Getting Started

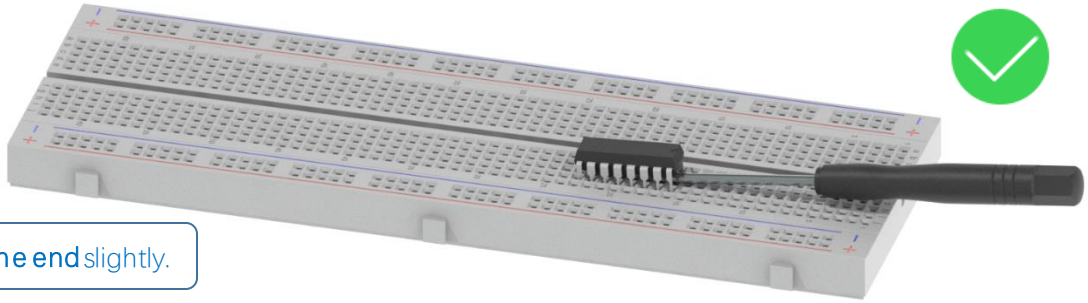
Thank you for choosing Freenove products!
After you download the ZIP file we provide. Unzip it and you will get a folder contains several files and folders. There are three PDF files:

- 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_Complete_Starter_Kit_for_Raspberry_Pi\Processing
  The code in this PDF is in Java.
- Pi4j.pdf in Freenove_Complete_Starter_Kit_for_Raspberry_Pi\Pi4j
  The code in this PDF is in Java.

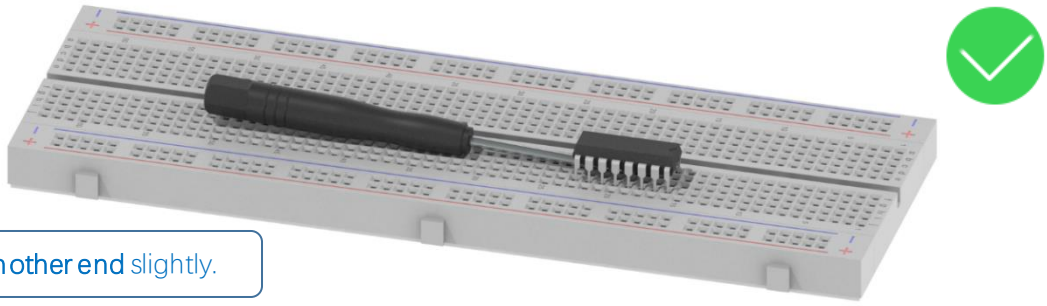
We recommend you to start with Tutorial.pdf or Tutorial_GPIOZero.pdf first.
If you want to start with Processing.pdf or skip some chapters of Tutorial.pdf, you need to finish necessary steps in Chapter 7 AD/DA of Tutorial.pdf first.

Remove the Chips

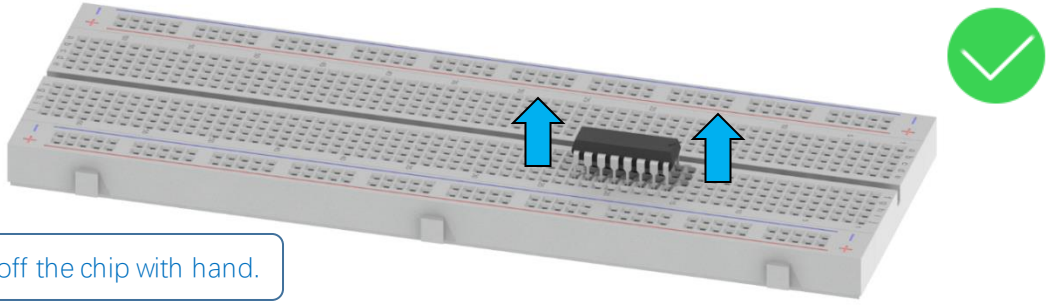
Some chips and modules are inserted into the breadboard to protect their pins.
You need to remove them from breadboard before use. (There is no need to remove GPIO Extension Board.)
Please find a tool (like a little screw driver) to handle them like below:



Step 1, lift one end slightly.

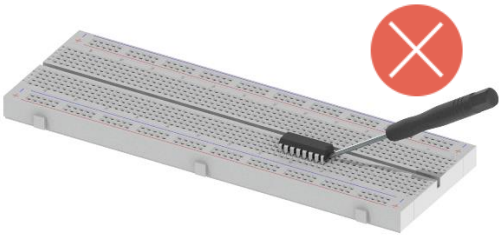


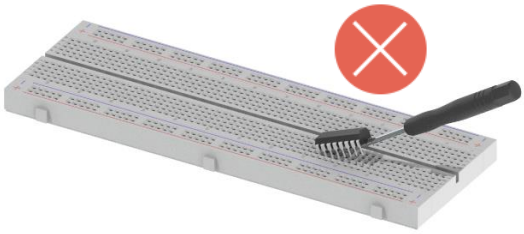
Step 2, lift another end slightly.



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

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

Contents

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**. We provide C 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:

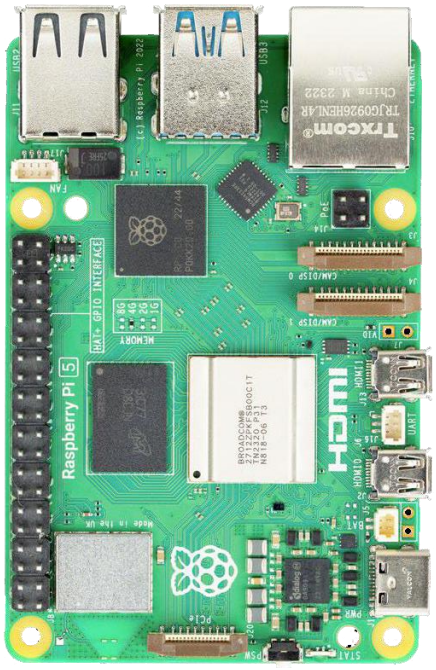
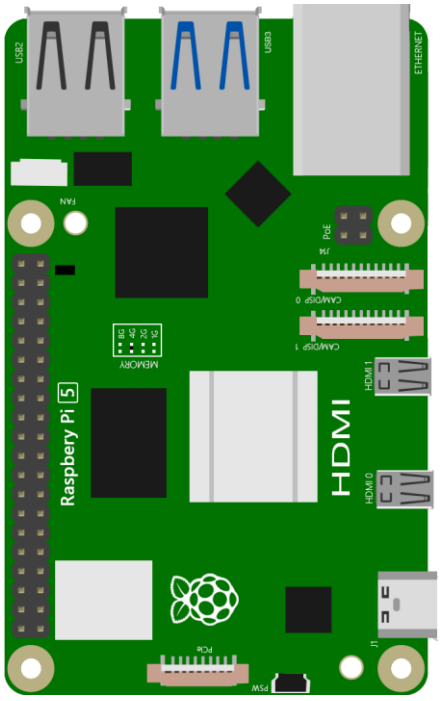
support@freenove.com

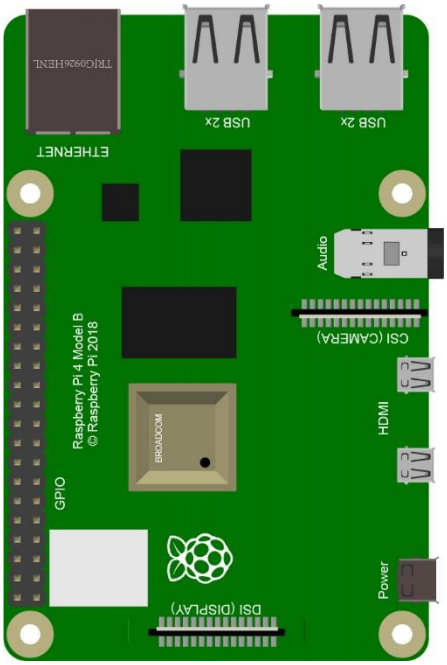
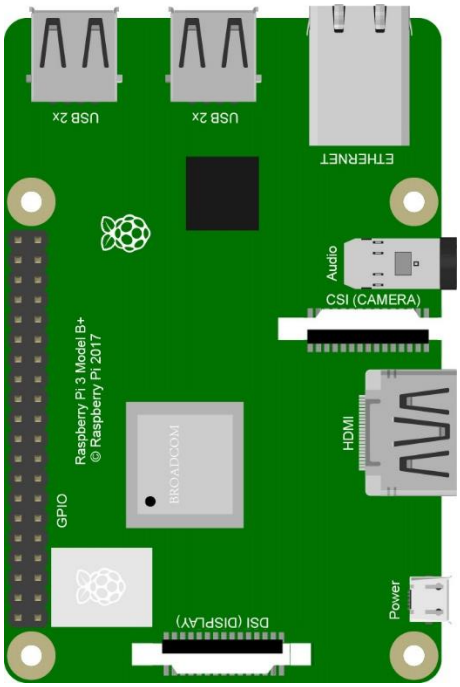
Raspberry Pi

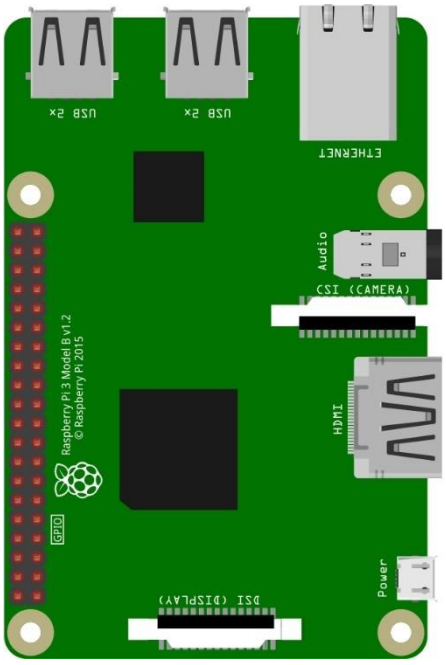
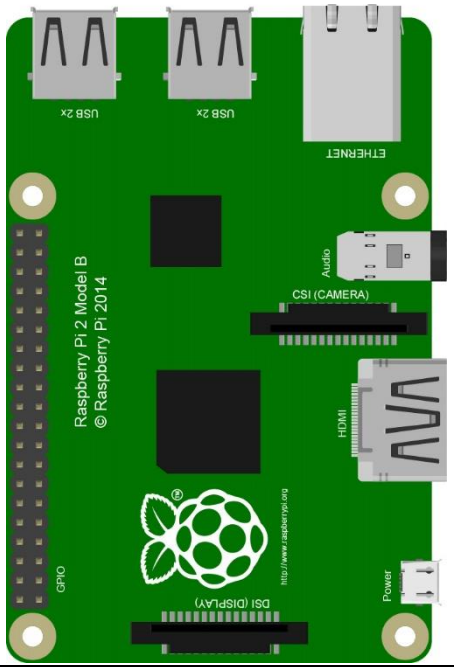
So far, at this writing, Raspberry Pi has advanced to its fifth generation product offering. Version changes are accompanied by increases in upgrades in hardware and capabilities.

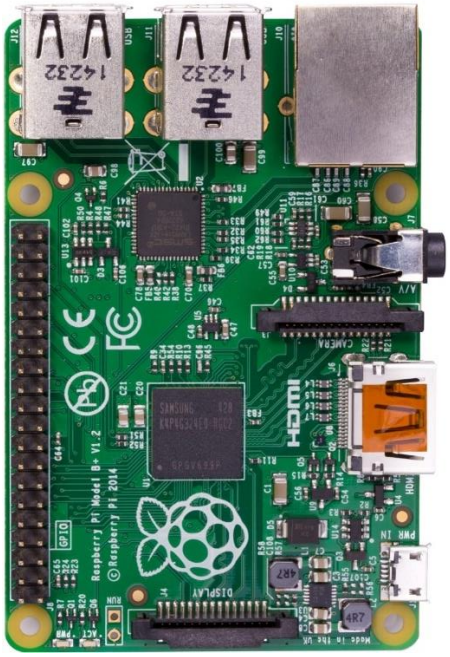
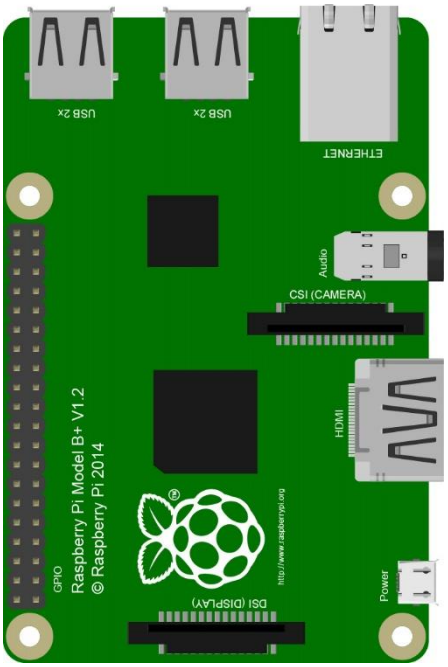
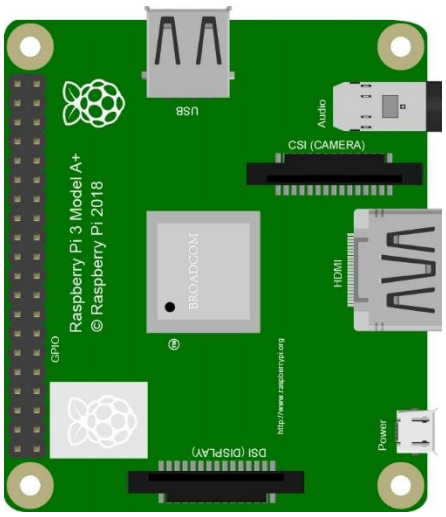
The A type and B type versions of the first generation products have been discontinued due to various reasons. What is most important is that other popular and currently available versions are consistent in the order and number of pins and their assigned designation of function, making compatibility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

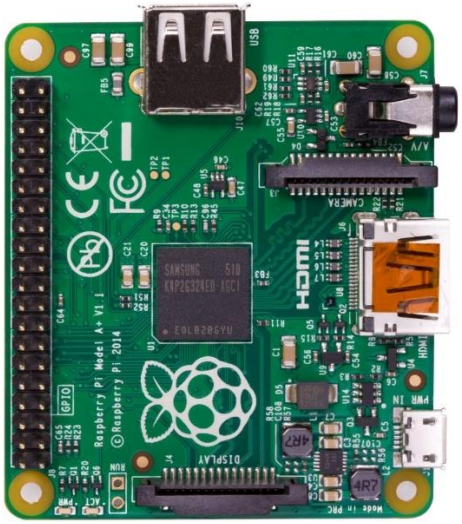
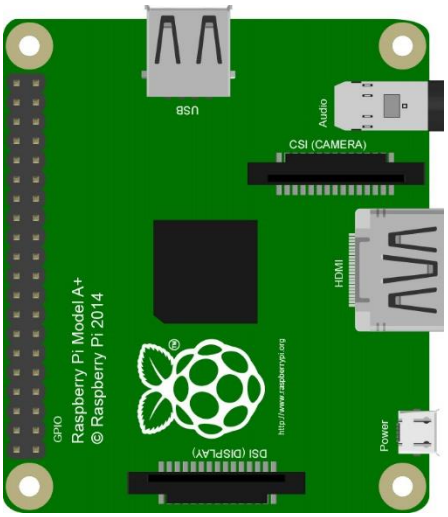
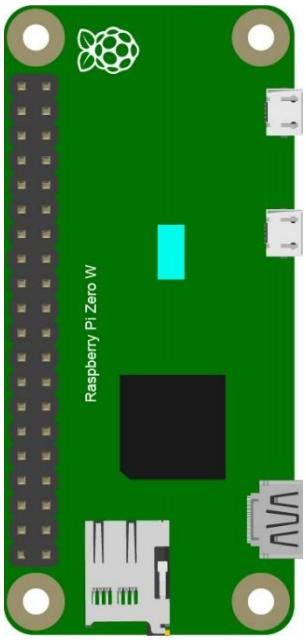
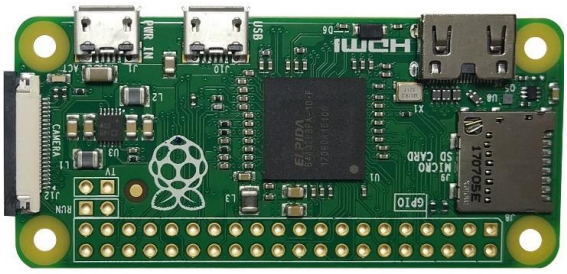
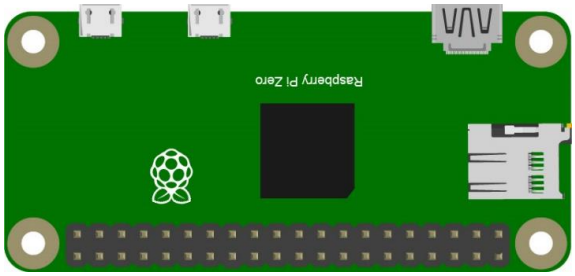
Below are the raspberry pi pictures and model pictures supported by this product. They have 40 pins.

Practicality picture of Raspberry Pi 5:	Model diagram of Raspberry Pi 5:
	

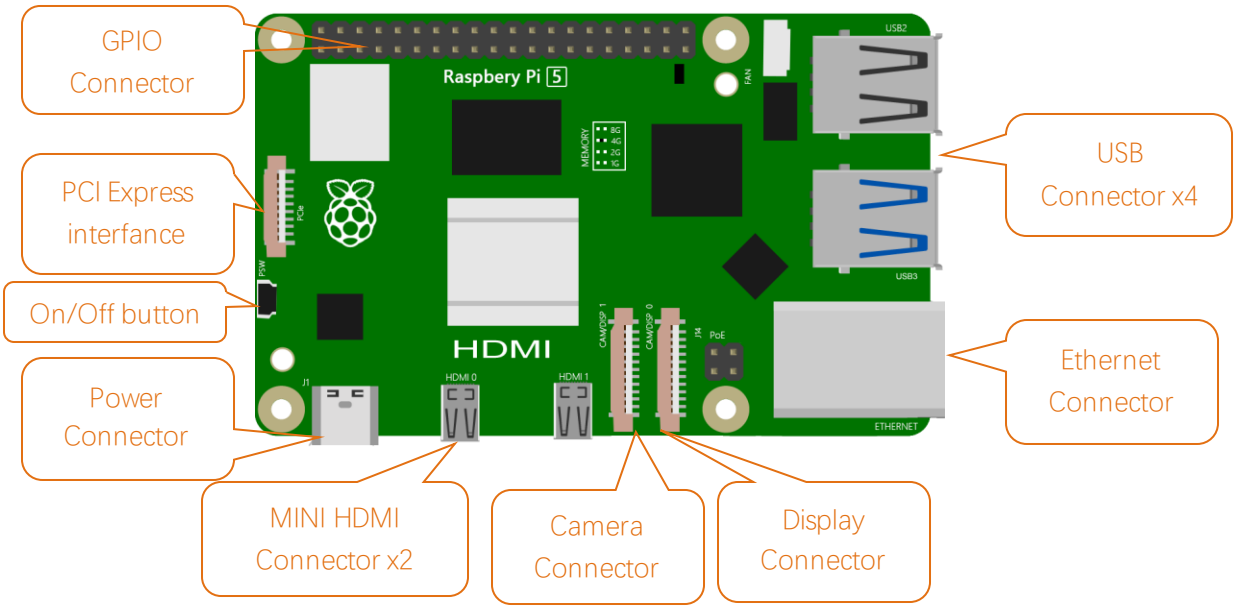
Actual image of Raspberry Pi 4 Model B: 	CAD image of Raspberry Pi 4 Model B: 
Actual image of Raspberry Pi 3 Model B+: 	CAD image of Raspberry Pi 3 Model B+: 

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: 

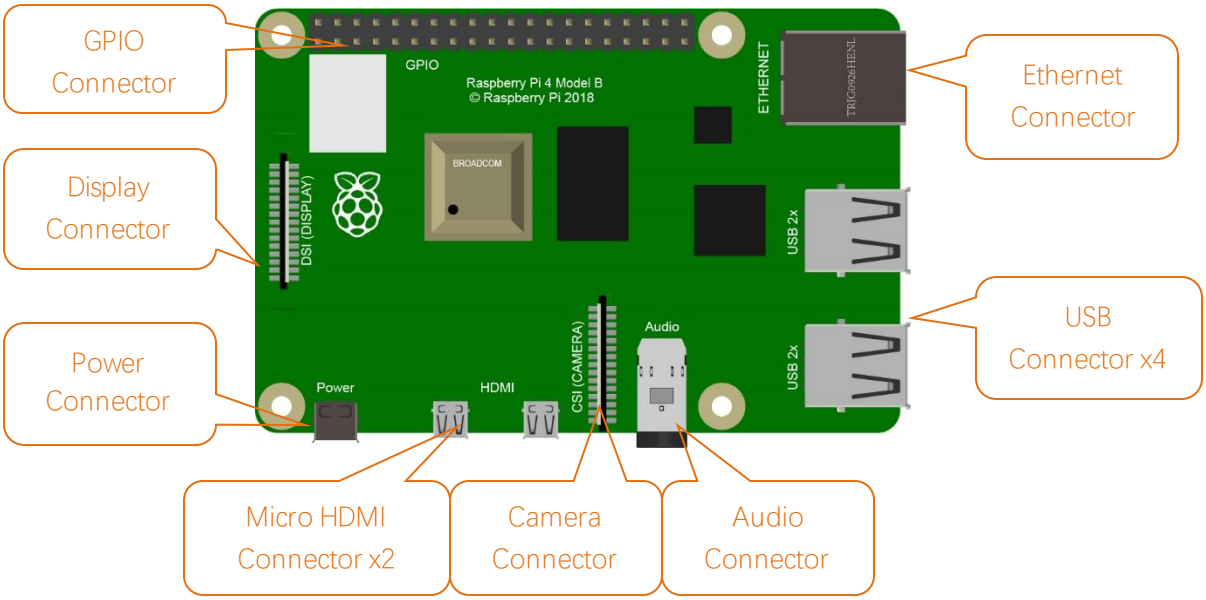
Actual image of Raspberry Pi 1 Model B+: 	CAD image of Raspberry Pi 1 Model B+: 
Actual image of Raspberry Pi 3 Model A+: 	CAD image of Raspberry Pi 3 Model A+: 

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: 

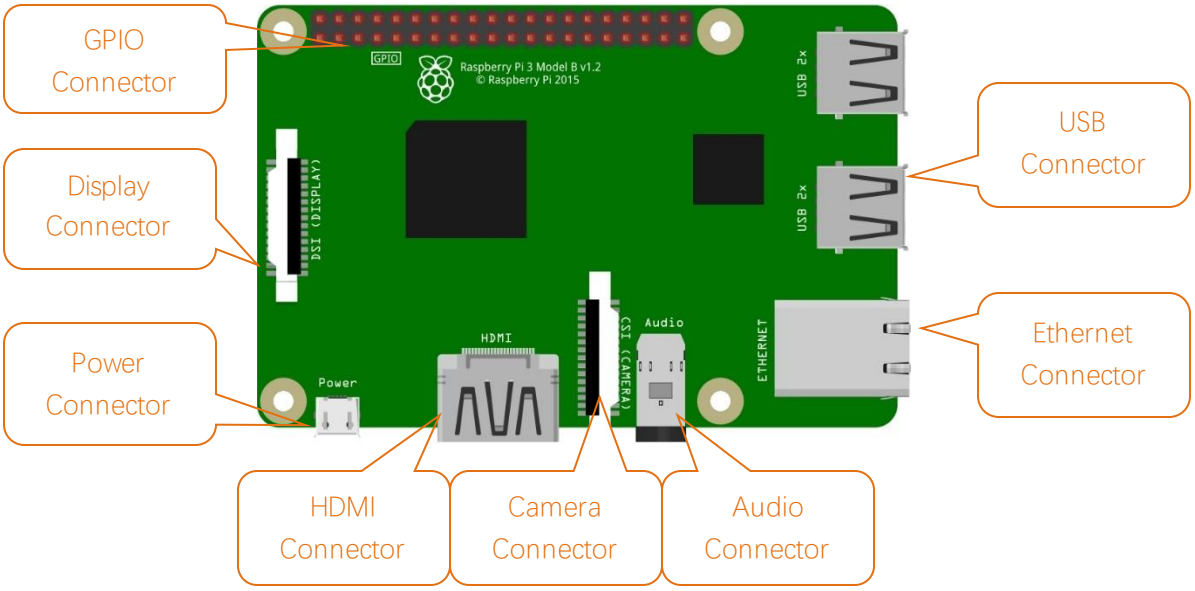
Below are the raspberry pi pictures and model pictures supported by this product. They have 40 pins.
Hardware interface diagram of RPi 5 is shown below:



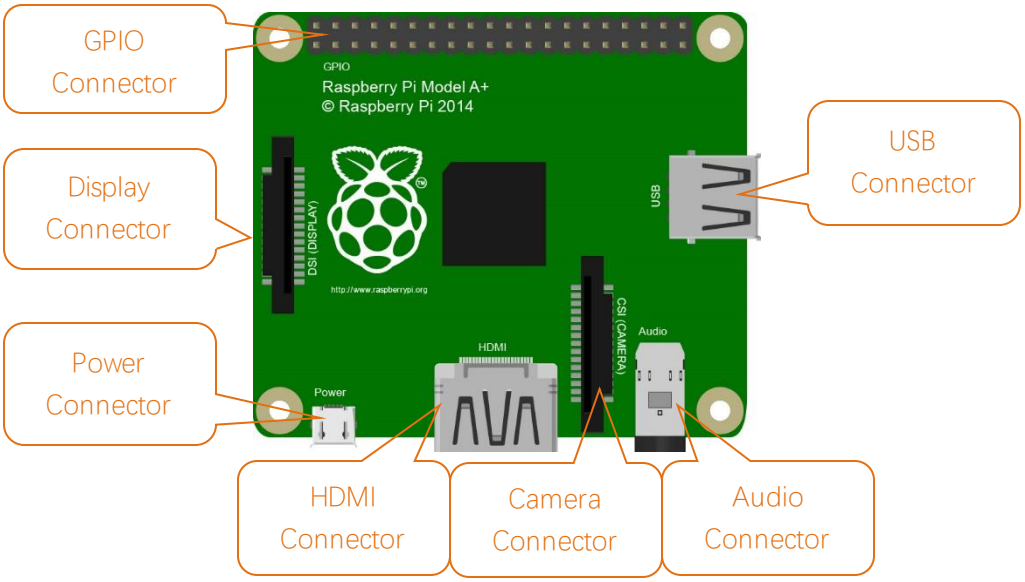
Hardware interface diagram of RPi 4B is shown below:



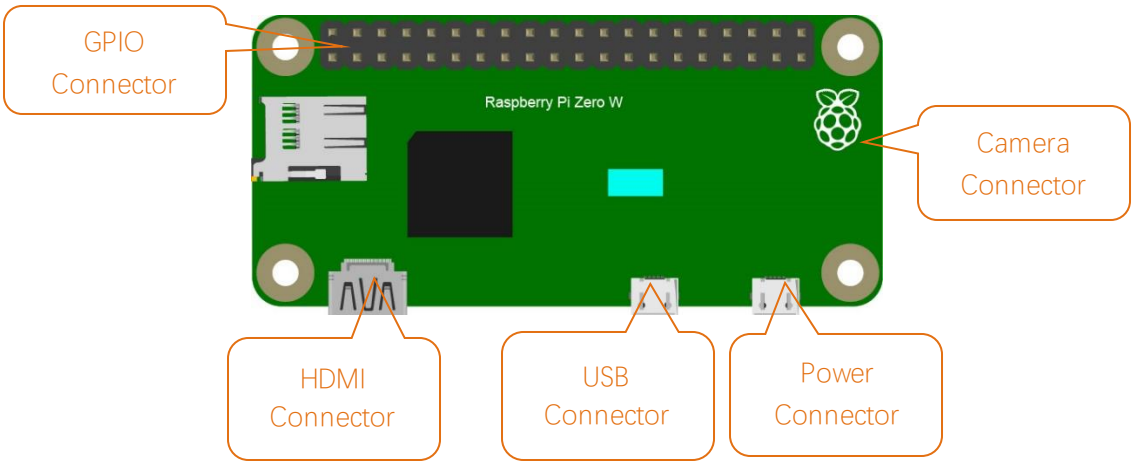
Hardware interface diagram of RPi 3B+/3B/2B/1B+:



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



Hardware interface diagram of RPi Zero/Zero W:

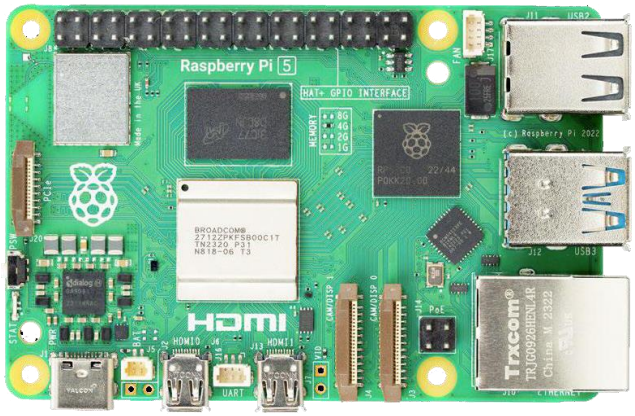
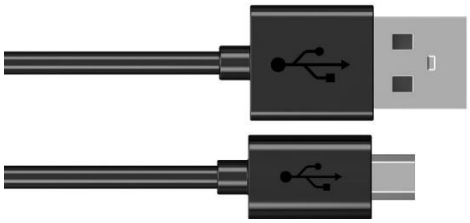


Installing an Operating System

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.

<table>
<tr><th></th><th>Pi Zero</th><th>Pi A+</th><th>Pi Zero W</th><th>Pi 3A+</th><th>Pi B+/2B</th><th>Pi 3B/3B+</th><th>Pi 4B</th><th>Pi 5</th></tr>
<tr><td>Monitor</td><td colspan="8">Yes (All)</td></tr>
<tr><td>Mouse</td><td colspan="8">Yes (All)</td></tr>
<tr><td>Keyboard</td><td colspan="8">Yes (All)</td></tr>
<tr><td>Micro-HDMI to HDMI Adapter & Cable</td><td>Yes</td><td>No</td><td>Yes</td><td>No</td><td>No</td><td>No</td><td>No</td><td>No</td></tr>
<tr><td>Micro-HDMI to HDMI Adapter & Cable</td><td colspan="6">No</td><td colspan="2">Yes</td></tr>
<tr><td>Micro-USB to USB-A Adapter & Cable (Micro USB OTG Cable)</td><td>Yes</td><td>No</td><td>Yes</td><td colspan="5">No</td></tr>
<tr><td>USB HUB</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>No</td><td>No</td><td>No</td><td>No</td></tr>
<tr><td>USB to Ethernet Interface</td><td rowspan="2" colspan="2">select one from two or select two from two</td><td colspan="2">optional</td><td>Internal Integration</td><td rowspan="2" colspan="3">Internal Integration</td></tr>
<tr><td>USB Wi-Fi Receiver</td><td colspan="2">Internal Integration</td><td>optional</td></tr>
</table>

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
Micro-USB to USB-A Adapter & Cable (Micro USB OTG Cable)	Yes	Yes	No	NO		
USB to Ethernet interface	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

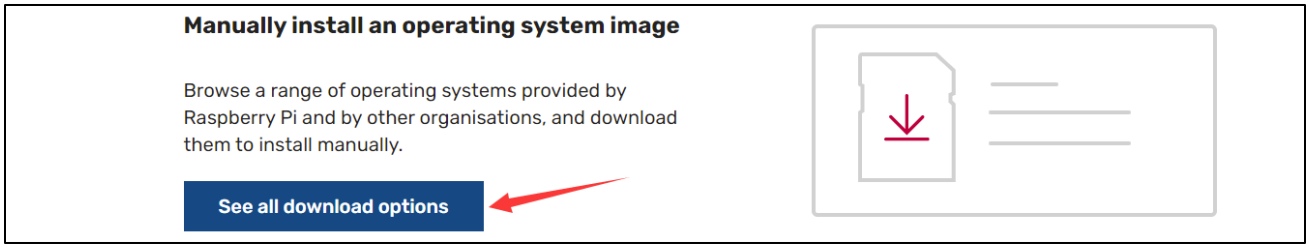
Automatically Method

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.

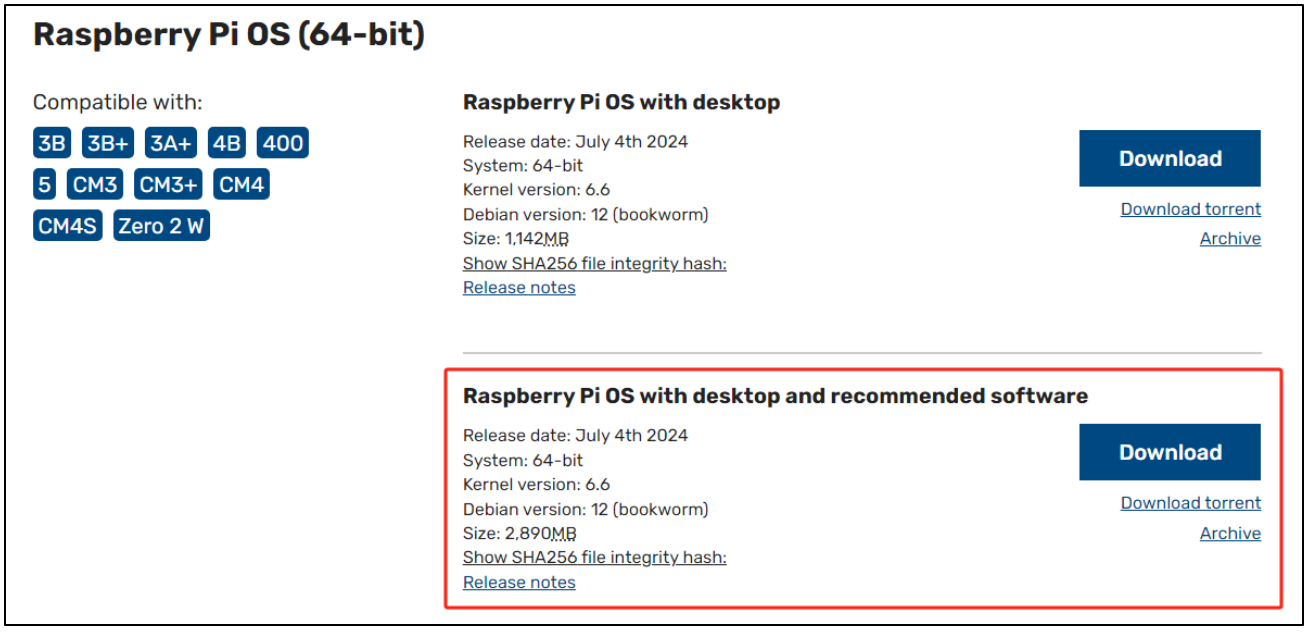
Manually Method

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

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



The image is for reference only, please select the latest version.

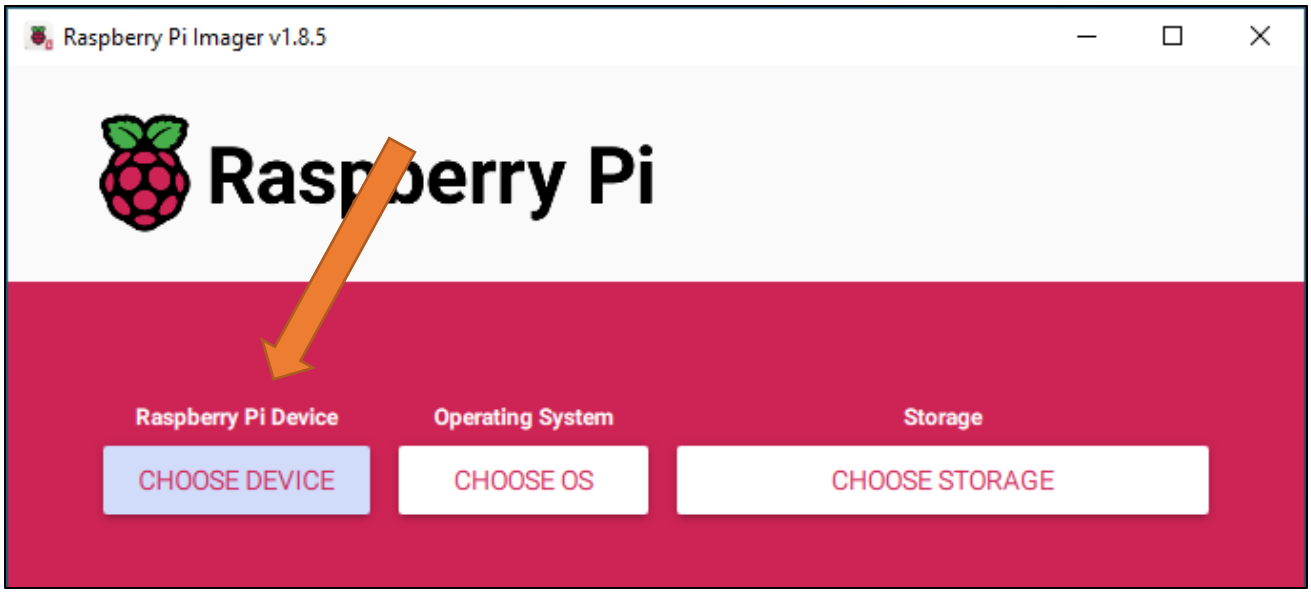


Then the zip file is downloaded.

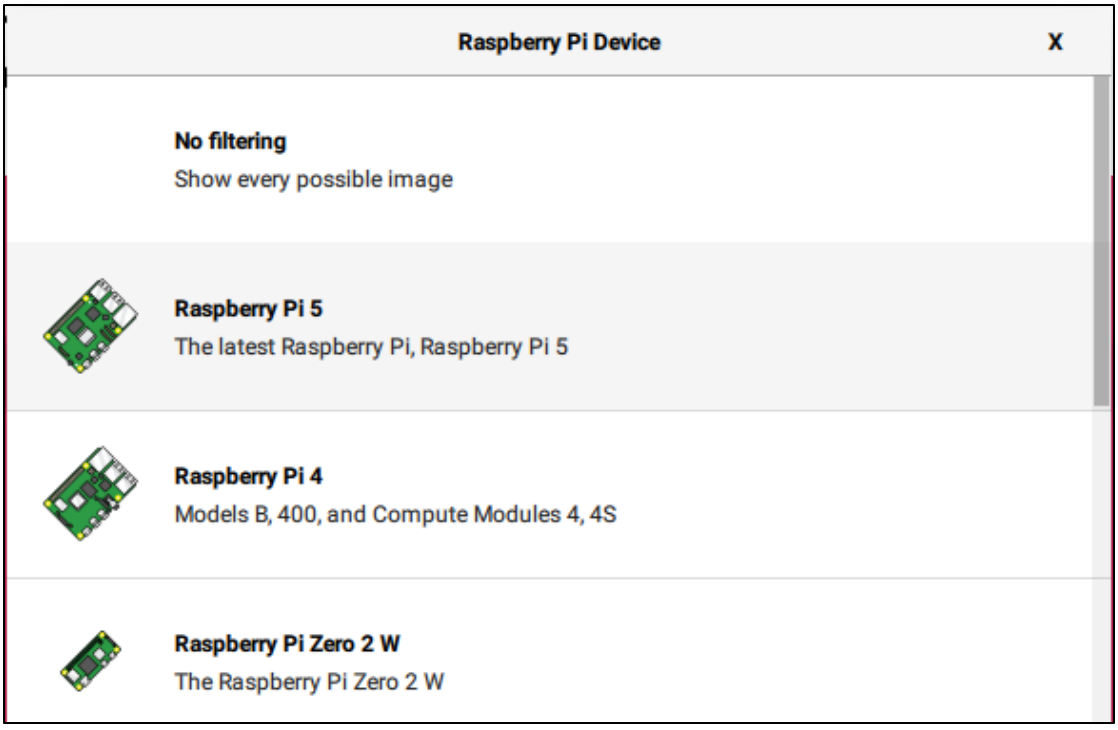
Write System to Micro SD Card

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

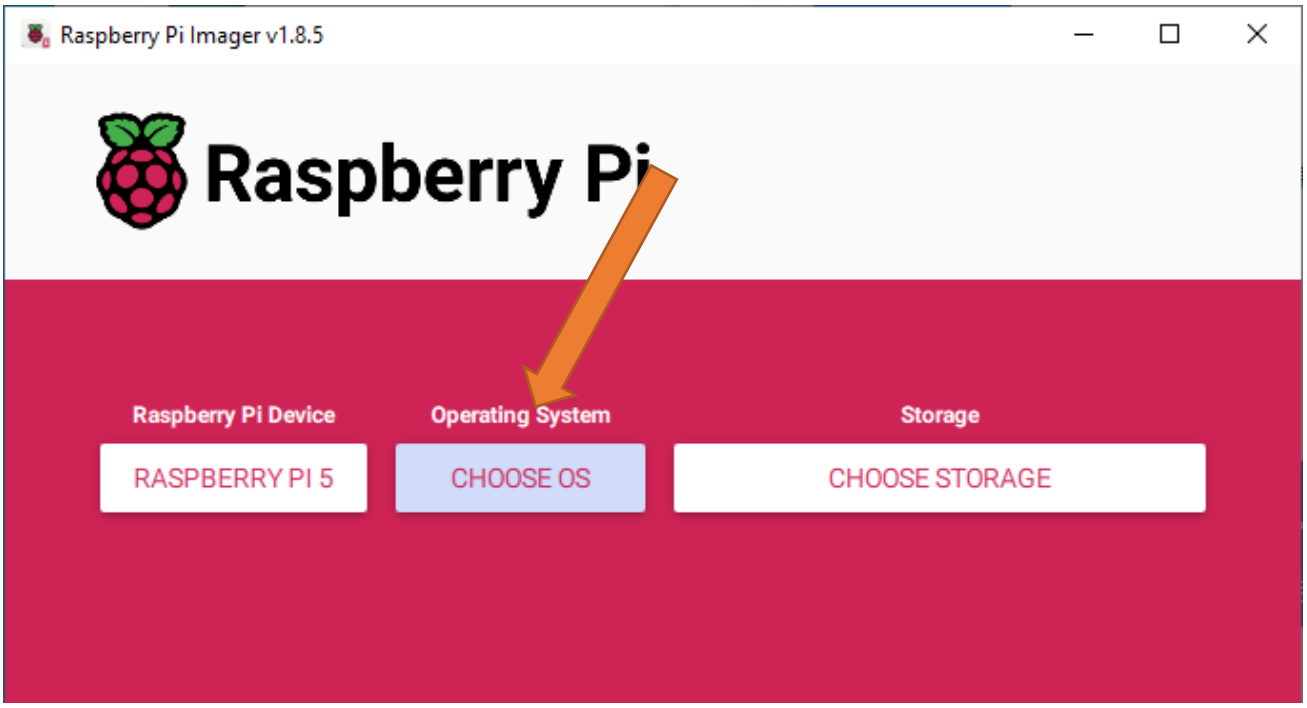
Then open imager toll. Clicked Choose Device.



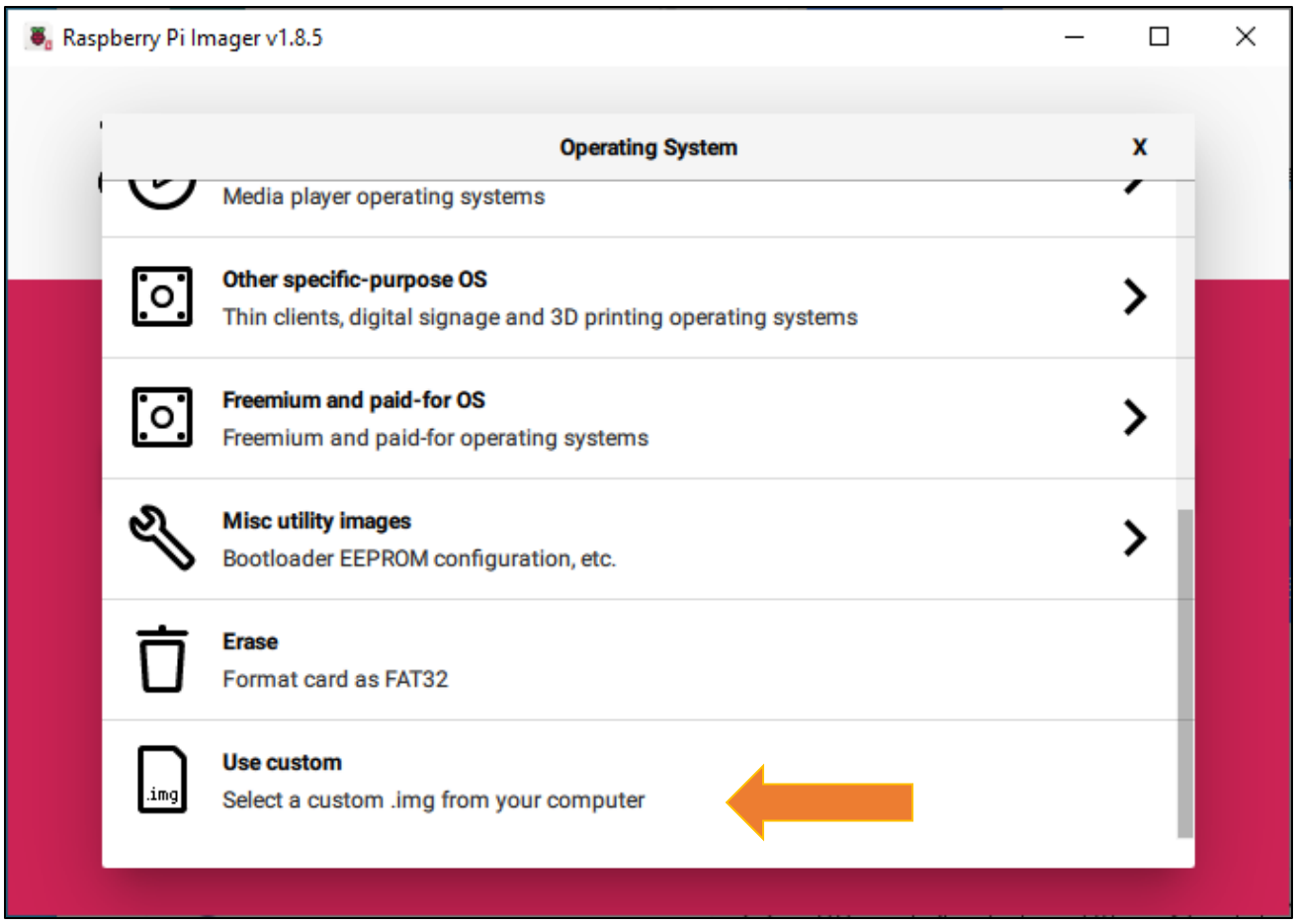
Select a Raspberry PI Device based on your Raspberry PI version. It will help us filter out the right version of the system for the Raspberry PI.



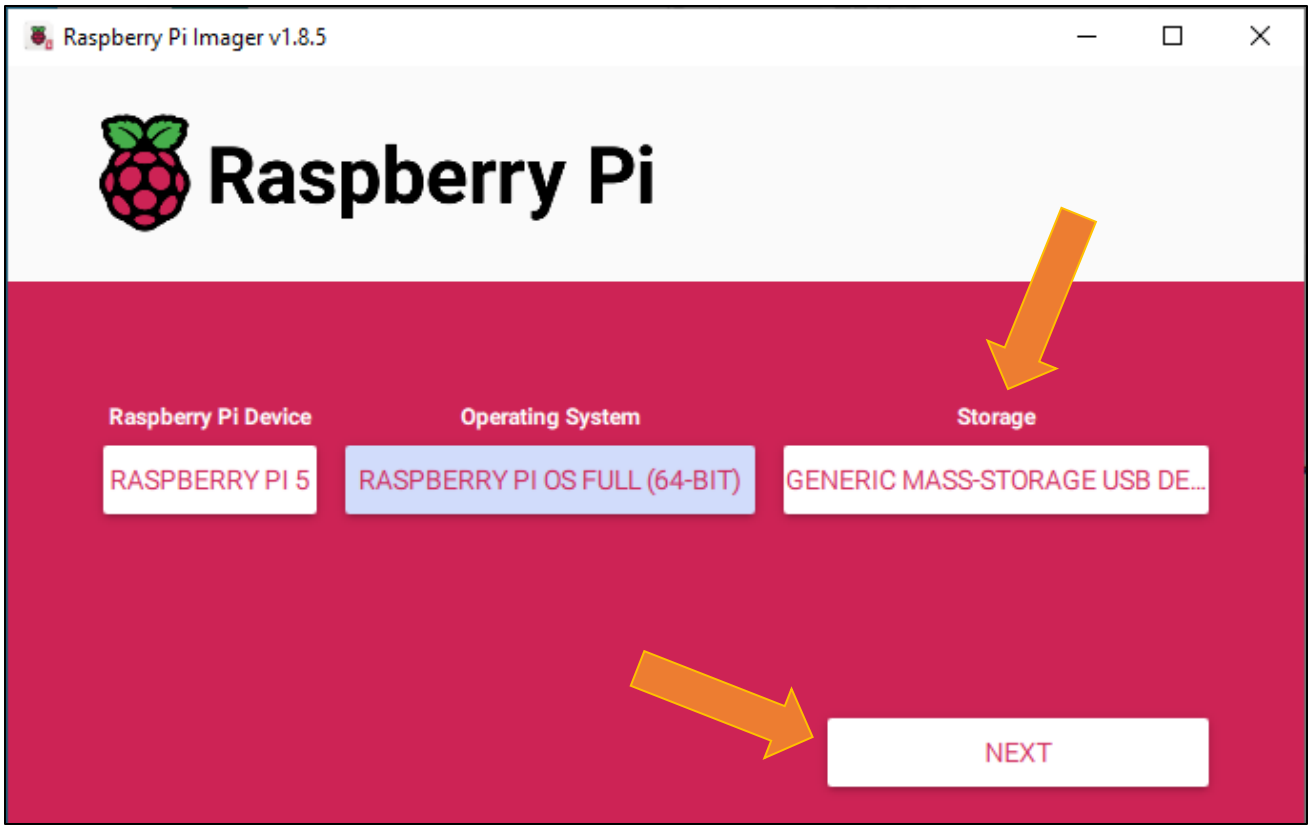
Clicked Operating System.



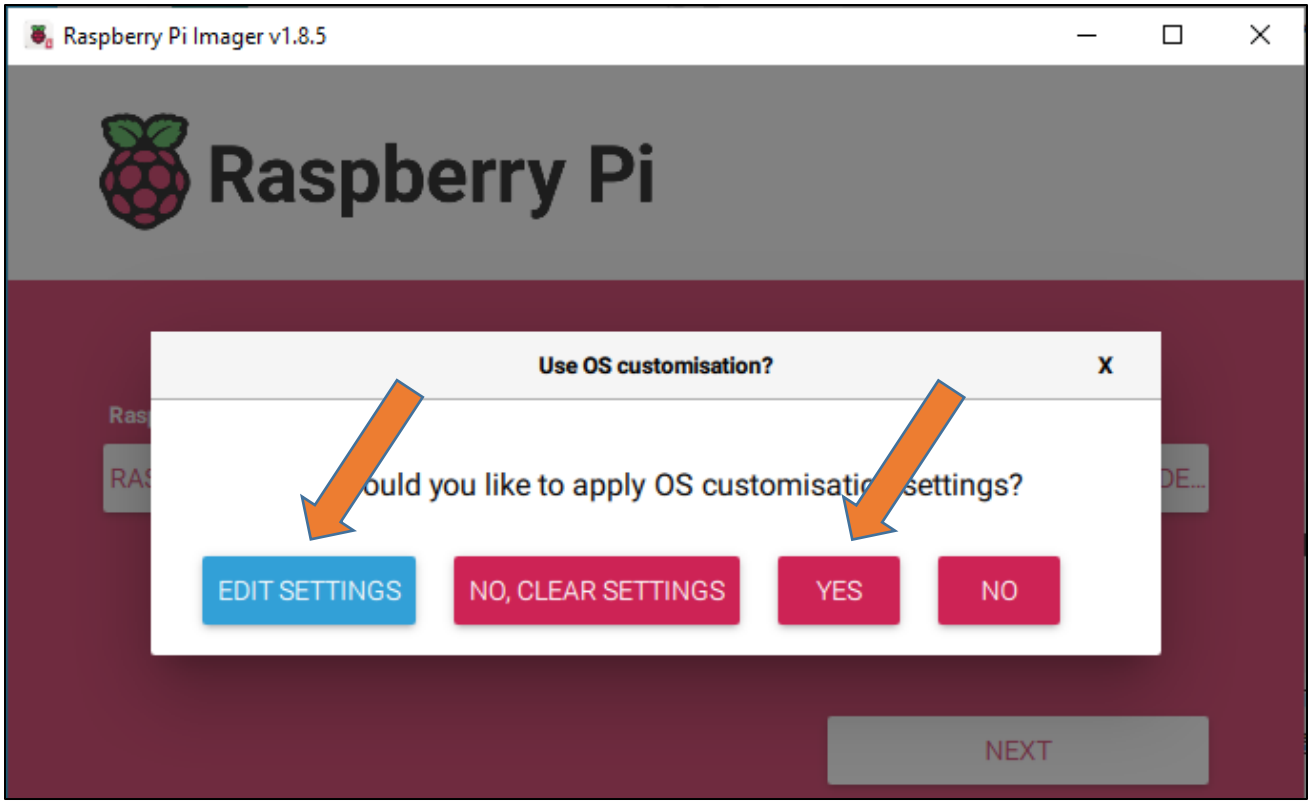
Choose system that you just downloaded in Use custom.



Choose the SD card. Then click "Next".

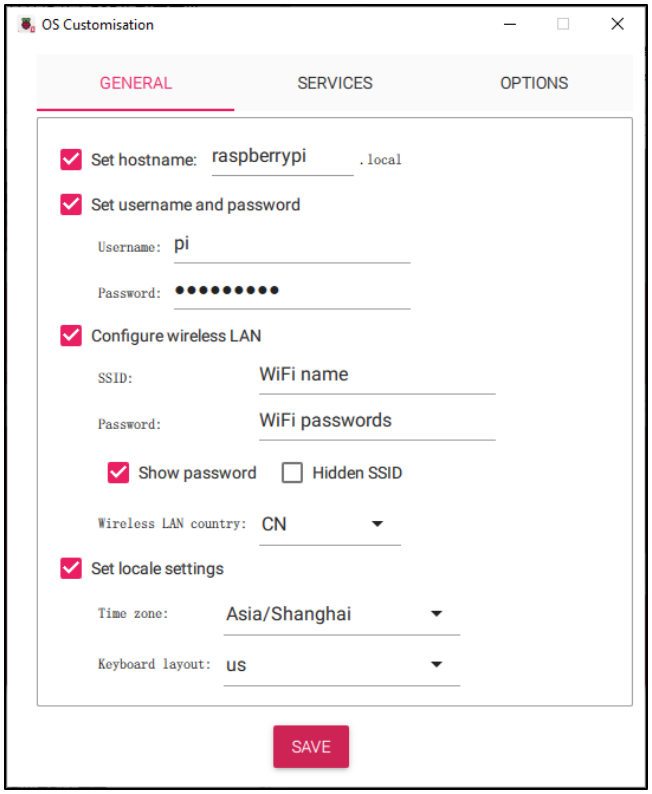


You can configure the Raspberry PI according to your needs.

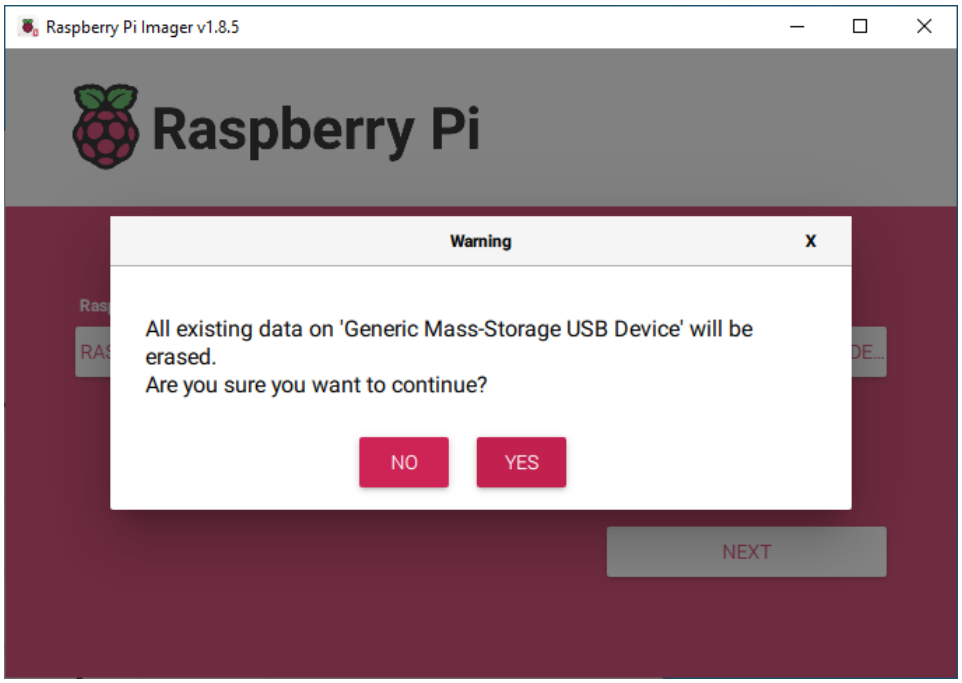


Enable ssh and configure WiFi

On the GENERAL screen, configure your information based on your actual situation.

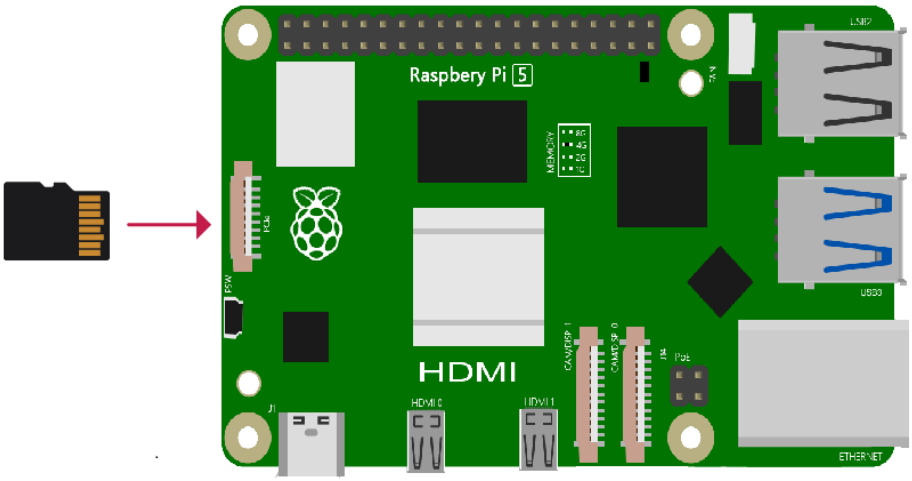


Click Save, in the new screen, click Yes, wait for SD to brush into the Raspberry system.



Insert SD card

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



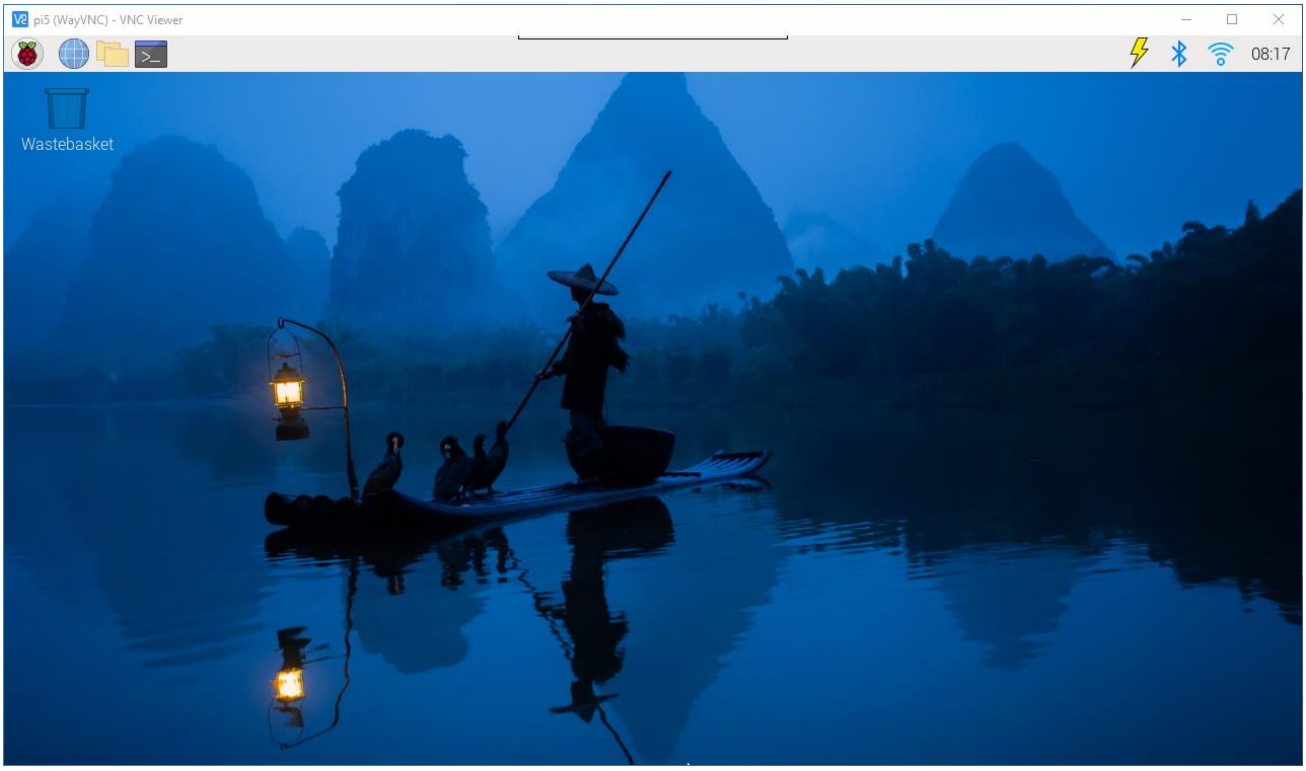
Connect to the power supply and wait for the Raspberry PI to turn on.

Getting Started with Raspberry Pi

Monitor desktop

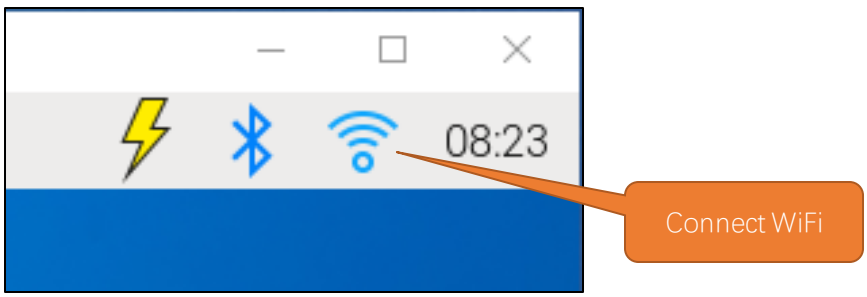
If you do not have a spare monitor, please skip to next section Remote desktop & VNC. If you have a spare monitor, please follow the steps in this section.

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:

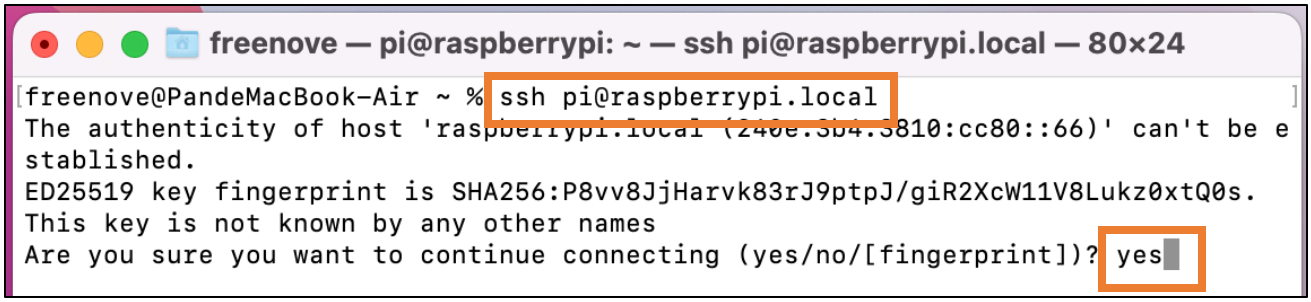
MAC OS remote desktop and Windows OS remote desktop.

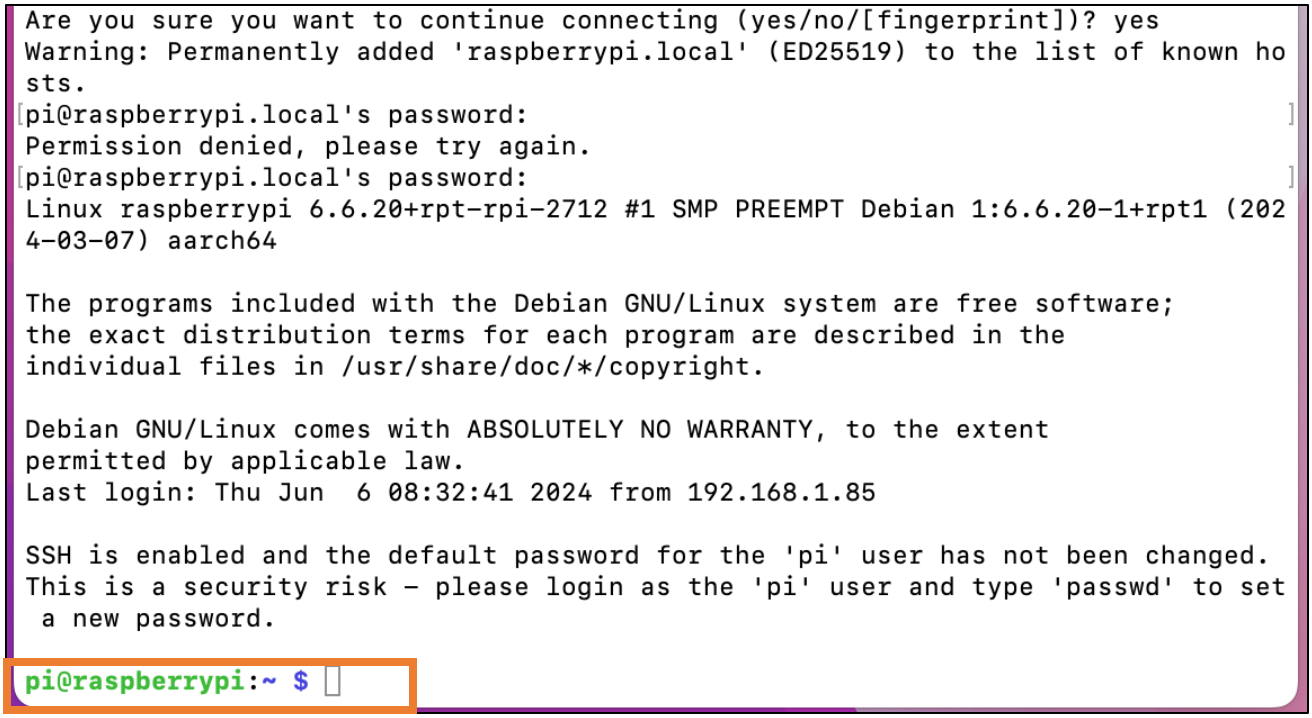
MAC OS Remote Desktop

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.





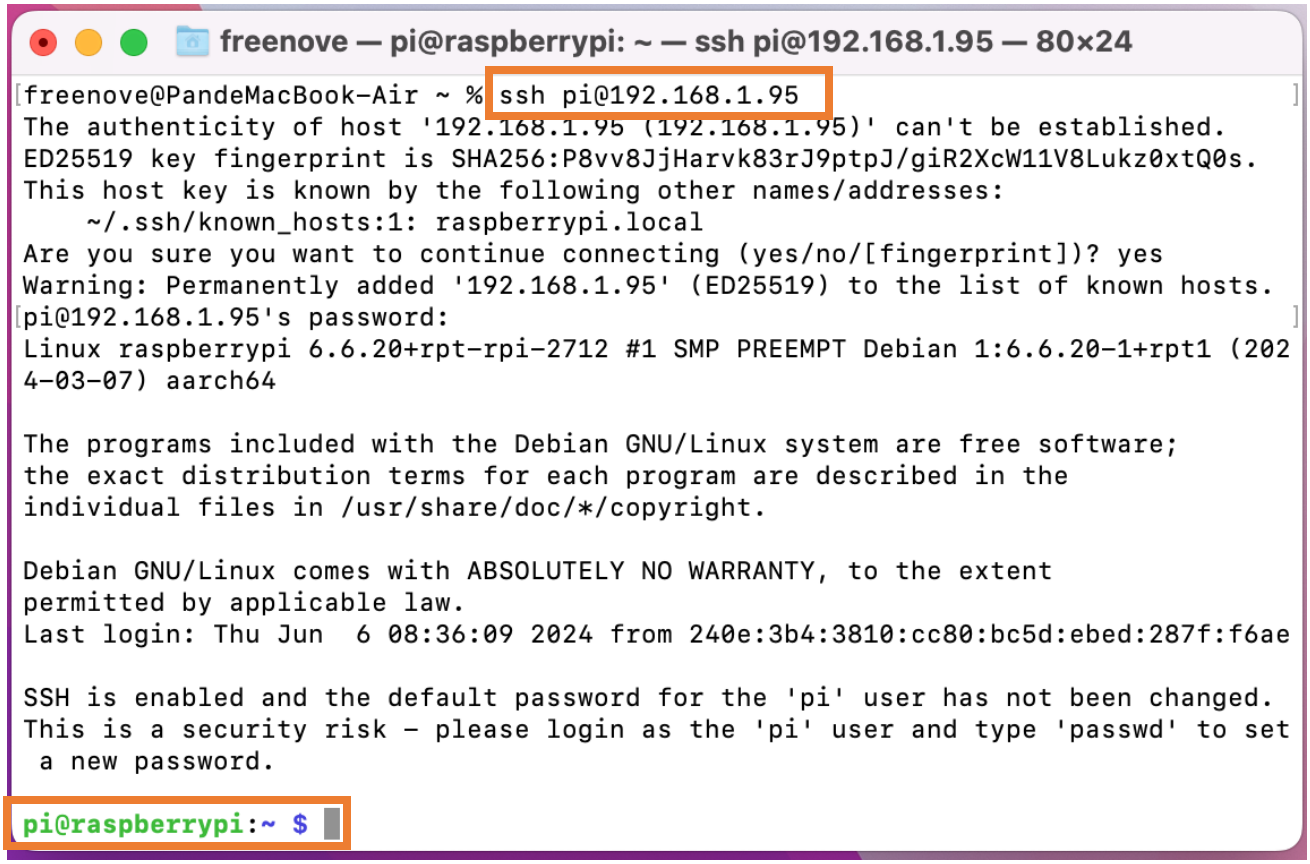
You can also use the IP address to log in Pi.

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.



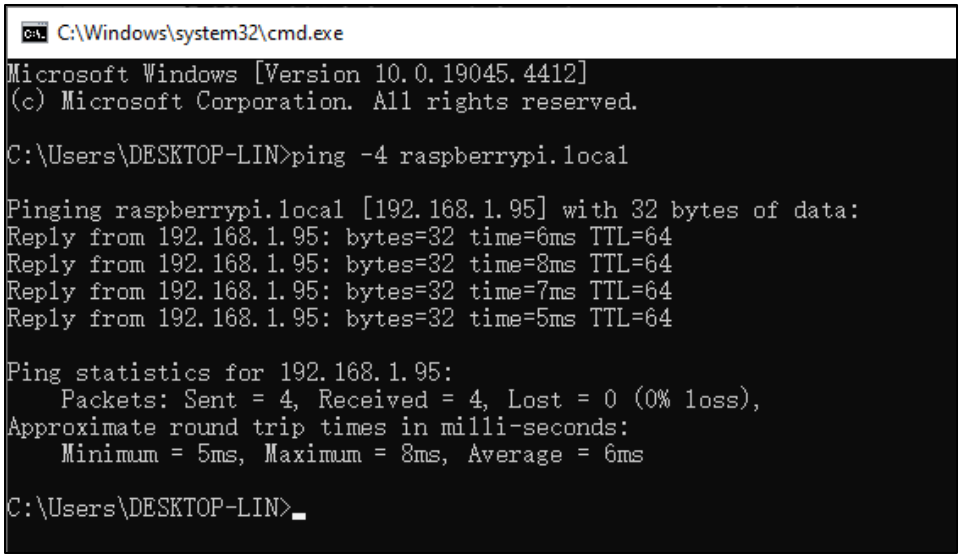
Then you can skip to VNC Viewer.

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
```



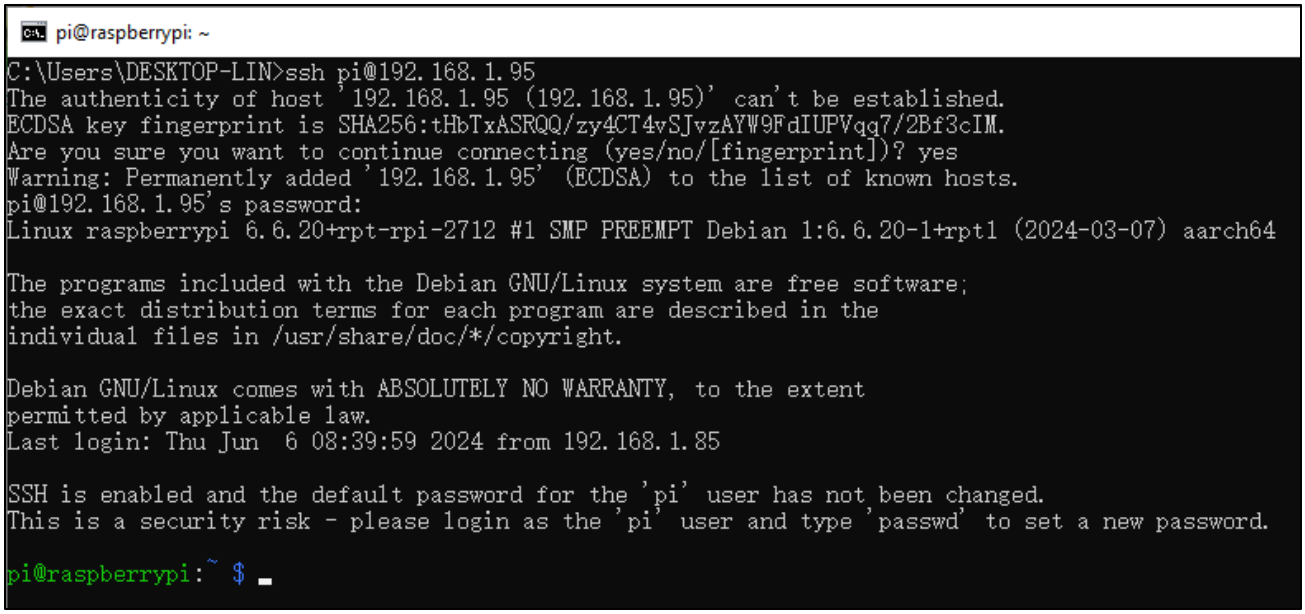
Then 192.168.1.147 is my Raspberry Pi IP.

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@xxxxxxxxxx(IP address)
```

Enter the following command:

```
ssh pi@192.168.1.95
```

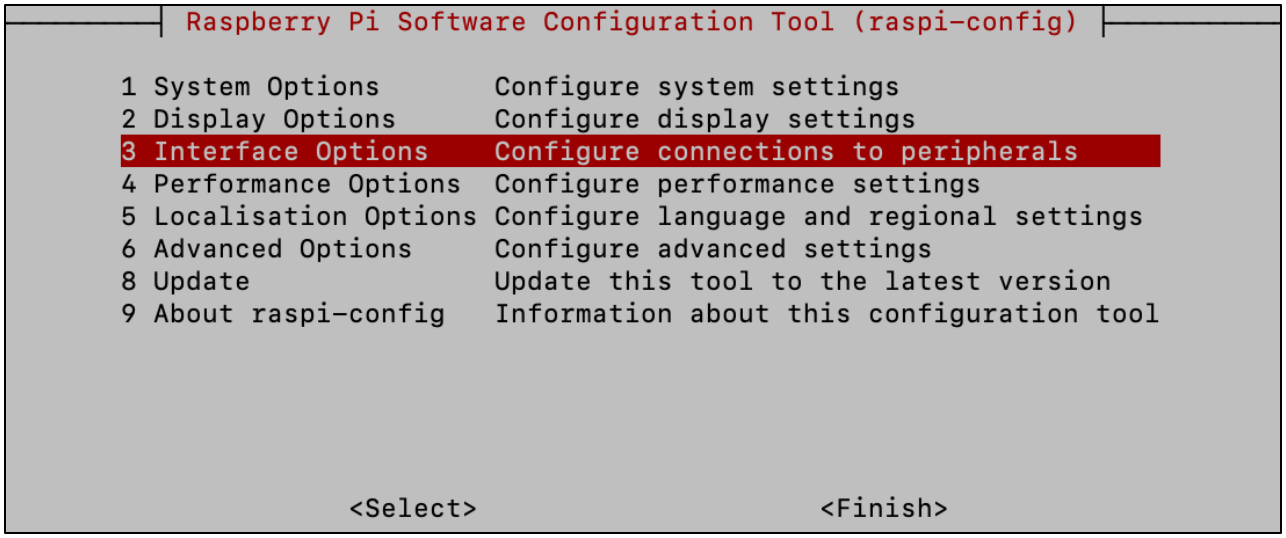


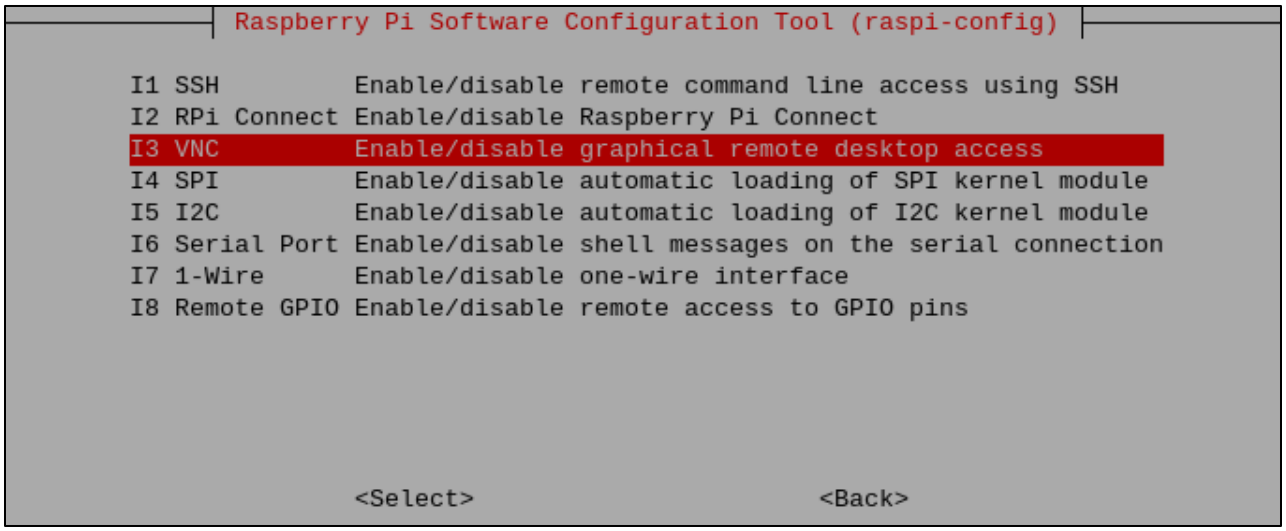
Enable VNC

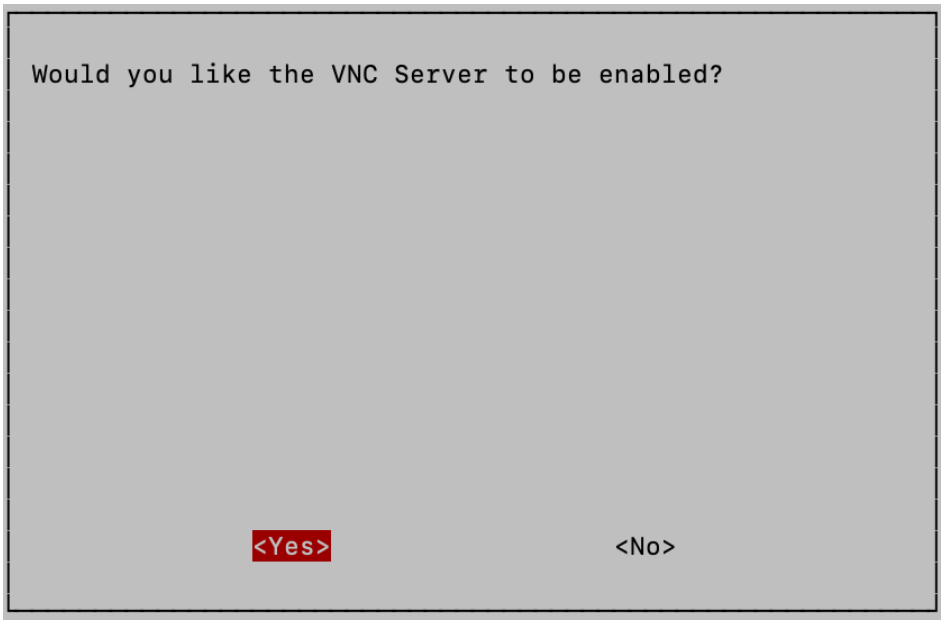
Type the following command. Select Interface Options→P5 VNC → Enter→Yes→OK. Here Raspberry Pi may need be restarted, and choose ok. Then open VNC interface.

```
sudo raspi-config
```

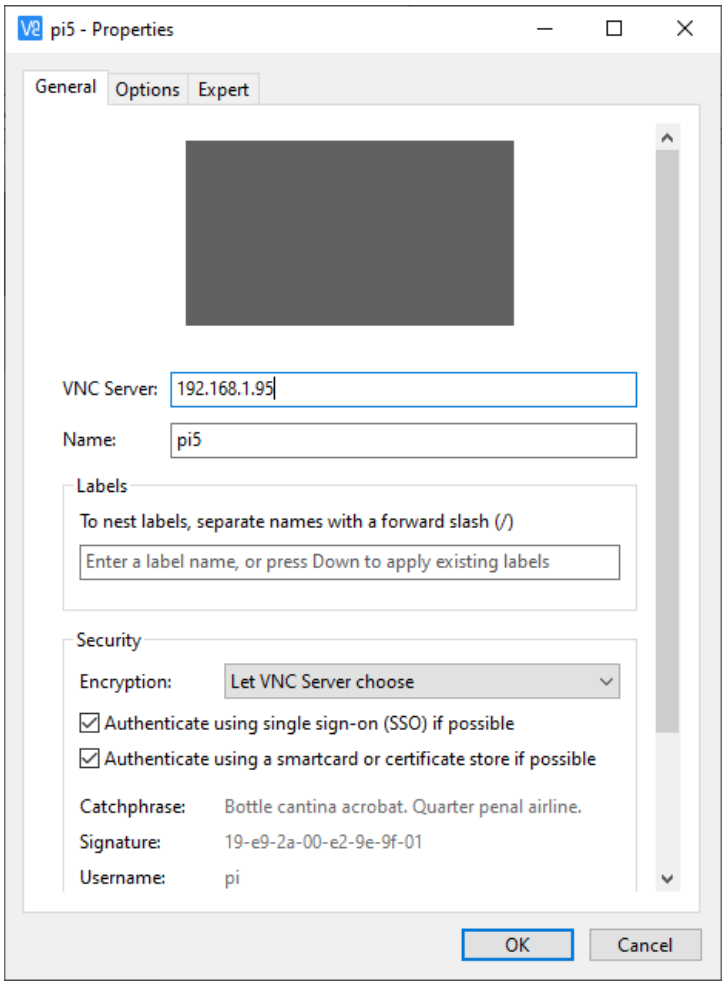
```
SSH is enabled and the default password for the 'pi' user has not been changed.
This is a security risk - please login as the 'pi' user and type 'passwd' to set
 a new password.

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





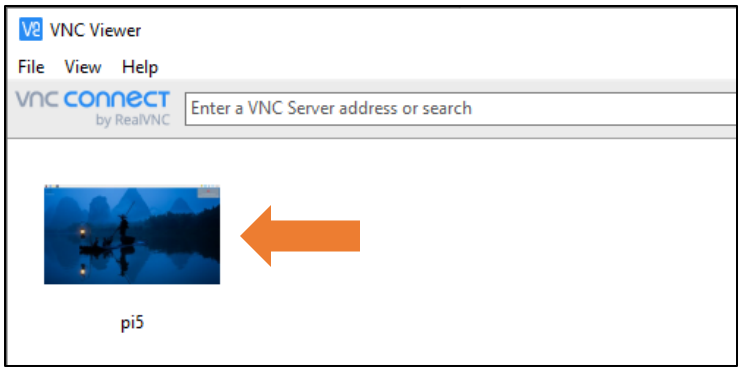


Then download and install VNC Viewer according to your computer system by click following link:
https://www.realvnc.com/en/connect/download/viewer/
After installation is completed, open VNC Viewer. Click File → New Connection. The interface is shown below.

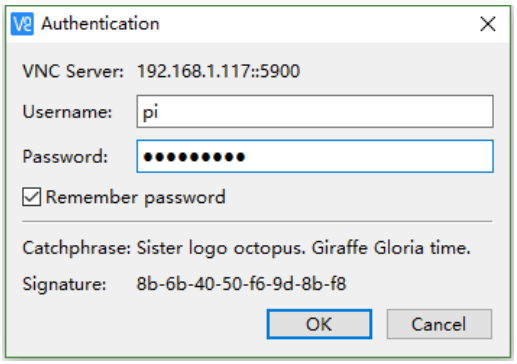


Enter ip address of your Raspberry Pi and fill in a name. Then click OK.

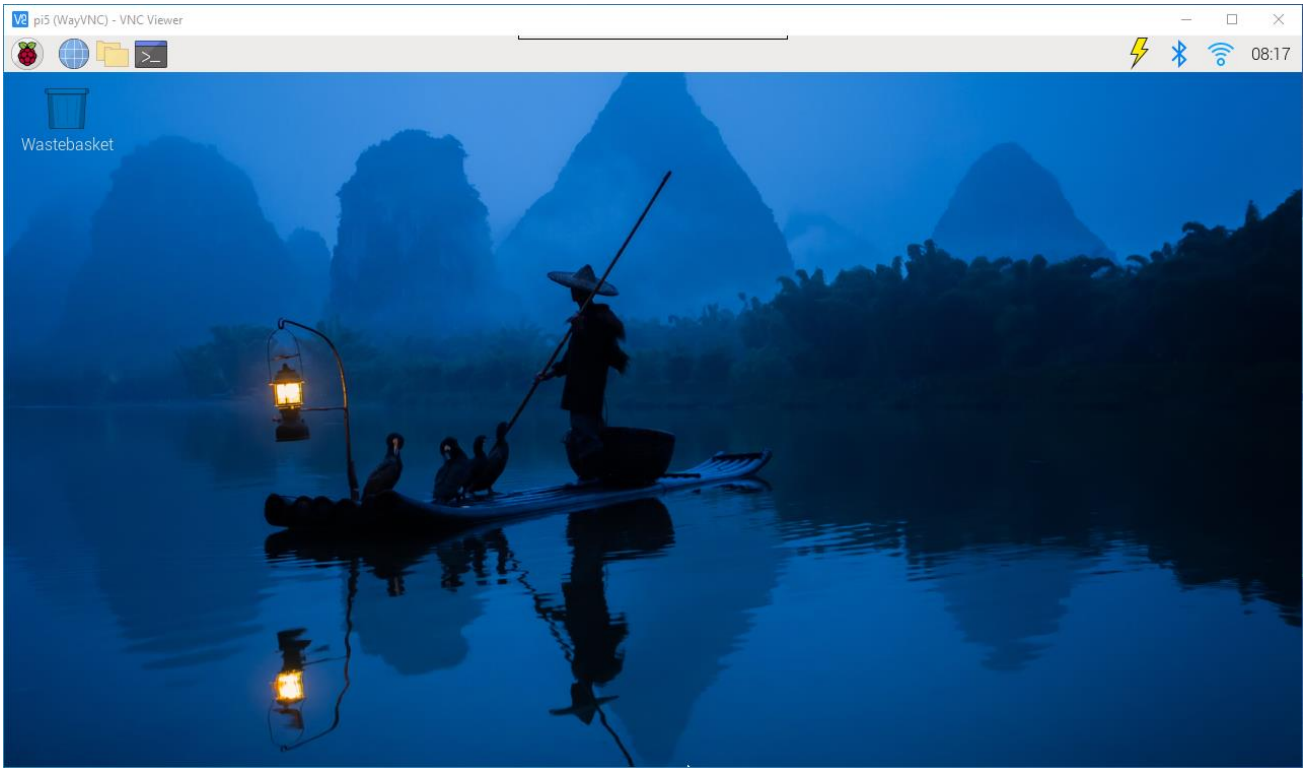
Then on the VNC Viewer panel, double-click new connection you just created,



and the following dialog box pops up.



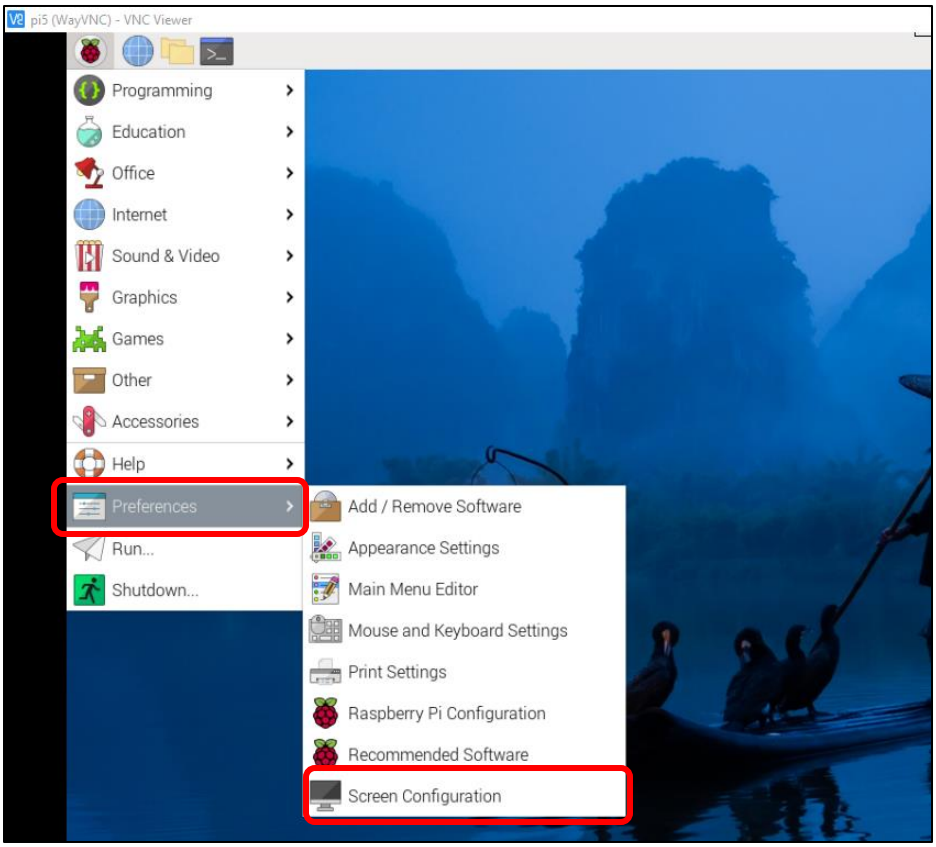
Enter username: **pi** and Password: **raspberry**. And click OK.



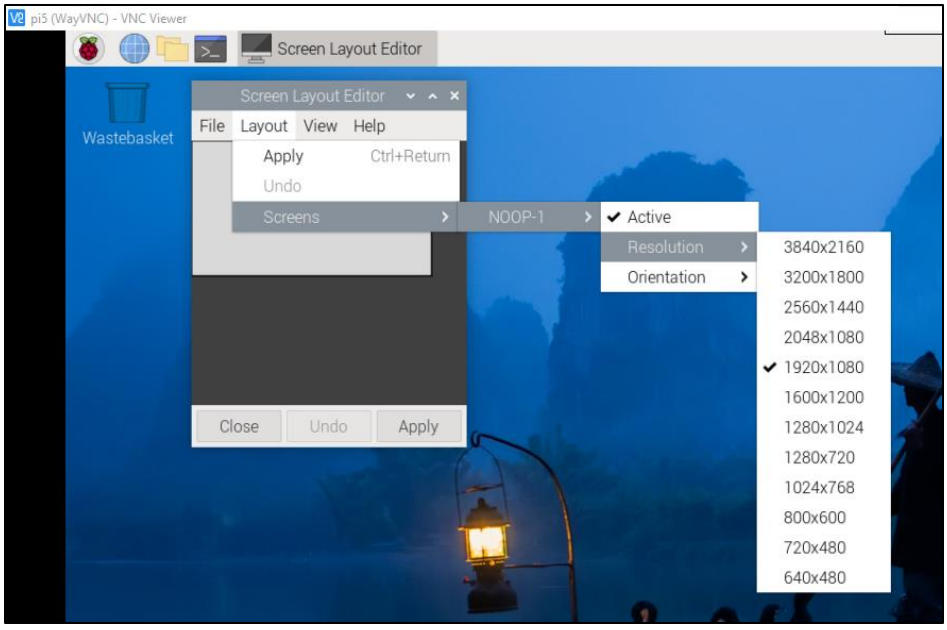
Here, you have logged in to Raspberry Pi successfully by using VNC Viewer

Set Resolution

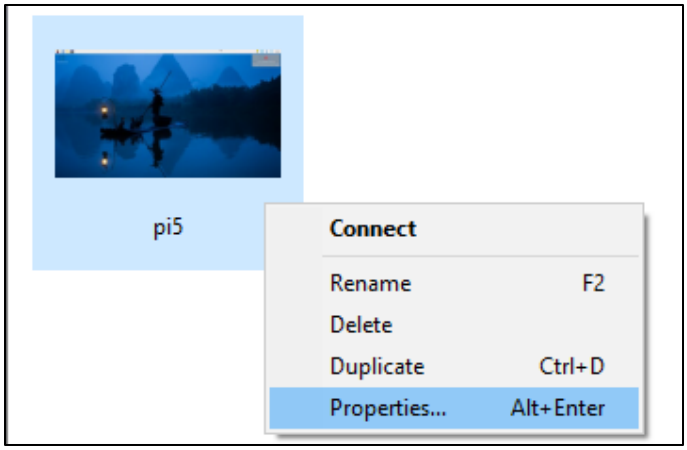
You can also set other resolutions.

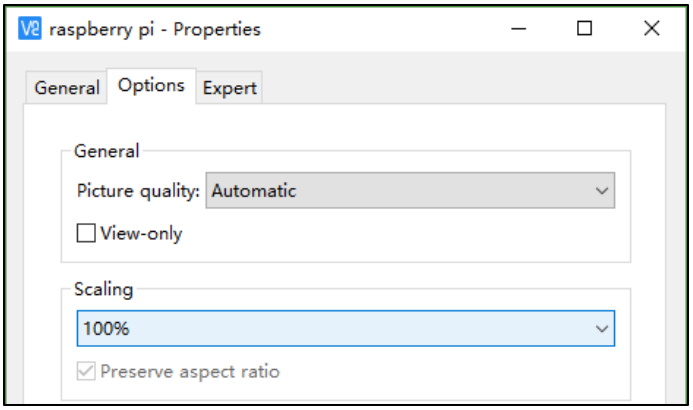


If you don't know what resolution to set properly, you can try 1920x1080.

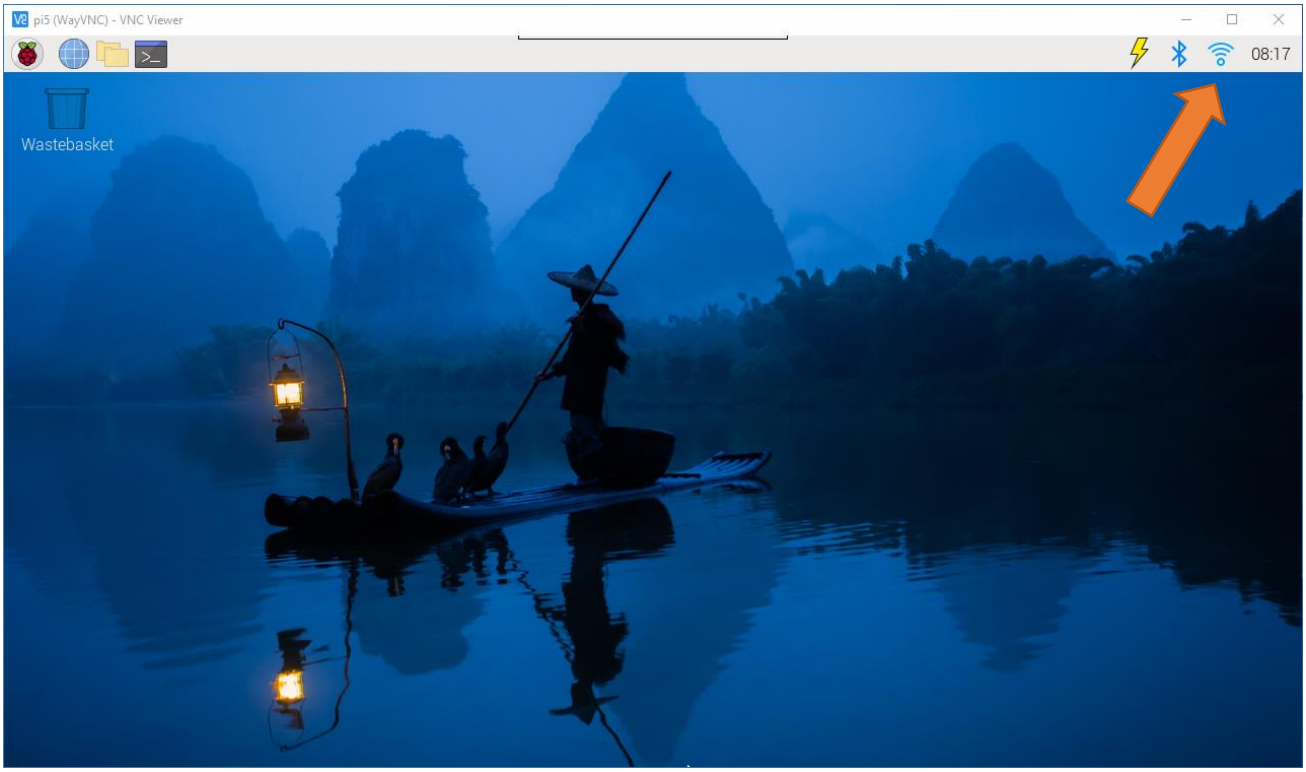


In addition, your VNC Viewer window may zoom your Raspberry Pi desktop. You can change it. On your VNC View control panel, click right key. And select Properties->Options label->Scaling. Then set proper scaling.





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.

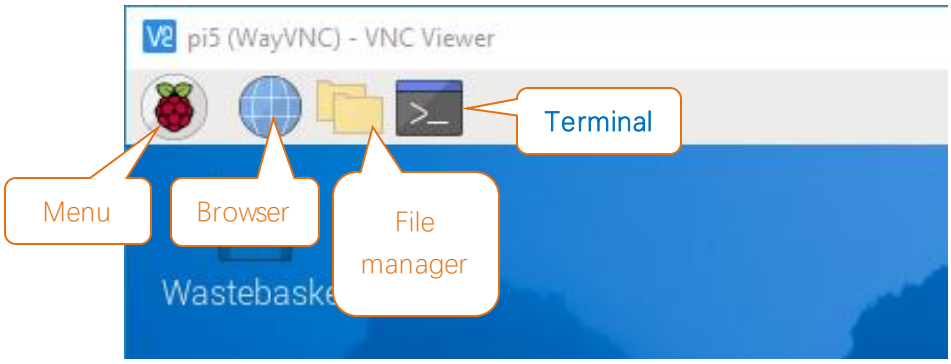


Chapter 0 Preparation

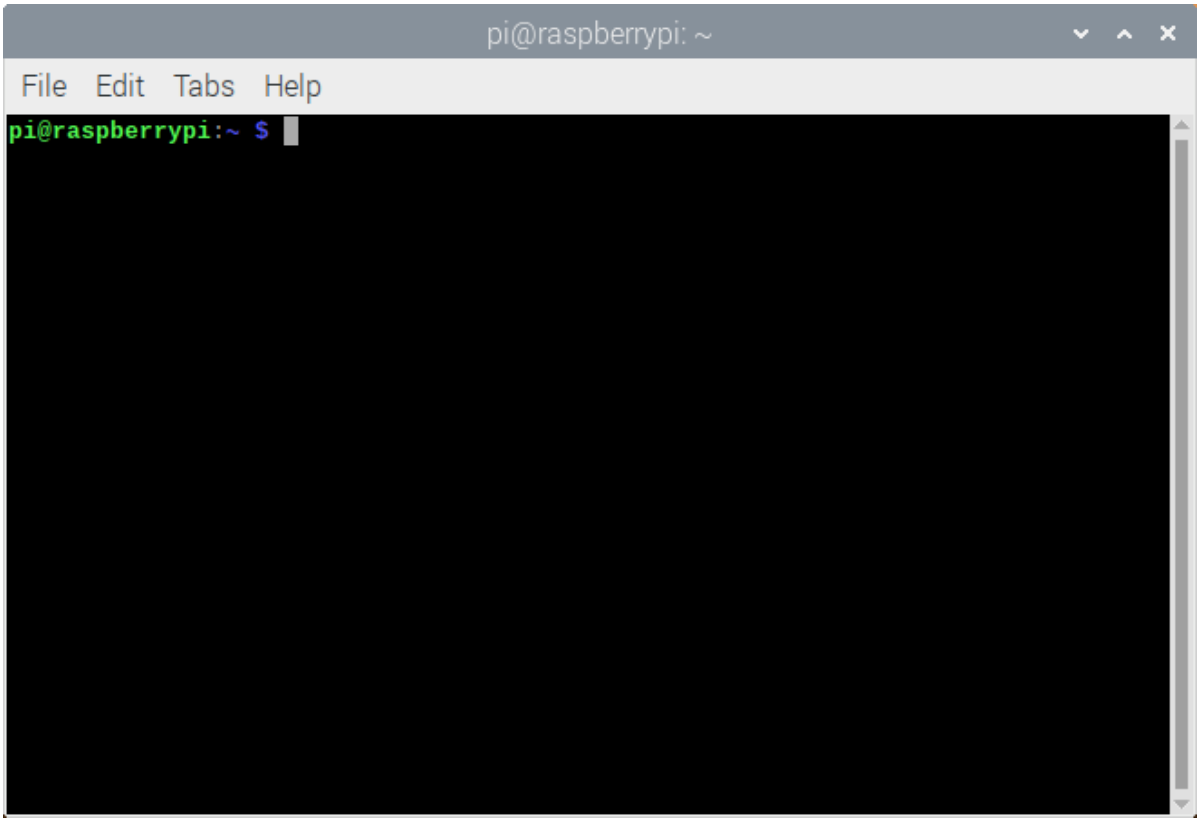
Why "Chapter 0"? Because in program code the first number is 0. We choose to follow this rule. In this chapter, we will do some necessary foundational preparation work: Start your Raspberry Pi and install some necessary libraries.

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.

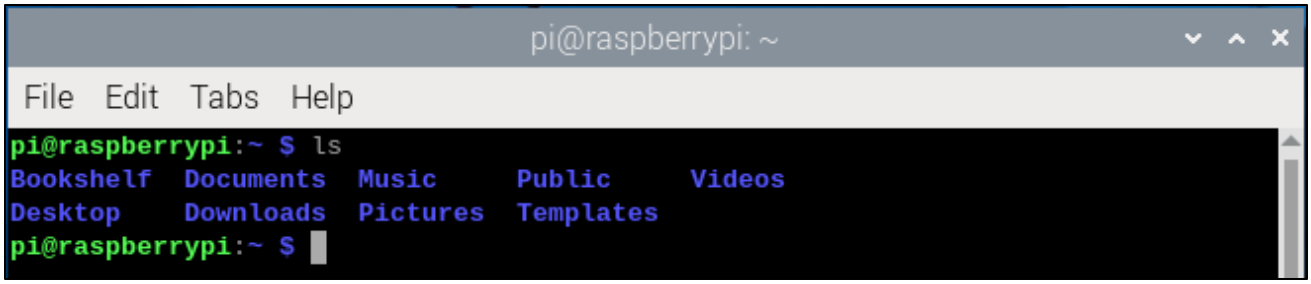


When you click the Terminal icon, following interface appears.



Note: The Linux is case sensitive.

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



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
ls	Lists information about the FILEs (the current directory by default) and entries alphabetically.
cd	Changes directory
sudo + cmd	Executes cmd under root authority
./	Under current directory
gcc	GNU Compiler Collection
git clone URL	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.

Pi4j Introduction

Pi4J is a Java I/O library specially designed for Raspberry Pi platform.

The Pi4J project aims to provide Java programs with access, control and communication to the core I/O functions of the Raspberry Pi, enabling Java programmers to easily access and control the full I/O capabilities of the Raspberry Pi platform. It abstracts the low-level native integration and interrupt monitoring to enable Java programmers to focus on implementing their application business logic.

It is recommended to use JBang to run pi4j code. JBang allows you to execute Java code with dependencies as a single file without the need for a full Maven or Gradle project. You also don't need to compile your code. So it's a very easy way to get started with Java and Pi4J.

https://www.pi4j.com/examples/jbang/

To learn more about Pi4J, please refer to the documentation linked below:
https://www.pi4j.com/documentation/

Download Code

Run the following command to download the code to Raspberry Pi.

```
cd ~
git clone --depth 1 https://github.com/Freenove/Freenove_Projects_Kit_for_Raspberry_Pi.git
```

Run the command to rename the folder.

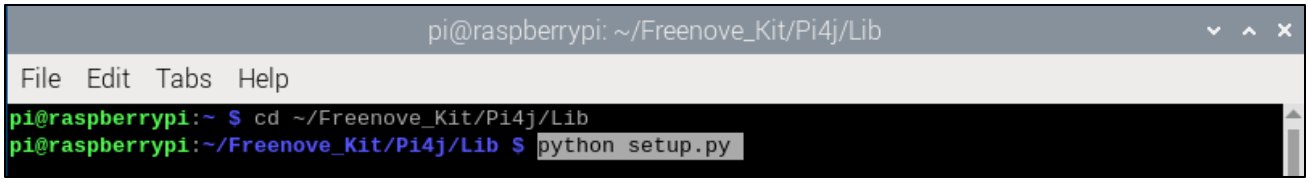
```
mv Freenove_Projects_Kit_for_Raspberry_Pi/ Freenove_Kit/
```

Installation of JBang

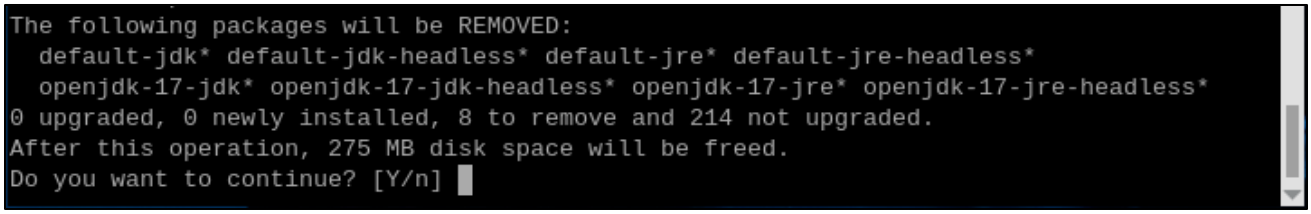
Run the following commands one by one to install jbang.

```
cd ~/Freenove_Kit/Pi4j/Lib
python setup.py
```

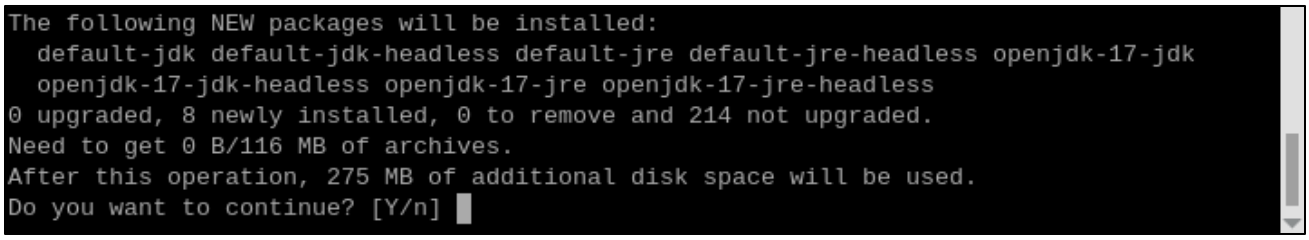
Please note that sudo is not applicable here.



The built-in default-jdk library is not complete, so we need to uninstall and reinstall it.
Enter 'Y' to uninstall it.



Enter 'Y' again to install the full default-jdk library.



When you see the messages below, it indicates that the installation is almost finished.
You can run the following commands one by one to check whether jbang is installed.

```
source ~/.bashrc
jbang --version
```

```
Successfully extracted and moved contents of jbang-0.119.0.tar to /home/pi/.jbang
Added export PATH="$HOME/.jbang/bin:$PATH" to /home/pi/.bashrc

Please run the following command in your terminal to update your PATH:
1, source ~/.bashrc
2, jbang --version
pi@raspberrypi:~/Freenove_Kit/Pi4j/Lib $ source ~/.bashrc
pi@raspberrypi:~/Freenove_Kit/Pi4j/Lib $ jbang --version
0.119.0
pi@raspberrypi:~/Freenove_Kit/Pi4j/Lib $
```

When you see the results as above, it means that jbang is already installed.

Installation of Geany

Geany is installed on Raspberry Pi OS by default.

You can run the following command to see if Geany is installed.

```
geany --version
```

If geany is not installed on your OS, please run the following command to install it.

```
sudo apt-get install geany
```

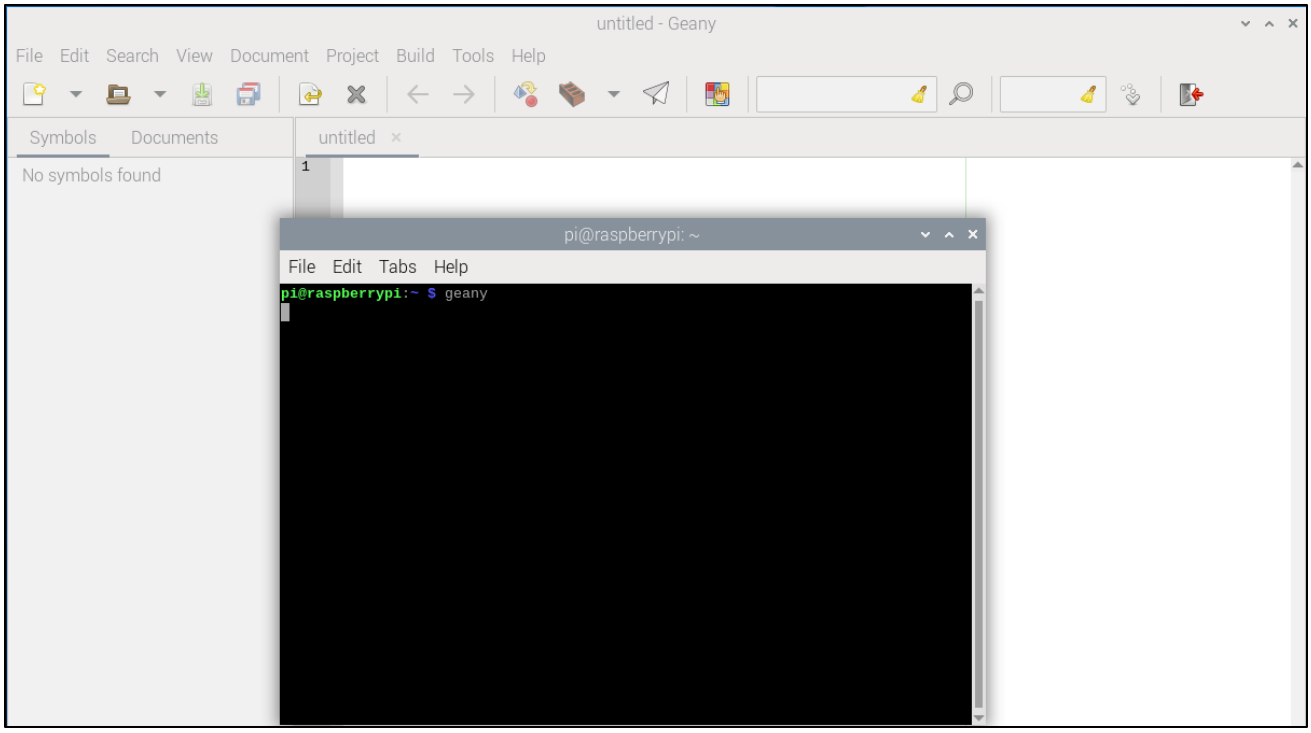
```
pi@raspberrypi:~ $ geany --version
bash: geany: command not found
pi@raspberrypi:~ $ sudo apt-get install geany
```

Geany Configuration

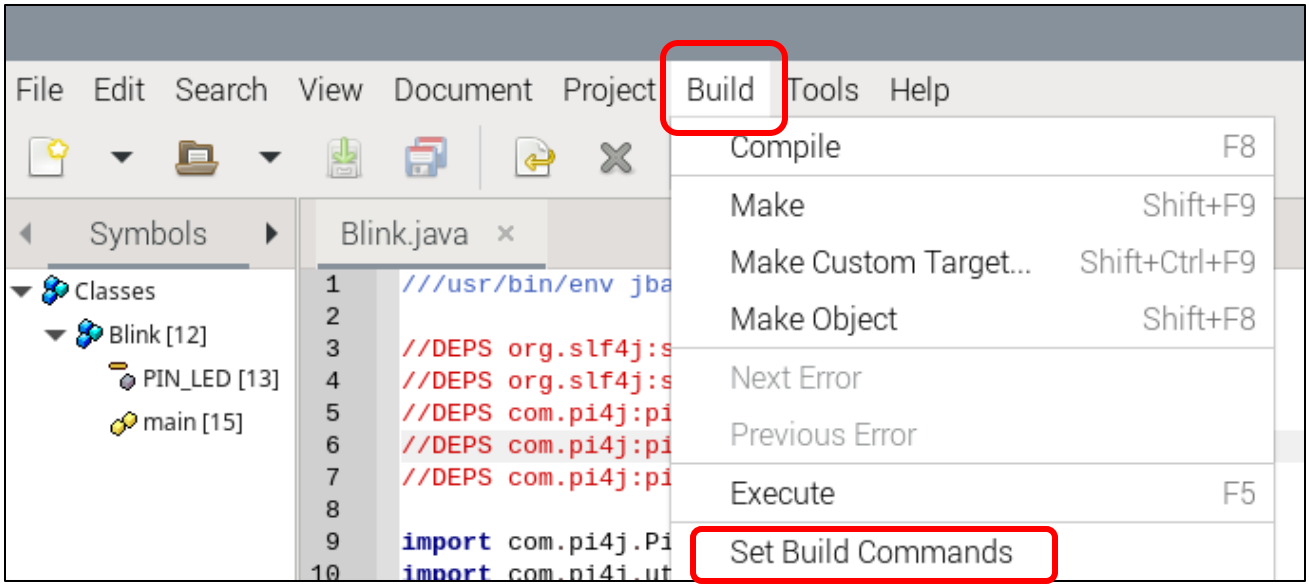
Run the command to open Geany software.

```
geany
```

As can be seen below, Geany is open after the command is run.



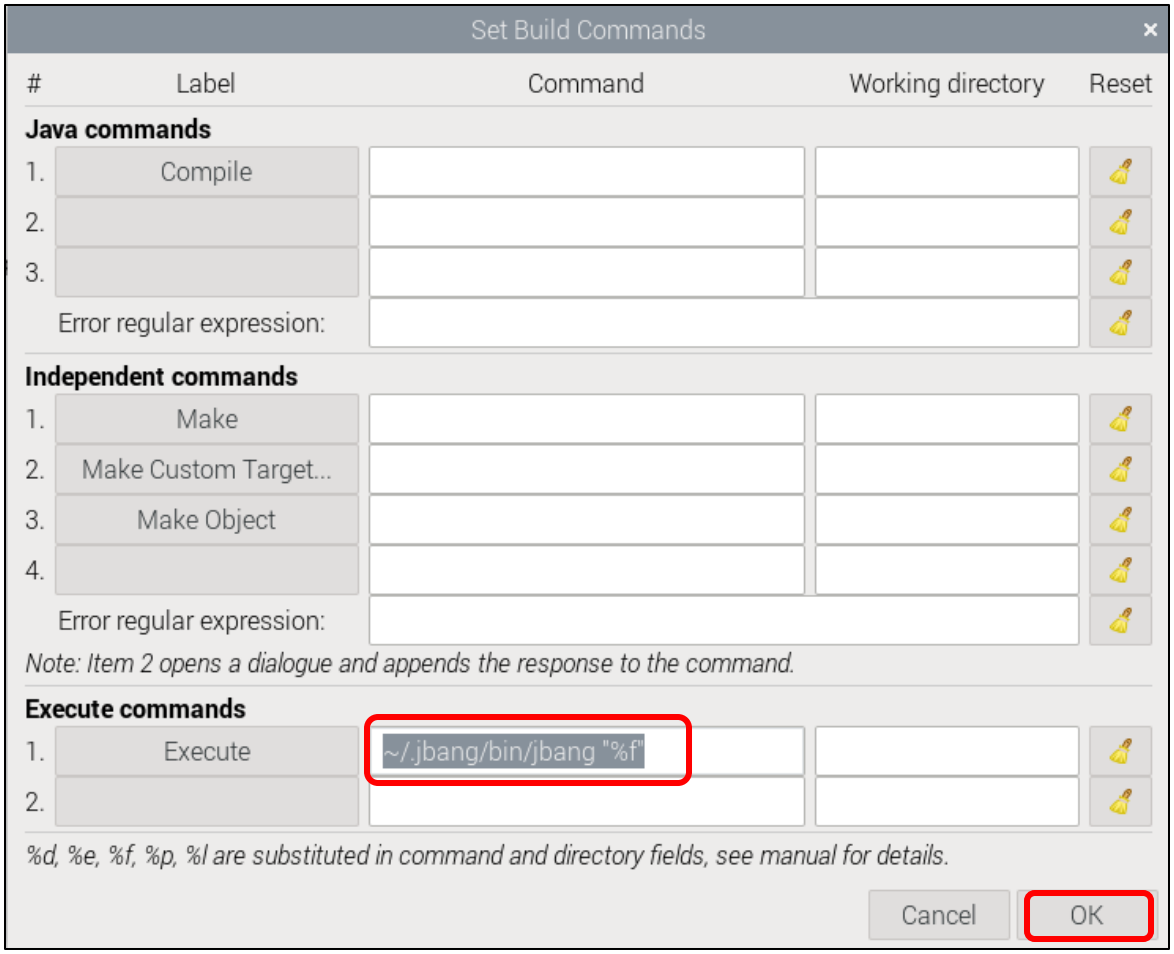
Click Build -> Set Build Commands on the menu bar.



In the pop-up window, enter the following command.

```
~/.jbang/bin/jbang "%f"
```

The detailed operation is as illustrated below:



So far, you can use Geany to open, edit, and run the code of the Pi4J tutorial.

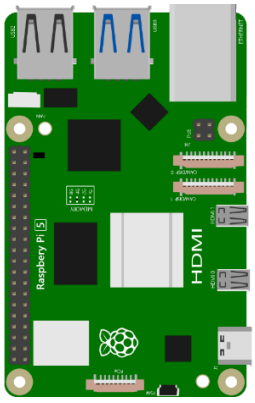
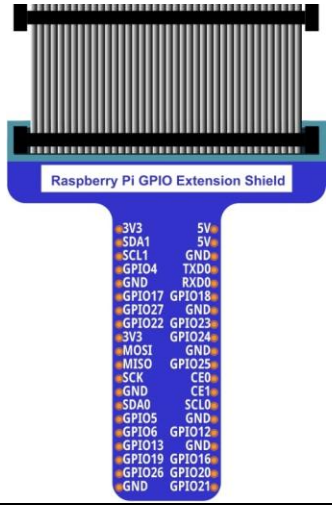
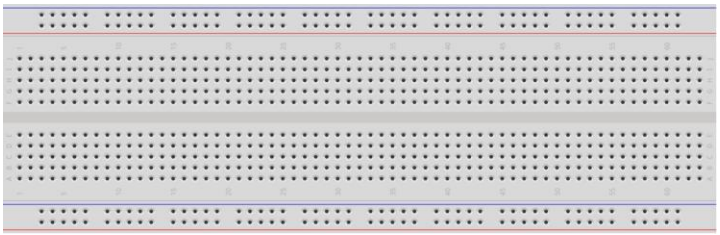
Chapter 1 LED

We will still start from Blink LED in this chapter, and learn the usage of some commonly used functions of Processing Software.

Project 1.1 Blink

In this project, we will Pi4J to control the Raspberry Pi's GPIO, so as to control the LED to blink.

Component List

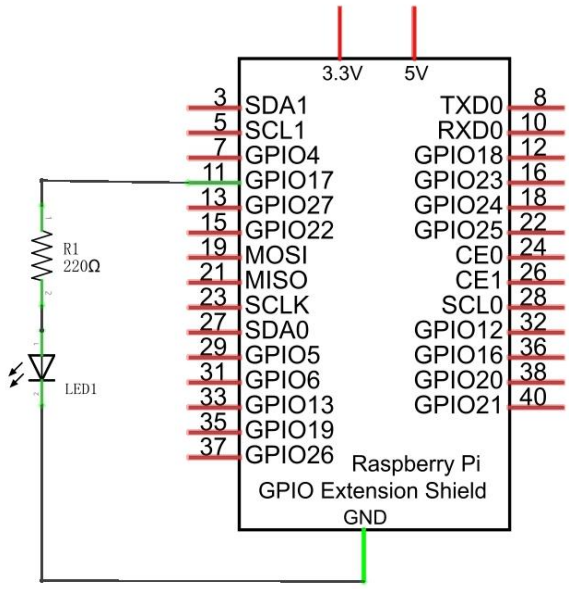
<table>
<tr><td>Raspberry Pi
(Recommended: Raspberry Pi 5 / 4B / 3B+ / 3B
Compatible: 3A+ / 2B / 1B+ / 1A+ / Zero W / Zero)
  </td><td>GPIO Extension Board & Ribbon Cable
 
</td></tr>
<tr><td colspan="2">Breadboard x1
  </td></tr>
<tr><td>LED x1
  </td><td>Resistor 220Ω x1
  </td><td>Jumper
Specific quantity depends on the circuit.
  </td></tr>
</table>

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).

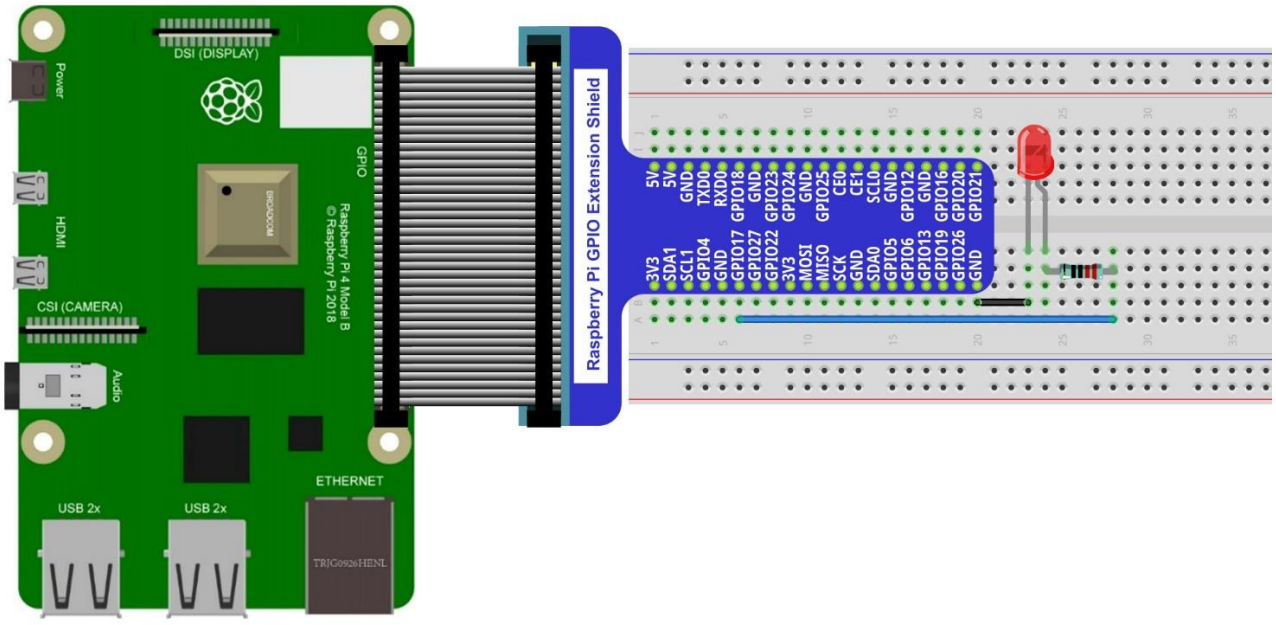
Build the circuit according to the circuit and hardware diagrams. After the circuit is built and verified correct, connect the RPi to GPIO Extension Shield. CAUTION: Avoid any possible short circuits (especially connecting 5V or GND, 3.3V and GND)!

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



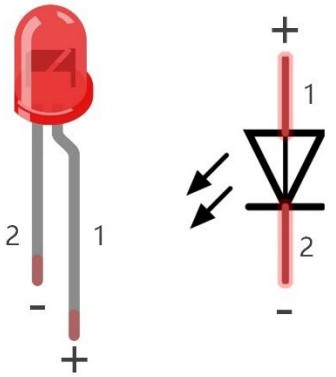
Because the numbering of the GPIO Extension Shield is the same as that of the RPi GPIO, future hardware connection diagrams will only show that part of breadboard and GPIO Extension Shield.

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			

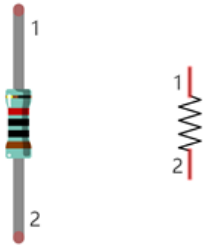
Note: LEDs cannot be directly connected to a power supply, which usually ends in a damaged component. A resistor with a specified resistance value must be connected in series to the LED you plan to use.

Resistor

Resistors use Ohms (Ω) as the unit of measurement of their resistance (R). 1MΩ=1000kΩ, 1kΩ=1000Ω.

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

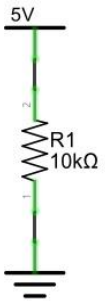
On the left, we see a physical representation of a resistor, and the right is the symbol used to represent the presence of a resistor in a circuit diagram or schematic.



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/10kΩ=0.0005A=0.5mA.

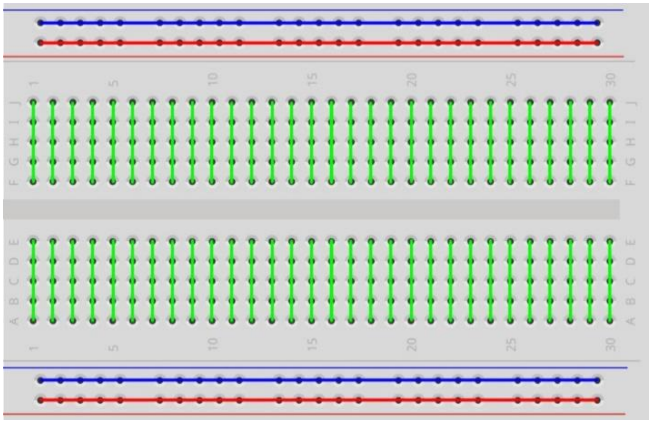


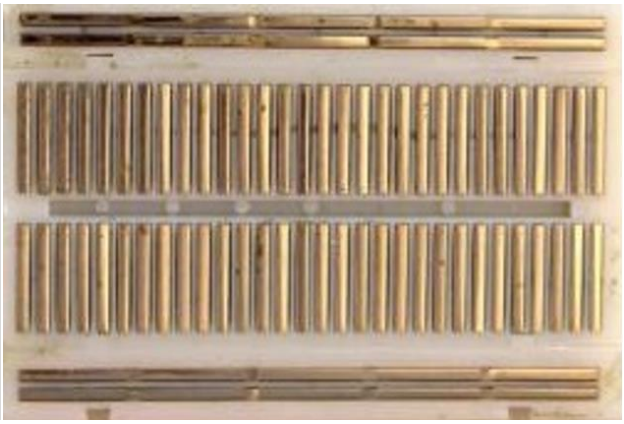
WARNING: Never connect the two poles of a power supply with anything of low resistance value (i.e. a metal object or bare wire) this is a Short and results in high current that may damage the power supply and electronic components.

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

Breadboard

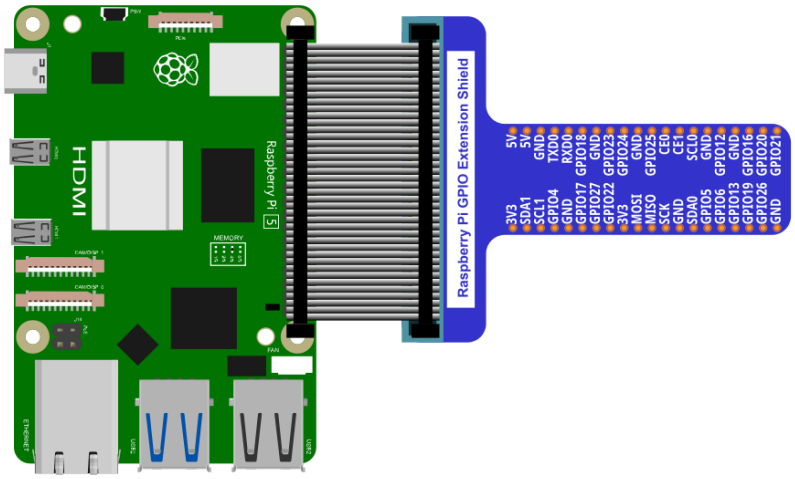
Here we have a small breadboard as an example of how the rows of holes (sockets) are electrically attached. The left picture shows the ways the pins have shared electrical connection and the right picture shows the actual internal metal, which connect these rows electrically.





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.



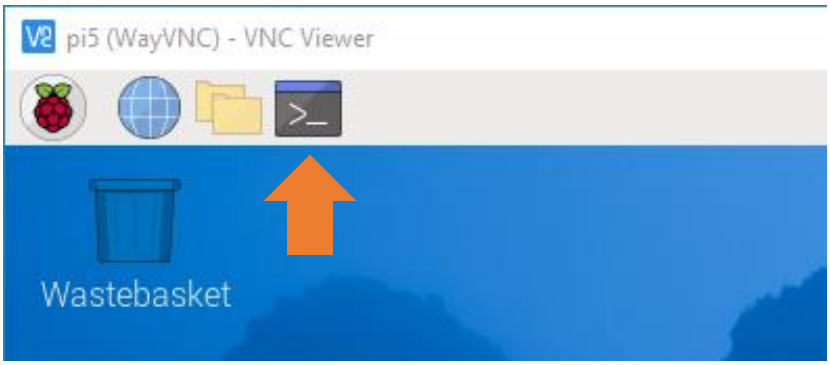
Sketch

According to the circuit, when the GPIO17 of Raspberry Pi output level is high, the LED turns ON. Conversely, when the GPIO17 Raspberry Pi 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.

Sketch_01_Blink

First, enter where the project is located:

```
cd ~/Freenove_Kit/Pi4j/Sketches/Sketch_01_Blink
```



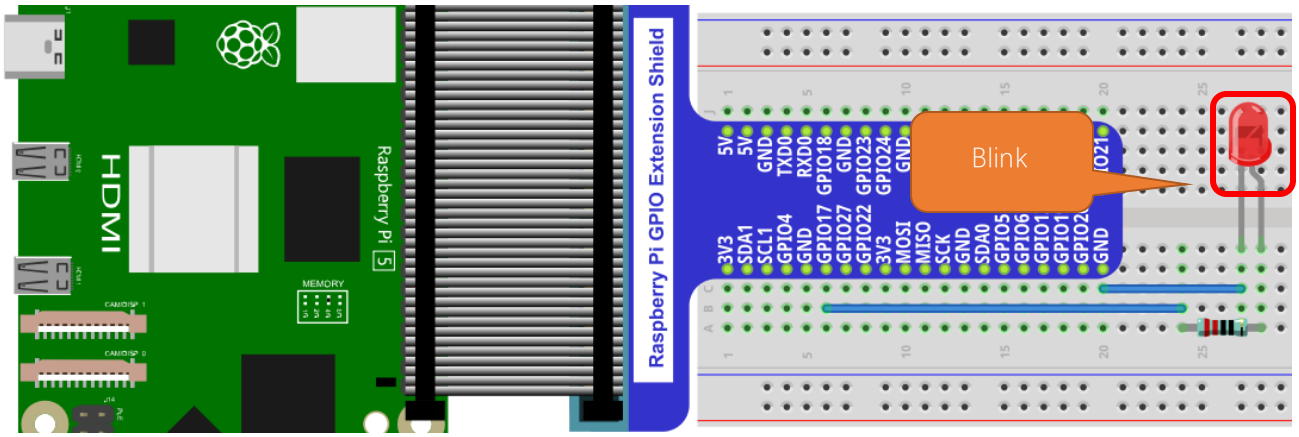

```
pi@raspberrypi:~ $ cd Freenove_Kit/Pi4j/Sketches/Sketch_01_Blink/
pi@raspberrypi:~/Freenove_Kit/Pi4j/Sketches/Sketch_01_Blink $
```

Enter the command to run the code.

```
jbang Blink.java
```

```
pi@raspberrypi:~/Freenove_Kit/Pi4j/Sketches/Sketch_01_Blink $ jbang Blink.java
```

Upon the code runs, you can see the onboard blue LED blinks.



And on Raspberry Pi Terminal, you can see the corresponding messages printed.

```
[main] INFO com.pi4j.util.Console - LED low
[main] INFO com.pi4j.util.Console - LED high
[main] INFO com.pi4j.util.Console - LED low
[main] INFO com.pi4j.util.Console - LED high
```

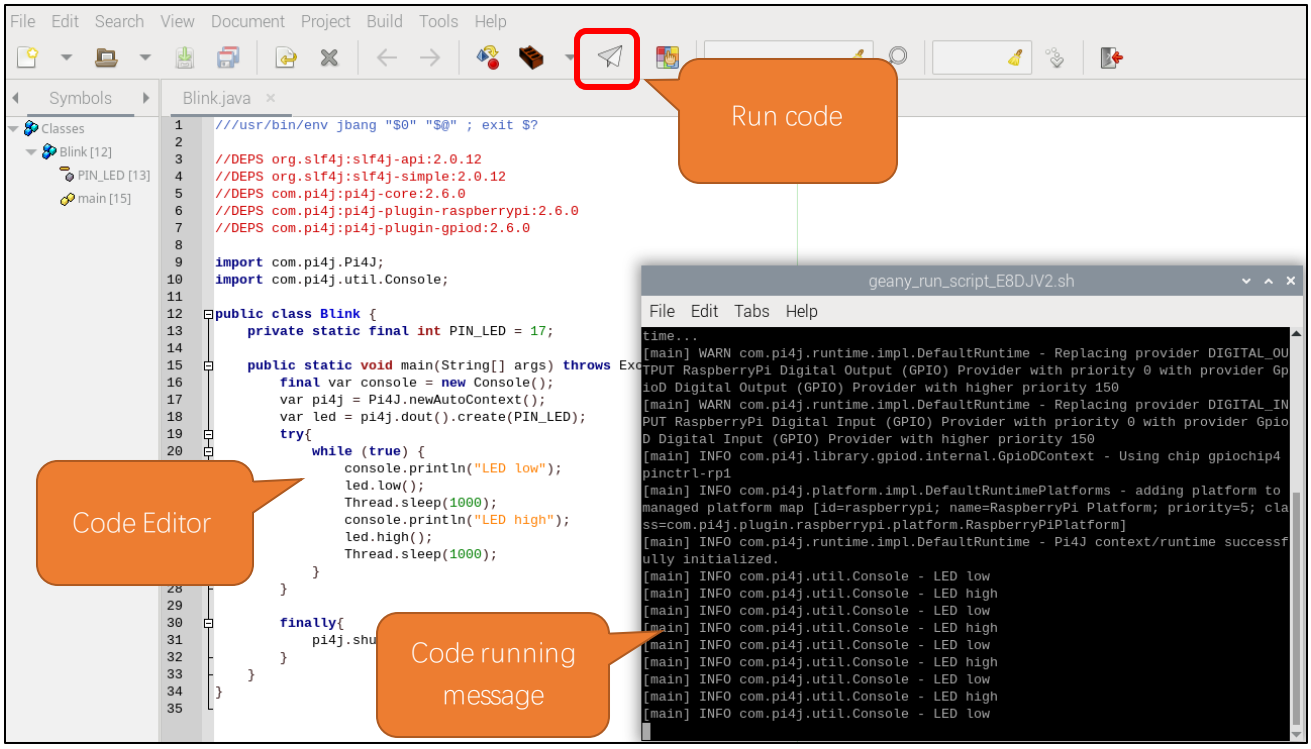
Press CTRL-C to exit the program.

```
^C[pi4j-shutdown] INFO com.pi4j.runtime.impl.DefaultRuntime - Shutting down Pi4J context/runtime...
[pi4j-shutdown] INFO com.pi4j.util.ExecutorPool - Shutting down executor pool Pi4J.RUNTIME
[pi4j-shutdown] INFO com.pi4j.runtime.impl.DefaultRuntime - Pi4J context/runtime successfully shutdow
n. Dispatching shutdown event.
pi@raspberrypi:~/Freenove_Kit/Pi4j/Sketches/Sketch_01_Blink $
```

If you want to view or modify the code, you can open the code with Geany with the following command.

geany Blink.java

Click the icon to run the code.



If the code fails to run, please check Geany Configuration.

The following is program code:

```
///usr/bin/env jbang "$0" "$@" ; exit $?S

//DEPS org.slf4j:slf4j-api:2.0.12
//DEPS org.slf4j:slf4j-simple:2.0.12
//DEPS com.pi4j:pi4j-core:2.6.0
//DEPS com.pi4j:pi4j-plugin-raspberrypi:2.6.0
//DEPS com.pi4j:pi4j-plugin-gpiod:2.6.0

import com.pi4j.Pi4J;
import com.pi4j.util.Console;

public class Blink {
    private static final int PIN_LED = 17;

    public static void main(String[] args) throws Exception {
        final var console = new Console();
        var pi4j = Pi4J.newAutoContext();
        var led = pi4j.dout().create(PIN_LED);
        try{
            while (true) {
```

```
21                  console.println("LED low");
22                  led.low();
23                  Thread.sleep(1000);
24                  console.println("LED high");
25                  led.high();
26                  Thread.sleep(1000);
27              }
28          }
29          finally{
30              pi4j.shutdown();
31          }
32      }
33  }
```

At the beginning of the code, we use shebang command to inform Raspberry Pi that we are going to use JBangto run Java script.

```
///usr/bin/env jbang "$0" "$@" ; exit $?
```

Likewise, we specify the dependencies required for the script to run. This includes the different components of the SLF4J logging library and the Pi4J library and their version numbers.

```
//DEPS org.slf4j:slf4j-api:2.0.12
//DEPS org.slf4j:slf4j-simple:2.0.12
//DEPS com.pi4j:pi4j-core:2.6.0
//DEPS com.pi4j:pi4j-plugin-raspberrypi:2.6.0
//DEPS com.pi4j:pi4j-plugin-gpiod:2.6.0
```

Import Pi4J library and the Console class to facilitate creating and managing contexts and printing messages on the console.

```
import com.pi4j.Pi4J;
import com.pi4j.util.Console;
```

Assign the GPIO pin to the LED, and configure it as output mode.

```
    private static final int PIN_LED = 17;


    public static void main(String[] args) throws Exception {
        final var console = new Console();
        var pi4j = Pi4J.newAutoContext();
        var led = pi4j.dout().create(PIN_LED);
```

Use the try…finally structure to ensure the smooth running of the code.

```
        try{

        }
        finally{

        }
```

Make the LED turn on and off once every 1 second, repeat this process, and print prompt messages.

```
        while (true) {
            console.println("LED low"); // Print a prompt message on the terminal
            led.low();                  // turn off led
            Thread.sleep(1000);         // delay 1 second
            console.println("LED high"); // Print a prompt message on the terminal
            led.high();                  // turn on led
            Thread.sleep(1000);          // delay 1 second
        }
```

Chapter 2 Flowing Light

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

Project 2.1 Flowing Water Light

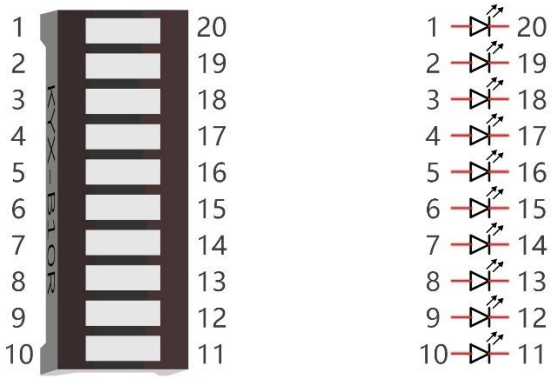
In this project, we use a number of LEDs to make a flowing water light.

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 		

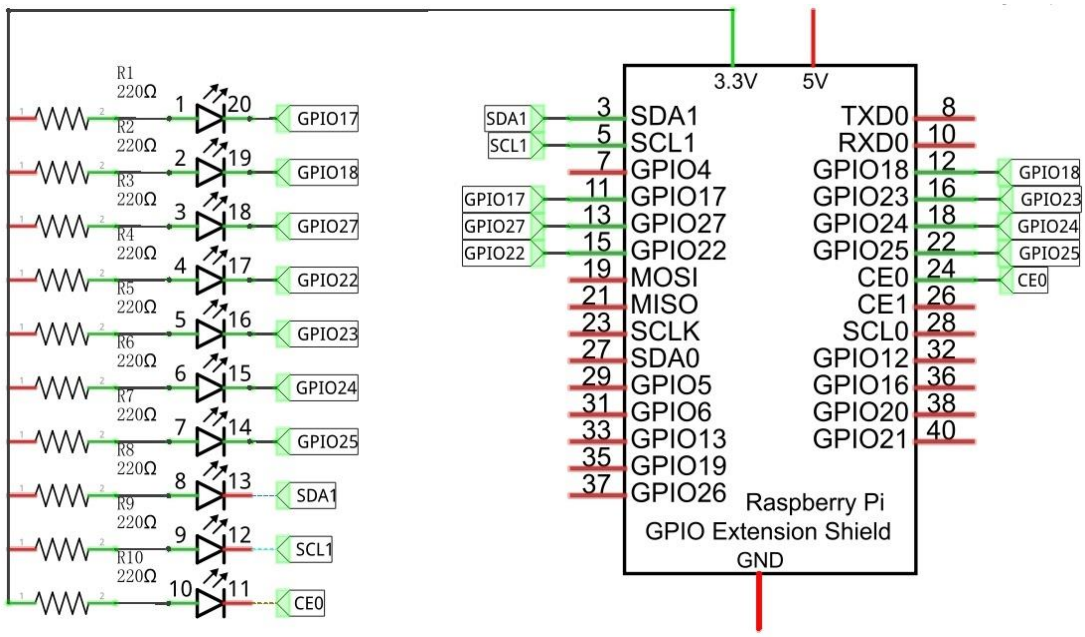
Bar Graph LED

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.

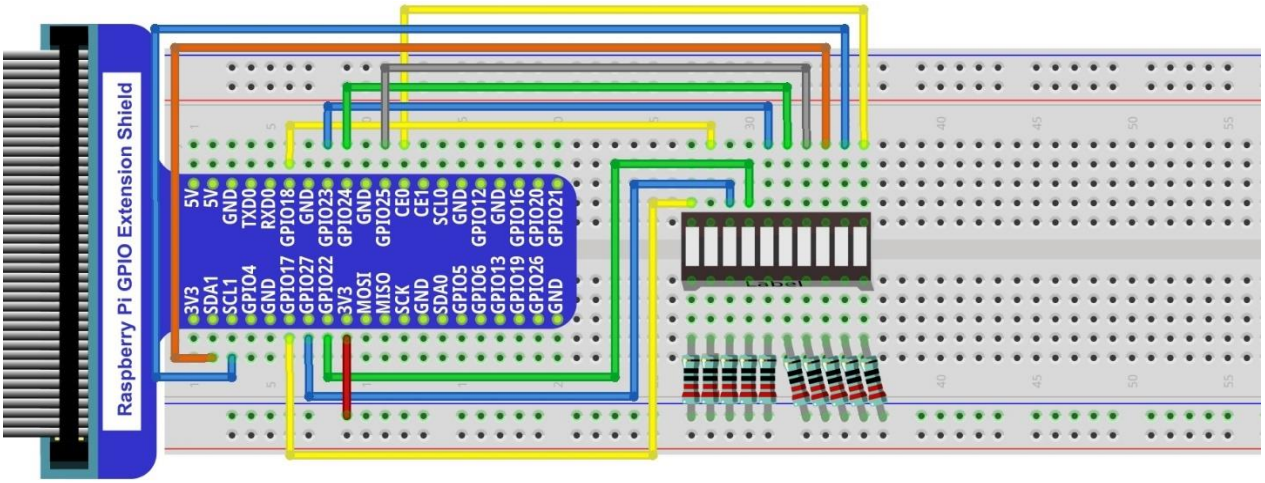


Circuit

Schematic diagram



Hardware connection.



If LEDbar doesn't work, rotate LEDbar 180° to try. The label is random.

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

If you have any concerns, please send an email to: support@freenove.com

Sketch

In this chapter, we will introduce how to control multiple LEDs with various GPIOs, and make the LEDs present a flowing effect.

Sketch_02_FlowingLight

First, enter where the project is located:

```
cd ~/Freenove_Kit/Pi4j/Sketches/Sketch_02_FlowingLight
```

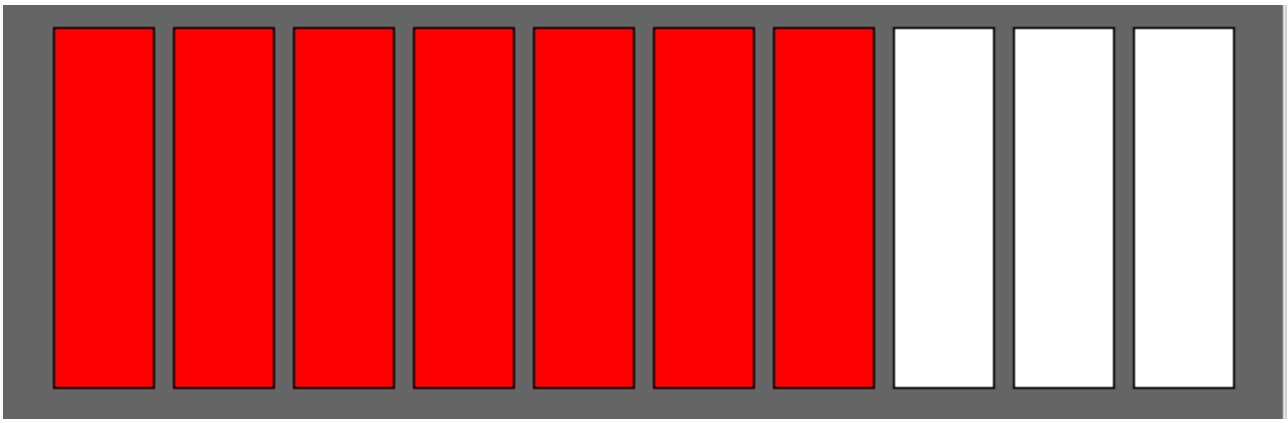
```
pi@raspberrypi:~ $ cd ~/Freenove_Kit/Pi4j/Sketches/Sketch_02_FlowingLight
pi@raspberrypi:~/Freenove_Kit/Pi4j/Sketches/Sketch_02_FlowingLight $
```

Enter the command to run the code.

```
jbang FlowingLight.java
```

```
pi@raspberrypi:~/Freenove_Kit/Pi4j/Sketches/Sketch_02_FlowingLight $ jbang FlowingLight.java
```

When the code is running, you can see the LedBar lights up in a flowing effect.



On the Raspberry Pi Terminal, you can see messages printed.

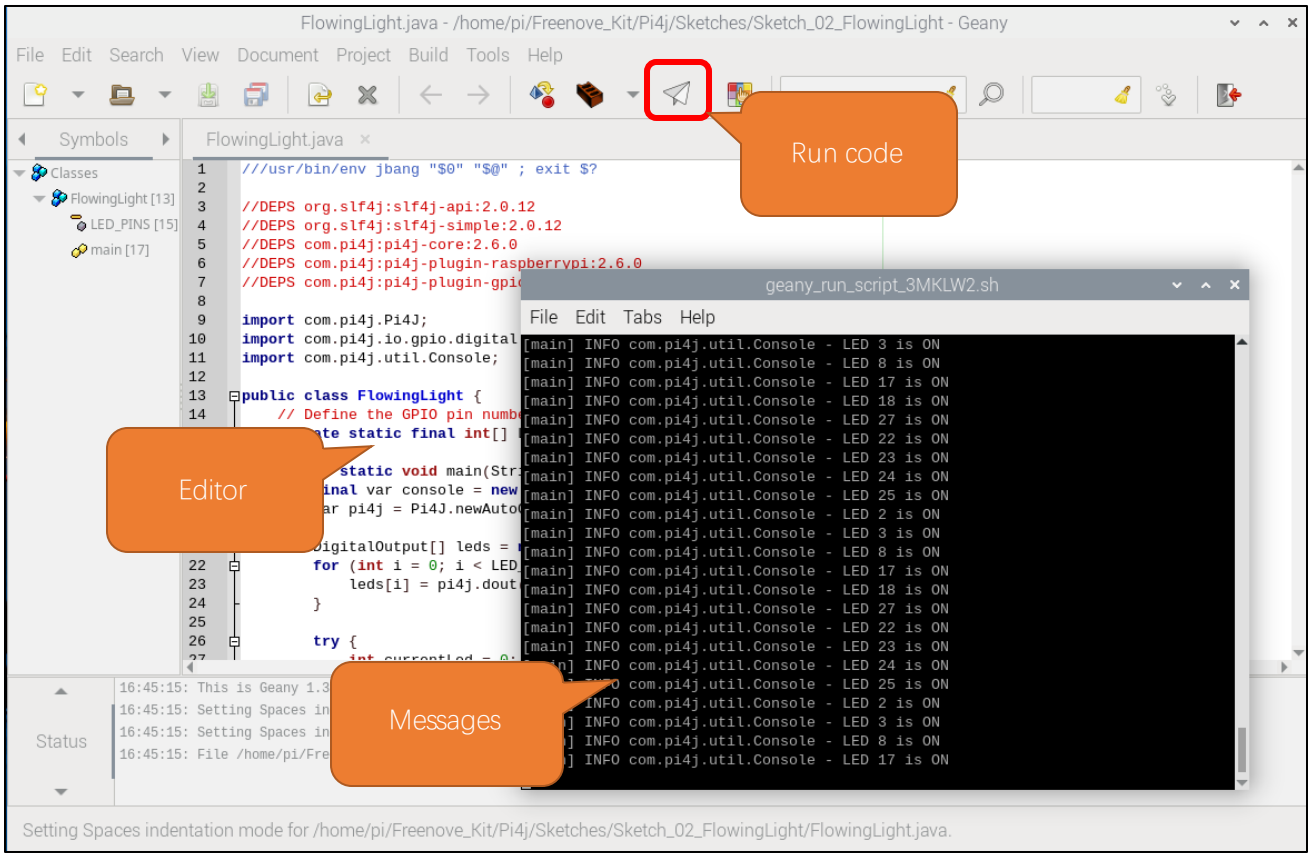
```
[main] INFO com.pi4j.util.Console - LED 17 is ON
[main] INFO com.pi4j.util.Console - LED 18 is ON
[main] INFO com.pi4j.util.Console - LED 27 is ON
[main] INFO com.pi4j.util.Console - LED 22 is ON
[main] INFO com.pi4j.util.Console - LED 23 is ON
[main] INFO com.pi4j.util.Console - LED 24 is ON
[main] INFO com.pi4j.util.Console - LED 25 is ON
[main] INFO com.pi4j.util.Console - LED 2 is ON
[main] INFO com.pi4j.util.Console - LED 3 is ON
[main] INFO com.pi4j.util.Console - LED 8 is ON
```

Press CTRL+C to exit the code.

You can view and edit the code with Geany by running the following command.

geany FlowingLight.java

Click the icon to run the code.



If the code fails to run, please check Geany Configuration.

The following is program code:

```
///usr/bin/env jbang "$0" "$@" ; exit $?

//DEPS org.slf4j:slf4j-api:2.0.12
//DEPS org.slf4j:slf4j-simple:2.0.12
//DEPS com.pi4j:pi4j-core:2.6.0
//DEPS com.pi4j:pi4j-plugin-raspberrypi:2.6.0
//DEPS com.pi4j:pi4j-plugin-gpiod:2.6.0

import com.pi4j.Pi4J;
import com.pi4j.io.gpio.digital.DigitalOutput;
import com.pi4j.util.Console;

public class FlowingLight {
    // Define the GPIO pin number for the LED.
    private static final int[] LED_PINS = {17, 18, 27, 22, 23, 24, 25, 2, 3, 8};

    public static void main(String[] args) throws Exception {
```

```
18          final var console = new Console();
19          var pi4j = Pi4J.newAutoContext();
20
21          DigitalOutput[] leds = new DigitalOutput[LED_PINS.length];
22          for (int i = 0; i < LED_PINS.length; i++) {
23              leds[i] = pi4j.dout().create(LED_PINS[i]);
24          }
25
26          try {
27              int currentLed = 0;
28              while (true) {
29                  console.println("LED " + LED_PINS[currentLed] + " is ON");
30                  for (DigitalOutput led : leds) {
31                      led.low();
32                  }
33                  leds[currentLed].high();
34                  Thread.sleep(100);
35                  currentLed = (currentLed + 1) % LED_PINS.length;
36              }
37          } finally {
38              pi4j.shutdown();
39          }
40      }
41  }
```

Import the classes of Pi4J library for GPIO control and simple console output.

```
import com.pi4j.Pi4J;
import com.pi4j.io.gpio.digital.DigitalOutput;
import com.pi4j.util.Console;
```

Define an array that includes the GPIO numbers connecting to LEDs.

```
    // Define the GPIO pin number for the LED.
    private static final int[] LED_PINS = {17, 18, 27, 22, 23, 24, 25, 2, 3, 8};
```

Create a DigitalOutput array based on the GPIO array that controls the LEDs, and create a DigitalOutput instance for each pin.

```
DigitalOutput[] leds = new DigitalOutput[LED_PINS.length];
        for (int i = 0; i < LED_PINS.length; i++) {
            leds[i] = pi4j.dout().create(LED_PINS[i]);
        }
```

Iterate through all LEDs and turn them off (set to low level).

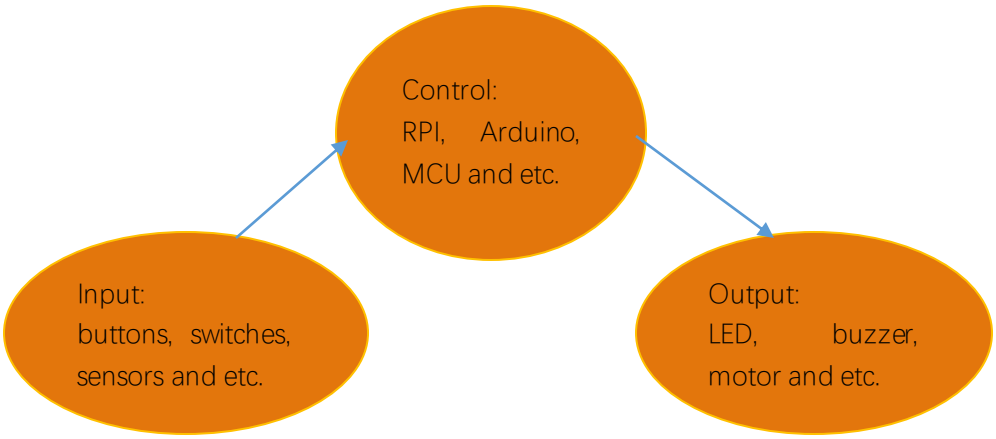
```
                for (DigitalOutput led : leds) {
                    led.low();
                }
```

Use ‘currentLed’ to record the position of the LED that is lit, recalculate the position of the lit LED every 100 milliseconds, and print a prompt message to the console. At the same time, turn off all LEDs except the LED at the position recorded by ‘currentLed’.

```
            int currentLed = 0;
            while (true) {
                console.println("LED " + LED_PINS[currentLed] + " is ON");
                for (DigitalOutput led : leds) {
                    led.low();
                }
                leds[currentLed].high();
                Thread.sleep(100);
                currentLed = (currentLed + 1) % LED_PINS.length;
            }
```

Chapter 3 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 3.1 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

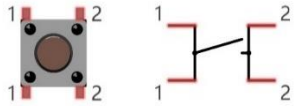
Raspberry Pi (with 40 GPIO) x1 GPIO Extension Board & Wire x1 Breadboard x1	LED x1 	Resistor 220Ω x1 	Resistor 10kΩ x2 	Push Button Switch x1 
Jumper Wire 				

Please Note: In the code "button" represents switch action.

Component knowledge

Push Button Switch

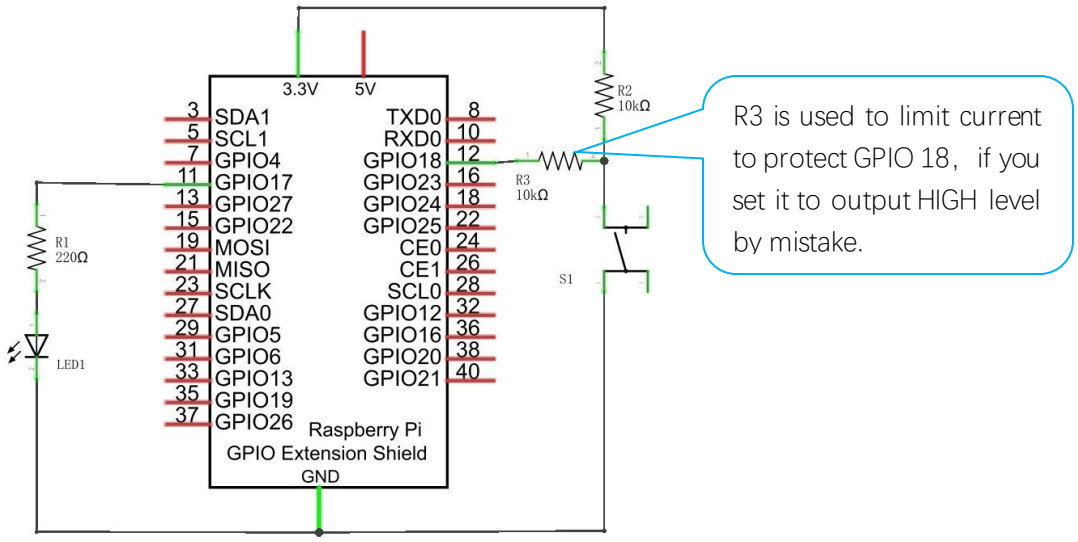
This type of Push Button Switch has 4 pins (2 Pole Switch). Two pins on the left are connected, and both left and right sides are the same per the illustration:



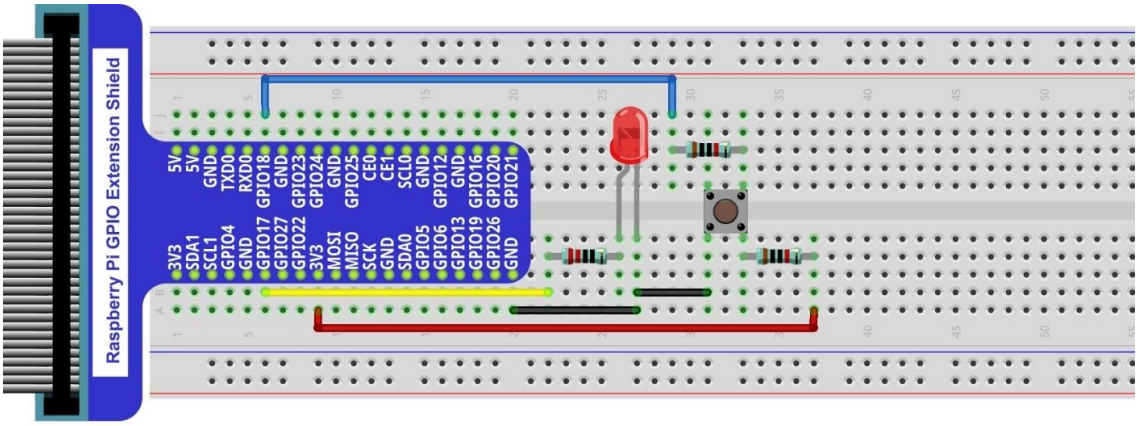
When the button on the switch is pressed, the circuit is completed (your project is Powered ON).

Circuit

Schematic diagram



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



If you have any concerns, please send an email to: support@freenove.com

Sketch

In this chapter, we will introduce how to use the button to control the LED.

Sketch_03_ButtonLED

First, enter where the project is located:

```
cd ~/Freenove_Kit/Pi4j/Sketches/Sketch_03_ButtonLED
```

```
pi@raspberrypi:~ $ cd ~/Freenove_Kit/Pi4j/Sketches/Sketch_03_ButtonLED
pi@raspberrypi:~/Freenove_Kit/Pi4j/Sketches/Sketch_03_ButtonLED $
```

Enter the command to run the code.

```
jbang ButtonLED.java
```

```
pi@raspberrypi:~/Freenove_Kit/Pi4j/Sketches/Sketch_03_ButtonLED $ jbang ButtonLED.java
```

When the code is running, press the button and you can see the LED is lit; release it and the LED goes off.

On the Raspberry Pi terminal, you will see the corresponding messages printed.

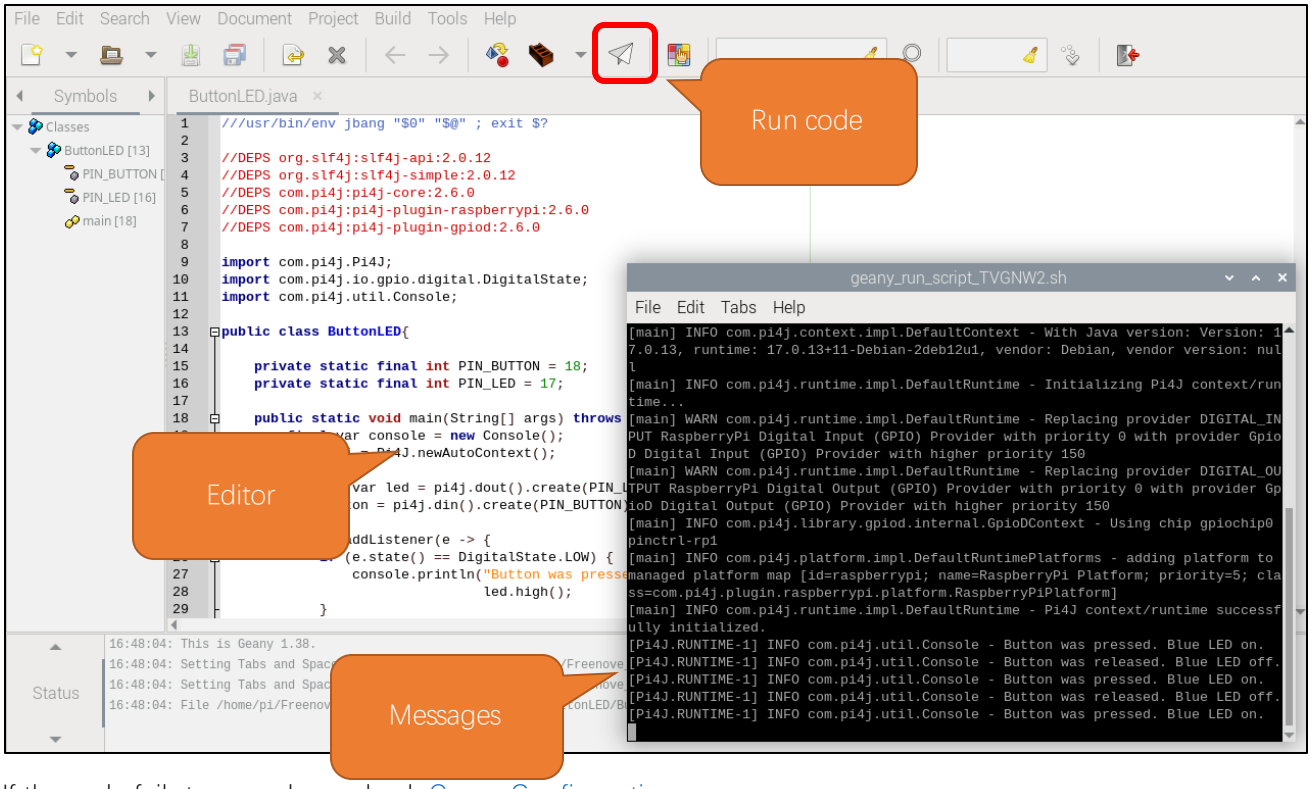
```
[Pi4J.RUNTIME-1] INFO com.pi4j.util.Console - Button was pressed. Blue LED on.
[Pi4J.RUNTIME-1] INFO com.pi4j.util.Console - Button was released. Blue LED off.
[Pi4J.RUNTIME-1] INFO com.pi4j.util.Console - Button was pressed. Blue LED on.
[Pi4J.RUNTIME-1] INFO com.pi4j.util.Console - Button was released. Blue LED off.
[Pi4J.RUNTIME-1] INFO com.pi4j.util.Console - Button was pressed. Blue LED on.
[Pi4J.RUNTIME-1] INFO com.pi4j.util.Console - Button was released. Blue LED off.
[Pi4J.RUNTIME-1] INFO com.pi4j.util.Console - Button was pressed. Blue LED on.
[Pi4J.RUNTIME-1] INFO com.pi4j.util.Console - Button was released. Blue LED off.
```

Press Ctrl+C to exit the code.

You can open the code with geany to view and edit it.

geany ButtonLED.java

Click the icon to run the code.



If the code fails to run, please check Geany Configuration.

The following is program code:

```
1  ///usr/bin/env jbang "$0" "$@" ; exit $?
2
3  //DEPS org.slf4j:slf4j-api:2.0.12
4  //DEPS org.slf4j:slf4j-simple:2.0.12
5  //DEPS com.pi4j:pi4j-core:2.6.0
6  //DEPS com.pi4j:pi4j-plugin-raspberrypi:2.6.0
7  //DEPS com.pi4j:pi4j-plugin-gpiod:2.6.0
8
9  import com.pi4j.Pi4J;
10 import com.pi4j.io.gpio.digital.DigitalState;
11 import com.pi4j.util.Console;
12
13 public class ButtonLED{
14
15     private static final int PIN_BUTTON = 18;
16     private static final int PIN_LED = 17;
17
18     public static void main(String[] args) throws Exception {
```

```
19          final var console = new Console();
20          var pi4j = Pi4J.newAutoContext();
21
22          var led = pi4j.dout().create(PIN_LED);
23          var button = pi4j.din().create(PIN_BUTTON);
24
25          button.addListener(e -> {
26              if (e.state() == DigitalState.LOW) {
27                  console.println("Button was pressed. Blue LED on.");
28                  led.high();
29              }
30              else if(e.state() == DigitalState.HIGH){
31                  console.println("Button was released. Blue LED off.");
32                  led.low();
33              }
34          });
35
36          try{
37              while (true) {
38                  Thread.sleep(500);
39              }
40          }
41          finally{
42              pi4j.shutdown();
43          }
44      }
45  }
```

Import the classes of Pi4J library for GPIO control and simple console output.

```
import com.pi4j.Pi4J;
import com.pi4j.io.gpio.digital.DigitalState;
import com.pi4j.util.Console;
```

Define the GPIO numbers for the button and LED.

```
    private static final int PIN_BUTTON = 18;
    private static final int PIN_LED = 17;
```

Create a Console instance for printing logs or messages.
Create a Pi4J context to manage the GPIO interface.
Create an LED output pin object, connected to the pin specified by PIN_LED.
Create a button input pin object, connected to the pin specified by PIN_BUTTON.

```
final var console = new Console();
var pi4j = Pi4J.newAutoContext();
var led = pi4j.dout().create(PIN_LED);
var button = pi4j.din().create(PIN_BUTTON);
```

Add a listener event to the button, which is triggered when the button's state changes.
When the button is pressed, its state is low, and we control the LED to light up.
When the button is released, its state is high, and we control the LED to turn off.

```
button.addListener(e -> {
    if (e.state() == DigitalState.LOW) {
        console.println("Button was pressed. Blue LED on.");
        led.high();
    }
    else if(e.state() == DigitalState.HIGH){
        console.println("Button was released. Blue LED off.");
        led.low();
    }
});
```

Nothing needs to be done in the main loop. Just set it in an infinite loop and ensure that the Pi4J context is closed when the program ends.

```
try{
    while (true) {
        Thread.sleep(500);
    }
}
finally{
    pi4j.shutdown();
}
```

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.

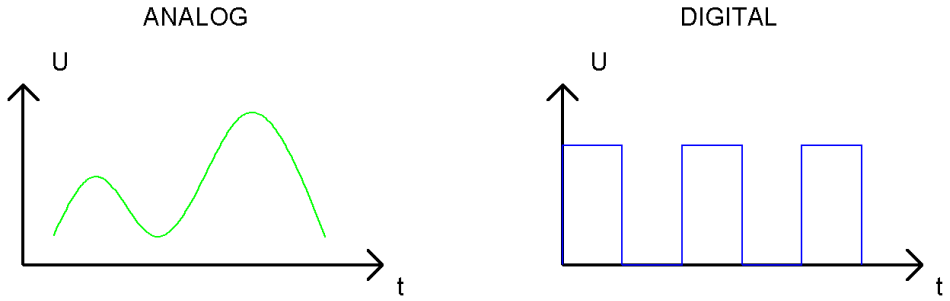
Component List

<table>
<tr><td>Raspberry Pi x1
GPIO Extension Board & Wire x1
Breadboard x1</td><td rowspan="2">LED x1
  </td><td rowspan="2">Resistor 220Ω x1
  </td></tr>
<tr><td>Jumper M/M x2
  </td></tr>
</table>

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℃ to 10℃. 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.



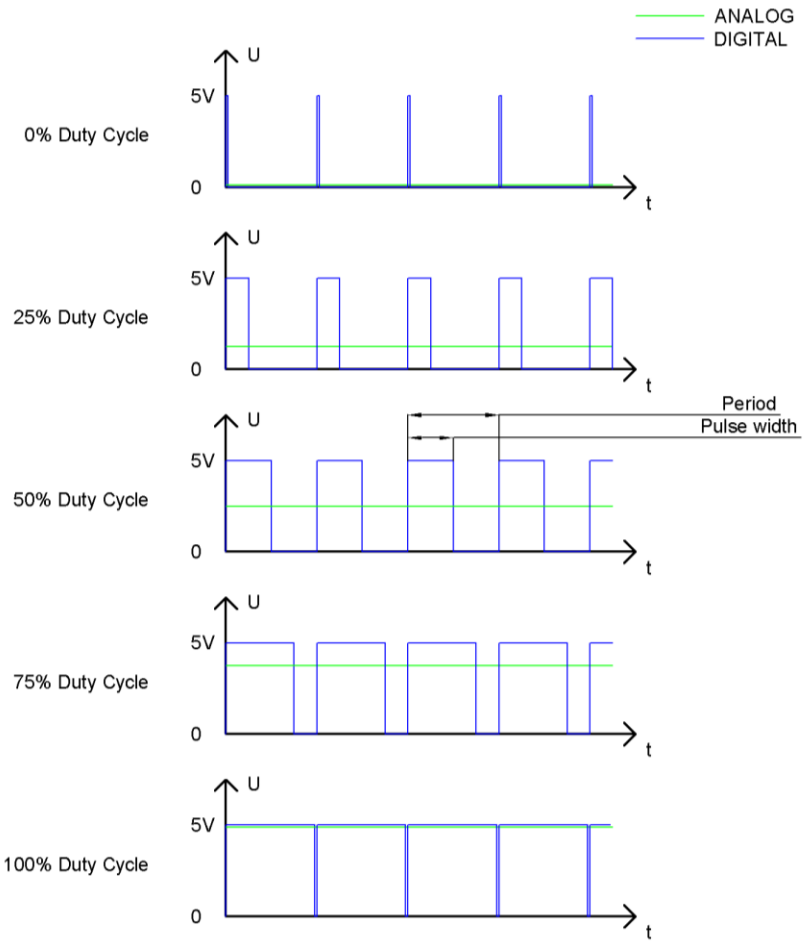
Note that the Analog signals are curved waves and the Digital signals are "Square Waves".

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.

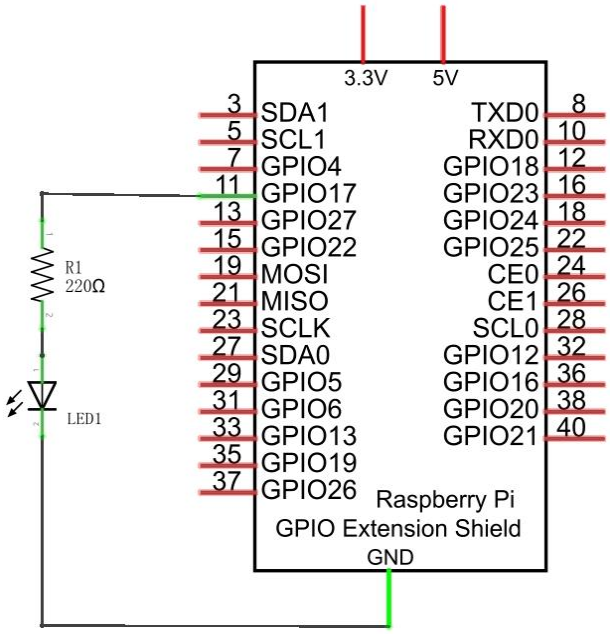
The wiringPi library of C provides both a hardware PWM and a software PWM method.

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.

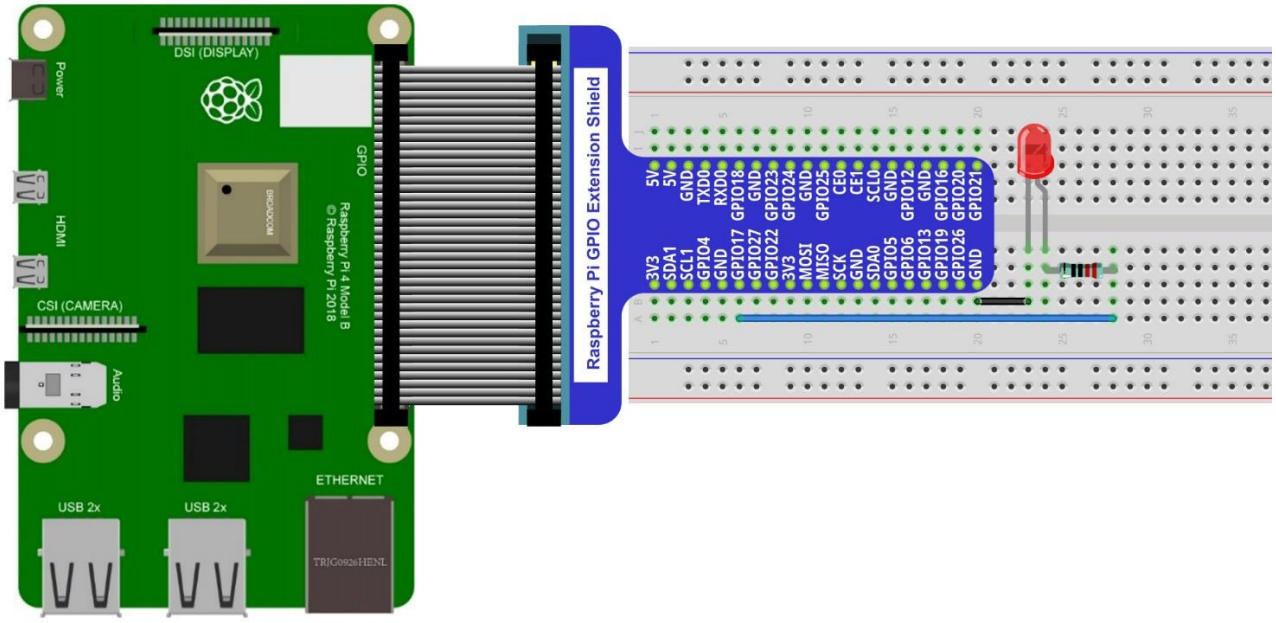
In order to keep the results running consistently, we will use PWM.

Circuit

Schematic diagram



Hardware connection



If you have any concerns, please send an email to: support@freenove.com

Sketch

In this chapter, we will learn how to make the LED to present a breathing effect.

Sketch_04_BreathingLED

First, enter where the project is located:

```
cd ~/Freenove_Kit/Pi4j/Sketches/Sketch_04_BreathingLED
```

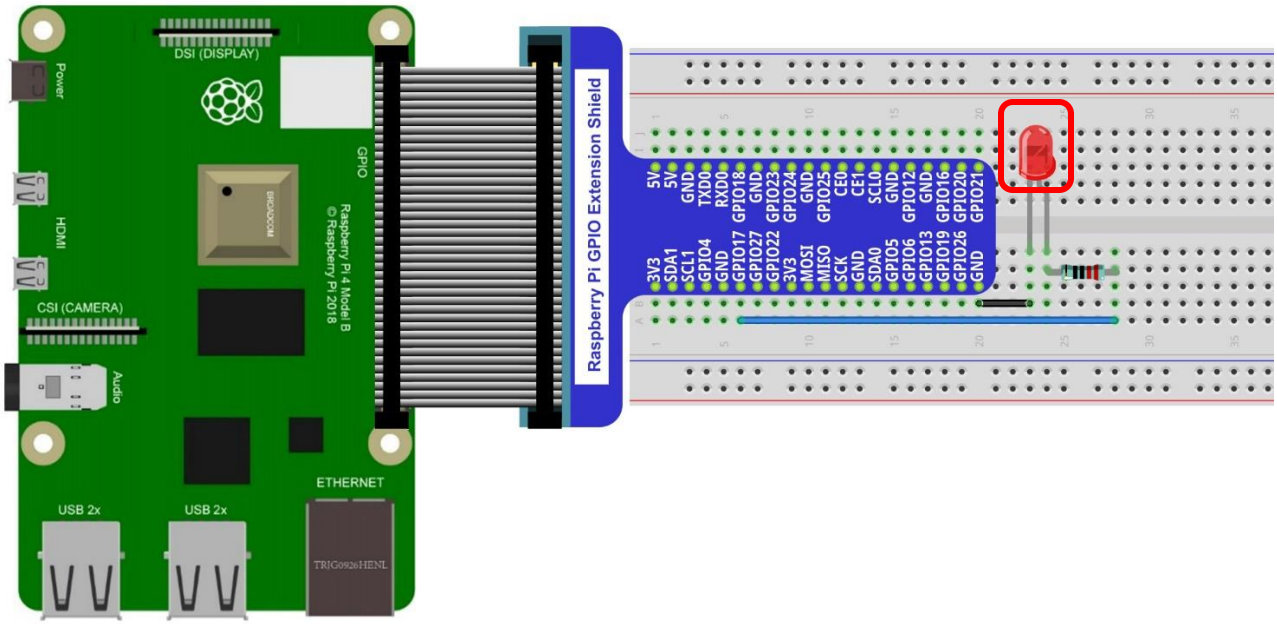
```
pi@raspberrypi:~ $ cd ~/Freenove_Kit/Pi4j/Sketches/Sketch_04_BreathingLED
pi@raspberrypi:~/Freenove_Kit/Pi4j/Sketches/Sketch_04_BreathingLED $
```

You can enter the command to run the code.

```
jbang BreathingLED.java
```

```
pi@raspberrypi:~ $ cd ~/Freenove_Kit/Pi4j/Sketches/Sketch_04_BreathingLED
pi@raspberrypi:~/Freenove_Kit/Pi4j/Sketches/Sketch_04_BreathingLED $ jbang BreathingLED.java
```

When the code is running, you can see the LED lights up from dim to bright and then from bright to dim, and the process repeats.



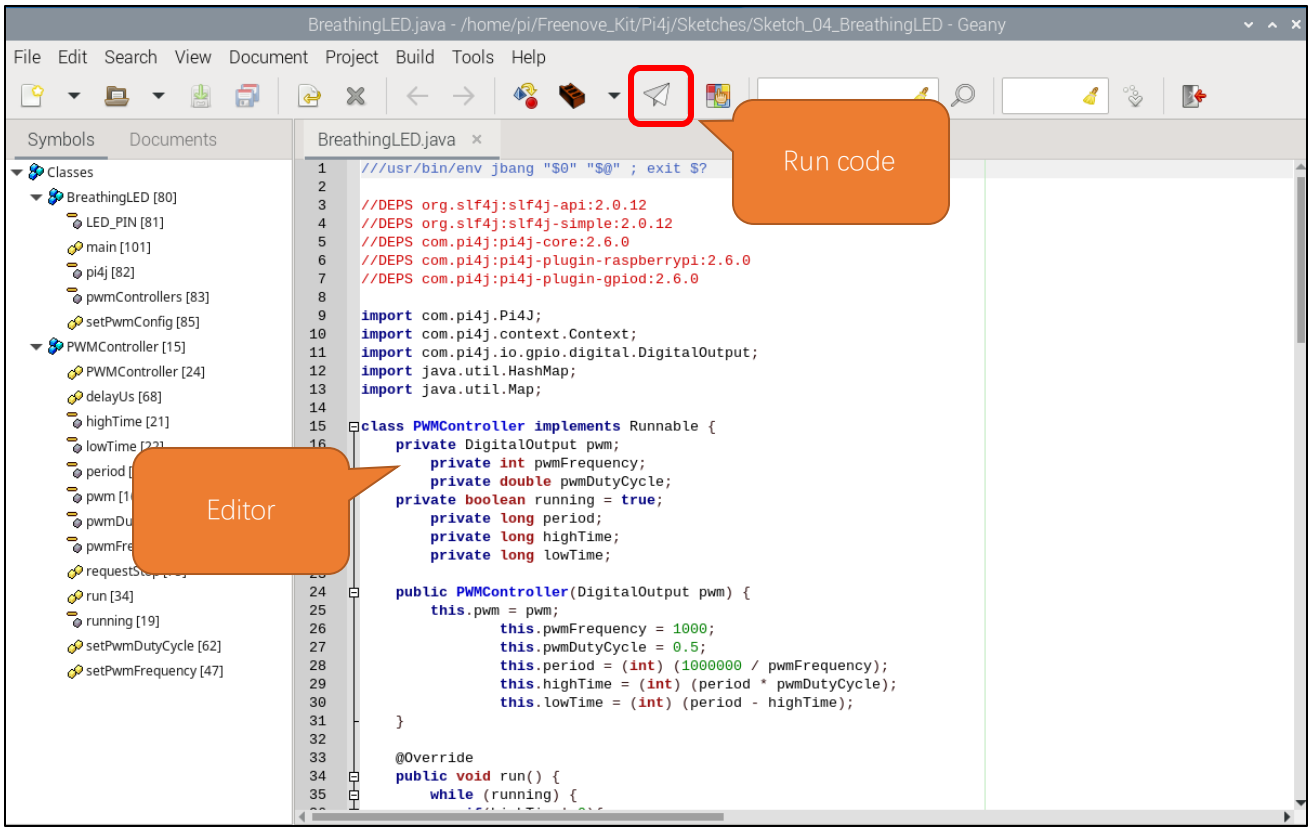
Press Ctrl-C to exit the code.

```
[main] INFO com.pi4j.runtime.impl.DefaultRuntime - Pi4J context/runtime successfully initialized.
^C[pi4j-shutdown] INFO com.pi4j.runtime.impl.DefaultRuntime - Shutting down Pi4J context/runtime.
..
[pi4j-shutdown] INFO com.pi4j.util.ExecutorPool - Shutting down executor pool Pi4J.RUNTIME
[pi4j-shutdown] INFO com.pi4j.runtime.impl.DefaultRuntime - Pi4J context/runtime successfully shu
tdown. Dispatching shutdown event.
pi@raspberrypi:~/Freenove_Kit/Pi4j/Sketches/Sketch_04_BreathingLED $
```

You can open the code with Geany to view and edit it.

geany BreathingLED.java

Click the icon to run the code.



If the code fails to run, please check Geany Configuration.

The following is program code:

```
1  ///usr/bin/env jbang "$0" "$@" ; exit $?
2
3  //DEPS org.slf4j:slf4j-api:2.0.12
4  //DEPS org.slf4j:slf4j-simple:2.0.12
5  //DEPS com.pi4j:pi4j-core:2.6.0
6  //DEPS com.pi4j:pi4j-plugin-raspberrypi:2.6.0
7  //DEPS com.pi4j:pi4j-plugin-gpiod:2.6.0
8
9  import com.pi4j.Pi4J;
10 import com.pi4j.context.Context;
11 import com.pi4j.io.gpio.digital.DigitalOutput;
12 import java.util.HashMap;
13 import java.util.Map;
14
15 class PWMController implements Runnable {
16     private DigitalOutput pwm;
17     private int pwmFrequency;
```

```
18      private double pwmDutyCycle;
19      private boolean running = true;
20      private long period;
21      private long highTime;
22      private long lowTime;
23
24      public PWMController(DigitalOutput pwm) {
25          this.pwm = pwm;
26          this.pwmFrequency = 1000;
27          this.pwmDutyCycle = 0.5;
28          this.period = (int) (1000000 / pwmFrequency);
29          this.highTime = (int) (period * pwmDutyCycle);
30          this.lowTime = (int) (period - highTime);
31      }
32
33      @Override
34      public void run() {
35          while (running) {
36              if(highTime!=0){
37                  pwm.high();
38                  delayUs(highTime);
39              }
40              if(lowTime!=0){
41                  pwm.low();
42                  delayUs(lowTime);
43              }
44          }
45      }
46
47      public void setPwmFrequency(int frequency) {
48          if(frequency!=0){
49              this.pwmFrequency = frequency;
50              this.period = (int) (1000000 / pwmFrequency);
51              this.highTime = (int) (period * pwmDutyCycle);
52              this.lowTime = (int) (period - highTime);
53          }
54          else{
55              this.pwmFrequency = 0;
56              this.period = (int) (1000);
57              this.highTime = (int) (0);
58              this.lowTime = (int) (period - highTime);
59          }
60      }
61
```

```
62      public void setPwmDutyCycle(double dutyCycle) {
63          this.pwmDutyCycle = dutyCycle;
64          this.highTime = (int) (period * pwmDutyCycle);
65          this.lowTime = (int) (period - highTime);
66      }
67
68      private void delayUs(long us) {
69          long startTime = System.nanoTime();
70          long endTime = startTime + (us * 1000);
71          while (System.nanoTime() < endTime) {
72          }
73      }
74
75      public void requestStop() {
76          running = false;
77      }
78  }
79
80  public class BreathingLED {
81      private static int   LED_PIN = 17;
82      private static final Context pi4j = Pi4J.newAutoContext();
83      private static final Map<Integer, PWMController> pwmControllers = new HashMap<>();
84
85      public static void setPwmConfig(int pin) throws Exception {
86          DigitalOutput led = pi4j.dout().create(pin);
87          PWMController = new PWMController(led);
88          Thread pwmThread = new Thread(pwmController, "PWM LED Controller" + pin);
89          pwmControllers.put(pin, pwmController);
90          pwmThread.start();
91          Runtime.getRuntime().addShutdownHook(new Thread(() -> {
92              pwmController.requestStop();
93              try {
94                  pwmThread.join();
95              } catch (InterruptedException e) {
96                  Thread.currentThread().interrupt();
97              }
98          }));
99      }
100
101     public static void main(String[] args) throws Exception {
102         setPwmConfig(LED_PIN);
103         PWMController BreathingLed = pwmControllers.get(LED_PIN);
104         try {
105                 while (true) {
```

```
                    double dutyCycle = 0.01;
                    while (dutyCycle < 1) {
                        BreathingLed.setPwmDutyCycle(dutyCycle);
                        dutyCycle += 0.01;
                        Thread.sleep(10);
                    }
                    while (dutyCycle > 0) {
                        BreathingLed.setPwmDutyCycle(dutyCycle);
                        dutyCycle -= 0.01;
                        Thread.sleep(10);
                    }
                }
            }
        finally {
            for (PWMController controller : pwmControllers.values()) {
                controller.requestStop();
            }
            pi4j.shutdown();
        }
    }
}
```

Use JBange to run the script and automatically process the declared dependencies.

```
///usr/bin/env jbang "$0" "$@" ; exit $?

//DEPS org.slf4j:slf4j-api:2.0.12
//DEPS org.slf4j:slf4j-simple:2.0.12
//DEPS com.pi4j:pi4j-core:2.6.0
//DEPS com.pi4j:pi4j-plugin-raspberrypi:2.6.0
//DEPS com.pi4j:pi4j-plugin-gpiod:2.6.0
```

Import Pi4J library, context management, digital output interface, HashMap class, and Map interface.

```
import com.pi4j.Pi4J;
import com.pi4j.context.Context;
import com.pi4j.io.gpio.digital.DigitalOutput;
import java.util.HashMap;
import java.util.Map;
```

Pi4j only has 4 hardware PWM pins, and the use of these pins is greatly limited, so we use software PWM to control the LED. Although software PWM is not as precise as hardware PWM, it can be applied to any GPIO.
To implement software PWM, we have written a PWMController class to control the GPIO output of PWM. Since PWMController implements the Runnable interface, it can be used to create a Thread object, passing an instance of PWMController as the target to the Thread constructor, and then starting this thread. In this way, the run method of PWMController will be executed in a new thread, allowing it to perform PWM control tasks concurrently.

```
class PWMController implements Runnable {
……
}
```

Define variables to configure PWM's parameters.

```
    private DigitalOutput pwm;
    private int pwmFrequency;
    private double pwmDutyCycle;
    private boolean running = true;
    private long period;
    private long highTime;
    private long lowTime;
```

Constructor, to initialize various parameters of the PWM controller.

```
    public PWMController(DigitalOutput pwm) {
        this.pwm = pwm;
        this.pwmFrequency = 1000;
        this.pwmDutyCycle = 0.5;
        this.period = (int) (1000000 / pwmFrequency);
        this.highTime = (int) (period * pwmDutyCycle);
        this.lowTime = (int) (period - highTime);
    }
```

This is a simple delay method in microsecond.

```
    private void delayUs(long us) {
        long startTime = System.nanoTime();
        long endTime = startTime + (us * 1000);
        while (System.nanoTime() < endTime) {
        }
    }
```

The functions to set PWM frenqunency.

```
    public void setPwmFrequency(int frequency) {
        if(frequency!=0){
            this.pwmFrequency = frequency;
            this.period = (int) (1000000 / pwmFrequency);
            this.highTime = (int) (period * pwmDutyCycle);
            this.lowTime = (int) (period - highTime);
        }
        else{
            this.pwmFrequency = 0;
            this.period = (int) (1000);
            this.highTime = (int) (0);
            this.lowTime = (int) (period - highTime);
        }
    }
```

The functions to set PWM duty cycle.

```
    public void setPwmDutyCycle(double dutyCycle) {
        this.pwmDutyCycle = dutyCycle;
        this.highTime = (int) (period * pwmDutyCycle);
        this.lowTime = (int) (period - highTime);
    }
```

@Override means that the run method overrides the method in the parent class or implements the interface. This method allows the pin to output PWM signals.

```
    @Override
    public void run() {
        while (running) {
            if(highTime!=0){
                pwm.high();
                delayUs(highTime);
            }
            if(lowTime!=0){
                pwm.low();
                delayUs(lowTime);
            }
        }
    }
```

Request to stop the PWM controller. The PWMController class is used in the thread. When running is false, exit the thread.

```
    public void requestStop() {
        running = false;
    }
```

Define the pins that control PWM and create an integer Map variable pwmControllers to store the mapping of PWMController objects.

```
    private static int   LED_PIN = 17;
    private static final Context pi4j = Pi4J.newAutoContext();
    private static final Map<Integer, PWMController> pwmControllers = new HashMap<>();
```

The PWM configuration function only needs to fill in the GPIO number in the parameter. The code will automatically apply for a PWMController object and create a corresponding thread to run it. At the same time, the PWMController is stored in pwmControllers and then the thread is started.

```
    public static void setPwmConfig(int pin) throws Exception {
        DigitalOutput led = pi4j.dout().create(pin);
        PWMController pwmController = new PWMController(led);
        Thread pwmThread = new Thread(pwmController, "PWM LED Controller" + pin);
        pwmControllers.put(pin, pwmController);
        pwmThread.start();
        ……
    }
```

Add JVM shutdown hook to ensure PWM controller is stopped on JVM shutdown.

```
        Runtime.getRuntime().addShutdownHook(new Thread(() -> {
            pwmController.requestStop();
            try {
                pwmThread.join();
            } catch (InterruptedException e) {
                Thread.currentThread().interrupt();
            }
        }));
```

The main program, which is used to test the effect of making the LED breathe.

```
    public static void main(String[] args) throws Exception {
        ……
    }
```

Configure PWM and associate it with pin.

```
        setPwmConfig(LED_PIN);
```

Obtain PWM controller corresponding to the pin.

```
        PWMController BreathingLed = pwmControllers.get(LED_PIN);
```

The duty cycle value is changed every 10 milliseconds, so that the LED cycles from dark to bright and then from bright to dark.

```
        try {
                while (true) {
                    double dutyCycle = 0.01;
                    while (dutyCycle < 1) {
                        BreathingLed.setPwmDutyCycle(dutyCycle);
                        dutyCycle += 0.01;
                        Thread.sleep(10);
                    }
                    while (dutyCycle > 0) {
                        BreathingLed.setPwmDutyCycle(dutyCycle);
                        dutyCycle -= 0.01;
                        Thread.sleep(10);
                    }
                }
            }
```

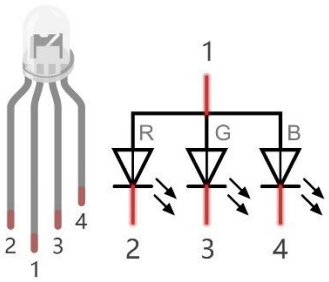
When exiting the main loop, first close all PWM controller threads and then close the pi4j context.

```
        finally {
            for (PWMController controller : pwmControllers.values()) {
                controller.requestStop();
            }
            pi4j.shutdown();
        }
```

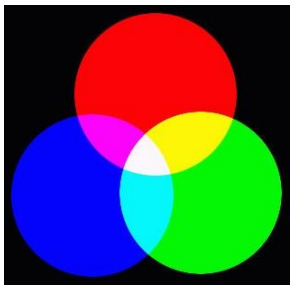
Chapter 5 RGB LED

In this chapter, we will learn how to control an 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 an 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.



RGB

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 RainbowLED

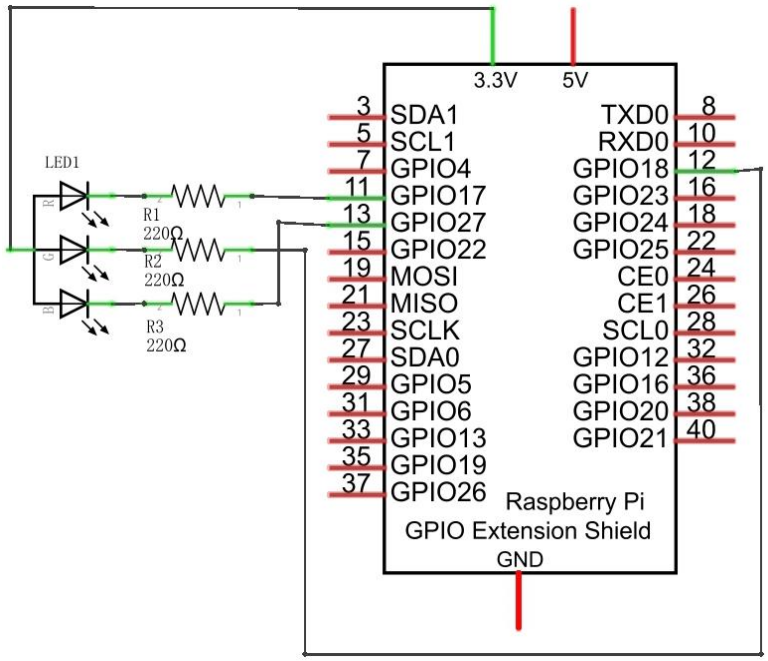
In this project, we will make a multicolored LED, which we can program the RGB LED to automatically change colors.

Component List

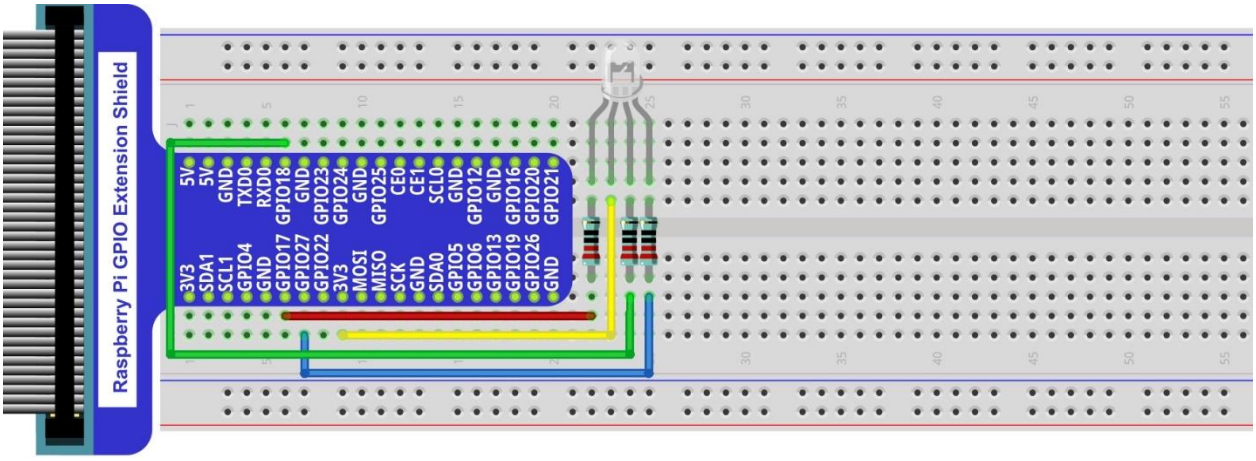
Raspberry Pi x1 GPIO Extension Board & Wire x1 Breadboard x1	RGBLED x1 	Resistor 220Ω x3 
Jumper M/M x4 		

Circuit

Schematic diagram



Hardware connection



If you have any concerns, please send an email to: support@freenove.com

Sketch

In this chapter, we will control the RGB LED with 3 PWMs.

Sketch_05_RainbowLED

First, enter where the project is located:

```
cd ~/Freenove_Kit/Pi4j/Sketches/Sketch_05_RainbowLED
```

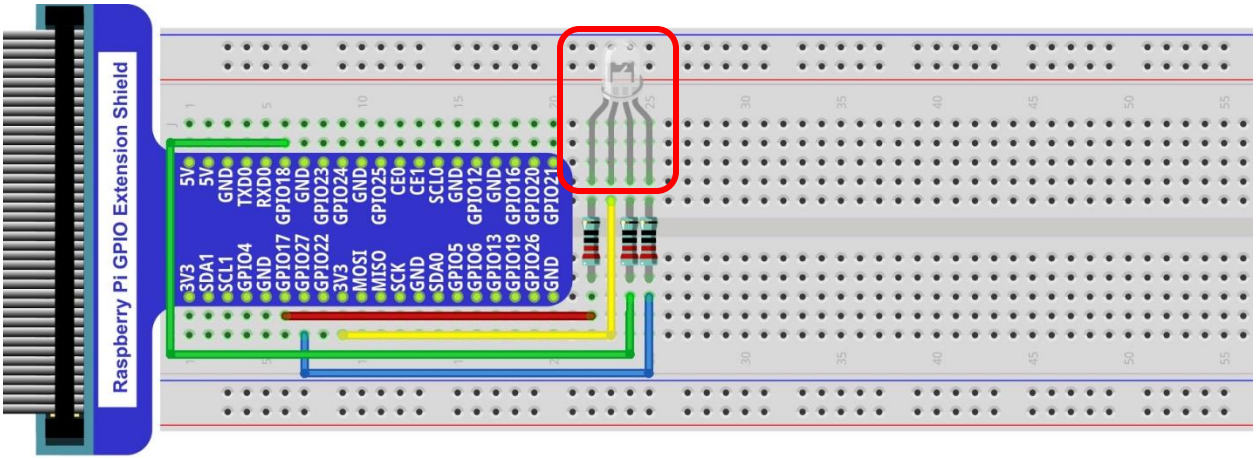
```
pi@raspberrypi:~ $ cd ~/Freenove_Kit/Pi4j/Sketches/Sketch_05_RainbowLED
pi@raspberrypi:~/Freenove_Kit/Pi4j/Sketches/Sketch_05_RainbowLED $
```

Enter the command to run the code.

```
jbang RainbowLED.java
```

```
pi@raspberrypi:~ $ cd ~/Freenove_Kit/Pi4j/Sketches/Sketch_05_RainbowLED
pi@raspberrypi:~/Freenove_Kit/Pi4j/Sketches/Sketch_05_RainbowLED $ jbang RainbowLED.java
```

When the code is running, the RGB LED randomly emits various colors.




```
[main] INFO com.pi4j.util.Console - R:69  G:68, B:10
[main] INFO com.pi4j.util.Console - R:80  G:33, B:96
[main] INFO com.pi4j.util.Console - R:43  G:33, B:87
[main] INFO com.pi4j.util.Console - R:28  G:17, B:98
[main] INFO com.pi4j.util.Console - R:16  G:33, B:55
[main] INFO com.pi4j.util.Console - R:81  G:88, B:53
[main] INFO com.pi4j.util.Console - R:45  G:98, B:82
[main] INFO com.pi4j.util.Console - R:52  G:73, B:45
```

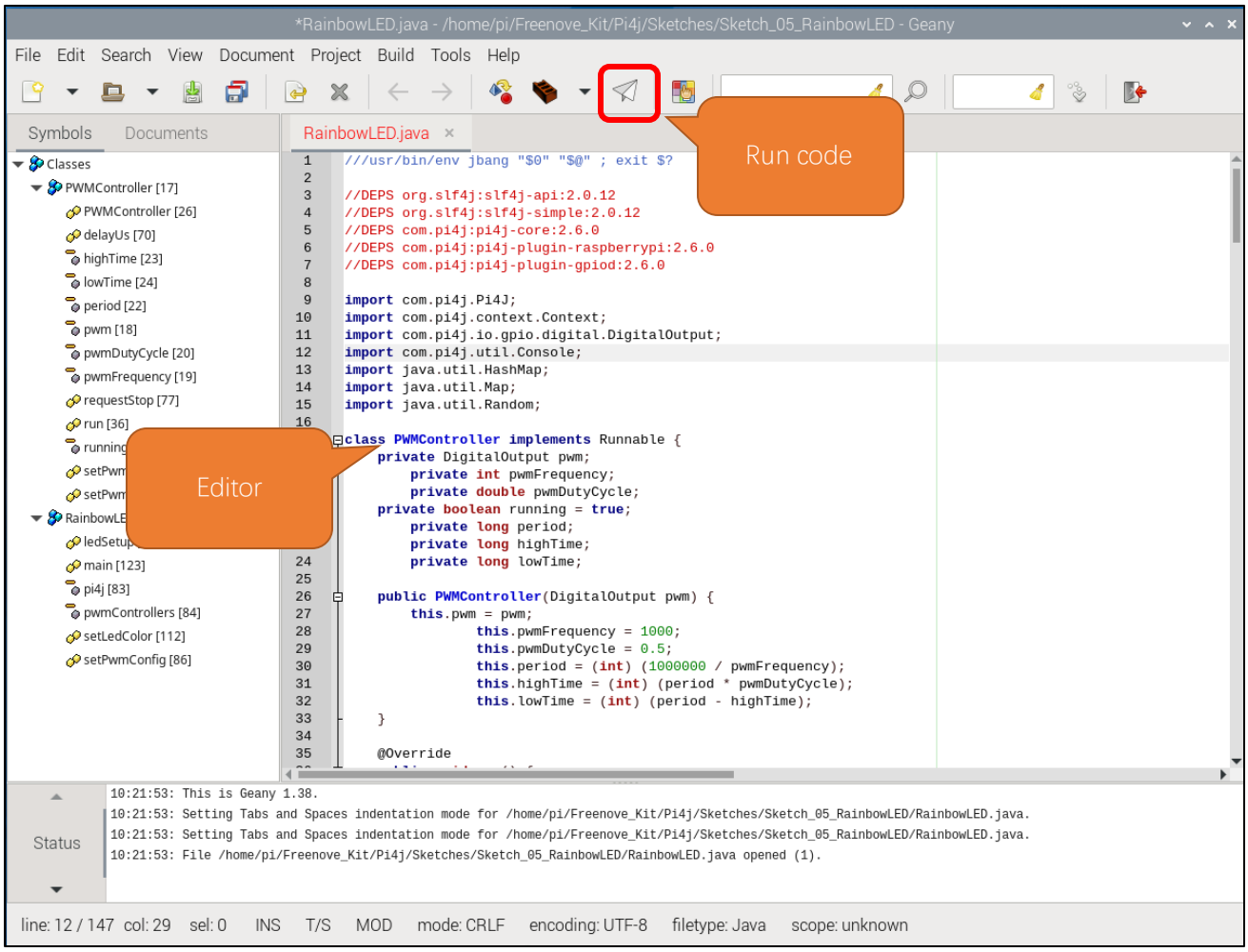
Press Ctr+C to exit the program.

```
[main] INFO com.pi4j.util.Console - R:60  G:6, B:66
[main] INFO com.pi4j.util.Console - R:69  G:87, B:89
^C[pi4j-shutdown] INFO com.pi4j.runtime.impl.DefaultRuntime - Shutting down Pi4J context/runtime
...
[pi4j-shutdown] INFO com.pi4j.util.ExecutorPool - Shutting down executor pool Pi4J.RUNTIME
[pi4j-shutdown] INFO com.pi4j.runtime.impl.DefaultRuntime - Pi4J context/runtime successfully sh
utdown. Dispatching shutdown event.
pi@raspberrypi:~/Freenove_Kit/Pi4j/Sketches/Sketch_05_RainbowLED $
```

You can open the code with Geany to view and edit it, with the following command.

```
geany RainbowLED.java
```

Click the icon to run the code.



If the code fails to run, please check Geany Configuration.

The following is program code:

```
///usr/bin/env jbang "$0" "$@" ; exit $?

//DEPS org.slf4j:slf4j-api:2.0.12
//DEPS org.slf4j:slf4j-simple:2.0.12
//DEPS com.pi4j:pi4j-core:2.6.0
//DEPS com.pi4j:pi4j-plugin-raspberrypi:2.6.0
//DEPS com.pi4j:pi4j-plugin-gpiod:2.6.0

import com.pi4j.Pi4J;
import com.pi4j.context.Context;
import com.pi4j.io.gpio.digital.DigitalOutput;
import com.pi4j.util.Console;
import java.util.HashMap;
```

```
14  import java.util.Map;
15  import java.util.Random;
16
17  class PWMController implements Runnable {
…       ……
80  }
81
82  public class RainbowLED {
83      private static final Context pi4j = Pi4J.newAutoContext();
84      private static final Map<Integer, PWMController> pwmControllers = new HashMap<>();
85
86      public static void setPwmConfig(int pin) throws Exception {
…           ……
100     }
101
102     public static void ledSetup(int[] pins) {
103         for (int pin : pins) {
104             try {
105                 setPwmConfig(pin);
106             } catch (Exception e) {
107                 e.printStackTrace();
108             }
109         }
110     }
111
112     public static void setLedColor(int[] pins, int r, int g, int b) {
113         if (pins.length >= 3) {
114             PWMController red = pwmControllers.get(pins[0]);
115             PWMController green = pwmControllers.get(pins[1]);
116             PWMController blue = pwmControllers.get(pins[2]);
117             if (red != null) red.setPwmDutyCycle((double) r / 100.0);
118             if (green != null) green.setPwmDutyCycle((double) g / 100.0);
119             if (blue != null) blue.setPwmDutyCycle((double) b / 100.0);
120         }
121     }
122
123     public static void main(String[] args) throws Exception {
124         final var console = new Console();
125         int[] LED_PINS = {17, 18, 27};
126         Random = new Random();
127
128         try {
129             ledSetup(LED_PINS);
130             while (true) {
```

```
131                 int red = random.nextInt(101);
132                 int green = random.nextInt(101);
133                 int blue = random.nextInt(101);
134                 console.println("R:%d  G:%d, B:%d", red, green, blue);
134                 setLedColor(LED_PINS, red, green, blue);
135                 Thread.sleep(500);
136             }
137         }
138         finally {
139             for (PWMController controller : pwmControllers.values()) {
140                 controller.requestStop();
141             }
142             pi4j.shutdown();
143         }
144     }
145 }
```

Import Pi4j library, context management, digital output interface, HashMap class and Map interface, and random function library.

```
import com.pi4j.Pi4J;
import com.pi4j.context.Context;
import com.pi4j.io.gpio.digital.DigitalOutput;
import com.pi4j.util.Console;
import java.util.HashMap;
import java.util.Map;
import java.util.Random;
```

Initialize the pins corresponding to the RGB lights and print a stack trace if an exception occurs.

```
    public static void ledSetup(int[] pins) {
        for (int pin : pins) {
            try {
                setPwmConfig(pin);
            } catch (Exception e) {
                e.printStackTrace();
            }
        }
    }
```

Configure the RGB colored lights and adjust the brightness of the LED by adjusting the duty cycle of PWM.

```
    public static void setLedColor(int[] pins, int r, int g, int b) {
        if (pins.length >= 3) {
            PWMController red = pwmControllers.get(pins[0]);
            PWMController green = pwmControllers.get(pins[1]);
            PWMController blue = pwmControllers.get(pins[2]);
            if (red != null) red.setPwmDutyCycle((double) r / 100.0);
            if (green != null) green.setPwmDutyCycle((double) g / 100.0);
            if (blue != null) blue.setPwmDutyCycle((double) b / 100.0);
        }
    }
```

Create a console instance, define an array of GPIO pins for LED connections, and create a random number generator instance.

```
        final var console = new Console();
        int[] LED_PINS = {17, 18, 27};
        Random = new Random();
```

Initialize the array of GPIO pins connected to the LEDs, generate 3 new random numbers every 500 milliseconds as brightness values for the RGB lights, and print prompt messages on the console.

```
        try {
            ledSetup(LED_PINS);
            while (true) {
                int red = random.nextInt(101);
                int green = random.nextInt(101);
                int blue = random.nextInt(101);
                console.println("R:%d  G:%d, B:%d", red, green, blue);
                setLedColor(LED_PINS, red, green, blue);
                Thread.sleep(500);
            }
        }
```

At the end of the program, stop all PWM controllers and close the Pi4J context.

```
        finally {
            for (PWMController controller : pwmControllers.values()) {
                controller.requestStop();
            }
            pi4j.shutdown();
        }
```

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

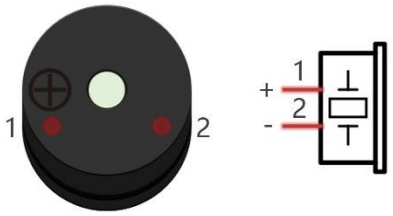
<table>
<tr><td colspan="2">Raspberry Pi (with 40 GPIO) x1
GPIO Extension Board & Ribbon Cable x1
Breadboard x1</td><td colspan="3">Jumper Wire
  </td></tr>
<tr><td>NPN transistorx1
(S8050)
  </td><td>Active buzzer x1
  </td><td>Push Button Switch x1
  </td><td>Resistor 1kΩ x1
  </td><td>Resistor 10kΩ x2
  </td></tr>
</table>

Component knowledge

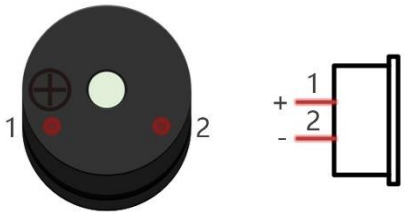
Buzzer

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 buzzer



Passive buzzer



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

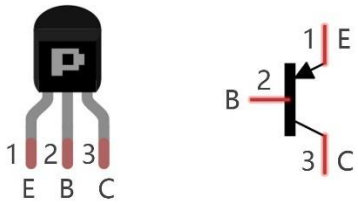
Passive buzzer bottom

Transistors

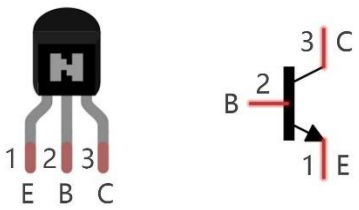
A transistor is required in this project due to the buzzer's current being so great that GPIO of RPi's output capability cannot meet the power requirement necessary for operation. A NPN transistor is needed here to amplify the current.

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



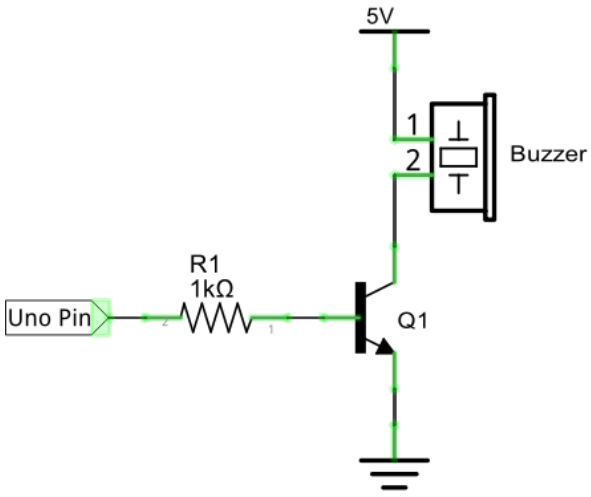
In our kit, the PNP transistor is marked with 8550, and the NPN transistor is marked with 8050.

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.

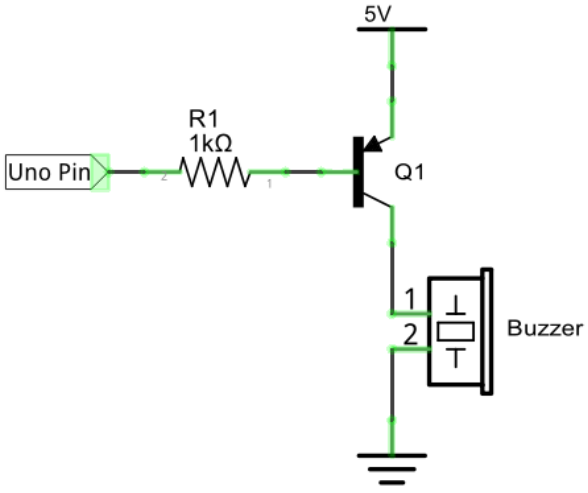
When we use a NPN transistor to drive a buzzer, we often use the following method. If GPIO outputs high level, current will flow through R1 (Resistor 1), the transistor conducts current and the buzzer will make sounds. If GPIO outputs low level, no current will flow through R1, the transistor will not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

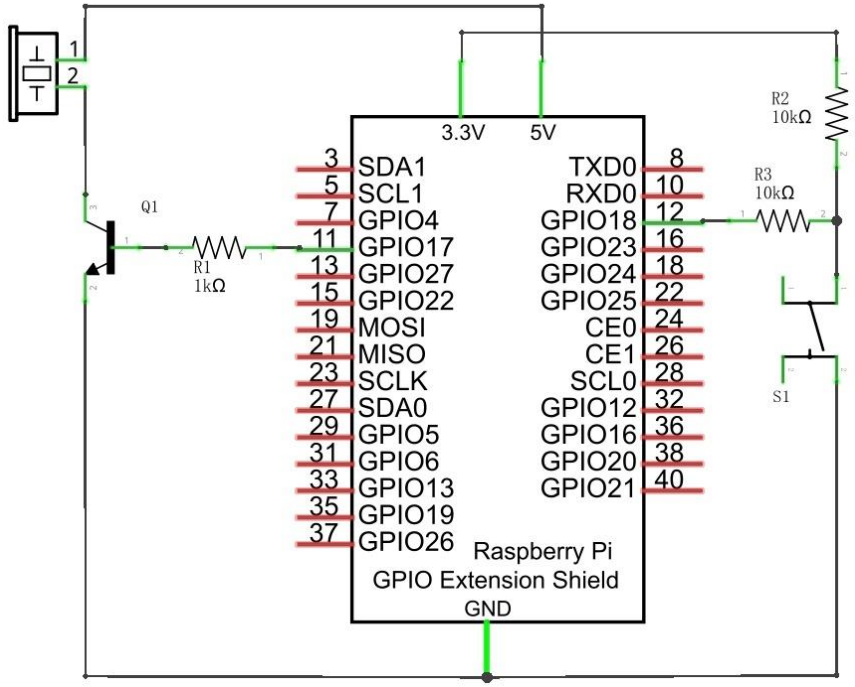


PNP transistor to drive buzzer

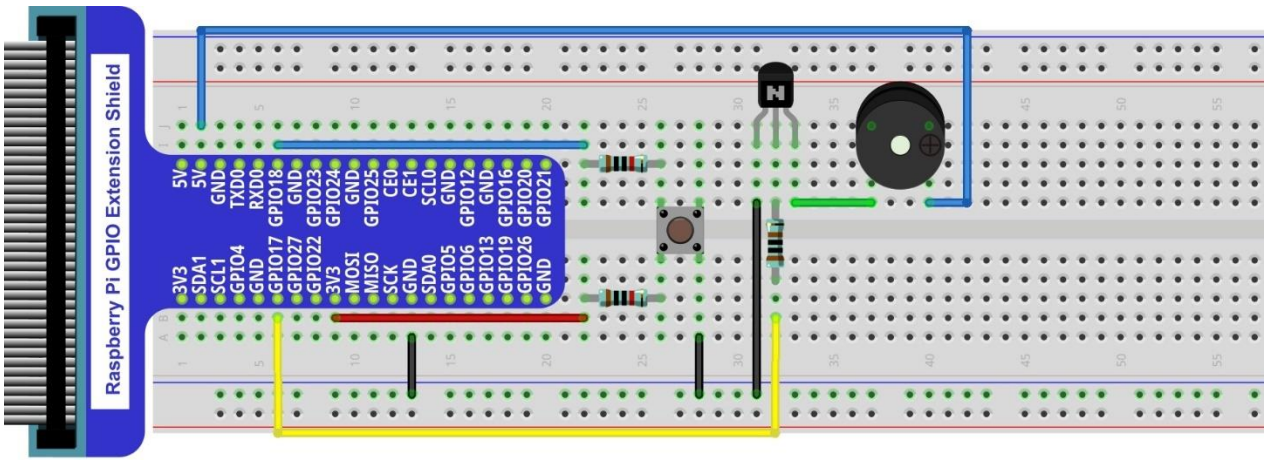


Circuit

Schematic diagram



Hardware connection



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).

If you have any concerns, please send an email to: support@freenove.com

Sketch

In this chapter, we use a button to control the active buzzer. The code is similar to that in Chapter 3.

Sketch_06_1_Doorbell

First, enter where the project is located:

```
cd ~/Freenove_Kit/Pi4j/Sketches/Sketch_06_1_Doorbell
```

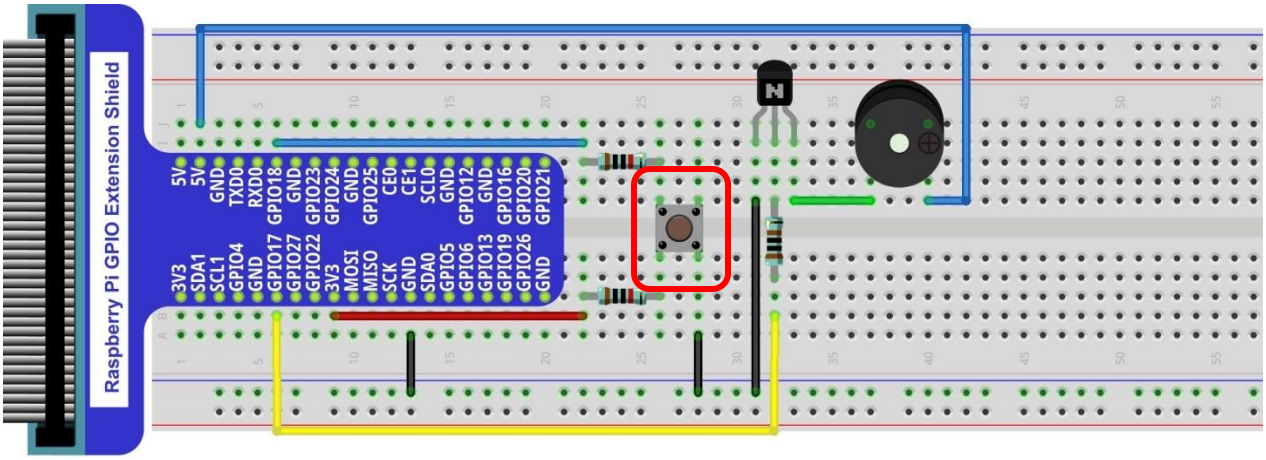
```
pi@raspberrypi:~ $ cd ~/Freenove_Kit/Pi4j/Sketches/Sketch_06_1_Doorbell
pi@raspberrypi:~/Freenove_Kit/Pi4j/Sketches/Sketch_06_1_Doorbell $
```

Enter the command to run the code.

```
jbang Doorbell.java
```

```
pi@raspberrypi:~ $ cd ~/Freenove_Kit/Pi4j/Sketches/Sketch_06_1_Doorbell
pi@raspberrypi:~/Freenove_Kit/Pi4j/Sketches/Sketch_06_1_Doorbell $ jbang Doorbell.java
```

During the code running, press the button to sound the buzzer and release the button to stop it.



You can see messages printed on the terminal.

```
[Pi4J.RUNTIME-1] INFO com.pi4j.util.Console - buzzer turned on.  >>>
[Pi4J.RUNTIME-1] INFO com.pi4j.util.Console - buzzer turned off. >>>
[Pi4J.RUNTIME-1] INFO com.pi4j.util.Console - buzzer turned on.  >>>
[Pi4J.RUNTIME-1] INFO com.pi4j.util.Console - buzzer turned off. >>>
```

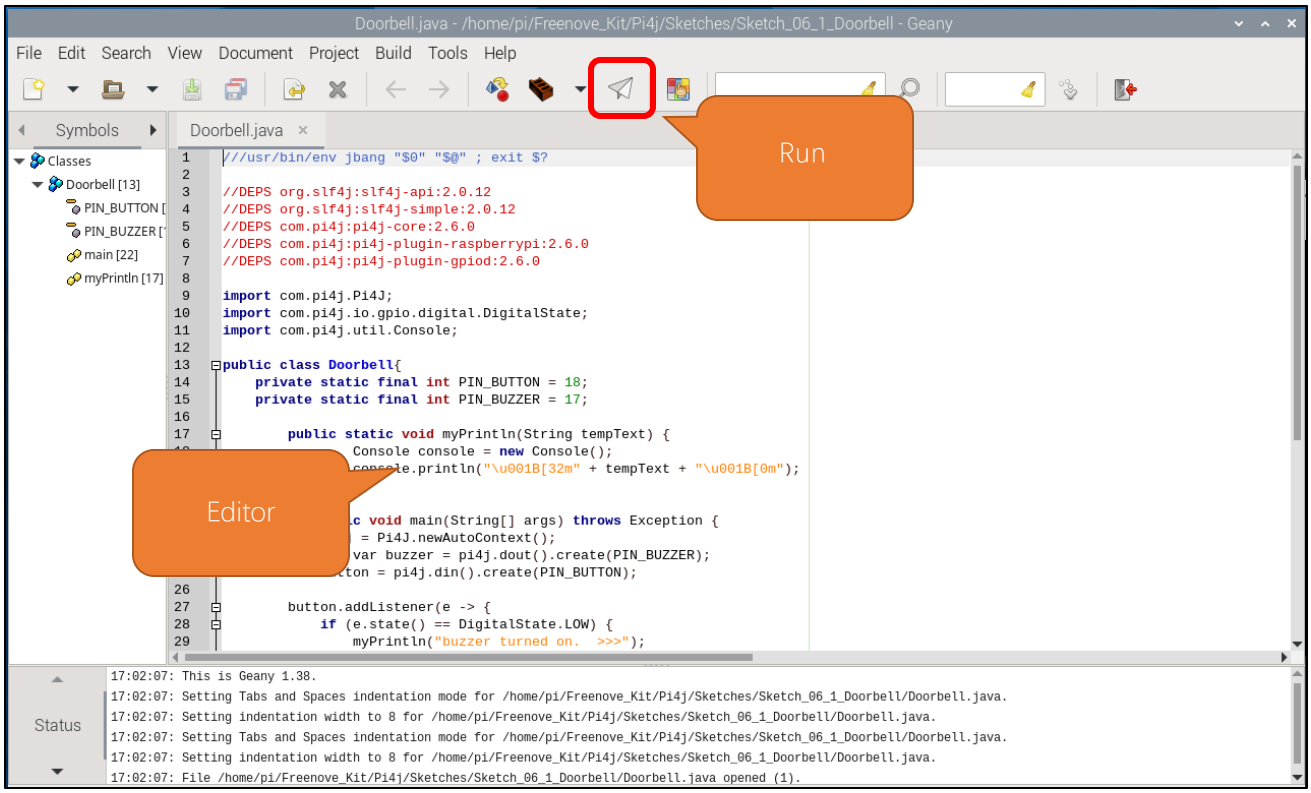
Press Ctrl+C to exit the code.

```
^C[pi4j-shutdown] INFO com.pi4j.runtime.impl.DefaultRuntime - Shutting down Pi4J context/runtime...
[pi4j-shutdown] INFO com.pi4j.plugin.gpiod.provider.gpio.digital.GpioDDigitalInput - Shutdown input listener for DIN-21
[pi4j-shutdown] INFO com.pi4j.util.ExecutorPool - Shutting down executor pool Pi4J.RUNTIME
[pi4j-shutdown] INFO com.pi4j.runtime.impl.DefaultRuntime - Pi4J context/runtime successfully shutdown. Dispatching shutdown event.
pi@raspberrypi:~/Freenove_Kit/Pi4j/Sketches/Sketch_06_1_Doorbell $
```

You can open the code with Geany to view and edit it, with the following command.

```
geany Doorbell.java
```

Click the icon to run the code.



If the code fails to run, please check Geany Configuration.

The following is program code:

```
1  ///usr/bin/env jbang "$0" "$@" ; exit $?
2
3  //DEPS org.slf4j:slf4j-api:2.0.12
4  //DEPS org.slf4j:slf4j-simple:2.0.12
5  //DEPS com.pi4j:pi4j-core:2.6.0
6  //DEPS com.pi4j:pi4j-plugin-raspberrypi:2.6.0
7  //DEPS com.pi4j:pi4j-plugin-gpiod:2.6.0
8
9  import com.pi4j.Pi4J;
10 import com.pi4j.io.gpio.digital.DigitalState;
11 import com.pi4j.util.Console;
12
13 public class Doorbell{
14
15     private static final int PIN_BUTTON = 18;
16     private static final int PIN_BUZZER = 17;
17
18     public static void myPrintln(String tempText) {
```

```
19          Console console = new Console();
20          console.println("\u001B[32m" + tempText + "\u001B[0m");
21      }
22
23      public static void main(String[] args) throws Exception {
24          var pi4j = Pi4J.newAutoContext();
25          var buzzer = pi4j.dout().create(PIN_BUZZER);
26          var button = pi4j.din().create(PIN_BUTTON);
27
28          button.addListener(e -> {
29              if (e.state() == DigitalState.LOW) {
30                  myPrintln("buzzer turned on.  >>>");
31                  buzzer.high();
32              }
33              else if(e.state() == DigitalState.HIGH){
34                  myPrintln("buzzer turned off. >>>");
35                  buzzer.low();
36              }
37          });
38
39          try{
40              while (true) {
41                  Thread.sleep(500);
42              }
43          }
44          finally{
45              pi4j.shutdown();
46          }
47      }
48  }
```

Please note that as the code is similar to that in chapter 3, here we do not explain it again.

In order to make the prompt messages printed by the terminal more conspicuous, we wrote the myprintln function to wrap the console.println function.

```
    public static void myPrintln(String tempText) {
        Console console = new Console();
        console.println("\u001B[32m" + tempText + "\u001B[0m");
    }
```

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.

Sketch

In this chapter, we use button to control the passive buzzer to make sound.
Sketch_06_2_Alertor
First, enter where the project is located:

```
cd ~/Freenove_Kit/Pi4j/Sketches/Sketch_06_2_Alertor
```

```
pi@raspberrypi:~ $ cd ~/Freenove_Kit/Pi4j/Sketches/Sketch_06_2_Alertor/
pi@raspberrypi:~/Freenove_Kit/Pi4j/Sketches/Sketch_06_2_Alertor $
```

Enter the command to run the code.

```
jbang Alertor.java
```

```
pi@raspberrypi:~ $ cd ~/Freenove_Kit/Pi4j/Sketches/Sketch_06_2_Alertor/
pi@raspberrypi:~/Freenove_Kit/Pi4j/Sketches/Sketch_06_2_Alertor $ jbang Alertor.java
```

When the code is running, press the button to sound the buzzer and release to stop it.

You can see messages printed on the terminal.

```
[main] INFO com.pi4j.util.Console - buzzer turned off. >>>
[main] INFO com.pi4j.util.Console - buzzer turned on.  >>>
[main] INFO com.pi4j.util.Console - buzzer turned on.  >>>
[main] INFO com.pi4j.util.Console - buzzer turned off. >>>
[main] INFO com.pi4j.util.Console - buzzer turned off. >>>
[main] INFO com.pi4j.util.Console - buzzer turned off. >>>
```

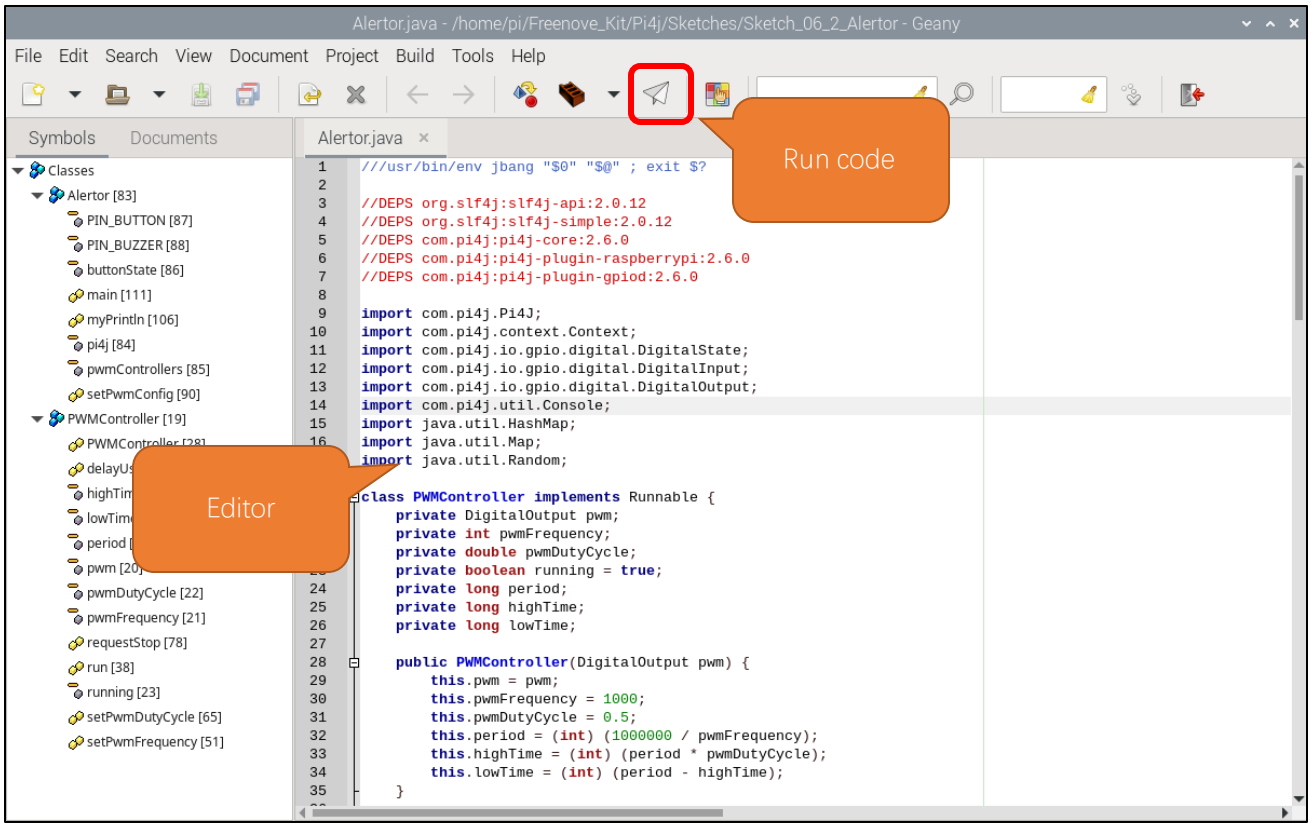
Press ctrl+C to exit the code.

```
^C[pi4j-shutdown] INFO com.pi4j.runtime.impl.DefaultRuntime - Shutting down Pi4J context/runtime...
[pi4j-shutdown] INFO com.pi4j.plugin.gpiod.provider.gpio.digital.GpioDDigitalInput - Shutdown input listener for DIN-20
[pi4j-shutdown] INFO com.pi4j.util.ExecutorPool - Shutting down executor pool Pi4J.RUNTIME
[pi4j-shutdown] INFO com.pi4j.runtime.impl.DefaultRuntime - Pi4J context/runtime successfully shutdown. Dispatching shut
down event.
```

You can open the code with Geany to view and edit it, with the following command.

```
geany Alertor.java
```

Click the icon to run the code.



If the code fails to run, please check Geany Configuration.

The following is program code:

```
///usr/bin/env jbang "$0" "$@" ; exit $?

//DEPS org.slf4j:slf4j-api:2.0.12
//DEPS org.slf4j:slf4j-simple:2.0.12
//DEPS com.pi4j:pi4j-core:2.6.0
//DEPS com.pi4j:pi4j-plugin-raspberrypi:2.6.0
//DEPS com.pi4j:pi4j-plugin-gpiod:2.6.0

import com.pi4j.Pi4J;
import com.pi4j.context.Context;
import com.pi4j.io.gpio.digital.DigitalState;
import com.pi4j.io.gpio.digital.DigitalInput;
import com.pi4j.io.gpio.digital.DigitalOutput;
import com.pi4j.util.Console;
import java.util.HashMap;
import java.util.Map;
import java.util.Random;
```

```
18
19  class PWMController implements Runnable {
...     ......
81  }
82
83  public class Alertor {
84      private static final Context pi4j = Pi4J.newAutoContext();
85      private static final Map<Integer, PWMController> pwmControllers = new HashMap<>();
86      private static volatile int buttonState = 0;
87      private static int PIN_BUTTON = 18;
88      private static int PIN_BUZZER = 17;
89
90      public static void setPwmConfig(int pin) throws Exception {
91          DigitalOutput pwm = pi4j.dout().create(pin);
92          PWMController pwmController = new PWMController(pwm);
93          Thread pwmThread = new Thread(pwmController, "PWM Controller" + pin);
94          pwmControllers.put(pin, pwmController);
95          pwmThread.start();
96          Runtime.getRuntime().addShutdownHook(new Thread(() -> {
97              pwmController.requestStop();
98              try {
99                  pwmThread.join();
100             } catch (InterruptedException e) {
101                 Thread.currentThread().interrupt();
102             }
103         }));
104     }
105
106     public static void myPrintln(String tempText) {
107         Console console = new Console();
108         console.println("\u001B[32m" + tempText + "\u001B[0m");
109     }
110
111     public static void main(String[] args) throws Exception {
112         DigitalInput button = pi4j.din().create(PIN_BUTTON);
113         button.addListener(e -> {
114             buttonState = e.state() == DigitalState.LOW ? 1 : 0;
115         });
116         setPwmConfig(PIN_BUZZER);
117         PWMController buzzer = pwmControllers.get(PIN_BUZZER);
118         buzzer.setPwmFrequency(0);
119         buzzer.setPwmDutyCycle(0.5);
120         try {
121             while (true) {
```

```
122                 if (buttonState == 1) {
123                     myPrintln("buzzer turned on.  >>>");
124                     buzzer.setPwmFrequency(1000);
125                 } else {
126                     myPrintln("buzzer turned off. >>>");
127                     buzzer.setPwmFrequency(0);
128                 }
129                 Thread.sleep(100);
130             }
131         }
132         finally {
133             for (PWMController controller : pwmControllers.values()) {
134                 controller.requestStop();
135             }
136             pi4j.shutdown();
137         }
138     }
139 }
```

Create a pi4j context for manipulating the GPIOs, and define the GPIO numbers that control the keys and buzzer.

```
    private static final Context pi4j = Pi4J.newAutoContext();
    private static final Map<Integer, PWMController> pwmControllers = new HashMap<>();
    private static volatile int buttonState = 0;
    private static int PIN_BUTTON = 18;
    private static int PIN_BUZZER = 17;
```

Initialize the button input pin, create a monitoring event, and assign the key value to buttonState when the button state changes.

```
        DigitalInput button = pi4j.din().create(PIN_BUTTON);
        button.addListener(e -> {
            buttonState = e.state() == DigitalState.LOW ? 1 : 0;
        });
```

Initialize the PWM pin that controls the passive buzzer.

```
        setPwmConfig(PIN_BUZZER);
        PWMController buzzer = pwmControllers.get(PIN_BUZZER);
        buzzer.setPwmFrequency(0);
        buzzer.setPwmDutyCycle(0.5);
```

When buttonState is 1, the passive buzzer sounds, and when buttonState is 0, the buzzer sound is turned off. Print the information in the console.

```
                if (buttonState == 1) {
                    myPrintln("buzzer turned on.  >>>");
                    buzzer.setPwmFrequency(1000);
                } else {
                    myPrintln("buzzer turned off. >>>");
                    buzzer.setPwmFrequency(0);
                }
```

What's Next?

THANK YOU for participating in this learning experience!

We have reached the end of this Tutorial. If you find errors, omissions, or if you have suggestions and/or questions about the Tutorial or component contents of this Kit, please feel free to contact us:
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 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.
http://www.freenove.com/

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