

## Getting Started

### Thank you for choosing Freenove products!

After you download the ZIP file we provide. Unzip it and you will get a folder contains several files and folders. There are three PDF files:

- **Tutorial.pdf**  
It contains basic operations such as installing system for Raspberry Pi.  
**The code in this PDF is in C.**
- **Tutorial\_GPIOZero.pdf**  
It contains basic operations such as installing system for Raspberry Pi.  
**The code in this PDF is in Python.**
- **Processing.pdf** in Freenove\_Basic\_Starter\_Kit\_for\_Raspberry\_Pi\Processing  
**The code in this PDF is in Java.**

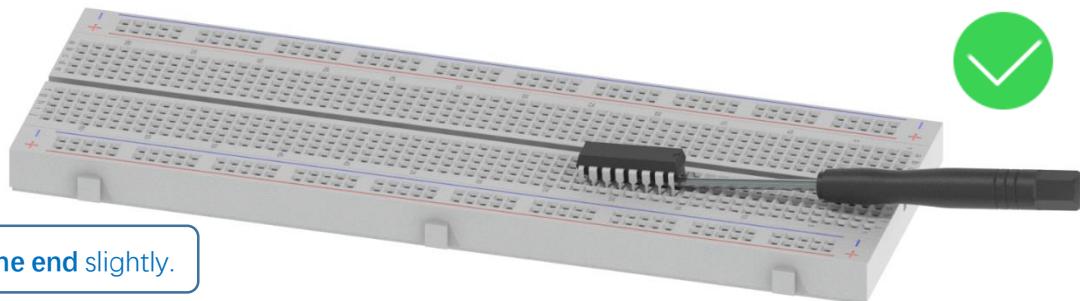
We recommend you to start with **Tutorial.pdf** or **Tutorial\_GPIOZero.pdf** first.

If you want to start with Processing.pdf or skip some chapters of Tutorial.pdf, you need to finish necessary steps in **Chapter 7 AD/DA** of **Tutorial.pdf** first.

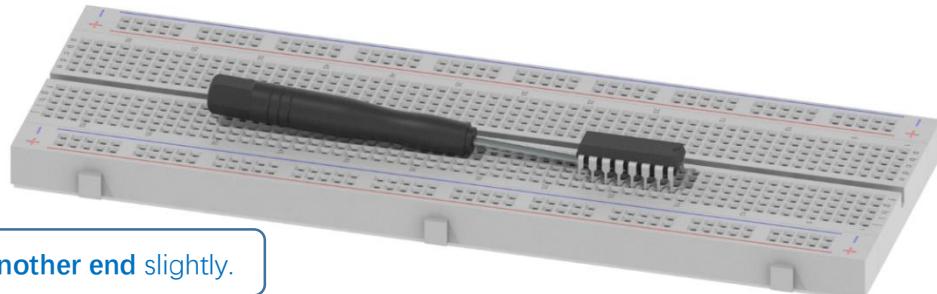
## Remove the Chips

Some chips and modules are inserted into the breadboard to protect their pins.

You need to remove them from breadboard before use. (There is no need to remove GPIO Extension Board.) Please find a tool (like a little screw driver) to handle them like below:



Step 1, lift **one end** slightly.

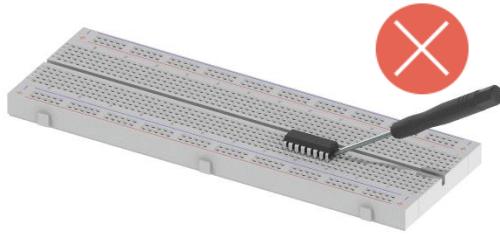


Step 2, lift **another end** slightly.



Step 3, take off the chip with hand.

Avoid lifting one end with big angle directly.



## Get Support and Offer Input

Freenove provides free and responsive product and technical support, including but not limited to:

- Product quality issues
- Product use and build issues
- Questions regarding the technology employed in our products for learning and education
- Your input and opinions are always welcome
- We also encourage your ideas and suggestions for new products and product improvements

For any of the above, you may send us an email to:

**[support@freenove.com](mailto:support@freenove.com)**

## Safety and Precautions

Please follow the following safety precautions when using or storing this product:

- Keep this product out of the reach of children under 6 years old.
- This product should be used only when there is adult supervision present as young children lack necessary judgment regarding safety and the consequences of product misuse.
- This product contains small parts and parts, which are sharp. This product contains electrically conductive parts. Use caution with electrically conductive parts near or around power supplies, batteries and powered (live) circuits.
- When the product is turned ON, activated or tested, some parts will move or rotate. To avoid injuries to hands and fingers, keep them away from any moving parts!
- It is possible that an improperly connected or shorted circuit may cause overheating. Should this happen, immediately disconnect the power supply or remove the batteries and do not touch anything until it

cools down! When everything is safe and cool, review the product tutorial to identify the cause.

- Only operate the product in accordance with the instructions and guidelines of this tutorial, otherwise parts may be damaged or you could be injured.
- Store the product in a cool dry place and avoid exposing the product to direct sunlight.
- After use, always turn the power OFF and remove or unplug the batteries before storing.

## About Freenove

Freenove provides open source electronic products and services worldwide.

Freenove is committed to assist customers in their education of robotics, programming and electronic circuits so that they may transform their creative ideas into prototypes and new and innovative products. To this end, our services include but are not limited to:

- Educational and Entertaining Project Kits for Robots, Smart Cars and Drones
- Educational Kits to Learn Robotic Software Systems for Arduino, Raspberry Pi and micro:bit
- Electronic Component Assortments, Electronic Modules and Specialized Tools
- Product Development and Customization Services**

You can find more about Freenove and get our latest news and updates through our website:

<http://www.freenove.com>

## Copyright

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Raspberry Pi® is a trademark of Raspberry Pi Foundation (<https://www.raspberrypi.org/>).

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## Preface

Raspberry Pi is a low cost, **credit card sized computer** that plugs into a computer monitor or TV, and uses a standard keyboard and mouse. It is an incredibly capable little device that enables people of all ages to explore computing, and to learn how to program in a variety of computer languages like Scratch and Python. It is capable of doing everything you would expect from a desktop computer, such as browsing the internet, playing high-definition video content, creating spreadsheets, performing word-processing, and playing video games. For more information, you can refer to Raspberry Pi official [website](#). For clarification, this tutorial will also reference Raspberry Pi as RPi, RPI and RasPi.

In this tutorial, most chapters consist of **Components List**, **Component Knowledge**, **Circuit**, and **Code (Python code)**. We provide Python code for each project in this tutorial. After completing this tutorial, you can learn Java by reading Processing.pdf.

This kit does not contain [\*\*Raspberry and its accessories\*\*](#). You can also use the components and modules in this kit to create projects of your own design.

Additionally, if you encounter any issues or have questions about this tutorial or the contents of kit, you can always contact us for free technical support at:

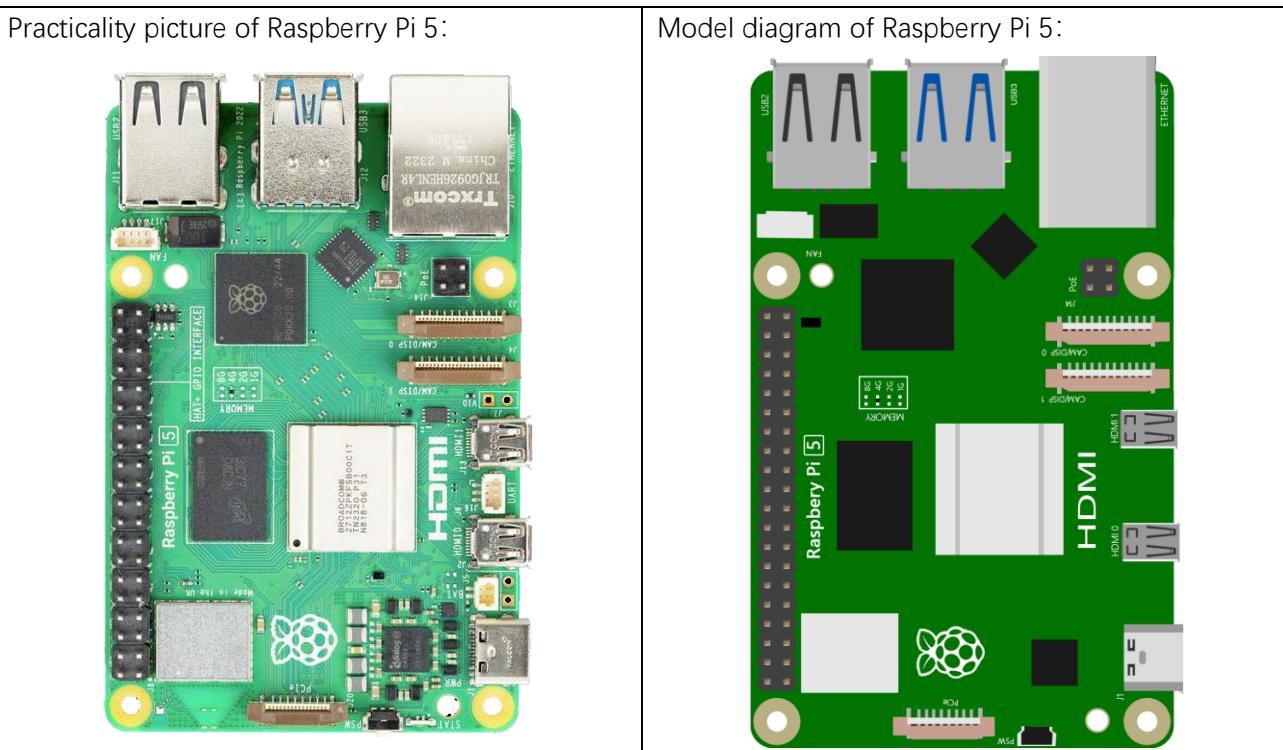
**[support@freenove.com](mailto:support@freenove.com)**

# Raspberry Pi

So far, at this writing, Raspberry Pi has advanced to its fifth generation product offering. Version changes are accompanied by increases in upgrades in hardware and capabilities.

The A type and B type versions of the first generation products have been discontinued due to various reasons. What is most important is that other popular and currently available versions are consistent in the order and number of pins and their assigned designation of function, making compatibility of peripheral devices greatly enhanced between versions.

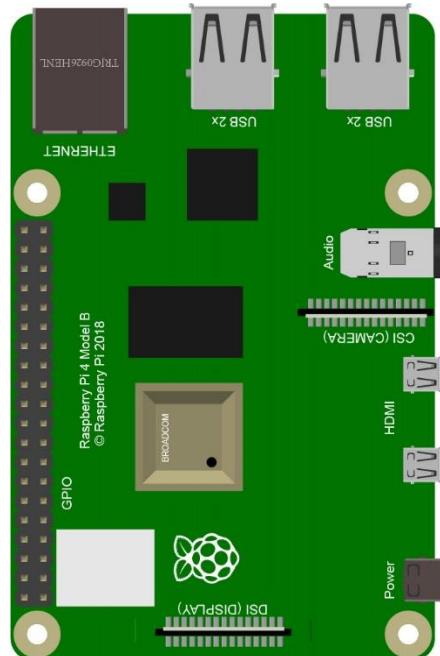
Below are the raspberry pi pictures and model pictures supported by this product. They have 40 pins.



Actual image of Raspberry Pi 4 Model B:



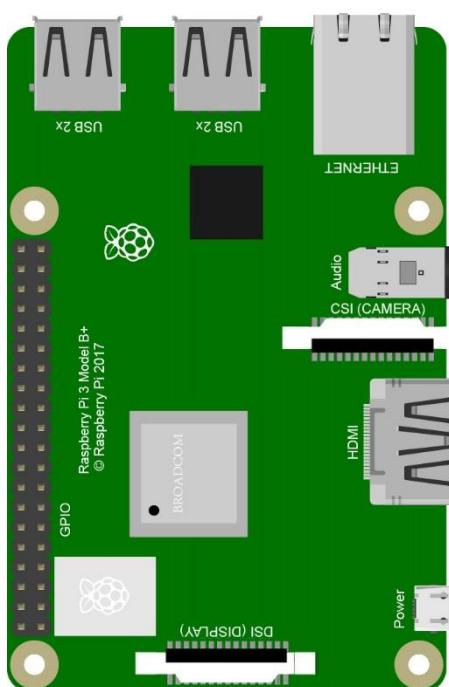
CAD image of Raspberry Pi 4 Model B:



Actual image of Raspberry Pi 3 Model B+:



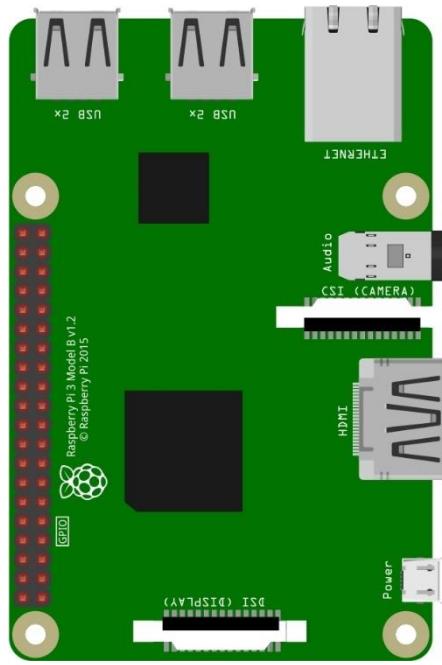
CAD image of Raspberry Pi 3 Model B+:



Actual image of Raspberry Pi 3 Model B:



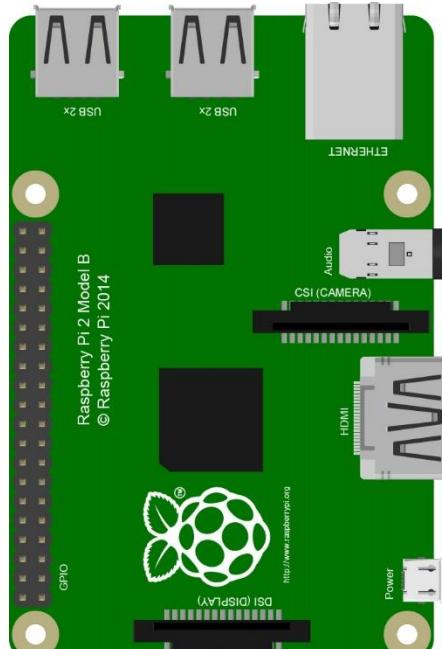
CAD image of Raspberry Pi 3 Model B:



Actual image of Raspberry Pi 2 Model B:



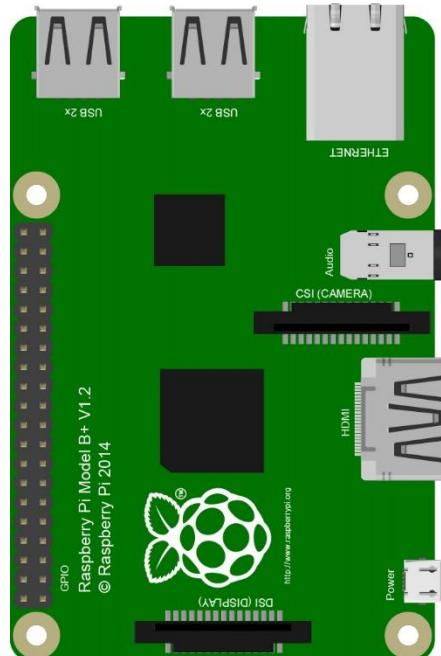
CAD image of Raspberry Pi 2 Model B:



Actual image of Raspberry Pi 1 Model B+:



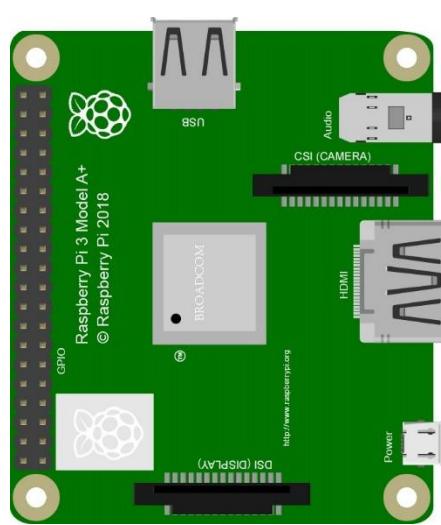
CAD image of Raspberry Pi 1 Model B+:



Actual image of Raspberry Pi 3 Model A+:



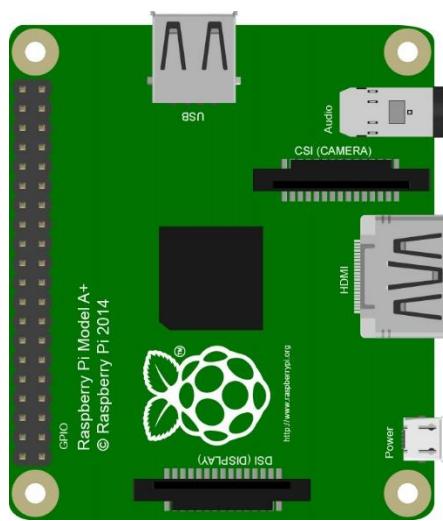
CAD image of Raspberry Pi 3 Model A+:



Actual image of Raspberry Pi 1 Model A+:



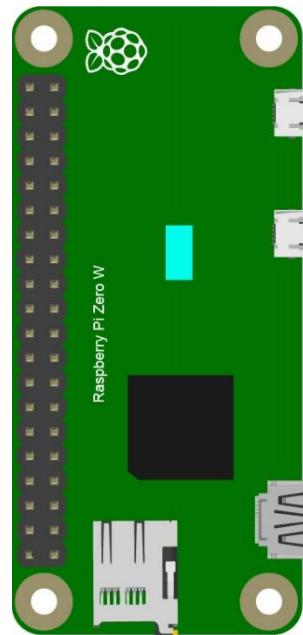
CAD image of Raspberry Pi 1 Model A+:



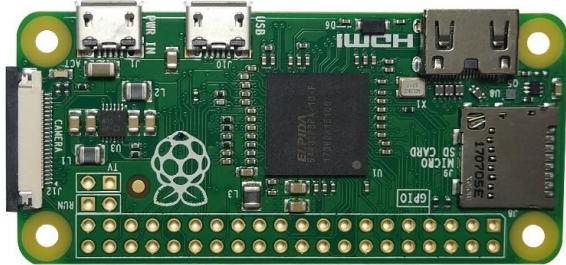
Actual image of Raspberry Pi Zero W:



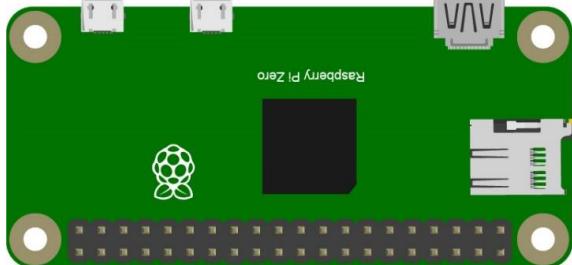
CAD image of Raspberry Pi Zero W:



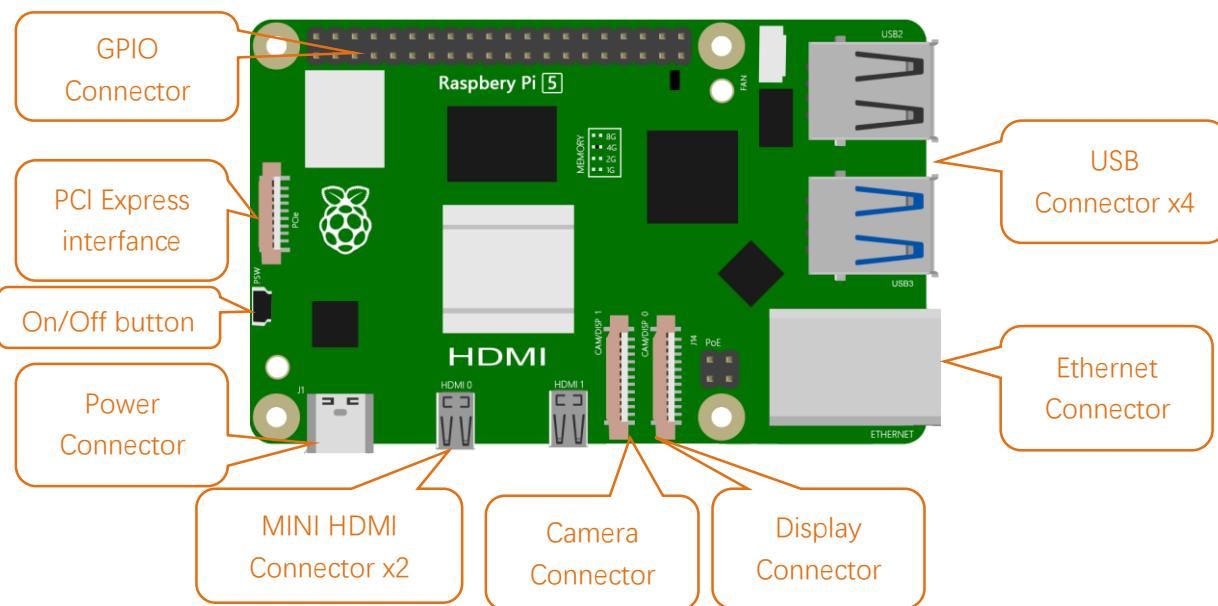
Actual image of Raspberry Pi Zero:



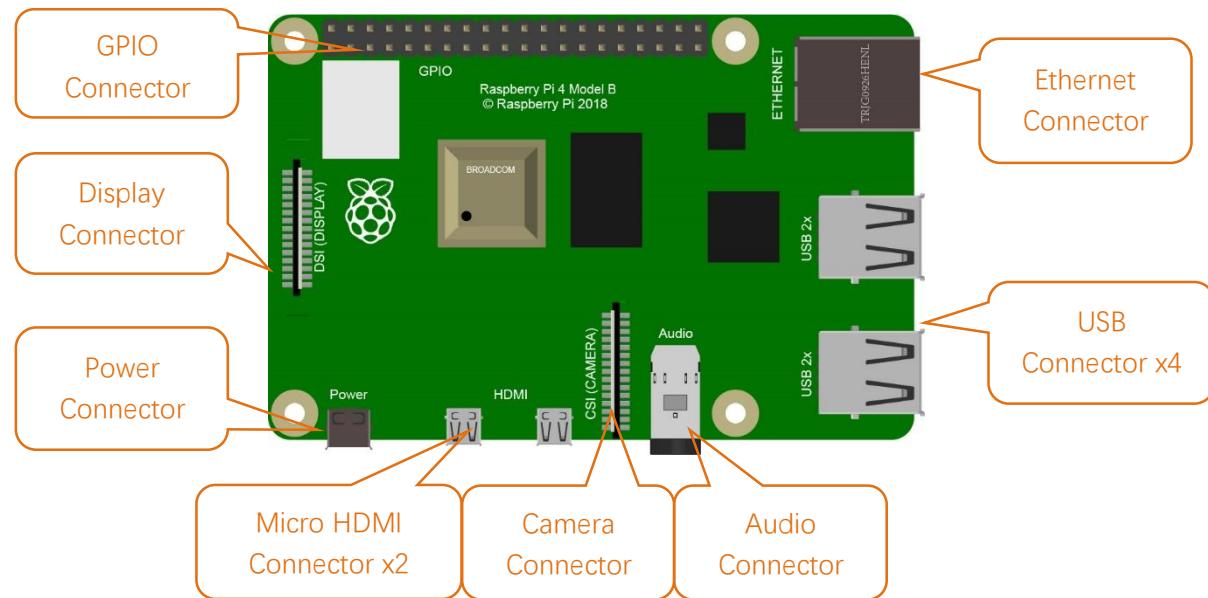
CAD image of Raspberry Pi Zero:



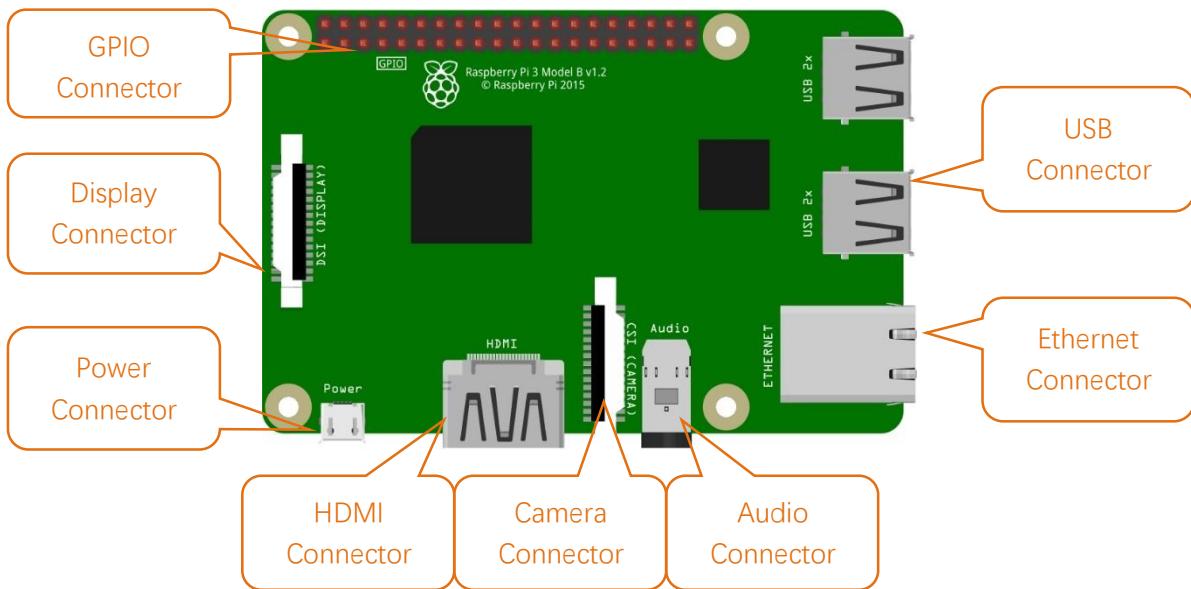
Below are the raspberry pi pictures and model pictures supported by this product. They have 40 pins. Hardware interface diagram of RPi 5 is shown below:



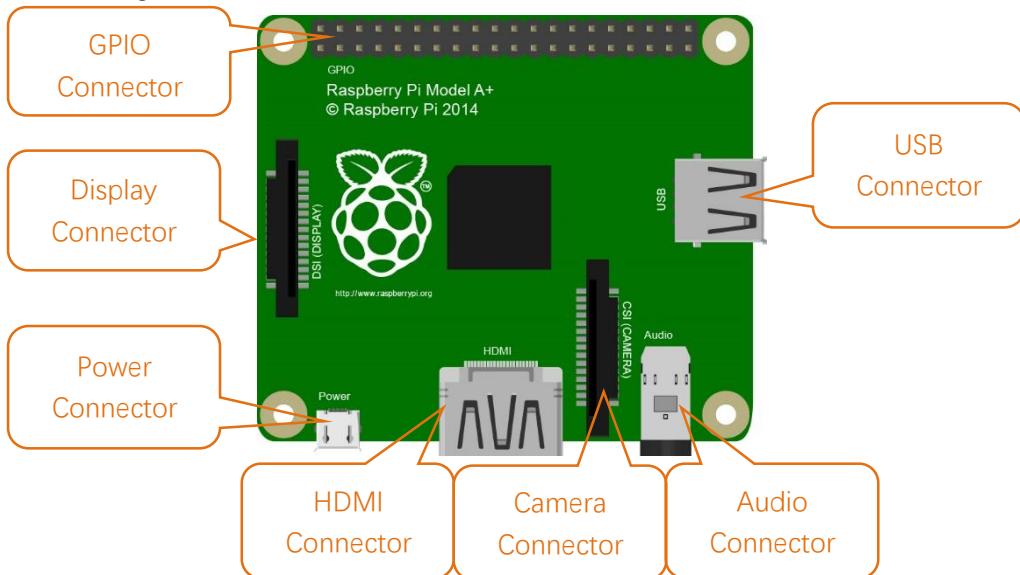
Hardware interface diagram of RPi 4B is shown below:



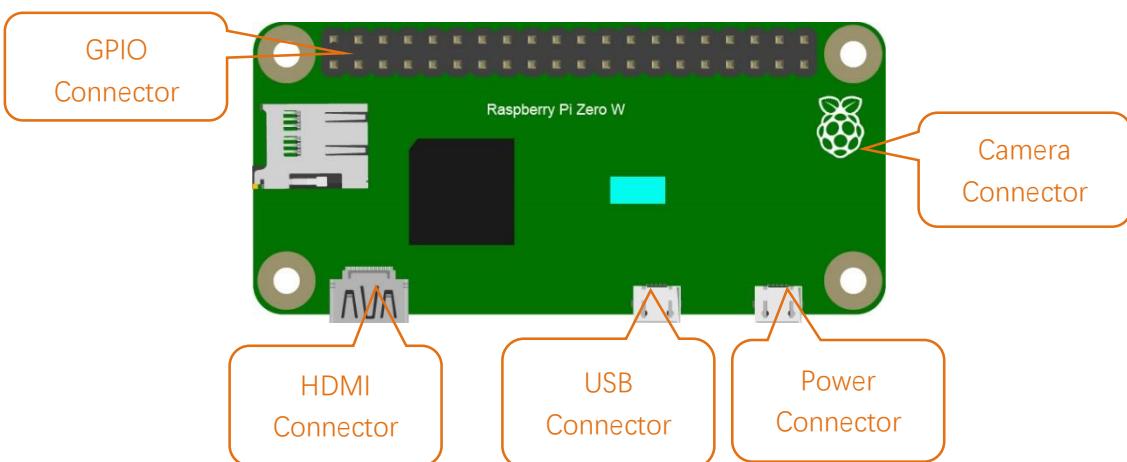
Hardware interface diagram of RPi 3B+/3B/2B/1B+:



Hardware interface diagram of RPi 3A+/A+:



Hardware interface diagram of RPi Zero/Zero W:

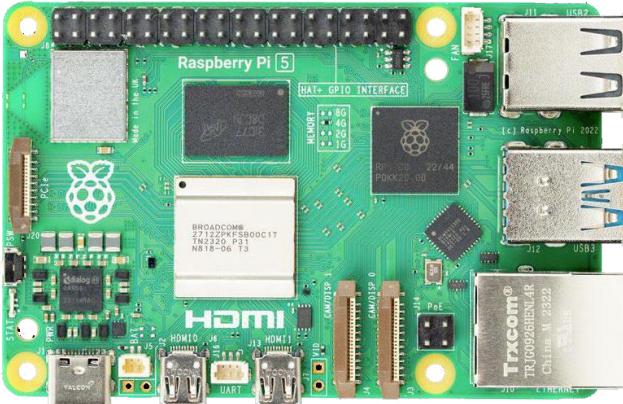


# Installing an Operating System

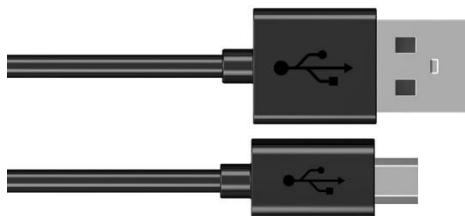
The first step is to install an operating system on your RPi so that it can be programmed and function. If you have installed a system in your RPi, you can start from Chapter 0 Preparation.

## Component List

### Required Components

Any Raspberry Pi with 40 GPIO	5V/3A Power Adapter. Note: Different versions of Raspberry Pi have different power requirements (please check the power requirements for yours on the chart in the following page.)
	

Micro or Type-C USB Cable x1	Micro SD Card (TF Card) x1, Card Reader x1
------------------------------	--





Power requirements of various versions of Raspberry Pi are shown in following table:

Product	Recommended PSU current capacity	Maximum total USB peripheral current draw	Typical bare-board active current consumption
Raspberry Pi 1 Model A	700mA	500mA	200mA
Raspberry Pi 1 Model B	1.2A	500mA	500mA
Raspberry Pi 1 Model A+	700mA	500mA	180mA
Raspberry Pi 1 Model B+	1.8A	1.2A	330mA
Raspberry Pi 2 Model B	1.8A	1.2A	350mA
Raspberry Pi 3 Model B	2.5A	1.2A	400mA
Raspberry Pi 3 Model A+	2.5A	Limited by PSU, board, and connector ratings only.	350mA
Raspberry Pi 3 Model B+	2.5A	1.2A	500mA
Raspberry Pi 4 Model B	3.0A	1.2A	600mA
Raspberry Pi 5	5.0A	1.6A (600mA if using a 3A power supply)	800mA
Raspberry Pi 400	3.0A	1.2A	800mA
Raspberry Pi Zero	1.2A	Limited by PSU, board, and connector ratings only	100mA
Raspberry Pi Zero W	1.2A	Limited by PSU, board, and connector ratings only.	150mA
Raspberry Pi Zero 2 W	2A	Limited by PSU, board, and connector ratings only.	350mA

For more details, please refer to <https://www.raspberrypi.org/help/faqs/#powerReqs>

In addition, RPi also needs an Ethernet network cable used to connect it to a WAN (Wide Area Network).

The Raspberry Pi 5 provides 1.6A of power to downstream USB peripherals when connected to a power supply capable of 5A at +5V (25W). When connected to any other compatible power supply, the Raspberry Pi 5 restricts downstream USB devices to 600mA of power.

## Optional Components

Under normal circumstances, there are two ways to login to Raspberry Pi: 1) Using a stand-alone monitor. 2) Using a remote desktop or laptop computer monitor “sharing” the PC monitor with your RPi.

## Required Accessories for Monitor

If you choose to use an independent monitor, mouse and keyboard, you also need the following accessories:

1. A display with a HDMI interface
2. A Mouse and a Keyboard with an USB interface

As to Pi Zero and Pi Zero W, you also need the following accessories:

1. A Mini-HDMI to HDMI Adapter and Cable.
2. A Micro-USB to USB-A Adapter and Cable (Micro USB OTG Cable).
3. A USB HUB.
4. USB to Ethernet Interface or USB Wi-Fi receiver.

For different Raspberry Pi Modules, the optional items may vary slightly but they all aim to convert the interfaces to Raspberry Pi standards.

	Pi Zero	Pi A+	Pi Zero W	Pi 3A+	Pi B+/2B	Pi 3B/3B+	Pi 4B	Pi 5
<b>Monitor</b>						Yes (All)		
<b>Mouse</b>						Yes (All)		
<b>Keyboard</b>						Yes (All)		
<b>Micro-HDMI to HDMI Adapter &amp; Cable</b>	Yes	No	Yes	No	No	No	No	No
<b>Micro-HDMI to HDMI Adapter &amp; Cable</b>				No			Yes	
<b>Micro-USB to USB-A Adapter &amp; Cable (Micro USB OTG Cable)</b>	Yes	No	Yes			No		
<b>USB HUB</b>	Yes	Yes	Yes	Yes	No	No	No	No
<b>USB to Ethernet Interface</b>	select one from two or select two from two		optional		Internal Integration	Internal Integration		
<b>USB Wi-Fi Receiver</b>			Internal Integration		optional			



## Required Accessories for Remote Desktop

If you do not have an independent monitor, or if you want to use a remote desktop, you first need to login to Raspberry Pi through SSH, and then open the VNC or RDP service. This requires the following accessories.

	Pi Zero	Pi Zero W	Pi A+	Pi 3A+	Pi B+/2B	Pi 3B/3B+/4B/5
<b>Micro-USB to USB-A Adapter &amp; Cable (Micro USB OTG Cable)</b>	Yes	Yes	No			NO
<b>USB to Ethernet interface</b>	Yes	Yes	Yes			

## Raspberry Pi OS

Without Screen - Use Raspberry Pi - under Windows PC: <https://youtu.be/YND0RUuP-to>

With Screen - Use Raspberry Pi - under Windows PC: <https://youtu.be/HEywFsFrj3I>

### Automatically Method

You can follow the official method to install the system for raspberry pi via visiting link below:

<https://projects.raspberrypi.org/en/projects/raspberry-pi-setting-up/2>

In this way, the system will be downloaded **automatically** via the application.

### Manually Method

After installing the Imager Tool in the **link above**. You can **also** download the system **manually** first.

Visit <https://www.raspberrypi.org/downloads/>

#### Manually install an operating system image

Browse a range of operating systems provided by Raspberry Pi and by other organisations, and download them to install manually.

[See all download options](#)



## Operating system images

Many operating systems are available for Raspberry Pi, including Raspberry Pi OS, our official supported operating system, and operating systems from other organisations.

[Raspberry Pi Imager](#) is the quick and easy way to install an operating system to a microSD card ready to use with your Raspberry Pi. Alternatively, choose from the operating systems below, available to download and install manually.

Download:  
[Raspberry Pi OS \(32-bit\)](#)  
[Raspberry Pi Desktop](#)  
[Third-Party operating systems](#)

### Raspberry Pi OS

Compatible with:

[All Raspberry Pi models](#)



#### Raspberry Pi OS with desktop and recommended software

Release date: January 11th 2021  
 Kernel version: 5.4  
 Size: 2.863MB  
[Show SHA256 file integrity hash](#)  
[Release notes](#)

[Download](#)

[Download torrent](#)



And then the zip file is downloaded.

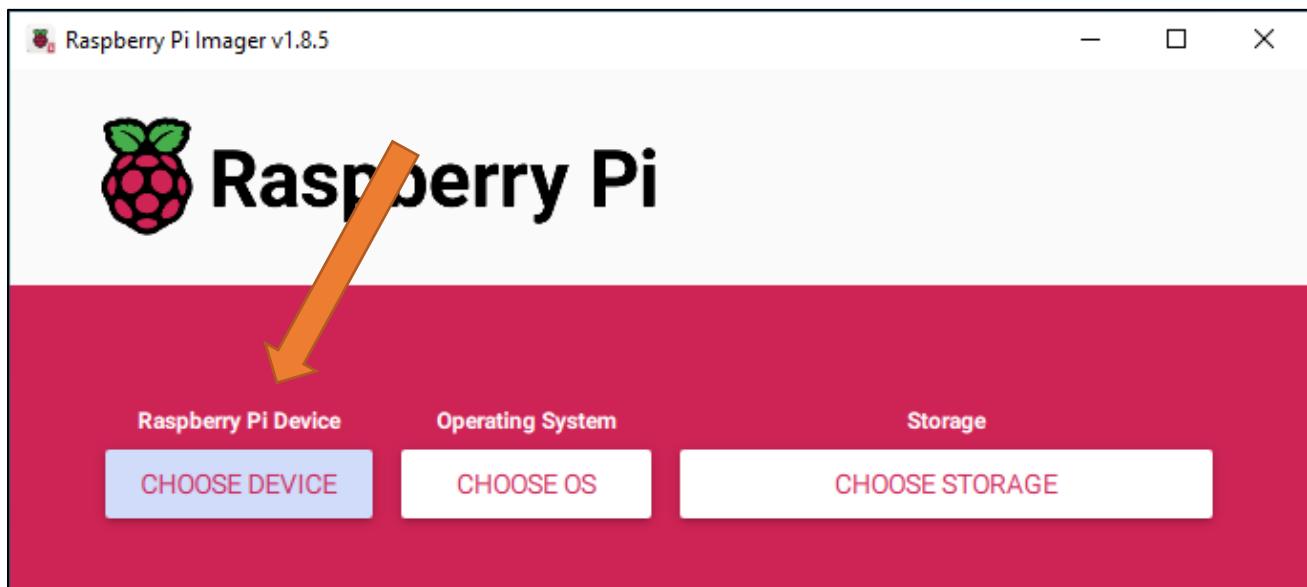


### Write System to Micro SD Card

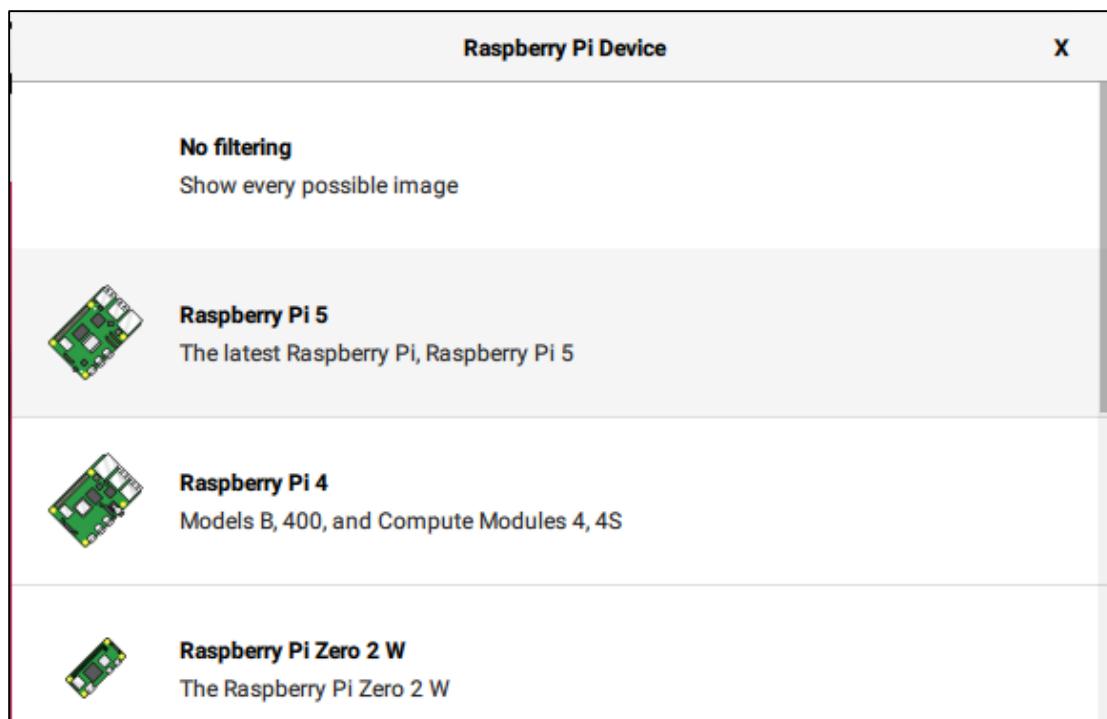
First, put your Micro **SD card** into card reader and connect it to USB port of PC.



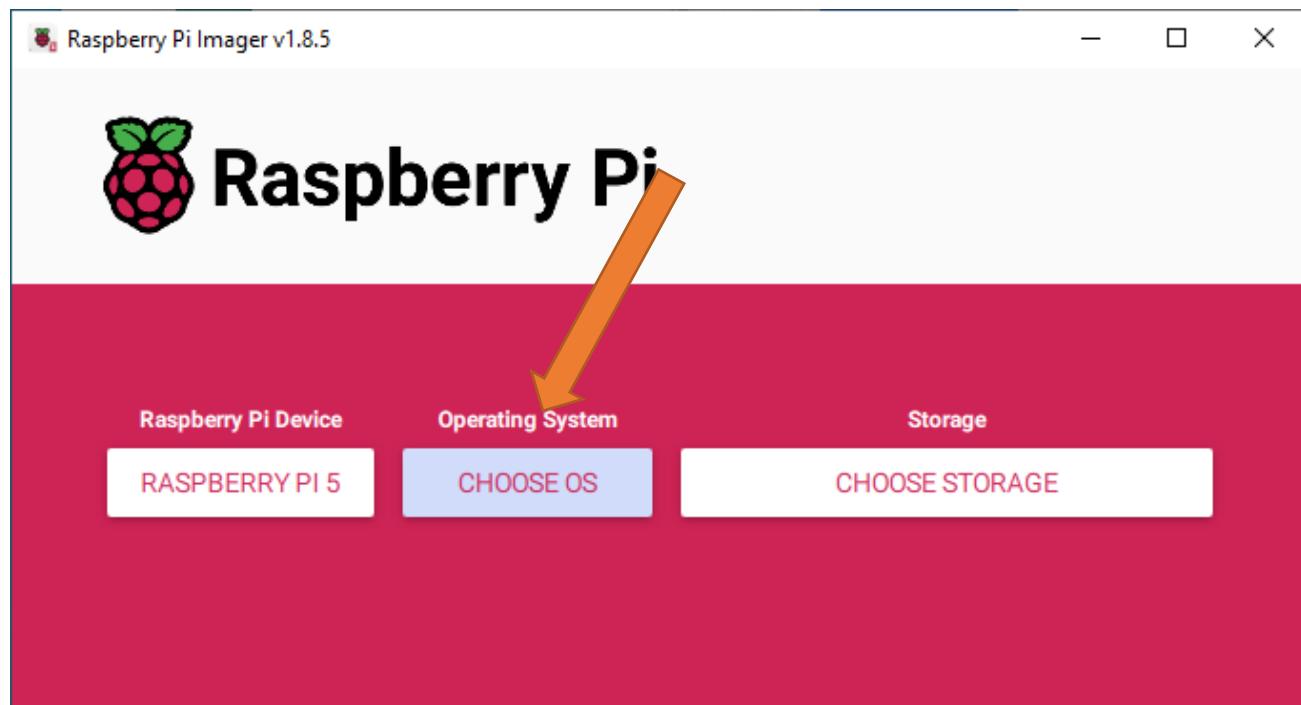
Then open imager toll. Clicked Choose Device.



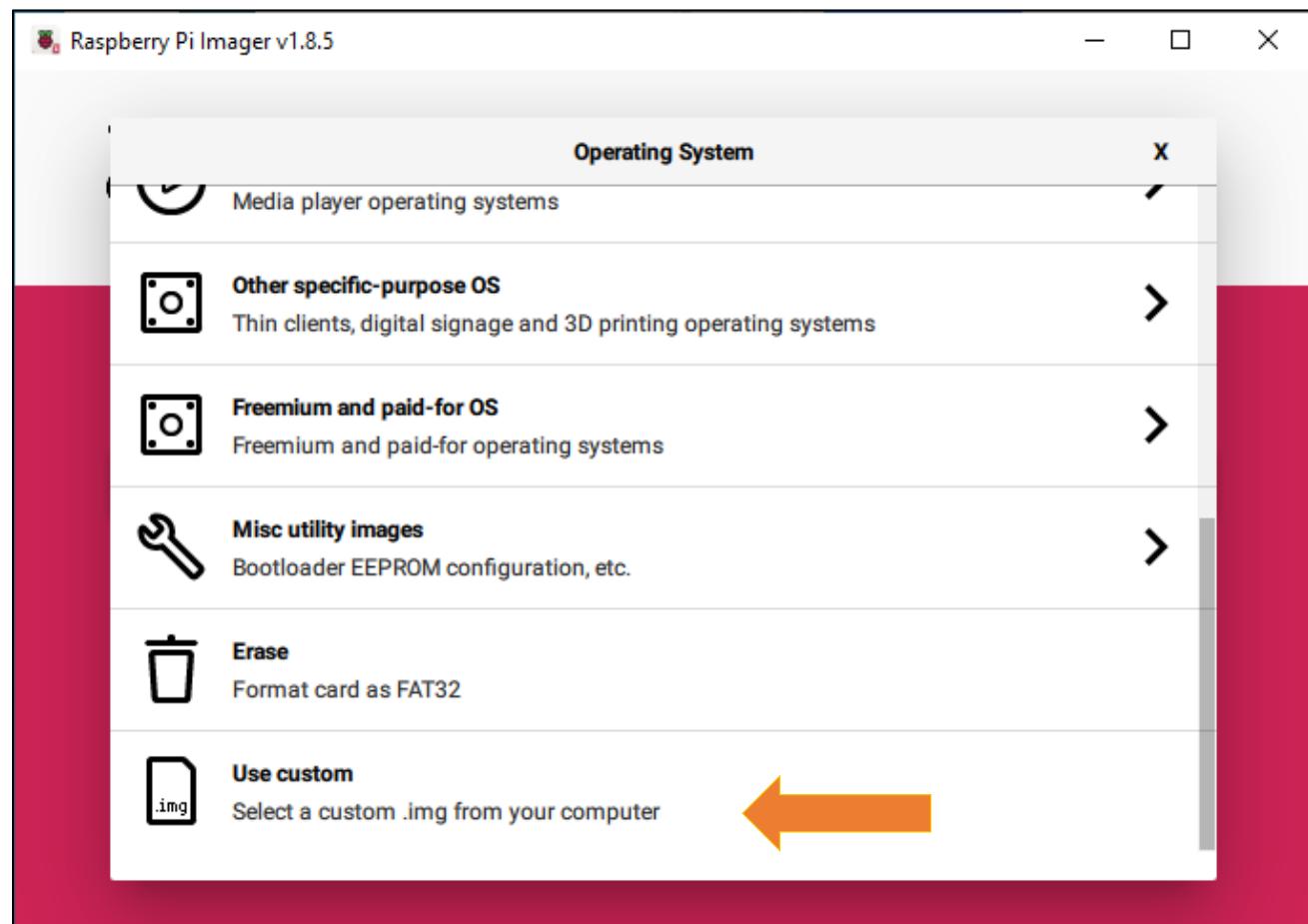
Select a Raspberry PI Device based on your Raspberry PI version. It will help us filter out the right version of the system for the Raspberry PI.



Clicked Operating System.

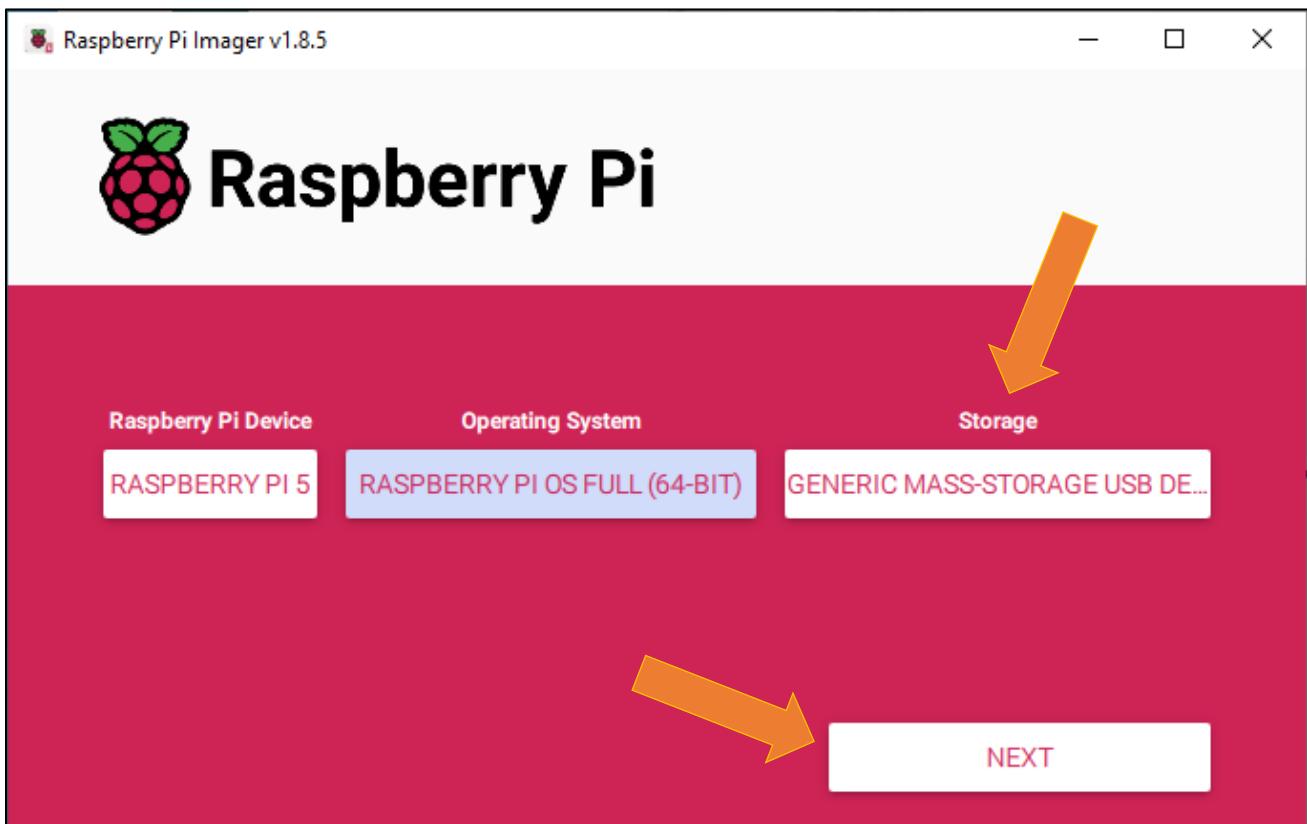


Choose system that you just downloaded in Use custom.

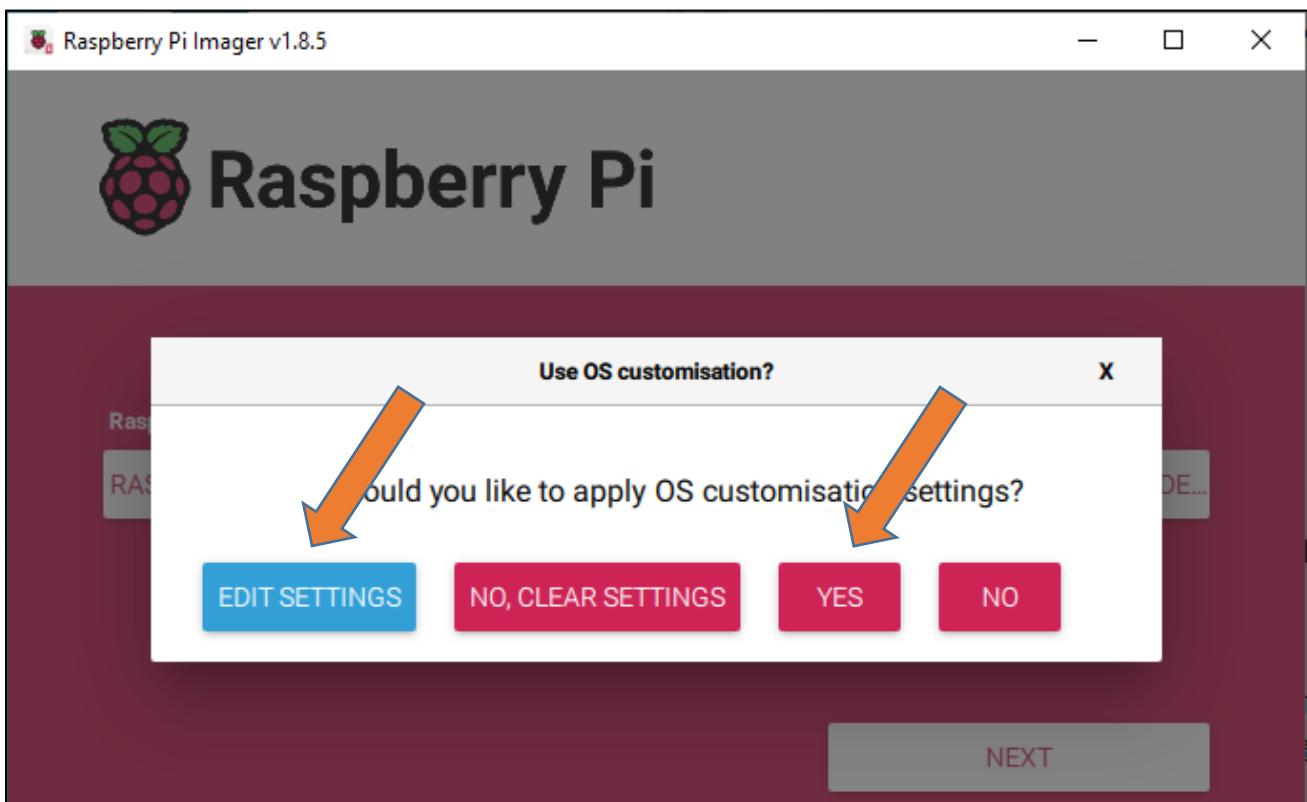




Choose the SD card. Then click "Next".

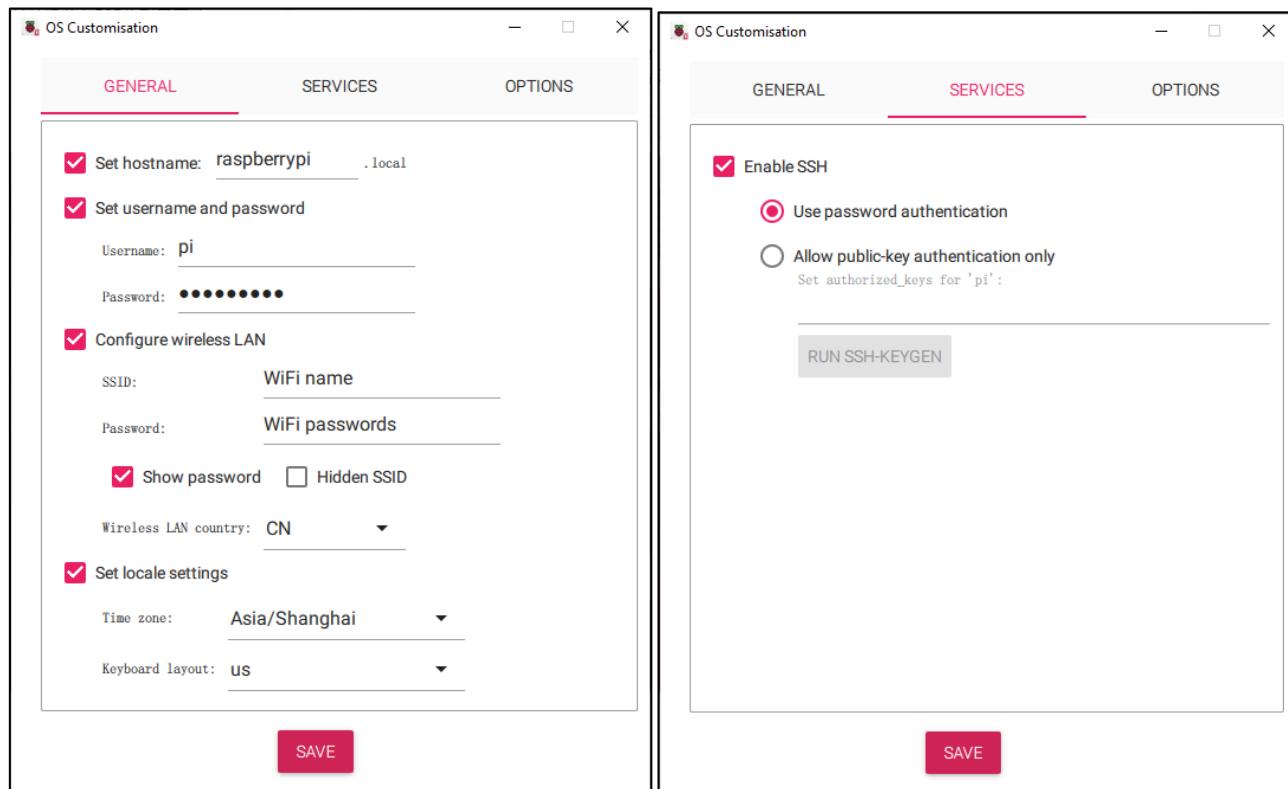


You can configure the Raspberry Pi according to your needs.

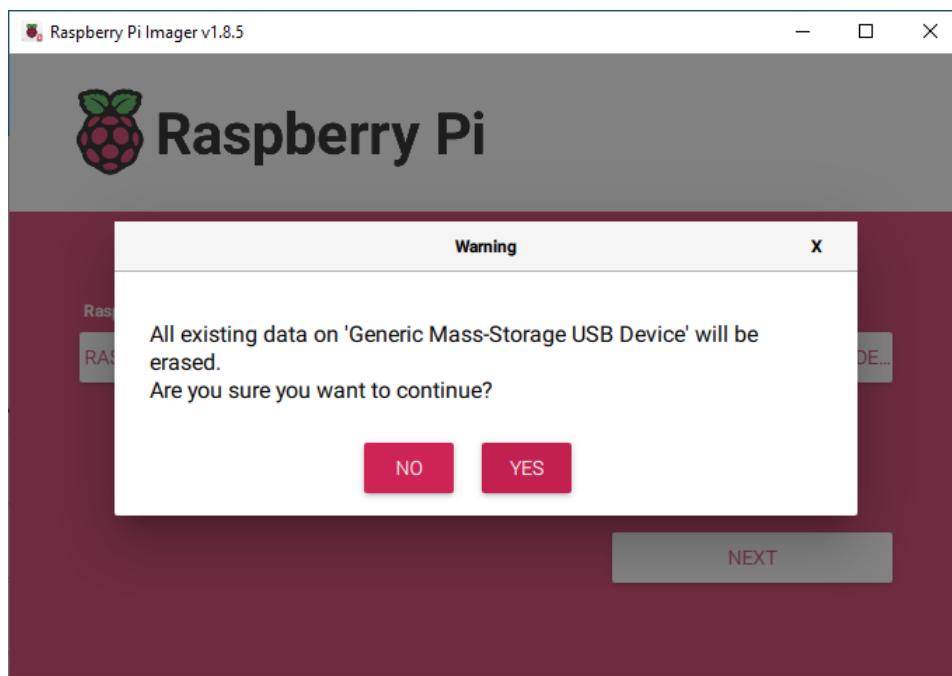


## Enable ssh and configure WiFi

On the GENERAL screen, configure your information based on your actual situation.  
Enable SSH on the SERVICES page.



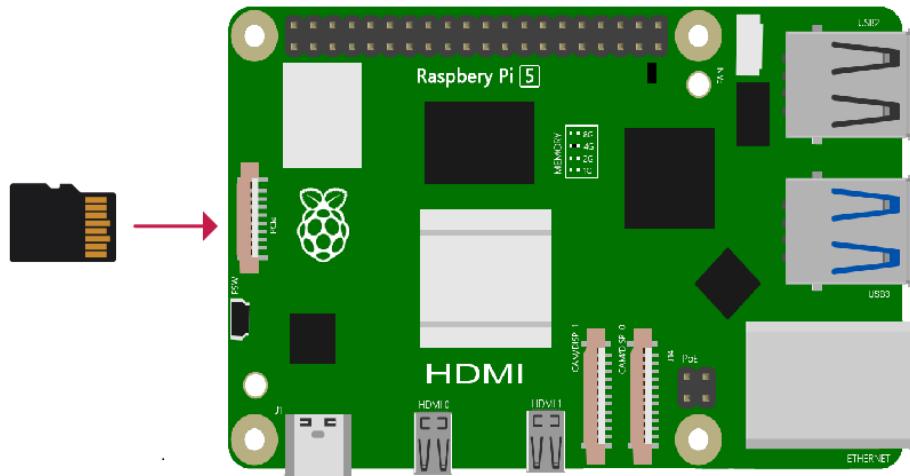
Click Save, in the new screen, click Yes, wait for SD to brush into the Raspberry system.





## Insert SD card

Then remove SD card from card reader and insert it into Raspberry Pi.



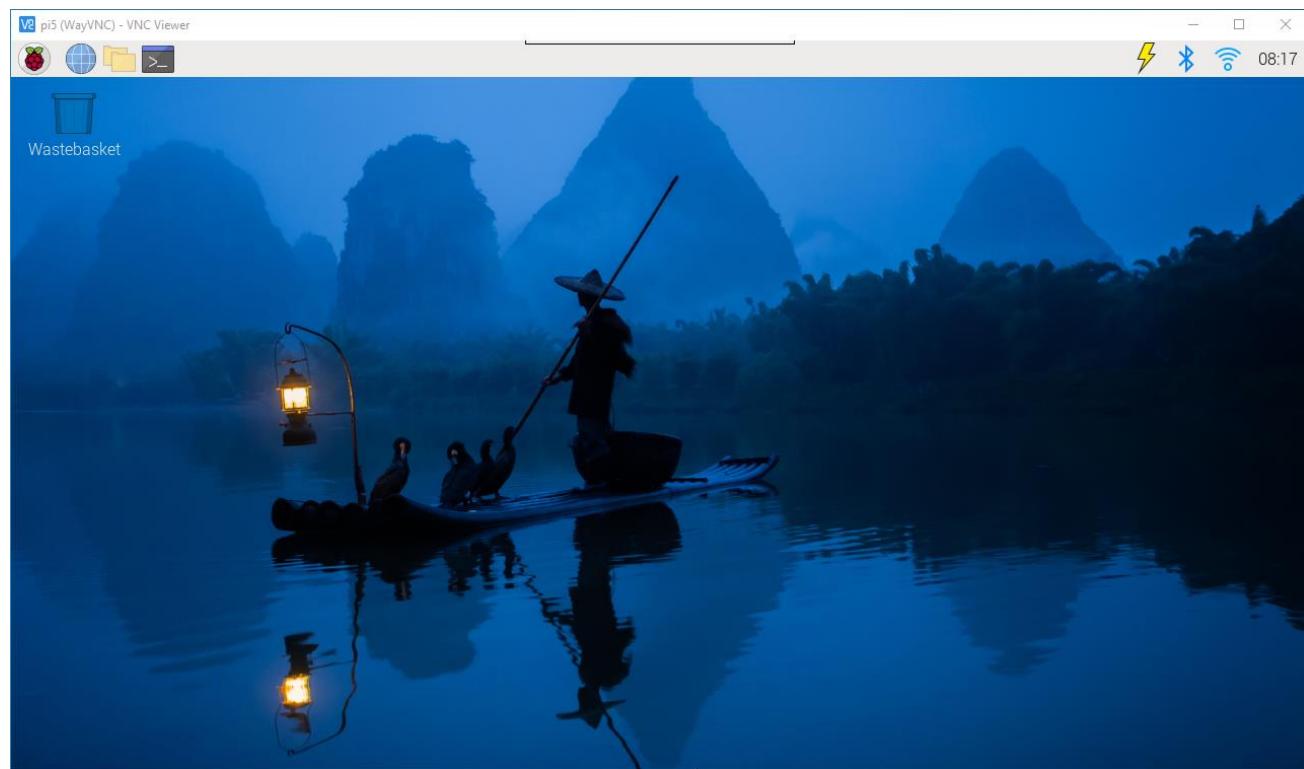
Connect to the power supply and wait for the Raspberry PI to turn on.

## Getting Started with Raspberry Pi

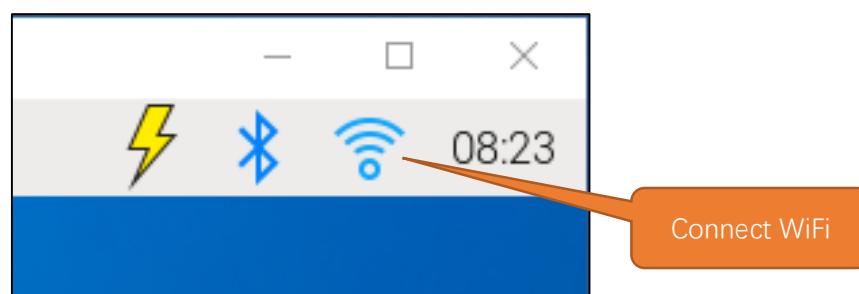
### Monitor desktop

If you do not have a spare monitor, please skip to next section [Remote desktop & VNC](#). If you have a spare monitor, please follow the steps in this section.

After the system is written successfully, take out Micro SD Card and put it into the SD card slot of RPi. Then connect your RPi to the monitor through the HDMI port, attach your mouse and keyboard through the USB ports, attach a network cable to the network port and finally, connect your power supply (making sure that it meets the specifications required by your RPi Module Version). Your RPi should start (power up). Later, after setup, you will need to enter your user name and password to login. The default user name: pi; password: raspberry. After login, you should see the following screen.



Congratulations! You have successfully installed the RASPBERRY PI OS operating system on your RPi. Raspberry Pi 5, 4B, 3B+/3B integrates a Wi-Fi adaptor. You can use it to connect to your Wi-Fi. Then you can use the wireless remote desktop to control your RPi. This will be helpful for the following work. Raspberry Pi of other models can use wireless remote desktop through accessing an external USB wireless card.



## Remote desktop & VNC

If you have logged in Raspberry Pi via display, you can skip to [VNC Viewer](#).

If you don't have a spare display, mouse and keyboard for your RPi, you can use a remote desktop to share a display, keyboard, and mouse with your PC. Below is how to use:

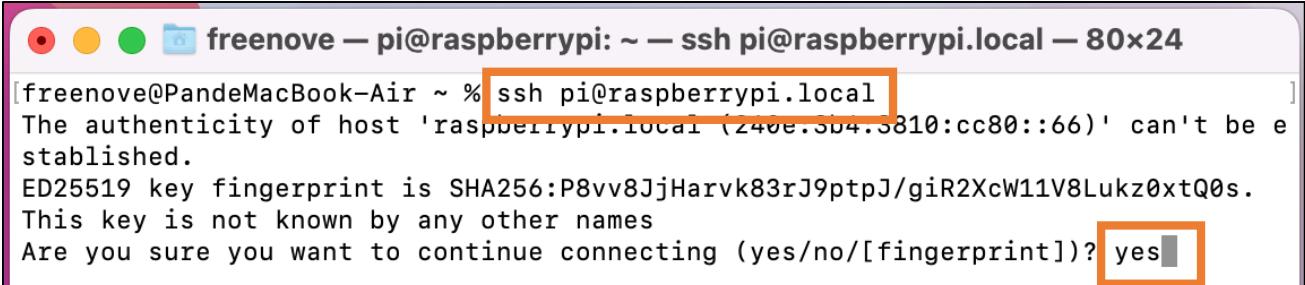
[MAC OS remote desktop](#) and [Windows OS remote desktop](#).

### MAC OS Remote Desktop

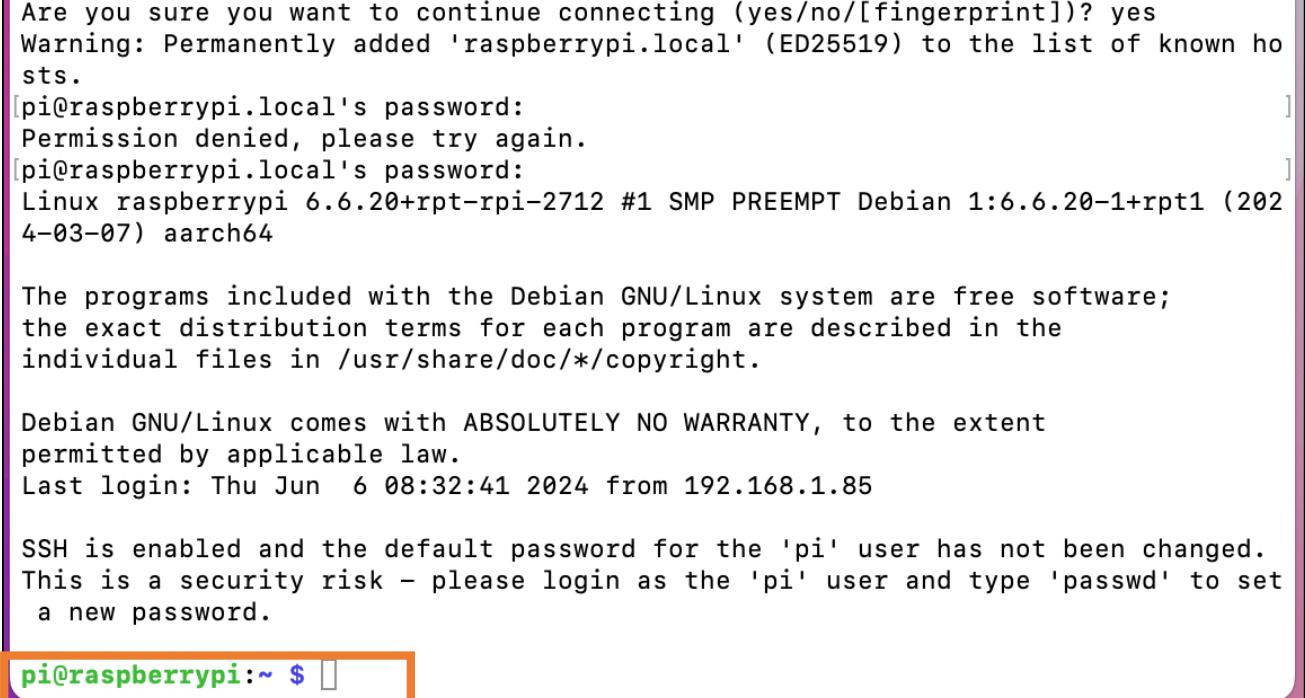
Open the terminal and type following command. **If this command doesn't work, please move to next page.**

```
ssh pi@raspberrypi.local
```

The password is **raspberry** by default, case sensitive. You may need to type **yes** during the process.



```
freenove — pi@raspberrypi: ~ — ssh pi@raspberrypi.local — 80x24
[freenove@PandeMacBook-Air ~ % ssh pi@raspberrypi.local
The authenticity of host 'raspberrypi.local (240e.3b4.3810:cc80::66)' can't be established.
ED25519 key fingerprint is SHA256:P8vv8JjHarvk83rJ9ptpJ/giR2XcW11V8Lukz0xtQ0s.
This key is not known by any other names
Are you sure you want to continue connecting (yes/no/[fingerprint])? yes]
```



```
Are you sure you want to continue connecting (yes/no/[fingerprint])? yes
Warning: Permanently added 'raspberrypi.local' (ED25519) to the list of known hosts.
[pi@raspberrypi.local's password:
Permission denied, please try again.
[pi@raspberrypi.local's password:
Linux raspberrypi 6.6.20+rpi-2712 #1 SMP PREEMPT Debian 1:6.6.20-1+rpi1 (202
4-03-07) aarch64

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.
Last login: Thu Jun  6 08:32:41 2024 from 192.168.1.85

SSH is enabled and the default password for the 'pi' user has not been changed.
This is a security risk - please login as the 'pi' user and type 'passwd' to set
a new password.

pi@raspberrypi:~ $ ]
```

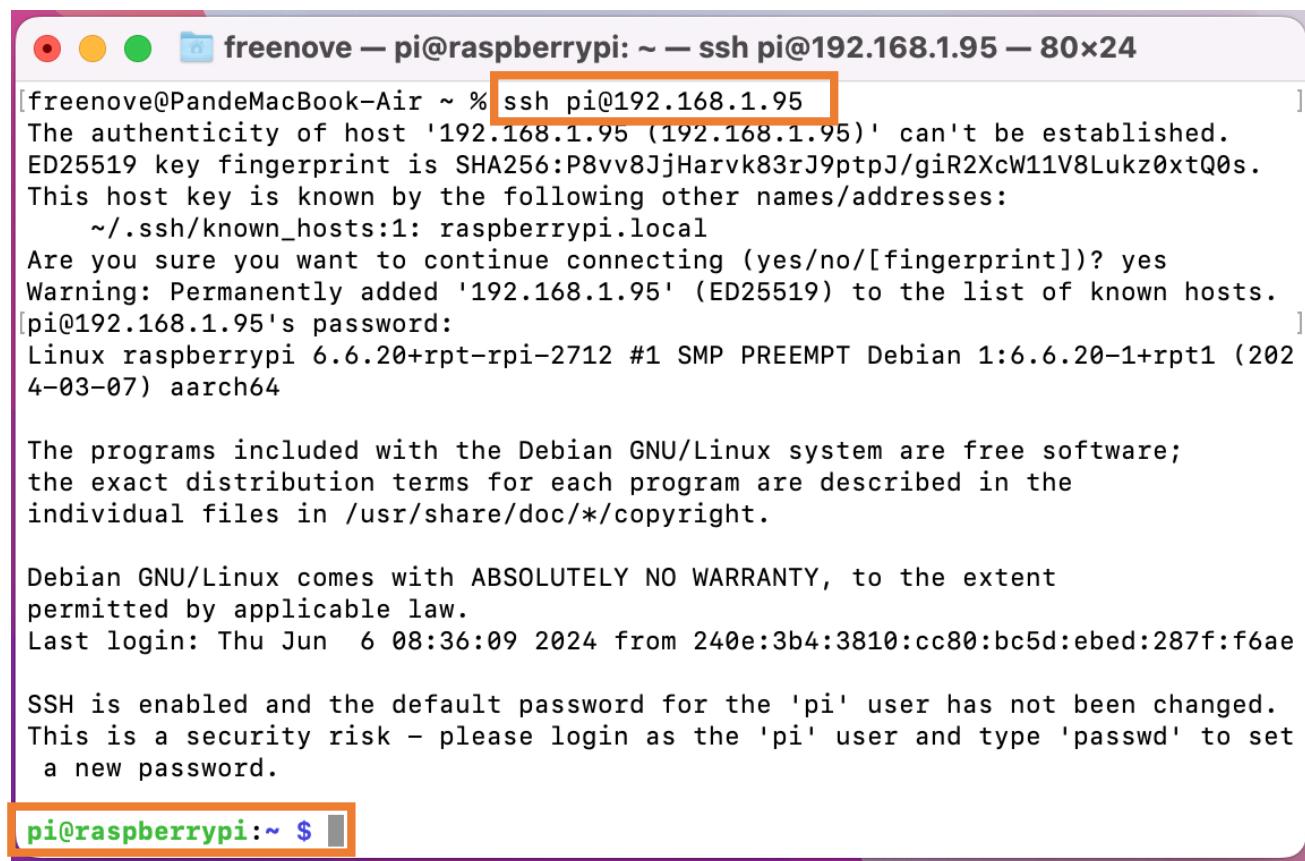
You can also use the IP address to log in Pi.

Enter **router** client to **inquiry IP address** named "raspberry pi". For example, I have inquired to **my RPi IP address, and it is "192.168.1.95"**.

Open the terminal and type following command.

```
ssh pi@192.168.1.95
```

When you see **pi@raspberrypi:~ \$**, you have logged in Pi successfully. Then you can skip to next section.



```
freenove — pi@raspberrypi: ~ — ssh pi@192.168.1.95 — 80x24
[freenove@PandeMacBook-Air ~ % ssh pi@192.168.1.95
The authenticity of host '192.168.1.95 (192.168.1.95)' can't be established.
ED25519 key fingerprint is SHA256:P8vv8JjHarvk83rJ9ptpJ/giR2XcW11V8Lukz0xtQ0s.
This host key is known by the following other names/addresses:
    ~/.ssh/known_hosts:1: raspberrypi.local
Are you sure you want to continue connecting (yes/no/[fingerprint])? yes
Warning: Permanently added '192.168.1.95' (ED25519) to the list of known hosts.
[pi@192.168.1.95's password:
Linux raspberrypi 6.6.20+rpt-rpi-2712 #1 SMP PREEMPT Debian 1:6.6.20-1+rpt1 (202
4-03-07) aarch64

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.
Last login: Thu Jun  6 08:36:09 2024 from 240e:3b4:3810:cc80:bc5d:ebed:287f:f6ae

SSH is enabled and the default password for the 'pi' user has not been changed.
This is a security risk - please login as the 'pi' user and type 'passwd' to set
a new password.

pi@raspberrypi:~ $ ]
```

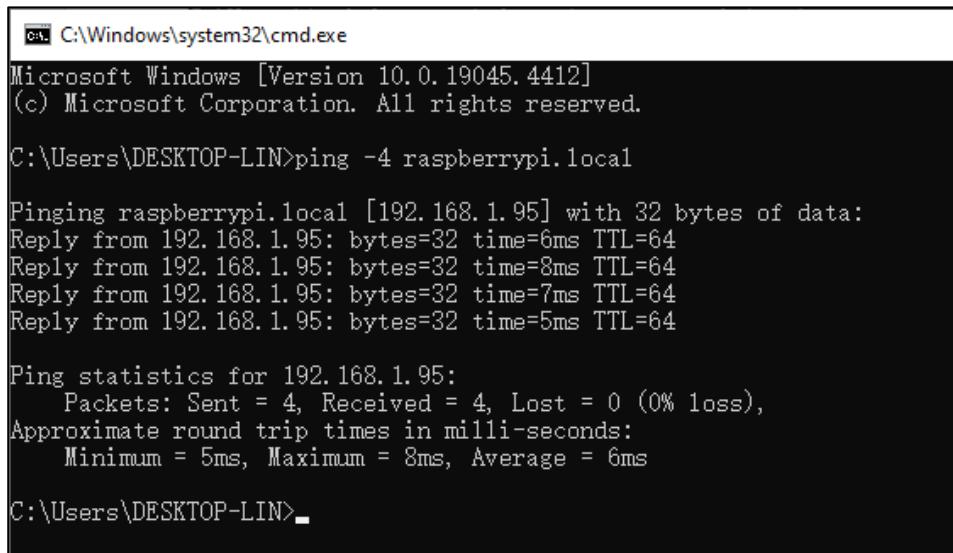
Then you can skip to [VNC Viewer](#).

## Windows OS Remote Desktop

If you are using win10, you can use follow way to login Raspberry Pi without desktop.

Press Win+R. Enter cmd. Then use this command to check IP:

```
ping -4 raspberrypi.local
```



```
C:\Windows\system32\cmd.exe
Microsoft Windows [Version 10.0.19045.4412]
(c) Microsoft Corporation. All rights reserved.

C:\Users\DESKTOP-LIN>ping -4 raspberrypi.local

Pinging raspberrypi.local [192.168.1.95] with 32 bytes of data:
Reply from 192.168.1.95: bytes=32 time=6ms TTL=64
Reply from 192.168.1.95: bytes=32 time=8ms TTL=64
Reply from 192.168.1.95: bytes=32 time=7ms TTL=64
Reply from 192.168.1.95: bytes=32 time=5ms TTL=64

Ping statistics for 192.168.1.95:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
    Approximate round trip times in milli-seconds:
        Minimum = 5ms, Maximum = 8ms, Average = 6ms

C:\Users\DESKTOP-LIN>
```

Then 192.168.1.147 is my Raspberry Pi IP.

Or enter router client to inquiry IP address named "raspberrypi". For example, I have inquired to **my RPi IP address, and it is "192.168.1.95"**.

```
ssh pi@xxxxxxxxxxxx(IP address)
```

Enter the following command:

```
ssh pi@192.168.1.95
```



```
pi@raspberrypi: ~
C:\Users\DESKTOP-LIN>ssh pi@192.168.1.95
The authenticity of host '192.168.1.95 (192.168.1.95)' can't be established.
ECDSA key fingerprint is SHA256:tHbTxASRQQ/zy4CT4vSJvzAYW9FdIUPVqq7/2Bf3cIM.
Are you sure you want to continue connecting (yes/no/[fingerprint])? yes
Warning: Permanently added '192.168.1.95' (ECDSA) to the list of known hosts.
pi@192.168.1.95's password:
Linux raspberrypi 6.6.20+rpt-rpi-2712 #1 SMP PREEMPT Debian 1:6.6.20-1+rpt1 (2024-03-07) aarch64

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.
Last login: Thu Jun  6 08:39:59 2024 from 192.168.1.85

SSH is enabled and the default password for the 'pi' user has not been changed.
This is a security risk - please login as the 'pi' user and type 'passwd' to set a new password.

pi@raspberrypi: ~ $
```

## VNC Viewer & VNC

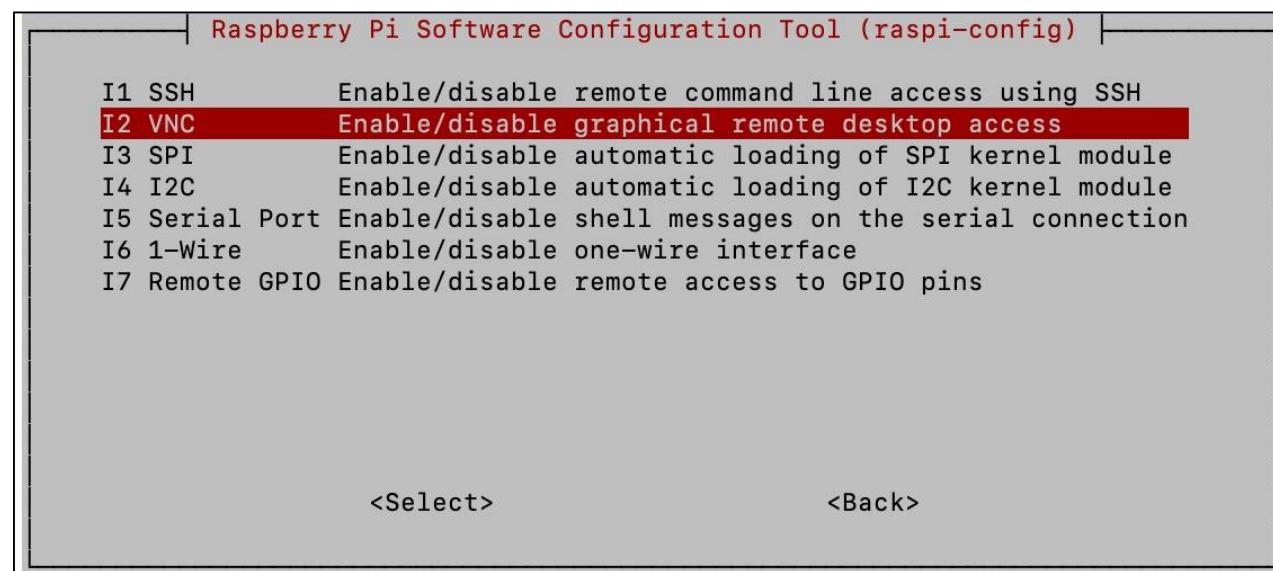
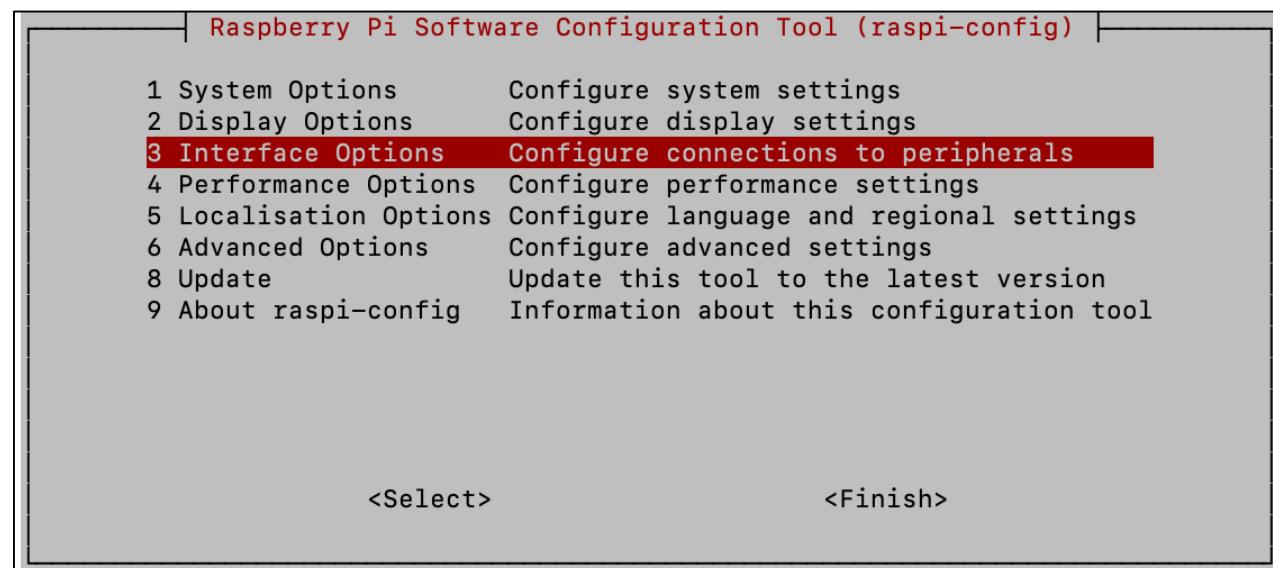
### Enable VNC

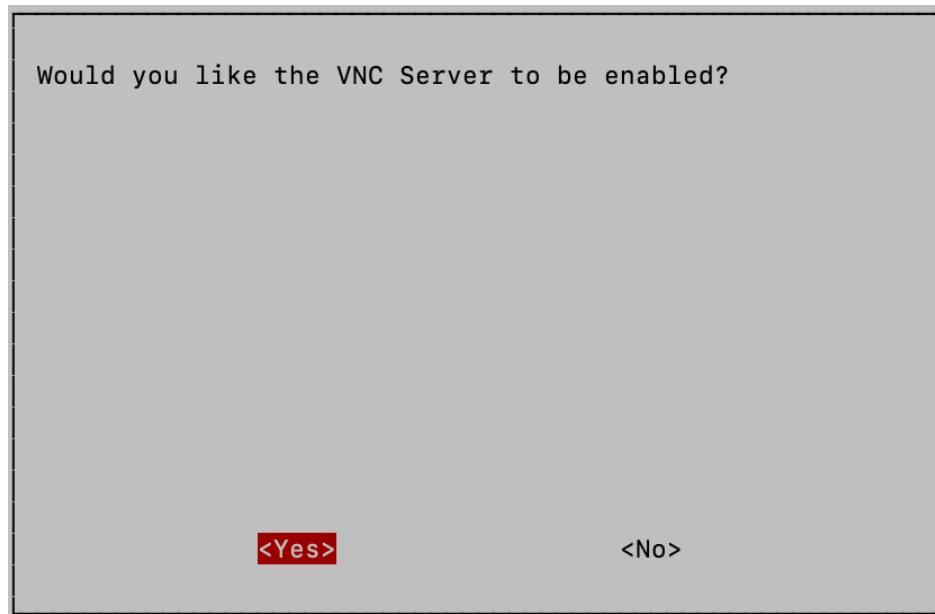
Type the following command. And select Interface Options → P5 VNC → Enter → Yes → OK. Here Raspberry Pi may need be restarted, and choose ok. Then open VNC interface.

```
sudo raspi-config
```

```
SSH is enabled and the default password for the 'pi' user has not been changed.  
This is a security risk - please login as the 'pi' user and type 'passwd' to set  
a new password.
```

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

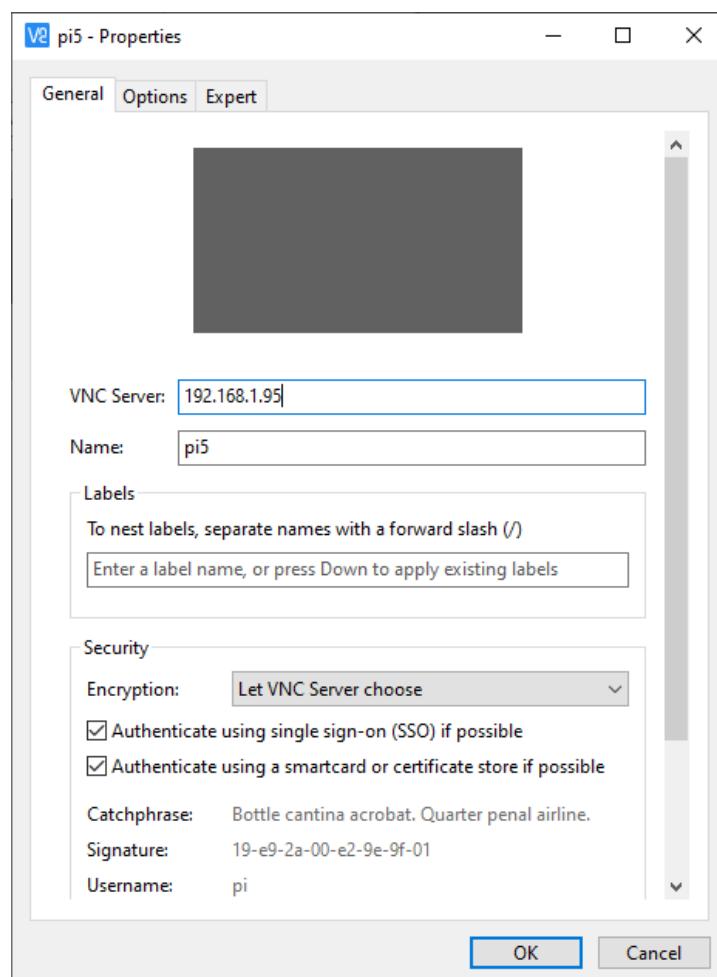




Then download and install VNC Viewer according to your computer system by click following link:

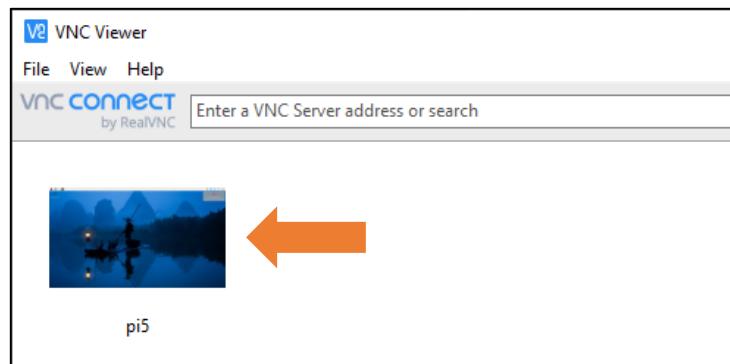
<https://www.realvnc.com/en/connect/download/viewer/>

After installation is completed, open VNC Viewer. And click File → New Connection. Then the interface is shown below.

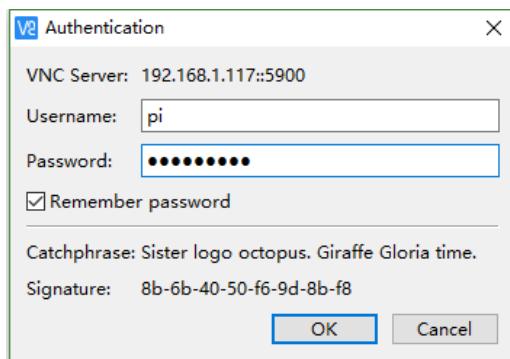


Enter ip address of your Raspberry Pi and fill in a name. Then click OK.

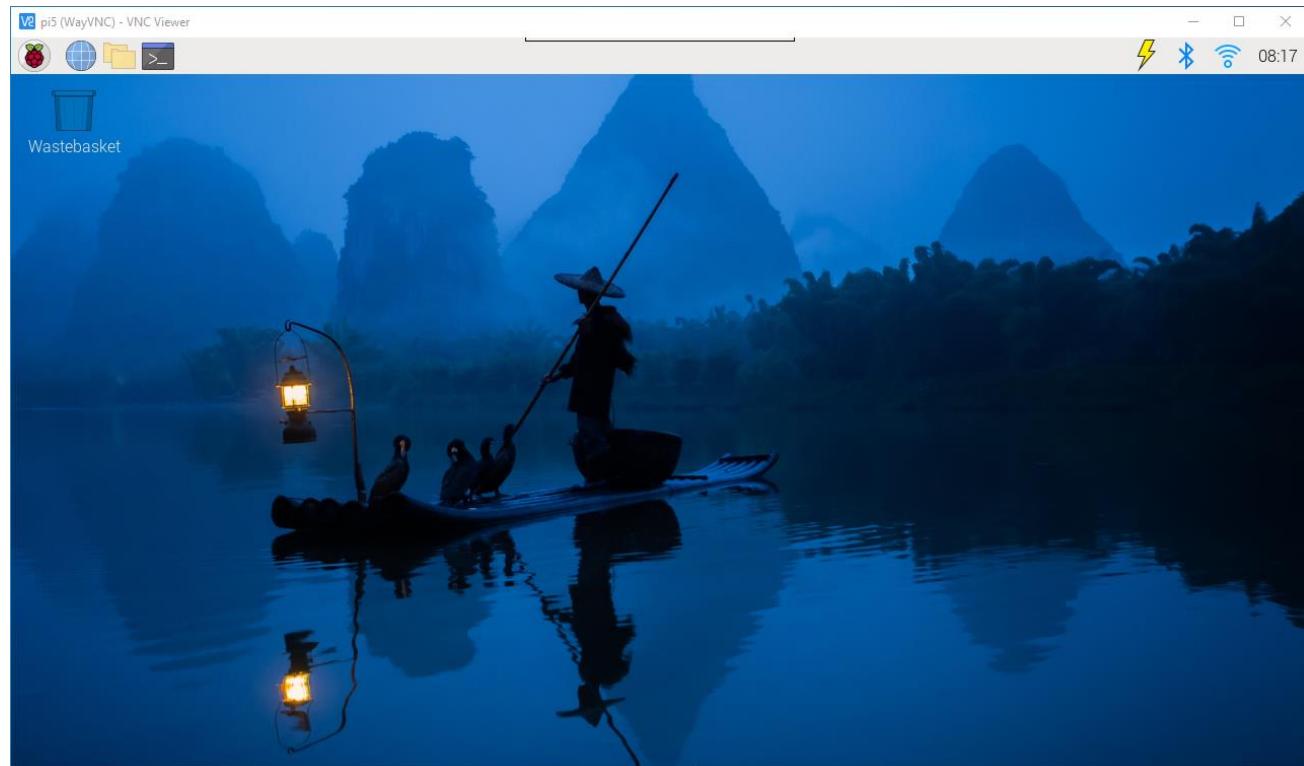
Then on the VNC Viewer panel, double-click new connection you just created,



and the following dialog box pops up.



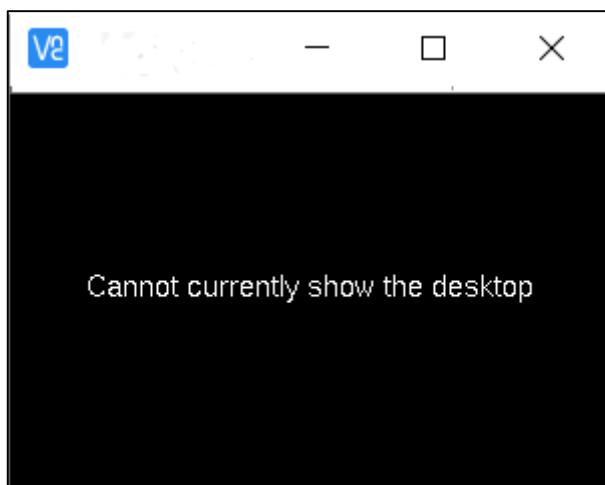
Enter username: **pi** and Password: **raspberry**. And click OK.



Here, you have logged in to Raspberry Pi successfully by using VNC Viewer

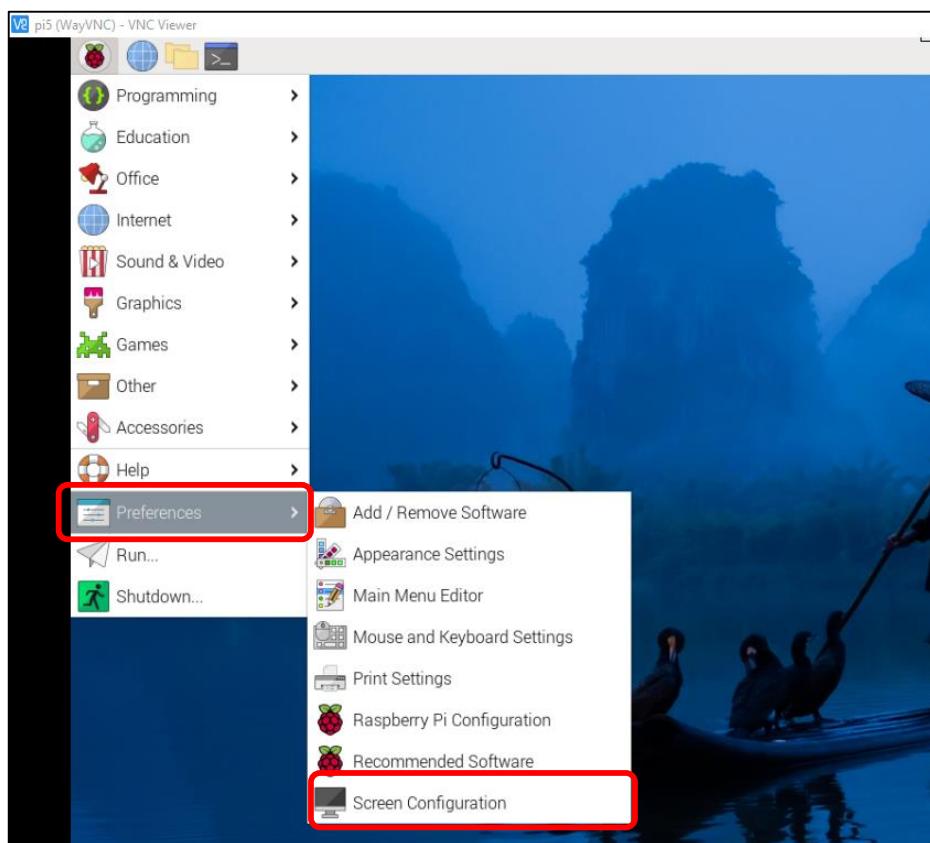


If there is black window, please [set resolution](#).

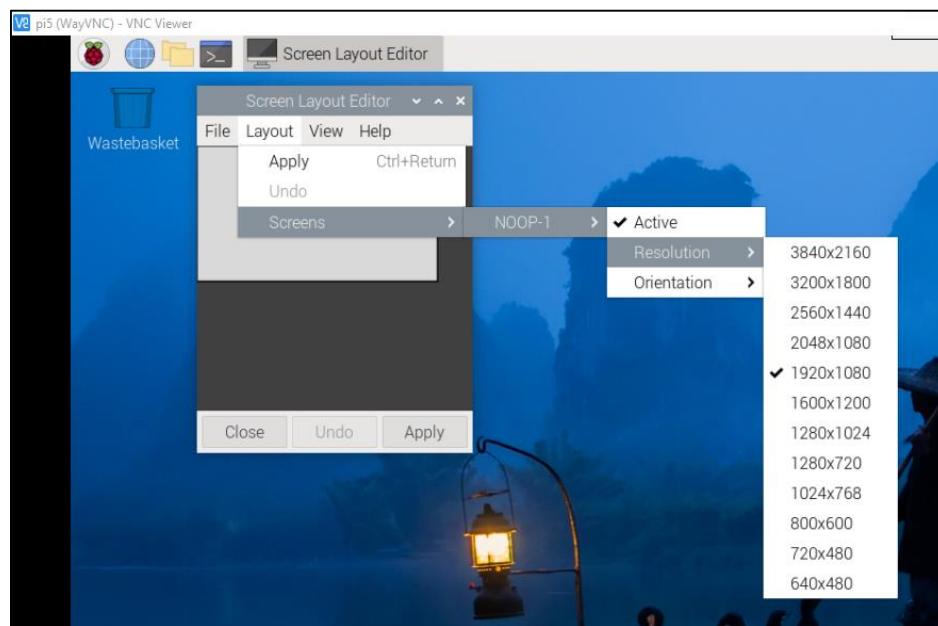


## Set Resolution

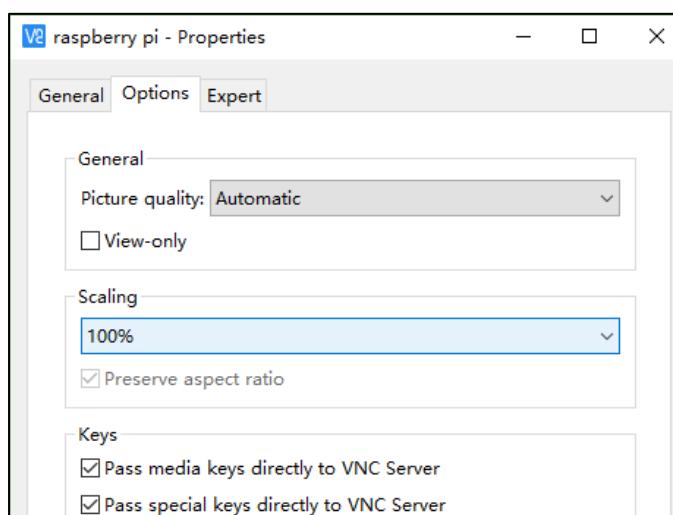
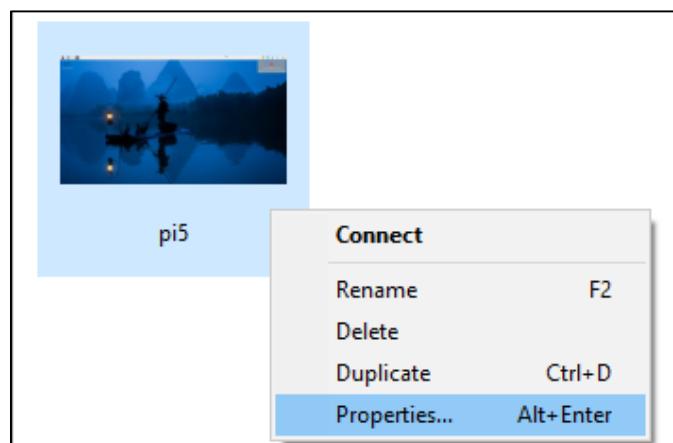
You can also set other resolutions.



If you don't know what resolution to set properly, you can try 1920x1080.



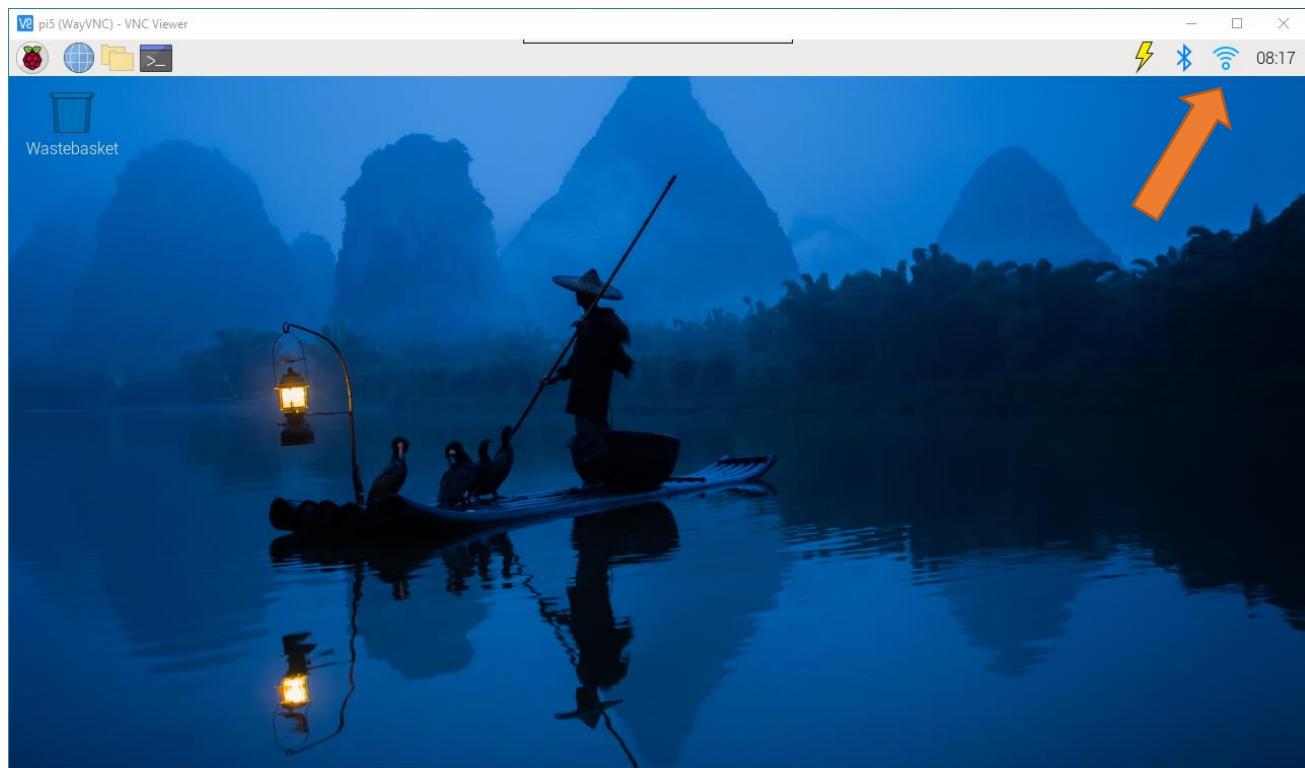
In addition, your VNC Viewer window may zoom your Raspberry Pi desktop. You can change it. On your VNC View control panel, click right key. And select Properties->Options label->Scaling. Then set proper scaling.





Here, you have logged in to Raspberry Pi successfully by using VNC Viewer and operated proper setting.

Raspberry Pi 5/4B/3B+/3B integrates a Wi-Fi adaptor. If you did not connect Pi to WiFi. You can connect it to wirelessly control the robot.



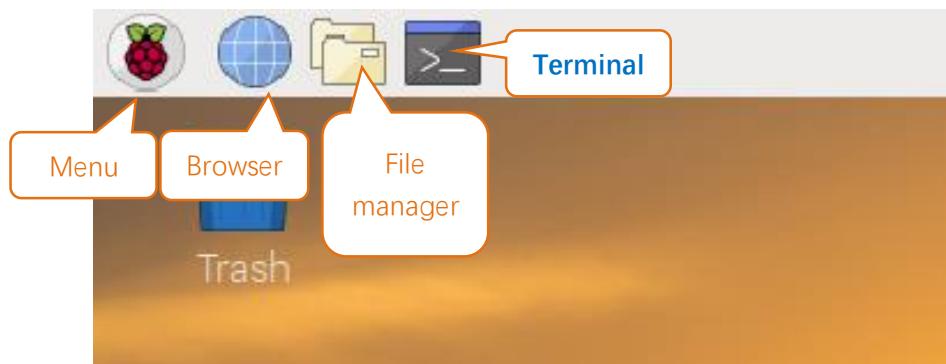
# Chapter 0 Preparation

Why “Chapter 0”? Because in program code the first number is 0. We choose to follow this rule. In this chapter, we will do some necessary foundational preparation work: Start your Raspberry Pi and install some necessary libraries.

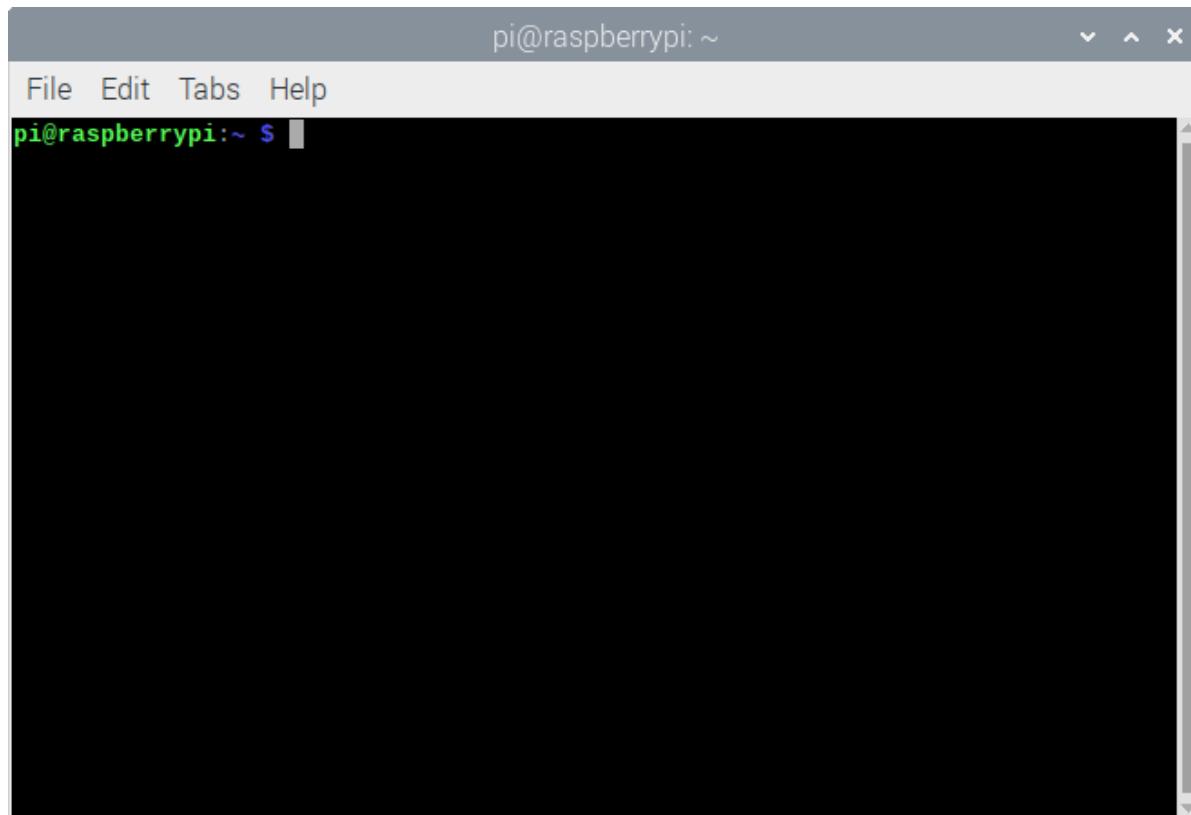
## Linux Command

Raspberry Pi OS is based on the Linux Operation System. Now we will introduce you to some frequently used Linux commands and rules.

First, open the Terminal. All commands are executed in Terminal.



When you click the Terminal icon, following interface appears.





### Note: The Linux is case sensitive.

First, type “ls” into the Terminal and press the “Enter” key. The result is shown below:

```
pi@raspberrypi:~ $ ls
Desktop
Documents
Downloads
Freenove_Three-wheeled_Smart_Car_Kit_for_Raspberry_Pi
Freenove_Ultimate_Starter_Kit_for_Raspberry_Pi
MagPi
mu_code

Music
Pictures
Public
Templates
thinclient_drives
Videos
```

The “ls” command lists information about the files (the current directory by default).

Content between “\$” and “pi@raspberrypi:” is the current working path. “~” represents the user directory, which refers to “/home/pi” here.

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

“cd” is used to change directory. “/” represents the root directory.

```
pi@raspberrypi:~ $ cd /usr
pi@raspberrypi:/usr $ ls
bin  games  include  lib  local  man  sbin  share  src
pi@raspberrypi:/usr $ cd ~
pi@raspberrypi:~ $
```

Later in this Tutorial, we will often change the working path. Typing commands under the wrong directory may cause errors and break the execution of further commands.

Many frequently used commands and instructions can be found in the following reference table.

Command	instruction
<b>ls</b>	Lists information about the FILEs (the current directory by default) and entries alphabetically.
<b>cd</b>	Changes directory
<b>sudo + cmd</b>	Executes cmd under root authority
<b>./</b>	Under current directory
<b>gcc</b>	GNU Compiler Collection
<b>git clone URL</b>	Use git tool to clone the contents of specified repository, and URL in the repository address.

There are many commands, which will come later. For more details about commands. You can refer to:

<http://www.linux-commands-examples.com>

## Shortcut Key

Now, we will introduce several commonly used shortcuts that are very useful in Terminal.

1. **Up and Down Arrow Keys:** Pressing “↑” (the Up key) will go backwards through the command history and pressing “↓” (the Down Key) will go forwards through the command history.

2. **Tab Key:** The Tab key can automatically complete the command/path you want to type. When there is only one eligible option, the command/path will be completely typed as soon as you press the Tab key even you only type one character of the command/path.

As shown below, under the '~' directory, you enter the Documents directory with the "cd" command. After typing "cd D", pressing the Tab key (there is no response), pressing the Tab key again then all the files/folders that begin with "D" will be listed. Continue to type the letters "oc" and then pressing the Tab key, the "Documents" is typed automatically.

```
pi@raspberrypi:~ $ cd D
Desktop/  Documents/ Downloads/
pi@raspberrypi:~ $ cd Doc█
```

```
pi@raspberrypi:~ $ cd D
Desktop/  Documents/ Downloads/
pi@raspberrypi:~ $ cd Documents/
```

## Install GPIO Zero Python library

GPIO Zero is a simple interface to GPIO devices with Raspberry Pi. GPIO Zero is installed by default in the Raspberry Pi OS desktop image, and the Raspberry Pi Desktop image for PC/Mac, both available from raspberrypi.org. Follow these guides to installing on Raspberry Pi OS Lite and other operating systems.

### GPIO Zero Python library Installation Steps

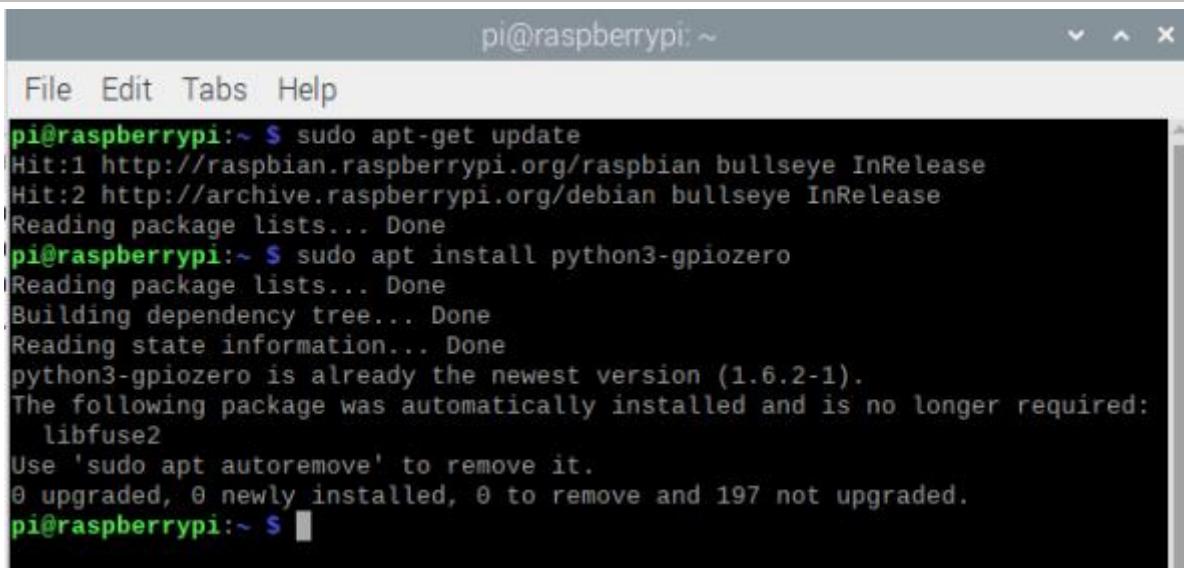
To install the GPIO Zero Python library, please open the Terminal and then follow the steps and commands below.

Note: For a command containing many lines, execute them one line at a time.

Enter the following commands **one by one** in the **terminal** to install GPIO Zero:

```
sudo apt-get update
```

```
sudo apt install python3-gpiozero
```



The terminal window shows the following output:

```
pi@raspberrypi:~ $ sudo apt-get update
Hit:1 http://raspbian.raspberrypi.org/raspbian bullseye InRelease
Hit:2 http://archive.raspberrypi.org/debian bullseye InRelease
Reading package lists... Done
pi@raspberrypi:~ $ sudo apt install python3-gpiozero
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
python3-gpiozero is already the newest version (1.6.2-1).
The following package was automatically installed and is no longer required:
  libfuse2
Use 'sudo apt autoremove' to remove it.
0 upgraded, 0 newly installed, 0 to remove and 197 not upgraded.
pi@raspberrypi:~ $
```

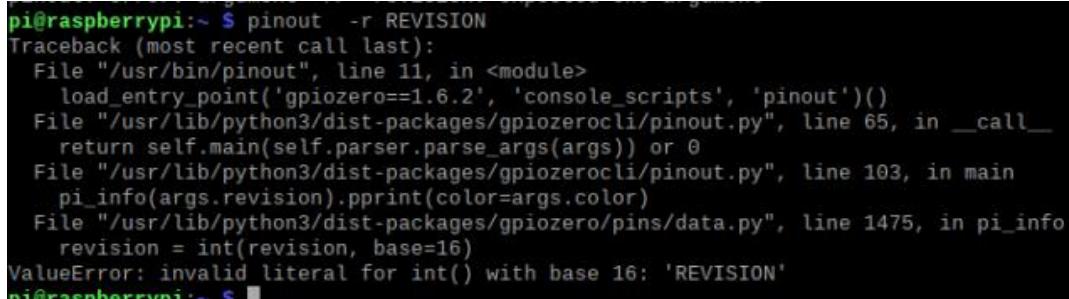
If you're using another operating system on your Raspberry Pi, you may need to use pip to install GPIO Zero instead. Install pip using get-pip and then type:

```
sudo pip3 install gpiozero
```

Run the gpiozero command to check the installation:

```
pinout -r REVISION
```

That should give you some confidence that the installation was a success.



The terminal window shows the following output:

```
pi@raspberrypi:~ $ pinout -r REVISION
Traceback (most recent call last):
  File "/usr/bin/pinout", line 11, in <module>
    load_entry_point('gpiozero==1.6.2', 'console_scripts', 'pinout')()
  File "/usr/lib/python3/dist-packages/gpiozerocli/pinout.py", line 65, in __call__
    return self.main(self.parser.parse_args()) or 0
  File "/usr/lib/python3/dist-packages/gpiozerocli/pinout.py", line 103, in main
    pi_info(args.revision).pprint(color=args.color)
  File "/usr/lib/python3/dist-packages/gpiozero/pins/data.py", line 1475, in pi_info
    revision = int(revision, base=16)
ValueError: invalid literal for int() with base 16: 'REVISION'
pi@raspberrypi:~ $
```

## Obtain the Project Code

After the above installation is completed, you can visit our official website (<http://www.freenove.com>) or our GitHub resources at (<https://github.com/freenove>) to download the latest available project code.

In this tutorial, we provide Python language code for each project.

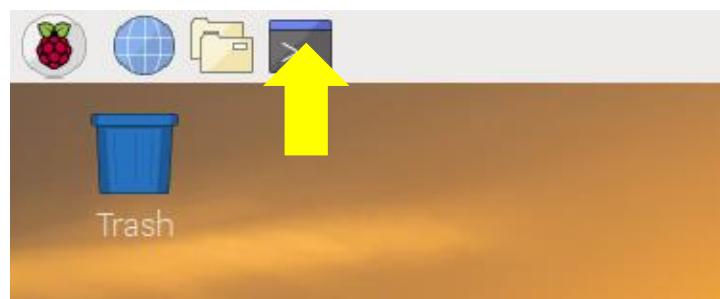
This is the method for obtaining the code:

In the pi directory of the RPi terminal, enter the following command.

```
cd
```

```
git clone --depth 1 https://github.com/freenove/Freenove_Basic_Starter_Kit_for_Raspberry_Pi
```

(**There is no need for a password. If you get some errors, please check your commands.**)

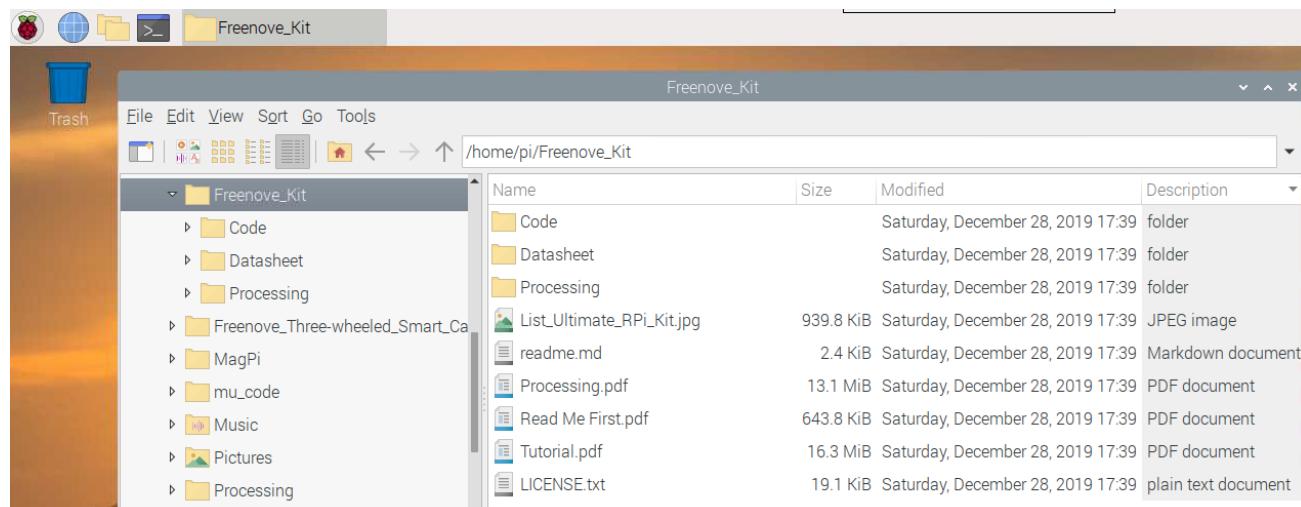


After the download is completed, a new folder "Freenove\_Basic\_Starter\_Kit\_for\_Raspberry\_Pi" is generated, which contains all of the tutorials and required code.

This folder name seems a little too long. We can simply rename it by using the following command.

```
mv Freenove_Basic_Starter_Kit_for_Raspberry_Pi/Freenove_Kit/
```

"Freenove\_Kit" is now the new and much shorter folder name.



If you have no experience with Python, we suggest that you refer to this website for basic information and knowledge.

<https://python.swaroopch.com/basics.html>



## Python2 & Python3

Python code, used in our kits, can now run on Python2 and Python3. **Python3 is recommend**. If you want to use Python2, please make sure your Python version is 2.7 or above. Python2 and Python3 are not fully compatible. However, Python2.6 and Python2.7 are transitional versions to python3, therefore you can also use Python2.6 and 2.7 to execute some Python3 code.

You can type “python2” or “python3” respectively into Terminal to check if python has been installed. Press Ctrl-Z to exit.

```
pi@raspberrypi:~ $ python2
Python 2.7.18 (default, Jul 14 2021, 08:11:37)
[GCC 10.2.1 20210110] on linux2
Type "help", "copyright", "credits" or "license" for more information.
>>>
[1]+  Stopped                  python2
pi@raspberrypi:~ $ python3
Python 3.9.2 (default, Mar 12 2021, 04:06:34)
[GCC 10.2.1 20210110] on linux
Type "help", "copyright", "credits" or "license" for more information.
>>>
[2]+  Stopped                  python3
pi@raspberrypi:~ $
```

Type “python”, and Terminal shows that it links to python3.

```
pi@raspberrypi:~ $ python
Python 3.9.2 (default, Mar 12 2021, 04:06:34)
[GCC 10.2.1 20210110] on linux
Type "help", "copyright", "credits" or "license" for more information.
>>>
[3]+  Stopped                  python
^Xpi@raspberrypi:~ $
```

## Set Python3 as default python

First, execute python to check the default python on your raspberry Pi. Press Ctrl-Z to exit.

```
pi@raspberrypi:~ $ python
Python 3.9.2 (default, Mar 12 2021, 04:06:34)
[GCC 10.2.1 20210110] on linux
Type "help", "copyright", "credits" or "license" for more information.
>>>
[3]+  Stopped                  python
^Xpi@raspberrypi:~ $
```

If it is python3, you can skip this section.

**If it is python2, you need execute the following commands to set default python to python3.**

1. Enter directory /usr/bin

```
cd /usr/bin
```

2. Delete the originalpython link.

```
sudo rm python
```

3. Create new python links to python.

```
sudo ln -s python3 python
```

4. Check python. Press Ctrl-Z to exit.

```
python
```

```
pi@raspberrypi:/usr/bin $ sudo rm python
pi@raspberrypi:/usr/bin $ sudo ln -s python3 python
pi@raspberrypi:/usr/bin $ python
Python 3.5.3 (default, Jan 19 2017, 14:11:04)
[GCC 6.3.0 20170124] on linux
Type "help", "copyright", "credits" or "license" for more information.
>>>
```

If you want to set python2 as default python in **other projects**, just repeat the commands above and change python3 to python2.



## Shortcut Key

Now, we will introduce several shortcuts that are very **useful** and **commonly used** in terminal.

1. **up and down arrow keys**. History commands can be quickly brought back by using up and down arrow keys, which are very useful when you need to reuse certain commands.

When you need to type commands, pressing “↑” will go backwards through the history of typed commands, and pressing “↓” will go forwards through the history of typed command.

2. **Tab key**. The Tab key can automatically complete the command/path you want to type. When there are multiple commands/paths conforming to the already typed letter, pressing Tab key once won't have any result. And pressing Tab key again will list all the eligible options. This command/path will be completely typed as soon as you press the Tab key when there is only one eligible option.

As shown below, under the ‘~’directory, enter the Documents directory with the “cd” command. After typing “cd D”, press Tab key, then there is no response. Press Tab key again, then all the files/folders that begin with “D” is listed. Continue to type the character “oc”, then press the Tab key, and then “Documents” is completely typed automatically.

```
pi@raspberrypi:~ $ cd D
Desktop/  Documents/ Downloads/
pi@raspberrypi:~ $ cd Doc█
```

```
pi@raspberrypi:~ $ cd D
Desktop/  Documents/ Downloads/
pi@raspberrypi:~ $ cd Documents/
```

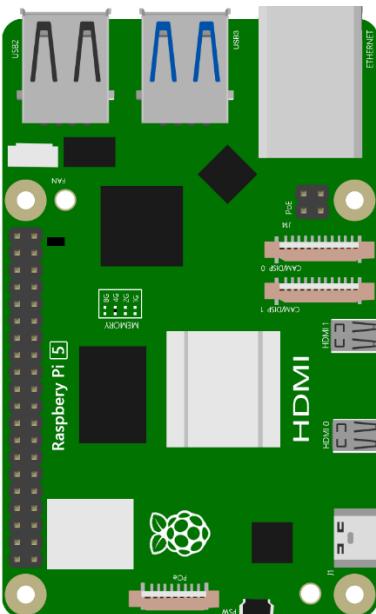
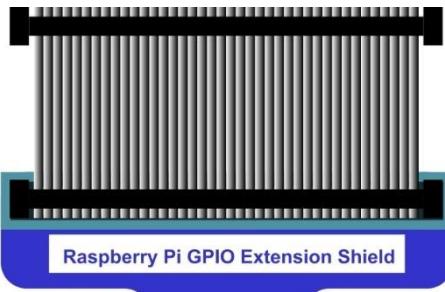
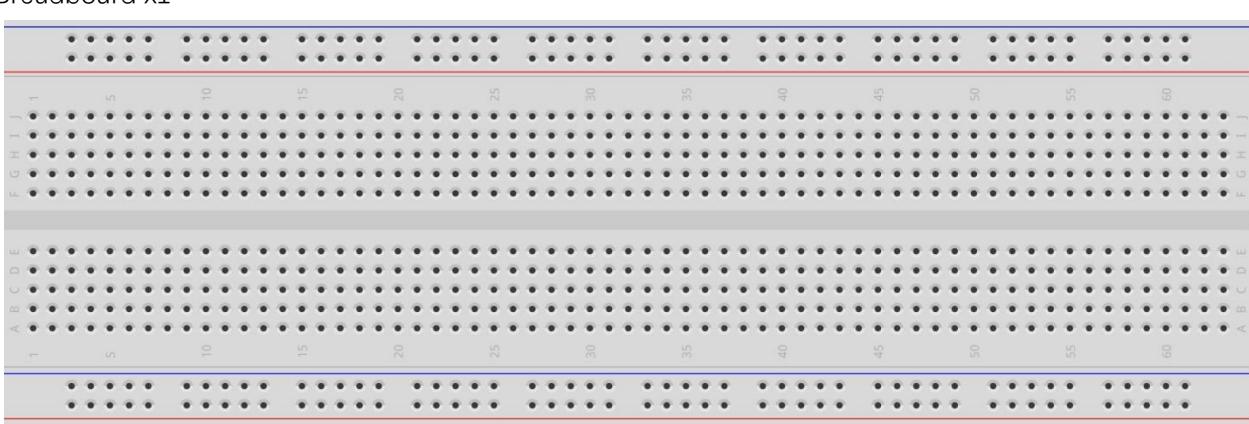
# Chapter 1 LED

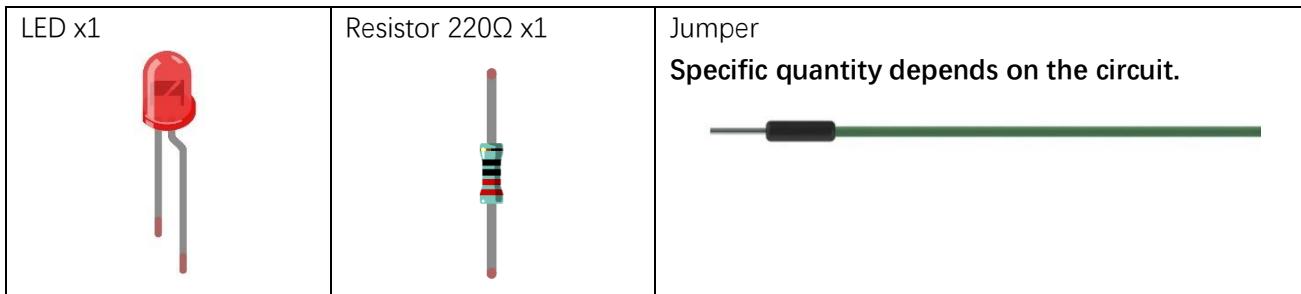
This chapter is the Start Point in the journey to build and explore RPi electronic projects. We will start with simple “Blink” project.

## Project 1.1 Blink

In this project, we will use RPi to control blinking a common LED.

## Component List

<p>Raspberry Pi (Recommended: Raspberry Pi 4B / 3B+ / 3B Compatible: 3A+ / 2B / 1B+ / 1A+ / Zero W / Zero)</p> 	<p>GPIO Extension Board &amp; Ribbon Cable</p>  <table border="1"> <tbody> <tr><td>3V3</td><td>5V</td></tr> <tr><td>SDA1</td><td>5V</td></tr> <tr><td>SCL1</td><td>GND</td></tr> <tr><td>GPIO4</td><td>TXD0</td></tr> <tr><td>GND</td><td>RXD0</td></tr> <tr><td>GPIO17</td><td>GPIO18</td></tr> <tr><td>GPIO27</td><td>GND</td></tr> <tr><td>GPIO22</td><td>GPIO23</td></tr> <tr><td>3V3</td><td>GPIO24</td></tr> <tr><td>MOSI</td><td>GND</td></tr> <tr><td>MISO</td><td>GPIO25</td></tr> <tr><td>SCK</td><td>CE0</td></tr> <tr><td>GND</td><td>CE1</td></tr> <tr><td>SDA0</td><td>SCL0</td></tr> <tr><td>GPIO5</td><td>GND</td></tr> <tr><td>GPIO6</td><td>GPIO12</td></tr> <tr><td>GPIO13</td><td>GND</td></tr> <tr><td>GPIO19</td><td>GPIO16</td></tr> <tr><td>GPIO26</td><td>GPIO20</td></tr> <tr><td>GND</td><td>GPIO21</td></tr> </tbody> </table>	3V3	5V	SDA1	5V	SCL1	GND	GPIO4	TXD0	GND	RXD0	GPIO17	GPIO18	GPIO27	GND	GPIO22	GPIO23	3V3	GPIO24	MOSI	GND	MISO	GPIO25	SCK	CE0	GND	CE1	SDA0	SCL0	GPIO5	GND	GPIO6	GPIO12	GPIO13	GND	GPIO19	GPIO16	GPIO26	GPIO20	GND	GPIO21
3V3	5V																																								
SDA1	5V																																								
SCL1	GND																																								
GPIO4	TXD0																																								
GND	RXD0																																								
GPIO17	GPIO18																																								
GPIO27	GND																																								
GPIO22	GPIO23																																								
3V3	GPIO24																																								
MOSI	GND																																								
MISO	GPIO25																																								
SCK	CE0																																								
GND	CE1																																								
SDA0	SCL0																																								
GPIO5	GND																																								
GPIO6	GPIO12																																								
GPIO13	GND																																								
GPIO19	GPIO16																																								
GPIO26	GPIO20																																								
GND	GPIO21																																								
<p>Breadboard x1</p> 																																									



In the components list, 3B GPIO, Extension Shield Raspberry and Breadboard are necessary for each project. Later, they will be reference by text only (no images as in above).

## GPIO

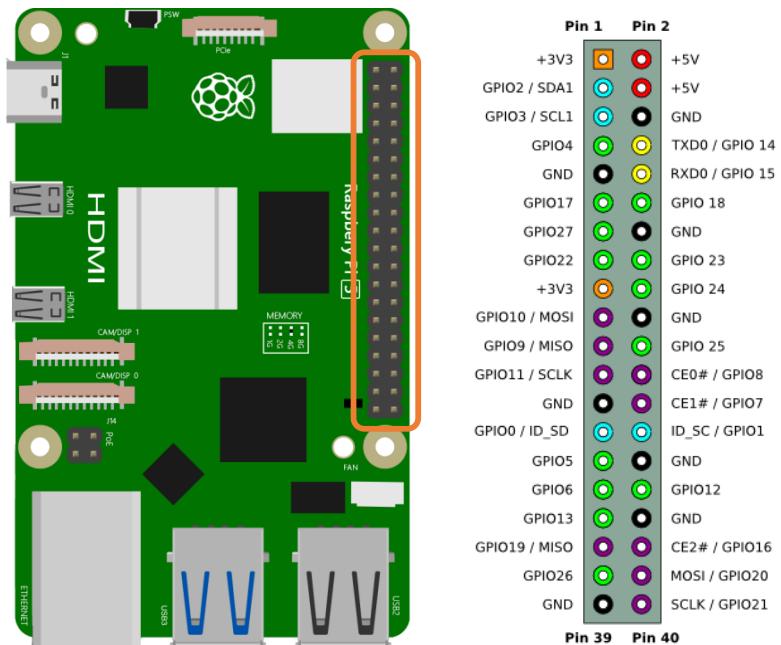
GPIO: General Purpose Input/Output. Here we will introduce the specific function of the pins on the Raspberry Pi and how you can utilize them in all sorts of ways in your projects. Most RPi Module pins can be used as either an input or output, depending on your program and its functions.

When programming GPIO pins there are 3 different ways to reference them: GPIO Numbering, Physical Numbering and WiringPi GPIO Numbering.

### BCM GPIO Numbering

The Raspberry Pi CPU uses Broadcom (BCM) processing chips BCM2835, BCM2836 or BCM2837. GPIO pin numbers are assigned by the processing chip manufacturer and are how the computer recognizes each pin. The pin numbers themselves do not make sense or have meaning as they are only a form of identification. Since their numeric values and physical locations have no specific order, there is no way to remember them so you will need to have a printed reference or a reference board that fits over the pins.

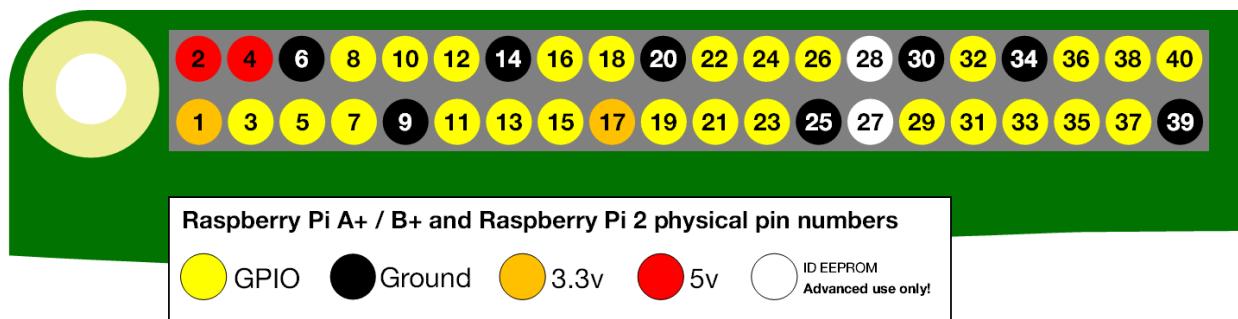
Each pin's functional assignment is defined in the image below:



For more details about pin definition of GPIO, please refer to <http://pinout.xyz/>

## PHYSICAL Numbering

Another way to refer to the pins is by simply counting across and down from pin 1 at the top left (nearest to the SD card). This is 'Physical Numbering', as shown below:



## GPIO Numbering

You can use the following command to view their correlation.

## Pinout

```
pi@raspberrypi: ~
File Edit Tabs Help
pi@raspberrypi:~ $ pinout
[Diagram of the Raspberry Pi Model 3A+ V1.0 board showing pinout and component connections]
Revision : 9020e0
SoC : BCM2837
RAM : 512MB
Storage : MicroSD
USB ports : 1 (of which 0 USB3)
Ethernet ports : 0 (0Mbps max. speed)
Wi-fi : True
Bluetooth : True
Camera ports (CSI) : 1
Display ports (DSI) : 1

J8:
 3V3 (1) (2) 5V
 GPIO2 (3) (4) 5V
 GPIO3 (5) (6) GND
 GPIO4 (7) (8) GPIO14
   GND (9) (10) GPIO15
 GPIO17 (11) (12) GPIO18
 GPIO27 (13) (14) GND
 GPIO22 (15) (16) GPIO23
  3V3 (17) (18) GPIO24
 GPIO10 (19) (20) GND
 GPIO9 (21) (22) GPIO25
 GPIO11 (23) (24) GPIO8
   GND (25) (26) GPIO7
 GPIO0 (27) (28) GPIO1
 GPIO5 (29) (30) GND
 GPIO6 (31) (32) GPIO12
 GPIO13 (33) (34) GND
 GPIO19 (35) (36) GPIO16
 GPIO26 (37) (38) GPIO20
   GND (39) (40) GPIO21

For further information, please refer to https://pinout.xyz/
pi@raspberrypi:~ $ ]
```

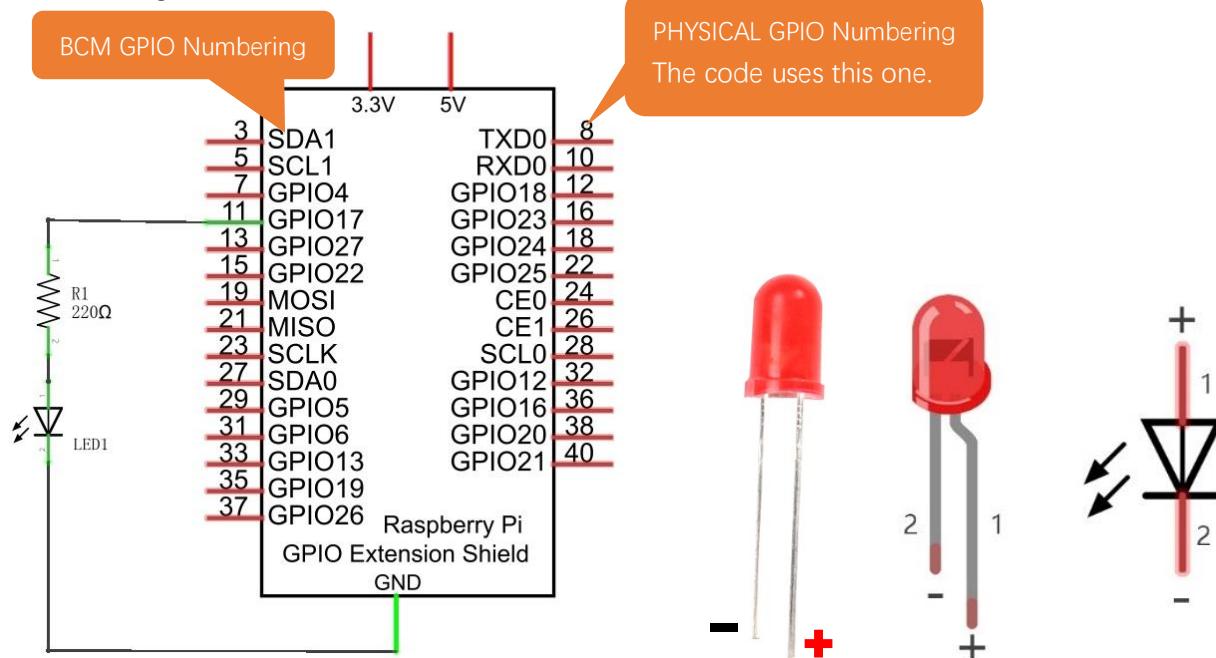
## Circuit

First, disconnect your RPi from the GPIO Extension Shield. Then build the circuit according to the circuit and hardware diagrams. After the circuit is built and verified correct, connect the RPi to GPIO Extension Shield.

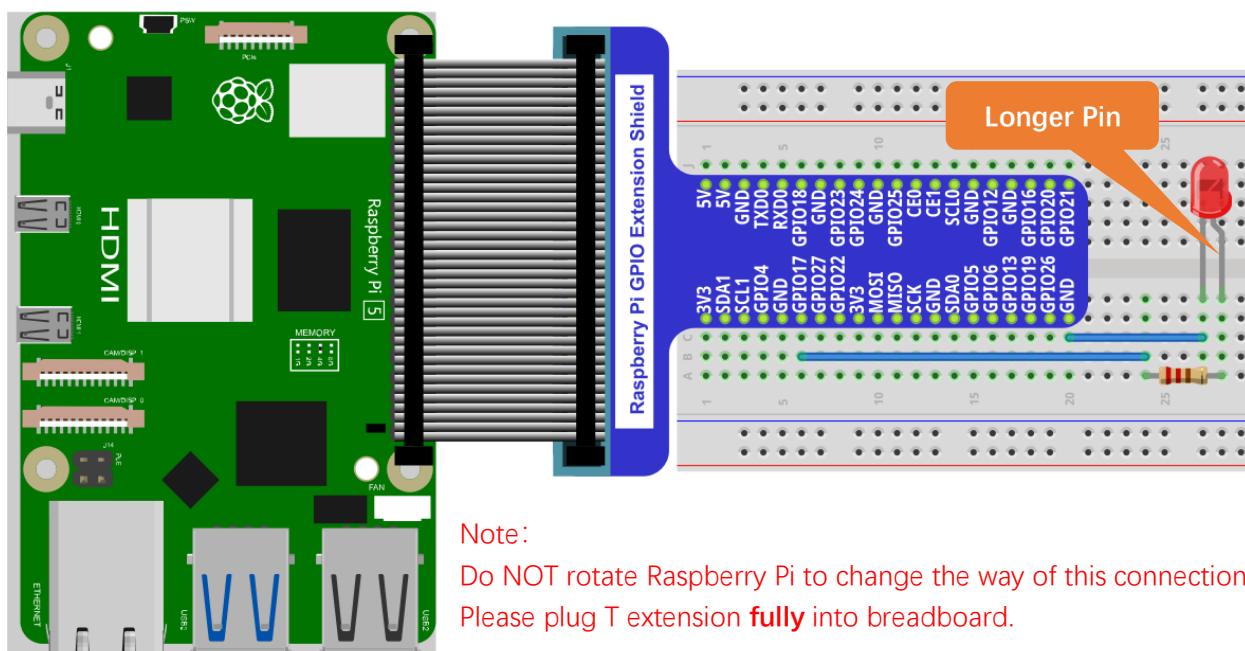
**CAUTION:** Avoid any possible short circuits (especially connecting 5V or GND, 3.3V and GND)!

**WARNING:** A short circuit can cause high current in your circuit, create excessive component heat and cause permanent damage to your RPi!

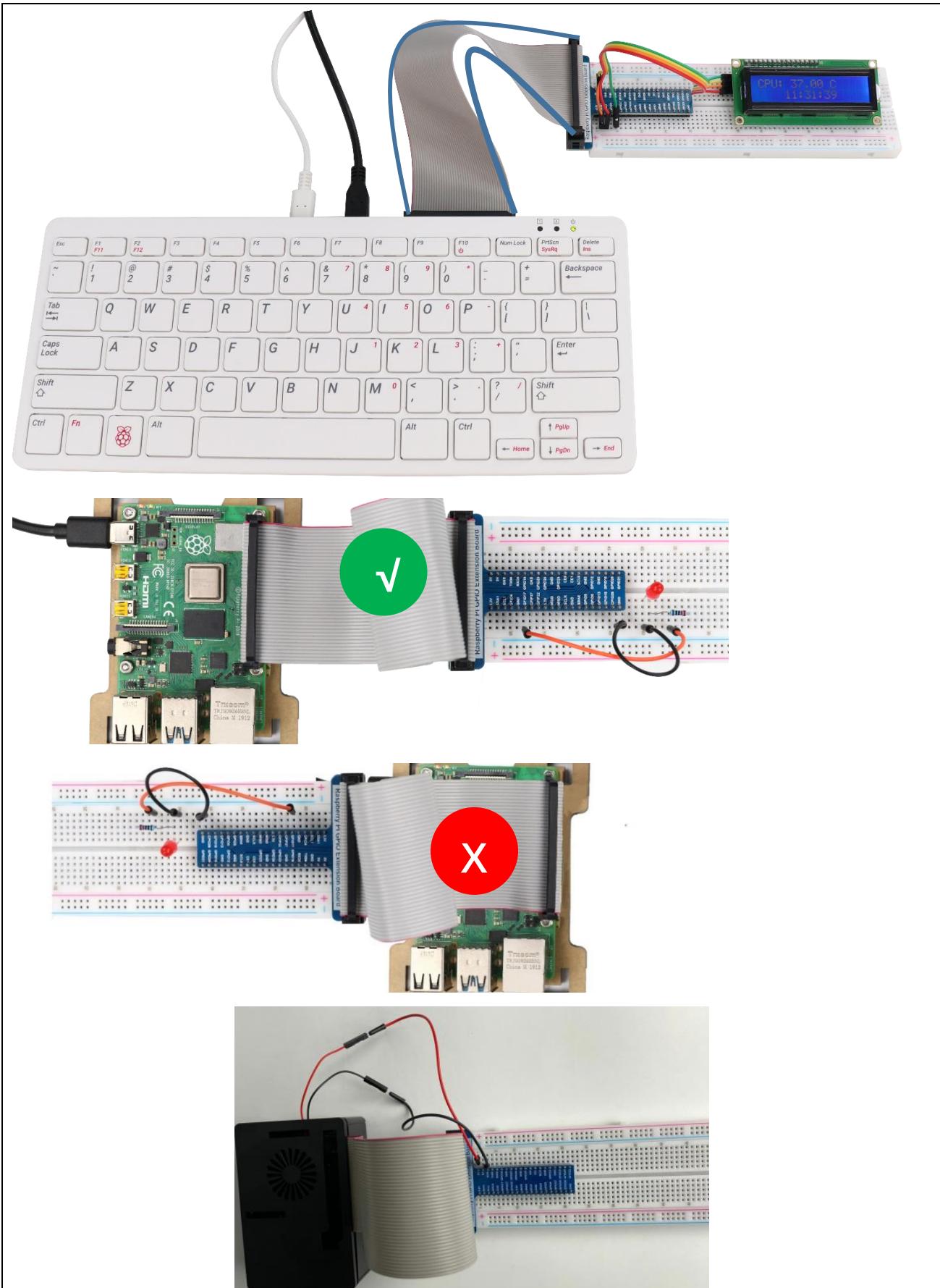
Schematic diagram



Hardware connection. If you need any support, please contact us via: [support@freenove.com](mailto:support@freenove.com)



The connection of **Raspberry Pi T extension board** is as below. **Don't reverse the ribbon.**



If you have a fan, you can connect it to 5V GND of breadboard via jumper wires.



### How to distinguish resistors?

There are only three kind of resistors in this kit.

The one with 1 red ring is  $10\text{K}\Omega$  

The one with 2 red rings is  $220\Omega$  

The one with 0 red ring is  $1\text{K}\Omega$  

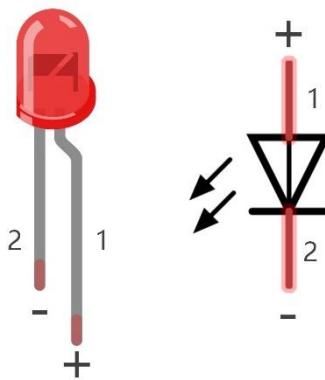
Future hardware connection diagrams will only show that part of breadboard and GPIO Extension Shield.

## Component knowledge

### LED

An LED is a type of diode. All diodes only work if current is flowing in the correct direction and have two Poles. An LED will only work (light up) if the longer pin (+) of LED is connected to the positive output from a power source and the shorter pin is connected to the negative (-) output, which is also referred to as Ground (GND). This type of component is known as "Polar" (think One-Way Street).

All common 2 lead diodes are the same in this respect. Diodes work only if the voltage of its positive electrode is higher than its negative electrode and there is a narrow range of operating voltage for most all common diodes of 1.9 and 3.4V. If you use much more than 3.3V the LED will be damaged and burnt out.



LED	Voltage	Maximum current	Recommended current
Red	1.9-2.2V	20mA	10mA
Green	2.9-3.4V	10mA	5mA
Blue	2.9-3.4V	10mA	5mA

Volt ampere characteristics conform to diode

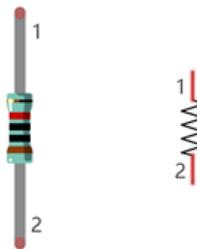
Note: LEDs cannot be directly connected to a power supply, which usually ends in a damaged component. A resistor with a specified resistance value must be connected in series to the LED you plan to use.

### Resistor

Resistors use Ohms ( $\Omega$ ) as the unit of measurement of their resistance ( $R$ ).  $1M\Omega=1000k\Omega$ ,  $1k\Omega=1000\Omega$ .

A resistor is a passive electrical component that limits or regulates the flow of current in an electronic circuit.

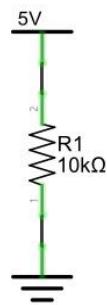
On the left, we see a physical representation of a resistor, and the right is the symbol used to represent the presence of a resistor in a circuit diagram or schematic.



The bands of color on a resistor is a shorthand code used to identify its resistance value. For more details of resistor color codes, please refer to the card in the kit package.

With a fixed voltage, there will be less current output with greater resistance added to the circuit. The relationship between Current, Voltage and Resistance can be expressed by this formula:  $I=V/R$  known as Ohm's Law where  $I$  = Current,  $V$  = Voltage and  $R$  = Resistance. Knowing the values of any two of these allows you to solve the value of the third.

In the following diagram, the current through R1 is:  $I=U/R=5V/10k\Omega=0.0005A=0.5mA$ .

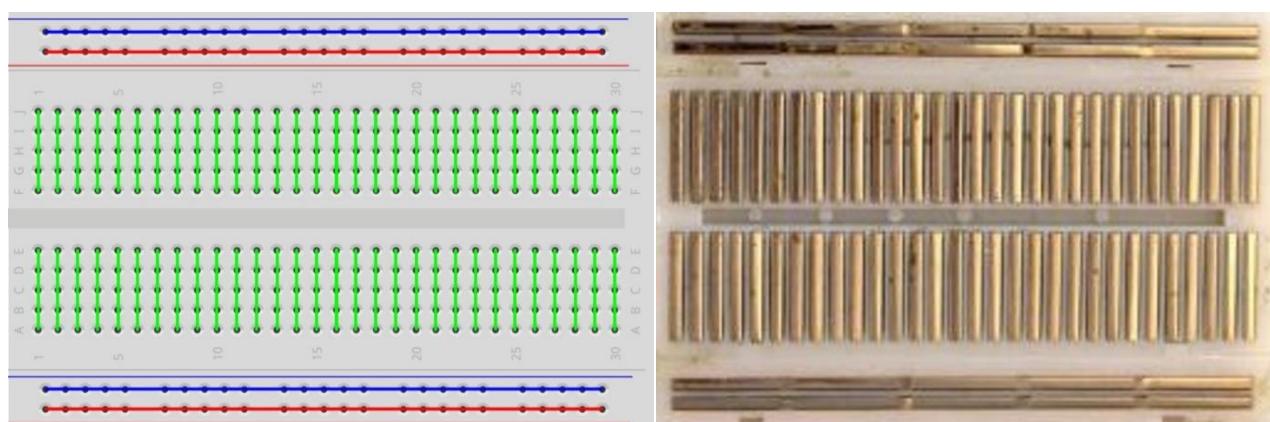


**WARNING:** Never connect the two poles of a power supply with anything of low resistance value (i.e. a metal object or bare wire) this is a Short and results in high current that may damage the power supply and electronic components.

Note: Unlike LEDs and Diodes, Resistors have no poles and are non-polar (it does not matter which direction you insert them into a circuit, it will work the same)

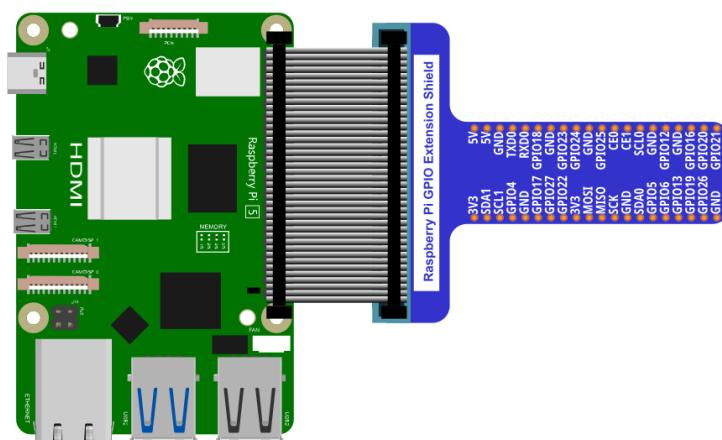
### Breadboard

Here we have a small breadboard as an example of how the rows of holes (sockets) are electrically attached. The left picture shows the ways the pins have shared electrical connection and the right picture shows the actual internal metal, which connect these rows electrically.



### GPIO Extension Board

GPIO board is a convenient way to connect the RPi I/O ports to the breadboard directly. The GPIO pin sequence on Extension Board is identical to the GPIO pin sequence of RPi.





## Code

According to the circuit, when the GPIO17 of RPi output level is high, the LED turns ON. Conversely, when the GPIO17 RPi output level is low, the LED turns OFF. Therefore, we can let GPIO17 cycle output high and output low level to make the LED blink. We will use Python code to achieve the target.

### Python Code 1.1.1 Blink

Now, we will use Python language to make a LED blink.

First, observe the project result, and then learn about the code in detail.

If you have any concerns, please contact us via: [support@freenove.com](mailto:support@freenove.com)

1. Use cd command to enter 01.1.1\_Blink directory of Python code.

```
cd ~/Freenove_Kit/Code/Python_GPIOZero_Code/01.1.1_Blink
```

2. Use python command to execute python code blink.py.

```
python Blink.py
```

The LED starts blinking.

```
pi@raspberrypi: ~/Freenove_Kit/Code/Python_GPIOZero_Code/01.1.1_Blink
File Edit Tabs Help
pi@raspberrypi:~ $ cd ~/Freenove_Kit/Code/Python_GPIOZero_Code/01.1.1_Blink
pi@raspberrypi:~/Freenove_Kit/Code/Python_GPIOZero_Code/01.1.1_Blink $ python Blink.py
Program is starting ...

led turned on >>>
led turned off <<<
led turned on >>>
led turned off <<<
^CEnding program
pi@raspberrypi:~/Freenove_Kit/Code/Python_GPIOZero_Code/01.1.1_Blink $
```

You can press “Ctrl+C” to end the program. The following is the program code:

```
1 from gpiozero import LED
2 from time import sleep
3
4 led = LED(17)          # define LED pin according to BCM Numbering
5 #led = LED("J8:11")    # BOARD Numbering
6 ''
7 # pins numbering, the following lines are all equivalent
8 led = LED(17)          # BCM
9 led = LED("GPIO17")    # BCM
10 led = LED("BCM17")     # BCM
11 led = LED("BOARD11")   # BOARD
12 led = LED("WPI0")      # WiringPi
13 led = LED("J8:11")     # BOARD
14 ''
15 def loop():
16     while True:
```

```

17     led.on()      # turn on LED
18     print ('led turned on >>>') # print message on terminal
19     sleep(1)      # wait 1 second
20     led.off()     # turn off LED
21     print ('led turned off <<<') # print message on terminal
22     sleep(1)      # wait 1 second
23
24 if __name__ == '__main__':    # Program entrance
25     print ('Program is starting ... \n')
26     try:
27         loop()
28     except KeyboardInterrupt: # Press ctrl-c to end the program.
29         print("Ending program")

```

Import the LED class from the gpiozero library.

```
from gpiozero import LED
```

Create an LED assembly for controlling the LED.

```
led = LED(17)          # define LED pin according to BCM Numbering
```

Turn on LED device.

```
led.on()      # turn on LED
```

Turn off LED devices.

```
led.off()     # turn off LED
```

The main function turns on the LED for one second and then turns it off for one second, which repeats endless.

```

def loop():
    while True:
        led.on()      # turn on LED
        print ('led turned on >>>') # print message on terminal
        sleep(1)      # wait 1 second
        led.off()     # turn off LED
        print ('led turned off <<<') # print message on terminal
        sleep(1)      # wait 1 second

```

## Reference

About GPIO Zero:

### GPIO Zero

A simple interface to GPIO devices with Raspberry Pi, Using the GPIO Zero library makes it easy to get started with controlling GPIO devices with Python. The library is comprehensively documented at

<https://gpiozero.readthedocs.io/en/stable/>

<https://github.com/gpiozero/gpiozero>

For more information about the methods used by the LED class in the GPIO Zero library,please refer to:

[https://gpiozero.readthedocs.io/en/stable/api\\_output.html#led](https://gpiozero.readthedocs.io/en/stable/api_output.html#led)

For more information about the methods used by the DigitalOutputDevice class in the GPIO Zero library,please refer to:

[https://gpiozero.readthedocs.io/en/stable/api\\_output.html#digitaloutputdevice](https://gpiozero.readthedocs.io/en/stable/api_output.html#digitaloutputdevice)



“import time” time is a module of python.

<https://docs.python.org/2/library/time.html?highlight=time%20time#module-time>

In Python, libraries and functions used in a script must be imported by name at the top of the file, with the exception of the functions built into Python by default.

For example, to use the LED interface from GPIO Zero, it should be explicitly imported:

```
from gpiozero import LED
```

Now LED is available directly in your script:

```
led = LED(17)          # define LED pin according to BCM Numbering  
#led = LED("J8:11")    # BOARD Numbering
```

Alternatively, the whole GPIO Zero library can be imported:

```
import gpiozero
```

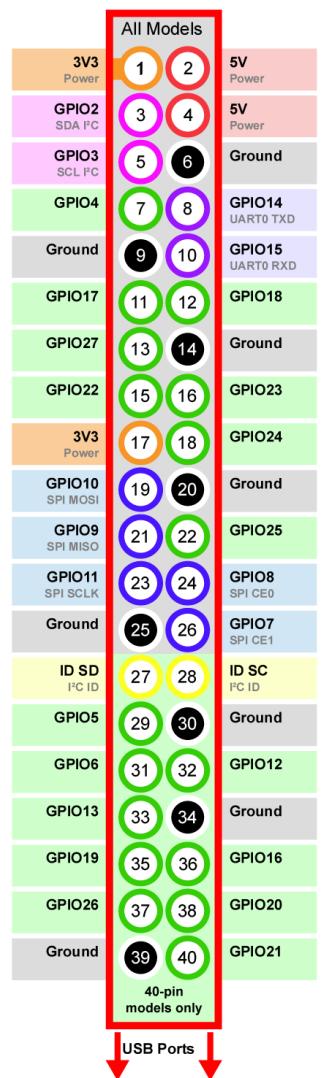
In this case, all references to items within GPIO Zero must be prefixed:

```
led = gpiozero.LED(17)      # define LED pin according to BCM Numbering  
#led = gpiozero.LED("J8:11") # BOARD Numbering
```

## Pin Numbering

This library uses Broadcom (BCM) pin numbering for the GPIO pins, as opposed to physical (BOARD) numbering. Unlike in the RPi.GPIO library, this is not configurable. However, translation from other schemes can be used by providing prefixes to pin numbers (see below).

Any pin marked "GPIO" in the diagram below can be used as a pin number. For example, if an LED was attached to "GPIO17" you would specify the pin number as 17 rather than 11:



If you wish to use physical (BOARD) numbering you can specify the pin number as "BOARD11". If you are familiar with the wiringPi pin numbers (another physical layout) you could use "WPIO" instead.

Finally, you can specify pins as "header:number", e.g. "J8:11" meaning physical pin 11 on header J8 (the GPIO header on modern Pis). Hence, the following lines are all equivalent:

```
led = LED(17)
led = LED("GPIO17")
led = LED("BCM17")
led = LED("BOARD11")
led = LED("WPIO")
led = LED("J8:11")
```





Note that these alternate schemes are merely translations. If you request the state of a device on the command line, the associated pin number will always be reported in the Broadcom (BCM) scheme:

```
led = LED("BOARD11")
led
<gpiozero.LED object on pin GPIO17, active_high=True, is_active=False>
```

**In this tutorial, we will use the default integer pin number in the Broadcom (BCM) layout.**

### GPIO Numbering Relationship

WingPi	BCM(Extension)	Physical		BCM(Extension)	WingPi
3.3V	3.3V	1	2	5V	5V
8	GPIO2/SDA1	3	4	5V	5V
9	GPIO3/SCL1	5	6	GND	GND
7	GPIO4	7	8	GPIO14/TXDO	15
GND	GND	9	10	GPIO15/RXDO	16
0	GPIO17	11	12	GPIO18	1
2	GPIO27	13	14	GND	GND
3	GPIO22	15	16	GPIO23	4
3.3V	3.3V	17	18	GPIO24	5
12	GPIO10/MOSI	19	20	GND	GND
13	GPIO9/MOIS	21	22	GPIO25	6
14	GPIO11/SCLK	23	24	GPIO8/CE0	10
GND	GND	25	26	GPIO7/CE1	11
30	GPIO0/SDA0	27	28	GPIO1/SCLO	31
21	GPIO5	29	30	GND	GND
22	GPIO6	31	32	GPIO12	26
23	GPIO13	33	34	GND	GND
24	GPIO19	35	36	GPIO16	27
25	GPIO26	37	38	GPIO20	28
GND	GND	39	40	GPIO21	29

In loop(), there is a while loop, which is an endless loop (a while loop). That is, the program will always be executed in this loop, unless it is ended because of external factors. In this loop, set LED output high level, then the LED turns ON. After a period of time delay, set LED output low level, then the LED turns OFF, which is followed by a delay. Repeat the loop, then LED will start blinking.

```
def loop():
    while True:
        led.on()      # turn on LED
        print ('led turned on >>>') # print message on terminal
        sleep(1)     # wait 1 second
        led.off()    # turn off LED
        print ('led turned off <<<') # print message on terminal
        sleep(1)     # wait 1 second
```

In gpiozero, at the end of your script, cleanup is run automatically, restoring your GPIO pins to the state they were found. To explicitly close a connection to a pin, you can manually call the close() method on a device object:

```
led = LED(17)
```

```
led.on()  
led  
<gpiozero.LED object on pin GPIO17, active_high=True, is_active=True>  
led.close()  
led  
<gpiozero.LED object closed>
```

This means that you can reuse the pin for another device, and that despite turning the LED on (and hence, the pin high), after calling close() it is restored to its previous state (LED off, pin low).

In this tutorial, most projects have added an active run cleanup program to restore the GPIO pin to the found default state.



## Freenove Car, Robot and other products for Raspberry Pi

We also have car and robot kits for Raspberry Pi. You can visit our website for details.

<https://www.amazon.com/freenove>

### FNK0043 Freenove 4WD Smart Car Kit for Raspberry Pi



<https://www.youtube.com/watch?v=4Zv0GZUQjZc>

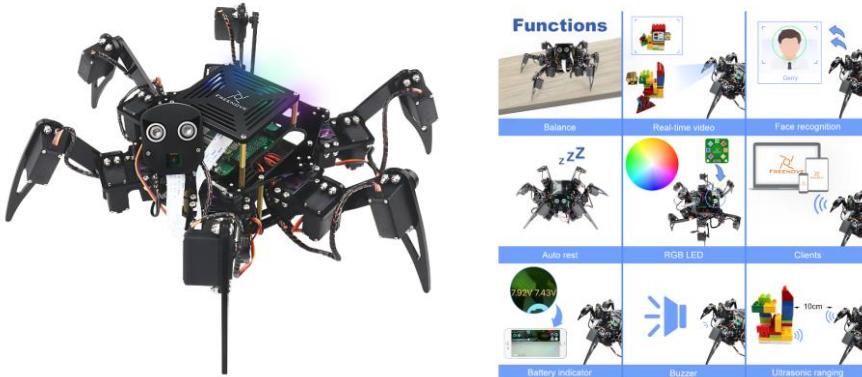
### FNK0050 Freenove Robot Dog Kit for Raspberry Pi



[https://www.youtube.com/watch?v=7BmlZ8\\_R9d4](https://www.youtube.com/watch?v=7BmlZ8_R9d4)

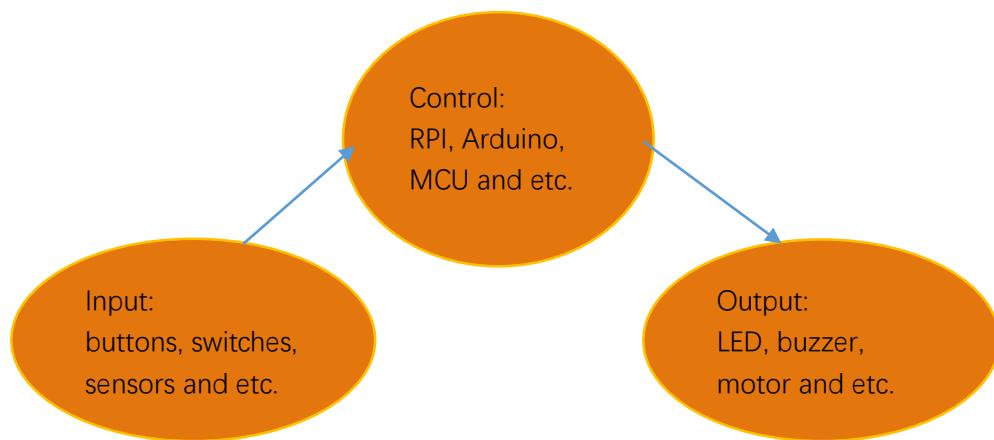
### FNK0052 Freenove\_Big\_Hexapod\_Robot\_Kit\_for\_Raspberry\_Pi

<https://youtu.be/LvghnJ2DNZ0>



## Chapter 2 Buttons & LEDs

Usually, there are three essential parts in a complete automatic control device: INPUT, OUTPUT, and CONTROL. In last section, the LED module was the output part and RPI was the control part. In practical applications, we not only make LEDs flash, but also make a device sense the surrounding environment, receive instructions and then take the appropriate action such as turn on LEDs, make a buzzer beep and so on.



Next, we will build a simple control system to control an LED through a push button switch.

### Project 2.1 Push Button Switch & LED

In the project, we will control the LED state through a Push Button Switch. When the button is pressed, our LED will turn ON, and when it is released, the LED will turn OFF. This describes a Momentary Switch.

### Component List

Raspberry Pi (with 40 GPIO) x1 GPIO Extension Board & Wire x1 Breadboard x1	LED x1	Resistor 220Ω x1	Resistor 10kΩ x2	Push Button Switch x1
Jumper Wire				

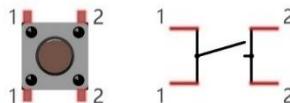
Please Note: In the code “button” represents switch action.



## Component knowledge

### Push Button Switch

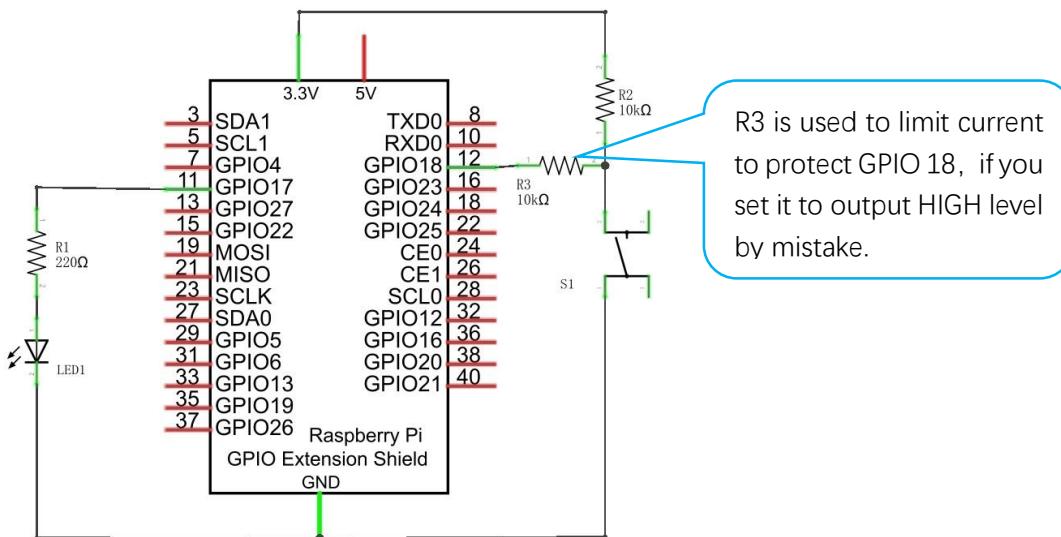
This type of Push Button Switch has 4 pins (2 Pole Switch). Two pins on the left are connected, and both left and right sides are the same per the illustration:



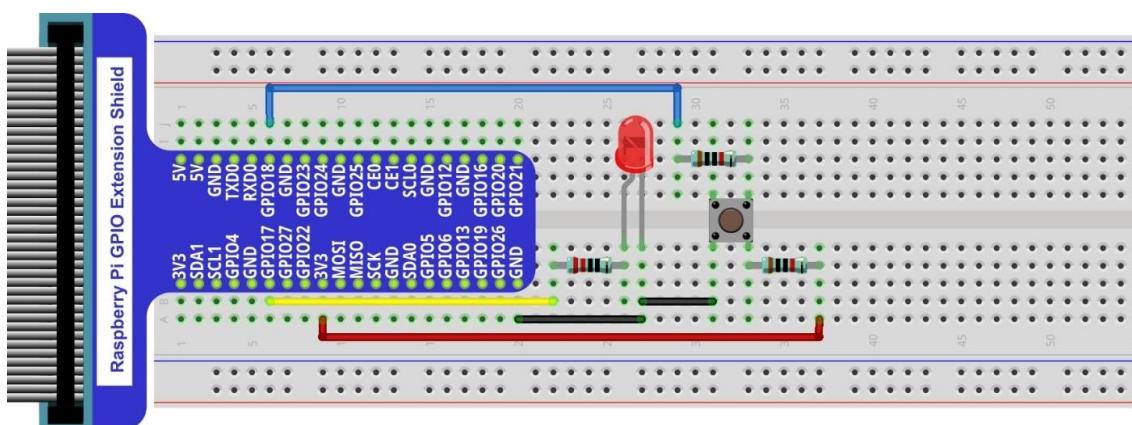
When the button on the switch is pressed, the circuit is completed (your project is Powered ON).

## Circuit

Schematic diagram



Hardware connection. If you need any support, please feel free to contact us via:[support@freenove.com](mailto:support@freenove.com)

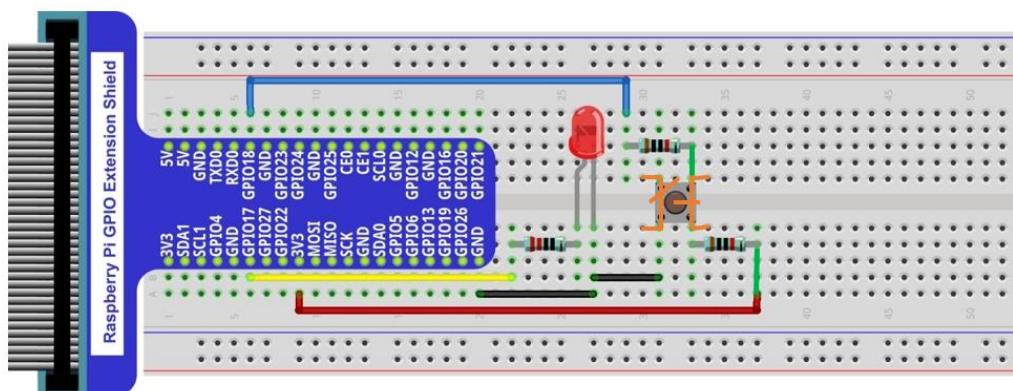


There are two kinds of push button switch in this kit.

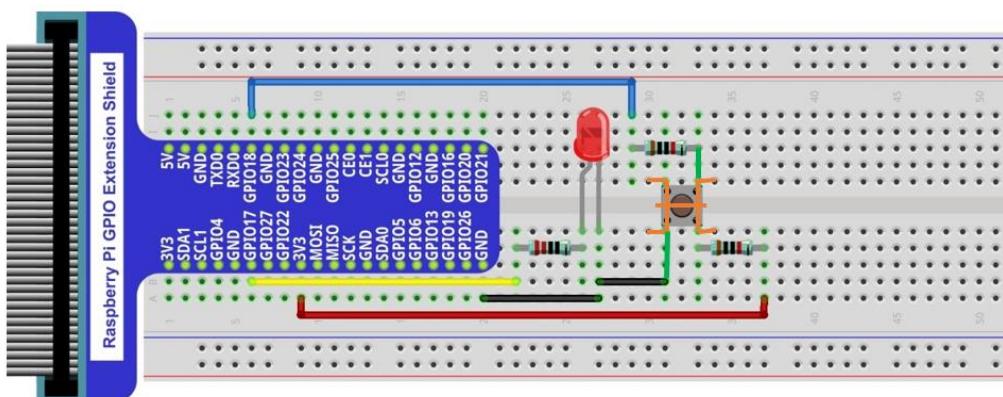
**The smaller push button switches are contained in a plastic bag.**

This is how it works.

When button switch is released:



When button switch is pressed:



## Code

This project is designed for learning how to use Push Button Switch to control an LED. We first need to read the state of switch, and then determine whether to turn the LED ON in accordance to the state of the switch.

### Python Code 2.1.1 ButtonLED

First, observe the project result, then learn about the code in detail. Remember in code "button" = switch function

If you have any concerns, please contact us via: [support@freenove.com](mailto:support@freenove.com)

1. Use cd command to enter 02.1.1\_ButtonLED directory of Python code.

```
cd ~/Freenove_Kit/Code/Python_GPIOZero_Code/02.1.1_ButtonLED
```

2. Use Python command to execute btnLED.py.

```
python ButtonLED.py
```

Then the Terminal window continues to show the characters "led off...", press the switch button and the LED turns ON and then Terminal window shows "led on...". Release the button, then LED turns OFF and then the terminal window text "led off..." appears. You can press "Ctrl+C" at any time to terminate the program.

The following is the program code:

```
1  from gpiozero import LED, Button
2
```

```

3 led = LED(17)      # define LED pin according to BCM Numbering
4 button = Button(18) # define Button pin according to BCM Numbering
5
6 def loop():
7     while True:
8         if button.is_pressed: # if button is pressed
9             led.on()          # turn on led
10            print("Button is pressed, led turned on >>>") # print information on terminal
11        else : # if button is released
12            led.off() # turn off led
13            print("Button is released, led turned off <<<")
14
15 if __name__ == '__main__':    # Program entrance
16     print ('Program is starting... ')
17     try:
18         loop()
19     except KeyboardInterrupt: # Press ctrl-c to end the program.
        print("Ending program")

```

Import the Button class that controls Button from the gpiozero library.

```
from gpiozero import LED, Button
```

Define GPIO17 as the LED control pin and GPIO18 as the button control pin. The button is set to the input mode with a pull-up resistor by default.

```
led = LED(17)      # define LED pin according to BCM Numbering
button = Button(18) # define Button pin according to BCM Numbering
```

The loop continuously determines whether the key is pressed. When the button is pressed, the variable button.is\_pressed has a value of 1 and the LED lights up. Otherwise, the LED will be off.

```
def loop():
    while True:
        if button.is_pressed: # if button is pressed
            led.on()          # turn on led
            print("Button is pressed, led turned on >>>") # print information on terminal
        else : # if button is released
            led.off() # turn off led
            print("Button is released, led turned on <<<")
```

For more information about GPIOZero, please refer to the link below:

<https://gpiozero.readthedocs.io/en/stable/>

For more information about the methods used by the Button class in the GPIO Zero library,please refer to:

[https://gpiozero.readthedocs.io/en/stable/api\\_input.html#button](https://gpiozero.readthedocs.io/en/stable/api_input.html#button)

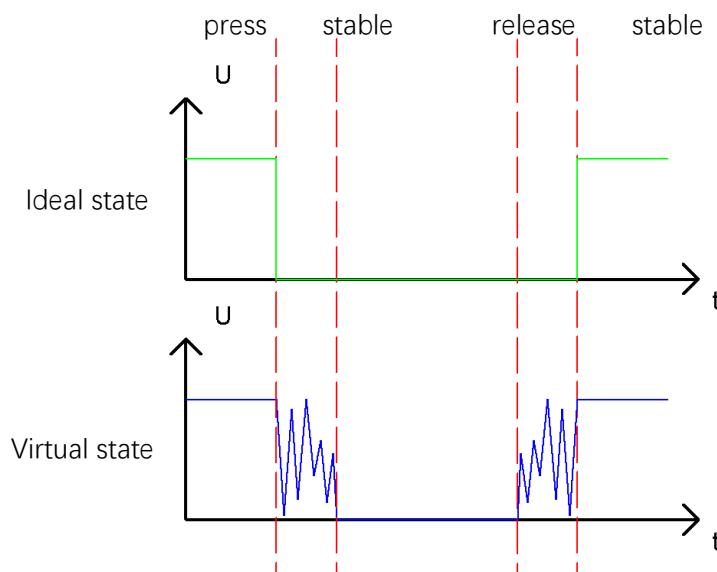
## Project 2.2 MINI Table Lamp

We will also use a Push Button Switch, LED and RPi to make a MINI Table Lamp but this will function differently: Press the button, the LED will turn ON, and pressing the button again, the LED turns OFF. The ON switch action is no longer momentary (like a door bell) but remains ON without needing to continually press on the Button Switch.

First, let us learn something about the push button switch.

### Debounce a Push Button Switch

When a Momentary Push Button Switch is pressed, it will not change from one state to another state immediately. Due to tiny mechanical vibrations, there will be a short period of continuous buffeting before it stabilizes in a new state too fast for Humans to detect but not for computer microcontrollers. The same is true when the push button switch is released. This unwanted phenomenon is known as “bounce”.



Therefore, if we can directly detect the state of the Push Button Switch, there are multiple pressing and releasing actions in one pressing cycle. This buffeting will mislead the high-speed operation of the microcontroller to cause many false decisions. Therefore, we need to eliminate the impact of buffeting. Our solution: to judge the state of the button multiple times. Only when the button state is stable (consistent) over a period of time, can it indicate that the button is actually in the ON state (being pressed).

This project needs the same components and circuits as we used in the previous section.

## Code

In this project, we still detect the state of Push Button Switch to control an LED. Here we need to define a variable to define the state of LED. When the button switch is pressed once, the state of LED will be changed once. This will allow the circuit to act as a virtual table lamp.

### Python Code 2.2.1 Tablelamp

First, observe the project result, and then learn about the code in detail.

If you have any concerns, please contact us via: [support@freenove.com](mailto:support@freenove.com)

1. Use cd command to enter 02.2.1\_Tablelamp directory of Python code

cd ~/Freenove\_Kit/Code/Python\_GPIOPin\_Code/02.2.1\_Tablelamp

2. Use python command to execute python code "Tablelamp.py".

python Tablelamp.py

When the program is executed, pressing the Button Switch once turns the LED ON. Pressing the Button Switch again turns the LED OFF.

```
1 from gpiozero import LED, Button
2 import time
3
4 led = LED(17) # define LED pin according to BCM Numbering
5 button = Button(18) # define Button pin according to BCM Numbering
6
7 def onButtonPressed(): # When button is pressed, this function will be executed
8     led.toggle()
9     if led.is_lit :
10         print("Led turned on >>>")
11     else :
12         print("Led turned off <<<")
13 def loop():
14     #Button detect
15     button.when_pressed = onButtonPressed
16     while True:
17         time.sleep(1)
18     def destroy():
19         led.close()
20         button.close()
21     if __name__ == '__main__': # Program entrance
22         print ('Program is starting... ')
23     try:
24         loop()
25     except KeyboardInterrupt: # Press ctrl-c to end the program.
26         destroy()
27         print("Ending program")
```

In GPIO Zero, you assign the when\_pressed and when\_released properties to set up callbacks on those actions.

Once it detects that the button is pressed, it executes the specified function onButtonPressed(). In the onButtonPressed function, the led.toggle() function reverses the state of the LED device. If it's on, turn it off; if it's off, turn it on. Each time the key is pressed, the state of the LED will change once.

```
def onButtonPressed(): # When button is pressed, this function will be executed
    led.toggle()
    if led.is_lit :
        print("Led turned on >>>")
    else :
        print("Led turned off <<<")

def loop():
    #Button detect
    button.when_pressed = onButtonPressed
    while True:
        time.sleep(1)
```

To explicitly close a connection to a pin, you can manually call the close() method on a device object:

```
def destroy():
    led.close()
    button.close()

except KeyboardInterrupt: # Press ctrl-c to end the program.
    destroy()
    print("Ending program")
```

For more information about the methods used by the Button class in the GPIO Zero library, please refer to:

[https://gpiozero.readthedocs.io/en/stable/api\\_input.html#button](https://gpiozero.readthedocs.io/en/stable/api_input.html#button)

# Chapter 3 LED Bar Graph

We have learned how to control one LED to blink. Next, we will learn how to control a number of LEDs.

## Project 3.1 Flowing Water Light

In this project, we use a number of LEDs to make a flowing water light.

### Component List

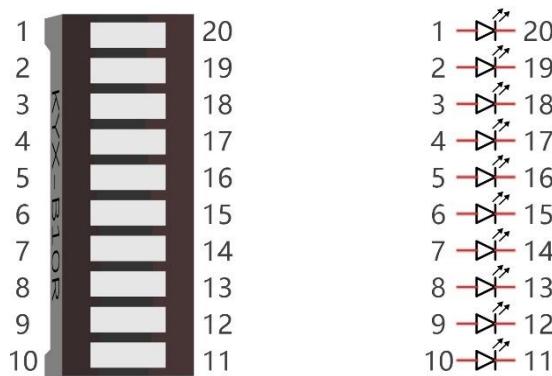
Raspberry Pi (with 40 GPIO) x1 GPIO Extension Board & Ribbon Cable x1 Breadboard x1	Bar Graph LED x1	Resistor 220Ω x10
Jumper Wire x 1		

### Component knowledge

Let us learn about the basic features of these components to use and understand them better.

#### Bar Graph LED

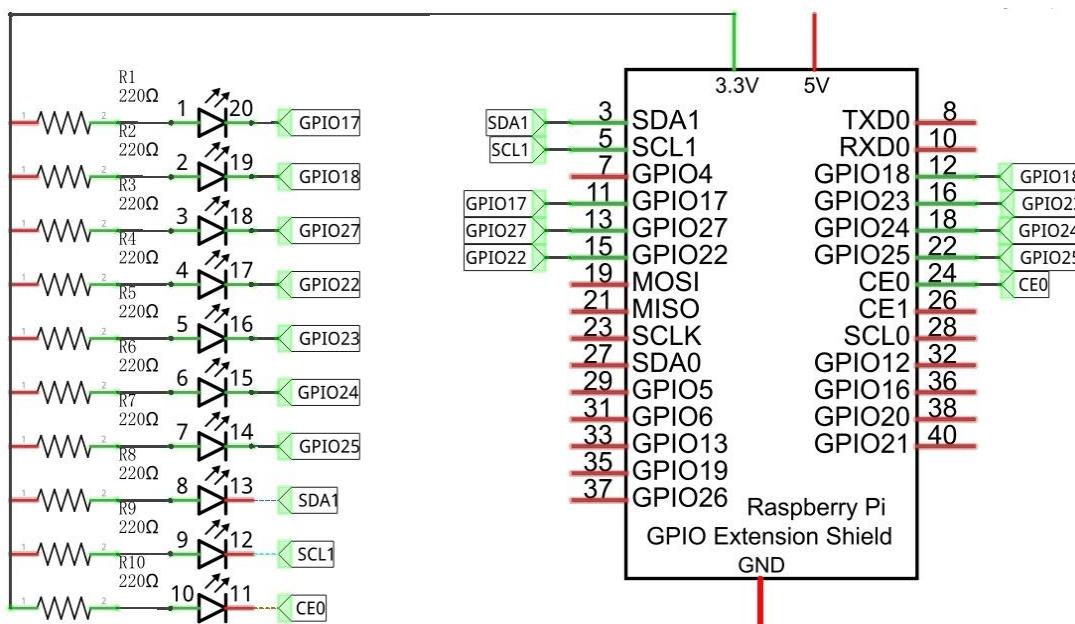
A Bar Graph LED has 10 LEDs integrated into one compact component. The two rows of pins at its bottom are paired to identify each LED like the single LED used earlier.



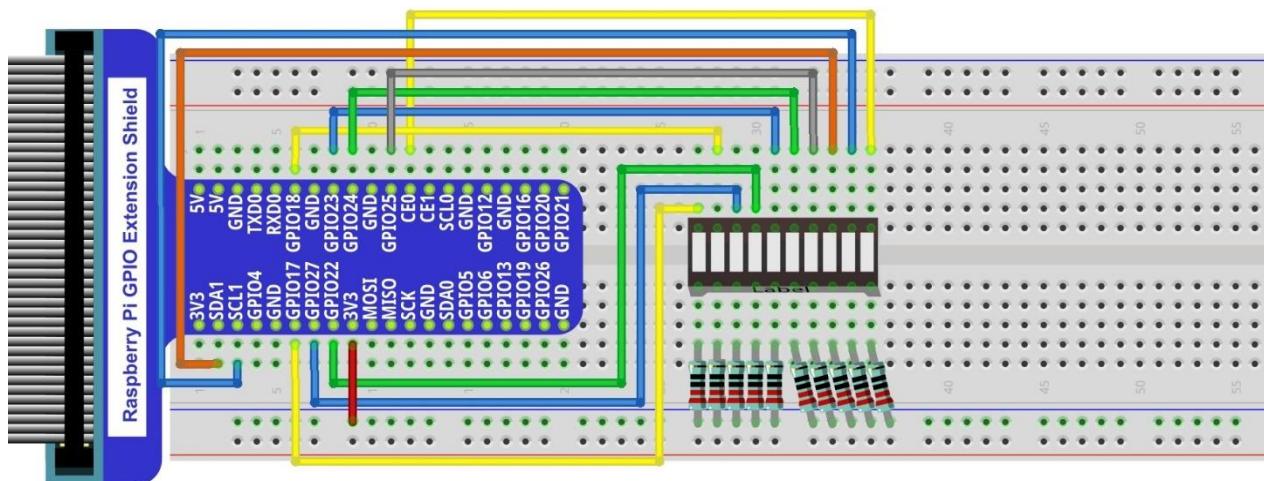
## Circuit

A reference system of labels is used in the circuit diagram below. Pins with the same network label are connected together.

Schematic diagram



Hardware connection. If you need any support, please free to contact us via: [support@freenove.com](mailto:support@freenove.com)



In this circuit, the cathodes of the LEDs are connected to the GPIO, which is different from the previous circuit. The LEDs turn ON when the GPIO output is low level in the program.

## Code

This project is designed to make a flowing water lamp, which are these actions: First turn LED #1 ON, then





turn it OFF. Then turn LED #2 ON, and then turn it OFF... and repeat the same to all 10 LEDs until the last LED is turned OFF. This process is repeated to achieve the “movements” of flowing water.

### Python Code 3.1.1 LightWater

First observe the project result, and then view the code.

**If you have any concerns, please contact us via: support@freenove.com**

1. Use cd command to enter 03.1.1\_LightWater directory of Python code.

```
cd ~/Freenove_Kit/Code/Python_GPIOZero_Code/03.1.1_LightWater
```

2. Use Python command to execute Python code “LightWater.py”.

```
python LightWater.py
```

After the program is executed, you will see that LED Bar Graph starts with the flowing water way to be turned on from left to right, and then from right to left.

The following is the program code:

```

1  from gpiozero import LEDBarGraph
2  from time import sleep
3
4  #ledPins = ["J8:11", "J8:12", "J8:13", "J8:15", "J8:16", "J8:18", "J8:22", "J8:3", "J8:5", "J8:24"]
5  ledPins = [17, 18, 27, 22, 23, 24, 25, 2, 3, 8]
6
7  leds = LEDBarGraph(*ledPins, active_high=False)
8
9  def loop():
10     while True:
11         for index in range(0, len(ledPins), 1):      # make led(on) move from left to right
12             leds.on(index)
13             sleep(0.1)
14             leds.off(index)
15         for index in range(len(ledPins)-1, -1, -1):  #move led(on) from right to left
16             leds.on(index)
17             sleep(0.1)
18             leds.off(index)
19
20     if __name__ == '__main__':      # Program entrance
21         print ('Program is starting... ')
22     try:
23         loop()
24     except KeyboardInterrupt: # Press ctrl-c to end the program.
25         print("Ending program")

```

Import the LEDBarGraph class that controls LED Bar Graph from the gpiozero library.

```
from gpiozero import LEDBarGraph
```

Create the LEDBarGraph class for controlling the LEDBarGraph.

```
ledPins = [17, 18, 27, 22, 23, 24, 25, 2, 3, 8]

leds = LEDBarGraph(*ledPins, active_high=False)
```

The LED is turned on or off by specifying the index of the LED, if no parameter is specified, the same Settings

are applied to all leds. `leds.off()` means that all leds are turned off.

```
for index in range(0, len(ledPins), 1):      # make led(on) move from left to right
    leds.on(index)
    sleep(0.1)
    leds.off(index)

for index in range(len(ledPins)-1, -1, -1):  #move led(on) from right to left
    leds.on(index)
    sleep(0.1)
    leds.off(index)
```

In the program, first define 10 pins connected to the LED and set them to output mode. In the `loop()` function, two for loops are used to make the lights flow from right to left and from left to right.

```
def loop():
    while True:
        for index in range(0, len(ledPins), 1):      # make led(on) move from left to right
            leds.on(index)
            sleep(0.1)
            leds.off(index)

        for index in range(len(ledPins)-1, -1, -1):  #move led(on) from right to left
            leds.on(index)
            sleep(0.1)
            leds.off(index)
```

For more information about the methods used by the `LEDBoard` class in the `GPIO Zero` library,please refer to:  
[https://gpiozero.readthedocs.io/en/stable/api\\_boards.html#ledboard](https://gpiozero.readthedocs.io/en/stable/api_boards.html#ledboard)

For more information about the methods used by the `LEDBarGraph` class in the `GPIO Zero` library,please refer to: [https://gpiozero.readthedocs.io/en/stable/api\\_boards.html#ledbargraph](https://gpiozero.readthedocs.io/en/stable/api_boards.html#ledbargraph)

In this experiment you can use the `LEDBoard` and `LEDBarGraph` classes to control the `LEDBarGraph`



# Chapter 4 Analog & PWM

In previous chapters, we learned that a Push Button Switch has two states: Pressed (ON) and Released (OFF), and an LED has a Light ON and OFF state. Is there a middle or intermediated state? We will next learn how to create an intermediate output state to achieve a partially bright (dim) LED.

First, let us learn how to control the brightness of an LED.

## Project 4.1 Breathing LED

We describe this project as a Breathing Light. This means that an LED that is OFF will then turn ON gradually and then gradually turn OFF like "breathing". Okay, so how do we control the brightness of an LED to create a Breathing Light? We will use PWM to achieve this goal.

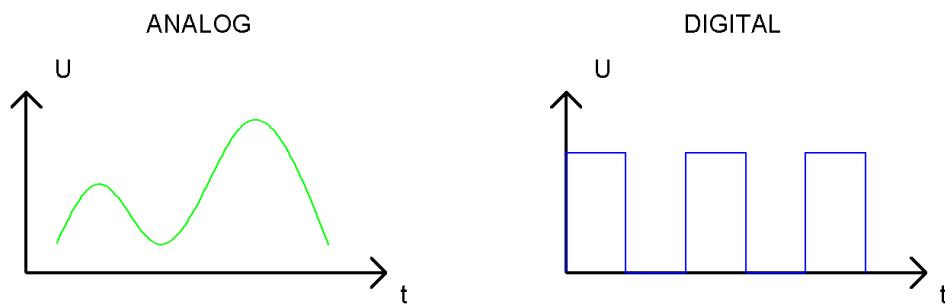
## Component List

Raspberry Pi (with 40 GPIO) x1 GPIO Extension Board & Ribbon Cable x1 Breadboard x1	LED x1	Resistor 220Ω x1
Jumper Wire 		

## Component Knowledge

### Analog & Digital

An Analog Signal is a continuous signal in both time and value. On the contrary, a Digital Signal or discrete-time signal is a time series consisting of a sequence of quantities. Most signals in life are analog signals. A familiar example of an Analog Signal would be how the temperature throughout the day is continuously changing and could not suddenly change instantaneously from 0°C to 10°C. However, Digital Signals can instantaneously change in value. This change is expressed in numbers as 1 and 0 (the basis of binary code). Their differences can more easily be seen when compared when graphed as below.



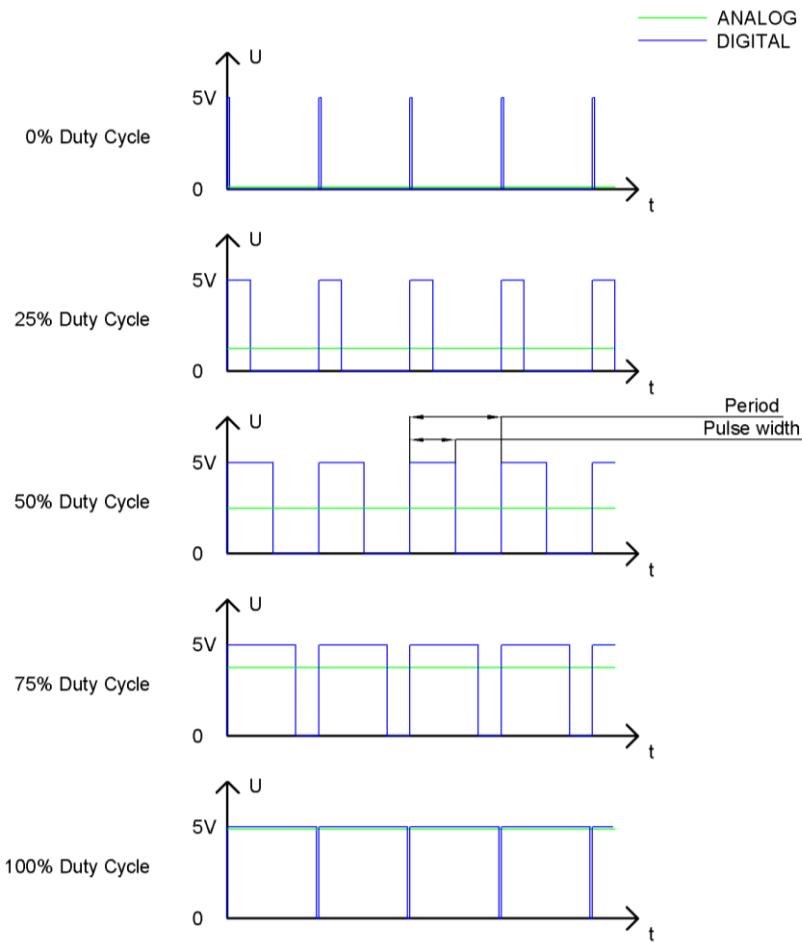
Note that the Analog signals are curved waves and the Digital signals are “Square Waves”.

In practical applications, we often use binary as the digital signal, that is a series of 0's and 1's. Since a binary signal only has two values (0 or 1) it has great stability and reliability. Lastly, both analog and digital signals can be converted into the other.

### PWM

PWM, Pulse-Width Modulation, is a very effective method for using digital signals to control analog circuits. Digital processors cannot directly output analog signals. PWM technology makes it very convenient to achieve this conversion (translation of digital to analog signals).

PWM technology uses digital pins to send certain frequencies of square waves, that is, the output of high levels and low levels, which alternately last for a while. The total time for each set of high levels and low levels is generally fixed, which is called the period (Note: the reciprocal of the period is frequency). The time of high level outputs are generally called “pulse width”, and the duty cycle is the percentage of the ratio of pulse duration, or pulse width (PW) to the total period (T) of the waveform. The longer the output of high levels last, the longer the duty cycle and the higher the corresponding voltage in the analog signal will be. The following figures show how the analog signal voltages vary between 0V-5V (high level is 5V) corresponding to the pulse width 0%-100%:



The longer the PWM duty cycle is, the higher the output power will be. Now that we understand this relationship, we can use PWM to control the brightness of an LED or the speed of DC motor and so on.

It is evident, from the above, that PWM is not actually analog but the effective value of voltage is equivalent to the corresponding analog value. Therefore, by using PWM, we can control the output power of to an LED and control other devices and modules to achieve multiple effects and actions.

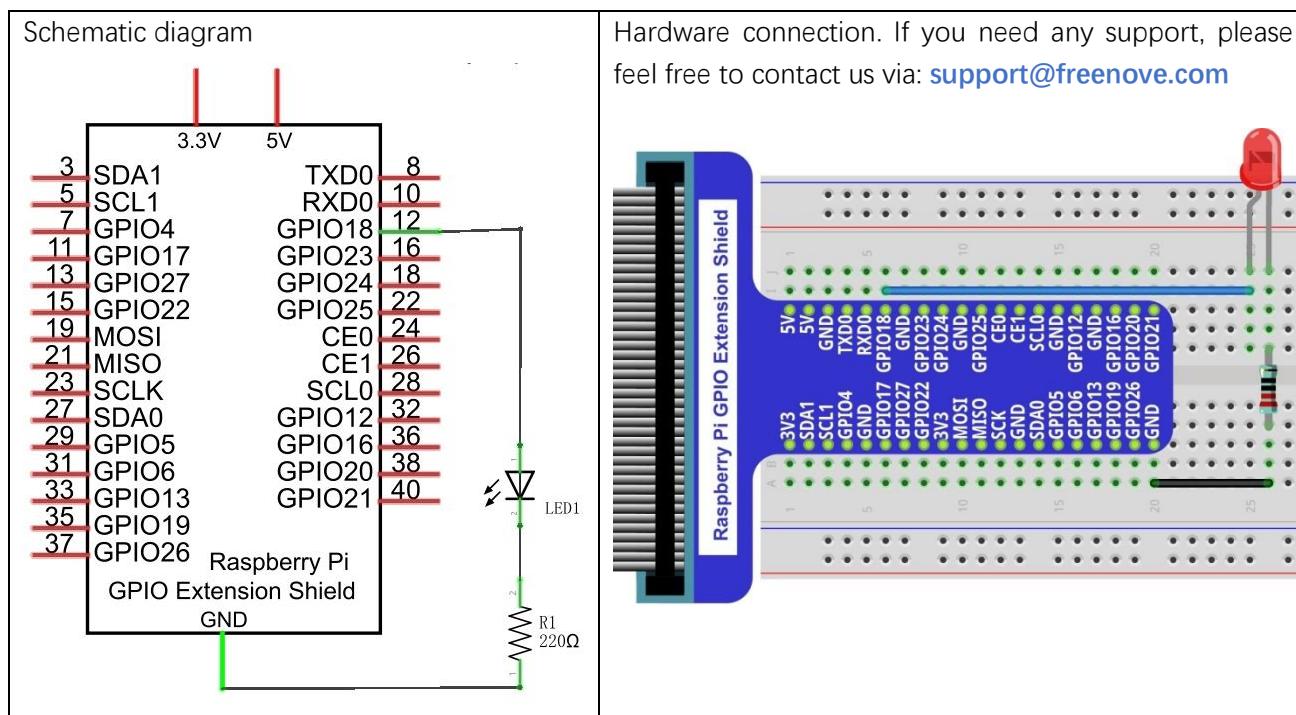
In RPi, GPIO18 pin has the ability to output to hardware via PWM with a 10-bit accuracy. This means that 100% of the pulse width can be divided into  $2^{10}=1024$  equal parts.

The wiringPi library of C provides both a hardware PWM and a software PWM method, while the wiringPi library of Python does not provide a hardware PWM method. There is only a software PWM option for Python.

The hardware PWM only needs to be configured, does not require CPU resources and is more precise in time control. The software PWM requires the CPU to work continuously by using code to output high level and low level. This part of the code is carried out by multi-threading, and the accuracy is relatively not high enough.

In order to keep the results running consistently, we will use software PWM.

## Circuit



## Code

This project uses the PWM output from the GPIO18 pin to make the pulse width gradually increase from 0% to 100% and then gradually decrease from 100% to 0% to make the LED glow brighter then dimmer.

### Python Code 4.1.1 BreathingLED

First, observe the project result, and then learn about the code in detail.

If you have any concerns, please contact us via: [support@freenove.com](mailto:support@freenove.com)

1. Use cd command to enter 04.1.1\_BreathingLED directory of Python code.

```
cd ~/Freenove_Kit/Code/Python_GPIOZero_Code/04.1.1_BreathingLED
```

2. Use the Python command to execute Python code "BreathingLED.py".

```
python BreathingLED.py
```

After the program is executed, you will see that the LED gradually turns ON and then gradually turns OFF similar to "breathing".

The following is the program code:

```

1  from gpiozero import PWMLED
2
3  import time
4
5  led = PWMLED(18 ,initial_value=0 ,frequency=1000)
6  def loop():
7      while True:
8          for b in range(0, 101, 1):      # make the led brighter
9              led.value = b / 100.0       # set dc value as the duty cycle

```



```

9          time.sleep(0.01)
10         time.sleep(1)
11         for b in range(100, -1, -1): # make the led darker
12             led.value = b / 100.0      # set dc value as the duty cycle
13             time.sleep(0.01)
14             time.sleep(1)
15     def destroy():
16         led.close()
17     if __name__ == '__main__':    # Program entrance
18         print ('Program is starting ... ')
19         try:
20             loop()
21         except KeyboardInterrupt: # Press ctrl-c to end the program.
22             destroy()
23             print("Ending program")

```

Import the PWMLED class that controls leds from the gpiozero library.

```
from gpiozero import PWMLED
```

Create the PWMLED class for controlling the LED.

```
led = PWMLED(18 ,initial_value=0 ,frequency=1000)
```

PWMLED is connected to GPIO18, and its PWM frequency is set to 1000HZ, and the initial duty cycle to 0%.

```
led = PWMLED(18 ,initial_value=0 ,frequency=1000) # Set the PWM frequency to 1000Hz and the
initial duty cycle to 0
```

There are two “for” loops used to control the breathing LED in the next endless “while” loop. The first loop outputs a power signal to the led PWM from 0% to 100% and the second loop outputs a power signal to the led PWM from 100% to 0%.

led.value represents:The duty cycle of the PWM device. 0.0 is off, 1.0 is fully on. led.value in between may be specified for varying levels of power in the device.

```

def loop():
    while True:
        for b in range(0, 101, 1):    # make the led brighter
            led.value = b / 100.0      # set dc value as the duty cycle
            time.sleep(0.01)
            time.sleep(1)
        for b in range(100, -1, -1): # make the led darker
            led.value = b / 100.0      # set dc value as the duty cycle
            time.sleep(0.01)
            time.sleep(1)

```

For more information about the methods used by the PWMLED class in the GPIO Zero library,please refer to:

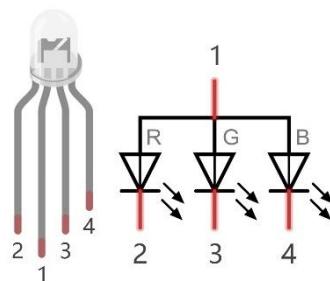
[https://gpiozero.readthedocs.io/en/stable/api\\_output.html#pwmled](https://gpiozero.readthedocs.io/en/stable/api_output.html#pwmled)

For more information about the methods used by the PWMOutputDevice class in the GPIO Zero library,please refer to: [https://gpiozero.readthedocs.io/en/stable/api\\_output.html#pwmoutputdevice](https://gpiozero.readthedocs.io/en/stable/api_output.html#pwmoutputdevice)

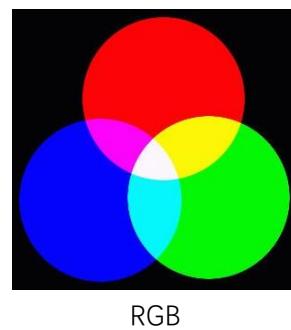
## Chapter 5 RGB LED

In this chapter, we will learn how to control a RGB LED.

An RGB LED has 3 LEDs integrated into one LED component. It can respectively emit Red, Green and Blue light. In order to do this, it requires 4 pins (this is also how you identify it). The long pin (1) is the common which is the Anode (+) or positive lead, the other 3 are the Cathodes (-) or negative leads. A rendering of a RGB LED and its electronic symbol are shown below. We can make RGB LED emit various colors of light and brightness by controlling the 3 Cathodes (2, 3 & 4) of the RGB LED



Red, Green, and Blue light are called 3 Primary Colors when discussing light (Note: for pigments such as paints, the 3 Primary Colors are Red, Blue and Yellow). When you combine these three Primary Colors of light with varied brightness, they can produce almost any color of visible light. Computer screens, single pixels of cell phone screens, neon lamps, etc. can all produce millions of colors due to phenomenon.



If we use a three 8 bit PWM to control the RGB LED, in theory, we can create  $2^8 * 2^8 * 2^8 = 16777216$  (16 million) colors through different combinations of RGB light brightness.

Next, we will use RGB LED to make a multicolored LED.

## Project 5.1 Multicolored LED

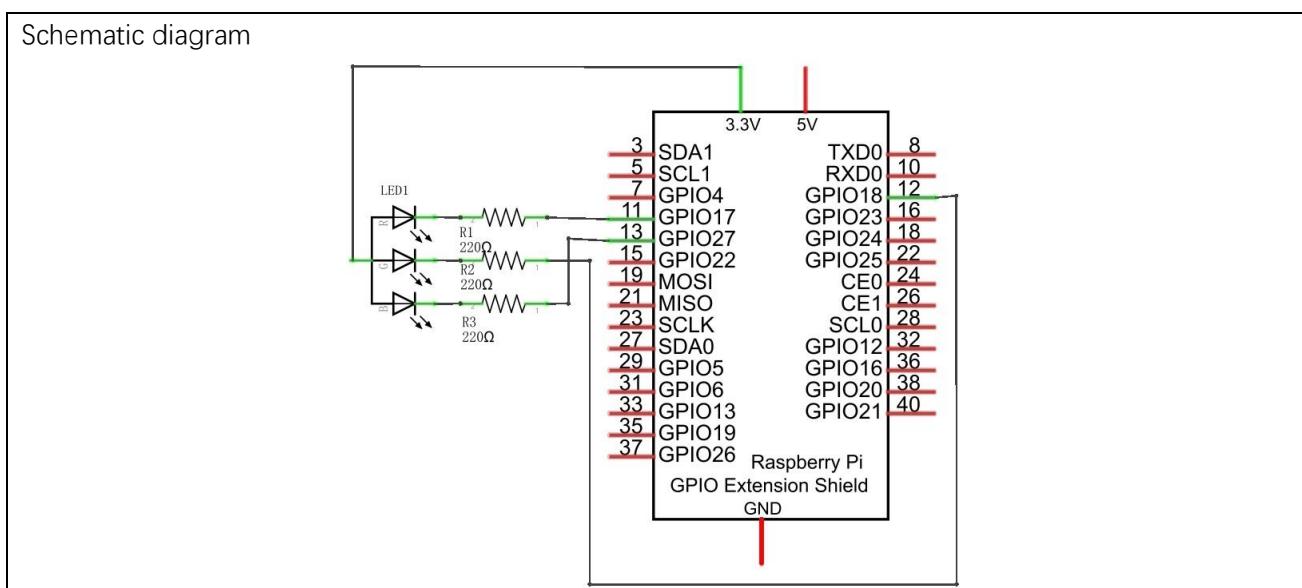
### Component List

Raspberry Pi (with 40 GPIO) x1	RGB LED x1	Resistor 220Ω x3
GPIO Extension Board & Wire x1		
Breadboard x1		

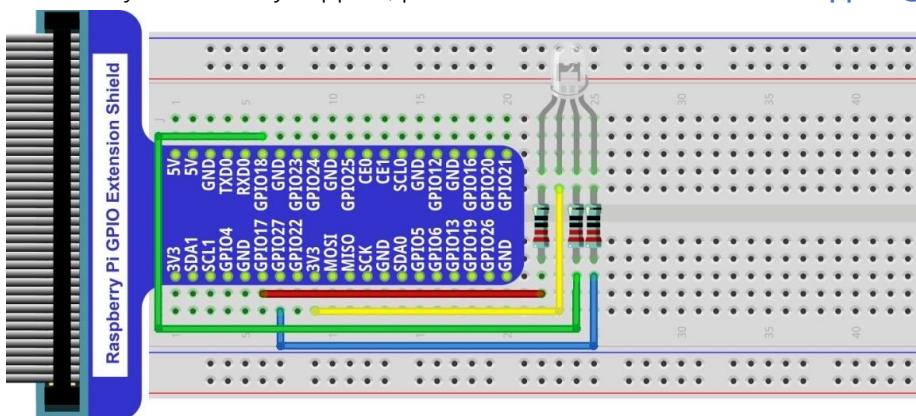
Jumper Wire



### Circuit



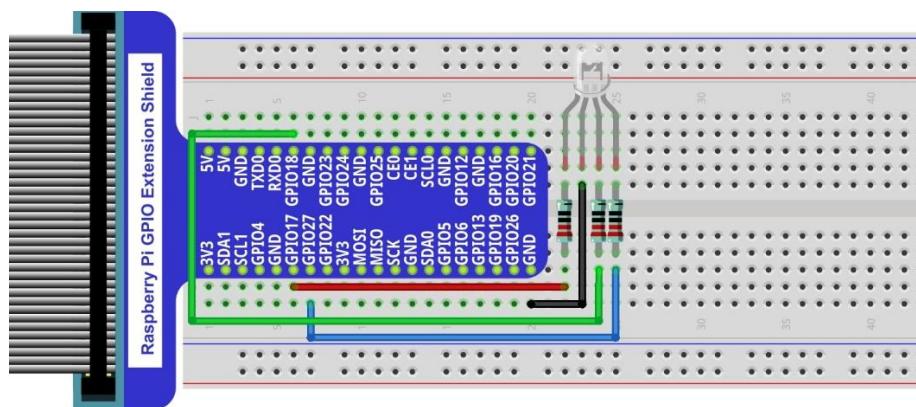
Hardware connection. If you need any support, please feel free to contact us via: [support@freenove.com](mailto:support@freenove.com)



In this kit, the RGB led is **Common anode**. The **voltage difference** between LED will make it work. There is no visible GND. The GPIO ports can also receive current while in output mode.

If circuit above doesn't work, the RGB LED may be common cathode. Please try following wiring.

There is no need to modify code for random color.



Code

We need to use RGBLED class to control RGBLED. The parameters for setting the RGBLED as common cathode or common anode are provided in the RGBLED class. You can set it according to the type of your RGB LED, and the default setting in our example code is based on common anode.

## Python Code 5.1.1 ColorfullLED

First, observe the project result, and then learn about the code in detail.

If you have any concerns, please contact us via: support@freenove.com

1. Use cd command to enter 05.1.1 ColorfullLED directory of Python code.

cd ~/Freenove\_Kit/Code/Python GPIOZero Code/05.1.1 ColorfulLED

## 2. Use python command

python ColorfulLED.py

After the program is executed, you

```
The following is the program code:  
1 from gpiozero import RGBLED  
2 import time  
3 import random  
4  
5 #led = RGBLED(red="J8:11", green="J8:12", blue="J8:13", active_high=False) # define the pins  
for R:11, G:12, B:13  
6 led = RGBLED(red=17, green=18, blue=27, active_high=False) # define the pins for  
R:GPIO17, G:GPIO18, B:GPIO027  
7 # If your RGBLED is a common cathode LED, set active_high to True  
8  
9 def setColor(r_val, g_val, b_val):      # change duty cycle for three pins to r_val, g_val, b_val  
10    led.red=r_val/100                      # change pwmRed duty cycle to r_val  
11    led.green = g_val/100                  # change pwmRed duty cycle to r_val  
12    led.blue = b_val/100                  # change pwmRed duty cycle to r_val  
13  
14 def loop():
```

```

15     while True :
16         r=random.randint(0, 100)    #get a random in (0, 100)
17         g=random.randint(0, 100)
18         b=random.randint(0, 100)
19         setColor(r,g,b)          #set random as a duty cycle value
20         print (' r=%d, g=%d, b=%d ' %(r ,g, b))
21         time.sleep(1)
22
23     def destroy():
24         led.close()
25
26     if __name__ == '__main__':      # Program entrance
27         print ('Program is starting ... ')
28         try:
29             loop()
30         except KeyboardInterrupt: # Press ctrl-c to end the program.
31             destroy()
32             print("Ending program")

```

Import the RGBLED class that controls RGBLED from the gpiozero library.

```
from gpiozero import RGBLED
```

Create the RGBLED class for controlling the RGBLED.

```
led = RGBLED(red=17, green=18, blue=27, active_high=False) # define the pins for
R:GPIO17, G:GPIO18, B:GPIO027
```

In the previous chapter, we learned how to make a pin output PWM using the Python language. In this project, we output to three pins via PWM. In the "while" loop of the "loop" function, we first generate three random numbers and then assign these three random numbers to the PWM values of the three pins, which will make the RGB LED randomly produce multiple colors.

```

def loop():
    while True :
        r=random.randint(0, 100)    #get a random in (0, 100)
        g=random.randint(0, 100)
        b=random.randint(0, 100)
        setColor(r,g,b)          #set random as a duty cycle value
        print (' r=%d, g=%d, b=%d ' %(r ,g, b))
        time.sleep(1)

```

For more information about the methods used by the RGBLED class in the GPIO Zero library,please refer to:

[https://gpiozero.readthedocs.io/en/stable/api\\_output.html#rgbled](https://gpiozero.readthedocs.io/en/stable/api_output.html#rgbled)

# Chapter 6 Buzzer

In this chapter, we will learn about buzzers and the sounds they make. And in our next project, we will use an active buzzer to make a doorbell and a passive buzzer to make an alarm.

## Project 6.1 Doorbell

We will make a doorbell with this functionality: when the Push Button Switch is pressed the buzzer sounds and when the button is released, the buzzer stops. This is a momentary switch function.

### Component List

Raspberry Pi (with 40 GPIO) x1 GPIO Extension Board & Ribbon Cable x1 Breadboard x1	Jumper Wire 			
NPN transistor x1 (S8050) 	Active buzzer x1 	Push Button Switch x1 	Resistor 1kΩ x1 	Resistor 10kΩ x2 

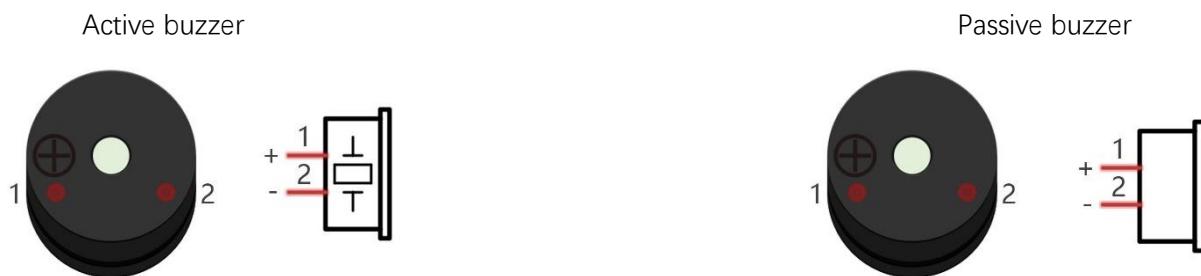




## Component knowledge

### Buzzer

A buzzer is an audio component. They are widely used in electronic devices such as calculators, electronic alarm clocks, automobile fault indicators, etc. There are both active and passive types of buzzers. Active buzzers have oscillator inside, these will sound as long as power is supplied. Passive buzzers require an external oscillator signal (generally using PWM with different frequencies) to make a sound.



Active buzzers are easier to use. Generally, they only make a specific sound frequency. Passive buzzers require an external circuit to make sounds, but passive buzzers can be controlled to make sounds of various frequencies. The resonant frequency of the passive buzzer in this Kit is 2kHz, which means the passive buzzer is the loudest when its resonant frequency is 2kHz.

### How to identify active and passive buzzer?

1. As a rule, there is a label on an active buzzer covering the hole where sound is emitted, but there are exceptions to this rule.
2. Active buzzers are more complex than passive buzzers in their manufacture. There are many circuits and crystal oscillator elements inside active buzzers; all of this is usually protected with a waterproof coating (and a housing) exposing only its pins from the underside. On the other hand, passive buzzers do not have protective coatings on their underside. From the pin holes, view of a passive buzzer, you can see the circuit board, coils, and a permanent magnet (all or any combination of these components depending on the model).



Active buzzer bottom



Passive buzzer bottom

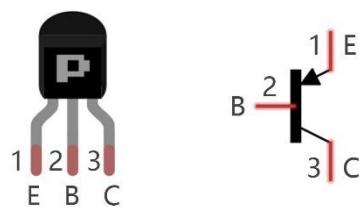
### Transistors

A transistor is required in this project due to the buzzer's current being so great that GPIO of RPi's output capability cannot meet the power requirement necessary for operation. A NPN transistor is needed here to

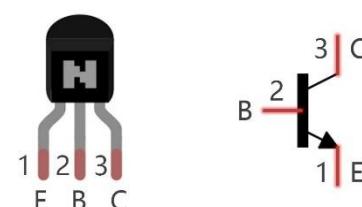
amplify the current.

Transistors, full name: semiconductor transistor, is a semiconductor device that controls current (think of a transistor as an electronic “amplifying or switching device”). Transistors can be used to amplify weak signals, or to work as a switch. Transistors have three electrodes (PINs): base (b), collector (c) and emitter (e). When there is current passing between “be” then “ce” will have a several-fold current increase (transistor magnification), in this configuration the transistor acts as an amplifier. When current produced by “be” exceeds a certain value, “ce” will limit the current output. at this point the transistor is working in its saturation region and acts like a switch. Transistors are available as two types as shown below: PNP and NPN,

PNP transistor



NPN transistor



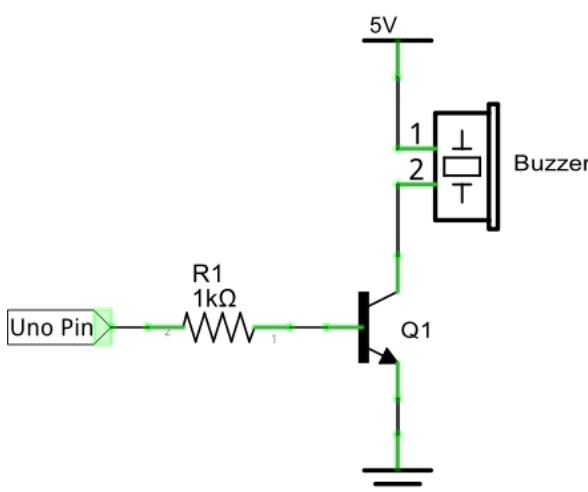
In our kit, the PNP transistor is marked with 8550, and the NPN transistor is marked with 8050.

Thanks to the transistor's characteristics, they are often used as switches in digital circuits. As micro-controllers output current capacity is very weak, we will use a transistor to amplify its current in order to drive components requiring higher current.

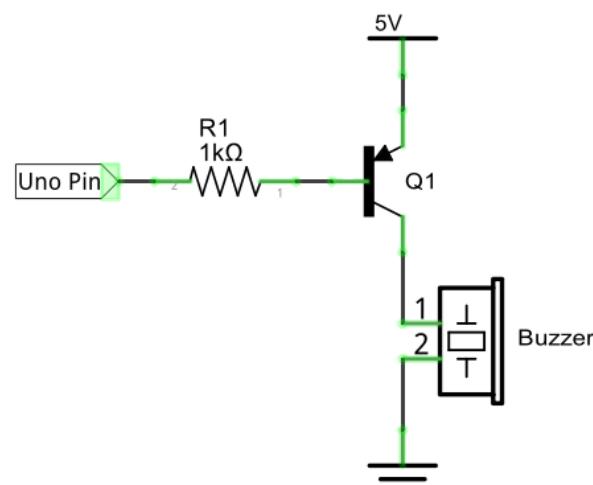
When we use a NPN transistor to drive a buzzer, we often use the following method. If GPIO outputs high level, current will flow through R1 (Resistor 1), the transistor conducts current and the buzzer will make sounds. If GPIO outputs low level, no current will flow through R1, the transistor will not conduct current and buzzer will remain silent (no sounds).

When we use a PNP transistor to drive a buzzer, we often use the following method. If GPIO outputs low level, current will flow through R1. The transistor conducts current and the buzzer will make sounds. If GPIO outputs high level, no current flows through R1, the transistor will not conduct current and buzzer will remain silent (no sounds). Below are the circuit schematics for both a NPN and PNP transistor to power a buzzer.

NPN transistor to drive buzzer

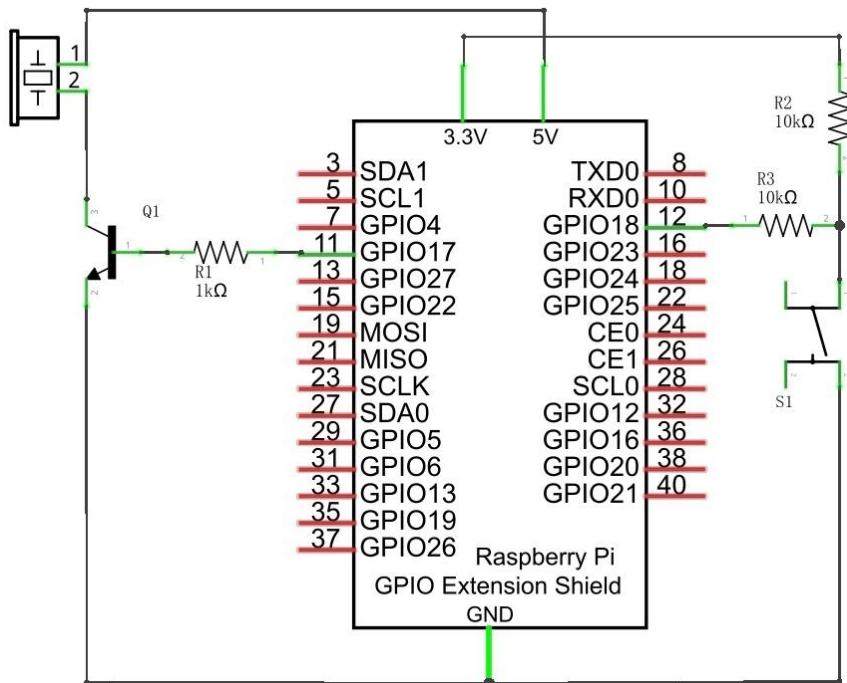


PNP transistor to drive buzzer

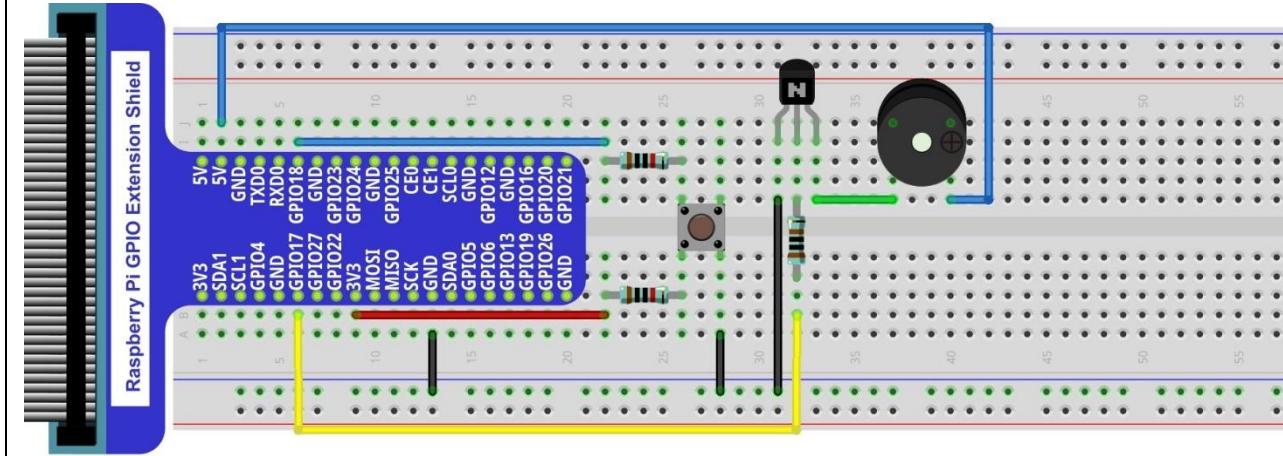


## Circuit

Schematic diagram with RPi GPIO Extension Shield.



Hardware connection. If you need any support, please feel free to contact us via: [support@freenove.com](mailto:support@freenove.com)



Note: in this circuit, the power supply for the buzzer is 5V, and pull-up resistor of the push button switch is connected to the 3.3V power feed. Actually, the buzzer can work when connected to the 3.3V power feed but this will produce a weak sound from the buzzer (not very loud).

## Code

In this project, a buzzer will be controlled by a push button switch. When the button switch is pressed, the buzzer sounds and when the button is released, the buzzer stops. It is analogous to our earlier project that controlled an LED ON and OFF.

### Python Code 6.1.1 Doorbell

First, observe the project result, then learn about the code in detail.

If you have any concerns, please contact us via: support@freenove.com

1. Use cd command to enter 06.1.1\_Doorbell directory of Python code.

cd ~/Freenove\_Kit/Code/Python\_GPIOPin\_Code/06.1.1\_Doorbell

2. Use python command to execute python code "Doorbell.py".

python Doorbell.py

After the program is executed, press the push button switch and the buzzer will sound. Release the push button switch and the buzzer will stop.

The following is the program code:

```
1  from gpiozero import Buzzer, Button
2  import time
3
4  buzzer = Buzzer(17)
5  button = Button(18)
6
7  def onButtonPressed():
8      buzzer.on()
9      print("Button is pressed, buzzer turned on >>>")
10
11 def onButtonReleased():
12     buzzer.off()
13     print("Button is released, buzzer turned on <<<")
14
15 def loop():
16     button.when_pressed = onButtonPressed
17     button.when_released = onButtonReleased
18     while True :
19         time.sleep(1)
20
21 def destroy():
22     buzzer.close()
23     button.close()
24
25 if __name__ == '__main__':      # Program entrance
26     print ('Program is starting ... ')
27     try:
28         loop()
29     except KeyboardInterrupt: # Press ctrl-c to end the program.
30         destroy()
31         print("Ending program")
```

The code is exactly the same as when we used a push button switch to control an LED. You can also try using





the PNP transistor to achieve the same results.

Import the Buzzer class that controls Buzzer from the gpiozero library.

```
from gpiozero import Buzzer, Button
```

Create the Buzzer class for controlling the Buzzer.

```
buzzer = Buzzer(17)
```

In GPIO Zero, you assign the when\_pressed and when\_released properties to set up callbacks on those actions.

Once it detects that the button is pressed, it executes the specified function onButtonPressed(). Once it detects that the button is released, it executes the specified function onButtonReleased()

```
def loop():
    button.when_pressed = onButtonPressed
    button.when_released = onButtonReleased
```

For more information about the methods used by the Buzzer class in the GPIO Zero library, please refer to:  
[https://gpiozero.readthedocs.io/en/stable/api\\_output.html#buzzer](https://gpiozero.readthedocs.io/en/stable/api_output.html#buzzer)

## Project 6.2 Alertor

Next, we will use a passive buzzer to make an alarm.

The list of components and the circuit is similar to the doorbell project. We only need to take the Doorbell circuit and replace the active buzzer with a passive buzzer.

### Code

In this project, our buzzer alarm is controlled by the push button switch. Press the push button switch and the buzzer will sound. Release the push button switch and the buzzer will stop.

As stated before, it is analogous to our earlier project that controlled an LED ON and OFF.

To control a passive buzzer requires PWM of certain sound frequency.

#### Python Code 6.2.1 Alertor

First observe the project result, and then learn about the code in detail.

If you have any concerns, please contact us via: support@freenove.com

1. Use cd command to enter 06.2.1\_Alertor directory of Python code.

```
cd ~/Freenove_Kit/Code/Python_GPIOZero_Code/06.2.1_Alertor
```

2. Use the python command to execute the Python code “Alertor.py”.

```
python Alertor.py
```

After the program is executed, press the push button switch and the buzzer will sound. Release the push button switch and the buzzer will stop.

The following is the program code:

```
1  from gpiozero import TonalBuzzer, Button
2  from gpiozero.tones import Tone
3  import time
4  import math
5
6  buzzer = TonalBuzzer(17)
7  button = Button(18) # define Button pin according to BCM Numbering
8
9  def loop():
10     while True:
11         if button.is_pressed: # if button is pressed
12             alertor()
13             print ('alertor turned on >>> ')
14         else :
15             stopAlertor()
16             print ('alertor turned off <<< ')
17
18     def alertor():
19         for x in range(0,361):      # Make frequency of the alertor consistent with the sine wave
20             sinVal = math.sin(x * (math.pi / 180.0))          # calculate the sine value
```



```

20      toneVal = 2000 + sinVal * 500    # Add to the resonant frequency with a Weighted
21      b.play(Tone(toneVal))    # Change Frequency of PWM to toneVal
22      time.sleep(0.001)
23
24  def stopAlertor():
25      buzzer.stop()
26
27  def destroy():
28      buzzer.close()
29
30  if __name__ == '__main__':      # Program entrance
31      print ('Program is starting... ')
32      try:
33          loop()
34      except KeyboardInterrupt: # Press ctrl-c to end the program.
35          destroy()
36          print("Ending program")

```

Define GPIO17 as the buzzer control pin, and GPIO18 as the button control pin to control the passive buzzer. It requires a certain frequency of PWM to control a passive buzzer, so the TonalBuzzer class is needed.

```

buzzer = TonalBuzzer(17)
button = Button(18) # define Button pin according to BCM Numbering

```

In the while loop loop of the main function, when the push button switch is pressed the subfunction alertor() will be called and the alarm will issue a warning sound. The frequency curve of the alarm is based on a sine curve. We need to calculate the sine value from 0 to 360 degrees and multiplied by a certain value (here this value is 500) plus the resonant frequency of buzzer. We can set the PWM frequency through Tone(toneVal).

```

def alertor():
    for x in range(0,361):      # Make frequency of the alertor consistent with the sine wave
        sinVal = math.sin(x * (math.pi / 180.0))           # calculate the sine value
        toneVal = 2000 + sinVal * 500    # Add to the resonant frequency with a Weighted
        b.play(Tone(toneVal))    # Change Frequency of PWM to toneVal
        time.sleep(0.001)

```

When the push button switch is released, the buzzer (in this case our Alarm) will stop.

```

def stopAlertor():
    buzzer.stop()

```

For more information about the methods used by the TonalBuzzer class in the GPIO Zero library,please refer to: [https://gpiozero.readthedocs.io/en/stable/api\\_output.html#tonalbuzzer](https://gpiozero.readthedocs.io/en/stable/api_output.html#tonalbuzzer)

# Chapter 7 Web IoT

In this chapter, we will learn how to use GPIO to control the RPi remotely via a network and how to build a WebIO service on the RPi.

This concept is known as “IoT” or Internet of Things. The development of IoT will greatly change our habits and make our lives more convenient and efficient

## Project 7.1 Remote LED

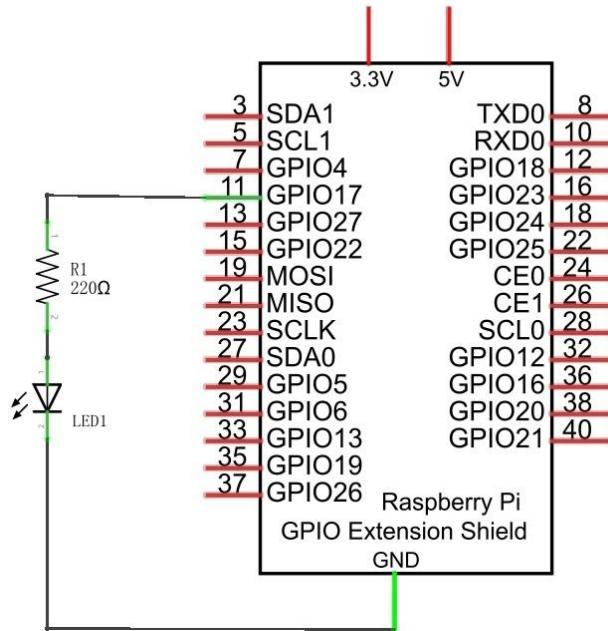
In this project, we need to build a WebIOPi service, and then use the RPi GPIO to control an LED through the web browser of phone or PC.

### Component List

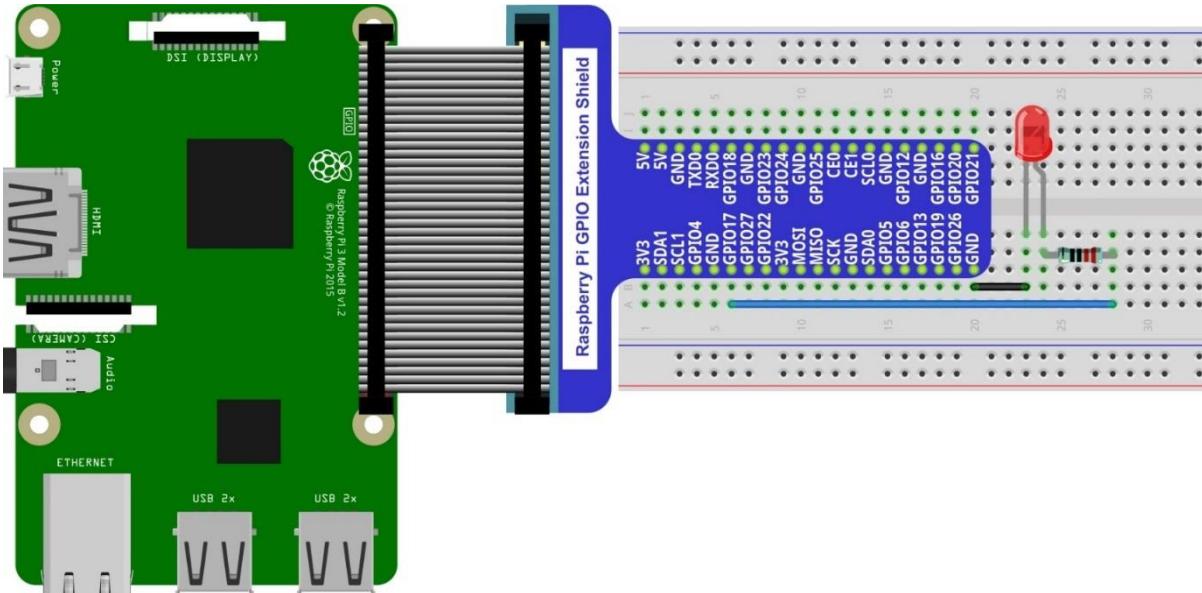
Raspberry Pi (with 40 GPIO) x1 GPIO Extension Board & Ribbon Cable x1 Breadboard x1	LED x1	Resistor 220Ω x1
Jumper M/M x2		

## Circuit

Schematic diagram



Hardware connection. If you need any support, please feel free to contact us via: [support@freenove.com](mailto:support@freenove.com)



## Solution from E-Tinkers

Here is a solution from blog E-Tinkers, author Henry Cheung. For more details, please refer to link below:  
<https://www.e-tinkers.com/2018/04/how-to-control-raspberry-pi-gpio-via-http-web-server/>

1, Make sure you have set python3 as default python. Then run following command in terminal to install http.server in your Raspberry Pi.

```
sudo apt-get install http.server
```

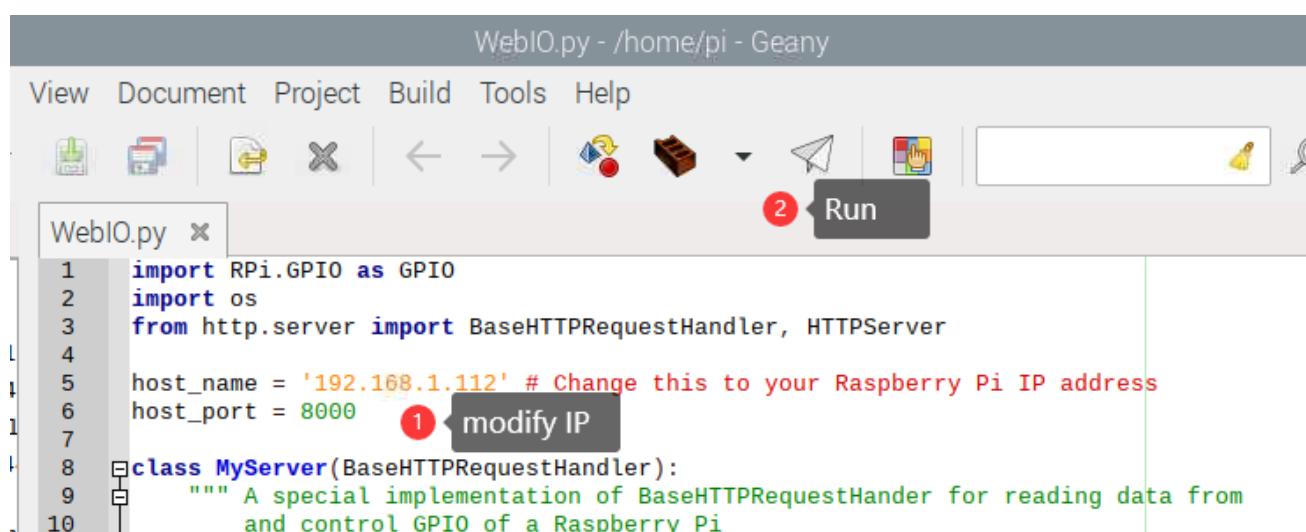
2, Open WebIO.py

```
cd ~/Freenove_Kit/Code/Python_GPIOPin_Code/7.1.1_WebIO  
geany WebIO.py
```

3, Change the host\_name into your Raspberry Pi IP address.

```
host_name = '192.168.1.112' # Change this to your Raspberry Pi IP address
```

Then run the code WebIO.py



3, Visit <http://192.168.1.112:8000/> in web brower on computer under local area networks. **Change IP to your Raspberry Pi IP address.**



# Welcome to my Raspberry Pi

Current GPU temperature is 53.0'C



## WebIOPi Service Framework

Note: If you have a Raspberry Pi 4B, you may have some trouble. The reason for changing the file in the configuration process is that the newer generation models of the RPi CPUs are different from the older ones and you may not be able to access the GPIO Header at the end of this tutorial. A solution to this is given in an online tutorial by from E-Tinkers blogger Henry Cheung. For more details, please refer to previous section.

The following is the key part of this chapter. The installation steps refer to WebIOPi official. And you also can directly refer to the official installation steps. The latest version (in 2016-6-27) of WebIOPi is 0.7.1. So, you may encounter some issues in using it. We will explain these issues and provide the solution in the following installation steps.

Here are the steps to build a WebIOPi:

### Installation

1. Get the installation package. You can use the following command to obtain.

```
wget https://github.com/Freenove/WebIOPi/archive/master.zip -O WebIOPi.zip
```

2. Extract the package and generate a folder named "WebIOPi-master". Then enter the folder.

```
unzip WebIOPi.zip
```

```
cd WebIOPi-master/WebIOPi-0.7.1
```

3. Patch for Raspberry Pi B+, 2B, 3B, 3B+.

```
patch -p1 -i webiopi-pi2bplus.patch
```

4. Run setup.sh to start the installation, the process takes a while and you will need to be patient.

```
sudo ./setup.sh
```

5. If setup.sh does not have permission to execute, execute the following command

```
sudo sh ./setup.sh
```

### Run

After the installation is completed, you can use the webiopi command to start running.

```
$ sudo webiopi [-h] [-c config] [-l log] [-s script] [-d] [port]
```

Options:

<b>-h, --help</b>	Display this help
<b>-c, --config</b> <b>file</b>	Load config from <b>file</b>
<b>-l, --log</b> <b>file</b>	<b>Log to file</b>
<b>-s, --script</b> <b>file</b>	Load script from <b>file</b>
<b>-d, --debug</b>	Enable DEBUG

Arguments:

<b>port</b>	Port to bind the HTTP Server
-------------	------------------------------

Run webiopi with verbose output and the default config file:

```
sudo webiopi -d -c /etc/webiopi/config
```

The Port is 8000 in default. Now WebIOPi has been launched. Keep it running.

## Access WebIOPi over local network

Under the same network, use a mobile phone or PC browser to open your RPi IP address, and add a port number like 8000. For example, my personal Raspberry Pi IP address is 192.168.1.109. Then, in the browser, I then should input: <http://192.168.1.109:8000/>

Default user is "webiopi" and password is "raspberry".

Then, enter the main control interface:

## WebIOPi Main Menu

## GPIO Header

Control and Debug the Raspberry Pi GPIO with a display which looks like the physical header.

## GPIO List

Control and Debug the Raspberry Pi GPIO ordered in a single column.

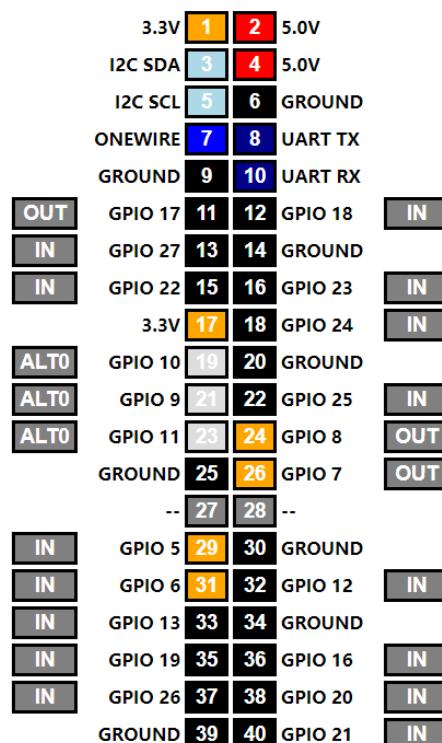
## Serial Monitor

Use the browser to play with Serial interfaces configured in WebIOPi.

## Devices Monitor

Control and Debug devices and circuits wired to your Pi and configured in WebIOPi.

Click on GPIO Header to enter the GPIO control interface.



#### Control methods:

- Click/Tap the OUT/IN button to change GPIO direction.
  - Click/Tap pins to change the GPIO output state.



## Completed

According to the circuit we build, set GPIO17 to OUT, then click Header11 to control the LED.

You can end the webioPi in the terminal by “Ctr+C”.

## What's Next?

THANK YOU for participating in this learning experience! If you have completed all of the projects successfully you can consider yourself a Raspberry Pi Master.

We have reached the end of this Tutorial. If you find errors, omissions or you have suggestions and/or questions about the Tutorial or component contents of this Kit, please feel free to contact us:  
[support@freenove.com](mailto:support@freenove.com)

We will make every effort to make changes and correct errors as soon as feasibly possible and publish a revised version.

If you are interesting in processing, you can study the Processing.pdf in the unzipped folder.

If you want to learn more about Arduino, Raspberry Pi, Smart Cars, Robotics and other interesting products in science and technology, please continue to visit our website. We will continue to launch fun, cost-effective, innovative and exciting products.

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