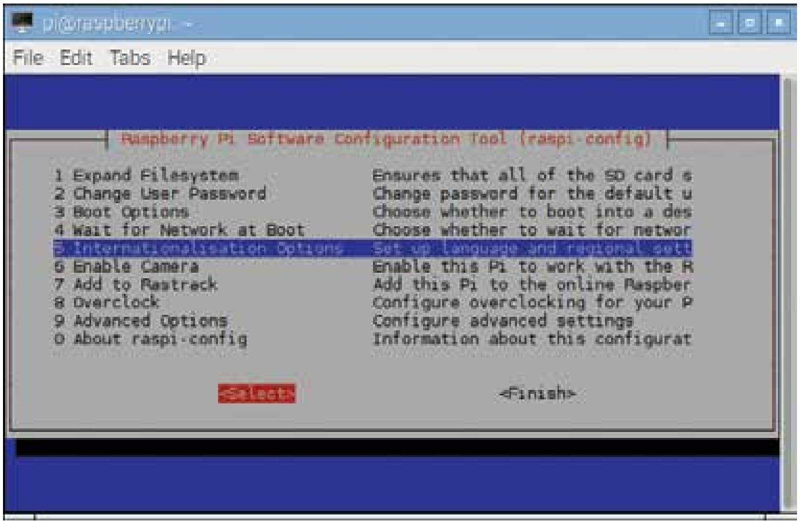
1. Click the "Terminal" launcher button to open a Terminal window that provides a command line prompt



2. Precisely type the command **sudo raspi-config** at the prompt, then hit Return to open the configuration tool



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



```
        Raspberry Pi Software Configuration Tool (raspi-config)

 1 Expand Filesystem              Ensures that all of the SD card s
 2 Change User Password           Change password for the default u
 3 Boot Options                   Choose whether to boot into a des
 4 Wait for Network at Boot       Choose whether to wait for networ
 5 Internationalisation Options   Set up language and regional sett
 6 Enable Camera                  Enable this Pi to work with the R
 7 Add to Rastrack                Add this Pi to the online Raspber
 8 Overclock                      Configure overclocking for your P
 9 Advanced Options               Configure advanced settings
 0 About raspi-config             Information about this configurat

              <Select>                       <Finish>
```

3. Use the keyboard up/down arrow keys to highlight an item you wish to configure

4. Hit the Return key to select a highlighted item and reveal its options, e.g. choose "Internationalisation Options"

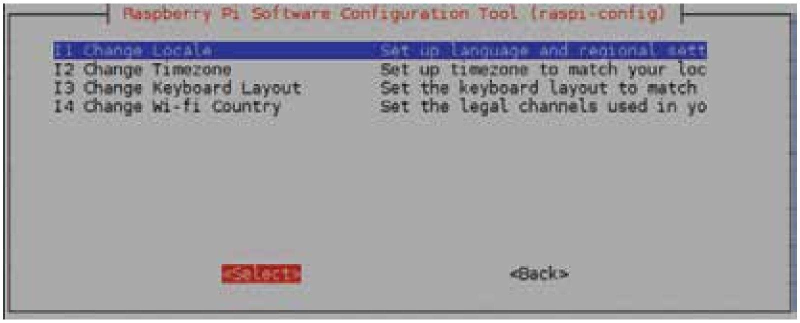
Don't forget

The **sudo** command provides administration privileges that allow system configuration changes.

Hot tip

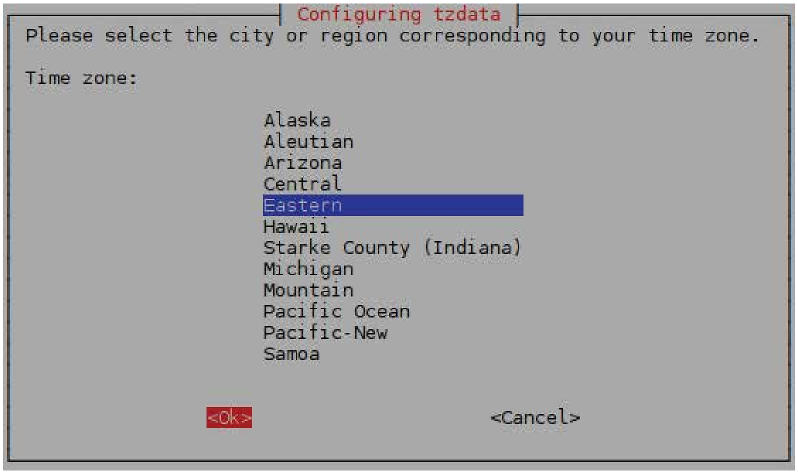
If the Raspberry Pi screen does not fill your monitor, choose the Advanced Options' "Overscan" configuration menu item then select the "Disable" option.

5. Use the arrow keys to now choose "Change Locale" and deselect the current character set from the list then select a character set for your locale – such as "en_US.UTF-8"



```
┤ Raspberry Pi Software Configuration Tool (raspi-config) ├

  I1 Change Locale                 Set up language and regional sett
  I2 Change Timezone               Set up timezone to match your loc
  I3 Change Keyboard Layout        Set the keyboard layout to match
  I4 Change Wi-fi Country          Set the legal channels used in yo



              <Select>                       <Back>
```

6. Choose "Change Timezone" and select your region and timezone – such as "America" then "Eastern"

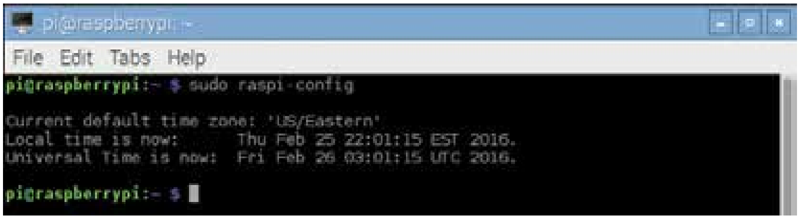


```
                    ┤ Configuring tzdata ├
 Please select the city or region corresponding to your time zone.

 Time zone:

                     Alaska
                     Aleutian
                     Arizona
                     Central
                     Eastern
                     Hawaii
                     Starke County (Indiana)
                     Michigan
                     Mountain
                     Pacific Ocean
                     Pacific-New
                     Samoa

                <Ok>                      <Cancel>
```

Hot tip

You can re-visit the configuration menu at any time from a command prompt by issuing the command **sudo raspi-config**.

7. Press the right arrow key to select "OK", then hit Return to apply the configuration change



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

Current default time zone: 'US/Eastern'
Local time is now:      Thu Feb 25 22:01:15 EST 2016.
Universal Time is now:  Fri Feb 26 03:01:15 UTC 2016.

pi@raspberrypi:~ $ 
```

Logging into the console

Where the Raspbian operating system is configured to not automatically start the graphical desktop, your Raspberry Pi will start up with the boot messages then display a login prompt where you must enter a username and password to proceed.

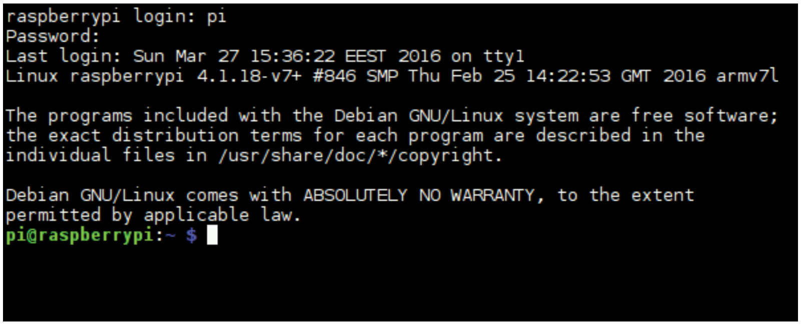
If you make a mistake entering the username or password you will simply be returned to the login prompt so you can try again.

The Raspbian system is supplied configured with a single default user named “pi” whose login password is “raspberry”. These can therefore be used at the login prompt to access the system at its Command-Line Interface (CLI). This is known as the “console” – historically describing the keyboard and monitor combination from the days before the mouse and graphical desktop. When a login attempt succeeds, a colorful user command prompt appears where you can enter commands to interact with the system.

1. Start up your Raspberry Pi and watch the boot process until a login prompt appears – type **pi** then hit Return

2. When the password prompt appears, type **raspberry** then hit Return – see the user prompt appear after system info

Linux is case-sensitive so you must always observe correct capitalization. For example, **pi**, **Pi**, and **PI** are distinctly different.

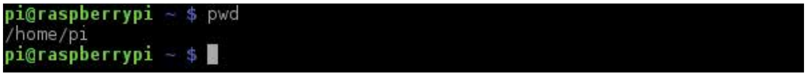


```
raspberrypi login: pi
Password:
Last login: Sun Mar 27 15:36:22 EEST 2016 on tty1
Linux raspberrypi 4.1.18-v7+ #846 SMP Thu Feb 25 14:22:53 GMT 2016 armv7l

The programs included with the Debian GNU/Linux system are free software;
the exact distribution terms for each program are described in the
individual files in /usr/share/doc/*/copyright.

Debian GNU/Linux comes with ABSOLUTELY NO WARRANTY, to the extent
permitted by applicable law.
pi@raspberrypi:~ $
```

The Raspberry Pi user prompt contains several components describing your username **pi**, machine name **raspberrypi** and current file location ~ (tilde – an alias for the **/home/pi** directory). You can confirm your current location on the filesystem at any time by entering the command **pwd** (print working directory).

The password will not be displayed as you type it at the password prompt – so it cannot be stolen from over your shoulder.

3. At the user prompt, type **pwd** then hit Return – see the current directory appear then another user prompt



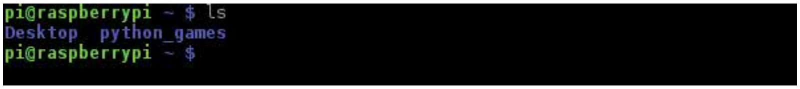
```
pi@raspberrypi ~ $ pwd
/home/pi
pi@raspberrypi ~ $
```

You can discover the contents of the current directory by entering the command **ls** (list sorted). This displays a list of folders and files within the current directory, but not hidden system files. Like most Linux commands, "switches" can be added after the command to change how they respond. So with the **ls** command, adding a **-a** switch will display all content, including system files.

Hot tip

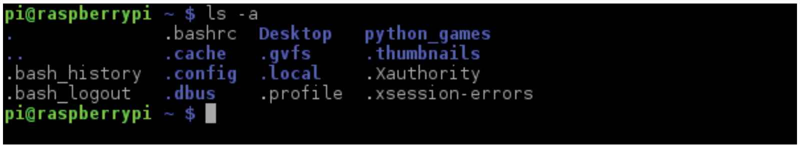
Switches can be combined, so that **ls -al** is equivalent to **ls -a -l** as both will display all content in long format.

4. At the user prompt, type **ls** then hit Return – see the current directory contents appear



```
pi@raspberrypi ~ $ ls
Desktop  python_games
pi@raspberrypi ~ $
```

5. Now, at the user prompt, type **ls -a** then hit Return – see the current directory contents including system files



```
pi@raspberrypi ~ $ ls -a
.                .bashrc  Desktop   python_games
..               .cache   .gvfs     .thumbnails
.bash_history    .config  .local    .Xauthority
.bash_logout     .dbus    .profile  .xsession-errors
pi@raspberrypi ~ $
```

Hot tip

Notice that system content names are prefixed by a period, and directories are blue color.

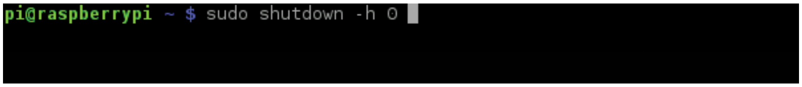
You can clear past command results using the **clear** command and discover switches available for any command, plus what they achieve, using the **man** command followed by the command name, e.g. **man ls** to display the switches for the **ls** command.

It is important to recognize that Linux is designed as a multi-user system, so regular users cannot perform all tasks – some can only be performed by the system administrator ("root" or "superuser"). But for convenience you can temporarily assume superuser status to do something with the **sudo** command, for example to close Raspberry Pi with the **shutdown** command. This accepts a **-h** (halt) switch or a **-r** (reboot) switch, followed by a number indicating a delay in minutes, or zero for no delay.

Hot tip

The system remembers your past commands – use the up and down arrow keyboard keys to scroll through them at the user prompt then hit Return to re-run your chosen past command.

6. Finally, at the user prompt, type **sudo shutdown -h 0** then hit Return – see the system close down immediately



```
pi@raspberrypi ~ $ sudo shutdown -h 0
```

Starting the desktop

Interacting with your Raspbian system at the Command-Line Interface (CLI) gives an insight into the power of commands. Many Linux “boxes” are used at just that level, especially web servers, but you will probably want to see a more familiar graphical desktop that lets you interact using your mouse.

With the Raspbian system, an “X” server provides a Graphical User Interface (GUI) that automatically employs a window manager to control running application windows.

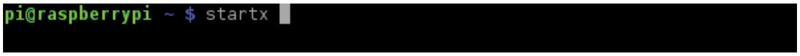
When you boot Raspbian, the X server will not automatically get started if you configure your system as a basic console. Simply issuing a **startx** command at the command prompt will start the X server and load the graphical desktop environment.

Hot tip

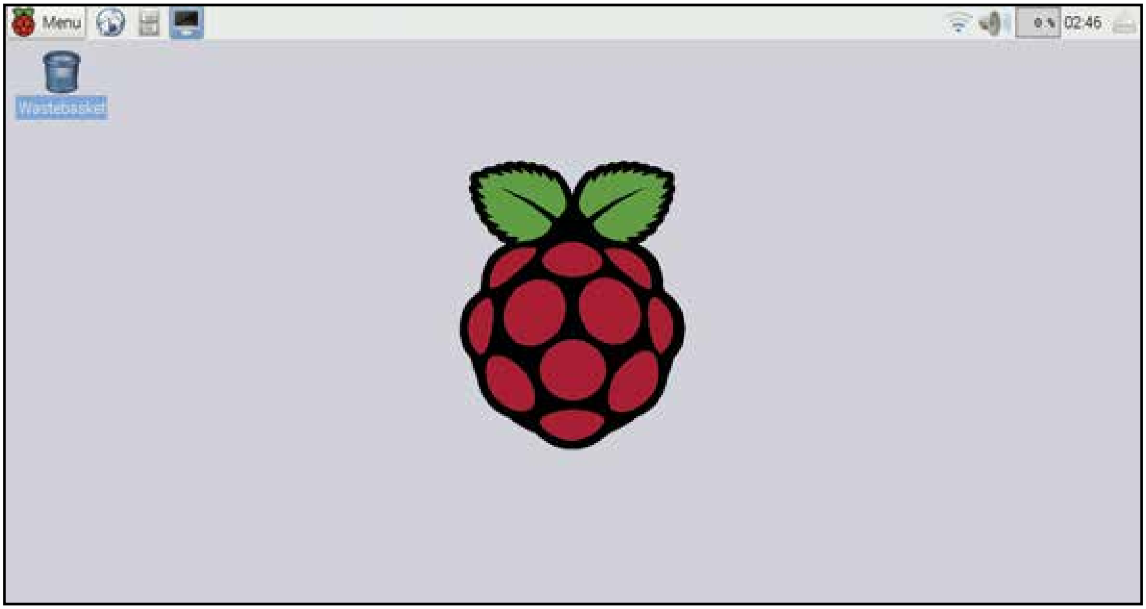
You can use Boot Options in the configuration tool to change how your system starts up (see page 20).

1. Start up your Raspberry Pi then log in to the system as the default user **pi** with the **raspberry** password

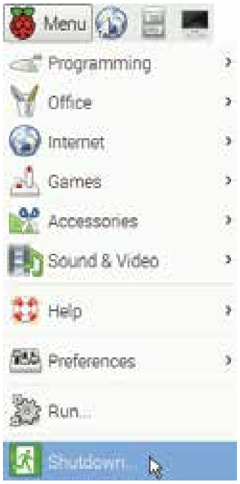
2. When the user prompt appears, type **startx** then hit Return – see the graphical desktop load in the screen

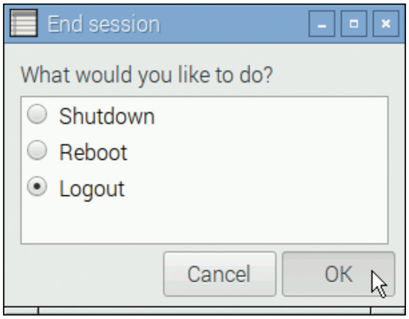


```
pi@raspberrypi ~ $ startx
```



3 Click the Menu button then select the Shutdown menu item – to launch the "End session" dialog box




End session

What would you like to do?

○ Shutdown
○ Reboot
● Logout

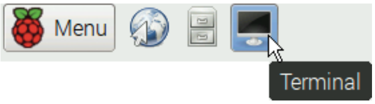
Features of the graphical desktop are described in the next chapter – but you may like to explore the menu items now.

4 Choose "Logout" then click **OK** to close the desktop

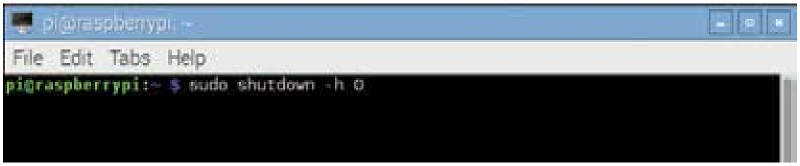
5 Enter your username and password to restart the desktop

If you wish to shutdown the system you can do so from the "End session" dialog or from a command prompt in a Terminal window or in a basic console.

1 Click the "Terminal" launcher button to open a Terminal window that provides a command line prompt



2 Precisely type the command **sudo shutdown -h 0** at the prompt, then hit Return to completely close the system



```
pi@raspberrypi:~ $ sudo shutdown -h 0
```

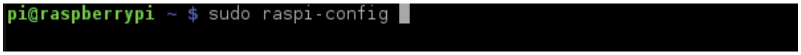
You can restart the system using the Reboot option in the "End session" dialog or from a command prompt by issuing the command **sudo shutdown -r 0**.

Automating the login

Unless you particularly wish to use your Raspberry Pi as a console system it becomes tedious to log in and start the X server manually, so the process can be automated using the configuration tool.

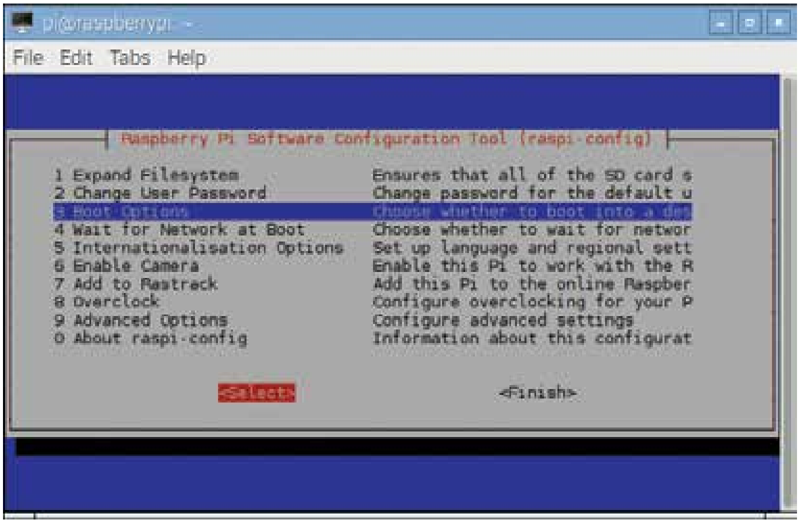
1. Start up your Raspberry Pi then log in to the system as the default user **pi** with the **raspberry** password

2. When the user prompt appears, type **sudo raspi-config** then hit Return – see the configuration tool appear



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

3. When the configuration menu appears, use the up/down keyboard arrow keys to choose the “Boot Options” item – then hit Return to select it



```
Raspberry Pi Software Configuration Tool (raspi-config)

1 Expand Filesystem              Ensures that all of the SD card s
2 Change User Password           Change password for the default u
3 Boot Options                   Choose whether to boot into a des
4 Wait for Network at Boot       Choose whether to wait for networ
5 Internationalisation Options   Set up language and regional sett
6 Enable Camera                  Enable this Pi to work with the R
7 Add to Rastrack                Add this Pi to the online Raspber
8 Overclock                      Configure overclocking for your P
9 Advanced Options               Configure advanced settings
0 About raspi-config             Information about this configurat

            <Select>                         <Finish>
```

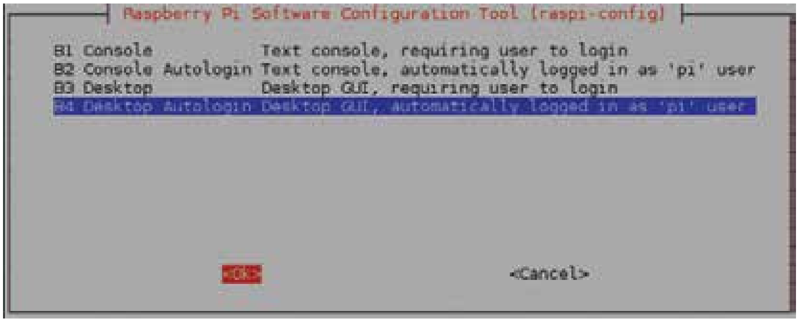
4. In the list of options that appears next, use the up/down keyboard arrow keys to choose the “Desktop Autologin” item – then hit Return to select it

Don't forget

You need to temporarily assume superuser status with **sudo** to make configuration changes.

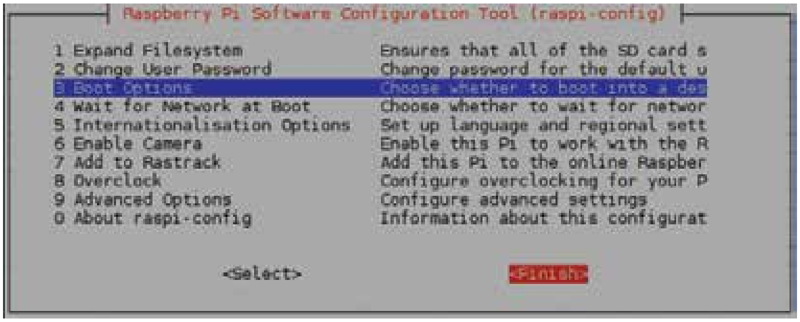
Beware

The “Overclock” menu item allows the ARM processor on some models of the Raspberry Pi to be run above their default speed to increase performance – but this may reduce the life of your Raspberry Pi.



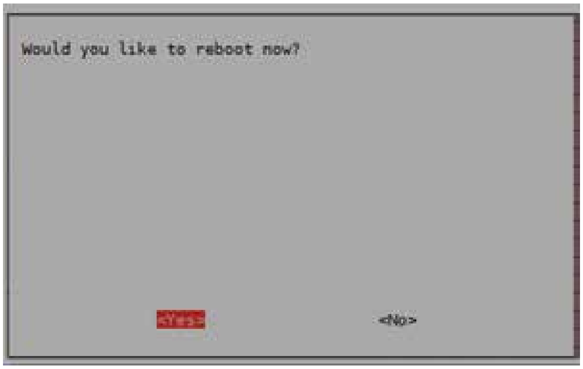
```
Raspberry Pi Software Configuration Tool (raspi-config)

B1 Console           Text console, requiring user to login
B2 Console Autologin Text console, automatically logged in as 'pi' user
B3 Desktop           Desktop GUI, requiring user to login
B4 Desktop Autologin Desktop GUI, automatically logged in as 'pi' user
```

5. Next, use the left-right keyboard arrow keys to choose "Finish" then hit Return to apply the configuration change



```
Raspberry Pi Software Configuration Tool (raspi-config)

1 Expand Filesystem              Ensures that all of the SD card s
2 Change User Password           Change password for the default u
3 Boot Options                   Choose whether to boot into a des
4 Wait for Network at Boot       Choose whether to wait for networ
5 Internationalisation Options   Set up language and regional sett
6 Enable Camera                  Enable this Pi to work with the R
7 Add to Rastrack                Add this Pi to the online Raspber
8 Overclock                      Configure overclocking for your P
9 Advanced Options               Configure advanced settings
0 About raspi-config             Information about this configurat
```

6. In the dialog that now appears use the left/right keyboard arrow keys to choose "Yes" – then hit Return to reboot the system straight to the GUI desktop



```
Would you like to reboot now?
```

Don't forget

Avoid changing the user password "raspberry" for the default user named "pi" in case you forget the new password.

Summary

- Raspberry Pi is an inexpensive credit-card sized computer developed to put fun back into learning about computing.
- Raspberry Pi has an ARM processor using System-on-Chip architecture and uses an SD card as its hard drive for economy.
- Peripheral components must be connected to the Raspberry Pi board to establish a complete computer system.
- The Raspbian Linux distro is recommended for beginners and must be written onto an SD card for use with Raspberry Pi.
- The Raspbian system has a configuration tool **raspi-config** in which you can change system options.
- The Raspbian distro is supplied configured with a default user name of "pi" whose login password is "raspberry".
- In a basic console, a login prompt appears in the Command-Line-Interface (CLI) after the boot messages have completed.
- After login, you can confirm your location on the filesystem by entering the command **pwd** (print working directory).
- You can discover the contents of the current directory folder by entering the command **ls** (list sorted).
- The **clear** command removes past command results and the **man** command can be used to discover command switches.
- Linux systems, such as Raspbian, are designed as multi-user systems so regular users cannot perform administrative tasks.
- You can temporarily assume superuser status to perform administrative tasks with the **sudo** command.
- With Raspbian, the X server provides a Graphical User Interface (GUI) desktop with a window manager.
- The desktop GUI can be started from a console prompt by entering the command **startx** or it can be automated by modifying the "Boot Options" with the configuration tool.