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References

You can download the sketches and references used in this product in the following websites:

<http://www.freenove.com> or <https://github.com/freenove>

Please pay more attention to two of the references:

- Read Me First.pdf It is recommended to read it first.
- Processing.pdf It is based on Java to create graphic interface to work with Raspberry Pi.

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Preface

Raspberry Pi is a low cost, **credit-card sized computer** that plugs into a computer monitor or TV, and uses a standard keyboard and mouse. It is 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 content for most projects is 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 complete 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 technical 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.

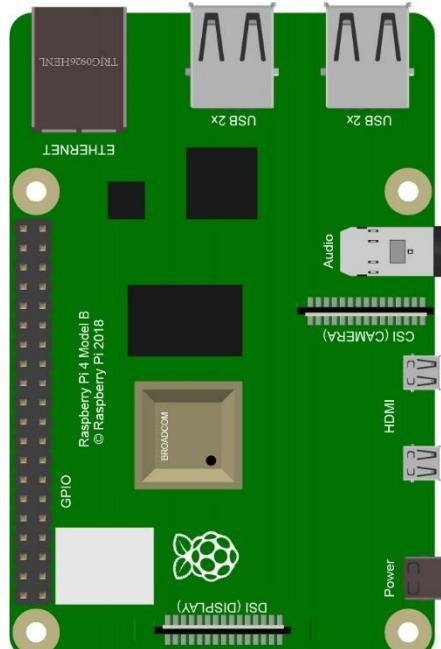
A type and B type, the first generation of products, have been stopped due to various reasons. Other versions are popular and active and the most important is that they are consistent in the order and number of pins, which makes the compatibility of peripheral devices greatly enhanced between different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

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

Practicality picture of Raspberry Pi 4 Model B:



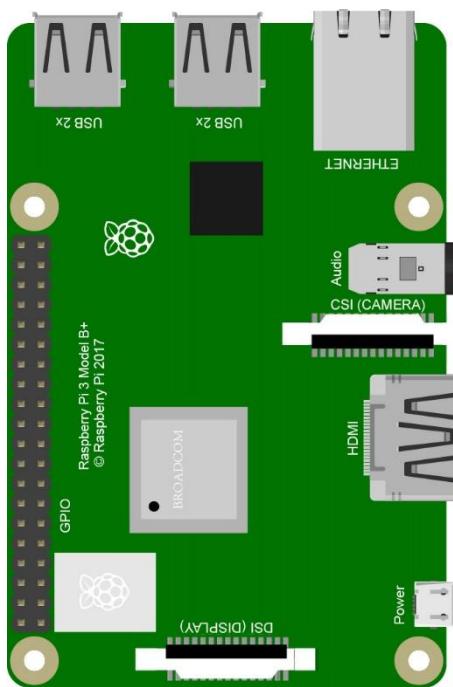
Model diagram of Raspberry Pi 4 Model B:



Practicality picture of Raspberry Pi 3 Model B+ :



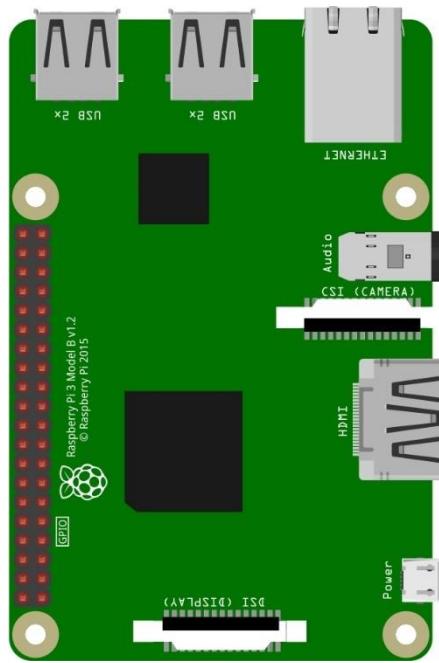
Model diagram of Raspberry Pi 3 Model B+ :



Practicality picture of Raspberry Pi 3 Model B :



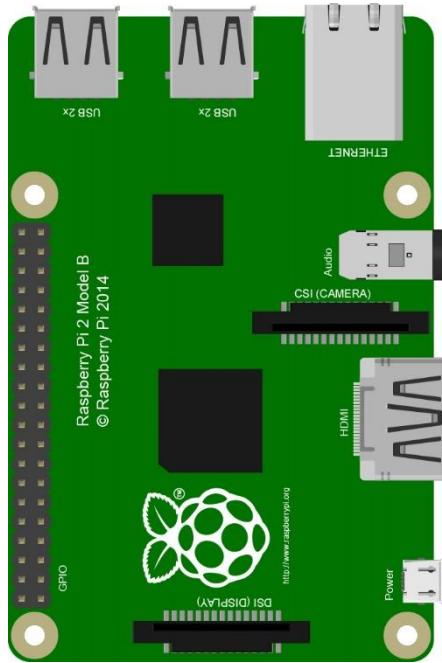
Model diagram of Raspberry Pi 3 Model B :



Practicality picture of Raspberry Pi 2 Model B:



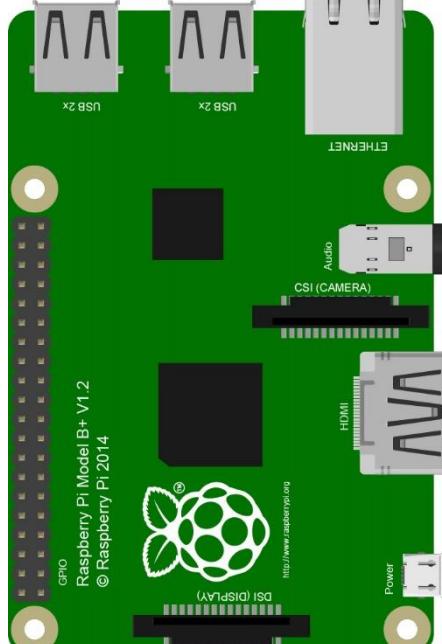
Model diagram of Raspberry Pi 2 Model B:



Practicality picture of Raspberry Pi 1 Model B+:



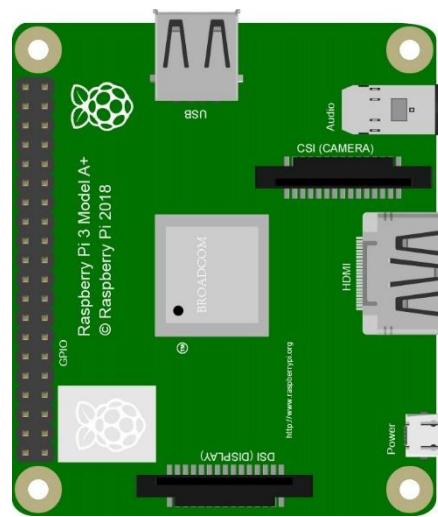
Model diagram of Raspberry Pi 1 Model B+:



Practicality picture of Raspberry Pi 3 Model A+:



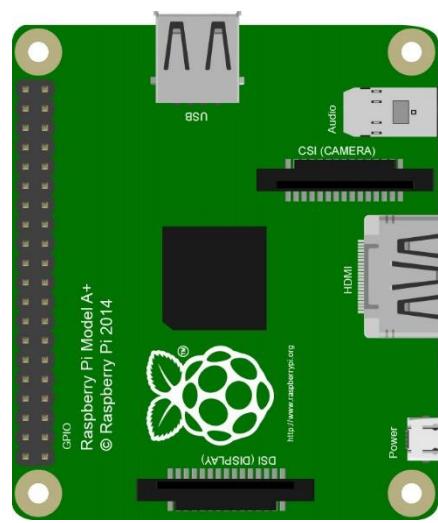
Model diagram of Raspberry Pi 3 Model A+:



Practicality picture of Raspberry Pi 1 Model A+:



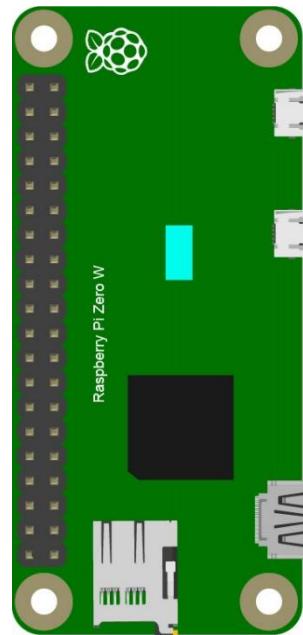
Model diagram of Raspberry Pi 1 Model A+:



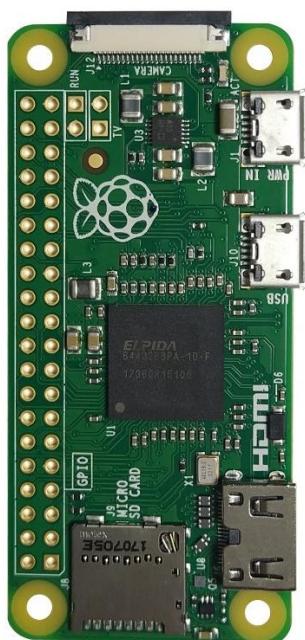
Practicality picture of Raspberry Pi Zero W:



Model diagram of Raspberry Pi Zero W:



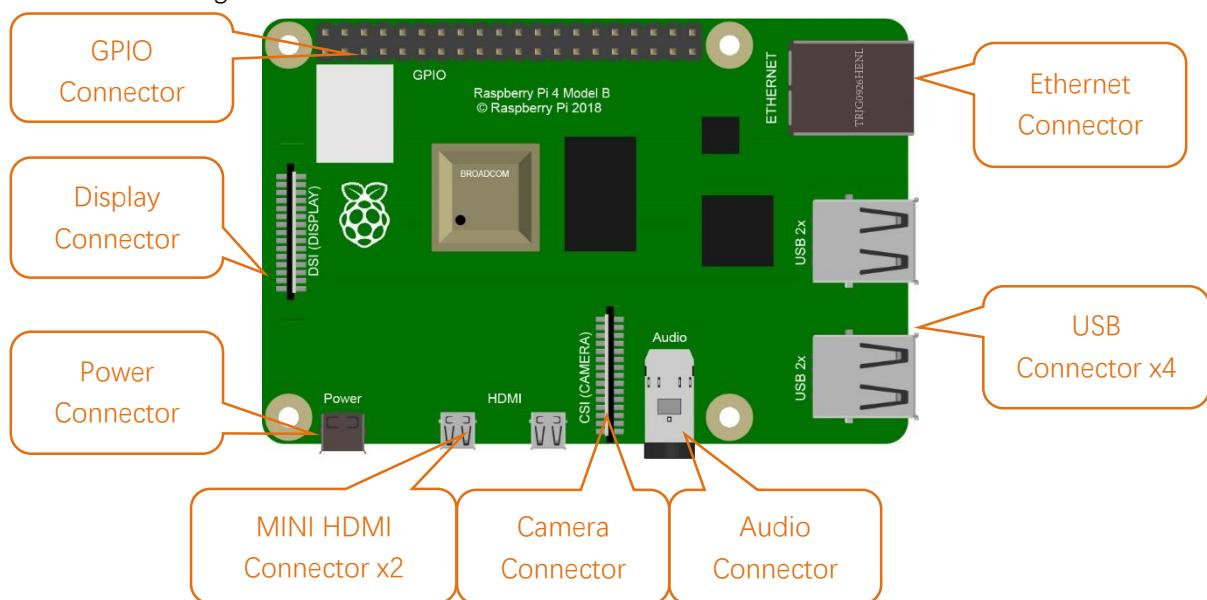
Practicality picture of Raspberry Pi Zero:



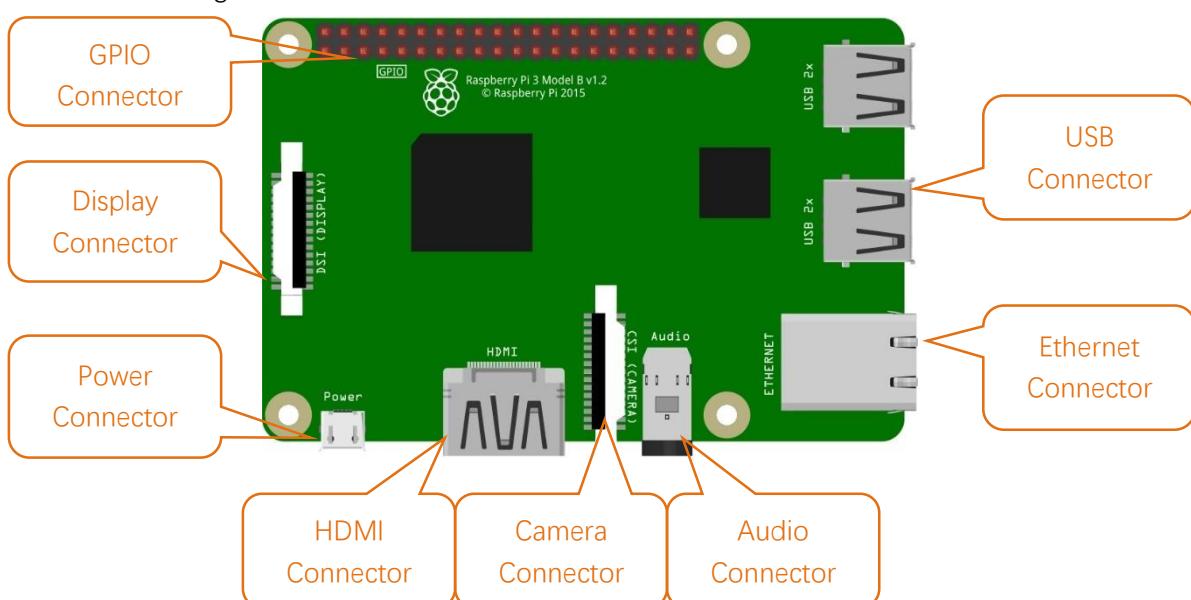
Model diagram of Raspberry Pi Zero:



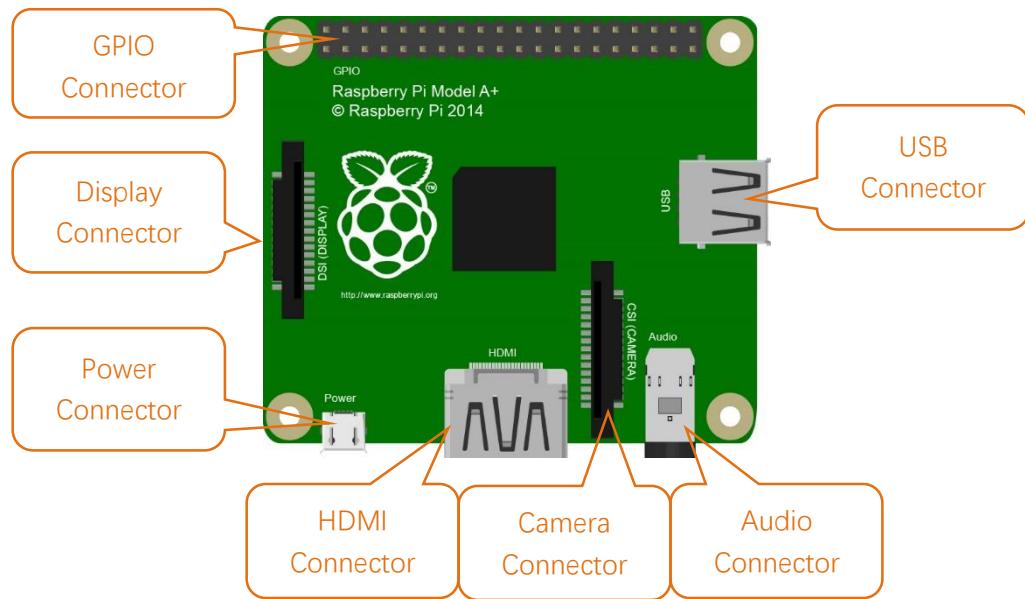
Hardware interface diagram of RPi 4B is shown below:



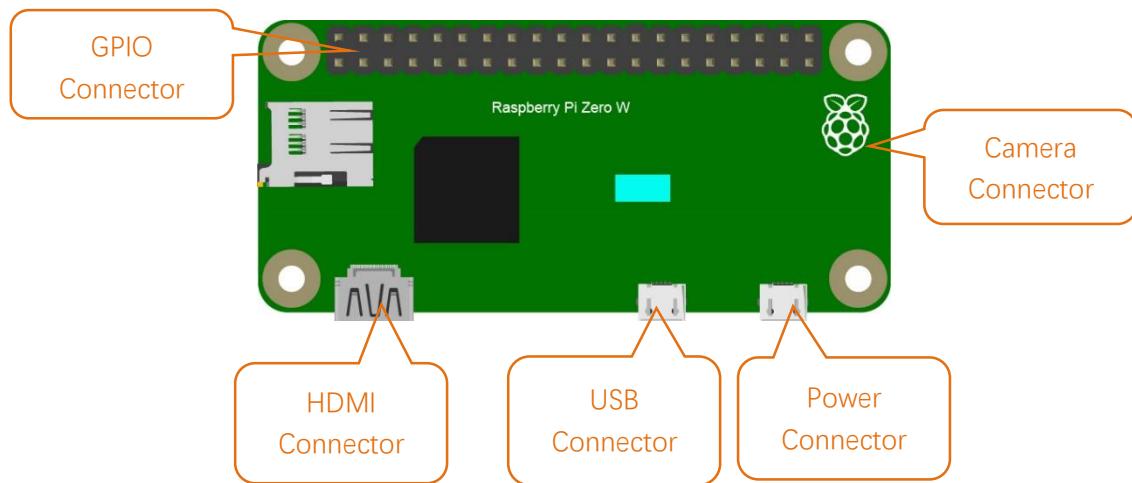
Hardware interface diagram of RPi 3B+/3B/2B/1B+ are shown below:



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



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

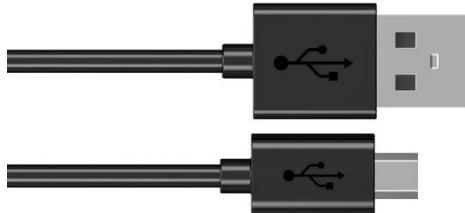


Install the System

Firstly, install a system for your RPi.

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 of these components are necessary. Among them, the power supply is required at least 5V/2.5A, because lack of power supply will lead to many abnormal problems, 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. In later projects, the components list with a RPi will contains these required components, using only RPi as a representative rather than presenting details.

Optional Components

Under normal circumstances, there are two ways to login to Raspberry Pi: using independent monitor, or 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 all of their aims are to convert the special interface to standard interface of standard Raspberry Pi.

	Pi Zero	Pi A+	Pi Zero W	Pi 3A+	Pi B+/2B	Pi 3B/3B+	Pi 4B
Monitor				Yes			
Mouse				Yes			
Keyboard				Yes			
Mini-HDMI to HDMI converter or wire	Yes	No	Yes	No	No	No	No
Micro-HDMI to HDMI converter & wire				No			Yes
Micro-USB to USB-A Receptacles converter & wire (Micro USB OTG wire)	Yes	No	Yes			No	
USB HUB	Yes	Yes	Yes	Yes	No	No	
USB transferring to Ethernet interface	select one from two or select two from two			optional	Internal Integration	Internal Integration	
USB Wi-Fi receiver				Internal Integration	optional		



Required Accessories for Remote Desktop

If you don't have an independent monitor, or 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.

	Pi Zero	Pi Zero W	Pi A+	Pi 3A+	Pi B+/2B	Pi 3B/3B+/4B
Micro-USB to USB-A Receptacles converter&wire (Micro USB OTG wire)	Yes	Yes	No			NO
USB transferring to Ethernet interface	Yes	Yes	Yes			

Raspbian System

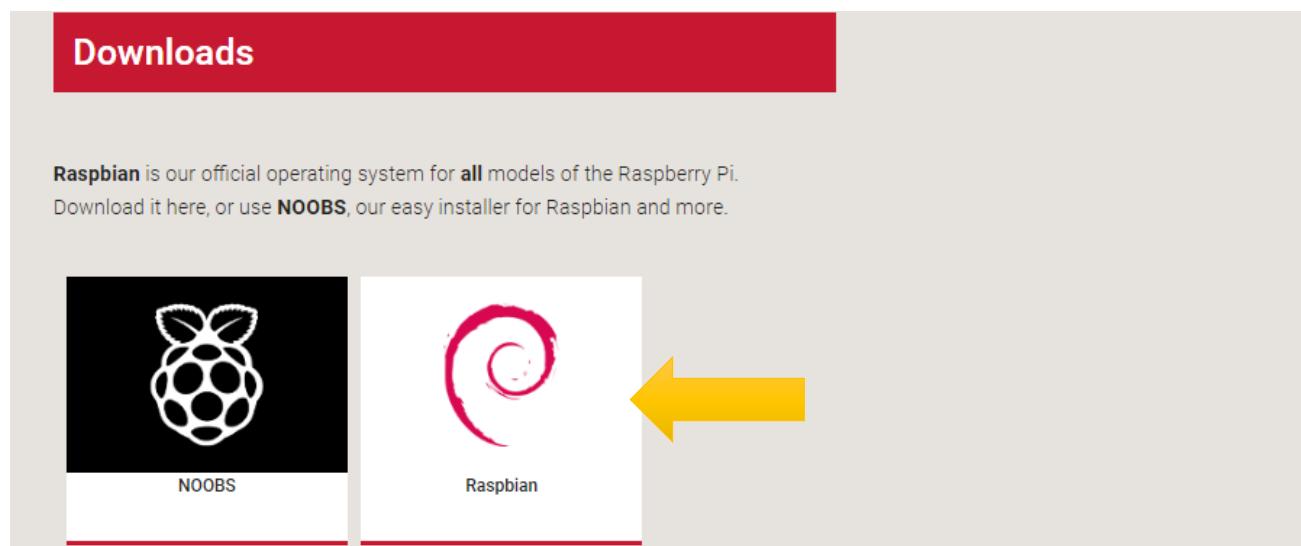
Tool and System image

Software Tool

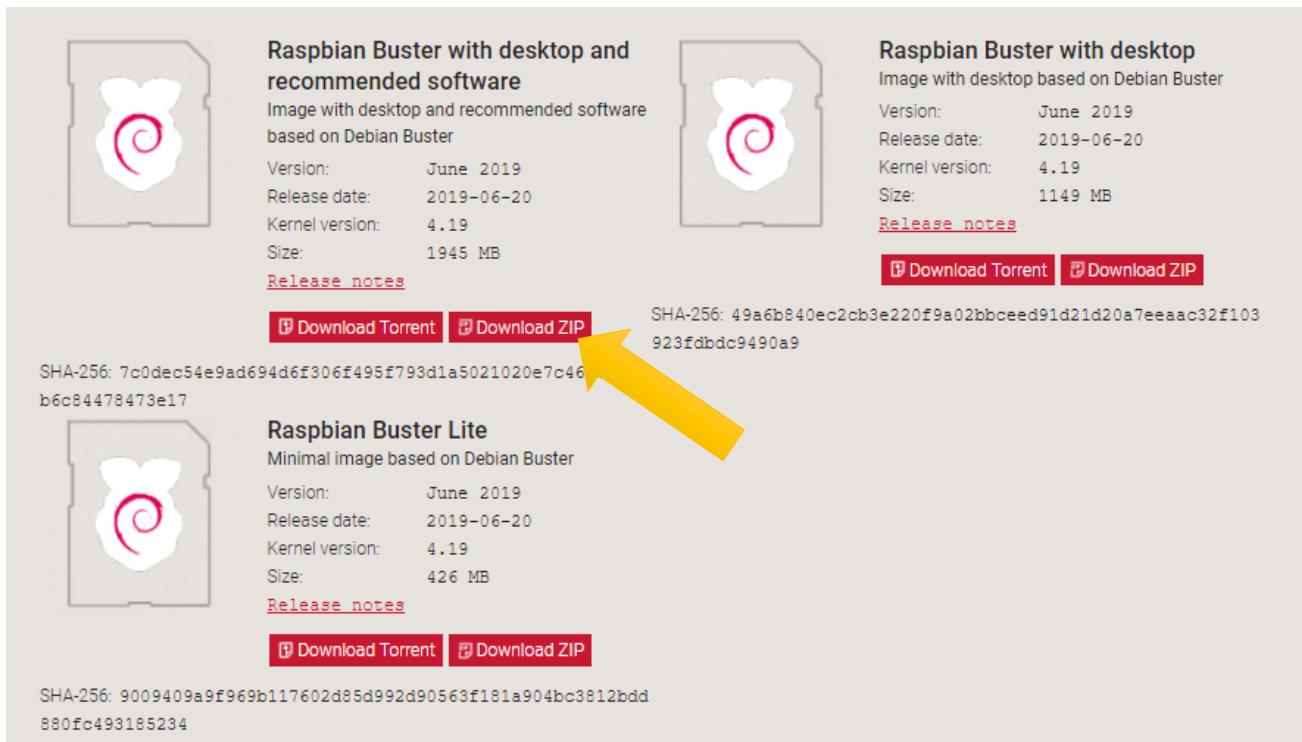
A tool Disk Imager Win32 is required to write system. You can download and install it through visiting the web site: <https://sourceforge.net/projects/win32diskimager/>

Selecting System

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.



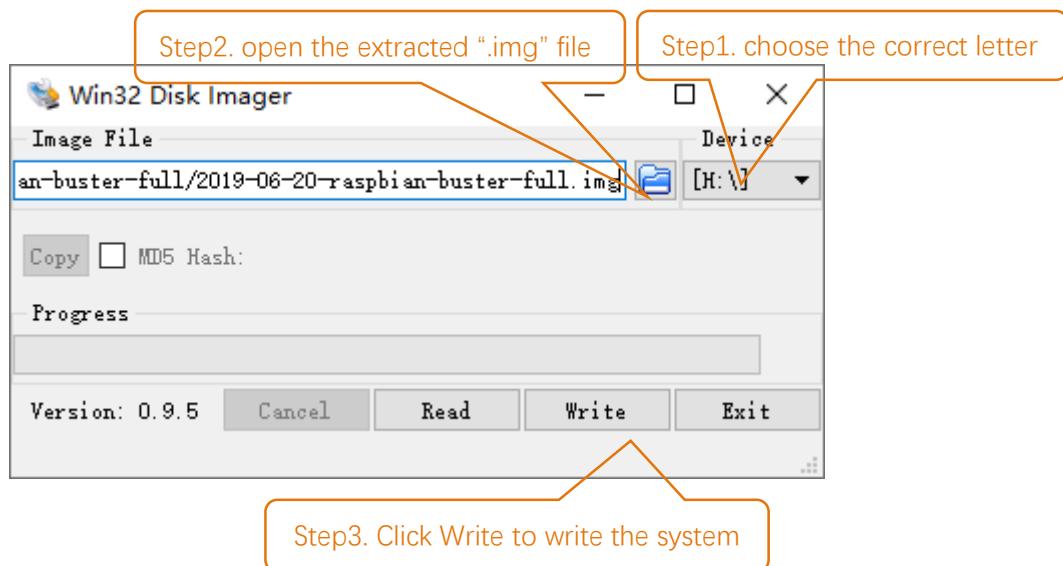
<https://www.raspberrypi.org/downloads/raspbian/>



After download, extract file with suffix (.img). Preparation is ready to start making the system.

Write System to Micro SD Card

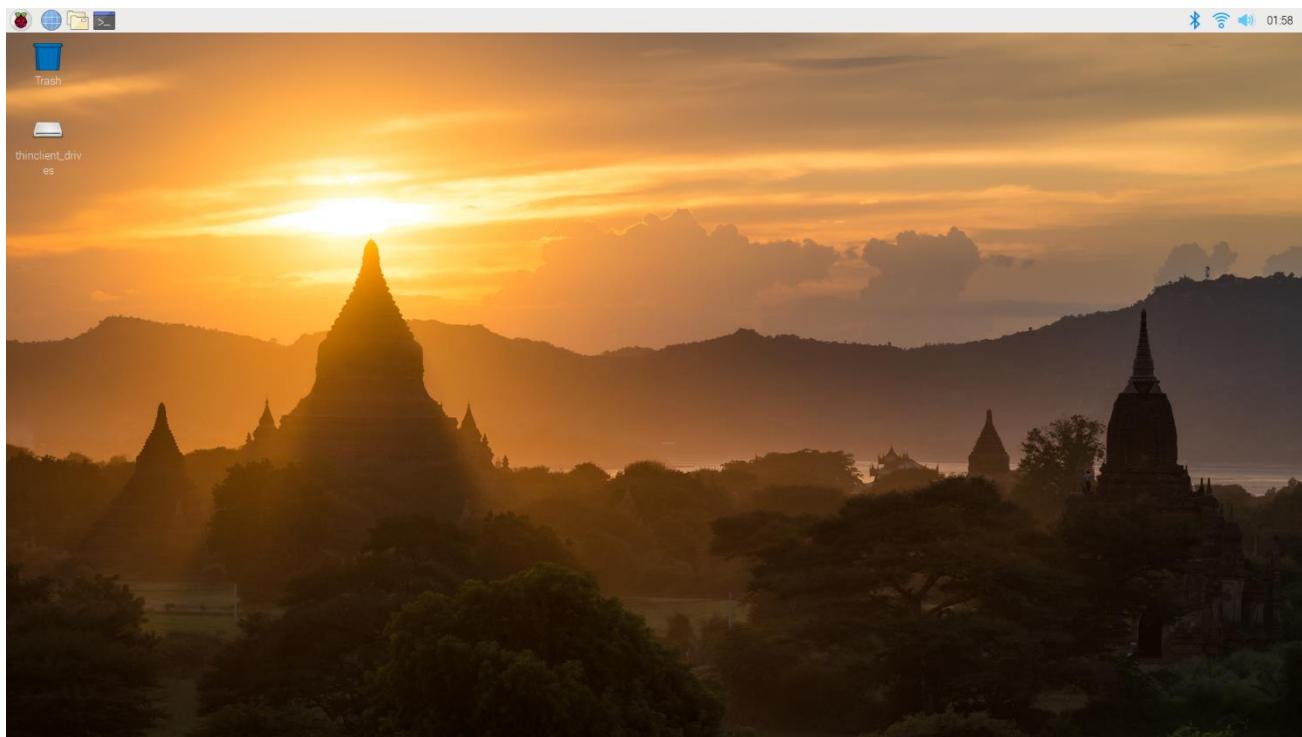
First, put your Micro SD card into card reader and connect it to USB port of PC. Then open Win32 disk imager, choose the correct letter of your Micro SD Card (here is "H"), open the extracted ".img" file and then click the "Write".



Start Raspberry Pi

If you don't have a spare monitor, please jumper 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 starts initially. 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.



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

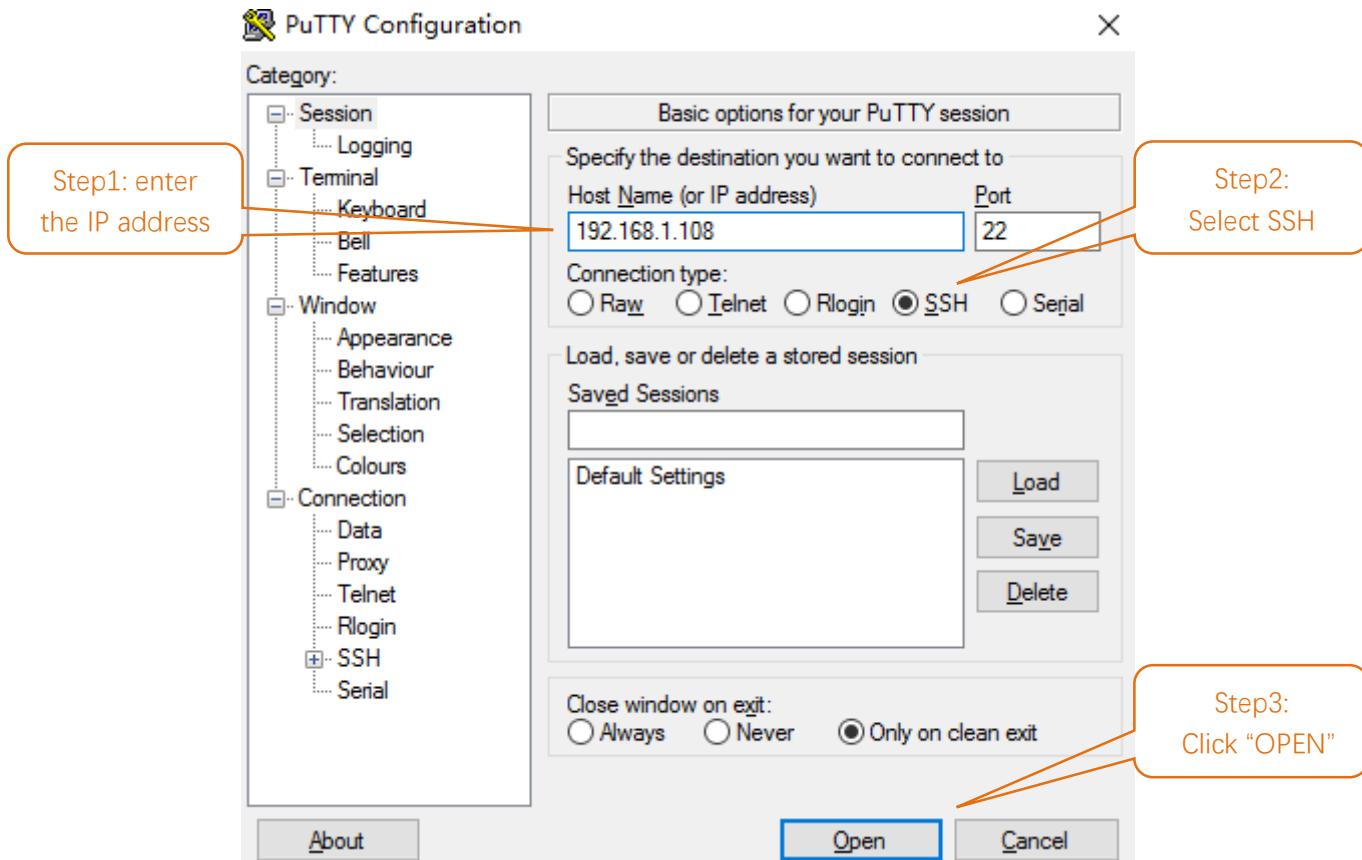
Under previous Raspbian system, SSH is opened by default. Under the latest version of Raspbian system, it is closed by default. So you need to open it first.

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, to ensure 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 starting RPi. Later, enter control terminal of the router to inquiry IP address named "raspberry pi". For example, I have inquired to 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".

PuTTY Security Alert

WARNING - POTENTIAL SECURITY BREACH!

The server's host key does not match the one PuTTY has cached in the registry. This means that either the server administrator has changed the host key, or you have actually connected to another computer pretending to be the server.

The new rsa2 key fingerprint is:
`ssh-rsa 2048 7a:e1:50:ba:dc:01:87:1b:a5:f9:d2:d4:12:d6:fe:ab`

If you were expecting this change and trust the new key, hit Yes to update PuTTY's cache and continue connecting.

If you want to carry on connecting but without updating the cache, hit No.

If you want to abandon the connection completely, hit Cancel. Hitting Cancel is the ONLY guaranteed safe choice.



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 output, press “Enter” to confirm.

```
PutTY (inactive)
login as:
```

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

```
pi@raspberrypi: ~
login as: pi
pi@192.168.1.108's password:

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

Debian GNU/Linux comes with ABSOLUTELY NO WARRANTY, to the extent
permitted by applicable law.
Last login: Tue May 10 23:51:04 2016
pi@raspberrypi:~ $
```

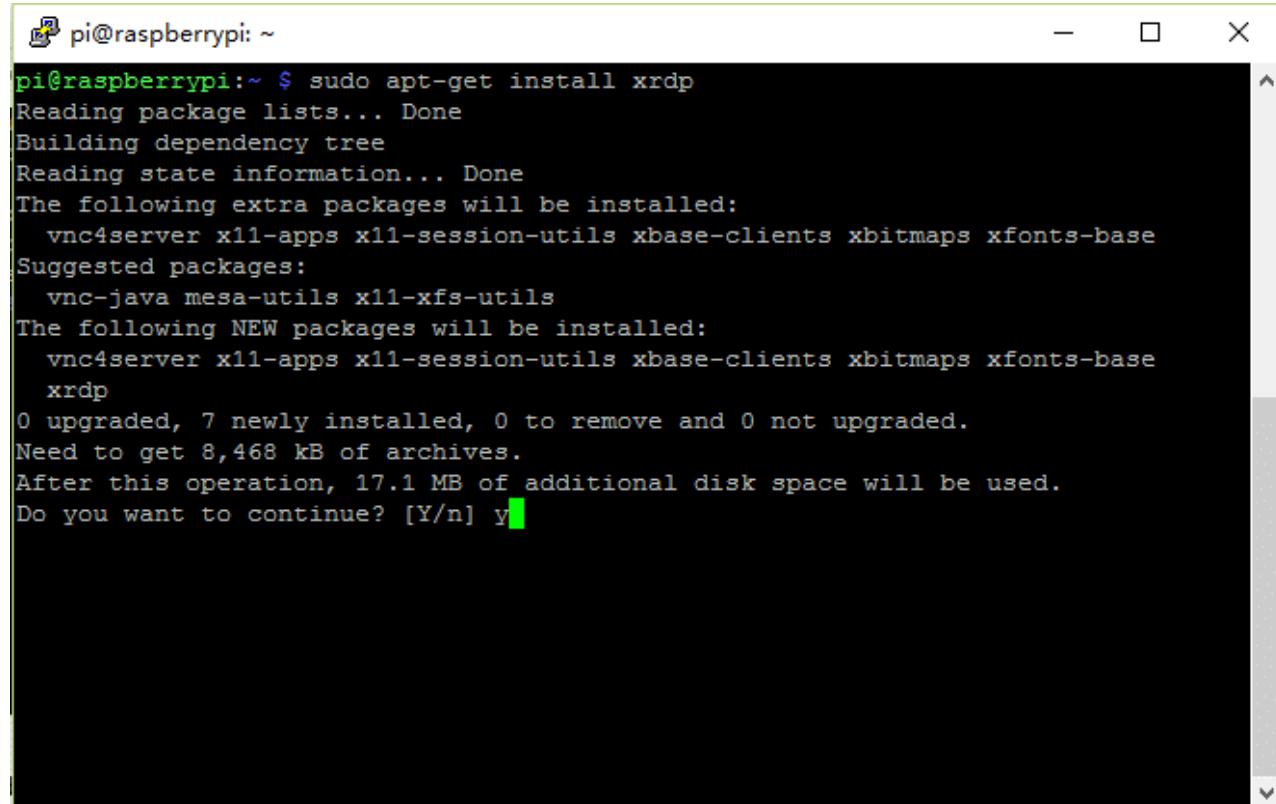
Remote Desktop Connection & xrdp

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 following command, then press enter to confirm:

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

Later, the installation starts.



A screenshot of a terminal window titled "pi@raspberrypi: ~". The window shows the output of the command "sudo apt-get install xrdp". The text in the terminal includes package lists, dependency building, state information, extra packages to be installed (vnc4server, x11-apps, x11-session-utils, xbase-clients, xbitmaps, xfonts-base), suggested packages (vnc-java, mesa-utils, x11-xfs-utils), new packages to be installed (vnc4server, x11-apps, x11-session-utils, xbase-clients, xbitmaps, xfonts-base, xrdp), upgrade counts, archive sizes, disk space usage, and a prompt asking if the user wants to continue with "y".

```
pi@raspberrypi:~ $ sudo apt-get install xrdp
Reading package lists... Done
Building dependency tree
Reading state information... Done
The following extra packages will be installed:
  vnc4server x11-apps x11-session-utils xbase-clients xbitmaps xfonts-base
Suggested packages:
  vnc-java mesa-utils x11-xfs-utils
The following NEW packages will be installed:
  vnc4server x11-apps x11-session-utils xbase-clients xbitmaps xfonts-base
  xrdp
0 upgraded, 7 newly installed, 0 to remove and 0 not upgraded.
Need to get 8,468 kB of archives.
After this operation, 17.1 MB of additional disk space will be used.
Do you want to continue? [Y/n] y
```

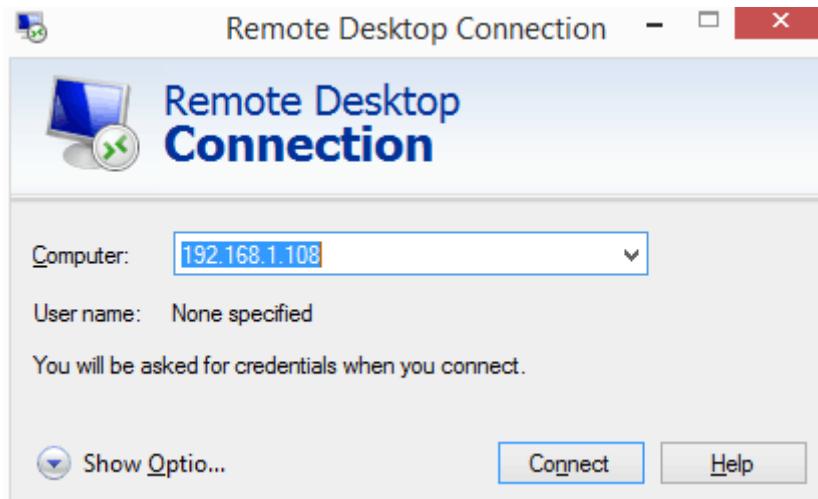
Enter "Y", press key "Enter" to confirm.

After the installation is completed, you can use Windows remote desktop applications to login to your RPi.

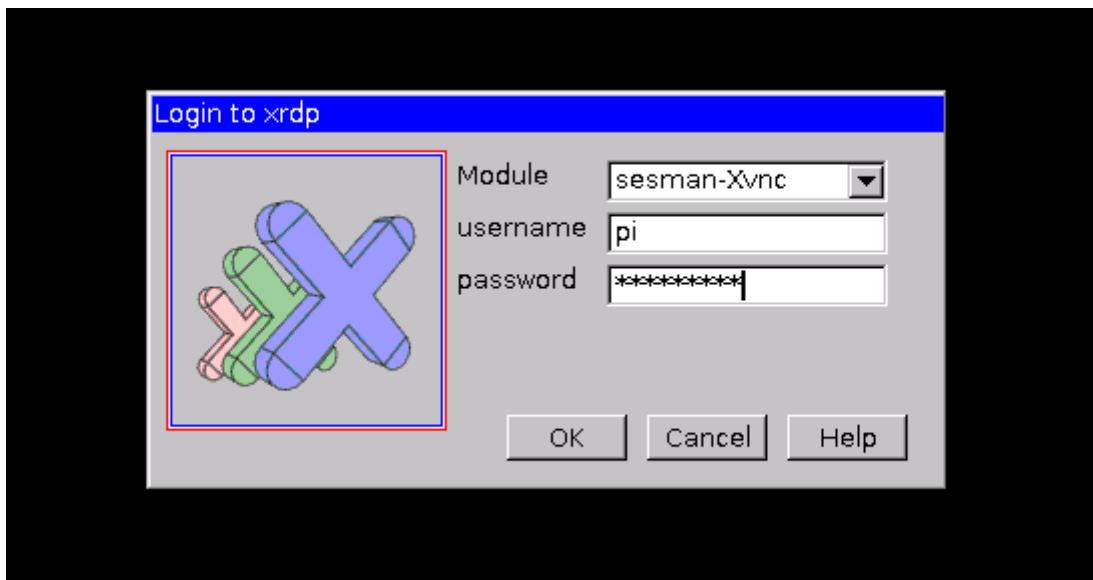


Login to Windows remote desktop

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.

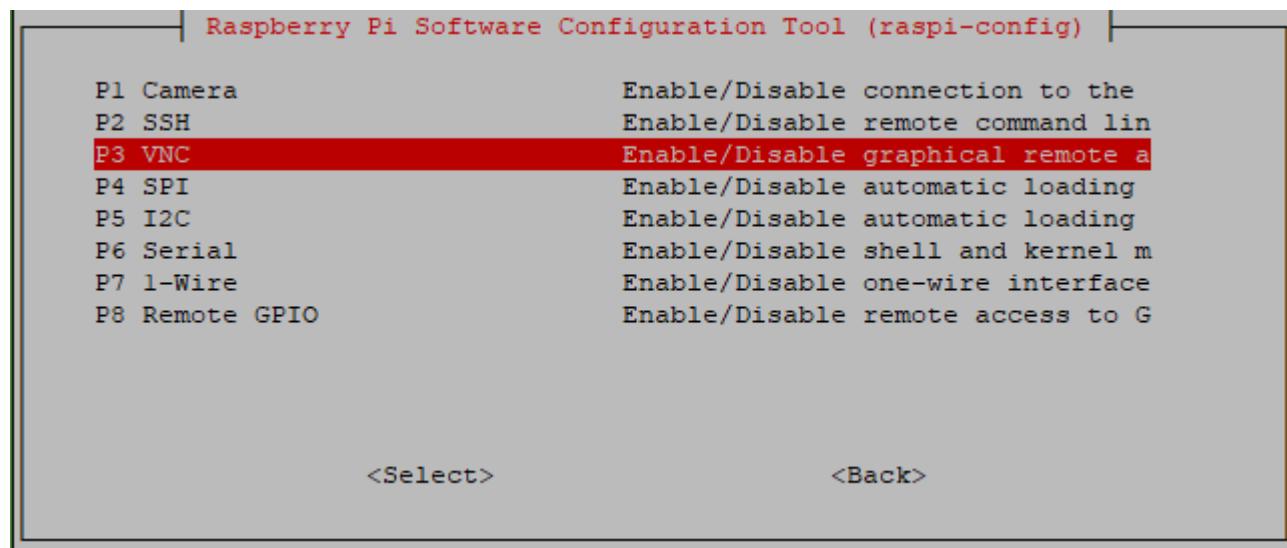
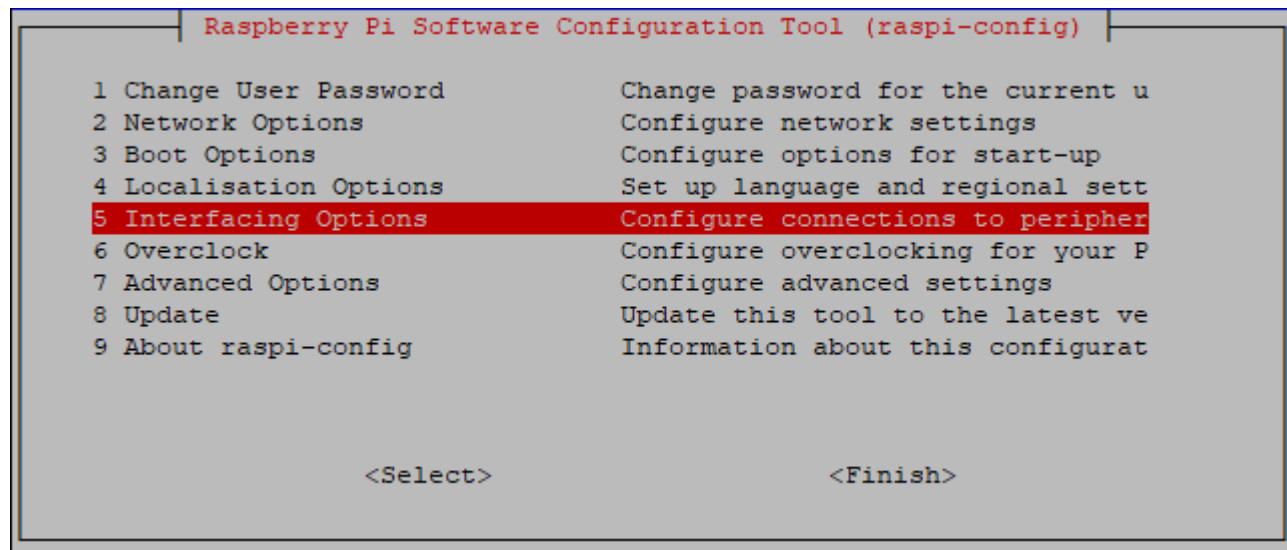


Here, you have successfully used the remote desktop login to RPi.

VNC Viewer & VNC

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

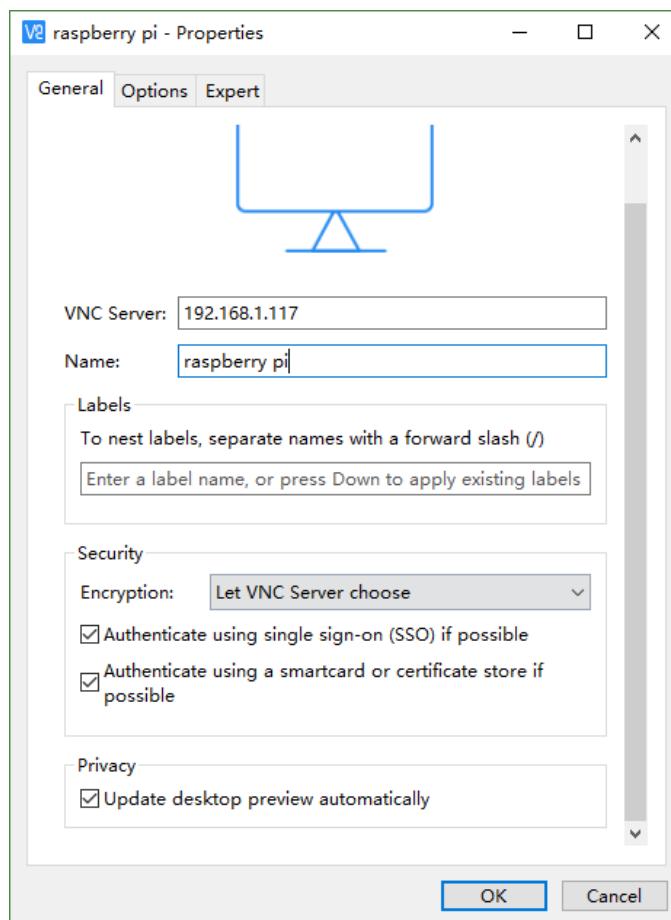
```
sudo raspi-config
```



Then download and install VNC Viewer by click following link:

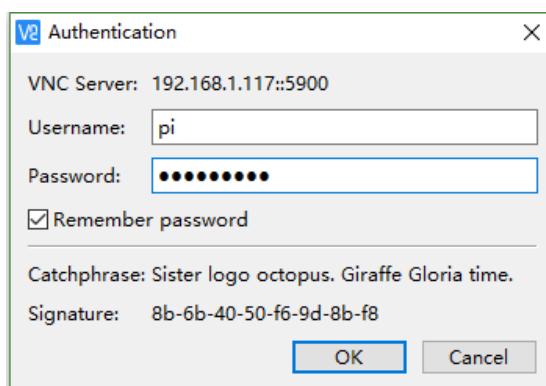
<https://www.realvnc.com/en/connect/download/viewer/windows/>

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.

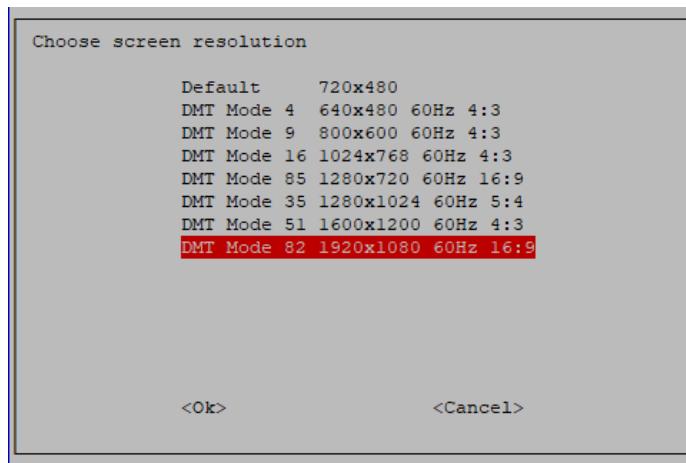


Here, you have logged in to Raspberry Pi successfully by using VNC Viewer

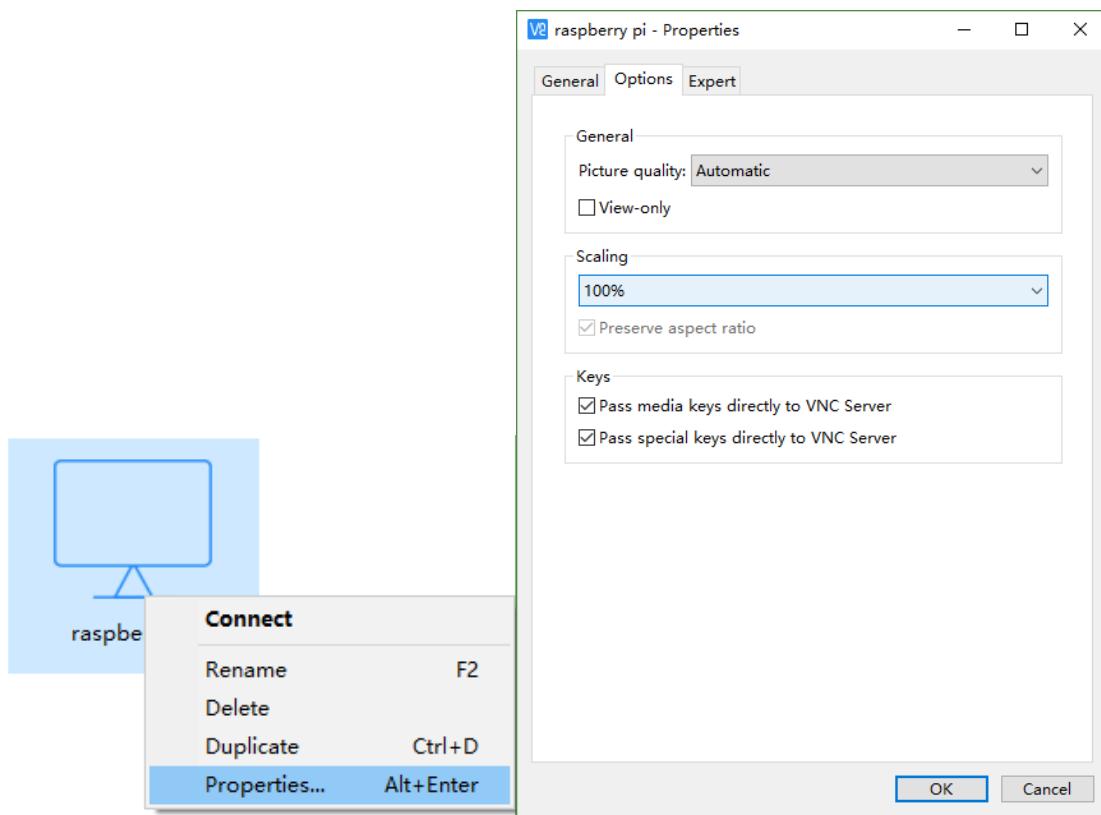
If you think resolution ratio is not OK, you can set a proper resolution ratio on set interface of Raspberry Pi.

`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.



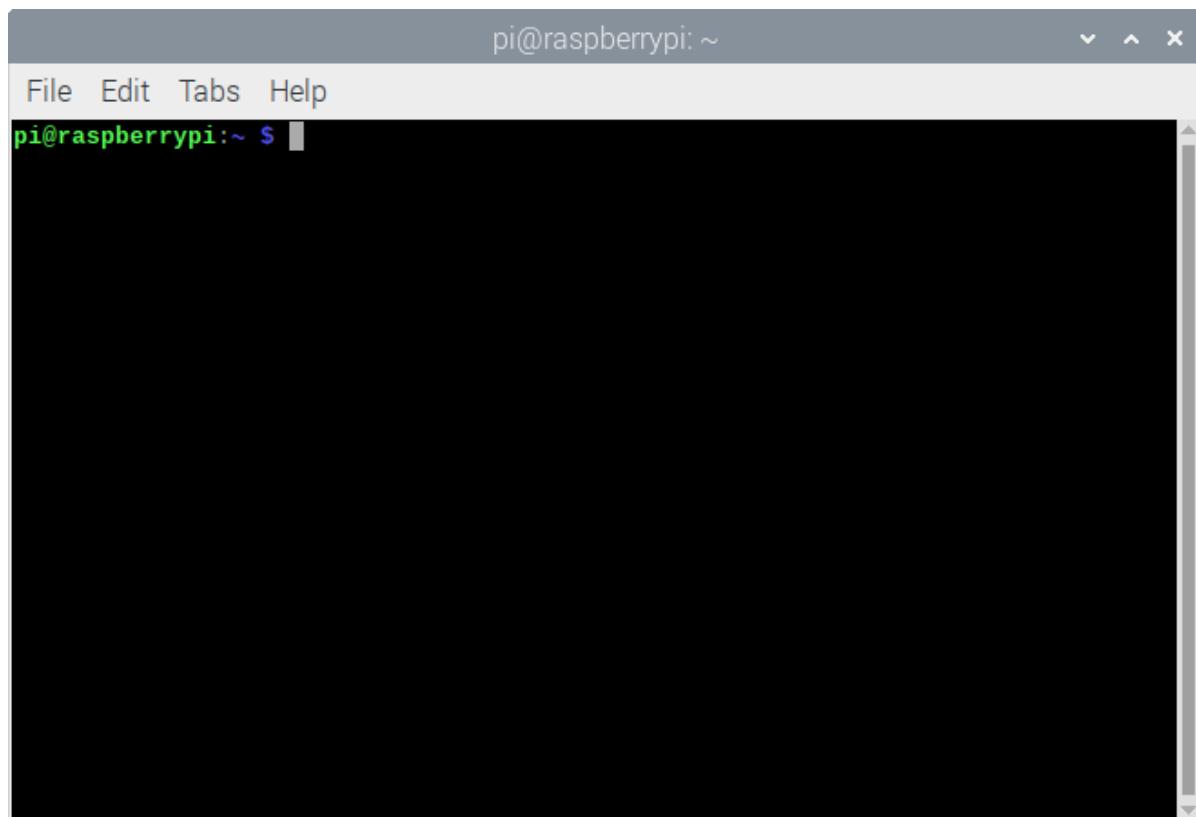
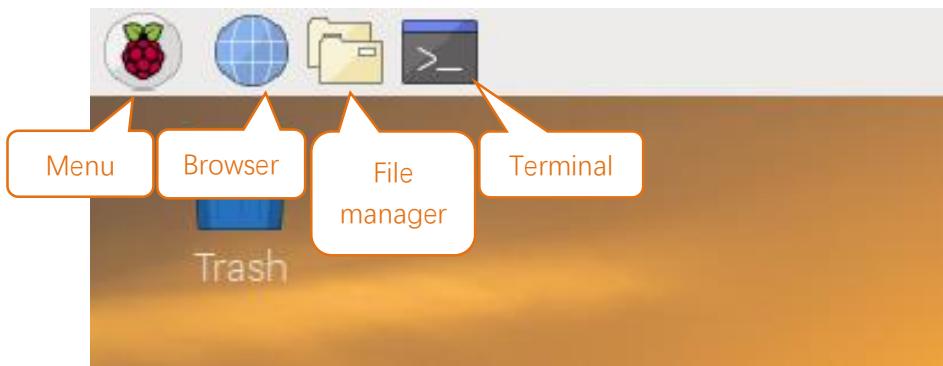
Chapter 0 Preparation

Why is “Chapter 0”? Because in the program code, all the counts are starting from 0. We choose to follow this rule (just a joke). 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 introduce some frequently-used Linux commands and usage methods.

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



And the terminal is case sensitive.

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

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

Music
Pictures
Public
Templates
thinclient_drives
Videos
```

"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 wrong working path will cause error messages. And the commands can not continue to be executed.

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_RFID_Starter_Kit_for_Raspberry_Pi
```

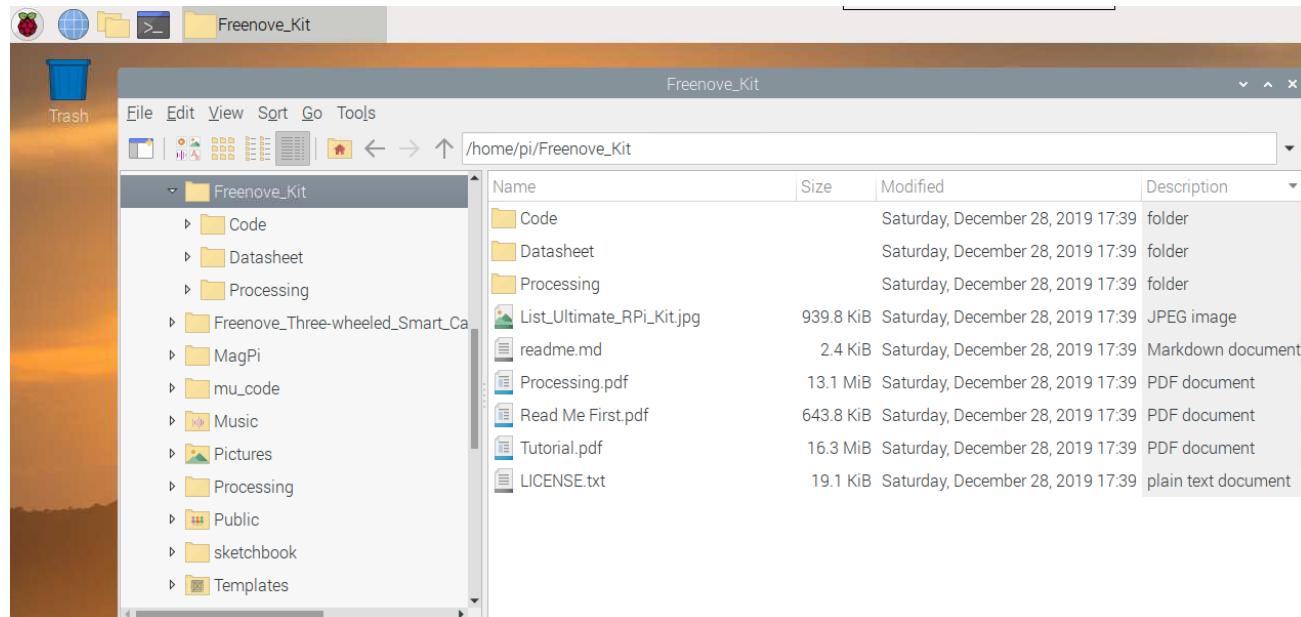
(There is no need for password. If you get some errors, please check if your commands is correct.)

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

The folder name seems a little too long. Here we rename it by following command.

```
mv Freenove_RFID_Starter_Kit_for_Raspberry_Pi/ Freenove_Kit/
```

Among them, "Freenove_Kit" represents the new folder name.



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

Python2 & Python3

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 recommend**. If you want to use python2, please make sure your Python version is above 2.7. Python2 and Python3 is not fully compatible. However, Python2.6 and Python2.7 are transition versions to python3. So you can also use Python2.6 and 2.7 to execute some Python3 code.

You can type python2 and python3 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 set Python3 as default Python actuators. please follow the 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 actuators, 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.
>>> 
```

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

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. First we will show how use vi and nano editor:

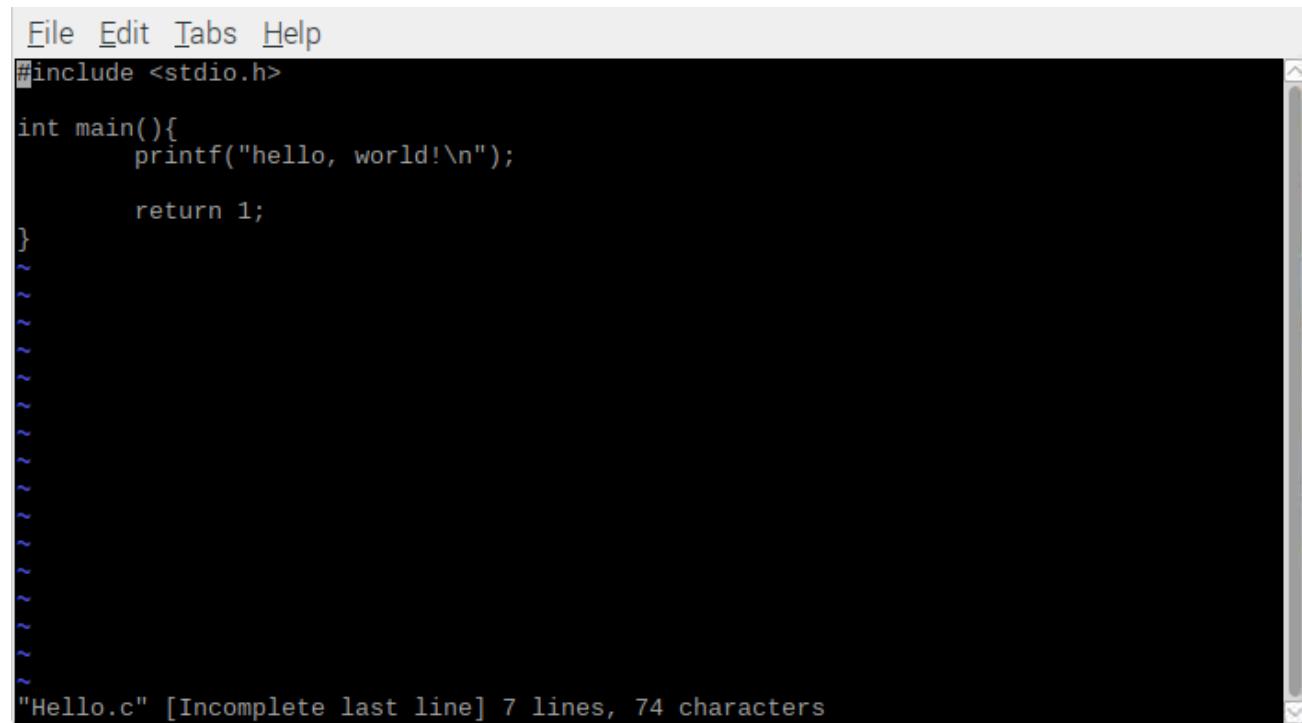
First, use cd command to enter the sample code folder.

```
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:



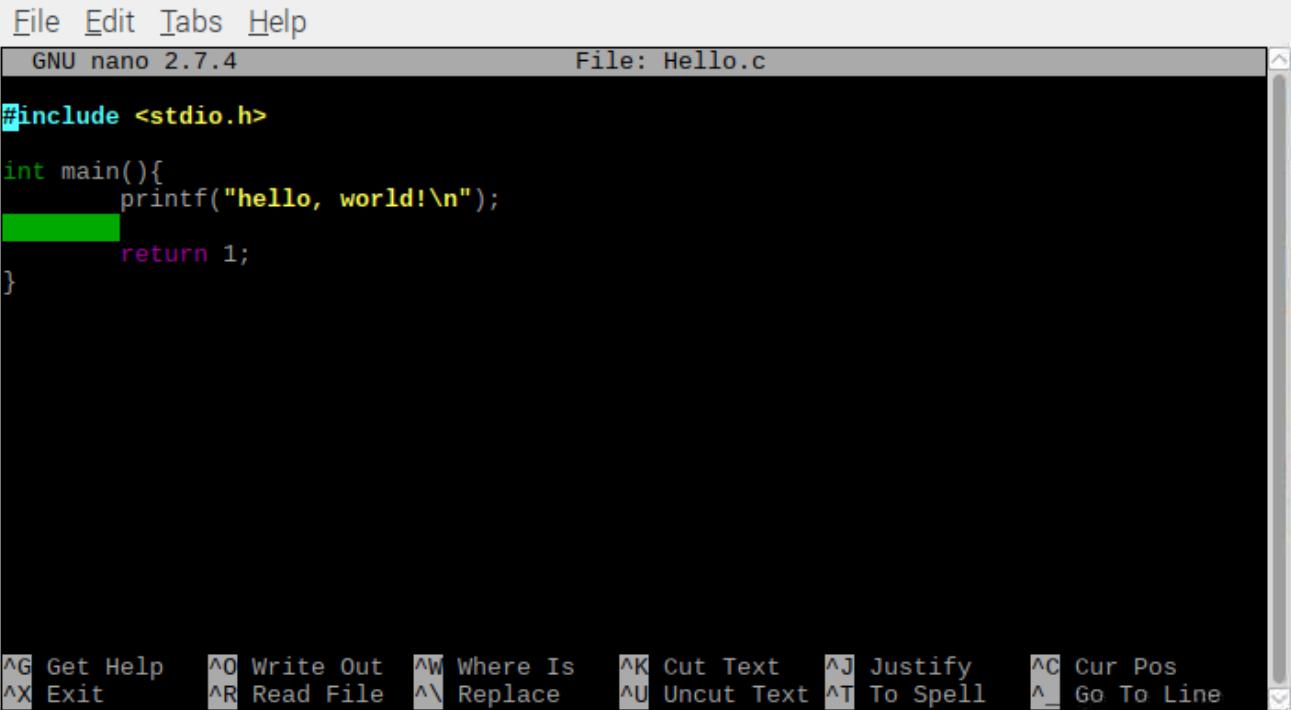
The screenshot shows the vi editor interface with a black background. At the top, there is a menu bar with options: File, Edit, Tabs, and Help. Below the menu, the code for "Hello.c" is displayed. The code consists of a single main function that prints "hello, world!\n" and returns 1. The code is written in C. At the bottom of the editor window, the status bar displays the message: "'Hello.c' [Incomplete last line] 7 lines, 74 characters".

nano

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

```
nano Hello.c
```

As is shown below:



The screenshot shows the nano text editor interface. The menu bar includes File, Edit, Tabs, and Help. The title bar indicates "GNU nano 2.7.4" and "File: Hello.c". The main editing area contains the following C code:

```
#include <stdio.h>
int main(){
    printf("Hello, world!\n");
    return 1;
}
```

The bottom status bar displays keyboard shortcuts for various functions like Get Help (^G), Write Out (^O), Where Is (^W), Cut Text (^K), Justify (^J), Cur Pos (^C), Exit (^X), Read File (^R), Replace (^V), Uncut Text (^U), To Spell (^T), and Go To Line (^L).

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.

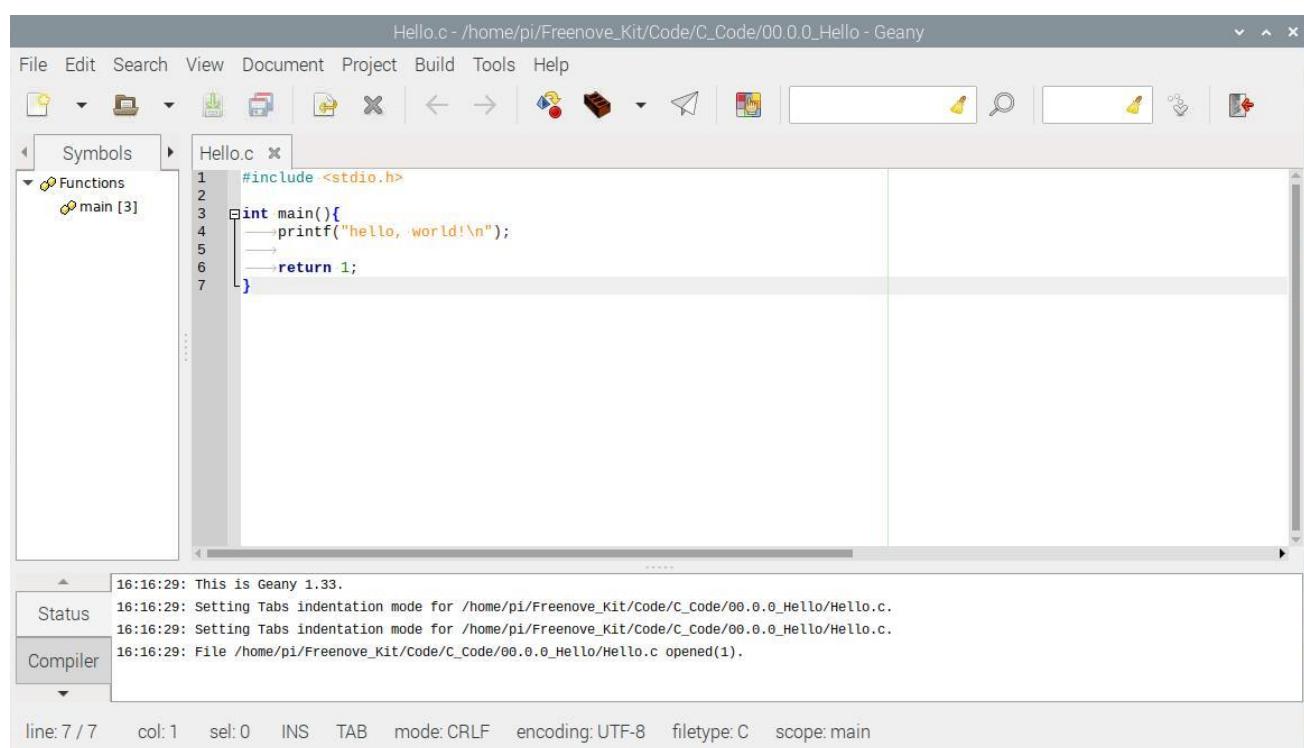
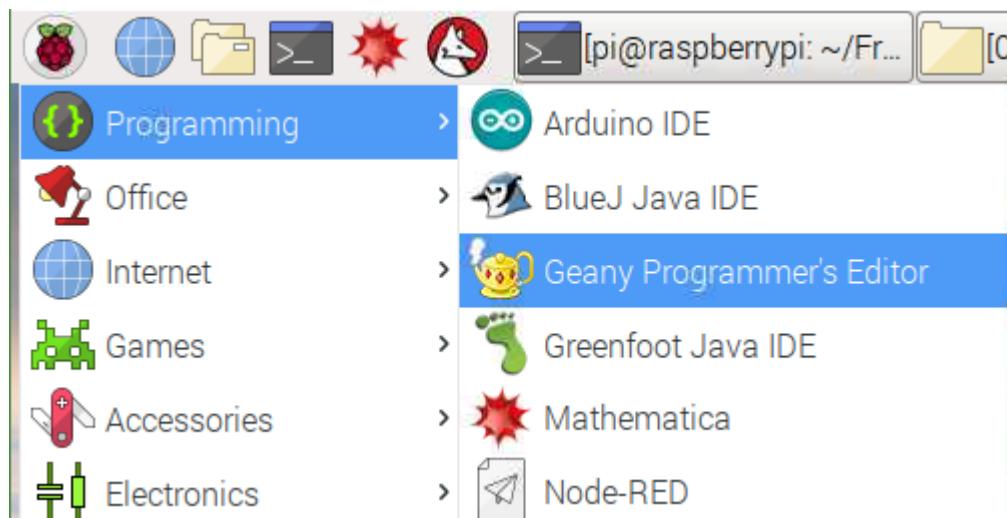
```
pi@raspberrypi:~/Freenove_Kit/Code/C_Code/00.0.0_Hello $ gcc Hello.c -o Hello
pi@raspberrypi:~/Freenove_Kit/Code/C_Code/00.0.0_Hello $ sudo ./Hello
Hello, world!
```

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

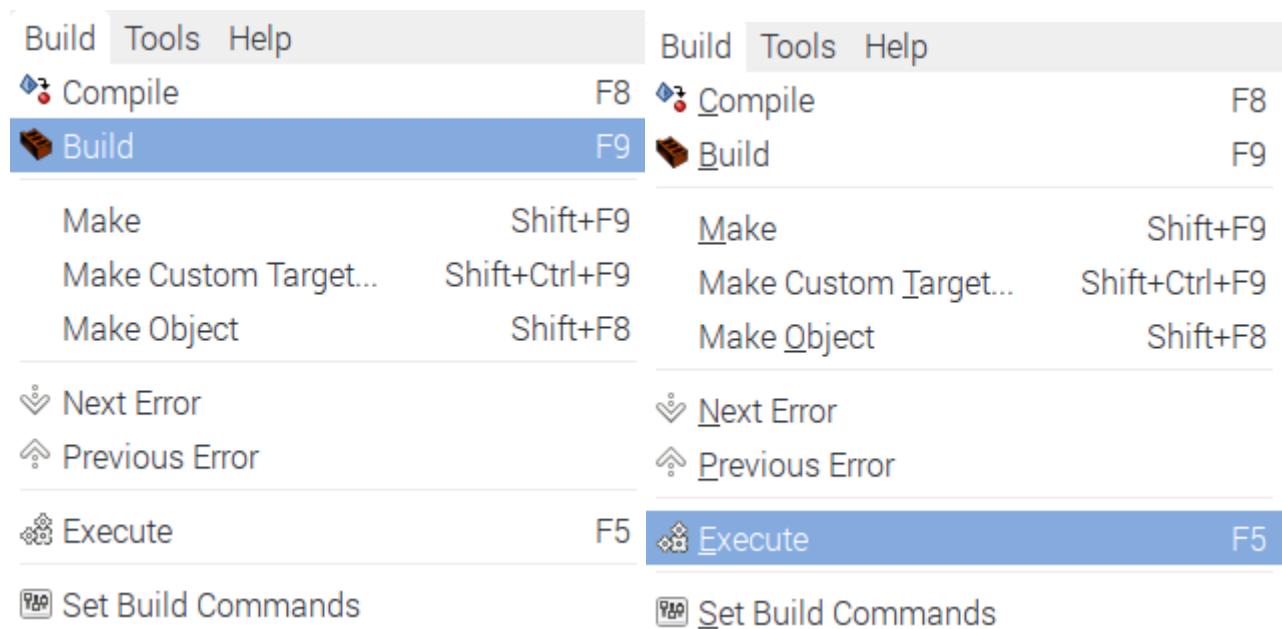
Or find and open Geany directly in the desktop main menu, and then click **File→Open** to open the "Hello.c", Or drag "Hello.c" to Geany directly.



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



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



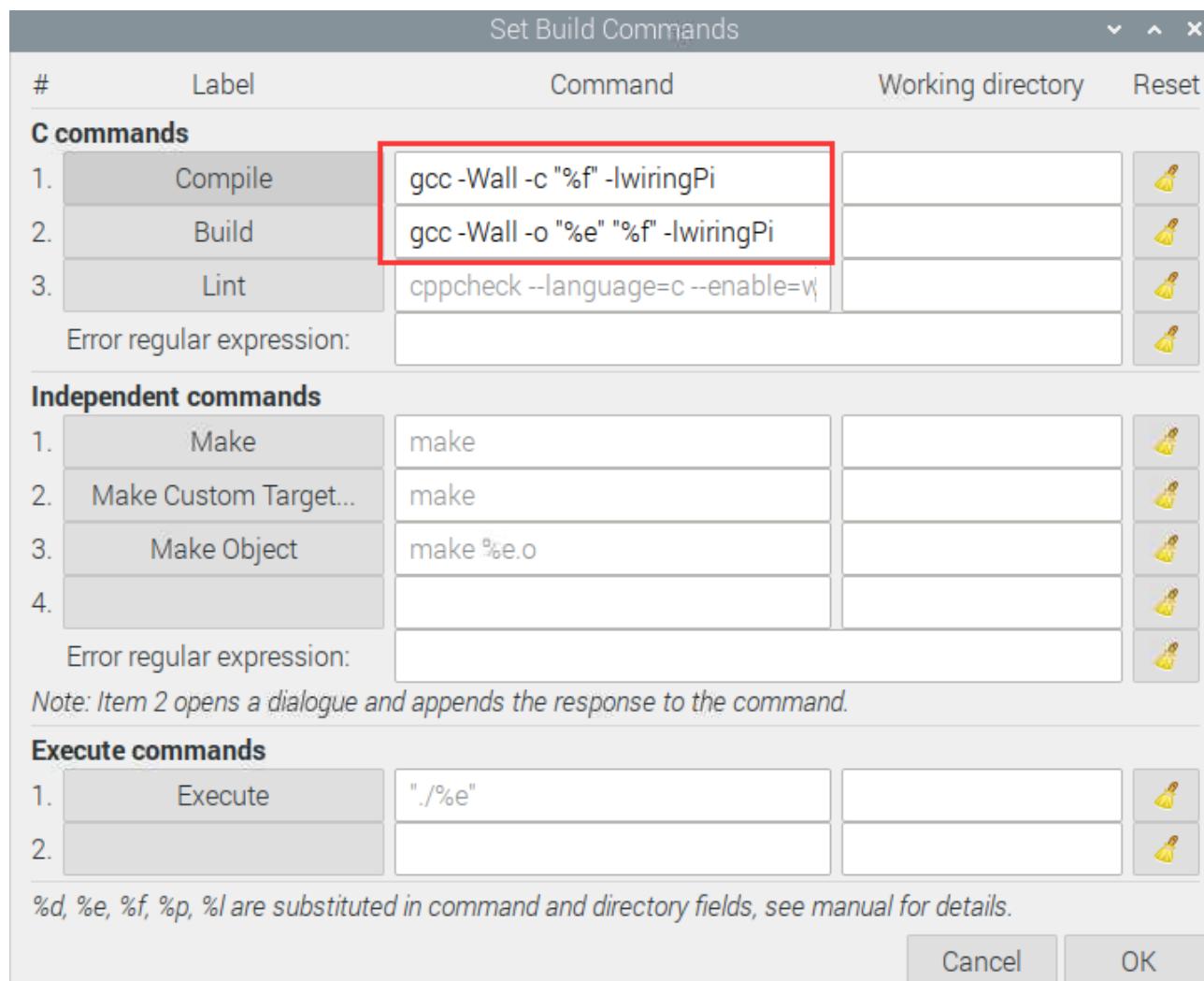
After the execution, there will be a terminal printing out the characters "Hello, World!", as shown below:

```
sh
File Edit Tabs Help
hello, world!

-----
(program exited with code: 1)
Press return to continue
```

A screenshot of a terminal window titled 'sh'. The window has a blue header bar with the title 'sh' and standard window control buttons (-, □, ×). The main area is black with white text. It displays the output of a program: 'hello, world!' followed by a dashed line, '(program exited with code: 1)', and the instruction 'Press return to continue'. A vertical scroll bar is visible on the right side of the terminal window.

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 are many other good code editors, and you can choose any one you like. In later projects, about the entry path and the compiler execute commands, we will operate the contents in the terminal as examples. We won't emphasize the code editing process, but will explain the contents of the code in details.



GPIO

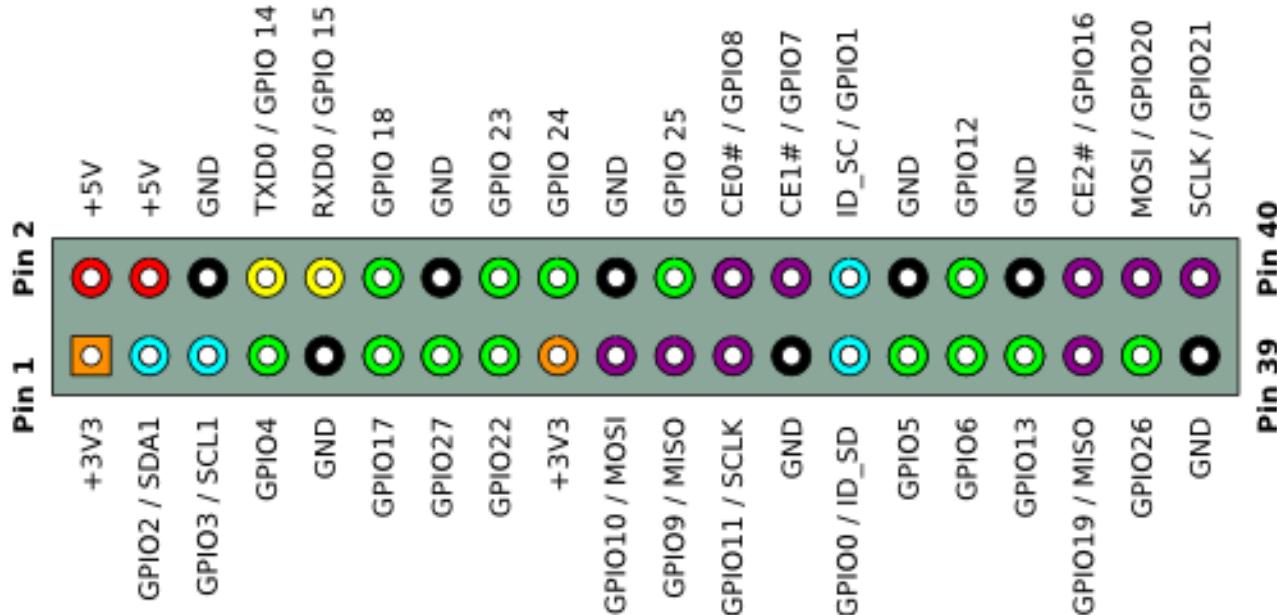
GPIO: General purpose input/output. We will introduce the specific feature of the pins on the Raspberry Pi and what you can do with them. You can use them for all sorts of purposes. Most of them can be used as either inputs or outputs, depending on your program.

When programming the GPIO pins there are 3 different ways to refer to them: GPIO numbering, physical numbering, WiringPi GPIO Numbering.

BCM GPIO Numbering

Raspberry Pi CPU use BCM2835/BCM2836/BCM2837 of Broadcom. GPIO pin number is set by chip manufacturer. These are the GPIO pins as that 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.

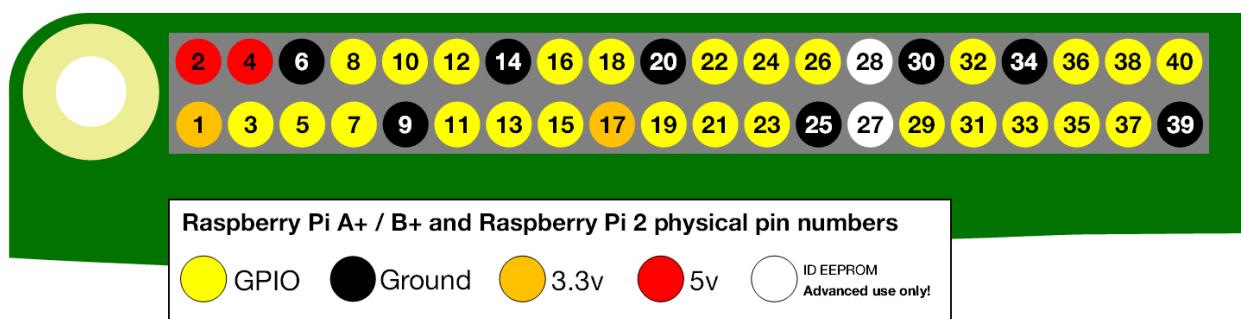
Each pin is defined as below:



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). This is 'physical numbering', as shown below:



WiringPi GPIO Numbering

Different from the previous mentioned two kinds of GPIO serial numbers, RPi GPIO serial number of the WiringPi was renumbered. Here we have three kinds of GPIO number mode: based on the number of BCM chip, based on the physical sequence number and based on wiringPi. The correspondence between these three GPIO numbers is shown below:

wiringPi Pin	BCM GPIO	Name	Header	Name	BCM GPIO	wiringPi Pin	
—	—	3.3v	1 2	5v	—	—	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/>)

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

```
gpio readall
```

Pi 3 Model B											
BCM	wPi	Name	Mode	V	Physical	V	Mode	Name	wPi	BCM	
		3.3v			1	2		5v			
2	8	SDA.1	ALTO	1	3	4		5V			
3	9	SCL.1	ALTO	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	ALTO	0	19	20		0v			
9	13	MISO	ALTO	0	21	22	0	IN	GPIO. 6	6	25
11	14	SCLK	ALTO	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

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, resulting in some commands can not be used properly. But it won't affect the next project. 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.

```
pi@raspberrypi:~ $ gpio -v
gpio version: 2.52
Copyright (c) 2012-2018 Gordon Henderson
This is free software with ABSOLUTELY NO WARRANTY.
For details type: gpio -warranty

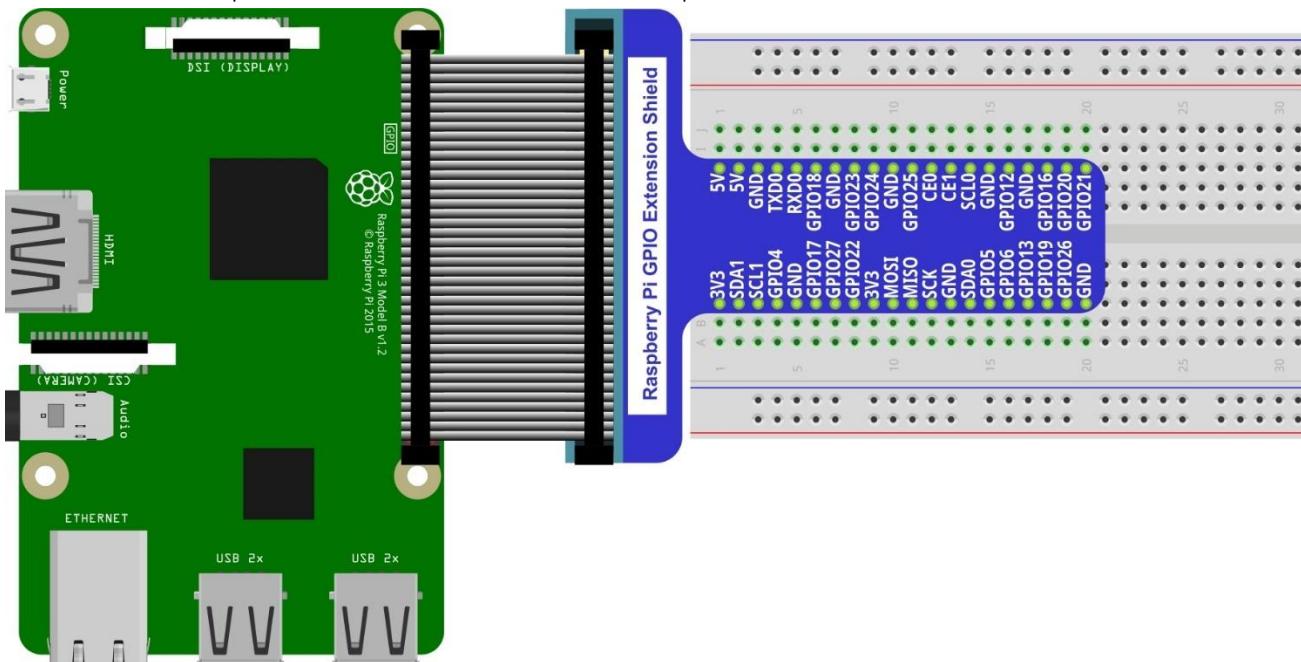
Raspberry Pi Details:
  Type: Pi 4B, Revision: 01, Memory: 1024MB, Maker: Sony
  * Device tree is enabled.
  *--> Raspberry Pi 4 Model B Rev 1.1
  * This Raspberry Pi supports user-level GPIO access.

pi@raspberrypi:~ $ gpio readall
+-----+-----+-----+-----+-----+-----+-----+-----+-----+
| 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 | IN   | TxD | 15  | 14
|      |      | 0v       |      |   |    9 |   10 | IN   | 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   | IN   | 0 |   19 |   20 |      | 0v  |      |
| 9   | 13  | MISO   | IN   | 0 |   21 |   22 | 0    | IN  | GPIO. 6 | 6  | 25
| 11  | 14  | SCLK   | IN   | 0 |   23 |   24 | 1    | IN  | CE0  | 10 | 8
|      |      | 0v       |      |   |   25 |   26 | 1    | IN  | 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 |
+-----+-----+-----+-----+-----+-----+-----+-----+-----+
```

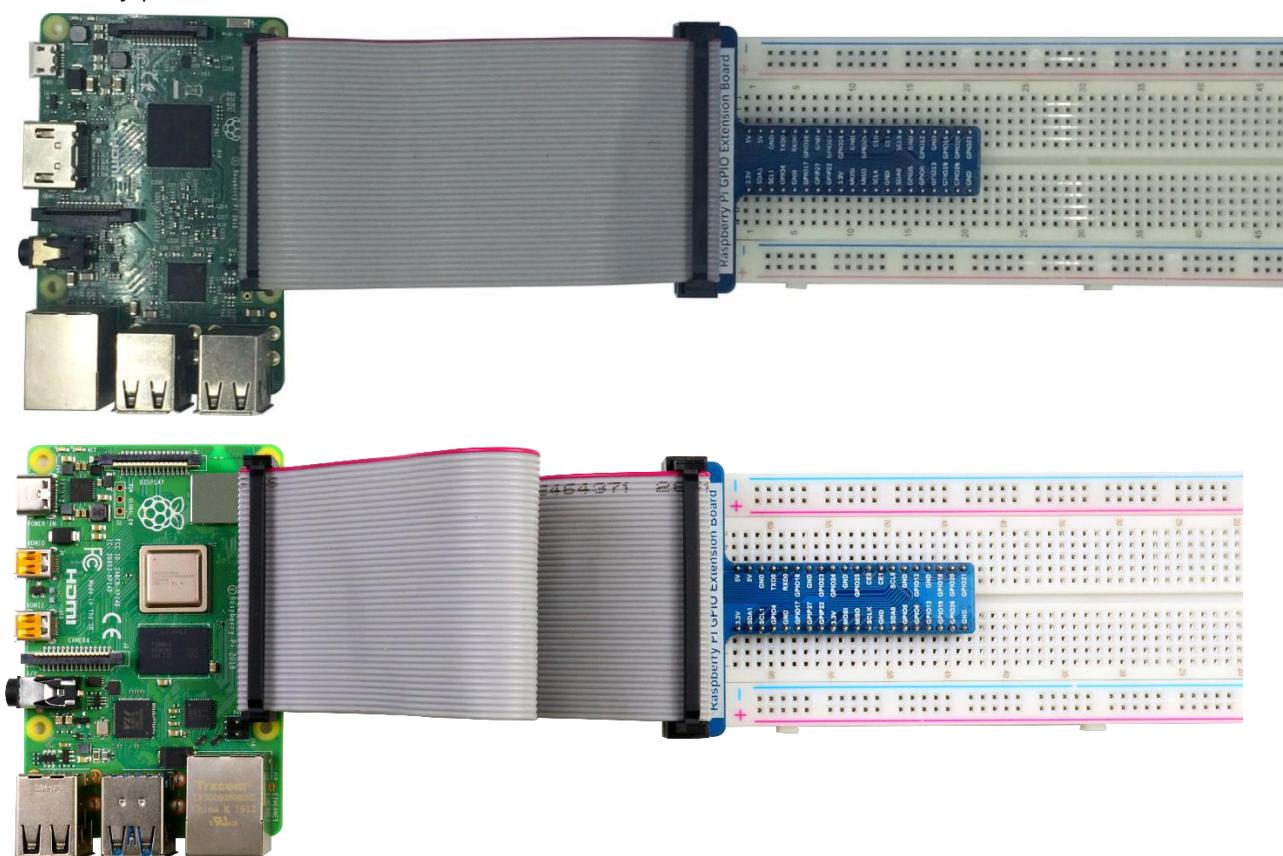
For more details about wiringPi, please refer to <http://wiringpi.com/>.

GPIO Extension Board

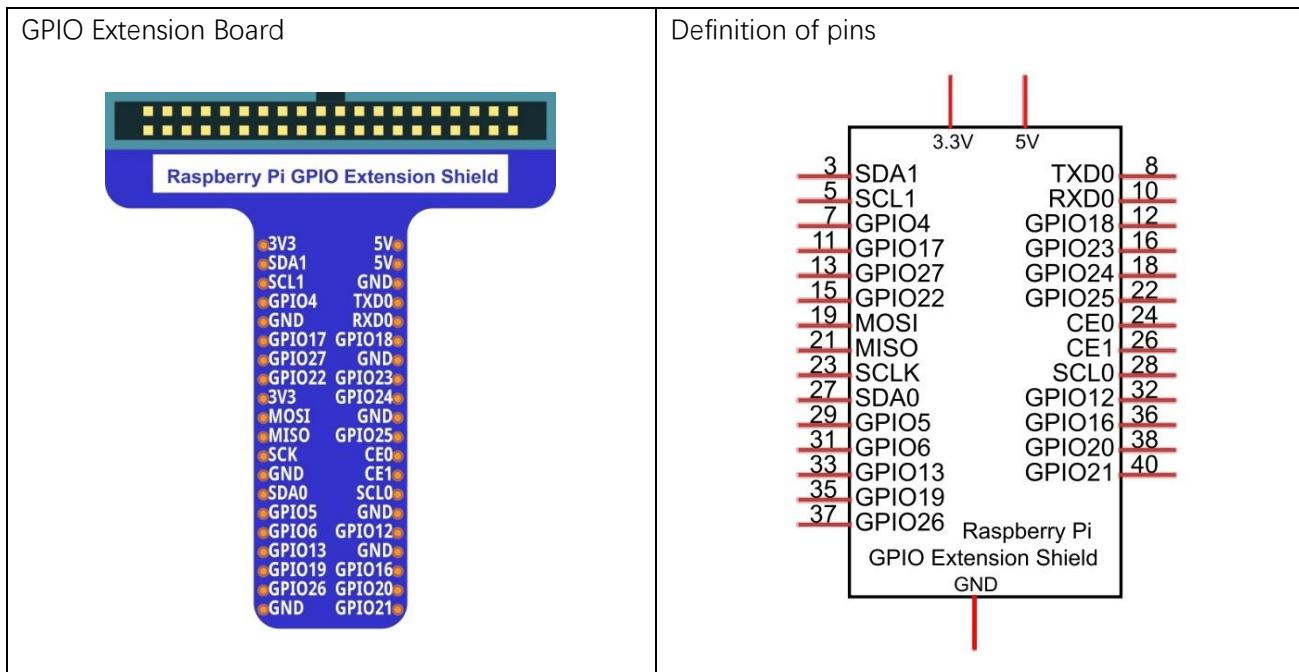
When we use RPi to do the project, we had better use GPIO, which is more convenient to extend all IO ports of RPi to the bread board directly. The GPIO sequence on Extension Board is identical to the GPIO sequence of RPi. Since the GPIO of different versions of RPi is different, the corresponding extensions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



Practicality picture of connection:

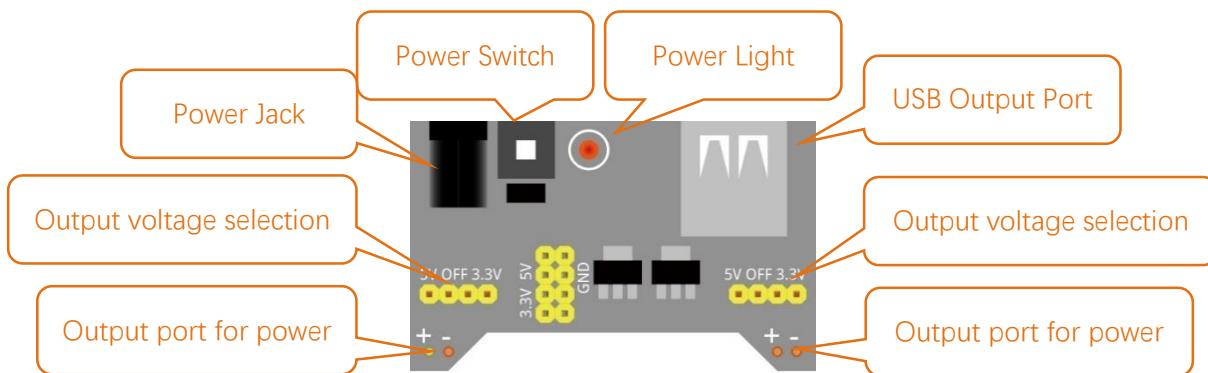


GPIO Extension Board and its schematic are shown below:

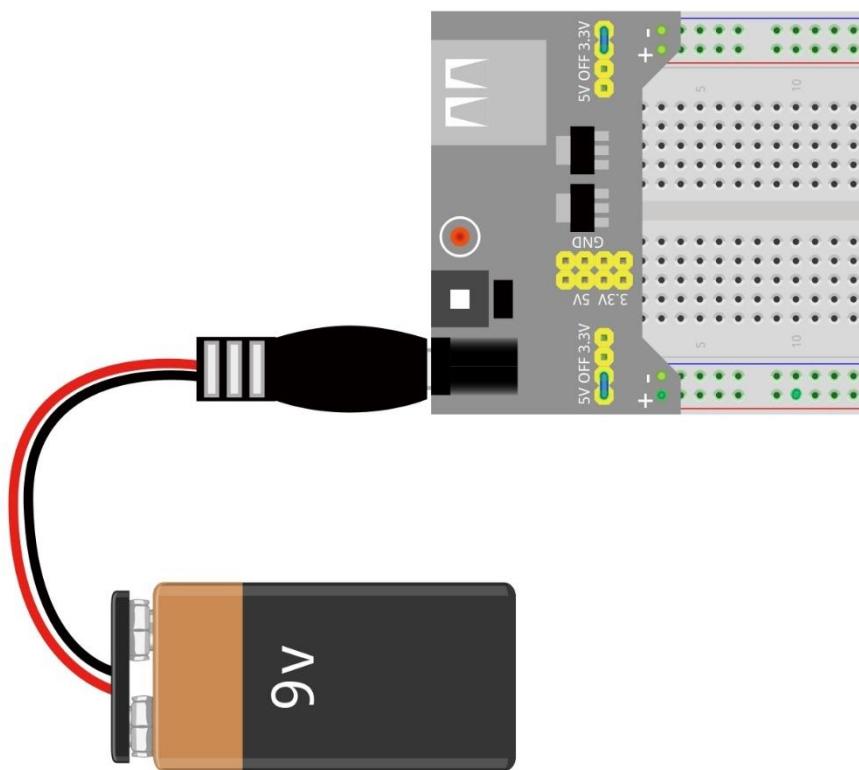


Breadboard Power Module

Breadboard Power Module is an independent board, which can provide independent 5V or 3.3V power for bread board 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 electronic circuit.



Chapter 1 LED

This chapter is the starting point of the journey to explore RPi electronic projects. Let's start with simple "Blink".

Project 1.1 Blink

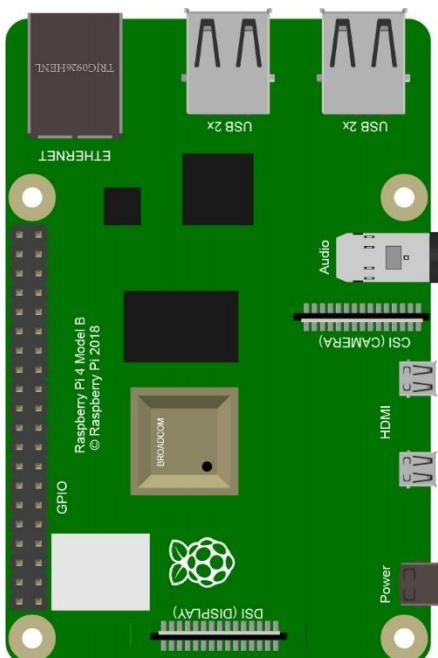
In this project, let's try to use RPi to control LED blinking.

Component List

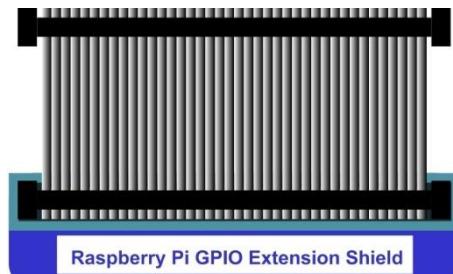
Raspberry Pi (

Recommended: Raspberry Pi 4B / 3B+ / 3B

Compatible: 3A+ / 2B / 1B+ / 1A+ / Zero W / Zero)

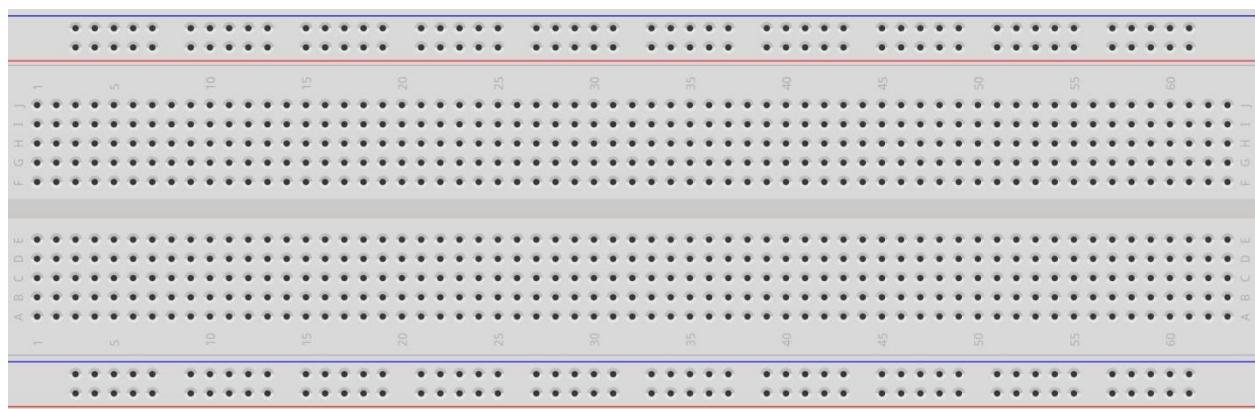


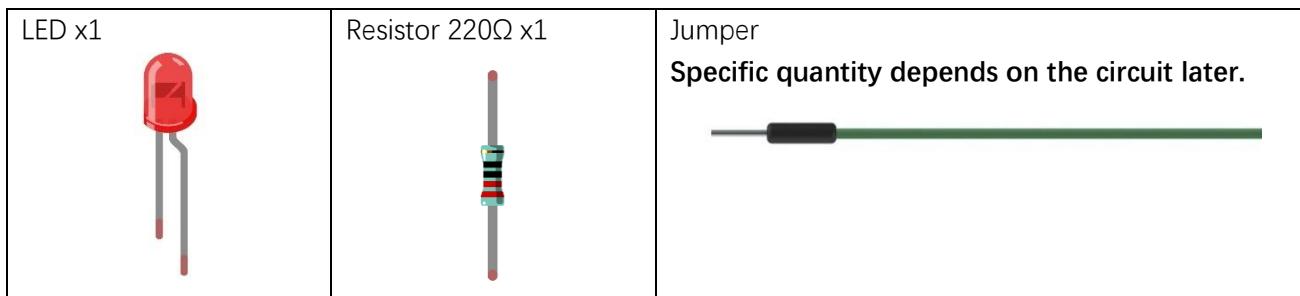
GPIO Extension Board & Wire x1



3V3	5V
SDA1	5V
SCL1	GND
GPIO4	TX0
GND	RX0
GPIO17	GPIO18
GPIO27	GND
GPIO22	GPIO23
3V3	GPIO24
MOSI	GND
MISO	GPIO25
SCK	CE0
GND	CE1
SDAO	SCL0
GPIO5	GND
GPIO6	GPIO12
GPIO13	GND
GPIO19	GPIO16
GPIO26	GPIO20
GND	GPIO21

BreadBoard x1





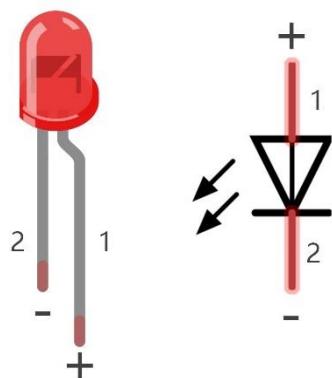
In the components list, 3B GPIO, Extension Shield Raspberry and Breadboard are necessary for each project. They will be listed only in text form later.

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 features 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

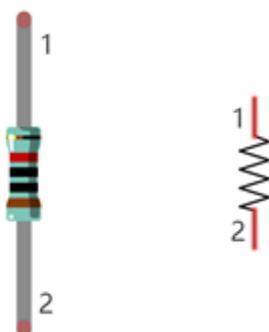
The LED can not be directly connected to power supply, which can damage component. A resistor with certain resistance must be connected in series in the circuit of LED.

Resistor

The unit of resistance(R) is ohm(Ω). $1M\Omega=1000k\Omega$, $1k\Omega=1000\Omega$.

Resistor is an electrical component that limits or regulates the flow of current in an electronic circuit.

The left is the appearance of resistor, and the right is the symbol of resistor represented in circuit.

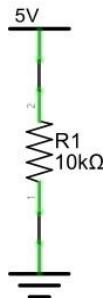


Color rings attached to the resistor is used to indicate its resistance. For more details of resistor color code, please refer to the appendix of this tutorial.



With the same voltage there will be less current with more resistance. And the links among current, voltage and resistance can be expressed by the formula below: $I=U/R$.

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



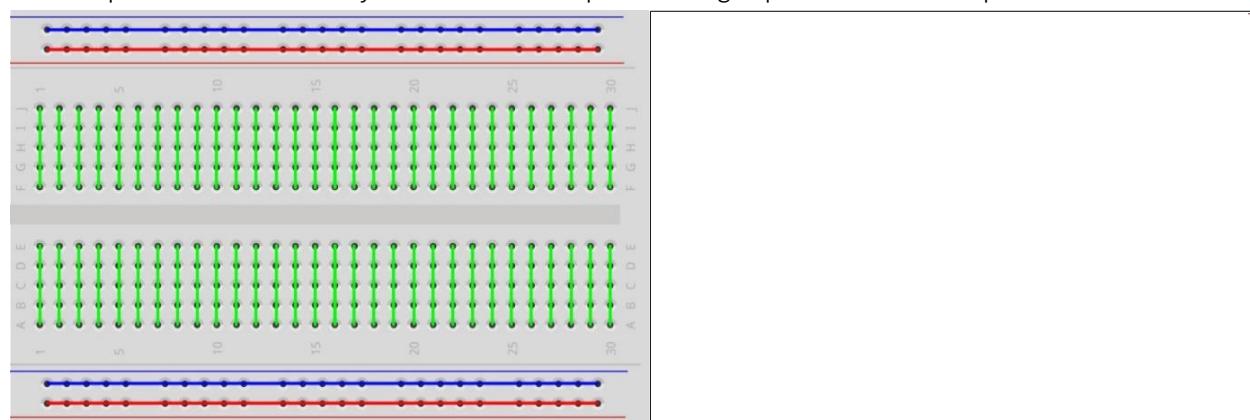
Do not connect the two poles of power supply with low resistance, which will make the current too high to damage electronic components.

And resistor has no poles.

Breadboard

Take a short breadboard as an example to introduce its feature, as below.

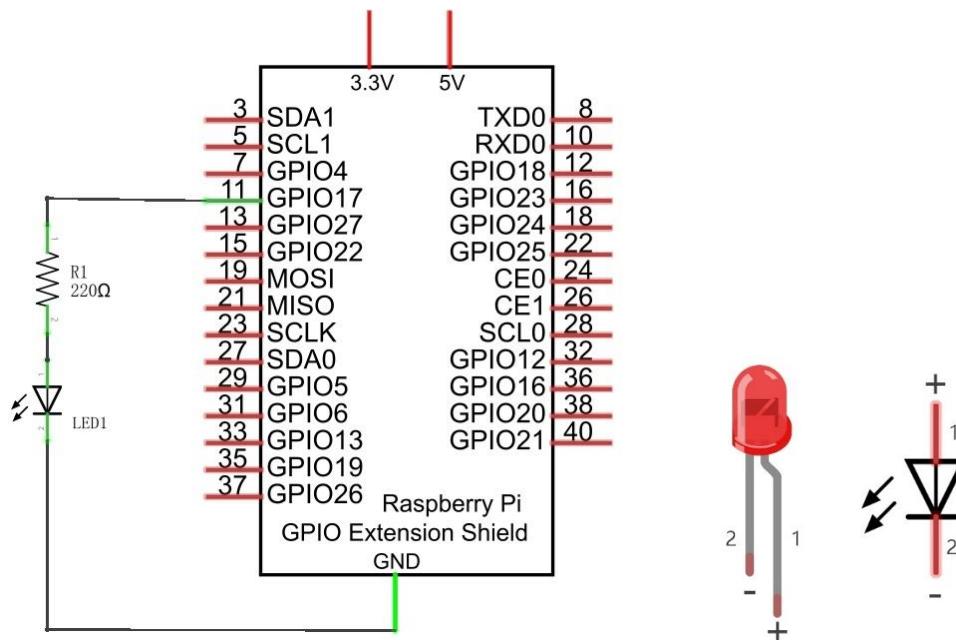
The left picture shows the way of connection of pins. The right picture shows the practical internal structure.



Circuit

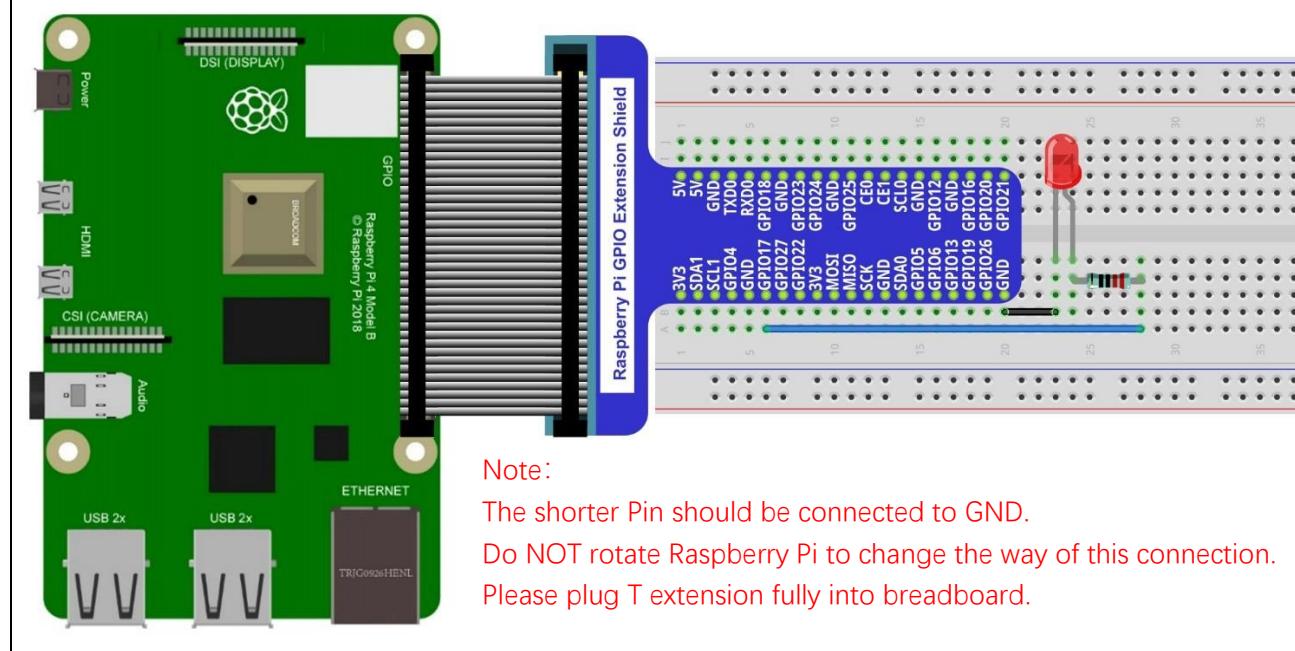
Disconnect RPi from GPIO Extension Shield first. Then build the circuit according to the circuit diagram and the hardware connection diagram. After the circuit is built and confirmed, connect RPi to GPIO Extension Shield. In addition, short circuit (especially 5V and GND, 3.3V and GND) should be avoid,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

Schematic diagram



Hardware connection.

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



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 output high level, LED is turned on. Conversely, when the GPIO17 RPi output low level, LED is turned off. Therefore, we can let GPIO17 output high and low level in cycle to make LED blink. We will use both C code and Python code to achieve the target.

C Code 1.1.1 Blink

First, execute command into the terminal one by one. Then observe the project result, and analyze the code. If you want to execute it with editor, please refer to section [Code Editor](#) to configure.

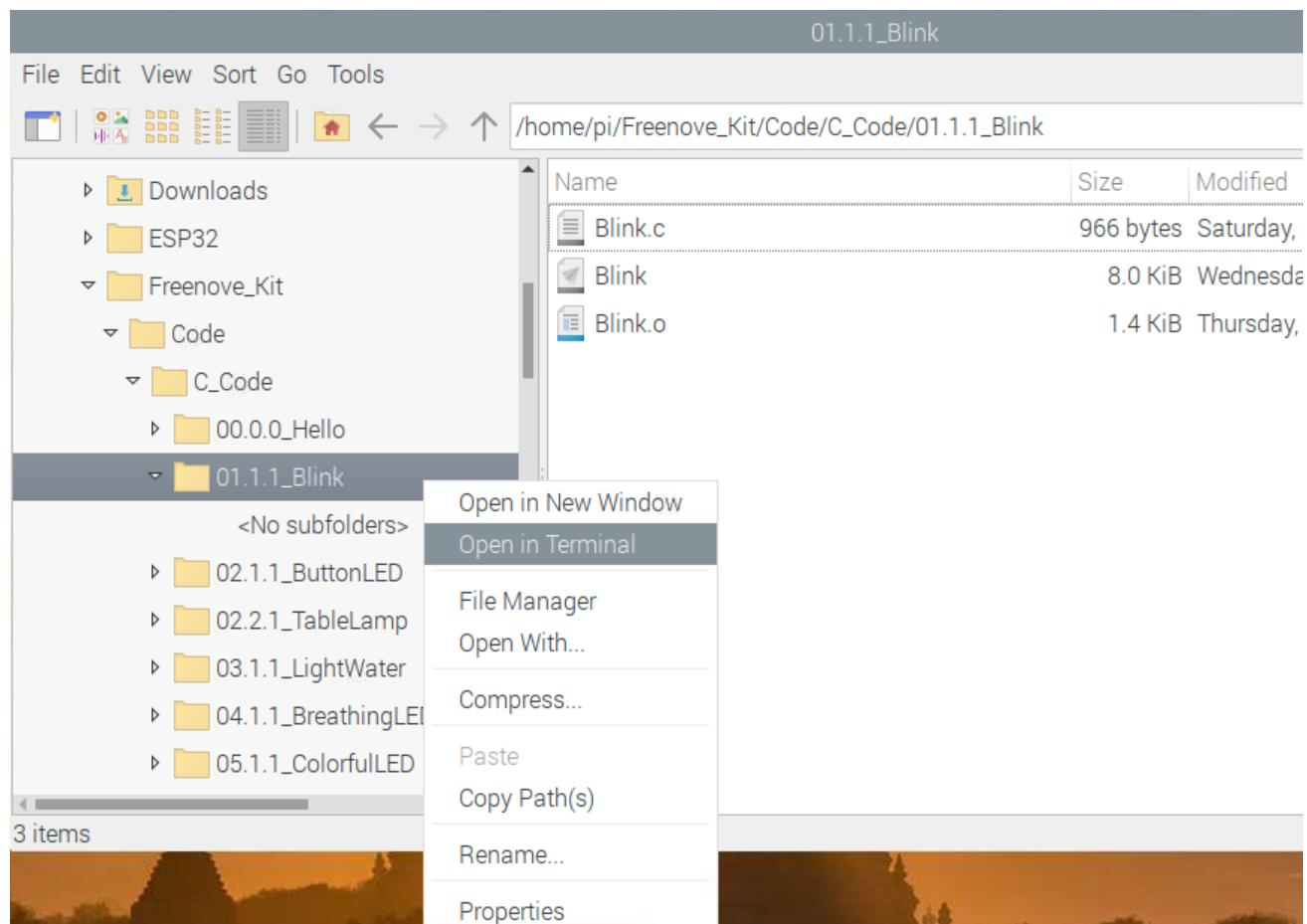
If you have any concerns, please contact us via: support@freenove.com

It is recommended to execute code as below.

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. In the folder tree on the left, 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 start blink.

```
pi@raspberrypi:~/Freenove_Kit/Code/C_Code/01.1.1_Blink$ 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:

```
1 #include <wiringPi.h>
2 #include <stdio.h>
3
4 #define ledPin    0 //define the led pin number
5
6 void main(void)
7 {
8     printf("Program is starting ... \n");
9
10    wiringPiSetup(); //Initialize wiringPi.
11
12    pinMode(ledPin, OUTPUT); //Set the pin mode
13    printf("Using pin%d\n", ledPin); //Output information on terminal
14    while(1) {
15        digitalWrite(ledPin, HIGH); //Make GPIO output HIGH level
16        printf("led turned on >>>\n"); //Output information on terminal
17        delay(1000); //Wait for 1 second
18        digitalWrite(ledPin, LOW); //Make GPIO output LOW level
19        printf("led turned off <<<\n"); //Output information on terminal
20        delay(1000); //Wait for 1 second
21    }
22 }
```

GPIO connected to ledPin in the circuit is GPIO17. And GPIO17 is defined as 0 in the wiringPi numbering. So ledPin should be defined as 0 pin. You can refer to the corresponding table in Chapter 0.

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

In the main function main(), initialize wiringPi first.

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

After the wiringPi is initialized successfully, set the ledPin to output mode. And then enter the while cycle, which is an endless loop. That is, the program will always be executed in this cycle, unless it is ended outside. In this cycle, 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
}
```

Among them, the configuration function for GPIO is shown below as:

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, please refer to <http://wiringpi.com/reference/>

Python Code 1.1.1 Blink

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

First, observe the project result, and then analyze 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
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:

```

1 import RPi.GPIO as GPIO
2 import time
3
4 ledPin = 11      # define ledPin
5
6 def setup():
7     GPIO.setmode(GPIO.BOARD)      # use PHYSICAL GPIO Numbering
8     GPIO.setup(ledPin, GPIO.OUT)   # set the ledPin to OUTPUT mode
9     GPIO.output(ledPin, GPIO.LOW)  # make ledPin output LOW level
10    print ('using pin%d' %ledPin)
11
12 def loop():
13     while True:
14         GPIO.output(ledPin, GPIO.HIGH) # make ledPin output HIGH level to turn on led
15         print ('led turned on >>>')      # print information on terminal
16         time.sleep(1)                  # Wait for 1 second
17         GPIO.output(ledPin, GPIO.LOW)   # make ledPin output LOW level to turn off led
18         print ('led turned off <<<')
19         time.sleep(1)                  # Wait for 1 second
20
21 def destroy():
22     GPIO.cleanup()                  # Release all GPIO
23
24 if __name__ == '__main__':      # Program entrance
```

```

25     print ('Program is starting ... \n')
26     setup()
27     try:
28         loop()
29     except KeyboardInterrupt: # Press ctrl-c to end the program.
30         destroy()

```

In subfunction `setup()`, `GPIO.setmode(GPIO.BOARD)` is used to set the serial number for GPIO based on physical location of the pin. `GPIO17` use pin 11 of the board, so define `ledPin` as 11 and set `ledPin` to output mode (output low level).

```

ledPin = 11      # define ledPin

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)

```

In `loop()`, there is a while cycle, which is an endless loop. That is, the program will always be executed in this cycle, unless it is ended outside. In this cycle, 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 cycle, 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()                  # Release all GPIO

```

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:

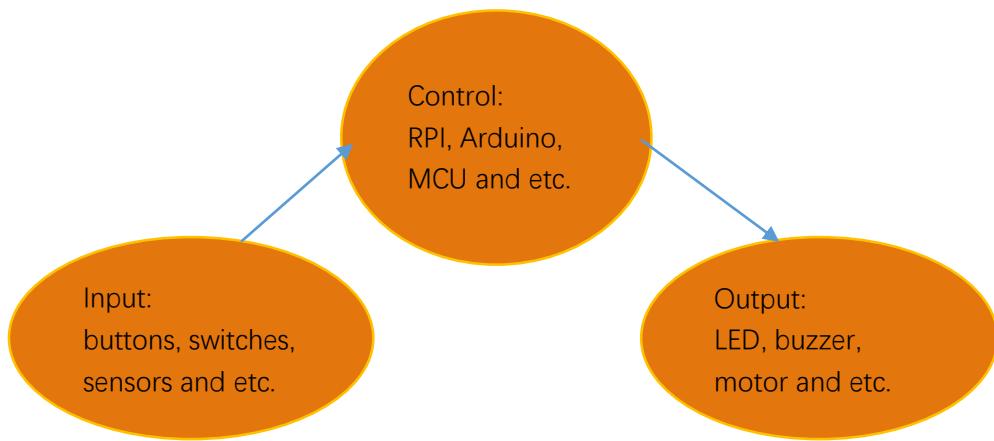
<https://sourceforge.net/p/raspberry-gpio-python/wiki/Examples/>

"import time" time is a module of python.

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

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 lights 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.

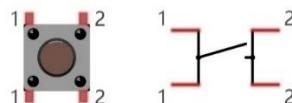
Component List

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

Component knowledge

Push button

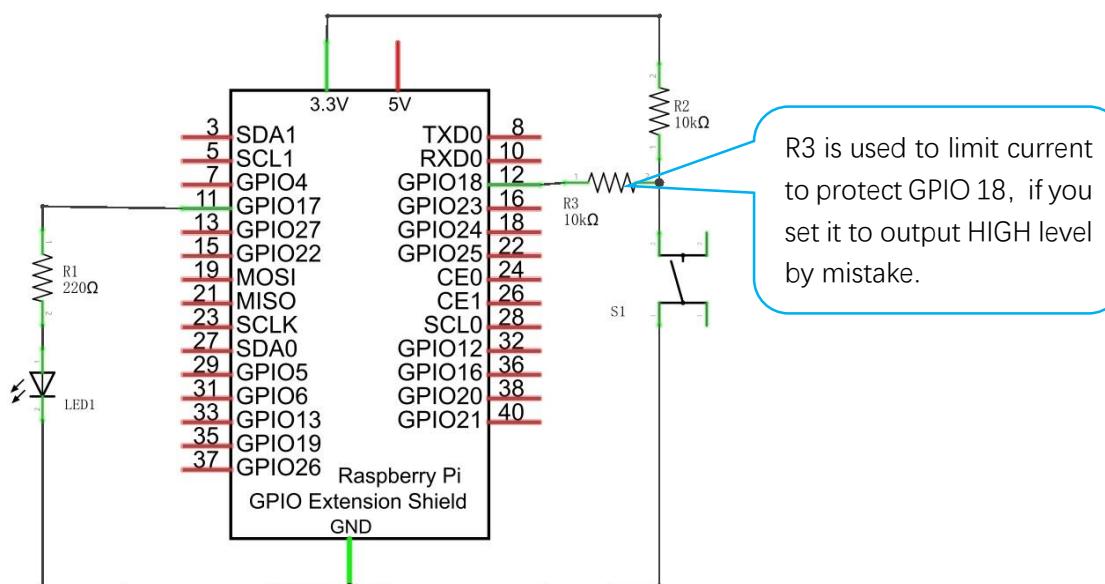
Push button has 4 pins. Two pins on the left is connected, and the right is similar as the left, which is shown in the below:



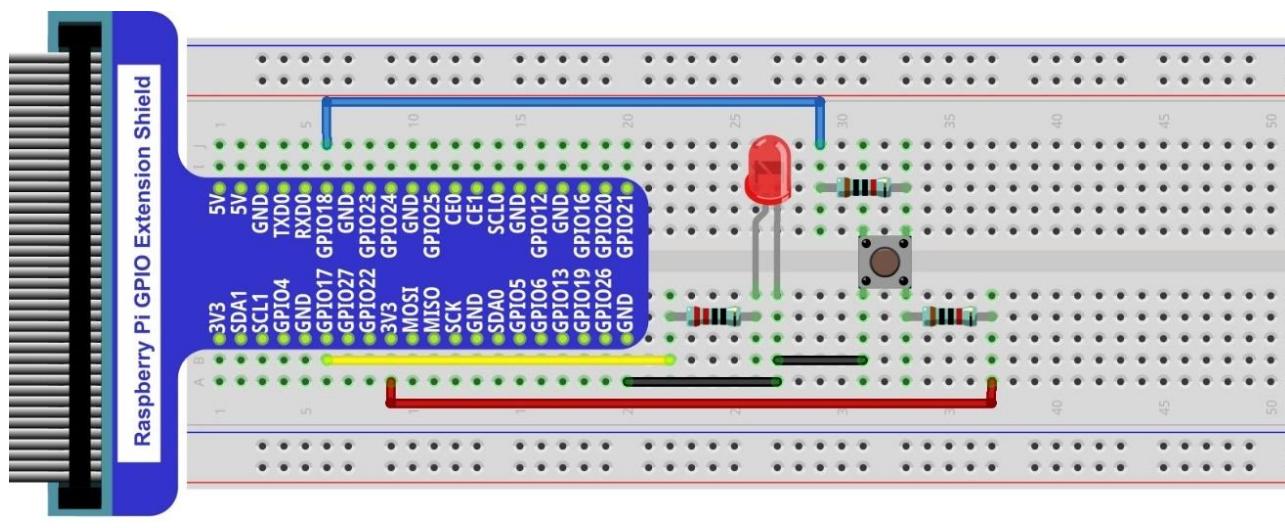
When the push button is pressed, the circuit is turned on.

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 analyze 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:

```

1 #include <wiringPi.h>
2 #include <stdio.h>
3
4 #define ledPin    0 //define the ledPin
5 #define buttonPin 1 //define the buttonPin
6
7 void main(void)
8 {
9     printf("Program is starting ... \n");
10
11     wiringPiSetup(); //Initialize wiringPi.
12
13     pinMode(ledPin, OUTPUT); //Set ledPin to output
14     pinMode(buttonPin, INPUT); //Set buttonPin to input
15
16     pullUpDnControl(buttonPin, PUD_UP); //pull up to HIGH level
17     while(1) {
18         if(digitalRead(buttonPin) == LOW){ //button is pressed
19             digitalWrite(ledPin, HIGH); //Make GPIO output HIGH level
20             printf("Button is pressed, led turned on >>\n"); //Output information on
21             terminal
22         }
23         else { //button is released
24             digitalWrite(ledPin, LOW); //Make GPIO output LOW level
25             printf("Button is released, led turned off <<\n"); //Output information on
26             terminal

```

```
27 }  
28 }  
29 }
```

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
```

In the while cycle of main function, use digitalWrite(buttonPin) to determine the state of Button. When the button is pressed, the function returns low level, the result of "if" is true, and then turn on LED. Or, 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 analyze 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:

```

1 import RPi.GPIO as GPIO
2
3 ledPin = 11      # define ledPin
4 buttonPin = 12    # define buttonPin
5
6 def setup():
7
8     GPIO.setmode(GPIO.BOARD)      # use PHYSICAL GPIO Numbering
9     GPIO.setup(ledPin, GPIO.OUT)   # set ledPin to OUTPUT mode
10    GPIO.setup(buttonPin, GPIO.IN, pull_up_down=GPIO.PUD_UP)    # set buttonPin to PULL UP
11    INPUT mode
12
13 def loop():
14     while True:
15         if GPIO.input(buttonPin)==GPIO.LOW: # if button is pressed
16             GPIO.output(ledPin,GPIO.HIGH)    # turn on led
17             print ('led turned on >>>')  # print information on terminal
18         else : # if button is released
19             GPIO.output(ledPin,GPIO.LOW) # turn off led
20             print ('led turned off <<<')
21
22 def destroy():
23     GPIO.cleanup()                  # Release GPIO resource
24
25 if __name__ == '__main__':      # Program entrance
26     print ('Program is starting...')
27     setup()
28     try:
29         loop()
30     except KeyboardInterrupt:  # Press ctrl-c to end the program.
31         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 while dead circulation, continue to judge whether the key 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 released
            GPIO.output(ledPin,GPIO.LOW) # turn off led
            print ('led turned off <<<')
```

Execute the function destroy (), close the program and release the 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.

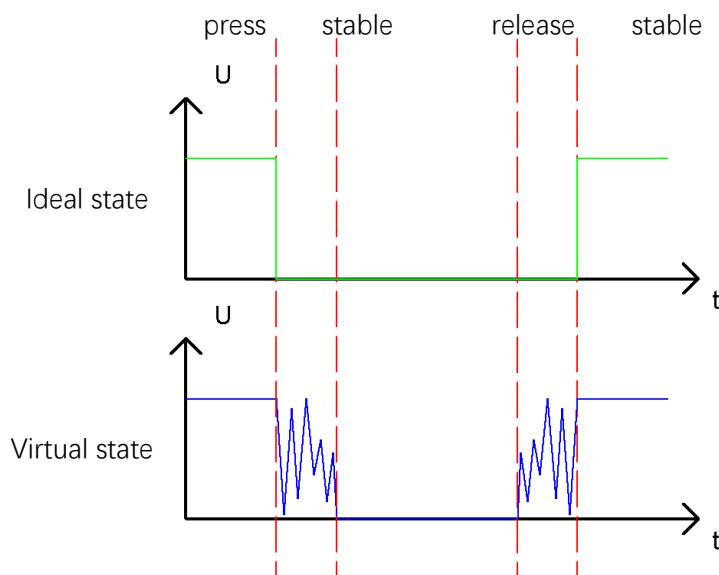
Project 2.2 MINI table lamp

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 becomes another state. And the releasing-situation is similar with that 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 circuits with the last section.

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 analyze 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.

```
1 #include <wiringPi.h>
2 #include <stdio.h>
3
4 #define ledPin    0 //define the ledPin
5 #define buttonPin 1 //define the buttonPin
6 int ledState=LOW; //store the State of led
7 int buttonState=HIGH; //store the State of button
8 int lastbuttonState=HIGH; //store the lastState of button
9 long lastChangeTime; //store the change time of button state
10 long captureTime=50; //set the stable time for button state
11 int reading;
12 int main(void)
13 {
14     printf("Program is starting... \n");
15
16     wiringPiSetup(); //Initialize wiringPi.
17
18     pinMode(ledPin, OUTPUT); Set ledPin to output
19     pinMode(buttonPin, INPUT); Set buttonPin to input
20
21     pullUpDnControl(buttonPin, PUD_UP); //pull up to high level
22     while(1) {
23         reading = digitalRead(buttonPin); //read the current state of button
24         if( reading != lastbuttonState){ //if the button state has changed, record the time
25             point
26             lastChangeTime = millis();
27     }
```

```

28     //if changing-state of the button last beyond the time we set, we consider that
29     //the current button state is an effective change rather than a buffeting
30     if(millis() - lastChangeTime > captureTime){
31         //if button state is changed, update the data.
32         if(reading != buttonState){
33             buttonState = reading;
34             //if the state is low, it means the action is pressing
35             if(buttonState == LOW){
36                 printf("Button is pressed!\n");
37                 ledState = !ledState; //Reverse the LED state
38                 if(ledState){
39                     printf("turn on LED ... \n");
40                 }
41                 else {
42                     printf("turn off LED ... \n");
43                 }
44             }
45             //if the state is high, it means the action is releasing
46             else {
47                 printf("Button is released!\n");
48             }
49         }
50     }
51     digitalWrite(ledPin, ledState);
52     lastbuttonState = reading;
53 }
54
55     return 0;
56 }
```

This code focuses on eliminating the buffeting 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 is, 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. Then duration will be judged again until the duration of there is a stable state exceeds the time we set.

```
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 analyze 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.

```
1 import RPi.GPIO as GPIO
2
3 ledPin = 11      # define ledPin
4 buttonPin = 12    # define buttonPin
5 ledState = False
6
7 def setup():
8     GPIO.setmode(GPIO.BOARD)      # use PHYSICAL GPIO Numbering
9     GPIO.setup(ledPin, GPIO.OUT)    # set ledPin to OUTPUT mode
10    GPIO.setup(buttonPin, GPIO.IN, pull_up_down=GPIO.PUD_UP)    # set buttonPin to PULL UP
11    INPUT mode
12
13 def buttonEvent(channel): # When button is pressed, this function will be executed
14     global ledState
15     print ('buttonEvent GPIO%d' %channel)
16     ledState = not ledState
17     if ledState :
18         print ('Led turned on >>>')
19     else :
20         print ('Led turned off <<<')
21     GPIO.output(ledPin, ledState)
22
23 def loop():
24     #Button detect
25     GPIO.add_event_detect(buttonPin,GPIO.FALLING,callback = buttonEvent,bouncetime=300)
26     while True:
27         pass
28
29 def destroy():
30     GPIO.cleanup()                  # Release GPIO resource
31
32 if __name__ == '__main__':      # Program entrance
33     print ('Program is starting...')
34     setup()
35     try:
```

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

RPi.GPIO provides us with a simple and effective function to eliminate the jitter, that is GPIO.add_event_detect(). It uses callback function. Once it detect that the buttonPin has a specified action FALLING, 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 target.

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. And the fourth parameter is used to set the jitter time.

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

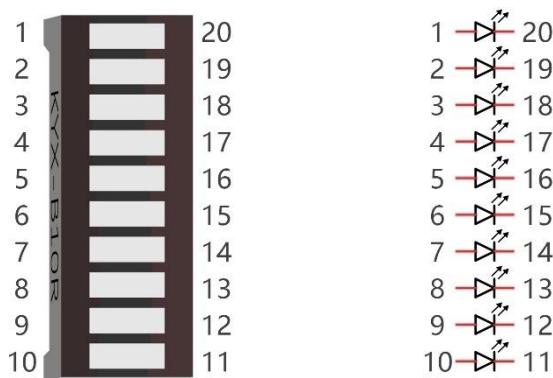
Raspberry Pi (with 40 GPIO) x1 GPIO Extension Board & Wire x1 BreadBoard x1	LED bar graph x1	Resistor 220Ω x10
Jumper		

Component knowledge

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

LED bar graph

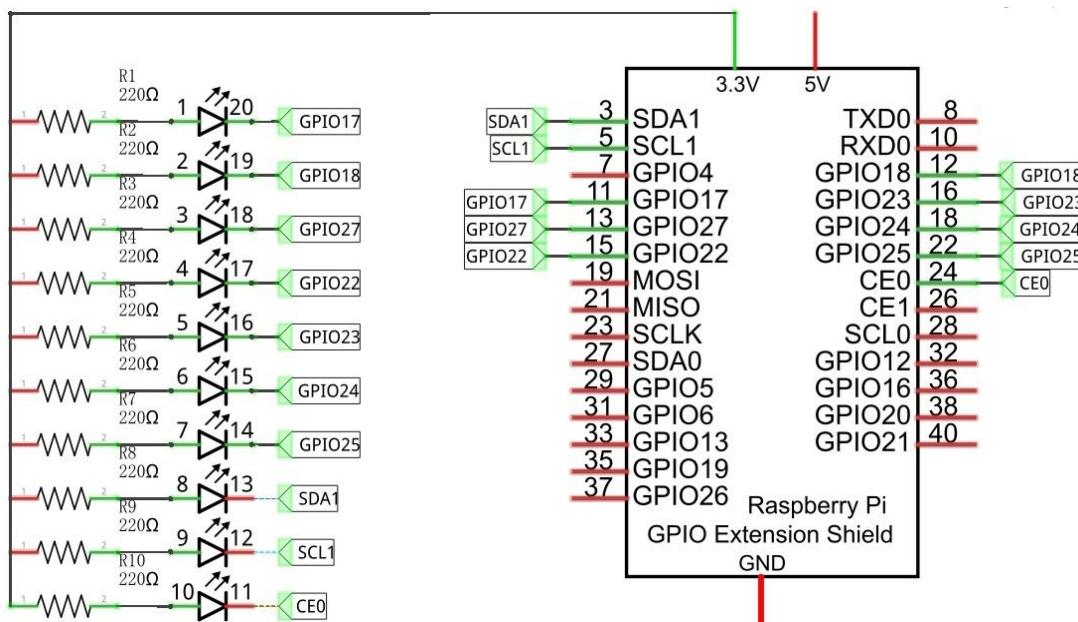
LED bar graph is a component Integration consist of 10 LEDs. There are two rows of pins at its bottom.



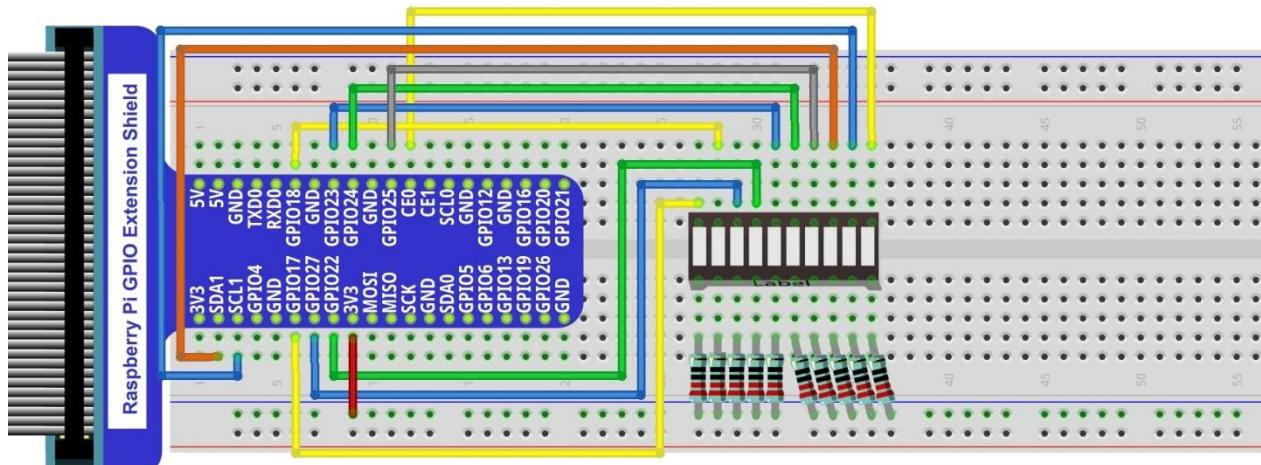
Circuit

The network label 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



In this circuit, the cathode of LED is connected to GPIO, which is the different from the front circuit. So, LED will be turned on when GPIO output low level in the program.

Code

This project is designed to make a water lamp. First turn on the first LED, then turn off it. Then turn on the second LED, and then turn 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 analyze 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:

```

1 #include <wiringPi.h>
2 #include <stdio.h>
3
4 #define ledCounts 10
5 int pins[ledCounts] = {0, 1, 2, 3, 4, 5, 6, 8, 9, 10};
6
7 void main(void)
8 {
9     int i;
10    printf("Program is starting ... \n");
11
12    wiringPiSetup(); //Initialize wiringPi.
13
14    for(i=0;i<ledCounts;i++) {      //Set pinMode for all led pins to output
15        pinMode(pins[i], OUTPUT);
16    }
17
18    while(1) {
19        for(i=0;i<ledCounts;i++) { // move led(on) from left to right
20            digitalWrite(pins[i], LOW);
21            delay(100);
22            digitalWrite(pins[i], HIGH);
23        }
24        for(i=ledCounts-1;i>-1;i--) { // move led(on) from right to left
25            digitalWrite(pins[i], LOW);
26            delay(100);
27            digitalWrite(pins[i], HIGH);
28        }
29    }
30}
```

```

27     }
28 }
29 }
```

In the program, configure the GPIO0-GPIO9 to output mode. Then, in the endless “while” cycle of main function, use two “for” cycle 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 analyze 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:

```

1 import RPi.GPIO as GPIO
2 import time
3
4 ledPins = [11, 12, 13, 15, 16, 18, 22, 3, 5, 24]
5
6 def setup():
7     GPIO.setmode(GPIO.BOARD)      # use PHYSICAL GPIO Numbering
8     GPIO.setup(ledPins, GPIO.OUT)  # set all ledPins to OUTPUT mode
9     GPIO.output(ledPins, GPIO.HIGH) # make all ledPins output HIGH level, turn off all led
10
11 def loop():
12     while True:
13         for pin in ledPins:      # make led(on) move from left to right
14             GPIO.output(pin, GPIO.LOW)
```

```
15         time.sleep(0.1)
16         GPIO.output(pin, GPIO.HIGH)
17     for pin in ledPins[::-1]:      # make led(on) move from right to left
18         GPIO.output(pin, GPIO.LOW)
19         time.sleep(0.1)
20         GPIO.output(pin, GPIO.HIGH)
21
22 def destroy():
23     GPIO.cleanup()                  # Release all GPIO
24
25 if __name__ == '__main__':        # Program entrance
26     print ('Program is starting...')
27     setup()
28     try:
29         loop()
30     except KeyboardInterrupt:    # Press ctrl-c to end the program.
31         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” cycles to realize flowing water light from right to left and from left to right. Among them, `ledPins[::-1]` is used to traverse 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, then how to enter a middle state? How to output an intermediate state to let LED "semi bright"? 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 target.

Component List

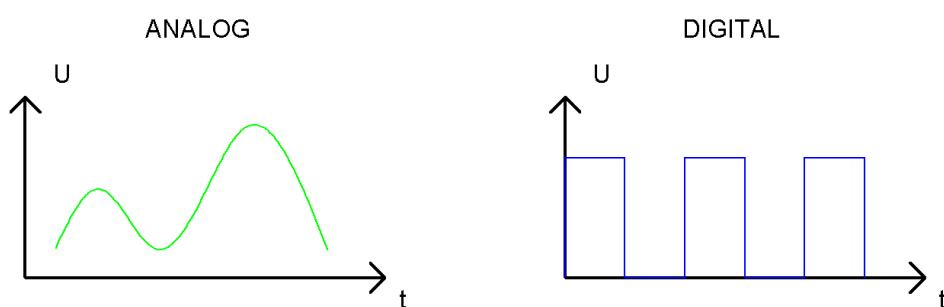
Raspberry Pi (with 40 GPIO) x1 GPIO Extension Board & Wire x1 BreadBoard x1	LED x1	Resistor 220Ω x1
Jumper		

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°C to 10°C, 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.



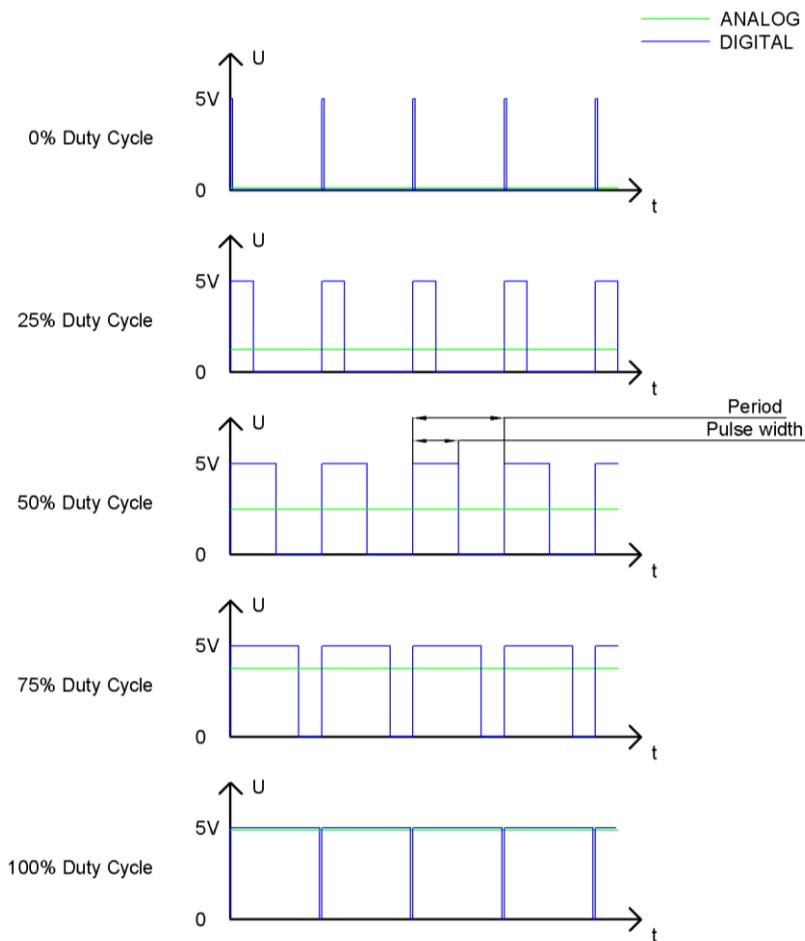
In practical application, we often use binary signal as digital signal, that is 0 and 1. The binary signal only has two forms (0 or 1), so it has strong stability. And digital signal and analog signal can be converted to each other.

PWM

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

PWM technology uses digital pins to send certain frequency of square waves, that is, the output of high level and low level that last for a while alternately. The total time for each set of high level and low level is generally fixed, which is called period (the reciprocal of the period is frequency). The time of high level outputting is generally called pulse width, and the percentage of pulse width is called duty cycle.

The longer the output of high level last, the larger the duty cycle and the larger the corresponding voltage in analog signal will be. The following figures show how the analog signals voltage vary between 0V-5V (high level is 5V) corresponding to the pulse width 0%-100%:



The larger PWM duty cycle is, the larger 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.

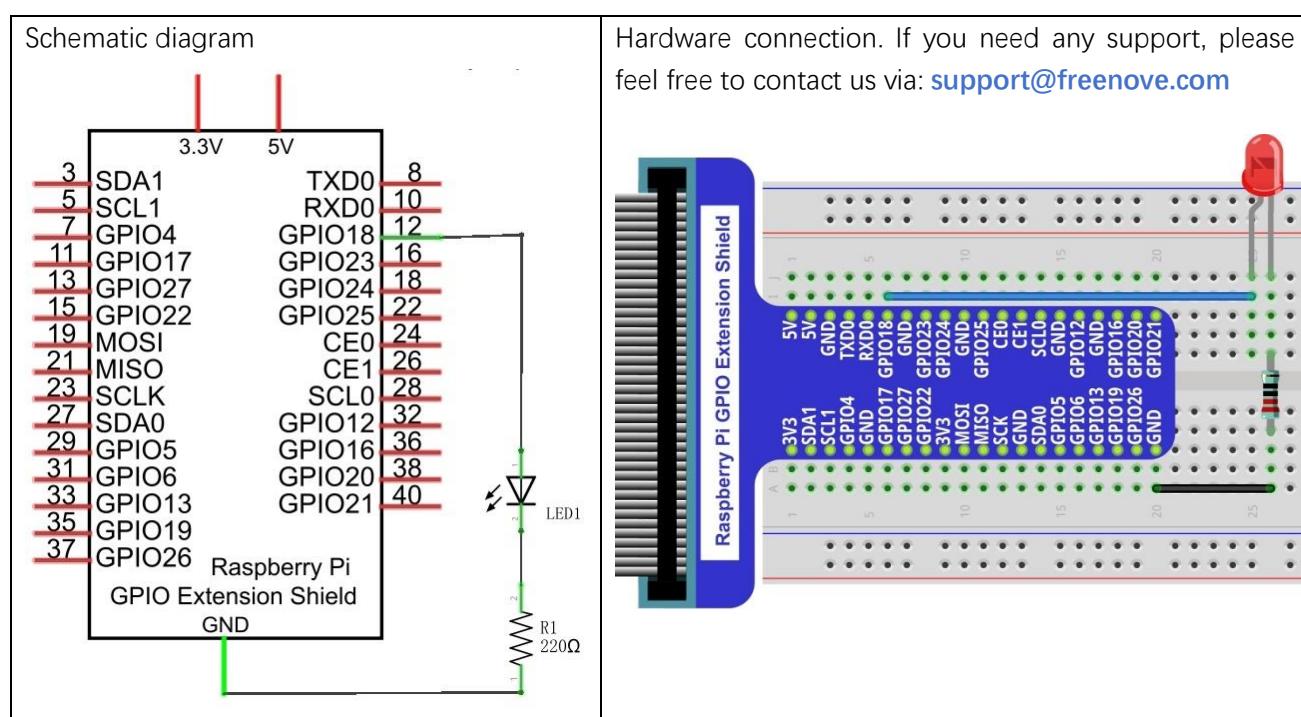
In RPi, only GPIO18 has the ability to output hardware PWM with a 10-bit accuracy, that is, 100% of the pulse width can be divided into $2^{10}=1024$ equal parts.

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 relatively not high enough.

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

Circuit



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 analyze 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:

```

1 #include <wiringPi.h>
2 #include <stdio.h>
3 #include <softPwm.h>
4
5 #define ledPin 1
6
7 void main(void)
8 {
9     int i;
10
11     printf("Program is starting ... \n");
12
13     wiringPiSetup(); //Initialize wiringPi.
14
15     softPwmCreate(ledPin, 0, 100); //Create SoftPWM pin
16
17     while(1) {
18         for(i=0;i<100;i++) { //make the led brighter
19             softPwmWrite(ledPin, i);
20             delay(20);
21         }
22         delay(300);
23         for(i=100;i>=0;i--) { //make the led darker
24             softPwmWrite(ledPin, i);
25             delay(20);
26         }
27         delay(300);
28     }
29 }
```

First, create a software PWM pin.

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

There are two “for” cycles in the next endless “while” cycle. 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 rate of the state change of LED by changing the parameters of the `delay()` function in the “for” cycle.

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 analyze 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:

```

1 import RPi.GPIO as GPIO
2 import time
3
4 LedPin = 12      # define the LedPin
5
6 def setup():
7     global p
8     GPIO.setmode(GPIO.BRD)      # use PHYSICAL GPIO Numbering
9     GPIO.setup(LedPin, GPIO.OUT) # set LedPin to OUTPUT mode
10    GPIO.output(LedPin, GPIO.LOW) # make ledPin output LOW level to turn off LED
11
12    p = GPIO.PWM(LedPin, 500)   # set PWM Frequency to 500Hz
13    p.start(0)                 # set initial Duty Cycle to 0
14
15 def loop():
16     while True:
17         for dc in range(0, 101, 1): # make the led brighter
18             p.ChangeDutyCycle(dc)   # set dc value as the duty cycle
19             time.sleep(0.01)
20             time.sleep(1)
21         for dc in range(100, -1, -1): # make the led darker
22             p.ChangeDutyCycle(dc)   # set dc value as the duty cycle
23             time.sleep(0.01)

```

```

24         time.sleep(1)
25
26     def destroy():
27         p.stop() # stop PWM
28         GPIO.cleanup() # Release all GPIO
29
30     if __name__ == '__main__':    # Program entrance
31         print ('Program is starting ... ')
32         setup()
33         try:
34             loop()
35         except KeyboardInterrupt: # Press ctrl-c to end the program.
36             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 Frequency to 500Hz
    p.start(0)                   # set initial Duty Cycle to 0

```

There are two “for” cycles used to realize breathing LED in the next endless “while” cycle. 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.

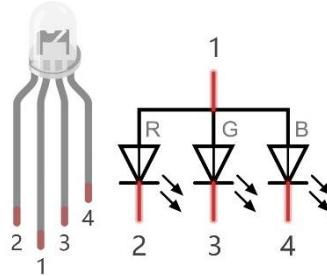
For more details about usage method for PWM of RPi.GPIO, please refer to:

<https://sourceforge.net/p/raspberry-gpio-python/wiki/PWM/>

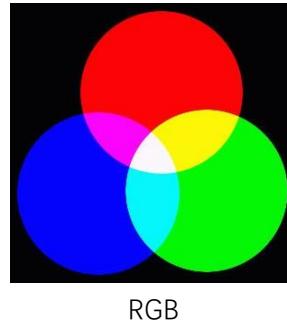
Chapter 5 RGBLED

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

RGB LED has integrated 3 LEDs that can respectively emit red, green and blue light. And it has 4 pins. The long pin (1) is the common port, that is, 3 LED's positive or negative port. The RGB LED with common positive port and its symbol are shown below. We can make RGB LED emit 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 all kinds of visible lights. 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) color through different combinations.

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

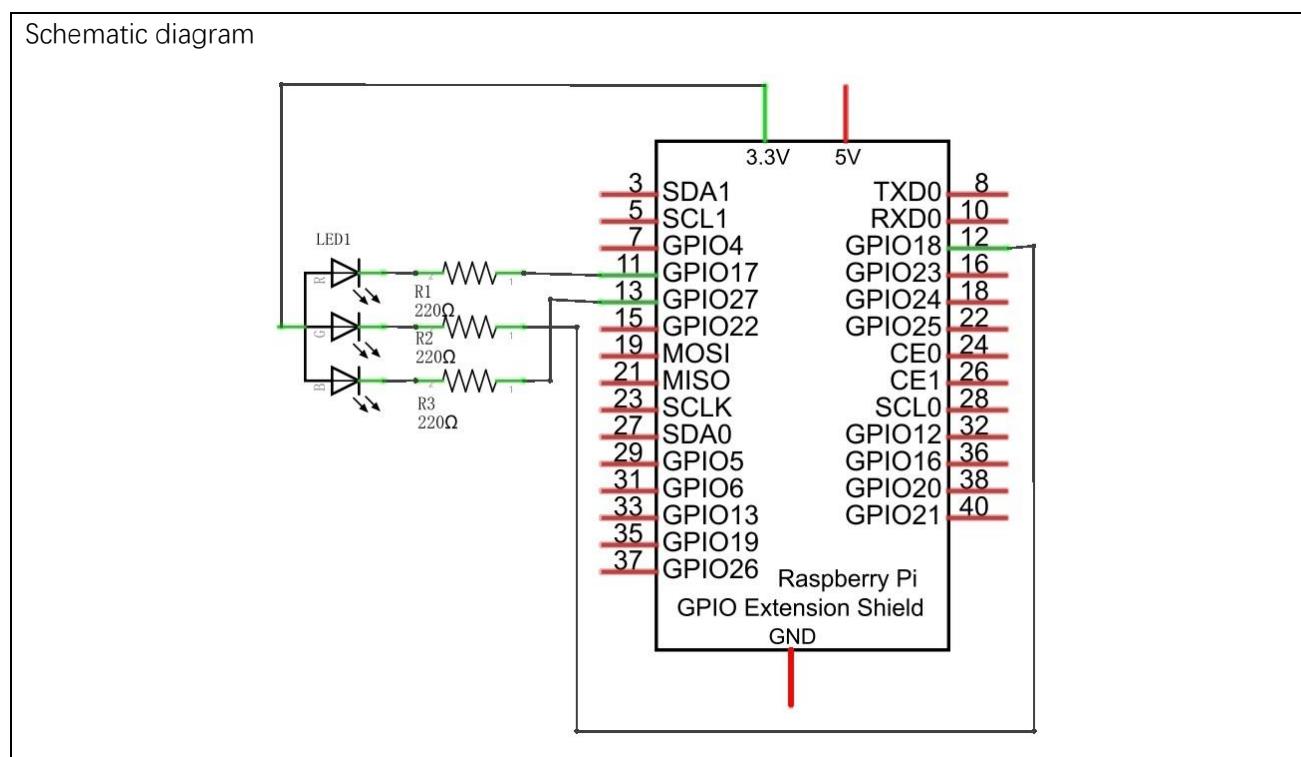
Project 5.1 Colorful LED

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

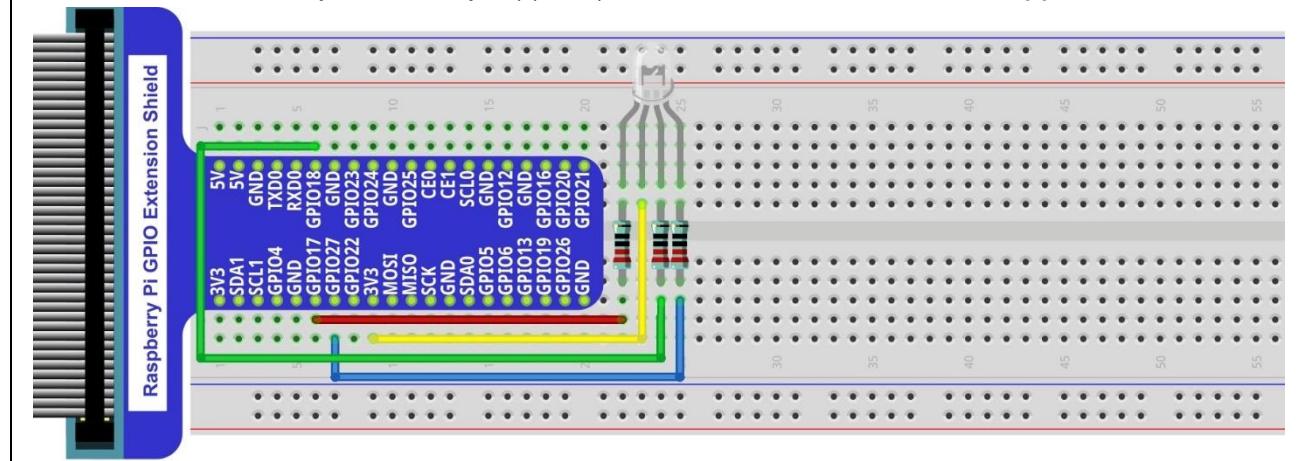
Component List

Raspberry Pi (with 40 GPIO) x1 GPIO Extension Board & Wire x1 BreadBoard x1	RGBLED x1	Resistor 220Ω x3
Jumper		

Circuit



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



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 analyze 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
```

2. 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 add the compiler.

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

3. 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:

```

1 #include <wiringPi.h>
2 #include <softPwm.h>
3 #include <stdio.h>
4 #include <stdlib.h>
5
6 #define ledPinRed    0
7 #define ledPinGreen   1
8 #define ledPinBlue    2
9
10 void setupLedPin(void)
11 {
12     softPwmCreate(ledPinRed, 0, 100); //Creat SoftPWM pin for red
13     softPwmCreate(ledPinGreen, 0, 100); //Creat SoftPWM pin for green
14     softPwmCreate(ledPinBlue, 0, 100); //Creat SoftPWM pin for blue
15 }
16
17 void setLedColor(int r, int g, int b)
18 {
19     softPwmWrite(ledPinRed, r); //Set the duty cycle
20     softPwmWrite(ledPinGreen, g); //Set the duty cycle
21     softPwmWrite(ledPinBlue, b); //Set the duty cycle
22 }
23
24 int main(void)
25 {
26     int r,g,b;
```

```

27
28     printf("Program is starting ... \n");
29
30     wiringPiSetup(); //Initialize wiringPi.
31
32     setupLedPin();
33     while(1) {
34         r=random()%100; //get a random in (0, 100)
35         g=random()%100; //get a random in (0, 100)
36         b=random()%100; //get a random in (0, 100)
37         setLedColor(r, g, b); //set random as the duty cycle value
38         printf("r=%d, g=%d, b=%d \n", r, g, b);
39         delay(300);
40     }
41     return 0;
42 }
```

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); //Creat SoftPWM pin for red
    softPwmCreate(ledPinGreen, 0, 100); //Creat SoftPWM pin for green
    softPwmCreate(ledPinBlue, 0, 100); //Creat 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” cycle 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 can be described as follows:

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 analyze 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 "ColorfullLED.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:

```

1 import RPi.GPIO as GPIO
2 import time
3 import random
4
5 pins = {'pinRed':11, 'pinGreen':12, 'pinBlue':13} # define the pins for RGBLED
6
7 def setup():
8     global pwmRed, pwmGreen, pwmBlue
9     GPIO.setmode(GPIO.BOARD)      # use PHYSICAL GPIO Numbering
10    GPIO.setup(pins, GPIO.OUT)    # set RGBLED pins to OUTPUT mode
11    GPIO.output(pins, GPIO.HIGH)  # make RGBLED pins output HIGH level
12    pwmRed = GPIO.PWM(pins['pinRed'], 2000)    # set PWM Frequnce to 2kHz
13    pwmGreen = GPIO.PWM(pins['pinGreen'], 2000)  # set PWM Frequnce to 2kHz
14    pwmBlue = GPIO.PWM(pins['pinBlue'], 2000)    # set PWM Frequnce to 2kHz
15    pwmRed.start(0)      # set initial Duty Cycle to 0
16    pwmGreen.start(0)
17    pwmBlue.start(0)
18
19 def setColor(r_val,g_val,b_val):      # change duty cycle for three pins to r_val,g_val,b_val
20     pwmRed.ChangeDutyCycle(r_val)      # change pwmRed duty cycle to r_val
21     pwmGreen.ChangeDutyCycle(g_val)
22     pwmBlue.ChangeDutyCycle(b_val)
23
24 def loop():
25     while True :
26         r=random.randint(0,100)  #get a random in (0,100)
27         g=random.randint(0,100)
28         b=random.randint(0,100)
29         setColor(r,g,b)        #set random as a duty cycle value

```

```

30         print (' r=%d, g=%d, b=%d ' %(r ,g, b))
31         time.sleep(0.3)
32
33     def destroy():
34         pwmRed.stop()
35         pwmGreen.stop()
36         pwmBlue.stop()
37         GPIO.cleanup()
38
39     if __name__ == '__main__':      # Program entrance
40         print ('Program is starting ... ')
41         setup()
42         try:
43             loop()
44         except KeyboardInterrupt: # Press ctrl-c to end the program.
45             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 exactly the same as last chapter. In the “while” cycle of “loop” function, we first obtain three random numbers, and then specify these three random numbers 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).

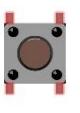
Chapter 6 Buzzer

In this chapter, we will learn a component that can sound, buzzer.

Project 6.1 Doorbell

We will make this kind of doorbell: when the button is pressed, the buzzer sounds; and when the button is released, the buzzer stops sounding.

Component List

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

Component knowledge

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 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 the pins of passive buzzer, you can even see the circuit board, coils, and permanent magnets directly.

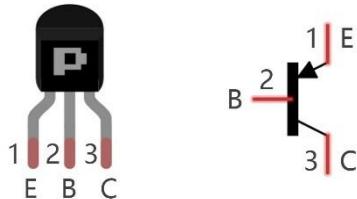
Transistor

Due to the current operating of buzzer is so large that GPIO of RPi output capability can not meet the requirement. A transistor of NPN type is needed here to amplify the current.

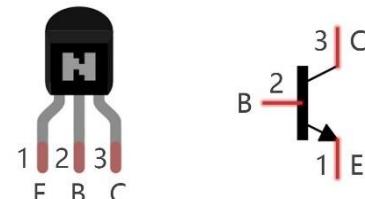


Transistor, the full name: semiconductor transistor, is a semiconductor device that controls current. Transistor can be used to amplify weak signal, or works as a switch. It has three electrodes(PINs): base (b), collector (c) and emitter (e). When there is current passing between "be", "ce" will allow 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

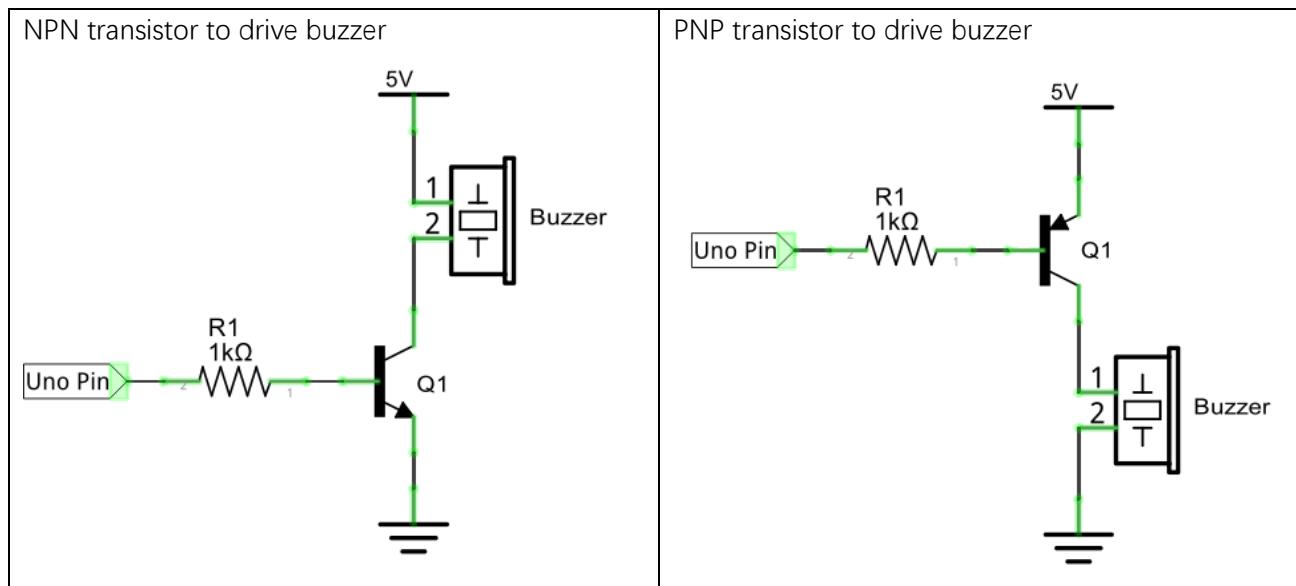


In our kit, the PNP transistor is marked with 8550, and the NPN transistor is marked with 8050.

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

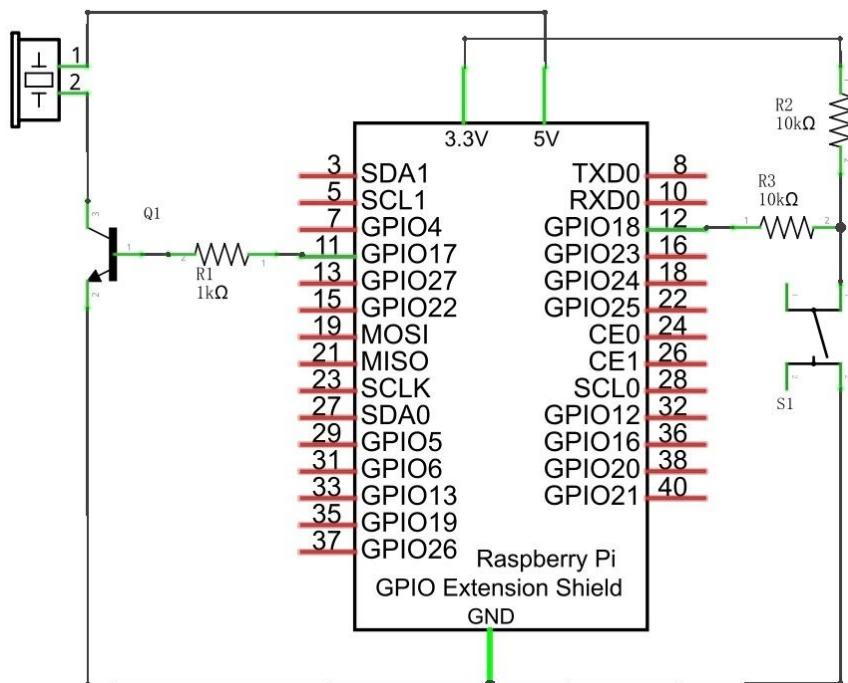
When use NPN transistor to drive buzzer, we often adopt the following method. If GPIO outputs high level, current will flow through R1, the transistor gets conducted, and the buzzer make a sound. If GPIO outputs low level, no current flows through R1, the transistor will not be conducted, and buzzer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

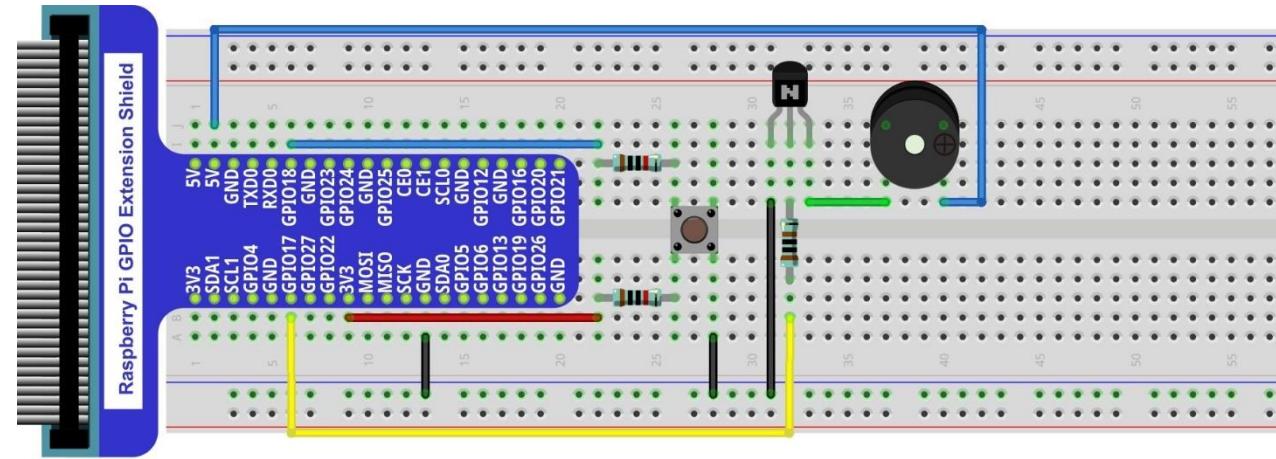


Circuit

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 sounds. And when the button is released, the buzzer stops sounding. 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 analyze 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 sounds. And when the button is release, the buzzer will stop sounding.

The following is the program code:

```

1 #include <wiringPi.h>
2 #include <stdio.h>
3
4 #define buzzerPin 0 //define the buzzerPin
5 #define buttonPin 1 //define the buttonPin
6
7 void main(void)
8 {
9     printf("Program is starting ... \n");
10
11     wiringPiSetup();
12
13     pinMode(buzzerPin, OUTPUT);
14     pinMode(buttonPin, INPUT);
15
16     pullUpDnControl(buttonPin, PUD_UP); //pull up to HIGH level
17     while(1) {
18
19         if(digitalRead(buttonPin) == LOW){ //button is pressed
20             digitalWrite(buzzerPin, HIGH); //Turn on buzzer
21             printf("buzzer turned on >> \n");
22         }
23         else { //button is released
24             digitalWrite(buzzerPin, LOW); //Turn off buzzer
25             printf("buzzer turned off << \n");
26         }
27     }
28 }
```

```
27 }  
28 }
```

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.

Python Code 6.1.1 Doorbell

First observe the project result, then analyze 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 sounds. And when the button is released, the buzzer will stop sounding.

The following is the program code:

```
1 import RPi.GPIO as GPIO  
2  
3 buzzerPin = 11      # define buzzerPin  
4 buttonPin = 12      # define buttonPin  
5  
6 def setup():  
7     GPIO.setmode(GPIO.BOARD)          # use PHYSICAL GPIO Numbering  
8     GPIO.setup(buzzerPin, GPIO.OUT)    # set buzzerPin to OUTPUT mode  
9     GPIO.setup(buttonPin, GPIO.IN, pull_up_down=GPIO.PUD_UP)    # set buttonPin to PULL UP  
10    INPUT mode  
11  
12    def loop():  
13        while True:  
14            if GPIO.input(buttonPin)==GPIO.LOW: # if button is pressed  
15                GPIO.output(buzzerPin,GPIO.HIGH) # turn on buzzer  
16                print ('buzzer turned on >>>')  
17            else : # if button is released  
18                GPIO.output(buzzerPin,GPIO.LOW) # turn off buzzer  
19                print ('buzzer turned off <<<')  
20  
21    def destroy():  
22        GPIO.cleanup()                  # Release all GPIO  
23  
24    if __name__ == '__main__':       # Program entrance  
25        print ('Program is starting...')  
26        setup()  
27        try:
```

```

28     loop()
29     except KeyboardInterrupt: # Press ctrl-c to end the program.
30         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 Alertor

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 with a passive buzzer.

Code

In this project, the buzzer alarm is controlled by the button. Press the button, then buzzer sounds. If you release the button, the buzzer will stop sounding. 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 sound.

C Code 6.2.1 Alertor

First observe the project result, and then analyze 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 sounds. And when the button is release, the buzzer will stop sounding.

The following is the program code:

```

1 #include <wiringPi.h>
2 #include <stdio.h>
3 #include <softTone.h>
4 #include <math.h>
5
6 #define buzzerPin    0 //define the buzzerPin
7 #define buttonPin    1 //define the buttonPin
8
9 void alertor(int pin) {
10     int x;
11     double sinVal, toneVal;

```

```
12     for(x=0;x<360;x++) { // frequency of the alertor is consistent with the sine wave
13         sinVal = sin(x * (M_PI / 180));           //Calculate the sine value
14         toneVal = 2000 + sinVal * 500;           //Add the resonant frequency and weighted sine
15         value
16         softToneWrite(pin, toneVal);           //output corresponding PWM
17         delay(1);
18     }
19 }
20 void stopAlertor(int pin){
21     softToneWrite(pin, 0);
22 }
23 int main(void)
24 {
25     printf("Program is starting ... \n");
26
27     wiringPiSetup();
28
29     pinMode(buzzerPin, OUTPUT);
30     pinMode(buttonPin, INPUT);
31     softToneCreate(buzzerPin); //set buzzerPin
32     pullUpDnControl(buttonPin, PUD_UP); //pull up to HIGH level
33     while(1) {
34         if(digitalRead(buttonPin) == LOW){ //button is pressed
35             alertor(buzzerPin); // turn on buzzer
36             printf("alertor turned on >> \n");
37         }
38         else { //button is released
39             stopAlertor(buzzerPin); // turn off buzzer
40             printf("alertor turned off << \n");
41         }
42     }
43     return 0;
44 }
```

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 though softToneCreate (buzzeRPin). Here softTone is dedicated 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 cycle 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 analyze 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:

```
1 import RPi.GPIO as GPIO
2 import time
3 import math
4
5 buzzerPin = 11      # define the buzzerPin
6 buttonPin = 12      # define the buttonPin
```

```
7
8 def setup():
9     global p
10    GPIO.setmode(GPIO.BOARD)          # Use PHYSICAL GPIO Numbering
11    GPIO.setup(buzzerPin, GPIO.OUT)   # set RGBLED pins to OUTPUT mode
12    GPIO.setup(buttonPin, GPIO.IN, pull_up_down=GPIO.PUD_UP)  # Set buttonPin to INPUT
13 mode, and pull up to HIGH level, 3.3V
14    p = GPIO.PWM(buzzerPin, 1)
15    p.start(0);
16
17 def loop():
18     while True:
19         if GPIO.input(buttonPin)==GPIO.LOW:
20             alertor()
21             print ('alertor turned on >>> ')
22         else :
23             stopAlertor()
24             print ('alertor turned off <<< ')
25 def alertor():
26     p.start(50)
27     for x in range(0,361):      # Make frequency of the alertor consistent with the sine wave
28         sinVal = math.sin(x * (math.pi / 180.0))          # calculate the sine value
29         toneVal = 2000 + sinVal * 500 # Add to the resonant frequency with a Weighted
30         p.ChangeFrequency(toneVal)      # Change Frequency of PWM to toneVal
31         time.sleep(0.001)
32
33 def stopAlertor():
34     p.stop()
35
36 def destroy():
37     GPIO.output(buzzerPin, GPIO.LOW)      # Turn off buzzer
38     GPIO.cleanup()                      # Release GPIO resource
39
40 if __name__ == '__main__':      # Program entrance
41     print ('Program is starting... ')
42     setup()
43     try:
44         loop()
45     except KeyboardInterrupt: # Press ctrl-c to end the program.
46         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 cycle 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()
```

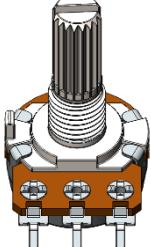
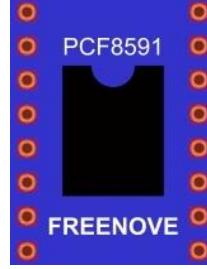
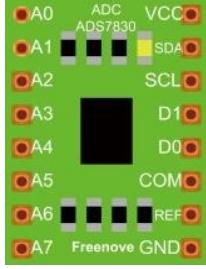
(Important)Chapter 7 ADC

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

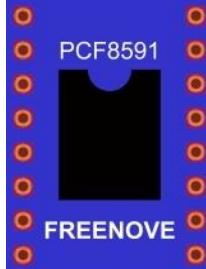
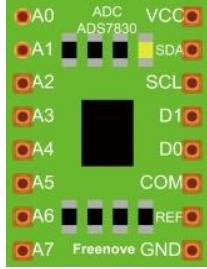
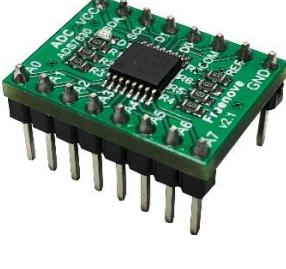
Project 7.1 Read the Voltage of Potentiometer

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

Component List

Raspberry Pi x1 GPIO Extension Board & Wire x1 BreadBoard x1	Jumper M/M x16 
Rotary potentiometer x1 	ADC module x1 Or   

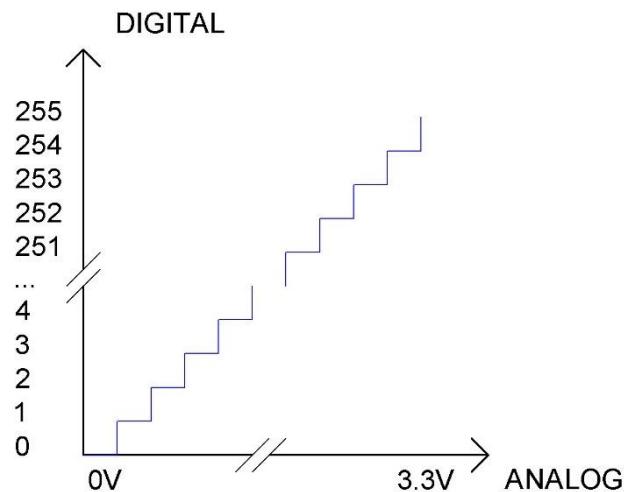
This product contains **only one ADC module**, which has two different types, PCF8591 and ADS7830. The functions involved in this tutorial are the same. Please build corresponding circuits according to different ADC module in your kit.

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 values. 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.

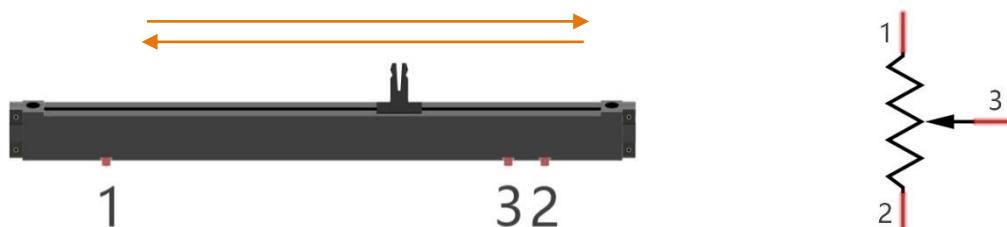
DAC

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 quantity is 1, the output voltage value is $3.3/256 *1$ V, and when the digital quantity is 128, the output voltage value is $3.3/256 *128=1.65$ V, the higher accuracy of DAC is, the higher the accuracy of output voltage value is.

Component knowledge

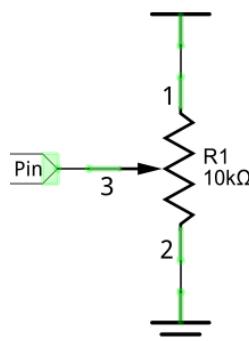
Potentiometer

Potentiometer is a resistive element with three Terminal part and the resistance can be adjusted according to a certain variation. 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.



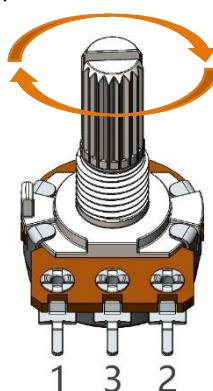
What between potentiometer pin 1 and pin 2 is the resistor body, and pins 3 is connected to brush. When brush moves from pins 1 to pin 2, the resistance between pin 1, and pin 3 will increase up to body resistance linearly, and the resistance between pin 2 and pin 3 will decrease down to 0 linearly.

In the circuit. The both sides of resistance body are often 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	I ² C-bus data input/output	
SCL	10	I ² C-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.

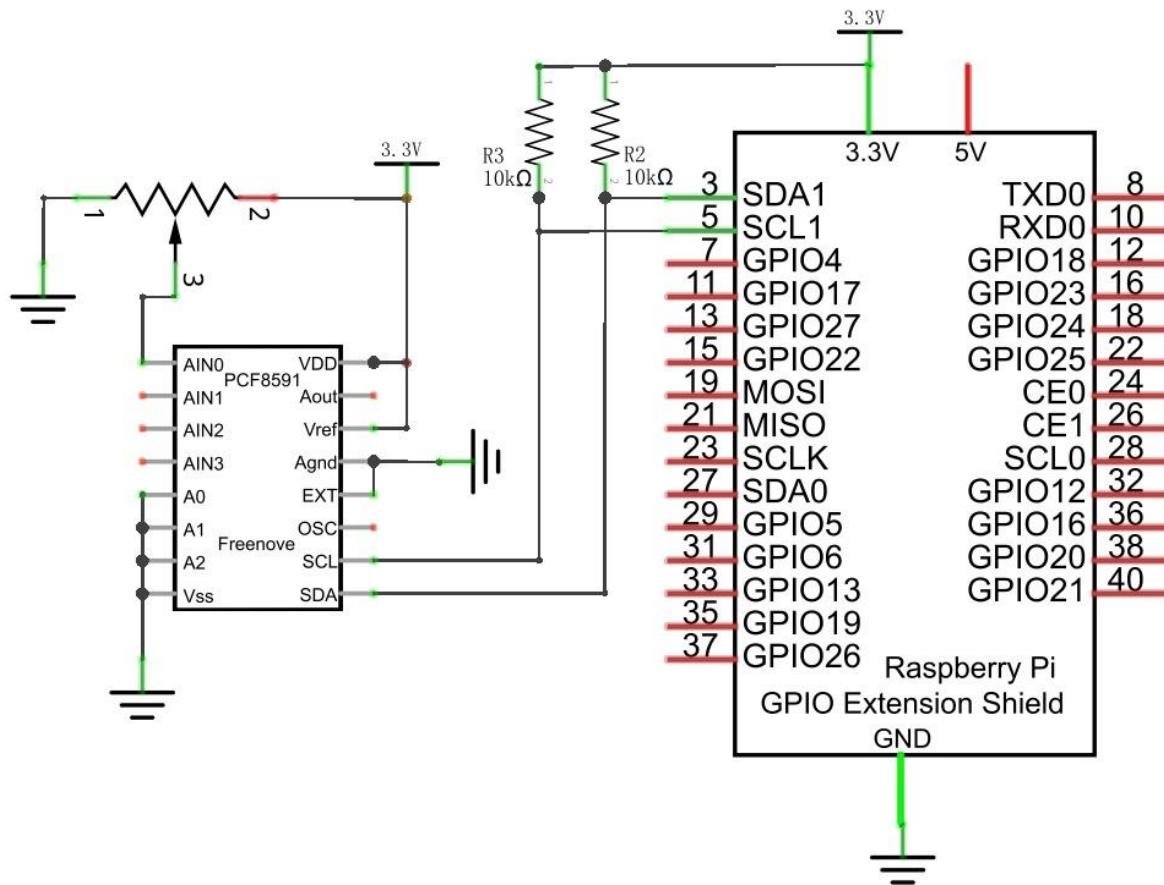
SYMBOL	PIN	DESCRIPTION	TOP VIEW
CH0	1	Analog input channels (A/D converter)	
CH1	2		
CH2	3		
CH3	4		
CH4	5		
CH5	6		
CH6	7		
CH7	8		
GND	9	Ground	
REF in/out	10	Internal +2.5V Reference, External Reference Input	
COM	11	Common to Analog Input Channel	
A0	12	Hardware address	
A1	13		
SCL	14	Serial Clock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

I2C communication

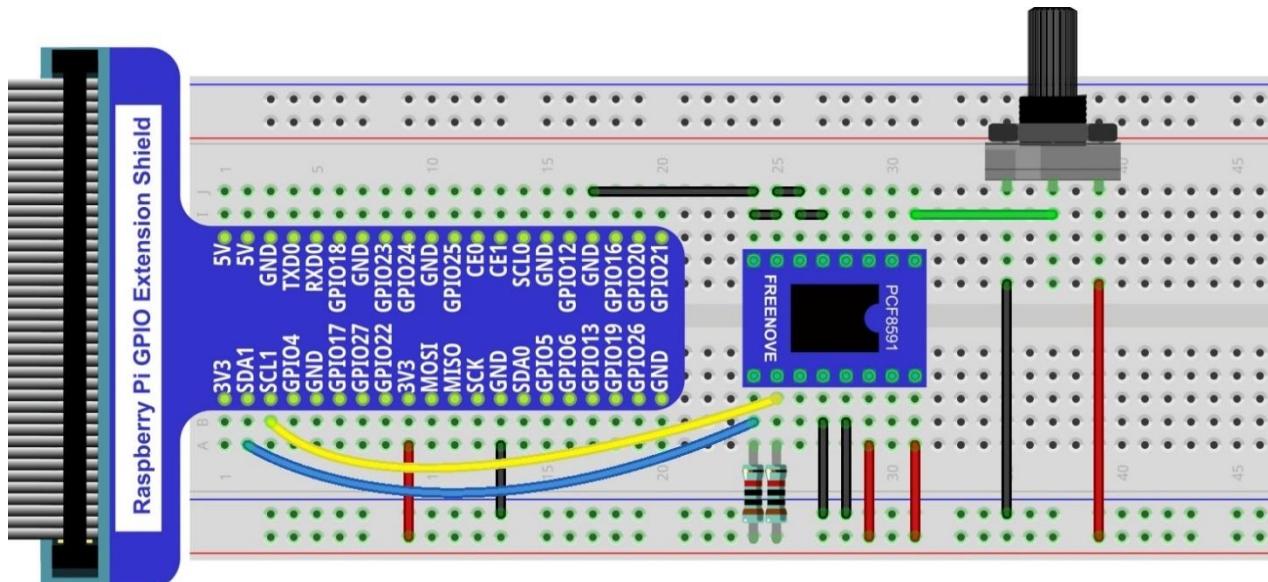
I2C(Inter-Integrated Circuit) is a two-wire serial communication mode, which can be used to connection of micro controller and its peripheral equipment. Devices using I2C communication must be connected to the serial data (SDA) line, and serial clock (SCL) line (called I2C bus). Each device has a unique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

Circuit with PCF8591

Schematic diagram



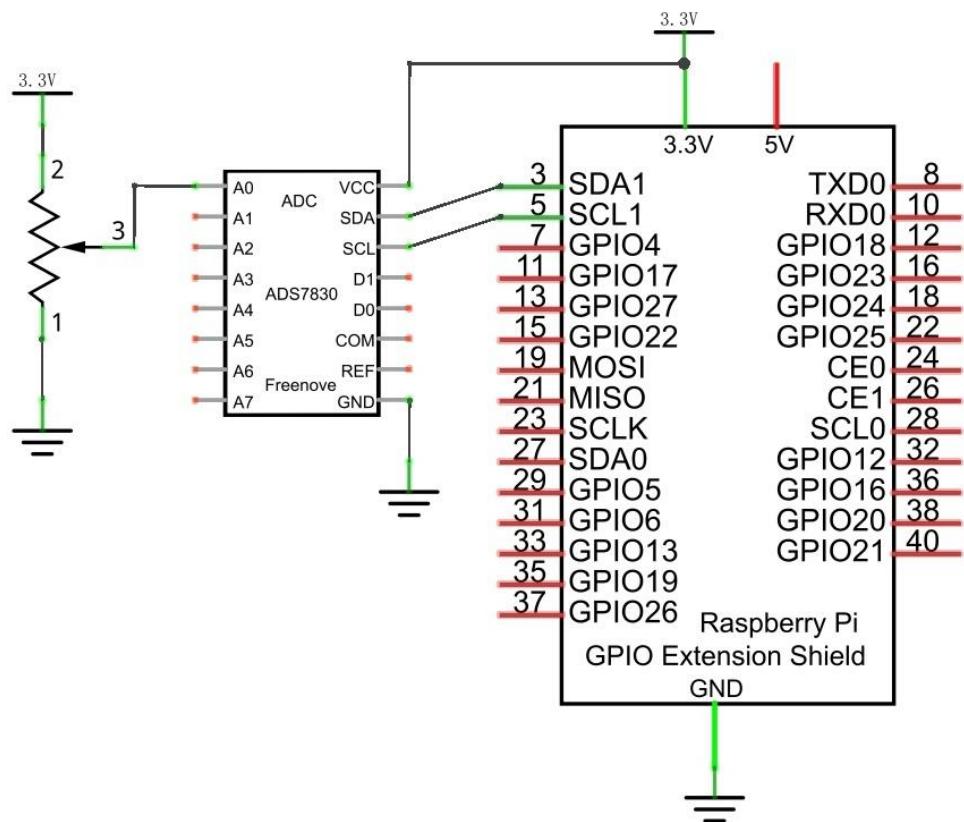
Hardware connection



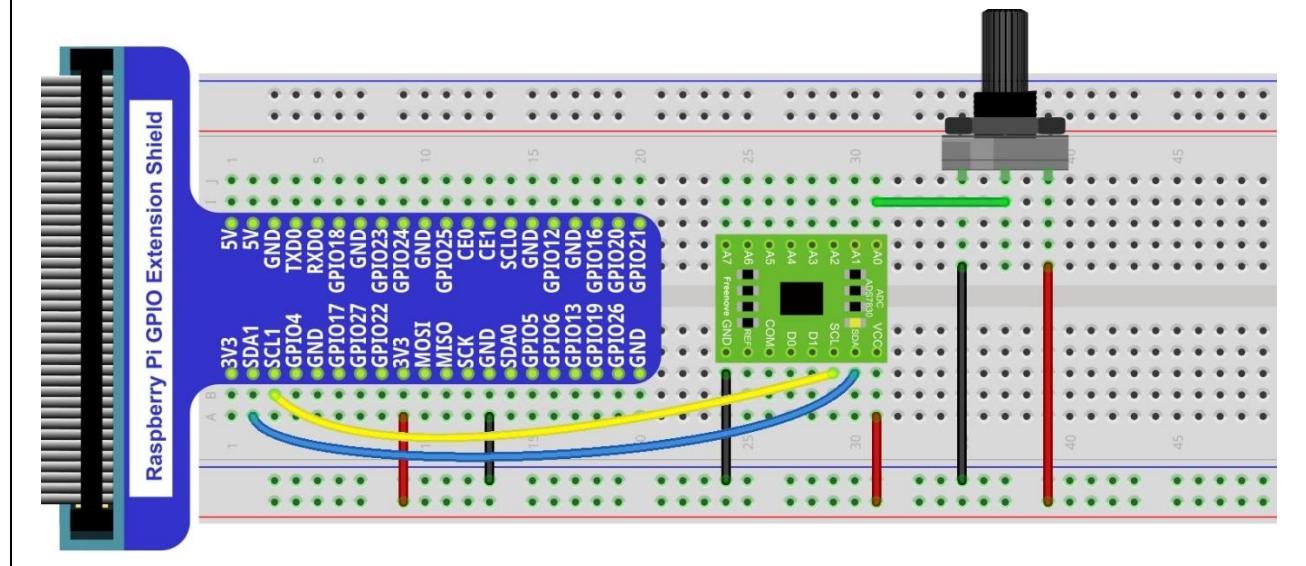
Please keep the **chip mark** consistent to make the chips under right direction and position.

Circuit with ADS7830

Schematic diagram



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



Configure I2C and Install Smbus

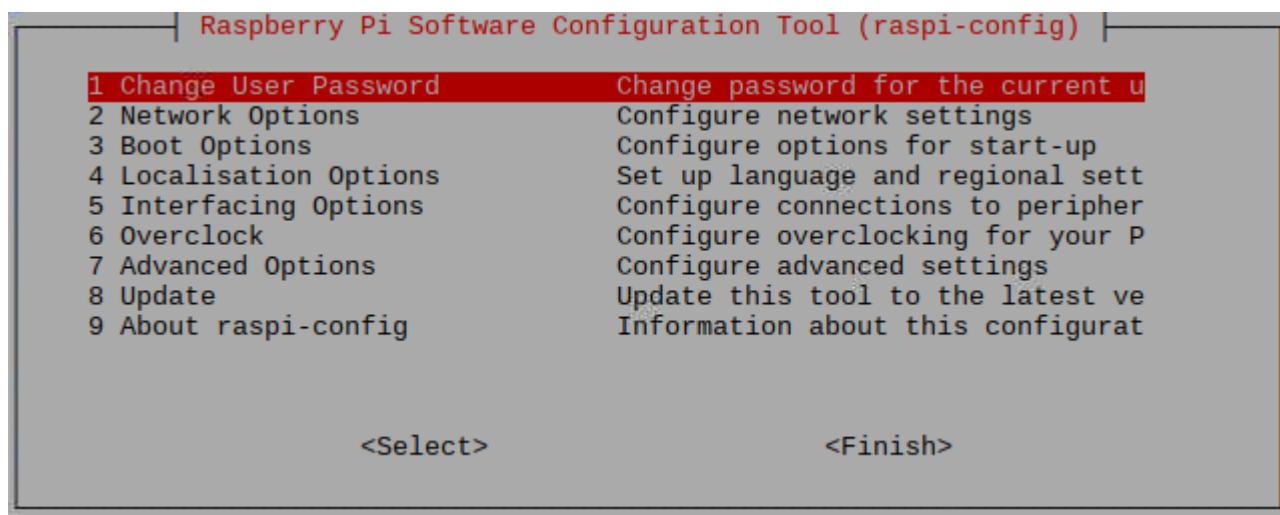
Enable I2C

The I2C interface raspberry pie is closed in default. You need to open it manually. You can enable the I2C interface in the following way.

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:

```
pi@raspberrypi:~ $ lsmod | grep i2c
i2c_bcm2708          4770  0
i2c_dev              5859  0
pi@raspberrypi:~ $
```

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 analyze 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 content.

```
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:

```
1 #include <wiringPi.h>
2 #include <wiringPiI2C.h>
3 #include <stdio.h>
4 #include <ADCDevice.hpp>
5
6 ADCDevice *adc; // Define an ADC Device class object
7
8 int main(void) {
9     adc = new ADCDevice();
10    printf("Program is starting ... \n");
11
12    if(adc->detectI2C(0x48)){ // Detect the pcf8591.
13        delete adc;
14        adc = new PCF8591(); // If detected, create an instance of PCF8591.
15    }
16    else if(adc->detectI2C(0x4b)){// Detect the ads7830
17        delete adc;
18        adc = new ADS7830(); // If detected, create an instance of ADS7830.
```

```

19 }
20 else{
21     printf("No correct I2C address found, \n"
22         "Please use command 'i2cdetect -y 1' to check the I2C address! \n"
23         "Program Exit. \n");
24     return -1;
25 }
26
27 while(1){
28     int adcValue = adc->analogRead(0); //read analog value of A0 pin
29     float voltage = (float)adcValue / 255.0 * 3.3; // Calculate voltage
30     printf("ADC value : %d , \tVoltage : %.2fV\n", adcValue, voltage);
31     delay(100);
32 }
33 }
```

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 detectI2C(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/ADCDevice-1.0.2
```

2. Unzip the file.

```
tar zxvf ADCDevice-1.0.2.tar.gz
```

3. Enter the unzipped folder.

```
cd ADCDevice-1.0.2
```

4. Install.

```
sudo python 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
```

Execute the following command. Observe the project result, and then analyze 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 : 169, Voltage : 2.19
ADC Value : 168, Voltage : 2.17
ADC Value : 168, Voltage : 2.17
```

The following is the code:

```
1 import time
2 from ADCDevice import *
3
4 adc = ADCDevice() # Define an ADCDevice class object
5
6 def setup():
7     global adc
8     if(adc.detectI2C(0x48)): # Detect the pcf8591.
9         adc = PCF8591()
```

```

10 elif(adc.detectI2C(0x4b)): # Detect the ads7830
11     adc = ADS7830()
12 else:
13     print("No correct I2C address found, \n"
14         "Please use command 'i2cdetect -y 1' to check the I2C address! \n"
15         "Program Exit. \n");
16     exit(-1)
17
18 def loop():
19     while True:
20         value = adc.analogRead(0)    # read the ADC value of channel 0
21         voltage = value / 255.0 * 3.3 # calculate the voltage value
22         print ('ADC Value : %d, Voltage : %.2f'%(value,voltage))
23         time.sleep(0.1)
24
25 def destroy():
26     adc.close()
27
28 if __name__ == '__main__': # Program entrance
29     print ('Program is starting ... ')
30     try:
31         setup()
32         loop()
33     except KeyboardInterrupt: # Press ctrl-c to end the program.
34         destroy()

```

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 detectI2C(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.

	<pre> 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" </pre>
--	--

```
"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)
```

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
```

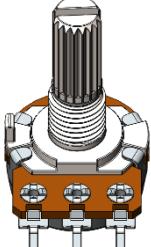
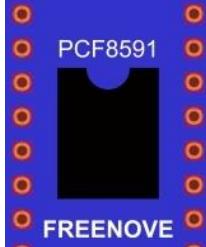
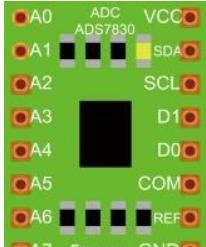
Chapter 8 Potentiometer & LED

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

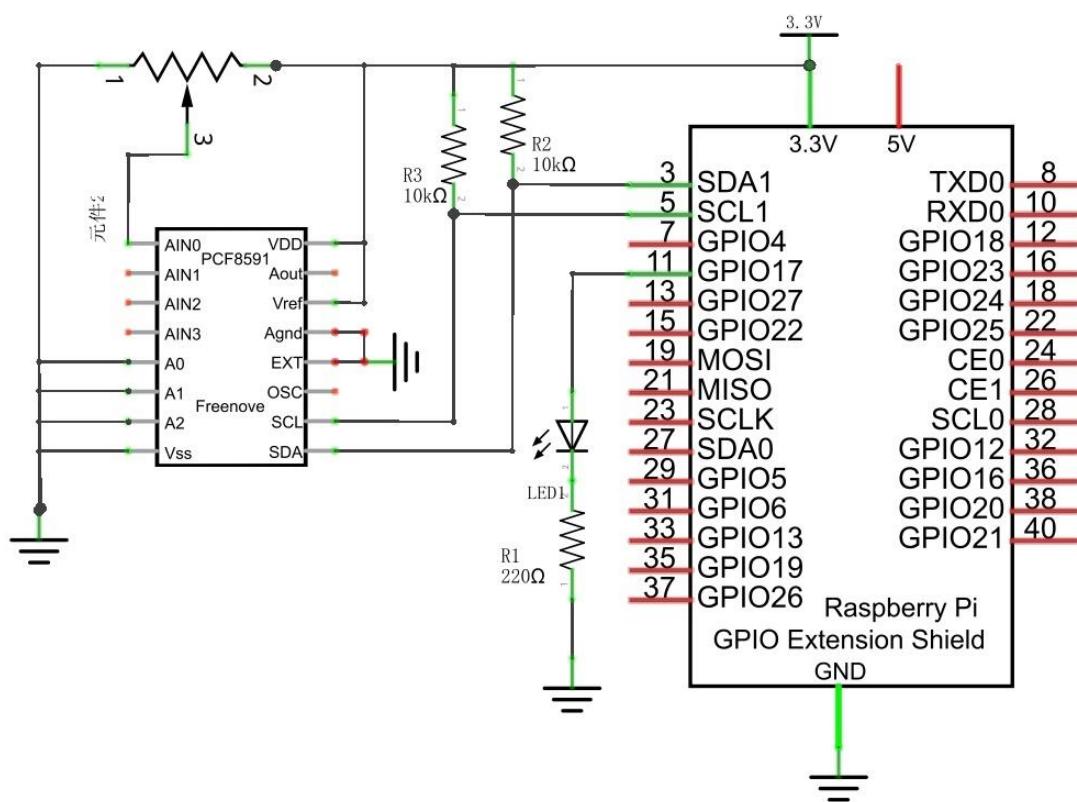
In this project, we will make a soft light. Use ADC Module to read ADC value of potentiometers and map it to duty cycle ratio of PWM used to control the brightness of LED. Then you can make the LED brightness changed by adjusting the potentiometer.

Component List

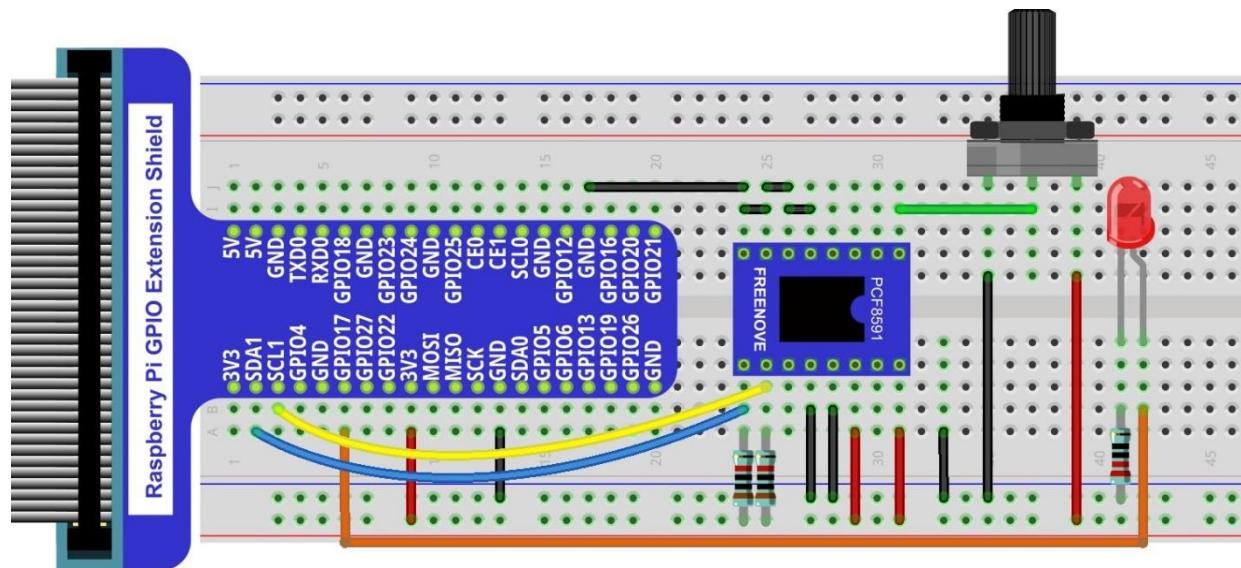
Raspberry Pi x1 GPIO Extension Board & Wire x1 BreadBoard x1	Jumper M/M x17
Rotary potentiometer x1 	ADC module x1  Or 

Circuit with PCF8591

Schematic diagram

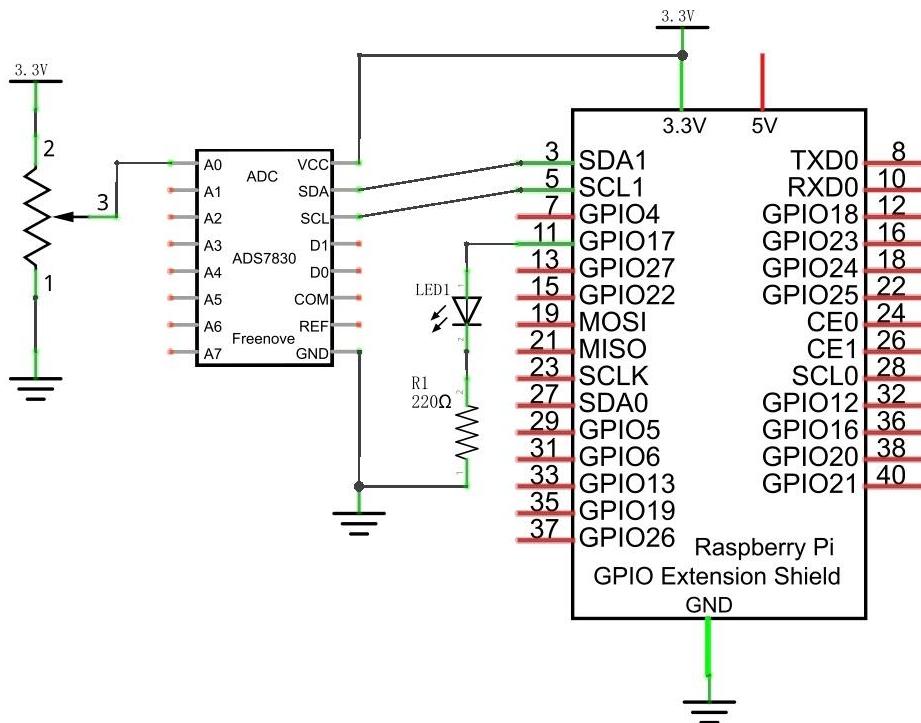


Hardware connection

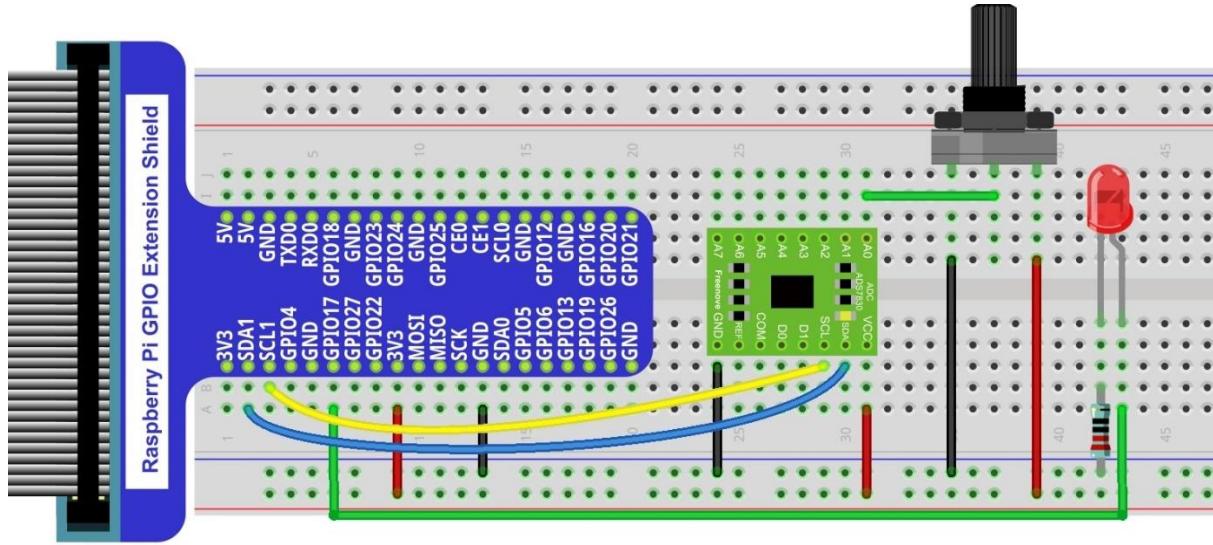


Circuit with ADS7830

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 analyze 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 quantity. And brightness of LED will be changed consequently.

The following is the code:

```
1 #include <wiringPi.h>
2 #include <stdio.h>
3 #include <softPwm.h>
4 #include <ADCDevice.hpp>
5
6 #define ledPin 0
7
8 ADCDevice *adc; // Define an ADC Device class object
9
10 int main(void) {
11     adc = new ADCDevice();
12     printf("Program is starting ... \n");
13
14     if(adc->detectI2C(0x48)){ // Detect the pcf8591.
15         delete adc;           // Free previously pointed memory
16         adc = new PCF8591(); // If detected, create an instance of PCF8591.
17     }
18     else if(adc->detectI2C(0x4b)){// Detect the ads7830
19         delete adc;           // Free previously pointed memory
20         adc = new ADS7830(); // If detected, create an instance of ADS7830.
21     }
22     else{
23         printf("No correct I2C address found, \n"
24             "Please use command 'i2cdetect -y 1' to check the I2C address! \n"
25     }
```

```
25     "Program Exit. \n");
26     return -1;
27 }
28 wiringPiSetup();
29 softPwmCreate(ledPin, 0, 100);
30 while(1){
31     int adcValue = adc->analogRead(0);      //read analog value of A0 pin
32     softPwmWrite(ledPin, adcValue*100/255);    // Mapping to PWM duty cycle
33     float voltage = (float)adcValue / 255.0 * 3.3; // Calculate voltage
34     printf("ADC value : %d , \tVoltage : %.2fV\n", adcValue, voltage);
35     delay(30);
36 }
37 return 0;
38 }
```

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 analyze 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 quantity. And brightness of LED will be changed consequently.

The following is the code:

```
1 import RPi.GPIO as GPIO
2 import time
3 from ADCDevice import *
4
5 ledPin = 11
6 adc = ADCDevice() # Define an ADCDevice class object
7
8 def setup():
9     global adc
10    if(adc.detectI2C(0x48)): # Detect the pcf8591.
11        adc = PCF8591()
12    elif(adc.detectI2C(0x4b)): # Detect the ads7830
13        adc = ADS7830()
14    else:
15        print("No correct I2C address found, \n"
16              "Please use command 'i2cdetect -y 1' to check the I2C address! \n"
17              "Program Exit. \n");
18        exit(-1)
19    global p
20    GPIO.setmode(GPIO.BCM)
21    GPIO.setup(ledPin,GPIO.OUT)
22    p = GPIO.PWM(ledPin,1000)
23    p.start(0)
24
25 def loop():
26     while True:
27         value = adc.analogRead(0)      # read the ADC value of channel 0
28         p.ChangeDutyCycle(value*100/255)      # Mapping to PWM duty cycle
29         voltage = value / 255.0 * 3.3 # calculate the voltage value
```

```
30     print (' ADC Value : %d, Voltage : %.2f' %(value,voltage))
31     time.sleep(0.03)
32
33 def destroy():
34     adc.close()
35
36 if __name__ == '__main__': # Program entrance
37     print (' Program is starting ... ')
38     try:
39         setup()
40         loop()
41     except KeyboardInterrupt: # Press ctrl-c to end the program.
42         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
```

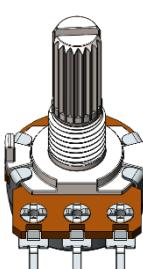
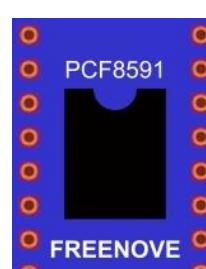
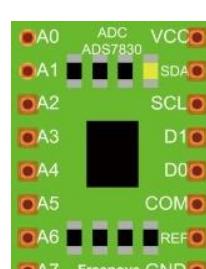
Chapter 9 Potentiometer & RGBLED

In this chapter, we will use 3 potentiometers to control the brightness of 3 LEDs of RGBLED to make it show different colors.

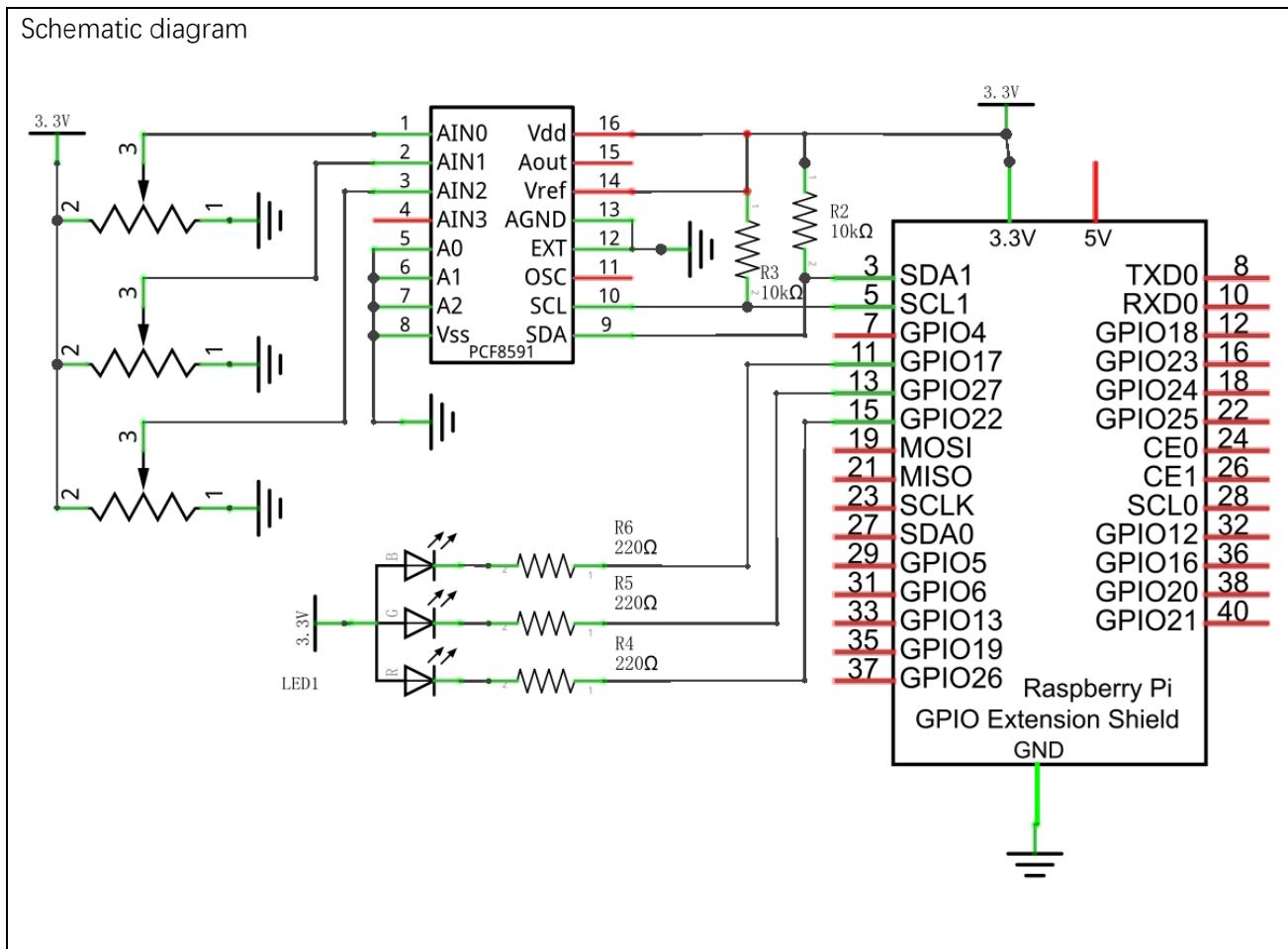
Project 9.1 Colorful Light

In this project, 3 potentiometers are used to control RGBLED and the principle is the same with the front soft light. Namely, read the voltage value of the potentiometer and then convert it to PWM used to control LED brightness. Difference is that the front one need only one LED, but this project needs a RGBLED (3 LEDs) .

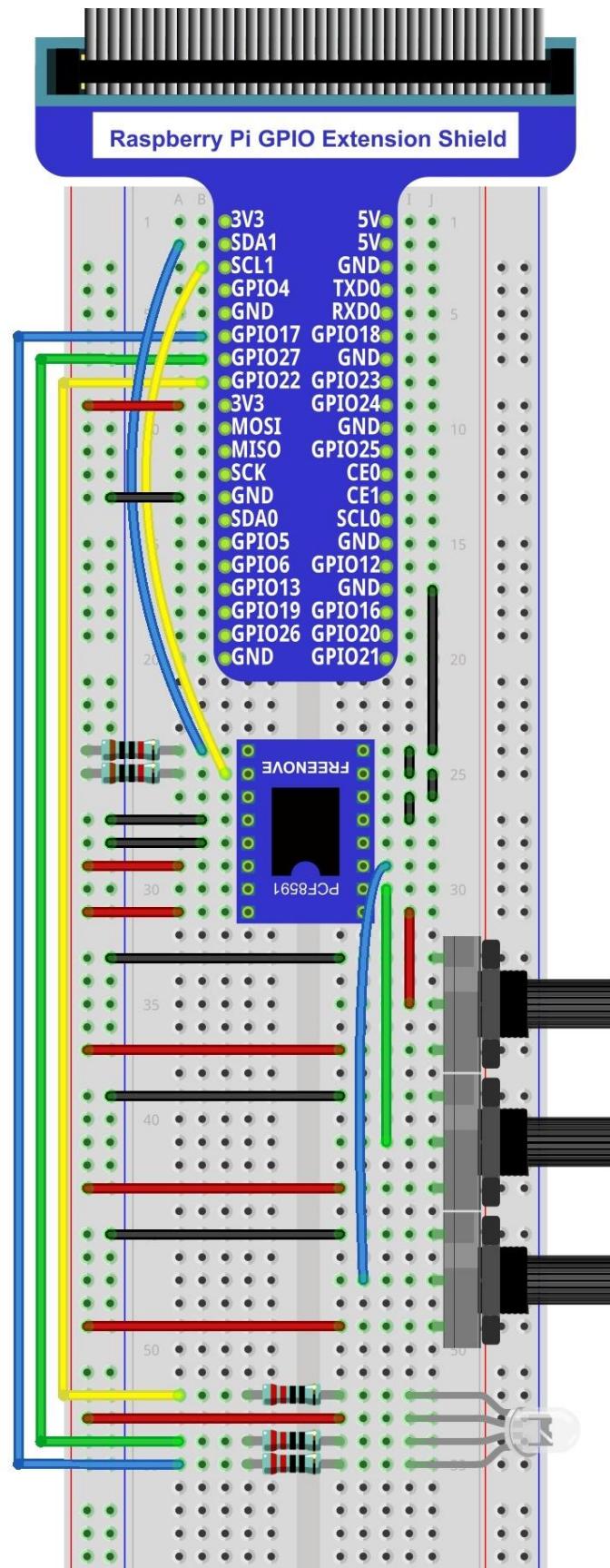
Component List

Raspberry Pi x1 GPIO Extension Board & Wire x1 BreadBoard x1	Jumper M/M x17 			
Rotary potentiometer x1 	ADC module x1  Or 	10kΩ x2 	220Ω x3 	RGBLED x1 

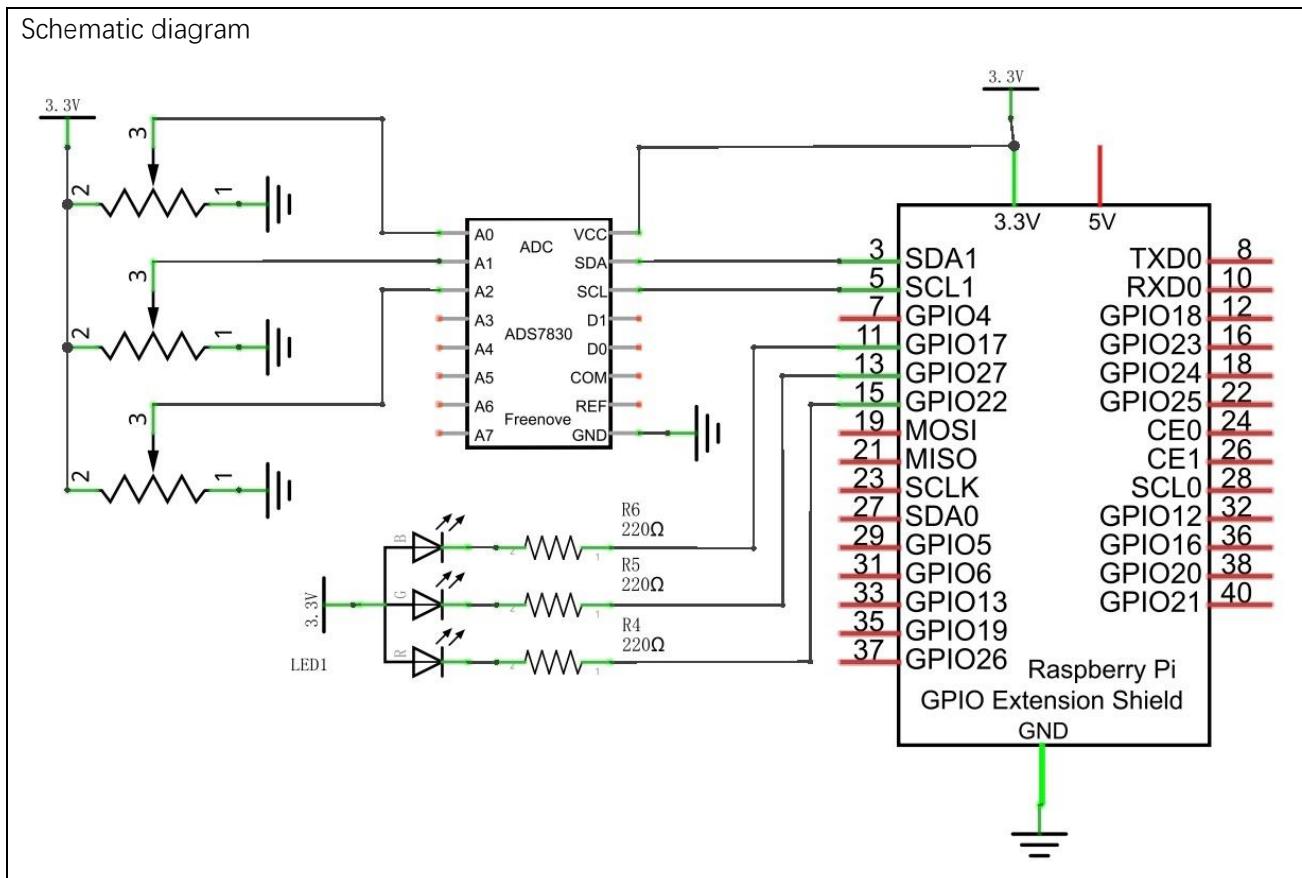
Circuit with PCF8591



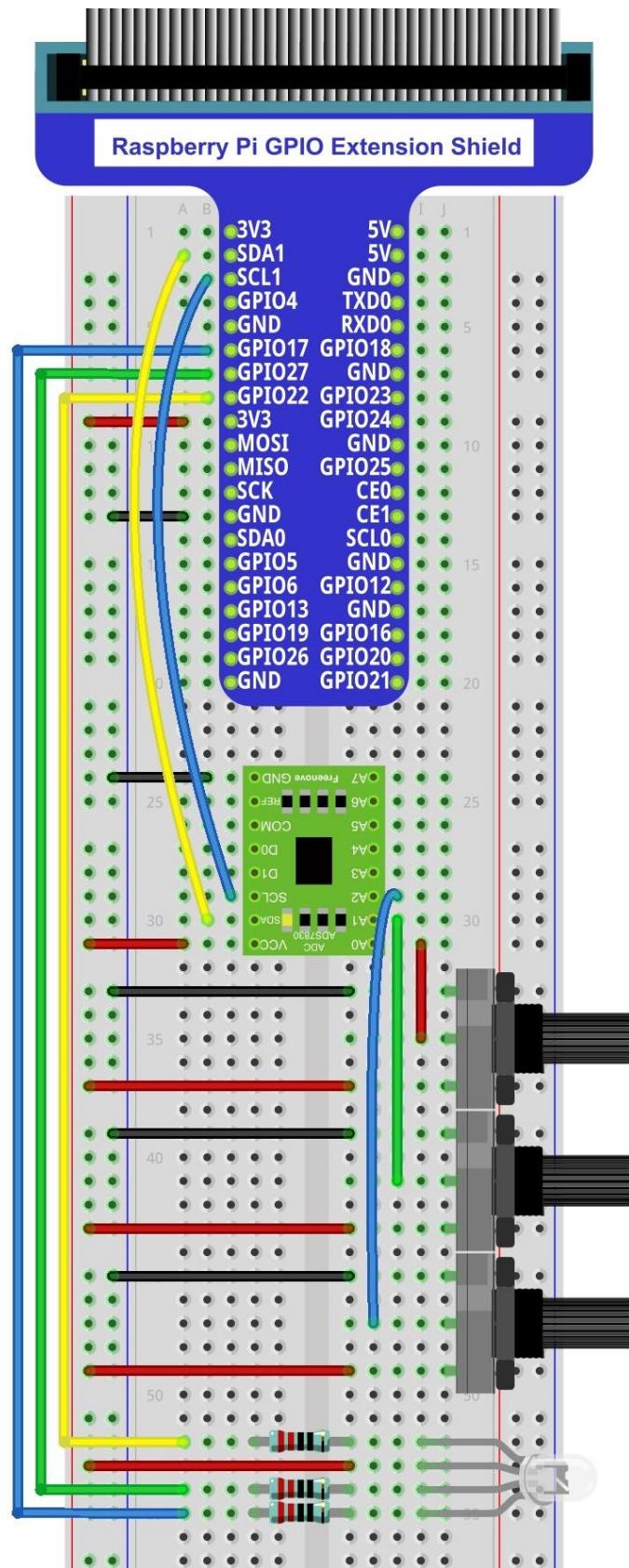
Hardware connection. If you need any support, please free to contact us via: support@freenove.com



Circuit with ADS7830



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



Code

C Code 9.1.1 Colorful 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 analyze the code.

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

1. Use cd command to enter 09.1.1_ColorfulSoftlight directory of C code.

```
cd ~/Freenove_Kit/Code/C_Code/09.1.1_ColorfulSoftlight
```

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

```
"ColorfulSoftlight".
```

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

3. Then run the generated file "ColorfulSoftlight".

```
sudo ./ColorfulSoftlight
```

After the program is executed, rotate one of potentiometers, then the color of RGBLED will change consequently. And the terminal window will print out the ADC value of each potentiometer.

```
ADC value val_Red: 147 ,      val_Green: 192 ,      val_Blue: 238
ADC value val_Red: 147 ,      val_Green: 192 ,      val_Blue: 206
ADC value val_Red: 147 ,      val_Green: 192 ,      val_Blue: 174
ADC value val_Red: 147 ,      val_Green: 192 ,      val_Blue: 152
ADC value val_Red: 147 ,      val_Green: 192 ,      val_Blue: 139
ADC value val_Red: 147 ,      val_Green: 192 ,      val_Blue: 138
ADC value val_Red: 147 ,      val_Green: 192 ,      val_Blue: 138
ADC value val_Red: 147 ,      val_Green: 192 ,      val_Blue: 138
ADC value val_Red: 147 ,      val_Green: 192 ,      val_Blue: 138
```

The following is the program code:

```
1 #include <wiringPi.h>
2 #include <stdio.h>
3 #include <softPwm.h>
4 #include <ADCDevice.hpp>
5
6 #define ledRedPin 3           //define 3 pins for RGBLED
7 #define ledGreenPin 2
8 #define ledBluePin 0
9
10 ADCDevice *adc; // Define an ADC Device class object
11
12 int main(void) {
13     adc = new ADCDevice();
14     printf("Program is starting ... \n");
15
16     if(adc->detectI2C(0x48)){ // Detect the pcf8591.
17         delete adc;          // Free previously pointed memory
```

```
18         adc = new PCF8591(); // If detected, create an instance of PCF8591.
19     }
20     else if(adc->detectI2C(0x4b)){// Detect the ads7830
21         delete adc; // Free previously pointed memory
22         adc = new ADS7830(); // If detected, create an instance of ADS7830.
23     }
24     else{
25         printf("No correct I2C address found, \n"
26             "Please use command 'i2cdetect -y 1' to check the I2C address! \n"
27             "Program Exit. \n");
28         return -1;
29     }
30     wiringPiSetup();
31     softPwmCreate(ledRedPin, 0, 100); //creat 3 PMW output pins for RGBLED
32     softPwmCreate(ledGreenPin, 0, 100);
33     softPwmCreate(ledBluePin, 0, 100);
34     while(1){
35         int val_Red = adc->analogRead(0); //read analog value of 3 potentiometers
36         int val_Green = adc->analogRead(1);
37         int val_Blue = adc->analogRead(2);
38         softPwmWrite(ledRedPin, val_Red*100/255); //map the read value of
39         potentiometers into PWM value and output it
40         softPwmWrite(ledGreenPin, val_Green*100/255);
41         softPwmWrite(ledBluePin, val_Blue*100/255);
42         //print out the read ADC value
43         printf("ADC value val_Red: %d ,\tval_Green: %d ,\tval_Blue: %d
44 \n", val_Red, val_Green, val_Blue);
45         delay(100);
46     }
47     return 0;
48 }
```

In the code, read the ADC value of 3 potentiometers and map it into PWM duty cycle to control the control 3 LEDs with different color of RGBLED, respectively.

Python Code 9.1.1 ColorfulSoftlight

If you did not [configure I2C](#), please refer to [Chapter 7](#). If you did, please move on.

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

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

1. Use cd command to enter 09.1.1_ColorfulSoftlight directory of Python code.

```
cd ~/Freenove_Kit/Code/Python_Code/09.1.1_ColorfulSoftlight
```

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

```
python ColorfulSoftlight.py
```

After the program is executed, rotate one of potentiometers, then the color of RGBLED will change consequently. And the terminal window will print out the ADC value of each potentiometer.

The following is the program code:

```

1 import RPi.GPIO as GPIO
2 import time
3 from ADCDevice import *
4
5 ledRedPin = 15      # define 3 pins for RGBLED
6 ledGreenPin = 13
7 ledBluePin = 11
8 adc = ADCDevice() # Define an ADCDevice class object
9
10 def setup():
11     global adc
12     if(adc.detectI2C(0x48)): # Detect the pcf8591.
13         adc = PCF8591()
14     elif(adc.detectI2C(0x4b)): # Detect the ads7830
15         adc = ADS7830()
16     else:
17         print("No correct I2C address found, \n"
18             "Please use command 'i2cdetect -y 1' to check the I2C address! \n"
19             "Program Exit. \n");
20         exit(-1)
21
22     global p_Red, p_Green, p_Blue
23     GPIO.setmode(GPIO.BCM)
24     GPIO.setup(ledRedPin,GPIO.OUT)      # set RGBLED pins to OUTPUT mode
25     GPIO.setup(ledGreenPin,GPIO.OUT)
26     GPIO.setup(ledBluePin,GPIO.OUT)
27
28     p_Red = GPIO.PWM(ledRedPin,1000)    # configure PWM for RGBLED pins, set PWM
29 Frequency to 1kHz
30     p_Red.start(0)
31     p_Green = GPIO.PWM(ledGreenPin,1000)
```

```
32     p_Green.start(0)
33     p_Blue = GPIO.PWM(ledBluePin, 1000)
34     p_Blue.start(0)
35
36 def loop():
37     while True:
38         value_Red = adc.analogRead(0)          # read ADC value of 3 potentiometers
39         value_Green = adc.analogRead(1)
40         value_Blue = adc.analogRead(2)
41         p_Red.ChangeDutyCycle(value_Red*100/255) # map the read value of potentiometers
42         into PWM value and output it
43         p_Green.ChangeDutyCycle(value_Green*100/255)
44         p_Blue.ChangeDutyCycle(value_Blue*100/255)
45         # print read ADC value
46         print (' ADC Value
47         value_Red: %d , \tvalue_Green: %d , \tvalue_Blue: %d' %(value_Red,value_Green,value_Blue))
48         time.sleep(0.01)
49
50 def destroy():
51     adc.close()
52     GPIO.cleanup()
53
54 if __name__ == '__main__': # Program entrance
55     print (' Program is starting ... ')
56     setup()
57     try:
58         loop()
59     except KeyboardInterrupt: # Press ctrl-c to end the program.
60         destroy()
```

In the code, read the ADC value of 3 potentiometers and map it into PWM duty cycle to control the control 3 LEDs with different color of RGBLED, respectively.



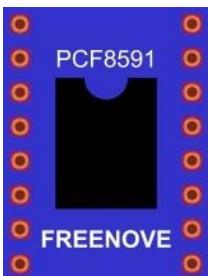
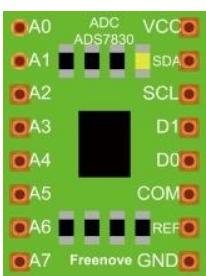
Chapter 10 Photoresistor & LED

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

Project 10.1 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.

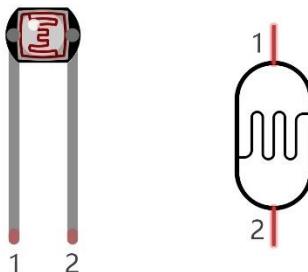
Component List

Raspberry Pi x1 GPIO Extension Board & Wire x1 BreadBoard x1	Jumper M/M			
Photoresistor x1 	ADC module x1  Or 	10kΩ x3 	220Ω x1 	LED x1 

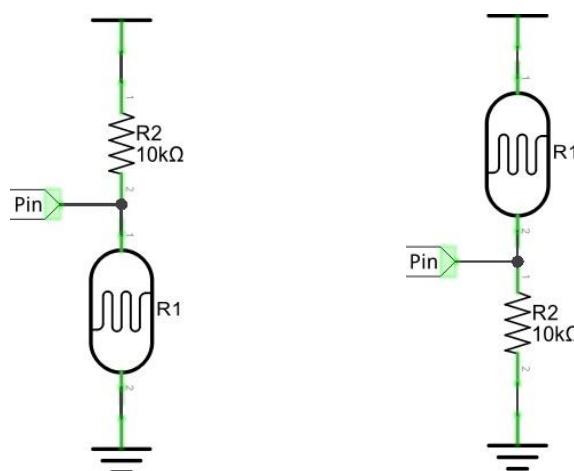
Component knowledge

Photoresistor

Photoresistor is a light sensitive resistor. When the strength that light casts onto the photoresistor surface is not the same, resistance of photoresistor will change. 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:

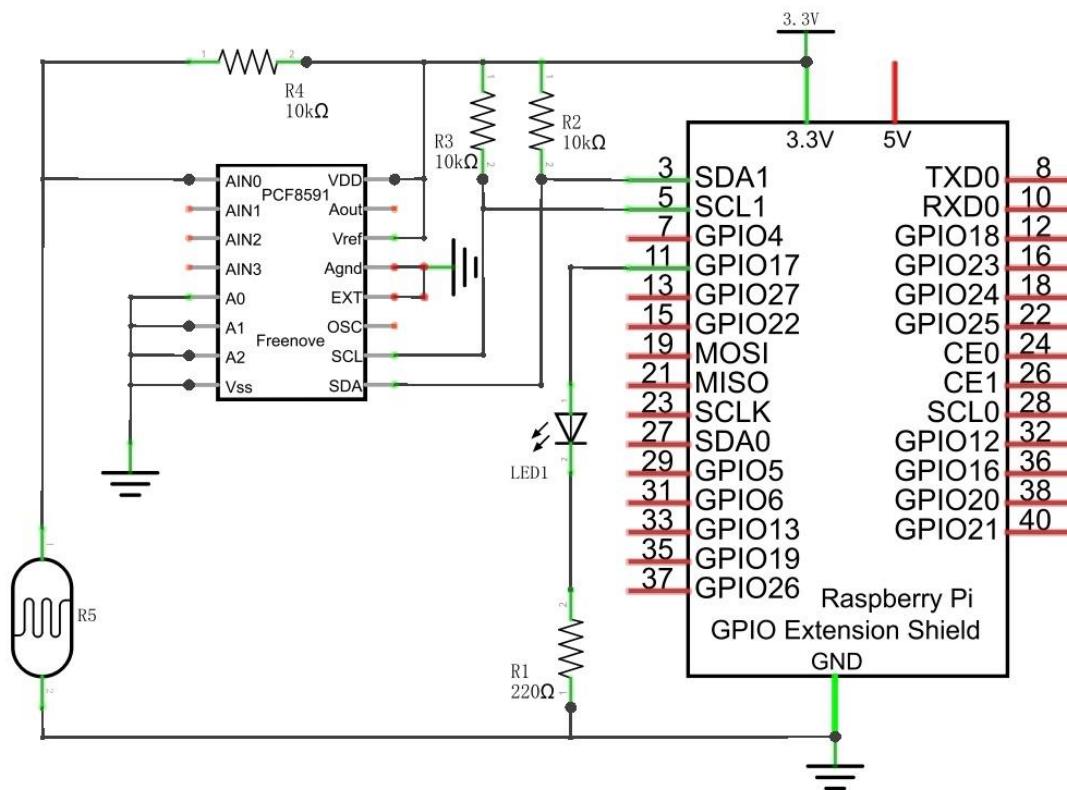


In the above circuit, when photoresistor resistance changes due to light intensity, voltage between photoresistor and resistor R1 will change, so light's intensity can be obtained by measuring the voltage.

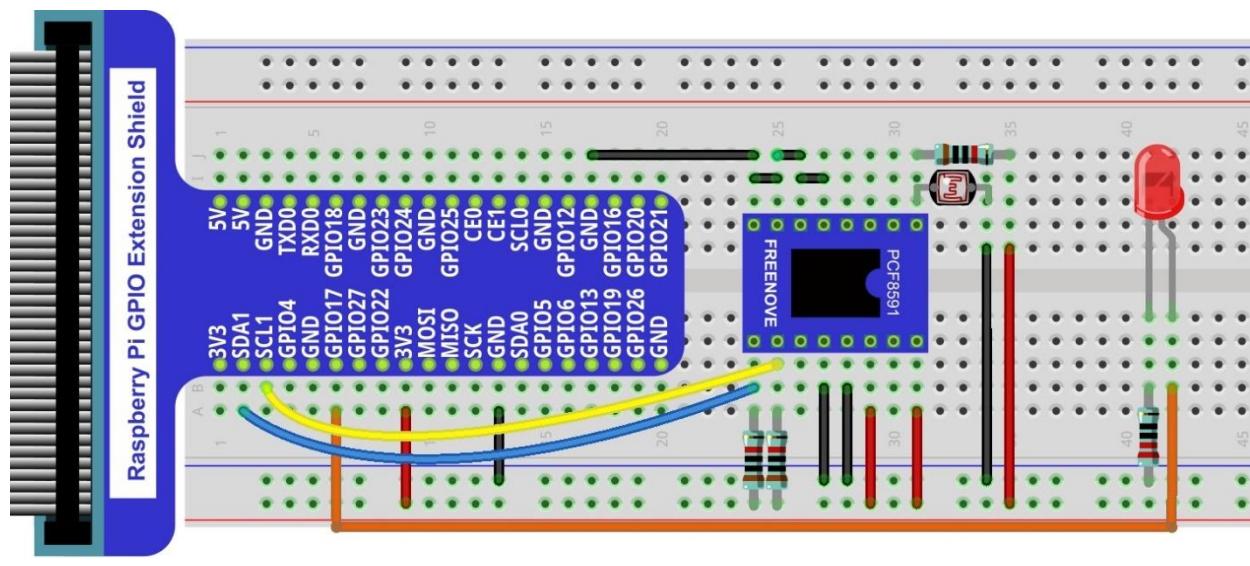
Circuit with PCF8591

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



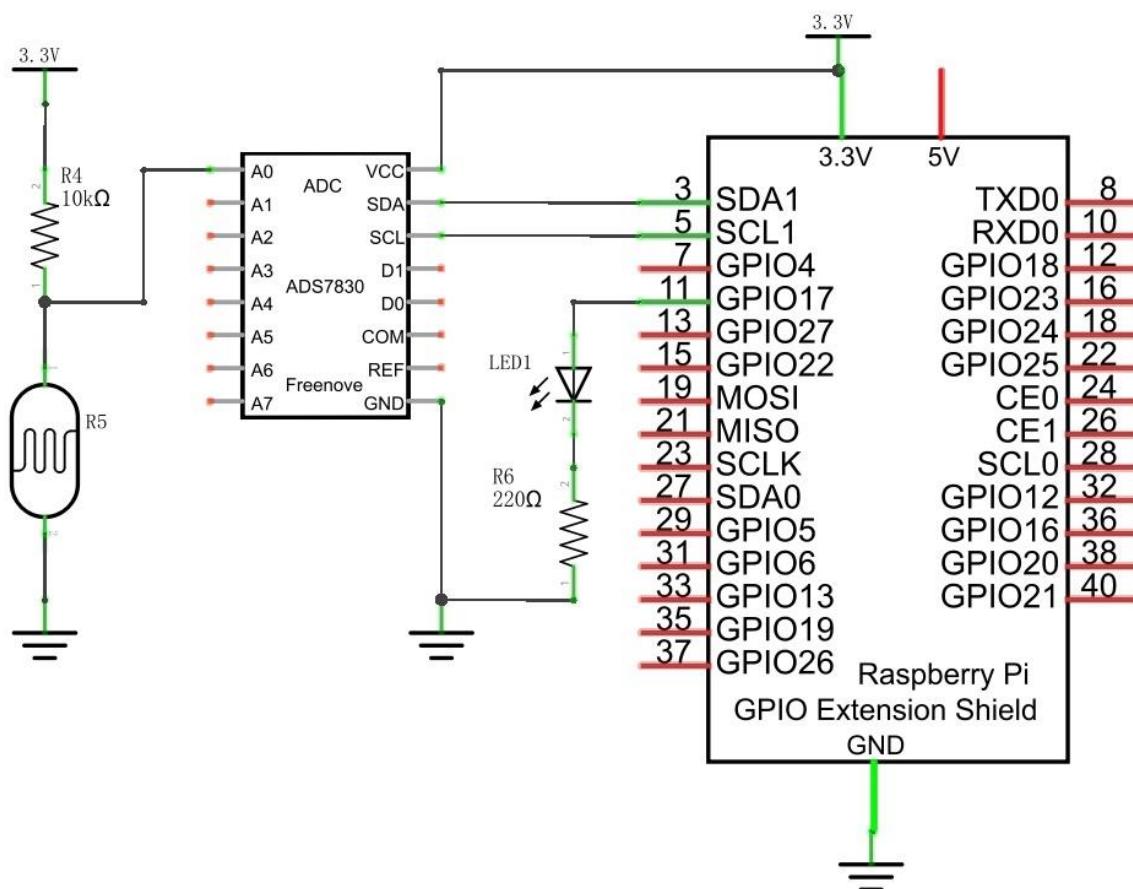
Hardware connection



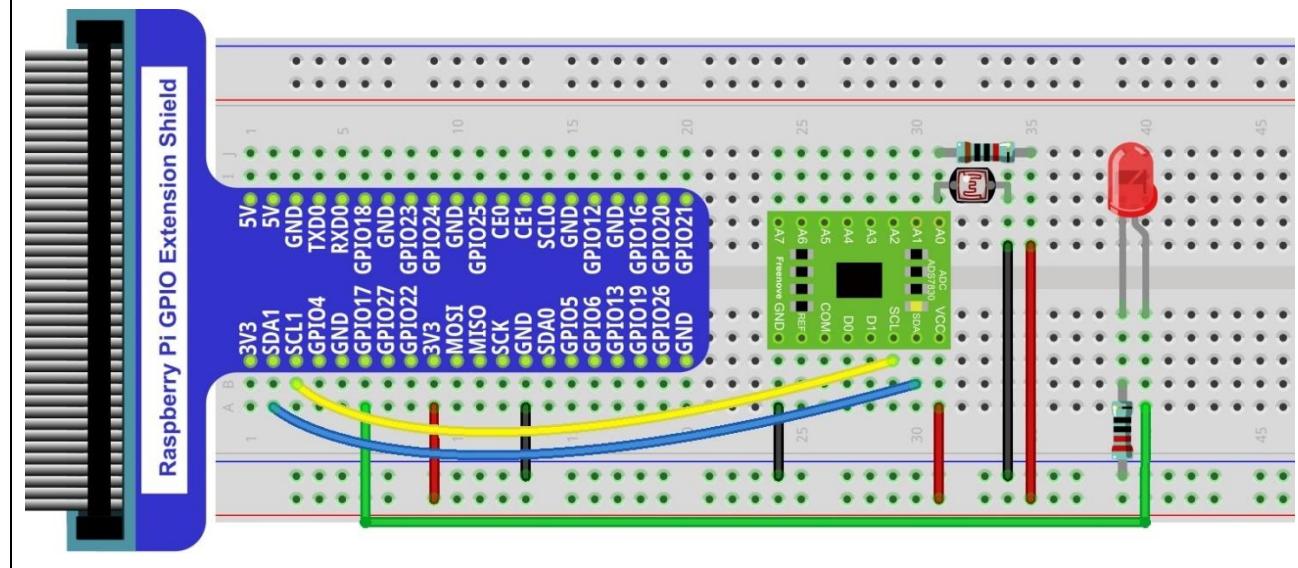
Circuit with ADS7830

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 10.1.1 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 analyze the code.

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

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

```
cd ~/Freenove_Kit/Code/C_Code/10.1.1_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 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 quantity.

The following is the program code:

```

1 #include <wiringPi.h>
2 #include <stdio.h>
3 #include <softPwm.h>
4 #include <ADCDevice.hpp>
5
6 #define ledPin 0
7
8 ADCDevice *adc; // Define an ADC Device class object
9
10 int main(void) {
11     adc = new ADCDevice();
12     printf("Program is starting ... \n");
13
14     if(adc->detectI2C(0x48)){ // Detect the pcf8591.
15         delete adc;           // Free previously pointed memory
16         adc = new PCF8591(); // If detected, create an instance of PCF8591.
17     }
18     else if(adc->detectI2C(0x4b)){// Detect the ads7830
19         delete adc;           // Free previously pointed memory
20         adc = new ADS7830(); // If detected, create an instance of ADS7830.
21     }
22     else{
23         printf("No correct I2C address found, \n"
24             "Please use command 'i2cdetect -y 1' to check the I2C address! \n"
25             "Program Exit. \n");

```

```
26         return -1;
27     }
28     wiringPiSetup();
29     softPwmCreate(ledPin, 0, 100);
30     while(1) {
31         int value = adc->analogRead(0); //read analog value of A0 pin
32         softPwmWrite(ledPin, value*100/255);
33         float voltage = (float)value / 255.0 * 3.3; // calculate voltage
34         printf("ADC value : %d , \tVoltage : %.2fV\n", value, voltage);
35         delay(100);
36     }
37     return 0;
38 }
```

Python Code 10.1.1 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 analyze 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/10.1.1_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 quantity.

The following is the program code:

```

1 import RPi.GPIO as GPIO
2 import time
3 from ADCDevice import *
4
5 ledPin = 11 # define ledPin
6 adc = ADCDevice() # Define an ADCDevice class object
7
8 def setup():
9     global adc
10    if(adc.detectI2C(0x48)): # Detect the pcf8591.
11        adc = PCF8591()
12    elif(adc.detectI2C(0x4b)): # Detect the ads7830
13        adc = ADS7830()
14    else:
15        print("No correct I2C address found, \n"
16              "Please use command 'i2cdetect -y 1' to check the I2C address! \n"
17              "Program Exit. \n");
18        exit(-1)
19    global p
20    GPIO.setmode(GPIO.BOARD)
21    GPIO.setup(ledPin,GPIO.OUT)    # set ledPin to OUTPUT mode
22    GPIO.output(ledPin,GPIO.LOW)
23
24    p = GPIO.PWM(ledPin,1000) # set PWM Frequnce to 1kHz
25    p.start(0)
26
27 def loop():
28     while True:
29         value = adc.analogRead(0)      # read the ADC value of channel 0
30         p.ChangeDutyCycle(value*100/255)
31         voltage = value / 255.0 * 3.3

```

```
32     print (' ADC Value : %d, Voltage : %.2f' %(value,voltage))
33     time.sleep(0.01)
34
35 def destroy():
36     adc.close()
37     GPIO.cleanup()
38
39 if __name__ == '__main__': # Program entrance
40     print (' Program is starting ... ')
41     setup()
42     try:
43         loop()
44     except KeyboardInterrupt: # Press ctrl-c to end the program.
45         destroy()
```

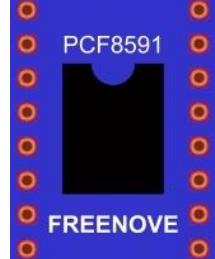
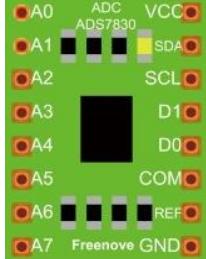
Chapter 11 Thermistor

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

Project 11.1 Thermometer

The resistance of thermistor will be changed with temperature change. So we can make a thermometer according to this feature.

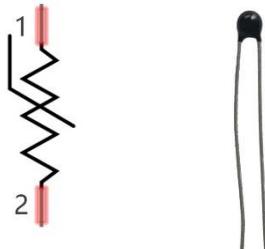
Component List

Raspberry Pi x1 GPIO Extension Board & Wire x1 BreadBoard x1	Jumper M/M
Thermistor x1	ADC module x1
	  or

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:

$$R_t = R \cdot \exp[B \cdot (1/T_2 - 1/T_1)]$$

Where:

Rt is the thermistor resistance under T2 temperature;

R is the nominal resistance of thermistor under T1 temperature;

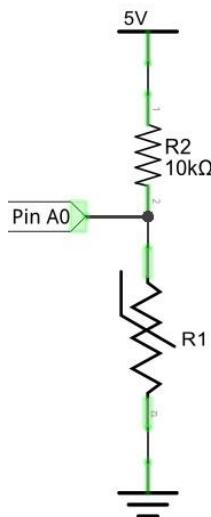
EXP[n] is nth power of E;

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 obtain resistance value of thermistor, and then can use the formula to obtain the temperature value.

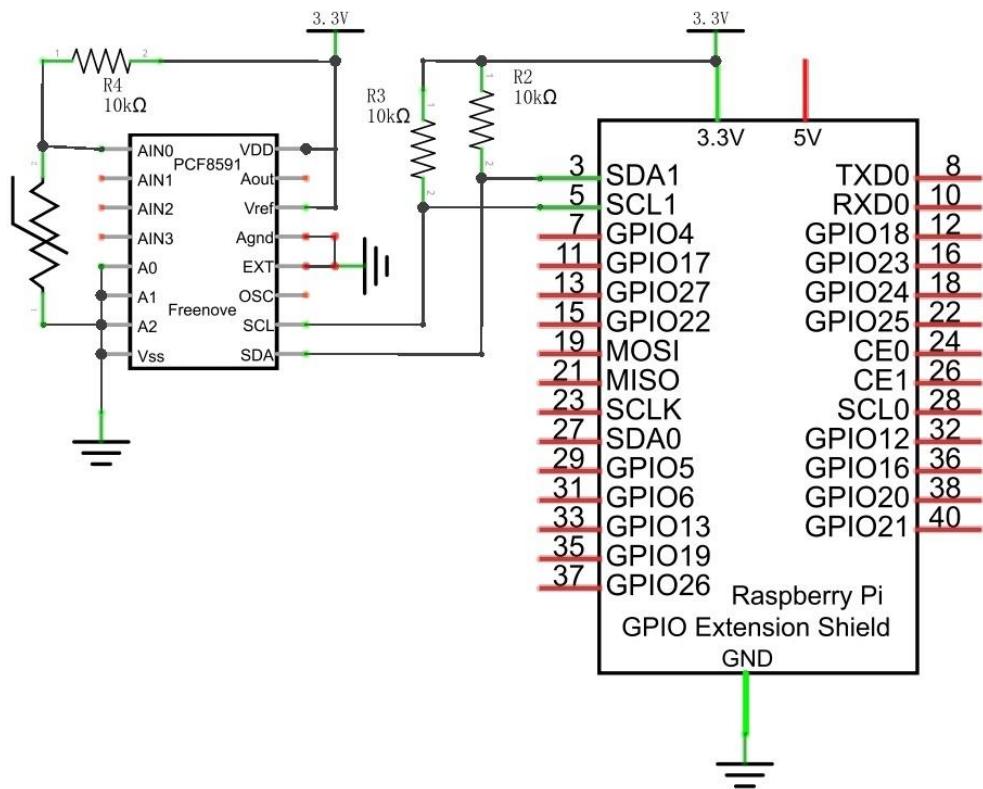
Consequently, the temperature formula can be concluded:

$$T_2 = 1/(1/T_1 + \ln(R_t/R)/B)$$

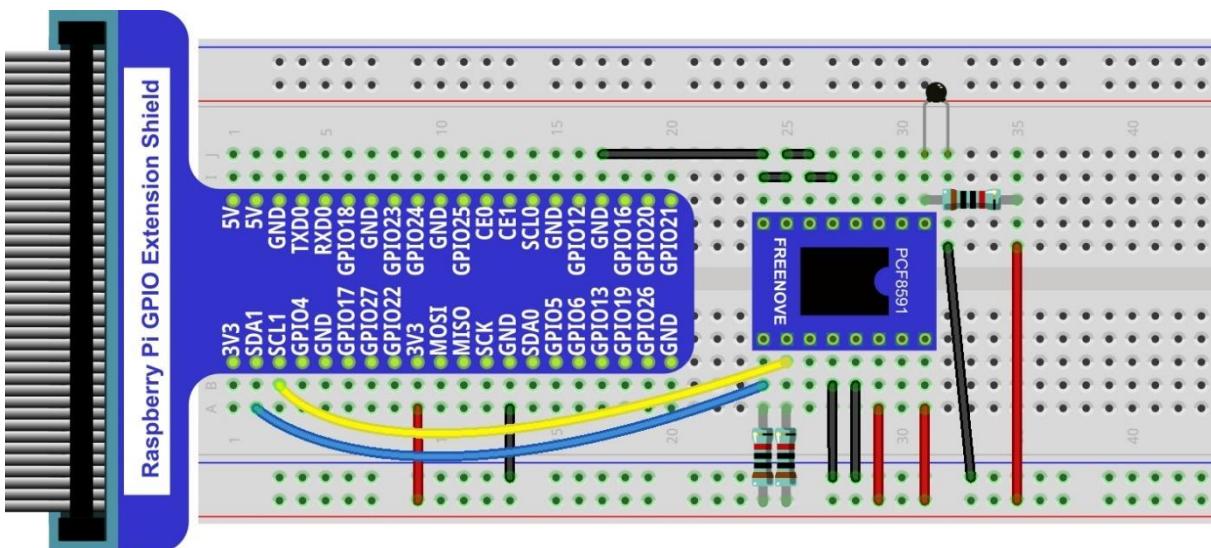
Circuit with PCF8591

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



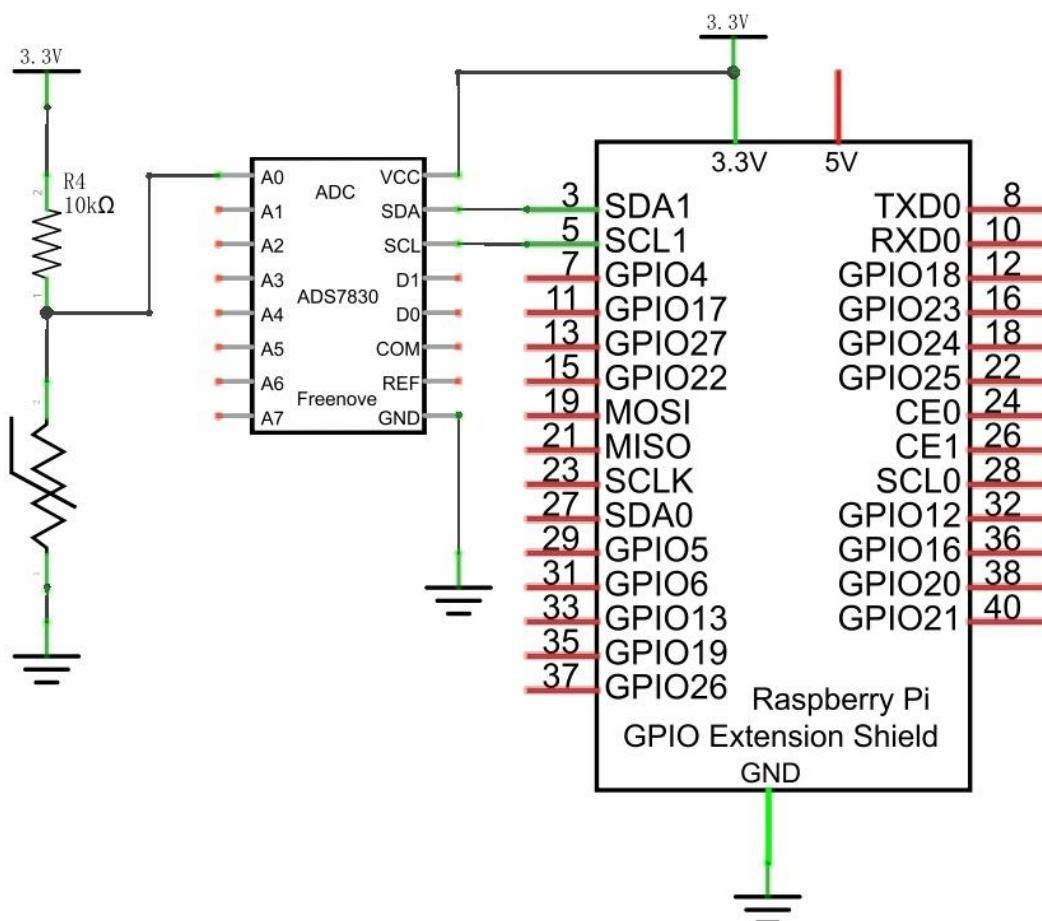
Hardware connection. If you need any support, please feel free to contact us via: support@freenove.com



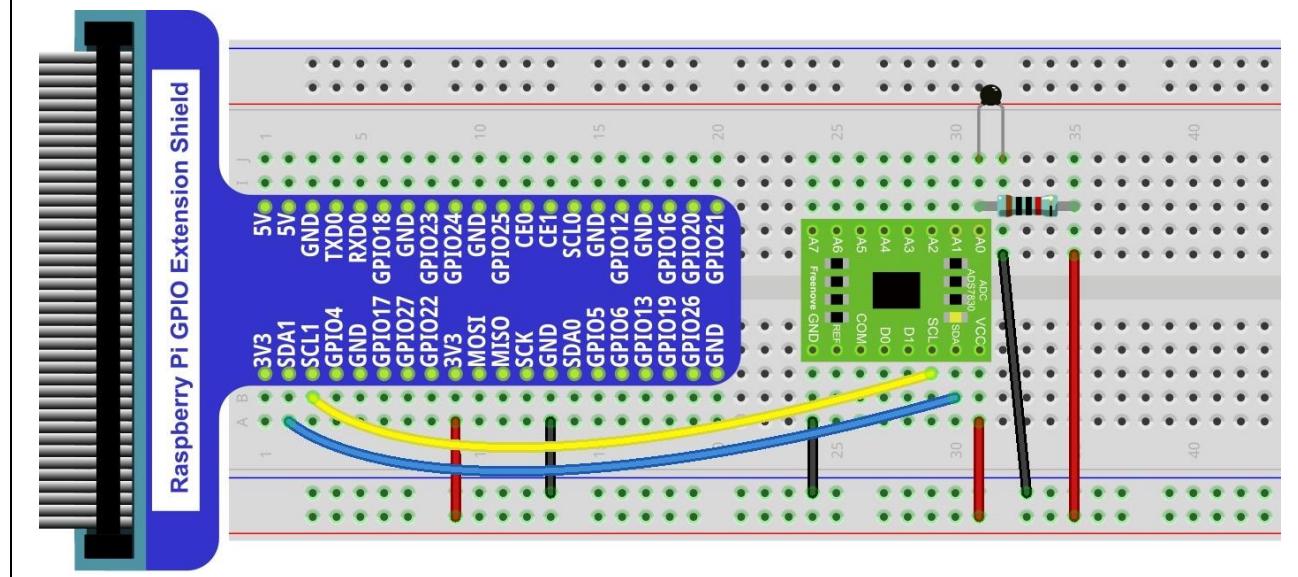
Circuit with ADS

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



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 11.1.1 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 analyze the code.

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

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

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

- 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 hand lasting for a while, then the temperature value will be increased.

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

The following is the code:

```
1 #include <wiringPi.h>
2 #include <stdio.h>
3 #include <math.h>
4 #include <ADCDevice.hpp>
5
6 ADCDevice *adc; // Define an ADC Device class object
7
8 int main(void) {
9     adc = new ADCDevice();
10    printf("Program is starting ... \n");
```

```
11
12     ifadc->detectI2C(0x48){ // Detect the pcf8591.
13         delete adc;           // Free previously pointed memory
14         adc = new PCF8591(); // If detected, create an instance of PCF8591.
15     }
16     else if(adc->detectI2C(0x4b)){// Detect the ads7830
17         delete adc;           // Free previously pointed memory
18         adc = new ADS7830(); // If detected, create an instance of ADS7830.
19     }
20     else{
21         printf("No correct I2C address found, \n"
22             "Please use command 'i2cdetect -y 1' to check the I2C address! \n"
23             "Program Exit. \n");
24         return -1;
25     }
26     printf("Program is starting ... \n");
27     while(1){
28         int adcValue = adc->analogRead(0); //read analog value A0 pin
29         float voltage = (float)adcValue / 255.0 * 3.3; // calculate voltage
30         float Rt = 10 * voltage / (3.3 - voltage); //calculate resistance value of
31 thermistor
32         float tempK = 1/(1/(273.15 + 25) + log(Rt/10)/3950.0); //calculate temperature
33 (Kelvin)
34         float tempC = tempK -273.15; //calculate temperature (Celsius)
35         printf("ADC value : %d ,\tVoltage : %.2fV,
36 \tTemperature : %.2fC\n",adcValue,voltage,tempC);
37         delay(100);
38     }
39     return 0;
40 }
```

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 front formula.

Python Code 11.1.1 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 analyze the code.

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

1. Use cd command to enter 11.1.1_Thermometer directory of Python code.

```
cd ~/Freenove_Kit/Code/Python_Code/11.1.1_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
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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:

```
1 import RPi.GPIO as GPIO
2 import time
3 import math
4 from ADCDevice import *
5
6 adc = ADCDevice() # Define an ADCDevice class object
7
8 def setup():
9     global adc
10    if(adc.detectI2C(0x48)): # Detect the pcf8591.
11        adc = PCF8591()
12    elif(adc.detectI2C(0x4b)): # Detect the ads7830
13        adc = ADS7830()
14    else:
15        print("No correct I2C address found, \n"
16              "Please use command 'i2cdetect -y 1' to check the I2C address! \n"
17              "Program Exit. \n");
18        exit(-1)
```

```
19
20 def loop():
21     while True:
22         value = adc.analogRead(0)          # read ADC value A0 pin
23         voltage = value / 255.0 * 3.3      # calculate voltage
24         Rt = 10 * voltage / (3.3 - voltage)    # calculate resistance value of thermistor
25         tempK = 1/(1/(273.15 + 25) + math.log(Rt/10)/3950.0) # calculate temperature
26         (Kelvin)
27         tempC = tempK -273.15           # calculate temperature (Celsius)
28         print ('ADC Value : %d, Voltage : %.2f,
29 Temperature : %.2f' %(value, voltage, tempC))
30         time.sleep(0.01)
31
32 def destroy():
33     adc.close()
34     GPIO.cleanup()
35
36 if __name__ == '__main__': # Program entrance
37     print ('Program is starting ... ')
38     setup()
39     try:
40         loop()
41     except KeyboardInterrupt: # Press ctrl-c to end the program.
42         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 front formula.

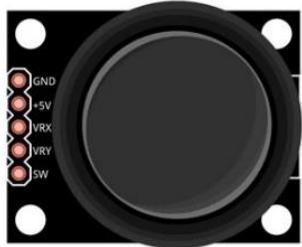
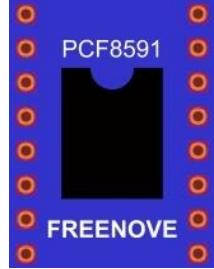
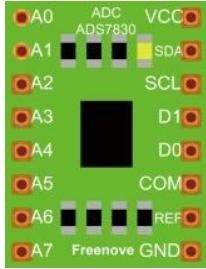
Chapter 12 Joystick

In the previous chapter, we have learned how to use rotary potentiometer. Now, let's learn a new electronic module Joystick which working on the same principle as rotary potentiometer.

Project 12.1 Joystick

In this project, we will read the output data of Joystick and print it to the screen.

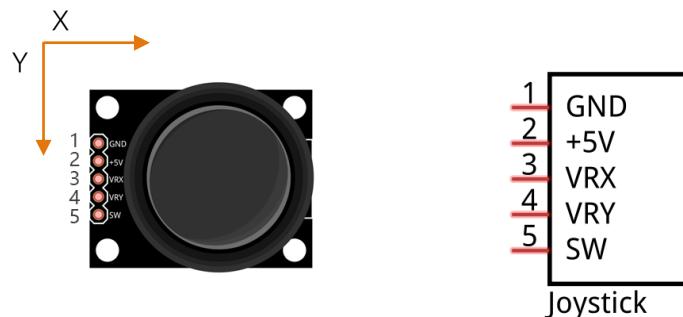
Component List

Raspberry Pi x1 GPIO Extension Board & Wire x1 BreadBoard x1	Jumper
Joystick x1	ADC module x1
	 <p>Or</p> 

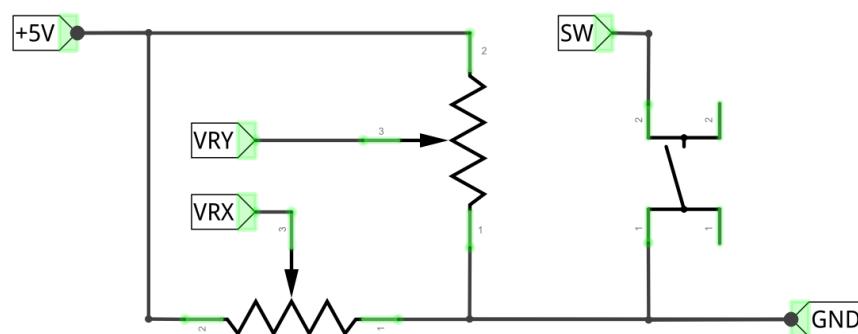
Component knowledge

Joystick

Joystick is a kind of sensor used with your fingers, which is widely used in gamepad and remote controller. It can shift in direction Y or direction X at the same time. And it can also be pressed in direction Z.



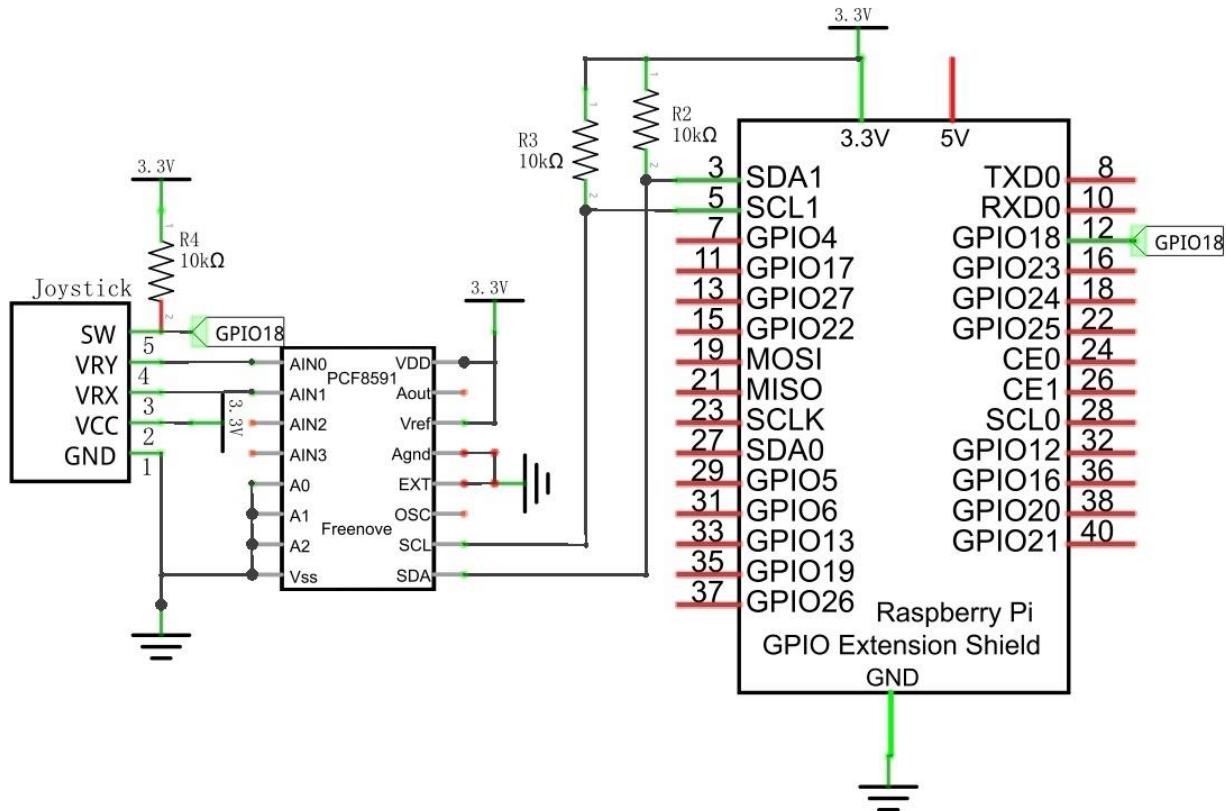
Two rotary potentiometers inside the joystick are set to detect the shift direction of finger, and a push button in vertical direction is set to detect the action of pressing.



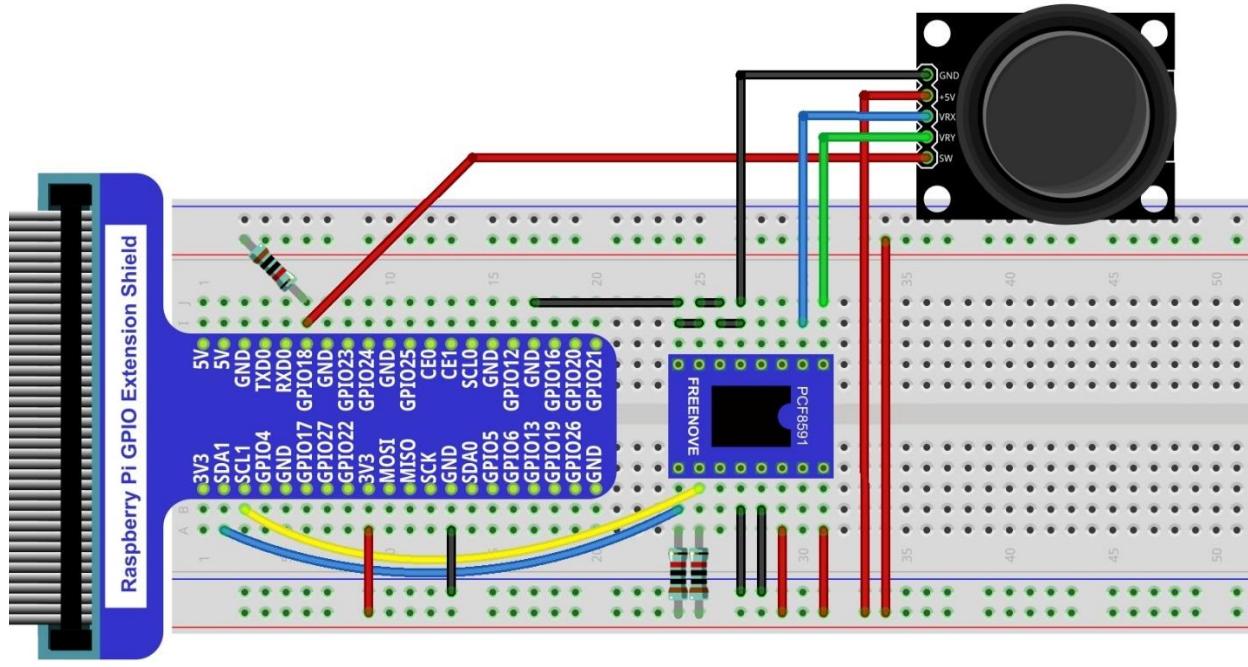
When read the data of joystick, there are some different between axis: data of X and Y axis is analog, which need to use ADC. Data of Z axis is digital, so you can directly use the GPIO to read, or you can also use ADC to read.

Circuit with PCF8591

Schematic diagram

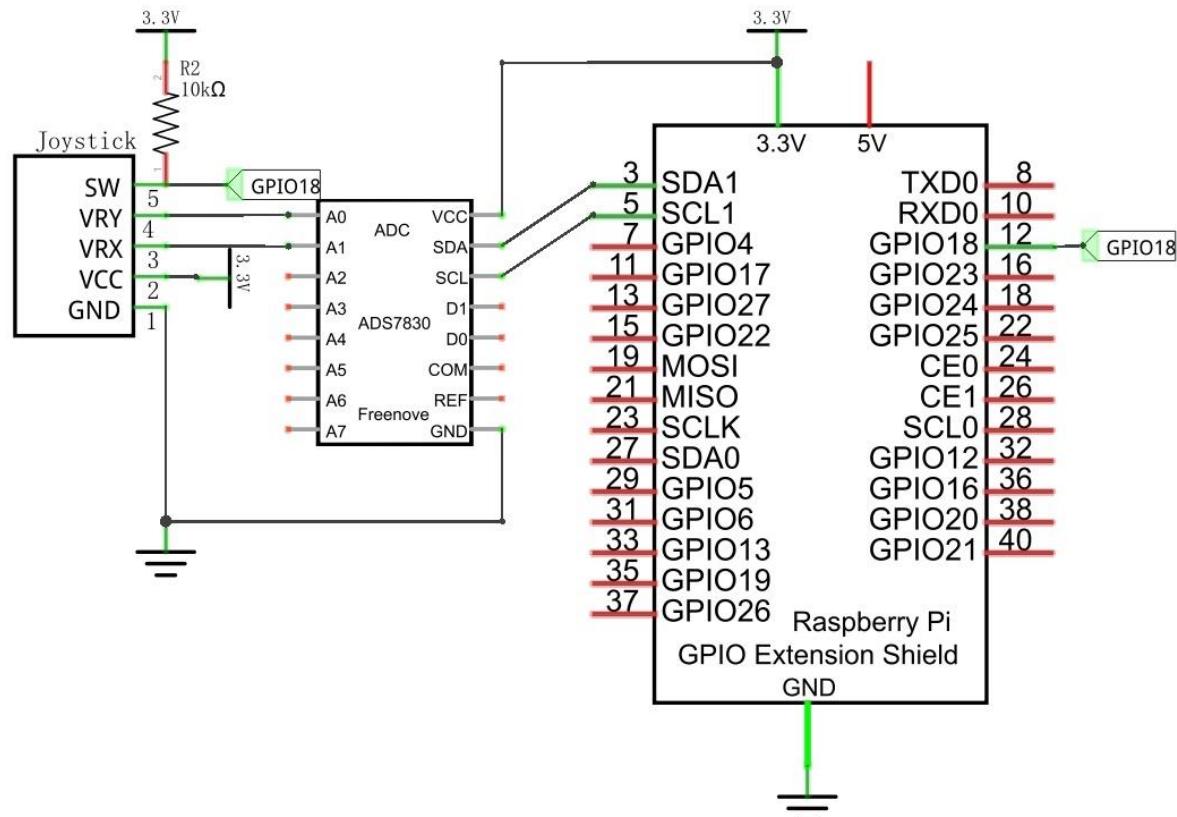


Hardware connection. If you need any support, please feel free to contact us via: support@freenove.com

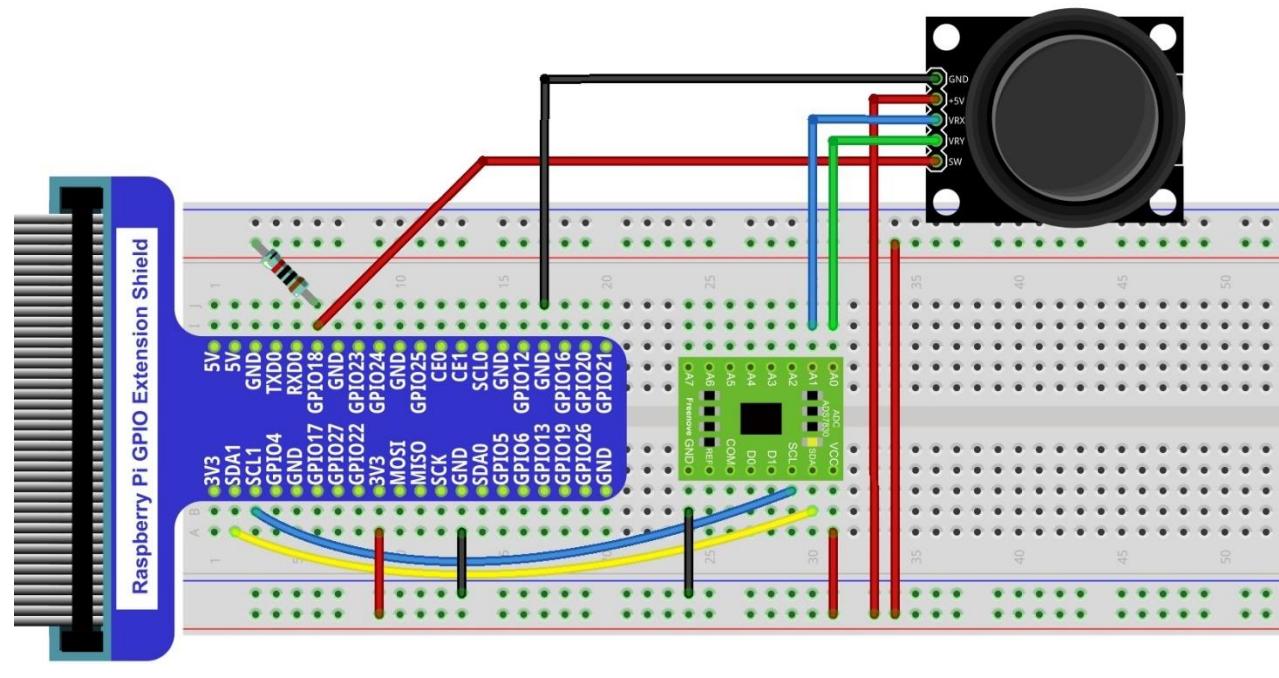


Circuit with ADS7830

Schematic diagram



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



Code

In this project code, we will read ADC value of X and Y axis of Joystick, and read digital quality of Z axis, then print these data out.

C Code 12.1.1 Joystick

If you did not [configure I2C](#), please refer to [Chapter 7](#). If you did, please move on.

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

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

1. Use cd command to enter 12.1.1_Joystick directory of C code.

```
cd ~/Freenove_Kit/Code/C_Code/12.1.1_Joystick
```

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

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

3. Then run the generated file "Joystick".

```
sudo ./Joystick
```

After Program is executed, the terminal window will print out the data of 3 axes X, Y, Z. And shifting the Joystick or pressing it will make those data change.

```
val_X: 128 , val_Y: 135 , val_Z: 1
val_X: 128 , val_Y: 155 , val_Z: 1
val_X: 255 , val_Y: 255 , val_Z: 1
val_X: 181 , val_Y: 255 , val_Z: 1
val_X: 128 , val_Y: 255 , val_Z: 1
val_X: 128 , val_Y: 180 , val_Z: 0
val_X: 128 , val_Y: 138 , val_Z: 0
val_X: 128 , val_Y: 137 , val_Z: 0
val_X: 128 , val_Y: 139 , val_Z: 0
val_X: 128 , val_Y: 139 , val_Z: 1
```

The flowing is the code:

```
1 #include <wiringPi.h>
2 #include <stdio.h>
3 #include <softPwm.h>
4 #include <ADCDevice.hpp>
5
6 #define Z_Pin 1      //define pin for axis Z
7
8 ADCDevice *adc; // Define an ADC Device class object
9
10 int main(void) {
11     adc = new ADCDevice();
12     printf("Program is starting ... \n");
13 }
```

```

14     if(adc->detectI2C(0x48)){    // Detect the pcf8591.
15         delete adc;           // Free previously pointed memory
16         adc = new PCF8591();   // If detected, create an instance of PCF8591.
17     }
18     else if(adc->detectI2C(0x4b)){// Detect the ads7830
19         delete adc;           // Free previously pointed memory
20         adc = new ADS7830();   // If detected, create an instance of ADS7830.
21     }
22     else{
23         printf("No correct I2C address found, \n"
24             "Please use command 'i2cdetect -y 1' to check the I2C address! \n"
25             "Program Exit. \n");
26         return -1;
27     }
28     wiringPiSetup();
29     pinMode(Z_Pin, INPUT);      //set Z_Pin as input pin and pull-up mode
30     pullUpDnControl(Z_Pin, PUD_UP);
31     while(1){
32         int val_Z = digitalRead(Z_Pin); //read digital value of axis Z
33         int val_Y = adc->analogRead(0); //read analog value of axis X and Y
34         int val_X = adc->analogRead(1);
35         printf("val_X: %d ,\tval_Y: %d ,\tval_Z: %d \n", val_X, val_Y, val_Z);
36         delay(100);
37     }
38     return 0;
39 }
```

In the code, configure Z_Pin to pull-up input mode. In while cycle of main function, use **analogRead ()** to read the value of axis X and Y and use **digitalRead ()** to read the value of axis Z, then print them out.

```

while(1){
    int val_Z = digitalRead(Z_Pin); //read digital value of axis Z
    int val_Y = adc->analogRead(0); //read analog value of axis X and Y
    int val_X = adc->analogRead(1);
    printf("val_X: %d ,\tval_Y: %d ,\tval_Z: %d \n", val_X, val_Y, val_Z);
    delay(100);
}
```

Python Code 12.1.1 Joystick

If you did not [configure I2C](#), please refer to [Chapter 7](#). If you did, please move on.

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

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

1. Use cd command to enter 12.1.1_Joystick directory of Python code.

```
cd ~/Freenove_Kit/Code/Python_Code/12.1.1_Joystick
```

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

```
python Joystick.py
```

After Program is executed, the terminal window will print out the data of 3 axes X, Y, Z. And shifting the Joystick or pressing it will make those data change.

```
value_X: 128 ,  value_Y: 135 ,  value_Z: 1
value_X: 128 ,  value_Y: 135 ,  value_Z: 1
value_X: 128 ,  value_Y: 135 ,  value_Z: 1
value_X: 128 ,  value_Y: 135 ,  value_Z: 0
value_X: 128 ,  value_Y: 135 ,  value_Z: 1
```

The following is the program code:

```
1 import RPi.GPIO as GPIO
2 import time
3 from ADCDevice import *
4
5 Z_Pin = 12      # define Z_Pin
6 adc = ADCDevice() # Define an ADCDevice class object
7
8 def setup():
9     global adc
10    if(adc.detectI2C(0x48)): # Detect the pcf8591.
11        adc = PCF8591()
12    elif(adc.detectI2C(0x4b)): # Detect the ads7830
13        adc = ADS7830()
14    else:
15        print("No correct I2C address found, \n"
16              "Please use command 'i2cdetect -y 1' to check the I2C address! \n"
17              "Program Exit. \n");
18        exit(-1)
19    GPIO.setmode(GPIO.BCM)
20    GPIO.setup(Z_Pin,GPIO.IN,GPIO.PUD_UP)    # set Z_Pin to pull-up mode
21 def loop():
22     while True:
23         val_Z = GPIO.input(Z_Pin)          # read digital value of axis Z
24         val_Y = adc.analogRead(0)          # read analog value of axis X and Y
25         val_X = adc.analogRead(1)
```

```
26     print (' value_X: %d ,\tvalue_Y: %d ,\tvalue_Z: %d' %(val_X,val_Y,val_Z))
27     time.sleep(0.01)
28
29 def destroy():
30     adc.close()
31     GPIO.cleanup()
32
33 if __name__ == '__main__':
34     print (' Program is starting ... ') # Program entrance
35     setup()
36     try:
37         loop()
38     except KeyboardInterrupt: # Press ctrl-c to end the program.
39         destroy()
```

In the code, configure Z_Pin to pull-up input mode. In while cycle of loop, use **analogRead ()** to read the value of axis X and Y and use **GPIO.input ()** to read the value of axis Z, then print them out.

```
while True:
    val_Z = GPIO.input(Z_Pin)      #read digital quality of axis Z
    val_Y = analogRead(0)          #read analog quality of axis X and Y
    val_X = analogRead(1)
    print (' value_X: %d ,\tvalue_Y: %d ,\tvalue_Z: %d' %(val_X,val_Y,val_Z))
    time.sleep(0.01)
```

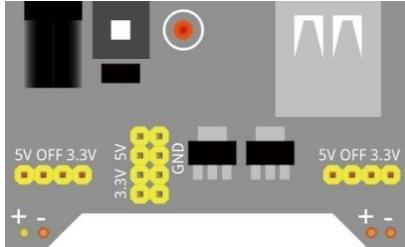
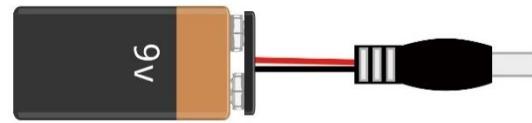
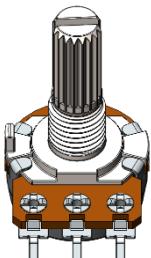
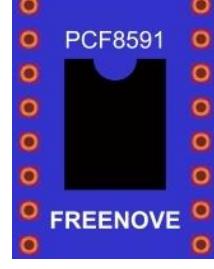
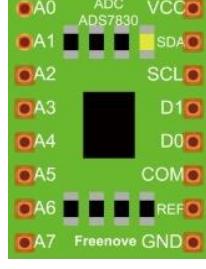
Chapter 13 Motor & Driver

In this chapter, we will learn some knowledge about DC motor and DC motor drive, and how to control the speed and direction of motor.

Project 13.1 Control Motor with Potentiometer

In this project, a potentiometer is used to control motor. When the potentiometer is in the midpoint position, the motor will stops rotating, and when away from the middle position, the motor speed increases. When potentiometer is adjusted to limited ends, the motor speed reaches maximum. When the potentiometer position is at different side of middle position, the direction of motor is different.

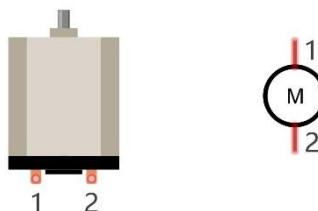
Component List

Raspberry Pi (with 40 GPIO) x1 GPIO Extension Board & Wire x1 BreadBoard x1	Jumper			
Breadboard power module x1 	9V Battery (provided by yourself) & battery cable 			
Rotary potentiometer x1 	Motor x1 	10kΩ x2 	ADC module x1  or 	L293D 

Component knowledge

Motor

Motor is a device that converts electrical energy into mechanical energy. Motor consists of two parts: stator and rotor. When motor works, the stationary part is stator, and the rotating part is rotor. Stator is usually the outer case of motor, and it has terminals to connect to the power. Rotor is usually the shaft of motor, and can drive other mechanical devices to run. Diagram below is a small DC motor with two pins.

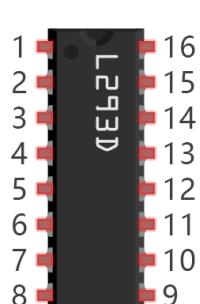


When motor get connected to the power supply, it will rotate in one direction. Reverse the polarity of power supply, then motor rotates in opposite direction.



L293D

L293D is a chip integrated with 4-channel motor drive. You can drive a unidirectional motor with 4 ports or a bi-directional motor with 2 port or a stepper motor.



1	Enable 1	+V	16
2	In 1	In 4	15
3	Out 1	Out 4	14
4	0V	0V	13
5	0V	0V	12
6	Out 2	Out 3	11
7	In 2	In 3	10
8	+Vmotor	Enable 2	9

L293D

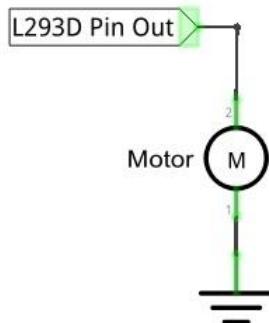
Port description of L293D module is as follows:

Pin name	Pin number	Description
In x	2, 7, 10, 15	Channel x digital signal input pin
Out x	3, 6, 11, 14	Channel x output pin, input high or low level according to In x pin, get connected to +Vmotor or 0V
Enable1	1	Channel 1 and channel 2 enable pin, high level enable
Enable2	9	Channel 3 and channel 4 enable pin, high level enable
0V	4, 5, 12, 13	Power cathode (GND)
+V	16	Positive electrode (VCC) of power supply, supply voltage 4.5~36V
+Vmotor	8	Positive electrode of load power supply, provide power supply for the Out pin x, the supply voltage is +V~36V

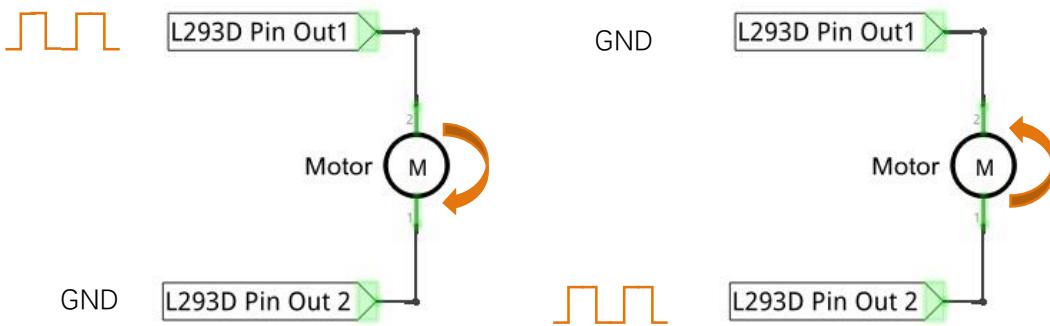
For more details, please see datasheet.

When using L293D to drive DC motor, there are usually two kinds of connection.

Following connection uses one channel, and it can control motor speed through PWM, but the motor can only rotate in one direction.



Following connection uses two channels: one channel outputs PWM wave, and another channel connects GND, so you can control the speed of motor. When these two channel signals are exchanged, the current direction of the motor can be reversed, and the motor will rotate in reverse direction. This can not only control the speed of motor, but also can control the steering of motor.

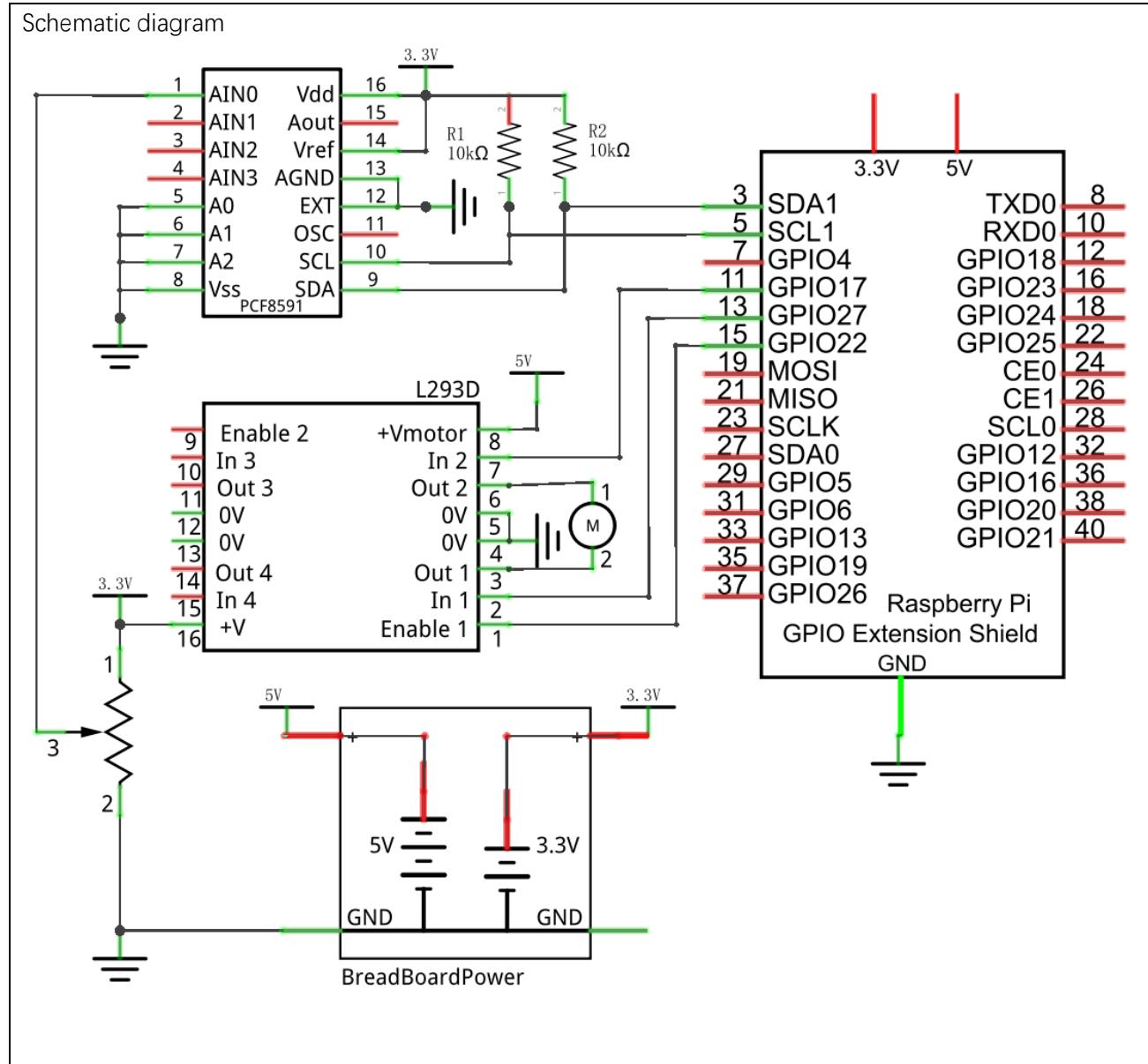


In actual use, motor is usually connected to the channel 1 and 2, output different level to in1 and in2 to control the rotation direction of the motor, and output PWM wave to Enable1 port to control the motor rotation speed. Or, get motor connected to the channel 3 and 4, output different level to in3 and in4 to control the motor's rotation direction, and output PWM wave to Enable2 pin to control the motor rotation speed.

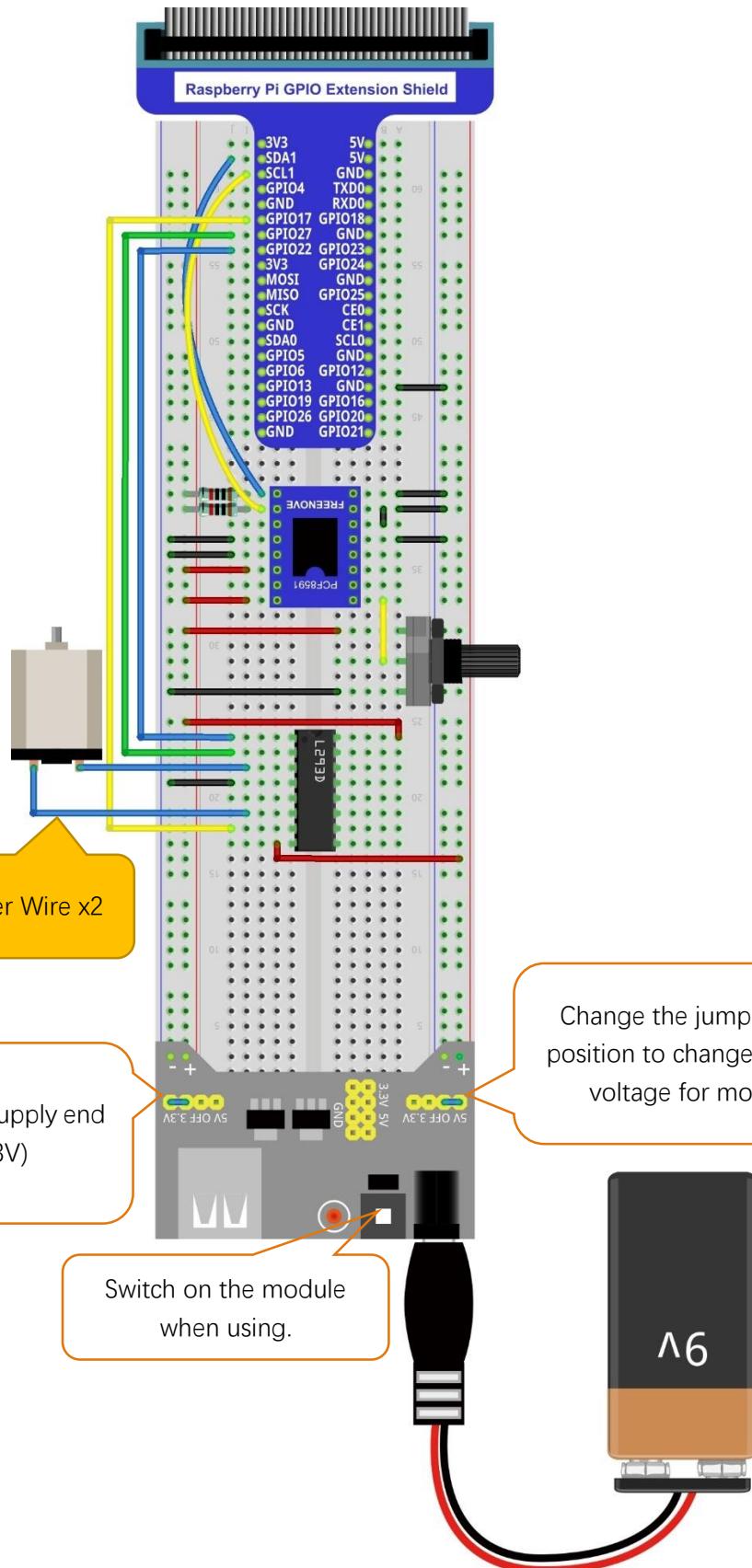
Circuit with PCF8591

When connecting the circuit, pay attention to that because the motor is a high-power component, do not use the power provided by the RPi, which may do damage to your RPi. the logic circuit can be powered by RPi power or external power supply which should have the common ground with RPi.

Schematic diagram



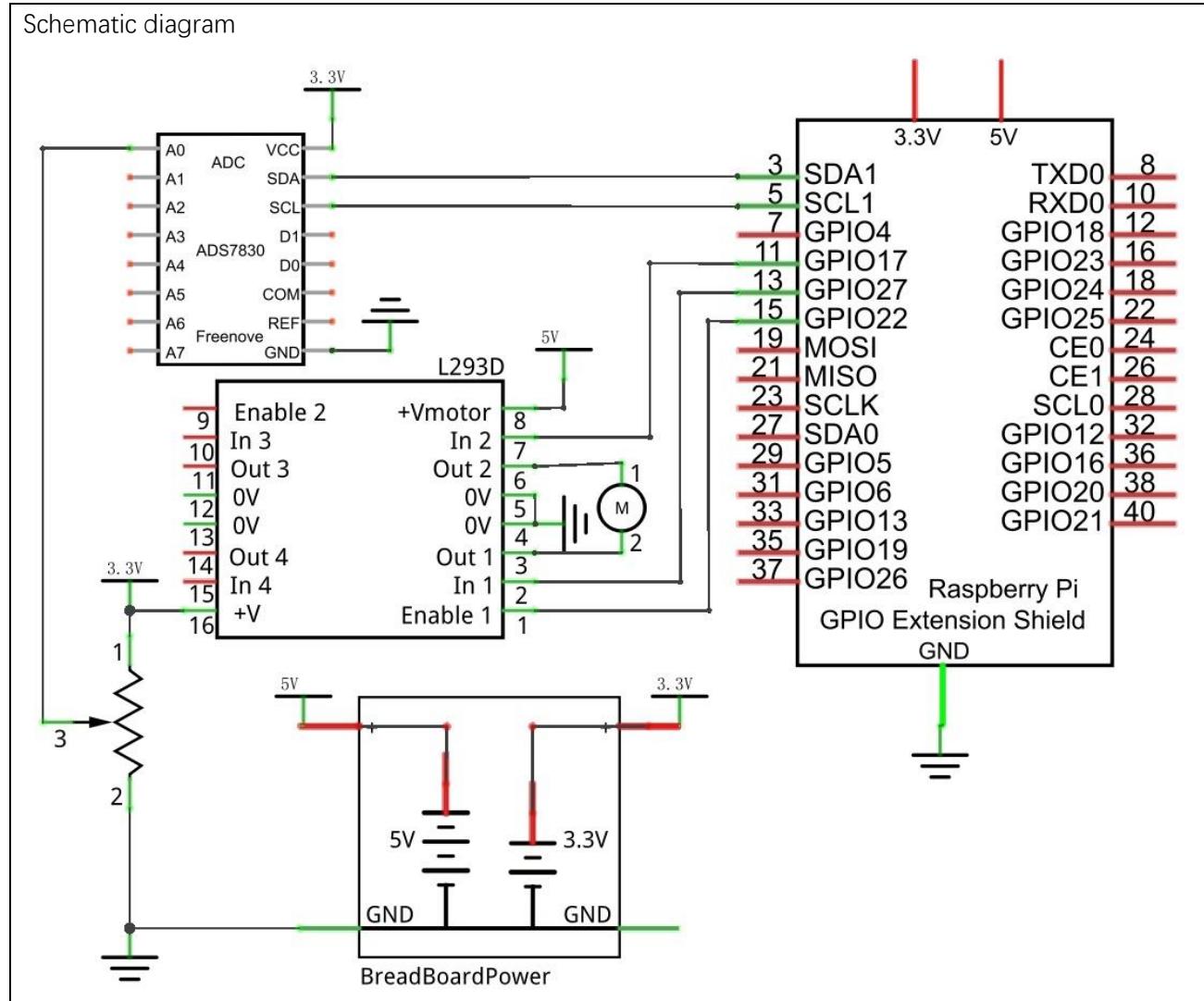
Hardware connection. If you need any support, please free to contact us via: support@freenove.com



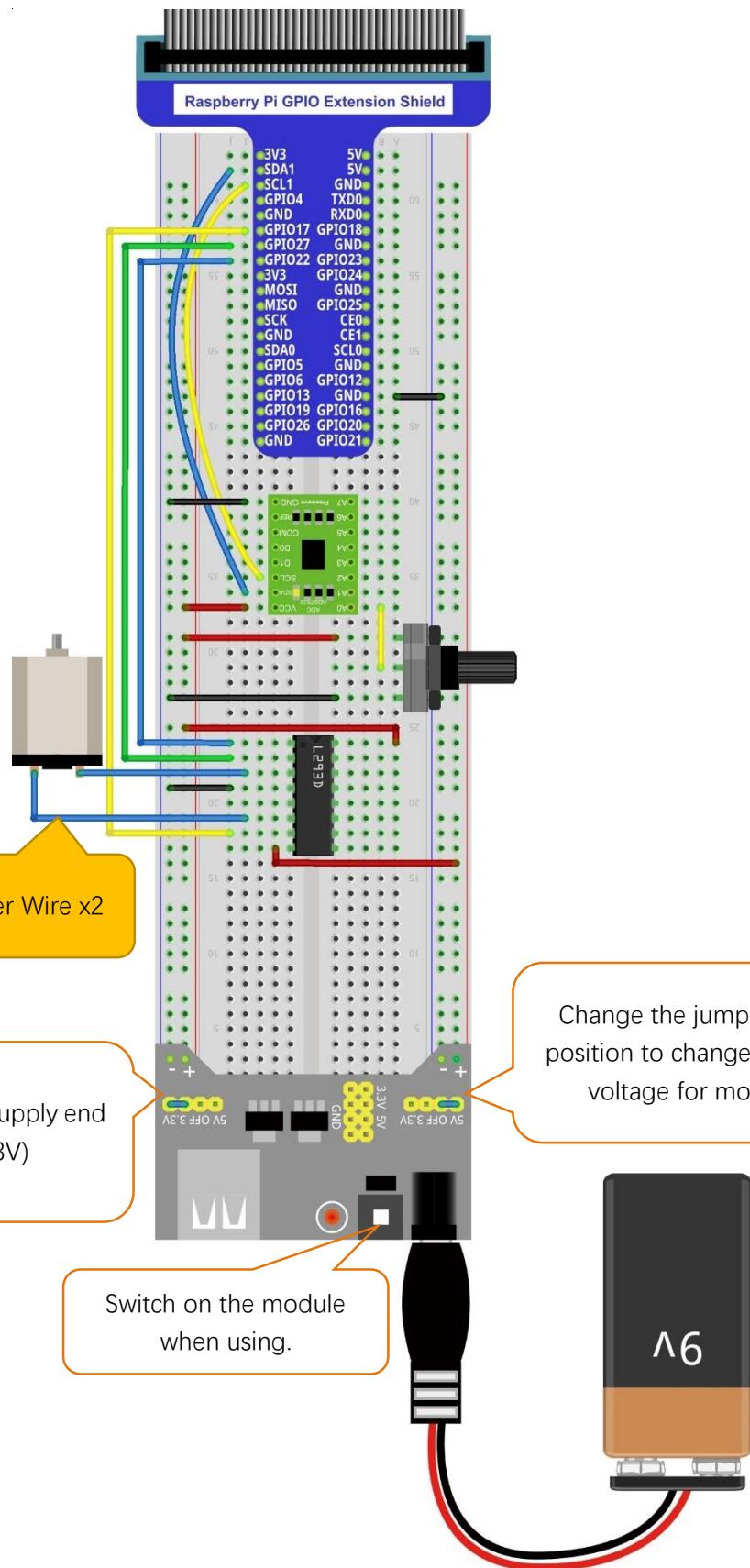
Circuit with ADS7830

When connecting the circuit, pay attention to that because the motor is a high-power component, do not use the power provided by the RPi, which may do damage to your RPi. the logic circuit can be powered by RPi power or external power supply which should have the common ground with RPi.

Schematic diagram



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



Code

In this project code, first read the ADC value, and then control the rotation direction and speed of the motor according to the value of the ADC.

C Code 13.1.1 Motor

If you did not [configure I2C](#), please refer to [Chapter 7](#). If you did, please move on.

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

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

1. Use cd command to enter 13.1.1_Motor directory of C code.

```
cd ~/Freenove_Kit/Code/C_Code/13.1.1_Motor
```

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

```
gcc Motor.c -o Motor -lwiringPi -lADCDevice
```

3. Then run the generated file "Motor".

```
sudo ./Motor
```

After the program is executed, adjust the potentiometer, then the rotation speed and direction of the motor will change with it. And when the potentiometer is turned to midpoint position, the motor stops running. When away from the middle position, the motor speed will increase. When to both ends, motor speed reaches to maximum. When the potentiometer is turned to different side of the middle position, the motor will run with different direction. Meanwhile, the terminal will print out ADC value of the potentiometer, the motor direction and the PWM duty cycle used to control motor speed.

```
turn Forward...
The PWM duty cycle is 66%
ADC value : 212
turn Forward...
The PWM duty cycle is 66%
ADC value : 212
turn Forward...
The PWM duty cycle is 66%
ADC value : 212
turn Forward...
The PWM duty cycle is 66%
ADC value : 212
turn Forward...
The PWM duty cycle is 66%
ADC value : 212
turn Forward...
```

The following is the code:

1	#include <wiringPi.h>
2	#include <stdio.h>
3	#include <softPwm.h>
4	#include <math.h>
5	#include <stdlib.h>
6	#include <ADCDevice.hpp>
7	



```

8 #define motorPin1    2      //define the pin connected to L293D
9 #define motorPin2    0
10#define enablePin     3
11
12ADCDevice *adc; // Define an ADC Device class object
13
14//Map function: map the value from a range to another range.
15long map(long value, long fromLow, long fromHigh, long toLow, long toHigh) {
16    return (toHigh-toLow)*(value-fromLow) / (fromHigh-fromLow) + toLow;
17}
18//motor function: determine the direction and speed of the motor according to the ADC
19void motor(int ADC) {
20    int value = ADC -128;
21    if(value>0) {
22        digitalWrite(motorPin1, HIGH);
23        digitalWrite(motorPin2, LOW);
24        printf("turn Forward... \n");
25    }
26    else if (value<0) {
27        digitalWrite(motorPin1, LOW);
28        digitalWrite(motorPin2, HIGH);
29        printf("turn Back... \n");
30    }
31    else {
32        digitalWrite(motorPin1, LOW);
33        digitalWrite(motorPin2, LOW);
34        printf("Motor Stop... \n");
35    }
36    softPwmWrite(enablePin, map(abs(value), 0, 128, 0, 100));
37    printf("The PWM duty cycle is %d%\n", abs(value)*100/127); //print the PWM duty cycle
38}
39int main(void) {
40    adc = new ADCDevice();
41    printf("Program is starting ... \n");
42
43    if(adc->detectI2C(0x48)){ // Detect the pcf8591.
44        delete adc;           // Free previously pointed memory
45        adc = new PCF8591(); // If detected, create an instance of PCF8591.
46    }
47    else if(adc->detectI2C(0x4b)){// Detect the ads7830
48        delete adc;           // Free previously pointed memory
49        adc = new ADS7830(); // If detected, create an instance of ADS7830.
50    }
51    else{

```

```

52     printf("No correct I2C address found, \n"
53     "Please use command 'i2cdetect -y 1' to check the I2C address! \n"
54     "Program Exit. \n");
55     return -1;
56 }
57 wiringPiSetup();
58 pinMode(enablePin, OUTPUT); //set mode for the pin
59 pinMode(motorPin1, OUTPUT);
60 pinMode(motorPin2, OUTPUT);
61 softPwmCreate(enablePin, 0, 100); //define PWM pin
62 while(1) {
63     int value = adc->analogRead(0); //read analog value of A0 pin
64     printf("ADC value : %d \n", value);
65     motor(value); //make the motor rotate with speed(analog value of A0 pin)
66     delay(100);
67 }
68 return 0;
69 }
```

We have been familiar with reading ADC value. So, let's learn directly subfunction void motor(int ADC): first, compare ADC value with 128 (value corresponding to midpoint). When the current ADC value is higher, motoRPin1 outputs high level and motoRPin2 outputs low level to control motor to run with forward rotation direction. When the current ADC value is lower, motoRPin1 outputs low level and motoRPin2 outputs high level to control motor run with reversed direction. When the ADC value is equal to 128, motoRPin1 and motoRPin2 output low level, then the motor stops. And then determine PWM duty cycle according to the difference between ADC value and 128. Because the absolute difference value stays within 0-128. We need to use the map() subfunction mapping the difference value to range of 0-255. Finally print out the duty cycle.

```

void motor(int ADC) {
    int value = ADC - 128;
    if(value>0) {
        digitalWrite(motoRPin1, HIGH);
        digitalWrite(motoRPin2, LOW);
        printf("turn Forward... \n");
    }
    else if (value<0) {
        digitalWrite(motoRPin1, LOW);
        digitalWrite(motoRPin2, HIGH);
        printf("turn Backward... \n");
    }
    else {
        digitalWrite(motoRPin1, LOW);
        digitalWrite(motoRPin2, LOW);
        printf("Motor Stop... \n");
    }
}
```

```
softPwmWrite(enablePin, map(abs(value), 0, 128, 0, 100));  
printf("The PWM duty cycle is %d%%\n", abs(value)*100/127); // print out PWM duty  
cycle.  
}
```

Python Code 13.1.1 Motor

If you did not [configure I2C and install Smbus](#), please refer to [Chapter 7](#). If you did, please move on. First observe the project result, and then analyze the code.

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

1. Use cd command to enter 13.1.1_Motor directory of Python code.

```
cd ~/Freenove_Kit/Code/Python_Code/13.1.1_Motor
```

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

```
python Motor.py
```

After the program is executed, adjust the potentiometer, then the rotation speed and direction of the motor will change with it. And when the potentiometer is turned to midpoint position, the motor stops running. When away from the middle position, the motor speed will increase. When to both ends, motor speed reach to maximum. When the potentiometer is turned to different side of the middle position, the motor will run with different direction. Meanwhile, the terminal will print out ADC value of the potentiometer, the motor direction and the PWM duty cycle used to control motor speed.

```
Turn Forward...
The PWM duty cycle is 100%

ADC Value : 255
Turn Forward...
The PWM duty cycle is 100%

ADC Value : 255
Turn Forward...
The PWM duty cycle is 100%

ADC Value : 255
Turn Forward...
The PWM duty cycle is 100%
```

The following is the code:

```
1 import RPi.GPIO as GPIO
2 import time
3 from ADCDevice import *

4
5 # define the pins connected to L293D
6 motoRPin1 = 13
7 motoRPin2 = 11
8 enablePin = 15
9 adc = ADCDevice() # Define an ADCDevice class object
10
11 def setup():
12     global adc
13     if(adc.detectI2C(0x48)): # Detect the pcf8591.
14         adc = PCF8591()
15     elif(adc.detectI2C(0x4b)): # Detect the ads7830
```

```

16         adc = ADS7830()
17     else:
18         print("No correct I2C address found, \n"
19             "Please use command 'i2cdetect -y 1' to check the I2C address! \n"
20             "Program Exit. \n");
21         exit(-1)
22     global p
23     GPIO.setmode(GPIO.BOARD)
24     GPIO.setup(motoRPin1,GPIO.OUT)    # set pins to OUTPUT mode
25     GPIO.setup(motoRPin2,GPIO.OUT)
26     GPIO.setup(enablePin,GPIO.OUT)
27
28     p = GPIO.PWM(enablePin, 1000) # creat PWM and set Frequency to 1KHz
29     p.start(0)
30
31 # mapNUM function: map the value from a range of mapping to another range.
32 def mapNUM(value,fromLow,fromHigh,toLow,toHigh):
33     return (toHigh-toLow)*(value-fromLow) / (fromHigh-fromLow) + toLow
34
35 # motor function: determine the direction and speed of the motor according to the input
36 ADC value input
37 def motor(ADC):
38     value = ADC -128
39     if (value > 0): # make motor turn forward
40         GPIO.output(motoRPin1,GPIO.HIGH) # motoRPin1 output HIGH level
41         GPIO.output(motoRPin2,GPIO.LOW)   # motoRPin2 output LOW level
42         print (' Turn Forward... ')
43     elif (value < 0): # make motor turn backward
44         GPIO.output(motoRPin1,GPIO.LOW)
45         GPIO.output(motoRPin2,GPIO.HIGH)
46         print (' Turn Backward... ')
47     else :
48         GPIO.output(motoRPin1,GPIO.LOW)
49         GPIO.output(motoRPin2,GPIO.LOW)
50         print (' Motor Stop... ')
51     p.start(mapNUM(abs(value),0,128,0,100))
52     print (' The PWM duty cycle is %d%%\n'%(abs(value)*100/127))    # print PMW duty cycle.
53
54 def loop():
55     while True:
56         value = adc.analogRead(0) # read ADC value of channel 0
57         print (' ADC Value : %d'%(value))
58         motor(value)
59         time.sleep(0.01)

```

```

60
61 def destroy():
62     GPIO.cleanup()
63
64 if __name__ == '__main__': # Program entrance
65     print ('Program is starting ... ')
66     setup()
67     try:
68         loop()
69     except KeyboardInterrupt: # Press ctrl-c to end the program.
70         destroy()

```

We have been familiar with reading ADC value. So, let's learn directly subfunction `def motor(ADC)`: first, compare ADC value with 128 (value corresponding to midpoint). When the current ADC value is higher, motoRPin1 outputs high level and motoRPin2 output low level to control motor to run with forward rotation direction. When the current ADC value is lower, motoRPin1 outputs low level and motoRPin2 outputs high level to control run with reversed direction. When the ADC value is equal to 128, make motoRPin1 and motoRPin2 output low level, then the motor stops. And then determine PWM duty cycle according to the difference between ADC value and 128. Because the absolute difference value stays within 0-128. We need to use the map () subfunction mapping the difference value to range of 0-100. Finally print out the duty cycle.

```

def motor(ADC):
    value = ADC -128
    if (value > 0):
        GPIO.output(motoRPin1,GPIO.HIGH)
        GPIO.output(motoRPin2,GPIO.LOW)
        print (' Turn Forward... ')
    elif (value < 0):
        GPIO.output(motoRPin1,GPIO.LOW)
        GPIO.output(motoRPin2,GPIO.HIGH)
        print (' Turn Backward... ')
    else :
        GPIO.output(motoRPin1,GPIO.LOW)
        GPIO.output(motoRPin2,GPIO.LOW)
        print (' Motor Stop... ')
    p.start(mapNUM(abs(value),0,128,0,100))
    print (' The PWM duty cycle is %d%%\n' %(abs(value)*100/127)) #print PWM duty cycle.

```

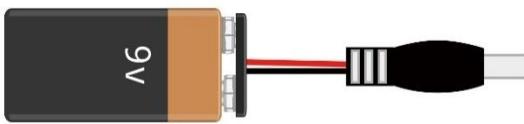
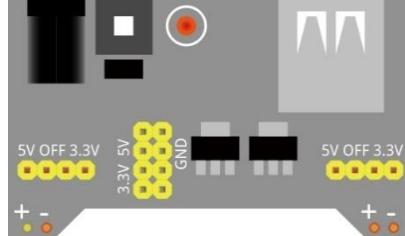
Chapter 14 Relay & Motor

In this chapter, we will learn a kind of special switch module, Relay Module.

Project 14.1.1 Relay & Motor

In this project, we will use a push button to control a relay and drive the motor.

Component List

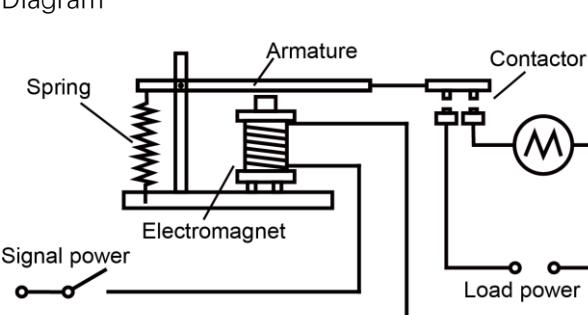
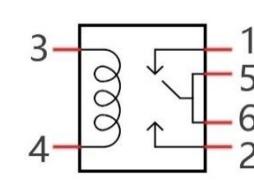
Raspberry Pi (with 40 GPIO) x1 GPIO Expansion Board & Wire x1 BreadBoard x1	Jumper
9V battery (prepared by yourself) & battery line	
Breadboard extension x1	Resistor 10kΩ x2 Resistor 1kΩ x1 Resistor 220Ω x1
	
NPN transistor x1	Push button x1
	
Relay x1	LED x1
	
Motor x1	Diode x1
	

Component knowledge

Relay

Relay is a safe switch which can use low power circuit to control high power circuit. It consists of electromagnet and contacts. The electromagnet is controlled by low power circuit and contacts is used in high power circuit. When the electromagnet is energized, it will attract contacts.

The following is a principle diagram of common relay and the feature and circuit symbol of 5V relay used in this project:

Diagram	Feature:	Symbol
		

Pin 5 and pin 6 are connected to each other inside. When the coil pin 3 and 4 get connected to 5V power supply, pin 1 will be disconnected from pin 5&6 and pin 2 will be connected to pin 5&6. So pin 1 is called close end, pin 2 is called open end.

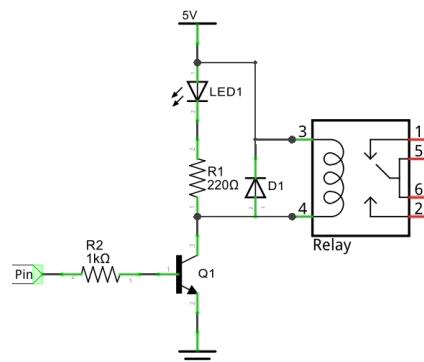
Inductor

The unit of inductance(L) is the henry (H). $1H=1000mH$, $1mH=1000\mu H$.

Inductor is an energy storage device that converts electrical energy into magnetic energy. Generally, it consists of winding coil, with a certain amount of inductance. Inductor will hinder the changing current passing through the inductor. When the current passing through inductor increases, it will attempt to hinder the increasing trend of current; and when the current passing through the inductor decreases, it will attempt to hinder the decreasing trend of current. So the current passing through inductor is not transient.



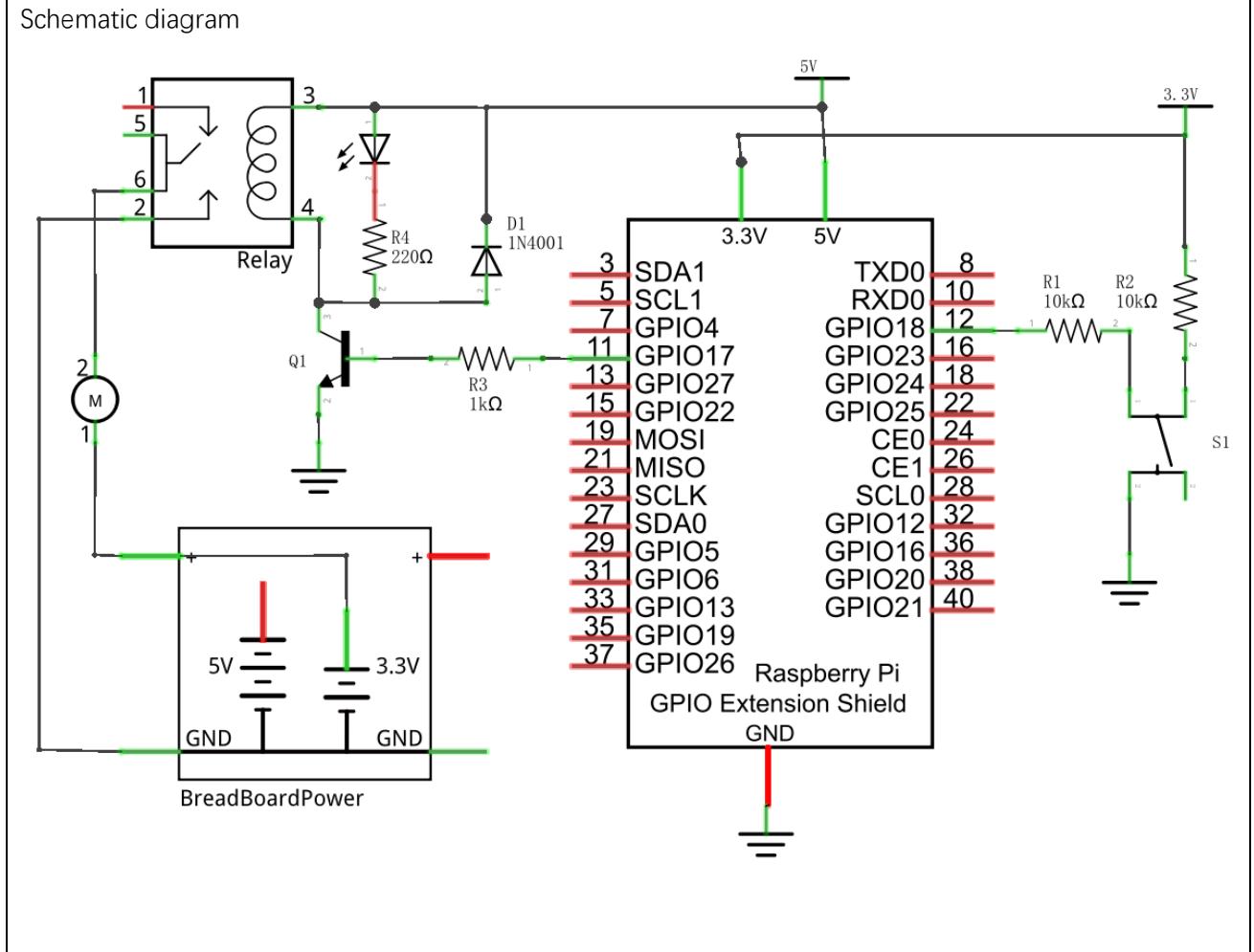
The reference circuit for relay is as follows. The coil of relay can be equivalent to inductor, when the transistor disconnects power supply of the relay, the current in the coil of the relay can't stop immediately, causing an impact on power supply. So a parallel diode will get connected to both ends of relay coil pin in reversing direction, then the current will pass through diode, avoiding the impact on power supply.



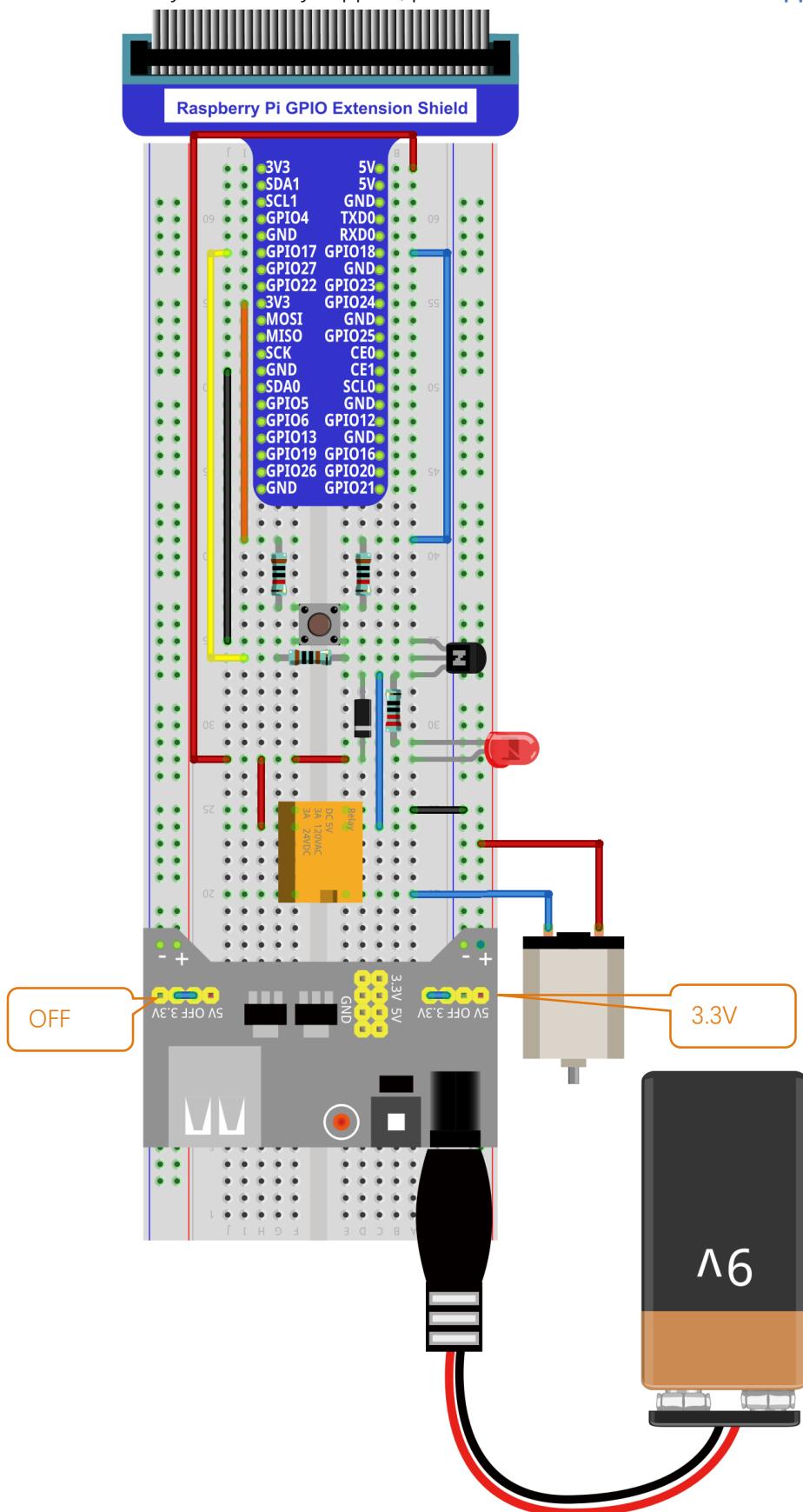
Circuit

Pay attention to the power supply voltage needed for the components in circuit, in which the relay needs power supply voltage 5V, and the motor needs 3.3V. Additionally, a LED is used as an indicator for the relay (turned on or turned off).

Schematic diagram



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



Code

The project code is in the same logic as TableLamp. Press the button to driver the transistor conducted. Because the relay and LED are connected in parallel, they will be opened at the same time. And if you press the button again, they will be closed.

C Code 14.1.1 Relay

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

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

1. Use cd command to enter 14.1.1_Relay directory of C code.

```
cd ~/Freenove_Kit/Code/C_Code/14.1.1_Relay
```

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

```
gcc Relay.c -o Relay -lwiringPi
```

3. Run the generated file "Relay".

```
sudo ./Relay
```

After the program is executed, press the button, then the relay is opened, the Motor starts to rotate and LED is turned on. If you press the button again, the relay is closed, the Motor stops running, and the LED is turned off.

The following is the program code:

```

1 #include <wiringPi.h>
2 #include <stdio.h>
3
4 #define relayPin 0      //define the relayPin
5 #define buttonPin 1      //define the buttonPin
6 int relayState=LOW;      //store the State of relay
7 int buttonState=HIGH; //store the State of button
8 int lastbuttonState=HIGH;//store the lastState of button
9 long lastChangeTime; //store the change time of button state
10 long captureTime=50; //set the button state stable time
11 int reading;
12 int main(void)
13 {
14     printf("Program is starting...\n");
15
16     wiringPiSetup();
17
18     pinMode(relayPin, OUTPUT);
19     pinMode(buttonPin, INPUT);
20     pullUpDnControl(buttonPin, PUD_UP); //pull up to high level
21     while(1){
22         reading = digitalRead(buttonPin); //read the current state of button
23         if( reading != lastbuttonState){ //if the button state changed ,record the time
24             point
25             lastChangeTime = millis();

```

```
26 }  
27 //if changing-state of the button last beyond the time we set,we considered that  
28 //the current button state is an effective change rather than a buffeting  
29 if(millis() - lastChangeTime > captureTime){  
30     //if button state is changed, update the data.  
31     if(reading != buttonState){  
32         buttonState = reading;  
33         //if the state is low, the action is pressing.  
34         if(buttonState == LOW){  
35             printf("Button is pressed!\n");  
36             relayState = !relayState;  
37             if(relayState){  
38                 printf("turn on relay ... \n");  
39             }  
40             else {  
41                 printf("turn off relay ... \n");  
42             }  
43         }  
44         //if the state is high, the action is releasing.  
45         else {  
46             printf("Button is released!\n");  
47         }  
48     }  
49 }  
50 digitalWrite(relayPin,relayState);  
51 lastbuttonState = reading;  
52 }  
53  
54 return 0;  
55 }
```

The code is in the same logic as TableLamp code above.

Python Code 14.1.1 Relay

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

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

1. Use cd command to enter 14.1.1_Relay directory of Python code.

```
cd ~/Freenove_Kit/Code/Python_Code/14.1.1_Relay
```

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

```
python Relay.py
```

After the program is executed, press the button, then the relay is opened, the Motor starts to rotate and LED is turned on. If you press the button again, the relay is closed, the Motor stops running, and the LED is turned off.

The following is the program code:

```

1 import RPi.GPIO as GPIO
2 import time
3
4 relayPin = 11      # define the relayPin
5 buttonPin = 12      # define the buttonPin
6 debounceTime = 50
7
8 def setup():
9     GPIO.setmode(GPIO.BCM)
10    GPIO.setup(relayPin, GPIO.OUT)    # set relayPin to OUTPUT mode
11    GPIO.setup(buttonPin, GPIO.IN)   # set buttonPin to INPUT mode
12
13 def loop():
14     relayState = False
15     lastChangeTime = round(time.time()*1000)
16     buttonState = GPIO.HIGH
17     lastButtonState = GPIO.HIGH
18     reading = GPIO.HIGH
19     while True:
20         reading = GPIO.input(buttonPin)
21         if reading != lastButtonState :
22             lastChangeTime = round(time.time()*1000)
23             if ((round(time.time()*1000) - lastChangeTime) > debounceTime):
24                 if reading != buttonState :
25                     buttonState = reading;
26                     if buttonState == GPIO.LOW:
27                         print("Button is pressed!")
28                         relayState = not relayState
29                         if relayState:
30                             print("Turn on relay ... ")
31                         else :
32                             print("Turn off relay ... ")
33                     else :
```

```
34             print("Button is released!")
35             GPIO.output(relayPin, relayState)
36             lastButtonState = reading # lastButtonState store latest state
37
38     def destroy():
39         GPIO.cleanup()
40
41     if __name__ == '__main__':      # Program entrance
42         print ('Program is starting...')
43         setup()
44         try:
45             loop()
46         except KeyboardInterrupt:    # Press ctrl-c to end the program.
47             destroy()
```

The code is in the same logic as TableLamp code above.



Chapter 15 Servo

We have learned how to control the speed and steering of the motor before. In this chapter, we will learn a kind of motor that can rotate to a specific angle, servo.

Project 15.1 Servo Sweep

First, let's learn how to make the servo rotate.

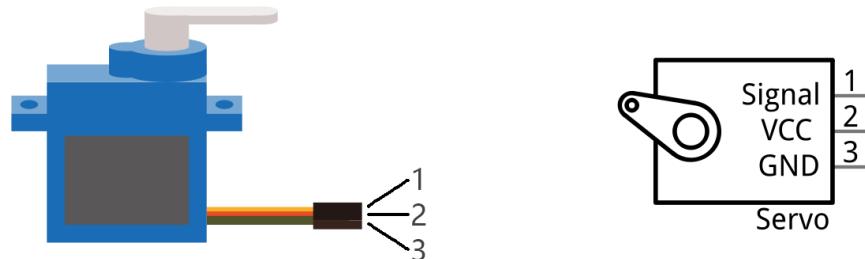
Component List

Raspberry Pi (with 40 GPIO) x1 GPIO Expansion Board & Wire x1 BreadBoard x1	Jumper
Servo x1	

Component knowledge

Servo

Servo is an auto-control system, consisting of DC motor, reduction gear, sensor and control circuit. Usually, it can rotate in the range of 180 degrees. Servo can output larger torque and is widely used in model airplane, robot and so on. It has three lines, including two for electric power line positive (2-VCC, red), negative (3-GND, brown), and the signal line (1-Signal, orange).



We use 50Hz PWM signal with a duty cycle in a certain range to drive the servo. The lasting time 0.5ms-2.5ms of PWM single cycle high level corresponds to the servo angle 0 degrees - 180 degree linearly. Part of the corresponding values are as follows:

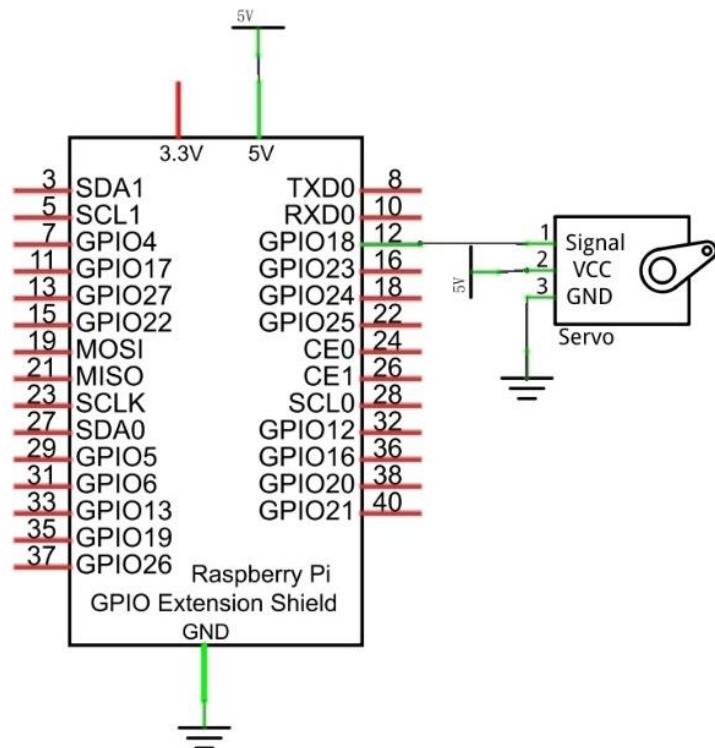
High level time	Servo angle
0.5ms	0 degree
1ms	45 degree
1.5ms	90 degree
2ms	135 degree
2.5ms	180 degree

When you change the servo signal, servo will rotate to the designated position.

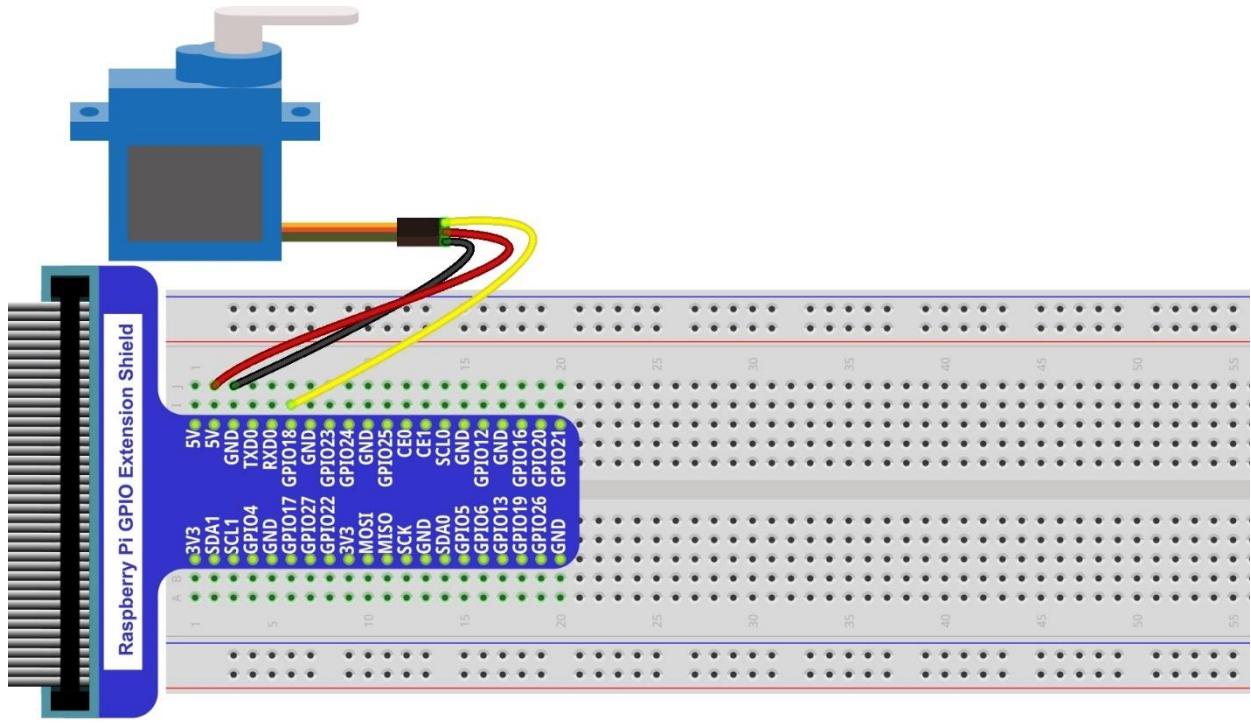
Circuit

Pay attention to the power supply for stepping motor is 5v, and don't confuse the line sequence.

Schematic diagram



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



Code

In this project, we make the servo rotate from 0 degrees to 180 degrees, and then from 180 degrees to 0 degrees.

C Code 15.1.1 Sweep

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

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

1. Use cd command to enter 15.1.1_Sweep directory of C code.

```
cd ~/Freenove_Kit/Code/C_Code/15.1.1_Sweep
```

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

```
gcc Sweep.c -o Sweep -lwiringPi
```

3. Run the generated file "Sweep".

```
sudo ./Sweep
```

After the program is executed, the servo will rotate from 0 degrees to 180 degrees, and then from 180 degrees to 0 degrees, circularly.

The following is the program code:

```
1 #include <wiringPi.h>
2 #include <softPwm.h>
3 #include <stdio.h>
4 #define OFFSET_MS 3      //Define the unit of servo pulse offset: 0.1ms
5 #define SERVO_MIN_MS 5+OFFSET_MS          //define the pulse duration for minimum angle of servo
6 #define SERVO_MAX_MS 25+OFFSET_MS        //define the pulse duration for maximum angle of servo
7
8 #define servoPin    1      //define the GPIO number connected to servo
9 long map(long value, long fromLow, long fromHigh, long toLow, long toHigh) {
10     return (toHigh-toLow)*(value-fromLow) / (fromHigh-fromLow) + toLow;
11 }
12 void servoInit(int pin){           //initialization function for servo PMW pin
13     softPwmCreate(pin, 0, 200);
14 }
15 void servoWrite(int pin, int angle){ //Specify a certain rotation angle (0-180) for the
16 servo
17     if(angle > 180)
18         angle = 180;
19     if(angle < 0)
20         angle = 0;
21     softPwmWrite(pin, map(angle, 0, 180, SERVO_MIN_MS, SERVO_MAX_MS));
22 }
23 void servoWriteMS(int pin, int ms){ //specific the unit for pulse(5-25ms) with specific
24 duration output by servo pin: 0.1ms
25     if(ms > SERVO_MAX_MS)
26         ms = SERVO_MAX_MS;
27     if(ms < SERVO_MIN_MS)
```

```

28     ms = SERVO_MIN_MS;
29     softPwmWrite(pin, ms);
30 }
31
32 int main(void)
33 {
34     int i;
35
36     printf("Program is starting ... \n");
37
38     wiringPiSetup();
39     servoInit(servoPin);           //initialize PWM pin of servo
40     while(1){
41         for(i=SEROV_MIN_MS;i<SERVO_MAX_MS;i++) { //make servo rotate from minimum angle to
42             maximum angle
43                 servoWriteMS(servoPin, i);
44                 delay(10);
45             }
46             delay(500);
47             for(i=SEROV_MAX_MS;i>SEROV_MIN_MS;i--) { //make servo rotate from maximum angle to
48             minimum angle
49                 servoWriteMS(servoPin, i);
50                 delay(10);
51             }
52             delay(500);
53     }
54     return 0;
55 }
```

50 Hz pulse, namely cycle for 20ms, is required to control Servo. In function **softPwmCreate** (int pin, int initialValue, int pwmRange), the unit of third parameter pwmRange is 100US, namely 0.1ms. In order to get the PWM with cycle of 20ms, the pwmRange shoule be set to 200. So in subfunction of **servoInit()**, we create a PWM pin with pwmRange 200.

```

void servoInit(int pin){           //initialization function for servo PWM pin
    softPwmCreate(pin, 0, 200);
}
```

As 0-180 degrees of servo corresponds to PWM pulse width 0.5-2.5ms, with PwmRange 200 and unit 0.1ms. So, in function **softPwmWrite** (int pin, int value), the scope 5-25 of parameter value corresponds to 0-180 degrees of servo. What's more, the number writen in subfunction **servoWriteMS()** should be within the range of 5-25. However, in practice, due to the manufacture error of each servo, pulse width will also have deviation. So we define a minimum pulse width and a maximum one and an error offset.

```

#define OFFSET_MS 3      //Define the unit of servo pulse offset: 0.1ms
#define SERVO_MIN_MS 5+OFFSET_MS      //define the pulse duration for minimum angle of
servo
```

```
#define SERVO_MAX_MS 25+OFFSET_MS      //define the pulse duration for maximum angle of
servo
.....
void servoWriteMS(int pin, int ms) {
    if(ms > SERVO_MAX_MS)
        ms = SERVO_MAX_MS;
    if(ms < SERVO_MIN_MS)
        ms = SERVO_MIN_MS;
    softPwmWrite(pin, ms);
}
```

In subfunction **servoWrite ()**, input directly angle (0-180 degrees), and map the angle to the pulse width and then output it.

```
void servoWrite(int pin, int angle){ //Specif a certain rotation angle (0-180) for the
servo
    if(angle > 180)
        angle = 180;
    if(angle < 0)
        angle = 0;
    softPwmWrite(pin, map(angle, 0, 180, SERVO_MIN_MS, SERVO_MAX_MS));
}
```

Finally, in the "while" cycle of main function, use two "for" cycle to make servo rotate from 0 degrees to 180 degrees, and then from 180 degrees to 0 degrees.

```
while(1) {
    for(i=SEROV_MIN_MS;i<SERVO_MAX_MS;i++){ //make servo rotate from minimum angle
to maximum angle
        servoWriteMS(servoPin, i);
        delay(10);
    }
    delay(500);
    for(i=SEROV_MAX_MS;i>SERVO_MIN_MS;i--){ //make servo rotate from maximum angle
to minimum angle
        servoWriteMS(servoPin, i);
        delay(10);
    }
    delay(500);
}
```

Python Code 15.1.1 Sweep

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

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

1. Use cd command to enter 15.1.1_Sweep directory of Python code.

```
cd ~/Freenove_Kit/Code/Python_Code/15.1.1_Sweep
```

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

```
python Sweep.py
```

After the program is executed, the servo will rotate from 0 degrees to 180 degrees, and then from 180 degrees to 0 degrees, circularly.

The following is the program code:

```

1 import RPi.GPIO as GPIO
2
3 OFFSE_DUTY = 0.5      #define pulse offset of servo
4 SERVO_MIN_DUTY = 2.5+OFFSE_DUTY    #define pulse duty cycle for minimum angle of servo
5 SERVO_MAX_DUTY = 12.5+OFFSE_DUTY  #define pulse duty cycle for maximum angle of servo
6 servoPin = 12
7
8 def map( value, fromLow, fromHigh, toLow, toHigh): # map a value from one range to another
9     return (toHigh-toLow)*(value-fromLow) / (fromHigh-fromLow) + toLow
10
11
12 def setup():
13     global p
14     GPIO.setmode(GPIO.BOARD)      # use PHYSICAL GPIO Numbering
15     GPIO.setup(servoPin, GPIO.OUT) # Set servoPin to OUTPUT mode
16     GPIO.output(servoPin, GPIO.LOW) # Make servoPin output LOW level
17
18     p = GPIO.PWM(servoPin, 50)    # set Frequece to 50Hz
19     p.start(0)                  # Set initial Duty Cycle to 0
20
21 def servoWrite(angle):      # make the servo rotate to specific angle, 0-180
22     if(angle<0):
23         angle = 0
24     elif(angle > 180):
25         angle = 180
26     p.ChangeDutyCycle(map(angle, 0, 180, SERVO_MIN_DUTY, SERVO_MAX_DUTY)) # map the angle to duty
27     cycle and output it
28
29 def loop():
30     while True:
31         for dc in range(0, 181, 1): # make servo rotate from 0 to 180 deg
32             servoWrite(dc)      # Write dc value to servo
33             time.sleep(0.001)

```

```

34     time.sleep(0.5)
35     for dc in range(180, -1, -1): # make servo rotate from 180 to 0 deg
36         servoWrite(dc)
37         time.sleep(0.001)
38     time.sleep(0.5)
39
40 def destroy():
41     p.stop()
42     GPIO.cleanup()
43
44 if __name__ == '__main__':      # Program entrance
45     print ('Program is starting...')
46     setup()
47     try:
48         loop()
49     except KeyboardInterrupt: # Press ctrl-c to end the program.
50         destroy()

```

50 Hz pulse, namely cycle for 20ms, is required to control Servo. So we need set PWM frequency of servoPin to 50Hz.

```
p = GPIO.PWM(servoPin, 50)      # Set Frequency to 50Hz
```

As 0-180 degrees of servo corresponds to PWM pulse width 0.5-2.5ms within cycle 20ms and to duty cycle 2.5%-12.5%. In subfunction **servoWrite** (angle), map the angle to duty cycle to output the PWM, then the servo will rotate a specific angle. However, in practice, due to the manufacture error of each servo, pulse width will also have deviation. So we define a minimum pulse width and a maximum one and an error offset.

```

OFFSE_DUTY = 0.5      #define pulse offset of servo
SERVO_MIN_DUTY = 2.5+OFFSE_DUTY    #define pulse duty cycle for minimum angle of servo
SERVO_MAX_DUTY = 12.5+OFFSE_DUTY   #define pulse duty cycle for maximum angle of servo
.....
def servoWrite(angle):      #make the servo rotate to specific angle (0-180 degrees)
    if(angle<0):
        angle = 0
    elif(angle > 180):
        angle = 180
    p.ChangeDutyCycle(map(angle, 0, 180, SERVO_MIN_DUTY, SERVO_MAX_DUTY))

```

Finally, in the "while" cycle of main function, use two "for" cycle to make servo rotate from 0 degrees to 180 degrees, and then from 180 degrees to 0 degrees.

```
def loop():
    while True:
        for dc in range(0, 181, 1):  #make servo rotate from 0° to 180°
            servoWrite(dc)          # Write to servo
            time.sleep(0.001)
            time.sleep(0.5)
        for dc in range(180, -1, -1): #make servo rotate from 180° to 0°
            servoWrite(dc)
            time.sleep(0.001)
            time.sleep(0.5)
```

Chapter 16 Stepping Motor

We have learned DC motor and servo before: the DC motor can rotate constantly but we can not make it rotate to a specific angle. On the contrary, the ordinary servo can rotate to a certain angle but can not rotate constantly. In this chapter, we will learn a motor which can rotate not only constantly, but also to a specific angle, stepping motor. Using stepping motor can achieve higher accuracy of mechanical motion easily.

Project 16.1 Stepping Motor

In this project, we will learn how to drive stepping motor, and understand its working principle.

Component List

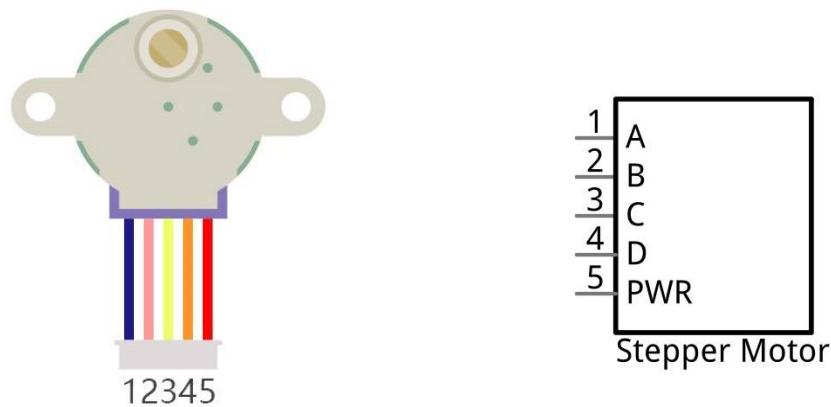
Raspberry Pi (with 40 GPIO) x1 GPIO Expansion Board & Wire x1 BreadBoard x1	Jumper
Stepping Motor x1	ULN2003 Stepping motorDriver x1

The diagram shows the components required for the project. It includes a Raspberry Pi (represented by a small orange square), a breadboard (represented by a grey rectangular board), and several jumper wires (represented by short black lines). Below these are the physical components: a silver-colored stepping motor with four leads (red, yellow, green, blue) and a green ULN2003 driver module. The driver module has various pins labeled, including power inputs (5V and GND), ground connections, and four input pins (IN1, IN2, IN3, IN4) for controlling the motor's rotation.

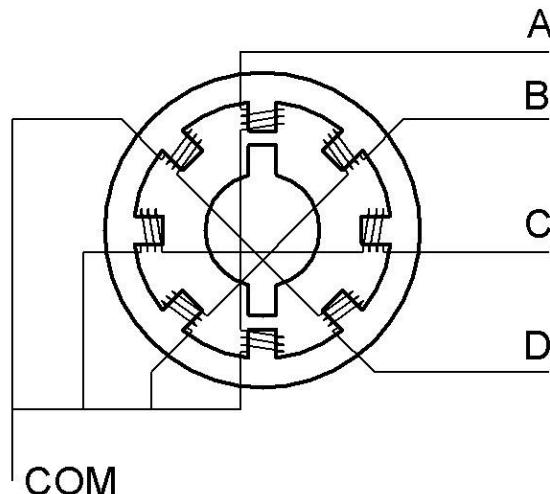
Component knowledge

Stepping Motor

Stepping motor is an open-loop control device which converts the electric pulse signal into angular displacement or linear displacement. In non-overload condition, the speed of the motor and the location of the stop depends only on the pulse signal frequency and pulse number, and not affected by the load changes. A small four-phase deceleration stepping motor is shown as follows:

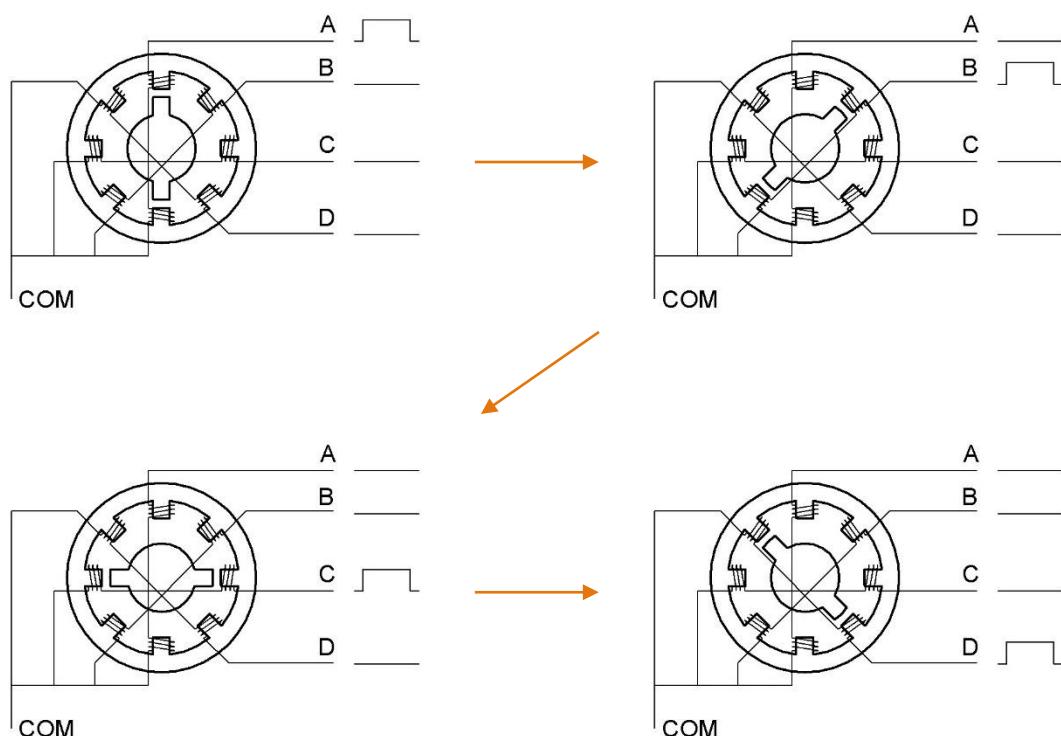


The schematic diagram of four-phase stepping motor is shown below:



The outside piece is the stator and the inside is the rotor of the motor. There are a certain number of coils, usually integer multiple of phases number, in the stator and when powered on, an electromagnet will be formed to attract a convex part (usually iron or permanent magnet) of the rotor. Therefore, the electric motor can be driven by conducting the coils on stator orderly.

A common driving process is as follows:



In the course above, the stepping motor rotates a certain angle once, which is called a step. By controlling the number of rotation steps, you can control the stepping motor rotation angle. By controlling the time between two steps, you can control the stepping motor rotation speed. When rotating clockwise, the order of coil powered on is: A→B→C→D→A→…… . And the rotor will rotate in accordance with the order, step by step down, called four steps four pats. If the coils is powered on in the reverse order, D→C→B→A→D→…… , the rotor will rotate in anti-clockwise direction.

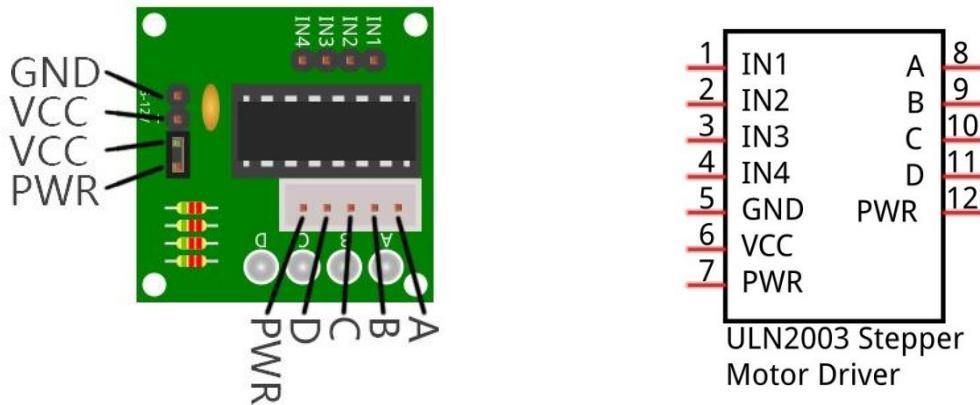
Stepping motor has other control methods, such as connect A phase, then connect A B phase, the stator will be located in the middle of the A B, only a half-step. This way can improve the stability of stepping motor, and reduce noise, the sequence of coil powered on is: A→AB→B→BC→C→CD→D→DA→A→…… , the rotor will rotate in accordance with the order, a half step by a half step, called four step eight pat. Equally, if the coil is powered on in reverse order, the stepping motor will rotate in reverse rotation.

The stator of stepping motor we use has 32 magnetic poles, so a circle needs 32 steps. The output shaft of the stepping motor is connected with a reduction gear set, and the reduction ratio is 1/64. So the final output shaft rotates a circle requiring a $32 \times 64 = 2048$ step.



ULN2003 Stepping motor driver

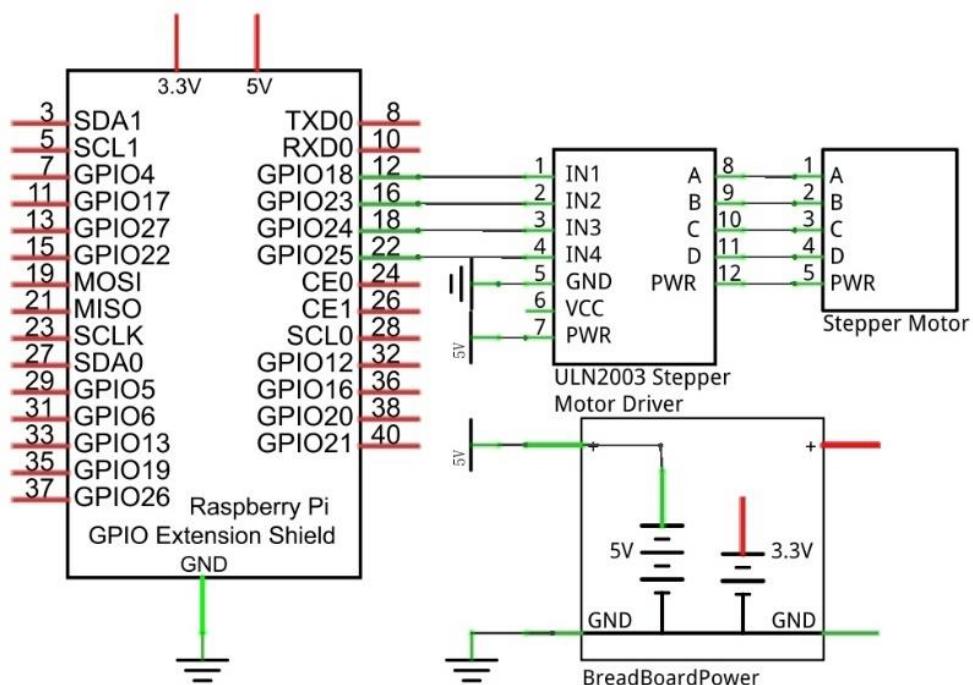
ULN2003 stepping motor driver is used to convert the weak signal into powerful control signal to drive the stepping motor. The input signal IN1-IN4 corresponds to the output signal A-D, and 4 LED is integrated in the board to indicate the state of signals. The PWR interface can be used as a power supply for stepping motor. By default, PWR and VCC are connected by a short circuit.



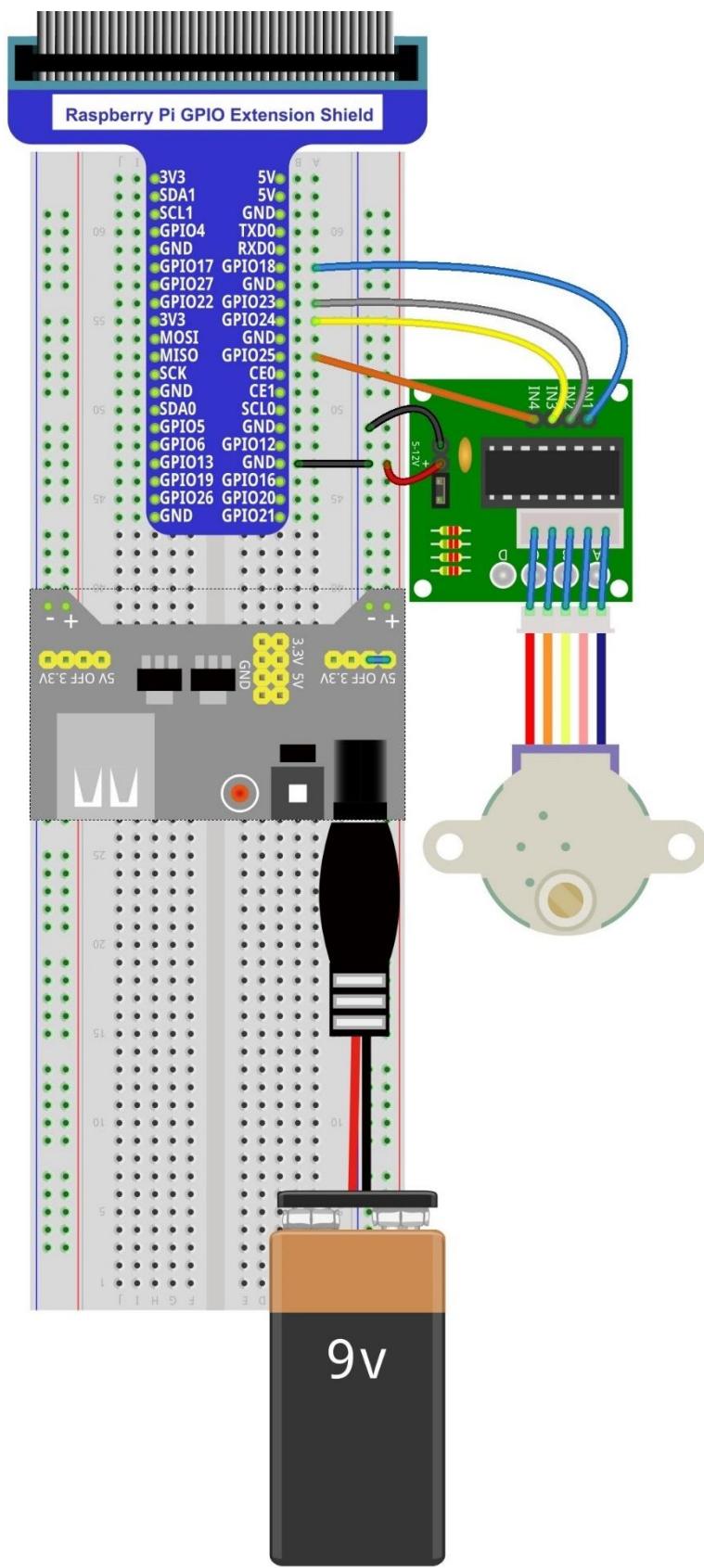
Circuit

When building the circuit, the rated voltage of the stepping motor 5V, and use the breadboard power supply independently, and do not use the RPi power supply. Additionally, breadboard power supply needs to share Ground with RPi.

Schematic diagram



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



Code

This code use four step four pat mode to drive the stepping motor forward and reverse direction.

C Code 16.1.1 SteppingMotor

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

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

1. Use cd command to enter 16.1.1_SteppingMotor directory of C code.

```
cd ~/Freenove_Kit/Code/C_Code/16.1.1_SteppingMotor
```

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

```
gcc SteppingMotor.c -o SteppingMotor -lwiringPi
```

3. Run the generated file "SteppingMotor".

```
sudo ./SteppingMotor
```

After the program is executed, the stepping motor will rotate 360° clockwise and then 360° anticlockwise, circularly.

The following is the program code:

```

1 #include <stdio.h>
2 #include <wiringPi.h>
3
4 const int motorPins[]={1, 4, 5, 6}; //define pins connected to four phase ABCD of stepper
5 motor
6 const int CCWStep[]={0x01, 0x02, 0x04, 0x08}; //define power supply order for coil for rotating
7 anticlockwise
8 const int CWStep[]={0x08, 0x04, 0x02, 0x01}; //define power supply order for coil for rotating
9 clockwise
10 //as for four phase stepping motor, four steps is a cycle. the function is used to drive the
11 stepping motor clockwise or anticlockwise to take four steps
12 void moveOnePeriod(int dir, int ms){
13     int i=0, j=0;
14     for (j=0;j<4;j++){ //cycle according to power supply order
15         for (i=0;i<4;i++){ //assign to each pin, a total of 4 pins
16             if(dir == 1) //power supply order clockwise
17                 digitalWrite(motorPins[i], (CCWStep[j] == (1<<i)) ? HIGH : LOW);
18             else //power supply order anticlockwise
19                 digitalWrite(motorPins[i], (CWStep[j] == (1<<i)) ? HIGH : LOW);
20             printf("motorPin %d, %d \n", motorPins[i], digitalRead(motorPins[i]));
21         }
22         printf("Step cycle!\n");
23         if(ms<3) //the delay can not be less than 3ms, otherwise it will exceed speed
24         limit of the motor
25             ms=3;
26         delay(ms);
27     }
28 }
```

```

29 //continuous rotation function, the parameter steps specifies the rotation cycles, every four
30 steps is a cycle
31 void moveSteps(int dir, int ms, int steps) {
32     int i;
33     for(i=0;i<steps;i++) {
34         moveOnePeriod(dir,ms);
35     }
36 }
37 void motorStop() { //function used to stop rotating
38     int i;
39     for(i=0;i<4;i++) {
40         digitalWrite(motorPins[i],LOW);
41     }
42 }
43 int main(void) {
44     int i;
45
46     printf("Program is starting ... \n");
47
48     wiringPiSetup();
49
50     for(i=0;i<4;i++) {
51         pinMode(motorPins[i],OUTPUT);
52     }
53
54     while(1) {
55         moveSteps(1,3,512); //rotating 360° clockwise, a total of 2048 steps in a circle,
56         namely, 512 cycles.
57         delay(500);
58         moveSteps(0,3,512); //rotating 360° anticlockwise
59         delay(500);
60     }
61     return 0;
62 }
```

In the code, define four pins of stepping motor and coil power supply order of four steps rotation mode.

```

const int motorPins[]={1,4,5,6}; //define pins connected to four phase ABCD of stepper
motor
const int CCWStep[]={0x01,0x02,0x04,0x08}; //define power supply order for coil for
rotating anticlockwise
const int CWStep[]={0x08,0x04,0x02,0x01}; //define power supply order for coil for
rotating clockwise
```

Subfunction **moveOnePeriod** ((int dir,int ms) will drive the stepping motor rotating four step clockwise or anticlockwise, four step as a cycle. Where parameter "dir" indicates the rotation direction, if "dir" is 1, the servo will rotate forward, otherwise it rotates to reverse direction. Parameter "ms" indicates the time between each



two steps. The "ms" of stepping motor used in this project is 3ms (the shortest time), less than 3ms will exceed the speed limit of stepping motor resulting in that motor can not rotate.

```
void moveOnePeriod(int dir, int ms) {
    int i=0, j=0;
    for (j=0;j<4;j++) { //cycle according to power supply order
        for (i=0;i<4;i++) { //assign to each pin, a total of 4 pins
            if(dir == 1) //power supply order clockwise
                digitalWrite(motorPins[i], (CCWStep[j] == (1<<i)) ? HIGH : LOW);
            else //power supply order anticlockwise
                digitalWrite(motorPins[i], (CWStep[j] == (1<<i)) ? HIGH : LOW);
            printf("motorPin %d, %d \n", motorPins[i], digitalRead(motorPins[i]));
        }
        printf("Step cycle!\n");
        if(ms<3) //the delay can not be less than 3ms, otherwise it will exceed
        speed limit of the motor
            ms=3;
        delay(ms);
    }
}
```

Subfunction **moveSteps** (int dir, int ms, int steps) is used to specific cycle number of stepping motor.

```
void moveSteps(int dir, int ms, int steps) {
    int i;
    for(i=0;i<steps;i++) {
        moveOnePeriod(dir, ms);
    }
}
```

Subfunction **motorStop ()** is used to stop the stepping motor.

```
void motorStop() { //function used to stop rotating
    int i;
    for(i=0;i<4;i++) {
        digitalWrite(motorPins[i], LOW);
    }
}
```

Finally, in the while cycle of main function, rotate one circle clockwise, and then one circle anticlockwise. According to the previous knowledge of the stepping motor, it can be known that the stepping motor rotation for one circle requires 2048 steps, that is, $2048/4=512$ cycle.

```
while(1) {
    moveSteps(1, 3, 512); //rotating 360° clockwise, a total of 2048 steps in a
    circle, namely, this function(four steps) will be called 512 times.
    delay(500);
    moveSteps(0, 3, 512); //rotating 360° anticlockwise
    delay(500);
}
```

Python Code 16.1.1 SteppingMotor

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

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

1. Use cd command to enter 16.1.1_SteppingMotor directory of Python code.

```
cd ~/Freenove_Kit/Code/Python_Code/16.1.1_SteppingMotor
```

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

```
python SteppingMotor.py
```

After the program is executed, the stepping motor will rotate 360° clockwise and then 360° anticlockwise, circularly.

The following is the program code:

```
1 import RPi.GPIO as GPIO
2 import time
3
4 motorPins = (12, 16, 18, 22)      # define pins connected to four phase ABCD of stepper motor
5 CCWStep = (0x01, 0x02, 0x04, 0x08) # define power supply order for rotating anticlockwise
6 CWStep = (0x08, 0x04, 0x02, 0x01)  # define power supply order for rotating clockwise
7
8 def setup():
9     GPIO.setmode(GPIO.BOARD)        # use PHYSICAL GPIO Numbering
10    for pin in motorPins:
11        GPIO.setup(pin, GPIO.OUT)
12
13    # as for four phase stepping motor, four steps is a cycle. the function is used to drive the
14    # stepping motor clockwise or anticlockwise to take four steps
15    def moveOnePeriod(direction, ms):
16        for j in range(0, 4, 1):      # cycle for power supply order
17            for i in range(0, 4, 1):  # assign to each pin
18                if (direction == 1):# power supply order clockwise
19                    GPIO.output(motorPins[i], ((CCWStep[j] == 1<<i) and GPIO.HIGH or GPIO.LOW))
20                else :                  # power supply order anticlockwise
21                    GPIO.output(motorPins[i], ((CWStep[j] == 1<<i) and GPIO.HIGH or GPIO.LOW))
22        if(ms<3):      # the delay can not be less than 3ms, otherwise it will exceed speed
23        # limit of the motor
24            ms = 3
25        time.sleep(ms*0.001)
26
27    # continuous rotation function, the parameter steps specifies the rotation cycles, every four
28    # steps is a cycle
29    def moveSteps(direction, ms, steps):
30        for i in range(steps):
31            moveOnePeriod(direction, ms)
32
33    # function used to stop motor
34    def motorStop():
```

```

35     for i in range(0, 4, 1):
36         GPIO.output(motorPins[i], GPIO.LOW)
37
38 def loop():
39     while True:
40         moveSteps(1, 3, 512) # rotating 360 deg clockwise, a total of 2048 steps in a circle,
41         512 cycles
42         time.sleep(0.5)
43         moveSteps(0, 3, 512) # rotating 360 deg anticlockwise
44         time.sleep(0.5)
45
46 def destroy():
47     GPIO.cleanup()          # Release resource
48
49 if __name__ == '__main__':    # Program entrance
50     print ('Program is starting...')
51     setup()
52     try:
53         loop()
54     except KeyboardInterrupt: # Press ctrl-c to end the program.
55         destroy()

```

In the code, define four pins of stepping motor and coil power supply order of four steps rotation mode.

```

motorPins = (12, 16, 18, 22)      #define pins connected to four phase ABCD of stepper
motor

CCWStep = (0x01, 0x02, 0x04, 0x08) #define power supply order for coil for rotating
anticlockwise

CWStep = (0x08, 0x04, 0x02, 0x01) #define power supply order for coil for rotating
clockwise

```

Subfunction **moveOnePeriod** (direction, ms) will drive the stepping motor rotating four step clockwise or anticlockwise, four step as a cycle. Where parameter "dir" indicates the rotation direction, if "dir" is 1, the servo will rotate forward, otherwise it rotates to reverse direction. Parameter "ms" indicates the time between each two steps. The "ms" of stepping motor used in this project is 3ms (the shortest time), less than 3ms will exceed the speed limit of stepping motor resulting in that motor can not rotate.

```

def moveOnePeriod(direction, ms):
    for j in range(0, 4, 1):      #cycle for power supply order
        for i in range(0, 4, 1):  #assign to each pin, a total of 4 pins
            if (direction == 1):#power supply order clockwise
                GPIO.output(motorPins[i], ((CCWStep[j] == 1<<i) and GPIO.HIGH or GPIO.LOW))
            else :                  #power supply order anticlockwise
                GPIO.output(motorPins[i], ((CWStep[j] == 1<<i) and GPIO.HIGH or GPIO.LOW))
            if(ms<3):             #the delay can not be less than 3ms, otherwise it will exceed
speed limit of the motor
            ms = 3

```

```
time.sleep(ms*0.001)
```

Subfunction **moveSteps** (direction, ms, steps) is used to specific cycle number of stepping motor.

```
def moveSteps(direction, ms, steps):
    for i in range(steps):
        moveOnePeriod(direction, ms)
```

Subfunction **motorStop** () is used to stop the stepping motor.

```
def motorStop():
    for i in range(0, 4, 1):
        GPIO.output(motorPins[i], GPIO.LOW)
```

Finally, in the while cycle of main function, rotate one circle clockwise, and then one circle anticlockwise. According to the previous knowledge of the stepping motor, it can be known that the stepping motor rotation for one circle requires 2048 steps, that is, $2048/4=512$ cycle.

```
while True:
    moveSteps(1, 3, 512) #rotating 360° clockwise, a total of 2048 steps in a
    circle, namely, 512 cycles.
    time.sleep(0.5)
    moveSteps(0, 3, 512) #rotating 360° anticlockwise
    time.sleep(0.5)
```

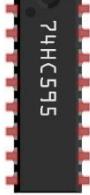
Chapter 17 74HC595 & LEDBar Graph

We have used LEDBar Graph to make a flowing water light, in which 10 GPIO ports of RPi is occupied. More GPIO ports mean that more peripherals can be connected to RPi, so GPIO resource is very precious. Can we make flowing water light with less GPIO? In this chapter, we will learn a component, 74HC595, which can achieve the target.

Project 17.1 Flowing Water Light

Now let's learn how to use 74HC595 to make a flowing water light with less GPIO.

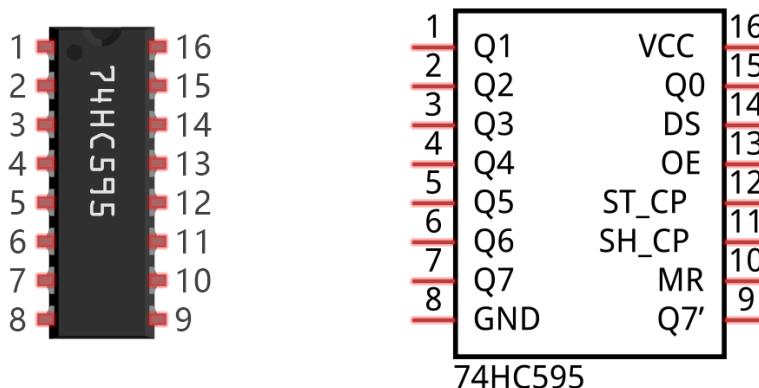
Component List

Raspberry Pi (with 40 GPIO) x1 GPIO Extension Board & Wire x1 BreadBoard x1	Jumper 	
74HC595 x1 	LEDBar Graph x1 	Resistor 220Ω x8 

Component knowledge

74HC595

74HC595 chip is used to convert serial data into parallel data. 74HC595 can convert the serial data of one byte to 8 bits, and send its corresponding level to the corresponding 8 ports. With this feature, 74HC595 can be used to expand the IO port of Raspberry Pi. At least 3 ports on the RPI board are need to control 8 ports of 74HC595.



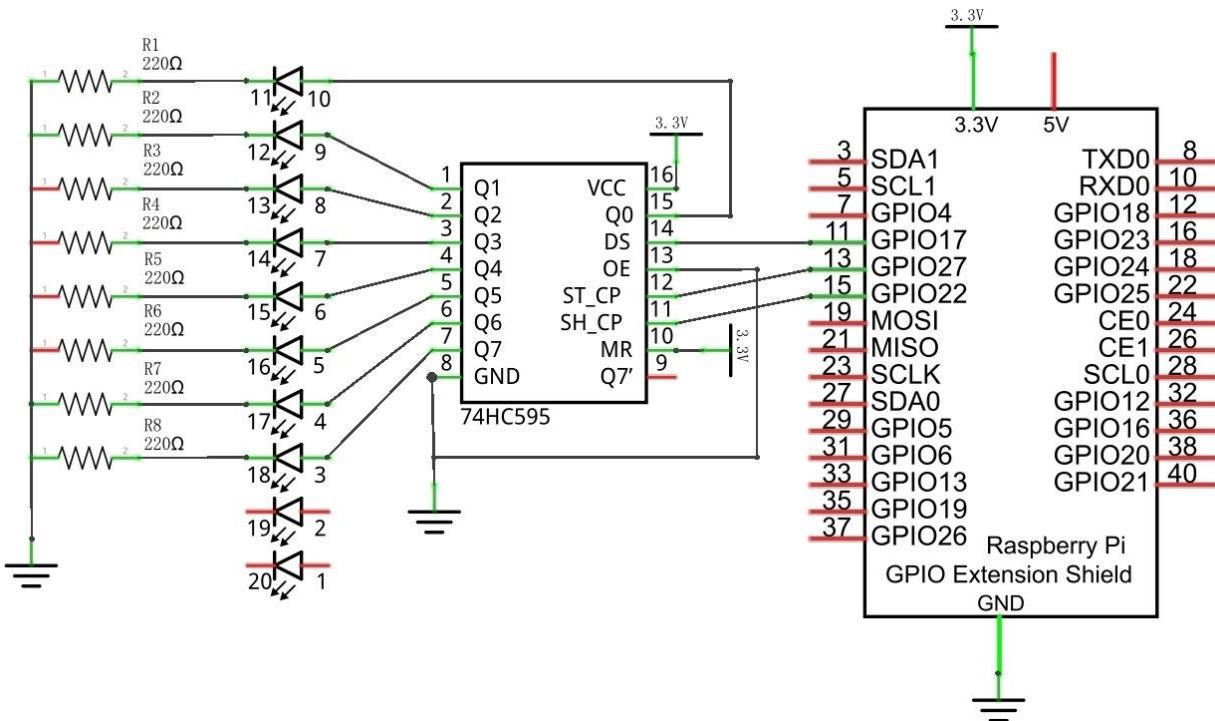
The ports of 74HC595 are described as follows:

Pin name	Pin number	Description
Q0-Q7	15, 1-7	Parallel data output
VCC	16	The positive electrode of power supply, the voltage is 2~6V
GND	8	The negative electrode of power supply
DS	14	Serial data Input
OE	13	Enable output, When this pin is in high level, Q0-Q7 is in high resistance state When this pin is in low level, Q0-Q7 is in output mode
ST_CP	12	Parallel update output: when its electrical level is rising, it will update the parallel data output.
SH_CP	11	Serial shift clock: when its electrical level is rising, serial data input register will do a shift.
MR	10	Remove shift register: When this pin is in low level, the content in shift register will be cleared .
Q7'	9	Serial data output: it can be connected to more 74HC595 in series.

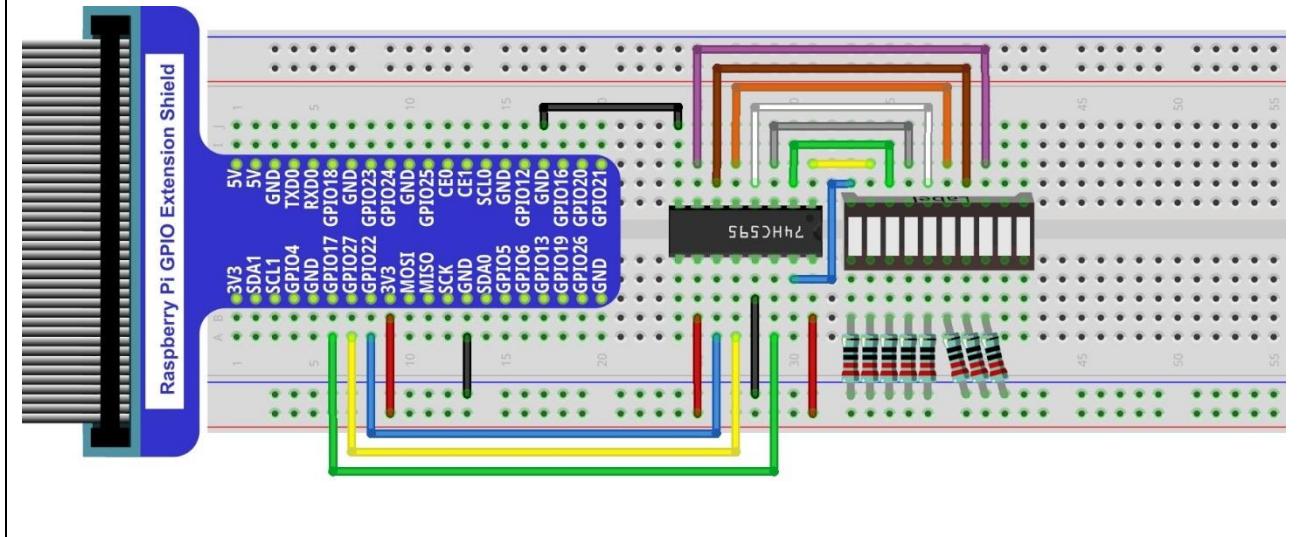
For more detail, please refer to the datasheet.

Circuit

Schematic diagram



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



Code

In this project, make a flowing water light with 74HC595 to learn its usage.

C Code 17.1.1 LightWater02

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

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

1. Use cd command to enter 17.1.1_LightWater02 directory of C code.

```
cd ~/Freenove_Kit/Code/C_Code/17.1.1_LightWater02
```

2. Use following command to compile "LightWater02.c" and generate executable file "LightWater02".

```
gcc LightWater02.c -o LightWater02 -lwiringPi
```

3. Then run the generated file "LightWater02".

```
sudo ./LightWater02
```

After the program is executed, LEDBar Graph begin to display flowing water light from left to right, then from right to left.

The following is the program code:

```
1 #include <wiringPi.h>
2 #include <stdio.h>
3 #include <wiringShift.h>
4
5 #define dataPin 0 //DS Pin of 74HC595(Pin14)
6 #define latchPin 2 //ST_CP Pin of 74HC595(Pin12)
7 #define clockPin 3 //CH_CP Pin of 74HC595(Pin11)
8
9 void _shiftOut(int dPin, int cPin, int order, int val) {
10     int i;
11     for(i = 0; i < 8; i++) {
12         digitalWrite(cPin, LOW);
13         if(order == LSBFIRST) {
14             digitalWrite(dPin, ((0x01&(val>>i)) == 0x01) ? HIGH : LOW);
15             delayMicroseconds(10);
16         }
17         else {//if(order == MSBFIRST) {
18             digitalWrite(dPin, ((0x80&(val<<i)) == 0x80) ? HIGH : LOW);
19             delayMicroseconds(10);
20         }
21         digitalWrite(cPin, HIGH);
22         delayMicroseconds(10);
23     }
24 }
25
26 int main(void)
27 {
28     int i;
```

```

29     unsigned char x;
30
31     printf("Program is starting ... \n");
32
33     wiringPiSetup();
34
35     pinMode(dataPin, OUTPUT);
36     pinMode(latchPin, OUTPUT);
37     pinMode(clockPin, OUTPUT);
38
39     while(1) {
40         x=0x01;
41         for(i=0;i<8;i++) {
42             digitalWrite(latchPin,LOW);           // Output low level to latchPin
43             _shiftOut(dataPin,clockPin,LSBFIRST,x);// Send serial data to 74HC595
44             digitalWrite(latchPin,HIGH);        //Output high level to latchPin, and 74HC595 will
45             update the data to the parallel output port.
46             x<<=1;           //make the variable move one bit to left once, then the bright LED
47             move one step to the left once.
48             delay(100);
49         }
50         x=0x80;
51         for(i=0;i<8;i++) {
52             digitalWrite(latchPin,LOW);
53             _shiftOut(dataPin,clockPin,LSBFIRST,x);
54             digitalWrite(latchPin,HIGH);
55             x>>=1;
56             delay(100);
57         }
58     }
59 }
```

In the code, we configure three pins to control the 74HC595. And define a one-byte variable to control the state of 8 LEDs through the 8 bits of the variable. The LED lights on when the corresponding bit is 1. If the variable is assigned to 0x01, that is 00000001 in binary, there will be only one LED on.

x=0x01;

In the “while” cycle of main function, use “for” cycle to send x to 74HC595 output pin to control the LED. In “for” cycle, x will be shift one bit to left in one cycle, then in the next round when data of x is sent to 74HC595, the LED turned on will move one bit to left once.

for(i=0;i<8;i++) {
 digitalWrite(latchPin,LOW); // Output low level to latchPin
 _shiftOut(dataPin,clockPin,LSBFIRST,x);// Send serial data to 74HC595
 digitalWrite(latchPin,HIGH); // Output high level to latchPin, and 74HC595
 will update the data to the parallel output port.

```

x<<=1; // make the variable move one bit to left once, then the bright LED
move one step to the left once.

delay(100);

}

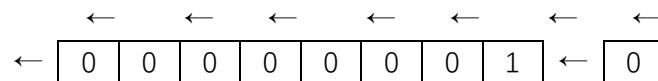
```

In second "for" cycle, the situation is the same. The difference is that x is shift from 0x80 to right in order.

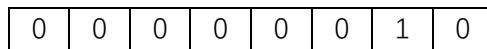
<< operator

"<<" is the left shift operator, which can make all bits of 1 byte shift by several bits to the left (high) direction and add 0 on the right (low). For example, shift binary 00000001 by 1 bit to left:

byte x = 1 << 1;

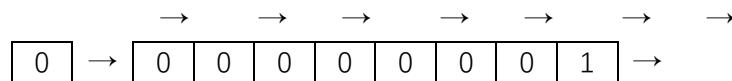


The result of x is 2 (binary 00000010) .

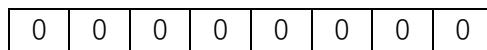


There is another similar operator " >> ". For example, shift binary 00000001 by 1 bit to right:

byte x = 1 >> 1;



The result of x is 0 (00000000) .



X <<= 1 is equivalent to x = x << 1 and x >>= 1 is equivalent to x = x >> 1

About shift function:

`uint8_t shiftIn(uint8_t dPin, uint8_t cPin, uint8_t order);`

This is used to shift an 8-bit data value in with the data appearing on the dPin and the clock being sent out on the cPin. Order is either LSBFIRST or MSBFIRST. The data is sampled after the cPin goes high. (So cPin high, sample data, cPin low, repeat for 8 bits) The 8-bit value is returned by the function.

`void shiftOut(uint8_t dPin, uint8_t cPin, uint8_t order, uint8_t val);`

`void _shiftOut(uint8_t dPin, uint8_t cPin, uint8_t order, uint8_t val);`

This is used to shift an 8-bit data value out with the data being sent out on dPin and the clock being sent out on the cPin. order is as above. Data is clocked out on the rising or falling edge - ie. dPin is set, then cPin is taken high then low - repeated for the 8 bits.

For more details about shift function, please refer to: <http://wiringpi.com/reference/shift-library/>



Python Code 17.1.1 LightWater02

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

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

1. Use cd command to enter 17.1.1_LightWater02 directory of Python code.

```
cd ~/Freenove_Kit/Code/Python_Code/17.1.1_LightWater02
```

2. Use python command to execute python code "LightWater02.py".

```
python LightWater02.py
```

After the program is executed, LEDBar Graph begin to display flowing water light from left to right, then from right to left.

The following is the program code:

```

1 import RPi.GPIO as GPIO
2 import time
3 # Defines the data bit that is transmitted preferentially in the shiftOut function.
4 LSBFIRST = 1
5 MSBFIRST = 2
6 # define the pins for 74HC595
7 dataPin = 11      # DS Pin of 74HC595(Pin14)
8 latchPin = 13     # ST_CP Pin of 74HC595(Pin12)
9 clockPin = 15     # CH_CP Pin of 74HC595(Pin11)
10
11 def setup():
12     GPIO.setmode(GPIO.BOARD)      # use PHYSICAL GPIO Numbering
13     GPIO.setup(dataPin, GPIO.OUT) # set pin to OUTPUT mode
14     GPIO.setup(latchPin, GPIO.OUT)
15     GPIO.setup(clockPin, GPIO.OUT)
16
17 # shiftOut function, use bit serial transmission.
18 def shiftOut(dPin, cPin, order, val):
19     for i in range(0, 8):
20         GPIO.output(cPin, GPIO.LOW);
21         if(order == LSBFIRST):
22             GPIO.output(dPin, (0x01&(val>>i)==0x01) and GPIO.HIGH or GPIO.LOW)
23         elif(order == MSBFIRST):
24             GPIO.output(dPin, (0x80&(val<<i)==0x80) and GPIO.HIGH or GPIO.LOW)
25         GPIO.output(cPin, GPIO.HIGH);
26
27 def loop():
28     while True:
29         x=0x01
30         for i in range(0, 8):
31             GPIO.output(latchPin,GPIO.LOW) # Output low level to latchPin
32             shiftOut(dataPin,clockPin,LSBFIRST,x) # Send serial data to 74HC595
33             GPIO.output(latchPin,GPIO.HIGH) # Output high level to latchPin, and 74HC595 will
34             update the data to the parallel output port.

```

```

35             x<<=1 # make the variable move one bit to left once, then the bright LED move one
36             step to the left once.
37             time.sleep(0.1)
38             x=0x80
39             for i in range(0,8):
40                 GPIO.output(latchPin,GPIO.LOW)
41                 shiftOut(dataPin,clockPin,LSBFIRST,x)
42                 GPIO.output(latchPin,GPIO.HIGH)
43             x>>=1
44             time.sleep(0.1)
45
46 def destroy():
47     GPIO.cleanup()
48
49 if __name__ == '__main__': # Program entrance
50     print ('Program is starting... ')
51     setup()
52     try:
53         loop()
54     except KeyboardInterrupt: # Press ctrl-c to end the program.
55         destroy()

```

In the code, we define a shiftOut() function, which is used to output value with bit in order. And where the dPin for the data pin, cPin for the clock and order for the priority bit flag (high or low). This function conforms to the operation mode of 74HC595. LSBFIRST and MSBFIRST are two different flow directions.

```

def shiftOut(dPin,cPin,order,val):
    for i in range(0,8):
        GPIO.output(cPin,GPIO.LOW);
        if(order == LSBFIRST):
            GPIO.output(dPin,(0x01&(val>>i)==0x01) and GPIO.HIGH or GPIO.LOW)
        elif(order == MSBFIRST):
            GPIO.output(dPin,(0x80&(val<<i)==0x80) and GPIO.HIGH or GPIO.LOW)
        GPIO.output(cPin,GPIO.HIGH);

```

In the loop() function, we use two "for" cycle to achieve the target. First, define a variable x=0x01, binary 00000001. When it is transferred to the output port of 74HC595, the low bit outputs high level, then a LED is turned on. Next, x is shifted one bit, when x is transferred to the output port of 74HC595 once again, the LED turned on will be shifted. Repeat the operation, the effect of flowing water light will be formed. If the direction of the shift operation for x is different, the flowing direction is different.

```

def loop():
    while True:
        x=0x01
        for i in range(0,8):
            GPIO.output(latchPin,GPIO.LOW) #Output low level to latchPin

```

```
shiftOut(dataPin, clockPin, LSBFIRST, x)#Send serial data to 74HC595
GPIO.output(latchPin,GPIO.HIGH)#Output high level to latchPin, and 74HC595
will update the data to the parallel output port.
x<<=1# make the variable move one bit to left once, then the bright LED move
one step to the left once.
time.sleep(0.1)
x=0x80
for i in range(0,8):
    GPIO.output(latchPin,GPIO.LOW)
    shiftOut(dataPin, clockPin, LSBFIRST, x)
    GPIO.output(latchPin,GPIO.HIGH)
    x>>=1
    time.sleep(0.1)
```

Chapter 18 74HC595 & 7-segment display.

In this chapter, we will learn a new component, 7-segment display.

Project 18.1 7-segment display.

We will use 74HC595 to control 7-segment display. and make it display sixteen decimal character "0-F".

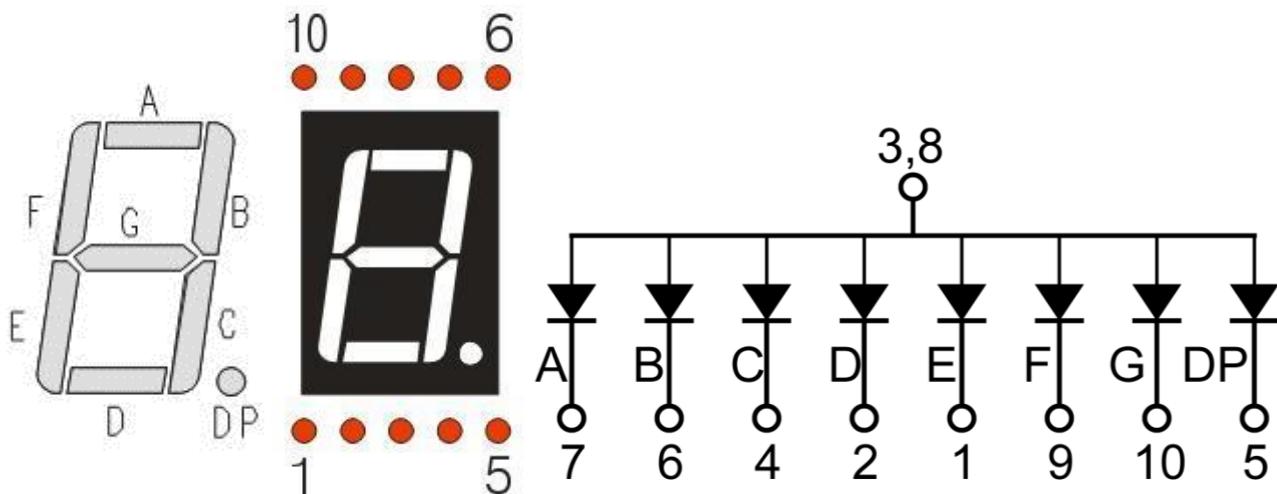
Component List

Raspberry Pi (with 40 GPIO) x1 GPIO Extension Board & Wire x1 BreadBoard x1	Jumper	
74HC595 x1	7-segment display x1	
		Resistor 220Ω x8

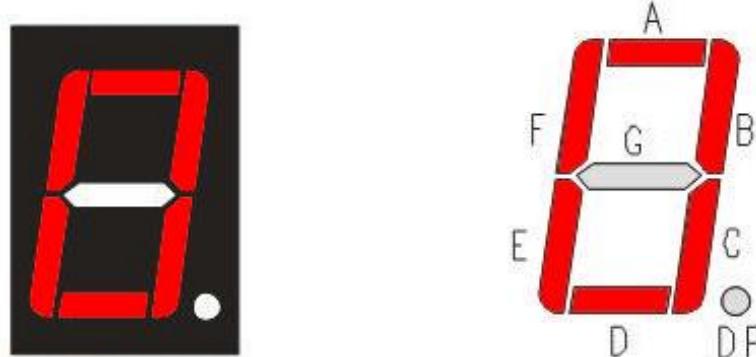
Component knowledge

7-segment display

7-segment display is a digital electronic display device. There is a figure of "8" and a decimal point, which consist of 8 LED. According to the difference about common cathode and anode, its internal structure and pins diagram is shown below:



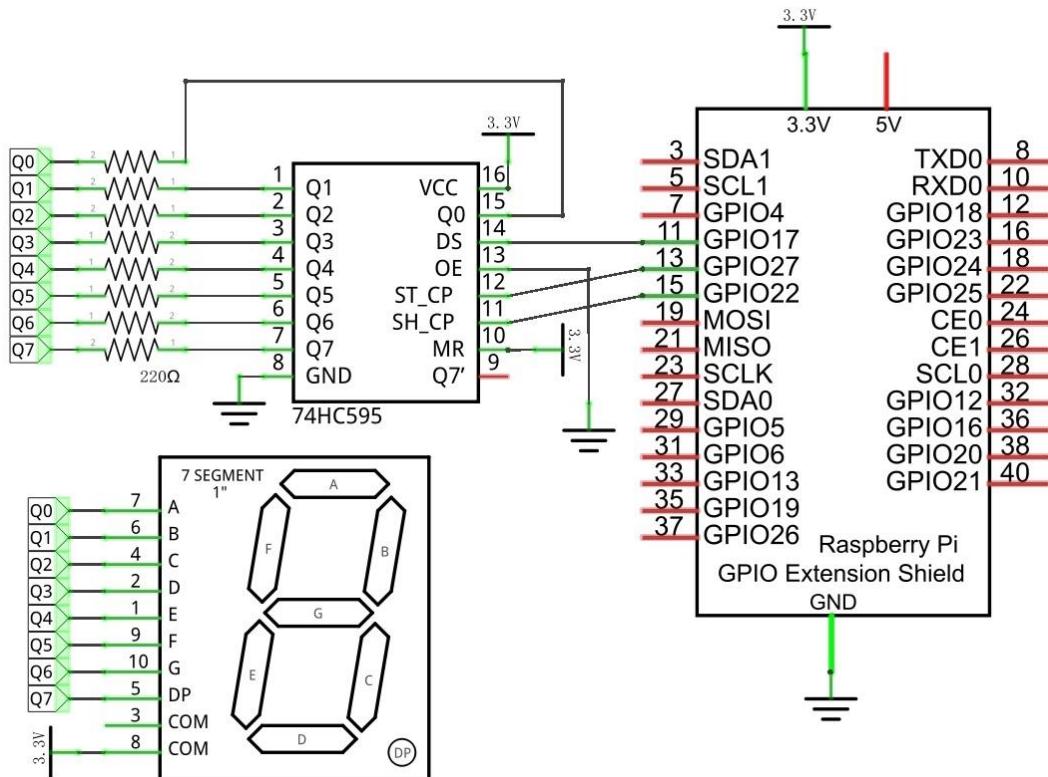
As is known from the above circuit diagram that we can control the state of each LED separately. So, through combining LED with different state, we can display different numbers. For example, display figure 0: we need to turn on LED segment A, B, C, D, E, F, and turn off LED segment G and DP.



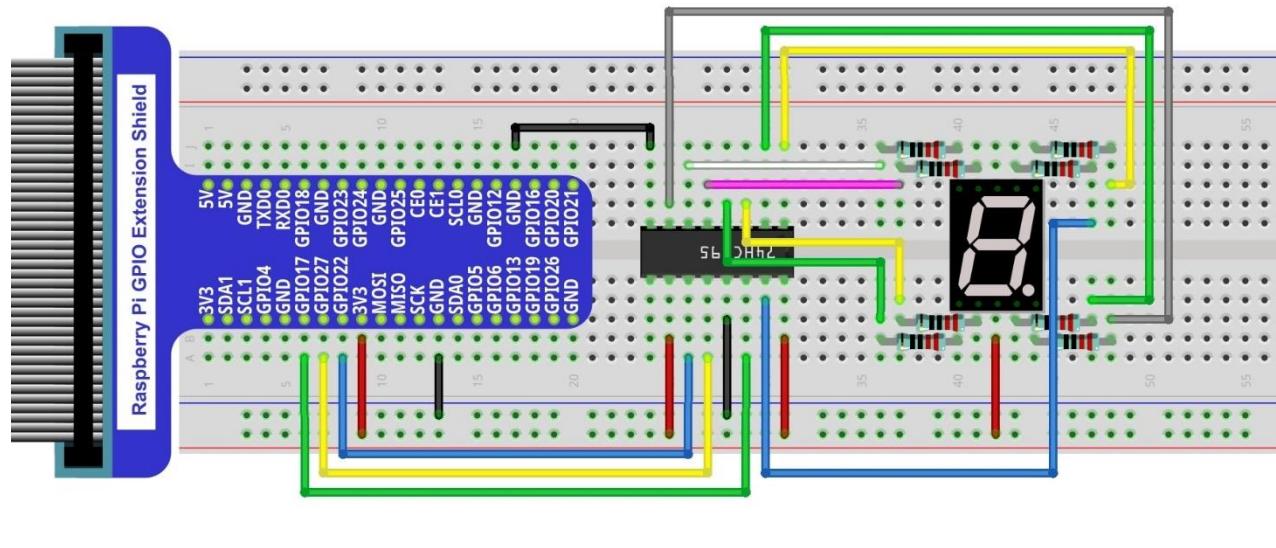
In this project, we use a display 7-segment (common anode). Therefore, when the input low level to a LED segment, the LED will be turned on. Define segment "A" as the lowest level, the segment "DP" as the highest level, that is, from high to low: "DP", "G", "F", "E", "D", "C", "B", "A". And character "0" corresponds to the code: 1100 0000b=0xc0.

Circuit

Schematic diagram



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



Code

In this code, uses 74HC595 to control the 7-segment display. The usage of 74HC595 is generally the same to last section. The content 74HC595 outputs is different. We need code character "0"- "F" one by one, and then output them with 74HC595.

C Code 18.1.1 SevenSegmentDisplay

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

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

1. Use cd command to enter 18.1.1_SevenSegmentDisplay directory of C code.

```
cd ~/Freenove_Kit/Code/C_Code/18.1.1_SevenSegmentDisplay
```

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

```
gcc SevenSegmentDisplay.c -o SevenSegmentDisplay -lwiringPi
```

3. Then run the generated file "SevenSegmentDisplay".

```
sudo ./SevenSegmentDisplay
```

After the program is executed, SevenSegmentDisplay starts to display the character "0"- "F" successively.

The following is the program code:

```

1 #include <wiringPi.h>
2 #include <stdio.h>
3 #include <wiringShift.h>
4
5 #define  dataPin  0 //DS Pin of 74HC595(Pin14)
6 #define  latchPin 2 //ST_CP Pin of 74HC595(Pin12)
7 #define  clockPin 3 //CH_CP Pin of 74HC595(Pin11)
8 //encoding for character 0-F of common anode SevenSegmentDisplay.
9 unsigned char
10 num[]={0xc0, 0xf9, 0xa4, 0xb0, 0x99, 0x92, 0x82, 0xf8, 0x80, 0x90, 0x88, 0x83, 0xc6, 0xa1, 0x86, 0x8e} ;
11
12 void _shiftOut(int dPin, int cPin, int order, int val) {
13     int i;
14     for(i = 0; i < 8; i++) {
15         digitalWrite(cPin, LOW);
16         if(order == LSBFIRST) {
17             digitalWrite(dPin, ((0x01&(val>>i)) == 0x01) ? HIGH : LOW);
18             delayMicroseconds(10);
19         }
20         else {//if(order == MSBFIRST) {
21             digitalWrite(dPin, ((0x80&(val<<i)) == 0x80) ? HIGH : LOW);
22             delayMicroseconds(10);
23         }
24         digitalWrite(cPin, HIGH);
25         delayMicroseconds(10);
26     }
}

```

```

27 }
28
29 int main(void)
30 {
31     int i;
32
33     printf("Program is starting ... \n");
34
35     wiringPiSetup();
36
37     pinMode(dataPin, OUTPUT);
38     pinMode(latchPin, OUTPUT);
39     pinMode(clockPin, OUTPUT);
40     while(1) {
41         for(i=0;i<sizeof(num);i++) {
42             digitalWrite(latchPin, LOW);
43             _shiftOut(dataPin, clockPin, MSBFIRST, num[i]); //Output the figures and the highest
44             level is transferred preferentially.
45             digitalWrite(latchPin, HIGH);
46             delay(500);
47         }
48         for(i=0;i<sizeof(num);i++) {
49             digitalWrite(latchPin, LOW);
50             _shiftOut(dataPin, clockPin, MSBFIRST, num[i] & 0x7f); //Use the "&0x7f" to display
51             the decimal point.
52             digitalWrite(latchPin, HIGH);
53             delay(500);
54         }
55     }
56     return 0;
57 }
```

First, put encoding of “0” - “F” into the array.

```

unsigned char
num[]={0xc0, 0xf9, 0xa4, 0xb0, 0x99, 0x92, 0x82, 0xf8, 0x80, 0x90, 0x88, 0x83, 0xc6, 0xa1, 0x86, 0x8e};
```

In the “for” cycle of loop() function, use 74HC595 to output contents of array “num” successively. SevenSegmentDisplay can correctly display the corresponding characters. Pay attention to that in shiftOut function, the transmission bit, flag bit highest bit will be transmitted preferentially.

```

for(i=0;i<sizeof(num);i++) {
    digitalWrite(latchPin, LOW);
    _shiftOut(dataPin, clockPin, MSBFIRST, num[i]); //Output the figures and the
    highest level is transferred preferentially.
    digitalWrite(latchPin, HIGH);
    delay(500);
}
```

If you want to display the decimal point, make the highest bit of each array become 0, which can be implemented easily by `num[i] & 0x7f`.

```
_shiftOut(dataPin, clockPin, MSBFIRST, num[i] & 0x7f);
```

Python Code 18.1.1 SevenSegmentDisplay

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

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

1. Use cd command to enter 18.1.1_SevenSegmentDisplay directory of Python code.

```
cd ~/Freenove_Kit/Code/Python_Code/18.1.1_SevenSegmentDisplay
```

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

```
python SevenSegmentDisplay.py
```

After the program is executed, SevenSegmentDisplay starts to display the character "0" - "F" successively.

The following is the program code:

```

1 import RPi.GPIO as GPIO
2 import time
3
4 LSBFIRST = 1
5 MSBFIRST = 2
6 #define the pins connect to 74HC595
7 dataPin    = 11      #DS Pin of 74HC595(Pin14)
8 latchPin   = 13      #ST_CP Pin of 74HC595(Pin12)
9 clockPin   = 15      #CH_CP Pin of 74HC595(Pin11)
10 #SevenSegmentDisplay display the character "0"- "F"successively
11 num = [0xc0, 0xf9, 0xa4, 0xb0, 0x99, 0x92, 0x82, 0xf8, 0x80, 0x90, 0x88, 0x83, 0xc6, 0xa1, 0x86, 0x8e]
12 def setup():
13     GPIO.setmode(GPIO.BOARD)      # Number GPIOs by its physical location
14     GPIO.setup(dataPin, GPIO.OUT)
15     GPIO.setup(latchPin, GPIO.OUT)
16     GPIO.setup(clockPin, GPIO.OUT)
17
18 def shiftOut(dPin, cPin, order, val):
19     for i in range(0, 8):
20         GPIO.output(cPin, GPIO.LOW);
21         if(order == LSBFIRST):
22             GPIO.output(dPin, (0x01&(val>>i)==0x01) and GPIO.HIGH or GPIO.LOW)
23         elif(order == MSBFIRST):
24             GPIO.output(dPin, (0x80&(val<<i)==0x80) and GPIO.HIGH or GPIO.LOW)
25         GPIO.output(cPin, GPIO.HIGH);
26
27 def loop():
28     while True:
29         for i in range(0, len(num)):
30             GPIO.output(latchPin, GPIO.LOW)

```

```

32         shiftOut(dataPin, clockPin, MSBFIRST, num[i])#Output the figures and the highest
33 level is transferred preferentially.
34         GPIO.output(latchPin,GPIO.HIGH)
35         time.sleep(0.5)
36     for i in range(0, len(num)):
37         GPIO.output(latchPin,GPIO.LOW)
38         shiftOut(dataPin, clockPin, MSBFIRST, num[i]&0x7f)#Use "&0x7f" to display the
39 decimal point.
40         GPIO.output(latchPin,GPIO.HIGH)
41         time.sleep(0.5)
42
43 def destroy():
44     GPIO.cleanup()
45
46 if __name__ == '__main__': # Program starting from here
47     print ('Program is starting... ')
48     setup()
49     try:
50         loop()
51     except KeyboardInterrupt:
52         destroy()

```

First, put encoding of “0”-“F” into the array.

```
num = [0xc0, 0xf9, 0xa4, 0xb0, 0x99, 0x92, 0x82, 0xf8, 0x80, 0x90, 0x88, 0x83, 0xc6, 0xa1, 0x86, 0x8e]
```

In the “for” cycle of loop() function, use 74HC595 to output contents of array “num” successively. SevenSegmentDisplay can correctly display the corresponding characters. Pay attention to that in shiftOut function, the transmission bit, flag bit highest bit will be transmitted preferentially.

```

for i in range(0, len(num)):
    GPIO.output(latchPin,GPIO.LOW)
    shiftOut(dataPin, clockPin, MSBFIRST, num[i])#Output the figures and the highest
level is transferred preferentially.
    GPIO.output(latchPin,GPIO.HIGH)
    time.sleep(0.5)

```

If you want to display the decimal point, make the highest bit of each array become 0, which can be implemented easily by num[i]&0x7f.

```
shiftOut(dataPin, clockPin, MSBFIRST, num[i]&0x7f) # Use "&0x7f" to display the decimal
point.
```



Project 18.2 4-Digit 7-segment display

Now, let's try to control more Digit 7-segment display

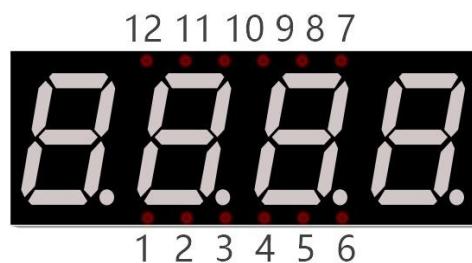
Component List

Raspberry Pi (with 40 GPIO) x1 GPIO Expansion Board & Wire x1 BreadBoard x1	Jumper
	
74HC595 x1	PNP transistor x4
	4-Digit 7-segment display x1
	Resistor 220Ω x8
	Resistor 1KΩ x4

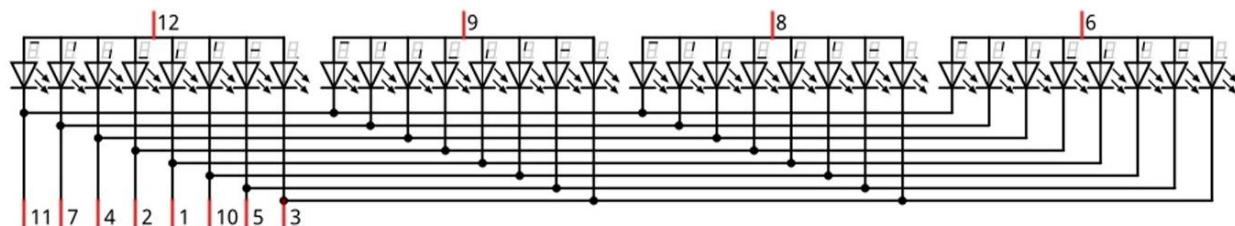
Component knowledge

4 Digit 7-Segment Display

4 Digit 7-segment display integrates four 7-segment display, so it can display more numbers. According to the difference about common cathode and anode, its internal structure and pins diagram is shown below:



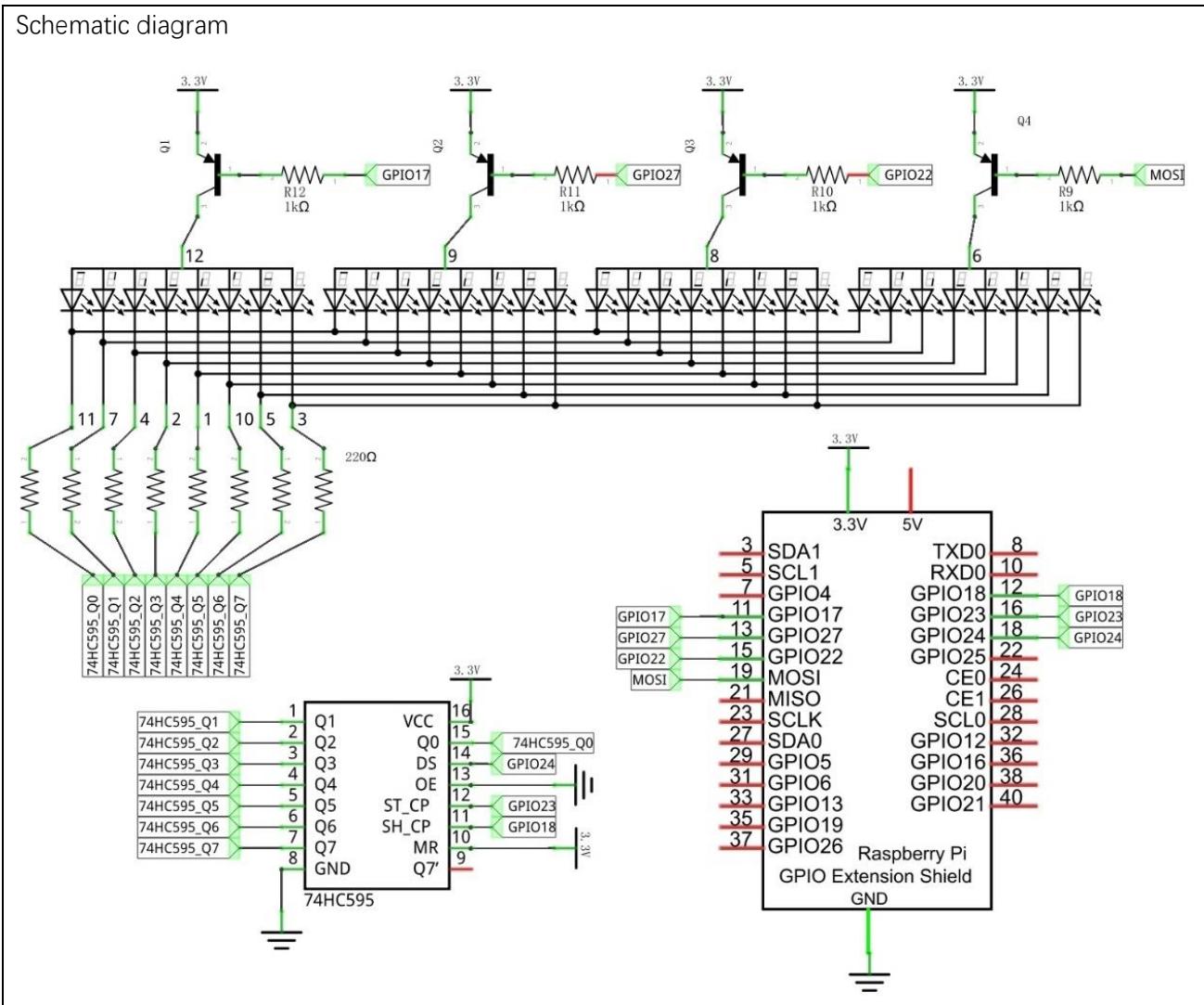
The internal circuit is shown below, and all 8 LED cathode pins of each 7-segment display are connected together.



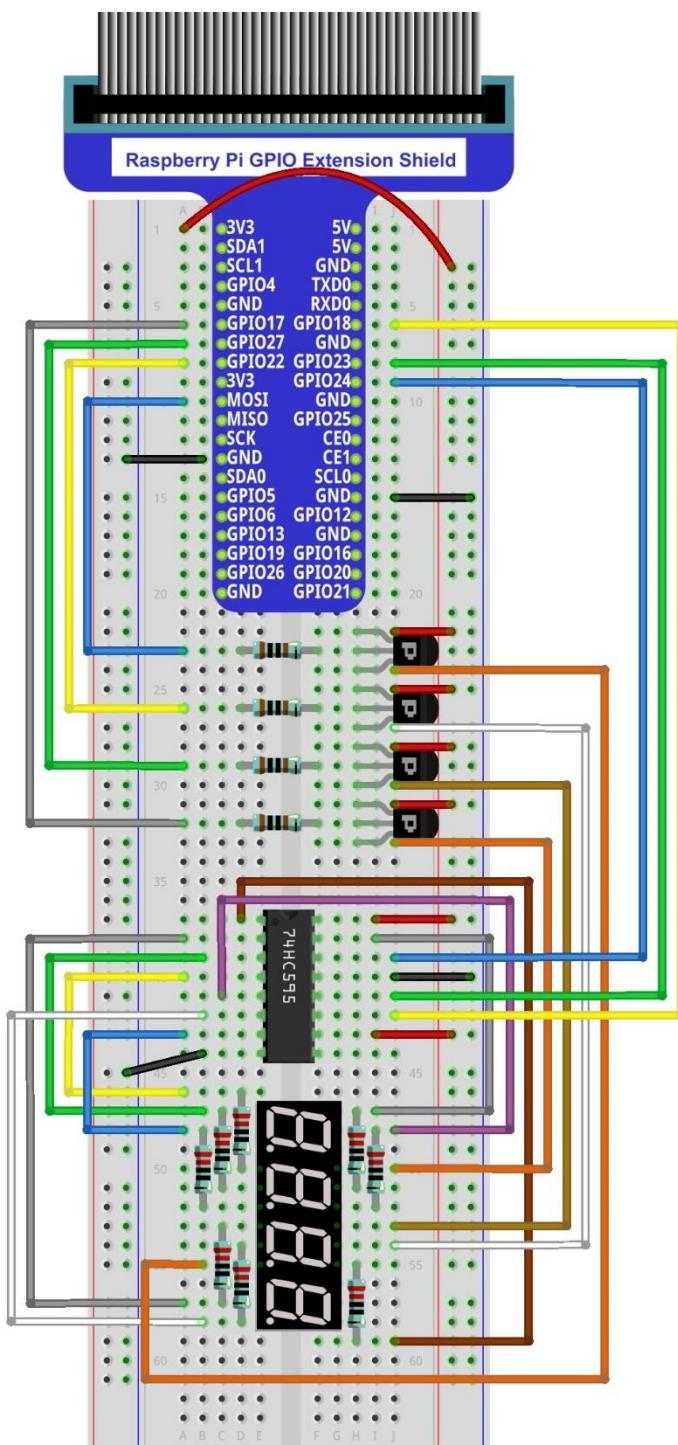
Display method of 4 Digit 7-segment display is similar to 1 Digit 7-segment display. The difference between them is that 4-Digit display in turn, one by one, not together. First send high level to common end of the first tube, and send low level to the rest of the three common end, and then send content to 8 LED cathode pins of the first tube. At this time, the first 7-segment display will display content and the rest three one in closed state.

Similarly, the second, third, fourth 7-segment display the content in turn, namely, scan display. Although the four numbers are displayed in turn separately, but this process is very fast, and due to the optical afterglow effect and people in vision persistence effect, we can see all 4 numbers at the same time. On the contrary, if each figure is displayed for a long time, you can see that the numbers are displayed separately.

Circuit



Hardware connection



Code

In this code, we use 74HC595 to control 4-Digit 7-segment display, and use dynamic scanning way to show the changing numbers.

C Code 18.2.1 StopWatch

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

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

1. Use cd command to enter 16.1.1_SteppingMotor directory of C code.

```
cd ~/Freenove_Kit/Code/C_Code/18.2.1_StopWatch
```

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

```
gcc StopWatch.c -o StopWatch -lwiringPi
```

3. Run the generated file "StopingMotor".

```
sudo ./StopWatch
```

After the program is executed, 4-Digit 7-segment start displaying a four-digit number dynamically, and the will plus 1 in each successive second.

The following is the program code:

```

1 #include <wiringPi.h>
2 #include <stdio.h>
3 #include <wiringShift.h>
4 #include <signal.h>
5 #include <unistd.h>
6 #define    dataPin      5 //DS Pin of 74HC595(Pin14)
7 #define    latchPin     4 //ST_CP Pin of 74HC595(Pin12)
8 #define    clockPin     1 //CH_CP Pin of 74HC595(Pin11)
9 const int digitPin[]={0, 2, 3, 12};           // Define 7-segment display common pin
10 // character 0~9 code of common anode 7-segment display
11 unsigned char num[]={0xc0, 0xf9, 0xa4, 0xb0, 0x99, 0x92, 0x82, 0xf8, 0x80, 0x90};
12 int counter = 0;    //variable counter, the number will be displayed by 7-segment display
13 //open one of the 7-segment display and close the remaining three, the parameter digit is
14 optional for 1, 2, 4, 8
15 void selectDigit(int digit){
16     digitalWrite(digitPin[0], ((digit&0x08) == 0x08) ? LOW : HIGH);
17     digitalWrite(digitPin[1], ((digit&0x04) == 0x04) ? LOW : HIGH);
18     digitalWrite(digitPin[2], ((digit&0x02) == 0x02) ? LOW : HIGH);
19     digitalWrite(digitPin[3], ((digit&0x01) == 0x01) ? LOW : HIGH);
20 }
21 void _shiftOut(int dPin, int cPin, int order, int val) {
22     int i;
23     for(i = 0; i < 8; i++) {
24         digitalWrite(cPin, LOW);
25         if(order == LSBFIRST) {
26             digitalWrite(dPin, ((0x01&(val>>i)) == 0x01) ? HIGH : LOW);
27             delayMicroseconds(1);

```

```
28     }
29     else {//if(order == MSBFIRST) {
30         digitalWrite(dPin, ((0x80&(val<<i)) == 0x80) ? HIGH : LOW);
31         delayMicroseconds(1);
32     }
33     digitalWrite(cPin, HIGH);
34     delayMicroseconds(1);
35 }
36 }
37 void outData(int8_t data){      //function used to output data for 74HC595
38     digitalWrite(latchPin,LOW);
39     _shiftOut(dataPin,clockPin,MSBFIRST,data);
40     digitalWrite(latchPin,HIGH);
41 }
42 void display(int dec){ //display function for 7-segment display
43     int delays = 1;
44     outData(0xff);
45     selectDigit(0x01);      //select the first, and display the single digit
46     outData(num[dec%10]);
47     delay(delays);        //display duration
48
49     outData(0xff);
50     selectDigit(0x02);      //select the second, and display the tens digit
51     outData(num[dec%100/10]);
52     delay(delays);
53
54     outData(0xff);
55     selectDigit(0x04);      //select the third, and display the hundreds digit
56     outData(num[dec%1000/100]);
57     delay(delays);
58
59     outData(0xff);
60     selectDigit(0x08);      //select the fourth, and display the thousands digit
61     outData(num[dec%10000/1000]);
62     delay(delays);
63 }
64 void timer(int sig){ //Timer function
65     if(sig == SIGALRM){ //If the signal is SIGALRM, the value of counter plus 1, and update
66     the number displayed by 7-segment display
67         counter++;
68         alarm(1);          //set the next timer time
69         printf("counter : %d \n",counter);
70     }
71 }
```

```

72 int main(void)
73 {
74     int i;
75
76     printf("Program is starting ... \n");
77
78     wiringPiSetup();
79
80     pinMode(dataPin, OUTPUT);           //set the pin connected to 74HC595 for output mode
81     pinMode(latchPin, OUTPUT);
82     pinMode(clockPin, OUTPUT);
83     //set the pin connected to 7-segment display common end to output mode
84     for(i=0;i<4;i++) {
85         pinMode(digitPin[i], OUTPUT);
86         digitalWrite(digitPin[i], HIGH);
87     }
88     signal(SIGALRM, timer); //configure the timer
89     alarm(1);             //set the time of timer to 1s
90     while(1) {
91         display(counter); //display the number counter
92     }
93     return 0;
94 }
```

First, define the pin of 74HC595 and 7-segment display common end, character encoding and a variable "counter" to be displayed counter.

```

#define      dataPin      5 //DS Pin of 74HC595(Pin14)
#define      latchPin     4 //ST_CP Pin of 74HC595(Pin12)
#define      clockPin     1 //CH_CP Pin of 74HC595(Pin11)
const int digitPin[]={0,2,3,12}; //Define the pin of 7-segment display common end
// character 0-9 code of common anode 7-segment display
unsigned char num[]={0xc0,0xf9,0xa4,0xb0,0x99,0x92,0x82,0xf8,0x80,0x90};
int counter = 0; //variable counter, the number will be displayed by 7-segment display
```

Subfunction **selectDigit** (int digit) function is used to open one of the 7-segment display and close the other 7-segment display, where the parameter digit value can be 1,2,4,8. Using "|" can open a number of 7-segment display.

```

void selectDigit(int digit){
    digitalWrite(digitPin[0], ((digit&0x08) == 0x08) ? LOW : HIGH);
    digitalWrite(digitPin[1], ((digit&0x04) == 0x04) ? LOW : HIGH);
    digitalWrite(digitPin[2], ((digit&0x02) == 0x02) ? LOW : HIGH);
    digitalWrite(digitPin[3], ((digit&0x01) == 0x01) ? LOW : HIGH);
}
```

Subfunction **outData** (int8_t data) is used to make the 74HC595 output a 8-bit data immediately.

```
void outData(int8_t data){      // function used to output data for 74HC595
    digitalWrite(latchPin, LOW);
    shiftOut(dataPin, clockPin, MSBFIRST, data);
    digitalWrite(latchPin, HIGH);
}
```

Subfunction **display** (int dec) is used to make 4-Digit 7-segment display a 4-bit integer. First open the common end of first 7-segment display and close to the other three, at this time, it can be used as 1-Digit 7-segment display. The first is used for displaying single digit of "dec", the second for tens digit, third for hundreds digit and fourth for thousands digit respectively. Each digit will be displayed for a period of time through using **delay** (). The time in this code is set very short, so you will see different digit is in a mess. If the time is set long enough, you will see that every digit is display independent.

```
void display(int dec){ //display function for 7-segment display
    selectDigit(0x01);      //select the first, and display the single digit
    outData(num[dec%10]);
    delay(1);                //display duration
    selectDigit(0x02);      //Select the second, and display the tens digit
    outData(num[dec%100/10]);
    delay(1);
    selectDigit(0x04);      //Select the third, and display the hundreds digit
    outData(num[dec%1000/100]);
    delay(1);
    selectDigit(0x08);      //Select the fourth, and display the thousands digit
    outData(num[dec%10000/1000]);
    delay(1);
}
```

Subfunction **timer** (int sig) is the timer function, which will set a alarm signal. This function will be executed once at set intervals. Accompanied by the execution, the variable counter will be added 1, and then reset the time of timer to 1s.

```
void timer(int sig){      //timer function
    if(sig == SIGALRM){ //If the signal is SIGALRM, the value of counter plus 1, and
        update the number displayed by 7-segment display
        counter++;
        alarm(1);          //set the next timer time
    }
}
```

Finally, in the main function, configure all the GPIO, and set the timer function.

```
pinMode(dataPin, OUTPUT);           //set the pin connected to 74HC595 for output mode
pinMode(latchPin, OUTPUT);
pinMode(clockPin, OUTPUT);
//set the pin connected to 7-segment display common end to output mode
for(i=0;i<4;i++) {
    pinMode(digitPin[i], OUTPUT);
    digitalWrite(digitPin[i], LOW);
}
signal(SIGALRM,timer); //configure the timer
alarm(1);             //set the time of timer to 1s
```

In the while cycle, make the digital display variable counter value. The value will change in function timer (), so the content displayed by 7-segment display will change accordingly.

```
while(1) {
    display(counter); //display number counter
}
```

Python Code 18.2.1 StopWatch

This code use four step four pat mode to drive the stepping motor forward and reverse direction.

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

1. Use cd command to enter 16.1.1_SteppingMotor directory of Python code.

```
cd ~/Freenove_Kit/Code/Python_Code/18.2.1_StopWatch
```

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

```
python Stopwatch.py
```

After the program is executed, 4-Digit 7-segment start displaying a four-digit number dynamically, and the will plus 1 in each successive second.

The following is the program code:

```
1 import RPi.GPIO as GPIO
2 import time
3 import threading
4
5 LSBFIRST = 1
6 MSBFIRST = 2
7 #define the pins connect to 74HC595
8 dataPin = 18      #DS Pin of 74HC595(Pin14)
9 latchPin = 16     #ST_CP Pin of 74HC595(Pin12)
10 clockPin = 12    #SH_CP Pin of 74HC595(Pin11)
11 num = (0xc0, 0xf9, 0xa4, 0xb0, 0x99, 0x92, 0x82, 0xf8, 0x80, 0x90)
12 digitPin = (11, 13, 15, 19)   # Define the pin of 7-segment display common end
13 counter = 0        # Variable counter, the number will be displayed by 7-segment display
14 t = 0              # define the Timer object
15 def setup():
16     GPIO.setmode(GPIO.BOARD)      # Number GPIOs by its physical location
17     GPIO.setup(dataPin, GPIO.OUT)    # Set pin mode to output
18     GPIO.setup(latchPin, GPIO.OUT)
19     GPIO.setup(clockPin, GPIO.OUT)
20     for pin in digitPin:
21         GPIO.setup(pin, GPIO.OUT)
22
23 def shiftOut(dPin, cPin, order, val):
24     for i in range(0, 8):
25         GPIO.output(cPin, GPIO.LOW);
26         if(order == LSBFIRST):
27             GPIO.output(dPin, (0x01&(val>>i)==0x01) and GPIO.HIGH or GPIO.LOW)
28         elif(order == MSBFIRST):
29             GPIO.output(dPin, (0x80&(val<<i)==0x80) and GPIO.HIGH or GPIO.LOW)
30         GPIO.output(cPin, GPIO.HIGH)
31
32 def outData(data):      #function used to output data for 74HC595
33     GPIO.output(latchPin, GPIO.LOW)
```

```
34     shiftOut(dataPin, clockPin, MSBFIRST, data)
35     GPIO.output(latchPin, GPIO.HIGH)
36
37 def selectDigit(digit): # Open one of the 7-segment display and close the remaining
38     three, the parameter digit is optional for 1, 2, 4, 8
39     GPIO.output(digitPin[0],GPIO.LOW if ((digit&0x08) == 0x08) else GPIO.HIGH)
40     GPIO.output(digitPin[1],GPIO.LOW if ((digit&0x04) == 0x04) else GPIO.HIGH)
41     GPIO.output(digitPin[2],GPIO.LOW if ((digit&0x02) == 0x02) else GPIO.HIGH)
42     GPIO.output(digitPin[3],GPIO.LOW if ((digit&0x01) == 0x01) else GPIO.HIGH)
43
44 def display(dec): #display function for 7-segment display
45     outData(0xff) #eliminate residual display
46     selectDigit(0x01) #Select the first, and display the single digit
47     outData(num[dec%10])
48     time.sleep(0.003) #display duration
49     outData(0xff)
50     selectDigit(0x02) # Select the second, and display the tens digit
51     outData(num[dec%100//10])
52     time.sleep(0.003)
53     outData(0xff)
54     selectDigit(0x04) # Select the third, and display the hundreds digit
55     outData(num[dec%1000//100])
56     time.sleep(0.003)
57     outData(0xff)
58     selectDigit(0x08) # Select the fourth, and display the thousands digit
59     outData(num[dec%10000//1000])
60     time.sleep(0.003)
61 def timer(): #timer function
62     global counter
63     global t
64     t = threading.Timer(1.0,timer) #reset time of timer to 1s
65     t.start() #Start timing
66     counter+=1
67     print ("counter : %d"%counter)
68
69 def loop():
70     global t
71     global counter
72     t = threading.Timer(1.0,timer) #set the timer
73     t.start() # Start timing
74     while True:
75         display(counter) # display the number counter
76
77 def destroy():
```

```

78     global t
79     GPIO.cleanup()
80     t.cancel()      #cancel the timer
81
82 if __name__ == '__main__':
83     print ('Program is starting... ')
84     setup()
85     try:
86         loop()
87     except KeyboardInterrupt:
88         destroy()

```

First, define the pin of 74HC595 and 7-segment display common end, character encoding and a variable "counter" to be displayed counter.

```

dataPin   = 18      #DS Pin of 74HC595(Pin14)
latchPin  = 16      #ST_CP Pin of 74HC595(Pin12)
clockPin = 12       #CH_CP Pin of 74HC595(Pin11)
num = (0xc0, 0xf9, 0xa4, 0xb0, 0x99, 0x92, 0x82, 0xf8, 0x80, 0x90)
digitPin = (11, 13, 15, 19)    # Define the pin of 7-segment display common end
counter = 0          # Variable counter, the number will be displayed by 7-segment display

```

Subfunction **selectDigit** (digit) function is used to open one of the 7-segment display and close the other 7-segment display, where the parameter digit value can be 1,2,4,8. Using "|" can open a number of 7-segment display.

```

def selectDigit(digit): #Open one of the 7-segment display and close the remaining three,
the parameter digit is optional for 1, 2, 4, 8
    GPIO.output(digitPin[0], GPIO.LOW if ((digit&0x08) == 0x08) else GPIO.HIGH)
    GPIO.output(digitPin[1], GPIO.LOW if ((digit&0x04) == 0x04) else GPIO.HIGH)
    GPIO.output(digitPin[2], GPIO.LOW if ((digit&0x02) == 0x02) else GPIO.HIGH)
    GPIO.output(digitPin[3], GPIO.LOW if ((digit&0x01) == 0x01) else GPIO.HIGH)

```

Subfunction **outData** (data) is used to make the 74HC595 output a 8-bit data immediately.

```

def outData(data):      #function used to output data for 74HC595
    GPIO.output(latchPin, GPIO.LOW)
    shiftOut(dataPin, clockPin, MSBFIRST, data)
    GPIO.output(latchPin, GPIO.HIGH)

```

Subfunction **display** (dec) is used to make 4-Digit 7-segment display a 4-bit integer. First open the common end of first 7-segment display and close to the other three, at this time, it can be used as 1-Digit 7-segment display. The first is used for displaying single digit of "dec", the second for tens digit, third for hundreds digit and fourth for thousands digit respectively. Each digit will be displayed for a period of time through using **delay** (). The time in this code is set very short, so you will see different digit is in a mess. If the time is set long enough, you will see that every digit is display independent.

```

def display(dec):  #display function for 7-segment display
    outData(0xff)  #eliminate residual display
    selectDigit(0x01) #Select the first, and display the single digit
    outData(num[dec%10])
    time.sleep(0.003) #display duration

```

```

outData(0xff)
selectDigit(0x02) #Select the second, and display the tens digit
outData(num[dec%100/10])
time.sleep(0.003)
outData(0xff)
selectDigit(0x04) #Select the third, and display the hundreds digit
outData(num[dec%1000/100])
time.sleep(0.003)
outData(0xff)
selectDigit(0x08) #Select the fourth, and display the thousands digit
outData(num[dec%10000/1000])
time.sleep(0.003)

```

Subfunction **timer()** is the timer callback function. When the time is up, this function will be executed. Accompanied by the execution, the variable counter will be added 1, and then reset the time of timer to 1s. 1s later, the function will be executed again.

```

def timer():      #timer function
    global counter
    global t
    t = threading.Timer(1.0,timer)      #reset time of timer to 1s
    t.start()                         #Start timing
    counter+=1
    print ("counter : %d"%counter)

```

Subfunction **setup()**, configure all input output modes for the GPIO pin used.

Finally, in loop function, make the digital tube display variable counter value in the while cycle. The value will change in function **timer()**, so the content displayed by 7-segment display will change accordingly.

```

def loop():
    global t
    global counter
    t = threading.Timer(1.0,timer)      # set the timer
    t.start()                         #Start timing
    while True:
        display(counter)           #display the number counter

```

After the program is executed, press "Ctrl+C", then subfunction **destroy()** will be executed, and GPIO resources and timers will be released in this subfunction.

```

def destroy():  # When 'Ctrl+C' is pressed, the function is executed.
    global t
    GPIO.cleanup()
    t.cancel()      # cancel the timer

```

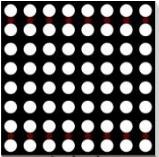
Chapter 19 74HC595 & LED Matrix

We have learned how to use 74HC595 to control LEDBar Graph and Seven-SegmentDisplay. And we will continue to use the 74HC595 to control more LED, LEDMatrix.

Project 19.1 LED Matrix

In this project, we will use two 74HC595 to control a monochrome LEDMatrix (8*8) to make it display some graphics and characters.

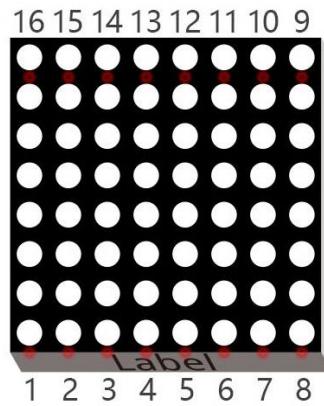
Component List

Raspberry Pi (with 40 GPIO) x1 GPIO Extension Board & Wire x1 BreadBoard x1	Jumper	
74HC595 x2	8*8 LEDMatrix x1	
		Resistor 220Ω x8

Component knowledge

LED matrix

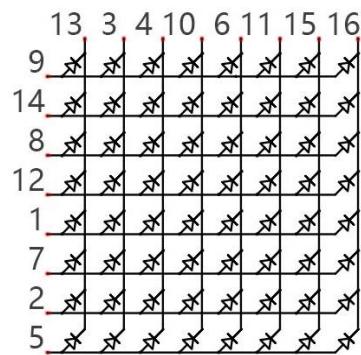
LED matrix is a rectangular display module that consists of several LEDs. The following is an 8*8 monochrome LED matrix with 64 LEDs (8 rows and 8 columns).



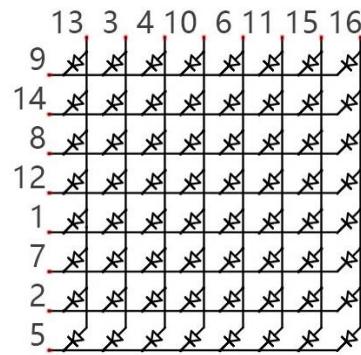
In order to facilitate the operation and save the ports, positive pole of LEDs in each row and negative pole of LEDs in each column are respectively connected together inside LED matrix module, which is called Common Anode. There is another form. Negative pole of LEDs in each row and positive pole of LEDs in each column are respectively connected together, which is called Common Cathode.

The one we use in this project is a common anode LEDMatrix.

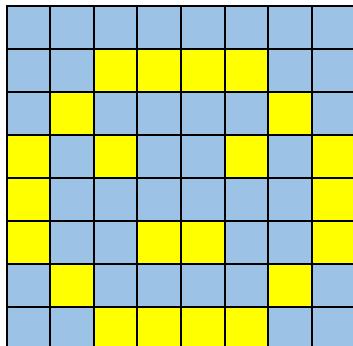
Connection mode of common anode



Connection mode of common cathode



Let us learn how connection mode of common anode works. Choose 16 ports on RPi board to connect to the 16 ports of LED Matrix. Configured one port in columns for low level, which make the column of the port selected. Then configure the eight ports in row to display content in the selected column. Delay for a moment. And then select the next column and outputs the corresponding content. This kind of operation to column is called scan. If you want to display the following image of a smiling face, you can display it in 8 columns, and each column is represented by one byte.



1	2	3	4	5	6	7	8
0	0	0	0	0	0	0	0
0	0	1	1	1	1	0	0
0	1	0	0	0	0	1	0
1	0	1	0	0	1	0	1
1	0	0	0	0	0	0	1
1	0	0	1	1	0	0	1
0	1	0	0	0	0	1	0
0	0	1	1	1	1	0	0

Column	Binary	Hexadecimal
1	0001 1100	0x1c
2	0010 0010	0x22
3	0101 0001	0x51
4	0100 0101	0x45
5	0100 0101	0x45
6	0101 0001	0x51
7	0010 0010	0x22
8	0001 1100	0x1c

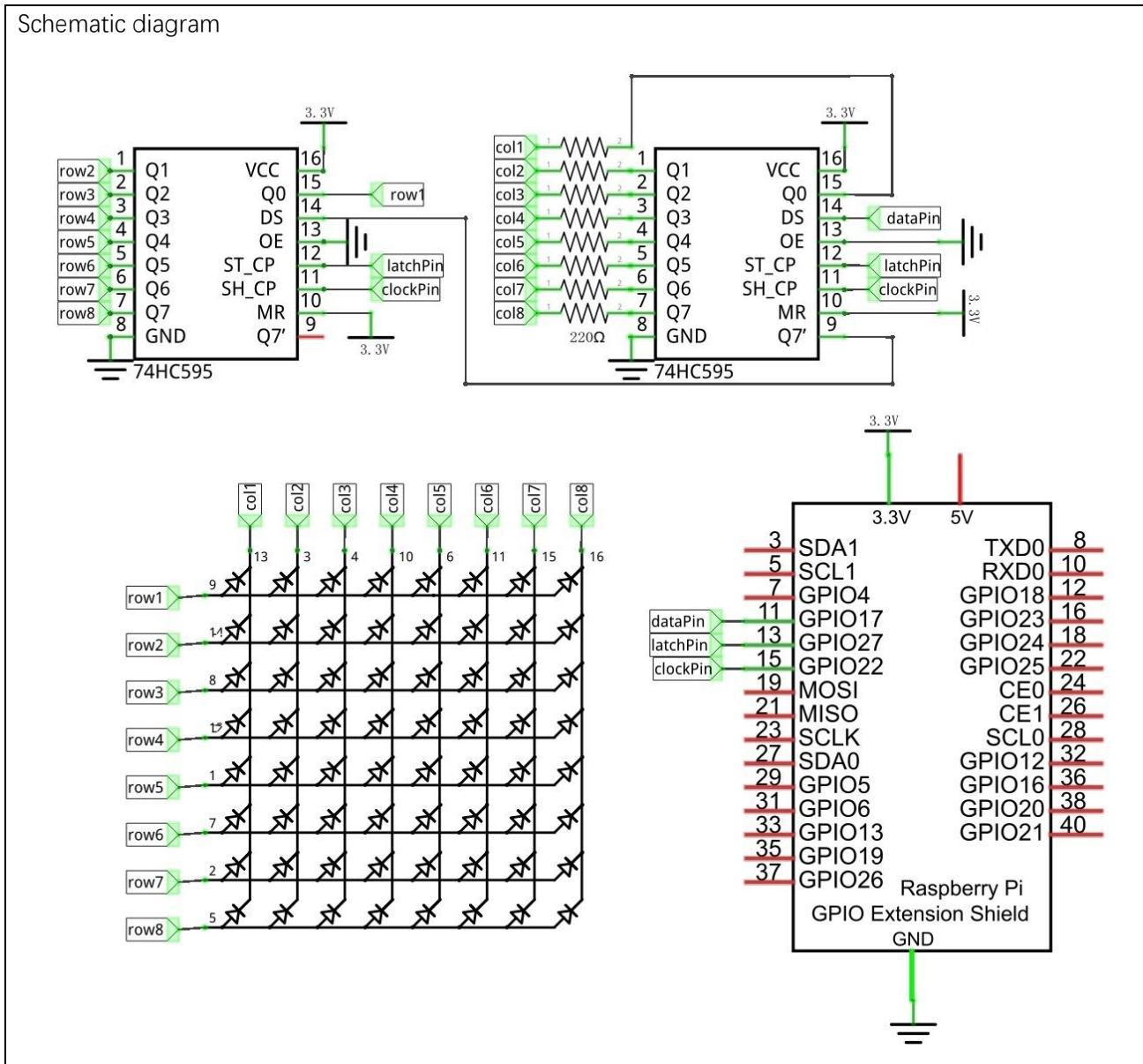
First, display the first column, then turn off the first column and display the second column..... turn off the seventh column and display the 8th column, and then start from the first column again like the control of Graph LEDBar. The whole progress will be repeated rapidly and circularly. Due to afterglow effect of LED and visual residual effect of human eyes, we will see a picture of a smiling face directly rather than LED are turned on one column by one column (although in fact it is the real situation).

Scanning rows is another display way of dot matrix. Whether scanning line or column, 16 GPIO are required. In order to save GPIO of control board, two 74HC595 is used. Every piece of 74HC595 has eight parallel output ports, so two pieces has 16 ports in total, just enough. The control line and data line of two 74HC595 are not all connected to the RPi, but connect Q7 pin of first stage 74HC595 to data pin of second one, namely, two 74HC595 are connected in series. It is the same to using one "74HC595" with 16 parallel output ports.

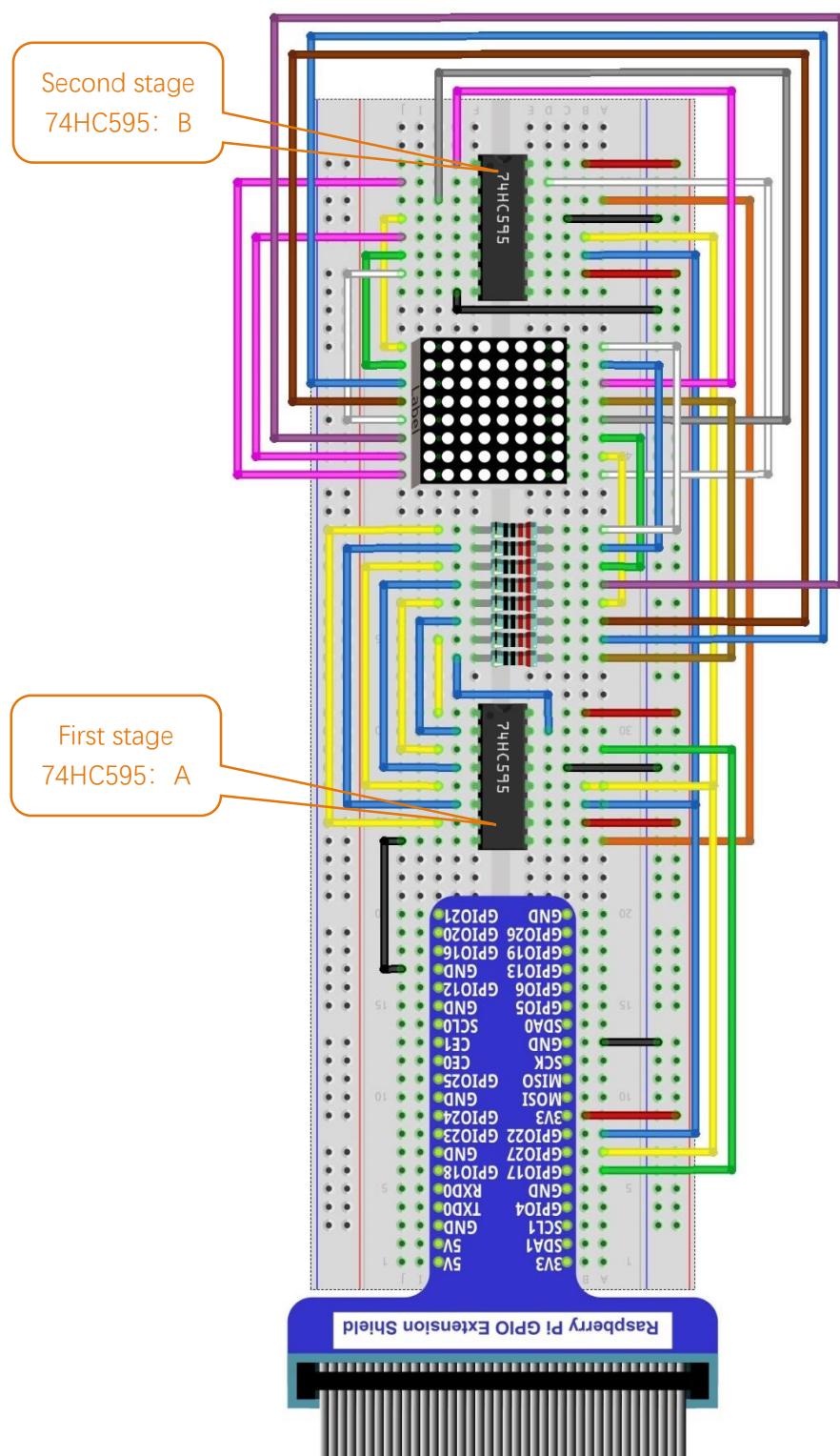
Circuit

In this project circuit, the power pin of 74HC595 is connected to 3.3V. It can also be connected to 5V to make LEDMatrix brighter.

Schematic diagram



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



Code

Two 74HC595 are used in this project used, one for controlling columns of LEDMatrix, another for lines. And two 74HC595 are connected in cascade way (series) and has 16 output port. Because shiftOut () function output 8-bit data once, twice shiftOut () function are required and data of second stage 74HC595 should be transmitted preferentially. There are two 74HC595 in this project circuit, A (first stage) and B (second stage). When the RPi uses shiftOut() function to send data "data1", data of A port will be "data1", and data of B will be 0. Next, use shiftOut() to send "data2", then data "data1" of A will be moved to B and new data "data2" will be moved to A. According to the circuit connection, line data should be sent first, then send column data. The following code will make LEDMatrix display a smiling face, and then display scrolling character "0-F".

C Code 19.1.1 LEDMatrix

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

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

1. Use cd command to enter 19.1.1_LEDMatrix directory of C language.

```
cd ~/Freenove_Kit/Code/C_Code/19.1.1_LEDMatrix
```

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

```
gcc LEDMatrix.c -o LEDMatrix -lwiringPi
```

3. Then run the generated file "LEDMatrix".

```
sudo ./LEDMatrix
```

After the program is executed, LEDMatrix will display a smiling face, and then the display scrolling character "0-F", circularly.

The following is the program code:

```

1 #include <wiringPi.h>
2 #include <stdio.h>
3 #include <wiringShift.h>
4
5 #define  dataPin 0 //DS Pin of 74HC595(Pin14)
6 #define  latchPin 2 //ST_CP Pin of 74HC595(Pin12)
7 #define  clockPin 3 //SH_CP Pin of 74HC595(Pin11)
8 // data of smile face
9 unsigned char pic[]={0x1c,0x22,0x51,0x45,0x45,0x51,0x22,0x1c} ;
10 unsigned char data[]={ // data of "0-F"
11     0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, // " "
12     0x00, 0x00, 0x3E, 0x41, 0x41, 0x3E, 0x00, 0x00, // "0"
13     0x00, 0x00, 0x21, 0x7F, 0x01, 0x00, 0x00, 0x00, // "1"
14     0x00, 0x00, 0x23, 0x45, 0x49, 0x31, 0x00, 0x00, // "2"
15     0x00, 0x00, 0x22, 0x49, 0x49, 0x36, 0x00, 0x00, // "3"
16     0x00, 0x00, 0x0E, 0x32, 0x7F, 0x02, 0x00, 0x00, // "4"
17     0x00, 0x00, 0x79, 0x49, 0x49, 0x46, 0x00, 0x00, // "5"
18     0x00, 0x00, 0x3E, 0x49, 0x49, 0x26, 0x00, 0x00, // "6"
19     0x00, 0x00, 0x60, 0x47, 0x48, 0x70, 0x00, 0x00, // "7"
20     0x00, 0x00, 0x36, 0x49, 0x49, 0x36, 0x00, 0x00, // "8"
21     0x00, 0x00, 0x32, 0x49, 0x49, 0x3E, 0x00, 0x00, // "9"

```

```
22     0x00, 0x00, 0x3F, 0x44, 0x44, 0x3F, 0x00, 0x00, // "A"
23     0x00, 0x00, 0x7F, 0x49, 0x49, 0x36, 0x00, 0x00, // "B"
24     0x00, 0x00, 0x3E, 0x41, 0x41, 0x22, 0x00, 0x00, // "C"
25     0x00, 0x00, 0x7F, 0x41, 0x41, 0x3E, 0x00, 0x00, // "D"
26     0x00, 0x00, 0x7F, 0x49, 0x49, 0x41, 0x00, 0x00, // "E"
27     0x00, 0x00, 0x7F, 0x48, 0x48, 0x40, 0x00, 0x00, // "F"
28     0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, // " "
29 };
30 void _shiftOut(int dPin, int cPin, int order, int val) {
31     int i;
32     for(i = 0; i < 8; i++) {
33         digitalWrite(cPin, LOW);
34         if(order == LSBFIRST) {
35             digitalWrite(dPin, ((0x01&(val>>i)) == 0x01) ? HIGH : LOW);
36             delayMicroseconds(10);
37         }
38         else {//if(order == MSBFIRST) {
39             digitalWrite(dPin, ((0x80&(val<<i)) == 0x80) ? HIGH : LOW);
40             delayMicroseconds(10);
41         }
42         digitalWrite(cPin, HIGH);
43         delayMicroseconds(10);
44     }
45 }
46 int main(void)
47 {
48     int i, j, k;
49     unsigned char x;
50
51     printf("Program is starting ... \n");
52
53     wiringPiSetup();
54
55     pinMode(dataPin, OUTPUT);
56     pinMode(latchPin, OUTPUT);
57     pinMode(clockPin, OUTPUT);
58     while(1) {
59         for(j=0; j<500; j++) { //Repeat enough times to display the smiling face a period of
60             time
61             x=0x80;
62             for(i=0; i<8; i++) {
63                 digitalWrite(latchPin, LOW);
64                 _shiftOut(dataPin, clockPin, MSBFIRST, pic[i]); // first shift data of line
65             information to the first stage 74HC595
```

```

66         _shiftOut(dataPin,clockPin,MSBFIRST,~x); //then shift data of column
67 information to the second stage 74HC959
68
69         digitalWrite(latchPin,HIGH); //Output data of two stage 74HC595 at the same
70 time
71         x>>=1; //display the next column
72         delay(1);
73     }
74 }
75 for(k=0;k<sizeof(data)-8;k++) { //sizeof(data) total number of "0-F" columns
76     for(j=0;j<20;j++) { //times of repeated displaying LEDMatrix in every frame, the
77 bigger the "j", the longer the display time
78         x=0x80; //Set the column information to start from the first column
79         for(i=k;i<8+k;i++) {
80             digitalWrite(latchPin,LOW);
81             _shiftOut(dataPin,clockPin,MSBFIRST,data[i]);
82             _shiftOut(dataPin,clockPin,MSBFIRST,~x);
83             digitalWrite(latchPin,HIGH);
84             x>>=1;
85             delay(1);
86         }
87     }
88 }
89 }
90 }
91 return 0;
92 }
```

The first “for” cycle in the “while” cycle is used to display a static smile. Display column information from left to right, one column by one column, totally 8 columns. Repeat 500 times to ensure display time enough.

```

for(j=0;j<500;j++) { // Repeat enough times to display the smiling face a period
of time
    x=0x80;
    for(i=0;i<8;i++) {
        digitalWrite(latchPin,LOW);
        shiftOut(dataPin,clockPin,MSBFIRST,pic[i]);
        shiftOut(dataPin,clockPin,MSBFIRST,~x);
        digitalWrite(latchPin,HIGH);
        x>>=1;
        delay(1);
    }
}
```

The second “for” cycle is used to display scrolling characters "0-F", totally $18*8=144$ columns. Display the 0-8 column, 1-9 column, 2-10 column..... 138-144 column in turn to achieve scrolling effect. The display of each frame is repeated a certain number of times, and the more times the number of repetitions, the longer the single frame display, the slower the rolling.

```
for(k=0;k<sizeof(data)-8;k++) { //sizeof(data) total number of "0-F" columns
    for(j=0;j<20;j++) {// times of repeated displaying LEDMatrix in every frame,
        the bigger the "j" , the longer the display time
        x=0x80; // Set the column information to start from the first column
        for(i=k;i<8+k;i++) {
            digitalWrite(latchPin, LOW);
            shiftOut(dataPin, clockPin, MSBFIRST, data[i]);
            shiftOut(dataPin, clockPin, MSBFIRST, ^x);
            digitalWrite(latchPin, HIGH);
            x>>=1;
            delay(1);
        }
    }
}
```

Python Code 19.1.1 LEDMatrix

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

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

1. Use cd command to enter 19.1.1_LEDMatrix directory of Python language.

cd ~/Freenove_Kit/Code/Python_Code/19.1.1_LEDMatrix

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

python LEDMatrix.py

After the program is executed, LEDMatrix will display a smiling face, and then the display scrolling character "0-F", circularly.

The following is the program code:

```

1 import RPi.GPIO as GPIO
2
3
4 LSBFIRST = 1
5 MSBFIRST = 2
6 #define the pins connect to 74HC595
7 dataPin = 11      #DS Pin of 74HC595(Pin14)
8 latchPin = 13     #ST_CP Pin of 74HC595(Pin12)
9 clockPin = 15     #SH_CP Pin of 74HC595(Pin11)
10 pic = [0x1c, 0x22, 0x51, 0x45, 0x45, 0x51, 0x22, 0x1c]# data of smiling face
11 data = [#data of "0-F"
12     0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, # ""
13     0x00, 0x00, 0x3E, 0x41, 0x41, 0x3E, 0x00, 0x00, # "0"
14     0x00, 0x00, 0x21, 0x7F, 0x01, 0x00, 0x00, 0x00, # "1"
15     0x00, 0x00, 0x23, 0x45, 0x49, 0x31, 0x00, 0x00, # "2"
16     0x00, 0x00, 0x22, 0x49, 0x49, 0x36, 0x00, 0x00, # "3"
17     0x00, 0x00, 0x0E, 0x32, 0x7F, 0x02, 0x00, 0x00, # "4"
18     0x00, 0x00, 0x79, 0x49, 0x49, 0x46, 0x00, 0x00, # "5"
19     0x00, 0x00, 0x3E, 0x49, 0x49, 0x26, 0x00, 0x00, # "6"
20     0x00, 0x00, 0x60, 0x47, 0x48, 0x70, 0x00, 0x00, # "7"
21     0x00, 0x00, 0x36, 0x49, 0x49, 0x36, 0x00, 0x00, # "8"
22     0x00, 0x00, 0x32, 0x49, 0x49, 0x3E, 0x00, 0x00, # "9"
23     0x00, 0x00, 0x3F, 0x44, 0x44, 0x3F, 0x00, 0x00, # "A"
24     0x00, 0x00, 0x7F, 0x49, 0x49, 0x36, 0x00, 0x00, # "B"
25     0x00, 0x00, 0x3E, 0x41, 0x41, 0x22, 0x00, 0x00, # "C"
26     0x00, 0x00, 0x7F, 0x41, 0x41, 0x3E, 0x00, 0x00, # "D"
27     0x00, 0x00, 0x7F, 0x49, 0x49, 0x41, 0x00, 0x00, # "E"
28     0x00, 0x00, 0x7F, 0x48, 0x48, 0x40, 0x00, 0x00, # "F"
29     0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, # ""
30 ]
31 def setup():
32     GPIO.setmode(GPIO.BOARD)      # Number GPIOs by its physical location
33     GPIO.setup(dataPin, GPIO.OUT)
34     GPIO.setup(latchPin, GPIO.OUT)

```

```
35     GPIO.setup(clockPin, GPIO.OUT)
36
37     def shiftOut(dPin,cPin,order,val):
38         for i in range(0,8):
39             GPIO.output(cPin,GPIO.LOW);
40             if(order == LSBFIRST):
41                 GPIO.output(dPin, (0x01&(val>>i)==0x01) and GPIO.HIGH or GPIO.LOW)
42             elif(order == MSBFIRST):
43                 GPIO.output(dPin, (0x80&(val<<i)==0x80) and GPIO.HIGH or GPIO.LOW)
44             GPIO.output(cPin,GPIO.HIGH);
45
46     def loop():
47         while True:
48             for j in range(0,500):# Repeat enough times to display the smiling face a period
49             of time
50                 x=0x80
51                 for i in range(0,8):
52                     GPIO.output(latchPin,GPIO.LOW)
53                     shiftOut(dataPin,clockPin,MSBFIRST,pic[i]) #first shift data of line
54             information to first stage 74HC959
55
56                     shiftOut(dataPin,clockPin,MSBFIRST,~x) #then shift data of column
57             information to second stage 74HC959
58                     GPIO.output(latchPin,GPIO.HIGH)# Output data of two stage 74HC595 at the
59             same time
60                     time.sleep(0.001)# display the next column
61                     x>>=1
62             for k in range(0,len(data)-8):#len(data) total number of "0-F" columns
63                 for j in range(0,20):# times of repeated displaying LEDMatrix in every frame,
64             the bigger the "j", the longer the display time.
65                 x=0x80      # Set the column information to start from the first column
66                 for i in range(k,k+8):
67                     GPIO.output(latchPin,GPIO.LOW)
68                     shiftOut(dataPin,clockPin,MSBFIRST,data[i])
69                     shiftOut(dataPin,clockPin,MSBFIRST,~x)
70                     GPIO.output(latchPin,GPIO.HIGH)
71                     time.sleep(0.001)
72                     x>>=1
73     def destroy():
74         GPIO.cleanup()
75     if __name__ == '__main__':
76         print ('Program is starting... ')
77         setup()
78         try:
```

```

79     loop()
80     except KeyboardInterrupt:
81         destroy()

```

The first “for” cycle in the “while” cycle is used to display a static smile. Display column information from left to right, one column by one column, totally 8 columns. Repeat 500 times to ensure display time enough.

```

        for j in range(0,500):# Repeat enough times to display the smiling face a period
of time
            x=0x80
            for i in range(0,8):
                GPIO.output(latchPin,GPIO.LOW)
                shiftOut(dataPin,clockPin,MSBFIRST,pic[i])#first shift data of line
information to first stage 74HC595
                shiftOut(dataPin,clockPin,MSBFIRST,~x)#then shift data of column
information to first stage 74HC595

                GPIO.output(latchPin,GPIO.HIGH)# Output data of two stage 74HC595 at the
same time.
                time.sleep(0.001)# display the next column
                x>>=1

```

The second “for” cycle is used to display scrolling characters "0-F", totally $18 \times 8 = 144$ columns. Display the 0-8 column, 1-9 column, 2-10 column..... 138-144 column in turn to achieve scrolling effect. The display of each frame is repeated a certain number of times, and the more times the number of repetitions, the longer the single frame display, the slower the rolling.

```

        for k in range(0,len(data)-8):#len(data) total number of "0-F" columns.
            for j in range(0,20):# times of repeated displaying LEDMatrix in every frame,
the bigger the "j" , the longer the display time
                x=0x80      # Set the column information to start from the first column
                for i in range(k,k+8):
                    GPIO.output(latchPin,GPIO.LOW)
                    shiftOut(dataPin,clockPin,MSBFIRST,data[i])
                    shiftOut(dataPin,clockPin,MSBFIRST,~x)
                    GPIO.output(latchPin,GPIO.HIGH)
                    time.sleep(0.001)
                x>>=1

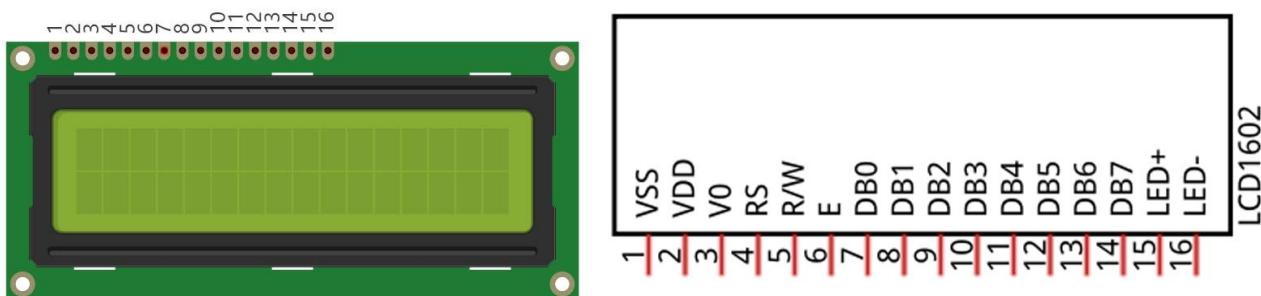
```

Chapter 20 LCD1602

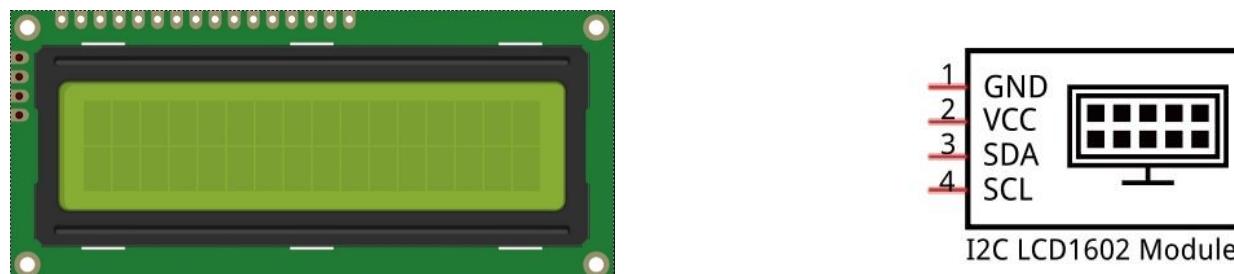
In this chapter, we will learn a display screen, LCD1602.

Project 20.1 I2C LCD1602

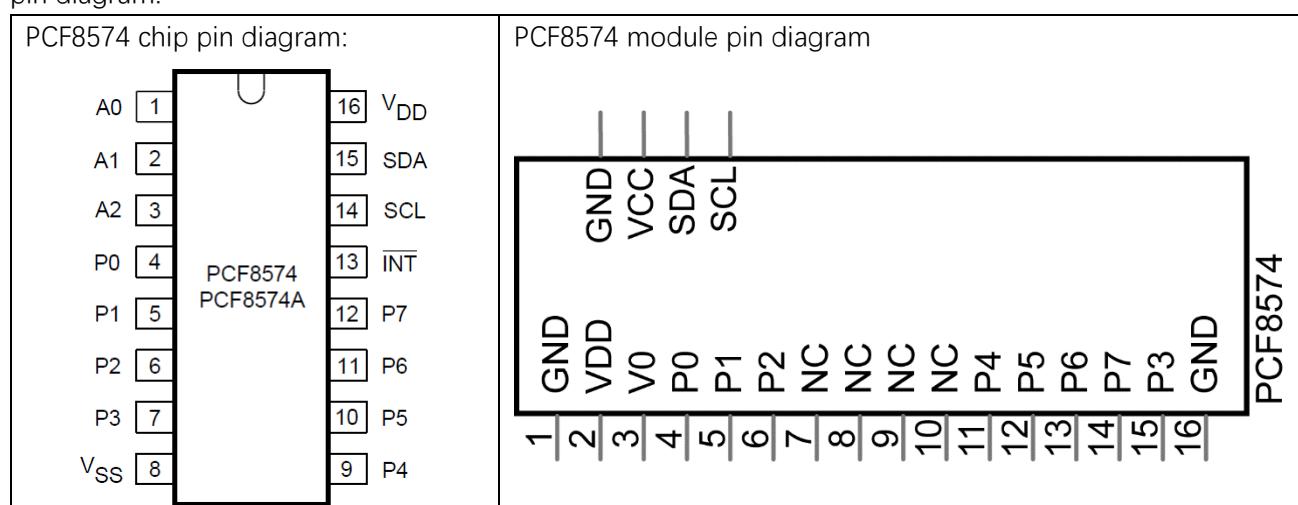
LCD1602 can display 2 lines of characters in 16 columns. It can display numbers, letters, symbols, ASCII code and so on. As shown below is a monochrome LCD1602 display screen, and its circuit pin diagram:



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

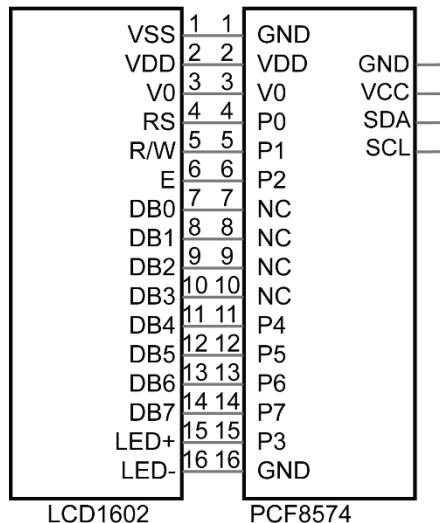


The serial-to-parallel chip used in this module is PCF8574T (PCF8574AT), and its default I2C address is 0x27(0x3F), and you can view all the RPI bus on your I2C device address through command "i2cdetect -y 1" to. (refer to the "configuration I2C" section below) below is the PCF8574 pin schematic diagram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



PCF8574 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.

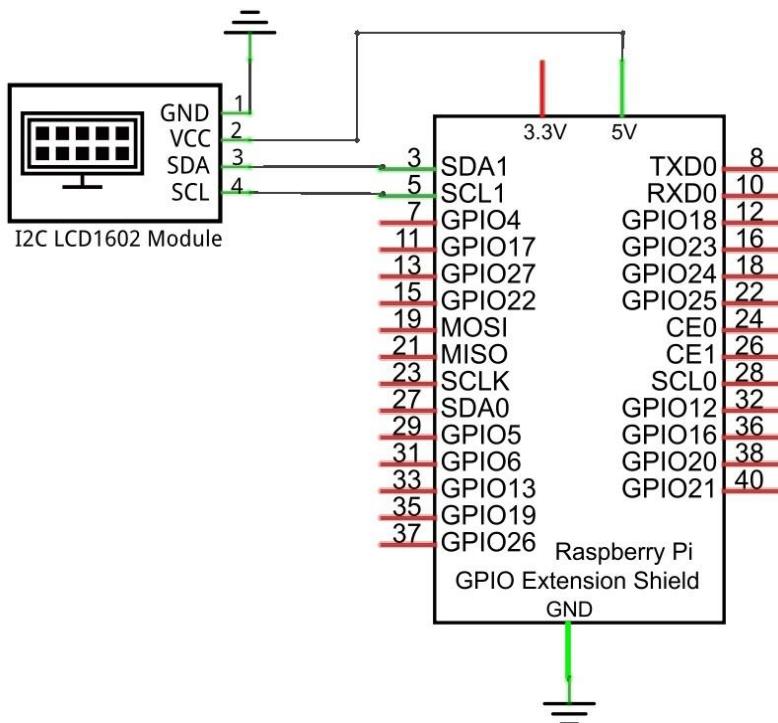
Component List

Raspberry Pi (with 40 GPIO) x1 GPIO Extension Board & Wire x1 BreadBoard x1	Jumper
I ² C LCD1602 Module x1	

Circuit

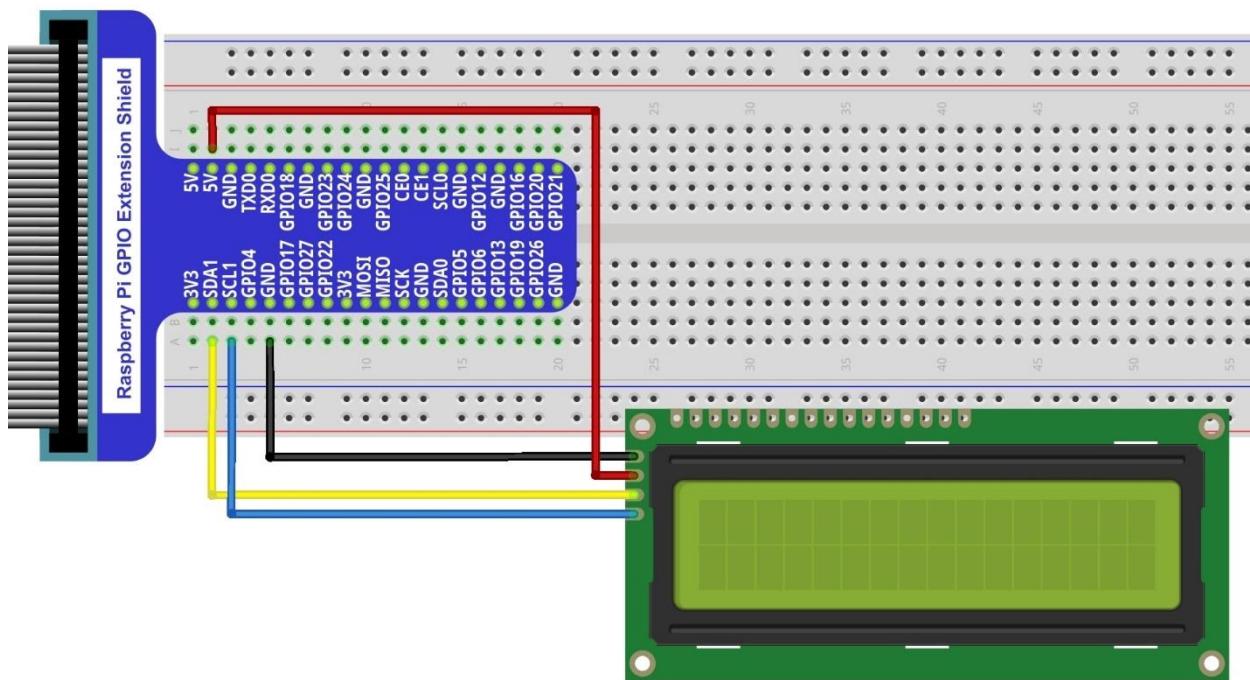
Note that the power supply for I2CLCD1602 in this circuit is 5V.

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 20.1.1 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 analyze the code.

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

1. Use cd command to enter 20.1.1_I2CLCD1602 directory of C code.

```
cd ~/Freenove_Kit/Code/C_Code/20.1.1_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.

```
14 // #define pcf8574_address 0x27      // default I2C address of Pcf8574
15 #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:

```
1 #include <stdlib.h>
2 #include <stdio.h>
3 #include <wiringPi.h>
4 #include <pcf8574.h>
5 #include <lcd.h>
6 #include <time.h>
7
8 // #define pcf8574_address 0x27      // default I2C address of Pcf8574
9 #define pcf8574_address 0x3F        // default I2C address of Pcf8574A
10 #define BASE 64                  // BASE any number above 64
11 // Define the output pins of the PCF8574, which are directly connected to the LCD1602 pin.
```

```
12 #define RS      BASE+0
13 #define RW      BASE+1
14 #define EN      BASE+2
15 #define LED     BASE+3
16 #define D4      BASE+4
17 #define D5      BASE+5
18 #define D6      BASE+6
19 #define D7      BASE+7
20
21 int lcdhd;// used to handle LCD
22 void printCPUtemperature() {// sub function used to print CPU temperature
23     FILE *fp;
24     char str_temp[15];
25     float CPU_temp;
26     // CPU temperature data is stored in this directory.
27     fp=fopen("/sys/class/thermal/thermal_zone0/temp","r");
28     fgets(str_temp,15,fp);      // read file temp
29     CPU_temp = atof(str_temp)/1000.0; // convert to Celsius degrees
30     printf("CPU's temperature : %.2f \n",CPU_temp);
31     lcdPosition(lcdhd,0,0);      // set the LCD cursor position to (0,0)
32     lcdPrintf(lcdhd,"CPU:%.2fC",CPU_temp); // Display CPU temperature on LCD
33     fclose(fp);
34 }
35 void printDataTime() //used to print system time
36     time_t rawtime;
37     struct tm *timeinfo;
38     time(&rawtime); // get system time
39     timeinfo = localtime(&rawtime); //convert to local time
40     printf("%s \n",asctime(timeinfo));
41     lcdPosition(lcdhd,0,1); // set the LCD cursor position to (0,1)
42     lcdPrintf(lcdhd,"Time:%d:%d:%d",timeinfo->tm_hour,timeinfo->tm_min,timeinfo->tm_sec);
43 //Display system time on LCD
44 }
45 int main(void) {
46     int i;
47
48     printf("Program is starting ... \n");
49
50     wiringPiSetup();
51
52     pcf8574Setup(BASE,pcf8574_address); //initialize PCF8574
53     for(i=0;i<8;i++) {
54         pinMode(BASE+i,OUTPUT); //set PCF8574 port to output mode
55     }
```

```

56     digitalWrite(LED, HIGH);      //turn on LCD backlight
57     digitalWrite(RW, LOW);       //allow writing to LCD
58     lcdhd = lcdInit(2, 16, 4, RS, EN, D4, D5, D6, D7, 0, 0, 0, 0); // initialize LCD and return "handle"
59 used to handle LCD
60     if(lcdhd == -1) {
61         printf("lcdInit failed !");
62         return 1;
63     }
64     while(1) {
65         printCPUtemperature(); //print CPU temperature
66         printDataTime();      // print system time
67         delay(1000);
68     }
69     return 0;
70 }
```

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 20.1.1 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 analyze the code.

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

1. Use cd command to enter 20.1.1_I2CLCD1602 directory of Python code.

```
cd ~/Freenove_Kit/Code/Python_Code/20.1.1_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:

```

1  from PCF8574 import PCF8574_GPIO
2  from Adafruit_LCD1602 import Adafruit_CharLCD
3
4  from time import sleep, strftime
5  from datetime import datetime
6
7  def get_cpu_temp():      # get CPU temperature and store it into file
8      "/sys/class/thermal/thermal_zone0/temp"
9      tmp = open('/sys/class/thermal/thermal_zone0/temp')
10     cpu = tmp.read()
11     tmp.close()
12     return '{:.2f}'.format(float(cpu)/1000) + ' C'
13
14 def get_time_now():      # get system time

```

```

15     return datetime.now().strftime('%H:%M:%S')
16
17 def loop():
18     mcp.output(3, 1)      # turn on LCD backlight
19     lcd.begin(16, 2)      # set number of LCD lines and columns
20     while(True):
21         #lcd.clear()
22         lcd.setCursor(0, 0) # set cursor position
23         lcd.message('CPU: ' + get_cpu_temp()+'\n')# display CPU temperature
24         lcd.message(get_time_now())    # display the time
25         sleep(1)
26
27 def destroy():
28     lcd.clear()
29
30 PCF8574_address = 0x27 # I2C address of the PCF8574 chip.
31 PCF8574A_address = 0x3F # I2C address of the PCF8574A chip.
32 # Create PCF8574 GPIO adapter.
33 try:
34     mcp = PCF8574_GPIO(PCF8574_address)
35 except:
36     try:
37         mcp = PCF8574_GPIO(PCF8574A_address)
38     except:
39         print ('I2C Address Error !')
40         exit(1)
41 # Create LCD, passing in MCP GPIO adapter.
42 lcd = Adafruit_CharLCD(pin_rs=0, pin_e=2, pins_db=[4, 5, 6, 7], GPIO=mcp)
43
44 if __name__ == '__main__':
45     print ('Program is starting ... ')
46     try:
47         loop()
48     except KeyboardInterrupt:
49         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 cycle, 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.

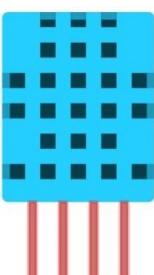
Chapter 21 Hygrothermograph DHT11

In this chapter, we will learn a commonly used sensor, Hygrothermograph DHT11.

Project 21.1 Hygrothermograph

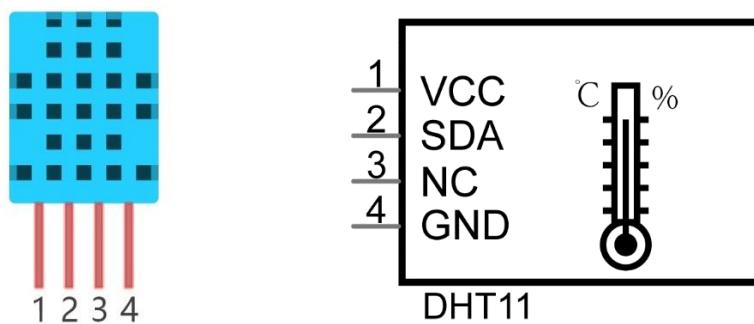
Hygrothermograph is an important tool in our life to remind us of keeping warm and replenishing moisture in time. In this project, we will use RPi to read temperature and humidity data of DHT11.

Component List

Raspberry Pi (with 40 GPIO) x1 GPIO Expansion Board & Wire x1 BreadBoard x1	DHT11 x1 	Resistor 10kΩ x1 
Jumper 		

Component knowledge

Temperature & Humidity Sensor DHT11 is a compound temperature & humidity sensor, and the output digital signal has been calibrated inside.



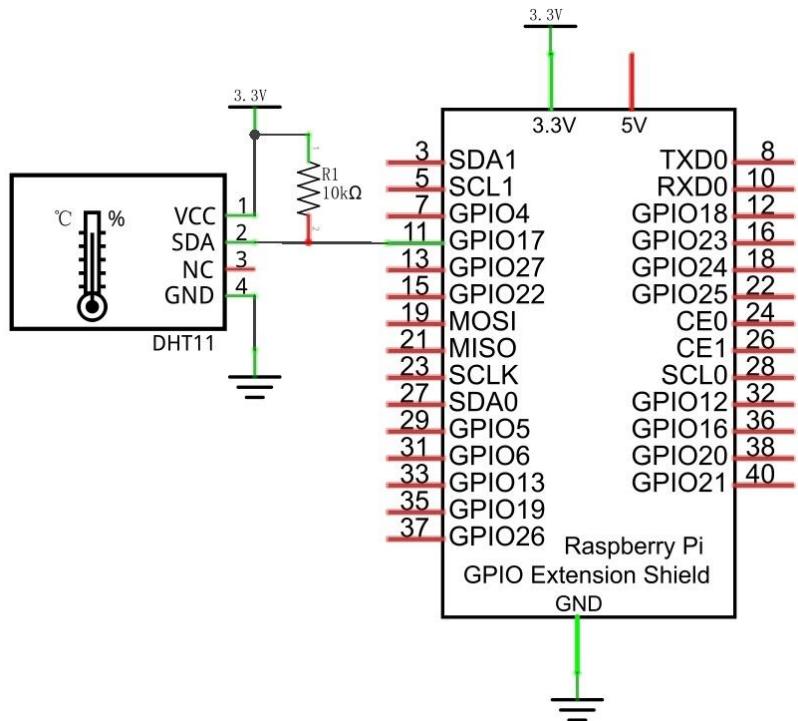
It has 1S's initialization time after powered up. The operating voltage is within the range of 3.3V-5.5V. SDA pin is a data pin, which is used to communicate with other device.

NC pin (Not Connected Pin) are pins found on various integrated circuit packages. Those pins have no functional purpose to the outside circuit (but may have unexposed functionality). Those pins should not be connected to any of the circuit connections.

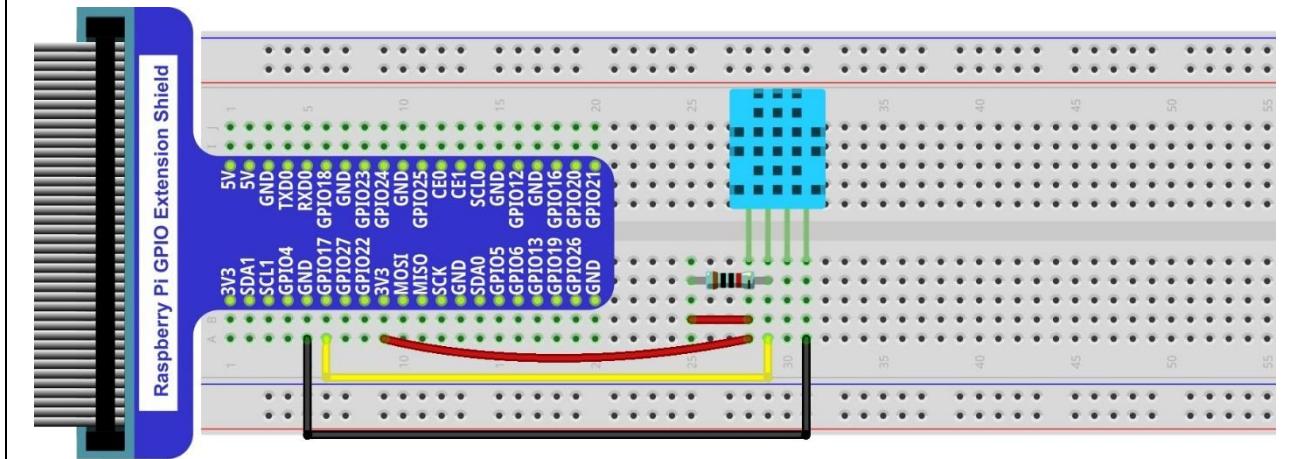


Circuit

Schematic diagram



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



Code

The code is used to read the temperature and humidity data of DHT11, and print them out.

C Code 21.1.1 DHT11

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

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

1. Use cd command to enter 21.1.1_DHT11 directory of C code.

```
cd ~/Freenove_Kit/Code/C_Code/21.1.1_DHT11
```

2. Code of this project contains a custom header file. Use the following command to compile the code DHT11.cpp and DHT.cpp and generate executable file DHT11. And the custom header file will be compiled at the same time.

```
gcc DHT.cpp DHT11.cpp -o DHT11 -lwiringPi
```

3. Run the generated file "DHT11".

```
sudo ./DHT11
```

After the program is executed, the terminal window will display the current total number of reading times, the read state, as well as the temperature and humidity value. As is shown below:

```
The sumCnt is : 1
DHT11,OK!
Humidity is 57.00 %,      Temperature is 30.00 *C

The sumCnt is : 2
DHT11,OK!
Humidity is 57.00 %,      Temperature is 30.00 *C

The sumCnt is : 3
DHT11,OK!
Humidity is 57.00 %,      Temperature is 30.00 *C

The sumCnt is : 4
DHT11,OK!
Humidity is 57.00 %,      Temperature is 29.00 *C
```

The following is the program code:

```

1 #include <wiringPi.h>
2 #include <stdio.h>
3 #include <stdint.h>
4 #include "DHT.hpp"

5
6 #define DHT11_Pin 0 //define the pin of sensor
7
8 int main() {
9     DHT dht;          //create a DHT class object
10    int chk,sumCnt;//chk:read the return value of sensor; sumCnt:times of reading sensor
11
12    printf("Program is starting ... \n");
13
14    wiringPiSetup();
```

```

15
16     while(1) {
17         chk = dht.readDHT11(DHT11_Pin); //read DHT11 and get a return value. Then determine
18         whether data read is normal according to the return value.
19         sumCnt++;           //counting number of reading times
20         printf("The sumCnt is : %d \n", sumCnt);
21         switch(chk) {
22             case DHTLIB_OK:      //if the return value is DHTLIB_OK, the data is normal.
23                 printf("DHT11, OK! \n");
24                 break;
25             case DHTLIB_ERROR_CHECKSUM:    //data check has errors
26                 printf("DHTLIB_ERROR_CHECKSUM! \n");
27                 break;
28             case DHTLIB_ERROR_TIMEOUT:    //reading DHT times out
29                 printf("DHTLIB_ERROR_TIMEOUT! \n");
30                 break;
31             case DHTLIB_INVALID_VALUE:    //other errors
32                 printf("DHTLIB_INVALID_VALUE! \n");
33                 break;
34         }
35         printf("Humidity is %.2f %%, \t Temperature is %.2f
36 *C\n\n", dht.humidity, dht.temperature);
37         delay(2000);
38     }
39     return 1;
40 }
```

In this project code, we use a custom library file "DHT.hpp". It is located in the same directory with program files "DHT11.cpp" and "DHT.cpp", and methods for reading DHT sensor are provided in the library file. By using this library, we can easily read the DHT sensor. First create a DHT class object in the code.

	DHT dht;
--	----------

And then in the "while" cycle, use `chk = dht.readDHT11 (DHT11_Pin)` to read the DHT11, and determine whether the data read is normal according to the return value "chk". And then use variable sumCnt to record number of reading times.

	<pre> while(1) { chk = dht.readDHT11(DHT11_Pin); //read DHT11 and get a return value. Then determine whether data read is normal according to the return value. sumCnt++; //count number of times of reading printf("The sumCnt is : %d \n", sumCnt); switch(chk) { case DHTLIB_OK: //if the return value is DHTLIB_OK, the data is normal. printf("DHT11, OK! \n"); break; case DHTLIB_ERROR_CHECKSUM: //data check has errors printf("DHTLIB_ERROR_CHECKSUM! \n"); } }</pre>
--	--

```
        break;
    case DHTLIB_ERROR_TIMEOUT:      //reading DHT times out
        printf("DHTLIB_ERROR_TIMEOUT! \n");
        break;
    case DHTLIB_INVALID_VALUE:      //other errors
        printf("DHTLIB_INVALID_VALUE! \n");
        break;
}
```

Finally print the results:

```
printf("Humidity is %.2f %%, \t Temperature is %.2f *C\n\n", dht.humidity, dht.temperature);
```

Library file "DHT.hpp" contains a DHT class and his public member functions int **readDHT11** (int pin) is used to read sensor DHT11 and store the temperature and humidity data read to member variables double humidity and temperature. The implementation method of the function is included in the file "DHT.cpp".

```
1 #include <wiringPi.h>
2 #include <stdio.h>
3 #include <stdint.h>
4
5 //read return flag of sensor
6 #define DHTLIB_OK          0
7 #define DHTLIB_ERROR_CHECKSUM -1
8 #define DHTLIB_ERROR_TIMEOUT -2
9 #define DHTLIB_INVALID_VALUE -999
10
11 #define DHTLIB_DHT11_WAKEUP 18
12 #define DHTLIB_DHT_WAKEUP   1
13
14 #define DHTLIB_TIMEOUT       100
15
16 class DHT{
17     public:
18         double humidity, temperature; //use to store temperature and humidity data read
19         int readDHT11(int pin); //read DHT11
20     private:
21         int bits[5]; //Buffer to receiver data
22         int readSensor(int pin, int wakeupDelay); //
23
24 };
```

Python Code 21.1.1 DHT11

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

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

1. Use cd command to enter 21.1.1_DHT11 directory of Python code.

```
cd ~/Freenove_Kit/Code/Python_Code/21.1.1_DHT11
```

2. Use python command to execute code "DHT11.py".

```
python DHT11.py
```

After the program is executed, the terminal window will display the current total number of read, the read state, as well as the temperature and humidity value. As is shown below:

```
Program is starting ...
The sumCnt is : 1,      chk : 0
DHT11,OK!
Humidity : 62.00,      Temperature : 30.00

The sumCnt is : 2,      chk : 0
DHT11,OK!
Humidity : 63.00,      Temperature : 30.00

The sumCnt is : 3,      chk : 0
DHT11,OK!
Humidity : 62.00,      Temperature : 30.00

The sumCnt is : 4,      chk : 0
DHT11,OK!
Humidity : 62.00,      Temperature : 30.00
```

The following is the program code:

```
1 import RPi.GPIO as GPIO
2 import time
3 import Freenove_DHT as DHT
4 DHTPin = 11      #define the pin of DHT11
5
6 def loop():
7     dht = DHT.DHT(DHTPin)    #create a DHT class object
8     sumCnt = 0                #number of reading times
9     while(True):
10         sumCnt += 1          #counting number of reading times
11         chk = dht.readDHT11() #read DHT11 and get a return value. Then determine
12         whether data read is normal according to the return value.
13         print ("The sumCnt is : %d, \t chk : %d"%(sumCnt,chk))
14         if (chk is dht.DHTLIB_OK):      #read DHT11 and get a return value. Then
15         determine whether data read is normal according to the return value.
16             print("DHT11,OK!")
17         elif(chk is dht.DHTLIB_ERROR_CHECKSUM): #data check has errors
18             print("DHTLIB_ERROR_CHECKSUM!!")
19         elif(chk is dht.DHTLIB_ERROR_TIMEOUT): #reading DHT times out
```

```

20         print("DHTLIB_ERROR_TIMEOUT!")
21     else:           #other errors
22         print("Other error!")
23
24     print("Humidity : %.2f, \t Temperature : %.2f \n%(dht.humidity, dht.temperature)")
25     time.sleep(2)
26
27 if __name__ == '__main__':
28     print (' Program is starting ... ')
29     try:
30         loop()
31     except KeyboardInterrupt:
32         GPIO.cleanup()
33         exit()

```

In this project code, we use a module "**Freenove_DHT.py**", which provide method of reading sensor DHT. It is located in the same directory with program files "**DHT11.py**". By using this library, we can easily read the DHT sensor. First create a DHT class object in the code.

	<code>dht = DHT.DHT(DHTPin) #create a DHT class object</code>
--	--

And then in the "while" cycle, use `chk = dht.readDHT11(DHTPin)` to read the DHT11, and determine whether the data read is normal according to the return value "chk". And then use variable sumCnt to record number of reading times.

	<pre> while(True): sumCnt += 1 #counting number of reading times chk = dht.readDHT11(DHTPin) #read DHT11 and get a return value. Then determine whether data read is normal according to the return value. print ("The sumCnt is : %d, \t chk : %d"%(sumCnt, chk)) if (chk is dht.DHTLIB_OK): #read DHT11 and get a return value. Then determine whether data read is normal according to the return value. print("DHT11,OK!") elif(chk is dht.DHTLIB_ERROR_CHECKSUM): #data check has errors print("DHTLIB_ERROR_CHECKSUM!") elif(chk is dht.DHTLIB_ERROR_TIMEOUT): #reading DHT times out print("DHTLIB_ERROR_TIMEOUT!") else: #other errors print("Other error!") </pre>
--	---

Finally print the results:

	<code>print("Humidity : %.2f, \t Temperature : %.2f \n%(dht.humidity, dht.temperature))</code>
--	--



Module "Freenove_DHT.py" contains a DHT class. And class functions def **readDHT11** (pin) is used to read sensor DHT11 and store the temperature and humidity data read to member variables humidity and temperature.

Freenove_DHT Module

This is a Python module for reading the temperature and humidity data of the DHT sensor. Partial functions and variables are described as follows:

Variable **humidity**: store humidity data read from sensor

Variable **temperature**: store temperature data read from sensor

def readDHT11 (pin): read the temperature and humidity of sensor DHT11, and return values used to determine whether the data is normal.

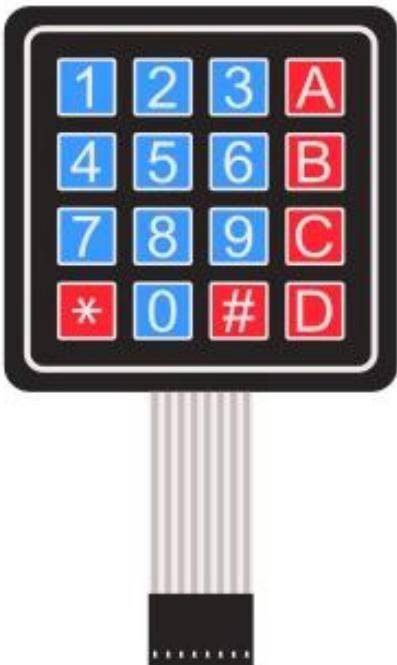
Chapter 22 Matrix Keypad

We have learned usage of a single button before. In this chapter, we will learn a device which integrates a number of key, matrix keyboard.

Project 22.1 Matrix Keypad

In this project, we will try to get every key code on the Keypad work.

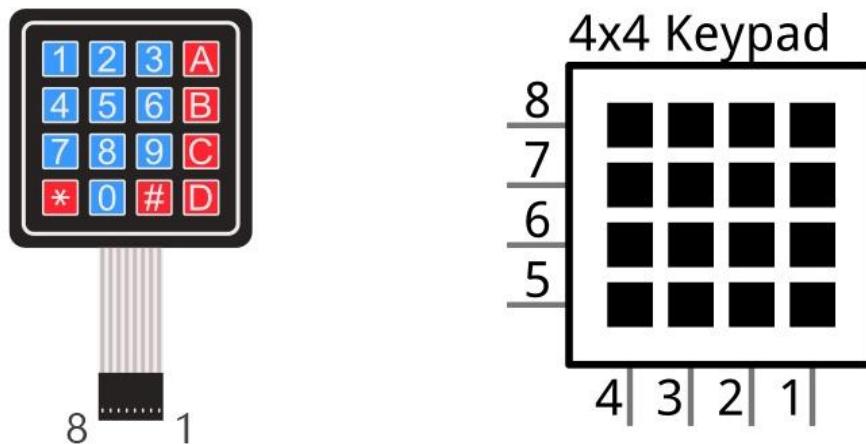
Component List

Raspberry Pi (with 40 GPIO) x1 GPIO Expansion Board & Wire x1 BreadBoard x1	4x4 Matrix Keypad x1
Jumper	 A diagram showing a 4x4 Matrix Keypad connected to a Raspberry Pi. The keypad is a black square with a grid of 16 colored keys: blue for numbers 1-9, red for symbols '*', '#', and 'A-D'. It is connected to a grey ribbon cable with black pins. The cable connects to a breadboard, which is then connected to the Raspberry Pi's GPIO pins.

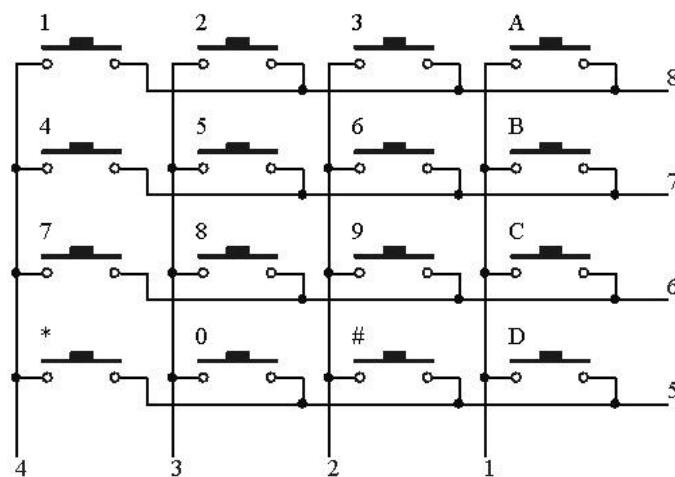
Component knowledge

4x4 Matrix Keypad

Keypad is a device that integrates a number of keys. As is shown below, a 4x4 Keypad integrates 16 keys:

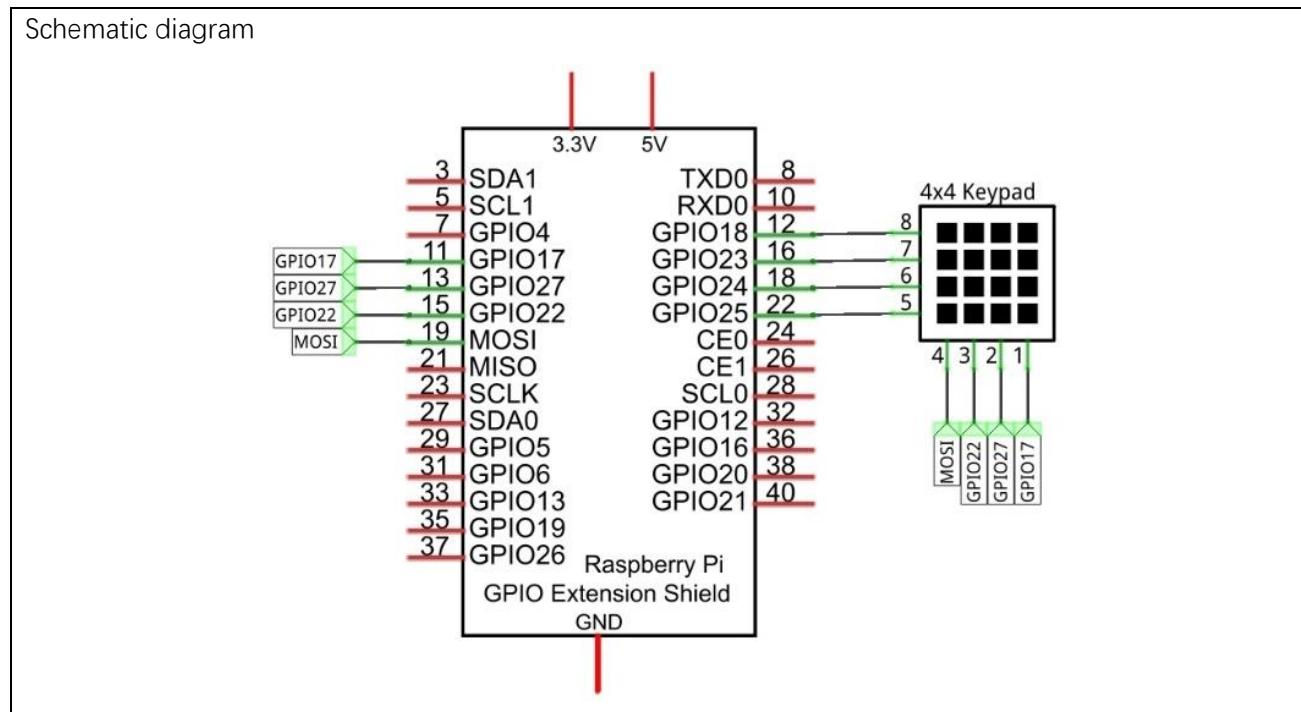


Like the integration of LED matrix, in 4x4 Keypad each row of keys is connected in with one pin and it is the same as each column. Such connection can reduce the occupation of processor port. Internal circuit is shown below.

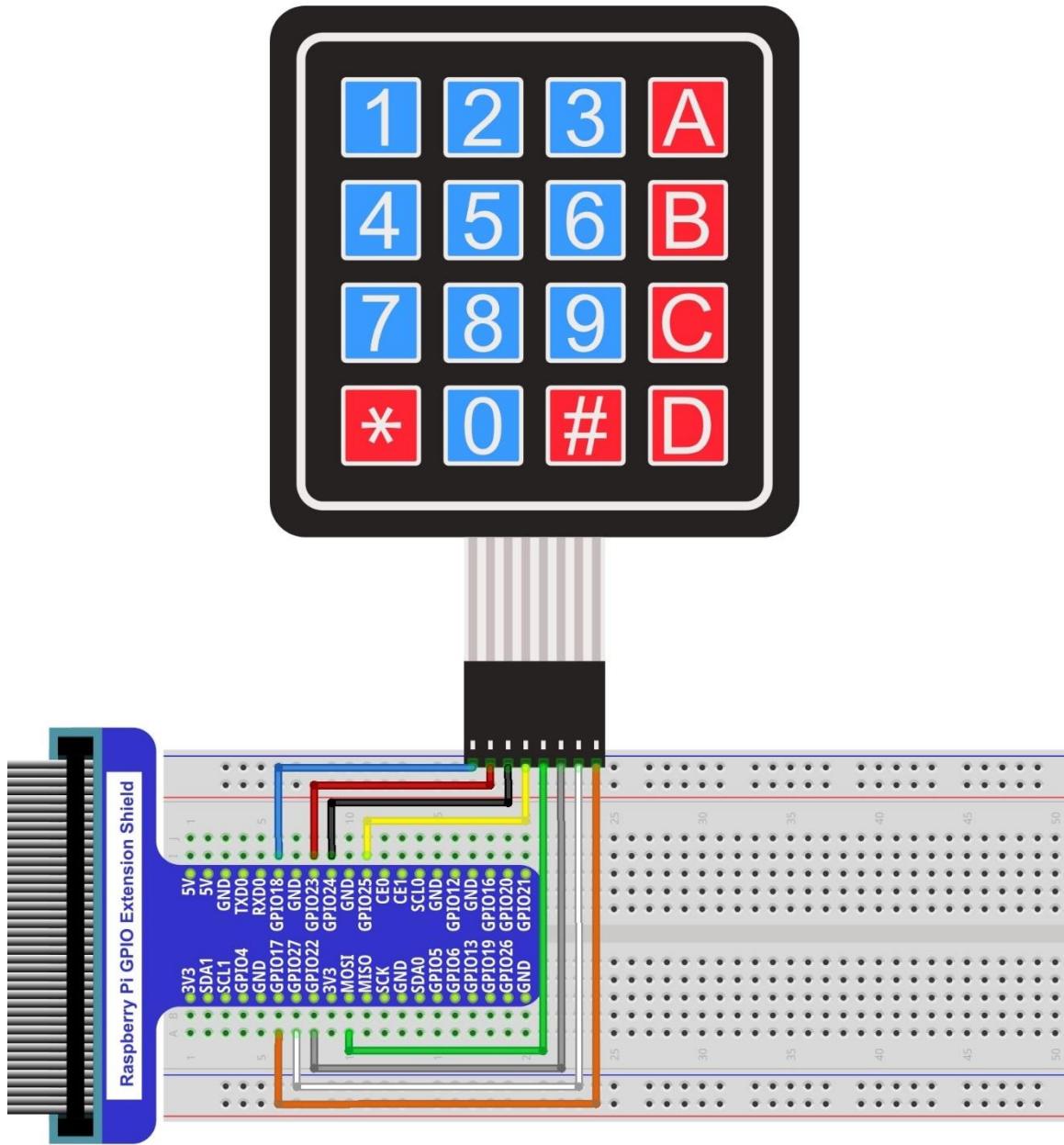


The usage method is similar to the Matrix LED, namely, uses a row scan or column scanning method to detect the state of key on each column or row. Take column scanning method as an example, send low level to the first 1 column (Pin1), detect level state of row 5, 6, 7, 8 to judge whether the key A, B, C, D are pressed. And then send low level to column 2, 3, 4 in turn to detect whether other keys are pressed. Then, you can get the state of all keys.

Circuit



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



Code

This code is used to obtain all key code of 4x4 Matrix Keypad, when one of keys is pressed, the key code will be printed out in the terminal window.

C Code 22.1.1 MatrixKeypad

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

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

1. Use cd command to enter 22.1.1_MatrixKeypad directory of C code.

```
cd ~/Freenove_Kit/Code/C_Code/22.1.1_MatrixKeypad
```

2. Code of this project contains a custom header file. Use the following command to compile the code MatrixKeypad.cpp, Keypad.cpp and Key.cpp generate executable file MatrixKeypad. And the custom header file will be compiled at the same time.

```
gcc MatrixKeypad.cpp Keypad.cpp Key.cpp -o MatrixKeypad -lwiringPi
```

3. Run the generated file "MatrixKeypad".

```
sudo ./MatrixKeypad
```

After the program is executed, press any key on the MatrixKeypad, the terminal will print out the corresponding key code. As is shown below:

```
Program is starting ...
You Pressed key : 1
You Pressed key : 2
You Pressed key : 3
You Pressed key : 4
You Pressed key : 5
You Pressed key : 6
You Pressed key : 7
You Pressed key : 8
You Pressed key : 9
You Pressed key : 0
You Pressed key : A
You Pressed key : B
You Pressed key : C
You Pressed key : D
You Pressed key : *
You Pressed key : #
```

The following is the program code:

```
1 #include "Keypad.hpp"
2 #include <stdio.h>
3 const byte ROWS = 4; //four rows
4 const byte COLS = 4; //four columns
5 char keys[ROWS][COLS] = { //key code
6     {'1','2','3','A'},
7     {'4','5','6','B'},
8     {'7','8','9','C'},
9     {'*','0','#','D'}
10 };
11 byte rowPins[ROWS] = {1, 4, 5, 6 }; //define the row pins for the keypad
12 byte colPins[COLS] = {12, 3, 2, 0 }; //define the column pins for the keypad
```

```

13 //create Keypad object
14 Keypad keypad = Keypad( makeKeymap(keys), rowPins, colPins, ROWS, COLS );
15
16 int main() {
17     printf("Program is starting ... \n");
18
19     wiringPiSetup();
20
21     char key = 0;
22     keypad.setDebounceTime(50);
23     while(1) {
24         key = keypad.getKey(); //get the state of keys
25         if (key){ //if a key is pressed, print out its key code
26             printf("You Pressed key : %c \n",key);
27         }
28     }
29     return 1;
30 }
```

In this project code, we use two custom library file "**Keypad.hpp**" and "**Key.hpp**". They are located in the same directory with program files "**MatrixKeypad.cpp**", "**Keypad.cpp**" and "**Key.cpp**". Library Keypad is transplanted from the Arduino library Keypad. And this library file provides a method to read the keyboard. By using this library, we can easily read the matrix keyboard.

First, define the information of the matrix keyboard used in this project: the number of rows and columns, code of each key and GPIO pin connected to each column and each row. It is necessary to include the header file "**Keypad.hpp**".

```

#include "Keypad.hpp"
#include <stdio.h>
const byte ROWS = 4; //four rows
const byte COLS = 4; //four columns
char keys[ROWS][COLS] = { //key code
    {'1','2','3','A'},
    {'4','5','6','B'},
    {'7','8','9','C'},
    {'*','0','#','D'}
};
byte rowPins[ROWS] = {1, 4, 5, 6}; //connect to the row pinouts of the keypad
byte colPins[COLS] = {12,3, 2, 0}; //connect to the column pinouts of the keypad
```

And then, based on the above information, instantiate a Keypad class object to operate the matrix keyboard.

```
Keypad keypad = Keypad( makeKeymap(keys), rowPins, colPins, ROWS, COLS );
```

Set the debounce time to 50ms, and this value can be set based on the actual use of the keyboard flexibly, with default time 10ms.

```
keypad.setDebounceTime(50);
```

In the "while" cycle, use the function key= keypad.getKey () to read the keyboard constantly. If there is a key pressed, its key code will be stored in the variable "key", then be printed out.

```
while(1) {
    key = keypad.getKey(); //get the state of keys
    if (key){           // if a key is pressed, print out its key code
        printf("You Pressed key : %c \n",key);
    }
}
```

The library Keypad used for RPi is transplanted from the Arduino library Keypad. And the source files can be obtained by visiting <http://playground.arduino.cc/Code/Keypad>. As for transplanted function library, the function and method of all classes, functions, variables, etc. are the same as the original library. Partial contents of the Keypad library are described below:

class Keypad**Keypad(char *userKeymap, byte *row, byte *col, byte numRows, byte numCols);**

Constructor, the parameters are: key code of keyboard, row pin, column pin, the number of rows, the number of columns.

char getKey();

Get the key code of the pressed key. If no key is pressed, the return value is NULL.

void setDebounceTime(uint);

Set the debounce time. And the default time is 10ms.

void setHoldTime(uint);

Set the time when the key holds stable state after pressed.

bool isPressed(char keyChar);

Judge whether the key with code "keyChar" is pressed.

char waitForKey();

Wait for a key to be pressed, and return key code of the pressed key.

KeyState getState();

Get state of the keys.

bool keyStateChanged();

Judge whether there is a change of key state, then return True or False.

For More information about Keypad, please visit: <http://playground.arduino.cc/Code/Keypad> or through the opening file "Keypad.hpp".

Python Code 22.1.1 MatrixKeypad

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

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

1. Use cd command to enter 22.1.1_MatrixKeypad directory of Python code.

```
cd ~/Freenove_Kit/Code/Python_Code/22.1.1_MatrixKeypad
```

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

```
python MatrixKeypad.py
```

After the program is executed, press any key on the MatrixKeypad, the terminal will print out the corresponding key code. As is shown below:

```
Program is starting ...
You Pressed Key : 1
You Pressed Key : 2
You Pressed Key : 3
You Pressed Key : 4
You Pressed Key : 5
You Pressed Key : 6
You Pressed Key : 7
You Pressed Key : 8
You Pressed Key : 9
You Pressed Key : *
You Pressed Key : 0
You Pressed Key : #
You Pressed Key : A
You Pressed Key : B
You Pressed Key : C
You Pressed Key : D
```

The following is the program code:

```
1 import RPi.GPIO as GPIO
2 import Keypad      #import module Keypad
3 ROWS = 4          # number of rows of the Keypad
4 COLS = 4          #number of columns of the Keypad
5 keys = [  '1','2','3','A',
6             '4','5','6','B',
7             '7','8','9','C',
8             '*', '0', '#', 'D'   ]
9 rowsPins = [12, 16, 18, 22]      #connect to the row pinouts of the keypad
10 colsPins = [19, 15, 13, 11]      #connect to the column pinouts of the keypad
11
12 def loop():
13     keypad = Keypad.Keypad(keys, rowsPins, colsPins, ROWS, COLS)    #creat Keypad object
14     keypad.setDebounceTime(50)      #set the debounce time
15     while(True):
16         key = keypad.getKey()      #obtain the state of keys
17         if(key != keypad.NULL):    #if there is key pressed, print its key code.
18             print ("You Pressed Key : %c %(key)")
19
20     if __name__ == '__main__':
21         print ("Program is starting ... ")
```

```

22     try:
23         loop()
24     except KeyboardInterrupt:
25         GPIO.cleanup()

```

In this project code, we use two custom module "Keypad.py", which is located in the same directory with program file "MatrixKeypad.py". And this library file, which is transplanted from Arduino function library Keypad, provides a method to read the keyboard. By using this library, we can easily read the matrix keyboard. First, import module Keypad. Then define the information of the matrix keyboard used in this project: the number of rows and columns, code of each key and GPIO pin connected to each column and each row.

```

import Keypad      #import module Keypad
ROWS = 4          #number of rows of the Keypad
COLS = 4          #number of columns of the Keypad
keys = [ '1', '2', '3', 'A',
         '4', '5', '6', 'B',
         '7', '8', '9', 'C',
         '*', '0', '#', 'D' ]
rowsPins = [12, 16, 18, 22]      #connect to the row pinouts of the keypad
colsPins = [19, 15, 13, 11]      #connect to the column pinouts of the keypad

```

And then, based on the above information, instantiate a Keypad class object to operate the matrix keyboard.

```
keypad = Keypad.Keypad(keys, rowsPins, colsPins, ROWS, COLS)
```

Set the debounce time to 50ms, and this value can be set based on the actual use of the keyboard flexibly, with default time 10ms.

```
keypad.setDebounceTime(50)
```

In the "while" cycle, use the function key= keypad.getKey () to read the keyboard constantly. If there is a key pressed, its key code will be stored in the variable "key", and then be printed out.

```

while(True):
    key = keypad.getKey()      #get the state of keys
    if(key != keypad.NULL):   # if a key is pressed, print out its key code
        print ("You Pressed Key : %c %(key)")

```

The library Keypad used for RPi is transplanted from the Arduino library Keypad. The source files is written by language C++ and translated to Python can be obtained by visiting <http://playground.arduino.cc/Code/Keypad>. As for transplanted function library, the function and method of all classes, functions, variables, etc. are the same as the original library. Partial contents of the Keypad library are described below:

```
class Keypad  
def __init__(self, usrKeyMap, row_Pins, col_Pins, num_Rows, num_Cols):  
    Constructed function, the parameters are: key code of keyboard, row pin, column pin, the number of rows,  
    the number of columns.  
def getKey(self):  
    Get a pressed key. If no key is pressed, the return value is keypad NULL.  
def setDebounceTime(self, ms):  
    Set the debounce time. And the default time is 10ms.  
def setHoldTime(self, ms):  
    Set the time when the key holds stable state after pressed.  
def isPressed(keyChar):  
    Judge wether the key with code "keyChar" is pressed.  
def waitForKey():  
    Wait for a key to be pressed, and return key code of the pressed key.  
def getState():  
    Get state of the keys.  
def keyStateChanged():  
    Judge whether there is a change of key state, then return True or False.
```

For More information about Keypad, please visit: <http://playground.arduino.cc/Code/Keypad> or through the opening file "Keypad.py".

Chapter 23 Ultrasonic Ranging

In this chapter, we learn a module which use ultrasonic to measure distance, HC SR04.

Project 23.1 Ultrasonic Ranging

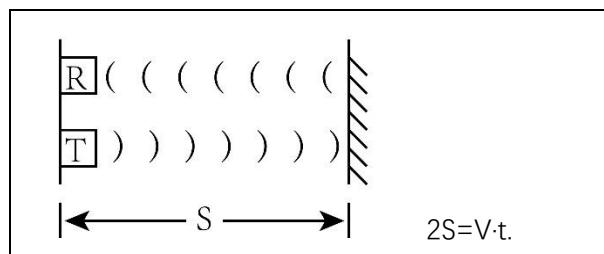
In this project, we use ultrasonic ranging module to measure distance, and print out the data in the terminal.

Component List

Raspberry Pi (with 40 GPIO) x1 GPIO Expansion Board & Wire x1 BreadBoard x1	HC SR04 x1
Jumper 	

Component Knowledge

Ultrasonic ranging module use the principle that ultrasonic will reflect when it encounters obstacles. Start counting the time when ultrasonic is transmitted. And when ultrasonic encounters an obstacle, it will reflect back. The counting will end after ultrasonic is received, and the time difference is the total time of ultrasonic from transmitting to receiving. Because the speed of sound in air is constant, and is about $v=340\text{m/s}$. So we can calculate the distance between the model and the obstacle: $s=vt/2$.



Ultrasonic module integrates a transmitter and a receiver. The transmitter is used to convert electrical signals (electrical energy) into sound waves (mechanical energy) and the function of the receiver is opposite. The object picture and the diagram of HC SR04 ultrasonic module are shown below:



Pin description:

VCC	power supply pin
Trig	trigger pin
Echo	Echo pin
GND	GND

Technical specs:

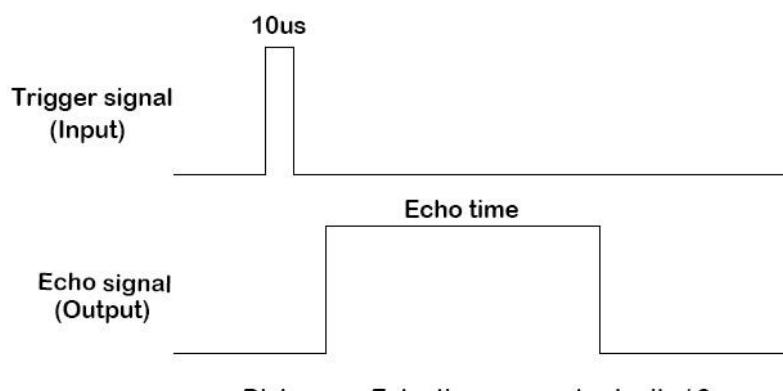
Working voltage: 5V

Working current: 12mA

Minimum measured distance: 2cm

Maximum measured distance: 200cm

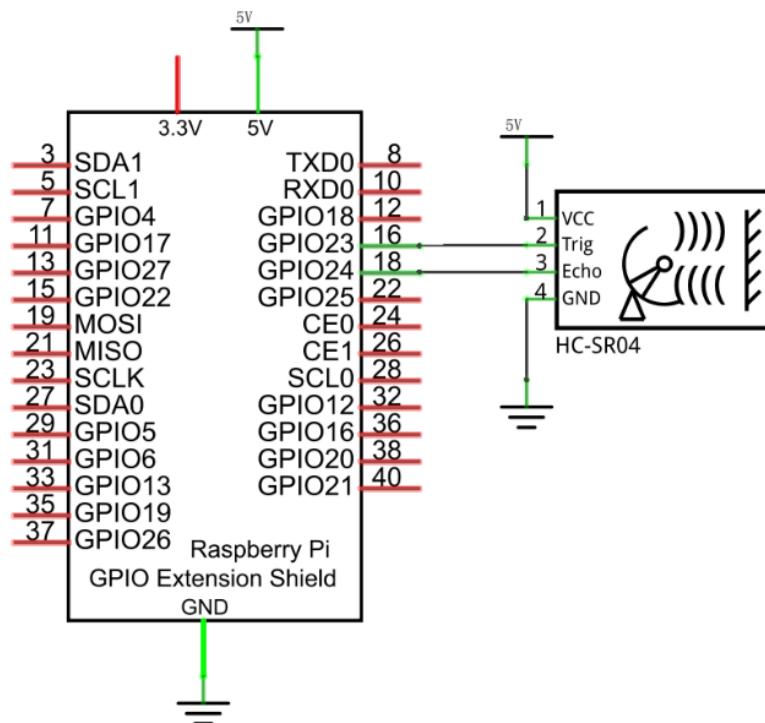
Instructions for use: output a high-level pulse in Trig pin lasting for least 10uS. Then the module begins to transmit ultrasonic. At the same time, the Echo pin will be pulled up. When the module receives the returned ultrasonic, the Echo pin will be pulled down. The duration of high level in Echo pin is the total time of the ultrasonic from transmitting to receiving, $s=vt/2$.



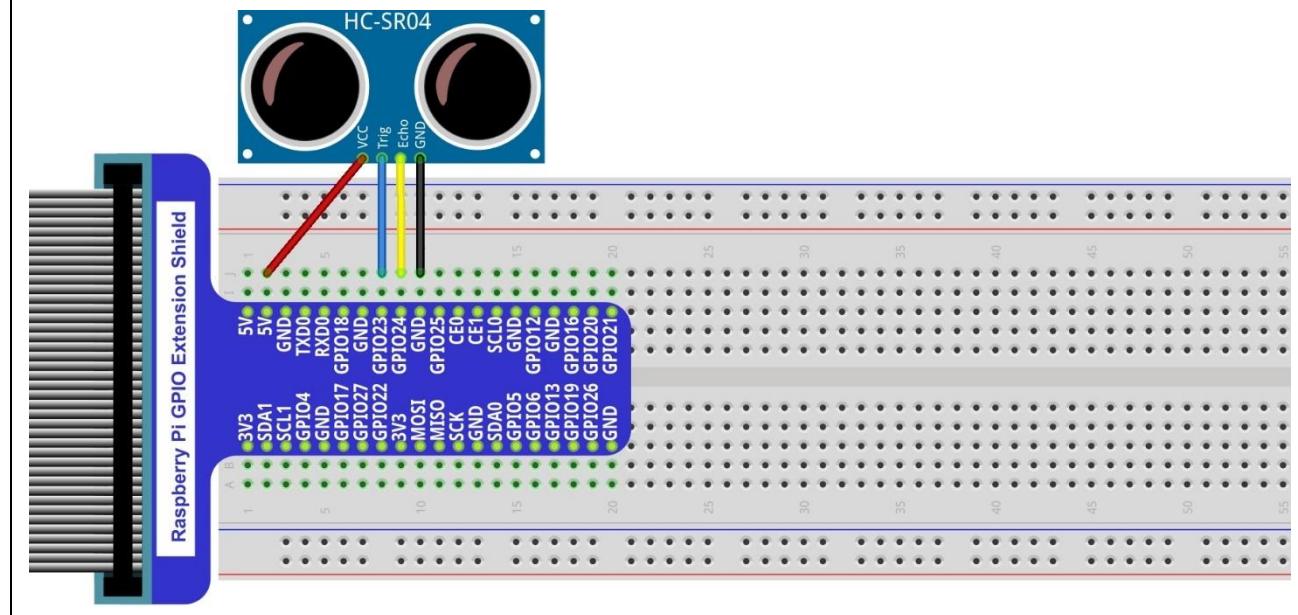
Circuit

Note that the voltage of ultrasonic module is 5V in the circuit.

Schematic diagram



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



Code

C Code 23.1.1 UltrasonicRanging

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

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

1. Use cd command to enter 23.1.1_UltrasonicRanging directory of C code.

```
cd ~/Freenove_Kit/Code/C_Code/23.1.1_UltrasonicRanging
```

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

```
gcc UltrasonicRanging.c -o UltrasonicRanging -lwiringPi
```

3. Then run the generated file "UltrasonicRanging".

```
sudo ./UltrasonicRanging
```

After the program is executed, make the detector of ultrasonic ranging module aim at the plane of an object, then the distance between the ultrasonic module and the object will be displayed in the terminal. As is shown below:

```
The distance is : 198.82 cm
The distance is : 198.37 cm
The distance is : 198.37 cm
The distance is : 199.63 cm
The distance is : 197.52 cm
The distance is : 198.39 cm
The distance is : 198.41 cm
```

The following is the program code:

```

1 #include <wiringPi.h>
2 #include <stdio.h>
3 #include <sys/time.h>
4
5 #define trigPin 4
6 #define echoPin 5
7 #define MAX_DISTANCE 220          // define the maximum measured distance
8 #define timeOut MAX_DISTANCE*60 // calculate timeout according to the maximum measured
9 distance
10 //function pulseIn: obtain pulse time of a pin
11 int pulseIn(int pin, int level, int timeout);
12 float getSonar(){ //get the measurement result of ultrasonic module with unit: cm
13     long pingTime;
14     float distance;
15     digitalWrite(trigPin,HIGH); //send 10us high level to trigPin
16     delayMicroseconds(10);
17     digitalWrite(trigPin,LOW);
18     pingTime = pulseIn(echoPin,HIGH,timeOut); //read plus time of echoPin
19     distance = (float)pingTime * 340.0 / 2.0 / 10000.0; //calculate distance with sound speed
20     340m/s
21     return distance;

```

```

22 }
23
24 int main() {
25     printf("Program is starting ... \n");
26
27     wiringPiSetup();
28
29     float distance = 0;
30     pinMode(trigPin, OUTPUT);
31     pinMode(echoPin, INPUT);
32     while(1) {
33         distance = getSonar();
34         printf("The distance is : %.2f cm\n", distance);
35         delay(1000);
36     }
37     return 1;
38 }
```

First, define the pins and the maximum measurement distance.

```
#define trigPin 4
#define echoPin 5
#define MAX_DISTANCE 220          //define the maximum measured distance
```

If the module does not return high level, we can not wait forever. So we need to calculate the lasting time over maximum distance, that is, time Out. $\text{timOut} = 2 * \text{MAX_DISTANCE} / 100 / 340 * 1000000$. The constant part behind is approximately equal to 58.8.

```
#define timeOut MAX_DISTANCE*60
```

Subfunction **getSonar ()** function is used to start the ultrasonic module for a measurement, and return the measured distance with unit cm. In this function, first let trigPin send 10us high level to start the ultrasonic module. Then use **pulseIn ()** to read ultrasonic module and return the duration of high level. Finally calculate the measured distance according to the time.

```
float getSonar(){ // get the measurement results of ultrasonic module, with unit: cm
    long pingTime;
    float distance;
    digitalWrite(trigPin, HIGH); //trigPin send 10us high level
    delayMicroseconds(10);
    digitalWrite(trigPin, LOW);
    pingTime = pulseIn(echoPin, HIGH, timeOut); //read plus time of echoPin
    distance = (float)pingTime * 340.0 / 2.0 / 10000.0; // the sound speed is 340m/s, and
    calculate distance
    return distance;
}
```

Finally, in the while loop of main function, get the measurement distance and print it out constantly.

```
while(1) {
    distance = getSonar();
    printf("The distance is : %.2f cm\n", distance);
    delay(1000);
}
```

About function **pulseIn()**:

int pulseIn(int pin, int level, int timeout);

Return the length of the pulse (in microseconds) or 0 if no pulse is completed before the timeout (unsigned long).

Python Code 23.1.1 UltrasonicRanging

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

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

1. Use cd command to enter 23.1.1_UltrasonicRanging directory of Python code.

```
cd ~/Freenove_Kit/Code/Python_Code/23.1.1_UltrasonicRanging
```

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

```
python UltrasonicRanging.py
```

After the program is executed, make the detector of ultrasonic ranging module aim at the plane of an object, then the distance between the ultrasonic module and the object will be displayed in the terminal. As is shown below:

```
The distance is : 198.75 cm
The distance is : 199.22 cm
The distance is : 198.42 cm
The distance is : 198.74 cm
The distance is : 198.37 cm
The distance is : 198.47 cm
The distance is : 198.41 cm
```

The following is the program code:

```
1 import RPi.GPIO as GPIO
2 import time
3
4 trigPin = 16
5 echoPin = 18
6 MAX_DISTANCE = 220          #define the maximum measured distance(cm)
7 timeOut = MAX_DISTANCE*60   #calculate timeout(μs) according to the maximum measured
8 distance
9
10 def pulseIn(pin,level,timeOut): # function pulseIn: obtain pulse time of a pin
11     t0 = time.time()
12     while(GPIO.input(pin) != level):
13         if((time.time() - t0) > timeOut*0.000001):
14             return 0;
15         t0 = time.time()
16     while(GPIO.input(pin) == level):
```

```

17     if((time.time() - t0) > timeOut*0.000001):
18         return 0;
19     pulseTime = (time.time() - t0)*1000000
20     return pulseTime
21
22 def getSonar():      #get the measurement results of ultrasonic module,with unit: cm
23     GPIO.output(trigPin,GPIO.HIGH)      #make trigPin send 10us high level
24     time.sleep(0.00001)      #10us
25     GPIO.output(trigPin,GPIO.LOW)
26     pingTime = pulseIn(echoPin,GPIO.HIGH,timeOut)    #read plus time of echoPin
27     distance = pingTime * 340.0 / 2.0 / 10000.0      # the sound speed is 340m/s, and
28 calculate distance (cm)
29     return distance
30
31 def setup():
32     print ('Program is starting...')
33     GPIO.setmode(GPIO.BOARD)      #numbers GPIOs by physical location
34     GPIO.setup(trigPin, GPIO.OUT)  # set trigPin to output mode
35     GPIO.setup(echoPin, GPIO.IN)   # set echoPin to input mode
36
37 def loop():
38     while(True):
39         distance = getSonar()
40         print ("The distance is : %.2f cm"%(distance))
41         time.sleep(1)
42
43 if __name__ == '__main__':      #program start from here
44     setup()
45     try:
46         loop()
47     except KeyboardInterrupt:
48         GPIO.cleanup()

```

First, define the pins and the maximum measurement distance.

```

trigPin = 16
echoPin = 18
MAX_DISTANCE = 220      # define the maximum measured distance

```

If the module does not return high level, we can not wait forever. So we need to calculate the lasting time over maximum distance, that is, $\text{timeOut}(\mu\text{s}) = \frac{2 \times \text{MAX_DISTANCE}}{340} \times 1000000$. The constant part behind is approximately equal to 58.8.

```
timeOut = MAX_DISTANCE*60
```

Subfunction **getSonar ()** function is used to start the ultrasonic module for a measurement, and return the measured distance with unit cm. In this function, first let trigPin send 10us high level to start the ultrasonic module. Then use **pulseIn ()** to read ultrasonic module and return the duration of high level. Finally calculate the measured distance according to the time.

```
def getSonar():      #get the measurement results of ultrasonic module, with unit: cm
    GPIO.output(trigPin,GPIO.HIGH)      #make trigPin send 10us high level
    time.sleep(0.00001)      #10us
    GPIO.output(trigPin,GPIO.LOW)
    pingTime = pulseIn(echoPin,GPIO.HIGH,timeOut)    #read plus time of echoPin
    distance = pingTime * 340.0 / 2.0 / 10000.0      # the sound speed is 340m/s, and
    calculate distance
    return distance
```

Finally, in the while loop of main function, get the measurement distance and print it out constantly.

```
while(True):
    distance = getSonar()
    print ("The distance is : %.2f cm"%distance)
    time.sleep(1)
```

About function **def pulseIn(pin, level, timeOut):**

def pulseIn(pin,level,timeOut):

Return the length of the pulse (in microseconds) or 0 if no pulse is completed before the timeout (unsigned long).

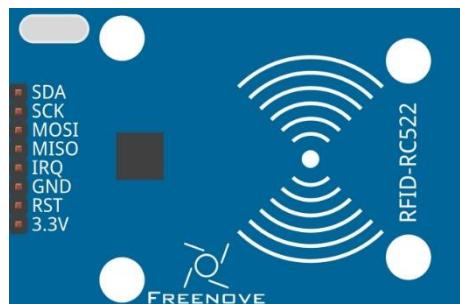
Chapter 24 RFID

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

Project 24.1 RFID

In this project, we will use RC522 RFID card reader to read and write the M1-S50 card.

Component List

Raspberry Pi 3B x1 GPIO Extension Board & Wire x1 BreadBoard x1 Jumper M/F x7	 A blue printed circuit board (PCB) labeled "RFID-RC522". It features several pins labeled SDA, SCK, MOSI, MISO, IRQ, GND, RST, and 3.3V. There are also two white circular pads at the top and bottom. A small FREENOVE logo is visible at the bottom left.
Mifare1 S50 Standard card x1	 A standard rectangular grey Mifare1 S50 card.

Component Knowledge

RFID

RFID (Radio Frequency Identification) is a wireless communication technology. A complete RFID system is generally composed of the responder and reader. Generally, we use tags as responders, and each tag has a unique code, which is attached to the object to identify the target object. The reader is a device for reading (or writing) tag information.

Products derived from RFID technology can be divided into three categories: passive RFID products, active RFID products and semi active RFID products. And Passive RFID products are the earliest, the most mature and most widely used products in the market among others. It can be seen everywhere in our daily life such as, the bus card, dining card, bank card, hotel access cards, etc., and all of these belong to close-range contact recognition. The main operating frequency of Passive RFID products are: 125KHZ (low frequency), 13.56MHZ (high frequency), 433MHZ (ultrahigh frequency), 915MHZ (ultrahigh frequency). Active and semi active RFID products work at higher frequencies.

The RFID module we use is a passive RFID product with the operating frequency of 13.56MHz.

MFRC522

The MFRC522 is a highly integrated reader/writer IC for contactless communication at 13.56MHz.

The MFRC522's internal transmitter is able to drive a reader/writer antenna designed to communicate with ISO/IEC 14443 A/MIFARE cards and transponders without additional active circuitry. The receiver module provides a robust and efficient implementation for demodulating and decoding signals from ISO/IEC 14443 A/MIFARE compatible cards and transponders. The digital module manages the complete ISO/IEC 14443A framing and error detection (parity and CRC) functionality

This RFID Module uses MFRC522 as the control chip, and SPI (Peripheral Interface Serial) as the reserved interface.

Technical specs:

Operating Voltage	13~26mA (DC) \3. 3V
Idle current	10~13mA (DC) \3. 3V
Sleep current in the	<80uA
Peak current	<30mA
Operating frequency	13. 56MHz
Supported card type	Mifare1 S50、Mifare1 S70、Mifare Ultralight、Mifare Pro、Mifare Desfire
Size	40mmX60mm
Operation temperature	20~80 degrees (Celsius)
Storage temperature	40~85 degrees (Celsius)
Operation humidity	5%~95% (Relative humidity)

Mifare1 S50 Card

Mifare S50 is often called Mifare Standard with the capacity of 1K bytes. And each card has a 4-bytes global unique identifier number (USN/UID), which can be rewritten 100 thousand times and read infinite times. Its storage period can last for 10 years. The ordinary Mifare1 S50 Card and non-standard Mifare1 S50 Card equipped for Freenove RFID Kit are shown below.

The Mifare S50 capacity (1K byte) is divided into 16 sectors (Sector0-Sector15). Each sector contains 4 data

block (Block0-Block3. 64 blocks of 16 sectors will be numbered according absolute address, from 0 to 63). And each block contains 16 bytes (Byte0-Byte15), $64 \times 16 = 1024$. As is shown in the following table:

Sector No.	Block No.	Storage area	Block type	Absolute block No.
sector 0	block 0	vendor code	vendor block	0
	block 1		data block	1
	block 2		data block	2
	block 3	Password A-access control-password B	control block	3
sector 1	block 0		data block	4
	block 1		data block	5
	block 2		data block	6
	block 3	Password A-access control-password B	control block	7
.....
sector 15	block 0		data block	60
	block 1		data block	61
	block 2		data block	62
	block 3	Password A-access control-password B	control block	63

Each sector has a set of independent password and access control which are put in the last block of each sector, and the block is also known as sector trailer, that is Block 3 in each sector. Sector 0, block 0 (namely absolute address 0) of S50 is used to store the vendor code, which has been solidified and can't be changed, and the card serial number is stored here. In addition to the manufacturer and the control block, the rest of the cards are data blocks, which can be used to store data. Data block can be used for two kinds of applications:
(1) used as general data storage and can be operated for reading and writing.
(2) used as data value, and can be operated for initializing the value, adding value, subtracting and reading the value.

The sector trailer block in each sector is the control block, including a 6-byte password A, 4-byte access control and 6-byte password B. For example, the control block of a brand new card is as follows:

A0 A1 A2 A3 A4 A5	FF 07 80 69	B0 B1 B2 B3 B4 B5
password A	access control	password B

The default password of a brand new card is generally 0A1A2A3A4A5 for password A, B0B1B2B3B4B5 for password B, or both the password A and password B are 6 FF. Access control is used to set the access conditions for each block (including the control block itself) in a sector.

Blocks of S50 are divided into data blocks and control blocks. There are four operations, "read", "write", "add value", "subtract value (including transmission and storage)" for data blocks, and there are two operations, "read" and "write" for control blocks.

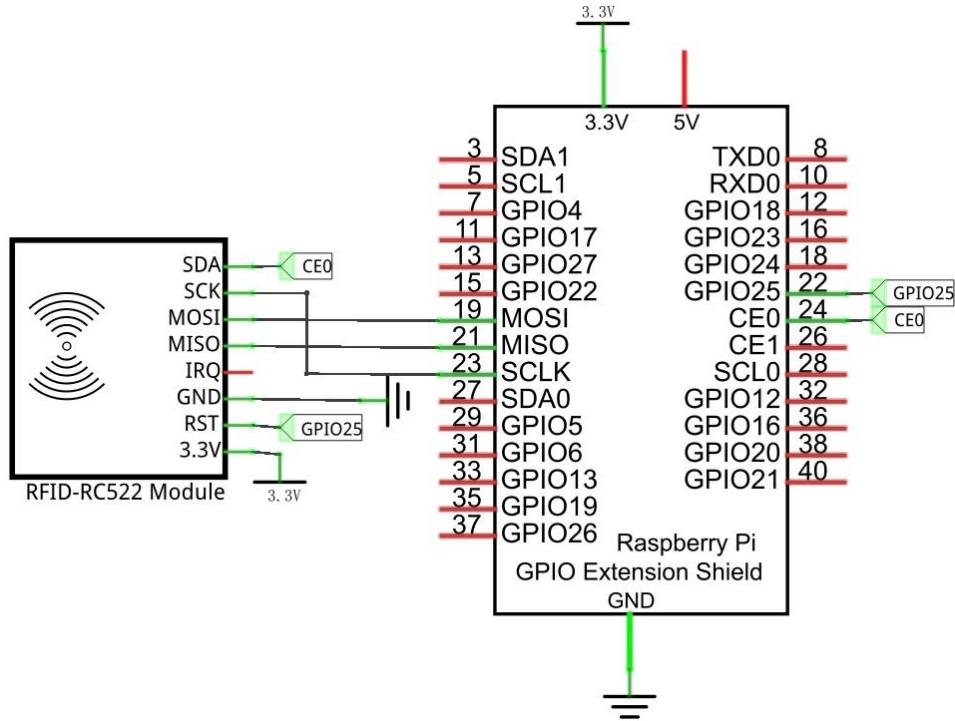
For more details about how to set data blocks and control blocks, please refer to Datasheet.

By default, after verifying password A or password B, we can do reading or writing operation to data blocks. And after verifying password A, we can do reading or writing operation to control blocks. But password A can never be read. If you choose to verify password A and then you forget the password A, the block will never be able to read again. **It is highly recommended that beginners should not try to change the contents of control blocks.**

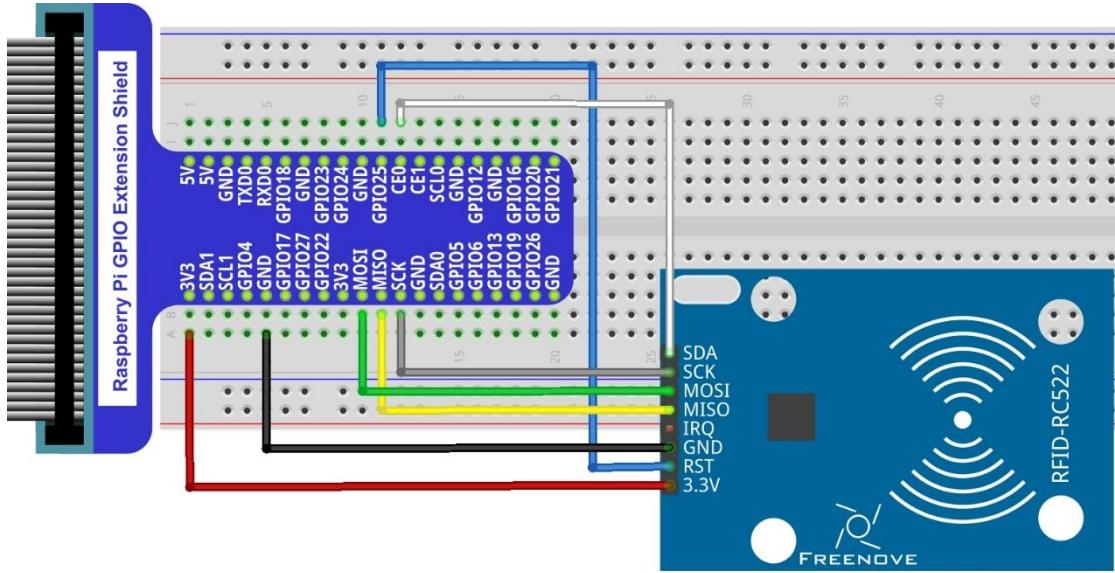
For Mifare1 S50 card equipped for Freenove RFID Kit, the default password A and B is FFFFFFFFFF.

Circuit

Schematic diagram:



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



Configure SPI

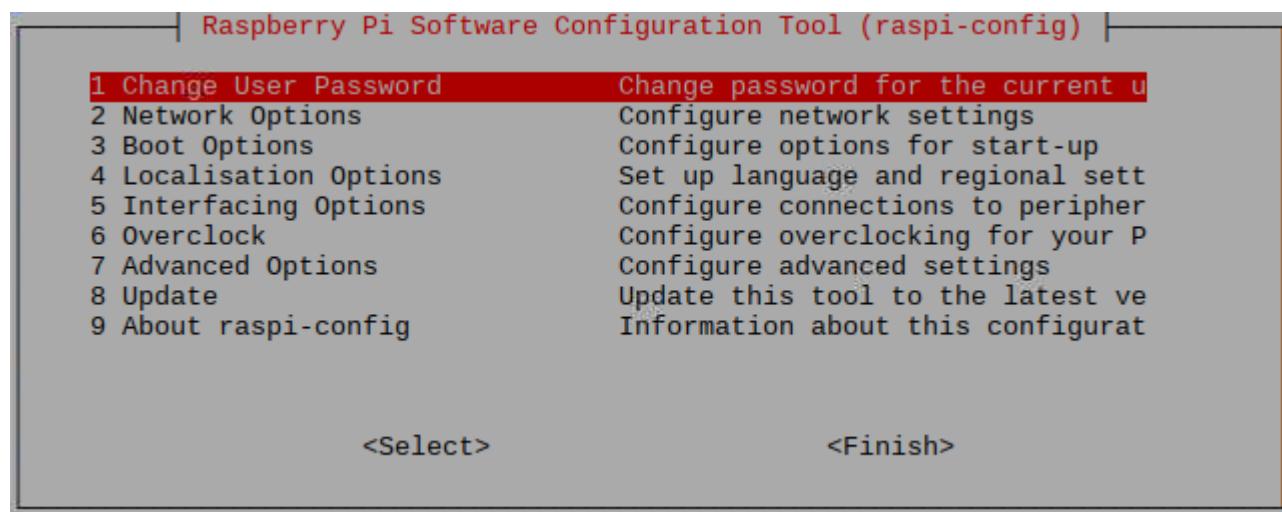
Enable SPI

The SPI interface raspberry pie is closed in default. You need to open it manually. You can enable the SPI interface in the following way.

Type command in the terminal:

```
sudo raspi-config
```

Then open the following dialog box:



Choose “5 Interfacing Options” → “P4 SPI” → “Yes” → “Finish” in order and restart your RPi later. Then the SPI module is started.

Type the following command to check whether the module SPI is loaded successfully:

```
ls /dev/sp*
```

The following result indicates that the module SPI has been loaded successfully:

```
pi@raspberrypi:~ $ ls /dev/sp*
/dev/spidev0.0  /dev/spidev0.1
```

Install Python module SPI-Py

If you use Python language to write the code, please follow the step below to install the module SPI-Py. If you use C/C++ language, you can skip this step.

Open the terminal and type the following command to install:

```
git clone https://github.com/Freenove/SPI-Py
cd SPI-Py
sudo python setup.py install
```

Code

The project code use human-computer interaction command line mode to read and write the M1-S50 card.

C Code 24.1.1 RFID

First observe the running result, and then analyze the code.

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

1. Use cd command to enter 24.1.1_RFID directory of C code.

```
cd Freenove_RFID_Starter_Kit_for_Raspberry_Pi/Code/C_Code/24.1.1_RFID
```

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

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

3. Then run the generated file "RFID".

```
sudo ./RFID
```

After the program is executed, the following contents will be displayed in the terminal:

```
pi@raspberrypi:~/Freenove_RFID_Starter_Kit_for_Raspberry_Pi/Code/C_Code/24.1.1_RFID$ sudo ./build.sh
Build finished!
pi@raspberrypi:~/Freenove_RFID_Starter_Kit_for_Raspberry_Pi/Code/C_Code/24.1.1_RFID$ sudo ./RFID
Try to open device /dev/spidev0.0
Device opened
Device Number:3
SPI mode [OK]
SPI word bits[OK]
SPI max speed[OK]
User Space RC522 Application
RC522>■
```

Here, type the command “quit” to exit the program.

Type command "scan", then the program begins to detect whether there is a card close to the sensing area of MFRC522 reader. Place an M1-S50 card in the sensing area. The following results indicate that the M1-S50 card has been detected, the UID of which is E6CF5C8EFB (HEX).

```
RC522>scan
Scanning
.....Card detected    0xE6 0xCF 0x5C 0x8E, Check Sum = 0xFB
Card Selected, Type:PICC_TYPE_MIFARE_1K
RC522>E6CF5C8E>■
```

When the Card is placed in the sensing area, you can read and write the card through the following command.

```
Usage:
      read <blockstart>
      dump
      halt
      clean <blockaddr>
      write <blockaddr> <data>
```

In the command read<blockstart>, the parameter blockstart is the address of the data block, and the range is 0-63. This command is used to display all the data from blockstart address to the end of the sector. For example, sector 0 contains data block 0,1,2,3. Using the command read 0 can display all contents of data block 0,1,2,3. Using the command read 1 can display all contents of data block 1,2,3. As is shown below:

```
RC522>E6CF5C8E>read 0
read
Auth Block (0x00) with key 0xFF 0xFF 0xFF 0xFF 0xFF ...OK
Read block address 0x00 ....OK read 144 bits
Read block address 0x01 ....OK read 144 bits
Read block address 0x02 ....OK read 144 bits
Read block address 0x03 ....OK read 144 bits
  0: e6 cf 5c 8e fb 08 04 00 62 63 64 65 66 67 68 69 : ..\.....bcdefghi
  16: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 : .....
  32: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 : .....
  48: 00 00 00 00 00 ff 07 80 69 ff ff ff ff ff ff : .....i.....
RC522>E6CF5C8E>read 1
read
Auth Block (0x01) with key 0xFF 0xFF 0xFF 0xFF 0xFF ...OK
Read block address 0x01 ....OK read 144 bits
Read block address 0x02 ....OK read 144 bits
Read block address 0x03 ....OK read 144 bits
  0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 : .....
  16: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 : .....
  32: 00 00 00 00 00 00 ff 07 80 69 ff ff ff ff ff : .....i.....
RC522>E6CF5C8E>
```

Command dump is used to display the content of all data blocks in all sectors.

Command <address> <data> is used to write "data" to data block with address "address". Where the address range is 0-63 and the data length is 0-16. For example, if you want to write the string "Freenove" to the data block with address "1", you can type the following command.

```
write 1 Freenove
RC522>E6CF5C8E>write 1 Freenove
write
Auth Block (0x01) with key 0xFF 0xFF 0xFF 0xFF 0xFF ...OK
Try to write block 1 with 8 byte data...OK
```

Read the contents of this sector and check the data just written.

```
read 0
The following results indicate that the string "Freenove" has been written successfully into the data block 1.
Read block address 0x03 ....OK read 144 bits
  0: e6 cf 5c 8e fb 08 04 00 62 63 64 65 66 67 68 69 : ..\.....bcdefghi
  16: 46 72 65 65 6e 6f 76 65 00 00 00 00 00 00 00 00 : Freenove.....
  32: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 : .....
  48: 00 00 00 00 00 ff 07 80 69 ff ff ff ff ff : .....i.....
```

Command clean <address> is used remove the contents of the data block with address "address". For example, if you want to clear the contents of the data block 1 that has just been written, you can type the following command.

```
clean 1
RC522>E6CF5C8E>clean 1
clean
Auth Block (0x01) with key 0xFF 0xFF 0xFF 0xFF 0xFF ...OK
Try to clean block 1...OK
```

Read the contents of data blocks in this sector again to test whether the data is erased. The following results indicate that the contents of data block 1 have been erased.

```
RC522>E6CF5C8E>read 0
read
Auth Block (0x00) with key 0xFF 0xFF 0xFF 0xFF 0xFF ...OK
Read block address 0x00 ....OK read 144 bits
Read block address 0x01 ....OK read 144 bits
Read block address 0x02 ....OK read 144 bits
Read block address 0x03 ....OK read 144 bits
  0: e6 cf 5c 8e fb 08 04 00 62 63 64 65 66 67 68 69 : ..\.....bcdefghi
  16: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 : .....
  32: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 : .....
  48: 00 00 00 00 00 ff 07 80 69 ff ff ff ff ff ff : .....i.....
```

Command halt is used to quit the selection state of the card.

```
RC522>E6CF5C8E>halt
halt
Halt
RC522>
```

The following is the program code:

```
1 #include <stdio.h>
2 #include <stdint.h>
3 #include <unistd.h>
4 #include <string.h>
5 #include <getopt.h>
6 #include <stdlib.h>
7 #include "mfrc522.h"
8 #define DISP_COMMANDLINE() printf("RC522>")
9
10 int scan_loop(uint8_t *CardID);
11 int tag_select(uint8_t *CardID);
12 int main(int argc, char **argv) {
13     MFRC522_Status_t ret;
14     //Recognized card ID
15     uint8_t CardID[5] = { 0x00, };
16     static char command_buffer[1024];
17
18     ret = MFRC522_Init('A');
19     if (ret < 0) {
20         perror("Failed to initialize");
21         exit(-1);
22     }
23
24     printf("User Space RC522 Application\r\n");
25
26     while (1) {
27         /*Main Loop Start*/
28         DISP_COMMANDLINE();
29     }
```

```
30     scanf("%s", command_buffer);
31     if (strcmp(command_buffer, "scan") == 0) {
32         puts("Scanning");
33         while (1) {
34             ret = MFRC522_Check(CardID);
35             if (ret != MI_OK) {
36                 printf(".");
37                 fflush(stdout);
38                 continue;
39             }
40             ret |= tag_select(CardID);
41             if (ret == MI_OK) {
42                 ret = scan_loop(CardID);
43                 if (ret < 0) {
44                     goto END_SCAN;
45                 } else if (ret == 1) {
46                     goto HALT;
47                 }
48             }
49         }
50         END_SCAN: printf("Card error... ");
51         HALT: puts("Halt");
52     } else if (strcmp(command_buffer, "quit") == 0
53             || strcmp(command_buffer, "exit") == 0) {
54         return 0;
55     } else {
56         puts("Unknown command");
57         puts("scan:scan card and dump");
58         puts("quit:exit program");
59     }
60     /*Main Loop End*/
61 }
62 }
63 int scan_loop(uint8_t *CardID) {
64
65     while (1) {
66
67         char input[32];
68         int block_start;
69         DISP_COMMANDLINE();
70         printf("%02X%02X%02X%02X>, CardID[0], CardID[1], CardID[2], CardID[3]);
71         scanf("%s", input);
72         puts((char*)input);
73         if (strcmp(input, "halt") == 0) {
```

```
74         return 1;
75     } else if (strcmp(input, "dump") == 0) {
76         if (MFRC522_Debug_CardDump(CardID) < 0)
77             return -1;
78     } else if (strcmp(input, "read") == 0) {
79         scanf("%d", &block_start);
80         if (MFRC522_Debug_DumpSector(CardID, block_start) < 0) {
81             return -1;
82         }
83     } else if(strcmp(input, "clean") == 0) {
84         char c;
85         scanf("%d", &block_start);
86         while ((c = getchar()) != '\n' && c != EOF)
87             ;
88         if (MFRC522_Debug_Clean(CardID, block_start)) {
89             return -1;
90         }
91     }
92     } else if (strcmp(input, "write") == 0) {
93         char write_buffer[256];
94         size_t len = 0;
95         scanf("%d", &block_start);
96         scanf("%s", write_buffer);
97         if (len >= 0) {
98             if (MFRC522_Debug_Write(CardID, block_start, write_buffer,
99                     strlen(write_buffer)) < 0) {
100                 return -1;
101             }
102         }
103     } else {
104
105         printf(
106             "Usage:\r\n" "\tread <blockstart>\r\n" "\tdump\r\n"
107             "\thalt\r\n" "\tclean <blockaddr>\r\n" "\twrite <blockaddr> <data>\r\n");
108         return 0;
109     }
110 }
111 return 0;
112 }
113 int tag_select(uint8_t *CardID) {
114     int ret_int;
115     printf(
116         "Card detected      0x%02X 0x%02X 0x%02X 0x%02X, Check Sum = 0x%02X\r\n",
117         CardID[0], CardID[1], CardID[2], CardID[3], CardID[4]);
```

```

118     CardID[0], CardID[1], CardID[2], CardID[3], CardID[4]);
119     ret_int = MFRC522_SelectTag(CardID);
120     if (ret_int == 0) {
121         printf("Card Select Failed\r\n");
122         return -1;
123     } else {
124         printf("Card Selected, Type:%s\r\n",
125                MFRC522_TypeToString(MFRC522_ParseType(ret_int)));
126     }
127     ret_int = 0;
128     return ret_int;
129 }
```

In the code, first initialize the MFRC522. If the initialization fails, the program will exit.

```

ret = MFRC522_Init('A');
if (ret < 0) {
    perror("Failed to initialize");
    exit(-1);
}
```

In the main function, wait for the command input. If command "scan" is received, the function will begin to detect whether there is a card close to the sensing area. If a card is detected, the card will be selected and card UID will be acquired. Then enter the function scan_loop (). If command "quit" or "exit" is received, the program will exit.

```

scanf("%s", command_buffer);
if (strcmp(command_buffer, "scan") == 0) {
    puts("Scanning");
    while (1) {
        ret = MFRC522_Check(CardID);
        if (ret != MI_OK) {
            printf(".");
            fflush(stdout);
            continue;
        }
        ret |= tag_select(CardID);
        if (ret == MI_OK) {
            ret = scan_loop(CardID);
            if (ret < 0) {
                goto END_SCAN;
            } else if (ret == 1) {
                goto HALT;
            }
        }
    }
}
END_SCAN: printf("Card error... ");
HALT: puts("Halt");
```

```

} else if (strcmp(command_buffer, "quit") == 0
           || strcmp(command_buffer, "exit") == 0) {
    return 0;
} else {
    puts("Unknown command");
    puts("scan:scan card and dump");
    puts("quit:exit program");
}
/*Main Loop End*/
}

```

The function `scan_loop()` will detect command read, write, clean, halt, dump and do the corresponding processing to each command. The function of each command and the method have been introduced before.

```

int scan_loop(uint8_t *CardID) {

    while (1) {

        char input[32];
        int block_start;
        DISP_COMMANDLINE();
        printf("%02X%02X%02X%02X>, CardID[0], CardID[1], CardID[2], CardID[3]);
        scanf("%s", input);
        puts((char*)input);
        if (strcmp(input, "halt") == 0) {
            return 1;
        } else if (strcmp(input, "dump") == 0) {
            if (MFRC522_Debug_CardDump(CardID) < 0)
                return -1;
        } else if (strcmp(input, "read") == 0) {
            scanf("%d", &block_start);
            if (MFRC522_Debug_DumpSector(CardID, block_start) < 0) {
                return -1;
            }
        } else if (strcmp(input, "clean") == 0) {
            char c;
            scanf("%d", &block_start);
            while ((c = getchar()) != '\n' && c != EOF)
                ;
            if (MFRC522_Debug_Clean(CardID, block_start)) {
                return -1;
            }
        } else if (strcmp(input, "write") == 0) {
            char write_buffer[256];
            size_t len = 0;

```

```
scanf("%d", &block_start);
scanf("%s", write_buffer);
if (len >= 0) {
    if (MFRC522_Debug_Write(CardID, block_start, write_buffer,
        strlen(write_buffer)) < 0) {
        return -1;
    }
}
} else {

printf(
    "Usage:\r\n" "\tread <blockstart>\r\n" "\tdump\r\n" "\thalt\r\n"
    "\tclean <blockaddr>\r\n" "\twrite <blockaddr> <data>\r\n");
return 0;
}
}
return 0;
}
```

The header file "mfrc522.h" contains the associated operation method for the MFRC522. You can open the file to view all the definitions and functions.

Python Code 24.1.1 RFID

There are two code files for this project. They are respectively under Python2 folder and Python3 folder. **Their functions are the same, but they are not compatible.** Code under Python2 folder can only run on Python2. And code under Python3 folder can only run on Python3.

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

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

1. Use cd command to enter 24.1.1_RFID directory of Python code.

If you use Python2, it is needed to enter Python2 code folder.

```
cd ~/Freenove_RFID_Starter_Kit_for_Raspberry_Pi/Code/Python_Code/24.1.1_RFID/Python2
```

If you use Python3, it is needed to enter Python3 code folder.

```
cd ~/Freenove_RFID_Starter_Kit_for_Raspberry_Pi/Code/Python_Code/24.1.1_RFID/Python3
```

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

```
python RFID.py
```

After the program is executed, the following contents will be displayed in the terminal:

```
pi@raspberrypi:~/Freenove_RFID_Starter_Kit_for_Raspberry_Pi/Code/Python_Code/24.1.1_RFID $ python RFID.py
Program is starting ...
Press Ctrl-C to exit.
RC522> █
```

Here, type the command "quit" to exit the program.

Type command "scan", then the program begins to detect whether there is a card close to the sensing area of MFRC522 reader. Place an M1-S50 card in the sensing area. The following results indicate that the M1-S50 card has been detected, the UID of which is E6CF5C8EFB (HEX).

```
RC522> scan
scan
Scanning ...
Card detected
Card UID: ['0xe6', '0xcf', '0x5c', '0x8e', '0xfb']
Size: 8
RC522> E6CF5C8EFB> █
```

When the Card is placed in the sensing area, you can read and write the card through the following command.

```
Usage:
    read <blockstart>
    dump
    halt
    clean <blockaddr>
    write <blockaddr> <data>
```

In the command read<blockstart>, the parameter blockstart is the address of the data block, and the range is 0-63. As is shown below:

In the command read<blockstart>, the parameter blockstart is the address of the data block, and the range is 0-63. This command is used to read the data of data block with address "blockstart". For example, using command read 0 can display the content of data block 0. Using the command read 1 can display the content of data block 1. As is shown below:

Command dump is used to display the content of all data blocks in all sectors.

Command <address> <data> is used to write "data" to data block with address "address". Where the address range is 0-63 and the data length is 0-16. In the process of writing data to the data block, both the contents of data block before written and after written will be displayed. For example, if you want to write the string "Freenove" to the data block with address "1", you can type the following command.

write 1 Freenove

Command `clean <address>` is used remove the contents of the data block with address "address". For example, if you want to clear the contents of the data block 1 that has just been written, you can type the following command.

clean 1

```
RC522> E6CF5C8EFB> clean 1
['clean', '1']
Before cleaning , The data in block 1  is:
Sector 1 :  46 72 65 65 6e 6f 76 65 0 0 0 0 0 0 0 0 | Freenove
4 backdata &0x0F == 0xA 10
Data written
After cleaned , The data in block 1  is:
Sector 1 :  0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 |
```

Command halt is used to quit the selection state of the card

```
RC522> E6CF5C8EFB> halt  
['halt']  
RC522> █
```

The following is the program code (python2 code):

```
1 import RPi.GPIO as GPIO
2
3
4 # Create an object of the class MFRC522
5 mfc = MFRC522.MFRC522()
6
7 def dis_CommandLine():
8     print "RC522>",
9 def dis_CardID(cardID):
10    print "%2X%2X%2X%2X%2X>"%(cardID[0], cardID[1], cardID[2], cardID[3], cardID[4]),
11 def setup():
```

```
12     print "Program is starting ... "
13     print "Press Ctrl-C to exit."
14     pass
15
16 def loop():
17     while(True):
18         dis_CommandLine()
19         inCmd = raw_input()
20         print inCmd
21         if (inCmd == "scan"):
22             print "Scanning ... "
23             isScan = True
24             while isScan:
25                 # Scan for cards
26                 (status, TagType) = mfrc.MFRC522_Request(mfrc.PICC_REQIDL)
27                 # If a card is found
28                 if status == mfrc.MI_OK:
29                     print "Card detected"
30                     # Get the UID of the card
31                     (status,uid) = mfrc.MFRC522_Anticoll()
32                     # If we have the UID, continue
33                     if status == mfrc.MI_OK:
34                         print "Card UID: "+ str(map(hex,uid))
35                         # Select the scanned tag
36                         if mfrc.MFRC522_SelectTag(uid) == 0:
37                             print "MFRC522_SelectTag Failed!"
38                             if cmdloop(uid) < 1 :
39                                 isScan = False
40                         elif inCmd == "quit":
41                             destroy()
42                             exit(0)
43                         else :
44                             print "\tUnknown command\n"+"\tscan:scan card and dump\n"+"\tquit:exit
45 program\n"
46
47 def cmdloop(cardID):
48     pass
49     while(True):
50         dis_CommandLine()
51         dis_CardID(cardID)
52         inCmd = raw_input()
53         cmd = inCmd.split(" ")
54         print cmd
55         if(cmd[0] == "read"):
```

```
56     blockAddr = int(cmd[1])
57     if((blockAddr<0) or (blockAddr>63)):
58         print "Invalid Address!"
59     # This is the default key for authentication
60     key = [0xFF, 0xFF, 0xFF, 0xFF, 0xFF, 0xFF]
61     # Authenticate
62     status = mfrc.MFRC522_Auth(mfrc.PICC_AUTHENT1A, blockAddr, key, cardID)
63     # Check if authenticated
64     if status == mfrc.MI_OK:
65         mfrc.MFRC522_Readstr(blockAddr)
66     else:
67         print "Authentication error"
68         return 0
69
70 elif cmd[0] == "dump":
71     # This is the default key for authentication
72     key = [0xFF, 0xFF, 0xFF, 0xFF, 0xFF, 0xFF]
73     mfrc.MFRC522_Dump_Str(key, cardID)
74
75 elif cmd[0] == "write":
76     blockAddr = int(cmd[1])
77     if((blockAddr<0) or (blockAddr>63)):
78         print "Invalid Address!"
79     data = [0]*16
80     if(len(cmd)<2):
81         data = [0]*16
82     else:
83         data = cmd[2][0:17]
84         data = map(ord, data)
85     if len(data)<16:
86         data+=[0]*(16-len(data))
87     # This is the default key for authentication
88     key = [0xFF, 0xFF, 0xFF, 0xFF, 0xFF, 0xFF]
89     # Authenticate
90     status = mfrc.MFRC522_Auth(mfrc.PICC_AUTHENT1A, blockAddr, key, cardID)
91     # Check if authenticated
92     if status == mfrc.MI_OK:
93         print "Before writing , The data in block %d  is: %(blockAddr)
94         mfrc.MFRC522_Readstr(blockAddr)
95         mfrc.MFRC522_Write(blockAddr, data)
96         print "After written , The data in block %d  is: %(blockAddr)
97         mfrc.MFRC522_Readstr(blockAddr)
98     else:
99         print "Authentication error"
```

```

100         return 0
101
102     elif cmd[0] == "clean":
103         blockAddr = int(cmd[1])
104         if((blockAddr<0) or (blockAddr>63)):
105             print "Invalid Address!"
106         data = [0]*16
107         # This is the default key for authentication
108         key = [0xFF, 0xFF, 0xFF, 0xFF, 0xFF, 0xFF]
109         # Authenticate
110         status = mfrc.MFRC522_Auth(mfrc.PICC_AUTHENT1A, blockAddr, key, cardID)
111         # Check if authenticated
112         if status == mfrc.MI_OK:
113             print "Before cleaning , The data in block %d  is: %(blockAddr)
114             mfrc.MFRC522_Readstr(blockAddr)
115             mfrc.MFRC522_Write(blockAddr, data)
116             print "After cleaned , The data in block %d  is: %(blockAddr)
117             mfrc.MFRC522_Readstr(blockAddr)
118         else:
119             print "Authentication error"
120             return 0
121         elif cmd[0] == "halt":
122             return 0
123         else :
124             print "Usage:\r\n" "\tread <blockstart>\r\n" "\tdump\r\n" "\thalt\r\n"
125             "\tclean <blockaddr>\r\n" "\twrite <blockaddr> <data>\r\n"
126
127     def destroy():
128         GPIO.cleanup()
129
130     if __name__ == "__main__":
131         setup()
132         try:
133             loop()
134         except KeyboardInterrupt: # Ctrl+C captured, exit
135             destroy()

```

In the code, first create an MFRC522 class object.

```
mfrc = MFRC522.MFRC522()
```

In the function loop, wait for the command input. If command "scan" is received, the function will begin to detect whether there is a card close to the sensing area. If a card is detected, the card will be selected and card UID will be acquired. Then enter the function scan_loop (). If command "quit" or "exit" is received, the program will exit.

```

if (inCmd == "scan"):
    print "Scanning ... "

```

```
isScan = True
while isScan:
    .....
    if cmdloop(uid) < 1 :
        isScan = False
    elif inCmd == "quit":
        destroy()
        exit(0)
    else :
        print "\tUnknown command\n"+"\tscan:scan card and dump\n"+"\tquit:exit
program\n"
```

The function cmdloop() will detect command read, write, clean, halt, dump and do the corresponding processing to each command. The function of each command and the method have been introduced before.

```
def cmdloop(cardID):
    pass
    while(True):
        dis_CommandLine()
        dis_CardID(cardID)
        inCmd = raw_input()
        cmd = inCmd.split(" ")
        print cmd
        if(cmd[0] == "read"):
            .....
        elif cmd[0] == "dump":
            .....
        elif cmd[0] == "write":
            .....
        elif cmd[0] == "clean":
            .....
        elif cmd[0] == "halt":
            return 0
        else :
            print "Usage:\r\n" "\tread <blockstart>\r\n" "\tdump\r\n" "\thalt\r\n"
            "\tclean <blockaddr>\r\n" "\twrite <blockaddr> <data>\r\n"
```

The file "MFRC522.py" contains the associated operation method for the MFRC522. You can open the file to view all the definitions and functions.



Chapter 25 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 25.1 Remote LED

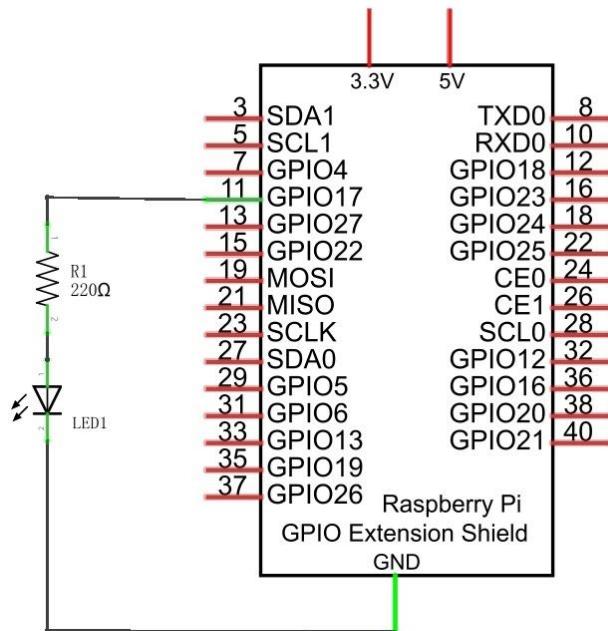
In this experiment, we need build a WebIOPi service, and then control the RPi GPIO to control a LED through Web browser of phone or PC.

Component List

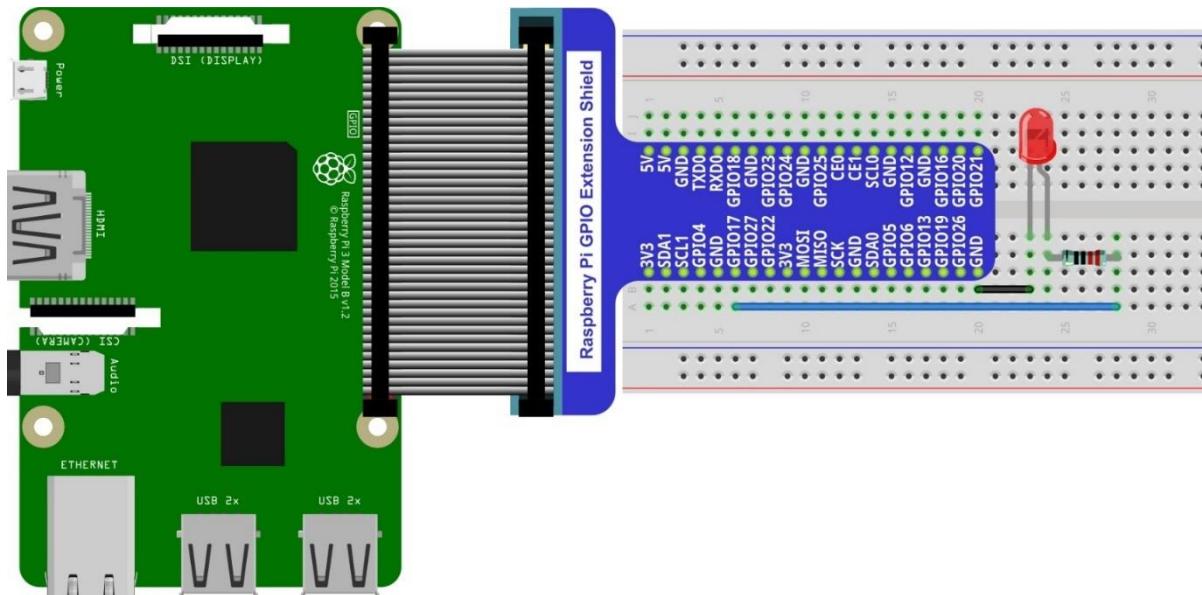
Raspberry Pi (with 40 GPIO) x1 GPIO Extension Board & Wire x1 BreadBoard x1	LED x1	Resistor 220Ω x1
Jumper M/M x2 		

Circuit

Schematic diagram



Hardware connection. If you need any support, please 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

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

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

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

```
unzip WebIOPi.zip
```

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

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

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

- Run setup.sh to start the installation, and the process need a period of time to wait.

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

- 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	GPIO 18 IN
IN	GPIO 27	13	14 GROUND
IN	GPIO 22	15	16 GPIO 23 IN
	3.3V	17	18 GPIO 24 IN
ALTO	GPIO 10	19	20 GROUND
ALTO	GPIO 9	21	22 GPIO 25 IN
ALTO	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 from 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 RFID 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