Welcome

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How to Start

First, read the document **Read Me First.pdf** in the unzipped folder.
If you did not download the zip file, please download it and unzip it.

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You may find somethings missing or broken, or some difficulty to learn the kit.
Freenove provides free and quick support, including but not limited to:

- Quality problems of products
- Problems in using products
- Questions for learning and technology
- Opinions and suggestions
- Ideas and thoughts

If you have any concerns, please send email to us:

support@freenove.com

And suggestions and feedbacks are welcomed. Many customers offered great feedbacks. According to that, we are keeping updating the kit and the tutorial to make it better. Thank you.

Safety

Pay attention to safety when using and storing this product:

- Do not expose children under 6 years of age to this product. Put it out of their reach.
- Children lack safety ability should use this product under the guardianship of adults.
- This product contains small and sharp parts. Do not swallow, prick and scratch to avoid injury.
- This product contains conductive parts. Do not hold them to touch power supply and other circuits.
- Some parts will rotate or move when it works. Do not touch them to avoid being bruised or scratched.
- The wrong operation may cause overheat. Do not touch and disconnect the power supply immediately.
- Operate in accordance with the requirements of the tutorial. Otherwise, the parts may be damaged.
- Store the product in a dry place and avoid direct sunlight.
- Turn off the power of the circuit before leaving.

About

Freenove provides open source electronic products and services.

Freenove is committed to helping customers learn programming and electronic knowledge, quickly realize their creative ideas and product prototypes and launching innovative products. Our services include:

- Kits of robots, smart cars and drones
- Kits for learning Arduino, Raspberry Pi and micro:bit
- Electronic components and modules, tools
- **Product customization service**

You can learn more about us or get our latest information through our website:

http://www.freenove.com

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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 a capable little device that enables people of all ages to explore computing, and to learn how to program in languages like Scratch and Python. It's capable of doing everything you'd expect a desktop computer to do, from browsing the internet and playing high-definition video, to making spreadsheets, word-processing, and playing games. For more information, you can refer to Raspberry Pi official website. We will call it RPi, RPI, RasPi later in this tutorial.

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

The supporting kit contains the accessory electronic components and modules needed to complete these projects. You can also use these components and modules to achieve your own creativity.

Additionally, if you have any difficulties or questions about this tutorial and the kit, you can always contact us for quick and free support:

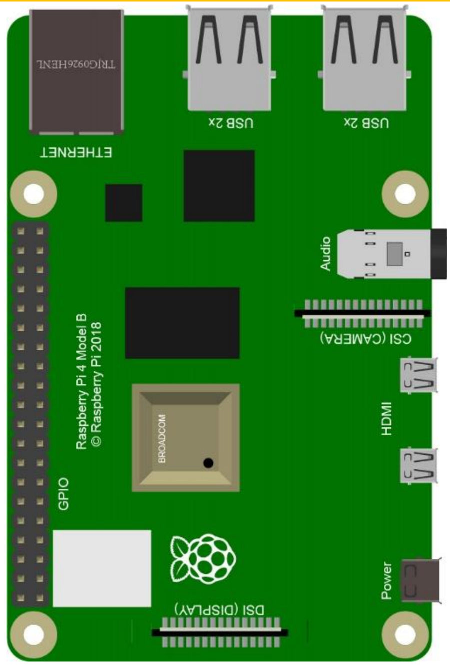
support@freenove.com

Raspberry Pi

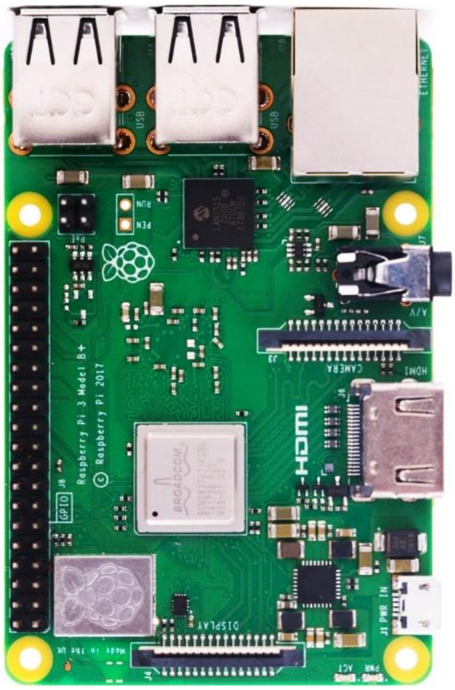
So far, Raspberry Pi has developed to the fourth generation. Changes in versions are accompanied by increase and upgrades in hardware.

A type and B type, the first generation of products, have been stopped due to various reasons. Other versions are popular and active and the most important is that they are consistent in the order and number of pins, which which greatly enhances the compatibility of peripheral devices between different versions.

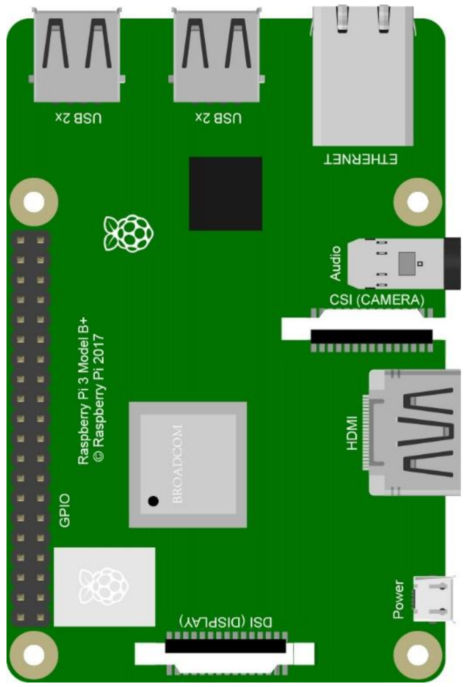
Below are the raspberry pi pictures and model pictures supported by this product. They have 40 pins.

Practicality picture of Raspberry Pi 4 Model B:	Model diagram of Raspberry Pi 4 Model B:
	

Practicality picture of Raspberry Pi 3 Model B+：

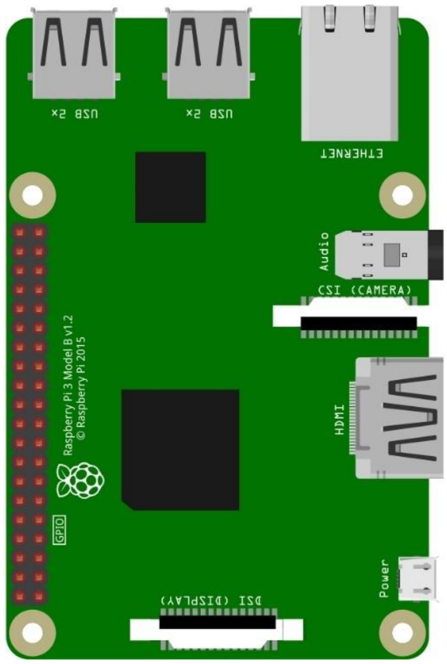


Model diagram of Raspberry Pi 3 Model B+：



Practicality picture of Raspberry Pi 3 Model B:

Model diagram of Raspberry Pi 3 Model B:



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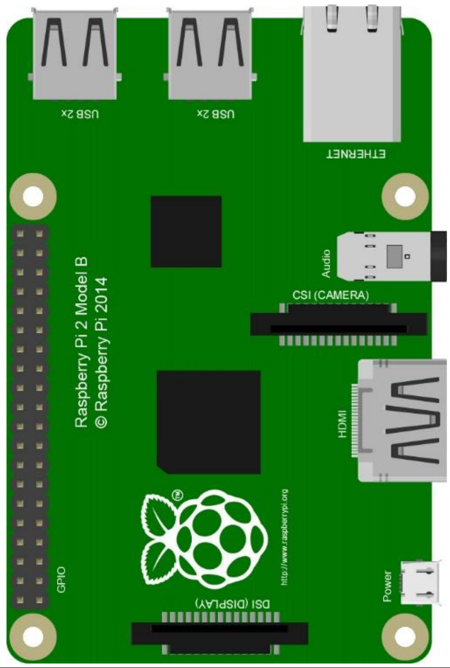
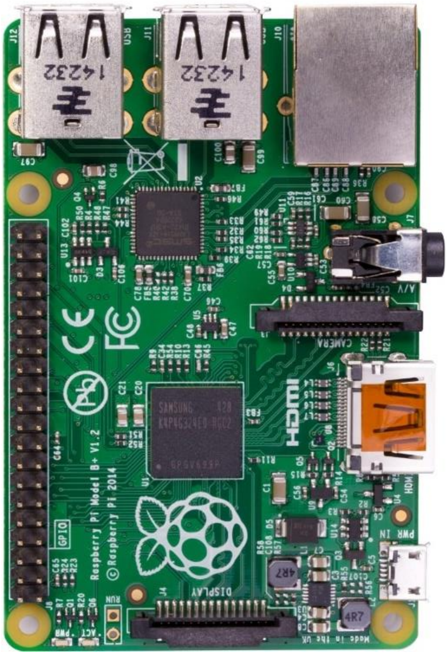
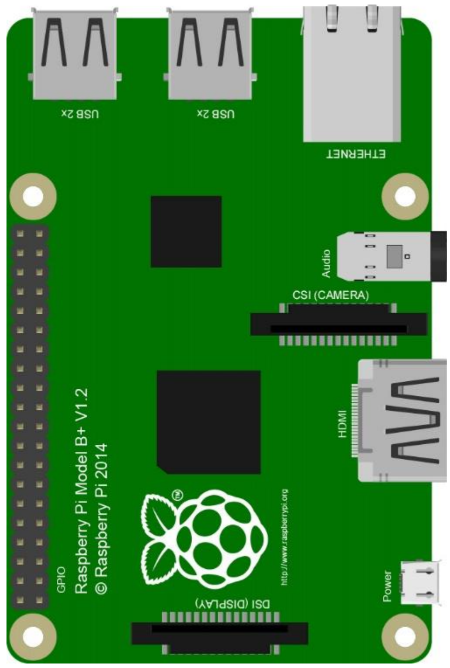
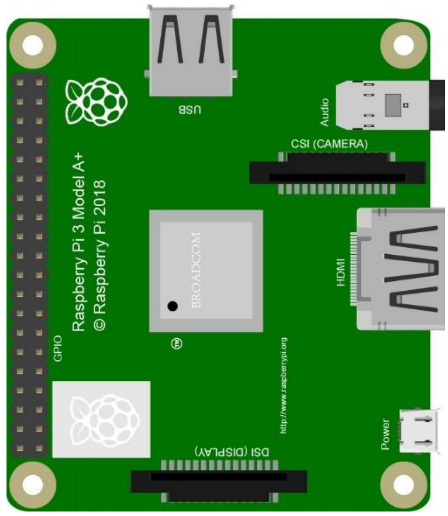
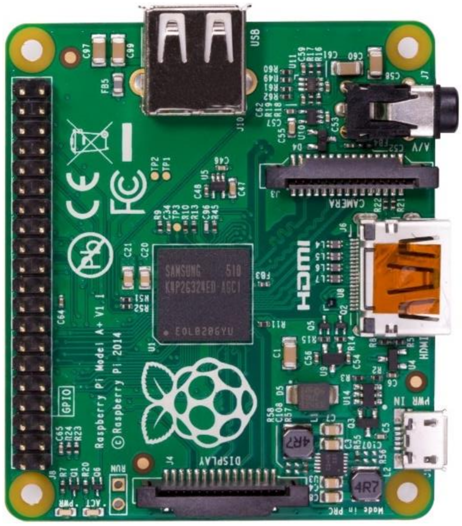
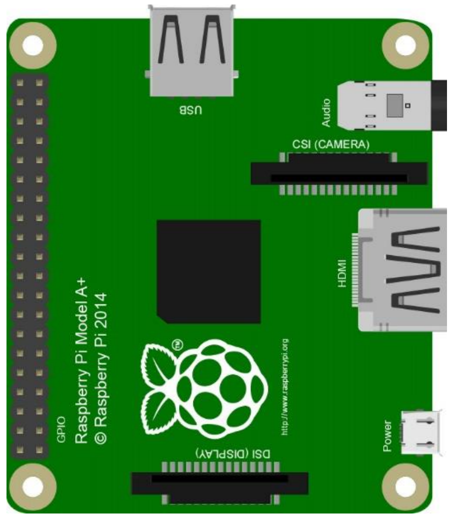
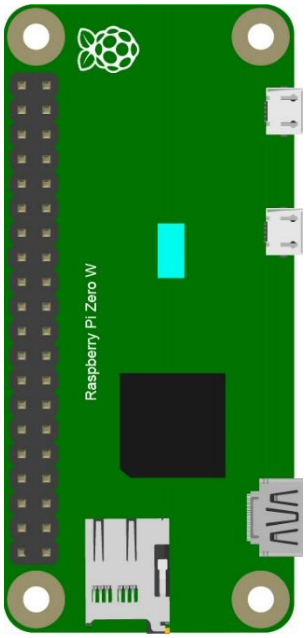
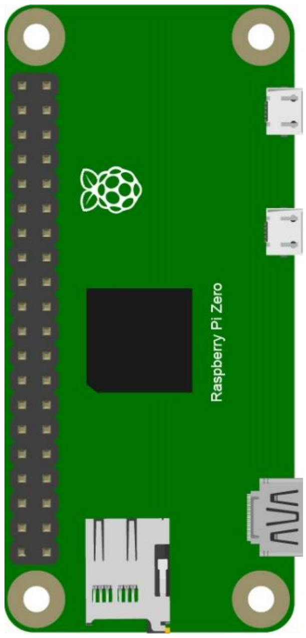
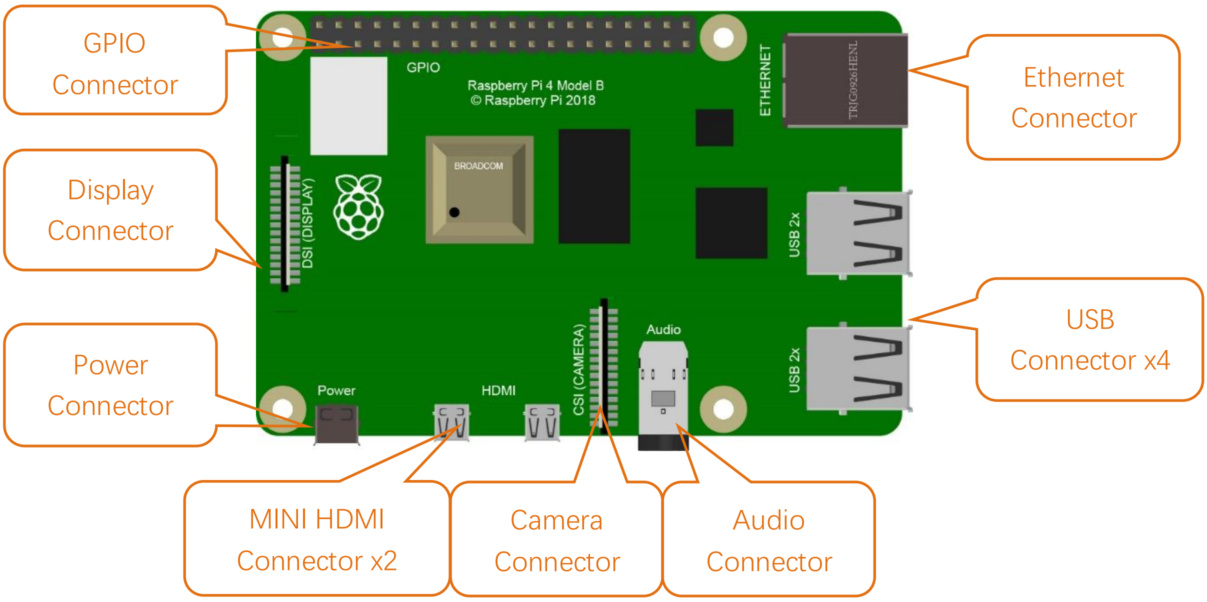
<td>Practicality picture of Raspberry Pi 2 Model B:
</td>
<td>Model diagram of Raspberry Pi 2 Model B:

</td>
</tr>
<tr>
<td>Practicality picture of Raspberry Pi 1 Model B+:
</td>
<td>Model diagram of Raspberry Pi 1 Model B+:

</td>
</tr>
</table>

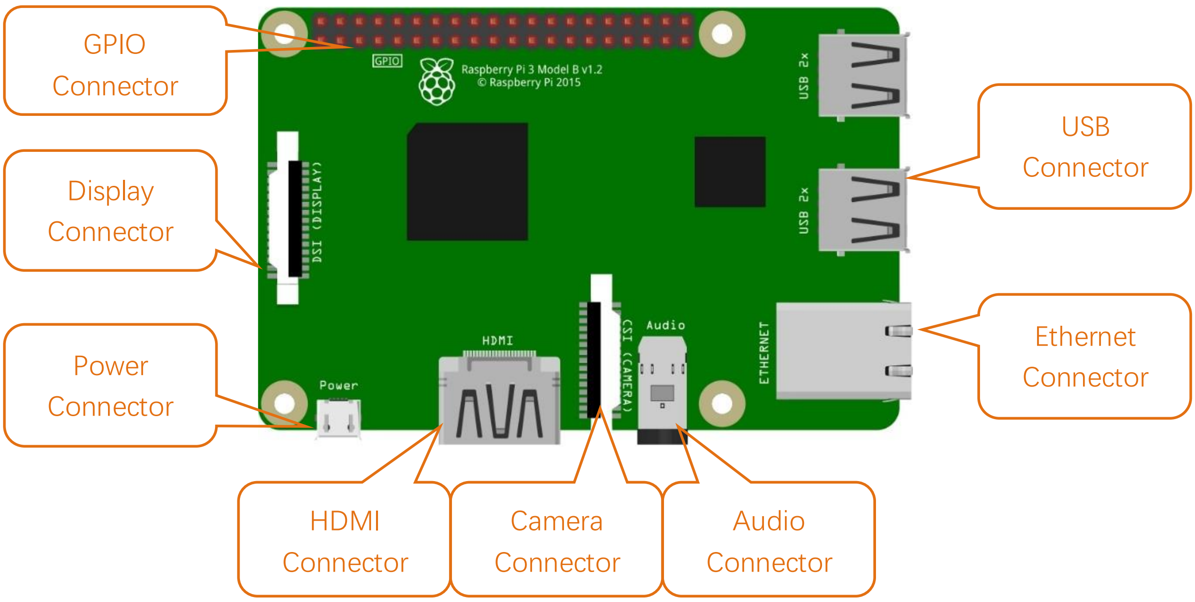
Practicality picture of Raspberry Pi 3 Model A+:	Model diagram of Raspberry Pi 3 Model A+:
	
Practicality picture of Raspberry Pi 1 Model A+:	Model diagram of Raspberry Pi 1 Model A+:
	

Practicality picture of Raspberry Pi Zero W: 	Model diagram of Raspberry Pi Zero W: 
Practicality picture of Raspberry Pi Zero: 	Model diagram of Raspberry Pi Zero: 

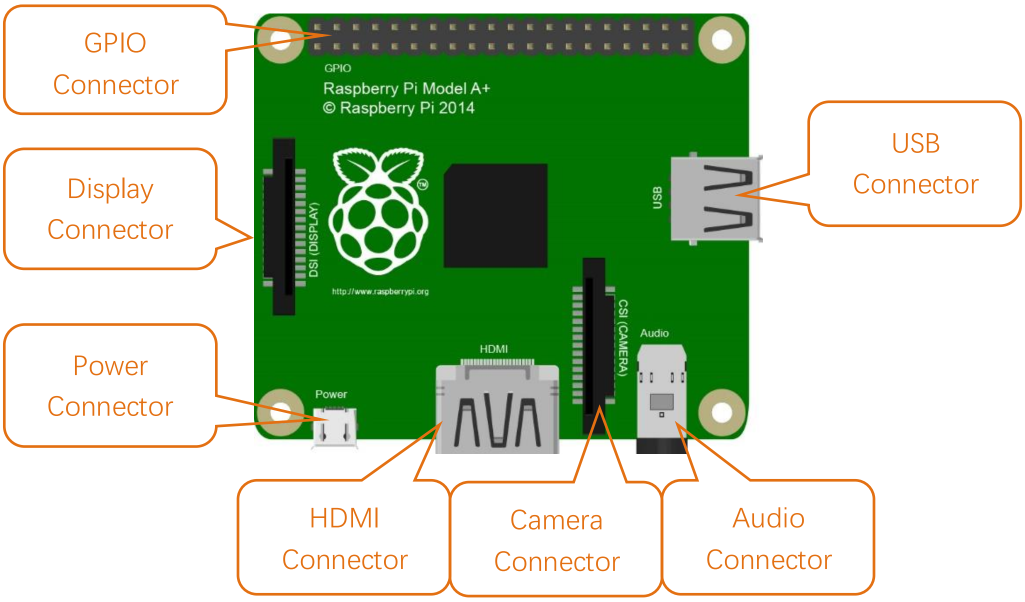
Hardware interface diagram of RPi 4B is shown below:



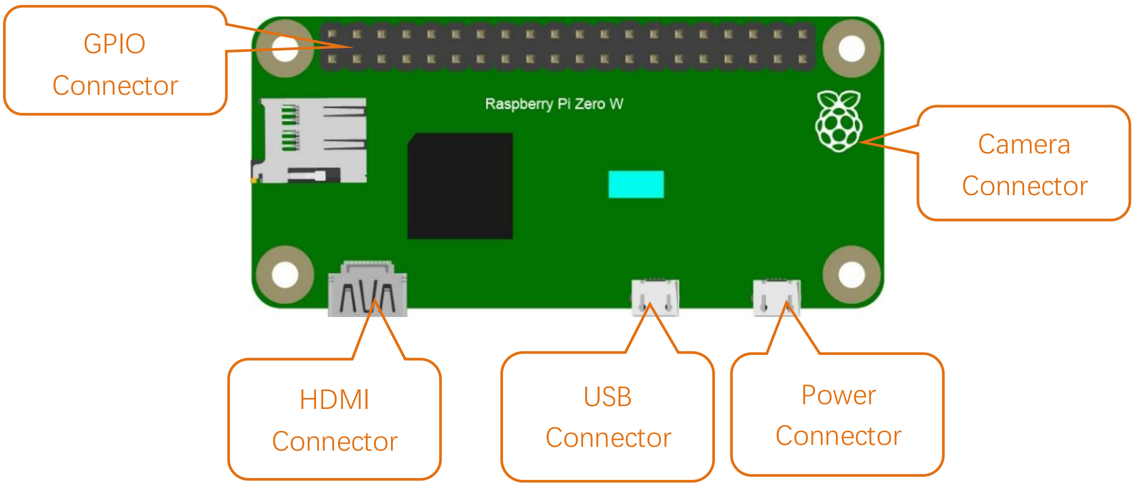
Hardware interface diagram of RPi 3B+/3B/2B/1B+ are shown below:



Hardware interface diagram of RPi 3A+/A+ is shown below:



Hardware interface diagram of RPi Zero/Zero W is shown below:

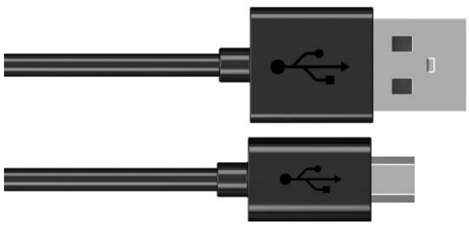


Install the System

Firstly, install a system for your RPi. If you have installed a system in your RPi.
You can start from Chapter 0 Preparation.

Component List

Required Components

Any Raspberry Pi 	5V/3A Power Adapter. Different versions of Raspberry Pi have different power requirements. 
Micro or Type-C USB Cable x1 	Micro SD Card(TF Card)x1, Card Reader x1 

Power requirement of different versions of Raspberry Pi is shown in following table:

Product	Recommended PSU current capacity	Maximum total USB peripheral current draw	Typical bare-board active current consumption
Raspberry Pi Model A	700mA	500mA	200mA
Raspberry Pi Model B	1.2A	500mA	500mA
Raspberry Pi Model A+	700mA	500mA	180mA
Raspberry Pi Model B+	1.8A	600mA/1.2A (switchable)	330mA
Raspberry Pi 2 Model B	1.8A	600mA/1.2A (switchable)	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 Zero W	1.2A	Limited by PSU, board, and connector ratings only.	150mA
Raspberry Pi Zero	1.2A	Limited by PSU, board, and connector ratings only	100mA

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

In addition, RPi also needs a network cable used to connect it to wide area network.

All these components are necessary. Among them, the power supply is required at least 5V/2.5A. Because a lack of sufficient power supply may lead to many abnormal problems and even damage to your RPi. So power supply with 5V/2.5A is highly recommend. SD Card Micro (recommended capacity 16GB or more) is a hard drive for RPi, which is used to store the system and personal files.

Optional Components

Under normal circumstances, there are two ways to login to Raspberry Pi: using independent monitor or using a remote desktop to share a monitor with your PC.

Required Accessories for Monitor

If you want to use independent monitor, mouse and keyboard, you also need the following accessories.
1.Display with HDMI interface
2.Mouse and Keyboard with USB interface

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

1. Mini-HDMI to HDMI converter&wire.
2. Micro-USB to USB-A Receptacles converter&wire (Micro USB OTG wire).
3. USB HUB.
4. USB transferring to Ethernet interface or USB Wi-Fi receiver.

For different Raspberry Pi, the optional items are slightly different. But they all aim to convert the special interface to standard interface of standard Raspberry Pi.

<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></tr>
<tr><td>Monitor</td><td colspan="7">Yes</td></tr>
<tr><td>Mouse</td><td colspan="7">Yes</td></tr>
<tr><td>Keyboard</td><td colspan="7">Yes</td></tr>
<tr><td>Mini-HDMI to HDMI converter or wire</td><td>Yes</td><td>No</td><td>Yes</td><td>No</td><td>No</td><td>No</td><td>No</td></tr>
<tr><td>Micro-HDMI to HDMI converter & wire</td><td colspan="6">No</td><td>Yes</td></tr>
<tr><td>Micro-USB to USB-A Receptacles converter & wire (Micro USB OTG wire)</td><td>Yes</td><td>No</td><td>Yes</td><td colspan="4">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></td></tr>
<tr><td>USB transferring to Ethernet interface</td><td colspan="2" rowspan="2">select one from two or select two from two</td><td colspan="2">optional</td><td>Internal Integration</td><td colspan="2" rowspan="2">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 don't have an independent monitor, or if you want to use a remote desktop, first you need to login to Raspberry Pi through SSH, then open the VNC or RDP service. So you need the following accessories.

<table>
<tr><th></th><th>Pi Zero</th><th>Pi Zero W</th><th>Pi A+</th><th>Pi 3A+</th><th>Pi B+/2B</th><th>Pi 3B/3B+/4B</th></tr>
<tr><td>Micro-USB to USB-A Receptacles converter&wire (Micro USB OTG wire)</td><td>Yes</td><td>Yes</td><td>No</td><td colspan="3" rowspan="2">NO</td></tr>
<tr><td>USB transferring to Ethernet interface</td><td>Yes</td><td>Yes</td><td>Yes</td></tr>
</table>

Raspbian System

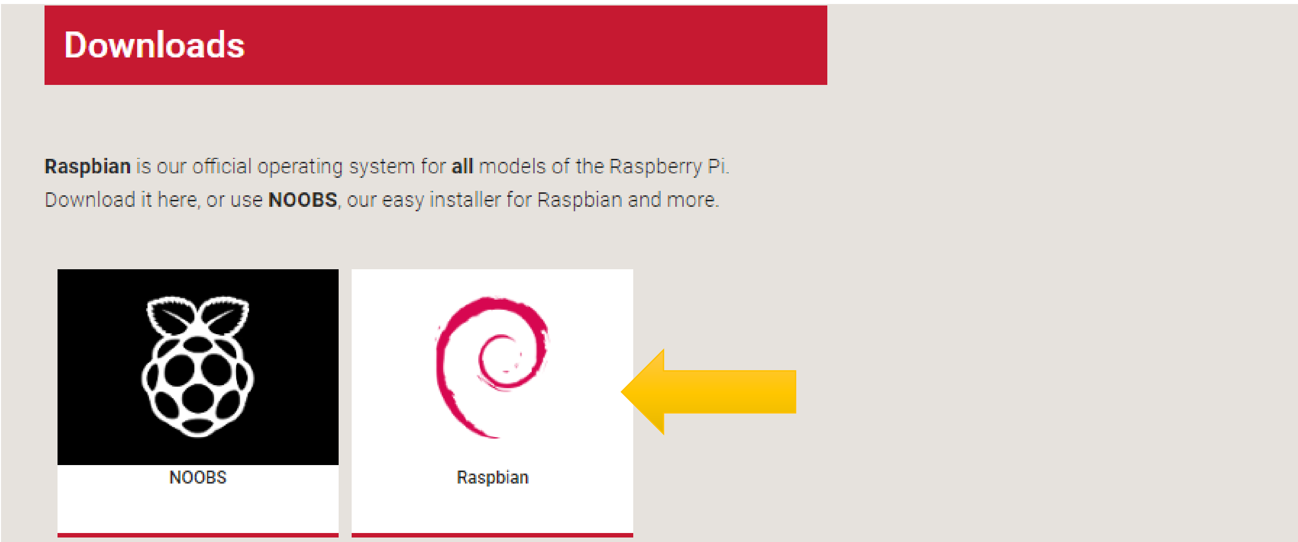
Official Method (Recommended)

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 download **automatically** via the application.

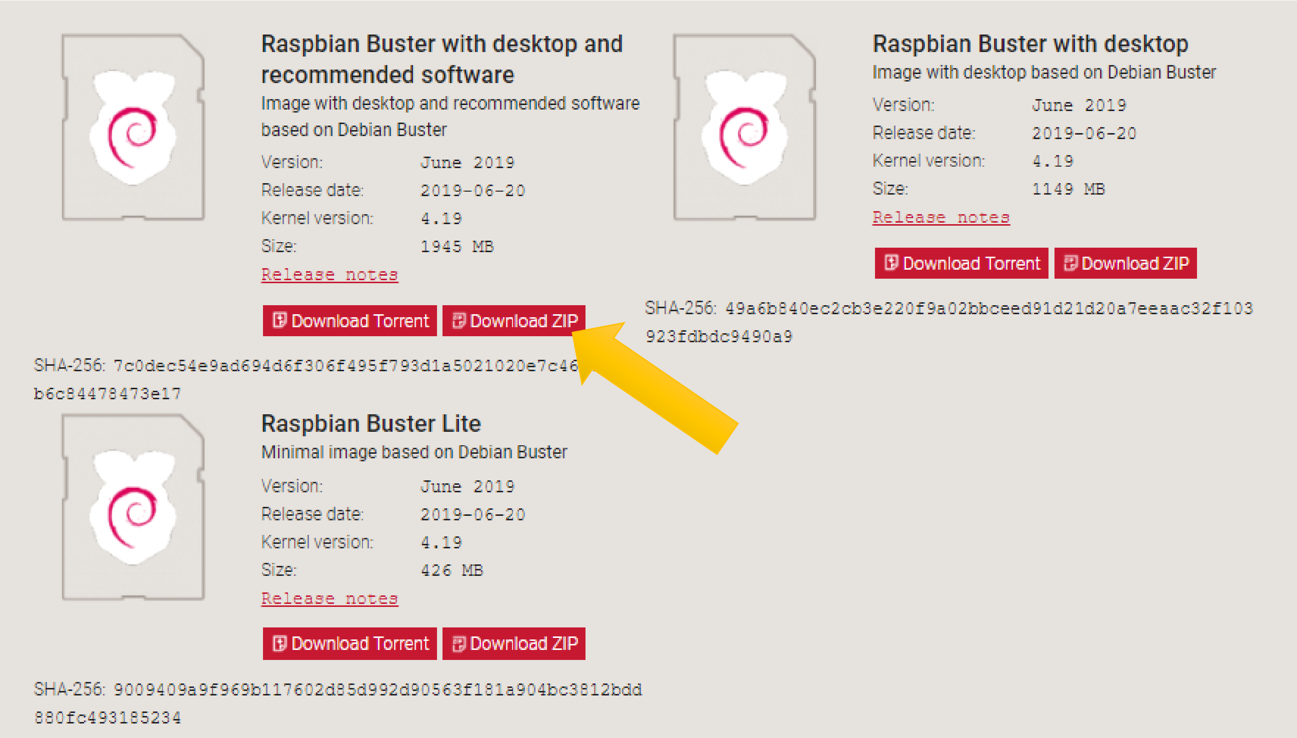
Download system manually (optional)

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

Visit RPi official website (https://www.RaspberryPi.org/), click "Downloads" and choose to download "RASPBIAN". RASPBIAN supported by RPI is an operating system based on Linux, which contains a number of contents required for RPi. We recommended RASPBIAN system to beginners. All projects in this tutorial are operated under the RASPBIAN system.



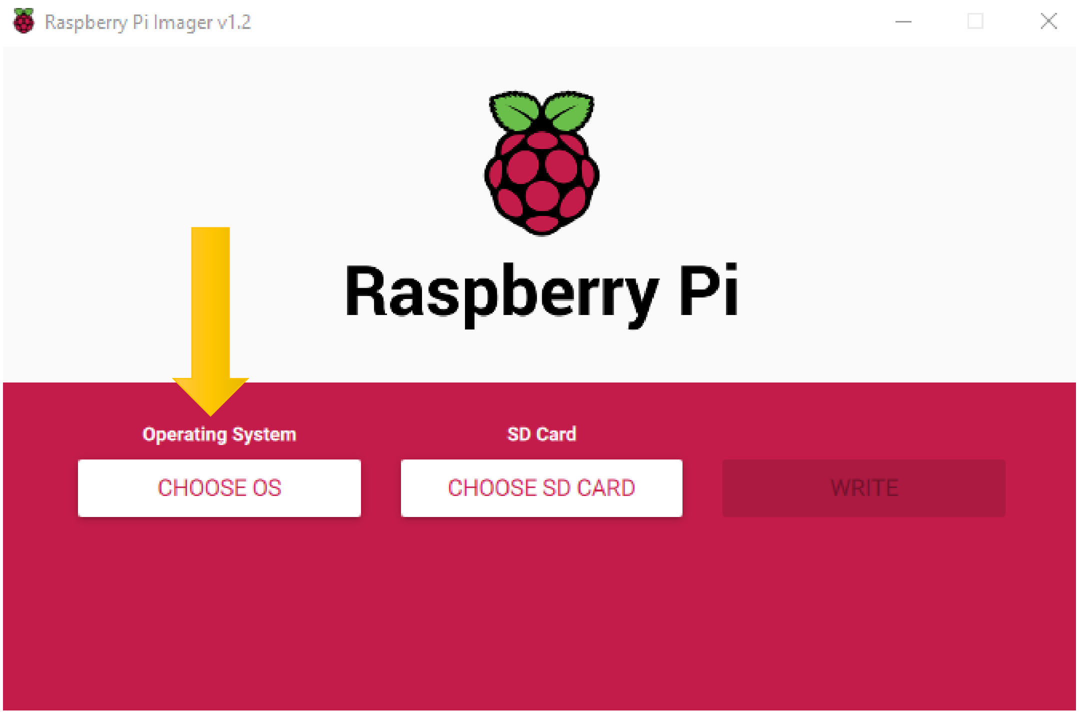
https://www.raspberrypi.org/downloads/raspbian/

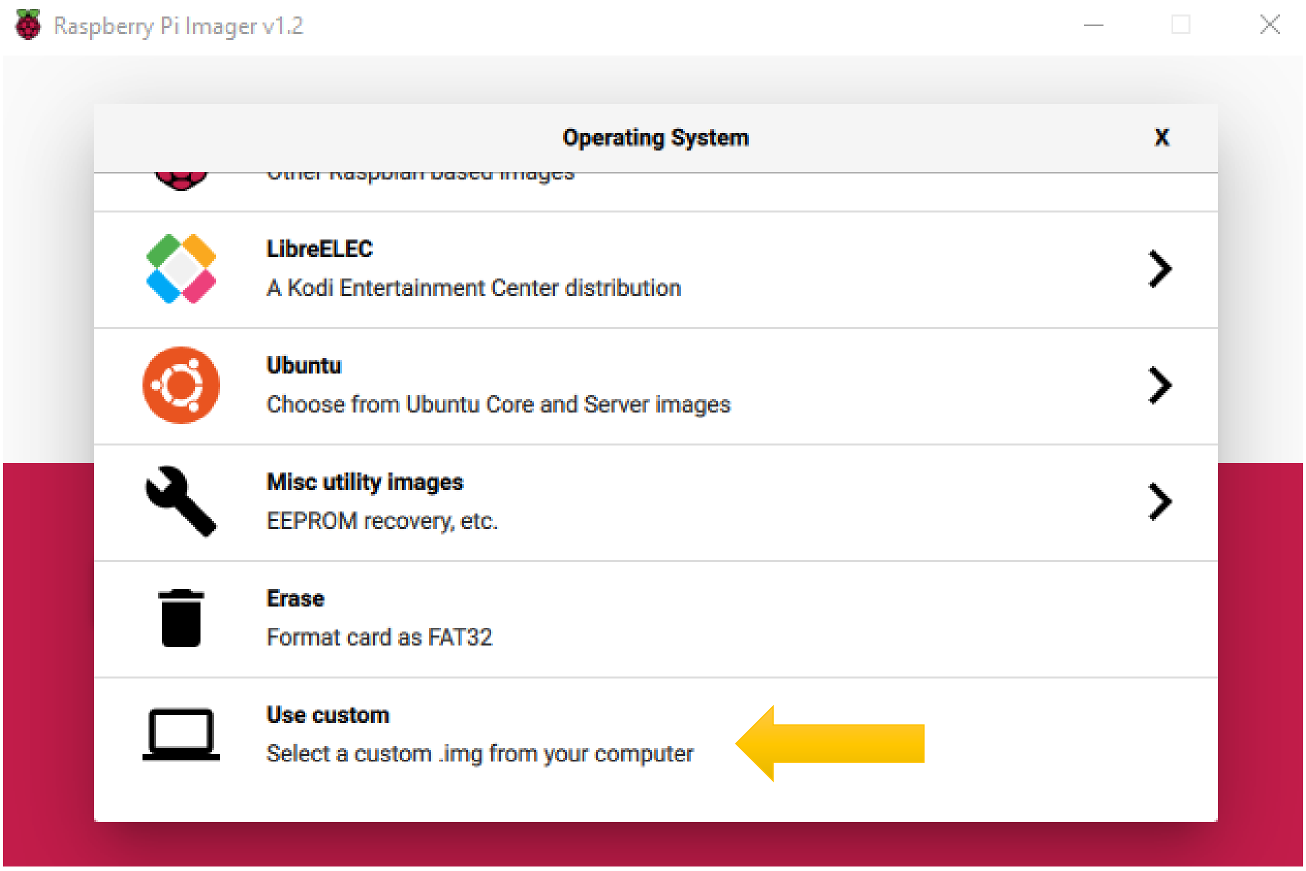


After the zip file is download.

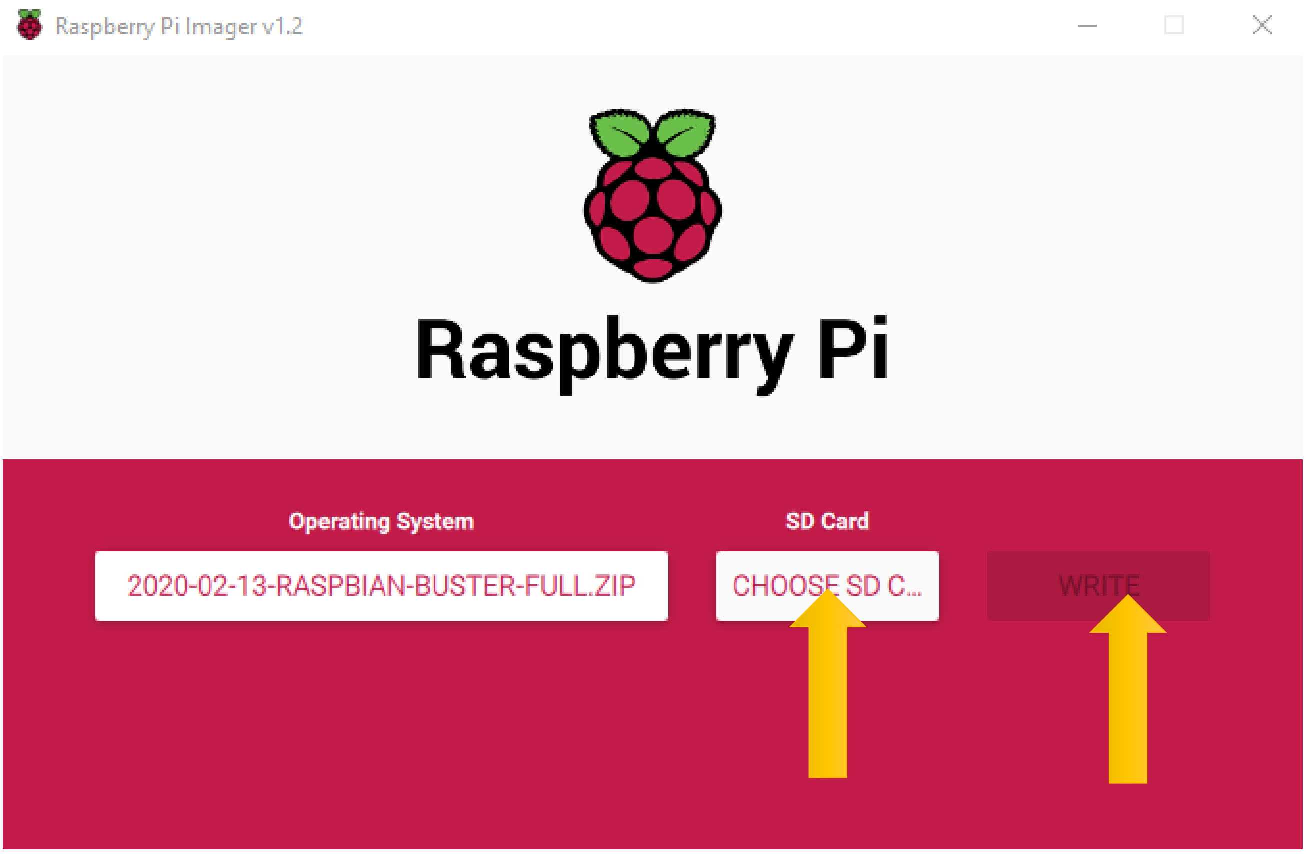
Write System to Micro SD Card

First, put your Micro **SD card** into card reader and connect it to USB port of PC. Then open imager toll, choose Choose system that you just download in Use custom.





Choose the SD card. Then click "WRITE".



Start Raspberry Pi

If you don't have a spare monitor, please jump to next section. If you have a spare monitor, please follow steps in this section.

After the system is written successfully, take out Micro SD Card and put it into the card slot of RPi. Then connect RPi to screen through the HDMI, to mouse and keyboard through the USB port, to network cable through the network card interface and to the power supply. Then your RPi will boot up. Later, you need to enter the user name and password to login. The default user name: pi; password: raspberry. Enter and login. After login, you can enter the following interface.

Now, you have successfully installed the RASPBIAN operating system for your RPi.

Raspberry Pi 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 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 remote desktop to control RPi under the Windows operating system.

Under windows, Raspberry Pi can be generally accessed remotely through two applications. The first one is the windows built-in application remote desktop, which corresponds to the Raspberry Pi xrdp service. The second one is the free application VNC Viewer, which corresponds to the VNC interface of Raspberry Pi. Each way has its own advantages. You can choose either one or two.

Windows	Raspberry Pi
Remote Desktop Connection	Xrdp
VNC Viewer	VNC

VNC Viewer can not only run under Windows, but also under system MAC, Linux, IOS, Android and so on.

SSH

Under previous Raspbian system, SSH is opened by default. Under the latest version of Raspbian system, it is closed by default. So you need to open it first.

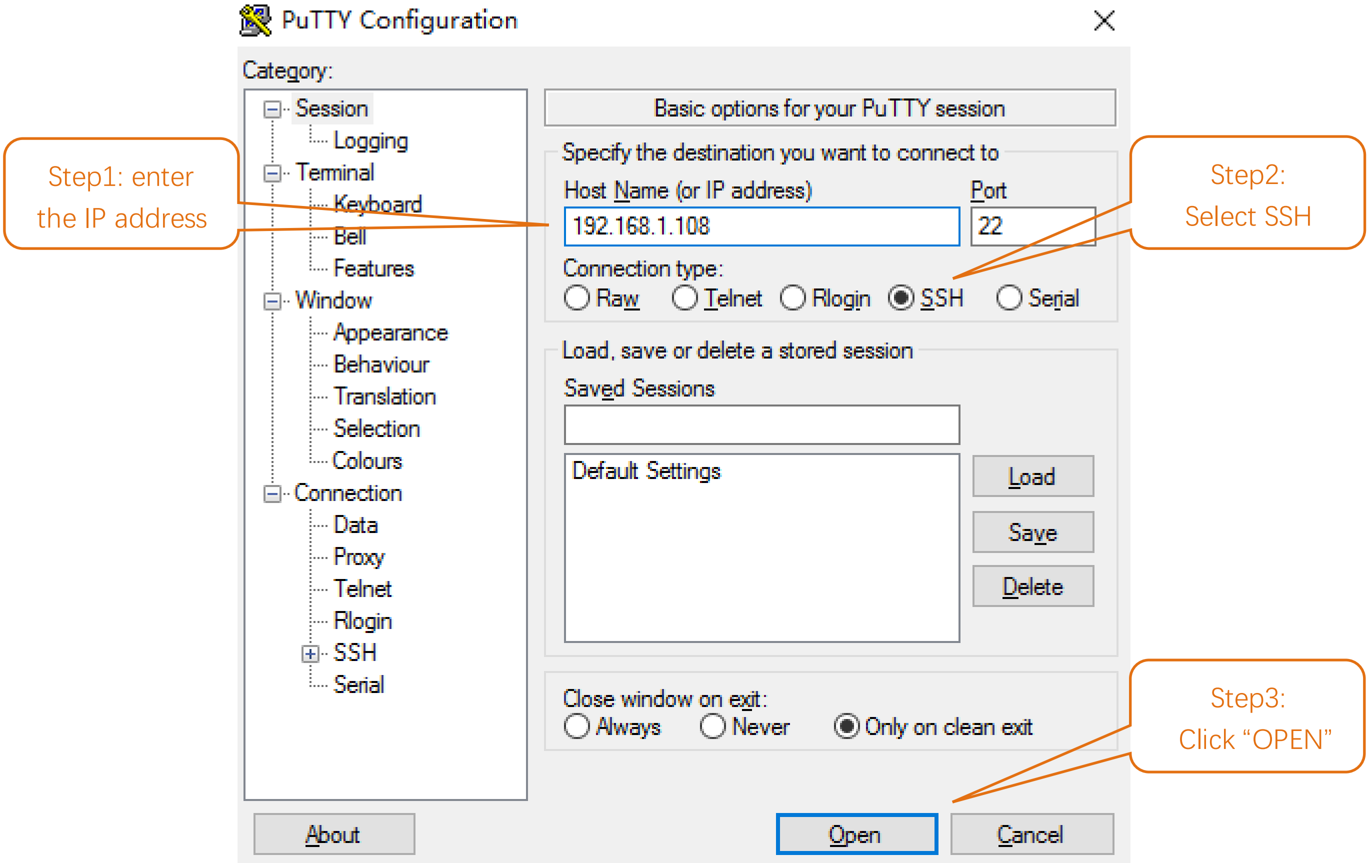
Method: after the system is written, create a folder named “ssh” under generated boot disk, then the SSH connection will be opened.

And then, download the tool software Putty. Its official address: http://www.putty.org/
Or download it here: http://www.chiark.greenend.org.uk/~sgtatham/putty/download.html

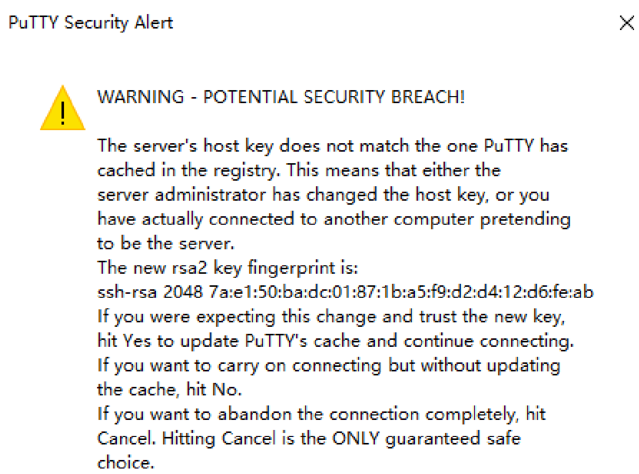
Then use cable to connect your RPi to the routers of your PC LAN, and make sure your PC and your RPi in the same LAN. Then put the system Micro SD Card prepared before into the slot of the RPi and turn on the power supply waiting for the RPi to start. Then find IP address named “raspberry pi” in router client.

.

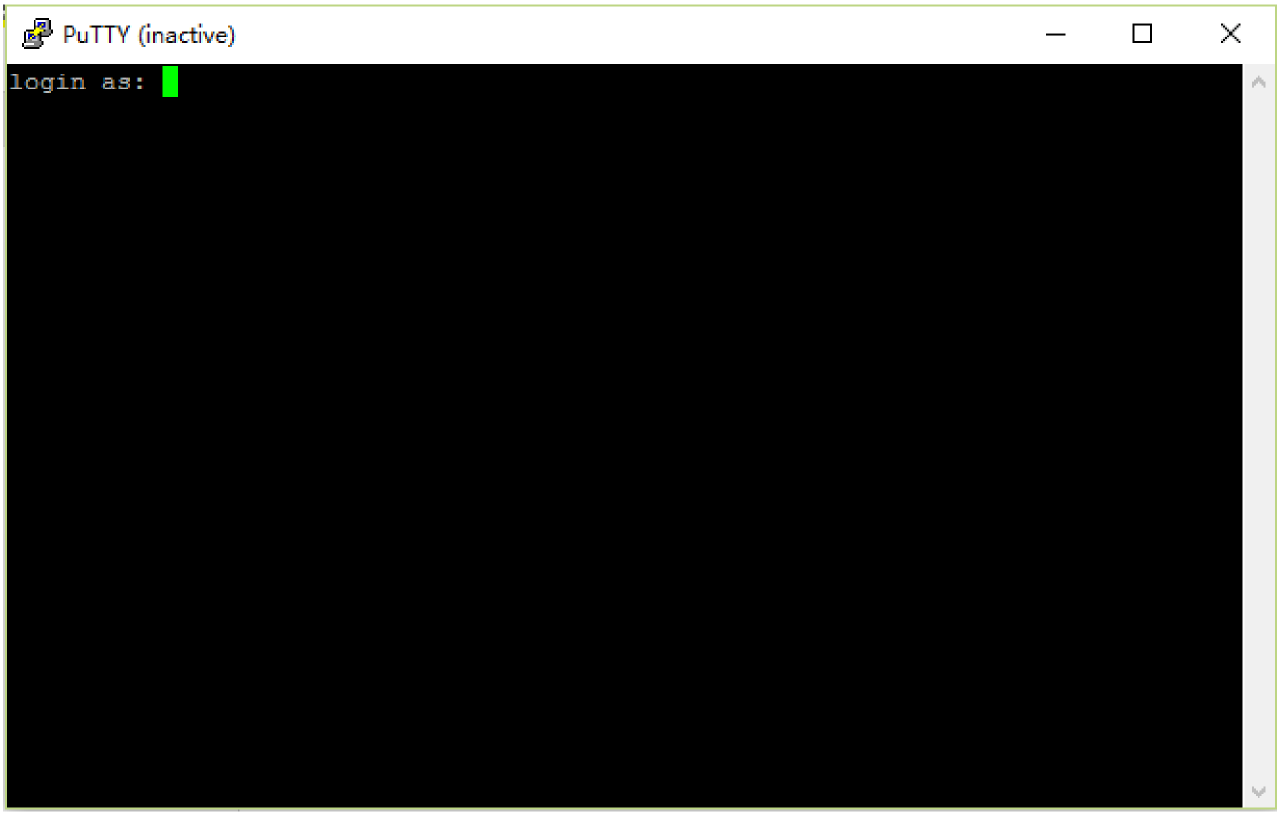
For example, I have found my RPi IP address, and it is “192.168.1.108". Then open Putty, enter the address, select SSH, and then click "OPEN", as shown below:



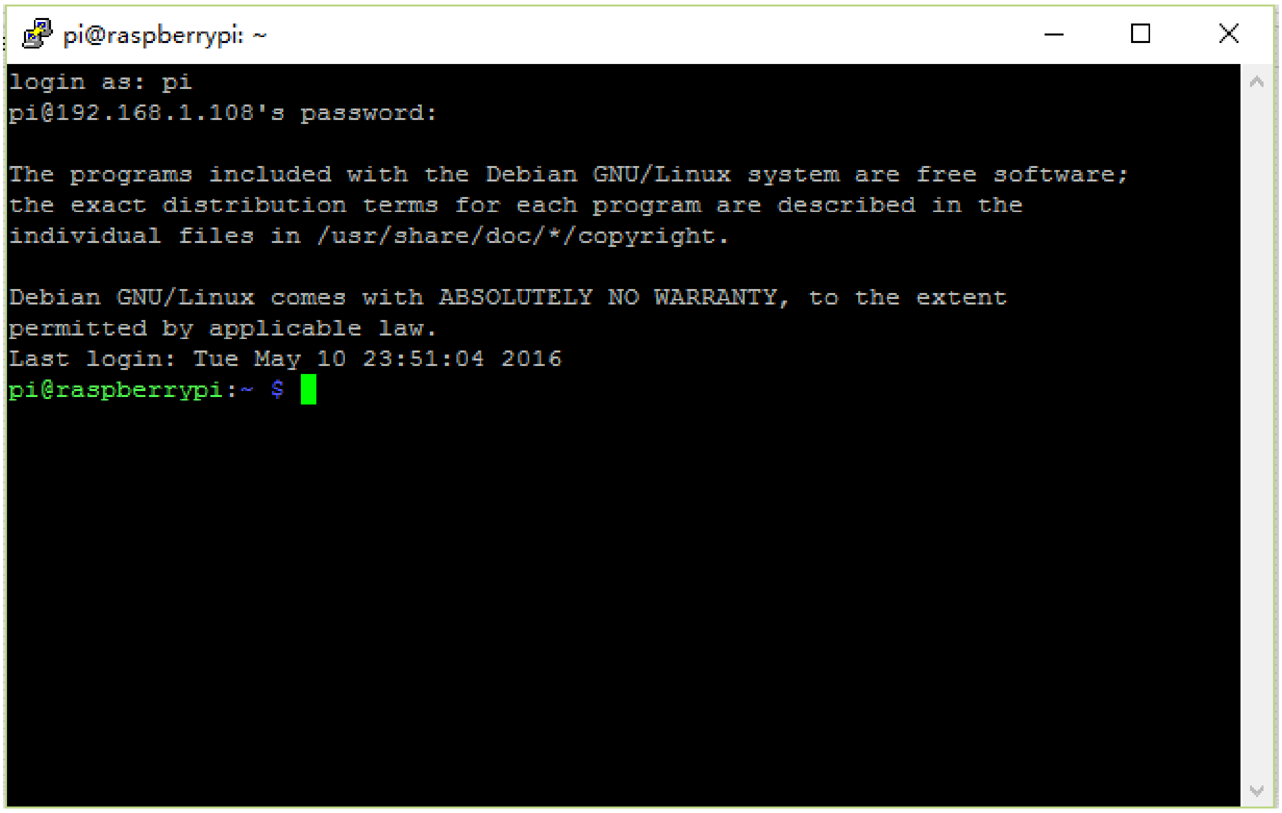
There will appear a security warning at first login. Just click “YES”.



Then there will be a login interface (RPi **default user name: pi; the password: raspberry**). When you enter the password, there will be no display on the screen. This is normal. After the correct input, press "Enter" to confirm.



Then enter the command line of RPi, which means that you have successfully login to RPi command line mode.



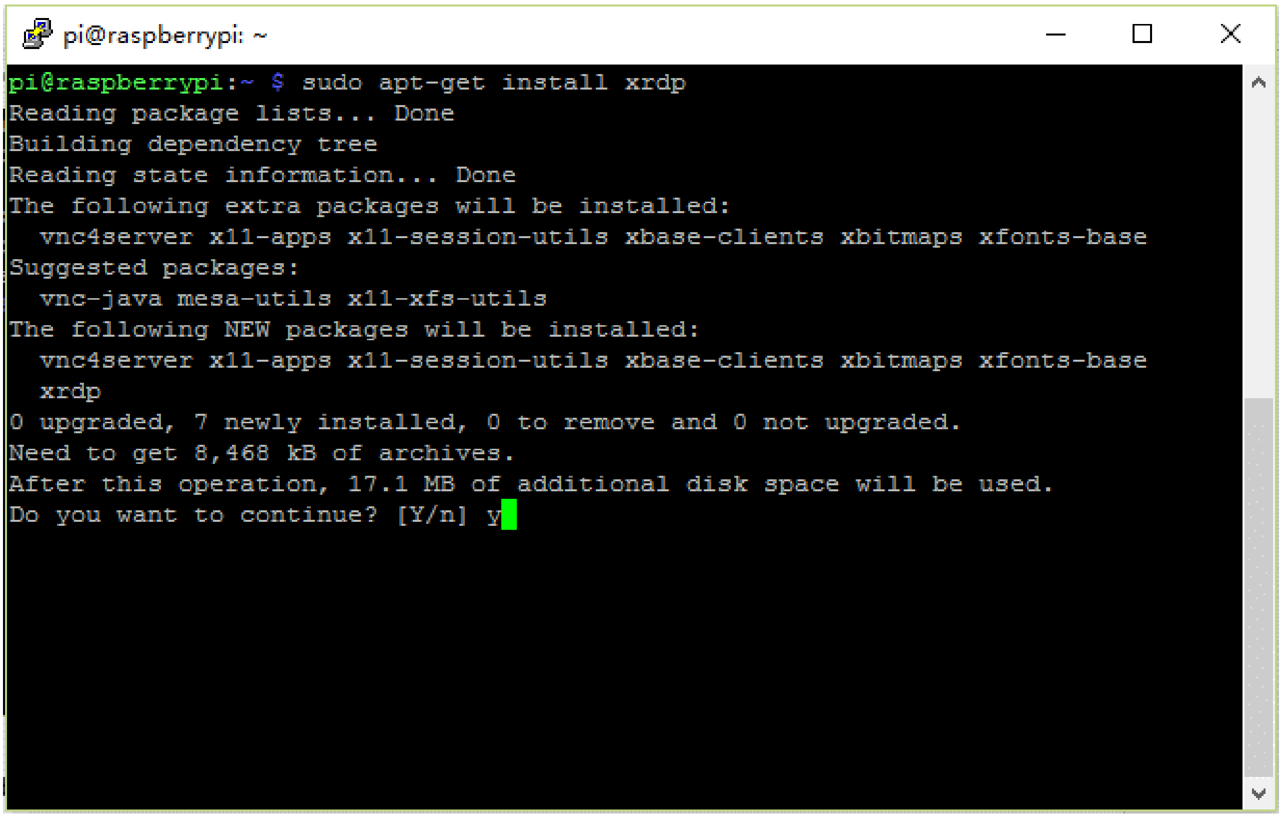
Remote Desktop Connection & xrdp

If you want to use built-in Remote Desktop Connection under Windows, you need install xrdp service on Raspberry Pi.

Next, install a xrdp service, an open source remote desktop protocol (rdp) server, for RPi. Type the command in the gray text box below, then press enter to confirm:

```
sudo apt-get install xrdp
```

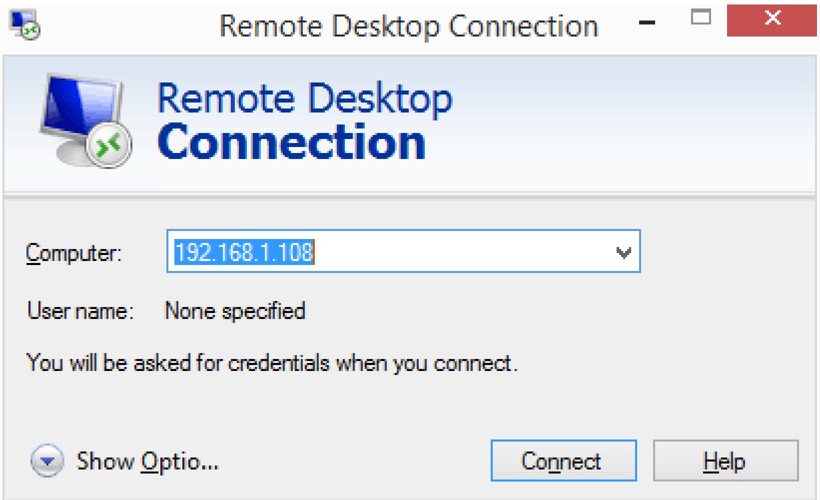
Later, the installation starts.



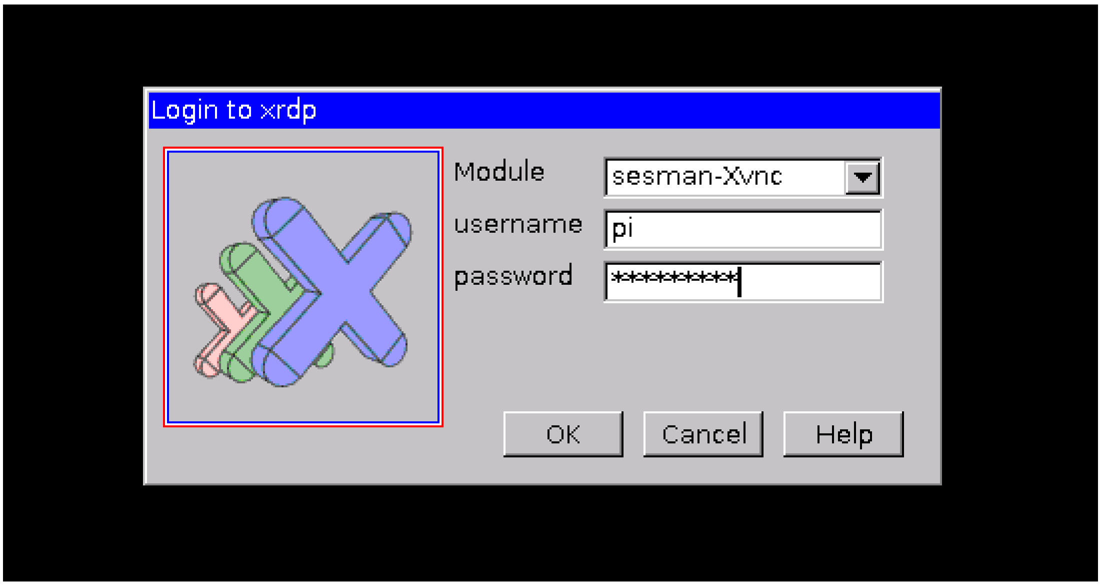
Enter "Y", press key “Enter” to confirm.
After the installation is completed, you can use Windows remote desktop applications to login to your RPi.

Login to Windows remote desktop

Use "WIN+R" or search function, open the remote desktop application "mstsc.exe" under Windows, enter the IP address of RPi and then click “Connect”.



Later, there will be xrdp login screen. Enter the user name and password of RPi (RPi default user name: pi; password: raspberry) and click “OK”.



Later, you can enter the RPi desktop system.

Here, you have successfully used the remote desktop login to RPi.

VNC Viewer & VNC

Type the following command.

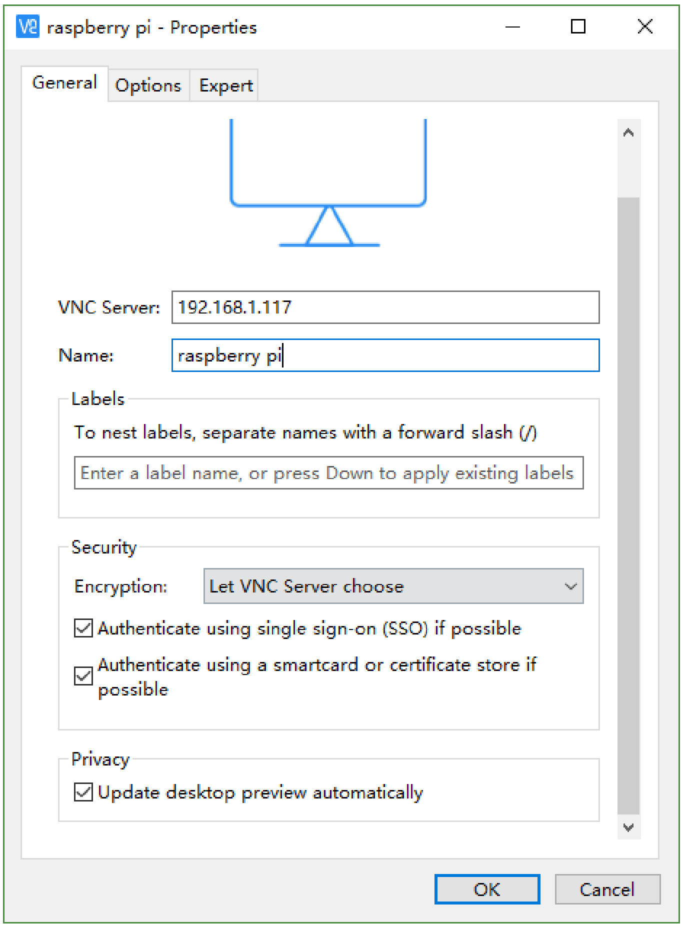
```
sudo raspi-config
```

And select 5 Interfacing Options→P3 VNC →Yes→OK→Finish. Here Raspberry Pi may need be restarted, and choose ok. Then open VNC interface.

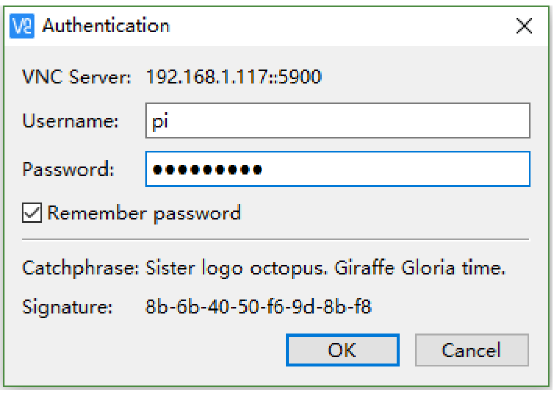
```
        Raspberry Pi Software Configuration Tool (raspi-config)

 1 Change User Password          Change password for the current u
 2 Network Options               Configure network settings
 3 Boot Options                  Configure options for start-up
 4 Localisation Options          Set up language and regional sett
 5 Interfacing Options           Configure connections to peripher
 6 Overclock                     Configure overclocking for your P
 7 Advanced Options              Configure advanced settings
 8 Update                        Update this tool to the latest ve
 9 About raspi-config            Information about this configurat

              <Select>                      <Finish>
```

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

 P1 Camera                       Enable/Disable connection to the
 P2 SSH                          Enable/Disable remote command lin
 P3 VNC                          Enable/Disable graphical remote a
 P4 SPI                          Enable/Disable automatic loading
 P5 I2C                          Enable/Disable automatic loading
 P6 Serial                       Enable/Disable shell and kernel m
 P7 1-Wire                       Enable/Disable one-wire interface
 P8 Remote GPIO                  Enable/Disable remote access to G

              <Select>                      <Back>
```

Then download and install VNC Viewer by click following link:
https://www.realvnc.com/en/connect/download/viewer/windows/
After installation is completed, open VNC Viewer. And click File → New Connection. Then the interface is shown below.



Enter ip address of your Raspberry Pi and fill in a Name. And click OK.
Then on the VNC Viewer panel, double-click new connection you just created, and the following dialog box pops up.



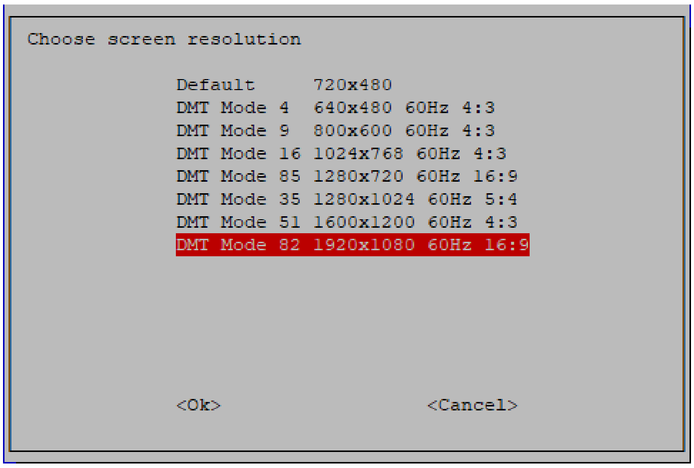
Enter username: pi and Password: raspberry. And click OK.

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

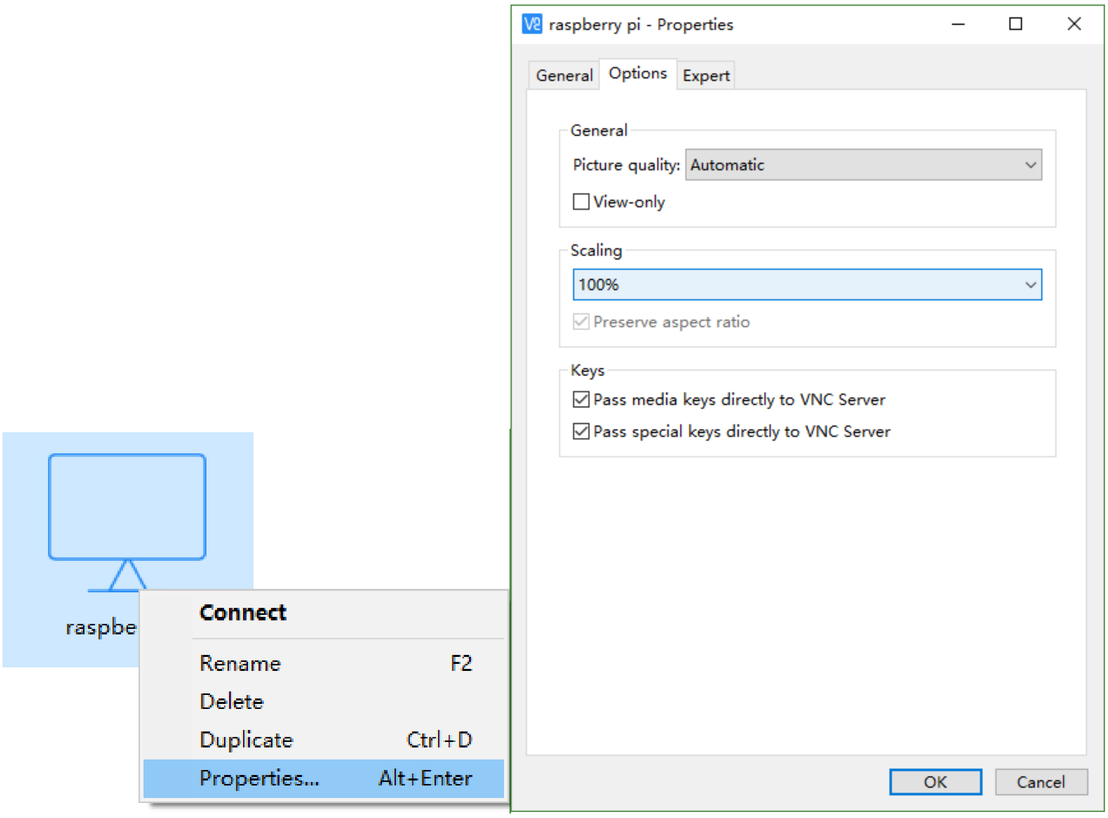
If the resolution ratio is not great or there is just a **black little window**, you can set a proper resolution ratio via steps below.

```
sudo raspi-config
```

Select 7 Advanced Options→A5 Resolution→proper resolution ratio(set by yourself)→OK. If it needs restart, just restart.



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. Then continue to do some preparation work: install a GPIO library wiringPi for your RPi.

Wi-Fi

Raspberry Pi 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.

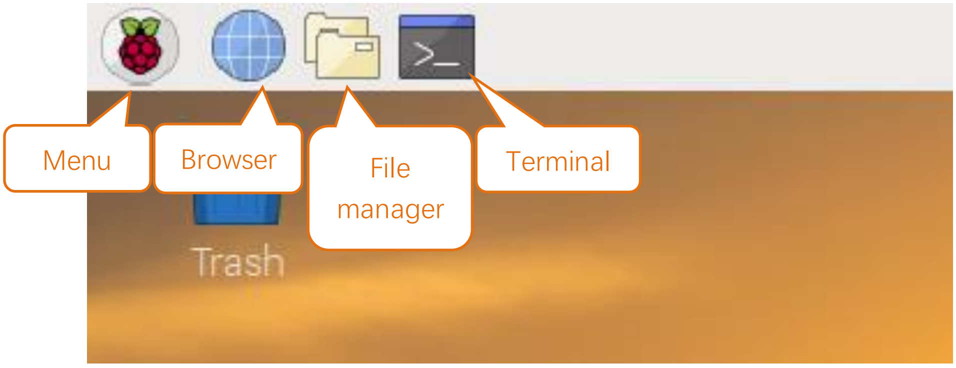
Chapter 0 Preparation

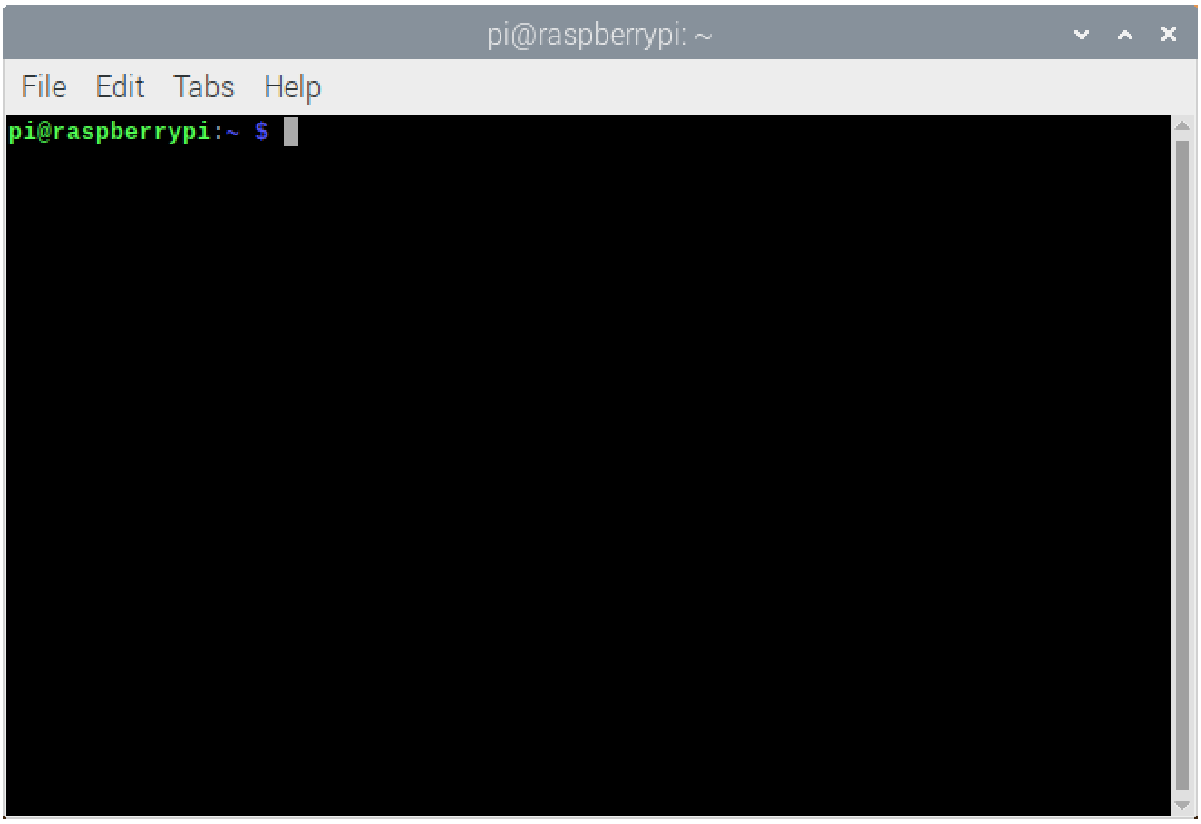
Why this Chapter 0? In the program code, all the counts are starting from 0. So we choose to follow this rule. In this chapter, we will do some necessary preparation work: start your Pi Raspberry and install some necessary libraries. If your Raspberry Pi can be started normally and used normally, you can skip this chapter.

Linux Command

Raspbian is based on Linux operation system. Now we will introduct some frequently-used Linux commands and usage.

First, opent terminal. All commands are executed in terminal.





And it is Linux which is case sensitive.

Then type “ls” in terminal and press “Enter” key. The result is shown below:

```
pi@raspberrypi: ~
File  Edit  Tabs  Help
pi@raspberrypi:~ $ ls
Desktop                                          Music
Documents                                        Pictures
Downloads                                        Public
Freenove_Three-wheeled_Smart_Car_Kit_for_Raspberry_Pi  Templates
Freenove_Ultimate_Starter_Kit_for_Raspberry_Pi   thinclient_drives
MagPi                                            Videos
mu_code
```

”ls”, List information about the FILEs (the current directory by default). Sort entries alphabetically.

Content between “$” and ”pi@raspberrypi:” is the current working path. “~” presents user directory. It is equal to “/home/pi” here. “pwd” can be used to view current working path.

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

“cd” is used to change directory. / presents 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:~ $
```

In later content, we will often change working path. Typing commands under the wrong directory may cause errors and break the execution of further commands. There are some frequently used commands and instructions in following table.

Command	instruction
ls	List information about the FILEs (the current directory by default). Sort entries alphabetically.
cd	Change directory
sudo + cmd	Excute 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 is the repository address.

There are many commands later. For more details about command. You can refer to:

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

Shortcut Key

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

1. **up and down arrow keys**. History commands can be quickly brought back by using up and down arrow keys, which are very useful when you need to reuse certain commands.
When you need to type command, pressing "↑" will bring back the previous command, and pressing "↓" will bring back the latter command.

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

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

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

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

Install WiringPi

WiringPi is a GPIO access library written in C for the BCM2835/BMC2836/ BMC2837 used in the Raspberry Pi. It's released under the GNU LGPLv3 license and is usable from C, C++ and many other languages with suitable wrappers (See below) It's designed to be familiar to people who have used the Arduino "wiring" system. (for more details, please refer to http://wiringpi.com/)

WiringPi Installation Steps

New Raspbian system has integrated this library. So it may prompt that you have installed it.
Open the terminal. Follow these steps and commands to complete the installation.
For command with many lines, execute them line by line.
Enter the following command in the terminal to install WiringPi:

```
sudo apt-get update
sudo apt-get upgrade
sudo apt-get install wiringpi
```

As shown below, the installation will be completed soon.

```
pi@raspberrypi:~ $ sudo apt-get install wiringpi
Reading package lists... Done
Building dependency tree
Reading state information... Done
The following packages were automatically installed and are no longer required:
  freetype2-doc rpi.gpio-common
Use 'sudo apt autoremove' to remove them.
The following NEW packages will be installed:
  wiringpi
0 upgraded, 1 newly installed, 0 to remove and 0 not upgraded.
Need to get 0 B/52.9 kB of archives.
After this operation, 0 B of additional disk space will be used.
Selecting previously unselected package wiringpi.
(Reading database ... 159071 files and directories currently installed.)
Preparing to unpack .../wiringpi_2.50_armhf.deb ...
Unpacking wiringpi (2.50) ...
Setting up wiringpi (2.50) ...
Processing triggers for man-db (2.8.5-2) ...
```

Run the gpio command to check the installation:

```
gpio -v
```

That should give you some confidence that it's working well.

```
pi@raspberrypi:~ $ gpio -v
gpio version: 2.50
Copyright (c) 2012-2018 Gordon Henderson
This is free software with ABSOLUTELY NO WARRANTY.
For details type: gpio -warranty

Raspberry Pi Details:
  Type: Unknown17, Revision: 01, Memory: 1024MB, Maker: Sony
  * Device tree is enabled.
  *--> Raspberry Pi 4 Model B Rev 1.1
  * This Raspberry Pi supports user-level GPIO access.
```

Obtain the Project Code

After the above work is done, you can visit our official website (http://www.freenove.com) or our github (https://github.com/freenove) to download the latest project code. We provide both **C** language and **Python** language code for each project in order to apply to user skilled in different languages.

Method for obtaining the code:
In the pi directory of the RPi terminal, enter the following command.

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

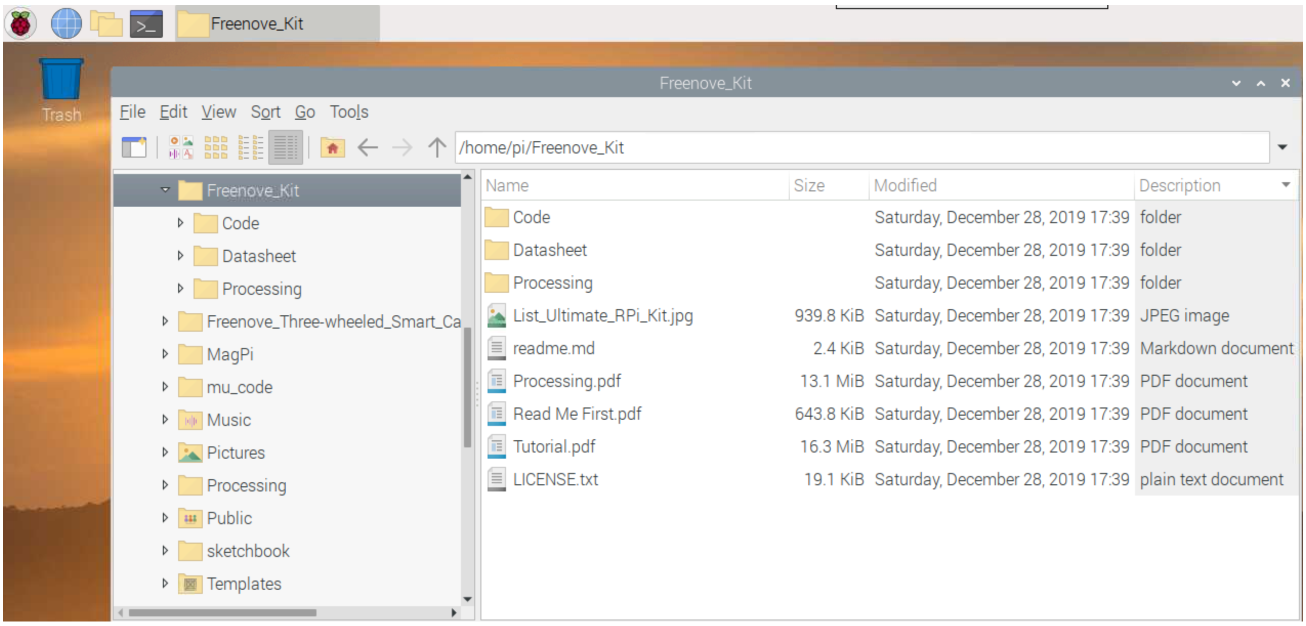
(There is no need for password. If you get some errors, please check if your commands is correct.)

After the download is complete, a new folder "Freenove_LCD_Starter_Kit_for_Raspberry_Pi" is generated, which contains all the tutorials and code.

The folder name is too long. Here we rename it by following command.

```
mv Freenove_LCD_Starter_Kit_for_Raspberry_Pi/ Freenove_Kit/
```

Among command above, "Freenove_Kit" represents the new folder name. You can also rename the folder directly.



If you never learned anything of python, it is recommended to refer to follow website for basic knowledge.
https://python.swaroopch.com/basics.html

Python2 & Python3 (necessary)

If you only use C/C++, you can skip this section.

Now Python code of our kits can run on Python2 and Python3. **Python3 is recommended**. If you want to use python2, please make sure your Python version is above 2.7. Python2 and Python3 is not fully compatible.

You can type python2 and python3 in the terminal respectively to check if python has been installed. Press **"Ctrl+Z"** to exit.

```
pi@raspberrypi:~ $ python2
Python 2.7.13 (default, Nov 24 2017, 17:33:09)
[GCC 6.3.0 20170516] on linux2
Type "help", "copyright", "credits" or "license" for more information.
>>>
[2]+  Stopped                 python2
pi@raspberrypi:~ $ python3
Python 3.5.3 (default, Jan 19 2017, 14:11:04)
[GCC 6.3.0 20170124] on linux
Type "help", "copyright", "credits" or "license" for more information.
>>>
```

Type python, and the terminal shows that it links to python2.

```
pi@raspberrypi:~ $ python
Python 2.7.13 (default, Nov 24 2017, 17:33:09)
[GCC 6.3.0 20170516] on linux2
Type "help", "copyright", "credits" or "license" for more information.
>>>
```

If you want to use editor Geany or Thonny, you need set Python3 as default Python first. Please follow steps below.

1. Enter directory /usr/bin

```
cd /usr/bin
```

2. Delete the old python link.

```
sudo rm python
```

3. Create new python links to python3.

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

4. Execute python to check whether the link succeeds.

```
python
```

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

If you want to set python2 as default python, repeat above steps and just change the third command to the following.

```
sudo ln -s python2 python
```

```
pi@raspberrypi:/usr/bin $ sudo rm python
pi@raspberrypi:/usr/bin $ sudo ln -s python2 python
pi@raspberrypi:/usr/bin $ python
Python 2.7.13 (default, Nov 24 2017, 17:33:09)
[GCC 6.3.0 20170516] on linux2
Type "help", "copyright", "credits" or "license" for more information.
>>>
```

Most code in our tutorial support python2 and python3.
For example, we will execute a same python file Hello.py with Python2 and Python3.
First, use Python2 to execute the code.

1. Use cd command to enter 00.0.0_Hello directory of Python code.

```
cd ~/Freenove_Kit/Code/Python_Code/00.0.0_Hello
```

2. Use python2 command to execute python code Hello.py.

```
python2 Hello.py
```

```
pi@raspberrypi:~ $ cd Freenove_Kit/Code/Python_Code/00.0.0_Hello/
pi@raspberrypi:~/Freenove_Kit/Code/Python_Code/00.0.0_Hello $ python2 Hello.py
Hello World!
```

Use Python3 to execute the code under same directory.

3. Use python3 command to execute python code Hello.py.

```
python3 Hello.py
```

```
pi@raspberrypi:~ $ cd Freenove_Kit/Code/Python_Code/00.0.0_Hello/
pi@raspberrypi:~/Freenove_Kit/Code/Python_Code/00.0.0_Hello $ python3 Hello.py
Hello World!
```

As you can see, we get same results.

Because the code for our kit supports Python2 and Python3. We just say python later, not specific Python2 or Python3. You can choose python version according to your situation.

Code Editor

This part is not necessary for later projects.

vi, nano, Geany

vi

Here we will introduce three kinds of code editor: vi, nano and Geany. Among them, nano and vi are used to edit files directly in the terminal. And Geany is an independent editing software, which is recommended for beginner. We will use the three editors to open an example code "Hello.c" respectively later. First we will show how use vi and nano editor:

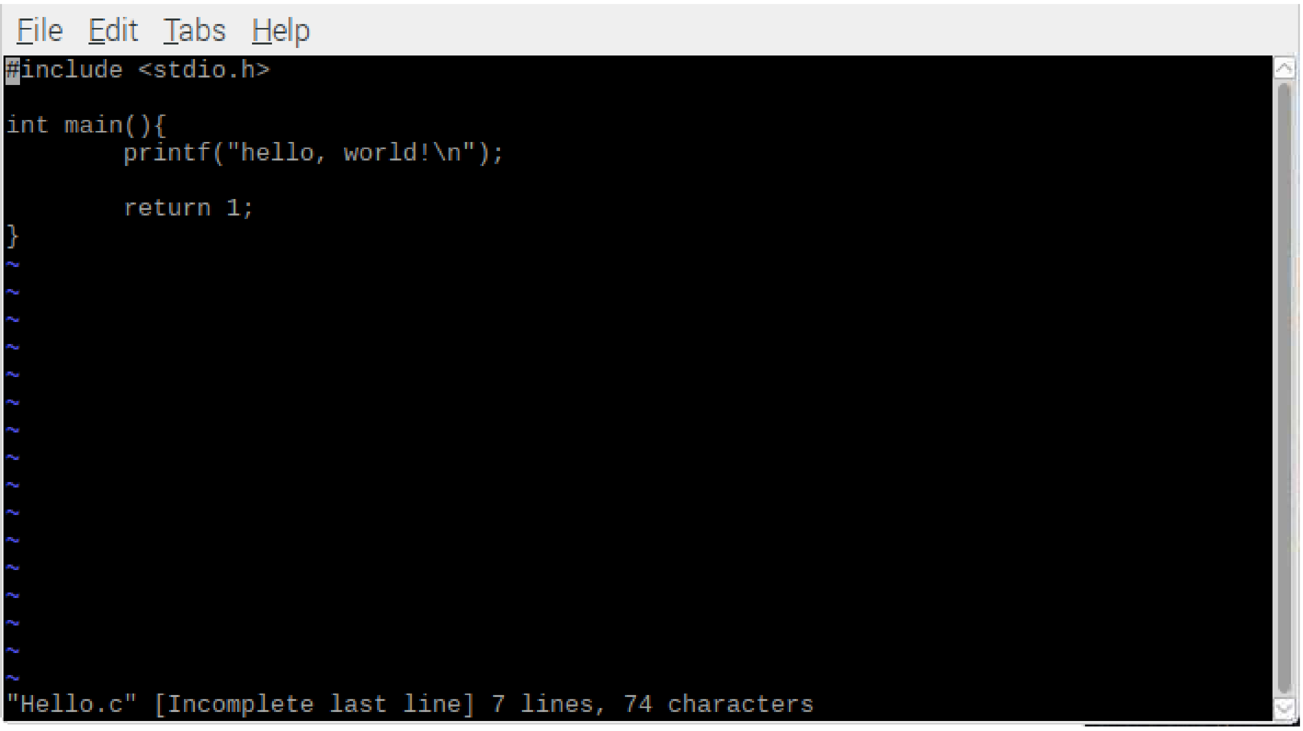
First, use cd command to enter the sample code folder.

```
cd ~
cd ~/Freenove_Kit/Code/C_Code/00.0.0_Hello
```

Use the vi editor to open the file "Hello.c", then press ": q" and “Enter” to exit.

```
vi Hello.c
```

As is shown below:

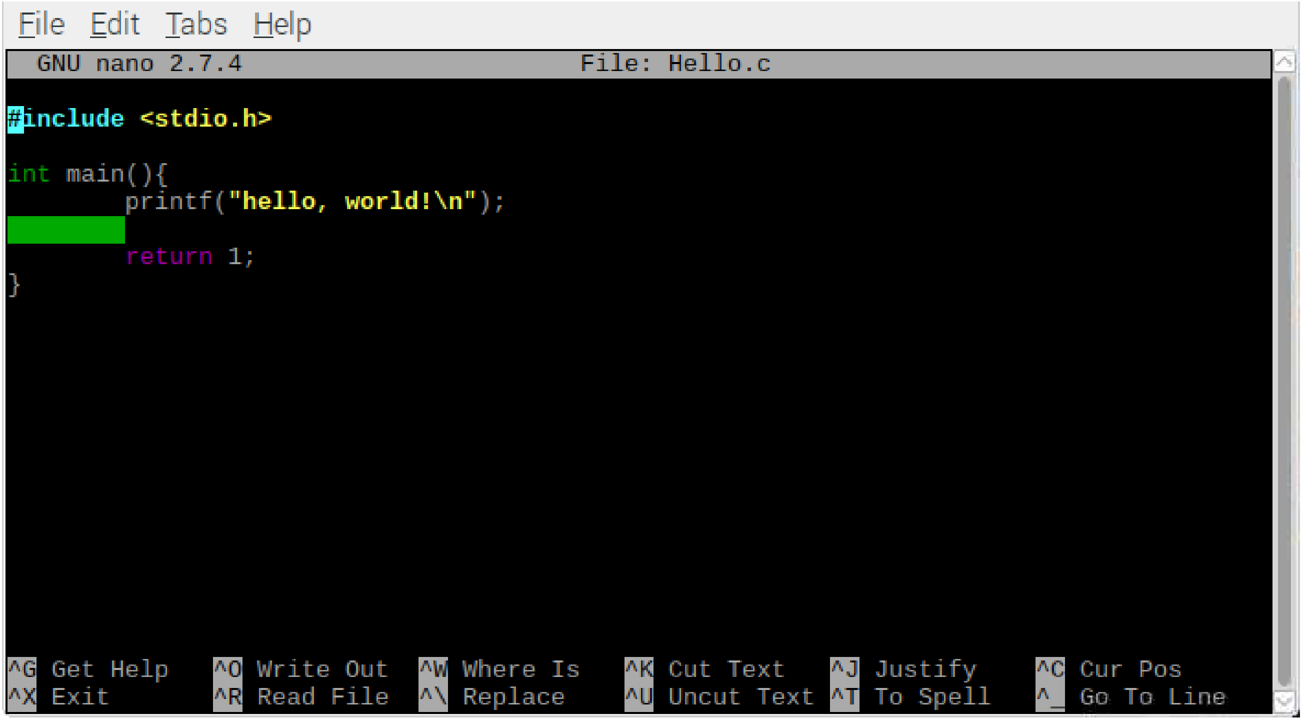


nano

Use the nano editor to open the file "Hello.c", then press " Ctrl+X " to exit.

```
nano Hello.c
```

As is shown below:



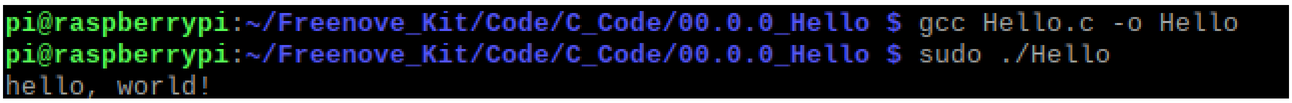
Use the following command to compile the code to generate the executable file "Hello".

```
gcc Hello.c  -o Hello
```

Use the following command to run the executable file "Hello".

```
sudo ./Hello
```

After the execution, "Hello, World!" is printed out in terminal.

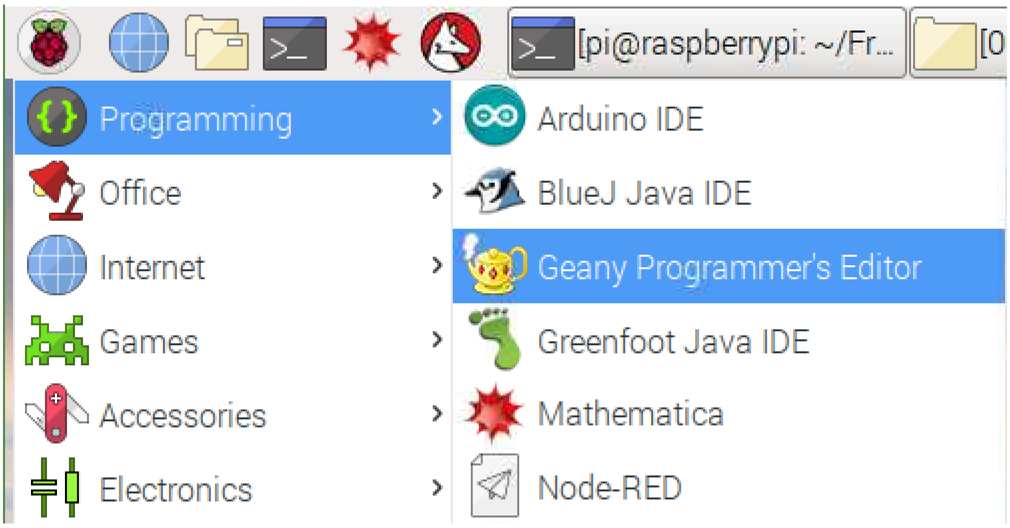


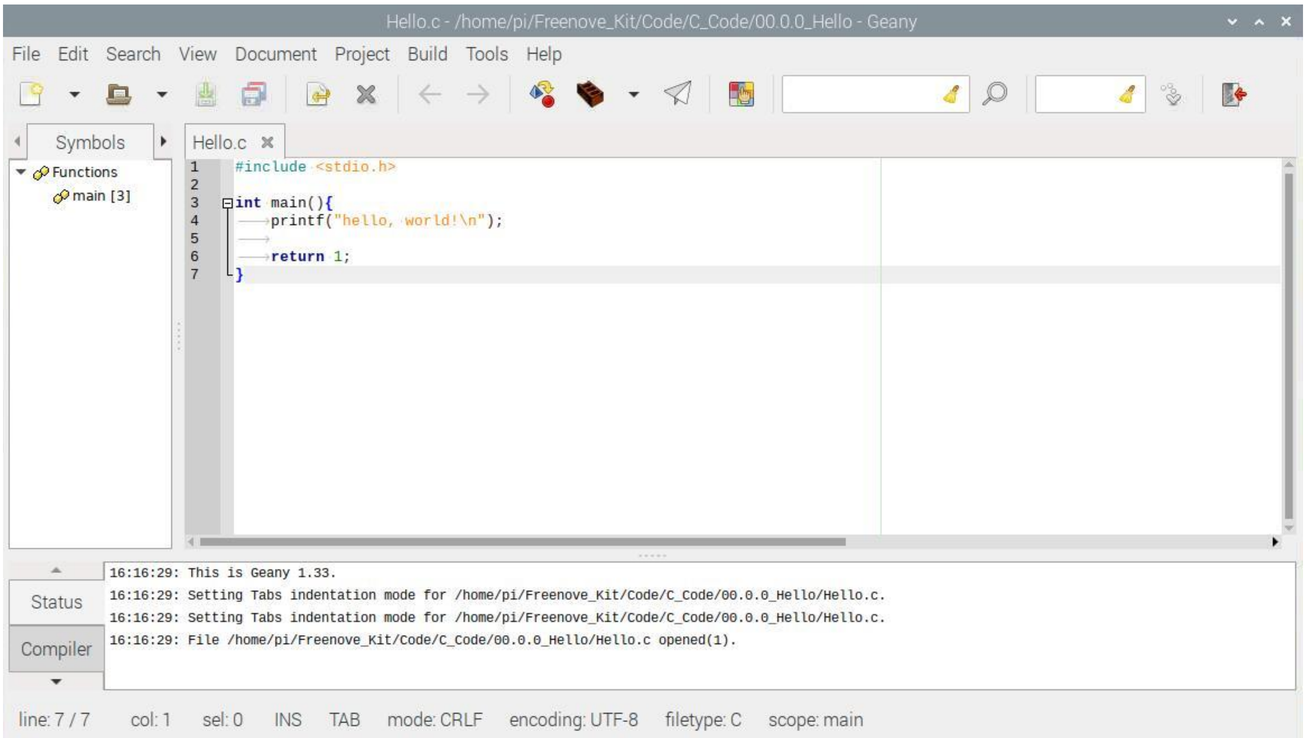
Geany

Next, learn to use the Geany editor. Use the following command to open the Geany in the sample file "Hello.c" file directory path.

```
geany Hello.c
```

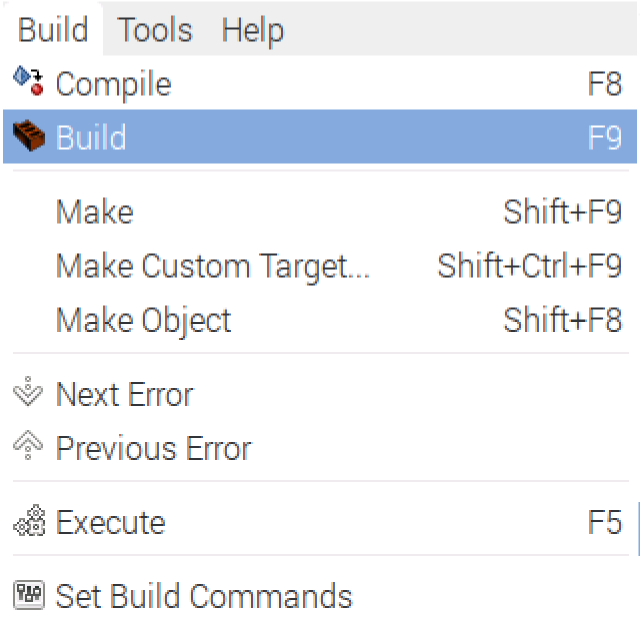
Or find and open Geany directly in the desktop main menu, and then click **File→Open** to open the "Hello.c", Or drag "Hello.c" to Geany directly.

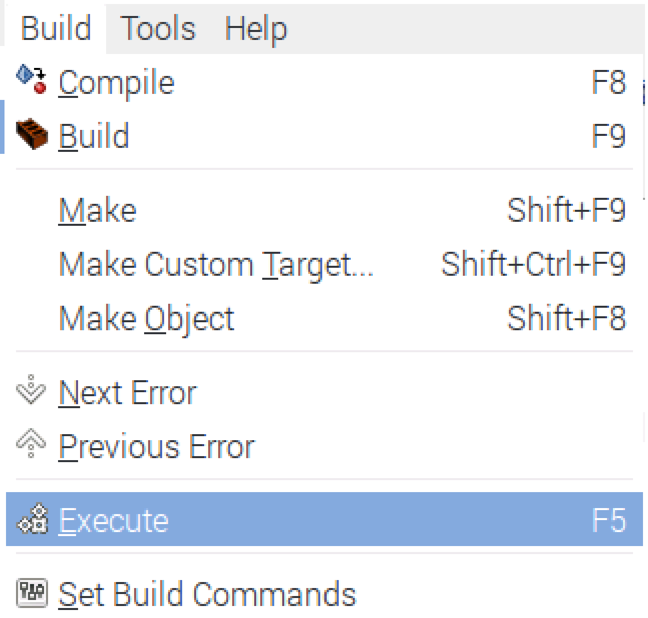




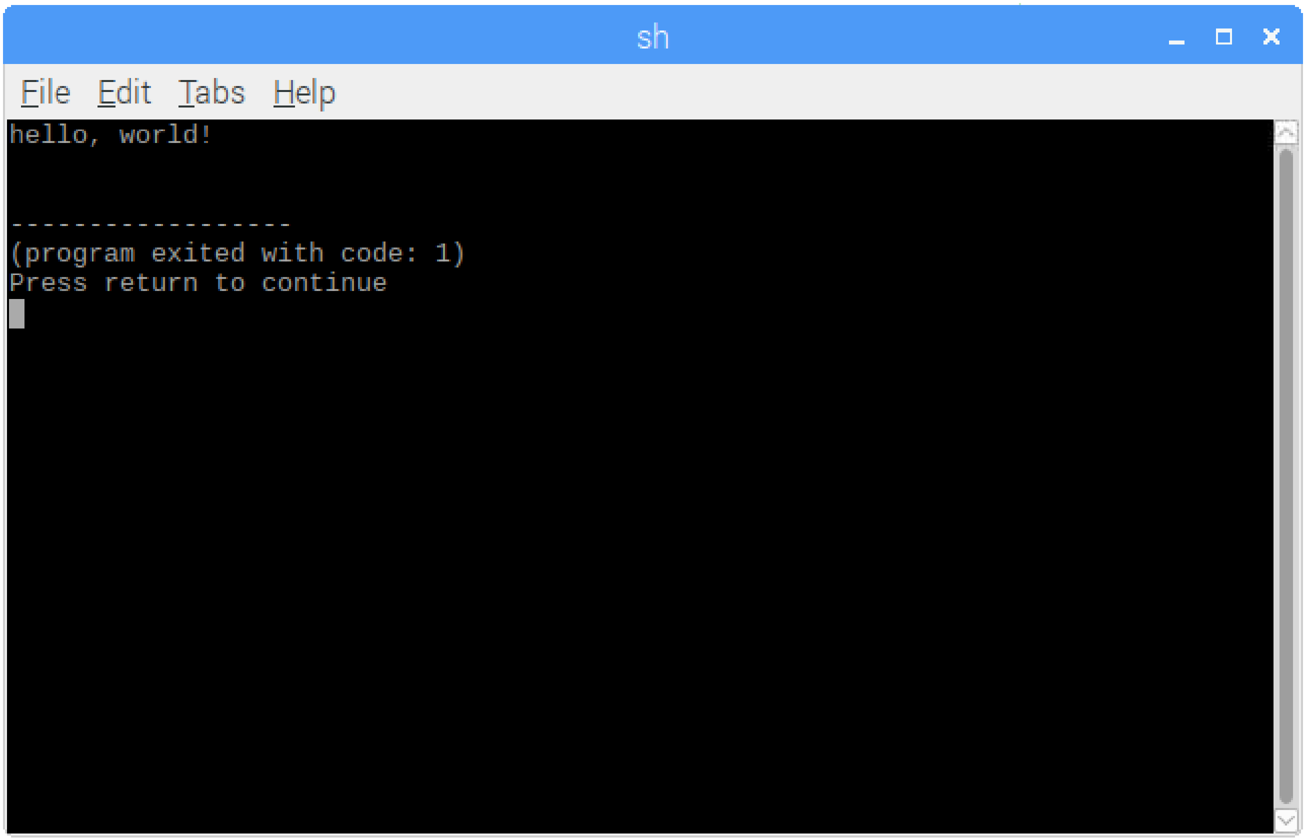
If you want to create a new code, click File→New→File→Save as (name.c or name.py). Then write the code.

Generate an executable file by clicking menu bar Build->Build, then execute the generated file by clicking menu bar Build->Execute.

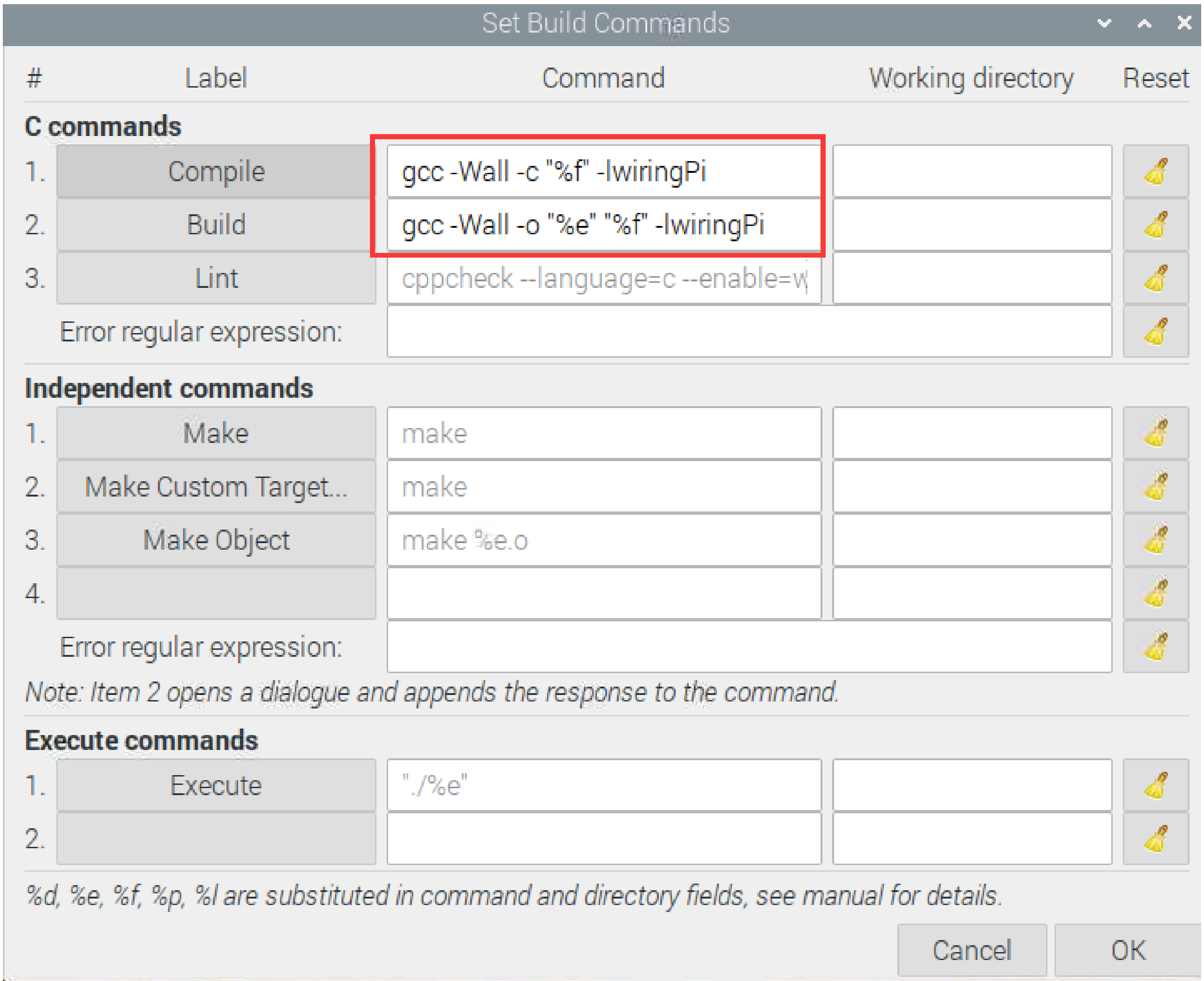




After the execution, a new terminal will output the characters “Hello, World!”, as shown below:



You can click Build->Set Build Commands to set compiler commands. In later projects, we will use various compiler command options. If you choose to use Geany, you will need change the compiler command here. As is shown below:



Summary

Here we have introduced three code editors. There also many other good code editors and you can choose any one you like.

In later projects, we will type commands in the terminal to execute code. We will explain the contents of the code in details. You can also the editors to execute code. It is recommended to set defaut python3 first. Because most editors use python3 to execute the code.

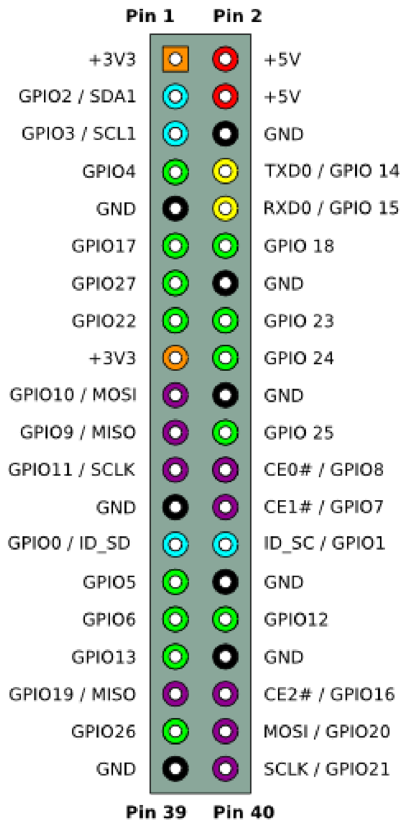
GPIO

GPIO: General purpose input/output. We will introduce the specific feature of the pins on the Raspberry Pi and what you can do with them. You can use them for all sorts of purposes. Most of them can be used as either inputs or outputs, depending on your program.
When programming the GPIO pins there are 3 different ways to refer to them: GPIO numbering, physical numbering, WiringPi GPIO Numbering.

BCM Numbering

Raspberry Pi CPU use BCM2835/BCM2836/BCM2837of Broadcom. GPIO pin number is set by chip manufacturer. These are the GPIO pins as that the computer recognizes. The numbers don't make any sense to humans. They jump all over the place, so there is no easy way to remember them. You will need a printed reference or a reference board that fits over the pins.

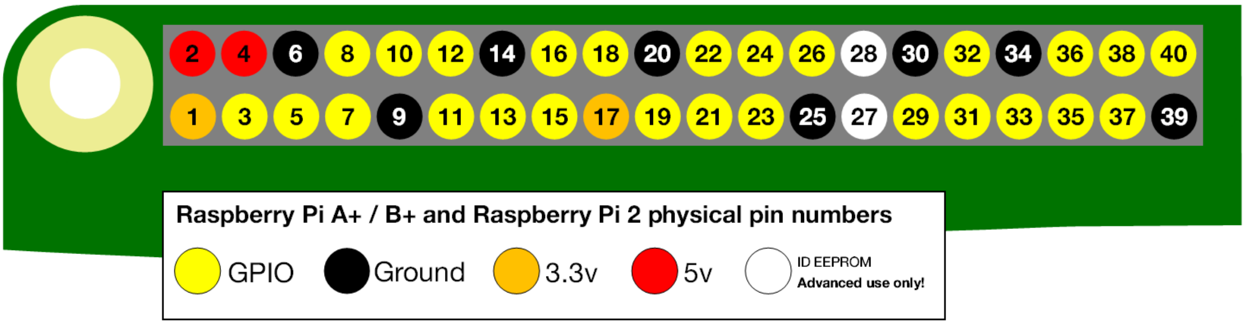
Each pin is defined as below:



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

Physical Numbering

Another way to refer to the pins is by simply counting across and down from pin 1 at the top left (nearest to the SD card). We will use this numbering in **python code**. This is physical numbering, as shown below:



WiringPi Numbering

RPi GPIO serial number of the WiringPi, different from the previous two types of GPIO serial numbers, is based on wiringPi and will be used in **C code**.

Here we have three kinds of GPIO number modes: based on the BCM chip number, relating to the physical sequence number and based on wiringPi. The correlation between these three GPIO numbers are shown below:

wiringPi Pin	BCM GPIO	Name	Header	Name	BCM GPIO	wiringPi Pin		
—	—	3.3v	1 | 2	5v	—	—	For Pi B	For A+, B+, 2B, 3B, 3B+, 4B, Zero
8	R1:0/R2:2	SDA	3 | 4	5v	—	—		
9	R1:1/R2:3	SCL	5 | 6	0v	—	—		
7	4	GPIO7	7 | 8	TxD	14	15		
—	—	0v	9 | 10	RxD	15	16		
0	17	GPIO0	11 | 12	GPIO1	18	1		
2	R1:21/R2:27	GPIO2	13 | 14	0v	—	—		
3	22	GPIO3	15 | 16	GPIO4	23	4		
—	—	3.3v	17 | 18	GPIO5	24	5		
12	10	MOSI	19 | 20	0v	—	—		
13	9	MISO	21 | 22	GPIO6	25	6		
14	11	SCLK	23 | 24	CE0	8	10		
—	—	0v	25 | 26	CE1	7	11		
30	0	SDA.0	27 | 28	SCL.0	1	31		
21	5	GPIO.21	29 | 30	0V				
22	6	GPIO.22	31 | 32	GPIO.26	12	26		
23	13	GPIO.23	33 | 34	0V				
24	19	GPIO.24	35 | 36	GPIO.27	16	27		
25	26	GPIO.25	37 | 38	GPIO.28	20	28		
		0V	39 | 40	GPIO.29	21	29		
wiringPi Pin	BCM GPIO	Name	Header	Name	BCM GPIO	wiringPi Pin		

(For more details, please refer to https://projects.drogon.net/raspberry-pi/wiringpi/pins/)

Sometimes, an Output port can receive current. So the port behaves partly as a power source, sometimes as a resistance. The direction means one can read or write the value of the port but what happens physically is different.

You can also use the following command to view their correlation.

```
gpio readall
```

```
pi@raspberrypi:~ $ gpio readall
 +-----+-----+---------+------+---+---Pi 3---+---+------+---------+-----+-----+
 | BCM | wPi |   Name  | Mode | V | Physical | V | Mode | Name    | wPi | BCM |
 +-----+-----+---------+------+---+----++----+---+------+---------+-----+-----+
 |     |     |    3.3v |      |   |  1 || 2  |   |      | 5v      |     |     |
 |   2 |   8 |   SDA.1 | ALT0 | 1 |  3 || 4  |   |      | 5V      |     |     |
 |   3 |   9 |   SCL.1 | ALT0 | 1 |  5 || 6  |   |      | 0v      |     |     |
 |   4 |   7 | GPIO. 7 |   IN | 1 |  7 || 8  | 1 | ALT5 | TxD     | 15  | 14  |
 |     |     |      0v |      |   |  9 || 10 | 1 | ALT5 | RxD     | 16  | 15  |
 |  17 |   0 | GPIO. 0 |   IN | 0 | 11 || 12 | 0 | IN   | GPIO. 1 | 1   | 18  |
 |  27 |   2 | GPIO. 2 |   IN | 0 | 13 || 14 |   |      | 0v      |     |     |
 |  22 |   3 | GPIO. 3 |   IN | 0 | 15 || 16 | 0 | IN   | GPIO. 4 | 4   | 23  |
 |     |     |    3.3v |      |   | 17 || 18 | 0 | IN   | GPIO. 5 | 5   | 24  |
 |  10 |  12 |    MOSI | ALT0 | 0 | 19 || 20 |   |      | 0v      |     |     |
 |   9 |  13 |    MISO | ALT0 | 0 | 21 || 22 | 0 | IN   | GPIO. 6 | 6   | 25  |
 |  11 |  14 |    SCLK | ALT0 | 0 | 23 || 24 | 1 | OUT  | CE0     | 10  | 8   |
 |     |     |      0v |      |   | 25 || 26 | 1 | OUT  | CE1     | 11  | 7   |
 |   0 |  30 |   SDA.0 |   IN | 1 | 27 || 28 | 1 | IN   | SCL.0   | 31  | 1   |
 |   5 |  21 | GPIO.21 |   IN | 1 | 29 || 30 |   |      | 0v      |     |     |
 |   6 |  22 | GPIO.22 |   IN | 1 | 31 || 32 | 0 | IN   | GPIO.26 | 26  | 12  |
 |  13 |  23 | GPIO.23 |   IN | 0 | 33 || 34 |   |      | 0v      |     |     |
 |  19 |  24 | GPIO.24 |   IN | 0 | 35 || 36 | 0 | IN   | GPIO.27 | 27  | 16  |
 |  26 |  25 | GPIO.25 |   IN | 0 | 37 || 38 | 0 | IN   | GPIO.28 | 28  | 20  |
 |     |     |      0v |      |   | 39 || 40 | 0 | IN   | GPIO.29 | 29  | 21  |
 +-----+-----+---------+------+---+----++----+---+------+---------+-----+-----+
 | BCM | wPi |   Name  | Mode | V | Physical | V | Mode | Name    | wPi | BCM |
 +-----+-----+---------+------+---+---Pi 3---+---+------+---------+-----+-----+
```

If you are using Raspberry Pi 4B, there will be errors when executing command "gpio readall". As is below:

```
pi@raspberrypi:~ $ gpio readall
Oops - unable to determine board type... model: 17
```

This is because the official version of the library supporting 4B has not yet been released, which result in commands not being executed properly. But it won't affect the following projects. For this problem, you can solve it by installing a patch. Just execute the commands below in the terminal.

```
wget https://project-downloads.drogon.net/wiringpi-latest.deb
sudo dpkg -i wiringpi-latest.deb
```

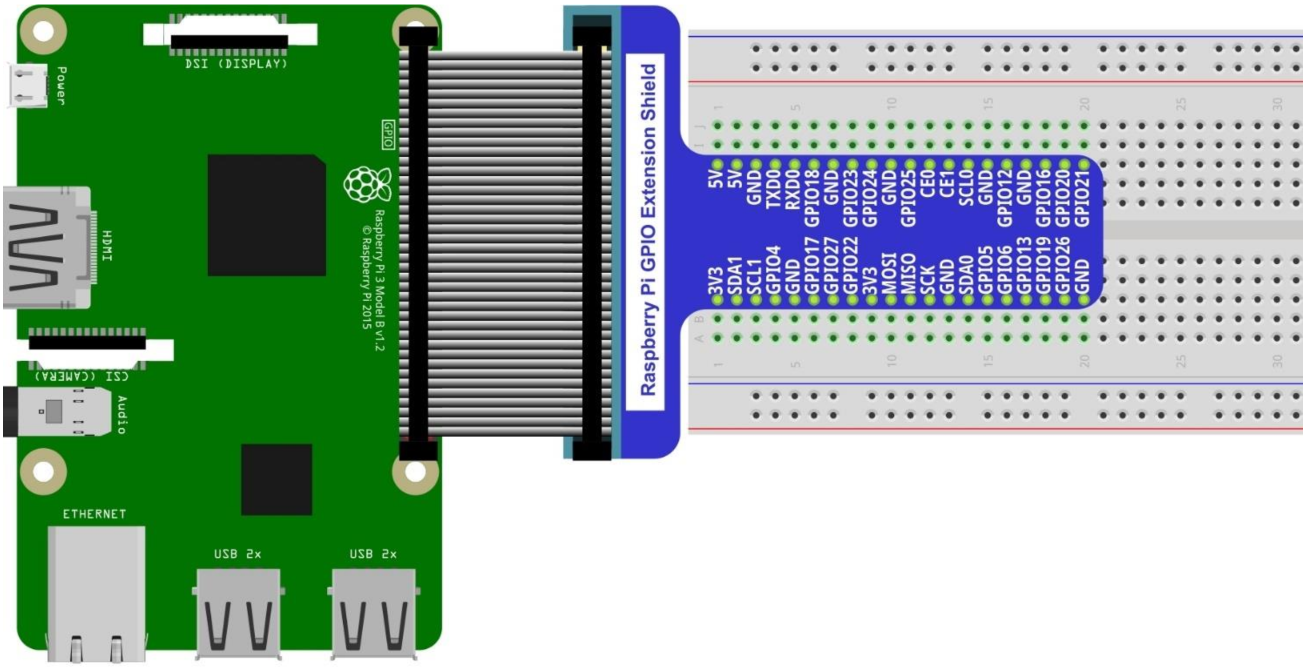
After the installation is completed, Execute "gpio-v" and "gpio readall" commands again.
For more details about wiringPi, please refer to http://wiringpi.com/ .

GPIO Numbering Relationship

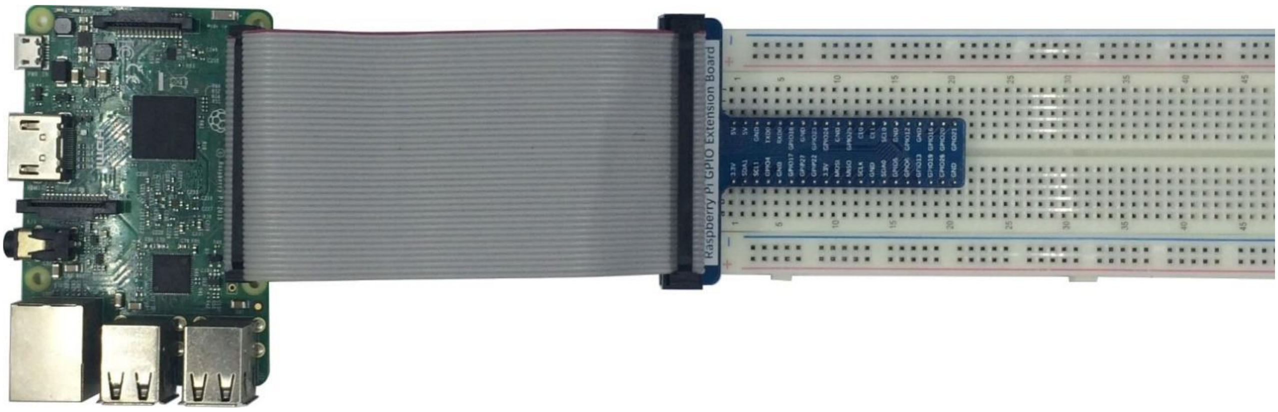
WingPi	BCM(Extension)	Physical		BCM(Extension)	WingPi
3.3V	**3.3V**	1	2	5V	**5V**
8	SDA1	3	4	**5V**	**5V**
9	SCL1	5	6	**GND**	**GND**
7	GPIO17	7	8	GPIO14/TXD0	15
GND	**GND**	9	10	GPIO15/RXD0	16
0	GPIO17	11	12	GPIO18	1
2	GPIO27	13	14	**GND**	**GND**
3	GPIO22	15	16	GPIO23	4
3.3V	**3.3V**	17	18	GPIO24	5
12	GPIO10/MOSI)	19	20	**GND**	**GND**
13	GPIO9/MOIS	21	22	GPIO25	6
14	GPIO11/SCLK	23	24	GPIO8 /CE0	10
GND	**GND**	25	26	GPIO7 CE1	11
30	GPIO0/SDA0	27	28	GPIO1 /SCL0	31
21	GPIO5	29	30	**GND**	**GND**
22	GPIO6	31	32	GPIO12	26
23	GPIO13	33	34	**GND**	**GND**
24	GPIO19	35	36	GPIO16	27
25	GPIO26	37	38	GPIO20	28
GND	**GND**	39	40	GPIO21	29

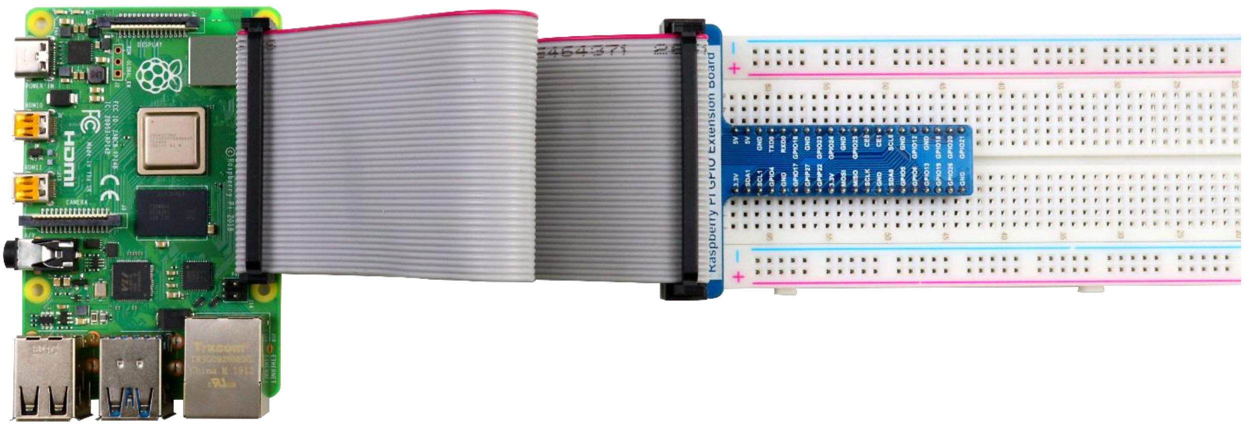
GPIO Extension Board

When we use RPi to do the project, we better make use of the GPIO, which is more convenient to extend all IO ports of RPi to the breadboard directly. The GPIO sequence on Extension Board is identical to the GPIO sequence of RPi. Since the GPIO of different versions of RPi is different, the corresponding extensions board are also different. For example, a GPIO extensions board with 40 pins is connected to RPi as follows:

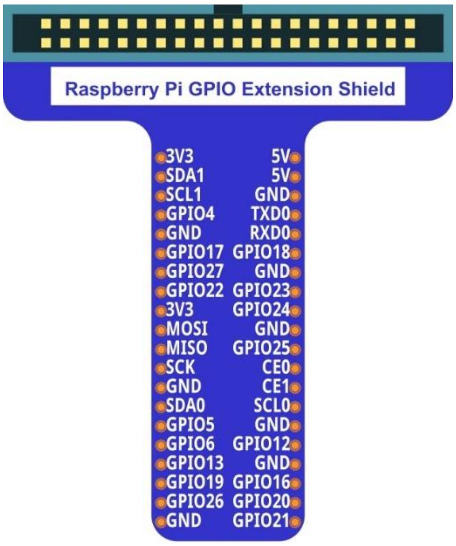


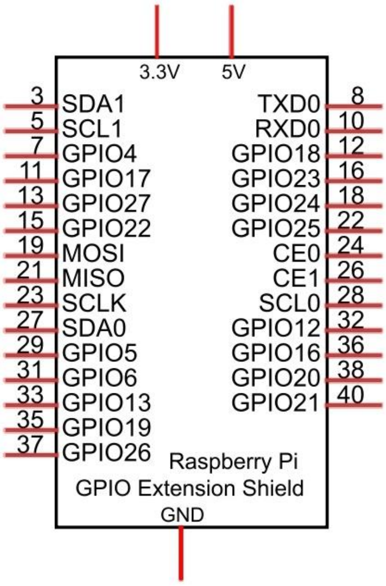
Practicality picture of connection:





GPIO Extension Board and its schematic are shown below:

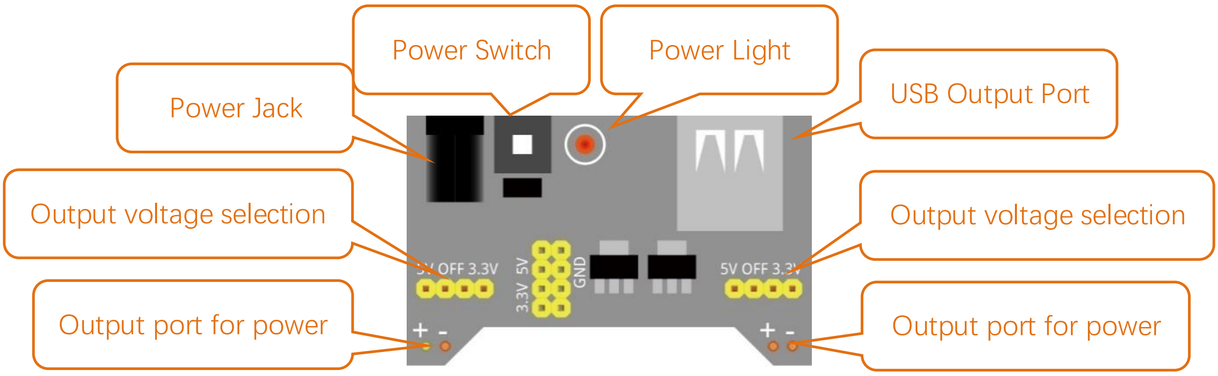
<table>
<tr><td>GPIO Extension Board</td><td>Definition of pins</td></tr>
<tr><td>


</td><td>


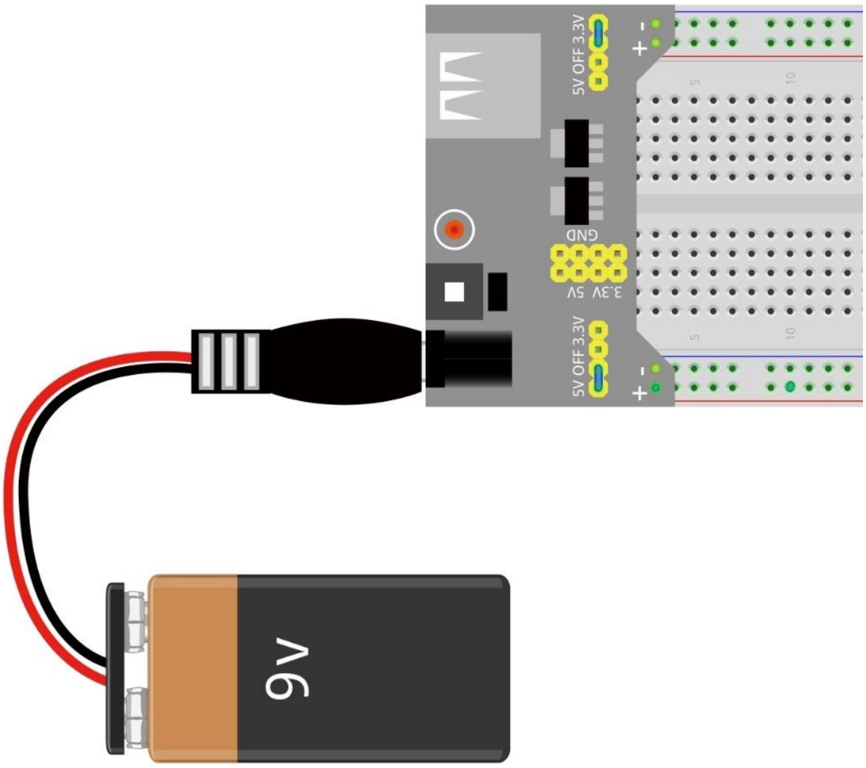
</td></tr>
</table>

Breadboard Power Module

Breadboard Power Module is an independent board, which can provide independent 5V or 3.3V power for breadboard when used to build the circuit, and it can avoid excessive load power damaging RPi power. The schematic diagram of the Breadboard Power Module is shown below:



The connection between Breadboard Power Module and Breadboard is shown below:



Next

Here, all preparations have been completed. Next, we will combine the RPi and electronic components to do a series of projects from easy to difficult and focus on explaining the relevant knowledge of their electronic circuit.

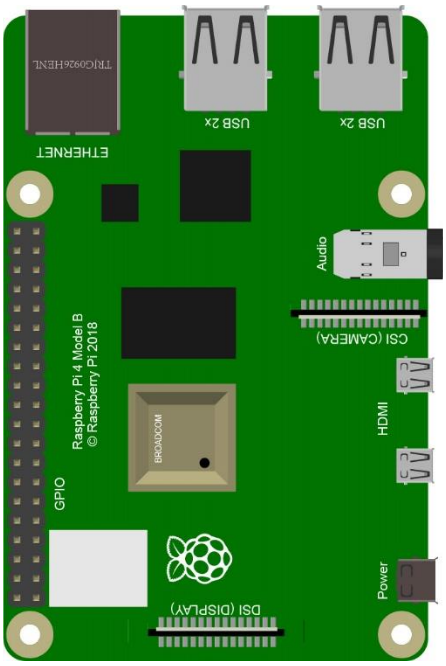
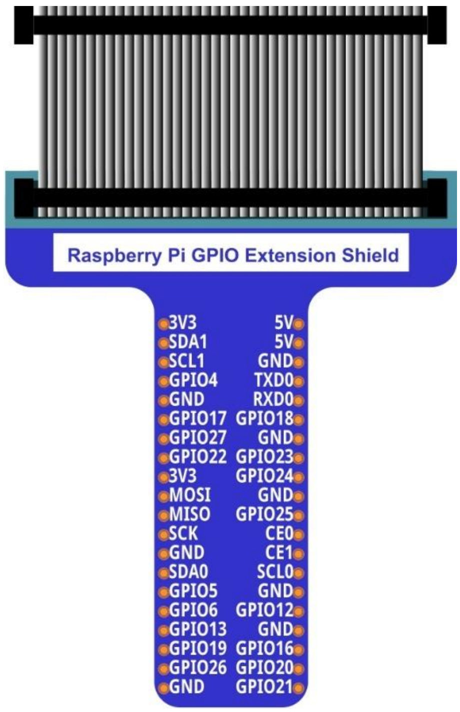
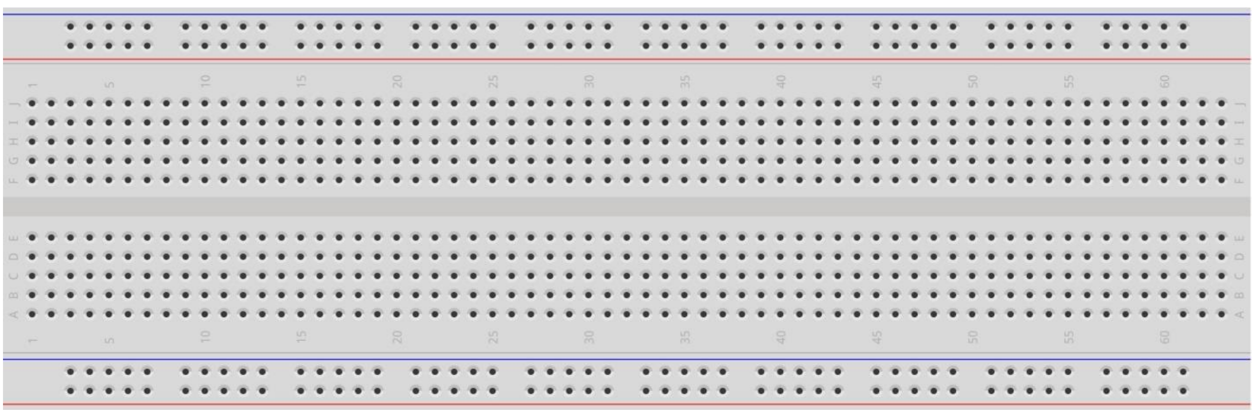
Chapter 1 LED

In Chapter 0, we have got the code for the projects.
This chapter is the starting point of the journey to explore RPi electronic projects. Let's start with simple "Blink".

Project 1.1 Blink

In this project, let's try to use RPi to control LED blinking.

Component List

Raspberry Pi (Recommended: Raspberry Pi 4B / 3B+ / 3B Compatible: 3A+ / 2B / 1B+ / 1A+ / Zero W / Zero) 	GPIO Extension Board & Wire x1 
Breadboard x1 	

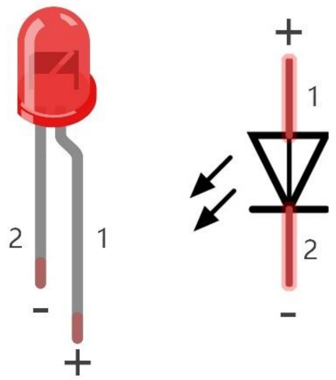
LED x1	Resistor 220Ω x1	Jumper
		**Specific quantity depends on the circuit later.** 

In the components list, 3B GPIO, Extension Shield Raspberry and Breadboard are necessary for each project. They will be listed only in text form later.

Component knowledge

LED

LED is a kind of diode. LED will shine only if the long pin of LED is connected to the positive electrode and the short pin is connected to negative electrode.
This is also the feature of the common diode. Diode works only if the voltage of its positive electrode is higher than its negative electrode.

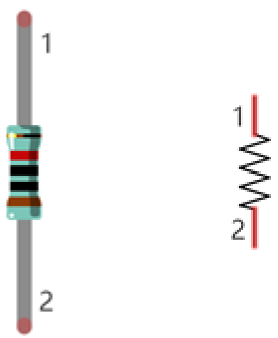


LED	Voltage	Maximum current	Recommended current
Red	1.9-2.2V	20mA	10mA
Green	2.9-3.4V	10mA	5mA
Blue	2.9-3.4V	10mA	5mA
Volt ampere characteristics conform to diode			

The LED can not be directly connected to power supply, which can damage component. A resistor with certain resistance must be connected in series in the circuit of LED.

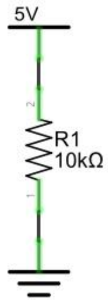
Resistor

The unit of resistance(R) is ohm(Ω). 1MΩ=1000kΩ, 1kΩ=1000Ω.
Resistor is an electrical component that limits or regulates the flow of current in an electronic circuit.
The left is the practicality of resistor, and the right is the symbol of resistor represented in circuit.



Color rings attached to the resistor is used to indicate its resistance. For more details of resistor color code, please refer to the resistor card in the package.

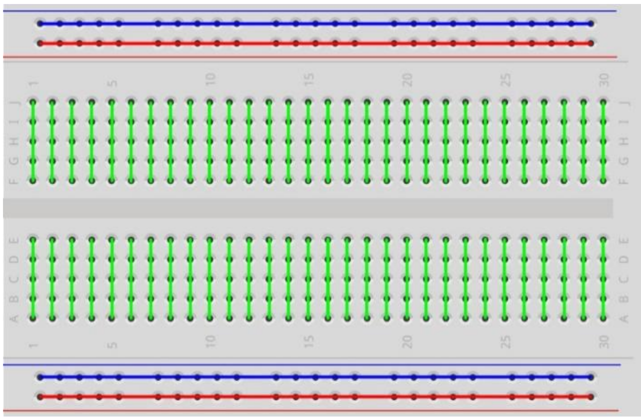
With the same voltage there will be less current with more resistance. And the link among current, voltage and resistance can be expressed by the formula below: I=U/R.
In the following diagram, the current through R1 is: I=U/R=5V/10kΩ=0.0005A=0.5mA.

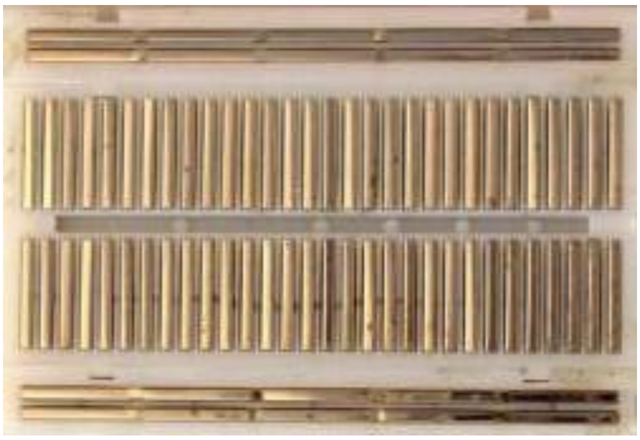


Do not connect the two poles of power supply with low resistance, which will make the current too high to damage power supply. And a resistor has no poles.

Breadboard

Take a short breadboard as an example to introduce its features, as below.
The left picture shows the way of connection of pins. The right picture shows the pratical internal structure.
The breadboard has no positive or negative pole inside. The blue or red line is as a mark for use.

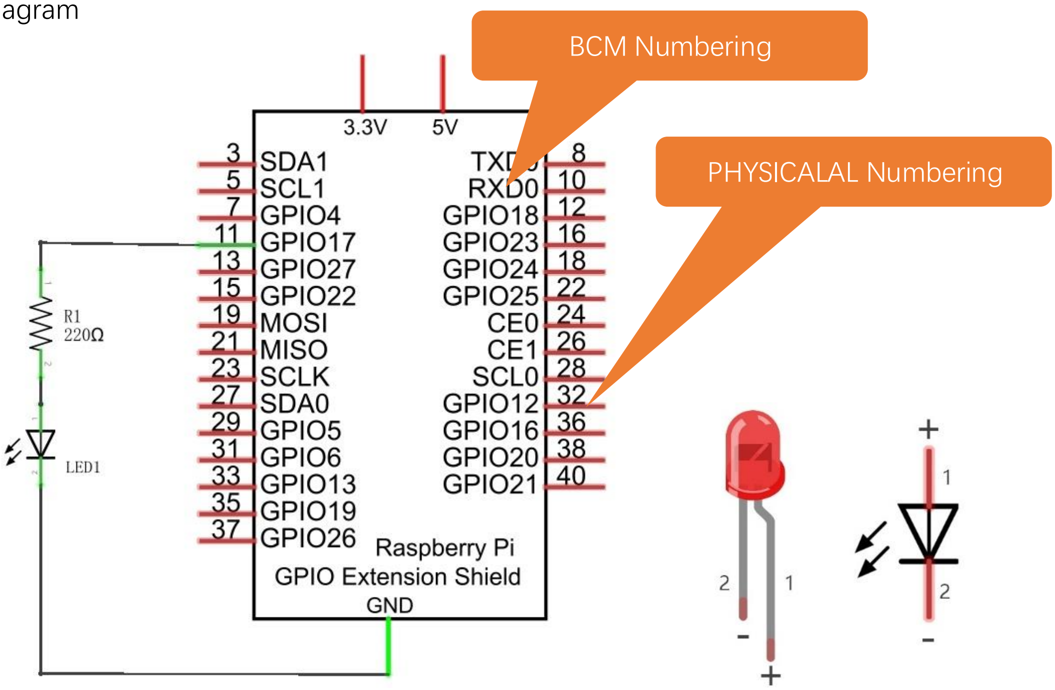




Circuit

Disconnect RPi from GPIO Extension Shield first. Then build the circuit according to the circuit diagram and the hardware connection diagram. After the circuit is built and confirmed, connect RPi to GPIO Extension Shield. In addition, Pay especially attention to avoid short circuit (especially 5V and GND, 3.3V and GND) as they may cause abnormal circuit work, or even damage to RPi.

Schematic diagram



Hardware connection.

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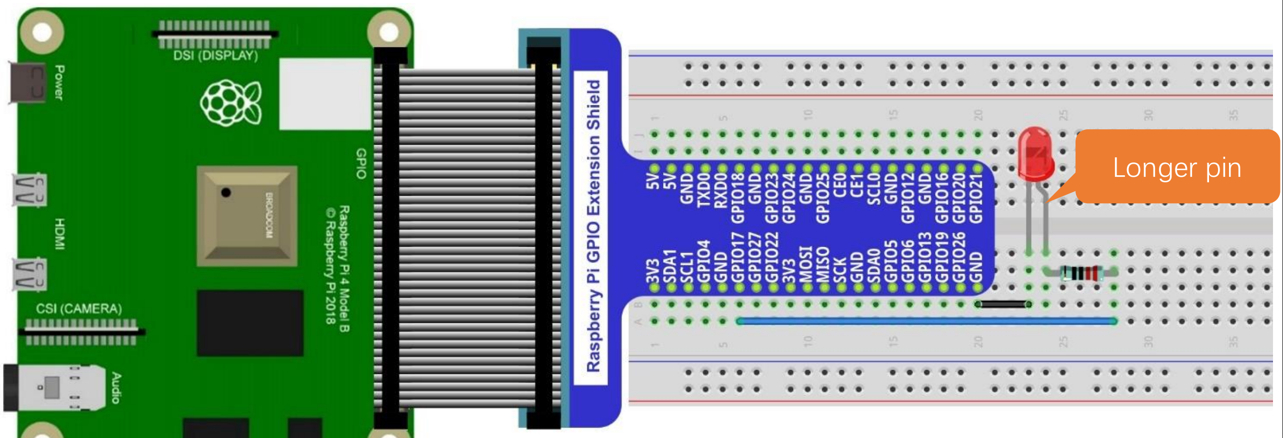

Note:
The shorter Pin should be connected to GND.
Do NOT rotate Raspberry Pi to change the way of this connection.
Please plug T extension fully into breadboard.

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

Code

According to the circuit, when the GPIO17 of RPi outputs HIGH level, LED is turned on. Conversely, when the GPIO17 RPi outputs LOW level, LED is turned off. Therefore, we can let GPIO17 outputs HIGH and LOW level in in turn to make LED blink. We will use both C code and Python code to achieve the goal.

C Code 1.1.1 Blink

First, execute command into the terminal one by one. Then observe the project result, and view the code.

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If you want to execute it with Geany, please refer to section Code Editor to configure.

It is recommended to execute code by using commands as below.

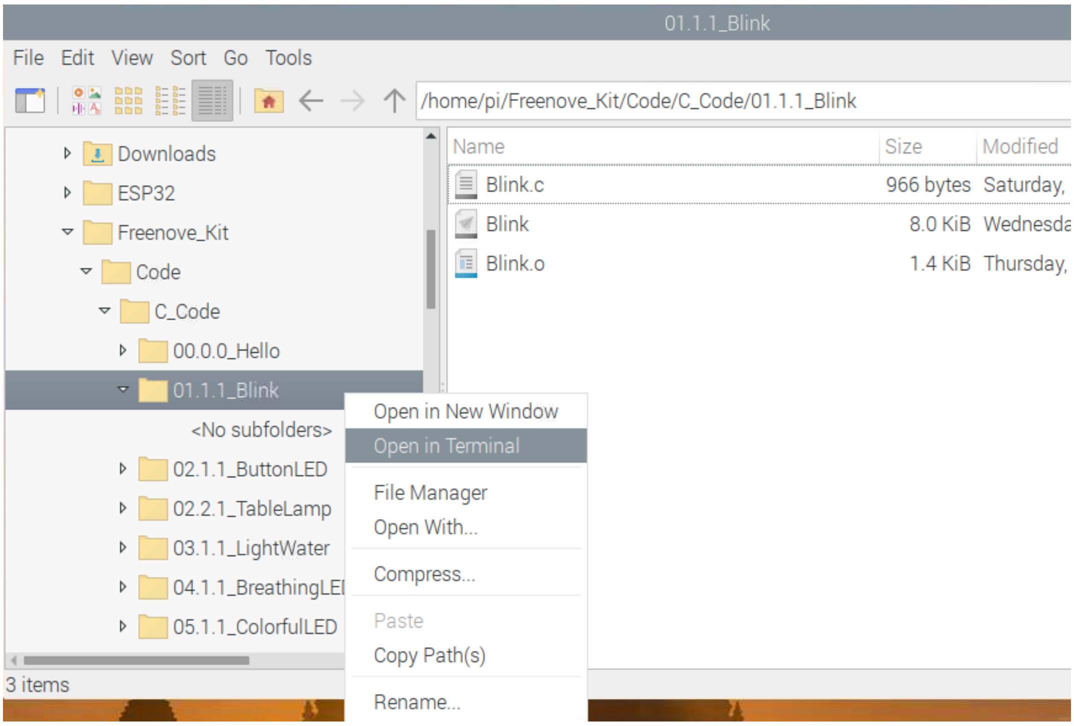
Update wiringPi by executing following commands one by one.

```
wget https://project-downloads.drogon.net/wiringpi-latest.deb
sudo dpkg -i wiringpi-latest.deb
```

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

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

You can also use the file browser. On the left of file manager, right-click the folder you want to enter, and click "Open in Terminal".



2. Use the following command to compile the code "Blink.c" and generate executable file "Blink".

"l" of "lwiringPi" is low case of "L".

```
gcc Blink.c -o Blink -lwiringPi
```

3. Then run the generated file "blink".

```
sudo ./Blink
```

Now, LED starts blinking.

```
pi@raspberrypi: ~/Freenove_Kit/Code/C_Code/01.1.1_Blink
File Edit Tabs Help
pi@raspberrypi:~ $ cd ~/Freenove_Kit/Code/C_Code/01.1.1_Blink/
pi@raspberrypi:~/Freenove_Kit/Code/C_Code/01.1.1_Blink $ gcc Blink.c -o Blink -lwiringPi
pi@raspberrypi:~/Freenove_Kit/Code/C_Code/01.1.1_Blink $ sudo ./Blink
Program is starting ...
Using pin0
led turned on >>>
led turned off <<<
```

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

```c
#include <wiringPi.h>
#include <stdio.h>

#define  ledPin    0  //define the led pin number according to WiringPi Numbering

void main(void)
{
    printf("Program is starting ... \n");

    wiringPiSetup();  //Initialize wiringPi.

    pinMode(ledPin, OUTPUT);//Set the pin mode
    printf("Using pin%d\n",%ledPin);    //Outputs information on terminal
    while(1){
        digitalWrite(ledPin, HIGH);  //Make GPIO outputs HIGH level
        printf("led turned on >>>\n");      //Outputs information on terminal
        delay(1000);                        //Wait for 1 second
        digitalWrite(ledPin, LOW);  //Make GPIO output LOW level
        printf("led turned off <<<\n");         //Outputs information on terminal
        delay(1000);                        //Wait for 1 second
    }
}
```

Among code above, there are two important functions as below:

`void pinMode(int pin, int mode);`

This sets the mode of a pin to either INPUT, OUTPUT, PWM_OUTPUT or GPIO_CLOCK. Note that only wiringPi pin 1 (BCM_GPIO 18) supports PWM output and only wiringPi pin 7 (BCM_GPIO 4) supports CLOCK output modes.

This function has no effect when in Sys mode. If you need to change the pin mode, then you can do it with the gpio program in a script before you start your program

`void digitalWrite (int pin, int value);`

Writes the value HIGH or LOW (1 or 0) to the given pin which must have been previously set as an output.

For more related functions of wiringPi, please refer to http://wiringpi.com/reference/

ledPin is connected to GPIO17 in BCM numbering (entension board uses BCM numbering). The code uses wiringPi library. And GPIO17(BCM) corresponds to 0(**wiringPi**). So ledPin should be defined as 0 pin. For more details, you can refer to **GPIO.**

```
#define  ledPin    0 //define the led pin number
```

GPIO Numbering Relationship

WingPi	BCM(Extension)	Physical		BCM(Extension)	WingPi
3.3V	3.3V	1	2	5V	5V
8	SDA1	3	4	5V	5V
9	SCL1	5	6	GND	GND
7	GPIO17	7	8	GPIO14/TXD0	15
GND	GND	9	10	GPIO15/RXD0	16
0	GPIO17	11	12	GPIO18	1
2	GPIO27	13	14	GND	GND
3	GPIO22	15	16	GPIO23	4
3.3V	3.3V	17	18	GPIO24	5
12	GPIO10/MOSI)	19	20	GND	GND
13	GPIO9/MOIS	21	22	GPIO25	6
14	GPIO11/SCLK	23	24	GPIO8 /CE0	10
GND	GND	25	26	GPIO7 CE1	11
30	GPIO0/SDA0	27	28	GPIO1 /SCL0	31
21	GPIO5	29	30	GND	GND
22	GPIO6	31	32	GPIO12	26
23	GPIO13	33	34	GND	GND
24	GPIO19	35	36	GPIO16	27
25	GPIO26	37	38	GPIO20	28
GND	GND	39	40	GPIO21	29

Initialize wiringPi first in the main function main(),.

```
    wiringPiSetup();  //Initialize wiringPi.
```

After the wiringPi is initialized successfully, set the ledPin to output mode. And then enter the endless while loop. That is, the program will always be executed in this loop, unless it is ended by operation outside the loop. In this loop, use digitalWrite (ledPin, HIGH) to make ledPin output HIGH level, then LED is turned on. After a period of time delay, use digitalWrite(ledPin, LOW) to make ledPin output LOW level, then LED is turned off, which is followed by a delay. Repeat the cycle, then LED will start blinking.

```
    pinMode(ledPin, OUTPUT);//Set the pin mode
    printf("Using pin%d\n",%ledPin);   //Output information on terminal
    while(1){
        digitalWrite(ledPin, HIGH);  //Make GPIO output HIGH level
        printf("led turned on >>>\n");      //Output information on terminal
        delay(1000);                        //Wait for 1 second
        digitalWrite(ledPin, LOW);  //Make GPIO output LOW level
        printf("led turned off <<<\n");         //Output information on terminal
        delay(1000);                        //Wait for 1 second
    }
```

Python Code 1.1.1 Blink

Next, we will use Python language to make LED blink.

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

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

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

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

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

```
python Blink.py
```

Now, LED start blinking.

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

using pin11
led turned on >>>
led turned off <<<
```

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

```python
import RPi.GPIO as GPIO
import time

ledPin = 11    # define ledPin Physical GPIO Numbering

def setup():
    GPIO.setmode(GPIO.BOARD)       # use Physical GPIO Numbering,
    GPIO.setup(ledPin, GPIO.OUT)   # set the ledPin to OUTPUT mode
    GPIO.output(ledPin, GPIO.LOW)  # make ledPin output LOW level
    print ('using pin%d'%ledPin)

def loop():
    while True:
        GPIO.output(ledPin, GPIO.HIGH)  # make ledPin output HIGH level to turn on led
        print ('led turned on >>>')        # print information on terminal
        time.sleep(1)                   # Wait for 1 second
        GPIO.output(ledPin, GPIO.LOW)   # make ledPin output LOW level to turn off led
        print ('led turned off <<<')
        time.sleep(1)                   # Wait for 1 second

def destroy():
    GPIO.cleanup()                      # Release all GPIO

if __name__ == '__main__':    # Program entrance
```

```
    print ('Program is starting ... \n')
    setup()
    try:
        loop()
    except KeyboardInterrupt:   # Press ctrl-c to end the program.
        destroy()
```

About RPi.GPIO:

`RPi.GPIO`
This is a Python module to control the GPIO on a Raspberry Pi. It includes basic output function and input function of GPIO, and function used to generate PWM.
`GPIO.setmode(mode)`
Set the mode for pin serial number of GPIO. mode=GPIO.BOARD, which represents the GPIO pin serial number is based on physical location of RPi. mode=GPIO.BCM, which represents the pin serial number is based on CPU of BCM chip.
`GPIO.setup(pin,mode)`
Set pin to input mode or output mode. "pin" for the GPIO pin, "mode" for INPUT or OUTPUT.
`GPIO.output(pin,mode)`
Set pin to output mode. "pin" for the GPIO pin, "mode" for HIGH (high level) or LOW (low level).

For more functions related to RPi.GPIO, please refer to:
https://sourceforge.net/p/raspberry-gpio-python/wiki/Examples/
"import time" time is a module of python.
https://docs.python.org/2/library/time.html?highlight=time%20time#module-time

LED Pin is connected to GPIO17 in BCM numbering (entension board uses BCM numbering). In subfunction setup(), GPIO.setmode (GPIO.BOARD) is used to set GPIO number according to Physical GPIO numbering. GPIO17(BCM) corresponds tp GPIO 11(Pysical). So we define ledPin as 11 and set ledPin to output mode. For more details, you can refer to **GPIO.**
If you want to use BCM numbering in the code, you need use this sentence GPIO.setmode(GPIO.BCM).

```
ledPin = 11    # define ledPin

def setup():
    GPIO.setmode(GPIO.BOARD)       # use Phsical GPIO Numbering
    GPIO.setup(ledPin, GPIO.OUT)   # set the ledPin to OUTPUT mode
    GPIO.output(ledPin, GPIO.LOW)  # make ledPin output LOW level
    print ('using pin%d'%ledPin)
```

GPIO Numbering Relationship

WingPi	BCM(Extension)	Physical		BCM(Extension)	WingPi
3.3V	**3.3V**	1	2	5V	**5V**
8	SDA1	3	4	**5V**	**5V**
9	SCL1	5	6	**GND**	**GND**
7	GPIO17	7	8	GPIO14/TXD0	15
GND	**GND**	9	10	GPIO15/RXD0	16
0	GPIO17	11	12	GPIO18	1
2	GPIO27	13	14	**GND**	**GND**
3	GPIO22	15	16	GPIO23	4
3.3V	**3.3V**	17	18	GPIO24	5
12	GPIO10/MOSI)	19	20	**GND**	**GND**
13	GPIO9/MOIS	21	22	GPIO25	6
14	GPIO11/SCLK	23	24	GPIO8 /CE0	10
GND	**GND**	25	26	GPIO7 CE1	11
30	GPIO0/SDA0	27	28	GPIO1 /SCL0	31
21	GPIO5	29	30	**GND**	**GND**
22	GPIO6	31	32	GPIO12	26
23	GPIO13	33	34	**GND**	**GND**
24	GPIO19	35	36	GPIO16	27
25	GPIO26	37	38	GPIO20	28
GND	**GND**	39	40	GPIO21	29

In loop(), there is an endless while loop. That is, the program will always be executed unless it is ended by operation outside the loop, like "Ctrl+C". In this loop, set ledPin output high level, then LED is turned on. After a period of time delay, set ledPin output low level, then LED is turned off, which is followed by a delay. Repeat the loop, then LED will start blinking.

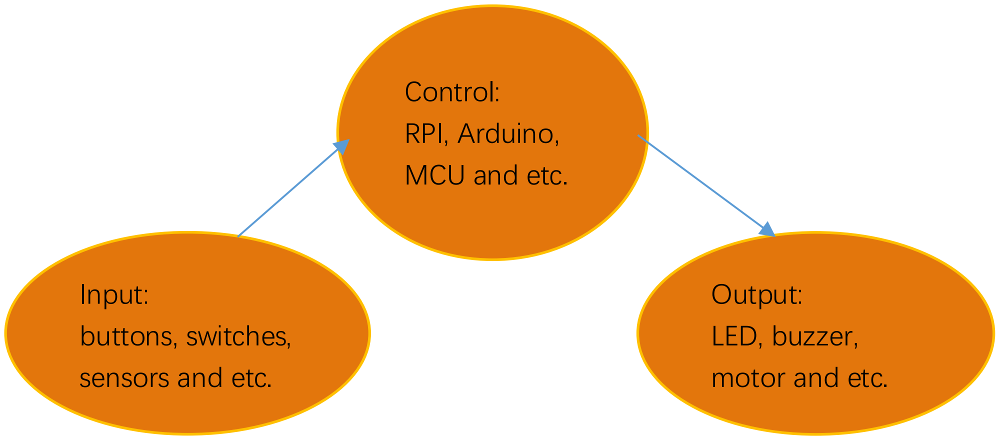
```
def loop():
    while True:
        GPIO.output(ledPin, GPIO.HIGH)  # make ledPin output HIGH level to turn on led
        print ('led turned on >>>')       # print information on terminal
        time.sleep(1)                  # Wait for 1 second
        GPIO.output(ledPin, GPIO.LOW)   # make ledPin output LOW level to turn off led
        print ('led turned off <<<')
        time.sleep(1)                  # Wait for 1 second
```

Finally, when the program is terminated, subfunction will be executed, the LED will be turned off and then the IO port will be released. If close the program terminal directly, the program will be terminated too, but finish() function will not be executed. So, GPIO resources won't be released, in the warning message may appear next time you use GPIO. So, it is not a good habit to close the program terminal directly.

```
def finish():
    GPIO.cleanup()                     # Reease all GPIO
```

Chapter 2 Button & LED

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

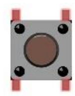


Next, we will build a simple control system to control LED through a button.

Project 2.1 Button & LED

In the project, we will control the LED state through a button. When the button is pressed, LED will be turn on, and when it is released, LED will be turn off.

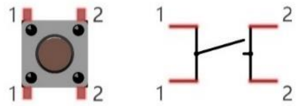
Component List

<table>
<tr><td>Raspberry Pi (with 40 GPIO) x1
GPIO Extension Board & Wire x1
Breadboard x1</td><td rowspan="2">LED x1
</td><td rowspan="2">Resistor 220Ω x1
</td><td rowspan="2">Resistor 10kΩ x2
</td><td rowspan="2">Push button x1
</td></tr>
<tr><td>Jumper
</td></tr>
</table>

Component knowledge

Push button

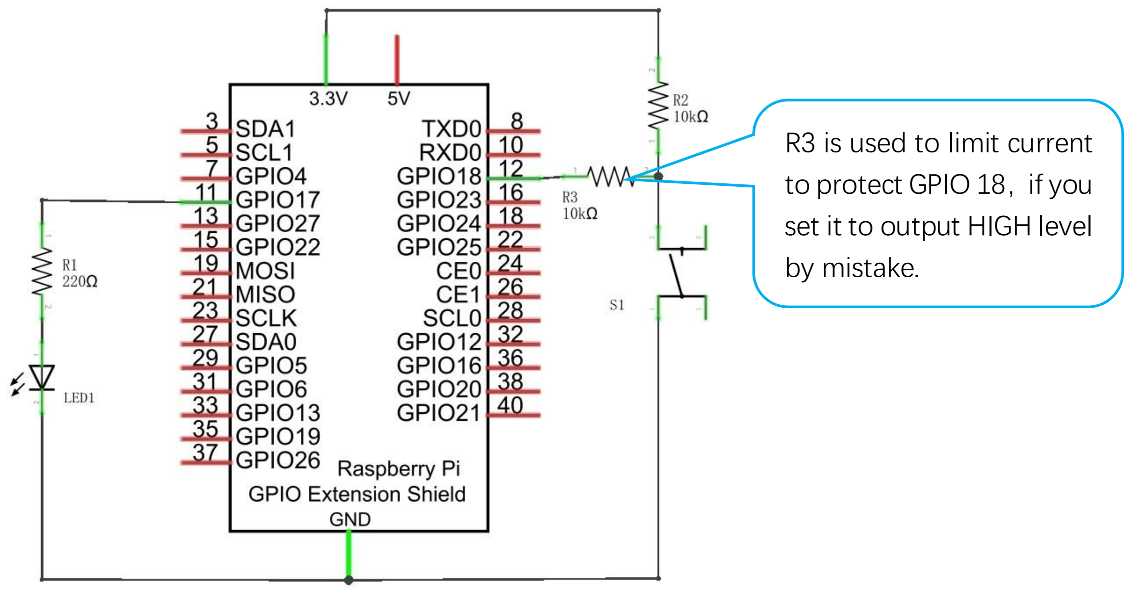
Push button has 4 pins. Two pins on the left is connected, and the right is similar as the left, which is shown in the below:



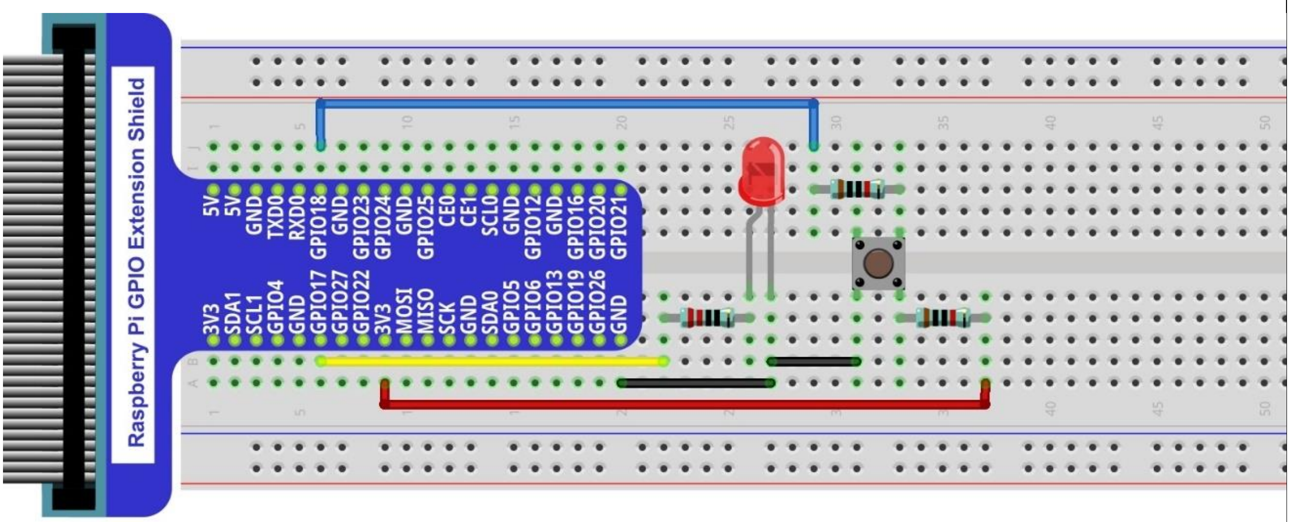
When the push button is pressed, the circuit is turned on.

Circuit

Schematic diagram



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



Code

This project is designed for learning how to use button to control LED. We first need to read the state of button, and then determine whether turn on LED according to the state of the button.

C Code 2.1.1 ButtonLED

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

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

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

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

2. Use the following command to compile the code "ButtonLED.c" and generate executable file "ButtonLED"

```
gcc ButtonLED.c -o ButtonLED -lwiringPi
```

3. Then run the generated file "ButtonLED".

```
sudo ./ButtonLED
```

Later, the terminal window continues to print out the characters "led off…". Press the button, then LED is turned on and then terminal window prints out the "led on…". Release the button, then LED is turned off and then terminal window prints out the "led off…". You can press "Ctrl+C" to terminate the program.

The following is the program code:

```
#include <wiringPi.h>
#include <stdio.h>

#define ledPin    0   //define the ledPin
#define buttonPin 1       //define the buttonPin

void  main(void)
{
    printf("Program is starting ... \n");

    wiringPiSetup();  //Initialize wiringPi.

    pinMode(ledPin, OUTPUT); //Set ledPin to output
    pinMode(buttonPin, INPUT);//Set buttonPin to input

    pullUpDnControl(buttonPin, PUD_UP);  //pull up to HIGH level
    while(1){
        if(digitalRead(buttonPin) == LOW){ //button is pressed
            digitalWrite(ledPin, HIGH);  //Make GPIO output HIGH level
            printf("Button is pressed, led turned on >>>\n");        //Output information on
terminal
        }
        else {                              //button is released
            digitalWrite(ledPin, LOW);  //Make GPIO output LOW level
            printf("Button is released, led turned off <<<\n");      //Output information on
terminal
```

```
            }
        }
}
```

In the circuit connection, LED and Button are connected with GPIO17 and GPIO18 respectively, which correspond to 0 and 1 respectively in wiringPI. So define ledPin and buttonPin as 0 and 1 respectively.

```
#define ledPin    0     //define the ledPin
#define buttonPin 1     //define the buttonPin
```

The while loop continues endlessly to judge the state of Button via digitalRead(buttonPin). When the button is pressed, the function returns low level, the result of "if" is true, and then turn on LED. Otherwise turn off LED.

```
if(digitalRead(buttonPin) == LOW){ //button has pressed down
            digitalWrite(ledPin, HIGH);   //led on
            printf("led on...\n");
        }
        else {              //button has released
            digitalWrite(ledPin, LOW);   //led off
            printf("...led off\n");
        }
```

Reference:

`int digitalRead (int pin);`
This function returns the value read at the given pin. It will be "**HIGH**" or "**LOW**"(1 or 0) depending on the logic level at the pin.

Python Code 2.1.1 ButtonLED

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

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

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

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

2. Use Python command to execute btnLED.py.

```
python ButtonLED.py
```

Later, the terminal window continue to print out the characters "led off…", press the button, then LED is turned on and then terminal window print out the "led on…". Release the button, then LED is turned off and then terminal window print out the "led off…". You can press "Ctrl+C" to terminate the program.

The following is the program code:

```python
import RPi.GPIO as GPIO

ledPin = 11     # define ledPin
buttonPin = 12    # define buttonPin

def setup():

    GPIO.setmode(GPIO.BOARD)       # use Physical GPIO Numbering
    GPIO.setup(ledPin, GPIO.OUT)   # set ledPin to OUTPUT mode
    GPIO.setup(buttonPin, GPIO.IN, pull_up_down=GPIO.PUD_UP)    # set buttonPin to PULL UP INPUT mode

def loop():
    while True:
        if GPIO.input(buttonPin)==GPIO.LOW: # if button is pressed
            GPIO.output(ledPin,GPIO.HIGH)   # turn on led
            print ('led turned on >>>')     # print information on terminal
        else : # if button is relessed
            GPIO.output(ledPin,GPIO.LOW) # turn off led
            print ('led turned off <<<')

def destroy():
    GPIO.cleanup()                     # Release GPIO resource

if __name__ == '__main__':     # Program entrance
    print ('Program is starting...')
    setup()
    try:
        loop()
    except KeyboardInterrupt:  # Press ctrl-c to end the program.
        destroy()
```

In subfunction setup (), GPIO.setmode (GPIO.BOARD) is used to set the serial number of the GPIO, which is based on physical location of the pin. So, GPIO17 and GPIO18 correspond to pin11 and pin12 respectively in the circuit. Then set ledPin to output mode, buttonPin to input mode with a pull resistor.

```
ledPin = 11     # define ledPin
buttonPin = 12     # define buttonPin

def setup():

    GPIO.setmode(GPIO.BOARD)       # use Physical GPIO Numbering
    GPIO.setup(ledPin, GPIO.OUT)    # set ledPin to OUTPUT mode
    GPIO.setup(buttonPin, GPIO.IN, pull_up_down=GPIO.PUD_UP)     # set buttonPin to PULL UP
INPUT mode
```

In the loop function, the endless loop while continue judging whether the button is pressed. When the button is pressed, the GPIO.input(buttonPin) will return low level, then the result of “if” is true, ledPin outputs high level, LED is turned on. Or, LED will be turned off.

```
def loop():
    while True:
        if GPIO.input(buttonPin)==GPIO.LOW: # if button is pressed
            GPIO.output(ledPin,GPIO.HIGH)   # turn on led
            print ('led turned on >>>')     # print information on terminal
        else : # if button is relessed
            GPIO.output(ledPin,GPIO.LOW) # turn off led
            print ('led turned off <<<')
```

Execute the function destroy (), which will close the program and release the RPI GPIO resource.
About function GPIO.input ():

GPIO.input()
This function returns the value read at the given pin. It will be “**HIGH**” or “**LOW**”(1 or 0) depending on the logic level at the pin.

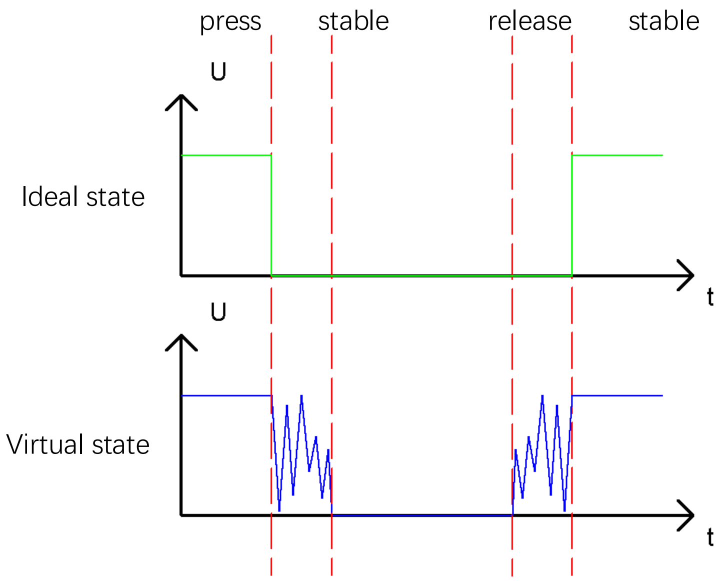
Project 2.2 MINI table lamp

We will also use a button, LED and RPi to make a MINI table lamp. But the function is different: Press the button, the LED will be turned on, and press the button again, the LED goes out.

First, let us learn some knowledge about the button.

Debounce for Push Button

When a Push Button is pressed, it will not change from one state to another state immediately. Due to mechanical vibration, there will be a continuous buffeting before it stabilizes in a new state. The same applies for the release process.



Therefore, if we directly detect the state of Push Button, there may be multiple pressing and releasing action in one pressing process. The buffeting will mislead the high-speed operation of the microcontroller to cause a lot of false judgments. So we need to eliminate the impact of buffeting. Our solution is: to judge the state of the button several times. Only when the button state is stable after a period of time, can it indicate that the button is pressed down.

This project needs the same components and circuit as in the last project.

Code

In the project, we still detect the state of Button to control LED. Here we need to define a variable to save the state of LED. And when the button is pressed once, the state of LED will be changed once. This has achieved the function of the table lamp.

C Code 2.2.1 Tablelamp

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

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

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

```
cd ~/Freenove_Kit/Code/C_Code/02.2.1_Tablelamp
```

2. Use following command to compile “Tablelamp.c” and generate executable file “Tablelamp”.

```
gcc Tablelamp.c -o Tablelamp -lwiringPi
```

3. Tablelamp. Then run the generated file “Tablelamp”.

```
sudo ./Tablelamp
```

When the program is executed, press the Button once, then LED is turned on. Press the Button another time, then LED is turned off.

```
#include <wiringPi.h>
#include <stdio.h>

#define ledPin    0   //define the ledPin
#define buttonPin 1       //define the buttonPin
int ledState=LOW;     //store the State of led
int buttonState=HIGH; //store the State of button
int lastbuttonState=HIGH;//store the lastState of button
long lastChangeTime;  //store the change time of button state
long captureTime=50;  //set the stable time for button state
int reading;
int main(void)
{
    printf("Program is starting...\n");

    wiringPiSetup(); //Initialize wiringPi.

    pinMode(ledPin, OUTPUT);    Set ledPin to output
    pinMode(buttonPin, INPUT); Set buttonPin to input

    pullUpDnControl(buttonPin, PUD_UP);  //pull up to high level
    while(1){
        reading = digitalRead(buttonPin); //read the current state of button
        if( reading != lastbuttonState){  //if the button state has changed, record the time
point
            lastChangeTime = millis();
        }
```

```
            //if changing-state of the button last beyond the time we set, we consider that
            //the current button state is an effective change rather than a buffeting
            if(millis() - lastChangeTime > captureTime){
                //if button state is changed, update the data.
                if(reading != buttonState){
                    buttonState = reading;
                    //if the state is low, it means the action is pressing
                    if(buttonState == LOW){
                        printf("Button is pressed!\n");
                        ledState = !ledState; //Reverse the LED state
                        if(ledState){
                            printf("turn on LED ...\n");
                        }
                        else {
                            printf("turn off LED ...\n");
                        }
                    }
                    //if the state is high, it means the action is releasing
                    else {
                        printf("Button is released!\n");
                    }
                }
            }
            digitalWrite(ledPin,ledState);
            lastbuttonState = reading;
        }

        return 0;
}
```

This code focuses on eliminating the buffering of button. We define several variables to save the state of LED and button. Then read the button state in while() constantly, and determine whether the state has changed. If it has, then record this time point.

```
reading = digitalRead(buttonPin); //read the current state of button
        if( reading != lastbuttonState){
            lastChangeTime = millis();
        }
```

millis()

This returns a number representing the number of milliseconds since your program called one of the wiringPiSetup functions. It returns an unsigned 32-bit number which wraps after 49 days.

Then according to just recorded time point, judge the duration of the button state change. If the duration exceeds captureTime (buffeting time) we set, it indicates that the state of the button has changed. During that time, the while() is still detecting the state of the button, so if there is a change, the time point of change will be updated. The duration will be evaluated again to see if there is a stable state.

```
        if(millis() - lastChangeTime > captureTime){
            //if button state is changed ,update the data.
            if(reading != buttonState){
                buttonState = reading;
```

Finally, judge the state of Button. And if it is low level, the changing state indicates that the button is pressed, if the state is high level, then the button is released. Here, we change the status of the LED variable, and then update the state of LED.

```
                if(buttonState == LOW){
                    printf("Button is pressed!\n");
                    ledState = !ledState; //Reverse the LED state
                    if(ledState){
                        printf("turn on LED ...\n");
                    }
                    else {
                        printf("turn off LED ...\n");
                    }
                }
                //if the state is high, it means the action is releasing
                else {
                    printf("Button is released!\n");
                }
```

Python Code 2.2.1 Tablelamp

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

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

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

```
cd ~/Freenove_Kit/Code/Python_Code/02.2.1_Tablelamp
```

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

```
python Tablelamp.py
```

When the program is executed, press the Button once, then LED is turned on. Press the Button another time, then LED is turned off.

```
import RPi.GPIO as GPIO
ledPin = 11       # define ledPin
buttonPin = 12    # define buttonPin
ledState = False
def setup():
    GPIO.setmode(GPIO.BOARD)        # use Physical GPIO Numbering
    GPIO.setup(ledPin, GPIO.OUT)    # set ledPin to OUTPUT mode
    GPIO.setup(buttonPin, GPIO.IN, pull_up_down=GPIO.PUD_UP)     # set buttonPin to PULL UP
INPUT mode

def buttonEvent(channel): # When button is pressed, this function will be executed
    global ledState
    print ('buttonEvent GPIO%d' %channel)
    ledState = not ledState
    if ledState :
        print ('Led turned on >>>')
    else :
        print ('Led turned off <<<')
    GPIO.output(ledPin,ledState)

def loop():
    #Button detect
    GPIO.add_event_detect(buttonPin,GPIO.FALLING,callback = buttonEvent,bouncetime=300)
    while True:
        pass

def destroy():
    GPIO.cleanup()                     # Release GPIO resource

if __name__ == '__main__':     # Program entrance
    print ('Program is starting...')
    setup()
    try:
        loop()
    except KeyboardInterrupt:  # Press ctrl-c to end the program.
```

```
        destroy()
```

GPIO.add_event_detect(channel, GPIO.RISING, callback=my_callback, bouncetime=200)

This is an event detection function.
The first parameter specifies the IO port to be detected.
The second parameter specifies the action to be detected.
The third parameter specified a function name, the function will be executed when the specified action is detected.
The fourth parameter is used to set the bounce time.

RPi.GPIO provides us with a simple and effective function to eliminate the bounce, that is GPIO.add_event_detect(). It uses a callback function. Once it detect that the buttonPin has a specified action FALLING, it will execute the specified function buttonEvent(). In the function buttonEvent, each time the ledState is reversed, the state of the LED will be updated.

```
def buttonEvent(channel): # When button is pressed, this function will be executed
    global ledState
    print ('buttonEvent GPIO%d' %channel)
    ledState = not ledState
    if ledState :
        print ('Led turned on >>>')
    else :
        print ('Led turned off <<<')
    GPIO.output(ledPin,ledState)

def loop():
    #Button detect
    GPIO.add_event_detect(buttonPin,GPIO.FALLING,callback = buttonEvent,bouncetime=300)
    while True:
        pass
```

Of course, you can also use the same programming idea of C code above to achieve this goal.

If there are two button pins, the function can be define as below:

```
def buttonEvent(channel): # When button is pressed, this function will be executed
    print ('buttonEvent GPIO%d' %channel)
def buttonEvent2(channel): # When button is pressed, this function will be executed
    print ('buttonEvent GPIO%d' %channel)

def loop():
    #Button detect
    GPIO.add_event_detect(buttonPin,GPIO.FALLING,callback = buttonEvent,bouncetime=300)
    GPIO.add_event_detect(buttonPin2,GPIO.FALLING,callback = buttonEvent2,bouncetime=300)
    while True:
        pass
```

Chapter 3 LEDBar Graph

We have learned how to control a LED blinking, and next we will learn how to control a number of LED.

Project 3.1 Flowing Water Light

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

Component List

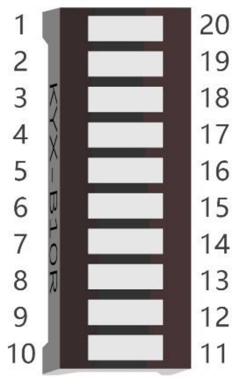
Raspberry Pi (with 40 GPIO) x1 GPIO Extension Board & Wire x1 Breadboard x1	LED bar graph x1 	Resistor 220Ω x10 
Jumper 		

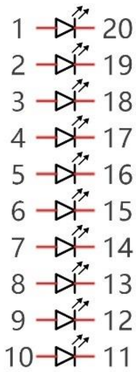
Component knowledge

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

LED bar graph

LED bar graph is a component Integration consisting of 10 LEDs. There are two rows of pins at its bottom.

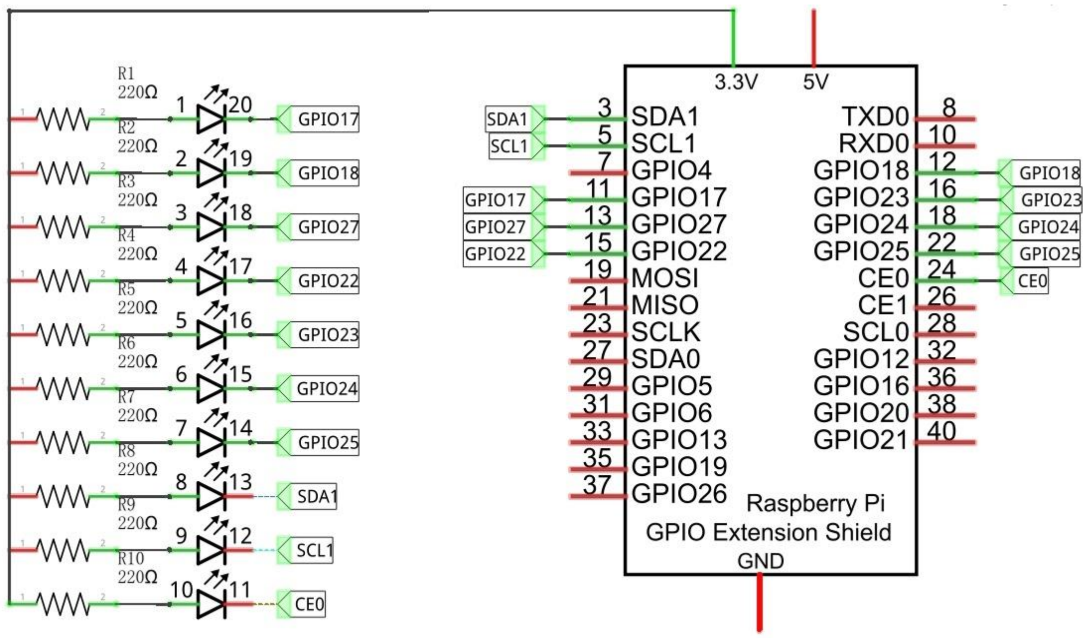




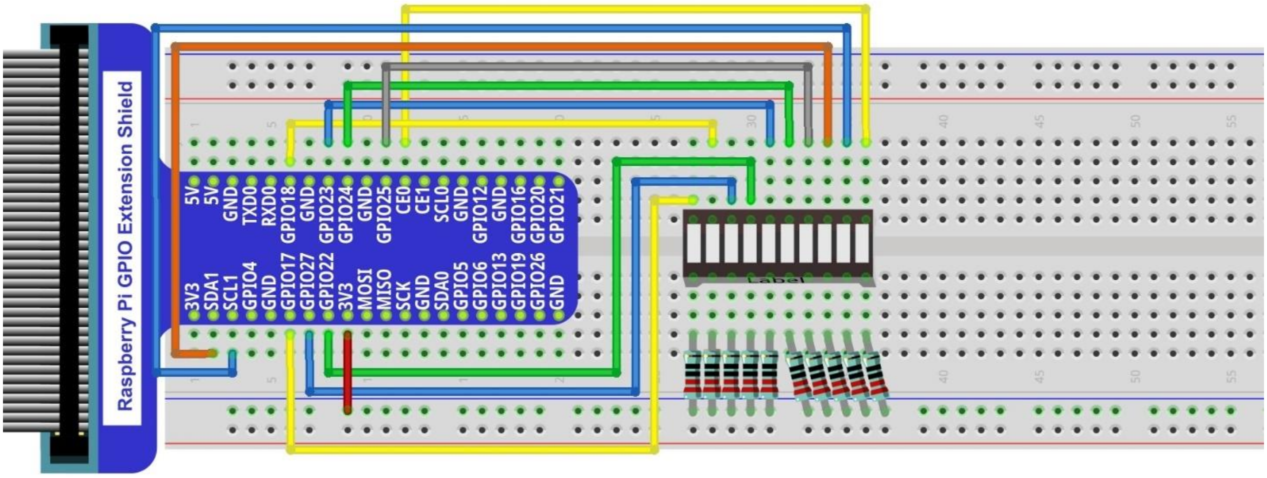
Circuit

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

Schematic diagram



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



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

In this circuit, the cathode of LED is connected to GPIO. The LED will be turned on when GPIO output low level in the program.

Code

This project is designed to make a water lamp. First turns on the first LED, then turns off it. Then turns on the second LED, and then turns off it....... Until the last LED is turned on, then is turned off. And repeats the process to achieve the effect of flowing water light.

C Code 3.1.1 LightWater

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

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

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

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

2. Use following command to compile “LightWater.c” and generate executable file “LightWater”.

```
gcc LightWater.c -o LightWater -lwiringPi
```

3. Then run the generated file “LightWater”.

```
sudo ./LightWater
```

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

The following is the program code:

```
#include <wiringPi.h>
#include <stdio.h>

#define ledCounts 10
int pins[ledCounts] = {0,1,2,3,4,5,6,8,9,10};

void main(void)
{
    int i;
    printf("Program is starting ... \n");

    wiringPiSetup(); //Initialize wiringPi.

    for(i=0;i<ledCounts;i++){       //Set pinMode for all led pins to output
        pinMode(pins[i], OUTPUT);
    }
    while(1){
        for(i=0;i<ledCounts;i++){   // move led(on) from left to right
            digitalWrite(pins[i],LOW);
            delay(100);
            digitalWrite(pins[i],HIGH);
        }
        for(i=ledCounts-1;i>-1;i--){   // move led(on) from right to left
            digitalWrite(pins[i],LOW);
            delay(100);
            digitalWrite(pins[i],HIGH);
```

```
        }
    }
}
```

In the program, configure the GPIO0-GPIO9 to output mode. Then, in the endless “while” loop of main function, use two “for” loop to realize flowing water light from left to right and from right to left.

```
    while(1){
        for(i=0;i<ledCounts;i++){   // move led(on) from left to right
            digitalWrite(pins[i],LOW);
            delay(100);
            digitalWrite(pins[i],HIGH);
        }
        for(i=ledCounts-1;i>-1;i--){   // move led(on) from right to left
            digitalWrite(pins[i],LOW);
            delay(100);
            digitalWrite(pins[i],HIGH);
        }
    }
}
```

Python Code 3.1.1 LightWater

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

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

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

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

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

```
python LightWater.py
```

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

The following is the program code:

```python
import RPi.GPIO as GPIO
import time

ledPins = [11, 12, 13, 15, 16, 18, 22, 3, 5, 24]

def setup():
    GPIO.setmode(GPIO.BOARD)        # use Physical GPIO Numbering
    GPIO.setup(ledPins, GPIO.OUT)   # set all ledPins to OUTPUT mode
    GPIO.output(ledPins, GPIO.HIGH) # make all ledPins output HIGH level, turn off all led

def loop():
    while True:
        for pin in ledPins:       # make led(on) move from left to right
            GPIO.output(pin, GPIO.LOW)
```

```
            time.sleep(0.1)
            GPIO.output(pin, GPIO.HIGH)
        for pin in ledPins[::-1]:       # make led(on) move from right to left
            GPIO.output(pin, GPIO.LOW)
            time.sleep(0.1)
            GPIO.output(pin, GPIO.HIGH)

def destroy():
    GPIO.cleanup()                     # Release all GPIO

if __name__ == '__main__':     # Program entrance
    print ('Program is starting...')
    setup()
    try:
        loop()
    except KeyboardInterrupt:  # Press ctrl-c to end the program.
        destroy()
```

In the program, first define 10 pins connected to LED, and set them to output mode in subfunction setup(). Then in the loop() function, use two "for" loops to realize flowing water light from right to left and from left to right. ledPins[::-1] is used to get elements of ledPins in reverse order.

```
def loop():
    while True:
        for pin in ledPins:      #make led on from left to right
            GPIO.output(pin, GPIO.LOW)
            time.sleep(0.1)
            GPIO.output(pin, GPIO.HIGH)
        for pin in ledPins[::-1]:        #make led on from right to left
            GPIO.output(pin, GPIO.LOW)
            time.sleep(0.1)
            GPIO.output(pin, GPIO.HIGH)
```

Chapter 4 Analog & PWM

In previous study, we have known that one button has two states: pressed and released, and LED has light-on/off state, but how to change the brightness? That's what we're going to learn.
First, let's learn how to control the brightness of a LED.

Project 4.1 Breathing LED

Breathing light, that is, LED is turned from off to on gradually, gradually from on to off, just like "breathing". So, how to control the brightness of a LED? We will use PWM to achieve this goal.

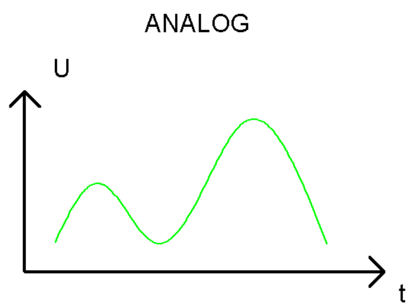
Component List

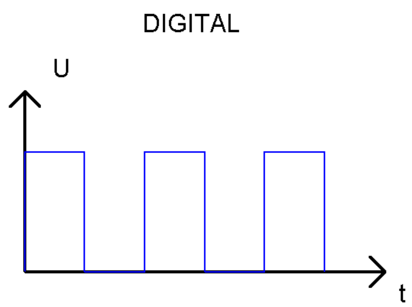
Raspberry Pi (with 40 GPIO) x1 GPIO Extension Board & Wire x1 Breadboard x1	LED x1 	Resistor 220Ω x1 
Jumper 		

Circuit knowledge

Analog & Digital

The analog signal is a continuous signal in time and value. On the contrary, digital signal is a discrete signal in time and value. Most signals in life are analog signals, for example, the temperature in one day is continuously changing, and will not appear a sudden change directly from 0℃ to 10℃, while the digital signal is a jump change, which can be directly from 1 to 0.
Their difference can be illustrated by the following figure.





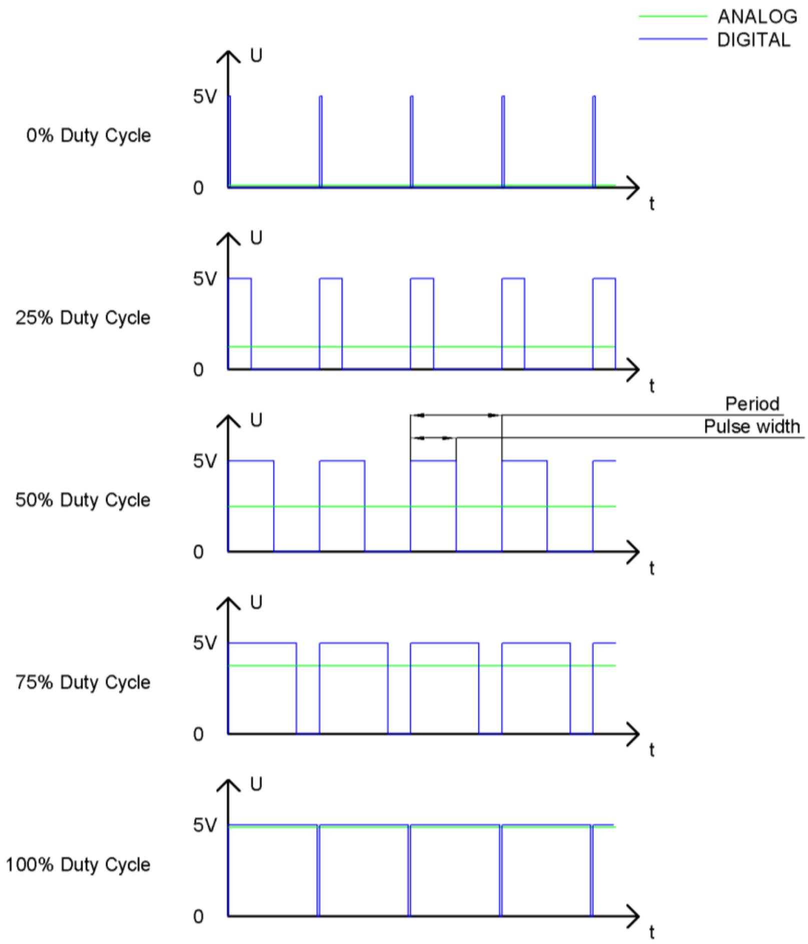
In practical applications, we often use binary signal as digital signal, that is 0 and 1. The binary signal only has two forms (0 or 1), so it has strong stability. And digital signal and analog signal can be converted to each other.

PWM

PWM, namely Pulse-Width Modulation, is a very effective technique for using digital signals to control analog circuits. The digital processors can not directly output analog signals. PWM technology make it very convenient to achieve this purpose.

PWM technology uses a digital pin to send a square wave of a certain frequency, that is, a high level and a low level output that alternate for a period of time. Generally, the total time of each group of high level and low level is fixed, called the cycle (the reciprocal of the cycle is the frequency). The time for high-level output is usually called the pulse width, and the percentage of the pulse width is called the duty cycle.

The longer the duration of the high level outputs, the greater the duty cycle, and the greater the corresponding voltage in the analog signal. The figure below shows how the analog signal voltage varies between 0V-5V (high level is 5V), corresponding to a pulse width of 0%-100%:



The larger PWM duty cycle is, the lager the output power will be. So we can use PWM to control the brightness of LED, the speed of DC motor and so on.

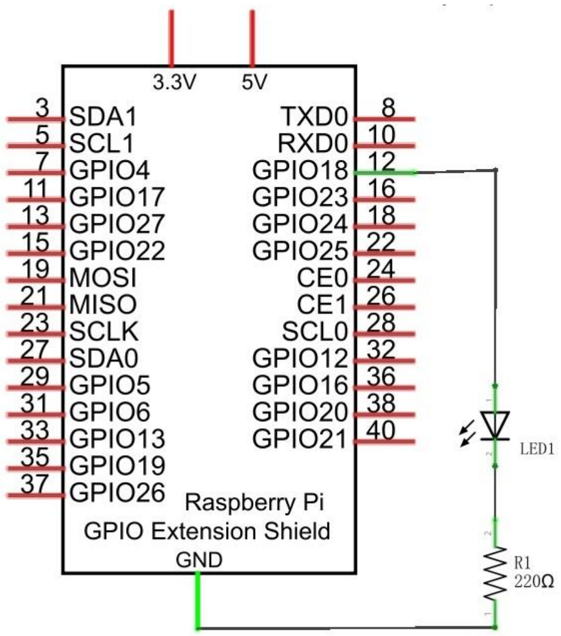
It is evident from the above that PWM is not real analog, and the effective value of the voltage is equivalent to the corresponding analog. so, we can control the output power of the LED and other output modules to achieve different effects.

In RPi, only GPIO18 has the ability to output hardware PWM with a 10-bit accuracy, that is, 100% of the pulse width can be divided into 2^{10}=1024 equal parts.
The wiringPi library of C provides a hardware PWM method and a software PWM method, while wiringPi library of Python doesn't provide hardware PWM method. There is only software PWM for Python.

The hardware PWM only needs to be configured, does not occupy CPU resources, and is more precise in time control. The software PWM requires the CPU to work all the time, using the code to output high level and low level. This part of the code is carried out in multi-thread, and the time precision is lower than the one of hardware PWM.

In order to keep the running results consistent, we adopt the way of software PWM.

Circuit

<table>
<tr><td>Schematic diagram</td><td>Hardware connection. If you need any support, please feel free to contact us via: support@freenove.com</td></tr>
<tr><td>


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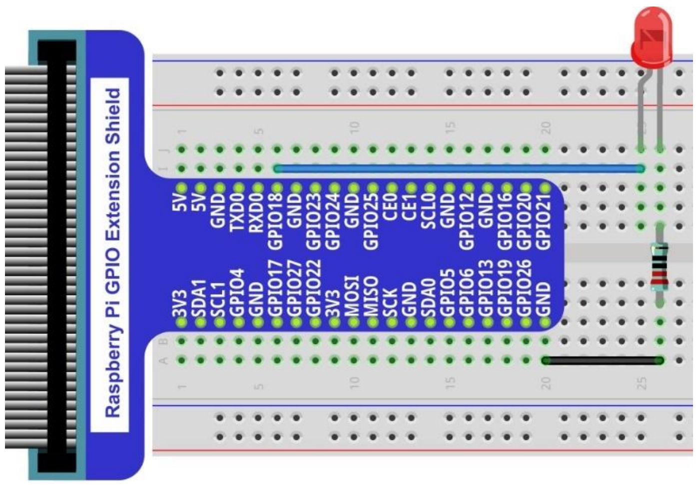


</td></tr>
</table>

Code

This project is designed to make PWM output GPIO18 with pulse width increasing from 0% to 100%, and then reducing from 100% to 0% gradually.

C Code 4.1.1 BreathingLED

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

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

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

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

2. Use following command to compile "BreathingLED.c" and generate executable file "BreathingLED".

```
gcc BreathingLED.c -o BreathingLED -lwiringPi
```

3. Then run the generated file “BreathingLED”

```
sudo ./BreathingLED
```

After the program is executed, you'll see that LED is turned from on to off and then from off to on gradually like breathing.

The following is the program code:

```
#include <wiringPi.h>
#include <stdio.h>
#include <softPwm.h>

#define ledPin    1

void main(void)
{
    int i;

    printf("Program is starting ... \n");

    wiringPiSetup();  //Initialize wiringPi.

    softPwmCreate(ledPin,  0, 100);//Create SoftPWM pin

    while(1){
        for(i=0;i<100;i++){  //make the led brighter
            softPwmWrite(ledPin, i);
            delay(20);
        }
        delay(300);
        for(i=100;i>=0;i--){  //make the led darker
            softPwmWrite(ledPin, i);
            delay(20);
        }
        delay(300);
    }
}
```

First, create a software PWM pin.

```
softPwmCreate(ledPin,  0, 100);//Create SoftPWM pin
```

There are two “for” loops in the next endless “while” loop. The first makes the ledPin output PWM from 0% to 100% and the second makes the ledPin output PWM from 100% to 0%.

```
    while(1){
        for(i=0;i<100;i++){
            softPwmWrite(ledPin, i);
            delay(20);
        }
        delay(300);
```

```
        for(i=100;i>=0;i--){
            softPwmWrite(ledPin, i);
            delay(20);
        }
        delay(300);
    }
```

You can also adjust the state change rate of LED by changing the value of the delay() function in the "for" loop.

int softPwmCreate (int pin, int initialValue, int pwmRange) ;
This creates a software controlled PWM pin.
void softPwmWrite (int pin, int value) ;
This updates the PWM value on the given pin.

For more details, please refer http://wiringpi.com/reference/software-pwm-library/

Python Code 4.1.1 BreathingLED

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

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

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

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

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

```
python BreathingLED.py
```

After the program is executed, you'll see that LED is turned from on to off and then from off to on gradually like breathing.

The following is the program code:

```python
import RPi.GPIO as GPIO
import time

LedPin = 12       # define the LedPin

def setup():
    global p
    GPIO.setmode(GPIO.BOARD)        # use Physical GPIO Numbering
    GPIO.setup(LedPin, GPIO.OUT)    # set LedPin to OUTPUT mode
    GPIO.output(LedPin, GPIO.LOW)   # make ledPin output LOW level to turn off LED

    p = GPIO.PWM(LedPin, 500)       # set PWM Frequence to 500Hz
    p.start(0)                      # set initial Duty Cycle to 0

def loop():
    while True:
        for dc in range(0, 101, 1):   # make the led brighter
            p.ChangeDutyCycle(dc)     # set dc value as the duty cycle
            time.sleep(0.01)
        time.sleep(1)
```

```
            for dc in range(100, -1, -1): # make the led darker
                p.ChangeDutyCycle(dc)     # set dc value as the duty cycle
                time.sleep(0.01)
            time.sleep(1)

def destroy():
    p.stop() # stop PWM
    GPIO.cleanup() # Release all GPIO

if __name__ == '__main__':     # Program entrance
    print ('Program is starting ... ')
    setup()
    try:
        loop()
    except KeyboardInterrupt:  # Press ctrl-c to end the program.
        destroy()
```

LED is connected to the IO port called GPIO18. And LedPin is defined as 12 and set to output mode according to the corresponding chart for pins. Then create a PWM instance and set the PWM frequency to 1000HZ, the initial duty cycle to 0%.

```
LedPin = 12      # define the LedPin

def setup():
    global p
    GPIO.setmode(GPIO.BOARD)       # use Physical GPIO Numbering
    GPIO.setup(LedPin, GPIO.OUT)   # set LedPin to OUTPUT mode
    GPIO.output(LedPin, GPIO.LOW)  # make ledPin output LOW level to turn off LED

    p = GPIO.PWM(LedPin, 500)      # set PWM Frequence to 500Hz
    p.start(0)                     # set initial Duty Cycle to 0
```

There are two “for” loops used to realize breathing LED in the next endless “while” loop. The first makes the ledPin output PWM from 0% to 100% and the second makes the ledPin output PWM from 100% to 0%.

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

The related functions of PWM are described as follows:

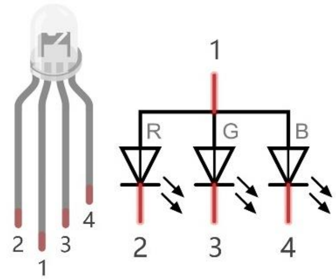
p = GPIO.PWM(channel, frequency)
To create a PWM instance:
p.start(dc)
To start PWM:， where dc is the duty cycle (0.0 <= dc <= 100.0)
p.ChangeFrequency(freq)
To change the frequency， where freq is the new frequency in Hz
p.ChangeDutyCycle(dc)
To change the duty cycle， where 0.0 <= dc <= 100.0
p.stop()
To stop PWM.

For more details about usage method for PWM of RPi.GPIO, please refer to:
https://sourceforge.net/p/raspberry-gpio-python/wiki/PWM/

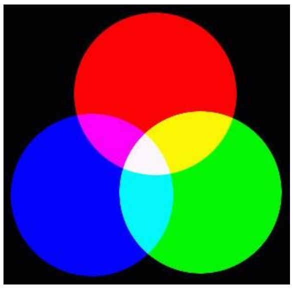
Chapter 5 RGBLED

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

RGB LED has 3 integrated LEDs that can respectively emit red, green and blue light. And it has 4 pins. The long pin (1) is the common pin, the other three are positive or negative pins of r, g, b. The RGB LED with common positive pin is shown below. We can make RGB LED show various colors of light by controlling these 3 LEDs to emit light with different brightness.



Red, green, and blue light are called 3 primary colors. When you combine these three primary-color light with different brightness, it can produce almost any kind of visible light. Computer screens, single pixel of cell phone screen, neon, and etc. are working under this principle.



RGB

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

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

Project 5.1 Colorful LED

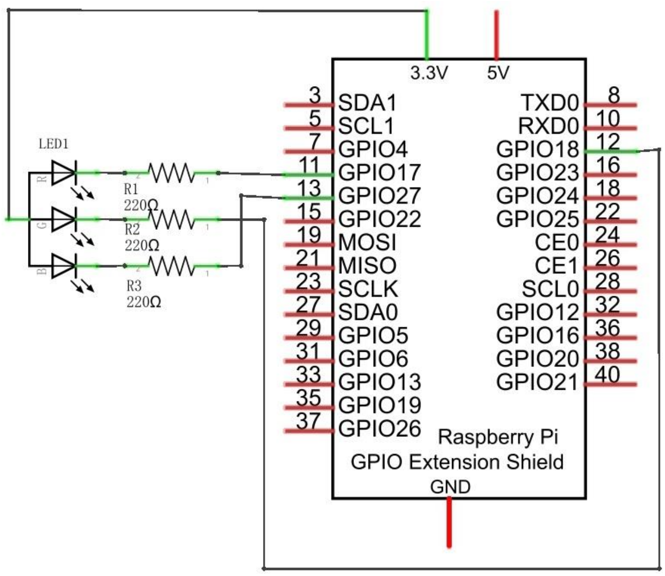
In this project, we will make a multicolored LED. And we can control RGBLED to switch different colors automatically.

Component List

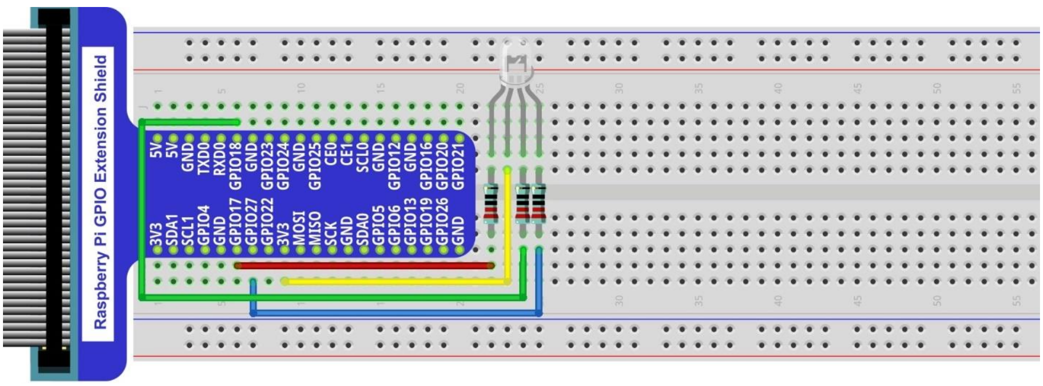
<table>
<tr><td>Raspberry Pi (with 40 GPIO) x1
GPIO Extension Board & Wire x1
Breadboard x1</td><td rowspan="2">RGBLED x1
</td><td rowspan="2">Resistor 220Ω x3
</td></tr>
<tr><td>Jumper
</td></tr>
</table>

Circuit

Schematic diagram



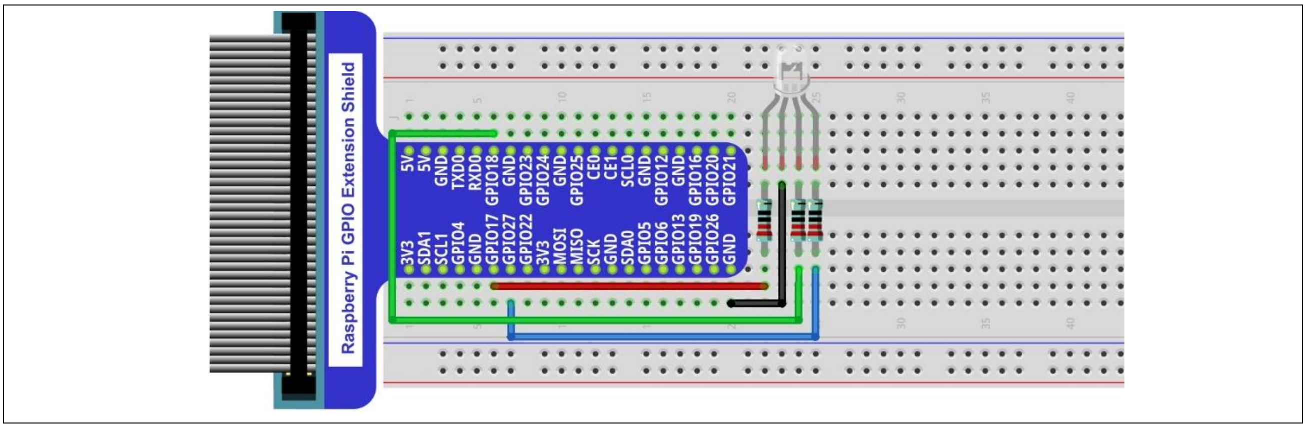
Hardware connection. If you need any support, please feel free to contact us via: **support@freenove.com**



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

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

There is no need to modify code for random color.



Code

Since this project requires 3 PWM, but in RPi, only one GPIO has the hardware capability to output PWM, we need to use the software to make the ordinary GPIO output PWM.

C Code 5.1.1 ColorfulLED

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

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

1. Use cd command to enter 05.1.1_ColorfulLED directory of C code.

```
cd ~/Freenove_Kit/Code/C_Code/05.1.1_ColorfulLED
```

Use following command to compile "ColorfulLED.c" and generate executable file "ColorfulLED". Note: in this project, the software PWM uses a multi-threading mechanism. So "-lpthread" option need to be added to the compiler.

```
gcc ColorfulLED.c -o ColorfulLED -lwiringPi -lpthread
```

2. And then run the generated by "ColorfulLED".

```
sudo ./ColorfulLED
```

After the program is executed, you will see that the RGBLED shows light of different color randomly.

The following is the program code:

```
#include <wiringPi.h>
#include <softPwm.h>
#include <stdio.h>
#include <stdlib.h>

#define ledPinRed    0
#define ledPinGreen  1
#define ledPinBlue   2

void setupLedPin(void)
{
    softPwmCreate(ledPinRed,  0,  100);  //Create SoftPWM pin for red
    softPwmCreate(ledPinGreen, 0,  100);  //Create SoftPWM pin for green
    softPwmCreate(ledPinBlue,  0,  100);  //Create SoftPWM pin for blue
}
```

```

void setLedColor(int r, int g, int b)
{
    softPwmWrite(ledPinRed,   r);  //Set the duty cycle
    softPwmWrite(ledPinGreen, g);   //Set the duty cycle
    softPwmWrite(ledPinBlue,  b);   //Set the duty cycle
}

int main(void)
{
    int r,g,b;

    printf("Program is starting ...\n");

    wiringPiSetup();  //Initialize wiringPi.

    setupLedPin();
    while(1){
        r=random()%100;  //get a random in (0,100)
        g=random()%100;  //get a random in (0,100)
        b=random()%100;  //get a random in (0,100)
        setLedColor(r,g,b);//set random as the duty cycle value
        printf("r=%d,  g=%d,  b=%d \n",r,g,b);
        delay(300);
    }
    return 0;
}
```

Since the RGB led is Common anode, the rgb value is 255-r, 255-g, 255-b.

For example, as we know that, rgb value of red is (255, 0, 0) . Here we should set value to (0, 255 ,255).

First, in subfunction of ledInit(), create the software PWM control pins used to control the R, G, B pin respectively.

```
void setupLedPin(void)
{
    softPwmCreate(ledPinRed,   0,  100);  //Create SoftPWM pin for red
    softPwmCreate(ledPinGreen,0,  100);   //Create SoftPWM pin for green
    softPwmCreate(ledPinBlue,  0,  100);   //Create SoftPWM pin for blue
}
```

Then create subfunction, and set the PWM of three pins.

```
void setLedColor(int r, int g, int b)
{
    softPwmWrite(ledPinRed,   r);  //Set the duty cycle
    softPwmWrite(ledPinGreen, g);   //Set the duty cycle
    softPwmWrite(ledPinBlue,  b);   //Set the duty cycle
}
```

Finally, in the "while" loop of main function, get three random numbers and specify them as the PWM duty cycle, which will be assigned to the corresponding pins. So RGBLED can switch the color randomly all the time.

```
    while(1){
        r=random()%100;  //get a random in (0,100)
        g=random()%100;  //get a random in (0,100)
        b=random()%100;  //get a random in (0,100)
        setLedColor(r,g,b);//set random as the duty cycle value
        printf("r=%d,  g=%d,  b=%d \n",r,g,b);
        delay(300);
    }
```

The related function of Software PWM is as below:

long random();

This function will return a random number.

For more details about Software PWM, please refer to: http://wiringpi.com/reference/software-pwm-library/

Python Code 5.1.1 ColorfulLED

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

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

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

```
cd ~/Freenove_Kit/Code/Python_Code/05.1.1_ColorfulLED
```

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

```
python ColorfulLED.py
```

After the program is executed, you will see that the RGBLED shows light of different color randomly.

The following is the program code:

```
import RPi.GPIO as GPIO
import time
import random

pins = {'pinRed':11, 'pinGreen':12, 'pinBlue':13}  # define the pins for RGBLED

def setup():
    global pwmRed,pwmGreen,pwmBlue
    GPIO.setmode(GPIO.BOARD)       # use Physical GPIO Numbering
    GPIO.setup(pins, GPIO.OUT)     # set RGBLED pins to OUTPUT mode
    GPIO.output(pins, GPIO.HIGH)   # make RGBLED pins output HIGH level
    pwmRed = GPIO.PWM(pins['pinRed'], 2000)      # set PWM Frequence to 2kHz
    pwmGreen = GPIO.PWM(pins['pinGreen'], 2000)  # set PWM Frequence to 2kHz
    pwmBlue = GPIO.PWM(pins['pinBlue'], 2000)    # set PWM Frequence to 2kHz
    pwmRed.start(0)      # set initial Duty Cycle to 0
    pwmGreen.start(0)
    pwmBlue.start(0)

def setColor(r_val,g_val,b_val):      # change duty cycle for three pins to r_val,g_val,b_val
    pwmRed.ChangeDutyCycle(r_val)     # change pwmRed duty cycle to r_val
```

```
        pwmGreen.ChangeDutyCycle(g_val)
        pwmBlue.ChangeDutyCycle(b_val)

def loop():
    while True :
        r=random.randint(0,100)  #get a random in (0,100)
        g=random.randint(0,100)
        b=random.randint(0,100)
        setColor(r,g,b)          #set random as a duty cycle value
        print ('r=%d, g=%d, b=%d ' %(r ,g, b))
        time.sleep(0.3)

def destroy():
    pwmRed.stop()
    pwmGreen.stop()
    pwmBlue.stop()
    GPIO.cleanup()

if __name__ == '__main__':     # Program entrance
    print ('Program is starting ... ')
    setup()
    try:
        loop()
    except KeyboardInterrupt:  # Press ctrl-c to end the program.
        destroy()
```

In last chapter, we have learned how to use python language to make a pin output PWM. In this project, we let three pins output PWM, and the usage is the same as last chapter. In the while loop of “loop” function, we first generate three random numbers, and then specify them as the PWM value of the three pins so that the RGBLED switching of different colors randomly.

```
def loop():
    while True :
        r=random.randint(0,100)  #get a random in (0,100)
        g=random.randint(0,100)
        b=random.randint(0,100)
        setColor(r,g,b)          #set random as a duty cycle value
        print ('r=%d, g=%d, b=%d ' %(r ,g, b))
        time.sleep(0.3)
```

About function randint():

random.randint(a, b)
The function can returns a random integer within the specified range (a, b).

Chapter 6 Buzzer

In this chapter, we will learn a component that can emit sounds: buzzer.

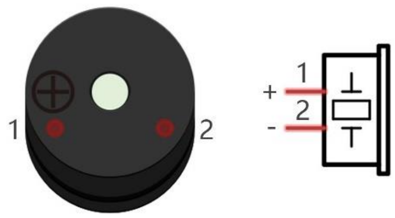
Project 6.1 Doorbell

We will make a doorbell: when the button is pressed, the buzzer makes sounds; and when the button is released, the buzzer make no sounds.

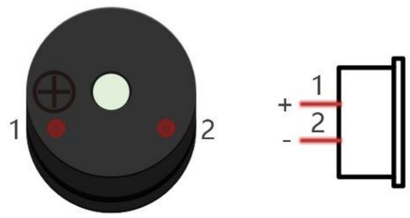
Buzzer

Buzzer is a sounding component, which is widely used in electronic devices such as calculator, electronic warning clock, alarm. Buzzer has active and passive type. Active buzzer has oscillator inside, and it will sound as long as it is supplied with power. Passive buzzer requires external oscillator signal (generally use PWM with different frequency) to make a sound.

Active buzzer



Passive buzzer



Active buzzer is easy to use. Generally, it can only make a specific frequency of sound. Passive buzzer requires an external circuit to make a sound, but it can be controlled to make a sound with different frequency. The resonant frequency of the passive buzzer is 2kHz, which means the passive buzzer is loudest when its resonant frequency is 2kHz.

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

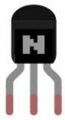
How to identify active and passive buzzer?

1. Usually, there is a **label** on the surface of **active** buzzer covering the vocal hole, but this is not an absolute judgment method.
2. Active buzzer is more complex than passive buzzer in manufacture. There are a lot of circuits and crystal oscillator elements inside active buzzer, which are covered with a waterproof coating, around its pins. Passive buzzer doesn't have these coatings. From bottom of passive buzzer, you can even see the circuit board, coils, and permanent magnets directly.

Active buzzer

Passive buzzer

Component List

Raspberry Pi (with 40 GPIO) x1 GPIO Extension Board & Wire x1 Breadboard x1		Jumper 		
NPN transistorx1 (S8050) 	Active buzzer x1 	Push button x1 	Resistor 1kΩ x1 	Resistor 10kΩ x2 

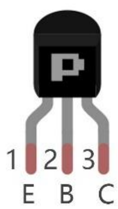
Component knowledge

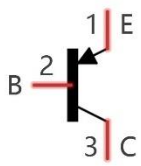
Transistor

Due to the high current needed by the buzzer to operate, the GPIO of the RPI can not meet that requirement. A transistor of NPN type is needed here to amplify the current.

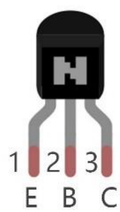
Transistor (semiconductor transistor) is a semiconductor device that controls current. Transistor can be used to amplify weak signal, or to work as a switch. It has three electrodes (PINs): base (b), collector (c) and emitter (e). When there is current passing between "be", "ce" will allow several-fold current (transistor magnification) pass, at this point, transistor works in the amplifying area. When current between "be" exceeds a certain value, "ce" will not allow current to increase any longer, at this point, transistor works in the saturation area. Transistor has two types shown below: PNP and NPN,

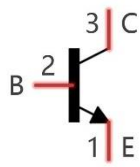
PNP transistor





NPN transistor

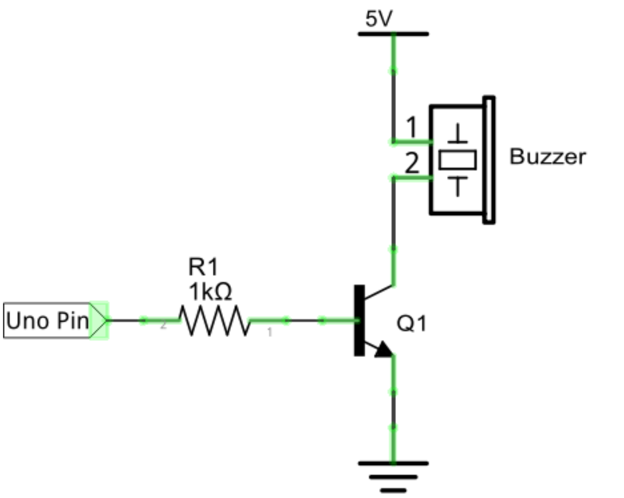
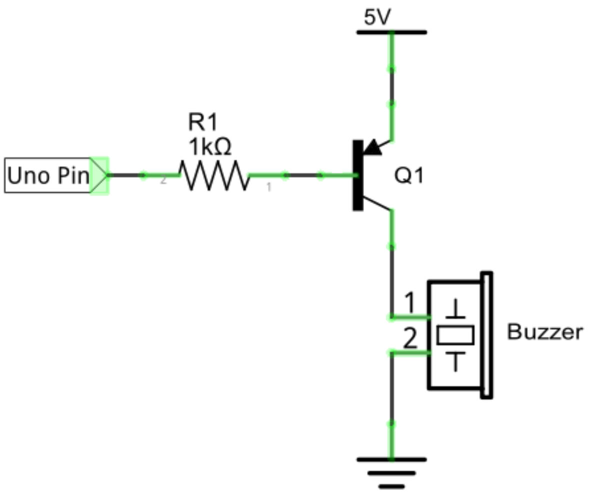




In our kit, the PNP transistor is marked with 8550, and the NPN transistor is marked with 8050.

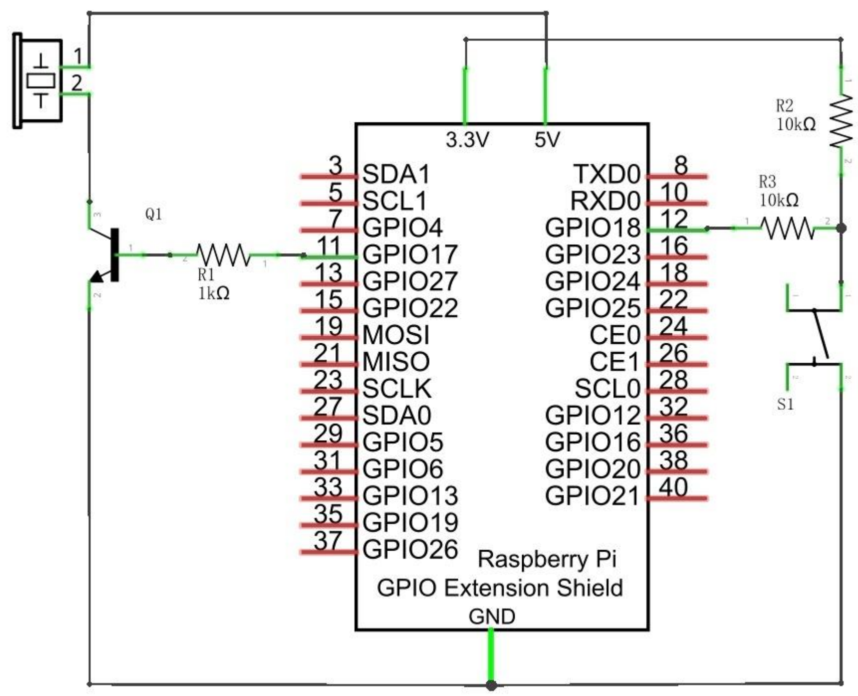
Due to the transistor characteristics, it is often used as a switch in digital circuits. However, micro-controller's capacity of output current is very weak. We will use the transistor to amplify current and drive large-current components.

When use NPN transistor to drive buzzer, we often adopt the following method. If GPIO outputs high level, current will flow through R1, the transistor conducts current, and the buzzer makes a sound. If GPIO outputs low level, no current flows through R1. The transistor will not conducts current, and buzzer will not sound. When use PNP transistor to drive buzzer, we often adopt the following method. If GPIO outputs low level, current will flow through R1, and the transistor conducts current, then buzzer makes a sound. If GPIO outputs high level, no current flows through R1. The transistor will not conducts current, and buzzer will not make sound.

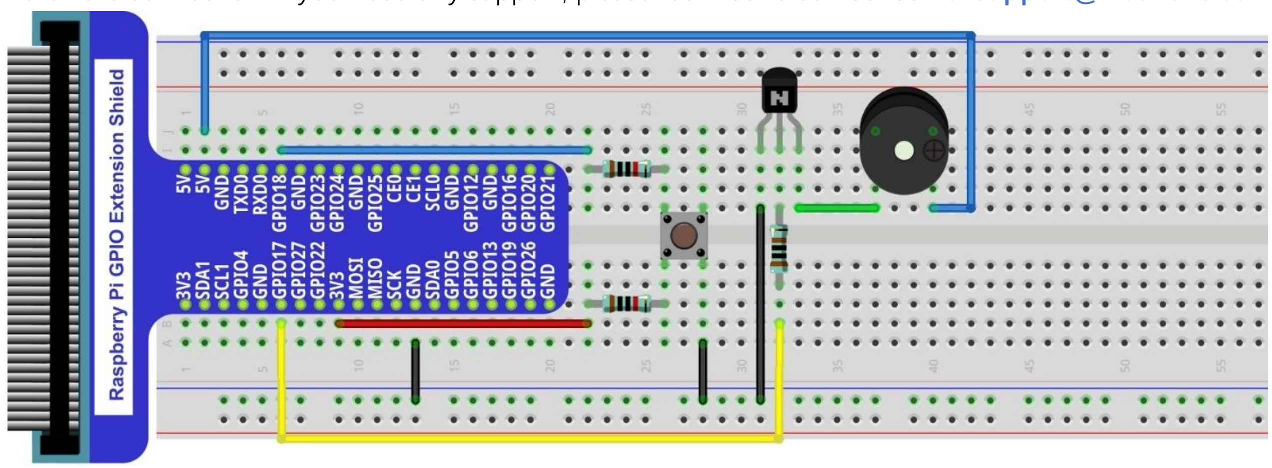
NPN transistor to drive buzzer	PNP transistor to drive buzzer
	

Circuit

Schematic diagram



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



Note: in this circuit, the power supply for buzzer is 5V, and pull-up resistor of the button connected to the power 3.3V. The buzzer can work when connected to power 3.3V, but it will reduce the loudness.

Code

In this project, buzzer is controlled by the button. When the button is pressed, the buzzer makes sounds. And when the button is released, the buzzer stops making sounds. In the logic, it is the same to using button to control LED.

C Code 6.1.1 Doorbell

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

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

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

```
cd ~/Freenove_Kit/Code/C_Code/06.1.1_Doorbell
```

2. Use following command to compile “Doorbell.c” and generate executable file “Doorbell.c”.

```
gcc Doorbell.c -o Doorbell -lwiringPi
```

3. Then run the generated file “Doorbell”.

```
sudo ./Doorbell
```

After the program is executed, press the button, then buzzer makes sounds. And when the button is released, the buzzer stops making sounds.

The following is the program code:

```
#include <wiringPi.h>
#include <stdio.h>

#define buzzerPin 0   //define the buzzerPin
#define buttonPin 1       //define the buttonPin

void main(void)
{
    printf("Program is starting ... \n");

    wiringPiSetup();

    pinMode(buzzerPin, OUTPUT);
    pinMode(buttonPin, INPUT);

    pullUpDnControl(buttonPin, PUD_UP);  //pull up to HIGH level
    while(1){

        if(digitalRead(buttonPin) == LOW){ //button is pressed
            digitalWrite(buzzerPin, HIGH);   //Turn on buzzer
            printf("buzzer turned on >>> \n");
        }
        else {                  //button is released
            digitalWrite(buzzerPin, LOW);   //Turn off buzzer
            printf("buzzer turned off <<< \n");
```

```
        }
    }
}
```

The code is exactly the same to using button to control LED logically.

Python Code 6.1.1 Doorbell

First observe the project result, then view the code.

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

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

```
cd ~/Freenove_Kit/Code/Python_Code/06.1.1_Doorbell
```

2. Use python command to execute python code “Doorbell.py”.

```
python Doorbell.py
```

After the program is executed, press the button, then buzzer makes sounds. And when the button is released, the buzzer stops making sounds.

The following is the program code:

```
import RPi.GPIO as GPIO

buzzerPin = 11    # define buzzerPin
buttonPin = 12    # define buttonPin

def setup():
    GPIO.setmode(GPIO.BOARD)        # use Physical GPIO Numbering
    GPIO.setup(buzzerPin, GPIO.OUT)   # set buzzerPin to OUTPUT mode
    GPIO.setup(buttonPin, GPIO.IN, pull_up_down=GPIO.PUD_UP)    # set buttonPin to PULL UP
INPUT mode

def loop():
    while True:
        if GPIO.input(buttonPin)==GPIO.LOW: # if button is pressed
            GPIO.output(buzzerPin,GPIO.HIGH) # turn on buzzer
            print ('buzzer turned on >>>')
        else : # if button is relessed
            GPIO.output(buzzerPin,GPIO.LOW) # turn off buzzer
            print ('buzzer turned off <<<')

def destroy():
    GPIO.cleanup()                     # Release all GPIO

if __name__ == '__main__':     # Program entrance
    print ('Program is starting...')
    setup()
    try:
```

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

The code is exactly the same to using button to control LED logically. You can try to use the PNP transistor to achieve the function of his circuit once again.

Project 6.2 Alarm

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

Component list and the circuit part is the similar to last section. In the Doorbell circuit, only the active buzzer needs to be replaced by a passive buzzer.

Code

In this project, the buzzer alarm is controlled by the button. In the logic, it is the same to using button to control LED. In the control method, passive buzzer requires PWM of certain frequency to makes sounds.

C Code 6.2.1 Alertor

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

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

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

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

2. Use following command to compile “Alertor.c” and generate executable file “Alertor”. “-lm” and “-lpthread” compiler options are needed to add here.

```
gcc Alertor.c -o Alertor -lwiringPi -lm -lpthread
```

3. Then run the generated file “Alertor”.

```
sudo ./Alertor
```

After the program is executed, press the button, then buzzer makes sounds. And when the button is released, the buzzer stop making sounds.

The following is the program code:

```
#include <wiringPi.h>
#include <stdio.h>
#include <softTone.h>
#include <math.h>

#define buzzerPin    0     //define the buzzerPin
#define buttonPin      1       //define the buttonPin

void alertor(int pin){
    int x;
    double sinVal, toneVal;
    for(x=0;x<360;x++){ // frequency of the alertor is consistent with the sine wave
```

```
        sinVal = sin(x * (M_PI / 180));         //Calculate the sine value
        toneVal = 2000 + sinVal * 500;      //Add the resonant frequency and weighted sine
value
        softToneWrite(pin,toneVal);            //output corresponding PWM
        delay(1);
    }
}
void stopAlertor(int pin){
    softToneWrite(pin,0);
}
int main(void)
{
    printf("Program is starting ... \n");

    wiringPiSetup();

    pinMode(buzzerPin, OUTPUT);
    pinMode(buttonPin, INPUT);
    softToneCreate(buzzerPin); //set buzzerPin
    pullUpDnControl(buttonPin, PUD_UP);  //pull up to HIGH level
    while(1){
        if(digitalRead(buttonPin) == LOW){ //button is pressed
            alertor(buzzerPin);   // turn on buzzer
            printf("alertor turned on >>> \n");
        }
        else {                 //button is released
            stopAlertor(buzzerPin);   // turn off buzzer
            printf("alertor turned off <<< \n");
        }
    }
    return 0;
}
```

The code is the same to the active buzzer logically, but the way to control the buzzer is different. Passive buzzer requires PWM of certain frequency to be controlled, so you need to create a software PWM pin though softToneCreate (buzzeRPin). Here softTone is designed to generate square wave with variable frequency and duty cycle fixed to 50%, which is a better choice for controlling the buzzer.

```
softToneCreate(buzzeRPin);
```

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

```
void alertor(int pin){
    int x;
    double sinVal, toneVal;
    for(x=0;x<360;x++){ //The frequency is based on the sine curve.
        sinVal = sin(x * (M_PI / 180));
        toneVal = 2000 + sinVal * 500;
        softToneWrite(pin,toneVal);
        delay(1);
    }
}
```

If you want to close the buzzer, just set PWM frequency of the buzzer pin to 0.

```
void stopAlertor(int pin){
    softToneWrite(pin,0);
}
```

The related functions of softTone is described as follows:

int softToneCreate (int pin) ;
This creates a software controlled tone pin.
void softToneWrite (int pin, int freq) ;
This updates the tone frequency value on the given pin.

For more details about softTone, please refer to :http://wiringpi.com/reference/software-tone-library/

Python Code 6.2.1 Alertor

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

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

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

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

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

```
python Alertor.py
```

After the program is executed, press the button, then the buzzer sounds. When the button is released, the buzzer will stop sounding.

The following is the program code:

```
import RPi.GPIO as GPIO
import time
import math

buzzerPin = 11    # define the buzzerPin
buttonPin = 12    # define the buttonPin
```

```python

def setup():
    global p
    GPIO.setmode(GPIO.BOARD)         # Use Physical GPIO Numbering
    GPIO.setup(buzzerPin, GPIO.OUT)   # set RGBLED pins to OUTPUT mode
    GPIO.setup(buttonPin, GPIO.IN, pull_up_down=GPIO.PUD_UP)    # Set buttonPin to INPUT
mode, and pull up to HIGH level, 3.3V
    p = GPIO.PWM(buzzerPin, 1)
    p.start(0);

def loop():
    while True:
        if GPIO.input(buttonPin)==GPIO.LOW:
            alertor()
            print ('alertor turned on >>> ')
        else :
            stopAlertor()
            print ('alertor turned off <<<')
def alertor():
    p.start(50)
    for x in range(0,361):     # Make frequency of the alertor consistent with the sine wave
        sinVal = math.sin(x * (math.pi / 180.0))         # calculate the sine value
        toneVal = 2000 + sinVal * 500  # Add to the resonant frequency with a Weighted
        p.ChangeFrequency(toneVal)     # Change Frequency of PWM to toneVal
        time.sleep(0.001)

def stopAlertor():
    p.stop()

def destroy():
    GPIO.output(buzzerPin, GPIO.LOW)     # Turn off buzzer
    GPIO.cleanup()                       # Release GPIO resource

if __name__ == '__main__':     # Program entrance
    print ('Program is starting...')
    setup()
    try:
        loop()
    except KeyboardInterrupt:  # Press ctrl-c to end the program.
        destroy()
```

The code is the same to the active buzzer logically, but the way to control the buzzer is different. Passive buzzer requires PWM of certain frequency to control, so you need to create a software PWM pin through softToneCreate (buzzeRPin). The way to create PWM is also introduced before in the sections about BreathingLED and RGBLED.

```
def setup():
    global p
    GPIO.setmode(GPIO.BOARD)         # Use Physical GPIO Numbering
    GPIO.setup(buzzerPin, GPIO.OUT)   # set RGBLED pins to OUTPUT mode
    GPIO.setup(buttonPin, GPIO.IN, pull_up_down=GPIO.PUD_UP)    # Set buttonPin to INPUT
mode, and pull up to HIGH level, 3.3V
    p = GPIO.PWM(buzzerPin, 1)
    p.start(0);
```

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

```
def alertor():
    p.start(50)
    for x in range(0,361):
        sinVal = math.sin(x * (math.pi / 180.0))
        toneVal = 2000 + sinVal * 500
        p.ChangeFrequency(toneVal)
        time.sleep(0.001)
```

When the button is released, the buzzer will be closed.

```
def stopAlertor():
    p.stop()
```

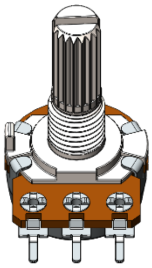
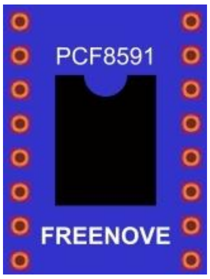
(**Important**)Chapter 7 ADC

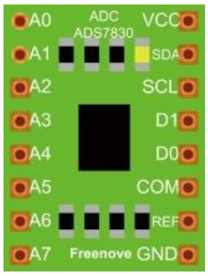
We have learned how to control the brightness of LED through PWM and understood that PWM is not really an analog feature before. In this chapter, we will learn how to read analog values through ADC Module, and convert them into digital.

Project 7.1 Read the Voltage of Potentiometer

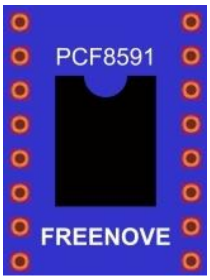
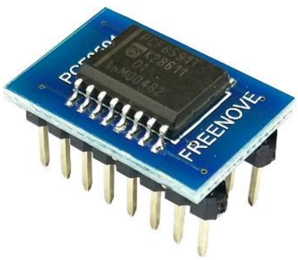
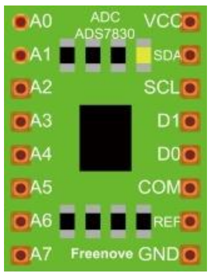
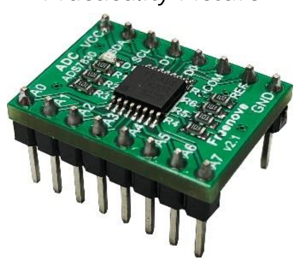
In this project, we will use the ADC function of ADC Module to read the voltage value of potentiometer.

Component List

<table>
<tr><td>Raspberry Pi x1
GPIO Extension Board & Wire x1
Breadboard x1</td><td colspan="2">Jumper M/M x16
</td></tr>
<tr><td>Rotary potentiometer x1
</td><td>ADC module x1


or

</td><td>Resistor 10kΩ x2
</td></tr>
</table>

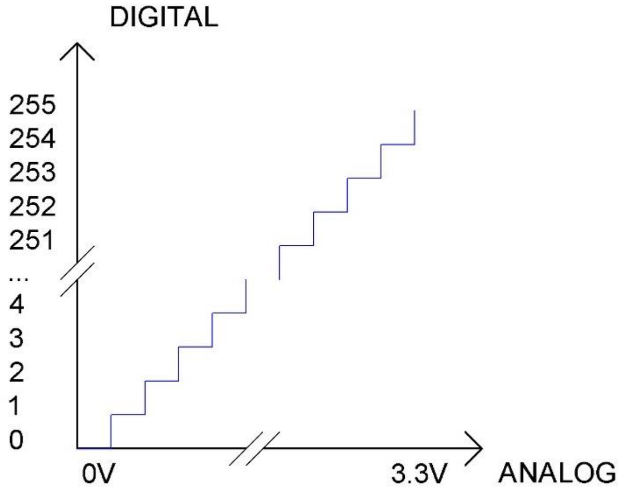
This product contains **only one ADC module**, which has two different types, PCF8591 and ADS7830. The functions involved in this tutorial are the same. Please build corresponding circuits according to different ADC module in your kit.

ADC module: PCF8591		**ADC module: ADS7830**	
Model diagram	Practicality Picture	Model diagram	Practicality Picture
			

Circuit knowledge

ADC

ADC, Analog-to-Digital Converter, is a device used to convert analog to digital. The range of the ADC module is 8 bits, that means the resolution is 2^8=256, and it represents the range (here is 3.3V) will be divided equally to 256 parts. The analog of each range corresponds to one ADC value. So the more bits ADC has, the denser the partition of analog will be, also the higher precision of the conversion will be.



Subsection 1: the analog in rang of 0V-3.3/256 V corresponds to digital 0;

Subsection 2: the analog in rang of 3.3 /256 V-2*3.3 /256V corresponds to digital 1;

...

The following analog will be divided accordingly.

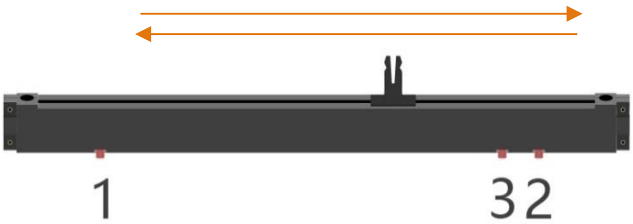
DAC

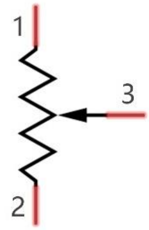
DAC, that is, Digital-to-Analog Converter, is the reverse process of ADC. The digital I/O port can output high level and low level, but cannot output an intermediate voltage value, which can be solved by DAC. PCF8591 has a DAC output pin with 8-bit accuracy, which can divide VDD (here is 3.3V) into 2^8=256 parts. For example, when the digital value is 1, the output voltage value is 3.3/256 *1 V, and when the digital value is 128, the output voltage value is 3.3/256 *128=1.65V, the higher accuracy of DAC is, the higher the accuracy of output voltage value is.

Component knowledge

Potentiometer

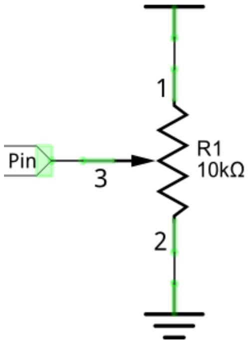
Potentiometer is a resistive element with three end parts and the resistance can be adjusted according to the posittion of the brush. Potentiometer is often made up by resistance and removable brush. When the brush moves along the resistor body, there will be resistance or voltage that has a certain relationship with displacement on the output side (3). Figure shown below is the linear sliding potentiometer and its symbol.





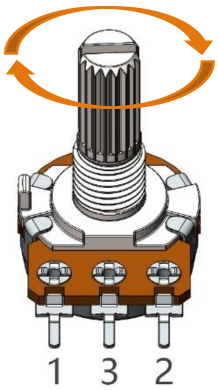
What between potentiometer pin 1 and pin 2 is the resistor body, and pins 3 is connected to brush. When brush moves from pin 1 to pin 2, the resistance between pin 1, and pin 3 will increase up to body resistance linearly, and the resistance between pin 2 and pin 3 will decrease down to 0 linearly.

In the circuit, the two end of main resistor are connected to the positive and negative electrode of the power. When you slide the brush pin 3, you can get a certain voltage in the range of the power supply.



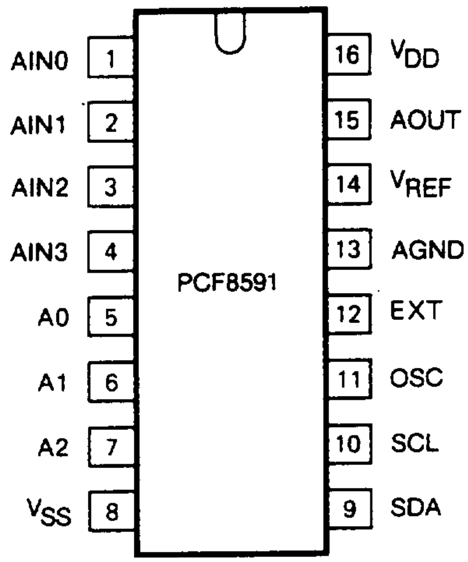
Rotary potentiometer

Rotary potentiometer and linear potentiometer have similar function; the only difference is: the resistance is adjusted through rotating the potentiometer.



PCF8591

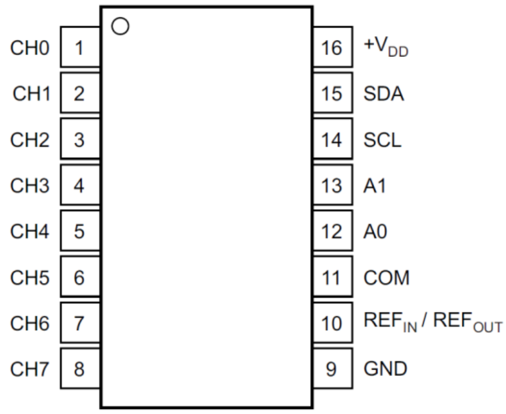
The PCF8591 is a single-chip, single-supply low power 8-bit CMOS data acquisition device with four analog inputs, one analog output and a serial I2C-bus interface. The following table is the pin definition diagram of PCF8591.

SYMBOL	PIN	DESCRIPTION	TOP VIEW
AIN0	1	Analog inputs (A/D converter)	
AIN1	2		
AIN2	3		
AIN3	4		
A0	5	Hardware address	
A1	6		
A2	7		
Vss	8	Negative supply voltage	
SDA	9	I2C-bus data input/output	
SCL	10	I2C-bus clock input	
OSC	11	Oscillator input/output	
EXT	12	external/internal switch for oscillator input	
AGND	13	Analog ground	
Vref	14	Voltage reference input	
AOUT	15	Analog output(D/A converter)	
Vdd	16	Positive supply voltage	

For more details about PCF8591, please refer to datasheet.

ADS7830

The ADS7830 is a single-supply, low-power, 8-bit data acquisition device that features a serial I2C interface and an 8-channel multiplexer. The following table is the pin definition diagram of ADS7830.

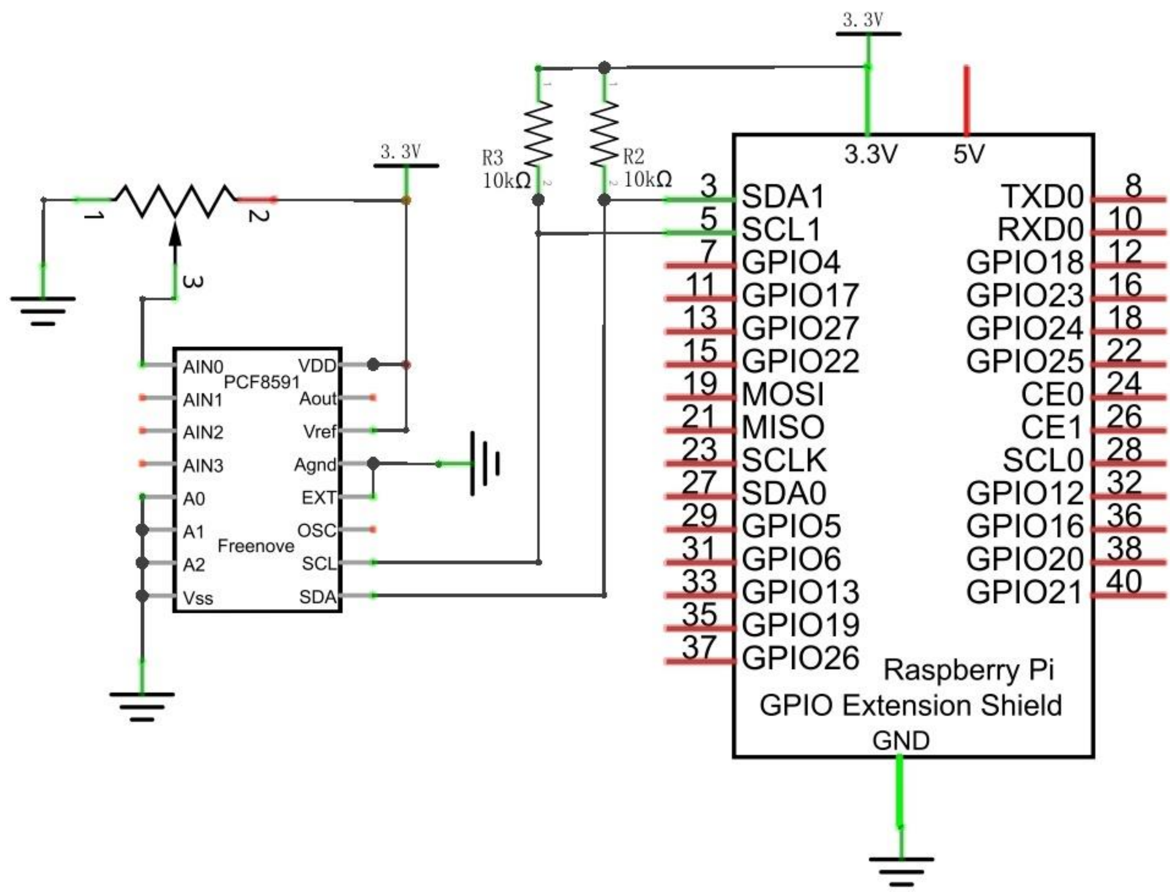
SYMBOL	PIN	DESCRIPTION	TOP VIEW
CH0	1	Analog input channels (A/D converter)	
CH1	2		
CH2	3		
CH3	4		
CH4	5		
CH5	6		
CH6	7		
CH7	8		
GND	9	Ground	
REF in/out	10	Internal +2.5V Reference, External Reference Input	
COM	11	Common to Analog Input Channel	
A0	12	Hardware address	
A1	13		
SCL	14	Serial Clock	
SDA	15	Serial Sata	
+VDD	16	Power Supply, 3.3V Nominal	

I2C communication

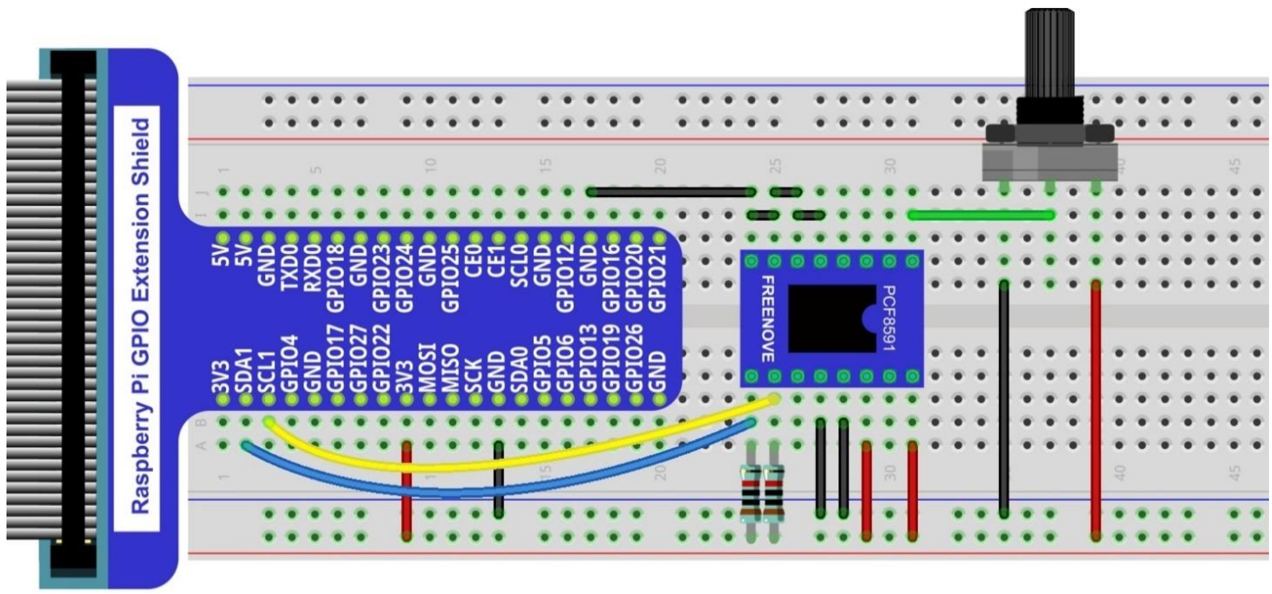
I2C(Inter-Integrated Circuit) is a two-wires serial communication mode, which can be used to connect a micro controller and its peripheral equipment. Devices using I2C communication must be connected to the serial data (SDA) line, and serial clock (SCL) line (called I2C bus). Each device has a unique address and can be used as a transmitter or receiver to communicate with devices connected to the bus.

Circuit with PCF8591

Schematic diagram



Hardware connection

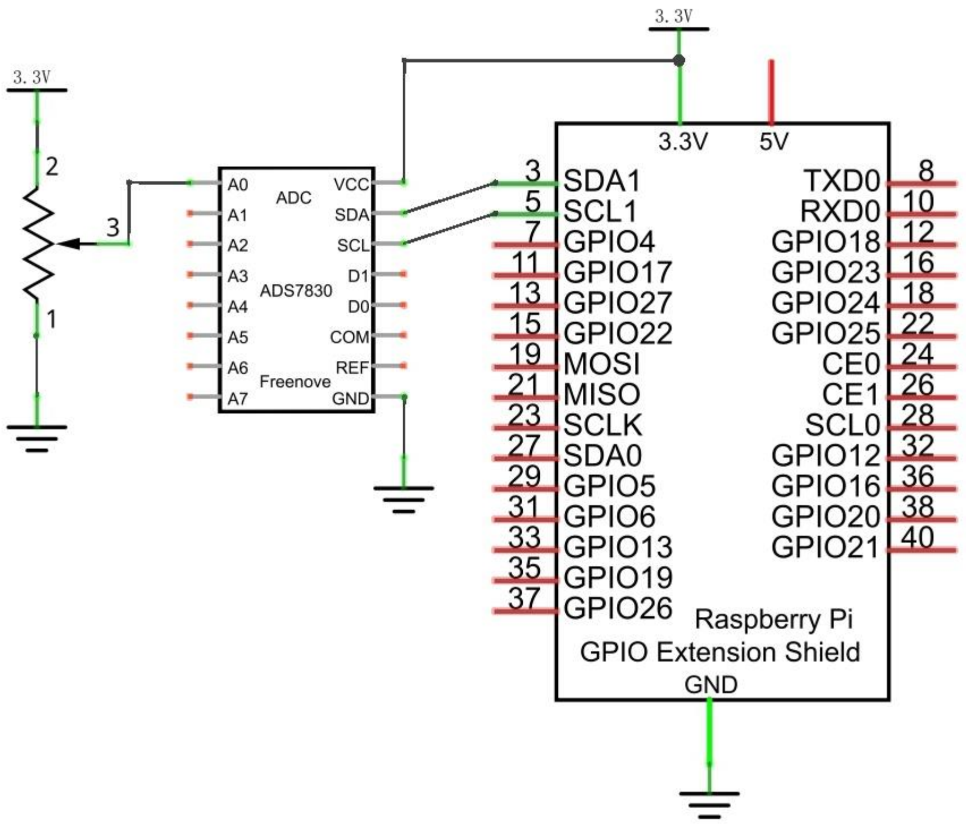


Please keep the **chip mark** consistent to make the chips under right direction and position.

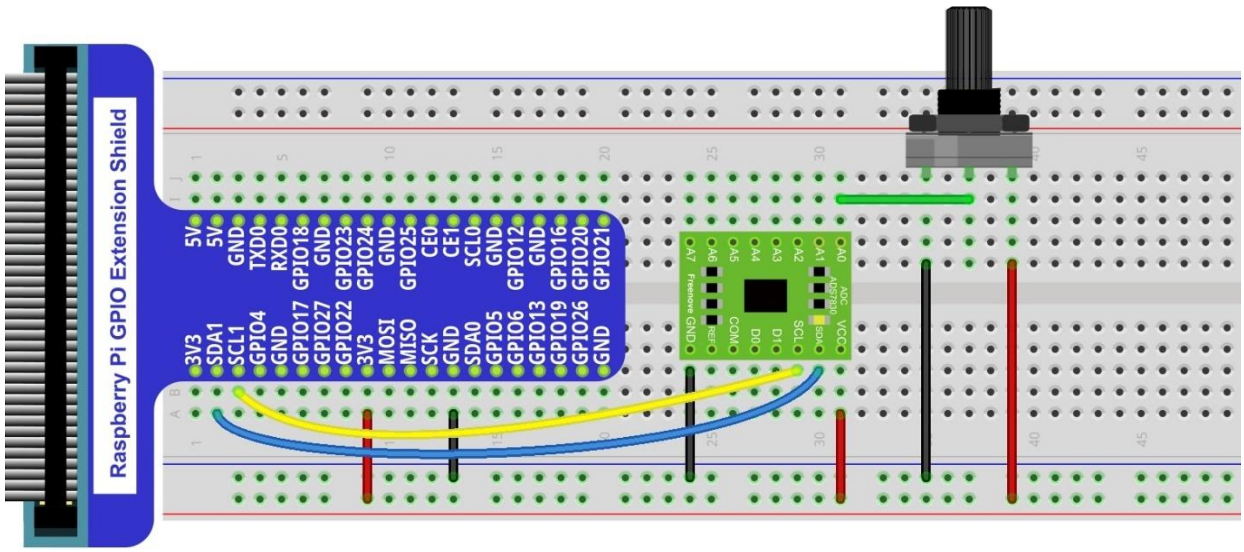
You need **install library** in this charpter. Don't skip the content.

Circuit with ADS7830

Schematic diagram



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



You need **install library** in this charpter. Don't skip the content.

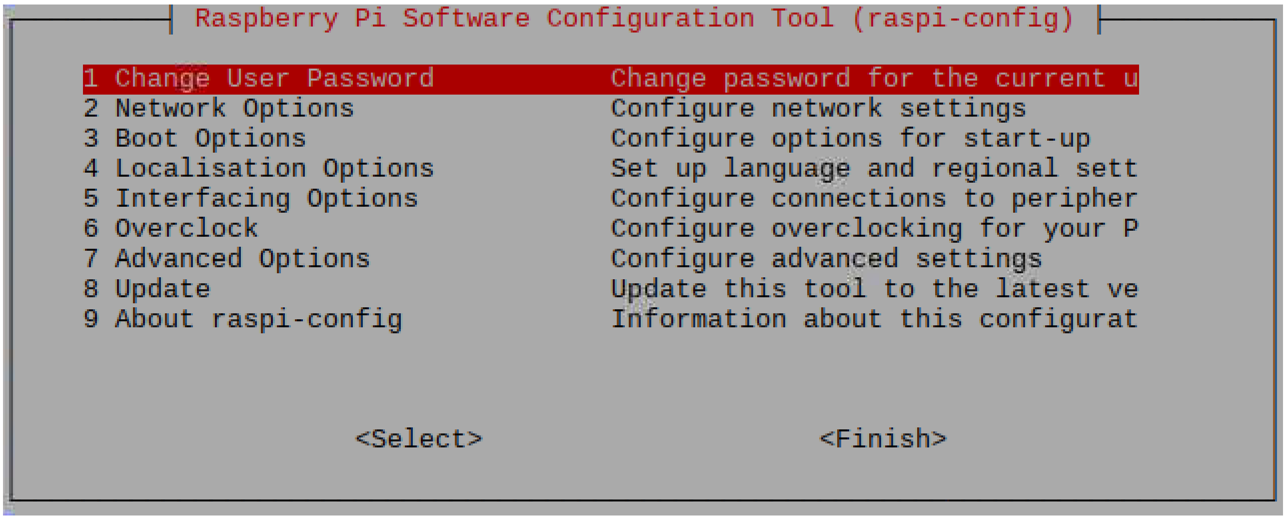
Configure I2C and Install Smbus

Enable I2C

The RPi I2C interface is disabled by deffault. You need to enable it as follows.Type command in the terminal:

```
sudo raspi-config
```

Then open the following dialog box:



Choose "5 Interfacing Options"→"P5 I2C"→"Yes"→"Finish" in order and restart your RPi later. Then the I2C module is started.

Type a command to check whether the I2C module is started:

```
lsmod | grep i2c
```

If the I2C module has been started, the following content will be shown. "bcm2708" refers to the CPU model. Different models of Raspberry Pi display different contents:

Install I2C-Tools

Type the command to install I2C-Tools. It is installed in Raspbian system by default.

```
sudo apt-get install i2c-tools
```

I2C device address detection:

```
i2cdetect -y 1
```

When you are using PCF8591, the result is below:

```
pi@raspberrypi:~ $ i2cdetect -y 1
     0  1  2  3  4  5  6  7  8  9  a  b  c  d  e  f
00:          -- -- -- -- -- -- -- -- -- -- -- -- --
10: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
20: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
30: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
40: -- -- -- -- -- -- -- -- 48 -- -- -- -- -- -- --
50: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
60: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
70: -- -- -- -- -- -- -- --
```

Here, 48 (HEX) is the I2C address of ADC Module(PCF8591).

When you are using ADS, the result is below:

```
pi@raspberrypi:~ $ i2cdetect -y 1
     0  1  2  3  4  5  6  7  8  9  a  b  c  d  e  f
00:          -- -- -- -- -- -- -- -- -- -- -- -- --
10: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
20: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
30: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
40: -- -- -- -- -- -- -- -- -- -- -- 4b -- -- -- --
50: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
60: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
70: -- -- -- -- -- -- -- --
```

Here, 4b (HEX) is the I2C address of ADC Module (ADS7830).

Install Smbus Module

```
sudo apt-get install python-smbus
```

Code

C Code 7.1.1 ADC

For C code, ADCDevice, a custom library, needs to be installed.

1. Use cd command to enter folder of ADCDevice library.

```
cd ~/Freenove_Kit/Libs/C-Libs/ADCDevice
```

2. Execute command below to install the library.

```
sh ./build.sh
```

Successful installation, without error prompts, is shown below:

```
pi@raspberrypi:~/Freenove_Kit/Libs/C-Libs/ADCDevice $ sh ./build.sh
build completed!
```

Next, execute the code of this project.

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

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

1. Use cd command to enter 07.1.1_ADC directory of C code.

```
cd ~/Freenove_Kit/Code/C_Code/07.1.1_ADC
```

2. Use following command to compile "ADC.cpp" and generate executable file "ADC".

```
g++ ADC.cpp -o ADC -lwiringPi -lADCDevice
```

3. Then run the generated file "ADC".

```
sudo ./ADC
```

After the program is executed, adjust the potentiometer, then the terminal will print out the potentiometer voltage value and the converted digital value.

```
ADC value : 135  ,      Voltage : 1.75V
ADC value : 135  ,      Voltage : 1.75V
ADC value : 136  ,      Voltage : 1.76V
ADC value : 141  ,      Voltage : 1.82V
ADC value : 144  ,      Voltage : 1.86V
ADC value : 146  ,      Voltage : 1.89V
ADC value : 148  ,      Voltage : 1.92V
ADC value : 149  ,      Voltage : 1.93V
ADC value : 149  ,      Voltage : 1.93V
ADC value : 144  ,      Voltage : 1.86V
ADC value : 143  ,      Voltage : 1.85V
ADC value : 143  ,      Voltage : 1.85V
ADC value : 142  ,      Voltage : 1.84V
ADC value : 141  ,      Voltage : 1.82V
```

The following is the code:

```
#include <wiringPi.h>
#include <wiringPiI2C.h>
#include <stdio.h>
#include <ADCDevice.hpp>

ADCDevice *adc;  // Define an ADC Device class object

int main(void){
    adc = new ADCDevice();
    printf("Program is starting ... \n");

    if(adc->detectI2C(0x48)){   // Detect the pcf8591.
        delete adc;
        adc = new PCF8591();    // If detected, create an instance of PCF8591.
    }
    else if(adc->detectI2C(0x4b)){// Detect the ads7830
        delete adc;
        adc = new ADS7830();      // If detected, create an instance of ADS7830.
```

```
    }
    else{
        printf("No correct I2C address found, \n"
        "Please use command 'i2cdetect -y 1' to check the I2C address! \n"
        "Program Exit. \n");
        return -1;
    }

    while(1){
        int adcValue = adc->analogRead(0);  //read analog value of A0 pin
        float voltage = (float)adcValue / 255.0 * 3.3;  // Calculate voltage
        printf("ADC value : %d  ,\tVoltage : %.2fV\n",adcValue,voltage);
        delay(100);
    }
}
```

In this code, a custom class library "ADCDevice" is used. It contains the method of using the ADC module in this product, through which the ADC module can be used easily and quickly. In the code, first create a class pointer adc, and then point the pointer to an instantiated object.

```
ADCDevice *adc;  // Define an ADC Device class object
......
adc = new ADCDevice();
```

Then use the member function detectIC(addr) in the class to detect the I2C module in the circuit. Different modules have different I2C addresses. Therefore, according to the different addresses, we can determine what the ADC module in the circuit is. When the correct module is detected, the pointer adc will point to the address of the object, and the previously pointed content is deleted to free memory. The default address of ADC module PCF8591 is 0x48, and that of ADC module ADS7830 is 0x4b.

```
    if(adc->detectI2C(0x48)){   // Detect the pcf8591.
        delete adc;
        adc = new PCF8591();     // If detected, create an instance of PCF8591.
    }
    else if(adc->detectI2C(0x4b)){// Detect the ads7830
        delete adc;
        adc = new ADS7830();       // If detected, create an instance of ADS7830.
    }
    else{
        printf("No correct I2C address found, \n"
        "Please use command 'i2cdetect -y 1' to check the I2C address! \n"
        "Program Exit. \n");
        return -1;
    }
```

When you have a class object pointer to a specific device, you can get the ADC value of the specific channel by calling the member function analogRead (chn) in this class

```
int adcValue = adc->analogRead(0);  //read analog value of A0 pin
```

Then according to the formula, the voltage value is calculated and printed on the terminal.

```
        float voltage = (float)adcValue / 255.0 * 3.3;  // Calculate voltage
        printf("ADC value : %d  ,\tVoltage : %.2fV\n",adcValue,voltage);
```

Reference

```
class ADCDevice
```

This is a base class. All ADC module classes are its derived classes. It has a real function and a virtual function.

```
int detectI2C(int addr);
```

This is a real function, which is used to detect whether the device with given I2C address exists. If it exists, return 1, otherwise return 0.

```
virtual int analogRead(int chn);
```

This is a virtual function that reads the ADC value of the specified channel. It is implemented in a derived class.

```
class PCF8591:public ADCDevice
class ADS7830:public ADCDevice
```

These two classes are derived from the ADCDevice class and mainly implement the function analogRead(chn).

```
int analogRead(int chn);
```

This returns the value read on the supplied analog input pin.

Parameter chn: For PCF8591, the range of chn is 0, 1, 2, 3. For ADS7830, the range of is 0, 1, 2, 3, 4, 5, 6, 7.

You can find the source file of this library in the folder below:

```
~/Freenove_Kit/Libs/C-Libs/ADCDevice/
```

Python Code 7.1.1 ADC

For Python code, ADCDevice, a custom module, needs to be installed.

1. Use cd command to enter folder of ADCDevice.

```
cd ~/Freenove_Kit/Libs/Python-Libs/
```

2. Unzip the file.

```
tar zxvf ADCDevice-1.0.3.tar.gz
```

3. Enter the unzipped folder.

```
cd ADCDevice-1.0.3
```

Install the library. Install library for python3.

```
sudo python3 setup.py install
```

Install library for python2.

```
sudo python2 setup.py install
```

Successful installation, without error prompts, is shown below:

```
Installed /usr/local/lib/python3.7/dist-packages/ADCDevice-1.0.2-py3.7.egg
Processing dependencies for ADCDevice==1.0.2
Finished processing dependencies for ADCDevice==1.0.2
```

First execute the following command. Observe the project result, and then view the code.

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

1. Use cd command to enter 07.1.1_ADC directory of Python code.

```
cd ~/Freenove_Kit/Code/Python_Code/07.1.1_ADC
```

2. Use the python command to execute the Python code "ADC.py".

```
python ADC.py
```

After the program is executed, adjust the potentiometer, then the terminal will print out the potentiometer voltage value and the converted digital content.

```
ADC Value : 168, Voltage : 2.17
ADC Value : 168, Voltage : 2.17
ADC Value : 168, Voltage : 2.17
ADC Value : 168, Voltage : 2.17
ADC Value : 168, Voltage : 2.17
ADC Value : 168, Voltage : 2.17
ADC Value : 168, Voltage : 2.17
ADC Value : 168, Voltage : 2.17
ADC Value : 169, Voltage : 2.19
ADC Value : 168, Voltage : 2.17
ADC Value : 168, Voltage : 2.17
```

The following is the code:

```
import time
from ADCDevice import *

adc = ADCDevice() # Define an ADCDevice class object

def setup():
    global adc
```

```
    if(adc.detectI2C(0x48)): # Detect the pcf8591.
        adc = PCF8591()
    elif(adc.detectI2C(0x4b)): # Detect the ads7830
        adc = ADS7830()
    else:
        print("No correct I2C address found, \n"
        "Please use command 'i2cdetect -y 1' to check the I2C address! \n"
        "Program Exit. \n");
        exit(-1)

def loop():
    while True:
        value = adc.analogRead(0)    # read the ADC value of channel 0
        voltage = value / 255.0 * 3.3  # calculate the voltage value
        print ('ADC Value : %d, Voltage : %.2f'%(value,voltage))
        time.sleep(0.1)

def destroy():
    adc.close()

if __name__ == '__main__':   # Program entrance
    print ('Program is starting ... ')
    try:
        setup()
        loop()
    except KeyboardInterrupt: # Press ctrl-c to end the program.
        destroy()
```

Reference

About smbus module:

smbus Module

That is System Management Bus.This module defines an object type that allows SMBus transactions on hosts running the Linux kernel. The host kernel must have I2C support, I2C device interface support, and a bus adapter driver. All of these can be either built-in to the kernel, or loaded from modules.

In Python, you can use help(smbus) to view the relevant function and their descriptions.

bus=smbus.SMBus(1): Create an SMBus class object.

bus.read_byte_data(address,cmd+chn): Read a byte of data from an address and return it.

bus.write_byte_data(address,cmd,value): Write a byte of data to an address.

`class ADCDevice(object)`

This is a base class. All ADC module classes are its derived classes.

`int detectI2C(int addr);`

This is a member function, which is used to detect whether the device with the given I2C address exists. If it exists, it returns true. Otherwise, it returns false

```
class PCF8591(ADCDevice)
class ADS7830(ADCDevice)
```

These two classes are derived from ADCDevice and the main function is analogRead(chn).

```
int analogRead(int chn);
```

This returns the value read on the supplied analog input pin.
Parameter chn: For PCF8591, the range of chn is 0, 1, 2, 3. For ADS7830, the range is 0, 1, 2, 3, 4, 5, 6, 7.

You can find the source file of this library in the folder below:

```
~/Freenove_Kit/Libs/Python-Libs/ADCDevice-1.0.2/src/ADCDevice/ADCdevice.py
```

In this code, a custom Python module "ADCDevice" is used. It contains the method of using the ADC module in this product, through which the ADC module can be used easily and quickly. In the code, first create an ADCDevice object adc.

```
adc = ADCDevice() # Define an ADCDevice class object
```

Then in setup(), use detecticIC(addr), the member function of ADCDevice, to detect the I2C module in the circuit. Different modules have different I2C addresses. Therefore, according to the different addresses, we can determine what the ADC module in the circuit is. When the correct module is detected, a device specific class object is created and assigned to adc. The default address of PCF8591 is 0x48, and that of ADS7830 is 0x4b.

```
def setup():
    global adc
    if(adc.detectI2C(0x48)): # Detect the pcf8591.
        adc = PCF8591()
    elif(adc.detectI2C(0x4b)): # Detect the ads7830
        adc = ADS7830()
    else:
        print("No correct I2C address found, \n"
        "Please use command 'i2cdetect -y 1' to check the I2C address! \n"
        "Program Exit. \n");
        exit(-1)
```

When you have a class object of a specific device, you can get the ADC value of the specified channel by calling the member function of this class, analogRead(chn). In loop(), get the ADC value of potentiometer.

```
        value = adc.analogRead(0)    # read the ADC value of channel 0
```

Then according to the formula, the voltage value is calculated and printed on the terminal monitor.

```
        voltage = value / 255.0 * 3.3  # calculate the voltage value
        print ('ADC Value : %d, Voltage : %.2f'%(value,voltage))
        time.sleep(0.1)
```

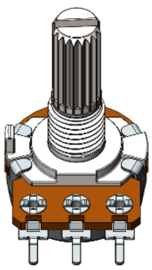
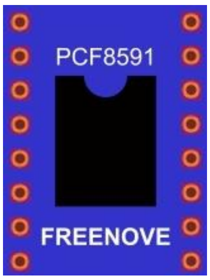
Chapter 8 Potentiometer & LED

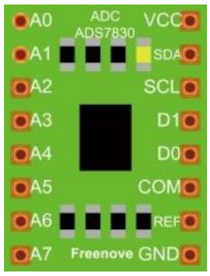
We have learned how to use ADC and PWM before. In this chapter, we learn to control the brightness of LED through a potentiometer.

Project 8.1 Soft Light

In this project, we will make a soft light. Use ADC Module to read ADC value of potentiometers and map it to duty cycle ratio of PWM used to control the brightness of LED. Then you can make the LED brightness changed by adjusting the potentiometer.

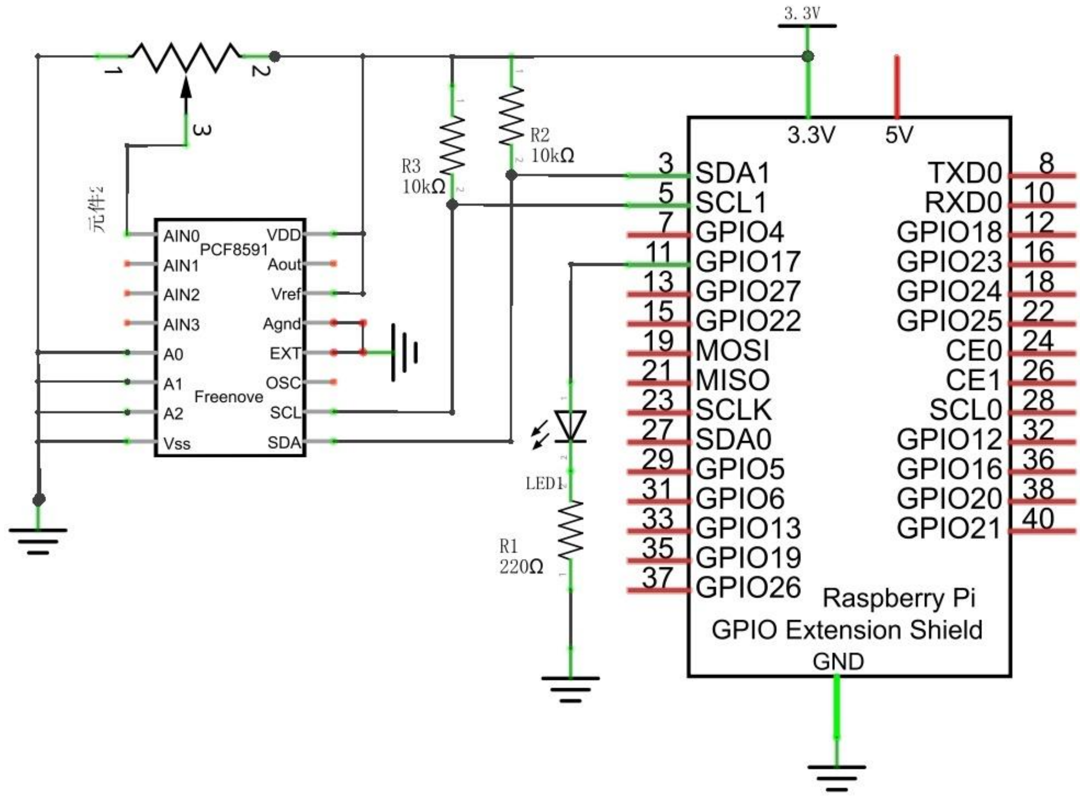
Component List

<table>
<tr><td colspan="2">Raspberry Pi x1
GPIO Extension Board & Wire x1
Breadboard x1</td><td colspan="3">Jumper M/M x17
</td></tr>
<tr><td>Rotary potentiometer x1
</td><td>ADC module x1


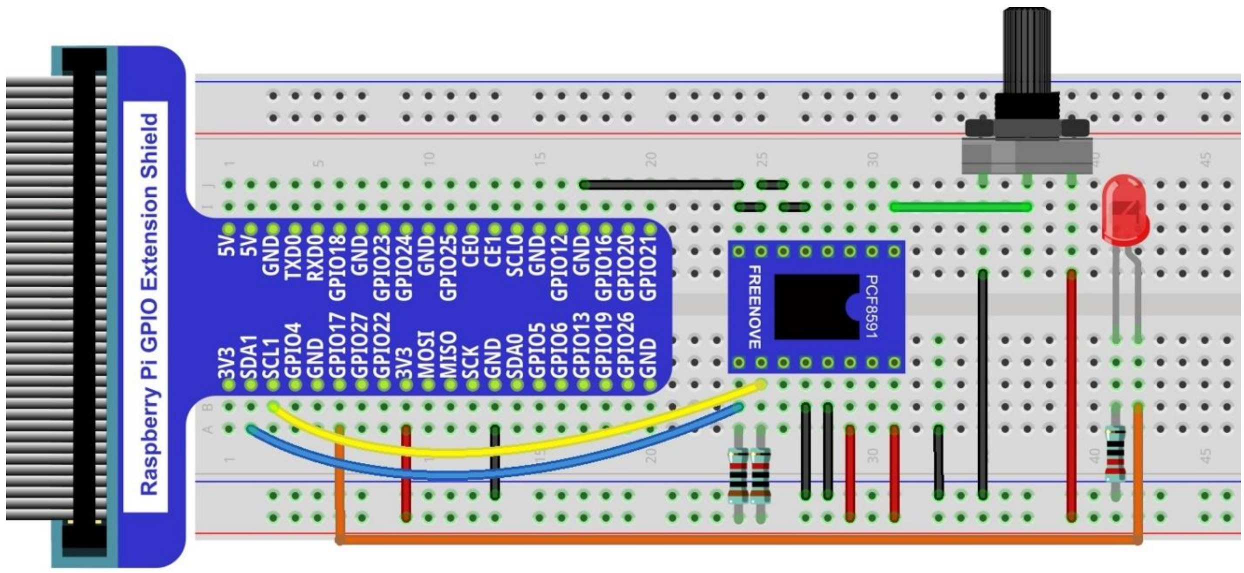
or

</td><td>10kΩ x2
</td><td>220Ω x1
</td><td>LED x1
</td></tr>
</table>

Circuit with PCF8591

Schematic diagram

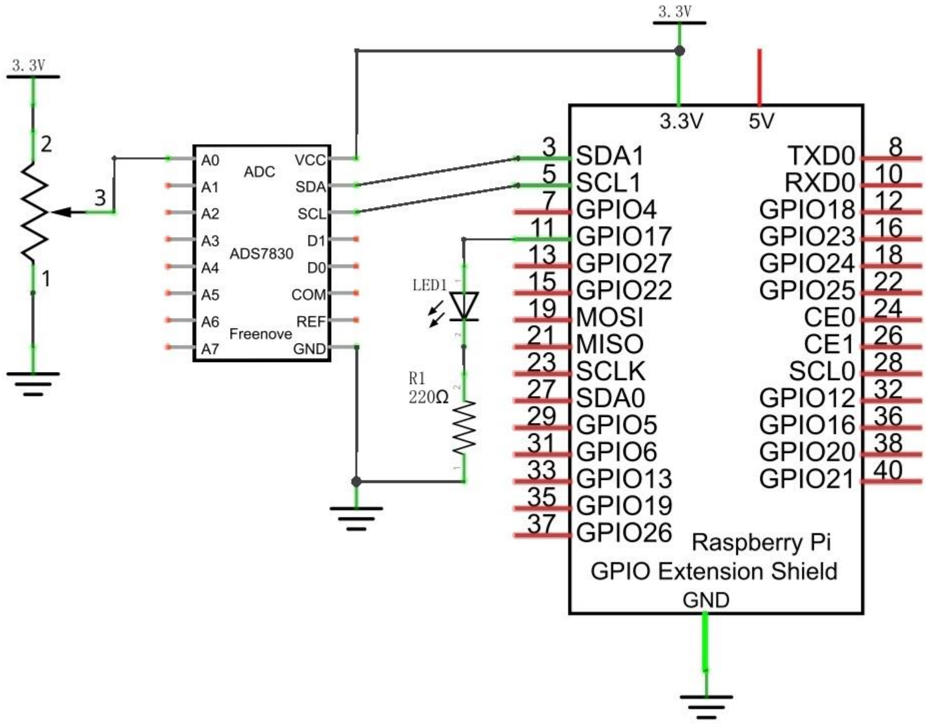


Hardware connection

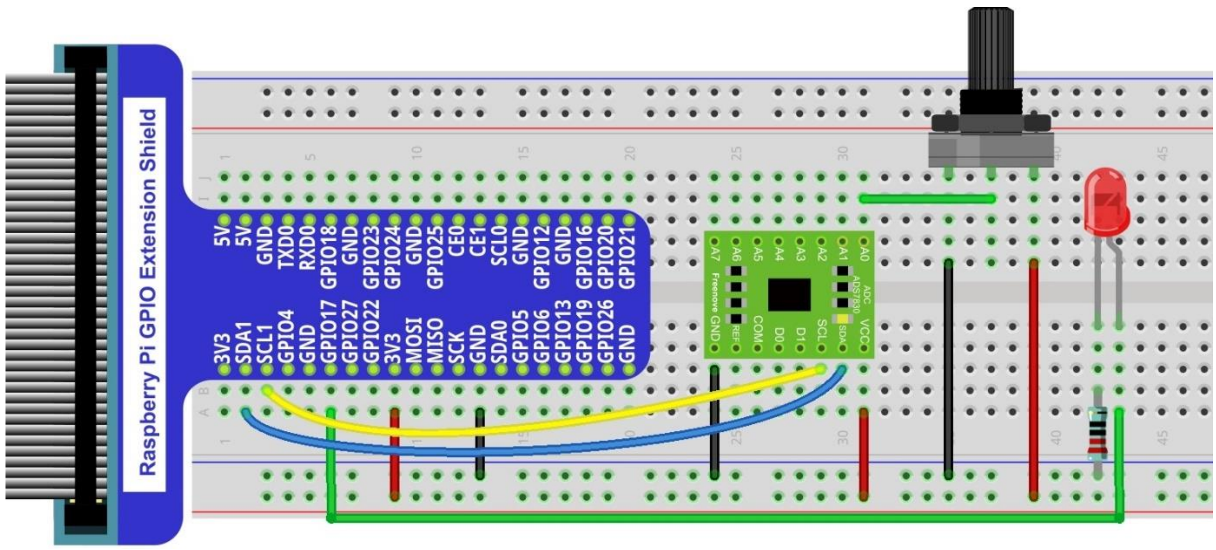


Circuit with ADS7830

Schematic diagram



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



Code

C Code 8.1.1 Softlight

If you did not configure I2C, please refer to Chapter 7. If you did, please move on.

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

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

1. Use cd command to enter 08.1.1_Softlight directory of C code.

```
cd ~/Freenove_Kit/Code/C_Code/08.1.1_Softlight
```

2. Use following command to compile “Softlight.cpp” and generate executable file “Softlight”.

```
g++ Softlight.cpp -o Softlight -lwiringPi -lADCDevice
```

3. Then run the generated file “Softlight”.

```
sudo ./Softlight
```

After the program is executed, adjust the potentiometer, then the terminal window will print out the voltage value of the potentiometer and the converted digital value. And brightness of LED will be changed consequently.

The following is the code:

```
#include <wiringPi.h>
#include <stdio.h>
#include <softPwm.h>
#include <ADCDevice.hpp>

#define ledPin 0

ADCDevice *adc;  // Define an ADC Device class object

int main(void){
    adc = new ADCDevice();
    printf("Program is starting ... \n");

    if(adc->detectI2C(0x48)){    // Detect the pcf8591.
        delete adc;                 // Free previously pointed memory
        adc = new PCF8591();    // If detected, create an instance of PCF8591.
    }
    else if(adc->detectI2C(0x4b)){// Detect the ads7830
        delete adc;               // Free previously pointed memory
        adc = new ADS7830();      // If detected, create an instance of ADS7830.
    }
    else{
        printf("No correct I2C address found, \n"
        "Please use command 'i2cdetect -y 1' to check the I2C address! \n"
```

```
            "Program Exit. \n");
            return -1;
        }
        wiringPiSetup();
        softPwmCreate(ledPin,0,100);
        while(1){
            int adcValue = adc->analogRead(0);    //read analog value of A0 pin
            softPwmWrite(ledPin,adcValue*100/255);    // Mapping to PWM duty cycle
            float voltage = (float)adcValue / 255.0 * 3.3;  // Calculate voltage
            printf("ADC value : %d  ,\tVoltage : %.2fV\n",adcValue,voltage);
            delay(30);
        }
        return 0;
}
```

In the code, read ADC value of potentiometers and map it to duty cycle of PWM to control LED brightness.

```
            int adcValue = adc->analogRead(0);    //read analog value of A0 pin
            softPwmWrite(ledPin,adcValue*100/255);    // Mapping to PWM duty cycle
```

Python Code 8.1.1 Softlight

If you did not configure I2C, please refer to Chapter 7. If you did, please move on.
First observe the project result, and then view the code.

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

1. Use cd command to enter 08.1.1_Softlight directory of Python code

```
cd ~/Freenove_Kit/Code/Python_Code/08.1.1_Softlight
```

2. Use the python command to execute the Python code "Softlight.py".

```
python Softlight.py
```

After the program is executed, adjust the potentiometer, then the terminal window will print out the voltage value of the potentiometer and the converted digital value. And brightness of LED will be changed consequently.

The following is the code:

```
import RPi.GPIO as GPIO
import time
from ADCDevice import *

ledPin = 11
adc = ADCDevice() # Define an ADCDevice class object

def setup():
    global adc
    if(adc.detectI2C(0x48)): # Detect the pcf8591.
        adc = PCF8591()
    elif(adc.detectI2C(0x4b)): # Detect the ads7830
        adc = ADS7830()
    else:
        print("No correct I2C address found, \n"
        "Please use command 'i2cdetect -y 1' to check the I2C address! \n"
        "Program Exit. \n");
        exit(-1)
    global p
    GPIO.setmode(GPIO.BOARD)
    GPIO.setup(ledPin,GPIO.OUT)
    p = GPIO.PWM(ledPin,1000)
    p.start(0)

def loop():
    while True:
        value = adc.analogRead(0)     # read the ADC value of channel 0
        p.ChangeDutyCycle(value*100/255)        # Mapping to PWM duty cycle
        voltage = value / 255.0 * 3.3  # calculate the voltage value
```

```
        print ('ADC Value : %d, Voltage : %.2f'%(value,voltage))
        time.sleep(0.03)

def destroy():
    adc.close()

if __name__ == '__main__':   # Program entrance
    print ('Program is starting ... ')
    try:
        setup()
        loop()
    except KeyboardInterrupt: # Press ctrl-c to end the program.
        destroy()
```

In the code, read ADC value of potentiometers and map it to duty cycle of PWM to control LED brightness.

```
        value = adc.analogRead(0)     # read the ADC value of channel 0
        p.ChangeDutyCycle(value*100/255)        # Mapping to PWM duty cycle
```

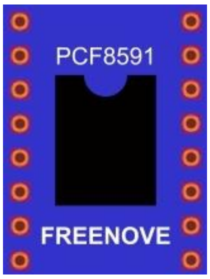
Chapter 9 Photoresistor & LED

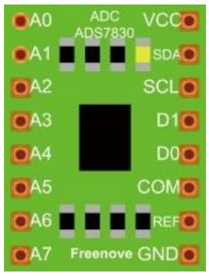
In this chapter, we will learn how to use photoresistor.

Project 9.1 NightLamp

Photoresistor is very sensitive to illumination strength. So we can use this feature to make a nightlamp, when ambient light gets darker, LED will become brighter automatically, and when the ambient light gets brighter, LED will become darker automatically.

Component List

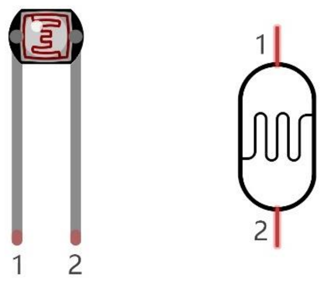
<table>
<tr><td colspan="2">Raspberry Pi x1
GPIO Extension Board & Wire x1
Breadboard x1</td><td colspan="4">Jumper M/M
</td></tr>
<tr><td>Photoresistor x1
</td><td colspan="2">ADC module x1


or

</td><td>10kΩ x3
</td><td>220Ω x1
</td><td>LED x1
</td></tr>
</table>

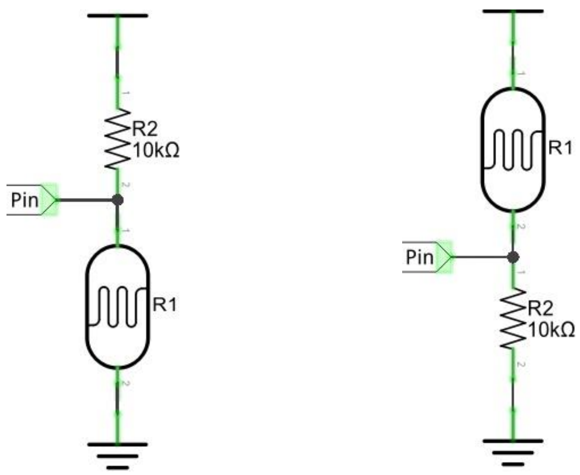
Component knowledge

Photoresistor

Photoresistor is a light sensitive resistor. The resistance of the photoresistor will vary accordingly to the light it receives on its surface. With this feature, we can use photoresistor to detect light intensity. Photoresistor and symbol are as follows.



The circuit below is often used to detect the change of photoresistor resistance:

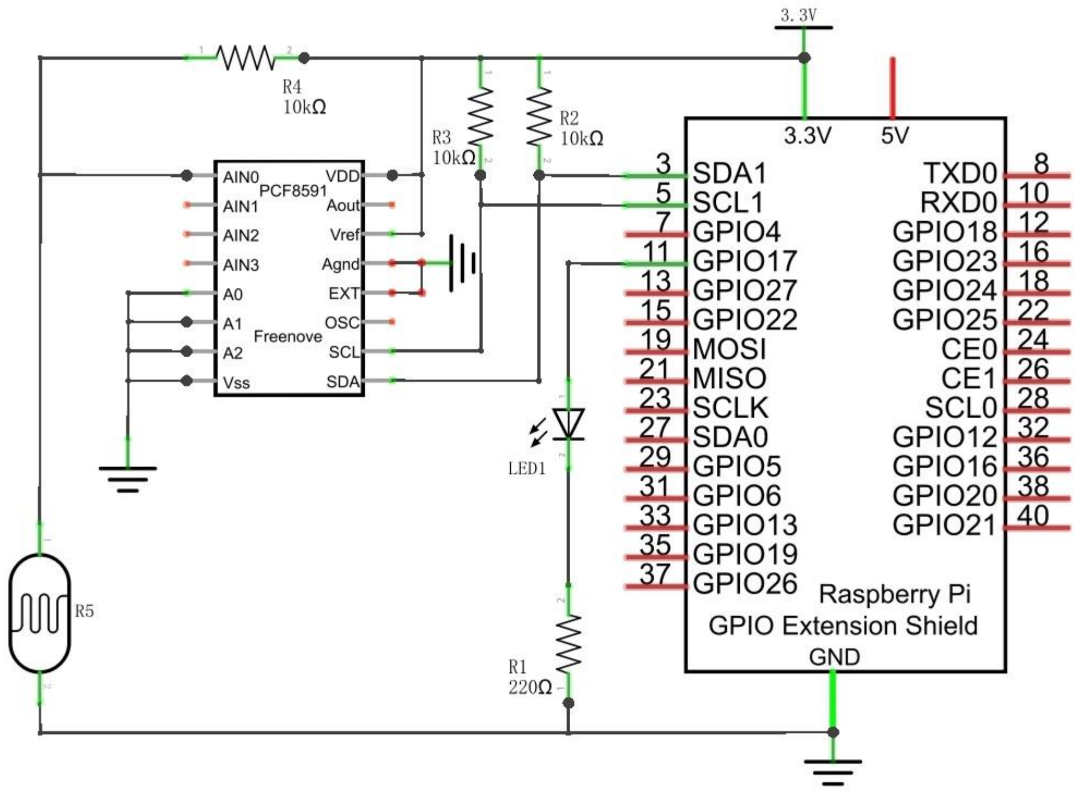


In the above circuit, when photoresistor resistance changes due to light intensity, voltage between photoresistor and resistor R1 will change, so light's intensity can be obtained by measuring the voltage.

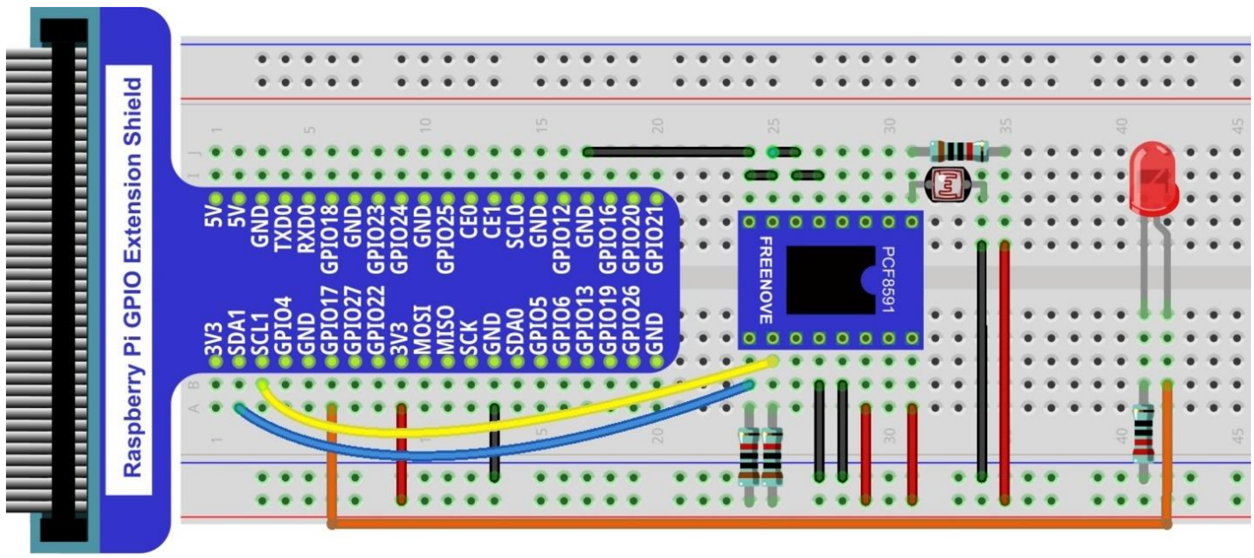
Circuit with PCF8591

The circuit of this experiment is similar to the project Soft light. The only difference is that the input signal of the AIN0 pin of ADC is changed from a potentiometer to combination of a photoresistor and a resistor.

Schematic diagram



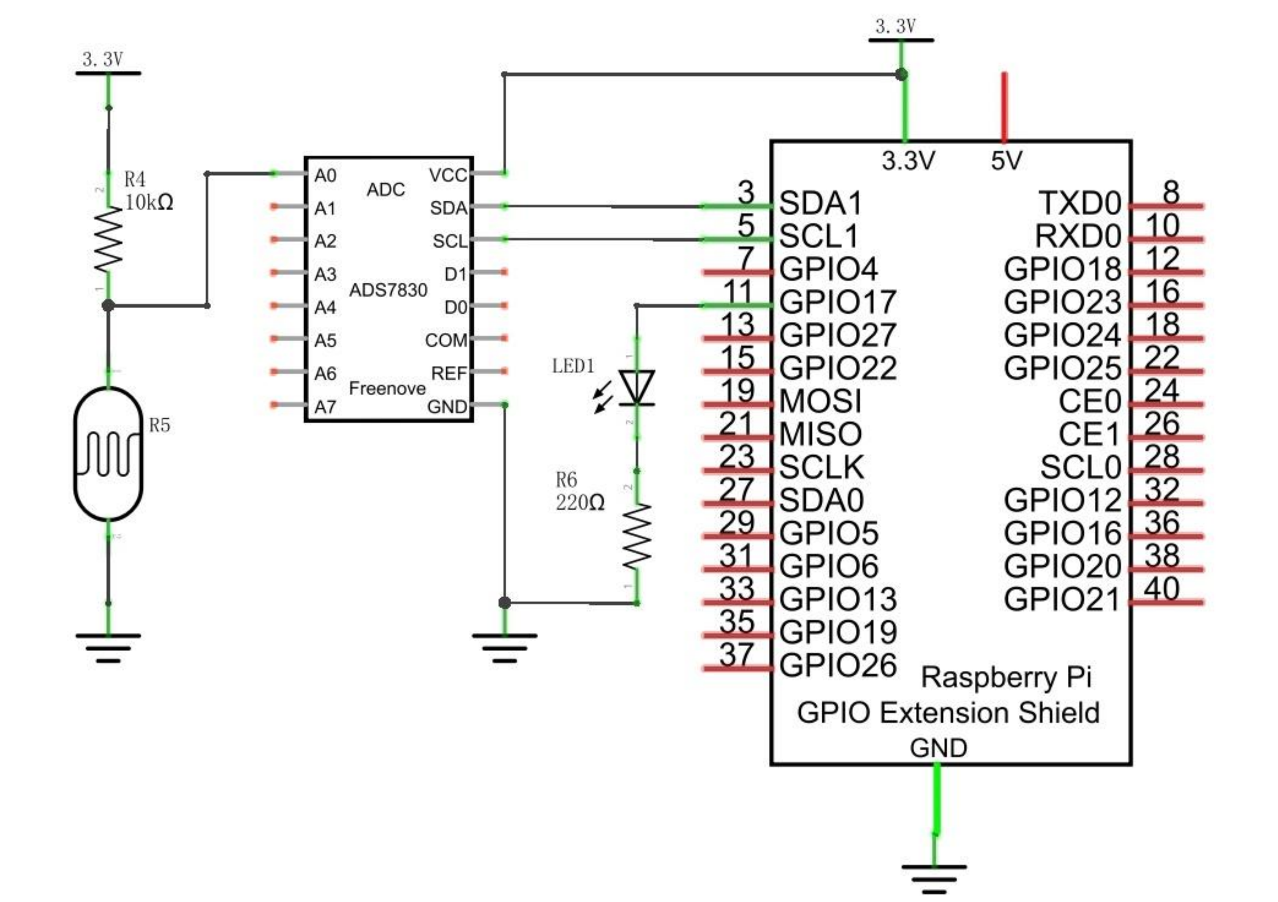
Hardware connection



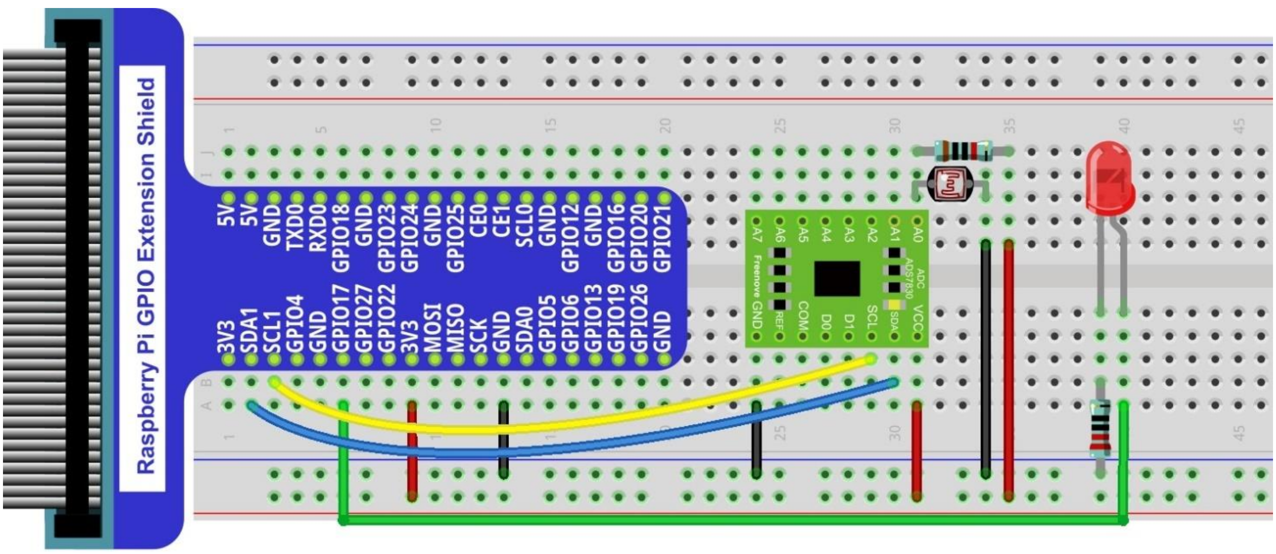
Circuit with ADS7830

The circuit of this project is similar to the project Soft light. The only difference is that the input signal of the AIN0 pin of ADC Module is changed from a potentiometer to combination of a photoresistor and a resistor.

Schematic diagram



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



Code

The code of this project is identical with the one in last chapter logically.

C Code 9.1.1 Nightlamp

If you did not configure I2C, please refer to Chapter 7. If you did, please move on.

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

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

1. Use cd command to enter 9.1.1_Nightlamp directory of C code.

```
cd ~/Freenove_Kit/Code/C_Code/9.1.1_Nightlamp
```

2. Use following command to compile “Nightlamp.cpp” and generate executable file “Nightlamp”.

```
g++ Nightlamp.cpp -o Nightlamp -lwiringPi -lADCDevice
```

3. Then run the generated file “Nightlamp”.

```
sudo ./Nightlamp
```

After the program is executed, when you cover the photosensitive resistance or make a flashlight toward the photoresistor, the brightness of LED will increase or weaken. And the terminal window will print out the current input voltage value of ADC module A0 pin and the converted digital value.

The following is the program code:

```
#include <wiringPi.h>
#include <stdio.h>
#include <softPwm.h>
#include <ADCDevice.hpp>

#define ledPin 0

ADCDevice *adc;  // Define an ADC Device class object

int main(void){
    adc = new ADCDevice();
    printf("Program is starting ... \n");

    if(adc->detectI2C(0x48)){    // Detect the pcf8591.
        delete adc;              // Free previously pointed memory
        adc = new PCF8591();     // If detected, create an instance of PCF8591.
    }
    else if(adc->detectI2C(0x4b)){// Detect the ads7830
        delete adc;               // Free previously pointed memory
        adc = new ADS7830();      // If detected, create an instance of ADS7830.
    }
    else{
        printf("No correct I2C address found, \n"
        "Please use command 'i2cdetect -y 1' to check the I2C address! \n"
        "Program Exit. \n");
```

```
            return -1;
        }
        wiringPiSetup();
        softPwmCreate(ledPin,0,100);
        while(1){
            int value = adc->analogRead(0);  //read analog value of A0 pin
            softPwmWrite(ledPin,value*100/255);
            float voltage = (float)value / 255.0 * 3.3;  // calculate voltage
            printf("ADC value : %d  ,\tVoltage : %.2fV\n",value,voltage);
            delay(100);
        }
        return 0;
}
```

Python Code 9.1.1 Nightlamp

If you did not configure I2C, please refer to Chapter 7. If you did, please move on.

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

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

1. Use cd command to enter 10.1_Nightlamp directory of Python code.

```
cd ~/Freenove_Kit/Code/Python_Code/9.1.1_Nightlamp
```

2. Use the python command to execute the Python code "Nightlamp.py".

```
python Nightlamp.py
```

After the program is executed, when you cover the photosensitive resistance or make a flashlight toward the photoresistor, the brightness of LED will be enhanced or weakened. And the terminal window will print out the current input voltage value of ADC module A0 pin and the converted digital value.

The following is the program code:

```python
import RPi.GPIO as GPIO
import time
from ADCDevice import *

ledPin = 11 # define ledPin
adc = ADCDevice() # Define an ADCDevice class object

def setup():
    global adc
    if(adc.detectI2C(0x48)): # Detect the pcf8591.
        adc = PCF8591()
    elif(adc.detectI2C(0x4b)): # Detect the ads7830
        adc = ADS7830()
    else:
        print("No correct I2C address found, \n"
        "Please use command 'i2cdetect -y 1' to check the I2C address! \n"
        "Program Exit. \n");
        exit(-1)
    global p
    GPIO.setmode(GPIO.BOARD)
    GPIO.setup(ledPin,GPIO.OUT)   # set ledPin to OUTPUT mode
    GPIO.output(ledPin,GPIO.LOW)

    p = GPIO.PWM(ledPin,1000) # set PWM Frequence to 1kHz
    p.start(0)

def loop():
    while True:
        value = adc.analogRead(0)    # read the ADC value of channel 0
        p.ChangeDutyCycle(value*100/255)
        voltage = value / 255.0 * 3.3
```

```
            print ('ADC Value : %d, Voltage : %.2f'%(value,voltage))
            time.sleep(0.01)

def destroy():
    adc.close()
    GPIO.cleanup()

if __name__ == '__main__':   # Program entrance
    print ('Program is starting ... ')
    setup()
    try:
        loop()
    except KeyboardInterrupt:  # Press ctrl-c to end the program.
        destroy()
```

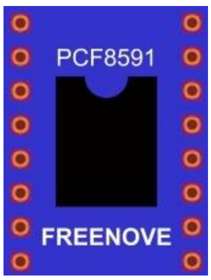
Chapter 10 Thermistor

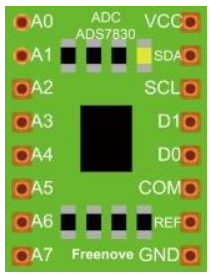
In this chapter, we will learn another new kind of resistor, the thermistor.

Project 10.1 Thermometer

The resistance of the thermistor will change with the ambiant temperature. So we can make a thermometer by using this feature.

Component List

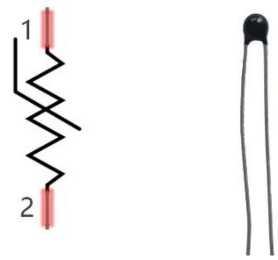
<table>
<tr><td colspan="2">Raspberry Pi x1
GPIO Extension Board & Wire x1
Breadboard x1</td><td colspan="2">Jumper M/M
</td></tr>
<tr><td>Thermistor x1
</td><td colspan="2">ADC module x1


or

</td><td>Resistor 10kΩ x3
</td></tr>
</table>

Component knowledge

Thermistor

Thermistor is a temperature sensitive resistor. When the temperature changes, resistance of thermistor will change. With this feature, we can use thermistor to detect temperature intensity. Thermistor and symbol are as follows.



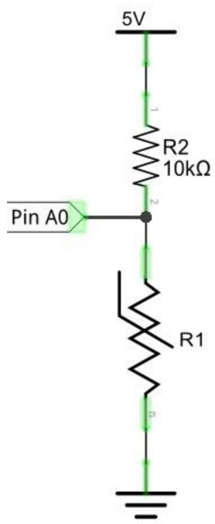
The relationship between resistance value and temperature of thermistor is:

Rt=R*EXP [B*(1/T2-1/T1)]

Where:

Rt is the thermistor resistance under T2 temperature;
R is in the nominal resistance of thermistor under T1 temperature;
EXP[n] is nth power of e;
B is for thermal index;
T1, T2 is Kelvin temperature (absolute temperature). Kelvin temperature=273.15+celsius temperature.

Parameters of the thermistor we use is: B=3950, R=10k, T1=25.
The circuit connection method of the thermistor is similar to photoresistor, like the following method:



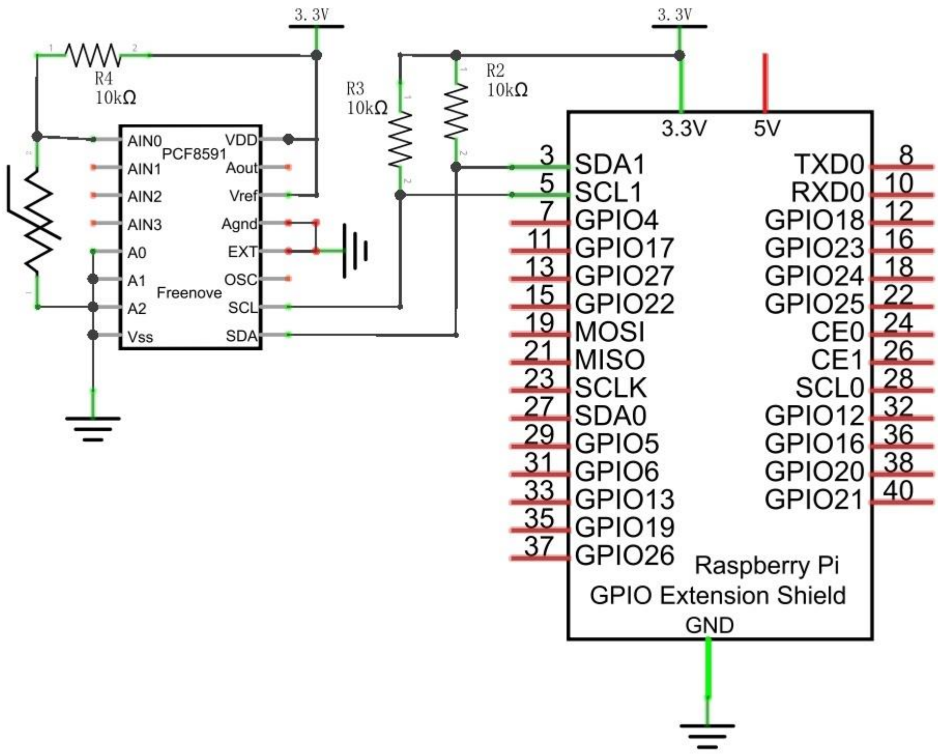
We can use the value measured by ADC converter to calculate the resistance value of thermistor, and then we can use the formula to calculate the temperature value.
The temperature formula can be caculated as below:

T2 = 1/(1/T1 + ln(Rt/R)/B)

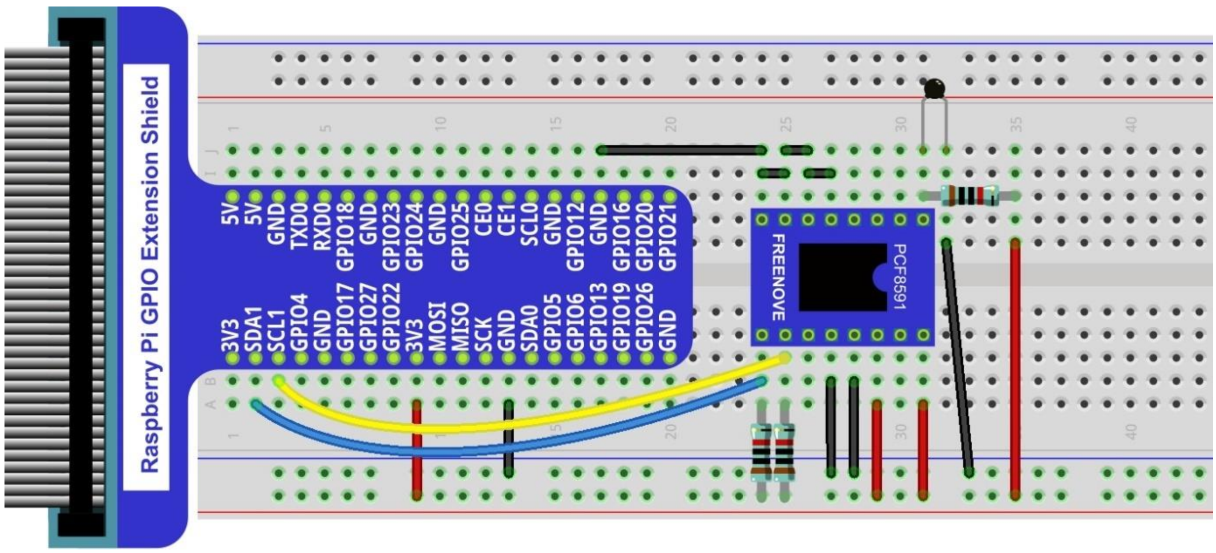
Circuit with PCF8591

The circuit of this project is similar to the one in last chapter. The only difference is that the photoresistor is replaced by the thermistor.

Schematic diagram



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

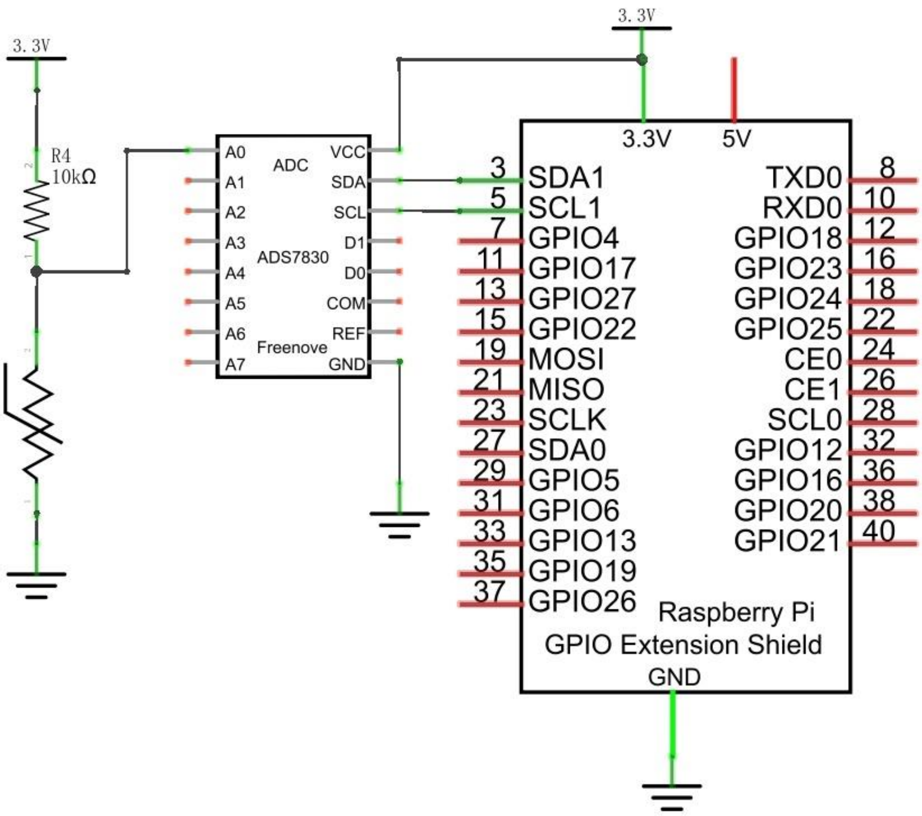


Thermistor is **has** longer pin than the one shown in circuit.

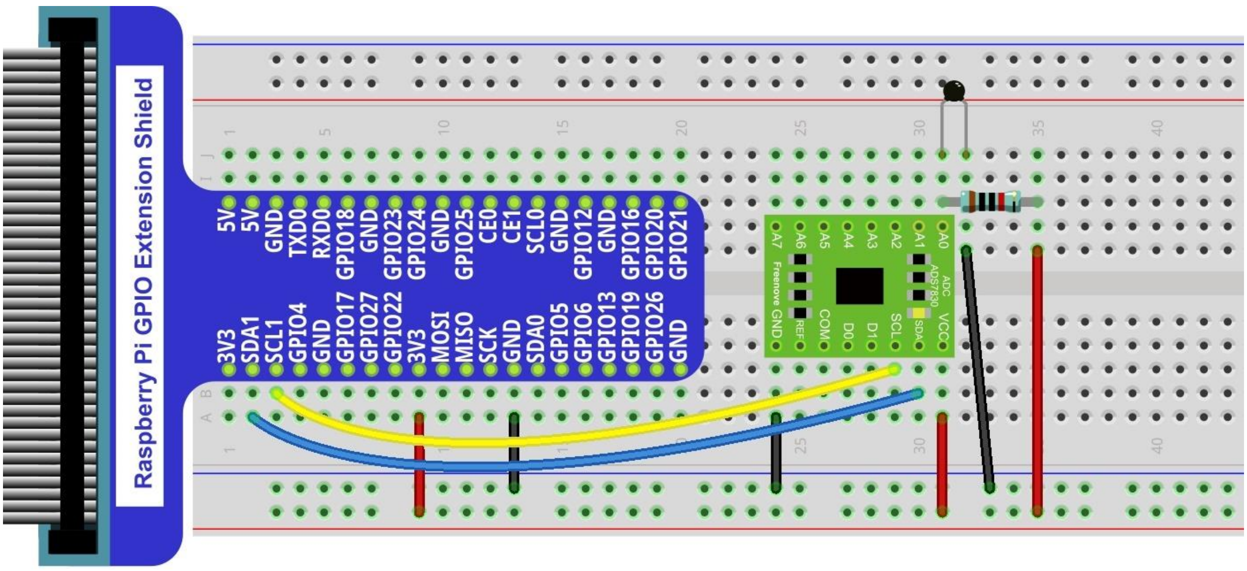
Circuit with ADS

The circuit of this project is similar to the one in last chapter. The only difference is that the photoresistor is replaced by the thermistor.

Schematic diagram



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



Thermistor is **has** longer pin than the one shown in circuit.

Code

In this project code, the ADC value is still needed to be read, and the difference is that a specific formula is used to calculate the temperature value.

C Code 10.1.1 Thermometer

If you did not configure I2C, please refer to Chapter 7. If you did, please move on.

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

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

1. Use cd command to enter 10.1.1_Thermometer directory of C code.

```
cd ~/Freenove_Kit/Code/C_Code/10.1.1_Thermometer
```

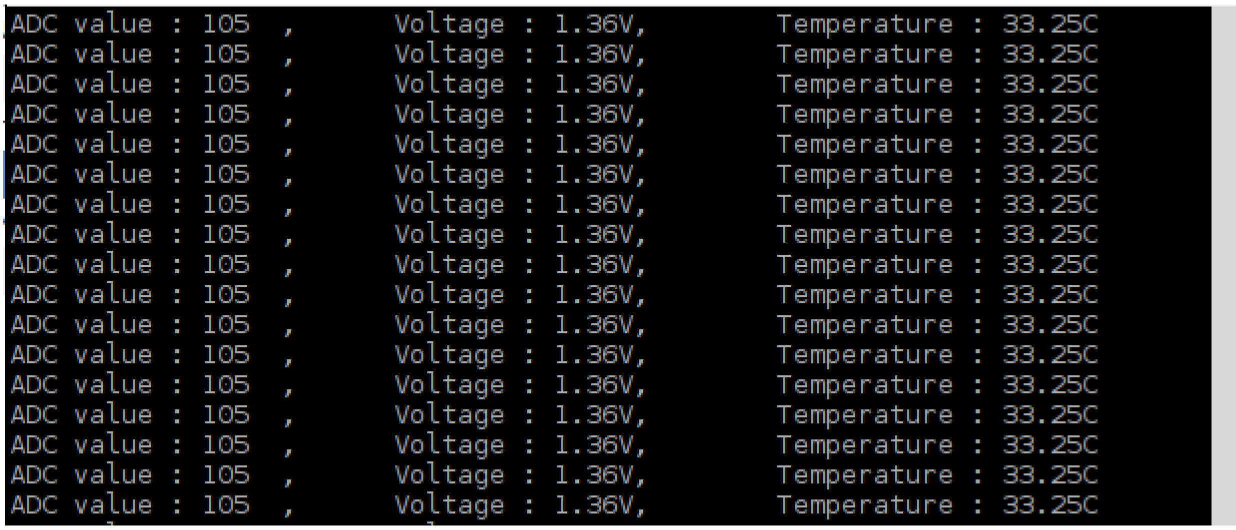
2 Use following command to compile "Thermometer.cpp" and generate executable file "Thermometer".

```
g++ Thermometer.cpp -o Thermometer -lwiringPi -lADCDevice
```

3 Then run the generated file "Thermometer".

```
sudo ./Thermometer
```

After the program is executed, the terminal window will print out the current ADC value, voltage value and temperature value. Try to pinch the thermistor (do not touch pin) with one hand for a while, then the temperature value will increase.



```
ADC value : 105  ,      Voltage : 1.36V,      Temperature : 33.25C
ADC value : 105  ,      Voltage : 1.36V,      Temperature : 33.25C
ADC value : 105  ,      Voltage : 1.36V,      Temperature : 33.25C
ADC value : 105  ,      Voltage : 1.36V,      Temperature : 33.25C
ADC value : 105  ,      Voltage : 1.36V,      Temperature : 33.25C
ADC value : 105  ,      Voltage : 1.36V,      Temperature : 33.25C
ADC value : 105  ,      Voltage : 1.36V,      Temperature : 33.25C
ADC value : 105  ,      Voltage : 1.36V,      Temperature : 33.25C
ADC value : 105  ,      Voltage : 1.36V,      Temperature : 33.25C
ADC value : 105  ,      Voltage : 1.36V,      Temperature : 33.25C
ADC value : 105  ,      Voltage : 1.36V,      Temperature : 33.25C
ADC value : 105  ,      Voltage : 1.36V,      Temperature : 33.25C
ADC value : 105  ,      Voltage : 1.36V,      Temperature : 33.25C
ADC value : 105  ,      Voltage : 1.36V,      Temperature : 33.25C
ADC value : 105  ,      Voltage : 1.36V,      Temperature : 33.25C
ADC value : 105  ,      Voltage : 1.36V,      Temperature : 33.25C
ADC value : 105  ,      Voltage : 1.36V,      Temperature : 33.25C
```

The following is the code:

```
#include <wiringPi.h>
#include <stdio.h>
#include <math.h>
#include <ADCDevice.hpp>

ADCDevice *adc;  // Define an ADC Device class object

int main(void){
    adc = new ADCDevice();
    printf("Program is starting ... \n");
```

```

    if(adc->detectI2C(0x48)){    // Detect the pcf8591.
        delete adc;                // Free previously pointed memory
        adc = new PCF8591();     // If detected, create an instance of PCF8591.
    }
    else if(adc->detectI2C(0x4b)){// Detect the ads7830
        delete adc;               // Free previously pointed memory
        adc = new ADS7830();      // If detected, create an instance of ADS7830.
    }
    else{
        printf("No correct I2C address found, \n"
        "Please use command 'i2cdetect -y 1' to check the I2C address! \n"
        "Program Exit. \n");
        return -1;
    }
    printf("Program is starting ... \n");
    while(1){
        int adcValue = adc->analogRead(0);  //read analog value A0 pin
        float voltage = (float)adcValue / 255.0 * 3.3;    // calculate voltage
        float Rt = 10 * voltage / (3.3 - voltage);        //calculate resistance value of
thermistor
        float tempK = 1/(1/(273.15 + 25) + log(Rt/10)/3950.0); //calculate temperature
(Kelvin)
        float tempC = tempK -273.15;        //calculate temperature (Celsius)
        printf("ADC value : %d  ,\tVoltage : %.2fV,
\tTemperature : %.2fC\n",adcValue,voltage,tempC);
        delay(100);
    }
    return 0;
}
```

In the code, read the ADC value of ADC module A0 port, and then calculate the voltage and the resistance of thermistor according to Ohms law. Finally, calculate the current temperature. according to the previous formula.

Python Code 10.1.1 Thermometer

If you did not configure I2C, please refer to Chapter 7. If you did, please move on.

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

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

1. Use cd command to enter 10.1.1_Thermometer directory of Python code.

```
cd ~/Freenove_Kit/Code/Python_Code/10.1.1_Thermometer
```

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

```
python Thermometer.py
```

After the program is executed, the terminal window will print out the current ADC value, voltage value and temperature value. Try to pinch the thermistor (do not touch pin) with hand lasting for a while, then the temperature value will be increased.

```
ADC Value : 107, Voltage : 1.38, Temperature : 32.48
ADC Value : 107, Voltage : 1.38, Temperature : 32.48
ADC Value : 107, Voltage : 1.38, Temperature : 32.48
ADC Value : 107, Voltage : 1.38, Temperature : 32.48
ADC Value : 107, Voltage : 1.38, Temperature : 32.48
ADC Value : 107, Voltage : 1.38, Temperature : 32.48
ADC Value : 107, Voltage : 1.38, Temperature : 32.48
ADC Value : 107, Voltage : 1.38, Temperature : 32.48
ADC Value : 107, Voltage : 1.38, Temperature : 32.48
ADC Value : 107, Voltage : 1.38, Temperature : 32.48
ADC Value : 107, Voltage : 1.38, Temperature : 32.48
ADC Value : 107, Voltage : 1.38, Temperature : 32.48
ADC Value : 107, Voltage : 1.38, Temperature : 32.48
ADC Value : 107, Voltage : 1.38, Temperature : 32.48
ADC Value : 107, Voltage : 1.38, Temperature : 32.48
```

The following is the code:

```python
import RPi.GPIO as GPIO
import time
import math
from ADCDevice import *

adc = ADCDevice() # Define an ADCDevice class object

def setup():
    global adc
    if(adc.detectI2C(0x48)): # Detect the pcf8591.
        adc = PCF8591()
    elif(adc.detectI2C(0x4b)): # Detect the ads7830
        adc = ADS7830()
    else:
        print("No correct I2C address found, \n"
        "Please use command 'i2cdetect -y 1' to check the I2C address! \n"
        "Program Exit. \n");
        exit(-1)
```

```

def loop():
    while True:
        value = adc.analogRead(0)        # read ADC value A0 pin
        voltage = value / 255.0 * 3.3        # calculate voltage
        Rt = 10 * voltage / (3.3 - voltage)     # calculate resistance value of thermistor
        tempK = 1/(1/(273.15 + 25) + math.log(Rt/10)/3950.0) # calculate temperature (Kelvin)
        tempC = tempK -273.15        # calculate temperature (Celsius)
        print ('ADC Value : %d, Voltage : %.2f, Temperature : %.2f'%(value,voltage,tempC))
        time.sleep(0.01)

def destroy():
    adc.close()
    GPIO.cleanup()

if __name__ == '__main__':  # Program entrance
    print ('Program is starting ... ')
    setup()
    try:
        loop()
    except KeyboardInterrupt: # Press ctrl-c to end the program.
        destroy()
```

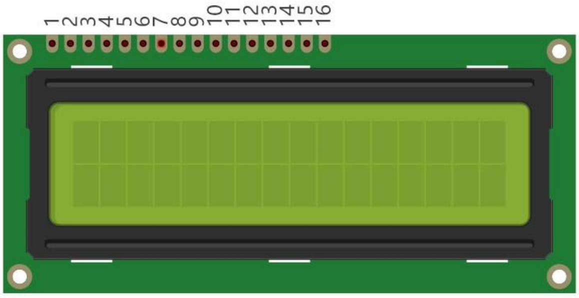
In the code, read the ADC value of ADC module A0 port, and then calculate the voltage and the resistance of thermistor according to Ohms law. Finally, calculate the current temperature. according to the previous formula.

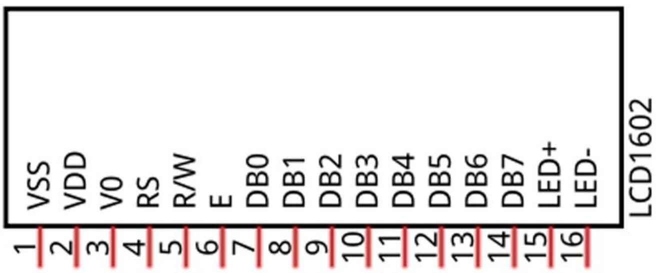
Chapter 11 LCD1602

In this chapter, we will learn a display screen, LCD1602.

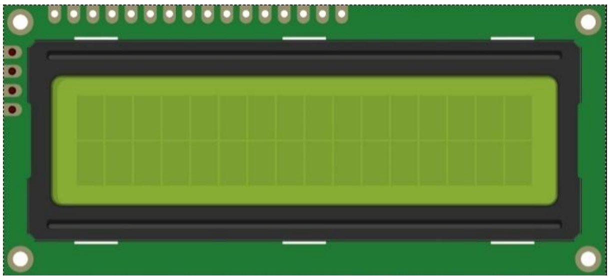
Project 11.1 I2C LCD1602

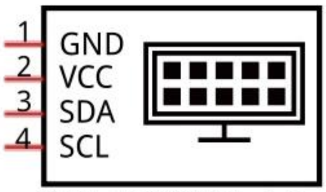
LCD1602 can display 2 lines of characters in 16 columns. It can display numbers, letters, symbols, ASCII code and so on. As shown below is a monochrome LCD1602 display screen，and its circuit pin diagram:





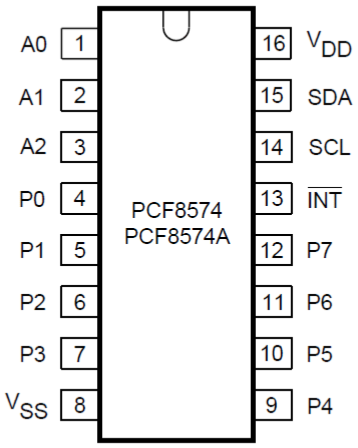
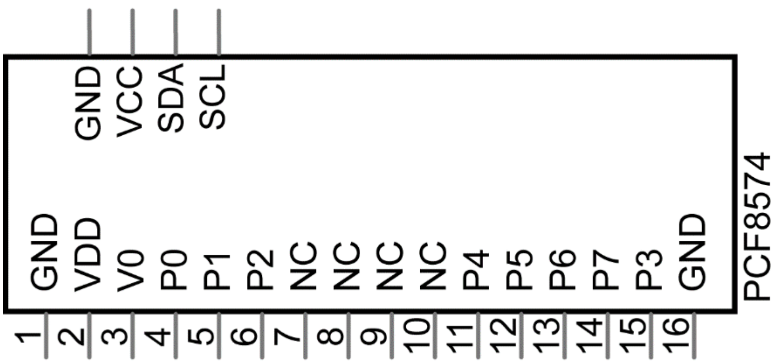
I2C LCD1602 integrates a I2C interface, which connects the serial-input &parallel-output module to LCD1602. We just use 4 lines to the operate LCD1602 easily.



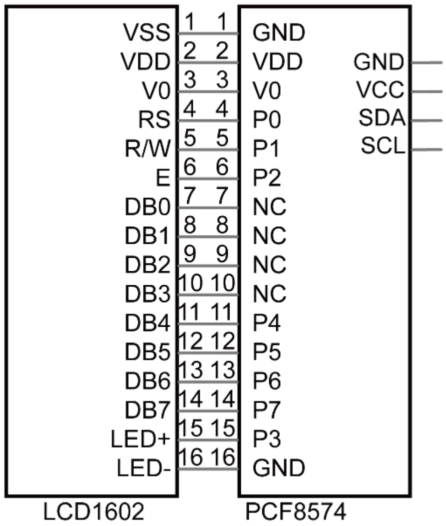


I2C LCD1602 Module

The serial-to-parallel chip used in this module is PCF8574T (PCF8574AT), and its default I2C address is 0x27(0x3F), and you can view all the RPI bus on your I2C device address through command "i2cdetect -y 1" to. (refer to the "configuration I2C" section below) below is the PCF8574 pin schematic diagram and the block pin diagram:

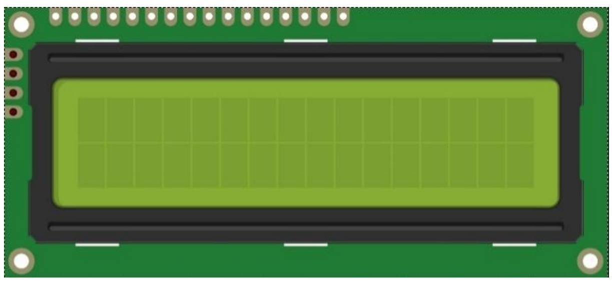
PCF8574 chip pin diagram:	PCF8574 module pin diagram
	

PCF8574 module pin and LCD1602 pin are corresponding to each other and connected with each other:



So, we can use just 4 pins to control LCD1602 with 16 pins easily through I2C interface.
In this project, we will use I2CLCD1602 to display some static characters and dynamic variables.

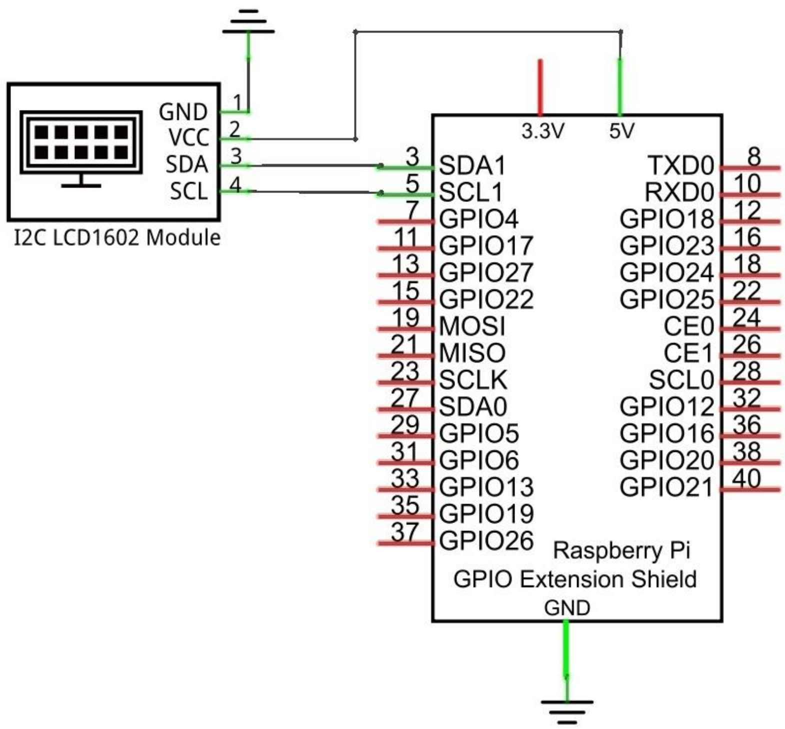
Component List

Raspberry Pi (with 40 GPIO) x1 GPIO Extension Board & Wire x1 Breadboard x1	Jumper 
I2C LCD1602 Module x1 	

Circuit

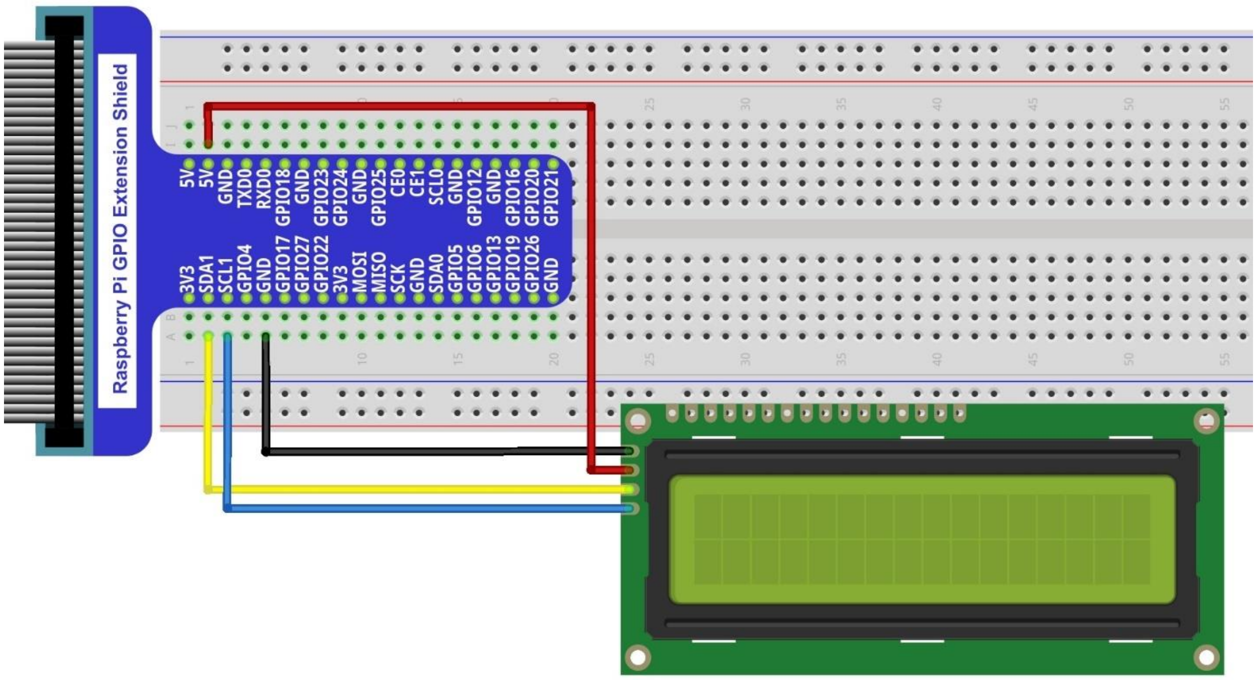
Note that the power supply for I2CLCD1602 in this circuit is 5V.

Schematic diagram



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

It is necessary to configure i2c and install Sumbus first on [chapter 7](#).



Code

This code will get the CPU temperature and system time of RPi, display them on LCD1602.

C Code 11.1.1 I2CLCD1602

If you did not configure I2C and install Sumbus, please refer to Chapter 7. If you did, please move on.

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

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

1. Use cd command to enter 11.1.1_ I2CLCD1602 directory of C code.

```
cd ~/Freenove_Kit/Code/C_Code/11.1.1_I2CLCD1602
```

2. Open the file I2CLCD1602.c, and find the macro definition "pcf8574_address". If your serial-to-parallel module uses chip PCF8574T, set the macro "pcf8574_address" value to 0x27.If your serial-to-parallel module uses chip PCF8574AT, set the macro "pcf8574_address" value to 0x3F.

```
//#define pcf8574_address 0x27        // default I2C address of Pcf8574
#define pcf8574_address 0x3F        // default I2C address of Pcf8574A
```

3. Use following command to compile "I2CLCD1602.c" and generate executable file "I2CLCD1602".

```
gcc I2CLCD1602.c -o I2CLCD1602 -lwiringPi -lwiringPiDev
```

4. Then run the generated file "I2CLCD1602".

```
sudo ./ I2CLCD1602
```

After the program is executed, LCD1602 screen will display current CPU temperature and system time.

If there is no display or the display is not clear, rotate white knob on back of LCD to adjust the contrast of LCD1602 until the screen can display clearly.

The following is the program code:

```
#include <stdlib.h>
#include <stdio.h>
#include <wiringPi.h>
#include <pcf8574.h>
#include <lcd.h>
#include <time.h>

//#define pcf8574_address 0x27        // default I2C address of Pcf8574
#define pcf8574_address 0x3F        // default I2C address of Pcf8574A
#define BASE 64         // BASE any number above 64
//Define the output pins of the PCF8574, which are directly connected to the LCD1602 pin.
```

```
#define RS      BASE+0
#define RW      BASE+1
#define EN      BASE+2
#define LED     BASE+3
#define D4      BASE+4
#define D5      BASE+5
#define D6      BASE+6
#define D7      BASE+7

int lcdhd;// used to handle LCD
void printCPUTemperature(){// sub function used to print CPU temperature
    FILE *fp;
    char str_temp[15];
    float CPU_temp;
    // CPU temperature data is stored in this directory.
    fp=fopen("/sys/class/thermal/thermal_zone0/temp","r");
    fgets(str_temp,15,fp);      // read file temp
    CPU_temp = atof(str_temp)/1000.0;   // convert to Celsius degrees
    printf("CPU's temperature : %.2f \n",CPU_temp);
    lcdPosition(lcdhd,0,0);     // set the LCD cursor position to (0,0)
    lcdPrintf(lcdhd,"CPU:%.2fC",CPU_temp);// Display CPU temperature on LCD
    fclose(fp);
}
void printDataTime(){//used to print system time
    time_t rawtime;
    struct tm *timeinfo;
    time(&rawtime);// get system time
    timeinfo = localtime(&rawtime);//convert to local time
    printf("%s \n",asctime(timeinfo));
    lcdPosition(lcdhd,0,1);// set the LCD cursor position to (0,1)
    lcdPrintf(lcdhd,"Time:%d:%d:%d",timeinfo->tm_hour,timeinfo->tm_min,timeinfo->tm_sec);
//Display system time on LCD
}
int main(void){
    int i;

    printf("Program is starting ...\n");

    wiringPiSetup();

    pcf8574Setup(BASE,pcf8574_address);//initialize PCF8574
    for(i=0;i<8;i++){
        pinMode(BASE+i,OUTPUT);     //set PCF8574 port to output mode
    }
```

```
    digitalWrite(LED,HIGH);     //turn on LCD backlight
    digitalWrite(RW,LOW);       //allow writing to LCD
    lcdhd = lcdInit(2,16,4,RS,EN,D4,D5,D6,D7,0,0,0,0);// initialize LCD and return “handle”
used to handle LCD
    if(lcdhd == -1){
        printf("lcdInit failed !");
        return 1;
    }
    while(1){
        printCPUTemperature();//print CPU temperature
        printDataTime();        // print system time
        delay(1000);
    }
    return 0;
}
```

It can be seen from the code that PCF8591 and PCF8574 have a lot of similarities, they are through the I2C interface to expand the GPIO RPI. First defines the I2C address of the PCF8574 and the Extension of the GPIO pin, which is connected to the GPIO pin of the LCD1602.

```
//#define pcf8574_address 0x27        // default I2C address of Pcf8574
#define pcf8574_address 0x3F       // default I2C address of Pcf8574A
#define BASE 64         // BASE is not less than 64
//////// Define the output pins of the PCF8574, which are directly connected to the
LCD1602 pin.
#define RS      BASE+0
#define RW      BASE+1
#define EN      BASE+2
#define LED     BASE+3
#define D4      BASE+4
#define D5      BASE+5
#define D6      BASE+6
#define D7      BASE+7
```

Then, in main function, initialize the PCF8574, set all the pins to output mode, and turn on the LCD1602 backlight.

```
    pcf8574Setup(BASE,pcf8574_address);// initialize PCF8574
    for(i=0;i<8;i++){
        pinMode(BASE+i,OUTPUT);     // set PCF8574 port to output mode
    }
    digitalWrite(LED,HIGH);     // turn on LCD backlight
```

Then use lcdInit() to initialize LCD1602 and set the RW pin of LCD1602 to 0 (namely, can be write) according to requirements of this function. The return value of the function called "Handle" is used to handle LCD1602" next.

```
        lcdhd = lcdInit(2,16,4,RS,EN,D4,D5,D6,D7,0,0,0,0);// initialize LCD and return
 “handle” used to handle LCD
```

Details about lcdInit():

int lcdInit (int rows, int cols, int bits, int rs, int strb, int d0, int d1, int d2, int d3, int d4, int d5, int d6, int d7) ;
This is the main initialization function and must be called before you use any other LCD functions. **Rows** and **cols** are the rows and columns on the display (e.g. 2, 16 or 4,20). **Bits** is the number of bits wide on the interface (4 or 8). The **rs** and **strb** represent the pin numbers of the displays RS pin and Strobe (E) pin. The parameters **d0** through **d7** are the pin numbers of the 8 data pins connected from the Pi to the display. Only the first 4 are used if you are running the display in 4-bit mode. The return value is the 'handle' to be used for all subsequent calls to the lcd library when dealing with that LCD, or -1 to indicate a fault. (Usually incorrect parameters) For more details about LCD Library, please refer to: https://projects.drogon.net/raspberry-pi/wiringpi/lcd-library/

In the next "while", two subfunctions are called to display the CPU temperature and the time. First look at subfunction printCPUTemperature(). The CPU temperature data is stored in the "/sys/class/thermal/thermal_zone0/temp " file. We need read contents of the file, and converts it to temperature value stored in variable CPU_temp, and use lcdPrintf() to display it on LCD.

```
void printCPUTemperature(){//subfunction used to print CPU temperature

    FILE *fp;
    char str_temp[15];
    float CPU_temp;
    // CPU temperature data is stored in this directory.
    fp=fopen("/sys/class/thermal/thermal_zone0/temp","r");
    fgets(str_temp,15,fp);       // read file temp
    CPU_temp = atof(str_temp)/1000.0;    // convert to Celsius degrees
    printf("CPU's temperature : %.2f \n",CPU_temp);
    lcdPosition(lcdhd,0,0);      // set the LCD cursor position to (0,0)
    lcdPrintf(lcdhd,"CPU:%.2fC",CPU_temp);// Display CPU temperature on LCD
    fclose(fp);
}
```

Details about lcdPosition() and lcdPrintf():

lcdPosition (int handle, int x, int y);
Set the position of the cursor for subsequent text entry.
lcdPutchar (int handle, uint8_t data) **lcdPuts (int handle, char *string)** **lcdPrintf (int handle, char *message, …)**
These output a single ASCII character, a string or a formatted string using the usual printf formatting commands.

Next is subfunction printDataTime() used to print system time. First, got the standard time and store it into variable rawtime, and then converted it to the local time and tore it into timeinfo, and finally display the time information on LCD1602.

```
void printDataTime(){//used to print system time
    time_t rawtime;
    struct tm *timeinfo;
```

```
    time(&rawtime);// get system time
    timeinfo = localtime(&rawtime);// convert to local time
    printf("%s \n",asctime(timeinfo));
    lcdPosition(lcdhd,0,1);// set the LCD cursor position to (0,1)
    lcdPrintf(lcdhd,"Time:%d:%d:%d",timeinfo->tm_hour,timeinfo->tm_min,timeinfo->tm_sec);
//Display system time on LCD
}
```

Python Code 11.1.1 I2CLCD1602

If you did not configure I2C and install Sumbus, please refer to Chapter 7. If you did, please move on.

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

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

1. Use cd command to enter 11.1.1_ I2CLCD1602 directory of Python code.

```
cd ~/Freenove_Kit/Code/Python_Code/11.1.1_I2CLCD1602
```

2. Use python command to execute python code "I2CLCD1602.py".

```
python I2CLCD1602.py
```

After the program is executed, LCD1602 screen will display current CPU temperature and system time.

If there is no display or the display is not clear, rotate white knob on back of LCD to adjust the contrast of LCD1602 until the screen can display clearly.

The following is the program code:

```
from PCF8574 import PCF8574_GPIO
from Adafruit_LCD1602 import Adafruit_CharLCD

from time import sleep, strftime
from datetime import datetime

def get_cpu_temp():     # get CPU temperature and store it into file
"/sys/class/thermal/thermal_zone0/temp"
    tmp = open('/sys/class/thermal/thermal_zone0/temp')
    cpu = tmp.read()
    tmp.close()
    return '{:.2f}'.format( float(cpu)/1000 ) + ' C'

def get_time_now():     # get system time
```

```
    return datetime.now().strftime('    %H:%M:%S')

def loop():
    mcp.output(3,1)     # turn on LCD backlight
    lcd.begin(16,2)     # set number of LCD lines and columns
    while(True):
        #lcd.clear()
        lcd.setCursor(0,0)  # set cursor position
        lcd.message( 'CPU: ' + get_cpu_temp()+'\n' )# display CPU temperature
        lcd.message( get_time_now() )   # display the time
        sleep(1)

def destroy():
    lcd.clear()

PCF8574_address = 0x27  # I2C address of the PCF8574 chip.
PCF8574A_address = 0x3F  # I2C address of the PCF8574A chip.
# Create PCF8574 GPIO adapter.
try:
    mcp = PCF8574_GPIO(PCF8574_address)
except:
    try:
        mcp = PCF8574_GPIO(PCF8574A_address)
    except:
        print ('I2C Address Error !')
        exit(1)
# Create LCD, passing in MCP GPIO adapter.
lcd = Adafruit_CharLCD(pin_rs=0, pin_e=2, pins_db=[4,5,6,7], GPIO=mcp)

if __name__ == '__main__':
    print ('Program is starting ... ')
    try:
        loop()
    except KeyboardInterrupt:
        destroy()
```

Two modules are used in the code, PCF8574.py and Adafruit_LCD1602.py. These two documents and the code file are stored in the same directory, and neither of them is dispensable. Please do not delete. PCF8574.py is used to provide I2C communication mode and operation method of some port for RPi and PCF8574 chip. Adafruit module Adafruit_LCD1602.py is used to provide some function operation method for LCD1602.

In the code, first get the object used to operate PCF8574 port, then get the object used to operate LCD1602.

```
address = 0x27  # I2C address of the PCF8574 chip.
# Create PCF8574 GPIO adapter.
mcp = PCF8574_GPIO(address)
```

```
# Create LCD, passing in MCP GPIO adapter.
lcd = Adafruit_CharLCD(pin_rs=0, pin_e=2, pins_db=[4,5,6,7], GPIO=mcp)
```

According to the circuit connection, port 3 of PCF8574 is connected to positive pole of LCD1602 backlight. Then in the loop () function, use of mcp.output(3,1) to turn on LCD1602 backlight, and set number of LCD lines and columns.

```
def loop():
    mcp.output(3,1)     # turn on the LCD backlight
    lcd.begin(16,2)     # set number of LCD lines and columns
```

In the next while loop, set the cursor position, and display the CPU temperature and time.

```
    while(True):
        #lcd.clear()
        lcd.setCursor(0,0)  # set cursor position
        lcd.message( 'CPU: ' + get_cpu_temp()+'\n' )# display CPU temperature
        lcd.message( get_time_now() )   # display the time
        sleep(1)
```

CPU temperature is stored in file "/sys/class/thermal/thermal_zone0/temp". Open the file and read content of the file, and then convert it to Celsius degrees and return. Subfunction used to get CPU temperature is shown below:

```
def get_cpu_temp():     # get CPU temperature and store it into file
  "/sys/class/thermal/thermal_zone0/temp"
    tmp = open('/sys/class/thermal/thermal_zone0/temp')
    cpu = tmp.read()
    tmp.close()
    return '{:.2f}'.format( float(cpu)/1000 ) + ' C'
```

Subfunction used to get time:

```
def get_time_now():     # get the time
    return datetime.now().strftime('    %H:%M:%S')
```

Details about PCF8574.py and Adafruit_LCD1602.py:

Module PCF8574

This module provides two classes **PCF8574_I2C** and **PCF8574_GPIO**.

Class **PCF8574_I2C**: provides reading and writing method for PCF8574.

Class **PCF8574_GPIO**: provides a standardized set of GPIO functions.

More information can be viewed through opening PCF8574.py.

Adafruit_LCD1602 Module

Module Adafruit_LCD1602

This module provides the basic operation method of LCD1602, including class Adafruit_CharLCD. Some member functions are described as follows:

def begin(self, cols, lines): set the number of lines and columns of the screen.

def clear(self): clear the screen

def setCursor(self, col, row): set the cursor position

def message(self, text): display contents

More information can be viewed through opening Adafruit_CharLCD.py.

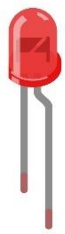
Chapter 12 WebIOPi & IOT

In this chapter, we will learn how to use GPIO to control RPi through remote network and how to build a WebIOPi service on the RPi.
"IOT" is Internet of Things. The development of IOT will greatly change our habits and make our lives more convenient and efficient.
"WebIOPi" is the Raspberry Pi Internet of Things Framework.After configuration for WebIOPi on your RPi is completed, you can use web browser on mobile phones, computers and other equipments to control, debug and use RPi GPIO conveniently. It also supports many commonly used communication protocol, such as serial, I2C, SPI, etc., and a lot of equipments, like AD/DA converter pcf8591 used before and so on. Then on this basis, through adding some peripheral circuits, you can create your own smart home.
For more details about WebIOPi, please refer to: http://webiopi.trouch.com/

Project 12.1 Remote LED

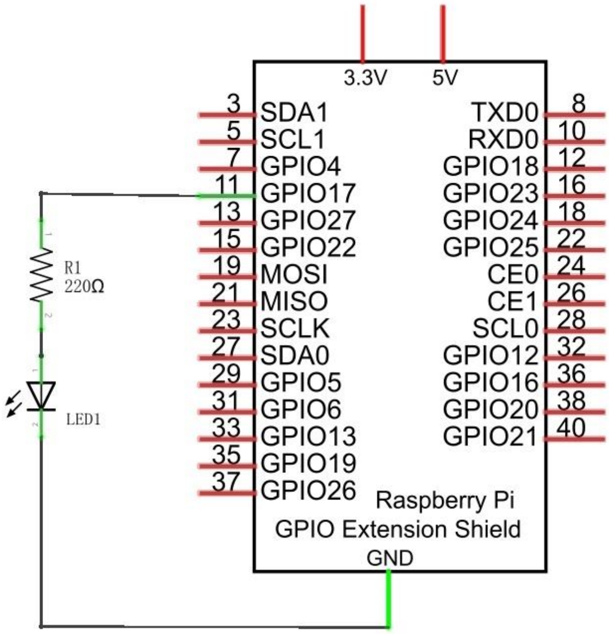
In this experiment, we need build a WebIOPi service, and then control the RPi GPIO to control a LED through Web browser of phone or PC.

Component List

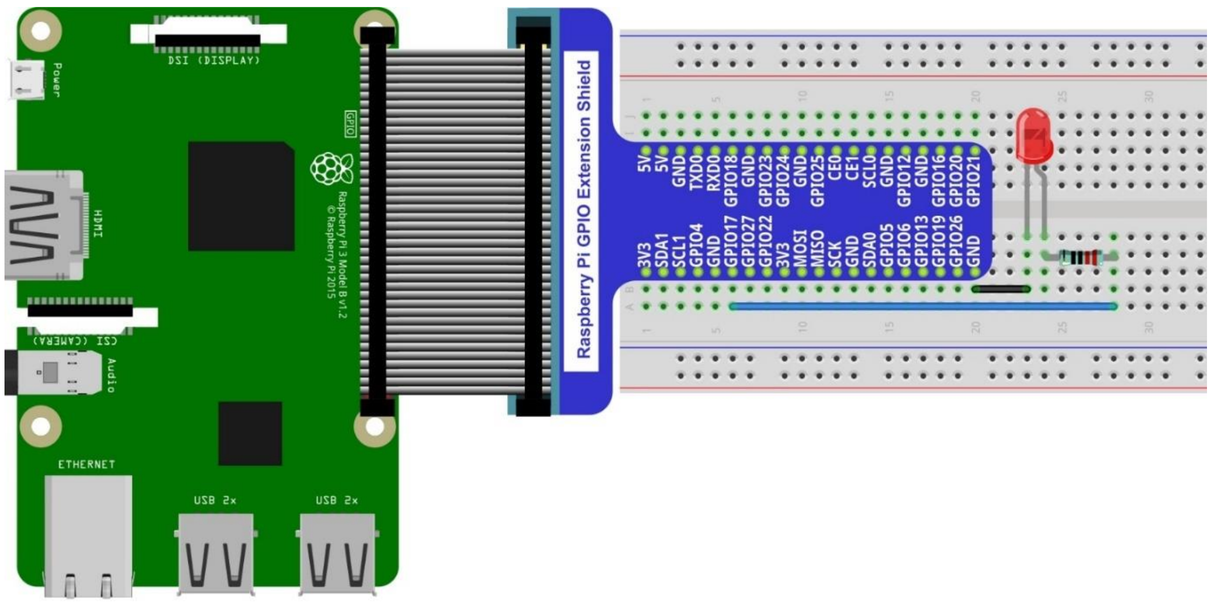
Raspberry Pi (with 40 GPIO) x1 GPIO Extension Board & Wire x1 Breadboard x1	LED x1 	Resistor 220Ω x1 
Jumper M/M x2 		

Circuit

Schematic diagram



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



Build WebIOPi Service Framework

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

Here are the steps to build WebIOPi:

Installation

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

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

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

```
unzip WebIOPi.zip
cd WebIOPi-master/WebIOPi-0.7.1
```

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

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

4. Run setup.sh to start the installation, and the process need a period of time to wait.

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

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

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

Run

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

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

    Options:
      -h, --help               Display this help
      -c, --config   file      Load config from file
      -l, --log      file      Log to file
      -s, --script   file      Load script from file
      -d, --debug              Enable DEBUG

    Arguments:
      port                     Port to bind the HTTP Server
```

For instance, to start with verbose output and the default config file :

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

The Port is 8000 in default.

Until now, WebIOPi has been launched, and you can press "Ctrl+C" to terminate service.

Access WebIOPi over local network

Under the same network, use mobile phone or PC browser to open your RPi IP address, and add port number like 8000. For example, my raspberry pi IP address is 192.168.1.109. Then, in the browser, should input: http://192.168.1.109:8000/

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

Then, enter the main control interface:

WebIOPi Main Menu

GPIO Header

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

GPIO List

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

Serial Monitor

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

Devices Monitor

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

Click on GPIO Header to enter the GPIO control interface.

	3.3V	1	2	5.0V	
	I2C SDA	3	4	5.0V	
	I2C SCL	5	6	GROUND	
	ONEWIRE	7	8	UART TX	
	GROUND	9	10	UART RX	
OUT	GPIO 17	11	12	GPIO 18	IN
IN	GPIO 27	13	14	GROUND	
IN	GPIO 22	15	16	GPIO 23	IN
	3.3V	17	18	GPIO 24	IN
ALT0	GPIO 10	19	20	GROUND	
ALT0	GPIO 9	21	22	GPIO 25	IN
ALT0	GPIO 11	23	24	GPIO 8	OUT
	GROUND	25	26	GPIO 7	OUT
	--	27	28	--	
IN	GPIO 5	29	30	GROUND	
IN	GPIO 6	31	32	GPIO 12	IN
IN	GPIO 13	33	34	GROUND	
IN	GPIO 19	35	36	GPIO 16	IN
IN	GPIO 26	37	38	GPIO 20	IN
	GROUND	39	40	GPIO 21	IN

Control methods:

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

Completed

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

About WebIOPi

(If you are using raspberry pie 4B, you may have some trouble. We will also finish the WebIOPi adaptation to raspberry 4B as soon as possible, and update it at the first time.)

The reason for changing file in the configuration process is that the model of new generation of RPi CPU is different form old one, which result in some of the issues during using.

WebIOPi has not provide corresponding installation package for latest RPi timely. Therefore, there are two changes in the configuration, and some BUG may exist to cause some problems to WebIOPi function. We look forward to that the author of WebIOPi to provide a complete set of the latest version of installation package to fit with RPi. WebIOPi can achieve far more than this, so we also look forward to learning and exploring with the funs.

What's next?

Thanks for your reading.

This tutorial is all over here. If you find any mistakes, omissions or you have other ideas and questions about contents of this tutorial or the kit and etc, please feel free to contact us: **support@freenove.com**
We will check and correct it as soon as possible.

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

If you want to learn more about Arduino, Raspberry Pi, smart cars, robots and other interesting products in science and technology, please continue to focus on our website. We will continue to launch cost-effective, innovative and exciting products.
http://www.freenove.com/

Thank you again for choosing Freenove products.

Warning

When you purchase or use Freenove LCD Starter Kit for Raspberry Pi, please note the following:

- This product contains small parts. Swallowing or improper operation can cause serious infections and death. Seek immediate medical attention when the accident happened.
- Do not allow children under 3 years old to play with or near this product. Please place this product in where children under 3 years of age cannot reach.
- Do not allow children lack of ability of safe to use this product alone without parental care.
- Never use this product and its parts near any AC electrical outlet or other circuits to avoid the potential risk of electric shock.
- Never use this product near any liquid and fire.
- Keep conductive materials away from this product.
- Never store or use this product in any extreme environments such as extreme hot or cold, high humidity and etc.
- Remember to turn off circuits when not in use this product or when left.
- Do not touch any moving and rotating parts of this product while they are operating.
- Some parts of this product may become warm to touch when used in certain circuit designs. This is normal. Improper operation may cause excessively overheating.
- Using this product not in accordance with the specification may cause damage to the product.

About

Freenove is an open-source electronics platform. Freenove is committed to helping customer quickly realize the creative idea and product prototypes, making it easy to get started for enthusiasts of programing and electronics and launching innovative open source products. Our services include:

- Electronic components and modules
- Learning kits for Arduino
- Learning kits for Raspberry Pi
- Learning kits for Technology
- Product customization service
- Robot kits
- Auxiliary tools for creations

Our code and circuit are open source. You can obtain the details and the latest information through visiting the following web sites:

http://www.freenove.com

https://github.com/freenove

Your comments and suggestions are warmly welcomed, and please send them to the following email address:

support@freenove.com

If you have any business matters, please feel free to contact us:

sale@freenove.com